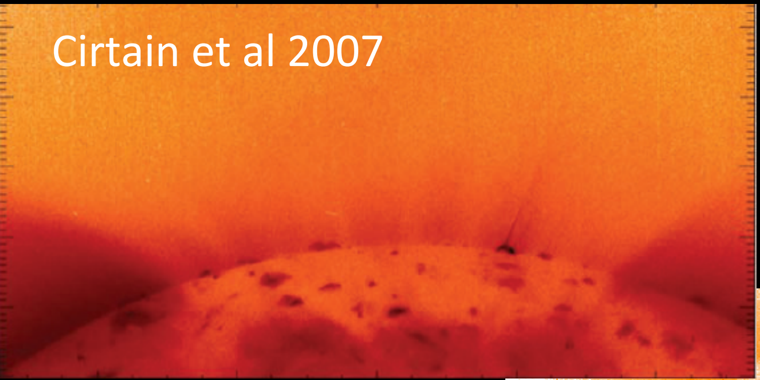
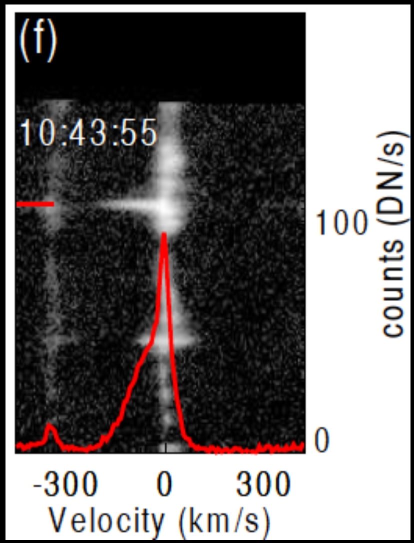
Observations of Jets

Davina Innes

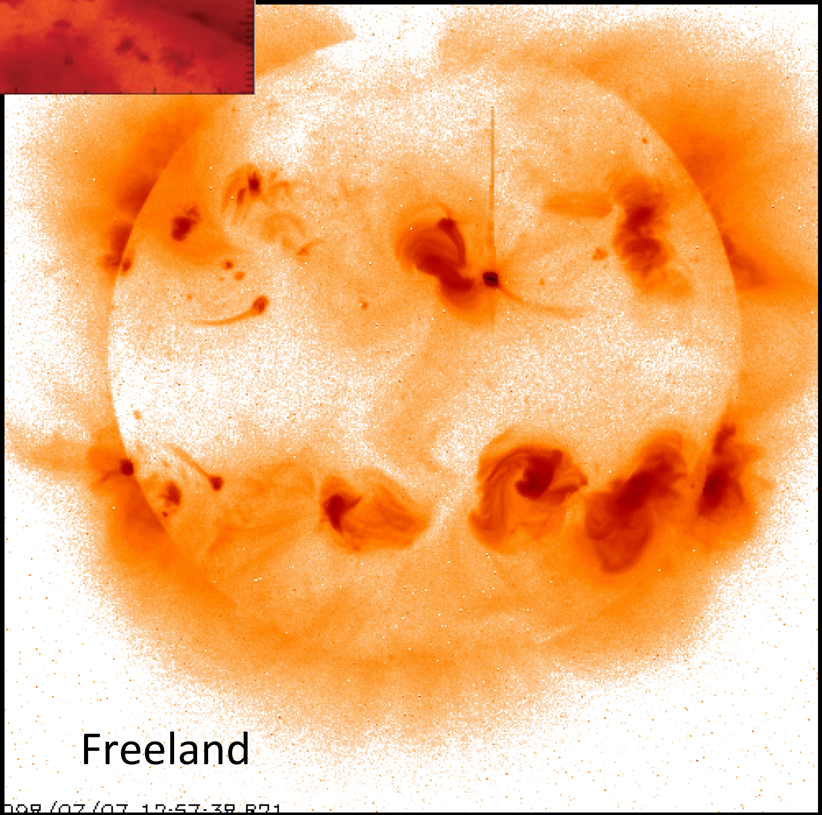
Transient….. Fast…. Collimated



Cirtain et al 2007



Innes et al 2015



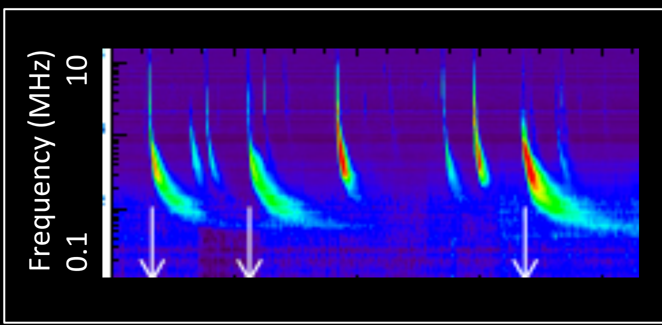
Freeland

Shibata et al 1992

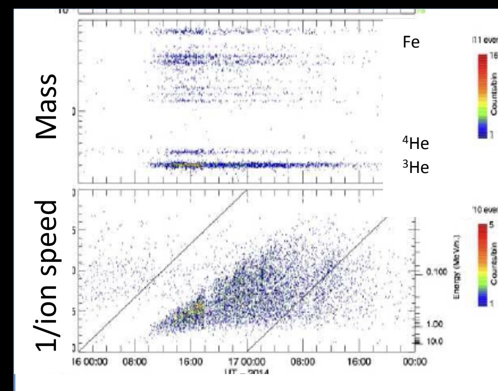
Jet categories

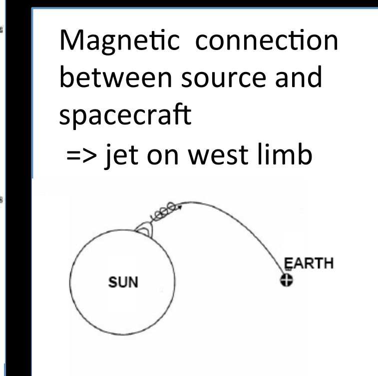
1. Interplanetary jets

Type III radio - sub-relativistic electrons



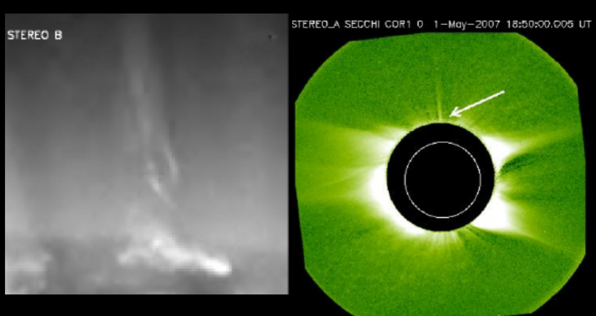
In situ - impulsive, anomalous abundances





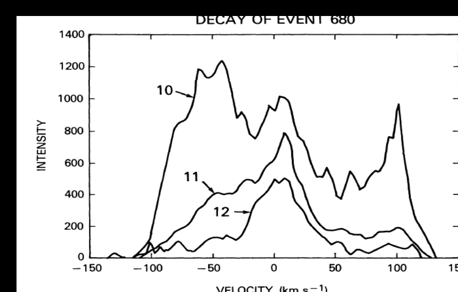
2. Coronal jets

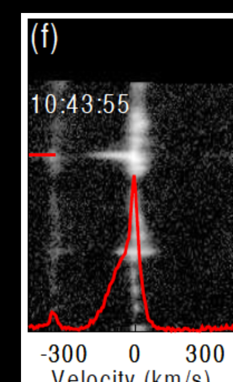
X-ray /EUV jets , macrospiclues



3. Transition region jets

Large Doppler shift events





4. Chromospheric jets

Spicules

Jet chronology

1877 Spicules – Secchi
1983 Transition region high Doppler-shift jets with HRTS – Brueckner and Bartoe
1992 X-ray jets with YOHKOH – Shibata et al. , Shimojo et al. 1986
1994 X-ray jets and radio type III – Aurass et al., Kundu et al. 1995, Pick et al. 2006
1996 X-ray and H-alpha jets – Canfield et al.
1998 Jets seen in coronagraph with SOHO – Wang et al.
1999 EUV jets with TRACE – Alexander and Fletcher
2006 X-ray jets and 3He, type III – Wang et al., Nitta et al.
2007 X-ray jets in polar coronal holes with Hinode – Cirtain et al.
2008 X-ray jets and hard X-ray, keV electrons, 3He, type III – Nitta et al., Krucker et al. 2011
2008 Helical jets with STEREO – Patsourakos et al.
2011 Jets and electron spikes – Klassen et al.
2015 EUV jets and filaments with AIA - Sterling et al.

1. Interplanetary Jets

Characteristics: Type III radio emission   Anomalous abundances   Electron spikes

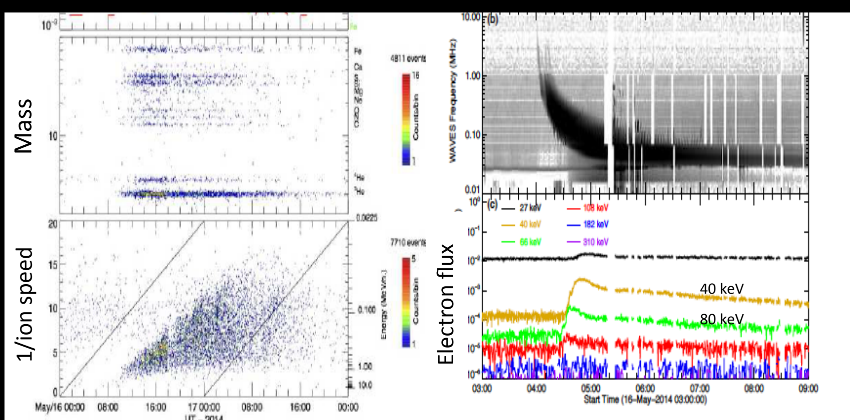
Sites: In or near active regions

1a. Isolated jets

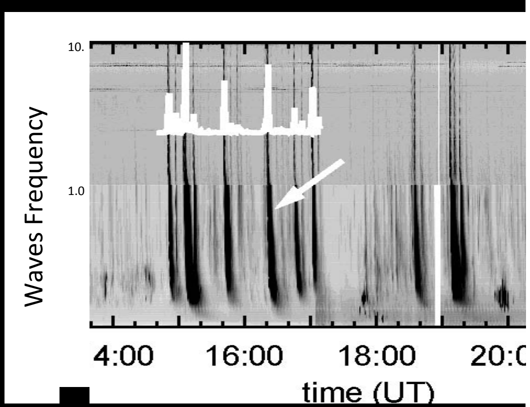
Flux emergence in a nearby coronal hole.
Flux emergence in Plage

1b. Multiple jets - Jets every 10-60 min

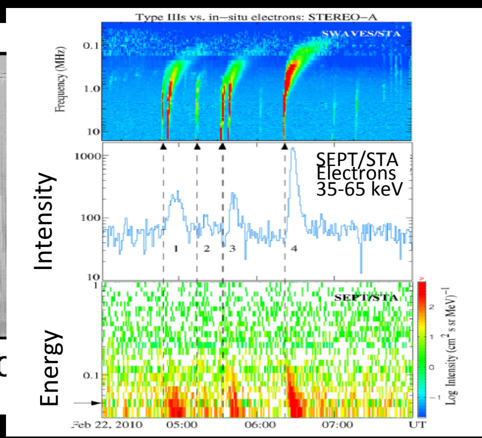
Edge of sunspots
Edge of plage?



Nitta et al. 2015

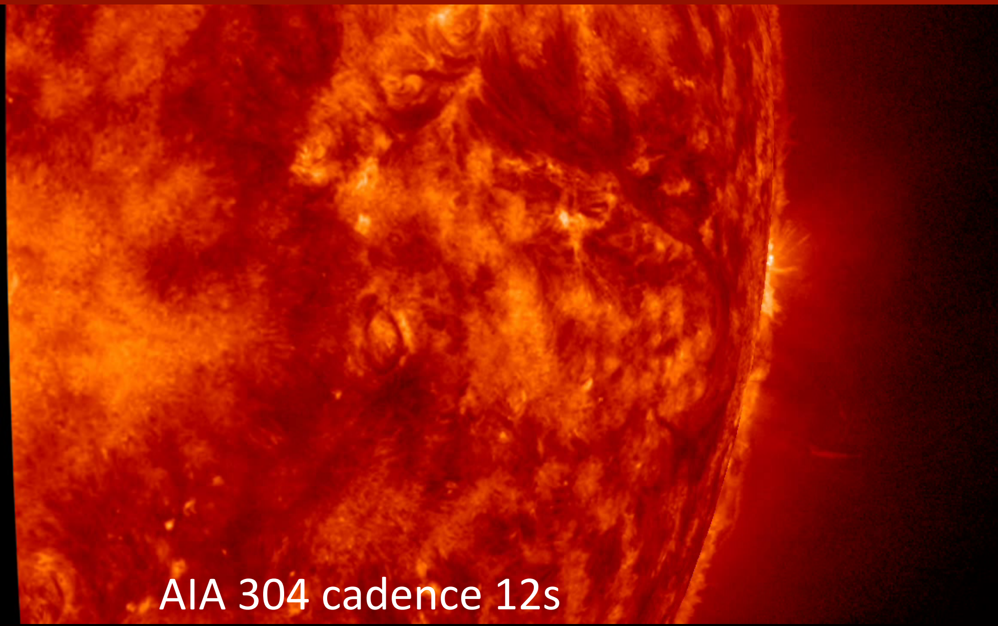


Innes et al 2011



Klassen et al 2011

1a. Isolated Jet

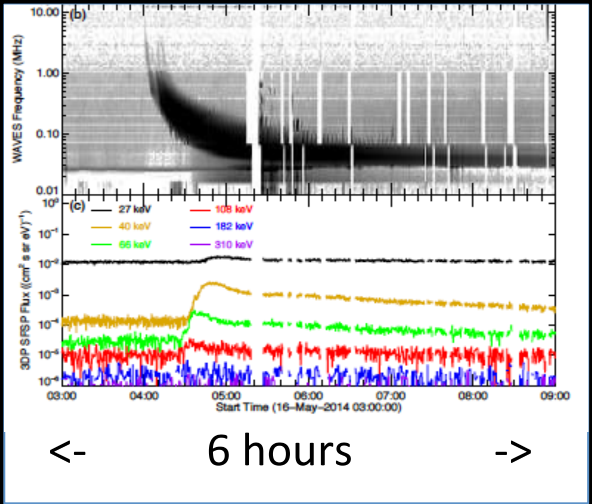


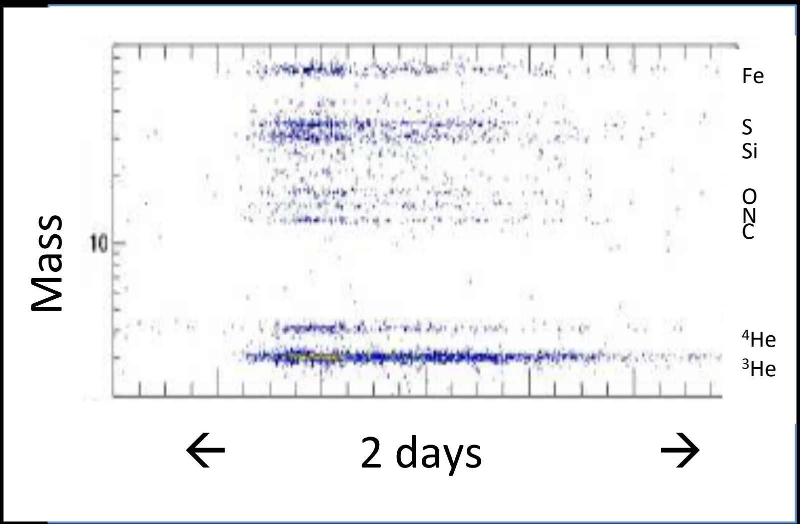
Largest ^{3}He abundance in survey of anomalous ^{3}He abundances with AIA and ACE (Nitta et al. 2015)

^{3}He/^{4}He = 15 (5x10^4 fast wind)

Single type III

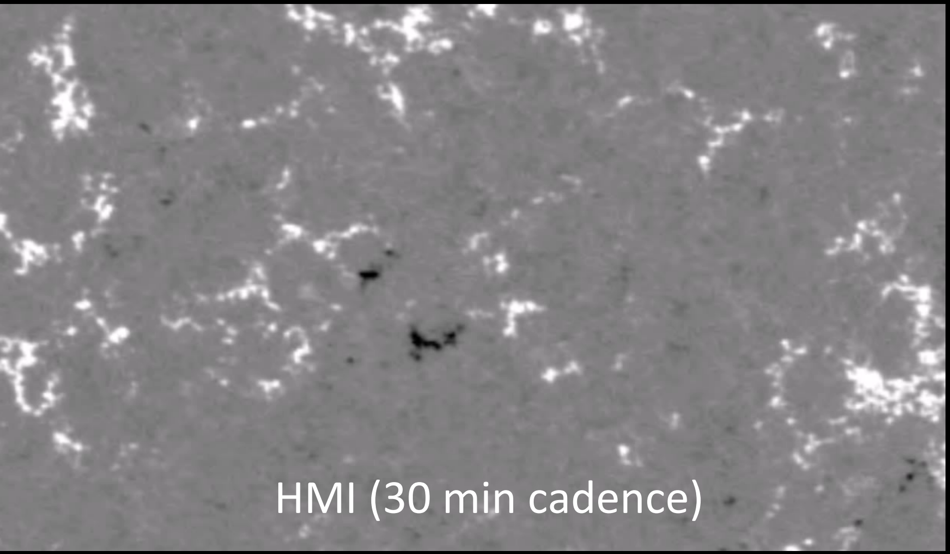
Enhanced 40-100 keV electrons



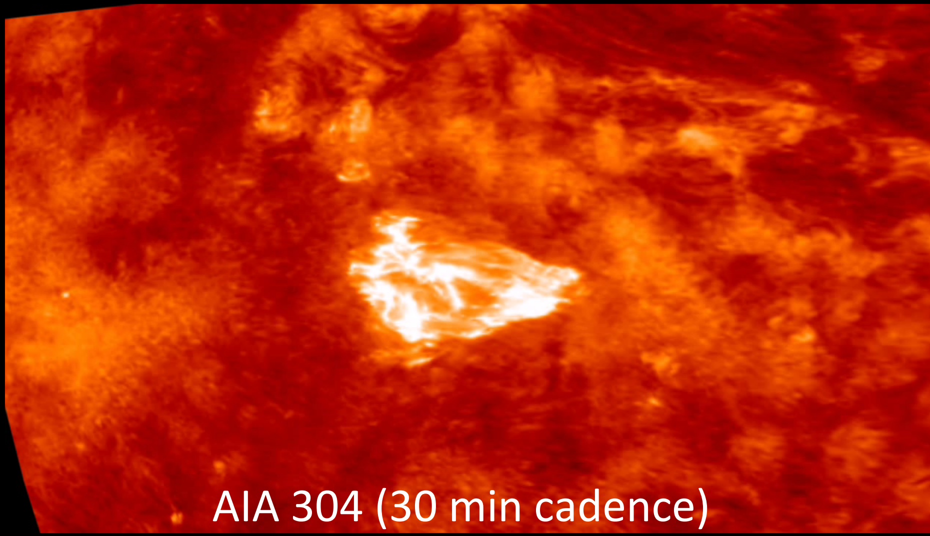


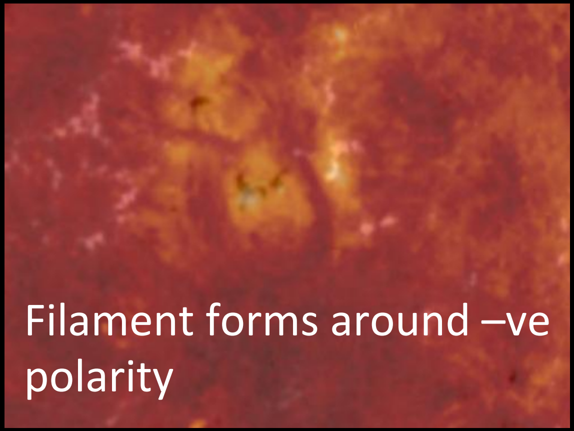
Formation of Jet
Flux emergence in coronal hole

Flux emergence starts 2.5 days before jet

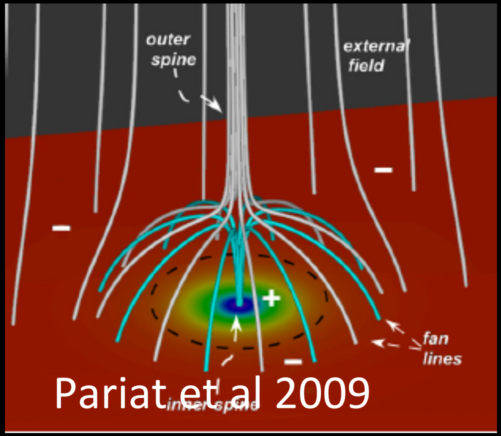


No jet at time of flux emergence

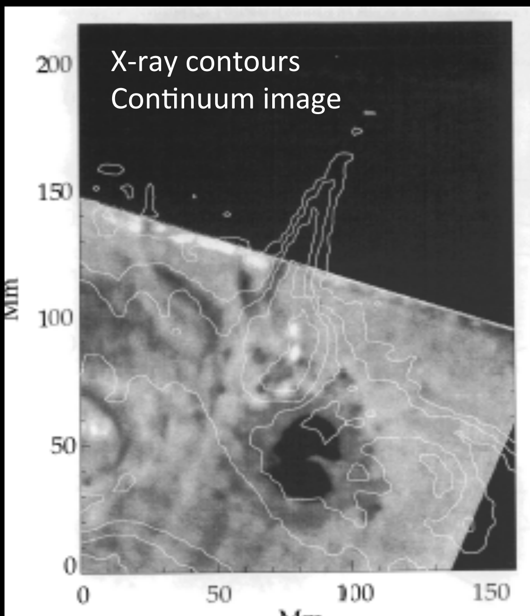




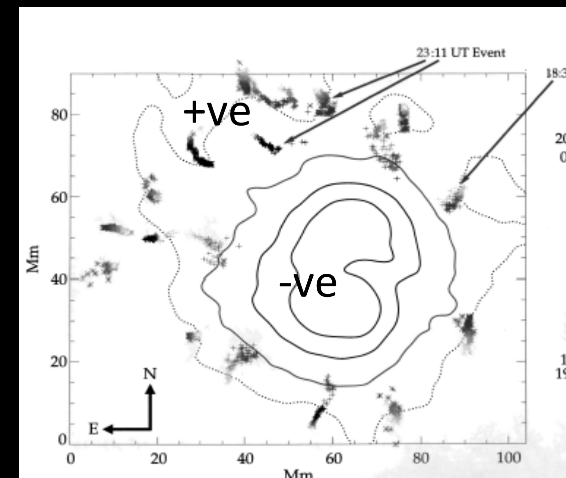
Magnetic configuration similar to jet model

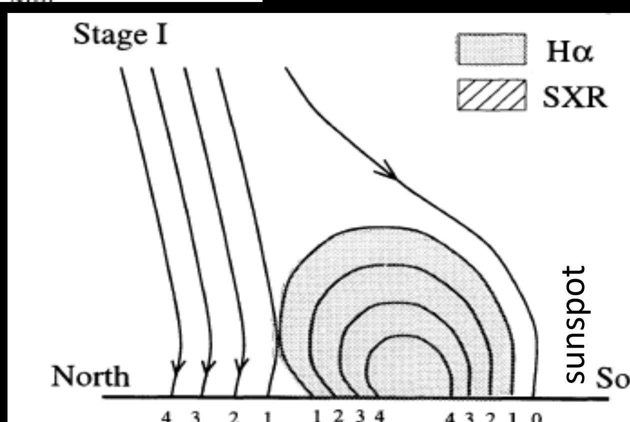


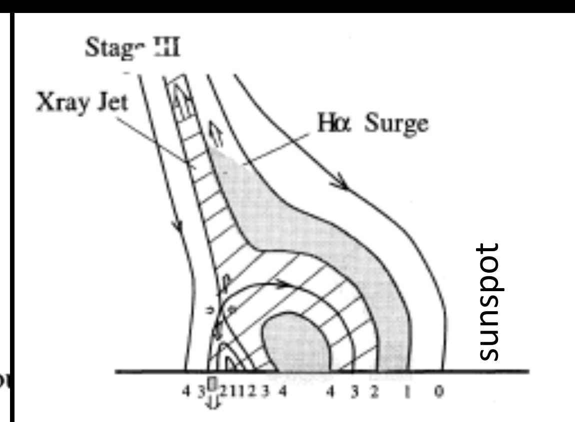
1b. Multiple Jets



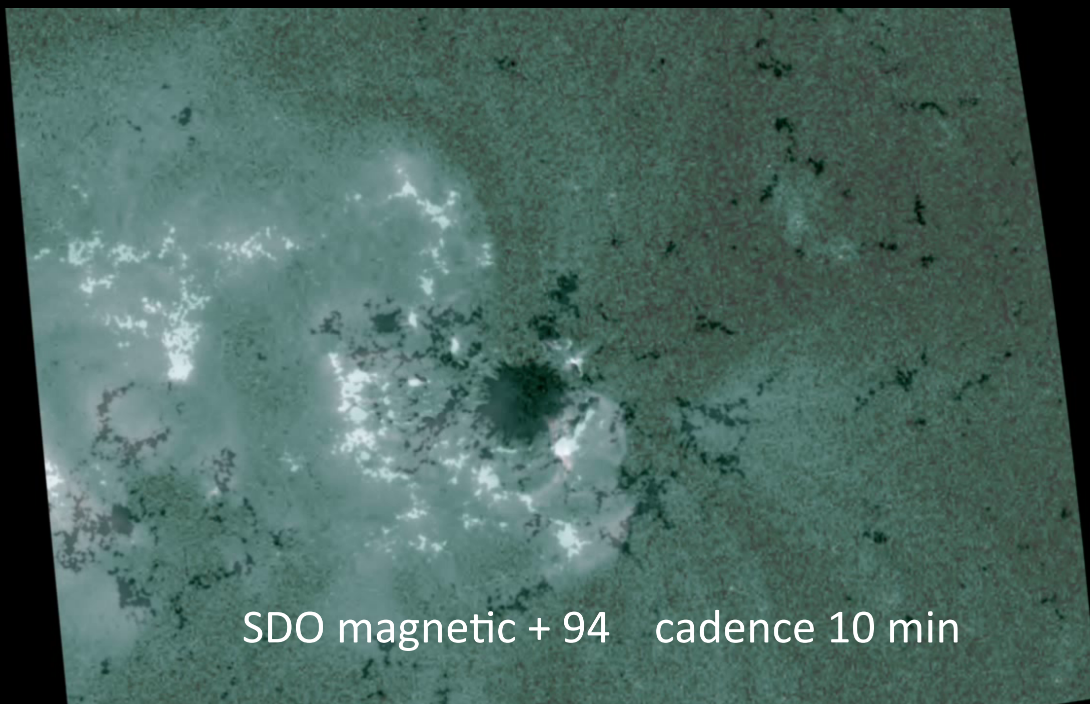
Canfield et al. (1996)
Nine X-ray with H-alpha jets in 9h.
Link with moving magnetic satellite flux around sunspot.
Penumbral filaments.







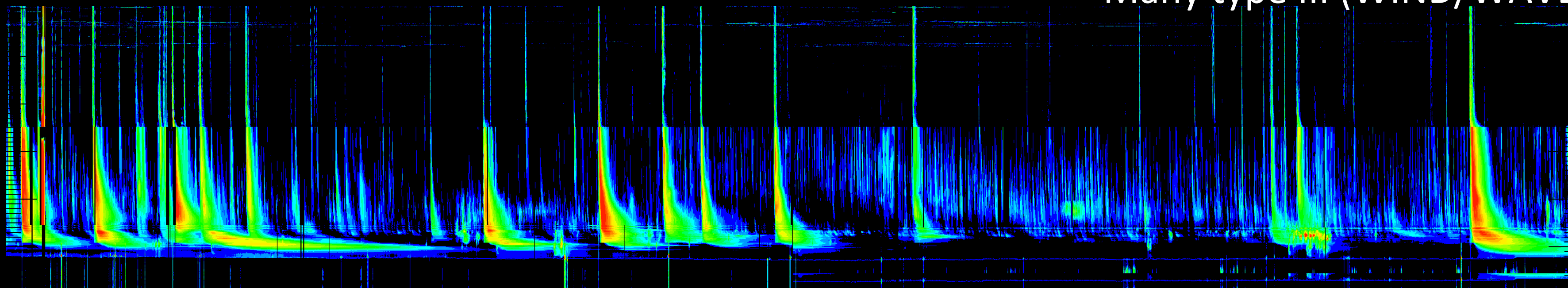
SDO - Multiple jets



Jets on edge of sunspot

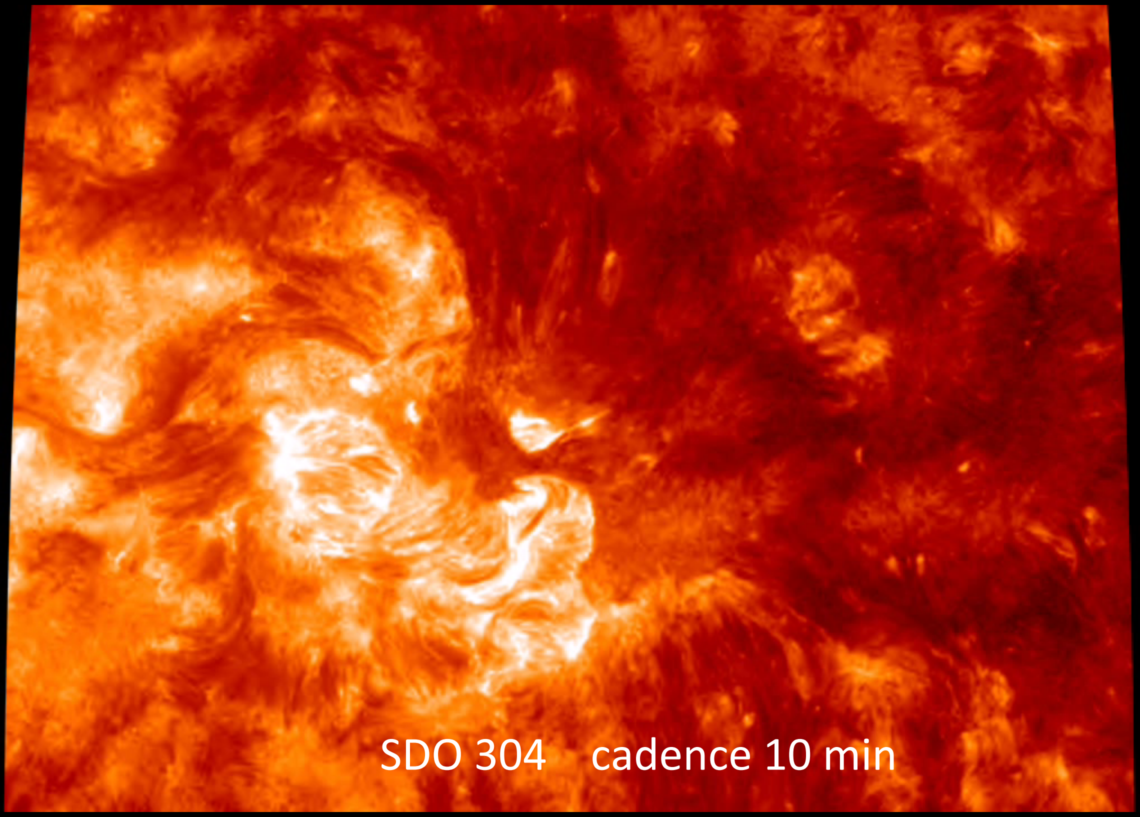
43 hours
Jets appear with minor polarity.

Many type III (WIND/WAVES)



Multiple jets

Jets on edge of sunspot



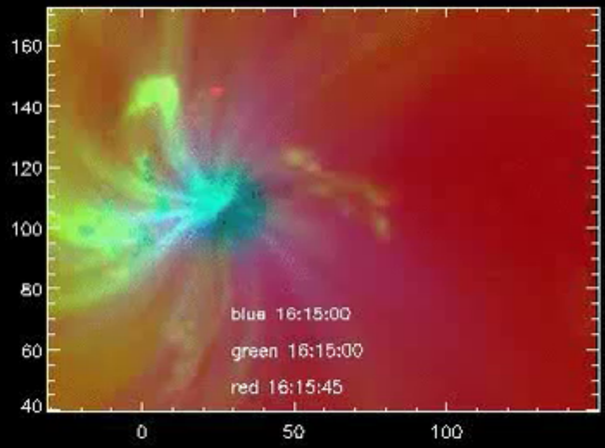
Simultaneous transition region jets

See poster by Chen et al

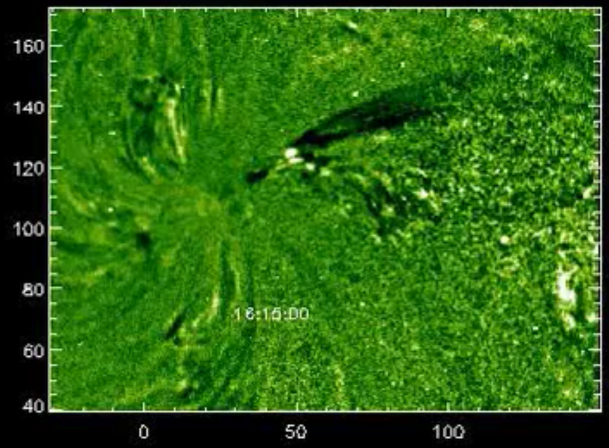
Multiple Jets

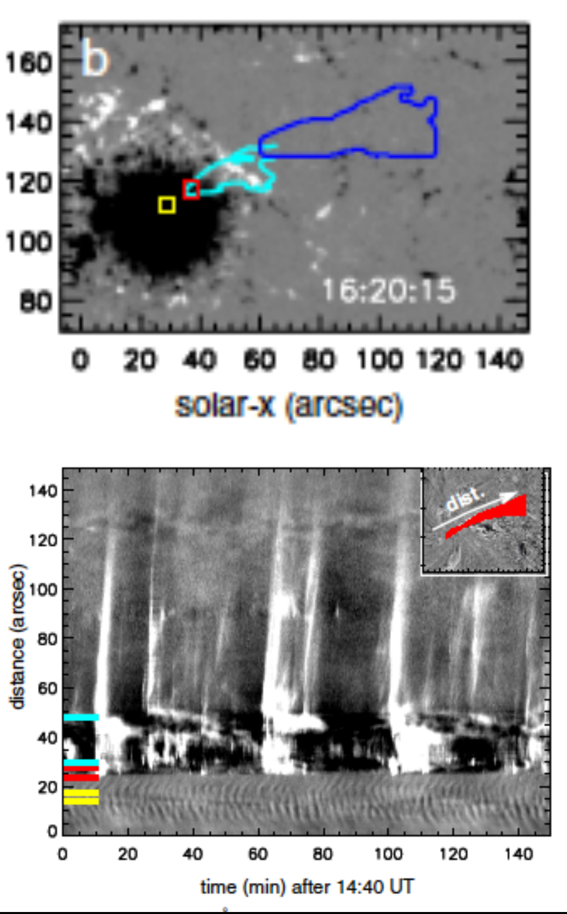
Jets from sunspot
Seven strong EUV jets - all with type III - in 140 min
No surges in 304 A.

Red: magnetic field   Blue: 304 Green:211



211 base difference

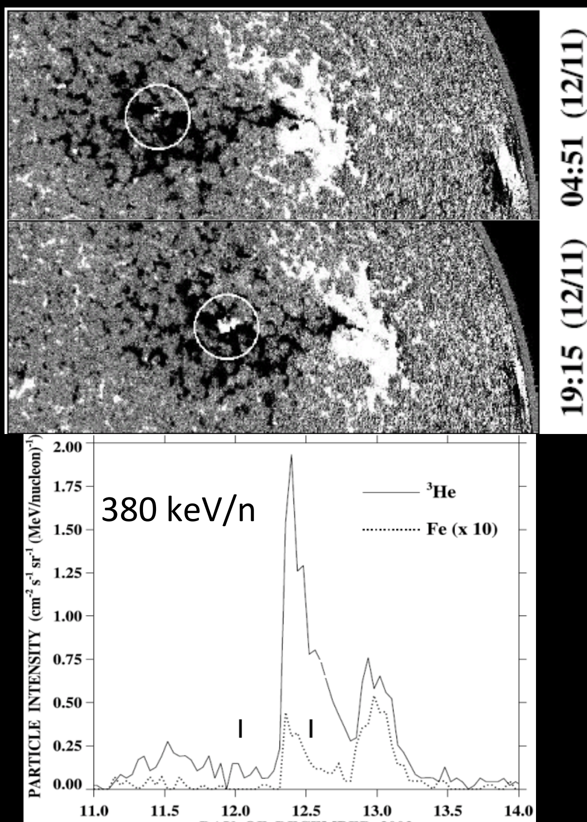




Reconnection between sunspot open field and closed field connecting to satellite flux
(Innes et al 2011)

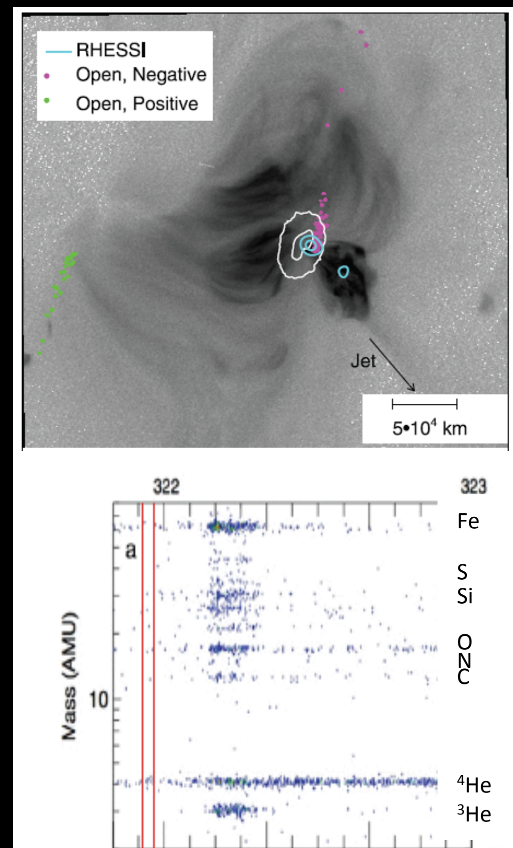
^{3}He origins
flux emergence/sunspot jet /coronal hole

Sites of preferential acceleration of ^{3}He



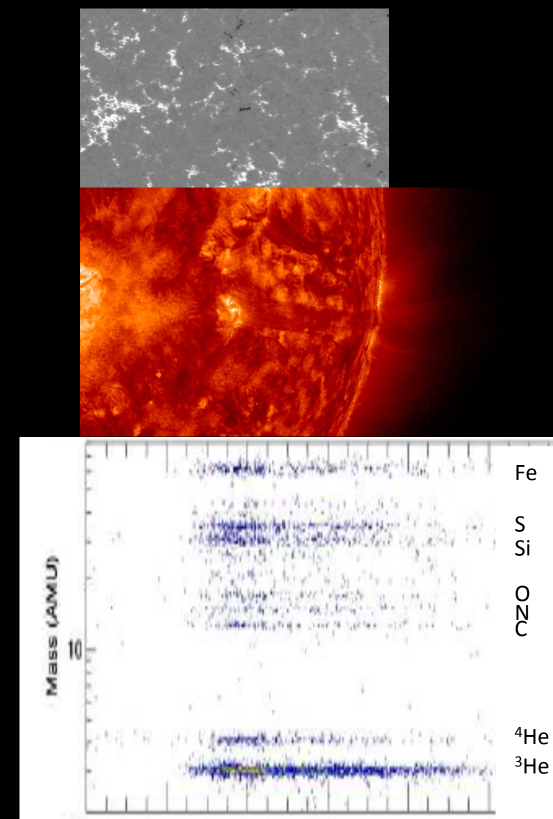
3 days
^{3}He/^{4}He=0.5

Wang et al, 2006



1 day
^{3}He/^{4}He=0.5

Nitta et al, 2008



2 days
^{3}He/^{4}He=15

Nitta et al 2015

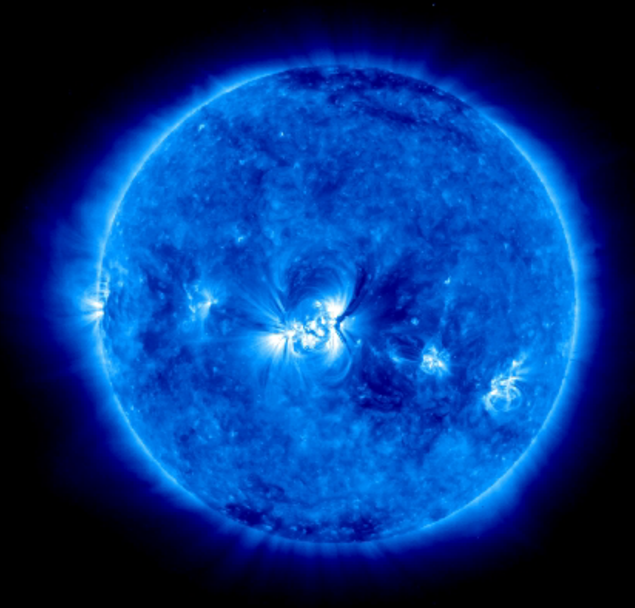
2. Coronal jets

X-ray/ EUV jets and macrospicules
No type III

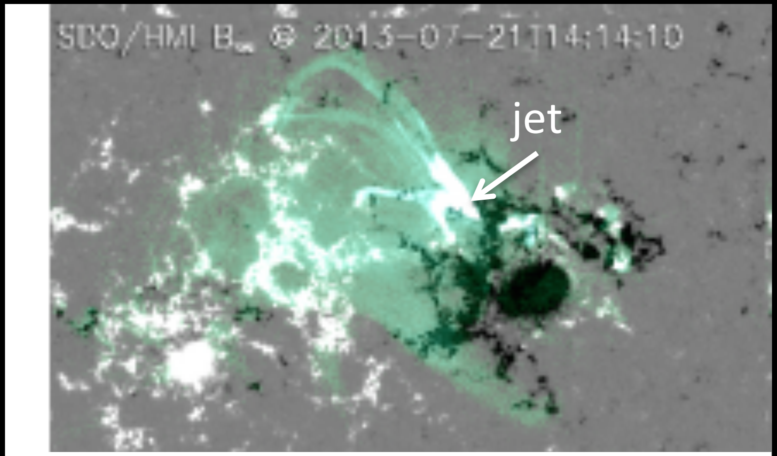
Too weak

Not open to interplanetary space

Polar coronal holes



Moving magnetic bipoles

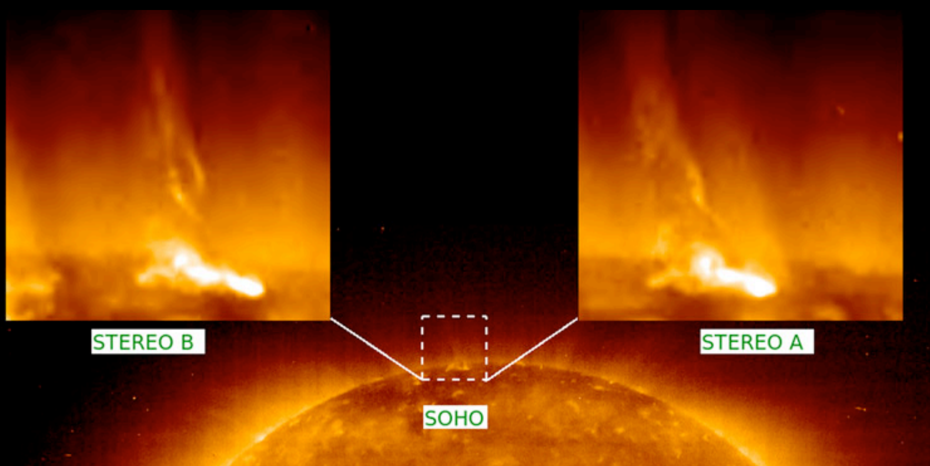


SDO/AIA 94 and HMI - B

Cheung et al 2015

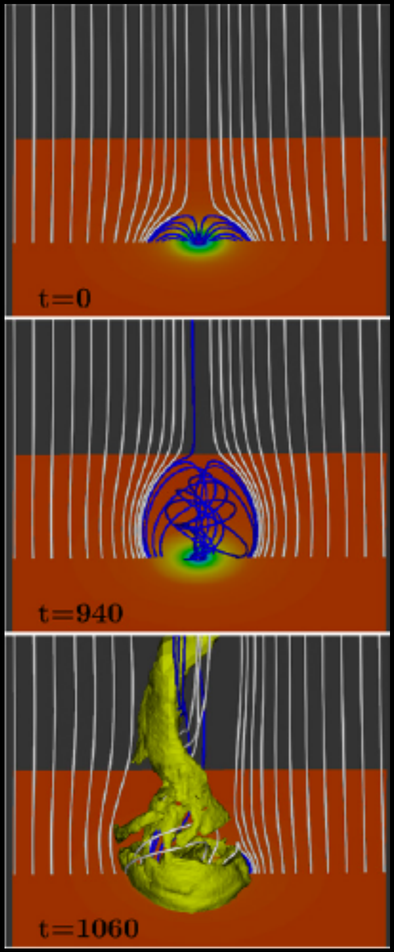
Helical jets

STEREO observations   171 A



Patsourakos et al 2007

Untwisting field



Blue- closed field

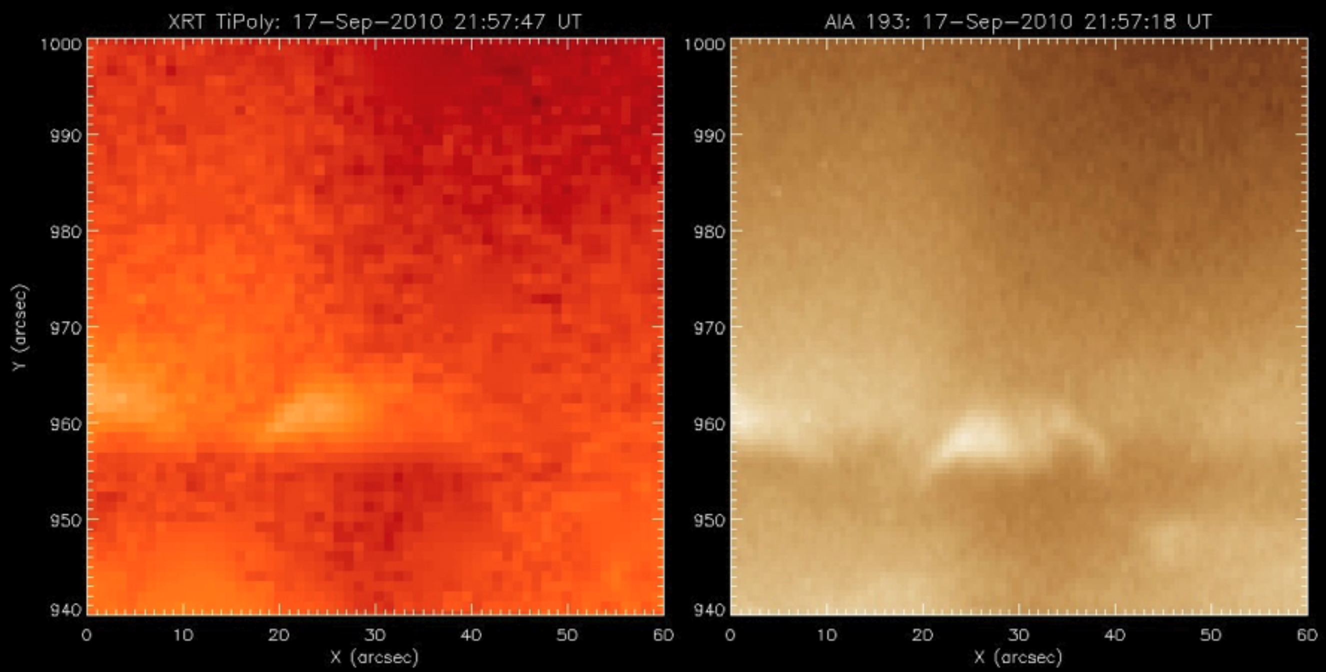
Yellow- density surface

Pariat 2009

Mini-filaments

XRT

AIA 193

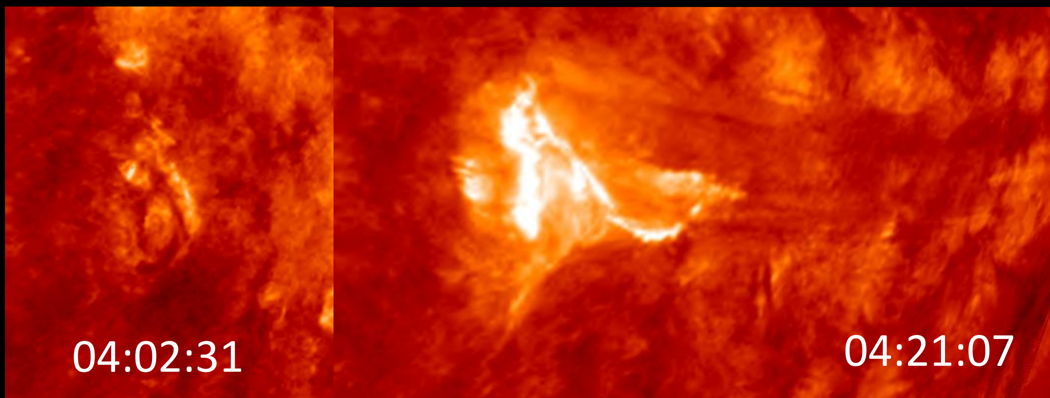


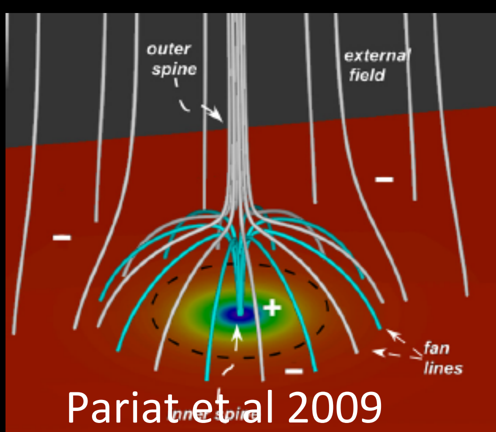
Sterling et al 2015

What is the role of the filament?
Is the eruption from the rising filament?

Filament eruption

On disk eruption

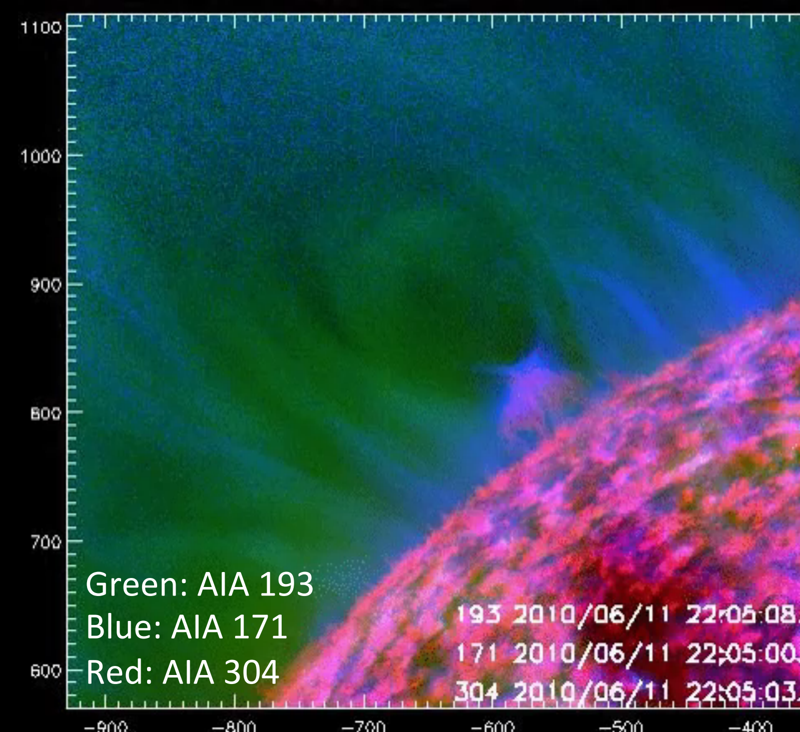




Pariat et al 2009

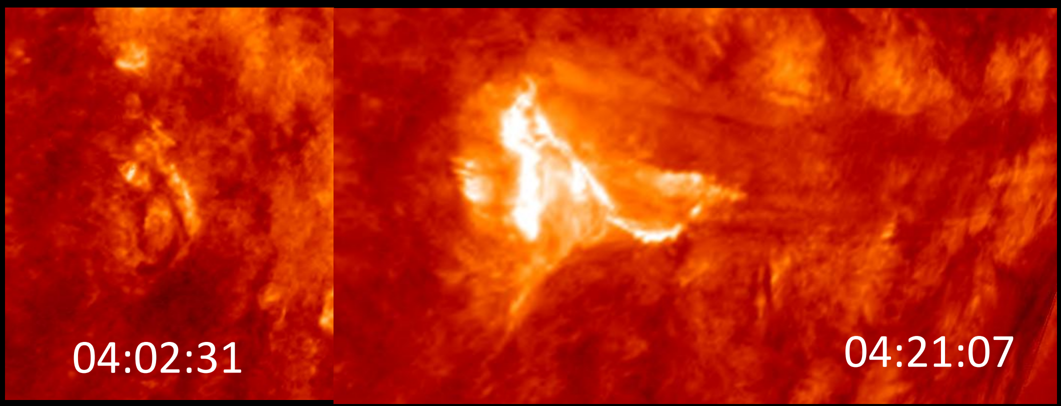
Filament lies in the dips of the flux rope.

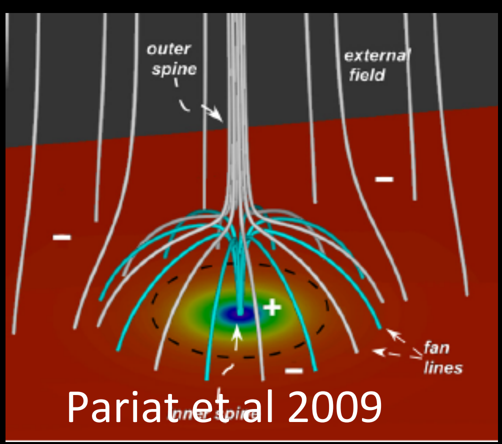
Corona above filaments



Filament eruption

On disk eruption



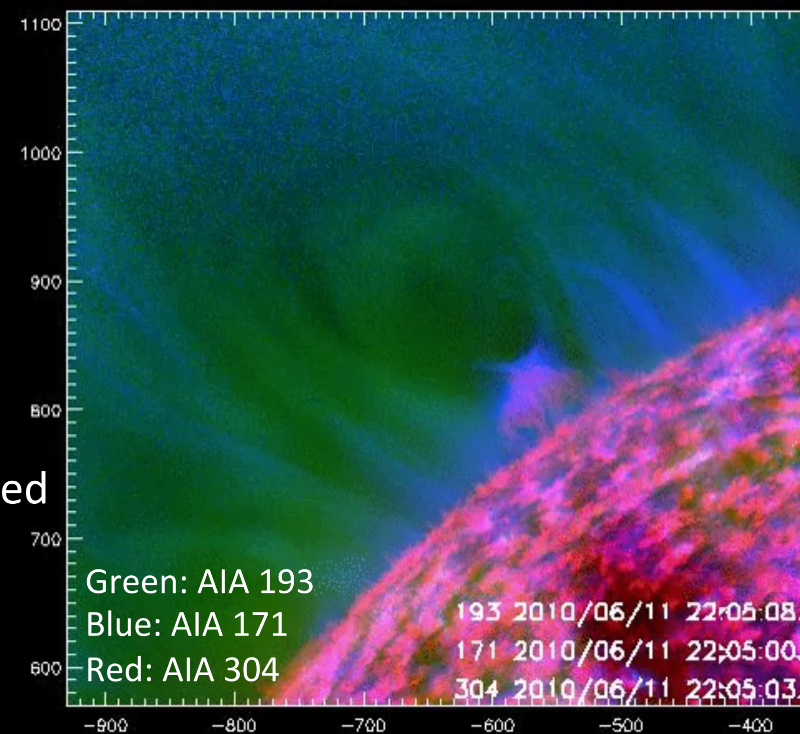


Pariat et al 2009

Filament lies in the dips of the flux rope.

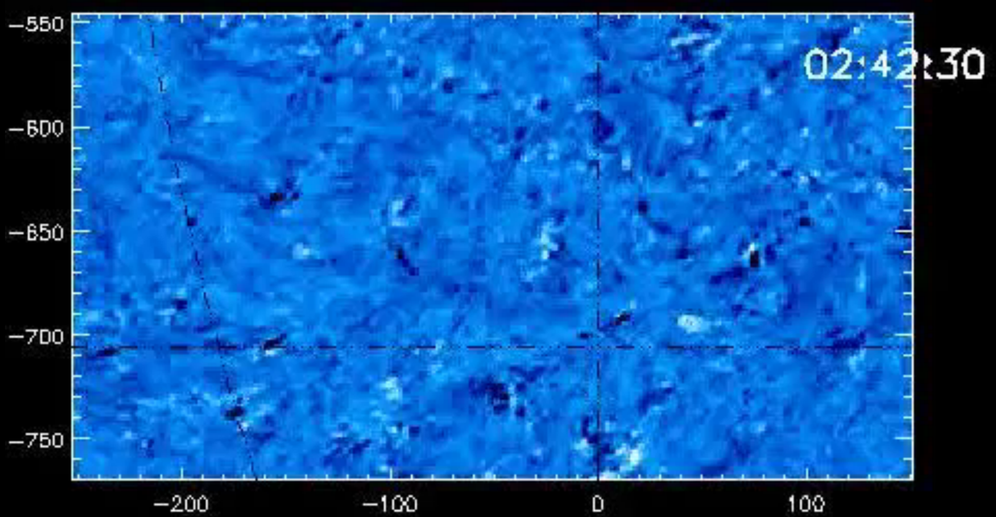
Eruption initiated by external reconnection

Corona above filaments

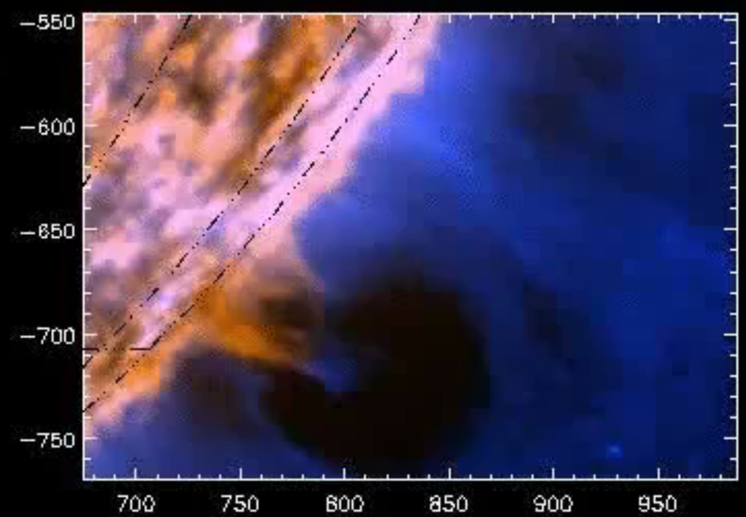


Quiet Sun Jets

STEREO in quadrature

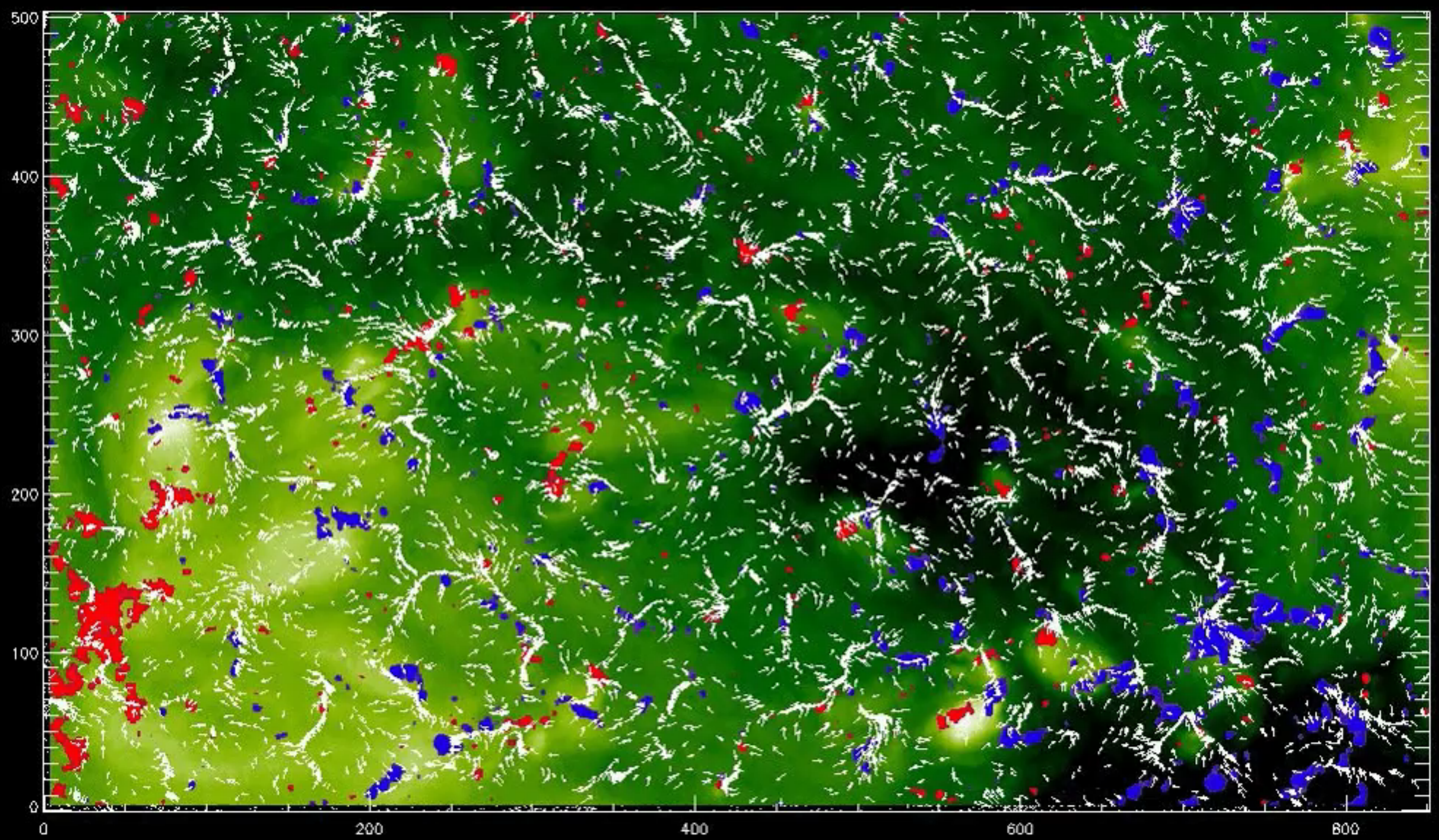


STEREO-A 171
Base difference



STEREO-B
304 and 171
composite

Supergranulation



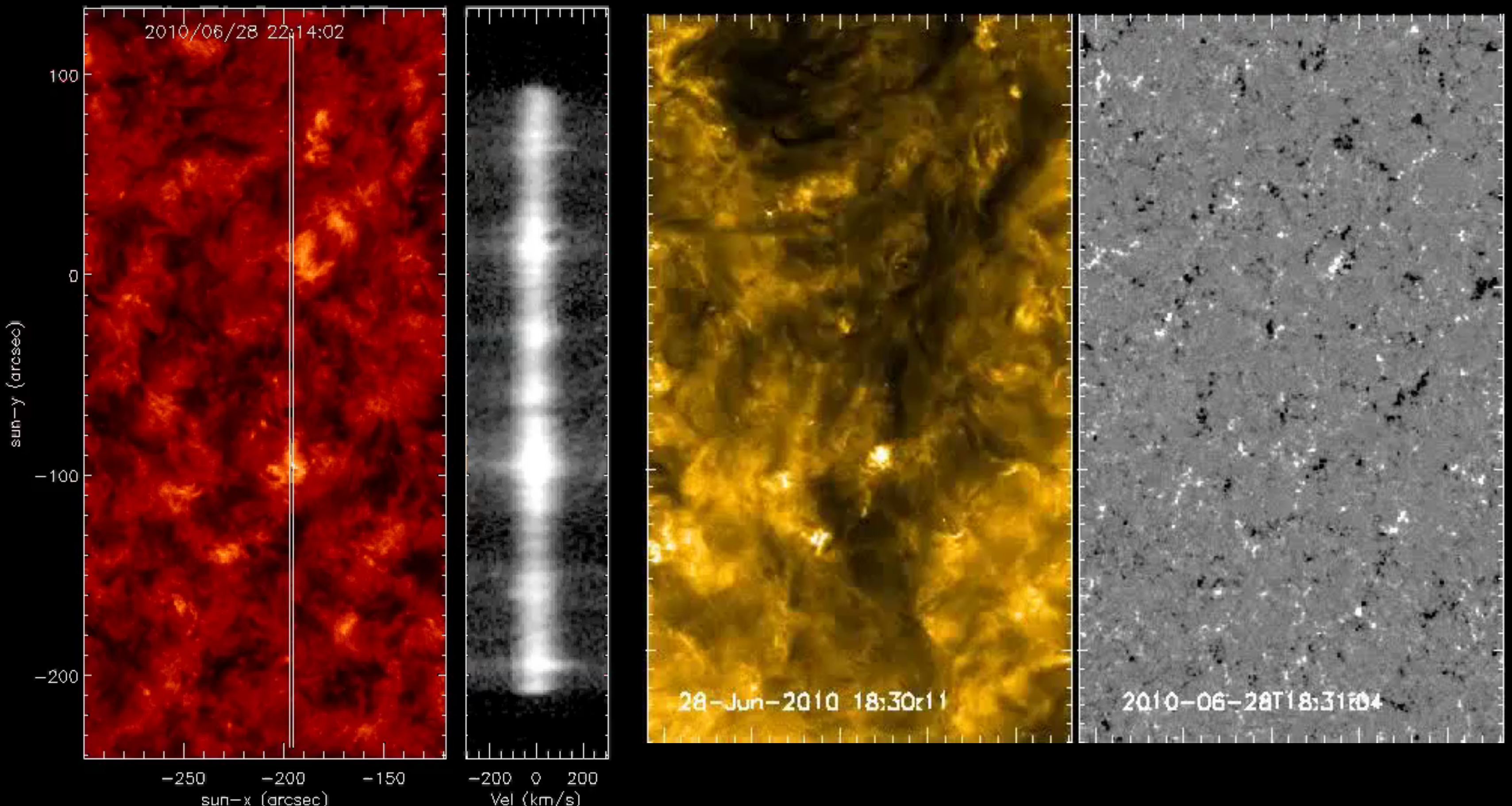
Images: STEREO 195
Red/blue: magnetic field
White: photospheric flow

Eruptions at the junctions of supergranular cells

Innes et al 2009

3. Transition region jets

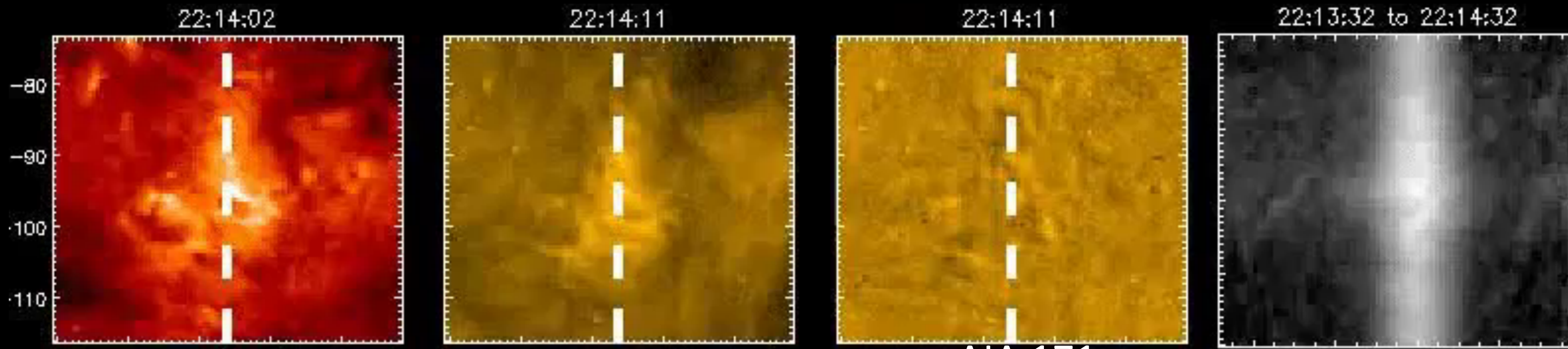
Cadence 60 s



AIA 304 SUMER O VI AIA 171 HMI

Transition Region jets

Small-scale jet a the periphery of an eruption at a supergranular junction



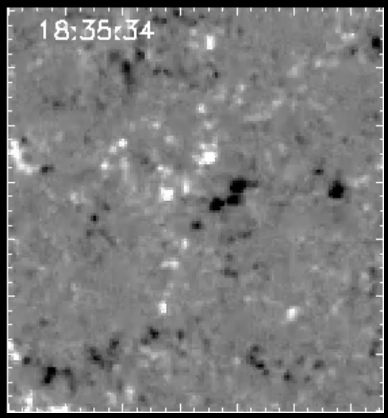
AIA 304

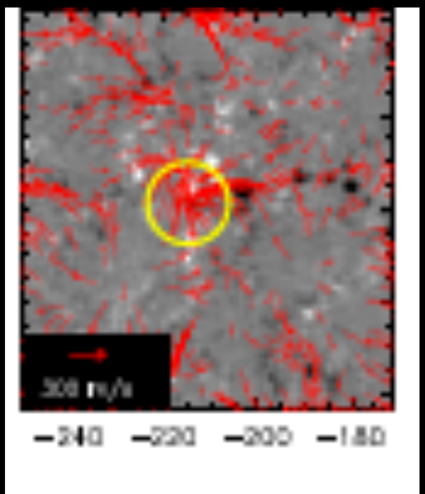
AIA 171

AIA 171
Base diff

SUMER OVI

HMI 2.5 hours





Red arrows: photospheric flows

Summary

Basic energy release process is reconnection.
Single or multiple jets depending on mechanism of energy storage.

Interplanetary and coronal jets:

Single: Slow storage due to twisting motions

e.g. after flux emergence in coronal holes or at intersection of supergranular cells.

Multiple: Annihilation of moving flux concentrations

e.g. of strong sunspot fields.

What controls the ^3He enrichment?

Transition region jets:

Multiple: Bursts of flux cancellation

e.g. during flux emergence, filament formation, small-scale flux cancellation

Multiple: At the base of larger-scale jets

Is there a slow storage mechanism for transition region jets?