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Cover Illustration: M31 - The Great Andromeda Galaxy

Library of Congress Control Number: 2007929733

Patrick Moore's Practical Astronomy Series ISSN 3192

ISBN-13: 978-0-387-71352-6 e-ISBN-13: 978-0-387-71353-3

Printed on acid-free paper.

9 8 7 6 5 4 3 2 1

springer.com

I dedicate this book to my wife ***Helga****, who understands my obsession, and whose favourite image was M13, but is now the wide field version of the Rosette.*

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Preface

I have recently discovered the most satisfying hobby so far, and to be frank, I have pursued quite a few hobbies in my time! This one encompasses computers, optics, precision mechanics, digital image processing and artistic appreciation, and it therefore satisfies just about every major interest I have in one go. The hobby is taking photographic images of the deep-sky.

I have not met anyone, so far, that has not been moved, sometimes to a great extent, by the images you will find within the pages of this book. Some people will actually admit to being frightened by the vastness of space that these images depict. I am not frightened by these images, but I am certainly awe-struck by them, and they do make me feel rather insignificant regarding the grand scale of things. I am also still firmly in the grip of being totally amazed that the capability to take such awe-inspiring images is now available to anyone with sufficient time and effort to dedicate to this most rewarding of hobbies.

This book has two aims. The first is to show you the richness, wonder, and beauty of deep-sky objects. The second is to show you how you can take these images for yourself, using readily available commercial equipment.

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

Greg Parker
Brockenhurst, Hampshire, U.K.
2007.

Acknowledgements

Firstly, I gratefully acknowledge the outstanding image processing work of PhotoShop guru Noel Carboni! Noel created all the marvellous deep-sky images you can see in Chapter 10 of this book, from my raw data acquired at the New Forest Observatory. In creating these works of art Noel has spent at least as much time bringing the best out of the data as I spent in collecting it – thank you Noel!!!

I was greatly helped in my early days of imaging by two people in particular, and both still continue to help me now. Many thanks go to Alan Chen on the Yahoo Starlight Xpress forum for showing me the way right back at the very beginning of my imaging work. Many thanks also go to Bud Guinn who can be found on the "Our Dark Skies" forum. Bud introduced me to ODS from the SX forum and has been a great help and inspiration ever since I started imaging – he has also offered me a great deal of encouragement, especially early on when I felt I was getting nowhere. Bud's introduction to the ODS group also led to my teaming up with Noel Carboni of course, and the rest as they say is history.

Last, but not least, many grateful thanks go to Dave Squibb of Tavistock in Devon, U.K. Dave was my "A" level Physics teacher at Tavistock Community College, and it was his dedication to the subject that subsequently led me to authoring a textbook on semiconductor device physics, and the book you now hold in your hands. Many, many thanks to you Dave!!

Greg Parker
Brockenhurst
U.K. 2006.

CHAPTER ONE

How did I start?

This Chapter may help if you are just starting out in deep-space imaging. Personally I find it very useful to see how other people entered the hobby, because in that way you can see what their major mistakes were, and hopefully you can then circumvent the major problems.

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, around January-February 2002, I was solely interested in carrying out visual work, 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 pretty useless at finding where all these Messier and Caldwell objects were hiding. I did not properly polar align the telescope, and I did not properly use the motor drives, so objects, when I did find them, 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. So, admitting defeat after around three months, I then bought the Celestron Nexstar 11 GPS Schmidt-Cassegrain reflector http://www.celestron.com/prod_pgs/tel/nx11gps.htm] with an Alt-Az computer-driven mount, and I spent the next two years happily carrying out visual observations. The Helios refractor is not totally unused however; I bring it out for photographing transits (Venus, Mercury) using the projection method.

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.

Then the night of Thursday 2nd May arrived, a clear crisp evening with good viewing, 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 night.

As I was primarily into observing, it wasn't too long before I invested in the superb Celestron Bino-Viewers [http://www.celestron.com/prod_pgs/accessories/optical_accessories.htm], 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 boring when I eventually did 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://www.starizona.com/hyperstar/] that converts the f#10 Nexstar 11GPS into an 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.starlight-xpress.co.uk/SXV/SXV-H9C.htm] was quite easy to make. 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.starlight-xpress.co.uk/SXV-M25.htm] coming in at 6 Megapixels, or the smaller SXV-H9C http://www.starlight-xpress.co.uk/SXV/SXV-H9C.htm coming in at 1.4 Megapixels. Both Starlight Xpress (Terry Platt) and Starizona (Dean) suggested the H9C as it would be much better matched to the 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] gives 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 designated SXVF, where the F indicates a very fast download capability.

So my initial imaging system was a standard Nexstar 11GPS in Alt-Az mode, SXV-H9C colour CCD imaging camera, and the Hyperstar lens. The first thing that had to be changed was the focuser on the Nexstar, 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://www.starizona.com/search.cfm?Category=0&Product=1&Keyword=microfocusser] 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

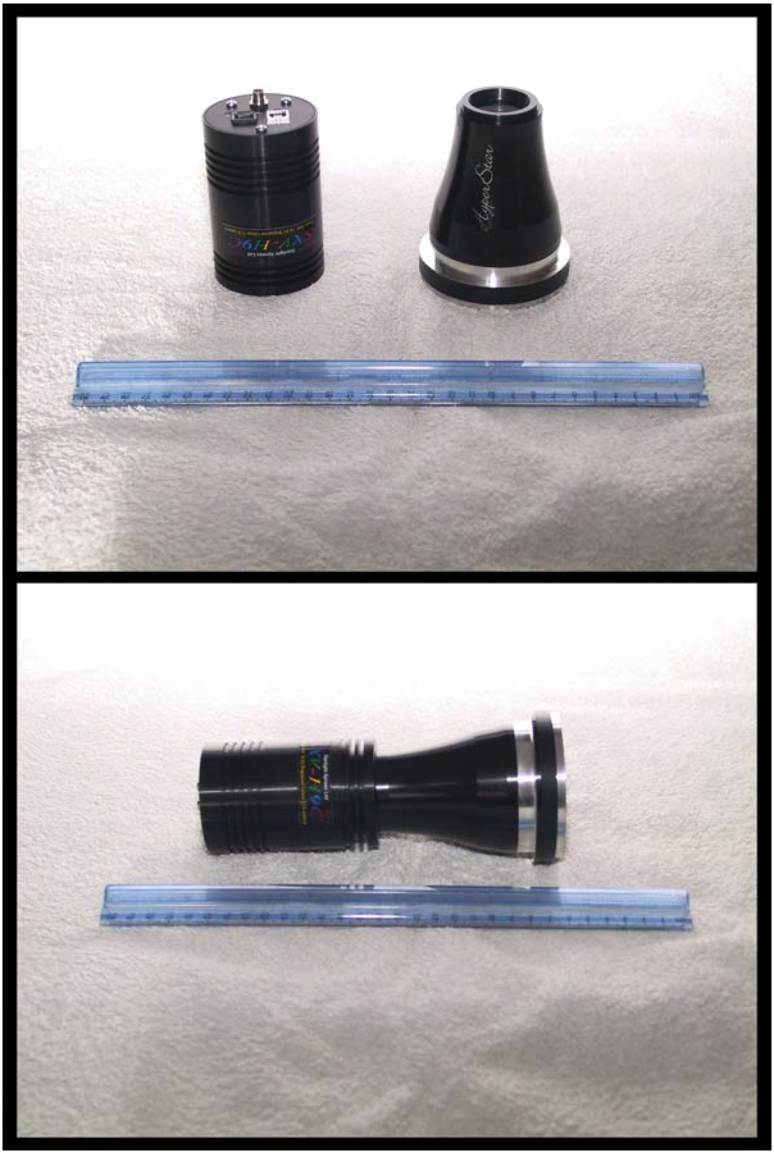

Figure 1.1. The Hyperstar lens assembly and the SXV-H9C one-shot colour CCD camera from Starlight Xpress. Bottom photo – the two elements connected.

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.

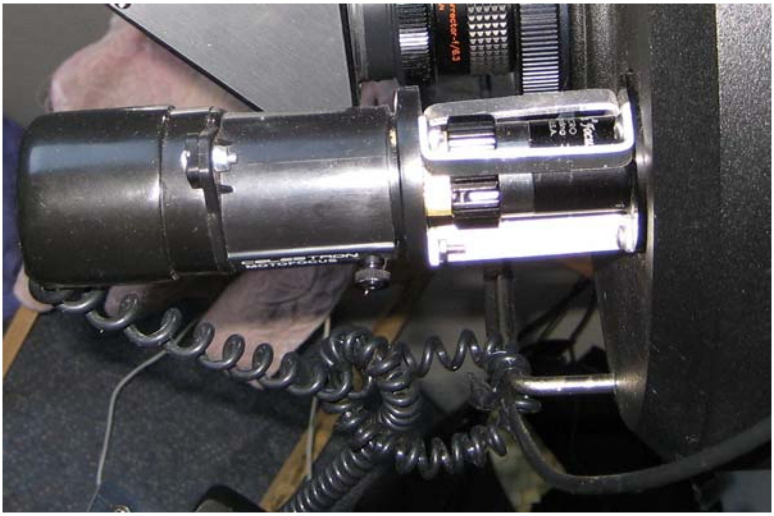

Figure 1.2. The standard Celestron electric focuser, mounted on home-built aluminium standoff pillars, to fit the Starizona "FeatherTouch" focuser.

Next I started to use stacking, remember the telescope was in Alt-Az mode, no problem, 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, 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.

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

As you can see the modification, using 2mm 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.

So, surely we must be there now? Equatorially aligned, fast imaging, large aperture scope, colour 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 images presented in Chapter 10 of this book that the stars are pretty round, with the exception possibly of some coma at 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 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

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

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 +/- 1mm 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 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 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" a Hyperstar system?

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

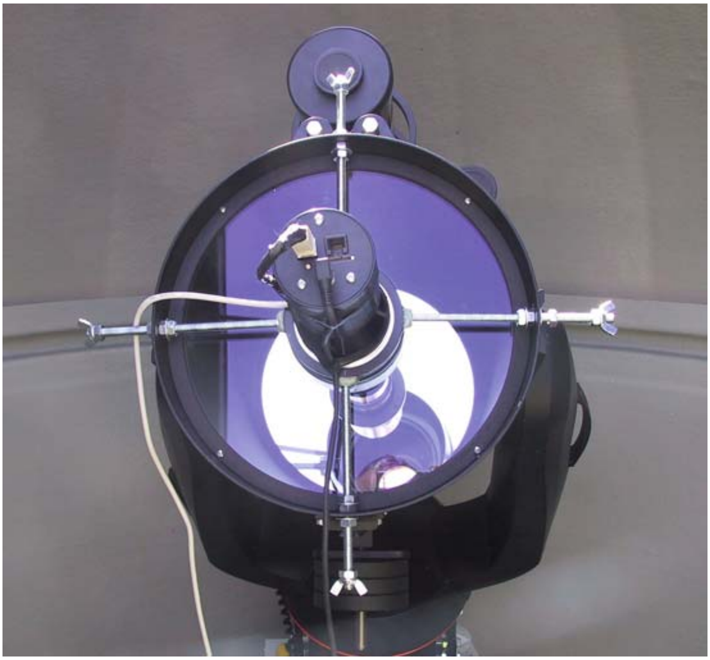

Figure 1.5. The threaded rod adjusters used to collimate the Hyperstar lens to the Nexstar 11 GPS. The threads are covered in black tape prior to imaging or you will get a very strange diffraction pattern around bright stars due to the fine threads.

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 2kg 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 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