Delaunay soient mauvaises et qu'il faudra s'orienter vers les variables de Poincaré au un système du même type. Un autre facteur du succès réside dans la manière dont les observations seront interprétées. Il est trés dangereux d'essayer d'interprèter sèparément les diverses inégalités fournies par les observations et séparées par des méthodes parfois peu rigoureuses. Il faudra, dans la mesure du possible, traiter la solution en bloc et déterminer en bloc toutes les inconnues, procédure qui est maintenant rendue possible par les grands calculateurs électroniques.

Enfin, je voudrais dire quelques mots des observations dont dispose le théoricien. Ce sont principalement:

(*a*) Le catalogue d'eclipses d'Ashbrook, commençant en 1668, mais assez pauvre en observations modernes qui sont insuffisamment nombreuses.

(*b*) La série photométrique de Harvard (1878–1903) sur laquelle est essentiellement basée la théorie de Sampson.

(*c*) Des données heliometriques et photographiques de la fin du siècle dernier.

(*d*) D'autres observations épases, se terminant presque toutes vers 1930.

Il y a donc un manque facheux d'observations modernes, qui seraient pourtant indispensables pour mieux avoir la théorie dans le proche avenir. L'Observatoire de Yale envisage de commencer une série d'observations. Il serait désirable et urgent que d'autres observatoires consacrent une partie de leurs moyens à ce problème.

8. SOME REMARKS ON THE FURTHER IMPROVEMENT, BY CONVENTIONAL AND NEW METHODS, OF ASTRONOMICAL CONSTANTS INVOLVED IN EPHEMERIS COMPUTATION

Eugene K. Rabe

Astronomers have been reluctant to change the values adopted for the planetary masses and other constants involved in the preparation of ephemerides. Such changes would destroy the homogeneity of the theories or numerical integrations and would complicate the task of subsequent improvements of the orbital elements and various constants. Also the inner accuracy of the theories of most major planets has proved to be rather limited, so that premature revisions of the planetary masses and other constants alone would not be sufficient to provide us with more precise ephemerides.

As soon as more precise theories or numerical integrations have been adopted, however, the situation is a quite different one. We then have, as in the cases of the 5 outer planets, orbital trajectories of very high internal accuracy, and in order to produce an ephemeris in the best possible agreement with observations, we may have to introduce more precise values of the planetary masses and related constants. A very good illustration of such a changed situation is the recent discovery by Krotkov and Dicke (**1**) of periodic oscillations of the order of $0''\cdot 25$ in the longitude of Jupiter, and their subsequent removal by Clemence (**2**) by means of an improved mass of Saturn. Obviously the situation will be similar for the inner planets, when more precise theories become available. For Mars, Clemence's new theory should very soon establish this changed situation. Then a better theory of the Earth's motion will be urgently required, too, since the computation of any geocentric ephemeris involves the orbit of the Earth-Moon system and the lunar equation.

In addition to the needs of astronomers, the space age is making new demands on the ephemerides of the major celestial bodies, too, as far as the accuracy of the predicted positions is concerned. The needs of astronautics have also added a new 'dimension', because for space probes the conversion of distances from astronomical into terrestrial units and *vice versa* is as important as the determination of directional co-ordinates. While previously the astronomer needed the solar parallax only for the reduction from topocentric to geocentric place, for which purpose in most cases a limited accuracy was sufficient, except for close approaches to the Earth, the astronaut requires the knowledge of this basic constant to the highest possible degree of accuracy.

The questions to be answered obviously are the following two. First, how accurately do we need to know the various constants, and secondly, what are the present prospects of obtaining them to the required degree of accuracy? The answer to the first question greatly depends on the inner accuracy of the improved, new planetary theories. Clemence undertook his new theory of Mars (3) with the aim of a precision of 0″·01 in longitude, and we may do well to adopt this figure as a standard criterion. This precision requires a formal accuracy of about 0″·0003 for most of the periodic terms involved, to allow for the accumulation of rounding errors, but the values used for the various disturbing masses have to be equal to the true values only to the extent of the ± 0″·01 precision. Since the largest periodic terms produced by the Earth and by Jupiter in the motion of Mars are of the order of 20″, a knowledge of these disturbing masses to 4 significant figures would be sufficient, as far as these periodic terms are concerned. It seems that such an accuracy has already been achieved in the determination of the mass of Jupiter. For the mass of the Earth-Moon system, this degree of accuracy should finally be secured in the near future, too, depending on the corresponding results for the solar parallax.

It must be recognized that the space age is not only making new demands on the precision of astronomical ephemerides, but that it also affords us entirely new possibilities for the more accurate determination of some of the basic constants involved in the construction of such ephemerides. The same space probe, for the launching of which the rocket engineers are interested in a more precise value of the astronomical unit, may actually, from the analysis of its observed motion, provide us with such an improved value of the solar parallax and of the mass of the Earth-Moon system. Similarly, Earth satellites approaching the Moon more closely, or lunar satellites should eventually give us results for the mass of the Moon and consequently for the constant of the lunar equation, which are superior in accuracy to all previous determinations by conventional astronomical methods.

As far as the solar parallax is concerned, the picture presented by the already numerous results obtained by 'space-age methods' is still confusing. If one looks at these results as exhibited in Table 1, then it is evident that they are scattered over a range quite comparable to the size of the discrepancy between the 'astronomical' determinations by Spencer Jones and Rabe. Clearly the probable errors listed with the results in Table 1 are not compatible with the differences between the various values, unless one discards all the determinations except for the three last ones obtained in 1961. On the other hand, it is reported that investigators in the U.S.S.R. have just obtained another Venus echo result in good agreement with the first two values listed in Table 1, but definitely not with the last three and supposedly more accurate ones obtained in 1961.

Table 1. Solar parallax results from new methods

Method	*Place, Year*	*Solar parallax*
Venus Radar Echoes	Millstone Hill (1958)	8″·8022 ± ″·0001
Venus Radar Echoes	Jodrell Bank (1959)	8·8020 ± ·0005
Artificial Planet, Pioneer V	Space Technology Laboratories (1960)	8·7974 ± ·0008
Venus Radar Echoes	Jodrell Bank (1961)	8·7943 ± ·0003
Venus Radar Echoes	Millstone Hill (1961)	8·79450 ± ·00008
Venus Radar Echoes	Jet Propulsion Laboratories (1961)	8·79443 ± ·00009

While the 1961 results listed in Table 1 seem to have a much greater weight than the earlier Venus echo determinations in 1958 and 1959, these previous derivations claim to be of very high precision, too, and agree surprisingly well with each other. The discrepancies are rather puzzling and suggest the involvement of some yet unknown systematic source of error. It is of some interest that the only dynamical determination, from Pioneer V, is in fair agreement with the comparable results from Eros.

The discrepancies exhibited in Table 1 not withstanding, one may yet expect to find either their explanation, or new and better results finally converging towards some definite value in the not too distant future. As soon as this is achieved and astronomers can agree on a solar parallax secured to the fourth significant figure, the ephemeris requirements postulated above can be satisfied, as far as the mass of Earth + Moon is involved. A still higher accuracy remains desirable, of course, for the conversion of distances from astronomical into terrestrial units.

Once the solar parallax and the mass of the Moon have been secured to a higher degree of precision from the various new methods now available, related constants such as that of the lunar equation and the constant of aberration may also be established more accurately. This short discussion does not attempt to exhaust all the aspects and all the constants involved. It seems justified, however, to conclude that space probes and the modern methods of radio astronomy will soon provide us with rather accurate values of some of those fundamental constants, which in turn will justify and require the construction of planetary theories and ephemerides of highest precision. Especially better theories of the Earth and of Venus, to be preceded perhaps by more rapidly obtainable numerical integrations of high internal accuracy, appear as some of the most urgent tasks and challenges now confronting celestial mechanics. It goes without saying that the availability of such precise ephemerides would in turn facilitate the determination of improved constants by means of conventional methods, such as a fuller utilization of all the observations of Eros, of Mars, and of Venus in corresponding differential corrections.

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9. ASTRONOMICAL AND ATOMIC TIME INVOLVED IN THE OBSERVATION OF ARTIFICIAL SATELLITES

W. Markowitz

The independent variable, t, in the orbit and in the ephemeris of a planet or satellite, natural or artificial, is Ephemeris Time. The term 'Ephemeris Time' is used in astronomy in two senses:

(*a*) In the general sense, as the independent variable of dynamical astronomy.

(*b*) As a specific measure of time, defined by a resolution adopted by the IAU.

The definition of E.T. in the sense of (*b*) is contained in a resolution adopted jointly by Commissions 4 and 31 at the tenth General Assembly (**1**). The basis of the measure of E.T. is the orbital motion of the Earth about the Sun. For the purpose of obtaining Ephemeris Time rapidly, other orbital motions may be used. Specific recommendations concerning the

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