Waves Might Heat Solar Atmosphere

Astronomers are working to unravel the mystery of the Sun’s superhot corona, but new work implicating magnetic waves isn’t the final word on the matter.

One of the long-standing mysteries of astronomy is why the Sun’s outer atmosphere is so darn hot. This layer, called the corona, is the wispy, extended halo visible in a total solar eclipse and blazes at millions of degrees. But the layer below the corona, called the chromosphere, is roughly one hundredth that temperature, and the solar surface beneath it is even cooler.

A close-up look by the STEREO spacecraft in 2008 shows a large, dark hole in the solar corona in the Sun's southern polar region. The fast solar wind is thought to stream out of such coronal holes.

NASA

The blazing corona mystery remains unsolved. But two new studies in the Astrophysical Journal suggest that one possible solution could pan out. Perhaps more convincingly, the solution — called Alfvénic waves — might explain how the fastest particles streaming out from the Sun attain such high speeds.

Alfvénic waves are oscillations that move along magnetic field lines like the vibrations in a plucked guitar string. They were first suggested as a driving force behind both the corona’s heat and the acceleration of the fast solar wind in the 1940s, but they weren’t observed until 2007, when a team of astronomers including Scott McIntosh (High Altitude Observatory, National Center for Atmospheric Research) caught sight of them by using the Coronal Multichannel Polarimeter, then at the National Solar Observatory in New Mexico. Last year, McIntosh and his colleagues discovered these waves permeate both the corona and the transition zone between the corona and the chromosphere.

Now, two independent teams have used observations by the Hinode spacecraft to cement the role these magnetic ripples play on the Sun.

Both teams used Hinode’s Extreme Ultraviolet Imaging Spectrometer to observe a hole in the corona over the Sun’s south pole. In coronal holes the Sun’s magnetic field lines stream out straight, instead of curving back down again in big loops. It’s from these regions that the particles that make up the fast solar wind stream forth, whizzing through space at 800 kilometers per second.

The astronomers observed spectral lines from the ionized gas in the coronal hole. The corona’s spectral lines can look wider due to the movement of hot, ionized gas along the line of sight. This extra line broadening correlates directly to the presence of Alfvénic waves, because the magnetic waves skosh the ions at a velocity that depends on the waves’ energy.
Erupting jets of gas show green in this false-color image by NASA's Solar Dynamics Observatory. Such jets could help heat the Sun's atmosphere, although researchers debate how much of a role they actually play.

*NASA / SDO / AIA*

The two teams used this line broadening to measure how much energy the Alfvénic waves carry at different heights in the corona. They both found that the wave energy dropped off rapidly within the lowest quarter or so of the solar atmosphere, suggesting that the energy is somehow being dumped into the corona’s lowest region, where temperatures already reach 1 million Kelvin. This energy would then be conducted by particle motion upward and outward. One team went on to calculate that the energy dissipated could provide up to 70% of that needed to heat the polar coronal hole and accelerate the fast solar wind.

The team is quick to point out that the results only give an upper limit — the lower limit is still zero. Plus, coronal holes are cooler than other parts of the Sun, and it looks like the magnetic waves deposit more energy in the cooler regions than in the atmosphere’s warmer parts at the heights both teams observed. How much Alfvénic waves could contribute to the corona’s temperature overall isn’t clear.

McIntosh says he’s excited that people are probing this enigmatic energy source in the Sun’s atmosphere. But while he’s convinced the waves must have an impact, he’s not so sure they’re needed to heat the material in the coronal holes — jets shooting up from the chromosphere might do that just fine. Riding these jets, the Alfvénic waves could then accelerate the jet-heated ions and send them rocketing outward into space.

Daniel Savin and Michael Hahn (both of Columbia University), two of the 70%-paper coauthors, say they don’t think outflows from below can heat the corona enough to match observations without the additional wave energy. Despite the disagreement, all the researchers agree that there’s no clear explanation yet for how the magnetic waves lose their energy to the corona.

These are only some of the ideas running amok. Other researchers favor “nanoflares,” bursts of energy released when magnetic field lines snap into new configurations. And a recent paper in *Nature* took the fact that the Alfvénic waves rotate and ran with it, suggesting “magnetic tornadoes” could channel energy into the corona. What the final answer is remains unknown.

Posted by Camille Carlisle, July 3, 2012

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