Astrophysicist's 2004 theory confirmed: Why the Sun's composition varies

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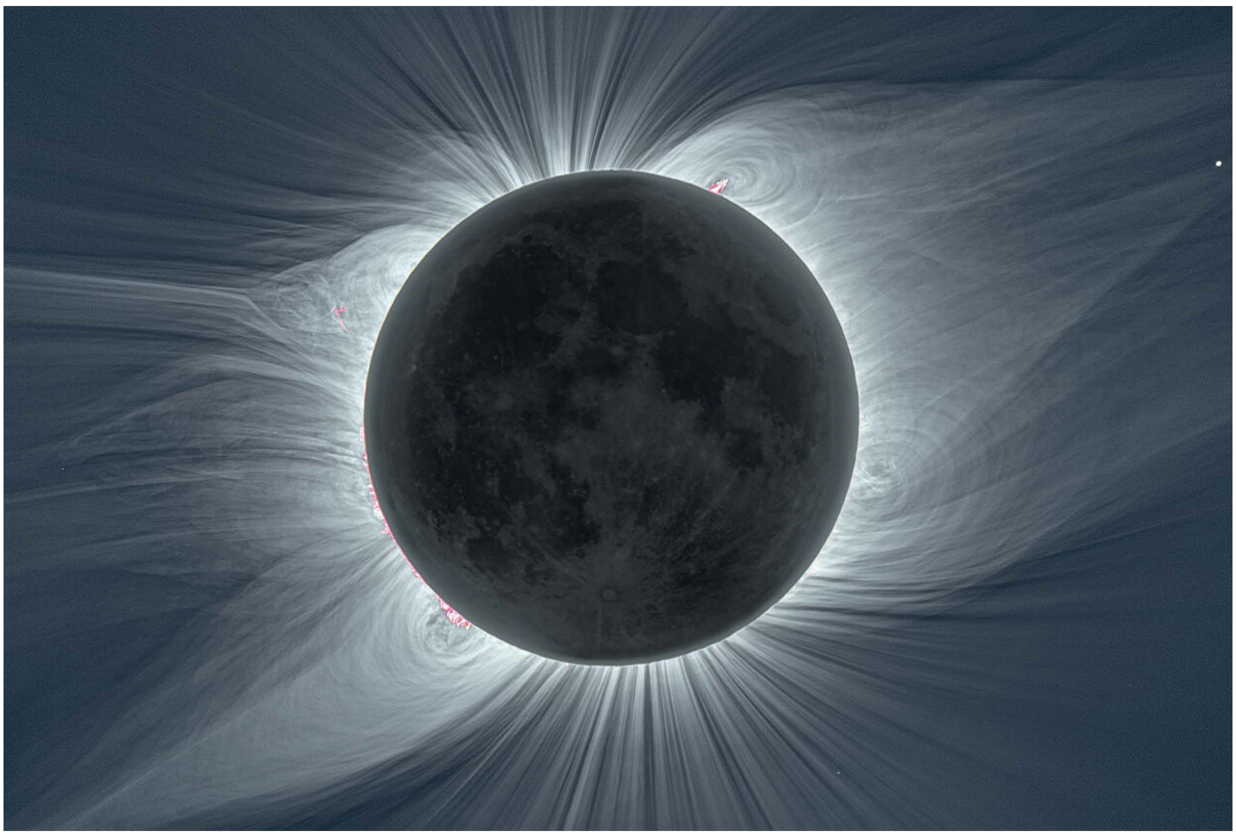

The solar corona viewed in white light during the total solar eclipse on Aug. 21, 2017 from Mitchell, Oregon. The moon blocks out the central part of the Sun, allowing the tenuous outer regions to be seen in full detail. The image is courtesy of Benjamin Boe and first published in "CME-induced Thermodynamic Changes in the Corona as Inferred from Fe XI and Fe XIV Emission Observations during the 2017 August 21 Total Solar Eclipse", Boe, Habbal, Druckmüller, Ding, Hodérova, & Štarha, Astrophysical Journal, 888, 100, (Jan. 10, 2020). Credit: American Astronomical Society (AAS)

About 17 years ago, J. Martin Laming, an astrophysicist at the U.S. Naval Research Laboratory, theorized why the chemical composition of the Sun's tenuous outermost layer differs from that lower down. His theory has recently been validated by combined observations of the Sun's magnetic waves from the Earth and from space.

His most recent scientific journal article describes how these magnetic waves modify chemical composition in a process completely new to solar physics or astrophysics, but already known in optical sciences, having been the subject of Nobel Prizes awarded to Steven Chu in 1997 and Arthur Ashkin in 2018.

Laming began exploring these phenomena in the mid-1990s, and first published the theory in 2004.

"It's satisfying to learn that the new observations demonstrate what happens 'under the hood' in the theory, and that it actually happens for real on the Sun," he said.

The Sun is made up of many layers. Astronomers call its outermost layer the solar corona, which is only visible from earth during a total solar eclipse. All solar activity in the corona is driven by the solar magnetic field. This activity consists of solar flares, coronal mass ejections, high-speed solar wind, and solar energetic particles. These various manifestations of solar activity are all propagated or triggered by oscillations or waves on the magnetic field lines.

"The very same waves, when they hit the lower solar regions, cause the change in chemical composition, which we see in the corona as this material moves upwards," Laming said. "In this way, the coronal chemical composition offers a new way to understand waves in the solar atmosphere, and new insights into the origins of solar activity."

Christoph Englert, head of the U.S. Naval Research Laboratory's Space Science Division, points out the benefits for predicting the Sun's weather and how Laming's theory could help predict changes in our ability to communicate on Earth.

"We estimate that the Sun is 91 percent hydrogen but the small fraction accounted for by minor ions like iron, silicon, or magnesium dominates the radiative output in ultraviolet and X-rays from the corona," he said. "If the abundance of these ions is changing, the radiative output changes."

"What happens on the Sun has significant effects on the Earth's upper atmosphere, which is important for communication and radar technologies that rely on over-the-horizon or ground-to-space radio frequency propagation," Englert said.

It also has an impact on objects in orbit. The radiation is absorbed in the Earth's upper atmospheric layers, which causes the upper atmosphere to form plasma, the ionosphere, and to expand and contract, influencing the atmospheric drag on satellites and orbital debris.

"The Sun also releases high energy particles," Laming said. "They can cause damage to satellites and other space objects. The high energy particles themselves are microscopic, but it's their speed that causes them to be dangerous to electronics, solar panels, and navigation equipment in space."

Englert said that reliably forecasting solar activity is a long-term goal, which requires us to understand the inner workings of our star. This latest achievement is a step in this direction.

"There is a long history of advances in astronomy seeding technological progress, going all the way back to Galileo," Englert said. "We are excited to carry on this tradition in support of the U.S. Navy."

More information: J. Martin Laming. The FIP and Inverse FIP Effects in Solar Flares. arXiv:2101.03038 [astro-ph.SR] arxiv.org/abs/2101.03038

D. Baker et al. Alfvenic Perturbations in a Sunspot Chromosphere Linked to Fractionated Plasma in the Corona. arXiv:2012.04308 [astro-ph.SR] arxiv.org/abs/2012.04308

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