

JD16

**The International Celestial Reference System:
Maintenance & Future Realization**

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Summary of IAU Joint Discussion 16, “The International Celestial Reference System, Maintenance and Future Realizations

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Abstract. The IAU Joint Discussion 16 (JD16) was held in conjunction with the XXVth General Assembly in July, 2003. Papers related to the maintenance of the International Celestial Reference System were presented in the one-day session, and these were followed by discussion that pointed out the need for standard nomenclature. This issue was addressed by the formation of a Division 1 Working Group on the subject. JD16 also pointed out the requirement for a dynamical expression for precession which was addressed by the creation of a Division 1 Working Group on Precession and the Ecliptic. It also showed that although plans are being implemented to provide reference frames for the future, there is a need for improved coordination of astrometric observations. Finally it should be noted that the discussion pointed out the concern for the future organization of IAU Division 1.

1. Introduction

The international Astronomical Union (IAU) Joint Discussion 16 (JD16) was held in connection with the XXVth General Assembly of the IAU in Sydney, Australia in July 2003. The title of the meeting was “The International Celestial Reference System, Maintenance and Future Realizations.” The International Celestial Reference System (ICRS) has recently been redefined with the adoption of an International Celestial Reference Frame (ICRF) and revised concepts and models to access the system. The ICRF is a radio reference frame and the current realization in optical wavelengths is the HIPPARCOS Catalogue. Maintenance and improvement of the ICRF requires continuing, coordinated observations.

Extension and densification of the system to other wavelengths remains as a work to be accomplished. It is also necessary at this time to anticipate the maintenance and extension of the ICRF to meet future needs. The models currently used in the definition of the system also require maintenance to ensure that they are able to meet improving observational accuracy in all wavelengths. The potential significant improvement of reference frames from the results of future space astrometry missions requires planning for the long-term realization of the ICRS. These topics were addressed by a series of invited and contributed presentations

2. Presentations

Session 1 of JD 16 was entitled “The International Celestial Reference Frame.” It was introduced with a paper by A. Fey and J. Souchay entitled “Status of the International Celestial Reference Frame.” C. Ma presented a paper, “Potential refinement of the ICRF” outlining plans to improve the frame. This was followed by a review of recent work done in the Geoscience Australian IVS analysis center by O. Titov. A. M. Gontier and M. Feissel provided a presentation “Contribution of stable radio sources to ICRF improvements” showing the importance of source position stability to the astrometric observations. M. Hosokawa completed the session with a paper that he prepared in conjunction with his colleagues entitled “Astrometric microlensing and degradation of reference frames” that pointed out the limitations on accuracy imposed by microlensing.

Session 2, “Extension of the International Celestial Reference Frame” contained presentations dealing with providing realizations of the reference system in other wavelengths. C. Jacobs in a paper that he prepared with his colleagues entitled “Extending the ICRF to higher radio frequencies: 24 and 43 GHz” pointed out the advantages to moving to higher frequencies. S. Urban followed with a presentation “Densification of the ICRF/HCRF in visible wavelengths” showing plans to improve the reference frame of most concern to the astronomical community. Extension to the infrared was discussed in the paper by N. Zacharias *et al.* entitled “Extending the ICRF into the infrared: 2MASS-UCAC astrometry.” C. Pinigin *et al.* presented a paper, “About progress of the link optical-radio systems,” and P. Charlot finished the session with a paper, “Source structure” describing recent work in characterizing source structure.

Session 3 dealt with models needed to analyze the astrometric observations that are used to produce the ICRF. V. Dehant in a paper “Geophysical nutation model” described the geophysical background of the recently adopted IAU 2000 precession-nutation model. P. Wallace provided practical implementation procedures in his paper, “Practical consequences of improved precession-nutation model.” The philosophy and status of the International Earth Rotation and Reference System Service (IERS) Conventions was described in a presentation by D. McCarthy and G. Petit. T. Fukushima showed a new determination of precession formulas and M. Soffel *et al.* discussed the relativistic concerns with the ICRS in their paper entitled “ICRS, ITRS and the IAU resolutions concerning relativity.” J. Vondrak described a reference frame provided largely by historical observations in visual wavelengths made to determine the Earth’s orientation in his paper “Earth orientation catalogue - An improved reference frame.” I. Platais closed the session with his paper “Astrometry with large un-astrometric telescopes” that outlined work that could be done to improve the ICRF that made use of instrumentation not usually used to make astrometric observation.

The final session was devoted to Space-Based Astrometry and Dynamical Reference Frames. It was introduced with a review of the status of space-based astrometric missions by R. Gaume. F. Mignard followed with a review of recent work on GAIA in his paper “Future space-based celestial reference frame,” and the Radio Astron project was described in a presentation by W. Zharov and colleagues. F. Mignard presented a paper by J. Kovalevsky entitled “Misleading proper motions of galactic objects at the mas level.” The relationship of modern

dynamical ephemerides to the ICRS was covered by M. Standish in his paper "Relating the dynamical frame and the ephemerides to the ICRF."

3. Posters

The work of JD16 was enhanced by a large number of poster contributions. These are listed below.

- Wang Wen-Jun, "Celestial three-pole rotations of the Earth."
 Hu Hui, "Optical positions of 55 radio stars."
 W. Dick, "The ICRS and the IERS information system."
 V. Martin, "Ground-based astrometry: optical-radio connection."
 P.C. Rocha Poppe, "Relativistic reference systems transformations."
 E. Khrutskaya, "Pul-3 catalog of 58483 stars on the Tycho-2 system."
 I. Kumkova, "ICRS-ITRS connection consistent with IAU(2000) resolutions."
 E. Pitjeva, "The planetary ephemerides EPM and their orientation to ICRF."
 M. Stavinschi, "Report of the WG: Future development of ground-based astrometry."
 B. Bucciarelli, "Astrometric measurements of radio-stars optical counterparts."
 M. Stavinschi, "Reference frames and ground-based astrometry."
 S. Lambert, "Coupling between the Earth's rotation rate and nutation."
 G. Bourda, "Temporal gravity field and modelisation of Earth rotation."
 G. Damljanovic, "ICRF densification via Hipparcos-2MASS cross identification."
 F. Mitsumi, "On the construction of radio reference frame using VERA."
 A. Fey, "Extending the ICRF to higher frequencies: imaging results."
 P. Fedorov, "The star positions and proper motions of stars around ERS."
 T. Yano, "Japanese astrometry satellite mission - JASMINE project."
 M. Zacharias, "The USNO extragalactic reference frame link program."
 A. Kahrin, "An-all wave classification and principle astrometry problem."
 D. Boboltz, "Testing the Hipparcos/ICRF link using radio-stars."
 J. Souchay, "Numerical approach to the free rotation of celestial bodies."
 G. Kaplan, "Another look at non-rotating origins."
 O. Roopesh, "IDV sources as ICRF sources: viability and benefits."
 O. Roopesh, "USNO/ATNF astrometry and imaging of southern ICRF sources."
 F. Bustos, "CDD-based astrometric measurements of photographic plates."
 M. Crosta, "Relativistic satellite attitude in the realization of space-borne astrometric catalogues."

4. Discussion

An open discussion prepared and led by P. K. Seidelmann followed the scheduled presentations. Notes from that discussion were taken by N. Zacharias and they form the basis of the following. To initiate the discussion, a list of reference system issues was presented to the participants. These are listed below along with relevant comments by participants.

Items for Discussion

a. Precession-nutation Model

- New precession theory?
- What angles - Newcomb or Williams?
- What nutation model?
- An abbreviated nutation theory with less accuracy?
- Include geodesic precession and nutation?
- Is it a BCRS or GCRS model?

b. Future of Equinox

- Introduce Earth Rotation Angle?
- Revise definition of ERA?
- Dual system by IERS?
- Dual system in almanacs?
- Transition period specified?
- For how long? 2004? Indefinitely?

c. Definition of equinox

- Inertial or rotating

d. Introduce Conventional ecliptic

- How defined, through x axis of ICRF? by node angle and obliquity?
- For what purpose?
- With what accuracy?

F. Mignard emphasized that the ecliptic moves and will change with time. D. McCarthy pointed out that this is a subject for the Working Group on precession and that a precise definition of the ecliptic is needed for planetary precession.

e. Terminology issues

- CIO and TIO or CEO and TEO?
- Stellar angle or Earth Rotation Angle?
- right ascensions from equinox only?
- right ascensions from CIO?
- other terms?

C. Hohenkerk remarked that some concepts seem odd, and that the user is not concerned "which" RA, Dec is used, as long as there is some RA, Dec.

f. Unification of Lists of Constants

- IAU Best Estimates
- IAU 1976 Astronomical Constants
- IERS Best Estimates
- IUGG List of Constants
- JPL DE 405 Constants
- Astronomical Almanac Constants Used
- Are all these necessary?

A joint IAU/IUGG committee?

g. Redefinition of UTC

UTC tied to UT1?

Use of “mean solar time”?

Leap seconds or not?

h. Implementation Issues

Who are the users?

What do users need?

What is really used by the IERS?

What is necessary for almanacs offices?

Standardized software?

Documentation required?

Dual availability for how long?

What to do now?

i. Roles of Organizations

WG on Reference systems of IAU Div I

IERS

IAU Comm 5

Others involved?

j. Possible Procedure

IAU /IUGG? WG on Reference Systems with subgroups established now

Dec 2004 WG proposals circulated

Mid 2005 Colloquium for discussion of proposals and draft resolutions

2006 Clarifying resolutions

k. Education Plan

Clear and convincing presentation of reference systems and justifications

Dissemination of information with proposals in Dec 2004

Distribution of 2005 Colloquium Proceedings

Wide distribution of any proposed resolutions well before IAU GA in 2006

In the general discussion following the presentation of the items for discussion K. Johnston said that some issues might not be solved earlier than 2006. P. Wallace argued that we need to get away from the “one-or-the-other” concept and that algorithms are now available for both paradigms so the user can choose. C. Jacobs noted that users need more education so that they can decide how complex they need to go for a given goal in accuracy. P. Wallace replied that there is a misconception that the “new paradigm is more complex,” and that this was not true. The non-rotating origin procedure is simpler in concept; like spherical trigonometry and vectors: they are both there to choose. A participant said that this is difficult at the moment, that there is a need for education, and that currently we don’t even know what to call things. K. Johnston suggested that there is no need for the general astronomers to make a change because current procedures are sufficient for their requirements. It is only the IERS and

space astrometry applications that are concerned about sub-milliarcsecond accuracies and need to use the new more accurate system. It was pointed out that this was true, but people needed to realize that the basic values were coming from new definitions and methods.

Division I Organization

At that point there was a break in the discussion, and T. Fukushima, President of Division I, presented some details regarding the future structure of Division I in the context of this discussion. He said that the ICRS WG has been dissolved because it was too large, with too many sub-tasks. As follow-up for two of the sub-tasks, two new Working Groups were being established. These are (1) precession and the ecliptic chaired by J. Hilton and (2) nomenclature in fundamental astronomy chaired by N. Capitaine.

The new IAU structure puts more emphasis on the Divisions and the Commissions are now dynamic, with a finite life time. It is possible to terminate commissions and to create new commissions upon request by the Division and approval by the IAU Executive Committee. Working groups can be established by approval of the Division, without Executive Committee contact. The approval process is fast, and can be done by e-mail, with no need to wait for a General Assembly.

Fukushima initiated a special committee for the re-organization of Division I. Members are T. Fukushima (chair), F. Mignard, I. Platais, G. Petit, and K. Seidelmann. For the 2003-2006 period (*i.e.* before the special committee issues their recommendations), the proposal for ICRS related issues is that Celestial Reference Frame issues will be directed to Commission 8 and that IERS related issues will be directed to Commission 19. A general discussion followed about the roles of Commissions 8 and 19.

A. Fey asked about the current members of the ICRS WG and whether their expertise would be lost until a re-organization was accomplished. Following some discussion T. Fukushima responded that the "WG ICRS" will continue to exist for the next six months. During that time a re-arrangement can be organized by e-mail.

5. Conclusion

The Joint Discussion pointed out the need for standard nomenclature. This issue was addressed by the formation of a Division 1 Working Group on nomenclature. It also pointed out the requirement for a dynamical expression for precession which was addressed by the creation of a Division 1 Working Group on Precession and the Ecliptic. JD 16 also showed that although plans are being implemented to provide reference frames for the future, there is a need for improved coordination of astrometric observations. Finally it should be noted that the discussion pointed out the concern for the future organization of IAU Division 1. The proceedings will be published and distributed by the U.S. Naval Observatory.