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The Evolution of Intelligent Design

A History of Starizona's HyperStar

By Scott Tucker

Any device that claims to inexpensively convert a mass-produced Schmidt-Cassegrain telescope into a high-speed, wide-field imaging system with excellent optical performance, sounds too good to be true. Telescopes for imaging are supposed to be expensive and astrophotography is supposed to be hard. At least, that used to be the way everyone thought.

But times have changed and technology has made astrophotography accessible to almost any amateur astronomer. Computerized telescopes and inexpensive CCD cameras have put equipment within the reach of the average stargazer. Now Starizona's HyperStar system makes deep-sky imaging not only affordable, but also extremely easy.

In 1997, Celestron released the Fastar 8 telescope. The scope featured a removable secondary mirror, allowing a Fastar lens to be installed, converting the scope from $f/10$ to $f/1.95$. This resulted in a 25-fold increase in speed, shortening exposure times dramatically and providing a much wider field of view. At the time, only relatively small CCD sensors were available to most amateur astronomers. The short focal

length of the telescope in Fastar configuration was ideal for these smaller cameras. In particular, the Fastar was designed to work with the Pixel-255 camera, an SBIG system sold through Celestron. An upgrade of the camera to the Pixel-237 model (later sold directly through SBIG as the ST-237 and then ST-237A), provided a larger chip, but was still small compared to most of today's cameras.

People seemed slow to catch on to the Fastar idea. Ten years ago most astrophotographers still used film, and a common lament regarding CCDs was that the field of view was too small, due to the small size of the sensors compared to film. Also, there may have been a belief that astrophotography was just supposed to be difficult. After all, the great historical astrophotographers like E. E. Barnard spent hours taking single exposures. There was a sense of pride in a kinship with the masters, spending hours



standing behind a scope, manually guiding through a crosshair eyepiece, wondering what in the world that noise was in the bushes. There was a certain machismo in being an astrophotographer, and the rewards for one's efforts were perceived to be greater because of the difficulty involved in obtaining them. Fortunately that mindset began to change, but it has been a slow revolution.

The Fastar 8 was never a big seller, but Celestron began to include the Fastar option on their popular computerized telescope, the Ultima 2000. The start of the computerized telescope age helped to popularize Fastar, but still relatively few astronomers were using the system. After spending some time with the Fastar system, Starizona realized the potential for high-

HYPERSTAR THE EVOLUTION OF INTELLIGENT DESIGN



Rosette Nebula – Image by Steve Loughran, HyperStar C8, QHYCCD QHY8 CCD Camera

speed CCD imaging. But there were still shortcomings, primarily in the limited size of the CCD cameras available. Still, as a means of getting successful results right away for a new astrophotographer, Fastar was a great system.

Celestron also released a Fastar lens for their 14-inch SCT, converting it from $f/11$ to $f/2.1$. However, like the 8-inch Fastar, the lens was designed to match the Pixel camera. As the digital photography revolution advanced, it became apparent that there would come a day when astrophotographers would outgrow Fastar. Once bigger CCDs became available to more astronomers, Fastar reached its limits.

Dean Koenig, owner of Starizona re-

calls his first experience with Fastar. “I was always an ‘oh, wow’ kind of observer; I loved visual observation. But the very first night I used a Fastar telescope, I was hooked on imaging. I was amazed that in a single 30-second exposure, I could see more than at the eyepiece of my 20-inch Dobsonian. I was sold.”

Koenig also realized the limitations of the system. So he posed a question to a friend and experienced optical designer. Was it possible to improve on the Fastar system? The answer came back “yes,” and HyperStar was born.

Fans of Celestron’s Ultima 2000 telescope had long been waiting for the day when the company introduced an 11-inch

go-to SCT. That day finally arrived with the release of the NexStar 11 GPS. In addition to providing lots of aperture with computerized functionality, the telescope featured the removable secondary mirror associated with the Fastar system. Many users of the NexStar 11 began eagerly awaiting the Fastar lens itself. However, production never began on the 11-inch Fastar lens. Conveniently, at the same time, the HyperStar lens from Starizona was finally coming together.

In 2002, Starizona released the first HyperStar lens, designed for the 11-inch Celestron. It improved on the Fastar lens in three regards: speed, performance, and compatibility. The first HyperStar converted the telescope to $f/1.8$, a 30-fold increase in speed over the standard $f/10$ configuration. The optical performance was improved over the original Fastar lens. And, perhaps best of all, the lens was compatible with a wider range of cameras. The Fastar lens was optimized for use with the 6-mm sensor in the Pixel-237 camera, while the new HyperStar lens accommodated sensors up to 11 mm.

With the introduction of HyperStar, high-speed CCD imaging started to become more popular, but again, the idea was slow to catch on. Larger CCDs and digital cameras began to bring about the death of film photography. Astrophotographers were starting to embrace the age of digital imaging. But the long-exposure mindset still existed. Plus, there was an ingrained opinion that mass-produced SCTs simply were not cut out for high-quality as-

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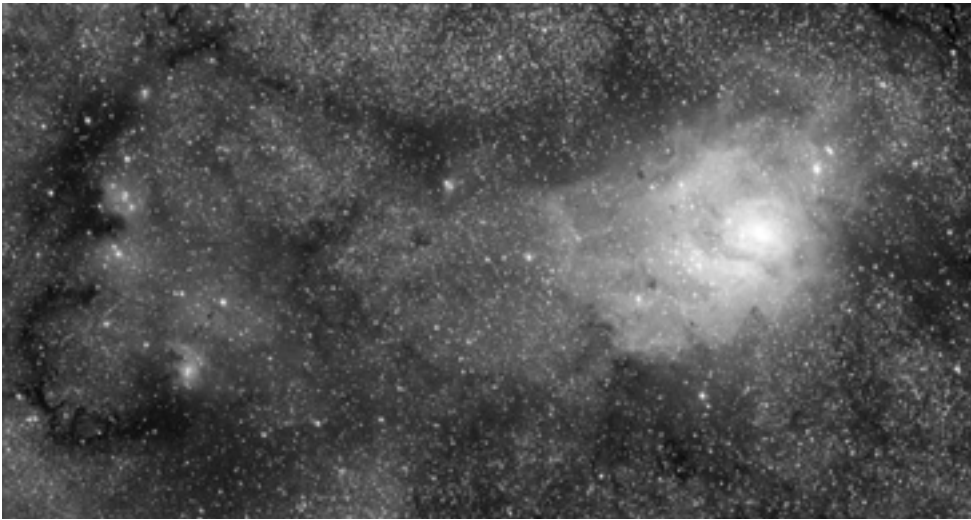
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M8 – Image by Gil Esquerdo, HyperStar C11, Starlight Xpress SXVF-H16 Camera, telescope in alt-azimuth mode

trophotography. Premium apochromatic refractors remained the telescope of choice for wide-field imaging.

Starizona followed up the 11-inch HyperStar lens with a model for the Celestron 14-inch SCT. The larger aperture of the C14 allowed for a larger CCD sensor to be used; in the first HyperStar C14 lens, up to a 15-mm sensor could be handled. At f/1.9, the HyperStar C14 was nearly 25 percent faster than the original Fastar.

I recall the first night out with Dean Koenig and the HyperStar C14. We tested the lens on David Levy's 14-inch SCT at Levy's observatory south of Tucson. We used the SBIG ST-10 camera for which the HyperStar had been optimized. Our first target was the Trifid Nebula. We aimed the telescope and took a 60-second exposure,

assuming this would be sufficient to at least see the object. We were using the first-generation ST-10, which used a parallel port connection. There was a 3-minute download period, which I think only added to the suspense of seeing the first image through the new HyperStar. When the image finally displayed on the computer screen we were amazed to see that not only was the Trifid there, it was completely overexposed! We shortened the exposure first to 30 seconds, then to 10 seconds, before getting an image that looked right. I remember laughing the entire time, thinking of all the time I had spent guiding 2-hour astrophotos with film – and here was a deep-sky object in 10 seconds!

A HyperStar lens for the 8-inch Celestron soon followed, making high-speed imaging available to users of the most pop-

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M31 – Image by Fred Lehman, HyperStar M14, Starlight Xpress SXVF-M25C Camera

ular-sized telescope. It was then discovered that Meade was shipping certain telescopes with removable secondary mirror assemblies. There were no comparable Fastar-type lenses from Meade, it just happened

that the way in which the secondary mirror assemblies were mounted, they were easily removable. A HyperStar lens for the 10-inch Meade was the next in the HyperStar family.

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The first major step toward the current line of HyperStars came with the design of the HyperStar lens for the Meade 14-inch SCT. Starizona went back and re-evaluated the design of the HyperStar to see what the ultimate limits of the design were. At the same time, the popularity of using digital SLR cameras for astrophotography was growing. The HyperStar M14 was thus designed to be compatible with not only CCD cameras, but also DSLRs. HyperStar could now cover sensors up to 27 mm in size.

The HyperStar C14 was redesigned to take advantage of the improved performance. As larger cameras became less expensive and available to more imagers, the demand for larger-format HyperStar lenses for the smaller telescopes grew. In early 2008, Starizona released the HyperStar 3 lens for the 8-inch Celestron, followed a few months later by the HyperStar 3 for the Celestron 11-inch. Both the 8-inch and 11-inch systems had been through two previous generations, improving optical performance and mechanical design, but remained limited to 11-mm sensors, hence the new models being designated HyperStar 3. 27-mm sensors were now compatible with most of the HyperStar lenses, and DSLRs in particular could be used with the 11- and 14-inch models.

Eventually, Celestron discontinued outfitting their telescopes with removable secondary mirrors. Also, the increasing popularity of the system made for a demand for older telescopes or new models without removable mirrors to be used with HyperStar. Starizona began manufacturing conversion kits to retrofit non-compatible telescopes to allow use of HyperStar lenses.

The HyperStar takes advantage of the fact that the primary mirror of an SCT operates at $f/2$. Thus the HyperStar is a field corrector rather than a focal reducer. Normally, the secondary mirror provides a 5x magnification factor, yielding an $f/10$ system with focus at the back of the telescope. By removing the secondary mirror, focus is moved to the front of the telescope, and the

HYPERSTAR THE EVOLUTION OF INTELLIGENT DESIGN

focal ratio goes to $f/2$. However, removing the secondary mirror induces aberrations that the secondary normally corrects, primarily spherical aberration. The HyperStar lens corrects not only for this aberration, but also coma, astigmatism, chromatic aberration and field curvature. The result is excellent optical performance across a very large field of view.

The telescope in HyperStar configuration outperforms the native $f/10$ system. In fact, stars are up to 12 times smaller at $f/2$ than at $f/10$, over the same size sensor. Performance rivals that of the best apochromatic refractors. Measurements of star sizes in images taken through a 4-inch apo refractor and a HyperStar C14 with the same camera are identical. Plus, the HyperStar system has an extra 10 inches of aperture and a focal ratio 8 times faster!

To arrive at this level of performance, a new mechanical feature had to be introduced into the HyperStar lens: the ability to collimate. It was discovered that performance, especially with the larger-format versions of the lenses, was not always equal across the full field. This is due to the fact that the primary mirror of the telescope is not always perfectly orthogonal to the optical axis. This can normally be compensated for by collimating the secondary mirror, but with HyperStar there is no secondary mirror. By making the HyperStar lenses collimatible, Starizona allowed the system to reach its full potential. Collimation is easily achieved with three sets of thumbscrews. To compliment the collimation system, the HyperStar lenses also feature independent camera rotation, allowing the camera to be oriented as desired while retaining the collimation of the system.

All components of the HyperStar lenses are manufactured in the USA and are hand assembled at Starizona. A HyperStar lens includes a counterweight (except for use with German equatorially mounted telescopes, where it is unnecessary), a holder to protect the secondary mirror while out of the telescope, and a custom-fit hard carrying case.

An adapter for one camera is included with the HyperStar lens, while others are available optionally. Each camera requires a separate adapter in order for the distance from the HyperStar lens to the camera's focal plane to be set correctly. This distance is very critical at $f/2$ and is crucial to getting the ideal performance out of the lens.

Switching from the standard $f/10$ configuration to the $f/2$ HyperStar mode takes just a couple minutes. Replacing the secondary mirror to go back to $f/10$ is equally quick. Collimation is retained thanks to an indexing pin and notch on the secondary mirror assembly, so no adjustment is necessary after using the HyperStar. Starizona's website features a short video showing how simple it is to install a HyperStar.

The high-speed imaging revolution is finally sweeping through the astrophotography community. Now compatible with a wide variety of cameras, the HyperStar system has become extremely popular. Once thought of as a useful gadget for new astronomers just getting their feet wet in as-

trography, HyperStar has become a mature imaging system, providing ease of use for beginners and high performance for advanced imagers.

I'm convinced the future of astronomy is imaging. The number of amateur astronomers engaged in astrophotography is growing rapidly. As light-pollution becomes ubiquitous, imaging becomes ever more essential to seeing the wonders of the night sky. HyperStar can be used like an extension of visual observing. The images come down to the computer with very little delay, and with typical exposures of 30 seconds, there is hardly any wait whatsoever. In fact, with a high-sensitivity video system, such as the Mallincam or Stellacam, it is possible to do deep-sky imaging in real time, making HyperStar the perfect teaching tool for schools, planetariums, and star parties.

Now that amateur astronomers have realized it's not necessary to wait and suffer to take astrophotos, the future of astronomy is here now. **AM**

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Deep-Sky Imaging with Starizona's Hyperstar

How the New Forest Observatory Re-discovered the Hyperstar

By Greg Parker

I took my very first deep-sky HyperStar image of M42 (see *Practical Astronomer* magazine, December 2007 issue, page 8) back in November 2004 from my New Forest Observatory in Brockenhurst, Hampshire, U.K. (www.newforestobservatory.com), shortly after buying the SXV-H9C one-shot colour CCD from Starlight Xpress.

In fact, I bought the HyperStar to go with my Celestron Nexstar 11 GPS scope over two and a half years earlier as it was always my intention to carry out deep-sky imaging. My decision to choose the Celestron scope in the first place was dictated by this amazing HyperStar device. I knew nothing about imaging at the time, but the concept was really cool (to me at least), and the scope with the HyperStar fitted looked like such a strange beast that I simply had to own one, if only to see how this thing actually worked.

The first HyperStar I bought from Starizona had no adjusters at all, not for collimation or for camera rotation, and it now

seems incredible that the first time I bolted that HyperStar to the C11, I achieved almost perfect collimation. I won't bore you with my particular learning curve of first going to equatorial mounting and then finding out about taking large numbers of sub-exposures and adding them altogether; instead I'll go straight to the turning point of my HyperStar experience.

One evening I wanted to image both M81 and M82 in the same field of view, but this meant the HyperStar would need rotating. No bother! I reached into the dew-shield and gave the whole secondary cell assembly a twist of a few degrees. I then took a sub to see what I got, and of course it was disaster time! I had completely lost the collimation, the star shapes were all peculiar, and I walked away feeling sick – for about a week. When the panic finally subsided and common-sense returned, it was clear to me that there was a position of perfect collimation (there was at least an existence proof). So the prob-



lem now became, how was I to return to this “magic” position?

The whole secondary mirror assembly had a clearance approaching 1 mm all around its circumference within the corrector plate, so I drilled four holes in my beloved C11 and fitted four screw rods at 90 degrees to each other as shown in **Image 1**. These screw rods allowed the secondary mirror assembly to be moved around within that 1-mm clearance in the collector plate, and by trial and error I could once again return to a collimated optical system. Fortunately, it really wasn't too difficult to achieve reasonable collimation, although to tell the truth, I never managed to get back to the level of collimation that I hit the very first time just by pure luck.

Then there followed a period of two years imaging with this wonderful system, and together with Noel Carboni (Florida, U.S.A.), who carries out all the image pro-

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cessing work on my raw data, we turned out some pretty impressive HyperStar deep-sky images [Image 2 seen on pages 40-41, and the image on cover]. It should be noted that we were doing this at a time when the consensus opinion was that you simply couldn't take high-quality images with the HyperStar system! Many deep-sky imagers on the forums were adamant that the HyperStar simply wasn't up to the job. I tried to get the message across that it was capable of stunning images – if it was properly collimated to the optical system – but my words largely fell on deaf ears.

The large output of work that followed over the next two years formed the basis of two major Exhibitions of deep-sky images held at the University of Southampton and at the main exhibition hall in Brockenhurst. There were around 50 framed A1 and A2 prints presented at each venue. In addition to the Exhibitions, many of the HyperStar images appeared in U.K. astronomical publications, including *Astronomy Now* and *Sky at Night Magazine*. The New Forest Observatory also appeared on BBC TV's "Inside Out" programme and on ITV's (independent channel) Meridian News. Finally, HyperStar images also appeared in the national daily newspapers, the *Daily Mail* and the *Daily Express*, so the amazing images that were the result of the innovative HyperStar system were being brought to the attention of a large U.K.-based audience.

Towards mid-2006, I fancied a change. I wanted to be able to take images with a bigger CCD camera, the Starlight Xpress SXVF-M25C, which is a 6-megapixel CCD compared to the SXV-H9Cs 1.4 megapixels, and I was also getting more than a little tired of collimating my rather Heath-Robinson setup on a fairly regular basis. To this end I changed my imaging system completely to a Takahashi Sky 90 refractor at $f/4.5$ as the main imaging scope, and the large SXVF-M25C one-shot colour camera as the main CCD imager. My beautiful C11 was now relegated to the role of guide-scope!

For nearly a year and a half I worked with the new setup and it was refreshing to

have such a large, flat, field of view with good star shapes across the whole 3.33 x 2.22 degrees this system gave me. I took some pretty fine images with this system, but these were marathon imaging sessions taking many hours of valuable imaging time to produce high-quality images. For example, the images of M31 and the Veil Nebula [Images 4 and 5 seen on pages 40-41] took in excess of 30 hours each of total imaging time, including narrowband data on top of the one-shot colour data. It should be noted that it took Noel Carboni about the same amount of time to process the data as it took me to acquire it in the first place. Taking images this way was proving to be very costly of our valuable time!

I was fortunate enough to be on a year's sabbatical leave from the University of Southampton during this period, so I could be out imaging every clear night, all through the night. But this luxury was due to come to an end in June 2008 and I was at a loss as to how I was to continue to turn out the volume of work.

On returning to the University in June 2008 there was an unexpected chain of events. I was to go out to Phoenix, Arizona, to accept some semiconductor deposition equipment for the University's new clean room facility. As we know, Arizona means Starizona, and I let Dean know I would be out there for a few days. To cut a long story short, Dean shipped the new version III HyperStar and a Starizona MicroTouch focuser to my hotel in Phoenix and I unpacked all the goodies the second I got back to the New Forest Observatory.

I know I shouldn't have attempted to get the HyperStar up and running whilst still jet-lagged, but I ignored my family's warnings and tried anyway. I managed to put the cog on the MicroTouch focuser the wrong

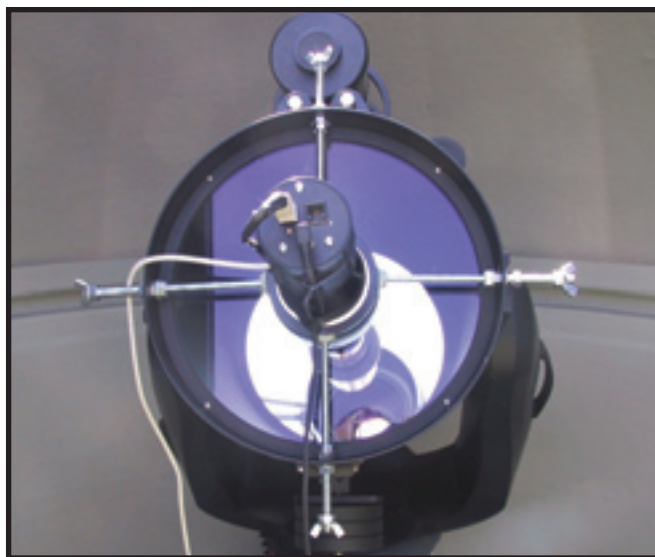


Image 1 The original Hyperstar Setup Showing the Added Adjuster Rods

way around, and I couldn't figure out how the HyperStar fitted to my scope, as I hadn't realised it came with the secondary mirror holder already fitted, and this needed to be removed to fit the HyperStar to the C11. Dean came to the rescue as usual, and a cou-

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DEEP-SKY IMAGING WITH STARIZONA'S HYPERSTAR

ple of e-mails later and I managed to put my new HyperStar III system together – and of course it's just wonderful! The new version III Hyperstar fitted to the C11, prior to the connecting wires being brought out at 90 degrees to one another, can be seen on page 35.

The new version III HyperStar has collimation and camera rotation adjusters built-in, so it is a complete doddle to get excellent collimation, very quickly, with the help of CCDWare's *CCDInspector*

(www.ccdware.com). In fact, I got better collimation using just 15-minutes of setting up time with the HyperStar III than I ever managed to achieve with the Sky 90 and SXVF-M25C combination, so this was a very promising start.

First light for the new HyperStar was the central part of NGC7000, and for this image I used manual focus as I hadn't managed to set up the MicroTouch focuser at this time. Noel Carboni worked his magic on the raw NGC7000 data and the result can be seen in

Image 6 on page 40. I was highly impressed at the star quality corner to corner, and the small amount of vignetting present was no worse than that I had seen with the Sky 90 at f/4.5. But of course, the main thing was that this image only took 56-minutes of total exposure time! I had returned once again to the world of ultra-fast HyperStar imaging, and I can tell you, it was a great relief!

So far we have had a terrible summer weather-wise in the U.K., so I have only managed to take three further images since that first light image, including this latest one of the Coathanger Cluster shown in **Image 7 on page 40.** Taken on the July 27 2008, this used the amazing MicroTouch focuser which really takes the pain out of finding focus with low f-number systems. This image is only composed of 71 subs at 2-minutes per sub, yet the extremely faint reflection nebula LBN 130 can be seen lying just above the Coathanger.

I should point out that the depth of focus with my setup is somewhere between 7 and 8 microns, where the diameter of a

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human hair is around 80 microns. So, you are trying to position a large, heavy, 11-inch diameter mirror to an accuracy approaching one-tenth the diameter of a human hair. Doing this manually with an electric focuser is an extremely frustrating business. Clicking on an icon and seeing the focus lock into an FWHM of 1.3 after just a few seconds is great fun! I am now really pleased to have a finely-tuned HyperStar imaging system at the New Forest Observatory once again, and I will keep this particular setup for a very long time to come.

But is there anything that can be done to improve the HyperStar system still further? I think there are a couple of things that will make the HyperStar perfect, for me at least. Firstly, it would be nice to be able to change the 2-inch filter through a slot in the side of the adapter nose piece. This way you could change filters without having to remove the CCD camera and break into the optical train. I believe Dean already has this small design change under consideration. The second change I'd like to see is the HyperStar

made to accommodate a full 35-mm sized CCD – but then again, deep-sky imagers always want more and more, and it might be physically impossible (I don't know) to fit a 35-mm sized CCD to an 11-inch diameter f/2 system using a HyperStar lens assembly.

There is a book explaining how I took all the original HyperStar images and the system tweaks I used to bring the best out of the setup called *Making Beautiful Deep-Sky Images*. It is part of the Patrick Moore "Practi-

cal Astronomy" series published by Springer and is available through Starizona.

A second book will be published by Springer in January 2009. This is a large format coffee-table book of HyperStar and Sky 90 deep-sky images called *Star Vistas*, (www.starvistas.com) with Forewords by Sir Arthur C. Clarke, Sir Patrick Moore and Dr. Brian May. This is a "pretty picture" book, pure and simple.

Until next time, I wish you all clear skies and happy imaging. ☽

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Image 2



Image 5

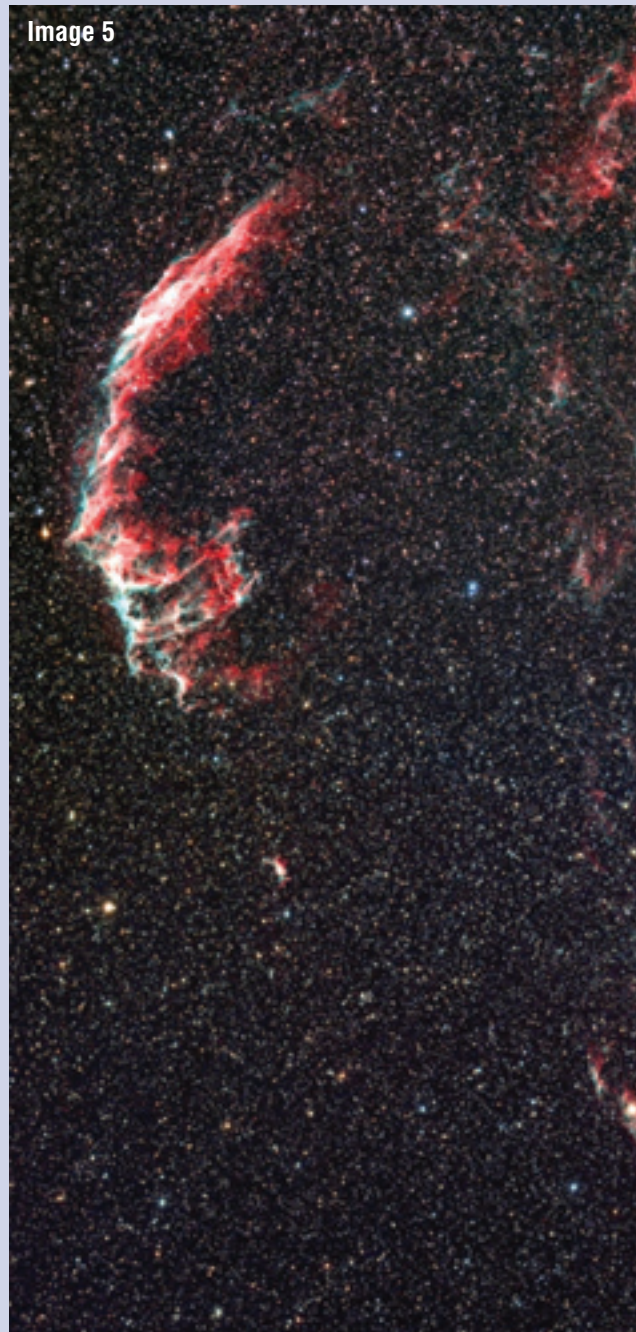


Image 6



Image 7



Image 3





Image 4



Image 2 – A 4-frame HyperStar Mosaic of the Pleiades

Image 3 – A 3-frame HyperStar Mosaic of the Horsehead Region

Image 4 – M31 Using the Sky 90/M25C

Image 5 – The Veil Nebula Using the Sky 90/M25C

Image 6 – First Light for the HyperStar III at the NFO

Image 7 – The Coathanger Cluster Courtesy of the HyperStar III