

DIVISION 1: FUNDAMENTAL ASTRONOMY (ASTRONOMIE FONDAMENTALE)
Report 1993-1996

President: J. Kovalevsky

Commission 4: Ephemerides
Commission 8: Positional astronomy
Commission 19: Rotation of the Earth
Commission 24: Photographic astrometry
Commission 31: Time

1. INTRODUCTION

The two years that elapsed since the establishment of Division 1 have been characterised by a large variety of tasks of common interest to the five Commissions forming the Division. This is shown in particular by the activity of the Working Groups on Astronomical Standards (Chairman, T. Fukushima) and on Reference Frames (Chairman, L.V. Morrison) which include members from the five Commissions and were actually Division 1 Working Groups. This is also reflected by the very close relationship that prevailed between Commissions 8 and 24. They actually are preparing an eventual merging between the two commissions by proposing that both commissions have the same Vice-President for the next term (E. Schilbach). Last, but not least, three of the Joint discussions accepted for the Kyoto General Assembly are sponsored by the whole Division, one of its Commissions being the proposer. However, these common actions are only a small fraction of the activity of each Commission as described in their reports.

2. HIGHLIGHTS

One may characterise the evolution of the domains covered by Division 1 by the expression "*dramatic improvements in accuracy*": This concerns:

- Time (Commission 31): The accuracy of the first atomic fountain caesium frequency standard ever built as well as the stability of the International Atomic time scale (TAI) are now to be expressed in terms of a few units in $\pm 10^{-15}$.
- Space Astrometry (Commission 24): The reduction of the Hipparcos data is now over. The accuracies achieved are of the order of one millisecond of arc. The Tycho Catalogue is less precise, but has more than one million stars.
- Celestial reference frames (Commission 19): The new celestial reference frame (ICRF), based upon VLBI observations of extragalactic radio-sources contains a set of 212 defining objects whose positions have in majority an accuracy better than (± 0.5 mas). Together with the finalisation of the Hipparcos Catalogue, this completes the requirements set up in 1991 by the IAU for implementing the new celestial reference system. The ICRF would become the new fundamental catalogue, and the Hipparcos catalogue will be the realisation of the system in optical wavelengths.
- Ground-based astrometry (Commission 8): Great expectations are put on the Navy Prototype Optical Interferometer near Flagstaff which has optical phase-closure capabilities. Millisecond of arc accuracies are expected.
- Planetary Ephemerides (Commission 4): The new JPL ephemeris DE 403 is available with an increased accuracy as compared with the preceding ones and is referred to the extragalactic reference system. Another point: a gain of a factor 10 is reported for the new analytical theories of the outer planets.

3. WORKING GROUPS

Two Working Groups are of interest to the full Division. They worked intensively during these two years and achieved results that are summarised here. A third Working Group, under the auspices of Commission 4, 7 and 19 on non-rigid Earth Nutation will present its report at the General Assembly.

3.1. WORKING GROUP ON REFERENCE FRAMES

Chaired by L.V. Morisson, this Working Group included:

F. Arias (Fr)	J. Kovalevsky (Fr)	J. Reynolds (Au)
W. Carter (USA)	I. Kumkova (Ru)	Shuhe Wang (Cn)
P. Charlot (Fr)	J.-F. Lestrade (Fr)	O. Sovers (USA)
T. Corbin (USA)	Li Zhigang (Cn)	E. Standish (USA)
T. Eubanks (USA)	C. Ma (USA)	C. de Veigt (De)
M. Feissel (Fr)	D. Mc Carthy (USA)	H. Walter (De)
A. Fey (USA)	M. Miyamoto (Jp)	G. White (Au)
T. Fukushima (Jp)	G. Nicholson (Za)	J. Williams (USA)
A.-M. Gontier (Fr)	A. Nothnagel (De)	Y. Yatskiv (Ue)
C. Jacobs (USA)	R. Preston (USA)	N. Zacharias (USA)
K. Johnston (USA)	Y. Requieme (Fr)	

The WG held three meetings in the period 1 July 93 to 30 October 96):

28-29 March 94, Hamburg Observatory
 13-14 February 95, CERGA (Grasse)
 7-8 October 96, Paris Observatory.

A Joint RGO-ESA Workshop entitled *Future Possibilities for Astrometry in Space* was held on 19-21 June 1995 in Cambridge, UK.

The New International Celestial Reference Frame

Most of the effort of the WG was directed towards setting up the new International Celestial Reference Frame (ICRF). This comprised two parts: (1) the selection of the high-precision VLBI radio positions of extragalactic sources which constitute the fundamental frame, and (2) the adoption of the high-precision catalogue from the Hipparcos space mission which constitutes the optical counterpart of the ICRF.

ICRF Catalogue

At its meeting on 13-14 Feb 95 the WGRF appointed a sub-group to draw up a list of extragalactic sources with high-precision VLBI positions and to carry out a thorough error-analysis of these positions. The time schedule for the work was dictated by the need to provide a list of final positions by October-95 in order to rotate the provisional Hipparcos Catalogue to the ICRS. The sub-group comprised:

C. Ma (GSFC), Coordinator	M. Eubanks & A Fey (USNO)
C. Jacobs & O. Sovers (JPL)	F. Arias & A-M Gontier (IERS).

The task involved re-analysing over 1 million VLBI observations, with careful attention to errors introduced by the tropospheric models and elevation limits, and adhering to common IERS standards regarding the tidal deformation, rotation and orientation of the Earth. Particular attention had to be paid to the structure of some sources and their variation with time which produced significant changes in their positions.

The sub-group constructed a catalogue of 610 sources observed with dual frequency X/S band Mark III VLBI up to July 1995. Quality criteria were used to classify the sources, and 212 with accuracies better than 1 mas were selected as defining sources. A subset of 133 sources with the very best accuracy were used to align the axes of the ICRF with the ICRS. This catalogue is described in the Report of Commission 19, pp. 56-57 of this volume.

Hipparcos Catalogue

Although the IAU WGRF was not responsible for carrying out the alignment of the Hipparcos Catalogue to the ICRS, it worked in close association with the Reference Frame Working Group of the Hipparcos mission which had that task. The Hipparcos Catalogue is described in the Report of Commission 24, p. 72 of this volume.

The raw data were analysed by two independent consortia (NDAC & FAST) and the results were merged to produce positions on a provisional rigid frame which was aligned approximately with the FK5 system. This rigid frame was rotated to the ICRS at the beginning of 1996, principally by linking the positions of about

20 radiostars to high-precision radio positions determined by phase-referencing with respect to sources in the ICRF. The accuracy of the alignment of the axes of the Hipparcos Catalogue to the ICRS at epoch 1991.25 is 0.6 mas. However, the relative internal accuracy of the frame is better than ~ 0.1 mas (at J1991.25).

The Hipparcos proper motions were referred to a non-rotating frame through the comparison with radio proper motions of 11 radiostars and the discussion of ground-based optical proper motions determined with respect to extragalactic nebulae. The accuracy of this link is 0.25 mas/yr. However, the relative internal rate of deformation of the frame is less than ~ 0.1 mas/yr.

IAU1997 Resolution

The WGRF decided to recommend to the XXIIIrd General Assembly, Kyoto, 1997, that the ICRF be adopted as the new international reference frame - replacing the FK5 - and that the Hipparcos Catalogue be adopted as the optical realization of that frame.

Maintenance and extension of the ICRF

The WGRF also considered how to maintain the accuracy of the ICRF and the link of Hipparcos to the ICRF. It recommended to the Directing Board of IERS that it should consider setting up a VLBI coordinating centre for the purpose of carrying out observations, analysis and other activities related to the maintenance of the ICRF. The IERS made a call for proposals and chose the National Earth Rotation Service (NEOS) in the USA as the coordinating centre.

Maintenance of the Hipparcos frame

The WGRF carried out a survey of activities in IAU Commissions 8 & 24 related to maintaining and densifying the Hipparcos frame. Dr. Kovalevsky circulated a critique of these activities to the WG and this was discussed during the meeting of the WGRF arranged for 7-8 Oct 96. The methods for keeping the frame of the Hipparcos Catalogue aligned with the ICRF included continuing radio and optical interferometric observations of radiostars. The WG considered how these activities might be coordinated in the future.

Densification of the Hipparcos frame

The Tycho Catalogue of a million stars with a median precision at J1991.25 of 25 mas is an important step in the densification of the Hipparcos frame. It is described in the Report of Commission 24. p. 73 of this volume.

Work is proceeding on deriving accurate proper motions for the Tycho Catalogue by re-reducing the Astrographic Catalogue to the Hipparcos system and using this to provide first epoch positions. In addition, a second Tycho data reduction is planned which will provide astrometry and 2-colour photometry for 3 million stars.

The WGRF considered how ground-based telescopes could be used to go deeper than the limit reached by Tycho. Astrographs and Meridian telescopes, upgraded with CCD cameras, have successfully mapped selected regions down to $V \sim 6$ with an accuracy of 70 mas. These will enable distortions to be removed from Schmidt plates and hence extend the Hipparcos frame to the limit of those plates. The SLOAN Digital Sky Survey should also achieve good accuracy for at least 5 million stars within 60 deg of the North Galactic Pole.

3.2. WORKING GROUP ON ASTRONOMICAL STANDARDS

In 1994, the IAU approved to continue the WG on Astronomical Standards (IAU/WGAS) one more triennium. T. Fukushima (NAO, Japan) was nominated to continue to chair it. This time the missions posed to this WG were threefold:

- 1) to maintain the "two-tier" mechanism on astronomical constants and the numerical values of related quantities,
- 2) to investigate the issue on general relativistic definitions of astronomical units and constants, and
- 3) to realize the idea to collect and authorize some basic software for fundamental astronomy, to be named as SOFA (Standards Of Fundamental Astronomy).

In order to cope with them, three sub-groups were set up in the WG:

- 1) Maintenance Committee of Astronomical Constants chaired by D.D. McCarthy (USNO, USA),

- 2) General Relativity Sub-Group chaired by V.A. Brumberg (IAA, Russia),
- 3) Review Board of SOFA chaired by P.T. Wallace (STARLINK, UK).

The maintenance committee is preparing the IAU (1997) best estimates of astronomical quantities. Very probably this will follow the part on constants of IERS Conventions (1996) (McCarthy ed., 1996), and therefore should be almost the same as the first version (Standish 1995). For the moment, the WG sees no necessity to update the IAU (1976) System of Astronomical Constants. It is still to be used for creating long-time standards such as Nautical Almanacs and star catalogs. One should note however that a Joint Discussion will specially consider the problems related to nutation and precession.

The general relativity sub-group has been exchanging opinions through E-mails extensively. In the course of discussions, the issue of the transformation of GM values was particularly discussed. This is one of the by-products caused by the change of astronomical time arguments adopted by the IAU in 1991.

The SOFA Board of Review has actively discussed the necessary items to prepare computational codes needed for the basic calculations and to provide them electronically. Thanks to the advent of Internet connections and WWW, the Board is seeking a way to utilize them maximally to establish and maintain SOFA. It also schedules issuing the announcement of opportunity for the set-up of SOFA Center(s) to support the project.

References

- McCarthy, D.D. (ed): "IERS Conventions (1996)", IERS Tech. Note No.21, Obs. de Paris, Paris.
Standish, E.M.; Highlights of Astronomy, 10, 180-184.