CONNECTION OF THE HIPPARCOS CATALOGUE TO THE EXTRAGALACTIC REFERENCE FRAME

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ABSTRACT

The IAU decided to replace the FK5 reference system by a celestial reference system based upon the positions of extragalactic radio-sources. This system now exists and is materialised by the International Celestial Reference Frame, ICRF. It was in addition requested that the Hipparcos catalogue be given in this system. The coordinate axes in which positions and proper motions are given (as determined by the Hipparcos data reduction procedures) constitute a provisional frame which is to some extent arbitrary. It was therefore necessary to determine the rotation and the yearly spin that must be applied to put the catalogue in the ICRF. Eleven teams, participated in this work using several different techniques: radio-interferometry, photographic plates, star catalogues linked to galaxies, HST observations, analysis of the Earth rotation determined with Hipparcos stars. The synthesis of their results by two different methods gave very similar results. The alignment of the Hipparcos catalogue with the ICRS is realised in position within ± 0.6 mas at the central epoch 1991.25 and in spin, within 0.25 mas per year.

Keywords: Hipparcos; reference frames.

1. INTRODUCTION

The combination, in the Hipparcos Catalogue, of exceptionally good precision and the very large number of stars involved, contributes to making it the best candidate to become the new fundamental catalogue for all purposes fulfilled until now by the FK5, the FK5 Extension and, in certain respects, by catalogues such as the PPM linked to it. Certainly, the Hipparcos Catalogue is not better in all respects than the FK5 – in particular for proper motions in the case of known or unknown astrometric binaries (Wielen et al., 1997) – but its overall quality designates it as the natural successor of FK5.

Now, it is well assessed that the FK5 reference system does not any more fulfill the demands of modern astrometry. Just to give an example, it is now proved that the FK5 constant of precession is wrong by 0.3 seconds of arc per century. Already for many years, the International Earth Rotation Service (IERS), was determining the Earth rotation parameters with respect to extragalactic objects using VLBI, then transcribed the results in the FK5 system to stay in conformity with the *official* system. The General Assembly of the IAU resolved in 1991 that the new celestial reference frame should be defined by a set of positions of extragalactic objects. This ensured that the reference coordinates do not rotate with respect to a large portion of the Universe surrounding our Galaxy. In this sense the new International Celestial Reference System (ICRS) is quasi-inertial. It is materialised (or represented) by a catalogue of positions of extragalactic radio-sources produced in 1995 by a group led by Chopo Ma (Ma & Feissel 1997) from position catalogues compiled by various VLBI networks during the last ten years. This was actually a rediscussion of the VLBI data, analogous to the work already done by IERS several times in the framework of its duties to monitor celestial reference frames.

This catalogue, called the International Celestial Reference Frame (ICRF), includes the positions of 606 extragalactic radio-sources out of which 212 are considered as fundamentally defining the frame. The positions of the other sources are given in this frame, but, because they have been less observed, they are less precise. The positions of these 212 defining sources are determined to better than 0.6 mas in α and δ, most of them having uncertainties smaller than 0.4 mas in α as well as in δ. These positions and those used for the link of Hipparcos Catalogue are given in the IERS report for 1996.

2. THE HIPPARCOS CONTRIBUTION

However, also in 1991, the IAU decided that the ICRS will not become the actual reference for astronomy until it is complemented by a catalogue in the optical range, having in mind the Hipparcos Catalogue, provided that it is given in the new system. To do this was the task of a working group appointed by the Hipparcos Science Team. Actually, several teams started working on this well before, in particular within the INCA and the FAST consortia. All stars that could be used for any of the possible link methods were selected as high priority stars by INCA, following the indications of the paper by Froeschlé and Kovalevsky (1982) and the analyses made by the INCA working group in charge of the preparation of the link (Argue 1989).

Eleven teams contributed to the work, using different methods and different observational data. A provisional Hipparcos frame was fixed by a special procedure through which the final FAST and NDAC astrometric results were merged into a provisional catalogue called H37C which was made available to the teams. Whenever positions of radio sources were involved, they were given in the IERS celestial reference system which later, became without any change, the ICRS mentioned above.

The task of the teams involved was to determine the components of either or both vectors representing a rigid body rotation of H37C to put it in the ICRS: the orientation offset ε of H37C at the catalogue epoch J1991.25 and the spin ω representing the yearly rate of change of the orientation offset. The method used, the results obtained by each team and the names of the scientists involved are described in Volume 3, Chapter 18 of the Catalogue (ESA 1997) and, with many additional details, in Kovalevsky et al., 1997. A summary is given hereafter:

(1) VLBI observations of 12 radio stars with the Deep Space Network and other VLBI networks. Both ε and ω with standard errors of 0.5 mas and 0.3 mas/yr respectively for each component were determined.

(2) MERLIN observations of radio stars. The short time of observations did not allow to determine ω; uncertainties on ε were of the order of 2.5 mas.

(3) VLA observations of radio stars. Only ε could be determined and the uncertainty obtained (5 mas) is due in part to the epoch (1986) too far from the mean Hipparcos epoch.

(4) Optical positions of compact radio-sources based upon CCD frames of 78 selected sources provided ε with an uncertainty of 5 mas.

(5) Observations with the Hubble Space Telescope allowed both ω and ε to be determined despite a very short observation time. The uncertainties are of the order of 2 mas in ε and 3 mas per year in ω.

(6) Use of the Lick proper motion programme which gives the proper motions of stars with respect to galaxies. Two independent solutions were obtained for ω with differences reaching 1 mas/yr. Magnitude effects are very important and pollute the solution.

(7) Use of the KSZ (Faint Star Catalogue) produced in Kiev, Moscow and Pulkovo. From 154 areas, and stars fainter than 9th magnitude, ω was obtained with uncertainties of the order of 0.7 mas/yr.

(8) Yale/San Juan Southern Proper motion programme. Several solutions were produced (two colours and two coordinates). The actual walue of the solution in ω is of the order of 0.5 mas/yr.

(9) Bonn plates of 13 fields taken with large epoch differences (70 to 100 years) yielded for ω uncertainties of the order of 0.6 mas/yr.

(10) Potsdam Schmidt plates taken at a shorter interval of time for 24 fields gave standard uncertainties of the order of 0.5 mas/yr which are seemingly over estimated. An estimation of 0.35 appears as being more correct.

(11) Comparison of Earth orientation parameters as obtained by VLBI and by visual astrometry rereduced with Hipparcos data provided results only on x and y components of ω and ε. Those in ε are not very reliable because of the epoch (1985), while the components in ω are good to better than 1 mas/yr.

3. THE RESULTS

The results provided by these teams were collected. They included the values of the components determined together with their estimated standard errors and the associated correlation matrices. To obtain a single solution out of these eleven different methods involved at first a discussion of the uncertainties and re-weighting for some of them. The synthesis was done by two different methods . One is described in Lindegren & Kovalevsky (1995) and the other in Kovalevsky et al. (1997). Both are equivalent to a weighted least-squares solution, but with different practical implementations. The weights retained were also slightly different, and the results obtained were very close, the differences being of the order of $\sigma_\varepsilon/3$ for ε, $\sigma_\omega/2$ for two components of ω and $1\sigma_\omega$ for the y component of ω. This led to increase slightly the standard errors of the parameters, and to adopt the mean value of the two solutions for the final result.

Because H37C is not a catalogue available, the actual values obtained and used for implementing the rotation of H37C into the ICRS have not been released. The resulting standard uncertainties are $\sigma_\varepsilon = 0.6$ mas, for the orientation at epoch and $\sigma_\omega = 0.25$ mas for the spin. These numbers apply to each of the three components of these vectors. The correlations between the components of ω and ε are smaller than 0.06 except that between ω_y and ε_y which is equal to 0.11. They may be ignored. The correlations between the components of any of the vectors are larger. Both determinations gave very similar values. Their means are:

For ε: $\rho_{xy} = +0.26$, $\rho_{xz} = +0.02$, $\rho_{yz} = -0.14$

For ω: $\rho_{xy} = +0.04$, $\rho_{xz} = -0.13$, $\rho_{yz} = -0.15$

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