Microfilament-Eruption Mechanism for Solar Spicules

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Abstract

Recent studies indicate that solar coronal jets result from eruption of small-scale filaments, or “microfilaments” (Sterling et al. 2015, Nature, 523, 437; Panesar et al. ApJL, 832L, 7). In many aspects, these coronal jets appear to be small-scale versions of long-recogized large-scale solar eruptions that are often accompanied by eruption of a large-scale filament and that produce solar flares and coronal mass ejections (CMEs). In coronal jets, a jet-base bright point (JBP) that is often observed to accompany the jet and that sits on the magnetic neutral line from which the microfilaments erupt, corresponds to the solar flare of large-scale filament eruptions. Large-scale eruptions are relatively uncommon (~1/day) and occur with relatively large-scale erupting filaments (~10⁵ km long). Coronal jets are more common (>100/s/day), but occur from erupting minifilaments of smaller size (~10⁴ km long). It is known that solar spicules are much more frequent (many millions/day) than coronal jets. Just as coronal jets are small-scale versions of large-scale eruptions, here we suggest that solar spicules might in turn be small-scale versions of coronal jets; we postulate that the spicules are produced by eruptions of “microfilaments” of length comparable to the width of observed spicules (~300 μm). A plot of the estimated number of the three respective phenomena (flares/CMEs, coronal jets, and spicules) occurring on the Sun at a given time, against the average sizes of erupting filaments, spicules, and the putative microfilaments, results in a size distribution that can be fit with a power-law within the estimated uncertainties.

Coronal jets (“minifilament eruptions”)

Coronal jets are seen in X-ray and EUV coronal images. They have a geyser-like appearance and can reach ~500,000 km with widths of ~8000 km, with lifetimes of ~10 minutes (Savcheva et al. 2017); these numbers are for polar coronal holes, but they are seen all over the Sun (e.g., Shpigel et al. 1996). Recent investigations indicate that many, if not all, coronal jets result from eruptions of small-scale filaments (“minifilaments”) of size ~8000 km (Sterling et al. 2015). (Figure 1.) These jets have a brightening at their base (jet-base bright point, JBP), analogous to flares, and the JBP/minifilament eruptions occur on magnetic neutral lines (e.g., Huang et al. 2012, Panesar et al. 2016). (Figure 2) Large-scale filament eruptions. Jet-producing erupting filaments have sizes ~8000 km, and based on observed rates and lifetimes in polar coronal holes (Savcheva et al. 2007), we estimate that there are ~5 jets occurring on the Sun on average at any given random time.

Large-Scale Eruptions (“filament eruptions”)

By “large-scale eruptions”, we mean the typical magnetic eruptions that make often result in coronal mass ejections (CMEs) and solar flares. Typically these begin with eruption of a filament, which range in size 3 x 10⁴ - 1 x 10⁵ km (Berger et al. 2003), from a magnetic neutral line. A flare then grows along the neutral line from which the filament erupted. We can make a rough estimate for the number of large-scale eruptions on the Sun at any given time in this way: there are 0.5-5 CMEs/day (Rust et al. 2004; Chen et al. 2011) and the duration of a strong flare is ~20 minutes (Sterling et al. 2002): from this, we deduce that there are ~0.03 CME-producing filament eruptions occur on the Sun at any given time. (That is, at the Sun randomly ~0.01-0.3 independent times a day’s size scale should show on average one large-scale filament eruption occurring.)

References

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References

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Figure 2. Distribution of released energy of erupting filament features at the base of solar jet eruptions and the JBP in solar jet eruptions. Right, middle, and left points are for filament eruptions of length ~500 km and typical solar flares, minifilament eruptions of length ~8000 km and typical CMEs, and large-scale erupting features, respectively, where the JBP in (g) is of a weaker jet in the background. North is upward and west is to the right.

Figure 3. Sample of minifilaments seen in Hinode/SDO CIV images, and the production of spicules by microfilament eruptions might explain why spicules spin, as do coronal jets. The expected small-scale neutral lines from which the microfilaments would be expected to erupt would be difficult to detect reliably with current instrumentation, but might be apparent with instrumentation of the near future. A full report on this work appears in Sterling and Moore 2016, ApJL, 829, L9.

Figure 1. Intensity of filament eruption leading to a coronal jet (modified version of Sterling et al. 2015). Figure 2. Black arrows show magnetic field lines, with arrows indicating polarity. Red field lines indicate field that been under reconnection. Reconnection, with red curve drawing reconnection evolution. (c) indicates a reconnection front in contrast colored large arc adjacent to a large blue closed loop. All over surging arc open field. By design the agent triggers the filament eruption from the large scale filament eruption. Reconnection of video line on the outer edge of the CaII image, with black arrow orientation, also for clarity with the reconnection front in the middle of the CaII image. Figure 2. Black arrows show magnetic field lines, with arrows indicating polarity. Red field lines indicate field that been under reconnection. Reconnection, with red curve drawing reconnection evolution. (c) indicates a reconnection front in contrast colored large arc adjacent to a large blue closed loop. All over surging arc open field. By design the agent triggers the filament eruption from the large scale filament eruption. Reconnection of video line on the outer edge of the CaII image, with black arrow orientation, also for clarity with the reconnection front in the middle of the CaII image.