Sunrise II: A second look at the Sun

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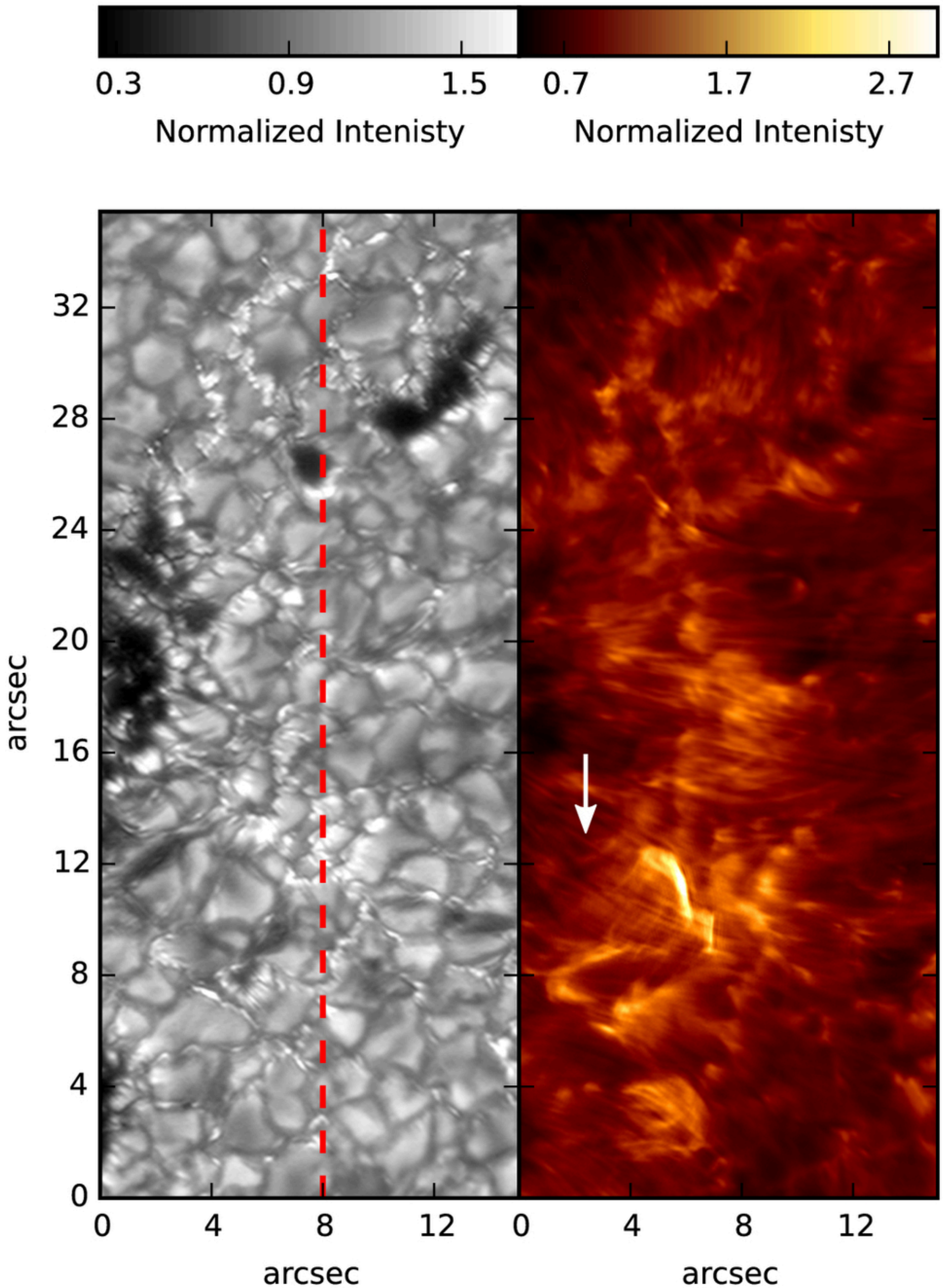
The solar observatory Sunrise is borne by a helium balloon to a float height of more than 35 kilometers. Credit: © MPS

scillating fibrils, explosive increases in temperature, and the footprints of coronal loops: 13 articles published today provide an overview of the results of the second flight of the balloon-borne solar observatory Sunrise.

During its two flights in 2009 and 2013, the balloon-borne solar observatory Sunrise experienced a unique view of our Sun: from a height of more than 35 kilometers and equipped with the largest solar telescope that had ever left Earth, Sunrise was able to resolve structures with a size of 50 kilometers in the Sun's ultraviolet (UV) light. The journal *Astrophysical Journal Supplement* now devotes a total of 13 articles to the results of the second flight of Sunrise. These are complemented by four articles based on data from the first flight that have now been analyzed. In this way, the special edition paints the most comprehensive and detailed picture of the boundary layer between the visible surface of the Sun and its atmosphere in ultraviolet light. The Special Issue reports, among other things, on hot explosions, oscillating fibril-like structures, and the origins of huge plasma flows. The Max Planck Institute for Solar System Research (MPS) in Germany, head of the Sunrise project, has a key stake in all 17 publications.

Many of the Sun's secrets are revealed only in the ultraviolet (UV) light that our star emits into space. However, since the Earth's atmosphere filters out most of this radiation, an observing position above this air layer is ideal for solar researchers. The balloon-borne solar observatory Sunrise offers access to this position - without the immense costs of a space mission. Carried by a huge helium balloon, Sunrise reaches an altitude of more than 35 kilometers, leaving most of the Earth's atmosphere underneath.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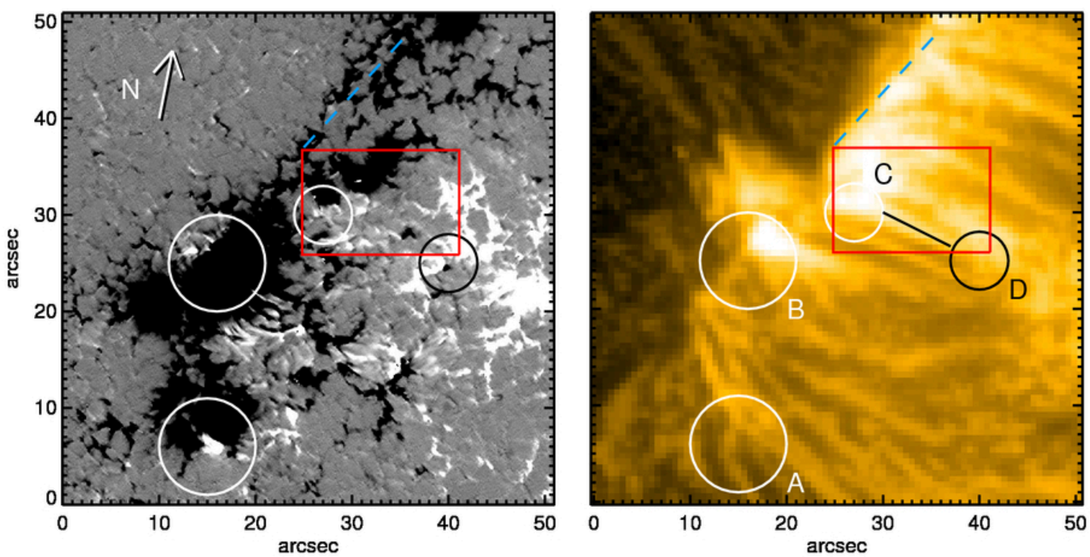
The Sun's visible surface (left) shows a pattern of so-called granules. They areevidence of hot plasma flows from the Sun's interior, that rise upward, are cooled off and sink down again. In the ultraviolet light from this region long fibril-like structures can be seen (right). Credit: © MPS

Twice already this concept has proven successful. While Sunrise witnessed an unexpectedly long activity minimum during its first flight in 2009, in 2013 our star presented itself from a more vigorous side: for almost six days, Sunrise had an excellent view of sunspots and active regions. MPS researchers published first results from this flight a few months later. More clearly than ever before, the UV data reveal fine structures in the Sun's lower atmosphere only a few kilometers in size such as bright points and long-drawn fibrils near the sunspots.

Since approximately one year, most of the Sunrise II data has been fully reduced and is now the basis of 13 of the articles published today. In these, the researchers for example elaborate their analysis of the fibril-like structures and determine their shape and lifetime. One of the results: their intensity and width fluctuate on time scales of a few seconds. Such detailed studies were made possible by the high resolution of Sunrise and the long series of observations.

"With a spatial resolution of 50 to 100 kilometers, Sunrise provides more accurate observational data in ultraviolet light than any other balloon-borne ore space-based solar telescope," says Prof. Dr. Sami K. Solanki, director at the MPS and head of the Sunrise mission. In addition, with its two instruments SuFI (Sunrise Filter Imager) and IMaX (Imaging Magentograph Experiment), Sunrise looks at a key region of solar research. In the area between the visible surface of the Sun, the photosphere, and the corona, the upper layer of the Sun's atmosphere, researchers hope to find answers to some of the most important open questions of solar physics: how is it possible that with approximately one million degrees the corona is significantly hotter than the photosphere with only 5000 degrees? In which way is the necessary energy from the photosphere transported into the corona and transformed into heat? What is the role of the Sun's dynamic, highly complex magnetic fields? "Everything points to the fact that small-scale and short-lived processes are decisive," says Sunrise project scientist Dr. Tino Riethmüller from the MPS.



A look at the footprints of coronal loops. Images obtained by NASA's Solar Synamics Observatory (right) on June 12th, 2013 show distinct plasma flows in the Sun's corona. Sunrise II data documents the magnetic fields that were present on the Sun at the same time and in the same place (left). Small regions, in which the magnetic polarity is opposite to that of the overall environment prove to be the origins of the loops. Credit: © MPS/SDO

Discovering these is the mission of Sunrise. On the first day of the second flight, for example, the observatory witnessed an Ellermann bomb, an explosive but localized increase in radiation intensity and temperature. This phenomenon generally occurs in developing active regions and is regarded as a sign of dramatic reconstruction in the Sun's magnetic field. Magnetic energy is thereby converted into heat, among other things. The simulations complementing the observational data suggest that these changes in the magnetic field architecture originate in the photosphere about 200 kilometers above the visible surface of the Sun.

Another process that connects the relatively cool photosphere with the hot corona are coronal loops, impressive arc-shaped plasma flows in the solar atmosphere. Some of them measure up to 100,000 kilometers in size. The starting points of these structures are often found in the vicinity of active regions. The Sunrise data now allow a precise view of these "footprints". They prove to be places of strong magnetic contrasts: small regions in which the magnetic polarity is opposed to their predominant environment. The interaction of these areas drives mass and energy transport into the atmosphere.

"The data of the two Sunrise flights are a true treasure trove for solar physics", says Solanki. The analysis of the data will continue for years. In addition, the MPS is currently planning a third flight of the balloon-borne observatory.

More information: The *Astrophysical Journal Supplement* Series, Special Issue on SUNRISE, March 2017.
iopscience.iop.org/issue/0067-0049/229/1

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