Merging of images in a binoscope; a practical quideline to building a

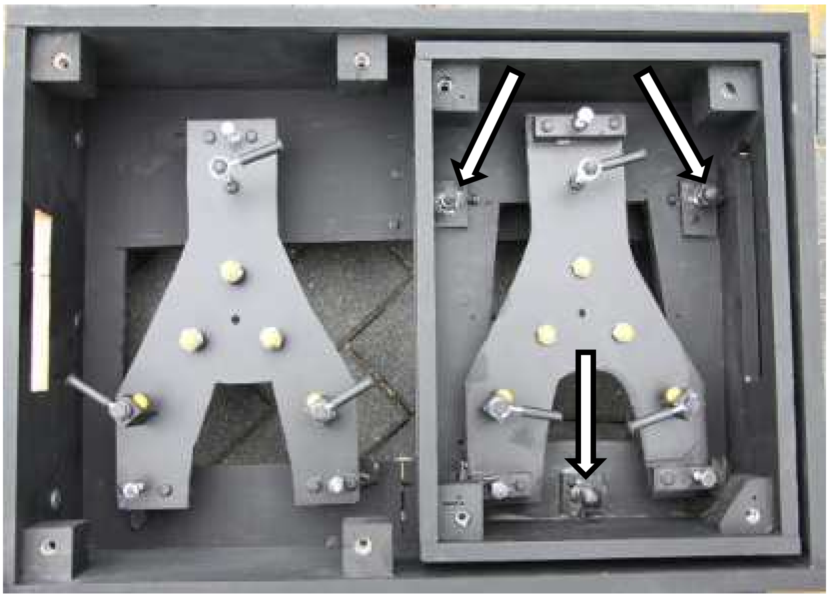
by Arie Otte

The term binoscope is often reserved for a Newtonian telescope with one mirror for each eye. Experienced observers claim that observing with a binoscope is superior to observing with a traditional 'mono-telescope' that has a comparably large, but only one big mirror. However, despite this advantage, binoscopes are not popular, presumably because they are difficult to make. But is this true? Probably one of the most challenging and difficult aspects of a binoscope is the need to precisely merge the images. Here I present different aspects of merging of images and provide practical solutions for building a binoscope in which these aspects can be adequately approached. This article intends to show that an ATM who can build a mono-Dobsonian telescope will also be able to building a binoscope.

The two independent optical systems of a binoscope have to produce two images that are both **well collimated** and **accurately merged** at the same time. If all parts of the optical train would be perfectly collimated and aligned, if all the angles of the scope would be perfectly square, if all mirrors (primary, secondary and tertiary) and the focusers would be centred perfectly, then images would be well-collimated and merged. Alas, no such thing as perfect exists, so images will probably not be perfectly collimated and will not be merged. In principle, merging is nothing else than that the optical paths of the two telescopes are brought together to create overlapping images . Two main approaches are that you 1) move one half of the binoscope in relation to the other half or 2) only move the optical paths, notably the primary mirrors. I've followed both approaches.

Merging of the images by tilting an entire half of the binoscope

In approach one to merge the two images, one entire half of the binoscope is slightly tilted in relation to the other half of the binoscope. In other words, the binoscope contains an entire telescope (consisting of the primary, secondary and tertiary mirrors) that can move independently within the space of the binoscope mirror box. I built such a set-up and it works very nicely (Picture 1, the right 'telescope' can move a bit). The main advantage of this method is that the quality of the images is not compromised by de-collimation, since no collimation of the primary mirror is involved.



__Picture 1:__ The right mirror box can move independently from the rest of the binoscope. The arrows indicate the ends of threaded rods that run through the bottom of the larger binoscope mirror box. By slightly turning them, the mirror box (and with that of course the rest of the telescope that is build on it) moves in relation to the other half of the binoscope. By doing this, the images merge.

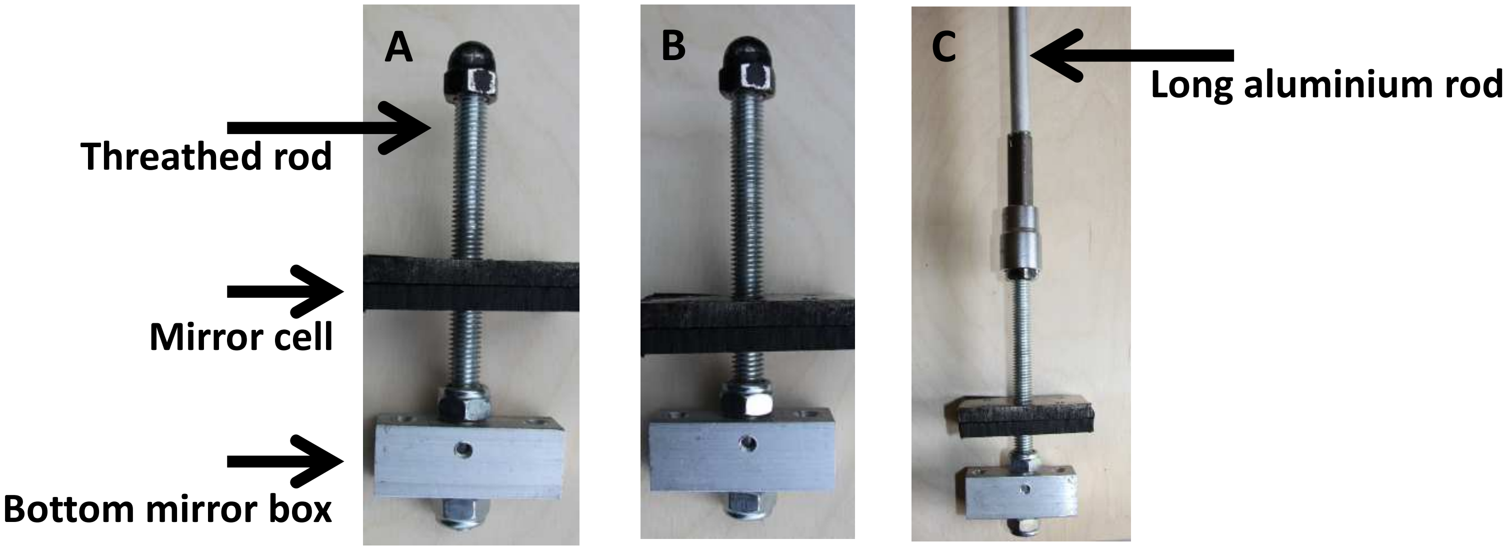
The disadvantage of this approach is though that the system is mechanically demanding. Specifically, when you move the binoscope up and down, images are more prone to ‘de-merge’, since changes are that there is some remaining slop in the system. Indeed, in my hands there always remained some slop in the threaded rods I used and that resulted in some separation of the images when moving the scope up and down.

Merging of the images by tilting the primary mirrors

I therefore opted for another procedure that involves bringing together the optical paths by means of just slightly tilting the mirrors. This implies that one moves the optical paths only, instead of an entire 'half-binoscope'. Starting from a merging/ co-collimation procedure described by David Moorhouse (http://www.binoscope.co.nz/), I found a rather unexpected and very simple modification in the sequence of normal collimation procedures that works very well. In summary, these are the subsequent steps:

1) Separately collimate each telescope without the tertiary mirrors in place: first the secondary mirrors, then the primary mirrors
2) Insert the diagonals with tertiary mirrors and collimate the tertiary mirrors
3) Merge star images by de-collimating the primary mirrors
4) Re-collimate the primary mirrors by adjusting the screws on the secondary mirror holders

Step 1. Separate collimation of each telescope <u>WITHOUT</u> the tertiary mirrors in place
Remove the diagonals with the tertiary mirrors and collimate both telescopes as a normal Newtonian telescope. Collimate the **secondary mirror** first, for instance with a single beam laser, and then collimate the **primary mirror** by tilting it. I collimate the primary mirrors with a Howie Glatter Barlowed laser, but any good Cheshire will do as well. Collimation by tilting the primary mirrors is done "from above". This means that turning the collimation bolts is not done from below the mirror box, as is the usual procedure in most mono-Dobsonian telescopes. Instead, the threaded rods go through and through both the bottom of the mirror box and the mirror cell (Picture 2, see for the legend for explanation).



Picture 2: *This is no real mirror cell, but an illustration of how collimation of the primary mirrors is achieved. A threaded rod goes through and through both the mirror cell and the bottom of the mirror box (A). When turning the knob, the mirror cell, and thus the primary mirror, moves up and down (compare A and B). This is an exaggeration, merely to illustrate the principle. A long aluminium rod (C) can be used to turn the collimation bolts (see also Picture 3).*

When turning the threaded rods, the mirror cell 'travels' up and down. I use long aluminium rods with handgrips to perform the task of turning the collimation bolts (Picture 2C and 3). To make things even more easier, the handgrips are at shoulder height, which allows turning the rods for merging, while looking through the eyepieces (see below)

Picture 3: *The long aluminium collimation rods that are used to collimate the primary mirrors. From my website:* http://www.arieotte-binoscopes.nl/Merging%20of%20the%20images%201.htm.

Picture 4: *The grips of the aluminium collimation rods are placed at shoulder height of the observer.*

Step 2. Collimation with the tertiary mirrors in place

Now insert the diagonals containing the tertiary mirrors (without eyepieces) and insert a single beam laser collimator in the focuser (Picture 5). The laser light will probably miss the centres of the primary mirrors. I re-aim the single laser beam back to the centres of the primary mirrors, this time by adjusting the **tertiary mirrors, not the secondary mirrors**. This is executed by a push-pull system on the plates on which the tertiary mirrors rest and that can move the tertiary mirrors (Picture 5). After having done this once, I rarely touch the tertiary mirrors ever again.

Picture 5: *The single beam Howie Glatter laser, placed in the focuser/ diagonal, containing the tertiary mirror. The small screws of the push-pull system that can move the tertiary mirror is indicated with white arrows.*

Step 3. Merging of the images by de-collimating the primary mirrors
When night falls I insert the eyepieces and have a look at the stars. There is a good chance that the images will be a bit separated. The images of any star or star field can now very simply be merged by adjusting the collimation bolts for the **primary mirrors**. That is: I slightly turn the long aluminium collimation rods that tilt the right and left primary mirrors until the images are merged (see Pictures 2 and 3). In this way, the optical paths of both telescopes are moved towards each other and become merged. Since the grips of the rods are at shoulder height, this is all being done while I look through both eyepieces.

However, while merging of the images is very easily achieved this way, there is one drawback: the tilting of the primary mirrors inevitably leads to some **de-collimation** of these primary mirrors! So in the next step the sharp images of stars need to be recovered.

Step 4. Re-collimation of the primary mirrors with the screws on the secondary mirror holders
I found out that an effective way to re-collimate the mirror systems is to simply adjust the screws on the secondary mirror holders that are normally used to collimate the **secondary mirror** (Picture 6).

Picture 6: *Adjustment screws on the secondary mirror. While in a mono-telescope these are used to collimate the secondary mirror, with a binoscope they are used to re-collimate the primary mirrors!*

Now tilting the secondary mirrors is used to collimate the primary mirrors! To follow collimation of the primary mirrors, I place the single beam laser in the so-called Howie Glatter tuBlug (Picture 7). However, I also use a Cheshire with the same results.

Picture 7: *Like Picture 5, but now the Howie Glatter tuBLUG (*[http://www.collimator.com//tublug.htm)](http://www.collimator.com//tublug.htm) *is placed between the single beam laser and the focuser/ diagonal. In this way, re-collimation of the primary mirrors can be followed with ease.*

With the tuBLUG, collimation is easy to accomplish, because you can see the 'Barlow donut' move while standing behind the binoscope (Picture 8). The movement in the middle and right pictures below indicates the degree of de-collimation of the primaries. The small opening of the Barlow lens should still be within the larger area of the Barlow donut (somewhat as in the middle picture above).

Picture 8: *The "Barlow donut" as seen in the tuBLUG. The movement of the donut indicates the degree of de-collimation of the primary mirrors. On the left a perfectly collimated primary mirror, in the middle the state of collimation as will probably be seen in practice. On the right an example of a collimated state that is way beyond what tolerances allow.*

In principle the tertiary mirrors will be out of collimation after adjusting the screws on the secondary mirrors. In practice the effects are neglectible, so I don't touch the tertiary mirrors again. So upon re-inserting the eyepieces and returning to the stars, they are probably perfectly merged by now. If not, again tweak the primary mirrors collimation rods for merging and correct collimation of the primary mirrors by tilting the secondary mirrors for a last time. This re-iteration of the steps 3 and 4 has to be done at most one or two times.

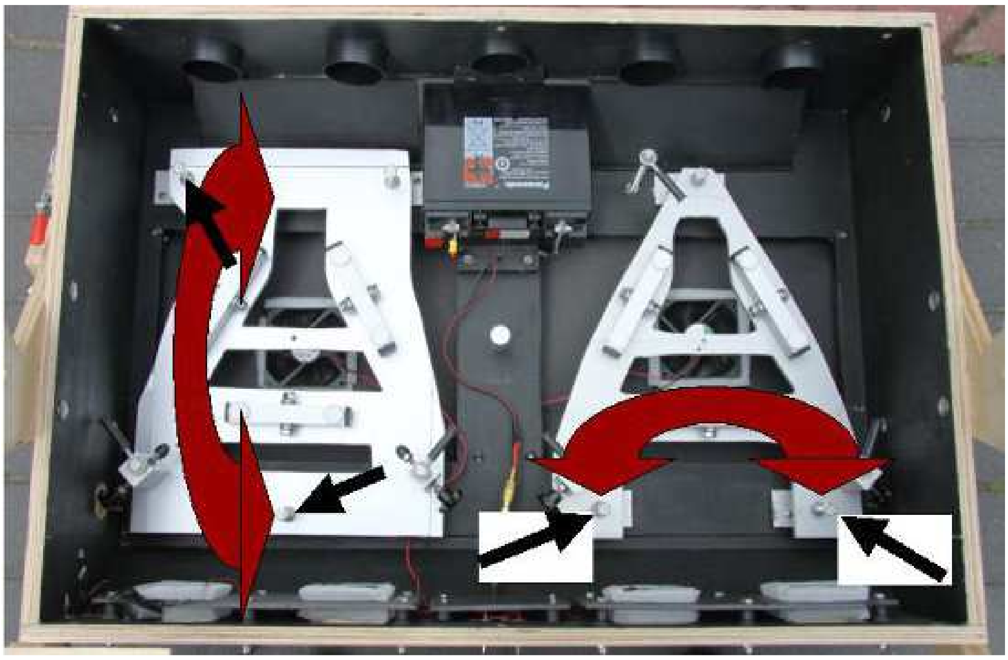
By following this strict order, star images will now be both well-collimated and accurately merged.

Not only that, when the entire binoscope structure is rigid enough, images will stay merged when moving the scope up and down. In fact, this is not different from a mono-Dobsonian telescope. When this has a rigid enough structure, collimation will stay near-perfect when moving the telescope up and down. Since merging of the images is strictly dependent on the collimated state of the optical system, a rigid binoscope structure in which collimation does not change, will result in well-merged images as well.

Horizontal and vertical merging of the images

Note in Picture 9 below that the collimation bolts of the two mirror cells (see the black arrows) are not placed in the same positions. The right mirror is collimated by two bolts closest to the mirror support, the left mirror is collimated by one bolt that has been placed between the mirror support, and another bolt at the left upper side of the mirror cell.

What does this imply? By turning only one of the two bolts of the RIGHT mirror cell, the right mirror will be tilted in a 'left-right' fashion, parallel to the long side of the mirror box. In contrast, by turning the one bolt of the LEFT mirror cell that is placed between the mirror support, the mirror will be tilted in an 'up-down' fashion, square to the long side of the mirror box. The large red arrows show these respective movements of both mirror cells that in principle must be perpendicular to each other. When looking back at picture 4, one can see that only three long aluminium rods are present: one for the left mirror and two for the right mirror. Why this seemingly complex procedure?

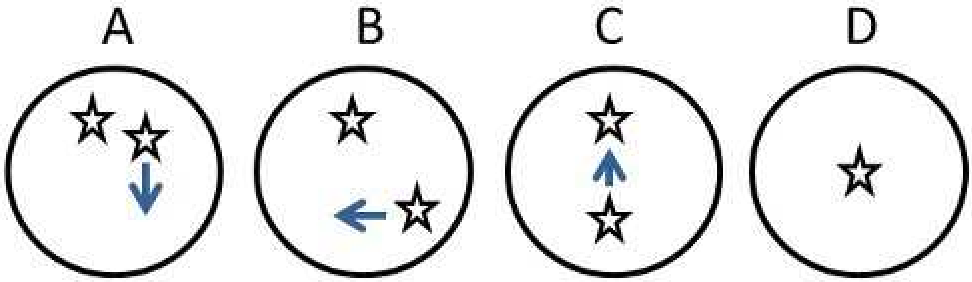


Picture 9: The left and right mirror cells (and thus the primary mirrors) are moved in different directions during collimation and merging of the images. The right mirror will be tilted in a 'left-right' fashion, the left mirror will be tilted in an 'up-down' fashion.

The answer lies in the way image merging is done (actually **HAS** to be done) in practice. With only two collimation bolts, placed at the bottom of the right mirror cell, the images can in principle be merged. Turning both collimation bolts simultaneously in the same direction, will move the images vertically up or down. But in the end, with only these two collimation bolts available, the images will have to be merged in a horizontal movement. I noted that when the images come close enough together, **the brain will interfere and snap the images together instantaneously**. This while you know that 'mechanically' they were not fused yet by the turning of the collimation bolts. It becomes a cause of constant eye strain, and a bad headache as the end result of a night observing!

This can simply be avoided by independently tilting the left mirror to move the left image vertically up and down. The merging procedure becomes as follows (Picture 10):

A. **keep the vertical axis of the images slightly misaligned on purpose, or even move them apart by turning the left mirror cell collimation bolt only,**
B. **now merge the images horizontally with one of the two right mirror cell collimation bolts,**
C. **when you see that horizontal convergence of the images has been reached, finalize by vertical merging.**



***Picture 10:** The stars are deliberately de-merged vertically (A), than merged in a horizontally manner (B), until stars are vertically aligned. Then stars are merged vertically (C and D).*

Why does this work? The brain can only snap together close images when they lie on the same axis as the eyes: horizontal. Not vertical misaligned images!!! So by purposely keeping the images vertically misaligned at first, you can now see where the 'real' horizontal merging point is, without the interference of the brain.

Conclusion

This article is intended to show that one, if not the most difficult aspect of building a binoscope, can be adequately handled, when taken proper precautions. I am aware of examples in which tilting of the primary mirrors is done while one has to bend etc. Also, the de-collimated state of the primary mirrors is often considered as an unavoidable fact of life. The above shows that none of this has to be the case and that it can be avoided and solved in a relatively simple way to obtain well collimated and sharp images in a binoscope.