LunaCal 4.0

Contents

Purpose of the software

LunaCal was written to predict the visibility of the Moon as a tool for observational lunar calendars. The main purpose of the software is to aid in the observation of the crescent Moon but is equally applicable to the limits of observation of other bright heavenly bodies. In addition it provides information about the location phase and magnitude also regarding the Sun, planets and bright stars. There is also a function for converting between calendars and time systems.

Installation

Go to the website of the Israeli New Moon Society (https://sites.google.com/site/moonsoc/) and click on "Download LunaCal".

If you do not have Visual Basic 2008 or later, click on "Download and install this first" to install the necessary components of Visual Basic Powerpacks.

Click on LunaCal 4.0 and run setup to install.

Tutorial - Getting started

The program is found in the start menu under Roy Hoffman.

On starting the program the likelihood of the Moon being visible will appear on the right hand, output, pane (fig. 1).

Click on the **Help** button at the bottom just left of center to see this file. You can continue working with the **Help** window open.

On the left are the parameters describing the observer's conditions.

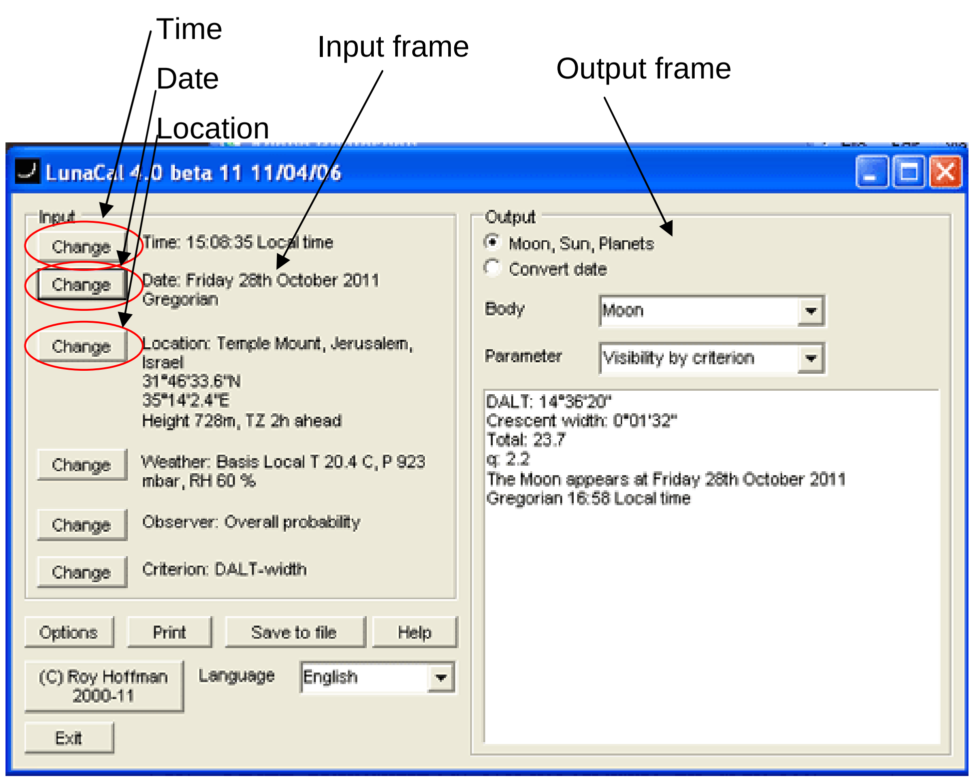

Figure 1. The LunaCal program's main window.

Set any condition by clicking **Change**.

The most important conditions at this stage are **Time**, **Date** and **Location**:

To change the time, click on **Change** next to the **Time**.

A **Time** window will appear. Choose the **Time type** (usually **Local time** but may be **UTC** or some other type).

Set the **Hours**, **Minutes** and **Seconds**.

You may choose 24 hour (**24 hr**) mode or **am/pm** mode (in which case select **a.m.** or **p.m.**).

To save, click on **OK**. Click on **Cancel** to discard the changes (you will be asked to confirm if you made changes). Click on **Default** to return to the time that the program was started (you will be asked to confirm).

To change the date, click on **Change** next to the **Date**.

A **Date** window will appear. Choose the **Date type** (usually **Gregorian** but may be **Hebrew**, **Islamic** or some other type).

If you chose a radix date such as Julian day (**JD**) then enter the **Day number**.

Usually you will choose a calendar date (**Gregorian**, **Hebrew**, **Islamic** or **Julian**) in which case enter the **Date of month**, select a **Month** and enter a **Year**. For years before 1 either choose the **BCE** option or enter a negative year.

To save, click on **OK** (or **Cancel** or **Default** as above).

To change the location, click on **Change** next to the **Location**.

You may either select **By name** and enter the location by name (**Country**, **Town/City**, **Neighborhood**) or select **By lat/long** and enter the **Latitude** and **Longitude**.

If entering **By name**, note that the **Country** refers to a state within the USA, Canada and Australia. **Town/City** may refer to a location outside a town such as a mountain or a forest. When entering a name the **Latitude** and **Longitude** and **Height above sea level** will automatically be updated.

If **By lat/long** is selected, you may enter a **Latitude** and **Longitude** by degrees, minutes and seconds (select **°'"/hm**) or by decimal degrees (select **Degs/Hours only**). The **Height above sea level** should also be set.

To save, click on **OK** (or **Cancel** or **Default** as above. **Default** gives the location of the **Temple Mount** in **Jerusalem**, **Israel**).

On the right hand side are the **Output** options and the results.

Selecting **Moon, Sun, Planets** gives information about the heavenly bodies.

Selecting **Convert date** allows conversion between calendars.

The results appear in the window on the lower right.

With **Moon, Sun, Planets** selected, choose the heavenly body next to **Body** and the **Parameter**. By default the program starts by showing the **Body** **Moon** and the **Parameter** **Visibility by criterion**. This displays the parameters of the lunar visibility criterion (by default different in altitude and crescent width – **DALT-width**). The

DALT-width criterion is a combination of the vertical angular distance between the Sun and the Moon and the angular width of the crescent. This is probably the most reliable simple criterion. The two parameters are listed along with a linear combination used in the ease of visibility calculation and the ease of visibility (q). If q is less than zero then the Moon is not visible to the naked eye. If q is less than one then the Moon might be visible and if it is one or more, the Moon is definitely visible. There follows a description of whether the Moon appears and when it is likely to be visible.

Try choosing the **Parameter** **Finder chart**. If the Moon is not a thin crescent, a message will appear stating that the Moon is visible for an extended period.

Change the **Date** so that the Moon is a visible crescent (for example **6th March 2011 Gregorian** for the default **Location** – the **Time** is irrelevant) and a diagram showing the position (altitude and azimuth) of the Moon will appear. A line appears for the Moon with times starting about half an hour before it is visible until it sets. Where it is dotted red, it is invisible. Dashed blue means that it might be visible and solid black means that it is definitely visible. A similar line usually appears for the position of the Sun, allowing one to measure their relative positions. If there is a bright planet close by, a line also appears for it since it can be used to locate the Moon. (In the case of **6th March 2011 Gregorian** for the default location, Jupiter appears above and left of the Moon.)

Select the **Parameter** **Probability** to see a plot of probability of visibility against time. Select the **Parameter** **Light curve** to see a plot of the Moon's brightness against the surrounding sky's illuminance. In addition, time labels appear on the curve and the curve is dotted red, dashed blue or solid black according to visibility just as for the **Finder chart**.

You may select many other **Parameter**s such as **Coordinates**, rise/set times, and **Magnitude**. You may also select parameters for the Sun, 5 major planets and stars down to magnitude 2.

With **Convert date** selected, choose a **Date type** to convert to. If the **Date type** is a calendar date (**Gregorian**, **Hebrew**, **Islamic** or **Julian**) then select the **Time type** to convert to. The result appears in the lower right of the window.

To print a copy of the visible windows to the default printer click on **Print**.

To save the text to a file click on **Save to file** and select a txt file to save to.

When you finish using the program, click on **Exit**.

Worked examples

Planning a Moon sighting

To plan a Moon sighting for the next New crescent Moon you will need to do the following: select the earliest date from which you want to search for the Moon, select the location, search for the next occurrence of the New crescent Moon and make a finder chart.

If you want to search from today then you do not need to change the date from the default. Otherwise, click on the **Change** button next to **Date**. A window will appear in which you can select the **Date type** and the other parameters (typically **Date of month**, **Month** and **Year**) that describe the date. Click on **OK** to save.

Choose the location by clicking on the **Change** button next to **Location**. Set the name of the location or the **Latitude**, **Longitude** and **Height above sea level**. If your **Country** is not listed, you will need to set the **Time zone** manually. Click on **OK** to save.

In the **Output** frame, select the **Moon, Sun, Planets** option. Next to **Body** select **Moon**. Next to **Parameter**, select **Next New Moon**. The date that the next New crescent Moon appears is then written in the output pane at the lower right. Click on **Change** next to **Date** and enter this date and click on **OK** to save.

Select the **Parameter** **Visibility by criterion** to see how difficult it will be to see the Moon.

Select the **Parameter** **Finder chart** to draw a diagram (fig. 2) showing when and where the Moon can be seen.

Select the **Parameter** **Probability** to see how the probability of visibility varies with time.

For example if the **Date** was set to 1st July 2012 Gregorian and the location to **Temple Mount**, **Jerusalem**, **Israel**, then the **Next New Moon** would be 20th July 2012. Setting the **Date** to Friday 20th July 2012, the **Parameter** **Visibility by criterion** gives the following:

DALT: 7°42'38" – represents the sky's darkness

Crescent width: 0°00'47" – represents the Moon's brightness

Total: 14.2 – combined parameter indicating ease of visibility

q: 0.4 – normalized parameter showing that the Moon will be difficult to see

The Moon appears at Friday 20th July 2012 Gregorian 20:06 Local time – the earliest time that the Moon might appear.

Use the **finder chart** (fig. 2) to find the Moon's position. A red dotted line indicates that the body is invisible to the naked eye, a blue dashed line indicates that it might be possible and a solid black line indicates that it is definitely visible (barring cloud). Beside the curve is the name of the Moon and ticks indicate the time. The position of the Sun shortly before it sets is shown in order to help in finding the Moon.

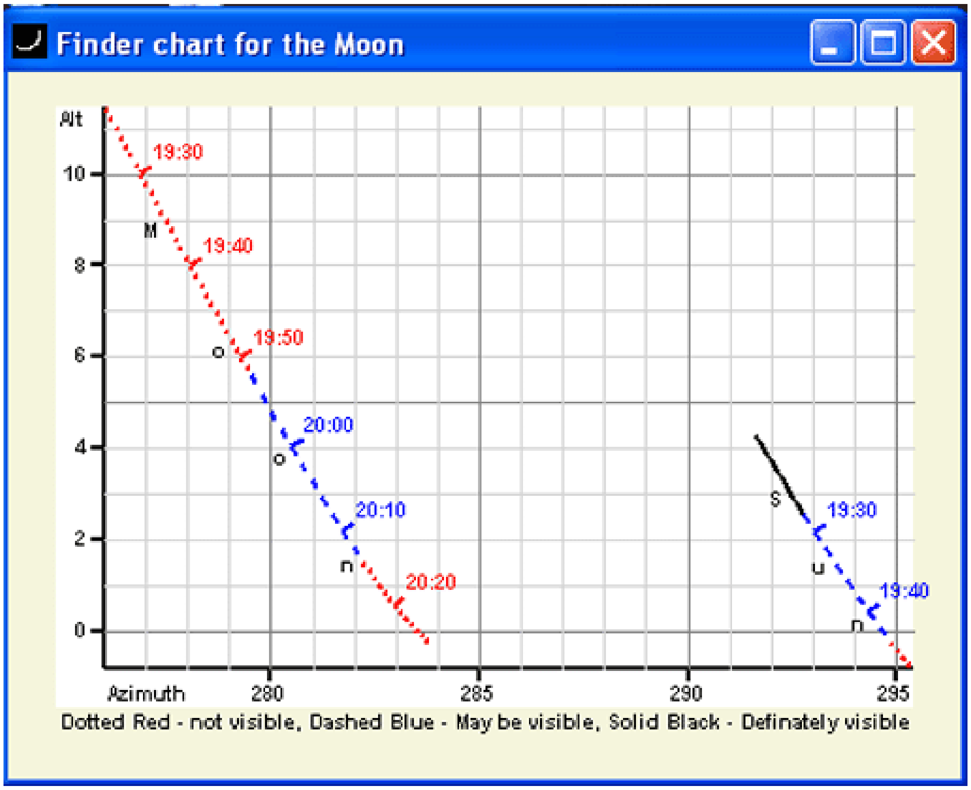

Figure 2. Finder chart showing the predicted appearance of the Moon.

By default this chart gives a result for an observer chosen at random. The program can be made to produce a personalized prediction that takes into account the observer's eyesight. In order to do this, record several observations at the limits of visibility (such as the first or last detection of the Moon, a planet or a bright star) on different occasions. Calculate the predicted probability of visibility at the time of detection. Table 1 shows the first detection times for the New crescent Moon by Roy Hoffman on ten occasions with the predicted probability of visibility at that time for each observation. Calculate the inverse complementary error function for each observation and take the mean (average) value. Click on **Change** next to **Observer**. Select **Personal probability** and enter the mean value (in this case -0.15) next to **Average performance**. This affects the visibility prediction especially in the **Finder chart** (fig. 3) and **Probability** plot.

Table 1. Observations of the New Moon by Roy Hoffman and their performance anaylsis.

Latitude	*Longitude*	*Height*	*Date*	*Time*	*Zone*	*P*	*erfc^{-1}(P)*
31.774	35.197	748	26 Feb 09	16:49	2	0.32	0.47
31.791	35.300	430	26 Apr 09	19:16	3	0.76	–0.71
31.791	35.300	430	25 May 09	19:48	3	0.73	–0.61
31.791	35.300	430	23 Jul 09	19:34	3	0.25	0.67
31.791	35.300	430	20 Sep 09	18:29	3	0.21	0.81
31.774	35.197	748	20 Oct 09	16:49	2	0.61	–0.28
31.774	35.197	748	18 Nov 09	16:37	2	0.75	–0.67
31.791	35.300	430	13 Jul 10	19:42	3	0.75	–0.67
31.794	35.298	498	11 Aug 10	19:48	3	0.63	–0.33
31.774	35.197	748	7 Nov 10	16:49	2	0.57	–0.18
						Mean	**–0.15**

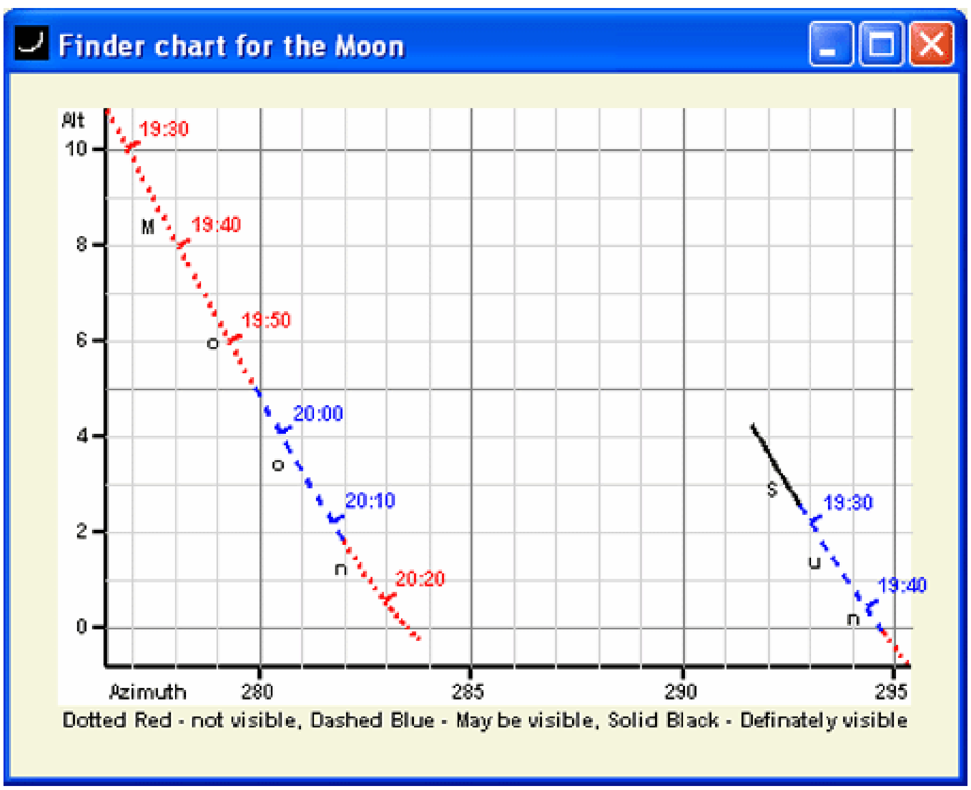

Figure 3. Finder chart showing the predicted appearance of the Moon adjusted for Roy Hoffman's eyesight. The period of visibility is reduced by a few minutes.

Converting a date

To convert a date, select a date, time and location as described above.

In the **Output** frame, select the **Convert date** option. Select the **Date type** and the **Time type** and the converted date and time will appear.

For example 27th October 2011 Gregorian (before sunset) converts to 29th Tishri 5772 Hebrew (fig. 4).

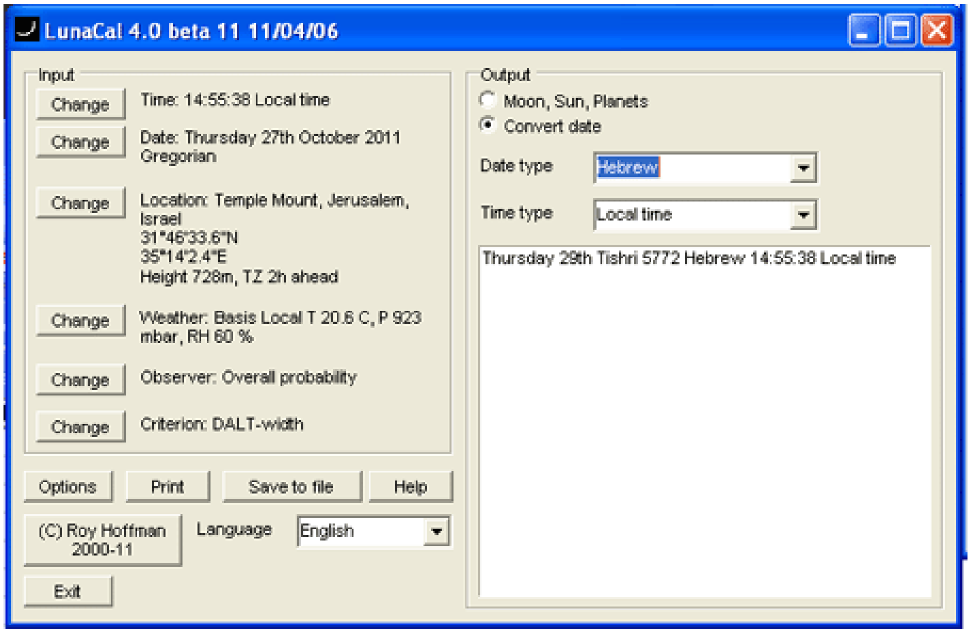

Figure 4. Example of date conversion from Gregorian to Hebrew calendars.

Finding a star or planet

To find a star or planet, select date, time and location as described above.

In the **Output** frame, select the **Moon, Sun, Planets** option. Next to **Body** select the star of planet. In the list, after the Sun and Moon, the planets are listed in their order: **Mercury**, **Venus**, **Mars**, **Jupiter** and **Saturn**. Afterwards there is a list of fixed stars down to the second magnitude in alphabetical order. Select the **Parameter** **Horizon coordinates**. This will give the location of the star or planet in the sky so that you can find it by altitude and azimuth.

Planning a planet or star sighting

To plan to see the first appearance or last disappearance of a planet or star, select date and location as described above.

In the **Output** frame, select the **Moon, Sun, Planets** option. Next to **Body** select the star of planet. Select the **Parameter** **Finder chart** to draw a diagram showing when and where the planet or star can be seen.

For example Mercury appears on 27th October 2011 between 17:11 and 17:40 as seen from Jerusalem (fig. 5).

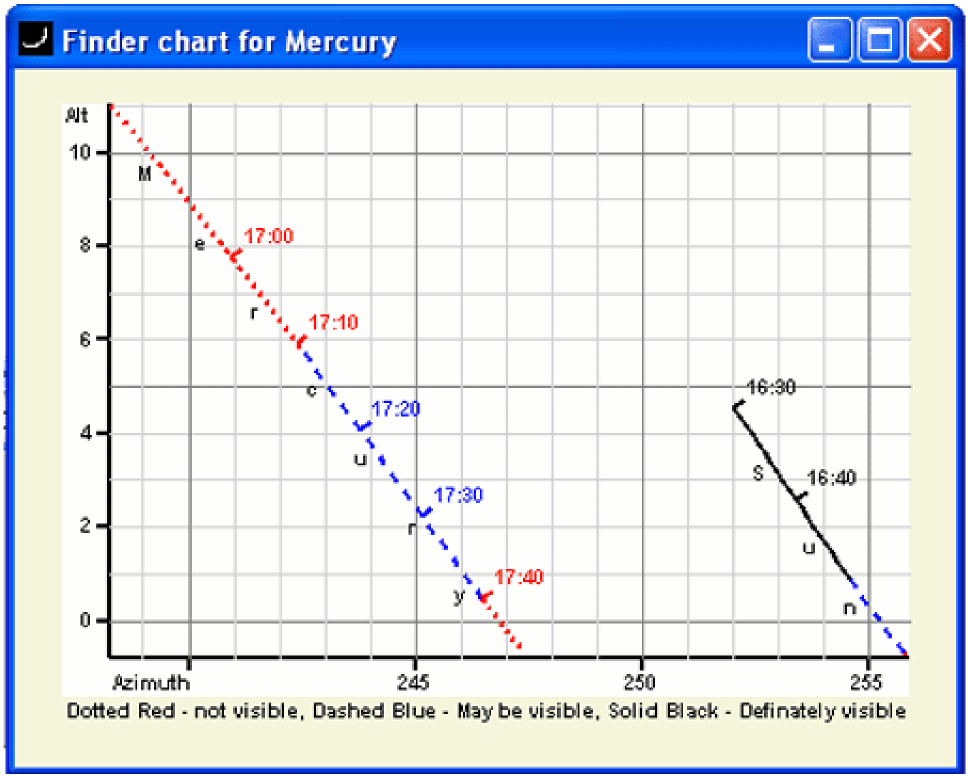

Figure 5. Example of a chart for observing a planet or start, in this case the planet Mercury.

Finding times of day: sunrise, noon, sunset, midnight and seasonal hours

Start by selecting the date and location as described above.

In the **Output** frame, select the **Moon, Sun, Planets** option. Next to **Body** select **Sun**. For sunrise, select the **Parameter Rise**. For sunset, select the **Parameter Set**.

For example, the Sun rises at 05:47 over a sea level horizon, 05:52 over a plane and 05:55 geometrically on 27th October 2011 from Jerusalem and sets at 16:59 over a sea level horizon, 16:55 over a plane and 16:51 geometrically.

For noon, select the **Convert date** option. Set the time to 6:00:00 day seasonal. The time of Noon will appear. For midnight, set the time to 6:00:00 night seasonal. For other seasonal hours set the seasonal time accordingly.

For example noon is 11:23 on 27th October 2011 from Jerusalem and midnight is 23:23.

Detailed description of the program

The Input frame

All windows except those only providing messages can be resized by dragging the borders or by expanding to full screen (and reduced) with the frame buttons at the top right.

The program starts in English mode. If you perchance find the program in Hebrew mode, change the language by selecting **אנגלית (English)** in the field **שפה** just right of center at the bottom.

On the left side of the main window is the **Input** frame. This contains the parameters describing the observation conditions: **Time**, **Date**, **Location**, **Weather**, **Observer**'s effect on probability and **Criterion** for lunar visibility. To change one of these parameters, click on **Change** next to the parameter. This will open a window with all the options for the parameter.

After making the changes, click on **OK** to save them. Click on **Cancel** to abandon the changes. If you have made any changes you will be asked if you want to abandon the changes: click **Yes** to abandon the changes and **No** to continue editing the changes. Click **Default** to load the default values. If the current values are not the default you will be asked if you want to abandon the current values: click **Yes** to abandon the current values and continue editing from the default values, and **No** to continue editing without changing the current values. When attempting to close the window, the validity of the input is checked. If it is invalid, then an explanation is given and the user returned to edit the values.

If the **Date** is of a radix type (**Fixed**, **JD**, **JDE** or **MJD**) then the **Time** is not applicable and cannot be changed.

The Time window

Click **Change** next to **Time** in the **Input** frame to change the **Time**.

By default the **Time** is the **Local time** when the program was started on the 24 hour clock.

The **Time type** may be selected from universal coordinated time (**UTC**), **Local time**, **Mean solar time**, **True solar time**, Greenwich mean sidereal time (**GMST**), local sidereal time (**LST**) and **Seasonal time**.

UTC is (within a second of) the mean solar time at the Greenwich meridian and is used as a standard time for the whole World.

The **Local time** is set by the government in each country or state and is usually within an hour of the local mean solar time. The parameters for **Local time** may be set manually or automatically in the Location window. The **Local time** may change with season (standard or daylight saving). The hour that is skipped upon changing to DST is invalid as input.

Mean solar time is the time according to the average local position of the Sun. Due to the geometric features of the Earth's orbit and its axial inclination, the Sun is seen to traverse the sky at a slightly uneven rate leading to deviations of up to 18 minutes in the observed time. The **Mean solar time** is the time according to the Sun's average apparent motion.

True solar time is the time according to the true local position of the Sun. As explained above, the Sun's apparent motion is slightly non-uniform deviates slightly from the **Mean solar time**. The **True solar time** is the time read from a correctly adjusted sundial.

GMST is the time according to the position of the point of Aries (zero right ascension) at the Greenwich meridian. This is used as a global time reference relative to the stars.

LST is the time according to the locally observed position of the point of Aries (zero right ascension). This is used as a local time reference relative to the stars.

Seasonal time is based on dividing the day (apparent sunrise to sunset) and night each into 12 hours. The length of the hours is different for each day and night. **Seasonal time** is often used in Jewish law.

Hours may be an integer from **0** to **23** in **24 hr** mode, **1** to **12** in **am/pm** mode and **0** to **11** for **Seasonal time**.

Minutes may be an integer from **0** to **59**.

Seconds may any number (including decimal fractions) from **0** but less than 60.

In the **Mode** frame, select **am/pm** for 12 hour clock and **24 hr** for 24 hour clock. **Seasonal time** is by definition a 12 hour clock so the **Mode** frame is inactive for **Seasonal time**.

The **am/pm** frame is used in the 12 hour clock to select **a.m.** or **p.m.** In **Seasonal time** it is used to select **Day** or **Night**.

The **Occurrence** frame is used for the few cases when a time occurs twice in one day. For example if a Gregorian day starts at 08:00 **GMST** then 23 hours 56 minutes later it is again 08:00 **GMST**. Therefore 08:02 **GMST** occurs twice in that day and it is necessary to select **1st time** or **2nd time**. This can occur for a **Gregorian** or **Julian** day with **GMST**, **LST**, and **Seasonal time**. It also occurs for **Local time** during the hour that is repeated during the change from daylight savings to standard time. For a **Hebrew** or **Islamic** day this can happen with any **Time type** except **Seasonal time**.

The Date window

Click **Change** next to **Date** in the **Input** frame to change the **Date**.

By default the **Date** is the **Gregorian** date according to local time when the program was started.

The **Date type** may be selected from **Fixed**, **JD**, **JDE**, **MJD**, **Julian**, **Gregorian**, **Hebrew** and **Islamic**. There are two categories of dates: fixed radix and calendar. Fixed radix dates (**Fixed**, **JD**, **JDE** and **MJD**) are real numbers that count the days (and fractions of days) from a fixed point in time. The **Time** window is not applicable when using fixed radix dates. Calendar dates (**Julian**, **Gregorian**, **Hebrew** and **Islamic**) have a day component consisting of a date, **Month** and **Year** that counts only whole days and is separate from the **Time** component that counts fractions of days.

Fixed is a fixed radix date that counts solar days from 2nd January 1 Julian at 00:00 UTC.

The Julian day number (**JD**) is a fixed radix date that counts solar days from 1st January 4713 BCE Julian at 12:00 UTC.

The Julian day ephemerides number (**JDE**) is a fixed radix date that counts ephemerides days from 1st January 4713 BCE Julian ephemerides at 12:00 UTC. The ephemerides day is always 24 hours long while the solar day is getting longer by about 4 ms per century with some minor variations. This gives a difference of just over a minute at present and increasing. The difference was larger in the past, several hours 3000 years ago.

The Modified Julian day number (**MJD**) is a fixed radix date that counts solar days from 17th November 1858 Gregorian at 00:00 UTC. It is used to reduce the size of the Julian day number by 2400000.5, making it more manageable.

The **Julian** calendar has 12 months (January to December) containing 28 to 31 days as follows: January 31, February 28 (29 in a leap year), March 31, April 30, May 31, June 30, July 31, August 31, September 30, October 31, November 30 and December 31. Every year divisible by 4 is a leap year. The Julian calendar was instituted in 46 BCE although the pattern of leap years was not finally fixed till 5 CE (some say 1 CE) and was widely used until it was gradually replaced around the World between the 16th and 20th centuries. It is still used by many Orthodox Christians as a religious calendar and in some parts of North Africa as an agricultural calendar. The Julian calendar is widely used as a measure of historic dates even retroactively prior to 5 CE. Prior to the year 1, the year may be expressed as zero or negative. Alternatively the year can be given as a positive number with the suffix BCE (before the common era).

The **Gregorian** calendar is like the Julian calendar except that there is no leap year on years divisible by 100 that are indivisible by 400. The Gregorian calendar was adopted around the World between the 16th and 20th centuries but may be used retroactively to describe historic dates.

The **Hebrew** calendar has 12 months in most years with an extra month in a leap year. The Hebrew calendar was originally determined by observation and may return to the observational method in the future but for about 1600 years has been determined by calculation. The Hebrew day starts at sunset. This program uses the calculated calendar that is the current practice even for historic dates prior to the calculated calendar. The Months are counted from Nissan but the year numbers change in the seventh month of Tishri. The months have the following number of days: Nissan 30, Iyar 29, Sivan 30, Tammuz 29, Av 30, Ellul 29, Tishri 30, Cheshvan 29 or 30, Kislev 29 or 30, Tevet 29, Shevat 30, Adar 29 (Adar I 30 in a leap year). In a leap year Adar II is added with 29 days. The lengths of the months of Cheshvan and Kislev are adjusted to make up the correct length of the year. If Kislev has 29 days then so does Chesvhan. Leap years occur seven times every 19 year cycle on years, 3, 6, 8, 11, 14, 17 and 19.

The **Islamic** calendar in this program is the arithmetic Islamic calendar often used for civil purposes. The religious calendar is determined by observation or other factors and does not necessarily match the arithmetic calendar. There are 12 months (from Muharram to Dhu-al-Hijjah) in the year which is slightly shorter than and therefore unconnected with the solar year. The Islamic calendar has been used in its current form since 10 AH (al hijri). The months contain 29 or 30 days and in the arithmetic calendar the months have the following lengths: Muharram 30, Safar 29, Rabi' al-awwal 30, Rabi' al-thani 29, Jamada al-Ula 30, Jamada al-thani 29, Rajab 30, Sha'aban 29, Ramadan 30, Shawwal 29, Dhu-al-Q'idah 30 and Dhu-al-Hijjah 29 in a regular year and 30 in a 'leap year'. Dhu-al-Hijjah has 30 days 11 times in a 30 year cycle in the arithmetic calendar. These years are called 'leap years', and occur on years 2, 5, 7, 10, 13, 16, 18, 21, 24, 26 and 29 of the 30 year cycle.

The **Day number** can only be set for a radix date: **Fixed**, **JD**, **JDE** and **MJD**. Set the date to the number of days since the epoch. The days are mean solar days except for **JDE** where they are ephemerides days. Fractions of days indicate the time. The epochs are the time from which the radix date is counted: for **Fixed**, 2nd January 1 Julian at 00:00 UTC; **JD**, 1st January 4713 BCE Julian at 12:00 UTC; **JDE**, 1st January 4713 BCE Julian ephemerides at 12:00 UTC; and **MJD**, 17th November 1858 Gregorian at 00:00 UTC.

The **Date of month** can only be set for a calendar date: **Julian**, **Gregorian**, **Hebrew** and **Islamic**. Whole numbers 1 through 28 to 31, depending on the number of days in the month are valid.

The **Month** can only be set for a calendar date: **Julian**, **Gregorian**, **Hebrew** and **Islamic**. The list relevant to the calendar type chosen will appear. Choose the month from the list. Adar II is only valid in Hebrew leap years.

The **Year** can only be set for a calendar date: **Julian**, **Gregorian**, **Hebrew** and **Islamic**. Choose a whole number with a magnitude up to approximately 30000. For years less than one, either zero or a negative number can be used with the **CE** option or a positive number may be used with the **BCE** options. Technically there is no equivalent to BCE in the Hebrew or Islamic calendars although the program allows its use. Note that the year before 1 CE is either '0' or '1 BCE' and the previous year is either '-1' or '2 BCE'.

The **BCE** (before common era) option may be used to indicate years prior to 1 as described above.

Use the **CE** (common era) option for positive years or if expressing earlier years as zero or negative as described above.

The Location window

Click **Change** next to **Location** in the **Input** frame to change the **Location** and automatic time zone settings.

By default the **Location** is the **Temple Mount**, **Jerusalem**, **Israel**, **31°46'33.6"N**, **35°14'2.4"E**, height **728m** with the Israeli time zone.

In the **Entry mode** frame, you may either select **By name** and enter the location by name (**Country**, **Town/City**, **Neighborhood**) or select **By lat/long** and enter the **Latitude** and **Longitude**. If changing the location **By name**, the **Latitude**, **Longitude** and **Height above sea level** are changed accordingly. If changing the location **By lat/long**, the location name becomes invalid.

The **Country** can be changed according to the alphabetical list. In the USA, Canada and Australia, **Country** refers to the state or province (*e. g.*, USA CA for California). If the **Country** is not on the list, you will need to set the **Latitude**, and **Longitude, Height above sea level** and **Time zone** manually. Even in **By lat/long** mode the **Country** can be changed for the purpose of setting the automatic time zone.

The **Town/City** can be changed according to the alphabetical list. **Town/City** also refers to places that are not populated by mountains and parks. If the **Town/City** is not on the list, you will need to set the **Latitude**, **Longitude** and **Height above sea level** manually.

The Neighborhood can be changed according to the alphabetical list. If the neighborhood is not on the list, you will need to set the **Latitude**, **Longitude** and **Height above sea level** manually.

In the **Decimal mode** frame, select the **°'"/hm** option to enter the **Latitude** and **Longitude** in degrees, minutes, and seconds and the **Time zone** in hours and minutes.

Select the **Degs/Hours only** option to enter the **Latitude** and **Longitude** in decimal degrees and the **Time zone** in decimal hours.

The **Latitude** is the geographic latitude. Changing the **Latitude** invalidates the location name fields. In **°'"/hm** mode, enter the integer degrees (**°**) 0-90, integer minutes (**'**) 0-59 and seconds (**"**) 0 up to less than 60. In mode, enter a decimal number from 0-90 for degrees (**°**). Select the option **North** or **South**.

The **Longitude** is the geographic latitude. Changing the **Longitude** invalidates the location name fields. In **°'"/hm** mode, enter the integer degrees (**°**) 0-180, integer minutes (**'**) 0-59 and seconds (**"**) 0 up to less than 60. In **Degs/Hours only** mode, enter a decimal number from 0-180 for degrees (**°**). Select the option **East** or **West**. For **Longitude** 180°, only option **West** is considered valid.

The **Height above sea level** is in meters and can be set between -1000 and 100000. Changing the **Height above sea level** does not invalidate the location name fields but does have an effect on the automatic weather parameters, sky brightness and rise/set times over a sea-level horizon.

The **Time zone** frame contains the parameters for manual setting of the **Time zone**. If the **Auto** option is selected in the **Auto TZ** subframe then the time zone and **DST** mode will be selected automatically according to the country. If the **Manual** option is selected then all the parameters in the Time zone frame will be used.

The manual **Time zone** is set in hours (**h**) and minutes (**m**) in **°'"/hm** mode. Hours may be an integer from 0 to 14. Minutes may be an integer from 0 to 59. The maximum is **14 h 0 m**. In **Degs/Hours only** mode, enter the number of hours as a decimal. Usually the Time zone is a whole number of hours but a few countries use fractional hours such as India, 5.5 hours.

Set the **Direction** to **Ahead of UT** (for most of the Eastern hemisphere) or **Behind UT** (for most of the Western hemisphere).

Choose the daylight savings mode in the **ST/DST** subframe: **ST** for standard (Winter) time and **DST** for daylight saving (Summer) time.

The Weather window

The **Weather** window is used to define the model used for weather conditions at the time of the observation. These conditions affect the apparent magnitude of an object, the brightness of the sky and refraction.

The default weather model is the **Local Basis**. The inactive numerical conditions for use with the **Manual** and **Fixed** models are those for Jerusalem.

The **Basis** of the weather model may be: **Global**, **Local**, **Manual** or **Fixed**.

The **Global**, **Local** and **Manual** models use a daily (diurnal) variation (fig. 6) and an annual (yearly) variation (fig. 7). The daily variation is at one extreme (maximum or minimum) at 14:30 mean solar time and the other extreme (minimum or maximum) at 02:30. The annual variation is at one extreme on 30th July and at the other extreme on 29th January.

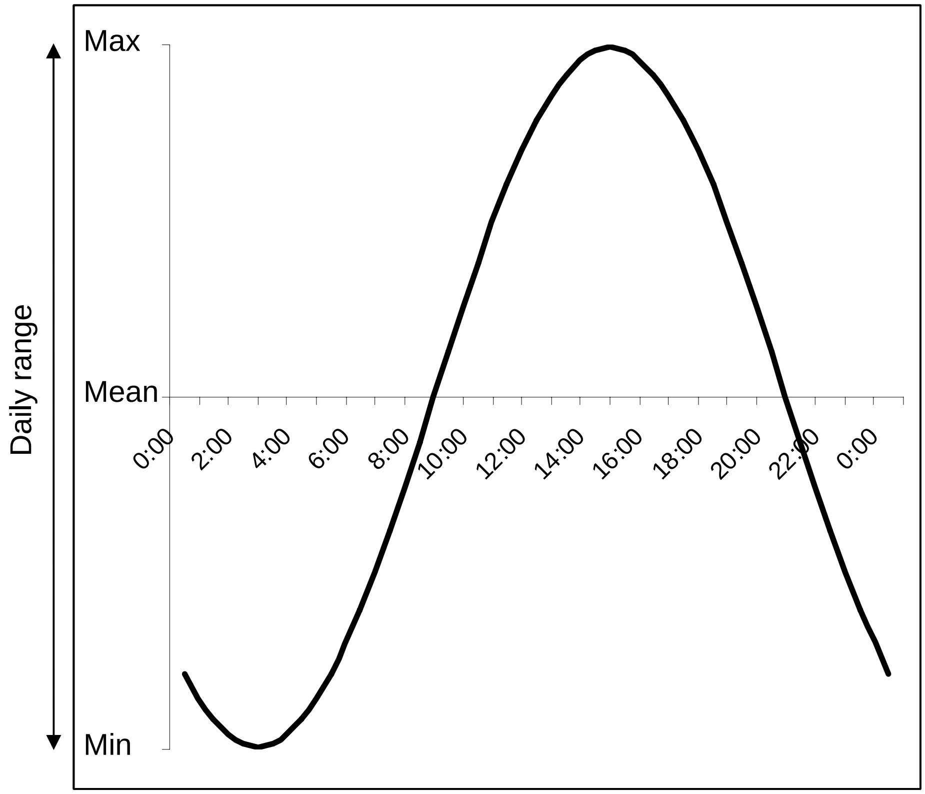

Figure 6. The daily (diurnal) variation of a weather parameter (Temperature, Pressure and Humidity)

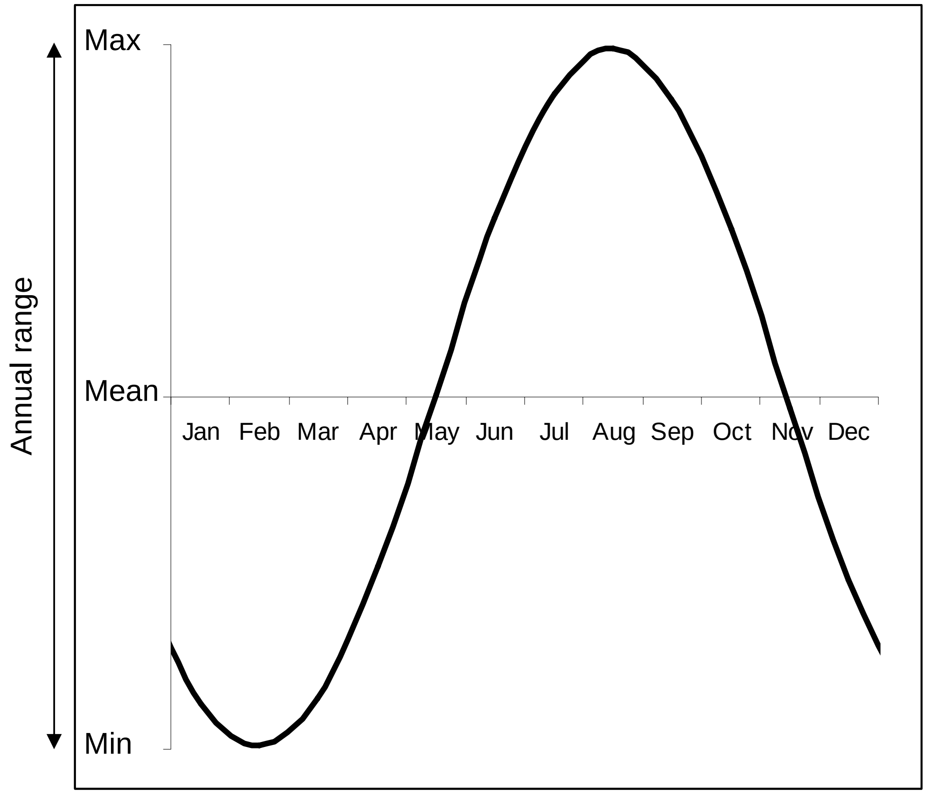

Figure 7. The annual (yearly) variation of a weather parameter (Temperature, Pressure and Humidity)

Global applies a global approximation to the weather conditions. Humidity is set to 50%. The pressure is set to (1010 + 10 sin (2φ + (φ – 45°)(φ < -45°)/3))exp(*h*/7143m) (where φ is latitude and *h* is height above sea level). The temperature is set to 27°C – 0.467|φ| - 0.0065 *h* + 50 sin φ cos(RAsun – 128°)/2 + 2 cos(360° *t* + *θ* – 218°)/2 (RAsun is the Sun's right ascension, *t* is the universal coordinated time in days and *θ* is the geographic longitude).

The **Local** model interpolates the local conditions including annual and diurnal (daily) variations from the three nearest locations in the database.

The **Manual** model allows the user to set the weather conditions and annual and diurnal variations. Under each of **Temperature**, **Pressure** and **Humidity**, set the **Mean**, **Daily range** and **Annual range**. The weather conditions are not allowed outside a reasonable range: temperature -90 to 70°C, pressure up to 1150 mbar and humidity 0-100%.

The **Fixed** model holds the weather conditions constant allowing the user to set the **Temperature**, **Pressure** and **Humidity** manually only in the column marked **Mean**.

The Observer window

The **Observer** window is used to define the personal capabilities of the observer.

By default, the observer's capability is ignored and the visibility of heavenly bodies calculated for the whole population. The default **Average performance** is inactivated and set to zero.

Select the **Overall probability** option to calculate the probability of observation for the general population. This primes the program to calculate the probability that someone picked at random will observe the object. This option should be used for forecasting the visibility to the general public.

Select the **Personal probability** option to calculate the probability that a particular person will see an object. Set the person's **Average performance** to his number of standard deviations from the mean performance for the population. To calculate the **Average performance**, record several observations at the limits of visibility (such as the first or last detection of the Moon, a planet or a bright star) on different occasions (for more details, see above in Worked examples: Planning a Moon sighting). With the **Overall probability** option selected, select the **Magnitude** **Parameter** for that object at the time and place observed and note the **Probability of visibility** (*P*) that results. Set the **Average performance** to the mean value of $\mathrm{erfc}^{-1}(P/100\%)$.

The Criterion window

The **Criterion** window sets the empirical lunar visibility criterion that is usually used by the program. (The criterion is ignored if the **Photometric** option in the **Moon calc.** frame of the **Options** window is selected.) The criterion may be chosen from a list of preset options or tailored from individual parameters. The criterion is made up of two components: **Sky's darkness** and **Moon's brightness**. The darker the sky and the brighter the Moon, the easier it is to see the Moon. For example, the DALT-width criterion uses the difference in altitude between the Moon and the Sun as a measure of the **Sky's darkness**, and the crescent width as a measure of the **Moon's brightness**.

By default the **DALT-width** criterion is selected and the inactive individual parameters are also set to the **DALT-width** criterion. This criterion was chosen as the default because it has been shown to be slightly better than the others.[1]

The **Criterion type** may be set to **User defined**, **Photometric**, **DALT-width**, **Maimonides**, **Ilyas**, **Yallop**, **SAAO** or **Karaite**.

Only when the **Criterion type** is set to **User defined** do the individual parameters become active. This option is used for building a non-standard lunar visibility criterion.

The **Photometric** criterion uses the inverse illuminance of the sky as the **Sky's darkness** and the magnitude of the Moon as the **Moon's brightness** at 0.6 of the lag time (time between geometric sunset and moonset) after the geometric sunset.

The **DALT-width** criterion uses the difference in altitude between the middle of the lunar crescent and the center of the Sun as the **Sky's darkness** and the apparent crescent width as the **Moon's brightness** at 0.6 of the lag time after the geometric sunset.

The **Maimonides** criterion uses the *keshet reiyah* (in degrees is ¼ of the lag time in minutes) as the **Sky's darkness** and ecliptic elongation of the Moon (*orech rishon*) as the **Moon's brightness** at 20 minutes after the geometric sunset. The sum of *keshet reiyah* and *orech rishon*, and the ease of visibility according to Maimonides is also reported under the option **Visibility by criterion**.

The **Ilyas** criterion uses the difference in altitude between the centers of the Moon and the Sun (ARCV) as the **Sky's darkness** and elongation of the Moon (ARCL) as the **Moon's brightness** at the geometric sunset. The ease of visibility according to the Ilyas C criterion is also reported under the option **Visibility by criterion**.

The **Yallop** criterion uses the difference in altitude between the centers of the Moon and the Sun (ARCV) as the **Sky's darkness** and a slightly modified geometric crescent width as the **Moon's brightness** at 4/9 of the lag time after the geometric sunset. Yallop's ease of visibility criterion (*q*) is also reported under the option **Visibility by criterion**.

The **SAAO** criterion is similar to the Ilyas criterion and uses the difference in altitude between the centers of the Moon and the Sun (ARCV) as the **Sky's darkness** and elongation of the Moon (ARCL) as the **Moon's brightness** at the geometric sunset. The Illyas C criterion is not reported as when the **Ilyas** option is chosen.

The **Karaite** criterion and uses the geometric lag time as the **Sky's darkness** and simple geometric fraction of the Moon illuminated as the **Moon's brightness** at the geometric sunset. The apparent illumination and topocentric distance is also reported under the option **Visibility by criterion**.

When the **User defined Criterion type** is selected then each parameter may be adjusted.

Sky's darkness may be set to **Lag**, **Keshet reiyah**, **DALT** and **Sky's illuminance**.

Lag is the time between geometric sunset and moonset. **Lag** is usually used in the **Karaite** criterion.

Keshet reiyah is in degrees ¼ of the lag time in minutes. **Keshet reiyah** is usually used in the **Maimonides** criterion

DALT is the difference in altitude between the Moon and the center of the Sun. **DALT** is usually used in the **DALT-width**, **Ilyas**, **Yallop** and **SAAO** criteria.

Sky's illuminance is the illuminance of the background sky near the Moon and is usually used in the **Photometric** criterion.

Measured to part of Moon describes from where on the Moon the **Sky's darkness** is measured (fig. 8): **Center** of the Moon's disk, middle of the **Limb** of the crescent or **Mid crescent** for the middle of the crescent.

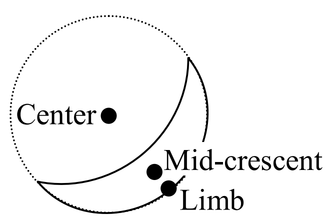

Figure 8. Explanation of Measured to part of Moon.

Moon's brightness may be set to **Age**, **Orech rishon**, **Elongation**, **% Illumination**, **% Illumination/d2** or **Magnitude**.

Age is the time since geocentric conjunction. This is not as good a measure as the others[1] since the Moon's apparent motion varies in its elongated orbit.

Orech rishon is the Moon's ecliptic elongation (the difference in ecliptic longitude between the Moon and the Sun) that is used in the Maimonides criterion.

Elongation of the Moon (the angular separation between the Moon and the Sun) also called ARCL is used in the Ilyas and SAAO critera.

% Illumination is the fraction of the Moon illuminated. This is used in the karaite criterion.

% Illumination/d2 is the fraction of the Moon illuminated divided by the square of its distance from Earth. This was a proposed adjustment to the Karaite criterion although it was found not to be significantly better at predicting lunar visibility.

Stellar **Magnitude** of the Moon is used in the photometric criterion.

Measured from may be set to **Geocentric**, **Topocentric**, **Yallop** or **Apparent**.

Geocentric refers to the positions of the Sun and the Moon as seen from the center of the Earth.

Topocentric refers to the positions of the Sun and the Moon as seen by an observer from the surface of the Earth.

Yallop is a combination of geocentric and topocentric for calculating the crescent width.

Apparent refers to the true width of the crescent or fraction of the Moon illuminated as seen from the surface of the Earth.

When is a number that can represent one of the following options: **Sun ° below horizon**, **Mins after/before sunset/rise**, **Fraction of lag from geometric** or **Fraction of lag from apparent**. This refers to the time when the calculation is applied.

Sun ° below horizon refers to the geometric altitude of the Sun.

Mins after/before sunset/rise is the amount of time after sunset or before sunrise used in the calculation.

Fraction of lag from geometric is the fraction of the geometric (center of the Sun to the center of the Moon without correction for atmospheric refraction) lag after the geometric sunset or before the geometric sunrise that is used to set the time for the calculation.

Fraction of lag from apparent is the fraction of the apparent (top limb of the Sun to the top limb of the Moon with correction for atmospheric refraction) lag after the apparent sunset or before the apparent sunrise that is used to set the time for the calculation.

The controls on the left side below the Input frame

Under the **Input** frame on the left are a number of controls: the **Options** button, the **Print** button, the **Save to file** button, the **Help** button the copyright button, the **Language** listbox and the **Exit** button.

The options button

The **Options** button opens the **Options** window that allows the user to adjust some of the functions of the program.

At the top left is the **Precision** frame this adjusts the precision to which the results are reported.

Normal sets the precision to approximately match the accuracy. This is the default setting.

Overprecise makes the program report results approximately an order of magnitude better than can be relied upon.

Way overprecise makes the program report results approximately two orders of magnitude better than can be relied upon.

At the bottom left is the **Speed probability calc.** frame. This determines the speed and accuracy of the probability calculation for heavenly bodies except for the Moon in **By criterion** mode. (By default, the visibility of the crescent Moon is calculated empirically by criterion and is not affected by the options in this frame.) This function adjusts the coarseness of the numerical integral of probability of visibility. The more the speed, the less the accuracy although on modern computers, speed is rarely a problem.

V. fast inaccurate carries out the calculation very fast with considerable loss of accuracy.

Fast less accurate carries out the calculation fast with slight loss of accuracy.

Normal accurate carries out the calculation at a reasonable speed with no significant of loss accuracy. This is the default setting.

V. slow not better carries out the calculation slowly with no significant increase in accuracy.

At the center top is the **Moon calc.** frame. By default **By criterion** is selected and the visibility of the crescent Moon is calculated empirically by a geometric criterion based on the Moon's brightness and the sky's darkness. If **Photometric** is selected then the visibility of the crescent Moon is calculated according to a photometric analysis.[2-4] At present the **By criterion** method is more accurate than the **Photometric** method for crescent Moons.[1]

In the center is the **Plot mode** frame which governs the appearance of the finder chart. In the **Full graph** mode, the diagram fills the frame. In the default **Proportional** mode, the vertical and horizontal scales are the same. In **Sketch** mode the diagram is minimalized without gridlines and with simplified explanations in the accompanying text.

At the top right is the **Testimony** frame. This defines the number of likely observers and affects the probability that there will be enough witnesses to testify about seeing the crescent Moon.

By selecting **Include women**, the calculation allows women in the population to be counted as witnesses. By default this is not selected because Jewish law does not allow women to testify about the Moon.

The **No. of witnesses** required for valid testimony is set by default to 2 in accordance with Jewish law. The more witnesses required, the less the likelihood of testimony.

The **Population** available is set by default to 700000 which is the approximate number that was within a day's travel from Jerusalem 2000 years ago. The larger the **Population**, the more likely that there will be testimony.

The likely number of observers (**Likely obs.**) is indicated at the bottom of the frame. It is 23 ppm of the population if women are not accepted and 46 ppm if they women are accepted.

The Print button

Click the **Print** button to print a copy of the open windows to the default printer.

The Save to file button

Click the **Save to file** button to save the parameters and text to a text file. A filesystem object will appear and you can select the filename to save to.

The Copy button

Click the **Copy** button to copy the parameters and text to the clipboard so that it can be pasted into another application.

The Help button

Click on the **Help** button at the bottom just left of center to see this file. You can continue working with the **Help** window open. To exit **Help**, click on the X at the top right of the window.

The copyright button

Click the copyright button to see the copyright notice.

The language list

You can select the **Language** (**English** or **Hebrew**) that the program uses from the list.

The Exit button

Click the **Exit** button or the X at the top right of the main window to close the program.

The Output frame

The **Output** frame is on the right side of the main window. The frame contains the options that choose the function to be performed and the results window.

The **Moon, Sun, Planets** option is used to provide parameters about the Sun, Moon, planets and stars. When this option is selected then the **Body** and **Parameter** may be selected from lists.

The **Convert date** option is used to convert between the date and time set in the **Input** frame to a different calendar or time system select from lists of **Date type** and **Time type**.

With the **Moon, Sun, Planets** option selected, the list of heavenly bodies (**Body**) includes the Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn and over 50 of the brightest stars (listed alphabetically).

The **Parameter** for all bodies may be selected from: **Horizon coordinates**, **Magnitude**, **Distance & size**, **Rise**, **Set**, **Ecliptic coordinates**, **Equatorial coordinates**, **Finder chart**, **Probability** and **Light curve**.

The **Horizon coordinates** give the altitude and azimuth of the object from the geocentric viewpoint (as seen from the center of the Earth), topocentric (as seen from the surface of the Earth) viewpoint and, if the object is above or not far below the horizon, apparent position corrected for refraction. For fixed stars only the geocentric coordinates are given because there is no significant difference from the topocentric coordinates. For the Moon, the apparent position of the lit portion and the angle over which the limb of the Moon would appear if placed on a clock face are given.

The **Magnitude** gives the magnitude above the atmosphere. If the object is above the horizon, the magnitude is given as seen through the atmosphere, the brightness of the sky near the object and its logarithm, and the probability of visibility are given.

The **Distance & size** gives the geocentric and topocentric distance in km (parsecs for fixed stars) and angular distance from the Sun (solar elongation). The illumination, phase angle (0° for a full phase and 180° for no illumination) and topocentric radius are given. For fixed stars only the geocentric distance and elongation and radius are given. The phase angle is 0° for a full phase and 180° for no illumination.

The **Rise** **Parameter** gives the time that the object rises. The geometric rise time is when the center of the object is on a level without correction for refraction. Apparent over a flat horizon is when the top of the object is on a level corrected for refraction. Apparent over sea level is when the top of the object appears over the sea which is seen just below the level when the observer is above sea level (fig. 9). The apparent rise time is dependent on fluctuations in the atmosphere and is accurate to about a minute at tropical and sub-tropical latitudes and less accurate at higher latitudes.

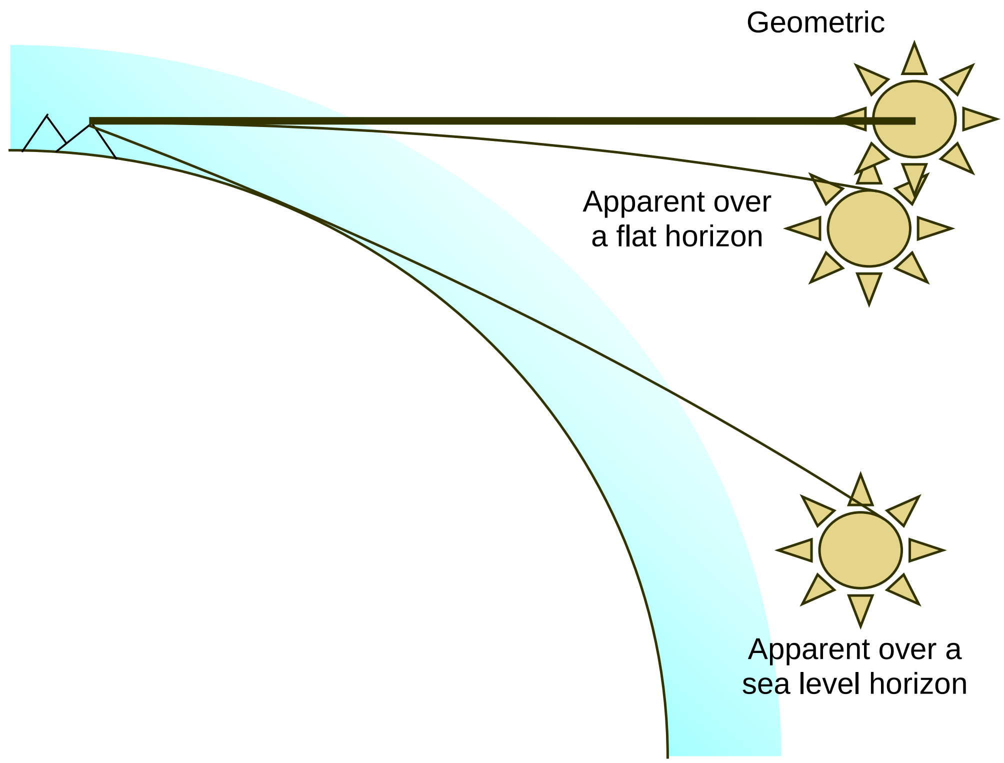

Figure 9. Explanation of rising and setting options: geometric, apparent over a flat horizon and apparent over a sea level horizon.

The **Set** **Parameter** gives the time that the object set. The geometric set time is when the center of the object is on a level without refraction. Apparent over a flat horizon is when the top of the object is on a level corrected for refraction. Apparent over sea level is when the top of the object disappears over the sea which is seen just below the level when the observer is above sea level (fig. 10). The apparent set time is dependent on fluctuations in the atmosphere and is accurate to about a minute at tropical and sub-tropical latitudes and less accurate at higher latitudes.

The **Ecliptic coordinates** relative to the plane in which the Sun appears to move across the sky give the longitude, declination and, ecliptic elongation (that is the difference in ecliptic longitude between the body and the Sun for the Moon this is known as orech rishon) of the object from the geocentric viewpoint (as seen from the center of the Earth), topocentric (as seen from the surface of the Earth). The illumination and phase angle are also given for the Moon and planets and the simplified geocentric values given for the Moon. The simplified geocentric illumination uses the approximation that the Earth and Moon are insignificantly small compared to the distances between them and the Sun. It is calculated using the formula 50(1-cos(geocentric elongation))%. For fixed stars only the geocentric coordinates are given because there is no significant difference from the topocentric coordinates.

The **Equatorial coordinates** relative to the celestial equator give the right ascension and declination of the object from the geocentric viewpoint (as seen from the center of the Earth), topocentric (as seen from the surface of the Earth). The right ascension is given in degrees and hours (hour = 15°). For fixed stars only the geocentric coordinates are given because there is no significant difference from the topocentric coordinates.

The **Finder chart** shows a graph (fig. 2) of altitude and azimuth for the body as it appears on that day. It indicates whether the body is visible. No chart is given if the body is invisible even with a telescope. A red dotted line indicates that the body is invisible to the naked eye, a blue dashed line indicates that it might be possible and a solid black line indicates that it is definitely visible (barring cloud). Beside the curve is the name of the body and ticks indicate the time. The position of the Sun shortly after it rises or shortly before it sets is shown. For the Moon, the planets Mercury, Venus and Jupiter may be shown if they are easier of nearly as easy to see as the Moon. If the **Option Plot mode Sketch** (fig. 12) is selected then a black and white schematic diagram is shown instead. The altitude and azimuth are not usually on the same scale for **Plot mode Full graph** (fig. 10) but are set to the same scale for (default) **Plot mode Proportional** (fig. 11).

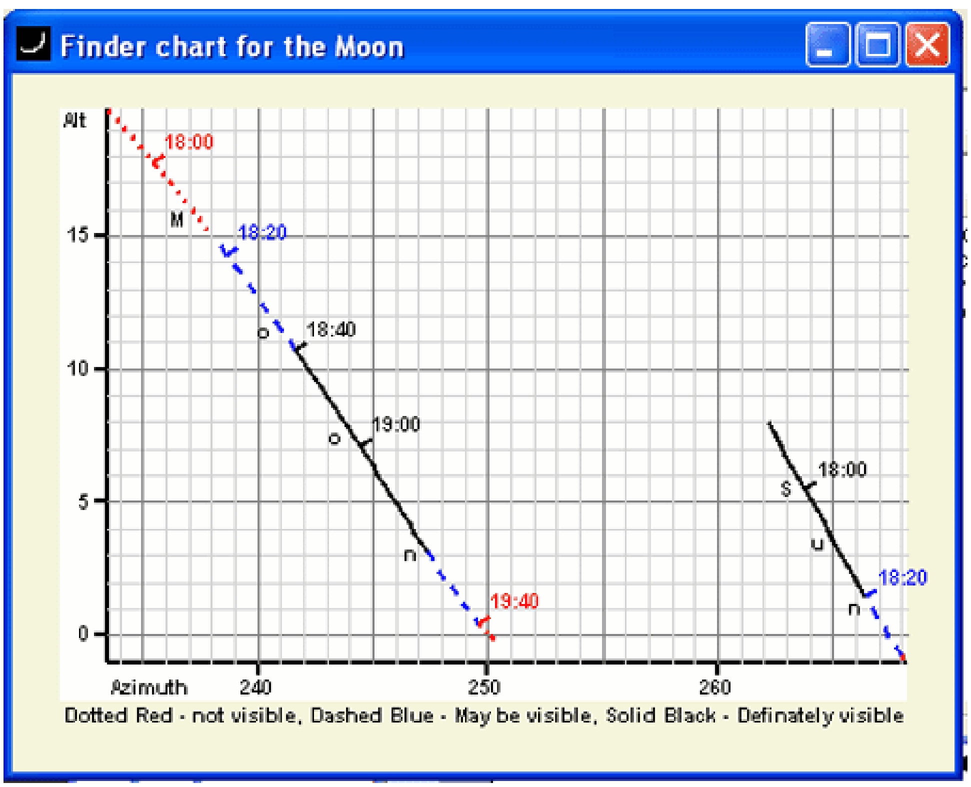

Figure 10. Finder chart with the Full graph option. The diagram fills the pane but the altitude and azimuth are on different scales.

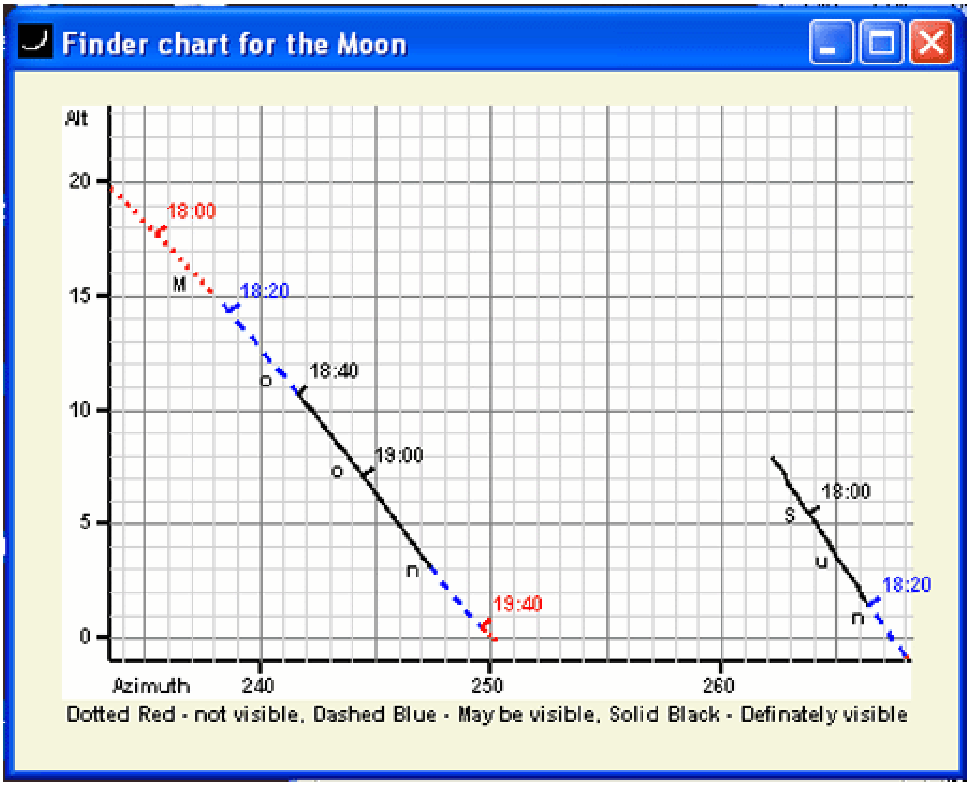

Figure 11. Finder chart with the default Proportional option. The altitude and azimuth have the same scale but the diagram does not fill the pane.

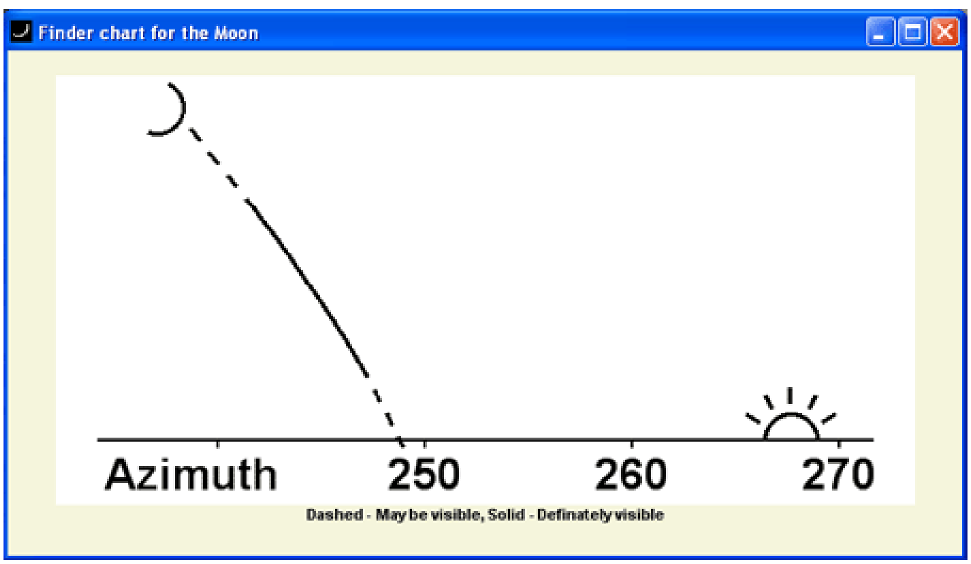

Figure 12. Finder chart with the Sketch option. This is a simplified schematic diagram.

The **Probability** method gives a graph of probability of visibility to the naked eye against time (fig. 13).

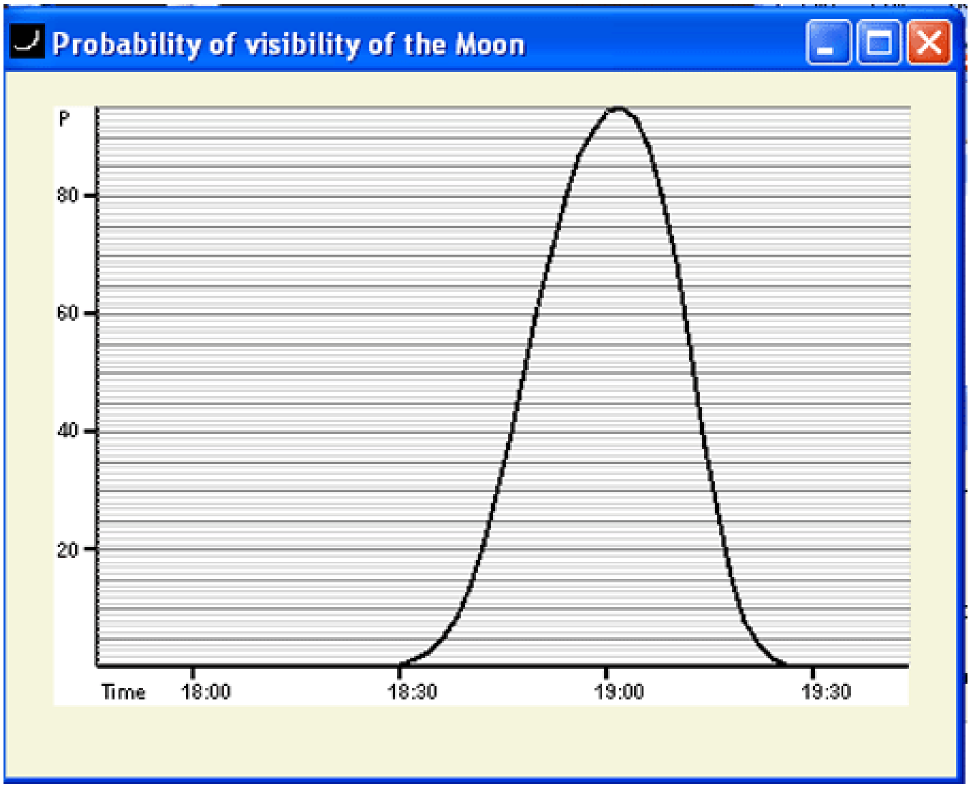

Figure 13. Probability plot showing the probability of naked eye visibility against time.

The **Light curve** shows a graph of stellar magnitude against sky brightness (fig. 14). Beside the curve the ticks indicate the time. A red dotted line indicates that the body is invisible to the naked eye, a blue dashed line indicates that it might be possible and a solid black line indicates that it is definitely visible (barring cloud).

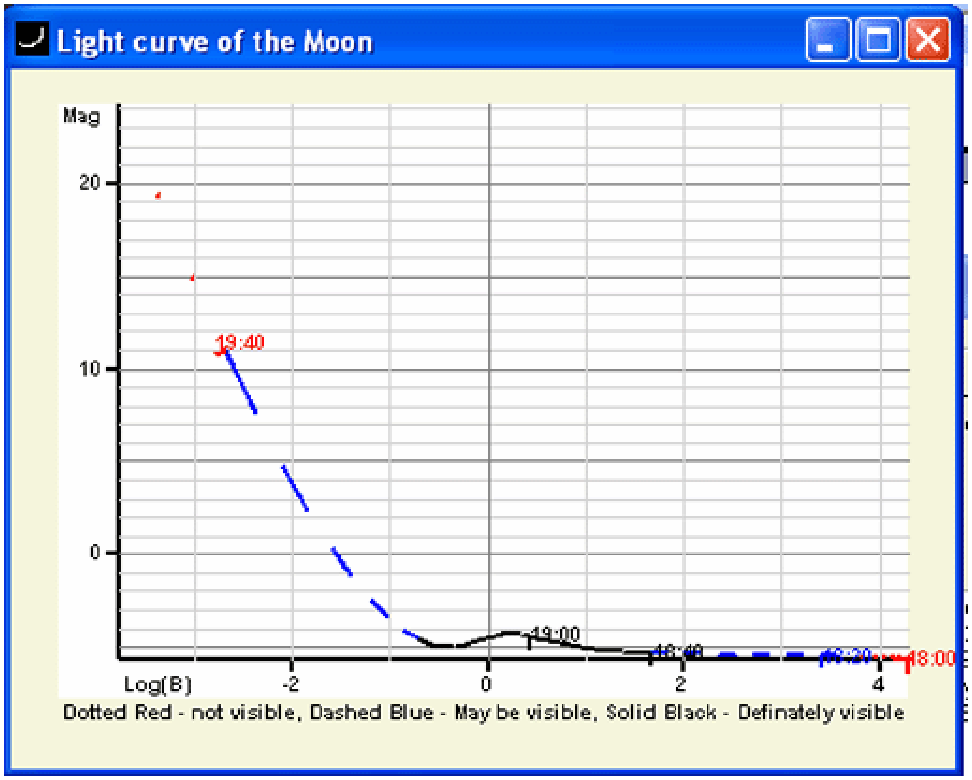

Figure 14. Light curve plot showing the magnitude against sky illuminance.

For the Sun only, there is an additional **Parameter**: **Next vernal equinox** that gives the date and time when the Sun next crosses from South to North as seen from the center of the Earth.

For the Moon there are a number of extra **Parameter**s: **Visibility by criterion**, **Next New Moon**, **Next old Moon**, **Next conjunction**, **Next full Moon** and **Next back-to-back Moon**.

Visibility by criterion gives the criterion parameters and, if the Moon is visible, states when the Moon appears to the naked eye for a New Moon or disappears for an old Moon. The criterion parameters are that for the sky's darkness (**Lag**, **Keshet reiyah**, **DALT** or **Sky's illuminance)** and the Moon's brightness (**Age**, **Orech rishon**, **Elongation**, **crescent width**, **% Illumination**, **% Illumination/d2** or **Magnitude**). A linear combination of sky's darkness and Moon's brightness is called the Total. This is normalized to give an ease of visibility parameter (q) that is less than zero for invisible, 0-1 for possibly visible and over 1 for definitely visible. For some criteria, additional values are given. For the Maimonides criterion the sum of *keshet reiyah* and *orech rishon* and an ease of visibility parameter based on Maimonides calculations given. For the Ilyas criterion, the Ilyas C value for ease of visibility is added. For the Yallop criterion, Yallap's ease of visibility value is added. For the Karaite criterion, the apparent illumination and topocentric distance are added.

Next New Moon gives the date when the next crescent New Moon will first appear.

Next old Moon gives the date when the next crescent old Moon will last appear.

Next conjunction gives the date and time of the next conjunction (no Moon). The geocentric conjunction is a seen from the center of the Earth, topocentric as seen from the surface of the Earth, mean is the average time for conjunction if the Moon's orbit were circular and calendrical (molad) is the value used for calculating the Hebrew calendar today which is currently about 2 hours after the mean conjunction.

Next full Moon gives the date and time of the next full Moon. The geocentric full Moon is a seen from the center of the Earth, topocentric as seen from the surface of the Earth, mean is the average time for full Moon if the Moon's orbit were circular and calendrical (nigud), which is currently about 2 hours after the mean full Moon, is the value used in the Hebrew calendar and used as a time-limit for saying *kiddush levanah*.

Next back-to-back Moon searches for the possibility that the New Moon will be seen the day after the old Moon was seen. This is a very rare occurrence that cannot happen at high latitudes. This function is slow because it has to search through hundreds of months. As it runs, the year being searched is displayed. If a search does not find an occurrence within 20 years, it will ask if you want to continue and if the latitude is too high, it will post a warning before starting.

For the **Convert date** option select the **Date type** and, for calendar dates, **Time type** to convert to from the lists.

Copyright

References

[1] "Rational Design of Lunar Visibility Criteria", R. E. Hoffman, *Observatory*, **125**, 156-168 (2005).

[2] "Prediction of the time of the new Moon's appearance" R. E. Hoffman and T. Kaatz, Yodei Binah, 1, 115-143, (2001)

[3] Schaefer, B. E., 1993, Vistas Astron., 36, 311.

[4] Schaefer, B. E., May 1998, Sky Telescop., 57.