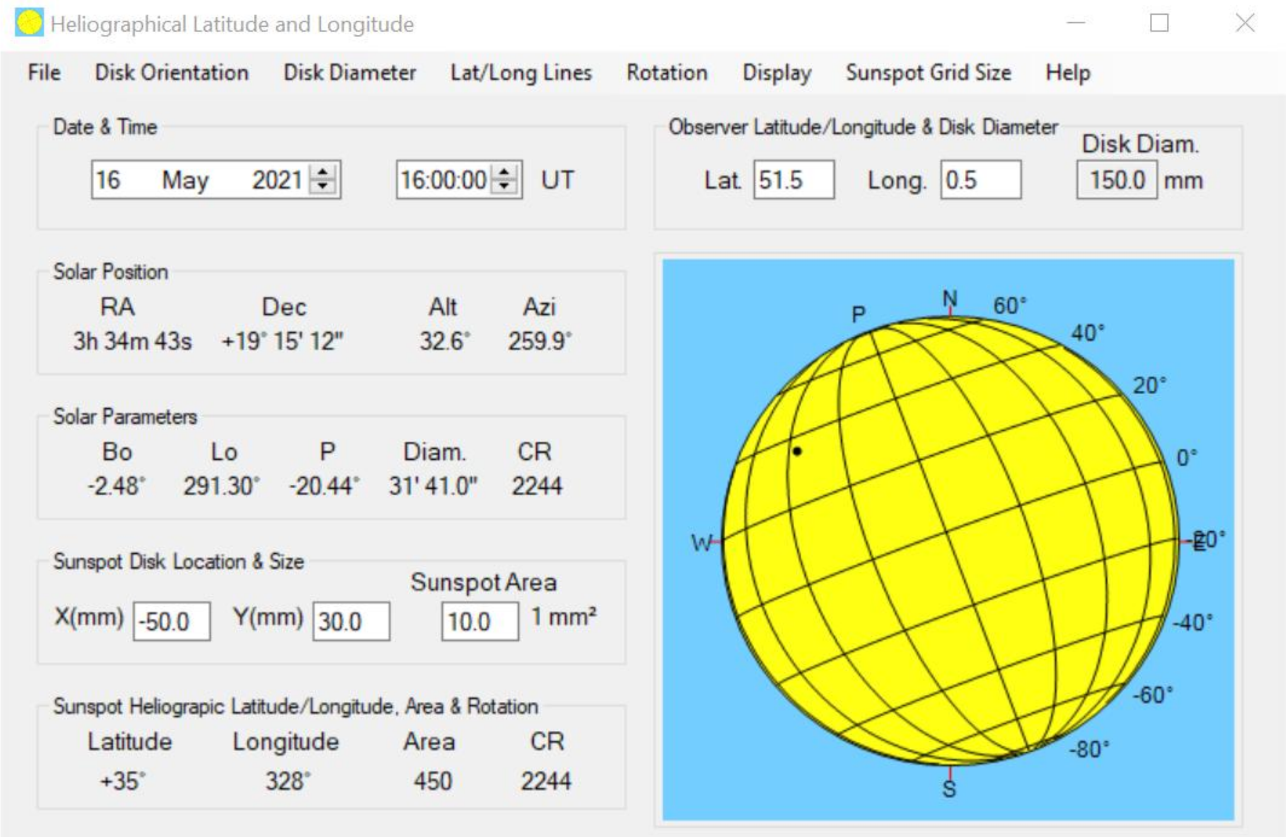
Helio v4.1 User Guide



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Contents

1. Introduction

As a solar observer who makes full disk drawings (see reference [1]) and who wished to determine the latitude/longitude and area of spots groups, I wanted an easy way of measuring these parameters without the need for lots of hand calculations. Thus, Helio was developed to drastically reduce the time required to reduce my solar observations. Helio v1.0 just calculated the latitude/longitude of a sunspot while the sunspot area calculation was added to Helio v2.0 (reference [2]). Version 3.2 of Helio includes the following features:

- Determine the solar position (RA, Dec, altitude and azimuth) and solar parameters (Bo, Lo, P, apparent diameter and Carrington rotation of the central meridian) for a given date and time, and observer latitude and longitude.
- Select the orientation of the solar disk (including equatorial and altazimuth).
- Display the central meridian, solar equator, latitude lines and longitude lines.
- Input or select the position of a sunspot directly on the solar disk.
- Calculate the sunspot latitude and longitude.
- Input the sunspot size and calculate the sunspot area (in millionths of a solar hemisphere).
- Display the Carrington Rotation number at the location of the sunspot.
- Track a sunspot across the disk and from one rotation to the next (or previous) using either Carrington or differential rotation rates.
- Produce a log file for sunspot measurements
- On-line help.

Version 4.0 was very similar to v3.2 except it has been re-written in Microsoft Visual Studio C# 2015 (rather than Borland C++). For v4.1, the appearance of the various lines, such as the central meridian or latitude lines, are displayed with better quality.

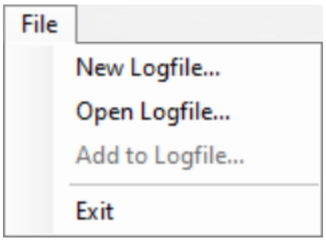
The Helio program can be using for the measurement of sunspot from not only disk drawing but also whole disk photographs or CCD images.

Warning: never look at the Sun with the naked eye or with any optical instrument unless you are familiar with safe solar observing methods.

2. Menus

Here the various menu items shown along the top of the Helio program are explained. Changes to users selectable parameters are stored in the Helio Settings file (see Appendix A) for subsequent executions of the Helio program (i.e. changes from initial setting only need to be performed once).

File



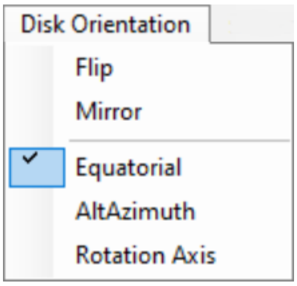
A logfile can be used to output your measurement results to a text file. 'New Logfile...' enables a new logfile to be opened while 'Open Logfile...' opens an existing logfile. The default logfile name for both menu items is HelioLogfile.txt. Note that using the 'New Logfile' menu item to open an existing logfile will remove any previous contents. Using the 'Open Logfile' menu item will append new measurement results to the end of the logfile. Once the logfile has been opened, measurements are added by using the 'Add to Logfile' menu item or by using the 'control left click' with the mouse (Appendix C) anywhere on the 'Solar disk display panel'. If this mouse method is used and the logfile has not been opened an error message will appear. The following are written to logfile for each measurement result (the heading for each parameter is given in brackets):-

- Date in year, month, day, hour, minute and second format (YYYY MM DD HH MM SS)
- Date in decimal year format (Date)
- Right Ascension of the Sun in Hours (RA)
- Declination of the Sun in degrees (Dec)
- Solar altitude in degrees (Alt)
- Solar azimuth in degrees (Azi)
- Solar parallactic angle in degrees (PA)
- Heliographic latitude in degrees (B0)
- Heliographic longitude in degrees (L0)
- Position angle of axis of rotation in degrees (P)
- Solar diameter in arc minutes (SDiam)
- Carrington rotation (CR)
- Disk orientation (of upper right quadrant) (DO)
- Disk diameter in mm (DDiam)
- Sunspot x coordinate in mm (X)
- Sunspot y coordinate in mm (Y)
- Measured size of sunspot in mm^2 (Size)
- Sunspot heliographic latitude in degrees (SLat)
- Sunspot heliographic longitude in degrees (SLong)
- Sunspot Carrington rotation (SCR)
- Sunspot area in millionths of the sun's visible hemisphere (Area)
- Observer latitude in degrees (OLat)
- Observer longitude in degrees (OLong).

A new logfile can be opened at any stage of using Helio (even after a previous logfile has been opened).

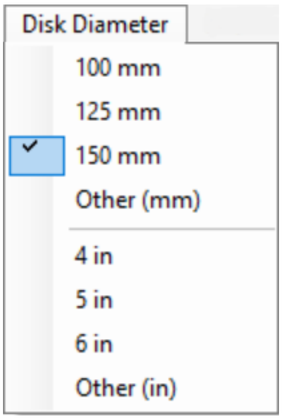
Using the Exit menu item exits the program.

Disk Orientation



With the menu item set to 'Equatorial' or AltAzimuth, the north/south and east/west orientation of the Sun display in Helio Viewer can be changed to correspond to that of your solar image depending on whether you are using an equatorial or altazimuth telescope mounting. Appendix D describes in more detail the orientation of the Sun using an altazimuth mounting. The 'Flip' menu item reverses the north and south solar cardinal points while the 'Mirror' menu reverses the east and west solar cardinal points. Note that the north/south cardinal points do not correspond to the north/south points of the solar central meridian (and thus to the poles of the Sun). Similarly, the east/west cardinal points do not correspond to the east/west points of the solar equator. This is due to the fact that the Sun's and Earth's axes of rotation are inclined by 7.25° and 23.5° to the vertical of the ecliptic plane respectively. Consequently, the position angle of the Sun's axis of rotation changes throughout the year (as does the latitude of the centre of the solar disk).

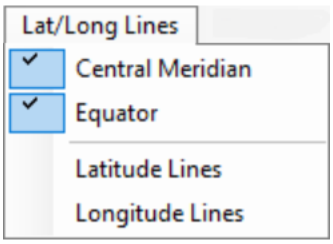
With the menu item set to 'Rotation' Axis, the vertical line through the centre of the Sun becomes the rotation axis of the Sun. Now 'Flip' reverses the top/bottom of the Sun while Mirror reverses the left/right of the Sun.



Disk Diameter

This menu enables the diameter of your solar image to be selected. There are 6 pre-set diameters (3 in mm and 7 in inches) and two user input diameters (one in mm and the other in inches). For the user selectable disk diameters, the input window at the upper right of the Helio window is used to input any diameter required. For the pre-set diameters, this input window in read-only.

Lat/Long Lines



The latitude and/or longitude lines can be displayed, as well as the central meridian and the equator by selecting the appropriate menu item. The north point of the central meridian is marked with a 'P' which corresponds to the position angle of the axis of rotation. Latitude and longitude lines spaced at 20° intervals can also be displayed.

Rotation

Solar latitude and longitudes are calculated assuming that the surface of the Sun rotates like a solid body with a fixed rotation rate. The sidereal period of rotation is 25.38 mean solar days, which corresponds to a mean synoptic rotation period of 27.2753 days. This rotation rate is known as the Carrington rotation period. We all know that the assumption that the Sun rotates as a solid body is incorrect and consequently, the rotation rate of the photosphere is fastest at the solar equator and slower towards the poles. This type of rotation is known as differential rotation.

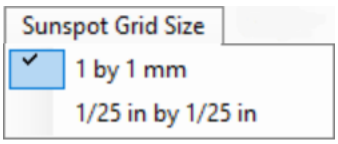
With a sunspot location measured, Helio can be used to track the movement of the sunspot with time, either forwards or backwards. The rotation rate used can be either or both of the Carrington and differential rates (see Appendix B). This is done by selecting the Carrington and/or the Differential menu items and then by altering the date or time. If the date/time is increased, the location of the sunspot on the solar disk will move in the direction of the solar rotation (towards the west) while the opposite will happen of the date/time is decreased. Should the sunspot pass round a limb, the sunspot on the solar disk will change from a solid disk to a hollow disk. Selecting a colour from the Colour menu item will change the colour of the sunspot on the disk. A label can also be displayed above the sunspot (C for Carrington or D for Differential). Colour and labels are useful if both the Carrington and differential rotation rates are selected.

Note that the parameters shown in the 'Sunspot disk location and size' panel (x, y and sunspot size) and the sunspot area do not change as the sunspot moves across the disk. If the differential rotation rate is selected, the heliographic longitude displayed is that determined by the differential rotation (heliographic latitude is not altered by differential rotation). If only the Carrington rate is selected, then the latitude and longitude remain constant. Appendix A gives details of the differential rotation rates as a function of latitude used in Helio.

This menu is useful seeing when a sunspot will pass around the solar limb and for the tracking of previous and future rotations of a sunspot.

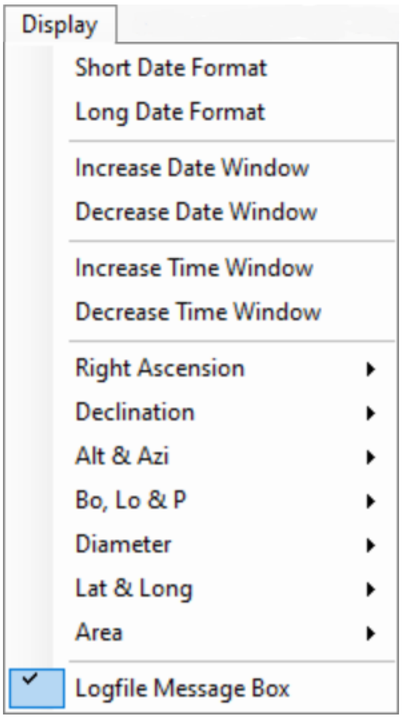
Sunspot Grid Size

For the measurement of sunspot area, a grid is used and the number of grid squares covering the sunspot is input into Helio. There is a choice of grid sizes: 1mm by 1mm or 1/25 inch by 1/25 inch.



Display

The user can select whether to display a short or long version of the date (e.g. 01/06/02 or 01 June 2002). The exact format for the date and time display within Helio depends on the settings of your computer. The size of the Date and Time window can be increased or decreased to be compatible with that of your computer. The user can change the precision to which the solar right ascension, solar declination, altitude and azimuth of the sun, the B0, L0 and P parameters, the solar diameter, sunspot latitude & longitude and sunspot area are displayed. For example, the sunspot latitude and longitude can be display either to a precision of 1 degree or 0.1 degree by selecting the appropriate sub-menu item. Finally, the user can select whether to display a message box every time a sunspot measurement is added to the Logfile.



Help

The help menu gives the welcome window and the about box. The welcome window appears when Helio is started for the first time and at every successive start if the tick box in the lower left is not ticked. The about box includes the web address where additional information about solar observing can be found (reference [1]).

3. Display

Here the various parts of the Helio display (as shown in the first page of this document) are explained:-

Menus

These are described in section 2.

Observer Latitude/Longitude & Disk Diameter Panel

Here user inputs their latitude and longitude for the calculation of the solar altitude and azimuth angles. For observers in the northern hemisphere, latitude is positive while those in the southern hemisphere, latitude is negative. Longitudes can be either in the range 0° to 360° or -180° to 180° where negative longitudes are to the west of the Greenwich meridian and positive longitudes are to the east of the Greenwich meridian.

The disk diameter box is used when the user inputs a selectable disk diameter via the 'Disk Diameter' menu.

Date & Time Panel

Here the date and time are selected. By default, pressing the up or down arrows to the right of the date will increase or decrease the day of the month. If the day to be increased is at the end of a month, then the month will automatically increment (the same is true for the year when a day is incremented from the last day of the year). The month or year can be increased/decreased by first highlighting the month or year (by clicking the month or year) and then pressing the up/down arrows. The time is altered in a similar way to the day (if the time increase/decrease straddles the start or end of a day, the date will also change). The date/time format and/or the size of the date/time boxes can be altered by using the 'Date & Time Display' menu.

Solar Position Panel

This panel shows the right ascension and declination of the Sun at the date and time selected in the above panel. Also shown at the solar altitude and azimuth angles of the Sun from the observer's latitude and longitude. If the Altazimuth disk orientation is selected, the parallactic angle η is also shown.

Solar Parameters Panel

The heliographic latitude & longitude of the centre of the disk are shown together with the position angle of the axis of rotation and disk diameter. Finally, the Carrington rotation number of the central meridian is given.

Sunspot Disk Location & Size Panel

Here the position of a sunspot with respect to the centre of the disk is input as well as the size of the sunspot for the area determination. The position is input by the x and y coordinates of the sunspot (x = 0 and y = 0 corresponds to the disk centre). For example, if the disk diameter is 100mm and a sunspot is on the right cardinal point (to the right of the disk centre) then it will have x = 50 and y = 0. If a sunspot is on the left cardinal point (to the left of the disk centre) then it will have x = -50 and y = 0. Similarly, if there were a sunspot on the top cardinal point will have x = 0 and y = 50 where as if there were a sunspot on the bottom cardinal point will have x = 0 and y = -50.

Rather than input the x and y coordinates in the two boxes in this panel, the user can click on the solar disk display to move the location of the sunspot (Appendix C). The value appearing in these two boxes changes to that of the mouse click.

The third box in this panel is used to input the size of a sunspot in either mm^2 or 1/25 in^2 (the units are changed via the 'Sunspot Grid Size' menu).

Sunspot Heliographic Latitude/Longitude, Area & Rotation Panel

This panel gives the heliographic location of the sunspot, the sunspot area and the Carrington rotation at the location of the sunspot. The sunspot latitude and longitude are given to the nearest degree. The sunspot area is given to the nearest 10 millionths of the Sun's visible hemisphere. If a sunspot is more than 60° away from the centre of the disk, the area is given in red text to indicate that the area measurement may be inaccurate (reference [5]).

Solar Disk Display

The solar disk display shows the Sun and surrounding sky. On the solar disk, the user can choose to include the central meridian, solar equator and latitudes and longitudes at 20° intervals (all via the 'Lat/Long Lines' menu). The north, east, south and west cardinal points are marked around the solar disk together with the position angle of the axis of rotation (if the central meridian is shown) and latitudes (if the solar equator and latitudes are shown). The small black dot shows the position of the sunspot as determined by the sunspot x and y coordinates (as selected by the x and y boxes or by clicking on the solar disk with the mouse).

4. Operation

The use of Helio for the measurement of sunspot latitude/longitude and area are outlined below.

Date & Time

It is firstly necessary to select the date and time corresponding to your observation (in UT). This is achieved by:

- selecting the day, month, year, hour, minute or second (by clicking on one of these so that it is highlighted) and using the up/down arrows to the right of the date and time boxes,
- selecting the day, month, year, hour, minute or second and using the key board up/down arrow keys or
- the day, year, hour, minute or second and typing the required number. Moving between the items within each window can be achieved by using the keyboard left and right arrow keys.

The size of the date & time windows can be altered using the 'Date & Time Display' menu to suit those of your computer settings.

Disk Orientation

The orientation of the Sun display towards the right of the Helio window needs to be the same as that of your observation. The orientation is changed using the 'Disk Orientation' menu. Assuming the orientation of your observations do not change, then this will only need to be altered for the first run of the Helio program.

Disk Diameter

You will need to enter the disk diameter of your observation into Helio using the 'Disk Diameter' menu.

Latitude/Longitude Lines

Latitude and/or longitude lines can be displayed using the 'Lat/Long Lines' menu, as can the solar equator and central meridian.

Logfile

The measurements you make can be stored in a logfile for further analysis. The contents of this logfile can be found in Section 2. The logfile is opened using the 'File' menu and measurements added using either the 'Add to Logfile' menu item or by right clicking anywhere on the 'Solar Disk Display'.

Observer Latitude and Longitude

The solar altitude and azimuth angles requires the observer latitude and longitude. These are input via the 'Observer Latitude/Longitude & Disk Diameter' panel.

Rotation

Once a sunspot measurement has been made, it is possible to track the movement of this sunspot across the solar disk. One or both of two different rotation rates (Appendix B) can be selected using the 'Rotation' menu. By altering the date or time the location of the sunspot will move across the disk (solid disk) and behind the Sun (hollow disk) and back onto the visible disk. This is particularly useful if you wish to track a sunspot from one rotation to the next.

Sunspot Area

The area of a sunspot is measured from your observation by counting the number of small squares that cover the sunspot. For Helio, these small squares are either 1 by 1mm or 1/25 by 1/25 inch (selected using the 'Sunspot Grid Size' menu). The number of squares is entered in the Sunspot Size box, and the resulting sunspot area, in millionths of the Sun's visible hemisphere, is output in the lower left panel. If the angular distance from the centre of the solar disk to the sunspot is more the 60°, then the sunspot area is shown in red. This indicates that the sunspot area is affected by foreshortening and so the sunspot area could be inaccurate (reference [5]). Also output is the Carrington Rotation at the location of the sunspot.

Sunspot X and Y Position

The position of a sunspot is measured from your observation and input into the x and y coordinate boxes. These coordinates are relative to the center of the disk (x = 0 and y = 0) and are measured in mm. Left clicking on the sun disk will give the x and y coordinate of this location and move the black disk to this location; this is useful for determining the coordinate required for the inputting of your sunspot positions. The sunspot latitude and longitude values are given in the lower left panel of the Helio window.

Example

Below is an example set of input parameters and the corresponding set of output parameters including the sunspot latitude/longitude and area.

Inputs
Date: 1st January 2002
Time: 11h 10m UT
Disk Diameter: 150mm
Observer Latitude: 51.5°
Observer Longitude: 0°
Disk Orientation (of upper right quadrant): Equatorial & NE
x: -27mm
y: -22mm
Sunspot size: 10 mm^2

Outputs
RA: 18h 47m 13s
Dec: -22° 59' 38"
Alt: 14.1°
Azi: 167.3°
B0: -3.07°
L0: 73.58°
P: +1.90°
Diam: 32' 35.0"
CR (on central meridian): 1984
Latitude: -21°

Longitude: 95°
Area: 320 millionths of the Sun's visible hemisphere
CR (at sunspot): 1984

References

[1] Meadows, P.J., 'Solar Observing', http://www.petermeadows.com.

[2] Meadows, P.J., 'Spot Check', Sky & Telescope, **101**(5), 72 (2001).

[3] Waldmeier, M., 1955, 'Ergebnisse und Probleme der Sonnenforschung'. 2nd ed. Leipzig, Geest u. Portig.

[4] Bray, R.J & Loughhead, R.E., 1964, 'Sunspots', Dover Publications, 1979.

[5] Meadows, P.J., 'The measurement of sunspot area', Journal of the British Astronomical Association, **112**(6), 353-356 (2002). http://adsabs.harvard.edu/full/2002JBAA..112..353M

Glossary

- Altitude: the angular distance of the Sun above the observer's horizon
- Azimuth: the angular distance measured along the horizon from the north point through east.
- Central meridian: great circle passing through the poles and the centre of the solar disk (as a straight line from the position angle of the north end of the axis of rotation passing through the centre of the disk)
- Declination: the angular distance on the celestial sphere north and south of the celestial equator.
- Parallactic angle: the angle between the great circles that pass through the Sun and the zenith and the Sun and the celestial pole.
- Right ascension: right ascension is the angular distance on the celestial sphere measured eastwards along the celestial equator from the vernal equinox.
- Sidereal period of rotation: the rotation period of the Sun relative to the stars.
- Synoptic period of rotation: the rotation period of the Sun as seen from the Earth.
- UT: Universal time

Appendix A: Helio Settings File

This file contains the user selected parameters. The contents of the file should not be changed via a text editor - they are altered by selecting the user parameters from within the Helio program itself. Below, the default parameters are given together with a brief explanation.

Parameter	Explanation
false	Welcome window ticked (true or false)
1	Flip disk orientation setting (1 or -1)
1	Mirror disk orientation setting (1 or -1)
mm	Disk diameter units (mm or inch)
150	Disk diameter
long	Date format (long or short)
60 75 180 72 258 19	Short date, time and UT caption left position and width
29 140 200 72 278 19	Long date, time and UT caption left position and width
mm	Sunspot size units (mm or inch)
51.5 0.5	Observer latitude and longitude
true	Central meridian displayed (true or false)
true	Solar equator displayed (true or false)
false	Latitude lines displayed (true or false)
false	Longitude lines displayed (true or false)
false bla false	Carrington rotation set (true or false), colour of sunspot and label displayed (true or false)
false bla false	Differential rotation set (true or false), colour of sunspot and label displayed (true or false)
1	Disk orientation set to either Equatorial (1), Altazimith (3) or Rotation Axis (2)
3	Precision setting for Right Ascension
3	Precision setting for Declination
2	Precision setting for Altitude and Azimuth
2	Precision setting for B0, L0 and P
2	Precision setting for Solar Diameter
1	Precision setting for Sunspot Latitude and Longitude
1	Precision setting for Sunspot Area
0	Setting for LogFile Message Display

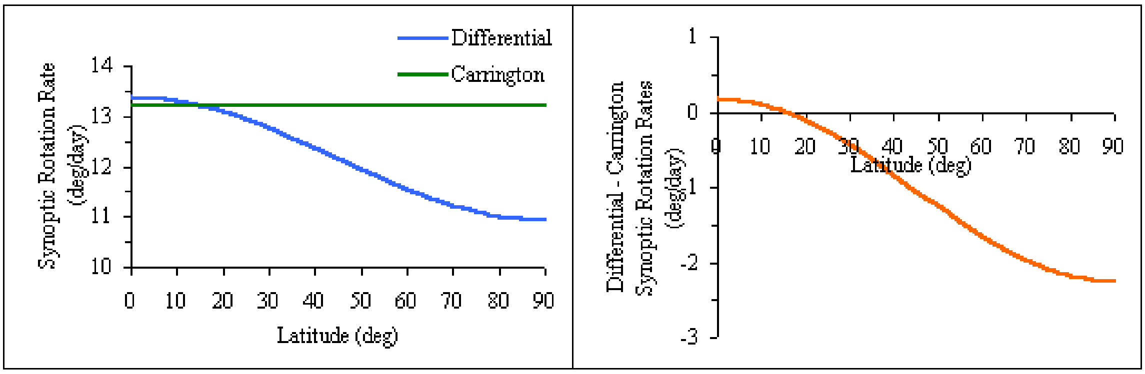
Appendix B: Differential Rotation

The expression used for the differential rotation in Helio is (references [3, 4]):-

$$\omega = 14.37 - 2.60\sin^2 B \quad \text{(deg/day)}$$

where, ω = Sidereal rotation rate and B = Heliographic latitude (deg). The following table shows the differential sidereal rate derived using the above expression as a function of heliographic latitude together with the differential and Carrington synoptic rotation rates. The final column gives the difference between the differential and Carrington rotation rates. The plots below show graphically the data in the table.

Latitude (B) (deg)	Differential Sidereal Rate (deg/day)	Differential Synoptic Rate (deg/day)	Carrington Synoptic Rate (deg/day)	Differential - Carrington Rates (deg/day)
0	14.37	13.37	13.20	0.17
5	14.35	13.35	13.20	0.15
10	14.29	13.30	13.20	0.10
15	14.20	13.21	13.20	0.01
20	14.07	13.09	13.20	-0.11
25	13.91	12.94	13.20	-0.26
30	13.72	12.77	13.20	-0.43
35	13.51	12.58	13.20	-0.62
40	13.30	12.37	13.20	-0.83
45	13.07	12.16	13.20	-1.04
50	12.84	11.95	13.20	-1.25
55	12.63	11.75	13.20	-1.45
60	12.42	11.56	13.20	-1.64
65	12.23	11.38	13.20	-1.81
70	12.07	11.24	13.20	-1.96
75	11.94	11.11	13.20	-2.08
80	11.85	11.03	13.20	-2.17
85	11.79	10.97	13.20	-2.23
90	11.77	10.95	13.20	-2.25



Appendix C: Mouse Controls and Tab Order

The following mouse controls are used within Helio:

Mouse Control	Function
Left Click	Moves the sunspot on the solar disk to the position of the mouse click and calculate heliographic latitude and longitude
Control Left Click	Opens or adds data to the log file

The date, time, x, y and sunspot size boxes are in ascending tab order. Thus pressing tab moves the cursor between these boxes and in this order (shift tab moves the cursor between these boxes in the other order). This is useful if:

- you have several measurement for a single observation when you wish to move from x to y and size in succession for one measurement and then back to x for the start of the next measurement or

- if you have another observation and wish to alter the date/time before making sunspot measurements.

Appendix D: Orientation of the Sun using Altazimuth Telescope Mountings

Determining the orientation of the Sun using an altazimuth telescope mounting is more difficult than using the equatorial type of mounting. With a telescope on an equatorial mounting, the top and bottom points on the solar disk are on a great circle that passes through the celestial pole and that is perpendicular to the celestial equator. This means that the north and south cardinal points are always at the top or bottom of the solar disk and the east and west cardinal point are to the left or right of the solar disk, depending on whether the solar image is mirrored and/or flipped and which hemisphere you are observing from. Using an altazimuth mounting the top and bottom points on the solar disk are on a great circle that passes through the zenith that is perpendicular to the horizon. Now the cardinal points of the solar disk slowly change from sunrise to sunset. Only when the Sun is on the meridian and hence due south, are the cardinal points coincident with the top, bottom, left and right points of the solar disk.

The differences in orientation of the Sun for the two telescope mounting types is illustrated in Figure 1 when the Sun has just risen and is just about to set at the spring equinox (i.e. when the Sun is on the celestial equator). A rectangular field of view is shown for the two mounting types. The angle between these fields of view is the same angle as between the great circles that pass through the middle of the Sun and the celestial pole and the zenith. This angle is known as the parallactic angle (η) and is also shown in Figure 1. Only when the Sun is on the meridian do the two fields of view coincide and hence when η is zero.

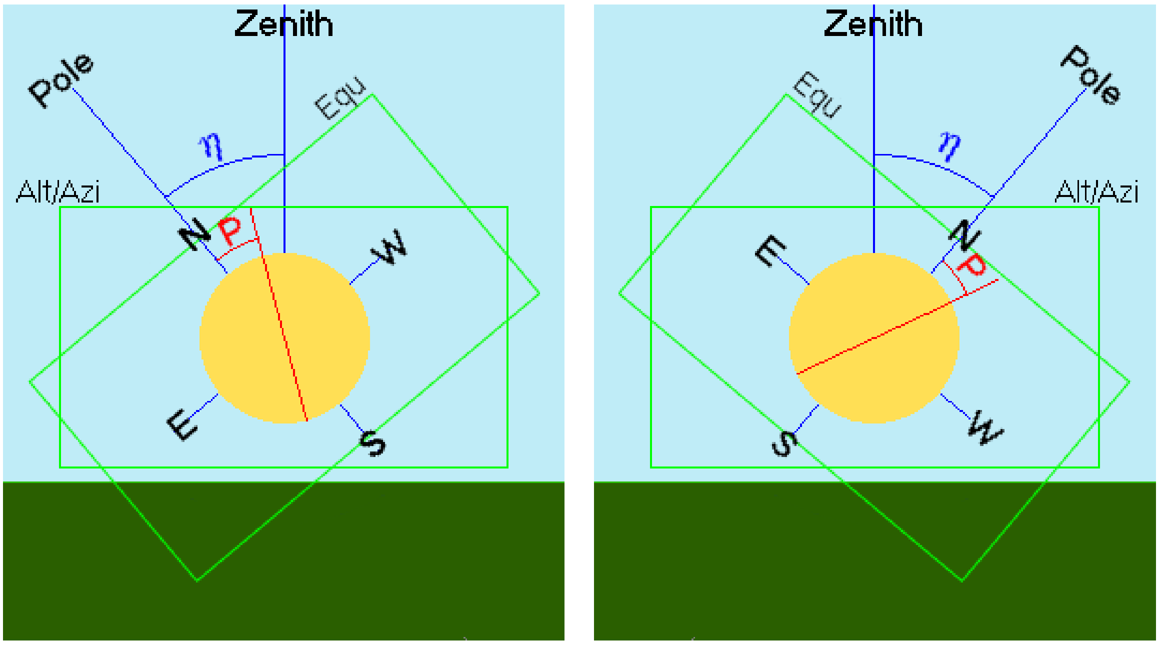


Figure 1. The naked eye view of the Sun just after sunrise and just before sunset at the spring equinox and for a northern hemisphere observer when the solar rotation angle, P, is about -25°. The two rectangles show the field of view for an alt/azi and equatorial telescope mounting.

The parallactic angle can be calculated using one of the expressions given below:

$\sin(\eta) = \sin(A).\cos(\phi)/\cos(\delta)$

$\cos(\eta) = (\sin(\phi) - \sin(\delta).\cos(z))/(\cos(\delta).\sin(z))$

$\cos(\eta) = (\sin(\phi).\sin(z) - \cos(\phi).\cos(z).\cos(A))/\cos(\delta)$

where ϕ = observer latitude, δ = declination and z = zenith distance (altitude = 90 - z) and A is azimuth angle of the Sun.

The parallactic angle has a positive value if the Sun is to the west of the meridian and negative to the east. The range of η values for an observer at 50°N and on the Greenwich meridian is shown in Figure 2. The dotted lines show when the Sun is on the equator (i.e. at the time of sunrise and sunset). The solid black curve is for a parallactic angle of 0° which is when the Sun is on the meridian (i.e. due south); the offset between this curve from 12 hours is the equation of time.

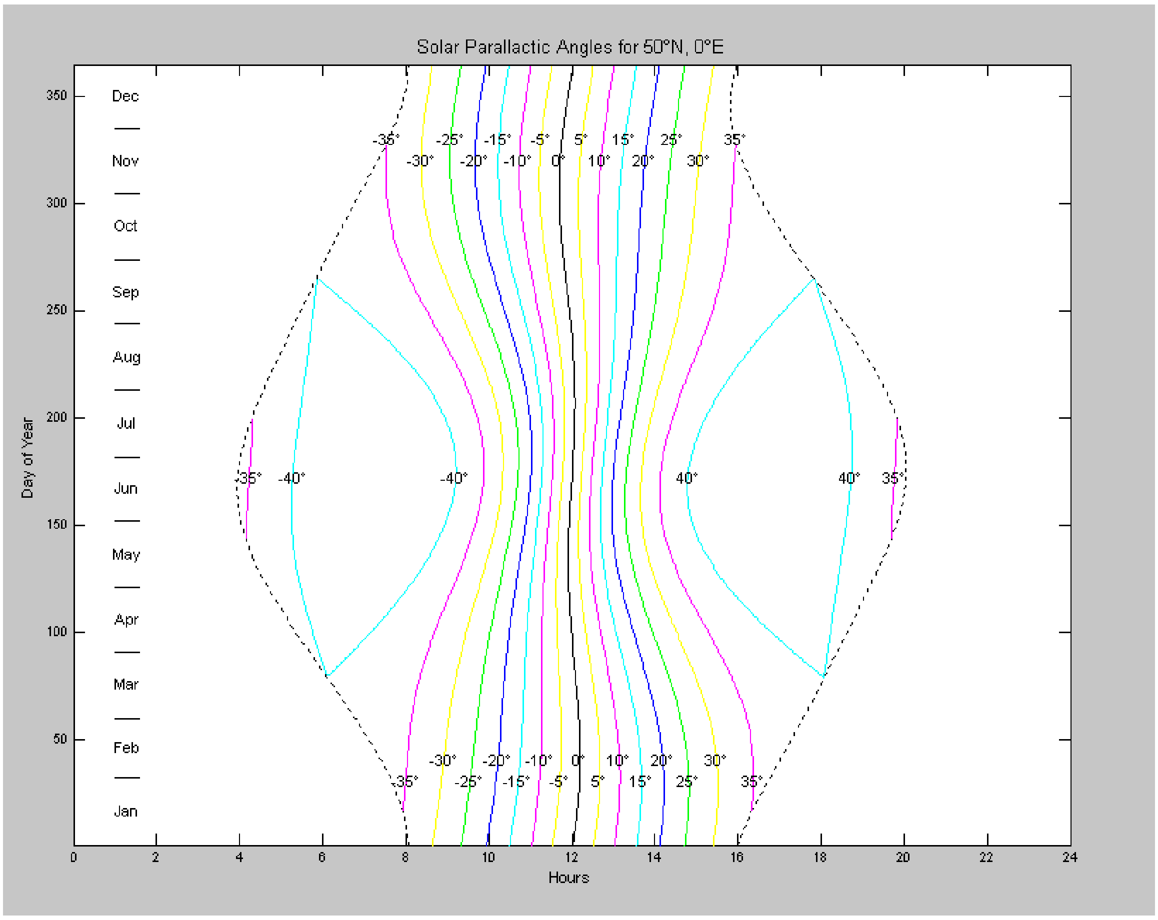


Figure 2. Solar parallactic angles for an observer at 50˚N, 0˚E during the period of a year. Time in UT. At this latitude the maximum and minimum values of η during the year are -44.5˚ and 44.5˚.

Many of the parameters measured by solar observers are separated into the northern and southern hemispheres of the solar disk. The rotation axis of the Sun is offset from the north cardinal point by the position angle of the solar rotation axis, P. The angle P is positive if to the east of the north cardinal point. So if an observer wishes to orientate their field of view with the solar rotation axis using an altazimuth mounting then it is necessary to rotate the field of view by a combination of the parallactic and solar rotation axis angles. This angle, T, is given by η - P. Figure 3 shows the combination of the parallactic and solar rotation axis angles, T, throughout the year.

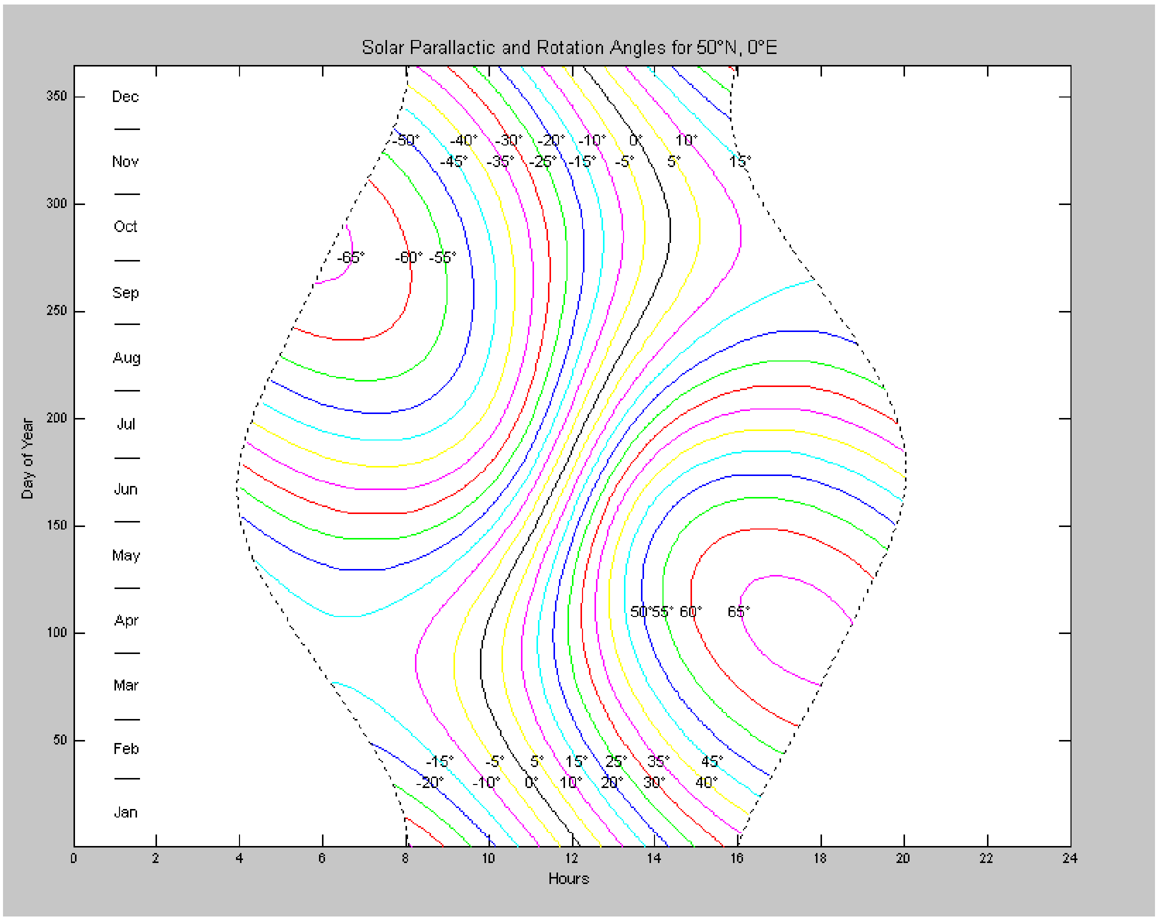
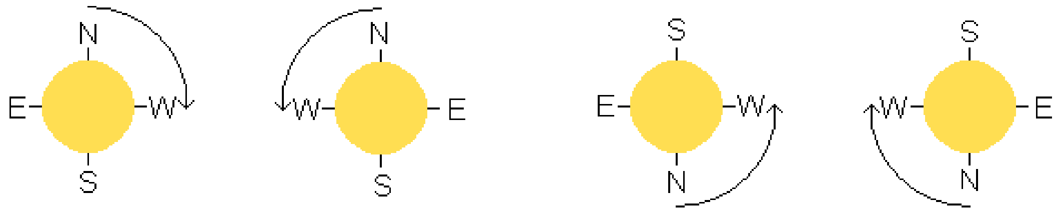


Figure 3. Solar parallactic and solar rotation angles for an observer at 50˚N, 0˚E during the period of a year. Time in UT. The maximum and minimum values of T during the year are -66.7˚ and 66.7˚.

For a naked eye view of the Sun for an observer in the northern hemisphere a positive value of T means that the field of view needs to be rotated clockwise to ensure that the rotation axis of the Sun appears vertical when using an altazimuth telescope mounting. This is shown in Figure 4a for all possible orientations depending on whether the solar image is mirrored and/or flipped. Figure 4b is for southern hemisphere observers.

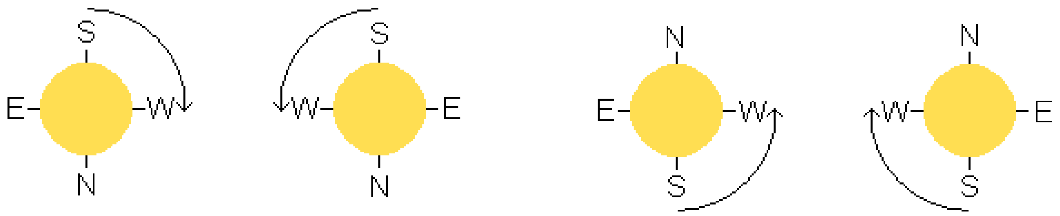
A method to determine the orientation of the field of view is to move the telescope in vertical and horizontal directions when the Sun is on or close to the meridian. Before moving the telescope, the solar disk should be in the centre of the field of view. For a northern hemisphere observer, moving the telescope upwards, the last portion of the solar disk visible will be the north cardinal point. Moving the telescope to the left, the last portion of the solar disk will be the eastern cardinal point. For a southern hemisphere observer, moving the telescope upwards the last portion of the solar disk being visible will be the south cardinal point. Moving the telescope to the left the last portion of the solar disk will be the eastern cardinal point.

How the required rotation is achieved depends on the particular telescope and mounting but could include rotation of an eyepiece that includes a cross-hair. Thus instead of rotating the telescope itself, the eyepiece could be rotated.



Naked Eye Mirror Flip Mirror & Flip

Figure 4a. The naked eye orientation of the Sun (left) for a northern hemisphere observer and when on the meridian together with mirrored and/or flipped orientations. The arrow indicates the rotation direction for a positive values of η or T.



Naked Eye Mirror Flip Mirror & Flip

Figure 4b. The naked eye orientation of the Sun (left) for a southern hemisphere observer and when on the meridian together with mirrored and/or flipped orientations. The arrow indicates the rotation direction for a positive values of η or T.