Sun's tenuous outer tendrils revealed in spectacular movies from European Solar Telescope

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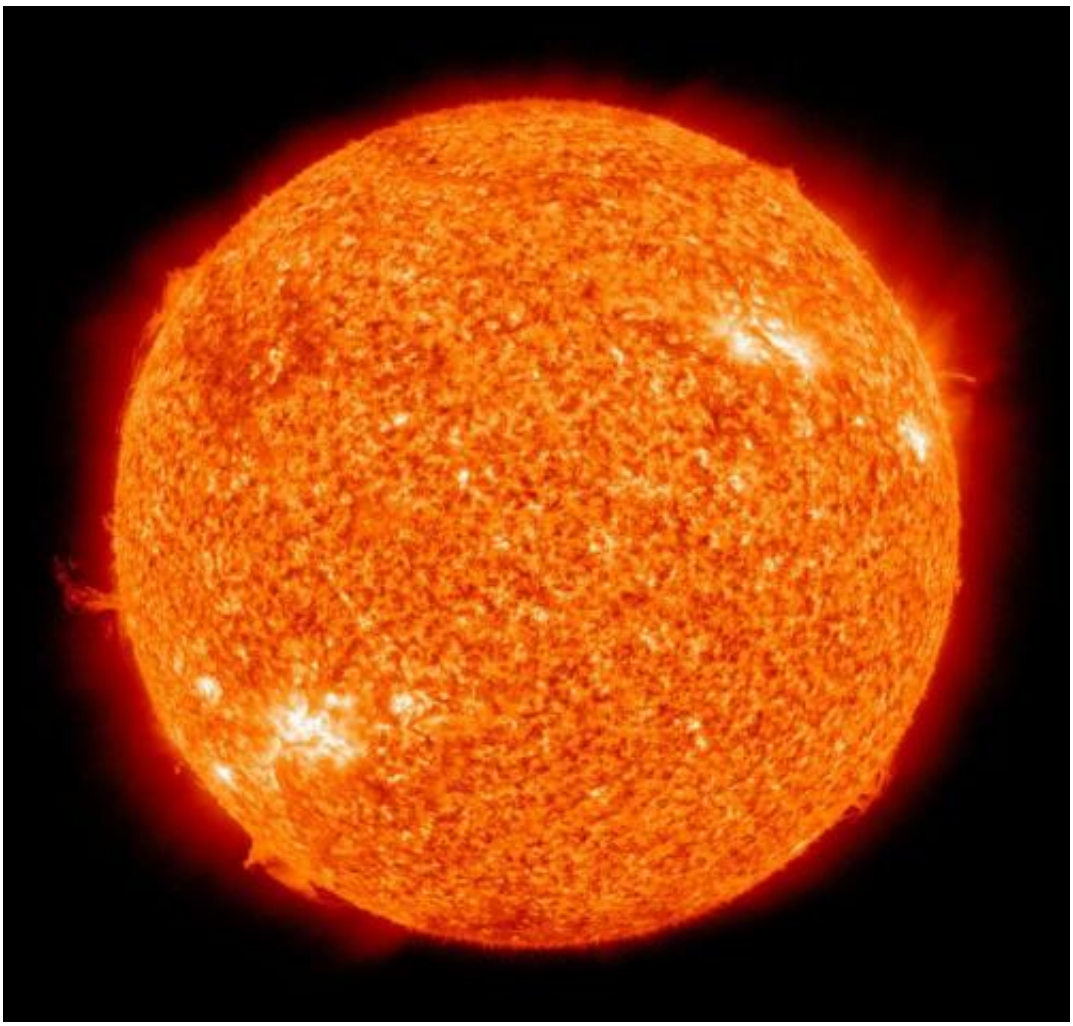

The Sun by the Atmospheric Imaging Assembly of NASA's Solar Dynamics Observatory. Credit: NASA

New and exciting extreme ultraviolet views of the Sun's high corona from ESA's PROBA2 mission reveal mysteriously beautiful, tenuous structure extending surprisingly far from the Sun itself. The spectacular movies from the Royal Observatory of Belgium's SWAP instrument on the ESA technology demonstration testbed PROBA2, revealing previously unseen feathery structure in the region where the solar wind is accelerated, were presented today at the Triennial Earth-Sun Summit (TESS) meeting between the American Astronomical Society's Solar Physics Division (AAS/SPD) and the American Geophysical Union's Space Physics and Aeronomy section (AGU/SPA) in Indianapolis, Ind.

EUV images of the Sun's dynamic corona, with its dramatic eruptions and bright network of magnetic loops, have become familiar thanks to telescopes on space-based observatories like the 20 year-old Solar and Heliospheric Observatory (SOHO) and the more recent Solar Dynamics Observatory (SDO). But new movies from the SWAP telescope on PROBA2, a European mini-satellite launched in November 2009, reveal a new and surprising picture of this region. While SWAP also sees the hot magnetic loops glowing in ultraviolet in the low corona that these other observatories revealed, new observations show that overlying these more familiar features is a region dominated by tenuous, filamentary structures that wrap around loops and voids in the low corona and extend outwards and into interplanetary space.

While the low corona is the domain of dynamic events like solar flares, which can heat the surrounding plasma to tens of millions of degrees, the new observations from SWAP reveal a slowly evolving, much more stable region where the connection between the Sun itself and the solar wind that fills interplanetary space is born. SWAP observations reveal surprisingly long-lived fan-shaped structures that extend to heights larger than 700,000 km above the Sun's surface—structures that are, in some cases, larger than the Sun itself. Understanding what physical processes are responsible for the formation of these structures is key to

determining the nature of the complex relationship between the corona and the solar wind.

"Over the past few years, SWAP has observed an increasing number of these bright, fan-like structures that extend up to a million kilometers from the Sun" said Dr. Daniel Seaton, lead scientist for the SWAP instrument at the Royal Observatory of Belgium. "These fans are linked to structures we sometimes see at even greater heights in white light observations from coronagraphs and eclipses, but just as often they appear to behave very differently. They sometimes curve dramatically towards the solar poles and wrap around intense bundles of coiled magnetic field and cool, dense plasma called prominences."

Seen in time-lapse movies from the SWAP imager, the effect is striking, revealing a vivid, three-dimensional corona unlike anything solar physicists have observed before.

The new observations might also provide clues to unraveling the unusual behavior of the Sun's magnetic activity cycle, a 22-year cycle of magnetic activity and inactivity that in recent years has confounded solar scientists' expectations. Typically, the Sun goes through a highly predictable evolution from quiet, to active, and back again as its magnetic field evolves. The present cycle was slow to rise and has not produced nearly as much activity as previous cycles. At the same time, the Sun's northern and southern hemispheres, which typically evolve independently to some extent, have become almost completely decoupled.

The new SWAP movies of the long-term evolution of the EUV corona over the rising phase of solar cycle 24 reveals clear links to both the sunspot number, a key indicator of solar activity, and the discordant activity of the two hemispheres. Unusually, the activity of the low solar atmosphere has been largely dominated by a single hemisphere, the

north, whose activity has also manifested far from the solar surface. The new analysis of the bright, fan-like structures that dominate the SWAP observations has revealed some of the reasons for their appearance, which has been linked with the rise of solar activity in the past five years. The analysis also helps explain why fans occasionally disappear from the observations as well.

"These EUV coronal fans seem to be rooted in low-latitude magnetic regions without sunspots, and they trace open magnetic field lines overlying closed arcades linking to the solar pole. As soon as new magnetic flux emerges near the magnetic sheet foot points, the fans break down," said Anik De Groof, a scientist at the European Space Agency who led the latest analysis of these observations. "The fact that the fans primarily appear in the northern hemisphere may be related to the rather unusual polar magnetic field reversal in Cycle 24. However, more data and analysis of both SWAP and magnetic field measurements will be needed to give a firm conclusion."

Whatever clues the new observations might offer to the nature of the evolution of solar activity, for scientists they raise as many questions as they answer, questions they hope upcoming solar missions will answer. PROBA2's sister mission, PROBA3, will observe the same innermost region of solar corona in white light using two spacecraft, flying in formation, to generate an artificial eclipse. Solar Orbiter, meanwhile, will leave Earth orbit altogether, flying out of the ecliptic to higher solar latitudes to observe the Sun's poles at a distance inside the orbit of Mercury to reveal the magnetic structure of the region where many of the fan structures seen by SWAP are anchored.

More information: * "SWAP Observations of the Long-Term, Large-Scale Evolution of the Extreme-Ultraviolet Solar Corona." Seaton, D. B., De Groof, A. et al., 2013 November 1, *Astrophysical Journal*, Vol. 777, No. 1. dx.doi.org/10.1088/0004-637X/777/1/72,

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* "Observations of a Hybrid Double-Streamer/Pseudostreamer in the Solar Corona," L. A. Rachmeler et al., 2014 May 20, *Astrophysical Journal Letters*, Vol. 787, No. 1 dx.doi.org/10.1088/2041-8205/787/1/L3 , arxiv.org/abs/1312.3153

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