COMPLEX STUDY OF ASTRONOMICAL DATA ARRAYS

L. Khalyavina

Poltava Gravimetrical Observatory, NAS of Ukraine
27/29 Myasoyedova Str., 36029 Poltava, Ukraine
e-mail: pgohal@mail.ru

Some questions concerning of complex analysis of all available information about observations of stars with prismatic astrolabe are discussed. This analysis is indispensable for enhancing the validity of long series of station coordinates, which was derived in the past. We suppose that application of new information technologies to arrays of astronomical data should improve the accuracy of ground-based astrometry, which is restricted by atmosphere influences.

INTRODUCTION

The astrometric measurements of stations coordinates practically were completed to beginning of the 1990s. The question about the future development of ground-based astrometry has not final decision of the IAU Working Group (Commission N 8), but speech about coordinates definitions does not go any more [8]. In 1997 at discussion of this question in Prague the opinion was not so unambiguous. Some scientists insisted on using of astronomical definitions as complementary technology, certainly, under condition of improvement or creation of a hi-tech tool such as photo-electric astrolabe [1, 2, 7].

The data arrays of observations obtained during the 20th century, are still useful at refinement of proper motions of stars, at study of slow variations of coordinates of stations in geodynamics. Long-term sets of latitude variations observations are stored in Poltava. They were obtained with three instruments. Their common duration is more than 60 years. The programs of observations contain many stars, proper motions of which are not submitted yet in new catalogues such as ARIHIP, FK6. The integrated study of latitude sets obtained from parallel observations with different instruments, allows checking up on the identity of the information about geodynamics effects and about influences of observational conditions. Such analysis gives unexpected results. For example, the hypothesis about refractional anomalies, as main source of latitudes distortions, was not confirmed. The comparison of instant values of latitude, obtained with the Zeiss Zenith Telescope and an astrolabe for the same physical moments, shows no correlation for deviations of instant latitudes from their smooth components. So, for the period of observations 1964.5–1974.5, characterized by high quality of observations for both instruments, the correlation coefficient is $K = -0.028$. There are also questions at joint study of slow variations of latitude.

We suppose that prolongation of astronomical observations in Poltava is very important for correct decision of the listed tasks. As since 1990 the complete data capture automation was carried out, the opportunity of handling by extended files of the information has appeared. Here we represent some results of the broadened analysis of information, which was derived from observations with prismatic astrolabe.

TESTING OF INSTRUMENTAL SYSTEM STABILITY

The stability of instrumental system is one of the important tasks connected with the study of slow variations of coordinates. The opportunity of repeated laboratory measurements as well realizations of special observations has allowed us to detect an origin of dominant instrumental errors determining the stability of system [4]. In order to take into account the influences of these errors, a method was offered for estimating the index correction to coordinates meanings [5].

DETAILED STUDY OF METROLOGICAL ATTRIBUTES OF SEPARATE STARS

The question about of metrological reliability of determined coordinates is considered by means of the common analysis of results of separate stars observations. Investigated parameter is correction of height of a star relatively of conventional almucantar with parameters (λ_0, φ_0, z_0), which are accepted longitude, latitude and instrumental zenith distance, respectively. The structure of a sequence of height corrections sorted by time for

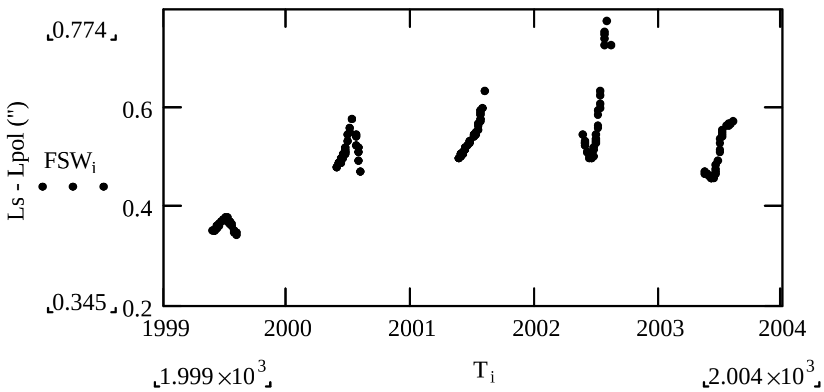


Figure 1. Non-polar variations of height corrections for the star **809** (FK5) in 1999–2003

each i-th star is submitted by expression:

$$\delta h_{ij} = 15 \sin A_i \cdot [(\mathrm{UT0} - \mathrm{UTC}) + \delta\, u] + \cos A_i \cdot (\Delta\varphi + \delta\varphi) + \Delta z_j + e_{ij}, \quad (1)$$

where A_i is the azimuth of the star, Δz_j is the correction of zenith distance for j-th evening, e_{ij} is the observational error. Two first summands characterize a smooth component of height changes arising due to polar (UT0–UTC, $\Delta\varphi$) and non-polar ($\delta\, u$, $\delta\varphi$) local zenith displacements.

The convergence of an array of the given heights $\{\delta h'_{ij} = \delta h_{ij} - \Delta z_j\}^N$ characterizes quality of observation of the i-th star during a season. The quality of measured star height for j-th evening can be estimated by deviation $\delta h'_{ij}$ from smooth component of the empirical set of heights. Using these deviations for assignment the weights to observations of the stars, it was possible to improve the convergence for set fragments of latitude (σ^w), on about 20% (Table 1).

Table 1. Convergence index for latitude arrays

Set fragment	Sample dimension	σ	σ^w
1983.6–1985.3	409	0.153″	0.120″
1998.7–1999.9	270	0.112	0.097
2002.9–2003.9	207	0.106	0.088

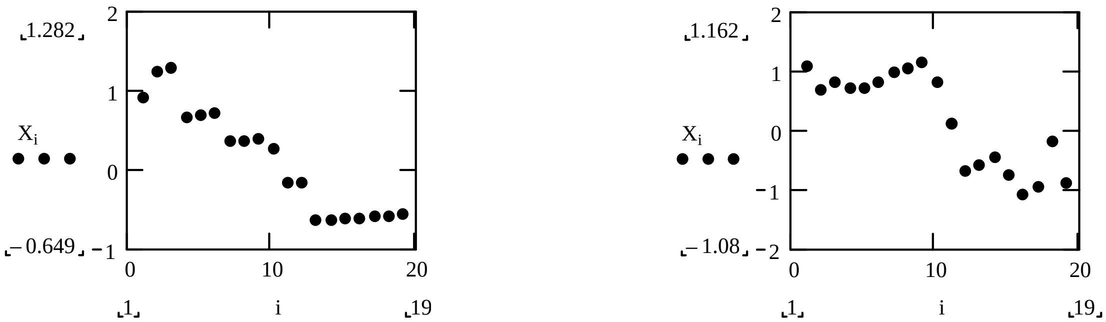
Smooth components of non-polar changes of stars heights ($L_s - L_{pol}$) are useful as well. Here L_s is a trend of an empirical array $\{\delta h'_{ij}\}^N$, L_{pol} is the polar component, which is easy for calculating by using the data about Earth orientation parameters. Non-polar component characterizes a stability of the measured heights of a star during season of observations and dynamics of systematic shifts from year to year (Fig. 1). It is important for the control of instrumental system stability. The complex analysis of non-polar components derived for some stars subsystems, for example, stars having close azimuth, is necessary to detect the real displacement of local zenith.

USE OF INFORMATION ABOUT PRIMARY DATA OF OBSERVATIONS

The primary observational data, stored in machine-readable form, give opportunity to restore the pattern of star maintenance in every action of registration. For this purpose, the method of "dispersion of contacts", offered by Gubanov was used [3]. It allows us to determine **relative** distortions of zenith distance of a star in every i-th moment of its registration:

$$\delta z_i = 15 \cdot \cos\varphi \cdot \sin A \cdot \Theta_i \cdot \mathrm{sign}(A - \pi), \quad (2)$$

where φ is the latitude of station, A is a zimuth of star, $\Theta_i = T_i - T_i^*$ is the deviation of the real moment T_i from predicted moment T_i^*, which corresponds to ideal registration. The first approximation for calculating ideal moments can be presented as $T_i^* = T_{mean} + C \cdot (i - 12.5)$, where $C = R(t°\mathrm{C})/(60 \cdot \cos\varphi \cdot \sin A)$ corresponds



a) August 15, 1998 b) September 25, 1998

Figure 2. Registration pictures of the star **70** with dominant instrumental corrections ($X_i = \delta z_i('')$)

to "reference" value of an interval between the successive contacts of a star registrering, $R(t°\mathrm{C})$ is instrumental constant.

At all variety of patterns reproducing registration of stars, the structural similarity of many processes pays attention. The set examination of the observations examples with qualitatively various conditions has allowed us to distinguish the limited number of scenarios. The most characteristic types are such.

The instrumental. When an atmospheric turbulence is absent, the corrections prevail, which are necessary for fitting the speed of automatic maintenance system. As the deviation of speed in the given azimuth is constant, the corrections, which will be carried out, have always indirect character. The example of instrumental type corrections is submitted in Fig. 2. They, as a rule, are as jumps and look like steps. It is easy to explain this by accumulation of an error up to some threshold, when the observer notices its influence and quickly reacts to correct readout of registration time. The personal reactions of the observers are differed due to specificity of perception of the star images coincidence.

The chaotic. At presence of the atmospheric turbulence there are structures having others various forms. But in these sets some characteristic pictures also repeat. There are short fluctuations of zenith-distance around of unbiased position. Their influence on distortion of the measured star position is not appreciable. But often the processes arise, at which the shifts of zenithal corrections have the character of long-term hits. They strongly displace the measured position of a star. Most frequently there are processes, which in nonlinear dynamics are described as "singular disturbances" [6]. Their examples are submitted in Fig. 3. Another scenario is noticed, which is characterized by appreciable deviations of the measured positions of stars too. It can be named as "an primary excessive exit from balance". In this case the corrections are conducted in true direction with anomalistic intensity, but real star position has not been achieved.

Thus, each registration picture carries the information about dominant sources of distortions. The recognizing of dominant source of error allows carrying out selection of the most reliable measurements of a star zenith distance.

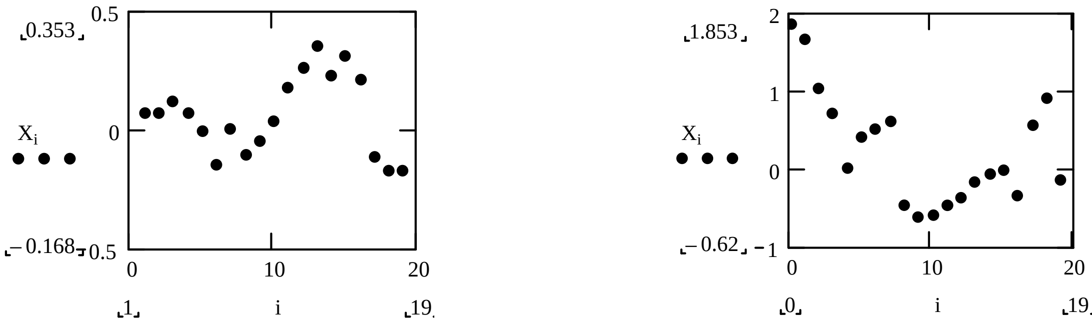
How to use this information for revising the observational moments? It is obvious that each of 24 registration contacts is not equipollent. For the majority of stars observed with astrolabe the registration is simulated as linear process:

$$T_i = T_k^* + dt \cdot (i - k), \tag{3}$$

where T_k^* is the hypothetically true moment, $dt = C$ is "reference" interval between the successive contacts of registration. So, the task is consisted in searching in a array from 24 moments such T_k, which we shall name as "basic contact", when the measured meaning of zenith distance of a star $z(T_k)$ as much as possible corresponds to the true $z^*(T_k)$, *i.e.*, $|z(T_k) - z^*(T_k| = min$. For instrumental type of corrections, obviously, the most probable candidates for "basic contacts" are the moments after performance the next correction. They are marked by jumps in the zenith distance meaning. As a rule, there are a few such contacts and they are well coordinated one to another.

The simple algorithm of a "basic contacts" method was realized. Using of this method allows effectively removing a regular part of instrumental distortions of time determinations. It is confirmed by data of Table 2.

More complex algorithm for the "basic contacts" determination is required. It should take into account the effects specified by anomalistic influences of atmosphere. It is necessary to select the means of main measured parameters of a star registration and to install the principles of the coordination of all collected information. The set of restrictions on the measured parameters should diminish the uncertainty in choice of



a) August 6, 1998 b) September 12, 1998

Figure 3. Registration pictures of the star **70** with dominant turbulence influences

Table 2. Estimations of systematic corrections of UT0–UTC derived by using the "basic contacts" method for different groups (Gn) of stars

Season of observations	δ UT ($G3$)	δ UT ($G4$)	δ UT ($G5$)
1991	–	-0.0138^s	-0.0118^s
1992	-0.0102^s	−0.0121	−0.0076
1998	−0.0079	−0.0096	−0.0106
1999	−0.0061	−0.0050	−0.0068
2000	−0.0080	−0.0078	−0.0078

disturbance model and meanings of "basic contacts".

Whether it is possible to improve estimations of the positions of stars at obvious influence of atmospheric instability? We believe that the answer is possible to find, by carrying out the complex analysis of the cash information with application of the new information technologies and principles of nonlinear dynamics.

[1] *Chollet F.* Astrometrie au sol. Cas des Astrolabes // Reference systems and frames in the space era: present and future astrometric programmes: Journees 1997, Prague, Sept. 22–24, 1997.–P. 216–217.

[2] *Debarbat S.* Ground-based astrometric observations in the space era: The case of the Danjon astrolabe // Reference systems and frames in the space era: present and future astrometric programmes: Journees 1997, Prague, Sept. 22–24, 1997.–P. 194–196.

[3] *Gubanov V. S.* Generalized Method of Leastsquares. Theory and Application in astrometry.–St.-Petersburg: Nauka, 1997.–318 p. (in Russian).

[4] *Khalyavina L.* About the systematic deformations of the almucantar derived from observations with a prismatic astrolabe in Poltava // Kinematics and Physics of Celestial Bodies.–1999.–**15**, N 2.–P. 177–188.

[5] *Khalyavina L., Kislitsa K., Borisyuk T., et al.* New version of the latitude set derived from observations with a prismatic astrolabe in Poltava // Kinematics and Physics of Celestial Bodies.–2001.–**17**, N 4.–P. 372–382.

[6] *Malinetsky G. G.* Chaos. Structure. Calculational experiment.–Moscow: URSS, 2002.–255 p. (in Russian).

[7] *Stavinschi M.* Is there a future for classical astrometry? // Reference systems and frames in the space era: present and future astrometric programmes: Journees 1997, Prague, Sept. 22–24, 1997.–P. 189–193.

[8] *Stavinshi M., Kovalevsky M.* Report 2000–2003 IAU Division 1. Working Group FDGBA // [http://aira.astro.ro/wg/].