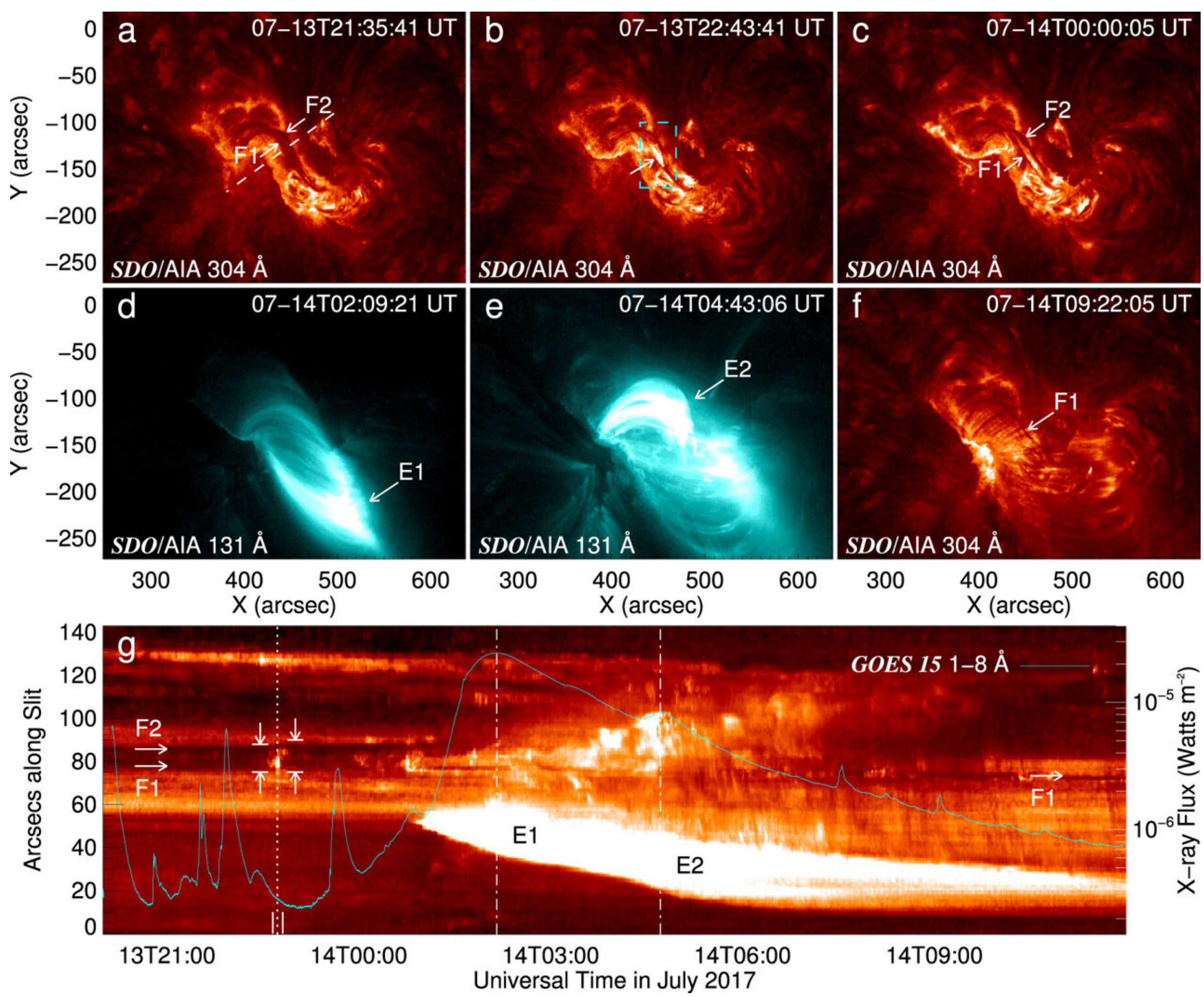
Definite spectroscopic evidence for magnetic reconnection in splitting of solar filament structure

January 18 2023, by Li Yuan



Splitting and partial eruption of the filament structure. (a)–(f) Images of SDO/AIA 304 Å ((a)–(c), (f)) and 131 Å ((d)–(e)). (g) Time–distance profile created by stacking AIA 304 Å images along the dashed line in (a), overlaid with GOES-15 1–8 Å X-ray flux in cyan color. The field of views (FOVs) of (a)–(f) are the same, whose coordinates are differentially rotated and are aligned to those of (b). "F1" and "F2" in (a), (c), (f), and (g) indicate the lower and upper filament branches, respectively. In (b) the arrow marks a brightening region between the two branches signifying the splitting. "E1" and "E2" in (d)–(e) denote two flares associated with the partial eruption. In (g) the dotted line on the left indicates the approximate time of the splitting, and the nearby two pairs of arrows illustrate the total width of the two filament branches before and after the splitting; the two dashed–dotted lines mark the times of the X-ray flux peaks of flares "E1" and "E2." The dashed rectangle in (b) represents the FOV of the IRIS raster scan displayed in Figures 2(c)–(e), and the two short vertical bars in (g) denote that the duration of the raster scan that overlaps the splitting. An animation for (a)–(c) is available, which begins at 07-13T22:00 UT and ends at 07-14T06:00 UT. The lines, arrows, and other annotations are removed in the animation. The real-time animation duration is ~34 s. Credit: *The Astrophysical Journal Letters* (2022). DOI: 10.3847/2041-8213/ac9dfd

Magnetic reconnection is a universal process that changes magnetic topology and converts magnetic energy to plasma kinetic energy. Spatially resolved spectroscopic observations covering extended regions in the solar atmosphere are rare, and thus the distribution and energy partition of reconnection remain unclear.

A filament is a darker and denser structure in the solar atmosphere. Doppler shifts of bidirectional outflows, as definite evidence for reconnection, have not been detected in solar filament splitting so far.

However, now, researchers led by Dr. Hu Huidong from the National Space Science Center of the Chinese Academy of Sciences, along with their collaborators from Max Planck Institute for Solar System Research in Germany and Nanjing University in China, have reported a magnetic-reconnection event that caused the splitting of a solar filament structure, based on spatially resolved spectroscopic data from the Interface Region Imaging Spectrograph (IRIS) and images from the Solar Dynamics Observatory (SDO).

The study was published in *The Astrophysical Journal Letters*.

"The filament structure was split into two upper and lower branches by magnetic reconnection, which eventually erupted partially, with the upper branch ejected and the lower branch retained," said Dr. Hu.

Neighboring large blue- and redshifts (more than 50 km/s) of the Si IV line in the brightening region between the two filament branches were revealed, which spatially corresponded to large nonthermal widths and enhanced intensities of the Si IV line. These are clear signatures of magnetic reconnection. The length of the reconnection region is unprecedentedly no less than 14,000 km.

A double Gaussian fit of the line spectra illustrated blue- and redshifts (up to ~150 km/s) of the upward and downward outflows. The reduction of the overall line width indicated that the line-of-sight velocities decreased remarkably after the bidirectional outflows left the reconnection site. Line broadening on the blue wing several arcseconds away from the reconnection site was observed, which might be indicative of turbulence that was induced when the upward outflow interacted with the upper filament branch.

Differential-emission-measure analysis showed that the temperature during the reconnection was ~14 MK, ~9 MK higher than that before the reconnection. The electron density was $\sim 3.9\times10^{10}$ cm^{-3}, about twice that before the reconnection. The total thermal energy was estimated to be $\sim 1.3\times10^{27}$ ergs, which was much larger than the kinetic energy.

"Our study has provided definite spectroscopic evidence for the splitting of a filament structure by magnetic reconnection," said Dr. Hu. "The reconnection is in an extended region with an unprecedented length, and the thermal energy overwhelmingly dominates the kinetic energy in this reconnection event."

More information: Huidong Hu et al, Spectroscopic and Imaging Observations of Spatially Extended Magnetic Reconnection in the Splitting of a Solar Filament Structure, *The Astrophysical Journal Letters* (2022). DOI: 10.3847/2041-8213/ac9dfd

Provided by Chinese Academy of Sciences