EPM2002 and EPM2002C – two versions of high accuracy numerical planetary ephemerides constructed for TDB and TCB time scales

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To be consistent with IAU resolutions ICRS should be treated as four–dimensional reference frame with TCB time scale in which planetary ephemerides should be constructed. For correlation and comparison with the widespread JPL's DE ephemerides our EPM ephemerides have been created up to now in TDB time scale, close to T_{eph} used for the DEs ephemerides. The conversion to TCB time scale might not and did not allow greater accuracy of ephemerides and adjusted parameters and has been done for convenience of users treating VLBI and Earth satellite observations. These new ephemerides (EPM2002C) cannot be used for ephemeris applications of satellites of major planets, if ephemerides of satellites have been created in TDB time scale.

The last versions of the EPM ephemerides [1] have been produced by simultaneous numerical integration of the equations of motion of nine planets, the Sun, the Moon, lunar physical libration and 300 asteroids over a 125–year time interval (1886–2011) performed in the Parameterized Post–Newtonian metric for the harmonic coordinates ($\alpha = 0$) and General Relativity values ($\beta = \gamma = 1$). For the five biggest minor planets their mutual perturbations are accounted, for other asteroids such perturbations are neglected. Numerical integration of the equations of motion in the barycentric coordinate frame of J2000.0 has been carried out by the Everhart method of nineteenth order. We used the lunar–planetary integrator embedded to the program package ERA [2]. The masses of planets as well as the provisional initial conditions correspond to the ephemerides DE405 [3]. The values of GM_i and initial coordinates of all celestial bodies involved in integration have been multiplied by $(1 + L_B)$ for the construction of EPM2002C ephemerides in TCB time scale in accordance with the IAU resolutions (see, for example, Brumberg and Groten [4]). Because EPM ephemerides are very close to DE405 ephemerides the value $L_B = 1.55051976772 \cdot 10^{-8}$, obtained for relationship between TCB and TDB of DE405 ephemerides, has been used.

As shown by Standish and Fienga [5] the accuracy of the planetary ephemerides deteriorates due to the the perturbations of many asteroids whose masses are not well known. So, studies of the estimations of masses of the most relevant 300 asteroids have been made. The last published diameters of asteroids based on IRAS data [6] and observations of occultations of stars by minor planets [7] have been used, and the mean density for the C, S, M taxonomy class has been estimated in the process of treating observations. The perturbing effects of remaining asteroids have been modelled as being caused by a circular ring in the ecliptical plane [8]. Mass M of the ring and its radius R are considered as solved–for parameters. The estimate $M_{ring} = (3.6 \pm 1) \cdot 10^{-10} M_{\odot}$ is obtained. Consequently, for the total mass of the main asteroid belt we have $M_{belt} = (16.6 \pm 2) \cdot 10^{-10} M_{\odot}$. Both versions of EPM2002 and EPM2002C ephemerides have been fitted to data totaling about 150000 observations including different American and Russian radiometric observations of planets and spacecrafts (1961-2001), CCD astromertic observations of outer planets, and meridian transits of XXth century. Adjustment of EPM2002 and EPM2002C ephemerides onto the ICRF has been accomplished by inclusion of VLBI measurements of spacecrafts near Mars and Venus. For EPM2002 and EPM2002C ephemerides the rms residuals for observations are identical, and the formal standard deviations of all solution parameters and their values (except orbital elements of the planets) or corrections to the initial orbital elements of planets coincide within formal uncertainties as it would be expected.

Along with the planetary ephemerides the improved ephemerides of the orbital and rotational motion of the Moon have been fitted by processing LLR observations 1979-2001. The last version of this theory accounting for a number of subtle selenodynamical effects is described in [9].

The Fortran program to calculate the rectangular coordinates of Sun, Moon, and nine major planets with the help of the polynomial approximation by means of Chebyshev's polynomials will be available from anonymous FTP:

//quasar.ipa.nw.ru/incoming/era .

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