Kitchen table collimation of a Cassegrain-type reflector

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A method of daytime collimation of a Cassegrain-type reflecting telescope is described, which uses a circular target aligned on the optical axis of the primary mirror. Basic construction details are given for making a suitable target and a procedure is outlined for collimating both Schmidt–Cassegrain and Ritchey–Chrétien telescopes.

Introduction

The holy grail of collimation for any reflecting telescope is the perfect alignment of the optical axes of the primary and secondary mirrors onto a single path, to minimise aberrations. It goes without saying that with a properly collimated telescope, a suitable target placed squarely and accurately on the optical axis of the primary will appear centred and distortion-free when viewed through the eyepiece. Putting these two statements together raises the interesting prospect of being able to use an on-axis target as an alignment aid for daytime collimation of a Cassegrain-type telescope.

A precise position on the optical axis of the primary mirror can be determined easily by setting a point source of light at the centre of curvature of the mirror, defined as the point where a spot of light will reflect back to the same point. The fact that the mirror may be spherical, parabolic or hyperbolic is immaterial for this purpose, since any aberration of the returned beam is very small and in any case will be symmetrical about the optical axis and will not affect the ability to bring the image to an adequate focus overlying the point source. A target centred on this point is the basis of this approach to optical alignment.

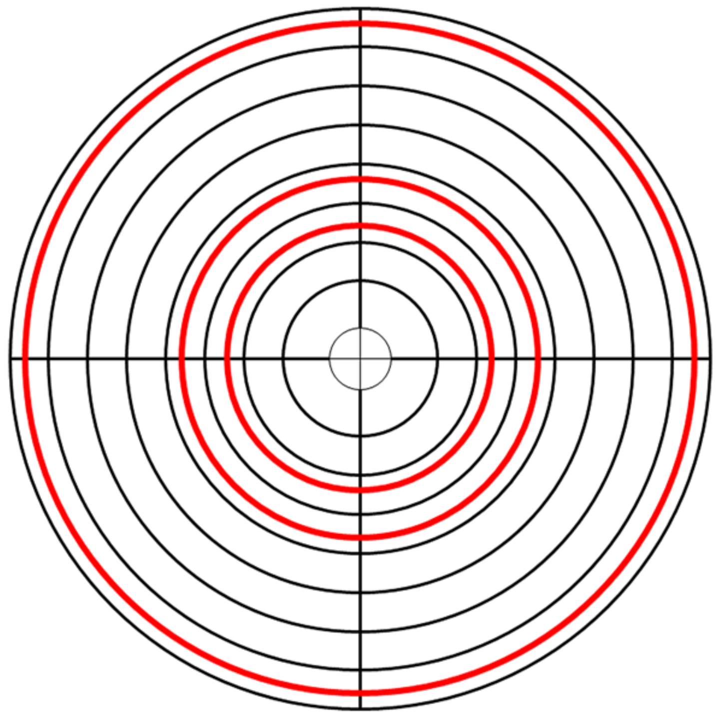

Figure 2. The collimation target pattern; concentric target rings up to the maximum diameter of the primary mirror, with an accurately marked centre point.

Current daytime collimation techniques

I have been unable to find an accepted 'standard' daytime collimation routine for an SCT. Manufacturers' instruction manuals and other respected sources invariably describe only star collimation,[1,2] typically adjusting first for symmetry of the shadow of the secondary mirror when off-focus at moderate magnification, followed by symmetry of on-focus Airy rings at high magnification. Several collimation aids exist in the market place that attempt to bridge the gap that exists between what can be achieved with daylight techniques and the need to make final adjustments using a suitable star, with examples ranging from the artificial star to complex (and expensive) laser-based products.[3]

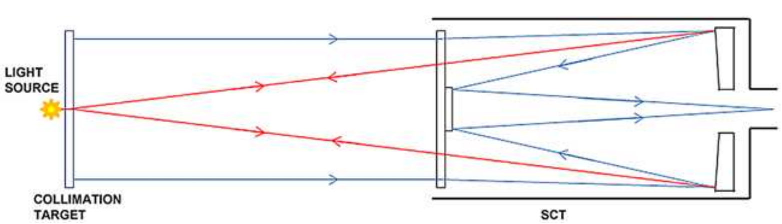

Figure 1. General arrangement of telescope with collimation target aligned on the optical axis of the primary mirror.

For the Ritchey–Chrétien, the manufacturer-recommended collimation routine relies heavily on the coincidence of the optical and mechanical symmetry of the telescope design.[4] An internet search reveals a number of techniques devised to refine the adjustments to a near-perfect optical alignment using star collimation, but are far from simple procedures.[5] For both SCT and RC designs, viewing the 'hall of mirrors' effect of multiple primary/secondary reflections from the front of the telescope is a useful check of symmetry, but of limited use in making the adjustments necessary to achieving it.

The collimation target

A suitable collimation target for the current approach is a series of concentric rings drawn on a piece of card and arranged around a central spot of light. The maximum ring diameter should be the same as the diameter of the primary mirror. A typical pattern is shown in Figure 2 and can be downloaded from the South Downs Planetarium website as a pdf file;[6] when printed to the full width of an A4 sheet it is suitable for reflectors up to 200mm.

If you are downloading the target image, then for preference print it out on photo paper to maximise the contrast of the lines. If you want to make a target for a larger diameter primary mirror, then draw it directly onto thin coated card with a pair of compasses from a school geometry set, using a felt tip pen to make good solid circles that are easily seen at a distance. The important rings, shown in red, are sized to be a few millimetres less than the diameter of the primary mirror and a few millimetres more than the diameter of the secondary mirror respectively. With an overall diameter of 8 inches (203mm), the red circles on Figure 2 are suitable for an 8" SCT or an 8" Ritchey–Chrétien. The other circles and the crosshairs are simply visual aids for assessing the symmetry of the image at the eyepiece.

Make a clean small hole in the exact centre – between half and one millimetre diameter is fine – then hold the card in front of and close up to a lamp and you will have a target of concentric rings about a pinpoint light source. If the card is not fully opaque, back it with a sheet of kitchen foil or similar and remake the pinhole.

Taping the target over the shade of an anglepoise-style desk lamp or small torch is the quick way of trying out this method, although it is a little awkward in practice because of the need to be able to move the target about with precision. A more permanent arrangement that is much easier to use is shown in Figures 3 and 4, where the target and light source are fixed to a sheet of thin ply or MDF board and mounted on a simple photographic tripod.

To complete the 'kit of parts' needed for this procedure you will also need a collimation eyepiece, available commercially as a Cheshire eyepiece, or homemade from an eyepiece cap, 35mm film canister or similar (see Figure 5).

Figure 5. Showing a Cheshire eyepiece alongside a 35mm film canister with a small hole drilled through the exact centre of the base, for use as a collimation eyepiece.

The method

Arrange the telescope horizontally on a flat surface facing the collimation target such that the distance between the two can be varied easily by sliding the telescope backwards and forwards. The kitchen table is ideal, hence the title of this article. Roughly determine the centre of curvature of the primary mirror by looking into the telescope and moving closer or further away until you find the point at which your eye appears enormous. Place the collimation target at this range with its pinpoint light source squarely in front of the telescope and then slide the target and telescope closer or further apart until the returned spot of light is sharp on the target surface. Figure 1 shows the general arrangement. If the reflected spot is too dim, cautiously open up the pinhole source a little.

Now very carefully adjust the target position until the returned spot of light overlays the pinpoint source. This can be made easier and more accurate if you slightly increase the distance between telescope and target to defocus the image to a doughnut ring three or four millimetres diameter; the rather dim ring is much easier to get symmetrically over the much brighter light source than simply aligning two sharp spots when one is so much brighter than the other (Figure 6). Accurate alignment to well within one millimetre is the aim, and is easily achieved. Check that the target is still reasonably square to the telescope; it is now accurately on the optical axis of the primary mirror. Figure 7 illustrates the requirement.

With a collimation eyepiece (Figure 5) in place in the eyepiece holder look into the telescope, remembering that what you are looking at is a symmetrical, on-axis target as seen by its reflection in both the primary and the secondary mirror. If the telescope is accurately set up, the outer ring of the target should lie neatly and evenly spaced around the rim of the field of view (usually the exit aperture of the telescope housing) and the inner ring of the target should be seen symmetrically around

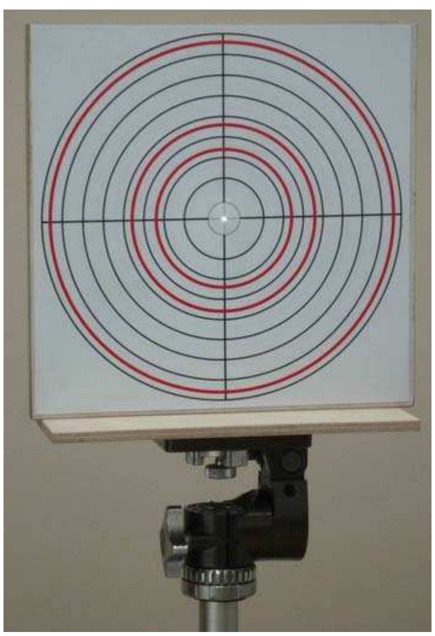

Figure 3. The target image pasted onto a sheet of thin MDF board and mounted on a conventional photographic tripod makes the light spots much easier to align. Drill a 1mm hole through the exact centre of the cross-hairs and fix a light source as in Figure 4.

Figure 4. An LED headtorch, bought from a local high street store for £1, makes a convenient light source. Modify it down to one LED, counterbore the MDF board to get the LED as close behind the pinhole as possible and fix it in place with double sided sticky pads.

Figure 6. The defocused returned doughnut ring alongside the point source....

Figure 7. ....and accurately aligned over it.

the rim of the secondary mirror holder (as in Figure 8). Any misalignment is immediately obvious and can be adjusted out as appropriate to the type of telescope being set up.

For an SCT it is simply a matter of adjusting the tilt of the secondary until the outer red ring on the target is symmetrical with the outer rim of the FOV, taking care as you do so that you don't knock the telescope out of alignment with the target in the process. The inner red ring of the target should simultaneously sit around the rim of the secondary.

RC collimation is less straightforward because of the separate tilt adjustment of both mirrors. The first step is to adjust the tilt of the primary to get the outer target ring into the FOV. This obviously throws out the alignment of the primary with the on-axis collimation target, which needs to be continually corrected as you progress. Then adjust the secondary to align the reflected centre spot from the collimation eyepiece with the ring on the centre of the secondary mirror, at which point it will be necessary to repeat the whole process to converge rapidly to a satisfactory symmetry of both outer and inner target rings in the viewed image. 'Before' and 'after' photos, Figures 8 and 9, show the performance of a Ritchey–Chrétien set up to the manufacturer's conventional collimation instructions (Figure 9) and then re-aligned to this method (Figure 10).

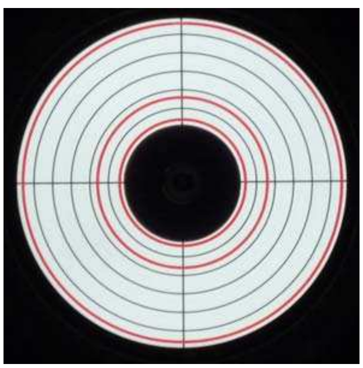

Figure 8. The view through the focusing tube of a collimated SCT.

Summary

I own a conventional SCT and an 8-inch Ritchey–Chrétien, and find that both can be easily collimated to a good standard with the method described here. How good a standard is a little subjective, but in my experience it certainly equates to, and is probably better than, both the use of an artificial star and the common 'off-focus' star test. In this method, the target image is stable whilst adjusting the secondary mirror, whereas the traditional approach requires the star to be continually re-centred in the FOV, in itself making this collimation process much easier and quicker to perform. It is particularly effective at setting the primary mirror alignment on a Ritchey–Chrétien to a much better state of collimation than the conventional 'mechanical' alignment process, and is the only daytime method that I am aware of that will do so.

Overall, the visual symmetry of the target image at the eyepiece brings considerable confidence about the general state of collimation of the telescope. Along the way there are also the side benefits of having a direct visual indication of the extent to which the smallest of adjustments affects the image, and all the convenience of working indoors when trying to achieve an equal torque on adjustment screws.

It cannot be perfect of course, since any visual alignment of this type must be subject to error and the symmetry has still relied on several mechanical references such the telescope front rim and the secondary mirror holder. Second order, more subtle effects like temperature, mirror flop and tube flex will also still exist when outdoors pointing at the sky, so the 'on-focus' Airy ring star test will always be necessary for peak performance. In my experience, however, this procedure gets closer to perfect collimation than any other of the several 'daytime' methods that I know of for the Cassegrain-type of telescope, and does it with ease and a high level of confidence.

As a final comment, it is worth noting that the procedure is not easily adapted for collimation of the Newtonian design. In the Cassegrain telescope, the only adjustment readily available is mirror tilt, whereas in the Newtonian design the secondary mirror has not only tilt but also rotation and axial movements to set, neither of which can be easily achieved simply by pointing the telescope at a collimation target. Well established daytime collimation routines exist for the Newtonian that take this into account, and achieve a high standard of accuracy that any variation of this procedure is unlikely to improve upon. Thus although the principles upon which this technique is based must hold for any reflector, its value for designs other than the Cassegrain-type may be limited to that of a useful confidence check.

Acknowledgments

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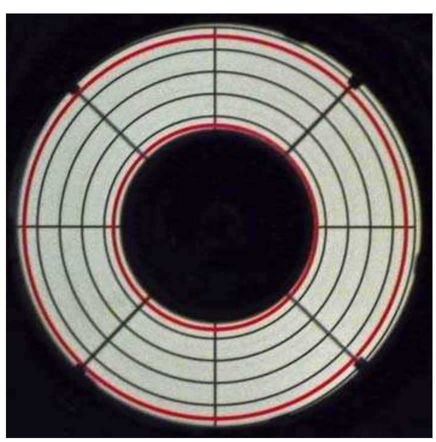

Figure 9. The target as viewed from the centre of the focusing tube with the telescope carefully set up according to conventional manufacturer's instructions. Misalignment of the target rings is obvious.

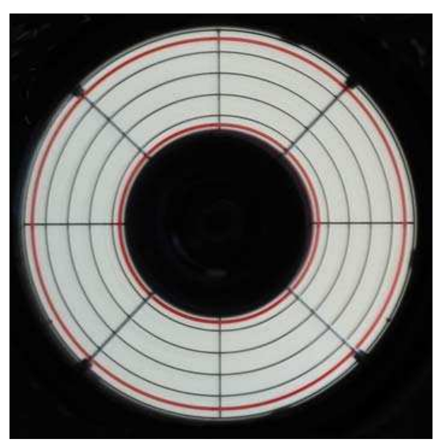

Figure 10. The same setup as Figure 9, but with the primary tilt adjusted using the method described in this article.