Cluster gets to grips with the magnetosphere

On 9 November 2001 RAS hosted the first UK meeting to discuss results from Cluster, itself the first mission to explore the Earth’s magnetosphere with four identically instrumented spacecraft – and thus fully resolve the complex spatial and temporal variations of the plasmas that fill space around the Earth. Mike Hapgood reports.

The RAS Discussion Meeting was entitled “Cluster – a new view of the magnetosphere” and began with an introductory talk by Mike Hapgood (RAL), who outlined the progress of the mission since its launch in the summer of 2000. He showed how the precession of the Cluster orbits around the Earth had allowed the mission to sample different plasma regions in an annual cycle; the first cycle had almost been completed. He went on to describe future plans – in particular how changes in spacecraft separation would allow Cluster scientists to study the different plasma regions at different scale lengths and thus study different aspects of the plasma behaviour.

The meeting included several talks by researchers involved in the instrument teams. These included talks from all three UK-led instrument teams: Malcolm Dunlop (Imperial College) discussed work with the FluxGate Magnetometer (FGM), Hugo Allelyne (Sheffield) presented results from the Digital Wave Processor (DWP) and Chris Owen (MSSL) discussed work with the Plasma Electron And Current Experiment (PEACE). In addition, Andrew Buckley (Sussex) reported on work with the particle correlator that forms part of DWP.

The meeting also heard talks on two non-UK instruments: results from the CIS experiment were discussed by Iannis Dandouras (Centre d’Etude Spatiale des Rayonnements, Toulouse) and those from the RAPID experiment by Patrick Daly (Max-Planck Institut für Aeronomie, Katalnburg-Lindau). At this early stage in the analysis of Cluster, all the instrument reports stressed the work to establish the reliable calibration of their instruments which is, of course, essential in order to compare data from different spacecraft.

An important aspect of Cluster science is the comparison of spacecraft measurements with simultaneous ground-based measurements. The combination of these two different techniques is often a powerful test of current theories and has been strongly exploited by the UK community. Jim Wild (Leicester) reported on progress in exploiting Cluster data in this context.

The meeting also included talks on analysis of data taken during crossings of the bow shock, the shock generated when the solar wind first encounters and is slowed down by the obstacle formed by Earth’s magnetosphere. This region is a key target for Cluster and is crossed by the spacecraft for about six months every year. Elizabeth Lucek (Imperial College) and Tim Horbury (Imperial College) reported on analyses of magnetometer data during crossings of the bow shock while Steve Schwartz (QMUL) reported on behaviour of electrons in this region.

A highlight of the meeting was a talk by David Southwood (Director of Science at ESA) on his long involvement with the work that led to Cluster. He particularly noted that the need for a Cluster-type mission had first been posed by Jim Dungey (Imperial College) in his inaugural lecture in 1965. It was fitting that Jim was able to attend the present meeting to see his idea turned into reality.

Mike Hapgood, Rutherford Appleton Laboratory.

Cluster: the story so far

Cluster hit the headlines in June 1996 in the worst possible way: the Ariane 5 rocket carrying the spacecraft into orbit exploded. But such was the significance of the mission that ESA replaced the lost spacecraft and the quartet of satellites finally launched in 2000.

Cluster uses four satellites, flying and observing together, to investigate the distribution of particles and the strength, orientation and movement of magnetic fields around Earth. Much of the first part of the mission has been taken up with commissioning the 44 instruments, but scientific results are now coming in.

Cluster is already gathering important new data on the magnetopause and the bow shock. They have shown that the bow shock is much more complex and dynamic than was apparent, e.g. the bow shock moves through space at speeds of 5 or 6 km s⁻¹. They have also provided the first conclusive evidence that surface waves form on the magnetopause and propagate along its surface away from the Sun with speeds around 70 km s⁻².

Closer to the Earth, Cluster has also explored regions in the polar magnetosphere (around 20,000 km altitude) where electrons are accelerated downwards to form the aurora. Cluster results show that there are also adjacent regions in which electrons are accelerated upwards and that these are responsible for the “black aurora” – regions of exceptionally low brightness within bright aurora.

An important objective for Cluster is the study of the many types of plasma waves that are naturally generated in the magnetosphere. One example is the dawn chorus emission, which resembles birdsong when converted to sound. The existence of this wave emission has been known for many decades but its origin is not well understood. Cluster has now observed chorus simultaneously from several spacecraft and confirmed that it arises near the magnetic equator.

Further Cluster investigations are planned.

Mike Hapgood, Rutherford Appleton Laboratory.