4. EPHEMERIDES (ÉPHÉMÉRIDES)

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I. Introduction

The period of this Report includes 1984 January 1, the date which was probably the most drastic caesura in the history of astronomical almanacs. It seemed, therefore, appropriate to concentrate here to the general aspects rather than to describe the works going on at the particular almanac offices. It is, however, hoped that the past years with their developments and changes will be followed by a period of consolidation and continuity. This would be also of great benefit for the users of the almanacs who still need some time for getting accustomed to so many innovations.

II. International and National Ephemerides

1. GENERAL CHANGES

According to the Resolutions adopted at the IAU General Assemblies 1976, 1979, and 1982 many changes had to be introduced from 1984 January 1 onwards, namely:

(a) the IAU (1976) System of Astronomical Constants (Trans. IAU XVIB, 58);

(b) the 1980 IAU Theory of Nutation (Trans. IAU XVIIIA, 8);

(c) the new definitions of time and time scales (Trans. IAU XVIB, 58; XVIIB, 69; XVIIIB, 72);

(d) the Cartographic Coordinates and Rotational Elements of the Planets and Satellites (33.091.004);

(e) the new fundamental reference frame (Trans. IAU XVIB, 58).

Each ephemeris and data set as given in an almanac is affected by one or more of these changes. It should be remarked that slight modifications of the adopted values for the astronomical constants may be introduced either indirectly by the use of certain fundamental ephemerides or for other reasons which are mentioned in the explanation of the almanac.

2. THE FUNDAMENTAL SYSTEM

A particular remark is necessary with regard to item (e); in the Resolution adopted in 1976, it was recommended that the new fundamental reference frame should be defined by the positions and proper motions of the FK5 catalogue. This catalogue which is currently in preparation at the Astronomisches Rechen-Institut Heidelberg, is not yet available at the time when the almanacs for 1984 and some subsequent years are prepared. Only the correction of the FK4 equinox and its fictitious motion was available (Trans. IAU XVIIIA, 3) and could be applied whenever necessary. Nevertheless the FK5 can be regarded de jure as the fundamental reference system from 1984 January 1 onwards. Corrections for the transition from the

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FK4 to the FK5 system will be given in both analytical and tabulated form as soon as the FK5 catalogue is available, for those years from 1984 onwards in which the ephemerides in the almanacs had still to be based on the FK4 system.

In particular, this will also be true for the volumes "Apparent Places of Fundamental Stars". They are still based on the FK4 (except of the equinox correction); but for each year from 1984 until the first volume based on the FK5, for each star the reduction from FK4 to FK5 will be given containing both the systematic and the individual corrections.

3. BASIS OF THE EPHEMERIDES

Intentionally one has not adopted a certain theory or method as the basis for the ephemerides of the bodies of the solar system. Of course, there is a common agreement that the results should "best fit" the observations. There are in principle two different ways to approach that goal:

(1) The new fundamental ephemerides are derived by numerical integration and represent a most accurate, consistent set that can be calculated based on currently available observational data. They were cooperatively prepared by the Jet Propulsion Laboratory, Pasadena, and the U. S. Naval Observatory, Washington. The data as given in most of the almanacs are derived from these fundamental ephemerides. Ref.: E M Standish, P K Seidelmann (31.047.021); E M Standish (31.091.048); P K Seidelmann, R L Duncombe (31.091.030); X X Newhall et al. (34.046.003).

(2) The other method, which is used by the Bureau des Longitudes, Paris, consists in the development of new theories for the motions of the Sun, Moon, and planets as well as for the Galilean Satellites. The data as given in the Connaissance des Temps is based on these theories. Ref.: J-F Arlot (31.099.138); P Bretagnon (32.042.038); J-L Simon (33.042.026); G Francou et al. (34.046.007); M Chapront-Touzé, J Chapront (34.094.002); J Chapront, D T Vu (Astron. Astrophys. 141, 131).

The question which of these both methods is better and preferable, appears to be idle because each has its merits: The first may furnish more accurate results for the present period of time; the second permits to improve our knowledge on the long-term development and changes of the orbits. In any case, because both methods are based on practically the same observational material, the comparison of the results would also facilitate to reveal any defects or neglected effects.

4. ACCURACY, PRESENTATION, AND EXPLANATION

Improvement of the measurements required also a corresponding increase of accuracy in computing the ephemerides as given in the almanacs. This demand could be met partly by more powerful calculating means available; but also new computing techniques had to be developed and additional small effects which could be neglected in the past, were included.

Moreover, in some almanacs the presentation of the ephemerides and of other data has been more or less drastically modified. The main reason was to accommodate the form to the modern possibilities which the users had at their disposition, in particular the assistance of small computers. In many cases the most practicable realization of that aim was to tabulate interpolation coefficients in suitable intervals of time (e. g. The Astronomical Almanac, Connaissance des Temps, and, particularly, the Almanac for Computers). On the other hand, for the needs of occasional users the classical method of tabulation of the required data in a fixed interval (eventually with differences) offers some advantage (e. g. Astronomical Ephemeris of the USSR, Apparent Places of Fundamental Stars).

The introduction of all these changes of different kind required corresponding modifications of the explanation or even its re-writing for the 1984 editions of the almanacs. It seems, therefore, not necessary to enumerate in detail the changes which had been made in each almanac. Two examples only should be mentioned as exemplary:

(a) The Astronomical Almanac contains quite practice-orientated explanations given with each section of tabulation and accompanied by very useful examples.

(b) Both The Astronomical Almanac and the Japanese Ephemeris have added to the 1984 and 1985 edition respectively a Supplement which gives the basis of the new Ephemeris, i. e. a theoretical description of all fundamentals of the almanac including the necessary formulae and numerical values.

III. Recent Developments

The Commission should not restrict its activity to the almanacs and their production. There are now two quite distinct groups which do no longer use the ephemerides which are given in the almanacs:

(1) Formerly these ephemerides had been used not only for preparing the observations and for facilitating to find the objects to be observed on the sky, but also for comparing the ephemeris values with the observations, with the goal to improve the theory or at least some basic elements or constants, by analyzing the O-C's. For that use, the ephemerides had to be at least of the same precision as the observations. This utilization of the almanacs is, however, widely superseded. Most of the institutions which do such fundamental work have now large computers available; they are used not only for the reduction of the observations, but also for calculating the data directly from the theory rather than to interpolate them in an almanac. For some ephemerides one could therefore reduce the precision such that it is sufficient for prediction purposes.

(2) The other quite different group consists of those who have a small computer at their disposal. They would be able and willing to calculate by themselves the data which they formerly took from the almanacs. They are therefore interested to find formulae and practical prescriptions for this, which are not offered in the classical astronomical litterature. I do not think that this Commission should ignore that development (sometimes perhaps regarding it even as somewhat as a competition to the printed almanacs). The Commission should rather be interested that publications should be available which present the material in accordance with the adopted methods and constants. Good examples are T C van Flandern and F K Pulkkinen (26.021.032), Y Kubo, T Fukushima (Report Hydrogr. Res. Nos 15 and 16), and J Meeus (33.003.071).

IV. Long-term Ephemerides

Almanacs usually appear 1 - 3 years in advance. But in some cases one is interested to have ephemerides which are extended for a longer interval of time into the future. Without claiming completeness, some of them may be enumerated:

(1) Planetary and Lunar Coordinates for the years 1984 - 2000, by H. M. Nautical Almanac Office, Herstmonceux, (34.046.009) is the continuation of the volume for the years 1980 - 1984. The publication contains coordinates of the Sun, Moon, and planets to low precision for J2000.0 and some other predictions.

(2) Compact Data for Navigation and Astronomy for 1986 - 1990, to be published by H. M. Stationery Office, London.

(3) Another interesting publication which also covers the time up to 2000, giving also a star catalogue, but no positions of the Moon is: Star and Planet Catalogue (Equinox 2000.0) by S Nakano and A Otawara (34.002.082).

(4) Advanced predictions of eclipses for the next few years are, as usually,

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given in U.S. Nav. Obs. Circulars; they are currently prepared by A D Fiala and M R Lukac. Eclipse predictions for the years 1981 - 2000 are published also as Supplements to the Japanese Ephemeris 1980 to 1983.

(5) Longer intervals are covered by the Canon of Solar Eclipses -2003 to +2526 (Wien, 1983) and the Canon of Lunar Eclipses -2002 to +2526 (Wien, 1983), both by J Meeus and H Mucke, as well as the Canon of Lunar Eclipses from 1000 B.C. to A.D. 3000 by B-l Liu (34.002.068).

V. Reduction to apparent place

Due to the changes mentioned above, there is an urgent need for precise instructions for the reduction of mean positions (old and new system) to apparent positions (new system) and vice versa; special problems arise in the case of stars where reductions include those from one equinox to another and also from one epoch to another (i. e. taking account of proper motions). Several publications appeared on this subject, e. g. by

P Bretagnon, J Chapront (30.043.004);
G H Kaplan (31.043.001);
E M Standish (32.043.003);
S Aoki et al. (34.041.033);
F Chollet (37.041.007);
W Melbourne et al. (37.044.055);
T Lederle, H Schwan (37.046.018).

Unfortunately there are some, even small differences between the various proposed methods. The most divergent point is the question whether the transition from the old to the new system (particularly concerning the numerical values for precession) has to become effective on 1984 January 1 or at another epoch. Those who are not so familiar with the problems may be highly disturbed by all the nuances. It seems to be not necessary that the Commission expresses its opinion in favour of one method by a formal recommendation; but it would be highly desirable that the experts agree to one unified procedure (even by some compromise) - and that this procedure be communicated by a common publication of these experts.

VI. Formulae relating time scales

Resolution 3 of Commissions 4, 19 and 31 on the expression of UT1 in terms of GMST as adopted in 1979 (Trans. IAU XVIIB, 69) has been superseded by the Resolution 3 of Commissions 4, 19 and 31 on the expression for GMST at 0^hUT1 as adopted in 1982 (Trans. IAU XVIIIB, 72). S Aoki has emphasized that in consequence of that modification one has also to change the figures as given in the Note to the Resolution (Trans. IAU XVIIB, 70). Although the expressions with the corrected numerical values have been already published by S Aoki et al. (31.044.003), it appears appropriate to give here the new version of the Note according to the text proposed by S Aoki:

"Note: The followings are frequently used quantities which are also affected by the Resolution:

a) The interval of mean sidereal time in a mean solar day becomes

$$24^h + \frac{8\ 640\ 184^s.812\ 866 + 0^s.186\ 208T_u - 1^s.86 \cdot 10^{-5} T_u^2}{36525}$$

$$= \quad 86\ 636^s.555\ 367\ 908\ 72 + 0^s.000\ 005\ 098\ 10T_u - 5^s.1 \cdot 10^{-10} T_u^2,$$

b) The ratio of a sidereal day of 86400 mean sidereal seconds to this interval becomes

$$\frac{\text{mean sidereal day}}{\text{mean solar day}} =$$

$$0.997\ 269\ 566\ 329\ 0840 - 5.868\ 40 \cdot 10^{-11} T_u + 5.86 \cdot 10^{-15} T_u^2,$$

c) The ratio of the mean solar day to the mean solar day becomes

$$1.002\ 737\ 909\ 350\ 7954 + 5.900\ 58 \cdot 10^{-11} T_u - 5.89 \cdot 10^{-15} T_u^2,$$

d) Disregarding the secular variations, the equivalent measures of the lengths of the day at J2000.0 are

$$\begin{aligned} 1 \text{ mean sidereal day} &= 23^h 56^m 04^s.090\ 530\ 8329 \\ &= 86\ 164^s.090\ 530\ 8329 \text{ of mean solar time,} \\ \text{and } 1 \text{ mean solar day} &= 24^h 03^m 56^s.555\ 367\ 9087 \\ &= 86\ 636^s.555\ 367\ 9087 \text{ of mean sidereal time."} \end{aligned}$$

VII. IAU/IAG/COSPAR Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites

The 1982 Report of the IAU Working Group presented at the XVIIIth General Assembly has been published by M E Davies et al. (33.091.004). Tables give the recommended values for the directions of the north poles of rotation and the prime meridians of the planets and satellites referred to both the B1950.0 and J2000.0 standard coordinate systems. References for mapping these bodies are described. An appendix discusses the principal changes to the tables since 1979.

The International Association of Geodesy (IAG) suggested the establishment of a joint IAU/IAG working group to define reference systems for the planets and satellites. Since this falls into the activity of this Working Group, the IAU Executive Committee and the IAG agreed with the Joint Working Group which has been enlarged by members nominated by the IAG. COSPAR would endorse the activities of the Joint Working Group. The new name will therefore be as indicated above in the title.

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President of the Commission

https://doi.org/10.1017/S0251107X00006052 Published online by Cambridge University Press