X-Raying the MOJAVE Sample of Compact Extragalactic Radio Jets

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On behalf of:
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\textsuperscript{2} the Swift team,
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**MOJAVE (I and II): Monitoring of Jets in Active galactic nuclei with VLBA Experiments**

- Monitoring of a sample of 190 extragalactic compact jets using the VLBA at $\nu=15$ GHz ($\lambda=2$ cm)
- Structure and kinematics of AGN jets (superluminal motion!) and their relationship to other source properties such as $\gamma$-ray brightness
- Statistically complete Sample (MOJAVE-I; established in 2002)
- Since 2006: Extended MOJAVE sample contains all known EGRET AGN above declination $-20^\circ$ (MOJAVE-II)
- $\gamma$-bright sources are faster (Kellermann et al. 2004, ApJ, 609, 539), more compact (Kovalev et al. 2005, AJ, 130, 4273), and have higher Doppler factors (Lister & Homan 2005, AJ, 130, 1389)

[www.physics.purdue.edu/astro/MOJAVE/]
The MOJAVE program has just been awarded VLBA time for up to three new years (2+1)

Sampling will increase from 12 to 15 (18) sessions per year in the first (second) year of the GLAST era

We will be able to add new exciting GLAST sources to our monitoring, up to ~30 per year
Most of the brightest, compact extragalactic jets in the sky have never been observed above 2keV

50 MOJAVE sources observed by *ASCA*, *BeppoSax*, *Chandra*, and/or *XMM-Newton* (the 2cm-X-Sample)

In 35 out of 50 cases, a simple 1-PL model provides an adequate description of the source X-Ray spectrum.

Radio-Loud, core-dominated AGN have comparably simple X-ray spectra!

15 sources exhibit a soft-excess component.

Kadler et al. in prep.
The 2cm-X-Sample is representative of MOJAVE, but...

- ...only 50 sources for statistics
- ...many interesting objects have never been observed at 0.2-10 keV
- ...mostly non-simultaneous data and incomplete SEDs
- ...non-uniform data quality
Swift Survey of the MOJAVE Sample

- Swift fill-in program to observe ALL 190 sources currently monitored by MOJAVE
- ~50% never before observed at medium-energy X-rays
- 32 without any previous X-ray detection
PKS B1546+027

- \( z = 0.412 \) quasar
- Moderately bright X-ray source
  \( (2 \times 10^{-12} \text{ erg/s/cm}^2) \)
- Soft Excess
Current Status

- 25 observations completed (~10 kec)
- 17 observations begun
- All targets detected so far with the XRT
- Contemporaneous radio spectra from RATAN-600 program for all XRT/UVOT measurements
- From March 2007 on quasi-simultaneous Swift/VLBA observations
Hard X-Ray Detections with Swift/BAT

- BAT monitors the whole sky at 15-150keV
- Blazars at low-to-intermed redshift challenging for BAT (obs. Band coincides with spectral minimum)
- Nevertheless, 10 MOJAVE-I sources detected
- Mostly not the classical blazars
Hard X-Ray Detections with Swift/BAT

- Hard X-ray flares can be detected by BAT
- See, e.g., Mrk421
- From February 2007 on: BAT monitoring of all MOJAVE sources

Hard X-ray light curve; BAT daily averages;
Courtesy of H. Krimm and the BAT team (see: http://swift.gsfc.nasa.gov/docs/swift/results/transients)
Summary

MOJAVE is monitoring the radio- and $\gamma$-ray brightest AGN of the northern sky
Swift X-ray spectral survey coordinated with MOJAVE sessions
Pre-Swift: 50 sources, non-uniform, non-simultaneous
Swift/MOJAVE Liaison will produce
- a statistically complete X-ray spectral catalog of radio-loud, core-dominated AGN
- complementary VLBI- and X-ray spectral data
- quasi-simultaneously measured broadband SEDs with radio/optical/UV/X-ray data
Hard X-ray measurements/constraints provided by BAT
GLAST will complete the high-energy ends of the SEDs
Radio/X-Ray Correlations

Soft X-rays (0.5keV - 2keV):
Both spectral components correlate in luminosity with the VLBI jets.

Hard X-rays (2keV - 10keV):
No correlation for soft-excess components ⇒ Spectral curvature of soft-excess component
Correlation with Apparent Jet Speeds

- Hard power law photon indices independent of apparent VLBI jet speeds $\beta_{\text{app}}$
- Soft-excess power law photon indices correlate with $\beta_{\text{app}}$
- The slowest VLBI jets correspond to the steepest soft excess components.
- Spectral maximum of the curved soft-excess component may be related to the jet Lorentz factor.
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Distribution of Photon Indices

- Narrow distribution of hard power law photon indices:
  \[ \Gamma = 1.68, \sigma = 0.26 \]
- Flatter than radio-quiet AGN spectra (e.g., Reeves et al. 2000)
- Broad range of soft-excess power law photon indices up to 5.5
- Various mechanisms? Spectral curvature?
...and blazars are not the only extragalactic $\gamma$-ray sources, either -

Example: 3C111

- 3C111 is NOT a blazar but a BLRG
- 3EGJ0416+3650 is a bright 3rd-EGRET catalog source 
  ~1arcmin offset from 3C111
- Detection of 3C111 at $>1\text{GeV}$ more than 6 years after 
  CGRO’s “return to earth”
- 3EGJ0416+3650 is actually the superposition of two sources
- See also Cen A (Sreekumar et al. 1999, Astropart.Phys., 11, 221)