Swiss Ephemeris General Documentation

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Swiss Ephemeris

A Computer ephemeris for developers of astrological software

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1. Introduction

Swiss Ephemeris is a function package of astronomical calculations that serves the needs of astrologers, archeoastronomers, and, depending on purpose, also the needs of astronomers. It includes long-term ephemerides for the Sun, the Moon, the planets, more than 300.000 asteroids, historically relevant fixed stars and some "hypothetical" objects.

The precision of the Swiss Ephemeris is at least as good as that of the Astronomical Almanac, which follows current standards of ephemeris calculation. Swiss Ephemeris will, as we hope, be able to keep abreast to the scientific advances in ephemeris computation for the coming decades.

The Swiss Ephemeris package consists of source code in C, a DLL, a collection of ephemeris files and a few sample programs which demonstrate the use of the DLL and the Swiss Ephemeris graphical label. The ephemeris files contain compressed astronomical ephemerides.

Full C source code is included with the Swiss Ephemeris, so that non-Windows programmers can create a linkable or shared library in their environment and use it with their applications.

1.2. Licensing

The Swiss Ephemeris is not a product for end users. It is a toolset for programmers to build into their astrological software.

The Swiss Ephemeris is made available by its authors under a dual licensing system. The software developer, who uses any part of Swiss Ephemeris in his or her software, must choose between one of the two license models, which are:

To use Swiss Ephemeris, the licensing conditions imposed by Astrodienst for Swiss Ephemeris must be fulfilled. A copy of the license file is found in file LICENSE.

Please note: Since Swiss Ephemeris release 2.10.01 the GPL license has been replaced with the AGPL license, as one of the options in Astrodienst's dual licensing model.

2. Description of the ephemerides

2.1. Planetary and lunar ephemerides

2.1.1. Three ephemerides

The Swiss Ephemeris package allows planetary and lunar computations from any of the following three astronomical ephemerides:

The Swiss Ephemeris

The core part of Swiss Ephemeris is a compression of the JPL-Ephemeris DE431, which covers roughly the time range 13.000 BCE to 17.000 CE. Using a sophisticated mechanism, we succeeded in reducing JPL's 2.8 GB storage to only 99 MB. The compressed version agrees with the JPL Ephemeris to 1 milli-arcsecond (0.001"). Since the inherent uncertainty of the JPL ephemeris for most of its time range is a lot greater, the Swiss Ephemeris should be completely satisfying even for computations demanding very high accuracy.

(Before 2014, the Swiss Ephemeris was based on JPL Ephemeris DE406. Its 200 MB were compressed to 18 MB. The time range of the DE406 was 3000 BCE to 3000 CE or 6000 years. We had extended this time range to 10.800 years, from 2 Jan 5401 BCE to 31 Dec 5399 CE. The details of this extension are described below in section 2.1.5. To make sure that you work with current data, please check the date of the ephemeris files. They must be 2014 or later.)

Each Swiss Ephemeris file covers a period of 600 years; there are 50 planetary files, 50 Moon files for the whole time range of almost 30.000 years and 18 main-asteroid files for the time range of 10.800 years.

The file names are as follows:

Planetary file	Moon file	Main asteroid file	Time range
Seplm132.se1	Semom132.se1		11 Aug 13000 BCE – 12602 BCE
Seplm126.se1	Semom126.se1		12601 BCE – 12002 BCE
Seplm120.se1	Semom120.se1		12001 BCE – 11402 BCE
Seplm114.se1	Semom114.se1		11401 BCE – 10802 BCE
Seplm108.se1	Semom108.se1		10801 BCE – 10202 BCE
Seplm102.se1	Semom102.se1		10201 BCE – 9602 BCE
Seplm96.se1	Semom96.se1		9601 BCE – 9002 BCE
Seplm90.se1	Semom90.se1		9001 BCE – 8402 BCE
Seplm84.se1	Semom84.se1		8401 BCE – 7802 BCE
Seplm78.se1	Semom78.se1		7801 BCE – 7202 BCE
Seplm72.se1	Semom72.se1		7201 BCE – 6602 BCE
Seplm66.se1	Semom66.se1		6601 BCE – 6002 BCE
Seplm60.se1	Semom60.se1		6001 BCE – 5402 BCE
seplm54.se1	semom54.se1	seasm54.se1	5401 BCE – 4802 BCE
seplm48.se1	semom48.se1	seasm48.se1	4801 BCE – 4202 BCE

Planetary file	Moon file	Main asteroid file	Time range
seplm42.se1	semom42.se1	seasm42.se1	4201 BCE – 3602 BCE
seplm36.se1	semom36.se1	seasm36.se1	3601 BCE – 3002 BCE
seplm30.se1	semom30.se1	seasm30.se1	3001 BCE – 2402 BCE
seplm24.se1	semom24.se1	seasm24.se1	2401 BCE – 1802 BCE
seplm18.se1	semom18.se1	seasm18.se1	1801 BCE – 1202 BCE
seplm12.se1	semom12.se1	seasm12.se1	1201 BCE – 602 BCE
seplm06.se1	semom06.se1	seasm06.se1	601 BCE – 2 BCE
sepl_00.se1	semo_00.se1	seas_00.se1	1 BCE – 599 CE
sepl_06.se1	semo_06.se1	seas_06.se1	600 CE – 1199 CE
sepl_12.se1	semo_12.se1	seas_12.se1	1200 CE – 1799 CE
sepl_18.se1	semo_18.se1	seas_18.se1	1800 CE – 2399 CE
sepl_24.se1	semo_24.se1	seas_24.se1	2400 CE – 2999 CE
sepl_30.se1	semo_30.se1	seas_30.se1	3000 CE – 3599 CE
sepl_36.se1	semo_36.se1	seas_36.se1	3600 CE – 4199 CE
sepl_42.se1	semo_42.se1	seas_42.se1	4200 CE – 4799 CE
sepl_48.se1	semo_48.se1	seas_48.se1	4800 CE – 5399 CE
sepl_54.se1	semo_54.se1		5400 CE – 5999 CE
sepl_60.se1	semo_60.se1		6000 CE – 6599 CE
sepl_66.se1	semo_66.se1		6600 CE – 7199 CE
sepl_72.se1	semo_72.se1		7200 CE – 7799 CE
sepl_78.se1	semo_78.se1		7800 CE – 8399 CE
sepl_84.se1	semo_84.se1		8400 CE – 8999 CE
sepl_90.se1	semo_90.se1		9000 CE – 9599 CE
sepl_96.se1	semo_96.se1		9600 CE – 10199 CE
sepl_102.se1	semo_102.se1		10200 CE – 10799 CE
sepl_108.se1	semo_108.se1		10800 CE – 11399 CE
sepl_114.se1	semo_114.se1		11400 CE – 11999 CE
sepl_120.se1	semo_120.se1		12000 CE – 12599 CE
sepl_126.se1	semo_126.se1		12600 CE – 13199 CE
sepl_132.se1	semo_132.se1		13200 CE – 13799 CE
sepl_138.se1	semo_138.se1		13800 CE – 14399 CE
sepl_144.se1	semo_144.se1		14400 CE – 14999 CE
sepl_150.se1	semo_150.se1		15000 CE – 15599 CE
sepl_156.se1	semo_156.se1		15600 CE – 16199 CE
sepl_162.se1	semo_162.se1		16200 CE – 7 Jan 16800 CE

All Swiss Ephemeris files have the file suffix .se1. A planetary file is about 500 kb, a lunar file 1300 kb. Swiss Ephemeris files are available for download from Astrodienst's web server.

The time range of the Swiss Ephemeris Versions until 1.80, which were based on JPL Ephemeris DE406 and some extension created by Astrodienst, work for the following time range:

- Start date: 2 Jan 5401 BCE (-5400) Jul. = JD -251291.5
- End date: 31 Dec 5399 CE (Greg. Cal.) = JD 3693368.5

Versions since 2.00, which are based on JPL Ephemeris DE431, work for the following time range:

- Start date: 11 Aug 13000 BCE (-12999) Jul. = JD -3026604.5
- End date: 7 Jan 16800 CE Greg. = JD 7857139.5

Please note that versions prior to 2.00 are not able to correctly handle the JPL ephemeris DE431.

A note on year numbering There are two numbering systems for years before the year 1 CE. The historical numbering system (indicated with BCE) has no year zero. Year 1 BCE is followed directly by year 1 CE.

The astronomical year numbering system does have a year zero; years before the common era are indicated by negative year numbers. The sequence is year -1, year 0, year 1 CE.

The historical year 1 BCE corresponds to astronomical year 0,

the historical year 2 BCE corresponds to astronomical year -1, etc.

In this and other documents related to the Swiss Ephemeris we use both systems of year numbering. When we write a negative year number, it is astronomical style; when we write BCE, it is historical style.

The Moshier Ephemeris

This is a semi-analytical approximation of the JPL planetary and lunar ephemerides DE404, developed by Steve Moshier. Its deviation from JPL is below 1 arc second with the planets and a few arc seconds with the Moon. No data files are required for this ephemeris, as all data are linked into the program code already.

This may be sufficient accuracy for most purposes, since the Moon moves 1 arc second in 2 time seconds and the Sun 2.5 arc seconds in one minute.

The advantage of the Moshier mode of the Swiss Ephemeris is that it needs no disk storage. Its disadvantage, besides the limited precision, is reduced speed: it is about 10 times slower than JPL mode and the compressed JPL mode (described above).

The Moshier Ephemeris covers the interval from 3000 BCE to 3000 CE. However, Moshier notes that “the adjustment for the inner planets is strictly valid only from 1350 B.C. to 3000 A.D., but may be used to 3000 B.C. with some loss of precision”. And: “The Moon’s position is calculated by a modified version of the lunar theory of Chapront-Touze’ and Chapront. This has a precision of 0.5 arc second relative to DE404 for all dates between 1369 B.C. and 3000 A.D.” (Moshier, http://www.moshier.net/aadoc.html).

Note: The Moshier ephemeris is deprecated as part of Swiss Ephemeris. It wil be removed in the the next major release.

The full JPL Ephemeris

This is the full precision state-of-the-art ephemeris. It provides the highest precision and is the basis of the Astronomical Almanac. Time range:

Start date: 9 Dec 13002 BCE (-13001) Jul. = JD -3027215.5 End date: 11 Jan 17000 CE Greg. = JD 7930192.5

JPL is the Jet Propulsion Laboratory of NASA in Pasadena, CA, USA (see http://www.jpl.nasa.gov). Since many years this institute, which is in charge of the planetary missions of NASA, has been the source of the highest precision planetary ephemerides. The currently newest version of JPL ephemeris is the DE430/DE431.

There are several versions of the JPL Ephemeris. The version is indicated by the DE-number. A higher number indicates a more recent version. SWISSEPH should be able to read any JPL file from DE200 upwards.

Accuracy of JPL ephemerides DE403/404 (1996) and DE405/406 (1998) According to a paper (see below) by Standish and others on DE403 (of which DE406 is only a slight refinement), the accuracy of this ephemeris can be partly estimated from its difference from DE200:

With the inner planets, Standish shows that within the period 1600 – 2160 there is a maximum difference of 0.1 – 0.2” which is mainly due to a mean motion error of DE200. This means that the absolute precision of DE406 is estimated significantly better than 0.1” over that period. However, for the period 1980 – 2000 the deviations between DE200 and DE406 are below 0.01” for all planets, and for this period the JPL integration has been fit to measurements by radar and laser interferometry, which are extremely precise.

With the outer planets, Standish’s diagrams show that there are large differences of several ” around 1600, and he says that these deviations are due to the inherent uncertainty of extrapolating the orbits beyond the period of accurate observational data. The uncertainty of Pluto exceeds 1” before 1910 and after 2010, and increases rapidly in more remote past or future.

With the Moon, there is an increasing difference of 0.9”/cty2 between 1750 and 2169. It is mainly caused by errors in LE200 (Lunar Ephemeris).

The differences between DE200 and DE403 (DE406) can be summarized as follows:

year range	planet	difference
1980 – 2000	all planets	< 0.01”,
1600 – 1980	Sun – Jupiter	a few 0.1”
1900 – 1980	Saturn – Neptune	a few 0.1”
1600 – 1900	Saturn – Neptune	a few ”
1750 – 2169	Moon	a few “.

(see: E.M. Standish, X.X. Newhall, J.G. Williams, and W.M. Folkner, JPL Planetary and Lunar Ephemerides, DE403/LE403, JPL Interoffice Memorandum IOM 314.10-127, May 22, 1995, pp. 7f.)

Comparison of JPL ephemerides DE406 (1998) with DE431 (2013)

Differences DE431-DE406 for 3000 BCE to 3000 CE:

planet	difference
Moon	< 7” (TT), < 2” (UT)
Sun, Mercury, Venus	< 0.4”
Mars	< 2”
Jupiter	< 6”
Saturn	< 0.1”
Uranus	< 28”
Neptune	< 53”
Pluto	< 129”

Moon, position (DE431) – position (DE406) in TT and UT

(Delta T adjusted to tidal acceleration of lunar ephemeris)

Year	**dL(TT)**	**dL(UT)**	**dB(TT)**	**dB(UT)**
-2999	6.33”	-0.30”	-0.01”	0.05”
-2500	5.91”	-0.62”	-0.85”	-0.32”
-2000	3.39”	-1.21”	-0.59”	-0.20”
-1500	1.74”	-1.49”	-0.06”	-0.01”
-1000	1.06”	-1.50”	0.30”	0.12”
-500	0.63”	-1.40”	0.28”	0.09”
0	0.13”	-0.99”	0.11”	0.05”
500	-0.08”	-0.99”	-0.03”	0.05”
1000	-0.12”	-0.38”	-0.08”	-0.06”
1500	-0.08”	-0.15”	-0.03”	-0.02”

Year	dL(TT)	dL(UT)	dB(TT)	dB(UT)
2000	0.00”	0.00”	0.00”	0.00”
2500	0.06”	0.06”	-0.02”	-0.02”
3000	0.10”	0.10”	-0.09”	-0.09”

Sun, position (DE431) – position (DE406) in TT and UT

Year	dL(TT)	dL(UT)
-2999	0.21”	-0.34”
-2500	0.11”	-0.33”
-2000	0.09”	-0.26”
-1500	0.04”	-0.22”
-1000	0.06”	-0.14”
-500	0.02”	-0.11”
0	0.02”	-0.06”
500	0.00”	-0.04”
1000	0.00”	-0.01”
1500	-0.00”	-0.01”
2000	-0.00”	-0.00”
2500	-0.00”	-0.00”
3000	-0.01”	-0.01”

Pluto, position (DE431) – position (DE406) in TT

Year	dL(TT)
-2999	66.31”
-2500	82.93”
-2000	100.17”
-1500	115.19”
-1000	126.50”
-500	127.46”
0	115.31”
500	92.43”
1000	63.06”
1500	31.17”
2000	-0.02”
2500	-28.38”
3000	-53.38”

The Swiss Ephemeris is based on the latest JPL file, and reproduces the full JPL precision with better than 1/1000 of an arc second, while requiring only a tenth storage. Therefore for most applications it makes little sense to get the full JPL file. Precision comparison can be done at the Astrodienst web server. The Swiss Ephemeris test page http://www.astro.com/swisseph/swetest.htm allows to compute planetary positions for any date using the full JPL ephemerides DE200, DE406, DE421, DE431, or the compressed Swiss Ephemeris or the Moshier ephemeris.

2.1.2. The Swiss Ephemeris Compared with Astronomical Almanac and JPL Horizons

Swiss Ephemeris and the Astronomical Almanac

The original JPL ephemeris provides barycentric equatorial Cartesian positions relative to the equinox 2000/ICRS. Moshier provides heliocentric positions. The conversions to apparent geocentric ecliptical positions were done using the algorithms and constants of the Astronomical Almanac as described in the "Explanatory Supplement to the Astronomical Almanac". Using the DE200 data file, it is possible to reproduce the positions given by the Astronomical Almanac 1984, 1995, 1996, and 1997 (on p. B37-38 in all editions) to the last digit. Editions of other years have not been checked. DE200 was used by Astronomical Almanac from 1984 to 2002. The sample positions given in the mentioned editions of Astronomical Almanac can also be reproduced using a recent version of the Swiss Ephemeris and a recent JPL ephemeris. The number of digits given in AA do not allow to see a difference. The Swiss Ephemeris has used DE405/DE406 since its beginning in 1997.

From 2003 to 2015, the Astronomical Almanac has been using JPL ephemeris DE405, and since Astronomical Almanac 2006 all relevant resolutions of the International Astronomical Union (IAU) have been implemented. Versions 1.70 and higher of the Swiss Ephemeris also follow these resolutions and reproduce the sample calculation given by AA2006 (p. B61-B63), AA2011 and AA2013 (both p. B68-B70) to the last digit, i.e. to better than 0.001 arc second. (To avoid confusion when checking AA2006, it may be useful to know that the JD given on page B62 does not have enough digits in order to produce the correct final result. With later AA2011 and AA2013, there is no such problem.)

The Swiss Ephemeris uses JPL Ephemeris DE431 since version 2.0 (2014). The Astronomical Almanac uses JPL Ephemeris DE430 since 2016. The Swiss Ephemeris and the Astronomical Almanac still perfectly agree.

Detailed instructions how to compare planetary positions as given by the Swiss Ephemeris with those of Astronomical Almanac are given in Appendix D at the end of this documentation.

Swiss Ephemeris and JPL Horizons System of NASA

The Swiss Ephemeris, from version 1.70 on, reproduces astrometric planetary positions of the JPL Horizons System precisely. However, there have been small differences of about 53 mas (milli-arcseconds) with apparent positions. The same deviations also occur if Horizons is compared with the example calculations given in the Astronomical Almanac.

With ephemerides relative to the equinox of date, Horizons uses a different reference ecliptic than Astronomical Almanac and Swiss Ephemeris. It follows IERS Conventions 1996 (p. 22), which is based on the old precession models IAU 1976 (Lieske) and nutation IAU 1980 (Wahr). On the other hand, the Astronomical Almanac and the Swiss Ephemeris follow IERS Conventions 2003 and 2010 with more recent precession and nutation models. As a result of the different reference ecliptics used, there is a constant offset of 53 mas in RA between Horizons and the Swiss Ephemeris.

It should be understood that these differences in apparent ephemerides are not the result of an error on the side of the Swiss Ephemeris and much less on the side of Horizons. Both systems are valid. According to private communication with Jon Giorgini (5 April 2021), there are also (low-priority) plans to implement the more recent conventions in Horizons as an option. With this option, the 53 mas-difference should disappear and the remaining error of about 1 mas will be due to free core nutation, which is considered by Horizons, but not by the Swiss Ephemeris.

Swiss Ephemeris versions 2.00 and higher contain code to reproduce positions of Horizons with a precision of about 1 mas for 1799 CE – today. From version 2.07 on, Horizons can be reproduced with a similar precision for its whole time range.

For best agreement with Horizons, current data files with Earth orientation parameters (EOP) must be downloaded from the IERS website and put into the ephemeris path. If they are not available, the Swiss

Ephemeris uses an approximation which reproduces Horizons still with an accuracy of about 2 mas between 1962 and present.

It must be noted that correct values for Earth orientation delta_psi and delta_epsilon are only available between 1962 and present. For all calculations before that, Horizons uses the *first* values of the EOP data, and for all calculations in the future, it uses the *last* values of the existing data. The resulting positions before 1962 thus do not have the same precision, but the ephemeris is at least continuous.

More information on this and technical details are found in the programmer's documentation and in the source code, file swephlib.h.

IERS Conventions 1996, 2003, and 2010 can be read or downloaded from here:

http://www.iers.org/IERS/EN/DataProducts/Conventions/conventions.html

Detailed instructions how to compare planetary positions as given by the Swiss Ephemeris with those of JPL are given in Appendix C at the end of this documentation.

Many thanks to Jon Giorgini, developer of the Horizons System, for explaining us the methods used at JPL.

2.1.3. The details of coordinate transformation

The following conversions are applied to the coordinates after reading the raw positions from the ephemeris files:

Correction for light-time

Since the planet's light needs time to reach the Earth, it is never seen where it actually is, but where it was some time before. Light-time amounts to a few minutes with the inner planets and a few hours with distant planets like Uranus, Neptune and Pluto. For the Moon, the light-time correction is about one second. With planets, light-time correction may be of the order of 20" in position, with the Moon 0.5"

Conversion from the solar system barycenter to the geocenter

Original JPL data are referred to the center of the gravity of the solar system. Apparent planetary positions are referred to an imaginary observer in the center of the Earth.

Light deflection by the gravity of the Sun

In the gravitational fields of the Sun and the planets light rays are bent. However, within the solar system only the Sun has enough mass to deflect light significantly. Gravity deflection is greatest for distant planets and stars, but never greater than 1.8". When a planet disappears behind the Sun, the Explanatory Supplement recommends to set the deflection = 0. To avoid discontinuities, we chose a different procedure. See Appendix A.

"Annual" aberration of light

The velocity of light is finite, and therefore the apparent direction of a moving body from a moving observer is never the same as it would be if both the planet and the observer stood still. For comparison: if you run through the rain, the rain seems to come from ahead even though it actually comes from above. Aberration may reach 20".

Frame Bias (ICRS to J2000)

JPL ephemerides since DE403/DE404 are referred to the International Celestial Reference System, a time-independent, non-rotating reference system which was introduced by the IAU in 1997. The planetary positions and speed vectors are rotated to the J2000 system. This transformation makes a difference of only about 0.0068 arc seconds in right ascension. (Implemented from Swiss Ephemeris 1.70 on)

Precession

Precession is the motion of the vernal equinox on the ecliptic. It results from the gravitational pull of the Sun, the Moon, and the planets on the equatorial bulge of the Earth. Original JPL data are referred to the mean equinox of the year 2000. Apparent planetary positions are referred to the equinox of date. (From Swiss Ephemeris 1.78 on, we use the precession model Vondrák/Capitaine/Wallace 2011.)

Nutation (true equinox of date)

A short-period oscillation of the vernal equinox. It results from the Moon's gravity which acts on the equatorial bulge of the Earth. The period of nutation is identical to the period of a cycle of the lunar node, i.e. 18.6 years. The difference between the true vernal point and the mean one is always below 17". (From Swiss Ephemeris 2.00, we use the nutation model IAU 2006. Since 1.70, we used nutation model IAU 2000. Older versions used the nutation model IAU 1980 (Wahr).)

Transformation from equatorial to ecliptic coordinates

For *precise speed* of the planets and the Moon, we had to make a special effort, because the *Explanatory Supplement* does not give algorithms that apply the above-mentioned transformations to speed. Since this is not a trivial job, the easiest way would have been to compute three positions in a small interval and determine the speed from the derivation of the parabola going through them. However, double float calculation does not guarantee a precision better than 0.1"/day. Depending on the time difference between the positions, speed is either good near station or during fast motion. Derivation from more positions and higher order polynomials would not help either.

Therefore we worked out a way to apply directly all the transformations to the barycentric speeds that can be derived from JPL or Swiss Ephemeris. The precision of daily motion is now better than 0.002" for all planets, and the computation is even a lot faster than it would have been from three positions. A position with speed takes in average only 1.66 times longer than one without speed, if a JPL or a Swiss Ephemeris position is computed. With Moshier, however, a computation with speed takes 2.5 times longer.

2.1.4. The Swiss Ephemeris compression mechanism

The idea behind our mechanism of ephemeris compression was developed by Dr. Peter Kammeyer of the U.S. Naval Observatory in 1987.

This is how it works: The ephemerides of the Moon and the inner planets require by far the greatest part of the storage. A more sophisticated mechanism is required for these than for the outer planets. Instead of the positions we store the differences between JPL and the mean orbits of the analytical theory VSOP87. These differences are a lot smaller than the position values, wherefore they require less storage. They are stored in Chebyshew polynomials covering a period of an anomalistic cycle each. (By the way, this is the reason, why the Swiss Ephemeris does not cover the time range of the full JPL ephemeris. The first ephemeris file begins on the date on which the last of the inner planets (including Mars) passes its first perihelion after the start date of the JPL ephemeris.)

With the outer planets from Jupiter through Pluto we use a simpler mechanism. We rotate the positions provided by the JPL ephemeris to the mean plane of the planet. This has the advantage that only two coordinates have high values, whereas the third one becomes very small. The data are stored in Chebyshew polynomials that cover a period of 4000 days each. (This is the reason, why Swiss Ephemeris stops before the end date of the JPL ephemeris.)

2.1.5. The extension of DE406-based ephemerides to 10.800 years

This Chapter is only relevant to those who use pre-2014, DE406-based ephemeris files of the Swiss Ephemeris.

The JPL ephemeris DE406 covers the time range from 3000 BCE to 3000 CE. While this is an excellent range covering all precisely known historical events, there are some types of ancient astrology and archeoastronomical research which would require a longer time range.

In December 1998 we have made an effort to extend the time range using our own numerical integration. The exact physical model used by Standish et. al. for the numerical integration of the DE406 ephemeris is not fully documented (at least we do not understand some details), so that we cannot use the same integration program as had been used at JPL for the creation of the original ephemeris.

The previous JPL ephemeris DE200, however, has been reproduced by Steve Moshier over a very long-time range with his numerical integrator, which was available to us. We used this software with start vectors taken at the end points of the DE406 time range. To test our numerical integrator, we ran it upwards from 3000 BCE to 600 BCE for a period of 2400 years and compared its results with the DE406 ephemeris itself. The agreement is excellent for all planets except the Moon (see table below). The lunar orbit creates a problem because the physical model for the Moon's libration and the effect of the tides on lunar motion is quite different in the DE406 from the model in the DE200. We varied the tidal coupling parameter (love number) and the longitudinal libration phase at the start epoch until we found the best agreement over a 2400-year test range between our integration and the JPL data. We could reproduce the Moon's motion over a 2400-time range with a maximum error of 12 arcseconds. For most of this time range the agreement is better than 5 arcsec.

With these modified parameters we ran the integration backward in time from 3000 BCE to 5400 BCE. It is reasonable to assume that the integration errors in the backward integration are not significantly different from the integration errors in the upward integration.

Planet	**max. error arcsec**	**avg. error arcsec**
Mercury	1.67	0.61
Venus	0.14	0.03
Earth	1.00	0.42
Mars	0.21	0.06
Jupiter	0.85	0.38
Saturn	0.59	0.24
Uranus	0.20	0.09
Neptune	0.12	0.06
Pluto	0.12	0.04
Moon	12.2	2.53
Sun	bary.	6.3

The same procedure was applied at the upper end of the DE406 range, to cover an extension period from 3000 CE to 5400 CE. The maximum integration errors as determined in the test run 3000 CE down to 600 CE are given in the table below.

Planet	**max. error arcsec**	**avg. error arcsec**
Mercury	2.01	0.69
Venus	0.06	0.02
Earth	0.33	0.14
Mars	1.69	0.82
Jupiter	0.09	0.05
Saturn	0.05	0.02
Uranus	0.16	0.07
Neptune	0.06	0.03
Pluto	0.11	0.04
Moon	8.89	3.43
Sun	bary.	0.61

Deviations in heliocentric longitude from new JPL ephemeris DE431 (2013), time range 5400 BCE to 3000 BCE

planet	difference
Moon (geocentric)	< 40”
Earth, Mercury, Venus	< 1.4”
Mars	< 4”
Jupiter	< 9”
Saturn	< 1.2”
Uranus	< 36”
Neptune	< 76”
Pluto	< 120”

2.1.6 Solar Ephemeris in the remote past

Since SE 2.00 and the introduction of JPL ephemerid DE431, there has been a small inaccuracy with solar ephemerides in the remote past. In 10.000 BCE, the ecliptic latitude of the Sun seems to oscillate between -36 and +36 arcsec. In reality, the solar latitude should be below 1 arcsec.

This phenomenon is caused by the precession theory Vondrak 2011 (A&A 534, A22 (2011)), whose precision is limited. On p. 2 the paper states:

“The goal of the present study is to find relatively simple expressions for all precession parameters (listed, e.g., by Hilton et al. 2006), the primary ones being the orientation parameters of the secularly-moving ecliptic and equator poles with respect to a fixed celestial frame. We require that the accuracy of these expressions is comparable to the IAU 2006 model near the epoch J2000.0, while lower accuracy is allowed outside the interval ±1000 years, gradually increasing up to several arcminutes at the extreme epochs ±200 millennia.”

This means that this theory is probably the best one available for current centuries but not necessarily perfect for the remote past.

The problem could be avoided if we used the precession theory Laskar 1986 or Owen 1990. However, precession Vondrak 2011 is better for recent centuries. This seems more relevant to us.

2.2. Lunar and Planetary Nodes and Apsides

2.2.1. Mean Lunar Node and Mean Lunar Apogee (Lilith, Black Moon in astrology)

JPL ephemerides do not include a mean lunar node or mean lunar apsis (perigee/apogee). We therefore have to derive them from different sources.

Our mean node and mean apogee are computed from Moshier’s lunar routine, which is an adjustment of the ELP2000-85 lunar theory to the JPL ephemeris on the interval from 3000 BCE to 3000 CE. Its deviation from the mean node of ELP2000-85 is 0 for J2000 and remains below 20 arc seconds for the whole period. With the apogee, the deviation reaches 3 arc minutes at 3000 BCE.

In order to cover the whole time range of DE431, we had to add some corrections to Moshier’s mean node and apsis, which we derived from the true node and apsis that result from the DE431 lunar ephemeris. Estimated precision is 1 arcsec, relative to DE431.

Notes for astrologers

Astrological Lilith or the Dark Moon is either the apogee (“aphelion”) of the lunar orbital ellipse or, according to some, its empty focal point. As seen from the geocenter, this makes no difference. Both of them are located in exactly the same direction. But the definition makes a difference for topocentric ephemerides.

The opposite point, the lunar perigee or orbital point closest to the Earth, is also known as Priapus. However, if Lilith is understood as the second focal point, an opposite point makes no sense, of course.

Originally, the term “Dark Moon” stood for a hypothetical second body that was believed to move around the Earth. There are still ephemerides circulating for such a body, but modern celestial mechanics clearly exclude the possibility of such an object. Later the term “Dark Moon” was used for the lunar apogee.

The Swiss Ephemeris apogee differs from the ephemeris given by Joëlle de Gravelaine in her book “Lilith, der schwarze Mond” (Astrodata 1990). The difference reaches several arc minutes. The mean apogee (or perigee) moves along the mean lunar orbit which has an inclination of 5 degrees. Therefore it has to be projected on the ecliptic. With de Gravelaine’s ephemeris, this was not taken into account. As a result of this projection, we also provide an ecliptic latitude of the apogee, which will be of importance if declinations are used.

There may be still another problem. The ’first’ focal point does not coincide with the geocenter but with the barycenter of the Earth-Moon-system. The difference is about 4700 km. If one took this into account, it would result in a monthly oscillation of the Black Moon. If one defines the Black Moon as the apogee, this oscillation would be about +/- 40 arc minutes. If one defines it as the second focus, the effect is a lot greater: +/- 6 degrees. However, we have neglected this effect.

[added by Alois 7-feb-2005, arising out of a discussion with Juan Revilla] The concept of ’mean lunar orbit’ means that short term. e.g. monthly, fluctuations must not be taken into account. In the temporal average, the EMB coincides with the geocenter. Therefore, when mean elements are computed, it is correct only to consider the geocenter, not the Earth-Moon Barycenter.

Computing topocentric positions of mean elements is also meaningless and should not be done.

2.2.2. The True Node

The ’true’ lunar node is usually considered the osculating node element of the momentary lunar orbit. I.e., the axis of the lunar nodes is the intersection line of the momentary orbital plane of the Moon and the plane of the ecliptic. Or in other words, the nodes are the intersections of the two great circles representing the momentary apparent orbit of the Moon and the ecliptic.

The nodes are considered important because they are connected with eclipses. They are the meeting points of the Sun and the Moon. From this point of view, a more correct definition might be: The axis of the lunar nodes is the intersection line of the momentary orbital plane of the Moon and the momentary orbital plane of the Sun.

This makes a difference, although a small one. Because of the monthly motion of the Earth around the Earth-Moon barycenter, the Sun is not exactly on the ecliptic but has a latitude, which, however, is always below an arc second. Therefore the momentary plane of the Sun’s motion is not identical with the ecliptic. For the true node, this would result in a difference in longitude of several arc seconds. However, Swiss Ephemeris computes the traditional version.

The advantage of the ’true’ nodes against the mean ones is that when the Moon is in exact conjunction with them, it has indeed a zero latitude. This is not so with the mean nodes.

In the strict sense of the word, even the “true” nodes are true only twice a month, viz. at the times when the Moon crosses the ecliptic. Positions given for the times in between those two points are based on the idea that celestial orbits can be approximated by elliptical elements or great circles. The monthly oscillation of the node is explained by the strong perturbation of the lunar orbit by the Sun. A different approach for the “true” node that would make sense, would be to interpolate between the true node passages. The monthly oscillation of the node would be suppressed, and the maximum deviation from the conventional “true” node would be about 20 arc minutes.

Precision of the true node

The true node can be computed from all of our three ephemerides. If you want a precision of the order of at least one arc second, you have to choose either the JPL or the Swiss Ephemeris.

Maximum differences

JPL-derived node – Swiss-Ephemeris-derived node ~ 0.1 arc second

JPL-derived node − Moshier-derived node ~ 70 arc seconds

(PLACALC was not better either. Its error was often > 1 arc minute.)

Distance of the true lunar node:

The distance of the true node is calculated on the basis of the osculating ellipse of date.

Small discontinuities in ephemeris of true node and apogee based on compressed file

If our compressed lunar ephemeris files semo*.se1 are used, then small discontinuities occur every 27.55 days at the segment boundaries of the compressed lunar orbit. The errors are small, but can be inconvenient if a smooth function is required for the osculating node and apogee. This problem does not occur if an original JPL ephemeris or the Moshier ephemeris is used.

2.2.3. The Osculating Apogee (astrological True Lilith or True Dark Moon)

The position of 'true Lilith' is given in the New International Ephemerides (NIE, Editions St. Michel) and in Francis Santoni 'Ephemerides de la lune noire vraie 1910-2010' (Editions St. Michel, 1993). Both Ephemerides coincide precisely.

The relation of this point to the mean apogee is not exactly of the same kind as the relation between the true node and the mean node. Like the 'true' node, it can be considered as an osculating orbital element of the lunar motion. But there is an important difference: The apogee contains the concept of the ellipse, whereas the node can be defined without thinking of an ellipse. As has been shown above, the node can be derived from orbital planes or great circles, which is not possible with the apogee. Now ellipses are good as a description of planetary orbits because planetary orbits are close to a two-body problem. But they are not good for the lunar orbit which is strongly perturbed by the gravity of the Sun (three-body problem). *The lunar orbit is far from being an ellipse!*

The osculating apogee is 'true' twice a month: when it is in exact conjunction with the Moon, the Moon is most distant from the Earth; and when it is in exact opposition to the Moon, the Moon is closest to the Earth. The motion in between those two points, is an oscillation with the period of a month. This oscillation is largely an artifact caused by the reduction of the Moon's orbit to a two-body problem. The amplitude of the oscillation of the *osculating* apogee around the mean apogee is +/- 30 degrees, while the *actual* apogee's deviation from the mean one never exceeds 5 degrees.

There is a small difference between the NIE's 'true Lilith' and our osculating apogee, which results from an inaccuracy in NIE. The error reaches 20 arc minutes. According to Santoni, the point was calculated using 'les 58 premiers termes correctifs au perigée moyen' published by Chapront and Chapront-Touzé. And he adds: "Nous constatons que même en utilisant ces 58 termes correctifs, l'erreur peut atteindre 0,5d!" (p. 13) We avoid this error, computing the orbital elements from the position and the speed vectors of the Moon. (By the way, there is also an error of +/- 1 arc minute in NIE's true node. The reason is probably the same.)

Precision

The osculating apogee can be computed from any one of the three ephemerides. If a precision of at least one arc second is required, one has to choose either the JPL or the Swiss Ephemeris.

Maximum differences

JPL-derived apogee − Swiss-Ephemeris-derived apogee ~ 0.9 arc second

JPL-derived apogee − Moshier-derived apogee ~ 360 arc seconds = 6 arc minutes!

There have been several other attempts to solve the problem of a 'true' apogee. They are not included in the SWISSEPH package. All of them work with a correction table.

They are listed in Santoni's 'Ephemerides de la lune noire vraie' mentioned above. With all of them, a value is added to the mean apogee depending on the angular distance of the Sun from the mean apogee. There is something to this idea. The actual apogees that take place once a month differ from the mean apogee by never more than 5 degrees and seem to move along a regular curve that is a function of the elongation of the mean apogee.

However, this curve does not have exactly the shape of a sine, as is assumed by all of those correction tables. And most of them have an amplitude of more than 10 degrees, which is a lot too high. The most realistic solution so far was the one proposed by Henry Gouchon in “Dictionnaire Astrologique”, Paris 1992, which is based on an amplitude of 5 degrees.

In “Meridian” 1/95, Dieter Koch has published another table that pays regard to the fact that the motion does not precisely have the shape of a sine. (Unfortunately, “Meridian” confused the labels of the columns of the apogee and the perigee.)

Small discontinuities in ephemeris of true node and apogee based on compressed file

See remarks in Chapter 2.2.2 on The True Node.

2.2.4. The Interpolated or Natural Apogee and Perigee (astrological Lilith and Priapus)

As has been said above, the osculating lunar apogee (so-called ‘true Lilith’) is a mathematical construct which assumes that the motion of the Moon is a two-body problem. This solution is obviously too simplistic. Although Kepler ellipses are a good means to describe planetary orbits, they fail with the orbit of the Moon, which is strongly perturbed by the gravitational pull of the Sun. This solar perturbation results in gigantic monthly oscillations in the ephemeris of the osculating apsides (the amplitude is 30 degrees). These oscillations have to be considered an *artifact* of the insufficient model, they do not really show a motion of the apsides.

A more sensible solution seems to be an interpolation between the real passages of the Moon through its apogees and perigees. It turns out that the motions of the lunar perigee and apogee form curves of different quality and the two points are usually not in opposition to each other. They are more or less opposite points only at times when the Sun is in conjunction with one of them or at an angle of 90° from them. The amplitude of their oscillation about the mean position is 5 degrees for the apogee and 25 degrees for the perigee.

This solution has been called the ”*interpolated*” or ”realistic” apogee and perigee by Dieter Koch in his publications. Juan Revilla prefers to call them the ”*natural*” apogee and perigee. Today, Dieter Koch would prefer the designation ”natural”. The designation ”interpolated” is a bit misleading, because it associates something that astrologers used to do every day in old days, when they still used to work with printed ephemerides and house tables.

Note on implementation (from Swiss Ephemeris Version 1.70 on)

Conventional interpolation algorithms do not work well in the case of the lunar apsides. The supporting points are too far away from each other in order to provide a good interpolation, the error estimation is greater than 1 degree for the perigee. Therefore, Dieter chose a different solution. He derived an ”interpolation method” from the analytical lunar theory which we have in the form of Moshier’s lunar ephemeris. This ”interpolation method” has not only the advantage that it probably makes more sense, but also that the curve and its derivation are both continuous.

Literature (in German):

- Dieter Koch, ”Was ist Lilith und welche Ephemeride ist richtig”, Meridian 1/95
- Dieter Koch and Bernhard Rindgen, ”Lilith und Priapus”, Frankfurt/Main, 2000.
- (http://www.vdhb.de/Lilith_und_Priapus/lilith_und_priapus.html)
- Juan Revilla, ”The Astronomical Variants of the Lunar Apogee - Black Moon”.
- http://www.expreso.co.cr/centaurs/blackMoon/barycentric.html

2.2.5. Planetary Nodes and Apsides

Differences between the Swiss Ephemeris and other ephemerides of the osculation nodes and apsides are probably due to different planetary ephemerides being used for their calculation. Small differences in the planetary ephemerides lead to greater differences in nodes and apsides.

Definitions of the nodes

Methods described in small font are not supported by the Swiss Ephemeris software.

The lunar nodes are defined by the intersection axis of the lunar orbital plane with the plane of the ecliptic. At the lunar nodes, the Moon crosses the plane of the ecliptic and its ecliptic latitude changes sign. There are similar nodes for the planets, but their definition is more complicated. Planetary nodes can be defined in the following ways:

- They can be understood as an axis defined by the intersection line of two orbital planes. E.g., the nodes of Mars are defined by the intersection line of the orbital plane of Mars with the plane of the ecliptic (or the orbital plane of the Earth).

Note: However, as Michael Erlewine points out in his elaborate web page on this topic (http://thenewage.com/resources/articles/interface.html), planetary nodes could be defined for any couple of planets. E.g. there is also an intersection line for the two orbital planes of Mars and Saturn. Such non-ecliptic nodes have not been implemented in the Swiss Ephemeris.

Because such lines are, in principle, infinite, the heliocentric and the geocentric positions of the planetary nodes will be the same. There are astrologers that use such heliocentric planetary nodes in geocentric charts.

The ascending and the descending node will, in this case, be in precise opposition.

- There is a second definition that leads to different geocentric ephemerides. The planetary nodes can be understood, not as an infinite axis, but as the two points at which a planetary orbit intersects with the ecliptic plane.

For the lunar nodes and heliocentric planetary nodes, this definition makes no difference from the definition 1). However, it does make a difference for geocentric planetary nodes, where, the nodal points on the planets orbit are transformed to the geocenter. The two points will not be in opposition anymore, or they will roughly be so with the outer planets. The advantage of these nodes is that when a planet is in conjunction with its node, then its ecliptic latitude will be zero. This is not true when a planet is in geocentric conjunction with its heliocentric node. (And neither is it always true for inner the planets, for Mercury and Venus.)

Note: There is another possibility, not implemented in the Swiss ephemeris: E.g., instead of considering the points of the Mars orbit that are located in the ecliptic plane, one might consider the points of the Earth's orbit that are located in the orbital plane of Mars. If one takes these points geocentrically, the ascending and the descending node will always form an approximate square. This possibility has not been implemented in the Swiss Ephemeris.

- Third, the planetary nodes could be defined as the intersection points of the plane defined by their momentary geocentric position and motion with the plane of the ecliptic. Here again, the ecliptic latitude would change sign at the moment when the planet were in conjunction with one of its nodes. This possibility has not been implemented in the Swiss Ephemeris.

Possible definitions for apsides and focal points

The lunar apsides - the lunar apogee and lunar perigee - have already been discussed further above. Similar points exist for the planets, as well, and they have been considered by astrologers. Also, as with the lunar apsides, there is a similar disagreement:

One may consider either the planetary *apsides*, i.e. the two points on a planetary orbit that are closest to the Sun and most distant from the Sun, resp. The former point is called the "*perihelion*" and the latter one the "*aphelion*". For a geocentric chart, these points could be transformed from the heliocenter to the geocenter.

However, Bernard Fitzwalter and Raymond Henry prefer to use the second focal points of the planetary orbits. And they call them the "black stars" or the "black Suns of the planets". The heliocentric positions of these points are identical to the heliocentric positions of the aphelia, but geocentric positions are not identical, because the focal points are much closer to the Sun than the aphelia. Most of them are even inside the Earth orbit.

The Swiss Ephemeris supports both points of view.

Special case: the Earth

The Earth is a special case. Instead of the motion of the Earth herself, the heliocentric motion of the Earth-Moon-Barycenter (EMB) is used to determine the osculating perihelion.

There is no node of the Earth orbit itself.

There is an axis around which the Earth's orbital plane slowly rotates due to planetary precession. The position points of this axis are not calculated by the Swiss Ephemeris.

Special case: the Sun

In addition to the Earth (EMB) apsides, our software computes so-to-say "apsides" of the solar orbit around the Earth, i.e. points on the orbit of the Sun where it is closest to and where it is farthest from the Earth. These points form an opposition and are used by some astrologers, e.g. by the Dutch astrologer George Bode or the Swiss astrologer Liduina Schmed. The "perigee", located at about 13 Capricorn, is called the "Black Sun", the other one, in Cancer, is called the "Diamond".

So, for a complete set of apsides, one might want to calculate them for the Sun and the Earth and all other planets.

Mean and osculating positions

There are serious problems about the ephemerides of planetary nodes and apsides. There are mean ones and osculating ones. Both are well-defined points in astronomy, but this does not necessarily mean that these definitions make sense for astrology. Mean points, on the one hand, are not true, i.e. if a planet is in precise conjunction with its mean node, this does not mean it be crossing the ecliptic plane exactly that moment. Osculating points, on the other hand, are based on the idealization of the planetary motions as two-body problems, where the gravity of the Sun and a single planet is considered and all other influences neglected. There are no planetary nodes or apsides, at least today, that really deserve the label "true".

Mean positions

Mean nodes and apsides can be computed for the Moon, the Earth and the planets Mercury – Neptune. They are taken from the planetary theory VSOP87. Mean points **cannot** be calculated for Pluto and the asteroids, because there is no planetary theory for them.

Although the Nasa has published mean elements for the planets Mercury – Pluto based on the JPL ephemeris DE200, we do not use them (so far), because their validity is limited to a 250 year period, because only linear rates are given, and because they are not based on a planetary theory.

(http://ssd.jpl.nasa.gov/elem_planets.html, "mean orbit solutions from a 250 yr. least squares fit of the DE 200 planetary ephemeris to a Keplerian orbit where each element is allowed to vary linearly with time")

The differences between the DE200 and the VSOP87 mean elements are considerable, though:

planet	**Node**	**Perihelion**
Mercury	3"	4"
Venus	3"	107"
Earth	-	35"
Mars	74"	4"
Jupiter	330"	1850"
Saturn	178"	1530"
Uranus	806"	6540"
Neptune	225"	11600" (>3°!)

Osculating nodes and apsides

Nodes and apsides can also be derived from the osculating orbital elements of a body, the parameters that define an ideal unperturbed elliptic (two-body) orbit for a given time. Celestial bodies would follow such orbits *if perturbations were to cease suddenly or if there were only two bodies (the Sun and the planet) involved in the motion and the motion were an ideal ellipse.* This ideal assumption makes it obvious that it would be misleading to call such nodes or apsides "true". It is more appropriate to call them "osculating". Osculating nodes and apsides are "true" only at the precise moments, when the body passes through them, but for the times in between, they are a mere mathematical construct, nothing to do with the nature of an orbit.

We tried to solve the problem by *interpolating* between actual passages of the planets through their nodes and apsides. However, this method works only well with Mercury. With all other planets, the supporting points are too far apart as to allow a sensible interpolation.

There is another problem about heliocentric ellipses. E.g. Neptune's orbit has often two perihelia and two aphelia (i. e. minima and maxima in heliocentric distance) within one revolution. As a result, there is a wild oscillation of the osculating or "true" perihelion (and aphelion), which is not due to a transformation of the orbital ellipse but rather due to the deviation of the heliocentric orbit from an elliptic shape. Neptune's orbit cannot be adequately represented by a heliocentric ellipse.

In actuality, Neptune's orbit is not heliocentric at all. The double perihelia and aphelia are an effect of the motion of the Sun about the solar system barycenter. This motion is a lot faster than the motion of Neptune, and Neptune cannot react to such fast displacements of the Sun. As a result, Neptune seems to move around the barycenter (or a mean Sun) rather than around the real Sun. In fact, Neptune's orbit around the barycenter is therefore closer to an ellipse than his orbit around the Sun. The same is also true, though less obvious, for Saturn, Uranus and Pluto, but not for Jupiter and the inner planets.

This fundamental problem about osculating ellipses of planetary orbits does of course not only affect the apsides but also the nodes.

As a solution, it seems reasonable to compute the osculating elements of slow planets from their barycentric motions rather than from their heliocentric motions. This procedure makes sense especially for Neptune, but also for all planets beyond Jupiter. It comes closer to the mean apsides and nodes for planets that have such points defined. For Pluto and all trans-Saturnian asteroids, this solution may be used as a substitute for "mean" nodes and apsides. Note, however, that there are considerable differences between barycentric osculating and mean nodes and apsides for Saturn, Uranus, and Neptune. (A few degrees! But heliocentric ones are worse.)

Anyway, neither the heliocentric nor the barycentric ellipse is a perfect representation of the nature of a planetary orbit. So, astrologers should not expect anything very reliable here either!

The best choice of method will probably be:

- For Mercury – Neptune: mean nodes and apsides.
- For asteroids that belong to the inner asteroid belt: osculating nodes/apsides from a heliocentric ellipse.
- For Pluto and transjovian asteroids: osculating nodes/apsides from a barycentric ellipse.

The modes of the Swiss Ephemeris function swe_nod_aps()

The function `swe_nod_aps()` can be run in the following modes:

1. Mean positions are given for nodes and apsides of Sun, Moon, Earth, and the planets up to Neptune. Osculating positions are given with Pluto and all asteroids. This is the default mode.
2. Osculating positions are returned for nodes and apsides of all planets.
3. Same as 2), but for planets and asteroids beyond Jupiter, a barycentric ellipse is used.
4. Same as 1), but for Pluto and asteroids beyond Jupiter, a barycentric ellipse is used.

For the reasons given above, method 4) seems to make best sense.

In all of these modes, the second focal point of the ellipse can be computed instead of the aphelion.

2.3. Asteroids

2.3.1. Asteroid ephemeris files

The standard distribution of SWISSEPH includes the main asteroids Ceres, Pallas, Juno, Vesta, as well as 2060 Chiron, and 5145 Pholus. To compute them, one must have the main-asteroid ephemeris files in the ephemeris directory.

The names of these files are of the following form:

seas_18.se1 main asteroids for 600 years from 1800 - 2400

The size of such a file is about 200 kb.

All other asteroids are available in separate files. The names of additional asteroid files look like:

se00433.se1 the file of asteroid no. 433 (= Eros)

These files cover the period 3000 BCE - 3000 CE.

A short version for the years 1500 – 2100 CE has the file name with an 's' imbedded, se00433s.se1.

The numerical integration of the all numbered asteroids is an ongoing effort. In December 1998, 8000 asteroids were numbered, and their orbits computed by the developers of Swiss Ephemeris. In January 2001, the list of numbered asteroids reached 20957, in January 2014 more than 380'000, in August 2021 there are 567'000.

Any asteroid can be called either with the JPL, the Swiss, or the Moshier ephemeris flag, and the results will be slightly different. The reason is that the solar position (which is needed for geocentric positions) will be taken from the ephemeris that has been specified.

Availability of asteroid files

- all short files (over 550'000) are available for free download at our ftp server ftp.astro.ch/pub/swisseph.

The purpose of providing this large number of files for download is that the user can pick those few asteroids he/she is interested in.

- for all named asteroids also a long (6000 years) file is available in the download area.

2.3.2. How the asteroids were computed

To generate our asteroid ephemerides, we have modified the numerical integrator of Steve Moshier, which was capable to rebuild the DE200 JPL ephemeris.

Orbital elements, with a few exceptions, were taken from the asteroid database computed by E. Bowell, Lowell Observatory, Flagstaff, Arizona (astorb.dat). After the introduction of the JPL database mpcorb.dat, we still keep working with the Lowell data because Lowell elements are given with one more digit, which can be relevant for long-term integrations.

For a few close-Sun-approaching asteroids like 1566 Icarus, we use the elements of JPL's DASTCOM database. Here, the Bowell elements are not good for long term integration because they do not account for relativity.

Our asteroid ephemerides take into account the gravitational perturbations of all planets, including the major asteroids Ceres, Pallas, and Vesta and also the Moon.

The mutual perturbations of Ceres, Pallas, and Vesta were included by iterative integration. The first run was done without mutual perturbations, the second one with the perturbing forces from the positions computed in the first run.

The precision of our integrator is very high. A test integration of the orbit of Mars with start date 2000 has shown a difference of only 0.0007 arc second from DE200 for the year 1600. We also compared our asteroid ephemerides with data from JPL's on-line ephemeris system "Horizons" which provides asteroid positions from 1600 on. Taking into account that Horizons does not consider the mutual perturbations of the major asteroids Ceres, Pallas and Vesta, the difference is never greater than a few 0.1 arcsec.

(However, the Swisseph asteroid ephemerides do consider those perturbations, which makes a difference of 10 arcsec for Ceres and 80 arcsec for Pallas. This means that our asteroid ephemerides are even better than the ones that JPL offers on the web.)

The accuracy limits are therefore not set by the algorithms of our program but by the inherent uncertainties in the orbital elements of the asteroids from which our integrator has to start.

Sources of errors are:

- Only some of the minor planets are known to better than an arc second for recent decades. (See also information below on Ceres, Chiron, and Pholus.)
- Bowells elements do not consider relativistic effects, which leads to significant errors with long-term integrations of a few close-Sun-approaching orbits (except 1566, 2212, 3200, 5786, and 16960, for which we use JPL elements that do take into account relativity).

The orbits of some asteroids are extremely sensitive to perturbations by major planets. E.g. 1862 Apollo becomes chaotic before the year 1870 CE when he passes Venus within a distance which is only one and a half the distance from the Moon to the Earth. In this moment, the small uncertainty of the initial elements provided by the Bowell database grows, so to speak, “into infinity”, so that it is impossible to determine the precise orbit prior to that date. Our integrator is able to detect such happenings and end the ephemeris generation to prevent our users working with meaningless data.

2.3.3. Ceres, Pallas, Juno, Vesta

The orbital elements of the four main asteroids Ceres, Pallas, Juno, and Vesta are known very precisely, because these planets have been discovered almost 200 years ago and observed very often since. On the other hand, their orbits are not as well-determined as the ones of the main planets. We estimate that the precision of the main asteroid ephemerides is better than 1 arc second for the whole 20th century. The deviations from the Astronomical Almanac positions can reach 0.5” (AA 1985 – 1997). But the tables in AA are based on older computations, whereas we used recent orbital elements. (s. AA 1997, page L14)

MPC elements have a precision of five digits with mean anomaly, perihelion, node, and inclination and seven digits with eccentricity and semi-axis. For the four main asteroids, this implies an uncertainty of a few arc seconds in 1600 CE and a few arc minutes in 3000 BCE.

2.3.4. Chiron

Positions of Chiron can be well computed for the time between 700 CE and 4650 CE. As a result of close encounters with Saturn in Sept. 720 CE and in 4606 CE we cannot trace its orbit beyond this time range. Small uncertainties in today’s orbital elements have chaotic effects before the year 700.

Do not rely on earlier Chiron ephemerides supplying a Chiron for Cesar’s, Jesus’, or Buddha’s birth chart. They are meaningless.

2.3.5. Pholus

Pholus is a minor planet with orbital characteristics that are similar to Chiron’s. It was discovered in 1992. Pholus’ orbital elements are not yet as well-established as Chiron’s. Our ephemeris is reliable from 1500 CE through now. Outside the 20th century it will probably have to be corrected by several arc minutes during the coming years.

2.3.6. Asteroid 99942 Apophis

99942 Apophis is a near-Earth asteroid which sometime in the future impact Earth. The ephemeris of this object is particularly uncertain after 13 April 2029 when it will have a very close encounter with the earth. Our ephemeris was created from data from JPL Horizons.

Horizons's ephemeris of Apophis after 2029 varies considerable depending on the start date and step width one uses in the Horizons web interface. (If you don't believe it, please try it out!) However, as pointed out by Jon Giorgini in a Mail to Dieter Koch of 1 April 2020, this variation is smaller than the uncertainty of the orbit.

We will have to update our ephemeris of Apophis after his close encounter with Earth in April 2029 in order to make it accurate at least until the year 2036.

2.3.7. Ceres - an application program for asteroid astrology

Dieter Koch has written the application program **Ceres** which allows to compute all kinds of lists for asteroid astrology. E.g. you can generate a list of all your natal asteroids ordered by position in the zodiac. But the program does much more:

- natal positions, synastries/transits, composite charts, progressions, primary directions etc.;
- geocentric, heliocentric, topocentric, house horoscopes;
- lists sorted by position in zodiac, by asteroid name, by declination etc.

The program is found in the Swiss Ephermeris download area in the folder "programs".

2.4. Planetary Centers of Body (COB) and Planetary Moons

Although nobody ever finds it worth mentioning and hardly anybody is aware of it, all hitherto ephemerides and astrology softwares provide only the **barycenter** of the Jupiter system, i.e. the center of mass of Jupiter together with all his moons, not the center of Jupiter's body or the real planet. And the same holds for all the other planets that have moons, except the earth. We call the center of the real planets the **centers of body (COB)**.

The difference between the barycenters and the COBs are small. The maximum geocentric angular distances are as follows:

planet	angular distance
Mars	(0.2 m, irrelevant to us)
Jupiter	0.075 arcsec (jd 2468233.5)
Saturn	0.053 arcsec (jd 2463601.5)
Uranus	0.0032 arcsec (jd 2446650.5)
Neptune	0.0036 arcsec (jd 2449131.5)
Pluto	0.088 arcsec (jd 2437372.5)

(from one-day-step calculations over 150 years)

Swiss Ephemeris versions 2.10 and higher can provide positions of the **centers of body of the planets** as well as some **planetary moons**, thanks to a joint effort by Walter Pullen and Dieter Koch.

The ephemerides were downloaded from JPL Horizons and then compressed using the Astrodienst software *chopt*, the same software that is also used to generate asteroid ephemeris files.

Currently, not all planetary moons are available to Swiss Ephemeris users.

Software developers who want to implement COB have to know that the performance of this calculation is not as good as with the barycenters. Moreover, the time range is currently limited to the years 1900 to 2047.

2.5. Comets and Interstellar Objects

The Swiss Ephemeris provides ephemerides of a few selected comets under the following pseudo-MPC numbers:

file	pseudo number	comet
s999032s.se1	999032 Churyumov-Ger	Comet 67P/Churyumov-Gerasimenko
s999043s.se1	999043 Neowise	Comet C/2020 F3 (NEOWISE)
s999044.se1	999044 Halley	Comet 1P/Halley
s999046.se1	999046 Hale-Bopp	Comet Hale-Bopp (C/1995 O1)
s999047.se1	999047 West	Comet West (C/1975 V1-A)
s999045.se1	999045 Oumuamua	1I/'Oumuamua (A/2017 U1)

The ephemerides of these objects were downloaded from JPL Horizons and compressed in the format of Swiss Ephemeris data files.

2.6. Fixed stars and Galactic Center

A database of fixed stars is included with Swiss Ephemeris. It contains about 800 stars, which can be computed with the **swe_fixstar()** function. The precision is about 0.001".

This database was originally based on the star catalogue of Steve Moshier. It was improved in 1999 by Valentin Abramov, Tartu, Estonia. He reordered the stars by constellation, added some stars, many names and alternative spellings of names.

In Feb. 2006 (Version 1.70) the fixed stars file was updated with data from the SIMBAD database.

(http://simbad.u-strasbg.fr/Simbad)

In Jan. 2011 (Version 1.77) a new fixed stars file sefstars.txt was created from the SIMBAD database with a data format that is compatible with the SIMBAD database. The file continues to be updated every few years.

2.7. Hypothetical bodies

We include some astrological factors in the ephemeris which have no astronomical basis – they have never been observed physically. As the purpose of the Swiss Ephemeris is astrology, we decided to drop our scientific view in this area and to be of service to those astrologers who use these 'hypothetical' planets and factors. Of course neither of our scientific sources, JPL or Steve Moshier, have anything to do with this part of the Swiss Ephemeris.

2.7.1. Uranian planets (Hamburg planets: Cupido, Hades, Zeus, Kronos, Apollon, Admetos, Vulkanus, Poseidon)

There have been discussions whether these factors are to be called 'planets' or 'Transneptunian points'. However, their inventors, the German astrologers Witte and Sieggrün, considered them to be planets. And moreover they behave like planets in as far as they circle around the Sun and obey its gravity.

On the other hand, if one looks at their orbital elements, it is obvious that these orbits are highly unrealistic. Some of them are perfect circles – something that does not exist in physical reality. The inclination of the orbits is zero, which is very improbable as well. The revised elements published by James Neely in Matrix Journal VII (1980) show small eccentricities for the four Witte planets, but they are still smaller than the eccentricity of Venus which has an almost circular orbit. This is again very improbable.

There are even more problems. An ephemeris computed with such elements describes an unperturbed motion, i.e. it takes into account only the Sun's gravity, not the gravitational influences of the other planets. This may result in an error of a degree within the 20th century, and greater errors for earlier centuries.

Also, note that none of the real transneptunian objects that have been discovered since 1992 can be identified with any of the Uranian planets.

SWISSEPH uses James Neely's revised orbital elements, because they agree better with the original position tables of Witte and Sieggrün.

The hypothetical planets can again be called with any of the three ephemeris flags. The solar position needed for geocentric positions will then be taken from the ephemeris specified.

2.7.2. Transpluto (Isis)

This hypothetical planet was postulated 1946 by the French astronomer M.E. Sevin because of otherwise unexplainable gravitational perturbations in the orbits of Uranus and Neptune.

However, this theory has been superseded by other attempts during the following decades, which proceeded from better observational data. They resulted in bodies and orbits completely different from what astrologers know as 'Isis-Transpluto'. More recent studies have shown that the perturbation residuals in the orbits of Uranus and Neptune are too small to allow postulation of a new planet. They can, to a great extent, be explained by observational errors or by systematic errors in sky maps.

In telescope observations, no hint could be discovered that this planet actually existed. Rumors that claim the opposite are wrong. Moreover, all of the transneptunian bodies that have been discovered since 1992 are very different from Isis-Transpluto.

Even if Sevin's computation were correct, it could only provide a rough position. To rely on arc minutes would be illusory. Neptune was more than a degree away from its theoretical position predicted by Leverrier and Adams.

Moreover, Transpluto's position is computed from a simple Kepler ellipse, disregarding the perturbations by other planets' gravities. Moreover, Sevin gives no orbital inclination.

Though Sevin gives no inclination for his Transpluto, you will realize that there is a small ecliptic latitude in positions computed by SWISSEPH. This mainly results from the fact that its orbital elements are referred to epoch 5.10.1772 whereas the ecliptic changes position with time.

The elements used by SWISSEPH are taken from "Die Sterne" 3/1952, p. 70. The article does not say which equinox they are referred to. Therefore, we fitted it to the Astron ephemeris which apparently uses the equinox of 1945 (which, however, is rather unusual!).

2.7.3. Harrington

This is another attempt to predict Planet X's orbit and position from perturbations in the orbits of Uranus and Neptune. It was published in The Astronomical Journal 96(4), October 1988, p. 1476ff. Its precision is meant to be of the order of +/- 30 degrees. According to Harrington there is also the possibility that it is actually located in the opposite constellation, i.e. Taurus instead of Scorpio. The planet has a mean solar distance of about 100 AU and a period of about 1000 years.

2.7.4. Nibiru

A highly speculative planet derived from the theory of Zecharia Sitchin, who is an expert in ancient Mesopotamian history and a "paleoastronomer". The elements have been supplied by Christian Woeltge, Hannover. This planet is interesting because of its bizarre orbit. It moves in clockwise direction and has a period of 3600 years. Its orbit is extremely eccentric. It has its perihelion within the asteroid belt, whereas its aphelion lies at about 12 times the mean distance of Pluto. In spite of its retrograde motion, it seems to move counterclockwise in recent centuries. The reason is that it is so slow that it does not even compensate the precession of the equinoxes.

2.7.5. Vulcan

This is a 'hypothetical' planet inside the orbit of Mercury (not identical to the "Uranian" planet Vulkanus). Orbital elements according to L.H. Weston. Note that the speed of this "planet" does not agree with the Kepler laws. It is too fast by 10 degrees per year.

2.7.6. Selena/White Moon

This is a 'hypothetical' second Moon of the Earth (or a third one, after the "Black Moon") of obscure provenance. Many Russian astrologers use it. Its distance from the Earth is more than 20 times the distance of the Moon and it moves about the Earth in 7 years. Its orbit is a perfect, unperturbed circle. Of course, the physical existence of such a body is not possible. The gravities of Sun, Earth, and Moon would strongly influence its orbit.

2.7.7. Dr. Waldemath's Black Moon

This is another hypothetical second Moon of the Earth, postulated by a Dr. Waldemath in the Monthly Wheather Review 1/1898. Its distance from the Earth is 2.67 times the distance of the Moon, its daily motion about 3 degrees. The orbital elements have been derived from Waldemath's original data. There are significant differences from elements used in earlier versions of Solar Fire, due to different interpretations of the values given by Waldemath. After a discussion between Graham Dawson and Dieter Koch it has been agreed that the new solution is more likely to be correct. The new ephemeris does not agree with Delphine Jay's ephemeris either, which is obviously inconsistent with Waldemath's data.

This body has never been confirmed. With its 700-km diameter and an apparent diameter of 2.5 arc min, this should have been possible very soon after Waldemath's publication.

2.7.8. The Planets X of Leverrier, Adams, Lowell and Pickering

These are the hypothetical planets that have led to the discovery of Neptune and Pluto or at least have been brought into connection with them. Their enormous deviations from true Neptune and Pluto may be interesting for astrologers who work with hypothetical bodies. E.g. Leverrier and Adams are good only around the 1840ies, the discovery epoch of Neptune. To check this, call the program swetest as follows:

$ swetest -p8 -dU -b1.1.1770 -n8 -s7305 -hel -fPTLBR -head

(i.e.: compute planet 8 (Neptune) - planet 'U' (Leverrier), from 1.1.1770, 8 times, in 7305-day-steps, heliocentrically. You can do this from the Internet web page swetest.htm. The output will be:)

	date	**diff. in longitude**	**diff. in latitude**	**diff. in solar distance**
Nep-Lev	01.01.1770	-18°0'52.3811	0°55'0.0332	-6.610753489
Nep-Lev	01.01.1790	-8°42'9.1113	1°42'55.7192	-4.257690148
Nep-Lev	02.01.1810	-3°49'45.2014	1°35'12.0858	-2.488363869

	date	**diff. in longitude**	**diff. in latitude**	**diff. in solar distance**
Nep-Lev	02.01.1830	-1°38'2.8076	0°35'57.0580	-2.112570665
Nep-Lev	02.01.1850	1°44'23.0943	-0°43'38.5357	-3.340858070
Nep-Lev	02.01.1870	9°17'34.4981	-1°39'24.1004	-5.513270186
Nep-Lev	02.01.1890	21°20'56.6250	-1°38'43.1479	-7.720578177
Nep-Lev	03.01.1910	36°27'56.1314	-0°41'59.4866	-9.265417529

One can see that the error is in the range of 2 degrees between 1830 and 1850 and grows very fast beyond that period.

2.8. Sidereal Ephemerides for Astrology

2.8.1. The problem of defining the zodiac

Western astrology mostly uses the *tropical* zodiac, in which 0° Aries is fixed at the vernal point. The vernal point is the point where the Sun is located at the spring equinox. By contrast, *sidereal* astrology uses a *sidereal* zodiac whose initial point is defined relative to the fixed stars. Sidereal astrology has a western as well as an eastern tradition.

Since the vernal point makes a slow motion relative to the fixed stars, the so-called precession of the equinox (1° in 71.6 years), the tropical and the sidereal zodiacs slowly drift apart. About 1500 - 2000 years ago, both zodiacs almost perfectly agreed with each other. However, in our time, the difference between them amounts to more than 20° and continues increasing.

While the definition of the tropical zodiac is very obvious and never questioned by astrologers, sidereal astrologers unfortunately disagree about where exactly in the sky the initial point of the sidereal zodiac should be located. There are numerous divergent ideas about it and, consequently, a considerable number of different ayanamshas. New ayanamshas are invented almost every year. Beginners in sidereal astrology are confronted with the difficult problem of deciding which ayanamsha to use, unless they choose to follow the recommendation of their teacher. Hindu astrologers and their western disciples mostly use the so-called Lahiri ayanamsha, whereas the western sidereal tradition mostly uses the Fagan/Bradley Ayanamsha.

Nowadays, sidereal ephemerides are derived from tropical ephemerides by subtracting a certain difference value from the tropical positions of the planets. This difference value is called *ayanamsha*. The Sanskrit term *ayanāṃśaḥ* is composed of the words *ayanam*, "course (of the Sun), half-year" and *aṃśaḥ*, "part", thus literally means "part of the course". It refers to the distance of a solstice from the initial point of the cardinal zodiac sign that is associated with it. This distance equals the distance of the vernal point from the sidereal Aries point. (The correct pronunciation of *ayanāṃśaḥ* is with "sh", although many write and pronounce it with an "s".)

Thus, sidereal planetary positions are usually computed from tropical positions using the equation:

sidereal_position = tropical_position – ayanamsha(t)

where *ayanamsha* is the difference between the two zodiacs at a given epoch.

The value of the ayanamsha of date is usually computed from the ayanamsha value at a particular start date and the speed of the vernal point, the so-called *precession rate,* in ecliptic longitude.

The zero point of the sidereal zodiac is therefore traditionally defined by the equation:

sidereal_0_Aries = tropical_0_Aries + ayanamsha(t).

As has been stated, the number of existing ayanamshas is considerable. The Swiss Ephemeris offers more than forty of them. At first glance, they all look arbitrary in their definitions, and there is no striking evidence – from a mere astronomical point of view – for anyone of them. However, a historical study shows at least that many of them are related to each other and the basic approaches are not so many.

2.8.2. The Babylonian tradition and the Fagan/Bradley ayanamsha

There have been several attempts to calculate the zero point of the Babylonian ecliptic from cuneiform lunar and planetary tablets. Positions were given relative to some siderealy fixed reference point. The main problem in fixing the zero point is the inaccuracy of ancient observations. Around 1900 F.X. Kugler found that the Babylonian star positions fell into three groups:

Kugler ayanamshas:

9)[1] ayanamsha = -5°40´, t0 = -100

10) ayanamsha = -4°16´, t0 = -100 Spica at 29 vi 26

11) ayanamsha = -3°25´, t0 = -100

In 1958, Peter Huber reviewed the topic in the light of new material and found:

12) Huber ayanamsha:

ayanamsha = -4°28´ +/- 20´, t0 = –100 Spica at 29 vi 07'59"

The standard deviation was 1°08'.

(**Note**, this ayanamsha was corrected with SE version 2.05. A wrong value of -4°34' had been taken over from Mercier, "Studies on the Transmission of Medieval Mathematical Astronomy", IIb, p. 49.)

In 1977 Raymond Mercier noted that the zero point might have been defined as the ecliptic point that culminated simultaneously with the star eta Piscium (Al Pherg). For this possibility, we compute:

13) Eta Piscium ayanamsha:

ayanamsha = -5°04'46", t0 = –129 Spica at 29 vi 21

Around 1950, Cyril Fagan, the founder of the modern western sidereal astrology, reintroduced the old Babylonian zodiac into astrology, placing the fixed star Spica near 29°00 Virgo. As a result of "rigorous statistical investigation" (astrological!) of solar and lunar ingress charts, Donald Bradley decided that the sidereal longitude of the vernal point must be computed from Spica at 29 vi 06'05" disregarding its proper motion. Fagan and Bradley defined their "synetic vernal point" as:

0) Fagan/Bradley ayanamsha:

ayanamsha = 24°02'31.36" for 1 Jan. 1950 with Spica at 29 vi 06'05" (without aberration)

(For the year –100, this ayanamsha places Spica at 29 vi 07'32".)

The difference between P. Huber's zodiac and the Fagan/Bradley ayanamsha is smaller than 1'.

According to a text by Fagan (found on the internet), Bradley "once opined in print prior to "New Tool" that it made more sense to consider Aldebaran and Antares, at 15 degrees of their respective signs, as prime fiducials than it did to use Spica at 29 Virgo". Such statements raise the question if the sidereal zodiac ought to be tied up to one of those stars.

For this possibility, Swiss Ephemeris gives an Aldebaran ayanamsha:

14) Aldebaran-Antares ayanamsha:

ayanamsha with Aldebaran at 15 ta 00'00" and Antares at 15 sc 00'17" around the year –100.

The difference between this ayanamsha and the Fagan/Bradley one is 1'06".

In 2010, the astronomy historian John P. Britton made another investigation in cuneiform astronomical tablets and corrected Huber's by a 7 arc minutes.

38) Britton ayanamsha:

ayanamsha = -3.2° +- 0.09°[2]; t0 = 1 Jan. 0 Spica at 29 vi 14'58".

[1] 9–11 = Swiss Ephemeris ayanamsha numbers
[2] 5'24"

(For the year -100, this ayanamsha places Spica at 29 vi 15'02".)

This ayanamsha deviates from the Fagan/Bradley aynamsa by 7 arc min.

Sources:

- Raymond Mercier, "Studies in the Medieval Conception of Precession", in 'Archives Internationales d'Histoire des Sciences', (1976) 26:197-220 (part I), and (1977) 27:33-71 (part II);
- Cyril Fagan and Brigadier R.C. Firebrace, -Primer of Sidereal Astrology, Isabella, MO, USA 1971;
- P. Huber, „Über den Nullpunkt der babylonischen Ekliptik", in: Centaurus 1958, 5, pp. 192-208;
- John P. Britton, "Studies in Babylonian lunar theory: part III. The introduction of the uniform zodiac", in Arch. Hist. Exact. Sci. (2010)64:617-663, p. 630.

42) Vettius Valens ayanamsha:

The ayanamsha used by Greek astrologers in late antiquity does not have a clear-cut definition. However, from extant charts it is known that the ayanamsha was about -3° in the year 150 CE. The following ayanamsha is derived from Vettius Valens' (2nd century CE) lunar positions, according to:

- James H. Holden, "The Classical Zodiac", in: AFA Journal of Research, vol. 7, no. 2 1995, p. 12.

2.8.3. The Hipparchan tradition

Raymond Mercier has shown that all of the ancient Greek and the medieval Arabic astronomical works located the zero point of the ecliptic somewhere between 10 and 22 arc minutes east of the star zeta Piscium. He is of the opinion that this definition goes back to the great Greek astronomer Hipparchus.

Mercier points out that according to Hipparchus' star catalogue, the stars alpha Arietis, beta Arietis, zeta Piscium, and Spica are in a very precise alignment on a great circle which goes through that zero point near zeta Piscium. Moreover, this great circle was identical with the horizon once a day at Hipparchus' geographical latitude of 36°. In other words, the zero point rose at the same time when the three mentioned stars in Aries and Pisces rose and when Spica set.

This would of course be a nice definition for the zero point, but unfortunately the stars were not really in such precise alignment. They were only assumed to be so.

Mercier gives the following ayanamshas for Hipparchus and Ptolemy (who used the same star catalogue as Hipparchus):

15) Hipparchus ayanamsha:

ayanamsha = -9°20' 27 June –128 (jd 1674484) zePsc 29pi33'49" Hipparchus

(According to Mercier's calculations, the Hipparchan zero point should have been between 12 and 22 arc min east of zePsc, but the Hipparchan ayanamsha, as given by Mercier, has actually the zero point 26' east of zePsc. This comes from the fact that Mercier refers to the Hipparchan position of zeta Piscium, which was at least rounded to 10', if correct at all.)

Using the information that Aries rose when Spica set at a geographical latitude of 36 degrees, the precise ayanamsha would be -8°58'13" for 27 June –128 (jd 1674484) and zePsc would be found at 29pi12', which is too far from the place where it ought to be.

Mercier also discusses the old Indian precession models and zodiac point definitions. He notes that, in the Sûryasiddhânta, the star zeta Piscium (in Sanskrit Revatî) has almost the same position as in the Greek sidereal zodiac, i.e. 29°50' in Pisces. On the other hand, however, Spica (in Sanskrit Citrâ) is given the longitude 30° Virgo. Unfortunately, these positions of Revatî and Citrâ/Spica are incompatible; either Spica or Revatî must be considered wrong.

Moreover, if the precession model of the Sûryasiddânta is used to compute an ayanamsha for the date of Hipparchus, it will turn out to be –9°14'01", which is very close to the Hipparchan value. The same calculation can be done with the Âryasiddânta, and the ayanamsha for Hipparchos' date will be –9°14'55".

For the Siddânta Shiromani the zero point turns out to be Revatî itself. By the way, this is also the zero point chosen by Copernicus! So, there is an astonishing agreement between Indian and Western traditions!

The same zero point near the star Revatî is also used by the so-called Ushâ-Shashî ayanamsha. It differs from the Hipparchan one by only 11 arc minutes.

4) Usha-Shashi ayanamsha:

ayanamsha = 18°39’39.46 1 Jan. 1900 zePsc (Revatî) 29pi50’ (today), 29pi45’ (Hipparchus’ epoch)

The Greek-Arabic-Hindu ayanamsha was zero around 560 CE. The tropical and the sidereal zero points were at exactly the same place.

In the year 556, under the Sassanian ruler Khusrau Anûshirwân, the astronomers of Persia met to correct their astronomical tables, the so-called Zîj al-Shâh. These tables are no longer extant, but they were the basis of later Arabic tables, the ones of al-Khwârizmî and the Toledan tables.

One of the most important cycles in Persian astronomy/astrology was the synodic cycle of Jupiter, which started and ended with the conjunctions of Jupiter with the Sun. This cycle happened to end in the year 564, and the conjunction of Jupiter with the Sun took place only one day after the spring equinox. And the spring equinox took place precisely 10 arcmin east of zePsc. This may be a mere coincidence from a present-day astronomical point of view, but for scientists of those days this was obviously the moment to redefine all astronomical data.

Mercier also shows that in the precession (trepidation) model used in that time and in other models used later by Arabic astronomers, precession was considered to be a phenomenon connected with “the movement of Jupiter, the calendar marker of the night sky, in its relation to the Sun, the time keeper of the daily sky”. Such theories were of course wrong, from the point of view of modern knowledge, but they show how important that date was considered to be.

After the Sassanian reform of astronomical tables, we have a new definition of the Greek-Arabic-Hindu sidereal zodiac (this is not explicitly stated by Mercier, however):

16) Sassanian ayanamsha:

ayanamsha = 0 18 Mar 564, 7:53:23 UT (jd /ET 1927135.8747793) Sassanian zePsc 29pi49’59”

The same zero point then reappears with a precision of 1’ in the Toledan tables, the Khwârizmian tables, the Sûrya Siddhânta, and the Ushâ-Shashî ayanamsha.

Sources:

- Raymond Mercier, “Studies in the Medieval Conception of Precession”, in Archives Internationales d’Histoire des Sciences, (1976) 26:197-220 (part I), and (1977) 27:33-71 (part II)

2.8.4. Suryasiddhanta and Aryabhata

The explanations given above are mainly derived from the article by Mercier. However, it is possible to derive ayanamshas from ancient Indian works themselves.

The planetary theory of the main work of ancient Indian astronomy, the Suryasiddhanta, uses the so-called Kaliyuga era as its zero point, i.e. the 18th February 3102 BCE, 0:00 local time at Ujjain, which is at geographic longitude of 75.7684565 east (Mahakala temple). This era is henceforth called “K0s”. This is also the zero date for the planetary theory of the ancient Indian astronomer Aryabhata, with the only difference that he reckons from Sunrise of the same date instead of midnight. We call this Aryabhatan Kaliyuga era “K0a”.

Aryabhata mentioned that he was 23 years old when exactly 3600 years had elapsed since the beginning of the Kaliyuga era. If 3600 years with a year length as defined by the Aryabhata are counted from K0a, we arrive at the 21st March, 499 CE, 6:56:55.57 UT. At this point of time the mean Sun is assumed to have returned to the beginning of the sidereal zodiac, and we can try to derive an ayanamsha from this information. There are two possible solutions, though:

1. We can find the place of the mean Sun at that time using modern astronomical algorithms and define this point as the beginning of the sidereal zodiac.
2. Since Aryabhata believed that the zodiac began at the vernal point, we can take the vernal point of this date as the zero point.

The same calculations can be done based on K0s and the year length of the Suryasiddhanta. The resulting date of Kali 3600 is the same day but about half an hour later: 7:30:31.57 UT.

Algorithms for the mean Sun were taken from: Simon et alii, "Numerical expressions for precession formulae and mean elements for the Moon and the planets", in: Astron. Astrophys. 282,663-683 (1994).

Suryasiddhanta/equinox ayanamshas with zero year 499 CE

21) ayanamsha = 0 21 Mar 499, 7:30:31.57 UT = 12:33:36 LMT at Ujjain, 75.7684565 E

Based on Suryasiddhanta: ingress of mean Sun into Aries at point of mean equinox of date.

22) ayanamsha = -0.21463395

Based on Suryasiddhanta again, but assuming ingress of mean Sun into Aries at true position of mean Sun at the same epoch.

Aryabhata/equinox ayanamshas with zero year 499 CE

23) ayanamsha = 0 21 Mar 499, 6:56:55.57 UT = 12 LMT, local noon at Ujjain, 75.7684565 E.

Based on Aryabhata, ingress of mean Sun into Aries at point of mean equinox of date.

24) ayanamsha = -0.23763238

Based on Aryabhata again, but assuming ingress of mean Sun into Aries at true position of mean Sun at the same epoch.

According to Govindasvamin (850 n. Chr.), Aryabhata and his disciples taught that the vernal point was at the beginning of sidereal Aries in the year 522 CE (= Shaka 444). This tradition probably goes back to an erroneous interpretation of Aryabhata's above-mentioned statement that he was 23 years old when 3600 had elapsed after the beginning of the Kaliyuga. For the sake of completeness, we therefore add the following ayanamsha:

37) Aryabhata/equinox ayanamsha with zero year 522 CE

ayanamsha = 0 21.3.522, 5:46:44 UT

Ayanamshas can also be derived from star positions given in the Suryasiddhanta. E.g., it states that the star Revati/zeta Piscium is at polar ecliptic longitude 359°50'.

25) Ayanamsha having Revati/zeta Piscium at polar longitude 359°50' in 499 CE

ayanamsha = -0.79167046 21 Mar 499, 7:30:31.57 UT = noon at Ujjain, 75.7684565 E.

Revati/zePsc at polar ecliptic longitude 359°50'

28) True Revati ayanamsha

Revati/zePsc is always exactly at longitude 359°50' (not polar!).

(Note, this was incorrectly implemented in SE 2.00 – SE 2.04. The Position of Revati was 0°. Only from SE 2.05 on, this ayanamsha is correct.)

Unfortunately, other star positions given in Suryasiddhanta are not compatible with the one of Revati. In particular the star Spica/Citra, which is stated to be at 180° exactly, has been used to create another bunch of ayanamshas (see next chapter).

Siddhantas usually assume the star Pushya (delta Cancri = Asellus Australis) at 106°. PVR Narasimha Rao believes this star to be the best anchor point for a sidereal zodiac. In the Kalapurusha theory, which assigns zodiac signs to parts of the human body, the sign of Cancer is assigned to the heart, and according to Vedic spiritual literature, the root of human existence is in the heart. Mr. Narasimha Rao therefore proposed the following ayanamsha:

29) True Pushya paksha ayanamsha

Pushya/deCnC is always exactly at longitude 106°.

Sources:

- Surya-Siddhanta: A Text Book of Hindu Astronomy by Ebenezer Burgess, ed. Phanindralal Gangooly (1989/1997) with a 45-page commentary by P. C. Sengupta (1935).
- D. Pingree, "Precession and Trepidation in Indian Astronomy", in JHA iii (1972), pp. 28f.

2.8.5. The Spica/Citra tradition and the Lahiri ayanamsha

For instructions how to reproduce ayanamsha values given in IAE, IENA, Rashtriya Panchang, and the Report of the ICRC, please read Appendix E of this documentation.

1) Lahiri ayanamsha (according to IAE 1985, our standard Lahiri ayanamsha):

ayanamsha = 23°15' 00".658 21 March 1956, 0:00 TDT Lahiri, Spica (2000) 179°58'58"

46) Lahiri ayanamsha (according to ICRC, and pre-1985 IAE and IENA):

ayanamsha = 23°15' 00".0 21 March 1956, 0:00 TDT Lahiri, Spica (2000) 179°58'59"

The "Lahiri ayanamsha" was introduced by the *Indian Calendar Reform Committee* (ICRC) on the occasion of the Indian calendar reform in 1955, when the ayanamsha based on the star Spica/Citra was declared the Indian standard. It was used henceforth not only in astrology but also for sidereal ephemerides and calendars published in India. However, the idea that the zodiac should be oriented towards the star Spica (Citra in Sanskrti) is older. The Indian astronomy historian S. B. Dixit (also written Dikshit) in his important work *History of Indian Astronomy* (= *Bharatiya Jyotih Shastra*) in 1896 arrived at the conclusion that, given the prominence that Vedic religion gave to the cardinal points of the tropical year, the Indian calendar should be reformed and no longer be calculated relative to the sidereal, but to the tropical zodiac. However, if such a reform could not be brought about due to the rigid conservatism of contemporary Vedic culture, then the ayanamsha should be chosen in such a way that the sidereal zero point would be in opposition to Spica. In this way, it would be in accordance with Grahalaghava, a work by the 16th century astronomer Ganeśa Daivajña which was still in use in the 20th century among Indian calendar makers. (*History of Indian Astronomy*, Part II, p. 323ff.).

Moreover, the Suryasiddhanta, the "standard work" of ancient Hindu astronomy, which was written in the first centuries CE, already placed Spica/Citra at 180°. Unfortunately, this statement is in contradiction with the positions of other stars, in particular with zeta Piscium/Revati at 359°50', which has caused a lot of confusion.

The ayanamsha based on the star Spica/Citra became known as "Lahiri ayanamsha". It was named after the Calcuttan astronomer and astrologer Nirmala Chandra Lahiri (1906-1980), who was a member of the Calendar Reform Committee that in 1955 made it the standard for Hindu sidereal calendars.

The committee decreed that the ayanamsha had the value 23°15' 00" on the 21 March 1956, 0:00 Ephemeris Time. It became the basis of ayanamsha values given in *Indian Ephemeris and Nautical Almanac (IENA)*, in *Indian Astronomical Ephemeris (IAE)*, as well as for the *Rashtriya Panchang* ("National Calendar/Almanac"). Although not explicitly mentioned, this ayanamsha value is *true, not mean*, as can be concluded from the values given in the 5-year calendar that is included in the Report of the ICRC.

(Side note concerning the decisions of the ICRC, in the words of Vishvas Vasuki in the Bharatiyavidvatparishat forum: "The committee created a civil solar calendar (equinox to equinox), a religious solar calendar based on a fixed ayanAMsha (=deviation from equinoctial colure) (23° 15') to prevent further drift from seasons, a religious lunar calendar closely tied to the religious solar calendar, a asterism tracking variable ayanAMsha (23° 15' 0", with annual correction) for the nakShatra wheel. The reason for standardizing religious calendars was to be able to determine office holidays.")

The definition of the ayanamsha was corrected in *Indian Astronomical Ephemeris* 1985 (see 1989, page 556, footnote):

”According to new determination of the location of equinox this initial value has been revised to 23°15’00”.658 and used in computing the mean ayanamsha with effect from 1985’.”

Exact information about the reasons for this change is unfortunately not given or is hard to get hold of. The mention of “mean ayanamsha” is misleading, though. Again, the value 23°15’00”.658 is true ayanamsha, i.e. it includes nutation and is relative to the true equinox of date. This must be concluded, at least, from true ayanamsha values published in yearly editions of the *Indian Astronomical Ephemeris (IAE)*.

For a comparison of Lahiri ayanamsa values and sidereal ephemerides with values given in *Indian Astronomical Ephemeris*, see Appendix E.

43) Lahiri (1940) ayanamsha:

ayanamsha = 22°26’45”.50 J1900.0 = 31 Dec. 1899, 12:00 TT Spica (2000) at 179°59’52”

In 1940, however, Lahiri had published a different Citra ayanamsha in his Bengali book *Panchanga Darpan*. Here, the value of “mean ayanamsha” is given as 22°26’45”.50 in 1900, whereas the official value for the same date is 22°27’38”. With the standard Lahiri ayanamsha, the position of Spica is “wrong”, i.e. it deviates from 180° by about an arc minute, whereas with this other ayanamsha it is almost exact. Lahiri obviously wanted to place the star exactly at 180° for current years. The standard Lahiri position of Spica is 179°59’04 in the year 2000, and 179°59’08 in 1900. According to the definition given in *Panchanga Darpan*, however calculated with rigorous precession algorithms, the position of Spica in 2000 was 179°59’52”.

The same book (*Panchanga Darpan*) was reprinted in 1967 and 1985, thus long after the standard definition of the Lahiri ayanamsha had been published by the Calendar Reform Committee. Thus, apparently, still considered this his definition of ayanamsha more correct than the one chosen by the ICRC.

44) Lahiri (1972, vernal equinox 285) ayanamsha:

ayanamsha = 0° 22 March 285 17:54:02 TT (Lahiri original: 17:48 ET) Spica (2000) at 179°58’35”

mean Sun’s ingress in Aries (using formulae from Simon et alii (1994))

(**true** Sun’s ingress was on 20 March 19:18:33 TT)

In his “Tables of the Sun”, p. IX, however, which appeared in 1972, Lahiri again gave a different definition of his ayanamsha:

“For this purpose the star *Spica* (Virginis) has been assigned a *Nirayaṇa* (i.e. sidereal; D.K.) longitude of 180°. But as the star has got proper motion, it cannot indicate a fixed initial point for all times, even when a fixed value of longitude is assigned to it. It has therefore been considered expedient to adopt the vernal equinoctial point of any specified date for this purpose. The mean equinoctial point of the mean vernal equinox day of 285 A.D., which occurred on March 22, 17^{h} 48^{m} Ephemeris time or 15^{h} 57^{m} U.T. of that year, has accordingly been adopted as the fixed initial point of the Sidereal or Indian *Nirayaṇa* system of Astronomy.”

Exactly the same initial date, however in Indian Standard Time, he gave in 1980, in the preface of his *Indian Ephemeris*. However, the star Spica/Citra still does play an important part:

”The initial point of this nirayana or sidereal zodiac was the same as the equinoctial point ... of the vernal equinox day of 285 A.D., the mean equinox of the year occurring on Sunday March 22, 21h 27m I S.T. At that time both the sayana (= tropical, D.K.) and the nirayana (= sidereal) longitudes of the star Citra (Spica) were the same as 180°00’03”, and the longitude of the Mean Moon was 351°67 and of Mean Sun 360°00. It was thus a mean new-moon day also.”

Thus, Lahiri actually wanted to base his ayanamsha on the mean equinox of a ”zero ayanamsha year”. I.e. the zero date of his ayanamsha should be the moment when the *mean* Sun was at zero aries tropically (mean equinox of date). Moreover he wanted to have a mean new-moon on the same day also and the star Citra/Spica at tropical 0° Libra/Tula exactly. (For testing, such an ayanamsha was added to the Swiss Ephemeris as ayanamsha No. 44.)

However, then Lahiri continues:

”Due to proper motion of the star, the nirayana longitude of Spica has however diminished by 65” during the period of 1695 years from 285 A.D. and now 179°58’58” according to the above ayanamsa system.”

And:

”The Indian Astronomical Ephemeris of the Government of India has adopted, on the basis of the recommendations of the Calendar Reform Committee, a value of ayanamsa which is less by only 5”.8 than the above.”

Apparently, this difference was small enough for him so that he considered it insignificant and, ”for the sake of uniformity”, took over the standard ayanamsha recommended by the CRC. The ayanamsha values and sidereal positions of the Sun and the Moon which he gives in his ephemeris are in perfect agreement with the standard ayanamsha, not with the above-given definition.

As to the 5.8” difference, it must be added that it is only found with the Newcomb precession model. If a modern standard model like IAU2006 or Vondrák is used, then the difference amounts to 23”.

In “Tables of the Sun”, Lahiri derives an ayanamsha value of 22°27’43”.5 for “1900, Jan. 0 (= 31 Dec. 1899; D.K.), 19^{h} 31^{m} ET”. Using a version of swetest which calculates uses Newcomb precession (the formulation of Kinoshita 1975), the following ayanamsha results for the same date:

swetest -b31.12.1899 -t19:31 -p -nonut -p0 -sid44 -sidbit4096

22°27’44.02069.

However, since Lahiri considered his zero date as essential to his ayanamsha, the Swiss Ephemeris calculates it using the modern precession model Vondrák 2011, which for the same date provides the value 22°28’ 0.90375.

From all this, it is obvious that there are several „Lahiri ayanamsha”, and the standard Lahiri ayanamsha which was adopted by the ICRC is not exactly what he had intended.

26) Ayanamsha having Spica/Citra at polar longitude 180° in 499 CE

ayanamsha = 2.11070444 21 Mar 499, 7:30:31.57 UT = noon at Ujjain, 75.7684565 E

Spica at polar ecliptic longitude 180° on equinox 499 Spica (2000) 180°50’ 3

As has been stated, the Suryasiddhanta gives the position of Spica/Citra as 180° in **polar** longitude (ecliptic longitude, but projection along meridian lines).

27) True Chitrapaksha ayanamsha

Spica is always exactly at 180° or 0° Libra in ecliptic longitude (not polar!).

Usually ayanamshas are defined by an epoch and an initial ayanamsha offset. However, if one wants to make sure that a particular fixed star always remains at a precise position, e. g. Spica at 180°, it does not work this way because the star has some proper motion and is not really fixed relative to a fixed reference frame.

In the year 285, when the star was conjunct the autumnal equinox, its position was 180°00’17 (swetest -b1.1.285 -pf -xfSpica -sid1 -true -bary -head -fTPL -s365 -n2). Only in the year 675 CE, its position was exactly 180°. The motion of the star is partly caused by its proper motion. Another part of its motion is apparent only, due to the so-called planetary precession, which causes very slow changes in the orientation of the ecliptic plane. As can be seen from the description of the other “Lahiri” or Spica-related ayanamshas, non of them has Spica exactly at 180° on 1 Jan. 2000.

The correct procedure, in order to have the star at a constant position, is to calculate the tropical position of Spica for the date and subtract it from the tropical position of the planet.

Many thanks to Vinay Jha, PVR Narasimha Rao, and Avtar Krishen Kaul, and D. Senthilathiban for their help in our attempt to understand this complicated matter.

2.8.6. Krishnamurti ayanamshas

The Swiss Ephemeris also has two ayanamshas named after the Indian astrologer K.S. Krishnamurti (1908-1972). They are very close to the Lahiri ayanamsha, with a difference of only 4 to 5 arcmin. In fact, he says that the difference between his ans Lahiri's ayanamsha is "negligible" (Krishnamurti, *Reader 1*, p. 57), but modern Hindu astrologers won't be happy with an uncertainty of several minutes of arc.

Unfortunately, Krishnamurti did not give very precise information about the definition of his ayanamsha (*Reader 1*, pp. 54-59). He says that the ayanamsha was zero in the year 291 CE, however, he does not give an exact date, which leaves an uncertainty in ayanamsha of 50". D. Senthilathiban assumes, following an old Indian tradition, that Krishnamurti must have had in mind the date of the equinox. Based on this assumption, the Swiss Ephemeris offers an ayanamsha defined as follows:

45) Krishnamurti/Senthilathiban ayanamsha (derived from zero ayanamsha year 291)

ayanamsha = 0, t0 = 21 March 291 CE, 6:10:29 TT (=4:02:45 UT) Spica at 180° 5'13

The exact timing was derived using the Swiss Ephemeris and based on the precession theory Vondrák 2011. Senthilathiban gives a slightly different time, 4:09 UT. This difference corresponds to less than 1 milliarcsec in precession and can be neglected. On the other hand, since Senthilathiban prefers to use the IAU standard model IAU 2006, whereas the Swiss Ephemeris uses precession Vondrák, his ayanamsha calculation for the year 2000 differs by about 0.2 arcsec from ours. This difference should be considered negligible, too. Modern calculation of precession will improve in the future, and this will lead to small changes in this ayanamsha, as well. The Vondrák model is particularly good for remote epochs.

In addition to the statement that zero ayanamsha year was 291, Krishnamurti also provides a table of ayanamsha values for the years 1840 to 2001 (*Reader 1*, p. 58). Unfortunately, the above ayanamsha definition based on the equinox of 291 CE does not agree well with this table. It provides values which are about 1 arcmin too high. Since Krishnamurti wrote in a time when the precession model of Newcomb was used, the comparison must of course be done using this precesion model.

A better representation of the table values is given by our other Krishnamurti ayanamsha:

5) Krishnamurti ayanamsha (derived from his ayanamsha table)

ayanamsha = 22.363889, t0 = 1 Jan 1900, Spica at 180° 4'52

This ayanamsha was provided by Graham Dawson (astrology program "Solar Fire"), who had taken it over from Robert Hand's program "Nova". We do not know who developed it and using what method. Assuming that the table values refer to 1 January of each year, the agreement is very good, with only a few exceptions. However, it must also be stated that Krishnamurti's table is not plausible for all years. This is obvious for the years 1918-1921 where identical values are repeated in a way that is not possible with a precession rate of about 50" per year.

1916	22	36
1917	22	37
1918	22	38
1919	22	38
1920	22	39
1921	22	39
1922	22	40
1923	22	41

The ayanamsha based on the year 291 (No. 45), if calculated using Newcomb precession, is about 54" arcsec higher than the one based on Krishnamurti's tables (No. 5). (With a modern precession it is even 72-73" higher).

Senthilathiban in his book, p. 126ff., proposes a different representation of the Krishnamurti table values, assuming that they are referred to the 13/14 April of each year, i.e. the date of the ingress of the Sun into sidereal Aries. While this assumption is possible, we cannot be certain about it since Krishnamurti himself does not tell us. In addition, the agreement of the two ayanamshas (Krishnamurti table ayanamsha and Krishnamurti/Senthilathiban) becomes even worse, not better.

Sources:

- Burgess, E., *The Surya Siddanta.* A Text-book of Hindu Astronomy, Delhi, 2000 (MLBD).

- Dikshit, S(ankara) B(alkrishna), *Bharatiya Jyotish Sastra (History of Indian Astronomy)* (Tr. from Marathi), Govt. of India, 1969, part I & II.
- Kollerstrom, Nick, „The Star Zodiac of Antiquity", in: *Culture & Cosmos*, Vol. 1, No.2, 1997).
- Lahiri, N. C., *Panchanga Darpan* (in Bengali), Calcutta, 1967 (Astro Research Bureau).
- Lahiri, N. C., *Tables of the Sun*, Calcutta, 1952 (Astro Research Bureau).
- Saha, M. N., and Lahiri, N. C., *Report of the Calendar Reform Committee*, C.S.I.R., New Delhi, 1955.
- The *Indian Astronomical Ephemeris* for the year 1989, Delhi (Positional Astronomy Centre, India Meteorological Department)
- P.V.R. Narasimha Rao, "Introducing Pushya-paksha Ayanamsha" (2013),
- http://www.vedicastrologer.org/articles/pp_ayanamsha.pdf.
- D. Senthilathiban, *Study of KP Ayanamsa with Modern Precession Theories*, Seoul, 2019.

2.8.7. The sidereal zodiac and the Galactic Center

The definition of the tropical zodiac is very simple and convincing. It starts at one of the two intersection points of the ecliptic and the celestial equator. Similarly, the definition for the house circle which is said to be an analogy of the zodiac, is very simple. It starts at one of the two intersection points of the ecliptic and the local horizon. Unfortunately, sidereal traditions do not provide such a simple definition for the sidereal zodiac. The sidereal zodiac is always fixed at some anchor star such as Citra (Spica), Revati (zeta Piscium), or Aldebaran and Antares.

Unfortunately, nobody can tell why any of these stars should be so important that it could be used as an anchor point for the zodiac. In addition, all these solutions are unattractive in that the fixed stars actually are not fixed forever but have a small proper motion which over a long period of time (such as several millennia) can result in a considerable change in position. While it is possible to tie the zodiac to the star Spica in a way that it remains at 0° Libra for all times, all other stars would change their positions relative to Spica and relative to this zodiac and would not be fixed at all. The appearance of the sky changes over long periods of time. In 100.000 years, the constellations will look very different from now, and the nakshatras (lunar mansions) will get confused. For this reason, a zodiac defined by positions of stars is unfortunately not able to provide an everlasting reference frame.

For such or also other reasons, some astrologers (Raymond Mardyks, Ernst Wilhelm, Rafael Gil Brand, Nick Anthony Fiorenza) have tried to define the sidereal zodiac using either the galactic centre or the node of the galactic equator with the ecliptic. It is obvious that this kind of solution, which would not depend on the position of a single star anymore, could provide a philosophically more convincing and very stable definition of the zodiac. Fixed stars would be allowed to change their positions over very long periods of time, but the zodiac could still be considered fixed and "sidereal".

The Swiss astrologer Bruno Huber has pointed out that every time the Galactic Center enters the next tropical sign, the vernal point enters the previous sidereal sign. E.g., around the time the vernal point will enter Aquarius (at the beginning of the so-called Age of Aquarius), the Galactic Center will enter from Sagittarius into Capricorn. Huber also notes that the ruler of the tropical sign of the Galactic Center is always the same as the ruler of the sidereal sign of the vernal point (at the moment it is Jupiter, but it will be Saturn in a few hundred years).

17) Galactic Center at 0 Sagittarius (and the beginning of nakshatra Mula)

A correction of the Fagan ayanamsha by about 2 degrees or a correction of the Lahiri ayanamsha by 3 degrees would place the Galactic Center at 0° Sagittarius. Philosophically, this would obviously make some sense. Therefore, we added an ayanamsha fixed at the Galactic Center in 1999 in Swiss Ephemeris 1.50, when we introduced sidereal ephemerides (suggestion by D. Koch, without any astrological background).

40) Galactic Center at 0 Capricorn (Cochrane Ayanamsha)

A modification of this ayanamsha was proposed by David Cochrane in 2017. He believes that it makes more sense to put the Galactic Centre at 0° Capricorn.

36) Dhruva Galactic Center Middle Mula Ayanamsha (Ernst Wilhelm)

A different solution was proposed by the American astrologer Ernst Wilhelm in 2004. He projects the galactic centre on the ecliptic in polar projection, i.e. along a great circle that passes through the celestial north pole (in Sanskrit dhruva) and the galactic centre. The point at which this great circle cuts the ecliptic is defined as the middle of the nakshatra Mula, which corresponds to sidereal 6°40’ Sagittarius.

For Hindu astrologers who follow a tradition oriented towards the star Revati (Piscium), this solution may be particularly interesting because when the galactic centre is in the middle of Mula, then Revati is almost exactly at the position it has in Suryasiddhanta, namely 29°50 Pisces. Also interesting in this context is the fact that the meaning of the Sanskrit word mūlam is “root, origin”. Mula may have been the first of the 27 nakshatras in very ancient times, before the Vedic nakshatra circle and the Hellenistic zodiac were conflated and Ashvini, which begins at 0° Aries, became the first nakshatra.

Sources:

- https://groups.yahoo.com/neo/groups/StudyingKala/conversations/topics/14656;
- private communication with D. Koch.

30) Galactic Centre in the Golden Section Scorpio/Aquarius (Rafael Gil Brand)

Another ayanamsha based on the galactic centre was proposed by the German-Spanish astrologer Rafael Gil Brand. Gil Brand places the galactic centre at the golden section between 0° Scorpion and 0° Aquarius. The axis between 0° Leo and 0° Aquarius is the axis of the astrological ruler system.

This ayanamsha is very close to the ayanamsha of the important Hindu astrologer B.V. Raman. (see below)

Sources:

- Rafael Gil Brand, Himmlische Matrix. Die Bedeutung der Würden in der Astrologie, Mössingen (Chiron), 2014.
- Rafael Gil Brand, ”Umrechnung von tropischen in siderische Positionen”, http://www.astrologie-zentrum.net/index.php/8-siderischer-tierkreis/5-umrechnung

2.8.8. The sidereal zodiac and the Galactic Equator

Another way to define the ayanamsha based on our galaxy would be to start the sidereal ecliptic at the intersection point of the ecliptic and the galactic plane (henceforth called the “galactic node”). At present, this point is located near 0 Capricorn. This definition of the ayanamsha would be analogous to the definitions of the tropical ecliptic and the house circle, both of which are also based on intersections of great circles. However, defining this galactic-ecliptic intersection point or node as sidereal 0 Aries would mean to break completely with the tradition, because it is far away from the traditional sidereal zero points.

The following ayanamshas belong in this category:

34) Skydram Ayanamsha (Raymond Mardyks)

(also known as Galactic Alignment Ayanamsha)

This ayanamsha was proposed in 1991 by the American astrologer Raymond Mardyks. It had the value 30° on the autumn equinox 1998. Consequently, the node (intersection point) of the galactic equator with the ecliptic was very close to sidereal 0° Sagittarius on the same date, and there was an interesting “cosmic alignment”: The galactic pole pointed exactly towards the autumnal equinoctial point, and the galactic-ecliptic node coincided with the winter solstitial point (tropical 0° Capricorn).

Mardyks’ calculation is based on the galactic coordinate system that was defined by the International Astronomical Union in 1958.

Source:

- Raymond Mardyks, “When Stars Touch the Earth”, in: The Mountain Astrologer Aug./Sept. 1991, pp. 1-4 and 47-48.
- Private communication between R. Mardyks and D. Koch in April 2016.

41) Galactic Node at 5 Sagittarius (Fiorenza Ayanamsha)

Another ayanamsha based on the galactic equator. It was invented by Nick Anthony Fiorenza and published in his book “The Star Chart. Sidereal Astrology and the Fixed Stars” in 2001. Fiorenza thinks that 1 Jan. 2000 should be taken as the date of the alignment of the solstitial points with the galactic node. He assumes an ayanamsha value of exactly 25° on this date. Thus, the vernal point fell on exactly 5° Pisces in 2000.

Source:

- https://www.lunarplanner.com/siderealastrology.html

31) Ayanamsha based on the Galactic Equator IAU 1958

This ayanamsha is based on galactic pole as defined by the IAU in 1958, and it is assumed that the galactic equator intersects with the ecliptic at sidereal 0° Sagittarius. This ayanamsha differs from the Skydram ayanamsha by only 19 arc seconds, but from Fioreza’s ayanamsha by slightly more than 5°.

32) Galactic Node at 0° Sagittarius

The galactic pole IAU 1958 is in fact outdated. According to more recent observations and calculations from the year 2010, the galactic node with the ecliptic must be corrected by 3’11”, and the ”Galactic Alignment” preponed to 1994 (instead of 1998). With this ayanamsha, the galactic node is fixed exactly at sidereal 0° Sagittarius.

Source:

- Liu/Zhu/Zhang, „Reconsidering the galactic coordinate system”, Astronomy & Astrophysics No. AA2010, Oct. 2010, p. 8.

33) Ardra Galactic Plane Ayanamsha

(= Galactic equator cuts ecliptic in the middle of Mula and the beginning of Ardra)

With this ayanamsha, the galactic equator cuts the ecliptic exactly in the middle of the nakshatra Mula. This means that the Milky Way passes through the middle of this lunar mansion. Here again, it is interesting that the Sanskrit word mūlam means ”root, origin”, and it seems that the circle of the lunar mansions originally began with this nakshatra. On the opposite side, the galactic equator cuts the ecliptic exactly at the beginning of the nakshatra Ārdrā (”the moist, green, succulent one”, feminine).

This ayanamsha was introduced by the American astrologer Ernst Wilhelm in 2004. He used a calculation of the galactic node by D. Koch from the year 2001, which had a small error of 2 arc seconds. The current implementation of this ayanamsha is based on a new position of the Galactic pole found by Chinese astronomers in 2010.

2.8.9. Other ayanamshas

35) True Mula Ayanamsha (K. Chandra Hari)

With this ayanamsha, the star Mula (Scorpionis) is assumed at 0° Sagittarius.

The Indian astrologer Chandra Hari is of the opinion that the lunar mansion Mula corresponds to the Muladhara Chakra. He refers to the doctrine of the Kalapurusha which assigns the 12 zodiac signs to parts of the human body. The initial point of Aries is considered to correspond to the crown and Pisces to the feet of the cosmic human being. In addition, Chandra Hari notes that Mula has the advantage to be located near the galactic centre and to have “no proper motion”. This ayanamsha is very close to the Fagan/Bradley ayanamsha. Chandra Hari believes it defines the original Babylonian zodiac.

(In reality, however, the star Mula (Scorpionis) has a small proper motion, too. As has been stated, the position of the galactic centre was not known to the ancient peoples. However, they were aware of the fact that the Milky Way crossed the ecliptic in this region of the sky.)

Sources:

- K. Chandra Hari, ”On the Origin of Sidereal Zodiac and Astronomy”, in: Indian Journal of History of Science, 33(4) 1998.
- Chandra Hari, ”Ayanāṃśa”, xa.yimg.com/kq/groups/26252194/1355927039/name/Ayanamsha.pdf.
- http://www.indiadivine.org/content/topic/1229109-true-ayanamsha-views-of-chandra-hari/.

The following ayanamshas were provided by Graham Dawson (“Solar Fire”), who had taken them over from Robert Hand’s Program “Nova”. Some were also contributed by David Cochrane. Explanations by D. Koch:

2) De Luce Ayanamsha

This ayanamsha was proposed by the American astrologer Robert DeLuce (1877-1964). It is fixed at the birth of Jesus, theoretically at 1 January 1 CE. However, DeLuce de facto used an ayanamsha of 26°24’47 in the year 1900, which corresponds to 4 June 1 BCE as zero ayanamsha date.

DeLuce believes that this ayanamsha was also used in ancient India. He draws this conclusion from the fact that the important ancient Indian astrologer Varahamihira, who assumed the solstices on the ingress days of the Sun into sidereal Cancer and Capricorn, allegedly lived in the 1st century BCE. This dating of Varahamihira has recently become popular under the influence of Hindu nationalist ideology (Hindutva). However, historically, it cannot be maintained. Varahamihira lived and wrote in the 6th century CE.

Sources:

- Robert DeLuce, Constellational Astrology According to the Hindu System, Los Angeles, 1963, p. 5.

3) Raman Ayanamsha

This ayanamsha was used by the great Indian astrologer Bangalore Venkata Raman (1912-1998). It is based on a statement by the medieval astronomer Bhaskara II (1184-1185), who assumed an ayanamsha of 11° in the year 1183 (according to Information given by Chandra Hari, unfortunately without giving his source). Raman himself mentioned the year 389 CE as year of zero ayanamsha in his book Hindu Predictive Astrology, pp. 378-379.

Although this ayanamsha is very close to the galactic ayanamsha of Gil Brand, Raman apparently did not think of the possibility to define the zodiac using the galactic centre.

Sources:

- Chandra Hari, ”Ayanāṃśa”, xa.yimg.com/kq/groups/26252194/1355927039/name/Ayanamsha.pdf.
- B.V. Raman, Hindu Predictive Astrology, pp. 378-379.

7) Shri Yukteshwar Ayanamsha

This ayanamsha was allegedly recommended by Swami Shri Yukteshwar Giri (1855-1936). We have taken over its definition from Graham Dawson. However, the definition given by Yukteshwar himself in the introduction of his work The Holy Science is a confusing. According to his “astronomical reference books”, the ayanamsha on the spring equinox 1894 was 20°54’36”. At the same time he believed that this was the distance of the spring equinox from the star Revati, which he put at the initial point of Aries. However, this is wrong, because on that date, Revati was actually 18°24’ away from the vernal point. The error is explained from the fact that Yukteshwar used the zero ayanamsha year 499 CE and an inaccurate Suryasiddhantic precession rate of 360°/24’000 years = 54 arcsec/year. Moreover, Yukteshwar is wrong in assigning the above-mentioned ayanamsha value to the year 1894; in reality it applies to 1893.

Since Yukteshwar’s precession rate is wrong by 4” per year, astro.com cannot reproduce his horoscopes accurately for epochs far from 1900. In 2000, the difference amounts to 6’40”.

Although this ayanamsha differs only a few arc seconds from the galactic ayanamsha of Gil Brand, Yukteshwar obviously did not intend to define the zodiac using the galactic centre. He actually intended a Revati-oriented ayanamsha, but committed the above-mentioned errors in his calculation.

Source:

- Swami Sri Yukteswar, The Holy Science, 1949, Yogoda Satsanga Society of India, p. xx.

8) JN Bhasin Ayanamsha

This ayanamsha was used by the Indian astrologer J.N. Bhasin (1908-1983).

6) Djwhal Khul Ayanamsha

This ayanamsha is based on the assumption that the Age of Aquarius will begin in the year 2117. This assumption is maintained by a theosophical society called Ageless Wisdom, and bases itself on a channeled message given in 1940 by a certain spiritual master called Djwhal Khul.

Graham Dawson commented it as follows (E-mail to Alois Treindl of 12 July 1999): "The "Djwhal Khul" ayanamsha originates from information in an article in the Journal of Esoteric Psychology, Volume 12, No 2, pp91-95, Fall 1998-1999 publ. Seven Ray Institute). It is based on an inference that the Age of Aquarius starts in the year 2117. I decided to use the 1st of July simply to minimize the possible error given that an exact date is not given."

On 7 July 2020, Clifford Ribaudo sent us additional information in a mail to Alois Treindl:
"Also, I know the"real" source of the 2117 date for the DK (= Djwhal Khul) Ayanamsa and the original provenance of it. It was not Lindsay or Robbins or the journal of Esoteric Psychology. My friend Keith Bailey, inherited a whole bunch of papers from Marion Walter's who was one of the members of the "DINA" group discussed in Alice Bailey's books. DK answered a question from Roberto Assagioli and in the answer he mentioned that "he would suggest the start of the Aquarian Age was 177 years from the date of writing.". A copy of that letter was given to Robbins and then at some point he mentioned it in Journal of Esoteric Psychology."

Sources:

- Philipp Lindsay, "The Beginning of the Age of Aquarius: 2,117 A.D.", http://esotericastrologer.org/newsletters/the-age-of-aquarius-ray-and-zodiac-cycles/.
- Esoteric Psychology, Volume 12, No 2, pp91-95, Fall 1998-1999 publ. Seven Ray Institute.

39) "Vedic Ayanamsha" according to Sunil Sheoran

This ayanamsha is derived from ancient Indian time cycles and astronomical information given in the Mahabharata. Its author, Mr. Sunil Sheoran, therefore calls this ayanamsha "Vedic".

Essential in Sheoran's argumentation is the assumption that the two Mahabharatan solar eclipses that were observed from Kurukshetra and Dvaraka were 18 years apart, not 36 years as is taught by tradition and the Mahabharata itself. Also essential to Sheoran's theory is his assumption that the traditional lengths of the yugas are too high and that in reality a period of four yugas (caturyuga/mahāyuga) should be 120 years rather than 12.000 divine years or 4.320.000 human years. From the mentioned eclipse pair and historical considerations, he derives that the Mahabharata war must have taken place in the year 827 BCE. Then he dates the beginning of the last Manvantara on the winter solstice 4174 BCE. This is Sheoran's ayanamsha zero date, to which he assigns the ayanamsha value -60°.

Moreover it must be mentioned that in Sheoran's opinion the nakshatra circle does not begin at the initial point of the zodiac, but that 0° Aries corresponds to 3°20' in Ashvini.

Unfortunately, there are serious problems at least in Sheoran linguistic argumentation. As to the time distance between the two eclipses, the Mahabharata itself states: ṣaṭtriṃśe varṣe, MBh 16.1.1 and 16.2.2. The correct translation of this expression is "in the 36th year", whereas Sheoran mistakenly attempts to read it as "3 x 6 = 18 years". In addition, in texts to do with the durations of the yugas Sheoran reads sahasrāṇi as "10" instead of "1000" and śatāni as "1" instead of "100". Unfortunately, Sanskrit dictionaries and grammar do not allow such translations.

Source:

- Sunil Sheoran, ”The Science of Time and Timeline of World History”, 2017, http://goo.gl/av6vEH .

2.8.10. Conclusions

We have found that there are basically five definitions, not counting the manifold variations:

1. the Babylonian zodiac with Spica at 29 Virgo or Aldebaran at 15 Taurus:
   - a) Fagan/Bradley;
   - b) refined with Aldebaran at 15 Tau;
   - c) P. Huber;
   - d) J.P. Britton.
2. the Greek-Hindu-Arabic zodiac with the zero point between 10 and 20’ east of zeta Piscium:
   - e) Hipparchus;
   - f) Ushâshashî;
   - g) Sassanian;
   - h) true Revati ayanamsha
3. the Hindu astrological zodiac with Spica at 0 Libra:
   - i) Lahiri
4. ayanamshas based on the Kaliyuga year 3600 or the 23rd year of life of Aryabhata.
5. galactic ayanamshas based on the position of the galactic centre or the galactic nodes (= intersection points of the galactic equator with the ecliptic).

No. 1 is historically the oldest one, but we are not sure about its precise astronomical definition. It could have been Aldebaran at 15 Taurus and Antares at 15 Scorpio.

2.8.11. Ayanamshas with different precession rates

Some Hindu astrologers use ayanamshas based on a special precession rate which is different from the modern precession algorithm used by the Swiss Ephemeris, usually the precession rate used by the inventor of these particular ayanamshas. They should be aware, however, that this approach makes only sense if the tropical ephemeris they use is based on exactly the same precession model. It is wrong to assume that tropical ephemerides are an absolute datum.

Modern ephemerides are generated relative to the *sidereal* reference frame ICRF (International Celestial Reference Frame), which is close to the mean equinox on 1 Jan. 2000, 12:00 TT. These *sidereal* “raw” ephemerides are transformed into *tropical* ephemerides using a modern precession model. There are several such models. Precession IAU 1976 (Lieske) is still used by JPL Horizons. The current standard model recommended by the IAU is IAU 2006 (Capitaine). The Swiss Ephemeris currently uses the precession model Vondrák (2011), which is particularly good for very-long-term ephemerides. It follows that tropical ephemerides will be different depending on the precession model that is used to generate them. The differences will be extremely small for planetary positions in current decades and centuries, but will grow considerably for remote epochs. It also follows that *if sidereal positions are calculated using a precession model different from the one that was used to create the tropical ephemerides, this is an inconsistent approach. In principle, the same precession model should be used for ayanamsha as was used for the creation of the underlying tropical ephemeris.*

Now, we have the following problem: Some ayanamshas were defined at a time when a different precession model was in use, either the precession model of Simon Newcomb (1895) or the precession model IAU 1976.

Using different precession models, we will have differences in all the three, tropical planetary positions, sidereal ephemeris positions, and ayanamsha values. Let us study these differences in a table that shows all the three for an ayanamsha that has its zero date on the equinox of the year 291 CE, on 21 March jul., 6:03 TT. (V stands for precession Vondrák; N for precession Newcomb):

Year	*diff. trop. long. Sun (prec V-N) in “*	*diff. ayanamsha (prec V-N) in “*	*diff. sid. long. Sun (prec V-N) in “*	*~ minus 17.650216”*
-3000	81.648098	64.059809	17.588289	-0.061927
-2500	77.891205	60.280286	17.610918	-0.039297
-2000	67.756729	50.128935	17.627794	-0.022422
-1500	55.131415	37.492205	17.639210	-0.011006
-1000	42.521677	24.875658	17.646019	-0.004197
-500	31.328666	13.679394	17.649271	-0.000944
0	22.109197	4.458959	17.650238	0.000022
equ.	291	17.650216	0.000000	17.650216
500	14.821773	-2.828337	17.650110	-0.000106
1000	9.060393	-8.589402	17.649795	-0.000421
1500	4.277578	-13.372189	17.649767	-0.000449
1600	3.393108	-14.256697	17.649806	-0.000410
1700	2.525093	-15.124766	17.649859	-0.000357
1800	1.671280	-15.978645	17.649925	-0.000291
1900	0.829937	-16.820066	17.650003	-0.000213
2000	0.000011	-17.650081	17.650093	-0.000123
2100	-0.818850	-18.469044	17.650194	-0.000022
2200	-1.626143	-19.276451	17.650307	0.000091
2300	-2.420577	-20.071012	17.650435	0.000219
2400	-3.199913	-20.850493	17.650580	0.000364
2500	-3.960945	-21.611692	17.650747	0.000531
3000	-7.300452	-24.952670	17.652218	0.002002
3500	-9.010479	-26.666760	17.656281	0.006065
4000	-7.165941	-24.832623	17.666682	0.016466

As can be seen, the choice of precession model has a noticeable impact on tropical ephemerides and the ayanamsha value. However, the difference in sidereal ephemerides remains almost constant for the whole period considered.

Now, let us assume this ayanamsha was introduced at a time when Newcomb precession was used, but we use tropical positions based on the modern precession model by Vondrak. *If we still want to keep the sidereal ephemerides unchanged*, the above table shows that we need not necessarily use the old precession model of Newcomb; instead, we can use modern precession Vondrák instead, but have to subtract a constant value of 17.65022”. The sidereal ephemeris will then remain identical, but the tropical ephemeris and the ayanamsha will change. Here, we must understand that the ayanamsha should not be taken as an absolute value, it should only indicate the difference between our tropical and our sidereal ephemeris. With a future update of the precession model in the Swiss Ephemeris, the tropical ephemeris and ayanamsha will change, but the sidereal ephemeris will not, because the ayanamsha value will be adjusted automatically.

Let us also study an explicit comparison of tropical and sidereal positions of the Sun based on both precession models Vondrák (V) and Newcomb (N) and also using the above-mentioned correction to the ayanamsha:

epoch	*tropical Sun*	*sidereal Sun*	*ayanamsha*
-1000 V	271°14'15.75001	289°05'52.63883	342°08'23.11118
-1000 N	271°14'58.27229	289°05'52.63457	342°09'05.63773
eq291 V	359°59'42.34978	0°00'00.00000	359°59'42.34978
eq291 N	0°00'00.00000	0°00'00.00000	0°00'00.00000
1900 V	280°08'54.75103	257°46'10.69049	22°22'44.06054
1900 N	280°08'55.58096	257°46'10.69027	22°22'44.89070
2000 V	279°51'44.39186	256°05'12.79708	23°46'31.59478
2000 N	279°51'44.39187	256°05'12.79695	23°46'31.59492

As can be seen, the tropical positions of the Sun and the ayanamshas, resulting from the two different precession models, are identical only at the initial epoch of the JPL ephemeris, on 1 Jan. 2000, whereas at other epochs they are different from each other. On the other hand, the sidereal positions of the Sun are practically identical at all times, independently of the precession model chosen.

Unfortunately, this makes the search for the "correct ayanamsha" even more confused than many believe. Sidereal astrologers use to ask the question whether Lahiri or Krishnamurti or whatever ayanamsha should be used, and they believe that the ayanamsha can be defined by some fixed value at some initial epoch. However, this is not correct. The start value or start date of an ayanamsha, as well as its value on any other date, depend on the precession model inherent in the tropical ephemeris used. This fact is usually forgotten.

Note, however, that this correction method is not used with all ayanamshas. The above example uses the equinox of the year 291 as zero ayanamsha date, which is actually the initial date of the Krishnamurti/Senthilathiban ayanamsha. In reality, the described correction method is not applied here. The ayanamsha is calculated using the current precession model of the Swiss Ephemeris (Vondrak 2011) without any correction. Sidereal ephemerides will be allowed to change whenever the precession model will be updated.

Nor should the correction be done with the definition of Lahiri ayanamsha as given by Lahiri himself in the preface of the 1980 edition of his "Indian ephemeris", where zero ayanamsha is defined as the mean Sun on the equinox in the year 285. When the Swiss Ephemeris updates the precession model, then the zero ayanamsha date will have to be corrected, and the ayanamsha calculation will also be done using the new precession model without any correction. This will have some impact on sidereal ephemerides, however an unavoidable one.

Moreover, a correction is not required with True Chitra Paksha ayanamsha and some other ayanamshas where the ayanamsha is based on the real position of a fixed star. When the Swiss Ephemeris updates the precession model, this will have practically no impact on the sidereal ephemerides or ayanamsha.

On the other hand, with the other definition of Lahiri ayanamsha as used by *Indian Astronomical Ephemeris*, a correction will be required because the definition is not based on some astronomical object or event, but on an arbitrary value at an arbitrary epoch, based on the precession model IAU 1976. A small correction will therefore be required to the ayanamsha in order to provide identical sidereal positions while using our standard precession model Vondrák 2011.

For each ayanamsha, a decision has to be taken individually what kind of approach is required.

We hope that the Swiss Ephemeris, from version 2.09 on, handles this correctly, and the user should not have to worry about precession models. One should be aware, however, that the values given for some ayanamshas will be different from those given in older literature. The reason is that the older literature defines the ayanamsha value based on a different tropical ephemeris (and precession model) than the Swiss Ephemeris.

The following ayanamshas have been corrected since version 2.09 by the following values:

ayanamsha	*correction*	*prec. model*
0 Fagan-Bradley	0.41256"	Newcomb
1 Lahiri	-0.13036"	IAU 1976

ayanamsha	*correction*	*prec. model*
3 Raman	0.82800”	Newcomb
5 Krishnamurti	0.82800”	Newcomb
43 Lahiri (1967)	0.82800”	Newcomb (new ayanamsha!)

2.8.12. On which ecliptic is the ayanamsha measured?

1. The traditional algorithm (implemented in Swiss Ephemeris as default mode) As has been stated, sidereal planetary positions are computed from the following equation:

sidereal_position = tropical_position – ayanamsha,

The ayanamsha of a given date t is computed from an initial value of the ayanamsha at some initial date (e.g. t0 = 1 Jan 1900) and the speed of the vernal point, the so-called precession rate:

ayanamsha(t) = ayanamsha(t0) + precession(t-t0).

Unfortunately, this procedure is not really clean because the two formulae do not operate on exactly the same plane. It may work sufficiently well in an ordinary astrologer’s practice. However, if very high accuracy is wanted over a long period of time, then this approach is too simplistic.

The precession of the equinox is not only a matter of ecliptical longitude, but a more complex phenomenon. It has two components:

- a) The soli-lunar precession: The combined gravitational pull of the > Sun and the Moon on the equatorial bulge of the Earth causes the > Earth axis to move very slowly, in the way of a spinning top. As a > result of this movement, the vernal point moves around the > ecliptic with a speed of about 50” per year. This cycle has a > period of roughly 26000 years.
- b) The planetary precession: The Earth orbit itself is not fixed. The > gravitational influence from the planets causes it to slowly > change its orientation. As a result, the obliquity of the ecliptic > currently decreases by 47” per century. This change also has some > impact on the position of the vernal point. (Note, however, that > relative to the ecliptic of a fixed date, the equator keeps an > almost constant angle, with a change of only a couple of 0.06” > cty-2.)

Because the ecliptic plane is not fixed, it is not fully correct to subtract an ayanamsha from the tropical position in order to get a sidereal position. Let us take, e.g., the Fagan/Bradley ayanamsha, which can be defined by:

ayanamsha = 24°02’31.36” + P(Je-Js),

where Js is the initial epoch or start date of the ayanamsha, in our case 1 Jan. 1950, and Je is the “end date” for which the ayanamsha is to be calculated.

24°02’31.36” is the value of the ayanamsha on the initial date Js = 1 Jan 1950. It is obviously measured on the ecliptic of Js itself. P(Je-Js) is the distance of the vernal point at the end epoch Je from the position of the vernal point on the start epoch Js = 1 Jan 1950. Again, this distance is measured on the ecliptic of Js.

Now, the value of ayanamsha is subtracted from a planetary position which is referred to the ecliptic of the epoch Je, (not Js!). This approach is not really correct. The error may be very small, but the ecliptic of Js and the ecliptic of Je are not exactly in the same plane.

Precession polynomials found in astronomical literature are also relative to Js. E.g. Indian Astronomical Ephemeris 1989 (IAE 1989), p. 525, gives the following formula:

$P_N = (5029.0966 + 2.22226 * T-0.000042 * T^2) * t + (1.11161 - 0.000127 * T) * t^2 - 0.000113 * t^3$
t= (Je - Js) / 36525 ; T= (Js-2451545) / 36525

If the start date Js is J2000 (i.e. 1 Jan. 2000, 12:00 TT), then the formula can also be written simpler:

$P_N = 5029.0966 * t + 1.11161 * t^2 - 0.000113*t^3$

According to IAE 1989, the resulting value PN is "referred to the fixed ecliptic and equinox of Js". Thus, in a really correct calculation this value should not be applied to a planetary or star position relative to the ecliptic and equinox of Je. However, this is exactly what is done when sidereal ephemerides are calculated from tropical ones.

As a result, an object that does not move relative to a fixed sidereal reference frame, still has an apparent motion relative a sidereal zodiac. If we compute its precise tropical position for several dates and then subtract the Fagan/Bradley or Lahiri ayanamsha for the same dates in order to get its sidereal position, then these positions will all be slightly different. This difference can be considerable over long periods of time. Let us give two examples to illustrate this phenomenon.

Long-term ephemeris of some fictitious star near the ecliptic that has no proper motion (small change in longitude):

Date	Longitude	Latitude
-12000	335°16'55.2211	0°55'48.9448
-11000	335°16'54.9139	0°47'55.3635
-10000	335°16'46.5976	0°40'31.4551
-9000	335°16'32.6822	0°33'40.6511
-8000	335°16'16.2249	0°27'23.8494
-7000	335°16'00.1841	0°21'41.0200
-6000	335°15'46.8390	0°16'32.9298
-5000	335°15'37.4554	0°12'01.7396
-4000	335°15'32.2252	0°08'10.3657
-3000	335°15'30.4535	0°05'01.3407
-2000	335°15'30.9235	0°02'35.9871
-1000	335°15'32.3268	0°00'54.2786
0	335°15'33.6425	-0°00'04.7450
1000	335°15'34.3645	-0°00'22.4060
2000	335°15'34.5249	-0°00'00.0196
3000	335°15'34.5216	0°01'01.1573

Long-term ephemeris of some fictitious star with high ecliptic latitude and no proper motion (bigger change in longitude value):

Date	Longitude	Latitude
-12000	25°48'34.9812	58°55'17.4484
-11000	25°33'30.5709	58°53'56.6536
-10000	25°18'18.1058	58°53'20.5302
-9000	25°03'09.2517	58°53'26.8693
-8000	24°48'12.6320	58°54'12.3747
-7000	24°33'33.6267	58°55'34.7330
-6000	24°19'16.3325	58°57'33.3978
-5000	24°05'25.4844	59°00'08.8842
-4000	23°52'06.9457	59°03'21.4346
-3000	23°39'26.8689	59°07'10.0515
-2000	23°27'30.5098	59°11'32.3495
-1000	23°16'21.6081	59°16'25.0618
0	23°06'02.6324	59°21'44.7241
1000	22°56'35.5649	59°27'28.1195
2000	22°48'02.6254	59°33'32.3371
3000	22°40'26.4786	59°39'54.5816

Exactly the same kind of thing happens to sidereal planetary positions if one calculates them in the traditional way. They are actually given relative to a moving reference frame. The “fixed zodiac” is not really fixed. When observed over long periods of time in quick motion, it seems to wobble.

The wobbling of the ecliptic plane also influences ayanamshas that are referred to the nodes of the galactic equator with the ecliptic.

2. Consistent ayanamsha relative to the ecliptic of date (implemented in Swiss Ephemeris >=2.09 as an option)

As described above, the traditional approach is to calculate the ayanamsha relative to the ecliptic of Js and then apply this value to tropical positions relative to the eclipitic of Je. This procedure is obviously inconsistent.

A possible consistent solution would be to calculate the precession and ayanamsha relative to the eclipitic of the end epoch Je rather than to the ecliptic of the start epoch Js. Then this value would be subtracted from tropical planetary or star positions on epoch Je. Although the wobbling effect still remains, and positions of a fixed object will have slightly different positions at different date, this procedure is at least consistent in itself.

The following table shows the differences of solar positions gained in this way from solar positions gained in the traditional (inconsistent) way based on Lahiri ayanamsha. The solar positions are always calculated form 1 January in the Gregorian year.

year	*diff in ”*
-3000	-9.633
-2500	-8.472
-2000	-7.049
-1500	-5.528
-1000	-4.052
-500	-2.735
0	-1.656
500	-0.854
1000	-0.334
1500	-0.067
1600	-0.040
1700	-0.020
1800	-0.007
1900	-0.001
1920	-0.000
1940	0.000
1960	0.000
1980	0.000
2000	-0.000
2020	-0.001
2040	-0.002
2060	-0.003
2080	-0.004
2100	-0.005
2200	-0.015
2300	-0.029
2400	-0.046
2500	-0.066
3000	-0.190
3500	-0.304

year	*diff in "*
4000	-0.357

Note that the differences are around a millisecond of arc or below for current decades, but greater than an arc second 2000 years ago.

However, if the reference epoch is in the remote past, e.g. when ayanamsha is calculated from a zero ayanamsha epoch on the equinox 285 CE, then the differences are near zero only near that epoch, but amount to 0.65" in 2020:

year	*diff in "*
-3000	-4.209
-2500	-3.250
-2000	-2.279
-1500	-1.408
-1000	-0.720
-500	-0.258
0	-0.032
500	-0.016
1000	-0.161
1500	-0.395
1600	-0.446
1700	-0.496
1800	-0.546
1900	-0.595
1920	-0.604
1940	-0.614
1960	-0.623
1980	-0.633
2000	-0.642
2020	-0.651
2040	-0.660
2060	-0.669
2080	-0.677
2100	-0.686
2200	-0.727
2300	-0.765
2400	-0.799
2500	-0.828
3000	-0.895
3500	-0.810
4000	-0.572

3. Projection onto the ecliptic of t0 (implemented in Swiss Ephemeris as an option)

The opposite solution, which would also be consistent, would be to project the planetary positions of end date Je onto the ecliptic of the start date of the ayanamsha JS using a correct coordinate transformation. E.g., for the Fagan/Bradley ayanamsha, this would be the mean ecliptic of 1950; for the Lahiri ayanamsha, the mean ecliptic of 21 March 1956.

If we follow this method, the wobbling effect described above under (1) (traditional ayanamsha method) will not occur, and an object that has no proper motion will keep its position forever.

The differences from the traditional method look quite similar to method 2 above, where the calculation is consistently done relative to the ecliptic of date:

year	*diff in* ”
-3000	-9.522
-2500	-9.089
-2000	-7.970
-1500	-6.402
-1000	-4.763
-500	-3.207
0	-1.897
500	-0.939
1000	-0.337
1500	-0.058
1600	-0.033
1700	-0.016
1800	-0.005
1900	-0.000
1920	-0.000
1940	0.000
1960	0.000
1980	0.000
2000	-0.000
2020	-0.001
2040	-0.001
2060	-0.002
2080	-0.003
2100	-0.004
2200	-0.008
2300	-0.014
2400	-0.019
2500	-0.024
3000	0.030
3500	0.318
4000	0.967

A comparison of the two consistent methods 2 and 3 provides the following differences, which are considerably smaller:

year	*diff in* ”
-3000	-0.111
-2500	0.617
-2000	0.921
-1500	0.874
-1000	0.711
-500	0.472
0	0.241
500	0.084
1000	0.003
1500	-0.009
1600	-0.006
1700	-0.004
1800	-0.002

year	*diff in "*
1900	-0.000
1920	0.000
1940	0.000
1960	0.000
1980	0.000
2000	0.000
2020	-0.000
2040	-0.001
2060	-0.001
2080	-0.001
2100	-0.002
2200	-0.006
2300	-0.015
2400	-0.027
2500	-0.042
3000	-0.219
3500	-0.621
4000	-1.324

A philosophical side note: This method is geometrically more correct than the traditional one, but still has a problem. For, if we want to refer everything to the ecliptic of some initial date t0, we will have to choose that date very carefully. Its ecliptic ought to be of "cosmic" importance. The ecliptic of 1950 or the one of 1900 or 1956 (Lahiri) are obviously meaningless and not suitable as a reference plane. So, how about some historical date on which the tropical and the sidereal zero point coincided? Although this may be considered as a kind of cosmic anniversary (the ancient Indians and Sassanians did so), the ecliptic plane of that time does not have an "eternal" value. E.g., it is different from the ecliptic plane of the previous anniversary around the year 26000 BCE, and it is also different from the ecliptic plane of the next cosmic anniversary around the year 26000 CE.

Thus, it may be wiser to use method 2, i.e. a consistent ayanamsha calculation on the ecliptic of date.

Method 3 can also be used for computations of the following kind:

c) Astronomers may want to calculate positions referred to a standard > equinox like J2000, B1950, or B1900, or to any other equinox.

d) Astrologers may be interested in the calculation of > precession-corrected transits. See explanations in the next > chapter.

e) The algorithm can be applied to any user-defined sidereal mode, if > the ecliptic of its reference date is considered to be > astrologically significant.

f) The algorithm makes the problems of the traditional method visible. > It shows the dimensions of the inherent inaccuracy of the > traditional method. (Calculate some star position using the > traditional method and compare it to the same star's position if > calculated using this method.)

For the planets and for centuries close to t0, the difference from the traditional procedure will be only a few arc seconds in longitude. Note that the Sun will have an ecliptical latitude of several arc minutes after a few centuries.

For the lunar nodes, the procedure is as follows:

Because the lunar nodes have to do with eclipses, they are actually points on the ecliptic of date, i.e. on the tropical zodiac. Therefore, we first compute the nodes as points on the ecliptic of date and then project them onto the sidereal zodiac. This procedure is very close to the traditional method of computing sidereal positions (a matter of arc seconds). However, the nodes will have a latitude of a couple of arc minutes.

For the axes and houses, we compute the points where the horizon or the house lines intersect with the sidereal plane of the zodiac, not with the ecliptic of date. Here, there are greater deviations from the traditional procedure. If t is 2000 years from t0, the difference between the ascendant positions might well be 1/2 degree.

4. Fixed-star-bound ecliptic (implemented in Swiss Ephemeris for some selected stars) One can use a stellar object as an anchor for the sidereal zodiac and make sure that a particular stellar object is always at a certain position on the ecliptic of date. E.g. one might want to have Spica always at 0 Libra or the Galactic Center always at 0 Sagittarius. There is nothing against this method from a geometrical point of view. But it must be noted that this system is not really fixed either, because it is still based on the true ecliptic of date, which is actually moving. Moreover, the fixed stars that are used as anchor stars have a small proper motion, as well. Thus, if Spica is assumed as a fixed point, then its proper motion, its aberration, its gravitational deflection, and its parallax will necessarily affect the position and motion of all other stars (in addition to their own proper motion, aberration, etc.). Note, the Galactic Centre (Sgr A*) is not really fixed either, but has a small apparent motion that reflects the motion of the Sun around it.

This solution has been implemented for the following stars and fixed positions:

- Spica/Citra at 180° ("True Chitra Paksha Ayanamsha")
- Revati (zeta Piscium) at 359°50'
- Pushya (Asellus Australis) at 106° (PVR Narasimha Rao)
- Mula (lambda Scorpionis) at 240° (Chandra Hari)
- Galactic centre at 0° Sagittarius
- Galactic centre at 0° Capricorn (David Cochrane)
- Galactic centre at golden section between 0° Sco and 0° Aqu (R. Gil
  Brand)
- Polar longitude of galactic centre in the middle of nakshatra Mula
  (E. Wilhelm)

With Swiss Ephemeris versions before 2.05, the apparent position of the star relative to the mean ecliptic plane of date was used as the reference point of the zodiac. E.g. with the True Chitra ayanamsha, the star Chitra/Spica had the apparent position 180° exactly. However, the true position was slightly different. Since version 2.05, the star is always exactly at 180°, not only its apparent, but also its true position.

5. Galactic-equator-based ayanamshas (implemented in Swiss Ephemeris) Some ayanamshas are based on the galactic node, i.e. the intersection of the galactic equator with the mean ecliptic of date. These ayanamshas include:

- Galactic equator (IAU 1958)
- Galactic equator true/modern
- Galactic equator in middle of Mula

(Note, the Mardyks ayanamsha, although derived from the galactic equator, does not work like this. It is calculated using the method described above under 1).)

The galactic node is calculated from the true position of the galactic pole, not the apparent one. As a result, if the position of the galactic pole is calculated using the ayanamsha that has the galactic node at 0° Sagittarius, then the true position of the pole is exactly at sidereal 150°, but its apparent position is slightly different from that.

Here again, it must be stated that the ecliptic plane used is the true ecliptic of date, which is moving, with the only difference that the initial point is defined by the intersection of the ecliptic with the galactic equator.

6. The long-term mean Earth-Sun plane (not implemented in Swiss Ephemeris) To avoid the problem of choice of a reference ecliptic, one could use a kind of "average ecliptic". The mechanism of the planetary precession mentioned above works in a similar way as the mechanism of the luni-solar precession. The motion of the Earth orbit can be compared to a spinning top, with the Earth mass equally distributed around the whole orbit. The other planets, especially Venus and Jupiter, cause it to move around an average position. But unfortunately, this "long-term mean Earth-Sun plane" is not really stable either, and therefore not suitable as a fixed reference frame.

The period of this cycle is about 75000 years. The angle between the long-term mean plane and the ecliptic of date is currently about 1°33', but it varies considerably. (This cycle must not be confused with the period between two maxima of the ecliptic obliquity, which is about 40000 years and often mentioned in the context of planetary precession. This is the time it takes the vernal point to return to the node of the ecliptic (its rotation point), and therefore the oscillation period of the ecliptic obliquity.)

7. The solar system rotation plane (implemented in Swiss Ephemeris as an option) The solar system as a whole has a rotation axis, too, and its equator is quite close to the ecliptic, with an inclination of 1°34'44" against the ecliptic of the year 2000. This plane is extremely stable and perhaps the only convincing candidate for a fixed zodiac plane.

This method avoids the problem of method 3). No particular ecliptic has to be chosen as a reference plane. The only remaining problem is the choice of the zero point.

It does not make much sense to use this algorithm for predefined sidereal modes. One can use it for user-defined ayanamshas.

2.8.13. More benefits from our new sidereal algorithms: standard equinoxes and precession-corrected transits

Method no. 3, the transformation to the ecliptic of t0, opens two more possibilities:

You can compute positions referred to any equinox, 2000, 1950, 1900, or whatever you want. This is sometimes useful when Swiss Ephemeris data ought to be compared with astronomical data, which are often referred to a standard equinox.

There are predefined sidereal modes for these standard equinoxes:

18) J2000

19) J1900

20) B1950

Moreover, it is possible to compute precession-corrected transits or synastries with very high precision. An astrological transit is defined as the passage of a planet over the position in your birth chart. Usually, astrologers assume that tropical positions on the ecliptic of the transit time has to be compared with the positions on the tropical ecliptic of the birth date. But it has been argued by some people that a transit would have to be referred to the ecliptic of the birth date. With the new Swiss Ephemeris algorithm (method no. 3) it is possible to compute the positions of the transit planets referred to the ecliptic of the birth date, i.e. the so-called precession-corrected transits. This is more precise than just correcting for the precession in longitude (see details in the programmer's documentation swephprg.doc, Ch. 8.1).

3. Apparent versus true planetary positions

The Swiss ephemeris provides the calculation of *apparent* or *true* planetary positions. Traditional astrology works with apparent positions. "Apparent" means that the position where we see the planet is used, not the one where it actually is. Because the light's speed is finite, a planet is never seen exactly where it is. (see above, 2.1.3 "The details of coordinate transformation", light-time and aberration) Astronomers therefore make a difference between apparent and true positions. However, this effect is below 1 arc minute.

Most astrological ephemerides provide apparent positions. However, this may be wrong. The use of apparent positions presupposes that astrological effects can be derived from one of the four fundamental forces of physics, which is impossible. Also, many astrologers think that astrological "effects" are a synchronistic phenomenon (the ones familiar with physics may refer to the Bell theorem). For such reasons, it might be more convincing to work with true positions.

Moreover, the Swiss Ephemeris supports so-called astrometric positions, which are used by astronomers when they measure positions of celestial bodies with respect to fixed stars. These calculations are of no use for astrology, though.

4. Geocentric, topocentric, heliocentric, barycentric, and planetocentric positions

More precisely speaking, common ephemerides tell us the position where we would see a planet if we stood in the center of the Earth and could see the sky. But it has often been argued that a planet's position ought to be referred to the geographic position of the observer (or the birth place). This can make a difference of several arc seconds with the planets and even more than a degree with the Moon! Such a position referred to the birth place is called the *topocentric* planetary position. The observation of transits over the Moon might help to find out whether or not this method works better.

For very precise topocentric calculations, the Swiss Ephemeris not only requires the geographic position, but also its altitude above sea. An altitude of 3000 m (e.g. Mexico City) may make a difference of more than 1 arc second with the Moon. With other bodies, this effect is of the amount of a 0.01". The altitudes are referred to the approximate Earth ellipsoid. Local irregularities of the geoid have been neglected.

Our topocentric lunar positions differ from the NASA positions (s. the Horizons Online Ephemeris System http://ssd.jpl.nasa.gov) by 0.2 - 0.3 arc sec. This corresponds to a geographic displacement by a few 100 m and is about the best accuracy possible. In the documentation of the Horizons System, it is written that: "The Earth is assumed to be a rigid body. ... These Earth-model approximations result in topocentric station location errors, with respect to the reference ellipsoid, of less than 500 meters."

The Swiss ephemeris also allows the computation of *apparent* or *true topocentric* positions.

With the lunar nodes and apogees, Swiss Ephemeris does not make a difference between topocentric and geocentric positions. There are many ways to define these points topocentrically. The simplest one is to understand them as axes rather than points somewhere in space. In this case, the geocentric and the topocentric positions are identical, because an axis is an infinite line that always points to the same direction, not depending on the observer's position.

Moreover, the Swiss Ephemeris supports the calculation of *heliocentric*, *barycentric,* and *planetetocentric* positions of the planets. *Heliocentric* positions are positions as seen from the center of the Sun rather than from the center of the Earth. *Barycentric* ones are positions as seen from the center of the solar system, which is always close to but not identical to the center of the Sun. And *planetocentric* positions are relative to the center of some other object (planet, moon) of the solar system.

5. Heliacal Events, Eclipses, Occultations, and Other Planetary Phenomena

5.1. Heliacal Events of the Moon, Planets and Stars

5.1.1. Introduction

From Swiss Ephemeris version 1.76 on, heliacal events have been included. The heliacal rising and setting of planets and stars was very important for ancient Babylonian and Greek astronomy and astrology. Also, first and last visibility of the Moon can be calculated, which are important for many calendars, e.g. the Islamic, Babylonian and ancient Jewish calendars.

The heliacal events that can be determined are:

- **Inferior planets**
  - Heliacal rising (morning first)
  - Heliacal setting (evening last)
  - Evening first
  - Morning last
- **Superior planets and stars**
  - Heliacal rising
  - Heliacal setting
- **Moon**
  - Evening first
  - Morning last

The acronychal risings and settings (also called cosmical settings) of superior planets are a different matter. They will be added in a future version of the Swiss Ephemeris.

The principles behind the calculation are based on the visibility criterion of Schaefer [1993, 2000], which includes dependencies on aspects of:

- **Position of celestial objects**

  like the position and magnitude of the Sun, Moon and the studied celestial object,

- **Location and optical properties observer**

  like his/her location (longitude, latitude, height), age, acuity and possible magnification of optical instruments (like binoculars)

- **Meteorological circumstances**

  mainly expressed in the astronomical extinction coefficient, which is determined by temperature, air pressure, humidity, visibility range (air quality).

- **Contrast between studied object and sky background**

  The observer's eye can on detect a certain amount of contract and this contract threshold is the main body of the calculations

In the following sections above aspects will be discussed briefly and an idea will be given what functions are available to calculate the heliacal events. Lastly the future developments will be discussed.

5.1.2. Aspect determining visibility

The theory behind this visibility criterion is explained by Schaefer [1993, 2000] and the implemented by Reijs [2003] and Koch [2009]. The general ideas behind this theory are explained in the following subsections.

Position of celestial objects

To determine the visibility of a celestial object it is important to know where the studied celestial object is and what other light sources are in the sky. Thus beside determining the position of the studied object and its magnitude, it also involves calculating the position of the Sun (the main source of light) and the Moon. This is common functions performed by Swiss Ephemeris.

Geographic location

The location of the observer determines the topocentric coordinates (incl. influence of refraction) of the celestial object and his/her height (and altitude of studied object) will have influence on the amount of airmass that is in the path of celestial object's light.

Optical properties of observer

The observer's eyes will determine the resolution and the contrast differences he/she can perceive (depending on age and acuity), furthermore the observer might use optical instruments (like binocular or telescope).

Meteorological circumstances

The meteorological circumstances are very important for determining the visibility of the celestial object. These circumstances influence the transparency of the airmass (due to Rayleigh & aerosol scattering and ozone & water absorption) between the celestial object and the observer's eye. This result in the astronomical extinction coefficient (AEC: ktot). As this is a complex environment, it is sometimes 'easier' to use a certain AEC, instead of calculating it from the meteorological circumstances.

The parameters are stored in the datm (Pressure [mbar], Temperature [C], Relative humidity [%], AEC [-]) array.

Contrast between object and sky background

All the above aspects influence the perceived brightness of the studied celestial object and its background sky. The contrast threshold between the studied object and the background will determine if the observer can detect the studied object.

5.1.3. Functions to determine the heliacal events

Two functions are seen as the spill of calculating the heliacal events:

Determining the contrast threshold (swe_vis_limit_magn)

Based on all the aspects mentioned earlier, the contrast threshold is determine which decides if the studied object is visible by the observer or not.

Iterations to determine when the studied object is really visible (swe_heliacal_ut)

In general this procedure works in such a way that it finds (through iterations) the day that conjunction/opposition between Sun and studied object happens and then it determines, close to Sun's rise or set (depending on the heliacal event), when the studied object is visible (by using the **swe_vis_limit_magn** function).

Geographic limitations of swe_heliacal_ut() and strange behavior of planets in high geographic latitudes

This function is limited to geographic latitudes between 60S and 60N. Beyond that the heliacal phenomena of the planets become erratic. We found cases of strange planetary behavior even at 55N.

An example:

At 0E, 55N, with an extinction coefficient 0.2, Mars had a heliacal rising on 25 Nov. 1957. But during the following weeks and months Mars did not constantly increase its height above the horizon before Sunrise. In contrary, it disappeared again, i.e. it did a "morning last" on 18 Feb. 1958. Three months later, on 14 May 1958, it did a second morning first (heliacal rising). The heliacal setting or evening last took place on 14 June 1959.

Currently, this special case is not handled by swe_heliacal_ut(). The function cannot detect "morning lasts" of Mars and following "second heliacal risings". The function only provides the heliacal rising of 25 Nov. 1957 and the next ordinary heliacal rising in its ordinary synodic cycle which took place on 11 June 1960.

However, we may find a solution for such problems in future releases of the Swiss Ephemeris and even extend the geographic range of swe_heliacal_ut() to beyond +/- 60.

Visibility of Venus and the Moon during day

For the Moon, swe_heliacal_ut() calculates the evening first and the morning last. For each event, the function returns the optimum visibility and a time of visibility start and visibility end. Note, that on the day of its morning last or evening first, the Moon is often visible for almost the whole day. It even happens that the crescent first becomes visible in the morning after its rising, then disappears, and again reappears during culmination, because the observation conditions are better as the Moon stands high above the horizon. The function swe_heliacal_ut() does not handle this in detail. Even if the Moon is visible after Sunrise, the function assumes that the end time of observation is at Sunrise. The evening fist is handled in the same way.

With Venus, we have a similar situation. Venus is often accessible to naked eye observation during day, and sometimes even during inferior conjunction, but usually only at a high altitude above the horizon. This means that it may be visible in the morning at its heliacal rising, then disappear and reappear during culmination. (Whoever does not believe me, please read the article by H.B. Curtis listed under "References".) The function swe_heliacal_ut() does not handle this case. If binoculars or a telescope is used, Venus may be even observable during most of the day on which it first appears in the east.

5.1.4. Future developments

The section of the Swiss Ephemeris software is still under development. The acronychal events of superior planets and stars will be added. And comparing other visibility criterions will be included; like Schoch's criterion [1928], Hoffman's overview [2005] and Caldwall & Laney criterion [2005].

5.1.5. References

- Caldwell, J.A.R., Laney, C.D., First visibility of the lunar crescent, http://www.saao.ac.za/public-info/Sun-Moon-stars/Moon-index/lunar-crescent-visibility/first-visibility-of-lunar-crescent/, 2005, viewed March, 30th, 2009
- H.B. Curtis, Venus Visible at inferior conjunction, in : Popular Astronomy vol. 18 (1936), p. 44; online at http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1936PA.....44...18C&data_type=PDF_HIGH&whole_p
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- Schoch, K., Astronomical and calendrical tables in Langdon. S., Fotheringham, K.J., The Venus tables of Amninzaduga: A solution of Babylonian chronology by means of Venus observations of the first dynasty, Oxford, 1928.

5.2. Eclipses, occultations, risings, settings, and other planetary phenomena

The Swiss Ephemeris also includes functions for many calculations concerning solar and lunar eclipses. You can:

- search for eclipses or occultations, globally or for a given geographical position;
- compute global or local circumstances of eclipses or occultations;
- compute the geographical position where an eclipse is central.

Moreover, you can compute for all planets and asteroids:

- risings and settings (also for stars);
- midheaven and lower heaven transits (also for stars);
- height of a body above the horizon (refracted and true, also for stars);
- phase angle;
- phase (illumined fraction of disc);
- elongation (angular distance between a planet and the Sun);
- apparent diameter of a planetary disc;
- apparent magnitude.

6. Sidereal Time, Ascendant, MC, Houses, Vertex

The Swiss Ephemeris package also includes a function that computes the Ascendant, the MC, the houses, the Vertex, and the Equatorial Ascendant (sometimes called ”East Point”).

6.1. Sidereal Time

Swiss Ephemeris versions until 1.80 used the IAU 1976 formula for Sidereal time. Since version 2.00 it uses sidereal time based on the IAU2006/2000 precession/nutation model.

As this solution is not good for the whole time range of JPL Ephemeris DE431, we only use it between 1850 and 2050. Outside this period, we use a solution based on the long term precession model Vondrak 2011, nutation IAU2000 and the mean motion of the Earth according to Simon & alii 1994. To make the function continuous we add some constant values to our long-term function before 1850 and after 2050.

Vondrak/Capitaine/Wallace, ”New precession expressions, valid for long time intervals”, in A&A 534, A22(2011).

Simon & alii, ”Precession formulae and mean elements for the Moon and the Planets”, A&A 282 (1994), p. 675/678.

6.2. Astrological House Systems

The following house methods have been implemented so far:

6.2.1. Placidus

This system is named after the Italian monk Placidus de Titis (1590-1668). The cusps are defined by divisions of semidiurnal and seminocturnal arcs. The 11th cusp is the point on the ecliptic that has completed 2/3 of its semidiurnal arc, the 12th cusp the point that has completed 1/3 of it. The 2nd cusp has completed 2/3 of its seminocturnal arc, and the 3rd cusp 1/3.

6.2.2. Koch/GOH

This system is called after the German astrologer Walter Koch (1895-1970). Actually it was invented by Fiedrich Zanzinger and Heinz Specht, but it was made known by Walter Koch. In German-speaking countries, it is also called the ”Geburtsorthäusersystem” (GOHS), i.e. the ”Birth place house system”. Walter Koch thought that this system was more related to the birth place than other systems, because all house cusps are computed with the ”polar height of the birth place”, which has the same value as the geographic latitude.

This argumentation shows actually a poor understanding of celestial geometry. With the Koch system, the house cusps are actually defined by horizon lines at different times. To calculate the cusps 11 and 12, one can take the time it took the MC degree to move from the horizon to the culmination, divide this time into three and see what ecliptic degree was on the horizon at the thirds. There is no reason why this procedure should be more related to the birth place than other house methods.

6.2.3. Regiomontanus

Named after the Johannes Müller (called ”Regiomontanus”, because he stemmed from Königsberg) (1436-1476).

The equator is divided into 12 equal parts and great circles are drawn through these divisions and the north and south points on the horizon. The intersection points of these circles with the ecliptic are the house cusps.

6.2.4. Campanus

Named after Giovanni di Campani (1233-1296).

The vertical great circle from east to west is divided into 12 equal parts and great circles are drawn through these divisions and the north and south points on the horizon. The intersection points of these circles with the ecliptic are the house cusps.

6.2.5. Equal Systems

Equal houses from Ascendant

The zodiac is divided into 12 houses of 30 degrees each starting from the Ascendant.

Equal houses from Midheaven

The zodiac is divided into 12 houses of 30 degrees each starting from MC + 90 degrees.

Vehlow-equal system

Equal houses with the Ascendant positioned in the middle of the first house.

Whole Sign houses

The first house starts at the beginning of the zodiac sign in which the ascendant is. Each house covers a complete sign. This method was used in Hellenistic astrology and is still used in Hindu astrology.

Whole Sign houses starting at 0° Aries

The first house starts at the beginning of Aries.

6.2.6. Porphyry Houses and Related House Systems

Porphyry Houses

Each quadrants is trisected in three equal parts on the ecliptic.

Sripati Houses

This is a traditional Indian house system. In a first step, Porphyry houses are calculated. The cusps of each new house will be the midpoint between the last and the current. So house 1 will be equal to:

H1' = (H1 - H12) / 2 + H12

H2' = (H2 - H1) / 2 + H1

And so on.

Pullen SD (Sinusoidal Delta, also known as "Neo-Porphyry")

This house system was invented in 1994 by Walter Pullen, the author of the astrology software Astrolog. Like the Porphyry house system, this house system is based on the idea that the division of the houses must be relative to the ecliptic sections of the quadrants only, not relative to the equator or diurnal arcs. For this reason, Pullen originally called it "Neo-Porphyry". However, the sizes of the houses of a quadrant are not equal. Pullen describes it as follows:

"Like Porphyry except instead of simply trisecting quadrants, fit the house widths to a sine wave such that the 2nd/5th/8th/11th houses are expanded or compressed more based on the relative size of their quadrants."

In practice, an ideal house size of 30° each is assumed, then half of the deviation of the quadrant from 90° is added to the middle house of the quadrant. The remaining half is bisected again into quarters, and a quarter is added to each of the remaining houses. Pullen himself puts it as follows:

"Sinusoidal Delta" (formerly "Neo-Porphyry") houses

Asc 12th 11th MC 9th 8th 7th

| | | | | | |

+----------+----------+----------+----------+----------+----------+

angle angle angle angle angle angle

x+n x x+n x+3n x+4n x+3n

In January 2016, in a discussion in the Swiss Ephemeris Yahoo Group, Alois Treindl criticized that Pullen's code only worked as long as the quadrants were greater than 30°, whereas negative house sizes resulted for the middle house of quadrants smaller than 30°. It was agreed upon that in such cases the size of the house had to be set to 0.

- https://groups.yahoo.com/neo/groups/swisseph/conversations/topics/5579
- https://groups.yahoo.com/neo/groups/swisseph/conversations/topics/5606

Pullen SR (Sinusoidal Ratio)

On 24 Jan. 2016, during the above-mentioned discussion in the Swiss Ephemeris Yahoo Group, Walter Pullen proposed a better solution of a sinusoidal division of the quadrants, which does not suffer from the same problem. He wrote:

"It's possible to do other than simply add sine wave offsets to houses (the "Sinusoidal Delta" house system above). Instead, let's proportion or ratio the entire house sizes themselves to each other based on the sine wave constants, or multiply instead of add. That results in using a "sinusoidal ratio" instead of a "sinusoidal delta", so this alternate method could be called "Sinusoidal Ratio houses". As before, let "x" be the smallest house in the compressed quadrant. There's a ratio "r" multiplied by it to get the slightly larger 10th and 12th houses. The value "r" starts out at 1.0 for 90 degree quadrants, and gradually increases as quadrant sizes differ. Houses in the large quadrant have "r" multiplied to "x" 3 times (or 4 times for the largest quadrant). That results in the (0r, 1r, 3r, 4r) distribution from the sine wave above. This is summarized in the chart below:"

”Sinusoidal Ratio” houses

Asc 12th 11th MC 9th 8th 7th

| | | | | | |

+----------+----------+----------+----------+----------+----------+

angle angle angle angle angle angle

rx x rx r^3x r^4x r^3x

“The unique values for ”r” and ”x” can be computed based on the quadrant size ”q”, given the equations rx + x + rx = q, $r^3x + r^4x + r^3x = 180 - q$.”

- https://groups.yahoo.com/neo/groups/swisseph/conversations/topics/5579

6.2.7. Axial rotation systems

Meridian system

The equator is partitioned into 12 equal parts starting from the ARMC. Then the ecliptic points are computed that have these divisions as their right ascension. Note: The ascendant is different from the 1st house cusp.

Carter’s poli-equatorial houses

The equator is partitioned into 12 equal parts starting from the right ascension of the ascendant. Then the ecliptic points are computed that have these divisions as their right ascension. Note: The MC is different from the 10th house cusp.

The prefix “poli-” might stand for “polar”. (Speculation by DK.)

Carter’s own words:

“...the houses are demarcated by circles passing through the celestial poles and dividing the equator into twelve equal arcs, the cusp of the 1st house passing through the ascendant. This system, therefore, agrees with the natural rotation of the heavens and also produces, as the Ptolemaic (equal) does not, distinctive cusps for each house ...”

- Charles Carter (1947, 2nd ed. 1978) Essays on the Foundations of Astrology. Theosophical Publishing House, London. p. 158-159.
- http://www.exeterastrologygroup.org.uk/2014/12/charles-carters-forgotten-house-system.html

6.2.8. The Morinus system

The equator is divided into 12 equal parts starting from the ARMC. The resulting 12 points on the equator are transformed into ecliptic coordinates. Note: The Ascendant is different from the 1st cusp, and the MC is different from the 10th cusp.

6.2.9. Horizontal system

The house cusps are defined by division of the horizon into 12 directions. The first house cusp is not identical with the Ascendant but is located precisely in the east.

6.2.10. The Polich-Page ("topocentric") system

This system was introduced in 1961 by Wendel Polich and A.P. Nelson Page. Its construction is rather abstract: The tangens of the polar height of the 11th house is the tangens of the geo. latitude divided by 3. (2/3 of it are taken for the 12th house cusp.) The philosophical reasons for this algorithm are obscure. Nor is this house system more "topocentric" (i.e. birth-place-related) than any other house system. (c.f. the misunderstanding with the "birth place system".) The "topocentric" house cusps are close to Placidus house cusps except for high geographical latitudes. It also works for latitudes beyond the polar circles, wherefore some consider it to be an improvement of the Placidus system. However, the striking philosophical idea behind Placidus, i.e. the division of diurnal and nocturnal arcs of points of the zodiac, is completely abandoned.

6.2.11. Alcabitus system

A method of house division which first appears with the Hellenistic astrologer Rhetorius (500 A.D.) but is named after Alcabitius, an Arabic astrologer, who lived in the 10th century A.D. This is the system used in a few remaining examples of ancient Greek horoscopes.

The MC and ASC are the 10th- and 1st- house cusps. The remaining cusps are determined by the trisection of the semidiurnal and seminocturnal arcs of the ascendant, measured on the celestial equator. The houses are formed by great circles that pass through these trisection points and the celestial north and south poles.

6.2.12. Gauquelin sectors

This is the "house" system used by the Gauquelin and their epigones and critics in statistical investigations in Astrology. Basically, it is identical with the Placidus house system, i.e. diurnal and nocturnal arcs of ecliptic points or planets are subdivided. There are a couple of differences, though.

- Up to 36 "sectors" (or house cusps) are used instead of 12 houses.
- The sectors are counted in clockwise direction.
- There are so-called plus (+) and minus (−) zones. The plus zones are the sectors that turned out to be significant in statistical investigations, e.g. many top sportsmen turned out to have their Mars in a plus zone. The plus sectors are the sectors 36 − 3, 9 − 12, 19 − 21, 28 − 30.
- More sophisticated algorithms are used to calculate the exact house position of a planet (see chapters 6.4 and 6.5 on house positions and Gauquelin sector positions of planets).

6.2.13. Krusinski/Pisa/Goelzer system

This house system was first published in 1994/1995 by three different authors independently of each other:

- by Bogdan Krusinski (Poland).
- by Milan Pisa (Czech Republic) under the name "Amphora house system".
- by Georg Goelzer (Switzerland) under the name "Ich-Kreis-Häusersystem" ("I-Circle house system").

Krusinski defines the house system as "… based on the great circle passing through ascendant and zenith. This circle is divided into 12 equal parts (1st cusp is ascendant, 10th cusp is zenith), then the resulting points are projected onto the ecliptic through meridian circles. The house cusps in space are half-circles perpendicular to the equator and running from the north to the south celestial pole through the resulting cusp points on the house circle. The points where they cross the ecliptic mark the ecliptic house cusps." (Krusinski, e-mail to Dieter Koch)

It may seem hard to believe that three persons could have discovered the same house system at almost the same time. But apparently this is what happened. Some more details are given here, in order to refute wrong accusations from the Czech side against Krusinski of having "stolen" the house system.

Out of the documents that Milan Pisa sent to Dieter Koch, the following are to be mentioned: Private correspondence from 1994 and 1995 on the house system between Pisa and German astrologers Böer and Schubert-Weller, two type-written (apparently unpublished) treatises in German on the house system dated from 1994. A printed booklet of 16 pages in Czech from 1997 on the theory of the house system ("Algoritmy noveho systemu astrologickych domu"). House tables computed by Michael Cifka for the geographical latitude of Prague, copyrighted from 1996. The house system was included in the Czech astrology software Astrolog v. 3.2 (APAS) in 1998. Pisa's first publication on the house system happened in spring 1997 in "Konstelace" No. 22, the periodical of the Czech Astrological Society.

Bogdan Krusinski first published the house system at an astrological congress in Poland, the ""XIV Szkola Astrologii Humanistycznej" held by Dr Leszek Weres, which took place between 15.08.1995 and 28.08.1995 in Pogorzelica at cost of the Baltic Sea." Since then Krusinski has distributed printed house tables for the Polish geographical latitudes 49-55° and floppy disks with house tables for latitudes 0-90°. In 1996, he offered his program code to Astrodienst for implementation of this house system into Astrodienst's then astronomical software Placalc. (At that time, however, Astrodienst was not interested in it.) In May 1997, Krusinski put the data on the web at

http://www.ci.uw.edu.pl/~bogdan/astrol.htm (now at http://www.astrologia.pl/main/domy.html).

In February 2006 he sent Swiss-Ephemeris-compatible program code in C for this house system to Astrodienst. This code was included into Swiss Ephemeris Version 1.70 and released on 8 March 2006.

Georg Goelzer describes the same house system in his book "Der Ich-Kosmos", which appeared in July 1995 at Dornach, Switzerland (Goetheanum). The book has a second volume with house tables according to the house method under discussion. The house tables were created by Ulrich Leyde. Goelzer also uses a house calculation programme which has the time stamp "9 April 1993" and produces the same house cusps.

By March 2006, when the house system was included in the Swiss Ephemeris under the name of "Krusinski houses", neither Krusinski nor Astrodienst knew about the works of Pisa and Goelzer. Goelzer heard of his co-discoverers only in 2012 and then contacted Astrodienst.

Conclusion: It seems that the house system was first "discovered" and published by Goelzer, but that Pisa and Krusinski also "discovered" it independently. We do not consider this a great miracle because the number of possible house constructions is quite limited.

6.2.14. APC house system

This house system was introduced by the Dutch astrologer L. Knegt and is used by the Dutch Werkgemeenschap van Astrologen (WvA, also known as "Ram school").

The parallel of declination that goes through the ascendant is divided in six equal parts both above and below the horizon. Position circles through the north and the south point on the horizon are drawn through the division points. The house cusps are where the position circles intersect the ecliptic.

Note, the house cusps 11, 12, 2, and 3 are not exactly opposite the cusps 5, 6, 8, and 9.

6.2.15. Sunshine house system

This house system was invented by Bob Makransky and published in 1988 in his book Primary Directions. A Primer of Calculation (free download: http://www.dearbrutus.com/buyprimarydirections.html).

The diurnal and nocturnal arcs of the Sun are trisected, and great circles are drawn through these trisection points and the north and the south point on the horizon. The intersection points of these great circles with the ecliptic are the house cusps. Note that the cusps 11, 12, 2, and 3 are not in exact opposition to the cusps 5, 6, 8, and 9.

For the polar region and during times where the Sun does not rise or set, the diurnal and nocturnal arc are assumed to be either 180° or 0°. If the diurnal arc is 0°, the house cusps 8 – 12 coincide with the meridian. If the nocturnal arc is 0°, the cusps 2 – 6 coincide with the meridian. As with the closely related Regiomontanus system, an MC below the horizon and IC above the horizon are exchanged.

6.2.16. Savard A house system

6.3. Vertex, Antivertex, East Point and Equatorial Ascendant etc.

The *Vertex* is the point of the ecliptic that is located precisely in western direction. The *Antivertex* is the opposition point and indicates the precise east in the horoscope. It is identical to the 1st house cusp in the horizon house system.

There is a lot of confusion about this, because there is also another point which is called the "East Point" but is usually not located in the east. In celestial geometry, the expression "East Point" means the point on the horizon which is in precise eastern direction. The equator goes through this point as well, at a right ascension which is equal to ARMC + 90 degrees. On the other hand, what some astrologers call the "East Point" is the point on the ecliptic whose right ascension is equal to ARMC + 90 (i.e. the right ascension of the horizontal East Point). This point can deviate from eastern direction by 23.45 degrees, the amount of the ecliptic obliquity. For this reason, the term "East Point" is not very well-chosen for this ecliptic point, and some astrologers (M. Munkasey) prefer to call it the *Equatorial Ascendant*, because it is identical to the Ascendant at a geographical latitude 0.

The Equatorial Ascendant is identical to the first house cusp of the *axial rotation system*.

Note: If a projection of the horizontal East Point on the ecliptic is wanted, it might seem more reasonable to use a projection rectangular to the ecliptic, not rectangular to the equator as is done by the users of the "East Point". The planets, as well, are not projected on the ecliptic in a right angle to the ecliptic.

The Swiss Ephemeris supports three more points connected with the house and angle calculation. They are part of Michael Munkasey's system of the *8 Personal Sensitive Points* (PSP). The PSP include the *Ascendant*, the *MC*, the *Vertex*, the *Equatorial Ascendant*, the *Aries Point*, the *Lunar Node*, and the *"Co-Ascendant"* and the *"Polar Ascendant"*.

The term *"Co-Ascendant"* seems to have been **invented twice** by two different people, and it **can mean two different things**. The one "Co-Ascendant" was invented by Walter Koch. To calculate it, one has to take the ARIC as an ARMC and compute the corresponding Ascendant for the birth place. The "Co-Ascendant" is then the opposition to this point.

The second "Co-Ascendant" stems from Michael Munkasey. It is the Ascendant computed for the natal ARMC and a latitude which has the value 90° - birth_latitude.

The "Polar Ascendant" finally was introduced by Michael Munkasey. It is the opposition point of Walter Koch's version of the "Co-Ascendant". However, the "Polar Ascendant" is not the same as an Ascendant computed for the birth time and one of the geographic poles of the Earth. At the geographic poles, the Ascendant is always 0 Aries or 0 Libra. This is not the case for Munkasey's "Polar Ascendant".

6.4. House cusps beyond the polar circle

Beyond the polar circle, we proceed as follows:

1. We make sure that the ascendant is always in the eastern hemisphere.
2. Placidus and Koch house cusps sometimes can, sometimes cannot be computed beyond the polar circles. Even the MC doesn't exist always, if one defines it in the Placidus manner. Our function therefore automatically switches to Porphyry houses (each quadrant is divided into three equal parts) and returns a warning.

3. Beyond the polar circles, the MC is sometimes below the horizon. The geometrical definition of the Campanus and Regiomontanus systems requires in such cases that the MC and the IC are swapped. The whole house system is then oriented in clockwise direction.

There are similar problems with the Vertex and the horizon house system for birth places in the tropics. The Vertex is defined as the point on the ecliptic that is located in precise western direction. The ecliptic east point is the opposition point and is called the Antivertex. Our program code makes sure that the Vertex (and the cusps 11, 12, 1, 2, 3 of the horizon house system) is always located in the western hemisphere. Note that for birthplaces on the equator the Vertex is always 0 Aries or 0 Libra.

Of course, there are no problems in the calculation of the Equatorial Ascendant for any place on Earth.

6.4.1. Implementation in other calculation modules:

PLACALC

Placalc is the predecessor of Swiss Ephemeris; it is a calculation module created by Astrodienst in 1988 and distributed as C source code. Beyond the polar circles, Placalc's house calculation did switch to Porphyry houses for all unequal house systems. Swiss Ephemeris still does so with the Placidus and Koch method, which are not defined in such cases. However, the computation of the MC and Ascendant was replaced by a different model in some cases: Swiss Ephemeris gives priority to the Ascendant, choosing it always as the eastern rising point of the ecliptic and accepting an MC below the horizon, whereas Placalc gave priority to the MC. The MC was always chosen as the intersection of the meridian with the ecliptic above the horizon. To keep the quadrants in the correct order, i.e. have an Ascendant in the left side of the chart, the Ascendant was switched by 180 degrees if necessary.

In the discussions between Alois Treindl and Dieter Koch during the development of the Swiss Ephemeris it was recognized that this model is more unnatural than the new model implemented in Swiss Ephemeris.

Placalc also made no difference between Placidus/Koch on one hand and Regiomontanus/Campanus on the other as Swiss Ephemeris does. In Swiss Ephemeris, the geometrical definition of Regiomontanus/Campanus is strictly followed, even for the price of getting the houses in "wrong" order. (see above, Chapter 4.1.)

ASTROLOG program as written by Walter Pullen

While the freeware program Astrolog contains the planetary routines of Placalc, it uses its own house calculation module by Walter Pullen. Various releases of Astrolog contain different approaches to this problem.

6.5. House position of a planet

The Swiss Ephemeris DLL also provides a function to compute the house position of a given body, i.e. in which house it is. This function can be used either to determine the house number of a planet or to compute its position in a *house horoscope*. (A house horoscope is a chart in which all houses are stretched or shortened to a size of 30 degrees. For unequal house systems, the zodiac is distorted so that one sign of the zodiac does not measure 30 house degrees)

Note that the actual house position of a planet is not always the one that it seems to be in an ordinary chart drawing. Because the planets are not always exactly located on the ecliptic but have a latitude, they can seemingly be located in the first house, but are actually visible above the horizon. In such a case, our program function will place the body in the 12th (or 11th or 10th) house, whatever celestial geometry requires. However, it is possible to get a house position in the "traditional" way, if one sets the ecliptic latitude to zero.

Although it is not possible to compute Placidus house cusps beyond the polar circle, this function will also provide Placidus house positions for polar regions. The situation is as follows:

The Placidus method works with the semidiurnal and seminocturnal arcs of the planets. Because in higher geographic latitudes some celestial bodies (the ones within the circumpolar circle) never rise or set, such arcs do not exist. To avoid this problem it has been proposed in such cases to start the diurnal motion of a circumpolar body at its "midnight" culmination and its nocturnal motion at its midday culmination. This procedure seems to have been proposed by Otto Ludwig in 1930. It allows to define a planet's house position even if it is within the circumpolar region, and even if you are born in the northernmost settlement of Greenland. However, this does not mean that it be possible to compute ecliptical house cusps for such locations. If one tried that, it would turn out that e.g. an 11th house cusp did not exist, but there were two 12th house cusps.

Note however, that circumpolar bodies may jump from the 7th house directly into the 12th one or from the 1st one directly into the 6th one.

The Koch method, on the other hand, cannot be helped even with this method. For some bodies it may work even beyond the polar circle, but for some it may fail even for latitudes beyond 60 degrees. With fixed stars, it may even fail in central Europe or USA. (Dieter Koch regrets the connection of his name with such a badly defined house system)

Note that Koch planets do strange jumps when they cross the meridian. This is not a computation error but an effect of the awkward definition of this house system. A planet can be east of the meridian but be located in the 9th house, or west of the meridian and in the 10th house. It is possible to avoid this problem or to make Koch house positions agree better with the Huber "hand calculation" method, if one sets the ecliptic latitude of the planets to zero. But this is not more correct from a geometrical point of view.

6.6. Gauquelin sector position of a planet

The calculation of the Gauquelin sector position of a planet is based on the same idea as the Placidus house system, i.e. diurnal and nocturnal arcs of ecliptic points or planets are subdivided.

Three different algorithms have been used by Gauquelin and others to determine the sector position of a planet.

- We can take the ecliptic point of the planet (ecliptical latitude ignored) and calculate the fraction of its diurnal or nocturnal arc it has completed
- We can take the true planetary position (taking into account ecliptical latitude) for the same calculation.
- We can use the exact times for rise and set of the planet to determine the ratio between the time the planet has already spent above (or below) the horizon and its diurnal (or nocturnal) arc. Times of rise and set are defined by the appearance or disappearance of the center of the planet's disks.

All three methods are supported by the Swiss Ephemeris.

Methods 1 and 2 also work for polar regions. The Placidus algorithm is used, and the Otto Ludwig method applied with circumpolar bodies. I.e. if a planet does not have a rise and set, the "midnight" and "midday" culminations are used to define its semidiurnal and seminocturnal arcs.

With method 3, we don't try to do similar. Because planets do not culminate exactly in the north or south, a planet can actually rise on the western part of the horizon in high geographic latitudes. Therefore, it does not seem appropriate to use meridian transits as culmination times. On the other hand, true culmination times are not always available. E.g. close to the geographic poles, the Sun culminates only twice a year.

6.7. Improvement of the Placidus house calculation in SE 2.09

Before Swiss Ephemeris 2.09, our calculation of Placidus house positions did not provide greatest possible precision with high geographic latitudes (noticed by D. Senthilathiban). The Placidus house cusps were calculated with only two iterations. This resulted in an accuracy of 1 arcsec until about the geographic latitude 56°. On higher latitudes, the error was greater for some cusps and for some time of the day. For latitudes extremely close to the polar circle the error could even become greater than a degree.

This problem has been fixed by using a variable number of iterations, which stops when the cusp converges, with n = 100 as maximum number of iterations. If the iteration does not converge with this maximum of iterations, we switch to Porphyry cusps and return a warning.

Example:

Old calculation with SE 2.08:

sweph2.08/swetest -b26.1.2000 -ut8:08 -house30,66.562,P -p

date (dmy) 26.1.2000 greg. 8:08:00 UT version 2.08

UT: 2451569.838888889 delta t: 63.849300 sec

TT: 2451569.839627885

geo. long 30.000000, lat 66.562000, alt 0.000000

Epsilon (t/m) 23°26'16.2121 23°26'21.3741

house 1 93°10'50.7734

house 2 93°35'32.4962

house 3 94°45' 1.3614

house 4 96°22'19.2129

house 5 99°30'38.8122

house 6 107°41'47.9654

New calculation with SE 2.09:

swetest -b26.1.2000 -ut8:08 -house30,66.562,P -p

date (dmy) 26.1.2000 greg. 8:08:00 UT version 2.08.00a

UT: 2451569.838888889 delta t: 63.849300 sec

TT: 2451569.839627885

geo. long 30.000000, lat 66.562000, alt 0.000000

Epsilon (t/m) 23°26'16.2121 23°26'21.3741

Nutation -0° 0'13.1306 -0° 0' 5.1621

Houses system P (Placidus) for long= 30° 0' 0.0000, lat= 66°33'43.2000

house 1 93°10'50.7734

house 2 93°35'32.4962

house 3 94°45' 1.3614

house 4 96°22'19.2129

house 5 99°34' 5.9429

house 6 109°14' 4.4696

7. ΔT (Delta T)

Ephemerides of planets are calculated using so called *Terrestrial Time* (which replaces former *Ephemeris Time* (ET)). Terrestrial time is a perfectly uniform time measure based on atomic clocks (SI seconds). Computations of sidereal time and houses, on the other hand, are calculated using *Universal Time* (UT). Universal Time is based on the rotational period of the Earth (the day), which is not perfectly uniform. The difference between TT (ET) and UT is called ΔT ("Delta T"), and is defined as $\Delta T = TT - UT$.

The Earth's rotation decreases slowly, currently at the rate of roughly 0.5 – 1 second per year, but in an irregular and unpredictable way. The value of ΔT cannot be calculated with accuracy for the future or the remote past. Future values of ΔT can only be determined in hindsight from astronomical observations. Observations of solar and lunar eclipses made by ancient Babylonians, Chinese, Greeks, Arabs, and scholars of the European Renaissance and early Modern Era can be used to determine the approximate value of ΔT for historical epochs after 720 BCE. For the remoter past or the future, estimations must be made. Numerous occultations of stars by the Moon have provided more exact values for ΔT for epochs after 1700. Since 1962, ΔT has been determined from extremely accurate measurements of the Earth rotation by the *International Earth Rotation and Reference Systems Service* (IERS).

Swiss Ephemeris Version 2.06 and later use the ΔT algorithms published in:

- Stephenson, F.R., Morrison, L.V., and Hohenkerk, C.Y., "Measurement of the Earth's Rotation: 720 BCE to CE 2015", Royal Society Proceedings A, 7 Dec 2016,

  http://rspa.royalsocietypublishing.org/lookup/doi/10.1098/rspa.2016.0404

These algorithms are used for epochs before 1 January 1955. From 1955 on we use the values provided by the Astronomical Almanac, pp. K8-9 (since AA 1986). From 1974 on we use values calculated from data of the Earth Orientation Department of the US Naval Observatory:

- (TAI-UTC) from: ftp://maia.usno.navy.mil/ser7/tai-utc.dat;
- (UT1-UTC) from: ftp://ftp.iers.org/products/eop/rapid/standard/finals.data; or
- ftp://maia.usno.navy.mil/ser7/finals.all;

  file description in: ftp://maia.usno.navy.mil/ser7/readme.finals.

Delta T = TAI-UT1 + 32.184 sec = (TAI-UTC) - (UT1-UTC) + 32.184 sec

For epochs before 1955, the ΔT function adjusts for a value of secular tidal acceleration ndot that is consistent with the ephemeris used (LE431 has ndot = -25.80 arcsec/cty^2, LE405/406 has ndot = -25.826 arcsec/cty^2, ELP2000 and DE200 ndot = -23.8946 arcsec/cty^2). The ΔT values of Astronomical Almanac are consistent with ndot = -26 arcsec/cty^2, those of Stephenson & alii 2016 with ndot = -25.85 arcsec/cty^2.

For the time after the last tabulated value, we use the formula of Stephenson (1997; p. 507), with a modification that avoids a discontinuity at the end of the tabulated period. A linear term is added that makes a slow transition from the table to the formula over a period of 100 years.

The ΔT algorithms have been changed with the Swiss Ephemeris releases 1.64 (Stephenson 1997), 1.72 (Morrison/Stephenson 2004), 1.77 (Espenak & Meeus) and 2.06 (Stephenson/Morrison/Hohenkerk). These updates have caused changes in ephemerides that are based on Universal Time.

Until version 2.05.01, the Swiss Ephemeris has used the ΔT values provided by Astronomical Almanac K8-9 starting from the year 1633. Before 1600, polynomials published by Espenak and Meeus (2006, see further below) were used. These formulae include the long-term formula by Morrison/Stephenson (2004, p. 332), which is used for epochs before -500. Between the value of 1600 and the value of 1633, a linear interpolation was made.

Differences in ΔT, SE 2.06 – SE 2.05 (new – old)

(with resulting differences for lunar and solar ephemerides calculated in UT)

Year	ΔT sec	Difference in ΔT (new-old)	L (Moon)	L (Sun)
-3000	75051	1174	644”	48”
-2500	60203	865	475”	36”
-2000	46979	588	323”	24”
-1500	35377	342	188”	14”
-1000	25398	129	71”	5”
-900	23596	90	49”	4”
-800	21860	52	29”	2”
-700	20142	-31	-17”	-1”
-600	18373	-229	-126”	-9”
-500	16769	-325	-179”	-13”
-400	15311	-119	-65”	-5”
-300	13981	-5	-3”	-0”
-200	12758	50	27”	2”
-100	11623	62	34”	3”
0	10557	43	24”	2”
100	9540	6	3”	0”
200	8554	-31	-17”	-1”
300	7578	-53	-29”	-2”
400	6593	-62	-34”	-3”
500	5590	-81	-45”	-3”
600	4596	-110	-60”	-5”
700	3649	-135	-74”	-6”
800	2786	-145	-80”	-6”
900	2045	-135	-74”	-6”
1000	1464	-94	-52”	-4”
1100	1063	-13	-7”	-1”
1200	802	76	42”	3”
1300	625	141	77”	6”
1400	473	157	86”	6”
1500	292	97	53”	4”
1600	89	-29	-16”	-1.2”
1700	14	6.5	3.6”	0.27”
1800	19	5.3	2.9”	0.22”
1900	-2.0	0.78	0.43”	0.03”
1920	22	0.47	0.26”	0.02”
1940	24	0.10	0.05”	0.00”
1960	33	0.00	0.00”	0.00”
1970	40	0.00	0.00”	0.00”
1980	51	0.00	0.00”	0.00”
1990	57	0.00	0.00”	0.00”
2000	64	0.00	0.00”	0.00”
2010	66	0.00	0.00”	0.00”
2020	70	0.00	0.00”	0.00”
2030	74	-5.9	-3.3”	-0.24”

Year	ΔT sec	Difference in ΔT (new-old)	L (Moon)	L (Sun)
2040	76	-21	-12”	-0.87”
2050	78	-37	-20”	-1.5”
2100	94	-119	-65”	-4.9”
2200	163	-265	-145”	-11”
2300	297	-397	-218”	-16”
2400	520	-503	-276”	-21”
2500	855	-558	-307”	-23”
3000	3292	-1004	-551”	-41”

Differences in ΔT, SE 1.77 – SE 1.76

Year	Difference in seconds (new - old)
-3000	3
-2000	2
-1100	1
-1001	29
-900	-45
-800	-57
-700	-696 (is a maximum!)
-500	-14
until	-200 3 > diff > -25
until	100 3 > diff > -15
until	500 3 > diff > -03
until	1600 4 > diff > -16
until	1630 1 > diff > -30
until	1700 0.1 | diff |
until	1900 0.01
until	2100 0.001

The differences for −1000 to +1630 are explained as follows:

Espenak & Meeus ignore Morrison & Stephenson’s values for -700 and -600, whereas the former Swiss Ephemeris versions used them. For -500 to +1600 Espenak & Meeus use polynomials whereas the former Swiss Ephemeris versions used a linear interpolation between Morrison / Stephenson’s tabulated values.

Differences in ΔT, SE 1.72 – SE 1.71

Year	Difference in seconds (new - old)
-3000	-4127
-2000	-2130
-1000	-760
0	-20
1000	-30
1600	10
1619	0.5
1620	0

Differences in ΔT, SE 1.64 – SE 1.63

Year	Difference in seconds (new - old)
-3000	2900
0	1200
1600	29
1619	60
1620	-0.6
1700	-0.4
1800	-0.1
1900	-0.02
1940	-0.001
1950	0
2000	0
2020	2
2100	23
3000	-400

In 1620, where the ΔT table of the Astronomical Almanac starts, there was a discontinuity of a whole minute in the old algorithms. This has been fixed with SE 1.64.

The smaller differences for the period 1620-1955 are due to a correction in the tidal acceleration of the Moon, which now has the same value as is also used by JPL for their T calculations.

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  http://rspa.royalsocietypublishing.org/lookup/doi/10.1098/rspa.2016.0404
- For a comprehensive collection of publications and formulae, see R.H. van Gent at http://www.phys.uu.nl/~vgent/astro/deltatime.htm.

8. Programming Environment

Swiss Ephemeris is written in portable C and the same code is used for creation of the 32-bit Windows DLL and the link library. All data files are fully portable between different hardware architectures.

To build the DLLs, we use Microsoft Visual C++ version 5.0 (for 32-bit).

The DLL has been successfully used in the following programming environments:

- Visual C++ 5.0 (sample code included in the distribution);
- Visual Basic 5.0 (sample code and VB declaration file included);
- Delphi 2 and Delphi 3 (32-bit, declaration file included).

As the number of users grows, our knowledge base about the interface details between programming environments and the DLL grows. All such information is added to the distributed Swiss Ephemeris and registered users are informed via an email mailing list.

Earlier version up to version 1.61 supported 16-bit Windows programming. Since then, 16-bit support has been dropped.

9. Swiss Ephemeris Functions

9.1. Swiss Ephemeris API

We give a short overview of the most important functions contained in the Swiss Ephemeris DLL. The detailed description of the programming interface is contained in the document swephprg.doc which is distributed together with the file you are reading.

9.1.1. Calculation of planets and stars

/* planets, Moon, asteroids, lunar nodes, apogees, fictitious bodies;

* input time must be ET/TT */

swe_calc();

/* same, but input time must be UT */

swe_calc_ut();

/* fixed stars; input time must be ET/TT */

swe_fixstar();

/* fixed stars; input time must be UT */

swe_fixstar_ut();

9.1.2. Date and time conversion

/* delta t from Julian day number

* Ephemeris time (ET) = Universal time (UT) + **swe_deltat**(UT)*/

swe_deltat();

/* Julian day number from year, month, day, hour, */

swe_date_conversion();

/* Julian day number from year, month, day, hour */

swe_julday();

/* year, month, day, hour from Julian day number */

swe_revjul();

/* UTC to Julian day number */

swe_utc_to_jd();

/* Julian day number TT to UTC */

swe_jdet_to_utc();

/* Julian day number UT1 to UTC */

swe_jdut1_to_utc();

/* utc to time zone or time zone to utc*/

swe_utc_time_zone();

/* get tidal acceleration used in **swe_deltat()** */

swe_get_tid_acc();

/* set tidal acceleration to be used in **swe_deltat()** */

swe_set_tid_acc();

9.1.3. Initialization, setup, and closing functions

/* set directory path of ephemeris files */

swe_set_ephe_path();

/* set name of JPL ephemeris file */

swe_set_jpl_file();

/* close Swiss Ephemeris */

swe_close();

9.1.4. House calculation

/* sidereal time */

swe_sidtime();

/* house cusps, ascendant, MC, armc, vertex */

swe_houses();

9.1.5. Auxiliary functions

/* coordinate transformation, from ecliptic to equator or vice-versa. */

swe_cotrans();

/* coordinate transformation of position and speed,

* from ecliptic to equator or vice-versa*/

swe_cotrans_sp();

/* get the name of a planet */

swe_get_planet_name();

/* normalization of any degree number to the range 0 ... 360 */

swe_degnorm();

9.1.6. Other functions that may be useful

PLACALC, the predecessor of SWISSEPH, included several functions that we do not need for SWISSEPH anymore. Nevertheless we include them again in our DLL, because some users of our software may have taken them over and use them in their applications. However, we gave them new names that were more consistent with SWISSEPH.

PLACALC used angular measurements in centiseconds a lot; a centisecond is 1/100 of an arc second. The C type CSEC or centisec is a 32-bit integer. CSEC was used because calculation with integer variables was considerably faster than floating point calculation on most CPUs in 1988, when PLACALC was written.

In the Swiss Ephemeris we have dropped the use of centiseconds and use double (64-bit floating point) for all angular measurements.

/* normalize argument into interval [0..DEG360]

* former function name: csnorm() */

swe_csnorm();

/* distance in centisecs p1 - p2 normalized to [0..360]

* former function name: difcsn() */

swe_difcsn();

/* distance in degrees * former function name: difdegn() */

swe_difdegn();

/* distance in centisecs p1 - p2 normalized to [-180..180[

* former function name: difcs2n() */

swe_difcs2n();

/* distance in degrees

* former function name: difdeg2n() */

swe_difdeg2n();

/* round second, but at 29.5959 always down

* former function name: roundsec() */

swe_csroundsec();

/* double to long with rounding, no overflow check

* former function name: d2l() */

swe_d2l();

/* Monday = 0, ... Sunday = 6

* former function name: day_of_week() */

swe_day_of_week();

/* centiseconds -> time string

* former function name: TimeString() */

swe_cs2timestr();

/* centiseconds -> longitude or latitude string

* former function name: LonLatString() */

swe_cs2lonlatstr();

/* centiseconds -> degrees string

* former function name: DegreeString() */

swe_cs2degstr();

Appendices

Appendix A.

The gravity deflection for a planet passing behind the Sun

The calculation of the apparent position of a planet involves a relativistic effect, which is the curvature of space by the gravity field of the Sun. This can also be described by a semi-classical algorithm, where the photon travelling from the planet to the observer is deflected in the Newtonian gravity field of the Sun, where the photon has a non-zero mass arising from its energy. To get the correct relativistic result, a correction factor 2.0 must be included in the calculation.

A problem arises when a planet disappears behind the solar disk, as seen from the Earth. Over the whole 6000 year time span of the Swiss Ephemeris, it happens often.

Planet Number of passes behind the Sun

Mercury 1723

Venus 456

Mars 412

Jupiter 793

Saturn 428

Uranus 1376

Neptune 543

Pluto 57

A typical occultation of a planet by the Solar disk, which has a diameter of approx. _ degree, has a duration of about 12 hours. For the outer planets it is mostly the speed of the Earth's movement which determines this duration.

Strictly speaking, there is no apparent position of a planet when it is eclipsed by the Sun. No photon from the planet reaches the observer's eye on Earth. Should one drop gravitational deflection, but keep aberration and light-time correction, or should one switch completely from apparent positions to true positions for occulted planets? In both cases, one would come up with an ephemeris which contains discontinuities, when at the moment of occultation at the Solar limb suddenly an effect is switched off.

Discontinuities in the ephemeris need to be avoided for several reasons. On the level of physics, there cannot be a discontinuity. The planet cannot jump from one position to another. On the level of mathematics, a non-steady function is a nightmare for computing any derived phenomena from this function, e.g. the time and duration of an astrological transit over a natal body, or an aspect of the planet.

Nobody seems to have handled this problem before in astronomical literature. To solve this problem, we have used the following approach: We replace the Sun, which is totally opaque for electromagnetic waves and not transparent for the photons coming from a planet behind it, by a transparent gravity field. This gravity field has the same strength and spatial distribution as the gravity field of the Sun. For photons from occulted planets, we compute their path and deflection in this gravity field, and from this calculation we get reasonable apparent positions also for occulted planets.

The calculation has been carried out with a semi-classical Newtonian model, which can be expected to give the correct relativistic result when it is multiplied with a correction factor 2. The mass of the Sun is mostly concentrated near its center; the outer regions of the Solar sphere have a low mass density. We used the a mass density distribution from the Solar standard model, assuming it to have spherical symmetry (our Sun mass distribution m® is from Michael Stix, The Sun, p. 47). The path of photons through this gravity field was computed by numerical integration. The application of this model in the actual ephemeris could then be greatly simplified by deriving an effective Solar mass which a photon "sees" when it passes close by or "through" the Sun. This effective mass depends only from the closest distance to the Solar center which a photon reaches when it travels from the occulted planet to the observer. The dependence of the effective mass from the occulted planet's distance is so small that it can be neglected for our target precision of 0.001 arc seconds.

For a remote planet just at the edge of the Solar disk the gravity deflection is about 1.8", always pointing away from the center of the Sun. This means that the planet is already slightly behind the Solar disk (with a diameter of 1800") when it appears to be at the limb, because the light bends around the Sun. When the planet now passes on a central path behind the Solar disk, the virtual gravity deflection we compute increases to 2.57 times the deflection at the limb, and this maximum is reached at _ of the Solar radius. Closer to the Solar center, the deflection drops and reaches zero for photons passing centrally through the Sun's gravity field.

We have discussed our approach with Dr. Myles Standish from JPL and here is his comment (private email to Alois Treindl, 12-Sep-1997):

> *"... it seems that your approach is entirely reasonable and can be easily justified as long as you choose a reasonable model for the density of the Sun. The solution may become more difficult if an ellipsoidal Sun is considered, but certainly that is an additional refinement which cannot be crucial."*

Appendix B.

A list of asteroids

```
# At the same time a brief introduction into asteroids
# =====================================================
#
# Literature:
# Lutz D. Schmadel, Dictionary of Minor Planet Names,
# Springer, Berlin, Heidelberg, New York
# Charles T. Kowal, Asteroids. Their Nature and Utilization,
# Whiley & Sons, 1996, Chichester, England
#
# What is an asteroid?
# --------------------
# Asteroids are small planets. Because there are too many
# of them and because most of them are quite small,
# astronomers did not like to call them "planets", but
# invented names like "asteroid" (Greek "star-like",
# because through telescopes they did not appear as planetary
# discs but as star like points) or "planetoid" (Greek
# "something like a planet"). However they are also often
```

```
# called minor planets.
# The minor planets can roughly be divided into two groups.
# There are the inner asteroids, the majority of which
# circles in the space between Mars and Jupiter, and
# there are the outer asteroids, which have their realm
# beyond Neptune. The first group consists of rather
# dense, Earth-like material, whereas the Transneptunians
# mainly consist of water ice and frozen gases. Many comets
# are descendants of the "asteroids" (or should one say
# "comets"?) belt beyond Neptune. The first Transneptunian
# objects (except Pluto) were discovered only after 1992
# and none of them has been given a name as yet.
#
# The largest asteroids
# ---------------------
# Most asteroids are actually only debris of collisions
# of small planets that formed in the beginning of the
# solar system. Only the largest ones are still more
# or less complete and round planets.
1 Ceres # 913 km goddess of corn and harvest
2 Pallas # 523 km goddess of wisdom, war and liberal arts
4 Vesta # 501 km goddess of the hEarth fire
10 Hygiea # 429 km goddess of health
511 Davida # 324 km after an astronomer David P. Todd
704 Interamnia # 338 km "between rivers", ancient name of
# its discovery place Teramo
65 Cybele # 308 km Phrygian Goddess, = Rhea, wife of Kronos-Saturn
52 Europa # 292 km beautiful mortal woman, mother of Minos by Zeus
87 Sylvia # 282 km
451 Patientia # 280 km patience
31 Euphrosyne # 270 km one of the three Graces, benevolence
15 Eunomia # 260 km one of the Hours, order and law
324 Bamberga # 252 km after a city in Bavaria
3 Juno # 248 km wife of Zeus
16 Psyche # 248 km "soul", name of a nymph
#
# Asteroid families
# -----------------
# Most asteroids live in families. There are several kinds
# of families.
# - There are families that are separated from each other
# by orbital resonances with Jupiter or other major planets.
# - Other families, the so-called Hirayama families, are the
# relics of asteroids that broke apart long ago when they
# collided with other asteroids.
# - Third, there are the Trojan asteroids that are caught
# in regions 60 degrees ahead or behind a major planet
# (Jupiter or Mars) by the combined gravitational forces
# of this planet and the Sun.
#
# Near Earth groups:
# ------------------
# Aten family: they cross Earth; mean distance from Sun is less than Earth
2062 Aten # an Egyptian Sun god
```

```
2100 Ra-Shalom # Ra is an Egyptian Sun god, Shalom is Hebrew "peace"
# was discovered during Camp David mid-east peace conference
#
# Apollo family: they cross Earth; mean distance is greater than Earth
1862 Apollo # Greek Sun god
1566 Icarus # wanted to fly to the sky, fell into the ocean
# Icarus crosses Mercury, Venus, Earth, and Mars
# and has his perihelion very close to the Sun
3200 Phaethon # wanted to drive the solar chariot, crashed in flames
# Phaethon crosses Mercury, Venus, Earth, and Mars
# and has his perihelion very close to the Sun
#
# Amor family: they cross Mars, approach Earth
1221 Amor # Roman love god
433 Eros # Greek love god
#
# Mars Trojans:
# -------------
5261 Eureka # a mars Trojan
#
# Main belt families:
# -------------------
# Hungarias: asteroid group at 1.95 AU
434 Hungaria # after Hungary
# Floras: Hirayama family at 2.2 AU
8 Flora # goddess of flowers
# Phocaeas: asteroid group at 2.36 AU
25 Phocaea # maritime town in Ionia
# Koronis family: Hirayama family at 2.88 AU
158 Koronis # mother of Asklepios by Apollo
# Eos family: Hirayama family at 3.02 AU
221 Eos # goddess of dawn
# Themis family: Hirayama family at 3.13 AU
24 Themis # goddess of justice
#
# Hildas: asteroid belt at 4.0 AU, in 3:2 resonance with Jupiter
---------------------------------------------------------------
# The Hildas have fairly eccentric orbits and, at their
# aphelion, are very close to the orbit of Jupiter. However,
# at those times, Jupiter is ALWAYS somewhere else. As
# Jupiter approaches, the Hilda asteroids move towards
# their perihelion points.
153 Hilda # female first name, means "heroine"
# a single asteroid at 4.26 AU, in 4:3 resonance with Jupiter
279 Thule # mythical center of Magic in the uttermost north
#
# Jupiter Trojans:
# ----------------
# Only the Trojans behind Jupiter are actually named after Trojan heroes,
# whereas the "Trojans" ahead of Jupiter are named after Greek heroes that
# participated in the Trojan war. However there have been made some mistakes,
# i.e. there are some Trojan "spies" in the Greek army and some Greek "spies"
# in the Trojan army.
# Greeks ahead of Jupiter:
```

```
624 Hector # Trojan "spy" in the Greek army, by far the greatest
# Trojan hero and the greatest Trojan asteroid
588 Achilles # slayer of Hector
1143 Odysseus
# Trojans behind Jupiter:
1172 Äneas
3317 Paris
884 Priamus
#
# Jupiter-crossing asteroids:
# ---------------------------
3552 Don Quixote # perihelion near Mars, aphelion beyond Jupiter;
# you know Don Quixote, don't you?
944 Hidalgo # perihelion near Mars, aphelion near Saturn;
# after a Mexican national hero
5335 Damocles # perihelion near Mars, aphelion near Uranus;
# the man sitting below a sword suspended by a thread
#
# Centaurs:
# ---------
2060 Chiron # perihelion near Saturn, aphelion near Uranus
# educator of heros, specialist in healing and war arts
5145 Pholus # perihelion near Saturn, aphelion near Neptune
# seer of the gods, keeper of the wine of the Centaurs
7066 Nessus # perihelion near Saturn, aphelion in Pluto's mean distance
# ferryman, killed by Hercules, kills Hercules
#
# Plutinos:
# ---------
# These are objects with periods similar to Pluto, i.e. objects
# that resonate with the Neptune period in a 3:2 ratio.
# There are no Plutinos included in Swiss Ephemeris so far, but
# PLUTO himself is considered to be a Plutino type asteroid!
#
# Cubewanos:
# ----------
# These are non-Plutiono objects with periods greater than Pluto.
# The word "Cubewano" is derived from the preliminary designation
# of the first-discovered Cubewano: 1992 QB1
20001 1992 QB1 # will be given the name of a creation deity
# (fictitious catalogue number 20001!)
# Other Transplutonians:
20001 1996 TL66 # mean solar distance 85 AU, period 780 years
# Asteroids that challenge hypothetical planets astrology
------------------------------------------------------------------------------
42 Isis # not identical with "Isis-Transpluto"
# Egyptian lunar goddess
763 Cupido # different from Witte's Cupido
# Roman god of sexual desire
4341 Poseidon # not identical with Witte's Poseidon
# Greek name of Neptune
4464 Vulcano # compare Witte's Vulkanus
# and intramercurian hypothetical Vulcanus
# Roman fire god
```

```
5731 Zeus # different from Witte's Zeus
# Greek name of Jupiter
1862 Apollo # different from Witte's Apollon
# Greek god of the Sun
398 Admete # compare Witte's Admetos
# "the untamed one", daughter of Eurystheus
#
# Asteroids that challenge Dark Moon astrology
--------------------------------------------
1181 Lilith # not identical with Dark Moon 'Lilith'
# first evil wife of Adam
3753 Cruithne # often called the "second Moon" of Earth;
# actually not a Moon, but an asteroid that
# orbits around the Sun in a certain resonance
# with the Earth.
# After the first Celtic group to come to the British Isles.
# Also try the two points 60 degrees in front of and behind the
# Moon, the so called Lagrange points, where the combined
# gravitational forces of the Earth and the Moon might imprison
# rocks and stones. There have been some photographic hints
# that there are clouds of such material around these points.
# They are called the Kordylewski clouds.
#
# Other asteroids
# ---------------
5 Astraea # a goddess of justice
6 Hebe # goddess of youth
7 Iris # rainbow goddess, messenger of the gods
8 Flora # goddess of flowers and gardens
9 Metis # goddess of prudence
10 Hygiea # goddess of health
14 Irene # goddess of peace
16 Psyche # "soul", a nymph
19 Fortuna # goddess of fortune
#
# Some frequent names:
# --------------------
# There are thousands of female first names in the asteroids list.
# Very interesting for relationship charts!
78 Diana
170 Maria
234 Barbara
375 Ursula
412 Elisabetha
542 Susanna
#
# Wisdom asteroids:
# -----------------
134 Sophrosyne # equanimity, healthy mind and impartiality
197 Arete # virtue
227 Philosophia
251 Sophia # wisdom (Greek)
259 Aletheia # truth
275 Sapientia # wisdom (Latin)
```

```
#
# Love asteroids:
# ---------------
344 Desiderata
433 Eros
499 Venusia
763 Cupido
1221 Amor
1387 Kama # Indian god of sexual desire
1388 Aphrodite # Greek love Goddess
1389 Onnie # what is this, after 1387 and 1388 ?
1390 Abastumani # and this?
#
# The Nine Muses
# --------------
18 Melpomene # Muse of tragedy
22 Kalliope # Muse of heroic poetry
23 Thalia # Muse of comedy
27 Euterpe # Muse of music and lyric poetry
30 Urania # Muse of astronomy and astrology
33 Polyhymnia # Muse of singing and rhetoric
62 Erato # Muse of song and dance
81 Terpsichore # Muse of choral dance and song
84 Klio # Muse of history
#
# Money and big busyness asteroids
# --------------------------------
19 Fortuna # goddess of fortune
904 Rockefellia
1338 Duponta
3652 Soros
#
# Beatles asteroids:
# ------------------
4147 Lennon
4148 McCartney
4149 Harrison
4150 Starr
#
# Composer Asteroids:
# -------------------
2055 Dvorak
1814 Bach
1815 Beethoven
1034 Mozartia
3941 Haydn
And there are many more...
#
# Astrodienst asteroids:
# ----------------------
# Programmers group:
3045 Alois
2396 Kochi
2968 Iliya # Alois' dog
```

```
# artists group:
412 Elisabetha
# Production family:
612 Veronika
1376 Michelle
1343 Nicole
1716 Peter
# Children group
105 Artemis
1181 Lilith
# Special interest group
564 Dudu
349 Dembowska
484 Pittsburghia
#
# By the year 1997, the statistics of asteroid names looked as follows:
# Men (mostly family names) 2551
# Astronomers 1147
# Women (mostly first names) 684
# Mythological terms 542
# Cities, harbours buildings 497
# Scientists (no astronomers) 493
# Relatives of asteroid discoverers 277
# Writers 249
# Countries, provinces, islands 246
# Amateur astronomers 209
# Historical, political figures 176
# Composers, musicians, dancers 157
# Figures from literature, operas 145
# Rivers, seas, mountains 135
# Institutes, observatories 116
# Painters, sculptors 101
# Plants, trees, animals 63
```

Appendix C.

How to Compare the Swiss Ephemeris with Ephemerides of the JPL Horizons System

Time and again people complain that they find serious differences between the Swiss Ephemeris and JPL Horizons.

Comparing the Swiss Ephemeris with output from the JPL Horizons web interface is unfortunately not trivial. In the following, examples are given how you could proceed to arrive at "identical" positions.

First, if you use the Swiss Ephemeris test program swetest on your personal computer, please make sure you are using the most recent version of it. It can be downloaded from

- http://www.astro.com/ftp/swisseph/programs/.

Alternatively, you could use the online Swiss Ephemeris test page at

- http://www.astro.com/swisseph/swetest.htm .

Note that if you are using an old version of the Swiss Ephemeris, then your test results could be less satisfying.

If you choose to use swetest on your own computer, you must install the JPL data file de431.eph.

If the file is too big, then you can download the files sepl_18.se1 and semo_18.se1 from here:

- http://www.astro.com/ftp/swisseph/ephe/

Note, however, that our implementation of JPL algorithms works only with an original JPL file!

If the sepl* and semo* files are used, the algorithms of Astronomical Almanac will be used.

Using the online test page will be easier, because you need not worry about correct installation, and you will have the JPL data file available.

Test 1: Astrometric Positions ICRF/J2000

In your Internet browser call the following URL:

- http://ssd.jpl.nasa.gov/horizons.cgi

The following default settings appear:

Current Settings

Ephemeris Type [change] : **OBSERVER**
Target Body [change] : **Mars** [499]
Observer Location [change] : **Geocentric** [500]
Time Span [change] : Start=**2016-10-25**, Stop=**2016-11-24**, Step=**1 d**
Table Settings [change] : *defaults*
Display/Output [change] : *default* (formatted HTML)

Generate Ephemeris

This means, JPL proposes to calculate a geocentric ephemeris of Mars in one-day steps from today for a whole month.

If you click on the button "Generate Ephemeris", the following output will appear:

```
*****************************************************
Start time      : A.D. 2016-Oct-25 00:00:00.0000 UT
Stop  time      : A.D. 2016-Nov-24 00:00:00.0000 UT
Step-size       : 1440 minutes
*****************************************************
```

...

```
*****************************************************
 Date__(UT)__HR:MN     R.A._(ICRF/J2000.0)_DEC  AE
*****************************************************
$$SOE
 2016-Oct-25 00:00     19 22 24.47 -24 09 33.4   C
 2016-Oct-26 00:00     19 25 29.37 -24 02 30.7   C
 2016-Oct-27 00:00     19 28 34.34 -23 55 14.2   C
```

To reproduce this using the Swiss Ephemeris, one must call swetest with the following parameters:

swetest -b25.10.2016 -ut0 -p4 -j2000 -icrs -fTPAD -n3 -ejplde431.eph -noaberr -nodefl date (dmy) 25.10.2016 greg. 0:00:00 UT version 2.05.02b04

UT: 2457686.500000000 delta t: 68.423889 sec

TT: 2457686.500791943

Epsilon (true) 23°26'13.53062930

Nutation 0° 0' 0.00000000 0° 0' 0.00000000

25.10.2016 Mars 19h22'24.4737 -24° 9'33.4190

26.10.2016 Mars 19h25'29.3663 -24° 2'30.7408

27.10.2016 Mars 19h28'34.3430 -23°55'14.1576

If you are using the Swiss Ephemeris online test page, then you can enter the whole parameter string

-b25.10.2016 -ut0 -p4 -j2000 -icrs -fTPAD -n3 -ejplde431.eph -noaberr -nodefl

in the field "other options". You can ignore the other fields and leave them as they are.

The parameters "-j2000 -icrs -fTPAD" tell swetest to provide the positions in right ascension and declination relative to the reference frame ICRF/J2000.

The parameters "-noaberr -nodefl" tell the program to ignore aberration of light and gravitational light deflection, but include light-time in the calculation. These are so-called astrometric positions.

The parameter "-ejplde431.eph" tells swetest to use the newest JPL ephemeris DE431. Note this will only work if you have installed the DE431 data file on your computer or if you use the Swiss Ephemeris online test page.

The above comparison may be satisfying but it is not optimal. Please scroll up to "Current Settings" and click on [change] in the following line:

Table Settings [change] : defaults

In the lower table, activate the checkbox "extra precision", scroll down and click on "use settings above".

extra precision :	☑ -- output addition digits for RA/Dec quantities

Scroll down, click on the button "Use Settings Above".

Then click on the button "Generate Ephemeris" again.

Now JPL provides four more digits.

```
*******************************************************
 Date__(UT)__HR:MN     R.A.__________(ICRF)_________DEC
*******************************************************
$$SOE
 2016-Oct-25 00:00     19 22 24.473182 -24 09 33.42012
 2016-Oct-26 00:00     19 25 29.365769 -24 02 30.74199
 2016-Oct-27 00:00     19 28 34.342464 -23 55 14.15882
 2016-Oct-28 00:00     19 31 39.385894 -23 47 43.70900
```

The comparison is still not optimal, because it is made in Universal Time (UT), and UT is understood as UTC, whereas the Swiss Ephemeris defines the parameter -ut as UT1. Since the current version of the Swiss Ephemeris (2.05.01) does not know a parameter for UTC, comparisons should be made in Terrestrial Time (TT). If the input date is in the current or a future year, there also may be considerable differences in Delta T values used by JPL and Swiss Ephemeris.

To create an ephemeris for TT using JPL Horizons, scroll up to "Current Settings" and click on [change] in the following line:

Time Span [change] : Start=2016-10-25, Stop=2016-11-24, Step=1 d

In the Start Time field add "TT" behind the date.

Start Time: 2016-10-25 TT

Then click on the button "Use Specified Times". After that click on "Generate Ephemeris" again.

The new output shows:

```
*******************************************************
Start time      : A.D. 2016-Oct-25 00:00:00.0000 TT
Stop  time      : A.D. 2016-Nov-24 00:00:00.0000 TT
```

...

```
*******************************************************
 Date__(TT)__HR:MN     R.A.__________(ICRF)_________DEC
*******************************************************
$$SOE
 2016-Oct-25 00:00     19 22 24.327309 -24 09 33.74818
 2016-Oct-26 00:00     19 25 29.219822 -24 02 31.08105
 2016-Oct-27 00:00     19 28 34.196458 -23 55 14.50883
```

...

Then call swetest as follows:

swetest -b25.10.2016 -p4 -j2000 -icrs -fTPAD -n3 -ejplde431.eph -noaberr -nodefl

date (dmy) 25.10.2016 greg. 0:00:00 ET version 2.05.02b04

TT: 2457686.500000000

Epsilon (true) 23°26'13.5306

Nutation 0° 0' 0.0000 0° 0' 0.0000

25.10.2016 Mars 19h22'24.3273 -24° 9'33.7482

26.10.2016 Mars 19h25'29.2198 -24° 2'31.0810

27.10.2016 Mars 19h28'34.1965 -23°55'14.5088

Now the agreement is perfect, the precision thus better than 1 mas.

Test 2: Inertial Apparent Positions, RA and DE, in ICRF

Now we are going to test apparent positions relative to the International Celestial Reference Frame (ICRF). This option was introduced in JPL Horizons version 4.70 in June 2020.

In the current settings of JPL Horizons click on [change] in the following line:

Table Settings [change] : extra precision=YES

In the upper options table uncheck all checkboxes.

After that activate

checkbox 45: "Apparent RA & DE".

The table now looks as follows:

1. ☐ Astrometric RA & DEC
* 2. ☐ Apparent RA & DEC
3. ☐ Rates; RA & DEC
* 4. ☐ Apparent AZ & EL
5. ☐ Rates; AZ & EL
6. ☐ Satellite X & Y, pos. angle
7. ☐ Local apparent sidereal time
8. ☐ Airmass & extinction
9. ☐ Visual mag. & Surface Brght
10. ☐ Illuminated fraction
11. ☐ Defect of illumination
12. ☐ Satellite angular separ/vis.
13. ☐ Target angular diameter
14. ☐ Observer sub-lon & sub-lat
15. ☐ Sun sub-longitude & sub-latitude
16. ☐ Sub-Sun position angle & distance
17. ☐ North Pole position angle & distance
18. ☐ Heliocentric ecliptic lon. & lat.
19. ☐ Heliocentric range & range-rate
20. ☐ Observer range & range-rate
21. ☐ One-way (down-leg) light-time
22. ☐ Speed wrt Sun & observer
23. ☐ Sun-Observer-Target ELONG angle
24. ☐ Sun-Target-Observer ~PHASE angle
25. ☐ Target-Observer-Moon angle/ Illum%
26. ☐ Observer-Primary-Target angle
27. ☐ Sun-Target radial & -vel pos. angle
28. ☐ Orbit plane angle
29. ☐ Constellation ID
30. ☐ Delta-T (TDB - UT)
* 31. ☐ Observer ecliptic lon. & lat.
32. ☐ North pole RA & DEC
33. ☐ Galactic longitude & latitude
34. ☐ Local apparent SOLAR time
35. ☐ Earth->obs. site light-time
> 36. ☐ RA & DEC uncertainty
> 37. ☐ Plane-of-sky error ellipse
> 38. ☐ POS uncertainty (RSS)
> 39. ☐ Range & range-rate 3-sigmas
> 40. ☐ Doppler & delay 3-sigmas
41. ☐ True anomaly angle
42. ☐ Local apparent hour angle
43. ☐ PHASE angle & bisector
44. ☐ Apparent longitude Sun (L_s)
* 45. ☑ Inertial apparent RA & DEC
46. ☐ Rate: Inertial RA & DEC

Notes:
* affected by optional atmospheric refraction setting (below)
> statistical value that uses orbit covariance if available

Observer quantities are described in the HORIZONS documentation.

[Use Selected Settings] [Cancel]

Below the table click on "Use Selected Settings".

After that click on "Generate Ephemeris" again. The output will show:

```
*******************************************************
 Date__(TT)__HR:MN     RA_(ICRF-airless-apparent)__DEC
******************************************************
$$SOE
 2016-Oct-25 00:00     19 22 23.976157 -24 09 35.15250
 2016-Oct-26 00:00     19 25 28.862261 -24 02 32.51791
 2016-Oct-27 00:00     19 28 33.832546 -23 55 15.97897
```

Then call swetest as follows:

swetest -b25.10.2016 -p4 -j2000 -icrs -fTPAD -n3 -ejplde431.eph

date (dmy) 25.10.2016 greg. 0:00:00 TT version 2.08.00a

UT: 2457686.499207094 delta t: 68.507111 sec

TT: 2457686.500000000

Epsilon (t/m) 23°26'13.53063031 23°26'13.53063031

Nutation 0° 0' 0.00000000 0° 0' 0.00000000

25.10.2016 Mars 19h22'23.9762 -24° 9'35.1525

26.10.2016 Mars 19h25'28.8623 -24° 2'32.5179

27.10.2016 Mars 19h28'33.8325 -23°55'15.9790

This matches very well again, the differences being smaller than 0.001 arc second.

Test 3: Apparent Positions, True Equinox of Date, RA, DE, Ecliptic Longitude and Latitude

Now we are going to test apparent positions relative to the true equinox of date.

In the current settings of JPL Horizons click on [change] in the following line:

Table Settings [change] : extra precision=YES

In the upper options table uncheck all checkboxes.

After that activate

checkbox 2. "Inertial Apparent RA & DE" and

checkbox 31. "observer ecliptic lon. & lat."

The table now looks as follows:

1. ☐ Astrometric RA & DEC	16. ☐ Sub-Sun position angle & distance	* 31. ☑ Observer ecliptic lon. & lat.
* 2. ☑ Apparent RA & DEC	17. ☐ North Pole position angle & distance	32. ☐ North pole RA & DEC
3. ☐ Rates; RA & DEC	18. ☐ Heliocentric ecliptic lon. & lat.	33. ☐ Galactic longitude & latitude
* 4. ☐ Apparent AZ & EL	19. ☐ Heliocentric range & range-rate	34. ☐ Local apparent SOLAR time
5. ☐ Rates; AZ & EL	20. ☐ Observer range & range-rate	35. ☐ Earth->obs. site light-time
6. ☐ Satellite X & Y, pos. angle	21. ☐ One-way (down-leg) light-time	> 36. ☐ RA & DEC uncertainty
7. ☐ Local apparent sidereal time	22. ☐ Speed wrt Sun & observer	> 37. ☐ Plane-of-sky error ellipse
8. ☐ Airmass & extinction	23. ☐ Sun-Observer-Target ELONG angle	> 38. ☐ POS uncertainty (RSS)
9. ☐ Visual mag. & Surface Brght	24. ☐ Sun-Target-Observer ~PHASE angle	> 39. ☐ Range & range-rate 3-sigmas
10. ☐ Illuminated fraction	25. ☐ Target-Observer-Moon angle/ Illum%	> 40. ☐ Doppler & delay 3-sigmas
11. ☐ Defect of illumination	26. ☐ Observer-Primary-Target angle	41. ☐ True anomaly angle
12. ☐ Satellite angular separ/vis.	27. ☐ Sun-Target radial & -vel pos. angle	42. ☐ Local apparent hour angle
13. ☐ Target angular diameter	28. ☐ Orbit plane angle	43. ☐ PHASE angle & bisector
14. ☐ Observer sub-lon & sub-lat	29. ☐ Constellation ID	
15. ☐ Sun sub-longitude & sub-latitude	30. ☐ Delta-T (TDB - UT)	

Notes:
* affected by optional atmospheric refraction setting (below)
> statistical value that uses orbit covariance if available

Observer quantities are described in the HORIZONS documentation.

Use Selected Settings   Cancel

Below the table click on "Use Selected Settings".

After that click on "Generate Ephemeris" again. The output will show:

```
*****************************************************************************
 Date__(TT)__HR:MN     R.A.___(airless-apparent)___DEC    ObsEcLon     ObsEcLat
*****************************************************************************
$$SOE
 2016-Oct-25 00:00     19 23 24.484938 -24 07 29.02520 288.9700709  -2.0525054
 2016-Oct-26 00:00     19 26 29.272705 -24 00 22.24615 289.6832955  -2.0365322
 2016-Oct-27 00:00     19 29 34.140273 -23 53 01.57658 290.3981125  -2.0204724
```

Then call swetest as follows:

swetest -b25.10.2016 -p4 -fTPADlb -n3 -ejplde431.eph -jplhora

date (dmy) 25.10.2016 greg. 0:00:00 ET version 2.05.02b04

TT: 2457686.500000000

Epsilon (true) 23°26’ 5.1372

Nutation -0° 0’ 7.1942 -0° 0’ 8.4288

25.10.2016 Mars 19h23’24.4849 -24° 7’29.0250 288.9700710 -2.0525051

26.10.2016 Mars 19h26’29.2727 -24° 0’22.2459 289.6832956 -2.0365320

27.10.2016 Mars 19h29’34.1403 -23°53’ 1.5764 290.3981125 -2.0204721

This matches very well again, the differences being smaller than 0.001 arc second.

The parameter -jplhora tells the program to emulate the methods of JPL horizons.

Better precision for current or recent dates would require daily updates for unpredictable motions of the celestial pole (free core nutation) and other micro-improvements. We are not freaky enough to do that.

Test 4: Heliocentric Apparent Positions, Ecliptic Longitude and Latitude

Now, let us do the same calculations heliocentrically by changing the observer location to “@sun”.

Current Settings

Ephemeris Type [change] : **OBSERVER**
Target Body [change] : **Mars Barycenter** [4]
Observer Location [change] : **Sun (body center)** [500@10]
Time Span [change] : Start=**2016-10-25 00:00 TT**, Stop=**2016-11-10**, Step=**1 d**
Table Settings [change] : QUANTITIES=**2,31**; extra precision=**YES**
Display/Output [change] : *default* (formatted HTML)

Now the resulting ephemeris looks as follows:

```
 Date__(TT)__HR:MN     R.A.___(airless-apparent)___DEC    ObsEcLon    ObsEcLat
********************************************************************************
$$SOE
 2016-Oct-25 00:00     22 35 35.562477 +05 17 06.88287 333.2945586  -1.7951611
 2016-Oct-26 00:00     22 38 08.475569 +05 18 25.83012 333.9296466  -1.7901713
 2016-Oct-27 00:00     22 40 41.410807 +05 19 42.43376 334.5647784  -1.7849614
```

And we just add the parameter -hel to the swetest command we have used above:

swetest -b25.10.2016 -p4 -fTPADlb -n3 -ejplde431.eph -jplhora -hel

25.10.2016 Mars 22h24’25.8882 -11°53’ 6.8990 333.5274937 -1.7959670

26.10.2016 Mars 22h26’50.3458 -11°38’56.8013 334.1625958 -1.7909547

27.10.2016 Mars 22h29’14.5668 -11°24’42.1490 334.7977357 -1.7857221

Here, we have a considerable difference between Horizons and swetest. Why?

The answer is found when we scroll down in the Horizons output. There we read:

```
 'R.A.___(airless-apparent)___DEC' =
  Airless apparent right ascension and declination of the target center with
respect to the center/site body's IAU 2009 equator (z-axis) and the meridian
containing ICRF x-axis. Compensated for light-time, the gravitational
deflection of light, stellar aberration, and IAU spin axis.
```

So, they are using the 2009 equator of the Sun, whereas swetest uses the true Earth equator of date. There is nothing wrong with either calculation, just Horizons does something different than swetest. Horizons’s positions cannot be reproduced using swetest, and the swetest data cannot be reproduced using Horizons.

As for the other two values (ObsEcLon and ObsEcLat), Horizons states:

```
 'ObsEcLon    ObsEcLat' =
   For a non-Earth observer, IAU76/80 standard epoch (J2000) Earth ecliptic
longitude and latitude of the target centers' apparent position, with
light-time, gravitational deflection of light, and stellar aberrations.
```

This means that in order to reproduce these values, we have to add the following parameters "-j2000 -icrs" to swetest:

swetest -b25.10.2016 -p4 -fTPADlb -n3 -ejplde431.eph -jplhora -hel -j2000 -icrs

25.10.2016 Mars 22h23'32.8216 -11°58'15.5314 333.2945511 -1.7951619

26.10.2016 Mars 22h25'57.3574 -11°44' 6.7775 333.9296388 -1.7901721

27.10.2016 Mars 22h28'21.6564 -11°29'53.4295 334.5647705 -1.7849622

These values (the red ones) again match very well with Horizons's data ObsEcLon and ObsEcLat.

Test 5: Ephemerides before 1962

The swetest call of Test 3 can reproduce JPL Horizons positions very well for its whole time range. For dates in the year 1800, Horizons provides the following data:

```
**************************************************************************
 Date__(TT)__HR:MN     R.A.__(airls-apparent)__DEC    ObsEcLon    ObsEcLat
*************************************************************************
$$SOE
 1800-Oct-25 00:00     03 17 43.4888 +17 14 09.207  51.5928235  -0.9812193
 1800-Oct-26 00:00     03 16 26.6083 +17 12 27.674  51.2899910  -0.9289477
 1800-Oct-27 00:00     03 15 07.5295 +17 10 37.930  50.9781655  -0.8760415
```

Using the above swetest parameters, we get the following values from SE 2.07 on:

swetest -b25.10.1800 -p4 -fTPADlb -n3 -ejplde431.eph -jplhora

date (dmy) 25.10.1800 greg. 0:00:00 TT version 2.06.01b03

TT: 2378793.500000000

Epsilon (true) 23°28' 3.5798

Nutation -0° 0' 5.9992 0° 0' 8.9010

25.10.1800 Mars 3h17'43.4887 17°14' 9.2071 51.5928231 -0.9812193

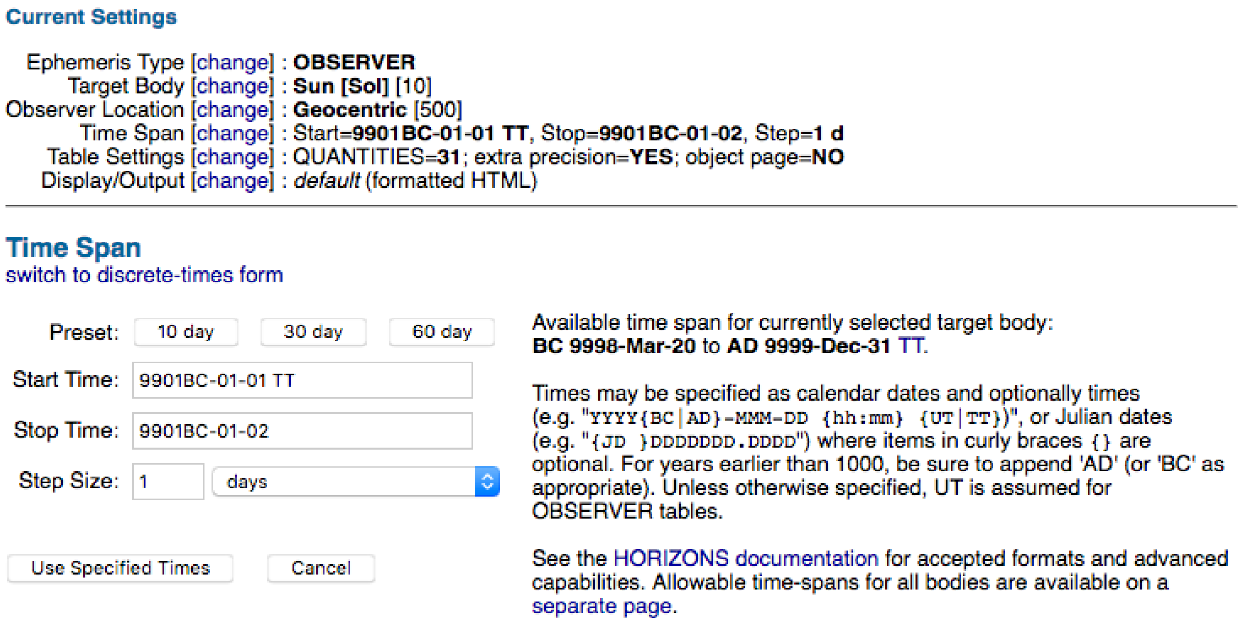
26.10.1800 Mars 3h16'26.6082 17°12'27.6742 51.2899907 -0.9289476

27.10.1800 Mars 3h15' 7.5294 17°10'37.9300 50.9781652 -0.8760415

This is better than 2 milliarcsec.

If comparing BCE dates, please note that the Swiss Ephemeris uses astronomical year numbering whereas JPL Horizons uses historical year numbering. The latter omits the year 0 so that the astronomical year 0 corresponds to the historical year 1 BCE.

E.g. you can set the date parameters in Horizons as follows:



The output is:

```
 Date__(TT)__HR:MN          ObsEcLon     ObsEcLat
***********************************************
$$SOE
b9901-Jan-01 00:00      206.2288432  -0.0001390
b9901-Jan-02 00:00      207.1940744  -0.0001709
$$EOE
```

This can be reproduced using the Swiss Ephemeris only **if the year is entered as -9900 (not 9901!)**:

swetest -b1.1.-9900 -p0 -fTPlb -ejplde431.eph -jplhora -n2

date (dmy) 1.1.-9900 jul. 0:00:00 TT version 2.06.01b03

TT: -1894917.500000000

Epsilon (true) 24° 9'53.63485083

Nutation 0° 0'14.26577554 0° 0' 0.69489094

01.01.-9900 Sun 206.2288423 -0.0001386

02.01.-9900 Sun 207.1940735 -0.0001706

The deviation amounts to only 3 milliarcsec.

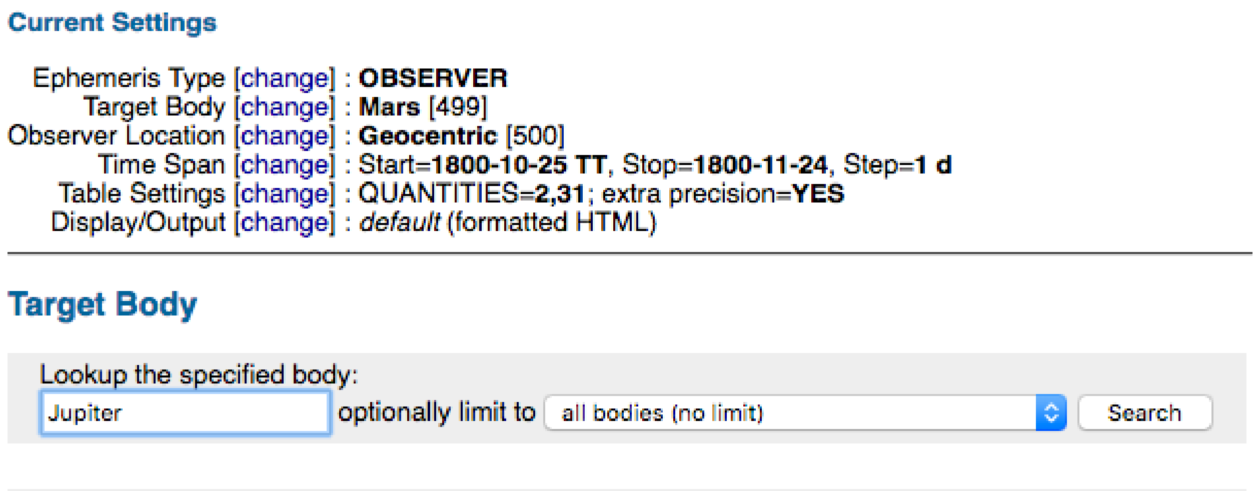
Test 6: Jupiter versus Jupiter Barycentre

There is another problem with planets that have a system of satellites, e.g. Jupiter.

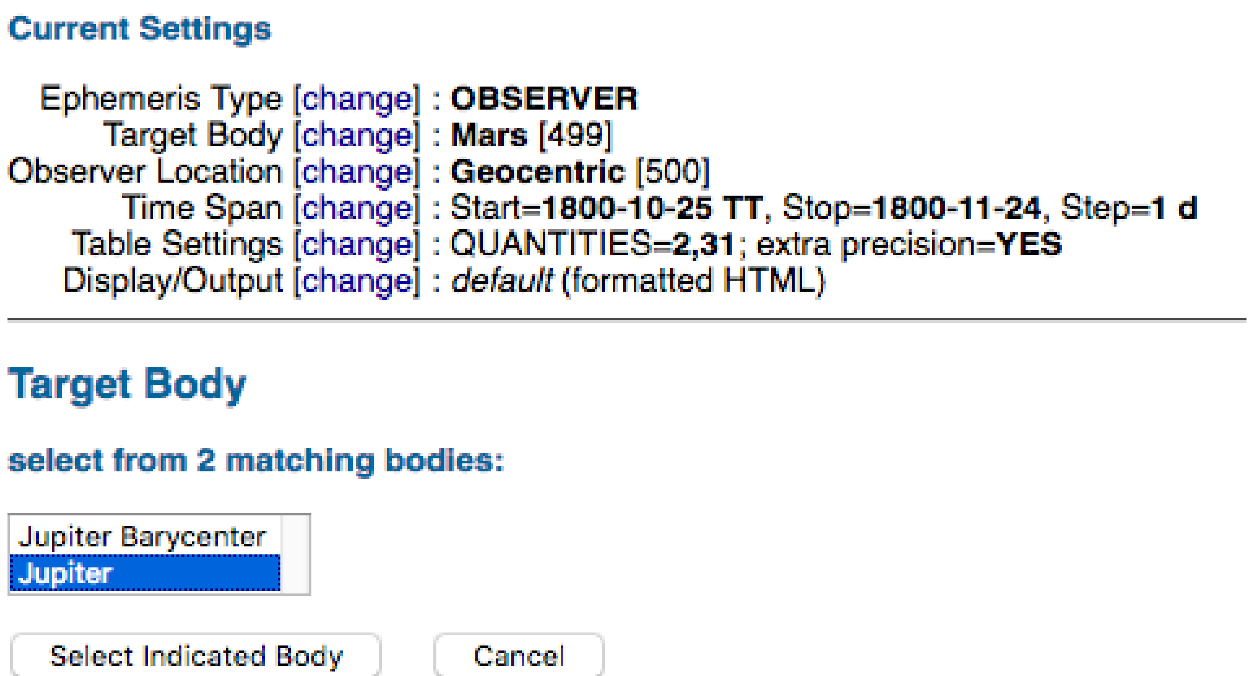
Scroll up and click on [change] in the following line:

Target Body [change] : Mars [499]

Then enter Jupiter in the field "Lookup the specified body" and click on the button "Search":



Then select "Jupiter" from the droplist and click on the button "Select Indicated Body":



After that, click on the button "Generate Ephemeris" again.

```
**************************************************************************
 Date__(TT)__HR:MN     R.A.__(airls-apparent)__DEC    ObsEcLon     ObsEcLat
*************************************************************************
$$SOE
 2016-Oct-25 00:00     12 37 35.2762 -02 50 16.599 189.7497503   1.1132116
 2016-Oct-26 00:00     12 38 21.2938 -02 55 05.752 189.9574460   1.1144625
 2016-Oct-27 00:00     12 39 07.1825 -02 59 53.719 190.1645071   1.1157503
```

Then call swetest using the same parameters that have been used for Mars:

swetest -b25.10.2016 -p5 -fTPADlb -n1 -ejplde431.eph -jplhora

date (dmy) 25.10.2016 greg. 0:00:00 ET version 2.05.02b04

TT: 2457686.500000000

Epsilon (true) 23°26' 5.1372

Nutation -0° 0' 7.1942 -0° 0' 8.4288

25.10.2016 Jupiter 12h37'35.2750 -2°50'16.5904 189.7497445 1.1132117

26.10.2016 Jupiter 12h38'21.2913 -2°55' 5.7347 189.9574345 1.1144628

27.10.2016 Jupiter 12h39' 7.1802 -2°59'53.7050 190.1644967 1.1157502

Here we find a difference that did not appear with Mars. It amounts to 0.02 arcsec.

This is explained by the fact that the Swiss Ephemeris provides the position of the barycentre of the system of Jupiter with his Moons, whereas JPL provides the position of the planet itself.

If we had selected "Jupiter Barycenter" in the drop list instead of "Jupiter", then we would have arrived at the following positions.

```
***************************************************************************
 Date__(TT)__HR:MN     R.A.__(airls-apparent)__DEC    ObsEcLon    ObsEcLat
***************************************************************************
$$SOE
 2016-Oct-25 00:00     12 37 35.2750 -02 50 16.591 189.7497445   1.1132116
 2016-Oct-26 00:00     12 38 21.2913 -02 55 05.735 189.9574345   1.1144627
 2016-Oct-27 00:00     12 39 07.1802 -02 59 53.705 190.1644968   1.1157501
```

This is very close to the value provided by the Swiss Ephemeris.

A similar effect could be observed with other planets that have Moons. In fact, it also appears with Mars, however his Moons are so extremely small that the effect did not appear in our comparison further above.

The fundamental JPL ephemeris DE431 does not provide the position of the centre of the disk of a planet, but only the centre of gravity of the planet's satellite system.

Test 7: Jupiter's Center of Body

Since Swiss Ephemeris version 2.10 (Nov. 2020), the center of Jupiter's body can also be calculated as follows:

swetest -b25.10.2016 -p5 -cob -fTPADlb -n3 -ejplde431.eph -jplhora (note -cob)

date (dmy) 25.10.2016 greg. 0:00:00 ET version 2.05.02b04

TT: 2457686.500000000

Epsilon (true) 23°26' 5.1372

Nutation -0° 0' 7.1942 -0° 0' 8.4288

25.10.2016 Jupiter 12h37'35.2762 -2°50'16.5997 189.7497501 1.1132113

26.10.2016 Jupiter 12h38'21.2937 -2°55' 5.7523 189.9574457 1.1144622

27.10.2016 Jupiter 12h39' 7.1824 -2°59'53.7197 190.1645068 1.1157500

The same output can also be generated using this command:

swetest -b25.10.2016 -pv -xv9599 -fTPADlb -n3 -ejplde431.eph -jplhora (note -pv -xv9599)

Horizons provides the following data:

```
***************************************************************************
 Date__(TT)__HR:MN     R.A.__(airls-apparent)__DEC    ObsEcLon    ObsEcLat
***************************************************************************
$$SOE
 2016-Oct-25 00:00     12 37 35.2762 -02 50 16.599 189.7497503   1.1132116
 2016-Oct-26 00:00     12 38 21.2938 -02 55 05.752 189.9574460   1.1144625
 2016-Oct-27 00:00     12 39 07.1825 -02 59 53.719 190.1645071   1.1157503
```

Again, we have an accuracy of 1 mas.

Important: All hitherto ephemerides and astrology softwares provide only the barycenter of the Jupiter system, i.e. the center of mass of Jupiter together with all his moons, not the center of Jupiter's body or the real planet.

Software developers who want to implement centers of body have to know that the performance of this calculation is not as good as with the barycenters. Moreover, the time range is currently limited to the years 1900 to 2047.

Test 8: Geocentric Position of a Planetary Moon

This test requires Swiss Ephemeris version 2.10 and the ephemeris files sepm* of directory sat.

We initialise Horizons to calculate geocentric apparent positions of Jupiter Moon Io:

Current Settings

Ephemeris Type [change] : **OBSERVER**
Target Body [change] : **Io (JI)** [501]
Observer Location [change] : **Geocentric** [500]
Time Span [change] : Start=**2016-10-25 00:00 TT**, Stop=**2016-11-10**, Step=**1 d**
Table Settings [change] : QUANTITIES=**31**; extra precision=**YES**
Display/Output [change] : *default* (formatted HTML)

The output is as follows:

```
 Date__(TT)__HR:MN        ObsEcLon    ObsEcLat
***********************************************
$$SOE
 2016-Oct-25 00:00     189.7447214   1.1123935
 2016-Oct-26 00:00     189.9522428   1.1156213
 2016-Oct-27 00:00     190.1792182   1.1144498
```

To reproduce this, swetest requires the parameters "-pv -xv9501". (For the numbering of the planetary Moons, we use Horizons's number + 9000, thus for Io 9000+501.)

swetest -b25.10.2016 -pv -xv9501 -fTPlb -n3 -ejplde431.eph -jplhora

25.10.2016 Io/Jupiter 189.7447220 1.1123951

26.10.2016 Io/Jupiter 189.9522434 1.1156229

27.10.2016 Io/Jupiter 190.1792187 1.1144514

Test 9: Planetocentric Position of a Planetary Moon

Now, we try the same choosing Jupiter himself as the observer location.

Depending on the selected moon, accuracy will usually be better than 1 arcsec, but not always. With some very-fast-moving, such as Phobos and Deimos, we cannot reach that.

Moreover, it must be noted that the current comparisons were made with Io's ephemeris of 11 September 2020. This date is given on the output page of Horizons:

Object Data Page

```
Revised: Sep 11, 2020          Io  / (Jupiter)                        501

SATELLITE PHYSICAL PROPERTIES:
 Radius (km)              = 1821.3 +- 0.2   Density (g cm^-3)   =  3.530 +- .006
```

Before a comparison is made, it should be made sure that Horizons has not updated its ephemeris.

The date of our Swiss Ephemeris file is seen in its header:

```
[dieter@as80 ~]$ more /home/ephe/sat/sepm9501*
SWISSEPH  1
sepm9501.se1
Copyright Astrodienst AG, Switzerland, 2020. Ephemeris based on JPL Ephemeris DE431.
009501 Io/Jupiter  Ephemeris / WWW_USER Thu Sep 17 11:11:38 2020 Pasadena, USA
```

If the "Revised" date in Horizons is younger than the one in the Swiss Ephemeris file, then it is likely that the latter is outdated and has lost accuracy.

Now, to do the comparison, in the field "Specify Origin: Named Body or Site", we enter "@599" for Jupiter, center of body.

Current Settings

Ephemeris Type [change] : **OBSERVER**
Target Body [change] : **Io (JI)** [501]
Observer Location [change] : **Jupiter (body center)** [500@599]
Time Span [change] : Start=**2016-10-25 00:00 TT**, Stop=**2016-11-10**, Step=**1 d**
Table Settings [change] : QUANTITIES=**31**; extra precision=**YES**
Display/Output [change] : *default* (formatted HTML)

The resulting output is:

```
 Date__(TT)__HR:MN        ObsEcLon    ObsEcLat
**********************************************
$$SOE
 2016-Oct-25 00:00     185.5872616  -1.0216307
 2016-Oct-26 00:00      28.8942452   1.7046442
 2016-Oct-27 00:00     232.9244661  -2.1166241
```

The swetest command to reproduce these data is:
swetest -b25.10.2016 -pv -xv9501 -pc9599 -fTPlb -n3 -ejplde431.eph -j2000 -icrs -jplhora

25.10.2016 Io/Jupiter 185.5872647 -1.0216308

26.10.2016 Io/Jupiter 28.8942489 1.7046449

27.10.2016 Io/Jupiter 232.9244695 -2.1166255

This demonstrates the high accuracy of the planetary moons in the Swiss Ephemeris very well. The difference is about 0.01".

If you want to compare other quantities in planetocentric mode, you will have to proceed as follows:

- choose the quantities in the Horizons interface

- click on "Generate Ephemeris"

- in the output, scroll down to the explanations at the bottom of the page

- read und try to understand what exactly Horizons does

- find out if swetest can do the same

In case it does not work, you are welcome to ask for help in the Swiss Ephemeris mailing list.

Please note that for quantity 2 (R.A. and Dec airless apparent), agreement between Horizons and swetest is not possible because Horizons uses the 2009 equator of the planet (e.g. Jupiter) whereas swetest always uses the true equator of date of the Earth.

For quantity 45, please use this command:

swetest -b25.10.2016 -pv -xv9501 -pc9599 -fTPAD -n3 -ejplde431.eph -j2000 -icrs

For quantity 1, this one:

swetest -b25.10.2016 -pv -xv9501 -pc9599 -fTPAD -n3 -ejplde431.eph -j2000 -icrs -noaberr -nodefl

Test 10: Topocentric Position of a Planet

To calculate the topocentric position of a planet proceed as follows:

Scroll up to “Current Settings”, change Target Body and select Venus.

After clicking on “Select Indicated Body”, change Time Span, edit

“Start Time” to “2015-09-01 05:00 TT” and

“Stop Time” to “2015-09-03”.

We choose a date near the heliacal rising of Venus, where the parallax effect is greater.

Then change Table Settings, activate only the checkboxes

2. Apparent RA & DEC and
31. Observer ecliptic lon. & lat.

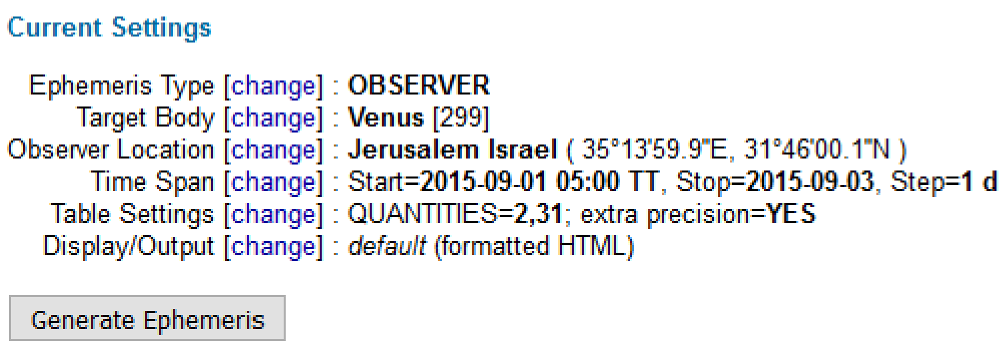
and uncheck all other options.

In the lower options table activate the option “extra precision”.

Scroll down and click on the button “Use Settings Above”.

Finally change Observer Location. In the field “Lookup Named Location” enter “Jerusalem” and click on the Button “Search”.

Now the current settings should look as follows:



Please check carefully if you have exactly these data and otherwise correct them.

Then click on “Generate Ephemeris”. The output is as follows:

```
*******************************************************************************
 Date__(TT)__HR:MN     R.A.__(airls-apparent)__DEC    ObsEcLon    ObsEcLat
*******************************************************************************
$$SOE
 2015-Sep-01 05:00 *m  09 00 32.0966 +09 03 13.614 134.9240535  -7.6248476
 2015-Sep-02 05:00 *m  08 59 56.4969 +09 12 43.098 134.7370776  -7.5147578
$$EOE
*******************************************************************************
```

In the current settings you see the geographic coordinates of Jerusalem as used by Horizons. You have to transform them into decimal values in order to use them with swetest.

Now call swetest as follows:

swetest -b01.09.2015 -t5 -p3 -fTPADlb -n2 -ejplde431.eph -jplhora -topo35.233305,31.766694,0

date (dmy) 1.9.2015 greg. 5:00:00 ET version 2.05.02b04

TT: 2457266.708333333

geo. long 35.233305, lat 31.766694, alt 0.000000

Epsilon (true) 23°26' 5.3157

Nutation 0° 0' 1.3321 -0° 0' 8.7886

01.09.2015 5:00:00 ET Venus 9h 0'32.0966 9° 3'13.6147 134.9240534 -7.6248475

02.09.2015 5:00:00 ET Venus 8h59'56.4969 9°12'43.0988 134.7370775 -7.5147577

This is very precise again. The geocentric positions would be:

swetest -b01.09.2015 -t5 -p3 -fTPADlb -n2 -ejplde431.eph -jplhora

date (dmy) 1.9.2015 greg. 5:00:00 ET version 2.05.02b04

TT: 2457266.708333333

Epsilon (true) 23°26' 5.3157

Nutation 0° 0' 1.3321 -0° 0' 8.7886

01.09.2015 5:00:00 ET Venus 9h 0'30.9799 9° 3'25.0943 134.9186940 -7.6230971

02.09.2015 5:00:00 ET Venus 8h59'55.4154 9°12'54.3289 134.7318831 -7.5130275

Note, if you specify the time as UT and call the Swiss Ephemeris with -ut5 (instead of -t5), then the deviation is slightly greater, because Horizons uses UTC, whereas the Swiss Ephemeris uses UT1. If the input date is in the current or a future year, there also may be differences in Delta T values used by JPL and the Swiss Ephemeris.

Significant deviations from Horizons only appear with the topocentric Moon, where our error can amount to 0.2 arcsec. We have not studied this difference so far, so do not know its exact cause.

Appendix D.

How to compare the Swiss Ephemeris with Ephemerides of the Astronomical Almanac (apparent positions)

Test 1: Astronomical Almanac online

Get a recent "Astronomical Almanac" from the library or your bookshelf. If you are too lazy to do that, go on the following page:

- http://asa.usno.navy.mil/SecE/Section_E.html

and click on "Geocentric equatorial coordinates".

The position of Mars for today (25 Oct 2016), 0:00 TT, is given as:

Mars 19 23 24.488 -24 07 29.03 1.2088279

Then call swetest using the following parameters:

swetest -b25.10.2016 -p4 -fTPADR -ejplde431.eph

date (dmy) 25.10.2016 greg. 0:00:00 ET version 2.05.02b04

TT: 2457686.500000000

Epsilon (true) 23°26' 5.1018

Nutation -0° 0' 7.1942 -0° 0' 8.4288

25.10.2016 Mars 19h23'24.4884 -24° 7'29.0249 1.208903220

There is a difference in the distance value R. The reason is that AA combines apparent RA and DE with true distance.

To arrive at the same distance value, call swetest as follows:

swetest -b25.10.2016 -p4 -fTPR -ejplde431.eph -true

date (dmy) 25.10.2016 greg. 0:00:00 ET version 2.05.02b04

TT: 2457686.500000000

Epsilon (true) 23°26' 5.1018

Nutation -0° 0' 7.1942 -0° 0' 8.4288

25.10.2016 Mars 1.208827910

which is identical to AA, but has more digits.

Test 2: Astronomical Almanac printed

If you are not too lazy to get a printed AA of a recent year or manage to get pages B68-B70 from AA 2016 in google books, there you will find an additional digit both in right ascension and declination.

Page B68 gives an example how to calculate the apparent position of Venus for 17 April 2016 12:00 UT1, assuming Delta T as 68s.

On p. B69, the corresponding TT is given as JD 2457496.000787.

On p. B70, the result is given as RA = 0h55m33s.8912, DE = 4°23'25".333.

The Swiss Ephemeris provides the same result if called with the following parameters:

swetest -bj2457496.000787 -p3 -fTPAD -ejplde431.eph

date (dmy) 17.4.2016 greg. 12:01:08 ET version 2.05.02b04

TT: 2457496.000787000

Epsilon (true) 23°26' 5.0046

Nutation -0° 0' 3.8526 -0° 0' 8.7703

17.04.2016 12:01:08 ET Venus 0h55'53.8912 4°23'25.3326

You may find that there is a difference of about 0.052 arcsec between JPL Horizons and Astronomical Almanac. For more information on this, please read the following paragraph in the general documentation of the Swiss Ephemeris:

- http://www.astro.com/swisseph/swisseph.htm?lang=g#_Toc443485363

(2.1.2.2 Swiss Ephemeris and JPL Horizons System)

Appendix E.

How to compare the Swiss Ephemeris Lahiri Ayanamsha with *Indian Astronomical Ephemeris* (IAE)

Problems

The ayanamsha values and explanations given in *Indian Astronomical Ephemeris* are unfortunately confusing. Clarification is difficult to achieve because older issues of IAE are difficult to get hold of, even for Indian members of the Swiss Ephemeris mailing list. In May 2020, I (D.K.) contacted the *Positional Astronomy Centre (PAC)* in Kolkata, the publisher of IAE, for precise information. On 29 June, I received a reply from L.M. Jyoti of PAC. My questions were not answered in detail, but Mr. Jyoti confirmed the correctness of my findings and said they would be important for "further modification of calculation of Indian Astronomical Ephemeris".

As to the precession model used, we know from IAE 1989, p. 525, that "Use of the Newcomb's value for general precession has been discontinued in this publication with effect from 1985". In what follows, a new precession formula is given which is taken Lieske's publication for the IAU1976 system.

In IAE 2019, p. 445, the following information is given:

"The algorithms for precession were based on the IAU (1976) value for the rate of general precession in ecliptic longitude. Nutation was given by the 1980 IAU Theory of Nutation. However, IAU (1976) rate of precession had been overestimated by approximately 3 milliarcseconds per year. Further observations also revealed periodic errors of a few milliarcseconds in the 1980 IAU Theory of Nutation."
"As part of the 2000 IAU resolutions, the IAU 2000A precession-nutation model was introduced, based on an updated value for the rate of precession and a completely new nutation theory."

So, which of the two precession models is used in IAE2019? Model IAU 1976 or IAU 2000A?

And there is more confusion:

In its original definition, "Lahiri" ayanamsha had the value 23°15'00" on the 21 March 1956, 0:00 Ephemeris Time. The definition was corrected by 0.658" in Indian Astronomical Ephemeris 1989, page 556, footnote:

"According to new determination of the location of equinox this initial value has been revised to 23°15'00".658 and used in computing the mean ayanamsha with effect from 1985'."

Thus, the mean (!) value of ayanamsha on the said date should be 23°15'00".658.

Again, in IAE 2019, p. 385, it says that the ayanamsha on this date was 23°15'00" exactly!

So, which initial value is actually used? Could the former be mean and the later true? This can be ruled out because nutation on that date was over 16".

More information is unfortunately not given or is hard to get hold of.

How to reproduce true ayanamshas given in IAE

IAE 2019, p. 427, gives a table of true ayanamsha values for the year 2019 and part of 2020. The values are given with a precision of 0.1 arcsec. They can be reproduced very precisely using the following assumptions:

- The initial value 23°15' 00".658 is true, not mean (!) ayanamsha.

- The precession model used is Lieske 1976 (IAU1976) and the nutation model is Wahr 1980.

The swetest command to be used is:

swetest -b1.1.2019 -ut0 -pb -sid1 -sidbit8192 -fTL -s3 -n130 (SE 2.09 required!)

This program call works from SE 2.09 on. The parameter -sidbit8192 causes the program to use this ayanamsha's original precession model, which is IAU1976. Please understand that this is only a test option. If you use it for horoscopes, the accuracy of the ephemeris will be reduced.

Date 2019		Ayanamsa		
		°	′	″
Jan.	1	24	07	06.0
	4	24	07	06.6
	7	24	07	07.3
	10	24	07	07.8
	13	24	07	08.1
	16	24	07	08.4
	19	24	07	09.1
	22	24	07	09.9
	25	24	07	10.2
	28	24	07	10.4
	31	24	07	10.9

swetest -b1.1.2019 -ut0 -pb -sid1 -sidbit8192 -fTL -s3 -n11 (SE 2.09 required!)

01.01.2019 24° 7' 5.9864

04.01.2019 24° 7' 6.5976

07.01.2019 24° 7' 7.3284

10.01.2019 24° 7' 7.8480

13.01.2019 24° 7' 8.1073

16.01.2019 24° 7' 8.3970

19.01.2019 24° 7' 9.0676

22.01.2019 24° 7' 9.8815

25.01.2019 24° 7'10.2273

28.01.2019 24° 7'10.4251

31.01.2019 24° 7'10.9122

This looks like perfect agreement. Only some very few values, outside the above list, differ by 0.1", which seems to be due to a systematic difference smaller than 0.001" (apparently in precession, not nutation!) which can show up in a different rounding.

However, the tabe in IAE 2020 gives greater differences. The rounded value often differs by 0.1". Something seems to have been changed, whatever that may be.

Date 2020	Ayanamsa		
	°	′	″
Jan. 1	24	07	54.8
4	24	07	55.0
7	24	07	55.5
10	24	07	56.3
13	24	07	57.0
16	24	07	57.3
19	24	07	57.6
22	24	07	58.3
25	24	07	59.0
28	24	07	59.4
31	24	07	59.5

swetest -b1.1.2020 -ut0 -pb -sid1 -sidbit8192 -fTL -s3 -n11 (SE 2.09 required!)

01.01.2020 24° 7’54.8411

04.01.2020 24° 7’55.0918

07.01.2020 24° 7’55.5135

10.01.2020 24° 7’56.2988

13.01.2020 24° 7’57.0629

16.01.2020 24° 7’57.3750

19.01.2020 24° 7’57.6643

22.01.2020 24° 7’58.3258

25.01.2020 24° 7’59.0403

28.01.2020 24° 7’59.4289

31.01.2020 24° 7’59.5804

This is very strange. Is it bad manual rounding?

The table in IAE 1989, p. 512, can be reproduced with high accuracy again, except that it seems there are some typos. E.g., for 10 May 1989, we get the value 23°42’37.4128, whereas IAE has 23°42’37.0, which must be a typo because almost all other values are very accurate.

How to reproduce mean ayanamshas given in IAE

The mean ayanamshas given in IAE are more difficult to reproduce. This is strange, since the only difference between the true and the mean ayanamsha should be the nutation, as is also stated on the same page: ”True Ayanamsa = Mean Ayanamsa + Nutation in Longitude”. Since we can reproduce true ayanamshas so well, mean ayanamshas should not cause any problem. Unfortunately also, it is not clear what is meant by epoch ”1989.0”. Is it 1 Jan. 0:00 TT or 12:00 TT or is it the Besselian epoch?

Using precession IAU 1976 and interpreting ”1989.0” as 0:00 TT of 1 Jan., our results compare as follows with the mean ayanamshas in IAE 1989, p. 512 (Swiss Ephemeris version 2.09 is required for all these calculations):

swetest -b1.1.1950 -nonut -fPZ -p -sid1 -sidbit8192 |grep ayanamsa
TT: 2433282.500000000 ayanamsa = 23°09’31.2539 (Lahiri) (IAE 1989: 23°09’30.79”) diff = 0.46”

swetest -b1.1.1989 -nonut -fPZ -p -sid1 -sidbit8192 |grep ayanamsa
TT: 2447527.500000000 ayanamsa = 23°42'12.3717 (Lahiri) (IAE 1989: 23°42'12.34") diff = 0.03"

swetest -b1.1.1990 -nonut -fPZ -p -sid1 -sidbit8192 |grep ayanamsa
TT: 2447892.500000000 ayanamsa = 23°43'02.6259 (Lahiri) (IAE 1989: 23°43'02.62") diff = 0.01"

The 1950 value has a considerably greater difference. This is explained by the fact that exactly the same value is given in "Indian Ephemeris and Nautical Almanac" (IENA) 1965, thus in a publication from a time before precession IAU 1976 existed. (IENA is the predecessor of IAE, which started in 1978.) It therefore seems that this value was taken over from an older publication, not calculated anew.

This obvious inconsistency of data is unfortunately not documented.

For IAE 2019, p. 429, we find the following differences in mean ayanamshas, if the time assumed is 12:00 TT on 1 Jan.(!):

swetest -b1.1.2000 -t12 -p -sid1 -fTL -nonut -sidbit8192

TT: 2451545.000000000 ayanamsa = 23°51'25.5324 (Lahiri) (IAE 2019: 23°51'25".53) diff = 0.00"

swetest -b1.1.2019 -t12 -p -sid1 -fTL -nonut -sidbit8192

TT: 2458485.000000000 ayanamsa = 24° 7'21.1353 (Lahiri) (IAE 2019: 23°07'21".20) diff = 0.06"

swetest -b1.1.2020 -t12 -p -sid1 -fTL -nonut -sidbit8192

TT: 2458850.000000000 ayanamsa = 24° 8'11.3962 (Lahiri) (IAE 2019: 23°08'11".46) diff = 0.06"

With no other precession model can we arrive at a better agreement with the mean ayanamsha. Perhaps they used some simplified precession algorithm, starting from an accurate value in 2000.

How to reproduce mean ayanamshas in Indian Ephemeris and Nautical Almanac (IENA)

IENA is the predecessor of IAE by which it was replaced in 1978. Its ayanamsha tables have exactly the same layout as IAE. Since ayanamsha was still based on the original ICRC definition (exactly 23°15' on 21 March 1956, its values must be compared with Swiss Ephemeris ayanamsha No. 46 (SE_SIDM_LAHIRI_ICRC).

The edition of 1973 explains the calculation of ayanamsha as follows:

474 EXPLANATION

PART V—INDIAN CALENDAR

The scope and significance of the information furnished in the section on *Indian Calendar* have been stated in the *Explanatory Note* on pages 402 and 403 at the beginning of the section. All calculations of this section have been done for the Central Station of India (82° 30′ E. Long. and 23° 11′ N. Lat.) and the results are given in Indian Standard Time.

For the calculation of *rāśis* and *nakṣatras* of this section, a fixed initial point on the ecliptic has been taken as the origin from which the longitudes are measured for this purpose. The tropical longitude of this initial point for March 21, 1956 is adopted as 23° 15′ 0″.0. The longitude of this initial point is known as *Ayanāṁśa* in Indian astronomy and the value of *ayanāṁśa* is to be subtracted from the tropical (or *sāyana*) longitudes of celestial objects to obtain the corresponding *nirayaṇa* longitudes of Indian astronomy. The value of mean ayanamsa for any date may be obtained from the following formula :

$$A = 22° 27' 37''.69 + 5025''.64\ T + 1''.11 T^2$$

where T is measured in tropical centuries from 1900.0 (Jan 0·813 E. T.)

$$\text{or } A = 22° 27' 37''.65 + 5025''.75 T + 1''.11 T^2$$

where T is in centuries of 36525 ephemeris days from 1900, January 0.5 E. T.

Unfortunately, we are not informed, that the value adopted in 1956 is true ayanamsha, what nutation value was subtracted, and how they arrived ath the given formulae.

On p. 445, it provides the following mean ayanamshas:

Ayanāṁśa = 23° 09′ 30″.79 + precession in longitude from 1950.0 to date.
= 23° 28′ 47″.00 + precession in longitude from 1973.0 to date.
= 23° 29′ 37″.27 + precession in longitude from 1974.0 to date.
Ayanāṁśa = Mean Ayanāṁśa + Nutation in longitude.

Using the above formula and the Besselian epoch, we get:

1950.0 tjd=2433282.42345905 23.1585533205 23°09'30.79195

1973.0 tjd=2441682.99403101 23.4797232708 23°28'47.00377

1974.0 tjd=2442048.23622979 23.4936879217 23°29'37.27652

This is pretty accurate. Now, the Swiss Ephemeris does not use the above formula but a rigorous precession calculation using the Kinoshita (1975) formulation of Newcomb precession. The mean ayanamshas for the same dates are:

(Swiss Ephemeris version 2.09 is required for all these calculations)

swetest -pb -fTL -bj2433282.42345905 -nonut -sid46 -sidbit8192 -s3 -n1

31.12.1949 22:09:47 TT 23° 9'30.72050620 (diff = 0.07")

swetest -pb -fTL -bj2441682.99403101 -nonut -sid46 -sidbit8192 -s3 -n1

31.12.1972 11:51:24 TT 23°28'46.93310 (diff = 0.07")

swetest -pb -fTL -bj2442048.23622979 -nonut -sid46 -sidbit8192 -s3 -n1

31.12.1973 17:40:10 TT 23°29'37.20587 (diff = 0.07")

The initital date for the above formula, i.e. 1900, Jan 0.5 ET = 31 Dec. 1899, 12 ET provides:

swetest -pb -fTL -bj2415020.0 -nonut -sid1 -sidbit8192 -s3 -n1

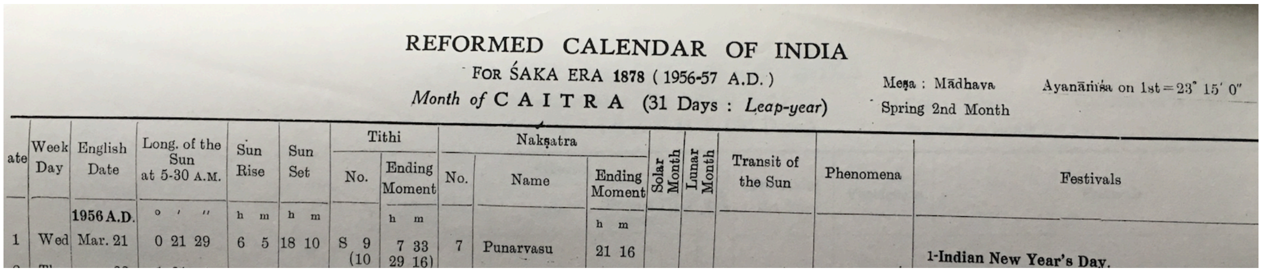
31.12.1899 12:00:00 TT 22°27'37.54705 (diff 0.1")

The reason for the constant difference of 0.07" from 1950 to 1973 could be that we chose the wrong initial ayanamsha value. True ayanamsha on 21 March 1956 was 23°15'. For mean aynamasha, we have to subtract nutation. We chose to subtract Woolard nutation, which was published 1953, however used by IENA/IAE only from 1960 on. Thus, a small correction of our initial value by 0.07" could help to reproduce the mean ayanamshas. With true ayanamshas, as given in IENA, however, an error of about 0.1 arcsec will remain, for unknown reasons.

Thus, there is currently no way to reproduce these values precisely using the Swiss Ephemeris because we do not have accurate information about what algorithms exactly were used. Another problem may be that the Swiss Ephemeris does its calculations in full precision, whereas IENA used some simplified algorithms.

How to reproduce true ayanamsha values given in the Report of the Calendar Reform Committee and in Rashtriya Panchang

The *Report of the ICRC* gives the ayanamsha value 23°15' 0" for the 1st of Caitra = 21 March 1956 (there are no page numbers).



REFORMED CALENDAR OF INDIA

FOR ŚAKA ERA 1878 (1956-57 A.D.)

Month of C A I T R A (31 Days : *Leap-year*)

Meṣa : Mādhava Ayanāṁśa on 1st = 23° 15′ 0″

Spring 2nd Month

ate	Week Day	English Date	Long. of the Sun at 5-30 A.M.	Sun Rise	Sun Set	Tithi No.	Tithi Ending Moment	Nakṣatra No.	Nakṣatra Name	Nakṣatra Ending Moment	Solar Month	Lunar Month	Transit of the Sun	Phenomena	Festivals
		1956 A.D.	° ′ ″	h m	h m		h m			h m					
1	Wed	Mar. 21	0 21 29	6 5	18 10	S 9 (10	7 33 29 16)	7	Punarvasu	21 16					1-Indian New Year's Day.

This can be reproduced as follows:

swetest -b21.3.1956 -p -sid46 -sidbit8192

date (dmy) 21.3.1956 greg. 0:00:00 TT version 2.08.00b

UT: 2435553.499636440 delta t: 31.411589 sec

TT: 2435553.500000000 ayanamsa = 23°15' 0.0000 (Lahiri ICRC)

For the 1st of Phalguna = 20 February 1959, it gives the ayanamsha value 23°17'16". Using swetest, this is reproduced as follows:

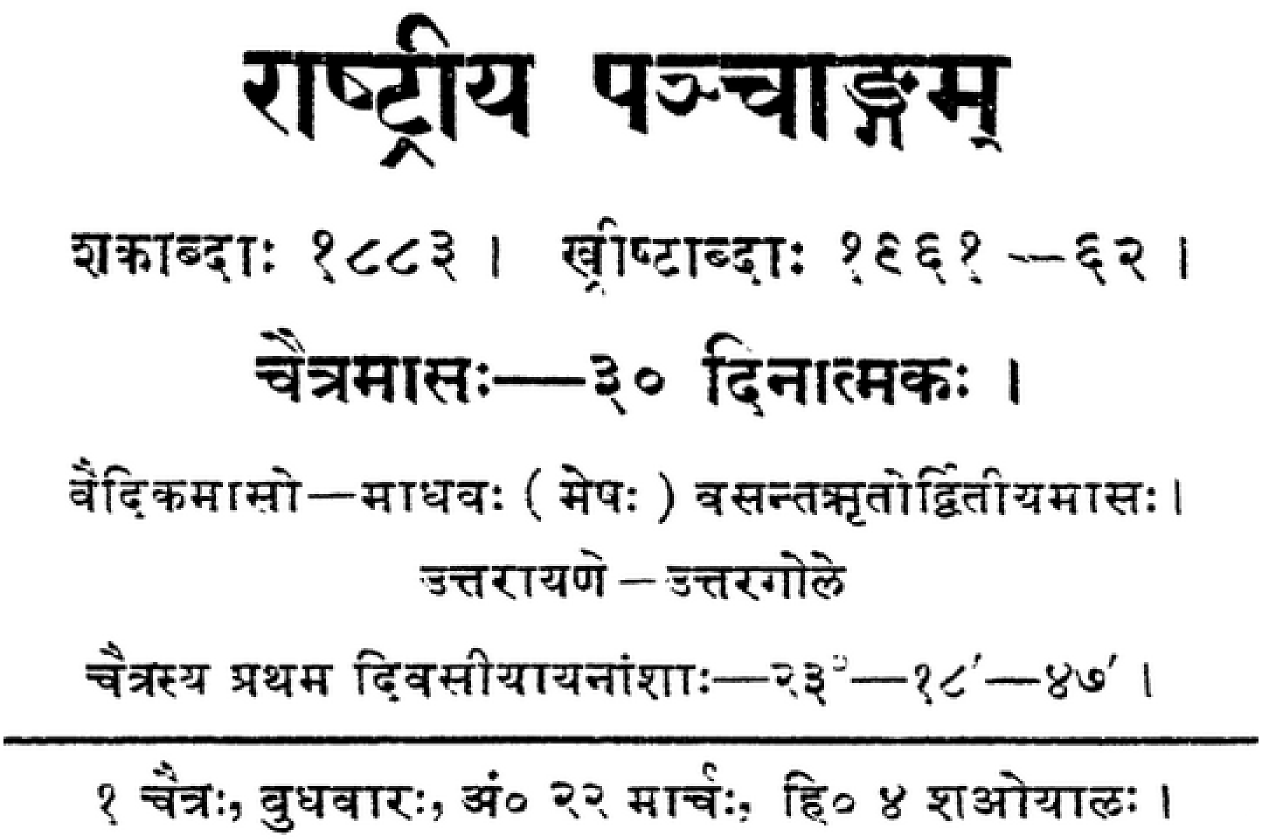
swetest -b20.2.1959 -p -sid46 -sidbit8192

date (dmy) 20.2.1959 greg. 0:00:00 TT version 2.08.00b

UT: 2436619.499620988 delta t: 32.746598 sec

TT: 2436619.500000000 ayanamsa = 23°17'15.9648 (Lahiri ICRC)

Rashtriya Panchang of *1961*, using the same ayanamsha, provides ayanamsha 23°18'47" on 1st of Caitra = 22 March 1961:



राष्ट्रीय पञ्चाङ्गम्

शकाब्दाः १८८३ । ख्रीष्टाब्दाः १९६१—६२ ।

चैत्रमासः—३० दिनात्मकः ।

वैदिकमासो—माधवः (मेषः) वसन्तऋतोर्द्वितीयमासः ।

उत्तरायणे—उत्तरगोले

चैत्रस्य प्रथम दिवसीयायनांशाः—२३°—१८′—४७′ ।

१ चैत्रः, बुधवारः, अं० २२ मार्चः, हि० ४ शओयालः ।

Using sweetest, we get:

swetest -b22.3.1961 -p -sid46 -sidbit8192

date (dmy) 22.3.1961 greg. 0:00:00 TT version 2.08.00b

UT: 2437380.499610181 delta t: 33.680306 sec

TT: 2437380.500000000 ayanamsa = 23°18'47.3511 (Lahiri ICRC)

Rashtriya Panchang of 2019 has the following value for the 1st of Caitra or 22 March 2019:

RASHTRIYA PANCHANG

1941 Saka Era, 5119-20 Kali Era, 2019 - 2020 A.D.

Month of CHAITRA : 30 days :: Vedic Month : Madhava (Mesha)

Nirayana months: 8 Chaitra, 5119 Kali to 7 Vaisakha, 5120 Kali :: 23 and 7 days

Vasanta Ritu : 2nd Month :: Uttarayana : Uttara Gola

Sun in Mina, enters Mesha on 24th :: Ayanamsa on 1st Chaitra : 24° 07′ 16″

Kali Ahargana : 1870099 - 1870128, *Julian Day :* 2458564.5 - 2458593.5

(Nirayana) Vaisakha begins on 24 Chaitra, 14 April, 2019

Friday, 1 Chaitra, (ni) 8 Chaitra, 22 March, 14 Rajab

swetest -b22.3.2019 -p -sid1 -sidbit8192

date (dmy) 22.3.2019 greg. 0:00:00 TT version 2.08.00b

UT: 2458564.499198334 delta t: 69.263905 sec

TT: 2458564.500000000 ayanamsa = 24° 7'16.2053 (Lahiri)

In a nutshell: Publications of IENA and IAE provide confusing and incomplete explanations for their calculation of ayanamsha. Due to the lack of reliable information, possibly also due to manual rounding errors and typos, it is difficult to accurately reproduce all data of IAE. Nevertheless, there is agreement to a second of arc or better.

It seems that precession IAU 1976 and nutation 1980 (Wahr) have been used since 1985 for true ayanamshas, and the Swiss Ephemeris can reproduce them accurately using ayanamsha No. 1 (SE_SIDM_LAHIRI), with some exceptions which are difficult to explain (IAE 2020). In editions of IAE/IENA before 1985, Newcomb precession and Woolard nutation was used, and their true ayanamshas can be reproduced with an accuracy of 0.1" using ayanamsha No. 46 (SE_SIDM_LAHIRI_ICRC). The reason for the remaining small error is unknown.

Important: In your software, *you should* ***not*** *use the option -sidbit8192 or the SE_SIDBIT…* that corresponds to it. It really only serves the purpose to test IAE values of ayanamsha, i.e. whether they are theoretically consistent with the Swiss Ephemeris. *Nor should you aim at exact agreement of Swiss Ephemeris ayanamsha values with IAE values* (up to 2020 at least), because the latter are based on outdated precession and nutation models. Also note that the option has practically no effect for planetary positions. E.g. let us calculate the position of the Sun for 3000 BCE with and without the option:

swetest -b21.3.-3000 -ut0 -p0 -sid1 -fTPL -s3 -n1 -nonut -sidbit8192

date (dmy) 21.3.-3000 jul. 0:00:00 UT version 2.09.01

UT: 625387.500000000 delta t: 75045.869961 sec

TT: 625388.368586458 ayanamsa = 314°45'13.0909 (Lahiri)

Epsilon (m) 24° 1'34.0132

21.03.-3000 Sun 21°24' 5.8667

swetest -b21.3.-3000 -ut0 -p0 -sid1 -fTPL -s3 -n1 -nonut

date (dmy) 21.3.-3000 jul. 0:00:00 UT version 2.09.01

UT: 625387.500000000 delta t: 75045.869961 sec

TT: 625388.368586458 ayanamsa = 314°44’30.0027 (Lahiri)

Epsilon (m) 24° 1’16.5231

21.03.-3000 Sun 21°24’ 5.9904

As can be seen, the position of the Sun is practically identical in both calculations, only the value of ayanamsha differs considerably. The reason is that the one calculation gives the ayanamsha relative to a tropical ephemeris which is based on the precession model IAU 1976 whereas the other provides a value relative to a tropical ephemeris which is based on the more modern precession model Vondrák 2011. Of course, the latter is desirable, not the former. For an in-depth understanding of this phenomenon, please study chapter 2.7.11 *Ayanamshas with different precession rates*.

Appendix F. Discussion of Differences between Versions

Differences between Swiss Ephemeris 1.70 and older versions

With version 1.70, the standard algorithms recommended by the IAU resolutions up to 2005 were implemented. The following calculations have been added or changed with Swiss Ephemeris version 1.70:

- ”Frame Bias” transformation from ICRS to J2000;
- Nutation IAU 2000B (could be switched to 2000A by the user);
- Precession model P03 (Capitaine/Wallace/Chapront 2003), including improvements in ecliptic obliquity and sidereal time that were achieved by this model.

The differences between the old and new planetary positions in ecliptic longitude (arc seconds) are:

Year	New − Old
2000	-0.00108
1995	0.02448
1980	0.05868
1970	0.10224
1950	0.15768
1900	0.30852
1800	0.58428
1799	-0.04644
1700	-0.07524
1500	-0.12636
1000	-0.25344
0	-0.53316
-1000	-0.85824
-2000	-1.40796
-3000	-3.33684
-4000	-10.64808
-5000	-32.68944
-5400	-49.15188

The discontinuity of the curve between 1800 and 1799 is explained by the fact that old versions of the Swiss Ephemeris used different precession models for different time ranges: the model IAU 1976 by Lieske for 1800-2200, and the precession model by Williams 1994 outside that time range.

Note: Precession model P03 is said to be accurate to 0.00005 arc second for CE 1000-3000.

The differences between version 1.70 and older versions for the future are as follows:

Year	Difference
2000	-0.00108
2010	-0.01620
2050	-0.14004
2100	-0.29448
2200	-0.61452
2201	0.05940
3000	0.27252
4000	0.48708
5000	0.47592
5400	0.40032

The discontinuity in 2200 has the same explanation as the one in 1800.

Jyotish / sidereal ephemerides The ephemeris changes by a constant value of about +0.3 arc second. This is because all our ayanamshas have the start epoch 1900, for which epoch precession was corrected by the same amount.

Fictitious planets / bodies from the orbital elements file seorbel.txt There are changes of several 0.1 arcsec, depending on the epoch of the orbital elements and the correction of precession as can be seen in the tables above.

The differences for ecliptic obliquity in arc seconds (new - old) are:

Year	Difference
5400	-1.71468
5000	-1.25244
4000	-0.63612
3000	-0.31788
2100	-0.06336
2000	-0.04212
1900	-0.02016
1800	0.01296
1700	0.04032
1600	0.06696
1500	0.09432
1000	0.22716
0	0.51444
-1000	1.07064
-2000	2.62908
-3000	6.68016
-4000	15.73272
-5000	33.54480
-5400	44.22924

The differences for sidereal time in seconds (new - old) are:

Year	Difference
5400	-2.544
5000	-1.461
4000	-0.122
3000	0.126
2100	0.019
2000	0.001
1900	0.019
1000	0.126
0	-0.122
-500	-0.594
-1000	-1.461
-2000	-5.029
-3000	-12.355
-4000	-25.330
-5000	-46.175
-5400	-57.273

Differences between Swiss Ephemeris 1.78 and 1.77

Former versions of the Swiss Ephemeris had used the precession model by Capitaine, Wallace, and Chapront of 2003 for the time range -5500 until 9500 and the precession model Laskar 1986 for epochs outside this time range. (Since planetary ephemerides are restricted to -5400 to +5400, Laskar precession is only relevant for calculations of fixed stars.)

Version 1.78 calculates precession and ecliptic obliquity according to Vondrák, Capitaine, and Wallace, "New precession expressions, valid for long time intervals", A&A 534, A22 (2011), which is good for +- 200 millennia.

This change has almost no ramifications for historical epochs. Planetary positions and the obliquity of the ecliptic change by less than an arc minute in 5400 BCE. However, for research concerning the prehistoric cave paintings (Lascaux, Altamira, etc., some of which may represent celestial constellations), fixed star positions are required for 15.000 BCE or even earlier (the Chauvet cave was painted in 33.000 BCE). Such calculations are now possible using the Swiss Ephemeris version 1.78 or higher. However, the Sun, Moon, and the planets remain restricted to the time range 5400 BCE to 5400 CE.

Differences (in arc sec) in precession (v. 1.78 – v. 1.77, test star was Aldebaran)

Only differences between -5500 and +9500 are differences Vondrák – P03. Those outside this time range are actually differences Vondrák – Laskar 1986.

Year	Difference
-20000	-26716"
-15000	-2691"
-10000	-256"
-5000	-3.95352"
-4000	-9.77940"
-3000	-7.00524"
-2000	-3.40524"
-1000	-1.23732"
0	-0.33948"
1000	-0.05400"
1800	-0.00108"
1900	-0.00036"
2000	0.00000"

Year	Difference
2100	-0.00036”
2200	-0.00072”
3000	0.03528”
4000	0.59904”
5000	2.90160”
10000	77”
15000	228”
19000	2839”
20000	5218”

Differences (in arc sec) in ecliptic obliquity:

Year	Difference
-20000	11074.43664”
-15000	3321.50652”
-10000	632.60532”
-5000	-33.42636”
0	0.01008”
1000	0.00972”
2000	0.00000”
3000	-0.01008”
4000	-0.05868”
10000	-72.91980”
15000	-772.91712”
20000	-3521.23488”

Differences between Swiss Ephemeris 2.00 and 1.80

These differences are explained by the fact that the Swiss Ephemeris is now based on JPL Ephemeris DE431, whereas before release 2.00 it was based on DE406. The differences are listed above in Ch. 2.1.1.3, see paragraph on “Comparison of JPL ephemerides DE406 (1998) with DE431 (2013)”.

Differences between Swiss Ephemeris 2.05.01 and 2.06

Swiss Ephemeris 2.06 has a new Delta T algorithm based on:

- Stephenson, F.R., Morrison, L.V., and Hohenkerk, C.Y., ”Measurement of the Earth’s Rotation: 720 BCE to CE 2015”, Royal Society Proceedings A, 7 Dec 2016,

http://rspa.royalsocietypublishing.org/lookup/doi/10.1098/rspa.2016.0404

The Swiss Ephemeris uses it for calculations before 1948.

Differences resulting from this update are shown in Chapter 7 on Delta T.

Appendix G.

Editing history

Date	what
14-sep-1997	Appendix A by Alois
15-sep-1997	split docu, swephprg.doc now separate (programming interface)
16-sep-1997	Dieter: absolute precision of JPL, position and speed transformations
24-sep-1997	Dieter: main asteroids
27-sep-1997	Alois: restructured for better HTML conversion, added public function list
8-oct-1997	Dieter: Chapter 4 (houses) added
28-nov-1997	Dieter: Chapter 5 (delta t) added
20-jan-1998	Dieter: Chapter 3 (more than...) added, Chapter 4 (houses) enlarged
14-jul-1998	Dieter: more about the precision of our asteroids
21-jul-1998	Alois: houses in PLACALC and ASTROLOG
27-jul-1998	Dieter: True node Chapter improved
2-sep-1998	Dieter: updated asteroid Chapter
29-nov-1998	Alois: added info on Public License and source code availability
4-dec-1998	Alois: updated asteroid file information
17-dec-1998	Alois: Section 2.1.5 added: extended time range to 10.800 years
17-dec-1998	Dieter: paragraphs on Chiron and Pholus ephemerides updated
12-jan-1999	Dieter: paragraph on eclipses
19-apr-1999	Dieter: paragraph on eclipses and planetary phenomena
21-jun-1999	Dieter: Chapter 2.27 on sidereal ephemerides
27-jul-1999	Dieter: Chapter 2.27 on sidereal ephemerides completed
15-feb-2000	Dieter: many things for Version 1.52
11-sep-2000	Dieter: a few additions for version 1.61
24-jul-2001	Dieter: a few additions for version 1.62
5-jan-2002	Alois: house calculation added to swetest for version 1.63
26-feb-2002	Dieter: Gauquelin sectors for version 1.64
12-jun-2003	Alois: code revisions for compatibility with 64-bit compilers, version 1.65
10-jul-2003	Dieter: Morinus houses for Version 1.66
12-jul-2004	Dieter: documentation of Delta T algorithms implemented with version 1.64
7-feb-2005	Alois: added note about mean lunar elements, section 2.2.1
22-feb-2006	Dieter: added documentation for version 1.70, see section 2.1.2.1-3
17-jul-2007	Dieter: updated documentation of Krusinski-Pisa house system.
28-nov-2007	Dieter: documentation of new Delta T calculation for version 1.72, see section 7
17-jun-2008	Alois: license change to dual license, GNU GPL or Professional License
31-mar-2009	Dieter: heliacal events
26-feb-2010	Alois: manual update, deleted references to CDROM
25-jan-2011	Dieter: Delta T updated, v. 1.77.
2-aug-2012	Dieter: new precession, v. 1.78.
23-apr-2013	Dieter: new ayanamshas
11-feb-2014	Dieter: many additions for v. 2.00
18-mar-2015	Dieter: documentation of APC house system and Pushya ayanamsha
21-oct-2015	Dieter: small correction in documentation of Lahiri ayanamsha
3-feb-2016	Dieter: documentation of house systems updated (equal, Porphyry, Pullen, Sripati)
22-apr-2016	Dieter: documentation of ayanamsha revised
10-jan-2017	Dieter: new Delta T
29-nov-2017	Dieter: update for comparison SwissEph - JPL Horizons using SE2.07; Ch. 2.1.6 added
4-jan-2018	Dieter: "Vedic"/Sheoran ayanamsha added
13-jun-2019	Dieter: small corrections for version 2.08
11-sep-2019	Simon Hren, documentation reformatted, merged with a recent unpublished update by Dieter
6-jan-2020	A few corrections by Simon Hren and updates by Dieter
24-jun-2020	Dieter: Chapters on ayanamsha improved; appendix E on Swiss Ephemeris versus IAE, IENA, RP

Date	what
24-jun-2020	Dieter: Appendix C: added Test 2a concerning inertial apparent positions with JPL Horizons
27-jun-2020	Dieter: small corrections in chapter 7 on Delta T
29-jun-2020	Dieter: small changes in Appendix E
1-dec-2020	Dieter: several Additions in Appendix E, concerning the centers of body of the planets, planetary moons, comets and 99942 Apophis
9-dec-2020	Dieter: "AD" replaced by "CE" and "BC" replaced by "BCE".
15-dec-2020	Alois: minor corrections
6-apr-2021	Dieter: Improved chapter 2.1.2.2. "Swiss Ephemeris and JPL Horizons System of Nasa"
11-aug-2021	Alois: converted from docx (Word) to md (Markdown) format as base format

Appendix H.

Swiss Ephemeris release history

1.00	30-sept-1997	what
1.01	9-oct-1997	simplified houses() and sidtime() functions, Vertex added.
1.02	16-oct-1997	houses() changed again
1.03	28-oct-1997	minor fixes
1.04	8-dec-1997	minor fixes
1.10	9-jan-1998	bug fix, pushed to all licensees
1.11	12-jan-1998	minor fixes
1.20	21-jan-1998	NEW: topocentric planets and house positions
1.21	28-jan-1998	Delphi declarations and sample for Delphi 1.0
1.22	2-feb-1998	asteroids moved to subdirectory. Swe_calc() finds them there.
1.23	11-feb-1998	two minor bug fixes.
1.24	7-mar-1998	documentation for Borland C++ Builder added
1.25	4-june-1998	sample for Borland Delphi-2 added
1.26	29-nov-1998	source added, Placalc API added
1.30	17-dec-1998	NEW: Time range extended to 10.800 years
1.31	12-jan-1999	NEW: Eclipses
1.40	19-apr-1999	NEW: planetary phenomena
1.50	27-jul-1999	NEW: sidereal ephemerides
1.52	15-feb-2000	several NEW features, minor bug fixes
1.60	15-feb-2000	major release with many new features and some minor bug fixes
1.61	11-sep-2000	minor release, additions to se_rise_trans(), swe_houses(), fictitious planets
1.62	23-jul-2001	minor release, fictitious Earth satellites, asteroid numbers > 55535 possible
1.63	5-jan-2002	minor release, house calculation added to swetest.c and swetest.exe
1.64	7-apr-2002	NEW: occultations of planets, minor bug fixes, new Delta T algorithms
1.65	12-jun-2003	minor release, small code renovations for 64-bit compilation
1.66	10-jul-2003	NEW: Morinus houses
1.67	31-mar-2005	minor release: Delta-T updated, minor bug fixes
1.70	2-mar-2006	IAU resolutions up to 2005 implemented; "interpolated" lunar apsides
1.72	28-nov-2007	Delta T calculation according to Morrison/Stephenson 2004
1.74	17-jun-2008	license model changed to dual license, GNU GPL or Professional License
1.76	31-mar-2009	NEW: Heliacal events
1.77	25-jan-2011	Delta T calculation updated acc. to Espenak/Meeus 2006, new fixed stars file

1.00	30-sept-1997	what
1.78	2-aug-2012	precession calculation updated acc. to Vondrák et alii 2012
1.79	23-apr-2013	new ayanamshas, improved precision of eclipse functions, minor bug fixes
1.80	3-sep-2013	security update and bugfixes
2.00	11-feb-2014	Swiss Ephemeris now based on JPL ephemeris DE431
2.01	18-mar-2015	bug fixes for version 2.00
2.02	11-aug-2015	new functions swe_deltat_ex() and swe_get_ayanamsa_ex(); bug fixes.
2.03	16-oct-2015	Swiss Ephemeris thread safe; minor bug fixes
2.04	21-oct-2015	V. 2.03 had DLL with calling convention ___cdecl; we return to _stdcall
2.05	22-apr-2015	new house methods, new ayanamshas, minor bug fixes
2.06	10-jan-2017	new Delta T, minor bug fixes
2.07	10-jan-2018	better performance of swe_fixstar() and swe_rise_trans()
2.08	13-jun-2019	update of Delta T and minor bug fixes
2.09	22-jul-2020	Improved Placidus houses, sidereal ephemerides, planetary magnitudes; minor bug fixes
2.10	10-dec-2020	NEW: planetary moons
2.10.01	5-may-2021	DE441 added to the list of usable JPL ephemerides
2.10.02	4-aug-2021	Added new functions swe_solcross etc.
2.10.03	27-aug-2022	bugfix release