The unique X-ray features of the jet in PKS 1055+201

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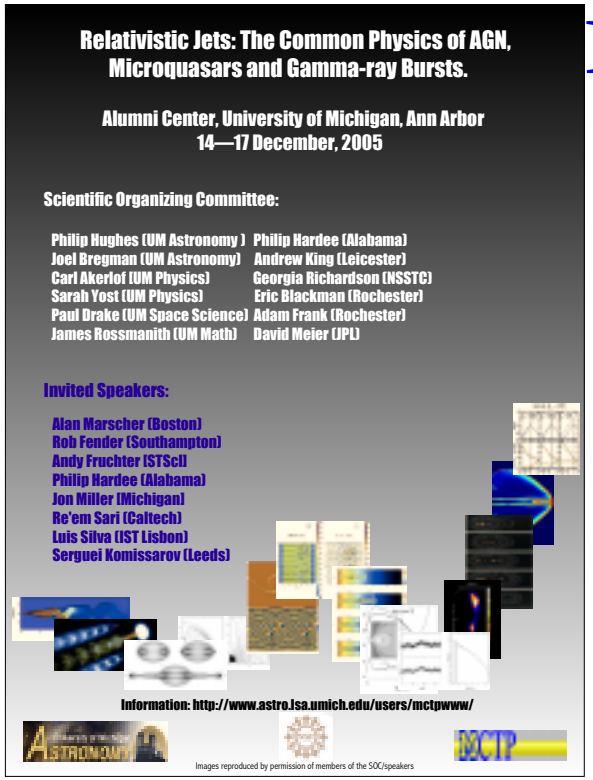
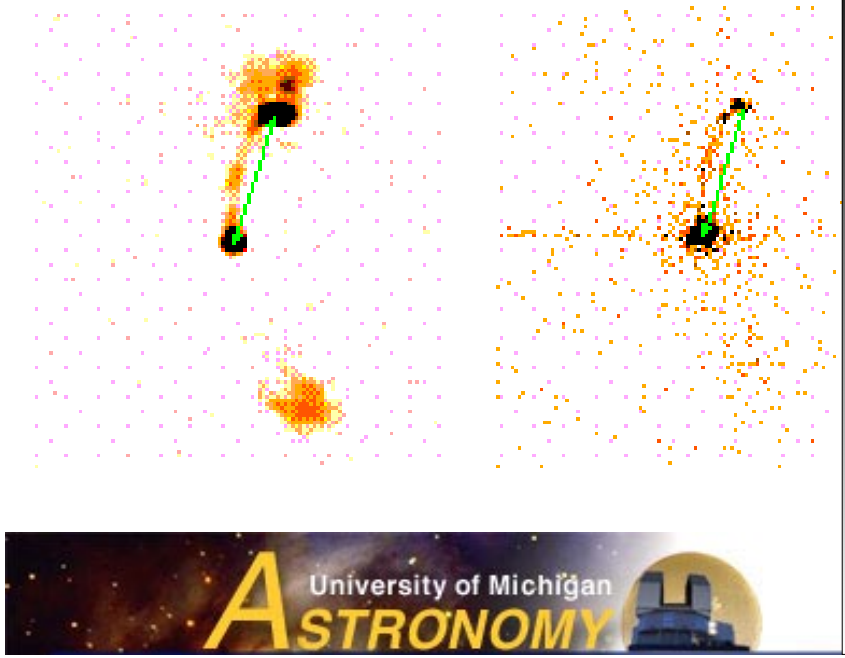


PKS 1055+201=4C 20.24



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 μ G,**
   - **Doppler factor δ about 6**
3. **What is Remarkable About 4C20.24?**

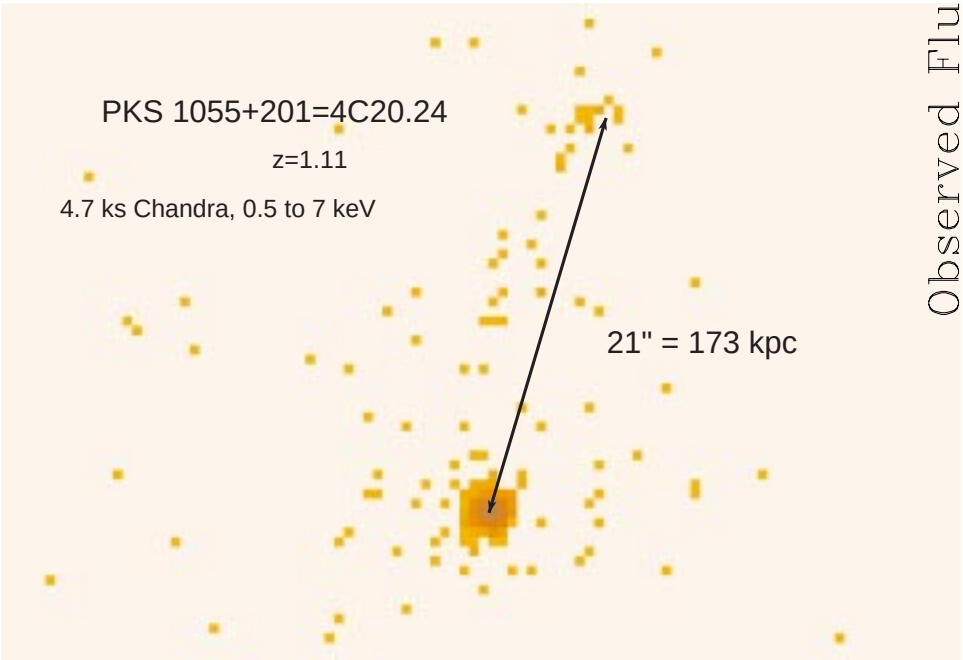
Outline

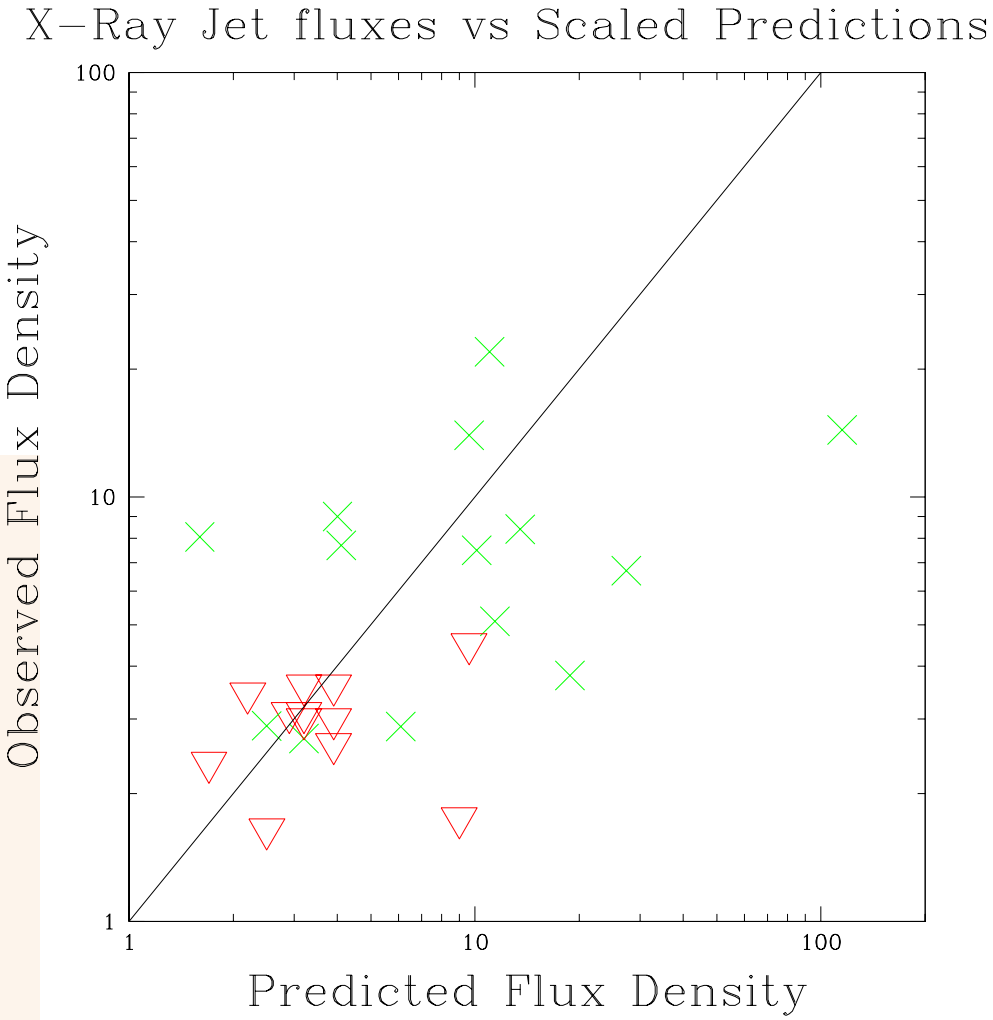
1. **Context of an X-ray Jet Survey**
2. **What is Normal About 4C20.24?**
3. **What is Remarkable About 4C20.24?**
   - **Extended X-ray emission symmetric around radio/X-ray jet**
   - **Similar extended X-ray emission around unseen counter-jet**
   - **Jets appear to be “swept” back from quasar**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

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**

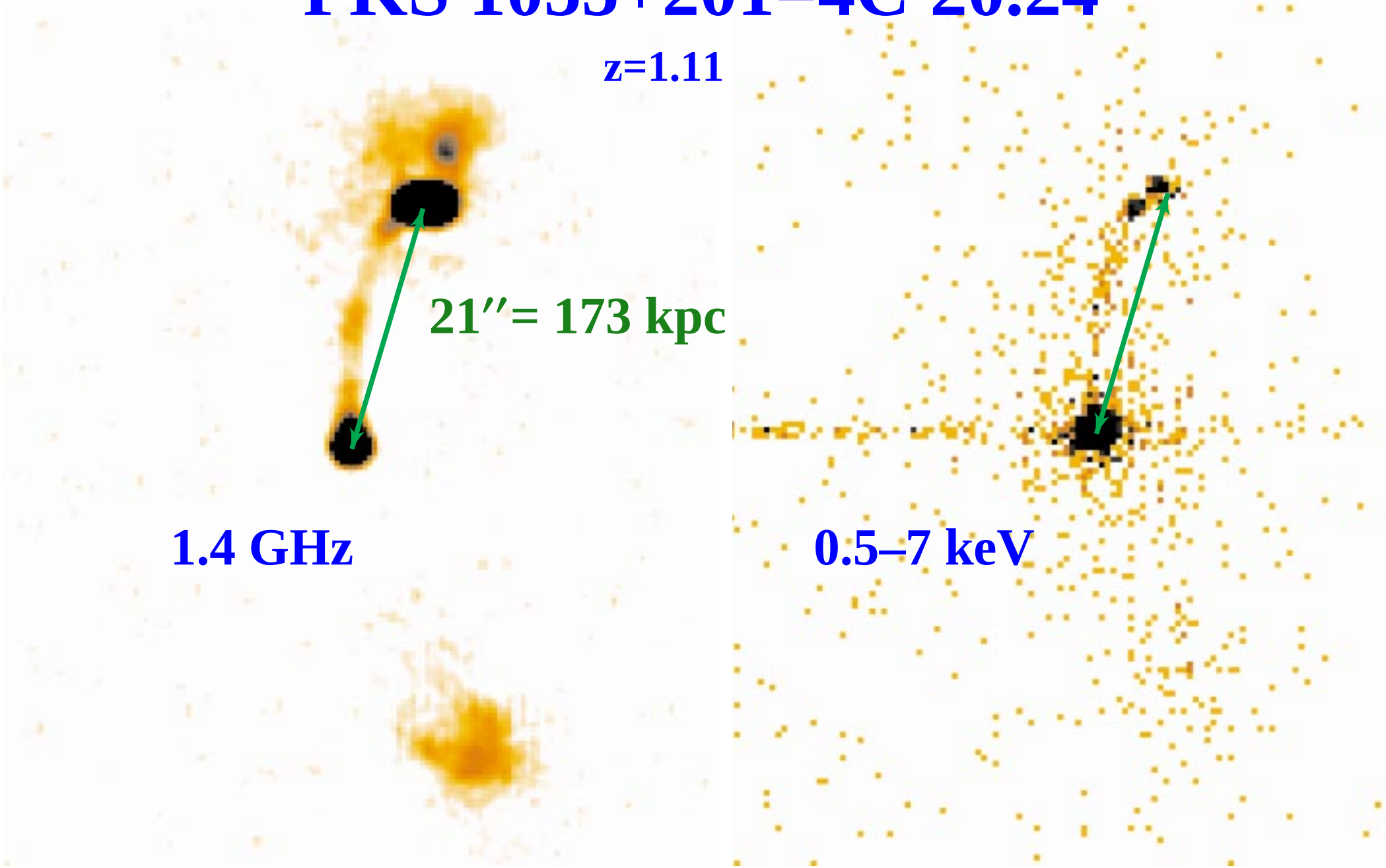
[a]Murphy, Browne & Perley 1993
[b]Lovell 1997





PKS 1055+201=4C 20.24

z=1.11



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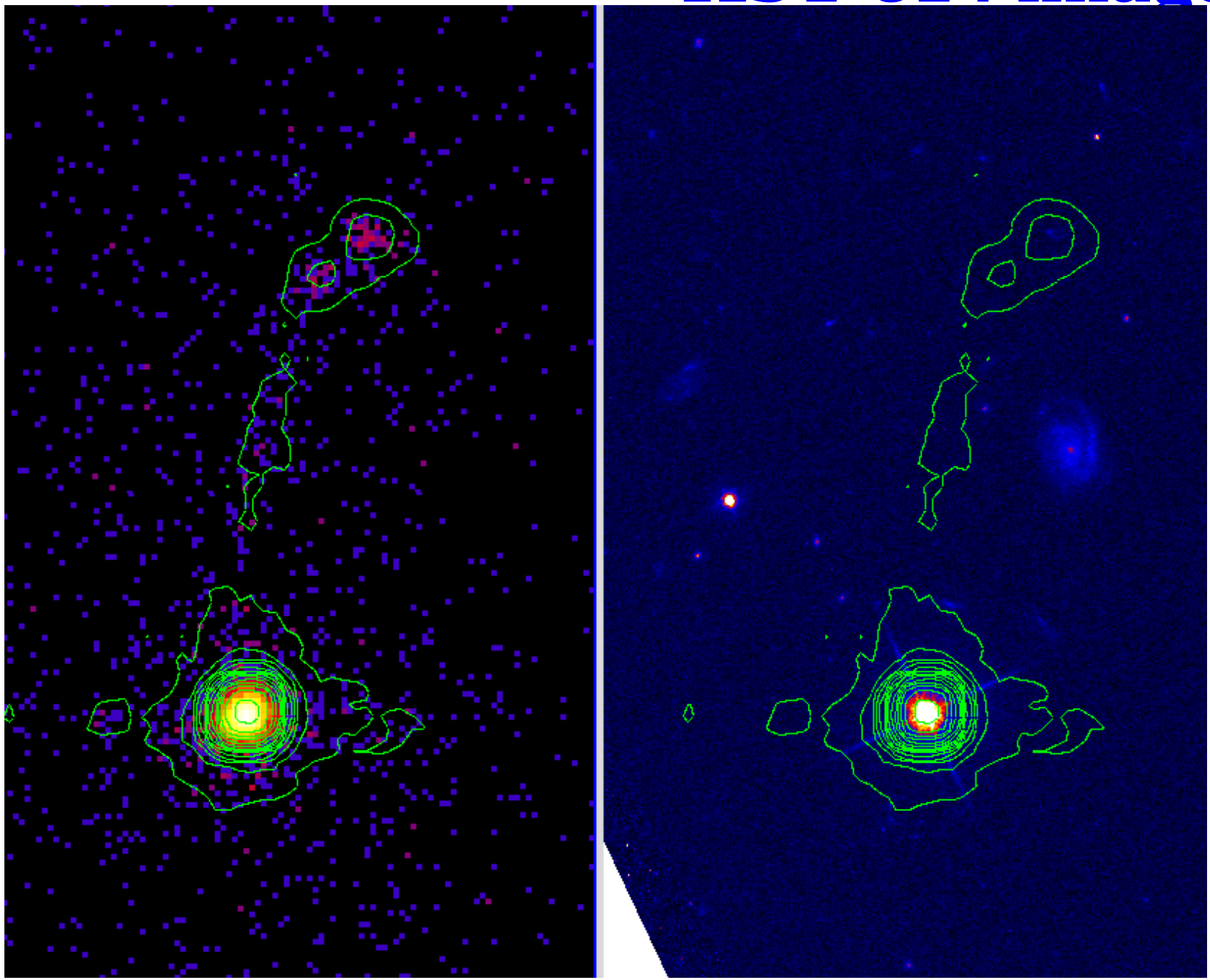

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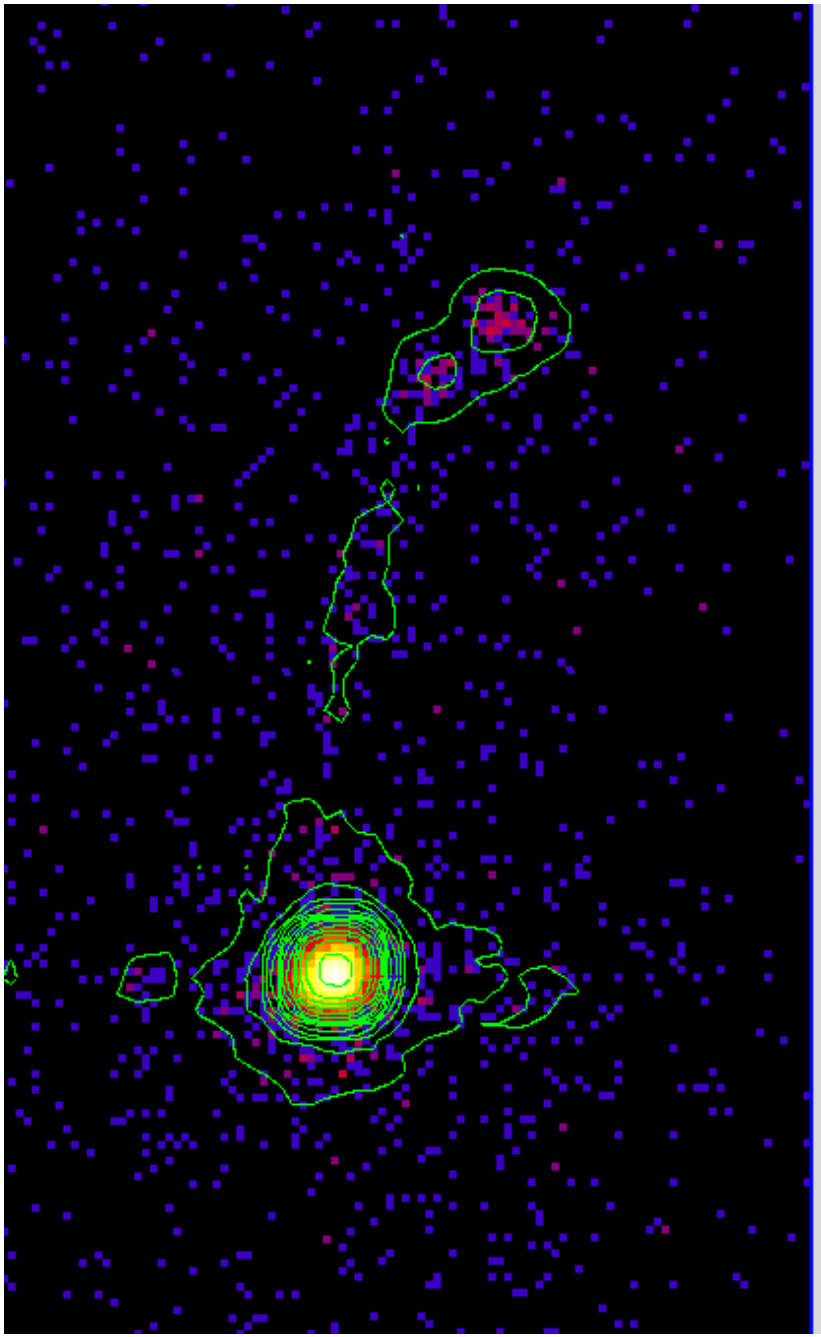

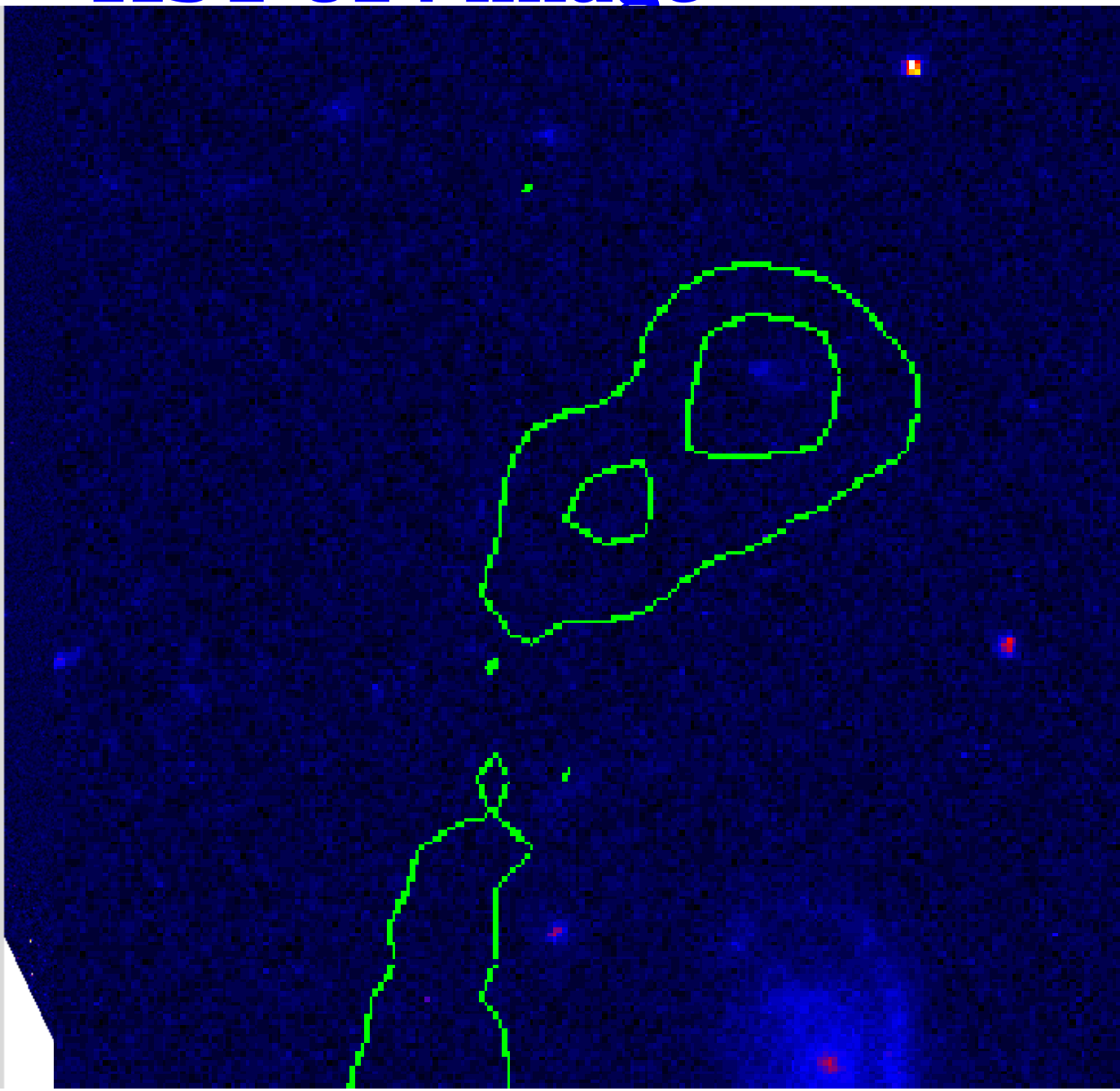

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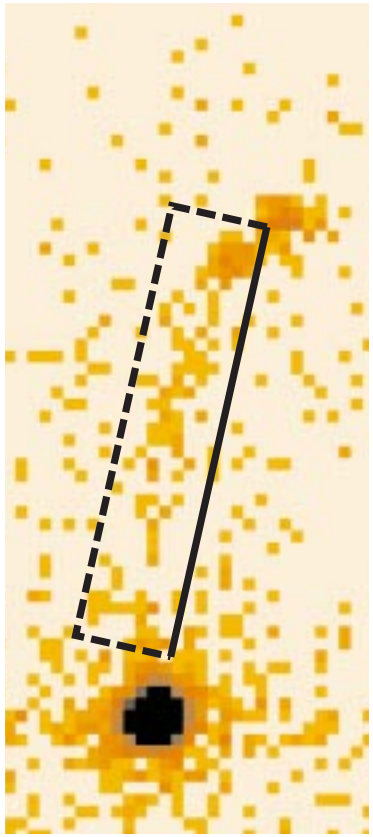

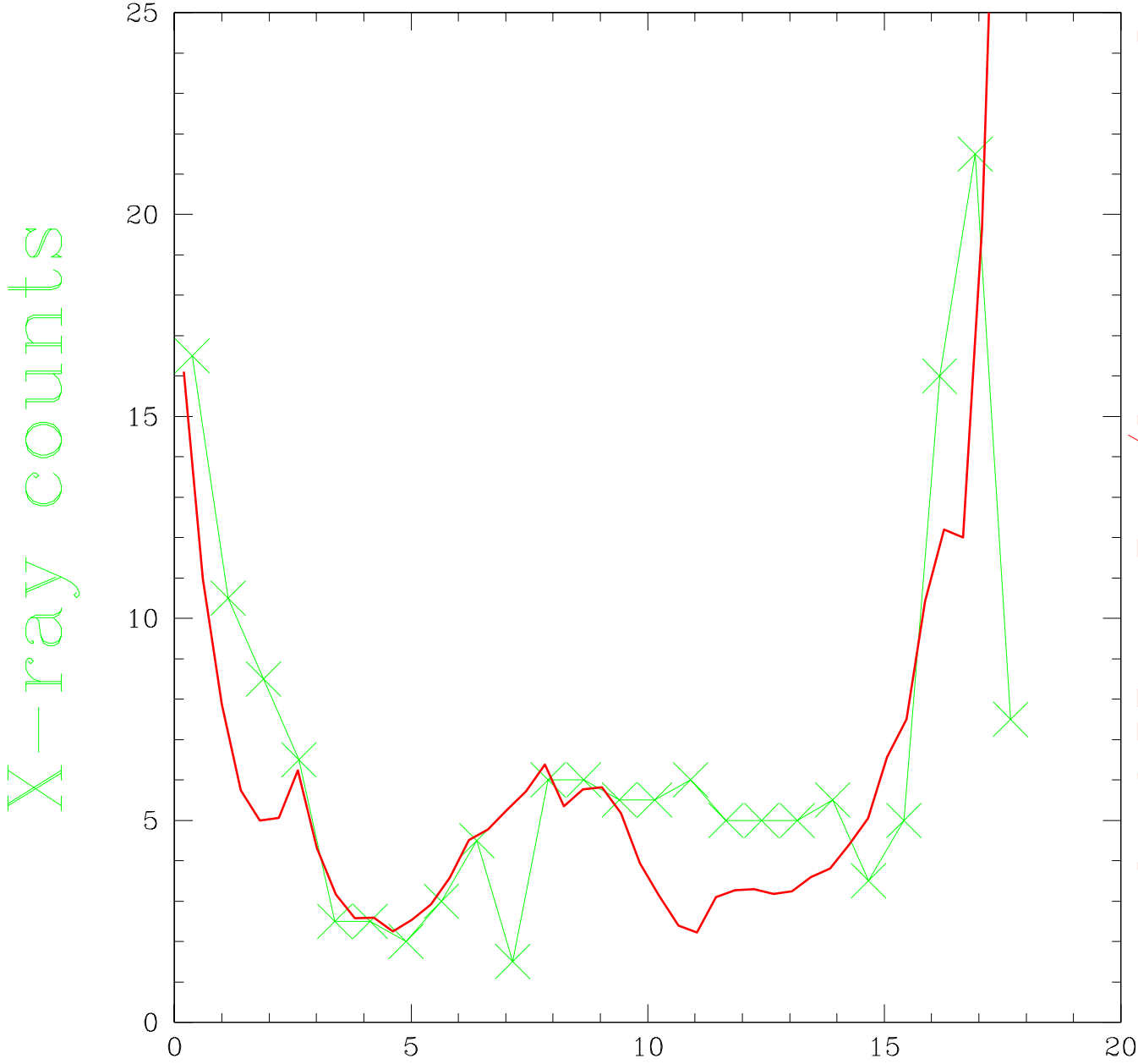

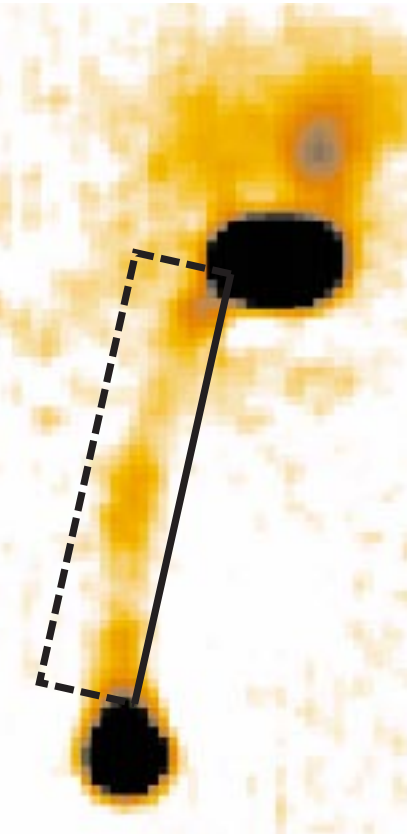

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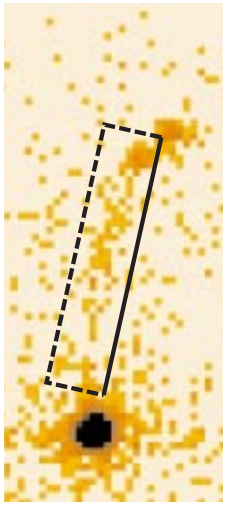

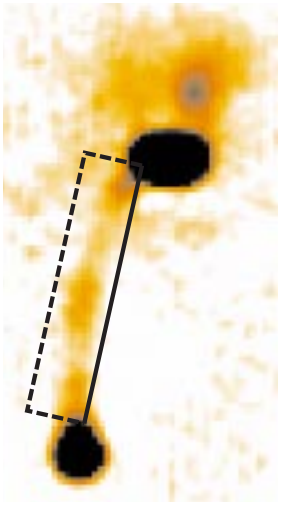

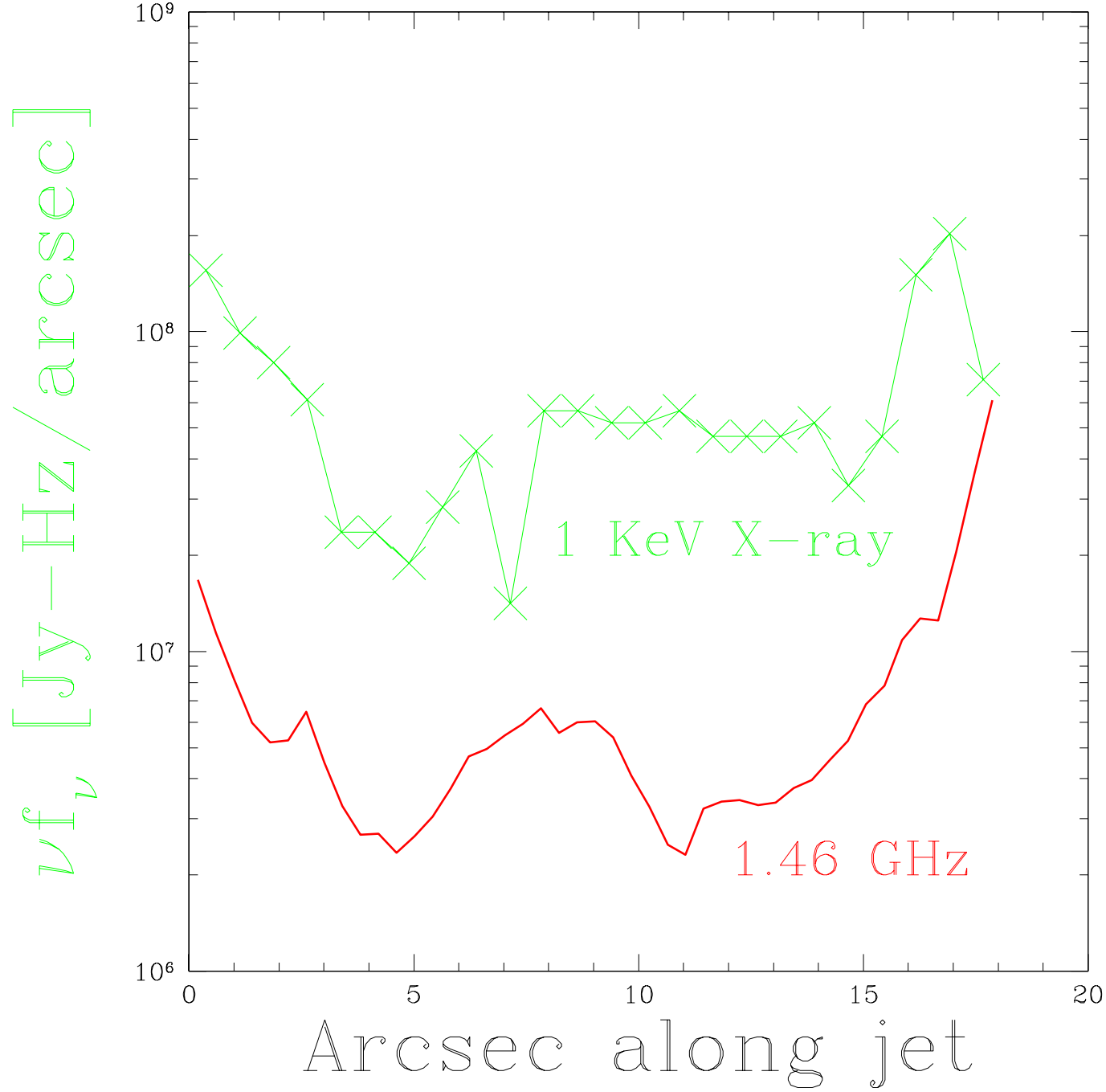

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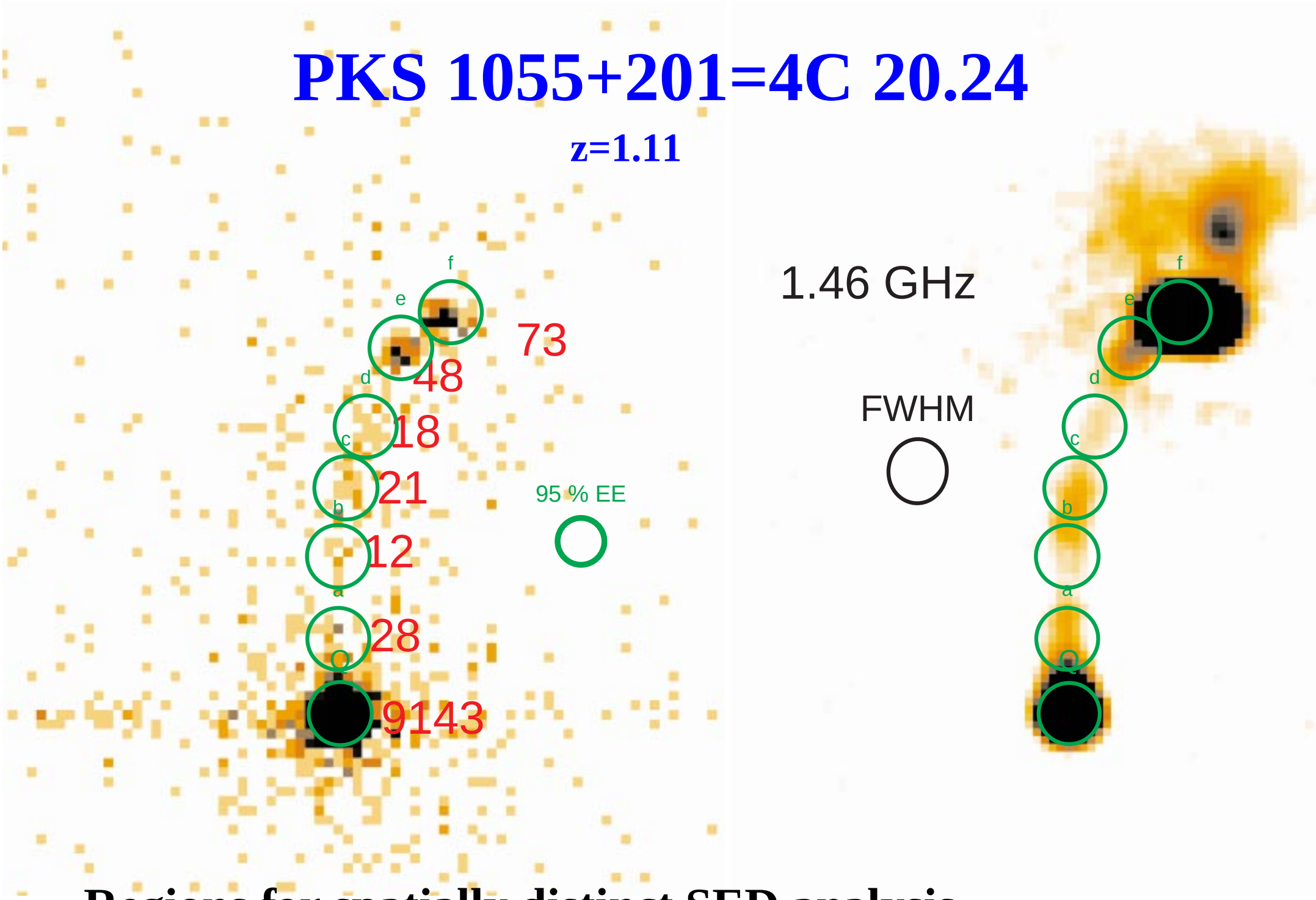
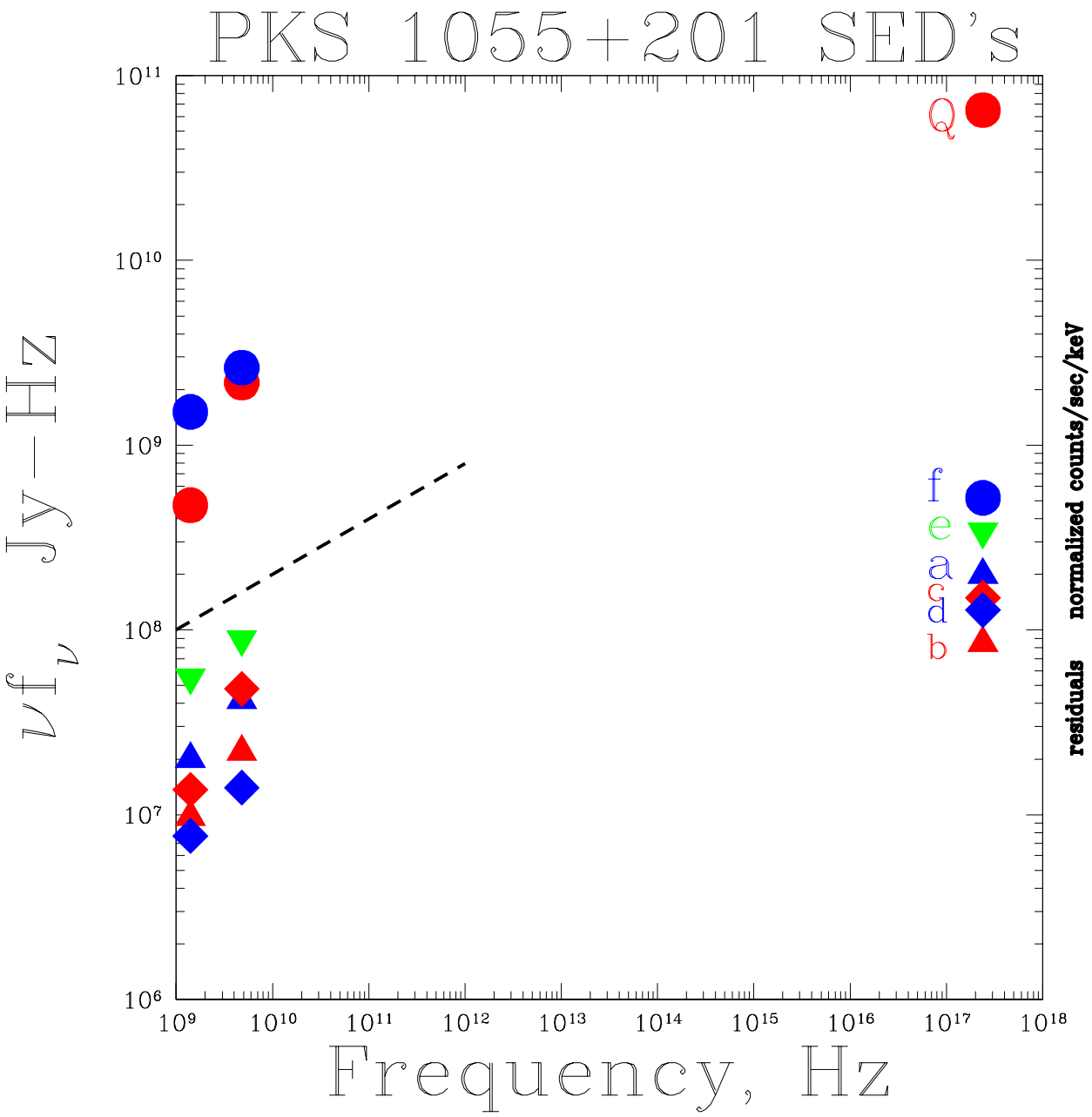
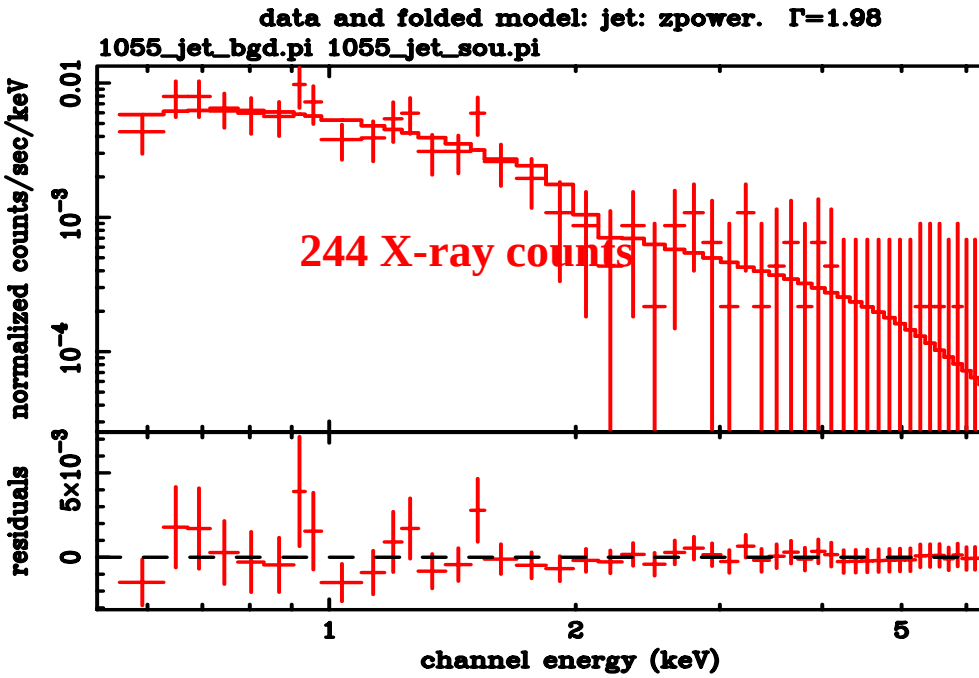
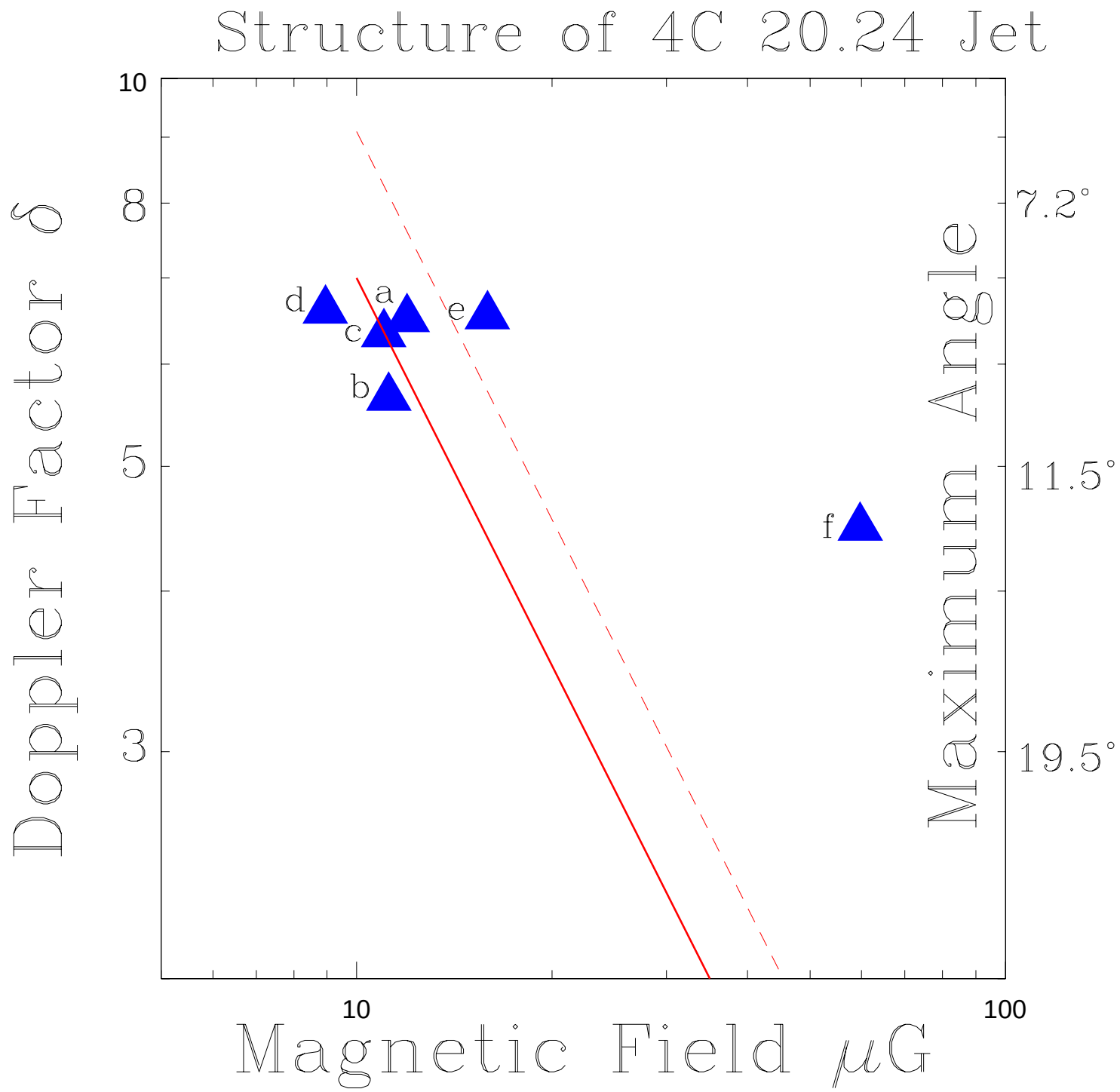


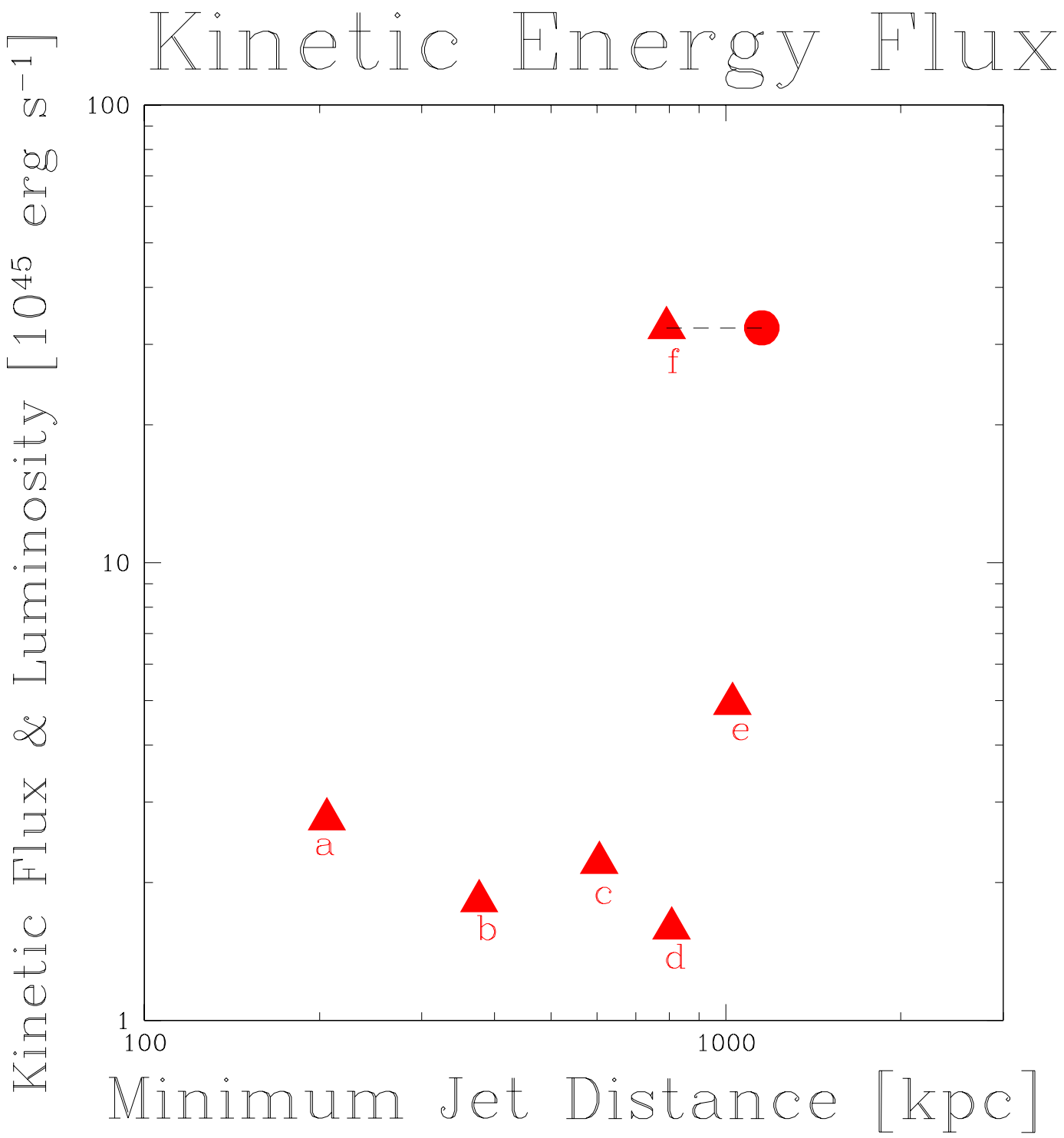
Regions for spatially distinct SED analysis.

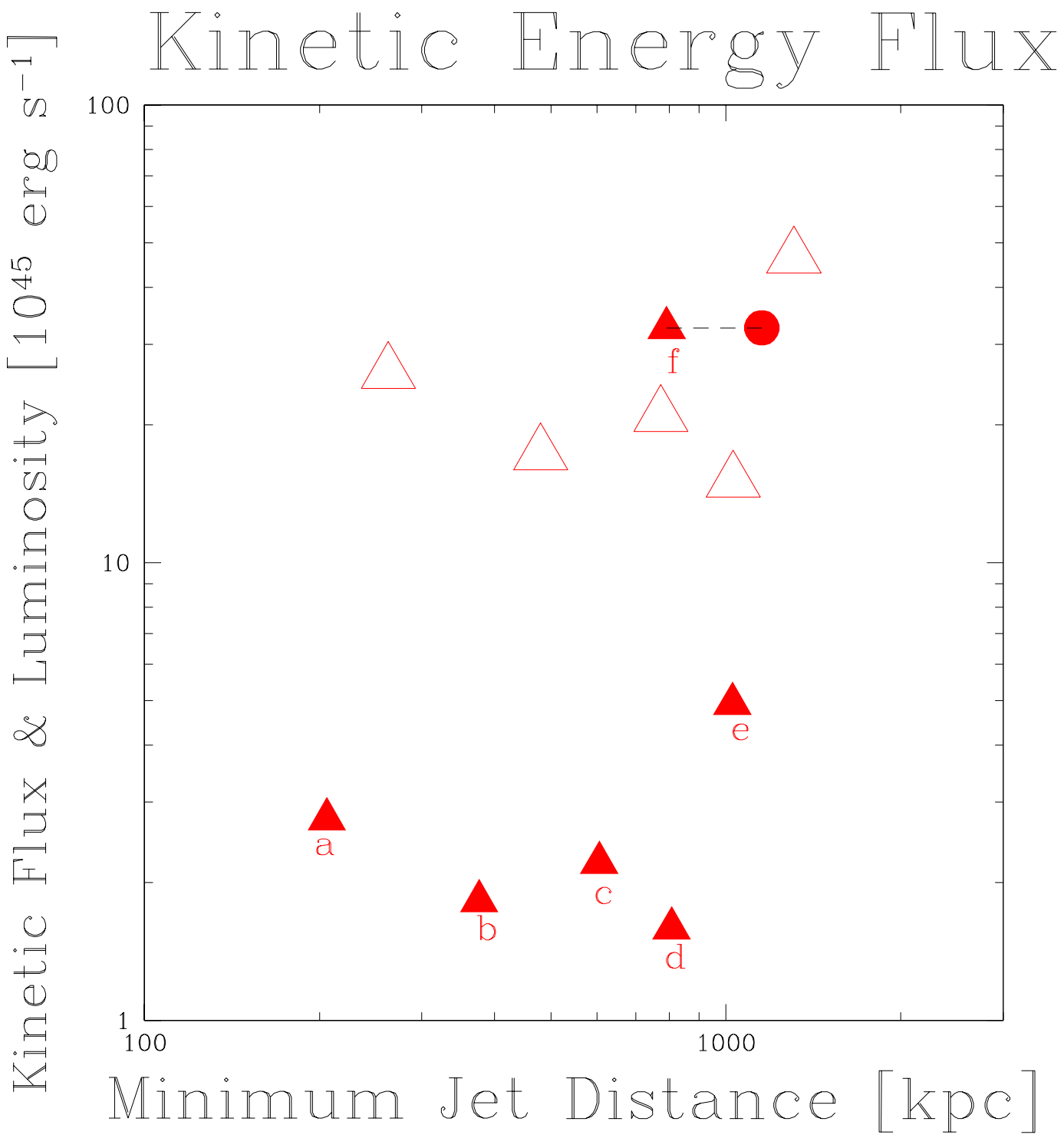
Spectral Energy Distribution for the Jet



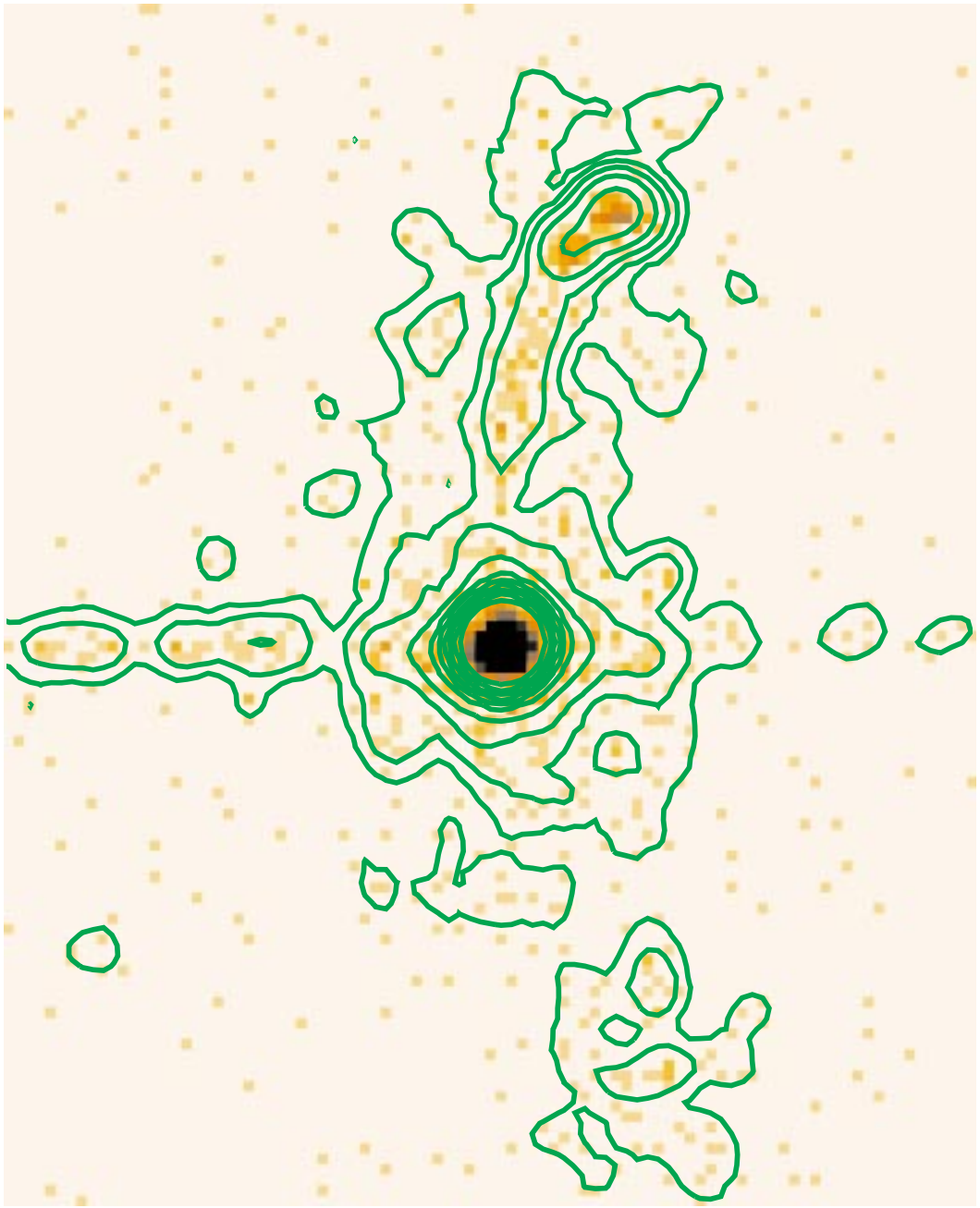


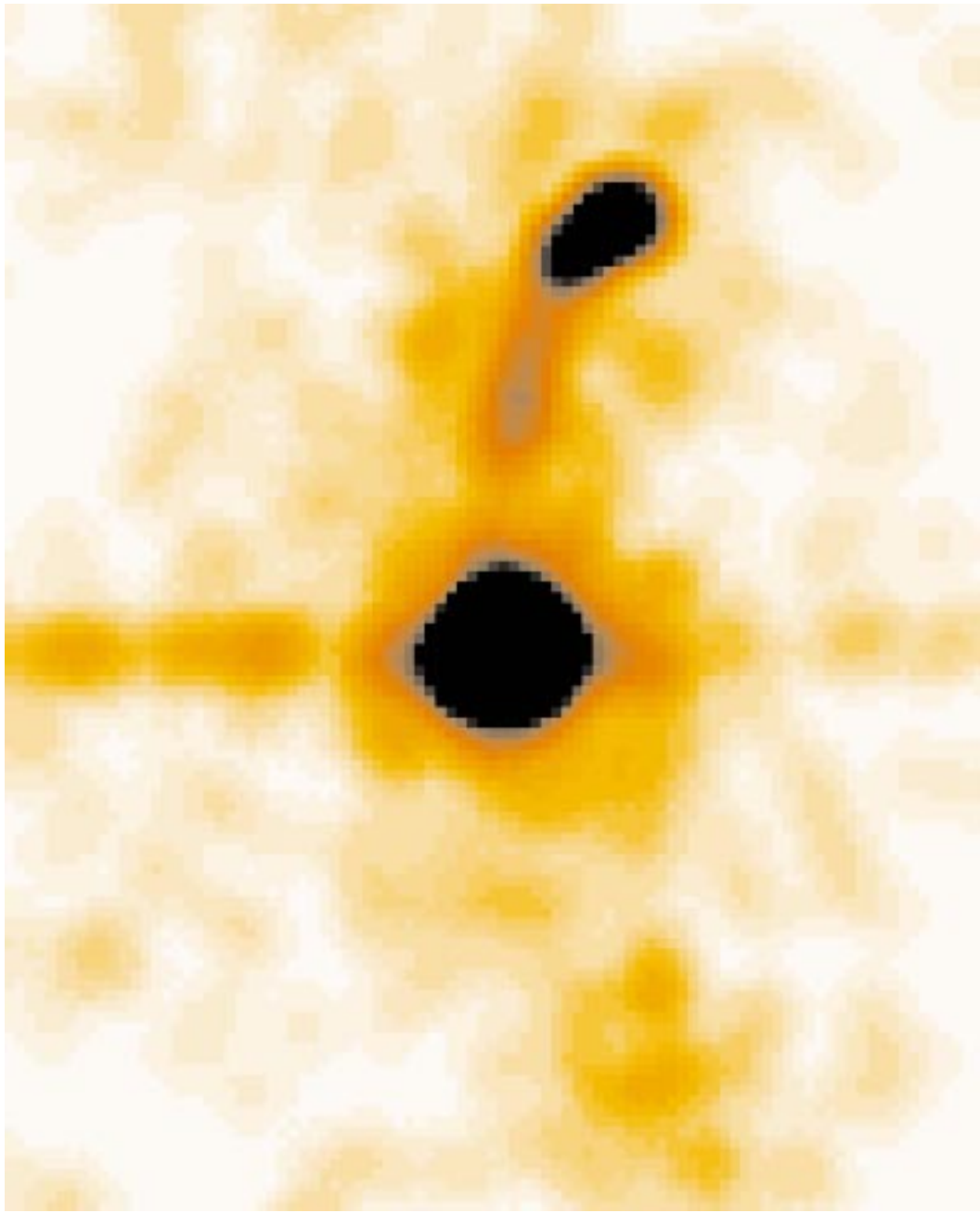

Structure of 4C 20.24 Jet
Doppler Factor δ
Maximum Angle
Magnetic Field μG
10
8
5
3
10
100
7.2°
11.5°
19.5°
a
b
c
d
e
f

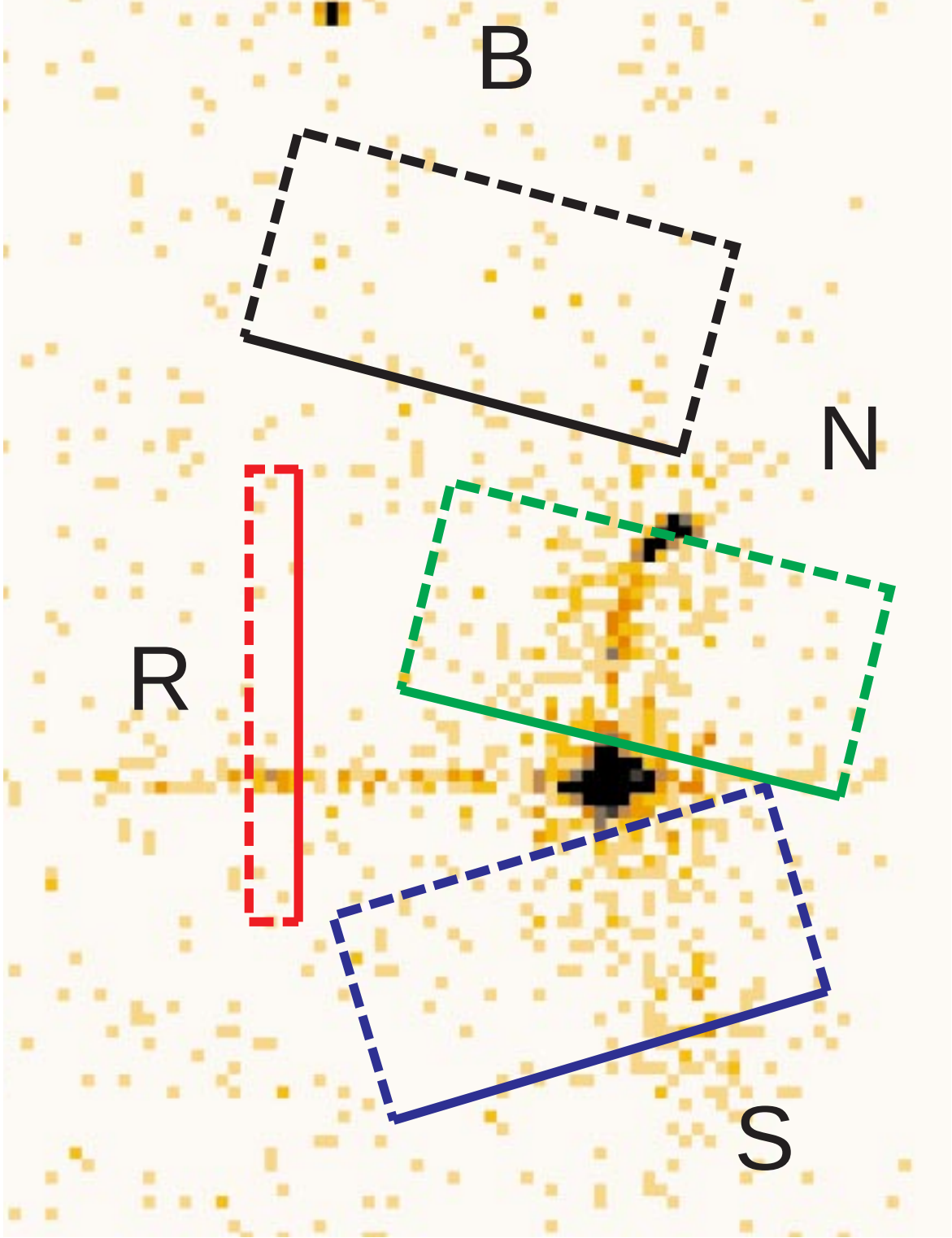

Kinetic Energy Flux
Kinetic Flux & Luminosity [1045 erg s-1]
100
10
1
100
1000
Minimum Jet Distance [kpc]
a
b
c
d
e
f

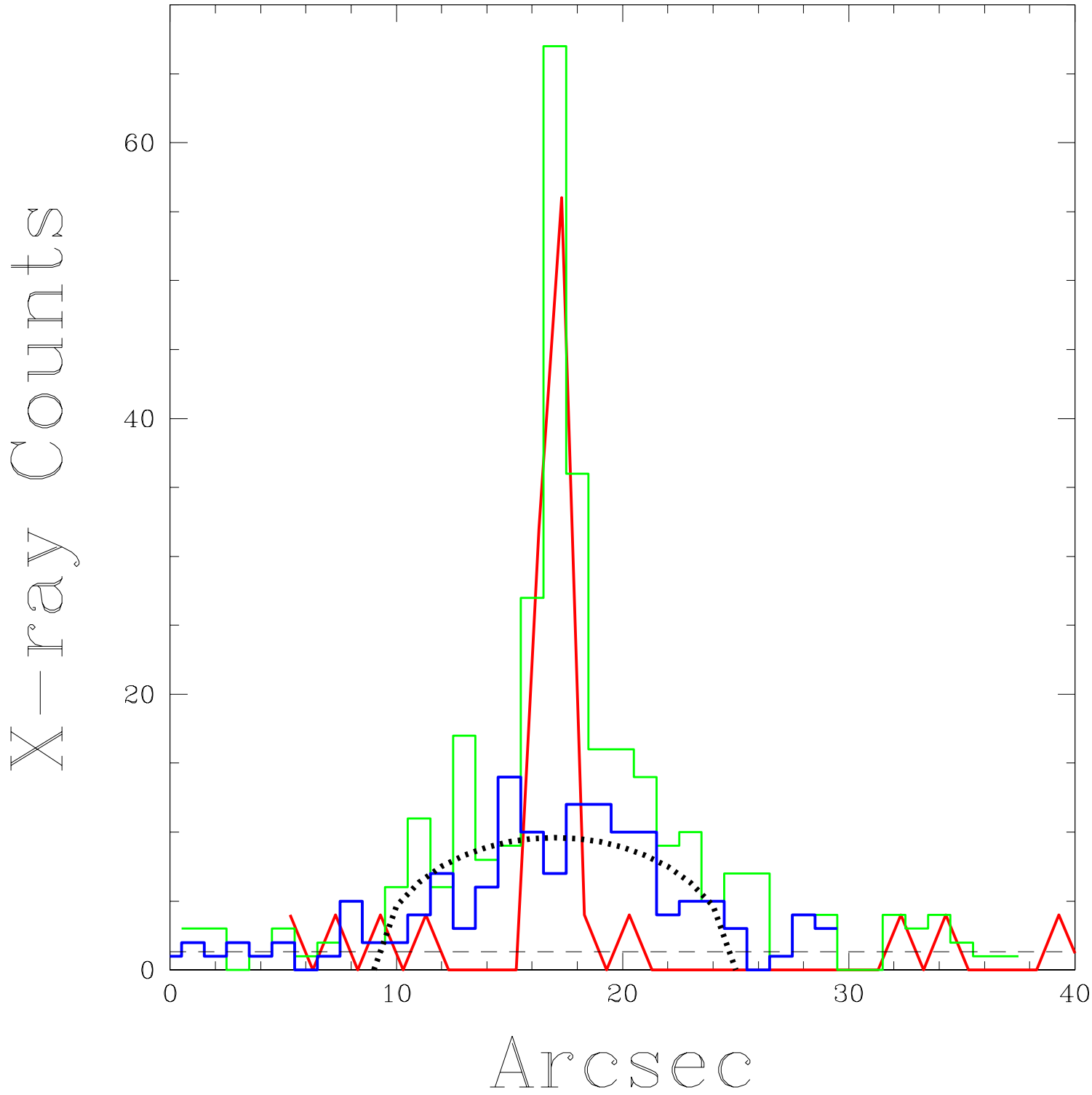

Kinetic Energy Flux
Kinetic Flux & Luminosity [1045 erg s−1]
100
10
1
100
1000
Minimum Jet Distance [kpc]
a
b
c
d
e
f

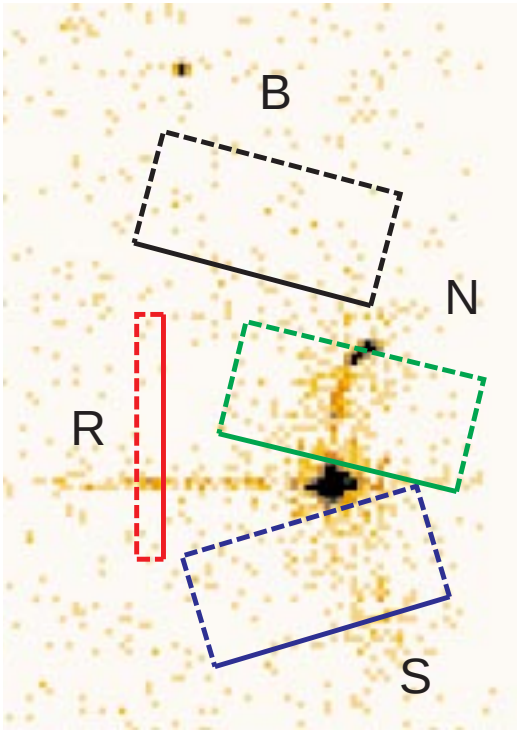
Broad X-ray Tube Surrounds Jets

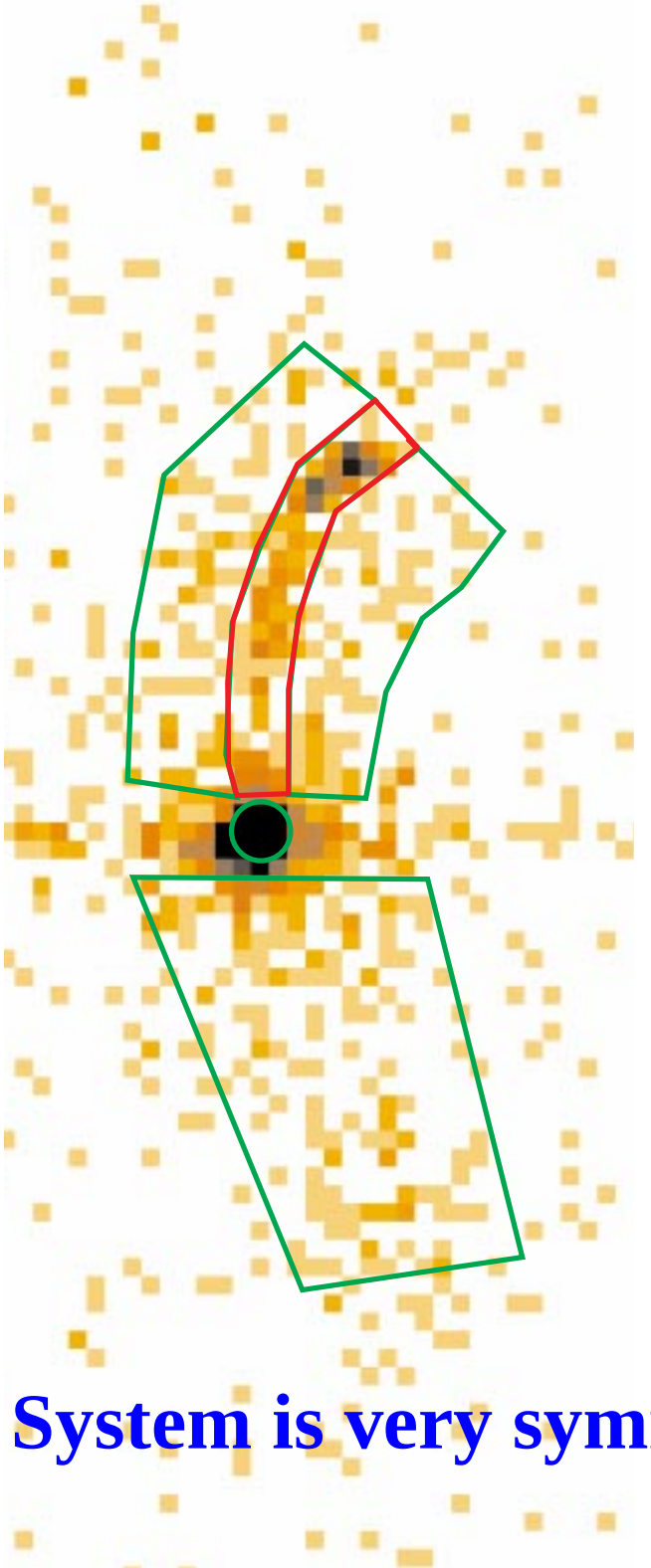


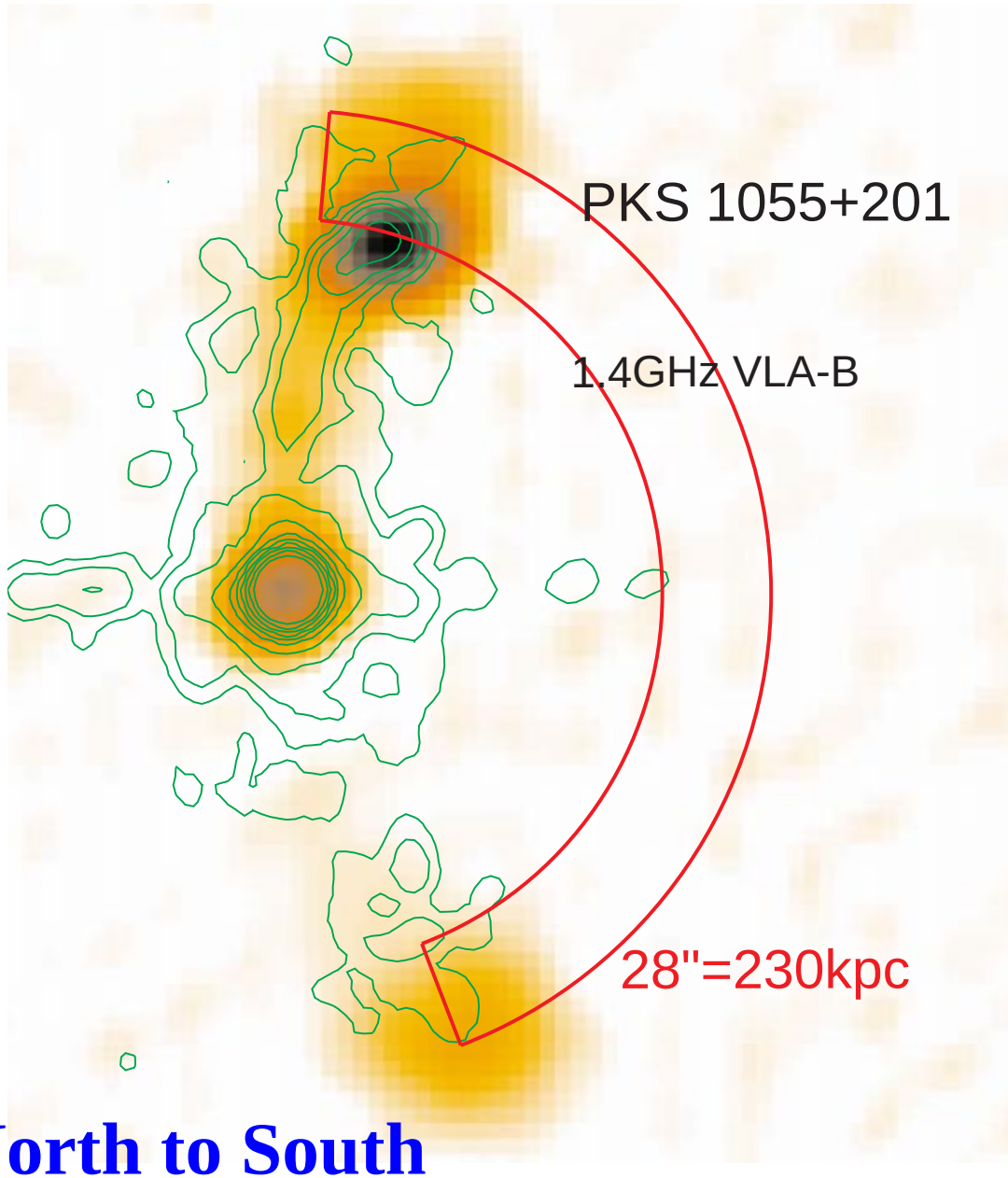



B
N
R
S


X-ray Counts
60
40
20
0
0
10
20
30
40
Arcsec

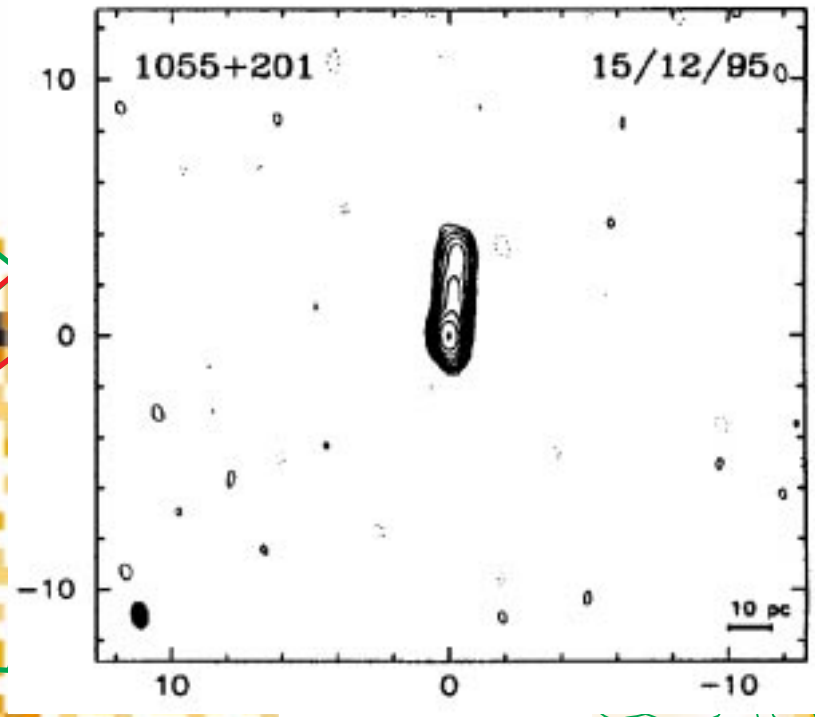

B
N
R
S





System is very symmetric North to South

Both Jets are swept to West



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

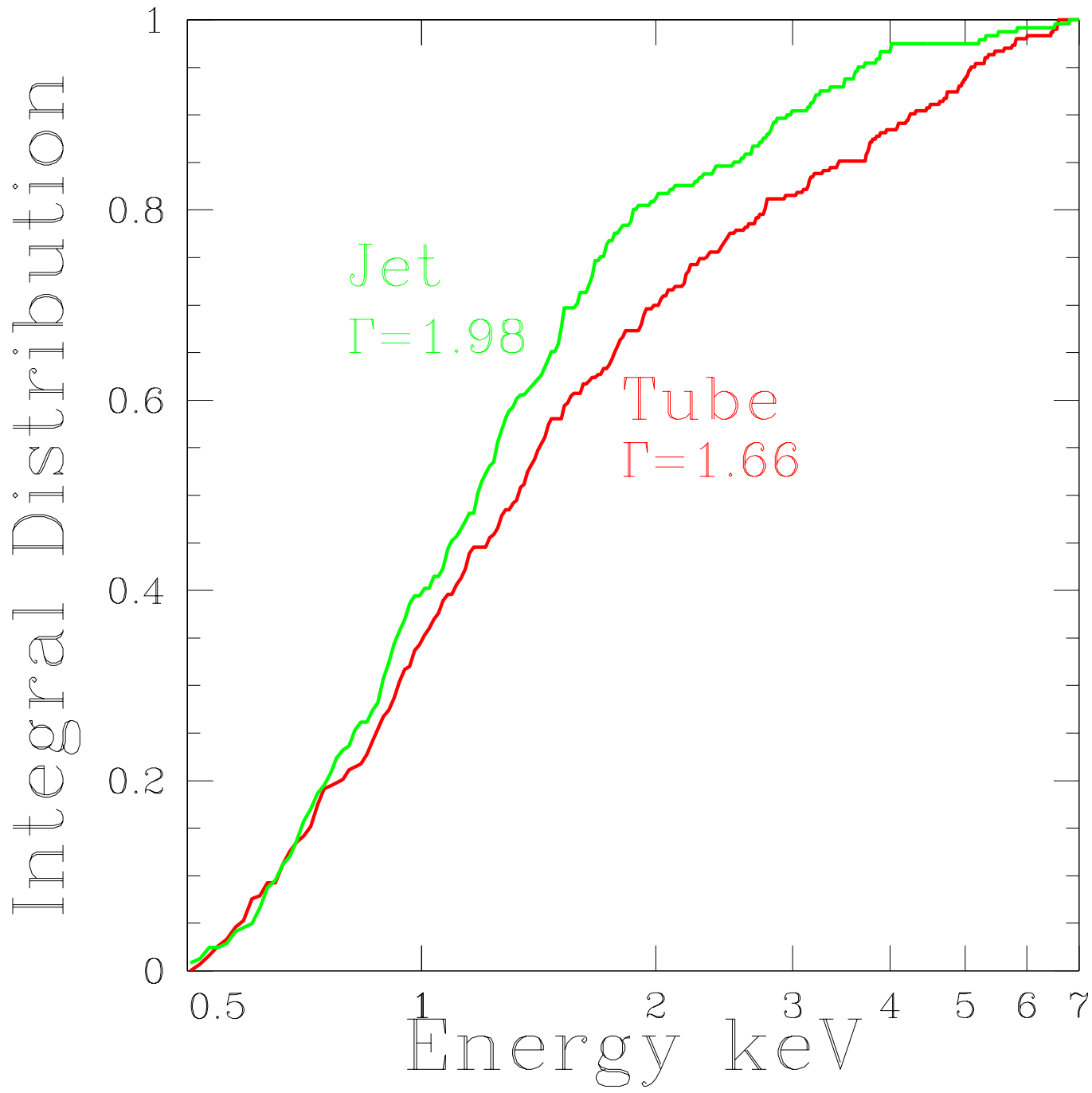
PKS 1055+201

1.4GHz VLA-B

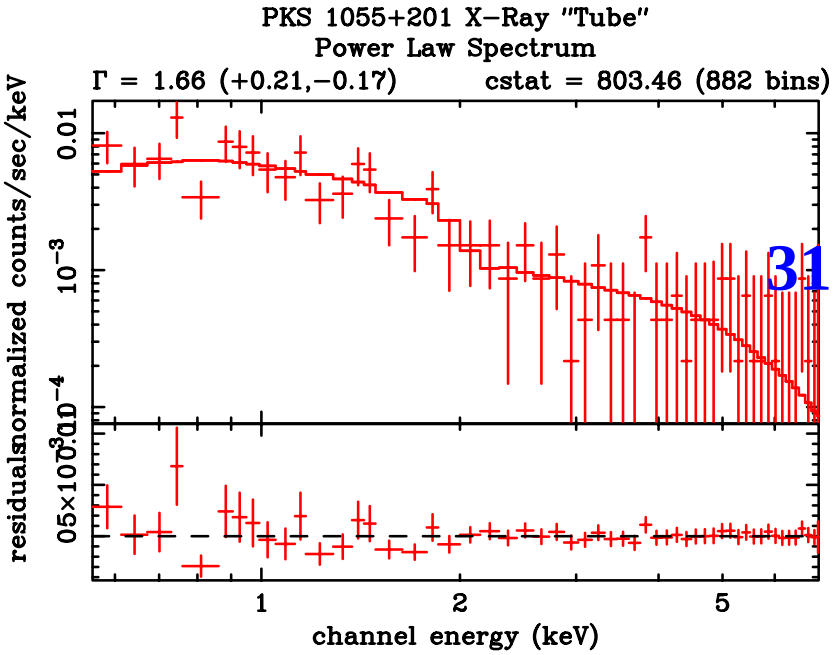
28"=230kpc

System is very symmetric North to South

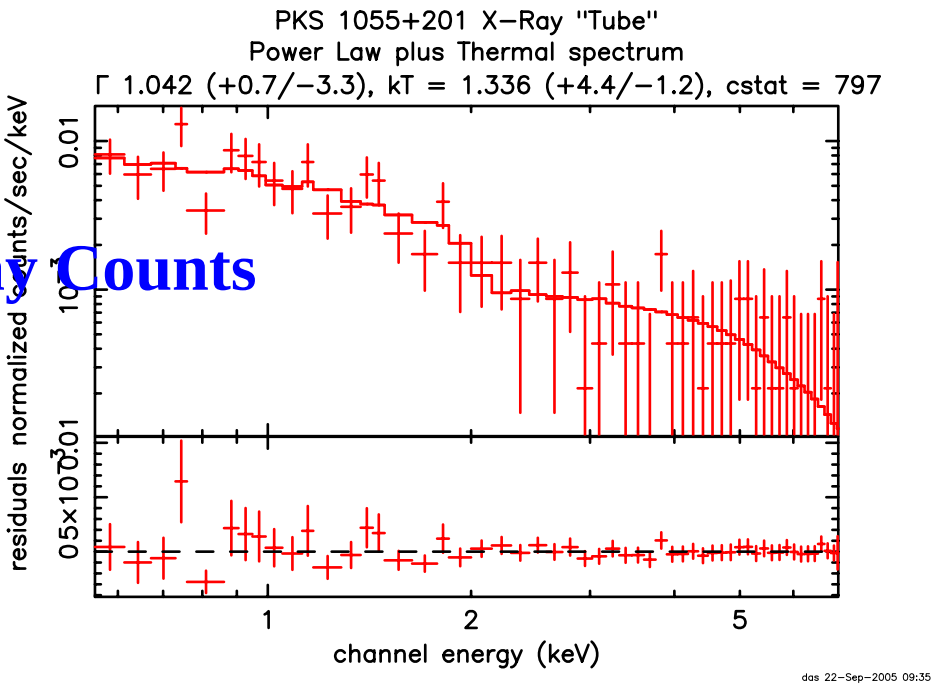
Jet spectrum is softer than Tube spectrum

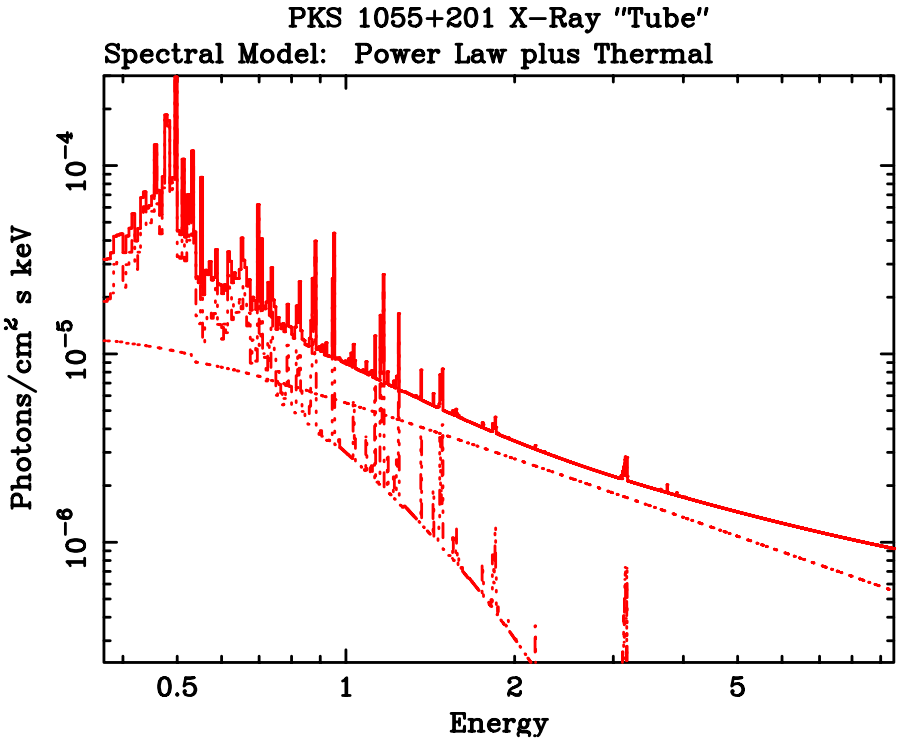


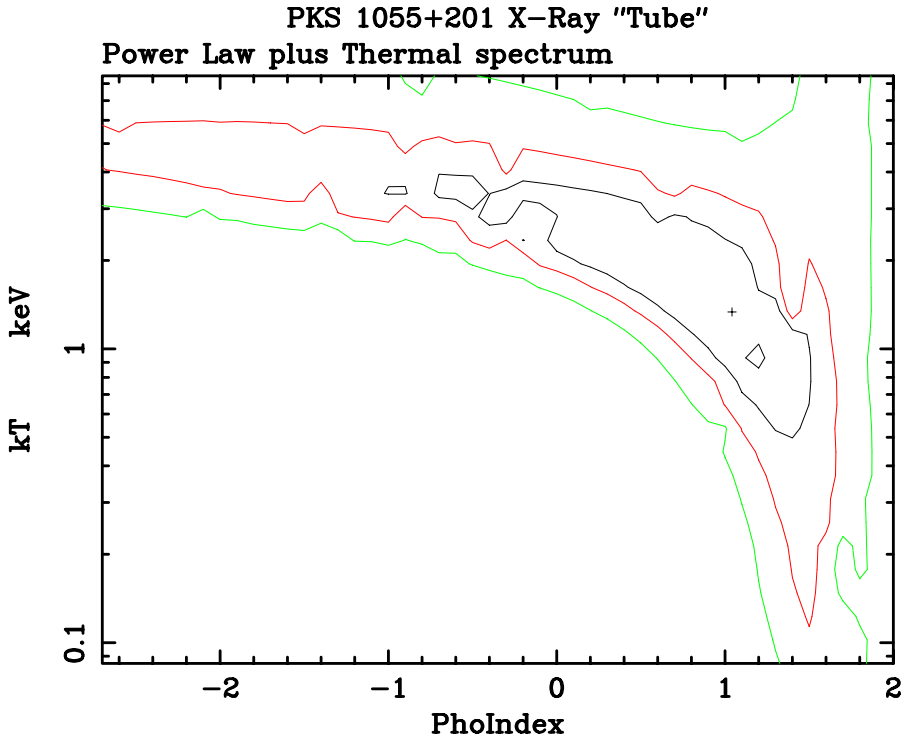
Extended X-ray “Tube”



310 X-ray Counts







Extended X-ray "Tube"

Thermal Interpretation

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

kT = 1.34 keV

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

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

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

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

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

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

Predict:

Fe Line at 3.2 keV

Cooler spectrum away from jet

Non-Thermal Interpretation

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

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

$n_e \approx 3\ 10^{-8}\ cm^{-3} \approx n_e$ 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 ≈ 10 μGauss**
   - **Doppler and Lorentz factors ≈ 6**
   - **Angle to line of sight ≤ 9°**
   - **Kinetic Flux 2×10^{45} ergs s^{-1}**
   - **Evidence for deceleration at terminal hotspot X-rays**
2. **Extended X-ray emitting "tube" surrounds jet**
   - **$L_x \approx 3.4\ 10^{44}$ ergs s^{-1}**
   - **Gas Heated by Jet?**
   - **Entrained material, part of jet or lobe structure?**
   - **Electrons diffusing out of jet?**
3. **Direct Evidence of an unseen counter jet**