How scientists used NASA data to predict the corona of the Aug. 21 Total Solar Eclipse

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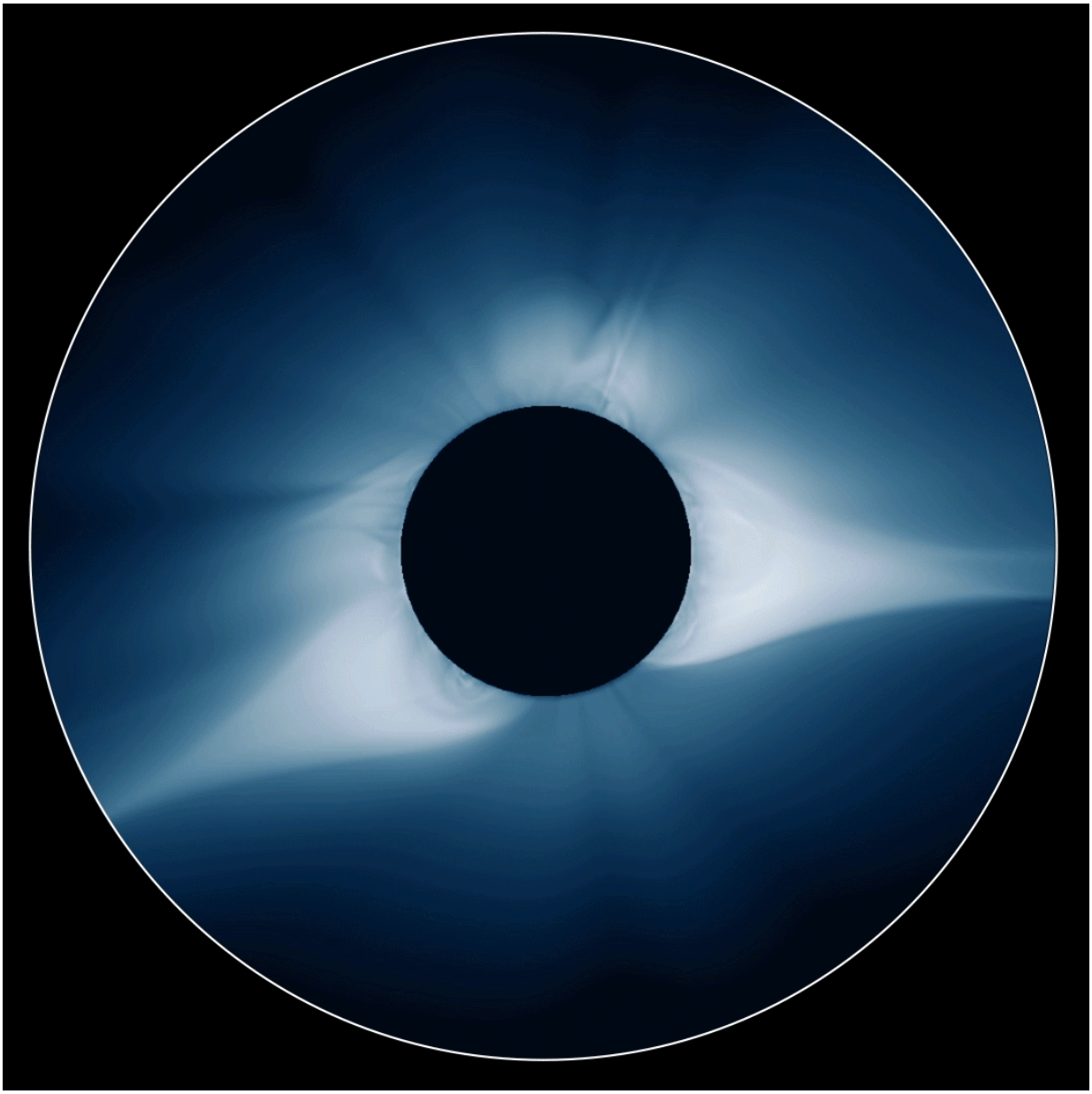

Predictive Science, Inc. developed a numerical model that simulated what the corona would look like during the Aug. 21, 2017 total solar eclipse. Credit: Predictive Science, Inc./Paul Holdorf/Joy Ng

When the total solar eclipse swept across the United States on Aug. 21, 2017, NASA satellites captured a diverse set of images from space. But days before the eclipse, some NASA satellites also enabled scientists to predict what the corona—the Sun's outer atmosphere—would look like during the eclipse, from the ground. In addition to offering a case study to test our predictive abilities, the predictions also enabled some eclipse scientists to choose their study targets in advance.

Predictive Science, Inc., San Diego, Calif.—a private computational physics research company supported by NASA, the National Science Foundation and the Air Force Office of Scientific Research—used data from NASA's Solar Dynamics Observatory, or SDO to develop an improved numerical model that simulated what the corona would look like during the total eclipse. Their model uses observations of magnetic fields on the Sun's surface and requires a wealth of supercomputing resources to predict how the magnetic field shapes the corona over time.

As the corona and solar material spread outward from the Sun, they can manifest themselves as disturbances in near-Earth space, known as space weather. "Space weather models must be able to characterize the structure of the corona in order to improve forecasts of the path and possible impacts of these events," Predictive Science president and scientist Jon Linker said.

One key tool are computer models that simulate events on the Sun before they even happen. This comparing of models and observations is a core aspect of heliophysics—the field of science dedicated to

understanding the Sun and its dynamic influence throughout the solar system. Without the ability to measure the corona directly, heliophysicists test their theories by using complex computer simulations.

Eclipses offer a unique opportunity for scientists to test such models. During the total eclipse, the Moon completely obscured the Sun's bright face, revealing the innermost part of the corona—the region where solar eruptions such as coronal mass ejections originate, but is difficult to observe under ordinary circumstances. By comparing their predictions to the observations gathered during the eclipse itself, researchers can assess and improve the performance of their coronal models.

The model the Predictive Science researchers used for their final prediction of the August 2017 eclipse was their most complex yet. In addition to SDO's maps of the Sun's magnetic field, it also utilized SDO observations of filaments—serpentine structures on the Sun's surface comprised of cool, dense solar material.

Greater complexity demands more computing hours, and each simulation required thousands of processers and took about two days of real time to complete. The research group ran their model on several supercomputers including facilities at the Texas Advanced Computer Center in Austin, Texas; the San Diego Supercomputer Center in California; and the Pleiades supercomputer at the NASA Advanced Supercomputing facility at NASA's Ames Research Center in Silicon Valley, California.

"Based on a very preliminary comparison, it looks like the model did very well in capturing features of the large-scale corona," Linker said. In its increased complexity, the model demonstrates that even the Sun's fine magnetic structures are intimately related to the vast structure of the corona.

While scientists were running their models, NASA's own Solar and Terrestrial Relations Observatory, or STEREO-A spacecraft, was also able to peer into the future and provide clues as to what the corona would look like the day of the eclipse. As the eclipse drew closer, due to STEREO-A's position behind the Sun and the particular rotation rates of the Sun and Earth, STEREO-A's view of the corona on Aug. 12, 2017, was virtually the same those within the path of totality would see nine days later on Aug. 21. That is, STEREO-A's vantage point is roughly nine days in advance of Earth's.

STEREO's key instruments include a pair of coronagraphs—telescopes that use a metal disk called an occulting disk to study the corona. Just like a total eclipse, the occulting disk blocks the Sun's bright light, making it possible to discern the surrounding corona.

Coronagraph images from Aug. 12 and 21 show great similarity; both feature a dominant three-streamer shape. Here, the STEREO image is compared to an image from the joint ESA/NASA Solar and Heliospheric Observatory, or SOHO, which was positioned to share Earth's view of the corona on Aug. 21. The slight difference in the location of the streamers is due to the fact that STEREO-A and SOHO view the Sun from slightly different angles.

"The small difference between the Aug. 12 and Aug. 21 images show the Sun's atmosphere evolves very slowly—as we expect it to, in its declining phase toward solar minimum," said Angelos Vourlidas, a STEREO science team member and heliophysicist at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. "The Sun is slowly going to sleep—but not quietly, as the recent spate of solar activity reminded us!"

Solar minimum is the period of lower solar activity in the Sun's natural approximately 11-year cycle. In times of greater solar activity, the

dynamic corona could have evolved too quickly to make such a prediction useful. But in these times nearing solar minimum, both Predictive Science and STEREO's eclipse predictions offered an opportunity for researchers to improve models and our understanding of the Sun's current activity.

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