Project Scientist Reports for SSWG, 2 Nov 2009

Report compiled, using inputs from Project Scientists, by Richard G. Marsden, acting head Solar System Missions Division (SRE-SM).

Satellites in Orbit

Ulysses: Richard Marsden

On 30 June, after 18 years, 8 months and 22 days of continuous operations, the Ulysses mission finally came to an end. A few days earlier, on 11 June, Ulysses became the longest running ESA-operated spacecraft, overtaking the previous record of 6822 days held by the International Ultraviolet Explorer (IUE). The data return for the second quarter of 2009 was significantly lower (factor of 4) than during the first quarter and the maximum supportable bit rate fell from 512 bps to 256 bps at the end of June. This rapid decline in mission return led ESA and NASA to decide that it was time to end spacecraft operations. So, at the end of the Deep Space network tracking pass on 30 June, both receivers were switched on and connected to the front and rear Low Gain Antennas, making communication with the spacecraft at some point in the future at least a technical possibility. The spacecraft S-band transmitter was then switched off, terminating the mission. At that point, Ulysses was 5.3 AU from the Earth and 4.75 AU from the Sun at 18.6° north solar latitude.

The outstanding scientific success of the mission is indisputable, and the data provided by the instruments on board Ulysses will continue to be exploited by the heliophysics community for many years to come. Ulysses is also remarkable in the breadth of science that has been addressed, with topics ranging from solar wind physics to cosmology, studies of the Saturnian rotation rate using radio observations and serendipitous encounters with comet tails. In addition to mapping the inner heliosphere for the first time from equator to the poles over almost two complete solar activity cycles, major discoveries have included the first in-situ measurements of interstellar dust and gas, and the first measurements of rare cosmic-ray isotopes. The extended lifetime of the mission has provided key insights into the long-term behaviour of the heliosphere, in particular those processes related to the Sun's 22-year magnetic cycle. Recent studies have focused on the effects on galactic cosmic rays of the current, extended, minimum in solar activity. Ulysses data have shown that the intensity of galactic cosmic ray protons may reach the highest level ever recorded if the lack of magnetic activity on the Sun continues.

At the time of writing, there are 1489 Ulysses-related refereed publications in print, of which 30 were published in 2009.

SOHO: Bernard Fleck

Using VIRGO data, C. Fröhlich (A&A 501, L27) showed that during the current solar minimum, the total solar irradiance (TSI) at 1 AU is more than 0.2 Wm-2 lower than it was during the previous minimum in 1996, which indicates for the first time a directly observed, long-term change of the Sun's total energy output. The solar UV irradiance does not show such a long-term trend. This suggests that the change in TSI is caused by a global temperature change of the Sun.

Howe et al. (ApJ 701, L87), using data from MDI and GONG, have studied the evolution of the migrating zonal flow pattern in the upper convection zone during the current extended solar minimum and compared it with that during the previous minimum. They found that the flow band associated with the new cycle has been moving more slowly to the equator than

was observed in the previous cycle. They speculate that this slower flow configuration is the cause of the prolonged minimum between cycles 23 and 24. The current position of the fast-rotating belt corresponds to that seen around the onset of activity in the previous cycle, suggesting a rapid increase in solar activity in the near future. If, on the other hand, the current low activity levels persist for much longer, the authors suggest that we may indeed be looking at an unusually weak cycle.

The solar tachocline is the region between the solar convection zone and the radiative zone. It is the transition zone where the latitudinal differential rotation of the convection zone changes to rigid rotation of the radiative interior. This region is of particular interest, as it is believed to play a key role for the Sun's dynamo. Previous studies based on global helioseismology techniques have revealed a distinct feature at the tachocline in the measured sound speed perturbation profile relative to a standard solar model. Global helioseismology, however, does not provide any information on possible latitudinal variations or asymmetries between the northern and southern hemisphere. Zhao et al. (ApJ 702, 1150) have developed a new local-area helioseismology technique and applied it to MDI data, which allowed them to construct the first full two-dimensional sound-speed perturbation image of the solar tachocline. While there are still uncertainties about possible instrumental effects, their analysis shows tantalizing hints of a latitudinal dependence of the sound-speed perturbation. In a follow-up analysis they are investigating solar cycle effects of the tachocline variations.

Two SOHO Workshops have been held during the reporting period: the STEREO-3/SOHO-22 Workshop "Three Eyes on the Sun - Multi-spacecraft studies of the corona and impacts on the heliosphere," that took place from 27 April to 1 May in Bournemouth, UK, and SOHO-23 "Understanding a Peculiar Solar Minimum" in Northeast Harbor, Maine, from 21 to 25 September.

At the time of writing of this report, 3507 papers based on SOHO observations have been published in the refereed literature since launch, of which 217 in 2009.

Cluster/Double Star: Matt Taylor

A paper by Kiyani et al. (Phys. Rev. Lett., August 2009) examines the dissipation range of collisionless plasma turbulence using Cluster magnetic field data. The observations show a crossover from multifractal scaling of the inertial range, characteristic of fully developed turbulence, to global scale invariance or monoscaling in the dissipation range. These results present strong observational constraint on theories of dissipation mechanisms in turbulent collisionless plasma.
Using data from the Cluster mission, Sahraoui et al. (Phys. Rev. Lett., June 2009) have discovered a mechanism that can account for the heating of the solar wind. Cluster data were used to successfully discriminate between a number of theoretical models and, for the time periods analyzed, a remarkable agreement was found with one model in particular. This result may be applicable in other astrophysical contexts such as the heating of the solar corona.
The plasmasphere, discovered at the beginning of the space age, has remained largely an unexplored territory. Now, with innovative observational techniques, new light is being shed on this key region of the magnetosphere. The book 'The Earth's Plasmasphere: a Cluster and Image perspective' was recently published by Springer.

As of end of September 2009, 1063 papers have been published in the refereed literature using Cluster and Double star data.

Mars Express: Olivier Witasse

An article entitled "Observed variations of methane on Mars unexplained by known atmospheric chemistry and physics", written by the Mars Express interdisciplinary scientist F. Forget, has been published in Nature on 6 August 2009. Photochemistry as currently understood does not produce measurable variations in methane concentrations, as reported by the observations. The recent result from ground-based measurements implies an unidentified methane loss process that is 600 times faster than predicted by standard photochemistry.

The OMEGA principal investigator was awarded the Fred Whipple award (American Geophysical Union), in recognition of significant and sustained contributions to the field of planetary sciences. The justification is as follows: "The contribution in combining the use of experimental space science through spacecraft instrumentation and quantitative analysis of spectroscopic measurements have helped to change our views about Mars and our approaches to thinking about the history of Mars, and have helped to redefine the directions for the future of the Mars program. In addition, the contributions to developing and sustaining strong international collaborations in space science helped lay the foundation for the current plans to develop joint missions and a joint program between NASA and ESA."

A Mars Advanced School, sponsored by ESA, was held in Jiaxing, Zhejiang Province, China, on July 20-24. About 40 graduate and postdoctoral students, as well as researchers, from mainland China and Taiwan, attended, with teaching staff from Europe and China. This initiative contributes to the development of Chinese expertise in planetary sciences, and fosters collaboration between China and Europe in the space science activities.

The report "Mars Express: the Scientific Investigations" (ESA SP-1291) was published in August 2009.

At the time of writing, the total number of refereed articles published since orbit insertion is 372, of which 72 in 2009.

Venus Express: Håkan Svedhem

Ozone has been detected for the first time in the atmosphere of Venus. The concentration found using the SpicaV instrument on Venus Express is much lower than on the Earth (and even than on Mars), so heating by UV absorption as in Earth's stratosphere is not expected; the implications for the chemistry in this region are nevertheless important.

By exploiting the spectral windows in the near infrared that allow monitoring of the thermal properties of the surface of the planet, the Virtis team has now built a map of the full southern hemisphere showing surface temperature and emissivity. These maps show a number of areas that may contain surface rock of a more evolved type than the basaltic rock which is the only type so far identified on the surface of Venus. The precise type of rock still remains to be determined. These maps are also used for the search of active volcanic regions, but so far no such regions have been identified.

Papers from the ESLAB symposium 2009 'International conference on comparative planetology: Venus-Earth –Mars', held 11-15 May will be published in a special issue of Planetary and Space Science. By end of September about 20 manuscripts had been received and another 10 are expected to be submitted shortly.

The number of papers related to Venus Express published since launch is 119, with 34 so far in 2009.

Rosetta: Rita Schulz

The scientific preparation of the Rosetta fly-by at asteroid (21) Lutetia (10 July 2010) is progressing well. The "Lutetia Fly-By Preparation Workshop" held in Frascati (20-22 October 2009) was dedicated to further refine the scientific case and identify in detail the requirements for the operation of the instruments as well as possible conflicts between requirements. The results of this workshop will be presented and discussed at the forthcoming 27th SWT meeting where the science priorities for the measurements during the Lutetia fly-by shall be agreed, on which basis the RSOC will pursue the detailed planning of the Science Operations in close collaboration with the PI Teams and the RMOC.

The preparations of the third and last Earth swing-by, scheduled for 13 November 2009, are proceeding as planned. The closest approach will be at a distance of 2480 km above the surface of the Earth (8850 km from centre) at about 07:45 UTC. After this final Earth swing-by the spacecraft will be correctly positioned for the encounter with asteroid (21) Lutetia and its heliocentric velocity will be sufficiently high to allow for the rendezvous with its target comet 67P/Churyumov-Gerasimenko in 2014.

The scientific results of the Rosetta fly-by at asteroid (2867) Steins are being published together in one single Special Issue of Planetary and Space Science (approx. 120-140 pages), to appear in time for the Lutetia flyby.

The total number of Rosetta-related publications since launch is 168, of which 50 were published in 2009.

Hinode: Bernard Fleck

Understanding how the outer atmospheres of the Sun and other stars are heated to multi-million degree temperatures is one of the cornerstone problems of space science. One of the leading candidates to solve the coronal heating problem are nanoflares, short and intense heat pulses within spatially unresolved magnetic strands. The frequent occurrence of nanoflares requires that flare-hot (~10 MK) plasma be present in the corona at all times. Its detection has proved elusive until now, in part because the intensities are predicted to be very faint as this ultra-hot plasma cools very quickly. An Italian-American team of scientists now claims to have finally detected the smoking gun (Reale et al., ApJ 698, 756). Observations from XRT and EIS on Hinode have revealed that ultra-hot plasma is widespread in solar active regions. The hot (10 MK) component is a minor component of the total emission measure distribution, much smaller (3%) than the cooler ~3 MK dominant component. The small emission measure of the hot component explains why it has been elusive so far: it is overwhelmed by the cooler component along the line of sight, and only the higher sensitivity of XRT and EIS allowed its first ever detection.

On the other hand, using data from SOT and EIS on Hinode and SUMER on SOHO, De Pontieu et al. (ApJ 701, L1) show that energy deposition at in the corona itself cannot be the only source of coronal heating. Their results suggest that a significant part of the heating and energizing of the coronal plasma occurs at low heights, in the chromoshere, in association with chromospheric jets. They quantified the asymmetry of spectral UV and EUV lines observed with EIS and SUMER and identified faint but ubiquitous upflows with velocities of 50-100 km/s for a large temperature range from 100,000 to several million degrees. These pervasive upflows are found to be spatiotemporally correlated with the recently discovered, cool (10,000 K) chromospheric jets or "Type II" spicules. The authors suggest that a significant fraction of the plasma propelled upward in these jets or spicules is heated to coronal temperatures, providing the corona with hot plasma.

At the time of writing, 252 papers based on Hinode observations have been published in the refereed literature since launch, of which 93 in 2009.

Projects under Development

BepiColombo: Johannes Benkhoff

An intermediate status review on the actions from the BepiColombo PDR in May was held on September 11, 2009. The outcome of the meeting was quite positive. Seven out of nine previously critical technical issues are now categorised as normal work. Industry has shown an overall system mass margin of ~11% for the nominal mission in 2014 and ~10% for the back-up mission in 2015. A change of the orbit is not the baseline to establish these margins.

One open point is still the performance of the solar arrays and the power availability for science operations during some parts of the mission (+/- a few days around perihelion). Testing on Solar Array substrates at high temperatures (230°C, which would be needed during perihelion) did not produce the expected results. In the worst case this could mean accepting lower solar array performance and related power restrictions impacting payload operations. Instrument-by-instrument analyses have been performed in order to better understand the extent to which the expected science return may be affected.

The ESA Executive has appointed an independent expert group to look into the "scientific value for money" of the current BepiColombo mission. This would include a comparison between BepiColombo and NASA's MESSENGER mission, and a review of the Mercury-related science community (how large, how many Co-Is on the instruments, science publications, etc.) in comparison to other Cornerstone missions of ESA.

On September 15 a session on new results from Mercury was held during the annual EUROPLANET meeting in Potsdam. The session was very well attended. New results from two MESSENGER flybys and modeling results were given. The session showed that the interest in Mercury science among the science community is steadily growing.

All the papers for the special issue on the science outcome and instruments of BepiColombo Planetary Space Science were accepted and the issue will be published soon. Most of the in total 20 papers are already available on-line.