Magnetic Field of Sun

The Sun is a magnetic star. The thermonuclear furnace in its 15-million-degree core heats and churns the electrically conducting plasma in the outer third of the Sun in much the same way as a stove heats and churns boiling water. This part of the Sun is called the convective zone. Plasma in motion drives a dynamo that generates a global magnetic field as well as smaller-scale local fields. As these magnetic fields emerge through the Sun's visible surface (the photosphere), they form sunspots and other active regions and create complex and dynamic plasma structures in the Sun's upper atmosphere (corona). The Sun's magnetic fields store enormous amounts of energy, which can be released gradually or explosively. Explosive energy release occurs in flares and coronal mass ejections (CMEs). Flares are intense releases of energy in the form of electromagnetic radiation and energetic particles; CMEs are transient events in which huge quantities of coronal plasma and magnetic fields are propelled into the heliosphere, sometimes at initial speeds in excess of 1,000 kilometers per second.

The Sun's magnetic activity increases and decreases in a nearly regular cycle, as is seen in the rise and fall of the number of sunspots every 11 years. (Shaped by intense, local magnetic activity, sunspots are some whatcooler than the surrounding gases, and therefore appear darker.) With increasing magnetic activity, changes occur in the structure of the corona and the solar wind, while CMEs and flares become more frequent. Around the peak of the solar cycle, the Sun's global magnetic field "flips"—that is, the north magnetic pole becomes the south magnetic pole, and vice versa! Not surprisingly, the Sun's effect on the solar system ebbs and flows with its magnetic cycle. For example, solar-cycle-driven changes in the structure of the solar wind are thought to cause variations in the shape of the heliospheric "bubble." Of more immediate concern to us here on Earth is the increase in space weather disturbances during the periods of high solar activity. Such perturbations, and potential impacts on satellites, radio communications, and high-flying humans, are triggered by encounters of fast CMEs with Earth's magnetic field

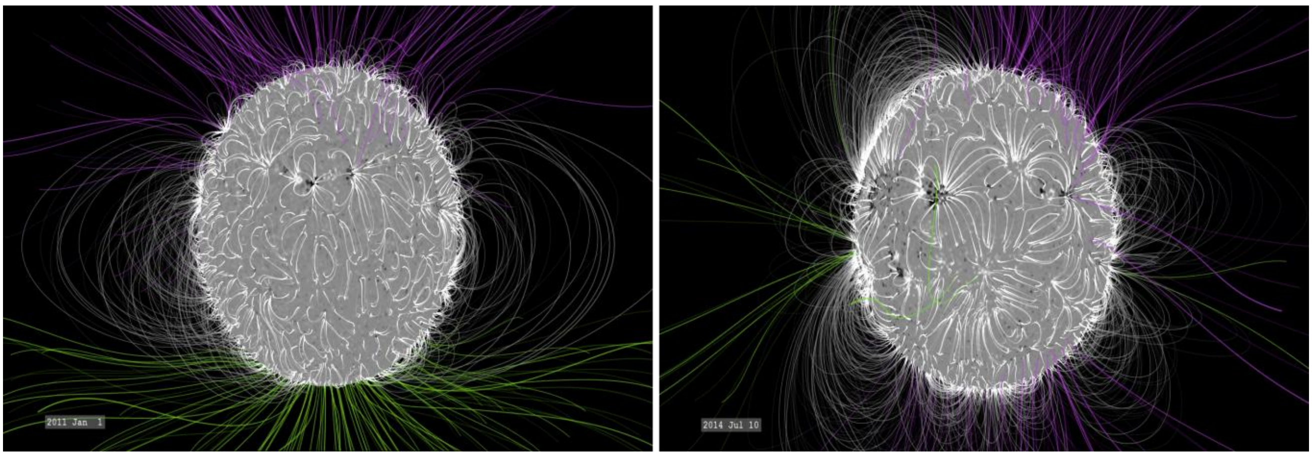


Fig: This comparison shows the relative complexity of the solar magnetic field between January 2011 (left) and July 2014. In January 2011, three years after solar minimum, the field is still relatively simple, with open field lines concentrated near the poles. At solar maximum, in July 2014, the structure is much more complex, with closed and open field lines poking out all over – ideal conditions for solar explosions.

Credits: NASA's Goddard Space Flight Center/Bridgman

How does the Sun's magnetic field work?

The sun has a large and complex magnetic field.

Magnetic fields are created by things that are magnetic (like iron magnets) or by moving charged particles. A magnetic field is the description of the force a magnetic object exerts in the space surrounding the magnetic object. A force is a push or pull. To learn more about forces and magnetic fields, please visit The University of Colorado Physics 2000 website.

When charged particles move around really fast they create magnetic fields. The Sun is made of positively charged ions and negatively charged electrons in a state of matter called plasma. Since the Sun is made of charged particles, magnetic fields are created by the movement of the particles.

The Sun's charged particles move in three ways due to the Sun's high temperatures and the movement of its axis, which influence each other to make the Sun's magnetic field complex:

The Sun's high temperatures cause the positively charged ions and negatively charged electrons that make up its plasma to move around a lot. The moving plasma creates many complicated magnetic fields that twist and turn.

The extremely hot plasma that blows off the Sun as the solar wind also causes a magnetic field.

The plasma in the Sun also rotates around the Sun's axis. The plasma near the poles rotates slower than the plasma at the equator causing twisting and stretching of magnetic fields, too.

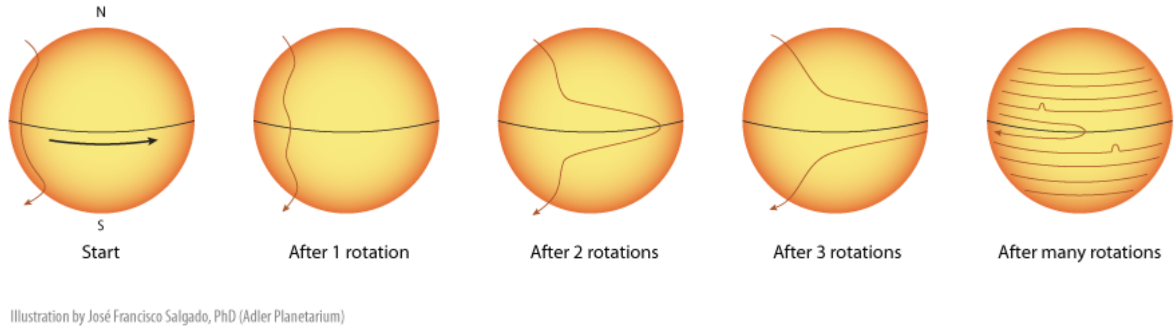


Fig: The Sun's magnetic field is shown in a series of illustrated images with the poles and equator indicated. The magnetic field lines change as the Sun rotates. After 1, 2, and 3 rotations the magnetic field line gets progressively wrapped around the Sun, becoming stretched as it nears the equator. After many rotations the magnetic field is complex and wrapped tightly around the Sun in many loops.

Image Credit: José Francisco Salgado, PhD (Adler Planetarium)

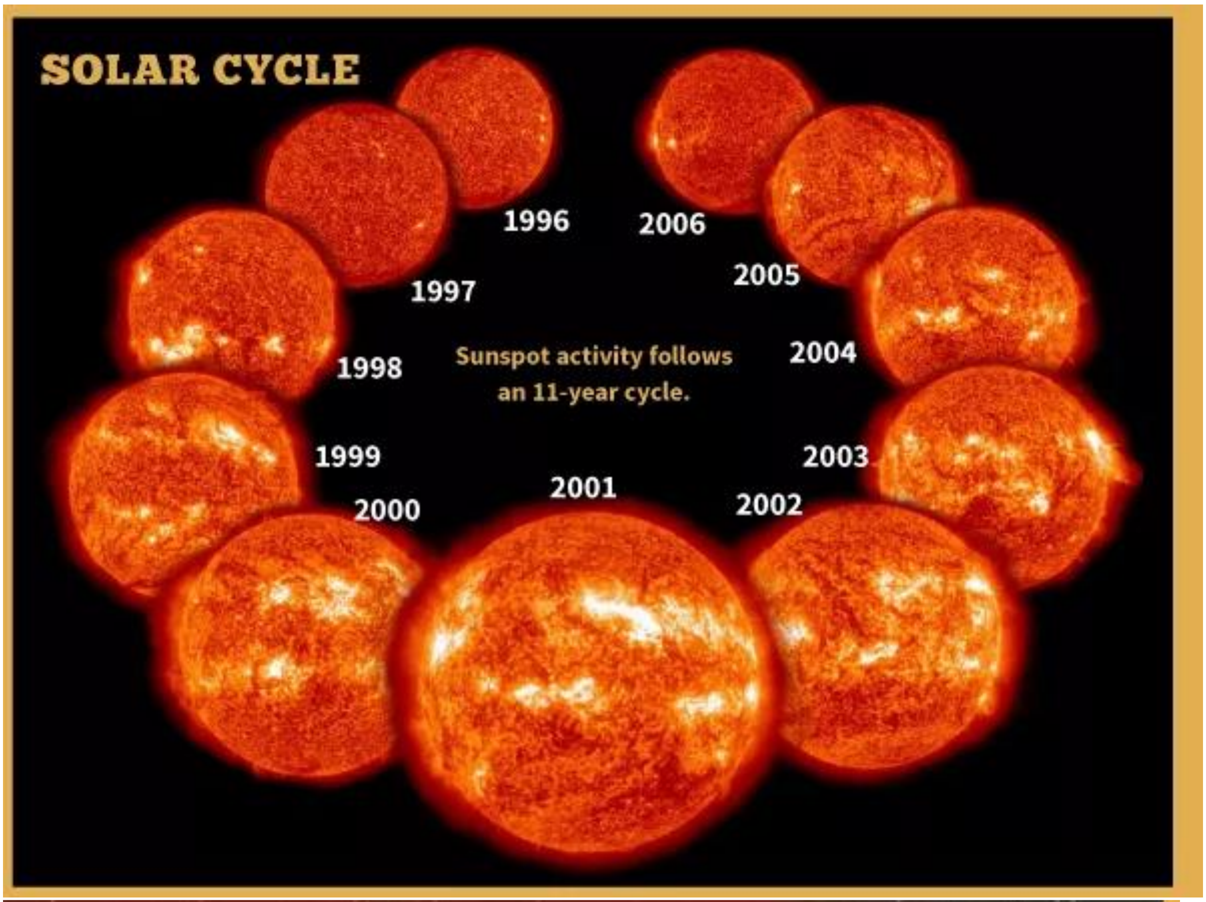
Those motions of the Sun's plasma interact and influence each other to form the Sun's entire magnetic field.

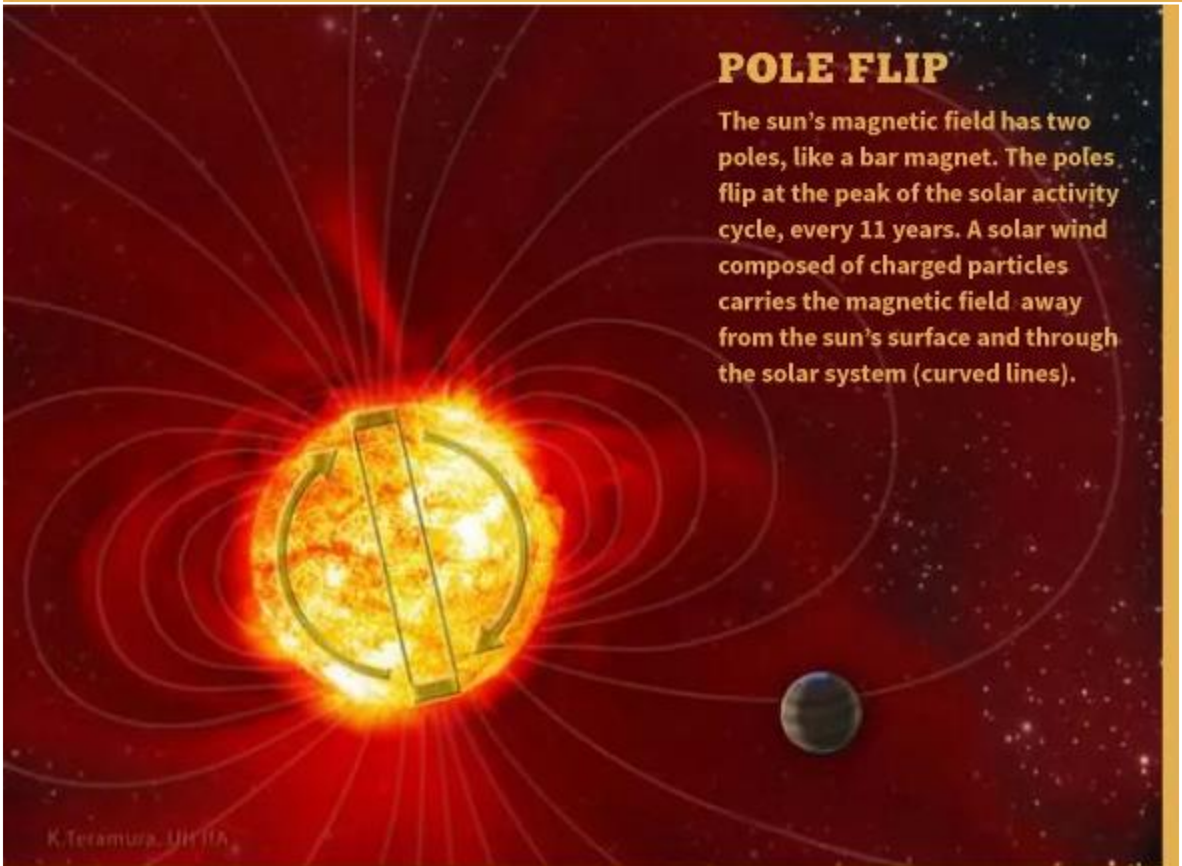
Close to the Sun's surface the magnetic fields are twisted and complex. Further away from the Sun's Surface, some general trends emerge. The magnetic field is stronger near the poles and weaker at the Sun's equator. However, even at the Sun's equator, where the magnetic field is weaker, it is still around 100 times stronger than the Earth's magnetic field.

In addition to being complex, the Sun's magnetic field is also large. It influences the motion of charged particles well beyond the orbits of the known planets, to distances of around 75-100 times the distance of the Earth to the Sun.

STRINGS AND LOOPS OF SOLAR MATERIAL ALIGN ALONG MAGNETIC-FIELD LINES (CREDIT: NASA)

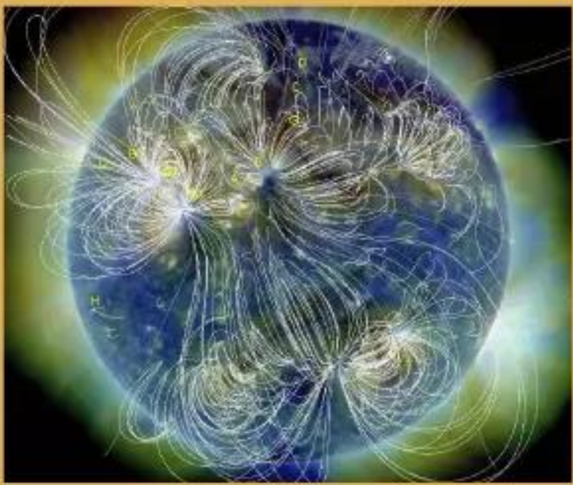
Electric currents within the sun generate a magnetic field that spreads throughout the solar system. The field causes activity at the surface of the sun, surging and ebbing in a regular cycle. At the peak of the cycle, the polarity of the field flips, during a time of maximum sunspot activity.





Credit: Karen Teramura/University of Hawaii

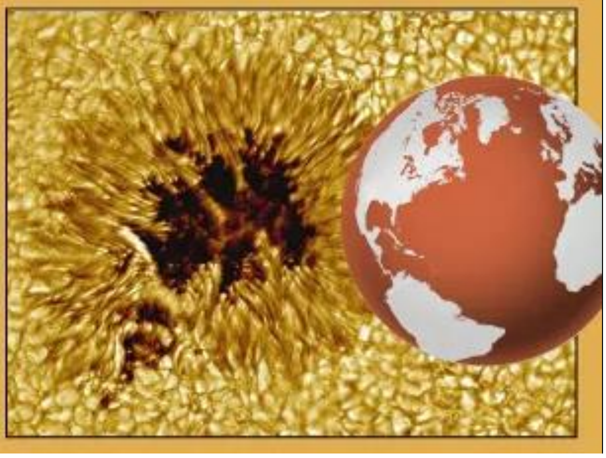
The sun is not a solid ball, but rather like a fluid. It exhibits differential rotation, meaning the surface moves at different speeds depending on latitude. This results in the magnetic-field lines getting wound up. When the winding gets extreme (far right), the magnetic-field lines "snap," causing solar flares at those locations on the surface.

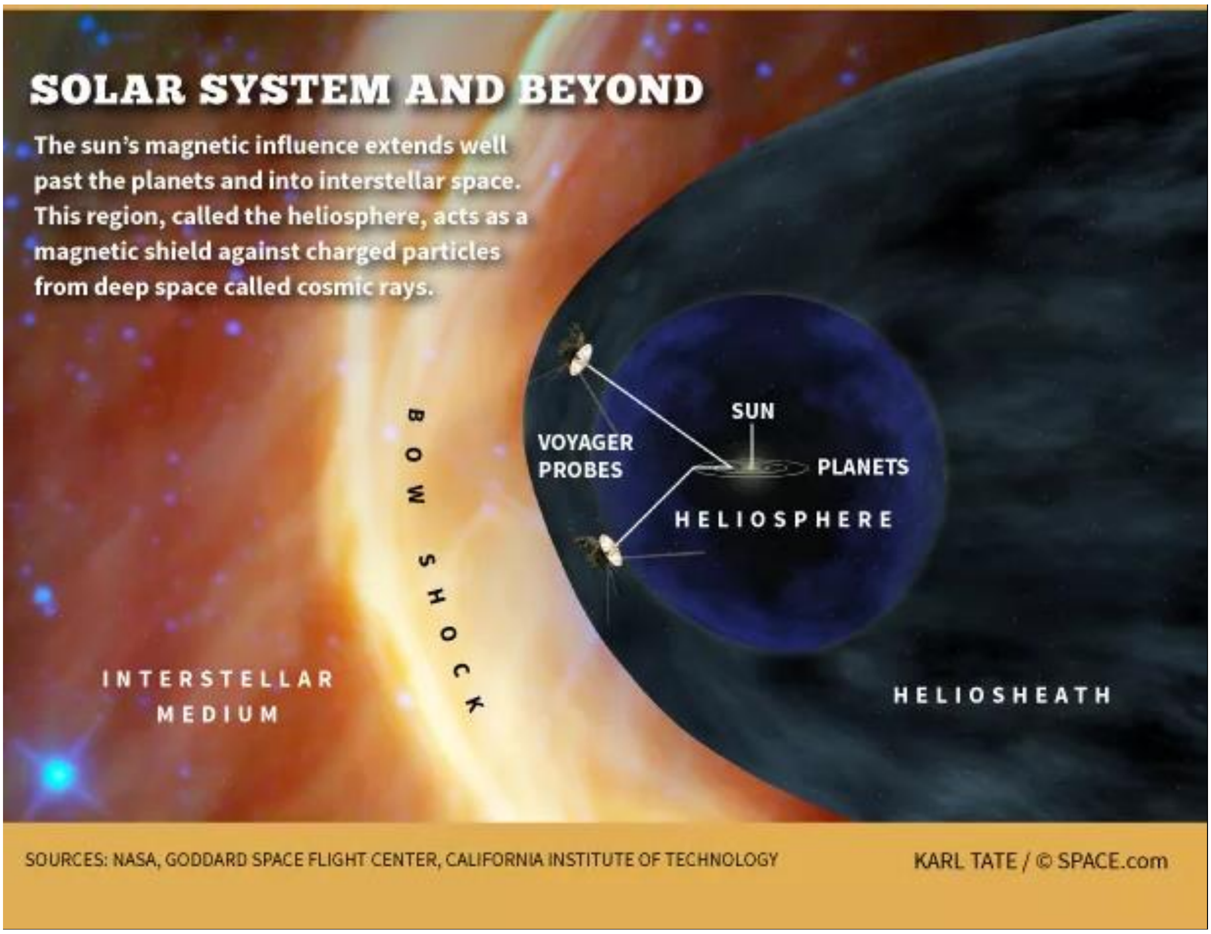


AT LEFT: Extreme ultraviolet photo of the sun during a major eruption. The white marks represent the twisted magnetic-field lines that follow the "snap-ping" described above.

BELOW, LEFT: Loops and filaments of solar material follow the magnetic field lines.

BELOW, RIGHT: Sunspot to scale with Earth.





The sun's magnetic field drives changes on its surface and beyond.
(Image: © by Karl Tate, Infographics Artist)

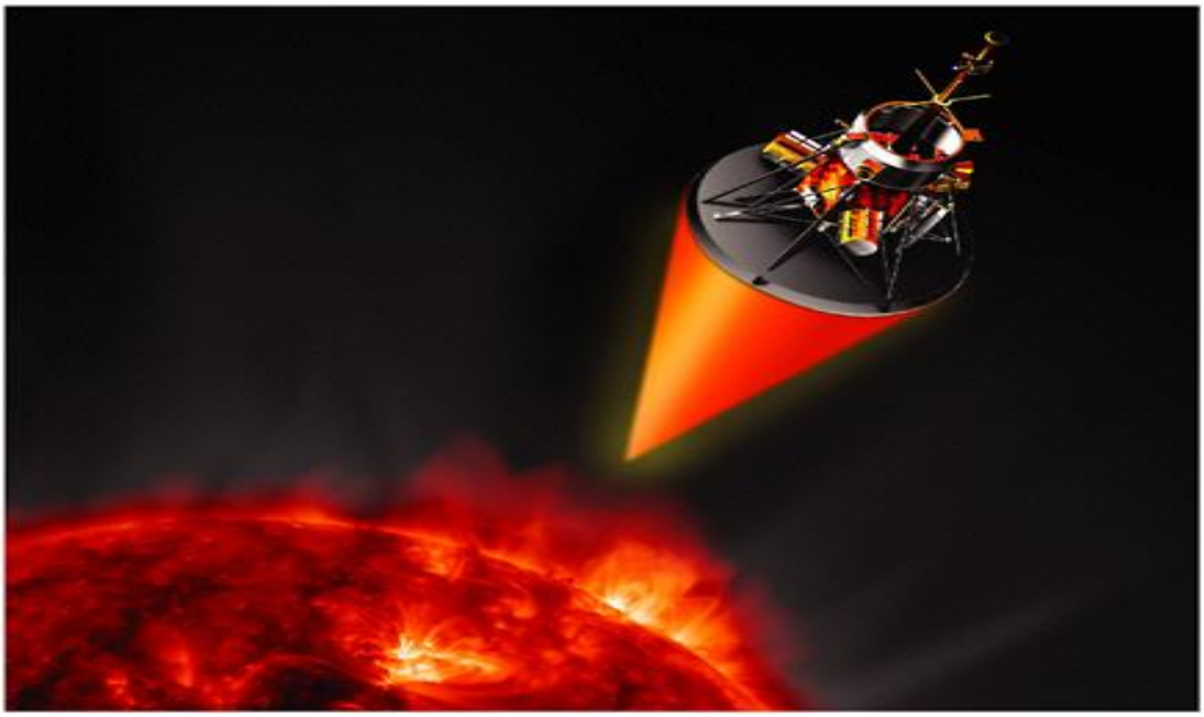


Fig: The first spacecraft to explore the near-Sun region, Solar Probe will revolutionize our basic understanding of the expanding solar atmosphere.

References:

1. https://www.nasa.gov/feature/goddard/2016/understanding-the-magnetic-sun
2. https://www.nap.edu/read/11188/chapter/4
3. http://ibex.swri.edu/students/How_does_the_Sun.shtml
4. https://www.space.com/22393-sun-magnetic-field-explained-infographic.html