by John Crilly

A PRIMER ON COLLIMATION OF NEWTONIAN TELESCOPES

This brief article is intended to help the new owner of a Newtonian telescope to learn adjust his instrument to produce quality images. It is NOT the last word in collimation, and readers are encouraged to pursue the subject in greater depth to learn of more complete methods.

WHAT IS A NEWTONIAN TELESCOPE AND WHAT DOES COLLIMATION HAVE TO DO WITH IT?

A Newtonian telescope at its simplest consists of a tube with a primary mirror (normally a paraboloid) centered within this tube near one end and a focuser extending from the side of the tube near the other, with a flat secondary mirror inside the tube at a 45 degree angle. Collimation is the process of adjusting the mirrors so that light entering the open end of the tube is accurately reflected by the primary mirror to the secondary mirror, and then by the secondary into the center of the focuser's draw tube. Accurate collimation is necessary for good performance, especially in the faster Newtonians so popular today. Missing the center of a fast parabolic mirror by only a few millimeters will cause significant degradation of image quality. The good news is that collimation is neither complex nor difficult - it just needs to be done correctly and accurately.

HOW CAN IT BE ACHIEVED?

Methods commonly used to collimate Newtonians include the sight tube, the Cheshire eyepiece (frequently those two are combined into one device), the laser, the Barlowed laser, the autocollimator (in this context, "auto" means

“self” rather than “automatic”!), and the appearance of the Airy disk at high (30X or greater per inch of aperture) magnifications. The standard advice to new telescope owners is to use either a Cheshire eyepiece or other device to place the user’s eye in the center of the focuser tube and to proceed by observing and adjusting the placement of various reflections. This can be confusing to the new telescope owner so, although that method certainly works, I’m going to discuss instead a method which is easier to learn quickly. For the purposes of this article I’ll concentrate on the fastest and easiest (and most repeatable) method, even though it involves a modest expense. This is the laser collimator, readily available for $50-$75 - specifically one with a side window for observing the return beam. A typical such unit is available here:
http://www.speednetllc.com/dbaastronomyproducts/Laser%20Collimator.htm

This end of the collimator is inserted into the focuser

Here the switch and the side window can be seen

The laser collimator is a device which is placed in the focuser as though it were an eyepiece, and which directs a narrow beam of visible red light down the precise center of that tube. In a Newtonian telescope which is in perfect collimation this beam will be reflected from the center of the secondary mirror to the center of the primary mirror, from there back up to the secondary again, and from there back into the focuser drawtube, striking the collimator at the same point from which the beam exits. The collimator has a window in the side through which a target concentric with the outgoing beam can be observed so that when the return beam isn't quite centered it can be seen striking the target. When the return beam disappears down the center hole, it's centered. The procedure is quick and easy, and avoids confusion - if the scope is collimated (or if it isn't) the user will know it without question.

The following is a very basic procedure which a beginner should have no trouble managing. I want to repeat here that there are plenty of other ways to do the job - I just want to give a newbie a good shot at getting his or her telescope working from day one. Purists may ask about secondary offsets or focuser drawtube alignment, but for the purposes of this article I'm going to ignore those factors. As the user gains experience and knowledge he or she is free to explore those issues. **The order of the steps is critical - don't try to switch them or the results will be disappointing**.

The first step will be to adjust the position and rotation of the secondary mirror so it is centered on the focuser and oriented straight toward it. Then we will adjust the secondary tilt so that it is aimed at the primary mirror. Finally, we will adjust the tilt of the primary mirror so it is aimed at the secondary mirror.

PREPARATION

Before beginning the process of laser collimation, the primary mirror must be center-spotted. Many of the popular Newtonians are sold with the primary spot already in place on the primary mirror. It will be obvious - usually it's done by installing a reinforcing ring (often used to strengthen punched holes in sheets of paper) in the PRECISE center of the mirror (for the purposes of this article, we will presume that the optical center of the paraboloid mirror shape is at the physical center of the mirror). If such a ring is present, it's probably worth checking to see that it is truly centered. If one isn't present, the user will need to install one. Be careful about centering it; as mentioned above a few millimeters makes a big difference. The presence of the ring has no effect on operation, as the center of the primary is blocked by the secondary and doesn't do anything anyway.

Typical reinforcement rings

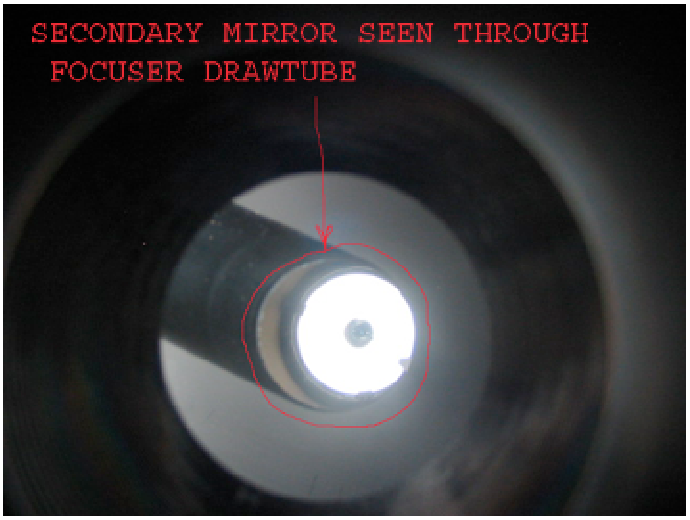
One easy way to determine the precise center of the primary is to cut a disk of paper exactly the same diameter as the mirror. Folding the paper disk in half, and then in half again, will result in a disk with two intersecting fold lines. Where those lines meet is the center. A hole slightly larger than the collimation ring to be installed can then be cut in the paper at this location. Placing the paper over the mirror, the ring can be installed through the hole.

Done!

The collimator itself should be checked to ensure that its beam is centered properly. This can be done by placing it into the focuser and rotating it while watching the beam strike the secondary or the primary. If the spot moves when the laser is rotated the laser is off-center and must be adjusted before use. If the spot remains stationary everything is fine.

LET'S GET STARTED

ADJUSTING THE SECONDARY MIRROR POSITION



This photo was taken with the camera much closer to the focuser than the eye position described below so the secondary holder can be seen. To accurately center the secondary it's desirable to move the eye farther out so the secondary nearly fills the field of view looking into the tube. Note that the bright disk seen off-center within the secondary mirror is the reflection of the primary mirror. It's off-center in the secondary because we haven't yet adjusted the secondary tilt. If the primary's reflection is confusing to the user during this step a sheet of paper may be temporarily placed within the tube to block the view of the primary mirror.

This process begins with looking into the focuser at the secondary mirror. It's necessary to carefully place your eye in the center of the drawtube. Moving your eye away from the focuser until the mirror just barely fills the field of view will reveal any error in secondary position. The secondary isn't round, but when properly adjusted it appears round from this angle. The position should be adjusted until the mirror is centered up and down (toward or away from the primary) - then rotated until it appears perfectly round. The secondary mirror tends to remain in position for extended periods once properly adjusted so future collimations will probably not involve repeating this step - though it should be checked each time.

SECONDARY HOLDER AND ADJUSTMENT SCREWS

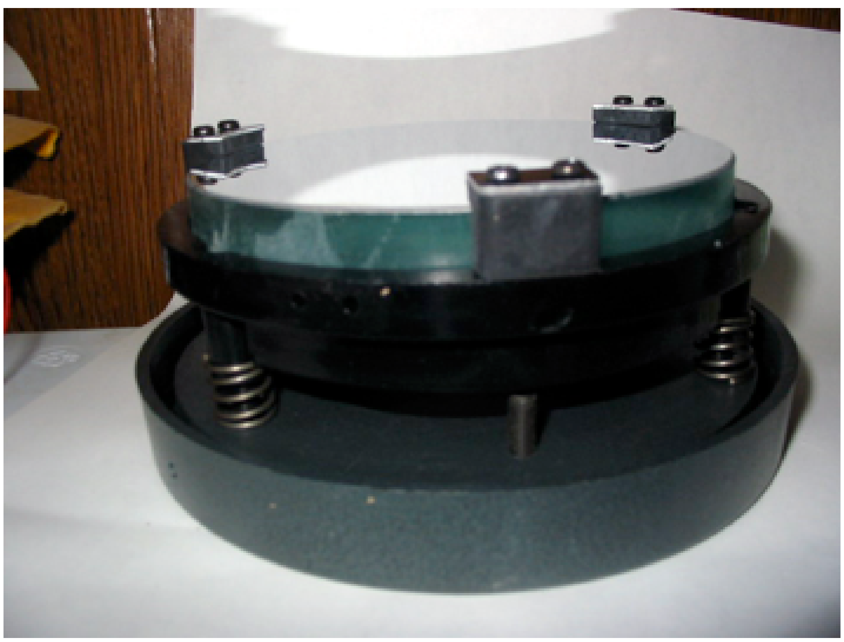
This photo shows the secondary mirror holder and the adjustment screws for the secondary mirror. The center bolt **(NOTE - THIS BOLT IS WHAT HOLDS THE SECONDARY. IF IT IS PERMITTED TO COME COMPLETELY LOOSE, THE SECONDARY MIRROR WILL DROP ONTO THE PRIMARY!)** pulls the mirror holder toward the top of the telescope, while the three bolts around the perimeter push it away. All should be tight when collimation is complete. Loosening (carefully!) the center bolt permits the secondary mirror to be rotated. To lower the mirror, this bolt must be loosened and the three outer bolts retightened to hold it in the new position. To raise it requires the three bolts to be loosened so the center bolt can be used to draw the mirror upwards.

ADJUSTING THE SECONDARY TILT

It gets easier from this point! Install the collimator now and turn it on. Now that the secondary is in position we just need to tilt the secondary until the beam strikes the primary in the center of the reinforcing ring. The three outer screws accomplish this. Loosen any one of the three and observe which way the spot moves. By adjusting and tightening them in the right sequence the spot will be moved to the correct location. Make sure all the adjustments are tight when you are finished or the collimation won't hold when the telescope is moved.

ADJUSTING THE PRIMARY TILT

Here are the primary mirror's collimation screws.
Note the warning below about placing the telescope in this position!



Inside view of two adjusting screws and one locking screw

There are two sets of three adjustment screws. One set is used to adjust the tilt of the primary mirror; the other three lock it into position once it's positioned correctly. The usual setup is that the three with screwdriver slots are the locking screws and the thumbscrews are used for the adjustment. To begin, we'll loosen the lock screws to permit adjustments. When it's done, we'll make sure to remember to tighten the locking screws so the adjustment will hold.

NOTE: The photo above shows the optical tube pointing downwards. That is for the purpose of making the photo easy to take. NEVER aim a Newtonian telescope downward unless you know for certain that the primary cell is designed to retain it in that position. Many larger Newtonians use a type of primary mirror cell which relies on gravity to hold the mirror in place - placing such a telescope as pictured would result in disaster.

ADJUSTING PRIMARY TILT

This is where we adjust the primary mirror to make the return beam re-enter the laser at the exit point. With the laser inserted into the focuser and turned on, we first look to see that the return beam is at least striking the secondary. If it's not visible, holding a piece of paper or cardboard above the tube will reveal whether the beam is missing the secondary and heading off into space. Once the spot is striking the secondary mirror, the next step is to aim it at the center of the secondary (near the spot made by the original beam). At that point it should be disappearing down the focuser tube (or striking the end of the collimator if it's sufficiently long to extend past the drawtube). If the spot is visible on the inside of the telescope tube, adjust the primary until it enters the focuser drawtube or the collimator. Now we can observe the target in the side of the collimator and finely adjust the primary until the beam disappears into the center hole. Carefully tighten the locking screws and observe to be sure the primary doesn't shift during this process. The job is done - or is it?

VERIFYING PROPER COLLIMATION

An easy way to check that collimation is in the ballpark is to focus on a relatively bright star at 50X to 100X magnification. In the Northern hemisphere Polaris is fine, and has the advantage of remaining within the field of view without manually tracking it while doing this test. Adjust the focuser until the defocused star appears as a doughnut shape filling _ of the field of view. In a properly collimated Newtonian telescope the dark center will be perfectly centered within the bright doughnut.

A more rigorous test is to use a higher magnification; at least 30X per inch of aperture and preferably as much greater than that as the seeing will permit. Polaris is again a handy target for those of us with a good view of it. When perfectly focused, the Airy disk should appear as a bright center spot with one or more dim rings immediately around it. With a dimmer star, or at lower ,magnifications, it may be necessary to take the telescope SLIGHTLY out of focus to bring out the rings. A Newtonian telescope in perfect collimation will place the bright spot precisely centered within the rings, and the rings should be complete.

THE GOOD NEWS

For one thing, the telescope is collimated and ready to use. For another, you now know how to do it and aren’t afraid to do it again (you are probably relieved that it was easier than it sounded when reading this!). More good news - the secondary is relatively lightweight - it will typically be right where you left it next time you go to use the telescope, Future collimations will probably involve adjusting only primary tilt, and if everything is properly tightened, that shouldn’t move very often either. It takes only a moment to insert the collimator and check it every time you use the telescope - and only a little longer if adjustment proves necessary.

Click to discuss this article in the forums