

ON THE HISTORY OF THE ASTRONOMICAL CONSTANTS

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1. INTRODUCTION. This paper summarizes, historical developments concerning star catalogues and the unification of astronomical constants, as well as related decisions about time. The text is mainly presented as a chronological list.

2. CONNAISSANCE DES TEMPS (CDT) AND THE NAUTICAL ALMANAC (NA)

The French ephemerides, CDT, created under Dalencé (1640-1707), was published, for the first time, for the year 1679. It was a very small book. Due to the duration of voyages, the navigators were used to employ the Desplaces' ephemerides established for ten years. After some time, the CDT appeared a few years in advance, which was not sufficient for navigators, but very appropriate to astronomers's uses. The reference meridian was the symmetry axis of the newly built *Observatoire Royal* of Louis the 14th, fixed on 1667 June 21. The NA appeared almost one century later, in 1767, under Maskelyne (1732-1811), the *Astronomer Royal* of the King of England.

Some major constants used in *Connaissance des Temps* up to 1868, have been, in chronological order:

1679: Data resulting from observations performed by astronomers; as examples: refraction studies from Picard (1620-1680), Cassini I (1625-1712), solar and lunar data from observations (various observers), satellites of Jupiter by Cassini I.

1785: Data issued from observations, catalogues, calculations; as examples: refraction after studies by Cassini I, Flamsteed (1646-1719), Bradley (1693-1762), La Caille (1713-1762), Le Monnier (1715-1799), catalogues of stars from La Caille, Tobias Mayer (1723-1762).

1868: CDT values for: *Precession* (discovered by Hipparchus (II cy BC)), further studies by Picard, Cassini I (17th century) and others (18th and 19th centuries): **50.2401''**; *Nutation*, discovered, by Bradley (1726): **9.2236''** from Peters (1806-1880); *Aberration*, discovered by Bradley (1729): **20.463''**; *Refraction* tables by Laplace (1749-1827). Satellites of Jupiter: tables by Damoiseau (1768-1846).

3. THE FIRST UNIFICATION OF STAR CATALOGUES AND CONSTANTS

1887: The *Carte du Ciel*, an international enterprise for cataloguing the sky, is launched by Mouchez (1821-1892), then director of *Observatoire de Paris*, and Gill (1843-1914), the director of The Cape Observatory.

1895: In view of a general catalogue of stars, the unification of constants to reduce the observations appeared necessary. Downing (1850-1917), the Superintendent of NA, requested the opinion of Løwy (1833-1907), the director of the CDT, placed under the responsibility of the *Bureau des Longitudes* in Paris; the Bureau agreed about the necessity of unification for astronomy, navigation and geodesy.

1896: *Conférence internationale des étoiles fondamentales* (Paris, *Bureau des longitudes*). Participants: Bauschinger (1860-1934, Berliner Jachbuch), Newcomb (1835-1909, Nautical Almanac, USA), Downing (1850-1897, Nautical Almanac, GB), Løwy (CDT), Tisserand (1845-1896, *Observatoire de Paris*), Backlund (1846-1916, Pulkovo Observatory), Gill (Southern hemisphere Observatories), Faye (1814-1902, president of the *Bureau des longitudes*); invited and secretariat: Sande Bakhuyzen (1838-1923, Leiden) and Trépiéd (1845-1907, Algiers Observatory).

The discussed and adopted values were: *Nutation*: Gill 9.2068''; Newcomb 9.214''; Chandler 9.198''; value suggested by Løwy and adopted : **9.21''**. *Aberration*: Løwy and Puiseux : 20.46''; Gill 20.467''; Newcomb 20.48''; value suggested by Løwy and adopted: **20.47''**. *Precession*: needed more research by Newcomb; by the end, adopted value: **50.2564''**. The decision was to apply the adopted values starting from 1901.

4. INTERNATIONAL MEETINGS FROM 1900 TO WORLD WAR I

1911: Upon invitation of B. Baillaud (1848-1934), then director of the *Observatoire de Paris*, a *Congrès international des éphémérides astronomiques* was held, in Paris (October 23-26). Among participants: Backlund (Pulkovo), Cohn (Berliner Jachbuch), Dyson (Greenwich), Eichelberger (American Ephemeris), Gill (UK), Perrine (Cordoba Observatory). *French side* : André, Baillaud, Bigourdan, Deslandres, Picard, Poincaré, Radau, with Andoyer and La Baume-Pluvinel as secretaries.

After the unification of time over the French territory (1891), the Airy Greenwich meridian line became the time reference (1911) in France, following meetings (Roma 1883 and Washington 1884). The *Système métrique décimal* (called sometimes MKS) included *Mètre*, *Kilogramme*, and the *seconde* (a fraction of the mean solar day), the second being added after a proposal said to be from Gauss (1777-1855).

1912: *Conférence internationale de l'heure* (Paris, *Bureau des longitudes*) after, in 1899, the first successful time signals by wireless telegraphy from Hamburg, later from *Observatoire de Paris* and the *Tour Eiffel* summit, up to 5000 kilometers (1910). A project is established (*Association internationale de l'Heure*, including a *Bureau international de l'heure*), with statutes and *Convention diplomatique*.

1913: *Conférence diplomatique* (Paris, October 20-26). Project accepted, signed by participants when approved by their governments. Limit for other signatures: 1914 February 1. The Convention (October 25), had to be in force up to 1920 December 31. B. Baillaud is at the head of the Bureau, to become "BIH" located at *Observatoire de Paris*. During the war, the *Observatoire de Paris Service de l'heure* and the BIH were maintained by B. Baillaud and Bigourdan (1851-1932). After the war, everything was more or less forgotten and new ideas came up.

1919: A meeting (Brussels, July 18-19) creates a *Conseil international des recherches*, including several international unions and, among them, the International Astronomical Union (UAI/IAU), divided into 32 commissions including number 4, *Commission des éphémérides*, and number 31, *Commission de l'heure*, the by-laws of which are signed on July 26. An official character is given to the BIH, at the *Observatoire de Paris*. Commissions 4 and 31 will, in the future take care of the fundamental astronomical constants and of the units. But, World War II was not far and a new cut came.

5. THE IAU 1964 AND 1976 SYSTEMS OF ASTRONOMICAL CONSTANTS

1950: *Colloque international* by the *Centre national de la recherche scientifique* (Paris Observatory, March 27-April 1) on the fundamental astronomical constants. Among the participants: Ambarzumian, Batrouchevitch, Brouwer, Clemence, Jeffreys, Kopff, Kilokov, Morgan, Nemiro, Sadler, Spencer Jones, Oort, Zverev. For France: Chazy, Danjon, Fayet, Mineur, Stoyko. The recommendation of the conference to the IAU on the System of astronomical constants was to apply no change to their conventional values.

1950, 1953, 1954, 1955, 1958: Five successive meetings concerning astrometry connected with time, ephemerides, constants, fundamental units and references for space and time. During the General Assemblies (GA) of the IAU, incoherences in the fundamental constants are pointed out (Dublin 1955) and news about the catalogue for fundamental stars (to be FK4) are given (Moscow 1958).

1961: GA of the IAU (Berkeley), Danjon (1890-1967) director of *Observatoire de Paris*, suggests an IAU symposium on *Le système de constantes astronomiques* to be held in 1963.

1963: IAU symposium N° 21 (Paris, May 27-31). Adoption of new values.

1964: GA of the IAU in Hamburg, during which the FK4 and the proposed set of constants are adopted by the IAU; their use is recommended in the national and international ephemerides as soon as possible; this was from 1968.

1976: GA of the IAU (Grenoble). After discussions (1964-1976), another complete set of constants associated to a model of precession is adopted in the "IAU 1976 System of astronomical constants". In parallel, evolution of the time unit: the second, related to the rotation of the Earth (UT) up to 1960, was replaced by its revolution with ET (*temps des éphémérides*) up to 1967, when the second was based upon a Caesium frequency. The first name, *temps atomique intégré*, was changed into *Temps atomique international*, after its new modern realization in 1972 and under its official name TAI in 1976.

Note: All the references can be found in: - Débarbat, S., Les fondements historiques d'un système de constantes unifiées (Journées 1994 "Systèmes de référence spatio-temporels", Paris, pp. 3-10); - Capitaine, N., Les constantes astronomiques fondamentales de 1896 à nos jours (in press in Actes des Journées Lalande-Lœwy, Paris 2007); - Symposium "The origins, achievement and influence of the Royal Observatory, Greenwich: 1675-1975" (Greenwich, 13-18 July 1975); - Lévy, J., La création de la Connaissance des temps (Vistas in Astronomy, 20, pp 75-77, 1977).