1. SOME OF THE MAIN RESULTS OF THE OBSERVATORY'S RESEARCH ACTIVITY

If one takes into account that the best contributions to the science, are those published in international journals, a review of results of Belgrade Astronomical Observatory's fellows having appeared in these publications will be presented, as well as catalogues which are commonly the results of an effort of many years, and represent a particular interest to the astronomy.

The interest for a very extensive list of line broadening data is particularly stimulated by the development of space astronomy where an extensive amount of spectroscopic information over large spectral regions of all kind of celestial objects has been and will be collected, stimulating the spectral–line–shape research.

It is difficult to state in general terms which are the relevant transitions since the atmospheric composition of a star is not known a priori, and many interesting groups of stars exist with very peculiar abundances as compared to the Sun. Consequently, stellar spectroscopy depends on very extensive list of elements and line transitions with their atomic and line broadening parameters.

In order to provide the corresponding atomic data for stellar envelope opacities calculations, an international "Opacity Project" providing essentially data on energy levels and oscillator strengths for a large number of atoms and ions, and a number of photoionisation cross sections and Stark broadening data as well, has been formed in 1984 . After the end of this project the subsequent "Iron Project" will provide data on electron impact excitation cross sections for atoms and ions along isoelectronic sequences. In order to complete as much as possible such data needed for astrophysical and laboratory plasma research and stellar opacity calculations, Dimitrijević and Sahal-Bréchot are making a continuous effort to provide Stark broadening data for a large set of atoms and ions. In Dimitrijević (1996), a programme to provide as much as possible complete set of Stark broadening data needed for stellar and laboratory plasma research has been exposed and results obtained up to now as well as the future plans have been discussed.

Stark broadening of S III and S IV lines has been considered several times experimentally and theoretically due to the increasing significance of the multiply – charged ion lines for research and modelling of hot, dense astrophysical and laboratory plasmas. Dimitrijević, Djeniže, Srećković and Platiša (1996) have investigated experimentally and theoretically Stark broadening data for lines from S III 4p-5s transition, not experimentally investigated up to now. The experimental results are compared with the theoretical results calculated by using the modified semiempirical approach, the approximate semiclassical approach and its modification. Since for

S IV, the new atomic energy level data enabling the full semiclassical perturbation calculation become available, the S IV lines have been considered as well.

Temperature dependence of the Stark widths (N III and F V) and shifts (N III and O IV) of the $3s^2S - 3p(^1S)^2P^o$ and $3p^2P^o - 3p(^1S)^2D$ transitions have been studied theoretically using the impact semiclassical method and experimentally observed in the plasma of a low pressure pulsed arc by Blagojević, Popović, Konjević and Dimitrijević (1996). Plasma electron densities were determined from the width of the He II P_α line while electron temperatures were measured from the relative line intensities.

To estimate the influence of different ions on the width and shift of the considered lines, evaluations of the plasma composition data were performed and, in conjunction with the theoretical results of Blagojević, Popović, Konjević and Dimitrijević (1996), the contribution of ion broadening was estimated. Within the estimated uncertainties experimental Stark widths agree well with the results of the obtained semiclassicall electron impact widths in the studied electron temperature range. For the conditions of the present experiment, estimated contribution of the ion broadening has never exceeded five percent of the total width. So, within the precision of this experiment it was not possible to detect its presence with certainty.

Along the boron isoelectronic sequence the experimental widths and shifts agree with semiclassical electron impact data predictions. In the case of O IV lines the inclusion of the energy levels with different parent terms in the semiclassical calculations of the Stark widths and shifts improved the agreement between theory and experiment considerably. Comparison of the experimental widths with simple theoretical formulas for estimation of plasma broadened linewidths show an agreement within the estimated uncertainties.

Line profiles study of carbon ions in different ionization stages is of importance for astrophysics due to the high cosmic abundance of carbon and due to the presence of spectral lines from its various ionization stages. Stark broadening parameters for C V lines are needed especially for hot and dense stars. A good example are PG 1159 pre-white dwarfs with effective temperature 100,000 – 140,000 K where carbon and helium are the dominant constituents (C/He = 0.5). Stark broadening of C V lines is also of interest for the diagnostic of laser-produced plasma and for the research of regularities and systematic trends. For such research of interest are P V lines as well. Recently e.g., estimates of the Stark widths for P V 4s-4p and 4p-4d transitions have been performed in a study on Stark broadening regularities within successive ionization stages of phosphorus, performed in 1990 by Srećković and co-workers.

Dimitrijević and Sahal-Bréchot (1996a), performed within the semiclassical-perturbation formalism an analysis of electron-, proton-, and ionized helium-impact line widths and shifts for 25 C V and 51 P V multiplets. Obtained results have been compared with other available theoretical data.

Lines of neutral magnesium are present in the Solar spectrum and the corresponding Stark broadening parameters are of interest for their analysis as well as for the diagnostic of Solar plasma. Especially the infrared lines of Mg I have been observed in the Solar spectrum at Kitt Peak and during the Atmos experiment on Spacelab. Due to the suitability of these lines for the solar atmosphere investigations and to the fact that with the increase of the principal quantum number the importance of Stark

broadening increases too, the corresponding Stark widths and shifts are of importance for the structure of the Solar atmosphere research and solar plasma diagnostic. Stark broadening data for Mg I lines are also of interest for laboratory plasma research and they have been investigated experimentally and theoretically in a number of papers. By using the semiclassical-perturbation formalism, Dimitrijević and Sahal-Bréchot (1996b) have calculated electron-, proton-, Mg II-, Si II-, Fe II-, and Ar II-impact line widths and shifts for 267 Mg I multiplets at an electron density of 10^{11} cm^{-3}, in order to provide the needed Stark broadening parameters of all important perturbers for investigation and modelling of Solar plasma. In order to check the applicability of Coulomb approximation method for the calculation of oscillator strengths, line width calculations with line strengths from TOP base (the complete package of the opacity project (OP) data with the database management system is usually referred to as TOP base), have been performed for particular cases as well. The conclusion is that for transitions between low levels small differences do exist. However, for lines that are of interest for solar infrared astrophysics, corresponding to transitions between high levels, the use of Bates and Damgaard oscillator strengths is sufficient for line widths.

Regemorter and Hoang Binh have discussed recently the important simplification of theory for solar Rydberg lines corresponding to the transitions between nearly degenerate states, where the differences of energy $E(n\ell, n\ell+1)$ are of the order of a few cm^{-1}. These energy differences are much larger than the width so that the considered lines are isolated. They are however considerably smaller than the energy distances to the other perturbing levels $n'\ell'$ which may be neglected so that the Stark broadening problem corresponds to a simple three level close coupling system including $n\ell, n\ell+1$ atomic energy levels. This approximation has been tested in detail. The analysis shows that the inelastic collision contribution practically does not vary with the addition of new perturbing levels and that the variation of strong collision contribution is also of the order of several percents. The elastic collision contribution has however a nonnegligable dependence on the perturbing level number. Since for solar Rydberg lines the elastic contribution to the width is by an order of magnitude smaller in comparison with other considered contributions, one may conclude that the approximation of Regemorter and Hoang Binh is very good for Stark widths of the considered lines. Since the elastic collisions have an important role in the Stark shift determination, for Stark shifts such approximation may become questionable.

Stark-broadening parameters for singly charged lithium lines are of particular interest for Stark broadening theory investigations since the He-like Li II spectrum is suitable for theoretical research. They are of interest for the examination of regularities and systematic trends within He isoelectronic sequence as well. For the systematic study of such regularities within an isoelectronic sequence we need the corresponding data for as much as possible larger number of successive ions and Li II is the first He - like ion of the series. Moreover, Stark broadening parameters of ion lines are of interest for solar and stellar opacities calculations, investigations of subphotospheric layers, stellar plasma modelling and diagnostic, abundance determinations, etc.

Dimitrijević and Sahal-Bréchot (1996c), have determined and analyzed electron-, proton-, and ionized helium-impact line widths and shifts for 29 Li II mul-

tiplets. The obtained results have been compared with the semiclassical results of Jones, Benett and Griem.

The analysis shows that the agreement between present calculation and calculations of Jones, Benett and Griem is better at higher temperatures, when the inelastic contribution to the width dominates, than at lower ones, when differences in cut-off procedure and the symmetrization influence are more significant.

Generally, the disagreement of present calculations with the calculations of Jones, Benett and Griem is greater than for He I. When we have transitions involving highly excited levels, when a close perturbing energy level exist, the Debye screening (not explicitly taken into account by Jones et al., but the corresponding correction is indicated) reduces present widths and shifts. Namely, for transitions involving highly excited levels (n, ℓ), the closest perturbing levels are $(n, \ell + 1)$ and $(n, \ell - 1)$. The difference of energy between (n, ℓ) and $(n, \ell + 1)$ or $(n, \ell - 1)$, which decreases when n increases becomes small. The dominant contribution to the widths and shifts come from the transitions $[(n, \ell) - (n, \ell + 1)]$ and $[(n, \ell) - (n, \ell - 1)]$. Typical impact parameters increase for the width and for the shift as well. Therefore the effect of the Debye shielding can not be negligible and reduces the widths and shifts. Likewise, at high densities the Debye length decreases and the width and shift linear behaviour with the density is no longer valid.

Finally the systematic trends of Stark broadening parameters within the $2s^3S$ - np^3P^o series have been investigated. The analysis shows a gradual change of Stark broadening parameters permitting the interpolation of new data or critical evaluation of mutual consistency of existing data.

By using the semiclassical-perturbation formalism Dimitrijević and Sahal-Bréchot (1996d), have analyzed electron-, proton-, and ionized argon-impact line widths and shifts for 31 multiplets of neutral selenium. The obtained results have been presented and discussed.

The Be III and B III lines are also present in stellar spectra. The Be III Stark broadening parameters are additionally interesting, since the surface content (abundance) of Be, involves problems correlated with nucleogenesis, mixing between the stellar atmosphere and interior, and stellar structure and evolution. Line profiles of Be and B in various ionization stages, are of interest for opacity calculations as well. Within the semiclassical-perturbation formalism Dimitrijević and Sahal-Bréchot (1996e), have considered electron-, proton-, and ionized helium-impact line widths and shifts for 12 multiplets of Be III and 27 multiplets of B III. The obtained results have been presented and compared with available experimental and theoretical data.

Strontium lines are present in solar and stellar spectra. E.g. Komarov and Basak (1993) have found neutral strontium lines in the spectra of Sun and two Praesepe's stars. They are also of interest since Sr is one of thermonuclear s – processes product in stars and its overabundance is observed in CH and metal deficient barium stars. Neutral strontium lines are also of interest for the investigation of laboratory plasmas. E.g., Sr I lines have been considered theoretically by Davis (1972), for research of a laser – generated barium plasma. In order to continue the research of Stark broadening parameters needed for the investigation of astrophysical and laboratory plasmas and to provide the needed Stark broadening data, Dimitrijević and Sahal-Bréchot (1996f),

have considered within the semiclassical-perturbation formalism electron-, proton-, and ionized helium-impact line widths and shifts for 33 Sr I multiplets.

In order to provide astrophysicists with the relevant data needed for the theoretical modelling of stellar spectra and stellar atmospheres, as well as for abundance determination and opacity calculations, also for atom and ion lines for which the semiclassical perturbation formalism cannot be applied in the appropriate way due to the lack of reliable data for the needed atomic energy levels, Popović and Dimitrijević (1996a) applied to such cases the simpler, modified semiempirical approach. They analysed the Stark broadening of As II, Br II, Sb II and I II spectral lines. For these heavy ions a sufficiently complete set of reliable atomic data for more sophisticated semiclassical calculations does not exist. Although, in general, abundances of heavy elements are low, the lines are present mainly in the spectra of CP stars, as e.g. very strong absorption lines in spectra of Hg-Mn star HR7775. The obtained results have been compared with available experimental values and with simple estimates. The improvement of the accuracy of the presented data, by the corresponding scaling using the knowledge on regularities and systematic trends, has been discussed as well.

Spectral lines of Xe II are present in spectra of hot Hg-Mn stars, where Stark broadening is the main pressure broadening mechanism. On the basis of analysis of the Xe II spectral lines, one can conclude that the abundance of Xe in Hg - Mn stars is about two times higher than in the Sun. Stark broadening of Xe II lines is important for laboratory plasma as well and a number of experimental and theoretical papers concerning Stark widths and shifts of Xe II lines have been published. Popović and Dimitrijević (1996b) have analyzed the Stark broadening within 20 Xe II multiplets, by using the modified semiempirical approach. The obtained results have been compared with numerous experimental and theoretical data.

Spectral lines of Sc II, Y II and Zr II are present in spectra of ϕ Her and o And, as well as in other hot stars. Lines of these ions are also observed in the Solar spectrum. Within the modified semiempirical approach, Popović and Dimitrijević (1996c) have analyzed Stark widths for 18 transitions of Sc II, Y II and Zr II, which are needed for stellar atmospheres investigations. The obtained results have been compared with simple estimates based on regularities and systematic trends. Conditions in hot stars atmospheres where Stark broadening is comparable to Doppler broadening or even larger, have been discussed as well.

On the basis of the semi-classical theory, the influence of $He + He^+ + e$ and $He_2^+ + e$ recombination and $He + He^*(n)$ ionization on the population of $He^*(n)$ atoms in helium plasma was considered by Mihajlov, Djurić and Dimitrijević (1996) and the corresponding rate coefficient were determined.

The principal result of the article is the demonstration of the fact that, previously neglected recombination processes

$$He_2^+ + e \Longrightarrow He^*(n) + He$$

$$He^+ + He + e \Longrightarrow He^*(n) + He,$$

in low temperature plasma, are important and in particular cases even dominant factor influencing the population of highly excited $He^*(n)$ atomic states. This fact is

stated by the comparison of these processes with the well known electron - electron - ion recombination processes. Similar but less significant fact is stated for the chemi - ionization processes

$$He^*(n) + He \Longrightarrow e + He_2^+$$

$$He^*(n) + He \Longrightarrow e + \begin{cases} He^+ + He \\ He + He^+ \end{cases}$$

The results are obtained for nonequilibrium He plasmas with atomic temperature T_a and electronic temperature T_e, within the ranges $2000\text{K} \leq T_a \leq 10000\text{K}$ and $2000\text{K} \leq T_e \leq 40000\text{K}$, with the principal quantum number $4 \leq n \leq 10$, for ionization degrees less than, or of the order of 10^{-3}. This results may be of interest for the laboratory as well as for astrophysical plasmas. The calculations are performed by using the semi-classical method, improved in comparison with previous articles. For the considered recombination processes, the rate coefficients for $T_e = T_a$ were presented as well. Such plasmas are e.g. plasmas in atmospheres of helium rich white dwarfs.

Mihajlov, Dimitrijević and Djurić (1996) have analyzed the recombination processes

$$H_2^+ + e \Longrightarrow H^*(n) + H$$

$$H^+ + H + e \Longrightarrow H^*(n) + H,$$

and have demonstrated that they may have an important or even a dominant role in comparison with other relevant recombination processes in relatively low-ionized hydrogen plasmas. Here H_2^+ is the molecular hydrogen ion in ground electronic state, while $H = H(1s)$, and H^+ and $H^*(n)$ are hydrogen ion and atom in a highly excited (Rydberg) state with the principle quantum number n.

The determination of the rate coefficients for the ionization processes:

$$H^*(n) + H \Longrightarrow e + H_2^+$$

$$H^*(n) + H \Longrightarrow e + \begin{cases} H^+ + H \\ H + H^+ \end{cases}$$

which occur always in parallel with the above mentioned recombination processes for the considered plasma conditions, has been performed as well. It has been shown that they must be taken into account for the Rydberg atomic states population calculations in partially ionized plasmas.

The calculations were carried out within the semi-classical theory, in the case of a non-equilibrium hydrogen plasma with atomic temperature T_a and electronic temperature T_e, in the domains $2000\text{K} \leq T_a \leq 10000\text{K}$ and $2000\text{K} \leq T_e \leq 30000\text{K}$, with the principal quantum number $4 \leq n \leq 10$. In the considered paper, Mihajlov, Dimitrijević and Djurić (1996) have also determined the conditions under which the analyzed processes are important for the kinetics of weakly ionized hydrogen plasma, as e.g. the solar atmosphere plasma.

The properties of stellar atmospheres as well as of their spectra result from the complex interactions between photons and gas particles during the radiative transfer throughout these outer layers of stars. Within this framework radiation transport plays a twofold role. On one hand, radiation field determines the structural and dynamical properties of the medium it propagates through, and on the other, it represents an important tool in the diagnostics of the plasma properties from its spectra.

Among other physical phenomena radiative transfer is, in general, the most complicated to deal with due to its non-local, non-linear and multi-mode nature.

Within the framework of the so-called structural approach – a new strategy for studying the stellar atmospheres – Atanacković-Vukmanović and Simonneau (1996) have reviewed the basic properties of the Iteration Factors Method on an instance of the linear two-level-atom line formation problem.

The method efficiently solves the radiative transfer problem within a simple iterative scheme. The improvement of the ordinary iteration procedure is achieved by the proper quasi-invariant functions – iteration factors – coupling (input/output) parameters in a block-diagram representation of a problem under study. By replacing the system of integro-differential radiative transfer equations by only one second-order differential equation with the iteration factors as its mean coefficients, the Iteration Factors Method avoids any matrix formulation. The rate of convergence to the exact solution is extremely high even under extreme NLTE conditions which are computationally the most difficult to deal with.

In Arlot, ... Protić-Benišek et al. 1996 a catalogue of the observations is presented containing the light-curves obtained during the PHEMU91 campaign of observations of the mutual phenomena of the Galilean satellites. Once every six years, the Earth and the Sun cross the equatorial plane of Jupiter and since the Galilean satellites have their orbital planes very close to the jovian equator, the satellites occult and eclipse each other during about six months. The 1991 period was additionally favourable, since the event happened during the opposition of Jupiter and the Sun, and since the declination of Jupiter was positive, which was more favourable for the observatories in the northern hemisphere.

Since there is no atmosphere around the Galilean satellites, the photometric observations may be very accurate (within an accuracy from 200 km for the best photographic observations to 700km for the eclipses by Jupiter).

Results of such observations are very useful in preparations of missions of the space probes exploring the Jovian system. Moreover, the motion of Galilean satellites, affected by numerous perturbations, is one of the most complex in celestial mechanics, and all the theoretical problems related to this motion are far from being solved.

A campaign of observations has been coordinated among 56 sites including Belgrade Astronomical Observatory (V. Prtotić-Benišek). The complete set of observations is composed of 371 lightcurves of 111 events.

Sadžakov, Dačić and Cvetković (1996), published an observational catalogue containing the positions of 146 high-luminosity stars, as well as the optical counterparts of 78 radio stars. These stars are of special interest for the study of the motions in the Galaxy. If the meridian observations of these stars (Cepheides, O and B type stars etc.) were to be repeated, a possibility of enhancing the accuracy of their positions

and proper motions would be offered. Consequently, a more accurate calculation of the space velocities and a more detailed study of the kinematics of high-luminosity stars would be attained.

In view of a relatively small number of stars in the observational programme, they added the 78 radio stars from a list of the Bordeaux Observatory. Their optical positions are necessary for as tight as possible linking of the FK5 to the extragalactic reference frame. These radio stars have belonged to a more comprehensive star list observed with the Automatic Meridian Circle at Bordeaux and they have been also included in the HIPPARCOS project. The above mentioned stars have been observed with the Large Meridian Circle of the Belgrade Observatory in the period 1991-1993.

REFERENCES

1. Arlot J. E., Barroso Jr. J., Berthier J., Blanco C., Bouchot P., Bourgeois J., Bulder H. J. J., Burchi R., Casas R., Chis D., Colas F., Colin J., D'Ambrosio V., De Angelis G., De Benedetto G., Denzau H., Descamps P., Di Paolantonio A., Federspiel M., Froeschlé M., Gomez-Forrellad J. M., Hainaut O., Helmer G., Hube D., Kidger M., Lecacheux J., Lefloch J. C., Mallama A., Martin B. E., Mellilo J. F., Meyer C., Molau S., Morando B., Nicolet B., Oprescu G., **Protić-Benišek V.**, Rapaport M., Riou A., Ruatti C., Sèvre F., Shkodrov V., Souchay J., Takami T., Tholen D., Thuillot W., Vasundhara R., Vu D. T., White G., Wilds R. P., Yoshiharu I., 1996, *A CATALOGUE OF THE OBSERVATIONS OF THE MUTUAL PHENOMENA OF THE GALILEAN SATELITES IN 1991*, Astron. Astrophys. Suppl. Series **93**, 1-140.

2. Atanacković-Vukmanović O., 1996, *SOLUTION OF LINE FORMATION PROBLEM BY USE OF ITERATION FACTORS*, Zh. Prikl. Spektrosk. **63**, 846-852.

3. Blagojević M., Popović M. V., Konjević N., Dimitrijević M. S., 1996, *PLASMA BROADENING AND SHIFTING OF SPECTRAL LINES ALONG THE ISOELECTRONIC SEQUENCE OF BORON* , Phys. Rev. E **54**, 743-756.

4. Dimitrijević M. S., 1996, *A PROGRAMME TO PROVIDE STARK BROADENING DATA FOR STELLAR AND LABORATORY PLASMA INVESTIGATIONS*, Zh. Prikl. Spektrosk. **63**, 810-815.

5. Dimitrijević M. S., Djeniže S., Srećković A., Platiša M., 1996, *ON THE S III AND S IV SPECTRAL LINES STARK BROADENING PARAMETERS*, Physica Scripta **53**, 545-548.

6. Dimitrijević M. S., Sahal-Bréchot S., 1996a, *STARK BROADENING OF SPECTRAL LINES OF MULTICHARGED IONS OF ASTROPHYSICAL INTEREST. XIII. C V AND P V*, Astron. Astrophys. Suppl. Series **115**, 351-552.

7. Dimitrijević M. S., Sahal-Bréchot S., 1996b, *STARK BROADENING OF SOLAR Mg I LINES*, Astron. Astrophys. Suppl. Series **117**, 127-129.

8. Dimitrijević M. S., Sahal-Bréchot S., 1996c, *STARK BROADENING OF Li II SPECTRAL LINES*, Physica Scripta **54**, 50-55.

9. Dimitrijević M. S., Sahal-Bréchot S., 1996d, *STARK BROADENING OF Se I SPECTRAL LINES*, Zh. Prikl. Spektrosk. **63**, 853-860.

10. Dimitrijević M. S., Sahal-Bréchot S., 1996e, *STARK BROADENING OF SPECTRAL LINES OF MULTICHARGED IONS OF ASTROPHYSICAL INTEREST. XIV. Be III AND B III*, Astron. Astrophys. Suppl. Series **119**, 369-371.

11. Dimitrijević M. S., Sahal-Bréchot S., 1996f, *STARK BROADENING OF Sr I SPECTRAL LINES*, Astron. Astrophys. Suppl. Series, **119**, 529-530.

12. Mihajlov A. A., Dimitrijević M. S., Djurić Z., 1996, *RATE COEFFICIENTSS OF COLLISIONAL H - H* (n) IONIZATION AND H - H^+-e AND H_2^+ - e RECOMBINATION*, Physica Scripta **53**, 159-166.

13. Mihajlov A. A., Djurić Z., Dimitrijević M. S., 1996, *THE INFLUENCE OF He - He^+-e AND He_2^+ - e RECOMBINATION AND He - He* (n) IONIZATION ON THE POPULATION OF He*(n) ATOMS IN HELIUM PLASMA*, J. Quant. Spectrosc. Radiat. Transfer **55**, 141-147.

14. Popović L. Č, Dimitrijević M. S., 1996a, *STARK BROADENING OF HEAVY ION LINES: As II, Br II, Sb II AND I II*, Physica Scripta **53**, 325-331.

15. Popović L. Č., Dimitrijević M. S., 1996b, *STARK BROADENING OF Xe II LINES*, Astron. Astrophys. Suppl. Series **116**, 359-365.

16. Popović L. Č., Dimitrijević M. S., 1996c, *STARK WIDTHS FOR ASTROPHYSICALLY IMPORTANT ns-np TRANSITIONS IN Sc II, Y II and Zr II SPECTRA*, Astron. Astrophys. Suppl. Series **120**, 373-374.

17. Sadžakov S., Dačić M., Cvetković Z., 1996, *A POSITION CATALOGUE OF 146 HLS STARS AND 78 RADIO STARS OBSERVED WITH THE BELGRADE MERIDIAN CIRCLE*, Bull. Astron. Belgrade **153**, 1-18.