The relationships between
The International Astronomical Union (IAU) and time

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Time and astronomy: a few historical aspects

Measurements of time before the adoption of atomic time

- The time based on the Earth's rotation was considered as being uniform until 1935.

- Up to the middle of the 20th century it was determined by astronomical observations (sidereal time converted to mean solar time, then to Universal time).

When polar motion within the Earth and irregularities of Earth's rotation have been known (secular and seasonal variations), the astronomers:

1) defined and realized several forms of UT to correct the observed UT0, for polar motion (UT1) and for seasonal variations (UT2);
2) adopted a new time scale, the *Ephemeris time,* ET, based on the orbital motion of the Earth around the Sun instead of on Earth's rotation, for celestial dynamics,
3) proposed, in 1952, the second defined as a fraction of the tropical year of 1900.

Definition of the second based on astronomy (before the 13th CGPM 1967-1968) definition

- Before 1960: 1st definition of the second

The unit of time, the second, was defined as the fraction 1/86 400 of the mean solar day. The exact definition of "mean solar day" was left to astronomers (cf. SI Brochure).

- 1960-1967: 2d definition of the second

The 11th CGPM (1960) adopted the definition given by the IAU based on the tropical year 1900:

The second is the fraction 1/31 556 925.9747 of the tropical year for 1900 January 0 at 12 hours ephemeris time.

IAU scientific topics linked with time

Time measurement as the base for high accuracy astro-geodetic techniques

- Very Long Baseline Interferometry (VLBI)observations of extragalactic radiosources,
- Satellite and lunar laser ranging (SLR, LLR), GNSS observations.

Applications: Realisation of reference frames, Earth rotation determination, etc.

Definition and realisation of timescales for astronomy

- Universal Time, *UT1*, based on Earth's rotation,
- Coordinated Universal Time, *UTC,* currently defined as:

UTC = *TAI* + *n*, where *n* is an integer number of s such that |UT1 − UTC| < 0.9 s

→ Introduction of leap seonds → issue of the future definition of UTC

- TCB, TCG, TT, TDB, timescales in the GR framework to be used for the reduction of asgronomical obsservations,
- Pulsar-based timescale: e.g. as provided by*The European pulsar timing array*).

Accurate determination of Earth's rotation

which is coordinated by the *International Earth Rotation and Reference Systems Service* (IERS)

The variations in Earth's rotation are provided by the quantity UT1 – UTC,

the difference between the UT1 parameter derived from observation and the uniform time scale UTC.

IAU 1985 Resolution

Resolution No. B 1
Responsibility for Time
Responsabilité de l'Heure

The International Astronomical Union,

recalling
1) that the establishment of International Atomic Time (TAI) and of Coordinated Universal Time (UTC) is one of the present tasks of the Bureau International de l'Heure (BIH), and

2) that the IAU is the main parent scientific Union of the BIH, the other parent unions being the International Union of Geodesy and Geophysics (IUGG) and the International Union of Radio Science (URSI), and

considering
1) that the atomic time scales, originally used mainly in astronomy, have now a much wider use, including numerous and important technical and public applications,

2) that TAI is based solely on physical measurements independent of astronomy,

3) that there exists an inter-governmental organization of which the Bureau International des Poids et Mesures (BIPM) is the Executive Body in charge of the unification of measurement of the major physical quantities,

4) that UTC is based both on TAI and on the astronomical time scale designated as Universal Time (UT1), and

5) the URSI recommendation A-1, 1984, relative to the transfer of TAI to the BIPM,

approves
of TAI being taken over entirely by the Bureau International des Poids et Mesures, under the responsibility of the International Committee of Weights and Measures (CIPM) and of the General Conference of Weights and Measures,

recommends
1) that the function of determining and announcing the leap seconds of the UTC system, as well as the function of determining and announcing the ΔUT1 corrections, be given to the new International Earth Rotation Service entrusted by the IAU and IUGG with the evaluation of the Earth rotation parameters, and

2) that a permanent committee, where the IAU will be represented, be created, under the sponsorship of CIPM in order to take care of the interest of TAI users, and

extends
to the Paris Observatory its thanks for the service provided to the international community by supporting the BIH.

Extract of IAU 1985 Resolution on time

recommends 1) that the function of determining and announcing the leap seconds of the UTC system, as well as the function of determining and announcing the ΔUT1 corrections, be given to the new International Earth Rotation Service entrusted by the IAU and IUGG with the evaluation of the Earth rotation parameters, and

2) that a permanent committee, where the IAU will be represented, be created, under the sponsorship of CIPM in order to take care of the interest of TAI users, and

IAU scientific bodies related to standards and time

- Division A Commission on *Fundamental standards*
- Division A Commission on *Earth Rotation*
- Division A Commission on *Solar System Ephemerides*
- Division A WG *Numerical Standards in Fundamental Astronomy*
- Division A WG *Standards of Fundamental Astronomy* (SOFA)
- Division A WG *(Links to) Time Metrology standards*

The IERS is a service of the IAU and IUGG and reports to IAU Commission « Earth Rotation) within IAU Division A Fundamental Astronomy

IAU WG « (Links to)Time Metrology Standards » - Functional

The Working Group with the link to time metrology standards within the IAU Division A has the objective of:

- enhancing the interaction between astronomers and the time and frequency metrology community.
- The time metrology community provides the reference time scale, of atomic nature, which is the basis of coordinate times used for space-time referencing in astronomy.
- The dynamical time scale based on precision timing of pulsars has the potential of improving the long-term standard of time.
- Changes forecasted in the next years will require common actions of astronomers and metrologists;
- examples are the possible new definition of the second consequence of the advent of optical clocks, and the contribution to the studies on the adoption of a uniform international reference time scale.

Affiliations with Division A WG Time Metrology Standards

CHAIR

Arias, Elisa		

WORKING GROUP MEMBERS

Archinal, Brent	Arias, Elisa	Brzeziński, Aleksander
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IAU Resolutions related to time

IAU 1985 Resolution B1 on the *ResponsibIlity for Time*

IAU 2000 Resolutions

B1.3 Definition of Barycentric Celestial Reference System and Geocentric Celestial Reference System

B1.5 Extended relativistic framework for time transformations and realisation of coordinate times in the solar system

B1.8 Definition and use of Celestial and Terrestrial Ephemeris Origins (new definition of UT1)

B1.9 Re-definition of Terrestrial Time TT

that TT be a time scale differing from TCG by a constant rate: $dTT/dTCG = 1-L_G$,

where $L_G = 6.969290134.10^{-10}$ is a defining constant,

Note : L_G was previously defined 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.

B2 Coordinated Universal Time which recommended

- *that the IAU establish a WG reporting to Div I at the Ga in 2003 to consider the redefinition of UTC,*
- *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*
- *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.*

IAU 2006 Resolution B3: *« Re-definition of Barycentric Dynamical Time, TDB »*

Resolution 2 of the 26th CGPM (2018)
On the definition of time scales (1)

recognizing that

- the mission of the BIPM is to ensure and promote the global comparability of measurements, including the provision of a coherent international system of units,
- the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG) with the International Association of Geodesy (IAG) are responsible for defining reference systems for Earth and space applications,
- the International Telecommunication Union Radiocommunication Sector (ITU-R) is responsible for coordinating the dissemination of time and frequency signals and making relevant recommendations,
- the International Earth Rotation and Reference Systems Service (IERS), a service of the IAU and IUGG, is responsible for providing information required to relate terrestrial and celestial reference systems, including time-varying measurements of the Earth's rotation angle, UT1 - UTC, the low-precision prediction of UT1 - UTC for time signal broadcasts, DUT1, and for deciding and announcing leap second insertions,

Resolution 2 of the 26th CGPM (2018) on the definition of time scales (2)

noting that

- Resolution A4 (1991) of the IAU defined, in Recommendations I and II, the Geocentric Reference System as a system of space-time coordinates for the Earth within the framework of general relativity, and, in Recommendation III, named the time coordinate of that reference system "Geocentric Coordinate Time" (TCG),
- Resolution A4 (1991) of the IAU further defined, in Recommendation IV, Terrestrial Time (TT) as another time coordinate in the Geocentric Reference System, differing from TCG by a constant rate; the unit of measurement of TT being chosen to agree with the SI second on the geoid,
- Resolution B1.9 (2000) of the IAU redefined TT to be a time scale differing from TCG by a constant rate: $d\mathrm{TT}/d\mathrm{TCG} = 1 - L_G$, where $L_G = 6.969\,290\,134 \times 10^{-10}$ is a defining constant (the numerical value of L_G was chosen to conform to the value $W_0 = 62\,636\,856.0\ \mathrm{m^2 s^{-2}}$ for the gravity potential on the geoid as recommended by Special Commission 3 of the IAG in 1999),
- the redefinition of TT in 2000 introduced an ambiguity between TT and TAI as the CCDS had stated in 1980 that TAI was to have "*the SI second as realized on the rotating geoid as the scale unit*" while the definition of TT does not refer to the geoid,

Resolution 2 of the 26th CGPM (2018) on the definition of time scales (3)

states that

- TAI is a continuous time scale produced by the BIPM based on the best realizations of the SI second, and is a realization of TT as defined by IAU Resolution B1.9 (2000),
- in the transformation from the proper time of a clock to TAI, the relativistic rate shift is computed with respect to the conventionally adopted equipotential $W_0 = 62\,636\,856.0\ \mathrm{m^2\,s^{-2}}$ of the Earth's gravity potential, which conforms to the constant L_G defining the rate of TT,
- as stated in the IAU Resolution A4 (1991), TT − TAI = 32.184 s exactly at 1 January 1977, 0h TAI at the geocentre, in order to ensure continuity of TT with Ephemeris Time,

- UTC produced by the BIPM, based on TAI, is the only recommended time scale for international reference and the basis of civil time in most countries,
- UTC differs from TAI only by an integral number of seconds as published by the BIPM,
- users can derive the rotation angle of the Earth by applying to UTC the observed or predicted values of UT1 − UTC, as provided by the IERS,