Ordinary Meeting, 2004 March 31

held at The Geological Society, Burlington House, Piccadilly, London W1

Tom Boles, President

Ron Johnson, Nick Hewitt and Nick James, Secretaries

Mr Boles opened the fifth Ordinary Meeting of the 114th session, and invited Dr Hewitt to read the minutes of the previous meeting, held at the fourth Observers' Workshop in Milton Keynes. The minutes were approved by members and signed. The President announced that 59 new members were proposed for election, and members approved those 23 proposed at the previous meeting. Mr Boles invited any newcomers to introduce themselves at the end of the evening's proceedings. Mr James reported that there were no newly approved Journal papers.

The next meeting was the fast-approaching Winchester Weekend, 2004 April 2-4, which would this year include an Instruments & Imaging Section Meeting. The next Ordinary Meeting would be on Saturday April 24 at Nottingham High School for Girls, during the fifth of the Association's series of Observers' Workshops. Finally, the President regretted to inform members of the death of Dr Janet Mattei, on March 22, after a long illness. Director of the American Association of Variable Star Observers for over 30 years, she had been noted for her warmth and personableness, and had long been seen as a bridge between the amateur and professional communities. Her death was described as a tremendous loss for all amateur astronomers.

The President then proceeded to introduce the evening's first speaker, Dr Meghan Gray of the University of Nottingham. Born in Nova Scotia, Dr Gray had travelled to the UK in 1997 to study for a PhD at the Institute of Astronomy in Cambridge. Since then she had worked at the Royal Observatory, Edinburgh, before moving onto her present post. Though her work had primarily centred around the subject of her present talk, gravitational lensing, more recently her interests had widened to include galaxy evolution.

Illuminating the Invisible: Uncovering Dark Matter with Gravitational Lensing

The speaker commenced with a Hubble Space Telescope (HST) image of galaxy cluster Abell 2218, a useful starting point as it illustrated two quintessential observations upon which her field was built. The first was that mass bends light; the second was the existence of dark matter. Within the cluster could be seen a number of galaxies, all of similar colour because they had formed together and were at similar stages along their evolutionary path. The speaker's first observation, that mass bends light, was derived from a number of arcs of much bluer colour, which appeared to be lensed images of a more distant galaxy. The latter deduction, that dark matter was required to explain the observed phenomenon, derived from the inability, by a substantial factor, of the estimated amount of visible luminous mass in the galaxy cluster to account for the magnitude of the observed lensing of the background galaxy. Dr Gray drew analogy between the HST view and an image of the Earth by night. Just as the latter revealed only those street-lit urban areas, the rest being shrouded in darkness, so our telescopes, sensitive only to glowing luminous matter, gave an incomplete image of the Universe.

The speaker explained that the term 'dark matter' on occasion caused confusion, for it was only *dark* in its non-emission of electromagnetic radiation. It might be more appropriately named 'transparent matter' in contrast with the dust lanes of *dark nebulae*, which blocked the passage of light, thus appearing dark. By contrast, dark matter was simply invisible. But, however ambiguous, the name 'dark matter' was here to stay.

Dr Gray explained that her talk would firstly summarise what we knew about dark matter, and how we had arrived at the conclusions we had. She would then provide an introduction to General Relativity as applied to gravitational lensing, before concluding with unanswered questions. The first evidence for dark matter, she explained, had arisen in 1933 when Fritz Zwicky, at Caltech, observed that galaxy clusters orbited around their centres more rapidly than could be explained. Unless there was significant mass in the cluster over and above what was visible, the cluster would fly apart. Extra mass was needed to act as gravitational "glue". Further observational evidence for dark matter would emerge in the 1970s, with the measurement of the rotation velocities of disc galaxies. In *most* cases, these too were also found to rotate faster than could be explained, particularly towards the edge of the disc. To explain the observed rotation profile, the galaxy had to sit in a halo of invisible, but gravitating, mass.

From such studies, astronomers had been able to pin down how much dark matter there was in the Universe: roughly 8kg for every kilogram of luminous matter. Thus, astronomical observations told us that, in total, dark matter significantly outweighed all the luminous matter, but was much more evenly spread out in space. However, the question of what dark matter was composed of was not one astronomers could answer; this was in the realm of particle physics. Formerly it had been thought that dark matter might be ordinary (baryonic) matter, possibly in the form of small planets, dim stars, black holes, or *massive compact halo objects* (MACHOs) in the outskirts of galaxies. However, in recent times, cosmologists, studying the initial proportions of hydrogen and helium which emerged from the furnace of the Big Bang through a process called nucleosynthesis, had been able to place stringent constraints on the amount of baryonic matter in the Universe which were compatible with their observations. The upper limit was less than 10% of the amount of dark matter required to fit the rotation velocity observations, and this led them to conclude that most dark matter must be of an exotic kind.

The speaker explained that this led to the presumption that dark matter was composed of a sea of invisible lone particles called *weakly interacting massive particles* (WIMPs), whose influence could only be felt by their gravitation. Particle physicists already anticipated such particles might exist from a theory known as *supersymmetry*, and had built a detector in a potash mine in Boulby, Yorkshire, where finely controlled conditions underground might allow the presence of WIMPs to be detected in the next few years.

Dr Gray moved on to discuss the history of our theoretical understanding of gravitational lensing, a story which could be traced back to Newton. His Theory of Gravity suggested that light might be attracted towards massive bodies in the same way as matter. In a moment of foresight, he proposed that light rays passing a mass such as the Sun might be bent towards it, though the effect was so small that it was to remain untested until 1919, four years after Einstein had proposed a new theory of gravity, General Relativity. This made the concrete prediction that the effect should be twice as large as predicted by Newton. Sir Authur Eddington realised that the total solar eclipse of that year would provide a unique opportunity to test the new theory. By noting the apparent positions of stars at small angular separations from the Sun, normally invisible in its glare, he hoped to measure the bending. In a hastily prepared experiment, he compared the positions of these stars on the day of the eclipse as compared to six months earlier, when the Sun had been elsewhere in the sky. Despite poor observing conditions, Eddington declared an observed shift of 1”75, matching exactly Einstein’s prediction. Subsequent re-examination of Eddington’s plates, however, had shown the data to be questionable, and it was somewhat serendipitous that his conclusion would later be verified by more accurate studies.

The speaker described how Fritz Zwicky, already mentioned for having discovered the first evidence for dark matter, would go on to predict with great accuracy the applications of the lensing induced by it. In 1936, he foresaw the use of gravitational lenses as telescopes to view magnified images of more distant objects, and also predicted that lensed images could be analysed to map the distribution of dark matter. These turned out to be accurate prophecies as to the focus of research sixty years on. In addition, the phenomenon had also been utilised to constrain cosmological parameters. Zwicky’s legacy was especially impressive since the first observation of dark matter lensing would not come until 1979: he was truly a man ahead of his time. The discovery would come when Walsh et al. stumbled serendipitously upon what appeared to be a pair of quasars at very close separation. However, these being rare objects, it was statistically unlikely that two should lie so close together, and moreover, when their spectra were found to be indistinguishable, the mystery deepened. These were, they eventually concluded, two images of the same object, traversing different paths around an intervening lens. Suddenly lensing was no longer confined to pure theory.

The behaviour of gravitational lenses could be divided into several classes, Dr Gray explained, and each had its unique applications. The smallest class produced an effect termed *microlensing*, where a compact stellar mass object within our Galaxy magnified the observed image of a more distant star as it passed in front of it. To terrestrial observers, the star would appear to brighten with a characteristic lightcurve, quite distinct from any stellar variability. While this possibility had been recognised for decades, the exactness of the required alignment meant that the occurrence would be rare and brief, perhaps one event per star in a million years, and prospects for observation were slim. With the recent advent of automated searches, however, it was now possible to observe many millions of stars on a regular basis, introducing the possibility of picking up a handful of events per year. Over the previous decade, the MACHO collaboration had undertaken such a project with many successful detections. The most interesting results from this had been information obtained about the lensing objects themselves, which often turned out to be very peculiar bodies. One recent event appeared to have been caused by a double star with a planet, which would theoretically appear so unstable as to have negligible lifetime.

The speaker next discussed lensing by entire galaxies, weighing around 10^{11} solar masses, of more distant galaxies or quasars. Termed *strong lensing*, this could precipitate three effects upon the image of its subject: magnification, distortion, or multiple images. One of the finest examples of all three was the so-called *Einstein Cross* (2237+030), in which four images of a quasar were seen around the low-redshift lens galaxy. In cases of near-exact alignment, a continuous halo-like ring around the lens galaxy could result, termed an *Einstein Ring*. In systems with multiple images, the curious possibility arose that the light path-length for the images might vary considerably, and if the lensed source exhibited any sudden variability in its luminosity, this difference could be measured. Indeed, such a phenomenon had now been successfully observed, and, in at least one case, a putative time offset of several years was identified between two of the images, implying a path difference of several lightyears.

The exciting potential of strong lensing to behave as a “telescope”, providing a magnified view of very distant objects, had begun to unfold with the discovery on 1997 July 30 of an image of a galaxy apparently at redshift 4.92. In the weeks preceding the meeting this record for the most distant object had been swept away by the claimed discovery of a lensed image of a redshift 7 galaxy by Kneib et al. on 2004 February 12. But this was only to be superseded by a claim of a redshift 10 discovery on 2004 March 1 by Pello et al. using the Very Large Telescope (VLT) in Chile.

Finally, Dr Gray discussed the subtler effects of lensing by more diffuse large-scale mass distributions such as clusters of galaxies, termed *weak lensing*. If a background field of galaxies were viewed through such a lens it would appear warped or sheared, and the distortion would be constant over larger angular scales than for strong lensing by smaller objects. It might lead to a stretching of the image of every background galaxy in a certain direction, for example. In that case, without any knowledge of the physical orientation or ellipticity of the galaxies, it was impossible to detect that any one galaxy appeared stretched. However, taking a field containing a large sample of galaxies, one would expect each to be randomly aligned. By averaging over their alignments, one could be pretty sure that weak lensing was at work if there was a significant bias towards a particular orientation. Typically, work in this field involved simulating the lensing of a hypothetical field of randomly aligned galaxies, and varying the lensing mass distribution until the statistical properties of the resultant image matched the observation. Thus, despite the subtlety of the effect, the underlying dark matter distribution could be discerned with some accuracy.

To close, the speaker outlined the unanswered questions of the field, including most fundamentally what dark matter was composed of. Also, it was not known how dark matter was distributed through the Universe, or how this had evolved throughout its cosmic history. Finally, the effect of dark matter upon the formation and evolution of galaxies was poorly understood. Following the applause, the President invited questions. When asked, with reference to rotation curves, why she had said “most” galaxies appeared to contain dark matter, rather than “all”, the speaker explained this was a difficult problem. There did appear to be a small number of galaxies with no evidence for dark matter, but this could not theoretically be explained, and needed further investigation. In a vote of thanks, the President congratulated the speaker for clearly explaining difficult maths, providing a very illuminating talk. Following further applause, the speaker invited Mr Martin Mobberley to deliver his regular Sky Notes.

The Spring Sky

Starting close to home, Mr Mobberley discussed the prospects for the forthcoming total lunar eclipse on May 4, though the UK was unfortunately not going to be a good observing location this time around. The eclipse would be visible at moonrise at 21h00 UT, already having reached totality. The Moon would still only be peeking above the south-eastern horizon at an altitude of 11° at the close of totality, so it seemed that only UK observers with particularly flat horizons would see it.

Further from home, NASA’s rover *Opportunity* had taken a break from surveying Martian geology to observe transits of the Martian moons across the solar disk. First, Deimos had transited the Sun on March 4, photographed by Opportunity’s PanCam at 3h04 UT. Phobos, the larger Martian moon, had later eclipsed the Sun’s edge on March 7, captured on camera at 2h46 UT. Never before had mankind made extraterrestrial eclipse observations. Also from Mars, the first images of the planet’s landscape from Europe’s Mars Express satellite were truly stunning. Craggy cliff faces towered around impact craters, the scars of past landslides clear to be seen. Even the tiniest details could be resolved, each pixel representing a distance of only 10m. By imaging some features at oblique angles, the landscape came to life, appearing to reach off towards the horizon.

Back on Earth, few could have failed to notice the particularly bright intruder which had appeared in the evening sky in recent weeks, shining brilliantly at mag –4. Though the surface of Venus was fairly featureless, the new apparition brought with it a renewed challenge for amateurs to image the so-called Ashen Light. Many visual observers claimed to have observed this apparent brightening of the shadowed side of Venus, as if the planet were itself glowing. However, none had yet been able to convincingly image it, and it remained without theoretical explanation. As the apparition drew to a close, the prospects for observation would improve as the shadowed portion of the surface grew larger. Around April 3, Venus would skirt within 30’ of the Pleiades, and the speaker pointed out that at this time, both objects, as well as Mars, would all be within 2° of the same declination, making easy observing for those with equatorial mounts.

The Association’s resident supernova hunters had been hard at work, Mark Armstrong having five new discoveries, and the President three, bringing the UK total to 130 discoveries. In addition, Nishimura and Liller had discovered a nova at mag 8.2 near the Sagittarius teapot on March 18, an area where there had been a number of similar events in recent times. Also notable was Peter Birtwhistle’s fourth asteroid discovery, 2004 DN25, on February 22, around mag 20-21. It seemed that he had beaten the automated searches of LINEAR and NEAT to it, and was particularly remarkable since in the past, great discoverers like Brian Manning had never picked up such objects until they were much brighter, typically mag 16-17.

A great deal of media excitement had stirred with the discovery of the most distant asteroid found to date, provisionally named ‘Sedna’. This was the latest in a flurry of discoveries of *transneptunians* (asteroids lying beyond the orbit of Neptune) in recent years. With the exception of Pluto, the first known example was 1992 QB1, discovered only twelve years ago. Since then, over 800 had been identified, five larger than 900km across, but the recent discovery of 2004 DW on February 17 was exceptional in that its size was estimated to be around 1,500km, at least half the size of Pluto. The possibility remained that it might be substantially larger since Pluto’s unusually high albedo made size comparison difficult by comparative brightness alone. If this were confirmed, 2004 DW would be the largest minor planet known, larger than Charon, and bringing Pluto’s status as a planet further into question. The speaker showed an image of 2004 DW on March 7 by Peter Birtwhistle, noting with amazement that the Moon had been one-day past full that night, 41° away. In the stacked image, of total exposure 42 minutes, the estimated magnitude of the minor planet was 18.8.

The discovery of 'Sedna', officially named 2003 VB12, had been announced on March 15 based on observations from the Palomar Observatory on 2003 November 14. Its highly eccentric orbit had perihelion at 76 AU, around twice the distance of Pluto, and aphelion at a remote 990 AU. It was presently close to perihelion, and appeared around mag 21. At 1,500km across, it was the second largest known transneptunian only to Pluto, but its distant aphelion was not the furthest known: the orbit of 2000 OO67 receded as far as 1010 AU from the Sun.

Nearer to home, asteroid 2004 FH had passed within 30,000 miles of the Earth on March 18, the closest recorded pass of an asteroid by the Earth. For comparison, the speaker gave the Moon's distance as 238,000 miles. However, at 20-metre diameter, the rock posed no threat to humanity at all, as if it were to collide with the Earth in the future it would simply burn up in the atmosphere.

Comet observers were eagerly awaiting C/2001 Q4's close pass by the Earth on May 7, dubbed by some "The Comet of 2004". Presently a southern hemisphere object at dec –65° and mag 5, it would surge northwards in the first week of May, becoming visible in the evening twilight shortly before its closest approach to the Earth, and it seemed possible that it might reach a peak brightness around mag 2 in mid-May. It would go on to reach perihelion on May 15, passing within a degree of the Beehive cluster (M44) on that night, grazing it with its tail. The speaker recommended this as an ideal photo opportunity. Remaining an easy northern hemisphere object, it would pass through Ursa Major in June, fading to fifth magnitude by this time. Heading off in a direction close to the north celestial pole, it would become circumpolar from the UK until 2008, and thus be permanently visible in the coming months as it faded out of sight.

The other exciting comet prospect for 2004, C/2002 T7, was no longer observable from northern latitudes, having produced many spectacular photographs during the course of February as it neared its April 23 perihelion, 0.61 AU from the Sun. Though it had been lost to northern observers in mid-March, if it were bright enough, it might just be visible around the time of perihelion, on the horizon in nautical twilight. Making closest approach to the Earth on May 19, it was hoped it would reach mag 0-1 for southern observers. The speaker had been asked whether it might be possible to observe both comets simultaneously from any location. Though difficult, it seemed both might be simultaneously visible from at latitude –10°, though not until both comets were well past their best.

For the more dedicated, C/2003 K4 would be visible throughout the summer, expected to peak at around mag 5 in the autumn. Presently a northern hemisphere object in Vulpecula at mag 11, it would gradually brighten over the summer months passing into Hercules and reaching mag 8 by July 1, before sinking southwards in September, a few weeks in advance of its October perihelion. Also, Comet Tabur would provide a challenging target, lurking just above dawn nautical twilight throughout May at mag 9. 43P/Wolf-Harrington was low in the western evening sky, passing close by Aldeberan on April 12 at around mag 13.

Jupiter and Saturn were well placed for UK observation, transiting at 6pm and 10pm respectively at the time of the meeting. Saturn's rings were wide open, and Damian Peach's most recent images revealed a markedly blue tinge to the southern polar regions. The speaker congratulated Mr Peach upon the fidelity of his images, and members applauded. In the past, there had been suggestions that the poles appeared bluer, rather similar to the hue of Uranus, when the rings were closing after a period of being wide open. The speaker speculated that this might be because when the poles emerged after a long period in shadow, the frigid surface conditions influenced their colour. In July, as the present tilt of the rings closed, the northern polar regions would emerge from behind the rings, and after spending many months in the shadow of the dark side of the planet, it would be interesting to see what colour they appeared. It was not just amateur observers who were returning superb images of Saturn: the Cassini probe was nearing its destination and had taken a number of images in the past few months, as it drew ever closer to an anticipated orbital insertion on July 1.

Variable star observers were urged to watch η-Geminorum, normally mag 3.2-3.4, previously observed to eclipse every 8.2 years. If the trend continued, an eclipse was anticipated in July, and Colin Henshaw had already reported a slight dip in its brightness in February. Finally, the speaker closed with the discovery of a new nebula by Jay McNeal, an amateur astronomer, using only a 3-inch aperture. The new nebula, close to M78 in Orion, remained somewhat of a mystery, having previously only been known in the infrared. Though uncomfortably close to evening twilight, it would be observable from the UK for a few weeks following the meeting, at an altitude of 20° above the western horizon at 20h30 UT.

Following the applause for another lively instalment, the President thanked the speaker before inviting Dr John Rogers, Director of the Association's Jupiter Section to present the evening's final talk.

The Winds Within Jupiter's Storms as Tracked by Amateurs around the World

Dr Rogers opened with a series of images of Jupiter by Damian Peach – known to many amateurs already for the unprecedented resolution achieved by his work. He was one of a number of amateurs who had now reached a critical threshold in the detail of their work, allowing them to monitor a range of features previously only visible in the images of the *Voyager* probe or in more recent times the *Hubble Space Telescope*. Modern photographic and CCD observations had the advantage over traditional visual work that not only could surface details be examined qualitatively, but also measured with great accuracy. It was of particular interest to trace the evolution of features, and their motions in the local and zonal winds. The most straightforward technique used was to compare images taken after an exact integer number of rotations of the planet, and pick out subtle changes and the motions of features by 'blinking' them. This had first been done with Voyager images, 25 years ago to the month.

However, Jupiter's ten-hour rotation period prevented any single observer from obtaining images after exactly one rotation period, except very close to opposition. Images at two or three rotation intervals were easier to obtain, but features tended to move too rapidly for such temporal resolution to be sufficient. For this reason, it was not only valuable to have observers achieving superbly high-resolution, but also to have such observers stationed at widely spread longitudes. The Jupiter Section now frequently received images from members on several continents – Europe, Australia, Eastern Asia and North America – and for the first time since Voyager, features could often be imaged after only a single rotation period.

The speaker went on to discuss a number of features of interest which could be traced by visual observers working with only medium-sized telescopes, and firstly, the Great Red Spot (GRS). Known to be a giant anticyclone, this could be observed to have a moderate degree of reddish colour at present. High-resolution imagery allowed narrow streaks to be tracked as they circulated around its rim, and their rotation speed could be determined. Secondly, the speaker discussed the white oval BA, the second largest anticyclone on the planet, and the only survivor of three great white ovals in the South Temperate Region which merged a few years ago.

Next, the speaker moved on to rifts in the Equatorial Belts, once again using a large number of images from Section members to illustrate the discussion. Covering first those in the South Equatorial Belt (SEB), it was explained that the rifts were bright turbulent streaks in cyclonic regions, known to be the expanding cloud-tops of giant thunderstorms. In the SEB, there were always such features following the GRS. Comparing images by 'blinking' revealed them to change rapidly within one or two rotation periods. In 2003 September, it became apparent that a separate large outbreak of rifts had occurred in the SEB during solar conjunction. In the North Equatorial Belt (NEB), similar streaks were also seen. Amateur images of such rifts revealed intricate turbulence and wind shear across the belt.

Moving on, the speaker discussed the familiar dark projections on the southern edge of the NEB, understood to be great waves in a rapid jet-stream. This year's amateur images had confirmed a discovery previously made using visual observations during the Voyager encounters, that these projections are sometimes intensified or disrupted upon passing a rifted region. This earlier discovery had been published in 1988.[1]

Finally, the speaker discussed a disturbance that had recently appeared in 2004 on the northern edge of the South Equatorial Belt. This was reminiscent of the 'South Equatorial Disturbance', a remarkable feature which was visible in the same region between 1999 and 2002. The new feature was possibly a revival of this old disturbance. Soon after passing the GRS, it manifested itself as a bright rift in the northern SEB, and white clouds could be traced emerging from the mouth of the rift and accelerating into the jet-stream.

As a general reflection, Dr Rogers remarked that the Section presently traced the evolution of surface features by selecting the best images, processing them appropriately, and examining them by eye. It seemed that this analysis could perhaps be substantially improved and automated. In this respect, however, the work of the Section was growing towards the complexity of a professional project, and it seemed likely that the development of such image processing tools would be worthy of a PhD project.

Dr Rogers closed by explaining what amateurs were now achieving in wavebands outside the visible. Methane filters, though still expensive, were now accessible to amateurs as well as professionals, and provided an insight into the chemistry of the clouds. Amongst other results, it was observed that Southern Equatorial Disturbances became bright in methane images around six months after erupting in the optical. By using CCDs with appropriate filters, amateurs were also now working in the near-infrared and ultraviolet, which probed cloud structures at varying depths within the atmosphere. Though time did not permit any discussion of the results of such work, many of the features previously mentioned were being studied.

Following the applause for Dr Rogers' well-illustrated talk, the President adjourned the meeting until the fifth Observers' Workshop, to be held on 2004 April 24 at Nottingham High School for Girls.

Dominic Ford

References

[1] Rogers, J.H., *JBAA*, **98**, 5, 234-240 (1988)