X-ray Jets in Superluminal Blazars

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We are currently investigating a complete sample of 32 sources selected from the MOJAVE sample of highly relativistically beamed quasar jets to examine the correlations between X-ray and radio emission on kiloparsec scales. Previous Chandra observations have detected X-ray jets in 12 of 18 members of the sample, and we are carrying out cycle-9 observations of the remaining 14 sources. Our initial high detection rate should yield a useful new list of X-ray jets for future detailed study with Chandra, Spitzer and HST. A primary goal of our survey is to better understand the mechanisms for large-scale X-ray jet emission, by using viewing angle and speed constraints on the sources derived from the MOJAVE VLBA kinematic monitoring program. We discuss the correlations between X-ray and radio knots in our new images and the relation between apparent bends and sudden decreases in the X-ray/radio ratio along the jets.

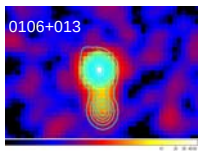
The Chandra-Blazar Sample

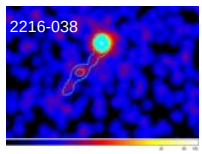
The complete survey consists of the following AGN:

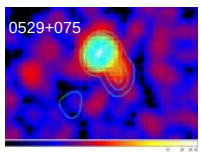
0106+013, **0119+115**, **0224+671**, 0234+285, **0415+379**, **0529+075**, 0605-085, 0836+710, 0923+392, **1045-188**, 1055+018, 1127-145, 1156+295, 1222+216, 1253-055, **1334-127**, 1485+718, 1510-089, **1637+574**,1641+399, **1800+440**, 1828+487, **1849+670**, 1928+738, 1957+405, **2155-152**, **2201+315**, **2216- 038**, 2251+158, **2345-167**

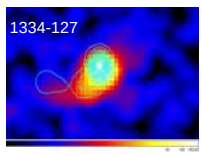
Sources which have not previously been observed by Chandra are listed in bold.

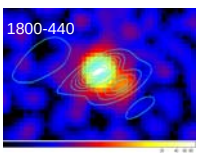
New Chandra X-ray images with 1.4 GHz radio contours are shown at right

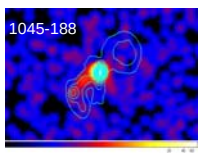


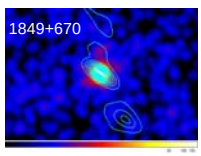


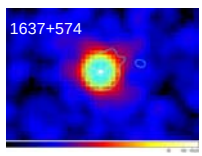












Selection Criteria

Radio Criteria:

• The sample is derived from the complete flux-limited MOJAVE sample of compact, radio loud AGN. (Lister and Homan 2005, AJ, 130, 1389)

• $\delta > -20°$ and $|b| > 2.5°$

•VLBA 15 GHZ correlated flux density exceeding 1.5 Jy at any epoch between 1994.0 and 2004.0

•Over 90% of these 135 objects are highly relativistically beamed blazars

X-Ray Criteria:

•Quasars having at least 100 mJy of extended radio emission at least 3" in extent at 1.4 GHz

•We have excluded BL Lac objects as they may belong to the less powerful FR-I population of jets

•Combining these two sets of criteria, we get a total of 32 sources in our Chandra blazar sample.

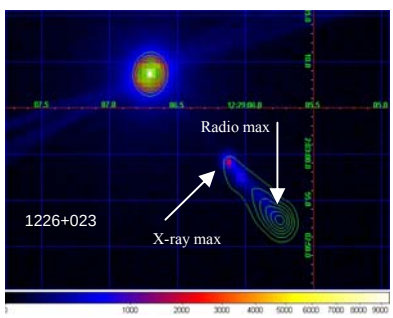
Observations

Survey results to date:

•18 of 26 of the sources have detectable X-ray jets

•Correlation between X-ray and radio jets in the new sources is generally high with the exception of those sources with strongly bent radio jets

•Six sources are awaiting Chandra scheduling



Jet Bending

In cases where the radio jet exhibits a bend there is a sharp decrease in the flux of the X-ray jet. An example of this is 1045-188 (see lower panel in above figure). This could occur because there is deceleration past the point of the bend, which may in turn limit the flow to mildly relativistic speeds by the end of the jet. A secondary factor may be a significant change in the magnetic field strength downstream of the bend. (Jorstad & Marscher, 2004ApJ...614..615J)

X-ray vs. Radio

Past Chandra studies of some AGN jets have revealed noticeable differences between the X-ray and radio jets. One example of this is 1226+023 (left). This source has an X-ray jet that has its maximum emission near the core and a radio jet which has its maximum emission much further down the jet. One-zone models seem to be too simple to model this jet. Two-zone models show that a synchrotron origin for the jet's x-rays require fewer additional assumptions than if an IC model were used. (Jester, 2006ApJ…648..900J)

Conclusions

•Our selection criteria based on highly compact, relativistically beamed radio jet emission has produced a high-yield method of detecting X-ray jets in AGN

•The detected X-ray jets are generally well-correlated with the radio jet morphology. Radio jets with major bends display less correlation with the X-rays in the region downstream of the bend.

•The wide range of apparent X-ray to radio ratios among the jets suggests that no single overall emission model can explain the X-ray morphologies. Work is currently underway to determine the precise radio/X-ray emission ratios along the jet.

•We have proposed follow-up Chandra and HST observations of selected AGN to obtain multiwavelength spectra of jet knots and investigate possible synchrotron and inverse-Compton models for their emission.