Scientist leads international team to crack 60-year-old mystery of Sun's magnetic waves

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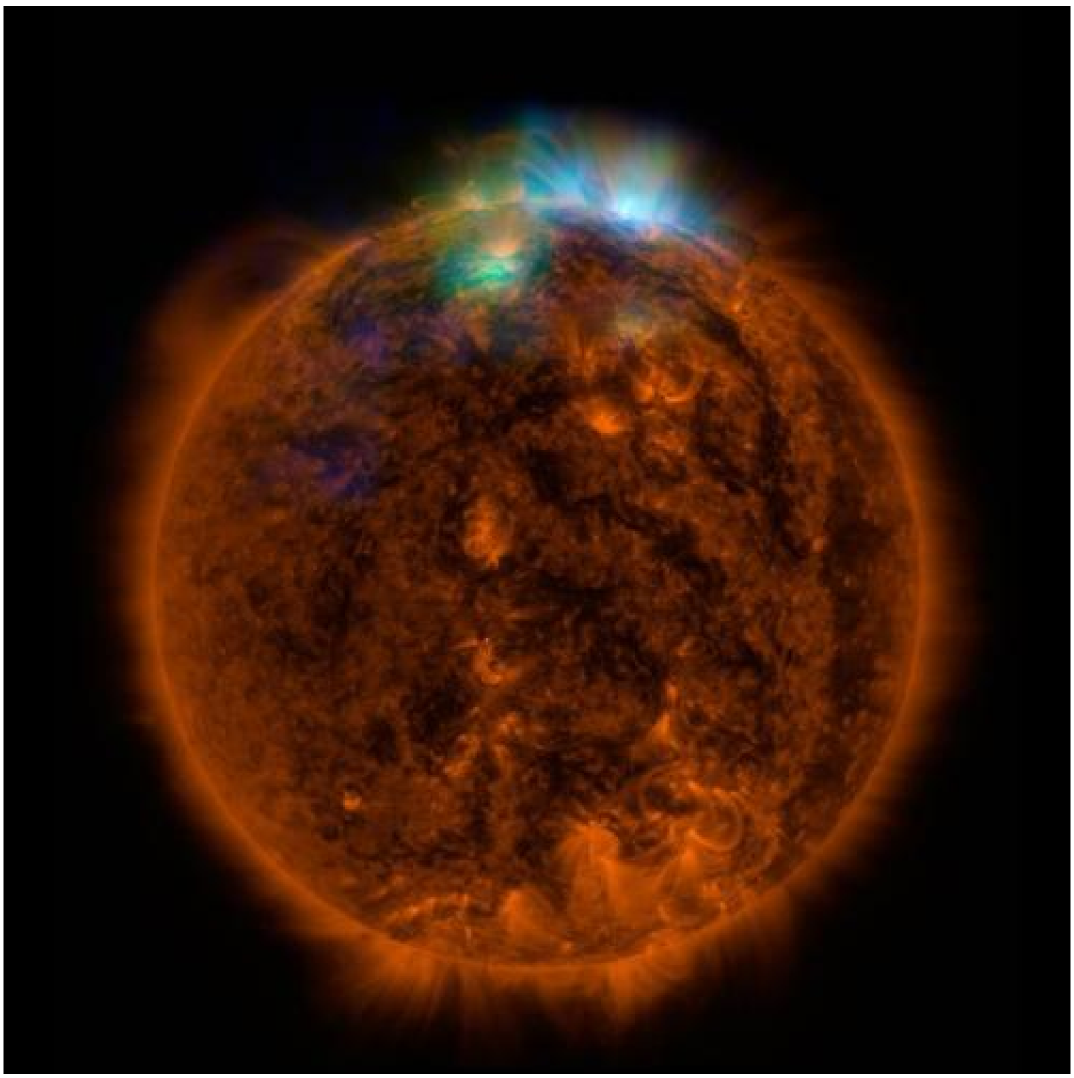

X-rays stream off the sun in this image showing observations from by NASA's Nuclear Spectroscopic Telescope Array, or NuSTAR, overlaid on a picture taken by NASA's Solar Dynamics Observatory (SDO). Credit: NASA

A Queen's University Belfast scientist has led an international team to the ground-breaking discovery of why the Sun's magnetic waves strengthen and grow as they emerge from its surface, which could help to solve the mystery of how the corona of the Sun maintains its multi-million degree temperatures.

For more than 60 years observations of the Sun have shown that as the magnetic waves leave the interior of the Sun they grow in strength but until now there has been no solid observational evidence as to why this was the case.

The corona's high temperatures have also always been a mystery. Usually the closer we are to a heat source, the warmer we feel. However, this is the opposite of what seems to happen on the Sun—its outer layers are warmer than the heat source at its surface.

Scientists have accepted for a long time that magnetic waves channel energy from the Sun's vast interior energy reservoir, which is powered by nuclear fusion, up into the outer regions of its atmosphere. Therefore, understanding how the wave motion is generated and spread throughout the Sun is of huge importance to researchers.

The team, which was led by Queen's, included 13 scientists, spanning five countries and 11 research institutes including University of Exeter; Northumbria University; the European Space Agency; Instituto de Astrofísica de Canarias, Spain; University of Oslo, Norway; the Italian Space Agency and California State University Northridge, USA.

The experts formed a consortium called "Waves in the Lower Solar Atmosphere (WaLSA)" to carry out the research and used advanced high-resolution observations from the National Science Foundation's Dunn Solar Telescope, New Mexico, to study the waves.

Dr. David Jess from the School of Mathematics and Physics at Queen's led the team of experts. He explains: "This new understanding of wave motion may help scientists uncover the missing piece in the puzzle of why the outer layers of the Sun are hotter than its surface, despite being further from the heat source.

"By breaking the Sun's light up into its basic colours, we were able to examine the behaviour of certain elements from the periodic table within its atmosphere, including silicon (formed close to the Sun's surface), calcium and helium (formed in the chromosphere where the wave amplification is most apparent).

"The variations in the elements allowed the speeds of the Sun's plasma to be uncovered. The timescales over which they evolve were benchmarked, which allowed the wave frequencies of the Sun to be recorded. This is similar to how a complex musical ensemble is deconstructed into basic notes and frequencies by visualising its musical score."

The team then used super computers to analyse the data through simulations. They found that the wave amplification process can be attributed to the formation of an 'acoustic resonator,' where significant changes in temperature between the surface of the Sun and its outer corona create boundaries that are partially reflective and act to trap the waves, allowing them to intensify and dramatically grow in strength.

The experts also found that the thickness of the resonance cavity -the distance between the significant temperature changes—is one of the main factors governing the characteristics of the detected wave motion.

Dr. Jess comments: "The effect that we have found through the research is similar to how an acoustic guitar changes the sound it emits through the shape of its hollow body. If we think of this analogy we can see how the waves captured in the Sun can grow and change as they exit its surface and move towards the outer layers and exterior."

Dr. Ben Snow, from the University of Exeter and a co-author of the study, said: "This new research opens the door to providing a new understanding of the mystery surrounding the Sun's magnetic waves. This is a crucial step towards explaining the coronal heating problem—where the temperature a few thousand km from the surface—is hotter than the heat source itself."

The findings of the study have been published in *Nature Astronomy*.

More information: David B. Jess et al. A chromospheric resonance cavity in a sunspot mapped with seismology, *Nature Astronomy* (2019). DOI: 10.1038/s41550-019-0945-2 , www.nature.com/articles/s41550-019-0945-2

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