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INFLUENCE OF REFERENCE FRAMES ON THE DETERMINATION OF LONGITUDES AND LONGITUDE DIFFERENCES

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Abstract. Within the framework of establishing the European longitude network in 1988, the longitude differences Munich-Vienna-Graz were determined by zenith distance observations with Danjon astrolabe. Two reference frames were used in the reduction of observations: *one dynamical*, specified by the FK5 catalogue and *the other kinematical*, specified by HIPPARCOS catalogue, the mathematical model serving for smoothing the measurements in both cases being the same. By comparing the longitudes obtained for Munich, Vienna and Graz from two reference frames a systematic difference was revealed of 3 msec, which is cancelled in the longitude difference determination.

1. INTRODUCTION

The establishing of the new European Longitude Network (ELN), involved several campaigns of precise determination of longitude differences between the national reference stations. One of the more recent campaigns was carried out in 1988 between Munich, Vienna and Graz stations. The observations were made by W. Wende according to equal zenith distances method with Danjon astrolabe (*Wende 1992*). Observed were FK5 stars with magnitudes between $m_v = 2$ and $m_v = 6$. This observational material was kindly ceded to these authors by Prof. Dr Rudolf Zigl and Dipl. Ing. Werner Wende.

In the course of 23 nights in 1988 at all three stations were observed 52 series. There were altogether 1604 star transits, comprising 19248 measurements. Some of the results of treatment and analysis of these measurements were published earlier *Perović & Cvetković 1998, Cvetković & Perović 1999, Cvetković & Perović 2000*).

The first author made comprehensive researches (*Cvetković 2002*) of the mathematical models of smoothing, alike of functional and stochasting ones, aimed at reducing the effects of the random and systematic errors. Out of 12 studied mathematical models the third functional one ($FM3$) was adopted, with the stochastic model (weight model P_{KD3}) since it manifested the best accordance with the observations. Besides, with this mathematical model the star positions from two reference frames were used in the reduction of observations, the dynamical one as given by FK5 catalogue, and the kinematical one - given by HIPPARCOS catalogue. The aim was to put under scrutiny the accordance of the obtained longitudes and longitude differences.

2. LONGITUDES AND LONGITUDE DIFFERENCES OBTAINED BY USING THE HIPPARCOS CATALOGUE

After smoothing the measurements using the best adopted mathematical model (i.e. $FM3 + P_{KD3}$) the longitudes were determined of three stations participators in the campaign: Munich, Vienna and Graz and, subsequently, their longitude differences.

The results of longitude determinations are given in Table 1 and those of the longitude differences in Table 2.

Table 1: Longitudes λ of three stations; σ_λ are the errors of their determination

Stations	λ [h m s]	σ_λ [s]
Munich	0 46 16.8747	0.00064
Vienna	1 05 20.9012	0.00076
Graz	1 01 58.5779	0.00080

Table 2: Longitude differences $\Delta\lambda$; $\sigma_{\Delta\lambda}$ – errors of their determination

From – To	$\Delta\lambda$ [h m s]	$\sigma_{\Delta\lambda}$ [s]
Munich – Graz	−0 15 41.7032	0.00090
Graz – Vienna	−0 03 22.3233	0.00104
Vienna – Munich	0 19 04.0265	0.00096

3. LONGITUDES AND LONGITUDE DIFFERENCES OBTAINED BY USING FK5 CATALOGUE

Research was made as to how much the star positions affect the longitudes and longitude differences determination. For this reason the measurements of the entire campaign were smoothed, including the star positions taken from FK5. The same mathematical smoothing model was used ($FM3 + P_{KD3}$).

The results of longitude determination, obtained by using the FK5 star positions are listed in Table 3, and those pertaining to longitude differences in Table 4. Given in these Tables are also the differences with respect to the values obtained using the HIPPARCOS catalogue.

Table 3: Longitudes λ of three stations; σ_λ are the errors of longitudes; $\lambda_{FK5} - \lambda_{Hipp}$ are the longitude differences resulting from using the star positions from FK5 and HIPPARCOS catalogues

Stations	λ [h m s]	σ_λ [s]	$\lambda_{FK5} - \lambda_{HIPP}$ [s]	$\sigma_{\lambda_{FK5}-\lambda_{HIPP}}$ [s]
Munich	0 46 16.8778	0.00065	0.0031	0.00091
Vienna	1 05 20.9041	0.00077	0.0029	0.00108
Graz	1 01 58.5809	0.00079	0.0030	0.00112

Table 4: Longitude differences $\Delta\lambda$; $\sigma_{\Delta\lambda}$ are errors of the longitude differences; $\Delta\lambda_{FK5} - \Delta\lambda_{HIPP}$ are the differences between longitude differences obtained by using star positions from FK5 and HIPPARCOS catalogues.

From – To	$\Delta\lambda$ [h m s]	$\sigma_{\Delta\lambda}$ [s]	$\Delta\lambda_{FK5} - \Delta\lambda_{HIPP}$ [s]
Munich – Graz	−0 15 41.7031	0.00091	0.0001
Graz – Vienna	−0 03 22.3232	0.00104	0.0001
Vienna – Munich	0 19 04.0263	0.00096	0.0002

4. DISCUSSION OF THE RESULTS

From Table 3 it is seen that the longitude differences $\lambda_{FK5} - \lambda_{Hipp}$ for all three stations are equal – ***0.0030 seconds of time***, originating from the difference of the two celestial reference frames.

The existence of the systematic difference between the FK5 reference frame and that of the HIPPARCOS has been investigated applying the F-test. The test statistics reads:

$$F = \frac{(\lambda_{FK5} - \lambda_{HIPP})^2}{(\sigma_{\lambda_{FK5}-\lambda_{HIPP}})^2} \,. \tag{1}$$

By comparing the test of the quantity F with the quantil F-distribution:

$$1^o \qquad F_M = \left(\frac{0.003138}{0.0009109}\right)^2 = 11.868 > 3.85 \approx F_{0.95;1;1280} \tag{2}$$

$$2^o \qquad F_B = \left(\frac{0.002929}{0.0010808}\right)^2 = 7.344 > 3.85 \approx F_{0.95;1;1280} \tag{3}$$

$$3^o \qquad F_C = \left(\frac{0.003049}{0.0011243}\right)^2 = 7.354 > 3.85 \approx F_{0.95;1;1280} \tag{4}$$

we conclude that ***there exists a systematic difference between the two reference frames.***

The FK5 catalogue frame is obtained by optical observations of the fundamental stars, being linked to the mean equator and dynamic equinox for J2000.0. The HIPPARCOS frame is kinematic one, linked to the direction toward the observed extragalactic radio sources through VLBI. The two frames involve a slight residual rotation that can be investigated by way of a comparison of positions and proper motions of fundamental stars in both catalogues. From the position differences one is able to determine the vector representing the difference of the orientation between the two reference frames. From the difference of the proper motions one might derive the vector representing the difference of rotation of the two frames. The preliminary results obtained from catalogue differences for all 1535 FK5 stars, referred to the epoch J1991.25 are given in the Preface to the HIPPARCOS catalogue.

The rigidly rotation (non-coincidence of the celestial coordinate directions) i.e. the difference of the star positions in FK5 and HIPPARCOS catalogues affect the longitude determination, but not the determination of longitude differences, as seen in Table 4. ***The differences $\Delta\lambda_{FK5} - \Delta\lambda_{HIPP}$ practically equal zero.***

5. CONCLUSION

One ought to state that in this campaign only one segment of the reference frame has been used. The observation programme contains only 121 FK5 stars (out of 1535), which is below 10% of the total number. Moreover, these stars are located in one part of the celestial sphere. Their declinations range from $+20^o$ to $+70^o$ and their right ascensions for the western transits are between 14^h and $20^h\!.5$ and for the eastern transits between 20^h and $25^h\!.5$. Nevertheless, *a constant longitude difference $\lambda_{FK5} - \lambda_{Hipp}$ has been obtained for all the three stations.* This, on one hand, is *a proof of the firm rotation between the two reference frames* and, on another, *a proof of the adequacy of the functional smoothing model and of the model of determining the observation weights.*

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