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Keepin' an Eye on the Sun

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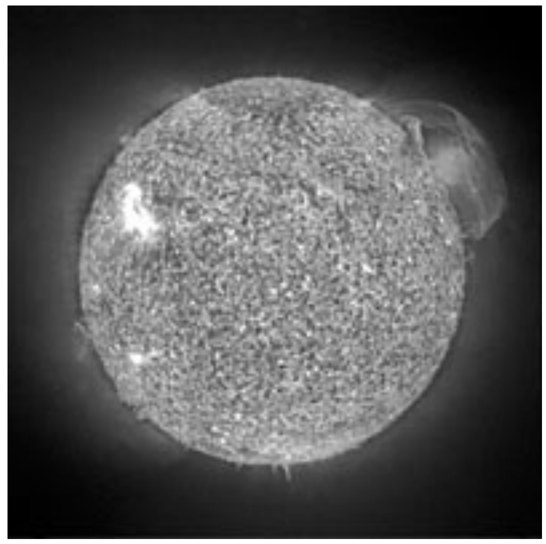
According to ancient beliefs and modern science alike, the Sun played a fundamental role in the creation of life on Earth. Our parent star is by far the largest object in our solar system-none of the planets can compete. At one hundred times the Earth in diameter, the Sun could hold about a million Earths. And majestic Jupiter, king of the planets? The Sun could swallow about 700 Jupiters! Sadly enough, however, the Sun enjoys no such distinction among the rest of the stars in the Universe. As far as stars go, the Sun is average in diameter, mass, and brightness. But it is our star, and as our distant ancestors concluded, our relationship with it is strong.



Up, up, and...back down. In a solar prominence, charged particles stream up from the Sun, spiraling around magnetic field structures poking out of the solar surface, and ultimately fall back along those structures into the Sun. In this photograph of the Sun made from NASA's Skylab space station in 1973, the prominence is almost 50 Earth diameters in size. Image courtesy of NASA.

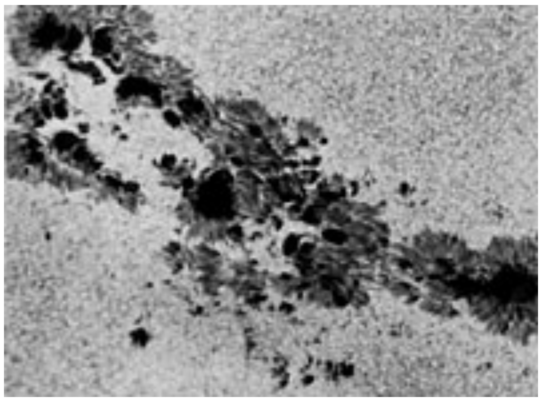
Worshipping the Sun as creator has been out of style for quite some time now, yet the Sun's formative influence has undeniably touched every living thing on Earth. Plants use the specific types of energy offered by the Sun to grow, and other creatures consume these plants for their own energy. As evolution would predict, animals' eyes sense the colors of light emitted most strongly by the Sun. Even cultural evolution exhibits Sol's influence, as Earthly motions relative to the Sun determine the day and the year.

The Earth completes exactly one rotation about its axis each day and exactly one orbit around the Sun each year. As the Earth rotates, any earthbound observer faces a different direction after a period of time, so fixed objects like the Sun or the stars around us seem to move (just as a painting on the wall would "rise" and "set" from your field of view if you spun yourself around). This explains sunrise and sunset, day and night. Climate changes across seasons can be explained by the tilt of the Earth's rotation axis. The northern hemisphere experiences summer when the north pole of the Earth tips toward the Sun, which makes our star appear high in the sky; half a year later the north pole points away, causing a northern hemisphere winter. And seasons in the southern hemisphere? Opposite to those in the north! The Sun pulls the Earth around in an orbit with gravitational attraction, in the same way a yo-yo can do an around-the-world because its string constantly pulls it toward the center of the circle. The yo-yo would fly off without the pull of the string, as would the Earth if the Sun lost its gravitational grip.

What of the Moon? It orbits the Earth just as the Earth orbits the Sun, so the relative positions of the three change constantly. About once every year and a half, the Sun, Earth, and Moon all fall on a line pointed to the Sun, the Moon briefly caught between the Sun and the Earth. When this happens, the Moon can actually block the Sun's light and one of nature's grandest spectacles results: a total solar eclipse (see "Shadow Play" in this issue). But the Sun is not totally darkened. Fortuitously for us earth dwellers, the Moon is roughly 400 times smaller than the Sun, and by coincidence it is also 400 times closer; hence, the two appear the same size in our sky. The tiny Moon can completely cover the disk of the Sun, blocking most of the emitted visible light, and reveal the Sun's faint outer atmosphere called the corona.

...a mass of incandescent gas

Like the Earth, the Sun has different layers with different properties, and like all other stars in the Universe, these layers are composed of material that is about 75% hydrogen and 25% helium by mass. Simply put, the Sun is a great ball of gas, hot enough to glow in every tier. In the very innermost part of the Sun, called its core, the temperature is about 15 million Kelvins, the density is 150 times that of water, and the pressure is over 200 billion times greater than atmospheric pressure here on Earth. This heavy, sweltering place is where the Sun's energy is produced via a process known as thermonuclear fusion. While fusion is difficult to mimic on Earth, the scorching belly of the Sun and other stars is a perfect environment for it. Here, the temperatures are high enough for hydrogen nuclei to smash together and form helium nuclei, releasing tremendous amounts of energy in various forms. Energy produced in the form of light keeps bouncing around inside the Sun, as though the Sun were made entirely of mirrors. A particle of light can take 30,000 years to reach the surface and escape! Energy in the form of small particles called neutrinos, however, can travel directly out of the Sun and into the Solar System. Neutrino observatories on Earth measure the continual wash of these tiny, fast-moving particles.



Those darned blemishes. Sunspots appear dark in contrast to the hot, surrounding photosphere. They are, in fact, quite hot; the Sun's contorted magnetic field suppresses gas motions below the photosphere in some areas, and blemish-like sunspots appear. Notice the mottled appearance of the photosphere; this is due to sub-photospheric gas motion called convection, and the size of those convecting gas parcels is about half the width of North America. Photo courtesy of National Solar Observatory/Sacramento Peak.

All that light released during nuclear reactions eventually works its way out of the Sun, and when it reaches the cold of space it starts flying. The Sun's thin, outer layers are called its atmosphere. And, like the Earth, the solar atmosphere has distinctive layers. The photosphere is the deepest atmospheric layer and is the one most easily visible to us. It can be considered the surface of the Sun, because almost all the Sun's light streams from it. A temperature of nearly 6000 Kelvins makes this gassy "surface" a little uncomfortable, though. Sitting on top of the photosphere is a thin, hot layer called the chromosphere. On top of the chromosphere sits the corona, crowning layer of the solar atmosphere.

Far more voluminous than the Sun itself, the low-density corona reaches all the way out to the planet Mercury and is composed of gas at a temperature of a few million Kelvins. Energy from the Sun drives coronal material even farther out into the Solar System. The charged particles from this swift solar wind sometimes cause magnetic storms as they blow past Earth. As a result, people at high northern and southern latitudes are treated to a spectacular show: beautiful, shimmering aurorae, also known as the northern and southern lights.

Some solar physicists are particularly interested in the corona because it harbors a great solar mystery. As one might expect, the hottest temperatures in the Sun are found in its energy-producing core, and the heat declines steadily outward toward the photosphere. Strangely enough, however, temperatures increase sharply through the solar atmosphere. Indeed, parts of the corona are nearly as hot as the core! Solar researchers have thought for several years that the heating may be due to energy transmitted up through the Sun's atmosphere by sound or magnetic waves. NASA and the European Space Agency launched the Solar and Heliospheric Observatory on December 2, 1995; recent observations by the space-based SoHO seem to indicate that magnetic waves generated near the Sun's surface travel up through the corona, depositing their energy there and making the corona hot. Because understanding the Sun is the key to understanding other stars, solar questions are among the most important in astrophysics.
