What is Magnetic Reconnection?
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Earth
Magnetic field lines
Magnetic reconnection occurring
Reconnection accelerates particles toward the Earth
(image credit: NASA)
The Solar Corona can release vast amounts of energy and matter when a loop of coronal plasma breaks and expands, propelling particles into the solar system at very high speeds. Because these loops trace the solar magnetic field, we must understand how magnetic fields break and recombine.

Controlled fusion energy is a major science and engineering goal of the 21st century. Hot plasmas must be confined in order to produce fusion. However, magnetic fields in such confined systems often spontaneously interact and reconfigure, allowing plasma to escape.

Understanding what causes these events requires answering:
- What is a plasma?
- How do plasmas have energy?

Magnetic reconnection is all around us.

In the stars

On Earth

This escape of plasma can occur when magnetic field in the hot plasma reconnects with magnetic field outside the hot plasma.
Plasmas also contain electric and magnetic fields that have a magnitude and direction at every point in space. These fields force the particles to move.

Plasma particles carry energy from their movement, just like the energy in a hot gas. This movement has the potential to heat up other material.

Surprisingly unlike common gasses, plasmas also carry energy in their electric and magnetic fields. Stronger fields have more energy.

Once we understand,
1. What a plasma is
2. What it means for a plasma to have energy
we can ask:

How does magnetic energy get converted into particle energy in explosive events throughout the universe?

Answer: Magnetic Reconnection
**Observation in interplanetary space:** The Sun and Earth both produce magnetic fields. Sometimes these fields do not align, as is shown at two points in interplanetary space in the shaded boxes above. When reconnection occurs in these boxes, it pushes particles along magnetic field lines toward the Earth.

**What happens during reconnection?**

In the process of **magnetic reconnection**, regions of plasma with opposite magnetic fields combine and annihilate. Energy from magnetic field strength is used to drive particles to the sides, resulting in particle energy from motion. This process occurs in interplanetary space, on the sun, and in fusion reactors.

**Reconnection in interplanetary space**

**Reconnection on the surface of the sun**

**Observation on the surface of the sun:** Inner regions of the sun generate loops of magnetic field which can reconnect (see figure to right) releasing large amounts of energy and sending particles flying into space along particle outflow paths.
Detailed reconnection explanation video:
(click video to open, and “x” at top right of video to exit window)

1. The fluid flows inward toward the reconnection point, or x-point, carrying field lines.
2. The field lines break and recombine at the x-point, where small scale interactions allow the magnetic field to unfreeze from the fluid.
3. Bent field lines try to straighten out, accelerating particles to the sides.

**Experiment:**
Reconnection can be studied in plasmas confined in vacuum chambers.

**Simulation:**
a reconnecting plasma can be simulated in a computer by following billions of particles and their fields at once. Simulation provides a comprehensive understanding of what happens at small and large size scales:
1. Every single particle is followed.
2. Large scale variables, such as global reconnected magnetic field (see figure at right), can be calculated that aren’t based on observations at one point in space.

Current research includes:
1. Satellite observation of reconnection between solar and Earth magnetic fields.
2. Experimental studies of reconnecting plasmas.
3. Simulation of more complex reconnecting systems.
Magnetic reconnection occurs all around us, quickly converting vast amounts of magnetic energy to particle energy. Through experiment, simulation, and observation, scientists are better able to answer questions about reconnection such as

1. How fast does reconnection occur?
2. How does the process depend on various parameters like geometry, density, and temperature?

Ultimately, this knowledge will contribute to our understanding of the world around us, helping us

1. Predict periods of intense solar activity, called solar storms, that can be damaging to satellites and may be caused by magnetic reconnection.
2. Reliably confine plasmas for fusion energy.