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

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minneapolis
american astronomical society

# 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 $\mu$ G,**
   - **Doppler factor $\delta$ about 6**
3. **What is Remarkable About 4C20.24?**

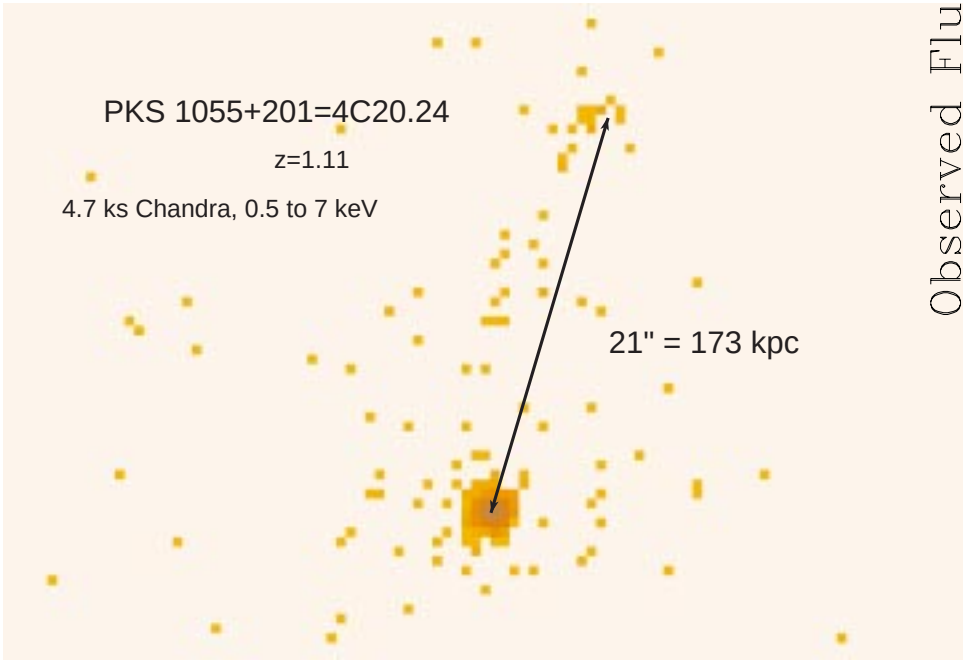
# Outline

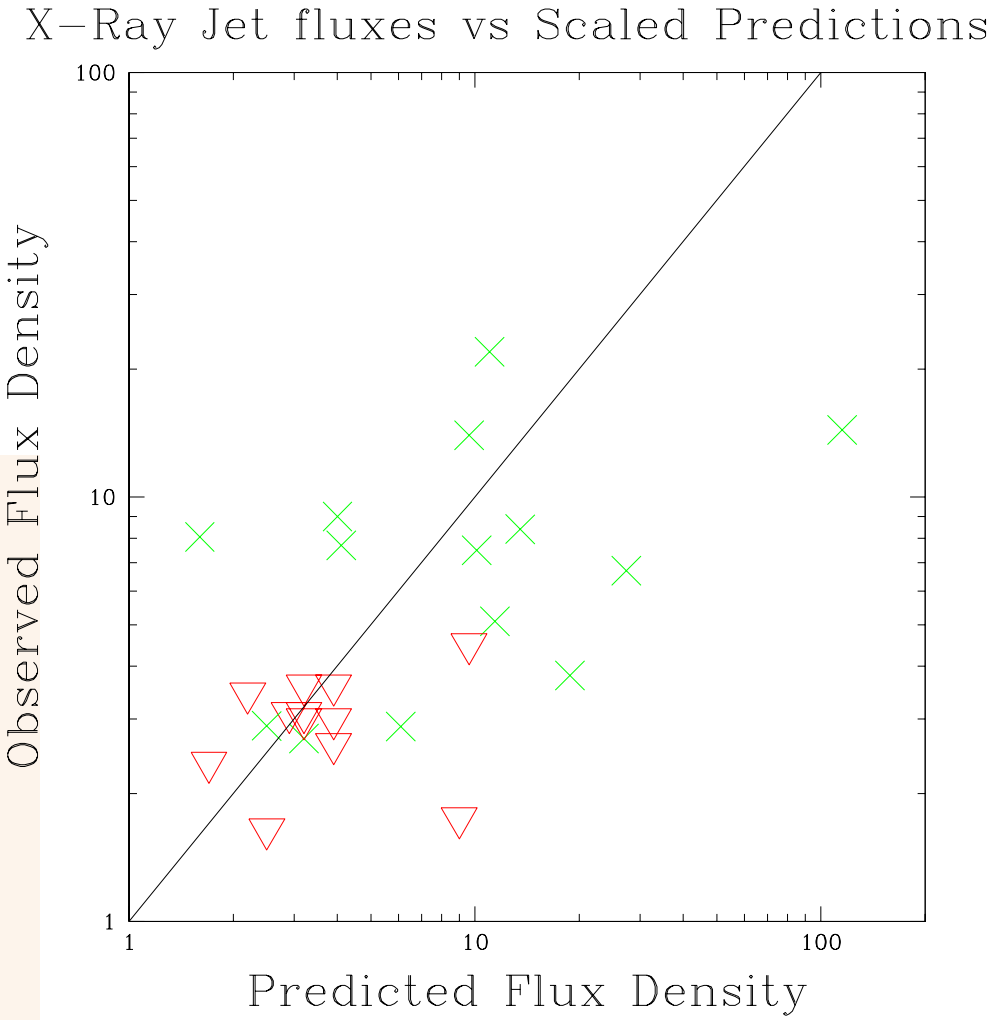
1. **Context of an X-ray Jet Survey**
2. **What is Normal About 4C20.24?**
3. **What is Remarkable About 4C20.24?**
   - **Extended X-ray emission symmetric around radio/X-ray jet**
   - **Similar extended X-ray emission around unseen counter-jet**
   - **Jets appear to be “swept” back from quasar**
   - **First case of seeing both the X-ray jet and the gas it is heating?**

# The Jet Sample

- **Flat Spectrum Quasars. Two Samples: $S_{5GHz} > 1Jy^a$ or $S_{2.7GHz} > 0.34\ Jy^b$**
- **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**

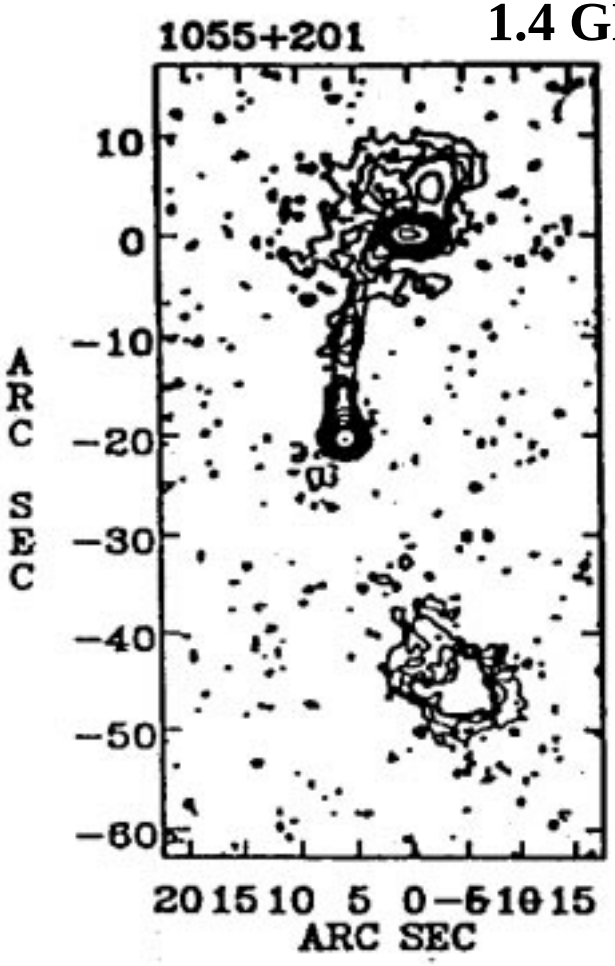
[a]Murphy, Browne & Perley 1993
[b]Lovell 1997

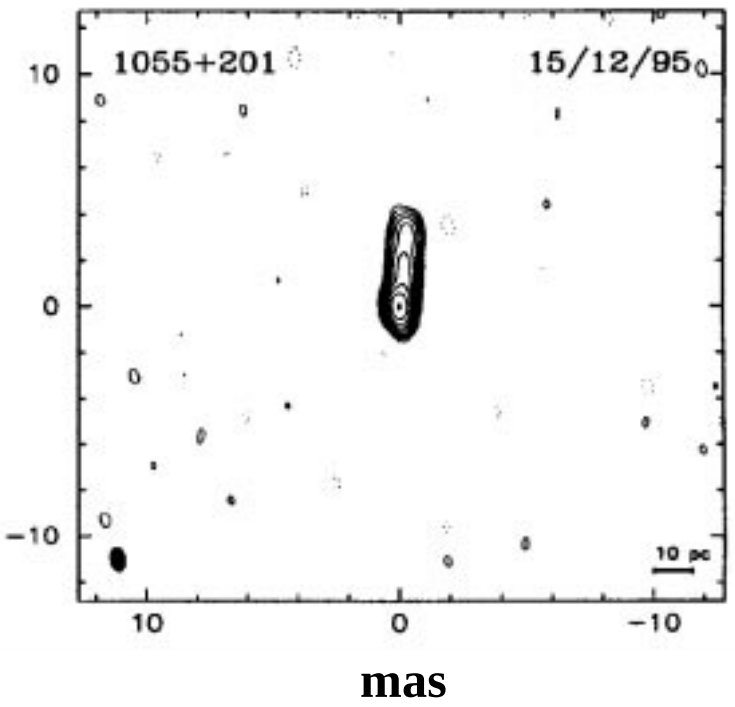


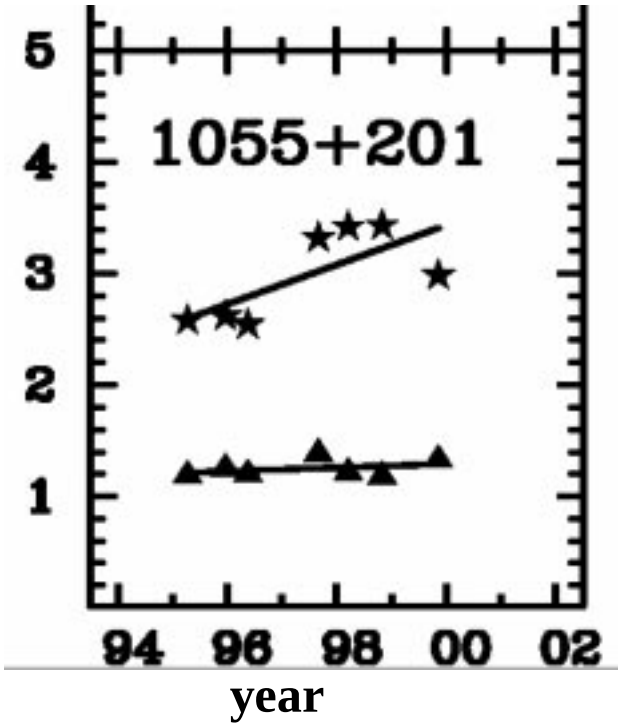
# PKS 1055+201=4C20.24

1.4 GHz




15 GHz




Kellerman et al. 2004,ApJ..609..539

Murphy et al. 1994,MNRAS..264..298

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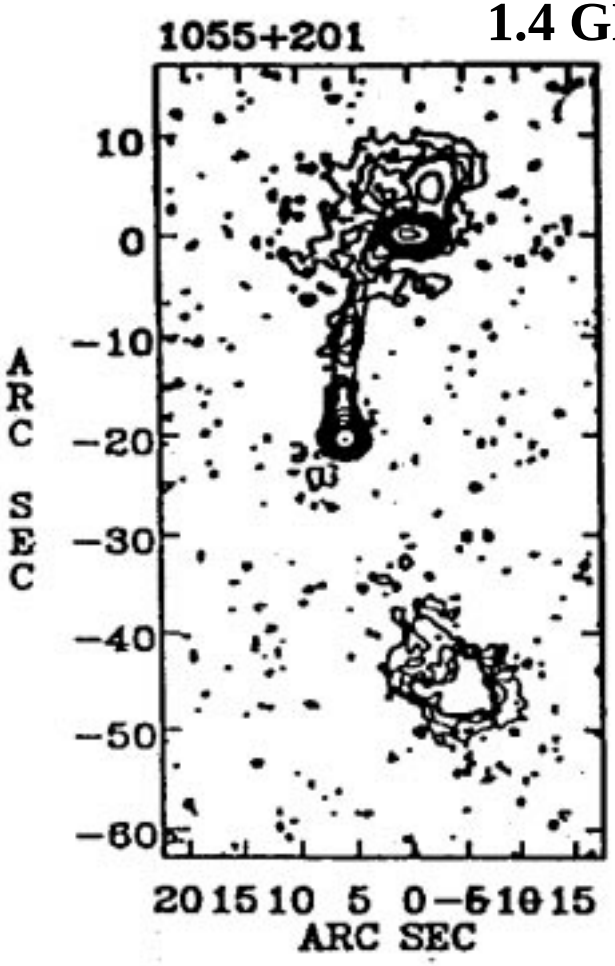
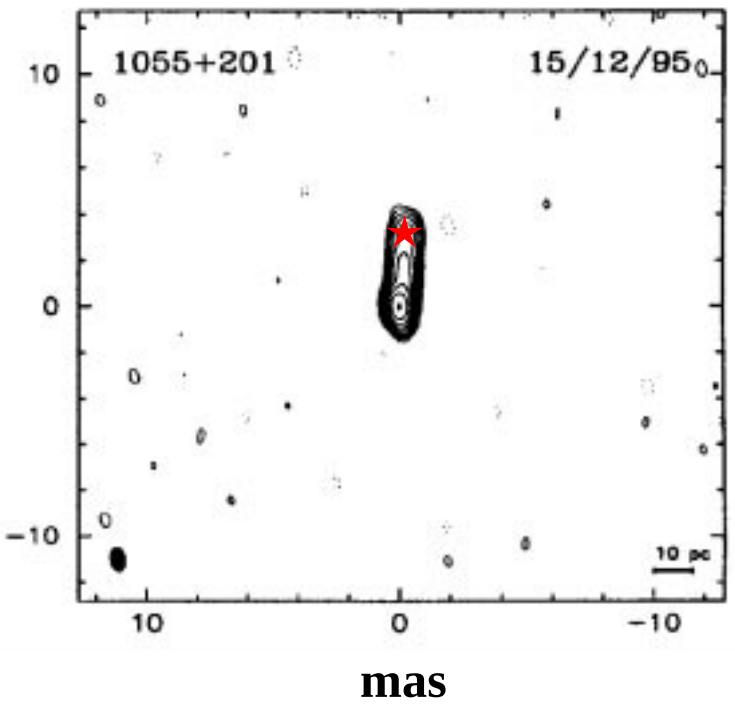
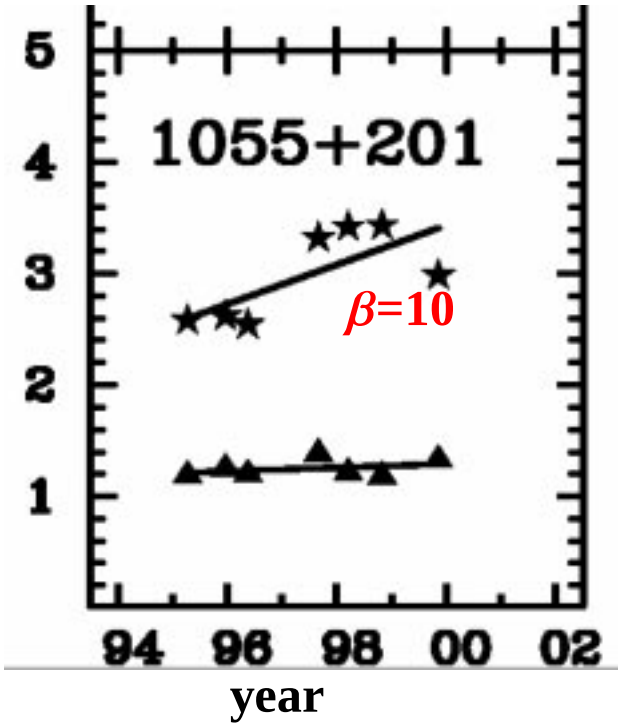



15 GHz

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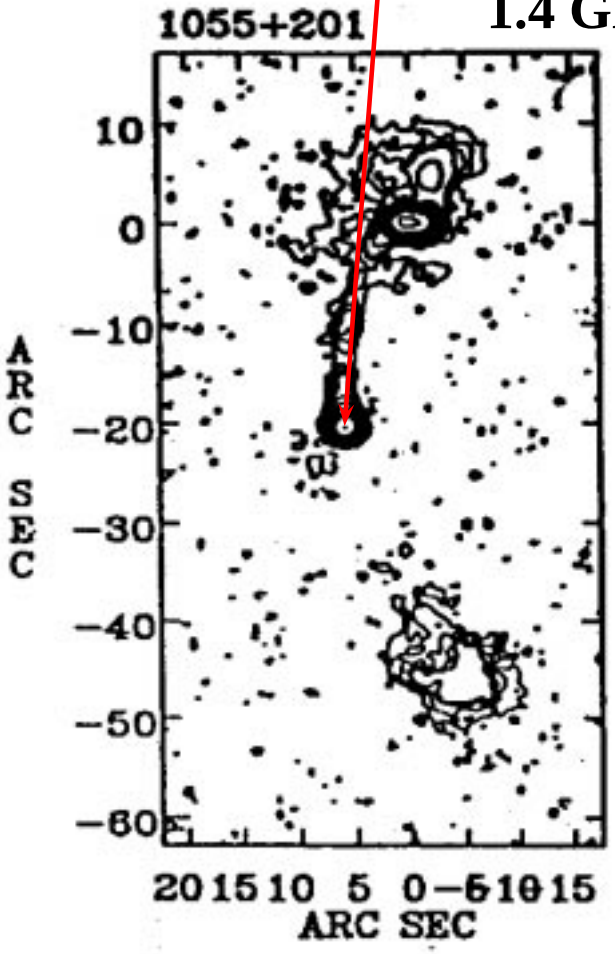
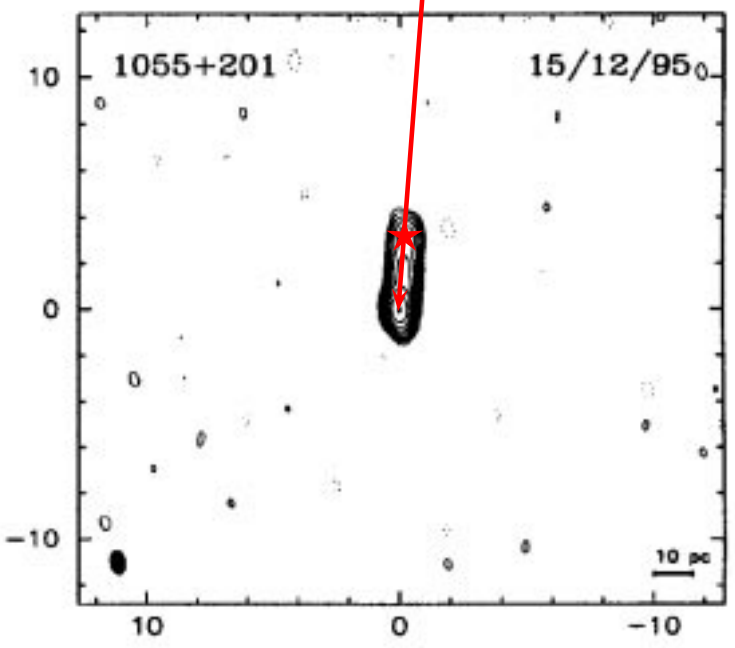
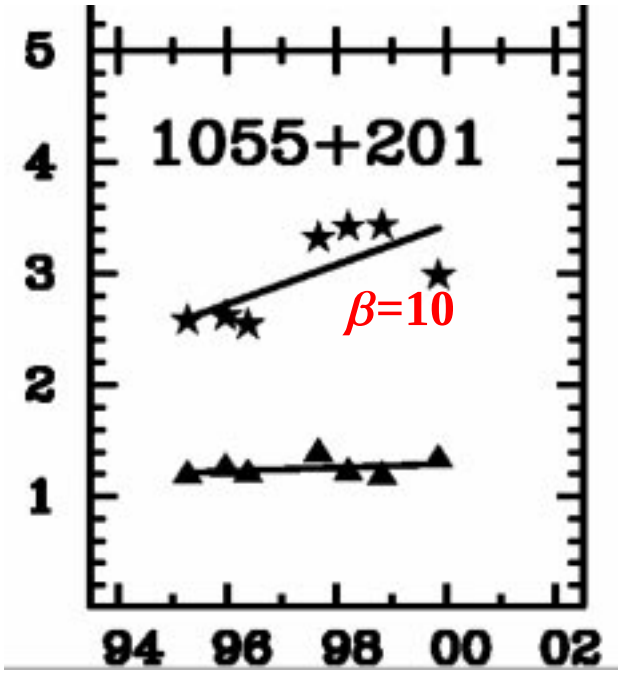



-5°




15 GHz

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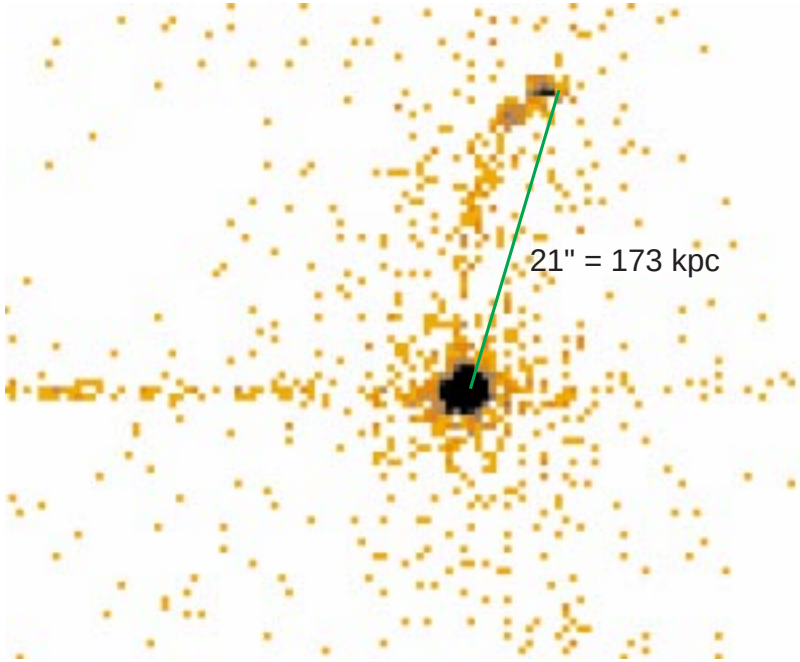
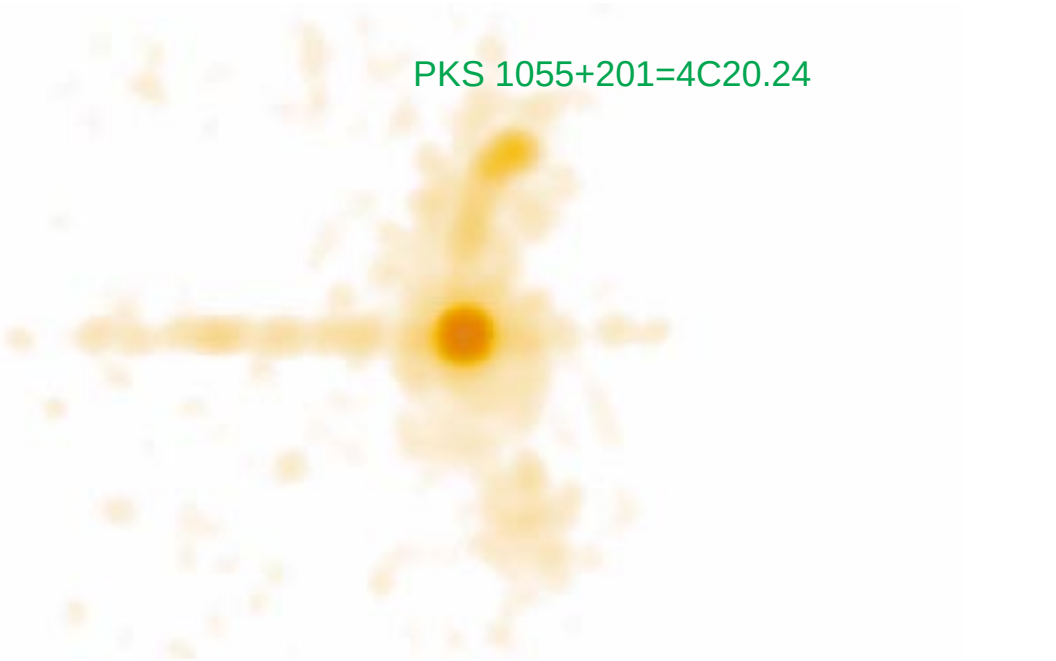

21" = 173 kpc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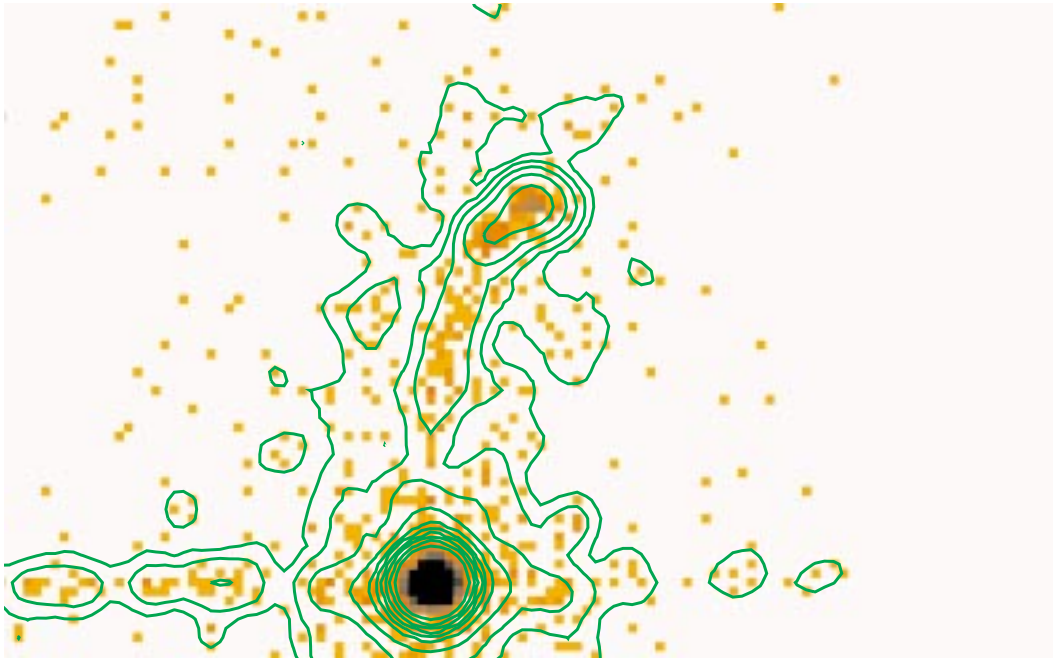
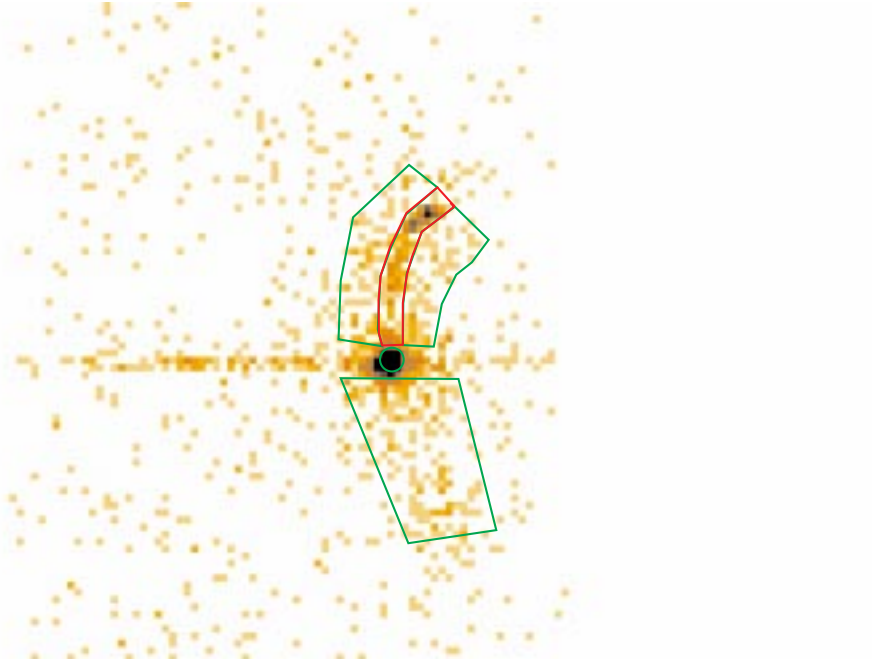
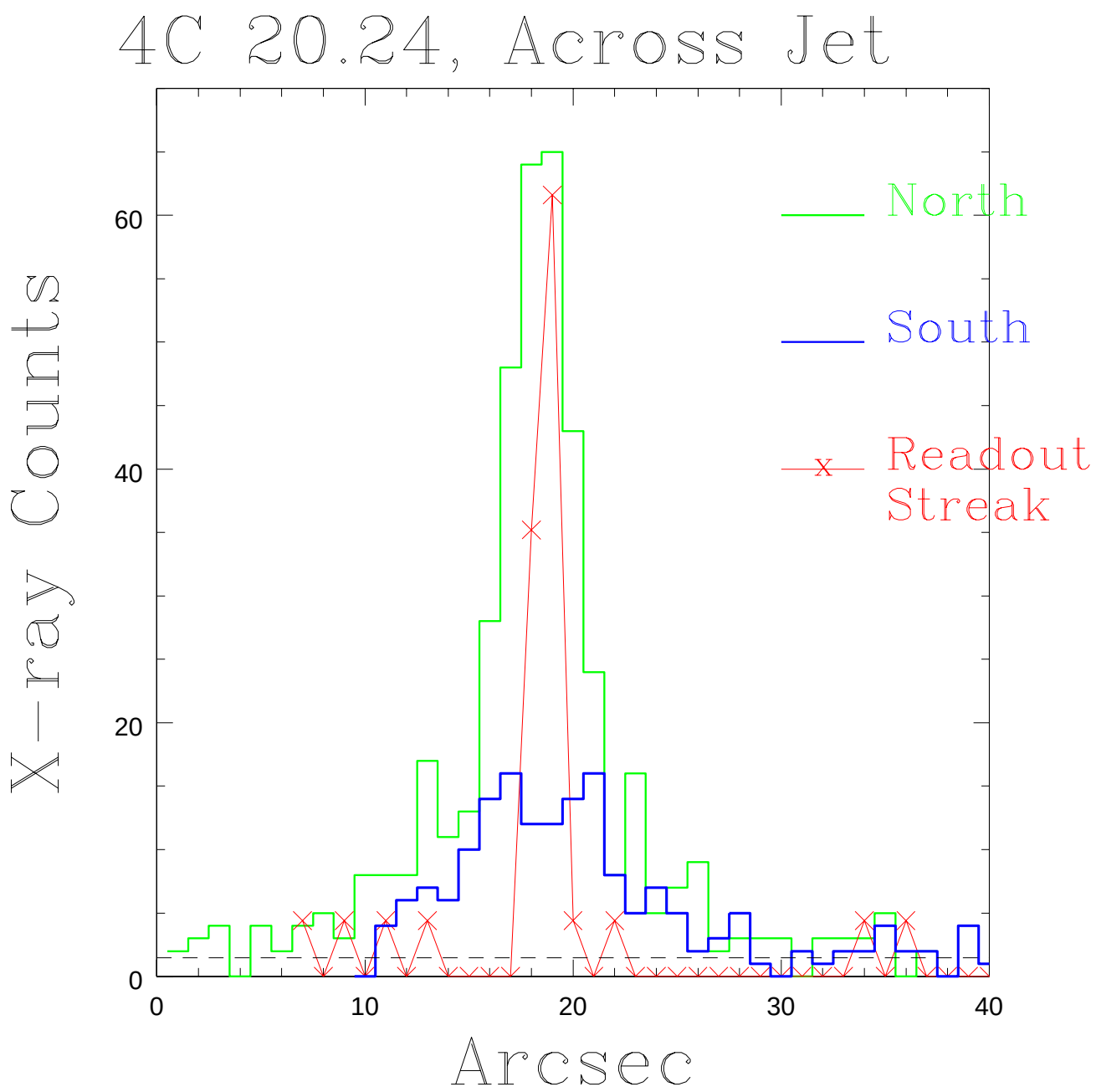
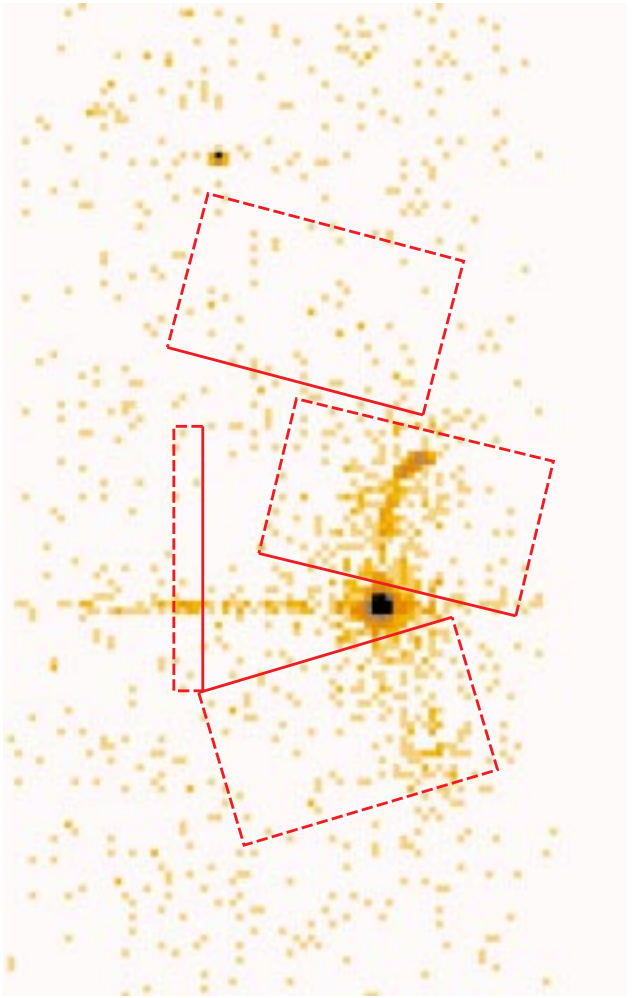
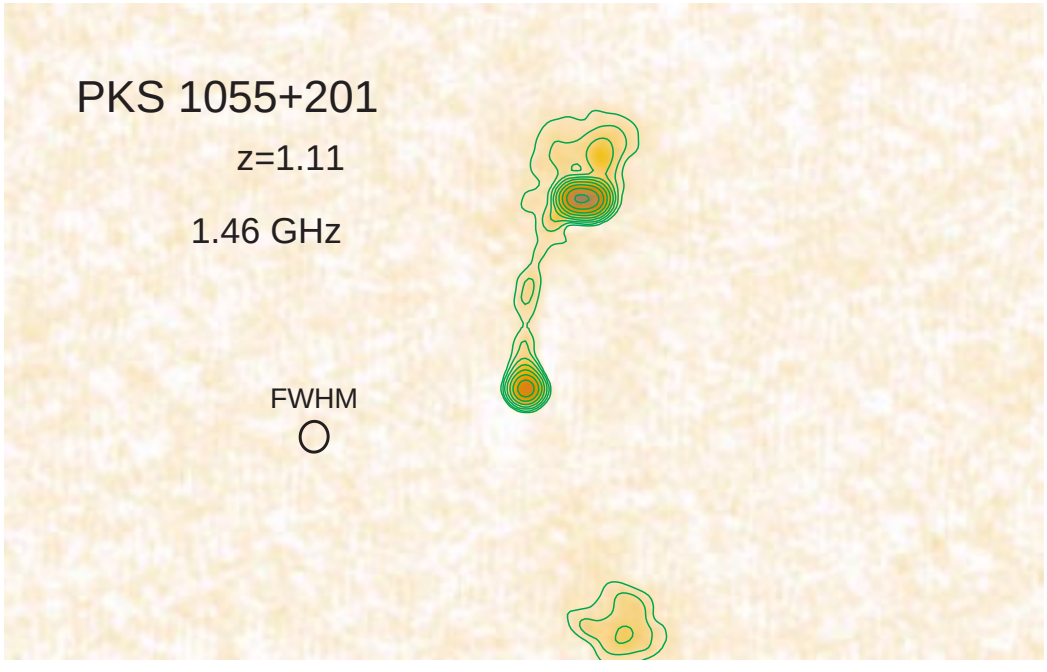
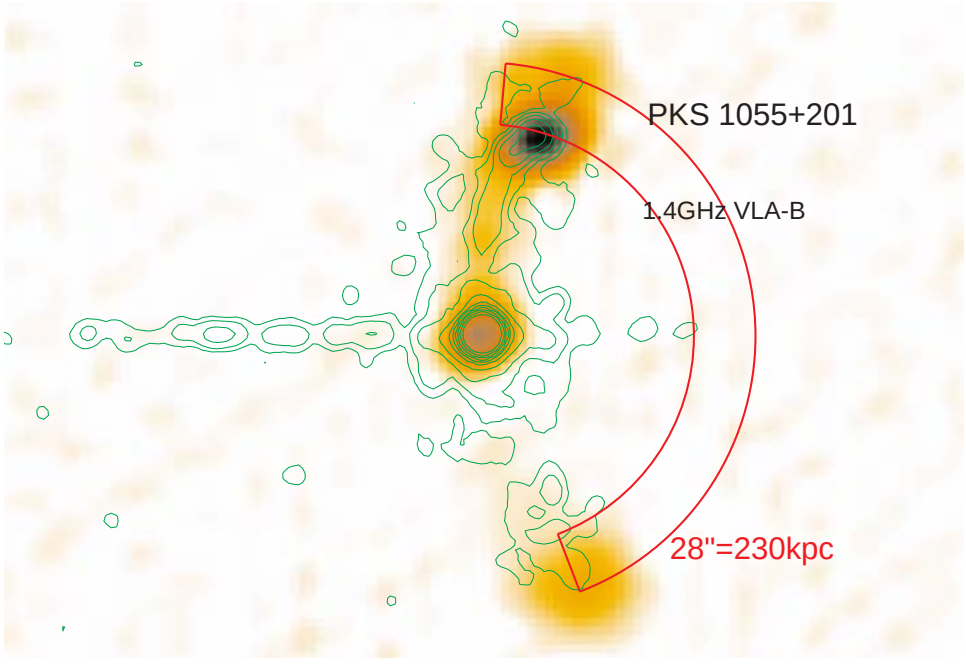


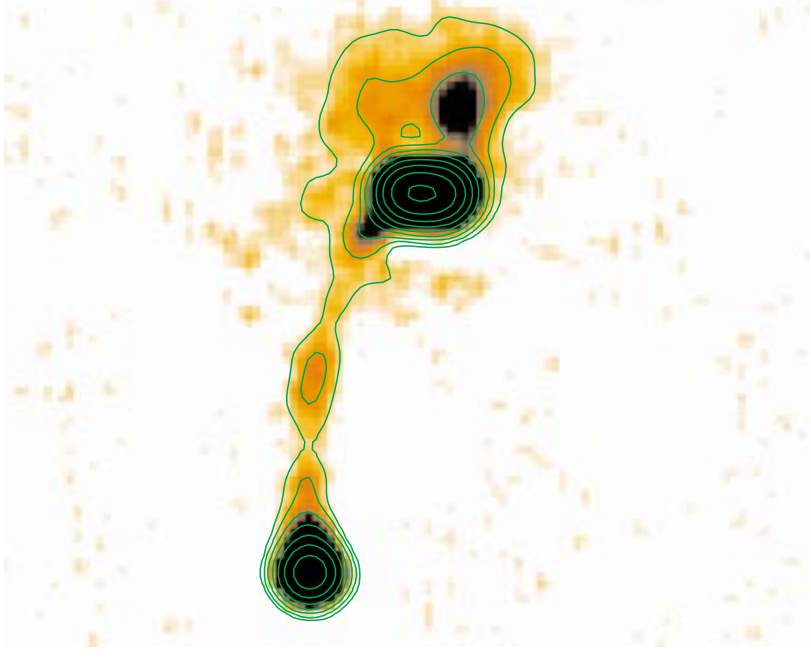


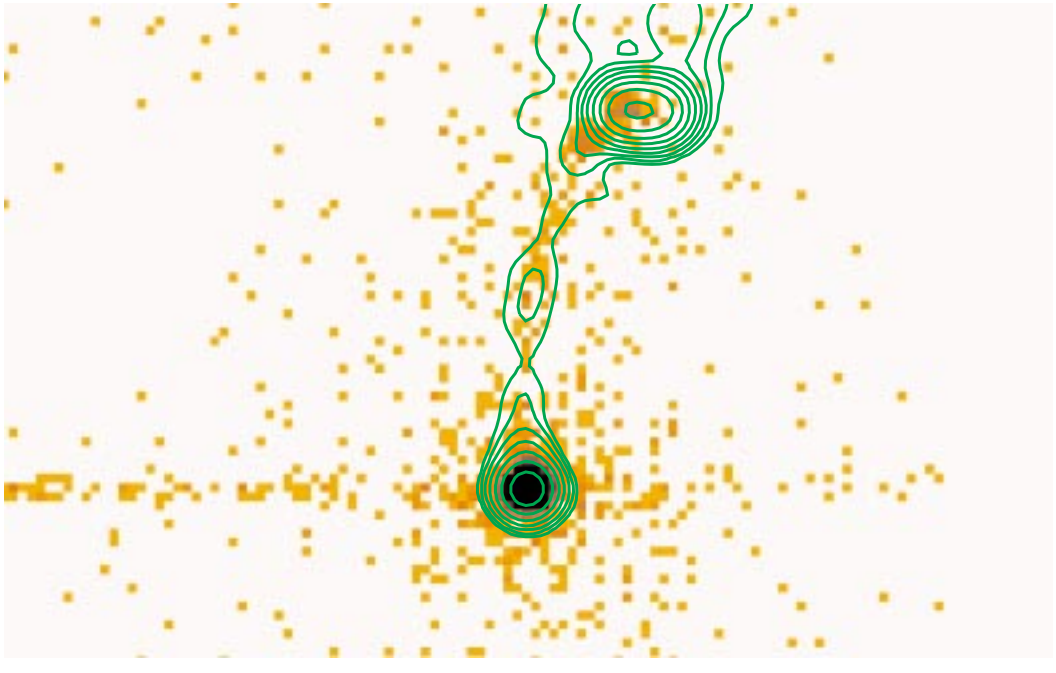

4C 20.24, Across Jet
X-ray Counts
Arcsec
North
South
Readout Streak
0
20
40
60
0
10
20
30
40



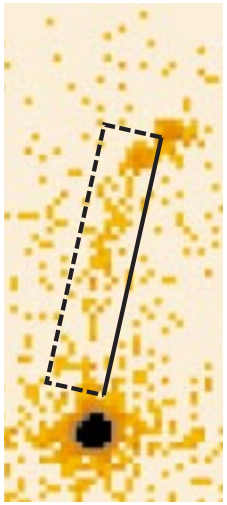

PKS 1055+201
z=1.11
1.46 GHz
FWHM

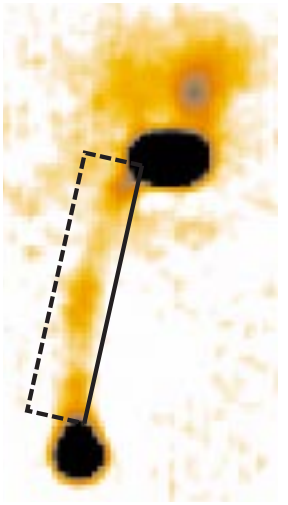

PKS 1055+201
1.4GHz VLA-B
28"=230kpc

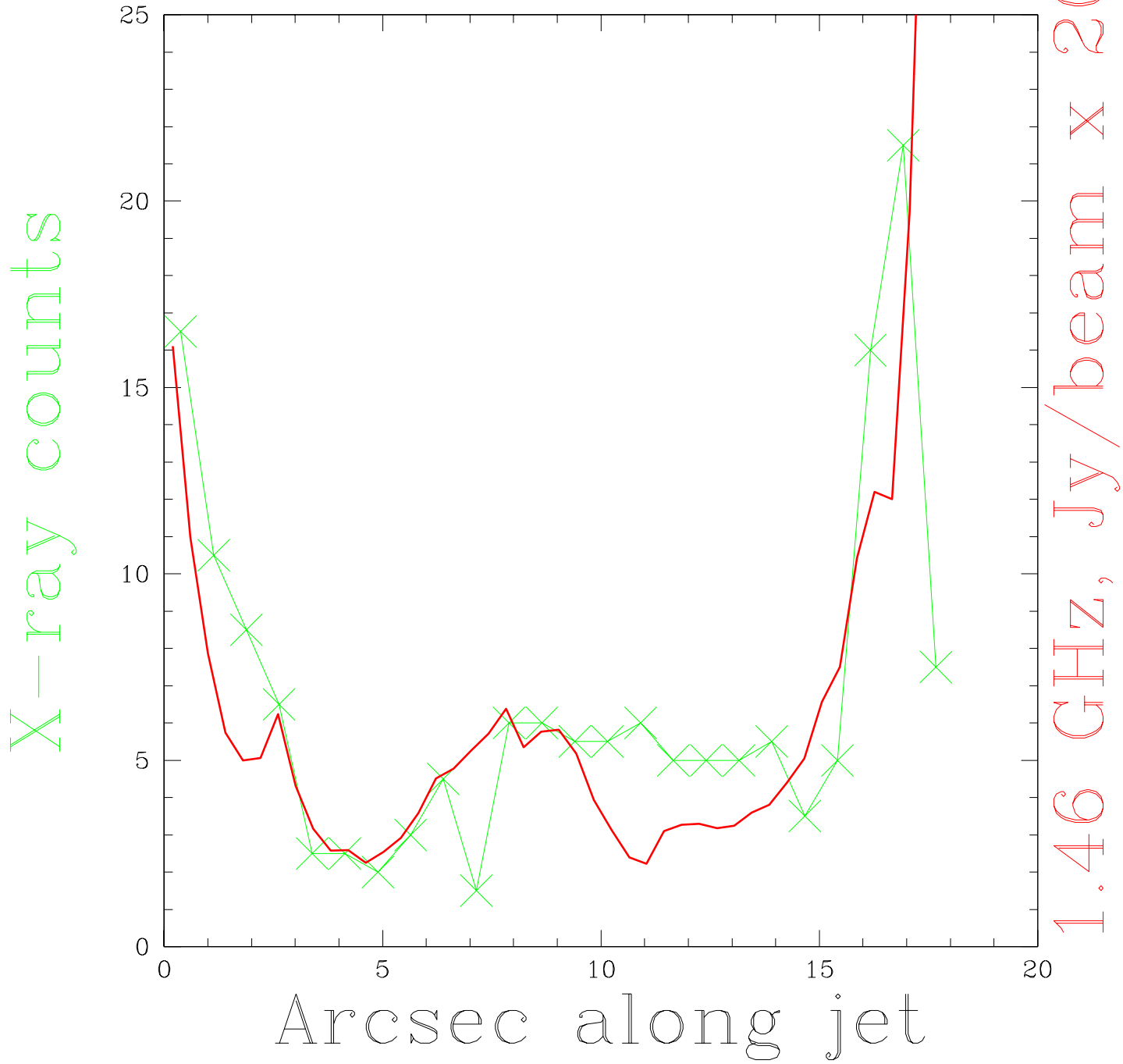




# PKS 1055+201 = 4C 20.24







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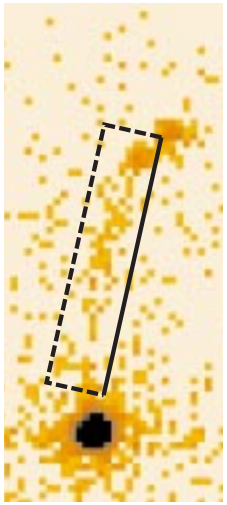
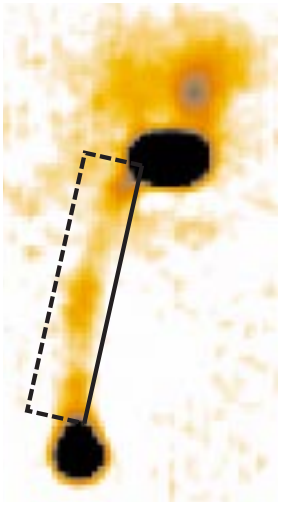
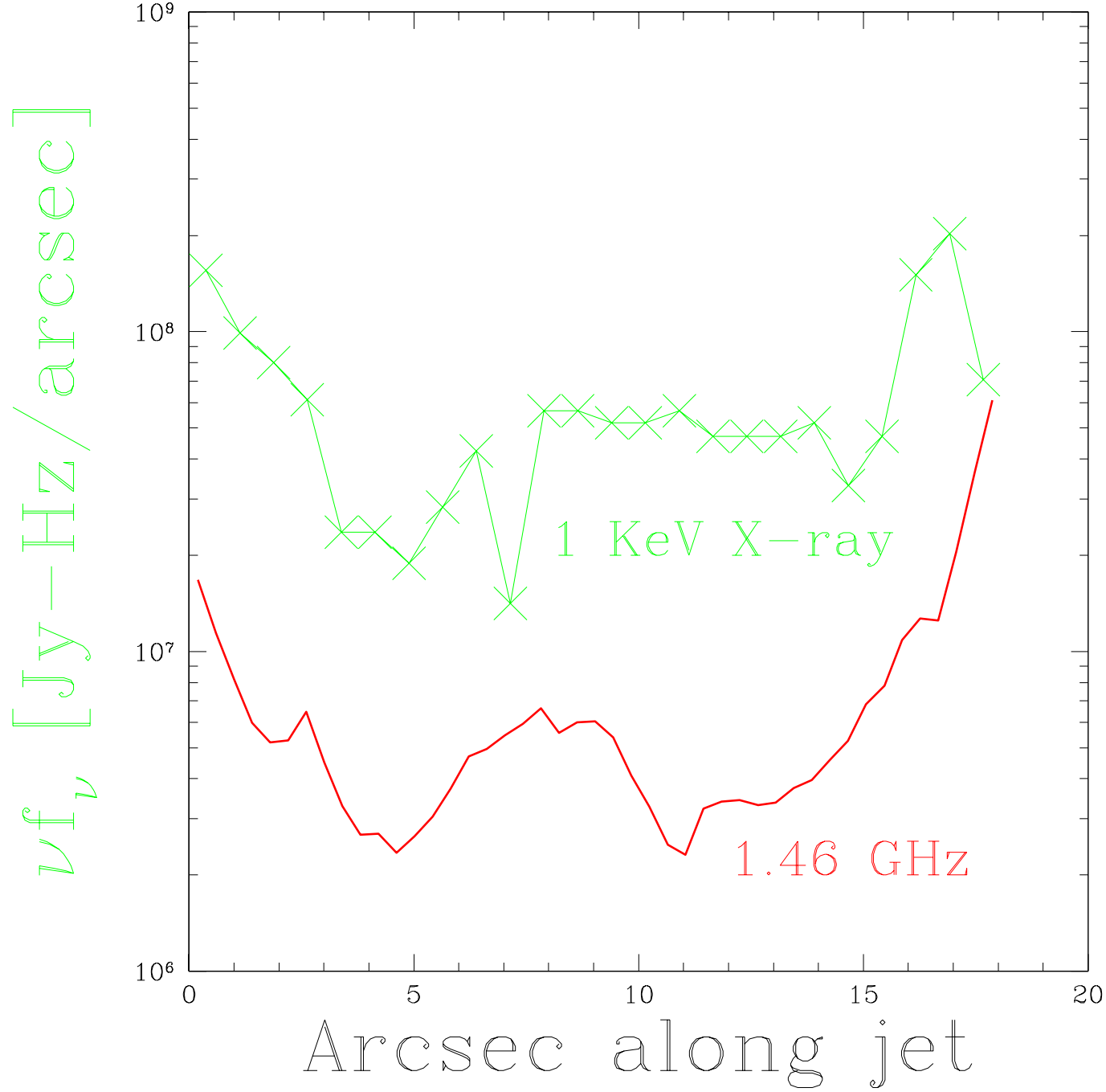
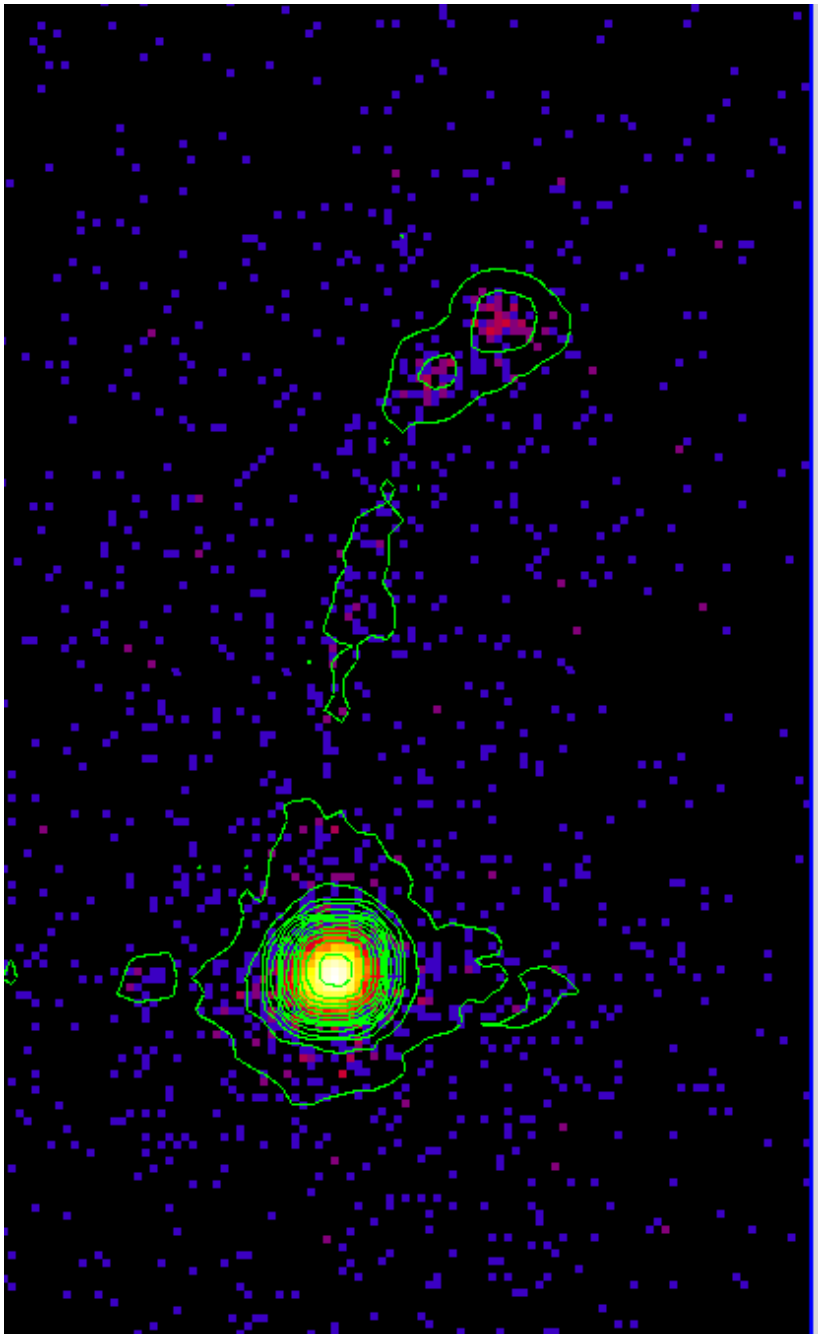
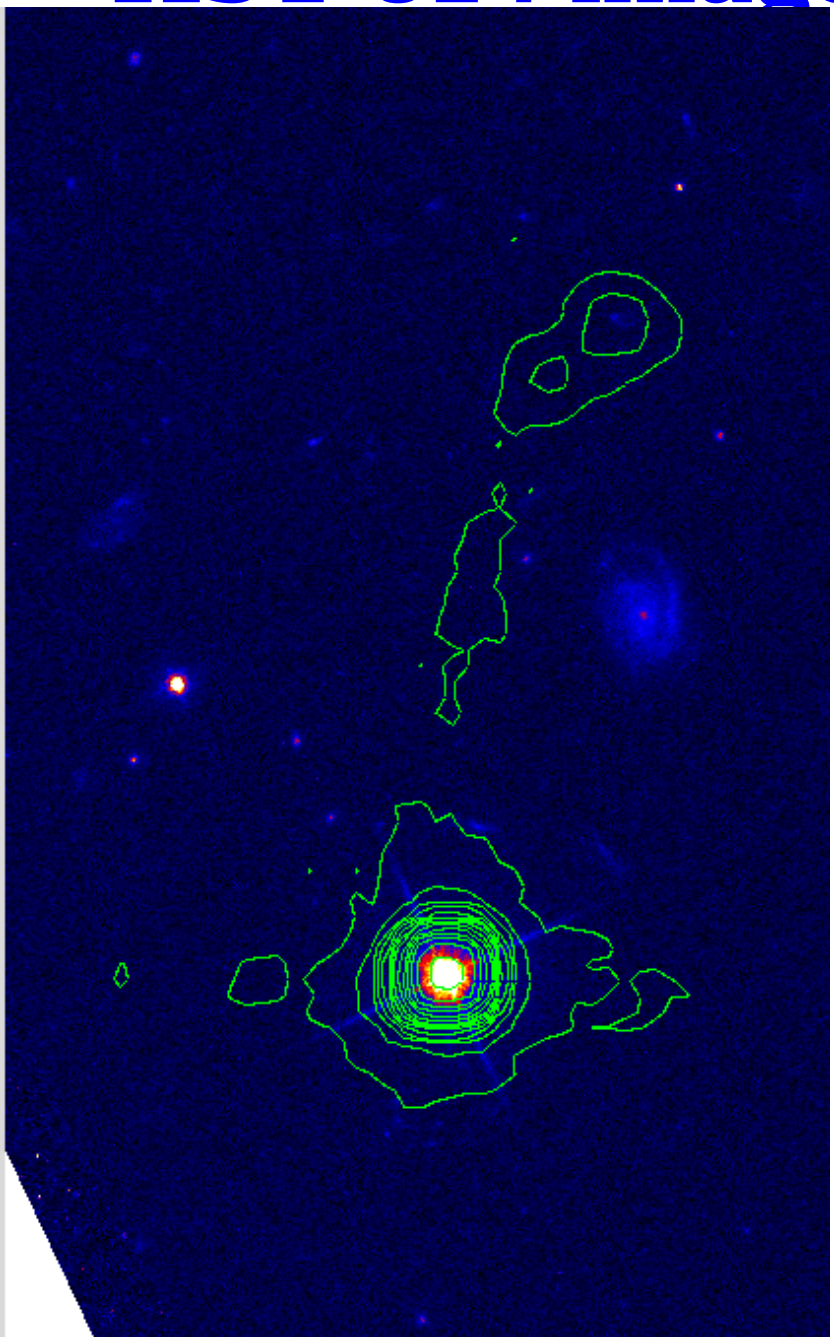


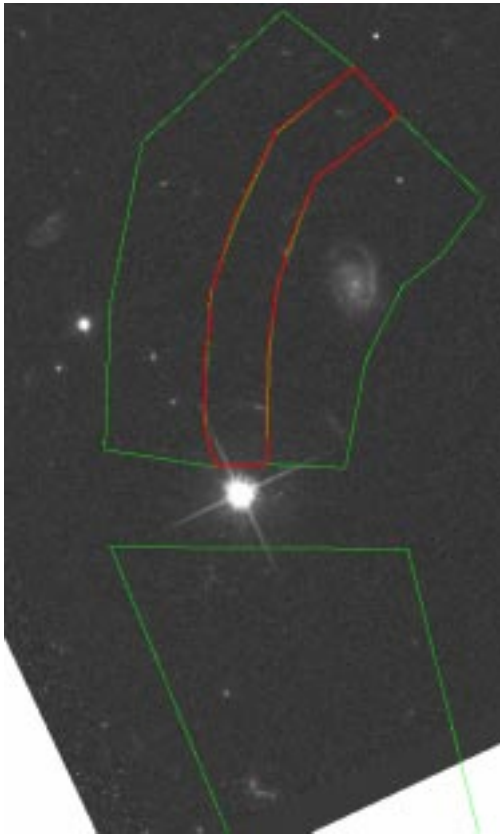


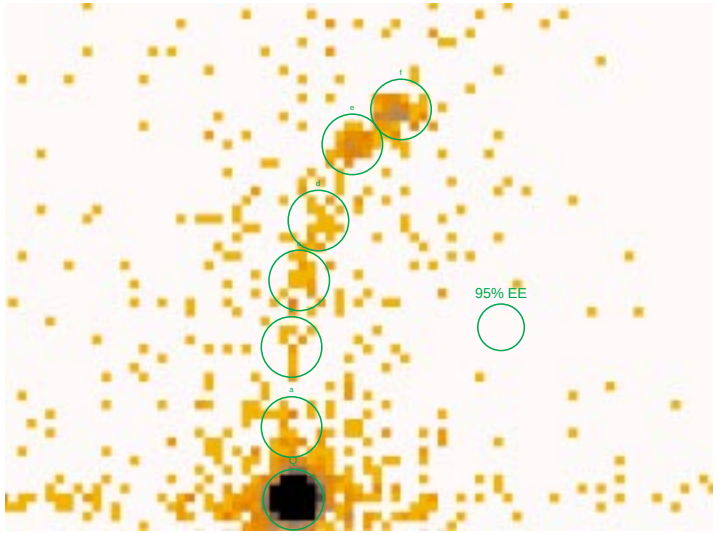


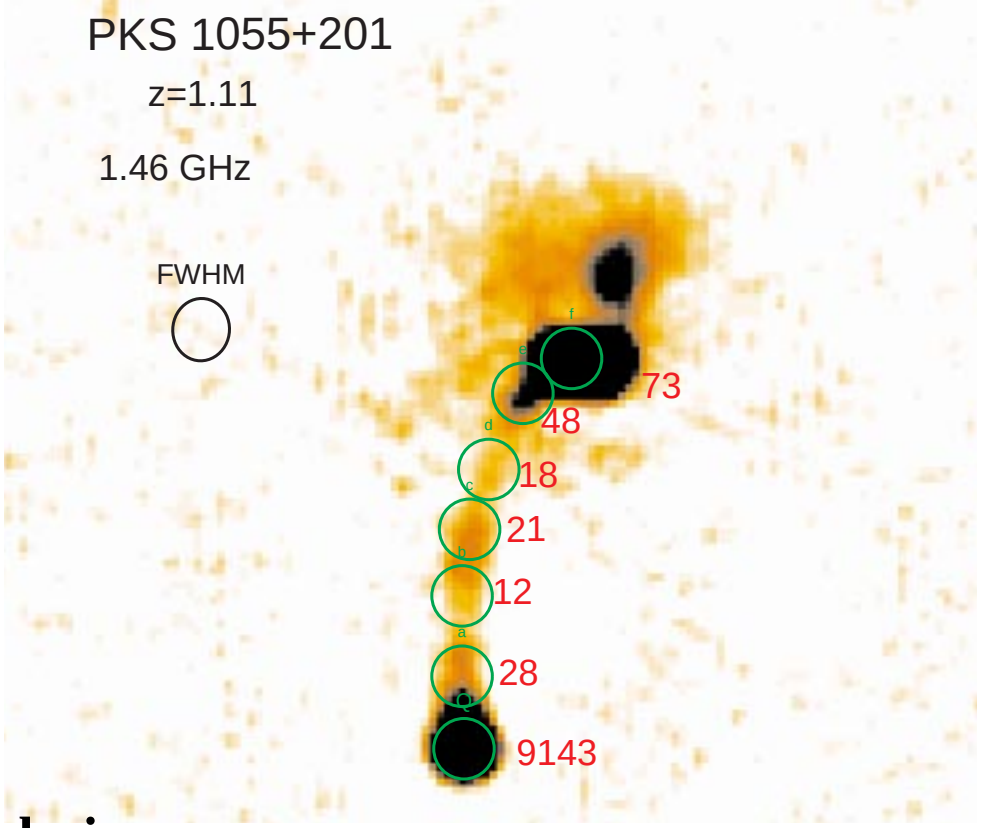
# HST 814 image



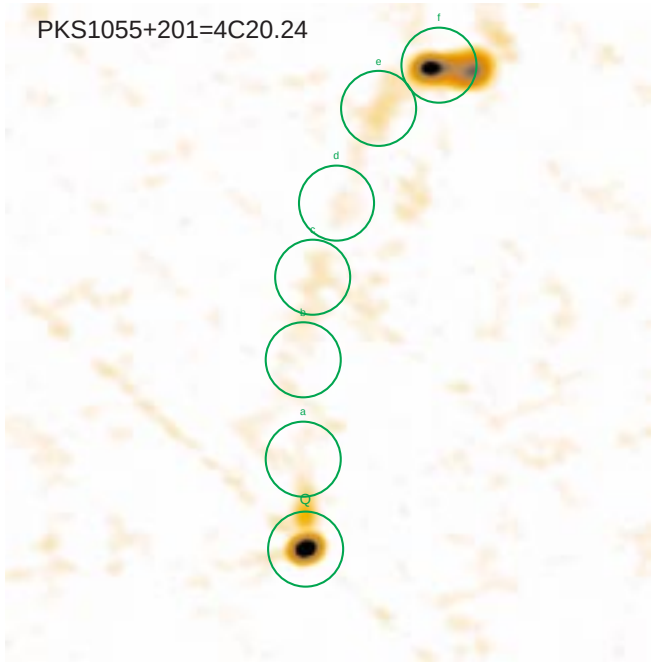




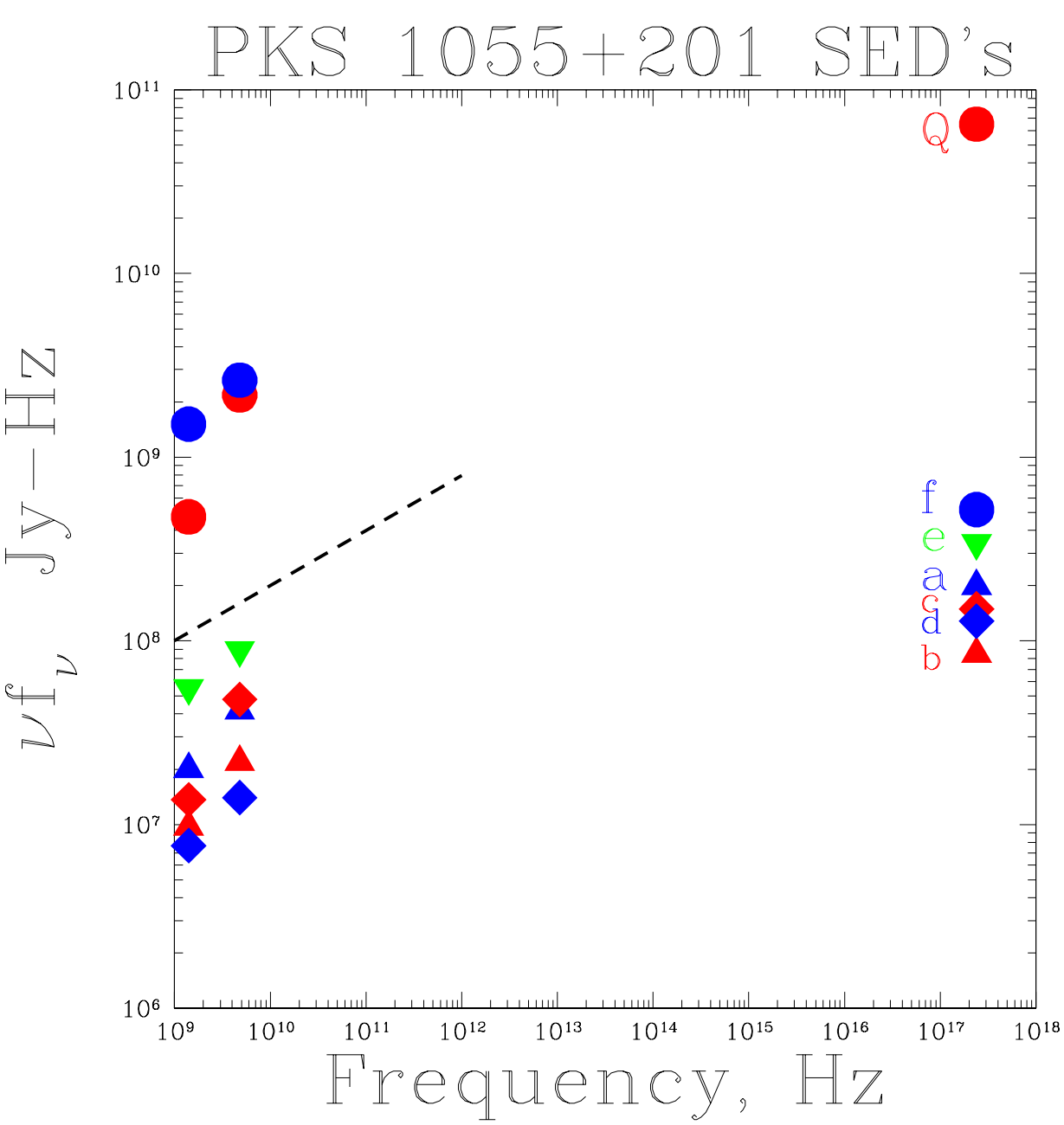


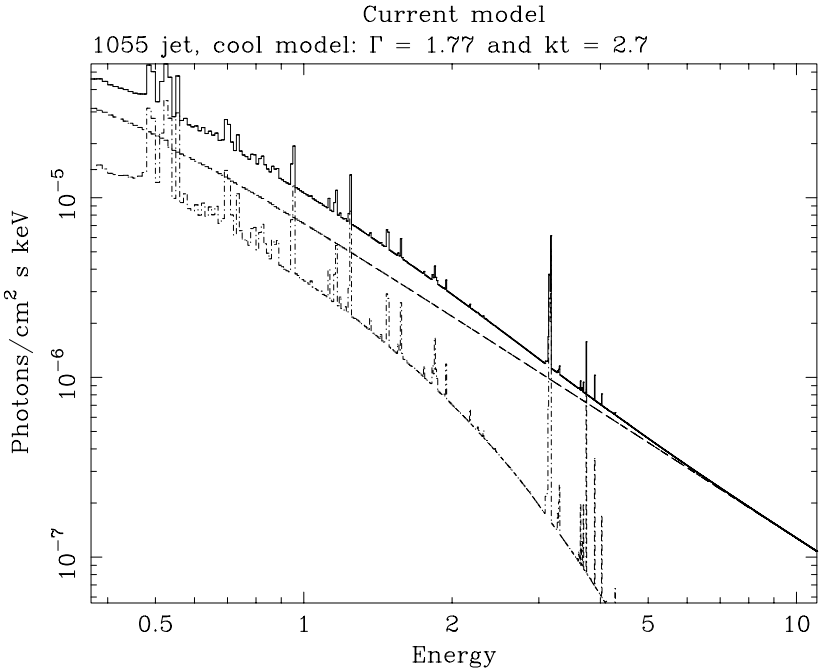



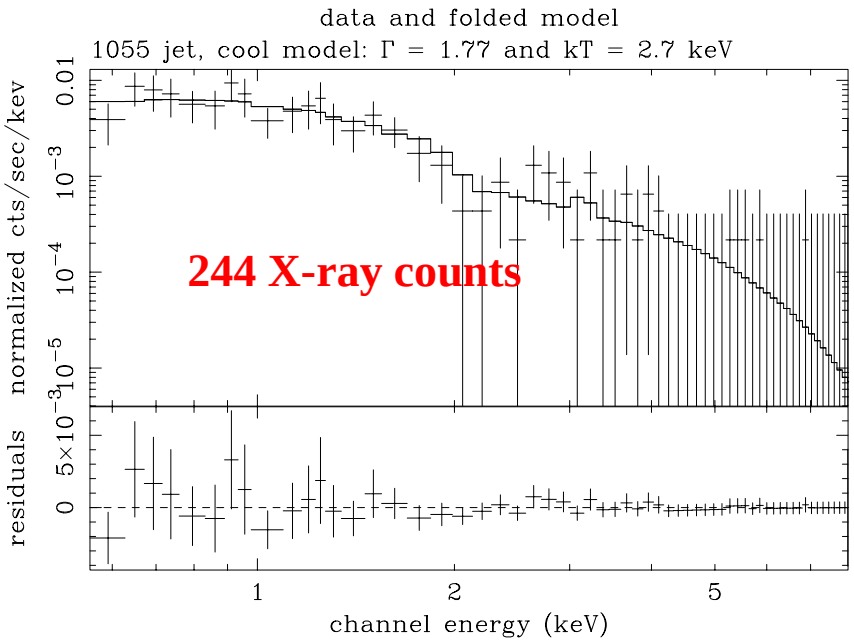

**Regions for spatially distinct SED analysis.**

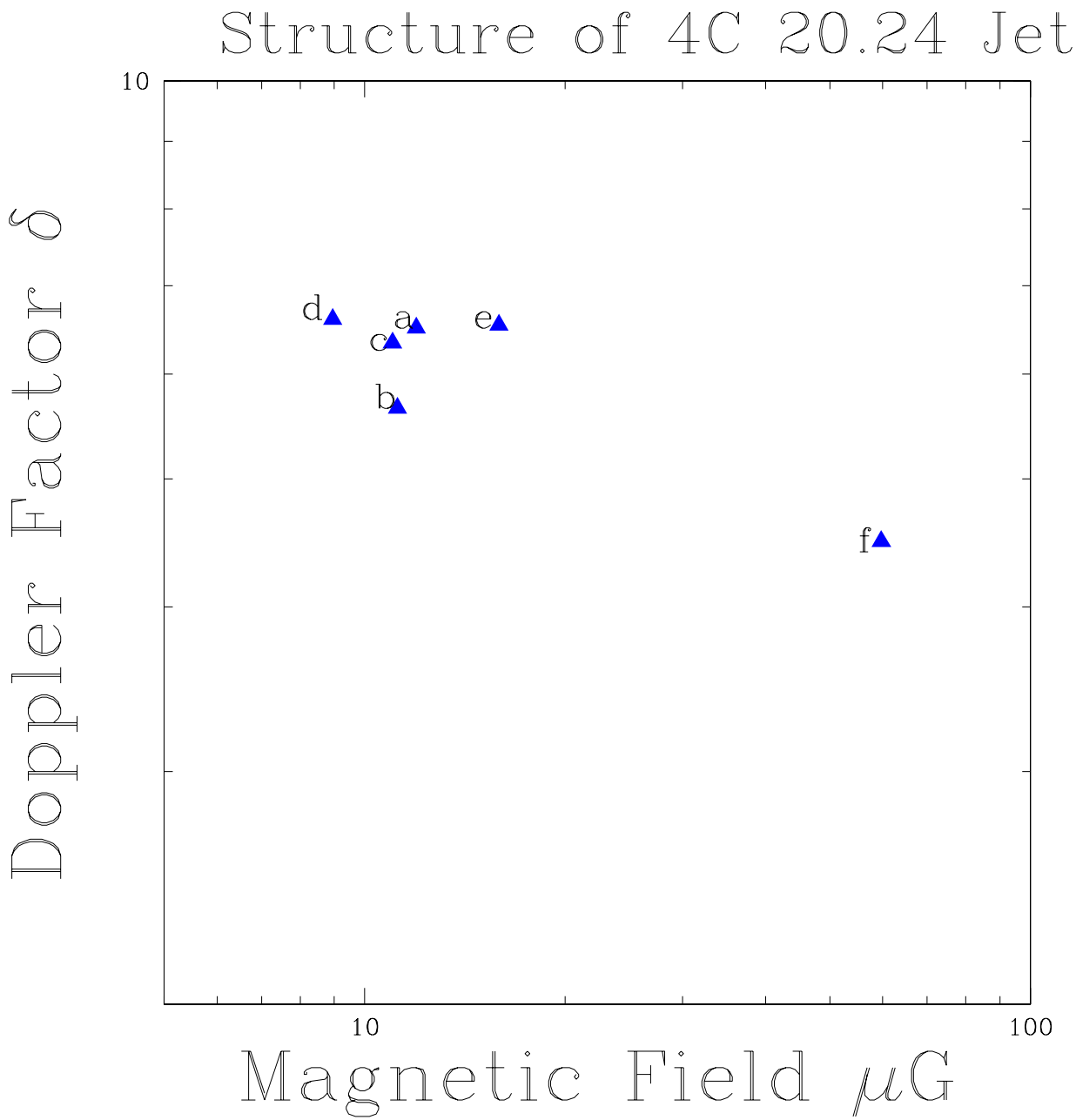


# Spectral Energy Distribution

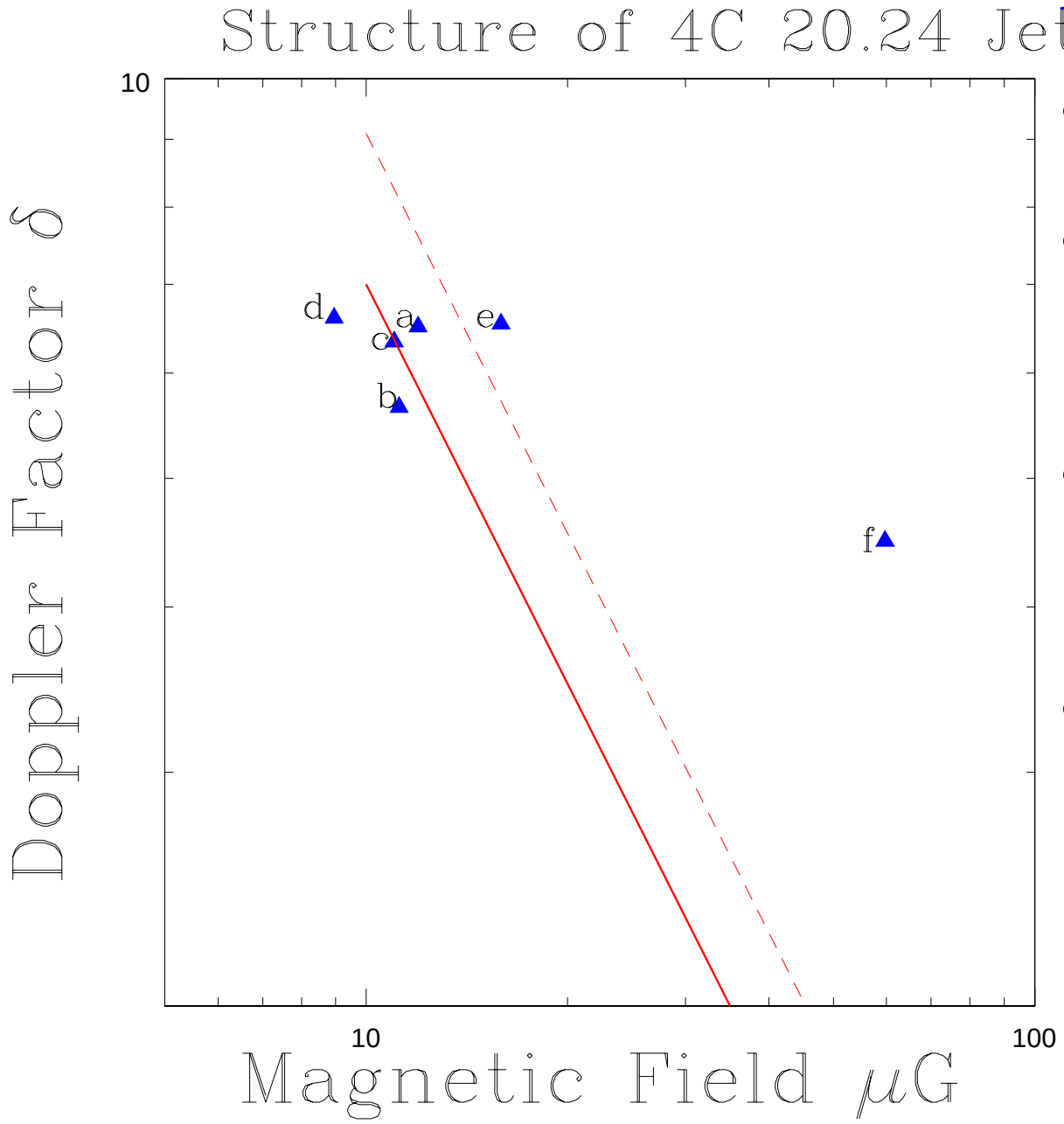


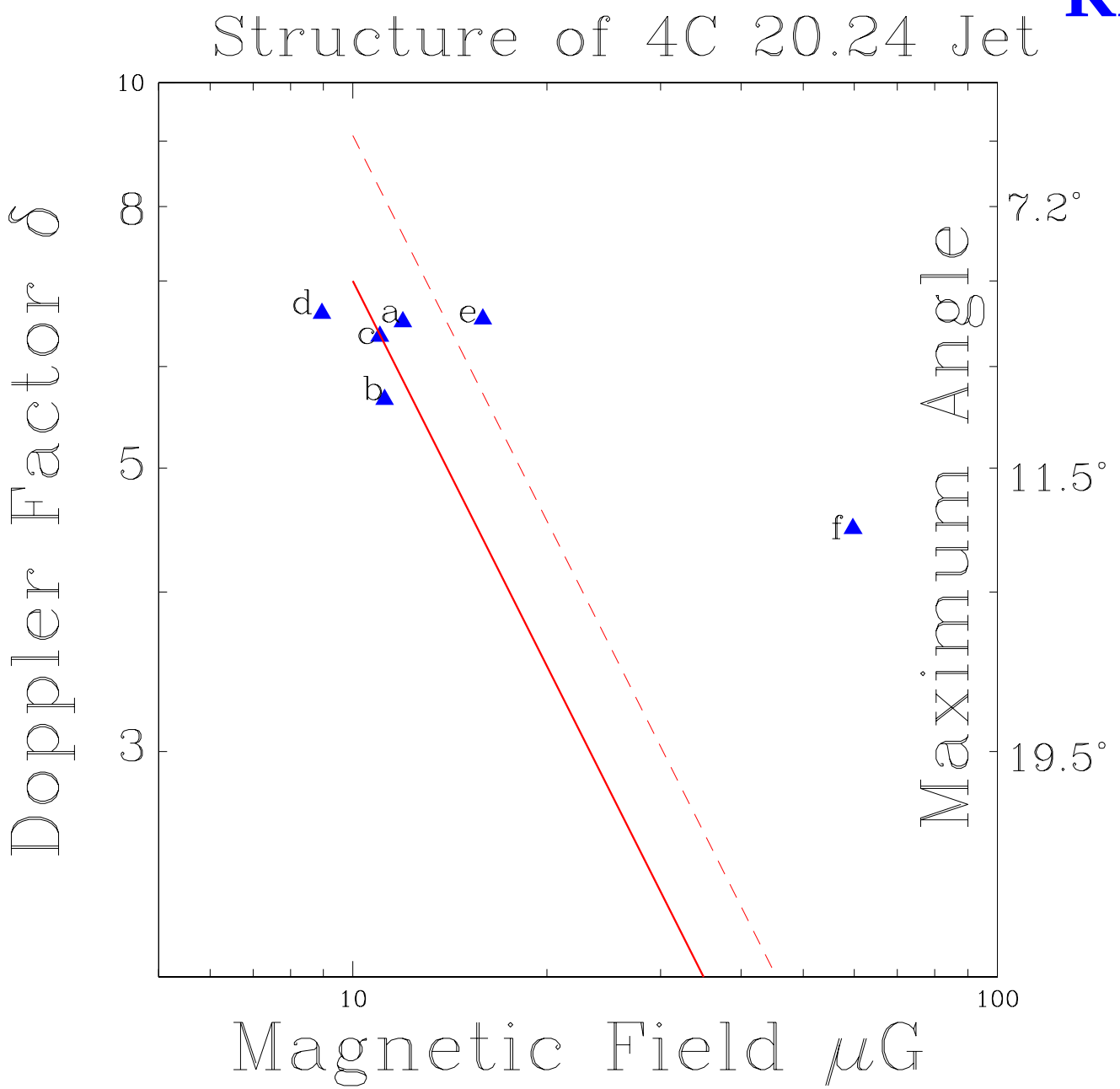




Structure of 4C 20.24 Jet
Doppler Factor δ
10
d
a
e
c
b
f
10
100
Magnetic Field μG

# Kinetic Energy Flux



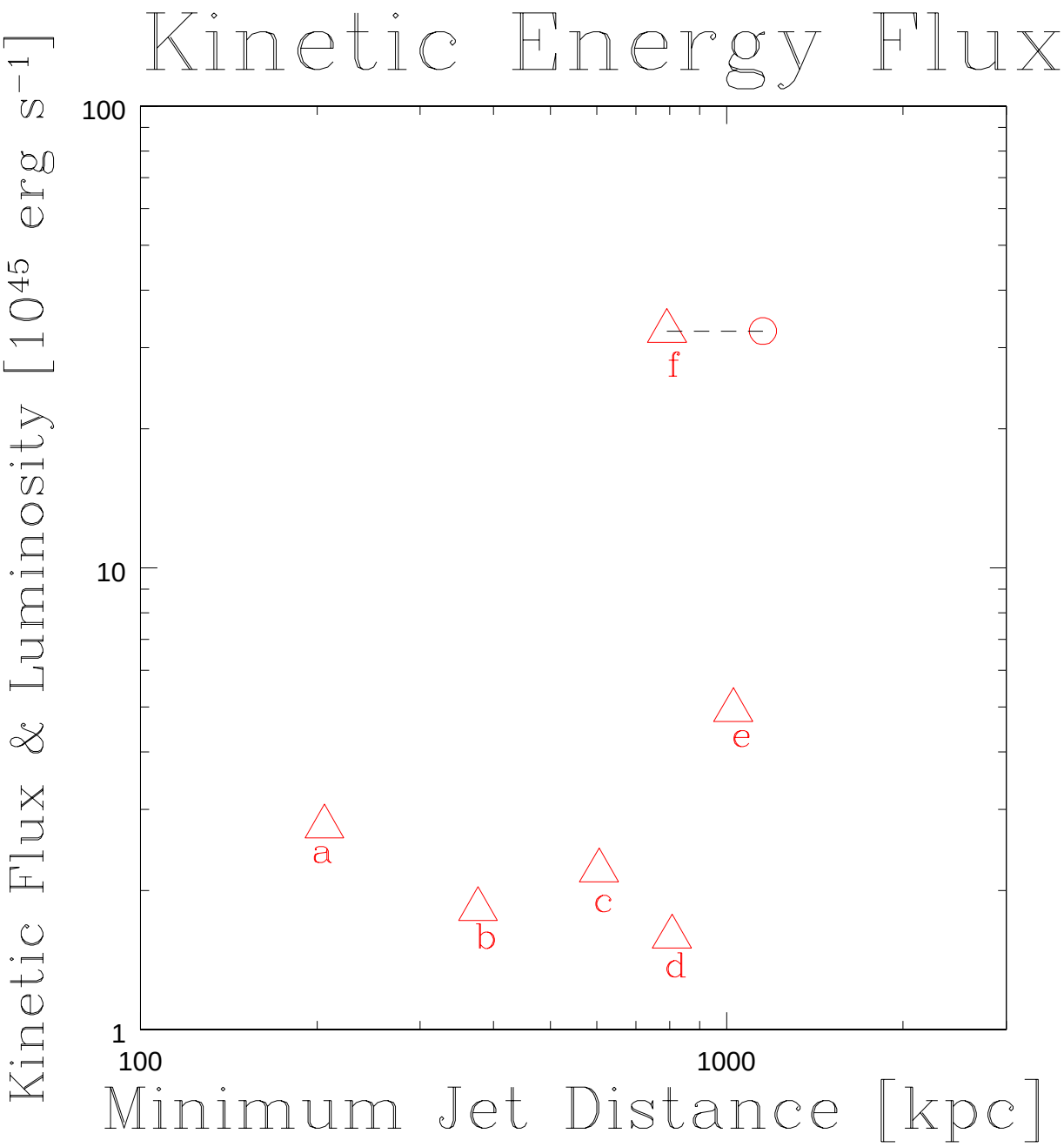

- $K = \pi r^2 \beta c \Gamma^2 (H - \rho_0 c^2/\Gamma)$
- H is enthalpy density, $H_B + H_e + H_p$
- For equipartition, $H = \frac{B^2}{8\pi}(2 + 4/3\,(1+k))$
- NOTE: K constant ⇒ $(B\,\Gamma)^2$ = constant




# Kinetic Energy Flux

- $K \approx \pi r^2 \beta c \Gamma^2 H$
- We take $\Gamma \approx \delta$

  $\delta = (\Gamma(1 - \beta \cos(\theta)))^{-1}$
- $\cos(\theta_{max}) = \frac{\delta - 1/\delta}{\sqrt{(\delta^2 - 1)}}$



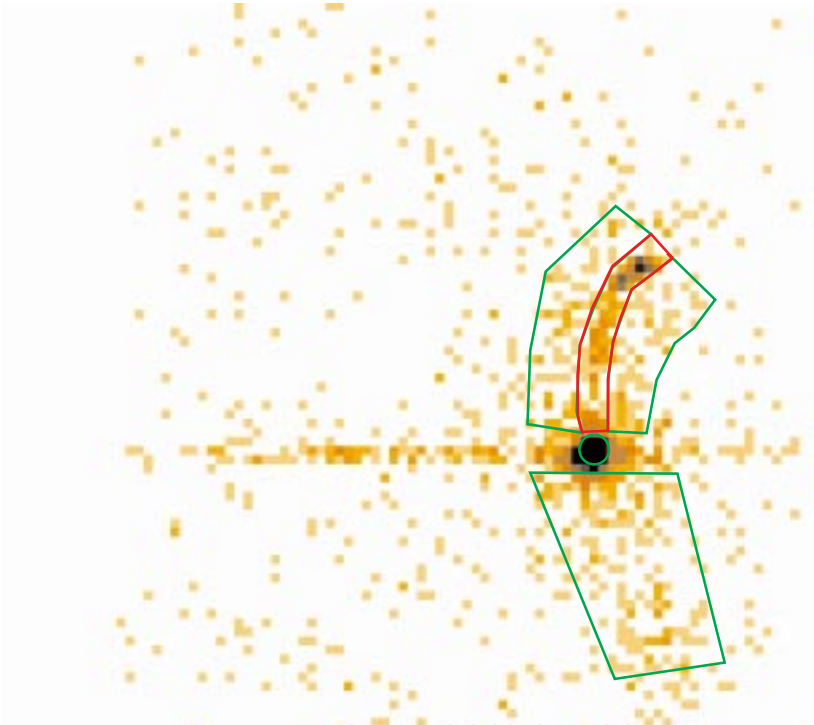

# Kinetic Energy Flux

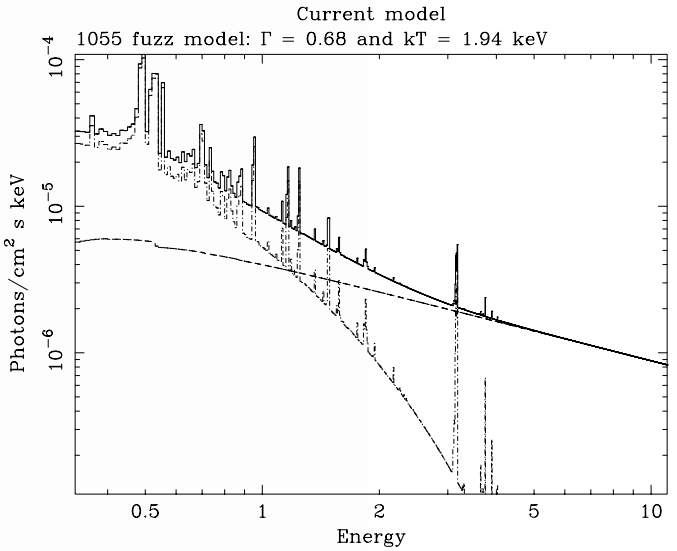
**We take:**

$$K \approx \pi r^2 \beta c \Gamma^2 H,$$

$$U_p = U_e$$

# 4C20.24 Extended X-ray Emission






$L_x$=3.4 $10^{44}$ ergs $s^{-1}$

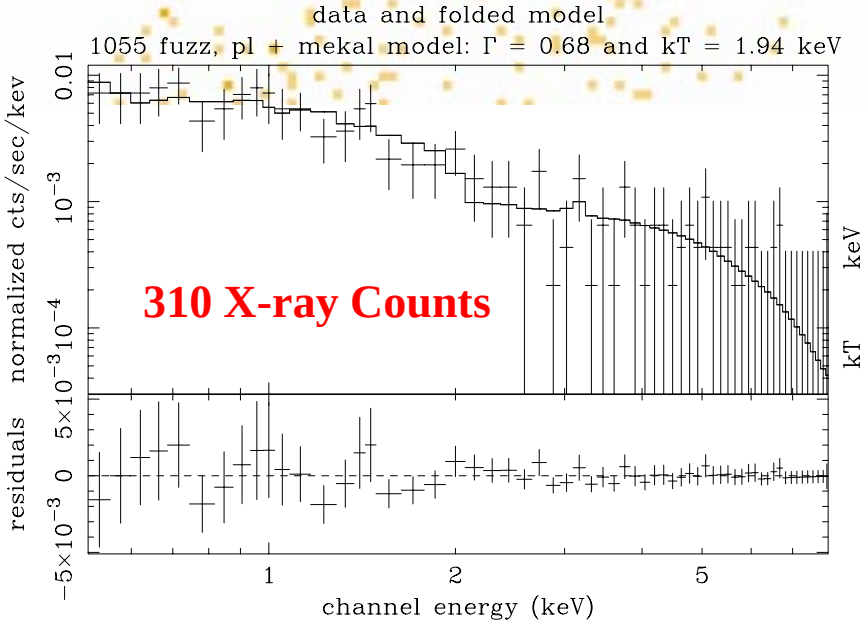
kT = 2 keV

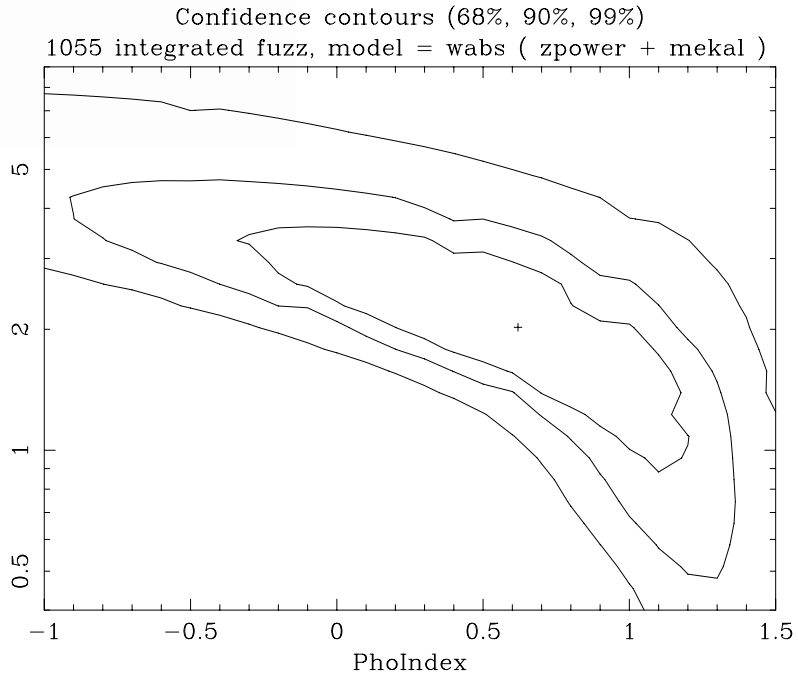
$n_e$=0.01 $cm^{-3}$

$t_{gas} \approx 4\ 10^8$ years

$P_{gas} \approx 10^{-10}$dyne $cm^{-2}$

$P_{gas} \approx 10 \times P_{jet}$



# Summary

1. **Detailed IC/CMB structure of a Mpc scale Jet**
   - **Magnetic fields ≈ 10 $\mu$Gauss**
   - **Doppler and Lorentz factors ≈ 6**
   - **Angle to line of sight ≈ 9°**
2. **Extended X-ray emitting region**
   - **$L_x \approx 3.4\ 10^{44}$ ergs $s^{-1}$**
   - **Gas Heated by Jet?**
   - **Entrained material, part of jet structure?**
3. **Direct Evidence of an unseen counter jet**