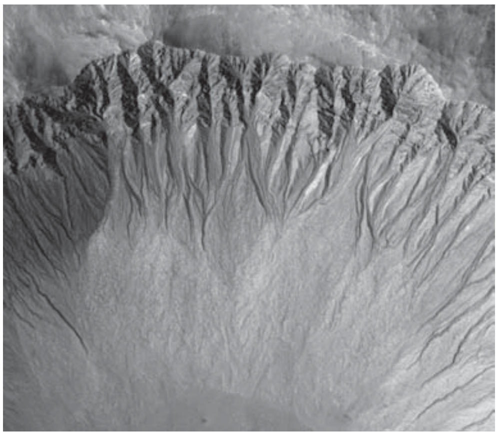
Meetings

Out-of-London meeting, Cambridge, 2005 September 02–04

Report by John H. Rogers

As a climax to two years which saw an unprecedented number of spacecraft making exciting encounters with planets and comets, including two European probes, the world's leading space scientists gathered in Cambridge, UK, for the annual meeting of the Division of Planetary Sciences of the American Astronomical Society. The BAA took advantage of this unique opportunity to hold our Out-of-London meeting on the preceding weekend, inviting leading scientists to talk about each of the major missions. These were interspersed with talks on amateur observations of the planets, some by BAA Section Directors and some by our opposite numbers from France and the USA.

Sessions on Friday evening and Sunday morning were held in the Institute of Astronomy, and the main session on Saturday was held at the Cavendish Laboratory. Accommodation was in Fitzwilliam College. The programme was organised by John Rogers and the accommodation by Jonathan Shanklin.



Erosion gullies on Mars revealed by *Mars Global Surveyor*. *NASA*

The meeting began on a sunny evening at the Institute of Astronomy, on schedule in spite of someone triggering the intruder alarm and bringing a visit from the University security patrol. First Tom Boles, the President, welcomed everyone, and the local organisers gave administrative notices. John Rogers then gave a short talk to set the scene, showing some iconic images. While amateurs had enjoyed several naked-eye comets, two space missions had made the first 'hands-on' probes of comets. While amateurs had developed imaging of the giant planets to superb resolution, *Cassini* was exploring the Saturn system from orbit and *Huygens* had landed on Titan. While amateurs were celebrating and observing the closest Mars opposition in history, the planet was being scrutinised at close quarters by three orbiters and two rovers.

As the main talk for the evening, **Professor Peter Mueller** (a *Mars Express* scientist, University College London) presented the talk prepared by **Prof Ronald Greeley** (a leading planetary geologist and climatologist, Arizona State University). Prof Greeley was unable to attend because members of his family had been in the track of Hurricane Katrina, which had just devastated the New Orleans area. His talk, on **'Mars observed by *Mars Odyssey* and *Mars Global Surveyor*'**, provided an overall introduction to Mars, as it has been thoroughly revealed by these two NASA spacecraft which have been orbiting the planet since 2001 and 1997 respectively. *Mars Global Surveyor* (*MGS*) had performed more than 30,000 orbits and recently returned its 200,000th image. Prof Greeley explained how Mars exemplifies surface processes that are common to most of the solid planets in different ways: impact cratering, tectonism, volcanism, and gradation (erosion). On Mars, much of the interest centres on water: *MGS* images have revealed many small gullies that seem to imply recent water flow, perhaps from melting snow. Much more ancient, there are layered rocks that might have been laid down in standing water – including some around the putative shoreline of an ancient ocean. *Mars Odyssey* is revealing the present distribution of water-ice in the martian surface. Other important agents are dust and sand: *MGS* has viewed numerous local dust storms and dust devils, and *Mars Odyssey* produced a dramatic thermal map of the spread of the 2001 global dust storm. Mars also has its own unique styles of tectonism and volcanism, and *MGS* has improved our understanding by producing the first accurate global maps of altitudes (the MOLA map) and magnetism. These spacecraft have laid the foundation for studies by others, some of which would be described later in this meeting, and others which had not yet reached Mars.

After the lectures, Jonathan Shanklin opened up the historic Northumberland and Thorrowgood refractors, and although no planets were on view, about 30 people took advantage of the clear skies to view Messier objects and double stars, while the rest of the delegates retired to restaurants and bars.

Saturday morning was devoted to Saturn and its moons. First **David Graham**, director of the BAA Saturn Section, reviewed **'Saturn observed from Earth'**. He illustrated the work of the famous visual observers throughout the 20th century, who studied phenomena ranging from edge-on ring presentations to Great White Spot outbreaks. Saturn's belts have subtle but varied colours, as illustrated by his own drawings with large reflectors, and by recent CCD images which showed colour changes within a year. At the latest opposition, CCD images dramatically showed the enhanced brightness of the rings on the night of opposition due to coherent backscatter in their icy particles.

Then **Prof Carolyn Porco** (principal investigator (PI) of the *Cassini* imaging system, from the Space Science Institute, Colorado [**http://www.ciclops.org**]) spoke on **'Saturn and its moons observed by *Cassini*'.** The lecture was a tour de force to match the dazzling success of the orbiter's mission so far – see adjacent report by Doug Ellison.

Prof John Zarnecki (PI of the *Huygens* surface science experiment, from the Open University in the UK **[http://pssri.open.ac.uk/missions/mis-casa1.htm]**) spoke about **'Titan observed by *Huygens*'**– a mission on which he had been working for 15 years. He illustrated the construction of the probe and its instruments, and recounted the near-fatal problem with the Doppler shift sensitivity of the receiver on *Cassini*, which necessitated re-routing the whole mission. But in the end, the descent and landing had been flawless, and instead of the expected 3 minutes of transmission from the surface of Titan, there had been 72 minutes recorded by the time *Cassini* went out of range, and at least 3h13m detected directly by radio telescopes on Earth. The descent images showed a landscape of channels and seashore which Prof Zarnecki likened to East Sussex seen from the air. The penetrometer record had initially suggested a surface with the consistency of creme brulée, i.e. soft under a brittle crust, but could also be interpreted as hitting a pebble before settling into sand or gravel. This would be consistent with the surface images, which showed gravel with rounded cobbles, attributable to quite modest rates of flow of liquid methane. Although solid, the surface was still 'damp' with methane, as a sudden puff of the gas was detected seconds after landing.

After lunch in the excellent Cavendish canteen, and the opportunity to see some posters showing the work of the BAA's planetary sections, delegates reassembled for a short **BAA Ordinary Meeting.** Then **Martin Mobberley** (BAA) presented his **'Sky Notes'.** One highlight of the summer had been a supernova discovered in M51, the Whirlpool Galaxy. Discoveries of more distant supernovae by Tom Boles and Mark Armstrong had brought the British total to 172. Tom Boles had also imaged the recently discovered '10th planet' in the Kuiper Belt, 2003 UB313. Mars was coming up to opposition, and images by Damian Peach and Dave Tyler showed remarkable detail. Stacked Webcam images can resolve features smaller than the nominal diffraction limit, as demonstrated by an image of γ Virginis (Porrima) at periastron, also by Damian Peach.

Dr John Rogers, Director of the BAA Jupiter Section, then spoke on **'Jupiter observed from Earth'**. Although Jupiter was not presently being studied by any spacecraft, amateur images and computer-based measurements were now able to track all the important features of the atmosphere in detail. Many observers were attaining very high resolution using webcams, and Dr Rogers showed how images of the same longitude at intervals of 1–3 jovian rotations could be 'blinked' to display the numerous rapid currents. Amateurs could record circulation in the Great Red Spot and mergers of long-lived ovals. Other observers now specialised in multispectral imaging using infrared and methane-band filters, which revealed clouds at different depths in the jovian atmosphere.

Dr Richard Schmude arrived just in time from the USA, representing the mainly amateur Association of Lunar and Planetary Observers, for which he is recorder for the Jupiter and Remote Planets Sections. He spoke about **'Jupiter, Uranus and Neptune observed from Earth'**, and relieved any afternoon somnolence by his very interactive lecturing style. For Jupiter, the ALPO has a project to look ▸p.281

Saturn and its moons observed by *Cassini*

Carolyn C. Porco, Space Science Institute, University of Colorado

Report by Doug Ellison

Prof Porco opened by explaining that on July 1st 2004, the most complex planetary spacecraft in Earth's history, *Cassini*, arrived at Saturn with a manoeuvre so perfect everyone involved thought they were dreaming. Of all the planetary systems, Saturn with its complex interaction between the planet, its atmosphere, the magnetosphere, the rings and its moons offers the best laboratory for planetary science in the solar system.

Prof Carolyn Porco. *Photo:Nick Hewitt*

The speaker previewed the primary mission, which will last some 4 years and include 82 satellite flybys, 44 of Titan, all better than any *Voyager* flyby, highlighting that the cameras were very well equipped: 'if you've got a science objective at Saturn, we've got a filter for it', with over 42 different filters available.

Prof Porco presented many stunning images taken by the pair of cameras (one narrow and one wide angle), and spoke of recent highlights. Studying Saturn itself, at about 37° south they have imaged a large storm called the 'Dragon' storm, and they hoped to study the full cycle of how these storms live and die. A short movie of images taken of the F ring with the small moons Prometheus and Pandora tugging at its structure drew a reaction from an enthralled audience. Prolonged studies showed that the F ring is actually in a dynamic spiral structure.

Iapetus studies have focused on the dark 'Cassini Regio' region, an area too dark for detailed study by the *Voyager* spacecraft, and have ruled out a volcanic origin for the very low albedo. Dark material is laid over the top of a lighter subsurface and contains organics, including HCN. Further images have shown a 20km tall equatorial ridge around this mysterious moon.

The speaker moved on to Enceladus and presented images of 'tiger stripes' – linear geological features near the south pole. The area has few craters, indicating a young surface, and other instruments have shown areas around the stripes to be several tens of Kelvin warmer than the rest of the moon, suggesting they are an area of some sort of venting from the interior.

The speaker then argued that the study of Titan alone would justify the *Cassini* mission, with some of the camera filters being designed specifically for the study of Titan's surface through narrow methane bands of visibility through the clouds. However the observations have been difficult to interpret because of the thick haze – various features have been seen, with lighter features being interpreted as ice and darker areas as organic material. Prof Porco then discussed the value of *Huygens* data in acting as an in-situ 'ground truth' for flyby observations, and stressed that in the remaining three years of the primary mission, and as much as a decade of a possible extended mission, Titan could offer an insight into conditions on the early Earth.

After a loud and lengthy round of applause, Prof Porco invited questions, the first of which asked about the 'spokes' which she had analysed with *Voyager* imagery some 20 years before. Prof Porco commented that current thinking is that whilst the 'spokes' certainly exist, they are only visible during times of lower angle of incidence between the Sun and the rings via a photoelectric effect, and that they expected them to be seen in the 2007 timeframe. She expressed an element of relief that they had not been seen to date, as the quantity and quality of data they have had so far is such that the scientists would not have had time to properly study the 'spokes' had they been visible.

A further questioner inquired as to the age of the rings. Prof Porco replied that they would study ring features and compare them to *Voyager* images, and study any changes in the orbits of the moons that influence the rings. The President then suggested that ring material might be being replenished in some way; the speaker replied that the rings may have formed as one or more outer solar system objects were tidally ripped apart by Saturn's gravity, or from collisions between Saturnian moons.

To further applause from the audience, the President thanked Prof Porco for taking time from her busy schedule to give us such an inspiring and profusely illustrated presentation.

Saturn viewed through Titan's upper atmosphere by *Cassini* in April 2005. *NASA/JPL/Space Science Inst.*

Comets observed by *Stardust* and *Deep Impact*

Mike A'Hearn, University of Maryland

Report by Doug Ellison

Prof A'Hearn introduced *Stardust* and *Deep Impact* as part of NASA's 'Discovery' programme of cheaper missions, with the two being complementary in their science but different in their methods. The speaker flicked between the two, comparing them at each stage of their missions.

Stardust was sent to take samples of the coma of Comet Wild 2 and return them for analysis on Earth: a taste of what gets lifted from the surface during outgassing. *Deep Impact* was sent to Comet Tempel 1 to determine the difference between what is on the surface and what is within the comet by sending an impactor to slam into it. Both are Jupiter-class comets, but Tempel 1 has recently had its perihelion reduced from around the orbit of Jupiter to just inside that of Mars.

The speaker gave a brief overview of our current best understanding of the origin and nature of comets. He then showed comparative images of the two spacecraft before launch, both being a similar size, equipped with solar arrays and instruments. *Stardust* also had strong Whipple shields to protect it from the particles it was sent to collect as it flew only 350km from the comet. He described the sample collector as looking a little like an ice cube tray, filled with a special material called **aerogel** that is made from glass but has a density of only 0.1% that of water. One side of this array was used to collect the comet particles, the other to collect interstellar particles during the long cruise phases of the mission.

The collision of comet Tempel 1 with the *Deep Impact* impactor spacecraft, imaged by the high-resolution camera on the flyby craft. *NASA/JPL/Caltech/Univ. Maryland*

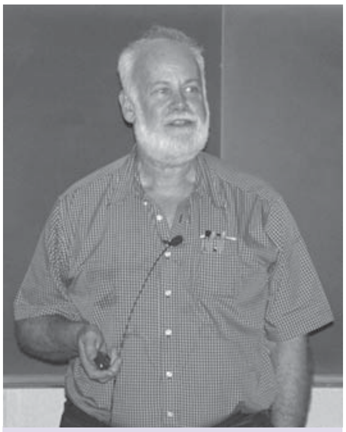
Moving to *Deep Impact*, the speaker showed images of the craft highlighting its two components, an impactor and a flyby spacecraft that sat above it. The impactor was made mainly of copper, the choice of a noble metal being important to avoid a reaction with any water content of the comet. Most spacecraft are built mainly of aluminium which would have reacted with water and thus contaminated spectra taken by the high resolution imager of the flyby spacecraft. The impactor was also hollowed out to reduce its density to around 4g/cm^3, optimised to maximise the excavation power of the impactor instead of turning it into a deeply penetrating probe that would eject little cometary material.

A'Hearn then compared the two mission designs of *Stardust* and *Deep Impact*, explaining that *Stardust* was a seven year mission to return samples whereas *Deep Impact* was over in around six months. Planning for the *Deep Impact* encounter was made more complex after the fortuitous super-extended mission of *Deep Space 1* to visit Comet Borrelly, images from which showed it to be near banana-shape. The original software designed to operate onboard the near autonomous impactor of *Deep Impact* a few years later would have targeted itself to actually miss the comet altogether, but was modified in light of the Borrelly results.

In January 2004, *Stardust* flew past the sunwards side of Wild 2, and Mike presented an excellent series of movies showing nucleus detail and coma jet details, revealing an object nothing like Borrelly neither in shape nor topographic features. Using various exposures with the *Stardust* camera, jets have been traced back to obvious features on the surface.

Turning to his own mission, A'Hearn then presented images and movies taken by three different cameras – those on the impactor, and the medium and high resolution imagers on the flyby spacecraft. The medium resolution imager showed an initial fast puff of around 5km/sec followed by a cone of much slower ejecta of several 100m/sec; toward the end of the ejection sequence, material was travelling as slow as 1cm/sec and literally crawling out of the crater.

The High Resolution Imager, which doubled as an infrared spectrometer, was found to be slightly out of focus once in orbit, but being of a Cassegrain design, much of the resolution was recovered via deconvolution due to the preservation of high frequency data in the shadow of the secondary. These higher resolution images showed no signs of 'chunks' within the ejecta, suggesting there is no crust on the surface of the comet.



Prof Mike A'Hearn. *Photo: Martin Mobberley*

Referring to new interpretations of data literally less than a week old, A'Hearn suggested an impact angle of between 20 and 35° above the horizontal, and on board measurement showed that the last 20 seconds of the impactor's flight, in which time it covered some 200km, was a rough ride, with one impact of around 1000mg and three between 1 and 10mg, imparting some forces on the impactor itself.

Further HRI data has been deconvolved to recover all the resolution that they expected before launch, and measurements from it showed an average surface albedo of less than 4%, and very little difference in colour across the surface of the comet. Deployed as an IR spectrometer, it measured the sunlit parts of the comet to be around 320K. The speaker noted that the surface jumps to this sort of temperature immediately after coming into sunlight, indicating little conductivity to the interior. Similarly, measurements of the impact measured temperatures of around 1500K.

The base of the ejecta cone stayed connected to the comet for as long as 45 minutes after impact, and an escape velocity of 0.05cm/s^2, a mass of 7×10^{13} kg and from this a bulk density of 0.6g/cm^3 was measured, but their own impact crater remained hidden from view by the ejecta. What was clear, however, was that the impact released vast quantities of water, CO_2 and organic material, but analysis was still ongoing given how little time the scientists have had to look at the data.

After resounding applause, the President invited questions. Regarding the size of the crater, the speaker suggested it would probably be around 80 to 100m, but they had not identified it yet. Another member inquired as to the potential for a follow-on mission for the flyby spacecraft. A'Hearn confirmed that they hoped to get funding to operate an extended mission with the still-healthy flyby spacecraft to Comet Boethin using an Earth gravity assist in January 2008, with the flyby being in December of that year, and whilst no funding for this has been secured, NASA management allowed the team to conduct a trajectory correction manoeuvre to leave this option open.

▸ for correlations between the size, ellipticity, and drift rate of ovals. This has shown that the faster-moving white ovals in the North Equatorial Belt are more elliptical. The ALPO also monitors the absolute brightness of the planets, and while Jupiter has shown no change, Uranus has faded by nearly 0.1 magnitude since 1991, while Neptune has brightened by a similar amount. Amateurs can now produce well-resolved colour images of Uranus, so there is the prospect of imaging cloud features as it approaches equinox.

Moving from the giant planets to comets, **Jonathan Shanklin**, Director of the BAA Comet Section, spoke on **'Comets observed from Earth'**. For comet discovery, amateurs now had stiff competition from the LINEAR and NEAT projects and from the SOHO spacecraft. SOHO had now discovered 1013 comets, mostly tiny sungrazers. Among these is the recently discovered Marsden group of mini-comets, which have an orbital period of about 5.5 years; some have been recorded at multiple perihelia. Nevertheless, the Comet Section still has a thriving programme of plotting visual lightcurves of comets. Visual observations remain ideal for this as they can record the full extent and brightness of the coma, whereas CCD images often miss the outer regions. Visual lightcurves have shown that comet 1P/Encke has not faded over the past 50 years. Other well-determined examples were for comet 2001 A2 (LINEAR), which showed a sudden turn-on, then variations with a rough period of 30–40 days; and comet 2004 Q2 (Machholz), which was unusual in showing a 'perfectly behaved lightcurve'. Mr Shanklin showed lightcurves of comet 9P/Tempel 1, the target of *Deep Impact*, from 1983, 1994 and 2005, and it was similarly well behaved each time although about one magnitude fainter in 2005. This set the scene for an account of the *Deep Impact* mission itself.


Prof Steven Squyres. *Nick Hewitt*

Prof Mike A'Hearn (PI of the *Deep Impact* mission, from the University of Maryland [**http://deepimpact.jpl.nasa.gov**]) spoke about **'Comets observed by *Stardust* and *Deep Impact*'** – see adjacent report by Doug Ellison.

Then we returned to Mars. All the space scientists had given outstanding talks, but the last of the day would thrill the audience most of all. **Prof Steven Squyres** (PI for the Mars Exploration Rovers, from Cornell University [**http://athena.cornell.edu**]) spoke on **'Mars observed by *Spirit* and *Opportunity*'.** He began with a scarily entertaining account of the development of the two rovers, with many pictures of disasters along the way, such as the 'terrible times with airbag and parachute development' on a gunnery range in Idaho. If the spacecraft landed, they would perform 'origami in reverse – the most frightening of all'. If they got moving, controllers would programme different levels of courage or cowardice into the vehicle depending on how scary the prospect ahead looked. And if the 'power tool' got stuck in a rock, a video simulation showed the fiasco that could result. But as we all know, the rovers did land and travel and performed the most rigorous investigative science ever done in real time at another planet: 'forensic science' as the speaker called it. Both landed at sites where remote sensing suggested that water had once been present. *Spirit* landed in Gusev crater which was thought to be a dried-out lake bed. But the analysis of the first rocks showed that they were basalt: 'The lava buried the good stuff.' But with a rover, 'if you don't like the neighbourhood you can go somewhere else' – so *Spirit* was driven to the hills, and even though 'its warranty had expired', it got to the base and found 'no more boring basalt'. *Spirit* had reached the top of the hill just before the meeting, and Prof Squyres explained how the geology had changed on the way up, consisting of ancient layered rocks – both meteoritic ejecta and basaltic sandstones – which had apparently been modified by water. Views from the hill included dust devils on the plain below, and martian sunsets, with Earth shining in the night sky.

Meanwhile, *Opportunity* landed in a small crater ('a hole-in-one') with outcrops of sedimentary layered rocks which had formed by soaking in dilute sulphuric acid, and the dark material of Sinus Meridiani turned out to be 'blueberries' made of haematite, formed by soaking of the sedimentary rock. Further exploration of a much larger crater revealed many more such layers, of which the deepest were formed from wind-blown sand dunes pre-dating the watery epoch. From there, *Opportunity* began a long drive south through low sand dunes, 'straight ahead at top speed with our eyes closed' until it got stuck in a dune. It took a month of testing in the lab and on Mars before they perfected the technique that succeeded in freeing it: 'Put it in reverse and gun it hard.' Now it was again travelling across rock layers with blueberries. In reply to an enquiry as to how long the rovers would last, Prof Squyres' answer was 'That's the question my wife keeps asking me.' The audience applauded this exciting talk enthusiastically, having gained a much deeper understanding of the intense effort required to operate this uniquely successful mission, and of the rich scientific insights that were being gained.

On Sunday morning, delegates returned to the Institute of Astronomy in its sun-dappled glade. **Christophe Pellier**, director of the Terrestrial Planets Section of the Société Astronomique de France, spoke about **'Mars and Venus observed from Earth'**. He showed examples of the best images now obtainable, both at highest resolution and with diverse filters, especially by Tomio Akutsu, Damian Peach, and M. Pellier himself. The best of Mars were at the closest-ever opposition of 2003. Several images even showed the shadow of Olympus Mons. Regarding filters, near-infrared (I-band) gave the best surface contrast, while blue showed white clouds most sensitively; and a green channel needs to be included in colour images to discriminate the yellow colour of dust storms. The regional dust storm around Hellas in 2003 July was particularly well followed, and *MGS* thermal imaging showed that it had been triggered by dust clouds spreading across the equator, from the Utopia basin via the Isidis basin. Such trans-equatorial dust clouds could now be identified on amateur images even though they had very low contrast. Amateur images of Venus are also now of remarkable quality. Ultraviolet images show a characteristic cloud pattern and the speaker showed his own timelapse movie showing 4 hours of Venus rotation. He was also the first amateur to image the thermal surface glow of the dark side at the infrared wavelength of 1 micron, in which dark patches are probably cooler highlands.

Finally, **Prof Peter Mueller** (representing the *Mars Express* camera team, from University College London) spoke about **'Mars observed by *Mars Express*'**. This European probe was the latest of the Martian orbiters, and he described its high-resolution stereo camera: when tested in Munich, it could see alpine cablecars 80km away. The team was now working out ages for martian surfaces from the images, assuming a cratering rate derived from the Moon. Although most of the volcanoes were billions of years old, parts of the great calderas had been resurfaced as recently as 150 million years ago, and dark dune-fields in north polar valleys were interpreted as ash from small but recently active volcanic cones. Likewise the team reported that water-ice, although mostly deposited billions of years ago, still exists beneath a dirt coating in glaciers around Olympus Mons, and in a 'frozen sea' in Elysium. Controversy about these conclusions was playing a valuable role in testing our knowledge of Mars. Moreover, the team were developing advanced image analysis techniques for automated mapping of both Mars and Earth, as visualised by a superb 'fly-over' movie of the Olympus Mons caldera.

After the formal conclusion of the meeting, some of the foreign guests took a tour of the Institute of Astronomy's telescopes, while some 15 of our own members embarked on a walking tour of Cambridge city's many sundials.

John H. Rogers, *Director, Jupiter Section*