

APPENDIX 1



The Angular Size of Objects in the Sky



We measure the size of objects in the sky in terms of degrees. The angular diameter of the Sun or the Moon is close to half a degree. There are 60 minutes (of arc) to one degree (of arc), and 60 seconds (of arc) to one minute (of arc). Instead of including – of arc – we normally just use degrees, minutes and seconds.

1 degree = 60 minutes.

1 minute = 60 seconds.

1 degree = 3,600 seconds.

This tells us that the Rosette nebula, which measures 80 minutes by 60 minutes, is a big object, since the diameter of the full Moon is only 30 minutes (or half a degree).

It is clearly very useful to know, by looking it up beforehand, what the angular size of the objects you want to image are. If your field of view is too different from the object size, either much bigger, or much smaller, then the final image is not going to look very impressive. For example, if you are using a Sky 90 with SXVF-M25C camera with a 3.33 by 2.22 degree field of view, it would not be a good idea to expect impressive results if you image the Sombrero galaxy. The Sombrero galaxy measures 8.7 by 3.5 minutes and would appear as a bright, but very small patch of light in the centre of your frame. Similarly, if you were imaging at $f\#6.3$ with the Nexstar 11 GPS scope and the SXVF-H9C colour camera, your field of view would be around 17.3 by 13 minutes, NGC7000 would not be the best target. In this case you would likely see just a general red glow of this

massive H-11 region over the whole frame, with very little structure apparent. It is for these reasons why it is a good idea to get a “feel” for the relative size of objects compared to your field of view.

It is also a good idea to get a feel of the size of your night sky, and how big or small objects will appear in your whole hemisphere of night sky. For example, let's say you have a telescope imaging system with a relatively large field of view of 1 degree by 1 degree and you point your telescope randomly in the sky. What is the chance that you will land on a chosen object? In other words how many square degrees of sky are there in a hemisphere?

I need to use radians measure to easily make the link to square degrees and compare with a hemisphere. So for an ordinary planar angle (not a solid angle) we find that π radians are equivalent to 180 degrees. In terms of solid angle (square degrees, or Steradians), 4π Steradians are the solid angle subtended by a whole sphere, and so a hemisphere subtends 2π Steradians.

Let's go through the maths:

- 1) 4π Steradians = Whole sphere.
- 2) $180/\pi$ = degrees per radian.
- 3) $(180/\pi)^2$ = square degrees per Steradian.
- 4) $2\pi \times (180/\pi)^2$ = square degrees for a hemisphere = 20,626 square degrees.

So the whole hemisphere of the night sky covers 20,626 square degrees, and our large field of view covers only 1 square degree, so randomly pointing our telescope at the sky with the hope of finding an object gives us a one in 20,626 chance of stumbling upon it. The sky is a BIG place to hunt for small objects.



The Designation of Deep-Sky Objects

I have no hesitation in letting you all know that I am totally and utterly confused by the designations used to name deep-sky objects.

This was clearly brought to my attention literally only a few days ago when I had just imaged the Christmas tree and Cone nebula area NGC2264 with the wide field setup. In the lower centre part of the image there is a very nice golden coloured open cluster – what is the name of this cluster? I looked everywhere and finally came upon it on Davide de Martin’s absolutely superb “SkyFactory” site <http://www.skyfactory.org/index.htm>. Davide listed this open cluster as OCL494, didn’t help too much as I had never heard of OCL either. What on Earth does OCL stand for?? Well I was a bit slow there I guess, but OCL stands for “Open Cluster” which I suppose makes sense. Still, I had never heard of this designation before, so it still wasn’t very enlightening.

I put the same question out on the Forums and got two further replies back! One said it was Cr 105, and another said it was Tr 5 or Trumpler 5. Now I thought at first that the guy who had answered Cr 105 had got it completely wrong since if you “Google” Cr 105 you get back something that is the 3rd furthest object from the Sun. But then if you persevere and delve a little deeper you find out that Cr also stands for “Collinder” and Collinder 105 is indeed this nice little open cluster in NGC2264. Mind you, so is Trumpler 5 or Tr 5, so OCL494, Cr 105 and Tr 5 are all the same thing, the pretty little golden coloured open cluster in the Christmas tree region of Monoceros. I find this all unbelievably confusing, so in order to help myself as much as you, I have put together the very brief list below which includes some of the designations you will have seen associated with my deep-sky images

in Chapter 11. This list is nowhere near comprehensive, it probably doesn't cover a 5th of the catalogues out there, but it may give you an idea where some of these obtuse names have come from. I have put the designations together in object list form.

General Deep-Sky Objects

There are only four designations that we come across on a regular basis for this category.

- 1) **M:** The well-known Messier catalogue named after Charles Messier who didn't want us confusing these vermin for precious comets. Total number of objects either 109 or 110, as an example M45 is the designation for the Pleiades open cluster in Taurus.
- 2) **Caldwell:** The Caldwell catalogue is named after Patrick Alfred Caldwell-Moore. Patrick came up with his own list of interesting objects not included in Messier's catalogue, and unlike the M objects, the Caldwell objects cover both hemispheres. Patrick did not use "Moore" as there would have been confusion with the Messier (M) objects. There are 109 Caldwell objects for you to discover. Caldwell 1 (the most northerly Caldwell object) is NGC 188 an open cluster in Cepheus.
- 3) **IC:** The "Index Catalogue". Most of the objects in this catalogue had been discovered photographically, and Dreyer created this list from two indexes between 1884-1894 and 1895-1907. IC1318 is the huge Gamma Cygni nebulosity in central Cygnus.
- 4) **NGC:** The well-known "New General Catalog". Again a Dreyer masterpiece, with most of the objects having been discovered visually. Go to this fantastic resource <http://www.ngcic.org/default.htm> to find every NGC object listed with an accompanying black and white photo and data! NGC7000 is the huge North America nebula in Cygnus.

Diffuse Nebula

Again there are four designations that I have come across with the diffuse nebulae, but many more exist.

- 1) **Ced:** "Cederblad" from S. Cederblad "Catalog of Bright Diffuse Galactic Nebulae" 1946. Ced 214 is a nice emission nebula in Cepheus.
- 2) **Gum:** From C.S. Gum, "A survey of Southern HII regions". THE Gum nebula (Gum 56) is a huge supernova remnant in the constellations Puppis and Vela. This huge region is something like 40 degrees across, and extremely faint.
- 3) **Sh2:** The "Sharpless" catalogue from S.Sharpless "A Catalogue of HII regions" 1959. Sharpless 2-155 is the Cave Nebula (also Caldwell 9).

- 4) **vdB**: From “van den Burgh” 1966 “A study of reflection nebulae”. The Elephant’s Trunk Nebula is vdB142 in the massive HII region IC1396 in Cepheus.

Dark Nebulae

There’s one very-well known catalogue here due to Barnard.

- 1) **B**: “Barnard”. From “Catalogue of 349 Dark Objects in the Sky”, 1927. The most famous member of this listing is of course B33, the Horsehead Nebula in Orion.

Open Clusters

This is the category that caused me all that confusion with the open cluster in NGC2264.

- 1) **OCL**: Now this actually took a lot of tracking down! It is apparently from “The Catalogue of Star Clusters and Associations”. OCL494 is that nice open cluster in NGC2264 in Monoceros.
- 2) **Tr**: From Trümpler “Preliminary results on the distances, dimensions and space distribution of open star clusters” 1930. Trumpler 14 has one of the highest concentrations of massive, luminous stars in the Galaxy. Situated towards the edge of a large molecular cloud Trumpler 14 is part of the Eta Carina complex, which contains eight star clusters.
- 3) **Cr**: “Collinder” From P.Collinder “On structured properties of open galactic clusters and their spatial distribution” 1931. A catalogue of 471 open clusters. Collinder 470 is the cluster associated with the Cocoon nebula [IC5146, Caldwell 19].
- 4) **Mel**: P.J. Melotte, “A catalogue of star clusters shown on the Franklin-Adams chart plates” 1915. Mel 111 is the Coma Berenices star cluster.

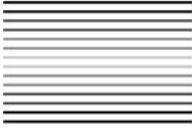
Galaxies

- 1) **Arp**: Halton Arp, “Atlas of Peculiar Galaxies”, 1966. My favourite Arp galaxy is NGC2276 (Arp 25) in Cepheus.
- 2) **Holm**: “Holmberg”. There are 9 Holmberg galaxies, 1,2,3 & 9 are in the M81 region and 4 & 5 are in the M101 region. You can just about make out Holmberg IX in the image of M81 in Chapter 11, it lies very close to M81 itself.
- 3) **Mrk**: “Markarian”. A catalogue of 1515 galaxies by B.E.Markarian et al. Markarian 421 is an active galaxy (blazar) in Ursa Major.

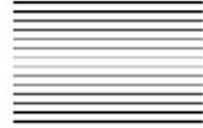
Galaxy Clusters

- 1) **Abell:** G.O. Abell, "The distribution of rich clusters of galaxies" 1958. Abell 2065 is a group of galaxies in Corona Borealis lying at a distance of 1.5 billion light years.

As I mentioned in the Introduction, this is a far from complete listing, and much more information can be found at <http://www.gis.net/~vickers/images/Prefixes.pdf> and at http://www.sctscopes.net/Glossaries/DSO_Database_Notations.pdf.



Physics World Article



The article that appeared in the September 2002 issue of Physics World was fairly heavily edited, to the extent that some of the meaning was lost entirely. Below you will find something a little closer to the original manuscript.

The Most Amazing 2¹/₂ Hours of my Life – So Far!

If you have been fortunate in your choice of day job, there comes a time around middle-age, when if you're very lucky you can afford to buy the toys you wished you'd had as a child. Some people at this crisis point in their lives opt for sports cars, or even powerful motorbikes – I on the other hand decided to buy a lovely 6-inch refracting telescope. This Helios branded telescope was incredibly powerful and gave me great views of the Planets, as well as nice views of the Orion nebula and the Andromeda galaxy. This was not a “goto” telescope, although it did come with a motor-controlled German Equatorial mount. The lack of computer-controlled “goto” was a firm decision on my part. I didn't want a computer finding all these wonderful deep-sky objects, I wanted to do that all by myself and

have the “fun” of being able to hop from object to object without any computer-aided help. I have to admit I didn’t have much fun! I was too inexperienced to find my way around the Heavens, and all those Messier and Caldwell objects still remained quite elusive. So after a couple of months I admitted defeat and bought a Celestron Nexstar 11 GPS telescope, computer-controlled and an on-board GPS system for accurate position location and for setting up the local time. This advanced telescope also tells you which stars you should align against to set it up for an evening’s observing.

When the telescope finally arrived I could not wait to start observing. As with all new astronomical gear it was the proverbial “cloud-magnet” so it was a week or so before I could take it outside for its initial trial run. On the first clear evening I took it outside and followed the instructions (to the best of my ability at the time) and was quite disappointed with the instrument. The telescope couldn’t even locate Jupiter even though it was blazing away up there for all with a pair of eyes to see. I later realised that this was due to me wrongly calibrating the telescope by mistaking Capella for Procyon and therefore invalidating the two-star align (I cannot remember what the second alignment star was, or how I could have possibly got “align success” with one guide star being completely wrong, but that’s what happened).

After a few more days of overcast weather the evening of Thursday 2nd May 2002 finally fell clear. Out came the telescope, which I managed to set up properly this time by using the correct alignment stars. By 9.30 p.m. I had observed Jupiter and its moons for half an hour and it was now time to try the handset again to see if I could find those elusive Messiers and other deep-sky objects.

Not knowing what would be visible that night I simply typed in “M3” and off the telescope went. The motors whirred for maybe a minute, the last little whir being used to take up the gears’ backlash. Expecting to see nothing through the eyepiece I was totally amazed to see a fuzzy ball of light glowing right in the middle of the eyepiece. Never having seen this object before [M3 is in fact a very nice example of a globular cluster], or anything like it, I thought this must have been a fluke and just a lucky “hit”.

Pushing my luck I typed in another number: M88. Off went the telescope again and this time there was a galaxy right in the middle of the eyepiece! Now although several decades of scientific training should have told me that I couldn’t have been so lucky twice in a row, I was not entirely convinced that this still wasn’t just chance. However, I was very excited by all this and got my wife to take a look through the eyepiece. She was not too impressed – and I guess that for £3,000 you might expect to see at least the Starship Enterprise come into view.

I was not daunted. I went indoors and brought out my Norton’s 2000.0 star atlas – I knew its day would come, and today was the day! It was about 10.00 p.m. when I opened the page on “Interesting Objects Maps 9 and 10, clusters, nebulae and galaxies”. I typed in the name of the first object on the page – NGC 3132 – and set the telescope running. As in the early classic computer game – nothing happened! The handset indicated that the object was below the horizon and so it would not slew the telescope. I then went to the second object on the list – NGC 3242 – a planetary nebula in Hydra called the “ghost of Jupiter” – I’d never even heard of this one before. This time the motors whirred into life and the stars flew across the field of view. The motors wound down and I looked through the

eyepiece just as the gear backlash was being taken up. An amazing glowing object quickly locked itself into the centre of the eyepiece. It was indeed the ghost of Jupiter, and a marvellous sight in the eyepiece!

Like a kid in a sweetshop, I now had this whole mass of clusters, nebulae and galaxies all ready to be viewed. All I had to do was type in the Messier or NGC number. This was so good it seemed unreal. During the next hour I worked my way down the list in Norton's and logged 27 out of the 34 objects on that page. It was an incredible experience. Getting greedy I turned to a different page in Norton's and started on another list of objects. If you have not seen M13 – the great globular cluster in Hercules – through a reasonably sized telescope, you must, it is simply breathtaking.

Just after midnight the sky clouded over and I had to stop. It was just as well really as I may have perished outside from the cold if I had not been forced to give up the evening's viewing. With regards to new discoveries [for me at least], it was, at the time, the most amazing two and a half hours of my life.

So how can I possibly summarise an experience like that? It is very difficult of course, but I can offer a comparison. A few years ago I bought a sub-notebook computer (a Libretto) that was a little larger than a videocassette and weighed just one kilogram. I fitted a 40Gb hard drive to this machine, which meant that I could carry in one hand – and have access to – not just the whole Encyclopaedia Britannica, but actually something like twenty times the data content of the whole of the Encyclopaedia Britannica. Even Star Trek (First Generation) was not that bold.

Now I have a computer-controlled telescope that can take me accurately to any object in the night sky just by typing the coordinates into a handset. This is a totally amazing piece of technology, and it is available to the general public at effectively very low cost, thanks to mass-production techniques. We may live in “interesting” times, but as Physicists we also live in truly amazing times.

Greg Parker is professor of photonics at the University of Southampton. He lives in the New Forest with his Wife, Son and Nexstar 11 GPS telescope.

Greg Parker

B.Sc. (1st Class Hons), Ph.D. C.Phys. C.Eng. F.Inst.P.



Greg is currently Professor of Photonics, and Head of the Nanoscale Systems Integration Group at the University of Southampton, Hampshire, U.K.

He was born in Barking, Essex (U.K.) on April 20th 1954. His first life changing experience was moving to New Zealand with his parents for a couple of years at age 12. This has led to a lifelong love of sandy beaches and good surf.

On leaving school he joined the Harwell and Culham laboratories and started a life in research. In 1975 he went to the University of Sussex to take his first degree in Physics, Mathematics, and Astronomy, he graduated in 1978 with 1st Class Honours. He then joined the Philips Research Laboratories at Redhill, Surrey, U.K. where he carried out research into new Silicon-based electronic devices. At the same time he enrolled for a Ph.D. at the University of Surrey on the work he was undertaking at Philips. He was awarded the Ph.D. in December 1982 and spent a further 5 years in different industries until he joined the University of Southampton in April 1987.

His University research is primarily into nanoscale optical devices and circuits, called Photonic Crystals, and in December 2000 he was made Professor of Photonics having begun his Academic career as a Junior Lecturer. In July 2001 he span out the photonics company Mesophotonics Ltd. based on his Photonic Crystal research. He has also created three other successful companies, one of which is his Consultancy business Parker Technology - <http://hometown.aol.co.uk/mobiusltd/myhomepage/business.html>

He has published over 120-refereed scientific papers, an undergraduate textbook on the physics of semiconductor devices, and has 14 filed Patents.

Greg's interest in Astronomy goes back to his very early childhood, but took a major boost when he lived within the Dartmoor National Park and had crystal clear skies (virtually no light pollution) for many nights of the year. He will never forget the awesome sight of a completely light pollution free sky as he looked out of his tent flap somewhere in the middle of Dartmoor on a warm Summer's evening in 1970. Today he is a CCD imager [<http://mstecker.com/pages/appparker.htm>] taking images of deep-sky objects with a technology that he never dreamed would exist in his lifetime. Since any sufficiently advanced technology is indistinguishable from magic (pace Clarke!) – he is clearly a firm believer in magic. His observatory can be seen at <http://hometown.aol.co.uk/mobiusltd/myhomepage/photopersonal.html> and his CCD imaging page can be found here <http://hometown.aol.co.uk/mobiusltd/myhomepage/computer.html>.

Greg lives in the New Forest, Hampshire, U.K. with his wife, son, cat, dog, Celestron Nexstar 11 GPS reflecting telescope, Sky 90 refractor, and Sony VAIO PCG-C1MHP. He is a fully certified nerd, Star Trek fan (original series), and very proud of it.

University Website Biography

Light has always been a defining factor in the life of Greg Parker, Professor of Photonics at the University of Southampton's School of Electronics and Computer Science.

It began with a young boy's love of the stars in the night sky and his fascination with his father's photographic collection, taken whilst he served in the First World War in Afghanistan & Egypt - he was actually in Luxor at the time

Howard Carter discovered Tutankhamen's tomb. This followed through to Greg's internationally acclaimed career in photonics and his own passion for capturing images of deep-sky objects. "These things go into your subconscious mind and make a really big impact although you don't realise it at the time. Then, years later, they resurface".

He vividly remembers the year the Daily Express featured the world's first ruby laser on its front cover. "It was around 1963–1964, three or four years after the laser was invented by Maiman in America," he recalls. This groundbreaking invention featured a ruby rod in the middle of a spiral Xenon flash tube and resulted in the 10-year-old disembowelling old watches to retrieve the rubies from their mechanisms.

"I dug the rubies out and got a magnifying glass to shine the Sun on them, hoping to make a laser. Of course I never did but I must have spent a year trying to do this and it was a big letdown", he says. The disappointment, however, didn't put him off: "That was when laser and light and flashtubes all started for me," he adds.

His early career was spent studying and working in industry. On leaving school he joined the Harwell & Culham laboratories, also taking an HNC in applied physics at Oxford Polytechnic. Having gained a taste for study, he went to Sussex University to read maths, physics and astronomy, graduating with first class honours in 1978. He then joined the Philips Research Laboratories in Redhill and enrolled for a PhD at the University of Surrey.

Greg joined Southampton's Department of Electronics, as it was then, in 1987. The move was partly prompted by the onset of change in the big research labs. "The grass was beginning to look a lot greener on the other side," he says. "Over the last 20 years a lot of those places have gone. You just can't play anymore and they've become very commercial. It's difficult to be inventive and innovative in industry, it doesn't accommodate free thinkers very well whereas a university will".

He steadily climbed the ranks at Southampton, specialising in novel growth systems for Silicon compatible materials and Silicon-based optoelectronics, and was appointed Chair of Photonics in 2000. During his time, Greg has designed, built and developed four LPCVD systems for the Microelectronics Group, published over 120-refereed papers, created three successful companies and is now group leader for the Nanoscale Systems Integration Group.

Around 1994 Greg had a Eureka moment with the creation of the world's first photonic crystal to work at optical wavelengths. The cry, however, didn't come until many months after their unintentional fabrication. "I had an EPSRC grant to make very thin, tall wires of single crystal Silicon," he says. "One of the early steps in the process is a sheet of Silicon with very deep holes going down into it. This was just a precursor to the process and didn't mean anything to me at the time."

The project was successfully completed and the samples were stored on the shelf. Six months later he was reading an article on photonic crystals - something he'd never heard of before but he now suspected the precursors could be linked to them. At a colleague's suggestion he took some careful measurements and realised he had created the world's first photonic crystal to work in the infrared region.

Greg convinced BTG plc to invest in the new photonic crystal technology and they invested £2.8 million in the spin out company Mesophotonics Limited in 2001. The technology allows light to be bent, routed and processed at a sub-millimetre scale resulting in a low cost, high volume production of integrated optical devices. "They are no more than an array of holes in an optical wave guide but by placing the holes in a certain manner you can create lots of different functionality," says Greg. A second round investment of £5.5 million was attracted in late 2003.

Another dimension to Greg's career in light is his interest in photography, first sparked by his father. "Dad was born in 1900 in the squalor of the East End and to get away from a pretty grim existence he joined up very early in World War I," he says, "for some reason he decided he was going to do photography out in Afghanistan." As a result the Parker boys grew up in a house surrounded by boxes of old photographs. "It obviously had a big impact on me and my older brother. He was a forensic photographer in Scotland Yard for 33 years," he adds.

In 1985 Greg created the first portable high-power, high-speed flash unit with a 1/40,000 second duration for his older brother Alan. A design that, 20 years after development, remains virtually unchanged and is still in use by award-winning nature photographer Andy Harmer.

Greg's own photography necessitates a slightly longer exposure time; he needs two to three hours for his deep-sky imaging work. In July 2006 he will stage his first exhibition of astrophotography at the University of Southampton library. The work will be entirely his own from beginning to end; all images on display will have been photographed, printed, mounted and framed by Parker himself.

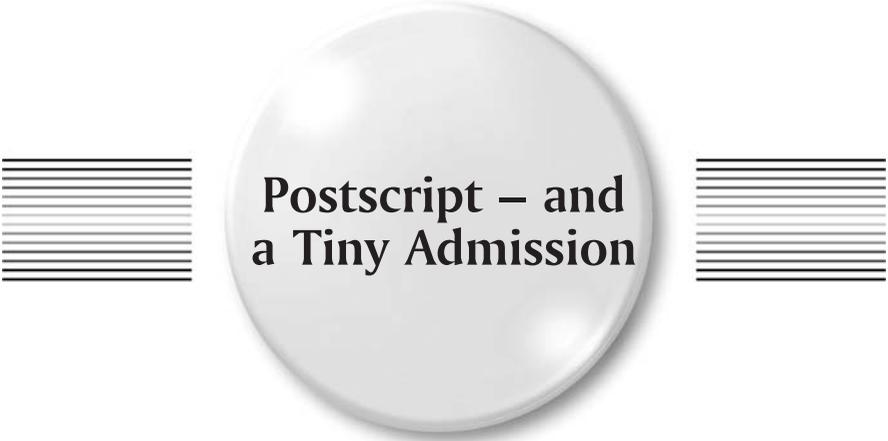
He readily admits it can be an addictive obsession but one he is keen to share, and use to inspire others. He says, "I want other people to come in and see what a guy off the street did within a year with something you can buy commercially that someone with an ordinary job can afford. I wouldn't have believed it!"

Although Greg has been stargazing for over 40 years and has his own mini dome observatory in his New Forest garden, he only started imaging the skies in November 2004.

"CCD cameras with long exposure times have only been around for about ten years and it's only in the last five or six years you could get them at a reasonable price to do the job," he says. "I started imaging literally one year ago but the technology allows you to do it as long as you're au fait with computers".

The camera downloads the data which Greg then processes digitally using Adobe Photoshop. This enables him to manipulate the picture and bring out the faint detail. The result is a galaxy of prints that bring the splendours of the cosmos to life.

"That's why it's a great one for me," he says, "it brings together optics, the stars, photography and the computational processing. It's got the lot in the one hobby." And helps provides light relief to an academic career immersed in luminescence.



Postscript – and a Tiny Admission

I really hope you have found many useful tips and items in perusing this book that will help you on your way to create those spectacular “Gendler” type images. I am of course quite proud of the images you see within the pages of this book, and I was also quite proud, and very excited by, my very first images – which to be blunt were pretty hopeless in comparison with the ones you see reproduced here. But history has also taught me that given sufficient time and effort, the images in this book will also be relegated to the bin as I continue to learn and develop this fascinating hobby.

So to the admission – as I write these words, I have only been imaging for around 2 years! Some of the images you see will have been taken a few weeks later than 2 years, but the bulk will have been taken within 18 months of starting the hobby. This gives you a baseline reference of what can be done given sufficient dedication to the task of sorting out your complete system out; that is your imaging system, and your digital darkroom.

It might seem a little presumptuous to write a book such as this with so little “real” imaging experience, and I am very well aware of the gaping holes in my understanding of astronomical imaging, and astronomy in general, but I am also aware of the pitfalls of trying to write an Introductory book from the perspective of an “expert”. I have written a top-selling introductory text on Semiconductor Physics, and I wrote this book within two years of giving the first lectures on the subject. The book has been extremely well received by students around the World, and I have many letters of thanks from students who were struggling with the subject until they discovered my book. Why should this be so? It is

because I *did* write the book so soon after teaching the subject. I could still clearly remember all those silly little problems that come along when studying a new subject for the first time, and I could answer those problems in a simple and straightforward way that appealed to new students of the subject. Also, in writing the book so soon after teaching the Physics, I was still very far from being an “expert” in the subject, and still had clear recollections of all those irritating little things that had me scratching my head for hours at a time. I know that if I had left writing the book for a few more years I would not have been able to help the beginner as much as I have done, simply because I would have forgotten about all those silly little things that caused me so much trouble, they would have become “obvious” with the passing of time. How do I know this? Because I am at that stage now, I know semiconductor physics well enough that already some of the topics that caused me great difficulty are now trivial and not worthy of my time – this in turn makes me less useful to the new student who is finding difficulty with the subject – I am already beginning to “dismiss the base rungs by which we ascend”.

So, that’s why I moved so quickly to get this book written. I hope it has been instructional and answered some of the basic questions that you might have had burning inside you. I have certainly really enjoyed writing it.

It only leaves me to wish you clear, dark skies, and many, many hours of happy deep-sky imaging!

All the best,
Greg Parker
Brockenhurst
U.K. 2006.



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