THE NEED FOR BETTER CO-OPERATION AND INTERCOMPARISON IN FUNDAMENTAL ASTROMETRY

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ABSTRACT

The present status and practice in the fundamental astrometry are analysed, and relying upon the findings the author suggests the organization of an international action aimed achieving better co-operation in the star position observations and celestial reference system determinations, as well as performing the intercomparison of the different techniques and methods.

INTRODUCTION

Increasing the measurement accuracy, the suitable planing and selection of observation programmes, the fruitful co-operation of astrometrical observatories - the internationally planned co-operation and work in general - are, undoubtedly, lasting requirements of astrometry. But these assume particular importance at the present time when a qualitative jump in this field is impending - we have in mind the forthcoming era of radio and space astrometry. These requirements are of great importance because it is absolutely necessary to achieve the tightest possible connection between the results of the past, present and future techniques, in order to better preserve the quantities and information collected so far. In the past no such organized interconnection existed and for this reason precious data, collected by hard work, lose in worth with time. This represents great loss considering that astrometry has to furnish data pertaining to various times. We have to remind that since the earliest time up to the present more than 2300 catalogues (Ševarlić et al., 1978; Ševarlić et al., 1982) were worked out, containing approximately 8 million data on star positions - 3.8 million of these being in the observational catalogues. However it can be estimated (Teleki, 1980) that the overall utilization of the existing catalogue positions does not exceed 40% - a low percentage indeed. There are relatively few stars with the highly accurate positions - only about 39000 stars, brighter than B=10, the positions are known with the standard deviation

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(for the epoch 1988.0) smaller than $\pm 0''.25$ (Requième, 1982). Therefore we have to take necessary steps - one among them being better planing - in order to increase the utilization of the astrometrical data. But this is possible only within the scheme of a good international coordination.

ASTROMETRICAL PRACTICE

What is the current state of affairs? Each observatory, or rather each observer, quite independently of others, conceives observational programmes, makes observations and data processing by methods he prefers, and in the end the results are published. In other words, there are no uniform standards of planing, observations and data processing. Admittedly, it is very hard to elaborate such standards to be universal. But it is a well known fact that at the processing of astrometrical data use is frequently made of some empirical - physically groundless - corrections. These corrections only seemingly increase the accuracy of results. Increasing of number of observations, as an expedient for removing instrumental and other influences, is the common practice (by virtue of the law of great numbers). Every effort is made to increase the internal accuracy and no care is usually taken of real accuracy, possessing physical legality. About this latter we evidently can judge only by making comparison with the relevant data obtained at other observatories with other instruments.

The absolute meridian observations may be adduced as an example. The star positions deduced are given in the instrumental system - that is in an isolated (local) system.

Aside from the star observations, the positions of the Sun, planets and/or minor planets are also observed, in order to obtain corrections $\Delta\alpha_o$ and $\Delta D = -\Delta\delta_o$ to the zero points of instrumental equatorial system. With them all the star positions, obtained in the given observational period, have to be corrected.

In this way the observational data are transmitted onto ephemeris basis - in fact, the "ephemeris" orientation of the instrumental coordinate system is thus provided. However, this is not quite exact orientation (e.g. Duma, 1982), yet certain connection with other catalogue systems is thus achieved.

Supose, there are two catalogues, observed in the same period and elaborated in the way indicated above, containing the same stars (or largely the same stars). What can we say of the differences $\Delta\alpha_i = \alpha_{i1} - \alpha_{i2}$ and $\Delta\delta_i = \delta_{i1} - \delta_{i2}$ of the coordinates of the stars common to both catalogues? These differences can be represented as folows (Fedorov, 1980):

$$\left.\begin{aligned} \Delta\alpha_i &= w - \operatorname{tg}\delta_i\,(u\cos\alpha_i + v\sin\alpha_i) + F_\alpha\ (\alpha_i, \delta_i) + \theta_\alpha \\ \Delta\delta_i &= -v\cos\alpha_i + u\sin\alpha_i + F_\delta\ (\alpha_i, \delta_i) + \theta_\delta \end{aligned}\right\} \quad (1)$$

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where: u, v, w - the angles, determining the relative orientation of axes of the two catalogue coordinate systems,
$F(\alpha_i, \delta_i)$, $F(\alpha_j, \delta_j)$ - systematic differences in the right ascensions and declinations in the two catalogues not depending on the different orientation of coordinate axes,
θ_α , θ_δ - random quatities.

The formulae (1) show that the values $\Delta\alpha_j$ and $\Delta\delta_j$ depend on the systematic differences of two kinds: the one is a consequence of the non-coincidence of the two instrumental coordinate systems - even after the "ephemeris" corrections $\Delta\alpha_o$ and $\Delta\delta_o$ have been applied, and the second one is due to the deformations in the instrumental systems. The origins of the quantities F_α and F_δ are to be searched for not only in the instruments and accessories, but also in the atmospherical and geophysical properties of the instrument's surroundings.

Suppose that the separation of the systematic and accidental errors is possible. Would it then be possible to determine all the unknowns in the formulae (1)? If both coordinates of n common stars are known, we get 2n equations of the type (1). The total number of the unknowns bearing a systematic character is (2n + 3). Consequently, the system (1), strictly speaking, is insoluble. How to proceed? It can be assumed that the respective values of F_α and F_δ are equal in certain zones, whereby the number of unknowns is reduced.

But in the common practice the quantities u, v and w are not being determined. Instead, mean corrections of the $\Delta\alpha_\alpha$, $\Delta\alpha_\delta$, etc. types are deduced - by graphic or analitical methods - from the quantities $\Delta\alpha_j$ and $\Delta\delta_j$. Unless the catalogues have been observed in the same period, the relevant systematic corrections to the proper motions are derived in a similar way.

This procedure of catalogue comparison displays a suite of shortcomings (e.g. Yatskiv, 1971), accordingly, the results obtained are not impeccable. Catalogue characteristics are inferred - by classic methods or by the method of random fields (Yatskiv, 1971) - which in fact furnish a kind of averaged values lacking exact physical meaning. This give rise to some difficulties. The mathematical, as distinct from the physical, description of the complex of influences cannot provide real corrections to the coordinates nor adequate improvement of the past or future observations with the same instrument. Real connection of the observational series obtained by different instruments and methods as well as in different observational periods cannot thereby be achieved.

The conculsions are similar concerning the quasiabsolute meridian observations, not involving the observations of the members of the solar system.

On the observations by differential method the reduction of the observational data to some system (fundamental) is performed through intermediary of the reference stars. Only partial connection with the

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reference (fundamental) system is thereby possible. This is why supplementary observations are necessary - mostly those of Küstner´s series. However, there is most often not a sufficient number of observations of these series, thus giving a physical interpretations of these corrections is impeded. Accordingly, our conclusions concerning absolute and quasiabsolute meridian observations keep, in principle, their validity for the differential observations as well.

POTENTIALITIES

The basic question is: how to achieve a more real connection between different instruments, methods and observations in different periods? In speaking about a real connection of the catalogues, we mean achieving more accurate star positions and thence a more homogeneous coordinate system, defined by them.

It is absolutely necessary to reduce, to the highest possible degree, the number of corrections not possesing a physical foundation. This implies: the improvement of instruments and their accessories, the objectivization of measurements, the investigations of the atmospheric influences of all kinds, the limitation of geophysical and geological influences, etc. The prevention on the whole should be secured. Consequently the key to the solution of the problem rests with the observatories themselves.

It is beyond the question that taking these or similar steps is not an easy matter. But the need makes it imperative for us to undertake the suggested measures. An international action is suggested because it is, in our view, only by better co-operation that we will be able to get astrometric data of higher quality.

Here are some suggestions:

a. It is impossible to regulate everything - because the conditions are different - but it would be very useful to agree upon a "code of behaviour" concerning the investigation of the instruments and their components, the protection of instruments against external influences, the basic processing of observational data, the analysis of obtained results, etc.

b. The improvement of instruments and their accessories as well as the objectivization of the observational data.

c. Establishing the criteria for cessation of the observations (Tucker, Teleki, 1978). In this, the magnitude of the internal and, especially, external errors should decide. Further informative consideration is the "cost-effectiveness" or "efficiency" - but this is chiefly the concern of the observatories and the observers.

d. Regular observations of Küstner´s or similar series, affording a more real connection with the reference (fundamental) system.

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e. The organization of such supplementary observations and investigations as would allow the getting of most complete information on instrumental and other influences. From this point of view some common observational programmes would be very useful, such as the following: observations of polarissimae, determination of the zenith coordinates and the analysis of the arcs between the stations zeniths, etc.

The observations of polarissimae (Zverev, 1954a) enable the determination to be made of the zero points of the vertical circle (pole points). Hence we can calculate the independent system of declinations. The determination of the value n of Bessel's formula becomes also possible. The right ascensions determination requires the knowledge of the quantity (u + m) from the observations of the clock stars. A great advantage derives from the fact that the polarissimae are observable during the whole night. Some deficiency of this procedure results from the observations having to be made off the meridian. At present the following stars can be used as polarissimae (Podobed, 1968): BD $+89^{\circ}1$ (10.56 magnitude), BD $+89^{\circ}3$ (9.06 magnitude), BD $+89^{\circ}37$ (10.06 magnitude) and CPD $-89^{\circ}38$ (9.5 magnitude). Accordingly, there are three stars in the vicinity of the north pole, and one star near the south pole. Yet these stars are relatively faint which accounts for some inconveniences.

The zenith stars are very suitable for the determination of station longitudes and latitudes (Zverev, 1954b). The FK4 zenith stars are observed and the coordinates of the station zenith on the sky as the auxiliary sphere are determined. The best solution implies the observation on the same night at all stations, but failing this, the observed values have to be reduced to the same moment. Thereupon, we can determine the arcs $\widehat{Z_i Z_j} = \Delta Z_{ij}$ of great circles between the zeniths of the selected stations. Mironov (1974) investigated 66 angles ΔZ_{ij} and found the annual terms clearly perceptible - even with the instruments at the same observatory. All this provides evidence that the source of the annual terms is in the instruments and the systematic catalogue errors, and not in the periodic motion of the continental plates.

CONCLUSIONS

In the above presentation we dwelt upon the problems of meridian astrometry, but, of course, we have to think also on other astrometric fields, other types of instruments (astrolabes, astrographs, etc.) and other methods of observations. In other words we have to embrace the fundamental astrometry as a whole.

It is essential to achieve - by better co-operation and planing of observations - the following objectives:

- the increase of catalogue accuracy,
- a better interconnection of different catalogues by an uniform system,

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- an extension of the general utilization of the astrometric observational data, and
- a unified evaluation, by general consensus, of the results of ground-based astrometry.

Provided a consensus - if not a perfect, certainly a more realistic one - on the ground-based astrometry will have been achieved, the following possibilities will present themselves:

- a better connection with the results of the space and radio astrometry, and
- a better planing of the future tasks of the ground-based fundamental astrometry.

All this calls for a good international co-operation. Therefore we suggest to the IAU Commission 8 to be the originator and the sponsor of setting up a working body having as its task a stronger co-operation in the star position observations and the celestial reference frame determinations, as well as the intercomparison of different techniques and methods.

This body would take care not only of the present astrometrical observations, but also of the old ones. By reprocessing of the old data, the possibility would be created of their increased utilization.

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Discussion:

HUGHES: As President of Commission 8 I feel called upon to respond. I certainly am and always have been in favor of international cooperation, and I hope I always will be. Beyond that, I have quite a list of very desirable things with which no one can disagree. The achievement of these would perhaps involve even more than what you have indicated. However, I suppose that we could discuss such possibilities in the future, but, frankly, I think in a way which is much more complex than what we could achieve right here and now.

EICHHORN: I would like to add one or two remarks. The points you have generally made appeared primarily coming from and directed to meridian astronomers. However, I suggest that your remarks are just as applicable to any astrometric work. The problems which you have pointed out are not going to just go away with HIPPARCOS or even a super-HIPPARCOS. There is always going to be a problem with proper modeling, and if one looks over the various methods of reducing observations from one "system" to another "system", one notices that, with one exception (cf. the proceedings of the 1982 Strasbourg IAU Colloquium No. 64) the concept of a system has never been rigorously defined. Everyone seems to take the system for granted and not in need of an explicit definition. Finally, I agree that for the reduction of data sets from one system to another, one must, ideally, know the exact mathematical form, including the parameters of the reduction model. Your equ. (1), as you pointed out correctly, is mathematically singular. It is, however, possible in principle to introduce certain reasonable and justified stochastic constraints which remove the singularity from the system. An algorithm for this has been published.