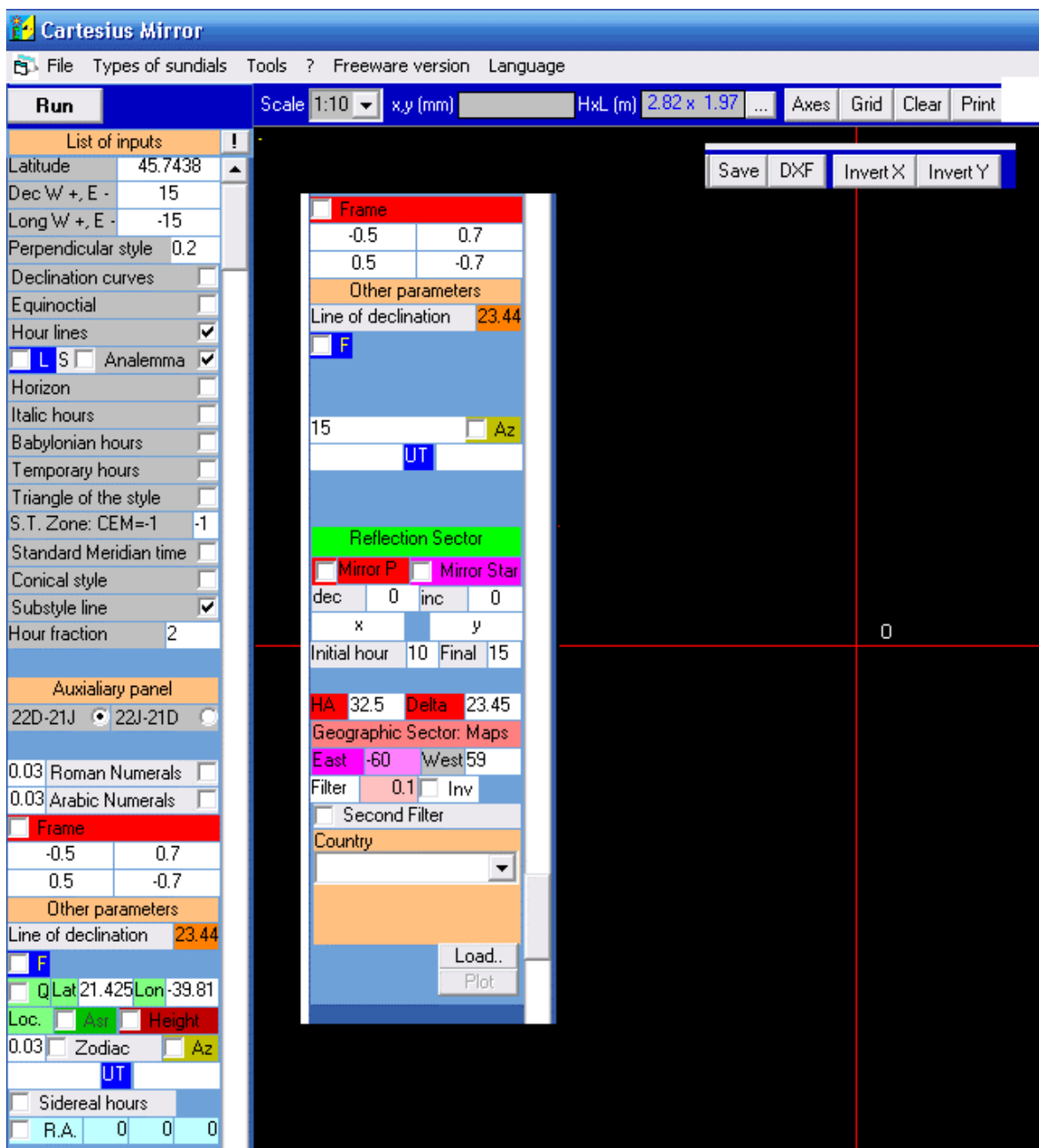


# Cartesius Mirror

## Introduction

The following instructions relate to flat sundials, cylindrical sundials and reflection ones. They have separate menus that show when you make a choice in the box "Types of sundials". However, since the main topic of the software regards flat sundials, when you start Cartesius Mirror the menu for these watches comes automatically. Some commands are common to the two menus but not all of them work the same way even if this differentiation is limited.

The maps, once projected, may have unwanted parts. For this purpose, some filters were introduced to eliminate as much as possible the presence of spurious lines. The procedure for keeping in bounds the maps of the reflection dials and the flat ones is slightly different since the former requires a

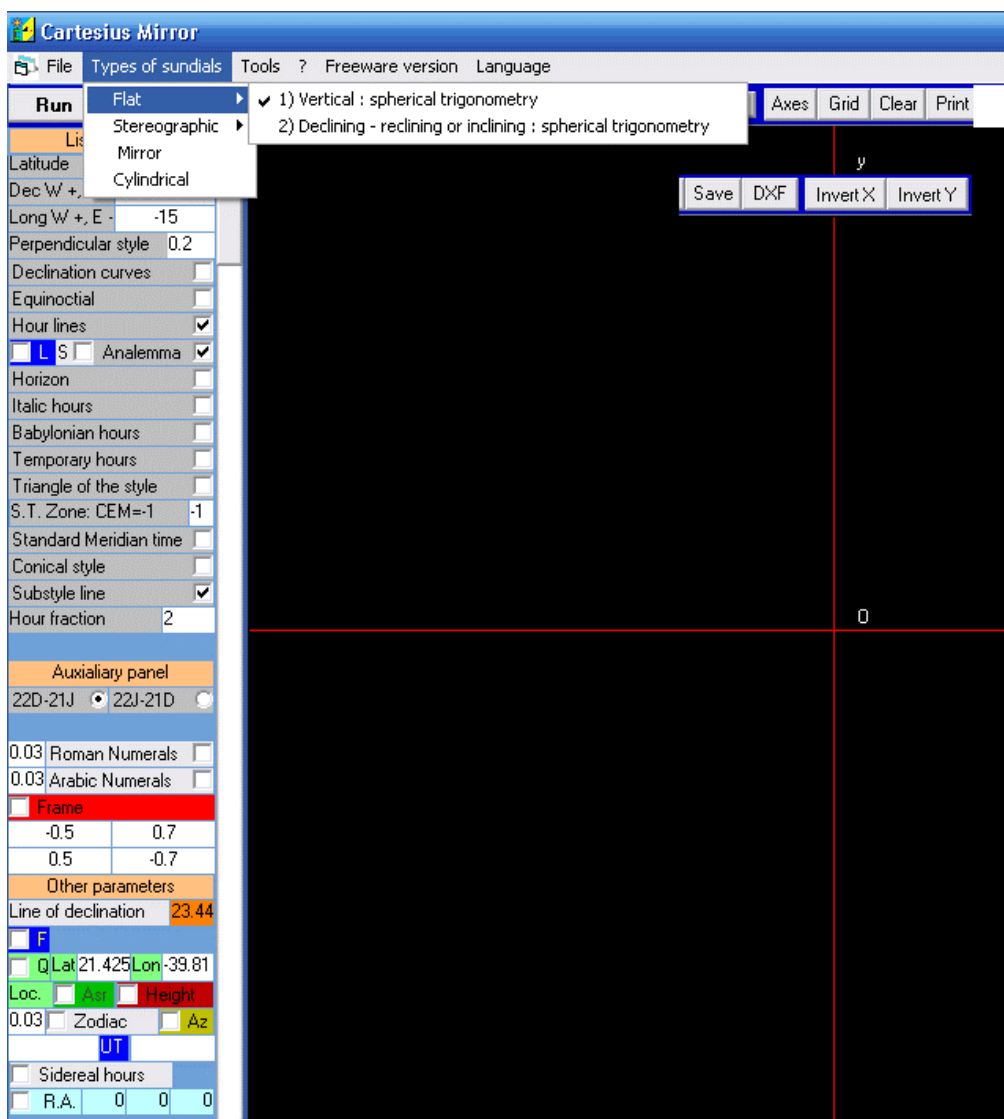


greater number of filters. The part of the instructions concerning sundials catoptrics is developed in the second part of the same.

### STARTUP MENU (composition)

**Cartesius Mirror** is a freeware program in Demo version, written in Visual Basic 6. It produces graph of sundials to scale 1:10 or 1:1 or DXF files. By using scale 1:1 it is possible to create a serial of prints A4 that can be joined together in order to have a sole large sheet. It is advisable to use an ink-jet printer for a more precise print. Other types of printers may cause distortion if they heat the paper. **Cartesius Mirror** easy to use – it has one basic screen with easy-to-follow commands. Cartesius Mirror also provides the graphics in DXF format for use with Autocad. These files are generated by clicking on the button available at the top of the screen. They are positioned on the C drive and are easily recognizable. Cartesius Mirror maintains the logic and structure of the other products in the same series. Who has inserted in the PC Visual Basic, or Autocad, Cartesius Mirror.exe works without problems. For other it is requested to start a setup package available in Astrolabium screen saver, downloadable from <http://sundials.anselmi.vda.it>. Once it is running the screen saver, Cartesius Mirror is enabled.

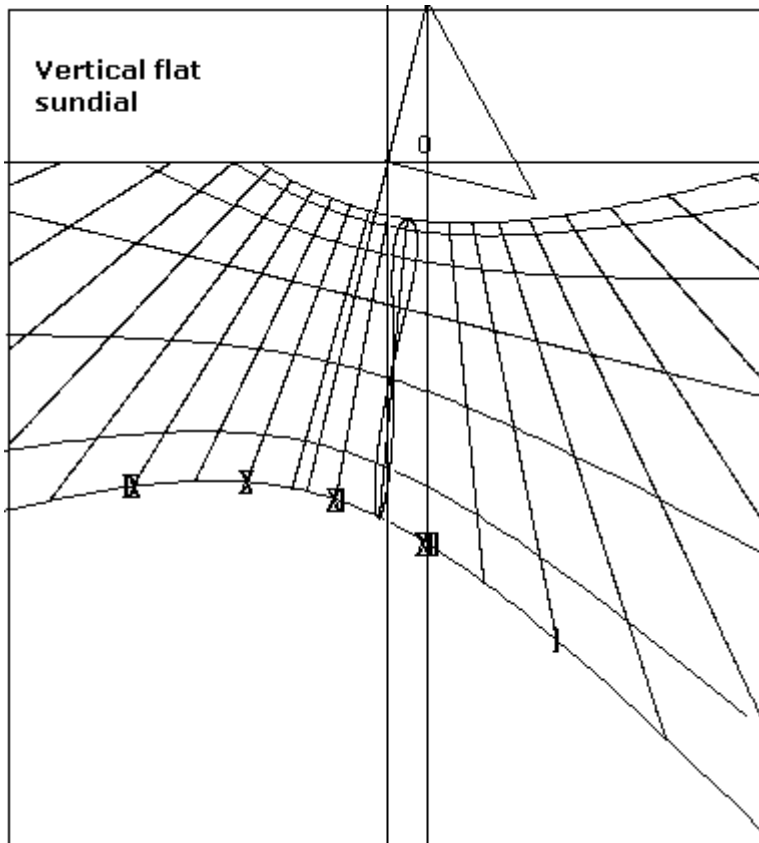
### MENU FOR FLAT SUNDIALS (composition)



When you start Cartesius Mirror a screen with a rich vertical menu on the left shows the commands that are easily understood and a black screen on which videos are made to the various graphs.

At the top, horizontally, some pop-up labels are visible that, once clicked, access to several commands including: **File** , which allows you to save a graphic file or the recovery of the same once saved, **Types of sundials** widely illustrated below and **Tools**. In this last area, you can transform degrees in decimal degrees and vice versa, the calculation of the declination of a dial, the calculation of the declination and inclination of the mirror. The frame below provides essential data relating to the sun, such as sun' azimuth, the equation of time and so on. Let us now see the various types of dial that can be made graphically.

When opening "Types of sundials " it is shown a frame that lists the various types. The first entry is Mirror, running reflection sundials. We note that the choice to address 1) is already clicked because this is pre-selected . By clicking on "Flat", it is evidence a list of 2 types of flat sundials: the 2) for vertical dials and the 3) for declining - inclined ones. We start therefore by this last choice to explain its features. Using the program 2) you will need to click the first choice, then you will get, after the "Run" command, the graph of a flat vertical (default) sundial by spherical trigonometry. Now you go on the menu and then you start filling in the various items that are actually already included but that you can obviously change depending on your convenience. From top to bottom, introduce the latitude in decimal degrees, the gnomonic declination in decimal degrees: positive westward, negative eastward. Then it follows the longitude in decimal degrees positive, west of Greenwich, otherwise negative, the primary purpose of which is to place the analemma of the mean time in the 12 o'clock hour civil ( wristwatch time, etc.). Then the length of the pillar (perpendicular style) in meters. Then it follows the other choices to introduce the diurnal lines of the zodiac signs, the equinoctial, the kind of hours as the astronomical, the mean time analemma, the horizon line, Italic hours, the Babylonian hours, the temporary hours, the triangle (rectangle) of the style represented overturned on the



planethat shows the pillar (perpendicular style), the polar style (hypotenuse ) and the second cathetus that is located above the substyle . By clicking on "local Standard time" you spin the range of astronomical hours until the clock indicates apparent solar time of the meridian of reference (Standard Time Zone = -1). A curiosity is represented by the conical style that in some cases can be made to indicate the Babylonian and Italian hours. It follows the substyle or straight draw below, then the fraction of an hour with subdivisions: 1 for an hour, 2 for halves, 4 for the quarters of an hour. With the voice 3), you must however also introduce the inclination of a vertical plane that is equal to  $0^\circ$  or  $90^\circ$ , depending on the following choice. For the zenith inclination put  $iz = 0$ , for that measured from the

horizontal plane put  $iz = 90$ . With 2) you get complete analemmas, semi analemmas, single or one for each hour. In order to get some combinations it is necessary to use the "L" key and the "S" key. If you click on "Analemma", before RUN, with L and S off you get one full analemma whose position depends on the longitude in use. If you click on "L" only, you obtain many analemmas, if you click on "S" only you get a single semi - analemma whose semester depends on the options 22 D - 21 J or 22 J - 21 D. Also clicking on "L" are obtained analemmas or partial analemmas per each hour.

### **Language**

English is the original language of Cartesius.

Cartesius may use one of the following languages: English, Italian, French.

Special glossary files are available: DBItalianoCMirr.txt, DBFranceseCMirr.txt, DBSpagnoloCMirr.txt and DBCMirr.txt.

The first three are the vocabularies of the voices used in the program; the last one is a file where the language used is uploaded. All these files must be kept near the icon of Cartesius.exe. Once Cartesius is switched on, a small label takes place on the upper side of the screen. Open the combo and choose the language. Then get out of Cartesius (switched it off) and switched it on again. If the procedure has been followed correctly, the voices of the menu will be available in the chosen language. If a file is saved in one language, it must be reopened in the same language in order to avoid mixture of voices in different language. I do advice to do an initial choice and not to change it in future. The use of English language does not need any glossary file. If the program is not in the presence of a txt file related - language, it only works in English.

### **How to save a file visualised on the screen**

Click on the voice "File" on the upper left side of the screen

Click on Save

A frame will appear where the name of the file must be chosen

Let us suppose that "Solary" is the chosen name

Write: "Solary.sun"(without asterisk)

Click on "Save" after having chosen the destination on the file

The saved files will be available in future with the same characteristics

### **How to download a saved file**

Click on the voice "File" on the upper left side of the screen

Look for and click on the same area where the file was saved

Once found the desired file click on it

After clicking on "Download", the saved file will be shown with its original characteristics on the screen.

### **How to save data menu**

There are other data that can be saved while preserving the values (not all) introduced on the menu. Let us see how you make them saved.

On the top left, there is the Run button (Run). Nearby there is a label on which is written "Data inserted" (list of inputs ) and a very small space with a sign similar to an exclamation point. Well, clicking on this square, you save the values in use at that time. When, after turning off the computer, you restart it, the latter values are found on the menu.

### **Data**

After the "Run" command, the label "Data" displays above in the menu, not available before the command. Clicking on the same it appears on the screen a series of data concerning the quadrant of the graph. With the program 2) you obtain, in addition, a series of data that can be used to trace the dial with a ruler and compass. You are advised to print it for a full view of the same.

### **How to change the coordinate axes**

In the upper side of the screen there is the box "Axes". Clicking on it a small frame appears showing the values in use. In general, these are default values.

The coordinate origin is located on the upper angle at left  $O(0,0)$ . The axes are orientated: x-axis positive towards the right; y-axis downwards, unlike the analytic geometry.

To the left of the box "Axes" there is nameless box and a small button. Clicking on it the dimensions of a cornice, multiplied by ten, appear. They relate to a frame to be inserted in a A4 sheet:  $H = 2.82$  metres,  $L = 1.97$  metres. This is the size of the screen in metres to scale 1: 1. Since it is in use the scale 1: 10 the screen is the tenth of the complete frame of the screen. The origin of the Cartesian coordinates utilized by Cartesius in the graph is worth half of the two sides. The origin of the Cartesian coordinates used in the graphs is located in  $1/3, 3333$  of the distance from the top side ( $y = 0$ ) and half from the left side ( $x = 0$ ). Therefore  $x = 0.98474$ ,  $y = 0.84579$ . In order to move the origin it is necessary to modify these values and then click on update. The operation is not handy as it is not immediate the conversion. The new values are automatically cancelled when Cartesius is switched off.

### **How the screen size can be changed**

You can change the default values:  $H = 2.82$  m,  $L = 1.97$  m for viewing a portion of the graph that normally falls out of range. Replace the default values with the new values and click update.

The entered values are deleted when you exit Cartesius.

### **Grid - The grid**

Clicking on "grid" a grid composed of A4 sheets appears making up the screen; they are 1 to 1 scale. Placing the cursor anywhere on the screen and clicking the box in the top left, identified by xy (mm) indicates the Cartesian coordinates of the selected point in mm as measured from the visible Axes when you click on it. At the same time, you see a rectangular numbered area equivalent to the A4 sheet in which the point lies.

### **Print**

Set the scale to 1:10. Clicking on PRINT, without having previously clicked on a zone of the screen, the print of the graph visible on the screen takes place at once. If, at contrary, one or more numbered rectangles have been clicked on, a special pop-up frame appears offering the option either of a print of the entire screen to scale 1:10 or the separate print of the numbered areas to scale 1:1.

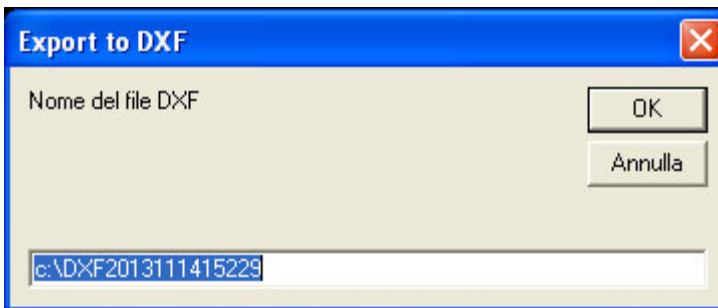
The precision of the print depends on your printers and not on Cartesius. Eventually superimposed written appears perfectly readable once printed.

### **Clear**

This command clears the screen.

### **Save**

This command saves the screen image in BMP heavy format.

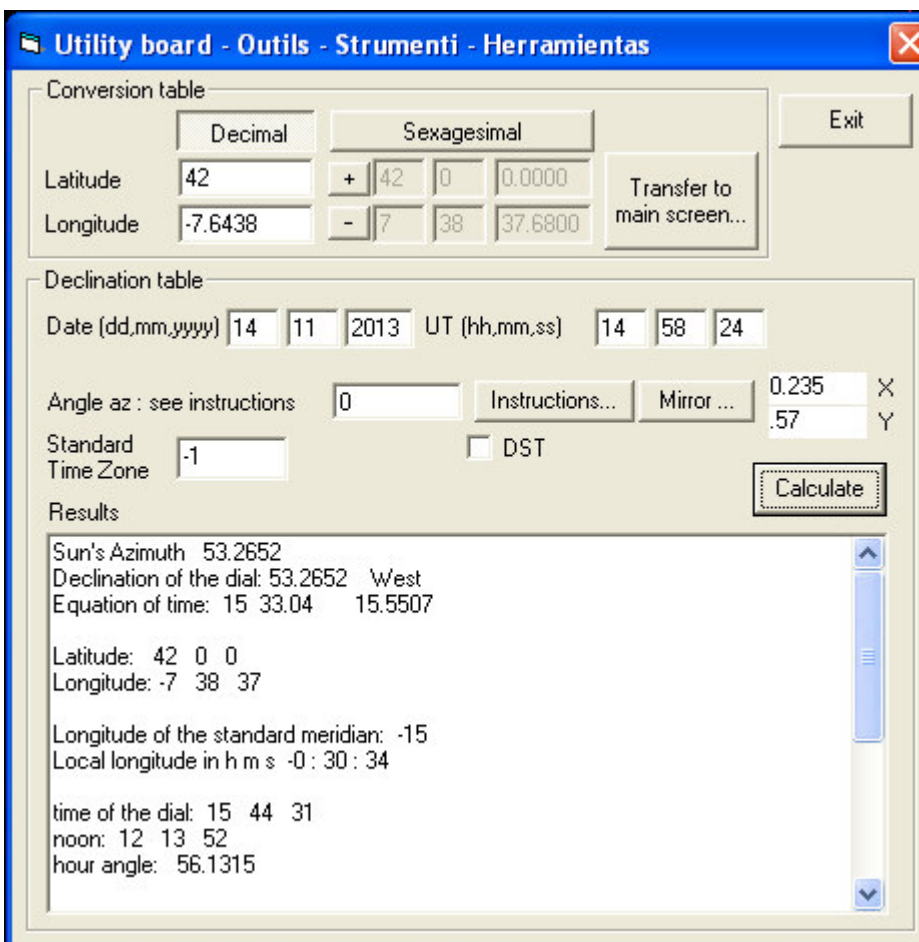


## DXF

For all sundials it is expected to export the graph in DXF format for use with Autocad . Click on the dxf button above the screen generates a DXF files that will be placed on your hard C disk. These files are identified by the group date - time that diversifies them.

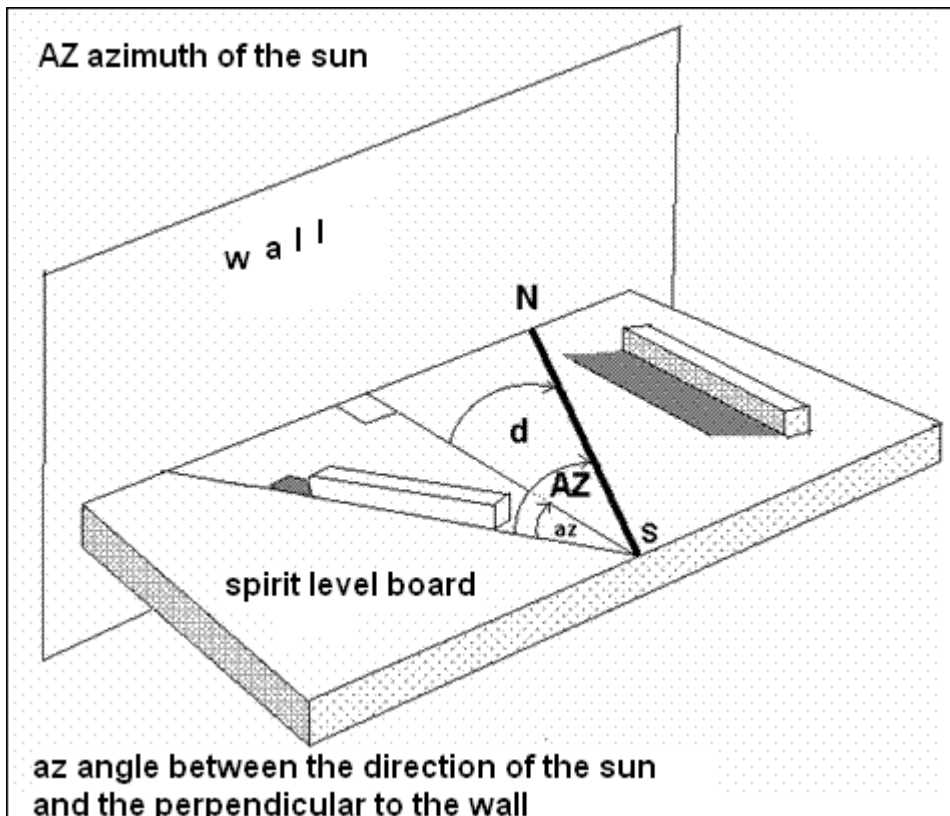
## Tools

Under the heading “Tools” there are available the “*instructions*” for calculating the wall (surface of the sundial) declination, by exploiting the azimuth of the sun and the perpendicular line to the wall. It is necessary the use of a rectangular wooden board leaning the wall in a perfect horizontal position. A precise watch or a radio controlled watch showing the GMT. A wooden parallelepiped whose dimensions are about 20 cm for 5 cm for 5 cm. In order to determine the direction of the sun, (the wooden solid) must be posed horizontally on the board and then dragged until its side shadow disappears. When this particular position is reached the parallelepiped is perfectly aligned with the sun. Using the same wooden solid as a rule, trace a segment by a pencil in order that this straight line crosses the perpendicular line to the wall. Then note down the exact time of the reading. It is advisable



to use a graph paper for recording the data. The gnomonic declination is due to the formula  $d = AZ - az$  where  $Az$  is the azimuth of the sun depending on the latitude, the longitude and the GMT and  $az$  is the angle between the traced line and the perpendicular to the surface measured from this last one with positive sign if clockwise. Cartesius calculates automatically the value ( $AZ$ ) once the data are introduced in the Utility Board and all the other operations. The sense of rotation of the angles represented in the instructions is in use with the azimuth. Please have a look at the survey shown in the “*instructions*” where there are

represented all the possible combinations of  $Az$  and  $az$ .

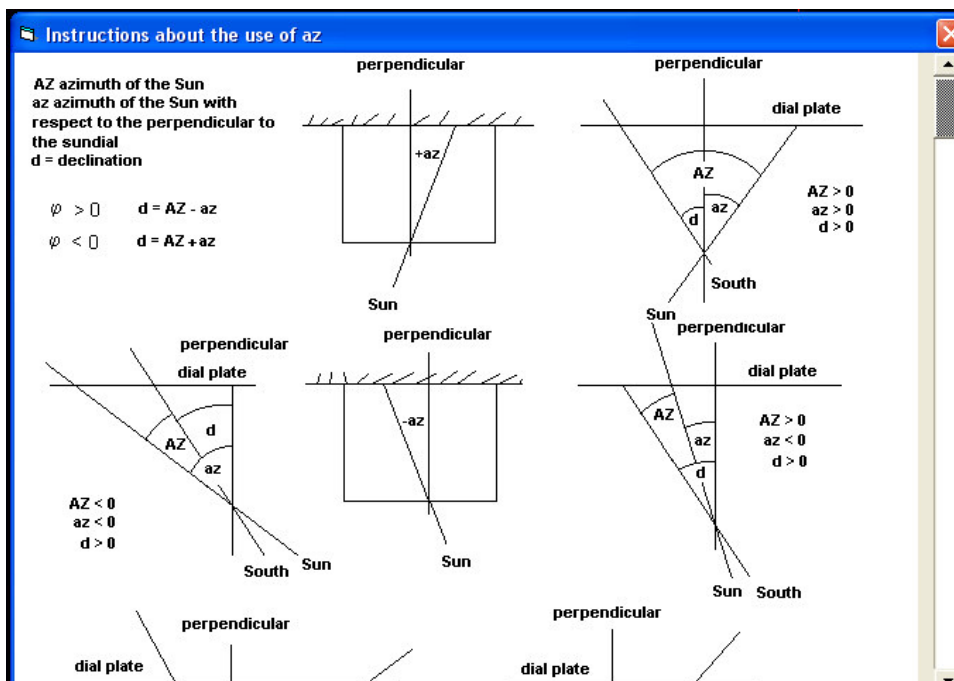


Use the Utility Board for calculating the declination of the dial. Suppose the latitude is 44.77738, the longitude -10.98418 (east of Greenwich), the date is 25<sup>th</sup> April 2009, the time (UT) of the measurement 10h 30p 15s and  $az = -12$ . After RUN you get: Sun's azimuth = -19.9204, declination of the dial = -7.9204 (east) plus other interesting data.

### Star Line

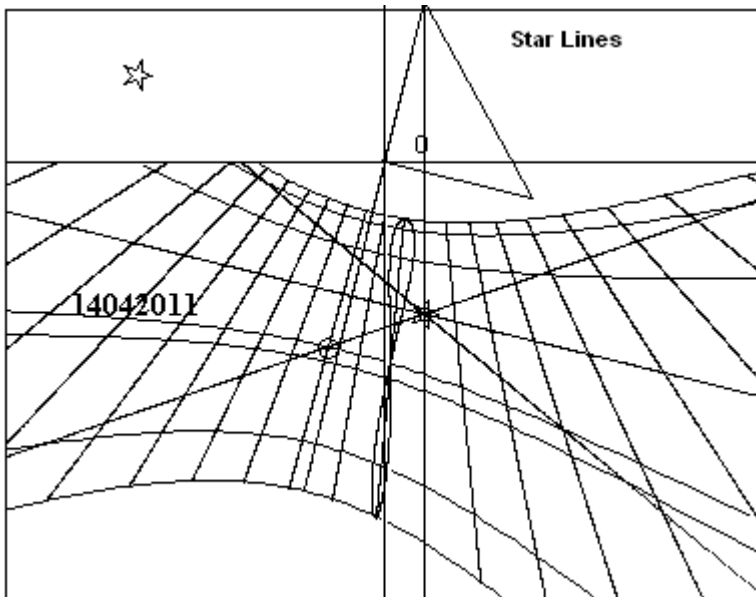
Besides representing sidereal hours available only with program 2), it is possible to know when a star is transiting over

the meridian. The R.A of the star and the declination of the sun on that date, must be introduced. For



instance, if we want to know when the vernal point is on meridian, we must introduce 0,0,0 values of the R.A. of this celestial point in the dedicated textbox on the bottom of the menu. After the command "RUN" two straight lines intersect in the point in which the equinoctial line meets the noon line. The yellow line is valid from the 21<sup>st</sup> of December until the 21<sup>st</sup> of June. The blue line from the 21<sup>st</sup> of June until the 21<sup>st</sup> of

December. The declination line corresponding to 14th April crosses the yellow line at about 10 and 30. In fact, the vernal point anticipates the sun of an hour and 30 p a month before the equinox. The blue star line concerning the 29<sup>st</sup> august, that is the other date in which the sun presents the same



declination, indicates that the vernal point crosses the meridian about 1 hour and half after the midnight. If you use “**T**ools” and introduce any date followed by RUN of this menu, the R.A. of the sun will be transferred to the main menu with the declination (delta). Now if you click on R.A. followed by “**R**UN” of the main menu, two star lines will show themselves.

**F** – this key (Function) allows the user to extend the properties of some functions or to modify them completely. It must be clicked before RUN.

When program n ° 2 is in use, the **F**

reduces the lines of declination from seven to three.

With programs n°2 and n°3), used with Zodiac, it places the zodiacal symbols on the analemma. With program 2 it modifies the style triangle showing the short style only; it traces the steeple Italian hours. If activated, while **diagram** is in use, it shows the execution data.

Clicking on “**D**ata” after “**R**UN”, the lighting of a flat sundial for  $\delta = 23.445^\circ$  displays. If “**F**” is clicked on before “**R**UN” the value used for the lighting relates to the “Line of declination”

**Definition:** In programs 2) and 3), it increases the points of the lines.

**Roman Numerals**, adds Roman Numerals on programs 2) and 3) in correspondence of the hour lines. The dimensions of the characters may be changed writing the wanted value in the textbox aside.

The digits may be moved from their initial position by varying the “Line of declination”.

**Arabic Numerals**, adds Arabic Numerals on certain programs in correspondence of the hour lines.

The dimensions of the characters may be changed writing the wanted value in the textbox aside

The digits may be moved from their initial position by varying the “Line of declination”.

The use of Roman Numerals and Arabic Numerals is reciprocally alternative.

The numbering of Italic, Babylonian and Temporary hours is possible only with program 2).

Nevertheless, the digits are fixed and not printable.

**Line of declination** is a daily line corresponding to an optional declination that may also represents a special date. The same line places the Roman numerals and the Arabic numerals on a invisible line.

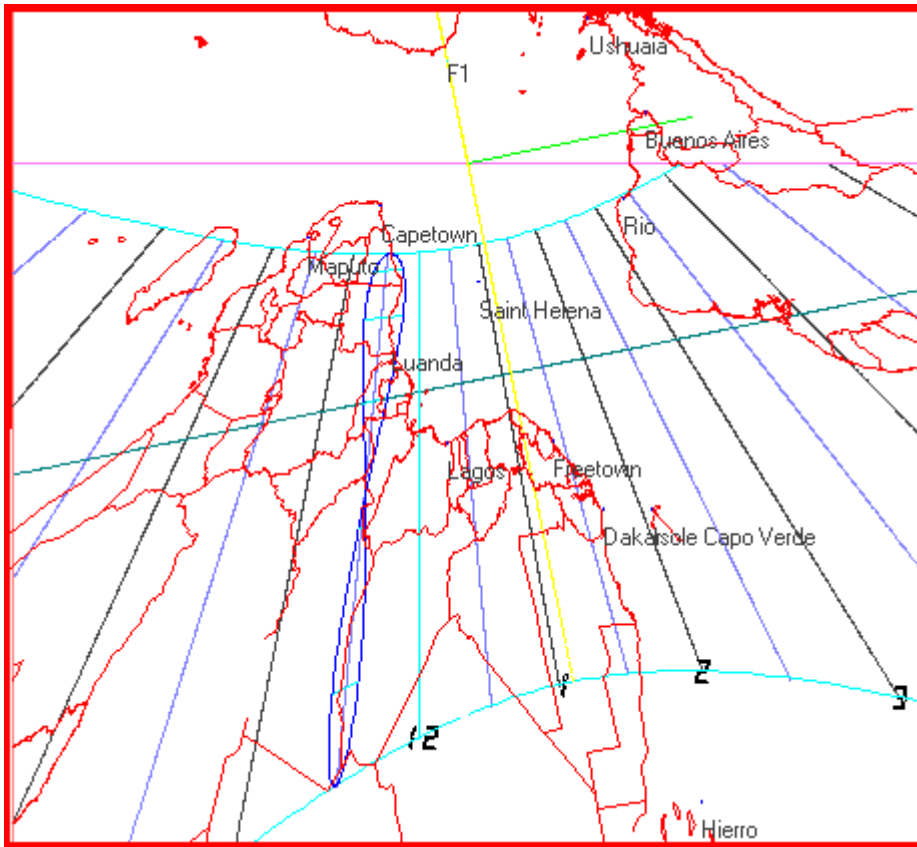
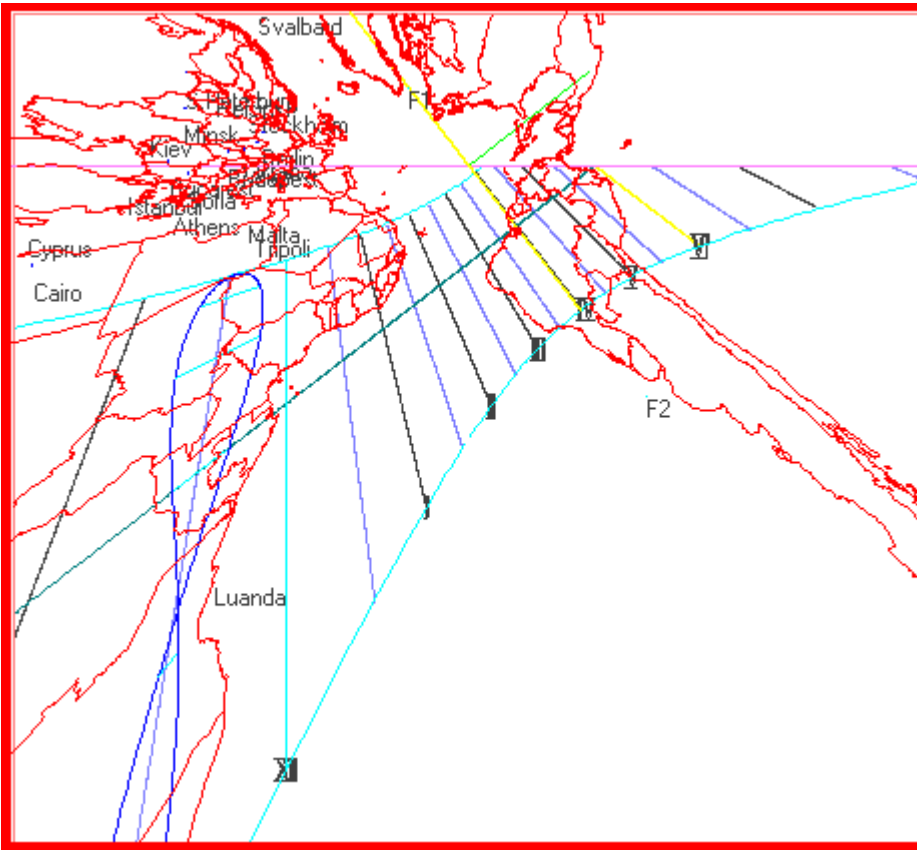
In general, it is necessary to click on “**F**” before “**R**UN” for tracing the wished line of date.

**Q**, initial of *Qibla*, indicates the direction of Mecca, because the default values refer to this locality, Holy Sanctuary for the Muslims. It is possible to get the indication of any place by inserting its latitude and longitude. The **Q** function makes appear a line of azimuth on the graph so that when the shadow of the style crosses it the sun shows the direction of this particular place. This function is not available with Mirror program.

**Loc**, overwriting “loc” with a name of a locality this word will appear on the graph but not on the print.

**Asr** is a Muslim prayer that should be said when the shadow of the style will reach it. Program 2 only





**Height, Almucantarats** – the graph will show the lines that represent the same angular height of the sun. Program 2) and 3).

**Zodiac** introduces the zodiacal symbols around the analemma but only with programs 2) and 3). The dimensions of the symbols are adjustable by the aside textbox.

**Az**, initials of azimuth, are segments of line that like the Quibla indicate the Azimuth. All the programs.

**P** - Point works with programs 2) and 3). After the command "Run" a red option button appears at the bottom of the menu. Clicking P, after having placed the longitude = 0, a small white star, surrounding a yellow circle, with blue interior, is positioned on the chart at the point with coordinates chosen with the values entered in the red textboxes (HA and Delta). This function can also be used for highlighting one or more geographical points by which to build a universal sundial. In this case, enter the latitude in degrees and decimals in the textbox delta while the longitude of the chosen location (in degrees and decimals) in the textbox HA. For example, if the sundial is being built in Milan (lat. =  $45^{\circ} 27' = 45,46^{\circ}$ , long. =  $-9^{\circ} 11' = -$

9,183°), and you want it to indicate the noon of Madrid (lat. = 40° 25' = 40,17 °, long. = 3° 42' = 3,7 °) then the value ± 40,17 should be entered in the textbox delta and 3,7 in the textbox HA. Cartesius is able to supply automatically the positioning of many capitals and famous places that materialize on the graph with a yellow circle and red interior, clicking on P with F clicked. The position of the localities shows, however, with east and west reversed. If you want to exchange the north with the south of the map click INV on the checkbox before P. The number of places available (max 156) depends in part on the values entered in the textboxes East and West that act as boundaries. There are two textboxes: the first on a pink background for the smaller number, the second with a white background for the bigger number. Universal sundials with geographical programs 2) and 3) can be furnished with a map. The universal sundial, so made, shows, in gnomonic projection, the profile of continents and countries that compose them. Since it is possible to invert the sign of the latitudes without affecting the function of the universal sundial there are two cases, which need to evaluate the appropriateness of the choice. The first of the two images (1b) shows the north at the top with all the European capitals but it has reversed geographical East with the West. There is a clear reason for this anomaly depending on the gnomonic projection.

The second image (a1), with the south at the top, maintains the normal appearance of a geographical map with the four cardinal points arranged in the traditional manner, even if inverted. With this choice, almost all images of European countries are lost while favouring those Southern ones. The sequence of the capitals of Europe must find its place or on the frame or on a specific band, continuing to correctly indicate the south of the northern countries and their longitude, but not the latitude.

To get the map you have to click on the bottom of the menu item Load in the combo Country. After a short while the voice World materializes. If you click on Plot, the graph forms a map that depends on the parameters of the dial: latitude, longitude, declination and inclination. However, if you act on the combo, you can choose one or more states that become visible on the screen after clicking on Plot .

### **Accuracy of the graph**

If you have slight differences between the measures introduced and the printed chart, you should proceed using the program 2) to quantify and eliminate the error. Enter a perpendicular style of 0.2 m as a reference. To print to 1:1 scale of the triangle of the style, and then check the length of the perpendicular style that hardly is of 0.2 m. To cancel any differences, which are generally below the half mm, multiply the length of the perpendicular style by a factor such as the next printing is in accordance with the length initially chosen. Example: Suppose that using a style of 0.2 m a print of 0.1999 m is found. The new length of the perpendicular style will be obtained by multiplying 0.2 by  $0.2 / 0.1999$  equal to 0.20001 to get the printout of a perpendicular style equal to 0.2 m.

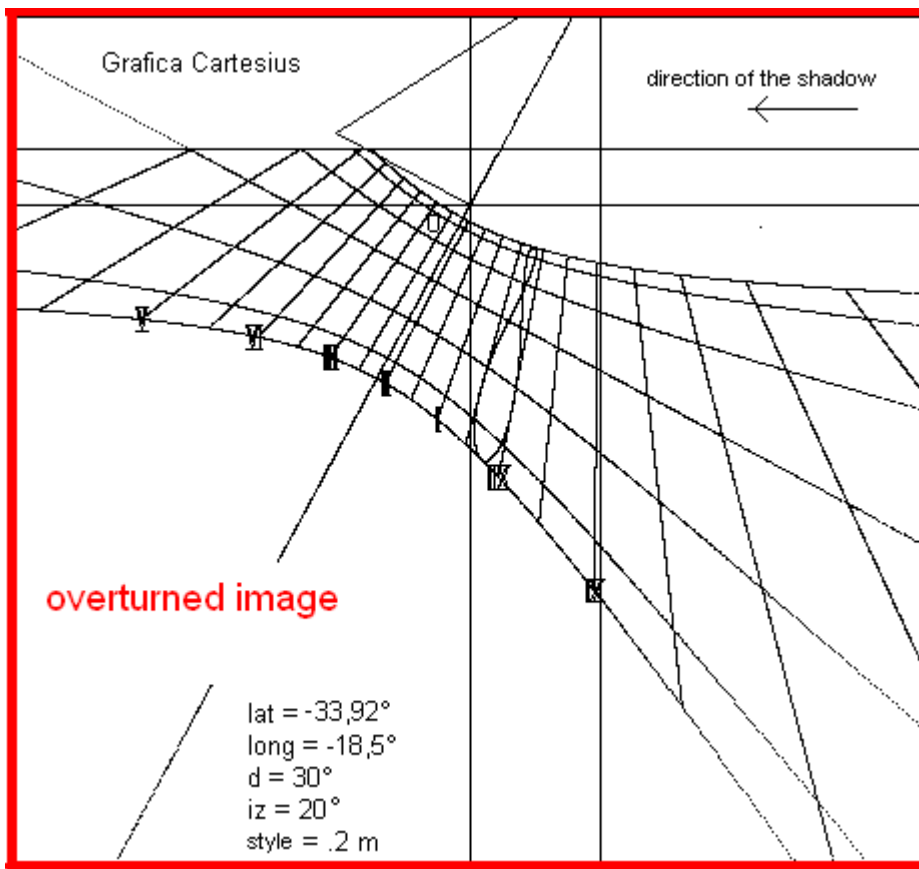
### **Reversing graphics**

Clicking on the screen on the item InvertX the graph shown is tilted horizontally. Clicking on InvertY is tilted vertically.

This function is valid also for printing; you may want to trace reflection sundials and flat sundials in the southern hemisphere.

### **Southern Hemisphere**

You can easily get sundials plans for the southern hemisphere using the program 3 ) , the only pre-ordered to provide the analemma for latitudes negative. You first need to click on F before creating the graph of the same clock in the northern hemisphere. Once you have the chart click on the button InvertX high above the screen. Immediately you get the graph required.



Let's see an example: you want to draw a sundial of Cape Town : latitude = -33,92 ° , -18,5 ° east longitude (approximately the same values of Tripoli in Libya, but in the northern hemisphere), declination 30 ° westward and tilt ( zenith ) = 20 ° from the vertical plane, short style = 0.2 meters. You first introduce the data of the corresponding quadrant of the northern hemisphere by placing latitude = 33,92 ° , long = -18,5 ° , d = 30 ° , style = 0,2 and iz = 20°; then click F on the menu. Then proceed with the "Run" command to obtain a graphic suited to draw a face in Puglia. The same

observation is not, however, valid for the analemma of the mean time that can not operate in the northern hemisphere. At this point, you should click on the button InvertX getting the rollover image that shows the graph of the dial in Cape Town in which was placed an arrow to show the movement of the style following the shadows indicating the hours. The Roman numerals corresponding should be read as reflected. The analemma was placed by assuming that South Africa is using the Central European Time zone. If not, you can draw this hour line according to the time zone of that country simply choosing the time zone in use before "Run".

**Filter** - The graphs obtained by the programs 2) and 3) may generate spurious lines, including the maps, which can be eliminated by changing the value that appears in the adjacent text box. We need to introduce a different value, generally smaller, and, therefore, repeat the chart with "Run".

### Tips to start immediately and continue easily

Immediately check the International Settings. Cartesius Mirror uses the decimal point. A different approach generates a graph DXF altered where the lines appear jagged.

First of all insert the four values of the frame in the following order from left to right: x1 = 0,5; y1 = 0,2 ;x2 = 0,5; y2 = -1. The framework laid down by the coordinates delimits the graph calculated that cannot overflow from the picture.

In order to become familiar with Cartesius Mirror it is suggested the range of several values to be used to facilitate the learning of software gradually.

Flat Dials. For programs 2) and 3) to introduce : latitude = 45 ° , declination = 20 ° , longitude = -7.6666 ° , style = 0,2 (m). For the number 2) choose Arabic numerals. For 3) add the inclination equal to 80 ° or the zenith one equal to 10°.

Diagram. After running or 2 ) or 3 ) Chart will provide the operational limits of the quadrant examined. For the diagram put radius  $R = 0,5$ .

### **Frame**

This function, that allows cordoning off the dial in order to determine the exact size, is also extended to functions that generate the DXF file for containing the extension of the opening file. Be very careful to enter the correct values of the coordinates that determine the size of the frame. A wrong choice of values may inhibit or restrict the viewing of the graph. In the lower part of the menu there is the ckbox "Frame" that puts a rectangular frame just clicking on it. Just below there are four txtboxes in which you must enter the Cartesian coordinates of two diagonally opposite points. The cornice is always working even if it does not appear. After entering the four coordinates and after function is activated by clicking on it the frame becomes visible. It can also be very useful to estimate the position of the sundial in the frame.

### **Cylindrical sundials**

This chapter deals specifically with the vertical cylindrical sundials of circular section, concave or convex.

It is necessary to introduce the latitude, the pillar length, the gnomonic declination, the longitude, the radius of the cylinder, and to specify whether it is concave or convex cylinder. The pillar (perpendicular style) is represented by a shaft perpendicular to the surface of the cylinder whose tip (Gnomonic Point) casts its shadow on the solid surface by providing the various indications: time, date or declination of the sun, etc.

By declination of the cylinder, we mean the angle formed by the radius on which is aligned the pillar and the south direction.

Since the cylinder is a developable solid on a flat surface, the graphs that are obtained by Cartesius are perfectly suitable for their direct application on the cylinder.

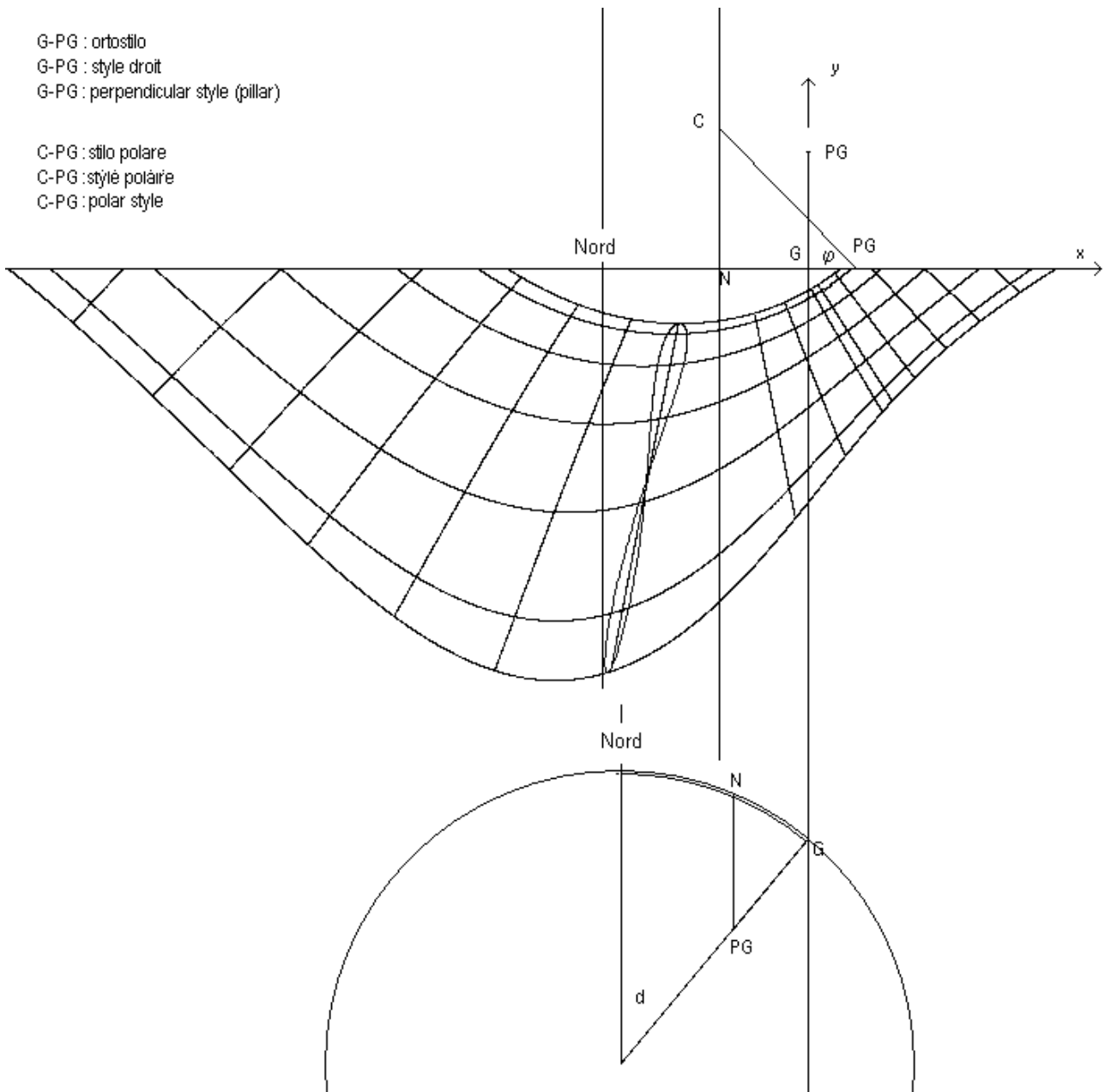
It is assumed as origin of the two-dimensional Cartesian coordinates of the graph the point G foot of the pillar, the point from which it protrudes. Therefore, if the cylindrical sundial declination is different from zero, the coordinate origin is not located on the North-South diameter,

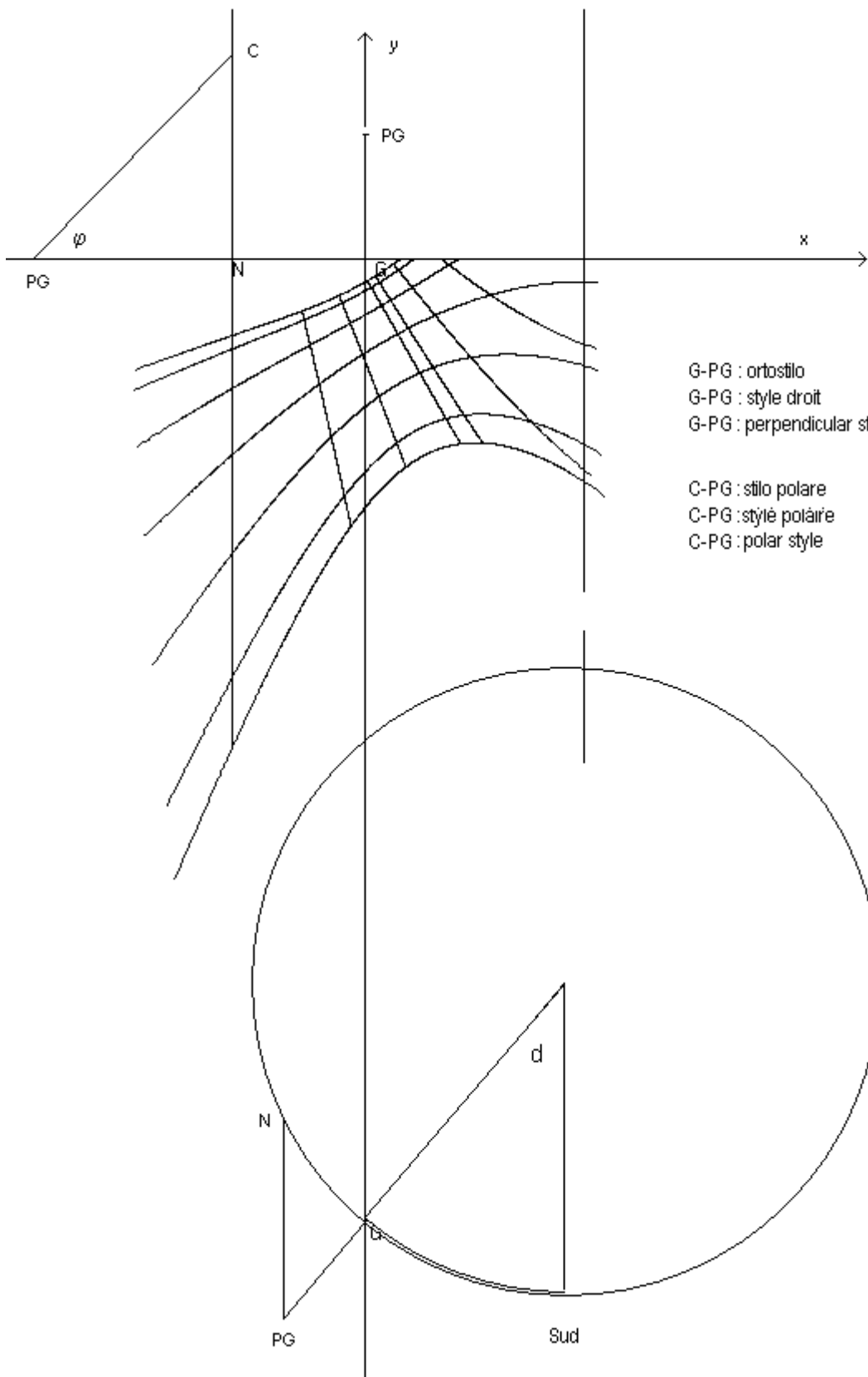
Polar style. You cannot always use this style easily due to objective difficulties of application. The program still provides the data of this tool and its position even when it is outside of the cylinder section as it can happen in the convex case. This style that allows the astronomical time reading not only on the tip of the shadow but also along all the same is not aligned with the G foot unless when  $d = 0$ . In each of the two graphics dedicated to the cylindrical dials, you can see at the top the overturned triangle of the style. As it can be seen, the right triangle that represents the polar style has been tilted laterally. The pillar or perpendicular style, instead, has been folded upwards.

The two graphs relate to a solar cylindrical concave dial and to a convex one, with the relevant sections.

G-PG : ortostilo  
G-PG : style droit  
G-PG : perpendicular style (pillar)

C-PG : stilo polare  
C-PG : style polaire  
C-PG : polar style





- G-PG : ortostilo
- G-PG : style droit
- G-PG : perpendicular style (pillar)
  
- C-PG : stilo polare
- C-PG : styie polaire
- C-PG : polar style

### **Cartesius Mirror** ( reflection section )

Cartesius Mirror is a software specially designed to make reflection sundials in graphical form. With the exception of a section reserved for sundials plans the rest is dedicated to catoptrics ones.

All types of sundials made by this new product of the Cartesius family can be equipped with a map. Therefore I suggest you also read the Rules of Cartesius 2013 where this topic is explained in great detail.

With Cartesius Mirror is also possible to design vertical and inclined sundials, in the southern hemisphere through the mirror reversal of the graphs. The table below is part of the instructions common to Cartesius 2013 and Cartesius Mirror. Given the complexity of the matter, this software is not suitable for beginners to whom I do not recommend its use. I wish to point out that Cartesius Mirror is not error free even if an extensive clearance was carried out during many tests. The authors assume no responsibility for any errors or misuse of this free software, specifically written for fans of gnomonics.

With Mirror Cartesius you must also download the file "World" and eventually the text of other languages without which all the entries are in English. Without the " Mondo.csv " you can not have maps to accompany the charts.

The CartesiusMirror.exe file, the file and the file Mondo.csv and the file texts of other languages (DBItalianoCMirr.txt, DBFranceseCMirr.txt, DBSpagnoloCMirr.txt) must be placed in the same folder or in the same operational area.

This section of Cartesius, reserved for reflexion sundials, it is particularly demanding and it requires a good knowledge of its content. I suggest the gradual learning also because the logic of this software is little intuitive.

The catoptrics sundial is composed of a flat mirror, reflecting the sunlight, and a flat surface that represents the screen on which the image of the sun is projected. Before performing any calculation you must select Mirror, above in the menu, clicking on " Types of Sundials ". The menu will change to accommodate the use of Mirror sundials.

After entering the latitude and the length of the perpendicular style, equal to the distance of the mirror from the plane of the dial, proceed with the input of other data. The mirror, for the purposes of calculation, is considered a flat surface, reduced to a point, coinciding with the gnomonic point.

The declination is understood in the traditional way: for declinations (d) of the dial, values from 0 ° to 180 °, when the dial is declining towards the west, and values between 0 ° - 180 °, in the opposite case. The same rule also applies to the declination (ds) of the mirror; however, the signs of the declination and inclination are not always so obvious.

The inclinations, izq of the dial and ize of the mirror, are zenith type and should be measured from the vertical plane in the following way: a vertical plane has zero inclination, a horizontal plane has 90 ° of tilt, a horizontal plane positioned on the ceiling has - 90 ° inclination. In order to determine the sign of the zenith inclination, you must ideally place yourself between the dial and the mirror. Consider the following basic configuration that serves as a guide to determine exactly how you should behave in other cases. Let' us orient the sundial to the north (d = 180 °) and the mirror towards the south (ds = 0 °). If the upper part of the dial is leaning, moving away from you, the value of the inclination is positive. If, on the contrary, the high part is approaching you (as if it were falling on you), the sign of the inclination is negative. This rule, which also applies to the mirror, is always applied, without exception, and not only when the plane is considered to be facing exactly north or south. Alternatively, to determine the value of the inclination, you can also use the formula  $iz = 90^\circ - Izh^\circ$  where the inclination is measured from the horizontal plane (  $Izh = 0^\circ$  ) to be interpreted in the following way: the inclination Izh varies between 0 ° and 180 °, values that correspond

respectively to the positions of a horizontal surface facing upward and to that of a horizontal plane facing downward, having as intermediate value  $I_{zh} = 90^\circ$ , the inclination of a flat vertical dial. In order to facilitate the use of Cartesius Mirror also to people having greater familiarity with the angle taken by the plane (also known as the zenith distance with respect to the normal to the mirror) by clicking on the option that allows you to switch from one type to another tilt you can directly input the value of the inclination measured from the horizontal plane for both the dial and the mirror. The graphics, however, always return the value of the zenith inclination.

The mirror is, for all intents and purposes, a flat surface of small size which has a declination and inclination .

It is positive or negative tilt considering the location of the observer, so the two surfaces of the reflection sundial (quadrant and mirror) as seen from an intermediate position, both showing positive slope even if in fact skewed in the opposite way. The difference between the two cases is provided by the declinations. Think of a concave dihedral lying horizontally whose faces represent the plane of the dial and that of the mirror. The sign assigned to the inclination is the same. The difference, however, is established by the different values of the declinations. The two surfaces of the example, having in common a horizontal line, present a difference in declination such as  $ds = 180 \pm d$ . The equations of the two planes  $\sin(d) * X - \tan(iz) * Y - \cos(d) * z = 0$  and  $\sin(ds) * X - \tan(izs) * Y - \cos(ds) * z = 0$ , for the same value of  $iz$  and  $izs$  are not actually the same plane because of the contribution of the different declinations. The mathematical problem underlying this theory is solved mainly by analytic geometry, in the Cartesian, monometer, orthogonal, three-dimensional G (X , Y, Z) system where the X-axis is pointing to the East, the Y-axis to the Zenith and the Z axis to the South. G, origin of coordinates, coincides with the foot of the mirror style.

The graph is displayed in the Cartesian, monometer, orthogonal, two-dimensional G (x , y) system which is located on the quadrant, where the origin of coordinates coincides with the foot of the mirror style. This system is also used for the measurement of the coordinates of the spot of light used for the calculation of the declination and inclination of the mirror. The X-axis is directed to the East.

### **The limits of the framework**

The graph, which is still represented in full, is limited by two barriers, one natural and the other structural: the geographical horizon and the line of separation between the reflective part and the non - reflective part of the mirror. The software differentiates the two sides of the mirror with a yellow line, between two yellow stars and a green one in between, sometimes through the frame, separating the useful part of the sundial from the other that would be activated using a mirror reflective both sides. The horizon

The horizon can appear horizontal, oblique or not appear at all. It is represented by a white color segment between the crescent moon and the sun. The two stars, when they occur, are always located on the frame. With the reflexion sundials, it is required careful attention as the useful part of the dial may appear within or beyond these two boundaries. Sometimes the charts are difficult to interpret.

### **The line of sub style**

A red dotted straight line starts in the origin of coordinates and then continues for a certain distance toward the centre of the sundial.

### **The dark green line of the mirror**

It always appears horizontal and always passes the crossing formed by the structural line and the horizon. Its ordinate is written directly to the side.



### **The foot of the mirror style**

This term refers to the projection of the gnomonic point on the dial: it coincides with the origin of coordinates G.

### **The triangle of the style**

With this misnomer, it is meant the implant of the style as a triangle whose vertices are the pole of the mirror, represented by a circular crown of cyan colour, the origin of the coordinates G and the mirror in a overturned position that appears as a red circular crown. The stretch of magenta colour from the origin of coordinates G (0,0,0) to the mirror N (x0, y0,z0) respects the length of the mirror style (distance between the origin and the mirror), the vector (yellow section) that from G (0,0,0) reaches the pole of the mirror indicates the direction in which the mirror is aimed towards the quadrant and the distance between the origin and the pole. The third side which represents the normal to the mirror, axis of rotation of the induced time plans, is as long as the distance between pole and mirror. The pole is in place while the mirror is flipped over. The angle between the normal and the pillar is equal to the angle between the two planes. If we consider that even the pillar is an oriented segment, the yellow vector represents the difference between the two vectors that come out from the gnomonic point.

### **The pole of the mirror**

The mirror is directed toward a point of the dial said "pole" that can be detected quite easily with the use of a laser pointer. Directing the beam of this tool on the mirror and by performing, for example, two reflections from two different points of the dial, then joining the ends of a first projection with a line, and those of the second with a line, the point of intersection of the two lines is the point sought. The inclination from the horizontal plane of the line joining this point with the mirror is equal to the zenith inclination of the same, given that this segment is a section of the normal to the mirror. When you activate the "triangle of style", then "Run" on the screen two circular crowns appear, one at the end of the magenta line (short style, pillar) symbolizing the mirror (red), the other just on the pole of the mirror (cyan). The magenta segment ends at the coordinate origin. The second circular crown (cyan) is positioned exactly in the image of the mirror (mirror pole) and the yellow segment (vector) represents the distance from G. With the activation of the "triangle of the style" also the profile of the mirror (yellow dotted line between two yellow stars and a mid green) becomes visible. The extension of the vector is perpendicular to the profile of the mirror. The position of the circular crown of the pole of the mirror, towards the horizon line, confirms the sign of its inclination: when it lies on the horizon line the mirror is vertical.

**The structural limit**, just explained, is, in fact, the common straight line to the plane of the mirror and that of the dial. When presenting it appears as a dotted line of yellow colour. A white star identifies the point of intersection of the two planes at  $y = 0$ . The structural line also appears when you activate the Plot. It's a red dotted segment that overlays the existing yellow one. The geographic map appears only in its useful part.

### **The horizon line**

The horizon can appear horizontal, oblique or not appear at all. It is represented by a white color segment between the crescent moon and the sun. The two stars, when they appear, are always located on the frame. With the reflexion sundials, it is required careful attention as the useful part of the dial may appear within or beyond these two boundaries. Sometimes the charts are difficult to interpret.

### **Mirror - Reflection Sun**

This function, at start-up, automatically places a magenta star at the point of coordinates HA and Delta.

### **Mirror Star**

This function can be activated by clicking on the homonymous checkbox in the lower part of the main menu. A cyan colour star is placed on the screen in the coordinates HA and Delta of the point indicating at the same time, the hour of dial (two decimal places, cyan) and the UT (four decimal places, white). For a given survey at the time and the place you need to use the table of instruments by entering the date, time, and then proceed with "Calculate". The already available hour now is not the time TU but that of the time zone selected on the menu. In Italy, where the time zone is -1, subtract an hour to get Universal Time. When daylight saving time is operative (in spring and in summer) you have to subtract two hours. The software interprets the time, however, inserted or found in these boxes marked TU, always as Universal Time.

Some numerical data, in red, can be read at the bottom of the screen including the angle of incidence of the light beam on the mirror.

### **The analemma of the mean time**

You can plot one or all of the analemmas whose number depends on the fraction of time in use. The analemma is positioned by the longitude and indicates the mean time at 12 o'clock (civil time, the wristwatch time in winter). Playing on the longitude it is also possible to draw the analemma of a different hour. To view more analemmas click on both the checkboxes "L" and "analemma" before "Run". If it fails or presents errors, trace the analemmas one at a time or using the voices of the textboxes "start time" and "end".

### **The Frame**

The graph is always limited by a rectangular frame whose dimensions depend on the values entered in the four white boxes under the heading "Frame". The frame is always active but not always visible. It only shows clicking on the homonymous checkbox. An incorrect configuration setting does not allow proper framing of the graph.

### **Numbering of hours**

The program provides both the indication of the hours by Roman or Arabic characters, and the indication of a single astronomical hour chosen by the user. Enabling this last option is done with a click through the Mirror Star checkbox and the values written in the textboxes of the Hour Angle and Delta. Therefore, time telling depends on the previous values: a cyan star will automatically appear on the graph in the chosen position showing the UT and the apparent time, in decimal form. A blue hour line represents hour 6 and hour 18. The 12 o'clock hour by a red line.

### **Meridian line**

It is the red hour line when you use the apparent time.

### **Azimuth Line**

It is possible to show, by clicking on checkbox AZ, an optional azimuth line as an aid to understanding the graph. The HA is used improperly as value of the azimuth angle.

### **Date line or declination**

A blue line is automatically drawn according to the declination inserted in the "line of declination." However, this line will be limited to the hours when the dial is operating. Once you have drawn the graph you can choose the start time and the end of the line, by entering the appropriate values in the "start time" and "end" textboxes, available on the main menu. After entering these values proceed with "Run".

### **The Italian hours**

Clicking on the item of the same name visible on the menu, after the "Run", Italic hours are shown. However, it is necessary to establish the limit values of the time system using the voices of the boxes "start time" and "end ". The default values are provisional and must be modified according to the characteristics of the clock solar reflection.

### **The Babylonian hours**

Clicking on the item of the same name visible on the menu, after the "Run", Babylonian hours are represented. However, it is necessary to establish the limit values of the time system using the voices of the boxes "start time" and "end ". The default values are provisional and must be modified according to the characteristics of the clock solar reflection.

### **The temporary hours**

Clicking on the item of the same name visible on the menu, after the "Run", temporary hours are represented. However, it is necessary to establish the limit values of this ancient hour system using the voices of the boxes "start time" and "end ". The default values are provisional and must be modified according to the characteristics of the sundial.

### **The astronomical hours corrected in longitude**

Clicking on "Standard Meridian Time" before the "Run" command, the hours reproduced take into account the local constant that will indicate the apparent time of the "Standard Time Zone" of reference.

### **Procedure for the detection of the wall declination**

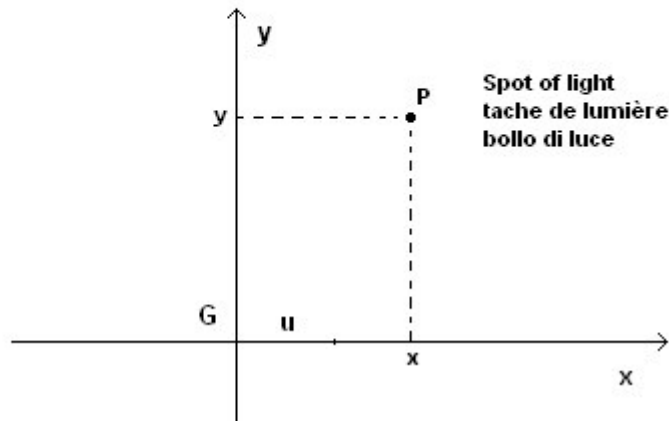
The choice of method is personal. Cartesius Mirror offers, however, a calculation routine accompanied by "Instructions ..." in the **Tools** board and amply illustrated in the first part of the regulation.

### **Procedure for the calculation of the declination of the mirror when it is vertical**

Please note that the coordinates of the light determined by the spot of light must be read on the quadrant together with, the time (UT) and the date.

On the main menu input the data of the reflexion dial: Latitude, longitude, declination, style, and inclination and put zero for the inclination (ds) of the face of the mirror. It is indifferent to introduce the value of the declination of the mirror because it represents the unknown and it will be ignored by

### Istruzioni per il rilevamento delle coordinate del bollo di luce



the algorithm. Do not proceed with the "Run" command but move in the box "Tools " where the latitude and longitude are found ready. Enter the date and time of the TU detection and the two readings (coordinates relieved on the quadrant) on the dial that must be written in the boxes next to " Mirror ... " and then proceed with " Calculate". Among the proposed results, the last one at the bottom of the

list, is the declination of the mirror, sought.

An example : lat =  $42^\circ$  , longitude =  $-7.6438^\circ$  , declination =  $160^\circ$  , style = 0.2 and inclination of the mirror = 0.

All these data: TU = 16:0:0, date 10.10.2013, x = 0,01849 , y = 0,06767 values measured on the dial to be included in the boxes.

After the use of " Calculate " button, you will get a set of data of which the last  $28.5^\circ$  is the declination of the mirror. This value should be introduced to the main menu under declination of the mirror. At the "Run" command you get the graph of the reflection dial. Please also click on the " Mirror ... " voice available on the toolbox where it is available a graph explaining how to measure the coordinates x, y.

### Procedure for the calculation of the declination of the mirror note his inclination

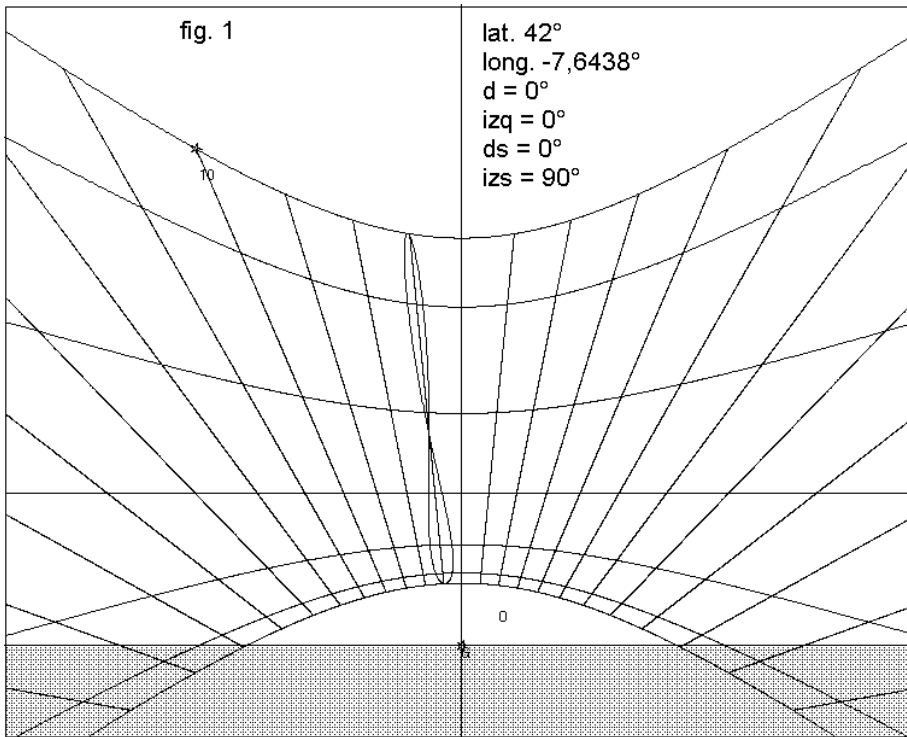
It was explained how you can detect the tilt of the mirror with the aid of a laser beam. If the mirror reflects at noon, you can trace the meridian line operating in multiple dates. Once drawn the meridian line, draw the horizontal line at the mirror on the surface of the future dial. Find the point of intersection of the vertical plane passing through the gnomonic point and the pole with the horizontal line. Said P this point, M that of the meridian line with the horizontal line and N the gnomonic point, the MNI angle is the declination of the mirror.

### Procedure for the simultaneous calculation of the declination and inclination of the mirror

This other procedure is the most complete because it can provide both the declination and inclination of the mirror according to the position of the spot of light. Once you have chosen the wall on which

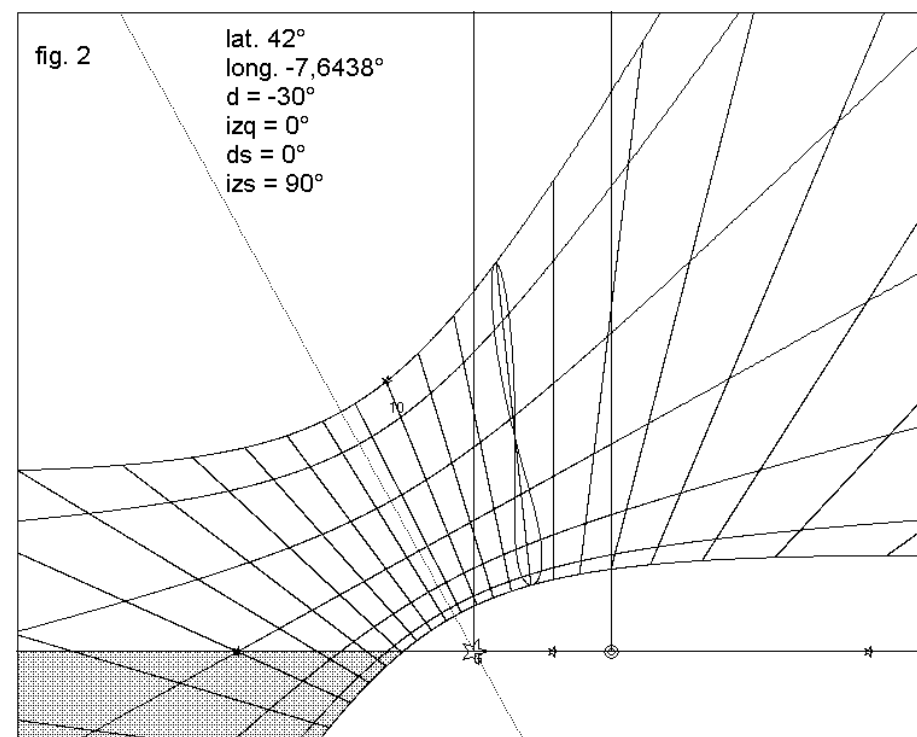
to plot dial set the mirror dial in a manner deemed, on that occasion, the better. The gnomonic projection of the point on the panel G represents the origin of a two-dimensional Cartesian coordinate system. They must, therefore, be known: latitude, longitude, declination and inclination of the wall and the distance of the mirror (pillar, mirror style).

When the mirror reflects take note of where the spot of light is observed, the exact time of Greenwich Mean Time ( GMT) and the date. Measure and note the distance (x, y ) of the centre of the spot of light from the coordinate axes. In this regard, see the

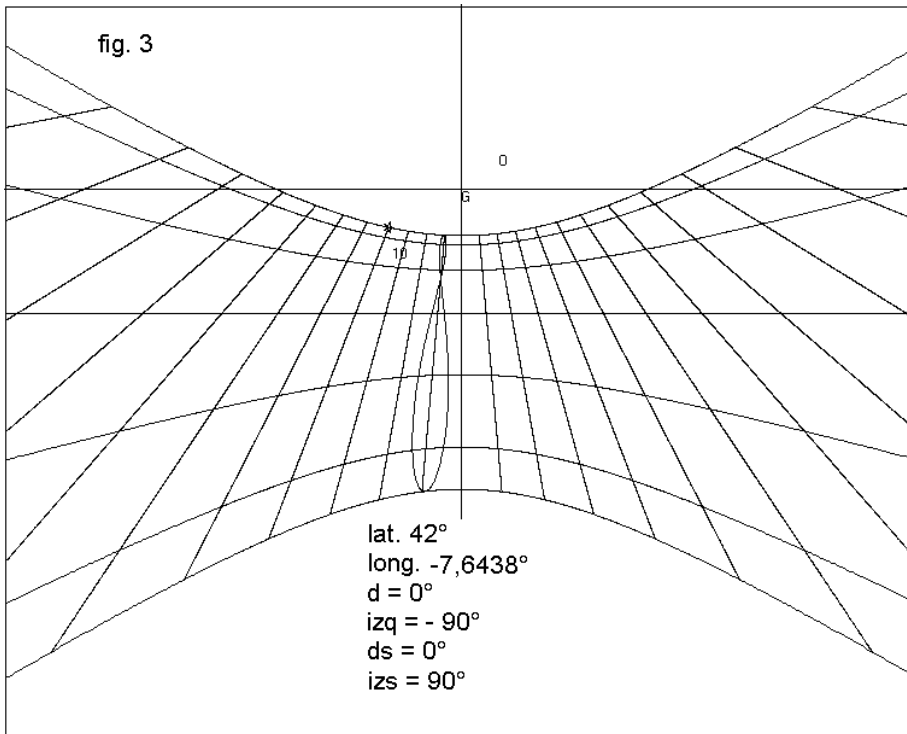


graphics explanation available on the Tools menu by clicking on " Mirror ... " .

Using Mirror Cartesius enter the latitude, longitude, declination, inclination and length of the pillar. In the bottom of the menu in the x and y boxes, enter the values you wrote down on the coordinates of the spot of light. Do not proceed with the "Run" command but open the table "Tools" at the top by clicking on the screen. Here you find the latitude and longitude ready. Enter the date and time of the TU detection, followed by the command "Calculate". In the boxes x , y of the main menu you can read the value of the declination and inclination of the mirror. These values must be copied back into the overlying boxes provided for the insertion of the declination and zenith inclination of the mirror. After "Run" you will get the graphic of the reflexion sundial calculated.



Let's see an example: you want to build a reflexion

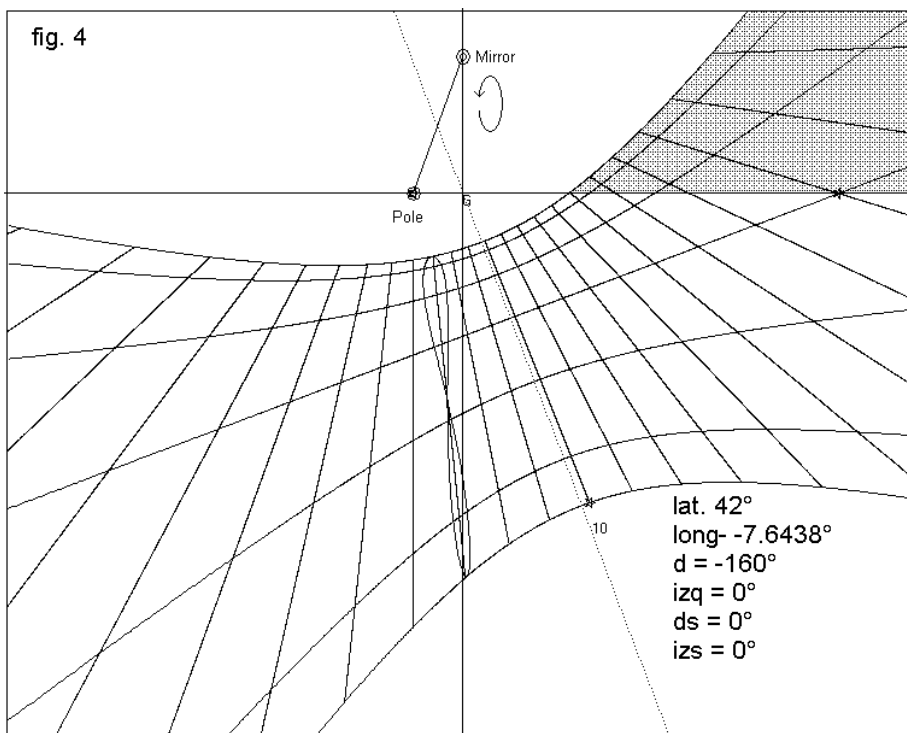


sundial of which you know the following data : latitude =  $42^\circ$  , longitude =  $-7,6438^\circ$  ( east), declination =  $-140^\circ$  ( east), inclination =  $20^\circ$  , pillar = 0,2 . The detection with the sun, which took place on 2nd November 2013, at 9 am TU provides the following coordinates of the spot of light measured on the dial:  $x = 0,02583$  ,  $y = -0,14662$  .

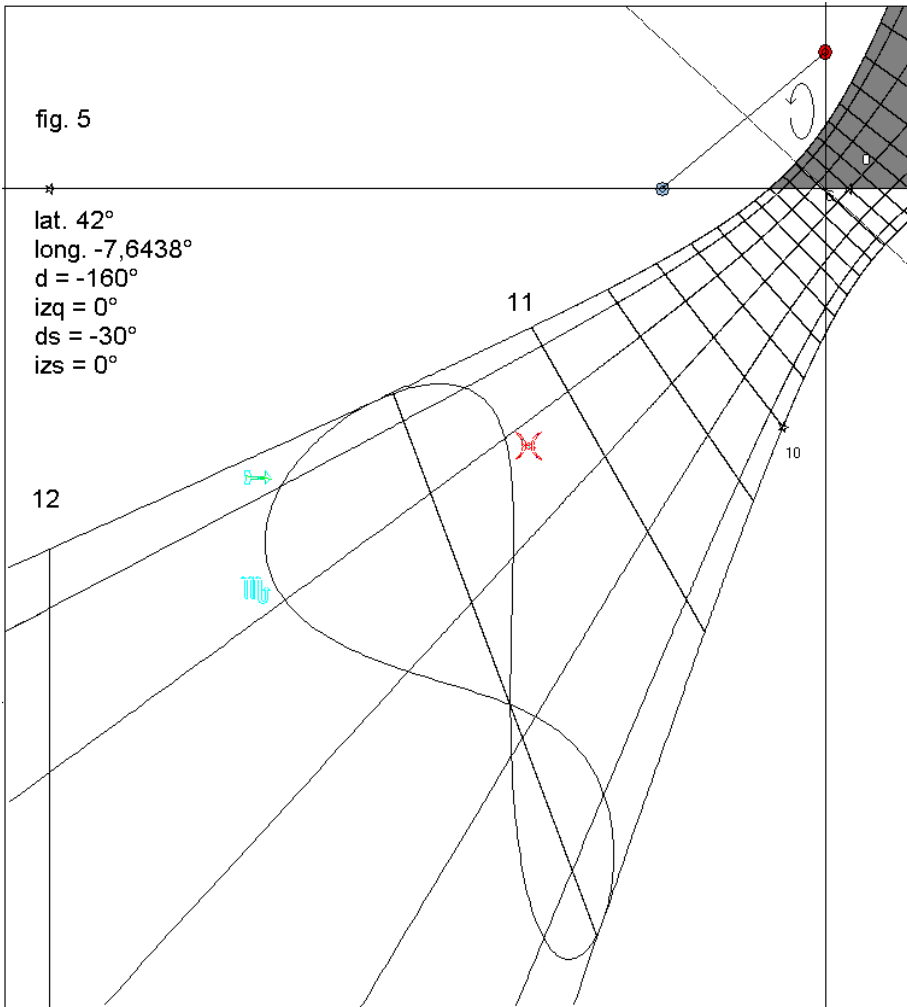
Introduce the data of the reflection dial in the boxes x, y of the main menu with the following coordinates: 0,02583, -0,14662 , and the others, date and time, in the table of instruments . Do

not proceed with the "Run" in the main menu but only with "Calculate" sub - menu. After the command "Calculate" there will be available the following values (or values very close) declination and inclination of the mirror in the bottom of the main menu: declination =  $-5^\circ$  , inclination =  $-20^\circ$  .

### Simulations to become familiar with the calculation of the declination and inclination of the mirror



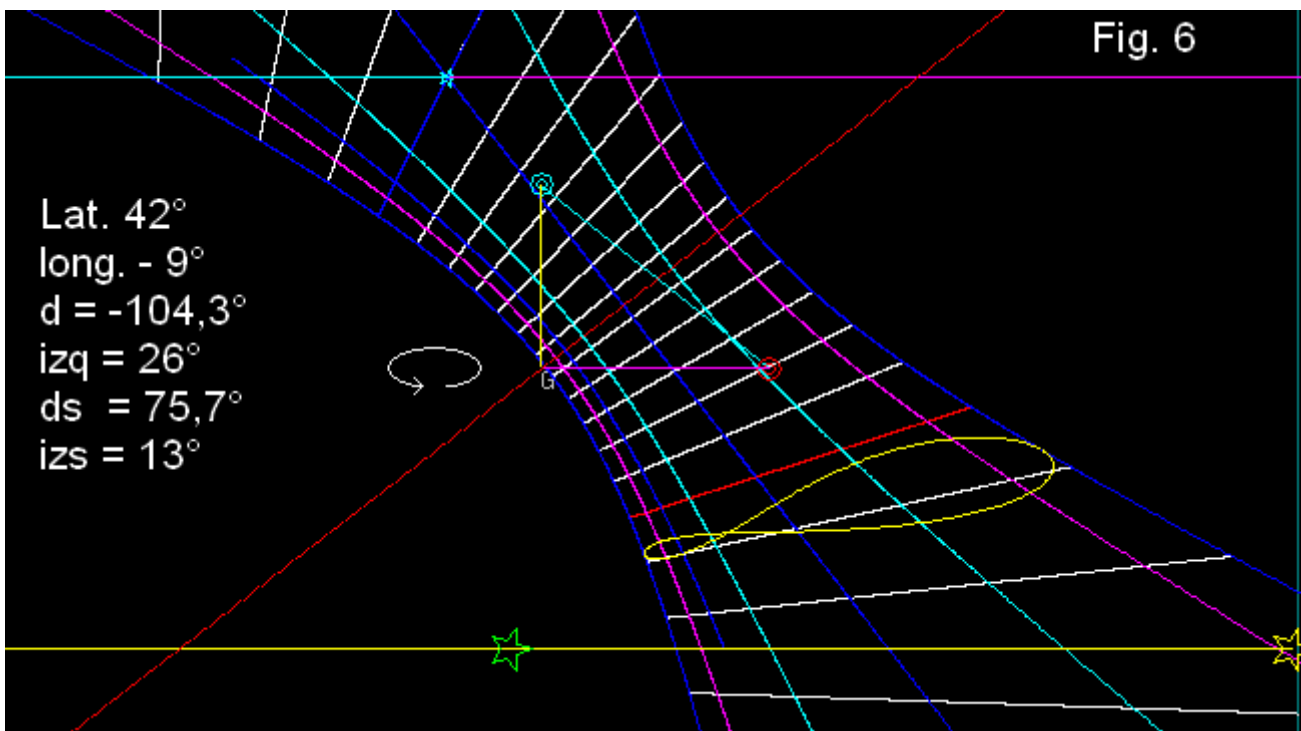
You can simulate the detection of the spot of light and calculate the declination and inclination of the mirror. Enter the latitude, declination, longitude, inclination and length of the style of the dial. These data must always be known when making a mirror sundial. Then introduce two values respectively for the declination and inclination of the mirror. These latter represent the unknown. The fact that they are known only serves to get reliable coordinates of the spot of light.



For example, these are the data to be used for the simulation: latitude =  $45^\circ$ , declination =  $150^\circ$ , longitude =  $-9^\circ$ , inclination =  $-15^\circ$  and style = 0.2. The length of the style in reality does not intervene in this calculation, but it still can not be null. You want to verify that the coordinates of the spot of light correspond to those of a mirror declining  $10^\circ$  and tilted by  $5^\circ$ .

Then enter these values in the boxes reserved for them at the bottom of the menu in the area reserved to Mirror Sundials.

Now open the table of instruments where one can find the latitude and longitude introduced in the main menu. Pose the Universal Time = 11 0 0 05



11 and the date 2013. Proceed with "Calculate" then close the table of instruments. Go ahead clicking on checkbox Mirror Star. Take note of the values that are found in the two boxes x , y of the main menu under the declination and inclination textboxes of the mirror. These values appear to be  $x = 0,30277$  ,  $y = -0,19153$  .

Now restart Cartesius Mirror, enter all the values for the dial, do not write anything in the two boxes of declination and inclination of the mirror. Rewrite the values you noted a moment ago in the same boxes in which they were read.

DO NOT proceed with "Run" but open the table of instruments including date of 5th November 2013 and the 11 hours 0 0 TU .

Go ahead, then, with "Calculate". You will notice that in the two boxes in which you transcribed the coordinate values of the spot of the light you will find available: declination of  $10^\circ$  and inclination equal to  $5^\circ$  .

In the first phase you got the coordinates of the spot knowing all the details of the dial in reflection , in the second stage you performed the reverse path: from the spot to the declination and inclination. It can perform a simulation even when the inclination of the mirror is zero with both the method just used and with that reserved for the calculation of the inclination knowing that this value is equal to zero .

NB It is important that the values used for the simulations correspond to real situations. For example, the time value TU of detection must be compatible with the hours of operation of the dial, in particular to ensure that the part really reflects the sun. If you do not use these precautions, the results become unreliable.

### **Sundials geographical**

Cartesius Mirror allows you to create sundials equipped with geographic map correctly positioned. This feature makes visible the selected map with the four cardinal points oriented in the usual way. The area selected by the joint action of the latitude, longitude and declination, will be between two longitudes which are written in the two boxes of which the one on the left (East) pink and the second (West) white.

The map is spread in a fan. In some cases, you may experience unwanted or incomplete parts.

To remedy these drawbacks you can intervene using single cards of the states to complete the extension. Unwanted parts, however, can be deleted after printing. See also the more detailed use of maps for traditional sundials in another section of the regulation.

### **Upload and use of maps**

Menu appears at the bottom of the area reserved for the geographical meridian. Click on "Upload" after a few seconds the Plot command activates. Clicking on this last command the geographical map in support of the sundial becomes visible on the screen. The areas displayed depend on the latitude, the longitude of the dial, its declination, its inclination, declination and inclination of the mirror. Moreover, the map is limited by the two extreme hour lines in which the hour angles act as longitude. To widen or tighten this fan shaped area just modify the values written in the two boxes west and east end of the menu area reserved for maps.

Click on Plot again and you will get a map with the new boundaries.

### **Single states**

By clicking on the combo, after "Load", a series of names of which the first is World becomes evident. However, if you decide not to accept World and choose the name of one of the states in the list, under the command Plot only the outline of the selected state will appear in red on the screen.



In some cases, the maps do not appear due to a filter (filter 2), which in general is very useful as it eliminates any unwanted parts that occur disturbing the overall picture.

In this case, try to click on the checkbox "Alternator Filter" at the bottom of the menu before the Plot command. Such checkbox must always not be clicked with the exception of when it is required its use.

### **Mirror P: The capital**

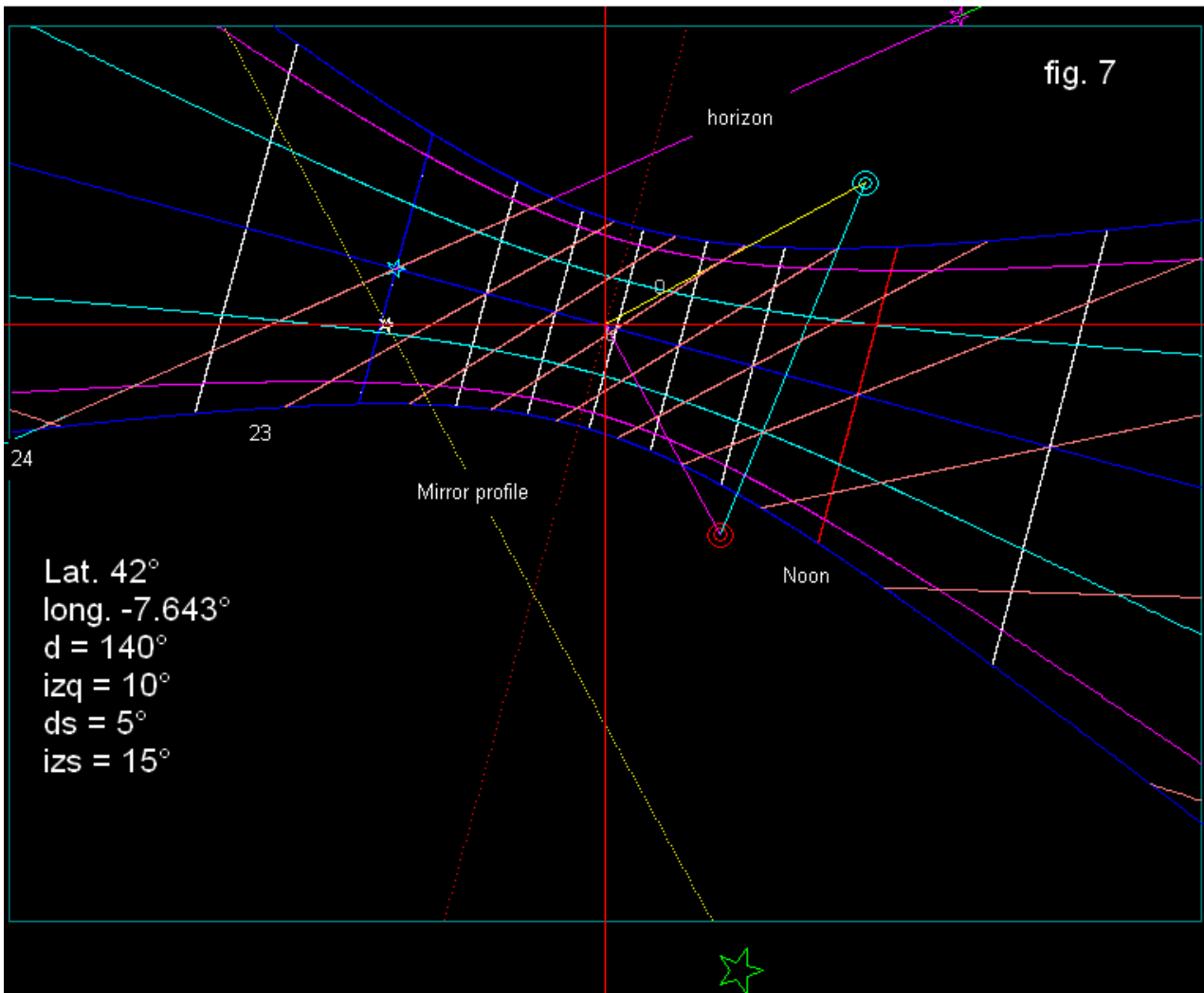
Clicking on checkbox with red frame, placed above the boxes reserved for the declination of the mirror, you will see the names and locations of the capitals of the states of the map. These names are only available in video.

### **The ckbox INV**

This check box reverses the poles of the map reproduced but only after the "Run".

**Filter 1** txtbox value of 0.2 indicates the number suggested because it was considered the most suitable. This parameter serves to vary the definition of the map. For smaller values, the filter becomes narrower and in some cases could be harmful, eliminating necessary parts.

**Filter 2 (Alternator)** This is the filter that selects the useful part of the mirror. In certain cases, to be



able to dispose of the map, it must be activated but, in general, it must not be clic

**To begin with**

Now let's see some cases, particularly simple:

1) The wall face is vertical, facing south and the mirror is horizontal. Lat =  $42^\circ$  ,  $d = 0^\circ$  , style = 0,15 ,  $ds = 0^\circ$  ,  $izes = 90^\circ$  .

The value of  $d$  to be inserted at the top of the menu in the txtbox of declination, the length of the style in the text box Mirror style. The other two values at the bottom, in the easily identifiable area. In this configuration the values  $n_x = 0$  ,  $n_y = 1$  ,  $n_z = 0$  of the direction cosines of the normal to the mirror match and confirm the horizontal position, verifiable on the screen after the "Run" command and visible graphic (Figure 1).

2) Now the wall of the dial is declining but still vertical and the mirror is horizontal. For example, if  $d = -30^\circ$  ,  $ds = 0^\circ$  ,  $izes = 90^\circ$  , at start - up you get a graph of the oblique solar quadrant ( Figure 2).

3) Always keeping the horizontal mirror now the spot of light is projected on the ceiling horizontally (Figure 3). Let us put  $d = 0^\circ$  ,  $izq = -90^\circ$  ,  $ds = 0^\circ$  ,  $izes = 90$ . After "Run" the graph No. 3 shows.

4) Now the dial is vertical but declining (-)  $160^\circ$  to the east, the mirror is south facing and is vertical. The circular crown on the horizon is the pole, the other one at the top because overturned, is the mirror (Figure 4).

5 ) In this example, the declination of the wall is  $-160^\circ$  ,  $izq = 0$  ,  $ds = -30$  ,  $izs = 0$  (Figure 5).

6) in Figure 6 we have  $d = -104,3^\circ$  , longitude =  $-9^\circ$  , style =  $0,15$  ,  $izq = 26^\circ$  ,  $ds = 75,7^\circ$  and  $izs = 13^\circ$  . The two planes have a common horizontal line (with yellow star) which is located at the bottom forming an angle of  $39^\circ$  . The useful part of the dial is between the two starred horizontal lines. The upper one is the horizon; the lower one is the limit due to the mirror. The triangle shows the yellow vector that indicates the direction the mirror is facing whose position is found by tilting the red circular crown until it is perpendicular to the origin G. The mirror is still facing west of  $75,7^\circ$  and is tilted of  $13^\circ$  . Given that the picture plane and the mirror are parallel to the horizontal plane, and given that the modules of the declinations are supplementary, rightly the vector appears (yellow) vertical because lying on a vertical plane (but is still tilted on the picture plane).

Figure 7 shows a sundial indicating astronomical and Italic hours. It is a particularly complex configuration in which the useful part of the dial is located in the field to the right of the horizon and the profile of the mirror.

Now let's see some universal geographical reflection sundials.

Figure 8 shows a mirror universal sundial for the city of Trieste. The technical data are latitude =  $45,65^\circ$  , longitude =  $-13,777^\circ$  , declination of the dial =  $160^\circ$  , distance of the mirror  $0,8$  m, declination and inclination of the mirror =  $0$ . The longitude has placed Trieste on the noon meridian. The colours are fictional but they give a clear idea of how it could be decorated such a dial.

Figure 9 shows a horizontal sundial on the ceiling with the mirror horizontal lower down.

#### Terms of use

### Condizioni d'uso

Cartesius Mirror è un programma freeware in versione demo proposto così com'è senza alcuna garanzia. Ne è concessa la cessione ad altri ma non la vendita che è rigorosamente vietata. Gli autori, che sono i proprietari intellettuali del software, non sono responsabili di eventuali disfunzioni o di un uso improprio dello stesso.

Riccardo Anselmi, dicembre 2016

Fig. 8

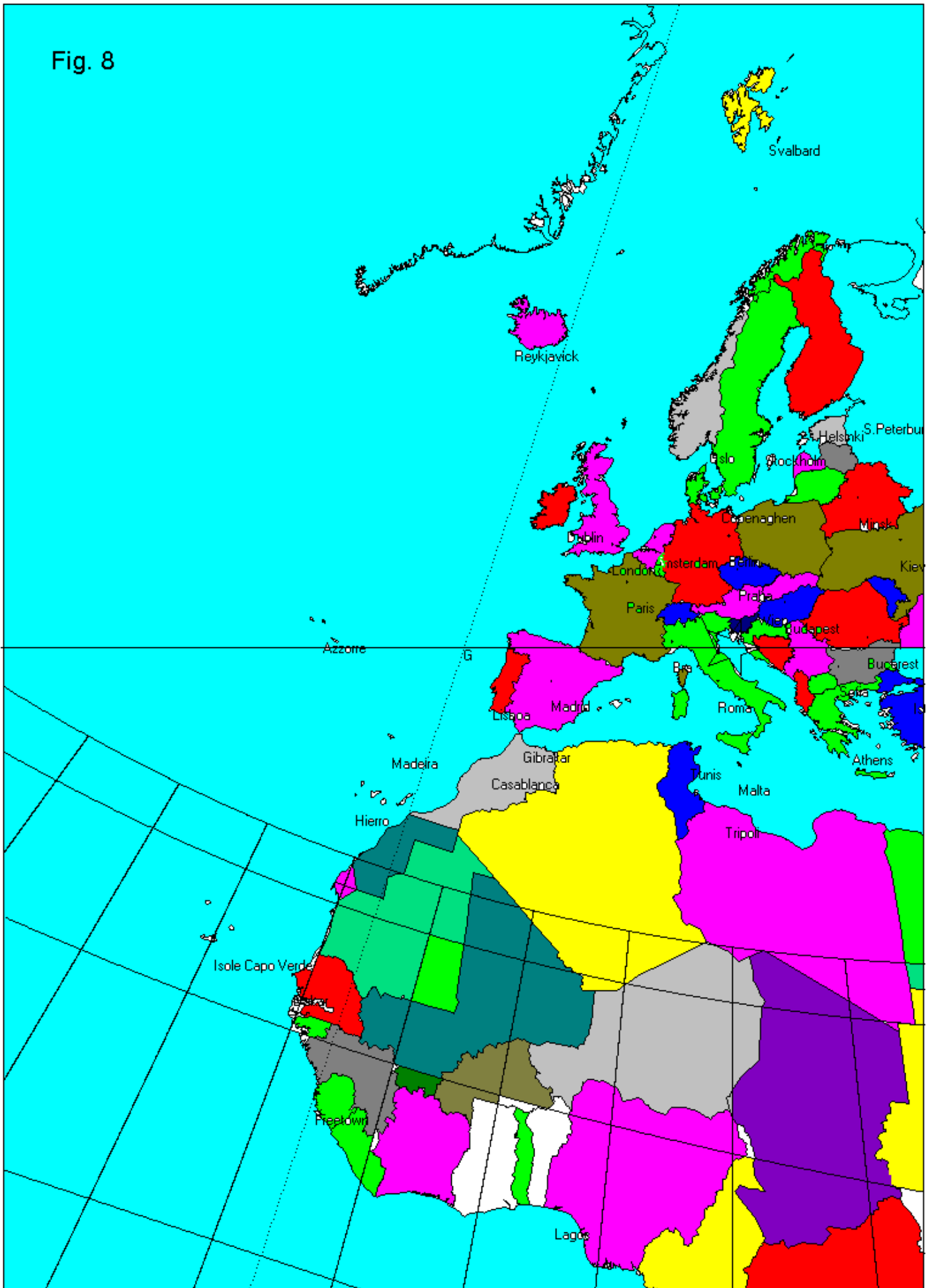
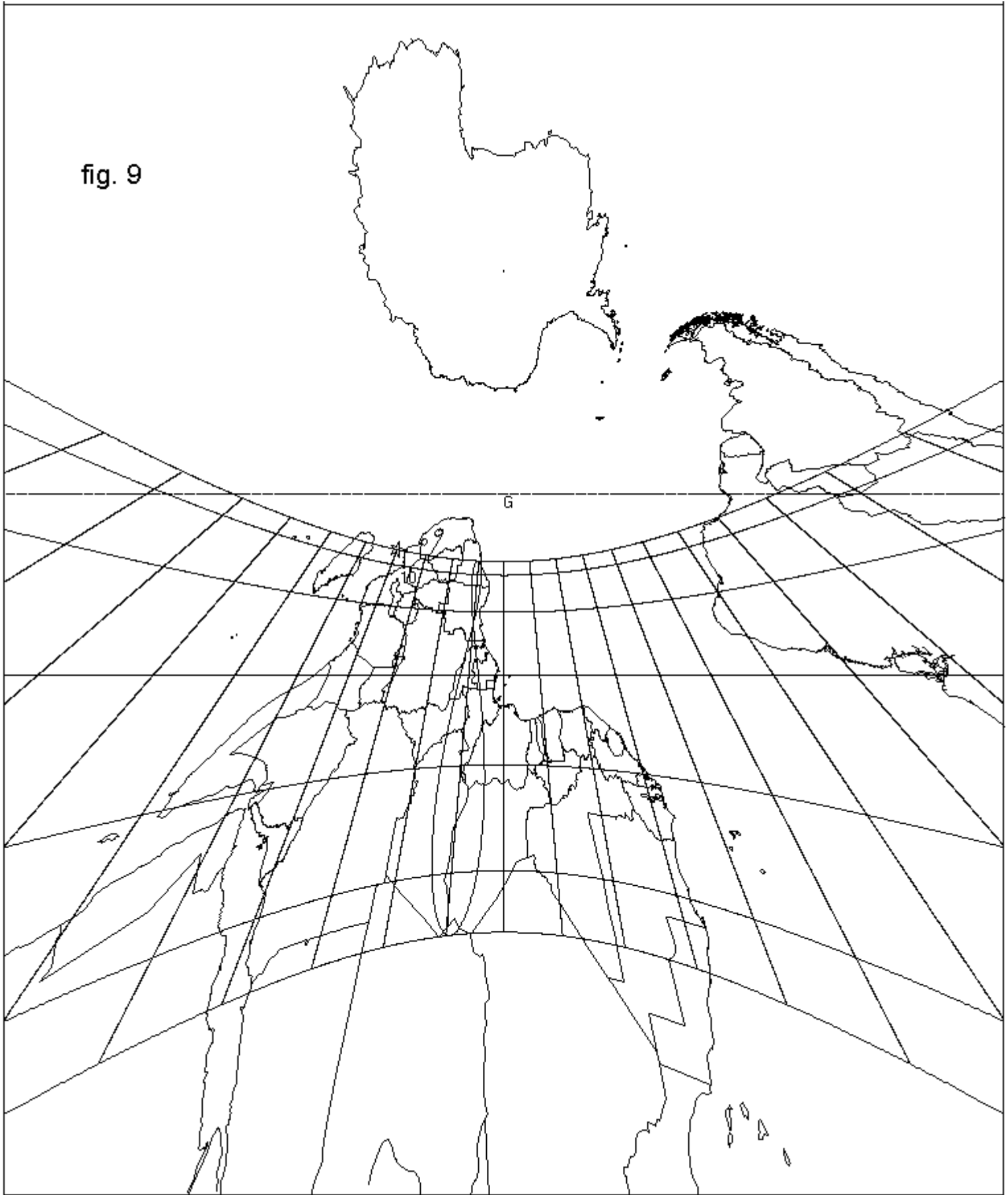


fig. 9



Cartesius Mirror is the demo version of a freeware program. It is made available to users in its current form and with no guarantees on as to its functioning. Use of the product is freely permitted but any salt thereof is strictly forbidden by law. The authors own the intellectual property rights to the program. They take no responsibility for any malfunctions or consequences arising from any improper use of the same.

Riccardo Anselmi, December 2016

## **Conditions d'utilisation**

Cartesius Mirror est un logiciel (freeware) gratuit, proposé sans aucune garantie. La cession aux tiers, à titre gracieux, est permise, mais non la vente qui est interdite. Les auteurs qui sont les propriétaires intellectuels du programme, se déclarent non responsables pour d'éventuels problèmes de fonctionnement ou pour la survenue de toutes les conséquences qui puissent être imputables à un mauvais usage du programme

Qui utilise Cartesius Mirror et les autres logiciels des mêmes auteurs le fait à ses risques et périls et sous sa propre responsabilité.

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For those who want to try the software immediately, simply click on Run to display the graph of a sundial in reflection for which data are: latitude  $42^\circ$ , longitude  $-7,6438^\circ$ ,  $160^\circ$  declination, pillar length 0,2 meters, declination and inclination of the mirror = 0. Cartesius Mirror will show a vertical declining reflection sundial calculated with analytic geometry and plane trigonometry.