Small-Scale Filament Eruptions Leading to Solar X-Ray Jets

Alphonse C. Sterling, Ronald L. Moore, David A. Falconer, & Mitzi Adams

(Supported by NASA's LWS program, and thanks to ISSI/Bern)
Introduction: Solar X-Ray Jets

- Observed since the Yohkoh days (Shibata et al. 1992; also Shimojo et al. 1996, etc.)
- Yohkoh (SXT) saw them mainly in active regions.
- Hinode/XRT found them to be plentiful in polar coronal holes (Cirtain et al. 2007; also Savcheva et al. 2007, etc.)
- In polar coronal holes: size~50,000 km x 8000 km; rate ~60/day (Savcheva et al. 2007).
- Often have a “hot loop” at the jet’s base.
- Often-discussed mechanism is based on emerging flux (“emerging-flux model”). (Shibata et al. 1992; see also Moore et al. 2010.)
- Many of the above ideas deduced from SXRs, and pre-SDO AIA observations.

Here we present observations of X-ray jets using high-resolution, high-cadence AIA observations, and discuss implications for the suggested emerging-flux mechanism.

A. Sterling, Apr 2015
TESS, Indianapolis
Emerging-Flux Model for (X-Ray) Jets

Supported by numerical simulations: Yokoyama & Shibata (1995), Nishizuka et al. (2008), Archontis et al. (2013), Moreno-Insertis et al. (2013), Fang et al. (2014), etc.
With this in mind, look at AIA data

- Studied 20 Hinode/XRT X-ray jets polar coronal holes during SDO period.

- These jets were randomly selected during a previous investigation (Moore et al. 2013).

- For first several jets, examined all seven SDO/AIA EUV channels.

- For remaining jets, only examined AIA 304, 171, 193, and 211Å channels (~0.05, 0.6, 1.6, and 2.0 MK, respectively).
Event 12
Event 18

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Event 3

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“Normal” Filament Eruption (TRACE)
Event 7

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“Normal” Filament Confined Eruption (AIA 304)
XRT

AIA 304

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- All 20 events show filament material ejected from location that brightens.

- “Standard” ejections (based on morphology) are sometimes fainter and harder to see than in “blowout” cases. Seem to be confined or near-confined eruptions.

- Average (over 18 cases) miniature-filament properties:
  - Length \( \sim (8 \pm 3) \times 10^3 \) km.
    (cf. “normal” filaments: \( 3 \times 10^4 \sim 1.1 \times 10^5 \) km; Bernasconi et al. 2005)
  - Pre-ejection \( <\text{velocity}> = 31 \pm 15 \) km/s.
Revised View of X-Ray Jet Formation
How About On-Disk Jets?

- Not done in this study, but...
- Adams et al. (2014) looked at on-disk coronal hole jet with AIA and HMI. Basic picture consistent with miniature filament eruption, with “flare” as the jet base brightening.
- Miniature filaments also seen by others, including Shen et al. (2012), Hong et al. (2014). (Also, Wang et al. 2000.)
- Other indications of eruptions making jets, e.g., Nisticò et al. (2009), Raouafi et al. (2010).
On-Disk Jet

Shen et al. (2012)

A. Sterling, Apr 2015 TESS, Indianapolis
What Causes Miniature-Filament Eruptions?

- Did not look on-disk in this study, due to polar view. But....

- Adams et al. (2014) found no emerging flux in the jet region. Filament erupted from location where flux canceled.

- Huang et al. (2012) and Young & Muglach (2014) found jet from location where flux canceled.

- Some others, e.g., Liu et al. (2011), Shen et al. (2012), and Hong et al. (2012) found jets from location of emerging flux+flux cancelation.
Summary

- We observed 20 Polar coronal hole X-ray jets with Hinode/XRT and SDO/AIA.
- Jets due to eruptions of miniature filaments: $<\text{length}> \sim (8\pm3) \times 10^3$ km; pre-ejection $<\text{velocity}> = 31\pm15$ km/s.
- Look like scaled-down larger-scale filament eruptions, where the jet-base hot-loop brightening corresponds to the flare.
- Roughly speaking, blowout jets correspond to ejective eruptions, and standard jets correspond to confined eruptions.
- Thus, the jet base hot loop is due to internal reconnection, not external reconnection. This may imply that brightenings due to external reconnection are inherently difficult in solar plasma (astrophysical) circumstances.
- For some on-disk EUV jets, the miniature-filament eruptions result from flux cancelation, but cannot rule out other causes. As with larger filaments, flux emergence possibly triggers some miniature-filament jet eruptions, but it does not seem to be the direct cause of the jet+hot loop for the cases we have explored here.
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Sterling & Moore (2001)

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Emerging-Flux Model for (X-Ray) Jets

(Moore et al. 2010)
Emerging-Flux Model for Blowout (X-Ray) Jets

(Moore et al. 2010)
AIA 304, HMI

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