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The Nautical Almanac 2021

Compiled with *Nautical Almanac* revision V2.5 - Mar 2020, using NOVAS version C3.1 - Mar 2011
The Almanac data have been produced with the JPL Ephemerides DE405

Warning and Terms of Usage:

The following pages have been generated by a computer program. Complex computer programs often have bugs and may produce wrong data. The data in this Nautical Almanac is believed to be accurate but no warranty is given for its correctness.

Use this Nautical Almanac only for training and exercising!

Compiled by Erik De Man (mail2erik@siranah.de) on Wed Sep 2 17:01:00 2020

Introduction

This Nautical Almanac contains the Ephemerides of the Sun, the Moon, Venus, Mars, Jupiter and Saturn. It is designed for determination of Position (geographical Latitude and Longitude) from astronomical observations (Altitude of Celestial Objects).

The data compiled in this Nautical Almanac is based on calculations done with the software package "NOVAS" from the U.S. Naval Observatory (<http://aa.usno.navy.mil/AA/software>). The basic ephemerides are taken from the "DE405" files published by the Jet Propulsion Laboratory (<http://ssd.jpl.nasa.gov>).

Values for "deltaT"

For the astrodynamical calculations, the following values for "delta T" (the difference between terrestrial time realized by atomic clocks and UT defined by the irregular rotation of the Earth) have been used:

Jan : 69.4 s	Apr : 69.4 s	Jul : 69.4 s	Oct : 69.4 s
Feb : 69.4 s	May : 69.4 s	Aug : 69.4 s	Nov : 69.4 s
Mar : 69.4 s	Jun : 69.4 s	Sep : 69.4 s	Dec : 69.4 s

Interpolation of the integral-hour GHA and Dec values

This Nautical Almanac uses a slightly different approach for the interpolation of the integral-hour values of Greenwich Hour Angle and Declination, compared to the techniques used in most commercially available Almanacs.

The almanac pages in this Nautical Almanac are compiled according to the following scheme:

UT	GHA		ddGHA	Dec		dDec
	°	'	'/h	°	'	'/h
...						
13:00	176	41.8	-31.3	S 23	09.6	+01.8
14:00	191	10.5	-31.3	S 23	11.4	+01.8
15:00	205	39.2	-31.3	S 23	13.2	+01.6
16:00	220	07.9	-31.3	S 23	14.8	+01.5
...						

The values for the Greenwich Hour Angle (GHA) and Declination (Dec) are given for the integral hours of Universal Time (UT). In the columns ddGHA and dDec the increment (+) or decrement (-) for the next one hour of time for the GHA and Dec are recorded. For the Greenwich Hour Angle (GHA) this value for increment/decrement is not the complete variation since each hour angle increases with about 15° per hour. The value ddGHA is only the increment/decrement additional to this fixed increment of 15° per hour. It is important to notice that for the interpolation of the GHA values, also this fixed increment of 15° per hour must be taken into account.

For more information please refer to the following web site: "<http://www.siranah.de/>"

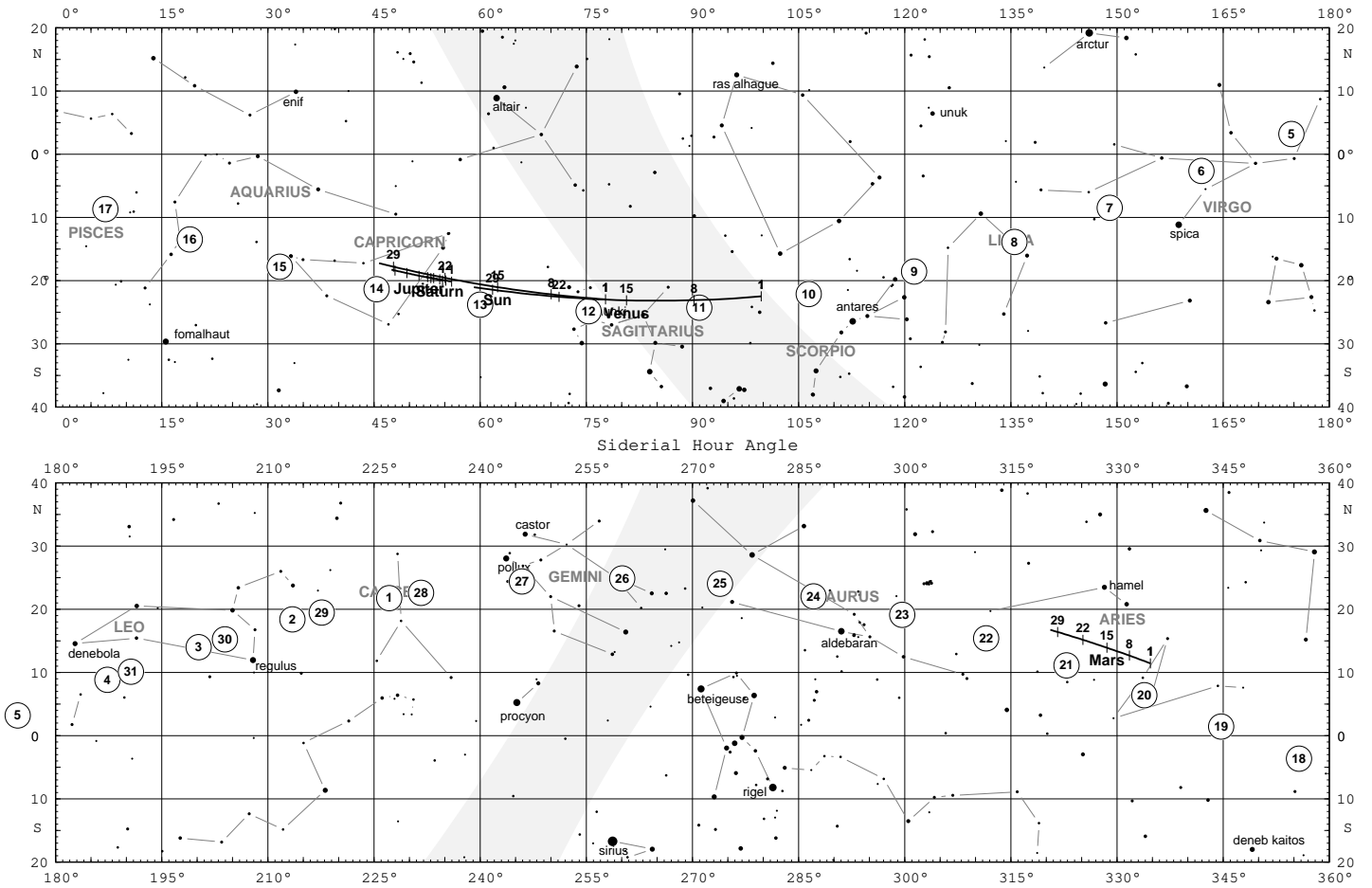
Positions of the Celestial Objects

The charts on the following pages show the position of the Celestial Objects used in this Nautical Almanac relative to the stars (celestial background). The charts can be used to find the location of the planets and also for the planning of astronomical observations.

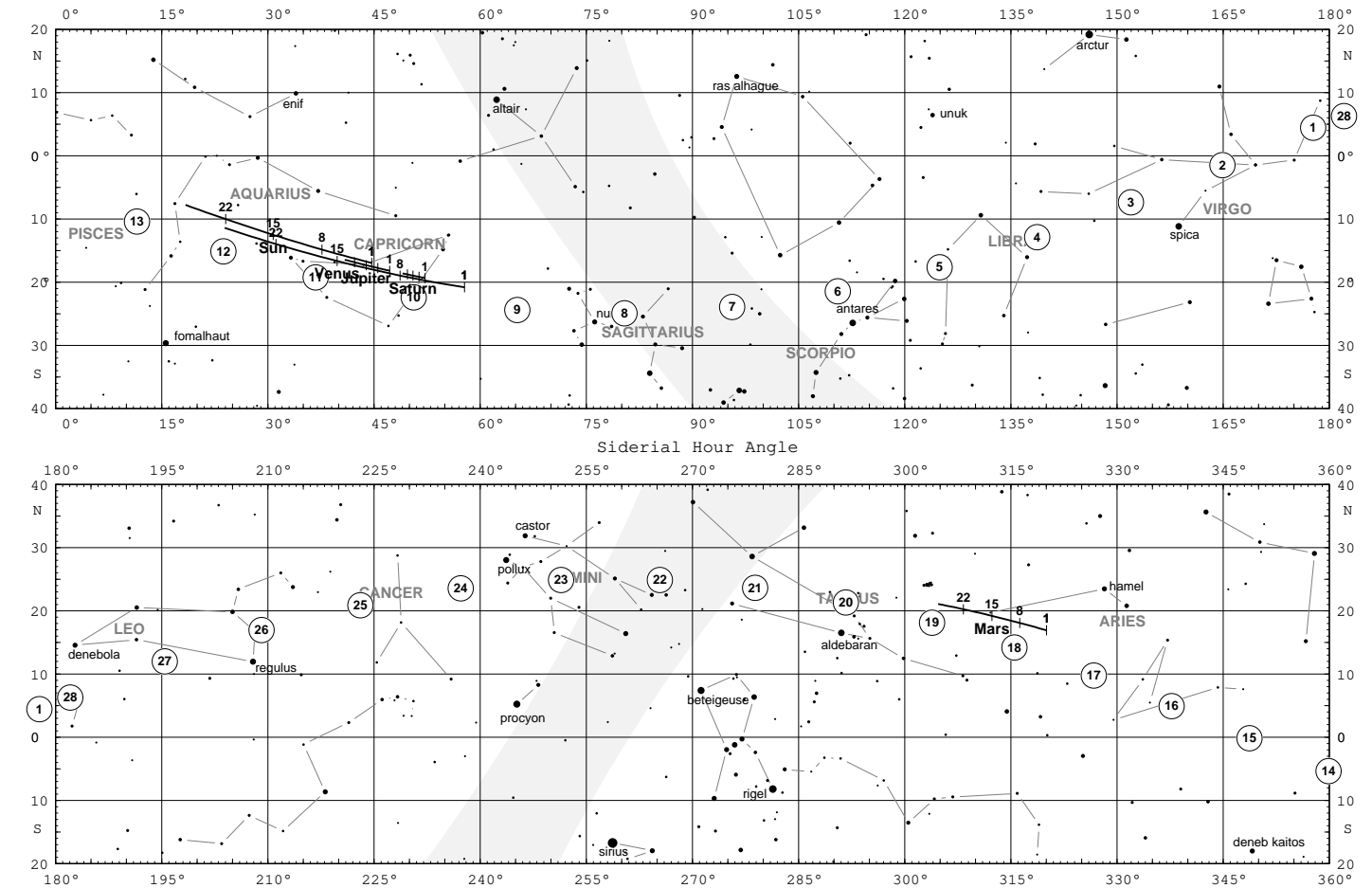
The charts are provided for each month of the year. Each chart has two parts showing a part of the celestial sphere around the ecliptic. Note that the position of the Celestial Equator (Declination = 0°) is not on the same position in the two different parts of each of the charts.

The changing position of a Celestial Object through the month is drawn as a solid line (not for the Moon). Marker ticks along this line are shown to indicate the position of the Object on the 1st, 8th, 15th, 22nd and 29th day of the month (at 12:00 UT). For Jupiter and Saturn only the first day is marked since their apparent position does not change significantly over the period of one month. The position of the Moon is shown by a small circle for each individual day of the month. Notice that the circles are much larger than the apparent size of the Moon.

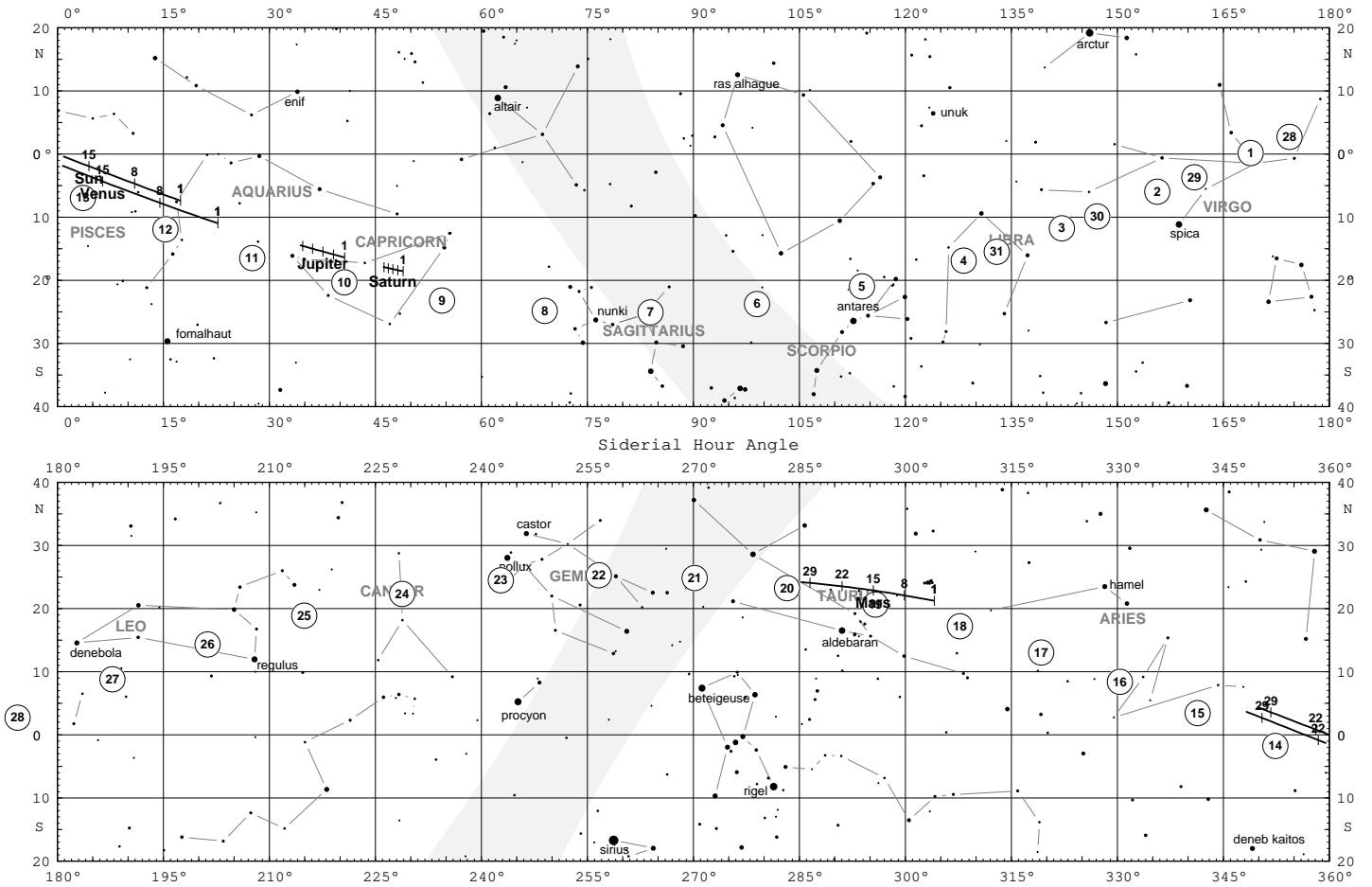
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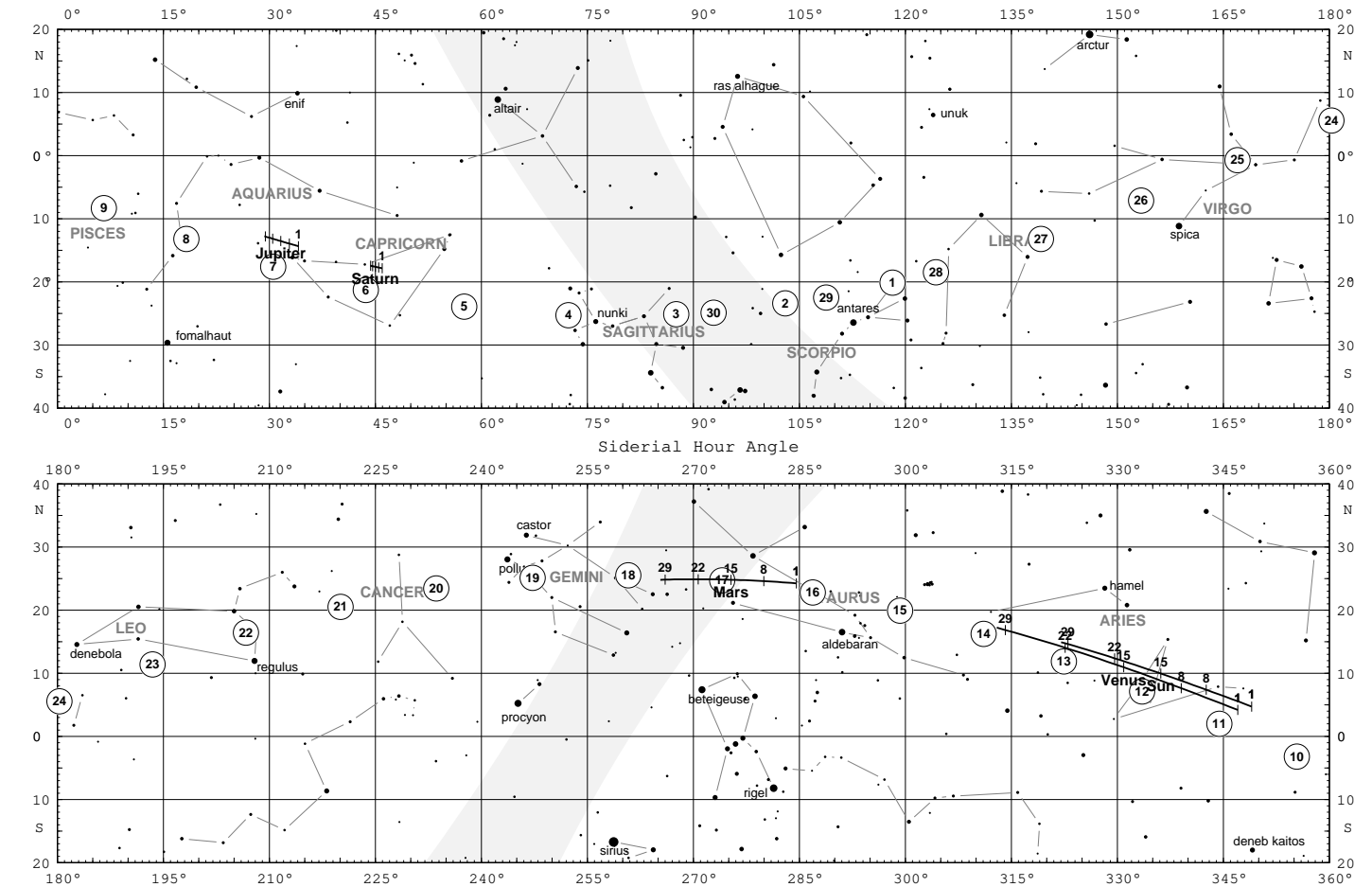
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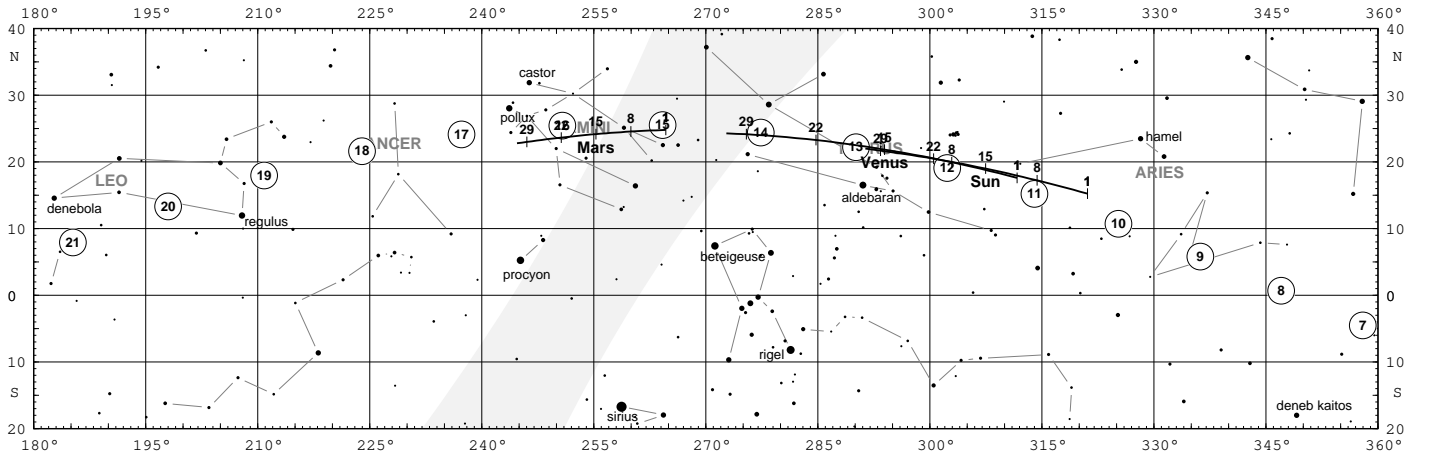
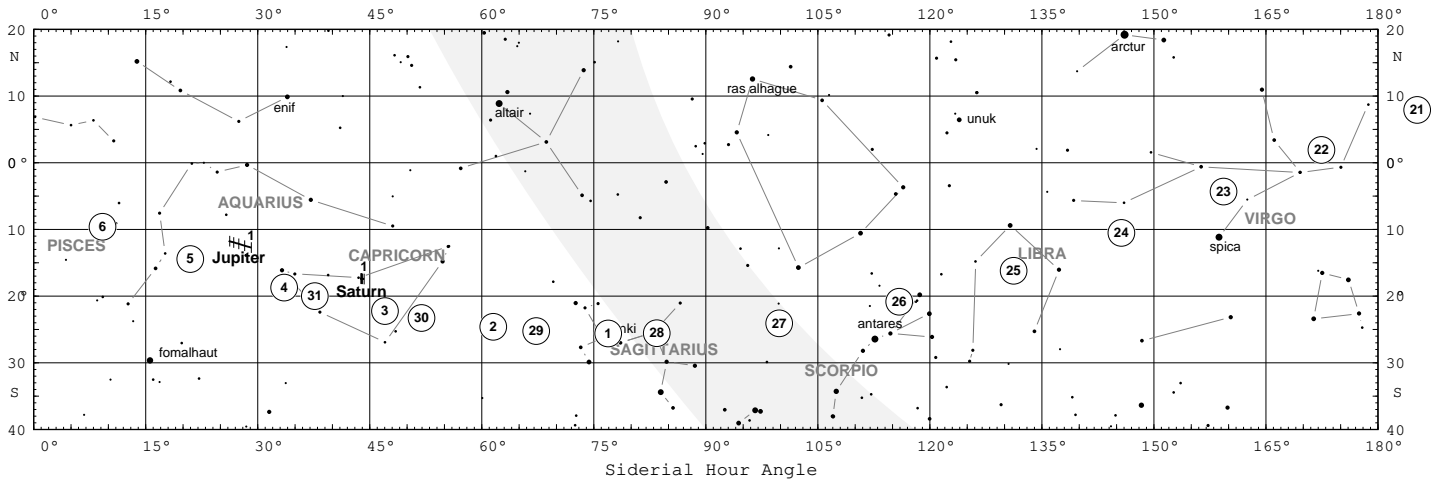
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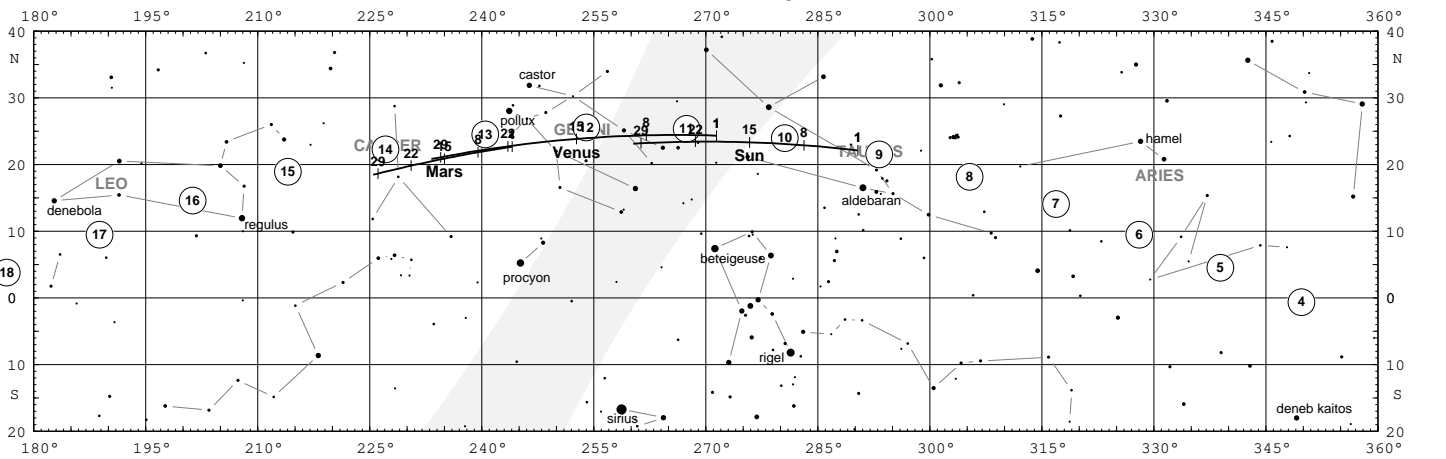
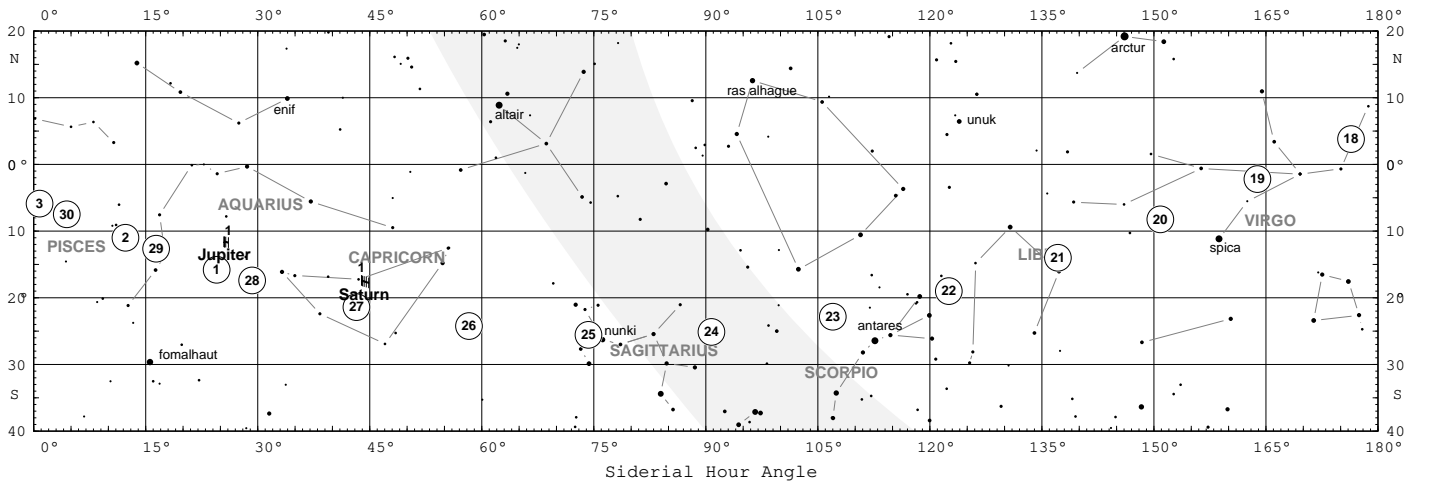
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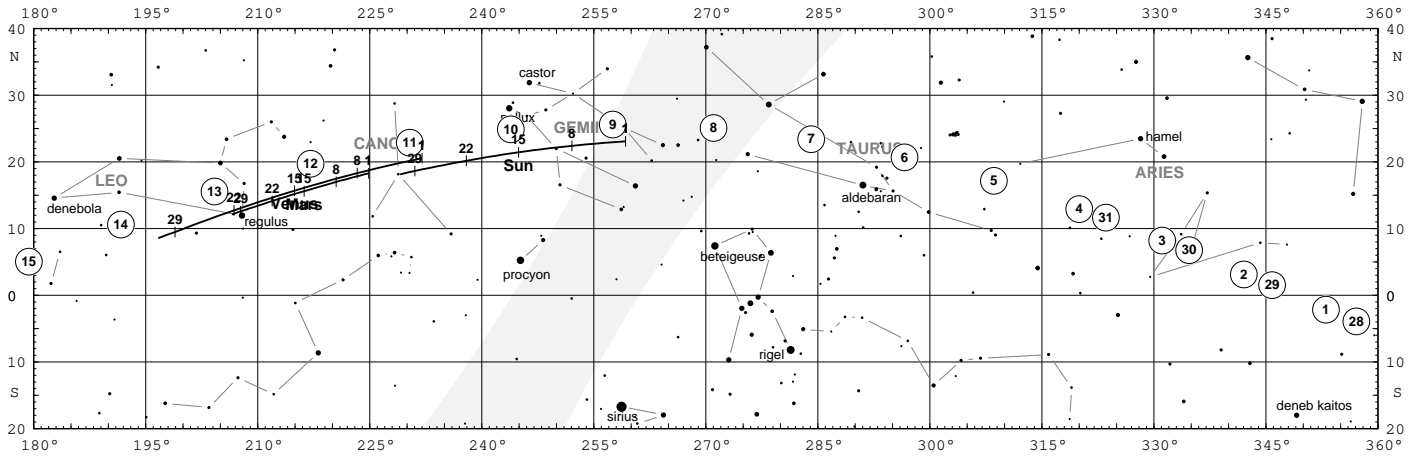
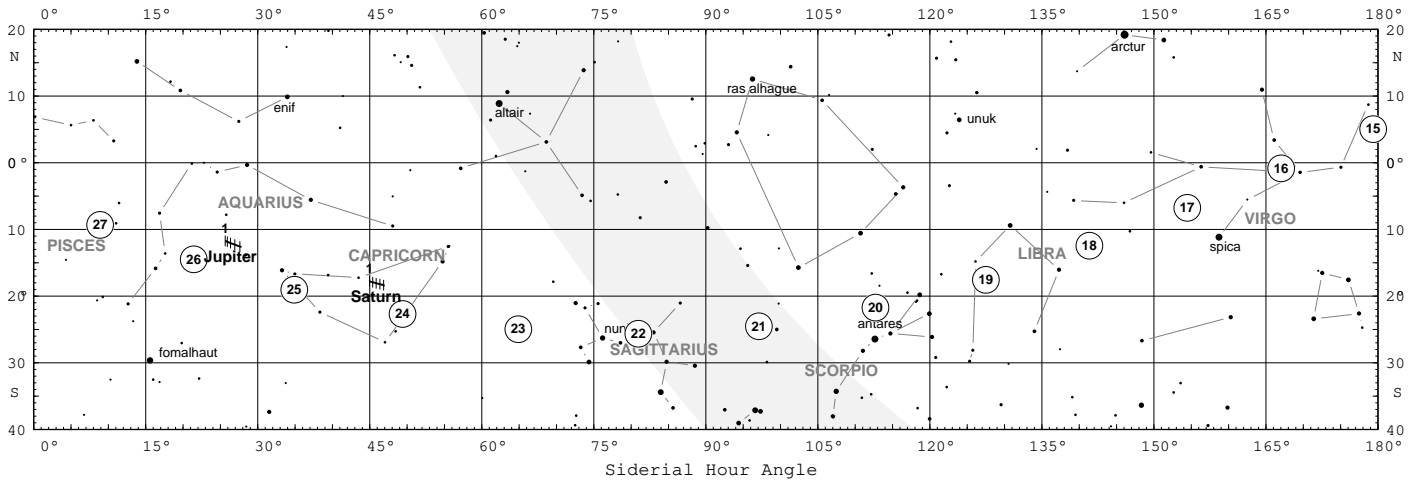
May 2021



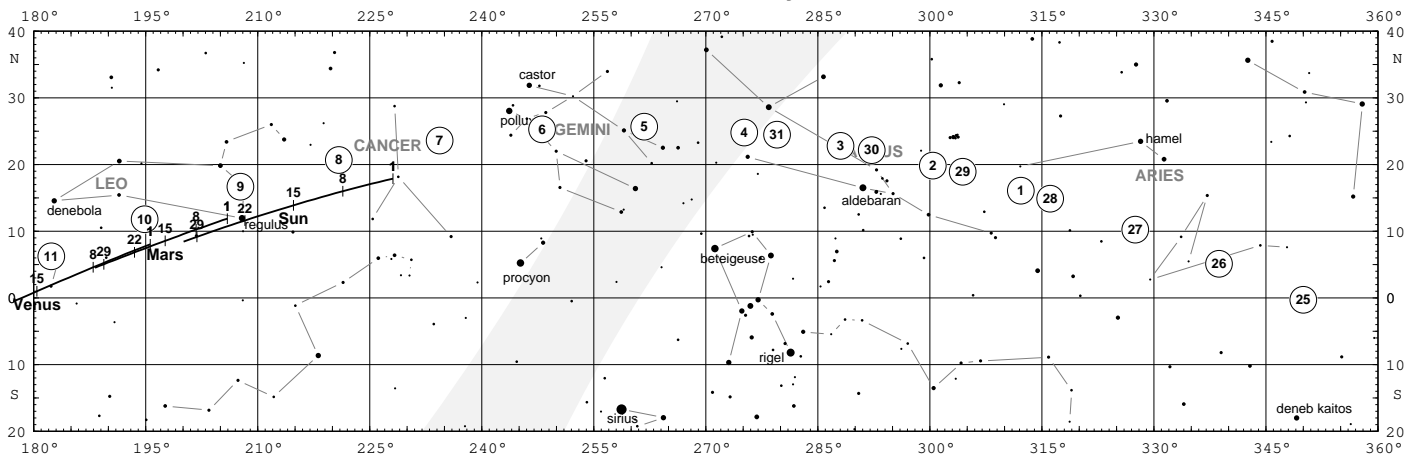
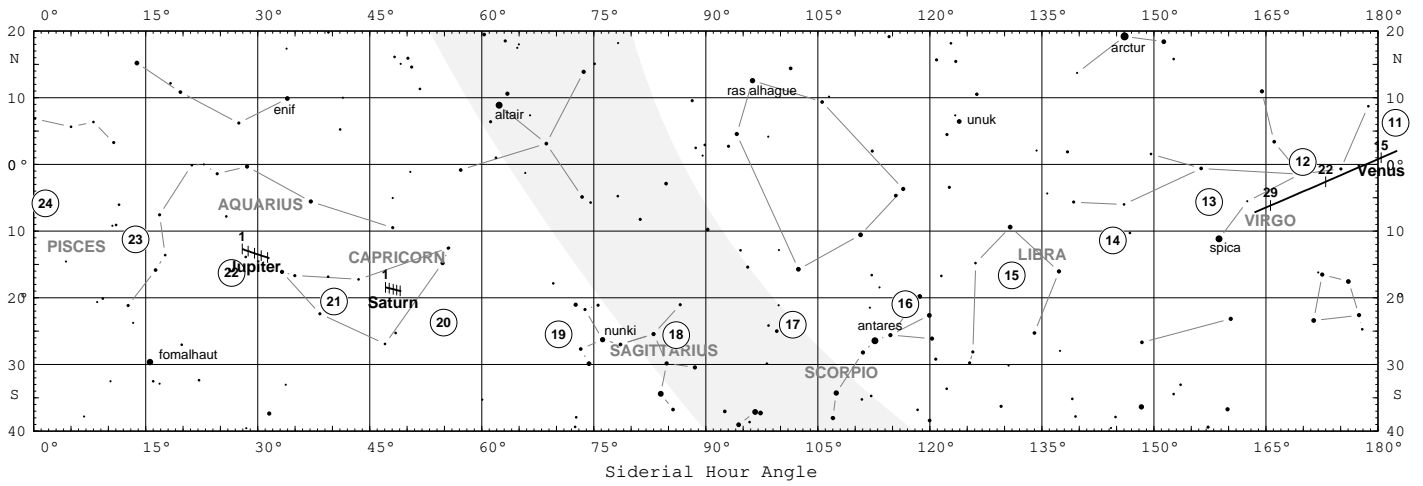
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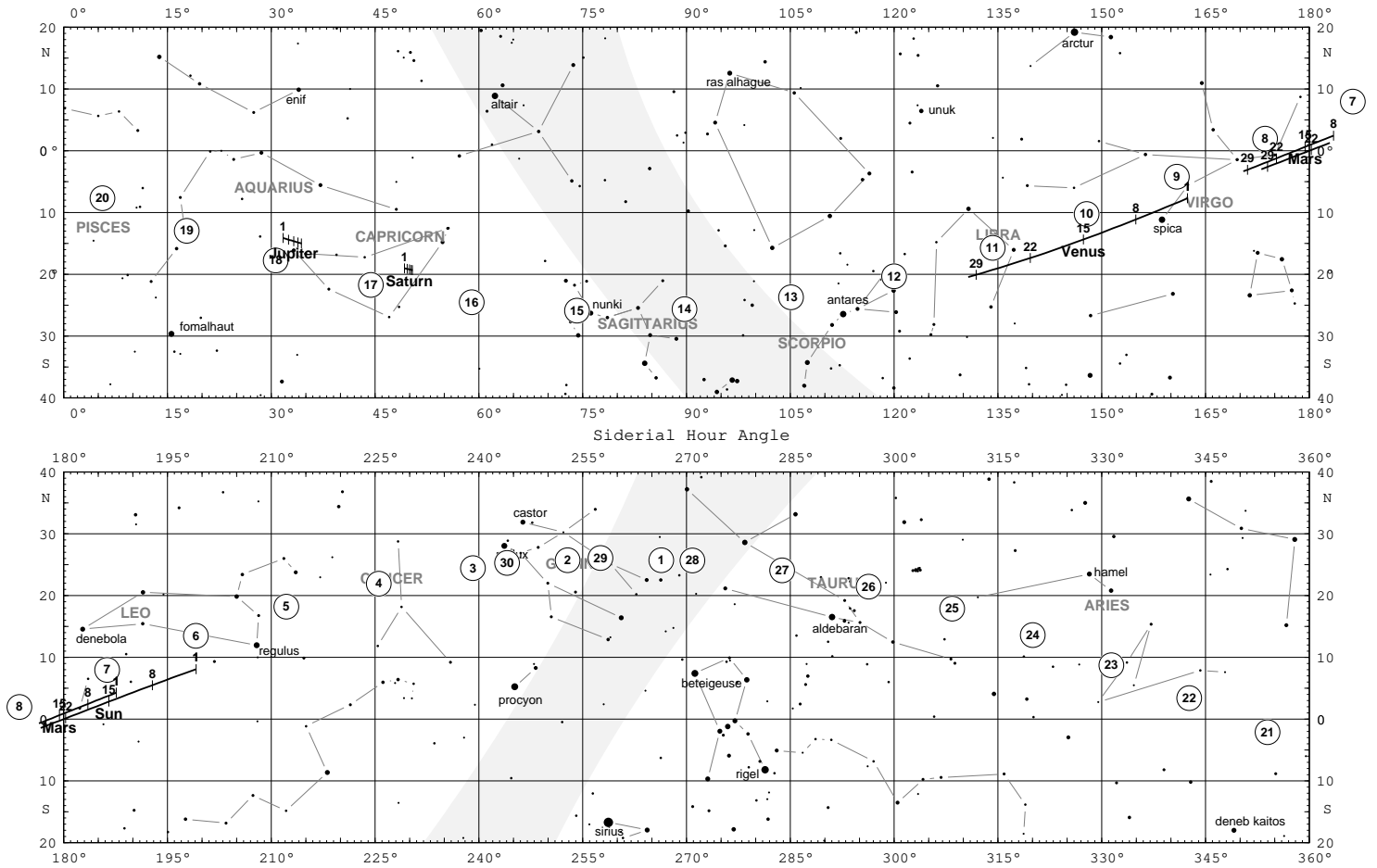
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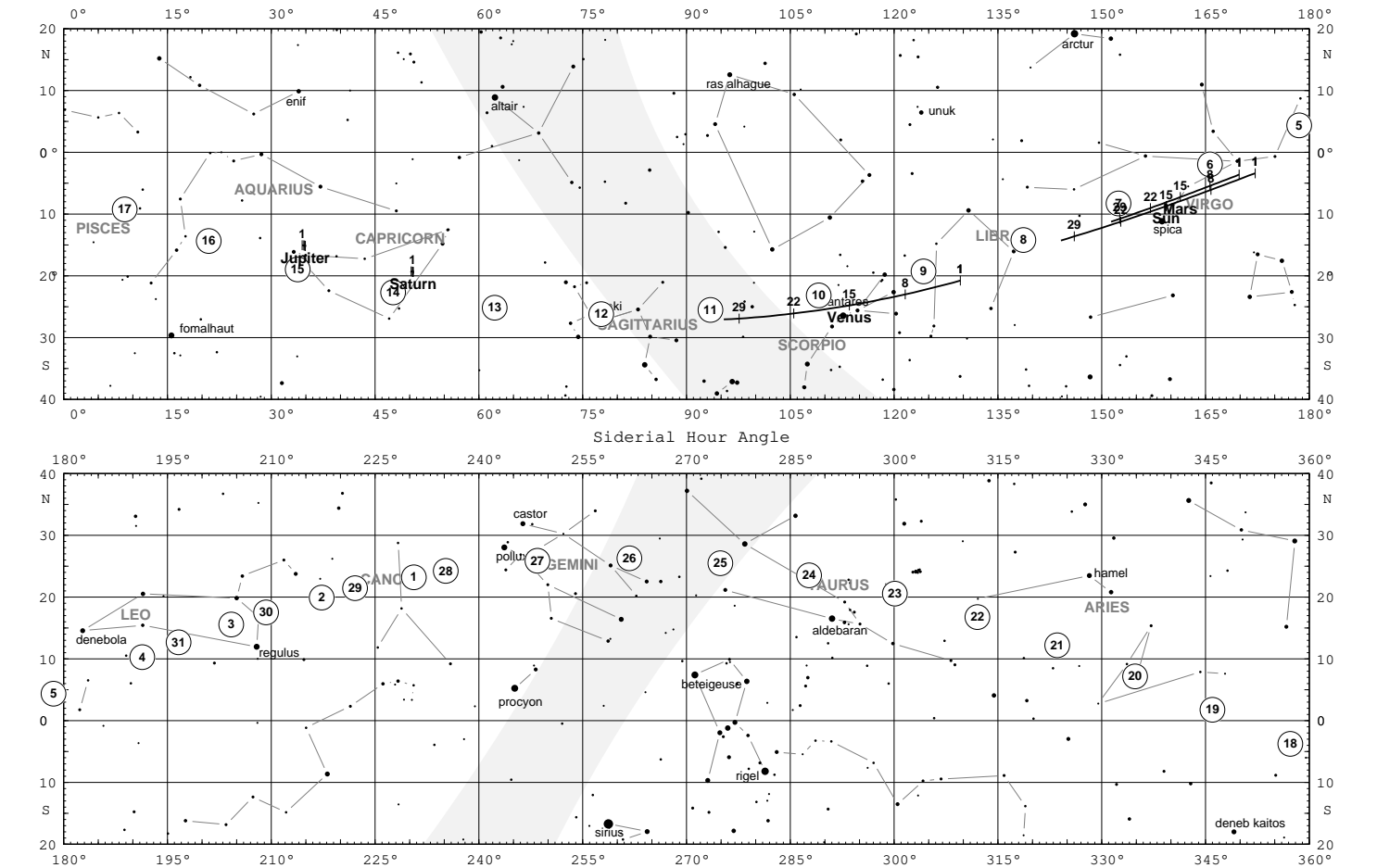
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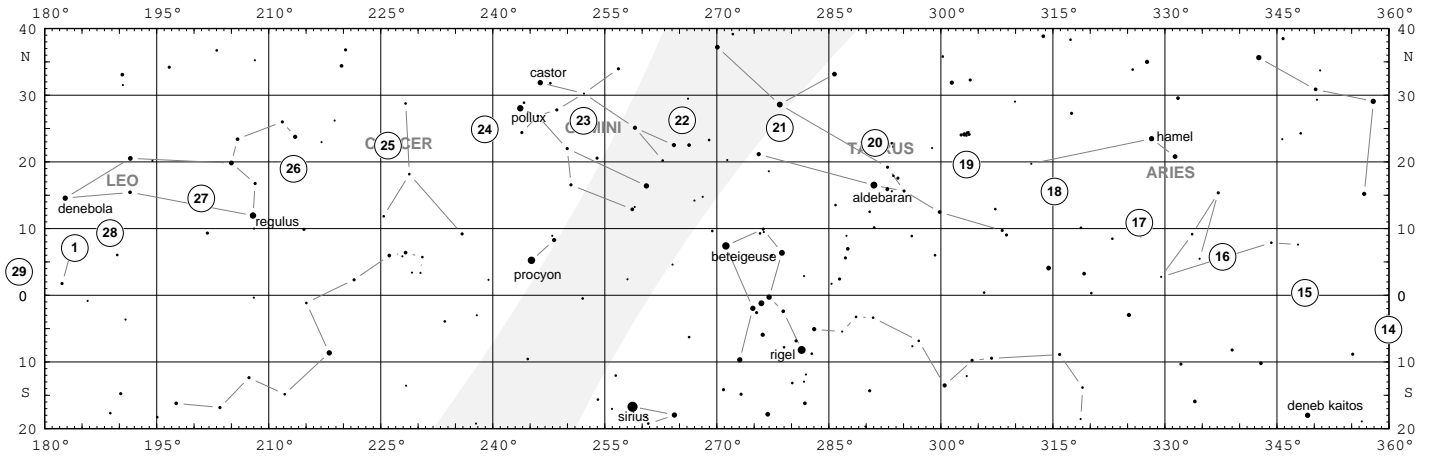
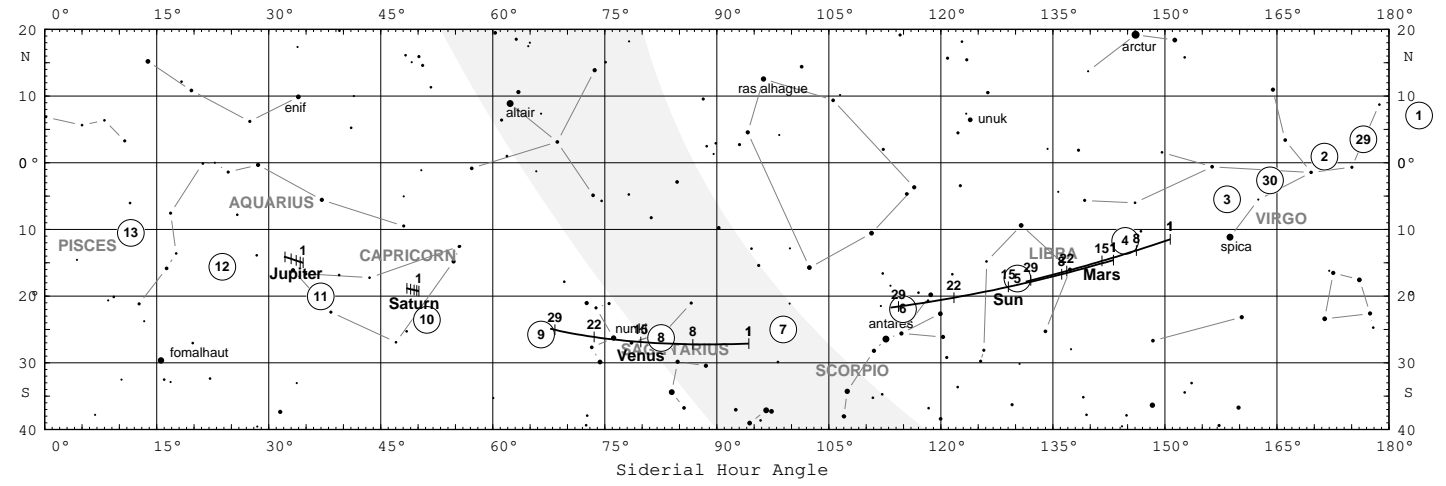
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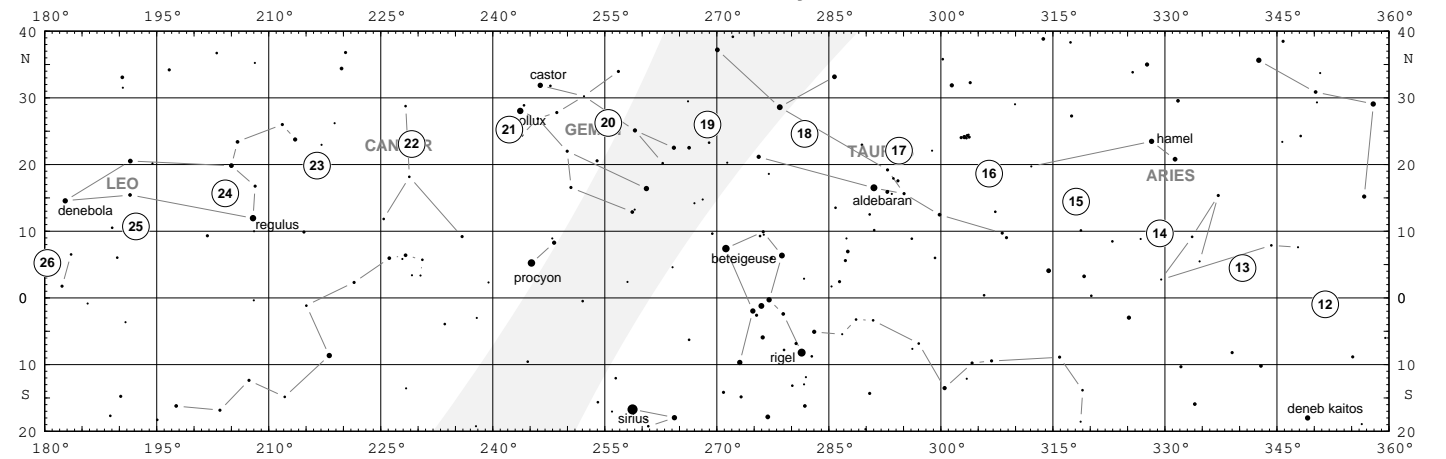
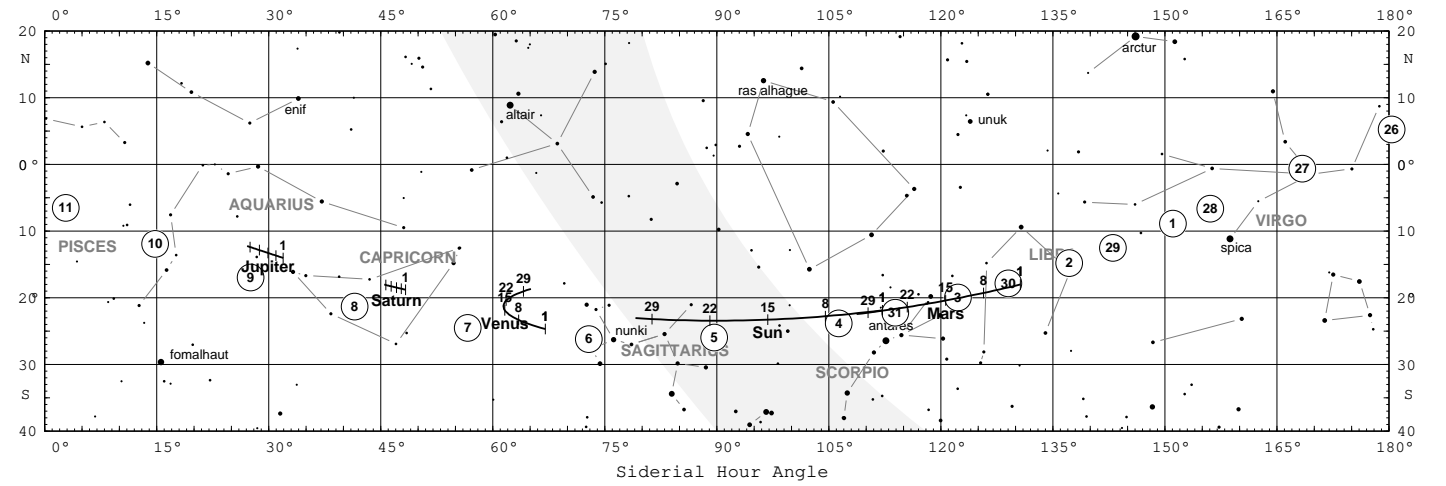
October 2021



November 2021





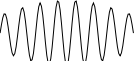
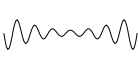




December 2021



Phases of the Moon

The following table lists the phases of the Moon through the year 2021. The table shows the day and the approximate time (in UTC) when the particular lunar phases occur. The calculations are based on the difference between the GHA of the Sun and the GHA of the Moon ($\Delta_{GHA} = GHA_{sun} - GHA_{moon}$). The constellations "new moon", "first quarter", "full Moon" and "last quarter" are obtained when Δ_{GHA} is equal to 0° , 90° , 180° and 270° respectively.

	 New Moon	 First Quarter	 Full Moon	 Last Quarter
January	Wed 13 04:06	Thu 21 04:16	Thu 28 17:14	Wed 6 11:23
February	Thu 11 16:00	Sat 20 03:03	Sat 27 04:40	Fri 5 01:24
March	Sat 13 05:53	Sun 21 14:15	Sun 28 15:21	Sat 6 05:34
April	Sun 11 23:02	Mon 19 21:07	Tue 27 01:47	Sun 4 05:21
May	Tue 11 17:55	Wed 19 06:43	Wed 26 11:05	Mon 3 08:05
June	Thu 10 11:01	Thu 17 22:36	Thu 24 18:34	Tue 1 20:41
July	Sat 10 00:23	Sat 17 15:09	Sat 24 01:00	Thu 1 21:03 Sat 31 22:28
August	Sun 8 10:57	Sun 15 23:20	Sun 22 08:32	Mon 30 14:37
September	Mon 6 20:57	Mon 13 23:17	Mon 20 19:49	Tue 28 23:39
October	Wed 6 08:05	Tue 12 21:08	Wed 20 12:26	Thu 28 08:27
November	Thu 4 20:16	Thu 11 00:32	Fri 19 08:44	Sat 27 00:13
December	Sat 4 07:56	Fri 10 17:13	Sun 19 04:41	Mon 27 00:43
Tidal Phase	spring 	neap 	spring 	neap 

Lunar Phases and Tides

The lunar phases may be used to roughly estimate the occurrence of spring and neap tides. Spring tide occurs around new and full moon. Neap tide occurs around the first and last quarter.

Each tidal region on Earth, has a characteristic "tidal delay" which, specifies the time difference between the occurrence of a particular lunar phase and the occurrence of the resulting tidal phase. The tidal delay can be a couple of hours for the open seas, or up to several days for branched tidal waters such as parts of the North Sea.

Reliable tidal predictions are obtained from a Tidal Almanac.

Lunar Eclipses

An eclipse of the Moon - or lunar eclipse - can only occur at Full Moon, and only if the Moon passes through some portion of the Earth's shadow. The Earth's shadow is composed of two concentric cone-shaped components. The outer or penumbral shadow is a region where the Earth blocks part (but not all) of the Sun's light from reaching the Moon. The inner or umbral shadow is a region where the Earth blocks all direct sunlight from reaching the Moon. Based on this, three types of lunar eclipses are distinguished:

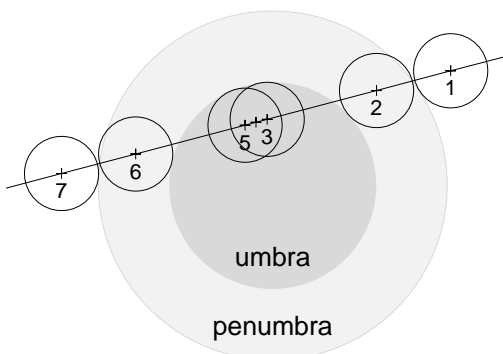
1. Penumbral Lunar Eclipse: the Moon passes through the Earth's penumbral shadow. These kind of eclipses are subtle and very difficult to observe.
2. Partial Lunar Eclipse: a part of the Moon passes through the Earth's umbral shadow.
3. Total Lunar Eclipse: the Moon passes entirely through the Earth's umbral shadow. During this phase of the eclipse the Moon will take a vibrant range of dark red and brown colors.

NOTICE: Eclipse contact times depend on the angular diameters of the Sun and Moon. The calculations in this Almanac are based on a perfect circular form for the limb of the Moon, and do not take into account effects of refraction of the sunlight in the Earth atmosphere. Since this is only an approximation of reality, contact times are accurate only within a couple of minutes.

The following lunar eclipses may be observed during the year 2021:

May 26 : a total lunar eclipse begin [May 26, 08:54 UTC] / end [May 26, 13:40 UTC]

$R_p = 1.308^\circ$
 $R_u = 0.776^\circ$
 $SD = 0.278^\circ$



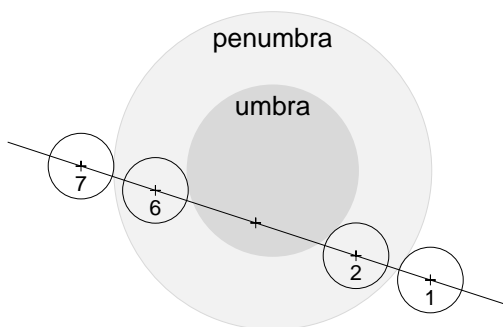
May 26

- | | |
|---------------|---------------------------------|
| 1 - 08:54 UTC | begin of penumbral eclipse (P1) |
| 2 - 09:49 UTC | begin of partial eclipse (U1) |
| 3 - 11:09 UTC | begin of total eclipse (U2) |
| 11:17 UTC | moment of greatest eclipse |
| 5 - 11:25 UTC | end of total eclips (U3) |
| 6 - 12:45 UTC | end of partial eclipse (U4) |
| 7 - 13:40 UTC | end of penumbral eclipse (P4) |

May 26

November 19 : a partial lunar eclipse begin [Nov 19, 06:08 UTC] / end [Nov 19, 11:54 UTC]

$R_p = 1.192^\circ$
 $R_u = 0.647^\circ$
 $SD = 0.246^\circ$



November 19

- | | |
|---------------|---------------------------------|
| 1 - 06:08 UTC | begin of penumbral eclipse (P1) |
| 2 - 07:22 UTC | begin of partial eclipse (U1) |
| 09:01 UTC | moment of greatest eclipse |
| 6 - 10:41 UTC | end of partial eclipse (U4) |
| 7 - 11:54 UTC | end of penumbral eclipse (P4) |

November 19

Solar Eclipses

An eclipse of the Sun - or solar eclipse - can only occur at New Moon, and only if the Earth passes through some portion of the Moon's shadow. Seen from the Earth, the Moon passes in front of the Sun and thus a part - or all - of the light of the Sun is eclipsed. The shadow cast by the Moon is composed of two concentric cone-shaped components. The outer or *penumbral* shadow zone is the region where the Moon blocks a part of the sunlight. The inner or *umbral* shadow zone is a region where the Moon blocks all sunlight. Based on this, three types of solar eclipses may be distinguished:

1. Total solar eclipse: occurs when the umbra of the Moon's shadow touches a region on the surface of the Earth.
2. Partial solar eclipse: occurs when the penumbra of the Moon's shadow passes over a region on the Earth's surface.
3. Annular solar eclipse: occurs when a region on the Earth's surface is in line with the umbra, but the distances are such that the tip of the umbra does not reach the Earth's surface

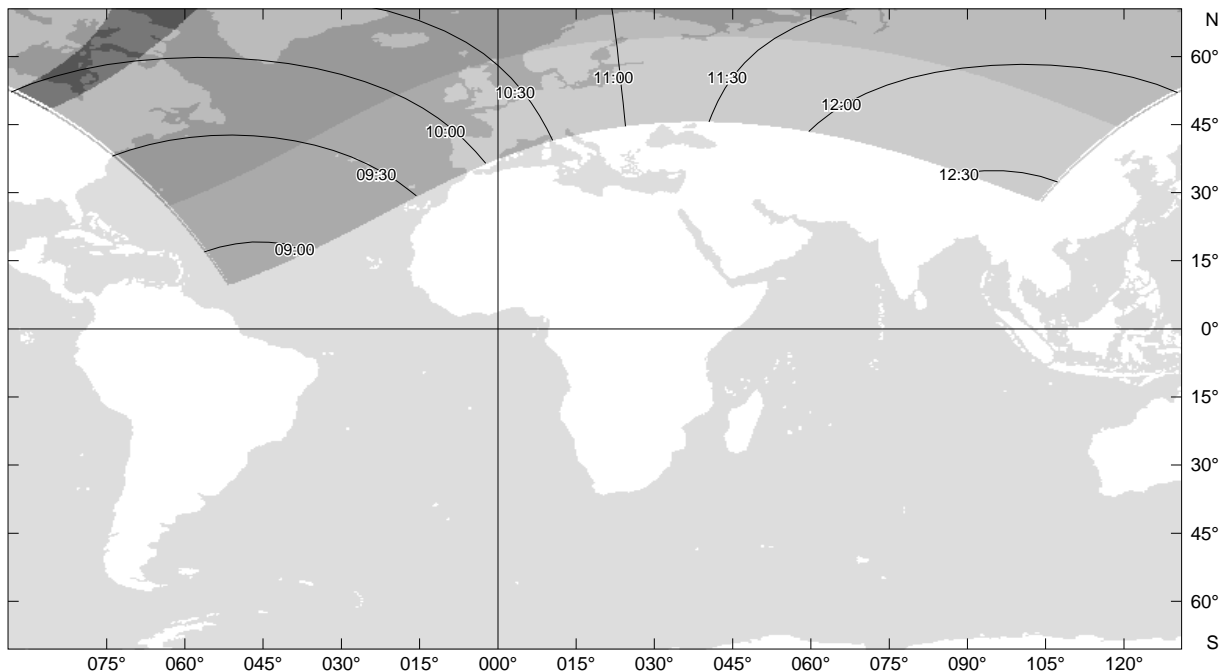
Because of the relative sizes of the Moon and Sun and their specific distances from the Earth, only a small part of the Earth surface is covered by the Moon shadow during a solar eclipse. Especially the path of totality is usually very narrow (a few hundreds of kilometers across). A much broader region is covered by the penumbral shadow of the Moon. However, an observer in this region will see only a partial solar eclipse.

The appearance of a specific solar eclipse can be summarized conveniently by mapping the path of totality and the region covered by the penumbral shadow of the Moon for the complete duration the eclipse. The lines of constant time, included in the charts, indicate the instances of greatest eclipse.

Warning: never look directly at the Sun without proper eye protection, even during an eclipse. Even when the Sun is partially covered, your eyes can be seriously damaged by looking directly at it. Sunglasses are not an adequate eye protection for viewing the Sun.

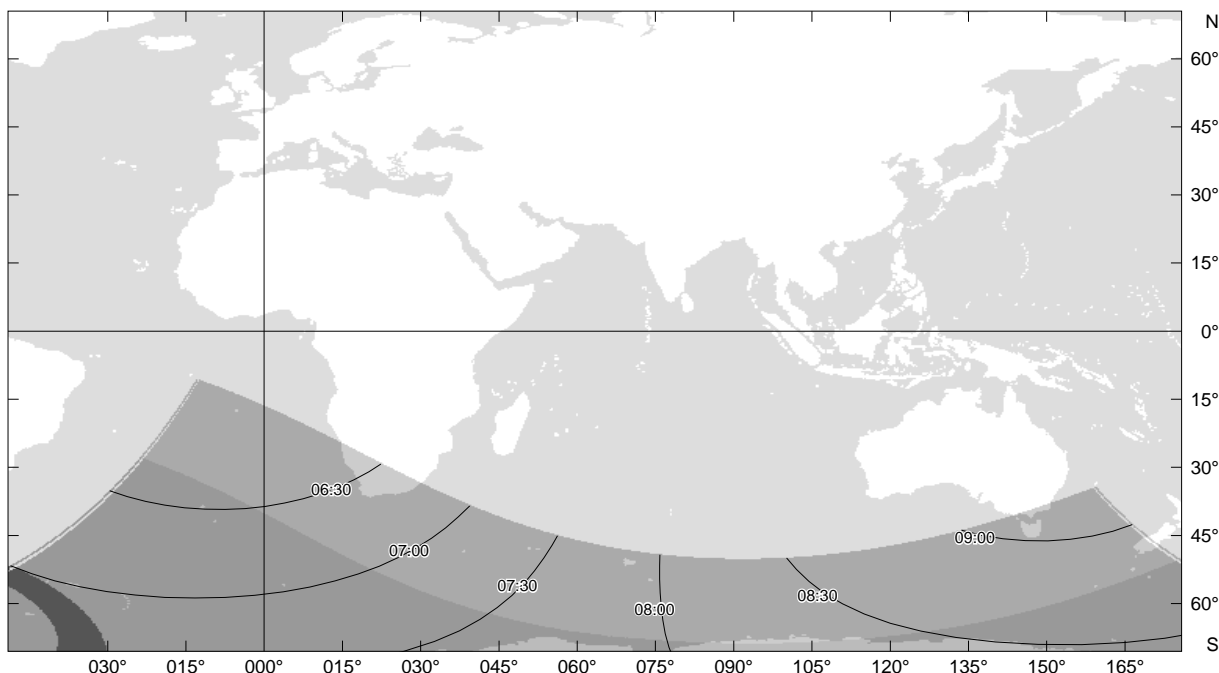
The following solar eclipses may be observed during the year 2021:

June 10 : annular solar eclipse begin [Jun 10, 08:12 UT] / end [Jun 10, 13:11 UT]



Circumstances at Moment of Greatest Eclipse		Fist Contacts (P1/U1)		Last Contacts (U4/P4)	
Time:	10:45 UT	Duration (full):	4.7 min	Penumbra	Umbra
Location:	N 82.3 W 062.4	Path Width:	637 km	08:12 UT	09:49 UT
				11:34 UT	13:11 UT

December 4 : total solar eclipse begin [Dec 4, 05:29 UT] / end [Dec 4, 09:38 UT]



Circumstances at Moment of Greatest Eclipse		Fist Contacts (P1/U1)		Last Contacts (U4/P4)	
Time:	07:37 UT	Duration (full):	2.0 min	Penumbra	Umbra
Location:	S 78.5 W 045.3	Path Width:	415 km	05:29 UT	07:00 UT
				08:07 UT	09:38 UT

Equation of Time

The "Equation of Time" is the difference between the Apparent Solar Time and the Mean Solar Time at the Prime Meridian of Greenwich. The value for the Equation of Time (EoT) for a specific day can be obtained from the Nautical Almanac. The section of the Sun records the "Greenwich Culmination Time" (GCT), which is the UT time at which the Geographical Position of the Sun transits the Prime Meridian of Greenwich. This is also the UT time of Local Apparent Noon for the Prime Meridian. Thus, the value for the Equation of Time is obtained from: $EoT = 12:00:00 - GCT$.

Examples:

GCT = 11:57:23

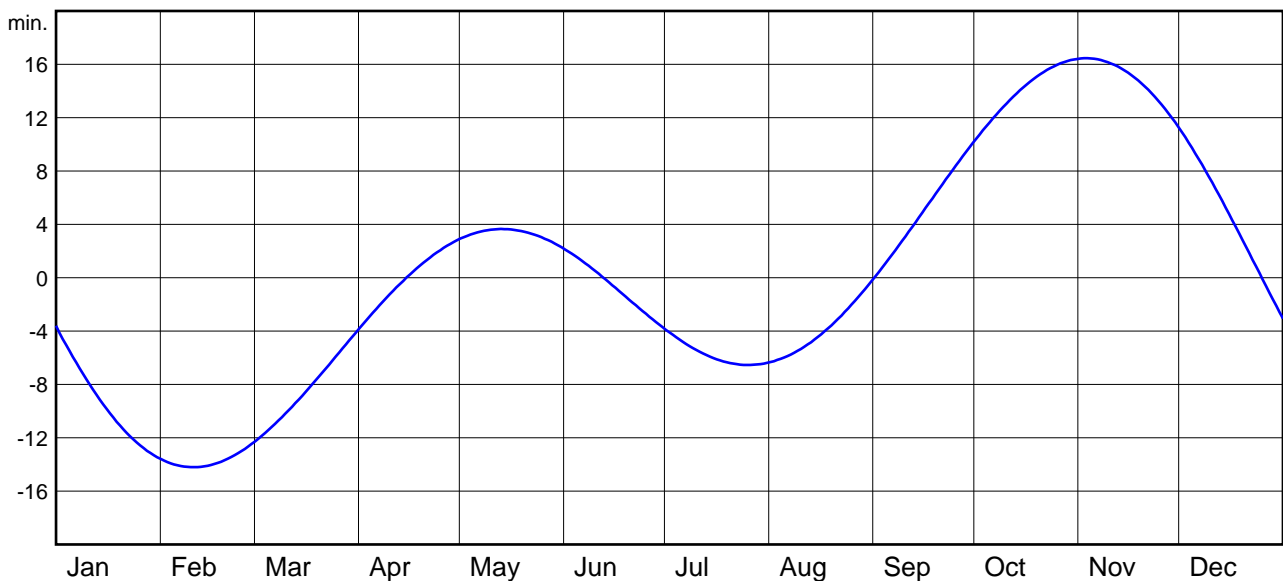
GCT = 12:01:57

EoT = 12:00:00 - 11:57:23 = +00:02:37

EoT = 12:00:00 - 12:01:57 = -00:01:57

Notice that EoT has a sign: positive if the Sun "culminates" before 12 UT (then Apparent Time is "leading" Mean Time) and negative if the Sun "culminates" after 12 UT (then Apparent Time is "lagging" Mean Time).

The graph below shows the values for the "Equation of Time" (in Minutes) for the year 2021.



Nautical Almanac

The following pages contain the coordinates of the Geographical Position (in Greenwich Hour Angle and Declination) for each integral hour of the year for the recorded celestial objects. Each page compiles the complete Almanac data for one day of the year. The time used in this Almanac is Universal Time (UT).

NOTICE:

This Nautical Almanac uses a slightly different approach for the interpolation of the integral-hour values of Greenwich Hour Angle and Declination, compared to the techniques used in most commercially available Almanacs.

For more information please refer to the following web site: "<http://www.siranah.de/>"

Abbreviations used in the Almanac tables:

UT	Universal Time
GHA	Greenwich Hour Angle
Dec	Declination
ddGHA	the increment of the GHA value for the next hour of time, additional to the "linear" increment of 15°/h
dDec	the increment of the Dec value for the next hour of time
SD	Semi-Diameter of the celestial object
HP	Horizontal Parallax
SHA	the Siderial Hour Angle of the celestial object
A	the "Age" of the moon cycle, according to the following scheme:

Units:

°	[degrees]
°	[degrees]
'	[minutes of arc]
'	[minutes of arc]
'	[minutes of arc]
'	[minutes of arc]
°	[degrees]
A = 00%	new moon
A = 25%	first quarter
A = 50%	full moon
A = 75%	last quarter

