Meetings

Out of London Weekend, 2006 April 21–23

held at the Science Block, University of Liverpool

Richard Miles, *President*
Ron Johnson, Nick James & Hazel Collett, *Secretaries*

The 2006 Out of London weekend comprised a joint meeting with the Liverpool Astronomical Society, which celebrated its 125th anniversary this year, and having been formed in 1881, proudly boasts its claim to be the oldest surviving such society in the world. Visitors from local societies such as Chester, Manchester, Salford, Stockport and Southport but also as far afield as Leeds, York, The Isle of Man, Edinburgh and a whole contingent from the South of England joined forces in a weekend of varied, informative and entertaining talks and displays.

'Dr Helen Smillett': Lyn Smith (left) and Hazel Collett

Starting on Friday evening April 21, Dr Helen Smillett, who we soon realised was not a person but an amalgam of two ladies, Lyn Smith and Hazel Collett (one could tell from the outset that what followed would be somewhat tongue-in-cheek) enlightened the assembly of 120 attentive listeners, of the rather spooky delights of the superstring theory. This aspect of cosmology was not for the faint-hearted, but it came across in a delightful presentation in the form of a rather zany double act. It won the audience's warm applause.

This was followed by Dr Allan Chapman, whose renowned infectious ebullience captured, as always, his listeners' undivided attention in a roundup of astronomy in the North West from the 17th century almost to the present day. He marvelled that this area had produced more dedicated astronomers than anywhere in the country, and spoke enthusiastically of the triumphs of Jeremiah Horrocks, (the first to calculate and observe a transit of Venus, in 1639) and through to William Gascoigne, William Crabtree, William Lassell and James Nasmyth, among others. His account of how the LAS and BAA were formed ended a most entertaining lecture.

Adjourning to the following morning, a very different, yet equally absorbing talk was given by the LAS Honorary Vice-President Murad Ghorbal on the mathematical and astronomical reasoning behind the construction of the Egyptian pyramids and the work done by Charles Piazzi Smyth, the Scottish Astronomer Royal from 1847 to 1888. Much of Smyth's work was derided by the astronomical community as fanciful, since he tried to convince them that the pyramids were designed by divine guidance.

Douglas Ellison then inspired the visitors with a detailed study of the discoveries made by the recently landed Martian Rovers, *Opportunity* and *Spirit*, the talk given more realism by the distribution to all present of 3D glasses and globules of haematite, which has been discovered in fair abundance on the surface of the planet.

His talk was interrupted by a pre-arranged internet connection in a half hour slot to the Faulkes Telescope (North), designed and built by Liverpool's John Moores University, on Mount Haleakala on the Hawaiian island of Maui. Whoops of exultation went up as successful observations, suggested by members present, were made of the comet 73P/Schwassman–Wachmann, seen clearly to be fragmenting; of M97, Jupiter and the edge-on galaxy NGC 4565. A first and a brilliant success story for the BAA!

Speakers and organisers at the Liverpool meeting. From left to right: Gerard Gilligan (LAS), David Galvin (LAS), Chris Banks (LAS), John Knott (LAS), Eric Jones, Doug Ellison, Nick James, Allan Chapman, Richard Miles, David Forshaw (LAS) and Murad Ghorbal. *Photos: Nick Hewitt*

The next speaker was Dr Eric Jones, also a long serving member of the LAS, on the intriguing subject of river bores. The British Isles has a quota of 22 rivers which produce bores of some interest, more than anywhere else, within such close confines, in the world. He spoke of the pull of the Moon and Sun and how they stretch and compress the oceans, producing the Earth's tidal system and how this affects the invasion of tidal waters in funnel-shaped estuaries. Bores can be mere trickles, or as in the Chinese Qiantang river a raging surge of bore heads which can uproot trees, hurl tons of rocks for hundreds of metres, knock a minibus from a jetty and kill people. Several members had not considered this aspect of astronomy and all found Dr Jones's talk most fascinating.

After lunch Dr Richard Miles (President) conducted a short BAA Ordinary Meeting, welcoming all to the 5th meeting of the 116th session, and thanking the Liverpool Astronomical Society for helping to organise the event and the University of Liverpool for the use of its facilities. Mrs Hazel Collett, Meetings Secretary, read the minutes of the meeting of 2006 March 22, which were accepted by the audience. Dr Miles then introduced the next speaker, Dr John Mason.

Dr Mason showed a series of excellent stills and videos of observations he had received of the March 29 total solar eclipse, most of which were contributed by those who had experienced a beautiful eclipse from the heart of the Libyan desert. Dr Allan Chapman, speaking once more, then rounded off a splendid day with his lively appraisal of Robert Stawell Ball (1840–1913), renowned for his books and papers on popular astronomy, and introduced by Dr Chapman as 'the Victorian Patrick Moore'.

Sunday morning dawned in glorious sunshine. Visitors congregated first at the Pex Hill Leighton Observatory, used by the LAS, to see the Sun in H-alpha and to hear a fascinating talk by Dave Thomson on the exciting work done by Telescope Technologies Ltd of Merseyside, which built not only the North Faulkes instruments but observatories in La Palma, Australia, India and China, the target being to construct, at the latest count, 50 telescopes throughout the world. A visit to Much Hoole Church, (Horrocks country) and Carr House had then been arranged. Both the Church and Carr House were open to the 40 or so people that went along and thanks are due to John and Jean who arranged everything from their end. Jane and Clive, the owners of Carr House, where the transit observation of 1639 was made, were most kind and, after showing everyone round, provided a welcoming cup of tea to one and all. The brilliant sunshine completed a most satisfying weekend.

David Forshaw

Ordinary Meeting, 2006 May 31

held at New Hunts House, Guys Hospital, London Bridge, London SE1

Richard Miles, *President*
Ron Johnson & Nick James, *Secretaries*

The President opened the sixth meeting of the 116th session, and, in the absence of the Meetings Secretary, invited Mr Martin Morgan–Taylor to read the minutes of the previous meeting, which were approved by members and duly signed. Mr Ron Johnson, Business Secretary, reported that two presents had been received since the last meeting, and the audience applauded the donors. The President said that 13 new members were proposed for election. Council had met twice since the last meeting; in April, it had approved 84 new members, subject to confirmation by the present audience, and a further 23 new members had been accepted earlier today. The meeting approved the election of these 107 individuals, and the President declared them duly elected.

Mr Nick James, Papers Secretary, said that at these two Council meetings, nine new papers had been accepted by Council for publication in the *Journal*:

'The parallactic angle and the solar observer' *by Peter Meadows*;
'The Leonid meteor shower in 2000' *by Neil Bone*;
'CG Draconis – a particularly active dwarf nova' by *Jeremy Shears et al.*;
'Determination of the superhump period of the dwarf nova V701 Tauri during the 2005 December superoutburst' by *Jeremy Shears et al.*;
'Stag Lane (Edgware) Observatory and the 10-inch Dall–Kirkham–Dall Cassegrain telescope' by *David Arditti*;
'James Wigglesworth and the Great Scarborough Telescope' by *Ray Emery*;
'Will the real Herr Kinau please stand up' by *Robert A. Garfinkle*;
'The Geminid meteor shower in 2001' by *Neil Bone*;
'Mare Orientale: the eastern sea in the west' by *Richard Baum*.

Dr Miles reported that the next meeting of the Association would be the Variable Star Section's annual meeting, to be held at the Rutherford Appleton Laboratory in Didcot, Oxfordshire, on Saturday June 3. The next Ordinary Meeting would take place during the annual Exhibition Meeting on June 24, which would once again be held at the Cavendish Laboratory in Cambridge. The talks on that occasion would include Martin Mobberley's final Sky Notes instalment before he stepped down from the job; this was surely a show not to be missed.

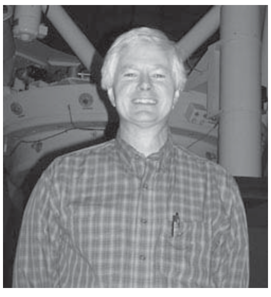
The President then introduced the evening's first speaker, Dr Arne Henden, Director of the American Association of Variable Star Observers (AAVSO). The President added that, in addition to sharing his expertise today, Dr Henden would also be attending the VSS meeting on the following Saturday; he expressed his gratitude to Dr Henden for offering such keen support to the Association's observers.

Let's collaborate! – a professional's perspective

Dr Henden remarked in opening that he had always considered himself a professional astronomer, but had also always felt the line between amateurs and professionals to be a very grey one. After all, the word 'amateur' derived from the Latin verb '*amare*' (to love), and whilst he was a professional in the sense that he earned his livelihood by his work, was he not also an amateur if he loved doing it? With this thought in mind, he was keen for both astronomical communities to acknowledge the common passion that they shared.

In recent times he could think of many examples where amateur – in the traditional sense of the label – astronomers had made very valuable contributions to the work of professionals. One example was in the *SETI@home* project, founded in 1999 by a professional team at the University of California, Berkeley. The Berkeley astronomers had wanted to search data from the Arecibo Radio Telescope for signals which were finely tuned to specific frequencies – too finely to be of plausible natural origin – and which might thus originate from alien radio communication. The computational demands of such a search, however, were far more than could be met by their own hardware. Their solution had been to invite PC users from around the world to donate computer time. A software package was devised which allowed users to set their desktop PCs to automatically detect when they were sitting idle, and to then switch to performing calculations for *SETI@home*. Motivated only by the excitement of wondering whether aliens might be seen, nearly a million home computer users had taken part since the project's inception, contributing between them a total of two million CPU years since 1999. At present, *SETI@home* was able to analyse data at a rate of 50Gb each day; the processing capability offered by their users was comparable to that of the world's fastest supercomputers.

Whilst *SETI@home* had not found any evidence for extra-terrestial intelligence, it had demonstrated a principle: if the public imagination was suitably caught by a project then so-called 'distributed computing' could offer a tremendous resource for data analysis. In the near future, another Berkeley team, *Stardust@home*, planned to start a similar project, this time analysing data from NASA's recently returned *Stardust* probe, sifting through high-resolution images of the probe's aerogel plates for evidence of dust grain impacts.



Dr Arne Henden *(Photo: AAVSO)*

These projects required little skill on the part of the amateur participants, but there were other examples where the expertise and devotion of amateurs seemed to exceed that of professionals. An example would be the task of searching for comets in images returned by the LASCO solar coronograph on NASA's *SOHO* satellite. NASA had opted to publish all data from this instrument live on the Web, a policy which was well-rewarded: the dominance of amateur eyes in the art had grown so great that professionals now scarcely tried to compete. The coronograph had recently celebrated its thousandth comet discovery since its launch in 1995.

The rôle of amateurs in astronomy had a long history. The speaker recalled that when Percival Lowell founded the Lowell Observatory at Flagstaff in 1894, he had done so at his own expense. Through the spectroscopic work of V. M. Slipher – a professional whom Lowell employed – the Observatory had discovered the expansion of the Universe. Here was a rare example of a professional employed by an amateur. A modern parallel to such philanthropy was being seen in the Allen Telescope Array, a SETI project in California currently under construction, being part-funded by Microsoft co-founder Paul Allen.

Dr Henden now turned to give his personal perspective on amateur astronomy, and Lowell's Observatory provided a useful link, as he recalled how he had first been enthused into astronomy by the experience of viewing the planets through the 24-inch refractor there. He went on to recall the books which he had read through his teens, the planetary observations he had made with his first 76mm instrument, and the 150mm Dynascope through which he had observed Comet Bennett in 1970. By the time of his authorship of *Astronomical Photometry* (1978), he was using a 406mm Boller & Chivens Cassegrain. In time, his passion for astronomy had led him to obtain his PhD from Indiana University in 1985.

Throughout these years, variable star observation had always been his main interest, leading him to become involved with the American Association of Variable Star Observers (AAVSO), of which he eventually became Director in 2004. The AAVSO would be the subject of the remainder of his talk.

Based in Cambridge, Massachusetts, its history stretched back to 1911. Today, it had 1,200 members, about 15% of whom were professional astronomers. The total number of observers who frequently submitted observations, however, was closer to 3,000. From them, around 600,000 observations were typically added each year to the 13 million which were already accessible from the AAVSO website. The speaker wanted to stress that visual observations remained as scientifically valuable to the AAVSO as those made with CCDs; around half of the data received remained in the form of visual observations. He also wanted to stress that the AAVSO was not a 'members only' organisation; in his view, true scientific enquiry knew no boundaries. Data was accepted from all, members and non-members alike.

The AAVSO's staff comprised ten paid workers, most of whom were graduate-level, though two held university positions, and one was a post-doctoral research scientist.

Dr Henden turned to outline some of the advantages which he perceived the amateur community to hold over professionals in the monitoring of variable stars. For one, the sheer number of amateur observatories around the globe made it possible to monitor very large numbers of objects. Their good geographic spread was of especial value when constructing light curves for objects which fluctuated on timescales of hours; a worldwide network effectively made 24-hour monitoring possible. Having so many distributed observing sites also alleviated the effects of local weather conditions, which professional survey instruments found hard to escape.

The long history of the AAVSO also brought its own advantages. The degree of continuity in its data archive was hard for professional surveys to rival, operating, as they did, typically for only a few years at a time. To study targets which exhibited variability over timescales of many years, this was irreplaceable; in some cases it allowed homogeneous lightcurves to be constructed over nearly a century. Dr Henden added that perhaps it was also true, if under-appreciated, that amateurs were often simply more competent than professional observers, possessing a much greater degree of familiarity with their instruments.

The objects studied by the AAVSO ranged from classic variable stars to more exotic objects, including supernovae and Gamma Ray Bursters (GRBs), and the speaker discussed the diverse scientific cases for studying each class. He explained that the Association was often approached by research teams requesting data for specific objects, and that the increasing frequency of such approaches in recent times suggested a healthy appreciation of the amateur community among professionals. Observing campaigns were organised in response to such requests, aiming to achieve especially well-sampled lightcurves for these objects over a few months. Earlier in the year, for example, several campaigns had been run for targets which were simultaneously being monitored by the *XMM-Newton* space-based X-ray observatory, in order to provide ground-based optical data to complement the X-ray variability data.

To close, the speaker listed some of those amateurs who had made especial contributions to the AAVSO, including, perhaps most notably, Edgar Smith, founder of the Calypso Observatory on Kitt Peak, now home to a 1.2-metre instrument which could regularly monitor ~10^4 targets. Smith hoped to be able to put this large aperture to use in the near future to discover exoplanets: the degree of photometric accuracy which could be achieved was potentially sufficient to detect the slight apparent faintening of stars as planets transited across their disks. This might open up a whole new avenue of research for the AAVSO. While such prospects were very exciting, the speaker also wanted to stress that they should not eclipse the work done by those with more modest equipment: the value of visual observers with binoculars was not to be forgotten.

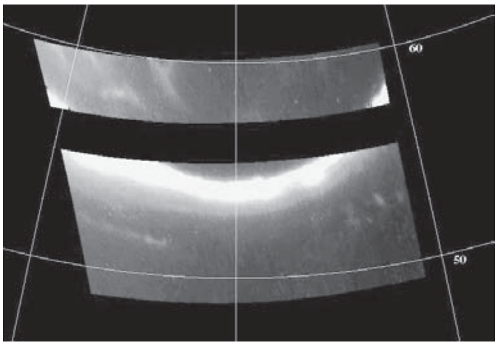
Following the applause, the President thanked Dr Henden for providing such an authoritative account of the AAVSO's work and invited questions.

A member asked whether the AAVSO accepted spectroscopic observations from amateurs. The speaker replied that they did and that this was a growth area; good spectroscopic equipment was now quite readily available and amateurs could make well-calibrated observations. Mr Maurice Gavin, in the audience, queried this: he remarked that he had submitted some spectra to the AAVSO's website recently, and that they had not appeared in the online archive. In reply, Dr Henden explained that there were some outstanding technical issues with the online retrieval of spectra, but that the submission process was working and filing incoming data correctly.

The President then introduced the evening's second speaker, Professor Steve Miller of University College, London. In addition to his work as a planetary scientist, Prof Miller was also a very active communicator of science; he headed the Department of Science and Technology Studies at UCL. Tonight, he would be talking about observations of aurorae in the atmospheres of the solar system's gas giants.

Bright lights on giant planets

Prof Miller explained that his scientific background was in chemistry rather than astronomy, but that he had become involved with planetary science, and especially aurorae, through an interest in the chemical composition of planetary atmospheres. The various colours seen in aurorae were powerful probes of the chemical constituents of atmospheres, and the speaker illustrated this with an image of the aurora borealis of our own planet. The deep red emission seen at the highest celestial altitudes could be attributed to atomic oxygen, and likewise the brighter green emission below it. To-



An auroral oval on Jupiter imaged by the *Galileo* spacecraft in 1996. *NASA/JPL*

wards the lower edge of the aurora, closest to the horizon, reddish-pink emission stemmed from molecular nitrogen.

Not only were such aurorae revealing the chemical makeup of the Earth's atmosphere, but the dominance of different colours at different altitudes was also revealing its vertical structure. Above a certain point, the homopause, the atmosphere's various constituents ceased to be well mixed, being instead gravitationally stratified according to mass. Because molecules weighed more than atoms, the reddish-pink emission of molecular nitrogen was seen at lower altitudes than the emission of atomic oxygen.

Images taken from high-altitude aircraft presented compelling evidence that auroral emission arose high in the upper atmosphere, Prof Miller explained – even from the highest-flying aircraft, one had to look upward to see it. Detailed study revealed it to emanate 70–200km above the Earth's surface.

The speaker then turned to discuss the physical origin of aurorae. He began with a schematic of the Earth's magnetic field, which he compared to that of a bar magnet: field lines emanated from the Earth's surface at its north magnetic pole, wrapped longitudinally around the planet, and reconverged upon its south magnetic pole. However, they were permanently distorted from those of a bar magnet by their interplay with the solar wind – a continuous stream of high-energy charged particles, flowing outwards from the Sun through the solar system at around 400 km/s.

Michael Faraday discovered in the 19th century that when electric currents traversed circular paths, magnetic fields were generated – the principle behind the electromagnet. Conversely, he had also found that in the presence of magnetic fields, a force was exerted upon charge-carrying particles which caused them to follow circular paths around the field lines.

Thus, when solar wind particles came under the influence of the Earth's magnetic field, their paths were bent: they began to circle around the magnetic field lines. Broadly speaking, the Earth's magnetic field could be said to be an obstacle to their outward flow through the solar system.

This interaction also bent the Earth's magnetic field lines. On the sunward side, this distortion took the form of a compression, and at an altitude of around 70,000km it exhibited an outer boundary called the magnetopause, outside of which the Sun's magnetic field dominated. It was upon impact with this boundary that solar wind particles came sharply into interaction with the Earth. More precisely, about 15,000km upstream of it, compressed solar wind material piled up against the boundary to form a bow shock. In the anti-solar direction, the distortion had the opposite effect, stretching out the Earth's magnetic field into a long tail called the magnetotail, about 190,000km in length.

Prof Miller noted that the most profound consequence of this interplay between the Earth's magnetic field and the solar wind for the human species was that it shielded the Earth's surface from ionising solar wind particles: without such a shield, we could not survive. Aurorae were surely a secondary consequence. They arose when solar wind particles descended into the Earth's atmosphere and collided with one of the various atomic or molecular gas particles around them, dumping their energy into the gas, often leaving the particles ionised or in excited states. The visible light of the aurora arose when these gas particles subsequently de-excited via photon emission, but Prof Miller added that the display of lights was not the only consequence of this process – it also caused a significant heating of the atmosphere.

This descent of solar wind particles into the Earth's atmosphere was only possible in the Earth's polar regions, because these were the only places where magnetic field lines were directed up out of the surface of the Earth; these were the only places where the solar wind particles, spiralling around the field lines, could descend towards the Earth. More specifically, aurorae were actually most frequently observed slightly away from the pole, where the magnetic field lines were at a slight slant to the surface, in a circular region called the auroral oval.

During an auroral display, the solar wind might dump energy into the Earth's atmosphere with a power of around 100GW, raising the temperature of the upper atmosphere by around 100K. This effect was very significant, though somewhat less dramatic than it sounded, since the absorption of solar UV radiation already heated this part of the atmosphere to around 1000K. The change made by aurora was thus a significant but not overwhelming 10%.

The speaker then turned to discuss the aurorae of other planets, and first of all, of Jupiter. Infrared images from the United Kingdom Infrared Telescope (UKIRT), on the summit of Mauna Kea, Hawaii, revealed compelling evidence for a bright auroral oval, not dissimilar to our own, on Jupiter. Prof Miller noted in passing that this was one of very few areas of work where ground-based telescopes could usefully be employed in planetary science; in the visible, the resolution of the Hubble Space Telescope (HST) ruled supreme. In addition to UKIRT, another ground-based infrared telescope, NASA's Infrared Telescope Facility (IRTF), also on the summit of Mauna Kea, provided a complementary facility to take high-resolution spectra of Jovian aurorae.

The emission seen in these images was arising high in Jupiter's atmosphere, at an altitude of 450–2000km above the surface. At this altitude, the atmosphere was thin, having a particle number density less than 10^{18} particles per cubic metre, but also apparently incredibly hot, ranging between 900 and 1100K. This compared with 400K for Saturn's upper atmosphere and 500–750K for that of Uranus. The speaker would return later to the puzzle of how the Jovian upper atmosphere came to be so hot.

The primary constituent of Jupiter's atmosphere was hydrogen gas, and so narrow-band images centred upon the Lyman transition lines of atomic hydrogen produced detailed maps of the excited gas. These lines lay in the ultraviolet part of the spectrum, unobservable from the ground because of absorption from the Earth's atmosphere, but could be imaged by the HST. Such images contained a wealth of information, both about the auroral oval and its neighbourhood; for the present talk, the speaker concentrated upon the former, specifically upon the question of how it compared with the Earth's auroral oval. Were the aurorae of Jupiter similarly controlled by the solar wind?

To answer this question, Prof Miller started by outlining what was known about the Jovian magnetosphere. It was a huge structure. Its magnetopause and bow shock lay a colossal 1–2 million km above Jupiter's surface; if these were visible structures, their projection on the night sky would appear 2½ times the size of a Full Moon from the Earth. The magnetotail was larger still, stretching 750 million km in the anti-solar direction – so far that it stretched beyond Saturn's orbit; Saturn could indeed pass through it. The Jovian magnetosphere was arguably the second largest 'structure' in the solar system after the Sun.

Apart from its sheer size, it differed from the Earth's magnetosphere in one additional respect, which arose from Jupiter's interaction with its nearest moon, Io. Orbiting at a mere 350,000km above Jupiter's surface – closer than the Earth–Moon distance – Io experienced extreme tidal gravitational forces, stirring up its internal structure. The resultant strain rendered Io the most volcanic body in the solar system, as had been compellingly seen in many images returned by the *Voyager* probes. Volcanic plumes spewed around a tonne of ionised material into the neighbourhood of Jupiter each second. This material spread out to form a thin circular sheet termed a plasma torus, extending out to a distance of a million km from Jupiter. When initially ejected from Io, this material would share its orbital period of 42 hours. However, because of its electrical charge, it interacted with the magnetic field of Jupiter, bringing about a rapid change in its rotation speed. For such a large planet, Jupiter was remarkably fast-spinning: in fact, it was not only the largest planet in the solar system, but also that with the shortest rotation period – a mere nine hours. As Jupiter spun, it carried its magnetic field around with it, and the effect of the interaction between this rapidly-rotating magnetic field and the plasma torus was to spin up the ionised material, draining rotational energy from Jupiter at a rate of 10TW – sufficient to completely halt Jupiter's rotation within 60 times the current age of the Universe.

The interaction was not quite strong enough, however, to completely bring the plasma torus into co-rotation with Jupiter, and the difference between the two rotation speeds was especially great at large radii. The resulting shear in electric field produced a gap in Jupiter's magnetosphere through which solar wind particles could break.

Prof Miller noted in passing that the plasma torus also seemed to have another effect: in recent HST images, a clear 'footprint' of auroral activity could be seen beneath Io, suggesting that its volcanic activity produced a secondary source of ions, in addition to the solar wind, which created their own aurorae. Rather curiously, Ganymede and Europa also had visible auroral footprints, despite not being appreciably volcanic; this remained unexplained.

Returning to the question of why Jupiter's upper atmosphere was so hot, the speaker discussed whether energy input from aurorae could be the answer. He explained that the effect of solar wind electrons upon the Jovian atmosphere was primarily to ionise hydrogen through the reactions:

$$H_2 + e^- \rightarrow H_2^+ + 2e^- \quad (1)$$
$$H_2^+ + H_2 \rightarrow H_3^+ + H \quad (2)$$

Emission lines, resulting from the rotational excitation and de-excitation of the H_3^+ ions produced on the right-hand side of reaction (2), were responsible for producing the infrared emission seen in the UKIRT images discussed earlier. By contrast, it was the second product on the right-hand side of reaction (2), the atomic hydrogen, which was responsible for the ultraviolet emission seen in the narrow-band Lyman-line images returned by the HST.

Across the whole planet, the energy input from the solar wind through these reactions could be calculated to be about 10^{14}W – more than two orders of magnitude in excess of the power absorbed by Jupiter from sunlight. Aurorae did thus seem a plausible mechanism for heating, although the situation was actually rather more complicated than suggested by this simple evaluation of power input alone. The bright infrared emission seen from H_3^+ ions demonstrated that they were very efficient at re-radiating absorbed energy, and thus much of the energy absorbed from solar wind particles seemed not to be retained by the planet's atmosphere.

Turning next to Saturn, the speaker explained that images of aurorae in its polar regions had been returned by the *Cassini* probe, but that they appeared to be rather modest as compared to those on Jupiter. It also appeared that those on Saturn were controlled exclusively by the solar wind, rather than any volcanism on its moons. Uranus also showed signs of aurorae, perhaps contributing up to 20% of its total emission, but they were rather difficult to image on account of being spread very widely and thinly across the planet's entire disk. The lack of an auroral oval on Uranus was not well understood, but could perhaps be attributed to the planet's unusual axial tilt, at 98° to its orbital plane.

The speaker closed with a brief discussion of the possible effects of aurorae on extrasolar planets. He remarked that over 100 planets had now been discovered around stars other than our own, and that many of them seemed to be gas giants not unlike Jupiter, but in very close orbits around their parent stars – perhaps as close as 1/20th of an astronomical unit. Such discoveries raised many questions about how these planets came to be found so close to their parent stars. One especial problem was that models of planetary atmospheres predicted that planets in such hot environments would completely boil away within a timescale of 10^5–10^6 years. In astronomical terms, these were very short timescales, and so we would not expect to observe such planets so close to stars.

Prof Miller argued that aurorae on these planets might have a rôle to play in extending their lifespans: the production of H_3^+ ions on their sunward sides could lead to very intense infrared emission in the H_3^+ rotational transitions. The cooling caused by this emission might have a thermostatic effect, preventing the atmosphere from boiling away. The speaker added that if this idea was correct, then the first direct detection of emission from exoplanets might well be in the form of H_3^+ emission lines in the spectra of their parent stars.

Following vigorous applause, the President thanked Prof Miller for his fascinating account and invited questions. A member asked at what wavelength the UKIRT images of Jovian aurorae had been taken. The speaker replied that they were taken in the atmospheric window around the photometric L-band, specifically, at 3.42 and 3.53μm.

The President then adjourned the proceedings until the annual Exhibition Meeting, to be held at the Cavendish Laboratory, Cambridge, on 2006 June 24.

Dominic Ford