Solar Orbiter and SDO Observations of an On-Disk Active Region Coronal Jet

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Abstract

Solar coronal jets are narrow, beam-like eruptions that occur in the solar corona. Jets occur in all types of solar environments, such as active regions (ARs), quiet regions (QRs), and in and around the edges of coronal holes (Panesar et al. 2018). Studies by Panesar et al. (2016) and Sterling et al. (2016) indicate that minifilament eruptions are triggered by flux cancellation at the underlying neutral line, minifilament eruptions drive coronal jets, and a jet bright point (JBP) appears on the neutral line in the wake of the erupting minifilament. We confirm this picture by analyzing a solar coronal jet at the edge of an active region on March 29, 2023, from 13:50 to 14:40. We used high-resolution and high temporal cadence extreme ultraviolet (EUV) images from the Extreme Ultraviolet Imager (EUI) onboard Solar Orbiter, as well as EUV images from the Atmospheric Imaging Assembly (AIA) and Helioseismic and Magnetic Imager (HMI) line-of-sight magnetograms onboard Solar Dynamics Observatory (SDO). We studied the jet's behavior by making movies of the jet with Python/SunPy for each instrument. With EUI and AIA data, we observed the initial lift-off of the minifilament, its unwinding, and final eruption. Its spire extends into the corona, and a bright JBP appears at the location of the erupting minifilament (Sterling et al. 2016). Before and during the minifilament eruption, the HMI magnetograms show opposite-polarity magnetic flux patches that converge and cancel at the neutral line under the JBP. These results support the idea that the eruption of small-scale filaments drives solar coronal jets and that minifilaments form due to magnetic flux cancellation.

Background

Solar coronal jets are long, narrow eruptions that occur in the solar corona. Jets are best seen in extreme ultraviolet and X-ray images and consist of a spire extending into the corona and a bright point at the edge of the base (JBP). Jets were first observed in detail by Yohkoh's Soft X-ray Telescope (SXT) (early 1990's), and in more detail by Hinode's X-ray Telescope (XRT) (early 2000's). For reviews of jets, see, e.g., Shimojo et al. 2000, Raouafi et al. 2016, Sterling et al. 2018. Early studies suggested that jets were a result of magnetic flux emergence. However, with the launch of the Solar Dynamics Observatory (SDO) in 2010 with its Atmospheric Imaging Assembly (AIA) and Helioseismic and Magnetic Imager (HMI), it was discovered that many coronal jets are driven by magnetic flux cancellation at the jet base resulting in minifilament eruptions (Panesar et al. 2016, Sterling et al. 2015). Jets in ARS, however, sometimes do not show clear erupting minifilament (Sterling et al. 2016). Here we test these ideas for an AR jet using higher-resolution and cadence images from the Extreme Ultraviolet Imager (EUI) on recently launched Solar Orbiter (SolO) satellite.

Instrumentation/Data

SolO/EUI	SDO/HMI	SDO/AIA
• Wavelength: 174 Å	• Temporal cadence: 45s	• Wavelength: 171 Å
• Temporal cadence: 3s	• Pixel size: 0.5"	• Temporal cadence: 12s
• Pixel size: 0.49"	• Distance from sun: 1 AU	• Pixel size: 0.6"
• Exposure time: 1.65s		• Exposure time: 1.99s
• Distance from sun: 0.4 AU		• Distance from sun: 1 AU

We studied EUV images from SDO/AIA and SolO/EUI to investigate jet behaviour and studied line-of-sight magnetograms from SDO/HMI to investigate jet formation. We used SolO/EUI High-Resolution Imager (HRI) 174 Å images, SDO/AIA 171 Å full-disk images, and HMI full-disk magnetograms. AIA and HMI data were cropped to view an on-disk active region and jet within the region. Because SolO is less than half as far from the sun than SDO, SolO sees events about 5 minutes before SDO does. SolO orbits the sun and sat 33° above the solar equator at the time of the jet. SDO orbits Earth and the angle between SDO and SolO was 3.5° at the time of our observations. All data was acquired though Python/Sunpy Fido search. SDO/AIA/HMI data was found through the Virtual Solar Observatory (VSOClient) and SolO/EUI data was found through the official repository of Solar Orbiter (SOARClient). We used Python/Sunpy to make movies of each instrument's data from 13:40 to 14:50 using sunpy.map. The results are shown bellow.

Observations

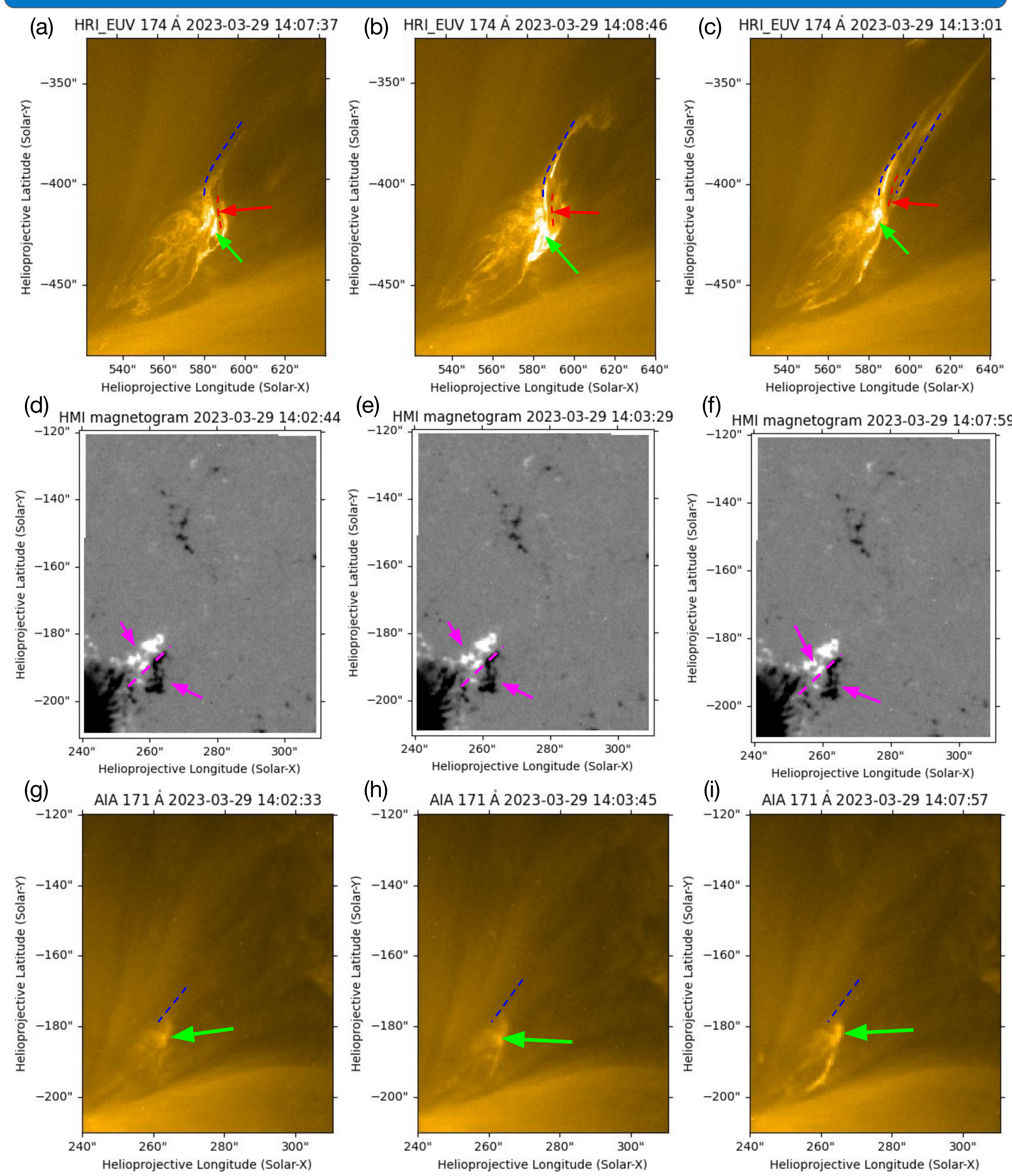

Fig. 1. Active region jet observed on March 29, 2023. (a)-(c) shows SolO/EUI images at 174 Å. (d)-(f) shows SDO/HMI magnetogram images. (g)-(i) shows SDO/AIA images at 171 Å. In panels (a)-(c), the red arrow and dashed line point toward and follow the minifiliment, the green arrow points toward the JBP, and the blue dashed line follows the spire. In panels (d)-(f), the pink dashed line represents the neutral line and the arrows point in the direction of convergence. In panels (g)-(i) the green arrow points toward the JPB and blue dashed line follows the spire. Each image in each column ((a), (d), (g)), ((b), (e), (h)), and ((c), (f), (i)) occur at approximately the same time. Note: SDO see the eruption 5 minutes after SolO.

Results

After examination of the active region solar jet in SolO/EUI for 50 minutes, the jet appears to lift off three times (shown in fig. 1 (a)-(c)). The spire, JBP, and minifilament are clearly seen in all three images, and unwinding is present over 14:0922-14:10:01 as seen in the difference between fig. 1 (b) and (c). The minifiliment erupts from 14:12:19 to 14:13:51 and is most clearly seen in fig. 1 (c). After examination of SDO/HMI data over the same time period, we notice that minifilament resides above the magnetic neutral line between majority-polarity flux (negative) and minority-polarity flux patch (positive). Although it is difficult to see over such a short period of time, the magnetic flux patches are seen to converge towards the neutral line and cancel with each other(seen in fig 1. (d)-(f)). SDO/AIA images support EUI images, although the jet's features are not as clearly seen. Still, the JBP and spire are visible, and eruption times are consistent with EUI observations. These results support the idea that the eruption of small-scale filaments drives solar coronal jets and that minifilaments form and erupt due to magnetic flux cancellation. In the schematic shown below, Panesar et al. 2016 describes the mechanisms behind minifilament formation and eruption in further detail.

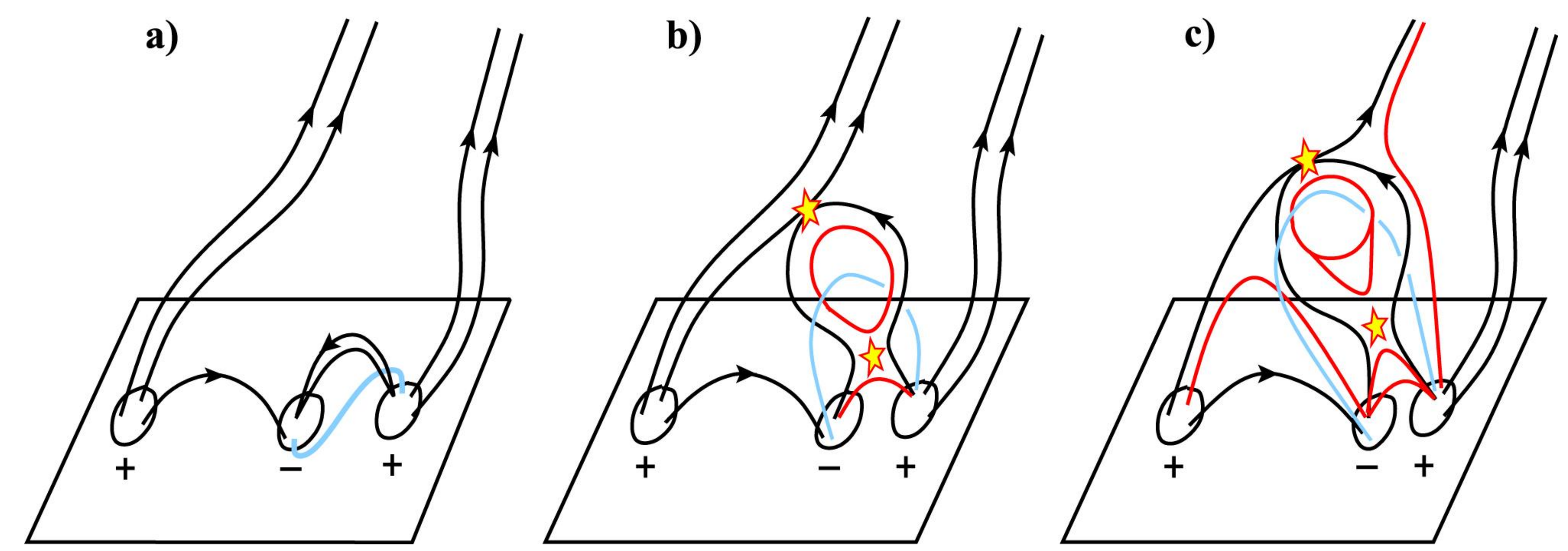

Fig. 2. Coronal jet evolution and formation schematic from Panesar et al. 2016. Black lines and rectangular box represents the magnetic field and the solar surface. Negative black ovals represent negative minority flux patch and positive black ovals represent positive majority flux patch. Flux cancellation is shown in the two rightmost ovals. The blue line in panels (a), (b), and (c) represents the sheared and twisted field holding the minifilament and the black lines above it represent the field enveloping the minifilament field. Yellow/Red stars show locations where reconnection takes place. Red lines in panels (b) and (c) represent newly reconnected field, which results from the internal (lower star) and external (upper star) magnetic reconnection of the field enveloping the erupting twisted flux rope. The far-reaching red line in panel (c) shows the newly reconnected open field along which the jet escapes.

Conclusion

In QR and CH, most jets form via flux cancellation, leading to minifilament eruption, making the jet spire and heating the jet base (Panesar et al. 2016, Sterling et al. 2015). In ARs jets, erupting minifilaments are sometimes not obvious (Sterling et al. 2016). Here, we have looked in detail at an AR jet using high-resolution and cadence EUI images and HMI magnetograms to see that this jet fundamentally behaves like most QR and CH jets.

References and Acknowledgements

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