THE JPL "LONG EPHEMERIS", DE102/LE51

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ABSTRACT A number of applications exist in astronomical research for planetary and lunar ephemerides covering an extended length of time. This paper discusses such a set of ephemerides, DE102/LE51, produced at JPL, covering the time 1411 B.C. to 3001 A.D. The ephemerides are dynamically self-consistent, in that the equations of motion were integrated simultaneously. They also represent the most accurately known positions covering such a time span. They have already been used by a number of different users in a variety of different applications.

I. INTRODUCTION

In 1977, it was decided to create a set of planetary and lunar ephemerides covering an extended length of time by integrating the equations of motion using the best set of initial conditions then available. The result of this long integration is described briefly in this paper. A full documentation of all aspects of the ephemeris (DE102/LE51) is now in press (see Newhall et al., 1982). In the present paper, a few features of DE102/LE51 are discussed and mention is made of possible applications with already existing examples being given.

II. THE CREATION OF DE102

The actual integration of DE102/LE51 was performed during many weekends (low computer rates) in the years 1977 and 1978. At the end, the individual files were merged and transformed into the final output format, producing a readable ephemeris covering the time span 1411 B.C. to 3001 A.D. This represents about 1.6 x 10^6 days and required approximately 5.6 x 10^6 integration steps. The program used a variable-order, variable-step-size integrator; the average step-size was about 0.29 days. Nearly 350 hours of Univac 1108 computer time was required.

V. V. Markellos and Y. Kozai (eds.), Dynamical Trapping and Evolution in the Solar System, 47–50.

A. Initial Conditions

The starting epoch of the integration was June 28, 1969 (JD 2440400.5), the ephemeris being integrated both forward and backward from this date. The initial conditions were the best available at that time and represented a least squares adjustment to a variety of observational data types. These included: 1) Lunar-laser ranging; 2) Mariner 9 and Viking Orbiter spacecraft ranging; 3) radar-ranging to Mercury, Venus, and Mars; and 4) Meridian circle optical data. These are described in detail in the paper cited above.

B. Equations of Motion

The equations of motion used in the integration included: 1) the n-body forces of the sun, moon, and the nine major planets; 2) the lunar librations; 3) isotropic, PPN-relativistic formulation; and 4) the perturbations from five asteroids. Though a number of the inherent constants have subsequently been modified, it is of importance to mention that the form of the equations of motion in DE102/LE51 has not been changed in any of the more recent ephemerides produced at JPL.

III. VARIOUS USES OF A LONG EPHEMERIS

There are a number of applications for which a long integrated ephemeris is a useful tool. Some of these are mentioned here.

A. Validation and Fit of an Analytical Theory

One may compare an analytical theory to an integrated ephemeris in order to locate incorrect or missing terms in the theory. Subsequently, one may fit the theory to the ephemeris instead of fitting to actual data. These methods have the advantages that: 1) equal mesh points are available, useful for spectral and Fourier analyses; 2) there is no observational error, in that the equations of motion are known exactly; and 3) the tedious process of data reduction is avoided. Such examples are the works of Stumpff (1981) and of Bretagnon (1980, 1981, and 1982). Also, Stephenson and Houlden (1981) have compared Tuckerman's Tables with DE102/LE51 in order to assess their accuracy.

B. Reduction of "Ancient" Observations

A computerized reduction of an observation is a relatively simple process with an integrated ephemeris. An ancient observation often contains valuable astronomical information when reduced with an accurate ephemeris. Such examples are the eclipse observations discussed by Muller (1975) and by Fiala (referred to by Rothschild, 1982), and the observation of Neptune by Galileo as discovered by Kowal and Drake (1980).

C. Quantitative Parameter Determinations

One sometimes wishes the value of an associated ephemeris parameter, averaged over a long period of time. Standish (1982) has used DE102/LE51 in determinations of the mean obliquity and dynamical equinox.

D. Integration of One-Body Orbits

The integration of the orbit of an asteroid or comet, for example, may be quickly accomplished using the pre-computed positions of the major planets as input data. Scholl (1982) has reported a reduction of nearly an order of magnitude in computer time for such a program as opposed to integrating the full n-body system.

IV. IMPROVEMENT OF DE102/LE51

Since the creation of DE102, there have been some significant improvements made to the initial conditions of subsequent ephemerides of JPL. As mentioned before, however, the equations of motion remain unchanged. As a result, it is possible to modify the coordinates of DE102 itself in order to reflect these improvements. Using the SET III formulation of Brouwer and Clemence (1961), one may improve DE102 to more accurately agreee with JPL's latest ephemeris, DE118. The SET III corrections have been determined by fitting the two ephemerides over the two centuries covered by DE118, 1850-2050. Extrapolation of the correction process seems to be valid. A more complete description is given in the cited reference (Newhall et al., 1982).

V. EXPORT TAPES

Various JPL ephemerides have been sent to over 100 users throughout the world. We now have the capability of producing computer tapes in directly machine-readable format for a variety of different computers including UNIVAC, IBM, CYBER, VAX, PDP, VAX, MODCOMP, and Honeywell. The complete package contains a user's guide and software for reading and interpolating the ephemerides, as well as the ephemerides themselves.

Anyone wishing a copy should contact the author.

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