

# RHESSI and TRACE Observations of Emerging Flux Reconnection in a Solar Jet on August 21, 2003

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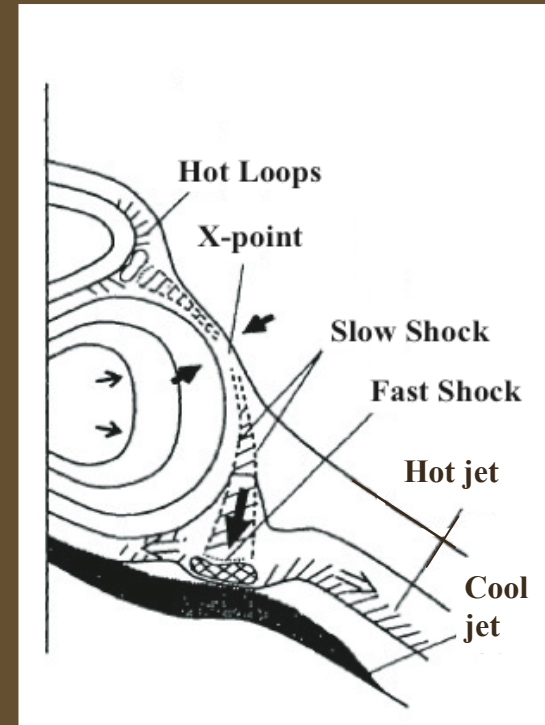
RHESSI Workshop 10, Annapolis, MD  
August 4, 2010

# Outline

- Recap of emerging flux jet model
- Comparison of RHESSI HXR and TRACE EUV images
  - Geometric alignment shows several properties of the emerging flux model
- What can we learn from radio observations?
  - Energetic electrons precede the jet, in the path of the jet.
  - Escaping and trapped electrons are responsible for the HXR emission.
- Conclusions

# Emerging Flux Model

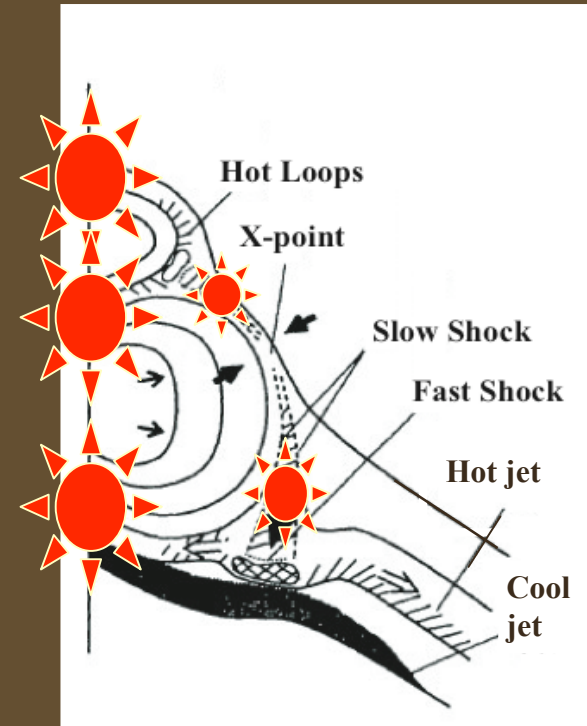
- Shibata--Heyvaerts model:
  - Emerging flux from chromosphere reconnects with overlying coronal field.
  - Coronal acceleration site and outflow jets
  - Cool and/or hot jets



(Shibata et. al, 1996)

# Emerging Flux Model

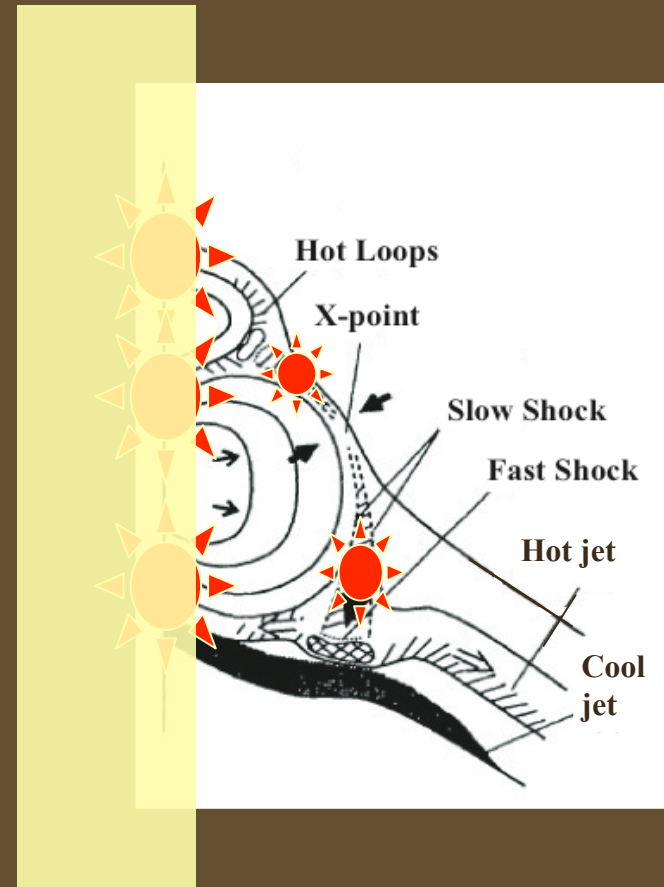
Expected locations of  
hard x-ray emission



# Emerging Flux Model

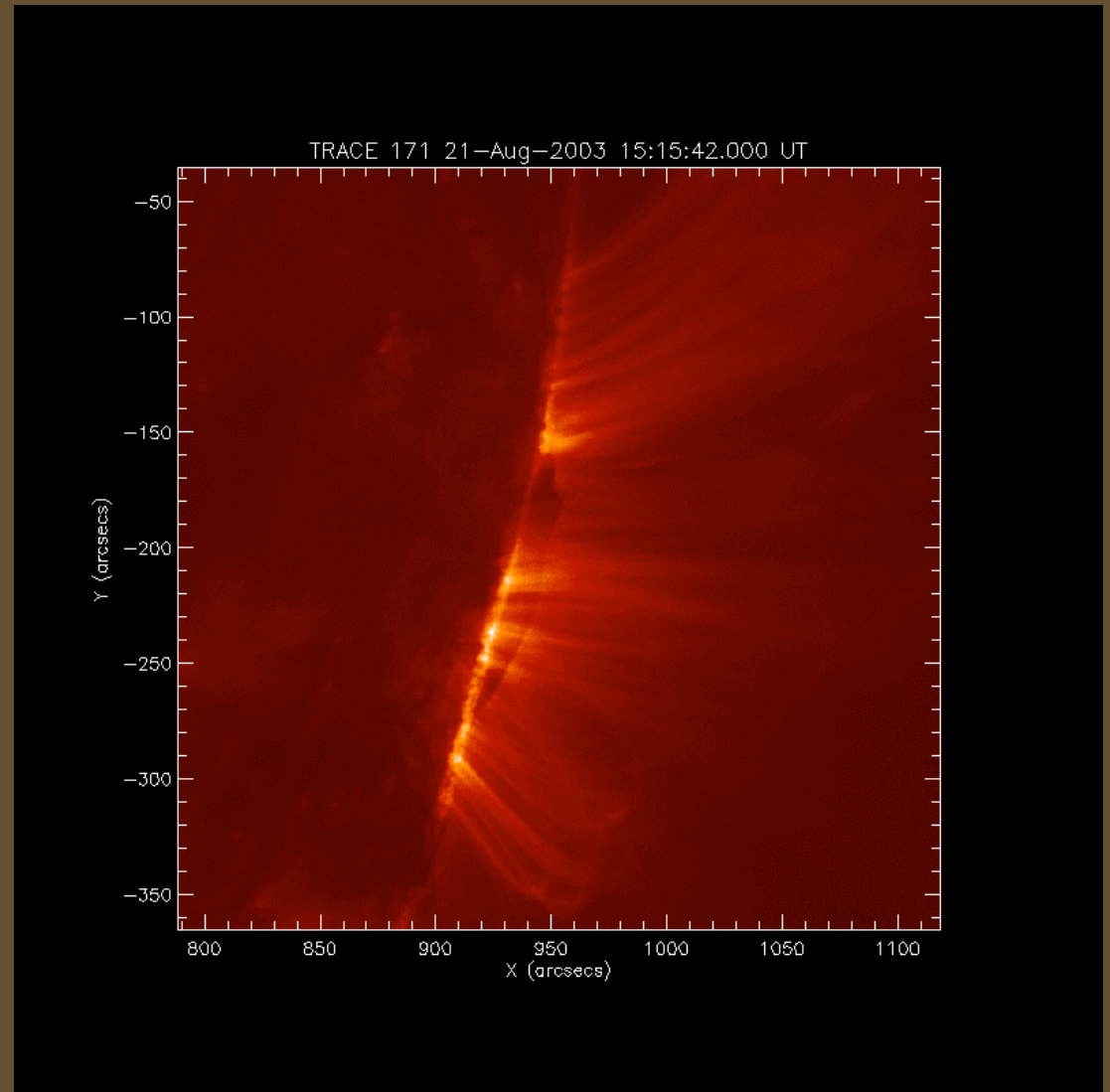
Expected locations of  
hard x-ray emission

if event is partially occulted



# August 21, 2003 jet

- EUV jet
  - 480 (+/- 50) km/s
- Associated flare:
  - GOES C class
  - 1-2 degrees occultation



TRACE 171

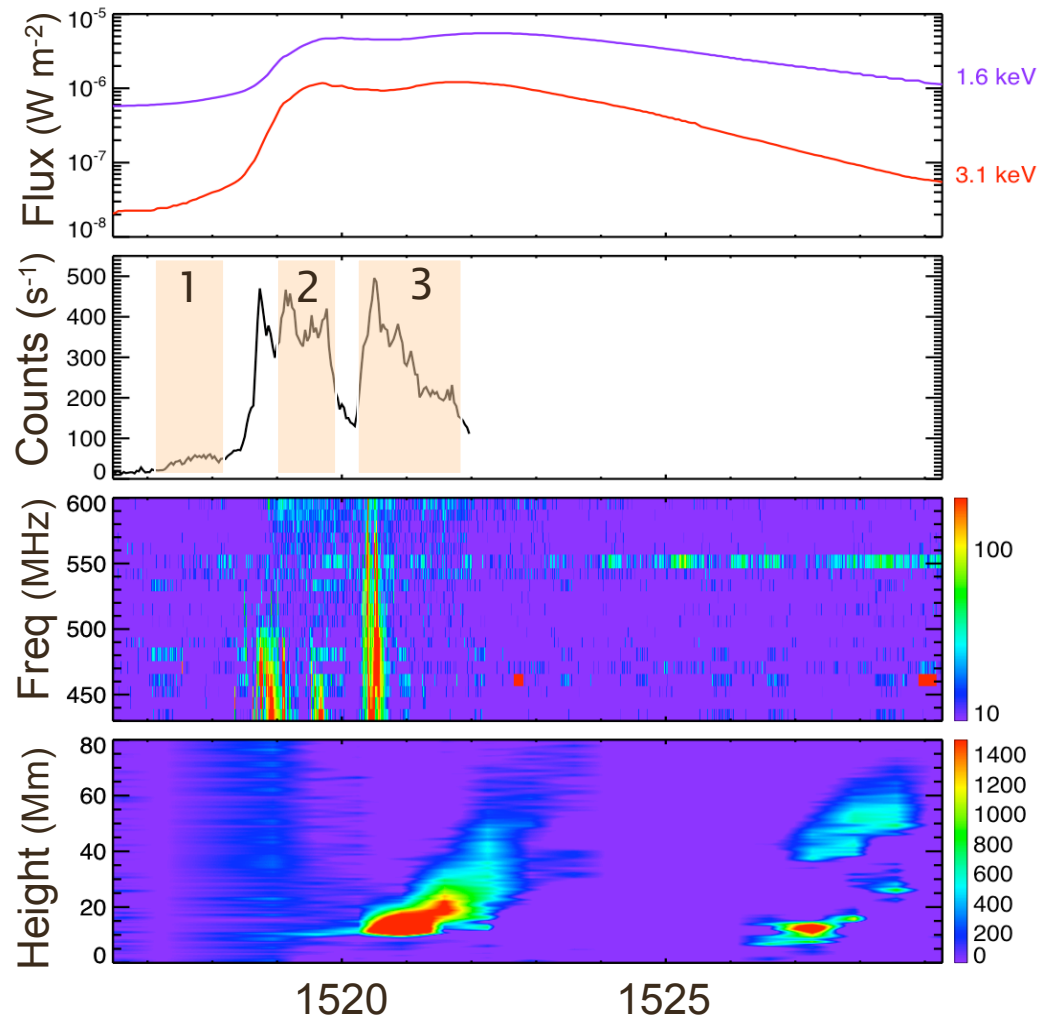
# Time profile

**SXR:** GOES  
1.6, 3.1 keV

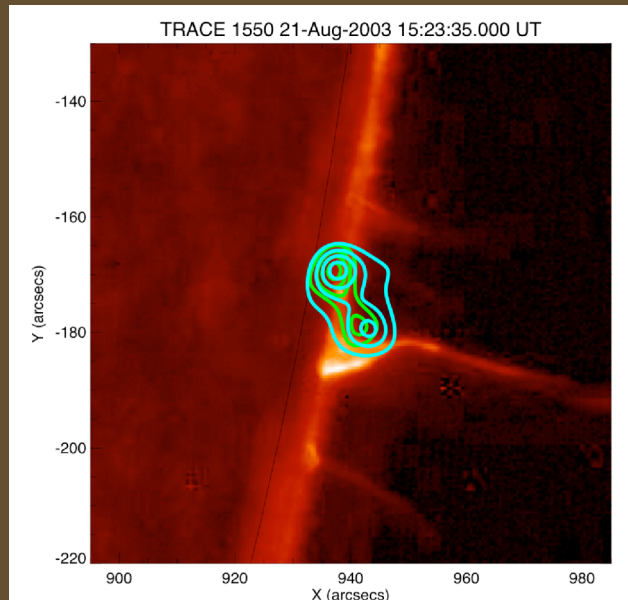
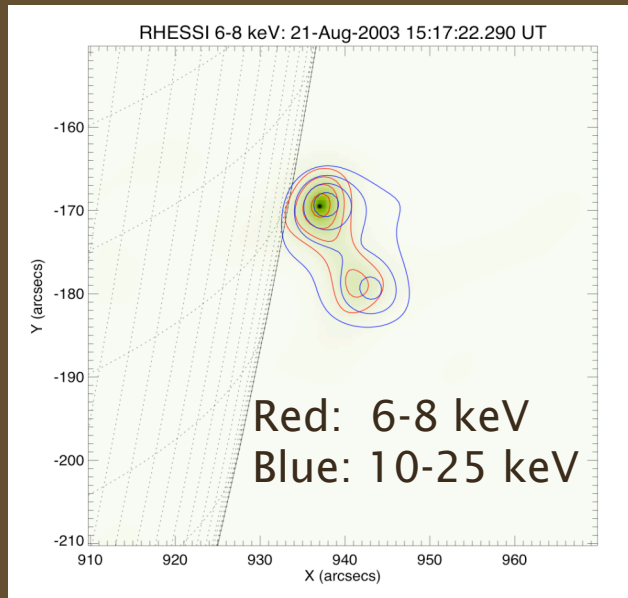
**HXR:** RHESSI  
25-50 keV

**Radio:** PHOENIX  
450-600 MHz

**EUV:** TRACE  
171 Å

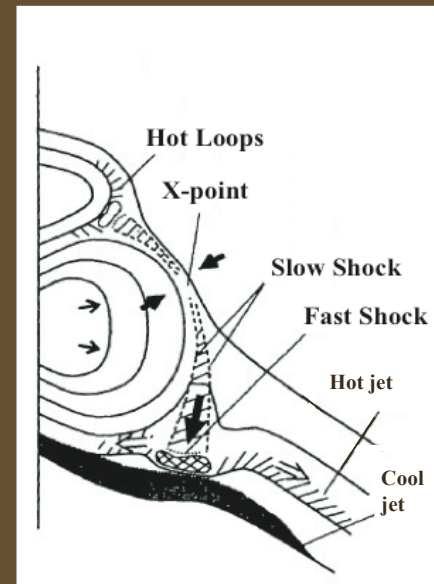


# High coronal source (Image 1)



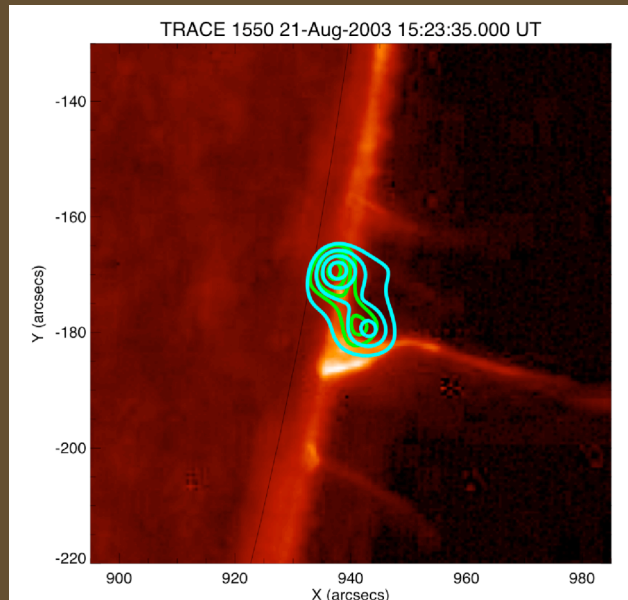
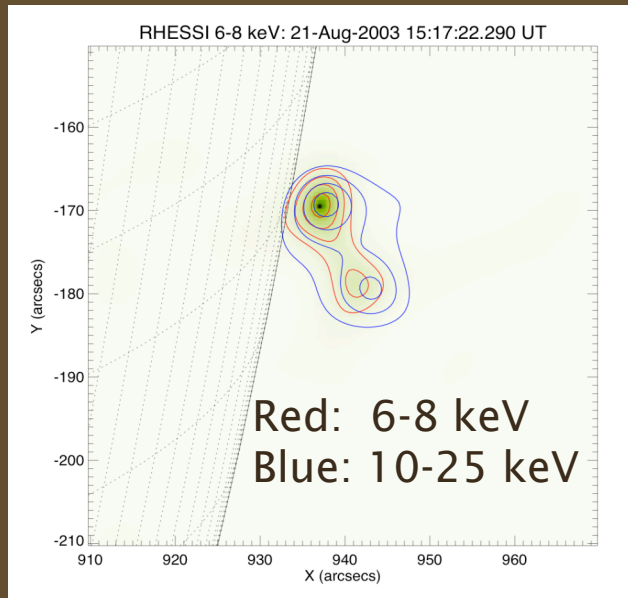
Contour levels 30, 50, 70, 90%

- Visible early (only)
- Thermal and nonthermal emission



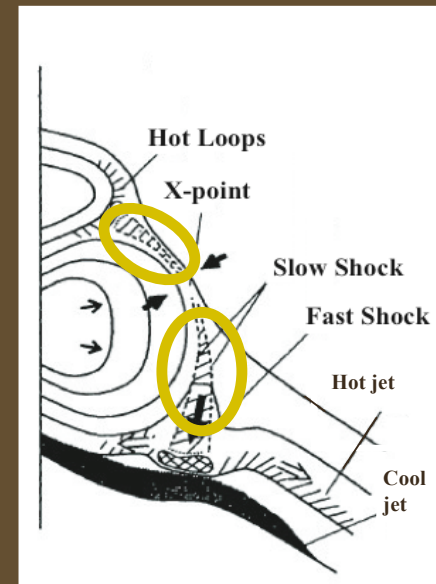


# High coronal source (Image 1)

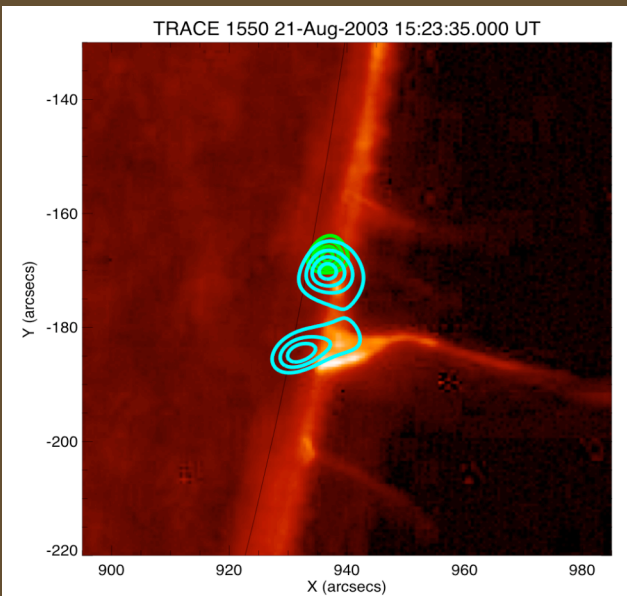
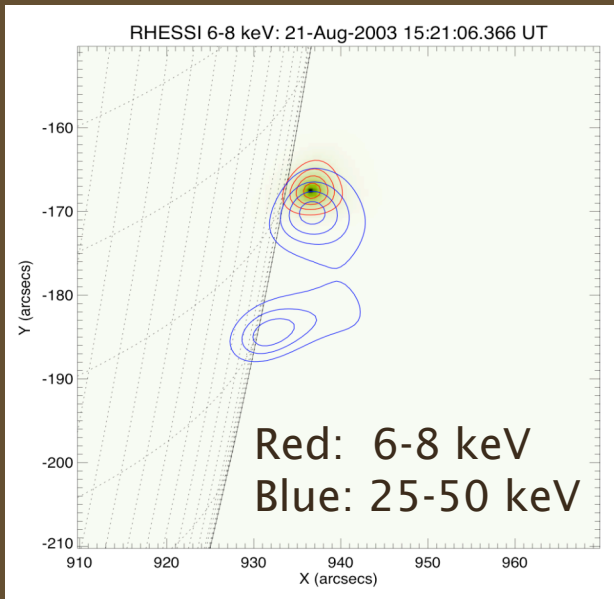


Contour levels 30, 50, 70, 90%

- Visible early (only)
- Thermal and nonthermal emission
- Reconnection outflow jets

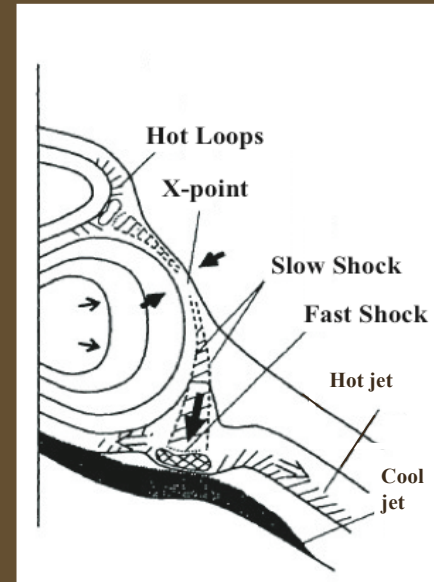


# Base of the jet (Image 3)

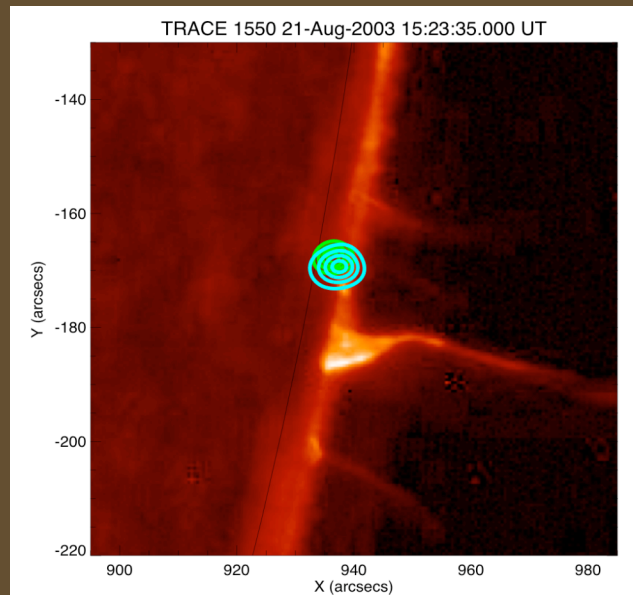
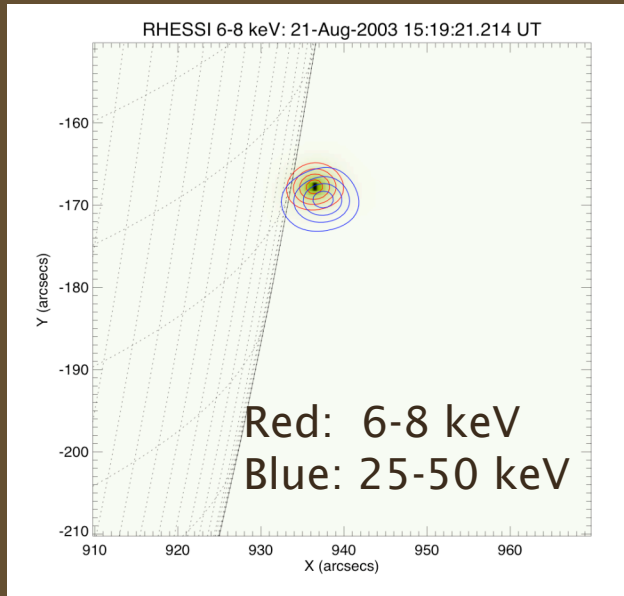


Contour levels 30, 50, 70, 90%

- Nonthermal emission
- No thermal emission



# Near-limb source (Image 2)



Contour levels 30, 50, 70, 90%

- Present throughout flare/jet.
- Thermal electron density:

$$n_{therm} = \sqrt{\frac{EM}{V}}$$

$$n_{therm} \sim 10^{11} \text{ cm}^{-3}$$

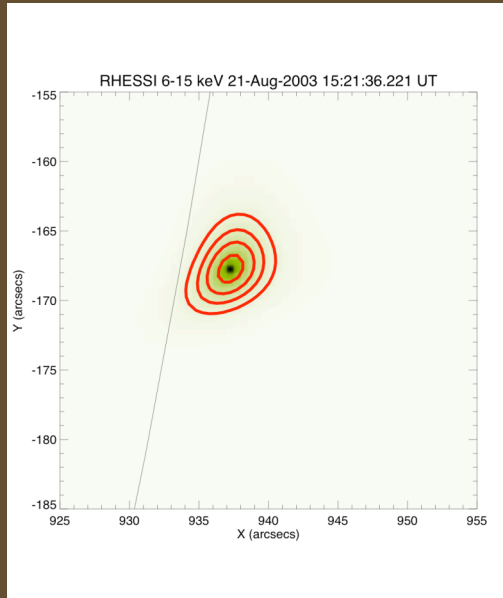
- Instantaneous nonthermal electron density at peak time:

$$\frac{dn}{dE} = 1.21 \times 10^{42} \gamma(\gamma - 1)^2 B\left(\gamma - \frac{1}{2}\right) \frac{AE^{-\gamma+1/2}}{n_i V}$$

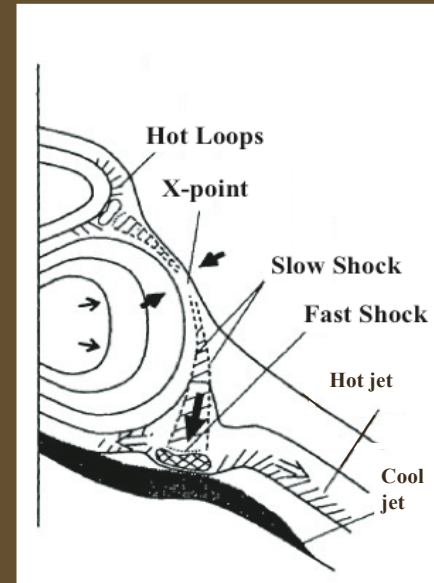
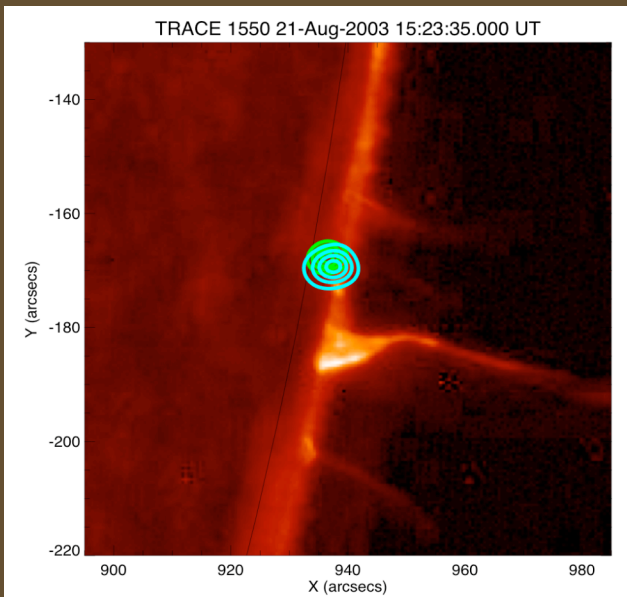
$$n_{nontherm} \sim 2 \times 10^8 \text{ cm}^{-3}$$

# Near-limb source (Image 2)

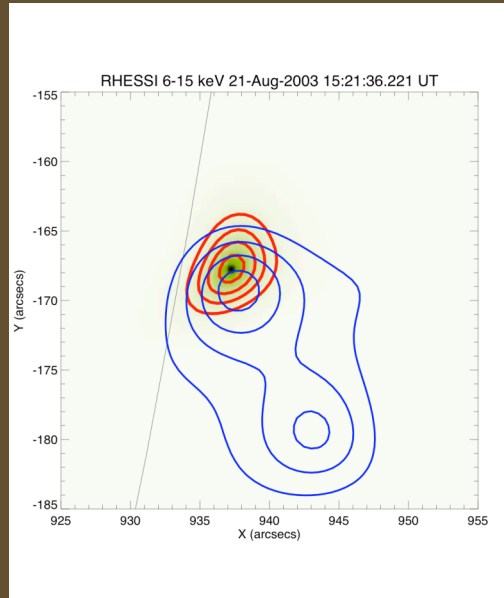
- Late in the flare, a small, hot loop becomes visible.



Contour levels 30, 50, 70, 90%

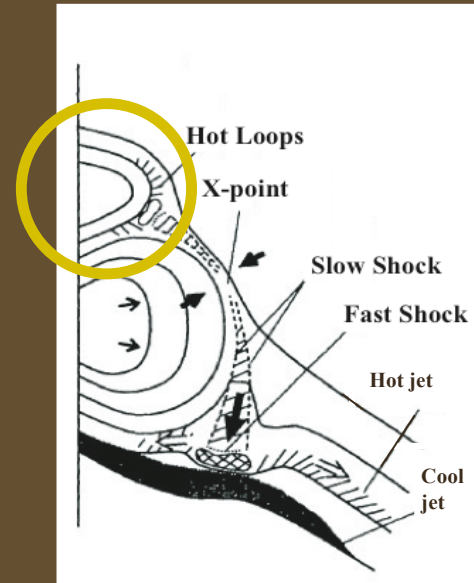
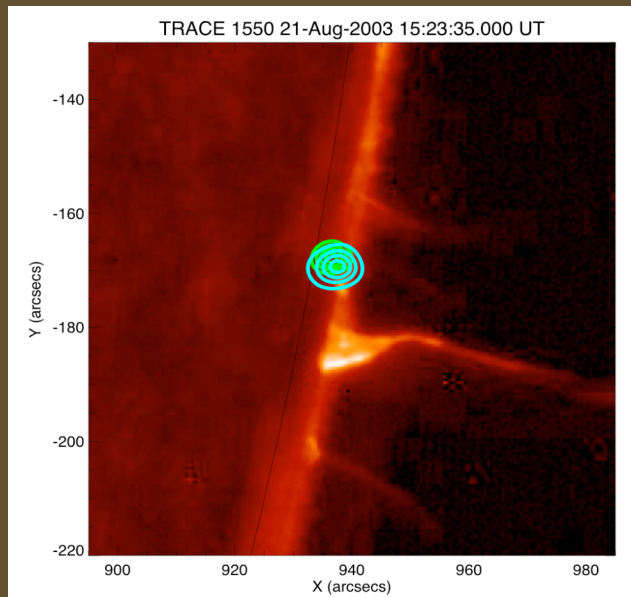


# Near-limb source (Image 2)

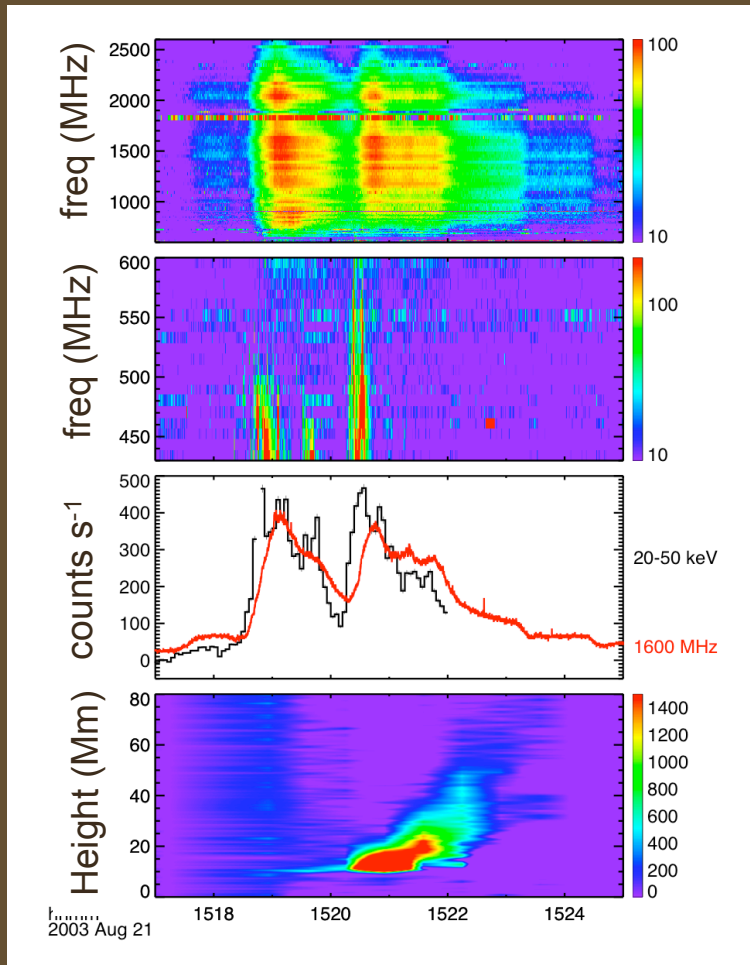


- Late in the flare, a small, hot loop becomes visible.
- This loop is also predicted by the emerging flux model.

Contour levels 30, 50, 70, 90%

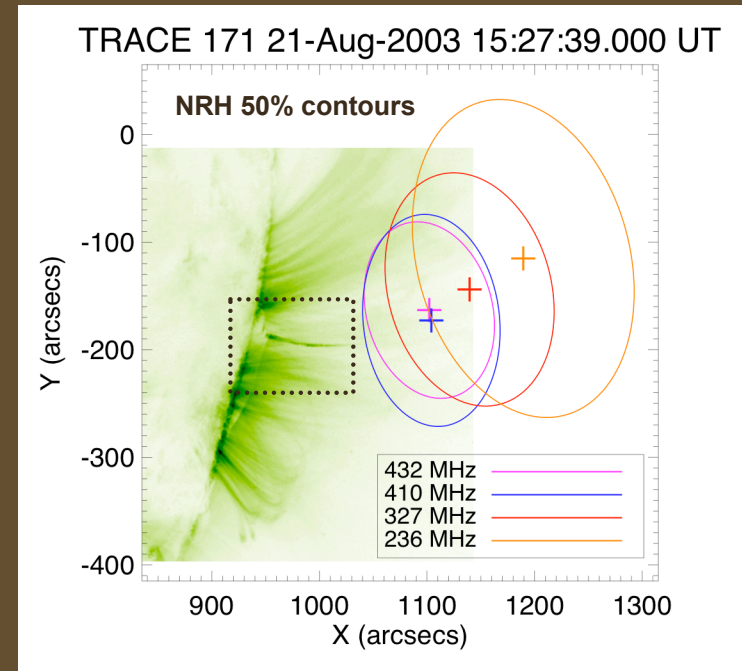
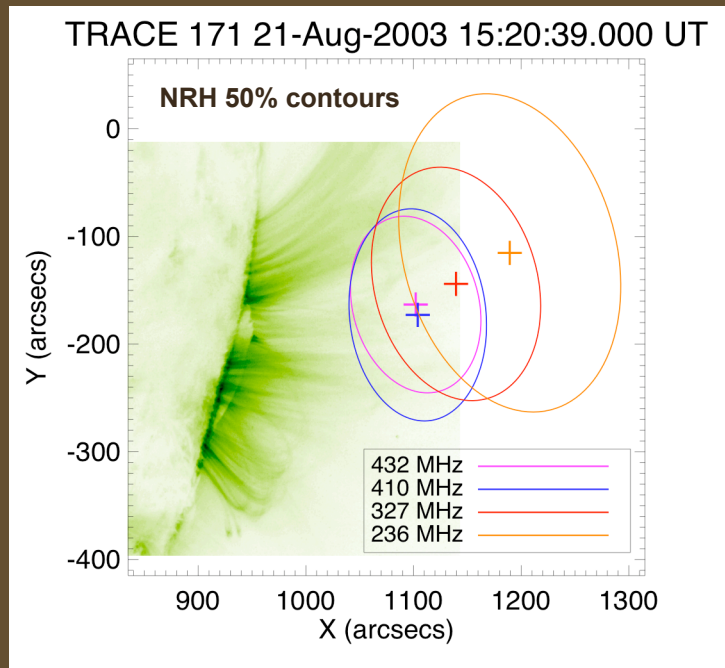


# Radio time profiles: PHOENIX



- Broadband GHz emission
  - plasma emission, trapped electrons
  - Possible gyrosynchrotron
- Type III bursts
- GHz emission matches nonthermal HXR profile
- Jet starts at last Type III burst

# Type III bursts: Nancay RadioHeliograph

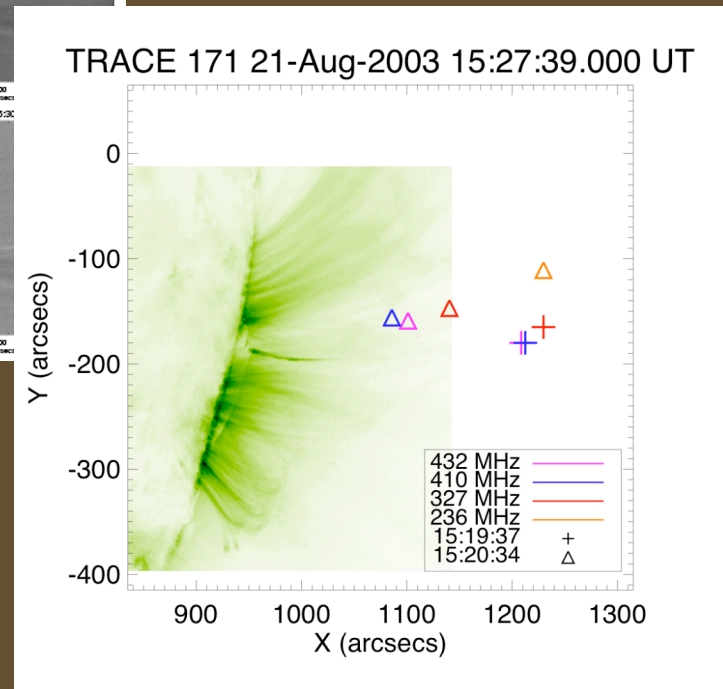
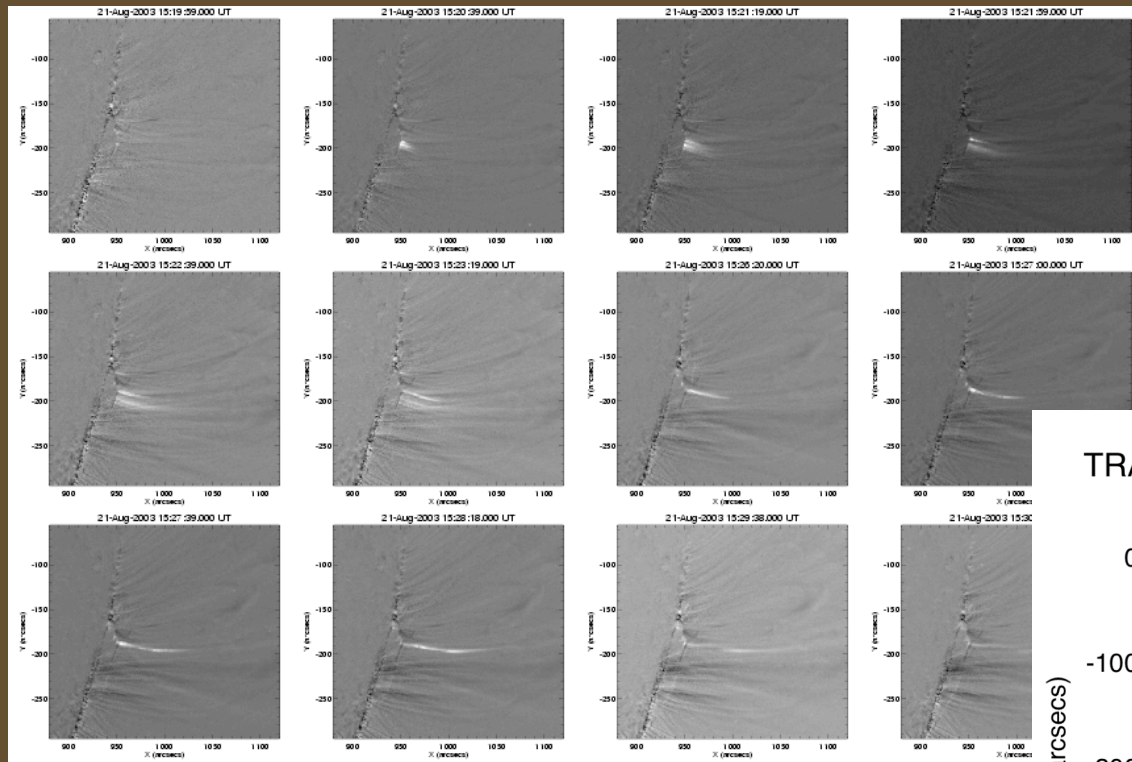


- Increasing source height with frequency
- Accelerated particles move along path later taken by jet
- Density scale height  $L = 52.4 \pm 3.5$  Mm
- Density at limb  $\sim 2 \times 10^{10} \text{ cm}^{-3}$

$$n \propto n_o e^{h/L}$$

$$2\pi f = \sqrt{\frac{ne^2}{m\epsilon_o}}$$

# Radio bursts and jet location



Northern migration of jet and  
Type III emitting beams



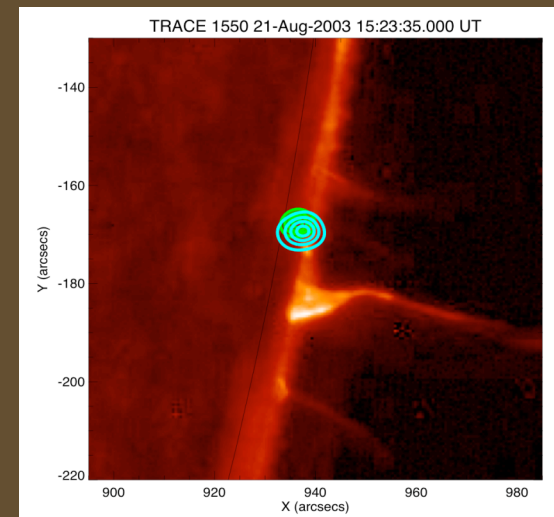
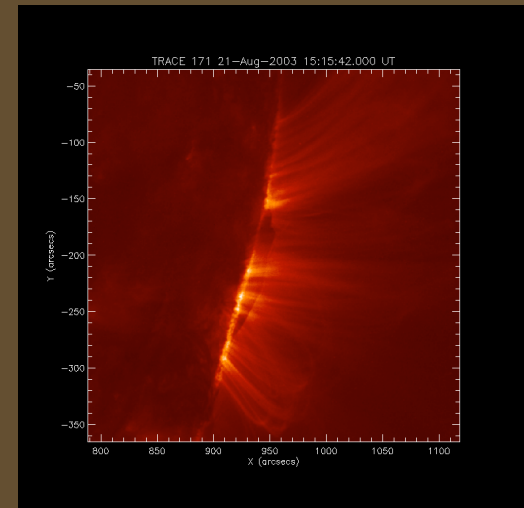
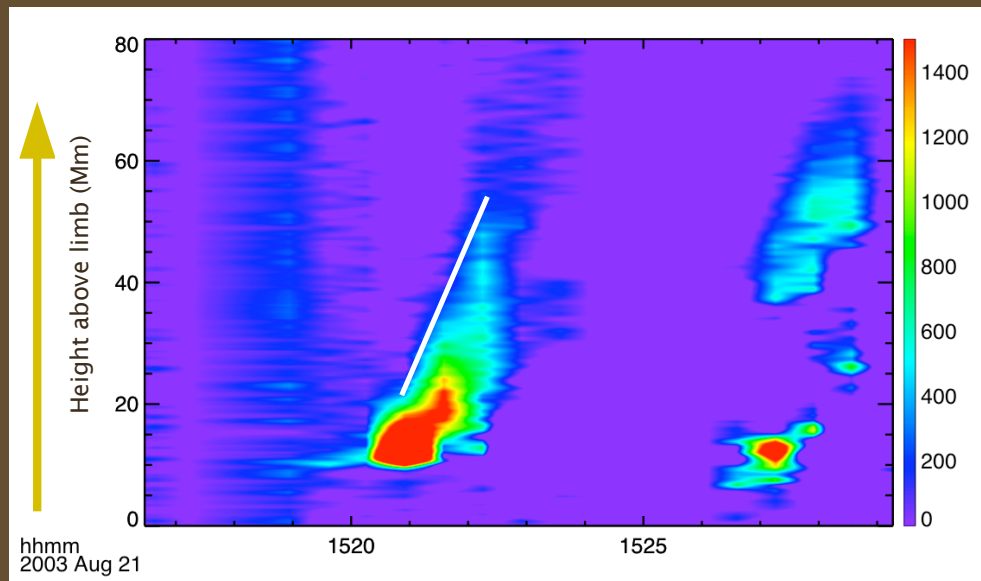
# Conclusions

- The following flare elements support the Heyvaerts-Shibata model of emerging flux:
  - Two early nonthermal coronal HXR sources
  - Nonthermal emission from the jet base at the start of the jet
  - A small, hot flare loop located opposite the jet
- Radio data temporally coincides with nonthermal HXR emission.
  - Type III bursts/escaping electrons precede the jet along the jet path. Northern migration is seen for both these phenomena.
  - Broadband decimetric bursts correlate with HXR emission and could be produced by trapped electrons.

Extra Slides

# TRACE images of the jet

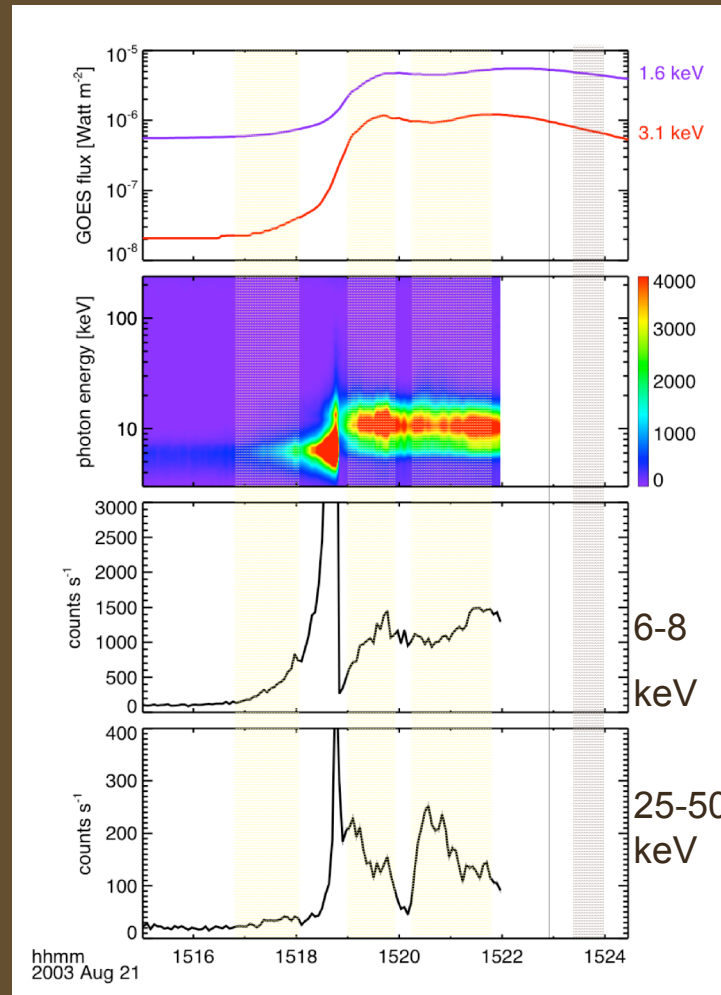
- Jet velocity found by fitting slope of intensity profile.
- $V_{\text{jet}} \sim 480 \text{ km/s (+/- 50 km/s)}$
- Velocity consistent with Alfvén speed or sound speed



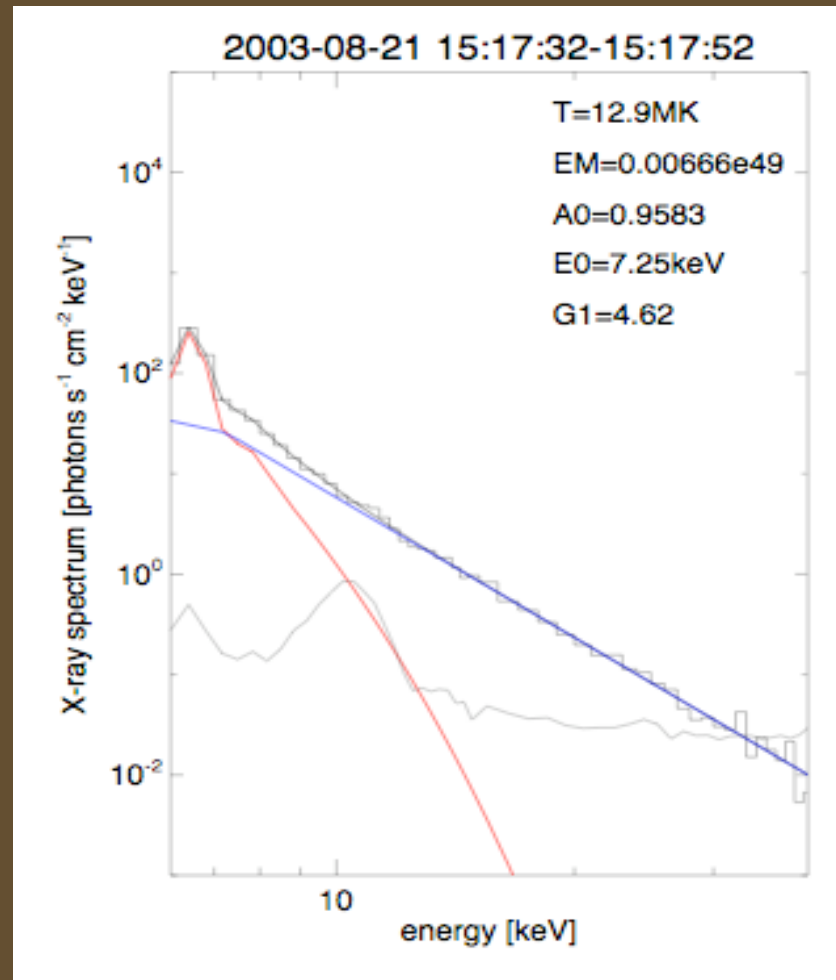
# Comparison with other jets

	Shimojo et. al. (1996)	Kim et. al. (2007)	Bain & Fletcher (2009)	Current study
Number events	100	3	1	1
Data source	Yohkoh	Hinode TRACE	RHESSI TRACE	RHESSI TRACE
Apparent velocity (km/s)	10–1000 (avg 200)	90–310	~500	~480
Jet length (km)	$10^3$ – $4 \times 10^5$ (avg $1.5 \times 10^5$ )	$1.1 \times 10^5$ – $5 \times 10^5$		at least $8.8 \times 10^4$
Jet lifetime	min. to hours	100–2000 sec		~1300 sec
Nonthermal emission			up to 30-50keV $\gamma=4.52$	up to 30-50keV $\gamma=4.0$

# August 21, 2003 flare: Time Profile



# Spectrum: time interval 1



# Spectrum: time interval 3

