Ordinary Meeting, 2007 January 31
held at New Hunts House, Guys Hospital, London Bridge, London SE1

Richard Miles, President

Ron Johnson, Hazel Collett and Nick James, Secretaries

The President opened the fourth meeting of the 117th Session and invited Mrs Hazel Collett to read the minutes of the previous meeting, which were approved by the audience and duly signed. He announced that 30 new members were proposed for election; those 26 who had been proposed at the previous meeting were approved and declared elected. Mr Nick James, Papers Secretary, announced that one paper had been approved for *Journal* publication:

[Barbados report – Title???], by Damian Peach

The President explained that it was customary for him, at this time in his Presidency, to propose a successor. He was pleased to recommend Mr Roger Pickard, Director of the Variable Star Section, for the post. Members applauded. He went on to give an update on the Association's recent star count exercise; members had been invited to count the number of stars visible in a patch of sky in Orion on certain dates in December and January and to submit their results together with the latitude and longitude of their observing site. The aim of the exercise had been to map the extent of light pollution across the country. Nearly 1,800 reports had been submitted, of which a preliminary analysis would be published shortly; initial indications were that a very good geographical coverage had been achieved. The Campaign for Dark Skies (CfDS) intended to conduct follow-up surveys in coming years, which would be compared against the current 'baseline' survey to monitor changes.

The next Ordinary Meeting would be held on March 28, together with a Special General Meeting. Before then, an *Observers' Workshop* would be held on February 24 at the Open University, and the Deep Sky Section's Annual Meeting would be held on March 3 at the Humfrey Rooms, Northampton.

The President then introduced the evening's first speaker, Prof Michael Rowan-Robinson of Imperial College, London. Prof Rowan-Robinson's research interests included infrared and sub-millimetre astronomy, and he was currently President of the Royal Astronomical Society.

The *Spitzer* Space Telescope

The *Spitzer* Space Telescope, Prof Rowan-Robinson explained, was the fourth and final spacecraft of NASA's *Great Observatories* programme. Its most famous sibling had been the *Hubble* Space Telescope (HST), launched in 1990, which remained operational, observing at near-infrared, optical and ultraviolet wavelengths. The speaker noted with regret, however, that its main camera, the *Advanced Camera for Surveys* (ACS) had failed only the previous day. *Spitzer*'s other siblings were the *Compton* Gamma Ray Observatory and the *Chandra* X-Ray Observatory, both launched in 1991. *Spitzer* had had a somewhat chequered history, which explained the long delay between the launch of these counterparts and its own in August 2003.

Spitzer observed at mid-to-far-infrared wavelengths, between 3.6 and 160 μm. Astronomy in the near-infrared had a long history, which could be traced back to William Herschel's initial discovery that the solar spectrum contained radiation at wavelengths longer than that of red light – the first indication that infrared light existed. Progress had been slow, however, especially in mid-to-far-infrared astronomy, because the Earth's atmosphere had been found to be highly opaque to infrared light in all but a few narrow wavelength windows; essentially, there was permanent cloud cover. Though some high-altitude balloon/aircraft-based experiments had achieved useful imaging in the 1960s and 1970s by getting above the Earth's atmosphere, it had not been until the launch of the space-based *InfraRed Astronomical Satellite* (IRAS) in 1983 that it had become possible on a large scale.

IRAS, a collaborative mission between the US, UK and the Netherlands, had been a survey instrument, which had mapped the entire sky at far-infrared wavelengths (25-100 μm). It had orbited along the Earth's day/night terminator, perpendicular to the ecliptic, pointing vertically away from the Earth to minimise any scatter of the Earth's thermal radiation into its tube. This configuration had mapped the whole sky over six months, as the Sun moved along the ecliptic. Over its eleven months of operation, *IRAS* had mapped most of the sky twice.

Most of the radiation detected by *IRAS* had been the thermal emission of small solid particles in inter-stellar space, called *dust*. Before *IRAS*, such particles had only been known to exist in dense clouds such as the Coalsack Nebula, and around star-forming regions such as M42. Perhaps the most significant discovery of *IRAS* had been the omnipresence of dust: thin wispy clouds of dust had been found to be spread throughout the whole of the Milky Way. Though almost invisible at visible wavelengths, their faint thermal radiation could be clearly detected in the far-infrared. By meteorological analogy, these clouds were now termed 'interstellar cirrus'.

The principal scientific interest in infrared astronomy since *IRAS* had lain in the fact that infrared emission seemed to trace very closely the formation of new stars. Stars seemed to form preferentially in dusty regions, M42 being a prime example. The optical opacity of such sites limited the amount which could be learnt about them at visible wavelengths; much more could be learnt from their dust emission – its temperature and morphology.

After *IRAS*, the next major advance had come with the building of the *James Clerk Maxwell Telescope* (JCMT) on the summit of Mauna Kea in Hawaii. This had been a UK project, seeing first light in 1987. Deep surveys with the JCMT had, quite unexpectedly, revealed a large number of distant galaxies which were incredibly bright in the infrared. These were typically so distant that their light had taken more than 10 billion years to reach us, and so we saw them as they had been only 2-3 billion years after the Big Bang. They were at least a hundred times – perhaps a thousand times – more luminous than the Milky Way. It was thought that they were forming vast numbers of new stars, and their brightness could be attributed to the many hot young stars within them. The Universe appeared to have been filled with such galaxies when it was 2-3 billion years old, and it seemed likely that most of the heavy elements seen today, such as carbon and oxygen, had been forged within the hot young stars in them.

In 1995, the European Space Agency (ESA) had followed up the success of *IRAS* with a new space-based infrared observatory, the *Infrared Space Observatory* (ISO). It had carried both cameras and spectrographs, though it was best remembered for the latter. The spectra of dusty regions provided clues about the chemical composition of the dust. Broad consensus had now been achieved: dust grains measured around 0.5 μm across and were composed of graphite and amorphous silicates – the best terrestrial analogues were, respectively, soot and sand. In addition, there was also evidence for complex organic molecules termed *polycyclic aromatic hydrocarbons* (PAHs) – these were toxic species, commonly found in car exhaust.

Prof Rowan-Robinson then outlined the scientific questions which *Spitzer* would address. Using dust emission as a tracer of star formation, and looking at galaxies as a function of distance, a principal aim was to map out when, in the history of the Universe, most of the stars formed. It was currently thought that stars had been formed in the greatest numbers when the Universe had been about 6 billion years old, around the time that our own Sun had formed. Ever since, star formation appeared to have been in decline. It was yet to be seen, however, how this model would change in the light of *Spitzer* observations.

The speaker then outlined the long and troubled history of *Spitzer*. It had been proposed in 1979, under the name of the *Space InfraRed Telescope Facility* (SIRTF). In 1984, a team of project scientists had been chosen, and it had been envisaged that the observatory would be launched aboard the *Shuttle*, in common with the other Great Observatories. In 1990, however, in the aftermath of the *Challenger* disaster of 1986, an unmanned launch had become the preferred option. It was thus decided to use a *Titan* rocket – one of NASA's standard heavy-lift launch vehicles. To fit the launch capacity of a *Titan*, a 1-m telescope, weighing 5.7 tonnes, had been designed; the budget had been $2 billion. The majority of the telescope's weight had been liquid helium, required to keep its optics cool so that their own thermal infrared emission would not swamp that of the sky.

In 1993, however, budget cuts had seen this design 'descoped' to a 2.7-tonne instrument which could be launched on an *Atlas* rocket – a smaller and cheaper launch vehicle. Further budget cuts in 1995 had forced the design to be cut back even further, to a 0.75-tonne telescope of 85-cm aperture which could be launched aboard a small *Delta* rocket for $450 million. It had been this design which had been launched in August 2003.

However, this descoping had not been as unfortunate as it might sound. Ingenuity on the part of the engineers had allowed the final telescope to achieve a very similar specification to that of the original 5.7-tonne design. This had been achieved by launching *Spitzer* not into Earth orbit, but into solar orbit; it followed the Earth around the Sun, trailing slightly behind it. Without the warming effect of Earthshine, and with a very efficient sunshield, *Spitzer* was in a very cold environment, minimising its need for active refrigeration. Some liquid helium was still required, but the amount much reduced. The supply had been designed to last for 2.5–5 years; in practice, *Spitzer*'s natural cooling seemed even more efficient than originally thought, and its helium supply was likely to last for 5.5 years. *Spitzer* was slowly moving further away from the Earth, and eventually radio communication would be lost, in around 2013. It would pass by the Earth again in around 2700.

Turning to present an overview of *Spitzer*'s early results, the speaker opened with an image of the star Formalhaut, which was seen to be surrounded by an infrared-bright disc. This was divided into two parts, the inner being apparently hotter than the outer. The speaker suggested that these two structures might be comparable to the Oort Cloud and zodiacal dust in our own Solar System.

The speaker then showed an image of the Elephant Trunk Nebula, a dark nebula super-imposed on the emission of the Garnet Star emission nebula (IC 1396). *Spitzer* images, as well as revealing the thermal emission of the obscuring dust which made the nebula dark at visible wavelengths, also showed a number of stars embedded within it. These were apparently newly-formed stars, obscured from view at visible wavelengths.

Prof Rowan-Robinson explained that his own research interest was in a survey called the *Spitzer Wide-area InfraRed Extragalactic* (SWIRE) survey. This was one of six *Legacy* projects which had been chosen by NASA to be allocated unusually long periods of observing time. Over a period of 851 hours, SWIRE had mapped 50 square degrees of sky – an area 250 times that of a Full Moon – and had detected nearly two million galaxies.

He hoped to use this to investigate which types of galaxies hosted most of the star formation in the Universe. He hoped to establish whether there was any systematic difference between the star formation seen in large galaxy clusters and that seen in more solitary galaxies. He also hoped that the survey would shed some light on the nature of the exceptionally luminous star-forming galaxies which had been detected by the JCMT.

To close, he remarked that there were several forthcoming space infrared telescopes due for launch within the next few years. A Japanese observatory, *ASTRO-F*, would fly later in 2007; ESA would fly the *Herschel* observatory in 2008; and the *James Webb Space Telescope* (JWST) was scheduled for launch in 2013 – this would be particularly exciting: a 6.5-m space infrared telescope.

Following the applause, Dr Nick Hewitt asked if *Spitzer* would be able to make any useful observations in the time between its running out of helium and the loss of radio communication. Prof Rowan-Robinson replied that *Spitzer* would lose its ability to observe in the far-infrared, but would still be able to take mid-infrared images. In due course, NASA would invite observing proposals.

The President then invited the evening's second speaker, Mr Geoffrey Johnstone, to present the month's sky notes.

The January Sky

Mr Johnstone opened with an overview of the events of the past couple of months, though he noted that the weather had been poor throughout. On December 17, Tom Boles had added one further supernova discovery to his tally, 2006ss in NGC 5579 – his 105th discovery. The speaker had enquired after Damian Peach's planetary imaging work, but the weather had been so bad of late that he had not attempted any imaging since November 4.

In December, Asteroid 2006 XD2 – measuring around 150×350 m – had passed by the Earth, making closest approach at 0.026 AU on December 24. Several members had caught glimpses of it through breaks in the cloud around December 17-20, when it had been 0.04–0.06 AU distant. By combining their photometry to construct a light-curve, it had been possible to estimate its rotation period; the speaker warmly congratulated all involved.

Without doubt the most notable event of recent weeks had been the apparition of Comet 2006 P1 (McNaught). This had reached many newspapers, where it had been hailed as the greatest comet since Hale-Bopp (1997). Such attention was perhaps surprising, given that the apparition had been visible from the UK for only one week, around January 7–14, and only then in evening twilight, for a few minutes each day. Furthermore, the apparition had been announced at rather short notice because it had come as a surprise: it had out-performed even the most optimistic forecasts. Two days after Comet McNaught had reached perihelion on January 12, it had peaked at mag –5.5, placing it as the brightest comet since 1965 S1 (Ikeya-Seki). Many members had captured stunning images, though the greatest sights had been seen only in the southern hemisphere, after its disappearance from the UK sky; around January 23, its naked-eye tail had been reported to reach 35° in length.

Mr Johnstone then turned to outline the prospects for the next two months. Venus was already a glorious and conspicuous sight in the evening sky, and would continue to improve until reaching maximum solar elongation (SE) on June 9. Close by, Mercury's evening apparition would reach a rather miserly maximum SE of 18.2° on February 7. Its next morning apparition would reach a more favourable maximum SE of 27.7° on March 22. Mars had passed solar conjunction on 2006 October 23, but still did not rise until 06:45 UT; it would not be readily observable until the autumn. Jupiter also was a late riser: it presently rose at 04:30 UT, and even in April, it would not rise until shortly before midnight UT. Saturn, however, was well placed, and would reach opposition on February 10; for the next two months, it would be visible all night.

The speaker then gave brief mention to prototypical variable star Mira in Cetus, whose light-curve followed a regular cycle, brightening from mag 8.5–10 to mag 2–5 over a period of around 100 days, then fading back over a period of around 200 days. Its next maximum would be in mid-March.

There would be a lack of good comets in the UK sky in coming months: the best prospect was Comet 2P/Encke, which might be a binocular object in late March and early April, though it would be low in evening twilight in Pisces/Aries. It would then be lost to the southern hemisphere, reaching perihelion on April 19 at around mag 3.

The speaker selected three lunar occultations for mention: those of Uranus on February 8, the Pleiades on February 23, and Saturn on March 2. To close, he reminded members of the forthcoming lunar eclipse on March 3, which would be taking place at a very convenient hour: greatest eclipse would be at 23:20 UT.

Following the applause for Mr Johnstone's talk, the President invited Mr Bob Marriott, Curator of Instruments, to make a brief announcement. Mr Marriott reported that a 12.25-inch reflector from the Association's instrument collection had recently moved to a new home in the grounds of Pendrell Hall in Staffordshire, where it would be used by an adult education centre. Further details could be found in the 2006 December issue of the *Journal*.[1]

The President then introduced the evening's final speaker, Dr Peter Wheatley, associate professor at the University of Warwick. Dr Wheatley would be speaking about a project of which he was a founder member: the Wide-Angle Search for Planets (WASP).

The Wide-Angle Search for Planets

The WASP project, Dr Wheatley explained, was searching for planetary systems around nearby stars. Before discussing that work, however, he reviewed our own Solar System as a point of reference. Excluding Pluto, there were eight known planets, of two distinct varieties. The inner four were *terrestrial* planets, with rocky surfaces and physical densities similar to the Earth's 5.5 g cm^{-3}. The outer four were *gas giants*, having gaseous surfaces and much lower physical densities – in Jupiter's case, 1.3 g cm^{-3}.

It was interesting to calculate how easy it would be to detect the planets of our Solar System from an observatory several light-years distant. One might imagine that their intrinsic faintness would be problematic, but this was in fact not so. The absolute magnitude of Jupiter – the magnitude with which it would be seen at a distance of 10 pc – was 27. Though this was faint, it would be quite within the reach of modern telescopes; in other words, a hypothetical civilisation living 10 pc away, with an exact replica of our state of technological development, would be able to detect it. The absolute magnitude of the Earth was 30 – though more challenging, even this would be a plausible photometric target.

The principal difficulty in imaging extra-solar planets (a.k.a. *exoplanets*) was not their faintness, but contrast. The absolute magnitude of the Sun was 4.8 – brighter than Jupiter by 22 magnitudes. Distinguishing planets from the glare of their host stars was a great challenge. Using large telescopes such as the 8.2-m Very Large Telescope (VLT) in Chile, fitted with adaptive optic systems to correct for atmospheric seeing and achieve sub-arcsecond angular resolution, this was now at the verge of feasibility. One exoplanet, orbiting a star called 2M1207, had now been imaged by the VLT. This, however, had been a five-Jupiter-mass (M_J) planet orbiting a brown dwarf, which itself weighed a mere 25 M_J – as the first ever image of an exoplanet, it was a profound achievement, but it was a far-cry from imaging anything akin to the Earth.

Looking ahead, the 40-m Extremely Large Telescope (ELT), proposed by the European Southern Observatory (ESO), would be able to image planetary systems similar to our own, but it was not scheduled to be built until 2020. The *Darwin* Observatory – a space-based constellation of four telescopes planned by ESA – would not only image exoplanets, but also take spectra of them. This would allow the composition of their atmospheres to be studied. Atmospheric scientists had identified certain features, termed *biomarkers*, which, if detected in an exoplanet spectrum, were thought to be sure indications of the presence of life. One example was ozone – O_3 – which indicated the presence of free oxygen atoms in a planet's atmosphere. Over time, one would expect free oxygen to react with rocks to become bound up in minerals; a continuing supply indicated replenishment and in turn respiring organisms. As with the ELT, however, *Darwin*'s work was some years distant: it was scheduled for launch around 2015. The remainder of this talk, therefore, would look at what was possible with current instrumentation. There were *indirect* techniques for detecting exoplanets, which did not obtain images of the planets themselves, but which inferred their presence by detecting their influence on their host stars.

The most prolific such technique worked by detecting the small motions of stars induced by the gravitational pull of planets orbiting them. Whilst simplified pictures always showed planets orbiting around stationary stars, more precisely, both revolved around their common centre of gravity. The motion of a star due to the gravitational pull of its planets was normally neglected because it was so small – as an example, whilst Jupiter orbited at more than 30,000 mph, the corresponding motion of the Sun was at a mere 30 mph – but if this motion could be detected, it allowed the presence of planets to be inferred from observations of their host stars alone.

This method – termed the *radial velocity* method – had yielded the first ever exoplanet discovery in 1995: a 0.46 M_J object orbiting 51 Peg. To date it had yielded more than 150 discoveries. Most of these planetary systems were rather unlike the Solar System – in them, large Jupiter-like planets were in close orbits around stars, often with orbital periods of only a few days. Part of the explanation of this was that massive planets in close orbits produced the most conspicuous radial motions in their host stars, and so were the easiest to detect. But it was still surprising that such planetary systems existed at all. Currently it was impossible to ask whether they were 'typical'; they were simply those which radial velocity searches were most apt to find.

Though radial velocity searches were the most prolific source of exoplanet discoveries to date, they revealed little about the physical nature of the objects found: only their masses and the eccentricities of their orbits. A complementary search strategy, and the only other to have been employed to date, worked by detecting the fractional dimming of stars when planets transited their faces. This method could only detect edge-on systems with planets of comparatively large radii – which produced detectable transits – but was more enlightening of the physics of the planets discovered.

Initially, this approach had been trialed on stars already known to have planetary systems from radial velocity measurements. One such star was HD209458, which a radial velocity survey in 1999 had discovered to have a 0.69 M_J planet orbiting it at a distance of 0.045 AU. In 2001, the brightness of HD209458 was observed to decrease by

1.7% for around 3 hours – the first detected transit of an exoplanet. A humble off-the-shelf 10” telescope had been used to make this detection; HD209458 was bright (mag 7.7), and so the photometry did not require a large aperture.

This detection had brought a much greater understanding of HD209458’s companion. From the degree of dimming during the transit could be estimated the companion’s radius; the larger the planet, the more light it would have obscured. The resulting radius estimate was 1.43 times that of Jupiter, suggesting the companion to be a gas giant, most probably inflated by the intense heat of HD209458, a mere 0.045 AU distant. Later in 2001, the HST had taken a spectrum of HD209458 during a subsequent transit, finding that the dimming in sodium spectral features was appreciably greater than that seen elsewhere in the spectrum. This was interpreted as evidence for a sodium-rich atmosphere around the companion planet. For the first time, some indication of the chemistry of an exoplanet was available.

Following up on this success, the speaker amongst others had set up two observatories, termed collectively *SuperWASP*, dedicated to the continuous monitoring of the brightnesses of around seven million stars. To give coverage of both hemispheres, sites in La Palma and South Africa had been chosen. Each observatory housed eight wide-angle telescopes, having between them a combined field-of-view of around 1% of the whole sky. To keep the cost down, off-the-shelf components had been used: 11-cm *Canon* telephoto lenses and standard 2048×2048 pixel CCD arrays.

Soon after these observatories had become operational, large numbers of stars had been identified as having suspect dips in their light-curves. Most of these had turned out to be variable or eclipsing binary stars. Before any of these dips could be declared exoplanet discoveries, an independent radial velocity detection was required as confirmation. After many disappointments, SuperWASP had recently made two confirmed discoveries, named WASP-1b and WASP-2b.

A significant outstanding question in planetary science was what determined the radius of gas-giant planets. Their masses and temperatures were undoubtedly important, but the details of their internal structures were not well understood. Exoplanets detected by both radial velocity and transit methods were valuable probes of this, because their masses, radii, and distances from their host stars, could all be estimated. SuperWASP would increase the number of such planets over coming years, and perhaps shed some light on this.

Following the applause, Mr Nick James asked how the automation of SuperWASP’s search procedure was progressing. Dr Wheatley replied that the construction of stellar light-curves and identification of transit candidates was now fully automated. However, it was still necessary for humans to manually inspect the light-curves of these candidates to confirm them as genuine.

The President then adjourned the meeting until March 28 at 5.30pm at the present venue.

Dominic Ford

References

[1] Marriott, R., *J. Brit. Astron. Assoc.*, **116**, 299 (2006)