Scrutiny of the Feet of Twenty Jetlets in EUV Coronal Plumes for Minority-polarity Magnetic Flux

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Abstract

Coronal jets are magnetically channeled narrow eruptions of plasma into the solar corona. Most jets are made by minifilament eruptions that are prepared and triggered by cancellation of opposite-polarity magnetic flux (Panesar et al. 2016). Jetlets are small-scale jets, first found by Raouafi & Stenborg (2014) when studying the bases of coronal plumes. Later, Panesar et al. (2018) found that jetlets also occur during flux cancellation at the edges of magnetic network lanes far from plume bases. They found their jetlets to have average base widths of 4000 km, average lifetimes of 3 minutes, and average speeds of 70 km/s. Their results indicate that jetlets are miniature versions of larger coronal jets. Here, we analyzed 20 plume-base jetlets using coronal EUV imaged data from the Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) and line-of-sight magnetograms from the SDO/Helioseismic and Magnetic Imager (HMI). The jetlets occurred at the (negative-polarity) bases of two plumes, each in a different coronal hole on the central disk. We made movies having the highest cadence possible – 12 s for AIA 171 Å images and 45 s for HMI magnetograms – to closely examine the evolution and polarity structure of the magnetic flux at the base of each jetlet and to estimate the jetlet's duration. The average jetlet duration was about 7 minutes. We looked for evidence of minority-polarity (positive) flux at the base of each jetlet. When positive flux was discernible, we judged whether it was canceling. Three events have obvious canceling minority flux at the base of the jetlet, 16 possibly have canceling minority flux, and only one out of the 20 has no hint of minority flux. While it does not rule out any other scenario for jetlet production, this result is consistent with all plume-base and other network jetlets being prepared and triggered by magnetic flux cancellation, with the minority-polarity flux usually being too weak to be definitely detected by HMI.

Introduction

Jets are thin columns of plasma that erupt into the solar corona, most of which occur as a result of magnetic flux cancellation (Panesar et al., 2016). Raouafi & Stenborg discovered jetlets in 2014, which were at the base of coronal plumes and appeared to be jets, but smaller. There have been some studies in the past done to investigate whether jetlets originate from magnetic flux cancellation, too. In 2018, Panesar et al. conducted a study using IRIS and SDO data which found that 9 of the 10 jetlets they studied had some evidence of flux cancellation at the base. Similarly, in 2019, Panesar et al. used sounding rocket (Hi-C) images of six jetlet-like events, four of which had evidence of flux cancellation. For this study, we decided to examine 20 jetlet events in December 2011 and November 2012, specifically looking for jetlet-foot flux cancellation, to either support or challenge the results of the previous work.

References

Panesar, N. K., Sterling, A. C., Moore, R. L., & Chakrapani, P. 2016, ApJL, 832, L7
Panesar, N. K., Sterling, A. C., Moore, R. L., et al. 2018, ApJL, 833,131
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Data and Methodology

Initially, our 20 jetlet events were found using Helioviewer. We noted down preliminary start/end times and images of each. To further investigate the jetlets, we used images from the Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly(AIA) and SDO/Helioseismic and Magnetic Imager (HMI). We used AIA 171 Å images because they are best for seeing plumes and jetlets. Data was downloaded via the Joint Science Operations Center (JSOC) website, at a cadence of 12s for the AIA 171 Å and 45s for the HMI magnetograms.

Our movies consisted of four panels: firstly, the AIA 171 Å images over the course of the jetlet event; then, the AIA 171 Å images again with the HMI contours overlaid; thirdly, the running difference of the AIA 171 Å images (not shown), with a 5-frame (one minute) time difference between the subtracted images; and finally, the HMI magnetograms. For all movies in December 2011, the threshold (dmin and dmax) values for AIA 171 Å were set to 50 and 1200 respectively, while for the November 2012 movies the dmin was 50 and the dmax was 400. The upper and lower HMI and contour levels varied for each movie, as we adjusted them to check for minority-polarity flux, however they all ranged from ±20-100. Prior to making movies out of the data, we derotated all of the images and normalized the AIA 171 Å images. We also used the running sum of two HMI magnetograms. The movies started either at the same time as the jetlet or a few minutes before, and all of them lasted at least 5 minutes after our initial estimate for when each jetlet ended (some of these estimates being adjusted by a few minutes after viewing the movies).

Results

Event number	Minority flux?	Estimated duration +-1 minute	App. coordinates of base	Edge or interior	HMI
Dec 1	Maybe (dimple)	7 minutes (19:08-19:15)	(19,195)	interior	100
Dec 2	Maybe (edge)	10 minutes (22:14-22:24)	(49,195)	edge	100
Dec 3	Maybe (dimple)	7 minutes (00:09-00:16)	(65,190)	interior	100
Dec 4	Maybe (dimple)	7 minutes (00:56-01:03)	(70,192)	interior	100
Dec 5	Maybe (dimple)	5 minutes (03:19-03:24)	(71,195)	interior	80
Dec 6	Maybe (dimple)	6 minutes (03:21-03:27)	(69,197)	interior	80
Dec 7	Maybe (dimple)	8 minutes (04:41-04:49)	(100,195)	interior	80
Dec 8	Maybe (dimple)	9 minutes (05:07-05:16)	(105,198)	interior	40
Dec 9	Maybe (dimple)	10 minutes (09:17-09:27)	(145,193)	interior	100
Dec 10	Yes	9 minutes (22:41-22:50)	(265,219)	edge	40
Nov 1	Maybe (dimple)	3 minutes (6:21-6:24)	(-82,390)	edge	80
Nov 2	Maybe (dimple)	7 minutes (8:09-8:16)	(-63,390)	interior	80
Nov 3	Maybe (edge)	4 minutes (8:52-8:56)	(-58,393)	edge	100
Nov 4	Maybe (dimple)	9 minutes (10:31-10:40)	(-48,393)	interior	80
Nov 5	No	5 minutes (11:26-11:31)	(-41,395)	interior	100
Nov 6	Maybe (edge)	6 minutes (11:55-12:01)	(-38,395)	edge	100
Nov 7	Yes	9 minutes (12:07-12:16)	(-32,395)	edge	40
Nov 8	Yes	6 minutes (12:19-12:25)	(-30,395)	edge	20
Nov 9	Maybe (edge)	5 minutes (13:24-13:29)	(-25,395)	edge	80
Nov 10	Maybe (edge)	9 minutes (13:36-13:45)	(-20,390)	edge	40

Table 1: A table showing the results of analyzing our jetlet events. The first column, starting from the left, labels each event. Next, we classify each jetlet as obviously having minority flux, as potentially having minority flux, or as not having any sign of minority flux. We go on to estimate the duration of the jetlet, before listing the approximate coordinates of the jetlet base. We also note whether the jetlet's foot can be found along the edge of the majority-polarity patch or within the interior. Finally, we record the HMI levels (the +- of the number listed) which we used to make these observations.

We analyzed 20 jetlet events at the base of two coronal plumes in equatorial coronal holes. 10 occurred in December 2011 (on the 16th and 17th) and 10 occurred in November 2012 (on the 4th). We used data from SDO/AIA and SDO/HMI to create movies which we then used to get estimates of the lifetimes of the jetlets as well as search for any evidence of minority-polarity magnetic flux at the base of the jetlets. We found that the average lifespan of our jetlets was 7.05 minutes and that 3 had good evidence of minority flux at the base, 16 had some evidence of minority flux at the base, and 1 had no sign of minority flux at the base. The results can be found in Table 1.

For all of our jetlets, the majority polarity was negative (black) and the minority polarity was positive (white). For those with "yes" or good evidence, we saw both positive and negative flux close to the base of the jetlet. A "maybe" or there being partial evidence means we saw both majority polarity and gray/neutral flux at the base of the jetlet- we call this a maybe because what looks like gray flux could be a sign that there is actually minority polarity flux present, and that it is too weak to be picked up by the HMI instrument. There were two types of maybes- those which were along the edge of the large patch of majority flux and overlapped with the gray flux on the outside of it, and those that were within the larger negative region, but had a "dimple" or small patch of gray flux right at the base of the jetlet. A "no" means that we could not find any sign of gray or minority flux close to the base of the jetlet, even after adjusting the HMI levels. Included below are examples of a "yes", a "maybe", and a "no." In our figures, we show the positive (green) and negative (red) contour lines of the the HMI images overlaid on top of the AIA 171 Å images.

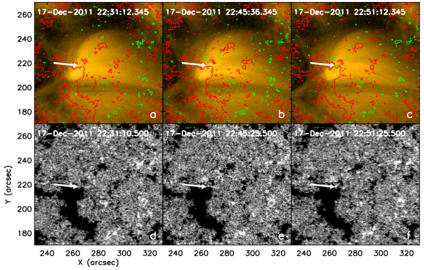

Figure 1: A jetlet event which occurred on December 17th, 2011 from 22:41-22:50. This event is identified in the table as "Dec 10". The arrows point to the base of the jetlet. Frames (a) and (d) show the region before the event, frames (b) and (e) show the region while the jetlet is active, and frames (c) and (f) show the region after the jetlet has dissipated. The jetlet is rooted at the edge of the negative magnetic flux lane and a small portion of white polarity is present at the base of the jetlet, most clearly visible in the (c) and (f) frames.

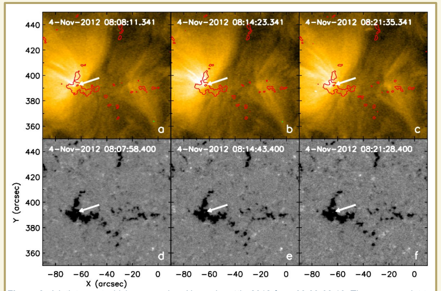

Figure 2: A jetlet event which occurred on November 4th, 2012 from 08:09-08:16. The arrows point to the base of the jetlet. Frames (a) and (d) show the region before the event, frames (b) and (e) show the region while the jetlet is active, and frames (c) and (f) show the region after the jetlet has dissipated. In this event, we can see a large portion of negative flux as well as a small "dimple" of gray flux right at the base of the jetlet. The dimple is best visible in frame (b). This could be an indicator that flux cancellation is taking place.

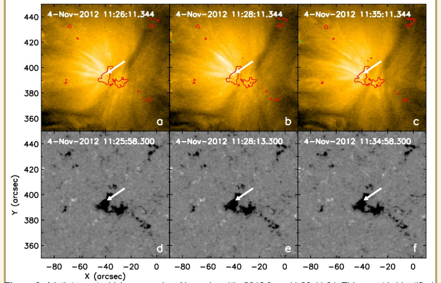

Figure 3: A jetlet event which occurred on November 4th, 2012 from 11:26-11:31. This event is identified in the table as "Nov 5". The arrows point to the base of the jetlet. Frames (a) and (d) show the region before the event, frames (b) and (e) show the region while the jetlet is active, and frames (c) and (f) show the region after the jetlet has dissipated. In this event, we can see no evidence of minority or gray flux at the base. The jetlet seems to occur on a region of solely black polarity.

Discussion and Conclusions

We have determined that of the 20 jetlet events we studied, 3 showed compelling evidence of minority flux at the base, 16 showed some evidence of base minority flux, and only one did not have any sign of minority flux. We have also found an average lifetime of about 7 minutes, which is not too far from other measurements of a jetlet's lifetime. These results are consistent with previous research which implies that magnetic flux cancellation is the catalyst for jetlets similarly to how it is for jets, as usually jetlets researched in previous studies also have at least some evidence of opposing flux at their feet.