Annual Meeting of the Deep Sky Section, 2011 March 12
held at Ashford Village Hall, Ashford Hill, Berkshire

Dr Stewart Moore, Director of the Deep Sky Section, welcomed the audience to the meeting and thanked Newbury Astronomical Society for hosting it. He especially thanked Ann Davies and David Boyd for arranging the refreshments. He explained that this year marked the thirtieth anniversary of the Section's foundation, in September 1981, and so this year's meeting would be a timely opportunity for several talks reviewing the changes seen over those three decades, but first he presented his Annual Review of the Section's work.

Annual Review

Dr Moore reported that 44 observers had submitted images to the Section since its previous meeting in March 2010. Three newsletters had been produced in that time, in May, September and January. For the first time, these had been circulated electronically as pdfs, making it possible to do better justice to the fine colour images that could be obtained with modern CCD cameras than was possible within the Section's printing budget. Black-and-white photocopies remained available on request to those members without internet access. Dr Moore added that he was always keen to receive contributions for these newsletters, and that he particularly welcomed images which were accompanied by notes about the equipment used or the story behind the observer's choice of target; this additional context could add considerably to the interest of the images.

Several observing projects had also been publicised to a wider audience by articles in the news section of the BAA *Journal*. Owen Brazell[1] and Grant Privett[2] had recently written articles about NGC 40 and Gyulbudaghian's nebula respectively, and the Director encouraged others to consider contributing similar articles.

Turning to describe the observations which Section members had made over the year, Dr Moore noted that the weather had been particularly unfavourable across the UK over the past few months. This was reflected by a lull in supernova discoveries by UK amateurs of late. Nonetheless, Ron Arbour had made one discovery in the past year, 2010hi in NGC 6621, discovered on September 1, bringing his tally to 24. Tom Boles had made nine discoveries over the year, most recently 2010js in UGC 4924, discovered on November 7, bringing his tally to 138.

The Section's project to observe Abell planetary nebulae had received a few new observations over the year, of Abells 12, 33, 36, 37, 39 and 50. Three of these images, those of Abells 33, 36 and 37, represented the first amateur observations of these objects to be received by the Section; lying in the magnitude range 11.5–14, these objects presented considerable challenges. A couple of even more difficult planetary nebulae had also been observed by the Section's most dedicated observers. Both Grant Privett and Maurace Gavin had successfully captured images of the Necklace nebula, an object newly discovered[3,4] in Sagitta in 2010 by the IPHAS survey[5,6]. Privett had also captured an image of the Soap Bubble Nebula (PN G75.5+1.7), another relatively recent discovery, this time by American amateur astronomer Dave Jurasevich in 2008 July and lying in Cygnus. Details of all of these observations could be found in the Section's January newsletter. Within the past few weeks, Privett had turned his attention to faint local group galaxies, submitting images of Leo 2, Leo A and Sextans B.

Turning to variable nebulae, the Director opened with a pair of images of Hubble's variable nebula, taken by Nick James in 2010 March and Maurace Gavin in 2010 November, which showed clear changes to the structure of the nebula over those eight months. Hind's nebula presented a fainter, more challenging target, but Dale Holt and Maurace Gavin had submitted images. Few observations of McNeil's nebula had been received in recent years, since the initial flurry of interest which had followed its discovery in 2004; there was an ongoing need for the Section to monitor it, and negative observations would be as useful in this regard as positive detections.

Gyulbudaghian's nebula had been well observed over the course of the year. At the previous Section meeting in 2010 March, it had been reported faint at mag 16.5, but it had subsequently gone on to brighten rapidly, peaking at mag 15.8 in the early summer. It now seemed to have faded again. David Boyd had recorded systematic photometric measurements of both the nebula and the variable star PV Cephei, 11" distant, thought to be the nebula's primary source of illumination. He had found that the nebula's lightcurve was a close match to that of PV Cephei, but shifted 32±4 days later. This shift could be explained if the physical separation of the star from the nebula was 32±4 lightdays, or 0.027±0.003 parsecs, which was consistent with other estimates of the nebula's distance and angular separation from PV Cephei. This work would be written up in full in a future issue of the BAA *Journal*.

Having reached the end of his Annual Review, the Director proceeded to deliver the next talk also, reviewing some of the changes in imaging technology seen over the 30-year history of the Section.

Then and Now: Thirty Years of Section Images

The Deep Sky Section had been founded in 1981, initially under the name of the *Photographic Section* at the 1981 September BAA Council meeting, before changing its name to the Deep Sky Section only a month later at the following Council meeting.[7] Its first Director had been Ron Arbour, now known for his work as a discoverer of supernovae, and from the beginning it had summarised its work in a triannual newsletter, initially titled the *Deep Sky Diary*, the first issue of which had appeared in 1982 April. The cover of this first issue had shown an image of the globular clusters around M31, captured by Geoffrey Johnstone on Kodak *Technical Pan 2415* film using a 10.5-inch f/5 Newtonian. On subsequent pages were photographs of M42, NGC 884 (the double cluster) and M31. Producing satisfactory printed reproductions of images like these had presented a considerable challenge at the time, and whilst the speaker noted that each of these original photographs had represented a considerable technical achievement at the time, he added with regret that the newsletter had done poor justice to them.

Turning to discuss the equipment used, he explained that in the early 1980s, astrophotographers had typically worked with Newtonian telescopes of 20–30cm aperture. Also popular had been Aero-Ektar lenses, often manufactured by Taylor-Hobson and bought as army spares. Of necessity, the targets chosen had been bright objects, usually stellar clusters or galaxies. Exposure times had been limited to around 10 minutes by the lack of automated guidance systems.

By contrast, there was now a trend that many astrophotographers preferred small aperture refractors on account of their high quality optics, though there were others who still used Schmidt-Cassegrain telescopes. For several years, film photography had been entirely superseded by digital imaging, using either digital SLR cameras or dedicated astronomical CCDs, on account of the more immediate feedback provided by the new devices, together with their improved linearity and quantum efficiency – i.e. sensitivity. Longer exposures, often exceeding eight hours, had been made possible by more accurate drive systems and by the advent of automated guiding. The ability of computers to read images directly from modern CCDs had allowed astrophotographers to stack huge numbers of short exposures using automated image stacking programs such as *Registax*. This meant that the need for drift to be completely eliminated over the whole length of the exposure was now much less pressing.

Dr Moore noted that the rise in length of exposures was at first sight surprising, given the greatly improved sensitivity of modern detectors. It was apparent that much fainter and more challenging targets were being chosen. He added that there had also been a rise in the use of narrow-band filters, especially among those in areas severely affected by light pollution, and that the inherently low transmission of such filters also necessitated longer exposures.

Turning to compare some of the images that he had recently received with those in the Section's archive, Dr Moore identified galaxies as objects that had been particularly difficult to photograph in the 1980s, on account of their low surface brightnesses. In an image of the interacting pair M81 and M82 from the early 1980s, it was tricky to make out the galaxies at all. The change was much more slight among images of open star clusters, which had often already been readily accessible in the early 1980s, as was illustrated by an early 1980s image of M45, recorded by Alan Dowdell on Kodak *Tri-X* film. The only dramatic change was that modern colour images could record star colours, whereas the earlier images were invariably black-and-white. An audience member remarked that it was a shame that Ron Arbour's absence from the meeting prevented a re-opening of the historical debate between *2415* and *Tri-X* film.

Images of globular star clusters had vastly improved, as a comparison of new and old images of M13 revealed. Here, the difficulty for film photographers had been the large dynamic range between the dense cores of clusters and their faint outer members; the reciprocity failure of photographic film had severely limited the available dynamic range.

Assessing which objects had been the most popular photographic targets in the 1980s, Dr Moore observed that the Andromeda Galaxy (M31) had been a particular favourite, likely because its brightness had singled it out as the only galaxy within which significant detail had been within easy reach at the time. The Section archive also had plentiful images of M33, M51, and more exotic targets such as Stephan's Quintet, though it was apparent that their low surface brightnesses had posed considerable challenges at the time. Orion's Horsehead nebula seemed almost unique in having retained a constant popularity throughout the past 30 years, probably because it had always been a significant photographic challenge, yet it was tantalisingly just within visual reach. For reference, the speaker showed a 10-minute exposure taken by John Fletcher in 1985 on Boots 1000 film, and a 51-minute exposure taken by Martin Mobberley in 1986 on *Tri-X* film.

The speaker closed by noting that images of planetary nebulae had been vastly improved by the advent of CCDs; old film images were almost invariably burnt out, showing little detail and appearing rather like out-of-focus stars. By contrast, modern images often revealed so much detail that the objects didn't resemble their visual monikers, such as the Swan, at all. The speaker expressed his thanks to Patricia Wainwright for having scanned the archival images used in his talk, and added that she was hoping eventually to scan the entire Section archive, which would then be made available on CD-ROM. Dr Moore then welcomed David Arditti to talk about his experiences using the f/2 HyperStar System.

Using the f/2 HyperStar System for Deep Sky Imaging

Dr Arditti explained that the HyperStar system was a means of reconfiguring widely available Schmidt-Cassegrain telescopes (SCTs), which typically had focal ratios of around f/10, into Schmidt camera configurations which had much faster focal ratios of around f/2. This change enlarged the telescope's field of view by a factor of around five, allowing wide-field images to be taken with short exposures. Dr Arditti explained that he had been using such a system for around 2½ years, but that, with the exception of the manufacturer's specifications and some enthusiastic reviews by Greg Parker[8], he had been surprised by how little he had seen written about people's experiences of using it. In this talk, he would describe his own experiences of using it from Edgware, London.

Dr Arditti explained that the HyperStar system had evolved out of an earlier product, Fastar, which had been developed by Celestron in the 1990s but which they had discontinued in 2005. Though many Celestron SCTs were still marketed as being *Fastar compatible*, now the only such kits available were manufactured by an independent Arizona-based company, Starizona, under the new brand name. In practice, conversion kits were now available from Starizona for many models of SCT which weren't marketed as being *Fastar compatible*, including a few Meade telescopes such as the 14" LX200. As well as offering support for a wider range of telescopes, Starizona also claimed to have reduced the spherical and chromatic aberration of the earlier system.

The purpose of converting an SCT into a Schmidt camera was explained in terms of the length of exposure needed by astrophotographers to record satisfactory images of various objects. For unresolved stars, the amount of light collected from the star scaled simply in proportion to the area of the aperture of the telescope. In other words, the required length of exposure was inversely proportional to the square of the diameter of its aperture. But for extended regions of resolved nebulosity, what mattered was the focal ratio – i.e. the focal length divided by the aperture diameter – of the telescope: the required length of exposure was inversely proportional to the square of this ratio. The reason for the difference was that longer focal lengths equated to higher magnifications, and higher magnifications meant that the light was more spread out across the sensor, with each pixel receiving less of it.

For effective deep sky imaging, telescopes needed both large apertures and also fast – i.e. small – focal ratios. In other words, it was important for the telescope to have a short focal length. Historically, one way of achieving this had been the Schmidt camera design of telescope, invented by Bernard Schmidt in 1930 and notably adopted by the 48-inch Samuel Oschin Schmidt Telescope used for the Palomar Observatory Sky Survey in 1949-58. In common with SCTs, Schmidt cameras brought light to a focus using a catadioptric combination of a refracting correlator plate followed by a spherical short-focal-length primary mirror. But from there onwards, the light path differed. In an SCT, the light went on to a secondary mirror, usually attached to the centre of the corrector plate, which bounced it back down the length of the telescope tube to emerge to the eyepiece through a hole drilled in the centre of the primary mirror. In total, the light traversed the length of the tube of the telescope twice between its reflection from the primary mirror and its reaching a focus, making the Schmidt-Cassegrain a relatively long focal length configuration, with a slow – i.e. large – focal ratio of typically around f/10.

Schmidt cameras achieved much faster focal ratios by removing the secondary mirror and bringing the light to a focus directly from the primary mirror, usually midway along the tube of the telescope. The light only traversed around half the length of the tube before reaching a focus from the primary mirror, equating to a much shorter focal length, and in turn a much faster focal ratio and larger field of view. Historically, a significant disadvantage of Schmidt cameras had been that their focal planes were heavily curved, requiring the use of non-flat photographic plates. Also, the placement of the focal plane in the middle of the telescope's optic tube, where it was impossible to mount an eyepiece, made them useless for anything other than photography. The first problem, at least, could now be alleviated by the use of a field-flattening lens immediately in front of the camera, at the slight expense of some chromatic aberration.

The process of converting an amateur f/10 SCT into an f/2 Schmidt camera required the secondary mirror and its mounting to be completely removed from the centre of the corrector plate, and replaced with a new assembly which could be clamped in its place. This new assembly comprised of a lens – to correct for the spherical aberration normally corrected by the secondary mirror of an SCT, and also to flattened the image plane – and a mounting for a camera – which could be either a dedicated astronomical CCD or a generic SLR camera. The size of the image on the sensor was well suited to the 27mm-diagonal chips used in most DSLRs.

However, as the camera was placed directly in front of the telescope's aperture, there was a strong incentive for it to be as compact as possible. In addition to the camera itself, cables had to be strung across the aperture to get to the camera; at the very least, a power cable and a USB cable would be needed. Hence, whilst DSLRs were supported, a more compact CCD might be preferred. The speaker used a QHY8 CCD camera that he had bought with his HyperStar system, and had found that the obstruction posed by the cables running to it didn't seem to cause serious image degradation on his 11" Celestron, except for some diffraction spikes around stars. He supposed that they would probably be barely noticeable on a 14"-aperture telescope, but would pose a very serious problem on telescopes smaller than his own. He added that he had taken especial care to clamp the cables firmly to the telescope's tube at the edge of the aperture before running them on to his computer. If this was not done, any snag in the cables would put force directly onto the camera, and thence onto the thin corrector plate onto which it was clamped. Another consideration was that placing any cooled camera so close to the corrector plate could cause it to dew up very rapidly, and the speaker added that he always made sure to use a heated dew shield.

The speaker added that each model of camera needed its own unique adaptor to interface it to HyperStar in order to achieve a sharp focus. The focussing mechanisms of SCTs could typically only move the primary mirror through a total distance of around 20mm, which was plentiful in the SCT configuration as the secondary mirror acted as a diverging lens, extending the focal length of the telescope by a factor of around five so that the eventual image plane could be shifted back and forth by as much as 100mm. In the Schmidt camera configuration, however, there was no such extension, and the sensor within any given camera needed to be finely positioned within the narrow focal range of the instrument by means of its own specific adaptor.

Turning to describe the process of converting an SCT for use with HyperStar, Dr Arditti explained that whilst a few Celestron SCTs – those marketed as *Fastar compatible* – needed no modification to receive it, most needed to have a conversion kit applied first. These kits were sold by Starizona, and were available for any Celestron SCT of aperture between 6" and 14", as well as the Meade 14" LX200, and comprised a new baffle tube, a new secondary mirror holder, and a counterweight. Describing the process of applying such a kit as 'fraught', the speaker explained that the telescope needed to be almost completely dismantled. The corrector plate needed to be removed from the front of the tube, and the secondary mirror and its holder unscrewed from the plate's centre. Dr Arditti remarked that his corrector plate had turned out to be glued in place, and that significant prising had been needed to free it from the baffle. Furthermore, he had not realised until too late that the corrector plate should not be rotated relative to its original orientation – one of its functions was to correct for the astigmatism of the primary mirror – and hence it was worth making a Tipp-Ex mark on its outer edge and on the baffle to show how it should be aligned.

Once the corrector plate was isolated, a new assembly could be clamped in place of the old secondary mirror holder; this new assembly could receive either a HyperStar unit, or a new replacement for the old secondary mirror holder. In addition, a counterweight was added to the telescope's eyepiece holder when in the HyperStar configuration, to balance the added weight of the camera at the front. Once a telescope had been converted for use with HyperStar, it was relatively straightforward to switch it between the SCT and Schmidt camera configurations; the process took perhaps a few minutes in a well-lit room. In the dark it was more fiddly; the speaker had dropped his secondary mirror on a recent attempt, though luckily it had come to no harm.

Turning to describe his experiences of using HyperStar, Dr Arditti identified a few potential limitations of the system. Firstly, it seemed difficult to use it with many autoguider systems, since there was nowhere where the light path could be split. Even SBIG cameras, which combined an autoguider and imaging CCD in the same unit, seemed ill-suited since their large packaging would obstruct too much of the telescope's aperture. In practice, he explained that he had resorted to using a separate guide telescope on the same mount when taking long exposures. Second, use of colour filters needed careful planning. Filters could be inserted into the HyperStar assembly, but the camera had to be removed to do so. This made it impossible to take images in multiple colours whilst preserving the alignment of the camera, and so colour imaging was difficult if not using a colour camera.

Perhaps the most serious ongoing nuisance that Dr Arditti had experienced was that very fine collimation seemed to be required. Having a fast focal ratio meant that the Schmidt camera configuration had a very small depth of focus – i.e. the image moved very quickly out of focus if the sensor was moved back or forth. Any slight misalignment of the sensor from the optic axis of the telescope made it impossible to get the whole field into focus at the same time. The speaker had found that his system generally needed re-collimation after every re-pointing, which he supposed to be caused by the weight of the camera warping the alignment of the assembly that it was attached to. This re-collimation process was fiddly as the adjustment screws were by now concealed inside the dew shield and behind the camera. A long screwdriver was needed, and when pointing close to the zenith, also a step-ladder. Long test exposures were often needed to test the collimation, since clear detections of many stars across the field were needed to ensure that they were all cleanly focussed, and the process often took over an hour.

After finding that he often couldn't achieve collimation at all, the speaker had investigated further. Dismantling his QHY8 camera, he had concluded that the sensor itself had been poorly collimated, by mounting it on the chuck of a lathe and turning it slowly by hand whilst reflecting a collimation laser beam off the surface of the CCD. He had, however, been able to improve matters by adjusting the screws used to mount the sensor until the direction of reflection was constant as the camera was rotated.

To close, the speaker showed a few of the fruits of his labours, though he added that he was generally more interested in the technical challenge of acquiring images than in processing them, which often got put off for 2–3 years. First, he showed an image of M31 stacked from 31 ten-minute exposures taken in 2009 September. He remarked that he had limited himself to exposures of a maximum of ten minutes as he lived below a flight path into Heathrow, and aircraft often passed through the widened field of his HyperStar setup. Other easy targets had included the close neighbours M42 and NGC 1977 in Orion, galaxies such as M109, and globular clusters such as M13. Some of these appeared surprisingly small in his large field of view.

Lastly, he showed the deepest image that he had ever taken with the system: a 12-hour exposure of a field in Cassiopeia, stacked from 84 ten-minute exposures, encompassing M52, NGC 7635, NGC 7538, and a vast number of field stars. The image had been taken over the course of successive nights between 2009 July 25 and 2009 September 12, but the speaker added, to laughter, that he had only got around to processing the data the previous night, for inclusion in his talk.

Following the applause, Nick James remarked that he had always been a little wary of supporting the whole weight of a camera on the corrector plate of an SCT. The speaker agreed, but said that in practice the corrector plate didn't appear to warp under its weight. An audience member asked whether the speaker felt the effort had been worthwhile, and how his results compared with what could be done with small-aperture refractors. The speaker thought in retrospect that his results were broadly comparable to what could be done with a refractor, but that he had nonetheless enjoyed the challenge of installing HyperStar.

The Director then invited Owen Brazell, usually best known as an observer of planetary nebulae, to talk on this occasion about galaxy clusters.

Galaxy Clusters for the Amateur

Mr Brazell opened by explaining that he would be talking about objects that were variously termed as either *galaxy groups* or *galaxy clusters*, but that the distinction between these terms was not well defined. Galaxy clusters generally had more known members than groups – perhaps more than thirty to fifty – but in some cases the nomenclature was determined by historical convention. For example, the Local Group of galaxies, of which the Milky Way was a member, was termed a *group* despite having more than forty known members.

Several catalogues provided amateurs with lists of targets that might be attempted. Perhaps the most approachable of these was the *Hickson Compact Groups of Galaxies* (HCG) catalogue[9], compiled by Paul Hickson in 1982. This presented the amateur with a manageable number of groups – exactly one hundred – typically comprising 8–10 members and comfortably within range of large-aperture amateur telescopes given a dark site. Among the catalogue's members were a number of well-known objects, including Stephan's Quintet (HCG 92) in Pegasus.

The more ambitious amateur might turn to the *Shakhbazian Compact Groups of Galaxies* (SHK) catalogue, compiled by Armenian astronomer Romelia Shakhbazian *et al*. over the years 1973–79 by systematically searching the plates of the Palomar Observatory Sky Survey (POSS). It listed 377 groups, typically comprising 5–15 members – so often richer than the members of the Hickson catalogue – but often at seriously challenging magnitudes in the range 14–19.

The *Abell Catalogue of Rich Clusters of Galaxies* presented a larger sample of 2,712 northern-hemisphere clusters, also found by searching the plates of the Palomar Observatory Sky Survey (POSS), and published by George Abell in 1958. The selection criterion used by Abell was that clusters had to contain around thirty or more bright members to be included. In 1989, this catalogue had been extended to cover the southern sky, enlarging it to 4,076 members.

Other catalogues of historical interest included Fwitz Zwicky's *Catalogue of Galaxies and Clusters of Galaxies* (CGCG), compiled over the years 1961–68, which offered a more complete set of 9,134 objects, but this was now rarely used. Halton Arp's *Atlas of Peculiar Galaxies*, published in 1966, listed 377 members, many of which were closely interacting pairs of galaxies.

To observe any galaxy group or cluster, it was essential to have a dark sky – few locations in the UK were suitable – and a good finder chart; even those using telescopes with digital setting circles would need the latter in order to identify and navigate around the members of richer clusters such as the Virgo cluster. Several computer packages and online resources were able to provide such charts. Mr Brazell added that, though he had a personal preference for undriven telescopes, a drive was hugely beneficial when seeking out very faint objects. Access to high quality eyepieces with a range of powers was also helpful – low powers being used for navigation and higher powers for trying to resolve fine detail within individual galaxies.

Turning to show images of a few of the best known clusters, Mr Brazell began with the Virgo cluster as it was the most accessible, containing a number of Messier objects as well as many much fainter members; it offered challenges with a wide range of difficulty levels. Wide-field imagers might like to try stitching together an image of the whole cluster, though the large area that it covered on the sky made it particularly necessary to have a good finder chart; it was easy to get lost. The Coma cluster, a little to the north and at a greater distance away from us, offered a tighter and slightly fainter condensation. One of the challenges here was the magnitude 7.2 field star HIP 63405 in the midst of the cluster, which could be rather dazzling in a large-aperture telescope.

Other targets which were accessible from the UK at this time of year included the Leo Triplet, comprising M65, M66 and the more challenging NGC 3628. Nearby, Hickson 44 offered a more challenging quartet of NGCs 3185, 3187, 3190 and 3193. The faintest member, NGC 3187, was especially challenging.

To close, Mr Brazell listed various books which were available to amateurs interested in observing these objects. The relevant volume of the Webb Society's *Deep Sky Observer's Handbook*[10] was now out of print, but amateur astronomer Alvin Huey maintained a website[11] which offered a wealth of information together with several self-published observing guides available for purchase.

Following the applause, Dr Nick Hewitt commented that collecting observations of all of the Hickson groups might be a nicely sized observing project for the Section to take on, given the catalogue's modest number of members. The meeting then broke for lunch, during which some audience members observed a solar flare through a solar telescope fitted with an Hα filter. After the break, the Director invited Grant Privett to speak.

Things that Fade in the Night: Variable Nebulae

Mr Privett commented that few deep sky objects changed in appearance from one decade to the next, and that this, combined with the large apertures needed to observe them, meant that amateurs had few opportunities to contribute scientifically significant observations of them which could compete with professional images. A small group of five known *variable nebulae* provided the only exceptions to this rule, varying in both brightness and morphology on week-long timescales. These were Hind's Nebula (NGC 1555) in Taurus; Hubble's variable nebula (NGC 2261) in Monoceros; NGC 6729 in Corona Australis; Gyulbudaghian's nebula, discovered in 1977 neighbouring the variable star PV Cephei; and McNeil's Nebula in Orion, recently discovered in January 2004 and thought to be associated with the infrared source IRAS 05436-0007.

All of these were reflection nebulae – nebulae which did not produce their own light, but scattered that of nearby stars. Their variability, in contrast to the unchanging appearance of most reflection nebulae, was thought to arise principally because they happened to be illuminated by variable stars, though in some cases the movement of dust lanes might give rise to added variability, casting transient shadows across regions of space measuring light-months across.

That such a small number of nebulae were known to vary in brightness was perhaps surprising given the large number of variable stars which were known to pervade the Milky Way. Was it really so rare for a reflection nebula to find itself close to such a star, or were many more variable nebulae waiting to be found? The speaker found the latter explanation the most likely, especially given the comparatively recent discovery of Gyulbudaghian's and McNeil's nebulae. The latter was absent from pre-discovery images of Orion going back several decades, suggesting that it had been optically faint for many years prior to its discovery in 2004, and so it seemed probable that more variable nebulae would spontaneously appear and be discovered in the future.

Amateur observations of such reflection nebulae could seek to answer a number of questions. Was the variability of each nebula purely the result of fluctuations in the brightness of a nearby variable star, following it exactly, or were there other contributing factors? Were there any colour or morphological changes associated with the variability? What timescales did the nebulae change over? The equipment needed to make observations which could usefully address these questions was modest: CCD photometry of adequate quality to construct a light curve was possible with a 4-inch aperture, while CCD imaging was possible with a 6-inch aperture. When the nebulae approached their peak brightness they were within reach of visual observers using large-aperture Dobsonians.

The speaker concluded by reporting on the Section's work over the past three years to monitor the variation of Gyulbudaghian's nebula – an object ideally placed for observation from the UK. Lying in Cepheus, at a declination of +68°, it was circumpolar across much of Europe, though it could nonetheless be challenging to observe in the spring. A particular stalwart of the project had been the Association's President, David Boyd, who had regularly contributed photometric measurements of sufficient quality to show that the nebula's brightness varied on short as well as long timescales; there could be, for example, considerable brightness fluctuations from one day to the next.

In addition to collating the observations submitted to the Section, the speaker had also scheduled regular observations using the Sierra Stars Observatory 0.61-metre robotic telescope in California. When the weather permitted these to go ahead, the sharp images that could be obtained from such a site revealed morphological changes which accompanied the nebula's brightness fluctuations, though the speaker added that these did not rule out the idea that the nebula's variability stemmed purely from the fluctuating illumination provided by the nearby variable star PV Cephei. The considerable light travel time across the nebula – over a month – meant that different parts of the nebula would be expected to mirror the variability of PV Cephei with differing time lags. As had previously been reported by the Director in his annual review, Dr Boyd had in fact observed the global average brightness of the nebula to closely follow variations in the brightness of PV Cephei, but with a lag of 32±4 days. If this was interpreted as the light travel time between the star and the nebula, it corresponded to a plausible separation of around 0.027±0.003 parsecs.

Following the applause, an audience member asked how Gyulbudaghian's nebula appeared at present. The speaker replied that it had undergone a deep fade, and that no nebulosity was visible even in his latest 300-second exposures from Sierra Stars. However, given its unpredictable nature, it might reappear at any moment, and he was as keen to receive reports of negative observations as positive detections. The Director then invited Geoffrey Johnstone to present a historical perspective on his experiences of astrophotography in the 1980s.

Astrophotography in the 1980s: Why I didn’t blow myself up

Mr Johnstone explained that he had first become interested in trying astrophotography for himself after seeing images in *Sky & Telescope* magazine in the early 1980s. Around this time he had bought his first large telescope, a 240mm f/5 Astrosystems Newtonian, which he had co-mounted with a 150mm f/7.5 Newtonian for use as a guidescope during long exposures. He went on to explain that a guidescope had been an especially important part of any system used for astrophotography at the time, since the available drive systems had been crude by modern standards. His own, for example, had produced a marked wobble of the field with each turn of its worm wheel, and whilst modern mounts could correct for such problems with periodic error correction, the technology had not existed in the 1980s.

To use the system, he had begun by visually locating and centring his chosen target in the field of the primary Newtonian. He had then turned to the eyepiece of the guidescope to select a suitable guide star within its field of view, and adjusted the guidescope's mount to centre the chosen star on the guidescope's cross-hair. This having been done, he could replace the eyepiece of the primary telescope with a camera and begin an exposure. Throughout the duration of the exposure – typically 20 to 50 minutes – he would sit at the eyepiece of the guidescope, visually monitoring the position of the guide star and nudging the mount to keep it centred. He recounted that his observatory had been housed in a rotating summer house, and that space had been limited; it had often been an uncomfortable squeeze to stay at the eyepiece as the telescope tracked across the sky. On at least one occasion he had found himself pushed hard against the wall and had had to cut his exposure short.

Turning to the question of choice of film, the speaker explained that he had used many different films, but most often either Kodak *Tri-X* – best suited for sharp images of stars – or Kodak *Technical Pan 2415* – better suited for nebulosity. He added that although the latter had only had a nominal ISO rating of 25, nominal ratings such as this in fact meant little when the film was used for astrophotography; all film emulsions suffered an effect known as *reciprocity failure*: they were optimised for use at a particular length of exposure – in the case of *2415*, around 1/250th second – and were less responsive when used in long slow astronomical exposures. However, his interest had been piqued when he had heard reports that hydrogen gas could be used to hyper-sensitise the film, as he had had industrial experience of working with the gas early in his life, growing bacteria samples in a pathological laboratory.

To hyper-sensitise the film, he had needed to place it in a vessel containing hydrogen gas at a temperature of 40°C for 7–8 hours. In industry, he had been able to create similar conditions by first connecting a sealed vessel to a vacuum pump to extract the air, before feeding a regulated quantity of hydrogen into it using a rubber balloon-like bladder which he had filled from a hydrogen cylinder. The speaker had reproduced similar conditions at home in a stainless steel developing tank, which he evacuated using a bicycle pump with inverted valve. He had produced hydrogen gas in a milk bottle, by mixing zinc with hydrochloric acid, and had piped it into the developing tank using rubber tubing from a home brewing kit. He had then heated the tank to the required temperature of 40°C using a fish tank heater.

He added that whilst his work had gained some notoriety among Section members for its hazardousness, hydrogen gas was no more dangerous than other widely-used flammable gases and only became explosive if allowed to mix with oxygen. Had it been available, using *forming gas* – an inert mixture of hydrogen and nitrogen – would have eliminated the risk altogether.

Mr Johnstone closed his talk with a series of photographs which he had taken using the method described, including images of M33, M51 and the Horsehead Nebula. He added that one of the main difficulties of film photography, as compared to modern CCD imaging, was the limited achievable dynamic range: it had been very difficult, for example, to avoid burning out the nuclei of globular clusters if the outer cluster members were to be visible at all.

Following the applause, the meeting broke for tea, after which the Director invited Dr Nick Hewitt to speak.

Active Galactic Nuclei, and why amateurs should observe them

Dr Hewitt explained that he would be arguing in his talk that active galactic nuclei (AGNs) deserved greater attention from amateur deep sky observers, even though they posed quite different observational challenges to more familiar deep sky objects. Their study was, he added, a comparatively recent development. Modern cosmology, and the vast distance scales it implied, had now become so well rehearsed that it seemed surprising that, as recently as 1920, Harlow Shapley and Heber Curtis had been able to debate whether spiral nebulae lay within or outside the Milky Way without clear victor.

The decisive evidence in that debate had been published in 1925: Edwin Hubble's measurements of the comparative faintness of Cepheid variable stars within these nebulae, made using the 100-inch Hooker Telescope on Mount Wilson, implied that they must be galaxies external to our own. The identification of active galaxies as a class distinct from others had begun 15 years later in 1940–2 with the work of Carl Seyfert, also working at the Mount Wilson Observatory. He had noticed that some galaxies, now known as *Seyfert galaxies*, had unusually bright point-like features at their centres; the clearest example was M77 in Cetus.

From here onwards, the study of AGNs had followed a more complicated path. It had gradually transpired that they could appear in a number of different observational guises depending upon the angle from which they were viewed. Many of these guises had been assigned separate names, and treated as entirely separate classes of object, until later theoretical work had shown them to be equivalent. For example, the rapid development of radio astronomy after the Second World War had given rise to the designations *radio galaxy* (1940s) – galaxies which produced unusually large amounts of radio radiation – *quasar* (early 1960s) – mysterious point-like sources of radio radiation in the sky – and *blazar* (mid-1970s) – quasars which showed dramatic variations in brightness. All of these objects would later be understood to be active galaxies viewed in different orientations.

The recognition that these represented some of the most powerful objects in the Universe had emerged from observations of quasars. In 1960, the position of the radio source 3C48 had been pinned down with sufficient accuracy to identify an optical counterpart whose spectrum indicated a redshift of 0.37, corresponding to a distance of several billion lightyears. That it could appear so bright in the radio sky, despite lying at such a great distance, implied that it must have a phenomenal luminosity, and the claim was not widely believed at first. The clinching evidence had come in 1963, when the radio source 3C273 had been occulted by the Moon. Precise timings of its disappearance and reappearance using the Parkes Radio Telescope had allowed an optical counterpart to be found for it also, and once again a spectrum was found that indicated a very great distance.

The speaker explained that it was now understood that black holes lay at the centres of active galaxies, and that their intensely bright nuclei were the result of gas accreting onto these black holes. As the gas approached the black hole's event horizon, it became heavily compressed and incredibly hot, forming an *accretion disc* which glowed at all wavelengths from radio waves through to X-rays. Though such accretion discs appeared bright from any direction, they produced two especially intense beams of radiation, which were highly collimated in either direction perpendicular to the disc. Objects observed as quasars represented those rare AGNs which happened to be viewed exactly along the directions of these narrow beams, which accounted both for their rarity and also for their astonishing brightnesses, even at very great distances.

Dr Hewitt went on to explain that amateurs could contribute scientifically useful observations of AGNs by monitoring their brightness changes. This was rather different from most deep-sky imaging: the nebulosity associated with the point-like nuclei of these objects was often beyond the reach of professional, let alone amateur, telescopes, and so there was no structure to resolve. He personally worked with a 115mm TMB apochromatic refractor and performed photometry on his images using the software package *AIP4WIN*.

A list of a few potential targets could be found in the BAA *Handbook*. Of these, one of the easiest to find was Mrk 421 as it lay a mere 2' south of the star 51 Ursa Majoris. Though the AAVSO quoted its magnitude as varying between 11.6 and 16, in practice it was usually close to mag 13. A more difficult object, of historical significance previously mentioned, was 3C273. Typically a little fainter than mag 13, it could be found in the Virgo cluster, but not within easy hopping distance of any readily accessible way-marker stars. One of the personal favourites of the speaker was 3C66A, a rather distant quasar lying at a distance of 4.5 billion lightyears, which varied between mag 13.5 and 15.5. He remarked that it was awe-inspiring to think that the light being detected from this quasar had set out on its journey at about the same time that the Solar System had been forming. Finally, more distant and more challenging objects still included the double quasar, Q0957+561, at around mag 16.5, and the Einstein cross, Q2237+030 at closer to mag 18.

After the applause, the Director invited Prof. Derek Ward-Thompson of the University of Cardiff to close the afternoon, as was traditional, with a professional perspective on the deep sky.

The Herschel Space Telescope and Star Formation

Prof. Ward-Thompson expressed his honour at having been invited to speak, recalling that he had been a member of the BAA himself in the 1970s. He explained that he would be talking about work he had recently been doing with data from the *Herschel Space Telescope*, a 3.5-metre telescope operated by the European Space Agency (ESA) which observed at far-infrared wavelengths. At these long wavelengths it was possible to see the faint thermal glow of cool objects which were only a few tens of Kelvin above absolute zero – i.e. below -200°C – but to do so required *Herschel*'s cameras to have incredibly low noise levels – so low that they had to be cooled to a temperature below 2K using liquid helium. The speaker added that the supply of coolant needed to maintain these low temperatures would be the limiting factor that would set the telescope's useful operating lifetime.

Herschel had been launched aboard an Araine 5 heavy launch vehicle on 14th May 2009, and had initially been planned to operate for three years, though it now seemed likely that its helium supply would stretch to at least 3.5 years. It orbited the Earth at an altitude of 1.5 million km – four times more distant than the Moon – at a point known as the second Lagrangian point, where it took exactly a year for it to circle the Earth. This was an orbit that it shared with several other long-wavelength telescopes, including *WMAP* and *Planck*, and which was useful because it kept the Sun and Earth in close conjunction all the year round. As the Sun and Earth were both exceedingly bright infrared sources, which the telescope had to be directed well away from, it was useful to keep them together in the sky so that observers only had to be mindful of a single exclusion zone when pointing the telescope.

The speaker explained that *Herschel* was being used to observe many different kinds of objects, including AGNs and local group galaxies, but that he would be concentrating on star-forming regions in this talk, and in particular on Gould's Belt, a ring of star-forming regions around the Sun, measuring around 3,000 lightyears across, and which included a number of famous groupings of stars including the Pleiades (M45) and the Orion Nebula (M42). He added that Gould's Belt was inclined at around 20° to the plane of the Milky Way, crossing it in Perseus and Scorpius, and that this made it particularly attractive to study, as parts of it were well separated from the confusing mass of stars in the Milky Way.

He explained that stars began their lives in dense clouds of cool hydrogen gas known as *molecular clouds*. These were often also referred to as *dark clouds*, because condensations of dust grains within them blocked the light of background stars and made them appear visually as dark patches on the sky. Within these clouds, the process of forming a star could begin if a clump of gas, referred to as a *prestellar core*, became sufficiently dense that its gravitational self-attraction was sufficient to overcome the gas pressure pushing it outwards. Once such cores had formed and begun to collapse under their own gravity, they began to gravitationally draw in more gas from their surroundings, forming an accretion disc similar to those found around AGNs. The accretion disc was of especial interest, as it could later evolve into a *protoplanetary disc*, and perhaps eventually into a planetary system around the star. The core itself would go on to evolve into a T Tauri type star – a kind of variable star often studied by amateurs – before becoming a main sequence star.

Turning to an infrared image that he had taken of the horsehead nebula, a familiar example of such a dark cloud, in 2006 using the SCUBA camera on the James Clerk Maxwell Telescope (JCMT) in Hawaii, he pointed out that his infrared image showed clear evidence of a warm condensation of material around the horse's throat.[12] This was a prestellar core, whose solar wind and radiation might be expected to blow the horsehead nebula apart within the next few million years.

The speaker explained that a long-standing puzzle about the process of star formation was the distribution of the masses of the stars that it produced, a distribution known as the *initial mass function*. This distribution seemed to be universal for all molecular clouds, regardless of their environments – i.e. all molecular clouds seemed to produce low mass and higher mass stars in roughly the same relative proportions. This suggested a distribution that stemmed from a very fundamental and universal underlying mechanism, but it was not clear what this mechanism was.

He went on to explain that with the advent of infrared telescopes over the past 20 years, it had become possible to measure the masses of individual prestellar cores within molecular clouds. It seemed that these potential precursors to stars shared a very similar distribution of masses to the stars that the cloud might eventually go on to form. This suggested that the mass of star which each core was going to evolve into was already set at this very early stage. Thus, the problem had been pushed back a level: the shape of the initial mass function appeared to directly mimic the shape of the mass distribution of the prestellar cores. But what caused the cores to form with the mass distribution that they did?

One of the aims of the *Herschel Space Telescope*'s survey of the Gould Belt was to observe large numbers of prestellar cores, in order to improve the statistical certainty with which their mass distribution was known, and to attempt to understand better the processes by which they evolved. Showing a few early images from the project, Prof. Ward-Thompson remarked that the sensitivity of *Herschel*'s cameras was so great that the pixel-to-pixel noise was determined by the light of very distant background galaxies, rather than the camera itself.

Turning to two contrasting star forming regions, in Aquilla and around Polaris, he noted that the cores in Aquilla appeared to follow the stellar initial mass function as expected, but shifted such that the cores were on average three times more massive than newly-born stars. He added that this was relatively simple to explain: it was likely that two-thirds of the material within each core would be lost in the initial burst of energy as the star warmed up.

However, the distribution of the masses of the cores around Polaris was different. Here, the cores once again followed the stellar initial mass function, but this time shifted such that they were less massive than typical newly-born stars. This was harder to explain: where could these cores get extra mass from? This, he argued, was perhaps a failed star-forming region, that would actually never be able to form stars. If this was the case, he hoped that by studying it, determining how it was different from regions like Aquilla, and why it hadn't managed to form stars, some clues would be given about the initial conditions needed to form stars. The speaker concluded with a selection of further early images from *Herschel*, though he added that it would take several years to finish the analysis of them.

Following the applause, the Director thanked Prof. Ward-Thompson, as well as all of the day's speakers. In closing the meeting, he thanked all those who had helped ensure its smooth running, and especially Ann Davies of Newbury Astronomical Society for providing the catering for tea, coffee and lunch. He thanked Owen Brazell for bringing along a sales stand for the Webb Society, Ann Davies for bringing along a sales stand for the BAA, and Nick Hewitt for providing a polypin of ale at lunchtime.

Dominic Ford

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