Amateur Astronomy Magazine

The Essential Journal for Amateur Astronomers Around the World!

How Amateur Astronomers Support ISS Space Photography

Process Widefield Images

How to shrink stars to optimize your astronomical data

Observing

Moving to Astronomy Heaven
Deep Dky Treasures
Looking South
On The Moon
Sunspots

Rebuilding a Classic Bill Schaefer Mount

Restoring a piece of amateur astronomy history

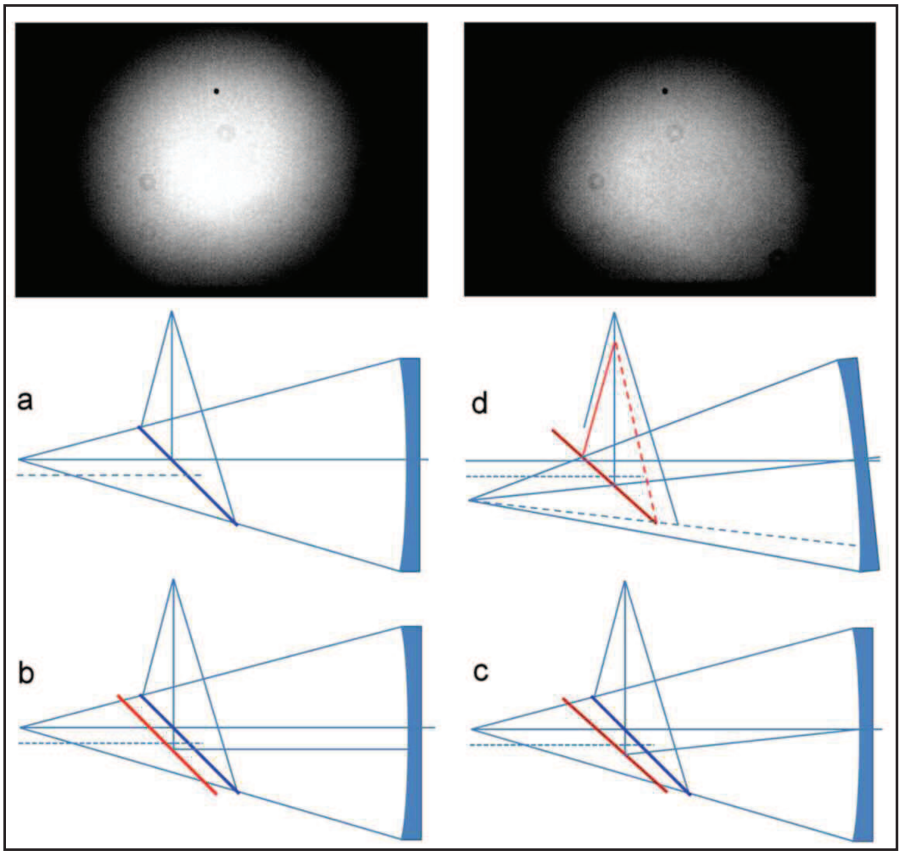
Issue 84
Fall 2014 $6.50 US

Correct Translation, Rotation and Skew Adjustment of the Newtonian Secondary by Combining Laser Collimation with Flat Field Vignetting

by Mike Blaber

Adjusting the secondary mirror on a Newtonian telescope must have a counterpart in other hobbies. Perhaps it is similar to trying synchroniziation of the dual carbs on an old MG; or maybe it's like trying to tune a pipe organ, who knows. The common thread is that such adjustments are critical to performance, technically demanding, and difficult to get right; also, it will gnaw away at your psyche until it is absolutely perfect, consuming hour upon hour of your precious time. In this regard one of the biggest mistakes you can make in life, I am convinced, is to buy a used Newtonian where the prior owner has "customized" it by installing a different focuser. It is even worse if it is a fast Newtonian - which is much more demanding in secondary alignment. Earlier this year I visited Japan where a colleague showed me a book on the evaluation of consumer telescope optics. One telescope stood out above the rest for price vs. performance - the Schmidt-Newtonian briefly manufactured a few years ago by Meade. As soon as I returned to the US a telescope of this type was advertised on a popular astronomy web site. It was a fast (F/4) Newtonian and the owner had replaced the focuser. I bought it.

Figure 1. effects of a translational error in the position of a Newtonian secondary mirror upon image vignetting. Panel a shows a correctly positioned secondary and the picture above is a flat field image indicated a centered vignette. In panel b the secondary has been moved forward away from the primary (shown in red). The optical axis from the focuser falls below the center of the primary. In panel c the incorrectly positioned secondary has been tilted (through laser collimation) to point at the center of the primary mirror. In panel d the primary mirror has been adjusted (through laser collimation) to point at the center of the focuser. The picture above panel d shows the effect of this translational secondary misalignment on the image vignette (optical axis running vertically in the image). The laser collimation is correct, but the vignette indicates a translational misalignment of the secondary.



My subsequent purchase was a cheap laser collimator, followed by an expensive laser collimator, and then followed by hours of disassembly and reassembly of the primary mirror, secondary mirror and focuser of the telescope (each time consumed by the fear of scratching the mirrors). I was plagued by distorted star images - there is something indescribably horrid about an astro image where the stars in one quadrant are noticeably distorted. The essential aspects of laser collimation are that 1) the secondary should be aligned to transmit light from the focuser to the center of the primary, and 2) the primary should be aligned to reflect light back to the center of the focuser. Adjustment of the primary is relatively simple - it precesses about its central axis according to the adjustment screws along its circumference. The secondary is much more complicated: there is the potential for translation (moving it towards, or away from the primary, and in the process moving relative to the focuser), also for rotation about the central (longitudinal) axis of the scope, as well as left and right skew (or yaw) in relationship to the longitudinal axis. One ambiguity is that left/right offset of the secondary mirror can be corrected in one of two ways - either rotation or skew; and therein lies the problem - how to correctly adjust the secondary? Going online to get an answer to this problem led to posted comments like "laser collimators lie, and I can prove it!" - in other words, confirming the adjustment ambiguity, but providing no solution.

The answer to this problem is conveniently provided by another problem - vignette. Vignetting is where the image is darker at the periphery than the center and is caused by some blockage of the off-axis rays in the optical axis. Incorrect translational, rotational and skew adjustment of the secondary has a major impact upon vignetting of the image - and, subsequently, can be utilized to correct such secondary misalignments. Figure 1 shows a Newtonian telescope and the effect of an incorrectly positioned secondary - one where it is moved forward of its correct position (i.e., away from the primary mirror). This is a translational error of position for the secondary. Laser collimation will tilt the secondary and primary mirrors to align the optical axis as described above; however, the translational misalignment will result in vignetting of the optical cone. This vignetting will be apparent in a flat field image (i.e., a short exposure of a flat illuminated field - like a cloudless sky during the day (or an electroluminescent panel).

This analysis of translational misalignment of the secondary indicates that evaluation and correction is achieved through a combination of laser collimation and vignette data - the goal of which is to have both a correct laser collimation and a centered vignette. What about rotation and skew misalignment? Figure 2 shows how this is similarly accomplished. The process starts with correct laser collimation, but a horizontally misaligned vignette. The left/right adjustment screws on the secondary are adjusted to skew (yaw) the secondary mirror so as to move the center of the vignette towards the center of the image. This adjustment shifts the laser beam away from the center of the primary mirror, and it is re-centered BY USING A ROTATION ADJUSTMENT of the secondary. The primary mirror centering is double-checked with the laser (this process usually does not alter it much) and the flat field vignette is checked to see that it is now centered (if not, repeat, or reverse the process slightly to correctly left/right position the vignette).

Thus, combining laser collimation with vignette centering allows you to evaluate and correct translational, rotational, and skew misalignments of the Newtonian secondary. The nice thing about this method is that you can do it during the daytime - any flat illuminated surface can suffice for the types of flat fields that the method requires. Any Newtonian you might acquire can be correctly adjusted no matter what modifications you, or a previous owner, might have performed.

Figure 2. Rotation/skew adjustment of the Newtonian secondary using laser collimation and vignette centering. Panel a shows a Newtonian secondary with rotational misalignment (the laser collimation, however, is correctly centered). The image above shows the associated vignette. The skew (yaw) adjustment screws on the secondary are used to shit the vignette towards the center. Panel b shows the corresponding effect upon the laser collimation on the primary mirror. Panel c illustrates how the laser beam is re-centered by rotation (counterclockwise) of the secondary. The image above panel c shows the effect of the adjustment - both the laser collimation and the vignette are centered.