

# The Remarkable X-ray Jet in the Quasar 4C 20.24

Dan Schwartz

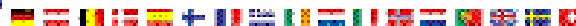
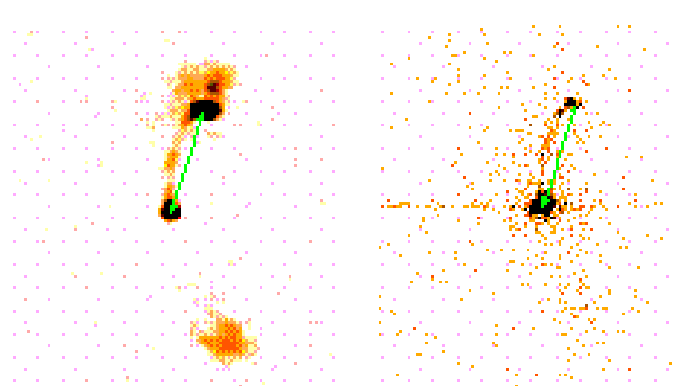
Smithsonian Astrophysical Observatory

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PKS 1055+201=4C 20.24



# Outline

## 1. Context of an X-ray Jet Survey

- Flat spectrum radio sources
- Extended radio jet longer than 2''
- Predict detectable X-ray flux in 5ks

## 2. What is Normal About 4C20.24?

## 3. What is Remarkable About 4C20.24?

# Outline

## 1. Context of an X-ray Jet Survey

## 2. What is Normal About 4C20.24?

- X-ray jet correlates with radio jet
- X-rays modelled as IC/CMB
- Magnetic field strength  $B$  about  $10 \mu\text{ G}$ ,
- Doppler factor  $\delta$  about 6

## 3. What is Remarkable About 4C20.24?

# Outline

**1. Context of an X-ray Jet Survey**

**2. What is Normal About 4C20.24?**

**3. What is Remarkable About 4C20.24?**

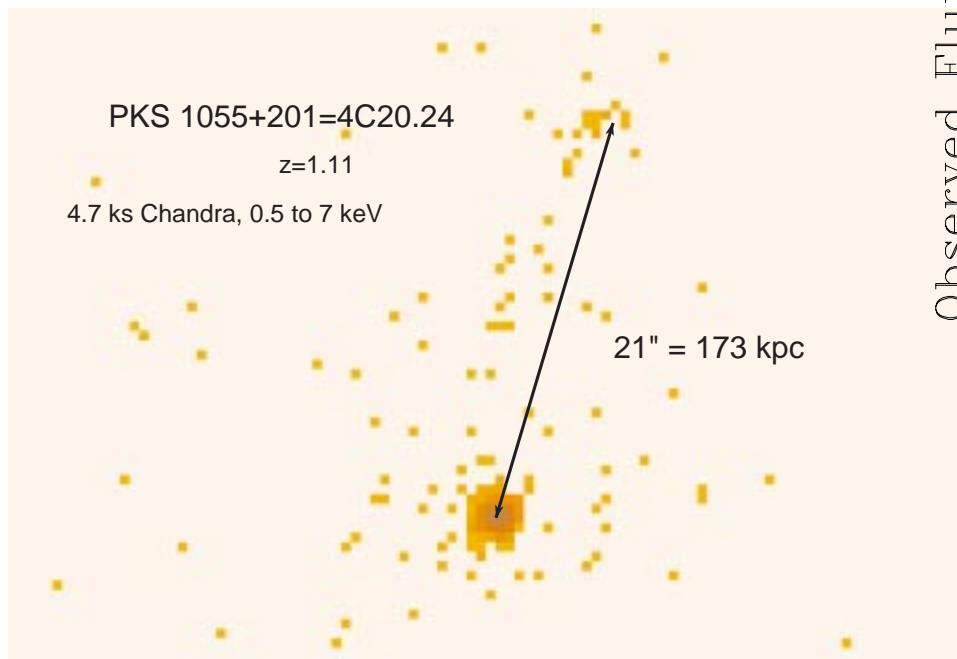
- **Extended X-ray emission tube symmetric around radio/X-ray jet**
- **Similar extended X-ray emission tube around unseen counter-jet**
- **Jets appear to be “swept” back from quasar**
- **Test case of seeing both the X-ray jet and its interaction with external medium?**

# The Jet Sample

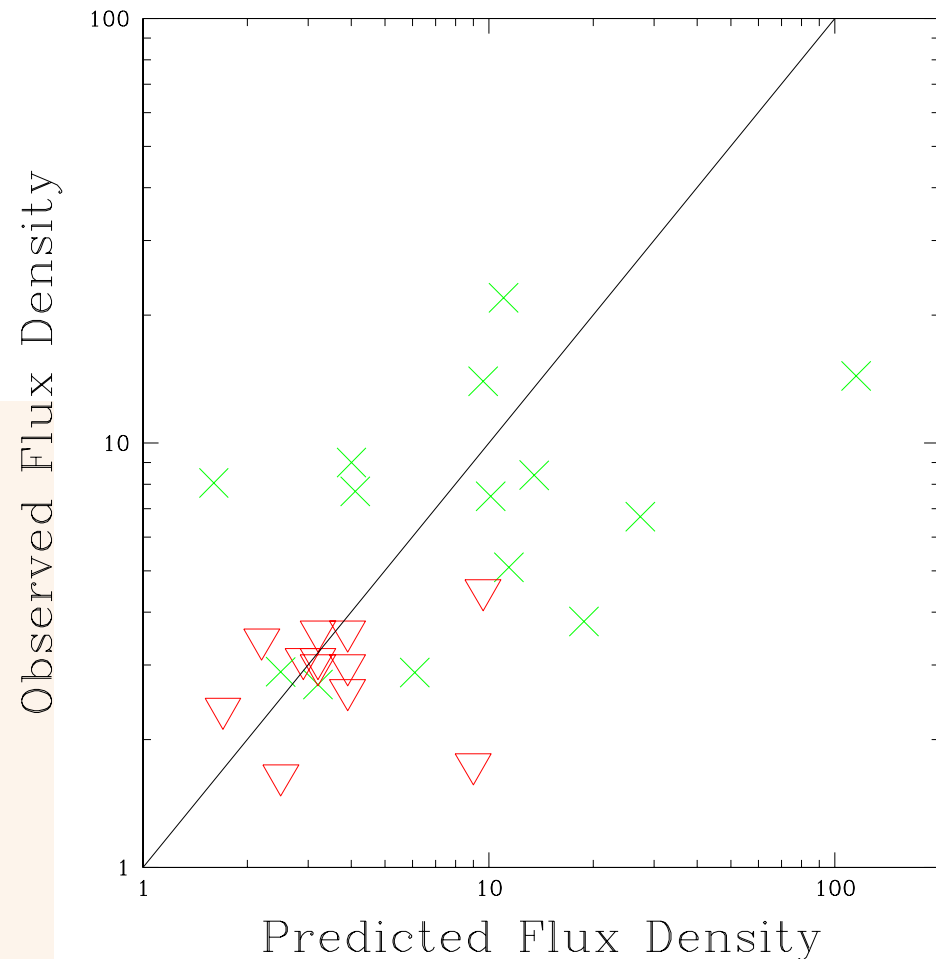
- **Flat Spectrum Quasars. Two Samples:  $S_{5\text{GHz}} > 1\text{Jy}^a$  or  $S_{2.7\text{GHz}} > 0.34\text{Jy}^b$**
- **Radio Maps with  $< 2''$  resolution have jets  $> 2''$  with detection expected by analogy to PKS 0637-752.**
- **Detected 22 of the first 37 Observed.**
- **Deeper *Chandra* Followup of 7**

<sup>a</sup>Murphy, Browne & Perley 1993

<sup>b</sup>Lovell 1997



X-Ray Jet fluxes vs Scaled Predictions



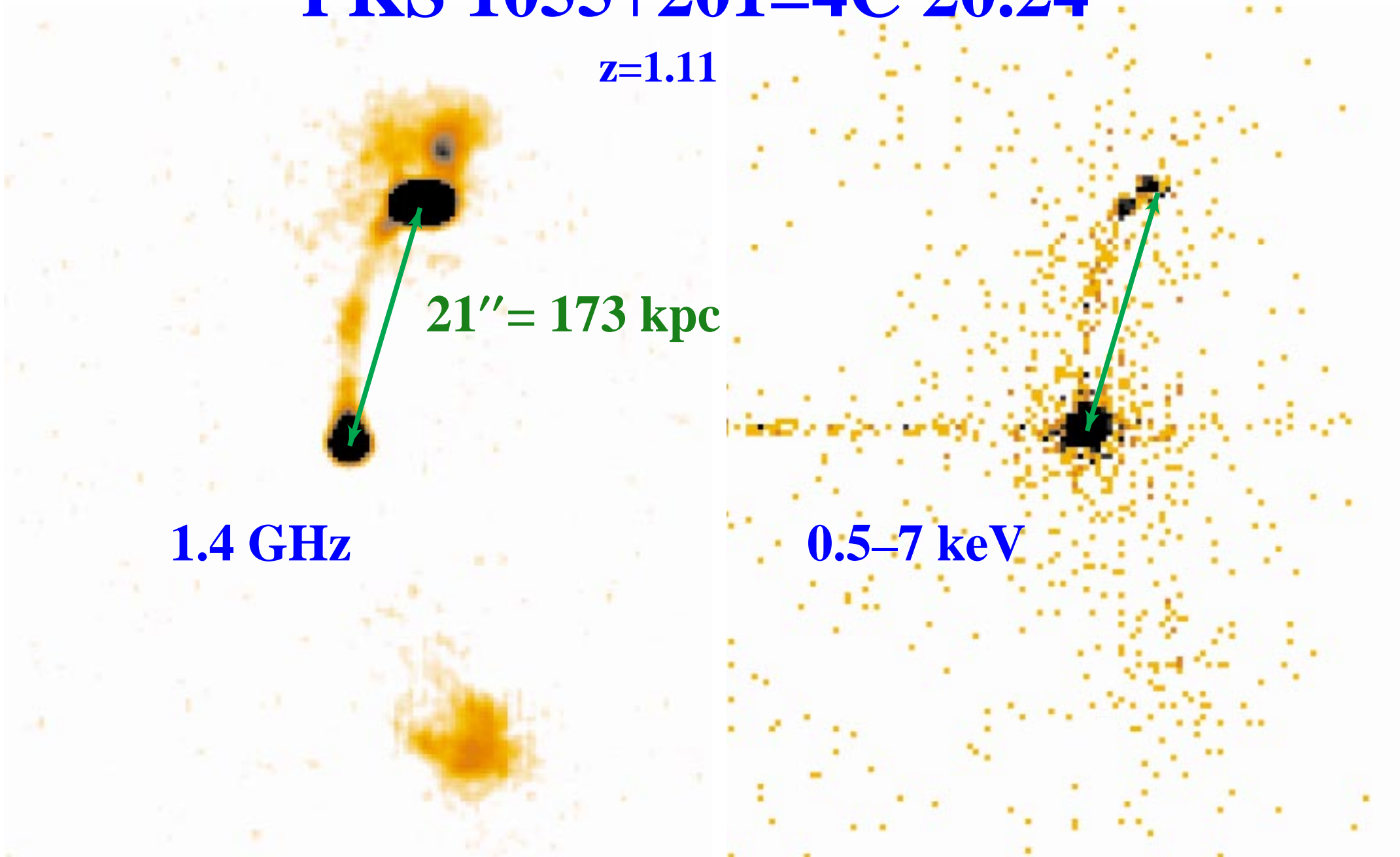
# PKS 1055+201=4C 20.24

$z=1.11$

$21'' = 173 \text{ kpc}$

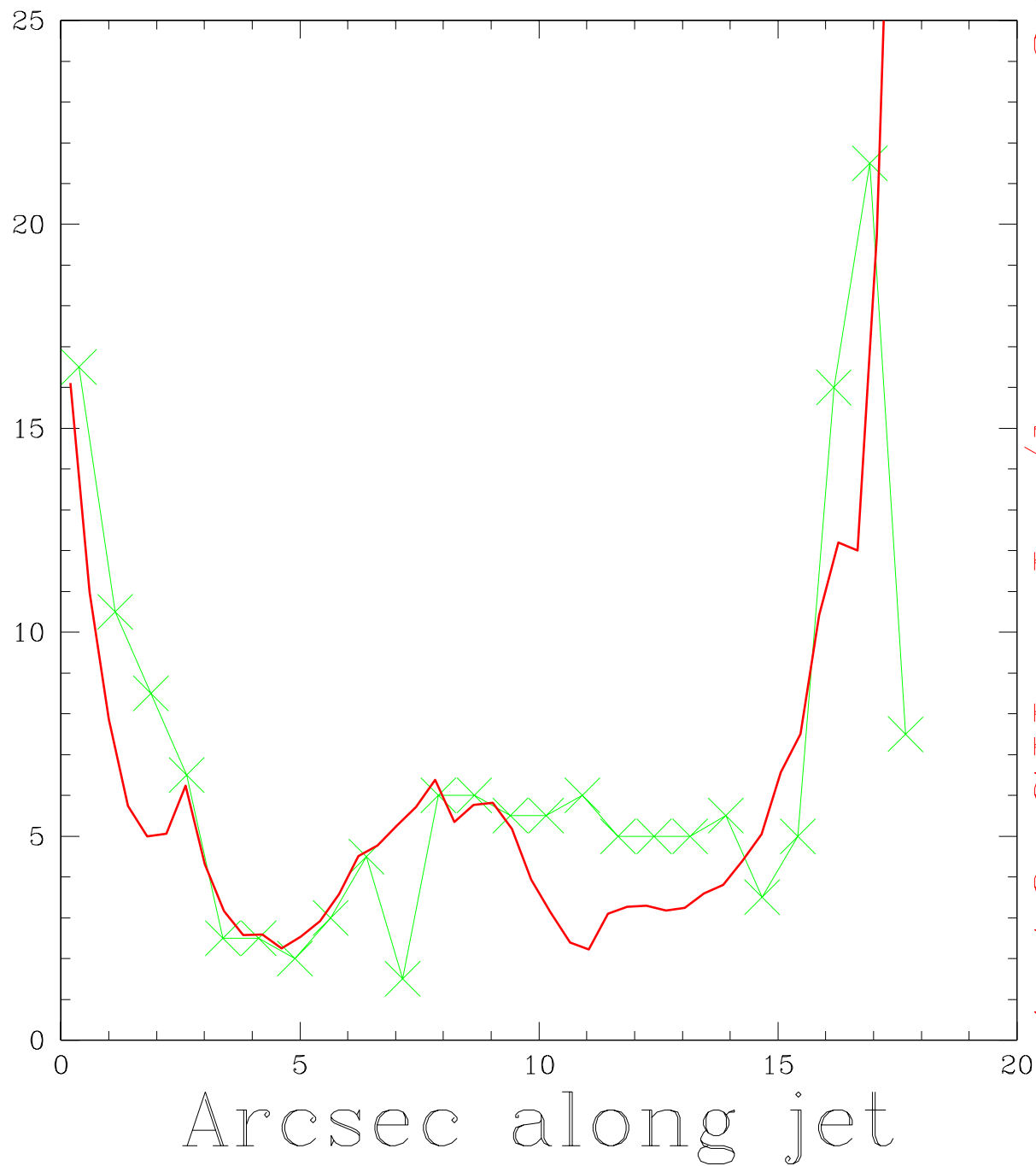
1.4 GHz

0.5–7 keV

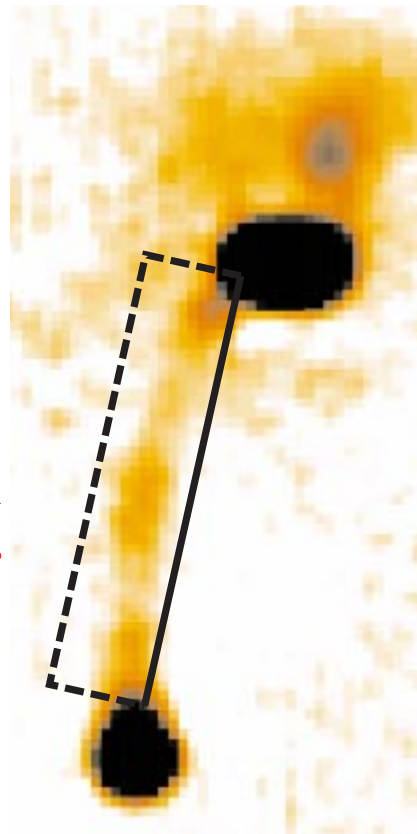
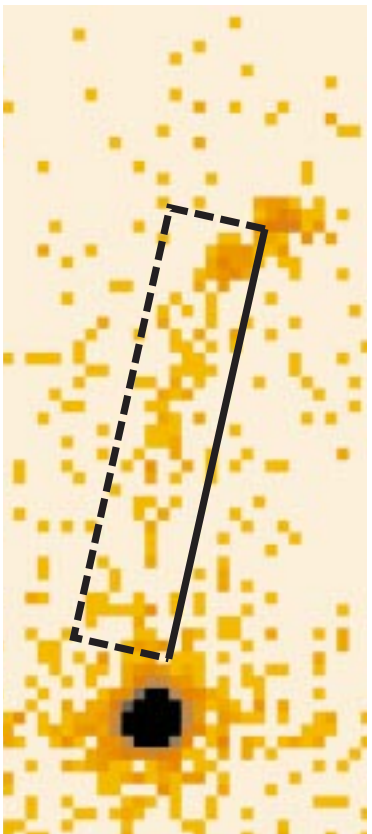


PKS 1055+201 = 4C 20.24

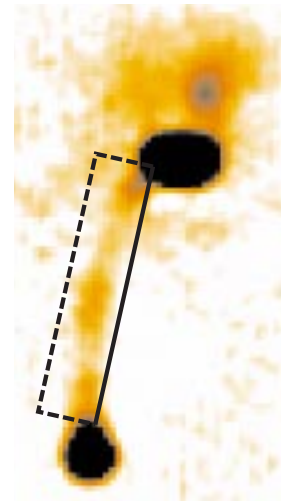
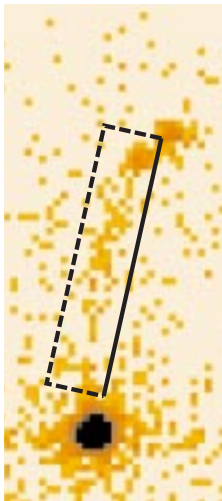
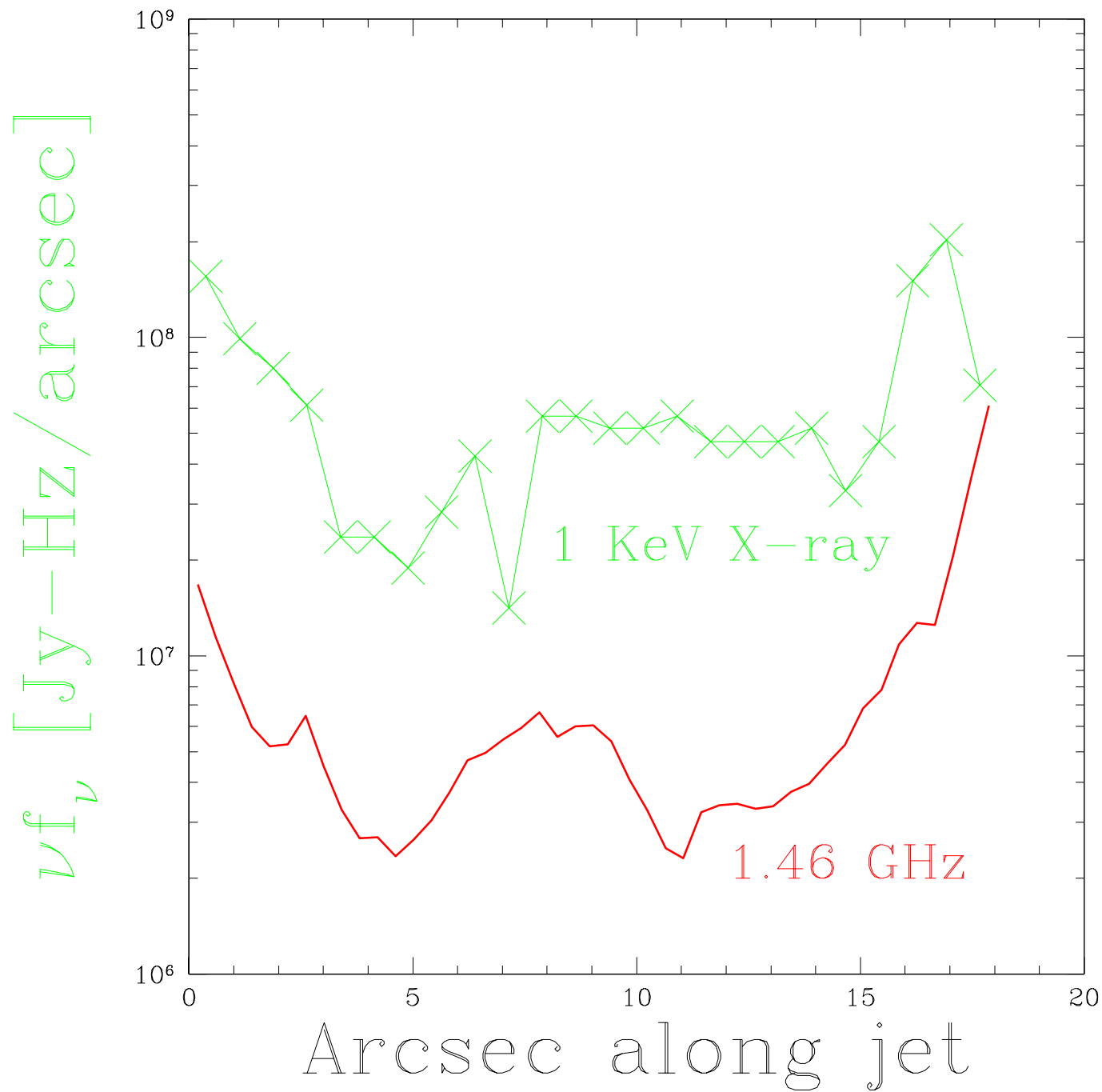
X-ray counts



1.46 GHz, Jy/beam x 200



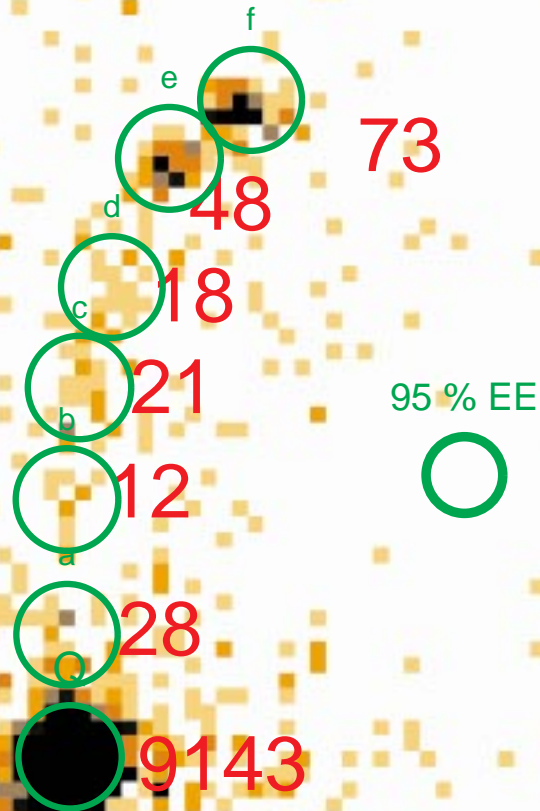
# PKS 1055+201 = 4C 20.24





# PKS 1055+201=4C 20.24

$z=1.11$



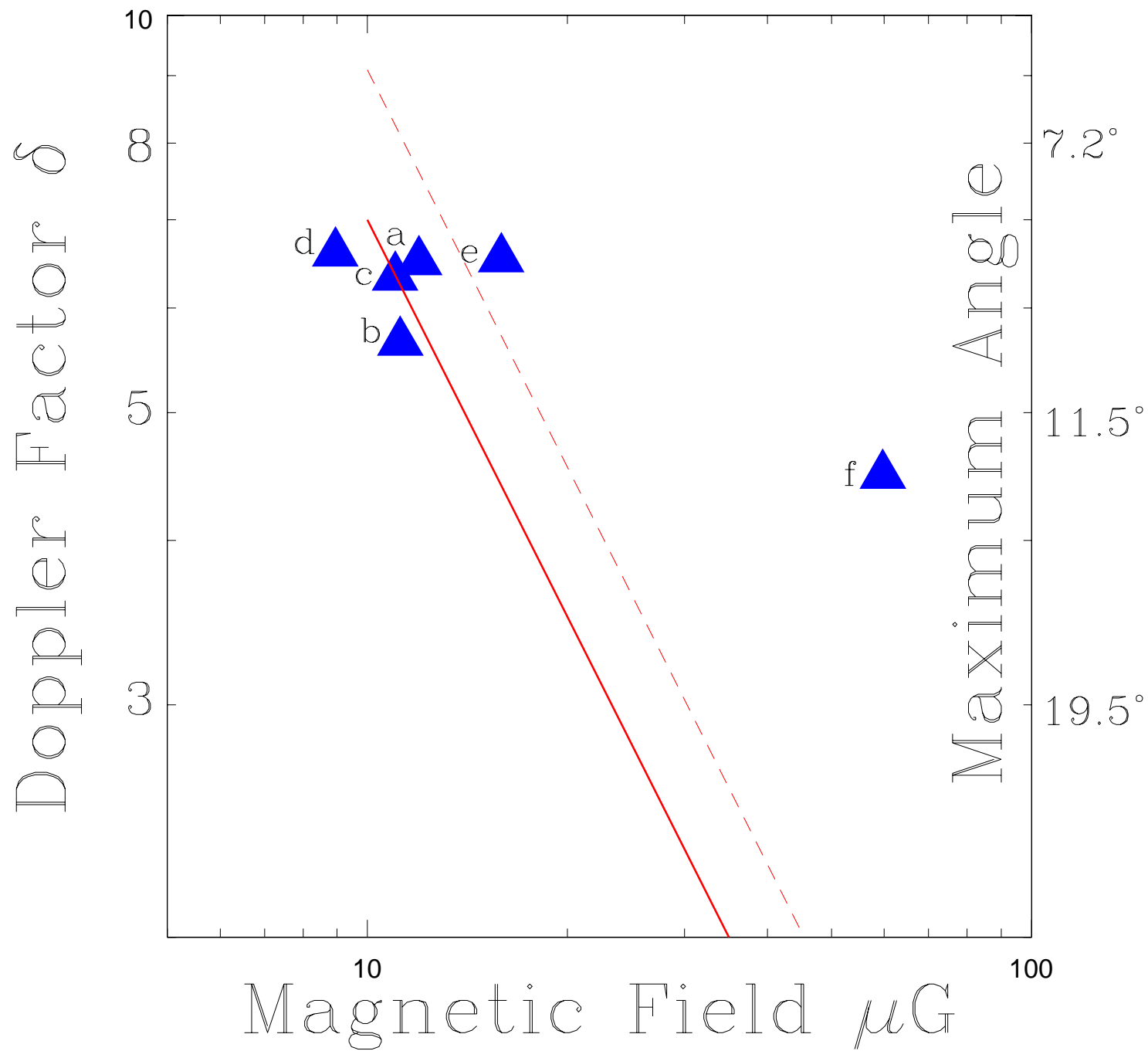
1.46 GHz

FWHM

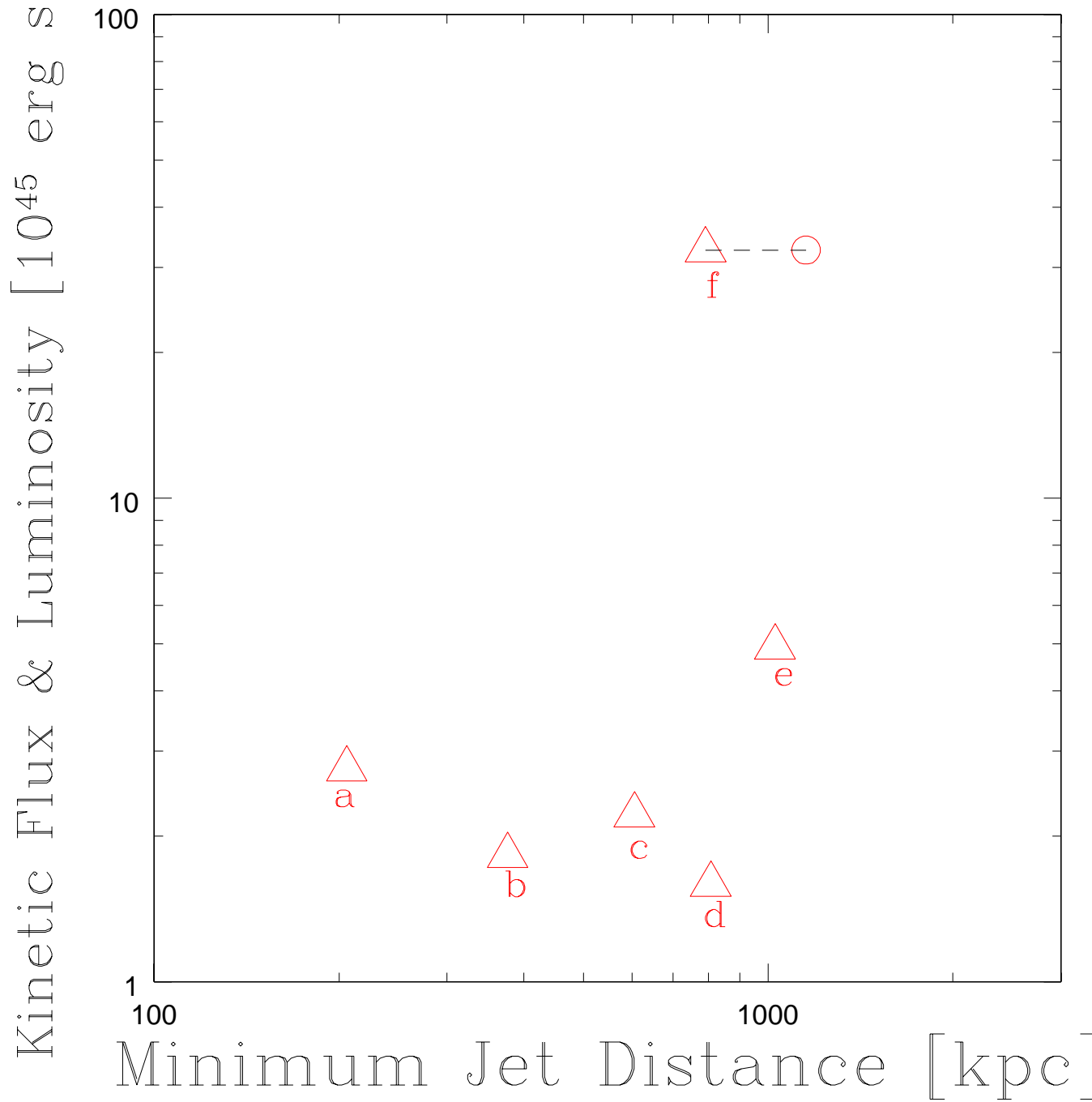


**Regions for spatially distinct SED analysis.**

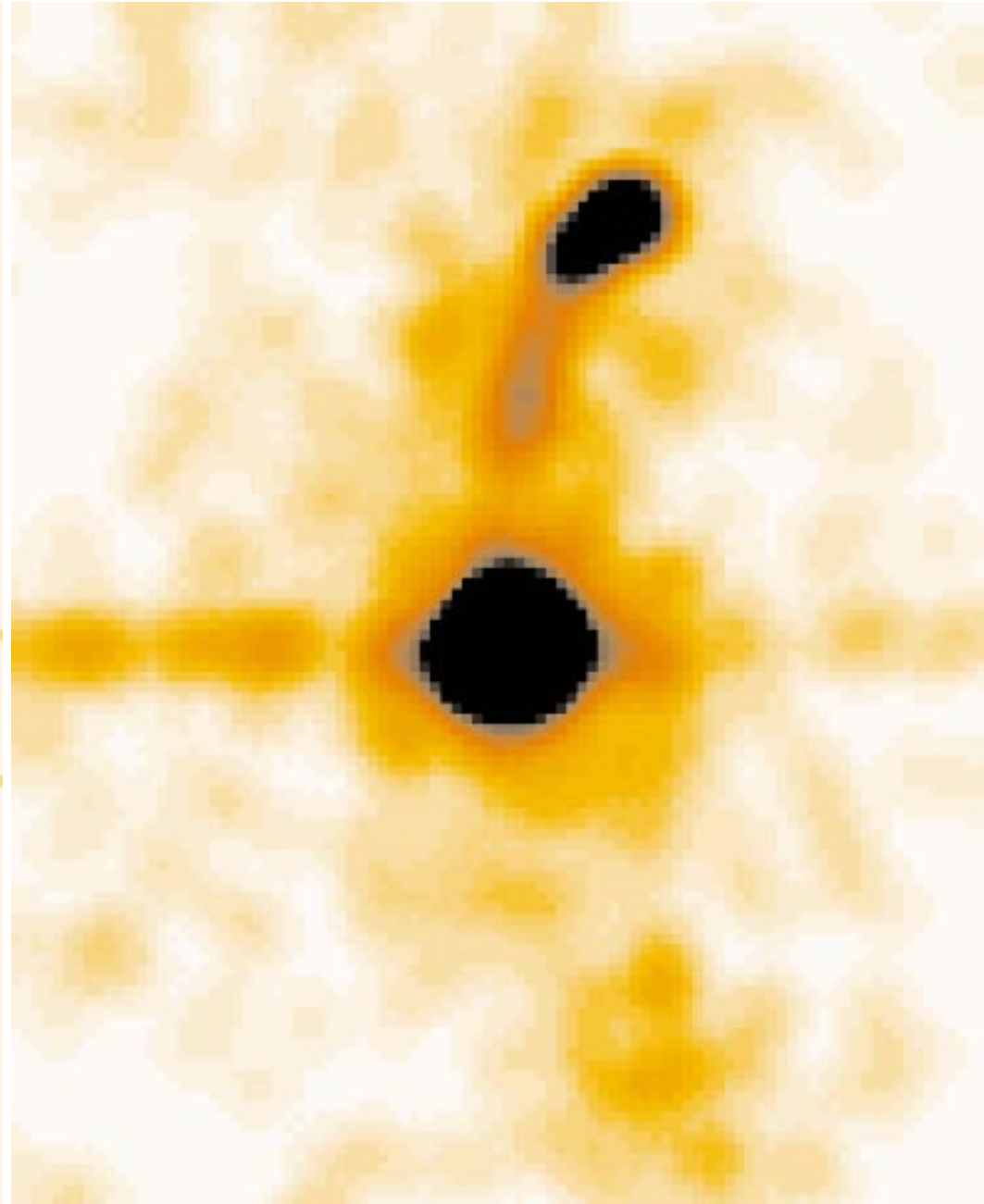
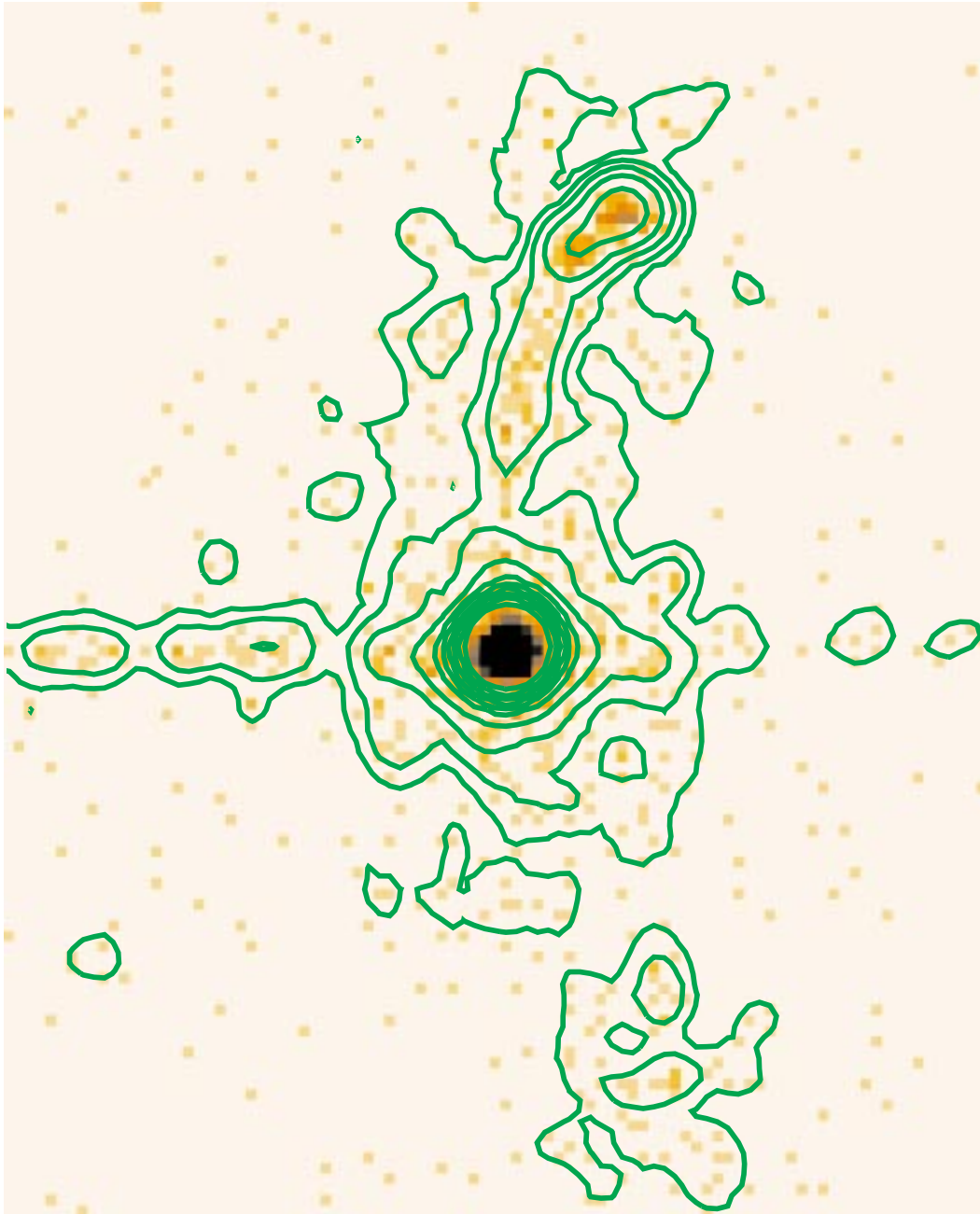
# Structure of 4C 20.24 Jet

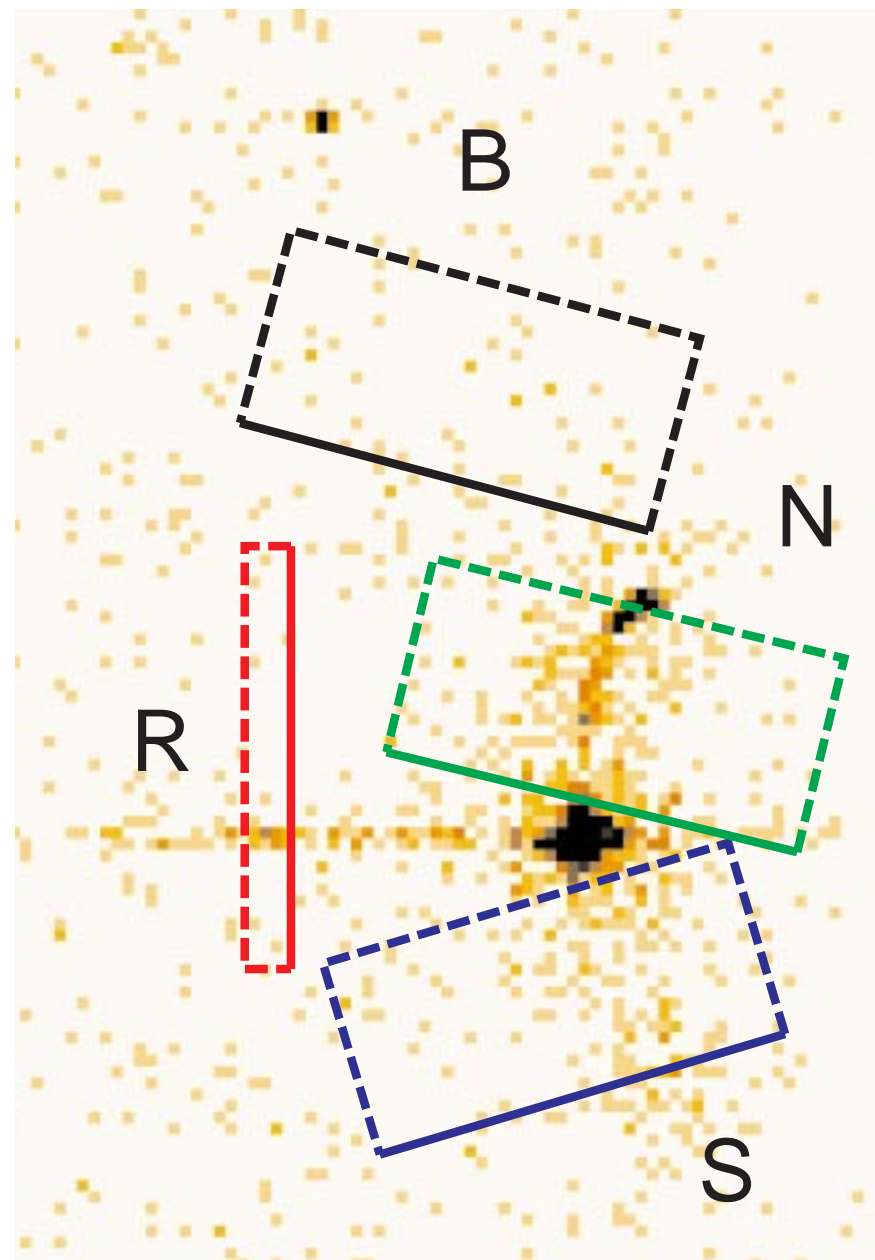
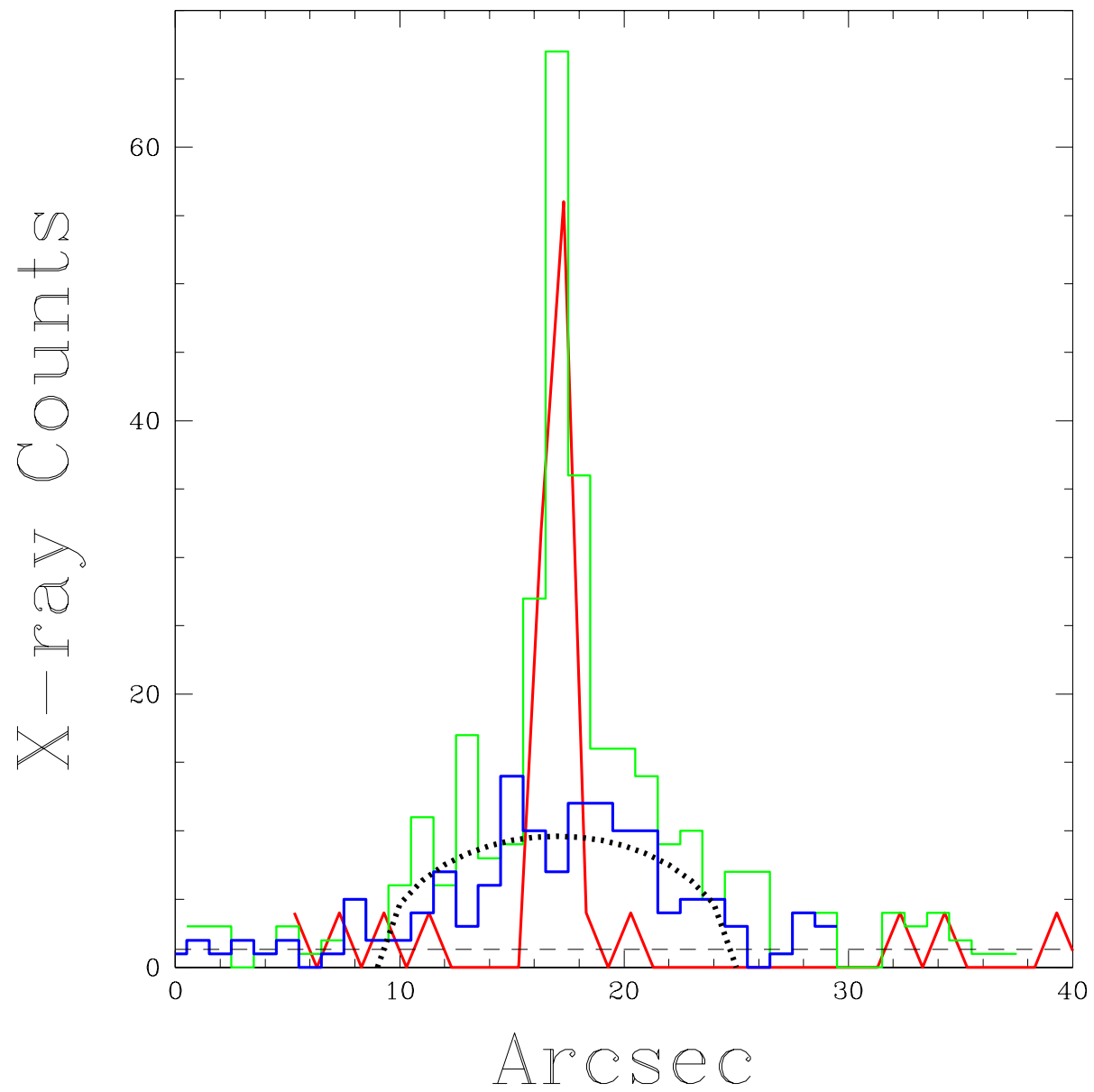


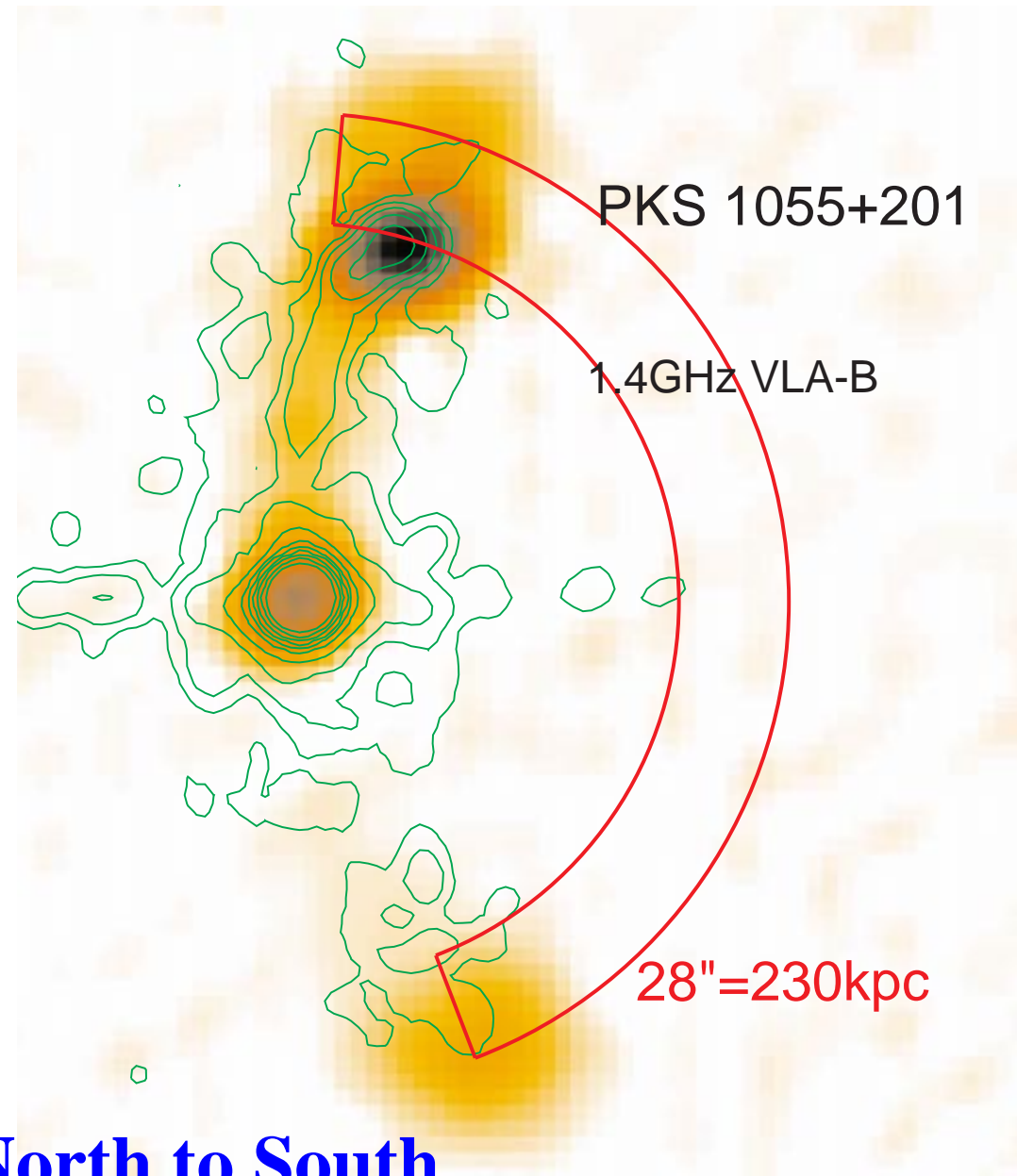
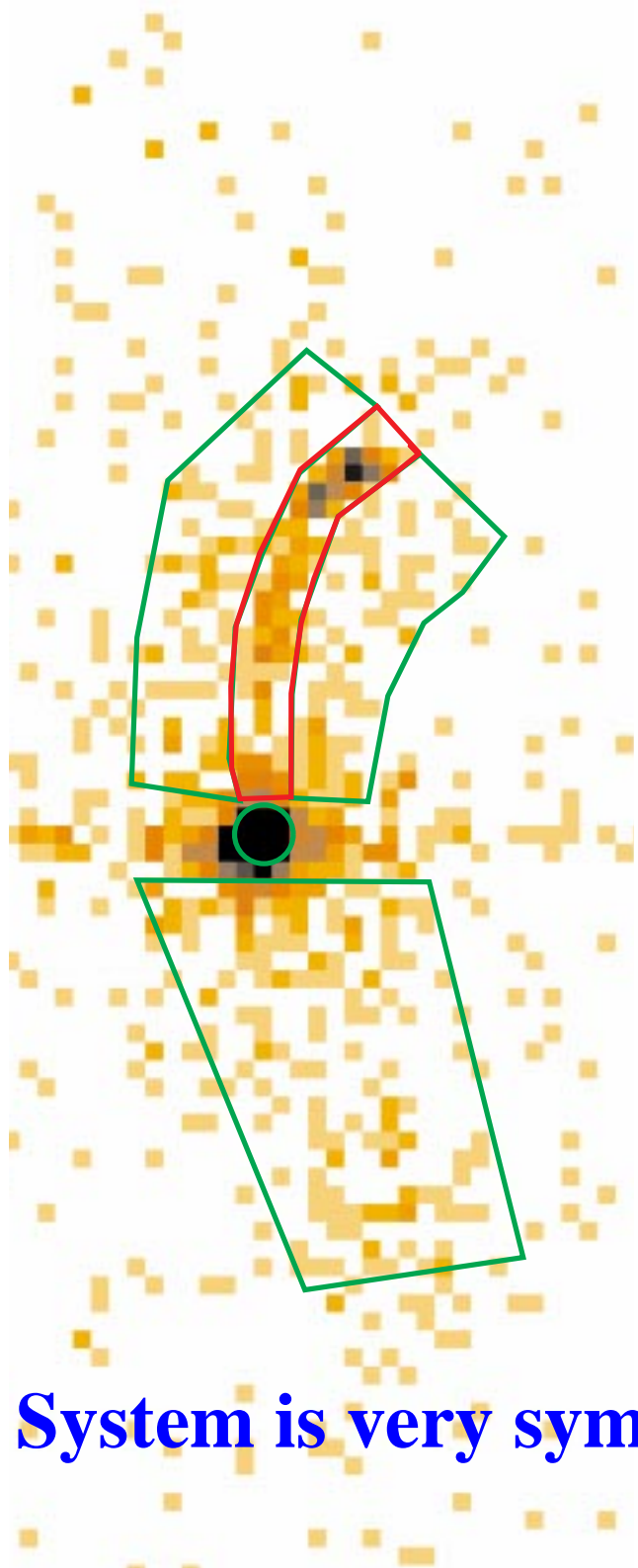
# Kinetic Energy Flux



# Broad X-ray Tube Surrounds Jets

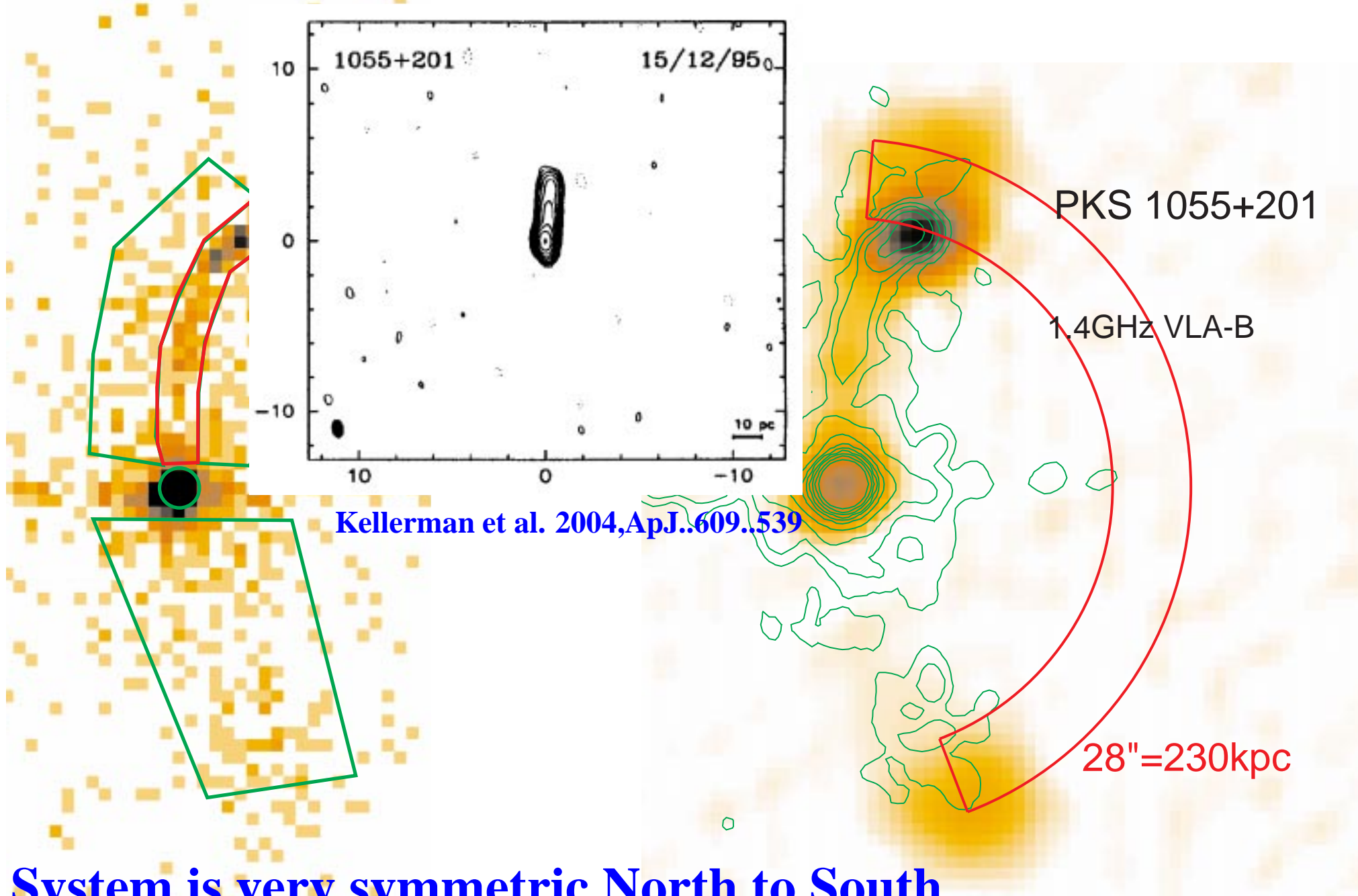






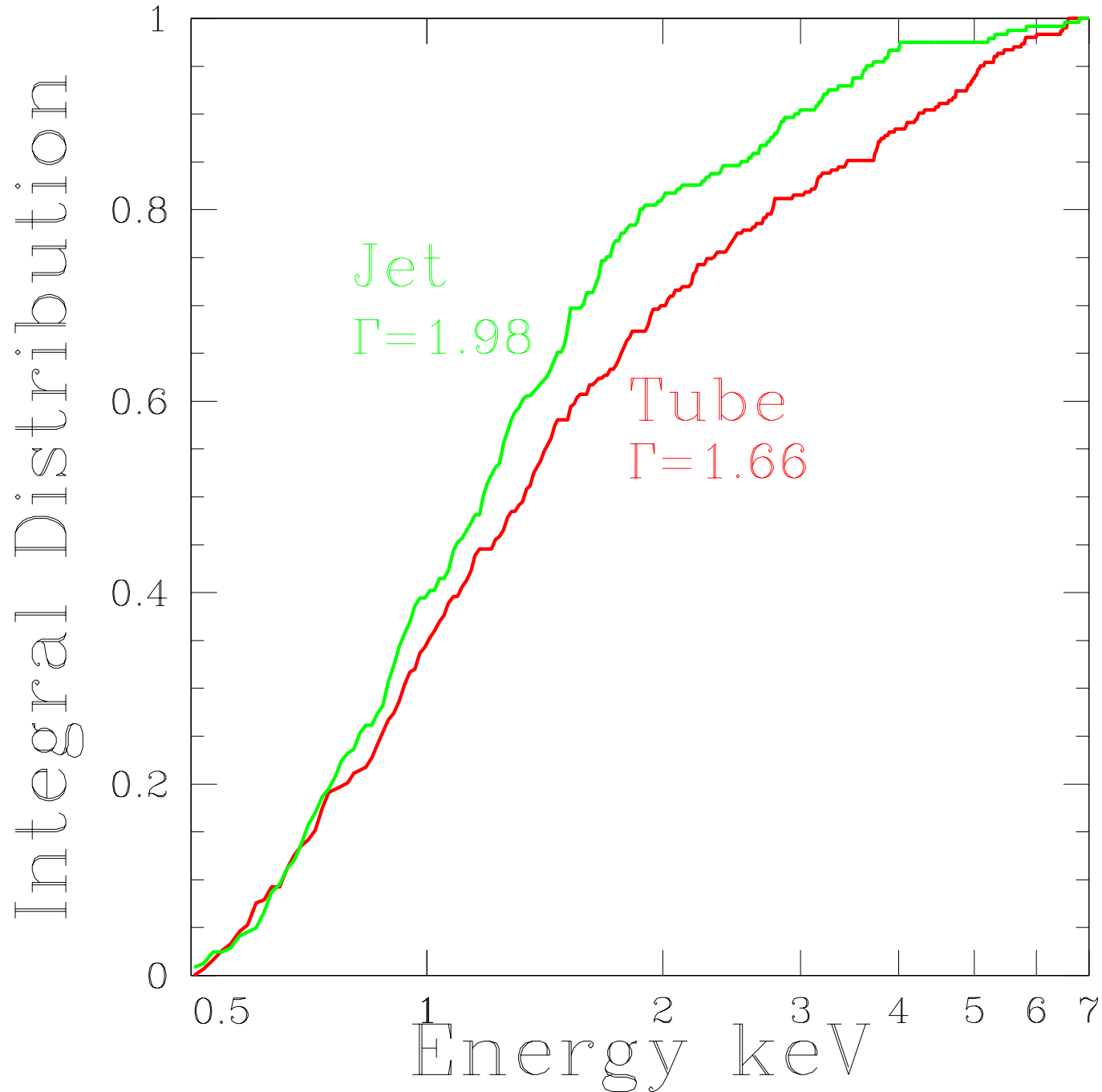
**System is very symmetric North to South**

# Both Jets are swept to West



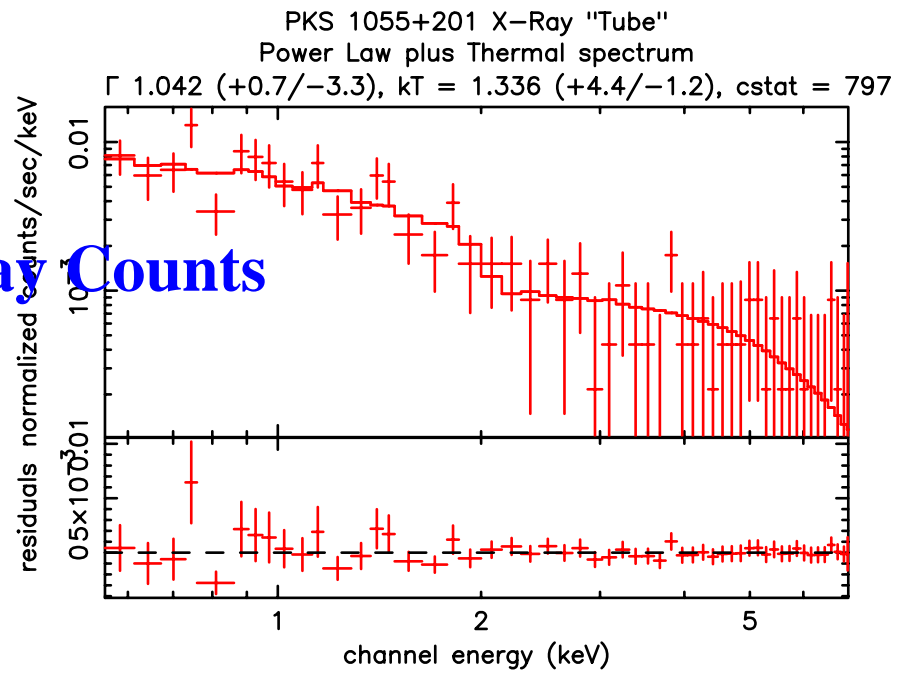
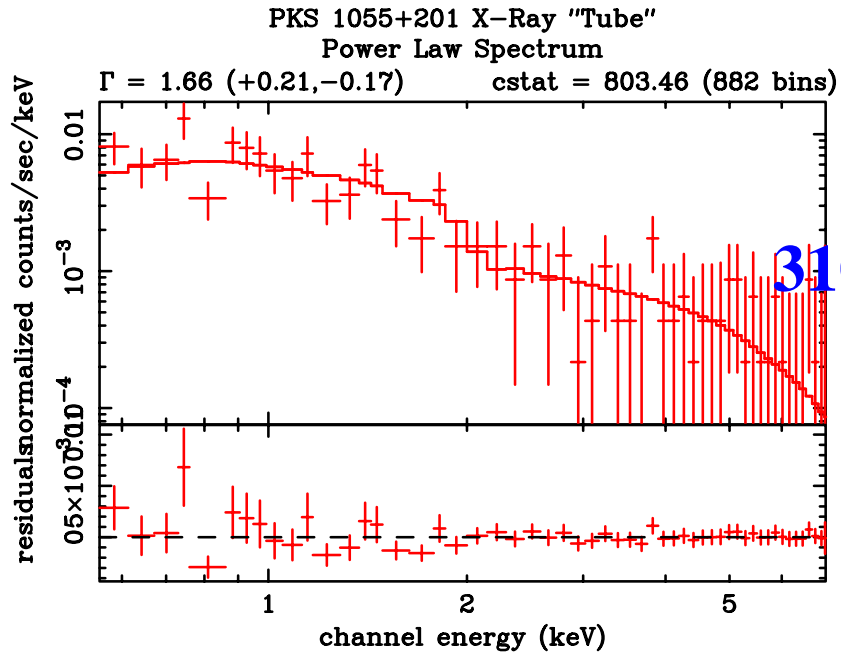
System is very symmetric North to South

# Jet spectrum is softer than Tube spectrum

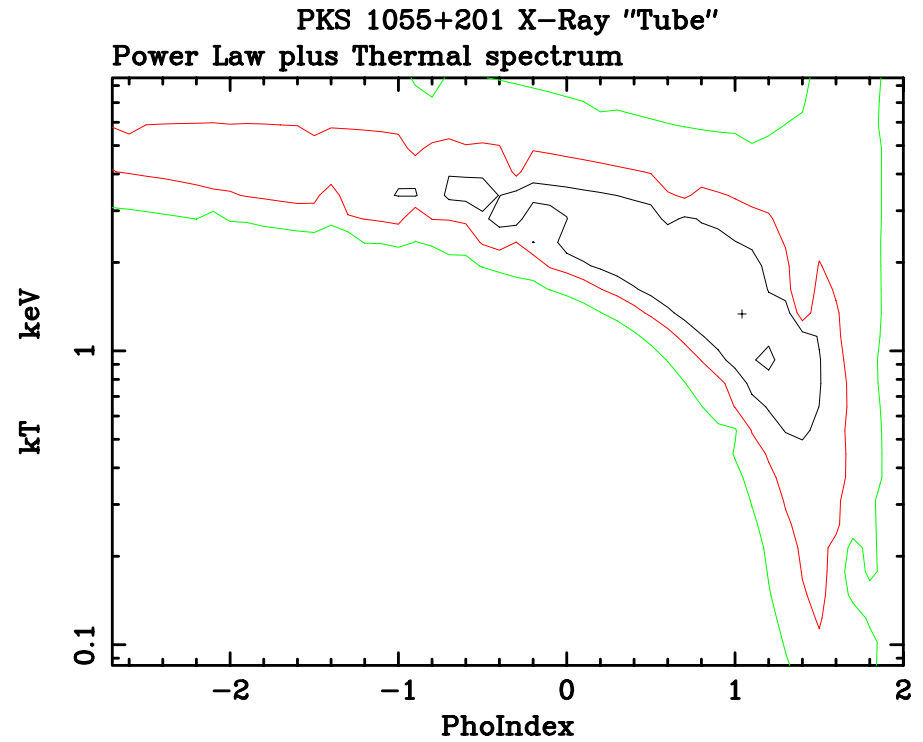
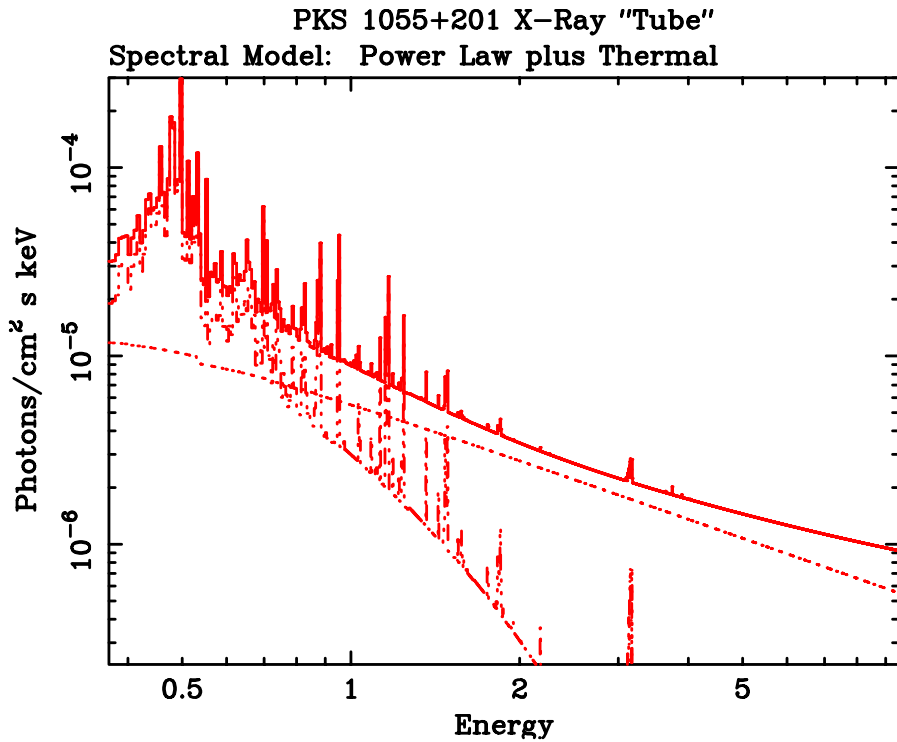




# Extended X-ray "Tube"



310 X-ray Counts



# Extended X-ray ‘Tube’

## Thermal Interpretation

$$L_x = 2.5 \times 10^{44} \text{ ergs s}^{-1}$$

$$kT = 1.34 \text{ keV}$$

$$n_e = 0.0054 \text{ cm}^{-3}$$

$$t_{\text{gas}} \approx 4 \times 10^9 \text{ years}$$

$$P_{\text{gas}} \approx 1.2 \times 10^{-11} \text{ dyne cm}^{-2}$$

$$P_{\text{gas}} \approx P_{\text{jet}}$$

$$U_{\text{gas}} \approx 1.5 \times 10^{61} \text{ ergs}$$

$$M_{\text{gas}} \approx 2 \times 10^{12} M_{\odot}$$

**Predict:**

**Fe Line at 3.2 keV**

**Cooler spectrum away from jet**

## Non-Thermal Interpretation

$$L_x = 5.4 \times 10^{44} \text{ ergs s}^{-1}$$

**Model: Electrons diffuse out of jet, into low magnetic field region, and are not in bulk relativistic motion.**

$$n_e \approx 3 \times 10^{-8} \text{ cm}^{-3} \approx n_e \text{ in jet}$$

**So  $1/\delta^2 \approx 3\%$  of electrons diffuse out**

**$\tau_e \approx 10^8$  yrs, against CMB**

**Radius of 65 kpc gives  $v_d \approx 300$  km/s**

**Predict:**

**Low frequency radio emission**

**Steeper spectrum away from jet**

# Summary

## 1. Detailed IC/CMB structure of a Mpc scale Jet

- Magnetic fields  $\approx 10 \mu\text{Gauss}$
- Doppler and Lorentz factors  $\approx 6$
- Angle to line of sight  $\leq 9^\circ$
- Kinetic Flux  $2 \times 10^{45} \text{ ergs s}^{-1}$
- **Need a  $\delta \approx 1$  model for terminal hotspot X-rays**

## 2. **Extended X-ray emitting “tube” surrounds jet**

- $L_x \approx 3.4 \cdot 10^{44} \text{ ergs s}^{-1}$
- Gas Heated by Jet?
- Entrained material, part of jet structure?
- Electrons diffusing out of jet?

## 3. **Direct Evidence of an unseen counter jet**