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 “minifilaments” (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-recognized 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 microfilament erupts, corresponds to larger-scale eruptions that occur at the neutral line from which the large-scale filament erupts. Large-scale eruptions are relatively uncommon (~1/day) and occur with relatively large-scale erupting filaments (~10^5 km long). Coronal jets are more common (~100/day), but occur from erupting minifilaments of smaller size (~10^4 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 km). 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, minifilaments, and the putative microfilaments, results in a size distribution that can be fit with a power-law within the estimated uncertainties. The counterparts of the flares of large-scale eruptions and the JBs of jets might be weak, pervasive, transient brightenings observed in Hinode/CaII 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.

Overview
At least many coronal jets appear to be miniature versions of large-scale eruptions. Specifically, both result from eruption of filament-like features: normal filaments in the case of large-scale eruptions, and smaller “minifilaments” in the case of coronal jets. Also, both phenomena have brightenings at their bases: solar filaments in the flares, and JBs at the base of the coronal jets. This suggests that the two phenomena, filament eruptions and flares on the one hand, and coronal jets and JBs on the other, are the same phenomena but on different size scales.

Besides size scale, another difference between these two features is their occurrence rate: the number of coronal jets is much larger than the number of large-scale eruptions. Spicules are also transient, jet-like phenomena, and are far more common than either large-scale eruptions or coronal jets. And, recent intriguing ideas for their formation not withstanding (e.g. DeRosa et al. 2004, Martínez-Sykora et al. 2017, see, e.g., Beiersberger 1998 and Sterling 2005 for older ideas), a full explanation for their cause is still outstanding.

A natural question to ask is whether the relationship between size-scale and occurrence rate of the relatively small-number of large-scale eruptions and the larger number of smaller-scale coronal jets, extends to the much-more frequent and smaller-scale spicules. We explore this idea by plotting the size scales (or expected size scales) of the filament-like features the erupt to form CMS, JBs, and spicules, against the measured occurrence rate of CMS, jets, and spicules. We then see whether this relationship between these quantities can fit by a power-law.

Large-Scale Eruptions (“filament eruptions”)
By “large-scale eruptions,” we mean the typical magnetic eruptions that make up most large-scale solar mass ejections (CMEs), and solar flares. Typically these begin with eruption of a filament, which range in size 3-10°×1.0-2.0° (Matsushita et al. 2005), 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 0.5-6 CMEs/day (Kosch et al. 2004; Chen et al. 2011), and the duration of a strong flare’s duration is ~20 min (Sterling et al. 2002); from this, we deduce that there are ~0.03 CME-producing typical filament eruptions occurring on the Sun at any time. (That is, looking at the Sun randomly 10:00-11:00 independent times a day’s time scale should show on average one large-scale filament eruption occurring.)

Coronal Jets (“minifilament eruptions”)
Coronal jets are seen in X-ray and EUV coronal images. They have a geyser-like appearance and can reach ~50,000 km with widths of ~800 km, with lifetimes of ~10 min (Schwenn et al. 2007); these numbers are for polar coronal-hole jets, but they are seen all over the Sun (e.g., Shimojo et al. 1996). Recent investigations indicate that many, if not all, coronal jets result from eruptions of small-scale filaments (“minifilaments”) of use ~800 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 jets/minifilament eruptions occur on magnetic neutral lines (e.g. Huang et al. 2007; Panesar et al. 2010). We find that the size scales of these “minifilament” eruptions closely match the size scales of large-scale eruptions, i.e., they erupt from minifilaments of length comparable to the width of observed spicules (~300 km). In the case of “filament eruptions” from solicitation panels, we use size scales of erupting mini filaments with 0.03 CME-producing typical filament eruptions occurring on the Sun at any time. (That is, looking at the Sun randomly 10:00-11:00 independent times a day’s time scale should show on average one large-scale filament eruption occurring.)

Results and Discussion
Figure 2 shows the number of eruption of filament-like features on the Sun at any given time, plotted against the size of the filament-like features, where the numbers are determined/estimated in the previous panels. We find that, within the uncertainty ranges (Sterling & Moore 2016), the values all fall on the same power law line. This supports that the filament-like eruption mechanisms that drive large-scale eruptions and coronal jets could drive ~10% of small-scale eruptions, and still be consistent with fitting the power-law distribution. A counterpart of the putative spicule-producing microfilament eruptions to the flares and the JBs of respectively, filament and minifilament eruptions, might be brightenings sometimes seen in near-Icelandic images (Figure 3).

Spicules (“microfilament eruptions”?)
Spicules are extremely common chromospheric jet-like features reaching heights ~5000 km. We speculate that, if they result from even smaller-scale eruptions of filament-like features ("microfilaments"), the erupting-microfilaments would have widths similar to spicule widths, or ~100 km (Pereira et al. 2012). Historical measurements place the number of spicules on the Sun at any given time as ~9 (Tide 1995-2000) or 10^4 (Abyai 1959, Lynch et al. 1977). We then see whether this relationship between these quantities can fit by a power-law.

References
https://ntrs.nasa.gov/search.jsp?R=20170012351 2019-05-31T05:09:45+00:00Z