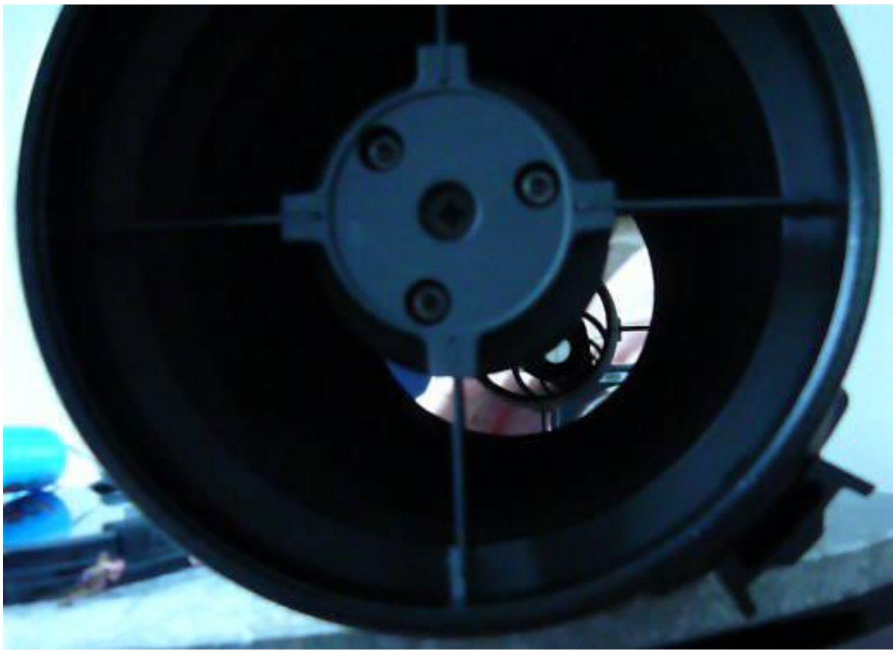
Collimating GSO Ritchey-Chretien Telescopes

Introduction

The Ritchey-Chretien telescope is designed with primary and secondary mirrors having hyperbolic figures to provide a flat field of focus over its field of view with an image devoid of coma, spherical aberration or astigmatism. The design offers an ideal imaging telescope since we have an aberration-free image from just two reflecting surfaces. However, to achieve the design goals, the mirrors must be:

a) parallel
b) have their optical axes coincident
c) be the correct distance apart

It is relatively straightforward to adjust the mirrors to be parallel. You can check the parallelism by gazing into the front of the telescope and inspecting the 'hall of mirrors' effect. The succession of multiple reflections of the mirrors should be straight and even.

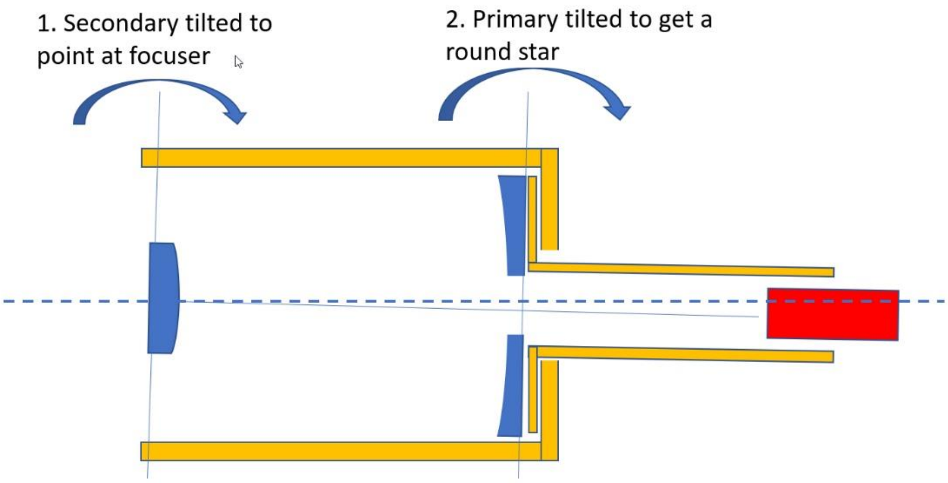


Adjusting the optical axes to be colinear is more complicated. The failing of the GSO design is that the focuser is attached to the primary mirror support plate instead of the backplate of the tube. Therefore, any movement of the primary mirror also moves the focuser. Any collimation method that relies on using a laser, or another pointing device in the focuser, is doomed to failure.

Using a laser, the collimation steps, typically are:

1) Put the laser in the focuser
2) Adjust the secondary mirror to centre the laser dot in the centre of the secondary
3) Now adjust the primary mirror to centralise the holographic pattern from the primary
4) Repeat forever

Collimating the telescope is made more complicated by the design of the support of the primary mirror in its holder. The design results in a small, unknown, pointing error of the mirror optical axis relative to the mirror holder.



Fundamentally, the telescope lacks a fixed reference that we can use to collimate. Usually, we would use the front spider as a fixed reference. We could then ensure the focuser points to the centre of the spider, say, using a laser and then use the focuser itself as a fixed reference to align the mirrors.

So we have to disregard using the focuser and introduce a new fixed reference to collimate the two mirrors. A plastic disc with a hole in the centre becomes our new reference. We will place the disc into the hole in the centre of the primary mirror where the hole in the centre of the disc will mark the centre of the primary mirror.

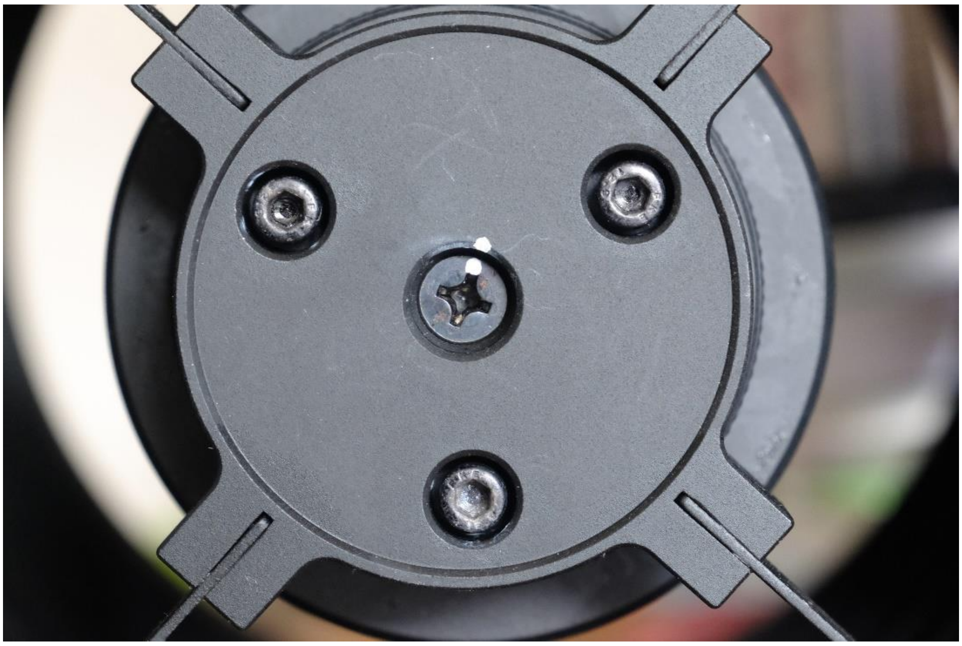
Preparation

For the first attempt at collimating the scope, I recommend dismounting it and putting it onto a firm horizontal surface with good access around it.

It might help to have a camera on a tripod to use as a viewpoint of the configuration as we adjust it. A camera with wifi is even more useful as we should then be able to view what the camera is looking at using an appropriate app on a mobile phone or tablet as we make the adjustments.

Remove the focuser and the extension tubes.

Using a spot of paint, mark the edge of the central screw holding the secondary mirror and the adjacent part of the secondary support to show the position of the screw. Also, mark the secondary mirror holder's side to indicate which way is ‘up’ for the mirror. The paint marks will ensure that you can put the mirror back in precisely the same position.



Now undo the central screw of the secondary mirror, while supporting the mirror in the other hand. Count the number of turns of the screw until it releases. If your scope is similar to mine, it should be around 8.5 turns. Let the secondary mirror rest on the inside of the tube.

Now remove the shade-tube. Reach into the telescope with both hands, and while supporting the shade-tube with one hand, gently unscrew it with the other. Let the shade-tube rest on the inside of the telescope.

The Plastic Disc

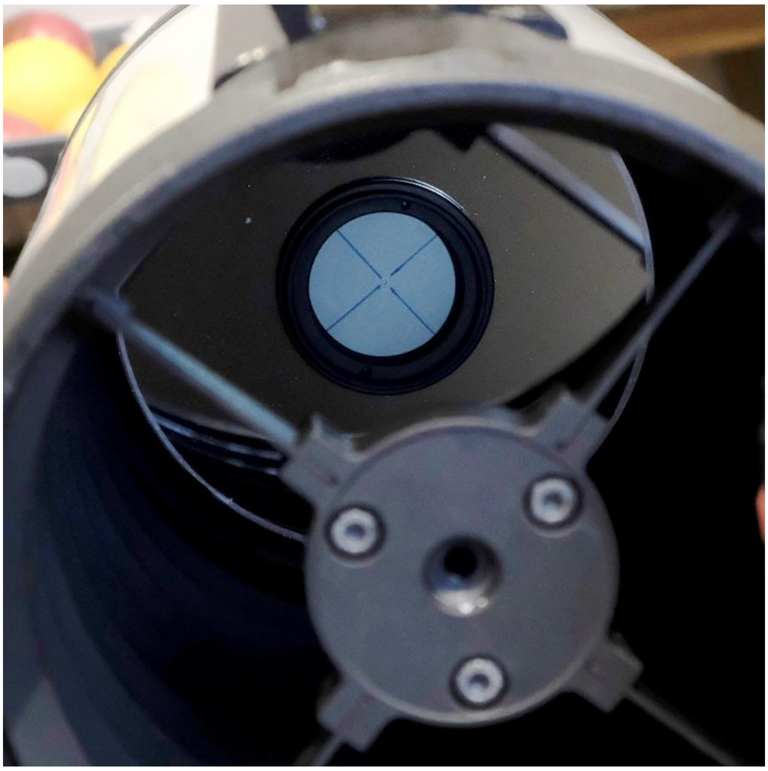
Carefully measure the inside diameter of the central hole in the primary mirror support. My RC8 measured as 58mm and an RC6 I have collimated needed a 47mm disc. Mark and cut out a plastic disc from say, 2mm, styrene and carefully drill (by hand works) a 1mm hole in the centre. Alternatively, you could use a good quality card that is easier to cut and has a softer edge. I've used plastic because it is more durable and the central hole is clean.

Now mark a cross on one side of the disc, through the hole. The cross will make the position of the hole easier to see during the procedure.

Place the plastic disc into the hole in the centre of the primary mirror. It should be a snug fit. If it is too loose, wrap a little tape evenly around the disc ensuring you don't push the central hole off-centre. If the disc is too big, you might need to rub some fine wet-n-dry paper around it.

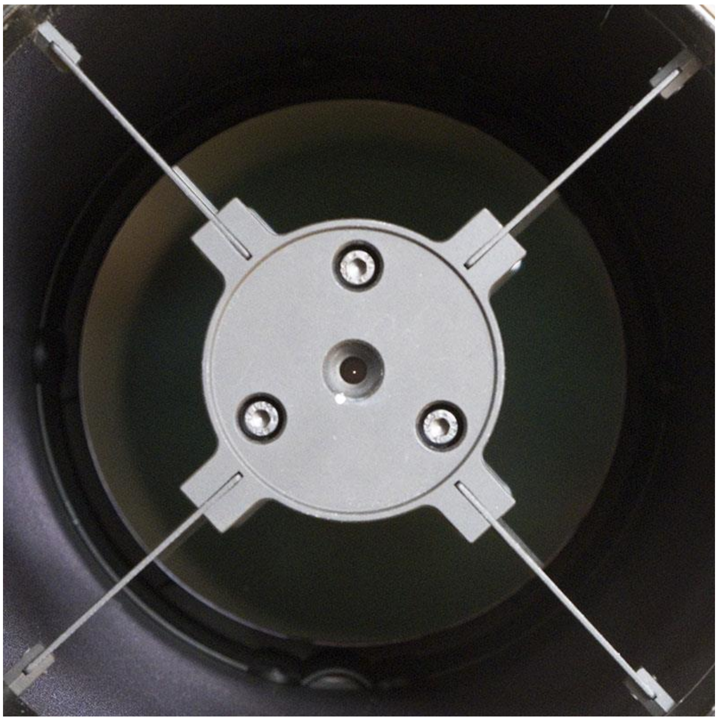
Be careful not to push the disc in too far, or else it will drop into a gap and is tricky to get out.

Here is a picture of a disc looking from the front of the tube. Note the cross I've marked on the disc.



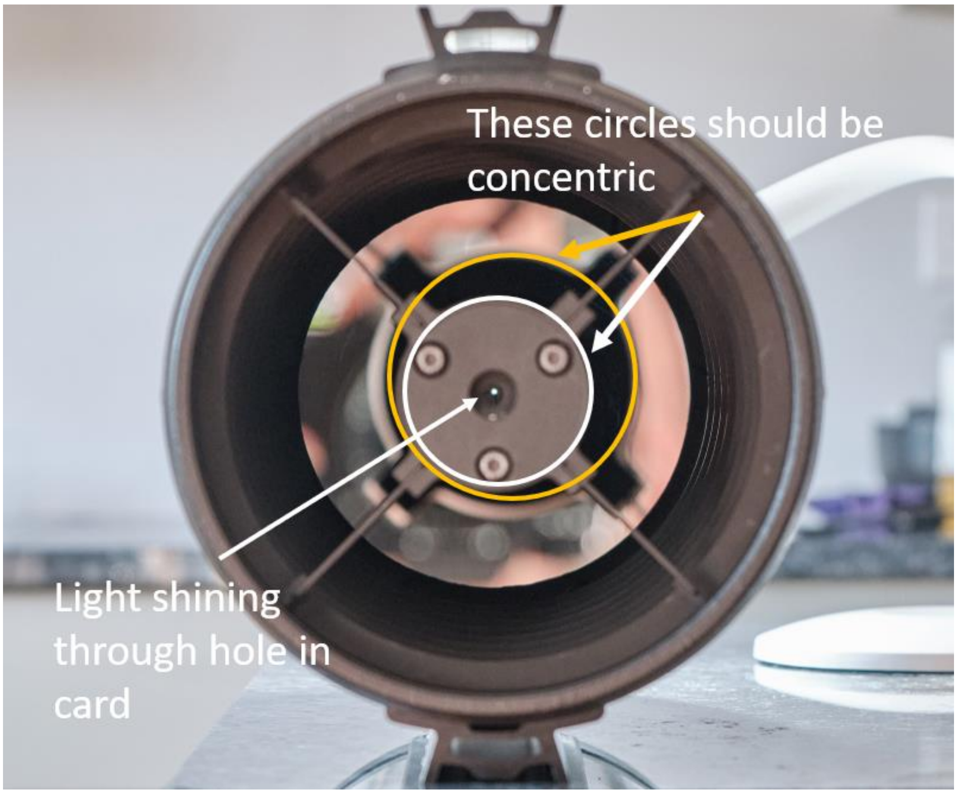
Aligning the Primary Mirror

Place a bright light behind the telescope. From the front of the tube, look through the central hole in the secondary mirror support, you should be able to see the hole in the centre of the plastic disc as a bright spot of light.

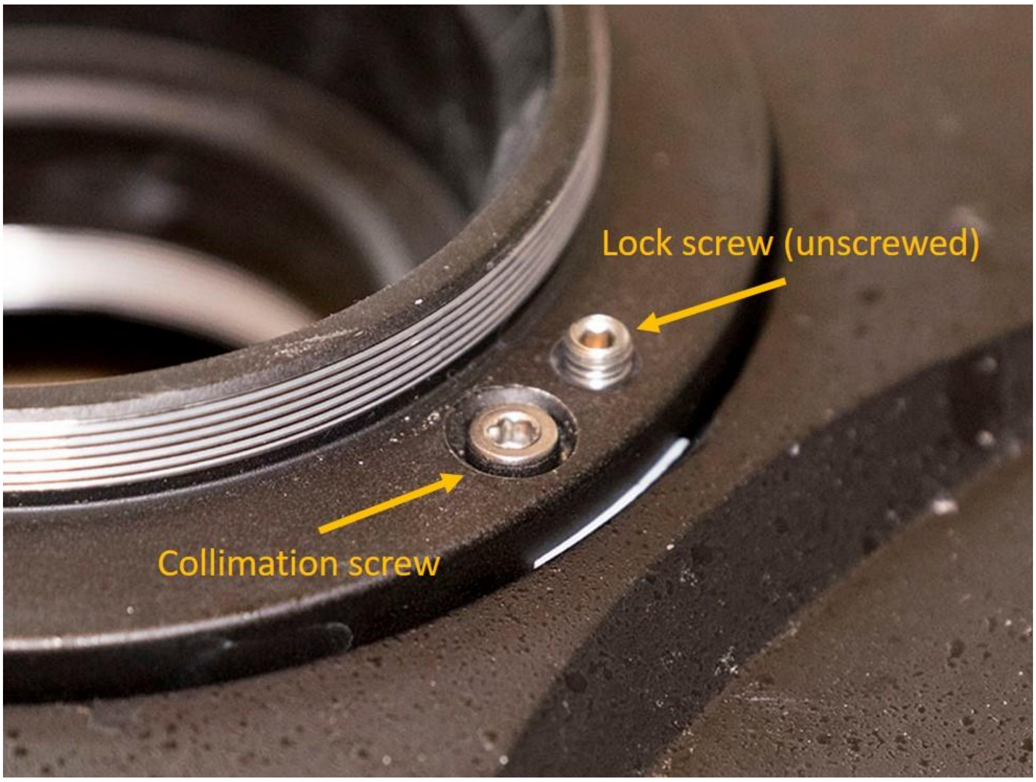


The task now is to adjust the primary mirror so that the support vanes and their reflections line up while the spot of light is dead centre in the secondary mirror hole.

Here is a picture looking into the front of an RC6 before I started adjusting the primary mirror. Note how the secondary support vanes and their reflections are certainly not lined up.

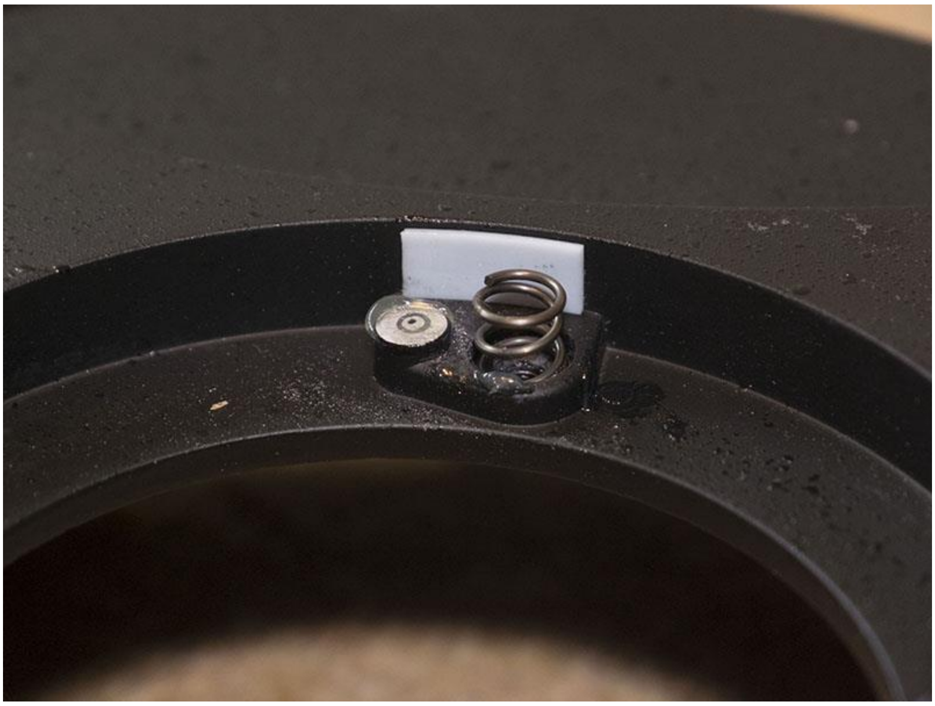


Here is a picture of the collimation screws:



The larger, silver-headed, collimation screw pulls the mirror towards you when tightened and pushes the mirror away when slackened. The smaller, black-headed, lock screw bears against the back of the mirror holder and locks it in place. You will need to slacken the lock screw before adjusting the collimation screw.

The back of the mirror holder, itself, looks like this.



Tightening the collimation screw will compress the spring. Note the bearing surface of the lock-screw to the left of the spring.

Adjust the three primary mirror a bit at a time. You could slightly loosen each of the small black lock screws, by, say a quarter of a turn and then adjust the larger, silver collimation screws until the support vanes and their reflections line up. Having a camera on a tripod looking into the front of the tube makes it more comfortable, and you can take a succession of pictures that you can inspect to judge success.

A note on using a camera: You need to have the camera some distance from the tube using a medium or telescopic lens to get enough depth of field. It takes time to align the camera to get the light spot in the centre of the secondary holder.

Once done, the primary mirror should be pointing square-on to the secondary support vanes. In this picture, you can see the adjustment is nearly complete.

Now snug up the small black lock screws on the primary – not too tight - and make a final check of the alignment.

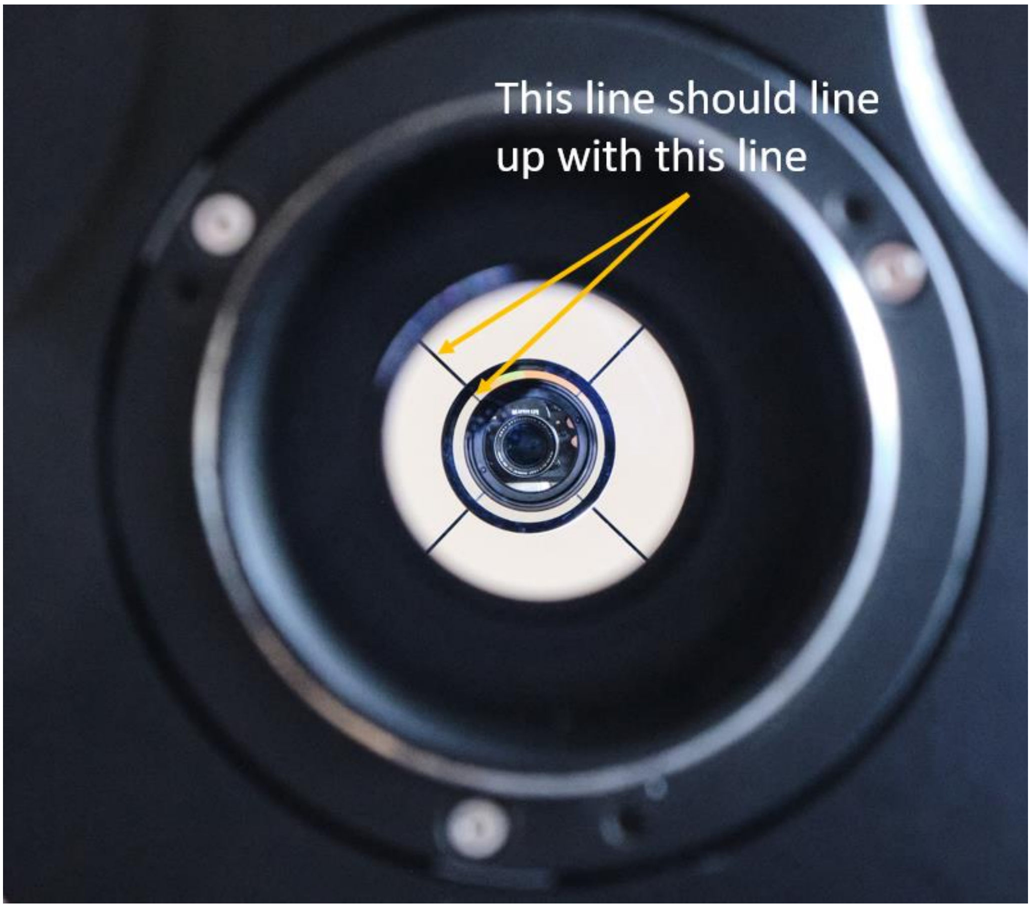
Note: a poorly collimated primary mirror will produce coma on stars at the centre of the field of view. You will need to make a final adjustment of the primary mirror on a star – by a tiny amount, hopefully. So, it is not <u>absolutely</u> critical to get the primary adjustment spot-on at this stage, but do take your time and try to get it as accurate as you can.

Aligning the Secondary Mirror

Replace the secondary mirror, aligning the paint marks and counting the number of screw turns.

As a first step, remove the plastic disc and look into the back of the scope tube. You will see the secondary mirror and the reflection of the secondary support vanes from the primary mirror. The vanes and their reflection should line up; see the picture, below. Note that you can also see the reflection of my camera in the secondary mirror.

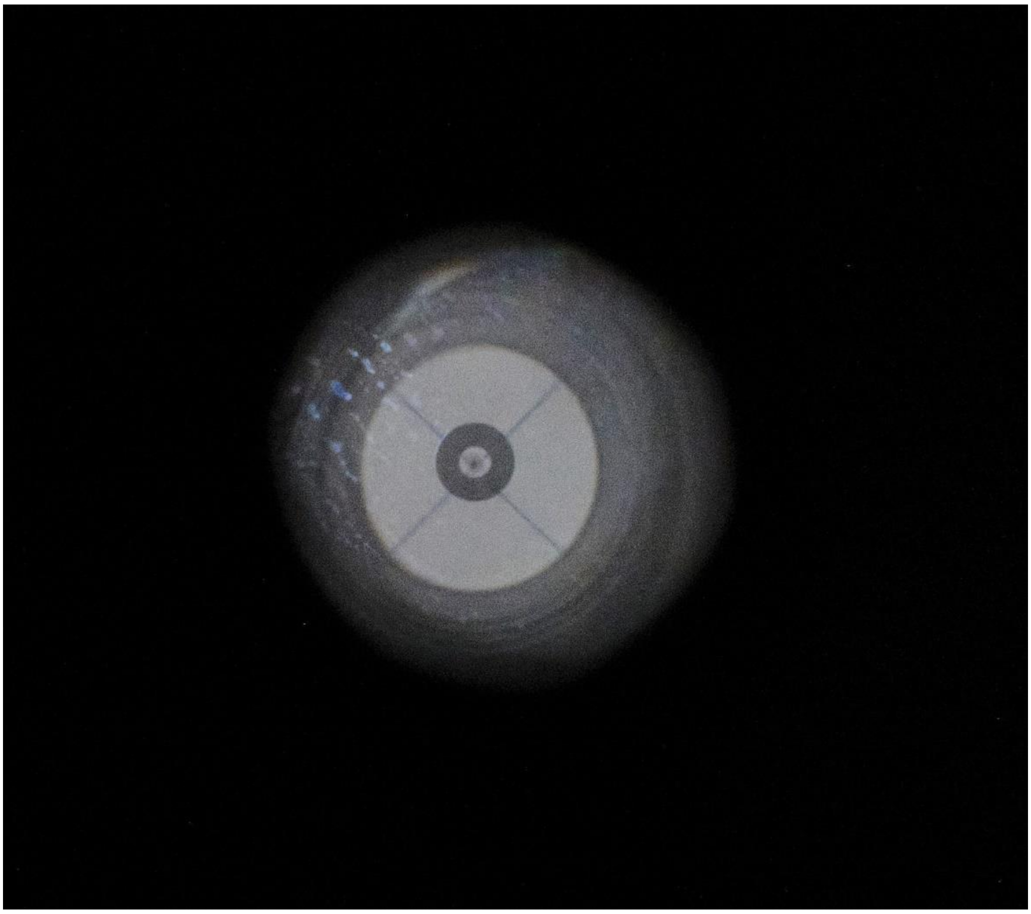
Adjust the secondary mirror to get the reflections of the secondary support vanes to line up.



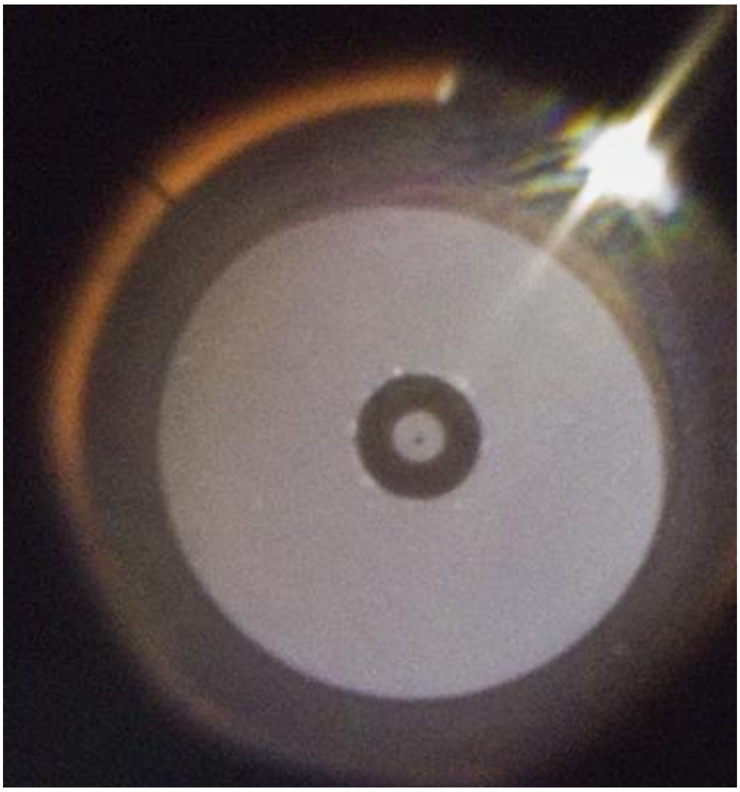
Now replace the plastic card into the primary mirror and look through the hole in the centre towards the primary mirror. Put a lamp at the front of the telescope, shining into the tube onto the plastic disc. Recall we removed the shade-tube earlier. If we had not done that, then the lamp would not be able to shine directly onto the plastic disc for this step.

Go to the back of the tube and look through the hole in the plastic disc. Look for the reflection of the hole in the plastic disc in the secondary mirror – the cross should help. Now adjust the secondary mirror until the reflection of the hole is centred in the secondary ring mark.

Here is a picture looking at the secondary of an RC6. See how the cross on the card makes it easier to see the reflection of the hole.



Here is a picture of my RC8 secondary, this time using a card without a cross. A little vertical adjustment is still needed here.



Adjust the secondary mirror to centre the reflection of the peep-hole into the secondary mirror adjustment ring. The routine is to very slightly slacken two screws, and then to tighten the third screw. Or, slightly loosen one screw and slightly tighten two screws, depending on what you need to tilt the secondary on its support screw. In the end, I found I was making the very slightest adjustment to the secondary screws, no more than a slight tightening or slackening.

Take care in which direction a particular adjustment moves the reflection of the peep-hole. I've found it to be counter-intuitive.

Take your time with this adjustment; you will need plenty of light and a good eye. A camera helps. This is the one time you will adjust the secondary. Once you're happy with this adjustment, we will not change the secondary alignment again.

Note: a correctly adjusted secondary mirror uniformly distributes the collimation of the scope over the field of view. A poorly adjusted secondary mirror will reveal itself in the appearance of aberrations (e.g. astigmatism – elongated stars) in one corner of an image.

Now replace the shade-tube. A note on putting the shade-tube back: be careful not to touch the mirror with the tube. Locate the tube onto the thread on the primary mirror clamp with one hand and <u>unscrew</u> it until you hear a click as the threads engage. Now carefully screw it in and not too tightly.

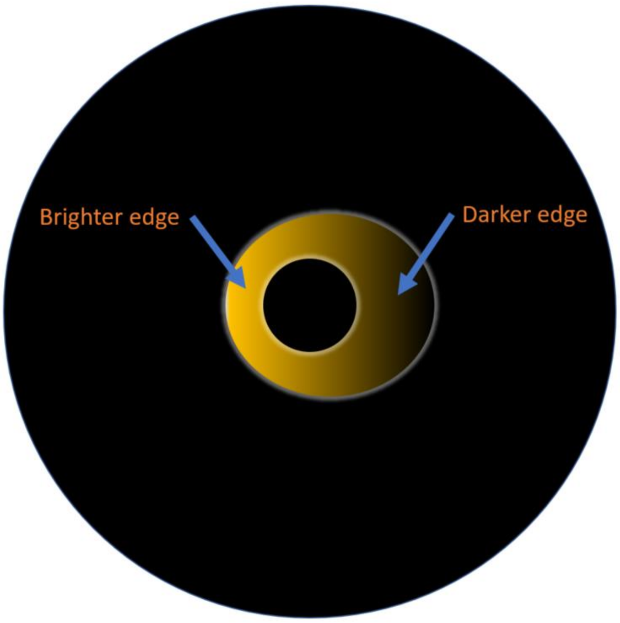
You're done. The next step is to check the collimation on a star next time the clouds clear.

A note on collimating the primary mirror on a star

You can wait for a clear night with good seeing or use an artificial star such as the Hubble artificial star.

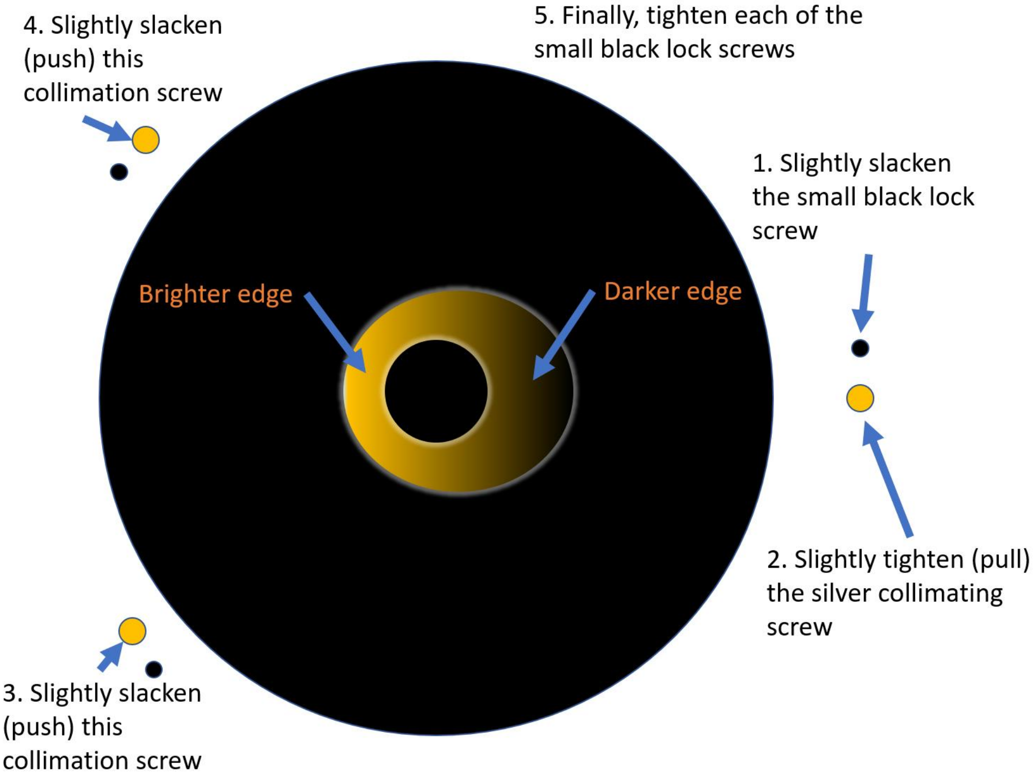
The traditional method is to focus on a central star with a short, say 6mm, eyepiece. Inspect the star image and adjust the focuser to slightly out of focus, out. That is adjusting the focuser slightly away from the tube. As the star image gets bigger, you should see the shadow of the secondary appear in the centre. This job is much easier if the seeing is steady and can be impossible if it is not.

Alternately, attach your camera to the scope and focus on a central star with the camera repeatedly taking short exposures. Now adjust the focuser slightly out of focus 'out'. Only go sufficiently out of focus to see the secondary shadow in the image. Is the secondary shadow in the centre? Or do you see something like this?



The diagram shows the appearance of a slightly out of focus star image (from a camera) in an out of collimation scope with coma. Note how the star is brighter on the left side compared with the right, and the shadow of the secondary mirror is offset to the left.

The task now is to adjust the primary mirror to move the shadow of the secondary to the right to centre it. To do this, adjust the collimation screws, as shown in the following diagram.



Begin by slightly slackening the small black lock screw on the right and then slightly tighten the collimation screw (the larger silver one).

I have a saying, “PULL the shadow of the secondary towards the PULL screw” to remind me which way it should move in a camera image.

A simple adjustment of one screw might be enough. However, you might need to adjust all three collimation screws to achieve the adjustment you need, depending on the required direction of change.

Note: each collimation screw pushes and pulls the primary mirror depending on the direction it is screwed. Each screw has an associated spring that pushes against the mirror holder – see the earlier picture. The smaller black, lock screw needs to be tightened (but not too tight) up to the mirror holder to ensure everything is nice and stiff. The focuser and camera all hang off these three screws, so the set-up needs to be stiff.

Here is an image from a well-collimated scope:

Note the tiny dot in the centre of the secondary shadow. This is Young’s Spot and its appearance in the centre of the secondary shadow a good sign that the scope is collimated.

If you use an eyepiece, the movements noted above are reversed,

The Metaguide software (free download) has a feature to help collimate a scope. It has the advantage that the software follows the star around the field of view as you make the adjustments and it has a very enlarged view of the star, enabling you to inspect the image more easily. The only snag with Metaguide is that you will need a video camera or webcam.

Here is a photo of a star image produced by Metaguide.

The star image at bottom right is round and symmetrical (well almost). The Metaguide collimation indicator is bang in the middle, indicating the scope is collimated.

Once collimated, the scope should hold its collimation over a long period. The only issues to be aware of is that the whole imaging train, focuser, camera etc., is supported by the three collimation screws. A heavy imaging train, say a large camera and a rotator. Will undoubtedly lead to flexing of the image train as the scope moves over the sky. You will see distorted stars in the corner of your images as a result.

The one thing we have not touched on here is ensuring the mirrors are the correct distance apart. If this is not the case, then the scope will be under or overcorrected and will exhibit spherical aberration giving 'soft' images. You can check the correct adjustment of the mirror spacing using a Ronchi grating.

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