Adjustment manual for WS 140/150/250

You need a small hexagonal key (delivered with the telescope)

I.

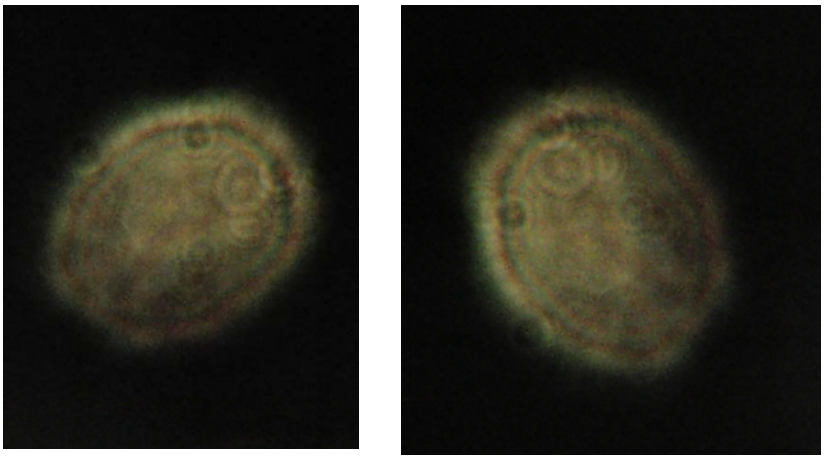
By the help of the following instructions each amateur should be able to readjust the mirror optics of the Schiefspiegler telescope easily. A short adjustment manual will show you, which screw should be turned in a defined direction to correct the image error of astigmatism. After you have some experience with this procedure you can correct small errors in a few minutes. Only change the position of the adjustment screws after you have analysed the shape of a star and found that it is elliptical (described below).

First, you should control if the optic is adjusted perfectly or needs a further correction.

For this purpose, you should observe a bright star and locate it at the central part of your field of view, using an eyepiece of medium power (magnification 100 -150). Adjust the focusser in such a way that you see the sharpest image of the star. Than you defocus the star by shifting the focussers position by some mm to the outside (extrafocal) and also move it a small amount to the inside (infocal). In both cases you should see a unifomly illuminated disk of the star with a circular shape like that shown in Fig. 3.
Both defocused images of the stars should be almost equal which is a sign of perfect adjustment of the optics. But if you observe an illuminated disk with clear elliptical shape (compare Fig. 1,2) than their might be some astigmatism present, which has to be compensated by turning the outer adjustment screws in a defined way. For adjustment, 5 screws connected to the mirror cells can be reached from the outside of the tube (see image below).
The star test should be done under good seeing conditions (stable and good weather conditions, bright stars near the Zenith should be prefered). You also have to wait for 0.5-1h to let the telescope cool down to the ambient air temperture. Otherwise the stellar disk will be not stable and its shape and illumination will always be in motion.

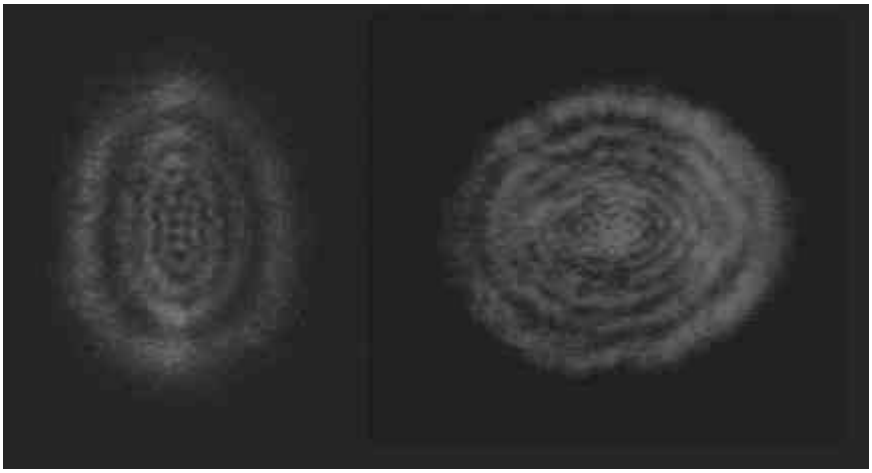
A readjustment of the optics is only neccessary, if an elliptical shape of the defocused star has been observed. First try to analyse the orientation of the ellipse, that means the orientation of the long and short axes. Therefore go from the infocal to the extrafocal position (or vice versa only by a few mm). You should see that the orientation of the ellipse has changed and rotates by 90°. This is a characteristic sign of astigmatism, which can be compensated by fine adjustment. For extreme cases of astigmatism, the ellipse will be deformed to a single illuminated line. You should decide whether the astigmatism is rotated with respect to the symmetry plane of the telescope (this situation is shown in Fig.1) or if astigmatism is orientated within the symmetry plane (this is shown in Fig. 2).
If you observe a situation very similar to Fig. 2, you can directly go to step 2 of the adjustment procedure. If you observe a situation like in Fig. 1 than you first have to rotate the ellipse (according to step 1 of the adjustment procedue) to obtain an ellipse orientated horizontally as shown in Fig. 2 . In the next step this ellipse will be converted to a circular shape (according to Fig. 3).

Fig. 1 Astigmatism of a defocused star is rotated with respect to the symmetry plane of the telescope:



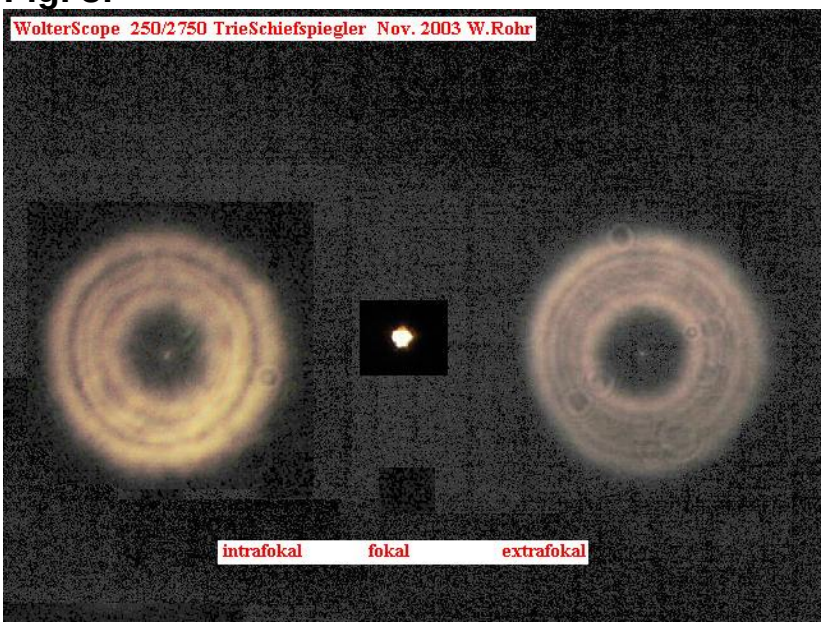
The left side of the image shows the defocused disk of a star with a focussers position shifted inside (infocal) with respect to the sharp image (focal) and the right image shows this defocused disk for an focussers position outside of focus (extrafocal). The images can also be reversed - with the left image corresponding to the extrafocal postion and the right image to the infocal position of the focusser.

Fig. 2 Astigmatism of defocused star is aligned along the symmetry plane of the telescope



The left side of the image shows the defocused disk of a star with a focussers position shifted inside (infocal) with respect to the sharp image (focal) and the right image shows this defocused disk for an focussers position outside of focus (extrafocal). The images might also be reversed, with the left image corresponding to the extrafocal position and the right image to the infocal position.

Fig. 3:



The left and right side of the image show the defocused disk of a star with a focussers position shifted inside with respect to the sharp image (focal) and outside of focus. In the center of Fig. 3 you see the Airy disk of the focused star. The corresponding diffraction rings are not resolved in this image.

Before you change the adjustment of the telescope make shure that your eyepiece or your eyes itself do not induce this image error . You should rotate the eyepiece, the ellipse should not rotate, otherwise your eyepiece is defect. Control the ellipse also with your other eye. If the ellipse also rotates by rotating your eyes, they need a correction. You should wear your contact lenses or spectacles, if necessary. After you have excluded this errors and astigmatism is still present, carefully read the following instructions to readjust your telescope. With a little experience, adjustment can be rather easily done and needs no complicate procedure or equipment.

Instructions for adjustment of the optics

(you need the hexgonal shaped screw-driver which is included)

The misalignment of the mirrors, which produce astigmatism can easily be repaired. For this purpose five adjustment screws are acessible at the outside of the tube, one screw at the forefront (**M2**) and four screws at the backfront (**S1, M1, S3, M3**), see the image below. An additional screw **S2** at the forefront is not needed here, it is only necessary for the pre-adjustment with the laserpointer (see below)
This adjustment screws change the tilt of the 1. mirror (S1, M1), 2. mirror (M2) and 3. mirror (M3, S3).
S1, S2 and S3 are located within the telescope´s plane of symmetry (saggital (horizontal) plane - this plane cuts all mirrors and the aperture at their centers) .
M1 and M2 are located along a direction perpendicular to this plane – denoted as the meridional (vertical) plane of the telescope optics.

Additional adjustment screws are located at the mirror cells inside of the tube. They should not be turned without special knowledge about precise optical adjustment. They have been aligned by the manufacturer very precisely in the autocollimation test setup.

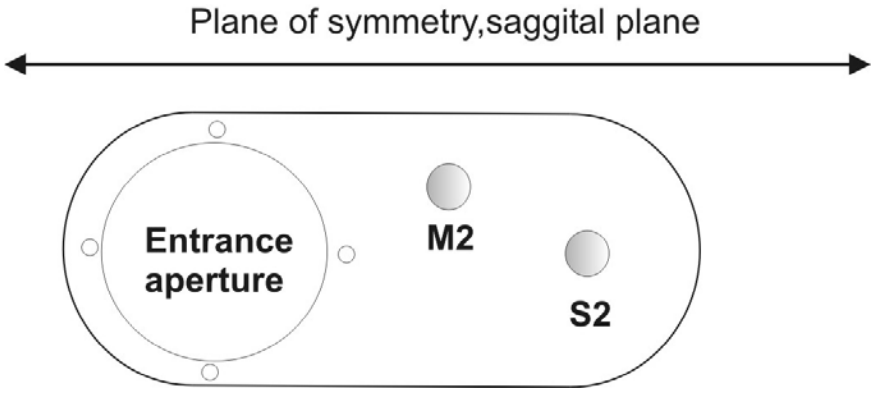
For the star test It will be necessary to use a mounting with a motor drive to correct the movement of the star.
If you do not have a mounting with motordrive you can make the star test by using the northern polar star, which does not move.
First locate your star at the center of your eyepiece of medium power (magnification 100-150). You should also get some knowledge of the surrounding stars to find the star again if it has moved to the edge of the eyepiece..
Your motor drive of the mounting should follow the star for several minutes, otherwise you have to readjust your mounting to realize a more accurate alignment.

Take care not to turn the adjustment screws to much, the star will get out of your field of view and it might be difficult to find it again. In most cases a total rotation of ¼ (90 degree) of certain screws is sufficient to correct the error. Later you can make the adjustment more precisely by using a high power eyepiece with magnifications of 200-300.

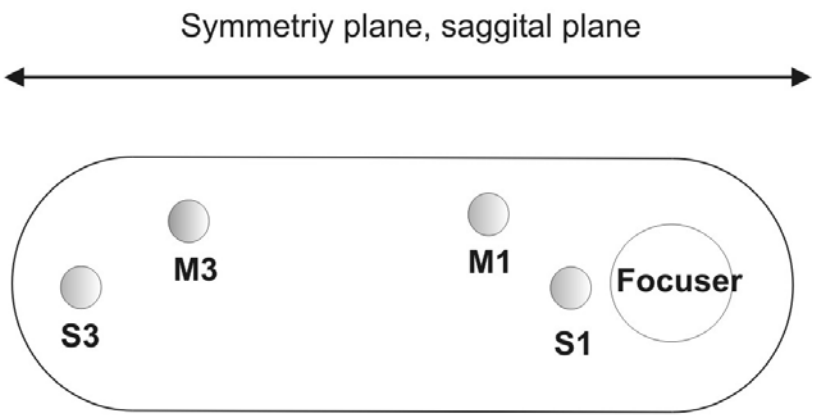
Position of screws for adjustment

Fig. 4a, b:

Position of adjustment screws at the forefront of the WolterScope 140/150/250



Position of adjusment screws at the backfont of the WolterScope 140/150/250



Rotated Astigmatism:
- correct with M1,M2(forefront)
Rotate towards symmetry plane

Astigmatism along symmetry plane:
- correct with saggital screws S1,S3 to obtain a circular disk

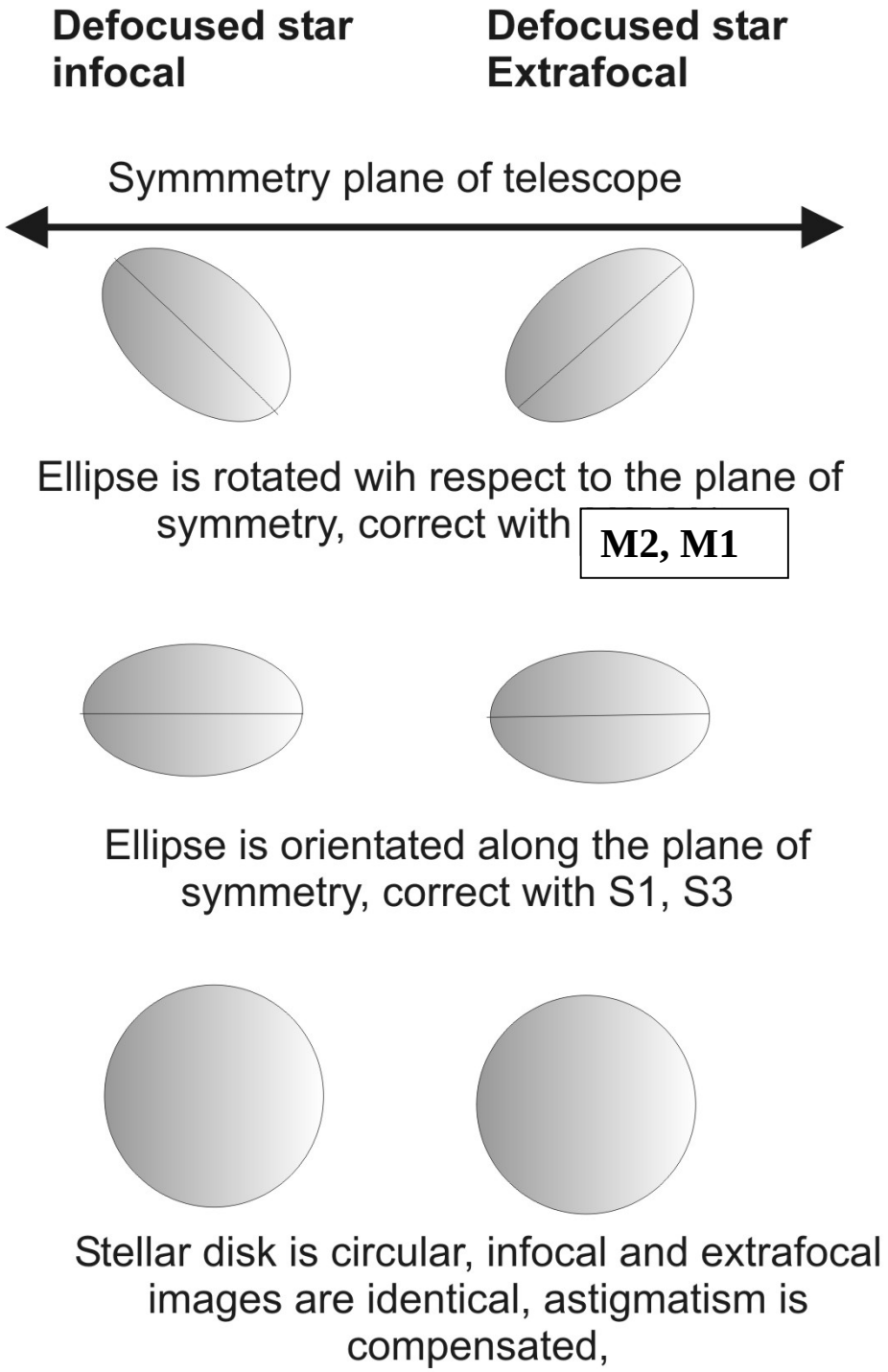
Adjustment is done in two steps:

In a first step you have to rotate the observed ellipse of the defocused star in such a way that one axis of the ellipse (the longer or shorter direction, it doesn`t matter which of them) is located within the plane of symmetry of the telescope (saggital, horizontal plane). The ellipse as seen in Fig. 1 has to be converted to an ellipse which is orientated horizontally, as seen in Fig. 2. In the second step the ellipse will be converted to a circular disk, like that shown in Fig. 3.

Maybe the observed ellipse of the defocused star is already orientated along the symmetry plane (compare Fig. 2), in this case you can directly go to the second adjustment step (2).

The image below (Fig. 5) shows the different stages of correction of astigmatism. The rotated ellipse is converted to an ellipse orientated along the plane of symmetry. By adjustment step 1. Thereafter the ellipse is transformed into a circular shape by adjustment step 2. Astigmatism is now corrected perfectly.

Fig. 5



Adjustment step 1:

The **orientation of the ellipse can be rotated** by turning the **screw M2 at the forefront** by a small amount in some direction (for example 1/4 rotation clock wise, not more). Thereafter look into the eyepiece, the star (it should be focused) has shifted from the center to a higher or lower position.
Now you have to turn the **screw M1 at the backside** by about ¼ turn in the other direction (in this example counter - clockwise). You should control the movement of the star in your eyepiece during rotation of this screw by one hand. By this treatment, you should move the star back to the center position of the eyepiece.
If your star can not reach the center exactly, you can move it along the symmetry plane (horizontally) **by rotating screw S3**. Now you should defocus the star by a small amount and decide, whether the ellipse has rotated towards the horizontal/vertical orientation or if the deviation is going larger now.
In the first case you can repeat this adjustment step by using smaller roations of your screws (M2-1/8 rotation clockwise and M1 - 1/8 rotation counter-clockwise). But if the ellipse deviates stronger from the horizontal/vertical orientation you have to change the orientation of rotating the screws (In this example M2 - ¼ rotation counter-clockwise and M1 - ¼ rotation clockwise).
In most cases small rotations of this two screws will be sufficient to align the ellipse in the horizontal/vertical direction. It does not matter if the deviation from a circular shape is going larger (the star looks moreelliptical) by this treatment. It is only neccessary to reach the correct orientation. If you are satiesfied with the result and obviousely can not see any deviation from the horizontal/vertical orientation, you can finish this procedure and can go on with adjustment step 2. This can be done more easily, because you have to turn only two screws (S1, S3) at the backfront and can directly control the movement of the star (which is done by one hand) in your eyepiece.

Adjustment step 2:

Make shure that your star is located again in the centre position of your eyepiece (by moving the fine control of your motor control unit).
Now turn screw **S1 by ¼ rotation in one direction (for example clockwise).** Look through the eyepiece, the star has moved away from the center of the image and might be located on the right or left side. **Thereafter you should rotate S3** by the same amount in the opposite direction (in our example by about ¼ rotation counter-clockwise). The star should reappear in the centre of your eyepiece, adjust the screw **S3** to bring the star exactly in the centrel position of the field of view.
Now you should check for astigmatism, defocus the star in both directions by changing the focussers position by some mm in both directions (not more). The elliptical shape of the star has been reduced and changed towards a circular shape or it might look more elliptical now. In the first case try to repeat the adjustment steps usin smaller rotations of the two screws. In the latter case you have to change the direction of rotating your screws and to repeat the adjustment steps (in this example **S1 by ¼ rotation counter-clockwise and S3 by ¼ rotation clockwise**). Take care that you do not lost the star, it should always reapear in the center of the image by turning the screw **S3**. The screw **S3** should always be turned in the opposite direction with respect to **S1** to locate the star in the eyepiece again.

Only screw **S1** was responsible for the correction of astigmatism, a certain tilt position exists, where the error will dissapear completely. The screw **S3** is only necessary to bring the star back to the central position. If you have lost the star during adjustment this results in a more or less strong deviation of the optical axis from the perfect position. You should change your eypiece to another one with smaller magnification to find the star again. In most cases you can find the star again and it can be shifted to the centre of view.
In the worst case - you have lost the star and are not able to make a perfect correction of the elipse - you should open the tube during daylight and make a pre-adjustment with the laserpointer as described below. This makes shure that the optical axis is aligned again. Adjmustment is also rather perfect after this procedure, only some small changes of mirror tilts are necessary to make the adjustment perfect.Therefore you should repeat the final adjustment steps 1 and 2.

If you go beyond the position of screws which yields perfect correction, the error will grow again and you have to change the direction of rotating the screws. Do not try to go beyond the limited way of travel of the screws, otherwise they might be damaged.

After you have almost obtained a circular shape of the disk of the defocused star, you can make the adjustment more precisely by using an eyepiece of smaller focal length (higher magnification up to about 300x). Try very small turns of the screws **S1 and S3** (1/8 turn or less will be sufficient) to remove the remaining error. For this critical check you have to wait for a night with good seeing conditions. It makes no sense to readjust your telescope during nights with unstable stellar disks.

This procedure adjusts the optics very precisely and you will bring it to its optimum performance. With some experience adjustment is done very easy. If you can get the help of a friend it will be more convenient for adjustment step 1. He/She can turn the screw M2 at the forefront and you can always look and control the movement of the star within the eypiece (to check for astigmatism) and readjust its position by turning the screw M1 next to you.

Short adjustment table:

In the short adjustment table all necessary steps for final adjustment are explained in a graphical way. In the left columm you see a certain orientation of the ellipse of the defocused star. All situations are given for an infocal position of the focusser. (focusser should be moved inside by some mm fom the sharpest image). In the corresponding 2. and 3. collumm, the table tells you, which screw you should turn in which direction to correct the error (the amount of rotation can not be specified, but you can find it easily by trial and error).

A final check of the optical quality and perfect adjustment can be performed under good seeing conditions. Observe a brigth star with an eyepiece of high power and focus sharply. You should see an almost dimensionless point like star surrounded by one ore more circular diffraction rings. The brigthness and shape of the ring should

be homogenous. More details of star testing are given in the book of H. Suiter (Star Testing of Astronomical Optics, Willmann-Bell 1988).

If you are not able to obtain a perfect adjustment of your Multi-Schiefspiegler, send the telescope back and we will do the adjustment for you without further costs. You have only to pay for the costs of shipment.

II.
Adjustment of the optical axis with Laserpointer and mirror-masks for WS 140/150/250:

By using a collimation laser you can easily adjust a mirror telescope with a centered secondary mirror (like a Newton, Cassegrain). The laser is attached to the focusser and you can observe the laserlight which was reflected back from the secondary mirror.
For Schiefspieglers this adjustment procedure is not possible, because there exists no centred secondary mirror.
For Schiefspieglers you can attach a laserpointer at the centre of the entrance aperture. Than the laserbeam hits the primary in its center and is reflected to the secondary mirror. All mirrors can be covered with masks with small bores which define the central ray going to and reflected from this mirror. Finally the laserbeam comes out at the focussers end.
The optical axis of the telescope is defined by the ray which connects the centre of the aperture to the centre of the primary mirror. If this central ray comes out within the centre of the focusser, the optical axis of the telescope is almost perfectly adjusted. This makes also shure that no vignetting of the light bundle occurs.

This adjustment procedure will be necessary after removal of the mirrors or if you lost a star during fine alignment and make some large undefined changes of the mirror tilts. In these cases you will see objects within the centre of your eyepiece, which have their orign at the sky at a certain angle with respect to the optical axis. For this tilted objects the telescope can not be adjusted perfectly by the fine adjustment procedcure. Than you get always astigmatism for stars located at the center of your field of view. If you can not correct this error by fine adjustment - you have first to do the adjustment of the optical axis as described below.

You can check and correct the adjustment of the optical axis by the following treatment:

Take off the tube cover on the top side and locate the telescope on a solid table. You can do this adjustment in a room or outside, but avoid direct sunlight.
Install the aperture mask with the laserpointer at the entrance aperture of the telescope. Thereafter install also the other 3 masks in front of the corresponding mirrors. The two **red masks (with bores 1,3)** should fit into the aluminium ring cells of the primary (bore 1) and tertiary mirror (bore 3). The mask(with bore 3) for the tertiary mirror should be rotatated in such a way, that the central line is orientated within the symmetry plane of the telescope (which connects all middlepoints of mirrors and entrance aperture)

You should press the masks a little bit into the ring cells, the plastic disks should be almost in contact with the mirrors surfaces.

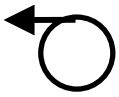
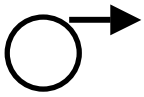
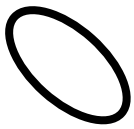
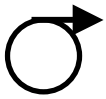
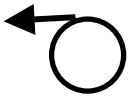
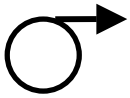
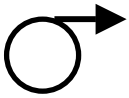
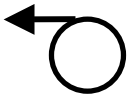
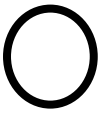
The other **plastic disk (with bores 2,2a,4,4a)** should be placed in front of the secondary mirror (it is located a distant apart from the mirrors surface). 2 bores a the lower and upper end of this disk should fit into preinstalled rods located in front of this mirror on the black mask. A small **transparent plastic disk** with a central hole should be placed into the focussers end.

Now you can switch on the laserpointer by pulling the plastic screw down (it is located in the middle of the laser plastic adapter). By using the 6 push and pull screws you can adjust the laserbeam in such a way that it hits the central bore of the primary mirrors aperture mask (**bore 1**). From the **primary mirror** the beam should be reflected into **bore 2 of the secondary mirror**. This should be adjusted with the adjustment screws **S1 and M1** of the **primary mirror** at the backfront. If the laserbeam enters through bore 2, it will be reflected through bore 2a and hits the tertiary mirror. You have to adjust the screws **S2, M2** at the forefront (tilts of the secondary mirror) in such a way that the laserbeam is centered within bore 3 at the tertiary mirror. From the tertiary mirror the light should be reflected back to bore 4 in front of the secondary mirror. To achieve this, you have to adjust screws **M3, S3** of the **tertiary mirror** at the backfront. The laserbeam passes through bore 4 and will depart from the secondary mirror through bore 4a. The laserbeam should come out of the telescope, located at the centre of the focussers end. There might be a small deviation of the lightbeam from the central position - than adjust the tilts of the tertiary mirror **S3, M3**.
Switch off the laserpointer during times you do not need it, the capacitiy of the batteries is not very high. You can change batteries by unscrewing the end cap of the laserpointer. The pointer should be almost centered within the plastic adapter, to make it possible that the light passes through the smalll bore in the aperture mask.

Adjustment of the optical axis is now ready and you can do a final adjustment according to the description above using a star. After doing the adjustment with the laser, the telescope is not adjusted perfectly, but the deviations will be very small. Final adjustment needs only some very small turns of the adjustment screws, no more than ¼ rotation.

Short adjustment table

Adjustment of astigmatism using a defocused star focuser is turned to a position inside with respect to focus:

View of a stellar disk with infocal position of the focusser (move it some mm inside from sharpest image)	**Correction with the following screw/orientation** **- only rotate screw by less than ¼ turn (90 degree)**	**Star is moved back to the center of view by the following screw/orientation** **- only rotate screw by less than ¼ turn (90 degree)**
	**M2 (2. mirror at the forefront)** **- rotate counter-clockwise** 	**M1 (1. mirror at the backfront)** **- rotate clockwise**  **do additional movement with S3 to shift the star horizontally**
	**M2 (2. mirror at the forefront)** **- rotate clockwise** 	**M1 (1. mirror at the backfont)** **- rotate counter-clockwise**  **do additional movement with S3 to shift the star horizontally**
	**S1 (1, mirror at the backfront)** **- rotate counter-clockwise** 	**S3 (3. mirror at the backfront)** **- rotate clockwise** 
	**S1 (1. mirror at the backfront)** **- rotate clockwise** 	**S3 (3. mirror at the backfront)** **- rotate counter-clockwise** 
	**Infocal and extrafocal stellar disk look equal and are almost circular.**	**Observe with higher magnification.**