# COLLIMATING A NEWTONIAN REFLECTOR TELESCOPE (Abbreviated Method)

**by**

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**January 2016**

Keeping a Newtonian reflector in proper collimation is necessary in order to observe sharp, coma-free star images. The "faster" the mirror, i.e., the lower its focal ratio (of focal length to diameter), the more important it is to collimate the telescope as accurately as possible.

The main symptom that your telescope is "out of collimation" is the inability to bring stars into sharp focus from one side of the field to the other at the same time. In extreme cases, star images may look like tiny comets which turn inside out with the "coma" facing the other way as the focuser is run in and out. It's a dead giveaway when the optimum focus is different from one side of the field to the other.

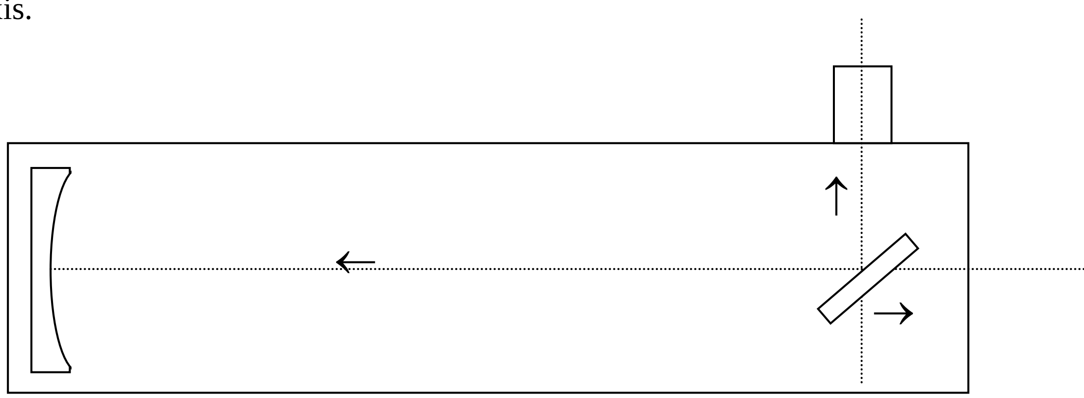
Many different collimation methods are in use. Some of them are absolute, but most methods only lead to an approximate collimation at best. If you are the owner of a fast (f/4 – f/5) Newtonian, you will need to go through the rigorous steps detailed in my previous 9-page article on "The One True Method".

Fortunately, long-focus (f/10) and medium-focus (f/6 – f/7) telescopes are rather forgiving of poor collimation. Most amateur astronomers can't tell any difference between the performance of long-focus telescopes collimated with the One True Method, and those "tuned up" using the abbreviated method presented here.

Any satisfactory collimation method should be easy to understand and carry out, and should not require several cycles of "iteration" (backtracking) before settling on an approximate result.

Ideally, only three steps are required to collimate a Newtonian perfectly:

1. Make the optical axis of the primary mirror coincident with the axis of the telescope tube;
2. Make the optical axis of the eyepiece holder perpendicular to the telescope tube; and
3. Position the surface of the diagonal mirror at the intersection of these two axes, and at a 45° angle to each axis.



In this abbreviated method, we omit Step 2, assuming that is unnecessary and/or not possible. In other words, the eyepiece holder "is the way it is", which is usually a satisfactory compromise.

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Steps 1 and 3 may then be done in either order, depending on the equipment used.

The purpose of Steps 1 and 2 is to get the optical axes of the mirror and the eyepiece at right angles to each other. The telescope tube is merely a convenient frame of reference for this operation. If the 90° angle between the axes is not achieved, then the "central ray" from a star to your eye will not strike the mirror or enter the eyepiece squarely (or both), causing coma and other aberrations.

In this abbreviated method, we will assume that the eyepiece drawtube is mounted perpendicular to the optical axis of the telescope, or very nearly so; in any event, it would be very difficult to correct for errors in the construction of the telescope.

There are many ways for carrying out Steps 1 and 3. Two which actually work will be discussed in the following pages.

**Step 1: Make the optical axis of the primary mirror coincident with the axis of the telescope tube.**

It is assumed that the mirror has been figured symmetrically, i.e., its optical axis passes through its physical center. It is also assumed that the mirror (in its cell) is physically centered in the telescope tube.

It is first necessary to paint a tiny dot on the exact center of the mirror. (This will not affect its performance, since this area is in the "shadow" of the diagonal.) Remove the primary mirror from the telescope. (It is not necessary to remove the mirror from its cell.) If necessary, clean the mirror using an approved procedure. Make a circular piece of cardboard, such as poster board or a manila file folder, the same diameter as the mirror. Use a compass, then cut out the circle. Use the compass point to enlarge the hole in the center slightly. Carefully lay the cardboard on the mirror. If necessary, cut notches where the mirror clips touch the face of the mirror. Then use a toothpick to apply a tiny drop of dark paint through the hole onto the mirror.

Optional: Some methods also require a larger "target" to be applied to the mirror; now is a good time to do it. As soon as the paint has dried thoroughly, attach a circular "gummed reinforcement", commonly used to prevent the holes in notebook paper from tearing, to the center of the mirror, centered on the paint spot. Replace the mirror in the telescope.

Low-tech method: Remove the diagonal or move it over to the side of the tube. Aim the telescope nearly horizontal or slightly upwards, so that it is convenient to look down the tube. Have an assistant turn the mirror-adjusting screws until the reflection of your eye is centered on the dot on the mirror **and** in the circular outline of the end of the tube. This is sufficient for high-f/ telescopes.

Medium-tech method: The improvement here is the use of a cardboard mask with a hole in the center to make sure you are positioning your eye at the center of the end of the tube. Make a circular cardboard mask to fit over the end of the telescope tube. Use a compass as before, but then use a hole punch, cork borer, or other device to make a ¼-inch hole in the center. Cut two V-shaped notches on opposite edges of the circle in order to admit enough light to see the spot on the mirror.

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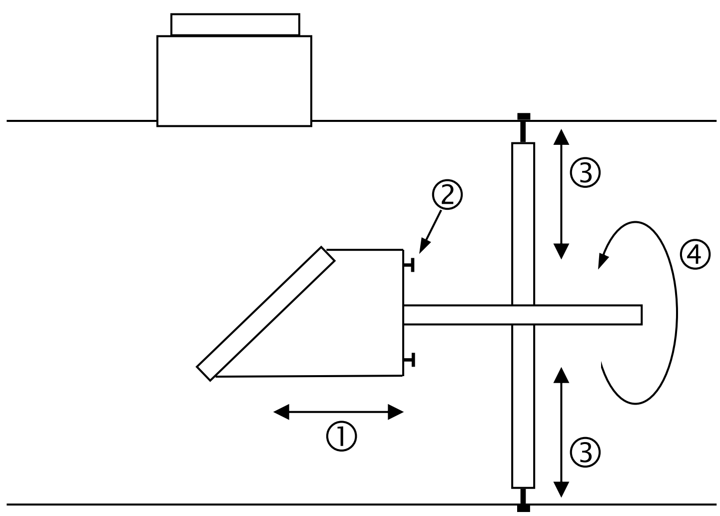
After removing the diagonal, tape the disk to the end of the tube. Look through the central hole while an assistant turns the mirror-adjusting screws until the reflection of the hole is centered on the dot on the mirror. This is considerably more accurate than trying to hold your head in the right place.

**Step 3: Position the surface of the diagonal mirror at the intersection of the two optical axes, and at a 45° angle to each axis.**

When the diagonal is properly positioned, it should appear circular rather than elliptical. Furthermore, its circular image must be centered in the eyepiece draw tube, and the reflection of the primary mirror and the diagonal's reflection in the primary mirror must all be concentric. And don't forget: you have to achieve all of this **only** by positioning the diagonal, without touching the primary mirror adjustment!

If you study the drawing of the Newtonian system on page 1, you will see that the front (reflective) surface of the diagonal must lie at the point where the optical axes of the primary mirror and of the eyepiece focuser intersect, in a plane that is tilted 45° to these axes. If this is done, the optical system is in perfect alignment and no coma or aberrations will be introduced. However, the diagonal's position *along* this plane is as yet undefined, and will be specified later for optimum results.

Ideally, a diagonal holder has four types of adjustments:
1. The mirror may be moved along the axis of the tube, varying its distance from the primary mirror.
2. The mirror may be aimed by three adjustment screws.
3. The mirror may be moved across the tube, varying its distance from the focuser.
4. The mirror may be rotated around the long axis of the tube.




As we did in Step 2 (adjusting the eyepiece holder), we are going to assume that the third adjustment mentioned above is unnecessary and/or impossible.

While the diagonal is out of the telescope, clean it if necessary. Mark the optical center of the diagonal with a tiny dot, using an ultra-fine-point "Sharpie" or some such pen. Theoretically, the optical center of the diagonal is not quite the same as its physical center, but is displaced along the ellipse ***towards*** the eyepiece holder and the open end of the telescope tube, i.e., ***away from*** the primary mirror.

As a result, when the diagonal is properly installed, its ***physical*** center will appear to be displaced ***away from*** the focuser and ***towards*** the primary mirror.

A thorough discussion of this topic, with diagrams and derivations, is given in the longer article, but the net result is this: The optical center of the diagonal is displaced by a distance equal to DM/4F, where D and F are the diameter and focal length of the primary mirror, in consistent units, and M is the length of the major (longer) axis of the diagonal, preferably in millimeters.

Example A: Suppose we have a 10-inch mirror with a 41.5-inch focal length (f/4.15 focal ratio). The major axis of the diagonal is 93 mm. We calculate the offset = (10 in × 93 mm) / (4 × 41.5 in) = 5.6 mm. This is nearly a quarter of an inch, and should definitely be taken into account.

Example B: Now let's consider a 4.25-inch mirror with a 48-inch focal length (f/11.3 focal ratio). The major axis of the diagonal is 25 mm. We calculate the offset = (4.25 in × 25 mm) / (4 × 48 in) = 0.55 mm. This is only about one-tenth the amount in Example A. This tiny offset may be ignored without any noticeable consequence.

The difference between Example A and Example B illustrates the principle that the faster the objective mirror, the more necessary it is to pay attention to the offset. It should be emphasized that if this offset of the diagonal is not performed, it will **not** introduce any coma or other aberrations, since the central rays are still being reflected at a perfect 90° angle. The only detrimental effect is a more pronounced falling-off of image brightness on one edge of the field compared to the other, due to the diagonal "missing" a portion of the light cone on that side. This is generally noticeable only in very fast optical systems; for slow mirrors, the light cone is so nearly cylindrical over short distances (i.e., from the leading to the trailing edge of the diagonal) that the required offset is negligible.

Method: Locate the physical center of the diagonal with a ruler. Make the tiny dot with the Sharpie, offset toward the eyepiece holder (away from the primary mirror) by the calculated amount. If the distance is too hard to measure (e.g., less than a millimeter), it may be ignored without consequence.

Reinstall the diagonal assembly in the telescope. Position the diagonal so that it is centered as seen through the eyepiece holder. This is made much easier if you make (or purchase) a "sighting tube", a dummy eyepiece (without lenses) which lets you sight through pinholes or inscribed rings to see exactly where it is aimed. Put it into the eyepiece holder, and adjust the diagonal longitudinally (adjustment 1, above) until the marked optical center of the diagonal is exactly on the axis of the eyepiece holder.

Now, the diagonal must be aimed at the center of the primary mirror. While looking through the eyepiece holder, use adjustments 2 (aiming screws) and 4 (rotation) to achieve perfect concentricity of the draw tube, the face of the diagonal, the reflection of the primary mirror in the diagonal, and the reflection of the diagonal in the primary mirror. Whatever you do, don't mess with the primary mirror; it's already properly set!

This completes the collimation of the optics of your telescope, using low-tech methods and equipment, and working around the fact that some adjustments (aiming the eyepiece drawtube and positioning the diagonal laterally) might be difficult or impossible, in the unlikely event they might be necessary.

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### Relatively fast high-tech method, using a laser collimating device

Instead of tracing light rays as they enter the telescope, reflect off of the primary mirror, and are finally diverted into the eyepiece holder, this method reverses the process. Light rays are generated at the eyepiece holder and are used to aim the diagonal precisely at the center of the primary mirror; then the mirror is adjusted until those rays strike the center of the diagonal and are reflected back through the eyepiece holder.

As before, it is necessary to mark the center of the primary mirror and the optical center of the diagonal mirror.

The diagonal should first be positioned longitudinally (adjustment 1) until its marked optical center is centered under the eyepiece holder, using the sighting tube as described previously. Alternatively, insert the laser collimator into the eyepiece holder, turn it on, and verify that the beam is striking the optical center of the diagonal. (A small dental mirror can be used to look at the surface of the diagonal while the laser collimator is in the eyepiece holder.) It might even be possible to observe the diagonal from the bottom end of the telescope, if there is enough space around the primary mirror cell.

Then, turn the diagonal’s aiming screws (adjustment 2) and its rotation (adjustment 4) until the laser beam strikes the marked spot at the center of the primary mirror.

Finally, turn the primary mirror’s adjustment screws until the laser beam strikes the center of the diagonal and disappears back into the center of the collimator.

It should be noted that this method works only when the two assumptions were valid, i.e., the drawtube is perpendicular to the telescope tube, and the diagonal is centered across the diameter of the telescope tube. Otherwise, there will be an infinite number of “false collimations” in which the primary mirror and the diagonal mirror are aimed at each other’s centers, but the axis of the eyepiece holder is not perpendicular to the axis of the primary mirror. If signs of poor collimation persist after completing these procedures, the longer method must be used.

Once the longer method has been satisfactorily completed, it is extremely unlikely that the drawtube would ever become non-perpendicular to the telescope tube, or that the diagonal would deviate from its correct lateral position, i.e., with its optical center on the optical axis of the primary mirror (and telescope tube). Consequently, this abbreviated method (low-tech or laser) may be used confidently for all subsequent collimations.