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The Borg 101 ED F/4 Astrograph

"It's a Borg – Resistance is Futile!"

By Craig Stark

If you could design your own refractor, what would it be? An achromat? An apochromat? Something small for travel or something larger to bring in the faint fuzzies and give more resolution? Would it be in a normal tube or an extra-short one to allow for binoviewing? Something geared for astrophotography or more for visual use?

We all have different answers to these questions and many of us will answer these questions differently when asked at different times. Unfortunately, when we buy a refractor, we're pretty well stuck with it. A focuser swap is about all we can do and that's not usually easy or affordable. I know - I just sold an excellent scope because I wasn't happy with the focuser when it came to using it for astrophotography.

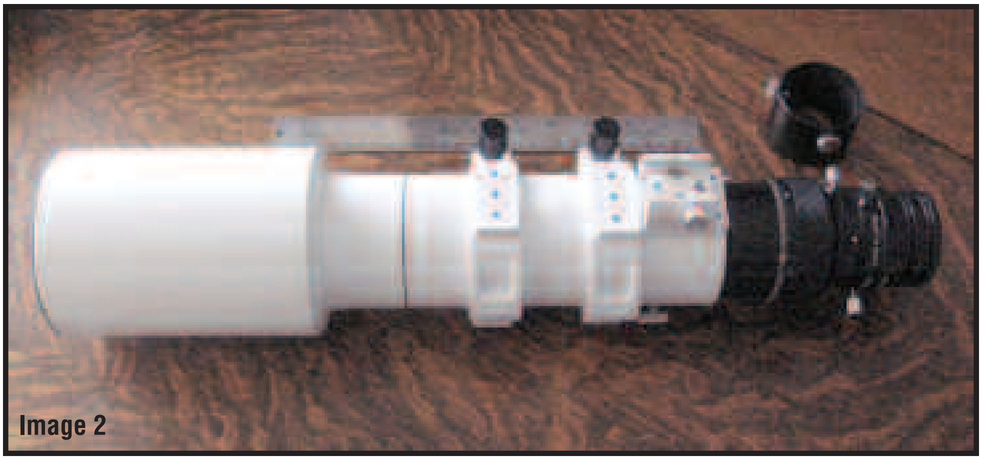
Into this quagmire, enter Borg Telescopes, sold in the USA by Astro Hutech (www.hutech.com), also known for their IDAS filters. Borg takes a different approach to telescope design than any other manufacturer. Borg telescopes are completely modular, made up entirely of interchangeable parts. Want a shorter main tube? Order a shorter main tube (or order both so you can have your choice). Want to start with an achromat and upgrade later to an APO? Order the achromat objective initially and later order the APO version. This approach is wonderfully versatile, but this versatility is what can put people off of Borg telescopes. Put simply, when you order a Borg, you're designing your own telescope from a long list of parts.

Reviewed here is a Borg 101 ED f/4.1 astrograph. Or, more precisely, it is a: 2101 + 7135 + 7749 + 7835 + 7704 + 7920 + 7601 (2 of these) + 7522 + 7505 + CB101 + 7083 + 7755. Imagine the following encounter at a star party, "Hey what do you have there?", "Why it's a 2101 + 7135 + 7749 + …" That's not going to go over too well or impress your guest very much. Having gotten my feet wet with the Borg system, I now simply reply, "It's a Borg – resistance is futile."

What's in the Box

Open up a new telescope and you expect to see, well, a telescope. Open up your box from Astro Hutech and what you see is,

The box of boxes that make up a Borg telescope as you receive it. This doesn't quite look like a telescope yet. But, have no fear, this collection of parts is soon to transform into a telescope.



The Borg 10 minutes later, fully assembled, looking like a telescope and not a collection of parts.

well… boxes (**Image 1**). Yes, this is a telescope and no, it's not in the black case there. The telescope comes as a collection of parts. Fortunately, Astro Hutech provides documentation and there are diagrams in there (and on the website) to show just how everything can fit together for the configuration or configurations chosen. About 10 minutes or so after I took the first shot here of all the boxes, I took this second shot of the fully assembled scope (**Image 2**). Assembly was smooth and painless and everything fit together perfectly – a testament to the consistent, precision machining and manufacturing of the parts. There were no extra screws, no time spent scratching my head, and no panicked calls to Ted at Astro Hutech. It really couldn't have been much simpler.

What's shown here is the scope I wanted, configured the way I wanted it with the optics I wanted, the reducer I wanted, the focuser I wanted, and the camera mounting gear I wanted. Nothing more, and nothing less.

Deciphering the Parts List: How I "Built" My Borg

OK, so it went together easily and there were no missing or extra parts. How did I get here? First, I did my homework. (As a professor, I'm convinced this is one reason Borgs aren't wildly popular – nobody likes to do homework…) The Astro Hutech website shows a number of "standard configurations." These are basic templates or starting locations. I do wish that they would list all the parts that go into each scope they show. Coverage here on the website is a bit spotty and, if improved, would go a long way to making the decisions easier. I started with the page on the "f/4 Astrographs" as I was in the market for something with a nice, wide field to mate with my APS-sized camera (CCD Labs Q8-HR) for very wide shots. In the PDF that describes the dedicated reducer that makes the second heart of the system (more on this later), you'll see a typical Borg system diagram like the one shown in **Image 3**.

What this shows is that if I choose the 101ED lens as my objective, I should mate this with the 7135 tube and drawtube, the 7749 draw tube holder, the f/4 reducer (consisting of the 7704 front, and 7704 rear), my choice of the 7835, 7837, or FTF-M57 focuser, and a camera adapter. Now, how do we know things like the 7835 is the focuser (apart from guessing based on its location?) Well, the full Borg parts list is linked under "Telescope components," giving you a long list of part numbers with prices, brief descriptions, and links to product pages with more of a description. In addition, the full catalog (circa 2003) is available in PDF format, organized by part type (with indices) and containing a good bit of information on each part.

In my case, since I wasn't going to use this much with a DSLR, but with a CCD that uses T-threads, the camera adapter wasn't needed. Their site listed a 7920 + 2x 7601 + 7522 as the correct choice for a Starlight Xpress setup. That served as a starting (and in my case ending) place for choosing the bits and pieces needed to get my CCD the correct distance from the reducer lens. A few other bits and pieces (rings, finder mount, etc.) and I was prepared.

Once I had my list of parts, I contacted Ted Ishikawa at Astro Hutech. Since I live just down the road a bit, I drove up to Astro Hutech to meet him and make sure I was getting the right set of parts. For those not so close, Ted is very responsive by e-mail and phone. He's also incredibly helpful and patient and clearly wants you to end up with the system that is tailored to your needs. He never tried to sell me extra bits and bobs and handled all of my questions well (I might add that at the time, he had no idea I was contemplating writing a review.)

101ED Lens+f/4 Super Reducer

The Borg f/4 Astrographs are designed around the f/4 Super Reducer. This is a two-

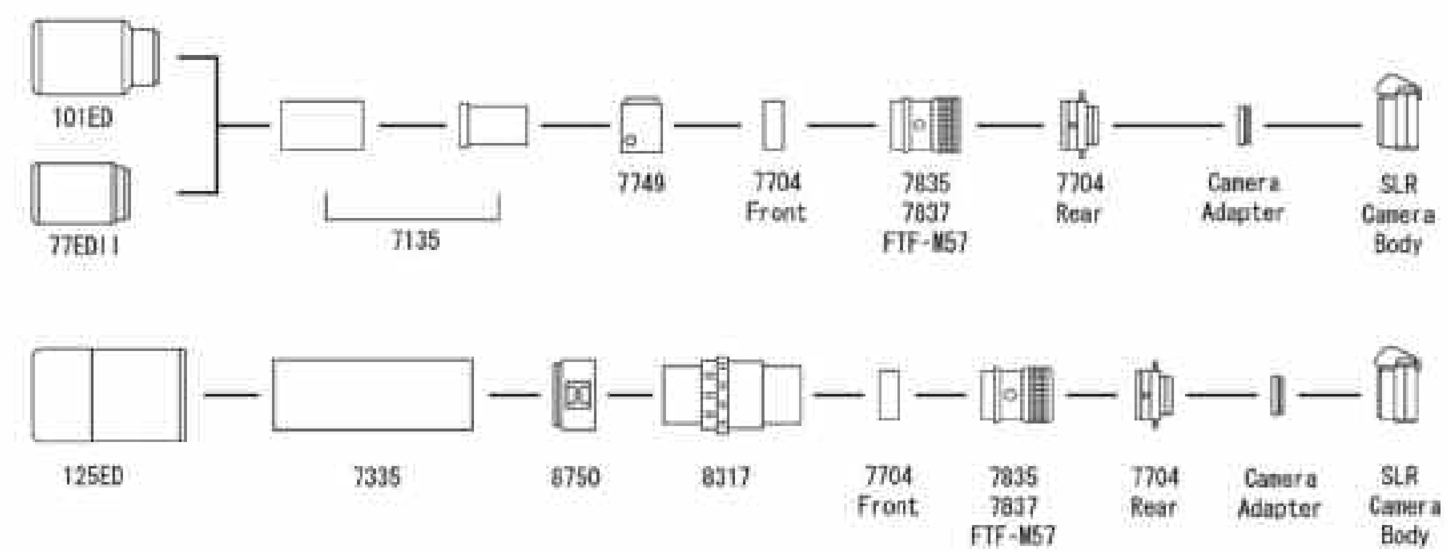


Image 3

The "system diagram" showing the components and options available when using the f/4 Super Reducer. Note, when not using the f/4 reducer, a wider array of options is available. Diagram used with permission from Hutech.

component assembly (one on each side of the focuser) that forms a four-lens system (with one element being of ED glass). This is designed to work with doublets such as the 77 EDII, 101 ED, and 125 ED Borg lenses such that together, they form a very flat, well-corrected 6-element system. (Note, I am not qualified to determine if this is a "true" Petzval, an "advanced" Petzval, or something just Petzval-esque.) In my case, it turns the 101 f/6.3 objective (640 mm) from a standard doublet capable of visual or photographic work into an f/4.1 (410 mm) astrograph. Of course, when I say it "turns it into" such a system, one can turn it back easily enough by just unscrewing a few parts from the focuser and replacing the focuser – something that would take just a few minutes.

The Super Reducer has a few twists. One of them, a literal twist, as it gives you the ability to rotate your camera free of any focus shift. It also has a filter slide that lets you slide 52-mm or 48-mm filters in and out of the light path (extra slides are available to keep your filters mounted). The only downside to this system that I found was that it was not wide enough to accept my Baader 2-inch filters. This issue is not unique to the Borg. The Baader filters are thicker than most by a good margin and also do not fit in the Astronomik filter drawer system.

Borg is one of the few telescope manufacturers who put any performance data on their site and, to my knowledge, only Astro-Physics consistently provides comparable amounts of performance data (Canon, to their credit, publishes MTF curves on their lenses). For example, the current 101 f/4 system has the following published graphs (note, there is an older objective + f/4 reducer set also on the site, but one designed for 6x7 film), shown in **Image 4** shown on next page (color added for clarity).

On the left we have plots of the spherical aberration for four different wavelengths of light (often labeled the longitudinal aberration plot). This shows where different colors reach focus (c=656 nm, d=589

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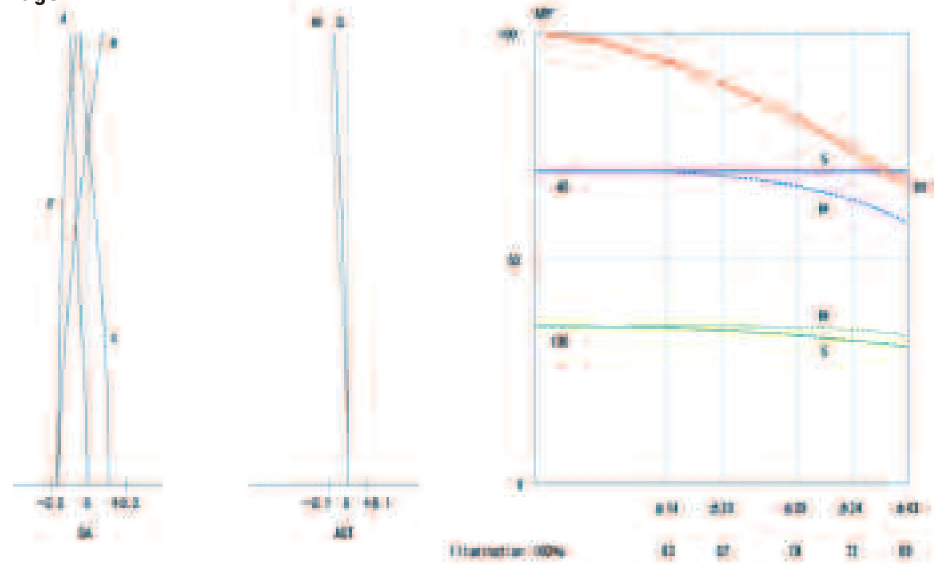
Image 4



Spherical aberration (left), astigmatism (middle) and combined percent-illumination and MTF data for the Borg 101 f/4. Diagram colorized and used with permission from Hutech.

nm, g=435 nm, F=486 nm). A perfect system would have all lines cross at a single point. In cases where they don't, some colors will be in focus and others will not. The result of this is chromatic aberration. Visually, since we will focus most likely on green light (where our eyes are most sensitive), this will often lead to the "purple halo" as violet light is not in focus. This isn't quite on level with the highest performing triplet Apos out there and is why some reviews have noted a touch of chromatic aberration on bright objects at high powers. But, this is a 400-mm f/4 astrograph. In this setup, you're not using it as a high-magnification lunar or planetary scope, but as a wide-field ("low power") scope. The proof will be in the pictures to see if this introduces enough chromatic aberration to be picked up with typical pixel sizes and targets.

In the middle, we see the astigmatism plot (M and S refer to directions meriodonal / tangential and sagittal / radial). The astigmatism plot shows a lot of information here. The bottom of the plot is the center of the image and the top is at the edge of a 22-mm image circle (i.e., 11 mm from the middle). A perfect lens system would show two vertical lines atop each other. If M and S diverge, we will see misshapen, astigmatic stars. If they track with each other, but deviate from 0, we will see the softening as the focus point has shifted. What we see here is that M and S are effectively atop each other and that there is only a minor deviation from vertical (approximately 0.1 mm). One could split the differ-

ence in focus and focus 5 mm from the center and balance this out. But, the stars should remain round to the edge.

On the right we have a combined %-illumination and MTF plot. The numbers on the bottom and the red line show the %-illumination at several circle-sizes (diameter). We see that for a 14-mm circle, the edge is 93% illuminated and for my 23-mm x 15-mm (27-mm diagonal) chip, I should expect illumination around 80% (I measured 85%).

The MTF, or Modulation Transfer Function, describes how "sharp" a lens is. The form here shows how much contrast there is in an image of a fine a line grating (100 and 40 lines / mm) as a function of distance from the center (x-axis) and angle of the lines (M = oriented perpendicular to the line from the middle of the image to a given point, S = oriented or parallel to that line). This shows us just how much off-axis "softening" of the image we can expect on high frequency (100 lines/mm, green lines) and low frequency (40 lines/mm, blue lines) components of the image. This is a very nice curve, letting one see that not much softening occurs out at 27 mm. One could go even beyond this before it would become objectionable. Note, these are extremely high-resolution targets. Canon is to be applauded for publishing MTF curves like these on their lenses, and they make very fine optics, used by many for wide-field astrophotography. But, they chose 10 lines/mm as their low frequency target and 30 lines/mm as their high frequency target. If you attempt to compare curves, keep in mind that the Canon's high-resolution target is lower resolution than the Borg's low-resolution target.

In the Field

I've gotten the Borg out on a number of occasions now and am pleased to report that I am quite impressed. I have gone through at least four refractors and three field flattener / reducers in an effort to find something I would be happy with and keep. The Borg is a keeper. Here's why.

Physical Characteristics

The Borg is about the same size and weighs less than a very nice triplet 80-mm scope I had. Yet, it gathers over 50% more light. It weighs only 5.5 pounds, making it easy on the mount and it fits inside a very svelte case. Want to travel with it? Unscrew the objective and put it in its nice bag and everything fits in even a small carry-on without concern. Despite weighing next to nothing and having a main tube the size of many 80-mm scopes, the thing is solid. There is no flex that I can find in it. In part this is due to the fact that for photography, there is no need to ever resort to a 2-inch or 1.25-inch eyepiece barrel. Everything screws in (with a very smooth feel). The one thing that does slide in and out (the main tube's drawtube) is clamped in place by two screws at 120 degrees (with the opposing side making the third contact point).

Focuser

The helical focuser works like a charm. Many readers have bad visions of helical focusers as they imagine the camera rotating during focus. The Borg helical focusers don't rotate the camera / eyepiece (one very low-cost one, the #4317 does, but this is the exception). Think of a SLR camera lens (before auto-focus or think of the zoom on your auto-focus DSLR). You rotate a ring and it changes focus. The "standard" model I chose has had no issue with camera load and it's almost impossible (if not impossible) to get it to move by any means other than rotating the ring. What's more is that it has no backlash I can detect at all. Oh, and it has index marks every 80 microns. So, as you're evaluating focus at various positions, you can return to the same spot within 80 microns (0.08 mm) just by using the index marks.

If you feel you must have a Crayford style focuser or the ability to connect to your computer for auto-focus, Astro Hutech offers a Feather Touch model that can be used instead, screwing straight into the 57-mm threads on the drawtube. While I love a Feather Touch focuser (I had one on one of my various small refractors I've gone through), for my purposes the helical was the better choice.

Images: On and Off-axis Sharpness, Color, Etc.

There's not much point to good mechanics in a scope if the optics don't hold up under scrutiny. Sure, it looks pretty and feels nice, but if the scope doesn't have it where the photons hit the silica, it's not of much use. I'm pleased to report the Borg passes here with flying colors (and really only colors that are meant to be there). While not as bright as Venus or the Moon, few would argue that M45 isn't bright. In **Image 5** shown on next page, we have some bright stars

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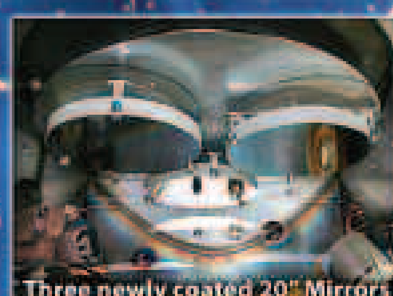

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Crop of the core of M45 showing performance in the center of the field on a target with wide dynamic range. Stars are crisp with no obvious issues. Reflections around brighter stars are off of the CCD coverslip, not off of anything in the Borg.

amidst a sea of blue reflection nebulosity (with some nice bright ones on a dark background). It's a non-trivial target for scope and camera alike and presents a good test of real-world control over chromatic aberration and contrast.

The images in **Image 6** were taken on a CCD Labs Q8-HR (DSLR sized chip) using Nebulosity, guided on a Takahashi EM-10 guided using PHD Guiding, an 8x50 finderscope cum-guide scope, and a Fishcamp Starfish. A total of 120 minutes (40 frames at 3 minutes each) were used. Bad Pixel Mapping was used in lieu of darks and processing was done in Nebulosity, PhotoShop, and PixInsight. No noise reduction, smoothing, or anything "local" was done and nothing was done that would specifically enhance or obscure chromatic aberration. First up, we have a crop of the core shown in **Image 5**. If I am truly obsessive I can just barely pick out a ring of violet around the stars on the black background. I have to be looking hard for it and zoom way in, and then I can only see it on a few stars. I can see the reflections off of the Sony ICX453's cover glass on the Sisters here. The fact that the reflection halos aren't centered on the stars indicates that my CCD isn't perfectly square. Despite this, the stars are nicely round.

Round stars in the center aren't tough to come by. What is tough is keeping them round as you move way out in the corners of a good-sized chip. While not the biggest chips out there, DSLR-sized (APS-sized) chips put a lot more demand on your optics off-axis performance than more modest sized chips. They often expose flaws you never knew you had. How does it do at the corners? Here, we have full-size crops from all four corners in **Image 6**. Stars are round with no noticeable aberrations. We're sharp to the edge.

While sharp to the edge, we're not 100% illuminated to the edge. I recorded a drop to about 85% illumination at the corners of the frame. This was easily taken out with a flat frame (real or artificial).

At f/4, your focus is critical. On my Vixen R200SS 8-inch f/4 Newt with a Baader MPCC, I actually use the fact that off-axis aberrations show up easily when out of focus to help fine-tune my focus. I tried that trick here, only to discover that, unfortunately, the Borg 101 doesn't make odd-shaped stars in the corners when slightly out of focus. They're just slightly out of focus. Here, in **Image 7**, we see the corner of a shot of the Rosette with the

whole frame just a touch out of focus.

Summary

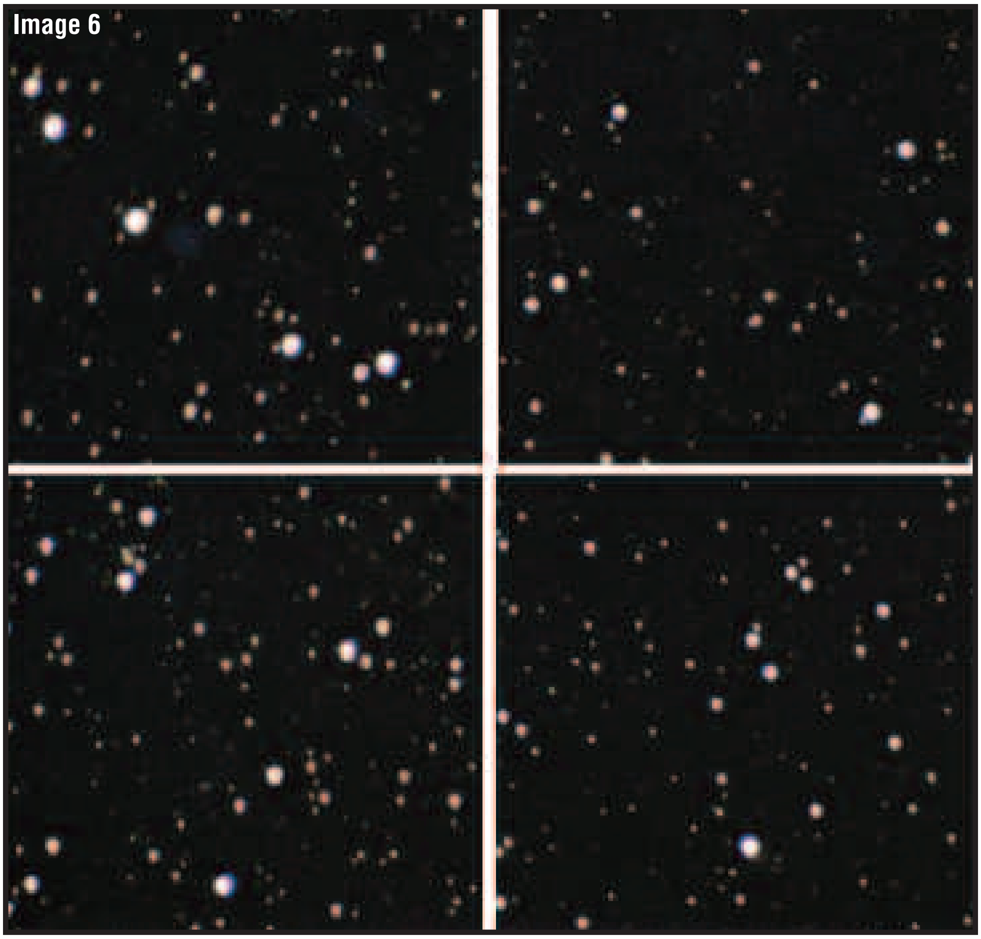
There are many excellent refractors out there these days at many different price points. The Borg 101 ED f/4 has a lot in common with other telescopes out there. It is portable (though more so than any other 4-inch I've seen), can put up very nice views (without the f/4 reducer, it's a fine visual scope), and should set the owner up for years of enjoyment. It has a number of things that set it apart from other scopes, however. Most notable is that it isn't one scope. It's whatever scope or set of scopes you want it to be. If I were hopping on a plane to Australia for a vacation, I'd love to bring a scope with me. I've never seen Omega Centuri and couldn't pass up the chance. Were the Borg purely an f/4 astrograph, I'd consider something else. But, in a few minutes, it's an f/6.3 scope that is easily packed in carry-on. If I have a camera here with a very different internal back-focus, it's simply a matter of swapping out extension tubes to get it to the right distance. Heck, if I decide that I want to be able to go wider, I can swap in a 77-mm objective to get to 330 mm. Decide to put a tax rebate to something bigger? I can swap in a 125-mm objective and a new tube, keeping the rest of the scope. Headed backpacking and don't want to take the nice ED objective with me? Swap in an achromat and consider it an insurance policy.

The point here is that the Borg can be anything you want and can change as your needs or desires change. The versatility here is almost limitless. No other scope / scope system on the market offers this kind of versatility.

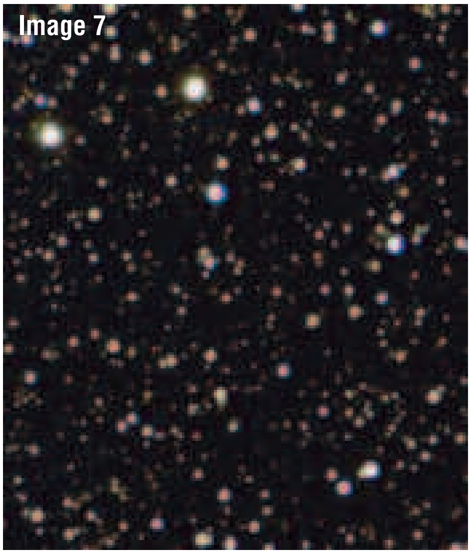
Versatility without performance would be useless, but the Borg delivers here as well. On axis and off, with a good-sized chip, the Borg delivers clean stars and nice contrast. Its mechanics make it very well suited to astrophotography to boot.

So far, I've yet to say anything really negative about the Borg. Were there things I would change if I could? Sure, but most are far from reasonable (it's not reasonable that it should cost $20 for example). Here's the small, semi-reasonable, nit-pick list: 1) I wish the focuser had a bit more travel. The drawtube setup works well to give you a rough focus, but more travel is never a bad thing. 2) It still does vignette a bit on the APS-sized chips, so I still need flats. 3) It would be nice if the filter slide held my Baader filters, but in my book, Baader gets the blame here for making filters a lot thicker than others. That's the list in its entirety and none of these are large issues or unexpected issues.

In closing, while one often doesn't show "first light" images, Figures 8, 9 and 10 (shown in the online magazine version of this article at www.astronomytechnologytoday.com) are the very first images I took one with the Borg (apart from one night of about 20 minutes of quick test shots to determine the optimal set of spacers for my camera). The fact that there were no kinks to work out, no mechanicals to rework, no duct tape to apply, etc. for it to perform this well speaks volumes. ATT



Crops of the four corners of the same shot of M45 showing performane at the edges of an APS-sized frame (27 mm diagonal). Stars are sharp and round with no obvious aberrations.



(Corner_Slight_Defocus) Crop of a corner of a shot of the Rosette Nebula taken with a slight defocus. While stars are softer than optimal and careful inspection can show the defocus, there are no other readily apparent aberrations.


Figure 8


Figure 9

Figure 10

Figures 8, 9 and 10

Sample full-field frames taken on the first night of imaging with the Borg. Total exposure time for each was 2-3 hours on a CCD Labs Q8-HR. Other equipment used: Takahashi EM-10 Temma, 8x50 finderscope converted into guide scope, Fishcamp Starfish guide camera, Nebulosity image capture software, and PHD Guiding.