Outflows from the Sun

Polar coronal hole observed with Hinode and SUMER

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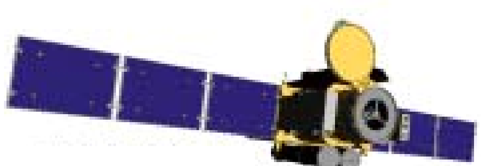
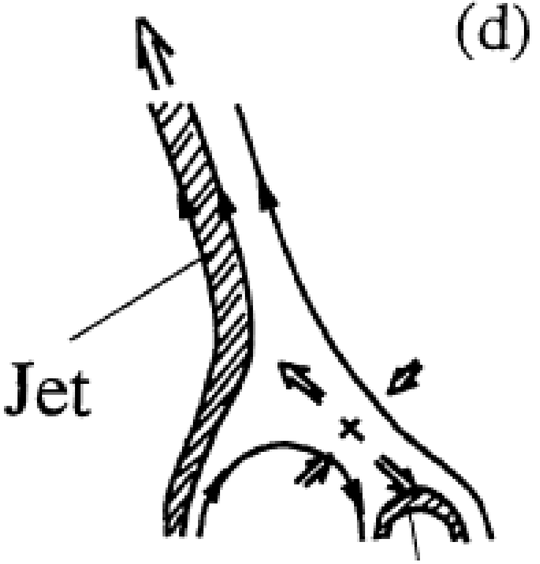
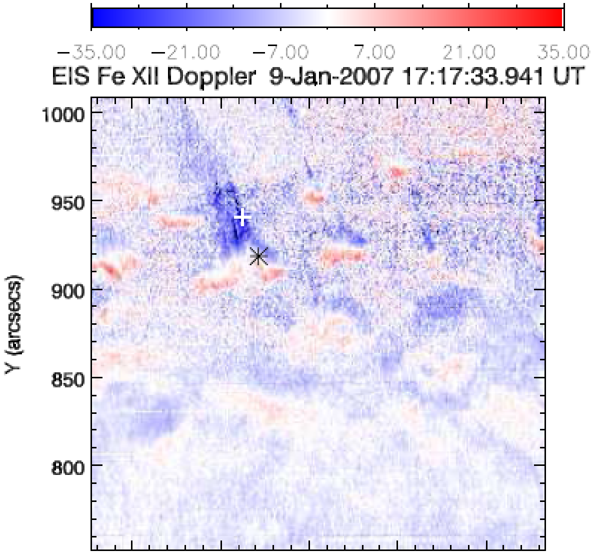


Hinode

Cirtain et al. (2007), Savcheva et al. (2007), and Shimojo (2007)



Shibata (1998)



Kamio et al. (2007)

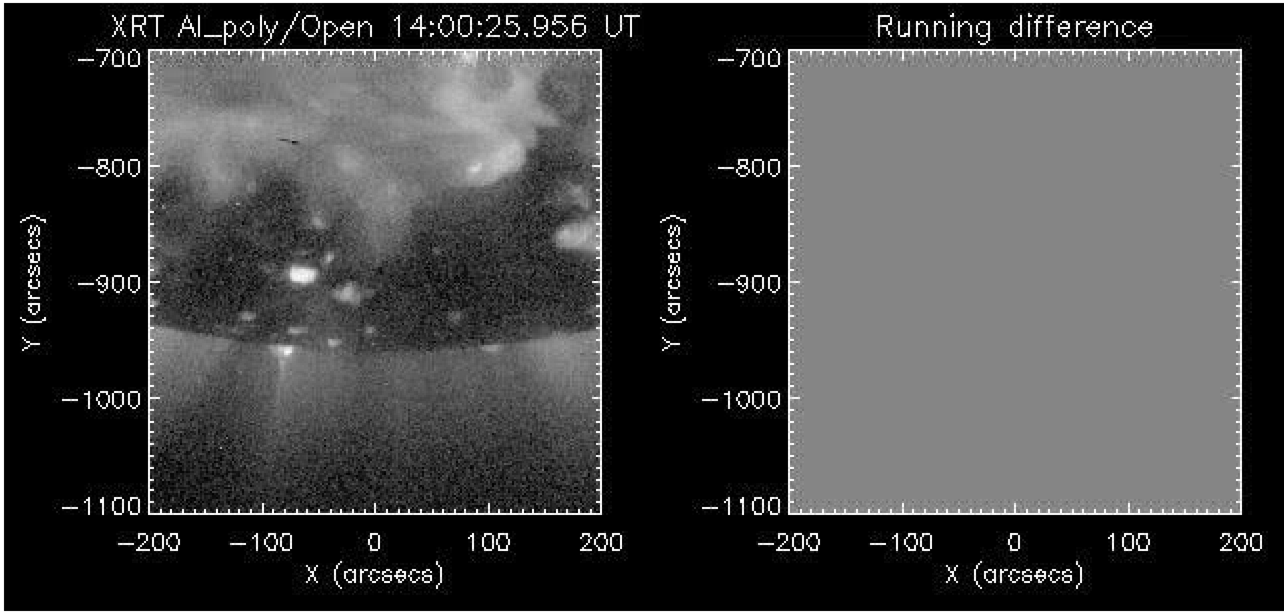
- Hinode observations revealed dynamic behaviour of jets in coronal holes.
- In order to understand heating and acceleration in the corona, study of the lower atmosphere and photospheric magnetic fields are important.

Observations

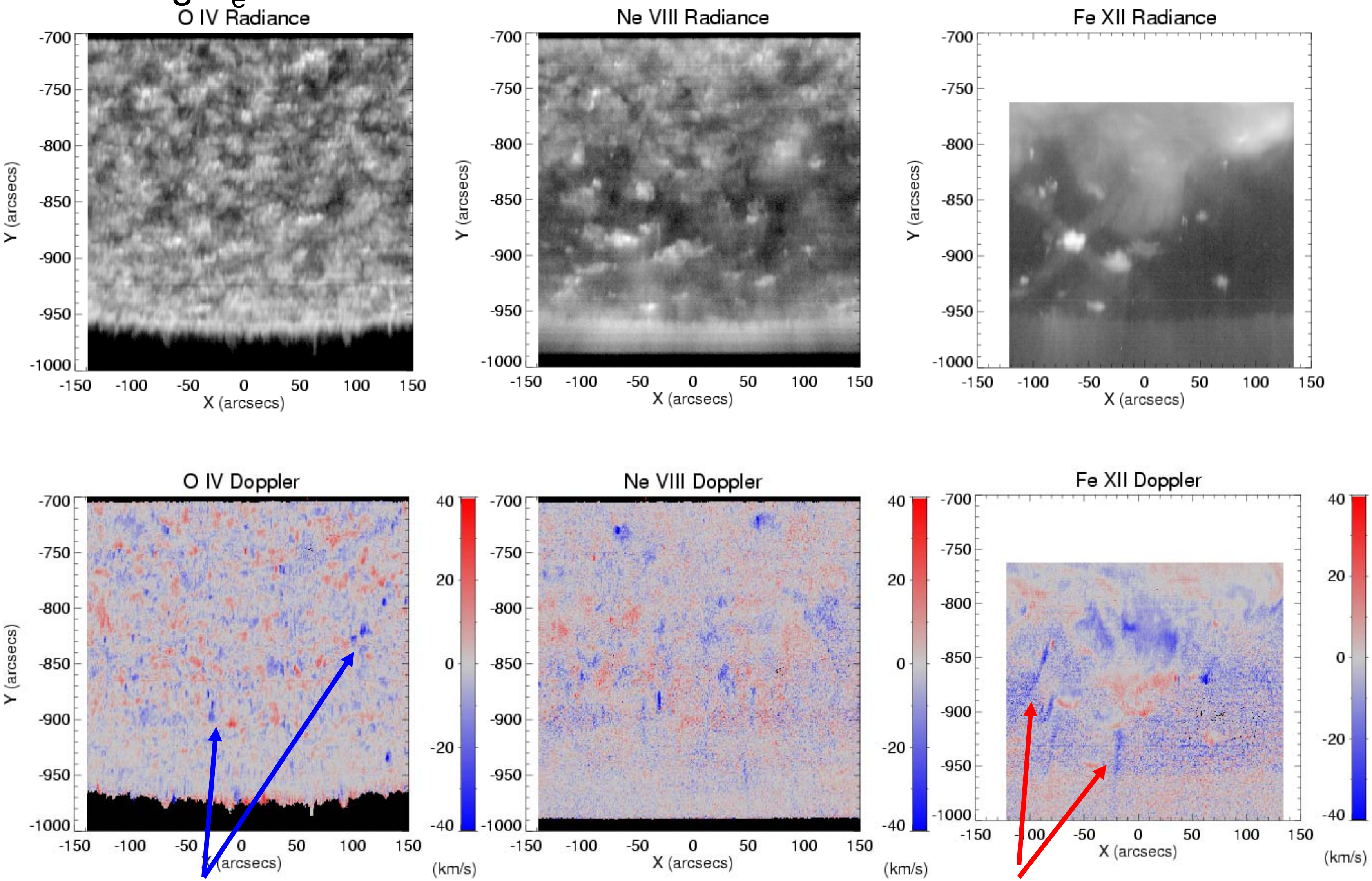
To find a connection between coronal jets and the photosphere

EIS: coronal lines
SUMER: transition region lines
SOT/SP: photospheric magnetic fields

- SUMER campaign
  2007 Apr 8
  14–18 UTC
- Southern polar coronal hole
- One big scan
  for spatial structure



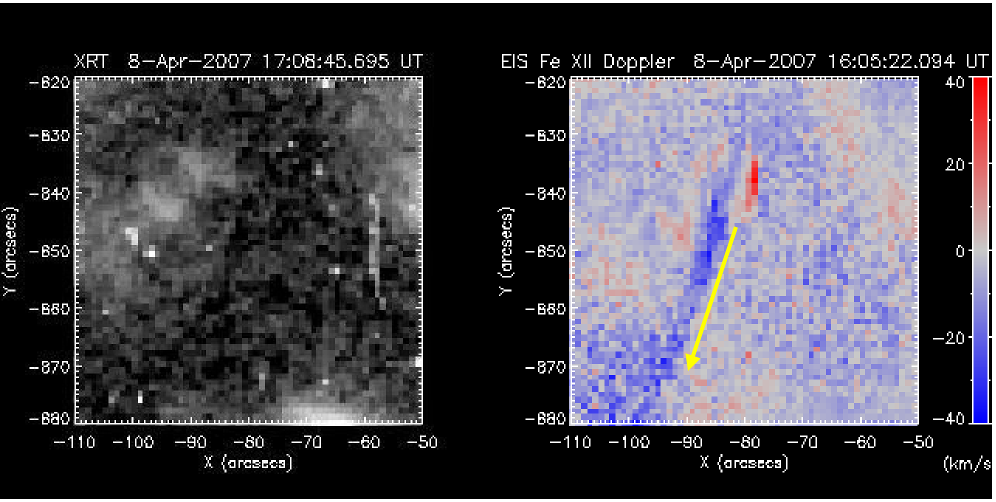
O IV, log T_e = 5.2 | Ne VIII, 5.8 | Fe XII, 6.1



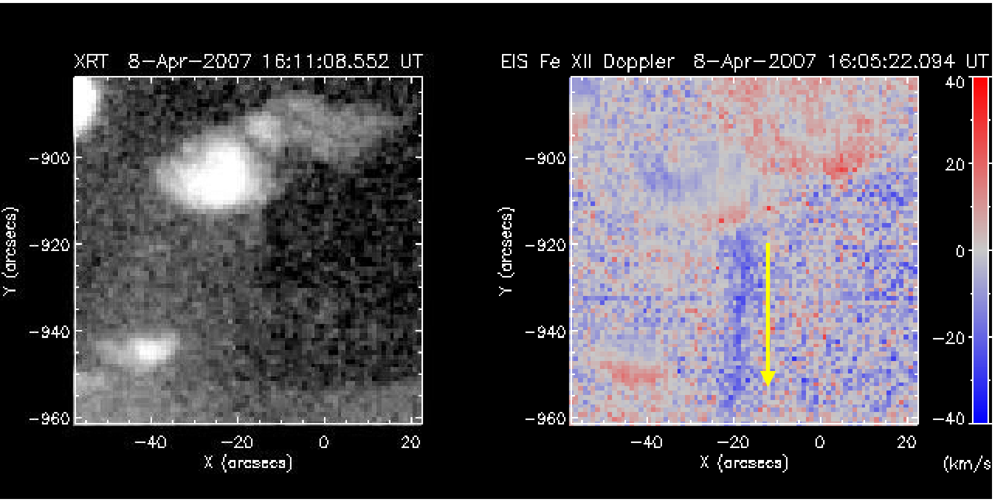
Cool upflows (only in TR)

- Coronal jets

Types of coronal jets



- Transient jet duration: 30 min drifting motion



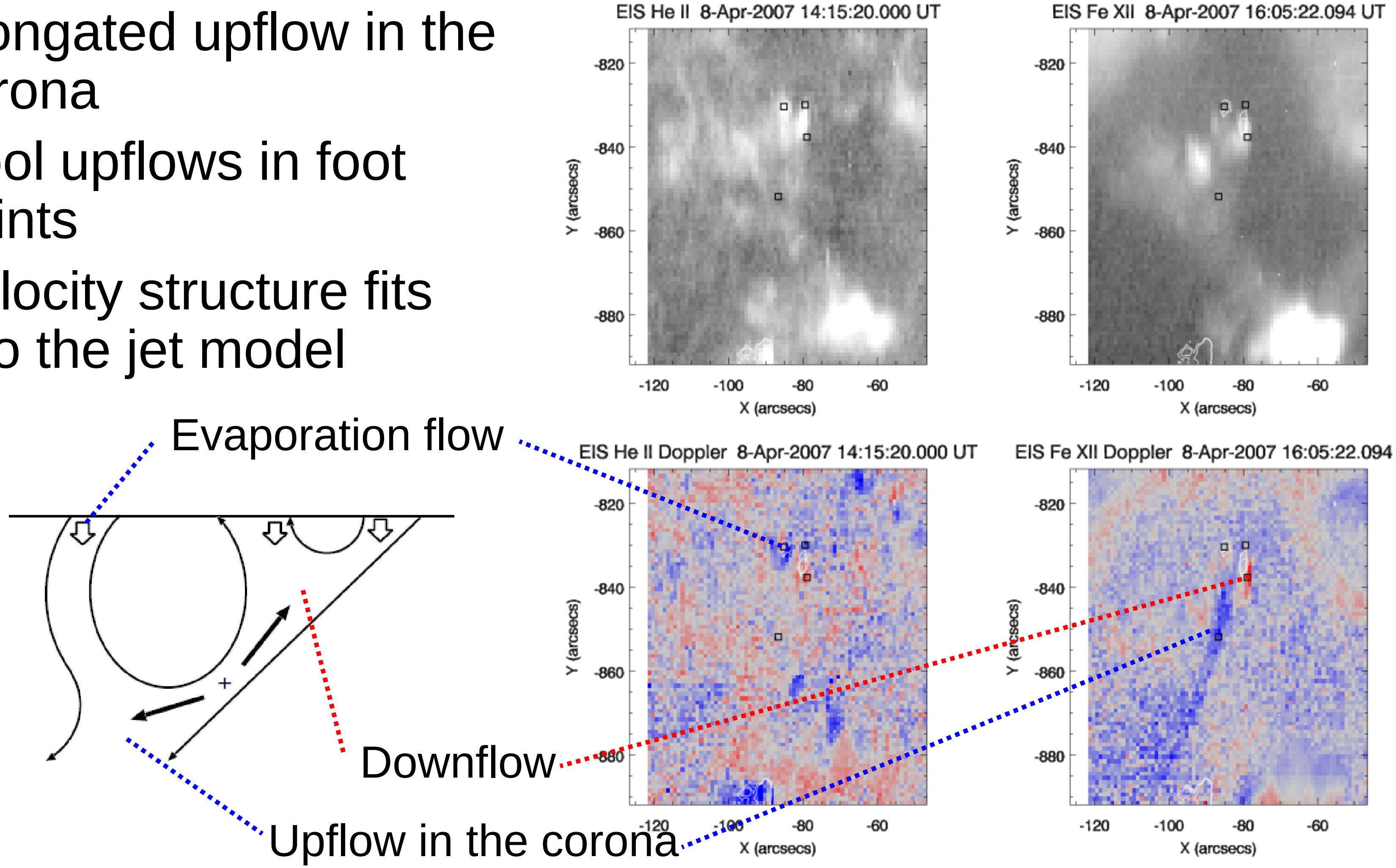
- Persistent jet duration > 1 hour associated with bright coronal loop

Transient jet

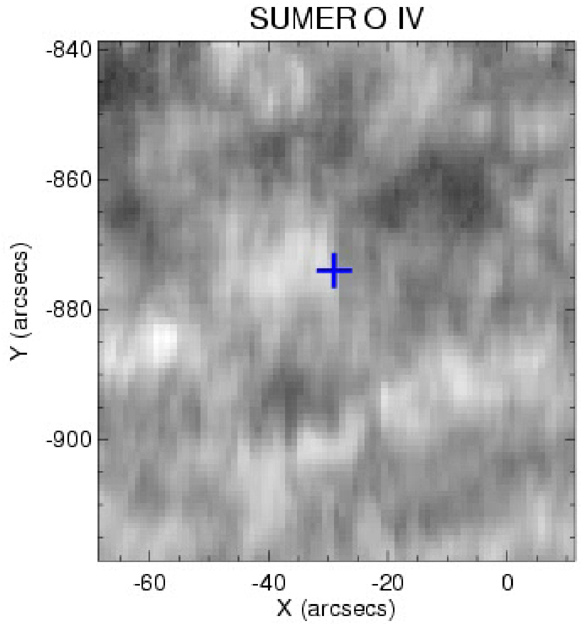
- Elongated upflow in the corona
- Cool upflows in foot points
- Velocity structure fits into the jet model

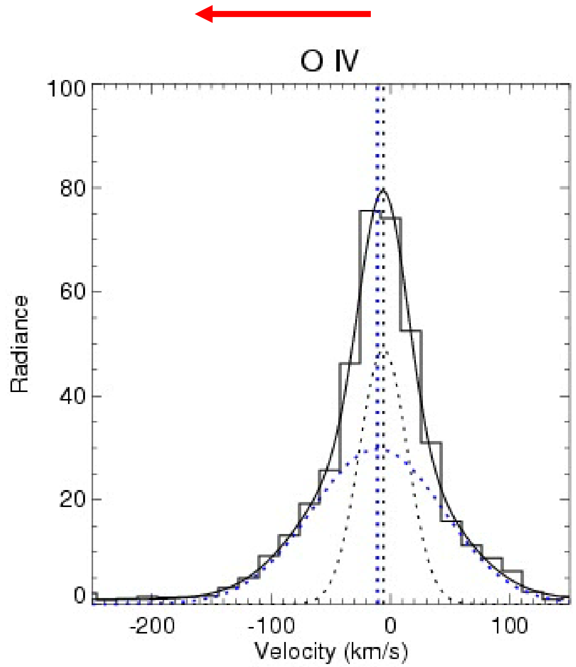
He II
log Te = 4.7

Fe XII
6.1

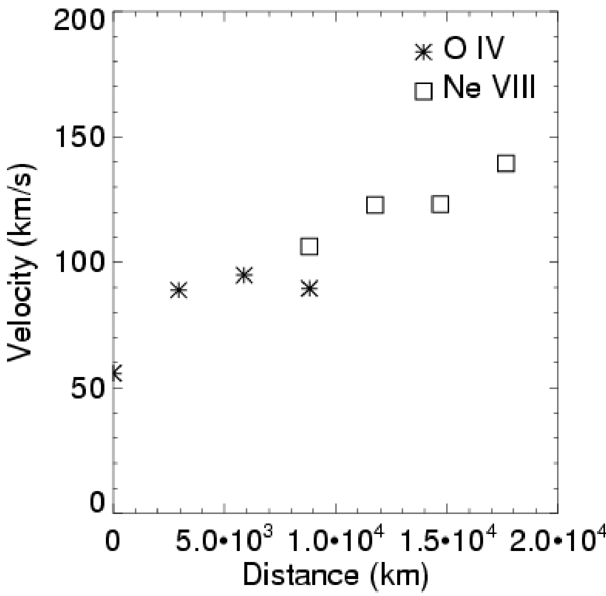


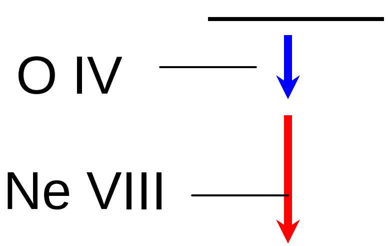
Acceleration in a transient jet





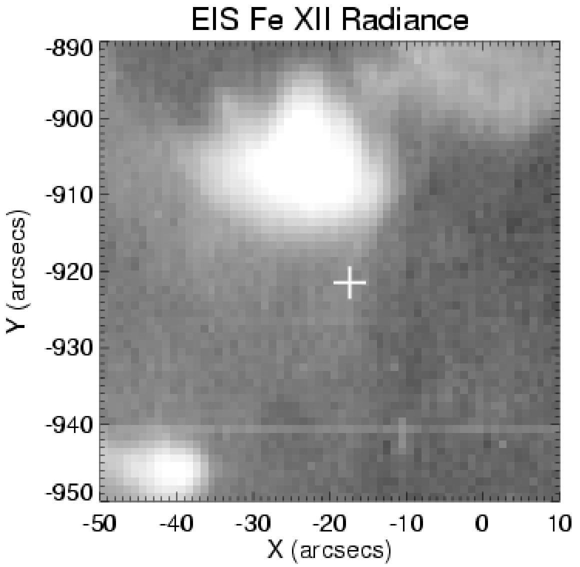
Spectrum

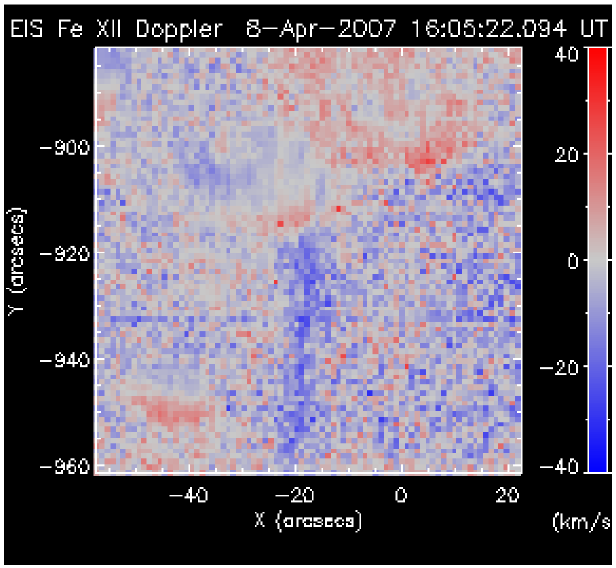




- Heating: O IV (5.2) ➔ Ne VIII (5.8)
- Continuous acceleration along the jet
  ➔ Chromospheric evaporation

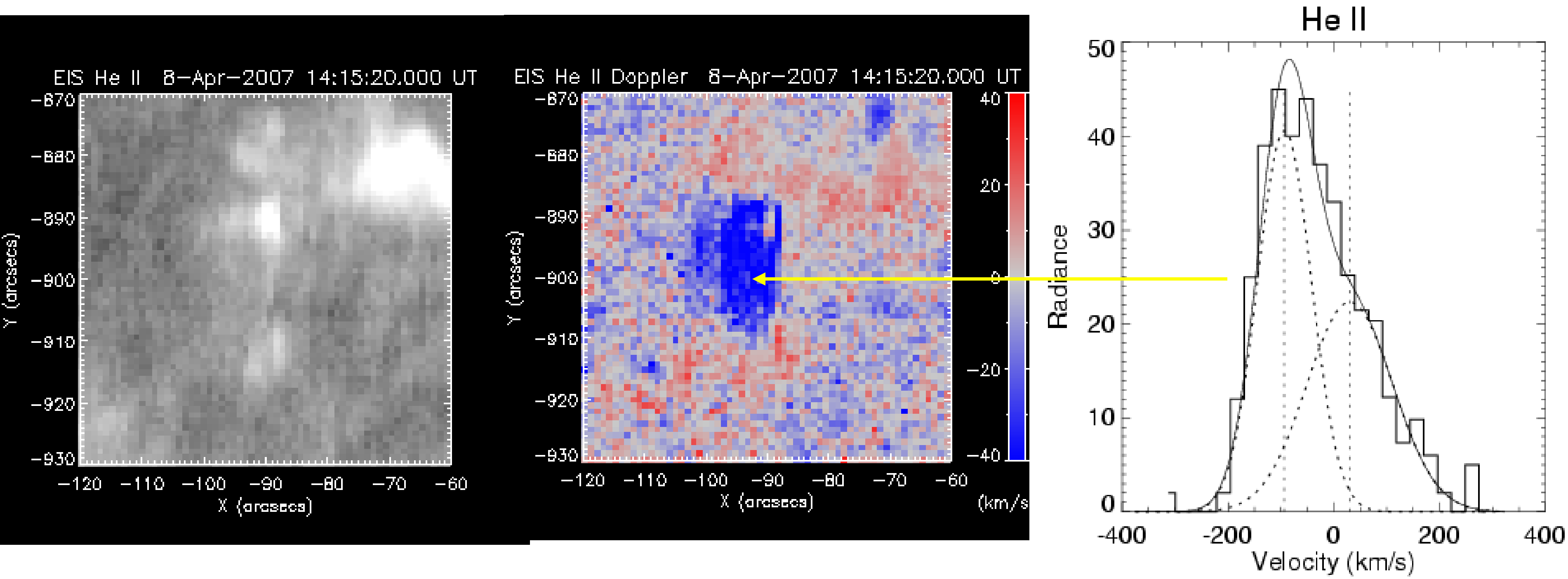
Persistent jets





- Associated with long lasting bright points (> 1 hour)
- Caused by gradual reconnection?
- The jet is very faint in radiance and is only detected by Doppler measurements.
- Small velocity (< 10km/s) in the bright point

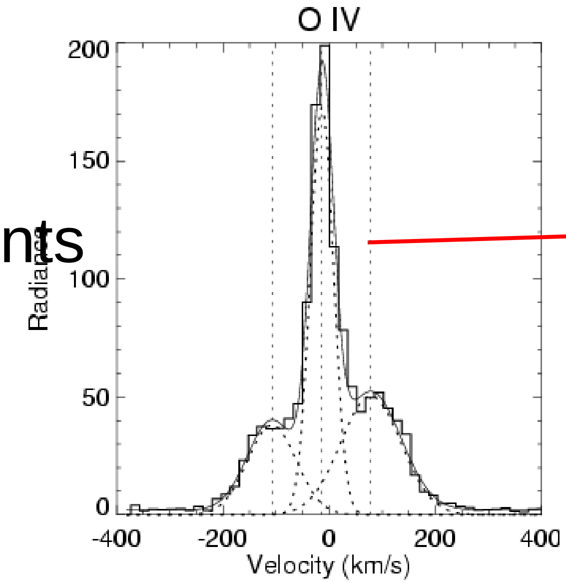
Cool upflows

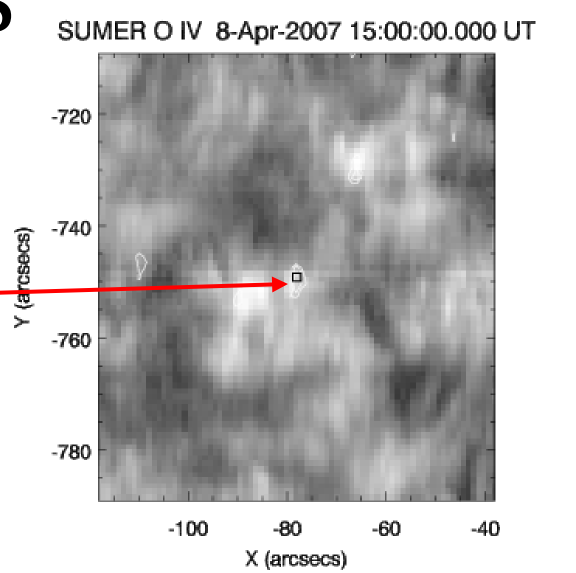


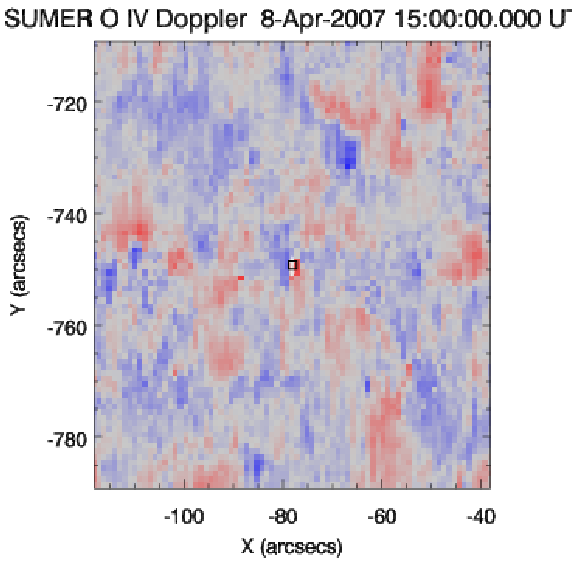
- Size of upflowing region: 10^4km
- Blue-shifted component: 100 km/s
- No counterpart in the corona.
- Possibly caused by low-lying fields in the transition region

Explosive events

- Broadened spectrum
- Blue and red components of about ±100 km/s
- No signature in the corona

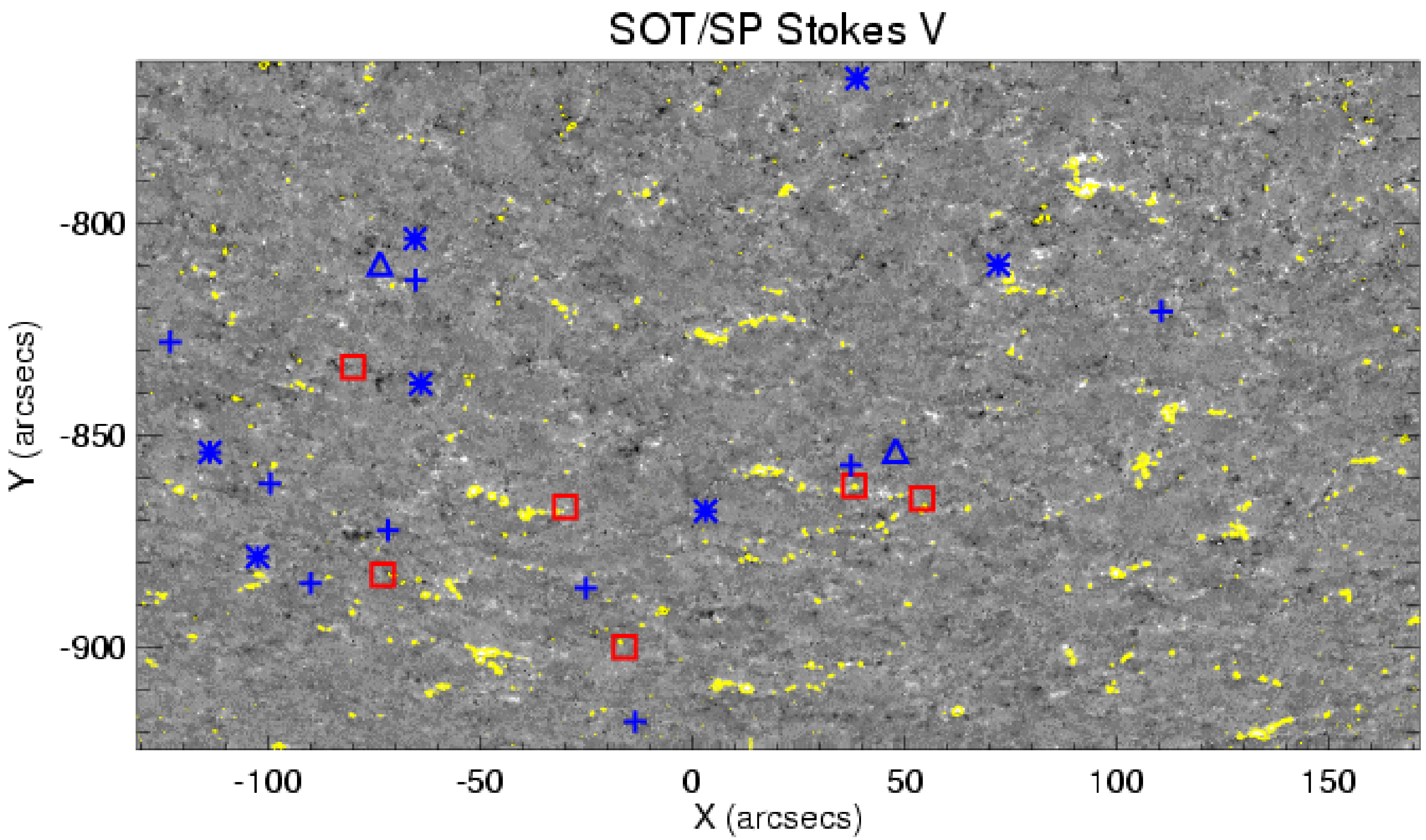






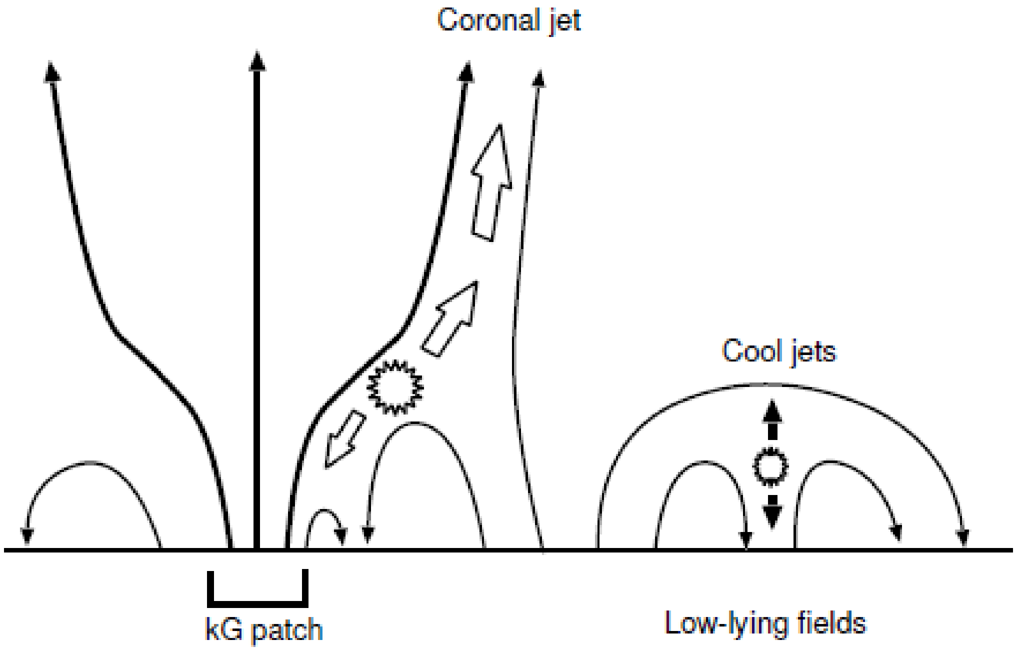
- Bi-directional flow caused by reconnection in the transition region (Innes et al 1997)

Relationship to magnetic fields



- Yellow – vertical kG field patches (Stokes Q)
- Coronal jet – associated with vertical kG patches
- Cool events – only a weak correlation with kG patches

Interpretation



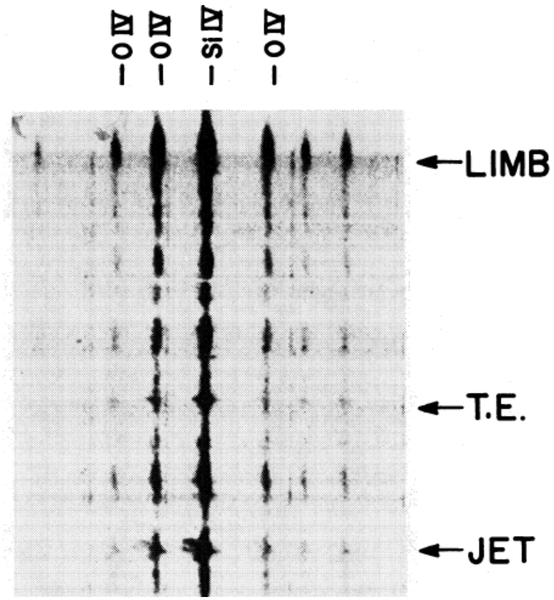
- Coronal jets are associated with strong fields which reach the higher corona.
- Cool events are caused by reconnections of low-lying fields (in the transition region or the chromosphere)

Summary

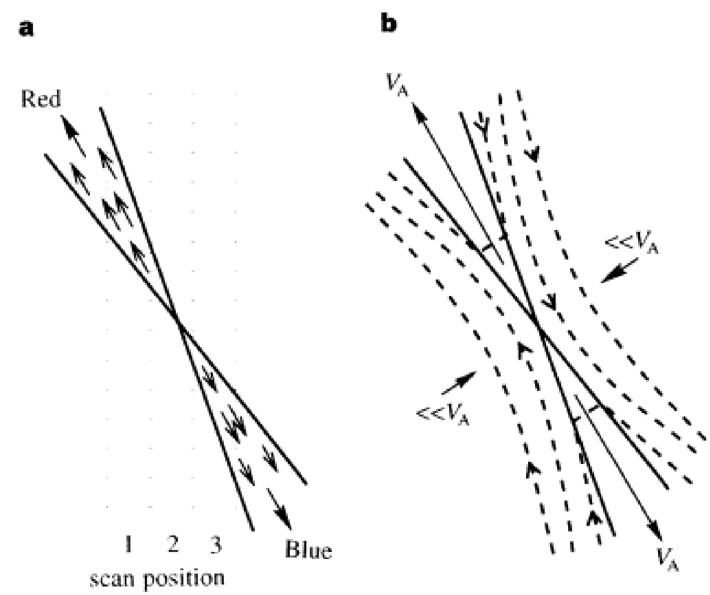
- Coronal jets are associated with strong vertical fields in the photosphere.
- Cool upflows and explosive events are ubiquitously found in the coronal hole. They might be connected to low-lying fields in the transition region.
- Continuous acceleration and heating were detected in a jet, which suggests chromospheric evaporation.
- Coronal jets are classified into persistent jets and transient jets.
- Observation of the transition region is important to understand the link between the corona and the photosphere.

Explosive events

- Explosive events are UV-spectrum broadening events ubiquitously occur in transition region.
- Bi-directional flows caused by reconnection.
- But their connection to magnetic fields in the photosphere have not established yet.



Brueckner & Bartoe (1983)



Innes et al. (1997)

Optical thickness of He II

- Possible causes of line broadenings
  - Turbulence
  - Opacity ($\tau >> 1$)
- He II λ 256.32 emission line

$$\tau = nL \frac{\pi^{0.5} e^2}{mc\nu_D} f$$

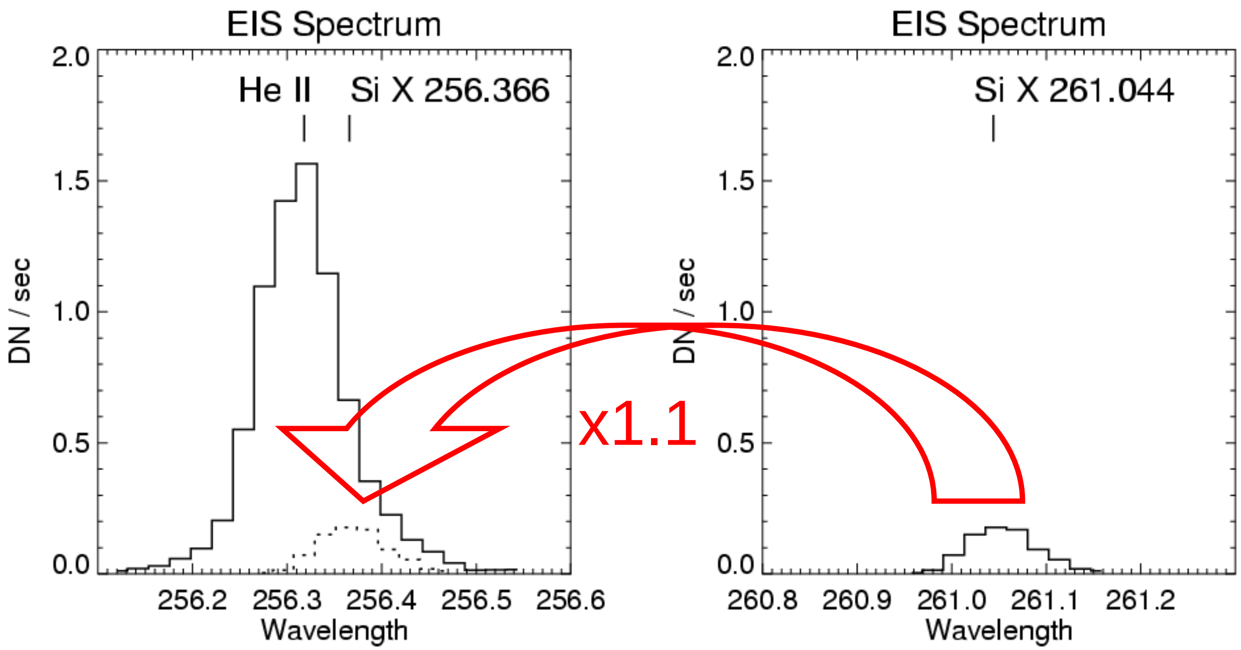
(Mariska 1992)

f (oscillator strength) = 0.10, VAL-C model atmosphere
$n_e=10^{10}cm^{-3}$, turbulent velocity=20 km/s, $T_e=5x10^4K$, L=30km
➔ $\tau_{HeII} = 1$ effectively thin emission

- H I and He I continuums

$\tau = \sigma$ n L
$\sigma_{HI} = 2x10^{-19}cm^2$, $\sigma_{HeI} = 2x10^{-18}cm^2$ (Anzer & Heinzel 2005)
➔ $\tau_{HI} = 5x10^{-5}$, $\tau_{HeI} = 2x10^{-3}$ optically thin

Compensation for Si X



- Red wing of He II is blended with Si X (log Te = 6.1)
- CHIANTI predicts constant intensity ratio (density independent) (Si X λ 256.366 / Si X λ 261.044 = 1.1)
- He II component is derived by subtracting Si X component