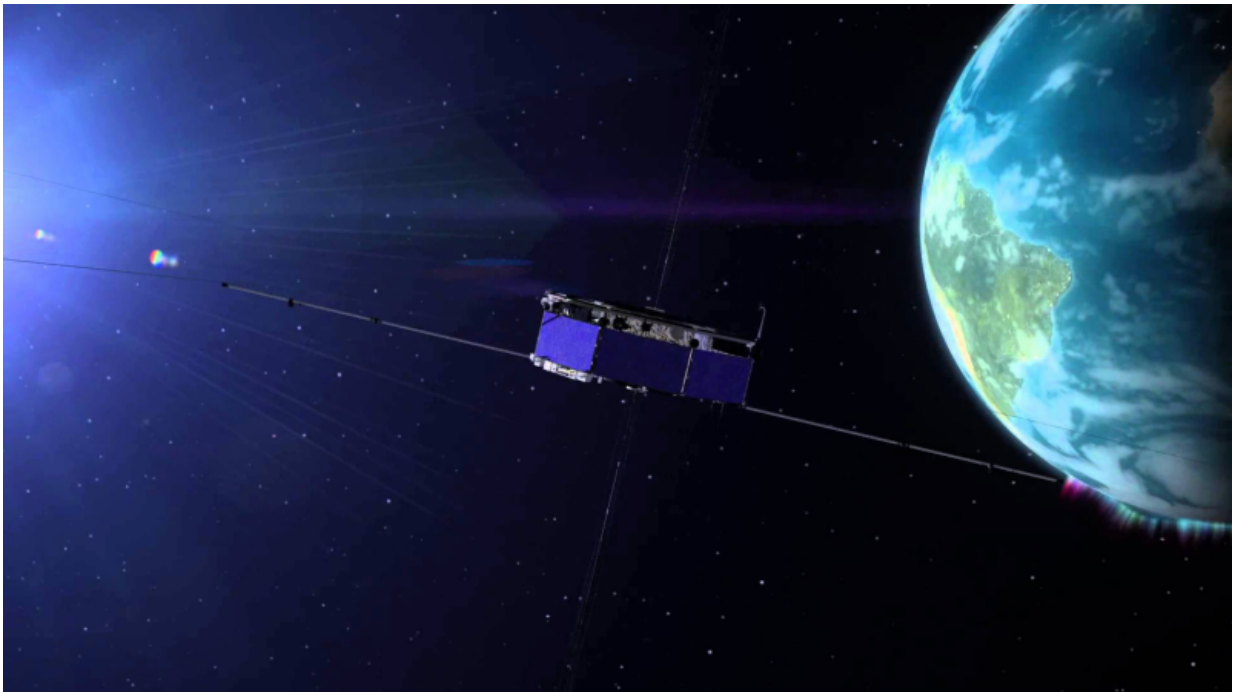


MMS mission delivers promising initial results

December 18 2015, by Sarah Frazier



The four identical spacecraft of NASA's Magnetospheric Multiscale, or MMS, mission (one of which is illustrated here) fly through the boundaries of Earth's magnetic field to study an explosive process of magnetic reconnection. Thought to be the driver behind everything from solar flares to aurora, magnetic reconnection creates a sudden reconfiguration of magnetic fields, releasing huge amounts of energy in the process. Credit: NASA's Goddard Space Flight Center

Just under four months into the science phase of the mission, NASA's

Magnetospheric Multiscale, or MMS, is delivering promising early results on a process called magnetic reconnection—a kind of magnetic explosion that's related to everything from the northern lights to solar flares.

The unprecedented set of MMS measurements will open up our understanding of the space environment surrounding Earth, allowing us to better understand what drives magnetic reconnection events. These giant magnetic bursts can send particles hurtling at near the speed of light and create oscillations in Earth's magnetic fields, affecting technology in space and interfering with radio communications. Scientists from the Southwest Research Institute, NASA, the University of Colorado Boulder and the Johns Hopkins University Applied Physics Laboratory presented an overview of MMS science and early results on Dec. 17, 2015, at the American Geophysical Union's Fall Meeting in San Francisco.

Planned for more than 10 years, the MMS mission started with the launch of four identical spacecraft on a single rocket in March 2015. Nine months later, the spacecraft are flying through the boundaries of Earth's magnetic system, the magnetosphere. Their initial orbit is taking them through the dayside boundaries of the magnetosphere—known as the magnetopause—where the solar wind and other solar events drive magnetic reconnection. Eventually, their orbit will loop out farther to carry them through the farthest reaches of the magnetosphere on the night side, where magnetic reconnection is thought to be driven by the build-up of stored energy.

"We've recorded over 2,000 magnetopause crossings since our science phase began," said Jim Burch, principal investigator for the MMS mission at Southwest Research Institute in San Antonio, Texas. "In that time, we've flown through hundreds of promising events."

MMS' four instrument suites and incredible measurement rates—a hundred times faster than ever before on certain instruments—is giving scientists their best look ever at magnetic reconnection. In fact, the mission's high resolution produces so much data it requires a scientist on duty during every MMS contact to prioritize which data is sent down from the spacecraft.

One of the key features of MMS is its scaling ability. The four spacecraft fly in a four-sided, pyramid-shaped formation called a tetrahedron, allowing them to build up three-dimensional views of the regions and events they fly through. Because the four spacecraft are controlled independently, the scale of their formation—and their observations—can be zoomed in or out by a factor of ten.

Though many people think of space as a completely empty vacuum, it's actually filled with electrically charged particles and electric and magnetic fields, which form a state of matter called plasma. All of this magnetic and electric energy means that magnetic reconnection plays a huge role in shaping the environment wherever plasma exists—whether that's on the sun, in interplanetary space, or at the boundaries of Earth's magnetic system.

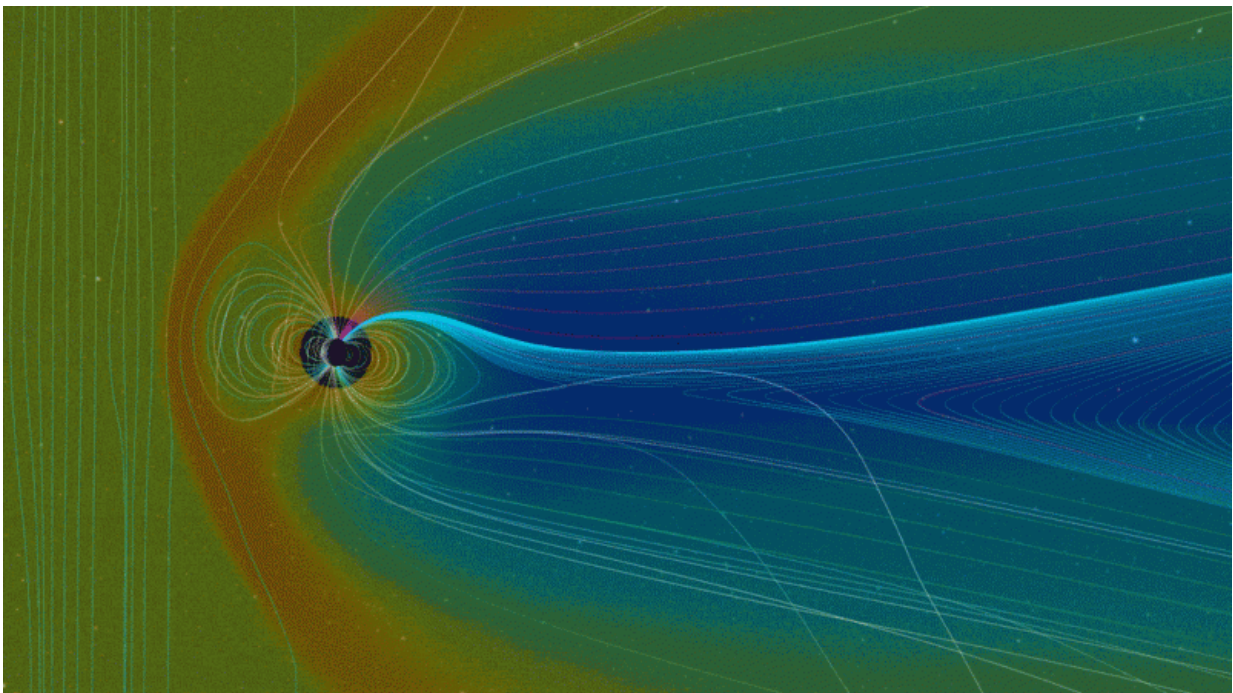
"We can see the effects of reconnection on the sun in the form of coronal mass ejections and solar flares," said Michael Hesse, lead co-investigator for theory and modeling on the MMS mission at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "But with MMS, we're finally able to observe the process of magnetic reconnection directly."

Magnetic reconnection is a process in which magnetic fields reconfigure suddenly, releasing huge amounts of energy. When [magnetic field](#) lines snap and join back together in new formations, some of the energy that was stored in the magnetic field is converted to particle energy in the

forms of heat and kinetic energy.

"Reconnection is a fundamental energy release process," said Hesse. "It impacts both the temperature and speed of particles in a plasma, two of the defining characteristics."

Katherine Goodrich, a graduate student at the University of Colorado Boulder, is working with measurements from a suite of six instruments to characterize the behavior of electric and magnetic fields at magnetic reconnection sites. This suite of instruments, the FIELDS suite—duplicated on each of the four MMS spacecraft—contains six sensors that work together to form a three-dimensional picture of the electric and magnetic fields near the spacecraft. This suite has a very high accuracy, in part due to the very long booms on each sensor.



The explosive realignment of magnetic fields -- known as magnetic reconnection -- is a thought to be a common process at the boundaries of Earth's magnetic

bubble. Magnetic reconnection can connect Earth's magnetic field to the interplanetary magnetic field carried by the solar wind or coronal mass ejections. NASA's Magnetospheric Multiscale, or MMS, mission studies magnetic reconnection by flying through the boundaries of Earth's magnetic field. Credit: NASA Goddard/SWRC/CCMC/SWMF

"The long booms allow us to measure the fields with minimal contamination from the electronics aboard the spacecraft," said Goodrich. Along the spin plane, the booms measure 400 feet from end to end—longer than a regulation soccer field. The booms on the axis of spin measure 100 feet from end to end.

Using FIELDS observations, Goodrich is looking for one of the smoking guns of magnetic reconnection, called a parallel electric field.

"What we're looking for is an alignment of electric and magnetic fields," said Goodrich. "This condition is impossible with a simplified understanding of plasma, but magnetic reconnection is anything but simple."

In the simplest view of plasma—known as ideal plasma—the charged particles spinning along magnetic field lines carry enough current to instantaneously short out any electric field parallel to the magnetic field. But in actuality, plasma doesn't ever behave quite that simply, so scientists must consider a more detailed, complex version of the physics to understand how and why reconnection is able to occur. Such rigorous models—known as non-ideal plasmas—open up the possibility for the creation of gaps in these zooming charged particles, allowing parallel electric fields to form for an observable length of time.

"These events would have to combine energy dissipation, particle

acceleration, and sudden changes in magnetic topology," said Goodrich. "Magnetic reconnection fits the bill perfectly."

Goodrich presented observations from MMS that showed how the FIELDS suite can spot examples of parallel electric fields at time scales down to half a second. Such observations show that MMS is flying directly through areas of interest that will help us better characterize the space environment around Earth.

Ian Cohen, a postdoctoral fellow at Johns Hopkins University Applied Physics Laboratory, or APL, uses a different instrument suite to identify and study the telltale particle behaviors that come with magnetic reconnection. Cohen works with two particle detectors aboard MMS: the Fly's Eye Energetic Particle Sensor, or FEEPS, and the Energetic Ion Spectrometer. The measurements are providing evidence for a mechanism by which particles can escape the Earth system and join the interplanetary medium.

When magnetic reconnection happens on the day-side, magnetic field lines from the sun connect directly to Earth's magnetic field.

"The linking of these magnetic fields means that particles can drift from within the magnetosphere to the boundary between Earth's magnetic field and the solar wind," said Cohen. "Once they get to that boundary, further reconnection events allow them to escape and float along the interplanetary magnetic field."

This magnetic sun-Earth connection also means that particles disrupted by magnetic reconnection spiral along these newly linked [magnetic field lines](#) toward Earth, allowing the evidence of magnetic reconnection to be seen even from tens of thousands of miles away.

Cohen presented MMS observations that are clearly able to distinguish

between the directions the particles are moving, which will help scientists better understand what mechanisms drive magnetic reconnection.

"All in all, the data we have gotten so far has just been astounding," said Burch. "Now we're sifting through those observations and we're going to be able to understand the drivers behind [magnetic reconnection](#) in a way never before possible."

Provided by NASA's Goddard Space Flight Center

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