Magnetic Flux Cancellation as the Trigger Mechanism of Solar Coronal Jets

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Abstract

Coronal jets are narrow eruptions in the solar corona, and are often observed in extreme ultraviolet (EUV) and X-ray images. They occur everywhere on the solar disk: in active regions, quiet regions, and coronal holes (Raouafi et al. 2016). Recent studies indicate that most coronal jets in quiet regions and coronal holes are driven by the eruption of a minifilament (Sterling et al. 2015), and that this eruption follows flux cancellation at the magnetic neutral line under the pre-eruption minifilament (Panesar et al. 2016). We confirm this picture for a large sample of jets in quiet regions and coronal holes using multithermal extreme ultraviolet (EUV) images from the Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) and line-of-sight magnetograms from the SDO/Heliospheric Imaging Magnetograph (HMI). We report observations of 60 randomly selected jets. We have analyzed the magnetic causes of these eruptions and measured the base size and the duration of each jet using routines in SolarSoft IDL. By examining the evolutionary changes in the magnetic field before, during, and after jet eruption, we found that each of these jets resulted from minifilament eruption triggered by flux cancellation at the neutral line. In agreement with the above studies, we found our jets to have an average base diameter of 7600 ± 2700 km and an average jet-growth duration of 9.0 ± 3.6 minutes. These observations confirm that minifilament eruption is the driver and that magnetic flux cancellation is the primary trigger mechanism for nearly all coronal hole and quiet region coronal jet eruptions. This study was carried out using multithermal (171 Å, 171 Å, 193 Å, and 211 Å) EUV images from SDO/AIA to study the evolution of the minifilament and jet spine. SDO/AIA produces high-resolution (0.6” pixel⁻¹) full-sun images in seven EUV wavelengths (Lemen et al. 2012). We primarily used 171 Å and 193 Å imagery. We found that the majority of jets were best seen in 171 Å (peak temperatures: 600,000 K: Lemen et al. 2012). We used 193 Å (peak temperatures: 1,500,000 K) and 211 Å (peak temperatures: 2,000,000 K) images to look at jets in coronal holes. To analyze the magnetic field evolution, we used magnetograms from SDO/HMI (Scherrer et al. 2012). This instrument produces high-resolution (0.5” pixel⁻¹) line-of-sight magnetograms which allow us to observe the photospheric magnetic field along the jet-base region. We use magnetograms to track the evolution of the photospheric magnetic flux in the jet-base region from approximately 5 hours prior to until 1 hour after jet eruption. For our study, we randomly selected 60 coronal jets in quiet regions and coronal holes using theNeuherre software (Mueller et al. 2017). We found 30 jets in quiet regions and 30 in coronal holes. We analyzed SDO/AIA and SDO/HMI for all 60 jets from the Joint Science Operations Center (JSOC): 2 hours of AIA data at a 1 minute cadence and 6 hours of HMI data at about a 5 minute cadence of a 200x150’’ area surrounding each jet. We then differentiated all of the HMI and AIA images with respect to a particular time in order to account for solar rotation. With the derotated data, we selected a smaller field of view for each event that focuses itself on the jet base region to center our measurements on and make movies of each jet.

Results

We have examined the evolution of 60 on-disk quiet-region and coronal hole jets using EUV images from SDO/AIA to track the structure of the jets as well as using line-of-sight magnetograms from SDO/HMI to analyze the magnetic field evolution of the jet base region. In this poster we show two detailed examples of coronal jets in one quiet region jet and figure 4 (coronal hole jet). Both jets exhibit a clear minifilament at the neutral line (figure 1a) and figure 4(a) prior to onset. The white boxes in figure 1(c-h) and figure 4(h) show the area in which we quantitatively measured the magnetic flux through time. We were careful to be aware of the measured magnetic flux flowing across the boundary of the box. As seen in figures 1(c-h) and 4(c-h), which display this flux through time, we find a clear pattern of flux cancellation before and during the eruption of both the quiet region and coronal hole jets. We confirmed this observation with the rest of the 60 jet sample. As the opposite polarity magnetic flux patches are cancelling at the neutral line (see figures 1(e-h) and 4(e-h)), the field enveloping the minifilament (minifilament field) destabilizes and begins to erupt (see figure 3(b)). This reconnection then produces the jet bright point (white arrow in figure 1(c) and figure 4(c)) at the neutral line. As the eruption continues, the minifilament field goes through external reconnection with the surrounding magnetic field (represented by the upper star in figure 3(b,c)), allowing the minifilament plasma to flow along that field line and become a part of the resulting jet spine (figure 3(c)). We find that the triggering mechanism for all 60 jets eruptions is flux cancellation, here shown by the two examples in figures 1 and 3. This observation is consistent with the findings of Panesar et al. (2016), who observed flux cancellation in a sample of 10 quiet-region coronal jets. Additionally, we present measurements of base width and duration for all 60 jets. Jet base width was measured by taking the average of three distinct measurements across the base in jet 171 at a 1 minute prior to jet spine eruption. By doing so, we found the average jet base 11A to be 7600 ± 2700 km. Jet duration was measured in 171 A from the initial brightening of the jet base spine to the瞬间 maximum. The jet's height in this sample had an average duration of 9.0 ± 3.6 minutes.

Conclusion

We report the trigger mechanism of 60 randomly selected, on-disk solar coronal jets in quiet regions and coronal holes, as well as the duration and base width of each jet. From our observations of the magnetic flux behavior of coronal jets in quiet regions and coronal holes, we find that prior to each jet eruption, a reconnection is present at the neutral line. This reconnection occurs due to continuous flux cancellation at the neutral line. Additionally, we find the average base width of 7600 ± 2700 km for our jets. We also find the 60 jets to have an average duration of 9.0 ± 3.6 minutes.

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Figure 1: Quiet region jet observed on 2016 November 25. Panels (a)-(d) show 171 Å intensity images. The red arrow in panel (a) points to the minifilament. The blue arrow in panel (b) designates the time of jet onset (16:09 UT).

Figure 2: Flux cancellation plot for 2016 November 25. Panels (a) and (b) show HMI magnetogram images of the same region. The boxed areas in panels (a) and (b) outline the measured flux plotted in figure 3. The green dashed line in panel (b) roughly outlines the magnetic neutral line where the magnetic fields meets prior to eruption.

Figure 3: From Panesar et al. (2016), this diagram shows the evolution of a coronal jet eruption with the rectangular box representing the solar surface and the ellipse representing both the positive and negative polarity magnetic flux patches. The blue line represents the magnetic flux which flows through the box and the red line represents the reverse polarity magnetic flux patch ($B_r$) within the box. External reconnection produces new field lines represented by the red lines in panel (c) including the bi-reaching red field line along which the jet escapes, forming the jet spine.

Figure 4: Evolution of a coronal hole jet observed on 2017 January 2. Panels (a)-(d) show 171 Å intensity images. The red arrow in panel (a) points to the minifilament. The blue arrows in panel (b) designate the jet spine next to the erupting filament. Panels (c) and (d) show HMI magnetogram images of the same region. The boxed areas in panels (c) and (d) outline the measured flux plotted in figure 5. The green dashed line in panel (b) roughly outlines the magnetic neutral line where the magnetic fields meets prior to eruption.

Figure 5: Flux cancellation plot for 2017 January 1. Panels (a) and (b) show 171 Å intensity images. The red arrow in panel (a) points to the minifilament. The white arrow in panel (b) shows that the bright point (BFP). The blue arrow in panel (c) indicates the jet spine next to the erupting filament. Panels (c) and (d) show HMI magnetogram images of the same region. The boxed areas in panels (c) and (d) outline the measured flux plotted in figure 6. The green dashed line in panel (d) roughly outlines the magnetic neutral line where the magnetic fields meet prior to eruption.

Figure 6: Histogram displaying the jet base width in kilometers of all 60 coronal jets. Average base width: 7600 ± 2700 km.

Figure 7: Histogram displaying the duration of jets in minutes from coronal to maximum jet spine at all 60 coronal jets. Average duration: 9.0 ± 3.6 minutes.