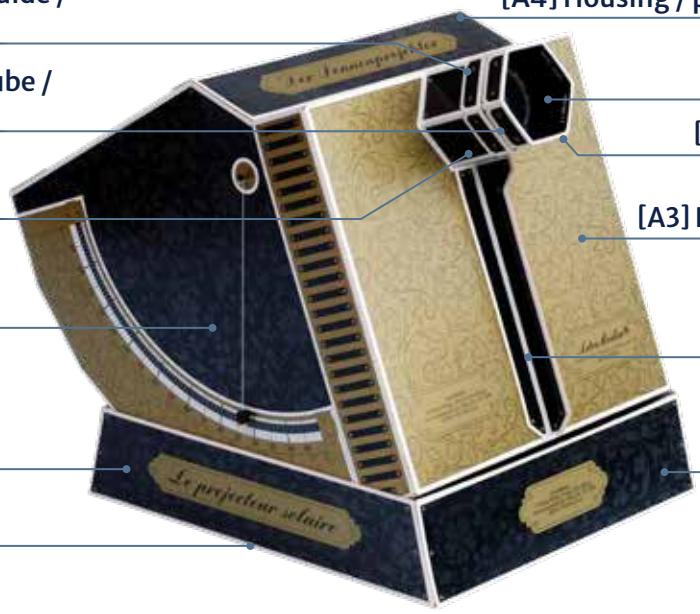
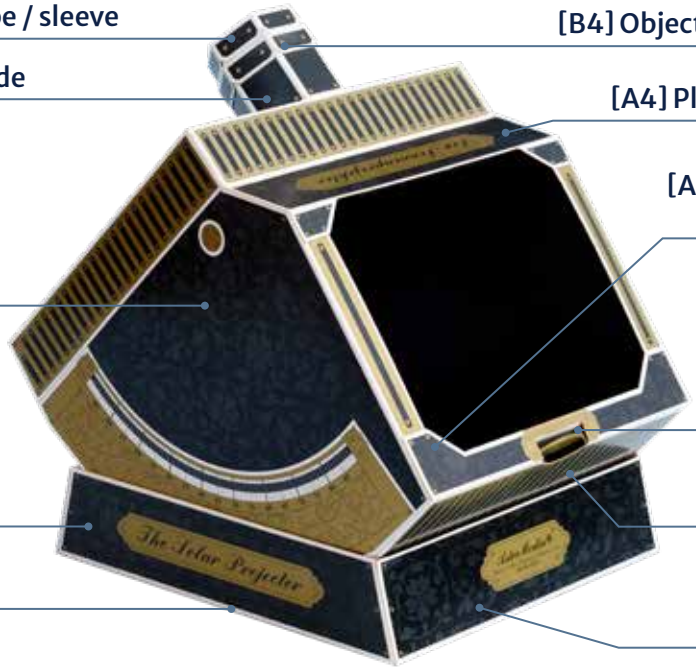
Instructions

The Solar Projector





AstroMedia

Hands-on Science Series

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The Solar Projector

Observing the Sun with a telescope is almost as old as the invention of the telescope itself, but it comes with considerable risks: Only a very dark filter can dim the sunlight enough to prevent eye damage. Today, reliable solar filters are available for this purpose, such as the BAADER AstroSolar® Safety Film.

The Solar Projector avoids this problem because, instead of looking directly at the Sun, the viewer sees an image created by a sophisticated optical system. This allows the Sun to be observed safely without a protective filter.

The Solar Projector uses the principle of the Camera Obscura (pinhole camera), which was used to observe solar eclipses as early as the 11th century and is still used in every camera today: Light falls through a small opening into a darkened chamber and creates an upside-down image of the outside world on the opposite side.

Instead of a simple pinhole, the Solar Projector has a lens and a convex mirror, which together act like a Galilean telescope and offer high magnification. A plane mirror redirects the image onto a screen to make viewing comfortable. The basic principle, however, is still that of the Camera Obscura.

This kit contains:

- **8 pre-cut cardboard sheets, A4**
- **1 OptiMedia achromatic lens OA69, Ø 31 mm, f = 250.0 mm**
- **1 convex mirror, Ø 16.5 mm / f = -10.2 mm**
- **1 convex mirror, Ø 16.5 mm / f = -14.0 mm**
- **1 plane acrylic mirror, 54 x 90 mm**

Please read before commencing:

Tips for successful assembly

1 To ensure a good quality result, the assembly instructions have been divided into many small steps. Please read each step thoroughly before beginning and allow yourself sufficient time.

You can find a detailed illustrated construction report here:

https://astromedia.de/pdf/SPR-E_Solar_Projector_BB.pdf

2 It is best to only remove the parts from the cardboard sheets as they are needed. Don't tear the pieces out of the cardboard, but cut through the small retaining bars with a craft knife. This will keep the edges completely smooth. Each part is labelled with its name and a part number consisting of a letter and a number, e.g. A2 .The letter designates the assembly section, the number the sequence within the section. The part number is printed on the front and/or back of the part and sometimes also on the cardboard next to it.

3 All fold lines are prepared by grooves or little cuts. They are folded either „forwards", i.e. towards you when you look at the printed front of the part, or „backwards", i.e. away from you. You can push down the folds with a folding bone or a small spoon to turn them into sharp edges.

4 Surfaces to be glued are printed in grey. There are symbols on the glue surfaces, indicating which other part is to be glued in this place: A2 indicates that part [A2] is to be glued here. The symbol ↻ indicates that the part is being glued to itself. Use a high quality solvent-based all-purpose glue. Solvent-based glue is better than water-based solvent-free glue: it dries faster and does not warp the cardboard. Please note: the plane and convex mirrors should only be glued in place with solvent-free glue or double-sided adhesive tape, as some solvents can damage the sensitive surfaces (see Steps 18 and 24).

5 Tip for using solvent-based all-purpose glue on small surfaces: Apply a not too thin layer of all-purpose glue to one side and press the parts together so that the glue is spread over both sides. Pull the parts apart again, remove any threads of glue and blow over them two or three times. Then press the parts together firmly and accurately - the bond will hold immediately. Please note: This technique should not be used with the mirrors or the lens to avoid glue threads. Better let the glue set normally, or use adhesive tape.

6

To fit the glass lens, you will need a rubber ring, also a thin thread and two small weights (e.g. glass or metal beads) for the quadrants to determine the height of the Sun. Perfectionists can use a black felt-tip pen to blacken white edges of apertures, lens mounts etc. before installation. You will also need some normal one-sided adhesive tape.

7

After the glue has set, you can clean up any protruding edges with sandpaper or a fine file, e.g. the AstroMedia Sandpaper Craft File (No. 400.SBF).

8

Please note: The surfaces of both convex mirrors made of acrylic glass are coated with aluminium and a protective layer of quartz. Nevertheless they are very delicate. Do not touch them with your fingers and, if necessary, only clean them with a cotton bud and de-ionised water with a dash of alcohol. The surface of the plane rectangular acrylic glass mirror is covered with a protective film. Only remove this after mounting the mirror.

The Housing

Parts on sheets 1, 2, 3, 4, and 5. *The projector housing is a box which is open at the top and holds the objective lens at the front. Its back wall and base form a stepwise rounded surface. This shape allows the Solar Projector to be set to any solar altitude in its base.*

Step 1

Remove the right side wall [A1] from the cardboard sheet and fold the tab on its top backwards. Do the same with the left side wall [A2].

Step 2

Remove the cardboard hexagon from the front wall [A3]. The front wall is divided into differently sized segments by several long grooves. The top segment has a white field for the plane mirror on its back. Fold this segment forwards and all other segments, including the side tabs, backwards.

Step 3

Fold both trapezoid-shaped tabs of the plane-mirror holder [A4] backwards and glue the piece onto the grey glue mark of the top segment of the front wall [A3]. The two trapezoid-shaped tabs will then jut out beyond the front wall. Use a book or similar to weigh down the pieces on your worktop until the glue has set to make sure they don't warp.

Step 4

Remove the small cardboard piece at the top of the back wall [A5]. Fold all grooves, including those for the side tabs, backwards. This creates the segments which form the curved back and base. Glue the long tab at the bottom behind the bottom segment of the front wall [A3]. This bottom segment is already part of the curved base, so that the printed decoration continues without break from one part to the next.

Step 5

Glue the long edge of the left side wall [A2] onto the equally long glue tab on the right hand side of the front wall [A3] (when viewed from the front). Now it should become clear how the segments of the curved back wall fit to the angular rounding of the side wall.

Step 6

Apply glue to the seven glue tabs on the back wall segments, lay the half-finished housing onto the left side wall and press the glue tabs firmly into position. Push them down from the inside of the housing and check at the same time from the outside that the edges of the back wall segments are exactly aligned with the edge of the side wall.

Step 7

As in Step 5, glue the right side wall [A1] onto the long glue tab of the front wall and then, as in Step 6, glue the tabs of the back wall segments onto the round edge of the side wall.

This completes the basic construction of the housing.

The Optical System

The optical system consists of the objective lens, a convex mirror, and a plane mirror. The objective lens focuses the incident sunlight. The convex mirror is located just in front of the focal point and reflects the rays, which fan out and are therefore magnified. Finally the light hits a tilted plane mirror that deflects it downwards onto the inside of the housing.

The Objective Lens

Parts on sheets 1, 2, and 5. *The Solar Projector's objective lens, OptiMedia OA69, is an achromatic lens: it is colour corrected. It consists of two lenses made of glasses with different refractive indices, cemented together. A simple lens would create a colour fringe at the edges of the image. The achromatic lens OA69 has a focal length of 250 mm, so its focal point lies 250 mm from the centre of the lens.*

Step 8

Fold the 6 long grooves of the objective guide [B1] backwards to form a hexagonal tube and glue the thin tab on one side of the tube onto the back of the opposite side. Then fold the 5 short tabs on one end of the tube forwards. Do not fold the long tab.

Step 9

First without glue, check that the objective guide fits from the inside through the hexagonal hole in the front wall of the housing, with the long tab pointing upwards. When the cardboard section between the housing front wall and the plane mirror holder is pushed downwards, it touches the long, unfolded tab of the objective guide. First glue only the short tabs of the objective guide to the inside of the front wall of the housing and make sure that the guide remains at right angles to the housing.

Step 10

Apply glue to both side tabs of the housing section mentioned in Step 9, as well as on the long, not folded flap of the objective guide. Glue this section onto the side wall of the housing and onto the long tab of the objective guide. Make sure that its edges are flush with the edges of the side walls of the housing. The last section of the front wall, the holder for the plane mirror, should not be glued on yet.

Step 11

Fold and glue the objective tube [B2] into a hexagonal tube.

Step 12

Remove the disc from the middle of the objective lens holder [B3], fold the 16 small tabs carefully forwards, and lay the piece on your work surface, so that the small tabs create a round, crown-like fence. The objective lens should be glued with its flat side facing down into this crown of small tabs. This is best done as follows: Clean dust and finger prints from the objective lens. Then carefully apply glue onto the inside of the small tabs (perfectionists can first paint the top edges of the small teeth with a black felt tip pen). Place the lens into the holder and wrap an elastic band around the tabs while the glue sets. Check that both the objective lens holder and the lens itself are lying flat on the work surface. This will make sure that the lens is not offset or sits at an angle inside the holder. It is not a problem if some glue gets onto the edge of the lens, because a 3.5 mm wide rim of the lens will be covered by an aperture. Glue that gets onto the main part of the lens needs to be removed with solvent.

Step 13

Fold the 6 right-angled tabs of the objective lens holder forwards. Then push the part with the lens first into the opening of the objective tube [B2] that has the grey marks for glueing on the inside. The tabs must be absolutely flush against the edge of the objective tube. This way you get a 24 mm deep black chamber, with the lens located at the bottom. Glue the tabs firmly in this position.

Step 14

Fold the parts of the objective guide sleeve [B4] and the objective tube sleeve [B5] backwards and glue them onto the marked areas around the opening of the objective guide and the objective tube.

Step 15

Fold the short and long groove of both supports for the objective guide [B6] and [B7] forwards. The folds divide the two parts into a small and a large glue tab and an even larger main part. Glue the main part of both supports together. Then glue the spread apart tabs onto the marked area on the front of the housing and the small tabs directly under the objective guide. This ensures that the objective tube remains perpendicular to the front wall and that the wall will not warp.

Step 16

Remove the disc from the hexagonal 23 mm objective aperture [B8] and reinforce the fold lines marked with perforations with some adhesive tape on the white back. This will prevent the tabs from being ripped off when the aperture is repeatedly removed and replaced with a different aperture. Then fold all tabs forwards and push the aperture from the inner side into the objective tube, the side with the hexagon first. The aperture is not glued in place so that it can always be removed later, using tweezers or a similar tool. Remove the discs from the hexagonal apertures [B9], [B10], [B11], and [B12] and save the apertures for later.

Step 17

Try pushing the objective tube into the objective guide. It should be easy to move back and forth, but it shouldn't slip on its own. To get the right amount of friction, you can stick one or more layers of 23 x 36 mm paper onto the inner surface of the objective guide. Perfectionists will prefer black paper.

The Plane Mirror

In order to project the image of the Sun onto the bottom of the Solar Projector, it is reflected downwards by a tilted plane mirror. This ensures that the projected picture, although horizontally inverted, remains vertically correct. After completion you can easily check this by observing a sunset. For the plane mirror use a glue that does not damage the protective paint or the mirror coating on the back, e.g. double-sided adhesive tape or a solvent-free adhesive. If you are unsure, try a corner of the mirror before glueing it in place.

Step 18

Glue the plane mirror with its grey side onto the inner side of the plane mirror holder. Glue it in place so that it lies concentrically under the mirror holder and its ends are flush with the upper edge of the latter. Because the mirror is slightly wider than the mirror holder, it will stick out by about a third into the inside of the projector. Wait until the glue has set completely before carrying on.

Step 19

Glue both side tabs of the plane mirror holder into the housing and make sure that the edges of the plane mirror holder are exactly parallel to the edge of the housing. This is very important, because it ensures that the plane mirror has exactly the correct angle to reflect the picture downwards. Both the trapezoid-shaped tabs on the left and right will be glued in place later. Do not remove the protective film yet.

The Convex Mirrors

Parts on sheets 5 and 8. *The two convex mirrors (outward curved mirrors) have negative focal lengths of -10.2mm and -14mm. This means they don't collect the light as a concave mirror with a positive focal length would do, they make the light fan out. The mirrors are mounted on two sides of a removable cassette which can be swapped around.*

Step 20

Remove the discs from the front [C1] and rear [C2] parts of the mirror cassette and fold the three surrounding narrow tabs forwards. Glue these parts onto the front and back of the middle part [C3] of the cassette so that the three are flush with each other at the rounded side.

Step 21

Fold the edge strip [C4] of the cassette and glue it around the outside of the folded-up tabs of the front [C1] and rear [C2] cassette parts. The rim of the cassette should not be wider than the edging strip. If necessary you can remove any excess cardboard carefully with a knife or file. Don't glue in the two convex mirrors yet.

Step 22

Remove the round disc from the slipcase for the cassette [C5] and lay the slipcase with the white side facing down on your working surface, so that the two parts with the cut-off corners point away from you and the 4 mm narrow tab points towards you. Fold the 4 mm narrow tab forwards and the other three tabs around the central rectangle backwards. Fold the two protruding tabs backwards, so that they lie flat against the glue marks on the other tab. Finally fold forwards the two tabs with angled edges on the right and left. Now the slipcase looks like in the following picture.

Step 23

Glue the two small tabs with sloped corners onto the top tab to form a flat box. Wait until the glue has set. Without applying any glue yet, hold the box onto the glue markings on the inside of the projector just under the top edge of the back wall, behind the round cutout. It should abut against the folded edge of the back wall. The two angled tabs should lie on the glue marks. Check that the cassette can be pushed in from the outside through the rounded opening. Glue the two angled

tabs of the slipcase in this position onto the inner side of the back wall. After the glue has set, glue the folded edge of the back wall onto the thin tab of the slipcase.

Step 24

Look at the outward curved side of the two convex mirrors. You should see an image of your head, bigger in one of them than in the other. The mirror with the smaller image is the one with the focal length of -10.2 mm. Glue it onto the cassette, on the side labelled "f = -10,2 mm". Glue the other mirror onto the other side. It is best to use double-sided adhesive tape for this.

Now all optical components are fitted.

Housing, Finishing Touches

Parts on sheets 5 and 6.

Step 25

On both sides of the housing there is a quadrant, a quarter circle with a degree scale. In order to determine the height of the Sun with this, you need two thin threads, to the ends of which you attach weights by glueing or knotting. As weights you can use beads made of metal, glass, or stone, or other small and heavy objects. Make a hole in the centre of the small circle at the centre- point of the quadrant, insert the end of the thread with a needle and attach it firmly on the inside of the projector. The weight should hang low enough that the thread is clearly visible against the scale.

Step 26

Glue the edge reinforcement of the housing [A6] onto the folded rim of the back wall. The right angled cut-out should be flush with the cut-out for the cassette. Now glue the two protruding ends of the reinforcement and the two trapezoid-shaped tabs of the plane mirror holder onto the folded rims of the side walls. This gives the Solar Projector a remarkable stability, despite the fact that the top is almost completely open.

Step 27

Fold the two side tabs of the projection surface [A7] backwards at right angles. Insert it into the housing with the angled tabs facing downwards. To ensure that it lies flat against the wall in the centre, you can bend it slightly in the opposite direction beforehand. It is advisable to glue it in place so that it does not fall down when the Sun is high. If required, it can be covered with highly reflective white or coloured paper or a grid template (see notes below).

Step 28

Remove the protective foil from the plane mirror. It might be necessary to lift a corner with a knife.

Now the Solar Projector itself is complete.

The Base

Parts on sheets 6, 7, and 8. *In order to adjust the angle of the Solar Projector between horizon and zenith, the base has a curved surface which holds the rounded back of the housing. This simple but efficient way of fitting the projector is known as a Dobsonian mount, after its inventor, and is often used for astronomical telescopes.*

Step 29

Fold the tabs of the trapezoid-shaped left outer side [D1] backwards and the many small tabs of the left inner side [D2] forwards. The top edge of the outer side is exactly as long as the straight edge of the inner side. Glue the inner side and the outer side back to back so that these two edges are flush.

Step 30

Repeat Step 29 with the right outer side [D3] and right inner side [D4].

Step 31

Fold the two tabs of the curved surface [D5] backwards and gently curve the surface by dragging the part over a straight table edge or similar, with the printed side facing downwards: the printed side should be on the inside the curvature. The curve should approximately fit the line of the tabs of the inner sides [D2] and [D4]. Knot a thread of yarn around the piece to retain the curved shape.

Step 32

Take one of the two outer sides, with the glued-on inner side and apply glue to the printed side of the small tabs. Lay the outer side face-down on your work surface, stand the curved surface [D5] on the inner side and glue the tabs to the back of the curved surface. Take care that the ends of the curved surface do not stick out beyond the ends of the inner side. Glue the other inner side onto the other edge of the curved surface in the same way. Remove the yarn after the glue has set.

Step 33

Fold all tabs of the base plate [D6] backwards and place it, printed side downwards, on your work surface. Glue first one, and then the other tab to the back of the two side pieces that are joined by the curved surface. It is best to do this as follows: Put glue on one of the two tabs and place the curved surface with the side pieces onto the base plate, so that the side pieces line up with the two tabs. To glue it in place it you can push against the pieces on the outside with your hand and on the inside with a pencil or similar. Glue the second tab the same way.

Step 34

Finally, you need to glue the front side [D7] and the rear side [D8] of the base onto the tabs of the two remaining openings. To make the Solar Projector more windproof, you can glue metal objects (large nuts, metal plates, etc.) onto the inside of the base to increase its weight. Lay the base on a flat surface for this and ensure that the base plate stays square against all edges while glueing. If the base still wobbles, simply glue small pieces of black cardboard under the corners that are too high.

Congratulations! *Now you've put it all together and you are ready for your "First Light", as astronomers call the time of first observation with a new piece of equipment. We wish you many interesting observations with your new Solar Projector! If you would like to tell us about your experiences during assembly or while using the projector, we would be delighted to receive your comments. We may be able to incorporate those into future editions of these instructions. Please send them to service@astromedia.de.*

How to use your Solar Projector

1

Slide the objective tube into the objective guide and the mirror cassette into the slipcase.

2

Put the Solar Projector on its base and point the objective tube towards the Sun so that the little bright point of light hits the convex mirror, somewhat above its centre.

3

Now focus the objective lens by moving it forwards and backwards until a clear image of the Sun appears on the projection screen.

4

The Sun moves, so the image of the Sun will also move. Turn and tilt the projector until the image is once again visible. You only need to change the focus of the objective lens if you swap the convex mirrors.

5

Important safety instructions: Do not leave the Solar Projector unattended with the lens pointing towards the Sun. The focused sunlight could otherwise move away from the convex mirror and burn a hole in the cardboard.

Warning! Never look directly at the Sun through the lens, as this can lead to serious eye damage!

Frequently Asked Questions

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What can I observe with my Solar Projector?

Most importantly sunspots, but also solar eclipses and planetary transits. Under good conditions it is even possible to observe the landscape.

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Are there always sunspots visible?

The number of sunspots changes over a cycle of approximately 11 years. The last maximum was in 2014, and we are currently (at time of writing in 2025) experiencing the next one. In 2019 was a minimum. When near a minimum, it can happen that sunspots are only visible with a very powerful telescope (with solar filter). You can find more information about sunspots on the internet at www.wikipedia.org or on NASA's official website.

Can sunspots change their size and position?

Yes, sunspots (which often consist of groups of smaller spots), grow and shrink. Over the course of several days, they move from left to right across the solar surface. The reason for this is the rotation of the Sun around its own axis (the rotation period is 25 days at the solar equator and 35–40 days near the poles). If you follow a sunspot near the centre of the solar disk over a few days it will get ever thinner because of perspective distortion.

How often can I see solar eclipses?

Approximately twice a year somewhere on Earth, but usually only in a small area, and often in very inaccessible places. Lists of solar eclipses can be found on Wikipedia.

What is a planetary transit?

The orbits of Mercury and Venus around the Sun lie within the orbit of the Earth. Therefore occasionally Mercury or Venus are exactly between the Earth and the Sun, so that for a short time you can see them as small black dots moving across the Sun. Such a planetary transit is a rare occasion, because the orbits of the planets don't lie in the exact same plane. Lists of planetary transits can be found on Wikipedia.

How can I tell whether what I am seeing is a sunspot or dust in the optical system?

Turn the Solar Projector a bit left and right so that the solar image moves around the projection screen. If the spot moves as well, it is a sunspot. If it doesn't, it is probably dust on the plane mirror or the screen. Dust on the lens doesn't show up as spots, it just makes the image poorer.

What are the grids below for?

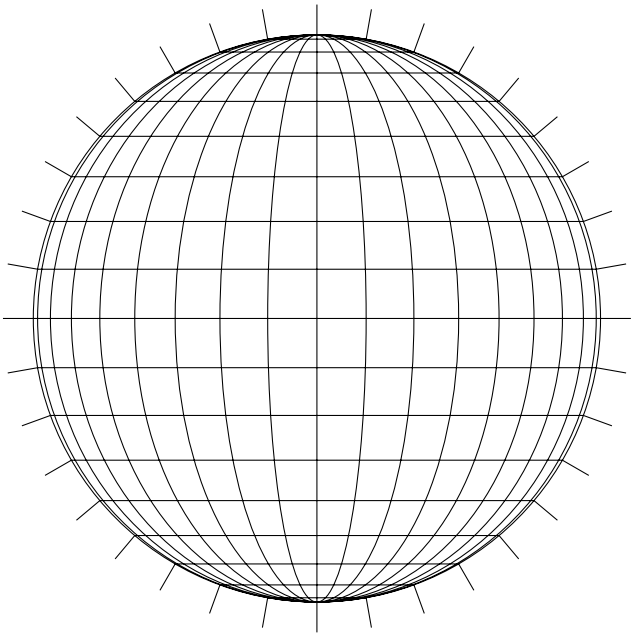
The grids are the same size as the solar image, depending on which convex mirror you choose. You can put them on the projection surface to record the exact position of sunspots and by making observations over a period of time, see how they have changed.

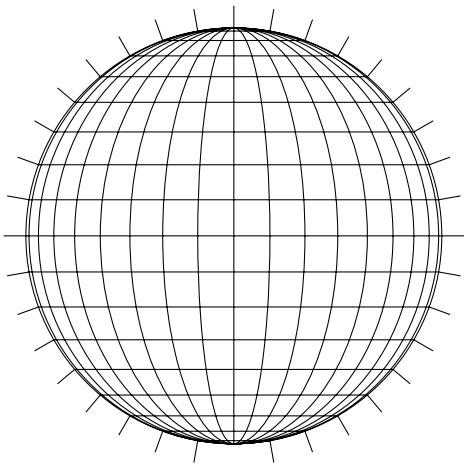
How can I determine the height of the Sun?

The height of the Sun is the angle you see it above the horizon. It can be read directly from the two quadrants. The Solar Projector must of course be placed on a flat horizontal surface. You can check this with a spirit level (for example the minispirit level from AstroMedia, article number 410.WAS) or by turning the Solar Projector once around its vertical axis. If the angle shown by the quadrants stays the same during the rotation, the surface is horizontal.

What are the hexagonal apertures for?

These apertures can be fitted behind the large aperture in the objective tube to reduce the aperture opening. Smaller apertures make the image sharper, but dimmer. That might be desirable, for example if you think the solar image is too bright. It can sometimes be easier to make out sunspots on a dimmer image.





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