

CHAPTER 4 LUNAR AND PLANETARY EPHEMERIDES

The planetary and lunar ephemerides recommended for the IERS standards are the JPL Development Ephemeris DE200 and the Lunar Ephemeris LE200. These have formed the basis for the *Astronomical Almanac* since 1984. DE200/LE200 should be used in the analysis of SLR and VLBI. However, in LLR analysis, parameters of the Earth-Moon system should be fit or a more recent lunar ephemeris should be used.

The ephemerides, DE200/LE200, were created from the 1950-based ephemerides, DE118/LE62. Their orientation with respect to the dynamical equinox of J2000.0 was described by Standish (1982). The data used in the fitting of DE118 was described by Standish (1990).

Associated with the ephemerides is the set of astronomical constants used in the creation of the ephemerides which are listed in Table 4.1. Many of these values do not agree exactly with those of the IAU 1976 or the current best estimates. Table 4.2 shows a comparison of the planetary masses among the IAU 1976, the DE200/LE200 and the current best estimates referred to as "1992". Also shown in the table are the references for the current best estimates. Differences, listed in Table 4.3, are necessary in order to provide a best fit of the ephemerides to the observational data. Constants are provided directly with the ephemerides and should be considered to be an integral part of them.

Table 4.1. JPL Planetary and Lunar Ephemerides DE200/LE200.

Scale (km/au)	149597870.66
Speed of light (km/sec)	299792.458
Obliquity of the ecliptic	23° 26' 21".4119
Earth-Moon mass ratio	81.300587
GM(Sun)/GM(Mercury)	6023600
GM(Sun)/GM(Venus)	408523.5
GM(Sun)/GM(Mars)	3098710
GM(Sun)/GM(Jupiter)	1047.350
GM(Sun)/GM(Saturn)	3498.0
GM(Sun)/GM(Uranus)	22960
GM(Sun)/GM(Neptune)	19314
GM(Sun)/GM(Pluto)	130000000
GM(Sun)/GM(Earth+Moon)	328900.55

Table 4.2. Comparison of planetary mass estimates expressed in reciprocal solar masses.

Planet	IAU (1976)	DE200	"1992"	Reference for "1992" estimate
Mercury	6023600.	6023600.	6023600.	Anderson, <i>et al.</i> , 1987b
Venus	408523.5	408523.5	408523.71	Sjogren, <i>et al.</i> , 1990
Earth & Moon	328900.5	328900.55	328900.56	Williams, 1991
Mars	3098710.	3098710.	3098708.	Null, 1969
Jupiter	1047.355	1047.350	1047.3486	Campbell, <i>et al.</i> , 1985
Saturn	3498.5	3498.0	3497.90	Campbell and Anderson, 1989
Uranus	22869.	22960.	22902.94	Anderson, <i>et al.</i> , 1987a
Neptune	19314.	19314.	19412.24	Tyler, <i>et al.</i> , 1989
Pluto	3000000.	130000000.	135000000.	Tholen and Buie, 1988

Table 4.3. IAU Values Which Differ From Those of DE200/LE200.

Scale (sec/au)	449.004782
(149597870.15...km/au)	
Moon-Earth mass ratio	0.0123002
(E/M = 81.30068...)	
Obliquity of the ecliptic	23° 26' 21"448

References

- Anderson, J. D., Campbell, J. K., Jacobson, R. A., Sweetnam, D. N., and Taylor, A. H., 1987a, "Radio Science with Voyager 2 at Uranus: Results on Masses and Densities of the Planet and Five Principal Satellites," *J. Geophys. Res.*, 92, pp. 14877-14883.
- Anderson, J. D., Colombo, G., Esposito, P. B., Lau, E. L., and Trager, G. B., 1987b, "The Mass Gravity Field and Ephemeris of Mercury," *Icarus*, 71, pp. 337-349.
- Campbell, J. K. and Anderson, J. D., 1989, "Gravity Field of the Saturnian System from Pioneer and Voyager Tracking Data," *Astron. J.*, 97, pp. 1485-1495.
- Campbell, J. K. and Synott, S. P., 1985, "Gravity Field of the Jovian System from Pioneer and Voyager Tracking Data," *Astron. J.*, 90, pp. 364-372.
- Null, G. W., 1969, "A Solution for the Mass and Dynamical Oblateness of Mars Using Mariner-IV Doppler Data," *Bull. American Astron. Soc.*, 1, p. 356.
- Sjogren, W. L., Trager, G. B., and Roldan G. R., 1990, "Venus: A Total Mass Estimate," *Geophys. Res. Let.*, 17, pp. 1485-1488.

- Standish, E. M., 1982, "Orientation of the JPL Ephemerides, DE200/LE200, to the Dynamical Equinox of J2000," *Astron. Astrophys.*, **114**, pp. 297-302.
- Standish, E. M., 1990, "The Observational Basis for JPL's DE200, the Planetary Ephemerides of the *Astronomical Almanac*," *Astron. Astrophys.*, **233**, pp. 252-271.
- Tholen, D. J. and Buie, M. W., 1988, "Circumstances for Pluto-Charon Mutual Events in 1989," *Astron. J.*, **233**, pp. 1977-1982.
- Tyler, G. L., Sweetnam, D. N., Anderson, J. D., Borutzki, S. E., Campbell, J. D., Eshelman, V. R., Gresh, D. L., Gurrola, E. M., Hinson, D. P., Kawashima, N., Kurinski, E. R., Levy, G. S., Lindal, G. F., Lyons, J. R., Marouf, E. A., Rosen, P. A., Simpson, R. A., and Wood, G. E., 1989, "Voyager Radio Science Observations of Neptune and Triton," *Science*, **246**, pp. 1466-1473.
- Williams, J. G., 1991, Private Communication (temporary result from JPL Lunar Laser Ranging analysis).