A IAU Resolutions Adopted at the XXIVth General Assembly

A.1 Resolution B1.1: Maintenance and Establishment of Reference Frames and Systems

The XXIVth International Astronomical Union

Noting

1. that Resolution B2 of the XXIIIrd General Assembly (1997) specifies that "the fundamental reference frame shall be the International Celestial Reference Frame (ICRF) constructed by the IAU Working Group on Reference Frames,"
2. that Resolution B2 of the XXIIIrd General Assembly(1997) specifies "That the Hipparcos Catalogue shall be the primary realization of the ICRS at optical wavelengths", and
3. the need for accurate definition of reference systems brought about by unprecedented precision, and

Recognizing

1. the importance of continuing operational observations made with Very Long Baseline Interferometry (VLBI) to maintain the ICRF,
2. the importance of VLBI observations to the operational determination of the parameters needed to specify the time-variable transformation between the International Celestial and Terrestrial Reference Frames,
3. the progressive shift between the Hipparcos frame and the ICRF, and
4. the need to maintain the optical realization as close as possible to the ICRF

Recommends

1. that IAU Division I maintain the Working Group on Celestial Reference Systems formed from Division I members to consult with the International Earth Rotation Service (IERS) regarding the maintenance of the ICRS,
2. that the IAU recognize the International VLBI service (IVS) for Geodesy and Astrometry as an IAU Service Organization,
3. that an official representative of the IVS be invited to participate in the IAU Working Group on Celestial Reference Systems,
4. that the IAU continue to provide an official representative to the IVS Directing Board,
5. that the astrometric and geodetic VLBI observing programs consider the requirements for maintenance of the ICRF and linking to the Hipparcos optical frame in the selection of sources to be observed (with emphasis on the Southern Hemisphere), design of observing networks, and the distribution of data, and
6. that the scientific community continue with high priority ground- and space-based observations (a) for the maintenance of the optical Hipparcos frame and frames at other wavelengths and (b) for the links of the frames to the ICRF.

A.2 Resolution B1.2: Hipparcos Celestial Reference Frame

The XXIVth International Astronomical Union

Noting

1. that Resolution B2 of the XXIIIrd General Assembly (1997) specifies, "That the Hipparcos Catalogue shall be the primary realization of the International Celestial Reference System (ICRS) at optical wavelengths,"
2. the need for this realization to be of the highest precision,
3. that the proper motions of many of the Hipparcos stars known, or suspected, to be multiple are adversely affected by uncorrected orbital motion,
4. the extensive use of the Hipparcos Catalogue as reference for the ICRS in extension to fainter stars,
5. the need to avoid confusion between the International Celestial Reference Frame (ICRF) and the Hipparcos frame, and
6. the progressive shift between the Hipparcos frame and the ICRF,

Recommends

1. that Resolution B2 of the XXIIIrd IAU General Assembly (1997) be amended by excluding from the optical realization of the ICRS all stars flagged C, G, O, V and X in the Hipparcos Catalogue, and
2. that this modified Hipparcos frame be labeled the Hipparcos Celestial Reference Frame (HCRF).

A.3 Resolution B1.3: Definition of Barycentric Celestial Reference System and Geocentric Celestial Reference System

The XXIVth International Astronomical Union

Considering

1. that the Resolution A4 of the XXIst General Assembly (1991) has defined a system of space-time coordinates for (a) the solar system (now called the Barycentric Celestial Reference System, (BCRS)) and (b) the Earth (now called the Geocentric Celestial Reference System (GCRS)), within the framework of General Relativity,
2. the desire to write the metric tensors both in the BCRS and in the GCRS in a compact and self-consistent form, and
3. the fact that considerable work in General Relativity has been done using the harmonic gauge that was found to be a useful and simplifying gauge for many kinds of applications,

Recommends

1. the choice of harmonic coordinates both for the barycentric and for the geocentric reference systems.
2. writing the time-time component and the space-space component of the barycentric metric $g_{\mu\nu}$ with barycentric coordinates $(t, \mathbf{x})$ (t = Barycentric Coordinate Time (TCB)) with a single scalar potential $w(t,\mathbf{x})$ that generalizes the Newtonian potential, and the space-time component with a vector potential $w^i(t, \mathbf{x})$; as a boundary condition it is assumed that these two potentials vanish far from the solar system,

   explicitly,

$$g_{00} = -1 + \frac{2w}{c^2} - \frac{2w^2}{c^4},$$
$$g_{0i} = -\frac{4}{c^3} w^i,$$
$$g_{ij} = \delta_{ij} \left(1 + \frac{2}{c^2} w\right),$$

with

$$w(t, \mathbf{x}) = G \int d^3x' \frac{\sigma(t, \mathbf{x}')}{|\mathbf{x} - \mathbf{x}'|} + \frac{1}{2c^2} G \frac{\partial^2}{\partial t^2} \int d^3x' \sigma(t, \mathbf{x}') |\mathbf{x} - \mathbf{x}'|$$
$$w^i(t, \mathbf{x}) = G \int d^3x' \frac{\sigma^i(t, \mathbf{x}')}{|\mathbf{x} - \mathbf{x}'|}.$$

Here, σ and σ^i are the gravitational mass and current densities, respectively.

3. writing the geocentric metric tensor $G_{\alpha\beta}$ with geocentric coordinates (T, $\mathbf{X}$) (T= Geocentric Coordinate Time (TCG)) in the same form as the barycentric one but with potentials W(T, $\mathbf{X}$) and W^a(T, $\mathbf{X}$); these geocentric potentials should be split into two parts — potentials W and W^a arising from the gravitational action of the Earth and external parts W_{ext} and W^a_{ext} due to tidal and inertial effects; the external parts of the metric potentials are assumed to vanish at the geocenter and admit an expansion into positive powers of $\mathbf{X}$, explicitly,

$$G_{00} = -1 + \frac{2W}{c^2} - \frac{2W^2}{c^4},$$
$$G_{0a} = -\frac{4}{c^3} W^a,$$
$$G_{ab} = \delta_{ab} \left(1 + \frac{2}{c^2} W\right).$$

The potentials W and W^a should be split according to

$$W(T, \mathbf{X}) = W_E(T, \mathbf{X}) + W_{ext}(T, \mathbf{X}),$$
$$W^a(T, \mathbf{X}) = W^a_E(T, \mathbf{X}) + W^a_{ext}(T, \mathbf{X}).$$

The Earth's potentials W_E and W^a_E are defined in the same way as w and w^i but with quantities calculated in the GCRS with integrals taken over the whole Earth.

4. using, if accuracy requires, the full post-Newtonian coordinate transformation between the BCRS and the GCRS as induced by the form of the corresponding metric tensors, explicitly, for the kinematically non-rotating GCRS (T=TCG, t=TCB, $r^i_E \equiv x^i - x^i_E(t)$ and a summation from 1 to 3 over equal indices is implied),

$$T = t - \frac{1}{c^2}\left[A(t) + v^i_E r^i_E\right] + \frac{1}{c^4}\left[B(t) + B^i(t) r^i_E + B^{ij}(t) r^i_E r^j_E + C(t, \mathbf{x})\right] + O(c^{-5}),$$
$$X^a = \delta_{ai}\left[r^i_E + \frac{1}{c^2}\left(\frac{1}{2} v^i_E v^j_E r^j_E + w_{ext}(\mathbf{x_E}) r^i_E + r^i_E a^j_E r^j_E - \frac{1}{2} a^i_E r^2_E\right)\right] + O(c^{-4}),$$

where

$$\frac{d}{dt}A(t) = \frac{1}{2} v^2_E + w_{ext}(\mathbf{x_E}),$$
$$\frac{d}{dt}B(t) = -\frac{1}{8} v^4_E - \frac{3}{2} v^2_E w_{ext}(\mathbf{x_E}) + 4 v^i_E w^i_{ext}(\mathbf{x_E}) + \frac{1}{2} w^2_{ext}(\mathbf{x_E}),$$
$$B^i(t) = -\frac{1}{2} v^2_E v^i_E + 4 w^i_{ext}(\mathbf{x_E}) - 3 v^i_E w_{ext}(\mathbf{x_E}),$$
$$B^{ij}(t) = -v^i_E \delta_{aj} Q^a + 2 \frac{\partial}{\partial x^j} w^i_{ext}(\mathbf{x_E}) - v^i_E \frac{\partial}{\partial x^j} w_{ext}(\mathbf{x_E}) + \frac{1}{2} \delta^{ij} \dot{w}_{ext}(\mathbf{x_E}),$$
$$C(t, \mathbf{x}) = -\frac{1}{10} r^2_E (\dot{a}^i_E r^i_E).$$

Here x^i_E, v^i_E, and a^i_E are the barycentric position, velocity and acceleration vectors of the Earth, the dot stands for the total derivative with respect to t, and

$$Q^a = \delta_{ai}\left[\frac{\partial}{\partial x_i} w_{ext}(\mathbf{x_E}) - a^i_E\right].$$

The external potentials, w_{ext} and w^i_{ext}, are given by

$$w_{ext} = \sum_{A \neq E} w_A, \quad w^i_{ext} = \sum_{A \neq E} w^i_A,$$

where E stands for the Earth and w_A and w^i_A are determined by the expressions for w and w^i with integrals taken over body A only.

Notes

It is to be understood that these expressions for w and w^i give g_{00} correct up to $O(c^{-5})$, g_{0i} up to $O(c^{-5})$, and g_{ij} up to $O(c^{-4})$. The densities σ and σ^i are determined by the components of the energy momentum tensor of the matter composing the solar system bodies as given in the references. Accuracies for $G_{\alpha\beta}$ in terms of c^{-n} correspond to those of $g_{\mu\nu}$.

The external potentials W_{ext} and W^a_{ext} can be written in the form

$$W_{ext} = W_{tidal} + W_{iner},$$
$$W^a_{ext} = W^a_{tidal} + W^a_{iner}.$$

W_{tidal} generalizes the Newtonian expression for the tidal potential. Post-Newtonian expressions for W_{tidal} and W^a_{tidal} can be found in the references. The potentials W_{iner}, W^a_{iner} are inertial contributions that are linear in X^a. The former is determined mainly by the coupling of the Earth's nonsphericity to the external potential. In the kinematically non-rotating Geocentric Celestial Reference System, W^a_{iner} describes the Coriolis force induced mainly by geodetic precession.

Finally, the local gravitational potentials W_E and W^a_E of the Earth are related to the barycentric gravitational potentials w_E and w^i_E by

$$W_E(T,\mathbf{X}) = w_e(t,\mathbf{x})\left(1 + \tfrac{2}{c^2}v_E^2\right) - \tfrac{4}{c^2}v^i_E w^i_E(t,\mathbf{x}) + O(c^{-4}),$$
$$W^a_E(T,\mathbf{X}) = \delta_{ai}(w^i_E(t,\mathbf{x}) - v^i_E w_E(t,\mathbf{x})) + O(c^{-2}).$$

References

Brumberg, V. A., Kopeikin, S. M., 1988, *Nuovo Cimento*, **B103**, 63.

Brumberg, V. A., 1991, *Essential Relativistic Celestial Mechanics*, Hilger, Bristol.

Damour, T., Soffel, M., Xu, C., *Phys. Rev. D*, **43**, 3273 (1991); **45**, 1017 (1992); **47**, 3124 (1993); **49**, 618 (1994).

Klioner, S. A., Voinov, A. V., 1993, *Phys Rev. D*, **48**, 1451.

Kopeikin, S. M., 1989, *Celest. Mech.*, **44**, 87.

A.4 Resolution B1.4: Post-Newtonian Potential Coefficients

The XXIVth International Astronomical Union

Considering

1. that for many applications in the fields of celestial mechanics and astrometry a suitable parametri-zation of the metric potentials (or multipole moments) outside the massive solar-system bodies in the form of expansions in terms of potential coefficients are extremely useful, and
2. that physically meaningful post-Newtonian potential coefficients can be derived from the literature,

Recommends

1. expansion of the post-Newtonian potential of the Earth in the Geocentric Celestial Reference System (GCRS) outside the Earth in the form

$$W_E(T,\mathbf{X}) = \frac{GM_E}{R}\left[1 + \sum_{l=2}^{\infty}\sum_{m=0}^{+l}\left(\frac{R_E}{R}\right)^l P_{lm}(\cos\theta)\left(C^E_{lm}(T)\cos m\phi + S^E_{lm}(T)\sin m\phi\right)\right],$$

where C^E_{lm} and S^E_{lm} are, to sufficient accuracy, equivalent to the post-Newtonian multipole moments introduced in (Damour *et al.*, *Phys. Rev. D*, **43**, 3273, 1991), θ and ϕ are the polar angles corresponding to the spatial coordinates X^a of the GCRS and $R = |X|$, and

2. expression of the vector potential outside the Earth, leading to the well-known Lense-Thirring effect, in terms of the Earth's total angular momentum vector $\mathbf{S_E}$ in the form
$$W^a_E(T,\mathbf{X}) = -\frac{G}{2}\frac{(\mathbf{X}\times\mathbf{S_E})^a}{R^3}.$$

A.5 Resolution B1.5: Extended Relativistic Framework for Time Transformations and Realization of Coordinate Times in the Solar System

The XXIVth International Astronomical Union

Considering

1. that the Resolution A4 of the XXIst General Assembly(1991) has defined systems of space-time coordinates for the solar system (Barycentric Reference System) and for the Earth (Geocentric Reference System), within the framework of General Relativity,
2. that Resolution B1.3 entitled "Definition of Barycentric Celestial Reference System and Geocentric Celestial Reference System" has renamed these systems the Barycentric Celestial Reference System (BCRS) and the Geocentric Celestial Reference System (GCRS), respectively, and has specified a general framework for expressing their metric tensor and defining coordinate transformations at the first post-Newtonian level,
3. that, based on the anticipated performance of atomic clocks, future time and frequency measurements will require practical application of this framework in the BCRS, and
4. that theoretical work requiring such expansions has already been performed,

Recommends

that for applications that concern time transformations and realization of coordinate times within the solar system, Resolution B1.3 be applied as follows:

1. the metric tensor be expressed as
$$\begin{aligned} g_{00} &= -\left(1-\frac{2}{c^2}(w_0(t,\mathbf{x})+w_L(t,\mathbf{x}))+\frac{2}{c^4}(w_0^2(t,\mathbf{x})+\Delta(t,\mathbf{x}))\right), \\ g_{0i} &= -\frac{4}{c^3}w^i(t,\mathbf{x}), \\ g_{ij} &= \left(1+\frac{2w_0(t,\mathbf{x})}{c^2}\right)\delta_{ij}, \end{aligned}$$
where (t $\equiv$ Barycentric Coordinate Time (TCB),$\mathbf{x}$) are the barycentric coordinates, $w_0 = G\sum_A M_A/r_A$ with the summation carried out over all solar system bodies A, $\mathbf{r}_A = \mathbf{x}-\mathbf{x}_A, \mathbf{x}_A$ are the coordinates of the center of mass of body A, r$_A$ = $|\mathbf{r_A}|$, and where w_L contains the expansion in terms of multipole moments [see their definition in the Resolution B1.4 entitled "Post-Newtonian Potential Coefficients"] required for each body. The vector potential $w^i(t,\mathbf{x} = \sum_A w^i_A(t,\mathbf{x})$ and the function $\Delta(t,\mathbf{x}) = \sum_A \Delta_A(t,\mathbf{x})$ are given in note 2.
2. the relation between TCB and Geocentric Coordinate Time (TCG) can be expressed to sufficient accuracy by

$$\begin{aligned} TCB - TCG &= c^{-2}[\int_{t_0}^{t}(\frac{v_E^2}{2}+w_{0ext}(\mathbf{x}_E))dt + v_E^i r_E^i] \\ &-c^{-4}[\int_{t_0}^{t}(-\frac{1}{8}v_E^4-\frac{3}{2}v_E^2 w_{0ext}(\mathbf{x}_E)+4v_E^i w_{ext}^i(\mathbf{x}_E)+\frac{1}{2}w_{0ext}^2(\mathbf{x}_E))dt \\ &-(3w_{0ext}(\mathbf{x}_E)+\frac{v_E^2}{2})v_E^i r_E^i], \end{aligned}$$

where v_E is the barycentric velocity of the Earth and where the index ext refers to summation over all bodies except the Earth.

Notes

1. *This formulation will provide an uncertainty not larger than* 5×10^{-18} *in rate and, for quasi-periodic terms, not larger than* 5×10^{-18} *in rate amplitude and 0.2 ps in phase amplitude, for locations farther than a few solar radii from the Sun. The same uncertainty also applies to the transformation between TCB and TCG for locations within 50000 km of the Earth. Uncertainties in the values of astronomical quantities may induce larger errors in the formulas.*

2. *Within the above mentioned uncertainties, it is sufficient to express the vector potential* $w^i_A(t,\mathbf{x})$ *of body A as*

$$w^i_A(t,\mathbf{x}) = G\left[\frac{-(\mathbf{r}_A\times\mathbf{S}_A)^i}{2r_A^3} + \frac{M_A v^i_A}{r_A}\right],$$

where $\mathbf{S}_A$ *is the total angular momentum of body A and* v^i_A *is the barycentric coordinate velocity of body A. As for the function* $\Delta_A(t,\mathbf{x})$ *it is sufficient to express it as*

$$\Delta_A(t,\mathbf{x}) = \frac{GM_A}{r_A}\left[-2v_a^2 + \sum_{B\neq A}\frac{GM_B}{r_{BA}} + \frac{1}{2}\left(\frac{(r^k_A v^k_A)^2}{r_A^2} + r^k_A a^k_A\right)\right] + \frac{2Gv^k_A(\mathbf{r}_A\times\mathbf{S}_A)^k}{r_A^3},$$

where $r_{BA} = |\mathbf{x}_B - \mathbf{x}_A|$ *and* a^k_A *is the barycentric coordinate acceleration of body A. In these formulas, the terms in* $\mathbf{S}_A$ *are needed only for Jupiter (*$S \approx 6.9\times10^{38} m^2 s^{-1} kg$*) and Saturn (*$S \approx 1.4 \times 10^{38} m^2 s^{-1} kg$*), in the immediate vicinity of these planets.*

3. *Because the present recommendation provides an extension of the IAU 1991 recommendations valid at the full first post-Newtonian level, the constants* L_C *and* L_B *that were introduced in the IAU 1991 recommendations should be defined as* $< TCG/TCB > = 1 - L_C$ *and* $< TT/TCB > = 1 - L_B$*, where TT refers to Terrestrial Time and* $<>$ *refers to a sufficiently long average taken at the geocenter. The most recent estimate of* L_C *is (Irwin, A. and Fukushima, T., Astron. Astroph.,* **348***, 642–652, 1999)*

$$L_C = 1.48082686741 \times 10^{-8} \pm 2 \times 10^{-17}.$$

From Resolution B1.9 on "Redefinition of Terrestrial Time TT", one infers $L_B = 1.55051976772 \times 10^{-8} \pm 2 \times 10^{-17}$ *by using the relation* $1 - L_B = (1 - L_C)(1 - L_G)$*.* L_G *is defined in Resolution B1.9.*

Because no unambiguous definition may be provided for L_B *and* L_C*, these constants should not be used in formulating time transformations when it would require knowing their value with an uncertainty of order* 1×10^{-16} *or less.*

4. *If TCB−TCG is computed using planetary ephemerides which are expressed in terms of a time argument (noted* T_{eph}*) which is close to Barycentric Dynamical Time (TDB), rather than in terms of TCB, the first integral in Recommendation 2 above may be computed as*

$$\int_{t_0}^{t}\left(\frac{v_E^2}{2} + w_{0ext}(\mathbf{x}_E)\right)dt = \left[\int_{T_{eph_0}}^{T_{eph}}\left(\frac{v_E^2}{2} + w_{0ext}(\mathbf{x}_E)\right)dt\right]/(1-L_B).$$

A.6 Resolution B1.6: IAU 2000 Precession-Nutation Model

The XXIVth International Astronomical Union

Recognizing

1. that the International Astronomical Union and the International Union of Geodesy and Geophysics Working Group (IAU-IUGG WG) on 'Non-rigid Earth Nutation Theory' has met its goals by
   (a) establishing new high precision rigid Earth nutation series, such as (1) SMART97 of Bretagnon *et al.*, 1998, *Astron. Astroph.*, **329**, 329–338; (2) REN2000 of Souchay *et al.*, 1999, *Astron. Astroph. Supl. Ser.*, **135**, 111–131; (3) RDAN97 of Roosbeek and Dehant 1999, *Celest. Mech.*, **70**, 215–253;
   (b) completing the comparison of new non-rigid Earth transfer functions for an Earth initially in non-hydrostatic equilibrium, incorporating mantle anelasticity and a Free Core Nutation period in agreement with observations,
   (c) noting that numerical integration models are not yet ready to incorporate dissipation in the core, and
   (d) noting the effects of other geophysical and astronomical phenomena that must be modelled, such as ocean and atmospheric tides, that need further development;
2. that, as instructed by IAU Recommendation C1 in 1994, the International Earth Rotation Service (IERS) will publish in the IERS Conventions (2000) a precession-nutation model that matches the observations with a weighted rms of 0.2 milliarcsecond (mas);
3. that semi-analytical geophysical theories of forced nutation are available which incorporate some or all of the following — anelasticity and electromagnetic couplings at the core-mantle and inner core-outer core boundaries, annual atmospheric tide, geodesic nutation, and ocean tide effects;
4. that ocean tide corrections are necessary at all nutation frequencies; and
5. that empirical models based on a resonance formula without further corrections do also exist;

Accepts

the conclusions of the IAU-IUGG WG on Non-rigid Earth Nutation Theory published by Dehant *et al.*, 1999, *Celest. Mech.* **72(4)**, 245–310 and the recent comparisons between the various possibilities, and

Recommends

that, beginning on 1 January 2003, the IAU 1976 Precession Model and IAU 1980 Theory of Nutation, be replaced by the precession-nutation model IAU 2000A (MHB2000, based on the transfer functions of Mathews, Herring and Buffett, 2000 - submitted to the *Journal of Geophysical Research*) for those who need a model at the 0.2 mas level, or its shorter version IAU 2000B for those who need a model only at the 1 mas level, together with their associated precession and obliquity rates, and their associated celestial pole offsets, as published in the IERS Conventions 2000, and

Encourages

1. the continuation of theoretical developments of non-rigid Earth nutation series,
2. the continuation of VLBI observations to increase the accuracy of the nutation series and the nutation model, and to monitor the unpredictable free core nutation, and
3. the development of new expressions for precession consistent with the IAU 2000A model.

A.7 Resolution B1.7: Definition of Celestial Intermediate Pole

The XXIVth International Astronomical Union

Noting

the need for accurate definition of reference systems brought about by unprecedented observational precision, and

Recognizing

1. the need to specify an axis with respect to which the Earth's angle of rotation is defined,
2. that the Celestial Ephemeris Pole (CEP) does not take account of diurnal and higher frequency variations in the Earth's orientation,

Recommends

1. that the Celestial Intermediate Pole (CIP) be the pole, the motion of which is specified in the Geocentric Celestial Reference System (GCRS, see Resolution B1.3) by motion of the Tisserand mean axis of the Earth with periods greater than two days,
2. that the direction of the CIP at J2000.0 be offset from the direction of the pole of the GCRS in a manner consistent with the IAU 2000A (see Resolution B1.6) precession-nutation model,
3. that the motion of the CIP in the GCRS be realized by the IAU 2000A model for precession and forced nutation for periods greater than two days plus additional time-dependent corrections provided by the International Earth Rotation Service (IERS) through appropriate astro-geodetic observations,
4. that the motion of the CIP in the International Terrestrial Reference System (ITRS) be provided by the IERS through appropriate astro-geodetic observations and models including high-frequency variations,
5. that for highest precision, corrections to the models for the motion of the CIP in the ITRS may be estimated using procedures specified by the IERS, and
6. that implementation of the CIP be on 1 January 2003.

Notes

1. *The forced nutations with periods less than two days are included in the model for the motion of the CIP in the ITRS.*
2. *The Tisserand mean axis of the Earth corresponds to the mean surface geographic axis, quoted B axis, in Seidelmann, 1982, Celest. Mech.,* **27***, 79–106.*
3. *As a consequence of this resolution, the Celestial Ephemeris Pole is no longer necessary.*

A.8 Resolution B1.8: Definition and use of Celestial and Terrestrial Ephemeris Origin

The XXIVth International Astronomical Union

Recognizing

1. the need for reference system definitions suitable for modern realizations of the conventional reference systems and consistent with observational precision,

2. the need for a rigorous definition of sidereal rotation of the Earth,
3. the desirability of describing the rotation of the Earth independently from its orbital motion, and

Noting

that the use of the "non-rotating origin" (Guinot, 1979) on the moving equator fulfills the above conditions and allows for a definition of UT1 which is insensitive to changes in models for precession and nutation at the microarcsecond level,

Recommends

1. the use of the "non-rotating origin" in the Geocentric Celestial Reference System (GCRS) and that this point be designated as the Celestial Ephemeris Origin (CEO) on the equator of the Celestial Intermediate Pole (CIP),
2. the use of the "non-rotating origin" in the International Terrestrial Reference System (ITRS) and that this point be designated as the Terrestrial Ephemeris Origin (TEO) on the equator of the CIP,
3. that UT1 be linearly proportional to the Earth Rotation Angle defined as the angle measured along the equator of the CIP between the unit vectors directed toward the CEO and the TEO,
4. that the transformation between the ITRS and GCRS be specified by the position of the CIP in the GCRS, the position of the CIP in the ITRS, and the Earth Rotation Angle,
5. that the International Earth Rotation Service (IERS) take steps to implement this by 1 January 2003, and
6. that the IERS will continue to provide users with data and algorithms for the conventional transformations.

Note

1. *The position of the CEO can be computed from the IAU 2000A model for precession and nutation of the CIP and from the current values of the offset of the CIP from the pole of the ICRF at J2000.0 using the development provided by Capitaine et al. (2000).*
2. *The position of the TEO is only slightly dependent on polar motion and can be extrapolated as done by Capitaine et al. (2000) using the IERS data.*
3. *The linear relationship between the Earth's rotation angle θ and UT1 should ensure the continuity in phase and rate of UT1 with the value obtained by the conventional relationship between Greenwich Mean Sidereal Time (GMST) and UT1. This is accomplished by the following relationship:*

$$\theta(UT1) = 2\pi(0.7790572732640 + 1.00273781191135448 \times (Julian\, UT1\, date - 2451545.0))$$

References

Guinot, B., 1979, in D.D. McCarthy and J.D. Pilkington (eds.), *Time and the Earth's Rotation*, D. Reidel Publ., 7–18.

Capitaine, N., Guinot, B, McCarthy, D.D., 2000, "Definition of the Celestial Ephemeris Origin and of UT1 in the International Celestial Reference Frame", *Astron. Astrophys.*, **355**, 398–405.

A.9 Resolution B1.9: Re-definition of Terrestrial Time TT

The XXIVth International Astronomical Union

Considering

1. that IAU Resolution A4 (1991) has defined Terrestrial Time (TT) in its Recommendation 4, and
2. that the intricacy and temporal changes inherent to the definition and realization of the geoid are a source of uncertainty in the definition and realization of TT, which may become, in the near future, the dominant source of uncertainty in realizing TT from atomic clocks,

Recommends

that TT be a time scale differing from TCG by a constant rate: $dTT/dTCG = 1\text{-}L_G$, where $L_G = 6.969290134 \times 10^{-10}$ is a defining constant,

Note

L_G was defined by the IAU Resolution A4 (1991) in its Recommendation 4 as equal to U_G/c^2 where U_G is the geopotential at the geoid. L_G is now used as a defining constant.

A.10 Resolution B2: Coordinated Universal Time

The XXIVth International Astronomical Union

Recognizing

1. that the definition of Coordinated Universal Time (UTC) relies on the astronomical observation of the UT1 time scale in order to introduce leap seconds,
2. that the unpredictable leap seconds affects modern communication and navigation systems,
3. that astronomical observations provide an accurate estimate of the secular deceleration of the Earth's rate of rotation

Recommends

1. that the IAU establish a working group reporting to Division I at the General Assembly in 2003 to consider the redefinition of UTC,
2. that this study discuss whether there is a requirement for leap seconds, the possibility of inserting leap seconds at pre-determined intervals, and the tolerance limits for UT1−UTC, and
3. that this study be undertaken in cooperation with the appropriate groups of the International Union of Radio Science (URSI), the International Telecommunications Union (ITU-R), the International Bureau for Weights and Measures (BIPM), the International Earth Rotation Service (IERS) and relevant navigational agencies.