Swiss Ephemeris: An Accurate Ephemeris Toolset for Astronomy and Astrology

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Introduction

The Swiss Ephemeris is a highly accurate ephemeris toolset developed since 1997 by Astrodienst (Koch and Triendl 2004). It is based upon the DE430/DE431 ephemerides from NASA's JPL (Folkner *et al.* 2014) and covers the time range 13,000 BC to AD 17,000. For both astronomical and astrological coordinates (true equinox of date), all corrections such as relativistic aberration, deflection of light in the gravity field of the Sun and others have been included. The Swiss Ephemeris is not a product that can be easily used by end users, but it is an accurate and fast toolset for programmers to build into their own astronomical or astrological software. A few examples where this toolset is used include the swephR package for the R environment (Stubner and Reijs 2019) and ARCHAEOCOSMO, which is used within both Excel and R (Reijs 2006). All discussed packages have open source versions.

To provide flexibility (mainly in processing and memory needs), Swiss Ephemeris can use three ephemerides, giving the user the choice of which to use. First there are the original JPL ephemerides data files. These data files need a lot of memory (around 3 GB) and provide the most accurate ephemeris at this moment. The second (and default) SE ephemeris uses Astrodienst's data files. Astrodienst used sophisticated compression techniques to reduce the original DE430/DE431 data files to around 100 MB. This compressed ephemeris reproduces the original JPL ephemerides results to within 0.001

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arcsecond accuracy. The third ephemeris is the built-in semi analytic theory fit to DE404 made in 1995 by Steve Moshier (Moshier 2019), which needs more processor capacity. It covers only the time range 3000 BC to AD 3000 and planetary positions are accurate to within 0.1 arcseconds, while lunar positions are accurate to within three arcseconds. The Swiss Ephemeris package switches automatically to the available most accurate ephemeris dependent on which ephemeris data files are installed. In addition to the astronomical planets contained in the JPL data files, Astrodienst has included asteroids and hypothetical bodies (some 385,000 of them). The Swiss Ephemeris is also fast: on a Linux test machine, 10,000 complete sets of 11 planetary positions were calculated in less than three seconds (using SE or JPL ephemeris, while Moshier's will be considerably slower), which means about 30 microseconds per planetary position.

Swiss Ephemeris functions include the following:

- Positions of planets, fixed stars, comets, asteroids, hypothetical bodies and Kepler elements;
- Many sidereal ephemerides for astrology;
- Heliacal events, eclipses, occultations and other planetary phenomena;
- Delta T, sidereal time, astrological house systems.

A test program called swetest (Astrodienst 2004) is available, which shows the functionality of Swiss Ephemeris. This is handy to determine the accuracy/precision of other astronomical or astrological programs. In Figure 1 the Swiss Ephemeris Test Page has been called (using the following input options: planet selection = 0123456789 and Moshier Ephemeris; output format = Plb; other options = –ut0).

```
swetest -b1.1.2002 -n1 -s1 -fPlb -p0123456789 -emos -ut0
date (dmy) 1.1.2002 greg.   0:00:00 UT           version 2.08
UT:  2452275.500000000     delta t: 64.300074 sec
TT:  2452275.500744214
Epsilon (t/m)    23°26'20.5365   23°26'20.4693
Nutation         -0° 0'16.4966    0° 0' 0.0672
Sun              280.3837325   0.0001424
Moon             121.1171222   2.9465677
Mercury          295.5849890  -2.0523181
Venus            277.1613429  -0.4017693
Mars             346.8814590  -0.7010880
Jupiter          100.6667699   0.0024534
Saturn           69.3237917  -1.8056570
Uranus           322.4583585  -0.7023242
Neptune          307.4445145   0.1051459
Pluto            256.0369047   9.7619435
```

FIGURE 1. Results from Swiss Ephemeris Test Page.

swephR

The Swiss Ephemeris is provided as a C library that can be integrated into applications meant for end users. However, this limits the possible use-cases to those provided by the application. For exploratory analysis it is useful to have all functions from the C API available within an environment meant for interactive use.

One such environment is the R system (R Core Team 2019), which was originally designed as a platform for statistical computing and graphics. With more than 15,000 extension packages available on CRAN (CRAN R-Project 2015), the R environment can nowadays be used for any data-related task.

The swephR package (Stubner and Reijs 2019) provides bindings to the full C API of the Swiss Ephemeris to R, making all the functionality of the Swiss Ephemeris available for interactive use (e.g. see Figure 2).

The swephR package contains the Moshier ephemeris. Users who have the Swiss Ephemeris or JPL DE430/DE431 data files available can configure them for use with swephR. Alternatively, the swephRdata package (Stubner 2018) can be installed, making the Swiss Ephemeris data files automatically available for swephR.

The functions in the swephR package follow the C API closely, making it easy to use for anybody familiar with the API. Further end-user targeted functions are available in the ARCHAEOCOSMO package (Reijs 2006).

```
library(swephR)
jdut <- swe_julday(year = 2002, month = 1, day = 1, hourd = 0,
                   gregflag = SE$GREG_CAL)

result <- swe_calc_ut(jd_ut = jdut, ipl = SE$SUN:SE$PLUTO,
                      iflag = SE$FLG_MOSEPH + SE$FLG_SPEED)
result$xx[, 1:2]
#>              [,1]          [,2]
#>  [1,] 280.3837325  0.000142402944
#>  [2,] 121.1171222  2.946567674516
#>  [3,] 295.5849890 -2.052318123408
#>  [4,] 277.1613429 -0.401769287266
#>  [5,] 346.8814590 -0.701087968201
#>  [6,] 100.6667699  0.002453380444
#>  [7,]  69.3237917 -1.805656981593
#>  [8,] 322.4583585 -0.702324211702
#>  [9,] 307.4445145  0.105145913891
#> [10,] 256.0369047  9.761943461550
```

FIGURE 2. Results of the same call that produced Figure 1, but now using swephR.

ARCHAEOCOSMO

The ARCHAEOCOSMO package (Reijs 2006) has a range of functions from astronomical and geodetic disciplines. It is available in two forms: an Excel add-in and an R package. The Excel add-in of ARCHEOCOSMO provides a user-friendly interface, if one is used to spreadsheet functions. The R package of ARCHAEOCOSMO makes it possible to access the ARCHAEOCOSMO functions through R (Reijs 2017). To use the astronomical functions, one needs to add the Swiss Ephemeris DLL library (for Windows) to the ARCHAEOCOSMO Excel add-in. The installation process is explained by Reijs (2006).

For most astronomical functions it utilises the Swiss Ephemeris. But other functions which are relevant in the archaeocosmology discipline are included, such as conversion between geocentric, topocentric and apparent angles; star phases; heliacal events (extinction angles, morning first, evening last, acronychal rise and cosmical set (Reijs 2012); solar-event phased-moon function (including equinoctial full Moon); calendar functions (Julian, Gregorian and Mayan); and harmonic sum functions to determine epoch-depending Kepler elements for Sun and Moon. Several heliacal events functions (morning first and evening last) were integrated in the Swiss Ephemeris toolset.

In Figure 3 one can see the results from ARCHAEOCOSMO (using Excel), using the same input options as used in Figure 1.

	A	D	E	F	G	H
1	Date (yyyy/mm/dd)	2002/1/1	Time UT	00:00:00	ARCHAEOCOSMO functions for Excel	
2	Version	2.08			=dll_version()	
3	UT	2452275.500000000			=jdutfromdate(D1,F1)	
4	DeltaT	64.300074			=DeltaTSE(D3)	
5	TT	2452275.500744210			=D3+D4/60/60/24	
6	Epsilon (m)	23°26'20.4693"			=Obliquity(D3,"sun",0)	
7		Longitude	Latitiude			
8	Sun	280.3837325	0.0001424		=ObjectLoc(D3,0,0,0,0,0,$A8,9)	=ObjectLoc(D3,0,0,0,0,0,$A8,8)
9	Moon	121.1171222	2.9465677		=ObjectLoc(D3,0,0,0,0,0,$A9,9)	=ObjectLoc(D3,0,0,0,0,0,$A9,8)
10	Mercury	295.5849890	-2.0523181		=ObjectLoc(D3,0,0,0,0,0,$A10,9)	=ObjectLoc(D3,0,0,0,0,0,$A10,8)
11	Venus	277.1613429	-0.4017693		=ObjectLoc(D3,0,0,0,0,0,$A11,9)	=ObjectLoc(D3,0,0,0,0,0,$A11,8)
12	Mars	346.8814590	-0.7010880		=ObjectLoc(D3,0,0,0,0,0,$A12,9)	=ObjectLoc(D3,0,0,0,0,0,$A12,8)
13	Jupiter	100.6667699	0.0024534		=ObjectLoc(D3,0,0,0,0,0,$A13,9)	=ObjectLoc(D3,0,0,0,0,0,$A13,8)
14	Saturn	69.3237917	-1.8056570		=ObjectLoc(D3,0,0,0,0,0,$A14,9)	=ObjectLoc(D3,0,0,0,0,0,$A14,8)
15	Uranus	322.4583585	-0.7023242		=ObjectLoc(D3,0,0,0,0,0,$A15,9)	=ObjectLoc(D3,0,0,0,0,0,$A15,8)
16	Neptune	307.4445145	0.1051459		=ObjectLoc(D3,0,0,0,0,0,$A16,9)	=ObjectLoc(D3,0,0,0,0,0,$A16,8)
17	Pluto	256.0369047	9.7619435		=ObjectLoc(D3,0,0,0,0,0,$A17,9)	=ObjectLoc(D3,0,0,0,0,0,$A17,8)

FIGURE 3. Results of the same call that produced Figure 1, but now using ARCHAEOCOSMO's Excel add-in.

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