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LONG-STANDING CONUNDRUM ON THE SUN'S ATMOSPHERE SOLVED

Relevant for: Geography | Topic: The Earth and the Solar System

Geyser-like jets: The solar spicules emanate from the interface of the corona and the photosphere. | Photo Credit: Tanmoy Samanta

The Sun is one of the most familiar celestial objects – it is on the sky everyday. Yet, it harbours many a puzzle for the solar physicist. One of the puzzles concerns its surface and atmospheric temperature. An international team of researchers including one at Indian Institute of Astrophysics, Bengaluru, has had a go at this question. These observations may have unravelled why the Sun's atmosphere is hotter than its surface.

The temperature at the core of the Sun is nearly 15 million degrees Celsius, while that at its surface layer, known as the photosphere, is merely 5,700 degrees C. The natural thing to expect is that still further outwards, in its atmosphere, known as the corona, the temperatures would be comparable to that at the surface (photosphere). However, the temperature of the corona is much higher. It starts increasing outside the photosphere, reaching a value of about one million degrees or more in the corona.

One would expect that as there are no extra sources of heat, when you move away from a hot object, the temperature steadily decreases. However, with respect to the Sun, after dropping to a low, the temperature again rises to one million degrees in the corona which stretches over several million kilometres from the surface of the Sun. This implies there should be a source heating the corona. The puzzle of coronal heating has been tackled by many theories. Now, in a paper published in *Science,* the team of solar physicists has made observations and matched it with an analysis that explains this conundrum.

The key to the puzzle lies in geyser-like jets known as solar spicules that emanate from the interface of the corona and the photosphere. While in a photograph these look like tiny hairlike projections, they are in fact 200-500 kilometres wide and shoot up to heights of about 5,000 km above the solar surface.

It has been suspected that these spicules act as conduits through which mass and energy from the lower atmosphere bypass the photosphere and reach the corona. The present study, led by Tanmoy Samanta and Hui Tian of Peking University, China, has deciphered how these spicules form and also shows that they act as conduits through which hot plasma is carried into the corona region.

"Our observations show that these spicules heat up while propagating upward, reaching the coronal temperature. They are made of plasma – a mixture of positive ions and negatively charged electrons," says Dr Samanta. Objects at different temperatures emit light of different wavelengths. "The coronal plasma emits light in extreme ultraviolet. We find an increase in coronal intensity (emission) as spicules propagate upwards," he explains.

The team did their observations using the 1.6-metre Goode Solar Telescope at the Big Bear Solar Observatory (BBSO), the world's largest solar telescope, with the NIRIS instrument. "This is a high-precision instrument and can measure magnetic fields with high sensitivity," says Dipankar Banerjee, from Indian Institute of Astrophysics and one of the authors of the paper. The researchers also matched these observations with simultaneous observations form the

Atmospheric Imaging Assembly in NASA's Solar Dynamic Observatory spacecraft.

The research involved taking many high-spatial-resolution images of the same region of the Sun within a short time. This is known as high-cadence. "Since spicules have a very short lifetime – from 10 to 100 seconds – to understand their dynamics, we need a higher cadence. This is also a limiting factor of many solar telescopes," says Dr Samanta.

The key findings are that bursts of spicules originate from the boundaries of web like networks of magnetic structures in the surface. Near their footpoints, there emerge magnetic elements that have opposite polarity to the existing magnetic network. When the structures with opposing polarity run into each other, they cancel out. This was seen at the footpoints of some spicules. "Exactly at the time of cancellation, we found the presence of spicules, which are also responsible for heating the upper atmosphere," says Dr Samanta, explaining how the spicules originate as per their observations.

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