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Proceedings of the 4th Yugoslav-Romanian Astronomical Meeting (4th YuRoAM)

Edited by M. S. Dimitrijević and L. Č. Popović

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1998

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4th Yugoslav-Romanian Astronomical Meeting

Belgrade, May 5-8, 1998

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PREFACE

We are proud to organize the 4^{th} Yugoslav-Romanian Astronomical Meeting (YuRoAM) and to publish this book containing the Proceedings. This conference is our small contribution to the friendship of our two peoples and to the better communication and the development of friendship and scientific collaboration between Romanian and Serbian astronomers.

During the visit of one of us (MSD) to the Astronomical observatory in Bucharest (9-14 May 1995), the agreement on collaboration has been signed on 12th May 1995 between Belgrade astronomical observatory and Romanian Astronomical institute whose members are the Astronomical observatories in Bucharest, Cluj-Napoca and Timishoara. One of the results of this visit was the common proposition to organize regular annual meetings of Yugoslav and Romanian astronomers in order to stimulate collaboration and friendship.

The first Romanian-Yugoslav Round Table on cooperation in astronomy has been organized in Timishoara on 20 July 1995, the second in Belgrade on 8th October 1996 and the third in Cluj-Napoca on 6th September 1997. There has been decided to organize the fourth meeting not as an one-day round table, but as a several-day meeting with a printed book of proceedings. This book and the 4^{th} YuRoAM are the realization of our decision and we hope that they will contribute to the collaboration, friendship and mutual relationship between Romanian and Yugoslav astronomers.

M. S. Dimitrijević
L. Č. Popović

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THE INTERGALACTIC PRESSURE AND SIZES OF THE GASEOUS HALOS OF FIELD GALAXIES

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Abstract. The problem of influence of the ambiental intergalactic pressure on extended gas associated with normal field galaxies is briefly discussed. It seems that characteristic radius of absorption in the context of simple two-phase halo model can not be explained as natural consequences of pressure equilibrium of the hot halo with the smooth intergalactic medium. This conclusion is based upon the stringent constraints on the temperature and density of the intergalactic plasma obtained through the CMBR measurements. On the other hand, ram-pressure stripping caused by the peculiar motion of galaxies does present a viable alternative for the hot halo truncation. It is shown that for a particular set of chosen parameters, a simple model is capable of producing the absolute upper limit on the extent of gas associated with the galaxy. The values obatined are quite compatible with the results of the recent QSO absorption-line studies. This indicates more important role of "environmental" effects on field galaxies than it is usually assumed.

1. INTRODUCTION

The question of existence and physical properties of the intergalactic medium (IGM) is one of the very active problems of foremost importance to a wide variety of cosmological and astophysical topics. Hereafter, we use the expression "intergalactic medium" in the sense of true ambiental, smooth (or weakly inhomogeneous) component of the baryonic content of the universe, in contradistinction to the intracluster medium (ICM), which is X-ray emitting gas which fills rich clusters of galaxies on one hand, and those high-velocity or halo clouds which are actually gravitationally associated with the individual galaxies, comprising the extended gaseous coronae, or halos. True IGM, therefore, must be mainly cosmological in origin, being the remnant of the processes of galaxy formation. However, it is not necessary to assume that the IGM is of primordial chemical composition, since a degree of mixing with the enriched gas expelled by normal galaxies is conceivable, and a possibility of existence of a generation of pregalactic Population III objects which could contribute to enrichment of the IGM with heavy elements remains open.

Historically, two major physical justifications for introducing the smooth IGM component were (1) the confinement of Lyα clouds (Sargent *et al.* 1980; Ostriker & Ikeuchi 1983), and (2) origin of the soft X-ray background (Marshall *et al.* 1980; Guilbert &

Fabian 1986). As it frequently happens in a dynamical branch of science, both of these were soon shown to be irrelevant. Namely, it is now clear, from the COBE constraints on the CMBR distorsion that the thermal pressure of the IGM is quite insufficient to provide confinement for the clouds with observed column density and the Doppler parameter distribution, and can hardly posses other properties required for creating the observed X-ray background (Barcons, Fabian, & Rees 1991, hereafter BFR). Even recently detected He II Gunn-Peterson effect (Davidsen, Kriss, & Zheng 1996) which comes nearest to the positive confirmation of elusive IGM, is not the final word, since very low-column density Lyα forest may as well be the source of the observed signal (Songaila, Hu, & Cowie 1995).

On the galactic side of the story, the focus of the recent discussions of dark matter in galaxy halos has shifted back to the dark matter in the form of baryons, since it seems clear that Big Bang nucleosynthesis (BBN) requires much more baryons than observed in the stars, interstellar medium (ISM) and ICM. In particular, the observations of rich cluster seem to indicate the cosmological density in baryons Ω_b higher than was suspected (Babul & Katz 1993). On the other hand, deep optical searches severely limit mass-to-light ratio of the dark matter in the halo of our Galaxy and the Local Group (Richstone *et al.* 1992; Hu *et al.* 1994; Flynn, Gould, & Bahcall 1996); similar limits come from gravitational microlensing (Dalcanton *et al.* 1994). In this situation, it seems natural to re-investigate the possibility that at least a part of the baryonic dark matter is in the form of gas—pressumably the same, or tightly related, gas which produces QSO absorption lines at low redshift, although other interpretations are possible (e.g. Pfenniger, Combes, & Martinet 1994; Gerhard & Silk 1996).

These are only some of plethora of arguments for invoking the galactic hot halo model (Bahcall & Spitzer 1969; Bregman 1981; Mo 1994; Mo & Miralda-Escudé 1996, hereafter MM96; Chiba & Nath 1997). According to general qualitative picture, the formation of the galactic structure left vast quantities of metal-poor gas in the halo heated by pregalactic shocks to the virial temperature (10^6 to 10^7 K). This is collisionally ionized hot phase (MM96). However, thermal instabilities set in, and the cold phase forms by cooling the fraction of the hot gas, and condensing into clouds at $T \sim 10^4$ K, mainly photoionized by the metagalctic ionizing background, in the pressure equilibrium with the hot halo. Clouds of the cold phase gradually sink toward the halo center in the galactic gravitational potential, but only some of them can reach the center before next major reheating - which occurs in mergers of equals. In the meantime, these clouds are actually what we see as (some of) the QSO absorption systems (Chiba & Nath 1997).

There are several merits in this picture. First, it is now clear that at least a fraction of low-redshift QSO absorption systems (both metal and Lyα) arise in galaxies: for metal lines that was shown, among others, by Sargent, Steidel & Boksenberg (1988), Bechtold & Ellingson (1992) and Petitjean & Bergeron (1994), and observations of redshift coincidences for low-redshift Lyα systems were performed by Lanzetta *et al.* (1995; hereafter LBTW), and recently strengthened by Chen *et al.* (1998). Second issue is its agreement with the necessity of having the extended gaseous halo to explain observed features of our Galaxy, for example both the high-velocity clouds (present day infall), and chemical composition of the disk (infall in early epochs); other infall models are developed in order to explain the redshift evolution of galactic luminosities (e.g. Phillipps 1993). Furthermore, the discovery of a highly-ionized species like O VI in QSO metal-line systems (Lu & Savage 1993) provided additional argument in favor of the hot, collisionally ionized halo model.

What is the characteristic size of these galactic halos? LBTW showed that, at low redshift, Lyα absorption is likely to arise at galactocentric radii smaller than $R_0 = 160\ h^{-1}$ kpc for a typical L_* galaxy. Chen *et al.* (1998) confirmed that result, slightly correcting the optimal value for R_0 to 149 h^{-1} kpc. This is obviously to be regarded as a lower limit for the extent of gas associated with a galaxy, since it is very difficult to imagine cold phase extending more than hot phase in which it originated. * On the other hand, these numbers are so large in comparison to the Holmberg radius (23 kpc for an L_* galaxy and $h = 0.5$), that it is highly improbable that hot gas can be extended *much* further than R_0. Even if the hot phase can be, at some point in the early galactic evolution, located at much greater distances, even a tiny interaction with nearby galaxies, or with an ambiental IGM (as we shall see) would strip off this very extended material. The physics of the cold phase formation also suggests that characteristic radii of hot and cold phase cannot be very different. In the further discussion, we shall assume that entire gas associated with a galaxy is located within the radius R, which is related to the galaxy luminosity (Chen *et al.* 1998) as

$$R = R_0 \left(\frac{L}{L_*}\right)^{0.35}, \tag{1}$$

R_0 being equal to 160 h^{-1} kpc (LBTW). However, the question of physical mechanisms for R_0 having that particular value has not been tackled yet. It is our goal in this paper to estimate the importance of both thermal and ram pressure of a smooth ambiental IGM for the sizes of hot halos of field galaxies. Both the enormous improvement in our understanding of the absorption properties of galaxies and the advent of new observational constraint on the elusive IGM represent a strong motivation in such an attempt.

2. THERMAL PRESSURE AT THE HOT HALO BOUNDARIES

In the simplest model of virialized halo parametrized by its circular velocity V_c, its density and temperature profile are given by the relations (MM96):

$$\rho(r) = \rho(r_c)\left[1 - K \ln\frac{r}{r_c}\right]^{\frac{3}{2}} \tag{2}$$

and

$$T(r) = T(r_c)\left[1 - K \ln\frac{r}{r_c}\right]. \tag{3}$$

The radius r_c where the cooling time of the gas is equal to t_m is the *cooling radius.* Inside it, the conditions of adiabaticity and hydrostatic equilibrium, lead to the equation of state $P \propto \rho^{5/3}$. Other notation is as follows: K is a dimensionless constant

---

* At least so for the normal-sized galaxies. Hereafter, we exclude the dwarf galaxies from our discussion (but see Wang, 1995).

equal to $K = \frac{2}{5} \frac{\mu V_c^2}{k_\mathrm{B} T(r_c)}$, k_B being the Boltzmann constant, μ average mass per particle, and $T(r_c)$ is the temperature at the cooling radius, by assumption equal to the virial temperature: $T(r_c) \equiv \mu V_c^2/2k_\mathrm{B}$. For a typical $V_c \simeq 220$ km s^{-1} corresponding to an L_* galaxy, this temperature is $T(r_c) = 3.9 \times 10^6$ K, and the constant K has the value $K = 0.8$. For $t_m = 5$ Gyr, cooling radius is $r_c = 102$ kpc.

In further discussion, we shall assume a constant global metallicity of the halo gas equal to $Z = 0.01\ Z_\odot$. This choice has several advantages. It characterizes extreme Population II objects, but in the same time is thermodynamically indistinguishable in comparison to the Population III properties, since so diluted metals are not efficient coolants any more, and the cooling curve stays practically the same down to the primordial chemical abundances $Z = 0$ (Böhringer & Hensler 1989). Its practical advantage is that we can use a nice analytical expression for the cooling function between 10^5 K and 10^7 K, i.e. in the interesting range (e.g. Lepp *et al.* 1985):

$$\Lambda(T) \approx 1.3 \times 10^{-19}\, T^{-\frac{1}{2}} \text{ erg cm}^3 \text{ s}^{-1}. \tag{4}$$

For the more exact numerical treatment see Sutherland & Dopita (1993). In the extension of this work, we shall investigate the effects of changing metallicity, as well as allowing metallicities to vary with galactocentric radius (as expected from scarce empirical data). We shall also take the parameter f_g in MM96 to be equal to 0.05, the value in agreement with the BBN predictions of the total baryon density. The average interval between reheating is set to $t_m = 5$ Gyr, although it can be shown that relevant results depend quite weakly on our choice for this parameter (Ćirković 1998).

As an illustration of the viability of the hot halo model, we briefly discuss the pressure at the halo-ISM interface. Inner boundary condition for hot halo model is that the pressure of coronal gas is to be equal to the pressure of ISM. One should be careful in choosing the inner boundary radius of the hot gas, since in the innermost regions it can not be in the hydrostatic equilibrium any more; instead, it will probably be in complicated dynamic disk-halo interaction through some form of the "galactic fountain" or wind mechanism (Shapiro & Field 1976; Norman & Ikeuchi 1989), which will generally tend to make the slope of the pressure curve shallower (when averaged over individual clouds) at small radii. Following Mo (1994), we choose as the core radius boundary the approximate size of the disk $R_d = 20$ kpc. The pressure of hot halo for our choice of parameters is then

$$\log \frac{P(R_d)}{k_\mathrm{B}} = 3.2 \text{ K cm}^{-3}. \tag{5}$$

On the empirical basis, pressure in the local ISM was estimated as $\log P/k_\mathrm{B} = 3.23$ K cm^{-3} (Spitzer 1978), or at large sample of measured clouds (Jenkins, Jura, & Loewenstein 1983) we have on the average

$$3.2 \leq \log P/k_\mathrm{B} \leq 3.8. \tag{6}$$

(See also Figs. 4, 5, 6, 7 and 8 in Wolfire *et al.* [1995] and the discussion therein.) All these measurements were made at galactocentric distances considerably smaller than R_d, so we expect them to be systematically (but not significantly) larger than our estimated value. We conclude that for a typical choice of parameters of the two-phase model, hot halo is in the global pressure equilibrium with the ISM at the inner boundary, as expected. Note that local conditions may be well outside of equilibrium, especially if a dynamical phenomenon like the galactic fountain takes place.

In discussing the thermal pressure at the outer boundary of the hot halos, it is necessary to have several restrictions in mind. It is far from certain that the gas outside of the cooling radius is in equilibrium, and that equations (eq. (2)) and (eq. (3)) are correctly describing state of matter at such large galactocentric distances. Nevertheless, we take it as a working hypothesis, with hope that future theoretical work will result in constructing more detailed picture of cooling and other relevant processes (thermal conduction, KH instability, etc.). The pressure of an ambiental IGM having the temperature $T_{\rm IGM}$ and cosmological density parameter $\Omega_{\rm IGM}$ can be written as

$$P/k_{\rm B} = 8.02 \times 10^{-6}\, T_{\rm IGM}\Omega_{\rm IGM}h^2(1+z)^3 \ {\rm K\ cm^{-3}}. \qquad (7)$$

This is only the pressure of the completely smooth component, and any over- or under-densities should be superimposed on the values obtained from eq. (7). The strongest constraints on the physical state if the intergalactic medium come from simultaneous consideration of the Gunn-Peterson limit, COBE measurements of the smoothness of CMBR and X-ray absorption against bright QSOs (BFR; Aldcroft *et al.* 1994). These results suggest only a relatively narrow range of admissible intergalactic pressures. Completely smooth IGM density is limited from above by the BBN constraint $\Omega_{\rm IGM} < 0.026\ h^{-2}$. We shall, therefore, assume $\Omega_{\rm IGM} = 0.1$ as the absolute upper limit to the quantity of smooth intergalactic gas. As discussed above, there is no established lower limit on $\Omega_{\rm IGM}$, but one can assume $\Omega_{\rm IGM} = 0.01$ as a typical "conservative" value. Note that with intergalactic density so low, the formation of galaxies must be a highly efficient process, much more efficient than actually implied by the recent numerical simulations (Cen & Ostriker 1993).

Low-temperature limit on $T_{\rm IGM}$ for any assumed density is given by the Lyα Gunn-Peterson effect (Giallongo, Cristiani, & Trevese 1992; Giallongo *et al.* 1994). It turns out that $T_{\rm IGM} > 10^5$ K is the necessary condition to be satisfied for all reasonable choices of $\Omega_{\rm IGM}$. On the other hand, Fig. 1a of BFR shows the maximal values of $T_{\rm IGM}$, as determined from the COBE data. It is generally between 10^6 and 10^7 K. Accordingly, in Fig. 1 of the present work, we took the highest possible values of pressure for a given $\Omega_{\rm IGM}$. The allowed variation of $P_{\rm IGM}/k_{\rm B}$ lies between the two horizontal lines, and is not only suprisingly small (testifying on the strength of the COBE constraints), but also quite discrepant with the pressure of the hot halo within the two-phase model and any reasonable galactocentric radius. Just for comparison, on the Fig. 1, we have marked the *maximal* extent of the cold (absorbing) phase, according to LBTW. We see that discrepancy between the halo and intergalactic thermal pressure is spanning about three orders of magnitude, and there is practically no possibility for the two to be in any sort of pressure equilibrium. Again, it is necessary to emphasize that this conclusion applies explicitly only to $z = 0$; as is seen, *inter alia*, from the Fig. 1b of BFR, situation may be profoundly different at early epoch of the galactic history.

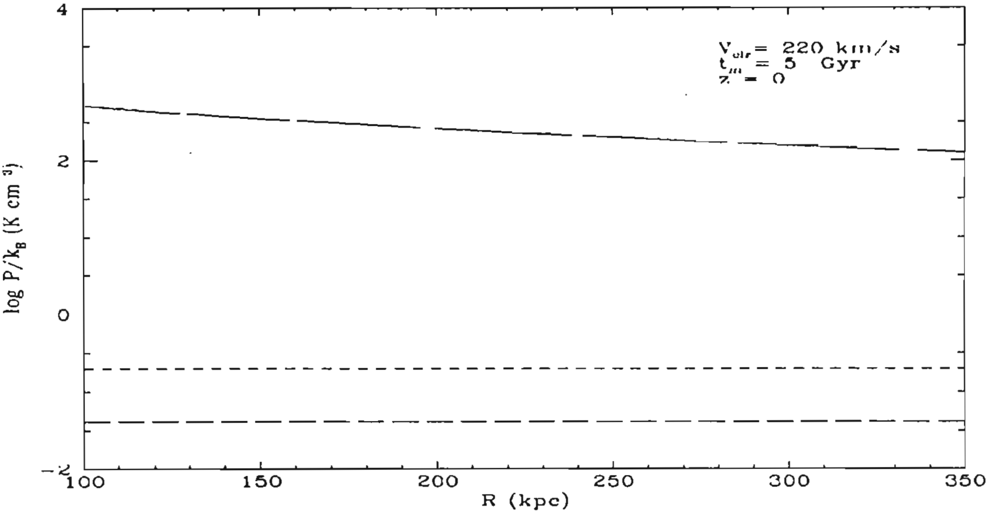

Fig. 1. Thermal pressure of the hot halo corresponding to an L_* galaxy as a function of galactocentric distance in the two-phase model, with other parameters: $f_g = 0.05$, $z = 0$ (present epoch) and $t_m = 5$ Gyr. Horizontal lines represent the *maximal* ambiental IGM pressure for $\Omega_{\rm IGM} = 0.1$ (short-dashed) and $\Omega_{\rm IGM} = 0.01$ (long-dashed line). Vertical tick denotes the LBTW low-redshift absorption radius for $h = 0.5$.

3. RAM-PRESSURE CONFINEMENT BY IGM

Ram-pressure stripping of gas from gravitationally bound astrophysical systems was discussed by many authors in the last quarter of century (Gunn & Gott 1972; Gisler 1979; Farouki & Shapiro 1980; Sarazin 1986; Sofue & Wakamatsu 1993; Sofue 1994) mainly in the context of stripping of the gas in cluster galaxies by dense ICM, but also in the context of depletion of globular cluster gas (Frank & Gisler 1976; Ninković 1985), and mass stripping of Lyα clouds in the minihalo model (Murakami & Ikeuchi 1994). The mechanism of the sweeping of gas by the ram pressure is well-established, although detailed results require sophisticated numerical modeling. We shall hereby limit ourselves to a very simple approach, and relegate more serious discussion to a later work.

The force law for the cloud of gas of size R at the galactocentric distance r in the scalar form is (see, for example, Sofue & Wakamatsu 1993):

$$m\frac{d^2r}{dt^2} = m\frac{\partial\Phi(r)}{\partial r} - \pi R^2\rho(r)(\Delta v)^2, \tag{8}$$

where Δv is the relative velocity of a cloud with respect to the galaxy. In further discussion we shall approximate $\Delta v = v_{\rm pec}$, where $v_{\rm pec}$ is the peculiar velocity of the galaxy with respect to the CMBR. this need not necessarily represent actual differential velocity of the galaxy in comparison to the local IGM. Still, we shall use this approximation in the present discussion, and relegating more detailed treatment to a later work. From the eq. (8) follows the Gunn & Gott (1972) criterion for the sweeping of the gas by ram pressure; in our notation we can write it as

$$\rho_{IGM}(\Delta v)^2 > \rho(r) v_0(r), \tag{9}$$

where $v_0(r)$ is the escape velocity at the considered point. On the right-hand side of the eq. (9), we have physical quantities dependent on galactocentric distance r. The critical case for which this inequality becomes equality (i.e. the forces on a volume element of gas are exactly balanced) can be described by $f(r_{\rm crit}) = 1$, where the dimensionless function f is given by

$$f(r) = \frac{\rho_{\rm IGM}}{\rho(r)}\frac{(\Delta v)^2 r}{2GM(r)} = 8.02\times 10^{-6}\,\frac{m_{\rm H}\mu\,\Omega_{\rm IGM}h^2(1+z)^3(\Delta v)^2 r}{2GM\rho(r_c)\left(1-0.8\ln\frac{r}{r_c}\right)^{3/2}}, \tag{10}$$

where $m_{\rm H}$ is the mass of hydrogen atom, and we approximated the total mass enclosed in radius r with the mass of entire L_* galaxy $M(r) \equiv M \approx 5\times 10^{11}\ M_\odot$ (since we are dealing here with very large galactocentric distances $r \gtrsim 10^2$ kpc, it is reasonable to assume that the dark matter distribution is truncated at some smaller radius). We have also used the relation (eq. (2)) for the density of the hot halo gas.

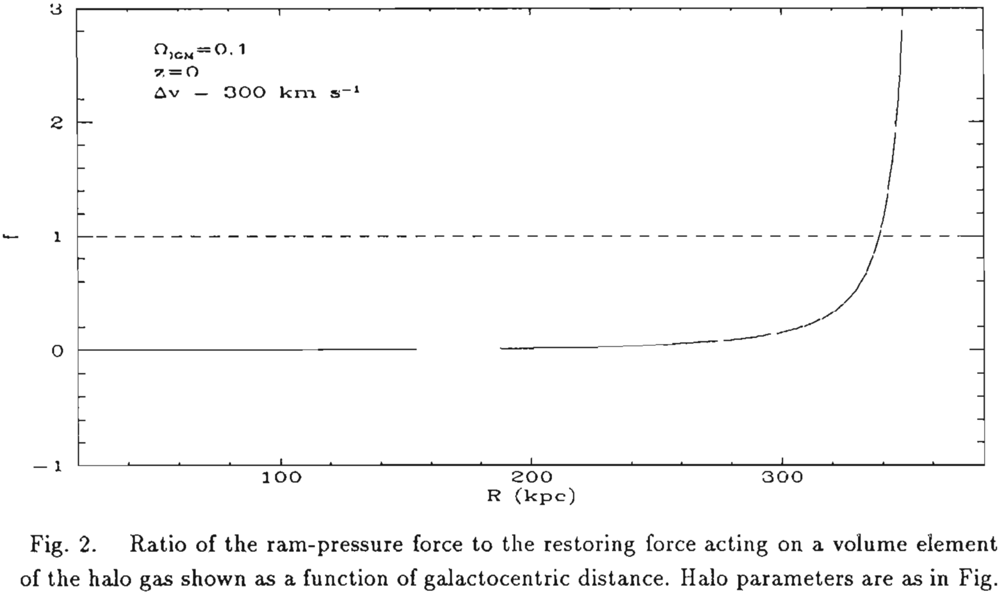

Fig. 2. Ratio of the ram-pressure force to the restoring force acting on a volume element of the halo gas shown as a function of galactocentric distance. Halo parameters are as in Fig. 1, and a differential velocity $\Delta v = v_{\rm pec} = 300$ km s^{-1} is assumed. Above the horizontal dashed line, gas is swept by the intergalactic ram-pressure, and after reaching steady-state can not be associated with the galactic halo.

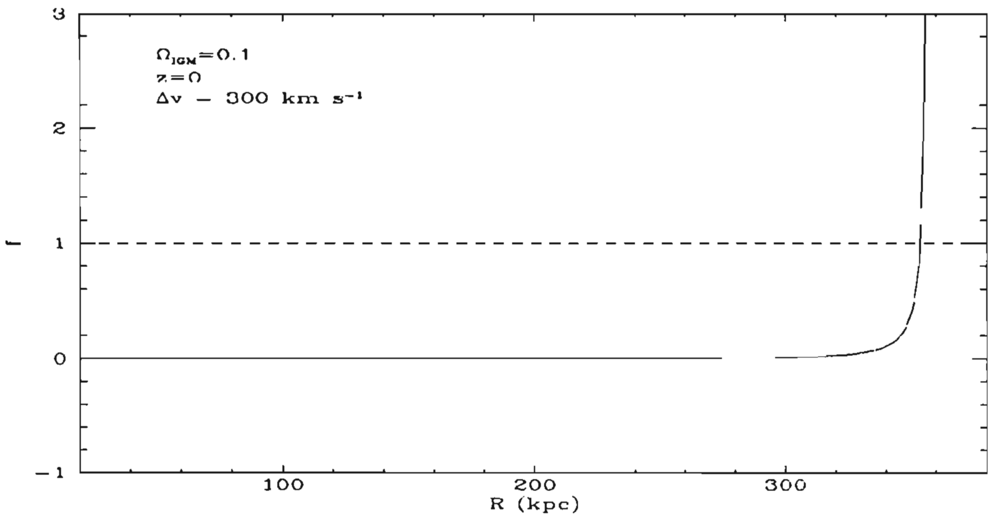

Fig. 3. The same as in Fig. 2, with the cosmological density parameter in IGM set to a "conservative" value of $\Omega_{\rm IGM} = 0.01$.

The resulting plot of function f vs. galactocentric distance at present epoch is shown in Figures 2 (for $\Omega_{\rm IGM} = 0.1$) and 3 (for $\Omega_{\rm IGM} = 0.01$). A typical peculiar velocity is assumed to be $\Delta v \approx 300$ km s^{-1} (e.g. Gavazzi *et al.* 1991; Courteau *et al.* 1993). We notice that, as expected, at small galactocentric distances, restoring force acting on a volume element of gas is completely dominant, and ram-pressure is completely negligible. It steeply increases when we consider distances $\gtrsim$300 kpc and after reaching equilibrium at critical radius of $\sim$ 318 kpc ($\Omega_{\rm IGM} = 0.1$) or $\sim$ 325 kpc ($\Omega_{\rm IGM} = 0.1$), continues to increase rapidly toward infinity (i.e. point where restoring force associated with the galaxy becomes negligible). In both Fig. 2 and Fig. 3, we see that gas at every point for which f is below the dashed horizontal line can be associated with galaxy, but the gas at points above the $f = 1$ line will be stripped on a short time-scale (as indicated by the large slope of f). It is essential to note that the critical radius for the ram-pressure stripping is intriguingly similar to the characteristic absorption radius R_0 in the eq. (1), as indicated by the absorption statistics of LBTW and Chen *et al.* (1998).

4. CONCLUSIONS AND PROSPECTS

Hot halo medium in a simple, two-phase model represents natural transition between the ISM and the IGM. We have hereby shown that pressure considerations quite agree with this picture. Ram-pressure stripping of the hot gas by the ambiental IGM seems to be a viable mechanism for confining the galactic halos. Typical critical radii of ram-pressure stripping ($\sim$ 320 kpc) are quite near to those values obtained from the absorption line studies for L_* galaxies. That does not, of course, proves that this is actually dominant mechanism for confinement of the hot halos. Other effects, thermal and gasdynamical instabilities may play very significant or dominant roles. Other difficulties involved with ram-pressure mechanism are sharp anisotropies and resulting flattening of the hot halos. Although there are some indications that ensembles of QSO absorbers may actually be flattened (Rauch & Haehnelt 1995), the question is far from clear. However, we may hope that the results presented here will encourage more sophisticated models of the same type to be investigated.

Model of ram-pressure confinement predicts an anticorrelation between the size of the halo and differential velocity of the galaxy with respect to the local IGM (peculiar velocity in our approximation). With plausible assumptions about thermal instabilities in the hot halo, this gives rise to a similar anticorrelation between peculiar velocity and maximal extent of the cold, photoionized phase, which can be, in principle, empirically established through the studies of the QSO absorption line systems. Unfortunately, the magnitude of this effect is still too small to be observationally checked, and there are as yet no peculiar velocity surveys in the absorption-selected samples of galaxies. But, looking back at the dynamic development of the absorption studies, we may hope that the enormously improved statistics of the near future will be able to resolve this question.

One of further interesting issues to be addressed in subsequent work is the question of redshift evolution of the galaxy-IGM interface. The thermal intergalactic pressure evolves very strongly with redshift: $P_{\rm IGM} \propto (1+z)^5$ in the simplest model (e.g. Peebles 1993). Thus, although it is unlikely, as we have shown, that it represents a major influence today, its enhancement for the factor of $\sim 10^3$ by the redshift $z = 3$ could change the situation. Parameters of the halo also change for $z > 0$, as shown in MM96, and further work is necessary to disentagle all these interconnected influences. On the other hand, the ram-pressure mechanism is subject to additional uncertainty in redshift evolution of peculiar velocities (which will partially offset the density increase). An attractive speculation is that these evolutionary effects might play some role in the transition between two distinct populations of Lyα absorption systems - a rapidly evolving intergalactic population dominating at high z, and a slowly evolving, strongly clustered galactic population dominating at $z < 1$ - as suggested by recent observations (e.g. Bahcall *et al.* 1996) as well as the investigations of the absorber autocorrelation function (Fernández-Soto *et al.* 1996; Cristiani *et al.* 1996). Obviously, much theoretical work remains to be done in this exciting field.

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THE EQUATION OF STATE OF A DEGENERATE FERMI GAS

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Abstract. An analytical expression for Fermi-Dirac integrals of arbitrary order is presented, and its applicability in obtaining an analytical EOS of a degenerate non-relativistic Fermi gas is discussed to some extent.

1. INTRODUCTION

Degenerate Fermi gases occur in a variety of systems studied in astrophysics and "laboratory" physics. Examples of such systems include white dwarfs and neutron stars, planetary interiors, ordinary metals and organic conductors.

The general form of the equation of state (EOS) of a non-relativistic degenerate Fermi gas has been determined more than half a century ago (for example, Chandrasekhar, 1939) as:

$$n_e = \frac{4\pi}{h^3}(2m_e k_B T)^{3/2} F_{1/2}(\eta) \tag{1}$$

All the symbols have their standardized meanings, and $F_{1/2}(\eta)$ denotes a particular case of the Fermi-Dirac (FD) integrals of order n:

$$F_n(\eta) = \int_0^\infty \frac{f(\epsilon)d\epsilon}{1+\exp[\beta(\epsilon-\mu)]} \tag{2}$$

where $f(\epsilon) = \epsilon^n$,n$\in$R,μ denotes the chemical potential, β is the inverse temperature, and $\eta = \beta\mu$.

The practical problem of the numerical evaluation of the FD integrals has been the object of several recent studies (such as Cloutman, 1989; Antia, 1993; Miralles and Van Riper, 1995). The purpose of the present paper is to obtain an analytical approximation to the FD integrals of arbitrary order, and to apply it to the problem of the EOS of a degenerate Fermi gas.

2. THE CALCULATIONS

Taking $k_B = 1$, and introducing a change of variables by

$$\epsilon - \mu = Tz \tag{3}$$

eq. (2) can be transformed into the following form:

$$F_n(\beta\mu) = T\int_{-\mu/T}^{\infty} \frac{f(\mu+Tz)}{1+\exp[z]} = \int_0^{\mu} f(\epsilon)d\epsilon + T\int_0^{\infty} \frac{f(\mu+Tz)-f(\mu-Tz)}{1+\exp[z]}dz \quad (4)$$

The difference of values of f in the last integral of eq. (4) can be developed into series as

$$f(\mu+Tz) - f(\mu-Tz) = \sum_{n=0}^{\infty}[1-(-1)^n]\frac{(Tz)^n}{n!}f^{(n)}(\mu) \quad (5)$$

Inserting eq. (5) into eq. (4) and using the fact that

$$\int_0^{\infty} \frac{x^{\alpha-1}}{1+\exp[z]}dx = (1-2^{1-\alpha})\Gamma(\alpha)\zeta(\alpha)$$

where $\Gamma(\alpha)$ and $\zeta(\alpha)$ denote the gamma function and Riemann's zeta function, one gets the following final form of the FD integrals of arbitrary order:

$$F_n(\beta\mu) = \int_0^{\mu} f(\epsilon)d\epsilon + T\sum_{n=0}^{\infty}\frac{f^{(n)}(\mu)}{n!}[1-(-1)^n]T^n(1-2^{-n})\Gamma(n+1)\zeta(n+1) \quad (6)$$

This expression is a generalization to arbitrary order and number of terms of existing partial results (for example, Landau and Lifchitz, 1976).

3. DISCUSSION

Inserting $n = 1/2$ into eq. (6) and limiting the sum to terms up to and including T^6, it follows that

$$F_{1/2}(\eta) \cong \frac{2}{3}\mu^{3/2}\left[1+\frac{\pi^2}{8}\left(\frac{T}{\mu}\right)^2+\frac{7\pi^4}{640}\left(\frac{T}{\mu}\right)^4+\frac{31\pi}{3072}\left(\frac{T}{\mu}\right)^6\right] \quad (7)$$

This result is impractical, because the chemical potential itself is a function of T and the number density of the Fermi gas. It can be shown from eq. (1) that this function can be approximated by the following developement:

$$\mu \cong \mu_0\left[1-\frac{\pi^2}{12}\left(\frac{T}{\mu_0}\right)^2+\frac{\pi^4}{720}\left(\frac{T}{\mu_0}\right)^4-\frac{\pi^6}{162}\left(\frac{T}{\mu_0}\right)^6+\frac{\pi^8}{754}\left(\frac{T}{\mu_0}\right)^8\right] \quad (8)$$

The symbol μ_0 denotes the chemical potential of the electron gas at T = 0 K, and it depends only on the particle number density. Inserting eq. (8) into eq. (7) and developing into series in T, one gets

$$F_{1/2}(T) \cong \frac{2}{3}\mu_0^{3/2}\left[1+\frac{\pi^4}{48}\left(\frac{T}{\mu_0}\right)^4+\frac{19\pi^6}{5760}\left(\frac{T}{\mu_0}\right)^6+\frac{\pi^8}{146}\left(\frac{T}{\mu_0}\right)^8\right] \quad (9)$$

Note that we have managed to express this FD integral as an explicite function of the particle number density and the temperature. This result is a distnct advantage over some previous numerical work (such as Cloutman, 1989), where the argument of this integral was left in the form $\beta\mu$, without taking into account the number-density and temperature dependences of the chemical potential.

How can eq. (9) be applied to in obtaining an analytical EOS of a degenerate Fermi gas? Inserting, at first, the known result for μ_0 into eq. (9), one would get an expression showing explicitely the dependence of a FD integral of the order 1/2 on the particle number density and temperature. Going a step further and inserting this result into eq. (1), one would get the required EOS, in the form of an equation relating the number density, temperature and various known constants (such as h and k_B). This result has the form

$$n_e - K_1 W n_e T^{3/2} - K_2 W n_e^{-5/3} T^{11/2} - K_3 W n_e^{-3} T^{15/2} - K_4 W n_e^{-13/3} T^{19/2} = 0 \quad (10)$$

where n_e denotes the number density of the electrons and all the other symbols denote different combinations of known constants. The low temperature limit of this equation, obtained by developing it into series in T up to terms including T^9, is solvable within S. Wolfram's MATHEMATICA 3 software package in a few minutes on a Pentium MMX/166 with 32 Mbytes RAM. The solution has the form

$$n \cong -\frac{1}{6^{1/4}}[[\frac{6K_3WT^{15/2} - 12K_1K_3W^2T^9 + 6K_1^2K_3W^3T^{21/2}}{1 - 3K_1WT^{3/2} + 3K_1^2T^3 - K_1^3W^3T^{9/2}} - << ... >> \quad (11)$$

where << .. >> denotes terms omitted due to space limitations.

We have thus obtained an analytical form of the EOS of a degenerate Fermi gas. The volume per particle, needed in some applications, is simply the inverse density. Our result is approximate, in the sense that the developement in eq. (9) is limited to a small number of terms. Increasing the number of terms and applying this EOS to real physical systems will be the subject of future work.

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ON THE STARK BROADENING OF Sc X LINES

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Abstract. Using a semiclassical approach, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 4 Sc X multiplets, for perturber densities $10^{19}-10^{22}$ cm^{-3} and temperatures T = 200,000 − 5,000,000 K.

1. INTRODUCTION

Scandium is present in stellar and solar plasma, so that the various atomic data concerning this element, including Stark broadening parameters of its spectral lines for various ionization stages are of interest for stellar and solar physics. Particularly for the modelling and theoretical considerations of subphotospheric layers, atomic data on higher ionization stages are of interest (Seaton, 1997). Of course, Stark broadening parameters for multiply charged scandium ion lines are as well of interest for the laboratory plasma research, testing and developping of the Stark broadening theory for multicharged ion lines, and investigations of systematic trends along isoelectronic sequences.

By using the semiclassical-perturbation formalism (Sahal-Bréchot 1969ab), we have calculated electron-, proton-, and He III-impact line widths and shifts for 4 scandium X multiplets. A short review of the formalism is given e.g. in Dimitrijević *et al.* (1991) and Dimitrijević and Sahal - Bréchot (1996).

2. RESULTS AND DISCUSSION

Energy levels for scandium X lines have been taken from Bashkin and Stoner (1978). All other details of calculations are given in Dimitrijević and Sahal-Bréchot (1998). Our results for electron-, proton-, and He III-impact line widths and shifts for 4 scandium X multiplets, for perturber densities $10^{19}-10^{22}$ cm^{-3} and temperatures T = 200,000 − 5,000,000 K, will be published elsewhere (Dimitrijević and Sahal-Bréchot, 1998). We present here in Table 1, only data for perturber density of 10^{19} cm^{-3}. We also specify a parameter C (Dimitrijević and S.Sahal-Bréchot, 1984), which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding full width at half maximum.

Table 1. This table shows electron- and proton-impact broadening full half-widths (FWHM) and shifts for Sc X for a perturber density of 10^{19} cm^{-3} and temperatures from 200,000 up to 5,000,000 K. By deviding C with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
Sc X 3S-3P	200000.	0.257E-01	-0.164E-03	0.146E-03	-0.876E-04
422.9 A	500000.	0.165E-01	-0.196E-03	0.473E-03	-0.225E-03
C=0.42E+22	1000000.	0.121E-01	-0.259E-03	0.871E-03	-0.393E-03
	2000000.	0.916E-02	-0.244E-03	0.127E-02	-0.579E-03
	3000000.	0.787E-02	-0.238E-03	0.146E-02	-0.706E-03
	5000000.	0.661E-02	-0.231E-03	0.165E-02	-0.815E-03
Sc X 3P-4S	200000.	0.499E-02	0.227E-03	0.606E-04	0.201E-03
147.3 A	500000.	0.337E-02	0.299E-03	0.251E-03	0.390E-03
C=0.14E+21	1000000.	0.258E-02	0.284E-03	0.440E-03	0.542E-03
	2000000.	0.203E-02	0.270E-03	0.643E-03	0.652E-03
	3000000.	0.178E-02	0.258E-03	0.756E-03	0.722E-03
	5000000.	0.151E-02	0.223E-03	0.915E-03	0.821E-03
Sc X 3P-5S	200000.	0.399E-02	0.376E-03	0.193E-03	0.380E-03
96.3 A	500000.	0.283E-02	0.427E-03	0.478E-03	0.622E-03
C=0.32E+20	1000000.	0.225E-02	0.425E-03	0.720E-03	0.760E-03
	2000000.	0.182E-02	0.401E-03	0.933E-03	0.910E-03
	3000000.	0.161E-02	0.358E-03	0.110E-02	0.101E-02
	5000000.	0.139E-02	0.301E-03	0.133E-02	0.111E-02
Sc X 3P-3D	200000.	0.206E-01	-0.669E-04	0.204E-03	-0.321E-04
357.5 A	500000.	0.133E-01	-0.681E-04	0.591E-03	-0.835E-04
C=0.30E+22	1000000.	0.970E-02	-0.969E-04	0.971E-03	-0.156E-03
	2000000.	0.731E-02	-0.794E-04	0.134E-02	-0.247E-03
	3000000.	0.629E-02	-0.788E-04	0.146E-02	-0.299E-03
	5000000.	0.530E-02	-0.730E-04	0.160E-02	-0.367E-03

Experimental data or other theoretical data on the scandium X Stark broadening parameters do not exist. The corresponding experimental data will be of course very useful for checking and further development and rafinement of the theory of multicharged ion lines.

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ON THE STARK BROADENING OF Mg XI LINES

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Abstract. Using a semiclassical approach, we have calculated electron-, proton-, and He III-impact line widths and shifts for 18 Mg XI multiplets.

1. INTRODUCTION

Data on magnesium spectral lines as well as on its various ionization stages are of interest for investigation of a number of physical processes in stellar, laboratory and technological plasmas. Data on Mg XI spectral lines are as well of interest for the study of systematic trends along helium isoelectronic sequence and for testing and developing of the Stark broadening theory for multicharged ions.

We have calculated here within the semiclassical-perturbation formalism (Sahal-Bréchot 1969ab), electron-, proton-, and He III-impact line widths and shifts for 18 Mg XI multiplets. A summary of the formalism is given e.g. in Dimitrijević *et al.* (1991) and will not be repeated here.

2. RESULTS AND DISCUSSION

As a continuation of our project to provide to astrophysicists and plasma physicists the needed Stark-broadening parameters (see Dimitrijević 1996, Dimitrijević and Sahal-Bréchot 1995 and references therein), electron-, proton-, and He III- impact Mg XI line widths and shifts have been calculated. Energy levels for Mg XI have been taken from Martin and Zalubas (1980). Our results for 18 Mg XI multiplets, for perturber densities 10^{18} - 10^{24} cm^{-3} and temperatures T = 500,000 - 5,000,000K will be published in Dimitrijević and Sahal-Bréchot (1998a,b).

Table 1
This table shows electron- and proton-impact broadening full half-widths (FWHM) and shifts for Mg XI (singlets) for a perturber density of 10^{19} cm^{-3} and temperatures from 500,000 up to 5,000,000 K. By deviding C with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used. The asterisk identifies cases for which the collision volume multiplied by the perturber density (the condition for validity of the impact approximation) lies between 0.1 and 0.5.

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
Mg XI 1S 2P	500000.	0.250E-05	-0.347E-07	0.147E-07	-0.400E-07
9.2 A	750000.	0.205E-05	-0.163E-07	0.287E-07	-0.594E-07
C=0.57E+18	1000000.	0.179E-05	-0.158E-07	0.451E-07	-0.768E-07
	2000000.	0.129E-05	-0.111E-07	0.116E-06	-0.129E-06
	3000000.	0.108E-05	-0.931E-08	0.171E-06	-0.158E-06
	5000000.	0.862E-06	-0.427E-08	0.268E-06	-0.201E-06
Mg XI 1S 3P	500000.	0.843E-05	-0.379E-06	0.235E-05	-0.276E-05
7.9 A	750000.	0.714E-05	-0.352E-06	0.355E-05	-0.330E-05
C=0.23E+17	1000000.	0.637E-05	-0.335E-06	0.444E-05	-0.354E-05
	2000000.	0.486E-05	-0.299E-06	0.652E-05	-0.428E-05
	3000000.	0.418E-05	-0.255E-06	0.795E-05	-0.473E-05
	5000000.	0.347E-05	-0.202E-06	0.971E-05	-0.529E-05
Mg XI 2S 2P	500000.	0.819E-01	-0.257E-02	0.984E-03	-0.425E-02
1473.6 A	750000.	0.681E-01	-0.247E-02	0.223E-02	-0.599E-02
C=0.15E+23	1000000.	0.600E-01	-0.241E-02	0.339E-02	-0.734E-02
	2000000.	0.446E-01	-0.231E-02	0.800E-02	-0.106E-01
	3000000.	0.378E-01	-0.222E-02	0.122E-01	-0.128E-01
	5000000.	0.309E-01	-0.191E-02	0.178E-01	-0.147E-01
Mg XI 2S 3P	500000.	0.401E-03	-0.192E-04	0.107E-03	-0.126E-03
52.7 A	750000.	0.341E-03	-0.185E-04	0.162E-03	-0.151E-03
C=0.11E+19	1000000.	0.304E-03	-0.176E-04	0.201E-03	-0.161E-03
	2000000.	0.233E-03	-0.160E-04	0.298E-03	-0.196E-03
	3000000.	0.201E-03	-0.140E-04	0.361E-03	-0.215E-03
	5000000.	0.167E-03	-0.114E-04	0.447E-03	-0.242E-03
Mg XI 3S 3P	500000.	4.89	-0.355	1.26	-1.49
5065.9 A	750000.	4.19	-0.347	1.89	-1.75
C=0.98E+22	1000000.	3.77	-0.336	2.26	-1.89
	2000000.	2.94	-0.308	3.34	-2.26
	3000000.	2.55	-0.270	4.06	-2.48
	5000000.	2.14	-0.222	5.06	-2.76

Table 1 continued

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
Mg XI 2P 3S	500000.	0.254E-03	0.246E-04	0.404E-04	0.676E-04
55.2 A	750000.	0.219E-03	0.244E-04	0.578E-04	0.830E-04
C=0.60E+19	1000000.	0.198E-03	0.239E-04	0.760E-04	0.940E-04
	2000000.	0.156E-03	0.222E-04	0.122E-03	0.113E-03
	3000000.	0.135E-03	0.198E-04	0.150E-03	0.125E-03
	5000000.	0.113E-03	0.166E-04	0.191E-03	0.142E-03
Mg XI 2P 4S	500000.	0.310E-03	0.432E-04	0.667E-04	0.952E-04
40.7 A	750000.	0.270E-03	0.427E-04	0.971E-04	0.112E-03
C=0.32E+19	1000000.	0.246E-03	0.422E-04	0.112E-03	0.121E-03
	2000000.	0.197E-03	0.389E-04	0.156E-03	0.144E-03
	3000000.	0.173E-03	0.344E-04	0.186E-03	0.159E-03
	5000000.	0.147E-03	0.289E-04	0.231E-03	0.177E-03
Mg XI 2P 5S	500000.	0.748E-03	0.109E-03	*0.440E-03	*0.426E-03
36.1 A	750000.	0.660E-03	0.105E-03	*0.530E-03	*0.485E-03
C=0.55E+18	1000000.	0.603E-03	0.979E-04	*0.601E-03	*0.520E-03
	2000000.	0.481E-03	0.896E-04	*0.793E-03	*0.602E-03
	3000000.	0.419E-03	0.789E-04	*0.928E-03	*0.659E-03
	5000000.	0.350E-03	0.641E-04	0.113E-02	0.734E-03
Mg XI 3P 4S	500000.	0.754E-02	0.816E-03	0.196E-02	0.224E-02
160.3 A	750000.	0.653E-02	0.803E-03	0.266E-02	0.252E-02
C=0.98E+19	1000000.	0.592E-02	0.788E-03	0.315E-02	0.273E-02
	2000000.	0.469E-02	0.723E-03	0.446E-02	0.326E-02
	3000000.	0.409E-02	0.637E-03	0.545E-02	0.360E-02
	5000000.	0.345E-02	0.530E-03	0.664E-02	0.391E-02
Mg XI 3P 5S	500000.	0.774E-02	0.102E-02	*0.409E-02	*0.388E-02
106.7 A	750000.	0.680E-02	0.978E-03	*0.494E-02	*0.441E-02
C=0.43E+19	1000000.	0.620E-02	0.914E-03	*0.560E-02	*0.473E-02
	2000000.	0.492E-02	0.836E-03	*0.757E-02	*0.554E-02
	3000000.	0.428E-02	0.735E-03	*0.895E-02	*0.591E-02
	5000000.	0.358E-02	0.597E-03	*0.110E-01	*0.658E-02
Mg XI 2P 3D	500000.	0.270E-03	0.103E-04	0.691E-04	0.806E-04
54.7 A	750000.	0.226E-03	0.999E-05	0.103E-03	0.994E-04
C=0.11E+19	1000000.	0.200E-03	0.924E-05	0.138E-03	0.111E-03
	2000000.	0.151E-03	0.930E-05	0.215E-03	0.134E-03
	3000000.	0.129E-03	0.857E-05	0.261E-03	0.148E-03
	5000000.	0.107E-03	0.718E-05	0.320E-03	0.167E-03

Here, only a sample of results is shown in Table 1. Parameter C (Dimitrijević and Sahal-Bréchot 1984), given also in Table 1, provides an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding electron-impact full width at half maximum. For each Stark broadening parameter shown in Table 1, the collision volume (V) multiplied by the perturber density (N) is much less than one and the impact approximation is valid (Sahal–Bréchot, 1969ab). Values for $NV > 0.5$ are not given and values for $0.1 < NV \leq 0.5$ are denoted by an asterisk.

The presented values may be of interest for a number of problems concerning the stellar, laboratory, fusion and laser produced plasma, and soft x-ray lasers modeling and research. The obtained results are of interest as well for the investigation of behaviour of Stark broadening parameters along isoelectronic sequences.

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ON THE STARK BROADENING OF Na X LINES

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Abstract. Using a semiclassical approach, we have calculated electron-, proton-, and He III-impact line widths and shifts for 57 Na X multiplets.

1. INTRODUCTION

For the consideration of physical processes in stellar, laboratory and technological plasmas, the data on spectral lines from sodium and its various ionization stages are of interest. Recently, Griem and Moreno (1990) and Fill and Schöning (1994) pointed out the importance of such results for the development of soft x-ray lasers, where Stark broadening data are needed to calculate gain values, model radiation trapping and to consider photoresonant pumping schemes.

In order to provide the Na X Stark broadening parameters,we have calculated within the semiclassical-perturbation formalism (Sahal-Bréchot 1969ab), electron-, proton-, and He III-impact line widths and shifts for 57 Na X multiplets. A summary of the formalism is given in Dimitrijević *et al.* (1991).

2. RESULTS AND DISCUSSION

In accordance with our project to provide to astrophysicists and plasma physicists the needed Stark-broadening parameters (see Dimitrijević 1996, Dimitrijević and Sahal-Bréchot 1995 and references therein), electron-, proton-, and He III- impact Na X line widths and shifts have been calculated. Energy levels for Na X have been taken from Martin and Zalubas (1981). Our results for 57 Na X multiplets, for perturber densities 10^{17} - 10^{24} cm^{-3} and temperatures T = 200,000 - 5,000,000K will be published in Dimitrijević and Sahal-Bréchot (1998a,b).

Table 1
This table shows electron- and proton-impact broadening full half-widths (FWHM) and shifts for Na X (singlets) for a perturber density of 10^{19} cm^{-3} and temperatures from 200,000 up to 5,000,000 K. By deviding C with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used. The asterisk identifies cases for which the collision volume multiplied by the perturber density (the condition for validity of the impact approximation) lies between 0.1 and 0.5.

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
Na X 2S-2P	200000.	0.174	-0.351E-02	0.326E-03	-0.314E-02
1646.9 A	500000.	0.114	-0.421E-02	0.241E-02	-0.772E-02
C=0.16E+23	1000000.	0.839E-01	-0.387E-02	0.739E-02	-0.126E-01
	2000000.	0.629E-01	-0.371E-02	0.147E-01	-0.175E-01
	3000000.	0.536E-01	-0.348E-02	0.216E-01	-0.201E-01
	5000000.	0.441E-01	-0.296E-02	0.294E-01	-0.230E-01
Na X 3S-3P	200000.	10.1	-0.553	0.842	-1.46
5666.0 A	500000.	7.07	-0.564	2.23	-2.37
C=0.12E+23	1000000.	5.50	-0.554	3.58	-2.88
	2000000.	4.31	-0.478	5.12	-3.45
	3000000.	3.75	-0.415	6.27	-3.74
	5000000.	3.15	-0.343	7.63	-4.15
Na X 3S-4P	200000.	0.250E-01	-0.114E-02	*0.694E-02	-0.728E-02
182.2 A	500000.	0.179E-01	-0.119E-02	*0.131E-01	-0.103E-01
C=0.46E+19	1000000.	0.141E-01	-0.126E-02	*0.184E-01	-0.127E-01
	2000000.	0.111E-01	-0.114E-02	*0.250E-01	-0.146E-01
	3000000.	0.974E-02	-0.970E-03	*0.287E-01	-0.156E-01
	5000000.	0.825E-02	-0.760E-03	*0.340E-01	-0.171E-01
Na X 3P-4S	200000.	0.200E-01	0.166E-02	0.276E-02	0.392E-02
190.9 A	500000.	0.146E-01	0.172E-02	0.595E-02	0.588E-02
C=0.13E+20	1000000.	0.116E-01	0.165E-02	0.866E-02	0.718E-02
	2000000.	0.918E-02	0.139E-02	0.119E-01	0.853E-02
	3000000.	0.800E-02	0.122E-02	0.142E-01	0.924E-02
	5000000.	0.672E-02	0.101E-02	0.173E-01	0.992E-02
Na X 3P-5S	200000.	0.184E-01	0.173E-02	*0.481E-02	*0.504E-02
129.2 A	500000.	0.138E-01	0.185E-02	*0.776E-02	*0.707E-02
C=0.60E+19	1000000.	0.110E-01	0.176E-02	*0.105E-01	*0.859E-02
	2000000.	0.874E-02	0.152E-02	*0.141E-01	*0.101E-01
	3000000.	0.760E-02	0.132E-02	*0.159E-01	*0.107E-01
	5000000.	0.636E-02	0.107E-02	*0.200E-01	*0.116E-01

Table 1 continued

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
Na X 3P-6S	200000.	0.261E-01	0.223E-02		
110.0 A	500000.	0.198E-01	0.243E-02		
C=0.26E+19	1000000.	0.158E-01	0.249E-02		
	2000000.	0.125E-01	0.231E-02		
	3000000.	0.109E-01	0.195E-02		
	5000000.	0.907E-02	0.154E-02		
Na X 4P-5S	200000.	0.262	0.205E-01	*0.754E-01	*0.678E-01
412.4 A	500000.	0.195	0.220E-01	*0.120	*0.975E-01
C=0.23E+20	1000000.	0.155	0.215E-01	*0.166	*0.119
	2000000.	0.123	0.189E-01	*0.218	*0.137
	3000000.	0.107	0.162E-01	*0.254	*0.144
	5000000.	0.903E-01	0.129E-01	*0.309	*0.163
Na X 4P-6S	200000.	0.182	0.141E-01		
264.6 A	500000.	0.137	0.153E-01		
C=0.96E+19	1000000.	0.109	0.159E-01		
	2000000.	0.866E-01	0.147E-01		
	3000000.	0.753E-01	0.124E-01		
	5000000.	0.630E-01	0.977E-02		
Na X 4P-7S	200000.	0.204	0.138E-01		
217.6 A	500000.	0.155	0.151E-01		
C=0.65E+19	1000000.	0.124	0.180E-01		
	2000000.	0.984E-01	0.175E-01		
	3000000.	0.854E-01	0.146E-01		
	5000000.	0.712E-01	0.110E-01		
Na X 4P-8S	200000.	0.259	0.127E-01		
195.2 A	500000.	0.199	0.153E-01		
C=0.35E+19	1000000.	0.159	0.222E-01		
	2000000.	0.126	0.229E-01		
	3000000.	0.110	0.188E-01		
	5000000.	0.914E-01	0.138E-01		

In Table 1, only a sample of results is shown. Parameter C (Dimitrijević and Sahal-Bréchot 1984), given also in Table 1, provides an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding electron-impact full width at half maximum. For each value given in Table 1, the collision volume (V) multiplied by the perturber density (N) is much less than one and the impact approximation is valid (Sahal–Bréchot, 1969ab). Values for NV > 0.5 are not given and values for $0.1 < \mathrm{NV} \leq 0.5$ are denoted by an asterisk.

We hope that the present results will be of interest for the investigation of Stark broadening theory, especially for the investigation of behaviour of Stark broadening parameters along isoelectronic sequences, as well as for the various problems concerning the stellar, laboratory, fusion and laser produced plasma, and soft x-ray lasers modeling and research.

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AGN MODELLING USING ACCRETION DISCS

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Abstract. Active galactic nuclei are modelled using the accretion disc model, with a central massive object, in this case a supermassive black hole. The gas slowly moves inward, under the implacable attraction of the black hole. The accretion disc has strong jets coming from the inner regions of the disc. The jets are made of ionized matter (electrons and protons). Due to shocks in the jet, protons are accelerated via the Fermi mechanism. The protons diffuse in the region above the disc, finally hitting the disc surface, which is where they came from, in the first place. Once inside the disc, the protons initiate specific interactions, giving birth to the X-ray component of the accretion disc spectrum. This cycle of matter is ideal for producing short term variability. Data is fitted to the UV-X-ray correlation of NGC 5548, as an example.

1. INTRODUCTION

Active Galactic Nuclei (AGN) are among the most studied objects in current astrophysical research. Their most striking characteristic is the enormous energy output, which, until not too long ago, looked like defying known physics. Various theories have been put forward to explain this powerful emission; a so called *unified model* evolved gradually (Blandford 1990). The important characteristic of this model is that, by varying its parameters one can get the observational signature of sources which seem to be of different nature - hence the *unification*. Indeed, in spite of the many differences, there seem to be common observational elements to all AGN: a bright compact nucleus, wide continuum, time variability.

All these lead to a picture of the system as consisting of a black hole or massive object, surrounded by an accretion disc, and possibly a torus of gas near the disc (Fig. 1 shows a cross-section of the system; the jets and torus are not shown).

In addition, there is enough experimental evidence that jets of matter can be thrown out of the so-called *boundary layer*, the region of the disc close to the black hole. Since the black hole very likely rotates with maximum speed ($a_\star$ as close to 1 as radiation pressure would allow it), the accretion disc extends to very small radii ($r_{min} = 1.23$, in gravitational radii).

Depending upon the relative importance of the model's constituents and also upon viewing angle, such a system yields different emissive signatures, accounting for a host of observationally different types of active nuclei. Indeed, the same object can look like a Seyfert 1, a Seyfert 2, a QSO or a quasar, largely due to the inclination angle to the observer, the mass of the black hole and the mass accretion rate. For example, in quasars the AGN system is seen almost face-on, this making only the core visible optically; jets are close to the line of sight. On the other hand, in radio galaxies (system seen edge-on) the jets may be more conspicuous than the central nucleus.

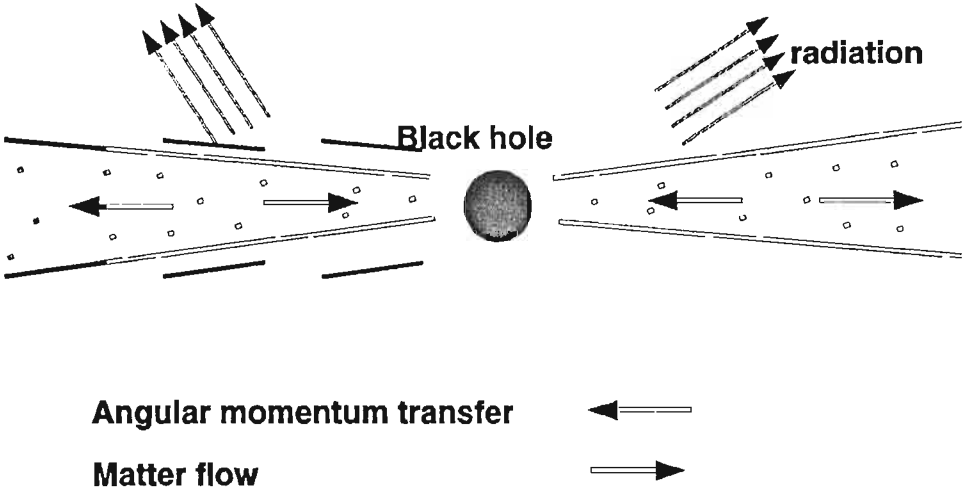

Fig. 1. Accretion disc around a black hole.

The gas in the accretion disc rotates around the black hole, with almost keplerian angular speed. Since ω is varying with radius, there will inevitably be friction between successive regions, and energy will be dissipated as heat due to viscosity effects. In the classical, steady, optically thick case, the spectrum of the heated disc has a characteristic $F_\nu \approx \nu^{1/3}$ specific flux (Frank, 1985).The resulting spectrum differs from the blackbody spectrum because regions that have different temperatures are geometrically separated, and superposition does not apply in this case to the specific flux.

Apart from the classical model, one can and should use the more elaborate models of Shakura and Sunyaev (Shakura & Sunyaev, 1973) and also the relativistic model of Novikov and Thorne (Novikov & Thorne, 1983)

2. DESCRIPTION OF THE MODEL

The basic ingredients of the model are those mentioned above: a massive black hole surrounded by an accretion disc. The accretion disc model used is essentially Novikov and Thorne's, but with the addition of a jet of matter starting from the central regions of the disc (A.C.Donea & P.L.Biermann 1996). This model accounts for the UV part of the spectrum of the accretion disc. The paramater defining the geometrical extent of the jet is r_j (positive, non-dimensional, higher r_j means larger jet). A fraction

q_m of the accretion energy is released into the jet. The jet consists of ionized matter (electrons and protons). Protons, rather than electrons get to be accelerated in shocks in the jet, through Fermi processes. The resulting accelerated protons have a power law distribution in energy as they diffuse out of the jet. We take the proton power of the jet to be a fraction of the jet power.

For the X-ray domain we use the model provided by Niemeyer and Biermann (1993). In this model, the protons diffuse in the region above the disc, due to magnetic field irregularities. For a steady, time-independent diffusion process, having a source of protons in the jet, most of the protons will hit the disc surface again and enter it, causing hadronic interactions. The resulting X-ray spectrum is largely dependent upon incoming proton power, with mass accretion rate playing a smaller role.

3. APPLICATION TO NGC 5548

NGC 5548 is a Seyfert I galaxy, with low redshift ($z = 0.0174$), whose emission is typical for its class. It has variability and its X-ray luminosity is moderate (L_{2-10} keV $= 4.5 \times 10^{43}$ergs s^{-1}). We use the data provided in Clavel (1992). It is known that the UV and X-ray emissions are correlated to within 1-2 days. We take the Hubble constant $H = 50$km/(sec · Mpc) for deriving the distance to the galaxy,

For the UV part, the 1350 Å continuum intensity is computed, while for X-rays, one computes the (almost) integral 2-10 kev flux. Experimental points and theoretical curves are then plotted.

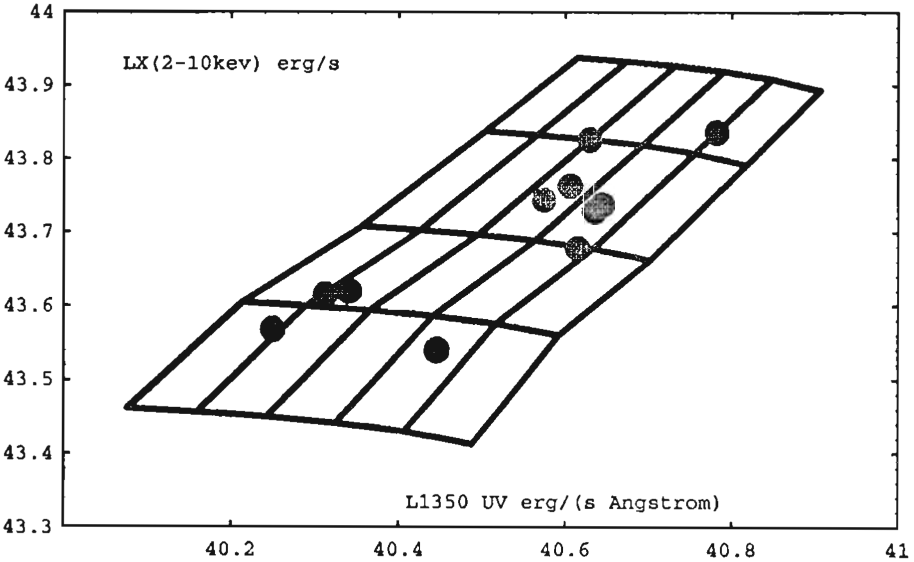

Fig. 2. UV - X-ray correlation diagram for NGC 5548.

Figure 2 shows the experimental data points (the dots) and the range of validity of the theoretical model (the lines). The decimal logarithms of the UV continuum and the X-ray fluxes are plotted. We use sub-Eddington accretion rates. $\eta = 30\%$ of the jet power is assumed to be converted into proton energy.The almost horizontal curves are for constant accretion rate $\dot{M}$ with, respectively, the values: 0.018, 0.023, 0.03, 0.04, 0.05, in $\frac{M_\odot}{yr}$ (increasing upwards). The other curves are for constant jet geometry parameter r_j: 4, 5, 6, 7, 8, and 9, respectively (increasing from right to left). The q_m parameter has the value of 0.1. Other parameters are: $M = 10^8 M_\odot$ (the central mass) and $a_\star = 0.9981$ (Kerr black hole).

The best fits are obtained with either Schwarzschild black holes of huge mass or Kerr black holes with less mass. To choose between the two variants we resort to variability time scale arguments. While the Schwarzschild case ($a_\star = 0$) is not excluded by the model, it would require central masses too large for the given (short) timescale of variability. The high inertia of systems with central mass higher than $10^8 M_\odot$, would make it hard for black holes with $a_\star$ significantly lower than 0.9981 (the maximally accepted value for Kerr black holes with accretion discs) to really fit the data.

4. CONCLUSIONS

The black hole and accretion disc model is a valid model for explaining AGN emission. Coupled with time and size arguments it is able to explain both the huge energy output and the short term variability of such objects. Kerr black holes with close to maximum angular velocity are preferred to Schwarzschild black holes.

Acknowledgements

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THE ORIGIN OF THE JET IN THE ACTIVE GALACTIC NUCLEI

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Abstract. The most recent optical and radio observations of AGN and the discovery of the quasi-periodic oscillations in X-ray binaries reveal the importance of searching the inner edge of the accretion disk assumed to be essential for the formation of the jet in any kind of AGN (either radio galaxy, or radio-loud or radio-quiet quasars, or Seyfert or Blazar, etc.). The discovery of variability of GRS 1915+105 in X-ray and radio has led to interesting results concerning the jet/disk symbiosis at small scale (microquasar scale).

The correlation between radio and the disk luminosities suggests the fact that the inner region of the accretion disk is the foot of the jet and the emissions observed along the jet are consequences of the efficient feeding of the jet from the disk. Following the unified scheme of the AGN, we investigated the jet/disk symbiosis paying attention to the accretion disk structure and the inner geometry of the system. The symbiotic system contains: a black hole, an accretion disk and the jet.

In recent years it was found that the astrophysical jets are the most energetic phenomena in AGN. They are connected to the black holes which are generally assume to exist in any active galactic nuclei (AGN) and to be the main sources of energy for any galaxy.

The AGN show a large variety of objects from the powerful radio galaxies, radio-loud quasars, radio-quiet quasars to Seyfert galaxies, Blazars, LINERS, etc. People ask the question "Are jets in any class of AGN?". An overview of the evidence for astrophysical jets in different types of AGN have been done by Falcke (1998). The recent HST and VLA observations reveal new aspects of the plasma outflows structure in AGN.These observations add bricks to the model that an AGN powered by a black hole fed by an accretion disk *must have jets.*

It is now generally accepted that jets and accretion processes (relativistic accretion disks) are strongly related. The recent review Livio (1997) shows that the accretion disk systems produce outflows and that the budget energy of the jet is controlled by the accretion rate onto the central engine.

It is known that AGN can approximately be divided into two main classes: radio-loud (RL) objects and radio-quiet (RQ) objects. The RL are only 10 percent of the AGN population and they reside in elliptical galaxies, while RQ seems to reside in a mix of spiral and elliptical galaxies (Kukula *et al.* 1997). Despite the differences in radio-loudness, the optical-ultraviolet spectra of both RL and RQ objects are very similar. This is the first indicator that accretion conditions do not differ much in these classes of AGN, since the optical-UV radiation is produced by the accretion disk around a black hole. Therefore, the difference in the radio power of the jet for RL and RQ, comes from the way in which the jet gets energy from the black hole/disk system. This supports the idea that the parameters which determine the total power of the jet and the radio activity of the AGN are those of the inner geometry of the system, nearby the event horizon .

A first way in analyzing the jets and last, but not least the emissions in AGN is to start looking at the inner edge of the accretion disk, the place where now it is believed that the jet is formed.

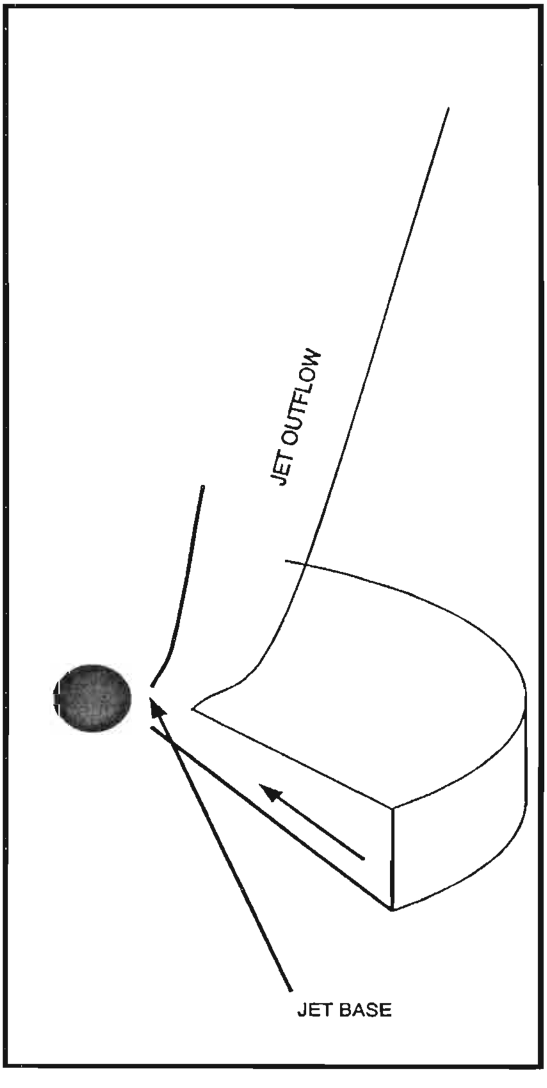

Fig. 1. Sketch of the inner region close to the compact object.

We are already familiar with the general adopted view of an AGN with the three essential constituents: the black hole, the jet and the accretion disk. The black hole may be rotating with the maximum angular momentum equal to $a_\star = 0.9981$, where $a_\star$ is its specific angular momentum divided by the mass of the black hole. The great observed luminosities observed in AGN require supermassive black holes with masses $M \in [10^8 M_\odot, 10^{10} M_\odot]$. The black holes possess deep gravitational potential wells and work like powerful engines. The second constituent is the accretion disk. One generally accepts that disk-like accretion is an efficient mechanism for converting the rest-mass energy into radiation. The jet completes the view of the central part of the quasars.

The notion that the jets and the accretion disks are symbiotically related originated since the first radio and optical observations revealed the parsec-scale of the AGN. Although, there are many uncertainties concerning the origin and the acceleration of the jets, many different types of mechanisms have been proposed for the formation of the jets. We note here the jet model driven by magnetic or radiation pressures (Lovelace *et al.*. (1994)) or the formation of the jet due to the magnetic activity of the accretion disks (Camenzind (1989)).

The standard theories for the emissions in quasars have been developed as results of the elaborated observations done over the whole range of energies of the spectra of quasars. Therefore, Blandford & Königl (1979) explained the emission from compact radio cores. Falcke *et al.*. (1995) add mass and energy conservation of the jet-disk system. The correlation between the accretion disk (UV) luminosity and the radio emission of the quasars (Falcke *et al.*. (1995a)) suggests that the compact core radio emission and the UV bump have a common energy source in all quasars. These elements have led Falcke *et al.*. (1995) to the concept of what we will refer to as jet-disk symbiosis. The standard disk model has been introduced in 1973 by Shakura & Sunyaev (1973) and Novikov & Thorne (1973). One needs to combine these models in order to provide a compact theory for the jet-disk symbiotic system. In the view of this point, we consider that the jet is fed by a geometrically thin disk and we assume that the inner part of the "standard" disk contains all energetic conditions necessary to form and to maintain a stable jet's configuration.

The presence of the jet changes the accretion disk boundary at the inner edge. Since this is the key in understanding the physics of powering the jet people have been looking deeply at the short variabilities in spectra, which may be connected to the inner regions of the accretion disks. The clues on the compact region in AGN may come from understanding at a little small scale of the similar phenomena happening in the stellar systems with black holes .

The most recent discoveries of the quasi periodic oscillations (QPOs) with the Rossi X-Ray Timing Explorer revealed that GRS 1915+105 is a galactic superluminal source having an accretion disk around a black hole of stellar mass. Mirabel *et al.*. (1998) find the correlation between the radio outbursts and the X-ray flares as being done by the fall of the material from the inner edge of the accretion disk into the black hole. Falcke & Biermann (1996) has included already in the unified model of the quasars this source which fits very well into the scheme, at the bottom of the distribution of black holes, jets and disk systems with low luminositites. This shows that, regardless the scale (big black holes or small black hole, core of the galaxies or stellar systems), the simple idea of a jet/disk coupling leds to insight of the origin of the jet.

Adopting the point of view that formation of jet is possible under all circumstances (Falcke 1998), whether there are AGN or stellar size systems, we investigate the effects of the presence of the jet on the structure of the accretion disk, and implicitly on the emission spectrum.

Important results concerning the base of the jet geometry are obtained. We estimate also the total energy delivered into the jet. The key point of the model is that the matter accreted towards a supermassive black hole is the primary source for mass outflows from the inner dense part of a disk and the fact that a large fraction of the energy from the inner disk is not radiated away but dissipated into the jet.

Because the kinetic energy in the jet has to be great enough in order to provide all sources of energy required by the nonthermal processes we stress the fact that a maximally rotating black hole is required. The rotating central object can supply through its gravitational potential well the energy necessary for driving and maintaining a stable jet in the AGN.

We assume that the jet starts between $R_{\rm ms}$, the last marginally stable orbit in the absence of a jet and the radius $R_{\rm jet}$ with $R_{\rm jet} > R_{\rm ms}$, extracting mass, energy and angular momentum from the disk (see Donea & Biermann (1996)). The presence of the jet will modify both the behaviour of the infalling matter across the radius $R_{\rm jet}$ and the structure of the relativistic disk. As we mentioned before, the gravitational potential energy released between the $R_{\rm ms}$ and the outer radius of the jet $R_{\rm jet}$ goes into the jet. Therefore, the total energy carried by the jet outside is strongly dependent on the mass and angular momentum of the black hole. Q_{jet} is the total power of the jet – including the rest energy of the expelled matter – and is expressed as:

$$Q_{jet} = L_{disk} - L_{disk}^{jet}$$

L_{disk}^{jet} is the total luminosity of a disk modified by the presence of the jet and L_{disk} is the total luminosity of the disk if there are no physical conditions to drive the jet. A large fraction of the total power of the jet is in magnetic fields and relativistic particles.

The conservation laws inside the disk are now modified by considering the presence of the jet. We work with two theoretical parameters: $R_{\rm jet}$ and q_m. We define q_m as the ratio between the mass loss rate due to the jet $\dot{M}_{\rm jet}$ and the disk accretion rate $\dot{M}_{\rm disk}$. The mass and angular momentum extraction from the disk makes it thinner and denser. The region between the radius of the last marginally stable circular orbit and the radius where we consider to be the outer radius of the jet no longer shows a disk-like structure.

The most important conclusion of our model is that the relativistic effects and the presence of the jet modify the locally emitted spectrum. In the optical UV range the general form of the spectra is not significantly changed. Most of the UV radiation originates from the inner region of disk outside $R_{\rm jet}$. Due to our theoretical assumption about the energy source of the jets, the shape of the spectrum coming from an "old" standard disk around a maximally rotating black hole is cut off at high frequencies, from extreme UV to soft X-ray range. We get also a small flattening of the spectra in the UV range if we take a thick base of the jet and a maximum ratio $q_m = 0.1$.

Emission lines of ionized helium are among the most important diagnostic indicators in the spectrum of the active galactic nuclei. The clouds surrounding the central active region of a quasar are ionized by the UV photons emitted by the disk. There are some arguments based on the width of the HeII lines emission and their correlation to the UV fluxes and soft X-ray fluxes in AGN. Netzer *et al.*. (1985) calculated the intensity of HeII lines and conclude that the UV continuum has to be approximately flat in νF_ν beyond the last measured point, from $3 \cdot 10^{15}$ Hz to 10^{16} Hz. Our model with a Kerr maximal rotating black hole and a relativistic disk driving the jet can explain the flatness of the spectrum in the UV range.

On the other hand, our disk model driving a jet in the innermost dense regions very close to a maximal Kerr black hole can replace all the simple models of the accretion thin disk surrounding a Schwarzschild black hole. Earlier attempts to fit UV data (Czerny & Elvis (1987)) need a few times the Eddington mass accretion limit, contradicting the geometrically thin disk approximation. We have interpreted the UV fluxes of the quasars working with sub-Eddington accretion rates and taking into account the presence of the jet.

We postulated that the jet and disk around a black hole are symbiotic features which can be found both in all types of active galactic nuclei and around the stellar mass black holes . Using the energy, mass and angular momentum conservation laws of the black hole-disk-jet system we can successfully model the UV "bump" of the quasars. Concerning the jet we conclude that the thickness of the base of the jet is limited by the necessity to have sufficient UV photon flux in order to explain the high luminosity of the disk. The total energy of the jet has the upper bound corresponding to the gravitational potential energy lost by the infalling gas between R_{ms} and R_{jet}.

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X-RAY EMISSION IN SOLAR FLARES

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Abstract. Understanding the mechanisms of the X-ray production in solar flares sheds new light on the X-ray emissions in stellar flares, and other kind of explosion events observed in accretion disks, novae and supernovae remnants. The acceleration mechanism of electrons and ions is the key point in understanding the flare process. Since the X-ray fluxes are direct signatures of the acceleration and heating processes which occur during the energetic events (the flares), details about the non-thermal electron distribution can be inferred.

1. INTRODUCTION

Recent high resolution spectra of the solar flare events reveal new aspects on the physics inside the Sun. A number of solar X-ray satellites, such as *SMM, Hinotori, Yohkoh, ASCA, Einstein* and many other have provided many spectroscopic data which have allowed much progress in the understanding of the solar corona.

The X-ray spectra are signatures of the existing of different populations of the electrons inside the plasma of the solar flares. It remains to look at every observed X-ray flux from the solar flares to find out the type of the electron (thermal or non-thermal) accounting for the soft and hard X-ray observed structures. Observations of X-rays allows us to study the plasma temperatures and the densities of the accelerated particles.

The X-ray spectra of the solar flares have continuum components over which a forest of emission lines overlap. Studies of the emission lines intensities and profiles can provide information on temperature, density, abundances, plasma flows and non-equilibrium conditions.

Energetic solar flares have three stages. In the first stage (of a few minutes) the soft X-ray flux increases above the background solar X-ray flux. In the second stage bursts of hard X-ray and gamma-ray appears (lasting few seconds). In the third stage hard X-ray and gamma-ray intensities taper off exponentially. During the last two stages, the soft X-ray intensity is growing, until later, it will return to the normal stage.

The three stages show that the electron population inside the hot plasma, during the flare evolution, is changing. From the X-ray spectra one can distinguish the radiation emitted by hot, thermal electrons (with Maxwellian distribution functions) from that emitted by the accelerated, nonthermal electrons (power-law distribution functions). Comparing the hard X-ray and soft X-ray fluxes, taken at different stages in the evolution of a solar flares, one can find details of the evolution in time of the electron distribution. The soft X-ray photons are bremsstrahlung photons emitted by thermal electrons of temperatures of several million degrees K. The hard X-ray spectrum is dominated by bremsstrahlung from the accelerated electrons with power law energy distribution.

2. NON-MAXWELLIAN ELECTRONS AND THE X-RAY EMISSION

Finding the electron distribution of the electrons and ions during the solar flares requires the understanding of the acceleration mechanism in solar flares, which in fact is not yet fully understood. From the radio fluxes one can deduce the number and the energy distribution of the highly accelerated electrons during the flares.

On the other hand, the solar corona is orders of magnitude hotter than the underlying chromosphere. Scudder (1992) has argued that the high coronal temperatures can be explained in terms of the non-thermal non-Maxwellian particle distribution at the coronal base. The obtaining of the non-Maxwellian electron distribution in the corona is a matter of the acceleration mechanisms, too.

The non-Maxwellian electrons fill the gap in phase space, between the thermal Maxwellian electrons and the solar cosmic ray electrons. The thermal pool is provided by the immense mass of the hot solar corona. Having an efficient injection mechanism the nonthermal population of the electrons has to bridge between the thermal and solar cosmic ray electrons.

An explanation of the X-ray emission as bremsstrahlung from the nonthermal electrons has been proposed by Donea & Biermann (1998) for the case of X-ray fluxes of the supernovae remnants. Since the acceleration of the electrons involves the shock acceleration processes and the magnetic field structure of the environment, a similar mechanism can accelerate electrons from the thermal pool in the hot flare plasma. The thermal electrons gain energies through the drift mechanism inside the thickness of the shock.

The X-ray emission spectra of hot, optically thin plasma were calculated by Kato (1976), Mewe (1972), Raymond and Smith (1977) for a range of plasma temperatures. Their work provides a complete reference for explaining the X-ray fluxes in supernova remnants and solar corona. A Maxwell distribution of electron velocities was assumed.

However, the solar flares and several supernova remnants show power-law spectra in the X-ray domain and this is the evidence of nonthermal emission from the shocked shells.

We have computed the photon generation using the bremsstrahlung cross sections reviewed by Blumenthal and Gould (1970). The differential cross sections for electrons that have supra-thermal energies have been kindly provided by A.W. Strong (Strong 1994). At high frequencies the bremsstrahlung production is dominated by the cosmic ray electrons.

A supra-thermal population of electrons introduces new elements in the analysis of the X-ray emission from the shocked plasma. The ionization state of the shocked plasma is different than the case when a Maxwellian population do the excitation-recombination work.

The supra-thermal electrons at energies of several keV produce line excitation, because the cross section for an electron on a Si, Mg, S or Fe ion has the resonance, at approximately the energies of the supra-thermal electrons (the collisional excitation by electrons varies as v_e^{-2} above the threshold, Osterbrock (1968)). Therefore, one expects even higher emission lines in the X-ray spectra from the hot plasma.

We analyze the ionization-recombination balance for the case of the Si^{+12} He-like line, which appears in the X-ray spectrum at the energy of 1.865 keV.

3. THE IONIZATION RATES BY ELECTRONIC COLLISIONS

For direct ionization cross sections we used the formula given by Arnaud and Rothenflug (1985). The ionization potential for a certain level is taken from Lotz (1967). One integrates over a power law velocity distribution of supra- thermal electrons. The coefficients of the ionization are computed for different injection energies of the supra-thermal electrons (see Figure 1.).

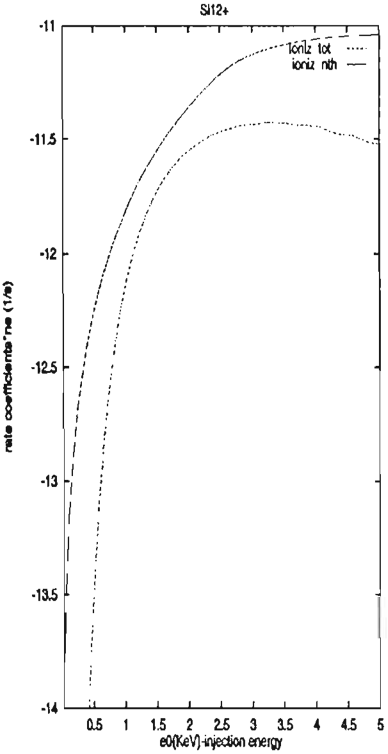

Fig. 1. The ionization rates (1/s) of Si^{+12} for a supra-thermal population of electrons starting at different injection energies. The ionization recombination rates (1/s) for Maxwellian electrons, having various temperatures T, is shown with the dashed line. For comparison to the supra-thermal case we made the analysis with respect to the ε_0 which is equal to $k_B T$. k_B is the Boltzmann's constant and ε_0 is the injection energy of the supra-thermal electrons. $T = 10^7$ K means $\varepsilon_0 = 0.87$ keV. The ionization coefficients are multiplied with an electron density $n_e = 0.1(1/\text{cm}^3)$. The n_e in solar flares is $10^8(1/\text{cm}^3)$.

We compare the ionization rates for two cases: a) when the plasma contains thermal electrons of temperature T and b) when these are replaced by transitional-thermal electrons and supra-thermal electrons. We assumed that only the ground level is significantly populated and we ignore all the other levels. The ionization rates corresponding to the ground level of Si^{+12} ion are shown in the Figure, for supra-thermal and thermal population of electrons, respectively. The supra-thermal electrons ionize faster than the thermal electrons, therefore the number of Si^{+12} ions in plasma is reduced. For an injection energy of 0.86 keV ($T = 10^7$K) the ionization rate is approximately half an order of magnitude higher than the Maxwellian case. It is likely that in some cases the ionization process is not fast enough for reducing the number of Si^{+12} ions.

4. CONCLUSION

Using the result from the previous section we stress the fact that the supra-thermal electrons can modify the ionization balance in the hot shell. Therefore, the emission lines will have different intensities compared to the equilibrium case when a thermal population of electrons is taken into account. We conclude that from the X-ray spectra of the solar flares one can find details about the nonthermal electrons distributions and the injection mechanisms. The nonthermal electrons produce power-law bremsstrahlung photons with hard X-ray energies and also contributes to the ionization state of the hot plasma.

The solar flares are the closest laboratories for searching the the three existing population of electrons: thermal, supra-thermal and relativistic.

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FUNDAMENTAL STELLAR AND PULSATION PARAMETERS OF THE Be STAR ζ Oph & P

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Abstract. Periodic line profile variations of ζ Oph have been followed in the He I $\lambda 6678 Å$ line at the brazilian Laboratório Nacional de Astrofísica (Pico dos Dias) observatory with a 1.60m B&C telescope using the coudé spectrograph equipped with a CCD camera. The high resolution ($R = 60\,000$, high signal-to-noise ratio spectra (more than 200 in continuum) were obtained during two observing runs carried out over 7 nights in 1996 May 3 to May 5 and May 30 to June 2.

The purpose of this investigation was to examine the variations in both time and wavelength using the two-dimensional Fourier Doppler imaging technique (FDI) and multiperiodic search time series analysis. We discuss the results in the frame of the non-radial pulsator model for the star. The most important oscillation modes and frequencies are determined as well as some fundamental stellar parameters. We detected several new modes and frequencies in addition to others found previously.

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2800 MHz SOLAR FLUX AND DANUBE RIVER FLUX, I

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Abstract. Spectral decomposition theorem has been applied to assert that exists a certain influence of solar activity, measured in Solar flux density at the frequency of 2800 Mhz, to water flux in Danube river at a station. A 7 years lag after maximal solar activity has been found using cross-correlations. Chi square test has been used for obtained results signification.

0. INTRODUCTION

Data analysis has shown that many hydrologic variables demonstrate an oscillatory character. Water supplies are of essential importance in everyday life as well as in agriculture, industry and economical planing.A precise prediction of their abundance or lack could be of enormous profit to the mankind. But no one does exactly know, yet, the precise mechanism of the hydrological cycle. One may only suppose what are the reasons of many phenomena occurance. Therefore a statistical or a probability investigation may be of some help.

In previous papers of mine I used Greenwich total sunspot areas, umbrae or penumbrae total areas and faculae total areas as promotors of river level or river flux variations. But, collecting of such solar activity data has been abandoned . Why, I could not find

the reasons. Or, I could not get them after the year 1992., in spite of my efforts of looking after them.

So, I turned myself to the use of data which are available : to the 2800 Mhz solar flux. The series of them are not so long as the previous ones, but I had to be satisfied with that what I could acquire.

1. DATA AND DATA PROCESSING

One station on the Danube river has been schoosen following the idea of Jean-Claud Pecker (1987), and experience of mine in more then ten year long investigations, that the use of many stations, at the same time, may distort instead to ameliorate the results.

For the solar activity parameter I choosed the Solar flux density at the frequency of 2800 Mhz, from the entire solar disc,in units of 10 to 22 Joules/second/square meter/ Hertz. Each number has been multiplied by 10 to supress the decimal point. Three sets of fluxes - the observed, the adjusted and the absolute - are summarized. Of the

three, the observed numbers are the least refined, since they contain fluctuations as large as 7% that arise from the changing Sun-Earth distance. In contrast, adjusted fluxes have this variation removed; the numbers which I have used equal the energy flux received by a detector located at the mean distance between Sun and Earth; the adjusted values are multiplied by 0.90 to compensate for uncertaintes in antenna gain and in waves reflected from the ground.
Following data notations have been used:

time series for *solar activity* (yearly means)::

OTTA - adjusted 2800 Mhz Solar Flux Density at the frequency 2800 MHz, expressed in Joules/second/square meter/Hertz, published by the National Geophysical Data Center, Boulder, Colorado, USA

time series for *Danube River Flux* (yearly means)::

BEVQ - Maximal River Flux, expressed in m3/s, published by the Federal Meteorological Bureau

BENQ - Minimal River Flux, expressed in m3/s, published by the Federal Meteorological Bureau.

I had, at my disposal, OTTA series starting by the year 1947 to 1997 (daily observations), and river flux series since 1931 to 1996 (monthly means).
The computer processing program limited my investigations, in the case of OTTA series, to the section between 1947 and 1996, as well as the series BEVQ and BENQ.
I used the Spectral Decomposition Theorem, which states that the energy, or variance, of any time series can be broken down into the contribution of statistically independent oscilllations of different frequencies (periods), for periodogram construction.
Each peak in the spectral periodicity function graph has been standing for a harmonic. The most outstanding one points toward the *Major Frequency (Period)*, and the next ones toward *Higher Harmonics*, toward the so-called *Overtones*.
Search for paired up independent oscillation, with the same periods (frequencies), in both correlated series, has been carried out.
The next supposition was that we have to do with two stationary time series, *Xt*, and *Yt*, and that we wish to asses the extent to which we can use the past of *Xt* to predict *Yt*; cross-correlations have been used as a criterion of evaluation. If the processes are zero mean, we define them, by means of cross-correlation, the *expected* value of *Yt*.
Fourier series residuals have been calculated for significance level evaluation. In the continuation a comparision of such frequency histogram with normal distribution function has been constructed. *Chi-square test* has been used as a conclusion.

2. RESULTS

The highest cross-correlations value has been obtained for the lag of seven years in the case of OTTA4796 versus BEVQ4796, or *2800 Mhz Solar flux density* influence to Maximal *river flux*, meaning that maximal river flux may follow, after a 7 year lag, the maximal 2800 Mhz solar flux.

The periodogram for OTTA series shows that there are seven independent fundamental oscillations - seven peaks. The major frequency has a period of 10.oo years (and 90 % of the total energy or variance), the first overtone of 5.55 years (3%), the second of 2.o8 years (1.7%), the third of 3.13 years (1.7%), the fourth of 4.55 years (1.5%), the fifth of 2.5 years (0.9%), and the sixth overtone a period of 3.84 years (0.6 % of the the whole energy).

Periodogram for BEVQ series has eight peaks - eight independent fundamental oscillations. The major frequency has a period of 10,oo years (23% of the total energy or variance), the first overtone of 2.27 years (16 %), the second of 3.33 years (16%), the third of 5.55 years (14%), the fourth of 2.63 years (13%), the fifth of 50.oo years(7%), the sixth of 4.16 years (5%) and the seventh overtone a period of 2.o8 years (4% of the whole energy)

As we may see three harmonics of the OTTA series have their responses in the BEVQ series. To the major period of the first corresponds as well as the major period of the second, to the first overtone the third,and to the second overtone of the first corresponds the seventh overtone of the second series. That means that in both phenomena there are three simple oscillations with corresponding equal periods. so we may suspect that solar flux rules over 40 % of river flux fluctuations.

Chi-square test for OTTA series' three of seven just mentioned independent frequencies gives the value of 1.06132 with 2 degrees of freedom and a significance level of 0.588217.

Chi-square test for the three of eight BEVQ independent frequencies gives the value of 3.58024 with 1 degree of freedom and a significance level of 0.0584706.

The application of the same programm to the BENQ series shew a periodogram with nine peaks. The major frequency has a period of 7.14 years (34% of the whole energy), the first overtone of 2.38 years (15%), the second of 50.oo years (12%), the third of 3.13 years (9%), the fourth of 5.oo years (8%), the fifth of 2.77 years (6%), the sixth of 3.85 years (5%), the seventh of 12.50 years (5%), and the eighth overtone has a 2.17 years period (2% of the whole energy).

There are only two corresponding componental oscillations. The third overtone of OTTA series has a response in the third overtone of the BENQ series, and to the sixth overtone of the first series corresponds the sixth overtone of the second series.

Chi-square test for two of seven independent frequencies of the OTTA series gives a value of 7.82511 with 3 degrees of freedom and a significance level of 0.0497678.

Chi-square test for two of nine independent frequencies of the BENQ series gives a value of 2.29391 with 2 degrees of freedom and a significance level of 0.317603.

3. CONCLUSION

According to periodograms and corresponding cross-correlations, the spectral decomposition theorem, applied to the **adjusted 2800 Mhz solar flux density**, series **OTTA**, expressed in Joules/second/square meter/Hertz, as a parameter pictureing one kind of Solar activity, from one side, and **maximal Danube river flux on a station**, series **BEVQ**,expressed in m3/s, from the other side, we got a right to announce that, in statistical sense, the Solar activity may influence, with the accuracy given, the maximal river flux in such a way that, after seven years of maximum solar activity a maximum flux,may occur at that station on Danube river.

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ELECTRON IMPACT IONIZATION AND ELECTRON ATTACHMENT CROSS SECTIONS OF SOME MOLECULES OF ASTROPHYSICAL IMPORTANCE

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Abstract Here an insigth is presented into efforts on total ionization and total electron attachment cross section measurements of small molecules of astrophysical interest, as a part of research in the Institute of Physics in Beograd.

1. INTRODUCTION

It was realized a long time ago that molecules do not exist only on Earth but also in atmospheres of other planets and in the interstellar space. To date, more that 60 molecular species have been detected, including some positive ions. Some of these molecular species are very different from what we traditionally call a molecule under normal physical conditions on the surface of Earth. Reviews on the subject, and lists of these molecular species were published by many authors, including Henderson (1972) Turner (1973), Green (1984), Rien (1985), Millar and Williams (1985) and Petrović (1986), part of them given in Table 1.

Table 1. Some molecules found in astrophysical objects, as part of lists given by numerous authors, like Rien (1985), Green (1984) etc.

Number of atoms	2	3	4	5	6
Molecule or Ion	H_2 **CO** CH CN CS C_2 OH NO CH^+ NS SO	$\mathbf{H_2O}$ $\mathbf{H_2S}$ $\mathbf{SO_2}$ **COS** HCN HNC HCO HNO	$\mathbf{NH_3}$ H_2CO CH_3 $\mathbf{C_2H_2}$ HNCO C_3O C_3N HNCS	$\mathbf{CH_4}$ SiH_4 CH_2NH HCOOH NH_2CHO	$\mathbf{CH_3OH}$ CH_3SH CH_3CN

Remark: Molecules for which total ionization cross sections have been measured in the Atomic Collision Physics Laboratory, Institute of Physics, Beograd, some of them published, are given in bold letters.

Particle densities in interstellar objects are much lower (10^2 - 10^5 [at/cm^3]) than on the surface of Earth or/and in laboratory under experimental conditions (10^8 - 10^{19} [at/cm^3]). Nevertheless in binary, or even ternary collisions, many reactions take place, that lead to formation and destruction of rather complex molecular species. Incident particles, as well as products of collisions can be neutral species, positive or negative ions. Apart of that, the composition of particles does change under the influence of radiation and electron impact.

For proper modeling and explanation of possible collision channels under interstellar conditions many data are needed that could be collected in laboratory experiments. Among them the most thoroughly approached are reactions caused by photon or/and electron collisions. As targets, until recently, neutral molecules were used, many of them found in interstellar space, too. Lately, experiments started with species that are traditionally called molecular fragments, such as OH, CH, CH_2, SH, etc. These experiments are more difficult to perform, since one has to prepare the target species not available under normal physical conditions. That includes formation of intense ion beams, mass separation, charge exchange and charged particle removal from the neutral particle beam. Even then, particles considered as targets, are rarely all in their ground state.

Only with rather well known characteristics of a particular particle collision, such as energy exchange, cross sections, angular distributions etc., the modeling of processes in interstellar space could lead to reliable explanations.

2. TOTAL ELECTRON IMPACT IONIZATION CROSS SECTION MEASUREMENTS

The electron impact ionization process was investigated for the first time by Lenard (1903). But, first reliable ionization cross sections for some atoms and molecules were published by Smith (1930). Since then measurements of ionization cross sections have been done in many laboratories around the world. Results of these experiments are collected by a few data centers, mainly to make them available to scientists active in plasma and fusion plasma physics, astrophysics, physical chemistry and radiation physics.

In the Atomic Collision Physics Laboratory of the Institute of Physics in Beograd, the first experimental apparatus for total ionization cross section measurements was constructed as early as 1963. Since then, this apparatus has been redesigned, improved and changed a few times. There were some periods when measurements were very active, and others when due to alterations of the apparatus they almost stopped.

Lately, the newest version of the experimental apparatus was put into operation. This time the targets were mostly small molecules that are formed in collision of protons within the high temperature plasma machines (Tokamak and the like) with walls covered by carbon, as well as those found in interstellar space. Details of the experimental apparatus were published (Kurepa et al. 1974)(Čadež et al. 1983)(Kurepa et al. 1991), while alterations introduced lately will be described in papers that will be reported and/or published shortly (Josifov et al. 1998)(Lukić et al. 1998).

Part of the apparatus where the interaction of the incident electron beam with the target molecules takes place is presented in Fig.1., the trochoidal electron monochromator as the electron beam source (Stamatović and Schutz 1969) not being shown. Ions, positive in the case of ionizing collisions, or negative in the case of electron attachment, are collected by applying a homogeneous electric field between electrodes of the parallel plate condenser. Further details of the measurement procedure can be found in already published papers.

The main source of error in electron ionization or electron attachment cross section determination comes from the measurement of the target gas pressure. Within the interaction chamber the target gas is at pressures between 10^{-5} [mbar] and 10^{-4} [mbar], while the background pressure is 10^{-7} [mbar]. For more reliable pressure measurements two new generation gauges were used lately. One is the capacitance manometer, the other is the spinning ball manometer, both calibrated by the manufacturer, with the claimed error of ±2 %. Common characteristics of these manometers is that all their parts are at the ambient temperature, so that within the system thermal transpiration does not change the accuracy of the gas pressure measurement. This was, namely, one of the biggest sources of error in most of earlier experiments. Not to be forgotten that in many cases the dissociation of target molecules on the hot filament of the ion gauge changes the composition of the gas and its apparent pressure inside the gauge.

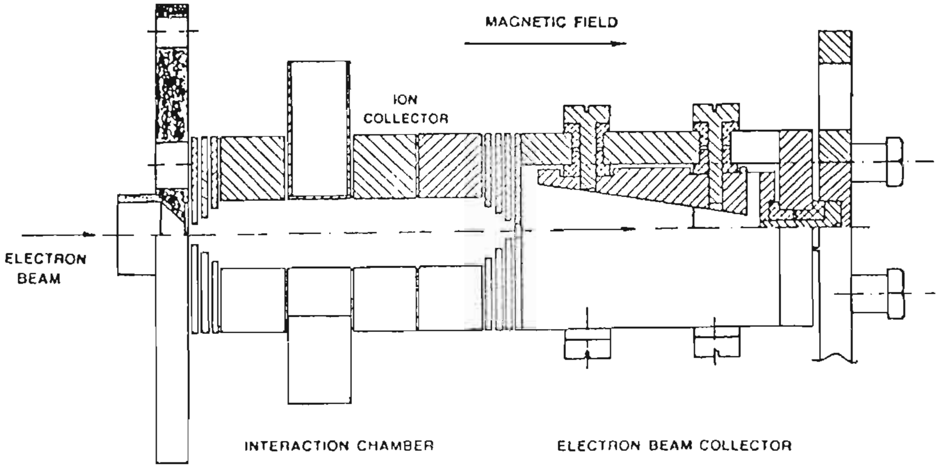

Figure 1. Schematic drawing of the interaction chamber with which the total ionization and total electron attachment cross sections were measured

Some results for molecules of great importance for astrophysical research, of total ionization cross section measurements are listed in Table 2. Already published are cross sections for SO_2 (Čadež et al. 1983) H_2S (Belić and Kurepa 1985) and H_2O (Đurić et al. 1988), while for those investigated lately NH_3 (Đurić et al. 1981)(Josifov 1997), NO_2 (Lukić 1997) COS (Lukić 1997) and C_2H_2 (Đurić et al. 1996)(Josifov et al. 1997) results are not yet published. The agreement of cross sections measured in our experiments with data of other authors is mostly good, sometimes even within the experimental error cited by two or more groups of authors. But, in some cases, the differences are rather big, reaching even 50 %. That is specially the case for the H_2O, H_2S and NH_3 molecules, all containing hydrogen atoms. This is the main reason why for these molecules measurements were repeated in a long period of time.

In search for explanation why these differences do appear, a new apparatus was constructed recently in the Institute of Physics, that is intended to measure angular and energy distributions of positive ions formed in dissociative ionization and/or negative ions from dissociative attachment processes. Already the first results in H_2 (Popović and Čadež 1993) and in H_2, H_2O and CH_4 (Kurepa et al., 1997) showed two important properties of H^+ ions. Firstly, there is a wide energy distribution, with ions of kinetic energy as high as 10 [eV], and secondly, the angular distribution of ions is, as a rule, not isotropic. The consequence to total ionization measurements can be serious. High kinetic energy ions could escape collection in the parallel condenser interaction chamber, partly those emitted in the forward and backward directions, and partly those emitted side- ways within the gap between the condenser electrodes. Although in experiments a special

Table 2. Total ionization cross sections of some molecules, in units of 10^{-20} [m^2]

Electron energy, in [eV]	**H_2O**	**H_2S**	**SO_2**	COS	NO_2	NH_3	C_2H_2
12	-	0,376	-	-	0,009	0,124	0,072
14	0,025	0.878	0,481	0,036	0,035	0.269	0,53
16	-	1,58	0,848	0,546	0,088	0,479	1,01
18	-	2,29	1,23	1,28	0,175	0,764	1,45
20	0,290	3,01	1,63	2,19	0,440	1,06	1,84
22	-	3,73	2,04	2,95	0,607	1,36	2,19
24	-	4,14	2,40	3,56	0,788	1,60	2,52
26	-	4,52	2,75	4,32	0,976	1,82	2,80
28	-	4,83	3,06	4,96	1,17	2,08	3,06
30	0,965	5,06	3,31	5,83	1,35	2,31	3,29
32	-	5,25	3,58	6,18	1,57	2,49	3,50
34	-	5,39	3,78	6,48	1,74	2,68	3,69
36	-	5,52	3,98	6,77	1,91	2,84	3,85
38	-	5,62	4,15	6,94	2,07	3,00	4,01
40	1,46	5,71	4,34	7,14	2,22	3,13	4,15
45	1,62	-	-	-	-	3,41	-
50	1,76	6,08	4,92	7,90	2,83	3,64	4,59
55	-	-	-	-	-	3,85	-
60	-	6,22	5,38	8,38	3,25	3,95	4,82
65	1,91	-	-	-	-	4,13	-
70	-	6,22	5,67	8,64	3,51	4,20	4,90
75	-	-	-	-	-	4,24	-
80	2,05	6,18	5.87	8,68	3,67	4,31	4,90
85	-	-	-	-	-	4,33	-
90	2,06	6,08	5,96	8,63	3,76	4,32	4,85
95	-	-	-	-	-	-	-
100	2,06	5,98	5,99	8,45	3,80	4,34	4,76
125	2,00	-	5,87	7,98	2,76	-	-
150	1,92	-	5,68	7,48	3,64	-	4,21
175	1,82	-	5,43	7,05	3,50	-	-
200	1,72	-	5,15	6,59	3,34	-	3,70

Remark: Bold are given molecules for which final cross sections values have been published. For others, final evaluation is completed and manuscripts are in phase of preparation for publishing.

calibration procedure is obligatory, that requires total collection of ions by increasing the electric field strength, a loss of high kinetic energy ions of the order of 2 - 5 % could be expected. Thus, that is a possible explanation for differences in cross sections obtained by different experimental groups. Special tests are under way to prove this hypotheses.

3. TOTAL ELECTRON ATTACHMENT CROSS SECTIONS

Electron attachment is a process in which the incident electron is resonantly attached to the molecule and a negative ion and a neutral fragments are formed after the decay of the negative and excited parent molecular ions. Processes of electron attachment do happen with electrons of rather low energy, usually nor exceeding 10 [eV].

Total electron attachment cross sections, i.e. without the analysis which negative ion is formed, were measured with the parallel plate interaction chamber, shown in Fig 1., too. These cross sections are, as a rule, lower than the total ionization cross sections by 2 - 3 orders of magnitude. In the experiment this has a consequence that electrometers that can determine ion current of the order of 10^{-15} [A] to 10^{11} [A] are needed. They are more difficult to calibrate absolutely, and in their use more often surface leakages do appear, making the experiment much more difficult to perform properly.

All molecules, listed in Table 2, that were investigated for their total ionization cross sections, have also electron attachment processes. So far, we measured and published data for H_2O (Đurić et al. 1988), H_2S (Belić and Kurepa, 1985), and SO_2 (Čadež et al., 1983), while values for NH_3 have been determined and reported (Đurić et al. 1981), but not published so far. The total electron attachment cross section curves for these four molecules are presented in Fig. 2. For the remaining three molecules NO_2, C_2H_2 and COS some preliminary investigations of other authors do exist for formation of various negative ions in electron attachment processes, but the results are not consistent, and no attempt to measure cross sections is kown to the author. Here, too, careful analysis of negative ion energy and angular distributions are needed in order to give a full description of the particular attachment process.

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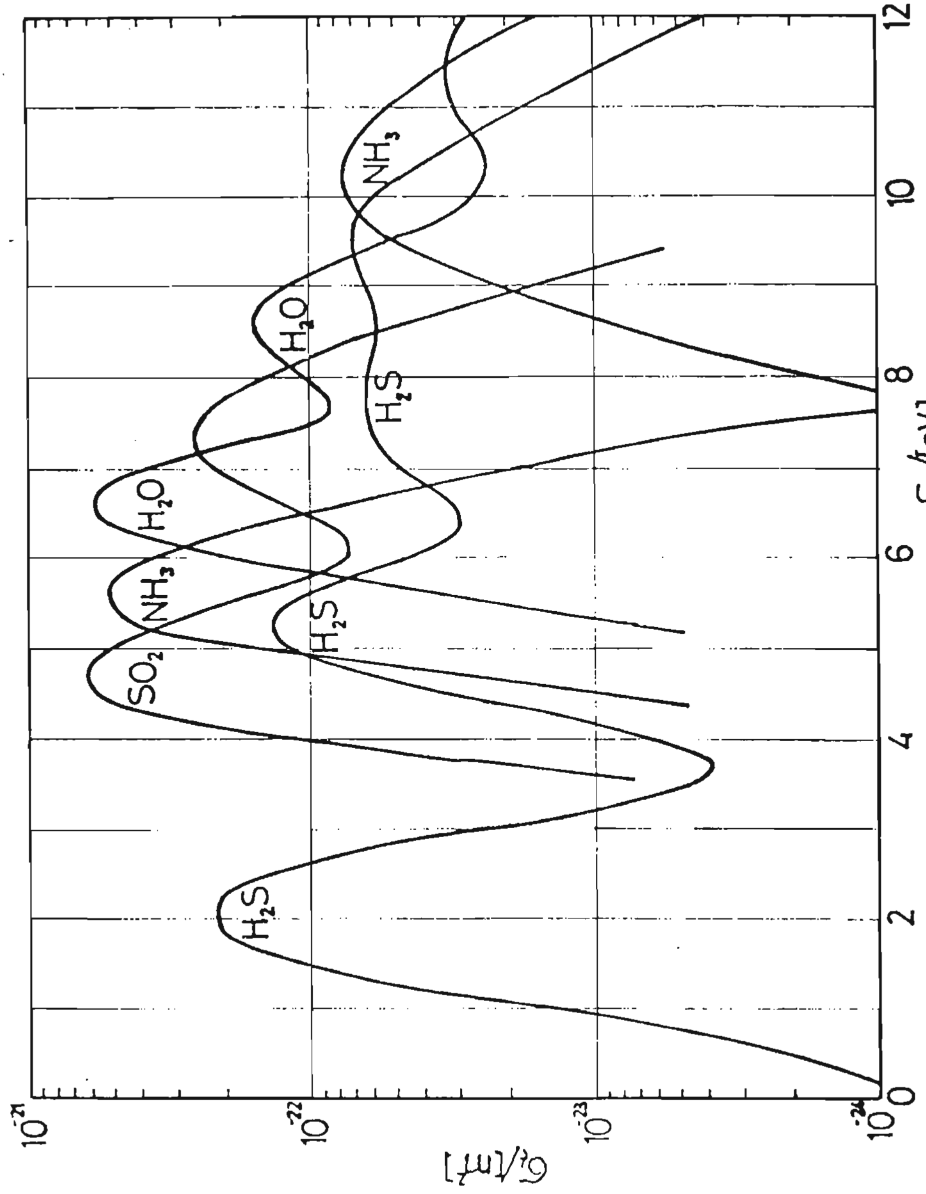

Figure 2. Total electron attachment cross sections of some molecules measured with the apparatus shown in Fig. 1., and published in journals

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STARK WIDTHS OF THE N V AND O V SPECTRAL LINES

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1. INTRODUCTION

Knowledge of N V and O V spectral lines Stark widths enable them for the spectroscopic diagnostics of hot stars and for the investigation of hot dense plasmas in laboratory. The role of the Stark broadening in astrophysics is explained by Griem (1974) and Dimitrijević (1989). In spite of this, the first measurements of N V and O V Stark FWHM (full-width at half intensity maximum, w) values were performed by Purić *et al.* (1987) and Böttcher *et al.* (1987, 1988) for N V and by Purić *et al.* (1988) for O V spectral lines. Several N V spectral lines have been investigated by Glenzer *et al.* (1992) and Blagojević *et al.* (1996). In meantime Dimitrijević and Sahal-Bréchot (1992) have been refered their calculated Stark FWHM values for the N V spectral lines. The aim of this work is to present the Stark FWHM value of the 455.428 nm O V spectral line, not measured before, to the knowledge of the authors. The Stark FWHM value of the 460.383 nm N V spectral line is also measured at 40 000 K electron temperature where measurements have not been performed up to day. In the case of the N V line our measured w value is compared with existing experimental and calculated data. For 455.428 nm O V spectral line no theoretical calculations exist, to the knowledge of the authors.

2. EXPERIMENT

The modified version of the linear low pressure pulsed arc (Djeniže *et al.* 1990; Milosavljević & Djeniže 1998) has been used as a plasma source. A pulsed discharge driven in a quartz discharge tube of 5 mm i.d. and has an effective plasma length of 5.8 cm. The tube has end-on quartz windows. On the opposite side of the electrodes the glass tube was expanded in order to reduce erosion of the glass wall (see Fig 1. in Djeniže *et al.* 1998) and also sputtering of the electrode material onto the quartz windows. The working gas was nitrogen and oxygen mixture (83% N_2 + 17% O_2) at 70 Pa filling pressure in flowing regime. Spectroscopic observation of isolated spectral lines were made end-on along the axis of the discharge tube. A capacitor of 14 μF was charged up to 3.0 kV and supplied discharge currents up to 7.7 kA. The line profiles were recorded by a shot by-shot technique using a photomultiplier (EMI 9789 QB) and a grating spectrograph (Zeiss PGS-2, reciprocal linear dispersion 0.73 nm/mm in the first order) system. The instrumental FWHM of 0.008 nm was obtained by using of the narrow spectral lines emitted by the hollow cathode discharge. The recorded profile of these lines have been of the Gaussian type within 7% accuracy in the range of the investigated spectral line wavelengths. The exit slit (10 μm) of the spectrograph with the calibrated photomultiplier was micrometrically traversed along the spectral plane in small wavelength steps (0.0073 nm). The photomultiplier signal was digitized using oscilloscope, interfaced to a computer. A sample output, as example, is shown in Fig. 1.

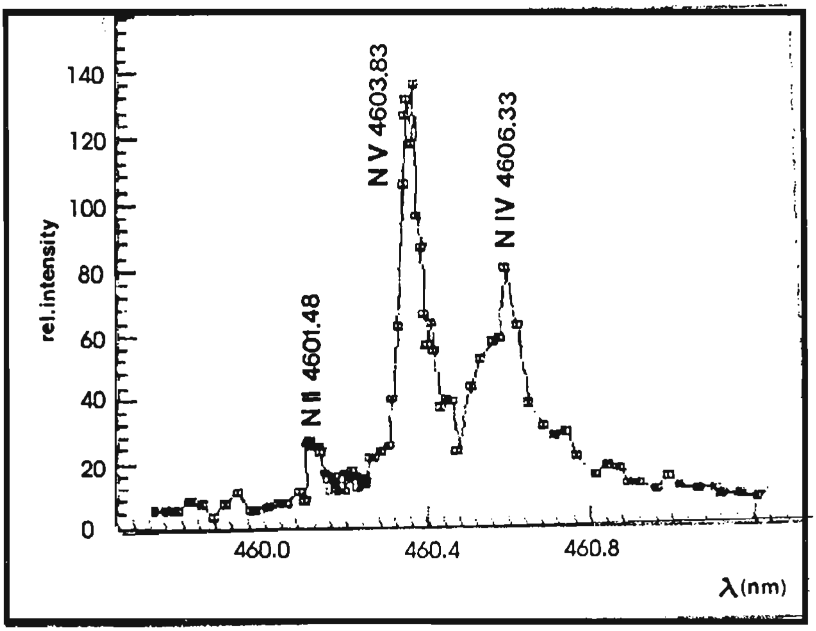

Fig. 1.

3. RECORDED SPECTRUM

The measured profiles were of the Voigt type due to the convolution of the Lorentzian Stark and Gaussian profiles caused by Doppler and instrumental broadening. For electron density and temperature obtained in our experiment the Lorentzian fraction in the Voigt profile was dominant. Van der Waals and resonance broadening were estimated to be smaller by more than an order of magnitude in comparison to Stark, Doppler and instrumental broadening. A standard deconvolution procedure (Davies & Vaughan 1963) was used. The deconvolution procedure was computerized using the least square algorithm. The Stark widths were measured with ±15% error. The selfabsorption was neglibigle becouse the smal concentration of the highly ionized (N V and O V) emitters. The plasma parameters were determined using standard diagnostic methods. The electron temperature was determined from the ratios of the relative intensities of the 348.49 nm N IV to 393.85 nm N III and the previous N III to

399.50 nm N II spectral lines,assuming the existence of LTE, with an estimated error of ±12%. All the necessary atomic parameters were taken from Wiese *et al.* (1966). The electron density decay was measured using a well know single wavelength He-Ne laser interferometer for the 632.8 nm transition with an estimated error of ±7%.

4. RESULTS

Our experimental results of the measured Stark FWHM (w) values at electron temperature (T in 10^4 K) and electron density (N in 10^{23} m^{-3}) are given in Table 1.

Table 1.

Emitter	Transition	Multiplet	λ (nm)	T	N	w_m (nm)
N V	3s - 3p	^{2}S - ^{2}P^0 (1)	460.383	4.0	2.0	0.059
O V	2p3p - 2p3d	^{1}P - ^{1}D^0 (7)	455.428	5.4	2.8	0.032

5. DISCUSSION

The theoretical Stark FWHM dependence on the electron temperature together with the values of the other authors and our experimental results (•) at the electron density $N = 1 \times 10^{23}$ m^{-3} are presented graphically in Fig. 2 assuming the domination of

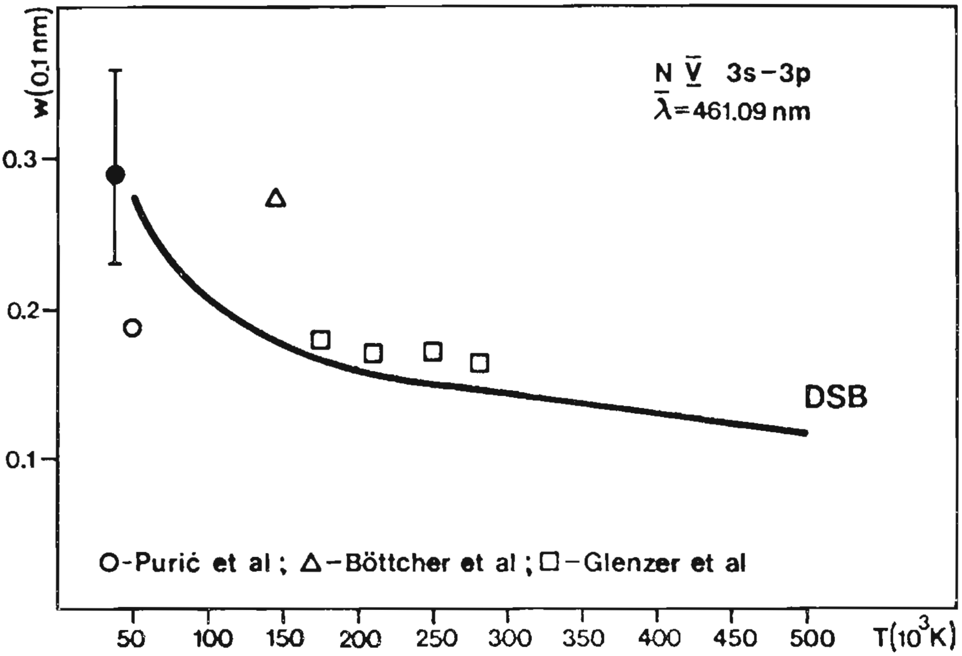

Fig. 2.

the electron impact mechanism to the line broadening. Solid line show the theoretical w values (DSB) calculated on the basis of the semiclassical-perturbation formalism, taked from Dimitrijević and Sahal-Bréchot (1992). $\overline{\lambda}$ is the mean wavelength for the multiplet. The error bar include the uncertainties of the width and electron density measurements.

6. STARK FWHM vs ELECTRON TEMPERATURE

One can conclude that our result, for the N V line, agree well with theoretical predictions (DSB). The same holds, also, for the results from Glenzer *et al.* (1992).

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MODELS WITH SPHERICAL SYMMETRY - DENSITY BEHAVIOUR

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Abstract. Models of stellar systems with spherical symmetry are considered. The attention is paid to the behaviour of the second density derivative provided that the density, itself, has a maximum at the centre to decrease outwards. In view of this the second derivative is negative at the centre and two possibilities arise: a monotonous behaviour or a change of sign resulting in a positive second density derivative in the outer parts of the system.

1. INTRODUCTION

The spherical symmetry is, certainly, the most simple one. Though such an assumption need not seem always sufficiently realistic, there are stellar systems to which it is applicable. The examples of star clusters, some subsystems of spiral galaxies (bulges, halos, perhaps, also dark coronae), as well as of elliptical galaxies, are well known.

In a recent paper of his (Ninković, 1998, hereafter referred to as Paper I) the present author carried out a general consideration of stellar-system models with spherical symmetry. In this consideration many particular models were mentioned. The density dependence on radius was analysed, but with regard to its first derivative. However, for the purpose of classifying the density models the behaviour of the second density derivative may be also of importance. Therefore, in the present paper one will pay more attention to the second derivative.

2. THE DENSITY BEHAVIOUR WITH RESPECT TO THE SECOND DERIVATIVE

For stellar-system models the density and the potential are, certainly, the two most important quantities, i. e. model characteristics. Since they are connected via Poisson's equation, it is possible to limit the consideration to the density only. In the case of spherical symmetry it depends on one argument only - radius or distance to the system centre. As already said above, the general dependence density-radius was subject in Paper I. Here it will be emphasized that on the basis of gravitational instability one should expect the density to be a decreasing radius function with a maximum at the centre. This means that the second density derivative has to be negative at the centre. Therefore, two possibilities arise: a monotonous behaviour without any change of sign or such a behaviour of the second density derivative where a change of sign occurs. In the former case the corresponding curve in the plot is said to be convex, in the latter one to be partly convex and partly concave. In this connexion one can give some examples, but before this another assumption will be introduced, i. e. the present analysis will be limited to the cases of finite central densities only. Therefore, any power density law (more precisely $\rho(r) = Kr^{-b}$, $K = const$, $b = const$, $0 \leq b < 3$), though exceptionally simple, will be beyond the scope of the present contribution.

A density function of the polynomial type (e. g. Ninković, 1991) corresponds to a convex plot. Bearing in mind the possibility of generalising the case considered in the mentioned paper one can write

$$\rho(r) = \rho(0)(1 - \sum_{i=2}^{n} \alpha_i \frac{r^i}{r_l^i}) ; \tag{1}$$

$\rho(r)$ is the density, r is the radius, r_l is the limiting radius of the system at which the density vanishes and α_i are dimensionless coefficients subjected to the following condition

$$\sum_{i=2}^{n} \alpha_i = 0 .$$

In view of the limiting radius definition the reason of introducing this condition is self-evident.

On the other hand there are density functions of fractional type - for example the generalised Schuster density law (e. g. Lohmann, 1964). For completeness the formula of this density law will be also given here

$$\rho(x) = \frac{\rho(0)}{(1 + x^2)^\beta} , \; \beta \geq 0 ; \tag{2}$$

x is the dimensionless radius - $x = r/r_c$, $r_c = const$. In this formula should be specified another parameter - the limiting radius (r_l or x_l in dimensionless form). However, if β exceeds $\frac{3}{2}$, it may be infinite with regard that the resulting total mass is, nevertheless, finite.

It is easily seen that in both cases ((1) and (2)) the density is a decreasing radius function. Also one should note the quadratic term concerning the radius appearing in both formulae - i. e. in (1) the power of r is not smaller than 2. This occurs due to the maximum required at the centre. In view of this the first density derivative is negative except at the centre where it is zero. As for the second one, it is easily seen that in the case of (1) it is always negative, including the centre, itself. On the contrary, for expression (2) the second density derivative, though negative at the very centre, changes its sign at a higher distance (inflexion point). Such a behaviour is reflected in the corresponding figures. Fig. 1 gives the plot density versus radius for formula (1); Fig. 2 presents the density dependence for the case of (2).

In addition to the generalised Schuster density law as an example of the density-versus-radius curve with inflexion point, one might mention another density law also belonging to the class of polytrope models (more extensively e. g. Ogorodnikov, 1958

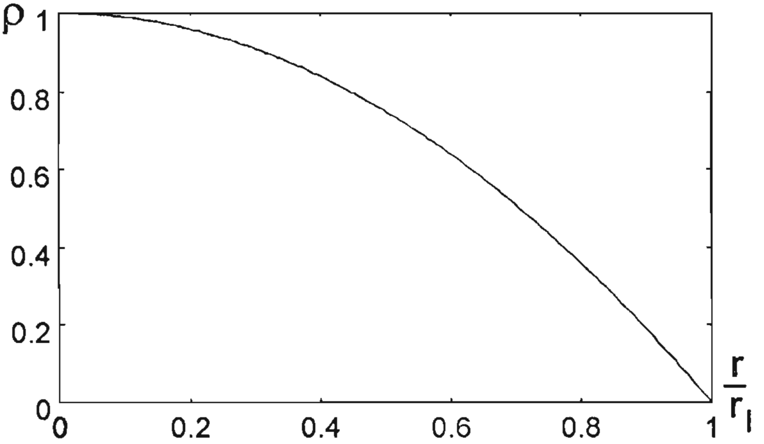

Fig. 1. Dependence density on radius according to (1) - $n = 2$; the desity unit is $\rho(0)$.

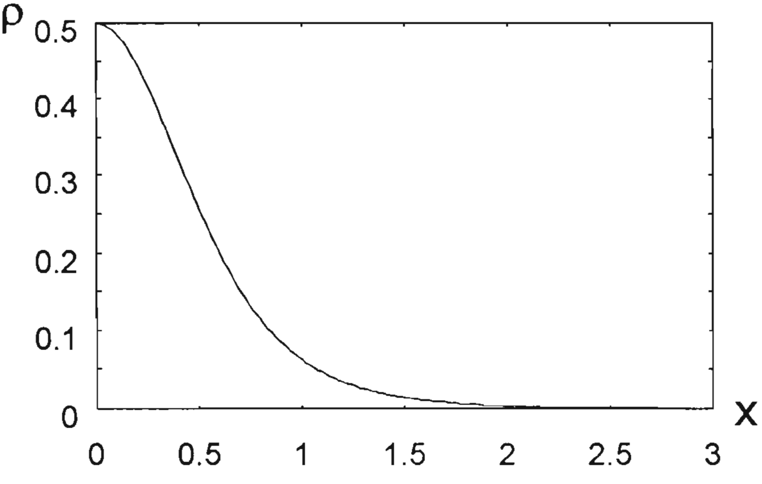

Fig. 2. Dependence density on radius according to (2) - $\beta = \frac{3}{2}$; the desity unit is $\rho(0)$, $x_l = 3$.

- p. 460); this is the case $n = 1$ (n polytrope index) where the density depends on the radius in the following way

$$\rho(x) = \rho(0)\frac{\sin x}{x} \ , \ 0 \leq x \leq \pi \ .$$

As in the case of (2) here x is also the dimensionless radius.

3. CONCLUSION

Thus, if the density functions without central singularities (for the case of spherical symmetry) are accepted as realistic, then one may indicate two types of them according to the density behaviour: those with an inflexion point and those without (density has a maximum at the centre to be decreasing outwards). With regard to the results of observations fitting one may infer that the former-type functions (with inflexion point) have proved themselves as more successful. Therefore, the most important (and still very preliminary) conclusion of the present analysis might be that in reality the gravitational-instability mechanism (e. g. Marochnik and Suchkov, 1984 - p. 251) is in favour of forming mass distributions characterised by a general density decreasing, a density maximum at the centre and an inflexion point in the periphery. Of course, it is clear that the steady state of a stellar system resulting in such a mass distribution must be stable. This conclusion can be easily enough extended towards other kinds of symmetry since in view of the geometry of equidensit surfaces the density can be represented as a function of one variable where this variable is the characteristic parameter of the given equidensit surfaces.

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A POSSIBLE EXTENSION OF THE SAITOU-TAKEUTI-TANAKA ONE-ZONE STELLAR MODEL

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Abstract. The Saitou-Takeuti-Tanaka one-zone stellar model is being extended by considering that the matter in the core-surrounding shell consists of a mixture of ideal gas and radiation. The dynamical system describing the behaviour of the shell is being tackled via a bifurcation analysis of the equilibria of the corresponding linearized system.

1. BASIC EQUATIONS

Since their apparition the one-zone stellar models proved their ability to predict many features of regular and irregular pulsating star light curves (see e.g. Baker 1966, Rudd & Rosenberg 1970, Stellingwerf 1972, Auvergne *et al.* 1981, Auvergne & Baglin 1985, Auvergne 1986, Stellingwerf *et al.* 1987, Saitou *et al.* 1989).

Consider a one-zone stellar model (Saitou *et al.* 1989) of mass M, featured by a rigid core of constant radius R_c and constant luminosity L_c, and by an envelope of mass m_s. Let the stellar radius ($R \gg R_c$) be time-dependent. Furthermore, we shall consider (e.g. Baker 1966) that the matter in the shell is a mixture of ideal gas and radiation.

We shall resort to the following well-known equations of stellar structure (see Kippenhahn & Weigert 1991):

$$\partial^2 r/\partial t^2 = -4\pi r^2(\partial P/\partial m) - Gm/r^2, \tag{1}$$

$$\partial l/\partial m = -c_V(\partial T/\partial t) + (\delta/\alpha)(P/\rho^2)(\partial \rho/\partial t), \tag{2}$$

$$l = [16\pi\sigma r^2/(3\kappa\rho)]\,(\partial T^4/\partial r), \tag{3}$$

namely motion equation, energy equation, and radiative energy transport equation in the diffusion approximation, respectively. The notations are: m = mass of the sphere of radius r, l = luminosity, P = pressure, T = temperature, ρ = density, c_V = specific heat at constant volume, κ = opacity, σ = Stefan-Boltzmann constant, G = Newtonian gravitational constant.

The goal of our paper is twofold: to establish the equations which describe the behaviour of the envelope in time, and to classify the equilibrium states with respect to the interplay among the parameters of the model.

Like Saitou *et al.* (1989) we introduce the following relations referring to the core-surrounding shell:

$$\partial P/\partial m = -P/m_s, \quad \partial l/\partial m = (L - L_c)/m_s, \quad \partial T^4/\partial r = -T^4/R, \tag{4}$$

where P, L, T stand for the pressure, radiative energy flux and temperature in the shell, respectively. Substituting (4) in (1)–(3), these ones turn to

$$\partial^2 R/\partial t^2 = -4\pi R^2 P/m_s - GM/R^2, \tag{5}$$

$$(L - L_c)/m_s = -c_V\,(\partial T/\partial t) + (\delta/\alpha)(P/\rho^2)(\partial\rho/\partial t), \tag{6}$$

$$L = 16\pi\sigma R T^4/(3\kappa\rho). \tag{7}$$

The hydrostatic equilibrium state implies $P_0/m_s = GM/(4\pi R_0^4)$, the subscript "0" corresponding to the equilibrium model with $X = X_0$, $X \in \{R, L, P, T, \rho, \kappa\}$, $L_0 = L_c$. As regards the properties of the stellar matter, we consider the following formulae for the equation of state and opacity law, respectively:

$$\rho = \rho_k P^{\alpha} T^{-\delta}, \tag{8}$$

$$\kappa = \kappa_k P^{\kappa_P} T^{\kappa_T}, \tag{9}$$

where ρ_k and κ_k are constants.

Let x and z be the relative variations of radius and pressure, respectively: $R = R_0(1+x)$, $P = P_0(1+z)$. We consequently derive

$$\begin{aligned}
\rho &= \rho_0(1+x)^{-3},\\
T &= T_0(1+x)^{3/\delta}(1+z)^{\alpha/\delta},\\
\kappa &= \kappa_0(1+x)^{3\kappa_T/\delta}(1+z)^{\kappa_P+\kappa_T\alpha/\delta},\\
L &= L_0(1+x)^{4(3+\delta-\kappa_T)/\delta}(1+z)^{[\alpha(4-\kappa_T)-\delta\kappa_P]/\delta},
\end{aligned}$$

with $\rho_0 = 3M/(4\pi R_0^3)$, $T_0 = \rho_k^{1/\delta}\,\rho_0^{-1/\delta}\,P_0^{\alpha/\delta}$, $\kappa_0 = \kappa_k P_0^{\kappa_P} T_0^{\kappa_T}$, and $L_0 = 16\pi\sigma R_0 T_0^4/(3\kappa_0\rho_0)$. With these relations, equations (5)–(7) lead to

$$\dot{x} = y, \tag{10}$$

$$\dot{y} = \Omega^2\left[(1+x)^2(1+z) - (1+x)^{-2}\right], \tag{11}$$

$$\begin{aligned}
\dot{z} = &-(3/\alpha)(1+x)^{2-3/\delta}(1+z)^{-\alpha/\delta}\left[(1+x)^{3(1/\delta-1)}(1+z)^{\alpha/\delta-1}+\gamma-1\right]y-\\
&-\varepsilon(\delta/\alpha)(1+x)^{-3/\delta}(1+z)^{1-\alpha/\delta}\left[(1+x)^{4(3+\delta-\kappa_T)/\delta}(1+z)^{[\alpha(4-\kappa_T)-\delta\kappa_P]/\delta}-1\right],
\end{aligned} \tag{12}$$

where $\Omega = GM/R_0^3$, $\gamma = c_P/c_V$, $\varepsilon = (\delta/\alpha)L_0/(m_s c_V T_0)$.

Note that in the case of a purely ideal gas shell we have $\alpha = \delta = 1$ (e.g. Kippenhahn & Weigert 1991). With these values, from equations (10)-(12) we retrieve those established by Saitou *et al.* (1989, eqs. (15a-c)).

2. EQUILIBRIA OF THE LINEARIZED SYSTEM

Here we shall limit ourselves to the classical first step in investigating the behaviour of a dynamical system: searching for the equilibria. This is a hard task in the case of equations (10)-(12), so we shall resort to the analysis of the equilibria of the linearized system. Linearizing (10)-(12), we get

$$\dot{x} = y \tag{13}$$

$$\dot{y} = 4x + z \tag{14}$$

$$\dot{z} = Ax + By + Cz \tag{15}$$

where $A = -4\varepsilon(3 + \delta - \kappa_T)/\alpha$, $B = -3\gamma/\alpha$, $C = -\varepsilon\left[\alpha(4 - \kappa_T) - \delta\kappa_P\right]/\alpha$, and we have chosen the units such that $\Omega^2 = 1$.

The corresponding characteristic equation reads

$$\lambda^3 - C\lambda^2 - (B+4)\lambda + (4C - A) = 0. \tag{16}$$

We shall distinguish two main situations. The most general one is $A \neq 4C$. In this case, the only equilibrium is the origin $(x, y, z) = (0, 0, 0)$. It is easy enough to see that this equilibrium is hyperbolic. This is of much help for our analysis, because the local behaviour of the solutions of the linearized system in the neighbourhood of hyperbolic equilibria is the same as for the nonlinear system (Hartman-Grobman theorem). Taking into account (16), we easily see that the origin is a sink (stable equilibrium) for $C < 0$, and a source (unstable equilibrium) for $C > 0$. In case there exist at least one root (16) with negative real part and at least one root of (16) with positive real part, the equilibrium at the origin is a saddle.

A less probable case is $A = 4C$. In this situation the equilibrium at origin is no more hyperbolic, therefore we can say nothing about the behaviour of the solutions of (10)-(12) in the neighbourhood of the origin. However, the fact that $|x|$ and $|z|$ are much smaller than 1 makes us analyze this case, too.

Denoting $q = 4x + z$, we reduce (13)-(15) to the two-dimensional system

$$\dot{q} = Cq + (4 + B)y, \tag{17}$$

$$\dot{y} = q. \tag{18}$$

If $B = -4$, the equilibrium $(q, y) = (0, y_e)$, with $y_e = \textit{constant}$, is stable for $C < 0$, and unstable for $C > 0$. Let us focus on the case $B \neq -4$; the only corresponding equilibrium is the origin $(q, y) = (0, 0)$, too. We differentiate several situations.

If $B < -4 - C^2/4$, the origin is a stable focus for $C < 0$, and an unstable focus for $C > 0$.

If $-4 - C^2/4 \leq B < -4$, the origin is a stable node for $C < 0$, and an unstable node for $C > 0$.

If $B > -4$, the origin is a saddle.

Finally, if $C = 0$, the equilibrium at origin is stable (a centre) for $B < -4$, and unstable for $B > -4$.

Of course, this preliminary bifurcation analysis can be made go deeper by tackling the whole possible interplay among the parameters A, B, C, especially for the most probable case of the hyperbolic equilibrium. Such a hard investigation (given the expression of A, B, C) will be done elsewhere.

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OBSERVATION OF THE GRAVITATIONAL EFFECT IN H_β OF AGNs

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Abstract. In this paper redshift difference between H_β and O III (4959,5007) lines as well as between Broad and Narrow components of H_β is discussed. We measured this difference in spectra of two Active Galactic Nuclei (AGNs): IIIZw2 and 3C120. The red asymmetry of the broad H_β as well as the redshift differences between Broad component of H_β and Narrow O III lines may be explained as the influence of a strong gravitational field in Broad Line Region of these galaxies.

1. INTRODUCTION

In spectra of many Active Galactic Nuclei (AGNs) an inner redshift difference between peak of narrow (high ionized) and broad (low ionized) lines exists (see e.g. Osterbrock *et al.* 1975, Peterson *et al.* 1985, Zheng & Sulentic 1990, Corbin 1990). Also, in spectra of some AGNs, especially in radio loud sorces, the H_β and other broad lines have strong red asymmetry (see e.g. Jackson & Browne 1989, Corbin 1995, Brotherton 1996). This asymmetry could not be explained only with contamination lines, e.g. H_β may be contamined by Fe II (4924,5018) and He I (4922,5016) lines (Jackson & Browne 1989).

In order to explain this inner redshift we have to consider that the whole Emitting Line Region (ELR) can be divided into two (see e.g. Netzer 1990, Osterbrock 1989) or three (see e.g. Bonatto & Pastoriza 1990, Brotherton 1996) physically distinct regions: Broad Line Region – BLR, Intermediate Line Region – ILR and Narrow Line Region – NLR. So, this inner shift difference can be explained as influence of effects which are different in these emitting regions. Usually, two mechanisms are considered as cause of the shift difference: 1) gravitational redshift effect, where the emitters located in BLR are in a stronger gravitational field than the emitters located in NLR and, 2) large-scale gas radial motions in the presence of electron-scattering opacity that steeply increases inward the emitting cloud (proposed by Kallman & Krolik 1986).

From our point of view both of the effects should be the cause of this shift difference, but there is a very large number of AGNs which have a redward asymmetry and, also, have a redshift difference between Broad Component (BC) and Narrow Component (NC) of a broad line, as well as between BC and Narrow Lines (NL). In these cases, we assume that the gravitational redshift causes the assyimmetry as well as the redshift difference. The influence of gravitational redshift effect has been discussed by our group ((Popović *et al.* 1994, Atanacković *et al.* 1994, Popović *et al.* 1995a, 1995b) and Corbin (1995). Corbin (1995, 1997) proposed that the redshift difference as well as the redward asymmetry observed in spectra of some radio loud quasars could be explained as influence of gravitation feild on spectral line profile. From our investigation (Popović *et al.* 1995a, 1995b) we have concluded that: 1) Gravitational redshift effect should be considerd in BLR, but in NLR, this effect is negligible; 2) The red asymmetry broadening of a line increase, while reduced redshift decreases with wavelength; 3) The red asymmetry probably could not be observed as an asymmetric profile of the broad component alone, but it can be observed in a composite line; 4) The gravitational redshift influence is larger on a line created in a thin than in a thick region. Also, considering that the BLR (closer to the central mass) is opticaly thin (see e.g. Corbin 1995, Brotherton 1996), the gravitational effect may be observable only in BC of a line, and one may expect that this effect can be observed as a shift of the BC of the line.

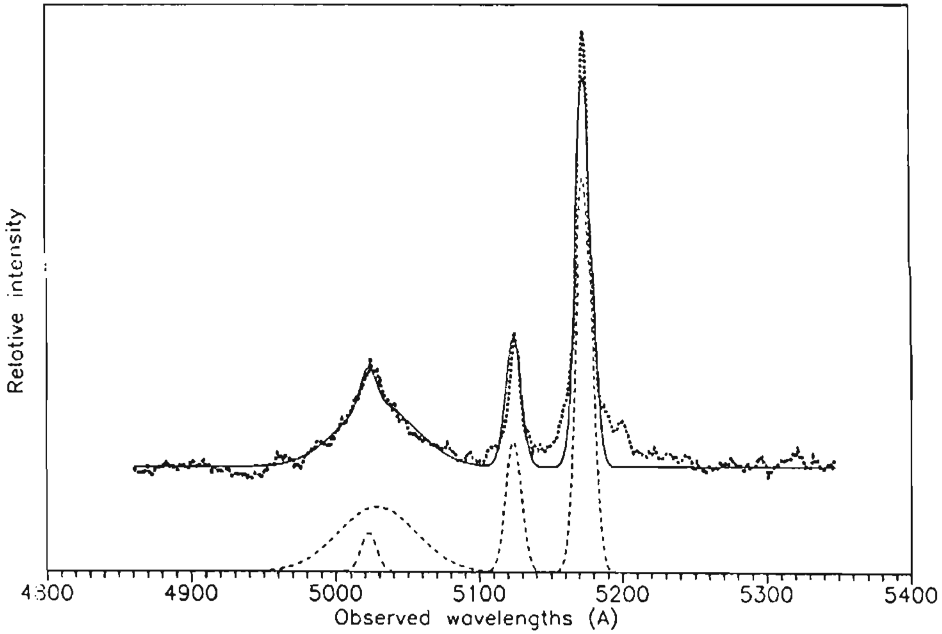

Fig. 1. An example of H_β and O III emission lines of the 3C120. The observed spectrum (dotted line) is fitted with several gaussians which are superposed (solid line). The resolved gaussians are shown at the bottom (dashed line).

Here we preliminarily analyse the shapes of H_β and O III (4959,5007) lines from the spectra of the two low-redshift Active Galactic Nuclei: IIIZw2 and 3C120. First, we try to resolve the broad H_β line into several gaussian components, which come from different regions. After that, we analyse these gaussian components. The gravitational redshift influence on the spectral line shapes can be taken as a contributor to the redshift of the H_β BC.

2. RESULTS AND DISCUSSION

There is no rapid variability in equivalent widths and in H_β line shapes of the galaxies 3C120 (see e.g. Chuvaev, 1980) and IIIZw2 (Popović *et al.* 1998). Hence, we have averaged common relative shift parameters from the spectra in the intervals 1979-1990 (3C120) and 1978-1983 (IIIZw2).

In our explanation of H_β and O III line shapes of the observed galaxies we choose the model with gas outflows in the BLR and partly in NLR with the presence of strong gravitational redshift effect in BLR (see Popović and Mediavilla 1997). Hence, the broadest line of the emitting gas may come from the region of strong gravitation field that can cause a part of the observed shift toward the red with respect to the narrow line component. However, in 3C120 the relative shift is negligible within the errors of measurements.

This shift has been obtained as a wavelength difference of the two corresponding gaussians (a narrow and a broad one) which are superposed to fit the observed H$_\beta$ profile, Fig.1 (solid line). Also, two narrow gaussians have been used to fit the OIII spectral lines.

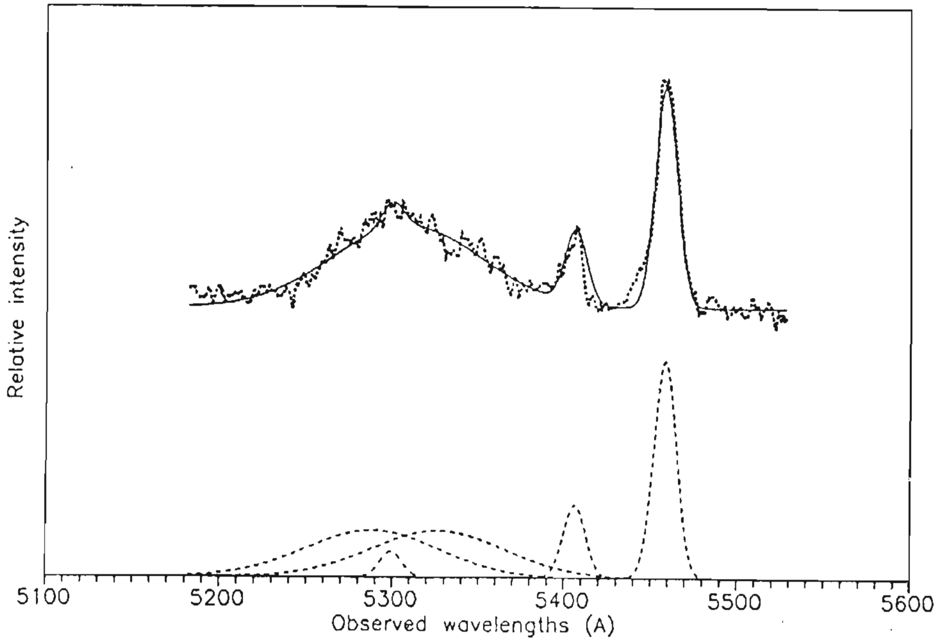

Fig. 2. One of the analyzed spectra of IIIZw2 fitted with several gaussians (solid line). Bottom: five gaussian components of the spectral line profiles (dashed line). Notice two broad gaussians fitting the BC of H$_\beta$ and their mean redshift with respect to the narrow one.

In the case of the IIIZw2 the BC of H_β is double peaked (see Popović *et al.* 1998). It suggests that in this line we can see the effects of an emitting disk. It is in agreement with the observation of continuum distribution noticed by Kaastra &

de Korte (1988), where an increase of the energy density in the optical part of the spectrum was explained as radiation of a blackbody disk. Hence, we a priori suppose that the two broad gaussians (from the approaching and receding sides of the disk) have the same width and intensity. Their mean relative redshift with respect to the NC amounts to 7.94 Å, what in velocity terms corresponds to 490 km/s. The result of the fitting is shown in Fig.2. It is in agreement with our theoretical investigation (Popović *et al.* 1995a, 1995b), and they may indicate that in the case of this Sy 1. galaxy the redshift difference and the red asymmetry of the broad H_β line can be explained with the gravitational redshift effect.

Further and more detailed analysis of these and some other spectra of the two galaxies is in progress.

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THE ELECTRON-IMPACT WIDTHS FOR 4s-4p OF Sr III LINES

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Abstract. In this paper we present Stark widths for five $5s - 5p$ transitions of Sr III calculated by using the modified semiempirical approach and jK coupling approximation.

1. INTRODUCTION

The electron-emitter/absorber collisions are cause of the main pressure broadening mechanism in atmospheres of hot stars. Consequently, the knowledge of the Stark broadening parameters is needed for the stellar atmosphere investigations and modeling. Also, Stark broadening data are needed for investigations and diagnostic of laboratory plasma.

In the case of emitters with complex spectra, where the usual LS coupling scheme is not applicable, as well as the more sophisticated methods as the semiclassical approach (Sahal-Bréchot 1969ab) due to the lack of atomic data, the simpler methods should be used. One of such methods for Stark broadening parameter calculations is the modified semiempirical approach (Dimitrijević & Konjević 1980, Popović & Dimitrijević 1996). It was shown in several papers (Popović & Dimitrijević 1996ab, 1997) that for an emitter with the complex spectrum, the modified semiempirical approach gives a good average accuracy.

Here we present Stark broadening parameters for five Sr III 5s-5p transitions, calculated by using the modified semiempirical approach and assuming jK coupling approximation.

2. THEORETICAL REMARKS

According to the MSE approach (Dimitrijević & Konjević 1980, Popović & Dimitrijević 1996) the electron impact full width (FHWM) of an ion line is given as

$$w_{MSE} = N\frac{8\pi}{3}\frac{\hbar^2}{m^2}\left(\frac{2m}{\pi kT}\right)^{1/2}\frac{\pi}{\sqrt{3}}\cdot\Big\{\sum_{\ell_i\pm1}\sum_{K_{i'}}\vec{\Re}^2[n_i\ell_i K_i, n_i(\ell_i\pm1)K_{i'}]\tilde{g}\left(\frac{E}{\Delta E_{\ell_i,\ell_i\pm1}}\right)+$$

$$+\sum_{\ell_f\pm1}\sum_{K_{f'}}\vec{\Re}^2[n_f\ell_f K_f, n_f(\ell_f\pm1)K_{f'}]\tilde{g}\left(\frac{E}{\Delta E_{\ell_f,\ell_f\pm1}}\right)+ \qquad (1)$$

$$+\Big(\sum_{i'}\vec{\Re}^2_{ii'}\Big)_{\Delta n\neq0} g(x_{n_i,n_i+1})+\Big(\sum_{f'}\vec{\Re}^2_{ff'}\Big)_{\Delta n\neq0} g(x_{n_f,n_f+1})\Big\},$$

where the initial level is denoted with i and the final one with f and the square of the matrix element $\{\vec{\Re}^2[n_k\ell_k K_{k'}, (\ell_k \pm 1)K_{k'}], \quad k = i, f\}$ is

$$\vec{\Re}^2[n_k\ell_k K_k, n_k(\ell_k \pm 1)K_{k'}] = \frac{\ell_>}{2J_k + 1} Q(j_p K\ell', \ell K')[R^{n_k(\ell_k \pm 1)}_{n_k\ell_k}]^2 \qquad (2)$$

and

$$(\sum_{k'} \vec{\Re}^2_{kk'})_{\Delta n \neq 0} = (\frac{3n_k}{2Z})^2 \frac{1}{9}(n_k^2 + 3\ell_k^2 + 3\ell_k + 11) \qquad (3)$$

where $\ell_> = \max(\ell_k, \ell_k \pm 1)$.

In Eqs. (1 – 3) N and T are electron density and temperature, respectively.

$$Q(j_p K\ell', \ell K') = (2K + 1)(2K' + 1)[W(j_p K\ell' 1; \ell K')]^2$$

is the multiplet factor for jK coupling approximation (see e.g. Sobelman 1992). The $[R^{n_k\ell_k \pm 1}_{n\ell}]$ is the radial integral, $g(x)$, and $\widetilde{g}(x)$ are the semiempirical (Griem 1968) and the modified semiempirical (Dimitrijević & Konjević 1980) Gaunt factors for Stark width and shift, respectively.

3. RESULTS AND DISCUSSION

Calculation of Stark widths for five Sr III lines was performed by using Eqs. 1-4. The atomic energy levels have been taken from Persson and Valind (1972). The necessary matrix elements have been calculated by using Eqs. 2 and 3. The data for the multiplet factor for jK coupling approximation were taken from Popović (1994).

Table 1. Stark width (FWHM) Sr III (5s – 5p) transitions for electron density of $10^{23}\mathrm{m}^{-3}$ as a function of temperature. The averaged wavelength of the multiplet is denoted as $\overline{\lambda}$. The jK coupling approximation was assumed.

Transition	T (K)	W (nm)
$(^2P_{3/2})\ 5s[3/2] - 5p[5/2]$ $\overline{\lambda} = 309.62$ nm	5000.	.172E-01
	10000.	.120E-01
	50000.	.530E-02
	100000.	.420E-02
	250000.	.393E-02
	500000.	.387E-02
$(^2P_{3/2})\ 5s[3/2] - 5p[3/2]$ $\overline{\lambda} = 287.08$ nm	5000.	.153E-01
	10000.	.107E-01
	50000.	.471E-02
	100000.	.373E-02
	250000.	.349E-02
	500000.	.344E-02

Table 1. continued

Transition	T (K)	W (nm)
($^2P_{3/2}$) $5s[3/2]-5p[1/2]$ $\overline{\lambda}=321.63$ nm	5000.	.183E-01
	10000.	.128E-01
	50000.	.563E-02
	100000.	.446E-02
	250000.	.418E-02
	500000.	.412E-02
($^2P_{1/2}$) $5s[1/2]-5p[3/2]$ $\overline{\lambda}=286.82$ nm	5000.	.154E-01
	10000.	.108E-01
	50000.	.473E-02
	100000.	.374E-02
	250000.	.349E-02
	500000.	.344E-02
($^2P_{1/2}$) $5s[1/2]-5p[1/2]$ $\overline{\lambda}=286.82$ nm	5000.	.154E-01
	10000.	.107E-01
	50000.	.472E-02
	100000.	.373E-02
	250000.	.348E-02
	500000.	.344E-02

In Table 1 we present results of our calculation of Stark widths and shifts for Sr III 5s – 5p transitions assuming jK coupling approximation, respectively.

In the case of Sr III there is not measured and calculated data. Here we give first results, and we hope that the data will be of interest for stellar as well as laboratory plasma spectroscopy.

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A NOTE ON THE MILKY WAY AS A BARRED GALAXY

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Abstract. We review recent research on the Milky Way galaxy and try to investigate whether its shape is similar to other barred galaxies. The emphasis is given on microlensing research because this method can be useful in determining the shape of the Galaxy with the minimal set of assumptions. By analyzing plots of the microlensing optical depth, τ as a function of galactic coordinates for different values of the axis ratio, q of the galactic halo, we have shown that observations are best described by a flattened halo with $0.2 \lesssim q \lesssim 0.6$.

1. INTRODUCTION

Over the last decade a growing list of evidence led us to accept the hypothesis proposed back in 1964 by de Vaucouleurs (e.g. Kuijken 1996): our Galaxy is a barred one. The arguments were initially based upon morphological considerations. The development of observational techniques broadens the possibilities of investigation of the central parts of the Milky Way in several research fields. All of them, however, confirm de Vaucouleurs' idea that the Milky Way is a SAB(rs) type galaxy, having a bar, weak rings, and a four-arms spiral structure (Vallée 1995).

We shall only mention here the following observational results (Kuijken 1996) that confirm these facts:

1. **photometric research** that include:
   a) surface photometry (Blitz and Spergel 1991; Dwek *et al.* 1995); and
   b) star counts (Gould, Bahcall and Flynn 1997; Nikolaev and Weinberg 1997)
2. **kinematical research** that include:
   a) gas kinematics (Binney *et al.* 1991); and
   b) stellar kinematics (Kuijken 1996, and references therein)
3. **gravitational microlensing (ML) researches**.

The existence of the bar successfully explains dynamical peculiarities observed in our Galaxy, and shows that they are normal features in a barred galaxy:

- stellar and gas dynamics in the Galactic center region (Binney *et al.* 1991),

– central activity definitely correlated with a presence of the bar in galaxies (Combes *et al.* 1995),

– a $2.6 \times 10^6 M_\odot$ black hole in the center of the Milky Way (Bower and Backer 1998; Falcke *et al.* 1998),

– the absence of HI and CO gas in the region $1.5\ \mathrm{kpc} \leq r \leq 3.5\ \mathrm{kpc}$, implying that the major axis of the bar is $r_{bar} \leq r_{cr}$, where $r_{cr} = 2.4$ kpc is the Milky Way's corotation radius (Binney and Tremaine 1987; Binney *et al.* 1991),

– a molecular ring at 3.5 kpc, which can be explained by gas accumulation near the outer Lindblad resonance radius ($r_{\mathrm{OLR}} = 4.1$ kpc in Milky Way) (Binney *et al.* 1991; Freundreich 1998),

– asymmetry in the distribution of the red clump stars in the bulge (OGLE) (Stanek 1995),

– asymmetries of the bulge photometric image (COBE-DIRBE) (Dwek 1995, Binney, Gerhard and Spergel 1996), and

– excess of gravitational microlensing events compared to the theoretical estimates (Paczyński *et al.* 1994) in the galactic bulge direction.

All observations agree that the value of the bar inclination angle (to the Sun-Galactic Centre line) is between 10° and 30°.

In this paper we will discuss gravitational ML research and try to establish the connection between the inner parts of our Galaxy (bar) and its outer parts (halo) using this new observational technique. The ultimate goal is to see how the Milky Way as barred galaxy can be compared to other barred spirals and whether some conclusions concerning the shape of the Galaxy can be drawn.

2. BARYONIC DARK MATTER CONTENT OF THE GALAXY

The dark matter (DM) content of the Milky Way is still unknown. From shape of its rotation curve (RC) (Merrifield 1992) one can see that a huge amount of mass still has to be identified. The difficulties in the determination of the RC led to uncertainties in the most important parameters such as the galactic constant R_0, which represents the distance to the Galactic center and the circular speed at the Solar radius, v_0 (Merrifield 1992, Olling and Merrifield 1998, Sackett 1997). Although the IAU 1986 standard values are: $R_0 = 8.5$ kpc and $v_0 = 220\,\mathrm{kms}^{-1}$ some recent estimates allow the smaller values: $R_0 = 7.1 \pm 0.4$ kpc and $v_0 = 184 \pm 8\,\mathrm{kms}^{-1}$ (Olling and Merrifield 1998). In this paper we adopt the value $R_0 = 8.5 \pm 0.5$ kpc (Feast and Whitelock 1997) based upon an analysis of Hipparcos proper motion of 220 Galactic Cepheids and $v_0 = 210 \pm 25\,\mathrm{kms}^{-1}$ that includes the best values from the HI analysis ($v_0 = 185\,\mathrm{kms}^{-1}$) and the estimated values based on the Sgr A* proper motion ($v_0 = 235\,\mathrm{kms}^{-1}$) (Sackett 1997).

Without going into the discussions about the content of the DM in the halo, we only state here that one part (presumably smaller) has to be in the baryonic form. Namely, cosmic nucleosynthesis predicts that (Turner 1996):

$$0.008 \lesssim \Omega_B\, h^2 \lesssim 0.024 \tag{1}$$

where Ω_B is the universal baryonic mass-density parameter ($\Omega_B = 8\pi G\rho_B/3H_0^2$) and $0.4 \lesssim h \lesssim 1.0$. "Silent" h is used in parametrization of the Hubble constant $H_0 = 100h\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$. Recent estimates (Fukugita, Hogan and Peebles 1998) give:

$$0.007 \lesssim \Omega_B \lesssim 0.041 \qquad (2)$$

with the "best guess" $\Omega_B \sim 0.021$ (for $H_0 = 70\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$).

Using the simplest dynamical estimate of the mass of the Galaxy (Kepler's third law):

$$GM(r) = v(r)^2 \qquad (3)$$

where $M(r)$ is the mass interior to r, v is the measured rotational velocity and r is the radius within which most of the light in galaxy is emitted. For luminous matter one can obtain:

$$0.003 \lesssim \Omega_{\mathrm{LUM}} \lesssim 0.007 \qquad (4)$$

(Roulet and Mollerach 1997, and references therein). This is consistent with severe limits on mass-to-light ratio in the Local Group imposed by deep blank sky surveys (Richstone *et al.* 1992; Hu *et al.* 1994; Flynn, Gould and Bahcall 1996), as well as with huge dynamical mass for the Milky Way inferred by Kulessa and Lynden-Bell (1992).

The mass in the halo is dominated by the matter that is not, at least easily, detectable. So, one can write:

$$\Omega_{\mathrm{HALO}} \gtrsim 0.1 \gtrsim 14\,\Omega_{\mathrm{LUM}}. \qquad (5)$$

It can be seen the equations (2) and (4) that dark baryonic matter must exist; various types of such material have been suggested: gaseous clouds of plasma or neutral atoms and molecules, snowballs or icy bodies similar to comets, stars, planets, white dwarfs, neutron stars and stellar or primordial black holes (e.g. Peebles 1993).

3. MICROLENSING – METHODS AND RESULTS

In searches for the baryonic DM content the method of microlensing has so far proved successful. Its name derives from the fact that lensing of distant objects is made by bodies with masses characteristic of a star or planet. Although the theoretical development of this idea started in 1964 (e.g. Peebles 1993, and references therein), it was the seminal paper by Paczyński (1986) that showed that one can search for ML events in the Milky Way halo if it is made of stars or brown dwarfs. Rapid development of observational and computer technology led to the detection of a significant number of ML events (e.g. Mellier, Bernardeau and Van Waerbeke 1998). The directions include Large and Small Magellanic Clouds (LMC and SMC) (Alcock *et al.* 1996, 1997b; Palanque-Delabrouille *et al.* 1998), Galactic bulge (Kiraga and Paczyński 1994) and M31 (Crotts 1996).

All these surveys give results concerning two important parameters: masses of the intervening objects and the optical depth. In the Table 1 we give the targets observed, names of the appropriate survey, mass ranges of the lenses, and corresponding optical depth.

Table 1. Targets in different ML surveys, the mass ranges of the lenses and optical depths.

Target	Survey	Mass range	Optical depth
LMC/SMC	MACHO	≈ 0.3 - $0.5\ M_\odot$	$\tau_{\rm LMC} = 2.9^{+1.4}_{-0.9} \times 10^{-7}$
			$\tau_{\rm SMC} = 1.5 - 3 \times 10^{-7}$
Gal. bulge	MACHO:DUO:OGLE	0.08 - $0.6\ M_\odot$	$\tau_{\rm bul} = 3.9^{+1.8}_{-1.2} \times 10^{-6}$
M31	KPNO	$\approx 10\ M_\odot$	$\tau_{\rm M31} = 5 - 10 \times 10^{-6}$
LMC/SMC	EROS2	0.85 - $8.7\ M_\odot$	$\tau_{\rm SMC} = 3.3 \times 10^{-7}$

Another important quantity, the optical depth, τ is used in discussion of ML and as we shall show, in determining the shape of the halo. It can be defined as the probability that at a given time a source star is being microlensed with an amplification larger than 1.34 (e.g. Roulet and Mollerach 1997).

Here we wish to investigate in more details one property of the halo of the Milky Way that has often been neglected: its shape. It is known from the work of Sackett and Gould (1993) that instead of the equation for the mass density in a spherical halo:

$$\rho(\mathbf{r}) = \frac{v_\infty^2}{4\pi G}\left(\frac{1}{a^2 + r^2}\right)\theta(R_T - r) \tag{6}$$

(where r is the Galactocentric radius, v_∞ is the asymptotic circular speed of the halo, a is the core radius of the halo and R_T is the truncation radius) one should use the generalized formula:

$$\rho(\mathbf{r}) = \frac{\tan\psi}{\psi}\frac{v_\infty^2}{4\pi G}\left(\frac{1}{a^2 + \zeta^2}\right)\theta(R_T - \zeta) \tag{7}$$

where $\zeta^2 = r^2 + z^2\tan^2\psi$ (z denotes height above the Galactic plane). Here the flattening parameter ψ is introduced: $\cos\psi = q = c/a$, i.e. its cosine is equal to the axis ratio and determines the shape of the halo En. En is related to q as $q = 1 - n/10$. Following Sackett and Gould (1993) we write the following expression for the estimate of the optical depth as a function of Galactic coordinates l (longitude) and b (latitude):

$$\tau(l,b) = \frac{\tan\psi}{\psi}\frac{v_\infty^2}{c^2}\frac{1}{D}\int_0^D \frac{dL(D-L)L}{(a^2 + R_0^2) - (2R_0\cos l\cos b)L + (1 + \sin^2 b\tan^2\psi)L^2} \tag{8}$$

where we put $R_0 = 8.5$ kpc and $a = 5$ (e.g. Alcock 1996). Now we integrate this equation and take $D = 50$ kpc (for LMC), $D = 63$ kpc (for SMC) and $D = 770$ kpc for M31. Although Sackett and Gould (1993) take values for q starting with $q = 0.4$ (shape E6) we will start with admittedly extreme value $q = 0.2$ (shape E8) required by some theories such as DDM (decaying dark matter) theory (Sciama 1997), based upon the recent Dehnen-Binney models of the Galaxy (Dehnen and Binney 1998). Attempts were made to show that this small value of q is not possible since $q = 0.75 \pm 0.25$ (Olling and Merrifield 1997), but at the cost that $R_0 = 7.1 \pm 0.4$ kpc (Olling and Merrifield 1998). We will nevertheless take into account such small value for q since we find DDM theory acceptable in solving different serious astrophysical and cosmological problems (e.g. Sciama 1993).

There are several other lines of reasoning suggesting a high degree of halo flattening in spiral galaxies. One is for long time suspected (e.g. Ninković 1985) flattening of the Population II subsystem, which may be a consequence of the residual rotation, or more probably, global flattening of the gravitational potential created by dark matter. The other is the behavior of the gas distributed in the halo. If the seminal idea of Bahcall and Spitzer (1969) of extended gaseous halos of normal galaxies producing narrow absorption features in the spectra of background objects is correct, as indicated by recent low-redshift measurements (Bergeron and Boissé 1991; Lanzetta *et al.* 1995), then the distribution of gas could tell us something about the shape of the gravitational potential. It is not a simple problem at all (see Barcons and Fabian 1987), but some results are quite suggestive. In an important recent paper, Rauch and Haehnelt (1995) have shown that for the most plausible values of Lyα cloud parameters, the conclusion that their axial ratio (thickness/transverse length) is less than 0.25 is inescapable. This conclusion does not depend on the exact choice of model for Lyα clouds, and, if the observations quoted above are correctly interpreted, would mean that the gaseous halos are also flattened by the same amount. One should keep in mind, though, that such absorption studies probe only "a tip of an iceberg", since these objects are ionized to extremely high degree, and may as well contain dominant part of the baryonic density in eq. (1).

Bearing this in mind, we solve the integral in the eq. (8) and give estimate for τ in several cases of particular interest:

- Optical depth $\tau(l, b)$ in the parametric space, with the parameter q fixed in steps of 0.2, i.e. $q = 0.2$, $q = 0.4$, $q = 0.6$, $q = 0.8$ and $q \approx 1$.
- Optical depth τ for different targets: LMC, SMC, M31 and Galactic bulge (bar) in order to see what value of q determines the optical depth that is closest to observed value in the appropriate survey.

Due to the space limitations, we hereby present just two three-dimensional plots. In the Figure 1, value of the optical depth τ is plotted against galactic coordinates l and b. This is an estimate for $q = 0.4$, but can easily be done for other values. One can use such plots (on the same or smaller angular scales) in order to choose observing direction where the optical depth reaches maximal values. Such an example is shown in the Figure 2 where we plotted optical depth as function of coordinates $l = 280.^\circ 5$ and $b = -32.^\circ 9$ of the Large Magellanic Cloud. Other plots and results of integration will be presented elsewhere.[1]

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[1] Some examples of plots and results of integration can be found in the postscript format at the following URL: `http://www.geocities.com/CapeCanaveral/7102/Belgrade-MACHO.html`, or from the authors by e-mail.

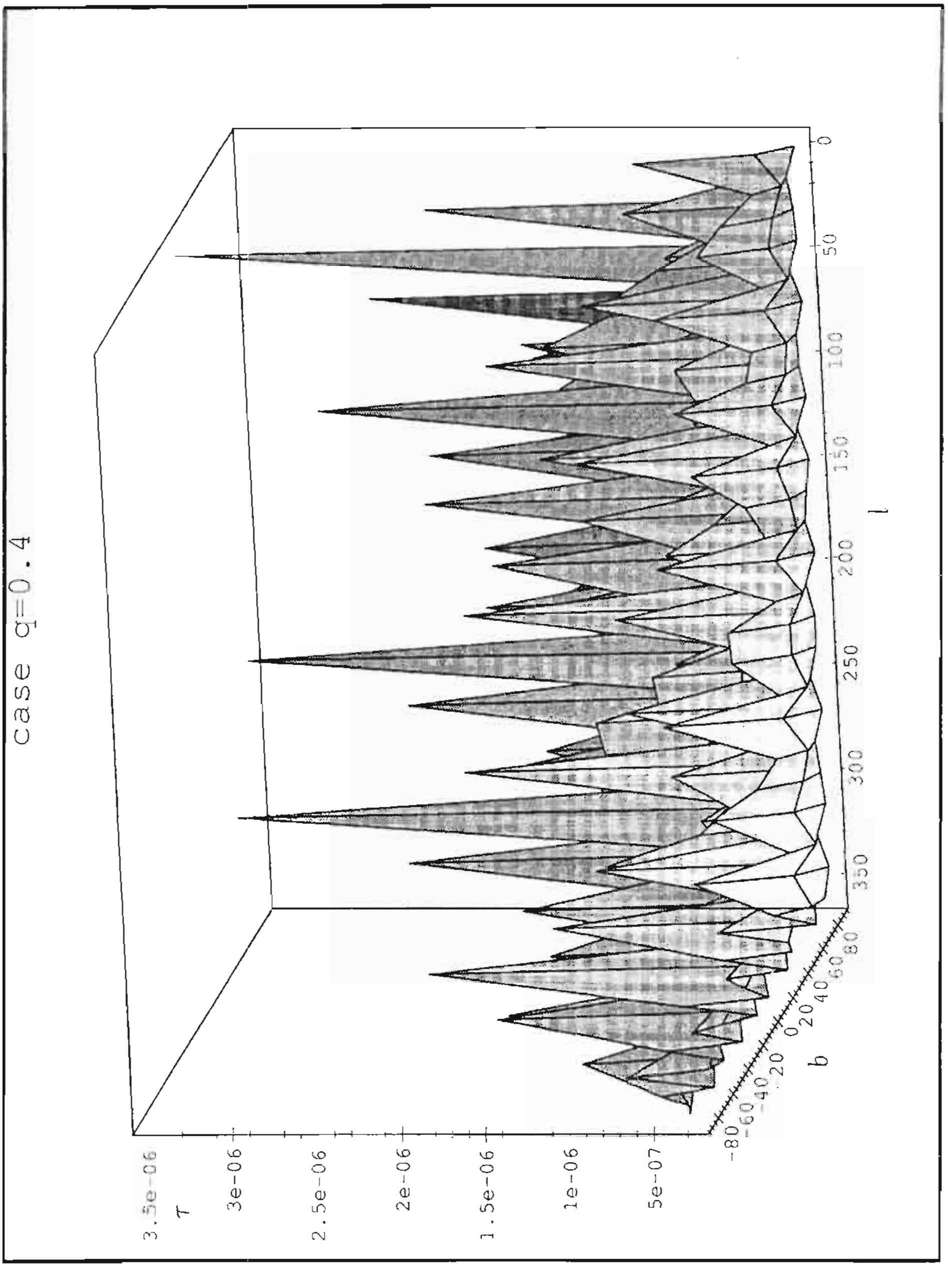

Fig. 1. Optical depth τ as a function of the galactic coordinates l and b. Distance to sources is taken to be 50 kpc and the axes ratio is $q = 0.4$.

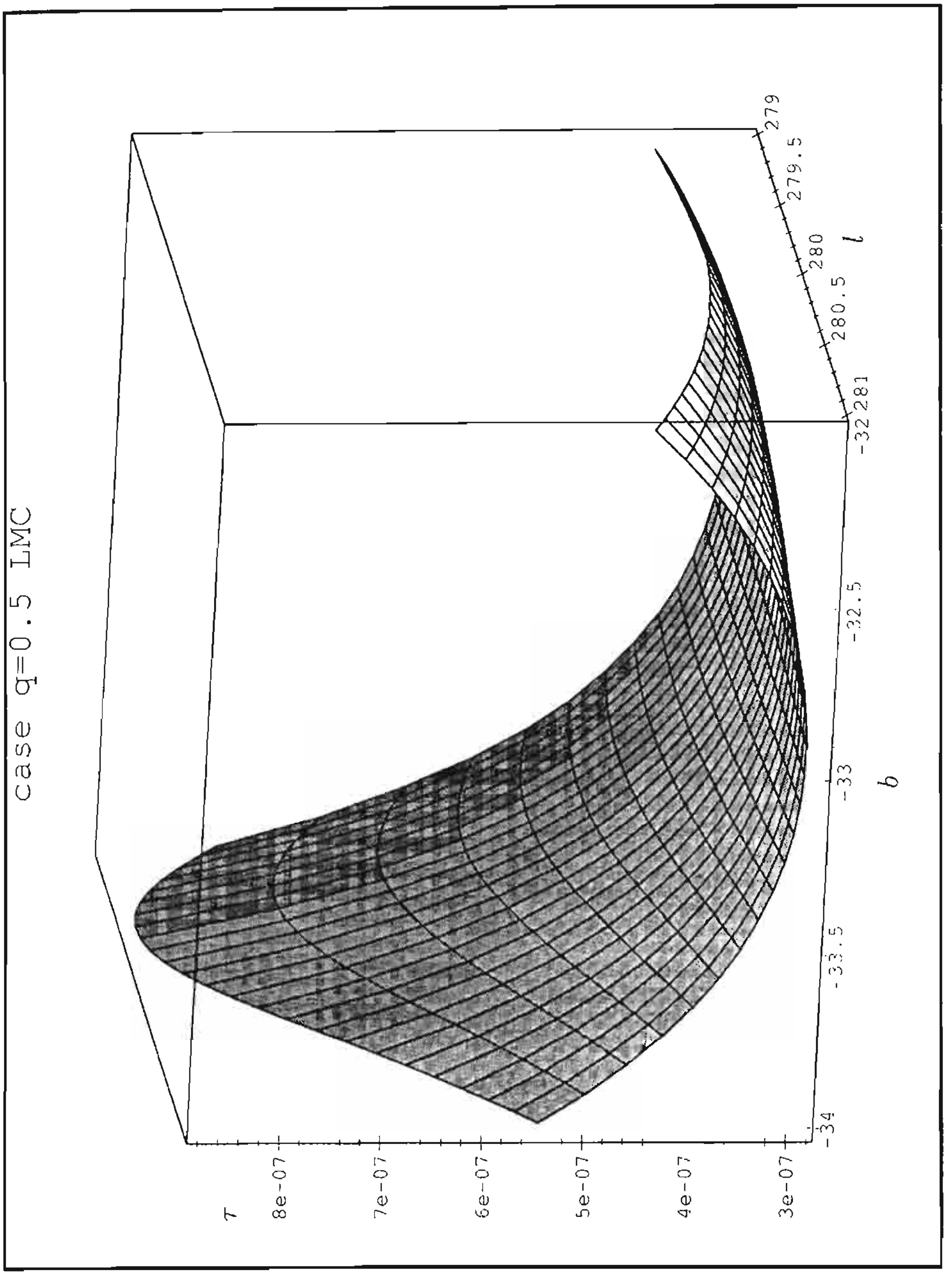

Fig. 2. Optical depth τ as a function of the galactic coordinates l and b for the Large Magellanic Cloud (LMC) for the axis ratio $q = 0.5$.

4. RESULTS AND CONCLUSIONS

After solving the integral in the eq. (8) for given values of the parameter q we looked for the values that match the optical depth obtained in various surveys. We found that the best agreement can be attained if we take $0.2 \lesssim q \lesssim 0.6$. Namely:

1. For the case of the LMC, that has been studied rather well, the measured value of the optical depth based upon the sample of 8 events is $\tau = 2.9^{+1.4}_{-0.9} \times 10^{-7}$ (Alcock 1997b) while we find that for $q = 0.5$ we have $\tau \approx 3 \times 10^{-7}$ (see Figure 2).
2. For the case of the SMC, that is studied less thoroughly, the optical depth is estimated as $\tau = 1.5 - 3 \times 10^{-7}$ (Alcock 1997c). Our results show that the model in the eq. (8) gives the value $\tau \gtrsim 4 \times 10^{-7}$ for $q \approx 0.5$ and above.
3. For the case of the galaxy M31 we found $\tau \approx 5 \times 10^{-6}$ which is an accordance with the estimates $5 - 10 \times 10^{-6}$ (Crotts 1996), under the assumption that $q \gtrsim 0.2$.
4. Determining τ towards the Galactic center is more complicated and we will not discuss it here. We only state that using the model in the eq. (8) we can estimate the halo contribution to the ML rate towards Galactic center which is between $\tau \approx 5 \times 10^{-8}$ ($q = 0.6$) and $\tau \approx 1.6 \times 10^{-7}$ ($q = 0.2$); the estimated range for the total optical depth towards Galactic center is ($\tau = 3.9^{+1.8}_{-1.2} \times 10^{-6}$) (Alcock 1997a).

From our estimates it is obvious that the spherical dark halo can be ruled out: the value for q lies in the interval: $0.2 \lesssim q \lesssim 0.6$. Recent research shows that it is not uncommon case with spiral galaxies (Sackett and Sparke 1990; Sackett *et al.* 1994; Olling 1995). Very recently, the observations of the gravitational lens system B1600+434, consisting of two spiral galaxies (G1 and G2), where G2 is a barred one, suggest that it has $q \gtrsim 0.4$ (Koopmans, de Bruyn and Jackson 1998).

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THE ELECTRON-IMPACT BROADENING PARAMETERS FOR Ti II LINES

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Abstract. Here we present the electron-impact broadening parameters for Ti II lines. Calculation was performed by using the modified semiempirical approach.

1. INTRODUCTION

In order to provide to astrophysicists and physicists the needed electron-impact broadening parameters, a large set of such data, obtained by using the semiclassical perturbation formalism (see e.g. Dimitrijević *et al.* 1991) and the modified semiempirical approach (Dimitrijević and Konjević 1980, for emitters with complex spectra see also Popović and Dimitrijević 1996, 1997), has been created (see Dimitrijević 1996 and references therein). Here we present our results for Ti II lines. The calculations were performed by using the modified semiempirical approach.

2. RESULTS AND DISCUSSION

Energy levels for Ti II were taken from Wiese and Musgrove (1989). Oscillator strengths have been calculated by using Bates and Damgaard (1949) method. Here we present only Stark widths and shifts for the most intensive lines from $a^4F - z^4G^0$ and $a^4F - z^4F^0$ multiplets. The Stark widths (w_x) of other lines from these multiplets may by calculated as

$$w_x = w_l(\frac{\lambda_x}{\lambda_l})^2 \qquad (1)$$

with error bars of ±30%. In Eq (1) w_l is the given Stark width and λ_l is the wavelength for the corresponding transition, while λ_x is the wavelength for the spectral line with width w_x. Besides the calculation with oscillator strengths within the Bates-Damgaard approximation, we performed as well, the same calculations by using different, calculated (Morton 1991) and measured (Danzmann and Kock 1980 and Blackwell *et al.* 1982, critically selected by Wiese and Musgrove 1989; Roberts *et al.* 1974) oscillator strengths, in order to analyze the influence of the different oscillator strengths values to electron-impact broadening parameters. The results of our investigation are presented in Figs. 1 and 2. As we can see in Figs. 1 and 2 the differences between results obtained with the oscillator strengths from different sources give discrepancy between calculated Stark widths within the error bars of the MSE method in the case of $a^4F_{9/2} - z^4F^0_{9/2}$, while for the transition $a^4F_{3/2} - z^4G^0_{5/2}$ the Stark widths calculated within the Bates-Damgaard approximation are significantly smaller than those calculated with oscillator strengths from Morton (1991) and experimental oscillator strengths. Complete results of our calculations will be published elsewhere (Tankosić *et al.* 1998).

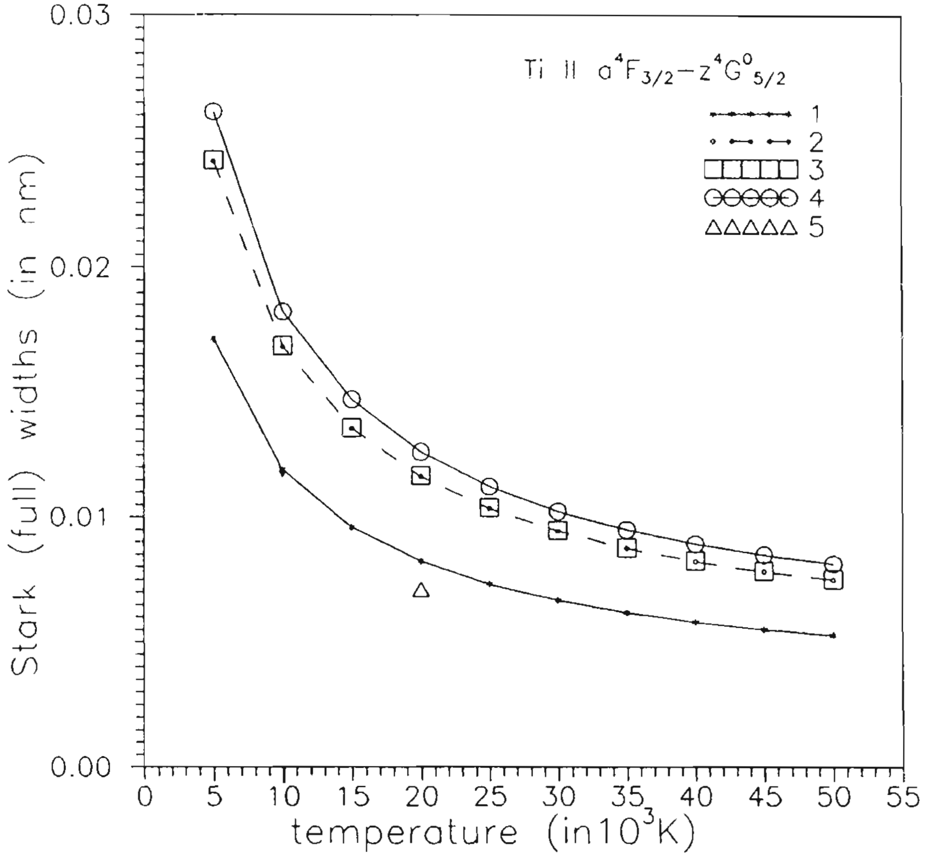

Fig. 1. Stark full width for Ti II $a^4F_{3/2} - z^4G^0_{5/2}$ (λ =338.47 nm) line as a function of temperature at an electron density of 10^{23}m^{-3}. Used notation: Results with- **1.**- oscillator strengths calculated by using the Bates-Damgaard method; **2.**- oscillator strengths given by Danzmann and Kock (1980) and Blackwell *et al.* (1982), critically selected by Wiese and Musgrove (1989); **3.**- oscillator strengths given by Roberts *et al.* (1974); **4.**- oscillator strengths given by Morton (1991). **5.**- The estimated Strak width on the basis of regularities and systematic trends given by Lakićević (1983)

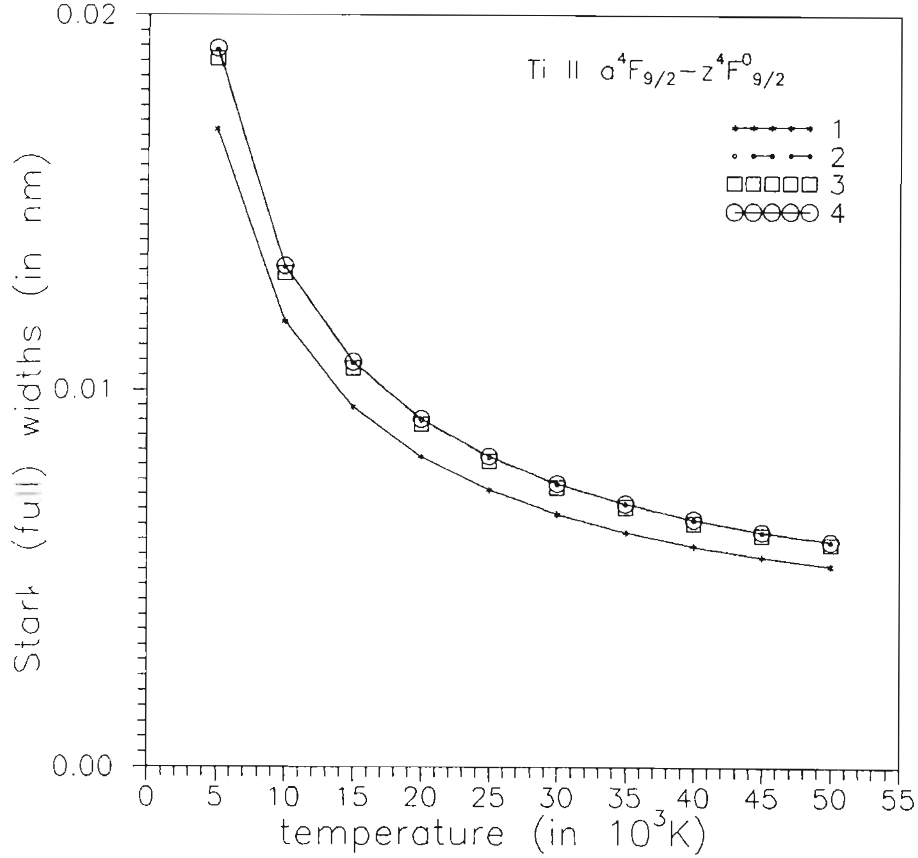

Fig. 2. Stark full width for Ti II $a^4F_{9/2} - z^4F^0_{9/2}$ (λ =323.55 nm) line as a function of temperature at an electron density of 10^{23}m^{-3}. Used notation: Results with- **1.**- oscillator strengths calculated by using Bates-Damgaard method; **2.**- oscillator strengths given by Danzmann and Kock (1980) and Blackwell *et al.* (1982), critically selected by Wiese and Musgrove (1989); **3.**- oscillator strengths given by Roberts *et al.* (1974); **4.**- oscillator strengths given by Morton (1991)

Table 1. Stark width (FWHM) and shift of Ti II lines at an electron density of 10^{23}m^{-3} as a function of temperature. The oscillator strengths were calculated in Bates-Damgaard approximation (Bates-Damgaard 1949).

Transition	T (K)	W (nm)	d (nm)
$a^4F_{3/2} - z^4G^0_{5/2}$ λ = 338.47 nm	5000.	0.171E-01	-0.389E-02
	10000.	0.119E-01	-0.278E-02
	20000.	0.822E-02	-0.201E-02
	30000.	0.666E-02	-0.169E-02
	40000.	0.580E-02	-0.149E-02
	50000.	0.528E-02	-0.138E-02

Table 1. continued

Transition	T (K)	W (nm)	d (nm)
$a^4F_{9/2} - z^4F^0_{9/2}$ $\lambda = 323.55$ nm	5000.	0.170E-01	-0.337E-02
	10000.	0.118E-01	-0.241E-02
	20000.	0.817E-02	-0.174E-02
	30000.	0.662E-02	-0.145E-02
	40000.	0.577E-02	-0.127E-02
	50000.	0.525E-02	-0.117E-02

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NONLINEAR COHERENT STRUCTURES IN PLASMAS AND FLUIDS

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Abstract. Nonlinear electrodynamic and hydrodynamic equations having solutions in the form of coherent stationary vortices and vortex chains are presented. In most cases they are capable of depicting the observed nonlinear structures in various laboratory and space plasmas.

Nonlinear coherent structures, double and monopole vortices (Hasegawa and Mima, 1977), and vortex chains (Shukla and Stenflo, 1995; Vranješ and Jovanović, 1997), resulting from the self-organization of both fusion and space plasmas, have attracted a lot of interest in the last twenty years. They may appear in various processes such as nonlinear interaction of a strong pump propagating through a plasma in the processes of plasma heating, with slow low frequency perturbations normally existing in plasmas (Jovanović and Vranješ, 1996), in the development of some plasma instabilities (Aleksić *et al.* 1996; Jovanović and Vranjě1990, 1994) etc. Recently it has been shown that equations describing low frequency electrostatic waves in a sheared plasma flow in the auroral ionosphere (Shukla *et al.* 1995) and waves in large self-gravitating astrophysical clouds (Shukla and Stenflo, 1995), possess solutions in the form of traveling vortex chains periodic in the direction of propagation and localized transversely to it. Recent satellite observations of electromagnetic structures in the Earth's ionosphere and magnetosphere, and corresponding theoretical model equations (Chmyrev *et al.* 1991), reveal that apart from monopole and dipole structures, there also may exist coherent solutions in the form of vortex chains. It is believed that the manifestation of such vortical structures in the magnetosphere are the discrete fluxes of electrons in active auroral forms, which occur due to acceleration of electrons by the electric field component directed along the magnetic field lines. Vortex solitons obtained recently from the Freja satellite (Wu *et al.* 1997) with characteristic spatial scales of 300-600 m, can be nicely described using standard nonlinear theory of drift waves, developed in order to describe the drift wave turbulence in present day tokamak machines.

A typical equation describing vortices may be derived using the standard model of two-component, electron-ion plasma immersed in an external magnetic field $B_0\vec{e}_z$, with the equilibrium density gradient dn_0/dx, and in the limit of low-frequency (in comparison with the ion gyrofrequency) electrostatic perturbations. Using standard hydrodynamic equations, i.e. the ion continuity and momentum equations, and the assumption of quasineutrality and Boltzmann distribution of electrons, one can obtain the well known Hasegawa-Mima equation (Hasegawa and Mima, 1977) which can be written in the form:

$$\frac{\partial}{\partial t}\left(\rho^2\nabla^2\Phi - \Phi\right) - \frac{\rho^2}{B_0}\left[(\nabla\Phi\times\vec{e}_z)\cdot\nabla\right]\left[\nabla^2\Phi - \frac{T_e}{\rho^2 e}\log\left(\frac{n_0}{\Omega_i}\right)\right] = 0. \qquad (1)$$

Here the assumption of cold ions is used and ρ, Ω_i, T_e, Φ are the ion gyroradius, ion gyrofrequency, electron temperature, and electrostatic potential, respectively. In the linear regime Eq. (1) describe ordinary drift waves. The most simple nonlinear process described by the above equation is the three wave interaction in plasmas. A characteristic cascading of wave energy towards larger and smaller wave numbers k can be easily demonstrated, meaning that the mode with the intermediate value of k may act as a pump. In the strongly nonlinear regime Eq. (1) possesses solution in the form of a double vortex traveling with a constant velocity perpendicularly both to the density gradient, and the magnetic field lines. Although it is not the soliton in the strict sense it is remarkably stable and may survive different types of perturbations like collisions with other vortices etc.

It is interesting to note that there exists an analogous equation in the hydrodynamic theory of Rossby vortices; exactly the same equation describing cyclones and anticyclones in the Earth's atmosphere may be obtained replacing Φ by the perturbation of the surface of the atmosphere δh, and the ion gyroradius by the Rossby-Obukhov radius r_R. The best known example of the monopole solution of the Rossby equation is the Great Red Spot on Jupiter, observed by R. Hooke as far back as in 1664, and described in his paper (Hooke, 1666). It is an anticyclone vortex which extends about 26 000 km in longitude and 13 000 km in latitude, drifting westward with the velocity of about 3 m/s, and can be modeled by relatively simple experiments with rotating fluids (Nezlin, 1986). The White Ovals, lasting for more than 50 years, and Brown Ovals (more than 10 years) are another examples of long lasting vortices on Jupiter.

Vortex-type structures may also be found in large self-gravitating magnetized plasma clouds (Jovanović and Vranješ, 1990). Starting from a model of a homogeneous cold plasma cloud we study Alfven-type two dimensional perturbations propagating perpendicularly to the magnetic field. Using standard electro-hydrodynamic equations with the gravitational effects included via Poisson equation one can obtain the following set of coupled nonlinear equations describing perturbations of electrostatic (Φ) and gravitational (Γ) potential:

$$\left[\frac{\partial}{\partial t} + \frac{1}{B_0}(\vec{e}_z\times\nabla_\perp\Phi)\cdot\nabla_\perp\right]\left[\frac{\Omega_i^2}{\omega_{pi}^2}\nabla_\perp\Phi - (\nabla_\perp^2+1)\Gamma\right] = 0, \qquad (2)$$

$$\left\{\frac{\partial}{\partial t} + \frac{1}{B_0}\left[\vec{e}_z\times\nabla_\perp\left(\Phi - \frac{\Omega_g^2}{\Omega_i^2}\Gamma\right)\right]\cdot\nabla_\perp\right\}\left[\nabla_\perp^2\Phi + (\nabla_\perp^2+1)\Gamma\right] = 0. \qquad (3)$$

Here the magnetic field is in the z-direction, $\nabla_\perp = \partial_x\vec{e}_x + \partial_y\vec{e}_y$, $\omega_g^2 = 4\pi G m_i n_0$, $\omega_{pi}^2 = e^2 n_0/m_i\epsilon_0$, and m_i is the ion mass. Nonlinear Eqs. (2), (3) have solutions in the form of double vortex with typical scale size of the order of Jeans' critical length.

It can be shown also that the gravitational collapse is a higher order effect, i.e. it occurs on a much longer time scale compared to the characteristic time (e.g. period of rotation) of the vortex.

Three dimensional nonlinear Rossby waves in rotating gravitating systems with a nonuniform angular velocity $\omega_0(x,y)\vec{e}_z$, and with a perpendicular equilibrium density gradient have been studied in Ref. Shukla and Stenflo, 1995). Using standard fluid equations one can obtain the following equation describing the perturbation of gravitational potential Γ:

$$\frac{\partial^2}{\partial t^2}\nabla_\perp^2\Gamma + \frac{1}{2\omega_0}\frac{\partial}{\partial t}J(\Gamma, \nabla_\perp^2\Gamma) + \frac{1}{\alpha - 2}\left(\frac{\partial}{\partial t}\nabla_\perp\Gamma \times \vec{e}_z\right)\nabla_\perp\left(\frac{\omega_g^2}{\omega_0}\right) + \frac{2}{\alpha - 2}\left(\omega_g^2 - \frac{\partial^2}{\partial t^2}\right)\frac{\partial^2\Gamma}{\partial z^2} = 0. \tag{4}$$

Here $\alpha = 2\pi G n_0/\omega_0^2 = \omega_g^2/2\omega_0^2$, $J(f,g) = \partial_x f \partial_y g - \partial_x g \partial_y f$. In the linear limit the above equation describe linear Rossby waves. In the strongly nonlinear case an analytical stationary solution of Eq. (4), traveling with a constant velocity u in the y-direction, for u satisfying certain conditions, can be written in the form:

$$\Gamma = 2u\omega_0 x + A\log 2\left[\cosh(kx) + \sqrt{1 - 1/a^2}\cos(ky)\right]. \tag{5}$$

For $a^2 > 1$ it represents a vortex street resembling the Kelvin-Stuart cat's eyes.

Similar solutions may be found numerically in the problem of self-generation of magnetic field (Vranješ and Jovanović, 1996). We study electromagnetic perturbations of electrons in an electron-ion plasma with heavy ions making neutralizing background, and with an electron flow in the basic state. Using the electron momentum and energy equation together with the Maxwell equations one can find the following nonlinear equation describing the generation of magnetic field:

$$\left(\frac{\partial}{\partial t} + \varphi'\frac{\partial}{\partial y} + \vec{e}_z \times \nabla B \cdot \nabla\right)(\nabla^2 - 1)B - \varphi'''\frac{\partial B}{\partial y} = 0. \tag{6}$$

This equation is derived on condition of a weak time dependence $\partial_t \ll \omega_{pe}$ (electron plasma frequency), for z-independent perturbations, and for the plasma flow given by $\vec{v}_0(x) = V_0 f(x)\vec{e}_y$, where we introduced $\varphi'(x) = f(x)$. In the linear case Eq. (6) belongs to the class of equations describing streaming instabilities. In the strongly nonlinear limit we look for stationary solutions traveling along the y-axis with the velocity u. Writing $\partial/\partial t = -u\partial/\partial y$, Eq. (6) can be integrated once, and for the flow profile symmetric around the phase velocity u it is solved numerically. The solutions are sought in the form:

$$B(x,y) = B_1(x) + \delta B_1(x)\cos(ky), \quad |\delta B_1(x)| << |B_1(x)|. \tag{7}$$

We found two different nonlinear modes, for even and odd B_1 and δB_1. In the first case the solution for the magnetic field is a two-dimensional, single vortex chain structure, localized along the gradient of the flow (x-axis), and periodic in the perpendicular direction (y-axis). In the second case it has the form of a double chain structure with much bigger periodicity length (smaller k_y) along the y-axis.

In both cases the self-generated magnetic filed yields a significant steepening of the electron flow profile. A similar situation was observed in the case of a magnetized plasma (Vranješ, 1998). In a local approach perpendicularly to the flow, double vortices driven by the density and temperature gradients are found. In a nonlocal case we obtain vortex chains driven by the flow.

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DAY-TIME OBSERVATIONS WITH THE BELGRADE MERIDIAN CIRCLE – REDUCTION OF THE INSTRUMENT PARAMETERS TO THE FK5 SYSTEM

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Abstract. Since 1973 the Belgrade Meridian Circle has been used in day-time observations of the Sun and the inner planets. The instrument parameters have been determined from the observation of the fundamental stars, reduced in the first period to the FK4 system and during the last several years to that of the FK5.

The positions of all the fundamental stars, as listed in the present paper, are reduced to the FK5 system and the $(O - C)$ corrections to the positions of the Sun, Mercury and Venus have subsequently been calculated.

1. INTRODUCTION

In parallel with the night observations with the Belgrade Meridian Circle, since 1973 day-time observations of the Sun and inner planets, conjointly with the appropriate fundamental stars have also been performed. These day-time observations became regular since 1975. In 1981 included in the programme of the observations of the Sun and the inner planets was also Mars. This observing programme has been kept uninterrupted throughout until 1994.

The basic objective of our observations of the Sun, planets and the fundamental stars was, in principle, the improvement of the orientation of the FK4. In addition, from the differences of the observed and the calculated positions of the planets, i.e. from the $(O - C)$ deviations on can derive corrections to the elements of their orbital motion. The results of these observations, i.e. the corrections of the equinox and equator involved by the FK4 catalogue have earlier been published already (Sadžakov et al. 1982; Sadžakov et al. 1992).

An analogous procedure is of course valid when the FK5 catalogue is concerned. For this to be performed all observations had to be reduced to the FK5 system. This is followed by treating the observational results in conformity with the fact that our observations were differential ones.

2. THE INSTRUMENT PARAMETERS AND REDUCING TO THE FK5 SYSTEM

The day-time observations of the Sun and the inner planets were carried out by series. A particular series included the observation of at least one solar system body (Sun, Mercury, Venus, later Mars) and a few fundamental stars, accessible to observation by day-time. Care has always been taken the stars to be close in time and declination to those of the observed solar sistem bodies. Nevertheless, it sometimes happened that no star, or one only, could be observed. Such series – with no one or with a single star observed. have not been considered. Otherwise, most of the series comprised both the Sun and Venus.

The right ascensions were derived according to Bessel formula. First the values of the parameter n was determined for each one of the series. This parameter was obtained alike from the day-time observations and from the night ones, whereby its variation has been taken into account. Upon introducing the parameter n and calculating the positions of the fundamental stars, particular amounts $(u + m)$ and their means have been deduced.

With the declinations the things are somewhat simpler. From the observations of the fundamental stars one parameter only is to be determined – the equator point M_o.

Bearing in mind that our pervious observations were reduced to the FK4 system, the question arises as to how much the $(O - C)$ deviations are affected if the apparent positions of the fundamental stars, from which the instrument parameters are deduced, are calculated in the FK5 system, i.e. if these parameters are reduced to the FK5 system. To answer this question we poceeded from expressions serving for the calculation of the instrument parameters.

The modified Bessel formula for the right ascension reads:

$$(u + m)\cos\delta + n\sin\delta = (\alpha - T)\cos\delta \ ,$$

where α is the apparent right ascension at the time of observation whose values will vary depending on the system within which the reduction is made. As evident from the above formula these changes in α will be reflected in the $(u + m)$ and n values.

In view of the fact that most of the stars observed during these day-time tours had declinations not much different from those of the Sun and the planets, it follows from the above formula that the changes in the $(u+m)$ parameter will chiefly be due to the changes in the right ascensions α. The correction to the mean value of this parameter in a given series will be:

$$\overline{\Delta(u + m)\cos\delta} \approx \overline{\Delta\alpha\cos\delta} \ ,$$

this all the more so since the n parametar is obtained separately.

Concerning the declination the equator point is obtained from the formula:

$$\begin{aligned} M_o &= M - \delta \qquad \text{at clamp east (CE) ;} \\ M_o &= M + \delta \qquad \text{at clamp west (CW) .} \end{aligned}$$

Accordingly, the mean value of the equator point position within a series will vary by the amount:

$$\overline{\Delta M_o} = \mp\,\overline{\Delta\delta} \ .$$

The positions of the Sun and the planets as obtained by observing within a particular series are to be corrected by a value equal to the correction to the corresponding instrument parameter, whereby our observations are linked to the FK5 catalogue.

3. RESULTS OF THE REDUCTION

By analysing the day-time observations, first of all the manner of determining the instrument parameters and the accuracy of calculation of particular positions, it has been inferred that the initial period 1975–1979 should not be taken into account concerning the orientation of the FK5 catalogue. The determination of the positions of the Sun, Mercury and Venus were rather often during this period linked to the night observations. Even though the possible variations of the parameters were taken into account, these have been determined under conditions differing considerably from those prevailing during the day-time observations. In other words the star observations from which the instrument parameters have been derived in many series have not been conjoint with those of the Sun and the planets. An extra problem was the determination of the clock rate. Such a mode of observations and their processing presented one of the principal causes of the very high accidental errors in $(O-C)$ deviations in this period (1975-1979).

The corrections to the instrument parameters expressed through the means of the corrections to the fundamental stars positions are displayed in Tables 1 and 2. Corrections to the parameter $\overline{\Delta(u+m)\cos\delta}$ (corr$_\alpha$), meaned according to seasons are listed in Table 1, along with the number of observed stars (n) and the number of the series (N). Table 2 contains the meaned corrections to the equator point $\overline{\Delta M_o}$ (corr$_\delta$) and the corresponding data on the number of stars observed (n) and the number of series (N).

Both of Tables are divided into two parts. In the first part, pertaining to the period 1979–1983, the star positions were reduced within the FK4 system. The second part, relating to the period 1984 1987, the reductions were carried out within the FK5 system (without the individual and systematic corrections to the star positions).

High correction ammounts in the first part of Table 1 are a consequence of the corrections to the equinox involved by the FK4 catalogue. A considerably lower amount of this correction is evident in the last year's quartal. As expected, after passing over to the FK5 system (1984–1987), no such season dependent variations do appear. The mean corrections to the equator point in the second part of Table 2 are shifted toward zero – which equally was expected.

It is to be indicated that in some of the seasons the instrument parameters were determined from the observations of well-night the same stars (conditioned by their visibility by day-time circumstances), so that the obtained mean values are practically dependent on the star selection enforced, i.e. on the individual star positions differences in the FK4 and FK5 catalogues.

Table 1. Corrections to the parameter $\overline{\Delta(u+m)\cos\delta}$

Year	Spring			Summer			Autumn			Winter		
	corr_α $0\overset{s}{.}001$	n	N	corr_α $0\overset{s}{.}001$	n	N	corr_α $0\overset{s}{.}001$	n	N	corr_α $0\overset{s}{.}001$	n	N
1979				+52	40	6	+49	38	7			
1980				+55	39	8	+47	30	8	+54	14	3
1981				+57	32	11	+37	17	6			
1982	+38	2	1	+49	12	5	+38	25	10	+62	21	7
1983				+41	2	1	+39	14	5	+54	11	2
mean	+38	2	1	+54	125	31	+44	124	36	+58	46	12
1984	−2	8	2	−6	2	1	−5	15	6	−6	10	4
1985	−3	21	7	−4	83	21	−5	26	11			
1986	−5	44	11	−5	24	9	−5	26	8	−4	21	5
1987	−8	6	3	−5	8	3	−4	28	8			
mean	−4	79	23	−4	117	34	−5	95	31	−5	31	9

Table 2. Corrections to the parameter $\overline{\Delta M_o}$

Year	Spring			Summer			Autumn			Winter		
	corr_α $0\overset{\prime\prime}{.}01$	n	N	corr_α $0\overset{\prime\prime}{.}01$	n	N	corr_α $0\overset{\prime\prime}{.}01$	n	N	corr_α $0\overset{\prime\prime}{.}01$	n	N
1979				−5	42	6	−2	37	7			
1980	0	5	1	−3	93	16	−3	33	9	−3	15	3
1981				+2	37	12	−3	18	6			
1982	−4	4	2	+2	12	5	−2	26	10	−10	20	6
1983				−6	2	1	−4	14	5	+3	11	2
mean	−2	9	3	−2	184	40	−3	128	37	−5	46	11
1984	+1	8	2	−5	2	1	−3	15	6	−3	10	4
1985	+1	21	7	+1	89	23	−3	26	11			
1986	−1	43	11	−1	24	9	−2	26	8	−1	21	5
1987	−3	6	3	+1	8	3	0	28	8			
mean	0	78	23	+1	123	36	−2	95	33	−2	31	9

4. CONCLUSION

The day-time observations of the Sun, planets and fundamental stars made with the Belgrade Meridian Circle may be used for the correction to the fundamental catalogues. In the present paper it is shown by what amounts, determined from the observations of the fundamental stars, the instrument parameters should be corrected in order to obtain the directly observed Sun and planets positions in the FK5 system. The low accuracy of our observations in the first period (1975–1979) makes them unsuitable for the task we originally envisaged.

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THE SMOOTHING OF THE POLAR MOTION DATA BY THE LEAST – SQUARE COLLOCATION METHOD

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Abstract. Three methods of the data smoothing: the least – square collocation (LSC), the Vondrák (WRV) and the cubic spline (SPL) are applied to the polar motion data. Some advantages of the smoothing by LSC method and the comparison with other two methods (WRV and SPL) of filtering and smoothing are shown.

1. INTRODUCTION

The astronomical data, as the polar motion data, represented by the observed values l_i, can be separated into the signal s_i (or the systematic changes of the measured values) and the random errors n_i (the errors of observations). We want to remove n_i from the raw data l_i before the analysis. Let the values n_i represent the white noise. The ideal method of smoothing is the one which removes only the random part from the raw data and does not change the systematic part (the signal).

In the astronomical practice (like it was in the practice of BIH and now of IERS) the WRV method is commonly accepted and the alternative method is SPL, but the SPL is not superior to WRV in any sense. The LSC method, first applied in geodesy, gave good results also in the astronomical practice for the last few years. We want to show here some advantages of the smoothing by LSC.

The LSC is a linear transform $s_i = Fl_i$. It is a method of stochastic filtering. With good knowledge of the autocovariances of the signal it is possible to filter the noise most optimally and to estimate $\hat{s}_i$ (close to s_i as much as possible). The theoretical base was established by Moritz (1980). To make the algorithm we used the paper by Gubanov and Petrov (1994) wherein some formulae were corrected for some mistakes, and also the paper Titov (1995).

The series l_i and s_i (where $i = 1, 2, ..., N$) are centred and equidistant. We use here the raw values of x and y – component of the polar motion (IERS, 1993) over the interval [JD 2437669 (04.I 1962) – JD 2440664 (18.III 1970)] and the input data are 5 days spaced ($N = 600$).

Let us consider the series l_i and s_i as vectors $\mathbf{l}$ and $\mathbf{s}$. Then, the problem of filtering the noise is to determine the operator F which satisfies the condition $||\hat{\mathbf{s}} - \mathbf{s}||^2 = min$

(Gubanov and Petrov, 1994). It is only necessary to know some of statistic characteristics of the signal (which can be known a priori), but not its mathematical model. In LSC we presume that the covariance function of the signal is known, the vector **n** does not have correlation, the signal and the noise are not mutually correlated.

By solving the problem of filtering by the LSC method, the autocovariance function of the signal (q_{ss}) should be obtained. There are several different ways to do it (Titov, 1995): using of the variance of the white noise σ_n^2 (obtained by approximation of raw data covariance function in vicinity of zero), using of the descending exponential model of covariance function or using of the covariance function obtained from independent observations.

We had already performed the filtering by LSC method after estimation the variance σ_n^2 (Damljanović, P.Jovanović and B.Jovanović, 1996). The autocovariance functions $q_{ll}(j)$ of the vector l and $q_{ss}(j)$ of the signal s can be estimated by the formulae presented by Gubanov and Petrov (1994). Then, $\sigma_n^2 = q_{ll}(0) - q_{ss}(0)$. The basic formula of LSC for filtering the noise is: $\hat{\mathbf{s}} = Q_{ss}Q_{ll}^{-1}\mathbf{l}$, where Q_{ss} and Q_{ll} are covariance matrices (with symmetric form) of the signal and raw data. A form of Q_{ss} and Q_{ll} was given by Damljanović *et al.* (1997), wherein the descending exponential model of covariance function was used.

Neither of algorithms, in our opinion, were sufficiently satisfactory. Therefore, in this paper we use q_{ll} and its approximation q_{ss}, but now the values $q_{ll}(j)$ (where $j = 0, 1, ..., N-1$) are fitted by elementary trigonometric functions using the B.Jovanović (BJ) method for approximation of arbitrary numerical data set as a sum of linear function, harmonics and exponential functions (B.Jovanović 1987, 1989, 1997).

2. RESULTS

The BJ method belongs to a class of algebraic harmonic analysis methods. The analytical representation of q_{ss} is developed here in the form

$$q_{ss}(j-1) = \sum_{i=1}^{m} A_i \cos(\omega_i t_j + \phi_i), \qquad j = \overline{1, N}$$

by use of BJ method and, thereupon, the LSC procedure is applied. In Table 1. are presented the calculated values for A_i, ω_i and ϕ_i (for the epoch JD 2437669); $m = 22$.

Raw and filtered data (by LSC, WRV and SPL) of x and y coordinates of the polar motion are shown in Fig. 1. and Fig. 2. The values smoothed by LSC follow better the raw data and differ remarkably from the ones obtained by other two methods (WRV and SPL). We determined the value of ε (the smoothing parameter of WRV) as explained in Vondrák (1977) and as we did it in Damljanović *et al.* (1997); $\varepsilon = 10^{-8}$ for x - component and $\varepsilon = 1.5 * 10^{-9}$ for y. The value of $\frac{\sigma_A}{\sqrt{2}}$ is $0''.019$ for both (x and y) components, where $\sigma_A = \sqrt{\frac{\sum_{i=1}^{N-1}(l_{i+1}-l_i)^2}{N-2}}$. The smoothing parameter S of SPL method (Reinsch, 1967) is the mean value of the confidence interval $[N - \sqrt{2N}, N + \sqrt{2N}]$ (for a normal distribution of errors). Hence, $S = 600$.

The values of standard deviations (σ) of the residuals, after smoothing by LSC, WRV and SPL, are: $0''.018$, $0''.019$ and $0''.020$ respectively, for x - coordinate ($0''.021$,

Table 1.

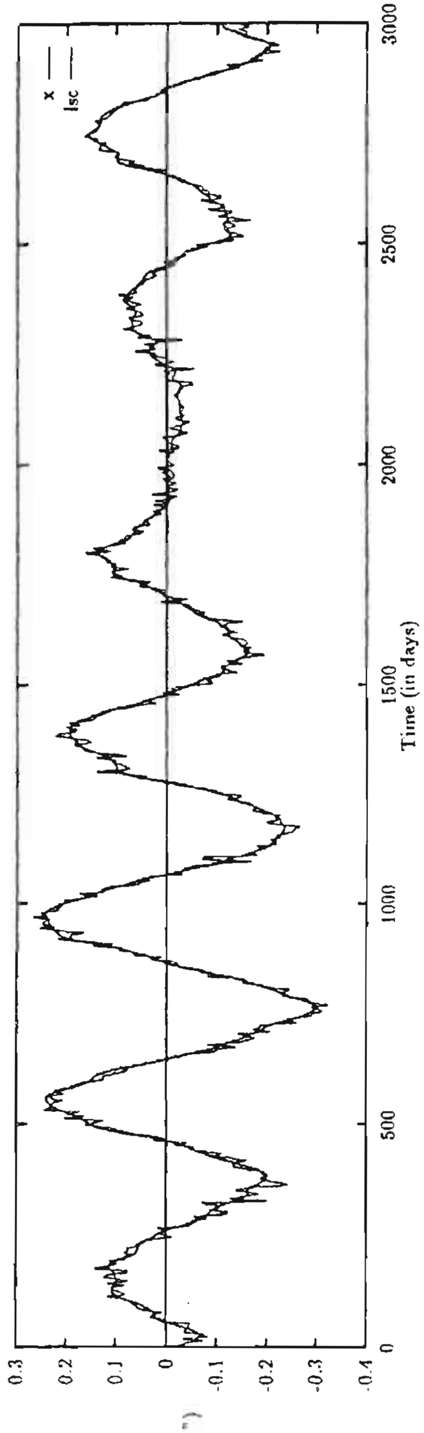
	x - coordinate			y - coordinate		
i	$A_i('')$	$\omega_i(rad/day)$	$\phi_i(^\circ)$	$A_i('')$	$\omega_i(rad/day)$	$\phi_i(^\circ)$
1	0.63971E-02	0.14518E-01	29.85	0.61126E-02	0.14518E-01	32.53
2	0.48210E-02	0.13865E-01	-40.26	0.48488E-02	0.13865E-01	-42.64
3	0.31260E-02	0.16396E-01	-27.96	0.27547E-02	0.16396E-01	-26.09
4	0.31050E-02	0.17238E-01	34.63	0.23006E-02	0.17238E-01	39.79
5	0.12951E-03	0.32444E-02	-50.28	0.99046E-04	0.38768E-02	44.99
6	0.10997E-03	0.20289E-01	-36.24	0.55450E-04	0.32444E-02	-44.70
7	0.86053E-04	0.38768E-02	45.76	0.34549E-04	0.77396E-02	-40.85
8	0.43833E-04	0.77396E-02	3.69	0.34367E-04	0.20289E-01	-111.39
9	0.31511E-04	0.29727E-01	39.41	0.15015E-04	0.29727E-01	94.10
10	0.16513E-04	0.26601E-01	-160.96	0.91291E-05	0.34666E-01	-28.39
11	0.11377E-04	0.43989E-01	-83.78	0.84060E-05	0.26601E-01	-14.56
12	0.72003E-05	0.51015E-01	77.95	0.51723E-05	0.10222E+00	-20.78
13	0.63945E-05	0.34666E-01	3.40	0.24350E-05	0.55799E-01	68.08
14	0.59154E-05	0.58496E-01	-44.56	0.23394E-05	0.69029E-01	-136.49
15	0.53794E-05	0.69029E-01	-161.07	0.18726E-05	0.84597E-01	42.04
16	0.42413E-05	0.55799E-01	-112.74	0.14712E-05	0.86671E-01	151.46
17	0.40723E-05	0.48301E-01	-128.11	0.14684E-05	0.43989E-01	-179.46
18	0.37985E-05	0.10222E+00	-128.60	0.13990E-05	0.80912E-01	-44.40
19	0.27058E-05	0.86671E-01	-39.40	0.13746E-05	0.91576E-01	153.43
20	0.21626E-05	0.91576E-01	174.63	0.11770E-05	0.51015E-01	169.33
21	0.17467E-05	0.84597E-01	65.41	0.10192E-05	0.48301E-01	127.80
22	0.12641E-05	0.80912E-01	167.22	0.78937E-06	0.58496E-01	-142.47

$0''.019$ and $0''.019$ for y). The residuals are the differences between the smoothing curve (by LSC, WRV and SPL) and the raw data. The amplitude periodograms, by direct Fourier transforms (FT), of these residuals are shown in Fig. 3. for x – coordinate (in Fig. 4. for y). The residual systematic errors exist in the case of WRV and SPL smoothing, because it's evident that the peaks for Chandler and annual periods by FT are remarkably greater than ones in the case of LSC. It was not possible to separate the Chandler and annual wobbles by FT (see Figures 3. and 4.) because of the short interval (about 8 years).

3. DISCUSSION

The LSC method does not require any smoothing parameter, and that is not the case in WRV and SPL methods. With good approximation of signal covariance function, the LSC is very suitable method for filtering the errors of observations. All three methods are flexible.

The largest systematic errors of residuals (after smoothing by WRV and SPL) appear in the Chandler residual and annual oscillations (see Fig. 3. and Fig. 4.), but in the case of LSC they are negligible. The systematic discrepances remain in the residuals because the WRV and SPL are the smoothing methods using the third



Raw and smoothed data (WRV and SPL)

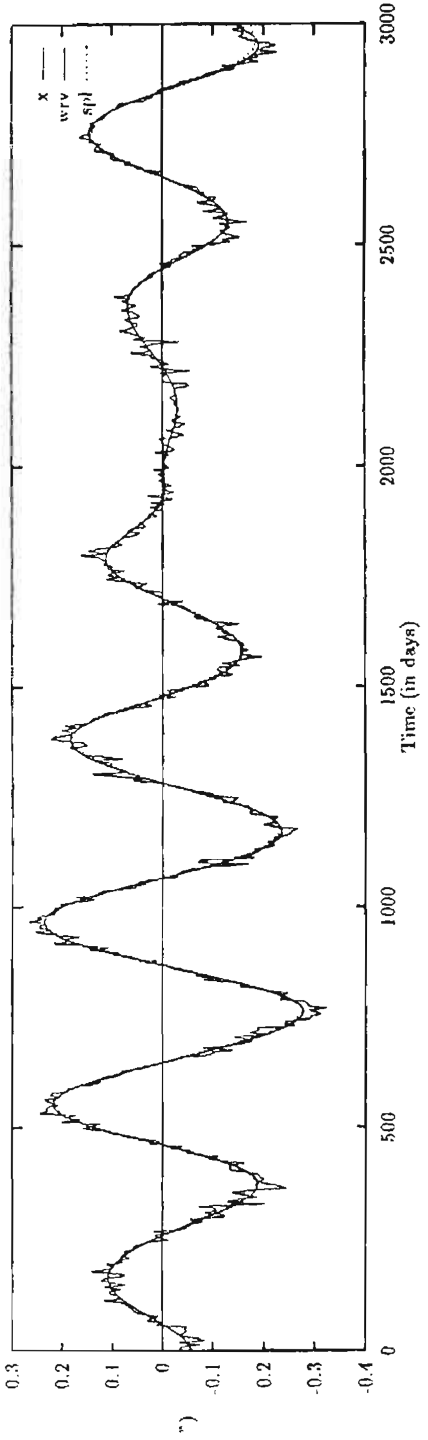
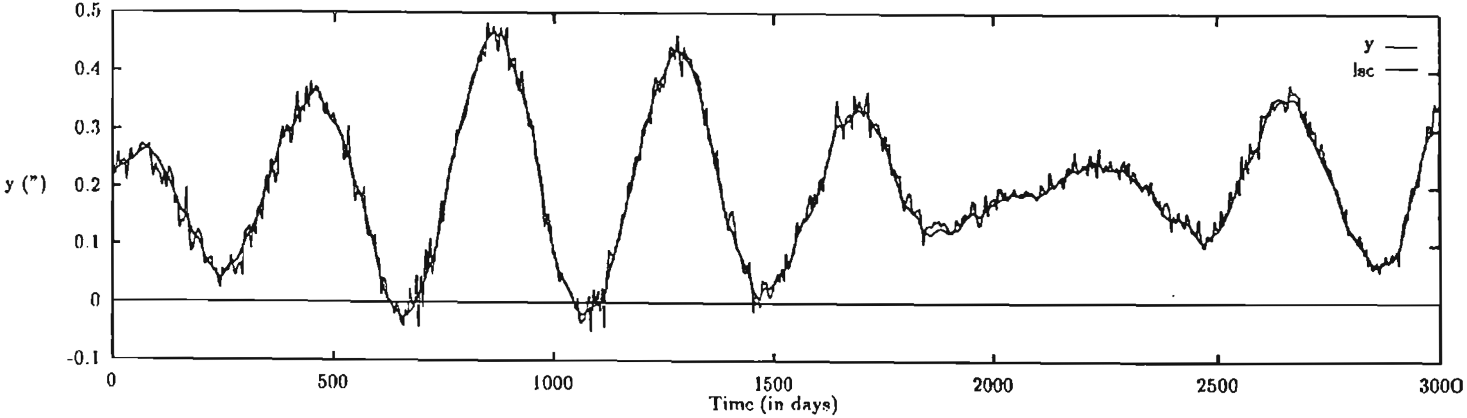


Fig. 1. Raw and smoothed data (LSC)



Raw and smoothed data (WRV and SPL)

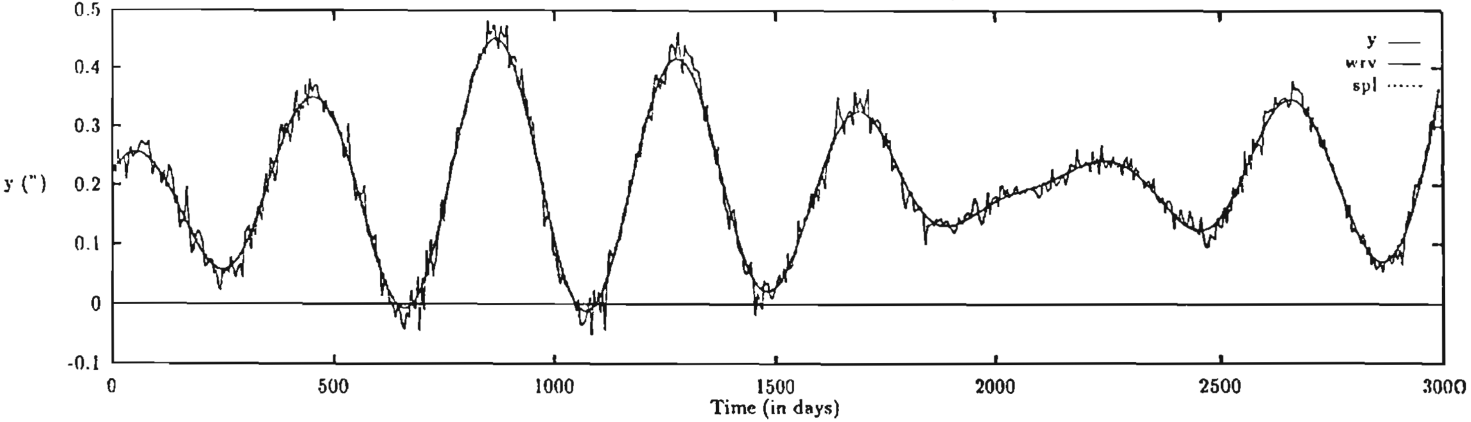


Fig. 2. Raw and smoothed data (LSC)

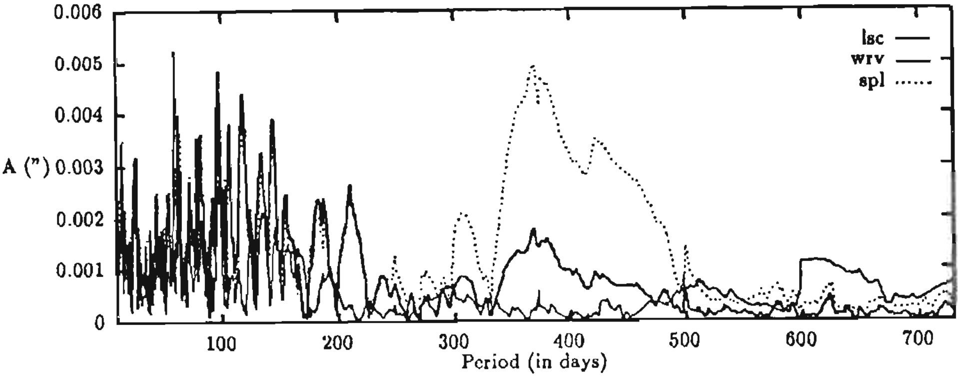


Fig. 3. FT of residuals (x - coordinate)

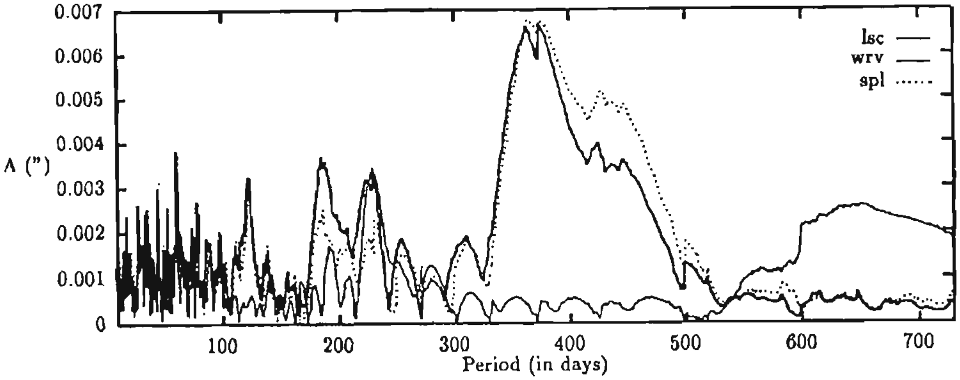


Fig. 4. FT of residuals (y - coordinate)

order polinomials, but the real data include a few harmonic oscillations. The smoothing curve by LSC better follows the raw data than WRV and SPL smoothing curves (especially at the beginning of the interval).

As it can be seen, the LSC method holds the indicated advantages and can be successfully used for the astronomical purposes.

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MERIDIAN ASTROMETRY IN ROMANIA

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Abstract. Bucharest Meridian Circle, installed in 1924, was used for improving the stellar reference frame. The results were published in the series of Bucharest Catalogues with studies concerning catalogues accuracy and the instrumental errors. The paper mention all the results, among with some important catalogues evaluation.

1. INTRODUCTION

After the founding of the Bucharest Observatory in 1908, the director, Professor Nicolae Coculescu, along with the former Ministry of Education, Spiru Haret, ordered in 1910 a meridian circle at the company Gauthier-Prin. The instrument - having a Steinheil-Merz objective (19 / 235 cm), micrometer with mechanical motion in right ascension, two declination circles (1m diameter, divided every 5′), 6 microscopes, a mercury pool and a level for the determination of the inclination - was installed in the interval 1924-1926 by the astronomer Gheorghe Demetrescu.

The first operation performed with this instrument was the evaluation of the dividing errors of the circles. Professor Demetrescu modified Bruns' method, and carried out this series of measurements with the aid of Constantin Drâmba, Nicolae Dinulescu, Călin Popovici and Gheorghe Petrescu. Obtained in 1932, the results, for mean square and probable square errors were 0".055 and 0".037 for a single diameter, and 0".032 and 0".022 for 6 microscopes measurments (Demetrescu and Drâmba, 1931).

The first astronomical observations were performed for longitudes and time determination, the first step for sistematic observations of stars passages. At that time the Meridian Circle was considered as one of the most performant instruments (Toma, 1992).

2. THE SERIES OF BUCHAREST CATALOGUES

Beginning with 1952, the methods of observation and reduction were tested on the Catalogue of Variable Stars (VS) (Drâmba, 1954) with the main contribution of Academician Gheorghe Demetrescu. The cooperation agreement (1953) between Bucharest Observatory and Pulkovo Main Observatory, by means of the Academies, started the works for building star catalogues in international cooperations. The Catalogue of Fundamental Faint Stars (FKSZ) (Drâmba, 1957) was the first which was compiled (Zverev and Polojentzev, 1958) and included in the preliminary Catalogue of Fundamental Faint Stars.

The interpretation of the instrumental errors and their effects on the final results create the opportunity to begin new programmes in the field of meridian astrometry. The Catalogue of Faint Stars (KSZ) (Marcus *et al.* 1972) contained a significant number of stellar positions (over 25000) in declination zone $(-11°, +11°)$, positions observed between 1955 and 1963. Under the supervision of Ella Marcus, eminent Romanian astrometrist, an important number of astronomers had observed and processed the catalogue. The main results, published in the catalogue, were the transforming FKSZ positions from the FK3 to FK4 system (Toma and Tudor, 1968), the computation of apparent places, the correction of KSZ positions with the systematic differences FK4-FK3 (Ionescu, 1972), the reduction to the 1950.0 equinox, the final analysis of the results and the computation of equatorial coordinates in the second approximation (Marcus *et al.* 1972). Other studies in this catalogue concern the effects of tube's flexion on stellar positions (Rusu, 1972), the variation of instrument's collimation, azimuth and inclination of rotational axis (Toma, 1972), determination of the instrumental system and statistical studies of the results.

The reference frame obtained was included in the general compilation of KSZ Catalogue, which was used as reference frame for Southern Reference Stars, AGK3R and FK5 Catalogues. There were published studies of comparison of KSZ frame with AGK3R (Marcus, 1979). The working group which elaborated this catalogue (KSZ) obtained in 1972 the Main Award "Gh. Lazăr" of the Romanian Academy.

As a result of the collaboration with the U.S. Naval Observatory, the Catalogue of Southern Reference Stars (SRS) and Bright Stars (BS) (Marcus *et al.* 1979), contained the coordinate frame in the observational zone $(-10°, +5°)$ for SRS and $(-11°, +6°)$ for BS, by means of differential observations in the FK4 system. The aim of this programme was to connect reference frames from Northern and Southern hemispheres. The reduction methods and the evalution of instrumental parameters were more effective and the final results were better, the number of inaccurate positions was minimum. The studies of the accuracy of the catalogue (Tudor and Toma, 1979; Popescu and Creţu, 1979; Niţă and Liculescu, 1979), are relevant for the quality of the work performed.

The results of the study of the system of FK4 reference stars (Popescu *et al.* 1979), shows no systematic in function of right ascension, figure 1.

In function of declination, figure 2 evaluate the systematic $(O-C)_\alpha$ differences in the observation zone $(-15°, +15°)$.

Tecnological development and the necessity of having more accurate positions and proper motions determined a strong research activity for the modernization of meridian circles. Classical micrometers were modified in order to detect stellar images by photometrical methods with important results in detecting faint stars and growing the efficiency of the observational process (Mazurier *et al.* 1977). The new technology allowed to observe 40-50 stars per hour (instead of 10-20 obtained with the classical micrometer) leading to a good accuracy in right ascension. The methods of photography or photoelectric investigation of the declination circle were an important gain in growing declination accuracy. In Bucharest Observatory these topics were not studied.

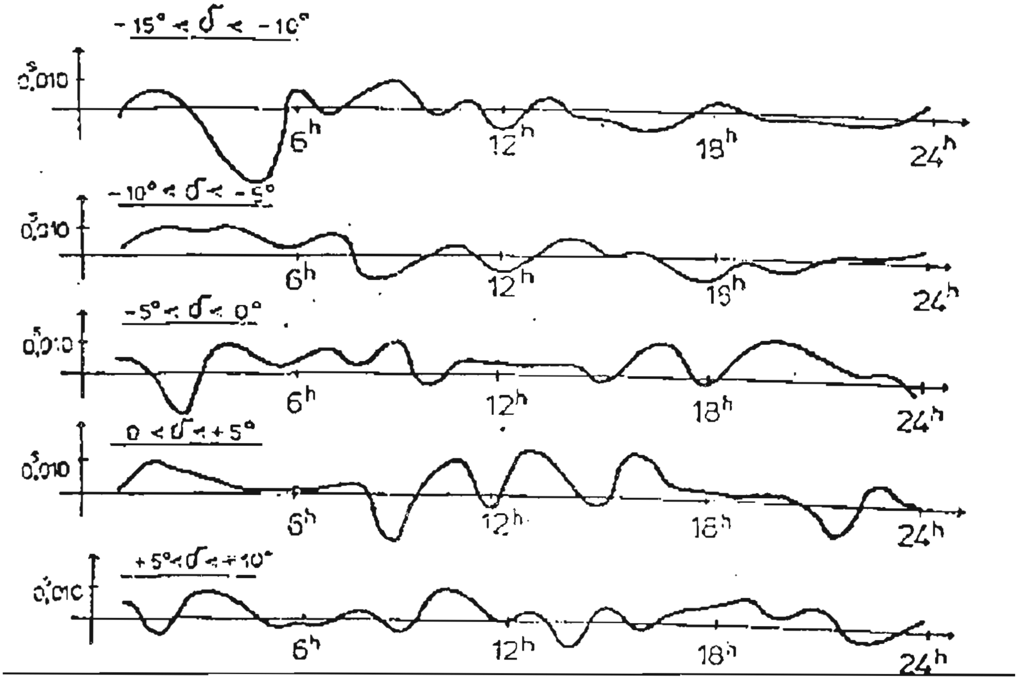

Fig. 1.

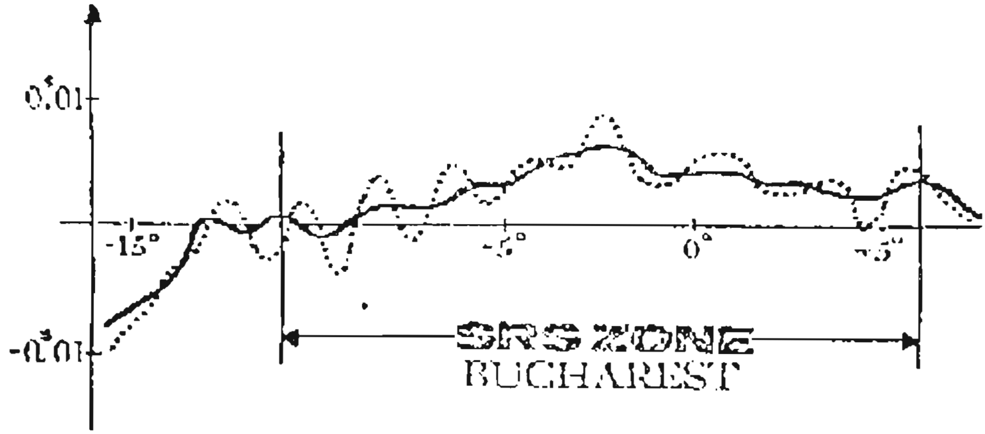

Fig. 2.

The Meridian Astrometry Group tried to observe complementary programmes that cannot be performed with photoelectric methods.

Reconsidering a recommendation of the IAU there were observed Double Stars Catalogue (DS1) declination zone (0°, +21°)and Bright Stars Catalogue (BS2) declination zone (+5°, +25°) (Popescu and Liculescu, 1997). The accuracy of these catalogues were studied (Popescu *et al.* 1991) and compared with other similar catalogues (Popescu and Liculescu, 1994).

The analyse of $\Delta_\alpha \cos\delta$ differences in function of right ascension for double stars and bright stars are showed in figure 3 and figure 4.

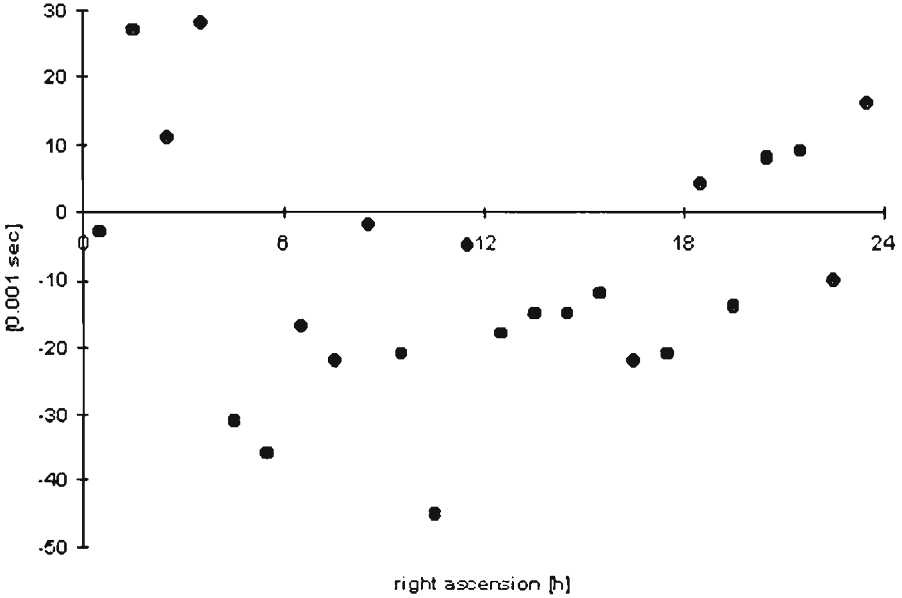

Fig. 3.

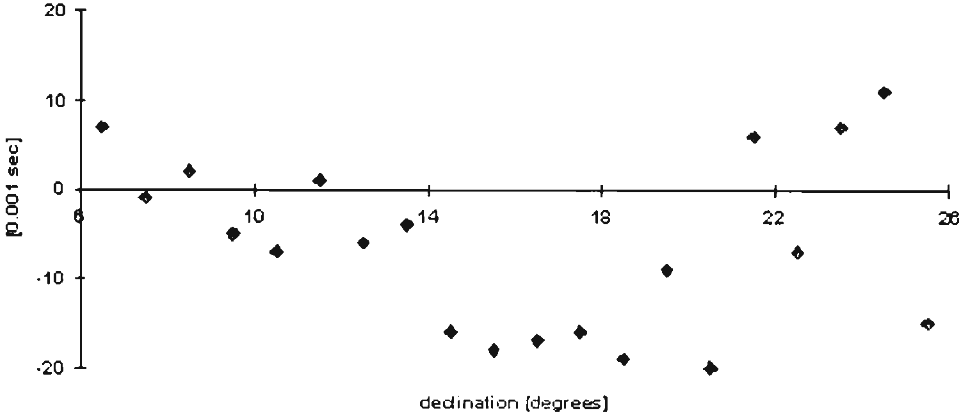

Fig. 4.

The study of the Earth's rotation has promoted new instruments: Danjon Astrolabes and Photographic Zenital Tubes. The Danjon Astrolabe, by means of its qualities (Chollet, 1993), using the equal heights method, was able to perform quasi-absolute determinations of stellar positions. The high accuracy of the results, allowed the determination of stellar positions referred to the vertex and important contributions in improving the reference systems (Chollet, 1995).

On the other hand, Photographic Zenital Tubes, using a different method, needed accurate zonal catalogues as reference frame. This was the reason of observing the NPZT Stellar Catalogue (NPZT), declination zone $(+41^\circ, +63^\circ)$, (Toma and Tudor, 1982) under the coordination of Tokyo Observatory. The programme was observed with Double Stars Catalogue (DS2), declination zone $(+40^\circ, +60^\circ)$. The final results in declination were included in the compilation of NPZT Catalogue; the results in right ascension being included in the second edition of NPZT Catalogue, results wich has been compared with other catalogues (Sadzakov, 1986).

In the idea of building zonal catalogues for the use of Photographic Zenital Tubes there were observed in collaboration with Ondrejov Observatory: PZT Catalogue (P1) (Toma *et al.* 1986) and PZT Catalogue (P2) (Popescu *et al.* 1987) declination zone $(+49^\circ, +50^\circ)$. In collaboration with Cagliari Observatory we elaborate PZT Catalogue (C) declination zone $(+39^\circ)$ (Liculescu *et al.* 1983). All these zonal catalogues were used for comparing the positions observed in Ondrejov and in Cagliari.

The last observed was Double Stars Catalogue (DS3), declination zone $(-5^\circ, +5^\circ)$ (Popescu and Liculescu, 1996).

Table 1 shows the catalogues from the series of Bucharest Catalogues, with the mean square errors for one observation: $\epsilon_\alpha \cos\delta$, units $\pm 0^s.001$; ε_δ, units $\pm 0''.01$.

3. ACTUAL TOPICS OF RESEARCH

The beginning of Hipparcos mission, its important objectives, produced a different approach of astrometric researches. The accuracy of the positions and proper motions obtained during the Hipparcos programme forced the old instruments to stop the observations. This was the case of Bucharest Meridian Circle. The instruments with higher preformances, modernized with CCD detectors can continue the meridian observations in order to improve the reference frames and Hipparcos system.

In the last years, in Bucharest Observatory we start the modernization of a Danjon Astrolabe borowed form Brussels Royal Observatory, in cooperation with the "Group of Reference Systems and Astrolabe", DANOF, Paris Observatory, group led by Dr. Fernand Chollet. There were made studies and instrumental improuvements of the astrolabe (Popescu *et al.* 1996), in order to analyse stellar images with a CCD camera (Popescu, 1996). The improvement of the optical system of the astrolabe by using a zerodur reflector prism will raise the accuracy of the positions and the efficiency of the observational process (Chollet, 1996).

Table 1.

Bucharest Catalogue of:	declination zone	period of observation	$\epsilon_\alpha \cos\delta$	ϵ_δ	references
Variable Stars (VS)	-10°,+75°	1952-1953	-	-	Dramba, C., 1954
Fundamental Faint Stars (FKSZ)	-30°,+90°	1953-1956	26	52	Dramba, C., 1957
Faint Stars (KSZ)	-11°,+11°	1955-1962	29	49	Marcus, E.,et al 1972
Southern Reference Stars (SRS)	-10°,+5°	1962-1967	18	32	Marcus, E.,et al 1979
Bright Stars (BS1)	-11°,+6°	1962-1967	18	32	Marcus, E.,et al 1979
Double Stars (DS1)	0°,+21°	1966-1971	25	29	Popescu, P., Liculescu, M., 1997
Bright Stars (BS2)	+5°,+25°	1966-1971	22	32	Popescu, P., Liculescu, M., 1997
Northern PZT Stars (NPZT)	+41°,+63°	1971-1975	16	29	Toma, E., Tudor, M., 1982
Double Stars (DS2)	+40°,+60°	1971-1976	-	-	-
PZT Stars (P2)	+49°,+50°	1972-1975	16	26	Popescu, P., et al 1987
PZT Stars (C)	+39°	1977-1979	19	28	Liculescu, M., et al 1983
PZT Stars (P1)	+49°,+50°	1980-1983			Toma, E., et al 1986
Double Stars (DS3)	-5°,+10°	1985-1989	27		Popescu, P., Liculescu, M.,1996

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PROCESSING OF CCD ASTROMETRIC OBSERVATIONS WITH THE BUCHAREST ASTROLABE

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Abstract. At the Bucharest Observatory, a CCD camera (COHU 4710) was adapted to the modified Danjon astrolabe. In order to be determinated the star passage time at the fixed zenithal distance, it is necessary to register all the succesive positions during its deplacement in the field. The number of frames acquired by the camera for one passage is about 25-40, depending on the transit velocity. Because of the very short acquisition time, the photocentre location requires a special centring algorithm.

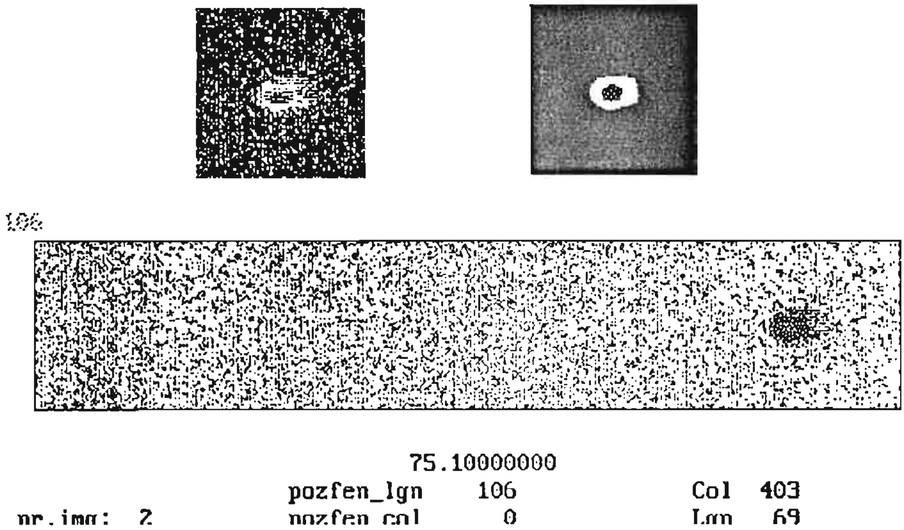
1. THE INFLUENCE OF PHYSICAL PARAMETERS UPON THE SHAPE AND POSITION OF IMAGES

The photoelectric detection development imposed the improvement of astrometrical observation techniques. The visual observations often contain systematical errors and cannot give enough accuracy in image centring process.The photoelectric devices used in astronomical observations allow us to save the information and to investigate it afterthat. The electrical output signal is either analogic (photomultipliers) or digital (CCD cameras).

In opposition with analogical centring techniques that cannot preserve the spatial resolution (Lindegren, 1977), the digital techniques are enabled to process the bidimensional images and offer the possibility of definition with great accuracy of the photocentre and limbs. The quality of a bidimensional image is influenced by both the quality of optical system and the atmosphere turbulence (Fried, 1965; Fried, 1966). In the absence of the atmosphere agitation, the quality of a star image and the photocentre detection accuracy are given by the set of internal optical parameters (diffraction, aberrations, and defocalisation) (Born & Wolf, 1993).

Assuming that the optical system is aberrations-free and well focused, the shape of a star image is given by the diffraction pattern. In the case of the modified Danjon astrolabe, the shape of the entering pupil is a vertical ellipse and the diffraction image is also an ellipse but horizontal.

In figure 1 can be observed the elliptical shape of the star image. In order to stress the ellipse, we have convoluted the original image with a Gaussian filter.



```
                          75.10000000
                    pozfen_lgn     106              Col  403
nr.img:   2         pozfen_col       0              Lgn   69
```

Fig. 1.

The instantaneous variations of the diffraction spot and the accidental variation of the image centre from the predicted position are generated by the atmospheric turbulence (Tatarski, 1967; Lindegren, 1978).

Because of the shortness of the acquisition time in the case of observations performed with a CCD camera adapted on the astrolabe (about 40 ms for an image), the atmosphere agitation is "frozen" and the angular dimensions of the image are given by the diffraction pattern and the accidental distortions of the light front. By studying the star trajectory (25-30 frames), the atmospheric turbulence (Fried, 1965; Fried, 1966) can be determined.

2. THE LOCATION PROCESS. IMAGE CENTERING TECHNIQUES

For sake of rapidity and precision (especially in the case of bright stars detection), two centering methods have been used: the momentum, and the derivative method.

The momentum method was widely described (Stetson, 1987; Stone, 1989; Lu Chun-lin, 1993). Along one of the axis of co-ordinates, the photocentre can result as the first order momentum of light intensity distribution:

$$X_{C_j} = \frac{\sum_i X_i(I(i,j) - N)}{\sum_i (I(i,j) - N)}; \quad Y_{C_i} = \frac{\sum_j Yj(I(i,j) - N)}{\sum_j (I(i,j) - N)},$$

where N is the background noise.

Unfortunately, this method is very sensitive to noise. In order to eliminate the spurious data, an threshold has been introduced, so that the distribution can be written as follows:

$$I(i,j) = (I(i,j) - N) \text{ if } I(i,j) \geq T;$$

$$I(i,j) = 0 \text{ if } I(i,j) < T.$$

The adopted value for T is one third the maximum intensity.

The derivative method was described (Stetson, 1979; Stone, 1989) and consists in computing the numerical first derivative of intensity distribution:

$$d = \frac{1}{2}(I(j,i-1) - I(j,i+1)) + \frac{1}{4}(I(j,i-2) - I(j,i+2)) + \frac{1}{6}(I(j,i-3) - I(j,i+3))$$

In the case of a Gaussian shaped intensity distribution, the centre is located at the point where the first derivative vanishes. In order to calculate the co-ordinates of this point, an iterative test must be imposed for determining where the derivative switches its sign. A simpler method consists in squaring the first derivative. The idea is to keep it all the time at positive values. The half distance between the two positive peaks gives us the photocentre.

Knowing the fact that the star intensity distribution for a short time integration has a quite irregular shape (image twinkling and quivering), we adopted a special centring algorithm. The explanations are given for the unidimensional case of light distribution. In the first step, the approximate star co-ordinates are found by pointing the mouse arrow upon the maximum isophote of the image, and the software "centres" a window of 100 by 100 pixels on these co-ordinates. Inside this window, we are looking for the maximum intensity co-ordinates (X_M, Y_M). For a set of eleven lines centered on $Y = Y_M$, we find the photocentre X_C by using one of the methods presented bellow.

The resulting set of data can be written:

$$X_{C_i} = X_{C_i}(Y_{M-i}), i \in [-5, +5].$$

By means of the least squares method, the data can be fitted to a stright line:

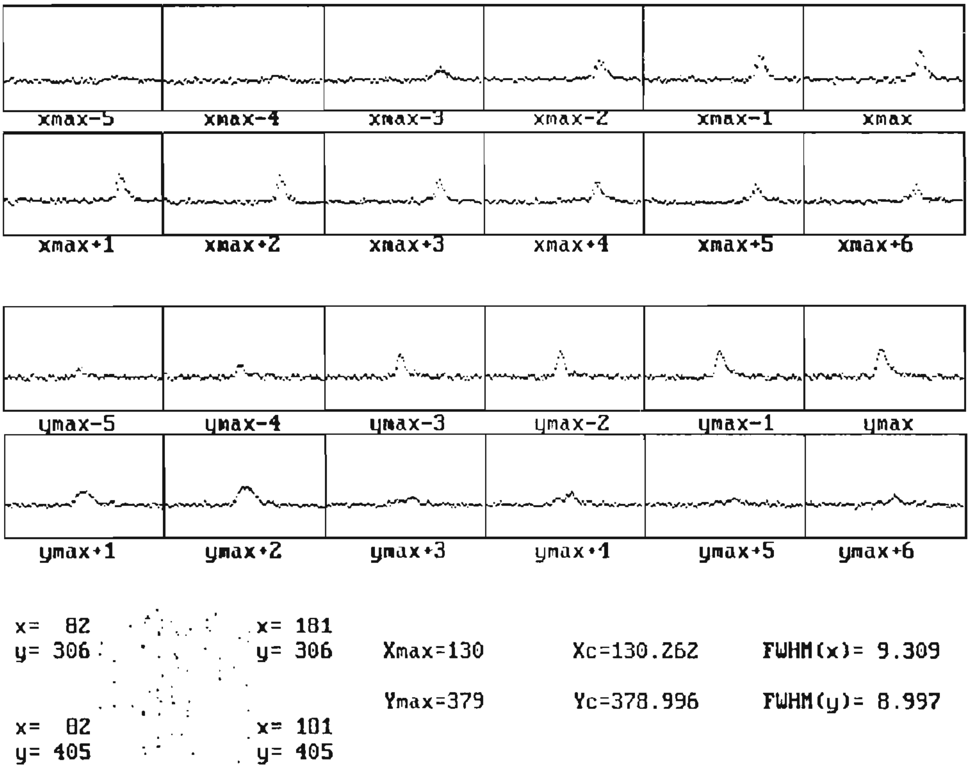
$$Y = a_1 \cdot X + b_1.$$

Similarly, on the Y axis, the regression line can be written as follows:

$$Y = a_2 \cdot X + b_2.$$

The co-ordinates of the star photocentre (X_C, Y_C) result from the intersection of the two regression lines.

In figure 2 are shown the intensity distributions of a star image along the two axis of co-ordinates.



```
Xmax=130          Xc=130.262        FWHM(x)= 9.309

Ymax=379          Yc=378.996        FWHM(y)= 8.997
```

Fig. 2.

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CATALOGUE OF DOUBLE STAR OBSERVATIONS MADE AT THE BELGRADE OBSERVATORY – CDSO

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Abstract. Information is presented about the newly formed data base at the Belgrade Observatory.

1. INTRODUCTION

The computation of the double star orbits at the Belgrade Observatory has been carried out from 1960 on, whereby the selection of the suitable pairs occupied from the beginning an important and prominent place in the process. The complete list of the measurements has been and remained the basic prerequisite of the successful selection of pairs. Very often the time consumed for completeing the measurement lists exceeded the one necessary for the orbit computation. Nevertheless, the measurement lists frequently remain uncomplete. Taking over the data from the Double Star Centre in previous time was practiced satisfactorily but difficulties are being met over several years already. Even on the assumption everything is functioning perfectly in the transfer of the observational data, the availability of the complete list remains the basic prerequisite in the orbit computation. It may make sense asking from the Centre the complete list only for the potentially suitable pairs but their defining is possible with possessing one's own data base. For this reason the observers and the orbit authors of the Belgrade Observatory decided on the keeping their internal data base of the double star measurements, apt to shorten the time needed for the orbit calculation. Many double star observers throughout the world are in possession of such data bases. At the Belgrade Observatory too, data bases of the double star observations have been kept from the very foundation of the Double and Multiple Star Group in 1951, however only for the pairs observed in Belgrade. Later on, the data base was enlarged to include other pairs too, but this work was interrupted during the years of computer technique being introduced.

2. CATALOGUE OF DOUBLE STAR OBSERVATIONS – CDSO

The computer recording of double star data was started in Belgrade in February 1996. This data base was named by the authors "Catalogue of Double Star Observations" or CDSO for short. It contains at present about 35 000 entries from upward of 100 references, among them also complete mesurements made at the Belgrade Observatory at the Zeiss Refractor 65/1055 cm along with the interferometric measurements (Mc. Alister 1988). Measurements made by many authors are entered (References), however complete achievements of some authors have not yet been finished. Entering the series of W. D. Heinz and P. Baize is intensively being worked on. Shorter measurement series have precedence over those more extensive on account of time. The observing data from the measurement series are entered in the following order:

- ADS number – in default of it – the discovere's designation, IDS number or BD number, in that sequence
- time of observation
- position angle
- separation of components
- number of measurements
- designation of system's multiplicity
- apparent magnitudes or difference of apparent magnitudes, if given
- observer's designation and notes, if any.

A few series were taken over from INTERNET by R. Pavlović, adapted to the catalogue form. The Catalogue is Being Realized as an ensamble of measurement series, with the possibility of singling out all the measurements of a particular pair. It had been planed several collaborators to participate in the data recording, but for the time being the whole business fell on this Catalogue's authors, aided by two students. The work on data entering will be continued. The justification of this project manifested itself alread during the brief two years period, although this data base was used only by the orbit authors in Belgrade. In the cited References are all the measurements series contained in the Catalogue up to now. The References are given in the alphabetical order of the authors.

3. CONCLUSION

The elaboration of the Catalogue of Double Star Observations – CDSO serves an important purpose: substantially enhancing the efficiency of future work of the double star astronomers at the Belgrade Observatory.

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PAST AND FUTURE OF ASTROMETRICAL WORK AT BELGRADE OBSERVATORY

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Abstract. There are ten instruments at the Belgrade Astronomical Observatory ($\lambda = 1^h22^m E$, $\varphi = +44^o48'$, $h = 254m$), mainly astrometric ones, and one of them (Bamberg equatorial of 35 cm) has never been mounted. The systematic astronomical observations have been performed as early as from 1935 by usung these instruments, and the majority of them is still in use. The Observatory has taken part in the realization of several dozens of international observing programs, campaigns concerning special phenomena, etc. Hence, it has today on its disposal a rich observational material comprising different fields of astrometrical and astrophysical research. Recently, the observations of Solar System bodies and double stars, as well as the studying of the selected solar spectral lines were improved by use of two CCD cameras - ST6 and ST7. The purchase of an ST8 camera will extend the work in some research fields and improve the quality of phenomena detection.

1. DYNAMICAL ASTRONOMY

The instruments with equatorial mounting permanently in use for the purpose of realizing various observing programs since the moment of their mounting are:

- Zeiss Refractor - aperture 65/1055 cm;
- Zeiss Refractor - aperture 20/302 cm with two photographic tubes with objectives aperture 16/80 cm;
- Zeiss Astrograph - aperture 16/80 cm with visual aperture 11/128 cm;
- Askania Photovisual Refractor - aperture 13.5/160 cm, i.e. 12.5/100 cm.

Each of them, individually, has additional devices and specialized cameras, including the CCD cameras used for all mentioned instruments.

Actual observing programs realized with these instruments according to adopted projects are:

- The 65/1055 refractor is permanently used in the observing of double and variable (eruptive especially) stars (CCD astrometry, photometry and polarimetry, micrometric measurements of pairs, as well as the finding of new double and multiple stars). With this instrument are also observed mutual phenomena of Jupiter's and Saturn's satellites, as well as the exceptional astronomical phenomena (transit of inner planet over the solar disc, solar and lunar eclipses, occultations of stars by the Solar system bodies, etc).

– The 20/302 refractor was used in the past for the purpose of regular observations of minor planets, comets and major planets. In 1973 it was reconstructed to become a solar spectrograph used in systematic observations of active processes on the Sun.

– The Zeiss Astrograph and Askania Refractor are known due to the numerous discoveries of minor planets from this Observatory and also due to other works important to the research of Solar System Dynamics. Today, thanks to the CCD cameras, they are included in regular observations of minor planets following special programs (ITA, NEO, etc), comets, occultations of major planet satellites, occultations of stars by the Moon and other Solar – System bodies. All data concerning these observations are sent to the corresponding international centers (Protitch – Benishek, 1989).

One should say that one Askania Refractor (35/700 cm) has never been mounted though it was planned in the programs where long-focus instruments are desirable.

2. ASTROMETRY

There are three fundamental instruments in the field of Fundamental astrometry: Meridian Circle, Transit Instrument and Vertical Circle. They were established in 1959 after 35 years of preservation in their cases due to financial problems.

Askania made, they were delivered to Belgrade Observatory as part of the World War I reparation.

The main characteristics of the instruments are: all three are of classical design, have objectives of 190 mm in diameter, focal distance of 2578 mm, visual eye – piece micrometer. The Meridian Circle and the Vertical Circle have 800 mm circles divided in each $2'$, with 4 micrometric microscopes, at both sides (E, W), for $1''$ readings.

The Meridian Circle and the Transit Instrument are situated in semicylindrical steel pavilions, approximatily on the same parallel, while the Vertical Circle is in the north angle of the equilateral triangle. The distances between the three pavilions are 75 – 85 meters.

The absolute observations of right ascensions and declinations of stars are planned to be carried out at the Transit Instrument and the Vertical Circle respectively. Differential determinations of α and δ are foreseen for the Meridian Circle.

After detailed examinations of the instrument's constants and certain technical reconstructions (especially at the Vertical Circle), preliminary observations started. In the mean time, vacuum meridian marks were built for the Transit Instrument at distances of 30 and 51 m, north and south, respectively. This original idea was realized by inserting two steel vacuum tubes ($\phi = 300mm$) between the marks objectives and the meridian marks themselves for the purpose of lessening the influence from the main obstacle of the precise azimuth determination – terrestrial refraction. Later, the action's full justification was shown.

After the preliminary observations by all three instruments, regular observations began. At the Transit Instrument and the Vertical Circle, simultaneous observations of Absolute Catalogue of 307 bright stars – zone ($+65^o$ – $+90^o$) took place. Unfortunately, due to the Observatory's irregular main clock, complete R.A. observations at the Transit Instrument had to be withdrawn, whilst the Catalogue of absolute declinations of 307 bright stars was published. The mean error of the catalogue declinations is $\varepsilon_\delta = \pm 0.''13$. The observations of major and minor planets also were carried out at the Vertical Circle. It was shown that the applied method of (O – C) determination cannot entirely eliminate the systematic effects connected with the time factor, temperature, flexure and refraction.

Several differential catalogues were made using the observations at the Meridian Circle, starting with the Catalogue of latitude stars (3956 stars). Declinations are given with an accuracy of $\pm 0.''34$. The second catalogue was the Catalogue of NPZT program with the position of 1685 stars (R.A. and Dec.). The mean square error of a single observation was $\varepsilon_\alpha \cos\delta = \pm 0.^s030$ and $\varepsilon_\delta = \pm 0.''24$. The other two catalogues realized by the Belgrade Meridian Circle were the Catalogue of double stars and the Catalogue of stars in the vicinity of radio sources, also with similar accuracy; for right ascensions $\pm 0.^s023 sec\delta$ and for declinations $\pm 0.''30$. Similar accuracy was achieved for the Catalogue of positions of 223 Ondrejov PZT stars and the Catalogue of positions of high luminosity stars (HLS) and radio stars which was the last one observed with this instrument.

At present all observations by Belgrade fundamental astrometrical instruments are practically suspended, due to the fact that visual and nonautomatical observations are not only obsolete but much below modern accuracy and efficiency. There is also a problem of magnitude limitation. Belgrade Astronomical Observatory is very much interested in complete modernization, for the beginning, one of the instruments, and believes that the selection of the Meridian Circle would be the best solution. CCD camera and automatical circle readings together with a good PC are the basic requirements to join the IAU ground based observation programs in which Belgrade Observatory would like to participate.

At the end of last year Belgrade Observatory entered a cooperation with Nikolaev Astronomical Observatory with intention to modernize the Belgrade Meridian Circle in the way the Nikolaev Automatic Meridian Circle was reconstructed. It is planned in the near future to install a CCD camera for the star transit registrations and to enable automatic circle readings as well as automatic star settings using a PC. The modernization will be carried out by experts from Nikolaev Observatory.

3. THE EARTH'S ROTATION

In the field of the Earth's rotation the Transit Instrument (Bamberg 100/1000 mm) and the visual zenith – telescope (Bamberg 110/1287 mm) were used. Due to this, the Time Service and the Latitude Service were established. The regular observations at zenith – telescope started at the beginning of 1949. The data were incorporated in IPMS (from 1956) and BIH (from 1967). With the original latitude data we took part in MERIT program, HIPPARCOS program, etc. The instrument is out of operation from 1995. The new reduction, in the FK5 reference system, with PPM Star Catalogue (Roeser and Bastian, 1991) and in line with MERIT Standards (Melbourne *et al.*, 1983), was done (Damljanović, Pejović, 1995). It was in accordance with the rules of the HIPPARCOS program. Then, the investigation of some systematic instrumental, personal, refraction and star position errors were realized (Damljanović, 1994, 1995). After that, an analysis of that homogeneous latitude series was finished. Now, it is necessary to continue the investigations of latitude variations with some new techniques or to carry out necessary modernization.

The regular observations with Transit Instrument exist for the period 1964 – 1986. The data were sent to BIH and IPMS, and the Universal Time determination data were included also in the MERIT program. The homogeneous results were prepared in accordance with IERS standards. An analysis on variation of local system $UT1_{BLI}$ was carried out (Jovanović *et al.*, 1993), too. It is necessary to replace this instrument with some of the new techniques and to continue the observations in the same subject.

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GALACTOCENTRIC ORBITS OF 26 MILKY-WAY GLOBULAR CLUSTERS

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Abstract. A sample of 26 Milky-Way globular clusters with determined proper motions is analysed. By using other necessary data and applying a specially chosen form for the Milky-Way potential the authors calculate their galactocentric orbits. For convenience the potential form chosen here is spherically symmetric giving account for the dark corona only, but it has no singularity.

1. INTRODUCTION

For various reasons it is probable that the globular clusters play an important role in the structure and evolution of the Galaxy. Therefore, their galactocentric motion has been subjected to many different studies (e. g. Frenk and White, 1980). A characteristic property of many of these studies is that they had to be carried out without knowing the proper motions of these objects. However, in the meantime the available material concerning the proper motions of the Milky-Way globular clusters has grown in both quantity and quality. Recently a list comprising all proper-motion determinations for the Milky-Way globular clusters ever done was compiled in 1994 by Colin and Dauphole. With regard that by combining the proper motions with other necessary data one can obtain the initial conditions, it is clear that by specifying the Milky-Way potential one can undertake the calculation of the corresponding galactocentric orbits. Such procedures have been already performed, not once (e. g. Dauphole *et al.* 1996 where the list of Colin and Dauphole mentioned above can be found). It is understandable that the results depend on the particular form of the gravitational potential assumed. Therefore, the intention of the present authors is to analyse the results emanating for the case of a spherically symmetric galactic potential assumed by them.

2. PROCEDURE

For many of the globular clusters contained in the list of Colin and Dauphole there has been more than one proper-motion determination. Therefore, in those cases where only one proper-motion determination is available we use it regardless of the quality. If more than one determination is available, we follow Dauphole *et al.* in their choice of the "best" determination. In this way we have at our disposal a sample of 26 Milky-Way globular clusters with known proper motions and also other data necessary for obtaining the initial conditions (celestial coordinates - either α, δ or l, b - heliocentric distance and line-of-sight velocity). The latter ones have been kindly put at our disposal by Dr E. Alfaro. The particular form of the Milky-Way potential assumed by us is spherically symmetric and the formula with the parameter values can be found in an earlier paper of one of us (Ninković, 1988). In the obtaining of the galactocentric position for each cluster we use a galactocentric Cartesian coordinate system in which the coordinates of the Sun are: $X_\odot = -8.5 kpc$, $Y_\odot = Z_\odot = 0$, i. e. the distance of the Sun to the galactic plane is neglected, whereas for its distance to the rotation axis is assumed the value recommended by the IAU. As for the velocity of the Sun in the same coordinate system we assume: $\dot{X}_\odot = \dot{Z}_\odot = 0$, $\dot{Y}_\odot = 220\ km\ s^{-1}$, i. e. the motion with respect to the LSR and the asymmetric drift are neglected, whereas for the circular velocity we assume again the value recommended by the IAU.

3. RESULTS

Our results are presented in Table I. The columns contain respectively: cluster identification, specific energy ($km^2\ s^{-2}$), specific angular momentum ($kpc\ km\ s^{-1}$ - specific means per unit mass), orbital inclination (in degrees - with respect to the galactic plane), perigalactic distance (kpc), apogalactic distance (kpc), orbital eccentricity, mean galactocentric distance (kpc) and maximum distance to the galactic plane (kpc). The eccentricity, the mean galactocentric distance and the maximum distance to the galactic plane are here defined as

$e = \frac{R_a - R_p}{R_a + R_p}$, $R_m = \frac{R_a + R_p}{2}$, $|Z|_{max} = R_a \sin i$,

respectively.

As seen, only one cluster (Pal 3) has a positive energy. This need not mean that it is an escaper. The potential assumed here corresponds to a total mass of the Galaxy of 433 $G\mathcal{M}_\odot$. It is chosen in such a way to yield a value of 500 $km\ s^{-1}$ for the local escape velocity. This quantity is, as well known, uncertain because it depends on the total mass of the Galaxy. It is very possible, bearing in mind certain kinds of evidence concerning the Local Group (e. g. Lee, 1993), that the total mass of the Milky Way exceeds 1 $T\mathcal{M}_\odot$. If this is really the case, our preliminary calculations show that then Pal 3 can remain in the potential well of the Galaxy. As for the other clusters, only NGC 5466 has a significant apogalactic distance ($> 100\ kpc$). This may be also understood as an indication of a higher Milky-Way total mass than that assumed here.

4. DISCUSSION AND CONCLUSIONS

This paper will contain no extensive conclusion. It is clear that any detailed galactocentric-orbit calculation must be based on a more rigorous potential form - for example an axially symmetric one.

We may only say that, as could be expected, globular clusters in general have sufficiently high orbital eccentricities, whereas the inclinations are rather equally distributed within the range $0^o - 180^o$. Two clear exceptions are NGC 104 and NGC 6838. We should note that in the coordinate system assumed here an inclination of

180^{o} means motion along the galactic rotation. On the other hand, the two exceptional cases are usually classified as disc globular clusters because they have metallicity over -1 (in our contribution such data are not given). Bearing in mind their inclinations and eccentricities we may say that expectations based on this connexion (with the galactic disc) are here confirmed.

Table I

name	E	J	i	R_p	R_a	e	R_m	$\lvert Z\rvert_{max}$
NGC 104	−111398.88	1434	156.5	5.46	8.42	0.21	6.94	3.36
NGC 288	−102160.12	1286	44.0	3.73	12.14	0.53	7.94	8.44
NGC 362	−115817.75	495	56.6	1.27	10.10	0.78	5.69	8.43
Pal 3	49407.55	33984	109.8	90.30	∞	>1	∞	∞
NGC 4147	−32323.09	5204	116.0	14.14	51.69	0.57	32.92	46.46
NGC 5024	−57232.38	3565	78.3	10.47	27.76	0.45	19.12	27.18
NGC 5139	−125421.92	744	43.3	2.30	7.72	0.54	5.01	5.30
NGC 5272	−99833.71	636	99.4	1.51	13.90	0.80	7.71	13.71
NGC 5466	−14223.45	5869	80.5	14.15	126.33	0.68	70.24	126.31
Pal 5	−83756.71	1795	91.1	4.92	17.52	0.56	11.22	17.52
NGC 5904	−55338.29	2154	109.0	4.95	32.64	0.74	18.80	30.86
NGC 6121	−135592.06	159	168.4	0.44	6.82	0.88	3.63	1.37
NGC 6171	−150197.88	533	140.5	2.24	3.95	0.28	3.10	2.51
NGC 6205	−76073.22	1368	73.9	3.21	21.66	0.74	12.44	20.81
NGC 6218	−128662.70	845	132.3	2.93	6.72	0.39	4.83	4.97
NGC 6254	−125409.31	312	72.8	0.82	8.39	0.82	4.61	8.01
NGC 6341	−109314.40	974	79.1	2.74	10.87	0.60	6.81	10.68
NGC 6397	−124517.49	741	167.2	2.26	7.91	0.56	5.09	1.76
NGC 6626	−137518.78	791	176.6	3.33	4.89	0.19	4.11	0.29
NGC 6656	−109359.91	935	172.1	2.60	10.94	0.62	6.77	1.51
NGC 6712	−129826.93	611	101.3	1.87	7.18	0.59	4.53	7.04
NGC 6779	−49317.18	1567	20.5	3.23	38.15	0.84	20.69	13.37
NGC 6838	−116047.61	1337	179.2	5.51	7.23	0.14	6.37	0.10
NGC 6934	−52670.83	3903	48.5	11.46	30.46	0.45	20.96	22.82
NGC 7078	−45078.49	2855	125.6	6.66	40.40	0.72	23.53	32.84
NGC 7089	−54223.68	4065	79.6	12.69	28.28	0.38	20.49	27.81

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ADVANCED THEORIES TO COMPUTE ASTEROID MEAN ELEMENTS

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Abstract. Asteroid mean orbital elements are obtained from osculating ones by removal of the short periodic perturbations. They represent the first step in the computation of asteroid proper elements, which are, in turn, obtained from the mean ones by removal of the long periodic perturbations. The algorithms for the purpose of computation of the mean elements used so far are accurate only to first order in the masses of the perturbing planets; still, the obtained mean elements have satisfactory accuracy for most of the asteroid belt. The degraded accuracy appears in the neighbourhoods of the main mean motion resonances, especially the 2 : 1. A number of algorithms capable of pushing this approximation to higher order is considered here; these are either the so called Breiter–type methods, or iterative methods. The former are obtained by applying some higher order numerical integration scheme, such as Runge-Kutta, to perform the transformation removing the short periodic perturbations from the initial conditions and fast angular variables from the equations of motion. The latter are fixed point iterative schemes, with the first oder theory as an iteration step, used to compute the inverse map from mean to osculating elements. The results of tests of several methods of both kinds, on a sample of asteroid orbits taken up to the edge of the 2 : 1 resonance, are presented and discussed. They indicate that the iterative methods are superior, in this specific application, to the Breiter–type methods. This is due to the cancellations occurring between second order perturbation terms: incomplete second order theories are thus less reliable than complete, fixed frequency theories of the first order.

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SPECIFIC DYNAMICAL FEATURES OF MANEV-TYPE PROBLEMS

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Abstract. The Manev-type problems (associated to a potential of the form $A/r + B/r^2$) model many concrete situations belonging to physics and astronomy. The equations of motion and the first integrals of energy and angular momentum are established. Resorting to McGehee's transformations, new, regularized equations of motion are found. Exploiting the rotational symmetry, the phase space dimension is reduced to 3, and clear pictures of the global flow can be obtained. All possible phase curves are surveyed and interpreted in terms of physical orbits. Specific dynamical features (as: motion on precessional conic sections, black hole effect, bounded orbits for nonnegative energy, unstable circular motion, radial librations, etc.) which cannot be met within the framework of classical models are pointed out.

1. INTRODUCTION

One of the most important problems of celestial mechanics is to find a model able to maintain the dynamical astronomy within the framework of classical mechanics (keeping the simplicity and the advantages of the Newtonian model), offering at the same time equally good justifications of the observed phenomena as the relativity. Such a model is that based on the $A/r + B/r^2$ potential (r = distance between particles, A, B = real constants). Newton himself was the first to consider this law, then Clairaut, but the one who based this model on physical principles was the Bulgarian physicist G. Manev (Maneff 1924, 1925, 1930a,b).

Fallen into oblivion for half a century, then pointed out by Hagihara (1975) as providing the same good theoretical approximations as the relativity (at the solar system level, at least), Manev's law and the Manev-type models were recently reconsidered in a series of studies initiated by Diacu (1993). Leaving aside the crucial result (for dynamical astronomy) established within this framework by Lacomba *et al.* (1991), the interest aroused by this problem is proved by the multitude of studies dedicated to the subject or related to. Among them we quote: Casasayas *et al.* (1993), Diacu *et al.* (1995, 1996), Mioc & Stoica (1995a,b,c,d, 1996, 1997a,b), Stoica (1995), Stoica & Mioc (1995, 1996a,b,c), Aparicio and Floria (1996), Delgado *et al.* (1996), Diacu (1996).

The importance of such studies is emphasized by the great variety of concrete physical and astronomical situations modellable via a potential of this kind. Besides classical models (Newton's law, radiative force, force-free field), models as: Fock's field (truncating the negligible terms), Reissner-Nordström field, a photogravitational field (perturbed or not), the two-body problem with equivalent gravitational parameter, the nongravitational homogeneous potentials,the motion of anoutward electron in the field of the nucleus (in a second approximation), etc. also join the Manev-type problems (see Moser 1975; McGehee 1981; Diacu 1990; Şelaru *et al.* 1992, 1993; Mioc & Stoica 1997b).

This paper constitutes itself in a survey of the dynamical properties of the Manev-type two-body problem. On the basis of the powerful tool of McGehee's transformations, the global flow of this problem in a reduced phase space can be fully described. The phase trajectories are translated in terms of physical orbits, then the dynamical features which cannot be met within the framework of classical models are pointed out.

2. EQUATIONS OF MOTION AND FIRST INTEGRALS

Consider the Manev–type two-body problem. We may reduce it to a central force problem (e.g. Diacu *et al.* 1995, 1996; Mioc & Stoica 1997b) and study the motion of one body (hereafter particle) with respect to a fixed frame originated in the other body (hereafter centre). This relative motion will be planar and described by the equation

$$\ddot{\mathbf{r}} = -(A/r^3 + 2B/r^4)\mathbf{r}, \tag{1}$$

where $\mathbf{r}$ = radius vector of the particle with respect to the centre, $r = |\mathbf{r}|$, and dots mark time-differentiation.

In polar coordinates (r, θ), eq.(1) turns to

$$\ddot{r} - r\dot{\theta}^2 = -A/r^2 - 2B/r^3, \tag{2}$$

$$r\ddot{\theta} + 2\dot{r}\dot{\theta} = 0. \tag{3}$$

The angular momentum is conserved, and (3) provides the first integral

$$r^2\dot{\theta} = C, \tag{4}$$

with C = constant of angular momentum. The integral of energy reads

$$\dot{r}^2 + r^2\dot{\theta}^2 = 2A/r + 2B/r^2 + h, \tag{5}$$

with h = constant of energy.

Our qualitative analysis uses the McGehee type transformations (McGehee 1974; for the respective technique applied to less general cases of our problem, see Diacu *et al.* 1995; Delgado *et al.* 1996). We formally multiply (5) by r^2 (a detailed justification of this step was given by Diacu *et al.* 1995), then introduce the transformations

$x = r\dot{r}$ and $y = r^2\dot{\theta}$, and finally rescale the time variable via $dt = r^2 ds$. After simple computations, the system (2)-(3) acquires the form (in which $' = d/ds$):

$$r' = rx, \tag{6}$$

$$\theta' = y,$$

$$x' = r(A + hr),$$

$$y' = 0,$$

with the first integrals of energy and angular momentum given respectively by

$$x^2 + y^2 - 2Ar - hr^2 = 2B; \tag{7}$$

$$y = C. \tag{8}$$

The usefulness of McGehee's transformations is clear: the collision singularity at $r = 0$ was blown up, and new, regularized equations of motion were provided.

3. REDUCED PHASE SPACE

Observe that θ does not appear explicitly in either regularized equations of motion (6) or energy integral (6). We can therefore reduce the 4- dimensional full phase space to dimension 3 (obtaining the reduced phase space RPS) by factorizing the flow to S^1 (recall that $\theta \in S^1$). Exploiting this rotational symmetry, characteristic to our problem, we are able to obtain clear pictures of the global flow.

To describe the flow in RPS, the energy is regarded as a parameter. By (7), one observes that in RPS every energy level (given by a fixed h) is homeomorphic with a quadric surface (nondegenerate or degenerate). The first integral (8) foliates the respective energy level into curves (even degenerate in some cases) lying in the parallel planes $y = C$.

The vector field (6) in RPS (with the equation for θ discarded) exhibits two kinds of equilibria. First, observe that

$$r = 0, \quad x^2 + y^2 = 2B \tag{9}$$

is a circle of equilibria. In other words, under McGehee's transformations, an orbit needs an infinite amount of fictitious time s to reach the collision.

On the other hand, it is easy to see that equilibria outside collision, located at

$$r = -A/h, \quad x = 0, \quad y = \pm\sqrt{2B - A^2/h}, \tag{10}$$

do exist if $2B \geq A^2/h$ and $A/h < 0$.

Diacu *et al.* (1996) depicted the global flow in RPS for the whole allowed interplay among the field parameters (A, B), energy constant (h), and angular momentul (C). Here we shall survey these results with special emphasis on their physical interpretation. Also we shall point out the dynamical features which cannot be met within the framework of the Newtonian model (or of some other classical models).

To characterize the various kinds of phase trajectories in RPS which are met in the Manev-type problem, we shall use the following symbolic notation:

$0 \rightarrow 0$: orbits ejecting from collision and then tending back to collision (the particle cannot escape);

$0 \rightarrow \infty$: orbits ejecting from collision and tending to infinity;

$0 \rightarrow UE$: orbits ejecting from collision and tending to an unstable equilibrium (at distance r_{UE} from the centre);

$UE \rightarrow \infty$: orbits ejecting from an unstable equilibrium and tending to infinity;

$UE \rightarrow 0$: orbits ejecting from an unstable equilibrium and tending to collision;

$\infty \rightarrow UE$: orbits coming from infinity and tending to an unstable equilibrium;

$\infty \rightarrow 0$: orbits coming from infinity and tending to collision;

$\infty \rightarrow \infty$: orbits coming from infinity and then tending back to infinity (the particle cannot collide with the centre);

UE: unstable equilibrium (at distance r_{UE} from the centre);

SE: stable equilibrium (at distance r_{SE} from the centre);

P: periodic orbits;

$\emptyset$: impossible real motion.

4. PHYSICAL MOTIONS

Before starting our survey, let us specify some general characteristics of the physical trajectories which correspond to the various types of RPS orbits. At the equilibria (10), if $y \neq 0$ ($C \neq 0$) the particle moves in a circular orbit around the centre; if $y = 0$ ($C = 0$) the particle is at rest with respect to the centre.

Outside RPS equilibria, if $y = 0$ the particle moves radially. If $y \neq 0$ the motion has a spiral character: precessional ellipses for $h < 0$; precessional parabolas for $h = 0$; precessional hyperbolas for $h > 0$ (Diacu *et al.* 1995; Delgado *et al.* 1996; Stoica & Mioc 1996c).

Another important feature is the existence of the black hole effect (Diacu *et al.* 1995): spiral collisions/ejections, which occur for $y \neq 0$. The particle spirals infinitely many times around the centre immediately before collision/after ejection.

By (7) and (9), it is clear that for $B < 0$ the motion is collisionless (Diacu *et al.* 1996); this result was also established by Saari (1974), but within a different framework and using another method.

Also, by (5), one observes that for $h < 0$ the motion is bounded (the particle cannot escape). The same formula points out the fact that, when the particle escapes, its asymptotic velocity at infinity is zero for $h = 0$, and positive for $h > 0$.

Lastly, the periodic trajectories in RPS represent in physical space elliptic- type noncollisional orbits. Leaving aside the case $A > 0$, $B = 0$ (for which the orbits are fixed ellipses), these trajectories are quasiperiodic - precessional ellipses which never close, filling densely an annulus, except a set of zero Lebesgue measure of periodic orbits -precessional ellipses, rosette-shaped, which close after a finite number of rotations (Delgado *et al.* 1996; Diacu *et al.* 1996).

Now we can survey the possible physical motions for the whole allowed interplay among A, B, h, and C $(= y)$. We shall keep the symbolic notations introduced at the end of Section 3, because their physical interpretation is now clear.

4. 1. CASE $B > 0$

Consider first $A > 0$ (Manev's or Fock's fields). If $h < 0$, we have

$$|y| > \sqrt{2B - A^2/h} \Rightarrow \emptyset, \quad |y| = \sqrt{2B - A^2/h} \Rightarrow SE,$$
$$\sqrt{2B} < |y| < \sqrt{2B - A^2/h} \Rightarrow P, \quad |y| \le \sqrt{2B} \Rightarrow 0 \to 0. \tag{11}$$

If $h \ge 0$, then

$$|y| \ge \sqrt{2B} \Rightarrow \infty \to \infty, \quad |y| < \sqrt{2B} \Rightarrow 0 \to \infty, \infty \to 0. \tag{12}$$

Consider now $A = 0$ (inverse-cubic attractive force). For $h < 0$, we have

$$|y| \ge \sqrt{2B} \Rightarrow \emptyset, \quad |y| < \sqrt{2B} \Rightarrow 0 \to 0. \tag{13}$$

If $h = 0$, then

$$|y| > \sqrt{2B} \Rightarrow \emptyset, \quad |y| = \sqrt{2B} \Rightarrow SE, \quad |y| < \sqrt{2B} \Rightarrow 0 \to \infty, \infty \to 0, \tag{14}$$

while for $h > 0$ we get

$$|y| > \sqrt{2B} \Rightarrow \infty \to \infty, \quad |y| \le \sqrt{2B} \Rightarrow 0 \to \infty, \infty \to 0. \tag{15}$$

Finally, consider $A < 0$ (the most rich case). If $h \le 0$, we have

$$|y| \ge \sqrt{2B} \Rightarrow \emptyset, \quad |y| < \sqrt{2B} \Rightarrow 0 \to 0. \tag{16}$$

If $0 < h < A^2/(2B)$, then

$$|y| \ge \sqrt{2B} \Rightarrow \infty \to \infty, \quad |y| < \sqrt{2B} \Rightarrow (0 \to 0) + (\infty \to \infty). \tag{17}$$

If $h = A^2/(2B)$, then:

$$|y| \ge \sqrt{2B} \Rightarrow \infty \to \infty, \quad 0 < |y| < \sqrt{2B} \Rightarrow (0 \to 0) + (\infty \to \infty),$$
$$y = 0 \Rightarrow 0 \to UE, UE \to 0, UE \to \infty, \infty \to UE, UE. \tag{18}$$

If $h > A^2/(2B)$, we obtain

$$|y| \ge \sqrt{2B} \Rightarrow \infty \to \infty, \quad \sqrt{2B - A^2/h} < |y| < \sqrt{2B} \Rightarrow (0 \to 0) + (\infty \to \infty),$$
$$|y| = \sqrt{2B - A^2/h} \Rightarrow 0 \to UE, UE \to 0, UE \to \infty, \infty \to UE, UE,$$
$$|y| < \sqrt{2B - A^2/h} \Rightarrow 0 \to \infty, \infty \to 0. \tag{19}$$

4. 2. CASE $B = 0$

Consider $A > 0$ (inverse-square attractive force, e.g. Newton's model). For $h < 0$, we have

$$\begin{gathered}|y| > A/\sqrt{-h} \Rightarrow \emptyset, \quad |y| = A/\sqrt{-h} \Rightarrow SE, \quad 0 < |y| < A/\sqrt{-h} \Rightarrow P, \\ y = 0 \Rightarrow 0 \rightarrow 0.\end{gathered} \tag{20}$$

If $h \geq 0$, we find

$$|y| > 0 \Rightarrow \infty \rightarrow \infty, \quad y = 0 \Rightarrow 0 \rightarrow \infty, \infty \rightarrow 0. \tag{21}$$

Consider now $A = 0$ (force-free field). For $h \leq 0$, we have

$$h < 0 \Rightarrow \emptyset, \quad h = 0 \Rightarrow UE, \tag{22}$$

while $h > 0$ leads to

$$|y| > 0 \Rightarrow \infty \rightarrow \infty, \quad y = 0 \Rightarrow 0 \rightarrow \infty, \infty \rightarrow 0. \tag{23}$$

Lastly, put $A < 0$ (inverse-square repelling force, e.g. the radiative force). We have

$$h \leq 0 \Rightarrow \emptyset, \quad h > 0 \Rightarrow \infty \rightarrow \infty. \tag{24}$$

4. 3. CASE $B < 0$

Put first $A > 0$. If $h < A^2/(2B)$, the real motion is impossible. For $h = A^2/(2B)$, we distinguish

$$|y| > 0 \Rightarrow \emptyset, \quad y = 0 \Rightarrow SE. \tag{25}$$

If $A^2/(2B) < h < 0$, we have

$$|y| > \sqrt{2B - A^2/h} \Rightarrow \emptyset, \quad |y| = \sqrt{2B - A^2/h} \Rightarrow SE, \quad |y| < \sqrt{2B - A^2/h} \Rightarrow P. \tag{26}$$

For nonnegative energy levels, we obtayin

$$h \geq 0 \Rightarrow \infty \rightarrow \infty. \tag{27}$$

Finally, consider $A \leq 0$ (fully repulsive force). We have

$$h \leq 0 \Rightarrow \emptyset, \quad h > 0 \Rightarrow \infty \rightarrow \infty. \tag{28}$$

5. SPECIFIC DYNAMICAL FEATURES

We have seen that the Manev-type problems include, as particular cases, different classical models (Newton's law, radiative force, force-free field). In what follows, we shall emphasize only those dynamical features which cannot be met within the framework of these classical situations.

A very important characteristic is the motion on precessional conic sections (for $C \neq 0$). We must point out here the fact that almost all motions on noncollisional precessional ellipses are quasiperiodic (except a set of measure zero of periodic orbits).

Another essential feature is the occurence of the black hole effect. The collisions are much more probable than in the Newtonian model, because the set of initial data leading to them has positive measure.

The existence of bounded orbits for $h \geq 0$ is unusual, too. There are stable circles for $h = 0$ (see (14)), or precessional parabolas and hyperbolas of the type $0 \to 0$ (see (16) and (17)-(19)).

We also have to mention the coexistence, for the same h and for the same C, of the trajectories of the type $0 \to 0$ and $\infty \to \infty$ (see (17)-(19)).

The existence of unstable circular motion for for $C \neq 0$ or unstable rest for $C = 0$ (corresponding to saddles in RPS) deserves to be mentioned, too. This generates radial (see (18) or spiral (see (19)) motions of the types $0 \to UE$, $UE \to 0$, $UE \to \infty$, $\infty \to UE$, which cannot be recovered in classical models.

Another unusual motion is that performed on precessional hyperbolas which turn their convexity to the centre (see (28)).

To end the list of these specific features, we have to emphasize the existence of the stable rest pointed out by (25) and the radial librations described by the last formula (26) for $y = 0$.

This survey provides an insight deep enough in the complexity of Manev-type problems.

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JACOBI INTEGRAL IN THE RESTRICTED CIRCULAR SCHWARZSCHILD-TYPE MANY-BODY PROBLEM

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Abstract. The planar Schwarzschild-type $(n+1)$-body problem with n equal masses admits, for certain initial conditions, a class of exact solutions consisting of regular polygons (the n equal masses at vertices, the $(n+1)$th mass at centre) of changing side length, and rotating nonuniformly around the centre. The various types of relative equilibria which are met among these configurations are taken as the basis for a 3-dimensional restricted problem. The existence of the Jacobi integral within this framework is proved.

1. INTRODUCTION

A special class of exact solutions in the Newtonian planar $(n+1)$-body problem $(n \geq 2)$ has been pointed out by Elmabsout (1988) in the case of n equal masses initially placed at the vertices of a regular polygon centered in the $(n+1)$th mass. Geometrically, the solution represents a regular polygon of constant sides, uniformly rotating around the central mass. Elmabsout (1990, 1994, 1996) also investigated the stability of this configuration. Grebenicov (1997) found a new class of exact solutions for the above problem: the configuration of rotating regular polygon is preserved, but this time the side length and the angular velocity are changing.

Among the configurations pointed out by Grebenicov, there are stable relative equilibria (uniformly rotating polygon of constant dimensions). Taking such a configuration as the basis for a 3-dimensional restricted problem, Grebenicov (1998) proved that the respective problem admits the Jacobi integral; Gadomski (1998) extended this result to homogeneous potentials.

In the present paper we tackle the more general case of Schwarzschild-type fields (featured by potentials of the form $\alpha/r + \beta/r^3$; r = distance between two particles; α, β = real nonzero constants), which model concrete problems belonging mainly to astronomy, but not only (see Stoica & Mioc (1997) and the references therein). Mioc *et al.* (1998) proved that, given the initial polygonal configuration considered by Elmabsout and Grebenicov, the respective $(n+1)$-body problem is equivalent to n separate, identical, Schwarzschild-type two-body problems, therefore the regular polygonal configuration is kept all along the motion, but the side length and the rotational velocity are variable in general. The motion of every particle with respect to the central mass is governed by the solution of the Schwarzschild-type two-body problem, whose qualitative behaviour was fully described by Stoica & Mioc (1997), for the whole allowed interplay among field parameters, angular momentum, and total energy. Obviously, every kind of evolution in the two-body problem corresponds to a behaviour of the polygon in the $(n+1)$-body problem.

Among the possible evolutions of the polygon, there are many types of relative equilibria (polygons identical with the initial one, stable or unstable, rotating or fixed). Considering the motion of an infinitesimal mass in the Schwarzschild-type field generated by such an equilibrium configuration, we prove that the corresponding restricted problem admits the first integral of Jacobi.

2. POLYGONAL PROBLEM

Consider the $(n+1)$-body problem with masses m_0, $m_k = m \neq m_0$ $(k = \overline{1,n})$, let $\mathbf{q}_k = (\xi_k, \eta_k, \zeta_k) \in \mathbf{R}^3$, $k = \overline{0,n}$, be the position vectors in an inertial frame, and let $\mathbf{q} = (\mathbf{q}_0, \mathbf{q}_1, \dots, \mathbf{q}_n) \in \mathbf{R}^{3n+3}$ be the configuration of the system. Let the $n+1$ particles be interacting according to a Schwarzschild-type law, characterized by the force function $U : \mathbf{R}^{3n+3} \setminus \Delta \to \mathbf{R}$, with

$$U(\mathbf{q}) = \sum_{0 \le i < k \le n} \left(\tilde{A}_{ki}/r_{ki} + \tilde{B}_{ki}/r_{ki}^3\right). \tag{1}$$

Here $r_{ki} = \mid \mathbf{q}_k - \mathbf{q}_i \mid$, $\Delta = \cup_{0 \le i < k \le n} \{\mathbf{q} \mid \mathbf{q}_i = \mathbf{q}_k\}$ stands for the collision set; $\tilde{A}_{ki}$, $\tilde{B}_{ki} : \mathbf{R}^2 \to \mathbf{R}$ feature the interaction between the k-th and the i-th particles: $\tilde{A}_{ki} = \tilde{A}(m_k, m_i) = \tilde{A}(m_i, m_k) = \tilde{A}_{ik}$ (of course, in our conditions, $\tilde{A}_{k0} = \tilde{A}_{j0} \neq \tilde{A}_{ji} = \tilde{A}_{ki}$, $k, i, j = \overline{1,n}$; similar relations hold for $\tilde{B}_{ki}$).

Consider the relative motion of the n equal masses with respect to m_0 . The relative position vectors will be $\mathbf{r}_k = (x_k, y_k, z_k) = (\xi_k - \xi_0, \eta_k - \eta_0, \zeta_k - \zeta_0)$, hence $r_{ki} = \mid \mathbf{r}_k - \mathbf{r}_i \mid$. With the abridging notations (for $k, i = \overline{1,n}$):

$$\begin{bmatrix} A \\ B \end{bmatrix} := \frac{m_0 + m}{m_0 m} \begin{bmatrix} \tilde{A}_{k0} \\ \tilde{B}_{k0} \end{bmatrix}, \quad \begin{bmatrix} A' \\ B' \end{bmatrix} := \frac{1}{m} \begin{bmatrix} \tilde{A}_{ki} \\ \tilde{B}_{ki} \end{bmatrix}, \quad \begin{bmatrix} A'' \\ B'' \end{bmatrix} := \frac{1}{m_0} \begin{bmatrix} \tilde{A}_{k0} \\ \tilde{B}_{k0} \end{bmatrix}, \tag{2}$$

and $r_k = |\mathbf{r}_k|$, the relative motion equations can be written

$$\ddot{\mathbf{r}}_k = -\left(A/r_k^3 + 3B/r_k^5\right)\mathbf{r}_k + \partial R_k(\mathbf{r}_k, t)/\partial \mathbf{r}_k, \quad k = \overline{1,n}. \tag{3}$$

where $R_k(\mathbf{r}_k, t) = \sum_{i=1, i\neq k}^{n} \left[\left(A'/r_{ki} + B'/r_{ki}^3\right) - \left(A''/r_i^3 + 3B''/r_i^5\right)\mathbf{r}_k \cdot \mathbf{r}_i\right]$.

Obviously, the problem admits the ten well-known first integrals. Among the integration constants, we denote $\tilde{h}$ = energy constant, $\tilde{\mathbf{C}}(\in \mathbf{R}^3)$ = angular momentum constant.

Mioc *et al.* (1998) tackled the planar case ($z_k = 0$, $k = \overline{1,n}$, all along the motion) in polar coordinates (r_k, θ_k), and proved the following result:

THEOREM 1. *Let the masses* m_0, $m_k = m \neq m_0$ $(k = \overline{1,n})$ *be interacting according to a Schwarzschild-type law. Let* m_k *be initially* $(t = 0)$ *situated at the vertices of* *a regular polygon centered in m_0, and let the initial velocities form a vector field symmetrical with respect to m_0. Then, all along the motion, the equal masses will form a regular polygon (centered in m_0), homothetic with the initial polygon, and rotating around m_0 with variable angular velocity. The motion of every mass m with respect to m_0 is given by the solution of the Schwarzschild-type two-body problem.*

This means that the relative motion of every mass $m_k = m$, $k = \overline{1,n}$, is governed by the equations

$$\left\{\begin{array}{l} \ddot{r}_k - r_k\dot{\theta}_k^2 = -\alpha/r_k^2 - 3\beta/r_k^4, \\ \qquad r_k\ddot{\theta}_k + 2\dot{r}_k\dot{\theta}_k = 0, \end{array}\right. \tag{4}$$

with the first integrals of energy and angular momentum

$$\dot{r}_k^2 + r_k^2\dot{\theta}_k^2 - 2\alpha/r_k - 2\beta/r_k^3 = h;$$
$$r_k^2\dot{\theta}_k = C,$$

(h and C being the respective constants), and with the regular polygonal solution

$$r_k(t) = r_i(t), \quad \theta_k(t) = \theta_1(t) + 2\pi(k-1)/n, \quad k, i = \overline{1,n}.$$

We have to emphasize that the parameters α, β (Mioc *et al.* 1997), h and C, common for every pair (m_0, $m_k = m$), generally differ from the corresponding parameters featuring the initial $(n+1)$-body problem.

3. RELATIVE EQUILIBRIA

Studying the Schwarzschild-type two-body problem, Stoica & Mioc (1997) pointed out equilibrium configurations: circular motion ($C \neq 0$) or rest ($C = 0$) at relative distance r_e, stable ($r_e = r_{SE}$) or unstable ($r_e = r_{UE}$), with $r_{SE} = \left(-2\alpha - \sqrt{4\alpha^2 + 3hC^2}\right)/(3h)$, $r_{UE} = \left(-2\alpha + \sqrt{4\alpha^2 + 3hC^2}\right)/(3h)$ (for $h = 0$, $r_{UE} = r_{UE}^* := \sqrt{\beta/\alpha}$), provided the existence of the radical.

We are now in the position to state the following result:

THEOREM 2. *There are relative equilibrium solutions ($r_k = r_e$, $k = \overline{1,n}$) of the Schwarzschild-type polygonal $(n+1)$-body problem. In case $\tilde{C} \neq 0$, the regular polygon of constant size rotates uniformly with the angular velocity $\omega := \dot{\theta}_k = C/r_e^2$. In case $\tilde{C} = 0$ ($C = 0$), the polygon is fixed ($\omega = 0$).*

Proof. Taking into account the above mentioned results obtained by Stoica & Mioc (1997), as well as Theorem 1, the proof of Theorem 2 follows immediately.•

Let us mention the situations in which the interplay among α, β, h, C leads to relative equilibria in the Schwarzschild-type problem. These situations are: (a) $\alpha > 0$, $\beta > 0$, $C \neq 0$, $-4\alpha^2/(3C^2) < h$; for $h < 0$, there exist r_{SE} and r_{UE} (see above); for $h \leq 0$ and $C^2 = 4\sqrt{\alpha\beta}$, there exists r_{UE}^*; for $h > 0$, there exists r_{UE}; (b) $\alpha < 0$, $\beta > 0$, $h > 0$; for both $C \neq 0$ and $C = 0$, there exists r_{UE}; (c) $\alpha > 0$, $\beta < 0$, $-4\alpha^2/(3C^2) < h < 0$; for both $C \neq 0$ and $C = 0$, there exists r_{SE}.

4. ASSOCIATED RESTRICTED PROBLEM: JACOBI INTEGRAL

We shall take such a relative equilibrium configuration as the basis for a 3-dimensional restricted problem. So, consider the motion of an infinitesimal mass μ in the Schwarzschild-type field generated by the (rotating or fixed) constant size polygon. Let $\mathbf{d} = (x, y, z) \in \mathbf{R}^3$ and $\mathbf{d}_k = (x - x_k, y - y_k, z - z_k) \in \mathbf{R}^3$, $k = \overline{1, n}$, be respectively the position vectors of μ with respect to m_0 and $m_k (= m)$, and denote $\rho = |\mathbf{d}|$, $\rho_k = |\mathbf{d}_k|$. It is needless to say that the 3-dimensional frame in which we tackle the motion of μ is originated in m_0 and has the polygon plane as fundamental plane.

The relative motion equations of μ read

$$\ddot{\mathbf{d}} = -\left(\hat{A}/\rho^3 + 3\hat{B}/\rho^5\right)\mathbf{d} + \partial R(\mathbf{d}, t)/\partial \mathbf{d}, \tag{5}$$

where $R(\mathbf{d}, t) = \sum_{k=1}^{n}\left[\left(\hat{A}'/\rho_k + \hat{B}'/\rho_k^3\right) - \left(A''/r_k^3 + 3B''/r_i^5\right)\mathbf{d}\cdot\mathbf{d}_k\right]$, and we denoted $(\hat{A}, \hat{B}, \hat{A}', \hat{B}') = (A, B, A', B')(m = \mu)$ (see (2); we must emphasize that $\hat{A}, \hat{B}, \hat{A}', \hat{B}'$ are finite nonzero quantities).

THEOREM 3. *The restricted problem associated to the relative equilibrium solutions of the Schwarzschild-type polygonal* $(n+1)$*-body problem admits the Jacobi first integral.*

Proof. Let us pass to a uniformly rotating frame (in which m_0, $m_k = m$, $k = \overline{1, n}$, are fixed) via the transformations

$$\begin{cases} x = X\cos(\omega t) - Y\sin(\omega t), \\ y = X\sin(\omega t) + Y\cos(\omega t), \\ z = Z, \end{cases}$$

and similarly for $(x_k, y_k, 0) \longrightarrow (X_k, Y_k, 0)$, $k = \overline{1, n}$. In the new variables, (5) - written in scalar form - become

$$\begin{cases} \ddot{X} - 2\omega\dot{Y} - \omega^2 X = -\left(\hat{A}/\rho^3 + 3\hat{B}/\rho^5\right)X + \partial R^*/\partial X, \\ \ddot{Y} + 2\omega\dot{X} - \omega^2 Y = -\left(\hat{A}/\rho^3 + 3\hat{B}/\rho^5\right)Y + \partial R^*/\partial Y, \\ \ddot{Z} = -\left(\hat{A}/\rho^3 + 3\hat{B}/\rho^5\right)Z + \partial R^*/\partial Z, \end{cases} \tag{6}$$

where $R^*(X, Y, Z) = R(x, y, z, t)$. Obviously, $\rho^2 = X^2 + Y^2 + Z^2$ and $\rho_k^2 = (X - X_k)^2 + (Y - Y_k)^2 + Z^2$.

Multiplying respectively equations (6) by $\dot{X}$, $\dot{Y}$, $\dot{Z}$, adding the resulting expressions together, then integrating with respect to time, we get

$$\left(\dot{X}^2 + \dot{Y}^2 + \dot{Z}^2\right)/2 = \omega^2\left(X^2 + Y^2\right)/2 + \left(\hat{A}/\rho + \hat{B}/\rho^3\right) + R^* + h^*/2, \tag{7}$$

where h^* is a constant of integration.

Observing that the relative equilibrium $\{r_k = r_e,\, \theta_k = \omega t + 2\pi(k-1)/n\}$ implies, in the new coordinates, $\sum_{k=1}^{n} X_k = 0$, $\sum_{k=1}^{n} Y_k = 0$, and replacing this in R^*, we easily obtain

$$\left(\dot{X}^2 + \dot{Y}^2 + \dot{Z}^2\right)/2 = \omega^2\left(X^2 + Y^2\right)/2 + \left(\hat{A}/\rho\right) + \hat{B}/\rho^3 + \sum_{k=1}^{n}\left(\hat{A}'/\rho_k + \hat{B}'/\rho_k^3\right) + h^*/2,$$

which is nothing but the Jacobi integral. Theorem 3 is proved.

To end, we have to emphasize that, although the qualitative result is the same, the set of relative equilibria which form the basis of our restricted problem is more rich (as regards stability/instability, or rotation/rest) than those revealed by Grebenicov's (1998) or Gadomski's (1998) papers.

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GENERALIZED TITIUS-BODE'S RULE AND ASTEROIDAL BELTS

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Abstract. The minimal possible radius of a planetary orbit in the Solar system is the Solar radius. Starting from this idea, it is shown that the Titius-Bode's rule for observed planetary distances from the Sun can be generalized. For an arbitrary choosen planet with order number k, as reference body, The TB-rule gets the form:

$$r_n = r_k \cdot \phi^{n-k}, \qquad n, k = 1, 2, 3...$$

Possible implications of this formula are considered, specially concerning of asteroids beyond the Neptune.

QUANTIZATION IN MACROSCOPIC GRAVITATIONAL FIELD

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Abstract. Planetary orbits in Solar system contain the condition of quantization for the momentum of impulse per mass unit. Some other analogies with atomic systems (e.g. validity of Bohr's formulae for distances, speeds and energies) are demonstrated.

MASS-RADIUS TEST FOR CENTRAL BODY IN PLANETARY SYSTEMS

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Abstract. The formula like the Bohr's one for hydrogen atom is used with two different minimal distances for calculation of planetary distances. The real radius of the central body and "transposited gravitational radius" (containing mass of the central body) are accepted as the minimal radius of the orbit (average distance). So introduced "quantum numbers" determined from orbital elements of planets or satelites give possibility for a test of mass or radius of the central body. It has been done for 47 UMa, 70 Vir, PSR 1257+12 and PSR 1829-10.

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H-ALPHA EMMISSION IN SOLAR CORONA

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Abstract. Some of earlier observations where H-alpha emission in solar corona mainly up to 0.6 solar radii above the Moon's limb was detected in eclipse and in daily coronagraphic observations are reviewed. A proper theoretical explanation of this cold chromospheric-type emission in the hot corona does not exist yet. A possible Belgrade Astronomical Observatory program for detection of H-alpha emission as large or small scale coronal structures is outlined.

1. INTRODUCTION

When one learns about the solar atmosphere it is usually presented in layers as photosphere, chromosphere and corona. But in reality the division is not that rigid. First, "reversing layer" between photosphere and chromosphere was invented.Then the chromospheric prominences were "admitted" to extend high in corona. Something here was called the transition region - but not the transition layer. Corona has been found lurking behind spicules. Finally, in spite of generally accepted high temperatures in corona (more than 10^6 K), some low excitation spectral lines corresponding to typical chromospheric temperatures (definitelly much less than 10^5K) were found in the inner as well as in the outer corona.

This process of comprehention wasn't an easy one. It has lasted for more than a century.Now most of solar physicists are convinced in the coronal origin of those low excitation emission regions. However, their sizes, locations in the corona, appearances, time-variations and possible theoretical explanation are not well established yet.

So, there is a need to observe such a phenomenon during the total solar eclipse in 1999.

2. SOME PREVIOUS OBSERVATIONS

The first observations of low excitation spectral lines in solar corona were recorded in the last century (Dermendjiev, 1997). Namely, Rayet during the 1868 eclipse noticed H-beta, D. as well as 530.3 nm spectral lines high above the prominences. Also, Janssen on the occassion of the 1871 eclipse spectroscopically (radial spectroscope slit) found hydrogen emission lines 10' above the Moon's limb.

Later on, mainly in the first half of this century, some observers did not believe in solar origin of the recorded low excitation emission in corona. It was suspected to be the chromospheric radiation scattered in the Earth's atmosphere or, in some cases, it was found to originate in the telescope. Here we review some more or less successful observations where the recorded "cold" emission was supposed to originate in the solar corona.

Colacevich (1953) in the 1952 eclipse registered H and K CaII and H-gamma lines at a distance 70' from the Moon's limb explaining them as local appearance of a diffuse prominence matter.

Conway *et al.* (1967) using the airborne observed spectra analysed the variations of CaII lines with height in corona. Except being present at the base of the corona (in the chromosphere), these lines reappeared at one solar radius above the limb.

Near an active prominence, but not connected with it, Gurtovenko and Alikayeva (1971) in the 1970 eclipse observed low excitation emission 40 Mm to 100 Mm high in the corona. At the same position a system of thin, dense streamers was found. Elaborating the same obsetvation, Alikayeva (1975) found H, He and some neutral metal emissions and estimated the intensity of this "cold" emission as being about 1000 times weaker than in prominence spectra. She also evaluated a possible temperature value between 10^4K and 3.10^4K, as well as the electron density between $10^9 cm^{-3}$ and $10^{10} cm^{-3}$.

Bappu *et al.* (1972) observed coronal spectrum during the 1970 Mexican eclipse. As the most sriking low excitation spectral lines they found HeI 587.6 nm and H-alpha followed by the less intense lines H and K CaII, H-gamma,H-dzeta, H-eta and D3 with the maximum intensity at about 0.5 solar radii above the Moon's limb. The typical coronal lines FeXIV 530.3 nm and FeX 637.4 nm appeared closer to the Moon's limb. The authors readily explained the phenomenon as "a cool column in the outher corona" and gave a survey of observational arguments in favor of the coronal origin of those emission spectral lines.

Following the arguments of Bappu *et al.* (1972), Cavallini and Righini (1975) re-examined the coronal spectrum obtained during the 1963 eclipse by Deutsch and Righini (1964). Now, they carefully resolved the coronal components and paid attention to the intensity ratio of H and K lines of CaII. They were able to construct a model of cold (about 10^5K) coronal regions that can take size comparable to a coronal hole.

Kononovich *et al.* (1994) used the 0.05 nm passband Halle filter at CaII 393.3 nm during the 1981 eclipse. In lower corona he found an emission of the intensity 10 to 100 times larger then in the coronal continuum. The emission line had a larger height gradient.

Some years ago, a program for daily monitoring coronal H-alpha structures started at Pic-du-Midi (Niot and Noens, 1997). They use the Lyot coronagraph and a three-cavity interference filter centered at H-alpha with a 0.33 nm passband. The program is concentrated at rapid and energetic H-alpha structures very close to the solar limb - what is needed for coopearation with SOHO. It is also ready to record slowly-varying, low intensity phenomena high in the corona. As some exemplary results the authors presented rapid time-variations of H-alpha emission flux lasting from some minutes to one or two hours and amounting to from less than one to more than ten "sunbrightness in 1 arcsec square surface".

On the occassion of the 1995 eclipse in India, Bagara *et al.* (1997) obtained a good

H-alpha 0.075 nm passband filtergram covering about a quadrant of NE corona. In that portion of the outer corona they did not find any H-alpha emitting "pockets".

Most recently, Foing (1998) during the the 1998 eclipse searched for the cold H-alpha emission in corona. Till the time of submitting this text for the press, no results were published yet. However, he suggests to try such observations in 1999.

3. MODELLING THE REGIONS OF COLD CORONAL EMISSIONS

There are no conclusive theoretical results on the possible origin of low excitation (chromospheric) spectral lines high in the corona. Most often it is assumed that the phenomenon is a transient one - a special short phase in the very complex MHD activity in corona.

A picture of small-scale H-alpha emission regions in sporadic coronal condensations was presented in Orrall's discussion (1965). This is an empirical model of a sporadic loop-like coronal condensation. Generally, the high temperature (10^6K) loops are about 15 000 km thick and radiate in Fe XIV 530.3 nm. Imbeded in some of these are bundles of fine H-alpha loops with thickness of 2000 km and temperature less than 10^5K. In a thin transition region between these two components the red FeX 637.4 nm emission is radiated. The region that emits the yellow CaXV 569.4 line (always present in spectra of coronal condensations) is much more extensive. Orrall suggests that in such places the hot coronal plasma cools, compresses and produces small-scale H-alpha emitting regions. Life-time of that kind of coronal condensations is usually several hours.

One of potential physical mechanisms that might cool coronal plasma is given by Dermedjiev (1997) who in some detail describes the idea (earlier proposed by Öhman) that certain changes of local magnetic field in corona can sometimes decelerate electrons and protons spiralling around the magnetic lines of force.The result is local decreasing of kinetic temperature and recombination of hydrogen atoms. The effect is a temporary one and might last as long as a quasi-adiabatic state maintains.

4. A POSSIBLE OBSERVATIONAL PROGRAM IN 1999

It seems reasonable to propose the search for: a) Large H-alpha structures of any shape in the whole corona, and b)Tiny H-alpha bundles within Fe XIV 530.3 nm loops of sporadic (temporary) coronal condensations.

In the first case it should be the monochromatic imaging through a H-alpha filter having the passband between 0.3nm and 0.5 nm. The corona up to about two solar radii above the limb has to be recorded photographically (red-sensitive emulsion!) and with a CCD camera. One long-exposure of full size frame is desirable. Or two or more complementary images covering much of the corona can be made during the eclipse totality.

In the second case, the fine structure of sporadic coronal condensations in H-alpha can be revealed in high-resolution images recorded as filtergrams (as above) or as slit spectrograms. Here one has to predict the regions of corona where the sporadic coronal condensations are to be expected. The precise aiming of the telescope is essential. Long exposures would be also useful. Also, a simultaneous recording of FeX 637.4 nm and FeXIV 530.3 nm coronal spectral lines would help the interpretation of the H-alpha images.

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OPTICAL POLARIZATION OF SOLAR CORONA – PROGRAM FOR TOTAL SOLAR ECLIPSE ON AVGUST 11, 1999.

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Abstract. It is proposed to observe the linear optical polarization in the inner solar corona as well as to measure the global polarization of the eclipsed Sun.

1. INTRODUCTION

In spite of a reasonably good van de Hulst's (1950) theoretical model describing general characteristics of solar corona optical polarization, it is still not in a satisfactory agreement with a number of observational facts. Due to the coronal fine structure and its variability, the real corona differs from the spherically symmetric model. This is especially seen in a different height dependence of optical polarization degree along the solar limb as well as in the polarization variations as a function of solar activity cicle.

2. THE PROPOSALS

Measurements of coronal polarization during a total solar eclipse is a good opportunity to answer some of the still open questions. Besides of many interesting polarization problems in small-scale coronal structures (streamers, condensations,...) there is a need to observe some large-scale, even global-scale, aspects of optical coronal polarization. Here we suggest two kinds of such observations for August 11, 1999. They compromise between the importance of the problems and our modest instrumental possibilities.

First program. Observation of linear optical polarization within the inner corona, right down to the chromospheric border, in order to re-measure its quite steep radial gradient. A special attention will be paid to the height interval 1.2 to 1.4 solar radiii above the solar limb to corroborate - or not - the existence of a plateau in the polarization degree as a function of height in corona (Kim et al.,1996). This plateau was not anticipated by van de Hulst's model.

Here we'll rely on a Zeiss refractor 6/80 cm, mounted equatorially, with a polarizing filter movable in 60-degree steps and on a CCD receiver which still has to be selected.

Second program. The aim is to measure global (integral) linear optical polarization of solar corona. This would be a continuation of our efforts to observe the Sun as a star and find a possible time-dependance of its optical polarization during a solar activity cicle (Vuletić et al., 1993).

The observation will be carried out with a very short focal length refractor containing a polarizing filter, a Fabry lens and a special diaphragm enabling in alternation the observations of the whole corona and of the selected near-by sky areas. The measurements will be done photoelectrically.

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FLASH SPECTRUM OBSERVATIONS AROUND THE BALMER JUMP

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Abstract. In this paper the theoretical background for analysis of the observed Balmer jump and an observational equipment for flash spectra observation during the second and third contacts of solar eclipse are presented.

1. INTRODUCTION

Total solar eclipses give an opportunity of high spatial resolution observations of the solar chromospheric spectrum during the two flash phases using fast electronic cameras as detectors. In low spectral resolution observations (higher degree of illumination of the spectrum) the frequency of observations could be as high as 20-30 Hz, that corresponds to spatial resolution of about 10-20 km. On the other hand, low spectral resolution observation can be used in the case of a continuous spectrum. The observation of the Balmer jump (an abrupt step in continuum level), from which the electron temperature can be obtained, satisfies these conditions. Because of that we introduce it into our observational program for the 11th August 1999 solar eclipse expedition as an experiment for high spatial resolution determination of chromospheric electron temperature.

2. THEORETICAL BACKGROUND

The intensity of continuum radiation in vicinity of wavelength 364.6 nm is enhanced. It is caused by Balmer continuum, which is the result of electron recombination to the second energy level in hydrogen atoms.

Theoretical considerations show that the radiation power (P) can be expressed by

$$P(\nu)d\nu = N_{HII}N_eE_{eff}d\nu,$$

where N_{HII} is the number density of ionized hydrogen, N_e is the number density of electrons, and E_{eff} is the effective emission coefficient. This coefficient is the sum of all free-bound and free-free transition radiative coefficients.

Emission coefficient depends on the electron temperature (T) of the gas. For instance, in the case of hydrogen atom the volume emission coefficient of free-bound transition is given by (Bray and Lunkhead, 1974, pp 154)

$$E_\nu = Const.g_{fb}n^{-3}N_{HII}N_eT^{-\frac{3}{2}}e^{\frac{h(\nu_n-\nu)}{(kT)}},$$

where g_{fb} is the Gaunt factor for a given energy level of atom, n is the principal quantum number, ν_n is the frequency at Balmer limit, ν is any other frequency higher or equal with ν_n, h is the Planck constant. In Balmer continuum n=2, g_{fb} =0.876, and the value of the constant depends on the used units (in CGS Const=2.15x10^{-32}).

If $\nu = \nu_n$, the emission coefficient depends on the product of electron and proton density, and on temperature. As above the temperature minimum level the source of electrons are almost only hydrogen atoms one can suppose that the number of electrons is equal to the number of protons. Then the emission coefficient is proportional to the product of square of electron density and temperature.

The Balmer jump is defined by $D = log(H_{\nu<\nu_n}/H_{\nu>\nu_n})$, where $H_{\nu<\nu_n}$ is the radiation flux at lower frequency and $H_{\nu>\nu_n}$ at higher frequency than the frequency of the Balmer limit.

If we suppose that the continuum radiation flux depends on ff and fb transitions in hydrogen atoms under thermodynamical equilibrium, then the Balmer jump can be expressed as (see, e.g., Emerson, 1997)

$$D = log \frac{g_{ff} + 2(\frac{\kappa_1}{kT}) \sum\limits_{i=3}^{\infty} i^{-3} g^i_{fb} e^{(\frac{\kappa_i}{kT})}}{g_{ff} + 2(\frac{\kappa_1}{kT}) \sum\limits_{i=2}^{\infty} i^{-3} g^i_{fb} e^{(\frac{\kappa_i}{kT})}},$$

where κ is the ionization potential of energy level i. In this case D depends only on electron temperature. So, by observing the Balmer jump we can get the electron temperature, and from emission coefficient of Balmer continuum, knowing the electron temperature, we can calculate the electron (proton) density.

The observations do not give the emission coefficient but its line-of-sight integral value:

$$I_\nu(x) = \int\limits_{-\infty}^{+\infty} E(x,y) e^{-\tau_\nu(x,y)} dy,$$

where x and y are the coordinates of a chromospheric element, τ is its optical depth.

If the observed intensity we express as (Bray and Loughhead, 1974, pp 150)

$$I_\nu(x) = \sum_i a_i e^{-\beta_i x},$$

the emission coefficient is

$$E_\nu(x) = \frac{1}{(2\pi R)^{\frac{1}{2}}} \sum_i a_i \beta_i^{\frac{1}{2}} e^{-\beta_i x},$$

where β is the intensity gradient with height and R is the solar radius. From the observed intensity distribution with height we can get the gradient, then the emission coefficient and finally the electron (proton) density.

3. FLASH SPECTROGRAPH

According to the mentioned research program it has been decided to construct a slitless grating spectrograph for the observation of the flash spectrum. It is a portable Newtonian instrument equatorially mounted, with an objective grating and a CCD camera as a radiation receiver. Of course, the camera has to be fast (capable to capture several full frames per second) and sufficiently sensitive in the wavelength interval 300 nm to 400 nm.

A 110 mm diameter 1140 mm focal length primary mirror has been combined with a 25 mm diagonal flat to form an off-axis Newtonian type reflector (Figure 1.). The off-axis arrangement is applied to make use of the whole grating aperture. The dispersion of about 2 to 4 nm/mm would be desirable. This is satisfied with a grating 51×51 mm size with 150 lines/mm. It can be used either in the first or in the second order to yield the suitable dispersion and a linear spectral resolution slightly higher than the resolution of the receiving CCD chip. Also, no spectral order separation measures would be necessary except, perhaps, for some filtering in the second order - depending on the spectral sensitivity of the CCD radiation receiver.

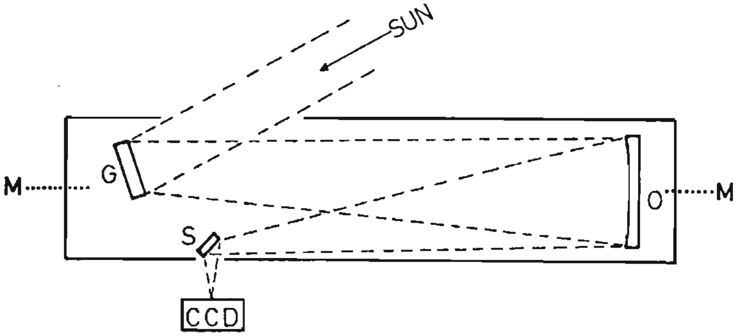

Fig. 1. Optical arrangement of the spectrograph. G - diffraction grating, O - objective mirror, S - secondary flat mirror, CCD -radiation receiver, SUN - direction from the observed point at the solar limb (O_2 or O_3 in Figure 2.), M ... M - rotational axis of the spectrograph (direction toward the points M_2 or M_3 in Figure 2.)

A 30 times magnifying finderscope with a Sun-protecting filter is attached to the main tube of the spectrograph. Its optical axis is parallel to the light rays incoming to the grating. This direction subtends an angle of about 30^o to the geometrical axis of the telescope tube. Actually, this angle is for $\kappa = 0.^o507$ greater than the sum of the incidence and the diffraction angle of the grating.

To align the direction of the spectral dispersion plane with the radial direction at the observed points of the second and third contacts at the solar disk, the main spectrograph tube can be rotated around the geometrical axis of the tube for preselected angular increment.

3. 1. ROTATION IN POSITION ANGLE

It seems normal to assume that, during the flash observation, the direction of spectral dispersion projects itself at the solar disk in radial direction. The easiest mechanical way to achieve transition in the position angle from the second to the third eclipse contact is to rotate the whole spectrograph tube around the axis of its cylindrical body. If proper bearings of the tube and a suitable angular scale (relative position angle) are provided, the necessary rotational increment between the tube positions of the second and the third eclipse contacts can be precalculated and engaged during the observation.

In the most frequent case when the two eclipse contacts (2nd and 3rd)fall at the opposite, east and west sides with respect to the terrestrial central meridian of the solar disk, The desired rotation of the spectrograph tube in position angle can be found consideration the relations in Figure 2. In this figure points S_2 and S_3 are the centers of the solar disk at the instants of the second and the third eclipse contacts respectively. The corresponding contact points at the solar limb are O_2 and O_3. These are the points where the spectrograph optical axis is aimed at times of the eclipse contacts, t_2 and t_3. At the same instants the rotational axis of the spectrograph tube is supposed to intersect the celestial sphere at points M_2 and M_3 respectively. P is the celestial North Pole and Z is the Zenith. Apparent solar radius is ρ and P_2 and P_3 are the position angles of the points O_2 and O_3 respectively (the heavy arcs along the corresponding solar limbs).

The desired rotational angular increment, ΔP, represents the angle necessary for the spectral dispersion plane at the instant t_2, namely O_2M_2, to rotate into position O_3M_3 at the instant t_3.

In the case of an equatorially mounted, and well oriented spectrograph, one can achieve ΔP rotation by rotating the spectrograph in the following way. First, one rotates the spectrograph around point M_2 counterclockwise for the angle P_2' (direction of spectral dispersion M_2S_2 being radial at the solar disk now becomes pointing northward, M_2P) then aims the spectrograph tube toward point M_3 (with spectral dispersion still oriented toward north, M_3P), and finally rotates the spectrograph around point M_3 for the angle P_3' counterclockwise returning the direction of spectral dispersion again into the radial position at the solar disk, M_3S_3. Namely, $\Delta P = P_2' + P_3'$. Here P_2' is the angle PM_2S_2 and P_3' is the angle PM_3S_3.

In the case of a well oriented alt-azimuth instrument, after the observation of the second eclipse contact, we similarly disintegrate ΔP in two increments taking instrumental vertical direction (M_2Z in M_2 or M_3Z in M_3) as the constant orientation reference during the transition of the spectrograph is pointing toward M_2 into its pointing toward M_3. The overall rotation is then

$$\Delta P = P_2' + P_3' + q_3 - q_2,$$

where q_2 and q_3 are the paralactic angles at points M_2 and M_3 respectively. In either case the rotation ΔP has to be performed in the clockwise sense (looking toward the Sun).

All quantities needed for rotation of an equatorial spectrograph can be found from the corresponding spherical triangles PS_2M_2 and PS_3M_3 as follows

$$P_2' = \arcsin(\frac{\sin P_2 \cos \delta_0}{\cos \delta_2}),$$

where δ_2 is the declination of point M_2, and δ_o is the Sun's declination at the middle of the eclipse totality. Here we neglect the changes of this quantity during the totality (that is always less than one arc min h^{-1}). The former can be found as

$$\delta_2 = \arcsin(\sin \delta_0 \cos(\gamma + \rho) + \cos \delta_0 \sin(\gamma + \rho) \cos P_2).$$

Accordingly follow the relations

$$P_3' = \arcsin(-\frac{\sin P_3 \cos \delta_0}{\cos \delta_3})$$

and

$$\delta_3 = \arcsin(\sin \delta_0 \cos(\gamma + \rho) + \cos \delta_0 \sin(\gamma + \rho) \cos P_3).$$

In these relations γ depends on the grating montage and on its working regime as $\gamma = K + \alpha + \beta$, where $K = 0.^o507$ is given by the spectrograph construction and α and β are the incidence and diffraction angles at the grating.

After evaluating δ_2 and δ_3, one obtains the complete positions of the points M_2 and M_3 knowing the hour angles of the Sun, H_{02} and H_{03}, at the eclipse contact instants t_2 and t_3 respectively. Then the hour angles of M_2 and M_3 are $H_2 = H_{02} + \Delta H_2, and$ $H_3 = H_{03} - \Delta H_3$, where ΔH_2 and ΔH_3 are the hour angle increments within the spherical triangles M_2PS_2 and M_3PS_3 respectively. These angles can be found from the same triangles as follows

$$\Delta H_2 = \arccos(\sin \delta_0 \sin \delta_2 + \cos \delta_0 \cos \delta_2 \cos(\gamma + \rho)), and$$

$$\Delta H_3 = \arccos(\sin \delta_0 \sin \delta_3 + \cos \delta_0 \cos \delta_3 \cos(\gamma + \rho)).$$

The paralactic angles q_2 and q_3 one finds from the positional spherical triangles PM_2Z and PM_3Z. The relations are

$$\tan q_2 = \frac{\sin H_2}{\tan \varphi \cos \delta_2 - \sin \delta_2 \cos H_2},$$

and

$$\tan q_3 = \frac{\sin H_3}{\tan \varphi \cos \delta_3 - \sin \delta_3 \cos H_3}.$$

Here φ is the geographical latitude of the observer's location.

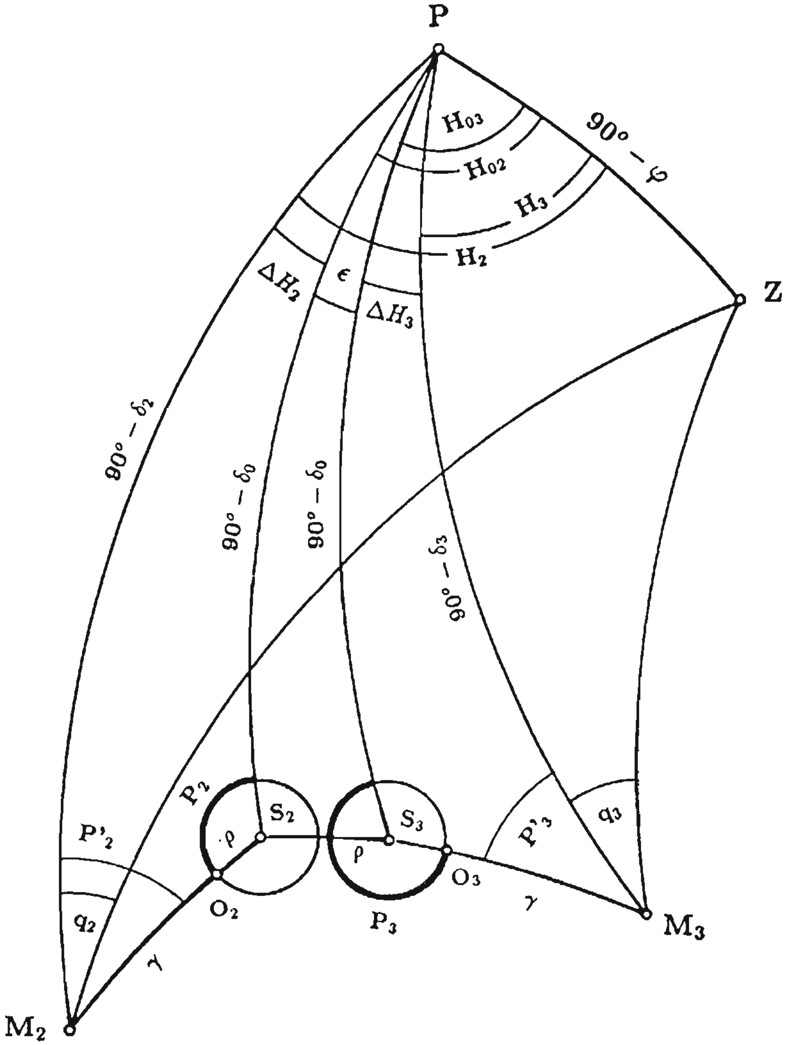

Fig. 2. Geometry of the spectrograph rotation. P - celestial North Pole, Z - Zenith, S_2 and S_3 - center of the solar disk at the instant of 2nd or 3rd eclipse contact, ρ - apparent radius of the solar disk, O_2 and O_3 - 2nd and 3rd contact points at the solar limb, M_2 and M_3 - points where the spectrograph rotational axis in succession intersects the celestial sphere, P_2 and P_3 - positional angles of the 2nd and 3rd eclipse contacts, γ - angular divergence of the spectrograph optical and rotational axes, H_{02}, H_{03} and δ_0 - solar equatorial coordinates.

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UP ON THE CLEAR SKY OF SERBIA

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Abstract. The part of activity of Astronomical Society "Belerofont" will be presented.

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EARTHBOUND ASTRONOMY

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1. INTRODUCTION

The phenomena that form the subject of *archaeoastronomy* are usually taking place on the line where the earth's surface (land or sea) meets the sky, that is *on the horizon.*

In our modern times such phenomena do not form part of the everyday experience either of the common people or even of professional astronomers. We live indeed in a world of "Lost Horizons". Not many people are in a position of being able directly to experience such events as the moment of *rising and setting of celestial bodies, the heliacal rise or cosmic setting* of certain stars or constellations. Nowadays these phenomena can be directly observed only under special conditions and at special locations, such as in the desert, on the open sea or from an aeroplane or balloon, even though they were part of the direct everyday experience of the ancient, or even the Mediaeval man. The skyline, still visible to our ancestors, is nowadays distorted by tall buildings, or even more often, is hidden under thick layers of atmospheric pollution.

2. ORIENTATION ATTEMPTS TOWARDS THE RISING SUN

In our investigation an attempt was made to reconstruct the *medieval method* of orientation of churches. The basic rule in church orientation — from early Christian times on — was that the axis of the building (the nave) must be aligned with the East-West direction (Barlai, 1997; Romano, 1992). We tried to replicate that method at the ruined church of the also ruined monastery at KANA, a former medieval settlement (12th c.) now inside of Budapest. Following the old ecclesiastic architects we marked the axis of the ruined nave with two sticks and tried to observe *on which day the two sticks and the rising solar disc can be seen in a straght line.*

It has been found that the polluted air covering Budapest prevented us from sighting the rising Sun on the horizon. The solar disc remained hidden by the layer until it reched an altitude of 2–4 degrees. (Due to this fact instead of the direct sighting we were compelled to measure a sequence of the solar positions above the horizon and used extrapolation to determine the East point.

Table 1. The altitude of the solar disc versus the angle deviation from the axis of the ruined church.

Angle	Alt.	Angle	Alt.
5.167	2.733	7.118	4.603
5.300	3.025	7.567	5.013
5.583	3.250	7.902	5.300
5.733	3.458	8.857	6.160
6.242	3.833	9.102	6.360

These data form the points of the straight line: $y = 3D0.892482x - 1.74634$.

3. MODERN OBSERVATIONAL ATTITUDES

The minds of modern astronomers are otherwise directed. The investigations of astrophysicists are carried out close to the zenith and restricted to narrow hour angles in order to minimise the influence of the atmospheric extinction.

Still, one of the most significant astronomical experiment of the modern age was associated with the *rising Moon.*

In the early months of 1946 American and Hungarian scientists attempted to send a radio signal off to the Moon and obtain an echo from it. Both experiments were motivated by military considerations, and were naturally independent of each other. The Hungarian experiments were led by professor *Zoltán Bay* and they took place in the research laboratory of the *TUNGSRAM Company* in Budapest. The American attempt was made under the direction of *Colonel DeWitt* (who was himself an amateur astronomer), and was carried out in Belmar (New Jersey) under the code name *DIANA*.

On the *10 January 1946* the Americans succeeded in obtaining the radar echo from the Moon. Due to the constraint that their (flat) aerial (antenna) could be rotated only round a vertical axis, it was oriented towards the *rising Moon* (the moonphase first quarter). The Hungarian effort bore fruit on the *6 February 1946.* The Hungarian aerial being fully mobile, it was possible to follow the Moon in its movement (Mészáros, 1996).

Lately even astronomical practice is giving way to investigation not even earthbound. Modern telescopes carried by artificial satellites or non-returnable probes are completely outside the Earth's atmosphere. The range of the information gathering and processing capacity is expanded to use wavelengths outside the range of visible light by making observations in the frequency-domains of X-rays, IR and UV radiation.

The neutrino-astronomers go even further by building their laboratories deep underground, so that they can hope to resolve eg the discrepancies that exist between the prediction of the theoretical solar model and the actually measured flux of solar neutrinos. Mighty underground laboratories, which can be regarded as neutrino-telescopes, already commissioned or just being under construction, stretch from the USA to Japan from the Caucasus mountain to the Italian Peninsula. Big bodies of water (the oceans, big lakes) are also being used for the detction of neutrinos of cosmic origin.

From the numerous neutrino experiments let us mention now only one being carried out in the water of *Lake Baikal in Siberia.* These experiments are a cooperative venture of *Russian, Hungarian and German* scientists. As the surface of the lake is frozen almost during the whole year, it has been possible to transport the measuring facilities on the thick layer of ice. Cables and photomultipliers which have to register the Cerenkov radiation from the nuclear reactions induced by neutrinos can simply be sunken into the water through a hole cut into the ice.

This shows that modern methods are applied below and on the Earth's surface, on the inside and outside of the atmosphere, in fact everywhere except on the skyline. This way, the horizon, the scene of the bulk of the ancients' observations and their greatest achievements, became the preserve of the archaeoastronomers' investigations, *a specialised field of spherical astronomy.*

It is justified indeed to refer to Archaeoatronomy as the *"Earthbound" branch of observational Astronomy.*

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ARCHAEOASTRONOMY AND ASTRONOMY IN CULTURE AND RELEVANT RESEARCH IN SERBIA

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Abstract. A short review of the development, meaning and significance of archaeoastronomy and astronomy in culture research has been presented. The corresponding research in Serbia has been discussed as well.

1. ARCHAEOASTRONOMY AND ASTRONOMY IN CULTURE

Archaeoastronomy has been developped (Aveni, 1986) as a result of investigations of the possible astronomical significance of architectural alignments and as a result of investigations of the astronomical significance of the Stonehenge, as well as of the investigation of astronomy and astronomical alignements in architecture in South America (Urton, 1981, 1990).

Actually in the world a considerable amount of high quality research is being generated in archaeoastronomy and ethnoastronomy. Such research is being developed in Romania and Bulgaria (see e.g. Proceedings of the first National symposium on archaeoastronomy, Tolbuchin, 1988). Aveni (1989) defined archaeoastronomy as "the study of the practice and use of astronomy among the ancient cultures of the world based upon all forms of evidence, written and unwritten". Ruggles (1991) stated that the word "ancient" can safely be removed from Aveni's definition to include ethnoastronomy in this definition.

Since 1988, when the first National symposium on archaeoastronomy has been held in Tolbuchin in Bulgaria, at least one archaeoastronomical symposium has been held in Europe each year, as e.g. in Venice 1989, (Romano and Traversari, 1991), "Current problems and future of archaeoastronomy", an annual series begun at Warszaw 1990 (Iwaniszewski, 1992), and the third "Oxford" International Symposium on Archaeoastronomy, St. Andrews, U. K., 1990 (Ruggles, 1991). The 1992 European Conference on "Current problems and future of archaeoastronomy" in Strasbourg, voted to establish an European Society for Cultural Astronomy (Société Européene pour l'Astronomie dans la Culture - SEAC). For the Annual Meeting held in Bochum 1994, SEAC Newsletter has been established as Newsletters confined to European activities in cultural astronomy.

Currently, courses in cultural astronomy exist at Leicester University, held by Clives Ruggles since 1990 as a third year optional course within the studies on Archaeology.

Also exists the British journal of *Archaeoastronomy* as the supplement to *Journal for the History of Astronomy.*

2. RESEARCH ON ARCHAEOASTRONOMY AND ETHNOASTRONOMY OR ASTRONOMY IN CULTURE IN SERBIA

In Serbia, a number of articles and books relevant to archaeoastronomical and ethnoastronomical research has been published (Cenev, 1985; Danić, 1960; Francisty, 1985, 1986; Grujić, 1930; Harisijadis, 1976; Jagić, 1922; Janićijević, 1992; Janković, 1951, 1954, 1954/55, 1957, 1958, 1959, 1960, 1961, 1966, 1967, 1968, 1979, 1985, 1986, 1988, 1989, 1994, 1997; Jovanović, 1981; Mole, 1922; Nikolić, 1961; Novaković, 1884; Radošević, 1975; Simovljević, 1974; Slavić, 1982; Tadić, 1985, 1986, 1988, 1989, 1990, 1991, 1993, 1995, 1997; Trpković, 1909; Vince *et al.* 1996). One can see that the very important role for such kind of researches had the VII National Conference of Yugoslav astronomers, held in Belgrade in 1985, on the occasion of 50th aniversary of the Astronomical Society "Rudjer Bošković", as the first topical conference on the history of astronomy. Particularly important is as well the work of Nenad Dj. Janković (1911-1997) who in a number of books and papers (Janković, 1951, 1954, 1954/55, 1957, 1985, 1989, 1994, 1997) has published the results of his research on astronomy in Serbian culture. A cornerstone is as well the paper of Vince, A., Jovanović, B., Vince, I., and Vince, O. (Vince *et al.* 1996), on Astronomical Orientations of Graves and Skeletons in Gomolava and Mokrin presented at the XI National Conference of Yugoslav Astronomers in Belgrade, in 1996, where for the first time in Serbia a team of astronomers and archaeologists made a common research on archaeoastronomy.

In order to coordinate and support the common research in archaeoastronomy and ethnoastronomy of astronomers and archaeologists as well as the other interested, a group for archaeoastronomy has been formed within the frame of the study group for interdisciplinary archaeology of the Serbian Archaeological Society and Belgrade Astronomical Observatory. The foundation of the group has been on the meeting held on Belgrade Astronomical Observatory on 12. VI 1996. Members of the group are: Milan. S. Dimitrijević, Director of the Belgrade Astronomical Observatory, president, Ištvan Vince, Scientific adviser at the Observatory and Professor of astrophysics at the Mathematical Faculty - the group for Astronomy, Živko Mikić, Professor of anthropology on the Phylosophical Faculty - the group for Archaeology, president of the Study group for interdisciplinary archaeology of the Serbian Archaeological Society, Borislav Jovanović, scientific adviser at Archaeological institute, Milorad Stojić, Archaeological institute, and Andor Vince, archaeologist. On the second meeting held on 12. XI 1996., the group joined Vesna Mijatović, archaeologist.

The aim of this lecture is to inform the astronomical community on the research and organizational work in archaeoastronomy and ethnoastronomy, in favour of the coordination of such research in our country and collaboration with Romanian colleagues.

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BELGRADE ASTRONOMICAL OBSERVATORY

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Abstract. A short review of history of the Belgrade Observatory is presented.

Belgrade Astronomical Observatory is one of the oldest scientific institutions in Serbia and the only autonomous astronomical institute in Yugoslavia. Its past development forms an important part of the history of science and culture in these regions. The decree of its founding conjointly with the Meteorological Observatory was signed on 20 March (7 April) 1887 by the Minister of Education and Church Affaires of Kingdom of Serbia Milan Kujundžić on the initiative of Milan Nedeljković (Belgrade 27. Sept. 1857 - Belgarde 27 Dec. 1950), a professor of the Grand School (Belgarde University). Nedeljković was appointed first director of the newly founded Observatory.

On 1 May 1871 Nedeljković started his activity at the provisory Observatory in the rented Geizler family's house. Here the Observatory was operating until 1 May 1891, when it was moved into its own building constructed meanwhile - the one which at present is Meteorological Observatory in the Karadjordje Park. In the minor museum section of this building there is, since the celebration of the Observatory's centenary in 1987, a room dedicated to the origins of astronomical science in Yugoslavia.

Nedeljković was at the head of the Observatory from 26 March (7 April) 1887 until 30 Jan 1924. A break took place only between 5 July 1899 and 31 Oct 1900, when he was sent into retirement for political reasons, in connection with the Ivandan attempt on King Milan, which was exploited by King Alexander for settling accounts with his political oponents. Nedeljković's place was filled during this period by Djordje Stanojević (Negotin, 7 April 1858 - Paris 24 Dec. 1921), the first Serbian astrophysicist, later on the rector of Belgrade University. Dj. Stanojević was a great popularizer of astronomy and science in general; he was the driving force in the introduction of electrical light in Belgrade, Užice, Čačak, Leskovac. He was the builder of the first hydro-electric power station in Serbia, a pioneer of industry of refrigerating appliances, the initiator of setting up a committee for cooling problems and of forming an international organization for cooling technique in Paris in 1903. He was also the pioneer of the color photogaphy in Serbia.

Apart from its importance for astronomy and meteorology, the newly built Observatory, headed by Nedeljković, was a cradle of the seismic and geomagnetic researches in Serbia. Nedeljković borrowed the instruments for geomagnetic measurements from Tege Miklosh Konkoly, the founder of the Budapest Astronomical Observatory, and took care of building an earth-magnetism pavilion. Thanks to Konkoly Nedeljković acquired in 1903 also a seismograph, installed next year in a special pavilion. The observations were carried out regularly and for these purposes the construction of what at present is the Seismological Institute was executed in 1906. This activuty was taken over by Nedeljković's assistent Jelenko Mihailović (Vrbica 11 Jan. 1869 - Belgrade 10 Oct. 1958) who worked at the Observatory since 1896.

During the Austro-Hungarian occupation in I World War the Observatory was ministred by Victor Konrad from Vienna. During their flight from Serbia the Austrians took away or destroyed all the instruments. However, thanks to his extraordinary and professional skill Nedeljković contrived to acquire in Germany after the war on account of war reparations, a number of instruments appertaining equipment for the new Observatory.

The instruments procured by Nedeljković constitute still practically the only observing basis of the Observatory, although some of them were taken away by the Germans during the II World War, two were ceded to each Ljubljana and Zagreb Universities (Djurković 1968) and some of the smaller ones being left unmounted.

Currently mounted in the appropriate pavilions are the following instruments procured by Nedeljković:

1. "Large Refractor" - ZEISS 650/10550mm. equatorial;
2. Solar spectrograph (monochromatic) LITTROW, 9000 mm/100.000 developed by adapting the ZEISS 200/3020 mm. equatorial with two astrocameras TESSAR and PETZVAL 160/800 mm.;
3. Large Meridian Circle ASKANIA 190/2578 mm.;
4. Large Transit Instrument ASKANIA 190/2578 mm;
5. Large Vertical Circle ASKANIA 190/2578 mm;
6. Astrograph ZEISS 160/800 mm.;
7. Photovisual refractor ZEISS 135/1000 mm. and 125/1000 mm.;
8. Transit Instrument BAMBERG 100/1000 mm. ;
9. Zenith-telescope ASKANIA 110/1287 mm.;

As Nedeljković was struggling for the new Observatory at which the acquired instruments were to be mounted and regular astronomical observations started, he suddenly was sent into retirement on 30 Jan. 1924. By ruling of the Faculty Council the Observatory was divided into two separate institutions: Astronomical Observatory and Meteorological Observatory of Belgrade University.

At the head of the Astronomical Observatory was appointed in 1925 Vojislav V. Mišković (Fužine 18 Jan. 1892 - Belgrade 25 Nov. 1976), at the time already a well established astronomer engaged at Nice Observatory, France. He began his astronomical studies in Budapest and Göttingen before the I World War. On his demobilsation at the end of 1918 from the Serbian Army, in which he served as a voluntieer, he was sent to France to complete his studies. He graduated in 1919 and was appointed assistent at the Marseille Observatory. Since 1922 he was engaged as an astronomer at the Nice Observatory, receiving his doctor's degree in 1924 at the Montpellier University. In 1925 he won French Academy Prize for his studies in stellar statistics. In the period 1919-1925 he published a score of papers in the French scientific journals, treating the observation of the minor planets and comets and the determination of their orbits. He came to Belgarde in 1926 taking, in addition to the Astronomical Observatory, charge of the newly established Chair of Theoretical and Practical Astronomy at the Faculty of Pfilosophy, whereas he was elected associated professor. In 1929 he was elected corresponding member of the Serbian Royal Academy and in 1939 its full member. He directed the Observatory's activity to a considerable degree toward mathematical and numerical works, wich yielded valuable results. On importance are numerical works connected with the Mathematical Climatology of M. Milanković as well as with Mišković's own Precession Tables.

In 1929 Mišković succeeded in getting funds for the constructions of a new, modern, observatory, at 6km distance southeast from the city's centre , occupying a 4.5 ha area at 253 m high Hill on Veliki Vračar, named since, along with the entire surrounding part of Belgrade, Zvezdara (=concerned with stars).

Exceptional and highly valued complex constituting the Astronomical Observatory was drawn up by Jan Dubovi, a member of GAMP (Group of Modern Outlook Architects) founded in 1928. It is thanks to this very achievement that Dubovi was conferred a doctor of science degree in Prague. The construction works were carried out in 1930 to 1932, the instruments being mounted during the following two years.

Mišković started also publishing the scientific periodical Méemoires de l'Obs. Astr. Belgrade (issued five volumes for: 1932, 1933, 1936, 1938 and 1949), Annuaire de l'Obs. Astr. Belgarde (six volumes for 1929 through 1934) containing sidereal time, short-period nutation terms, the mean and apparent places of 189 stars, newly discovered minor planets and directions for use. Nautički godišnjak (Nautical Almanc) for years 1934 through 1941) for navigation purpouses in the Navy and Godišnjak Našeg Neba (Almanac of our Sky) an astronmical calendar in Serbian, issued in the years 1930 to 1941 and 1948 to 1952 (the 1948 issue was edited by F. Dominko and the issues for 1949, 1950 and 1951 by B. Popović.

In 1935 academician Mišković assisted by P. Djurković (Srpska Trnova 1908 - Belgarde 5. Jan 1981) and F. Dominko (Vodnjan 26 July 1903 - Ljubljana 22 Feb. 1987) organized the Time and Longitude Service. In that same year Djurković determined Observatory's longitude. It was more accurately determined in 1938 under the direction of Mišković in cooperation with the Military- Geographic Institute, at that time located at Kalimegdan.

In 1936 Mišković, assisted by Milorad Protić, organized the Minor Planets and Sun Observation Service. In the same year P. Djurković discovered at the Uccle Observatory, Belgium, a minor planet, subsequently named 1605 Milanković and M. Protić, at the Belgrade Observatory, discovered the minor planet 1564 Serbia, which marked the opening of a long series of 43 minor planets discovered by the Belgarde astronomers. Protić alone, in the period 1936-1956, made 33 discoveries. Of the 43 minor planets owing their discovery to Belgarde astronomers, 12 have obtained permanent names, three of the discoveries having later been ascribed to other authors.

Besides Serbia, using his author's right, Protić gave the following names to tthe minor planets he discovered: 1507 Beograd, 1550 Tito, 1554 Yugoslavia, 1675 Simonida, 1724 Vladimir (after his grandson), 2244 Tesla and 2348 Mišković. P. Djurković discovered in the period 1936-1941, 5 minor planets, one of them - Zvezdara- named by him using his discover's prerogative. In 1980 Z. Knežević discovered on the photoplates taken according to his instructions at Piszkestetö Observatory, Hungary, four minor planets, one of which having obtained the name 3276 Paolicchi, after one of his colleagues in Italy. In 1991, as a mark of honour, a minor planet was given the name 3900 Knež ević - after our fellow. Another minor planet connected with the Belgrade Observatory is that named 1555 Dejan, after P. Djurković son. This activity, in time extended to include the comet observations, is currently conducted by Vojislava Protić-Benišek.

The founding in 1936 of the Minor Planet and Sun Observation Service denotes the completion of organization of the observing activity of the new Observatory. In that year Mišković started issuing Bulletin de l'Observatoire astronomique de Belgrade, a scientific periodical which from No. 145 for 1992 on appears under the name Bulletin astronomique de Belgrade. This periodical's editors have been: V. V. Mišković (1936-1940, 1943 – 1948 and 1952-1956), M. Protić (1941-1942, 1955-1960 and 1971-1975), B. Popović (1950), V. Oskanjan (1964), P. Djurković (1964-1970), M. Mijatov (Nos. 127-131 in 1976-1981), D. Zulević (Nos. 132-133, in 1982-1983), Dj. Teleki (Nos. 134-136 in 1984-1986) and M. S. Dimitrijević (No. 137 in 1987 successively up to date).

Since July 1941 at the Observatory were quartered German military. The Wehrmacht brought along profs. Grotrian and Kippenheur from Potsdam, the two having inscribed the Observatory's instruments as German property and dispatching to Germany the spectroheliograph and the comet searcher. On the terraces of the Obser-varoty's edifice and on the water storage building pill-boxes were erected for directing the flak, while the library was turned into officers mess. In the course of the liberation fightings in 1944 particulary heavy damages were inflicted on the main edifice, the water storage building and on "Large Refractor" pavilion. The Observatory's reconstruction was undertaken immediately after the war. Mišković remained its director until March 1946 when he submitted his resignation, accepted not before May 1948.

In 1945 P. Djurković started and edited the professional periodical Astonomska i Meteorološka Saopštenja (Astronomical and Meteorological Reports), published by the Observatory up to 1950 (seven issues in all). In 1947 Observatory started the series Publikacije Astronomske Opservatorije u Beogradu (Publications of Astronomical Observatory). Its editors in chief were: V. Oskanjan (No. 10), P. Djurković (Nos. 12-16), M. Protić (Nos. 17-19, 20-21) Dj. Teleki (Nos. 20, 26, 32, 34 and 35), M. Mijatov (Nos. 24, 25, 27-31), G. Popović (No. 33) and M. S. Dimitrijević (Nos. 36-59).

During 1947 P. Djurković, B.Ševarlić and Zaharije Brkić (Poljna 8 Nov. 1910 - Belgarde 24 April 1979) organized the Latitude Service wich, led by Ševarlić and Dj. Teleki (Senta 20 Aug. 1928 - Belgarde 23 Feb. 1987), was included into International Latitude Service on 7 October 1956. The Service was headed, after Ševarlić, who was active until 1963, by Dj. Teleki till 1968, Vladeta Milovanović till 1972 and from then on until his retirement by Radomir Grujić.

Up to 1 July the Observatory was, as it was before the war under the Belgarde University. From that date on, up to 18 Dec. 1950. it is under the iurisdiction of the Serbian Academy of Siences and after, under the Committee for Scientific Institutions, University and Scools for Higher Education of SR Serbia. This status was kept until 27 March 1954, when the Observatory became institution with independent financing at the Executive Council of SR Serbia. On 9 Aug. 1985 the Observatory obtained the status of autonomous scientific research institute with the Executive Council of the Assembly of SR Serbia as its founder, its name changed into Astronomical Observatory - Institute for Astronomical Researches. At the time it was financed by the Republic Community of Sciences of SR Serbia. After Community's dissolution it is being financed by the Republic Fund for Sience of Serbia through the scientific project " Physics and Motion of Celestical Bodies and Artificial Eatrh's Satellites" (1985-1990). Leading the Project were: Dj. Teleki (1985-1987), A. Kubičela (1987-1989) and M. Dimitrijević (1990). In the period 1991-1995 the Project is named " Physics and Motion of Celestical Bodies" and was led by M. Dimitrijević (1991-1993) and Z. Knežević (1993-1995). The Time and Latitude Services are financed directly from the budget of SR Serbia. On 12 May 1992 the Observatory became a scientific institute financed through the mentoined scientific project at the Republic Ministry for Science and Technology, its founder being the Government of Republic Serbia. On 20 Dec. 1994 the Obsevatory was re-registrated as a scientific institute, resuming its old name. For the period 1996-2000 project is named "Astronomical, Astrodynamical and Astrophysical Researches", being led by Z. Knežević.

When in May 1948 V. Mišković's resignation was accepted, to the post of Observatory's director was appointed academician Milutin Milanković (Dalj 28 May 1879 - Belgarde 12 Dec. 1958) who went down in history of science by his having explained the ice ages phenomenon through the slow changes in the Earth's insolation in consequence of the Earth's axsis inclination and its motion around Sun, undergoing changes produced by various influences. Milanković elucidated also the history of the climate of Earth and other planets, being the originator of the mathematical theory of the Earth's poles motion. The Observatory's direction was entrusted to the Observatory's Council, at the head of the which was the director and Council's president M. Milanković, with members Anton Bilimović, V. Mišković and Pavle Savić (Popović 1951). Milanković held this post till 26 June 1951.

During 1949 was completed the astro-geodetic pavilion, begun before the war. Mounted in it were the small transit instrument 10/100 cm., the zenith- telescope (11/110 cm., a small prism astrolabe and universal instrument (7/70 cm.). The pavilion housing up to then the small transit instrument was since named " Training Pavilion" as it was put at the disposal of students.

In 1951 P. Djurković organized the Double Star Service. Within this Service, subsequently named Group, were discovered over 200 new double and multiple stars, the bulk of the which is due to Georgije Popović, working in this Group since 1960, being at its head since 1976. Acting in this Group have been also Lj. Dačić and Vera Erceg (since 1967). Engaged in the works on these problems were also Danilo Zulević (since 1961), Dragomir Olević (at the Observatory since 1964, first in Group for Minor Planets, Comets and Satellites, then for a while in the Double Star Group), Rade Pavlović (since 1994) and Vesna Živkov (since 1996).

In this same year the Variable Stars Service was organized by Vasilije Oskanjan. In this he was joined by Aleksandar Kubičela and Jelisaveta Arsenijević (at the Obsevatory since 1956) whereby an impetuous development of the astrophysical researches took place later directed toward stellar and solar physics and astronomical spectroscopy. Initially it was the photometry of eruptive stars which was pursued. Since

1959, after Oskanjan's return from his specialization in the Soviet Union, it was the work in the field of polarimetry of eruptive stars that was taken up. Formally, the Astrophysical Group was founded in 1960. In 1969 and 1970 working in the Group was Trajče Angelov. In 1972 the Group was joined by Ištvan Vince, in 1980 by Gojko Djurašević, in 1983 by Slobodan Jankov, in 1984 by Milan Dimitrijević, in 1985 - 1996 by Vladimir Kršljanin, in 1989-1996 by Olga Atanacković-Vukmanović (at the Observatory since 1982 first in the Absolute Declinations Group), in 1992 by Luka Popović, in 1994 by Darko Jevremović in 1995 by Silvana Nikolić while Sanja Erkapić entered on standing employment in 1996, having up to then been on postgraduate studies, occasionally working on a part-time basis. Worth mentioning is the Group's successful expedition to Hvar to observe the total solar eclipse on 15 Feb. 1961. The Group was left in 1966 by V. Oskanjan. In 1972-73 A. Kubičela, to whose inventiveness one to thank for all the modern astrophysical measuring instuments the Observatory is in possession of, constucted a solar spectrograph using the "Small Refractor" ZEISS equatorial as supporting instrument wherewith he started the researches in the large scale photometric motions on the Sun, A. Kubičela, J. Arsenijević and I. Vince organized in 1980 an expedition to India for monitoring the total solar eclipse whereby three research programmes have been carried out. J. Arsenijević started in 1969 studying the radiation polarization in cool supergiants. In 1973 the researches in long period variations of polarizations in stars with emission lines (Be stars), aimed at studying the physical characteristics of atmospheres and envelopes of such objects. In 1984 the work on the astrophysical plasma spectroscopy was undertaken, with particular emphasis of the effect of the collision processes on the line shapes in the solar and stellar spectra. In 1987 the programme of tracking the sellected solar spectral lines during one solar cycle was taken up. in 1985 G. Djurašević began the work on modelling of active tight double stars and S. Jankov on methods of reconstructing the surface brightness of stellar disks based on the spectroscopic and photometric observations.

From 26 June 1951 to March 1954 the Observatory's director is again V. Mišković. After he went into retirement the Observatory was headed by M. Protić in the capacity of deputy director and from 21 Nov. 1956 to 21 Nov. 1960 as a director.

In 1953 the Time Service, heded by Zaharije Brkić, was included in the International Time Service. The scientific researches started in this period, culminated in doctoral dissertations of Z. Brkić (26 Nov 1958) and Lj. Mitić (20 June 1959), these being the first post-war doctorates in astronomy. The Time Service collaborated since 1962 with the International Polar Motion Service and since 1971 with the Soviet time Service. In 1963, in accordance with the agreement with the Military-Geographic Institute, the Observatory obtained a battery of quratz clocks with the accompanig equipment which made for the performance of the Time Service attaining a higher level, which resulted in the Observatory being ranked among the ten foremost in this domain in Europe. By virtue of agreement with the Federal Institute for Measures and Precious Metals from 1991, after preparatory construction works had been completed, cesium atomic and quartz clocks, belonging to the Institute were installed in an insulated compartment 10 m. below the ground, in the third cellar of the main Observatory's edifice, until 1997. Relying on them the Observatory maintained for a period the

Yugoslav time standard.

In 1956 the Minor Planets Identification Service was organized by Ružica Mitrinović. In 1957-1959 the Observatory participated successfully in the activities involved by the International Geophysical Year, such as Sun observations and researches in the Earth's rotation and geographic coordinates variation.

In the period 1957-1959 pavilions were builit in which, after 34 years, were mounted three large fundamental instruments, whereby the Observatory become one of the best equiped for researche in the field of fundamental astrometry. In addition, a number of auxilliary objects were constructed, a residental building and a road, all of which necessitated the Observatory's area to be enlarged to the present day 10 ha. The total investments involved by these works amount to a third of those 1929/30. This enabled three new scientific Groups to be established: Group for Relative Coordinates (Large Meridian Circle-headed by Lj. Dačić), Group for Absolute Right Ascensions (Large Transit Instrument - headed by Lj. Mitić) and the Group for Absolute Declinations (Large Vertical Circle - headed by Dj. Teleki). The scientific work in the field of astrometry, led by Lj. Mitić, Dj. Teleki, B. Ševarlić and S. Sadžakov, attained since the world standards. In the course of the last 30 years seven observational catalogues of star positions were produced with the Large Meridian Circle under guidance of Sofija Sadžakov, all of them as parts of the international observing programmes. For this achievment S. Sadžakov and M. Dačić were awarded Belgarde October Prize. S. Sadžakov, who joined the Observatory 1962, is the head of the Group for Relative Coordinates since 1972. The Group was joined in 1962 by I. Pakvor, who subsequently was transferred to the Group for Absolute Right Ascensions. In 1970 came Miodrag Dačić and in 1984 Zorica Stančić, married Cvetković. In 1989, mannaged by S. Sadžakov and Astronomical Observatory, started coordinated multidisciplinary researches in the Belgarde mean coordinates variation. These researches are being pursed at the Observatory itself and at a number of institutes engaged in the field of geomagnetism and seismology.

The Group for Absolute Declinations was headed by Dj. Teleki since its foudation in 1960 until his death in 1987, save for 1984 when that post was held by S. Sadžakov. Collaborating in this Group have been also M. Mijatov, B. Kubičela. Djuro Božičković Vladeta Milovanović, Veselka Trajkovska and Olga Atanacković-Vukmanović.

In 1970, according to a project conceived by Ljubiša A. Mitić, with I. Pakvor lending assistance in the execution, the Large Transit Instrument was provided with a system of vacuum meridian marks, unique in the world, enabling the accuracy of the measurements to reach their theoretical limit. With this instrument the first catalogue at this Observatory of absolute right ascensions was worked out, containing 308 stars. A catalogue of absolute declinations of these 308 stars elaborated the Large Vertical Circle.

After M. Protić at the head of the Observatory was Vasilije Oskanjan, first as acting director since 1960, then in 1964-1965 as the director. Following him, from July 1965 to 1970, the director was Pero Djurković. After him in the period 1971-1975 at the head of Observatory is again M. Protić. Since 1975, first as acting director and from 13 July 1977 to Sept 1981 as the director was M. Mijatov (Belgarde 3 July 1933 - Belgarde 19 Nov 1996). The director's post from 1982 to 1989 was held by

Miodrag Mitrović, in 1990-1993 by Ištvan Vince and from 21 Nov 1994 on by Milan Dimitrijević.

In 1986 on the part of the Assembly of SR Serbia and REC the project was adopted and funds allocated for the building of an astrophysical observing station at Rgaj mountain near Prokuplje. Due to the investments in the Republic having meanwhile been suspended, the project has not been realized yet.

In 1987, in the presence of a number of statesman and eminent guests from the country and abroad, the centenary of the Observatory's founding was solemny celebrated in the hall of the Assembly of Serbia. On the occasion of this jubilee three international and one Yugoslav scientific conferences were held: IAU Colloquium 100 "Fundamental Astrometry" (8-11 Nov. - Chairman SOC H. Eichorn, Gainsville, USA), International Symposium on Astronomical Refraction in memory of Dj. Teleki, former President of IAU Working Group on Astronomical Refraction (3-4 Nov., Chairman SOC V. Milovanović), Second International Symposium on Catastrophic Collisions of the Small Sollar System Bodies (8-11 Nov., Chariman SOC Zappala, Italy) and Second Workshop "Astrophysics in Yugoslavia" (8-10 Nov Chairman SOC M. Dimitrijević). During these festivities a minor museum was opened in the old Observatory's building in Karadjordje Park, one of its rooms being dedicated to the development of the Astronomical Observatory.

In 1994 there took place a reorganization of the Observatory's inner structure, resulting in the establishment of : Department of Astrophysics, Department of Dynamical Astronomy and Department of Astrometry.

In 1995 the Observatory participated in the organization of the International Russian-Yugoslav Conference "Newcomb and Fundamental Astrometry" in St. Petersburg, of the First Hungarian-Yugoslav Conference in Baja and the First Romanian-Yugoslav Round Table on collaboration in astronomy in Temishoara; it organized the First Yugoslav Conference on Spectral Line Shapes in Krivaja.

In 1996 the Observatory organized the Second Yugoslav-Romanian Round Table on collaboration in astromony in Belgarde and the Astophysics Section at the 18th Summer School and International Symposium on the Physics and Ionized Gases in Kotor. The Observatory participated in the organization of the First Belaruss-Yugoslav Conference on Physics and Dynamics of Laboratory and Astrophysical Plasma in Minsk. The Observatory's fellows presented their results at 13 international and 6 national conferences. They published 129 bibliogarphic items of which 16 in the international leading journals. It published 4 volumes of Publ. Astron. Obs. Belgrade and 2 Nos. of it periodical Bull. Aston. Belgarde.

In 1997 the Observatory organized in the framework of celebration of of its 110th anniversary the scientific conference "Development of Astronomy among Serbs". It took part also in the organizaton of the Third Romanian-Yugoslav Round Table on Cooperation in Astronomy in Kluj-Napoca, as well as in the Second Yugoslav Conference on Spectrl Line Shapes in Bela Crkva. It fellows presented their results at 13 international and 4 national conferences. They published 152 bibliographic items, 11 of which in international journals of the highest standing. It issued four publications of the series Publ. Astron. Obs. Belgrade and two Nos. of its periodical Bull. Astron. Belgarde.

From 1997 on Bulletin Astronomique de Belgrade is available on www through the Astronomical Data System (ADS) thanks to courtesy of the System's holders. The www adress is:

`http://adswww.harvard.edu/BOBeo`

Currently there are 41 employees at the Observatory 32 of them are astronomers.

In the course of its history the Belgrade Astronomical Observatory grew to an institution of great importance in the history of science and culture of the Serbian people, not only in the field of astronomy but also in meteorology, seismology and geomagnetics. Linked to this institution are the names of the famous personalities in the history of science who contributed to the Observatory, and the scientific achievmetns of Serbian astronomers in general, having earned esteem in the international scientific community as well as to the young having a good perspective, in our country too, in engaging in this beautiful and challenging science in an ambience enabling them to achieve results of the highest value.

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THE DEVELOPMENT OF THE BELGRADE ASTRONOMICAL OBSERVATORY BETWEEN 1887 AND 1941

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In the late seventies and early eighties of the XIX century with the territorial enlargement of the Principality of Serbia, which was followed by a change in her state status, at first as an independent principality and then as a kingdom (1882), arose material conditions allowing the foundation of institutions corresponding to economic and cultural necessities of a relatively ascending state community. An astronomical observatory is among such institutions. The reasons for its foundation were strengthened by forming the Cathedra of Astronomy and Meteorology at the Philosophical Faculty of the Belgrade Grand School in 1880 where after his return from a specialisation in these subjects in France came Milan Nedeljković in 1884. In late that year he took part in in the framework of a commission formed for the purpose of founding a network of meteorological stations throughout Serbia. From this unrealised project arose Nedeljković's initiative in founding in Belgrade a provisory observatory where astronomical, meteorological, geophysico- seismological and geomagnetic observations would have been performed and which would have been a centre of the network of meteorological stations. Such an observatory was founded by the Education Ministry in early 1887 and Nedeljković became its director. This post belonged to him till 1924, except during 1899 and 1900 when the director was Djordje Stanojević. The newly formed observatory was under the Grand School, i. e. under the University from 1905. It was situated within a private house in Belgrade where started the first meteorological observations in the middle of 1887. In 1891 the Observatory was moved into another building foreseen for it and which occupied an area of 1.8 *ha*. Today at that place is the Hydrometeorological Centre of Serbia. According to the data published in "Srpski tehnički list" No 1 for 1890, page 28 the preliminary price of this building was estimated to the sum of 30 222.39 expressed in the Serbian that-time currency.

Ten years after the foundation of the Observatory in the consideration of its activity it was emphasized that during this period of ten years it had missed both the personnel and money for performing the current activities (Mihailović, 1897). As for the network of meteorological stations, which was in a fast expansion beginning with 1894 working coordinated by the Observatory, it should be said that the time spent by an average observer at a meteorological station was between one and four years (Nedeljković, 1898; Djokć, 1996).

Between 1900 and 1904 the observations performed at numerous meteorological stations including the observatory, as well, were published in the observatory's publication named at first "Bulletin météorologique de l'Observatoire astronomique et météorologique de Belgrade-Serbie" and then renamed as "Bulletin mensuel de l'Observatoire Central de Belgrade". After this period the publishing of the results was interrupted, but the observations at the Observatory and meteorological stations were continued till the beginning of the First World War. Under the direction of the occupants during the war the Observatory was active from early 1916 by the autumn of 1918 and the results of the meteorological observations performed at it and at the meteorological stations served to V. Conrad, a Vienna meteorologist, for the purpose of studying the climatology of Serbia.

Though the Observatory was an institution of the Belgrade Grand School and afterwards of the Belgrade University, Nedeljković endeavoured to regulate its status as an independent institution through two law proposals from 1890 and 1904, but they never passed the parliament procedure. Compared to the meteorological observations the astronomical ones were insignificant. The Observatory had at its disposal some small astronomical instruments (three universal ones, altazimuth, a 45 *mm* transit instrument, a 5' Bardou refractor) and the latitude and longitude were determined with the altazimuth in 1897 and 1898 (Nedeljković, 1904). However, since the majority of these instruments was ruined during the First World War, after it Nedeljković, in Germany, between 1922 and 1924, began with procuring of a large collection of instruments, especially astronomical, using the funds due to the war reparations at the time when the new state - the Kingdom of Serbs, Croats and Slovenes, later on renamed as the Kingdom of Yugoslavia, - was formed. The total sum spent for the furnished instruments (astronomical, meteorological and geophysical) and equipment (books, machines, tools, furniture and mounting objects) exceeded 3.5 millions golden marks out of which 62.5% was foreseen for the purchase of astronomical instruments (Djokić, 1993) corresponding to 30 million that-time dinars (Mišković, 1929).

In early 1924 Nedeljković was retired and in the middle of the same year the Observatory was divided into two observatories - Astronomical and Meteorological - a decision in accordance with the newly arisen material conditions (Djokić, 1988). In view of Nedeljković's retirement in the following year of 1925 the Faculty of Philosophy of Belgrade University undertook steps towards appointing Dr Vojislav V. Mišković, astronomer at the Nice Observatory, practical-astronomy teacher and Observatory director. These positions were taken by Mišković in the autumn 1926 and his first endeavour was to found a Time Service at the Astronomical Observatory (Protić-Benišek and Djokić, 1989). Since one had to mount and activate a large number of astronomical instruments (650.350 *mm* and 200 *mm* refractors, three large 190 *mm* meridian instruments, 200 *mm* comet finder, 160 *mm* astrograph and a number of other smaller instruments) in conditions of permanently diminishing space at the existing location due to the broadenning of the city, during 1927 Mišković initiated an action of building a new observatory on the Fruška Gora at an altitude of 490 *m*. On the other hand at the old location were built one pavilion for the 200 *mm* refractor and two wooden ones for the 100 *mm* transit instrument and 70 *mm* astrolabe (with the latter one the geographic latitude of the Observatory was determined - Mišković,

1928) because this project was not realised during 1928. In a further phase of realising the building plan for a new observatory, in the middle of 1929, an area of 4 *ha* at the Eastern Vračar called Laudanov šanac (Laudan's trench) at an altitude of 252.75*m* was given by the Municipal Government to the University for the purpose of this building. The building, itself, was carried out according to the plans of Architect Jan Dubovi who made them following basic drafts and in cooperation with Mišković. It costed 4 057 449 dinars. The total credit was taken from "Državna hipotekarna banka" (State Mortgage Bank) in 1930 and its value was 9 557 000 dinars. In the mid 1932 the new observatory building was moved in. The observational activities were conditioned by the number and kind of mounted instruments (two refractors -650 *mm* and 200 *mm* - , 200 *mm* comet finder, 160 *mm* astrograph, 100 *mm* and 80 *mm* transit instruments). The results of the observations (sunspots, minor planets and comets, variable stars, meridian transits for the purpose of clock-correction C_p determining and meteorological elements) were published in "Bulletin de l'Observatoire Astronomique de Belgrade" which started in 1936. In addition to this publication the Observatory published also the following ones: "Annuaire" (1928), "Godišnjak našeg neba" (1929), "Mémoires" (1932), "Nautički godišnjak" (1933), "Publications" (1935) (within the parentheses are given the starting years).

The activity of the Observatory as a university institution was regulated by statutes published in 1936 and 1940. Between 1934 and 1941 the Observatory growth according to the available data was ascending by 1939 when it attained its maximum in the total number of employees (n), budget amount (B) and the number of published papers (N). In that time interval these elements were highly correlated. The correlation coefficient between the budget amount and the total number of employees is 0.99, between the total number of employees and the number of published papers it is 0.96, whereas between the budget amount and the number of published papers it is 0.94.

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PHILOSOPHIC ANTICIPATIONS AND SCIENTIFIC CONCEPTIONS OF THE RUSSIAN COSMISTS

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Abstract. Ever since the times of Leonardo da Vinci, Sirano de Bergerac, Jules Verne, the interest in the cosmic expanses has continuously grown; first dreams, then anticipations, thereupon philosophical and scientific conceptions, have been developing especially in the second half of the 19^{th} and during the 20^{th} centuries. These achievements constituted the foundation of the great transformations of the conditions of human life worldwide, but they aroused reflexions on big planetary hazards. Ehile the achievements of the West are more or less known, those of the Russian cosmists, due to the concurrence of circumstances, have only lately become the object of wider debates, for the part of the important documentation was, for various reasons was inaccessible to researchers or was only partially known.

The syntagm "Russian cosmists" stands for the numerous thinkers of very different expressions: philosophers, scientists, theologians-modernists. The Russian cosmism is a specific spiritual, philosophic-scientific orientation, displaying encyclopedic and independent synthetic expression of the Russian genius, having its beginnings somethime in the middle of the last century. Belonging to the circle of these thinkers have been numerous creatorors, among whom the most important are doubtless: N. F. Fedorov (1828-1903), philosopher, theologien, admired in a manner by Dostoevski, Tolstoi and Vladimir Salavev; K. E. Ciolkovski (1857-1935); V. I. Vernadski (1863-1945), a world-renwned scientists, the founder of biochemistry – a theory of the biosphere and the ionosphere; A. L. Gizevsli (1897-1964), scientist, philosopher, artist, particularly occupied with heliobiology. The cosmist ideas were another form of the maximalism, personified by therevolutionary Kibalcic, a participant in the attempt on the emperor Alexandar II, engaged simultaneously in drawing up plans for rockets, found as late as 1918 in the secret police files. The fate of the cosmists is, in general, personified by the men who brought into effect some of the projects as cosmists as was S. P. Korolev. In this connection many philosophical questions are currently raised as to the survival of mankind.

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ASTRONOMY TEACHING DEVELOPMENT AMONG SERBS, II

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ABSTRACT.Continuation of the paper in Publ.Astron.Obs.Belgrade No.56(1997),179. As a representative of the part of the northern regions, under administration of Pecuj, Novi Sad has been chosen, where almost all kinds of schools, existing in that times, have been located. A short review on elementary and secondary shools curricula, teachers, professors and textbooks.

ELEMENTARY AND SECONDARY SCHOOLS, IN GENERAL, IN NOVI SAD

ELEMENTARY SCHOOLS. - In the year 1703 the Serbian orthodox parish opened its Serbian Confessional Public Elementary School in Novi Sad. At that times the Government did not take care about teaching in schools - that was a private affair of the church. It has been thought that the school is an "adnexum" to the church. The priests were the teachers, and the main subject was the religious instruction. The textbooks were also of the religious character.

All elementary schools were divided into three kinds: country,so-called"*trivial*" schools, which had only one, eventually two classes, small-town schools with two separated classes, and town, "*main*" schools which had three separated classes. Only in the third kind there have been taught some basic notions in sciences and geography (if the pupil had an intention to continue its education in a secondary school). In the year 1856 the IV, and in 1868 the V and VI classes have been added..In the residency of the school department there was an elementary school, named "*normal*" - that one had normative character - all other should be ruled according to this one [Ognjanovic(1964)].

There were no much data left about teaching plans and programms because in the revolutionary years 1848/9 more than 2/3 parts of Novi Sad have been destroyed and burnt. So, we may use only the poor informations which have been left.

We will focus our atention only to astronomical curriculum. In the third class,in geography, it has been taught:"...The shape of the Earth and its rotation as well as its revolution around the Sun. Four seasons..." In the fourth "...The firmament,horizon,Sun,planets,the Earth and its shape, its rotation and revolution,Moon, and its phases, eclipses of the Sun and Moon, the main concepts about stars and the Universe..." ["Skolski list",1869,327].

In "Elementary Reading Book", for the first class, by Dr.Djordje P.Natosevic,Novi Sad, 1875, last two pages are dedicated to the firmament,Sun,Moon and stars. In the "Reading Book" for the second class, by the same author, five pages describe first notions about: firmament,Sun,Moon,stars, time,days and hours, Weeks, months and years, as well as popular riddles concerning same notions. The "Reading book" for the third class, by the same author, has nine pages on The path of the Sun, The shadow and the sunray, How does the Moon shine. The stars (with popular names of the stars and constellations).The fourth class' "Reading Book",written again by the same author, has seven pages on Earth' rotation, Eclipses, Stars.

SECONDARY SCHOOLS. - According to preserved manuscripts there existed between the years 1731 and 1789 the Orthodox Latin School in Petrovaradinski Sanac (Novi Sad got his name in the year 1748), with six classes. The main goal was to teach the pupils Latin.

The book No.Gr.47 PHILOSOPHICAL MANUSCRIPTS,preserved in orthodox monastery Grabovac, now in the Orthodox library in Sentandreja, belonged to ieromonk Arsenije Teofanovic. who noted them on lessons he attended during his education. This manuscript has six parts written in Latin.We will pay our attention only to that parts which are interesting from astronomical standpoint. The title of the first is PROLEGOMENA TO GENERAL PHILOSOPHY. It is divided into parts, chapters, sections and paragraphs. The first part is purely philosophical. The second Prolegomena to Cosmology has chapters : I.. Notion of the World; II.Part Of the Universe,Section I - *Simple Parts of the Universe*, Section II - *Genesis of the Primordial Cosmos*, Section III - *Physical Nature of theBodies*.

The third manuscript , in the same book,is The Science of Nature or Introduction to Physics with the subtitle On the Physical Nature. It is divided into tractates and they into chapters. The Tractate 7. considers The Motion, Tractate 8. has the title On Firmamentaly World And On Elements. Chapter 1. is named "On the Origins of the World", Chapter 3. speaks "On the Nature Of the Firmament",Chapter 4. has the title "On the Light of the Stars",Chapter 5. tells us "On the Motion Of the Bodies",in Chapter 6. one discusses "On Influences Of the Heavenly Landlords".

Notes in these manuscripts are very interesting. On the page 3o2a there is written:"1744, P.Varadini,A.Theophanovich",and on the page 399a:"Aprilis 16,1745.P.Varadini,ieromon. Arseniu Theophanovich" which tell us about place and time when Arsenije Teofanovic attended to classes.

In the manuscript No.Gr.49. A SHORT COURSE IN LOGIC - GENERAL DIALECTIC there is again and interesting note,on the page 2o2b,which informs us that A.Teofanovic on the 8th May 1745 completed his course in philosophy which was held by Dionisije Novakovic in Petrovaradinski Sanac. These three notes are enough to testify that in Petrovaradinski Sanac (Novi Sad) astronomy has been taught among other subjects.

Let us mention that there is one more manuscript under No.Gr.15.PROGNOSTIKON, written about 1768,where there are in Introduction, descriptions and characteristics of Moon,Mercury, Jupiter,Saturn, Sun and Venus [Jovanovic (1989),5].

In the years 1755/6 and 1756/7 one have used the Introductio in Orbis Hodierni Geographicam by Joannes Tomka-Saski [V.Stajic(1949),57].The lessons in geography were held on Tuesdays the whole forenoon (probably from 7 a.m. to 10 a.m.).According to Ratio Educationis from the year 1777, in the first and second class general notions from the mathematical geography should have been taught [V.Stajic(1949),171].

Let us notice that on the list of instruments which were given,on the 14th March 1788,to the director Andrej Gemza,there was an astrolabium with compass on a leg [V.Stajic(1949) 171]. Astrolabium is an ancient instrument used to measure the altitude of a celestial body. One simple form consisted of a graduated disc that could be suspended by a ring to hang in a vertical plane. Later replaced by sextant. Who used it and what for?

During the time there were several secondary schools, in Novi Sad, as well as schools of other confessions, attended by Serbs, concluding with Higher Girl's School (Girl's College). In all of them there were taught some parts of astronomical subjects, in geography and in physics,but we will let them out of consideration in this short reviewing. There is one exception which must be mentioned : The Serbian Teacher-Training School which has been established on the 1st May 1778 in Sombor. The last generation has been educated in the year 1811. Then, a year later The King's Paedagogium Of the Ilirian People (the Serbs have been named, sometimes, Ilirians),has been founded in Sentandreja,but in the year 1816 it has been transferred to Sombor again,and is existing there until to-day. One of the professors was Vasilije Bulic (1785-1826) who wrote a textbook on Mathematical Geography in the year 1824. We will list only the titles of chapters of it, so that one may see what has been,probably,taught in that school.Part A. The Earth As A Body In Universe And In Relation To Other Celestial Bodies. I.Planets of the Solar System (Mercury,Venus,Earth,Moon,Mars,Vesta,Juno,Ceres,Pallas,Jupiter,Saturn,Uranus). II. Comets or Tailed Stars. III.Fixed Stars. IV.Apparent Sight of the Firmament,False Representation of Celestial Bodies' Size.V. Twinkling And the Apparent Magnitude of Fixed Stars. VI. Zodiacal Light. Part B. The Earth Itself ... contains,among other purely geographical texts, refraction and dawns.

To complete the picture of this school we will cite parts of the Teaching Program,for the years 1865/6 and 1866/7,for geography. First class: 1.Celestial Bodies In General - Sun, Planets.Fixed Stars. 2. Earth. Proofs that the Earth is Round. Horizon. Equator,Meridian And Other Circles And Points On the Terrestrial Sphere And Their Meanings. 3. Rotation Of the Earth Around Its Axes,And Around the Sun. Days And Nights. Year. 4. Moon And Its Phenomena. Eclipses Of the Sun And Moon. 6. to 17. have no astronomical interest ["Skolski list" (1867),24o].

GRAND GYMNASIUM OF THE SERBIAN ORTHODOX PARISH IN NOVI SAD

As we mentioned, after the year 1789,when the Orthodox Latin School has been closed, there were several secondary schools in Novi Sad. In the years 1794 to 1796 one has tried to reestablish the serbian gymnasium, but the authorities did not wish to give the opportunity to minorities to educate their youth in their national spirit.

On the 8th February 181o Sava Vukovic undersigned his legacy of 2o.ooo forints for founding a serbiam gymnasium in Novi Sad. Other Serbs gave their contributions too so that on the 11th December 1811, by the ruler's resolution,the foundation has been granted. The teaching plan and the program should have been adapted to the sames in Serbian Orthodox Great Gymnasium in Sremski Karlovci.

EDUCATION. - The gymnasium, after many complications, started its life on the end of the first semester 1815. Step by step,year by year, this school have got six classes: four grammar and two humanity classes.

Curriculum has been accomodated to the Ratio Educationis, from the year 18o6. In the fourth class Ignjat Jovanovic (~1791-1868) taught in geography notions from mathematical geography. In the fifth class (humanitatis classis prima) Georgije Magarasevic (?-183o) teaches mathematical relations concerning the globe [V.Stajic(1949),197-198].

There is a Ratio Studiorum in Reg.Priv.G.n.u.R.Gymnasio Neoplantensi,from 11th April 1824,in Latin,where it has been written that in classis humanitatis secunda (sixth class) in physics one should teach :"...celestial bodies,solar system,on the example of Earth all mathematical-physical relations..." That was the programm according to which it has been taught from the beginning until that day [V.Stajic(1949),199].

Djordje Djordjevic (179o-1868),professor on same Gymnasium,wrote on the 8th November 1824 to Jakov Gercic, also a professor,asking from him the textbook on

geography written by Eisenmann [V.Stajic(1949),226].
The minutes from the professors' collegium session, held on the 27th October 1825 contains teaching directions.So, we may read that in the fourth class (of grammar) one should treat more widely the mathematical geography than it was the case in the second class (of grammar).The recommended textbook was Stern's Geographie, the 1822 edition (Details on textbooks and handbooks will be given in the separate section TEXTBOOKS).The professor was again Ignjat Jovanovic [V.Stajic(1949),2o5].In the second class of humanity (sixth class) Dr. Petar Jovanovic (18oo-1855) teaches in the year 1841/2, in the second semester, physics, especially astronomical physics [V.Pusibrk (1896),76].
On the 12th June 1849 the school discontinued its activity because of the bombardment of Novi Sad during the revolution 1848/9 [V.Stajic (1949),228]. Due to this destruction and fire we have so few informations about life and teaching in this Gymnasium in the preceding period.
After a pause,on the 13/25 October 1852,with a festive celebration the so-called "Small Gymnasium",with four classes has been opened. On the 8th July 1865 by means of the tzar's order the Gymnasium becomes a complete, with eight classes. In the school year 1865/6 there were opened the fifth and the sixth classes, in the next school year the seventh, and in 1867/8 as well as the eighth class.
More details on teaching plans and curriculum one may find in Programms (Annual Reports) which have been issued each year starting by the year 1867/8. In this academic year in geography, in the first class, professor Aleksandar Gavrilovic (1833-1871),with 3 hours a week,taught:"...Basic concepts in mathematical geography,and exact knowledge of the outer picture of the Earth...",using Bellinger's textbook. In the fourth class,with 3 hours a week, professor Vasa Pusibrk (1838-1917) in sciences taught:"... main parts of astronomy ..." according to the textbook by Kunzek. In the eighth class, again V.Pusibrk,with 3 hours a week, taught in sciences:"...Basic concepts in astronomy..."using Kunzek's textbook. In the school year 1868/9,in the first class, Milan Dimitrijevic taught the same curriculum in geography as in the previous year. The same case was in the fourth class,but under direction of Vasa Djurdjevic,and in the eighth there was only an hour weekly more,that is four hours a week.During the year 1869/7o Milan Dimitrijevic taught geography in the first class,without change.The same professor was in the fourth class,but in the eighth the textbook by Subic has been used now.
The school year 1870/1 brought changes. In the first taught Svetozar Savkovic as before, but in the fourth and in the eighth class astronomy dissapeared. One must say that the authorities,without any obvious reasons changed the curricula sending decisions,neglecting at the same time,the rights of autonomy given by the ruler's resolution.Dr. Milan Djordjevic taught in the year 1871/2 geography in the first class similarly as in the previous year. In 1872/3 and in 1873/4 Stevan Nedeljkovic taught geography in the first class in the same way as his colleagues did before.There were no changes in 1874/5. The same in 1875/6.
In 1876/7 Milan A.Jovanovic taught in the first class,with 3 hours a week, according to the textbook by Ribari:"...Basic concepts of mathematical and physical geography..." During 1877/8 Svetozar Savkovic taught again in the first class without change,but Andrija M.Matic started to teach sciences in eighth class, with 5 hours a week:"...meteorology and elements of mathematical geography..." using Subic's textbook.In 1878/9 Stevan

Milovanov taught geography in the first class,and A.M.Matic in the eighth without changes. 1879/8o brought some news. Mathematical and physical geography has been transferred to the third class,with 3 hours a week. Svetozar Savkovic taught using Ribari's textbook.With 4 hours a week S.Milovanov, in the eighth class, taught in sciences: "...Elements of Cosmography (short review of meteorological phenomena and elements of astronomy)..." according to Subic.

188o/1 added only one hour weekly to geography in the third class,and a new professor - Milan A.Jovanovic.The same taught in the eighth sciences. No essential changes in the academic year 1881/2,only a new professor ,S.Milovanov in the eighth. In 1882/3 S.Milovanov took over the third class too. During 1883/4 M.A.Jovanovic taught again in the third class,but with 2 hours a weekNo changes in the academic year 1884/5.School year 1885/6 brought new professors : V. Pusibrk to the third and A.M.Matic to the eighth class.A small change took place in 1886/7 : A.M.Matic taught in the third and S.Milovanov in the eighth class. In 1887/8 A.M.Matic took over both classes. S.Milovanov did the same thing in the year 1888/9.A.M.Matic repeated the same accomplishment in 1889/9o. M.A.Jovanovic taught in the third and S.Milovanov in the eighth class during the 189o/1.In 1891/2 V.Pusibrk was holding lessons in the third and A.M.Matic in the eighth.No changes in curricula were in the year 1892/3,only S.Milovanov taught in the eighth.The same in the year 1893/4.One must acknowledge some tolerance of the hungarian government because they approved the use of the textbook in physics by Hondle which has been translated and published in Serbia,in Beograd. 1894/5 V.Pusibrk remained in the third,but to the eighth returned A.M.Matic. 1895/6 S.Milovanov gave lectures in both classes. The introductory part of this Annual Report is a thorough paper "Origins And Development Of the Serbian Grand Gymnasium in Novi Sad" (which exists as a separate book too),by V.Pusibrk. One may see there that the principal Dr Djordje P.Natosevic and professor Jovan Djordjevic (1826-19oo):"...for lectures in astronomy acquired the necessary equipment..." To our great sorrow there is no date and no list!

In the academic year 1896/7 V.Pusibrk taught geography in the third,and A.M. Matic physics in the eighth class.During the year 1897/8 S.Milovanov replaced A.M.Matic in the eighth class.The textbook on Physics For Higher Classes Of the Secondary Schools,by Stevan Milovanov has been recommended.In the school year 1898/9 Djordje Vujaklija taught in the third and A.M.Matic in the eighth class.Dj.Vujaklija taught in the third and S.Milovanov in the eighth class during the academic year 1899/9oo.In the next year S.Milovanov was in the third and A. M.Matic in the eighth class.All along the school year 19o1/2 S.Milovanov taught in the eighth class. 19o2/3 A.M.Matic gave lessons in the third and S.Milovanov in the eighth class. The same case was in the next year.Second edition of the Physics and Mathematical - Physical Geography, by Andrija M.Matic, has been recommended to the pupils.

In the 19o4/5 academic year S.Milovanov taught geography with one hour more,a week,in the third class; the same professor was in the eighth class too.No changes in the following year.Starting by the academic year 19o6/7 "...the main parts of mathematical and physical geography..." have been introduced into geography in the first class too. Marko Vilic gave these lectures with 2 hours a week. A.M.Matic remained in the third and S.Milovanov in the eighth class.Nothing has altered in the next year.M.A.Jovanovic taught in the first,and S.Milovanov in the third and in the eighth class during 19o8/9. M.Vilic came again into the first,Dusan Jovanov started in the third and S.Milovanov remained in the eighth class in the school year 1909/10.

Because of the increased number of pupils there were two section of the first, Ia (M.A.Jovanovic), Ib (M.Vilic), and two sections of the third class, IIIa (D. Jovanov), IIIb (M.Vilic), VIII (taught by S.Milovanov) during the year 1910/1. Similar situation was in 1911/2 : Ia (S.Milovanov), Ib (M.A.Jovanovic), III (S. Milovanov) and VIII (A.M.Matic). During 1912/3 in Ia taught Dr.Velimir Juga, in Ib D.Jovanov, in III geography curriculum included: "...Elements of mathematical and physical geography with main concepts in physics...", and in VIII taught A. M.Matic. Abundance of schoolboys was as well as in 1913/4 : Ia (D.Jovanov), Ib (M.Vilic), IIIa (A.M.Matic), IIIb (S.Zamurovic), VIII (S.Milovanov). According to the inventory in the Collection of physics there were 23 pieces teaching aids for astronomy.It is a pitty that there was no list by names so we do not know what kind of instruments were in use.

In the first year of the World war I, 1914/5, astronomy disappeared in the first class, but A. M. Matic, who gave lessons in the third, had in curriculum for geography:"...In mathematical geography: Orientation.Shape of the Earth.How shall we represent the Earth. Consisting parts of the Earth:land,water and air. Firmament and apparent motion of the stars. Rotation of the Earth about its axes and its pace around the Sun.Earth' belts.Motion of the Moon..." The same professor taught in the eighth class:"...Elements of astronomy (Apparent motion of the firmament. Horizon and the equatorial coordinate system.Shape of the Earth. The Earth rotates around an axes.Zodiac.Ecliptical coordinate system. The consequences of the revolution of the Earth around the Sun. Time. Calendar. Planets. Sun. Stars. Moon.Satellites)..." In the next academic year the curriculum was the same in both classes. Professor was S.Milovanov. During 1916/7 Stanko Zamurovic taught in the third class and S. Milovanov in the eighth. In the academic year 1917/8 A.M.Matic taught in the third and S.Milovanov in the eighth class.

TEXTBOOKS. - As one could see recommended and really used textbooks and handbooks were written in Latin, German, Hungarian and Serbian.The same were the languages in which the lessons have been given.

We will list and comment them in acccordance to the order in which they came into the usage. In the case that we know it only by the name of the author we will give data with which we are familiar.

J.Belingera UPUTSTVO U GEOGRAFIJU (Introduction To Geography),translated into Serbian by Aleksandar Gavrilovic, Ignjat Fuks, Novi Sad, 1866, has been discussed thoroughly in Part I of this paper. We will now give the outlines. First section is devoted to "Foreknowledge In Cosmography", First chapter to "Celestial Bodies In General", and second to "Some Celestial Bodies In Particular". In use between the 1867/8 and 1874/5 school years in the first class.

LEHRBUCH DER EXPERIMENTAL PHYSIK (Textbook in Experimental Physics),by Dr.August Kunzek,Wien,1853.Used in IV classes between the 1867/8 and 1873/4 academic year.

LEHRBUCH DER PHYSIK MIT MATHEMATISCHER BEGRUENDUNG (Textbook In Physics With Mathematical Bases),Zum Gebrauch in den hoeheren Schulen und zum Selbstunterricht,by Dr.August Kunzek,Wilchelm Braumueller,Wien,1865,X+795 pp.Let us list only the titles of some paragraphs."Shape of the Celestial Bodies", "Gravitation", "Central Forces", "Optical Instruments", "Parallax", "Horizontal And Equatorial Coordinate Systems", "Apparent Annual Motion Of the Sun", "Precession, Nutation,

Secular Change of the Obliquity of the Ecliptic", "Planets And Satellites", "Perturbations", "Fixed Stars (Variables,Double)", "Nebulae". As one may see very serious treatment of the subject with mathematical proofs. In use in VIII classes in the 1867/8 and 1868/9 years
LEHRBUCH DER PHYSIK fuer Ober-Gymnasien und Ober-Realschulen, Pesth,1861, by Dr. Simon Subic. In use between the 1869/7o and 1882/3 in VIII classes.
GEOGRAPHIE, I. Theil, by Ribari has been used between 1876/7 and 1878/9 in the first,as well as in academic years 1879/8o and 188o/1 in the third classes.
FOLDRAJZ a gimnaziumok hasznalatara (Geography for gymnasiums),by Albert Scholtz Franklin Tarsulat, Budapest,1879, 14o pp.has been used in the third classes between school years 1881/2 and 1886/7. Purest geography without astronomy.
Dra.Wallentina FIZIKA za vise razrede srednjih skola (Physics for higher classes of secondary schools),translated from German by Dr.Oton Kucera,Zagreb,has been used in the VIII classes between the 1883/4 and 1890/1. Under the title Elements of Astronomy (Cosmography) there were the following chapters: 1. Apparent Diurnal Rotation of the Firmament. 2. Star Position Determination (Horizontal And Equatorial Coordinate System) 3. Sidereal Time. Sidereal Hour Angle. 4. Meridian and the Altitude of the Pole Determination on A Spot.5.Shape And Dimensions of the Earth. 6.Interpretation Of the Apparent Motion ofthe Celestial Bodies Under Assumption That the Earth is Rotating Around Its Axes. 7. Geographic Longitude Determination.8.Changes of Gravitation Because of the Rotation of the Earth Around Its Axes. 9.Apparent Annual Motion of the Sun. 1o. Interpretation Of the Apparent Diurnal Rotation And Apparent Annual Motion of the Sun.11. Ecliptical Coordinate System. 12. Calculation of the Diurnal Star Arc And Lasting of A Day.Seasons. 13. Apparent Solar Time And Solar Mean Time.Sidereal And Tropical Year. Sundial. Calendar. 14.Parallax.Distances to Celestial Bodies And Their Size Determination. 15. Motion Of the Planets. 16. Motion of the Earth' Moon. 17. Excerpts of the Newtonian Law of Gravitation. 18. Precession And Nutation. 19.Tides Phenomena. 2o.Notes On the Structure of Some Celestial Bodies. In the concluding part of the book there are 51 problems under the title "Cosmical Physics". Very thoroughly worked material, but, the language used in translation has been of the so-called "western" variant with which Serbs are not very familiar.
FIZIKA I MATEMATSKI I FIZIKALNI ZEMLJOPIS za III razred srednjih skola u Ugarskoj (Physics and Mathematical and Physical Geography for III Classes Of Secondary Schools in Hungary), by Andrija M.Matic, Second Edition, Braca M.Popovic, Novi Sad,19o1. The First Part belongs to physics. The Second Part is Mathematical and Physical Geography. 1. Orientation. 2.Shape of the Earth. 3.How Do We Represent the Earth. 4. How Is the Earth Represented On A Flat Sheet. 5.Composite Parts Of the Earth According to the Matter. 6.Firmament And Apparent Motion of the Stars. 7.Rotation of the Earth Around An Axes And Its Pace Around the Sun.8.Belts On the Earth, Warmth, Wind, Rain,Snow,etc. Water circulation on the Earth. Climate. 9.Motion of the Moon Around the Earth And With It Around the Sun.Eclipses. 1o.The Position of Our Earth In the Solar System. This is a textbook which a professor wrote for his pupils according to the curriculum. Very popular and clear. In use in III classes between1887/8 and 191o/1, and 1913/4 and 1917/8!
KISERLETI TERMESZETTAN (Experimental Sciences), by Ipoly Feher,Franklin Tarsulat Budapest, 1888, 424 pp. has a part named Elements of Cosmography with following paragraphs: 236. Firmament And Its Diurnal Motion. 237. The Shape of the Earth.Its

Rotation: Horizontal And Equtorial Coordinate Systems. 238.Apparent Motion Of the Sun: The Ecliptical Coordinate System. 239.Time Measuring. 24o.The Solar System. 241. Fixed Stars, Milky Way. Nebulae. Again a serious textbook with many details. In use in VIII classes between 1891/2 and 1893/4.

FIZIKA za vise razrede srednjih skola (Physics for higher classes of the secondary schools),by Dr.A.Handl,translated by Ivan Stozir,Fr.Zupan,Zagreb,189o,VIII+324 pp. with VI Part Elements of Astronomy. 349.Firmament. Horizon. 35o. Equatorial Coordinate System. 351.Diurnal Motion Of the Stars. 352.Meridian And Polar Altitude Determination. 353.Annual Motion Of the Sun. 354. Apparent Solar Time And Solar Mean Time. 355.Ecliptical Coordinate System.Motion of the Equinox.Year. 356.Fixed Stars. 357.Planets.358.Comets. 359.Meteors. 36o.Moon. 361.Earth. 362.Foucault's Experiment With A Pendulum.363. Tides. 364.Density Of the Earth, A serious textbook but, the translator, besides the "western" variant "invented" some new nouns and verbs and on that way made problems to serbian readers.In use in eighth classes during 1894/5 and 1896/7 academic years.

One more professor wrote a textbook for his pupils. FIZIKA za gornje razrede srednjih skola (Physics For the Higher Classes Of the Secondary Schools), by Stevan Milovanov, Serbian Great Gymnasium in Novi Sad,1897,II+3o8+VI pp.,in Chapter III.Mechanics of Rigid Bodies has a section: *General Gravitation* with paragraphs 6o.Keplerian Laws. 61 Gravitation. 62. Gravity . 63.Work of Gravity.Potential. 64.The Field Of Earth' Gravitation.Chapter VIII.Light Phenomena has paragraphs: ...1o2.Shadow (umbra and penumbra in Solar and Lunar eclipses)...112.Light Velocity... 127.Solar Spectrum. 128.Spectra Of the Glowing Bodies. 129.Absorption Spectra. 13o. Full Spectrum. 131.Influence of Glowing Bright Rays. 132. Colour Of Bodies: Firmament... 134.Rainbow.135.Chromatic Aberration...*Optical Instruments*...145. Refractors and Reflectors. 146.Astronomical or Keplerian Telescope. 147.Terrestrial Telescope. 148.Galileian Telescope. 149.Reflectors: Gregorian, Newtonian, Herschel Telescope...Chapter IX. Heat Phenomena... 182.Cosmical Sources Are Sun And Earth...Chapter XI. Magnetic Phenomena... 2o7.Elements of Terrestrial Magnetism: declination and inclination....Chapter XIV. Elements of Astronomy consists of paragraphs: 26o.Apparent Diurnal Motion Of the Firmament. 261.Horizontal And Equatorial Coordinate Systems. 262. Geographical Longitude And Latitude. 263. Distance of Two Spots.264. Shape of the Earth.Its Dimensions. 265.The Earth Rotates Around Its Axes. 266. Apparent Motion of the Sun In A Year.267.Relations Between Horizontal And Equatorial Coordinate Systems. 268. Zodiac.269. Ecliptical Coordinate System. 27o. Relations Between Ecliptical And Equatorial Coordinate Systems. 271. Consequences Of the Revolution of the Earth Around the Sun And the Fixed Obliquenes Of Its Axes. 272.Distance of the Sun; Solar Dimensions. 273.Time. 274.Calendar. 275. Precession And Nutation. 276.Planets. 277.System Of Planets.Some Of Planets. 278.Sun. 279.Stars. 28o.Moon;Satellites. 281.Meteorites And Bolids. 282.Comets And Falling Stars. The conclusion of the book is again consisted of problems.As one may see the author tried to give to his pupils the most in a very clear way. In use in VIII classes between academic years 1897/8 and 1917/8!

ZEMLJOPIS za ucenike srednjih skola,Prvi deo (Geography for the pupils of secondary schools,First Part),by Oton Varga,translated into Serbian by Milan A. Jovanovic,Srpska stamparija Dra Svetozara Miletica, Novi Sad,19o4,IV+97 pp. Pure geography. Used in the years 19o6/7 to 1913/4 in first classes.

CONCLUSION

Former investigators narrowed their attention only to geography.But,as one may see, thanks to Annual Reports we concluded that the astronomical matter has been taught more in physics.So,everybody interested in exploring must look on both sides!
In those years many other books, textbooks and handbooks on astronomy could be found in libraries of our schools, and in private too,so, it is sure that all of them have been read by scholars , but we were limited our attention only to those officially recommended and cited in Reports or papers on this subject. I read many interesting suggestions how astronomy should be taught,many manuscripts concerning this matter,in general, but the shortage of space is guilty that this installment meets the world so meager and quite naked. I hope that the next parts (which will contain as well as the popularisation of astronomy), will be shown in their genuine and shining abundance.

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SOME IMPORTANT DOCUMENTS OF MILUTIN MILANKOVIĆ'S LIFE AND WORK (1904 - 1938)

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Abstract. In this paper are shown some important datas and documents of Milutin Milanković's life and work. In the same time these six selected documents are very significant of national and scientific riches.

The most famous Serbian astronomer, climatologist and geophysics is Milutin Milanković (1879-1958), although he was the first civil engineer (Vienna, 1902). Two years later Milutin Milanković (see Fig. 1) finished his study in Vienna, too, and he became the first Serbian doctor of tehnical science. The title of his PhD thesis was "Beitrag zür Theorie der Druckkurven" and we can find that document (transcript of a diploma) in the Archive of the Serbian Academy of Science and Arts in Belgrade (Fig. 2, document 1).

Since 1909 until 1958 Milutin Milanković lived and worked in Belgrade, exept during the World War I when he was living in Budapest. For his mathematical and astrononical theory of climatic changes and others merits, Milutin Milnaković has became corresponding member of the Academy of the Natural Sciences (APN) of the Serbian Royal Academy, on March 7th, 1920 (Fig. 3, document 2). In that time president of Academy was Jovan Žujović, founder of geology and geological investigations in Serbia.

After fourteen years successful work like as a full professor of the Belgrade University, Milanković has got Royal Order the Saint Sava, 3rd degree. It was on June 25, 1923 (Fig. 4, document 3).

Milutin Milanković became full member of the Academy of the Natural Sciences of the Serbian Royal of Academy on March 7th, 1925, exactly after three years of his proclamation for corresponding member (Fig. 5, document 4). In that time president of Academy was Jovan Cvijić, one of the singers Milanković's document for selected at extraordinarily professor of the Belgrade University.

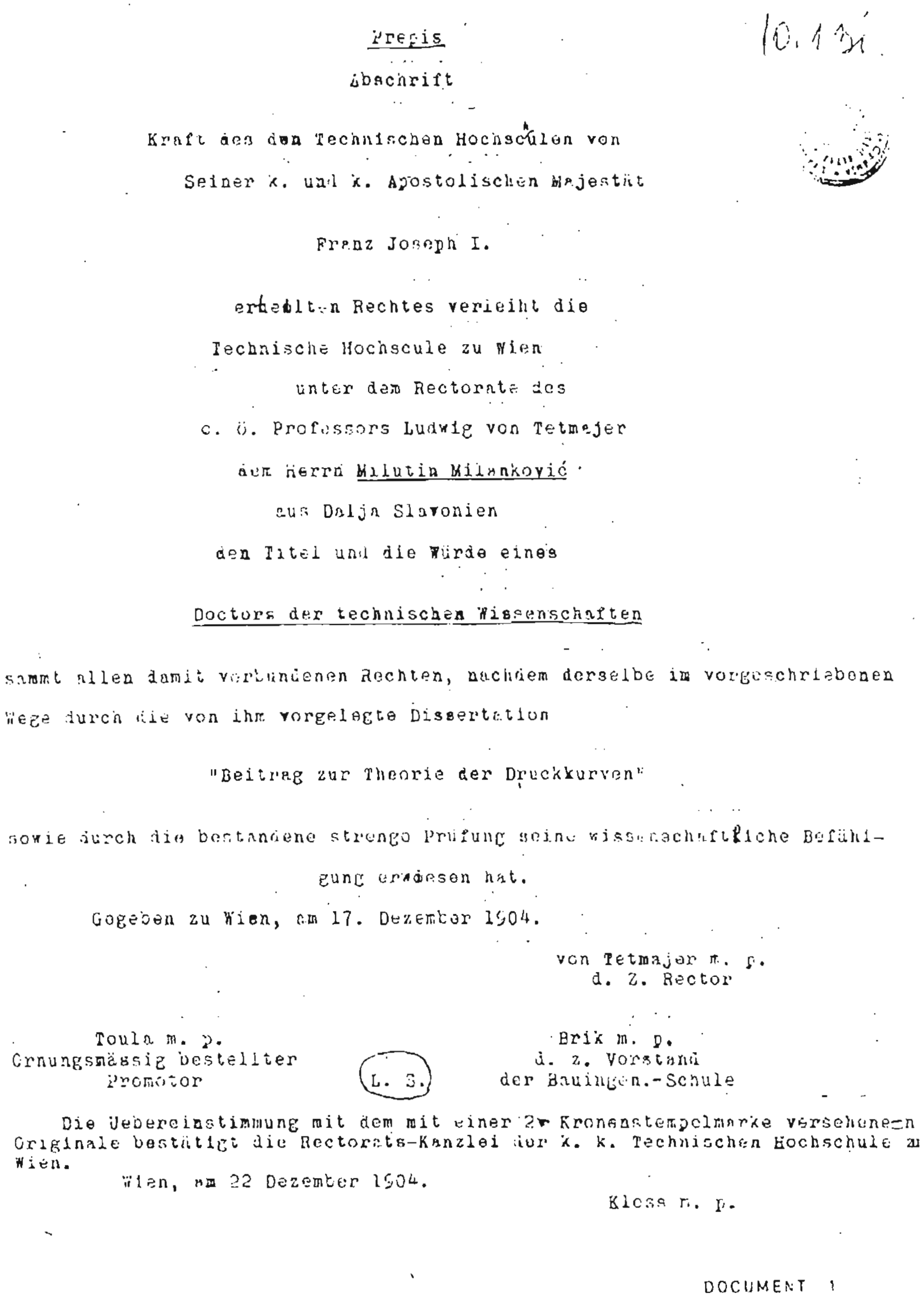
On December 16th, 1926 Ministry of Civil Engeneering authorized Milutin Milanković and he can public practice on all over the theritory of country (Fig. 6, document 5). During this year Milanković accepted an invitation by the Air Force Command for cooperating in the construction of military airfields in six airfields (Zemun, Pančevo, Kraljevo, Skoplje, Mostar and Zagreb). Although he has many obligations at Belgrade University and Academy, Milanković never forgot his first occupational.

King of Yugoslavia Petar II Karadjordjević on December 20th, 1938 awarded a decoration Milutin Milanković the Royal Order of Yugoslavia Crown, 3rd degree (Fig. 7, document 6). Milanković obtained the medal for his whole work in science, professorship, innovations etc.

All these original documents there are in the Archive of the Serbian Academy of Scinece and Arts in Belgrade with number 10131. Before his death, Milanković testamented documents to the Academy. These are important only, selected by personal view. Although small review select documents, they are very significant for his life and his development way in science. During his life Milanković already passed the border of his country. The documents demon- strate close connection with Serbia where Milanković lived and worked around sixty years.

After 1938 Milanković printed his famous book "Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem", (english translate as Canon of Insolation and the Ice-age Problem), but only last year we have Serbian translate as "Канон осунчавања Земље".

Fig. 1. Milutin Milanković (1879 - 1958), the great Serbian astronomer, climatologist and geophysics (paper G. Samojlov, 1955, Archive of the Serbian Academy of Science and Arts, No. 10131).



10.13i

Prepis

Abschrift

Kraft des den Technischen Hochschulen von
Seiner k. und k. Apostolischen Majestät
Franz Joseph I.
erteilten Rechtes verleiht die
Technische Hochscule zu Wien
unter dem Rectorate des
c. ö. Professors Ludwig von Tetmajer
dem Herrn Milutin Milanković
aus Dalja Slavonien
den Titel und die Würde eines

Doctors der technischen Wissenschaften

sammt allen damit verbundenen Rechten, nachdem derselbe im vorgeschriebenen Wege durch die von ihm vorgelegte Dissertation

"Beitrag zur Theorie der Druckkurven"

sowie durch die bestandene strenge Prüfung seine wissenschaftliche Befähigung erwiesen hat.

Gegeben zu Wien, am 17. Dezember 1904.

von Tetmajer m. p.
d. Z. Rector

Toula m. p.
Ornungsmässig bestellter
Promotor

L. S.

Brik m. p.
d. z. Vorstand
der Bauingen.-Schule

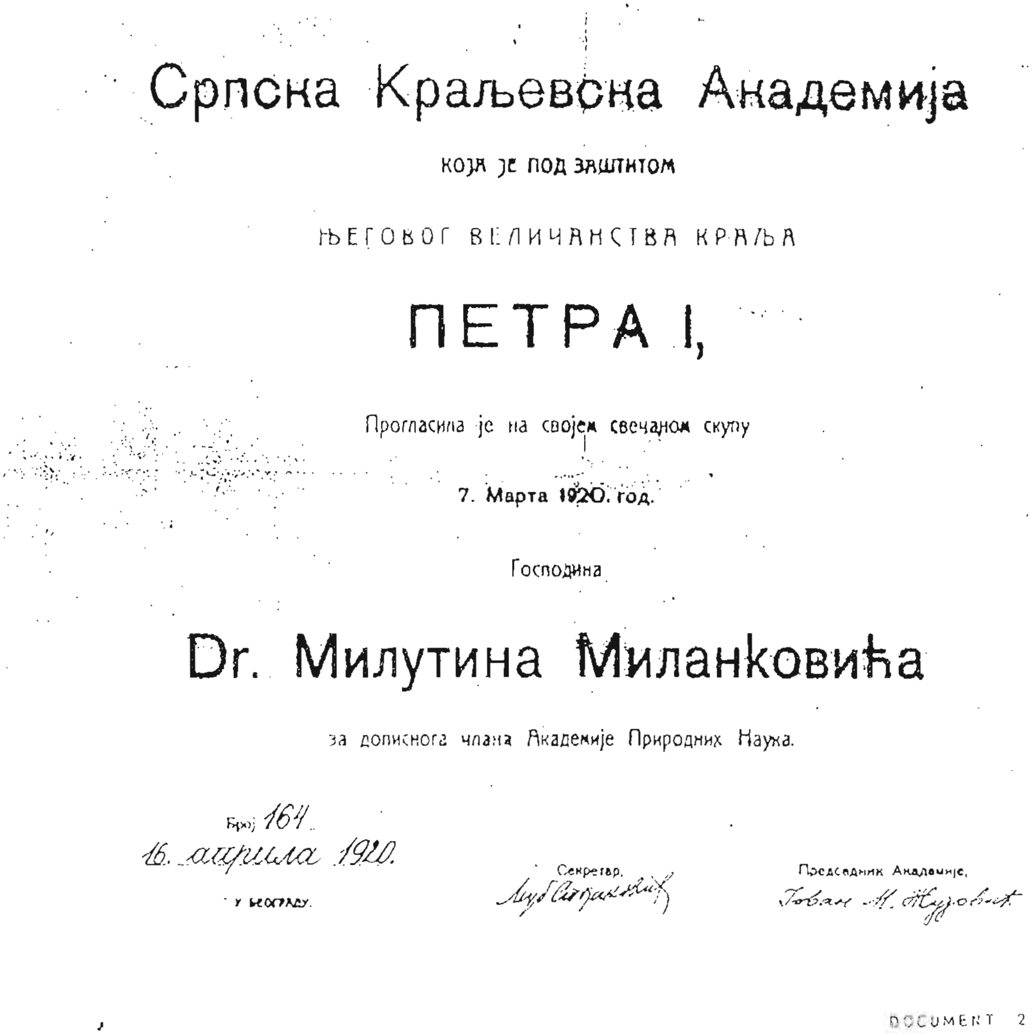
Die Uebereinstimmung mit dem mit einer 2 K Kronenstempelmarke versehenen Originale bestätigt die Rectorats-Kanzlei der k. k. Technischen Hochschule zu Wien.

Wien, am 22 Dezember 1904.

Kloss m. p.

DOCUMENT 1

Fig. 2. Copy of Milutin Milanković's diploma - the first Serbian doctor of tehnical science.



Српска Краљевска Академија

која је под заштитом

Његовог Величанства Краља

ПЕТРА I,

Прогласила је на својем свечаном скупу

7. Марта 1920. год.

Господина

Dr. Милутина Миланковића

за дописнога члана Академије Природних Наука.

Број 164.
16. априла 1920.
У Београду.

Секретар,
Љуб Стојановић

Председник Академије,
Јован М. Жујовић

DOCUMENT 2

Fig. 3. Document of corresponding member of the Academy of the Natural Sciences of the Serbian Royal Academy (March 7, 1920).

Његово Величанство

Александар I

по милости Божјој и вољи народној

Краљ Срба, Хрвата и Словенаца

благоволео је потписати следећи Указ

На предлог Нашег Министра Просвете

одликујемо:

Господина Дра Милутина Миланковића

Редовног професора на Београдском Универзитету

Краљевским орденом

Светога Саве

трећим (III) редом

Наш Министар Просвете

нека овај Указ изврши

Министар Просвете
М. Трифуновић с. р.

Александар с. р.

Бр. № 737
27. јануара 1923. год.
у Београду

Канцелар Краљевских ордена даје ову Повељу
Господину Др Милутину Миланковићу,
као доказ његовог одликовања.

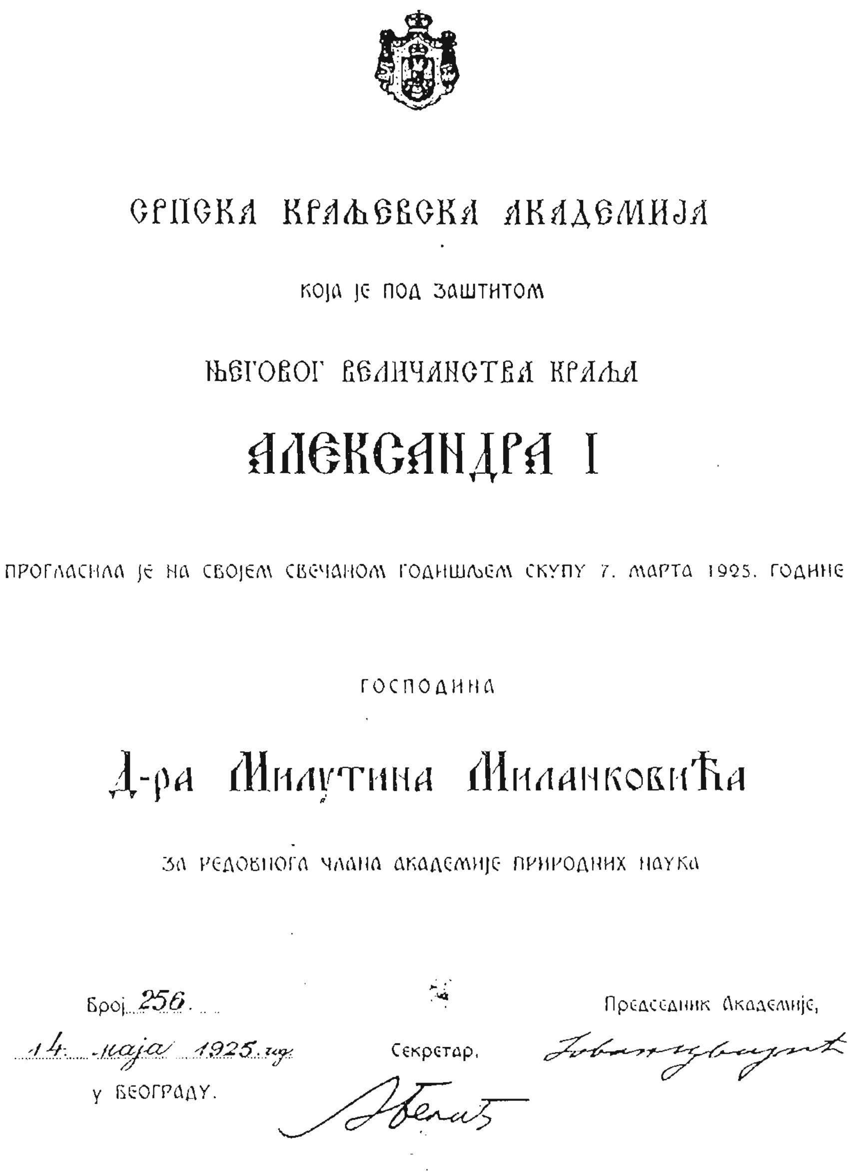
КО № 404
25. јуна 1923. год.
у Београду

Секретар
Канцеларије Краљевских ордена:
Ђорђе Ј. Грујић

Канцелар Краљевских ордена
генерал
Драг. Милутиновић

DOCUMENT 3

Fig. 4. The Royal Order of Saint Sava, 3rd degree (June 25, 1923).



СРПСКА КРАЉЕВСКА АКАДЕМИЈА

КОЈА ЈЕ ПОД ЗАШТИТОМ

ЊЕГОВОГ ВЕЛИЧАНСТВА КРАЉА

АЛЕКСАНДРА I

ПРОГЛАСИЛА ЈЕ НА СВОЈЕМ СВЕЧАНОМ ГОДИШЊЕМ СКУПУ 7. МАРТА 1925. ГОДИНЕ

ГОСПОДИНА

Д-ра Милутина Миланковића

ЗА РЕДОВНОГА ЧЛАНА АКАДЕМИЈЕ ПРИРОДНИХ НАУКА

Број 256.
14 маја 1925 год.
У БЕОГРАДУ.

Секретар,
Белић

Председник Академије,
Јован Цвијић

DOCUMENT 4

Fig. 5. Document of full member of the Academy of the Natural Sciences of the Serbian Royal Academy (March 7, 1925).

10.131

МИНИСТАРСТВО ГРАЂЕВИНА
КРАЉЕВИНЕ СРБА, ХРВАТА И СЛОВЕНАЦА

ОВЛАШЋЕЊЕ

На основи чл. 6. Привремене Уредбе о овлашћеним инжињерима и архитектима, и решења Министарског Савета од 31. децембра 1924. г. Бр. 37!25 ОДОБРАВАМ г. Милутину Миланковићу, редовном професору Универзитета из Београда да може вршити јавну праксу на целој територији Краљевине специјално из струке, грађевинског инжињерства а према чл. 8. тач. 1. Уредбе о овлашћеним инжињерима и архитектима.

Овлашћење се издаје по наплати таксе из Т. Бр. 257 таксене тарифе закона о таксама у 1000. – динара, која је на издатом овлашћењу утиснута и прописно поништена.

У Београду, 16. децембра 1926 године.

Бр. 35194

По овлашћењу
Министра Грађевина
Помоћник,

Радионица Мин. Грађевина 9.-III.-925. – 300.

DOCUMENT 5

Fig. 6. The authorized of Ministry of Civil Engeneering (December 16, 1926).

У име,
Његовог Величанства
ПЕТРА II.
по милости Божјој и вољи народној
КРАЉА ЈУГОСЛАВИЈЕ
Краљевски Намесници
благоволели су потписати следећи Указ
Желећи дати доказа Краљевског благоволења
одликују:
Господина Миланковића, М. Др. Милутина
професора универзитета
Краљевским орденом
Југословенске Круне
трећим (III) редом
ослобађајући га плаћања орденске таксе
Канцелар Краљевских Ордена
нека овај Указ изврши

К.О. № 6602
21 децембра 1938 год.
у Београду

Канцелар Краљевских Ордена
Панта М. Драшкић с.р.

Павле с.р.
Р. Станковић с.р.
Др. Перовић с.р.

Канцелар Краљевских ордена даје ову Повељу
Господину Миланковићу М. Др. Милутину
К.О. № 6602 као доказ истог ... одликовања

20 децембра 1938 год.
у Београду

Канцелар

Секретар

DOCUMENT 6

Fig. 7. The Royal Order of Yugoslavia Crown, 3rd degree (December 20, 1938).

Publ. Astron. Obs. Belgrade No. 60 (1998), 193 – 195 *Invited lecture*

CHAIR OF ASTRONOMY OF THE UNIVERSITY OF BELGRADE

J. MILOGRADOV-TURIN
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Abstract. The development of the Chair of Astronomy of the University of Belgrade is briefly described.

The University of Beograd is the only University in Yugoslavia with a Chair of Astronomy.

The begining of the university education in Serbia can be traced up to 1838, when "Licej" was founded in Kragujevac. Licej separated from "Gimnazija" in 1939 and was transfered to Belgrade in 1841.

Judging by the content of the textbooks elements of astronomy were lectured at the Licej. The first traces of teaching "physical" astronomy in the plans of Licej can be found for the year 1854/55.

The law about transformation of the Licej into the Great School, from 1963, did not include teaching of astronomy. This was corrected by the law about changes and additions from 1880, where it was regulated that astronomy was to be taught together with meteorology. Nevertheless, lectures did not started untill 1884, when Milan Nedeljković was elected to be the "suplent" - lecturer for these subjects. He became a professor in 1886. Therefore, 1880 is assumed to mark the foundation of the Chair of Astronomy in Belgrade, although jointly with meteorology untill 1924. When the University was founded in 1905, the Chair of Astronomy and Meteorology stayed within the Philosophical Faculty.

A great advance occured when Milutin Milanković was elected to be the professor of the University of Belgrade in 1909. He became the most famous serbian astronomer of the XX century. His best works concern the theory of climate and the celestial mechanics. He stayed a professor untill retirement in 1955.

The new regulation of the Philosophical Faculty introduced in 1925 for the first time treats astronomy as a separate teaching subject. The final educational sheme in 1927 established a separate study group for astronomy. It was named the III group of sciences and contained: Practical and Theoretical Astronomy; Celestial Mechanics, Theoretical Mathematics, Rational Mechanics, Physics and Meteorology. Vojislav Mišković who became the professor of the University of Beograd in 1925 lectured the Practical and Theoretical Astronomy. He was the director of the new Astronomical observatory in Belgrade, supervised its building and organized its work. He retired in 1962.

After the foundation of the Faculty of Sciences in 1947, the Chair of Celestial Mechanics and Astronomy was formed. Soon it changed the name into the Chair of Mechanics and Astronomy. The separation started in 1960 and ended in 1962; therefore this period can be taken as the time when an independent Chair of Astronomy is mentioned for the first time. Following the reorganization of the Faculty of Sciences, the Chair of Astronomy became the Institute of Astronomy in 1971 and the Chair of Astronomy again in 1995. Within the last change it stayed within the Mathematical Faculty.

Astrophysics was introduced for the firt time as an obligatory course at the Chaire of Astronomy in 1958. Since then it developed into several courses.

Important changes in teaching plans were introduced in 1961 when two separate study groups were formed: astrophysical and astronomical one. At the present time the Chair of Astronomy has ten full time members of staff, teaching fifteen astronomical courses. They are: General Astronomy, General Astrophysics, Reduction of Astronomical Data, for both groups; Theoretical Astrophysics, Practical Astrophysics, Stellar Structure and Evolution, Stellar Astronomy, Radio Astronomy, History and Teaching of Astronomy for students of the astrophysical branch; Theoretical Astronomy, Practical Astronomy, Positional Astronomy, Celestial Mechanics and Theory of the Motion of Artificial Earth Satellites, Ephemeridal Astronomy, Stellar Systems, for students of the astronomical branch.

At the present time the members of staff are:

STAFF

Dr Dragutin M. Djurović, full professor, dragutin@matf.bg.ac.yu
(Reduction of Astronomical Data (lectures and exercises))

Dr Trajko D. Angelov, full professor, trajko@matf.bg.ac.yu
(Stellar Structure and Evolution, Stellar Astronomy, Basics of Astrophysics (for students of physics))

Dr Mike S. Kuzmanoski, full professor, mike@matf.bg.ac.yu
(Positional Astronomy, Theoretical Astronomy)

Dr Jelena S. Milogradov-Turin, associate professor, jelenam@matf.bg.ac.yu
(Radio Astronomy, History and Teaching of Astronomy)

Dr Ištvan I. Vince, part time associate professor, ivince@aob.aob.bg.ac.yu
(Practical Astrophysics (lectures and exercises))

Dr Nadežda R. Pejović, associate professor, nada@matf.bg.ac.yu
(General Astronomy, Stellar Systems)

Dr Stevo D. Šegan, associate professor, ssegan@matf.bg.ac.yu
(Ephemeridal Astronomy, Practical Astronomy)

Dr Olga M. Atanacković-Vukmanović, assistant professor, olga@matf.bg.ac.yu
(General Astrophysics, Theoretical Astrophysics (lectures and exercises))

Dr Zlatko S. Ćatović, assistant professor, zlatko@matf.bg.ac.yu
(Celestial Mechanics and Theory of the Motion of Artificial Earth satellites, exercises for: General Astronomy, Practical Astronomy)

Mr Dejan V. Urošević, teaching assistant, dejanu@matf.bg.ac.yu
(exercises for: Radio Astronomy, Stellar Structure and Evolution, Stellar Astronomy, Basics of Astrophysics (for students of physics))

Andjelka B. Kovačević, junior teaching assistant, angela@alas.matf.bg.ac.yu
(exercises for: General Astronomy Theoretical Astronomy, Stellar systems. Ephemeridal Astronomy, Practical Astronomy)

Mirko G. Nagl, part time junior teaching assistant - postgraduate student
(exercises for: General Astrophysics, History and Teaching of Astronomy)

Starting from the foundation of the Chair of Astronomy 34 persons were engaged at undergraduate studies. The Chair of Astronomy educated 159 graduated students, 36 leaded to M.Sc. and 23 to Ph.D degrees. The first astronomy student graduated in 1936, the first M.Sc. degree was obtained in 1968 and the first Ph.D. degree in 1958.

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Publ. Astron. Obs. Belgrade No. 60 (1998), 196 - 200 *Contributed paper*

VAN GOGH AND STARRY SKY

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The mankind has a rare opportunity to meet the most intimate vision of life, nature and art of one of the greatest artists in the history, Vincent van Gogh, through a strange diary in a form of a remarkable collection of letters written to his brother Theo and friends like Paul Gauguin. Fully describing the painter's life and thoughts, Vincent van Gogh's "Letters" had been an inspiration to us as astronomers to inquire the starry sky motifs that had drown attention of this great 19th century painter (van Gogh 1985).

Vincent Willem van Gogh, born on March 30, 1853, in Netherlands, after a joyful childhood in a little Dutch village in a colorful countryside. At the age of 16 had walked into the artistic world through his uncle's art dealers company Goupil, that led him further to Paris and London. Disliking being the art dealer, he became dedicated to his father's profession as a preacher, but his mind disputed the Christian doctrine. Doing a missionary work in Belgium coal mines, not being able to accept the poverty and meaningless of human destinies, he lost faith and self confidence. Van Gogh had suffered from the first serious mental crisis around 1880, and after that he dedicated himself to the mankind through art, choosing to live on his brother's allowance only for food and paints.

After studying drawing at the Brussels Academy, van Gogh evolved very fast as a painter, and from 1881 to 1890 made his almost entire opus. His mental illness had, during all that time, been progressive, but the fact is that van Gogh had only shorter or longer periods without self-control - between the "attacks" he showed his extreme sensitivity and ingenious mind (Encyclopedia Britannica 1997). We took a liberty to believe (based on his own writings) that the mental disorder he had suffered from, did not influence the way he had painted the actual order of the celestial objects (very often the mirror- like symmetry, like in the "Starry Sky", and "Road with Cypress and a Star"), but it stressed his sensitivity to colors. The changes in the landscape could be attributed to the artist's composition of a painting itself, to gain the balance that the actual landscape surrounding the constellation he wanted to paint couldn't provide.

Big cities had exhausted van Gogh, and in February 1888 he went to Arles (the southeastern France) to, as he said, "look at nature under a brighter sky". As one of the examples of all of our statements, let us see the quotation from a letter referring to his masterpiece "Starry Night on the Rhone":

Arles; September 1888

> *My dear Theo,*
>
> *... Enclosed a little sketch of a square size 30 canvas, the starry sky actually painted at night under a gas jet. The sky is greenish-blue, the water royal blue, the ground mauve. The town is blue and violet, the gas is yellow and the reflections are russet-gold down to greenish-bronze. On the blue-green expanse of sky the Great Bear sparkles green and pink, its discreet pallor contrasts with the harsh gold of the gas.*
>
> *Vincent*[1]

We do not need a Planetarium simulation to see that September nights (around 11:00 p.m.) have the Great Bear (Big Dipper) in exactly the same position as in the painting. What is different from the actual landscape is the motif under the constellation. The Great Bear is above the northern horizon at that time, but probably because the poor landscape in that direction, van Gogh decided to paint the southwest view of Arles (Whitney, 1985).

But a Planetarium simulation becomes very useful for determining the aspects of another masterpiece – "Road with Cypress and Star".

After few months of working with Gaugain, from October 1888, in their community "Impressionists of the South", van Gogh had one of the strongest "attacks" of his illness, on the Christmas Eve 1888, and went to the hospital. From May 1989 he asked for a medical care in the asylum in Saint Rémy-de-Provence, when he realized that he had been more and more often disabled to work. Coming to that hospital, assured him that his illness could leave him enough time to work. There, in the landscape and colors of southern France, he started to paint, or, to be more precise, he tried all the time to express the real nature of olive trees and cypresses, yellow summer grass, and a sky. In a letter written to Gaugain a month after he left Saint Rémy on May 16, for Paris and Auvers-sur-Oise, van Gogh described "Road with Cypress and Star" in detail.

Auvers-sur-Oise; June 1890

> *My dear friend Gauguin,*
>
> *Thank you for having written to me again, old fellow, and rest assured that since my return I have thought of you every day...*
>
> *...I still have a cypress with a star from down there, a last attempt - a night sky with a moon without radiance, the slender crescent barely emerging from the opaque shadow cast by the earth - one star with an exaggerated brilliance, if you like, a soft brilliance of pink and green in the ultramarine sky, across which some clouds are hurrying. Below, a road bordered with tall yellow canes,*

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[1] URL: `http://van-gogh.org/docs/letters/p543.html`

> *behind these the blue Basses Alpes, an old inn with yellow lighted windows, and a very tall cypress, very straight, very somber.*
>
> *On the road, a yellow cart with a white horse in harness, and two late wayfarers. Very romantic, if you like, but also Provence, I think.*
>
> *I shall probably etch this and also other landscapes and subjects, memories of Provence, then I shall look forward to giving you one, a whole summary, rather deliberate and studied...*
>
> *Vincent*[2]

The peculiar scene of the Moon and two stars intrigued astronomer Charles Whitney from Harvard, and Albert Boime, art historian from the University of California, to do a research on what these objects could be.

We have done similar calculation using various computer program that all gave results that are in accordance with the data obtained by Whitney and Boime (Olson and Doescher 1988). There exists plenty of programs for personal computers that can be used for performing such a task. We mention here just few examples of astronomical programs that we used: (1) program *Skyglobe* that belongs to pre "Internet expansion" epoch, very quick and useful DOS shareware program that can be run on the old machines (i.e. 286 and up) with old graphic cards (i.e. Hercules) but also on the latest hardware, (2) program *SkyMap*[3] works on MS Windows (both 3.1 and 95 versions) and is also shareware – we performed most of operations for this paper using this program, (3) Unix X-windows Motif based program *xephem* made by Elwood Charles Downey[4] that is free and can be used for the most sophisticated professional astronomical needs. We also mention a scripting language *AstroScript* developed Peter Duffet – Smith (1997)

In the Figure 1 we plotted the positions of the Moon, Venus, Mercury and stars for April 20, 1890 for St. Rémy (longitude 4°50′ E and latitude 43°47′ at 40 minutes after sunset, i.e. 7:10 p.m. Visual magnitudes were: for Venus −3.90, for the Mercury −1.2 and for the Moon −5.8. The landscape van Gogh had painted, besides crescent Moon, following his own description in a letter, had "one star with an exaggerated brilliance..." Such a position of a very thin Moon and a bright "star" visible at a night time before the date he had left St. Rémy was found closely after sunset on April 20, 1890, when bright Venus, and extremely bright Mercury formed the same, but reversed like in a mirror, configuration.

No other appearance of the crescent Moon on the dates back when van Gogh arrived to St. Rémy was followed by such a composition with two extremely bright stars or planets. D. Olson and R. Doescher from the Southwest Texas State University even found the same event mentioned in Camille Flammarion's magazine *l'Astronomie* – very thin Moon in conjunction with a brilliant Venus and a close by Mercury on April 20. Our planetarium simulation showed that the Sun had set at 6:30 p.m., and the

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[2] URL: `http://van-gogh.org/docs/letters/p643.html`

[3] URL: `http://www.skymap.com`

[4] URL: `ftp://iraf.noao.edu/contrib/xephem/xephem_3.0/`.

trio was in the exact position as on the painting around 7:10 p.m. Comparing the landscape on a painting, it is clear how van Gogh could use a reversed position to make such a refined balance of the painting.

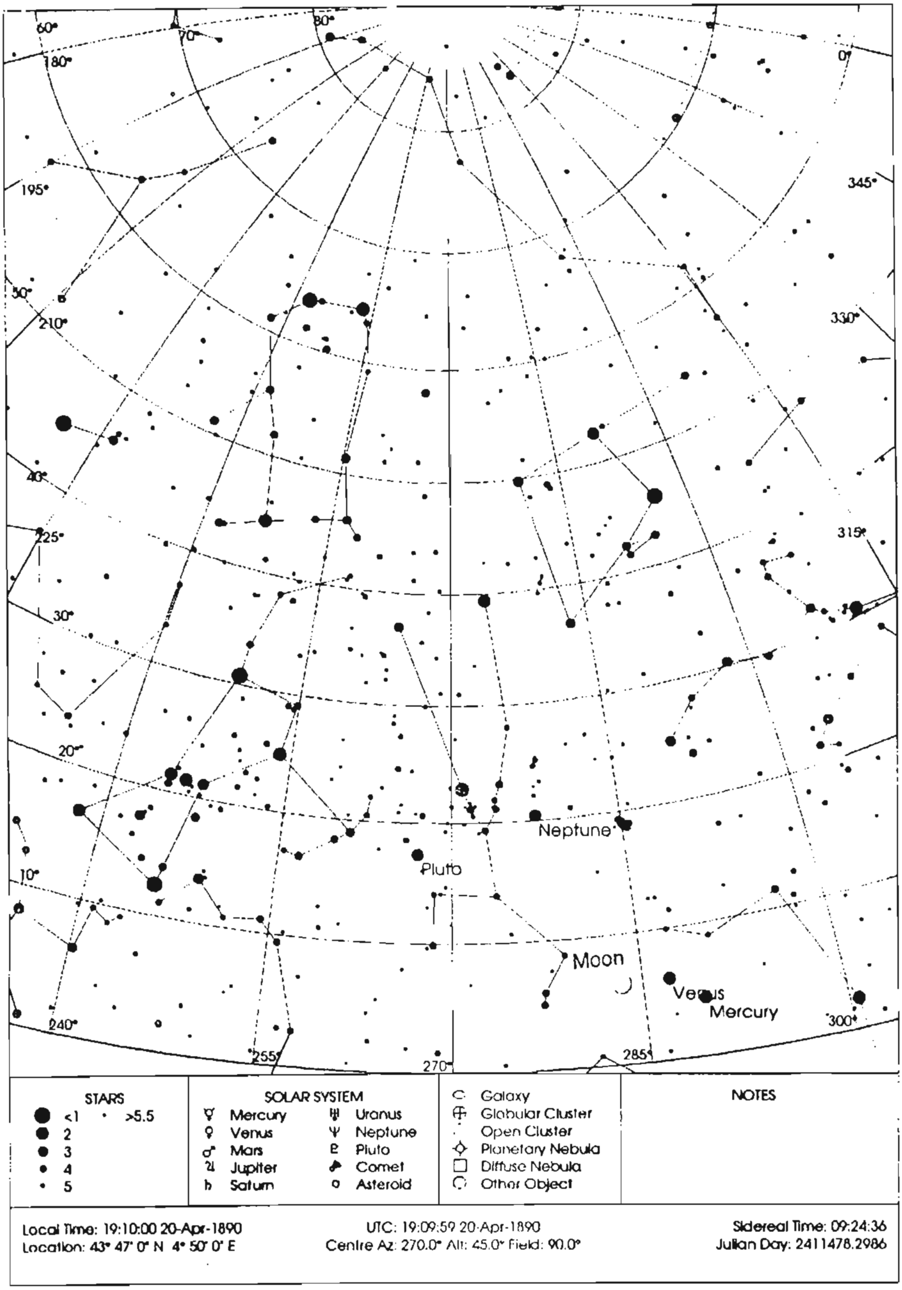

Fig. 1. Positions of the Moon, Venus and Mercury among stars as seen from St. Rémy on April 20, 1890 at 7:10 p.m.

Besides his paintings van Gogh himself described a consolation he used to find in a starry sky.

> *...And it does me good to do difficult things. That does not prevent me from having a terrible need of – shall I say the word? – of religion. Then I go out at night to paint the stars...*
>
> *Vincent*[5]

Acknowledgements

We would like to express our gratitude to Vladan Čelebonović, Milan Ćirković and Kristijan Lazić for helping us in preparing this paper.

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[5] URL: `http://van-gogh.org/docs/letters/p543.html`

Publ. Astron. Obs. Belgrade No. 60 (1998), 201 – 206 *Poster*

CRUX DISSIMULATA - SWASTICA

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The Appearance of Sirius, close to 19 th of July, in the zoodiac sign of Leo signified in ancient Greece the begining of the second part of the calendar year, which consisted of two parts (Grevs 1969). Actually, the zoomorfical prsentation of the Lion was a sign for the socond part, from July to December. Sirius was called in the antique times - the Gerion watch dog; in that mytological constelation he represented the father of the lion (Grevs 1969). One metal attache, found in Orašje, near Požarevac, shows the father and son, the and lion, in the form of Siamese Twins (Milenković 1996). The essential thing is, however, now the ancient mythological calendar practise, at that time a sort of primitive astronomy, understood the summer solsticium on 22 nd of June, the calendar mid-year, the moment of the strongest power of the sun, and at the same time, the moment when this power begins to wane(Beker 1992). The triple storage of the sun in the sky, in the time of the summer solsticium on 22 nd of June was understood as a death of the first part of the year and the birth of the second one. This was indentified with the dying of the dog star Sirius, the ancient Gerion's dog, Ortro. We mentioned before that Ortro's son was a lion, the second part of the Athenian year (Grevs 1969) the dying of a dog star Sirius was, according to the ancient Greek's belief, a temporary trip to underworld, /on the 22 nd of June/ and return on the 19 th of July. In that calendar - mytological constelation, the key moment was the 22 nd of june, when the sun revolved three times in the opposite way, from it's normal yourney from east to west.

That phenomena, the summer solsticium was marked in the spiritual life of prehistorical people, from the begining of agriculture in the early Stone Age, Neoliticum, as a sign of the Swastica - crux dissimulata (Ribakov 1981, Badurina 1992).

Special significance was dedicated to the graphical presentation of the swastica in the prehistorical cultures of Europe and Asia, connecting it closely to the attempt to stop the tremendous power of the sun, on 22 nd of June. For those ancient dwellers, the swastica was, in the first place the graphical, sign for a secret shiphre to open the skies and get the blessings in form of a rain.

But the problem of stopping the sun on 22 nd of June was not that simple, as it might appear. The ruler of the first part of a year was Otro's daughter - snake (Grevs 1969); and she had to die so that her brother - the lion - the second part of the year, could be born. Still, someone had to go down to the underworld and liberate the waters needed by the thyrsty fields (Ribakov 1967, Ribakov 1971) above - that was the role of dog star Sirius, who personally Sank into the underworld on 22 nd of June to be thriumphally back on the 19 th of July, with enough rain and waters to keep

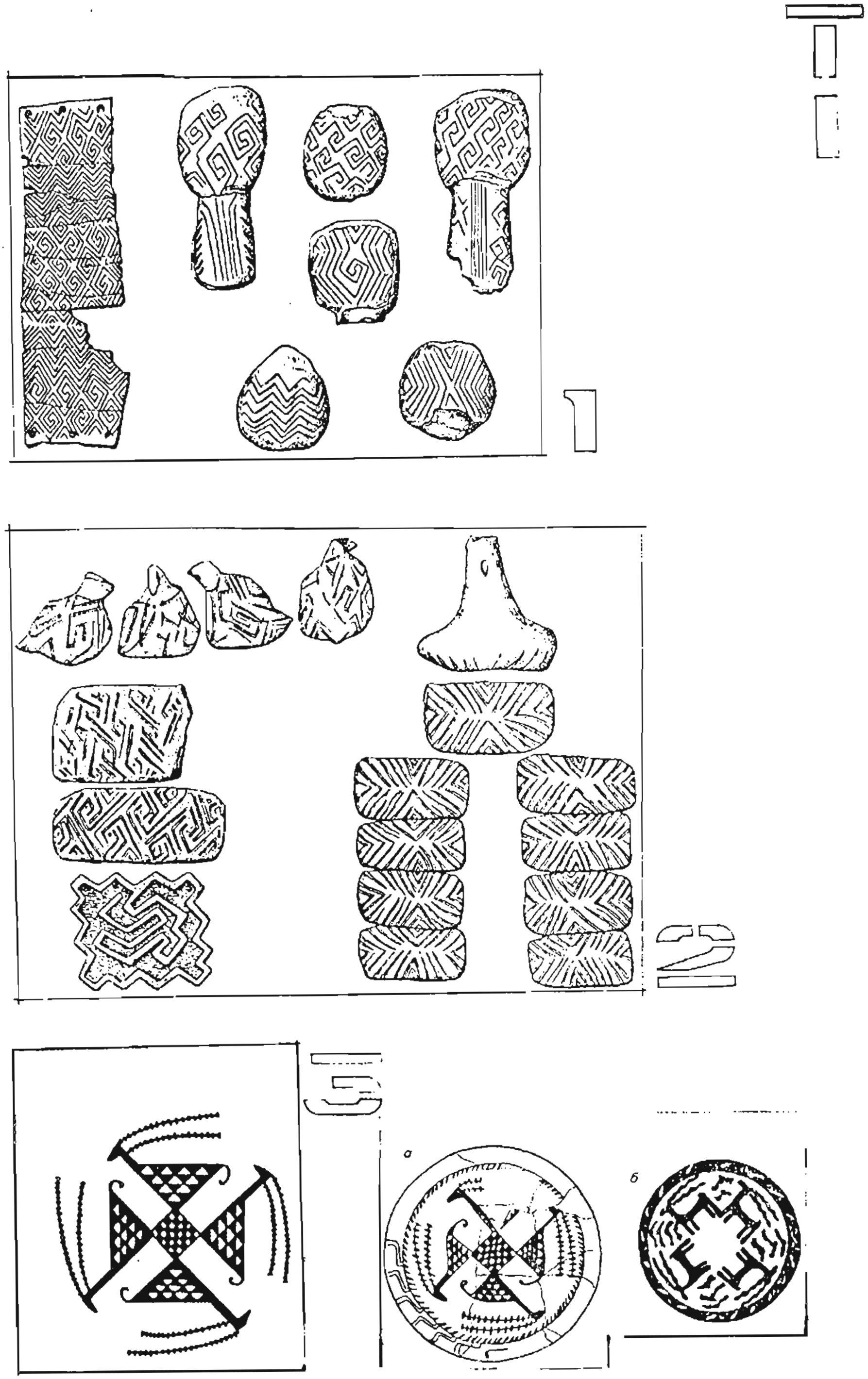


Fig. I: 1) Things with swastica from Paleolith (Ribakov 1981); 2) Things with the engraved swastica from Neolith (Ribakov 1981) 3) Things from Samara, Neolith 5000 years B.C. (Evsjukov 1988).

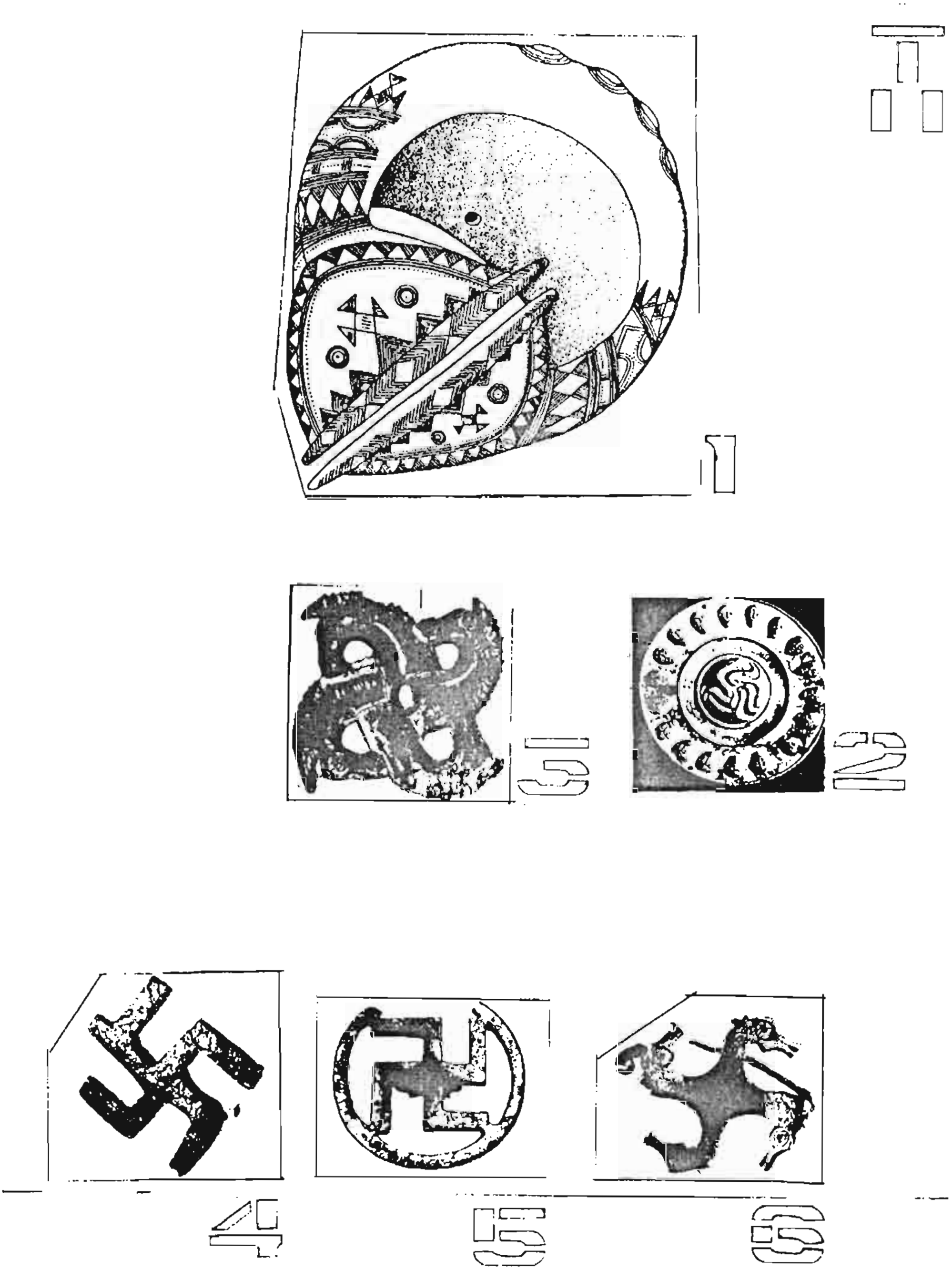
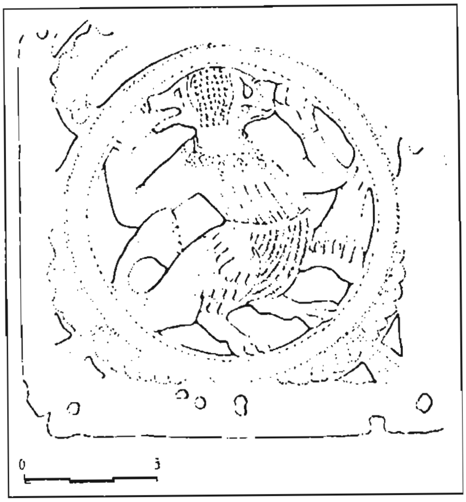


Fig. 2: 1) The braclet from Drmno (Garašanin 1975); 2) The rosette from Manerbio sull Mella, Italy (Charkey 1989); 3) St. Martha at Magdalena Hills, Slovenia, V - VI Centyry B.C. (Petrović 1992). 4) - 6 Swastica - shaped Roman things (Krunić et al. 1997)



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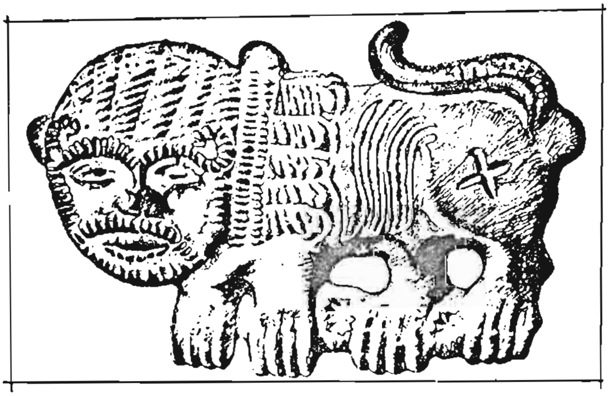

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Fig. 3: 1) The Aplika from Orashie, Pozharevac (Milenković 1996); 2) The Fibula with a lion and swastica from Volos, Greece (Čausidis 1994).

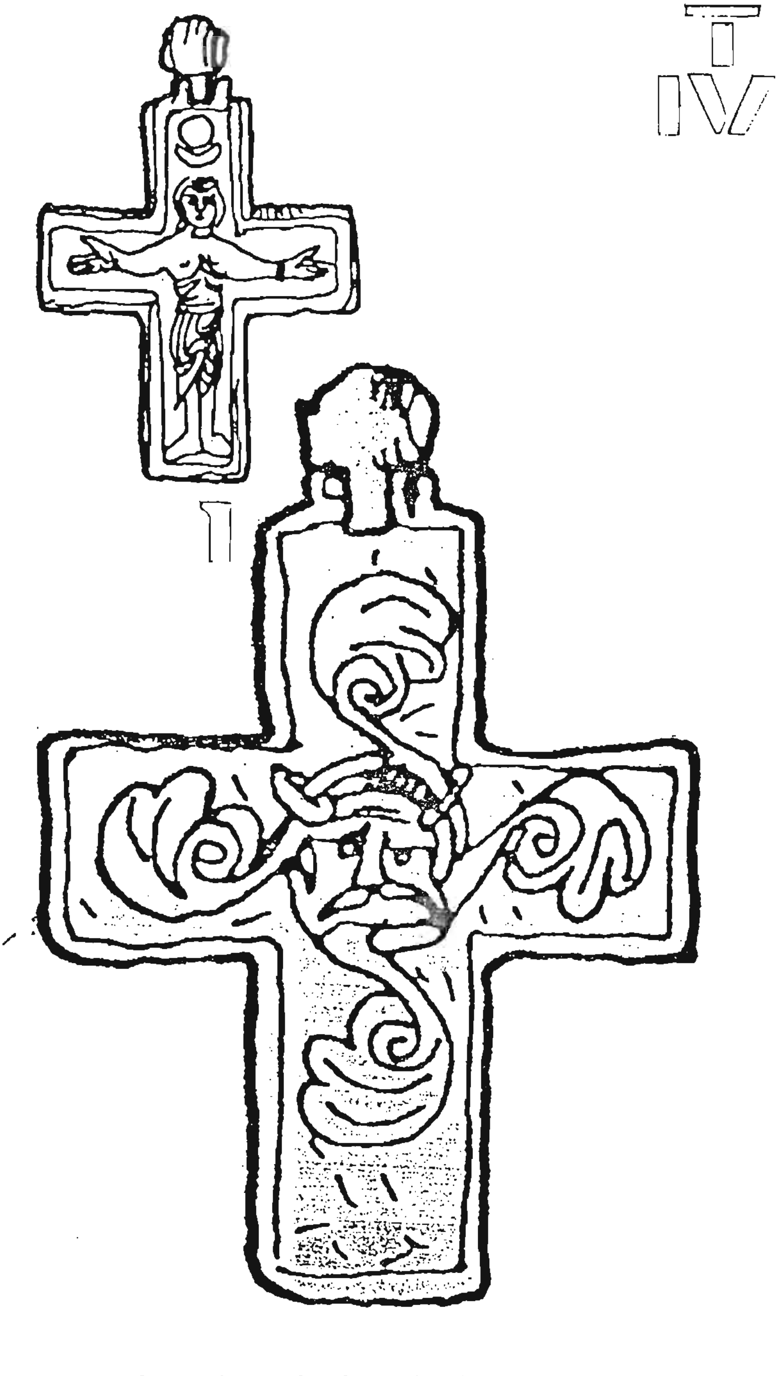

Fig. 4 The cross wuth swasica and a lion's head, XI - XII Century, Podebradi - Opochince, Czek Republic (Nehvatal 1978).

the nature alive [1].

Since it wasn't easy for the prehistorical man to depict the whole methafora, dying of a dog star, the sun stopage, Ortro and his rebirth, the salvatiom of the nature and the whole mankind was presented in a simbolic form od swastica.[2]

Apotropical powers of crux dissimulata meant in the same time a spiritual victory of a man, because it gave him all his vital powers. That's why for more than 10 000 years, man carved, painted, and modeled the Swastica on clay vessels, in methaphorical scenes, on jewelry, mosaics, and fresco decorations.

Crux dissimulata appeared also other things connected with everday life, sometimes even on those dedicated to the burial procession of the deciesed and his afterlife [3] Following this logic, the appereance of the Holy Cross of Jesus Christ has also developed from the prehistorical crux dissimulata - swastica but in this case, the idea of it is more sofisticated. The triple stopage of the sun is here identified with Christ's three day stay in grave, from Good Friday to Easter, wich enabled him and the whole mankind to redeem the sins on the way to the future salvation. [4]

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[1] Even in ancient antic Athens the new year was taken to begin with appearance of the dog - star, Sirius (Grevs 1969)

[2] that idea of the swastica as the driver of the /flow of time/ is best seen in Kelt's mithology where it is identical to the triple - branch lightning - "triskelon" which, by its stroke, enables the nature to start flowing (Cherkey 1989).

[3] the swastica or the artistic presentation of the Sun has been made eqval to the idea of the creator of life. So, a man's birth at the Earth is eqvivalent to the birth of the Sun and a man's death is taken eqval to death of the Sun.

[4] in the christian eshatology even more symbolic imortance has been given to the cross by identification of Jesus Christ and wood of the cross - the place of his punishment, and to the cross as a means of forgiveness of sins. In thenotion of Christ's deat the possibility of human dying as wellas the redeem of the Adam's and Eve's primordial sin have been cancelled.

Publl. Astron. Obs. Belgrade No. 60 (1998), 207 *Contributed paper*

AMATEUR ASTRONOMY IN YUGOSLAVIA

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Abstract. Amateur astronomy in Yugoslavia is connected with activities of five astronomical societies located in Belgrade, Novi Sad, Niš, Kragujevac and Zrenjanin.

Astronomical Society "Rudjer Bošković" from Belgrade was first amateur astronomical society in Balkan. It was founded in 1934 as "University's Astronomical Society". The founders of the Society were eight students from Faculty of Phylosophy in Belgrade. It was active till 1941. After the Second World War, the Society has continued activity since 1952 with the present name. Today the Society "R. Bošković" is the biggest one in Yugoslavia, it has about a thousand members and it disposes the so called People's Observatory located in Despot's Tower within the medieval Belgrade fortress "Kalemegdan" and a planetarium in down part of "Kalemegdan". Also, the Society is publishing the periodical "Vasiona" which contains popular astronomical papers (for more details see Popović 1997).

Astronomical Society "Novi Sad" - ADNOS from Novi Sad was founded in 1974. The Society disposes a small observatory located in a building in the Petrovaradin fortress. The Society has over 200 members (for more details see Francisty 1997).

Astronomical Society "Belerofont" from Kragujevac was grown from a small observatory called "Belerofont" with Meniskus Cassegrain Spigel telescope 150/2250 that was opened in 1986, during the Halley comet event. This Society has about a hundred members (for more details see Babović 1997).

Astronomical Society "Alpha" from Niš was founded in 1996, and it operates in Niš. The Society has about fifty members and it is planing to built a city opservatory (for more details see Sekulicić 1997).

Astronomical Society "Milutin Milanković" was founded in 1996 in Zrenjanin. The society has about a hundred members, manly students. Also, the Society is going to build a small observatory nearby Zrenjanin. The programme of the Society includes cooperation with primary and secondary schools (for more details see Naumovski and Bracić 1997).

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Publ. Astron. Obs. Belgrade No. 60 (1998), 208 - 211 *Contributed paper*

FROM THE STUDY "LIFE AND WORK OF PETAR MUSEN"

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Abstract. In this excerpt from the study "Life and Scientific Activity of Petar Musen" are given the data concerning the scientific activity of Dr Petar Musen (1912, Nikolaev, Russia - 1996, Greenbelt, USA), mathematician and astronomer who started his career in 1938 at the Belgrade Astronomical Observatory, staying there during almost four years, till 1942.

His life path, from Nikolaev, via Belgrade, Berlin and Cincinati to Greenbelt (Maryland, USA), was, above all, conditioned by his life determination to work, as a mathematician, in the field of celestial mechanics. The decisive part in this belongs to his first papers dating from the days he spent at the Belgrade Observatory.

He was a very respected investigator of the NASA Goddard Space Flight Center where he was engaged from 1959 till his retirement in 1978.

He developed a theory of artificial-satellite motion which served in the ephemeris computation for one of the first American satellites, Vanguard I. An excellent theoretician in the fields of celestial mechanics and theoretical astronomy he published a number of papers in the leading world scientific journals.

During the last years he lived alone in the neighbourhood of the Goddard Space Flight Center, the street name was Orbit Lane (what a coincidence for a man who devoted his entire active period of life to the computing of orbits of celestial bodies!), in the USA, state Maryland, far from the land always considered by him as his native country and to which he always wished to come back.

Unfortunately, this desire of his has never become reality. He died in October 1996 at the age of 84.

The idea of learning more, and writing about Petar Musen, in fact of saving from oblivion his name and life achievements, is not a new one. It has evolved and matured within two personalities independently, to be turned, after a conversation of a few years ago, into a unified desire of throwing more light upon his contribution to the scientific-thought development in our midst.

Both of us, Prof. Dragan Trifunović and myself, each one individually, have had different motives. His, certainly more pragmatical, was to present Petar Musen's creativity in mathematics and astronomy within a special study. Mine has been, as usually, a sentimental curiosity, making allowanceat at this moment for the closeness of the scientific fields to which both of us devoted ourselves.

Namely, even today, on the wall over my desk is the photograph of the first staff of the new Astronomical Observatory, from 1939. My inevitable question, from my earliest childhood, was: "Who is that man on the photograph standing by my father's side?" It has always the answer: Dr Petar Musen. Also I, to many persons asking me this question now, answer in the same way: Petar Musen. He is .... then I stop, being surprised, always from the beginning, how, in fact, about him also I practically know nothing. And not only I.

Petar Musen's life and scientific activity is almost unknown even to the staff members of the Astronomical Observatory, though he spent there several years engaged as a new member and then as a research fellow.

Petar Musen was born on January 16, 1912 in Nikolaev, Russia. His father Vladimir was a physician, his mother Nadezhda a housewife. Scant data concerning them indicate that in the late forties they lived at Velika Kikinda in a flat within a home for the aged persons.

It is not exactly known when Petar Musen with his parents came to the Kingdom of Yugoslavia. It is known only that he finished the secondary school - "Donski kadetski korpus" (Don Cadet Corps) - at Bileće and Goražde, but it remains for later, more detailed, studies to examine his biographical data from the times of his primary and secondary educations which doubtlessly took place in the Kingdom of Yugoslavia. What can be reliably established on the basis of the existing evidence at the Belgrade Observatory is that he graduated from the Chair of Mathematics of the Faculty of Philosophy in Belgrade and that, on April 22, 1937, he obtained his PhD in mathematics "O bazama neprekidnih funcija" (On the Bases of Continuous Functions" under the supervision of Prof. Dr Mihajlo Petrović - Alas.

A document from November 1937 leaves us irresolute. Namely, the Municipal Government of Dubrovnik under No 313/17095/37 delivers a domicile to Petar V. Musen born in 1912 in Nikolaev (Russia) a member of this local community and consequently a citizen of the Kingdom of Yugoslavia.

At present it is unknown how Petar Musen came to Dubrovnik. The most probable variant is that he was there a teacher in a secondary school, immediately after graduating.

Soon afterwards, (as evident from a document of the Ministry of Education of the Kingdom of Yugoslavia - Secondary School Department II, No 5967, from March 10, 1938) he obtained a young teacher's position as a bachelor of Philosophy in a modern-side gymnasium at Ćuprija with a salary of 1275 dinars a month.

In the meantime, in January 1938, Dr Petar Musen, living in Pančevo, Učiteljski konvikt (address), married Nina Granitova, a bachelor from Philosophy, daughter of Vladimir, a clerk in the Ministry of Transport and Nina Granitova, a housewife from Belgrade. Both families Granitov and Musen were emigrants from Russia due to the October Revolution. The Granitovs came from Tiflis (Tbilisi) where Nina was born, also in 1912.

The wedding ceremony took place in a Russian Orthodox Church in Belgrade and the rite was performed by the priest Vitalij Tarasev (Book of married persons I, 85, No 2 - Russian Trinity Church in Belgrade).

Toward the end of this same year, 1938, (more precisely on December 22, 1938) Dr Petar Musen sent a request to the Belgrade Astronomical Observatory asking to be appointed a junior clerk.

This request of his, followed by a requirement of Prof. Vojislav V. Mišković, Observatory Director, was sent to the Ministry of Education, General Department, on March 28, 1939. It was required for Dr Petar Musen to obtain a position of "činovnika-pripravnika-astronomskog opservatora VIII grupe pri Astronomskoj opservatoriji Univerziteta u Beogradu" (a free translation: a young staff member - astronomical observer at the Astronomical Observatory of Belgrade University).

A retroactive document on approving Dr Petar Musen's position at the Observatory was brought by the Ministry of Education on December 22, 1938.

In this way Petar Musen came to the Observatory and except Prof. Mišković, at that time already an academician, he was the only one with PhD at it.

He was cordially received by his colleagues: Ružica Mitrinović, Zaharije Brkić, Pero Djurković, Milorad Protić and Branislav Ševarlić.

His Observatory activity began in a way usual for that time: he was introduced into the work of only formed scientific groups, he learnt what were their basic tasks, he took part in the common preparation of Observatory publications such as: "Godišnjak našeg neba", "Nautički godišnjak", "Bulletin de l'Observatoire de Belgrade" and others. He also took part in preparing the ephemeris of minor planets, data on their heliocentric motion and in similar things.

In 1940 he, like other astronomers, made his dwelling within the Observatory.

In the Observatory Minutes from that time (the war had already begun) one finds the following lines:

On May 13, 1941 P. Musen reported that he had compared the data on unidentified asteroids.

On June 18, 1941 - under no 451 - P. V. Musen asked to undertake an extension of the theory concerning VI Jovian satellite which had not been thoroughly examined by that time.

On August 14, 1941 - under No 578 - P. V. Musen asked approval to begin introducing into the work of the Large-Refractor mechanism assisted by Z. Brkić.

On September 8, 1941 - under No 634 - P. V. Musen asked approval, after having been introduced into the Large-Refractor motion, to begin the determination of the instrument constants and to *devote himself to effective observations.*

He became the acting chief in the Service of Astronomical Calculations. At that time at the Observatory also worked Nina Musen as a calculator.

Her name one finds most frequently at the bottom of calculation forms of the Time Sevice, but also in other similar works: tape reading,time signal receiving, etc.

We also find this note: on January 10, 1941, Mrs Nina Musen requested a six-week leave because of her son's birth. The son of Petar and Nina Musen was named Djordje.

The war whirlwind,the sufferings of those discovering, even in the framework of a science like astronomy, the uncertainty of life gave rise in Musen anxiety and presentiments of an imminent danger.

Perhaps already a document of Education Ministry No 11927 of June 10, 1941 sent to the Observatory and requiring a list of its employees who were Jews (Musen was a Russian Jew) was decisive for Musen in resolving to leave Belgrade and Serbia.

On September 1, 1942, having not completed four years working at the Observatory Petar Musen made his resignation in the civil activity asking for it to be accepted. The reason was acceptance of a new position at the Astronomisches Rechen-Institut in Berlin.

Musen's resignation was presented by V. V. Mišković already on September 2, 1942 before the dean's office at the Faculty of Philosophy. In the meantime Musen, in an utmost haste, left the Observatory. His resignation was accepted only after a month. In late September Nina Musen also resigned her public service.

What was then with the Musens? A letter sent to Prof. Trifunović in 1991 offers at least a partial answer.

"I left my country (Yugoslavia) during the Second World War, because I was a "candidate" for the German gas-stoves and too many people knew about that. The threat of denunciation came even from the family of my former wife (immediately after coming to Berlin the Musens divorced) and it was hanging over my head. Prof. Kopff at the Astronomisches Rechen-Institut in Berlin sheltered me (he knew about my background, but kept silence). In Berlin during the war I was computing the orbits of minor planets. Prof. Kopff (let he rest in peace!) recommended me to Dr Herget at Cincinati Observatory".

A relatively short engagement in the scientific research at the Astronomical Observatory was decisive to the further scientific vocation of Dr P. Musen.

He devoted his time completely to the research in the fields of theoretical astronomy and celestial mechanics. Together with the leading astronomers of the International Center for Minor Planets and Comets in Cincinati (Ohio) he was engaged in particular problems of artificial-satellite motion (as early as in 1957). He worked on ephemeris improvememt of satellite "Vanguard I", to move to NASA Goddard Space Flight Center, Maryland, where he was very successful in improving the orbits of cosmic flying apparatus. He was engaged in the Laboratory of Theoretical Studies and Special Space Programs of this centre.

Numerous scientific papers about, which will be subject in the study "Life and Scientific Activity of Petar Musen", produce an exceptional contribution to the theory of motion of terrestrial natural and artificial satellites, to the theory of special perturbations, as well as to the theory of lunar motion.

For more than two decades Petar Musen lived near the Goddard in the street Orbit Lane 8804, Lanham, in American State of Maryland. Alone and sad, in his thought often in Knez-Mihajlova street - he writes to Prof. Trifunović:

"What an address you have on your letter!

How many times I was walking on Knez Mihajlova! I also must say that the University of Belgrade is an excellent University. I used to work in Germany and USA and always remembered my teachers and the University with a warm feeling and gratitude. ..."

In May 1997 to the author's address was sent a letter of Mr Nicholas Taube from the state of New York saying: "my uncle Petar Musen passed away in October 1996. ...

On a more pleasant note, I must tell you I spent many happy memorable hours as I was growing up listening to my Uncle talk fondly of his days and work at the Observatory."

With this the life circle of Dr Petar Musen, scientist and thinker, was closed.

A Russian and Serbian emigrant, a modest young man with glasses and in a poor suit on a photograph from 1938 added to the mosaic of world astronomical science and celestial mechanics a few valuable stonelets.

We are proud of him and them.

Publ. Astron. Obs. Belgrade No. 60 (1998), 212 – 217 *Invited lecture*

THE ASTRONOMICAL OBSERVATORY OF BUCHAREST HAS 90 YEARS

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Abstract. The two thousand years old evolution of the astronomy on the Romanian territory led in 1908 to the foundation of the Astronomical Observatory of Bucharest. Its beginnings, its development, as well as its regress during the period 1975-1990 are being shown. The new advances experienced after 1990 within the framework of the Astronomical Institute of the Romanian Academy are also presented. One ends by pointing out the present activity of the Institute, and some perspectives as well.

Maybe no science experienced such a spectacular evolution as the astronomy during this century. New theories, new discoveries changed fundamentally the vision we have had about the Universe few decades ago. Of course, essential contributions to this development are due to the great observatories, and to the frequent space missions, as well. But the contribution all the other observatories (spread all around the world and especially in Europe) have brought and still bring to the remarkable advance of astronomy must not be forgotten.

One of these observatories is situated since the dawn of this century in the South-Eastern zone of the old continent, in the middle of the Northern hemisphere. This is the Astronomical Observatory of Bucharest, the Capital of Romania, observatory which has turned 90 years on 1st of April 1998.

The existence of Romanian astronomical traditions, the advances of the astronomy along the second half of the 19th century, as well as the necessity of increasing the number of observation centres throughout the world led to the set up of this observatory.

When we speak about the Romanian astronomical traditions, we may go as far back as the beginning of the first millenium. Two thousand years ago, the Dacians - inhabitants of this land and, together with the Romans, ancestors of the Romanian people - raised a sanctuary in the Meridional Carpathians, at Grădiştea Muncelului, a sanctuary which still keep firm evidences of their astronomical knowledge.

Later, in early 6th century, the Christian Church tried to impose a more suitable chronological system. The author of this chronology was Dionysius Exiguus, a monk born in the Romanian parts, in Dobrogea. In AD 528, in his *Liber di Paschal*, he proposed the counting of years starting from Jesus Christ's birth.

Although the astronomy can be considered one of the oldest sciences, its really scientific substantiation dates only from the 16th and the 17th centuries. Concerns in astronomy can be recovered also in Romania during that period, and even before. We shall mention, for instance, the first astronomical observations performed in this part of Europe by the bishop Ioan Vitez (1408-1462). The observatory of Oradea was set up by him in 1445, before that raised by Tycho Brahe at Uraniborg.

A century later, Johannes Grass (Honterus) published *Rudimenta Cosmographica* (1548), which contained many elements of astronomy. The book had a great echo in that epoch, and saw 26 successive editions which have been used for a long time in Germany as textbooks of astronomy.

We can also mention the *Colligate* of Sibiu, in which Conrad Haas (1509-1579) described the stage rockets (and used this denomination) for the first time.

The 16th and the 17th centuries represented an important epoch from the standpoint of spreading the astronomical knowledge in the more and more numerous colleges founded in the three Romanian countries: Transylvania, Moldavia, and Wallachia.

Among the scholars of that period, we shall mention only the name of Hrisant Notara (Chrisandos Notaras), former disciple of G. D. Cassini at the Observatory of Paris. He left us the *Introduction ad geographiam et sphaeram* (Paris, 1716), the first Romanian scientific work which contained chapters dedicated to astronomy.

The 19th century brought deep changes in the whole Europe, implicitly in the Romanian countries. In 1859, Moldavia and Wallachia merged into the first modern Romanian state. This imposed reforms, not only in the political and social life, but also in education, this one being eventually oriented towards the western culture.

As Paris was the most important cultural centre of Europe in which astronomy was practised, the first students longing to learn the science of heaven were sent in the Capital of France. It is not interestless to recall that out of the first four Romanian doctoral theses (in mathematics) defended at Sorbonne, three dealt with celestial mechanics. We refer to: Spiru Haret's thesis (1878) on the stability of the major axes of planetary orbits, Constantin Gogu's thesis (1882) on the long-periodic inequality of the Moon's motion, and Nicolae Coculescu's thesis (1895) on the motion in a particular case of the three-body problem.

(By the way, also in Paris, but at the Observatory, directed then by Le Verrier, another young Romanian has been studying: Constantin Căpităneanu, the author of the first Romanian work of astronomical observations, *Determination of the Differences of Longitude between Jassy and Chernowitz.*)

All three above mentioned theses were eulogized by the renowned French scientists. For instance, Poincaré appreciated Haret's conclusions as a big surprise. The same Poincaré quoted Coculescu's results in his famous book *Leçons de mécanique céleste.* Gogu's researches proved their validity many decades later, when they were quoted in the theoretical works intended to prepare the lunar space missions. Moreover, when the international astronomical community named the formations discovered on the Moon's invisible face, the name of Spiru Haret was assigned to a crater.

Such well-appreciated results represented scarcely the start of researches to be continued in Romania. But in this country there was not a nucleus of astronomical research yet. The necessity of such a centre had been emphasized as far back as in 1870, when P. S. Aurelian, a remarkable political figure and a man of great culture, asked the government and the legislative body: how long Romania will still be deprived of such an important research institution, already existing in countries with much lower incomes? Another man of culture, well-known by the international scientific community of that time, Ştefan C. Hepites, applied repeatedly to the authorities, especially to the recently founded Academy, soliciting the set up of an astronomical institution. As a director of the Meteorological Observatory, he knew better than anyone else how necessary was the foundation of certain special services for: keeping the precise time, determining the geographical coordinates by astronomical methods, observing remarkable celestial phenomena, etc. To be more convincing, he elaborated a first historical sketch of the evolution of the Romanian astronomical knowledge, in order to prove that concerns in astronomy were familiar to our people, and a tradition in this field was already existing. Of course, both his scientific grounding and the epoch's custom determined him to ask for the set up of an astronomical observatory within the framework of the meteorological one.

The Board of Agriculture had purchased as far back as in 1888, for the Meteorological Institute and the Centre for Measures and Weights, an estate of Constantin Bozianu, ex-counsellor of the first Prince of the Romanian Countries, Alexandru Ioan Cuza (1859-1866). This ground was lying on the Filaret Hill, in Bucharest, at only three kilometers from the centre of the town. Here was raised, after four years only, the first stable building intended to astronomical observations: a small meridian hall of 16 m^2, which had to be endowed with a transit instrument of 1 m focal distance and 67 mm diameter of objective, installed on a pilaster whose basis was at 3.25 m under ground.

Finally,as a result of the insistences of Ştefan C. Hepites and Nicolae Coculescu, one decided the set up of the Meteorological and Astronomical Observatory. The foundation decree is dated 1st of April 1908 and is signed by the Minister of Worship and Education, Spiru Haret. Nicolae Coculescu was appointed as the first director of the Observatory.

The astronomy separated from meteorology only in 1920.

So, 90 years ago, it was created the first Romanian modern institution intended to study the Universe.

During the same year, another astronomical observatory, this time a private one, was founded in Basarabia, on the right-hand bank of the Nistru river, at Dubosarii Vechi. It was directed along 32 years by Nicolae Donici, one of the most interesting personalities of the Romanian and world astronomy. Born in 1884 in Basarabia, he worked until 1917 at the Imperial Academy in St. Petersburg. The stormy events which took place in February 1917 determined Donici to leave Russia for Odessa. But the communists reached Odessa, too, and Donici left his instruments, fixing his residence at his observatory, in Basarabia, recently retroceded to Romania. This situation had to last only until 1940, when the Soviet Union seized again Basarabia. Donici moved to Bucharest, but in 1944, when the communist danger had become impending, he left forever his native country for France, where he had to work at the

Observatory of Paris. Although founding member of the International Astronomical Union, active participant in the first six General Assemblies of this one, author of important works in astrophysics, observer of no less than six total solar eclipses, however the last years of his life constitute a genuine mystery. There are no documents recording the date and the place of his death.

The Observatories of Bucharest and Dubosarii Vechi were followed soon by two other observatories: that of Jassy (1913), directed by Constantin Popovici, and that of Cluj (1921), directed by Gheorghe Bratu. The observatory of Timişoara was built much later, in 1959, due to the endeavours of Ioan Curea.

The Observatory of Bucharest was and remained the most important observational centre, due especially to its initial endowments. Nicolae Coculescu did his best to purchase the most modern instruments of that time: the great meridian circle Gauthier-Prin (190/2350 mm) and the double astrograph Gauthier-Merz (380/6000 mm). Due to both their remarkable optical qualities and the care with which Gheorghe Demetrescu set them up, they still are considered among the performant instruments of this type.

Later on, other devices joined them: a Zeiss transit instrument (100/1000 mm), used from 1956 up to 1990 to the study of the irregularities of the Earth's rotation; a Cassegrain reflector (50/500/7000 mm), installed in a 5 m diameter dome; a Zeiss equatorial refractor (130/1950 mm), to which it was added a smaller refractor (100/1500 mm), endowed with an H_α filter, for solar observations; an AFU-75 photographic camera for artificial satellite observations; a Danjon astrolabe (100/3500 mm) recently transferred from Brussels; an hour service, endowed first with Belin quartz clocks, then with Rhode & Schwartz clocks, later with Romanian hydrogen masers, and very recently with a GPS time receiver; a modern computing base (a superscalar computer Silicon Graphics Power Challenge M, and a graphical workstation INDY connected to PCs).

The instruments worked in parallel with those of Cluj: the Newton reflector (508/2500 mm), the Prin refractor (203/3000 cm), the UFISZ-25-2 photographic camera for artificial satellite observations, and the recently purchased Schmidt-Cassegrain reflector Meade (400/4064 mm), and those of Timiş oara: the Cassegrain reflector (300/1690 mm). Most instruments have been modernized, especially by endowing them with CCD cameras.

During the inter-war period, the staff of the Observatory of Bucharest was extremely scanty. The very few astronomers performed both research and teaching. Nevertheless, some succeeded in becoming remarkable professors and, at the same time, researchers well appreciated by the international astronomical community. Out of them we mention: Constantin Popovici (1878-1956), Gheorghe Demetrescu (1885-1969), Constantin Pârvulescu (1890-1945), Nicolae Dinulescu (1906-1989), Constantin Drâmbă (1907-1997), Ella Marcus (1909-1982), Călin Popovici (1910-1977). Three of them also were directors of the Observatory: Constantin Popovici (1937-1943), Gheorghe Demetrescu (1943-1963), and Constantin Drâmbă (1963-1977).

In 1951, the Astronomical Observatory became an institution of the Romanian Academy. But, during the period 1975-1990, the Academy lost its research units, so that the Observatory was patronized by different institutions. In 1990 the Academy regained its fundamental research institutions; among them - the Observatory of Bucharest (on 1st of April 1990), this time within the framework of the Astronomical Institute.

After 22 December 1989, Romania experienced a new stage in its evolution, which was felt in the astronomical research, too.

To understand what the present stage of development means for the Romanian astronomical research, we have to recall some essential aspects. The last decades, especially the eighties, meant a total isolation from the scientific world, both western and eastern. The Romanian astronomers did not attend international scientific reunions; any cooperation with other observatories was stopped; the reference material was missing; the astronomical journal had been suppressed. Moreover, in the eighties one of the main purposes was the economic efficiency. This constituted always a hard problem to face for any fundamental science, astronomy included. So, the astronomers had to sacrifice many time and many energy to work under "economic" contracts which hardly allowed them to earn the living.

Given this situation, the return of the astronomical research to the Academy, as well as the reunion of the three main observatories (Bucharest, Cluj, and Timişoara) into a single institution, the *Astronomical Institute of the Romanian Academy*, meant a new orientation for the development of astronomy in this part of Europe.

The main topics approached during the present decade are: physics and evolution of stars, solar physics, celestial mechanics, dynamics of the solar system bodies, artificial satellite dynamics, cosmology, history of astronomy.

The most significant results are presented at the scientific sessions organized yearly by the Institute, as well as at various national and international reunions. At the same time, they are published in journals all over the world, or in the *Romanian Astronomical Journal*, which resumed since 1991 the former *Studii şi Cercetări de Astronomie* (suppressed in 1974). Other publications of the Institute are *Anuarul Astronomic*, *Observations solaires*, and *Annual Report*. The latter two ones are recently disseminated via Internet, too.

To fill as soon as possible the gaps appeared in the research of the last decades, we considered that one of the best ways is the specialization of the young researchers in the most famous academic centres. Ten young astronomers (namely about a quarter of the research staff) are preparing or have already defended their Ph.D. theses at universities as Yale, Bonn, or Heidelberg, or at observatories as those of Paris and Brussels.

The Institute cooperates officially with the Observatories of Athens, Belgrade, Brussels, Budapest, Moscow, Paris, Prague, Sofia, and Warsaw. Subsequently, there were organized or are in preparation reunions: the International Colloquium *PHESAT '95* (Bucharest, September 1994), the NATO Advanced Research Workshop *Theoretical and Observational Problems Related to Solar Eclipses* (Sinaia, June 1996), four Yugoslav-Romanian Astronomical Meetings (Timişoara, 1995; Belgrade, 1996; Cluj, 1997; Belgrade, 1998), two Romanian-Russian round tables (Bucharest, 1997; Moscow, 1998), two International Workshops on Celestial Mechanics and Space Dynamics (Cluj, 1997 amd 1998).

An exceptional astronomical event imposes a new pace of work to the Romanian astronomers: the total solar eclipse of 11 August 1999, whose maximum will be in Romania.

Here will be: the maximum duration of the eclipse (2^{min} 23^{s}), the maximum coverage of the Sun (103 %), the Sun's maximum height (59°), the maximum altitude for observing sites (more than 2500 m in the Meridional Carpathians). Moreover, Bucharest is the only capital city situated in the totality band, namely exactly on the centrality line. The Astronomical Institute has two observatories (Bucharest and Timişoara), the only in the world, able to observe the eclipse by means of stable instruments.

To use them in the most favourable conditions, the Institute, together with the Working Group "Eclipses" of the IAU, initiated a contest for the best programmes intended to observe the eclipse with stable instruments.

There will also be organized two summer schools for the young people that want to profit by this outstanding event in order to learn as much as possible from the specialists who will come in Bucharest to observe the eclipse. We refer to a NATO Advanced Study Institute meant to Ph.D. students and young researchers, and to an International School for Young Astronomers, under the aegis of the IAU, which has in view especially students from countries where the astronomy is still in an early stage of development.

Among other scientific sessions to be held in Romania in August 1999, we mention: the General Assembly of the International Union of the Amateur Astronomers, the Reunion of the Astronauts, the third edition of the World Conference on Salt.

All these international reunions, as well as the continuously growing interest proved by mass media and the public (in 1997 the Institute initiated, for the first time in Romania, "The Open Day"), require an increasing effort from the researchers. Yet more, they want to profit at the most by this event in order to ensure a convenient level of development to the astronomy in this part of Europe. In this context, our projects include an observation station situated at 100 km north of Bucharest, and an extension of the main building of the Observatory of Bucharest for a public Planetarium.

Of course, the amazing performances of the space techniques will change very soon the "image" of an astronomical observatory, that of the Bucharest one included. As the other ground-based observatories, our Observatory will receive the continuously increasing quantity of data transmitted from space, in order to process and interpret them. However, as it was pointed out recently at an international workshop (*Journées '97*) organized in Prague by the Czech, French, and Romanian astronomers, the ground-based observations still have a role to play. This is the reason for which we think that the centenary of the Observatory of Bucharest will find this institution in full activity, and its researchers will continue to contribute to the knowledge of the Universe at the dawn of the new millenium.

Publ. Astron. Obs. Belgrade No. 60 (1998), 218 – 225 *Invited lecture*

OLD SUNDIALS IN SERBIAN LANDS

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Abstract. By this paper we attempt to provide an insight into the history of gnomonics in Serbian lands. A survay, rather discontinuous, is presented of not numerous sundials in these regions dating back to diverse epochs.

1. INTRODUCTION

The sundials are attractive segment in the scientific and cultural heritage of every people. They are the object of interest of researches of various branches, who treat them from different aspects: according to historical periods, according to their construction, according to their belonging to clock systems within the framework of regional entities of various size. The most general is their division into *portative* and *stationary* sundials. As a rule first studied were portative sundials, from a stylistic viewpoint as work of applied art. This is the case with us too (Han, 1966). Unlike the portative sundials, most of which are stored in museums. The stationary sundials have first to be spotted. The last decades of the present century are noted for systematic researches in, and cataloguing of, the stationary sundials in a number of European countries.

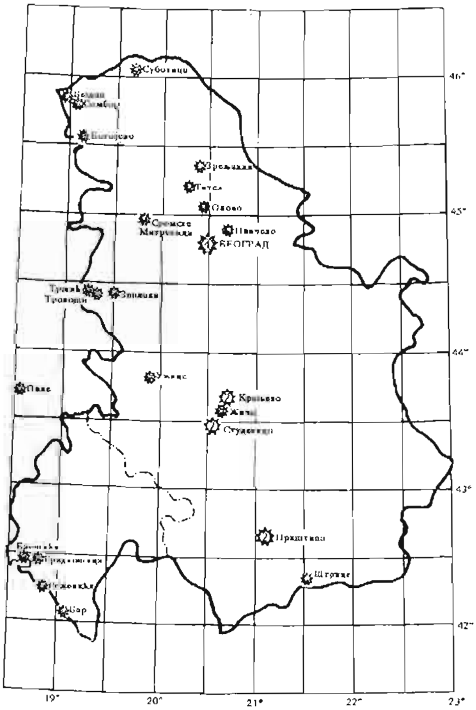

Fig. 1. The preliminary map of stationary sundials in Serbian lands.

Currently we do not dispose of sufficient data, such that would allow us to form any dependable idea of the sundials, extant or that have existed in the area of Serbia and Serbian lands. Their history can only fragmentary be reconstructed from the scarce specimens which have been preserved to our days and from fragments in the literature which, directly or indirectly, point to their existence. Table 1 is but a maigre framework for further researches in the history of gnomostics with us.

In what follows presented shortly will be our most interesting specimens of sundials, whereby we saw to it to avoid any repetition of what has already been written (Tadić, 1997).

2. CHRONOLOGICAL OVERVIEW OF OUR OLD SUNDIALS

The most ancient and most valuable found in our lands, is certainly the Roman sundial detected in 1981 at Sremska Mitrovica among the ruins of the Roman town Sirmium (Figs 2a, b).

Here we have to deal with an impressive sculptor composition consisting of marble, life-size, figures with a spherically carved sundial on their shoulders. Two of the figures – Atlantes and Heracles = recognizable at first glance, are no rarity in the antique sundials. The third figure might be Heracles' (half) tween brother Iphicles (Milošević, 1985) or Heracles' father Zeus (Tadić, 1988). The latter version is possibly nearer the truth: Atlantes – as the one holding the heavans – Heracles as the ruler of the Zodiac and a custodian of heavens Zeus – as the ruler of the heavens and finally the triade's crown, sundial – as infinitely diminished and reversed model of the same heavens.

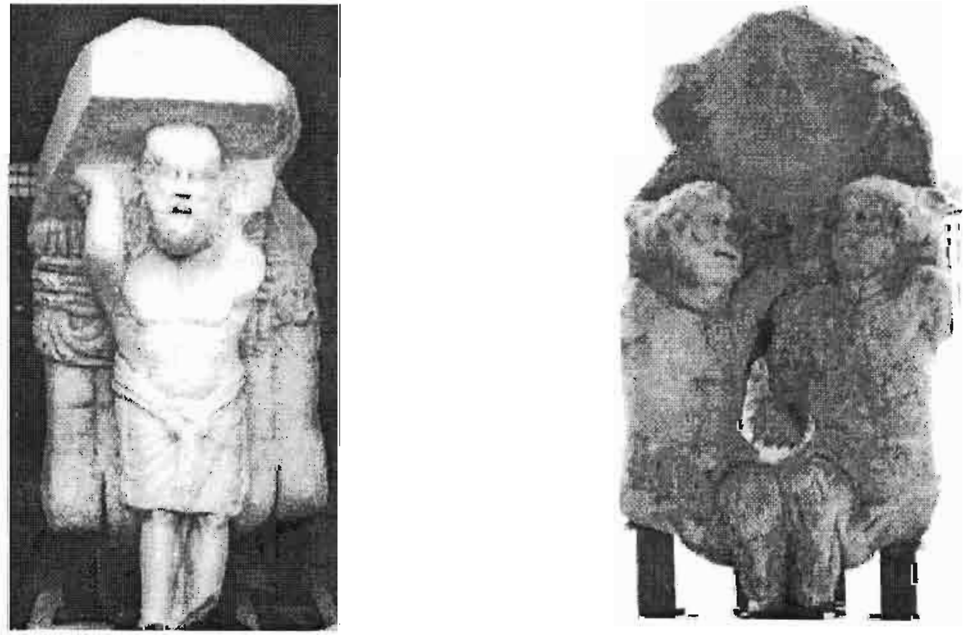

Fig. 2. Sculptor compositions: a) Atlantes and b) Heracles and Zeus (Iphicles?) with Sirmium's sundials on their shoulders.

Table 1. Sketch of chronology of gnomonics in Serbian lands.

Year or Century	Data relevant to the history of gnomonics with Serbs
7th c	Roman sundial in Sirmium – Sremska Mitrovica
1208	The earliest record of the Serbian word "Časovnik" (clock) in Hilandar typicon by St. Sava
1183-1196	Mediaeval sundial in Bogorodica (Our Lady) church in Studenica monastery
13th-15th c	A number of exact time specifications according to temporal hourly systems in the ancient Serbian records, epitaphs, genealogies and annals.
1404	The first ever mechanical clock in Russia at the Prince Court in Moscow, constructed by Serbian monk Lazar.
16th c	Data in the so-called "Bogišić manuscript" on the length of man's shadow in feet, according to months and temporal hours.
1746	Proceedings from an exact analysis by Rudjer Bošković (1711-1787) the Dubrovnikan J. L. Zuzorić published in Venice a treatise on the ancient Roman sundials of Beros type.
1828	Mural sundial in Zemun
1831	Mural sundial in Pančevo
1843-1852	Pictured mural sundial in Sombor, a work of the monk Jovan (Julian) Čokor (1810-1871).
1896	Mural sundial on the building of the German consulate in Belgrade.
1902	Prof. Milan Nedeljković published the book "Determination of time by means of sundials".
1931-1932	Prof. Vojislav Mišković (1892-1976) published an article "On sundials" in two parts.
1932	A horizontal sundial inside the Astronomical Observatory's grounds was constructed according to a design by prof. V. Mišković.
1934	Mural sundial (metal on brick) of the Orthodox boarding school in Belgrade, work of the architect Aleksandar Deroko (1894-1988).
1938	A second mural sundial of the same technique by architect A. Deroko on the Bishope's residence in Žiča Monastery.

The sundial is broken, less than half of the spherically carved base, with five hour lines which close the sectors for the 5th, 6th, 7th and 8th temporal hours. The celestial equator's projection cuts into halves the hour lines, an indication of the sundial having been adjusted to the altitude of the celestial pole above Sremska Mitrovica's horizon ($\varphi = 45^\circ$).

The triad with the sundial was dug out at the locality of an old Roman cemetery from the end of the First and the beginning of the Second centuries. Most probably it was within the structure of a mausoleum of some wealthy Sirmium's citizen (similar to Trimalhion in Petronyis Sotiricon).

Our only preserved sundial (Fig. 3a) is the one on the Bogorodica (Our Lady) church of Studenica monastery (Tadić, 1987). It is carved on the left pilistre next to the doorway of the south church vestibule, at about 4 m height. The semi-circle-shaped hour plate of 21 cm radius, is divided into 12 equal hour sectors. The sectors are numerated in Byzantine fashion by letters A, B, Г, Д, E, S, З, H. There is missing the last quadrant of the sundial, the one with the denotations Θ, I, IA, IB. There is no gnomon either, which must have been fixed perpendicularly on the wall, in the centre of the semi-circle shaped hour plate of the sundial (Fig. 3b).

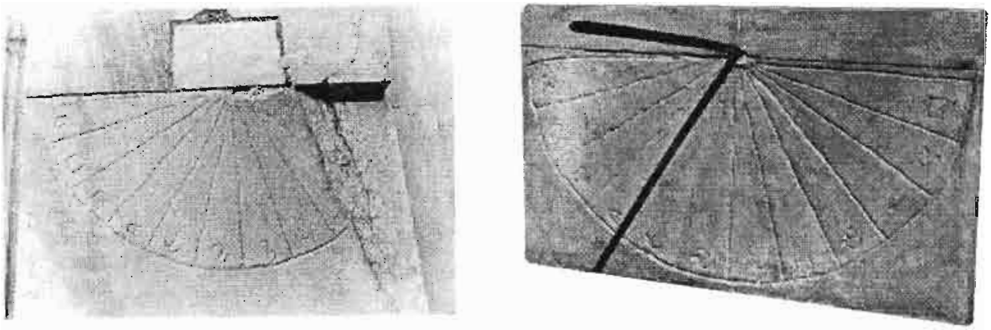

Fig. 3.

This kind of sundials with differing numbers of hour sectors (12, 8, 6, ...) have been manufactured on a massive scale in the Middle Ages. One may say that they were one of the peculiarities of that period. Strictly speaking these were not the sundials in the exact meaning of the word since their shadow did not conform with the temporal hour system then in force. On the other hand these improvised devices have by themselves, through their geometrically ordered dials, dictated a particular division of the day which, considering its duration of several centuries, might be taken as a particular hour system visual-temporal hour system.

The shape of the letters-numerals of the Studenica sundial suggests its being as old as the church itself, and this was built between 1183 and 1196.

No other medieval sundials have been preserved in the areas of Serbia and Serbian lands. Nevertheless their existence is indicated by numerous exact hour specifications in the medieval Serbian manuscripts. For fixing the first and the sixth – otherwise often mentioned – day's hours no sundial was necessary, they having been linked with the sunrise and the noon. But the mentioning of the ninth, third, fifth and seventh hour does not leave any doubt as to their existence. For example the hour of death of the Serbian king Dragutin (1282, at the ninth hour), the second Serbian patriarch Sava (1375, at the third hour), the emperor Lazar (1389, at the sixth or seventh hour), the despot Stefan (1427, at five hours by day).

The piece of information from the annals to the effect that the first mechanical clock in Russia was installed at the Prince's court in 1404 and that it was a work of the Serbian monk Lazar clearly betokens a tradition in Serbs of the clock workmanship. The medieval Serbian clock workmanship is atteszed to also by two sundials of "Studenica design" found on Hungarian territory. One of these is at the locality Rackeve (Serbian Kovin) on the wall of the Orthodox church whose foundations were laid by Serbs (Bartha, 1995). A similar one is on the Orthodox church in the village Grabocen (Bartha ....?). In their nortward mass migrations before Turks the Serbs carried with themselves in their memories also the Bysantine "recipe" of sundial making.

Preserved from the 16th century is the so-called "Bogišić" manuscript, containing data on the length of man's shadow in feet according to months, for each temporal hour (Novaković, 1884). These shadow leuths were determined for the fifth antique "climate", i.e. for the longest – 15 hours – of day-time (or according to Ptolemy, by the latitude $\varphi = 40°56'$).

Proceeding chronologically by leaps one should mention that Rudjer Bošković (1711-1787) was sporadically occupied with gnomonics too and that, to take an example, the Dubrovnikan J. L. Zuzorić (Zuzzeri) in 1746 published a treatment concerning the old sundial found among the ruins of an antique villa on the Rome's hill Tuscal, relying on a previous Bošković's analysis of this topic.

Of the sundials originating in the 19th century, of which we possess knowledge, particularly interesting is the mural sundial in Zemun from the year 1828 (Fig. 4a, b). Its polos has metalic footing and a two-part arc support adjustable to any wall irrespective of the wall's position. This simultaneously indicates that the Zemun gnomoner was not lacking orders, i.e. that this was not the only sundial he made.

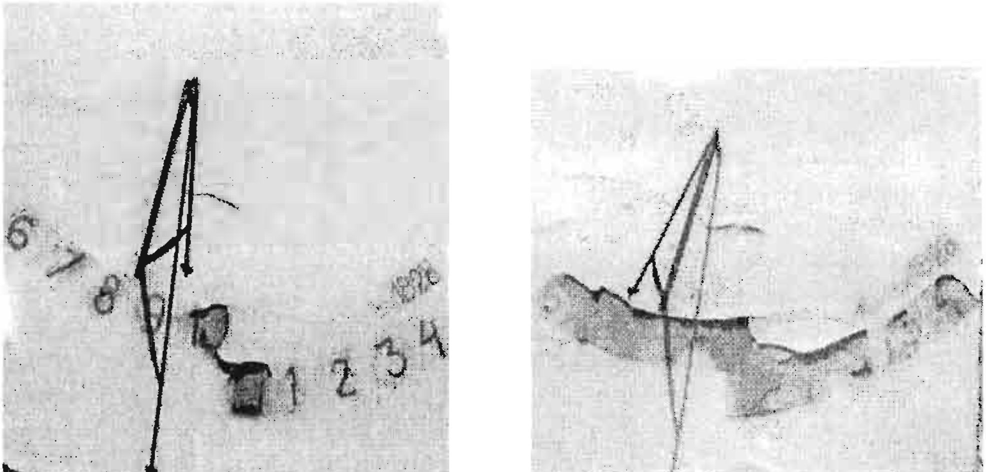

Fig. 4. a) The mural sundial in Zemun (1987), b) the mural sundial in Zemun (1997).

More important for the history of gnomonics (and astronomy) in Serbs is the pictured mural sundial in Sombor (Fig. 5a), made by the Serbian monk Jovan (Julian) Čokor (1810-1871) (Fig. 5b). between 1843 and 1852, while he was a professor and director of the local Serbian Teachers School (Jovanović, 1985). This sundial occupies an outstanding place – not thanks to its pictoral composition nor to its sarcastic motif – but because its hot-tempered author is considered the first amateur-astronomer with Serbs.

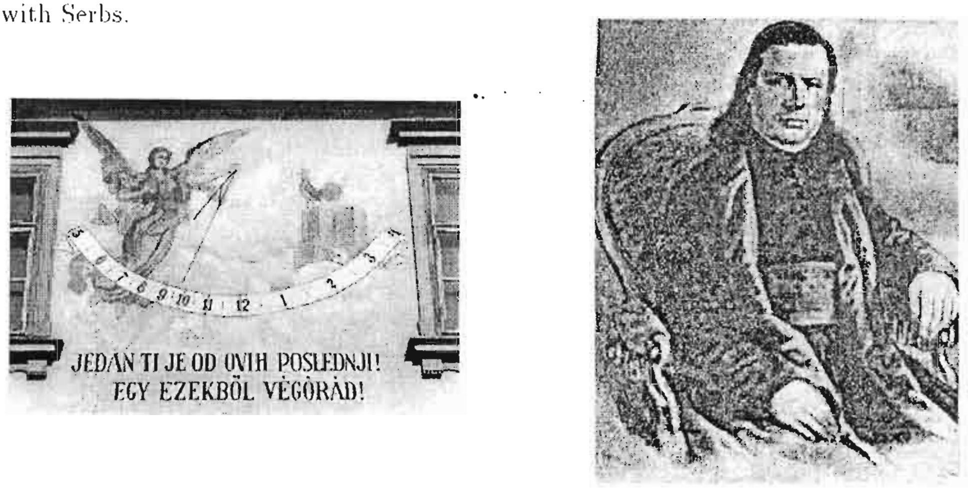

Fig. 5. a) The pictured mural sundial in Sombor. b) Jovan (Julian) Čokor.

The year 1887 saw the founding of the Astronomical and Meteorological Observatory in Belgrade. Its first director was Milan Nedeljković (1857-1950), a professor of astronomy and meteorology at the Grand School (University). Prof. Nedeljković published in 1902 the book "time determination with the aid of sundials". Nedeljković's book contains detailed instructions concerning the construction of the sundials, which were to serve in testing the accuracy of the clocks at the meteorological stations. The matter is in fact of gnomon and the determination of the true noon with it. This is but the first step in the construction of the sundial properly speking, something Nedeljković stated succinctly in the Supplement to the text, page VII, where he points out that when going over to the true sundial one is to draw hour lines by observing the gnomon's top "as the top of a fictive lever, inclined by the angle equal to the local latitude".

Nedeljković's successor, the second director of the Belgrade Observatory, professor Vojislav V. Mišković (1892-1976) published in "Godišnjak Našeg Neba" (Almanac of Our Sky) for 1932 an article "On sundials", to put it into effect next year by constructing within the newly built Observatory on Veliki Vračar a horizontal sundial (Fig. 6). This is the only sundial known to have been constructed by a professional astronomer. The sundial is located on the Observatory's meridian, midway between the pavilions of the Large and Small refractors. The stone plate (50 × 50 cm) is still there. No polos is there as the sundial is on a busy path, in particular by night.

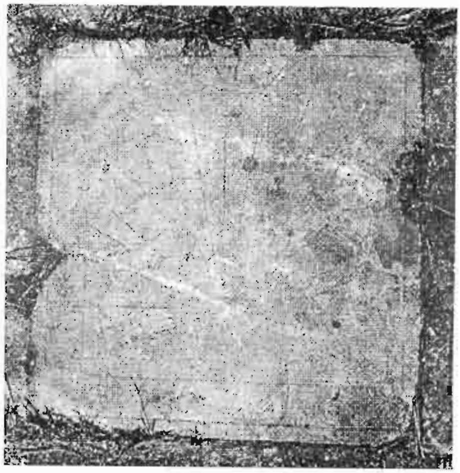

Fig. 6. The horizontal sundial on Astronomical Observatory.

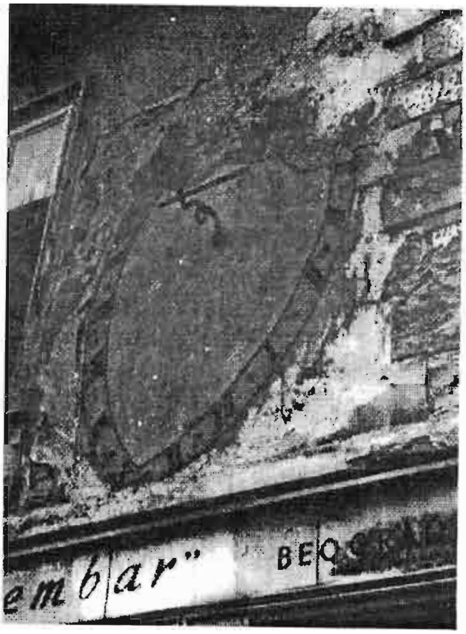

Fig. 7. The mural sundial in Pančevo.

In the following issue of the same almanac Mišković published the continuation of the article in which he gave instructions for making vertical sundials of all orientations. The two writings of profs. Nedeljković and Mišković are significant because in them we find defined, for the first time with us, the basic notions of the gnomonics.

In considering by inertia as "old" all the sundials before the Second World War let us conclude this presentation by mentioning the mural sundial on the Orthodox boarding school in Belgrade (1934) and the mural sundial on the Bishope's residence in Žiča monastery (1938) constructed by our eminent architect Aleksandar Deroko (1894-1948).

3. CONCLUSION

The medieval hour determination tradition was established in Serbian lands – Studenica sundial marking its beginning and the monk Lazar's Moscow clock its culmination. All this was interrupted by the Turk invasion. Under the Turkish rule the Serbs, with their "hands on sward" were cut off from the normal communications, thus from the general progress that meanwhile was making great strides in Europe. This is in part some explanation of why there is an obvious scarcity of sundials in Serbian lands. But this very circumstance imposes an obligation for their systematic protection.

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Publ. Astron. Obs. Belgrade No. 60 (1998), 226 – 229 *Poster*

MILAN J. ANDONOVIĆ (1849-1926) AND HIS CONTRIBUTION TO THE DEVELOPMENT OF ASTRONOMY AMONG SERBS

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Abstract. The name of Milan J. Andonović (1849-1926), Professor of Geodesy at the Grand School and University of Belgrade, is closely related with the development of astronomy among Serbs in the second half of the 19th century.

His most important work is a textbook for higher forms of secondary and teacher schools entitled "Kosmografija sa osnovnim astronomskim napomenama" (Cosmography with basic Astronomical Notes). In it the author using the contemporaneous astronomical literature succeeded in synthetising almost all the knowledges which were at the top of actuality in astronomical science. This book, published in Belgrade in 1888 and printed in the Royal Serbian State Printing House, was a real publishing achievement of that time: it has 530 pages, 25 tables and 141 figures. All was done following the manner of the best European textbook editions.

As a versatily educated person and following the progress of European scientific thought he considered that "the science of the universe" was a progressive one, a "powerful means in educating" and that it "makes superior by its very content everyone dealing with it".

It is difficult to say decisively what are prerequisites leading to the growth of knowledge in some fields of human activity, although the modern science of sciences has a standpoint of exact classification of premises.

However, as for the historiographic factors, they are undoubtedly decisive (in both positive and negative senses) to the development of general and special educating systems within a social community.

In Serbia of 19th century a few historical turnpoints and dates were important to her educational system.

From the fall of the Serbian medieval states till 1804 "even in hundred villages there were not a single school in any of them" as said by Vuk Karadžić (1852), except in monasteries.

One may say that only from 1830, with the proclamation of "Hatišerif", there begins free opening of schools which about 1841 reached a significant number in Serbia, as many as 631 (Janković, 1990; Karić, 1886). In 1833 a document concerning public schools within the Principality of Serbia ("Ustav narodni škola") was proclaimed by Prince Miloš. There is another similar document from 1844 ("Ustrojenije javnog učilišnog nastavlenija") by which the teaching in all schools in the Principality of Serbia was defined. In this connexion detailed programmes for primary and secondary schools were enacted, on the basis of which use was made of textbooks that were either compilations or translations of the most reputed foreign ones of that time. Besides, Serbian teachers and eminent experts of that time wrote their own textbooks. The tradition of science teaching in primary and secondary schools was largely developed. This, of course, concerns the "matematičko, fizičko i političko zemljopisanije" (mathematical, physical and political geography) within which the astronomical knowledges were also taught. Astronomical contents were also present in the physics textbooks.

A sufficiently important change took place in 1863 when according to a law concerning gymnasiums ("Zakon ustrojstva gimnazija") among the subjects was envisaged "matematičko i fizičko zemljopisanije" (mathematical and physical geography). In 1873 according to an amendment to this law geography should have be taught together with cosmography, in the 2nd, 3rd and 4th forms of gymnasiums (including both types, grammar and real ones) (Janković, 1990).

The need of adequate and adapted-to-time textbooks was very sharp so that beginning with 1850 during the next 50 years there appeared a number of them. In them astronomical topics were treated more or less successfully.

In the pleiad of the most prolific writers of textbooks and, in general, books containing astronomical topics from the mentioned period, in addition to Milan J. Andonović, there were also Jovan Dragašević, Vladimir Karić, Djordje Stanojević, Milan Nedeljković, Vuk Marinković and others.

In the entire textbook series of that time the most important is the one having appeared in Belgrade in 1888 entitled "Kosmografija sa osnovnim astronomskim napomenama" (Cosmography with basical Astronomical Notes) for higher forms of secondary and teacher schools by Milan J. Andonović (1849-1926), Professor of Geodesy at the Grand School.

Who was Milan J. Andonović? He graduated from the Engineering Faculty of the Belgrade University, continued his engineering education in Karlsruhe and Aachen as a holder of a state scholarship. For some time he was engaged as a real- gymnasium teacher in Belgrade (1875-1878). Then he left for Munich to join the Polytechnic University. There he acquired and widened his knowledge in geodesy and kindred sciences. In 1885 he became a lecturer of geodesy at the Grand School in Belgrade. There he founded the Geodesy Department; he also founded a private Academy of Geodesy and Civil Engineering.

Taward the end of his life he became an honorary member in the Royal Serbian Academy of Sciences.

He was an important person, man of practice, excellent exspert in many scientifical fields and a good pedagogue. He appears as the author of several papers on geodesy and kindred sciences; he also wrote statements with political contents, especially those concerning the national question.

The most important papers of Milan J. Andonović dealing with astronomy and geodesy are:

"Kosmografija sa osnovnim astronomskim napomenama" (Cosmography with basical Astronomical Notes), Beograd 1888;

"O kosmosu" (About Cosmos), Beograd 1889;

"Niža geodezija sa osobitim pogledom na katastarski pregled" (Lower Geodesy with a Special Reference to Cadastre Surveying), Beograd 1890;

"Oblik i veličina Zemlje" (Shape and Size of Earth), Beograd 1886;

"O obliku i veličini naše Zemlje" (On the Shape and Size of Our Earth), Beograd 1889;

"Osnove računa verovatnoće i teorije najmanjih kvadrata" (The Fundamentals of the Probability Calculus and of the Least-Square Theory), Beograd 1886.

As already said, Andonović's *Cosmography* is among the most important and most complete textbooks in Serbia of that time. Printed in Belgrade in the Royal Serbian State Printing House and prepared in a manner following the best European textbook editions it was a true publishing accomplishment of that time (Fig. 1). It contained 530 pages, 25 tables, 141 illustrations within the text and 5 out of text. A suitable map entitled "Polutarska zona i zodijak" (Equator Zone and Zodiac) was also given. For these illustrations Milan Andonović expressed his gratitude to Dr E. Weiss, Director of the Vienna Observatory, "who was very glad to take on to adorn this work with illustrations from his most recent work".

Using the astronomical literature actual at that time, above all the works of Wetzel, Müller, Klein, Bruns, Littrow and of a few others, he succeeded to synthetise in this textbook almost all the knowledge of current interest at that time in astronomy.

Accepting the "science on universe as a powerful means in education" Milan Andonović wished through this work to elevate "the school literature of that time towards that height at which it is also in the other progressive world" and simultaneously to make more easy and convenient for his pupils the studying of this science.

Giving at the beginning of his well conceived (but also too high priced) textbook "A Word in Advance" (preface) Andonović says:

"The science on universe as a natural science puts and leads a human being into the nature. It elevates and makes lofty by its very substance everyone engaged in it, it puts a human being to a viewpoint at which the natural, sound and true observing, as well as conceiving, of things is also possible."

In what follows he notes that he has enriched the cosmographical terminology by introducing new expressions and considers that "all necessary is to be denoted by Serbian terms", but unclear points appear for which he gives parallelly also the earlier terminology.

This textbook consists of eight parts in the framework of which there are 24 chapters and 181 sections. This time we shall not enter in details the analysis of the contents, but we present the titles of the chapters whence one can get an insight into what was comprised by the author with this book. Here are the contents: I. Star Sky, Rotation and Division of Celestial Sphere, II. Astrognosy of Visible Star Clusters, III. Shape and Size of our Earth, IV. Rotation of the Earth, V. Coordinate System in Astronomy, VI. Annual Solar Motion, VII. Annual Motion of the Earth around the Sun, VIII. Mathematical- geographical Notes, IX. On Time in General, X. On Counting, Time Division and Calendar, XI. Fixed Stars, XII. On the Solar System in General, XIII. On the Sun, XIV. The Major Planets, XV. Physical Description of the Major Planets, XVI. Moderate-Size Planets, XVII. "Tailed Stars" (Comets), XVIII. "Starlike Objects" (Meteorites), XIX. Nebular Halo (Zodiacal Light - the author's note), XX. Solving of a few Problems, XXI. Problems, XXII. Perturbations in the

Solar System and in General, XXIII. Tide and Ebb, XXIV. Notes on the Origin of the World.

These copious contents of the book miss an essential section - that dedicated to astronomical instruments and methods. Probably because the author planned to publish it two years later in another textbook entitled "Lower Geodesy with a Special Reference to Cadastre Surveying".

We note that the mathhematical methods applicable in astronomy found their place in the already published work "The Fundamentals of the Probability Calculus and of the Least-Square Theory".

Going to make this set of topical problems to broad public as close as possible Milan Andonović delivered popular lectures at the Grand School. On the shape and size of the Earth he delivered two lectures - the first one was printed in 1886 and the second one, delivered on December 18, 1888, was printed after one year. In these lectures he presented in an interesting way the knowledge on this matter by that time, beginning with the positions of the ancient peoples towards "European Measurements of Meridian Arc Length and Further Progress". Then he gives explicitely "the foundations on which it is concluded that the Earth has a spherical shape".

His public lecture "About Cosmos", printed in Belgrade in 1889, is a rich illustrated technical and poetical collage concerning the state of knowledge and importance of the "science of universe". On about 30 pages followed by a large number of illustrations (a total of 34) the author described our Solar System (Sun, Moon, planets, comets, meteors and zodiacal light) in an interesting way by using verses of poets inspired by the universe and celestial bodies (Dragaš, Lj. Nenadović and J. Jovanović-Zmaj).

At concluding this lecture he says "a detailed contact with individual celestial bodies, and approach to their mutual influences, and also learning of inevitable consequences of all of these influences, will be subject of later lectures".

At the end we should remember what was said by Andonović on the science of the universe: "The science of the universe is a progressive sience. It makes progress every day, its contents is being enlarged, the results obtained by it become every day more complete and more accurate".

Thus were formulated these sentences at the end of the last century. At the very end of the present century we are witnesses of an exceptional blossom of sciences and of incessant and fruitful successes of the astronomical thought.

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ASTRONOMICAL ORIENTATION OF SKELETONS IN THE EARLY ENEOLITHIC NECROPOLIS AT PODLOKANJ

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Abstract. In this paper analysis of orientation distribution will be presented concerning ten skeletons in the Podlokanj-Južne bašte necropolis. Data acquired this way support the theory that members of the Early Eneolithic Tiszabolgár-Bodrogkeresztúr culture orientated their dead toward the point of actual sunrise.

1. INTRODUCTION

The presence of the skeleton/grave orientation toward the azimuth of sunrise or sunset has been confirmed in case of several prehistoric necropoles. Orientation measurements have been conducted on Neolithic, Early Eneolithic and Bronze Age necropoles and it has been determined that skeletons are frequently being orientated toward the cardinal points of azimuth or the sunrise/sunset azimuth on the day of the burial (e.g., Schlosser and Čierny, 1982; Barlai, 1992; Barlai and Bognár-Kutzián, 1995; Vince *et al.* 1996).

Points of sunrise and sunset are on the exact east and west only on two days in a year, at summer and winter equinoxes. In the summer, sunrise azimuth moves toward the north, and in the winter toward the south. Degree of these deviations depends on latitude of the necropolis and the time of the year when the burial took place.

Having taken these facts into the consideration and assuming that there was a ritual of sunrise/sunset determined burials, then the exact position of the sun - the actual point of sunrise on the day of death or burial, would have to be established for the purpose of orientating the skeleton axis. If we analyse the angular distribution of skeleton orientation and then compare these results with the sunrise/sunset azimuth on the given latitude, we can establish a relation between burial customs and the azimuth of the actual sunrise (Vince *et al.* 1996).

2. THE NEKROPOLIS AT PODLOKANJ

The Podlokanj-Južne bašte excavation site is located in the northern region of Banat, at the junction of Yugoslav, Romanian and Hungarian border, at About 20 degrees east longitude and 46 degrees north latitude (Fig. 1). The necropolis belongs to the Early Eneolithic Tiszabolgár-Bodrogkeresztúr culture. During the excavations carried out in 1996. twelve graves were discovered containing skeletons in contracted position. Male skeletons were placed on the right, and female on the left-hand side.

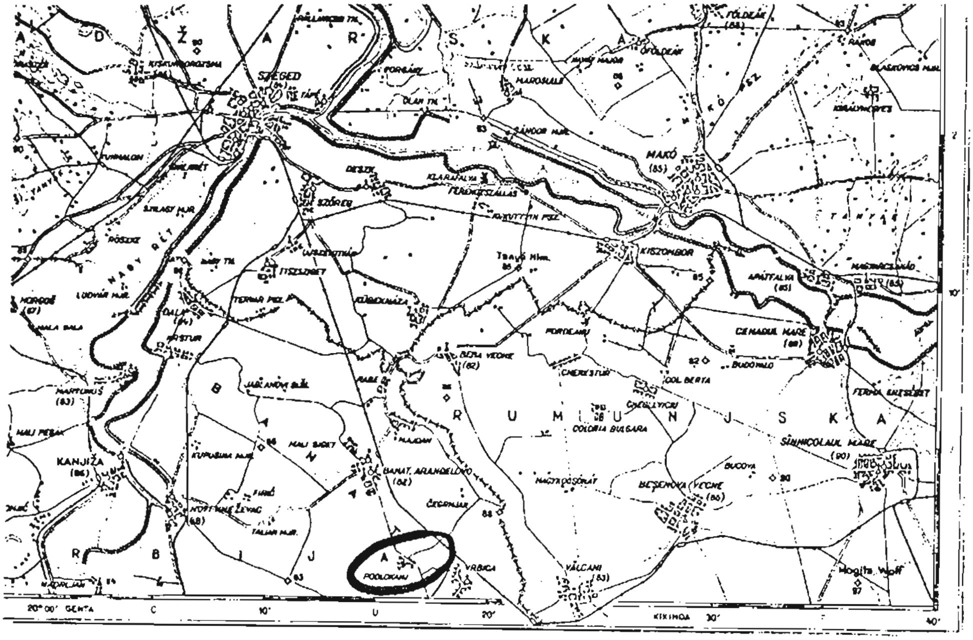

Fig. 1. Geographical position of Early Eneolithic Age nekropolis at Podlokanj.

The angle of skeleton orientation was determined on the basis of drawings of graves acquired from Grčki-Stanimirov (1997). The angle between the skeleton axes, determined by spinal column, and geographical north was measured clockwise (from north toward the east). Out of twelve excavated skeletons, the orientation was determined for ten (5 male and 5 female). In remaining two graves (graves No. 6 and 10) the bones were dislocated wich made determining orientation imposible.

Distribution of orientation angles and the number of skeletons are presented on histogram, while the difference of sunrise azimuths at summer and winter solsticies is presented by a horizontal bar (Fig. 2). The width of orientation distribution is almost identical to the difference of sunrise azimuths at summer and winter solsticies. The only two exceptions are graves No. 4 and 2, with deviations of few degrees. These deviations can be atributed to an error prehistoric gravediggers or/and archaeologists could have made when measuring the orientation of a grave. The results acquired indicate that bodies were orientated toward the azimuth of the sunrise on the day of their death or burial. Other researchers have came to similar results (Barlai, 1992; Barlai and Bognár-Kutzián, 1995).

Former studies indicate that mortality rate in spring and autumn is higher then in other seasons of the year. This has been a rule from prehistory untill this day, though that rate must have been higher in prehistory due to the unsanitary conditions (Barlai, 1992). As seen on the histogram, the skeleton angular distribution is orientated in the east-west direction, with three peaks: spring/summer, spring/autumn and autumn/winter peak. Mortality rate was the highest (60%) during the spring/autumn months (March/September and mid June), and the lowest (10%) during autumn/winter months when only one person was buried (in December). The other histogram peak shows increased mortality (30%) during spring/summer months (April/Septembar, May/August, May/July).

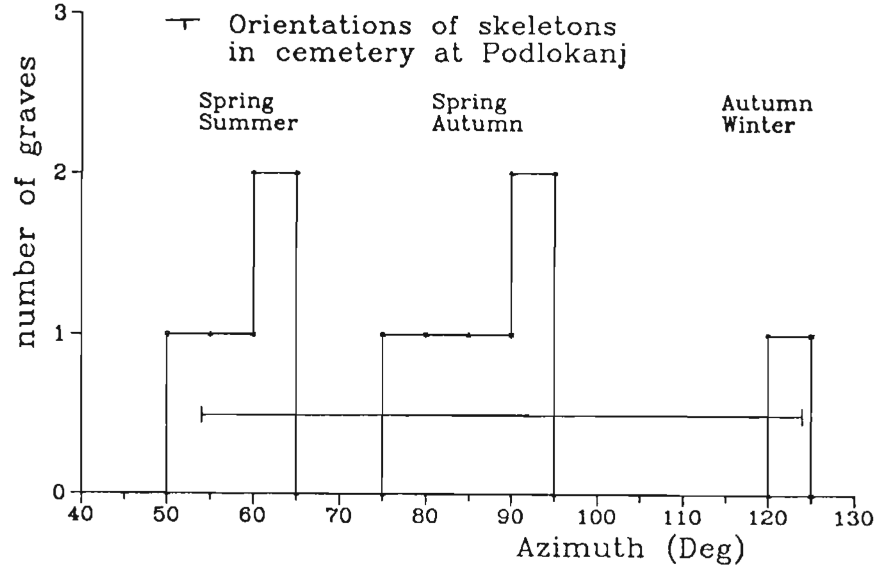

Fig. 2. Orientations of skeletons in necropolis at Podlokanj.

We could either assume that mortality during cold periods of the year was minimal or that due to the hardness of frozen soil graves were being dug only on special occasions (similar conclusion was drawn in case of the Gomolava necropolis as well (Vince *et al.* 1996)). If we take the second assumption as correct then questions like where were the bodies of those who died in winter baried or where were they kept untill the weather was more favorable, remain to be answered.

Differences in grave dimensions can be established on account of drawings of graves (Grčki-Stanimirov, 1997). At this stage it is important to mention that none of the graves is a child grave (assertion based on femur measurements) so that can not effect our further analysis. Assumption that smaller graves were dug during the colder period of the year, when ground was hard and frozen, has been examined and partly confirmed. For that purpose time of the burial was estimated and than compared with dimensions of the grave. This comparison showed that, within one sex group, larger graves were indeed dug during warmer periods of the year (Tab. 1). However, another interesting relation is this way revealed - as a rule female graves are larger than male ones (for 41 cm on average). Naturally, this could be attributed to the fact that female skeletons were accompanied with a greater number of ceramic vessels, but that did not seem to be crucial (e.g., Tab. 1., graves No. 11 and 9 with the same number of ceramic vessels). If they had another, maybe less practical reason, for making female graves larger, ramains to bee seen.

Table 1. The angle of skeletons, periods of the burial and grave dimensions data.

FEMALE

Grave	Angle of skel.	Burial date	Lenght (cm)	Width (cm)
4	53°	June 15	200	95
1	82°	April 2-3/September 10	160	140
9	87°	March 24-25/September 19-20	160	100
12	90°	March 19-20/September 24-25	145	95
2	122°	December 4-6	140	110

MALE

Grave	Angle of skel.	Burial date	Lenght (cm)	Width (cm)
7	55°	June 6-11	155	115
13	62°	May 13-15/July 30	125	80
5	78°	April 9-10/September 3	110	75
8	92°	March 15/September 28-29	105	55
11	63°	May 9-12/August 1-3	105	55

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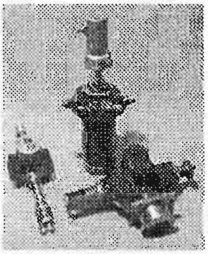

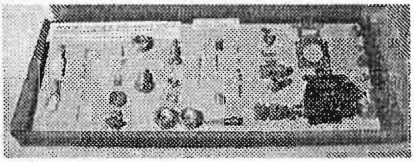

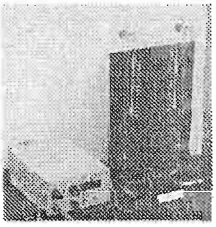

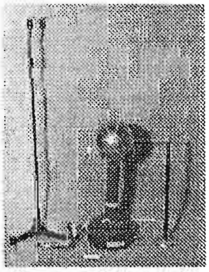

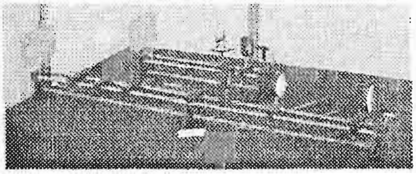

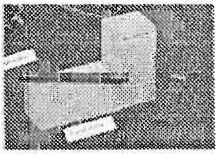

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