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CHEBYSHEV EPHEMERIDES FILES VSOP2013
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Ref: Simon J.-L., Francou G., Fienga A., Manche H., A&A 557, A49 (2013)

LIST OF FILES
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The Chebyshev Ephemerides VSOP2013 are given in 6 sequential files (ASCII).
Each file is related to a time span of 1500 years.

VSOP2013.m4000: Chebyshev Ephemerides VSOP2013 from -4500 to -3000
VSOP2013.m2000: Chebyshev Ephemerides VSOP2013 from -3000 to -1500
VSOP2013.m1000: Chebyshev Ephemerides VSOP2013 from -1500 to 0
VSOP2013.p1000: Chebyshev Ephemerides VSOP2013 from 0 to +1500
VSOP2013.p2000: Chebyshev Ephemerides VSOP2013 from +1500 to +3000
VSOP2013.p4000: Chebyshev Ephemerides VSOP2013 from +3000 to +4500

For the computation of planetary coordinates with the Chebyshev Ephemerides
it is necessary to build at first direct access files (binary files) from
the sequential files (ASCII files). Two Fortran programs are available for
that.

Program VSOP2013_binfile.f :
This program converts the sequential files into direct access files.

Program VSOP2013_compute.f:
This program computes planetary coordinates from a direct access file.

The file VSOP2013_ctl.txt contains planetary coordinates computed by the
program VSOP2013_compute.f and given as control values for the users.

DESCRIPTION OF THE CHEBYSHEV EPHEMERIDES VSOP2013
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The Chebyshev Ephemerides VSOP2013 were computed from the analytical
planetary solution VSOP2013 of the 8 planets Mercury, Venus, the Earth-Moon
barycenter, Mars, Jupiter, Saturn, Uranus, Neptune and the dwarf planet
Pluto.

They are constituted by developments of Chebyshev polynomials, functions of
time, for the heliocentric rectangular coordinates of the planets:
- the positions X, Y, Z expressed in astronomical unit,
- the velocities X', Y', Z' expressed in astronomical unit per day.

The frame of the planetary coordinates is defined by the dynamical equinox
and ecliptic J2000 (Julian Date 2451545.0).
The time used in VSOP2013 solutions is TDB (Barycentrc Dynamical Time).
This time can be considered equal to TAI + 32.184 s.
TAI: International Atomic Time.
The time unit is the thousand of Julian years from the standard epoch J2000
(Julian Date: 2451545.0).

Each Chebyshev Ephemerides file is valid for a time span of 1500 years:

```
VSOP2013.m4000 16/08/-4501 0h - 14/09/-3000 0h, JD   77294.5 -  625198.5)
VSOP2013.m2000 14/09/-3000 0h - 13/10/-1501 0h, JD  625198.5 - 1173102.5)
VSOP2013.m1000 13/10/-1501 0h - 11/11/-0001 0h, JD 1173102.5 - 1721006.5)
VSOP2013.p1000 11/11/-0001 0h - 10/12/ 1499 0h, JD 1721006.5 - 2268910.5)
VSOP2013.p2000 10/12/ 1499 0h - 28/01/ 3000 0h, JD 2268910.5 - 2816814.5)
VSOP2013.p4000 28/01/ 3000 0h - 09/03/ 4500 0h, JD 2816814.5 - 3364718.5)
```

The Chebyshev polynomials are built on basic time intervals of 32 days.
For each file, there are 17122 time intervals of 32 days which succeed one
another in the chronological order without discontinuity or superposing.
A time span contains 32 * 17122 = 547904 days (about 15 centuries).

Depending on the planet, the polynomials have between 7 to 14 Chebyshev
coefficients for each coordinates and the basic time interval of 32 days
are subdivided in 1 or 2 or 4 sub-intervals:

```
Mercury:    14 coefficients per coordinate over 4 sub-intervals of  8 days
Venus:      11 coefficients per coordinate over 2 sub-intervals of 16 days
Earth-Moon: 14 coefficients per coordinate over 2 sub-intervals of 16 days
Mars:       13 coefficients per coordinate over 1 sub-interval  of 32 days
Jupiter:    11 coefficients per coordinate over 1 sub-interval  of 32 days
Saturn:     10 coefficients per coordinate over 1 sub-interval  of 32 days
Uranus:      9 coefficients per coordinate over 1 sub-interval  of 32 days
Neptune:     7 coefficients per coordinate over 1 sub-interval  of 32 days
Pluto:       7 coefficients per coordinate over 1 sub-interval  of 32 days
```

There are in all 978 Chebyshev coefficients for the 6 coordinates of the 9
planets in each basic interval of 32 days.

Remark for Pluto:
The precision of the solution VSOP2013 of Pluto (issued from TOP2013)
decreases more quickly than for the other planets. The Chebyshev
Ephemerides of Pluto are given only for the time interval [1500 3000] in
the file VSOP2013.p2000. In the other files the coefficients corresponding
to Pluto are equal to zero.

ORGANIZATION OF CHEBYSHEV EPHEMERIDES FILES VSOP2013
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The Chebyshev Ephemerides files VSOP2013 given in this package are
sequential files (ASCII). Each one contains 17122 tables of coefficients of
Chebyshev polynomials which represent the heliocentric rectangular
coordinates of the 9 planets over the time intervals of 32 days i.e. 547904
days (about 15 centuries).

The first record of a file (header record) contains the values of the
characteristics of the Chebyshev Ephemerides in this file:
- Identification index of the solution VSOP2013 (2013).
- Julian dates of the time span limits of 547904 days.
- Size of the basic interval (32 days).
- Number of tables of Chebyshev coefficients.
- Number of the Chebyshev coefficients in a table.
- Rank in the table of the first coefficient corresponding to a planet.
- Number of coefficients per coordinate for each planet.
- Number of sub-intervals in the basic interval for each planet.

The following records contain the tables of the Chebyshev coefficients. In
each table, there are 2 Julian dates (beginning and the end of an interval
of 32 days) and the 978 Chebyshev coefficients of this interval.

For instance, here are the values of the characteristics of Chebyshev
Ephemerides in the header record of the file VSOP2013.p2000 [1500-3000]:

```
  2013
  2268910.5
  2816814.5
  32.0
  017122
  0978
  0001 0337 0469 0637 0715 0781 0841 0895 0937
  0014 0011 0014 0013 0011 0010 0009 0007 0007
  0004 0002 0002 0001 0001 0001 0001 0001 0001
```


INSTALLATION AND USING OF CHEBYCHEV EPHEMERIDES VSOP2013
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PROGRAM VSOP2013_binfile.f

This program converts a sequential Ephemerides files (ASCII) into a direct
access file (binary). The binary file has the same name than the ASCII file
with the extension ".bin".

A binary file has 17123 records of 7840 bytes.

- The first record (header record) contains the values of the
characteristics of Chebyshev Ephemerides corresponding to the binary file.

- The 17122 following records contain the tables of coefficients
corresponding to the 17122 basic time intervals of 32 days preceded by the
Julian dates of the beginning and the end of this time interval.

There are in all 978 Chebyshev coefficients and 2 dates (980 real*8
numbers) in each record of a binary file (i.e. 980 * 8 = 7840 bytes, or
3920 words of 4 bytes, or 1960 words of 2 bytes).

PROGRAM VSOP2013_compute.f

This program is an example of using a binary Chebyshev Ephemerides file
VSOP2013 for computing the heliocentric rectangular coordinates of the
planets (positions and velocities).

The subroutine Fortran VSOP2013 allows to substitute the time in the
Chebyshev polynomials for a date and a planet. The results of this example
are given in the file "VSOP2013_ctl.txt as check values for testing the
installation of the Ephemerides files.

Note:
Depending of the system and the Fortran compilation, the size of the
records (parameter "recl" in the statement "open") is expressed in bytes
(7840) or in words of 4 bytes (3920) or 2 bytes (1960).

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FRAME AND ACCURACY OF THE CHEBYCHEV EPHEMERIDES VSOP2013
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The planetary coordinates issued from the solutions VSOP2013 are referred
to the inertial frame defined by the dynamical equinox and ecliptic J2000
(JD 2451545.0) and they are also fitted to the numerical integration
INPOP10A which are referred to ICRF.

If X_E, Y_E, Z_E are the rectangular coordinates of a planet computed with the
Chebyshev Ephemerides VSOP2013, the rectangular coordinates of the planet
in equatorial frame of the ICRF, X_Q, Y_Q, Z_Q, are obtained by the following
rotation:

$$\begin{bmatrix} X_Q \\ Y_Q \\ Z_Q \end{bmatrix} = \begin{bmatrix} \cos\varphi & -\sin\varphi\cos\varepsilon & \sin\varphi\sin\varepsilon \\ \sin\varphi & \cos\varphi\cos\varepsilon & -\cos\varphi\sin\varepsilon \\ 0 & \sin\varepsilon & \cos\varepsilon \end{bmatrix} \begin{bmatrix} X_E \\ Y_E \\ Z_E \end{bmatrix}$$

with: $\varepsilon = 23°\ 26'\ 21.41136"$ et $\varphi = -0.05188"$

The accuracy of the planetary coordinates computed with the Chebyshev
Ephemerides VSOP2013 can be estimated by the biggest differences with the
coordinates issued from INPOP10A on the heliocentric longitudes the
different time spans.

	[-4500;-3000]	[-3000;-1500]	[-1500; 0000]
MERCURY	0.198"	0.163"	0.133"
VENUS	0.075"	0.061"	0.045"
EARTH-MOON	1.012"	0.343"	0.170"
MARS	1.463"	1.743"	0.988"
JUPITER	4.472"	2.315"	0.369"
SATURN	11.731"	7.364"	5.232"
URANUS	2.454"	0.728"	0.409"
NEPTUNE	1.136"	1.147"	0.583"

	[0000;+1500]	[+1500;+3000]	[+3000;+4500]
MERCURY	0.051"	0.014"	0.066"
VENUS	0.018"	0.002"	0.007"
EARTH-MOON	0.052"	0.018"	0.057"
MARS	1.277"	0.264"	1.031"
JUPITER	0.058"	0.038"	0.307"
SATURN	0.443"	0.224"	3.761"
URANUS	0.336"	0.042"	0.281"
NEPTUNE	0.142"	0.055"	0.087"
PLUTO	0.737"		