Shedding light on the sun

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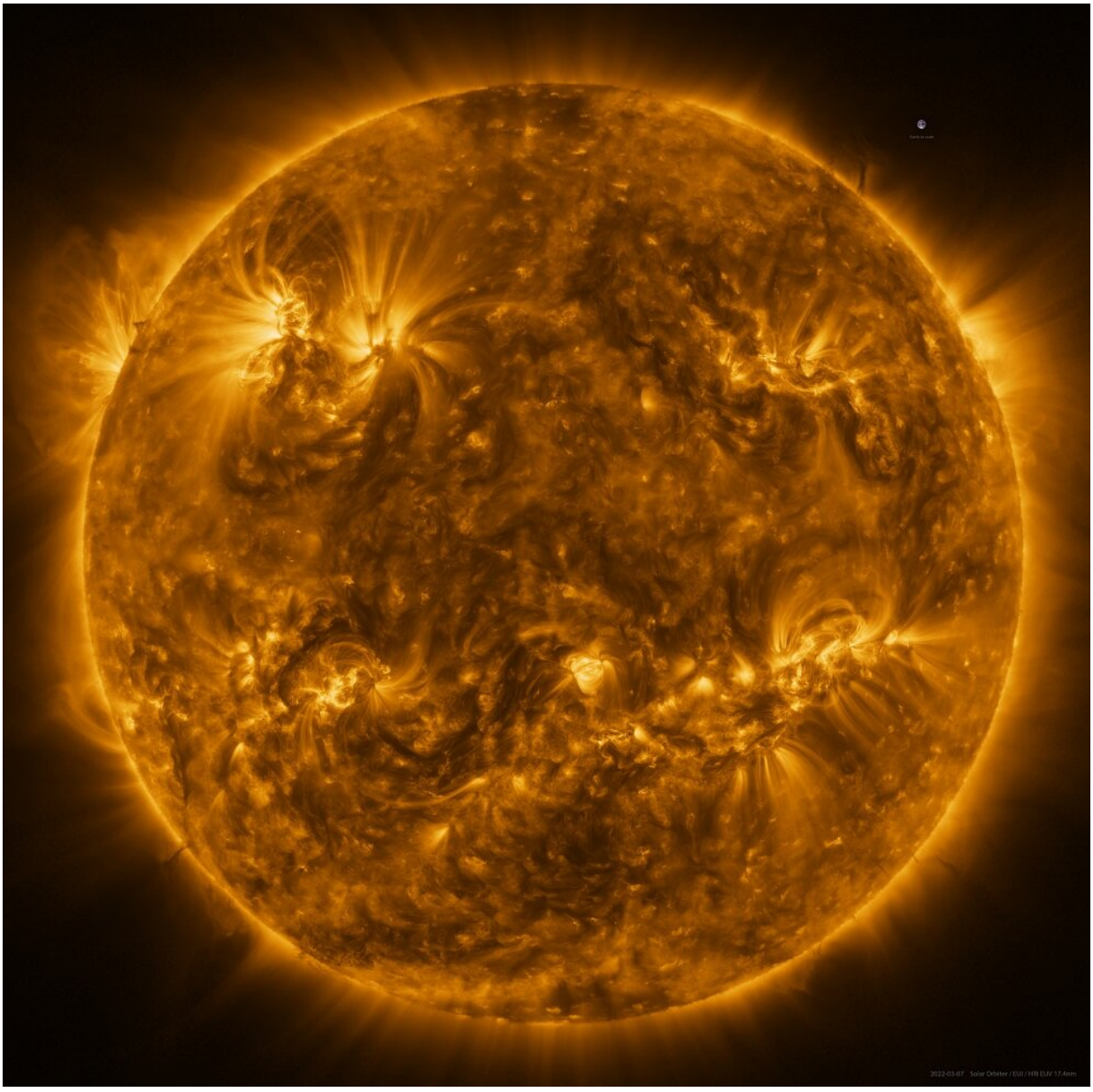

The Sun from a distance of 75 million kilometers. Credit: © ESA &

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As questions abound about the Earth's closest star, scientists are seeking answers critical to forecasting solar flares that threaten satellites and other electronics.

For most of humankind's history, it has been hard to explain the sun as anything other than a powerful deity.

For instance, the ancient Greek god Helios—the personification of the sun—raced his chariot across the sky to create night and day, whereas the ancient Egyptians worshiped their falcon-headed sun god, Ra, as creator of the universe.

Powerful surprises

Since then, science has revealed that, for example, the sun on average turns on its axis once every 28 days. But at its equator, the hot plasma ball rotates once every 25 days, while it takes around 35 days at the poles, creating a swirling soup of piping hot plasma.

Nonetheless, the power of the sun can still offer surprises, with blasts fierce enough to fry communication satellites or electronics on Earth. Scientists warn of more powerful solar flares as a peak of activity approaches in late 2024 and early 2025.

"There is this turbulent motion inside our star, called convection, that is a bit like how water wrinkles just before it boils," said Professor Sacha Brun, director of research at CEA Paris-Saclay, part of the French Alternative Energies and Atomic Energy Commission.

An infamous magnetic storm that hit Earth in September 1859, known as the Carrington Event, triggered spectacular auroras far from polar regions and sizzled telegraph systems around the world.

There have been more since. In 1989, a geomagnetic storm caused a blackout in Quebec, Canada, according to Brun.

Greater knowledge about the sun is needed to predict and understand such events.

That swirling ball of hydrogen and helium is also unimaginably hot—with core temperatures of 15 million °C. And it's ginormous—more than 1 million Earths fit inside the sun.

Its peaceful presence on a summer's day belies the intense nuclear reactions at its core that generate vast amounts of energy. The sun is a churning ball of plasma, with gases so hot that electrons are booted out of atoms, generating intense magnetic explosions from its surface that spew billions of tons of matter into space.

Magnetic charm

As it spins, the sun's mechanical energy turns into magnetic energy—a bit like the dynamo on a bicycle light, where pedal motion is converted into magnetic energy.

On the sun, twisty ribbons of magnetism rise and break out as sunspots, dark patches at the surface where the magnetic field is 3,000 times more intense than in the surrounding areas.

sunspots can trigger those solar flares that damage electrical equipment. But this activity isn't constant.

"The magnetism of the sun is variable over an 11-year cycle," said Brun, an astrophysicist.

Over that cycle, coronal mass ejections rise in frequency, from one every three days to an average of three per day at its peak.

"As we go further into the cycle, more outbursts will emerge from the sun," Brun said. "People don't realize that the Earth bathes in the turbulent magnetic atmosphere of our star."

So there's an obvious need to anticipate when such solar storms approach. For example, a solar flare in February 2022 knocked out 40 SpaceX commercial satellites by destroying their electronics.

Those energetic particles take just 15 minutes to reach Earth from the sun. The threat posed by magnetic clouds usually takes a few days, offering more time to brace for any onslaught.

Brun co-leads an EU-funded project called WHOLE SUN to understand the interior and exterior layers of the only star in the Earth's solar system.

Running for seven years through April 2026, the initiative focuses on the inner turbulence of the sun and the complex physics that turns the inner turmoil into magnetism in the outer layers.

This requires the most powerful supercomputers in the world. Yet forecasting solar flares means that scientists gain greater understanding of the insides of the sun.

A star is born

What about the distant past of the sun? It has been around for 4.6 billion

years—100 million years before Earth. Where and how it was formed would seem to be an impenetrable mystery.

Not so, according to Dr. Maria Lugaro at the Konkoly Observatory of the Hungarian Academy of Sciences.

Lugaro, an Italian astrophysicist, is researching this very question in the EU-funded RADIOSTAR project. It began in 2017 and runs through August this year.

"We believe that the sun wasn't born alone, but was born in a star-forming region where there's lots of stars," Lugaro said.

She is looking into this past by examining chemical fossils in meteorites today.

Radioactive atoms are unstable. They release energy and decay into so-called daughter atoms, over a certain length of time, which are measurable. The daughters are therefore chemical fossils, offering information about long-gone radioactive atoms.

Lugaro's research suggests that the sun originated in a stellar nursery that contained lots of siblings, including exploding stars—supernovas. But digging into the sun's history first requires finding meteorites, bits of rock formed before Earth.

These meteorites can contain traces of the radioactive atoms such as aluminum-26 and hafnium-182. It is known that these lived only a certain length of time. Together, traces of such atoms can be used as a radioactive clock to compute the age of the stars that made them, relative to the age of the sun.

Vivid discourse

Some radioactive atoms are made in only certain types of stars. Their presence in meteorites helps to recreate a picture of the sun's birthplace, albeit one that's up for debate.

It may be that the sun was birthed amid dust and gas clouds in a tempestuous region alongside supergiant stars and exploding stars.

Within perhaps 20 million years, the different stars begin to make their own way out of the nursery. But things are far from being scientifically settled.

"Every year there's debate: is the sun normal or is it a weird star?" said Lugaro. "It's quite fun."

More information:

- WHOLE SUN
- RADIOSTAR
- EU-funded space research and innovation

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