3.5.4 ICRS Centre

Introduction

The IAU has charged the IERS with the responsibility of monitoring the International Celestial Reference System (ICRS) and maintaining its current realization, the International Celestial Reference Frame (ICRF), and links with other celestial reference frames. Starting in 2001, these activities are run jointly by the ICRS Centre (Observatoire de Paris and US Naval Observatory) of the IERS and the International VLBI Service for Geodesy and Astrometry (IVS), in coordination with the IAU Working Group on the Reference System. The present report was jointly prepared by the Paris Observatory and U.S. Naval Observatory components of the ICRS Centre.

Different files provide information to characterize the objects involved in the construction of the ICRF (radio source nomenclature, physical characteristics of radio sources, astrometric behaviour of a set of sources, radio source structure). The database is available at URL <http://hpiers.obspm.fr/icrs-pc>, by anonymous ftp (<hpiers.obspm.fr/icrs-pc>), and on request to the ICRS Centre (<icrs-pc@hpopa.obspm.fr>).

In the following, we explain the contents of the various tasks which are devoted to the ICRS Centre, by explaining for each of them the studies which were developed in 2002.

Maintenance and Extension of the ICRF : Validation of Individual Celestial VLBI Reference Frames

Three individual celestial frames obtained from VLBI analysis and a compiled one had been submitted to the IERS for their validation. The four frames had been analysed and compared to the ICRF-Ext.1.

The reference frames analysed

RSC (BKGI) 02 R 01: This VLBI global combined solution was computed by the BKG VLBI Analysis Centre in cooperation with the VLBI group at the University of Bonn. For this solution, a worldwide set of VLBI observations over the period January 1984 – December 2001 has been processed with the software CALC 9.12/SOLVE release 2001.12.21. The orientation of the celestial frame has been defined by constraining to zero the sum of the right ascension and declination adjustments of the ICRF defining sources in RSC (BKGI) 02 R 01. Tropospheric gradients have been estimated in the solution.

RSC (GAOUA) 01 C 01: This frame has been elaborated at the Main Astronomical Observatory of the National Academy of Sciences of Ukraine. Radio source coordinates have been calculated by the combination of the four individual VLBI solutions submitted to the IERS and analyzed in the IERS Annual Report for 2000 (IERS, 2001). The Kyiv arclength method (Yatskiv and Kur'yanova, 1990) has been applied for the catalogue compilation. The axes of the compiled frame are aligned to the ICRS with an accuracy of 0.01 mas by the 202 ICRF defining sources present in RSC (GAOUA) 01 C 01.

RSC (IAA) 02 R 03: This celestial frame has been elaborated by the VLBI research group of the IAA Laboratory of New Methods in Astrometry and Geodynamics (NMAG) in St. Petersburg. The solution has been obtained with the new software QUASAR (version QUASAR_LSC) for VLBI data analysis by Least Squares Collocation Technique. NEOS-A VLBI data for the period 1993–2001 has been analysed for this solution. RSC (IAA) 02 R 03 has been aligned to the ICRS by not-net translation and no-net rotation constraints applied to source positions with respect to ICRF-Ext.1. Tropospheric gradients have been adjusted in the solution.

RSC (GSFC) 02 R 01: This VLBI solution has been elaborated at the Goddard Space Flight Centre, it has been constrained to be aligned to ICRF-Ext.1.

Table 1 gives the characteristics of the reference frames analyzed. Four categories of sources appear in the table: “defining”, “candidate” and “other” sources correspond to the classification of ICRF sources, “new” are the sources added in ICRF-Ext.1, “additional” is for sources not present in ICRF-Ext.1 and observed in VLBI programs.

Table 1: Analysed VLBI celestial reference frames. N = number of sources, m = mean standard error (Unit: mas).

Frame	Total	Defining		Candidate		Other		New		Addit.		
	n	n	m	n	m	n	m	n	m	n	m	(°)
RSC (BKGI) 02 R 01	594	209	0.13	216	0.13	102	0.04	44	0.24	23	0.76	–81;+84
RSC (GSFC) 02 R 01	552	202	0.07	201	0.08	101	0.03	35	0.11	13	0.17	–81;+84
RSC (IAA) 02 R 03	323	85	0.11	115	0.10	68	0.06	47	0.23	8	0.45	–44;+84
RSC (GAOUA) 01 C 01	670	211	0.06	277	0.09	102	0.02	59	0.14	21	0.22	–85;+84

Comparison of individual celestial frames to ICRF-Ext.1

All submitted individual VLBI frames have been compared to ICRF-Ext.1. Under the assumption that ICRF-Ext.1 is free from deformations, the systematic effects detected in the comparisons indicate the existence of deformations in the individual frames.

The algorithm of comparison is the one currently used at the ICRS Centre; the coordinate difference between two frames is modelled by a global rotation of the axes, represented by the angles A_1, A_2, A_3, and by a deformation represented by three parameters: one is a slope in right ascension as a function of the declination (D_α), another is a slope in declination as a function of the declination (D_δ), and the third one is a bias of the principal plane of the frame relative to that of the ICRF-Ext.1 (B_δ).

$$A_1 \,\mathrm{tg}\,\delta \cos\alpha + A_2 \,\mathrm{tg}\,\delta \sin\alpha - A_3 + D_\alpha(\delta-\delta_0) = \alpha_1 - \alpha_2$$

$$-A_1 \sin\alpha + A_2 \cos\alpha + D_\delta(\delta-\delta_0) + B_\delta = \delta_1 - \delta_2$$

Only defining sources common to each individual frame and the ICRF-Ext.1 have been used for the comparison. The parameters have been evaluated by a weighted least squares fit; the equations have been weighted using the inverse of the variance of the coordinate differences.

Formal uncertainties in radio source positions listed in the individual frames smaller than 0.01 mas were set to this value for the assignation of weights. The six fitted parameters allow to transform coordinates in the individual frames into ICRS.

Table 2 gives the global orientation between axes of the individual catalogues and those of the ICRS. Table 3 shows the systematic effects in the individual frames detected by their comparison to ICRF-Ext.1.

Table 2: Relative orientation between individual frames and the ICRF. A_1, A_2, A_3 are the small angles which transform coordinates from the individual frames into ICRF; N is the number of the common defining ICRF sources used for the comparison; r_α and r_δ are the weighted mean residuals in $\alpha \cos\delta$ and δ respectively. Unit: 0.001".

Frame	N	A_1	A_2	A_3	r_α	r_δ
RSC (BKGI) 02 R 01	209	+0.036±0.016	+0.004±0.016	–0.053±0.021	0.17	0.23
RSC (GSFC) 02 R 01	202	+0.000±0.018	–0.023±0.017	–0.044±0.023	0.18	0.24
RSC (IAA) 02 R 03	85	–0.009±0.024	+0.018±0.025	–0.023±0.036	0.15	0.23
RSC (GAOUA) 01 C 01	211	–0.003±0.016	–0.020±0.016	–0.022±0.021	0.17	0.22

Following the usual practice in VLBI work, constraints are applied to align the axes of the individual frames to ICRF. The origin of right ascensions of the individual frames agrees with the ICRF origin at a few tens of mas.

No deformations are detected in the individual frames when compared to ICRF. The principal plane of RSC (GSFC) 02 R 01 is bi-

Table 3: Slopes and biases evaluated in the comparisons between individual VLBI frames and ICRF. D_α, D_δ are the slopes in right ascension and in declination, respectively. B_δ is the bias in declination. Units: 0.001"/degree for the slopes, 0.001" for the biases.

Frame	D_α	D_δ	B_δ
RSC (BKGI) 02 R 01	–0.001±0.001	+0.000±0.000	+0.002±0.017
RSC (GSFC) 02 R 01	–0.001±0.001	+0.000±0.000	+0.028±0.018
RSC (IAA) 02 R 03	+0.001±0.001	–0.001±0.001	–0.005±0.038
RSC (GAOUA) 01 C 01	–0.001±0.001	+0.000±0.000	+0.014±0.017

ased by +0.028 mas from that of the ICRF; this bias is smaller than the value reported for RSC (GSFC) 01 R 01 in the IERS Annual Report 2000 (IERS, 2001).

E. Felicitas Arias, Sébastien Bouquillon, Anne-Marie Gontier

Investigation of Future Realisations of the ICRS

Involvement by ICRS Centre personnel in the celestial reference frame VLBI program continued in 2002, significantly increasing the number of observations of ICRF quasars in the southern celestial hemisphere and continuing an extensive observing program in the northern hemisphere. These observations are directed towards the elaboration of a second extension to the ICRF, expected to be issued in the following years.

In the coming decades, there will be significant advances in the area of space-based optical astrometry. Proposed and scheduled missions such as the National Aeronautics and Space Administration's (NASA) Space Interferometry Mission (SIM) and the European Space Agency's GAIA mission will achieve positional accuracies well beyond that presently obtained by any ground-based radio interferometric measurements.

During 2002, ICRS Centre personnel were involved in the Full-sky Astrometric Mapping Explorer (FAME) mission; an astrometric space mission to measure the position, parallax and proper motions of 40 million stars between 5th and 15th magnitude. In January 2002, NASA announced their decision to withdraw financial support for the FAME mission, citing continued uncertainty surrounding the development of the FAME Charged Coupled Devices (CCDs) and optics, instrument software development, and operations algorithm development, while noting a significant anticipated mission cost growth significantly exceeding the NASA mission cost cap. With the conclusion of NASA support for the FAME mission, no new NASA funds were received by the project, however, NASA did support project CCD technology development in 2002 through the funding of a secondary supplier with already disbursed FAME funds. In addition to the very successful procurement of CCDs, ICRS Centre personnel made important progress in optical system analysis, developing systems engineering tools to connect science requirements to engineering requirements. Using these tools ICRS Centre personnel developed a model of a three mirror anastigmat (TMA) telescope design that will satisfy FAME science requirements, costed out a newer version of the instrument, and developed a data simulator and analysis pipeline which helps further define system requirements. A systems engineering analysis of the PDR design of FAME, using CCDs from the secondary supplier and the TMA optics design, shows that a cumulative astrometric mission accuracy of 100 µas can be attained for 9th magnitude stars in the first 2 years of a FAME mission, with no radiation mitigation. As the FAME mission progress toward its planned 5 year duration, an astrometric accuracy of 50 µas can be achieved using radiation mitigation techniques available with the recently fabricated CCDs.

In October 2002 ICRS Centre personnel met with members of the DIVA project team, and were highly impressed with the DIVA mission design. DIVA, a German led astrometric space mission, is in many respects quite similar to the USNO led FAME mission, but with somewhat relaxed astrometric requirements for mission position, parallax and proper motion (150 µas, 200 µas, and 250 µas yr^{-1}, respectively) for a 2 year mission. Facing a significant budget shortfall, the DIVA project team and the FAME project team explored the potential for a collaborative merger of the DIVA and FAME programs. It was determined that the most promising avenue for closing the DIVA funding gap was for USNO to submit a funding proposal to NASA for a Mission of Opportunity. The next proposal opportunity is May 02, 2003.

Ralph Gaume

Monitor Source Structure

Observations of ICRF sources using the Very Long Baseline Array (VLBA), together with up to 10 geodetic antennas, continued. These VLBA RDV observations constitute a joint program between the U.S. Naval Observatory (USNO), Goddard Space Flight Center (GSFC) and the National Radio Astronomy Observatory (NRAO) for maintenance of the celestial and terrestrial reference frames. During each 24 hour VLBA RDV session, about 80 ICRF sources are observed at S/X-band (2.3/8.4 GHz). The VLBA observations taken under this program provide data suitable for imaging of the intrinsic structure of the extragalactic radio sources which make up the ICRF. Images are made at the USNO and are made available for use by anyone from the USNO Radio Reference Frame Image Database (RRFID). The RRFID can be accessed on the World Wide Web at <http://www.usno.navy.mil/RRFID/>. During the reporting period (2002), a total of 332 new images of 167 sources were added to the RRFID, including images of 7 sources not previously imaged.

Very Long Baseline Array observations to extend the ICRF to K-band (24 GHz) and Q band (43 GHz) (Jacobs et al. 2002, in International VLBI Service for Geodesy and Astrometry 2002 General Meeting Proceedings, edited by Nancy R. Vandenberg and Karen D. Baver, NASA/CP-2002-210002) began in May 2002. These observations are part of a joint program between NASA, the USNO, NRAO and Bordeaux Observatory. Images are produced from these observations by the USNO and made available through the RRFID. During the reporting period (2002), two VLBA high frequency experiments were calibrated and imaged adding 260 images of 65 sources to the RRFID.

The resulting intrinsic source structure information from the RRFID provides a valuable resource for evaluating the astrometric suitability of the extragalactic sources used to define the ICRF. Fey and Charlot (2000, Astrophysical Journal Supplement Series, Vol. 128, pp. 17–83) used RRFID data to quantify the magnitude of the expected effect of intrinsic source structure on astrometric bandwidth synthesis VLBI and presented their results in the form of a "Structure Index" for the observed sources. The "Structure Index" ranges from a value of 1 for the least contribution (best astrometric sources) to a value of 4 for the most contribution (worst astrometric sources). The "Structure Index" can be used as an estimate of the astrometric quality of the sources based on intrinsic structure. The distribution of "Structure Index" calculated from the first epoch of K/Q-band images (Charlot 2002, private communication) is shown in Figure 1. Also shown are values for the 28 sources observed in VLBA RDV31 at X-band which overlap with these sources. Note the shift toward lower values as the frequency of observation increases suggesting that structure contamination will be less pronounced at these higher frequencies.

The USNO and the Australia Telescope National Facility (ATNF) are collaborating in a continuing VLBI research program in Southern Hemisphere source imaging and astrometry using USNO, ATNF and ATNF-accessible facilities. These observations are aimed specifically toward improvement of the ICRF in the southern hemisphere through repeated high quality astrometry and imaging. Observations from this program are still under analysis.

Alan Fey

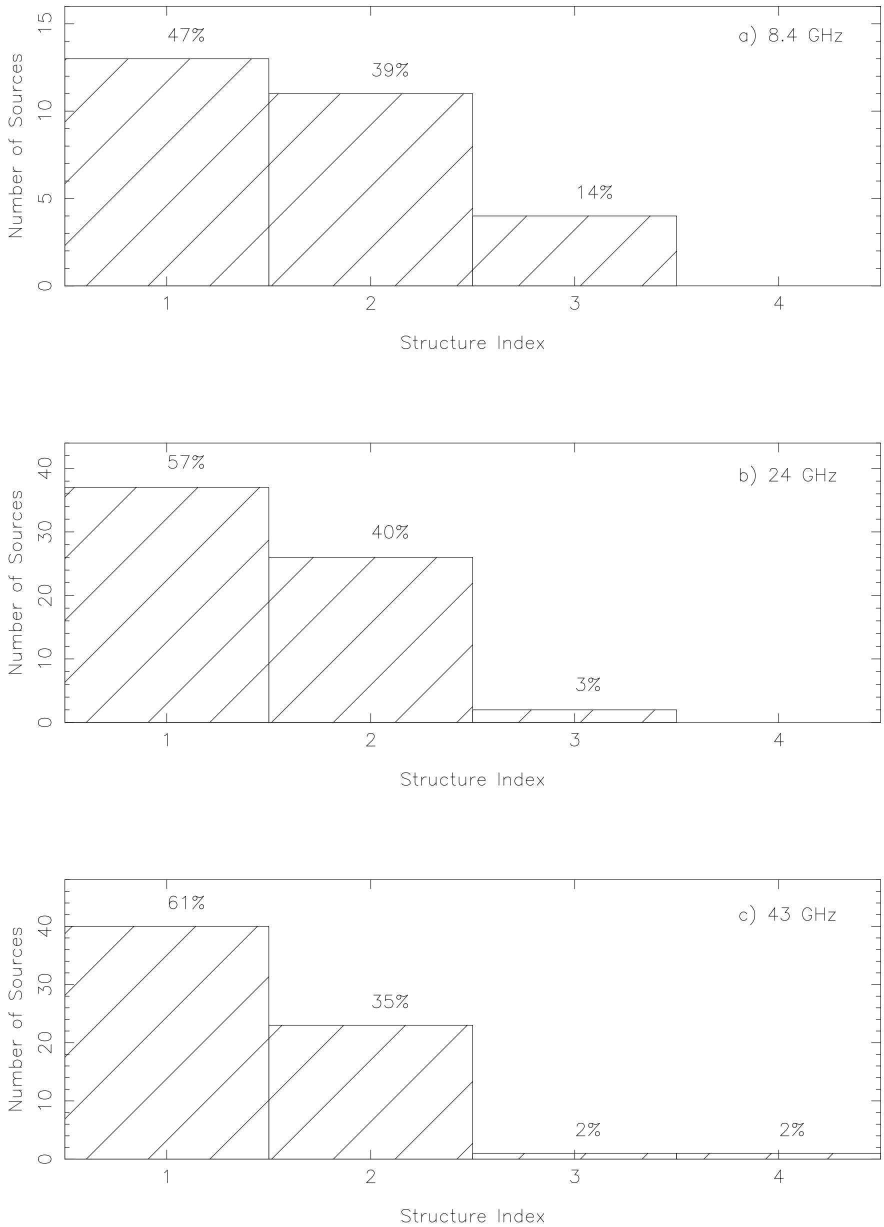

Figure 1: Distribution of "Structure Index" for sources at a) 8.4 GHz, b) 24 GHz, and c) 43 GHz. A total of 65 sources were observed at 24 and 43 GHz on 2002 May 15. Also shown are the values for the 28 overlap sources observed at 8.4 GHz on 2002 Jan 16.

Maintenance of the Time Stability of ICRF : Monitor Coordinates to Assess Astrometric Quality

In a paper submitted to Astronomy and Astrophysics, we propose a statistical scheme to select a subset of objects that would be used for the maintenance of the ICRF and the monitoring of the Earth's rotation.

The study is based on the series of individual source coordinates derived by A. Fey (USNO) over 1979–2002. The time series of source coordinates were obtained in three parallel analyses of the VLBI observing sessions up to May 2002. Each of the analysis derives time series of coordinates per session, for one third of the sources, the other two thirds being treated as “global”, i.e. with fixed positions over the total observation span. Each analysis includes a no-net-rotation (NNR) condition with respect to ICRF. To avoid inconsistencies that are due to the NNR condition realization in the three analyses, and that reach the level of 50 mas, we consider here for each source the time series of its coordinates referred to its global weighted mean.

The improvements in VLBI technology, the development of the observing network and the extension of the set of observed objects that took place in operational astrogeodetic VLBI brought the astrometric results to its current precision level towards the end of the eighties. Therefore, the proposed selection scheme is applied to data after 1989.5, i.e. 3.1 million observations of 707 sources, representing 87% of the total data set.

A set of stable sources is selected in a two-step process, as follows.

– A first selection is made on the basis of continuity criteria for one-year weighted average coordinates.

a) Length of observation period longer than five years.
b) More than two observations of the source in a given session.
c) One-year average coordinates based on at least three observations.
d) Not more than two successive years with no observations, given conditions (b), (c) are met.
e) At least half of the one-year averages available.

– The time series of yearly values are then analysed in order to derive

f) a linear drift (least squares estimation) and its normalized absolute value,
g) the Allan standard deviation of a one-year sampling time.

For each local coordinate ($\alpha \cos \delta$ and δ), two partial indices are defined, based on the values of the above statistics. The partial stability indices range from 1 (most stable) through 3 (least stable), with a rejection value (10) associated to very large drifts or standard deviations. The global stability index is defined as the average of the partial indices for $\alpha \cos \delta$ and δ, i.e. four values per source. The stable sources are those which get a stability index smaller than 2.5.

Out of the 362 pre-selected sources the stability scheme detects 199 stable ones, a number to be compared to the 212 defining sources in the ICRF. Table 4 gives the relationship of the global stability index with two ICRF qualifiers: the source status (defining/candidate/other) and ICRF structure index computed on the basis of source mapping. The structure qualifies the level of expected position disturbance (1 for the less disturbed, 4 for the most disturbed). The proposed list of selected sources is only poorly correlated with he current ICRF ones.

Table 4: Stability index and ICRF source qualifiers

Stability Index	Source status			Structure index		
	Def.	Can.	Oth.	1	2	3–4
1	33	26	15	53	21	12
2	48	42	34	83	33	14
3	2	1	4	17	12	8
4	58	61	34	79	32	19

To test their efficiency with respect to the maintenance of the axes of the celestial reference frame that they materialize, we consider the 13 yearly differential reference frames (1990.0 – 2002.0) that are formed by the set of stable sources observed for that year. The yearly differential rotation around the axes of the equatorial coordinate system are then computed for the 13 years. Table 5 lists efficiency estimates for the selected sources, and for the ICRF defining sources. These estimates are the usual standard deviation that characterizes the scatter of the sets of rotation angles, and their Allan standard deviations for one-year and four-year sampling times that characterize their stability in time. Note that if the time series of the rotation angles has white noise, the four-year Allan standard deviation will be equal to half the one-year one (square root of one fourth in sampling time). In the case of flicker noise, both values will be equal.

Table 5: Stability of the celestial reference frame orientation definition. Rms standard deviation and Allan standard deviation of the 1990–2002 yearly rotation angles. Unit: mas

212 defining sources			199 stable sources		
Std. Dev.	Allan Std. Dev. 1-yr	Allan Std. Dev. 4-yr	Std. Dev.	Allan Std. Dev. 1-yr	Allan Std. Dev. 4-yr
25.6	26.6	27.6	10.8	9.4	5.9

When compared to the current ICRF defining sources, the proposed selection scheme achieves improved time stability of yearly reference frames. The improvement is particularly striking in the long term. This stability implies enhanced internal consistency in time.

Martine Feissel-Vernier

Maintenance of the Link to Hipparcos and to Frames at Other Wavelengths

During the report period (2002) progress has been achieved by ICRS Centre personnel in 3 areas related to the maintenance of the Hipparcos link: UCAC project, comparison to 2MASS data and extragalactic link.

For the densification of the optical reference frame the UCAC project (USNO CCD Astrograph Catalog) continued. This all-sky survey will give 20 mas positions for stars in the 10 to 14 mag range, with a limiting magnitude of about R=16. From its current location at the Naval Observatory Flagstaff Station, 9263 more fields have been completed, now giving 87% total sky coverage. The 2nd data release (UCAC2) will become available in early 2003. Positions for about 50 million stars have been obtained. Proper motions are being derived from re-measurements of AGK2, NPM and SPM plates. In September 2002 the USNO B1 catalog was released, containing positions (on 150 mas level) and proper motions of about 1 billion stars, obtained from PMM measures of all major Schmidt surveys.

In December 2002 a comparison of UCAC2 positions with the infrared 2MASS catalog pre-release data was made. Both catalogs were taken at about the same epoch (around 2000) and both were independently reduced with respect to Tycho-2 stars. Only very small systematic differences (10 to 20 mas) between the 2 catalogs were found, depending on magnitude, color and declination zone. The precision of the 2MASS positions was confirmed to be about 80 mas.

Independantly, systematic positional differences between HIPPARCOS and the second incremental data release of the 2MASS catalogues were analysed (Damljanovic and Souchay, A & A to be subm.). After a cross-identification procedure leading to a total of 37 940 stars among the 117 955 Hipparcos stars (the second 2MASS incremental release covers only 47% of the sky), zonal differences were found with respect to equatorial coordinates, by applying linear regressions.

During his sabbatical stay at USNO, M.Assafin (Brazil) evaluated 4 CTIO observing runs of ICRF counterparts plus corresponding 1.6m LNA telescope data. The mean optical-radio position differences for 170 sources are –6 mas and –15 mas for RA and Dec, respectively, using preliminary UCAC survey data as reference stars. The additional astrograph calibration observations, not used in this pilot investigation, are needed to reduce systematic errors. In preparation for NASA's Space Interferometry Mission (SIM) a dozen ICRF sources were imaged at the NOFS 61-inch. This is the beginning of a long-term project to monitor possible optical centroid wandering of selected ICRF counterparts.

Norbert Zacharias

Link to the Dynamical Reference Frame and Specific Pulsar Astrometric Catalog Through Pulsar Analysis

The ephemerides of the Earth orbiting around the sun are necessary for the reduction of pulsar observations. Therefore the idea of associating pulsar timing technique with differential VLBI astrometry should provide high quality information about the position and motion of the equator, the ecliptic, the origin point of the ICRS.

Moreover, the sole analysis of signals of various pulsars should enable to construct an astrometric catalog containing the positions and the proper motions of a good number of pulsars (more than 30 observed at Nançay radiotelescope). The possibility of using high precision accumulated data coming from intensive campaigns for more than 10 years (Cognard et al., 1995) in that aim is more and more seriously investigated. In 2002 the campaign was very active, with a number of about 25 pulsars observed on a regularly basis.

Ismaël Cognard, Jean Souchay

Orientation of the Celestial Dynamical Ecliptic Reference Frame by Analysing Lunar Laser Ranging Data

The position of the inertial dynamical ecliptic at a given epoch with respect to the ICRS can be obtained from Lunar Laser Ranging (LLR) observations. The basic definitions concerned here are:

- the inertial dynamical ecliptic of J2000 and the ICRS reference equatorial plane;
- the inertial mean equinox of J2000 $\gamma_I^{(ICRS)}$ and the origin of right ascensions $o^{(ICRS)}$;
- the inclination of the inertial mean ecliptic on the ICRS equator $\varepsilon^{(ICRS)}$.

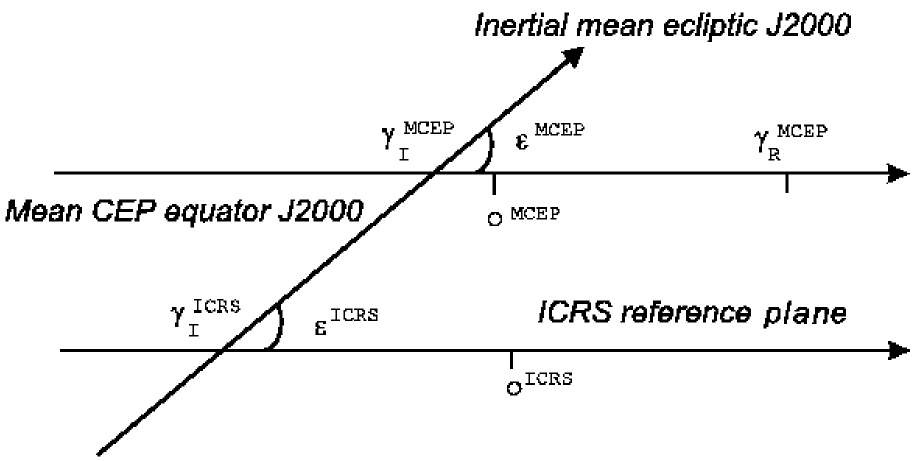

Figure 2: Position angles of the inertial mean ecliptic of J2000.

The ICRS equator and origin of right ascensions $o^{(ICRS)}$ are involved in the transformation of the rectangular coordinates of the LLR stations in the terrestrial reference frame to the celestial J2000 equatorial coordinates. This transformation has been realized according to the lunar solution which results from weighted fits of the semi-analytical theory ELP2000-96 (orbital motion of the Moon) to the LLR observations provided between 1970 and 2002. The precession-nutation matrix PN is computed via the conventional set of values recommended by IERS (1996), in particular the nutation corrections $\delta\varepsilon$ and $\delta\psi$ of the series EOP(C04) produced by the Earth Orientation Centre. The position of the inertial dynamical ecliptic of J2000 with respect to the ICRS is defined by the angles:

$$\varepsilon^{(ICRS)} = 23^\circ\ 26'\ 21.411\ 00'' \pm 0.000\ 05''$$
$$o^{(ICRS)}\gamma_I^{(ICRS)} = -55.4 \pm 0.1 \text{ mas}$$

By the same way, the position of the inertial dynamical ecliptic of J2000 can be obtained with respect to the reference frame linked to the mean Celestial Ephemeris Pole (CEP), noted here MCEP. In this case, we used another lunar solution, also issued from ELP2000-96 fitted to LLR data, where the precession-nutation is provided by analytical solutions: polynomial expressions of the precession and theory of nutation. Then, the position of the inertial dynamical ecliptic of J2000 with respect to the MCEP is defined by the angles:

$$\varepsilon^{(MCEP)} = 23^\circ\ 26'\ 21.405\ 64'' \pm 0.000\ 09''$$
$$o^{(MCEP)}\gamma_I^{(MCEP)} = -14.6 \pm 0.2 \text{ mas}$$

From the 2 solutions linked to ICRS and MCEP, we also determine the correction Δp to the IAU 1976 precession constant and the value of the distance between the two inertial mean equinox of J2000 $\gamma_I^{(ICRS)}$ and $\gamma_I^{(MCEP)}$:

$$\Delta p = -3.02 \pm 0.03 \text{ mas/a}$$
$$\gamma_I^{(ICRS)}\gamma_I^{(MCEP)} = 44.5 \pm 0.4 \text{ mas}$$

Orbital parameters of the Moon and of the Earth-Moon barycentre have also been fit, in particular the tidal component of the secular acceleration of the lunar longitude Γ which is related to a decrease in the Earth's rotation rate and an increase of the length of the day. The most recent determination is:

$$\Gamma = -25.858 \pm 0.003 \text{ ''/cy}^2$$

Remarks:

- The uncertainties mentioned in the above evaluations represent formal uncertainties resulting from the least square fitting. Realistic uncertainties can be estimated between five and ten times these values.

- Usually $\gamma_I^{(MCEP)}$ is named the “inertial” dynamical mean equinox of J2000. The separation from $\gamma_I^{(MCEP)}$ to the “rotational” dynamical mean equinox of J2000 $\gamma_R^{(MCEP)}$ is 93.66 mas.

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