CLUSTER AT THE EARTH'S BOW SHOCK

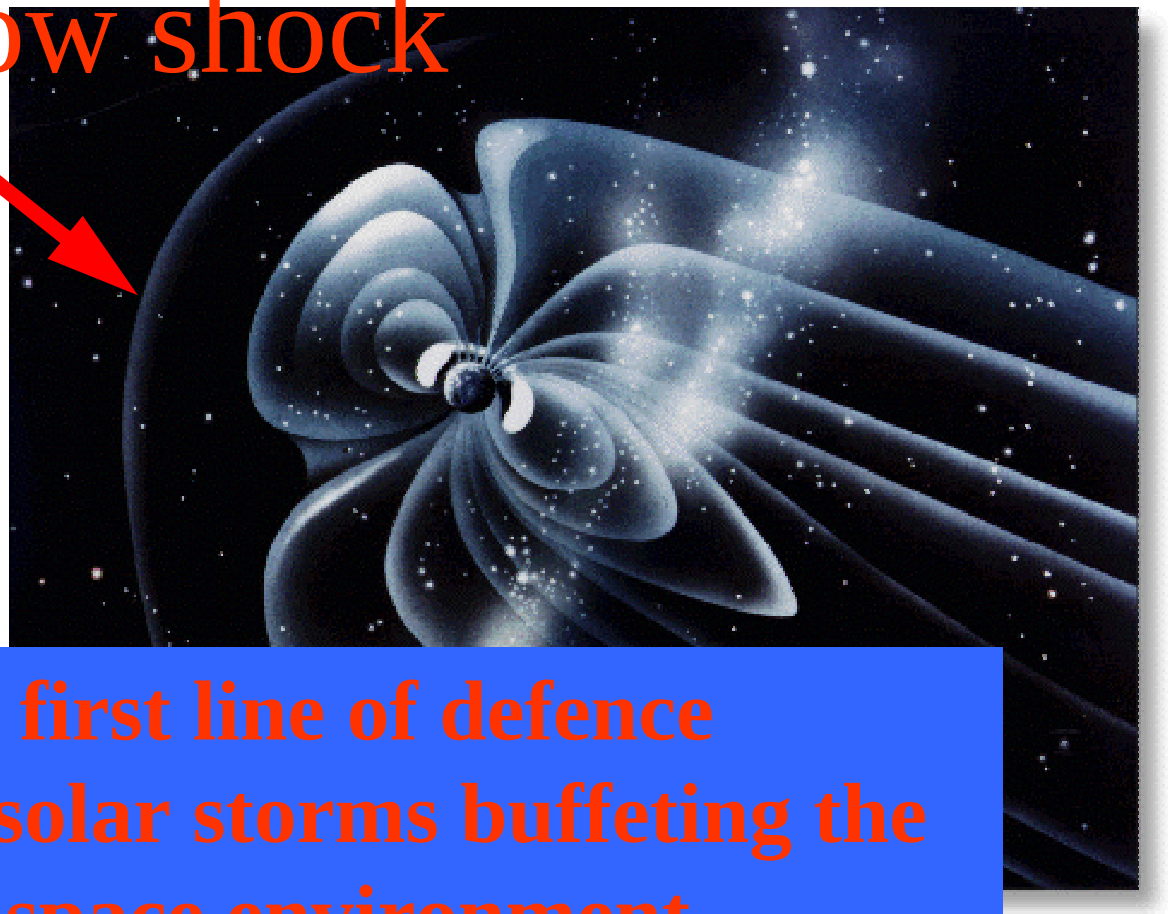
or how Cluster saw this important boundary of the the Earth's space environment in a completely new light at Christmas 2000

André Balogh

Imperial College, London

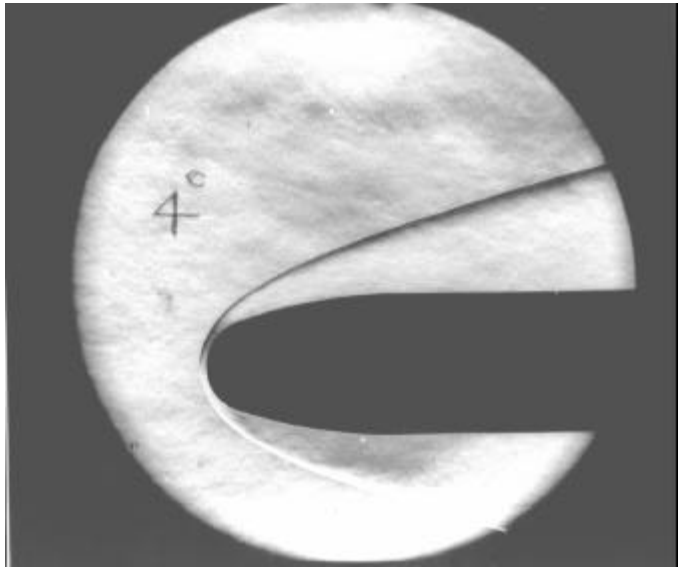
The magnetosphere is a complex system. But let us look at a simple view of the way it interacts with the solar wind. The subject of this presentation is …

the bow shock



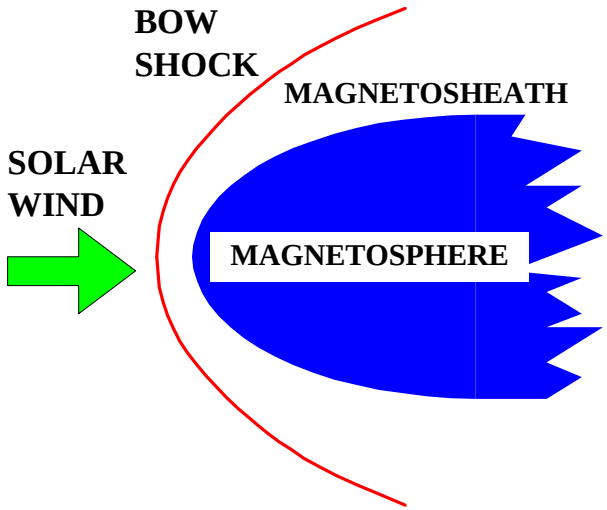
It is our first line of defence against solar storms buffeting the Earth's space environment

Shock waves



Schlieren image of a shock wave in Mach 9 flow taken in the Imperial College Department of Aeronautics No 2 hypersonic gun tunnel facility

A schematic view of the interaction of the solar wind with the magnetosphere.

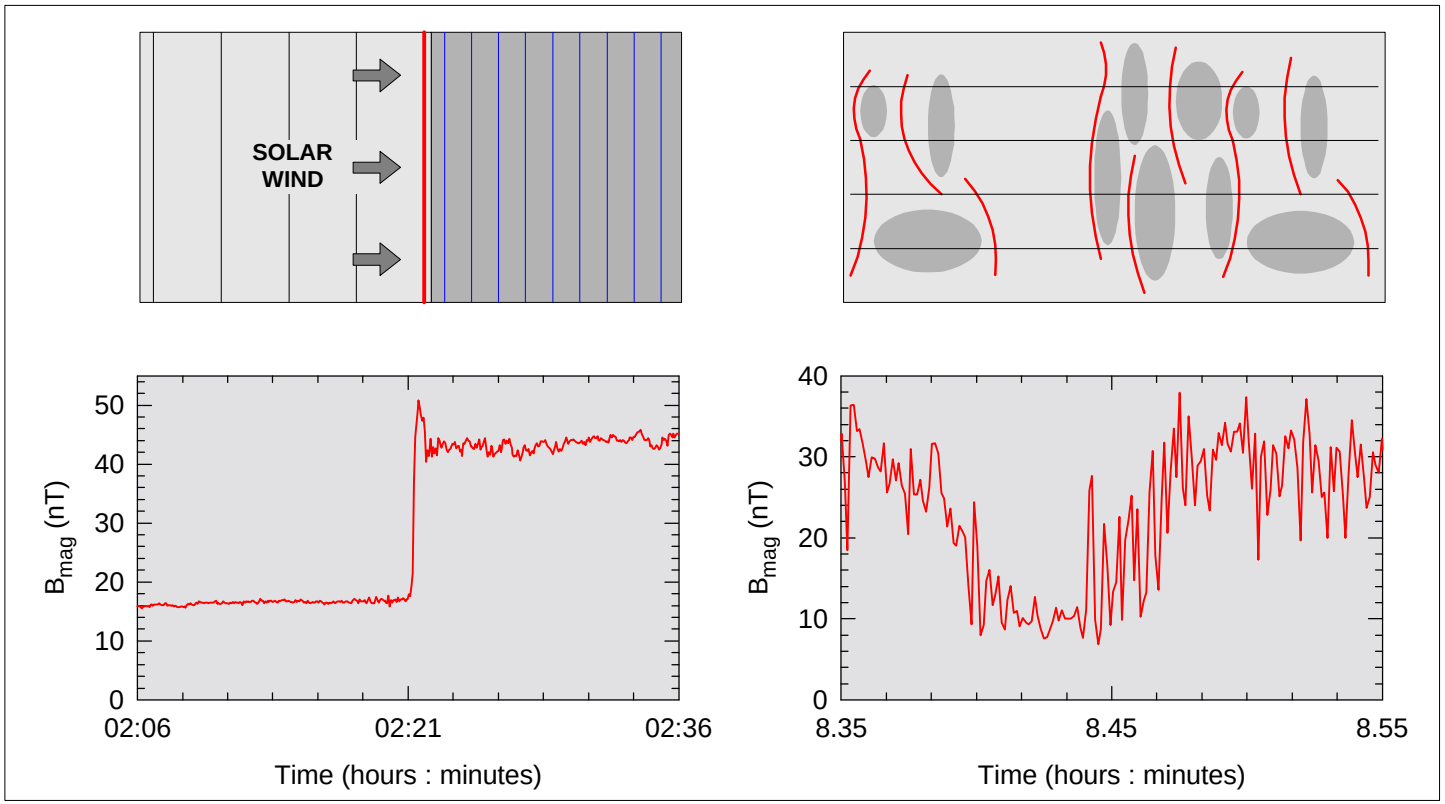


The magnetosheath is the region between the bow shock and the magnetosphere where the solar wind, slowed down at the shock, flows around the magnetosphere.

The bow shock depends on the direction of the magnetic field carried in the solar wind

Perpendicular shock: short, sharp jump, simple structure

Parallel shock: the shock front forms, breaks up, then re-forms; complex, fast varying structures

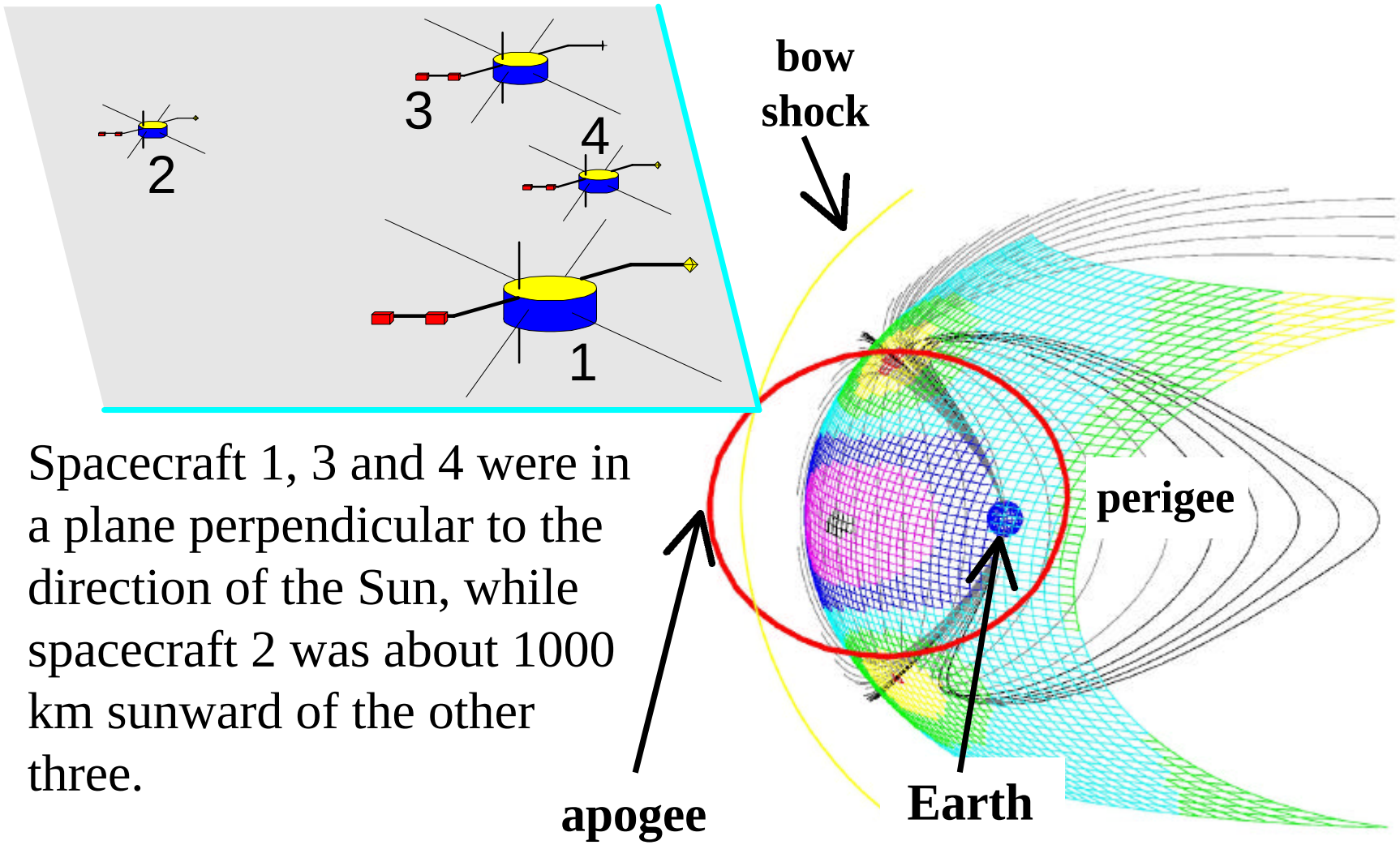


For the study of the bow shock, Cluster's four-spacecraft observations are essential:

- To determine the formation, structure and motion of the bow shock in response to different solar wind and interplanetary magnetic field conditions

- To determine the physical processes acting in this collisionless shock wave, applicable to shock waves in general

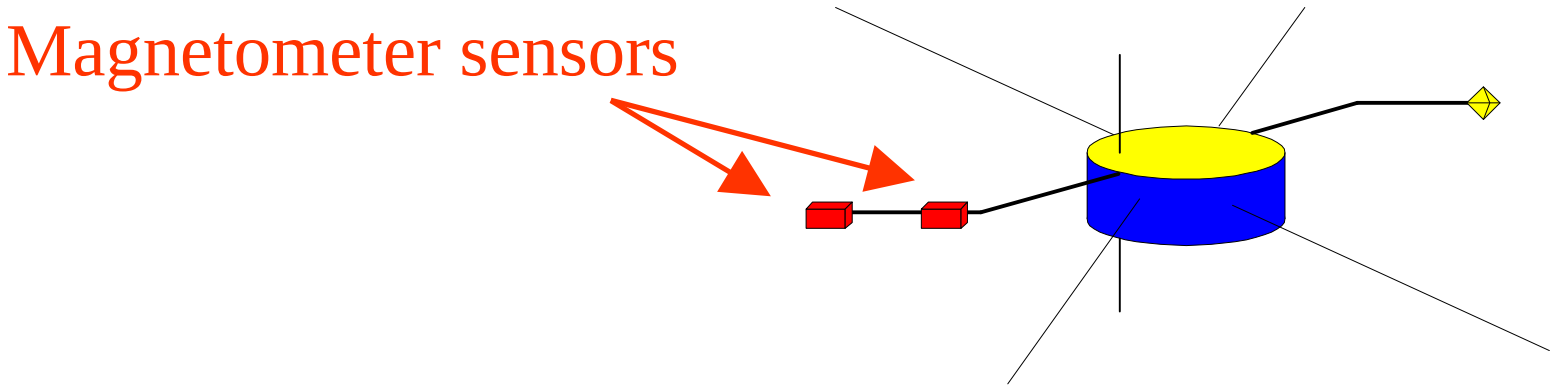
On 24-25 December 2000, the four Cluster spacecraft were near the apogee of their orbit, near the position of the bow shock



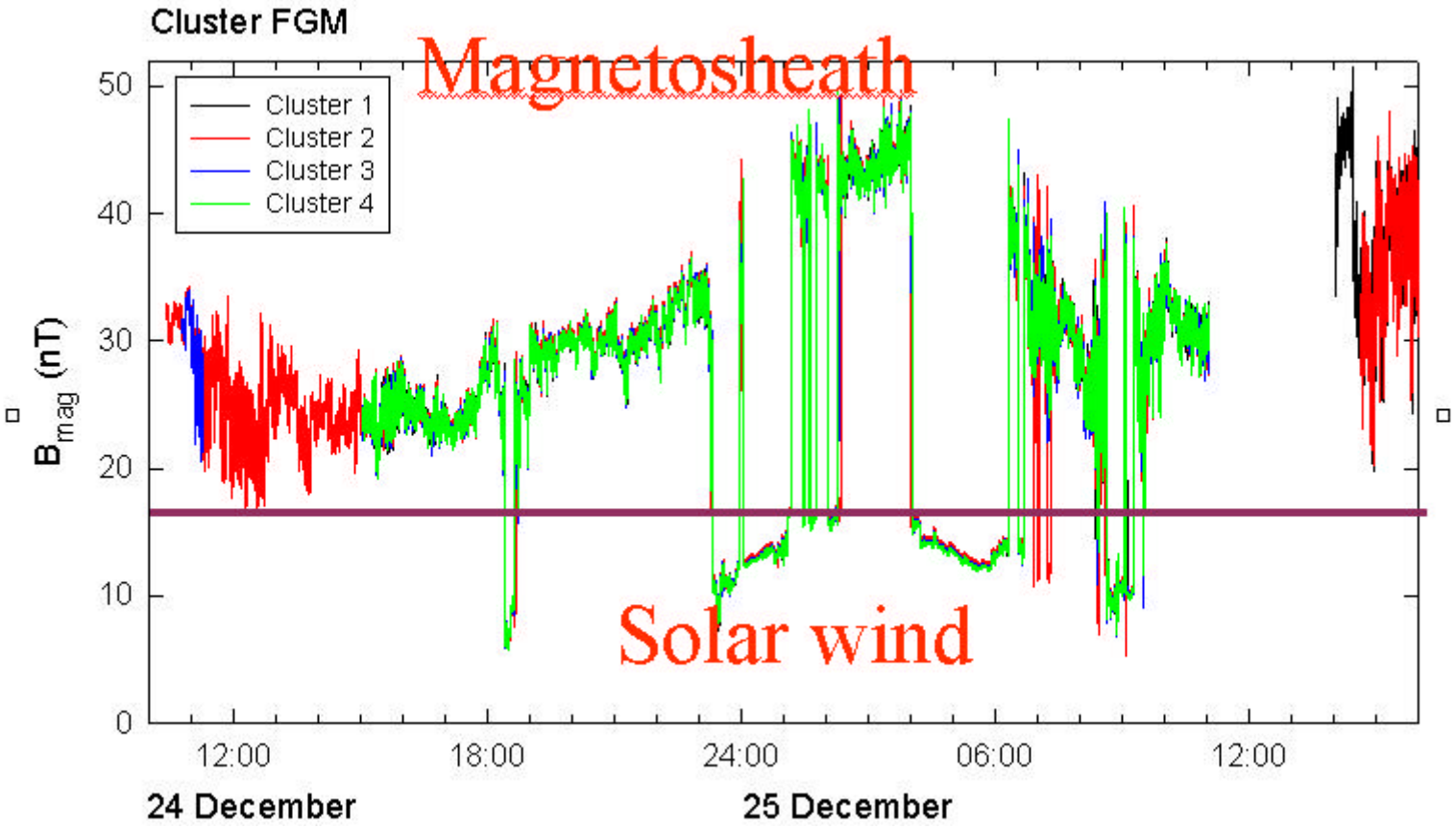
Spacecraft 1, 3 and 4 were in a plane perpendicular to the direction of the Sun, while spacecraft 2 was about 1000 km sunward of the other three.

In the following, we demonstrate the capability of the Cluster mission. Comparisons between the observations made at the four spacecraft reveals the dynamics of the bow shock in a completely new light.

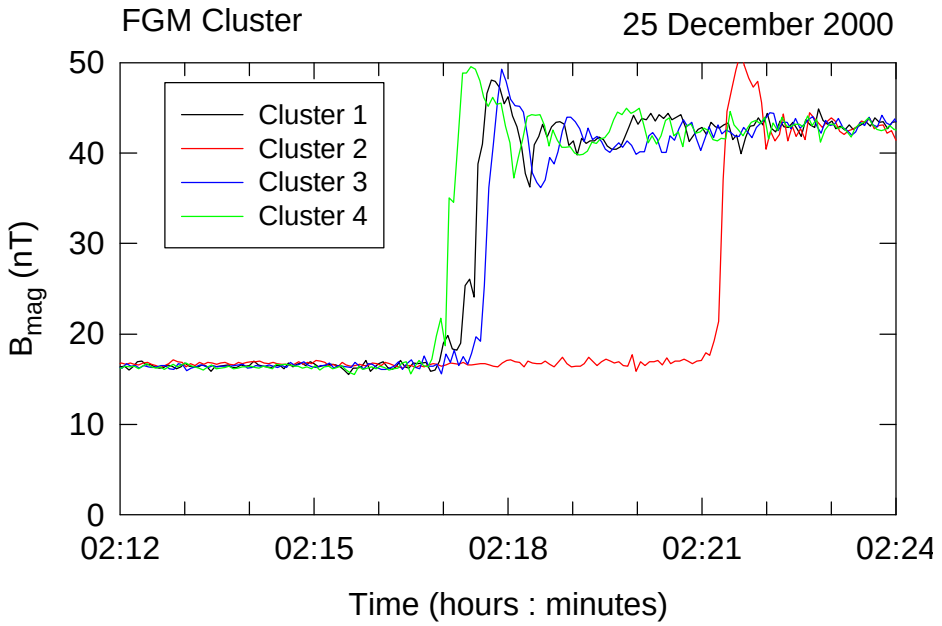
The measurements shown were made by the magnetometer (FGM) on Cluster.



As conditions in the solar wind fluctuated, the bow shock crossed and re-crossed over the four spacecraft, immersing them repeatedly either in the solar wind or the magnetosheath

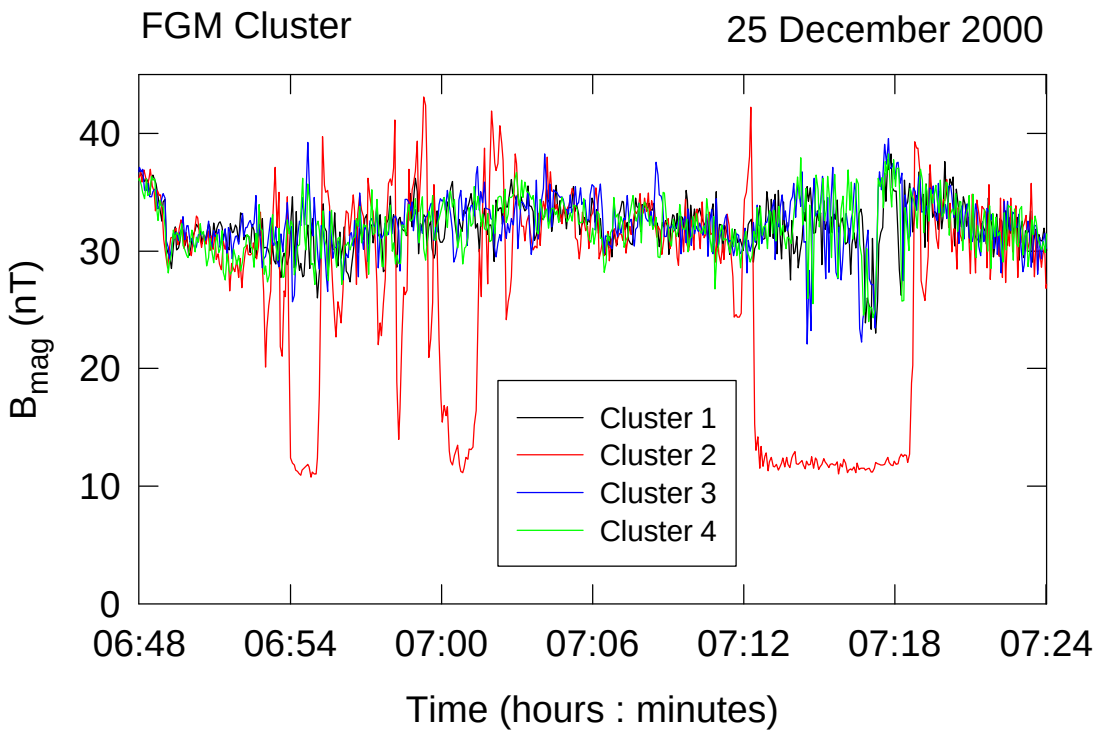


Some of the shock crossings were relatively simple, such as the example below. The bow shock, initially Earthward of the four spacecraft, moved slowly across them until all four were in the magnetosheath.

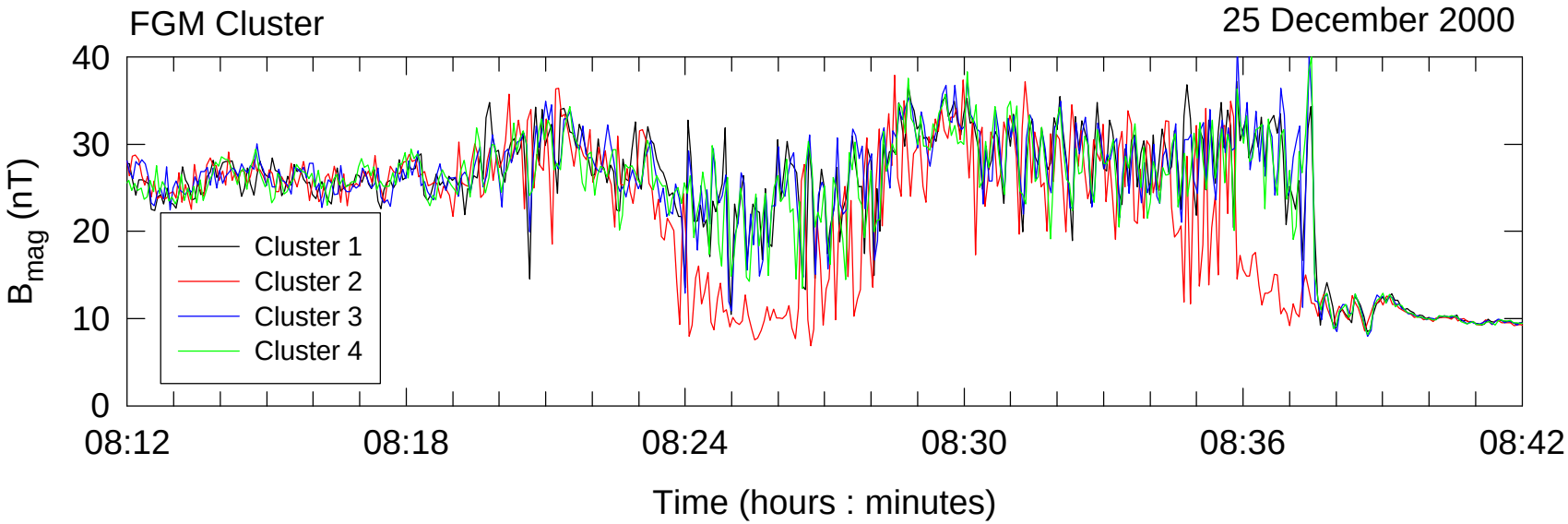


Spacecraft 2 was crossed last. We can easily estimate the speed of the shock wave as ~ 5 to 6 km/s

At a later time, the bow shock was first hovering very close to spacecraft 2 (06:50 to 07:03), then moved sunward of all four spacecraft (07:03 to 07:12). Later it stayed between spacecraft 2 and the other three spacecraft.



Later still, about 08:20, the magnetic field in the solar wind turned from being parallel to the shock surface to perpendicular to it. These conditions changed the nature of the bow shock and made it to form unstable, oscillating transitions between the solar wind and the magnetosheath.



Once again, comparing the bow shock signatures at the four spacecraft allows the nature of the shock and its structures to be studied for the first time.

Conclusions

- Even the initial observations on Cluster demonstrate an unprecedented capability to study the structures and dynamics of the Earth's magnetosphere:
  - For example, the bow shock has a complex, dynamic, three-dimensional structure, subject to rapid changes in response to changing solar wind conditions (expected, but never seen before !)

- The coordinated analysis of observations made by the Cluster instruments is the best ever means to understand the Earth's magnetosphere and the way it responds to changing conditions from the Sun.