TOP2013 FILES

G. FRANCOU & J.-L. SIMON (MAY 2013)

Ref: Simon J.-L., Francou G., Fienga A., Manche H., A&A 557, A49 (2013)

## INTRODUCTION

TOP2013 is an analytical solution for the four 4 planets Jupiter, Saturn, Uranus, Neptune and for the dwarf planet Pluto.

This solution is fitted to the numerical integration INPOP10a built at IMCCE, Paris Observatory (<u>http://www.imcce.fr/inpop</u>) over the time interval [1890-2000].

The reference system in the solution TOP2013 is defined by the dynamical equinox and ecliptic of J2000 (Julian Date 2451545.0).

The TOP2013 file is named: TOP2013.dat

## SOLUTIONS

=========

The file TOP2013 contains trigonometric series for the 6 elliptic variables which represent the motion of the planets. These series are functions of time (Periodic series and Poisson series).

List of the variables:

```
Elliptic elements:

Variable 1 : a = \text{semi-major axis (au)}

Variable 2 : \lambda = \text{mean longitude (radian)}

Variable 3 : k = e^*\cos(\varpi)

Variable 4 : h = e^*\sin(\varpi)

Variable 5 : q = \sin(i/2)^*\cos(\Omega)

Variable 6 : p = \sin(i/2)^*\sin(\Omega)

with:

e : \text{eccentricity}

\varpi : \text{perihelion longitude}

i : \text{inclination}

\Omega : \text{ascending node longitude}
```

TOP2013 series are characterized by 3 parameters:
the planet index 5-9 from Jupiter to Pluto,
the variable index from 1 to 6 (a, λ, k, h, q, p), or from 1 to 3 (X, Y, Z or L, B, R),
the time power α. TERMS OF SERIES

The terms of series are given under the form:  $T^{lpha}$  ( C cos  $\Phi$  + S sin  $\Phi$  )

- T is the time from J2000 (JD2451545.0) expressed in Thousand of Julian Years (365250 days)
- $\alpha$  is the time power of series (0 <=  $\alpha$  <= 12).
- C, S are the coefficients for the variable a (au), the variable  $\lambda$  (radian) and the variables, k, h, q, p (without unit).
- $\Phi$  is the argument: k.µ.T the coefficients k are integers and  $\mu$  is equal to (n5-n6)/880 in radian where n5 and n6 are the mean motions of Jupiter and Saturn.

RECORDS ORGANIZATION

There are two types of records. "HEADER" record: Characteristics of series (planet, variable, time power). "TERMS" records: Quantities k, C and S for each term of the series.

In the file TOP2013 the series are put in order of the planet (5-9) and the variables (1-6), and, for each variable, in order of the time power  $\alpha$ .

HEADER RECORD

==============

Spe	ec:	ifications:"	
ip	:	planet index	(integer)
iv	:	variable index	(integer)
it	:	time power $lpha$	(integer)
nt	:	number of terms in the series	(integer)

Planet index (ip): 5 : Jupiter 6 : Saturn 7 : Uranus 8 : Neptune 9 : Pluto Variable index (iv): 1:a, X, L 2 : λ, Υ, Β 3 : k, Z, R 4 : h 5 : q 6 : p Time power (it): =0 : Periodic terms >0 : Poisson terms

TERMS RECORDS \_\_\_\_\_ Fortran format: read (ifile,1002) k,c1,ie1,c2,ie2 1002 format (1x,i8,2(f22.16,i4)) Each "TERMS" record contains respectively the quantities k, C and S. Specifications: k(i) : numerical coefficient of  $\mu$ (integer) : mantissa of the coefficient C(i) (real\*8) c1 iel : exponent of the coefficient C(i) (integer) : mantissa of the coefficient S(i) (real\*8) c2 ie2 : exponent of the coefficient S(i) (integer) : period expressed in years (real\*8) р

The coefficients C and S are expressed in au for a, radian for  $\lambda,$  without unit for the other variables k, h, q, p.

TIME SCALE AND REFERENCE SYSTEM

The time used in TOP2013 series is TDB (Barycentrc Dynamical Time). This time can be considered equal to TAI + 32.184 s. TAI: International Atomic Time.

The solution TOP2013 is fitted to the numerical integration INPOP10a. over the time interval [1890-2000]. The TOP2013 coordinates are referred to the inertial frame defined by the dynamical equinox and ecliptic of J2000 (JD 2451545.0). The planetary coordinates of INPOP10a are referred in ICRF.

If  $X_E$ ,  $Y_E$ ,  $Z_E$  are the rectangular coordinates of a planet computed from TOP2013 the rectangular coordinates of the planet in equatorial frame of the ICRF,  $X_Q$ ,  $Y_Q$ ,  $Z_Q$ , may be obtained by the following rotation:

$\begin{bmatrix} X_Q \end{bmatrix}$		$\cos \varphi$	$-\sin\varphi\cos\varepsilon$	$\sin \varphi \sin \varepsilon$	$\begin{bmatrix} X_E \end{bmatrix}$
$Y_Q$	=	$\sin \varphi$	$\cos \varphi \cos \varepsilon$	$-\cos\varphi\sin\varepsilon$	$Y_E$
$\lfloor Z_Q \rfloor$		0	sin <i>ɛ</i>	$\cos\varepsilon$	$\left\lfloor Z_{E} \right\rfloor$

with:  $\mathcal{E} = 23^{\circ} 26' 21.41136''$  et  $\varphi = -0.05188''$ 

PRECISION

An estimation of the precision of the series TOPO2013 is given by the largest differences between TOP2013 and INPOP10a.

TIME INTERVAL [1890; 2000]

PLANET	a	λ	k	h	q	р	$\mathbf{L}$	В	R
Jupiter	0.473	0.84	20.7	28.0	16.7	10.8	1.19	0.45	1.901
Saturn	1.023	1.86	31.2	41.0	18.6	15.1	2.28	0.51	5.663
Uranus	16.550	1.70	50.9	48.5	18.5	15.3	3.18	0.73	13.756
Neptune	6.960	0.67	21.5	17.7	12.4	14.7	0.98	0.37	9.905
Pluto	124.710	2.85	198.1	185.8	56.9	23.3	10.83	3.19	118.419

Units: a (km),  $\lambda$  (mas), k, h, q, p (10<sup>-10</sup>). Heliocentric longitude L and latitude B (mas), Distance Sun-Planet R (km).

TIME INTERVAL [-4000; +8000]

PLANET	λ	$\mathbb{L}$	В	R
Jupiter	0.40	0.45	0.05	343
Saturn	0.74	0.89	0.08	1299
Uranus	0.42	0.70	0.04	4113
Neptune	0.39	0.78	0.06	5284

Units: mean longitude  $\lambda$  (arsecond), Heliocentric longitude L and latitude B (arcsecond), Distance Sun-Planet R (km).

COMPUTATION

The program TOP2013.f (Fortran) computes the planetary elliptic elements between 1890 and 2000 using the file TOP2013.dat. This program computes also the planetary rectangular coordinates referred to the dynamical ecliptic frame of J2000 and referred to the equatorial frame of ICRS.

Parameters of the program TOP2013: Starting date : 1890 June 6 (DJ 2411544.5) Number of dates : 11 Step : 4000 days.

The results are given in the file: TOP2013.out. The file TOP2013.ctl is given for checking these results.

The mean elements of the elliptic variables of the series TOP2013 are given in the file: TOP2013-secular.dat.

ADDITIONAL FILES

Two more files TOP2013 can be used for the 4 major planets Jupiter, Saturn, Uranus and Neptune.

1/ TOP2013XYZ.dat: this file contains the series of the rectangular heliocentric coordinates: X, Y, Z (au).

2/ TOP2013LBR.dat: this file contains the series of the spherical heliocentric coordinates: Longitude (L) and Latitude (B) in radian and the distance Sun-Planet (R) in astronomical unit.

These series are deduced from the series of elliptic variables given by the solution TOP2013 and the organization of these 2 files is the same as TOP2013.dat file.

The time scale (TDB) and the reference frame (dynamical ecliptic of J2000)) is those used in the solution TOP2013 and the reference system is defined by the dynamical equinox and ecliptic of J2000 (Julian Date 2451545.0).

The two programs TOP2013XYZ.f and TOP2013LBR.f (Fortran) computes 11 heliocentric rectangular and spherical coordinates of the 4 major planets, X, Y, Z and L, B, R, from 1890 to 2000 using respectively the files TOP2013XYZ.dat and TOP2013LBR.dat (step: 4000 days).

The results are given in the files: TOP2013XYZ.out and TOP2013LBR.out. The files TOP2013XYZ.ctl and TOP2013LBR.ctl are given for checking these results.