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/Helioseismic and Magnetic Imager (HMI). We report observations of 60 randomly selected jet eruptions. We have analyzed the magnetic cause 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.

Background

Solar coronal jets are narrow, short-lived eruptions that occur frequently throughout the entire solar disk (Raouafi et al. 2016). Quiet region coronal jets, and those on the edge of active regions. These eruptions are often observed in extreme ultraviolet (EUV) and X-ray emission (Raouafi et al. 2016). Previous EUV observations by Panesar et al. (2016) have observed an average base size of 17,000 ± 600 km and an average jet duration of 12 minutes. Recent studies indicate that most coronal jets in quiet regions (Panesar et al. 2016) and coronal holes are driven by the eruption of a minifilament (Sterling et al. 2015). Because Sterling et al. (2015) only looked at jets near the limb, they had no conclusive results regarding the magnetic origin of these minifilaments. This study by Panesar et al. (2016) followed this by investigating the magnetic origin of 10 coronal jets and observed a pattern of flux cancellation at the magnetic neutral line prior to the formation of a minifilament. Here we seek to confirm this observation of jet eruption triggering by flux cancellation with a larger sample of 60 jets.

Results

We have examined the evolution of 60 on-disc 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 paper, we show two detailed examples of coronal jets in figure 1 (quiet region jet) and figure 4 (coronal hole jet). Both jets exhibit a clear minifilament at the neutral line (figure 1(a) and figure 4(a)) prior to onset. The white boxes in figure 1(e-h) and figure 4(h) show the area in which we quantitatively measured the minor magnetic flux through time. We were careful to avoid parts of the measured minor flux flowing across the boundary of the box. As seen in panels 1(e) and 4(f), 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)).

Conclusion

We report the trigger mechanism of 60 randomly selected, on-disc 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 neutral line is present at the neutral line. This minifilament eruption due to continuous flux reconnection at the neutral line. Additionally, we find an 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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References


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 black arrow in panel (b) indicates the jet site prior to the eruption. The white arrow in panel (c) shows the minifilament bright point. The blue arrow in panel (d) indicates the bipolar prominence. The white arrow in panel (e) points to the minifilament. The white arrow in panel (f) shows the jet spire. By doing so, we are able to confirm the reconnection of the magnetic field lines at the neutral line.

Figure 2: Flux cancellation plot for 2016 November 25. The horizontal line marks the minority (negative) flux within the box in figure 1(a) as a function of time. The red line designates the time of jet onset (20:17 UT).

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 ellipses representing the positive and the negative polarity magnetic flux patches. The flux line represents the magnetic flux line whose ends are located by the magnetic field lines shown by the red arrows (source) and the negative minority flux patch (sink). The red arrows in the figure (a,b) show the reconnection between the magnetic flux lines. This reconnection begins at the neutral line (figure 3(a)) and continues along the field line until the jet erupts. This minifilament eruption takes place at the neutral line and results in internal reconnection within the minifilament field (represented by the lower star in figure 3(b,c)). This reconnection then produces the jet bright point (white arrow in figure 3(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 spire (figure 3(c)).

Figure 4: Evolution of a coronal hole jet observed on 2017 January 2. Panels (a,c) show 171 Å intensity images. The red arrow in panel (a) points to the minifilament. The white arrow in panel (c) shows that bright point (JB2). The blue arrows in panel (a) indicate the jet site prior to the eruption. The white arrow in panel (c) shows the jet spire. By doing so, we are able to confirm the reconnection of the magnetic field lines at the neutral line.

Figure 5: Flux cancellation plot for 2017 January 2. Plots the minority (negative) flux within the box in figure 4(a,b) as a function of time. The red line designates the time of jet onset (16:09 UT).