ATM Journal 11: Sizing Your Secondary Mirror
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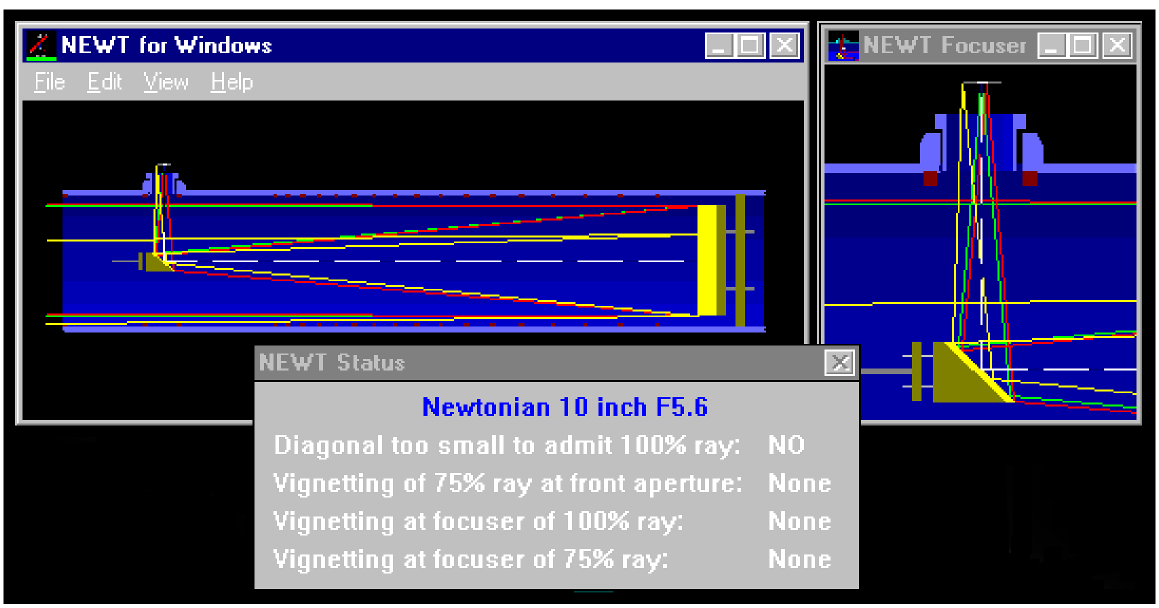
Assuming you've either ground your own mirror or bought one, the next major component of your telescope is the secondary assembly, which in a Newtonian telescope reflects light from your primary mirror out the side of the telescope into a focuser where the observer views the image through some suitable eyepiece.

Even for a complete do it yourselfer, secondary mirrors are normally one of the items that are not worth the both of making yourself. Quality secondary mirrors are problematic to make and relatively cheap so it's definitely suggested to just go out and buy one.

First of all, let's review how Newtonian Telescopes work, with the aid of the Dale Keller's excellent NEWT software package (see references below). As you can see below, the optical tube assembly of a Newtonian reflector consists of a paraboloidal primary mirror at the bottom of the tube plus a 45 degree flat mirror near the top end of the tube which redirects the light from the primary mirror out the side of the tube into a focuser.



The parameters that the ATM must consider when designing an optical tube assembly for a Newtonian telescope are primary diameter and focal length, diameter of the telescope tube or secondary cage, and size of the secondary mirror. The size of the secondary mirror must be large enough to intercept the light cone coming from the primary without allowing light to spill over while remaining small enough to minimize
diffraction, which robs the telescope of image contrast. Another parameter you will need to consider is the height of your focuser – the lower the better to prevent vignetting. NEWT provides an excellent mechanism to play with these parameters until you get the result you're looking for.

But how large should a secondary mirror be? An important consideration is the desired fully illuminated field of the telescope. This is not set in stone – for example, a telescope used primarily for planetary observation would opt for a smaller secondary (and thus experience some loss at the edge of the field) because minimizing diffraction by using a smaller secondary mirror is far more desirable than having a fully illuminated field because objects are generally centered in the field, making edge illumination irrelevant. Obviously the converse is true for short focus designs where a fully illuminated field is critical and secondary size is of less importance. As well, consider whether you plan to use 2" eyepieces in the telescope, which require a larger fully illuminated area. To calculate the minimum diagonal size required to catch all of the light from the primary (e.g. 100% illumination) use the following formulae:

FR = Focal ratio of primary
L = Distance from secondary mirror to focal plane

Calculating L for an existing telescope is easy, simply put some tape across the focuser and point the telescope at the moon. Rack the focuser in and out until the image focuses, then measure L. For a telescope that's not built yet this becomes more difficult – assume you use half the focuser travel available and measure the distance from the center of the tube to the point inside the focuser where you want the focal plane to fall.

To determine the minimum secondary size simply divide L by FR. Here's a small table of minimum secondary sizes based on L being ½ the diameter of the primary, plus 2" to the outside of the tub, plus 3" focuser travel.

	Diameter (in)									
	8	9	10	11	12.5	13.1	14	16	18	20
F-ratio										
4	2.00	2.13	2.25	2.38	2.56	2.64	2.75	3.00	3.25	3.50
4.5	1.78	1.89	2.00	2.11	2.28	2.34	2.44	2.67	2.89	3.11
5	1.60	1.70	1.80	1.90	2.05	2.11	2.20	2.40	2.60	2.80
6	1.33	1.42	1.50	1.58	1.71	1.76	1.83	2.00	2.17	2.33
7	1.14	1.21	1.29	1.36	1.46	1.51	1.57	1.71	1.86	2.00
8	1.00	1.06	1.13	1.19	1.28	1.32	1.38	1.50	1.63	1.75
9	0.89	0.94	1.00	1.06	1.14	1.17	1.22	1.33	1.44	1.56
10	0.80	0.85	0.90	0.95	1.03	1.06	1.10	1.20	1.30	1.40

It should be noted that focuser height is very important in minimizing the size of the secondary mirror. A higher focuser means you'll need a larger secondary mirror, whereas a low profile focuser minimizes the secondary size. For example, a three inch difference in an 8" f4 system increases the minimum secondary size from 2.00" to 2.75"! With NEWT you can also see if the optical system has any vignetting (components (mostly the edge of the focuser tube) intruding into the optical path.) Again, a taller or narrower focuser will result in vignetting of some portion of the light cone sooner than a low, wide focuser.

Using the above formula you can now plug the secondary size into NEWT and see if the combination of focuser and secondary result in an acceptably illuminated field.

It should be noted that going with the absolute minimum size can present problems as well. Many diagonal mirrors are rated to the size of the substrate rather than the usable mirror surface so you lose part of the surface to the bevel. Also, not all secondaries are completely flat out to the edge, so a bit of leeway is useful. Thus, it's normally prudent to select a secondary slightly larger than the minimum.

Another excellent piece of software useful in determining the optical characteristics required of your secondary mirror is SEC from a August 2000 Sky and Telescope article by Alan Adler. This software is extremely useful in making decisions as to what an acceptable level of loss of illumination is when considering secondary mirrors. For example, Alan Adler (Aug 200 S&T) suggests that 100% illumination at the centre of the field and 40% at the edge offers a good compromise between secondary size and image quality. While this difference means a full magnitude drop between edge and centre, for most observers this is acceptable and unnoticeable. Of course, variable star observers may have a different opinion!

For the more advanced ATM, the OSLO optical design program provides an advanced optical design platform for more esotheric types of telescopes.