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First Visualization of Magnetic Explosions in Space

Taking a "picture-puzzle" approach to "image" magnetic explosions in space.

DALLAS, Texas—Just as a nuclear explosion releases nuclear energy in a pulse, a magnetic explosion in space releases a magnetic energy pulse. Such magnetic explosions power the aurora, the Northern Lights, with approximately 1 terawatt (about twice the average electrical power consumption by the US) for about 30 minutes every two to four hours.

Could this explosive energy from space be harnessed for use here on Earth? That is still the stuff of science fiction, as it will require tremendous scientific investigation and advanced technology; we will need to thoroughly understand the physics of magnetic explosions in our space plasma, and obtain the capacity to capture the energy before it dissipates into the atmosphere.

These magnetic explosions in space are produced by a process known as magnetic reconnection. To picture reconnection, imagine two streaming contrails (counter-rotating vortex trails) billowing from the two wings of an aircraft at 30,000 feet. Under quiet atmospheric conditions, the white trails will, over time, pinch together to form periodic X-shaped regions spaced by oblong "islands." Simpler still, a link of old-fashioned hot dogs could also visually represent the shape of reconnection layers, and the regions between adjacent reconnection layers, structures called magnetic islands. Magnetic reconnection, however, distinguishes itself through fast plasma jets flowing away from the very thin "hot-dog" link where magnetic fields are annihilated and where magnetic energy is converted to heat the plasma and to produce the outflow jets.

Space scientists worldwide have been making strides in understanding magnetic reconnection in space. Physicists at the Space Science Center of the University of New Hampshire have recently discovered a "picture-puzzle" approach to visualize, for the first time, reconnection layers and magnetic islands using electrons (rather than photons as registered by cameras to make a photograph) measured by four satellites in the space mission Cluster.

In a picture puzzle, the task is to put the puzzle pieces in their right place so the picture can be revealed. By putting together snapshots of electrons moving with different speeds and directions (characterized by distribution functions) as measured by the four satellites in the order of northern most to southern most satellites, a pattern resembling the thin link between two hot-dog "islands" can be recognized (see Figure).

The ability to identify a reconnection layer and to delineate the exterior, boundary, and interior of magnetic islands provides the grounds to address a host of open questions about magnetic reconnection. Among them is the long-standing mystery of electron

acceleration during reconnection. The picture-puzzle approach helped scientists discover that the most powerful electron acceleration occurs within magnetic islands, and not at the reconnection layers, indicating energetic particles are produced in several steps during magnetic reconnection with the key step accomplished within magnetic islands.

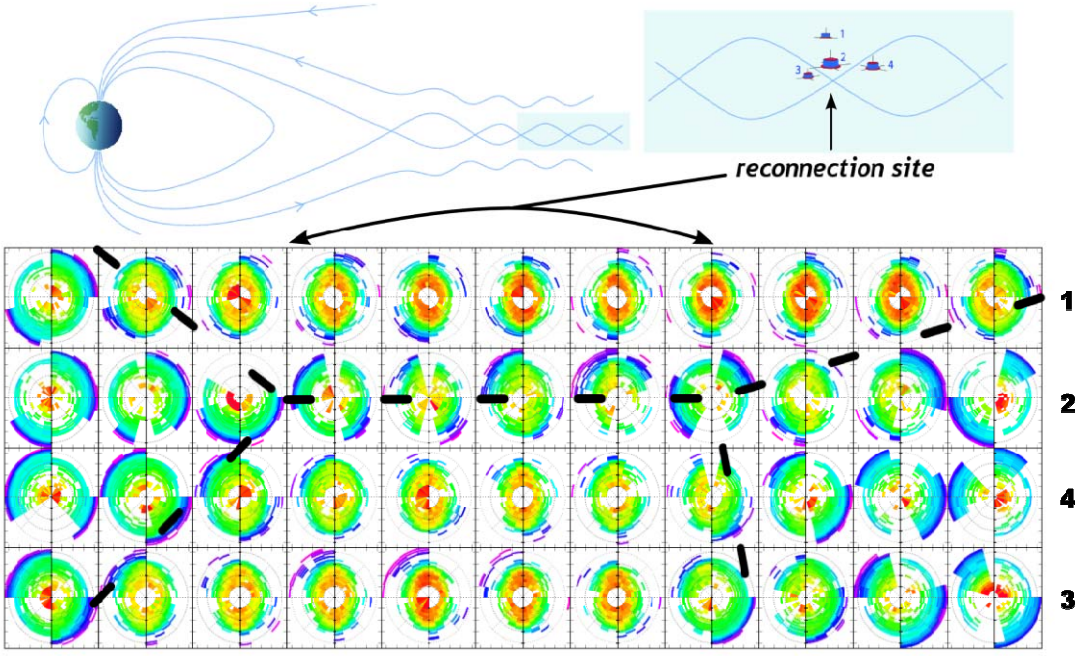

Figure 1: The picture of a reconnection layer and the edges of its neighboring magnetic islands revealed in an array of puzzle pieces, each an electron distribution function, measured by the four Cluster satellites. The dashed lines overlaid on the array roughly mark the reconnection layer and the island boundary.

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Multi-satellite observations of the electron diffusion region, neighboring islands, and electron acceleration

Invited Session JI1: Reconnection
2:00 PM-5:00PM, Tuesday, November 18, 2008
Landmark A

Further information:

[1] Nature Physics 4, 19 (2008)
[2] Journal of Geophysical Research, in press