Section 4: Aids to Focusing

The techniques covered so far -- visual focusing, and focusing using numeric data from the software -- can work and work well. But a variety of variables, including everything from the optics to the seeing conditions, can conspire at times to make focusing still seem like a chore. There are additional tricks available to give you more options for focusing. One of the more interesting options is to partially block the light path, which creates diffraction patterns in the image. You can then use those patterns to give you a clearer indication of when you are at critical focus.

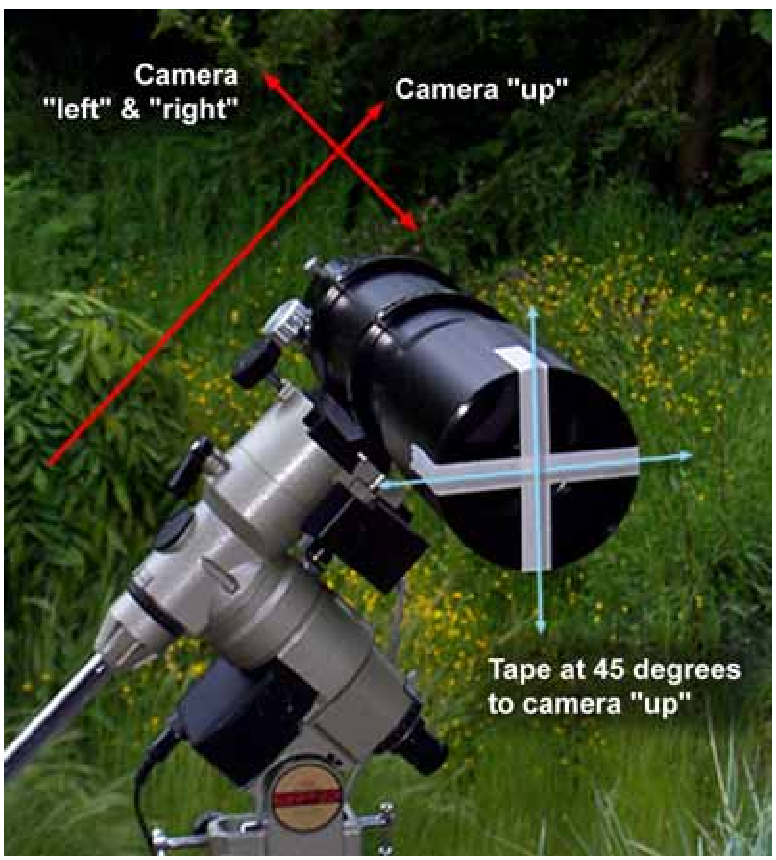
As always, you can also combine methods to better identify the best focus position.

We will explore two techniques in this section: a cross made out of masking tape, and various types of masks. There are other hardware focusing aids available (many of which you can make at home from readily available materials), and I'll give you a rundown on those at the end of this section.

Focusing with Diffraction Spikes

The spider that supports the secondary mirror in a Newtonian and many other kinds of telescopes serves as a built-in focusing aid. The vanes of the spider create diffraction spikes that sharpen noticeably at optimal focus. If your telescope doesn't have vanes, you can temporarily add various items to the front of your telescope to create diffraction spikes. Refractors don't have a secondary at all, and Schmidt-Cassegrains have a corrector plate instead of a spider. Both types are often used for CCD imaging, so I have a few suggestions for creating "artificial spiders" to create diffraction spikes on such telescopes.

Figure 2.4.1. Position the masking tape at 45 degrees from the camera's "up" orientation.



When you are done focusing, you remove whatever you've added and image in the normal manner.

One very practical method probably seems like the ultimate in low-tech: slap some masking tape across your telescope's dew shield. It probably even sounds ridiculous. But it not only works, it works very well.

Figure 2.4.1 shows how simple it is to set up your telescope with the MTFA (Masking Tape Focusing Aid). Just apply the tape to the end of the dew shield in a cross pattern. You don't even have to be super accurate about making everything equal; the technique works quite well with a slap-dash application of the tape. I used one-inch tape, but anything from 1/4" to an inch and a half should work fine. For those who are squeamish about applying anything sticky to their telescope tube, Paul Walsh, a Seattle area CCD imager, suggests building a cardboard lens cap with the tape affixed to the cap. As shown in figure 2.4.1, the tape will work best if it is at 45 degrees to the camera's "up" ori-

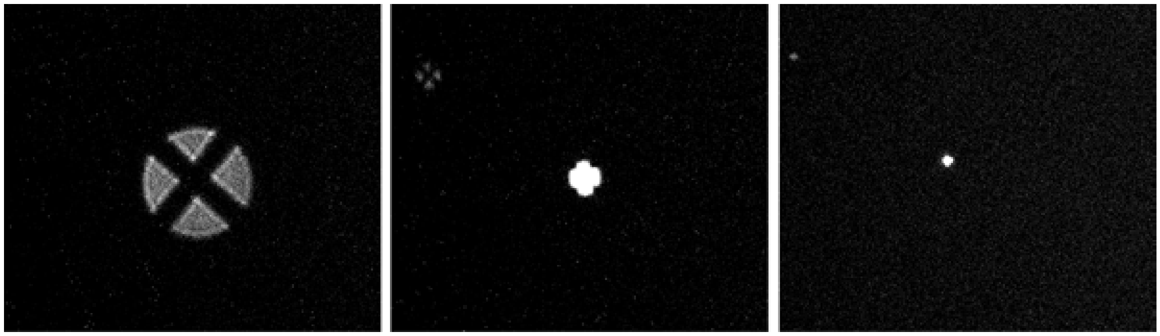


Figure 2.4.2. Left: Star well out of focus, showing shadow of masking tape. Center: Closer to focus, shadow is less prominent. Right: Close to focus, shadow disappears.

entation. The puts the diffraction spikes from the tape into the image diagonally. Running the spikes diagonally through the image pixels makes it easier to judge the exact width of the spikes. If the spikes line up too closely with the columns and rows of the CCD chip, it becomes harder to judge the exact width of the spikes.

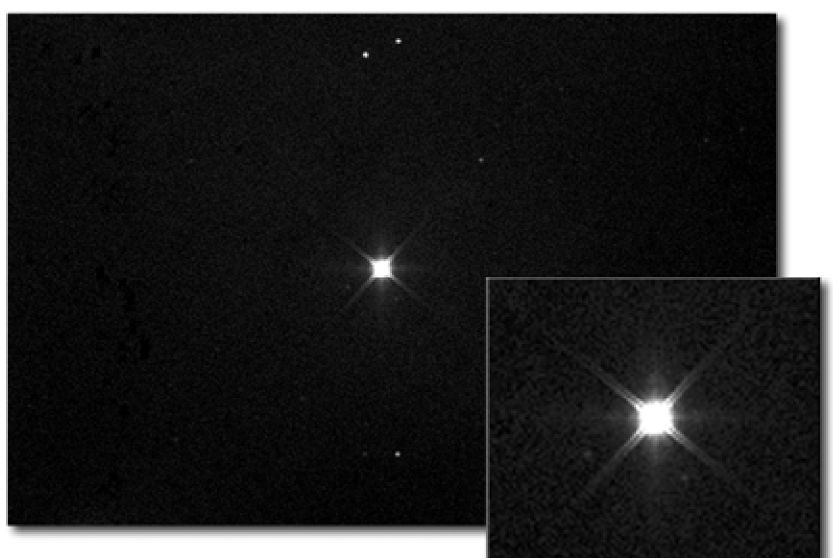
The tape blocks some of the light, and changes the diffraction pattern of the scope. Figure 2.4.2 shows three images at various stages of focus. At left, the star is far out of focus, and the shadow of the tape is obvious. The middle picture shows a point closer to focus, and the shadow is only clear in a dim star at upper left. At right, the star is close to focus and the shadow has disappeared. Very bright stars work best.

As you get close to focus, you may or may not see the desired diffraction spikes. If auto contrast is on, you may need to manually adjust contrast to get a clear view of the spikes. The effects from the tape are fairly subtle, and you may also have to increase your exposure time to see them. If you are using a binned image to do rough focus (which I recommend highly), you will need to switch to the highest available resolution mode in order to do final focus. Figure 2.4.3 shows what you should expect to see near focus in unbinned (1x1) mode, with a long enough exposure, and properly adjusted contrast. Note that outside of focus the diffraction spikes aren't simply thick, as they appear in 3x3 binned images; they are actually made up of two completely separate lines.

When the star is near focus, you will see spikes extending out from the star along the lines where the tape's shadow once was. The brighter and thinner the diffraction spikes are, the better your focus. The actual brightness and thinness will depend on your focal ratio and the physical characteristics of your tape or other material.

In CCDOPS, use Planet mode for final focusing. With other programs, take a binned image, select the subframe for final focusing, and then switch to 1x1 (unbinned) mode. Whatever software you use, make

Figure 2.4.3. The appearance of a star very close to focus in binning mode 3x3 (ST-8E camera).



sure you select an area around the star that is large enough to show the diffraction spikes at their full length. As you improve focus the spikes will get thinner and longer.

Figure 2.4.4 shows the process of selecting the star for focusing in Planet mode. When the lines merge, and are as narrow as you can get them, you are at critical focus.

TIP: Make sure you apply the tape to your refractor so that it makes a 45-degree angle with the camera's CCD chip. This will orient the spikes diagonally, which makes it easier to determine if the spikes are as thin as possible. If the spikes are lined up with the rows and columns of the pixels, you won't be able to analyze them as clearly.

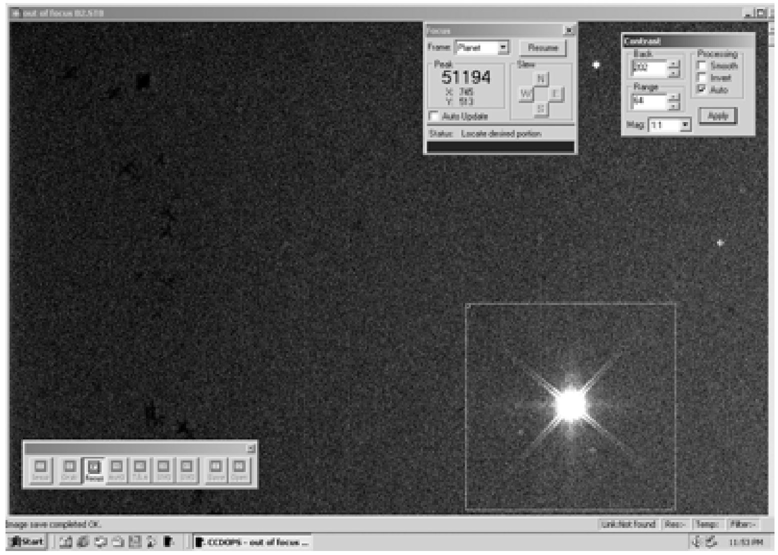
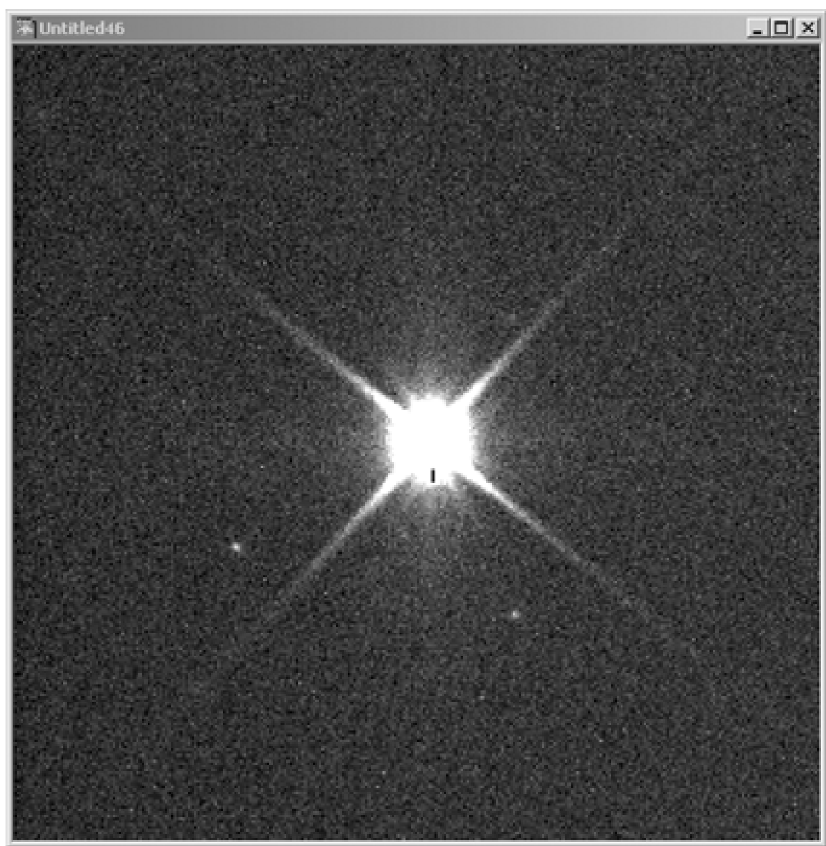


Figure 2.4.4. Select the area around the star you are using for focusing, allowing enough room for the diffraction spikes.

Figure 2.4.5 shows the spikes as they would appear at best focus. Note that there is a single line for each spike. The lines are not perfectly thin lines; they still have some width. They are a little thicker close the to star, and they thicken slightly as they get more distant from the star. Both of these effects are normal. Gauge the thickness of the spikes at their thinnest part.

Figure 2.4.5 also reveals a few other interesting details that tell us that we are in focus. There is a small amount of blooming occurring (the small black line near the bottom of the star image). The exposure is just a touch too long to be perfect, but since this image was taken during a real-world imaging session, I didn't let a little blooming make me start over -- the spikes are the important part of the image, and a little blooming does no harm. In fact, to get bright spikes, you may have to use a long enough exposure to cause some blooming. Don't sweat it -- it does no harm. The important thing is to get spikes that are bright enough to be easy to evaluate.

Figure 2.4.5. The appearance of the diffraction spikes around a well-focused star. Note point-like dim stars as well.



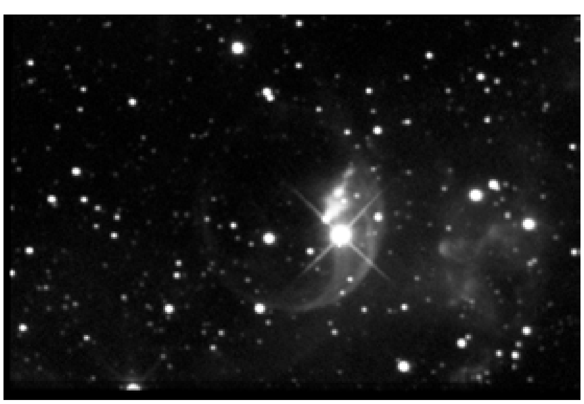
On the other hand, if they get too bright, you may not be able to judge their thickness accurately.

TIP: You may need to adjust the contrast of the image in order to see the spikes clearly. Play around with the Back and Range settings in CCDOPS, or the Min/Max settings in MaxIm DL, so that the spikes show up clearly. Don't make then too contrasty, however, or you won't be able to judge them properly. If they ar still to faint, use a longer exposure.

Also visible in figure 2.4.5 are two dim stars. As with the examples of dim stars shown earlier, these stars strongly illuminate a single pixel. I examined images just inside and outside of this focus position, and found that the two dim stars no longer had the bright core that indicates best focus. As I often recommend, I was able to use several techniques to cross-check the point of best focus. I also could have used brightest pixel or FWHM, or both, to further confirm best focus. Even with the tape, these other methods still work.

Some telescopes use a 3- or 4-vane spider to support a secondary mirror. The spider can act as a built-in focusing aid. The spider vanes are thin, so they are not as obvious in out-of-focus images as the masking tape is, but they can be useful for focusing on very bright stars as you get close to critical focus. Figure 2.4.6 shows an image of the Bubble Nebula taken with a Takahashi Mewlon 210, a Dall-Kirkham design Cassegrain. It has a 4-vane spider, and you can clearly see the vanes in this in-focus image.

Figure 2.4.6. The spider vanes on some telescopes make a good tool for judging focus quality.



Focusing with a Mask

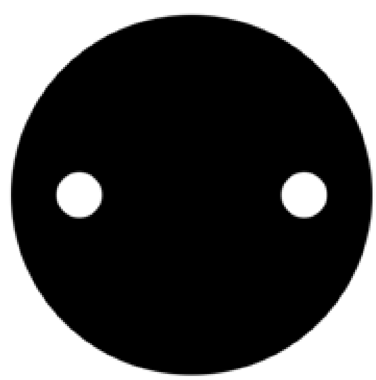
The principle behind the mask is very similar to that behind the masking tape: put an obstruction in the light path, and observe the changes in the diffraction pattern that occur as you move closer to focus. However, where the masking tape blocks a small portion of the aperture, and allows most of the light to go through, the mask blocks most of the light, and allows only a small amount to go through.

Figure 2.4.7 shows the pattern for one kind of mask. The dimensions shown are for an 8" mask, but in reality you need not be terribly careful about the size or placement of the two holes. You can even use three holes if you like. A piece of cardboard from a box, poster board, or other sources of cardboard can be cut and taped or wedged into the front of the scope. You can't have enough masking tape handy when CCD imaging!

Figure 2.4.8 shows two other patterns that I made and tested. I cut the masks out of cardboard, and tried them out on an Astro-Physics Traveler, a 4" APO refractor.

Figure 2.4.9 shows one of the masks I made. As things turned out, this funny little one with the two oddly-pointing triangles turned out to be the most useful. I made the masks from thin cardboard purchased at a local office-supply store. Any cardboard should work fine -- shirt cardboard, boxes, etc. It just has to be firm enough to hold its shape when you put it on the tele-

Figure 2.4.7. This simple mask is intended to help you focus more accurately.



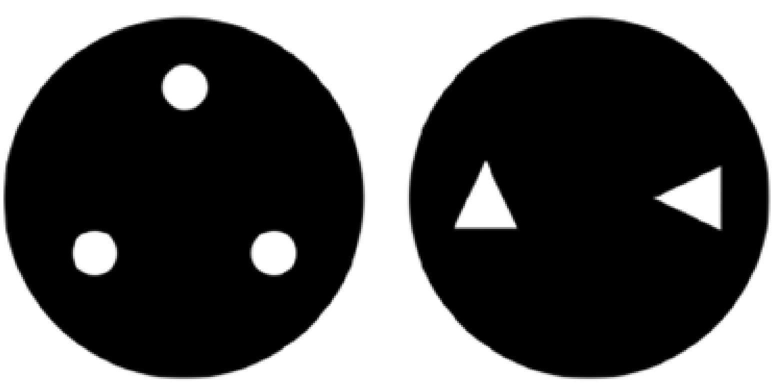


Figure 2.4.8. Two of the alternative masks I tested. The triangle mask worked best.

scope. I've even made masks from paper plates. Some paper plates, in fact, make a perfect force fit inside the rim of popular 8" SCTs.

The little tabs you see in figure 2.4.9 are designed to support the mask on the front end of your telescope. I found that they also work to wedge the mask inside of the dew shield on a slightly larger telescope when they are spread out a bit. No tape is needed unless there is a fair bit of wind. Even with the scope nearly horizontal (figure 2.4.10), the mask will stay in place. The trick is to put two of the tabs in a "V" at the top of the scope. If you try to hang it by only one tab at the top, it will slide right off unless the scope is nearly vertical.

Figure 2.4.11 shows the results of using three different types of masks to focus on a star. Each vertical column shows images taken through one type of mask. Each column stops at the point where I last found the mask useful approaching focus. The three holes start to crowd each other, and I didn't like using them. The two-hole mask holds up a little better, but when the two holes get close together, it's impossible to tell how close they are, or when they are actually co-incident. The two-triangle mask neatly solves this because it has diffraction spikes that line up at perfect focus.

One thing is immediately obvious from figure 2.4.11: the shape of the mask strongly affects what you will see when you are focusing. If there are two holes, you will see two bright spots. If there are three holes…you get the idea, I'm sure!

Figure 2.4.9. A simple focusing mask. The little tabs hold the mask on the front of the scope.

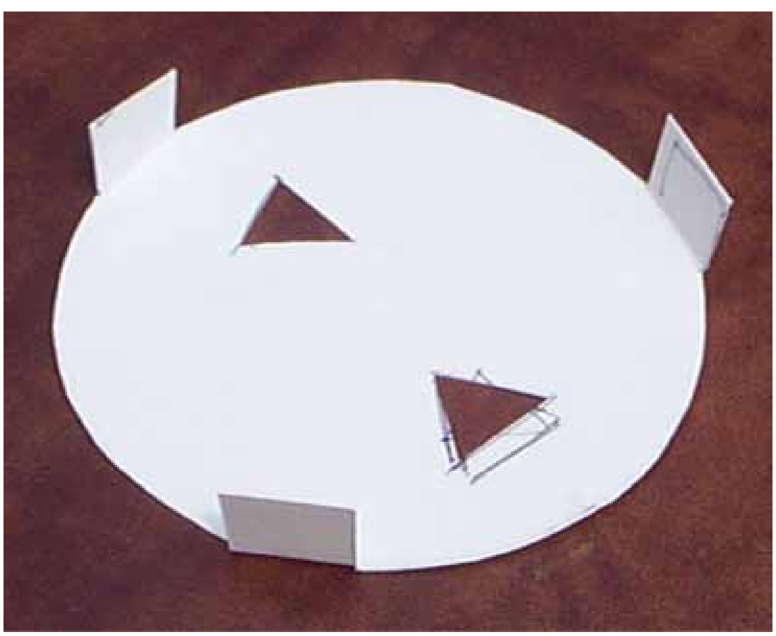
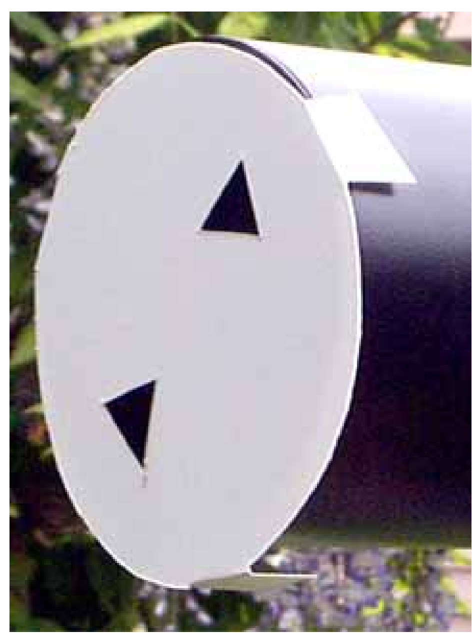


Figure 2.4.10. A mask in action.



The bottom row of images in figure 2.4.11 shows the appearance of the star when it is well outside of best focus. Everything is well spread out, and it's easy to tell that you are out of focus. The next row up shows the results after moving the focuser closer to best focus. The images are now smaller and closer together. This is a trend: as you get closer to focus, the separate images shrink and merge. The idea is to get everything to merge into a single image, indicating that you are at best focus.

In practice, this was often hard to do. The third row up from the bottom shows the problem: as the images get closer together, they merge with one another and it becomes hard to tell when they are exactly merged. In fact, I found it easier to focus visually than to try to tell when merging occurred.

The mask with the two triangles was an exception, however. The sharp corners of the triangles create diffraction effects, which are slightly visible in the second row, and much more visible close to focus in the third row. The triangle method was the most useful, and it was the only one that I could count on for telling when I was close to focus, as shown in the top row. There is only one image in the fourth row because there was only one technique that actually worked effectively close to focus.

Figure 2.4.12 shows the full extent of the diffraction spikes using the traingle mask. There are twelve of them, two for each point on each triangle. As with tape and spiders, you may need to increase your exposure time and/or adjust contrast to see the spikes clearly. The spikes help determine where the center of each triangle is, even when you can no longer see the triangles. Each pair of diffraction spikes define a line, and when all the lines appear to meet at the same point, you are at best focus.

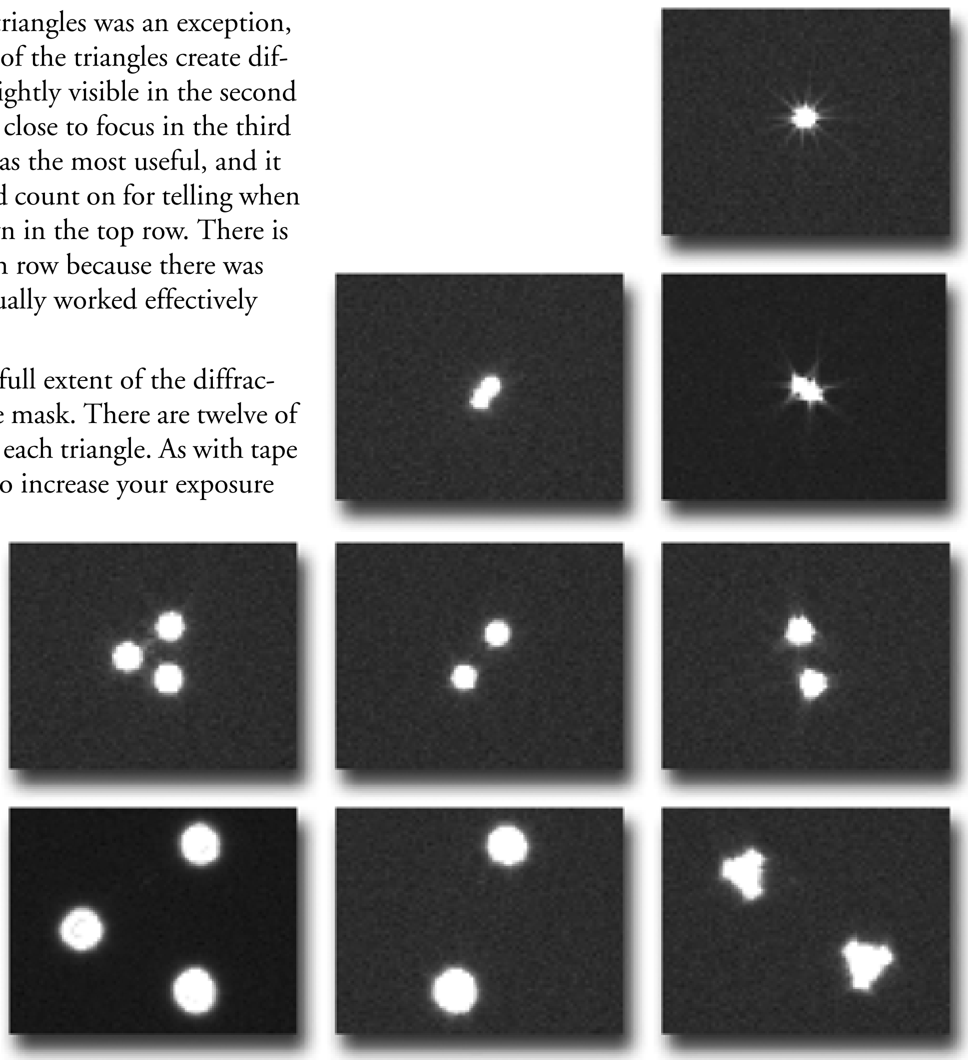


Figure 2.4.11. Results of using the three masks. Left: three round holes. Middle: two round holes. Right: two triangles. Out of focus at the bottom; improving focus as you move upward.

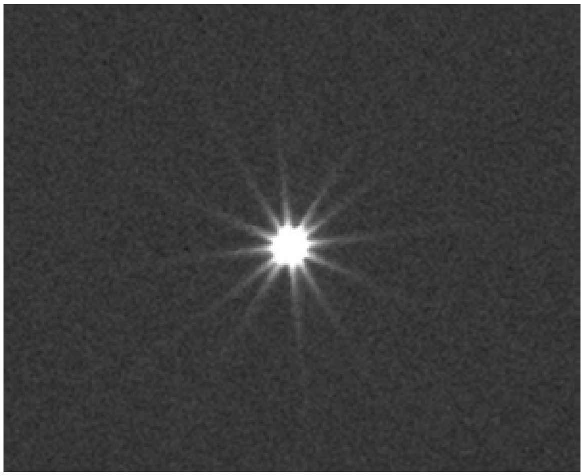


Figure 2.4.12. The mask with triangles creates diffraction spikes, which makes it easier to tell when the two images are merged. the spikes will all point to the same place when the images overlap.

In addition, the diffraction spikes get thinner as you get close to focus, so they function in two ways at once. I was able to use brightest pixel and FWHM as well while merging the two images, to provide additional data on when I had achieved best focus. Magnifying the image also helps.

Making the masks is extremely simple; they don't have to be very complex or precise. In fact, the "circles" don't have to be circles -- and the triangles work best in any case. I made all three masks in less than ten minutes using a carpenter's knife and light-weight cardboard.

Other Focusing Aids

There are a number of other objects and masks that you could put at the front of your telescope to help you figure out when you are at best focus. There are too many possibilities to cover them all here. Some work better than others; almost all of them are somewhere between cheap and free. For example, you can tape two small dowels in parallel across the front of your dew shield, creating a pair of lines in the out-of-focus image. As you approach focus, the lines start to merge. This technique is similar to the masking tape approach in ease of use, though the tape is more portable; you can carry a small roll in your pocket. A cross made of dowels also works.

This is an interesting area for experimentation. As long as you don't do any damage to your front optic, just about anything handy might be the perfect answer to perfect focus. Different items will provide different diffraction patterns, and if you can find one that works especially well for you, that's what really counts.