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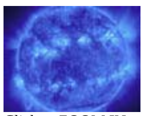

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Photo captions by Jane Vessels

Images by Fred Espenak (left); Solar and Heliospheric Observatory/Extreme-ultraviolet Imaging Telescope, European Space Agency and NASA

By **Curt Suplee**

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Our life-giving sun throws tempests that can scramble modern technology. New telescopes and satellites let scientists probe the secrets of the temperamental star.

Get a taste of what awaits you in print from this compelling excerpt.

It has been burning for 4.6 billion years, even before there was an Earth to bask in its all-sustaining glow. Yet it is only in the past two decades that scientists truly have begun to understand the thermonuclear reactor we call the sun.

By big-time galactic standards, our star is quite undistinguished. Sure, it's so huge that a million Earths would fit comfortably inside. And it's so dense that the sunbeams you see today began their journey from the center of the sun before the last ice age, taking hundreds of thousands of years to elbow their way out to the glowing photosphere before making the 8-minute, 93-million-mile (150-million-kilometer) trip across space to your eyes.

Yet the sun falls into the general stellar category of yellow runts called type G, a species so monotonously common that there are billions of them in the Milky Way alone. And it appears to be remarkably stable so far, with an energy output that varies no more than one-tenth of one percent over the course of a decade, and not much more over centuries.

But nothing else in the universe—save only our planet itself—is more immediately important to us. The sun is the origin of virtually all the energy that sustains life, the source of our weather, arbiter of our climate, and, of course, our closest connection to the processes that populate galaxies and power the cosmos.

"The sun is the Rosetta stone of astrophysics," says Göran Scharmer, director of Sweden's Institute for Solar Physics and whose observations with the Swedish 1-meter Solar Telescope on La Palma Island keep setting world records for high resolution. "But it is a stone that we haven't been able to decrypt entirely."

Even today, four centuries after Galileo and others stunned Europe by revealing that a spatter of spots moved across the solar surface, many of the most profound aspects of our local star remain shadowed in mystery. Now scientists are on the cusp of finding answers, thanks to a surge of international interest over the past 20 years—and to advances in computer modeling and new, high-tech instruments on the ground and in space that can monitor subtle aspects of solar behavior that were previously unrecognizable, and sometimes unimaginable.

"Before, it was solar dermatology," says Scharmer. "Now it's really astrophysics."

* * * * * *

MULTIMEDIA

See sunspots, solar flares, and other space weather in this series of compelling action images, computer simulations, and videos.

WALLPAPER

Brighten your desktop with an image of a sunspot and the blazing formation around it.

FLASHBACK

Flashback to June 19, 1936, when two events vied for Muscovites' attention: Author Maxim Gorky's death and a solar eclipse.

Although nearly everything that happens in and on the sun affects our planet, two kinds of explosive solar events impact Earthlings most severely. One is a solar flare, in which a small area above the solar surface suddenly roars to tens of millions of degrees, throwing off a surge of radiation that can cause communications blackouts, disable satellites, or theoretically, kill a spacewalking astronaut.

The other event is a coronal mass ejection (CME), in which billions of tons of charged particles escape from the sun's halo, the corona, at millions of miles an hour. When these behemoth clouds slam into Earth's protective magnetosphere, they squash the magnetic field lines and dump trillions of watts of power into Earth's upper atmosphere. This can overload power lines, causing massive blackouts, and destroy delicate instruments on anything in Earth orbit.

Often flares and CMEs occur together, as was the case last October when the fourth most powerful flare ever observed exploded. Back-to-back CMEs then smacked the planet. Thanks to modern detection equipment, we had enough warning to take preventive action. The atmosphere was so electrically charged that the northern lights were seen as far south as the Mediterranean, but little damage was done. By contrast, in 1989, when a fierce CME struck the Earth, it blew out HydroQuebec's power grid, leaving almost seven million people without electricity, and a multimillion-dollar damage bill.

Get the whole story in the pages of *National Geographic* magazine.

MORE TO EXPLORE

In More to Explore the *National Geographic* magazine team shares some of its best sources and other information. Special thanks to the Research Division.

Did You Know?

The Perfect Storm

In the fall of 1991 clashing high- and low-pressure weather systems joined over the western Atlantic Ocean to create a storm so unusual and fierce that the National Weather Service called it the perfect storm. The storm caused massive damage along the entire east coast of North America and the frightening loss of the swordfishing vessel *Andrea Gail* and its crew. As devastating as the storm was, weather on Earth, even catastrophic weather, is familiar to us—it can be forecast, we can fathom it.

But space weather? Indeed, the sun can hurl huge storms toward Earth, and sometimes the effects are severe. We heard a lot about a two-week spate of solar flares and coronal mass ejections (CMEs) that erupted in late October and early November 2003. However, for all their intensity, conditions were such that damage to satellites, communications systems, and electrical grids—technology we depend on in our daily lives—was much less than it could have been. In fact, on the upside of such stormy weather, many people were treated to dazzling auroras much farther south (farther north in the Southern Hemisphere) than usual.

What if conditions are not as favorable as they were last fall? Such was the case 145 years ago when the most intense magnetic storm in recorded history hit Earth. It was a CME—a term not coined until the 1970s—that combined all the ingredients for what's been dubbed the sun's perfect storm. The huge, highly magnetic, tremendously fast-moving cloud of electrified gases reached Earth in just 17 hours and 40 minutes—only in August 1972 has a CME ever reached Earth faster. It had speed, size, and intensity, but what finally branded it as a storm of historic proportion was the polarity of its inherent magnetic field: opposite Earth's. When the CME slammed into Earth's usually protective magnetic field, the fields connected, sending an intense power surge into our upper atmosphere. The electric circuits of the fledgling telegraph system were overwhelmed, shorting out the system in parts of the United States and Europe. Widespread fires broke out.

Could a perfect solar storm organize again? Yes. And it could paralyze today's technological systems. Scientists cannot predict precisely when it will happen, but there is no doubt that space storms matter as much to our modern lives as terrestrial tempests.

For a comprehensive review of the 1859 perfect storm, see: Tsurutani, B. T., et al., " The extreme magnetic storm of 1-2 September 1859," in the *Journal of Geophysical Research* (Vol. 108, No. A7, 2003).

—Barbara W. McConnell

Related Links

Stanford Solar Center
solar-center.stanford.edu/index.html
This comprehensive site answers many questions, explains historical beliefs about the sun, has games to play, and carries links to other useful sites.

Space Environment Center
www.sec.noaa.gov/index.html
Explore NOAA's official site for space weather data, alerts, and forecasts.

Space Weather
www.spaceweather.com
Find more information on current space weather and numerous useful links to information on the sun and its effect on Earth.

SOHO
sohowww.nascom.nasa.gov
Get details about the joint European Space Agency/NASA solar observatory.

Living With a Star
sec.gsfc.nasa.gov
The home page for the Sun-Earth Connection program. Includes links to past and present space-based solar observatories.

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