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Overview of the Special Issue on the First Science Results from the Second Flight of SUNRISE

The SUNRISE balloon-borne solar observatory had its first science flight in 2009 June and a second science flight in 2013 June. The science results of the first flight were published in a special issue of the Astrophysical Journal Letters in 2010. The science results from the second flight are presented in this special issue of the Astrophysical Journal Supplement.

The main goal of the SUNRISE observatory is to probe solar magneto-convection, i.e., the interaction between the Sun's magnetic field, convection, waves, etc., at a spatial resolution close to the diffraction limit of the telescope at a range of wavelengths, including wavelengths in the UV that are not or only very poorly observable from the ground. Both these aims require the observatory to float above most of the Earth's atmosphere. This is achieved by observing the Sun with a state-of-the-art telescope and instruments located above 99% of the Earth's atmosphere, carried there by a stratospheric balloon. The rationale to reach a resolution of between 50 and 100 km (depending on the wavelength) lies in the small-scale structure of the magnetic field in the solar lower atmosphere. To uncover the internal structure, interactions, and relevant physical processes within solar magnetic features, such a resolution is needed. Data from both flights of SUNRISE are unique in that they provide data that are free of seeing, with consistently high spatial resolution, higher than that of any other observations that have been obtained from another solar balloon-borne or space-based telescope.

The SUNRISE observatory is composed of a Gregory telescope with a 1 m diameter main mirror (making it the largest solar telescope so far to leave the ground), a complex light distribution and image stabilization system and two post focus instruments. One of these is a filter imager (SUNRISE filter imager, SuFI) working in the UV between 200 and 400 nm, while the other is a Fabry–Perot-based vector magnetograph (Imaging Magnetograph eXperiment, IMaX) observing in the 525.02 nm spectral line. The telescope and instrumentation are carried, pointed toward the Sun, and protected by a sturdy gondola. Various partners contributed to the different parts of the observatory, with the lead being taken by the Max Planck Institute for Solar System Research in Germany. Other major contributions have come from the Kiepenheuer Institute for Solar Physics, which is also in Germany, the High Altitude Observatory in the United States, and a Spanish consortium led by the Instituto de Astrofisica de Andalucia.

Both flights of the SUNRISE observatory started at ESRANGE in Kiruna, Sweden, where a zero-pressure balloon lifted the observatory to a float altitude of around 36 km. There, the winds carried it across the Atlantic, over Greenland and into northern Canada, where both missions ended, and the payload was brought down safely with all the major subsystems intact.

The first flight occurred at the activity minimum between solar cycles 23 and 24 when the Sun displayed basically no signs of activity, so only the quiet Sun could be observed. During the second flight, referred to in the following as SUNRISE II, the Sun displayed a fair amount of activity, so data could be obtained in the heart of an active region. Such data have allowed SUNRISE II to provide a number of novel results. Thus the first high-resolution images of the Sun in the Mg II k line were obtained by SUNRISE II. Initial results concerning just the Mg II k line images were published in 2013 and 2014. Further analysis of the data awaited its final reduction. This was completed in early 2016. The first results obtained from these finally reduced SUNRISE II data are presented in 13 publications of this special issue. In addition, this issue also contains 4 papers that make use of SUNRISE I data, which still provide unique information on the quiet Sun.

The science presented in the papers of this special issue is rich and varied. The science based on SUNRISE II data deals with the detailed study of discrete magnetic flux emergence events, of the brightness and magnetic field of pores, of a small-scale siphon flow, of the dynamics of moving magnetic features close to a pore and of the dynamics of magnetic bright points in regimes of different amounts of magnetic flux. A novel inversion technique for Stokes profiles is also developed and applied to SUNRISE II data. The Ca II H line recorded by SuFI in an active region is found to be dominated by slender fibrils whose properties, such as lifetimes, lengths, widths, etc. are determined, and the waves that they carry are identified (both kink- and sausage-mode waves), which are found to carry copious amounts of energy and hence may play an important role in heating the chromosphere in active regions. These fibrils are deemed to lie close to temperature minimum heights and are shown to follow the magnetic field lines (themselves obtained by finding a magnetohydrostatic solution based on the photospheric field measurements), thus forming a large-scale magnetic canopy. Numerous dynamic events are seen in the SUNRISE II data sets beyond the waves along fibrils and horizontal motions of magnetic bright points. In addition to a small flare occurring next to the location of magnetic flux emergence, these events include Ellerman bombs in the same general area and slender jets located between opposite magnetic polarities close to the footpoints of coronal loops. These jets may contribute to the heating of the overlying loops.

Finally, the set of papers in this special issue also covers new results obtained from the SUNRISE I data. These include relationships between the magnetic field and the intensity contrast in magnetic features relative to the quiet Sun. Among these relationships are the first at a number of wavelengths in the UV. They are also based on data recorded at a higher spatial resolution than generally done in the past. Also, a connection between local sinks of material and concentrations of magnetic fields is found, and the characteristics of waves travelling up and across magnetic bright points in the quiet Sun are obtained. Finally, the emergence rate of magnetic flux in the quiet Sun is addressed and it is shown that the higher resolution of SUNRISE data leads to an order of magnitude larger flux emergence rate than *Hinode*/SOT data if the same technique is applied.

Further analysis of the data recorded by both the first and second SUNRISE flights is ongoing, so numerous future publications employing SUNRISE data are expected. In addition, preparations have started for a third flight of the SUNRISE observatory.

The SUNRISE observatory and its two flights would never have been a success without the dedication and hard work of a large number of people at the various institutes involved. I would like to express my deep gratitude to them all. I would also like to thank the staff at ESRANGE and at the Columbia Scientific Ballooning Facility of NASA, as well as the editors and staff of the Astrophysical Journal.

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