Greg Parker

Making Beautiful Deep-Sky Images

Astrophotography with Affordable Equipment and Software

Second Edition

Patrick Moore's Practical Astronomy Series

The Patrick Moore Practical Astronomy Series

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Springer

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*I dedicate this book to my wife **Helga** who continues to support my obsession and who (also) no longer has a single favourite image.*

Preface to the Second Edition

A great deal has happened since the first edition of this book was published nine years ago in 2007. This new edition incorporates a lot of the changes and developments that have occurred in deep-sky imaging, and many of the tips and tricks I have learned throughout the past few years.

I took early retirement from the University of Southampton in 2010, which has allowed me to spend a great deal more time on my obsession and hobby. There have also been major changes at the New Forest Observatory ® and with the original Hyperstar, which has since been replaced by a collimatable Hyperstar III.

Also in this edition are new chapters on parallel imaging and on how to process professional data to make high-quality deep-sky images without having to capture any ancient photons of your own. I have learned more about processing images from astrophotographer Noel Carboni during the past nine years. With my better understanding of how to properly create and process images, I am pleased to say that a completely rewritten chapter on image processing has been incorporated into the 2nd Edition of this book.

This book also contains new deep-sky images that I have processed over time. While the first edition contained Noel Carboni's images, this book features new material and new pretty pictures, many from the parallel imaging array. Thank you for the interactive Internet processing lessons, Noel.

I really envy those of you who will embark on this adventure for the very first time after reading the contents of my book. Savour and record every moment, it is truly a unique life experience!

Brockenhurst, UK — Greg Parker
2016

Acknowledgements

Firstly, I would like to thank John Watson from Springer Publishing who contacted me just over a year ago and told me that Springer was interested in a Second Edition of "Making Beautiful Deep-Sky Images." I would also like to thank everyone at Springer who gave me the go-ahead for this project, and then followed through by helping me put this book together.

I continue to be extremely grateful to Noel Carboni for showing me the arcane secrets of processing deep-sky images. Noel has patiently sat with me through many hours of Radmin sessions, allowing me to see exactly what he does on his computer to monitor Florida, U.S.A., thousands of miles away. Your patience is boundless Noel, as is your knowledge of Photoshop.

I am still very grateful for Alan Chen's help on the Yahoo Starlight Xpress (SX) forum, and to Bud Guinn on the "Our Dark Skies" (ODS) forum, which no longer exists. Bud introduced me to ODS from the SX forum and has been a great help and inspiration to me since I first started imaging. Bud also introduced me to the deep-sky imaging guru Noel Carboni on the ODS forum – and the rest, as they say, is history.

Much thanks and appreciation goes to David Squibb of Tavistock, Devon, who was my "A"-level Physics teacher many decades ago. It was David's dedication to the Physics education that led me to write this book and a textbook on semiconductor device physics.

Finally, although I have already dedicated this book to her, I would like to mention that without my wife's continuing interest and support in something she doesn't even understand (although she really likes the results), this project would not have been started, let alone completed.

Brockenhurst, UK
2016

Greg Parker

Contents

Chapter 1

How did I start?

This chapter is meant to give you some idea of deep-space imaging if you are just starting out in the field. Personally, I find it very useful to see how other people entered the hobby, because then you can see what their major mistakes were and learn from them.

I am fortunate enough to live in a semi-rural location with reasonably dark skies. I was also in the fortunate financial position of being able to buy myself a reasonable-quality telescope. At this point in time, sometime in January or February of 2002, I was solely interested in carrying out visual work, which I knew nothing about, and had very little interest in imaging of any sort at all. So, as I wanted a good telescope for visual observation, I went for the biggest refractor that my budget would allow. My first purchase was a beautiful 6-inch Helios refractor with motor drives for both axes, and no computer control. This was a considered choice on my part, I wanted the "fun" of finding all the deep-sky objects I'd read about, using my own skills, no computers. The scope performed admirably and gave beautiful bright, high-contrast views of the planets, and also of large galaxies and nebulae. On the other hand, I did not perform admirably; I was clearly useless at finding where all these Messier and Caldwell objects were hiding. I did not properly polar align the telescope, and I did not use the motor drives correctly, so when I did find objects, they were always drifting out of the field of view. After returning to view the few objects I could find night after night I realised I had actually made a big mistake – I really did need the computer "goto" capability to get these evasive objects into my field of view. After admitting defeat after about three months, I bought the Celestron Nexstar 11 GPS Schmidt-Cassegrain reflector with an Alt-Az computer-driven mount (fork mount), and I spent the next two years happily carrying out visual observations.

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The first couple of outings with the Nexstar 11 GPS were very disappointing indeed, mainly because I didn't really know what I was doing and I was only just beginning to get to grips with the basics of the system; a system that seemed incredibly complicated to me at the time. In addition, setting up the "goto" required me to know the position of two alignment stars, so I had to start learning my way around the sky anyway, even if it was just to know what the brightest stars were called, and where they were located.

On a Thursday night in May, a clear crisp evening with good viewing settings, and what subsequently happened is the subject of a "Lateral Thoughts" article in the September 2002 issue of Physics World. To cut a long story short, this was the first time I had set the telescope up properly, and armed with my copy of Norton's, I quickly logged up 24 of the 27 objects listed on one page. I had never seen any of these objects before, and it really was a defining moment in my life and a night I shall never forget. My first ever views of M13, the Great Globular Cluster in Hercules, and NGC3242 a planetary nebula in Hydra called "the Ghost of Jupiter" are now permanently etched into my memory. I still get a "tingle" of excitement when I recall the beauty of that crisp, crystal-clear (Moonless) night.

As I was primarily into observing, it wasn't too long before I invested in the superb Celestron Bino-Viewers, which of course meant I then had to double up on all my eyepieces – an expensive move. This turned out to be a bit of a blow when I finally took the plunge and began CCD imaging, as I haven't looked through an eyepiece since. The first thing that I changed on the main scope was the totally abysmal holder for the little finder scope. I bought the Celestron "quick release" holder for the finder scope and to be honest this is the one Celestron should fit as standard as the supplied version simply isn't worth bothering with in my opinion. With the Celestron f#6.3 reducer/corrector and a few other optical accessories I was extremely happy observing for around two years. However, there are only a handful of objects that look truly spectacular through the eyepiece of an 11" reflector, and I found I was returning to these few objects time and time again. I was not searching out the less dramatic objects because, to be quite honest, I found them quite boring when I eventually did manage to track them down. It was clear that I was rapidly approaching the time when I needed to image the skies rather than just view them, so that I could see both faint and bright objects in all their glory, and in colour.

The move to create an imaging setup meant that I had to go for a permanent mounting rather than carrying the scope in and out of doors for each observing session. I will discuss my observatory in another chapter, but on reflection, I think I was very lucky not to have dropped the rather heavy Nexstar 11 GPS on its many trips in and out of the lounge door, with the rather large step down into the garden. So, the acquisition of a fibreglass dome also meant the purchase of a pier, and the fixing of the pier to a large concrete block in the ground. Details are covered in the observatory chapter, but the first major change from observing to imaging was the construction of the observatory.

To start serious deep-sky imaging I bought the Starlight Xpress SXV-H9C colour CCD. I had already purchased the Hyperstar lens from Starizona [http://starizona.com/acb/hyperstar/index.aspx] that converts the very slow f#10 Nexstar 11GPS into an extremely fast f#1.85 imaging system. It was the availability of the

Hyperstar lens assembly that led to my buying the Nexstar 11GPS over other similar makes of scope in the first place, just in case I wanted to move onto imaging at some later date. The decision to choose the Starlight Xpress SXV-H9C [http://www.sxccd.com/trius-sx9c] was quite easy to make (please note my original camera was not the Trius version shown in the link). I wanted a U.K. manufactured device in case it needed to be returned to base for repair. I also wanted a single shot colour camera as I was only interested in taking pretty pictures, and it seemed perverse to take monochrome images through at least 3 different filters and combine them all at the end when the job could actually be done in one go. So the final decision, for me, came down to either the massive SXV-M25C camera [http://www.sxccd.com/trius-sx25c] coming in at 6 Megapixels, or the smaller SXV-H9C coming in at a tiny 1.4 Megapixels. Both Starlight Xpress (Terry Platt) and Starizona (Dean) suggested the H9C as it would be much better matched to the (original) Hyperstar lens, and they have both been proved correct in practice. The M25C would have been far too large, and a lot of the chip's imaging capability would have been wasted due to the Hyperstar's small focal plane diameter. The SXV-H9C together with the Hyperstar lens [see Figure 1.1] gave me an extremely fast f#1.85 system with a field of view of 1 degree by three-quarters of a degree and a sampling of 2.57 arcseconds per pixel. For other "field reducer" systems, I found the Celestron f#6.3 reducer to be very nice, and the Meade f#3.3 to be unusable (due to vignetting and coma) at the lower f-numbers. It should be noted that all Starlight Xpress SXV imaging cameras are now of the more advanced Trius design.

So my initial imaging system was a standard Nexstar 11GPS in Alt-Az mode, SXV-H9C colour CCD imaging camera, and the original Hyperstar lens. The first thing that had to be changed was the focuser on the Nexstar 11, which turned out to be far too coarse for f#1.85 imaging. The depth of focus for the Hyperstar system on the 11 GPS is only around 7 microns; where the diameter of a human hair is on average around 80 microns. The standard Celestron focuser was replaced by the "FeatherTouch" focuser [http://starizona.com/acb/Feathertouch-SCT-MicroFocuser---Celestron-11-except-CPC-1100-P982C654.aspx] from Starizona, a straight replacement that gives coarse and fine focusing options using an outer and inner focusing knob. This is a truly superb product and it is indispensable for fine focusing if you are moving the main mirror of a large reflector to micron accuracy. At this point I also changed from taking a little VAIO laptop into the observatory to having a home-built 1GHz mini-ATX machine in permanent residence. Not having the portable little laptop made it difficult for me to manually focus the scope whilst trying to look at an image on the display, so the next addition was a Celestron motorised focuser that I modified to go onto the FeatherTouch focuser, see Figure 1.2. Now, whatever direction the telescope was pointing in, I could sit in front of the monitor and focus the scope with the hand-controller. At this point I could now start acquiring my first images. I was over the Moon (sorry) with my first efforts imaging M42, I thought they were fantastic, but I realise now of course that they were in fact very poor images. For a start, I did not use (or understand the benefits of) stacking sub-exposures, and I didn't realise how extremely poor the star shapes were either. More of very poor star shapes and the Hyperstar lens assembly a little later.

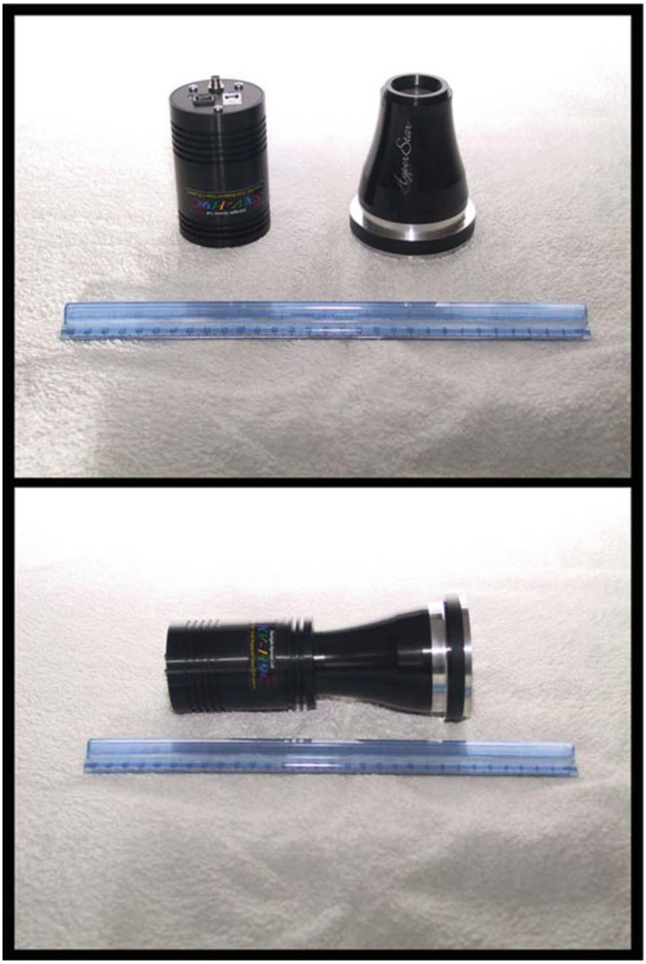

Figure 1.1 The Hyperstar lens assembly and the SXV-H9C one-shot colour CCD camera from Starlight Xpress. Bottom photo – the two elements connected.

Next, I started to use stacking, remember the telescope was in Alt-Az mode. The fast Hyperstar system meant I could take short sub-exposures (less than 30 seconds to prevent field rotation problems) and stack the subs together to get a reasonable final image. Except the supplied Starlight Xpress software would not stack AND rotate as was necessary for my field-rotated series of subs. Although the field rotation on any one sub was undetectable, if you took an hour's worth overall you could get several degrees of rotation that needed to be accounted for in the stacking software. So the next excursion was into different software packages. At first, I used AstroArt [http://www.msb-astroart.com/], a package I was very happy with, but I quickly moved onto Maxim DL for reasons I actually cannot now remember,

Figure 1.2 The standard Celestron electric focuser, mounted on home-built aluminium stand-off pillars, to fit the Starizona "FeatherTouch" focuser.

and I have stayed with Maxim DL ever since [http://www.cyanogen.com/]. At this stage Maxim DL was used for data (image) acquisition, and for all the image processing.

At this point, it would seem that things are entirely satisfactory, but of course the field rotation limitations of Alt-Az imaging finally got to me so I was forced to go equatorial. This required purchasing the Celestron heavy-duty wedge and adjusters (very naughty that the adjusters are bought separately Celestron) and I then had to redesign my all-aluminium Alt-Az pier for the new Equatorial system. The redesigned aluminium pier can be seen in Figure 1.3. Another thing I noted was the so-called "heavy duty" wedge was not so heavy duty after all, and it would shift a little depending on how the very heavy Nexstar 11GPS was cantilevered, i.e. the telescope's imaging position in the sky. Fortunately a very simple modification could rectify this design fault in the wedge, and I found that I did not have to reposition the wedge, after carrying out the first drift alignment, for over a year. The wedge modification can be seen in Figure 1.4.

As you can see the modification, using 2 mm thick Aluminium basically closes off the open box-section at the end of the wedge that led to the "warping" and loss of alignment when the scope was slewed across the sky.

Surely we must be there now? Equatorially aligned, fast imaging, large aperture scope, color CCD and software that both acquires the CCD data and carries out powerful image processing. Not quite, we still have the problem with "funny-shaped" stars, and sorting this one out took many months of effort and much pain. You will see from the original Hyperstar images presented in Chapter 13 of this book that the stars are pretty round, with the exception possibly of some coma at

Figure 1.3 The custom-made all-aluminium Equatorial mode pillar.

the extreme top corners of the field which is very hard to eradicate in any low f# optical system. I don't think you will find ANY other original Hyperstar/Fastar images that can show you decent round stars (unless they have been nicely "rounded" in software) across the whole field of view. The reason for this is quite nasty. An f#1.85 system is very unforgiving in alignment/focusing and the Hyperstar lens just sits in the secondary mirror cell. Now the secondary cell has some "slop" around the edge giving maybe +/- 1 mm of movement of the cell. Absolutely no bother if you have the standard secondary mirror in the cell, you just use the adjustment screws to set your collimation, but what about the f#1.85 Hyperstar lens? There was no adjustment in the initial design (the one that I had when I first started imaging of course have), and the placement of the lens within the corrector plate is a very hit or miss affair. I won't bore you with the details that

Figure 1.4 The modification made to the standard Celestron "heavy-duty" wedge. A 2 mm thick aluminium sheet is used to close off the open-ended box section of the wedge. Right-hand photo, the wedge in-situ.

made me persevere with getting this system finely tuned – suffice to say I knew there was a "sweet spot" where a collimated Hyperstar system would give very good results – so I had an "existence proof". Problem was, how do you "collimate" an original Hyperstar system that doesn't have any collimation adjustment screws?

I took a drill to my beloved Nexstar 11 GPS telescope, glued nuts to the outside of the secondary cell ring, and fitted four threaded rods that could physically push the Hyperstar assembly around within the corrector plate. The assembly can be seen in Figure 1.5. The collimation procedure is now exactly the same as for collimating the secondary mirror. Image an out of focus star and move the Hyperstar assembly to get symmetrical star patterns in the centre of the field of view; it is as difficult/easy as conventional reflector collimation. These four adjuster rods are the reason I get diffraction spikes around the brighter stars. I also got diffraction spikes before fitting the adjuster rods as the four cables from the back of the CCD need to somehow be routed out across the corrector plate. So, however you go about it, the Hyperstar assembly will give you some sort of diffraction pattern around bright stars.

Are we there yet? Sorry, not quite. It now became clear that for the fainter objects I wanted to image I needed to go for longer sub-exposures, I needed to move to auto guiding. This was a little more straightforward than I was expecting with only a couple of minor glitches to contend with. I bought the Starlight Xpress SXV auto guider camera, as this was compatible with the SXV-H9C. Maxim DL was already set up to be able to handle an auto guider with the SXV-H9C, so it was just a matter of buying a suitable guide-scope and I'd be ready to take some long exposures. I chose the superb little Celestron 80 wide-field scope as a guide scope. This is extremely light at only 2 kg and it operates at f#7.5, which meant that my auto guiding was very precise since I was only imaging at f#1.85. Typically during an imaging session the errors were less than 0.1 pixels. So what were the glitches? Well at first, the auto guiding simply did not work. It was fortunate that there was

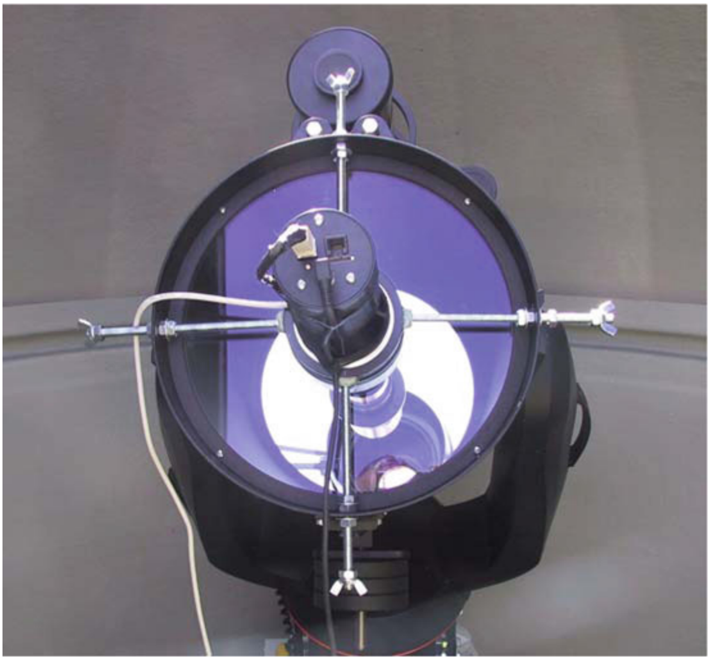

Figure 1.5 The threaded rod adjusters used to collimate the Hyperstar lens to the Nexstar 11 GPS. The threads are covered in black tape prior to imaging or you will get a very strange diffraction pattern around bright stars due to the fine threads.

a "manual control" in the Maxim software as this allowed you to see if you could physically move the scope by clicking on direction buttons. The scope did not move. It turned out that you couldn't use a standard "telephone" cable connection between the imaging CCD and the Nexstar 11 GPS; it doesn't have enough connections. I put together my own home-built solution and at last the software "talked" to the scope and I could start to try auto guiding. My first auto guiding session was very disappointing. The stars were badly trailed and I actually had better results without the auto-guiding being enabled. This was due to incorrect parameters being used in the auto-guiding program. With a couple of nights of trial and error I iterated to a set of guider parameters that seemed to work rather well, as stated earlier, the R.M.S. errors for an evening's observing were typically less than 0.1 pixels. I now use auto guiding for all subs longer than about 30 seconds, and no auto-guiding if my subs are less than this.

There was still yet another addition to the system, in truth I don't think you ever finally end up with a final stable configuration. The very fast Hyperstar lens was not only unforgiving in the precision needed to set it up, it was also very unforgiving in showing you how much local light pollution (sky glow) you had. In order to try and cut down the sky glow in my location I made one of the best accessory acquisitions yet – the Hutech IDAS light pollution filter. This filter together with the Hyperstar meant that I typically took sub-exposures of 120-seconds, without the filter I was limited to around 60 seconds before sky glow became intrusive. I did not properly recalibrate the system (with the filter in) to see just how far I could go before the sky glow became really intrusive again before I moved onto wide field refractor imaging; this was a big mistake on my part. However, from the experience gained with the refractor, I now estimate that I could have gone to 5 or 6-minute sub-exposures with the Hyperstar and IDAS filter before the light pollution once again reared its ugly head.

Now, we're just about there - surely. It's been a long fraught journey, and it's still far from over. I had to invest in a dehumidifier for the observatory [http://www.pulsarobservatories.com/] as living in the New Forest gave me severe condensation problems during the last few months of 2005. Severe, and costly, the damp wrote off my nice little 15" CRT monitor, and I don't think it did much for the computer's life expectancy either.

After a great deal of painstaking deliberation, I then finally opened my wallet (a painful experience) and invested in PhotoShop CS2, a worthwhile investment if you want to get the last 0.5 % out of your images. I also use Noel Carboni's PhotoShop actions extensively [http://www.prodigitalsoftware.com/Astronomy_Tools_For_Full_Version.html] and even better than that, Noel Carboni actually processes all of my images nowadays (that was back in 2005. Noel still processes some of my images, typically the ones I can't get to behave, but I now do a lot of the processing myself).

In terms of system reliability, it seems I have gained a couple of "hot-pixels" in the SXV-H9C that I can live with, and the azimuth motor of the Nexstar 11GPS simply stopped working a few months back. I know that this was due to leaving the scope totally unused for two months due to a spell of really bad weather. I replaced the motor assembly (surprisingly cheap considering what you get) and found on close examination what the problem was. The motor and worm gear "floats " over the main gear cog due to a sprung loaded swivel mount. The mount had seized (simply an Allen screw that had pinched itself up), so I have fixed the old motor drive and now have a spare. Michael Swanson was extremely helpful in showing me how to track down where the problem was (was it the motor, or the motor controller?) and if you have a Celestron scope you really should use his site and buy his book [https://www.amazon.co.uk/NexStar-Users-Guide-Patrick-Moore--Practical-Astronomy-ebook/dp/B00FBTTEVQ/ref=sr_1_1?ie=UTF8&qid=1464965740&sr=8-1&keywords=the+nexstar+user%27s+guide]. Don't run into unnecessary trouble like I did. If you have a long spell of bad weather, don't just leave the system untouched, go out and fire it up anyway a couple of times a week, it may just save you from severe grief when the skies finally clear. So have we now finally got there? No of course not, there have been some further recent changes to the system. The Celestron wide field guide scope has been replaced with a Takahashi Sky 90 refractor and f#4.5 reducer/corrector for wide field imaging. In order to make full use of the Sky 90's imaging plane I now also have the large format CCD camera SXVF-M25C to give me those very big field-of-views (FOVs) necessary for imaging objects like M31 with a single frame. The trusty Starlight Xpress SXV-H9C workhorse camera has been sold to a UKAI forum colleague and has gone to a good home (9 years on this is a sale I bitterly regret and I wish I had held onto that superb little camera). The Hyperstar has been removed altogether from the Nexstar 11 GPS and now if I am wide field imaging using the Sky 90, the Nexstar 11 GPS is relegated to the role of guide scope, which sounds, and looks, rather perverse. However, if I want high-resolution images of the smaller galaxies, I can put the big SXVF-M25C camera on the 11 GPS with an f#6.3 reducer/corrector, and then use the Sky 90 as the guide scope at f#5 (i.e. I remove the Sky 90 reducer/corrector lens). Lastly, the Nexstar 11 GPS hand-controller started to play up (the buttons got "sticky"), so I moved to the NexRemote software and now drive the telescope through the computer keyboard and a "Gamepad" controller. This is the system I currently have in place, and I don't think there is much that can be done to improve the system overall now without going for a replacement for the Nexstar 11 GPS itself. You can see the piggybacked Sky 90 on the Nexstar 11 GPS in Figure 1.6, and the 7' 6" diameter fibreglass dome garden observatory itself can be seen in Figure 1.7.

Would I choose the same overall setup if I were starting from scratch again? Well, with the price limitations I was working to I probably would. I like the look of the all-refractor alternatives, but for me the big aperture of a reflector, and the potential of f#1.85 imaging really take some beating. Maybe the 14" Celestron with a Hyperstar lens, but then that wouldn't fit too easily in my 7 foot 6 inch glass-fibre dome observatory, so maybe a new observatory and then…. and then…and then. You get the picture.

Celestron have brought out a Rowe-Ackermann Schmidt astrograph which gives f#2.2 imaging as it has effectively "built in" the Hyperstar lens to make an integrated optical unit [http://www.celestron.uk.com/productinfo.php/rowe-ackermann_schmidt_astrograph/telescopes/optical_tubes_ota/3863]

Stop Press!!! Just when you thought it was safe to go back into the water. I found in September 2006 that there is a conflict between the NexRemote software and Maxim DL configured for the SXVF-M25C camera (there was no problem with the H9C camera??). My immediate solution to this was to purchase a new programmable hand controller as this doesn't seem to conflict with Maxim DL (I don't think the big camera likes anything else running on another USB port). There was also a camera firmware upgrade needed for the new M25C camera as the colour planes were shifted in a peculiar way. Terry Platt responded very quickly to get this particular problem sorted. Finally (?) there was a light smear towards the right of bright stars, and a dark band above bright stars in the red channel. These problems were overcome by me soldering a Tantalum bead capacitor onto the M25C circuit board as described by Terry Platt in a private communication. My advice – when you get a system sorted and fine-tuned, don't change ANYTHING.

Stop Press 2!!! I live in the New Forest, Hampshire, U.K. but at times I wonder if I'm in a 3rd World country. We seem to suffer more than our fair share of power outages, and these cause severe grief if you're in the middle of an imaging session,