EFFECT OF COSMIC MICROWAVE BACKGROUND ON X-RAY RADIATION OF HIGH REDSHIFT JETS

Kathryn McKeough[1]

Aneta Siemiginowska[2], *Vinay Kashyap*[2] & *Nathan Stein*[3]

1. Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA 15289, USA
2. Harvard-Smithsonian Center for Astrophysics, 60 Garden St, Cambridge, MA 02138, USA
3. Harvard University, 1 Oxford St, Cambridge MA 02318, USA

Introduction & Background

- **Extragalactic jets** morphology →physical structure and emission sites

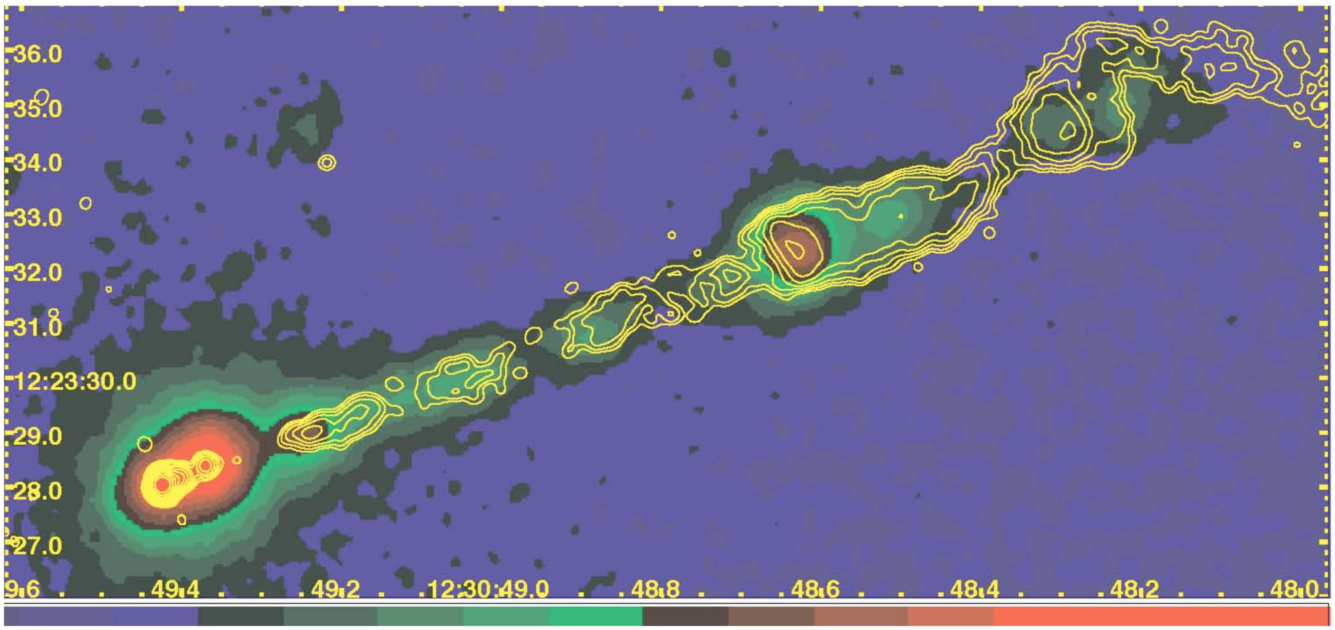
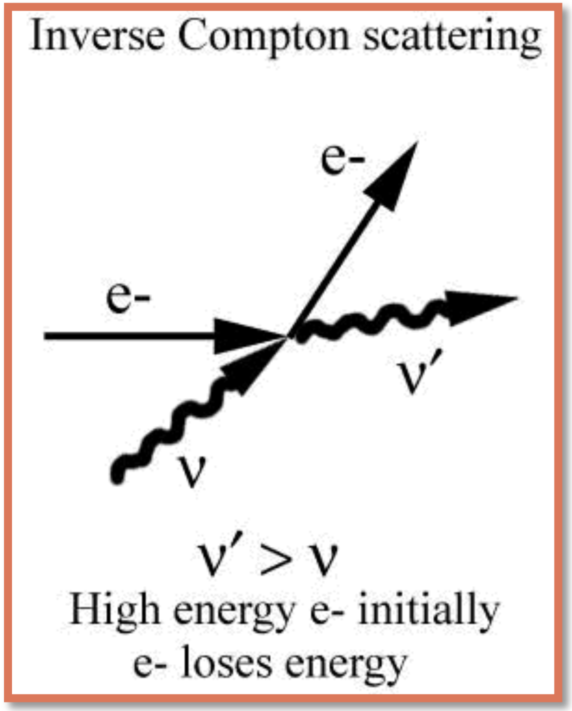
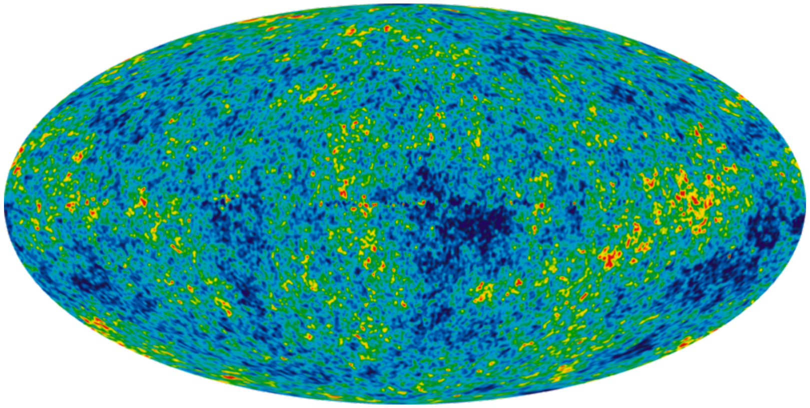


Image courtesy of: cxc.harvard.edu

Introduction & Background

- **Inverse Compton (IC) Scattering**
- **Cosmic Microwave Background (CMB) –** relativistic velocity creates higher energy density in jet frame





Images courtesy of: venables.asu.edu , map.gsfc.nasa.gov

Introduction & Background

- **Chandra X-ray Observatory**
  - Increased known X-ray jets from a few to 120
  - Highest angular resolution (<1/2 arcseconds)

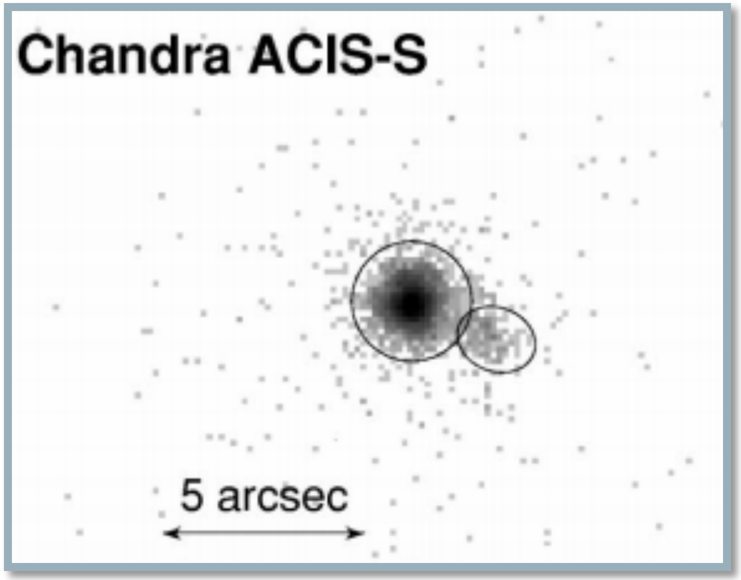


Image courtesy of: Siemiginowksa 2003; www.physics.udel.edu

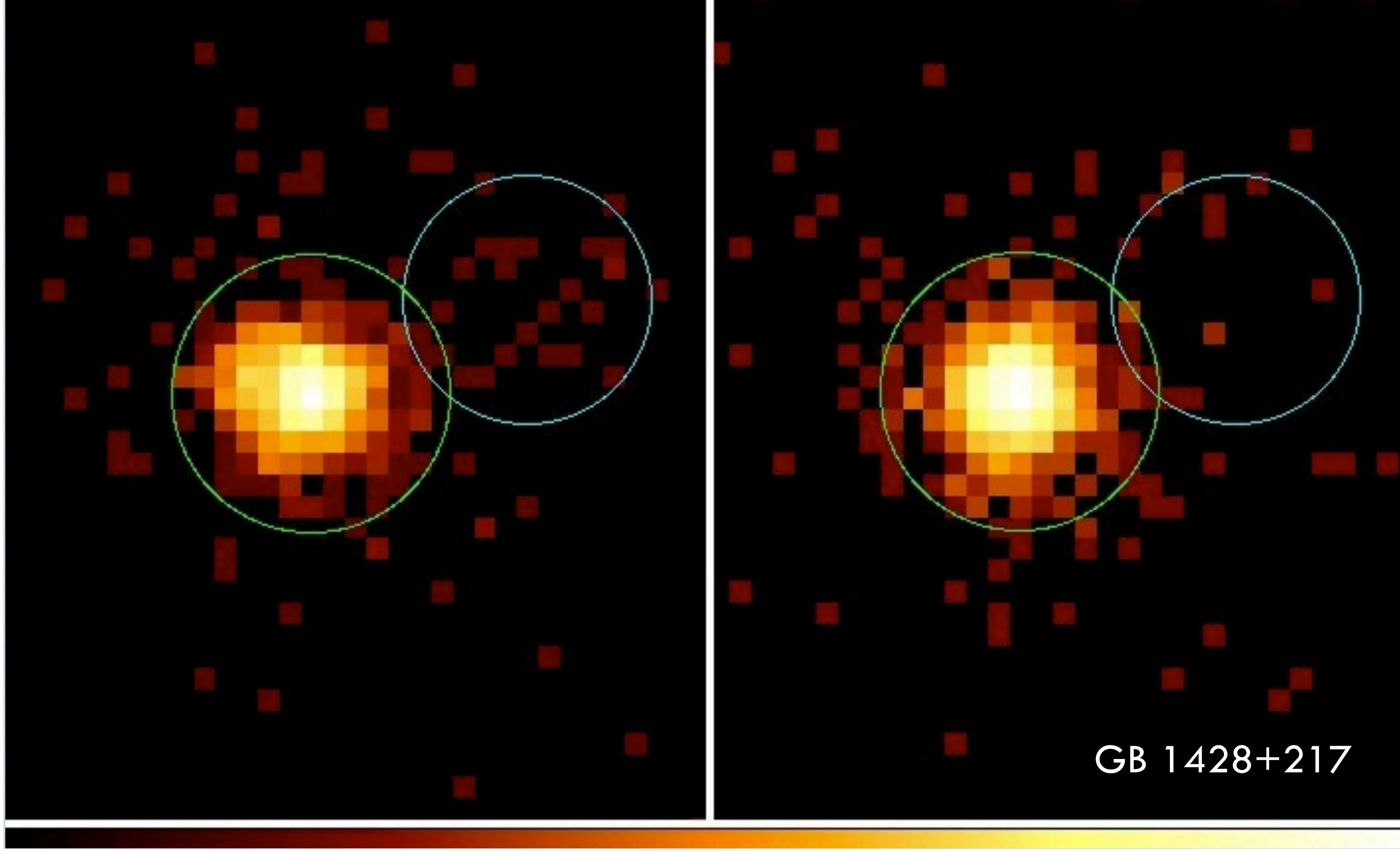
Motivation

- Current ways of detecting X-ray jets:
  - CIAO algorithms: wavdetect[1], vptdetect[2] & celldetect
  - By eye using smoothing and radio contours[3]
- **Low-Count Image Reconstruction and Analysis (LIRA)**
  - Bayesian analysis
  - More quantitative way to detect finite jet features

(1) Freeman et al. 2002
(2) Ebeling & Wiedenmann 1993
(3) Cheung et al.2012
(4) Conners & van Dyke 2007

Goal

To study effects of the IC effect due to CMB scattering on X-ray jet radiation in high redshift quasars by focusing on quantitative detection of X-ray jets and exploring the X-ray to radio emission properties.



X-Ray Sources

- Chandra X-ray Observatory with ACIS-S
- 11 quasars
- Jets detected by radio
- $2.1 < z < 4.72$

LIRA - Statistical Methods

- Bayes Theorem

$$p(\Lambda|\mathbf{X}) = \frac{\mathbf{p}(\mathbf{X}|\mathbf{\Lambda})\mathbf{p}(\mathbf{\Lambda})}{\mathbf{p}(\mathbf{X})}$$

- Multiscale Component
  - Two Poisson processes:
    - Predicted by known point source
    - Unknown secondary structure
- Markov Chain Monte Carlo

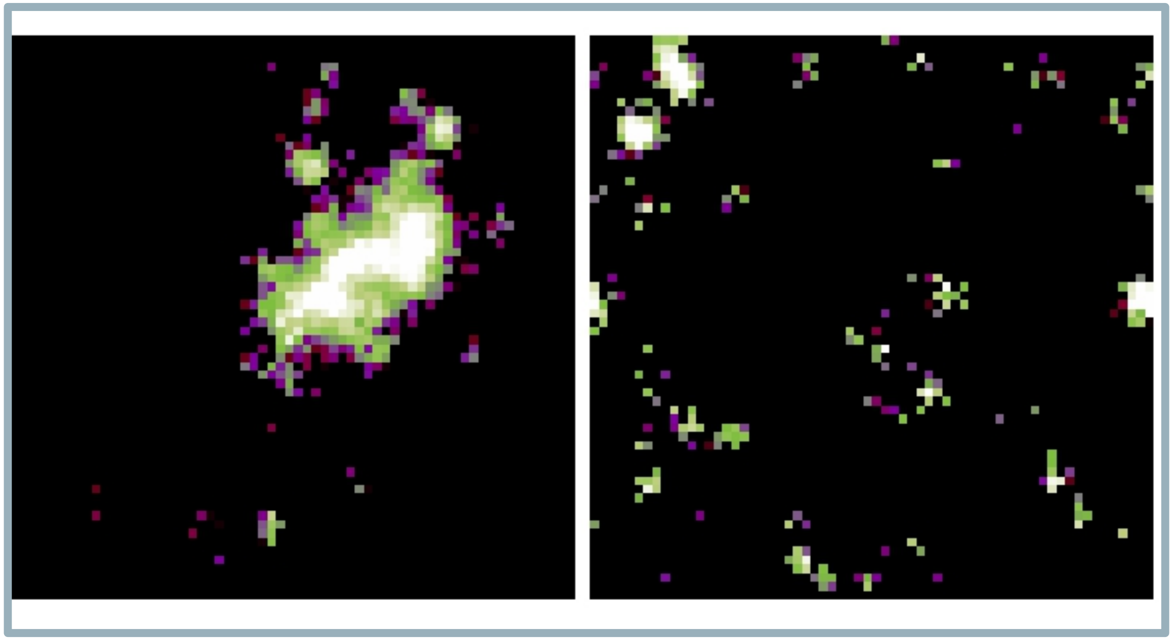
LIRA - Application to X-ray Images

INPUT:

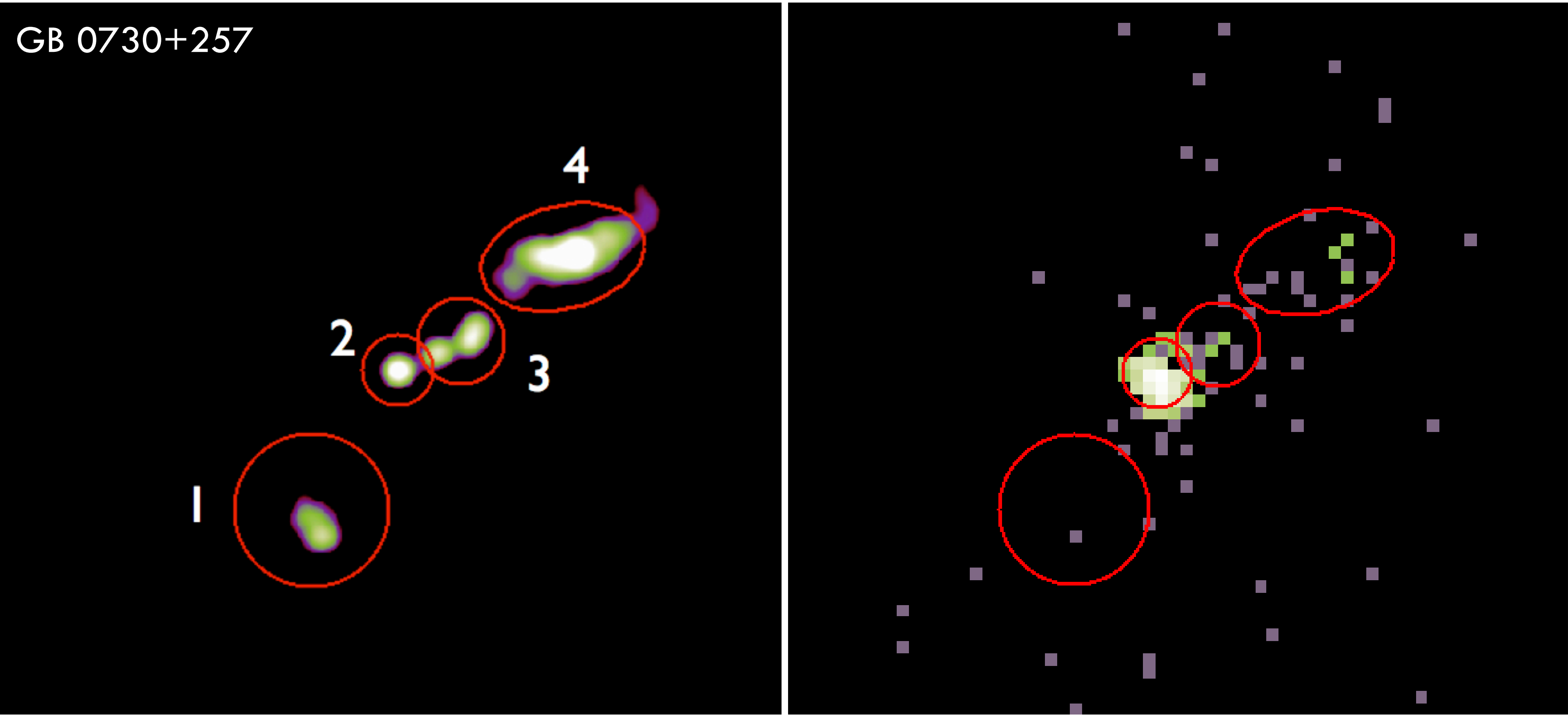
- Observed image
- 5x Null Simulations
- Baseline Model
- PSF
- Start Matrix

OUTPUT:

- Multiscale counts



Regions of Interest ROI



Significance Test

Multiscale counts too great to occur through statistical fluctuations → Multiscale component is better fit to real data than null simulations → Reject null model & Claim jet detection

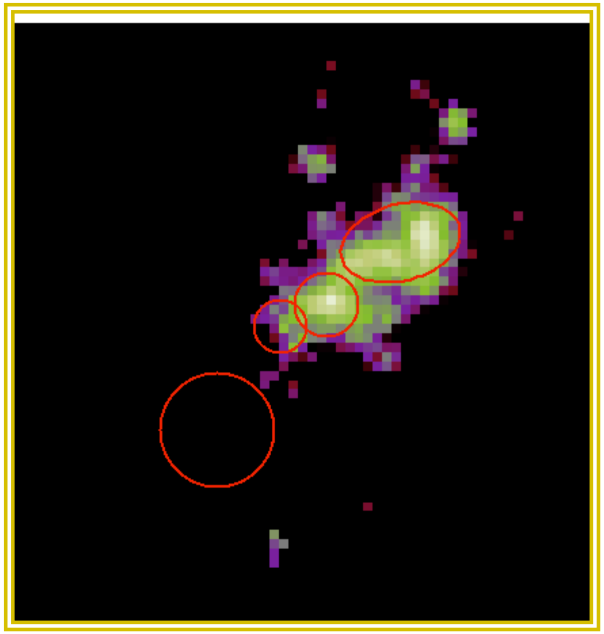
10 Significant Jet Detections

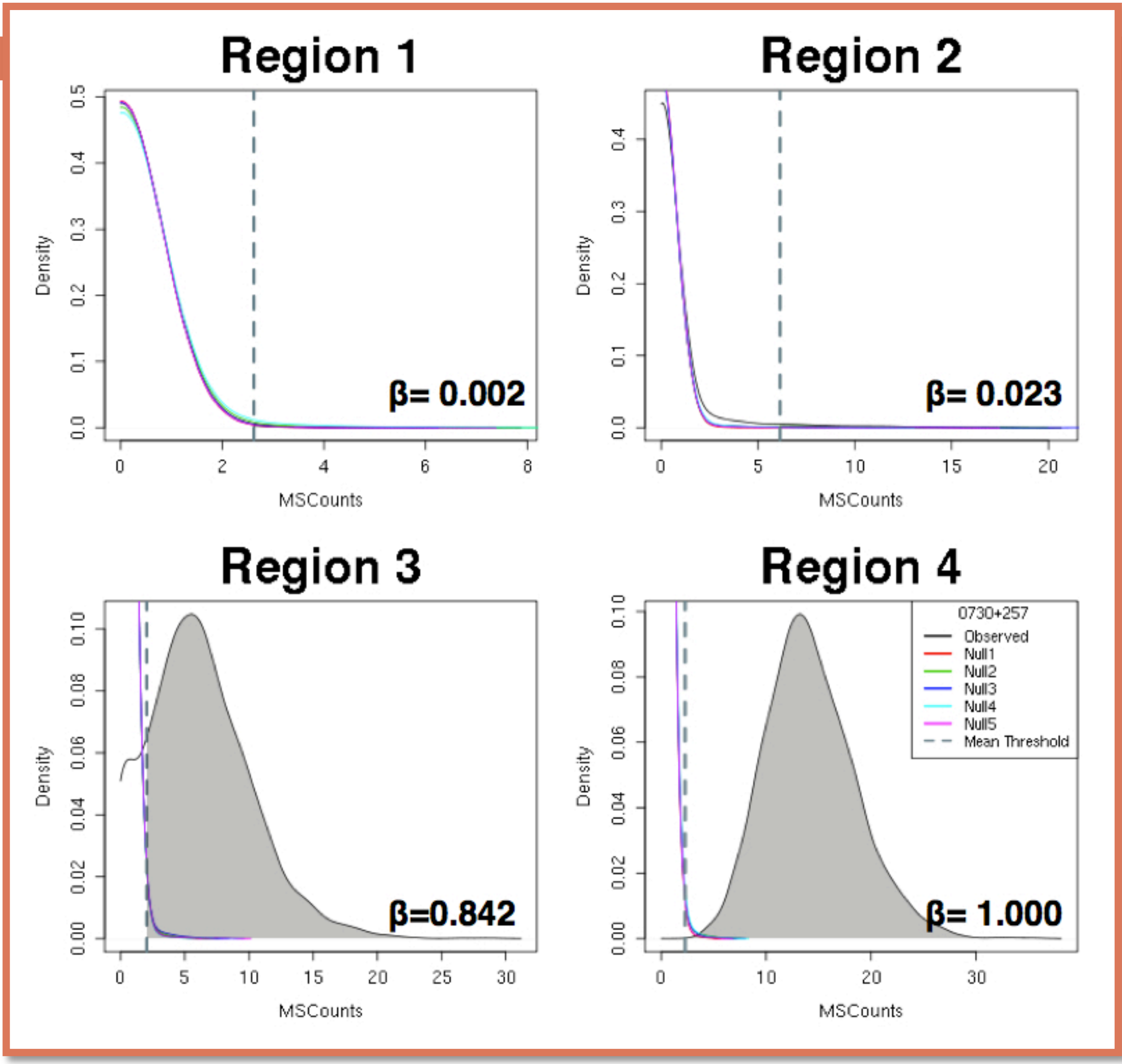
Significance Test

Type I error: alpha= 0.003
Type II error: beta= 0.5

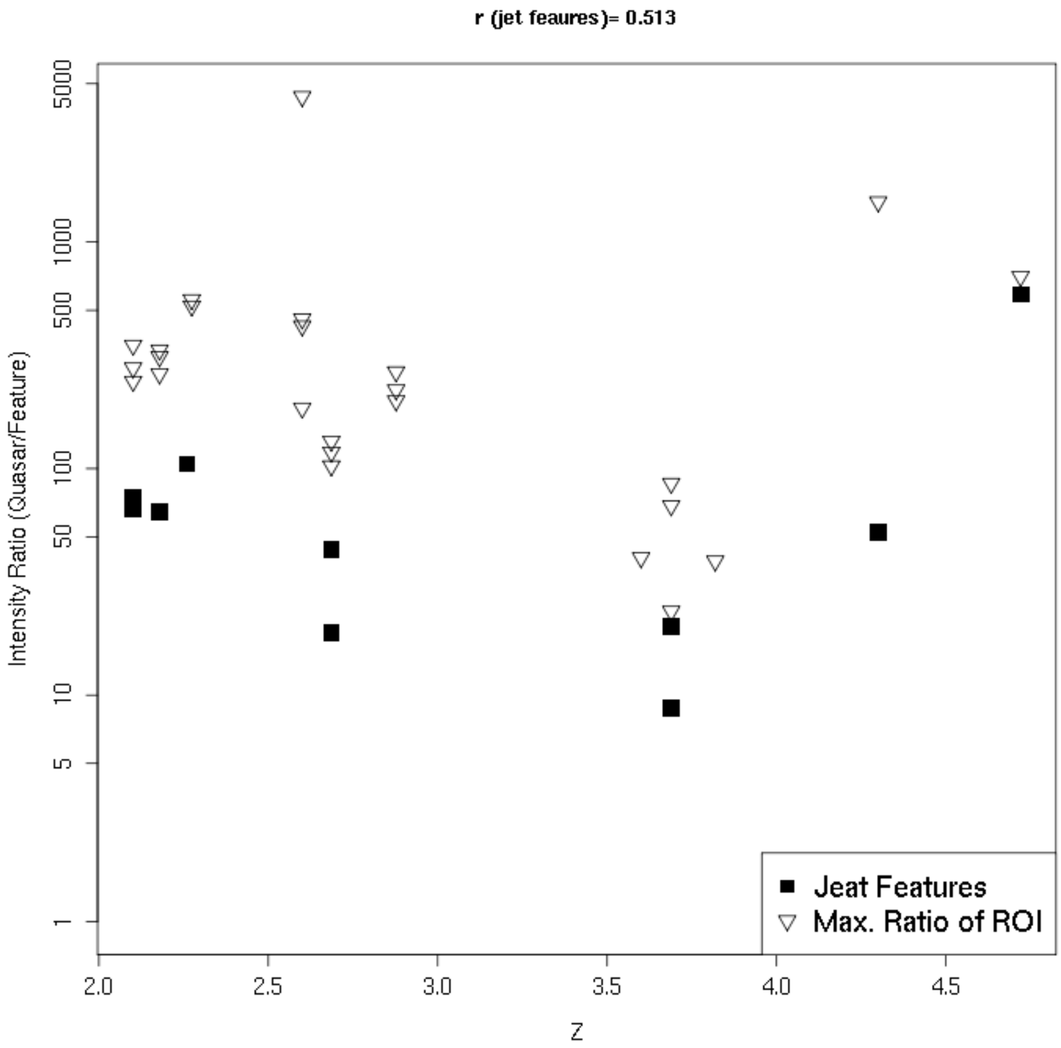
GB 0730+257

Distributions of multiscale counts in ROIs

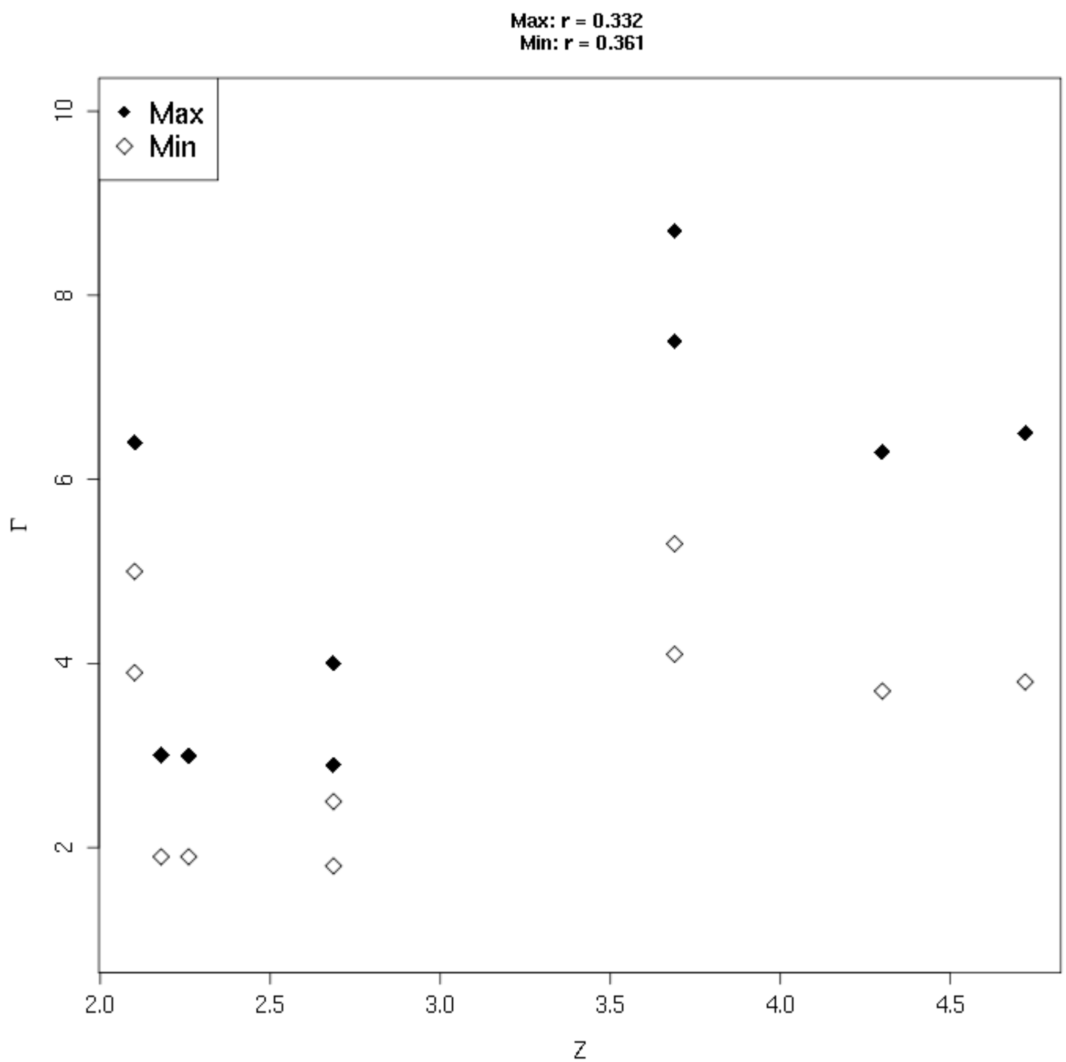




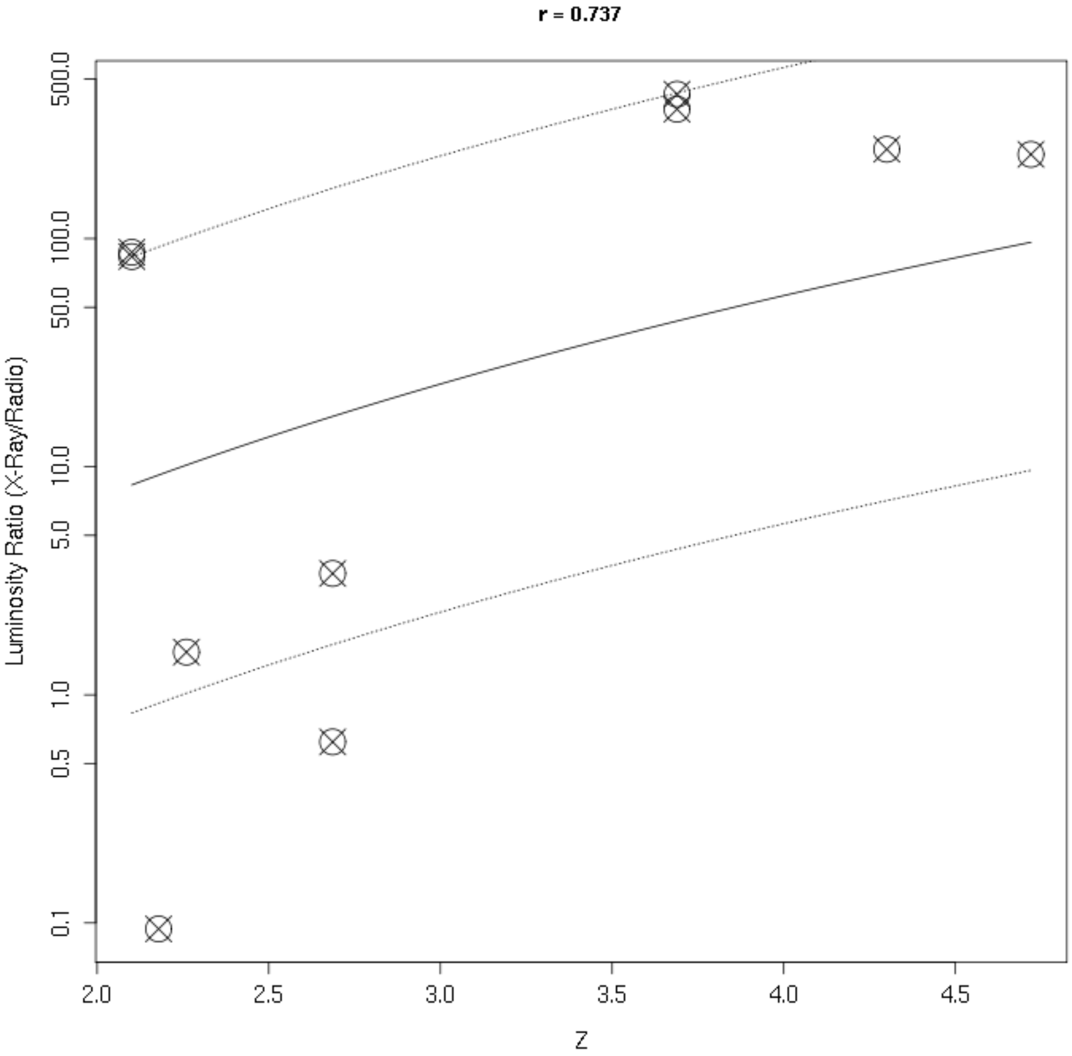
Jet v. Quasar X-ray Emission



Lorentz Factor v. Redshift



Luminosity Ratio (L_x / L_R)



$$L_X/L_R = 0.9(1+z)^2$$

Conclusion

- Detected several jet features using LIRA
- No relationship between intensity of jet/quasar emissions and redshift
- Calculation of jet beaming factors in high redshift
- Radio/X-ray luminosity consistent with CMB predictions

Aknowledgements

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The Proposers' Observatory Guide contains a detailed overview of the spacecraft and Science Instruments, general information required to write a proposal, as well as instructions for using proposal tools and simulating data. Last Updated 12/13/2012.

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We remember Alanna Connors (1956-2013), who was instrumental in the development of LIRA and its use for testing significances of features.

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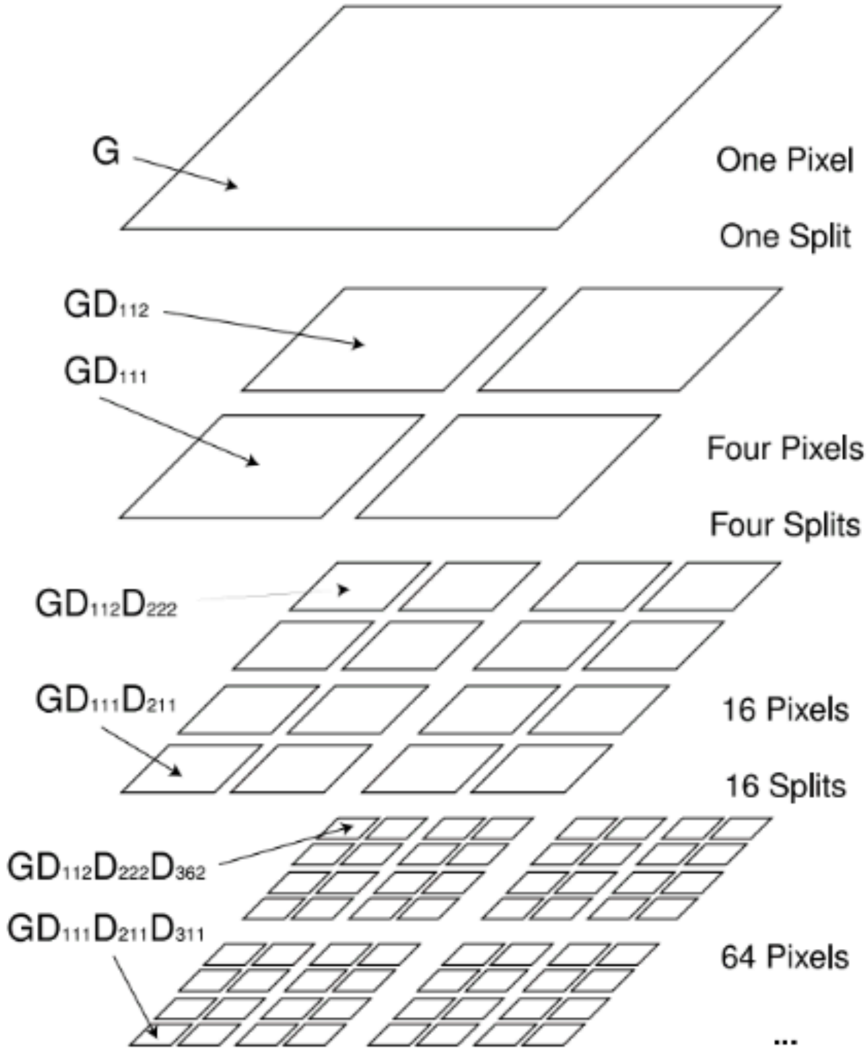
Extra Slides

Multiscale Representation

(reproduced from Esch 2004)



Properties of Jet Features v Quasar

Source Name	z	Region	Jet Strength[1]	Source Intensity [2]
GB 1428+4217	4.72	qso[3]	69.20	2236
		jet	3.81	2236
GB 1508+5714	4.3	knot	98.36	5139.5
		qso[3]	88.78	5139.5
0730+257	2.686	3	6.11	269
		4	14.26	269
1311-270	2.260	3	8.79	920
1318+113	2.179	3	8.87	570
J1834+612	2.274	1[3]	51.86	2513.9
0833+585	2.101	knot1	8.32	623
		knot2	9.45	623
J1421-0643	3.689	4.87	98	
		knot2	11.24	98

[1] Average multiscale counts after burn-in for regions of interest that have signifigant jet features

[2] Intensity of the source according to the baseline (null) model in counts. We assume that the exposure maps ar
uniform within the emasured quasars/feature regions.

[3] These regions are ignored in final discussion because they contain the point source represented by the baseline matri
(null model).

Beaming Parameters

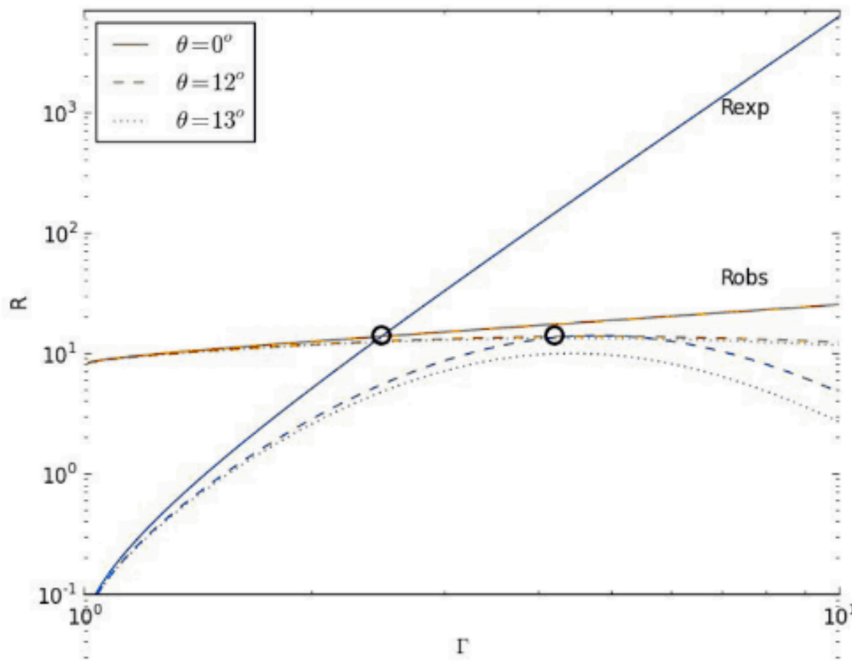


Table 8: Beaming Parameters of Jet Features

Source Name	z	Region	Max θ	Γ Range[1]
GB 1428+4217	4.72	jet	7.5	3.8-6.5
GB 1508+5714	4.3	knot	8.0	3.7-6.3
0730+257	2.686	3	12.0	2.5-4.0
		4	17.5	1.8-2.9
1311-270	2.260	3	16.25	1.9-3,0
1318+113	2.179	3	16.25	1.9-3.0
0833+585	2.101	knot1	5.75	5.0-9.42
		knot2	7.25	3.9-6.4
J1421-0643	3.689	knot1	5.25	5.3-8.7
		knot2	7.0	4.1-7.5

Luminosity of Jet Features: Xray v Radio

$$R_{exp} = (4 \times 10^{-13}(1+z)^4(1+u'_j)^2[\Gamma^2 - (1/4)])/(B'^2_{eq}/8\pi)$$

Source Name	z	Region	L_X (1) $[10^{44} \frac{ergs}{s}]$	L_R (2) $[10^{44} \frac{ergs}{s}]$	C_N (3)
GB 1428+4217	4.72	jet	8.19	0.035	1.12
GB 1508+5714	4.3	knot	5.42	0.022	0.63
0730+257	2.686	3	2.27	0.667	0.08
		4	1.61	2.584	0.03
1311-270	2.260	3	0.954	0.620	0.09
1318+113	2.179	3	0.560	5.945	0.01
0833+585	2.101	knot1	4.60	0.053	1.15
		knot2	2.97	0.036	1.96
J1421-0643	3.689	knot1	34.8	0.081	1.06
		knot2	14.4	0.039	1.65

[1] X-ray luminosity

[2] Radio luminosity at 4.85 GHz. They were estimated from their original observed frequency using the index for the observed synchrotron spectrum $\alpha = 0.8$.

[3] Normalization constant for CMB radiation. A function of the beaming parameters (Γ, θ) and the equipartition magnetic field.

Links

- M87 Jet
  - http://cxc.harvard.edu/newsletters/news_13/jets.html