S4-P17

Are Jets CMEs?
The Jet Response Mass Loading of Solar Wind Plasma

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Abstract

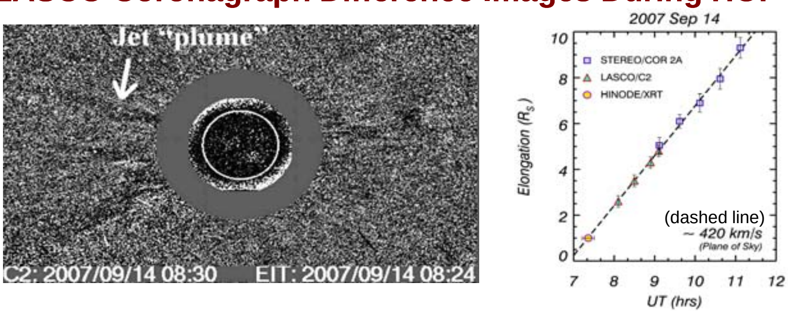
The brightest jets observed by the Hinode XRT produce high-speed responses and enhanced brightness that can be traced through coronagraph fields of view and into the heliosphere. Specifically, LASCO C2 and STEREO COR2 coronagraph images measure the coronal responses to some of the largest jets, and analyses using velocities from interplanetary scintillation (IPS) observations and from the Solar Mass Ejection Imager (SMEI) 3D reconstructions measure these jet responses in the heliosphere. We determine approximate masses and energies for these large jet responses over polar coronal hole regions, and relate them to the jet peak brightness spectrum observed by Hinode during a three-week survey period in September 2007. The analyses show that jets contribute about 2.5% of the total solar wind mass during this period. Assuming that this material outflow associated with jets continues globally throughout the solar cycle, we find that their total mass is nearly comparable to that of the globally combined CMEs. (http://ips.ucsd.edu; http://smei.ucsd.edu/)

1. Hinode X-ray Jets: HOP-2, September 5 – 22, 2007

Example: 2007 SEP 14 JET

The above sequence shows the outward motion of a jet.
Target Region: North Polar Region FoV: 1053 × 395 [arcsec x arcsec].
A total of 848 similar events were observed.

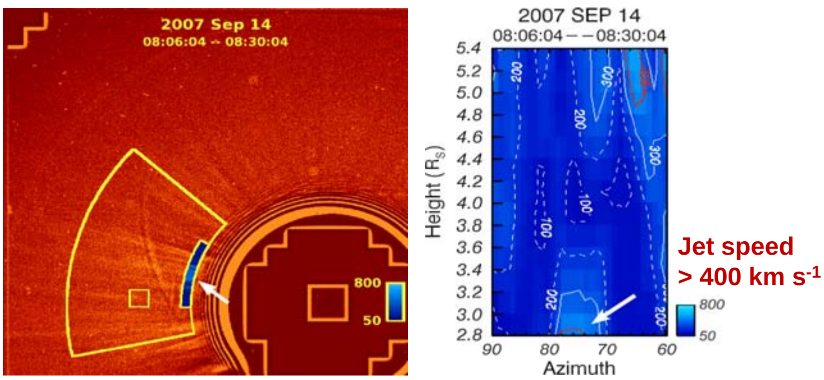
2. LASCO Coronagraph Difference Images During HOP-2



An elongation-time plot (right panel) of the jet response seen by direct measurement of successive LASCO C2 difference images (left panel). The jet response in C2 shows an outward speed of ~420 km s^{-1} on the sky plane.

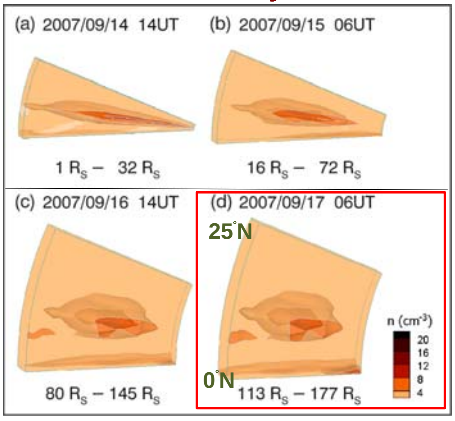
A C2 coronagraph movie can be download:
ftp://cass185.ucsd.edu/Presentations/2013_SHINE/C2_movie_20070914_Jet.wmv

3. 2D Cross Correlation of Coronal Optical Flow

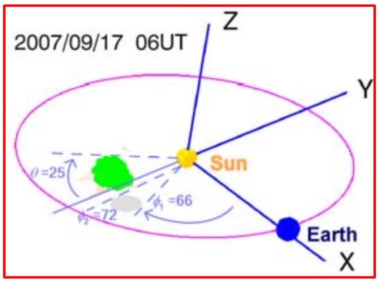


The 2D cross-correlation technique yields the speed by picking an area of sky on a coronagraph image (08:06:04 UT) and then exploring the highest correlation area on a later image (08:30:04 UT) over a portion defined by a yellow outer boundary. (Left) A LASCO C2 background-subtracted image over-plotted with the blue-colored correlation speed at 2.8Rs. (Right) A speed summary plot at different heights and azimuth angles devised by stepping the 0.2Rs correlation region outward. (Yu *et al.*, 2013a)

4. SMEI 3D Jet Analysis: 2007 SEP 14 JET



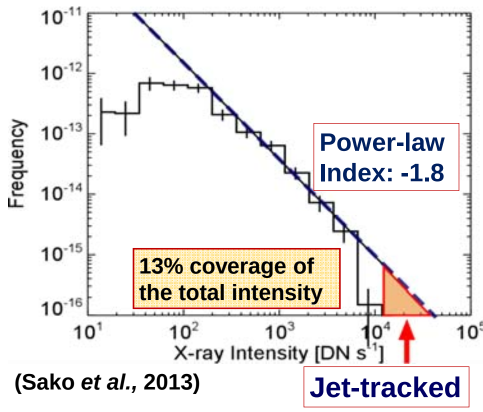
SMEI jet location with increasing solar distance (density normalized to 1AU)



SMEI 3D-reconstructed Volumetric analysis using data from panel (d), to left
Speed: ~ 525 km s^{-1}
Mass: ~10^{14}g
Energy:~10^{29}ergs

5. Jet's Mass Contribution to Solar Wind

We have tracked the solar wind density enhancements following three particularly large X-Ray jets observed in the *Hinode* XRT through the LASCO C2 and STEREO COR2A coronagraph fields of view and into the SMEI data set during September 2007. These jet responses all have similar masses ~10^{14}g and energies ~10^{29}ergs (Yu *et al.,* 2013b).



(Sako *et al.*, 2013)

(Left) A spectrum for the intensity distribution of the 844 X-ray polar jets observed by *Hinode*. The jet responses tracked here are from the brightest bin during the three-week survey period (red arrow).

The differential relationship of the jet number *N* v.s. brightness *I* is

$$\frac{dN}{dI} = aI^{-\alpha}.$$

The brightness distribution is

$$I\frac{dN}{dI} = aI^{1-\alpha}.$$

To determine the whole solar wind jet response, we extend the power law relationship to include smaller-intensity jets. The total brightness of all jets is

$$I_{total} = a\int_{I_{\min}}^{I_{\max}} dI\, I^{1-\alpha} = \frac{a}{2-\alpha}[I_{\max}^{2-\alpha} - I_{\min}^{2-\alpha}].$$

The power-law index of the intensity distribution is α=-1.8. Normalizing the brightest jet, I_{max}, to unity and defining an interval to be half of this brightness, I_{min}=I_{max}/2, we find the summed brightness of all jets from I_{min} to I_{max} is

$$I_{1/2} = \frac{a}{2-1.8}[1^{0.2} - 0.5^{0.2}] = a'[0.13].$$

This coverage is estimated to be 13% of the total intensity assuming jets are the same all over the Sun. Further, if we assume that the total X-ray brightness of the jet is proportional to the mass contained in the jet, *i.e.* mass expelled out from the corona when the X-ray jet occurred, we find that the jets contribute ~2.5% mass and ~1.2% energy to the solar wind.

6. Summary

- **The high speed responses measured in LASCO C2 coronagraph images show an association with *Hinode* jets.**
- **Jet responses measured in LASCO C2 and STEREO COR2 are also observed in the Solar Mass Ejection Imager (SMEI) analysis.**
- **We can determine the mass contained in a jet, the volume of a jet and its speed by tracing its density in the 3D SMEI analysis.**
- **The jets contribute ~2.5% mass and ~ 1.2% energy to the solar wind, as estimated by Ulysses observations.**

Primary References:

Sako, N., Shimojo, M., Watanabe, T., & Sekii, T., 2013, "A Statistical Study of Coronal Active Events in the North Polar Region", ApJ, 775, 22.

Yu, H.-S., Jackson, B. V., Clover, J. M., and Buffington, A., 2013a, "The Analysis of Polar Jet Responses Using Images From the LASCO C2 and STEREO COR 2 Coronagraphs", in Solar Wind Thirteen, 1539, 90.

Yu, H.-S., Jackson, B. V., Buffington, A., P. P. Hick, M. Shimojo, and N. Sako, 2013b, "The 3D Analysis of Hinode Polar Jets Using Images From LASCO C2, the STEREO COR2 Coronagraphs, and the Solar Mass Ejection Imager (SMEI)", submitted to ApJ.