A COMPREHENSIVE ASTROMETRIC DATA BASE: AN INSTRUMENT FOR COMBINING EARTH-BOUND OBSERVATIONS WITH HIPPARCOS DATA

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ABSTRACT: The astrometric data bank ARIGFH will contain all relevant astrometric data on stellar positions and proper motions of stars from ground-based observations and space missions. For each star in the ARIGFH, the best available position and proper motion shall be derived. We rediscuss the accuracy of proper motions and positions of fundamental stars, resulting from a combination of data in the FK5 with the expected results from a revised HIPPARCOS mission. The FK5 data could be significantly improved even by rather degraded positions from a revised HIPPARCOS mission.

1. THE ASTROMETRIC DATA BASE ARIGFH

The Astronomisches Rechen-Institut Heidelberg has started to collect 'all' relevant astrometric data on positions and proper motions of stars in a comprehensive astrometric data bank, called ARIGFH. Presently, we deal with the results from earth-bound observations, made with various types of instruments (meridian circles, astrographs etc.). In the future, the ARIGFH should also contain observations obtained from space, such as the HIPPARCOS and TYCHO data.

The ARIGFH is named in memory of the old German project 'GFH', i.e. Geschichte des Fixstern-Himmels. We do not use, however, the data published in the volumes of the GFH, since, for many reasons, it is preferable to go back to the original catalogues.

From all the data collected in the ARIGFH, we plan to derive the 'best' position and proper motion for each observed star. This would produce a comprehensive and most accurate general catalogue of stellar positions and proper motions (ARIGC). By keeping the data base always up-to-date, subsequent versions of the ARIGC, derived and improved in appropriate intervals of time, would then represent always a summary of our actual knowledge of stellar positions and proper motions.

J. H. Lieske and V. K. Abalakin (eds.), Inertial Coordinate System on the Sky, 483–488.

2. STRUCTURE AND STATUS OF THE ARIGFH

The ARIGFH will exist mainly in two versions: as an ARIGFHOBS and as an ARIGFHSYS. In the ARIGFHOBS, the 'direct' observations are listed. For this purpose, the positions will be reduced back to the original epoch and equinox of observation in order to get rid of the various constants of precession used over the centuries. The ARIGFHOBS will be already in a standard format suitable for further treatment.

Using the 'raw data' of the ARIGFHOBS and available fundamental systems, we shall then produce an ARIGFHSYS in which the positions and proper motions are, as far as possible, reduced to a common system (e.g. to the FK5 system at present, later perhaps to a HIPPARCOS or other system) and to a common equinox (e.g. J2000).

The general outline of the tasks for the ARIGFH and the ARIGC is the following: (1) All relevant astrometric catalogues have to be brought into a machine-readable form. (2) The stars in a catalogue have to be identified with the master catalogue of the ARIGFH. This master catalogue consists initially of the more than 500 000 stars of the CDA catalogue, and will be continuously supplemented by observed stars not found in the CDA. (3) Reduction of the astrometric data back to their original epochs and equinoxes of observation. (4) Determination of systematic corrections for each catalogue. Reduction of the astrometric data to a common system and equinox. (5) Determination of the position and, if possible, of the proper motion of each star of the ARIGFH within the fundamental system. This procedure corresponds basically to what is called an 'individual correction' in fundamental astrometry. The result will be the ARIGC.

At present, our main task is still to put the older astrometric catalogues into machine-readable form. The following steps have to be carried out: (1) Identification of suitable catalogues. We expect that the ARIGFH will finally contain more than 2000 individual astrometric catalogues. (2) Locating each catalogue in a library. It is astonishing how often the bibliographic information about an astrometric catalogue is very poor, causing a time-consuming search procedure. (3) Decision about which data given in the catalogue should be typed in which format (raw data or combined results ?, precession ?, cross-references ?, etc.). (4) Typing of the catalogue. Each catalogue is typed twice, by two independent persons, in order to eliminate typing errors. At present, about 1000 astrometric catalogues are available to us in machine-readable form, containing a few million observed positions.

Some subparts of the full ARIGC will probably be finished first. For example, the individual accuracy of the basic FK5 and of the bright extension of the FK5 could be checked and perhaps improved by using data from the ARIGFH. In the basic FK5, the individual observations made before about 1960 have not been included directly, but only through the use of the normal equations of the FK4 (for which in turn the normal equations of the FK3 have been used in order to represent the older catalogues ...). A complete and unified rediscussion of all the catalogues which have entered into the basic FK5 is

certainly desirable. For the bright extension of the FK5, only observations after about 1900 have been used, in contrast to the basic FK5. Hence we can expect an individual improvement of the proper motions of the stars of the bright extension of the FK5 by including older catalogues. Similarly, we hope to improve the individual accuracy of the faint extension of the FK5 by using more and older catalogues.

3. COMBINING HIPPARCOS DATA WITH EARTH-BOUND OBSERVATIONS

One of the motives for setting up the astrometric data base ARIGFH is to combine the results of the HIPPARCOS satellite mission with earth-bound observations. It has been shown in an earlier paper (Wielen 1988) that earth-bound observations would considerably improve the proper motions of the (nominal) HIPPARCOS mission. In view of the probably reduced accuracy of the revised mission with respect to the nominal HIPPARCOS mission, this seems now even more important. In such a combination of earth-bound observations with the HIPPARCOS and TYCHO data, older catalogues contribute more to the individual accuracy of the resulting proper motions than do very recent catalogues. This is due to the larger epoch differences and the often still acceptable positional accuracy of the older catalogues. Of course, systematic errors of the older catalogues have to be carefully eliminated by a reduction to a fundamental system (FK5 or HIPPARCOS system) before we can use such older catalogues for improving the individual accuracy of proper motions (and of predicted positions based on such proper motions).

In the following, we shall rediscuss the accuracy of the proper motions of stars in the FK5 resulting from a combination of earth-bound observations (represented here for simplicity by the FK5 itself) with data from the revised HIPPARCOS mission. At present, the accuracy of the HIPPARCOS data is highly uncertain, mainly due to the unknown duration of the revised mission. Hence, we shall use the typical mean error of a final HIPPARCOS position, $\varepsilon_{p,hipp}$, as a free parameter (within reasonable limits), and we shall assume (hopefully too pessimistically) that HIPPARCOS does not provide proper motions at all. The latter assumption is not very restrictive because it will turn out that proper motions based on a combination of HIPPARCOS positions alone with the earth-bound observations of FK5 stars cannot be significantly improved by corresponding HIPPARCOS proper motions.

In Table 2, we give the mean errors of a proper motion, $\varepsilon_{\mu,tot}$, derived from a combination of the data in a fundamental catalogue with a HIPPARCOS position which has an assumed mean error $\varepsilon_{p,hipp}$. The method for deriving these results has been described by Wielen (1988). The basic data for the fundamental catalogues, mainly provided kindly by H. Schwan (1989), are listed in Table 1. In order to show the importance of the older observations, I have constructed some 'rudimentary' catalogues, which contain only 'modern' observations, by eliminating older fundamental catalogues from the basic FK5 (e.g. FK5 minus FK3). This can be done by using the equations given by Wielen (1988).

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Table 1. Basic data for catalogues considered

Catalogue	Central epoch T	Mean error of position $\varepsilon_p(T)$ (mas)	Mean error of proper motion ε_μ (mas/year)
FK5 Basic	1950	20	0.7
FK5 Faint Extension	1940	70	3.0
FK3	1903	44	2.7
FK5 Basic minus FK3	1962	22	1.5
NFK ("FK2")	1880	70	4.8
FK5 Basic minus NFK	1956	21	1.0
HIPPARCOS revised mission	1990	$\varepsilon_{p,hipp}$ used as a parameter	? (neglected)

Table 2. Mean error $\varepsilon_{\mu,tot}$ of a proper motion based on a combination of a HIPPARCOS position with fundamental catalogues

Catalogue combined with HIPPARCOS	Assumed mean error in position for the revised HIPPARCOS mission $\varepsilon_{p,hipp}$ (mas)					(Catalogue alone)
	2	5	10	20	50	(∞)
	$\varepsilon_{\mu,tot}$ (mas/year)					
FK5 Basic	0.41	0.42	0.44	0.50	0.62	(0.70)
FK5 Faint Extension	1.27	1.27	1.28	1.31	1.49	(3.00)
FK3	0.48	0.50	0.51	0.54	0.74	(2.70)
FK5 Basic-FK3	0.70	0.71	0.75	0.87	1.19	(1.50)
NFK	0.63	0.63	0.64	0.66	0.77	(4.80)
FK5 Basic-NFK	0.53	0.54	0.57	0.66	0.88	(1.05)

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Table 3. Mean error $\varepsilon_{p,tot}(t)$ of a position predicted for an epoch t for $\varepsilon_{p,hipp}$ = 20 mas at T = 1990

	Catalogues and combinations			
	FK5 Basic		FK5 Faint Extension	
	alone	with HIPPARCOS	alone	with HIPPARCOS
Central epoch	1950	1970	1940	1986
$\varepsilon_{p,tot}$ (")	0.020	0.014	0.070	0.019
$\varepsilon_{\mu,tot}$ (mas/year)	0.70	0.50	3.00	1.31
Epoch t	$\varepsilon_{p,tot}(t)$ (")			
1990	0.034	0.017	0.166	0.020
1991	0.035	0.018	0.168	0.020
1992	0.036	0.018	0.171	0.021
1995	0.037	0.019	0.179	0.022
2000	0.040	0.021	0.193	0.026
2010	0.047	0.024	0.221	0.037

In Table 3, we have listed the mean error of a position predicted for an epoch t, $\varepsilon_{p,tot}(t)$, based on a combination of FK5 data with a HIPPARCOS position of $\varepsilon_{p,hipp}$ = 20 mas. The value of 20 mas is chosen as an example only, and is hopefully much too pessimistic.

The results presented in Table 2 show that the proper motions of the FK5 stars can be significantly improved by a HIPPARCOS position, even if the HIPPARCOS position is not as accurate as predicted by the nominal mission ($\varepsilon_{p,hipp}$ = 2 mas): The mean error $\varepsilon_{\mu,tot}$ of the proper motion of a star in the basic FK5 is typically decreased by a factor of about 1.5, that of a star in the faint extension of the FK5 by a factor of more than 2. The combination of the FK3, containing observations until about 1930 only, with HIPPARCOS gives nearly the same accuracy of proper motions as the basic FK5. Furthermore, the combination of the NFK, which used observations until about 1900, with HIPPARCOS produces still better proper motions than those given in the FK5 itself, if $\varepsilon_{p,hipp}$ is smaller than about 30 mas. All this proves again the special importance of older observations for deriving proper motions from a combination of ground-based observations with HIPPARCOS data.

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The improvement in accuracy of positions predicted on the basis of a combination of a HIPPARCOS position with FK5 data, with respect to the FK5 itself, is even more impressive: Table 3 shows that the positions predicted for the next two decades are improved by a factor of about 2 for the stars in the basic FK5, and by a factor of more than 6 for the stars in the faint extension, if we could use a HIPPARCOS position with $\epsilon_{p,hipp}$ = 20 mas or better. This is partially due to the improved accuracy of the proper motion (Table 2), but also due to the fact that the HIPPARCOS position at about 1990 is (hopefully) more accurate than the FK5 position for such a recent epoch.

We conclude that even a HIPPARCOS mission with an accuracy much degraded with respect to the nominal one, would allow a great improvement in the accuracy of both the proper motions and the positions (for recent or future epochs) of fundamental (and many other) stars. Since the present system of positions of the FK5 could also be significantly improved by results from the revised HIPPARCOS mission, a combination of HIPPARCOS data with earth-bound observations may result in a new catalogue (FK6) of fundamental stars.

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