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

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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: Siemiginowska 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
  \[ p(\Lambda|X) = \frac{p(X|\Lambda)p(\Lambda)}{p(X)} \]

- 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

GB 0730+257
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

GB 0730+257

Distributions of multiscale counts in ROIs

Type I error: $\alpha = 0.003$

Type II error: $\beta = 0.5$
Jet v. Quasar X-ray Emission
Lorentz Factor v. Redshift

Max: $r = 0.332$
Min: $r = 0.361$
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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This research has made use of data obtained from the Chandra Data Archive and the Chandra Source Catalog, and software provided by the Chandra X-ray Center (CXC) in the application packages CIAO, ChIPS, and Sherpa.

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.

This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

We thank Teddy Cheung for providing the VLA radio maps and Dan Harris for insightful discussion and comments.

We thank David van Dyk for useful comments and help with understanding LIRA and its outputs.

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


Extra Slides
Multiscale Representation
(reproduced from Esch 2004)
## Properties of Jet Features v Quasar

<table>
<thead>
<tr>
<th>Source Name</th>
<th>z</th>
<th>Region</th>
<th>Jet Strength</th>
<th>Source Intensity</th>
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<td>qso</td>
<td>69.20</td>
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</table>

1. Average multiscale counts after burn-in for regions of interest that have significant jet features.

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

3. These regions are ignored in final discussion because they contain the point source represented by the baseline matrix (null model).
Beaming Parameters

Table 8: Beaming Parameters of Jet Features

<table>
<thead>
<tr>
<th>Source Name</th>
<th>z</th>
<th>Region</th>
<th>Max $\theta$</th>
<th>$\Gamma$ Range</th>
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Luminosity of Jet Features: Xray v Radio

\[ R_{\exp} = \frac{4 \times 10^{-13} (1 + z)^4 (1 + u_j')^2 [\Gamma^2 - (1/4)]}{(B_{eq}^2/8\pi)} \]

<table>
<thead>
<tr>
<th>Source Name</th>
<th>z</th>
<th>Region</th>
<th>( L_X^{(1)} ) ( [10^{44} \text{ ergs s}^{-1}] )</th>
<th>( L_R^{(2)} ) ( [10^{44} \text{ ergs s}^{-1}] )</th>
<th>( C_N^{(3)} )</th>
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</table>

1X-ray luminosity

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

3Normalization constant for CMB radiation. A function of the beaming parameters \((\Gamma, \theta)\) and the equipartition magnetic field.
Links

- M87 Jet
  - [http://cxc.harvard.edu/newsletters/news_13/jets.html](http://cxc.harvard.edu/newsletters/news_13/jets.html)