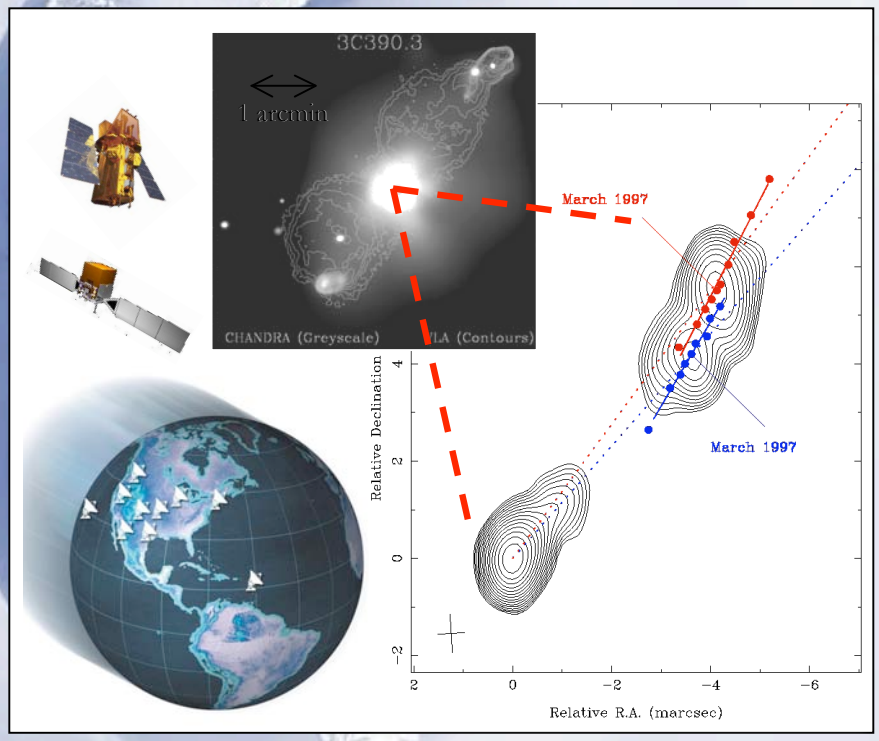
# X-Raying the MOJAVE Sample of Compact Extragalactic Radio Jets

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On behalf of:

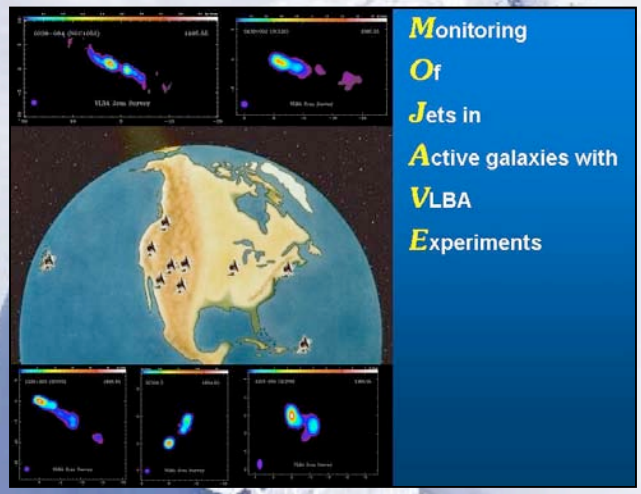
[1] the MOJAVE team,

[2] the Swift team,

[3] the GLAST/LAT AGN team

*First GLAST Symposium, Palo Alto, CA, February 7th 2007*

# *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° (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)


**Team Members:**

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www.physics.purdue.edu/astro/MOJAVE/

# *MOJAVE III*

- 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

# *X-Ray Observations of MOJAVE Sources: ~1990 to 2006*

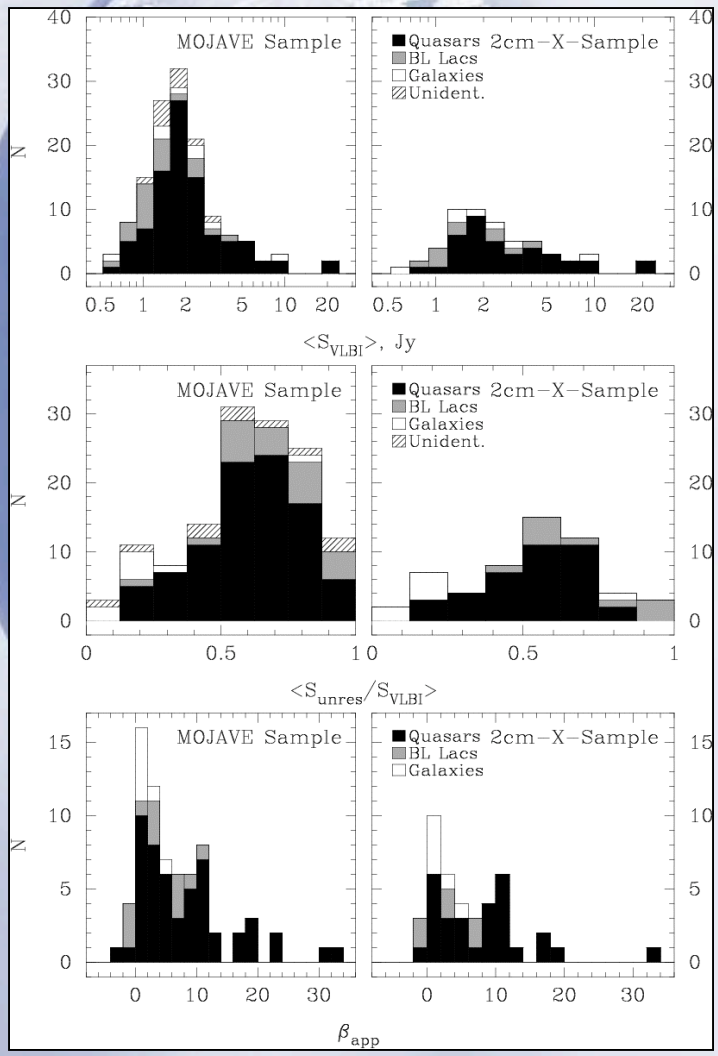
- Most of the brightest, compact extragalactic jets in the sky have never been observed above 2keV
- 50 MOJAVE sources observed by *ASCA*, *BeppoSax*, *Chandra*, and/or *XMM-Newton* (the 2cm-X-Sample)
- In 35 out of 50 cases, a simple 1-PL model provides an adequate description of the source X-Ray spectrum.

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

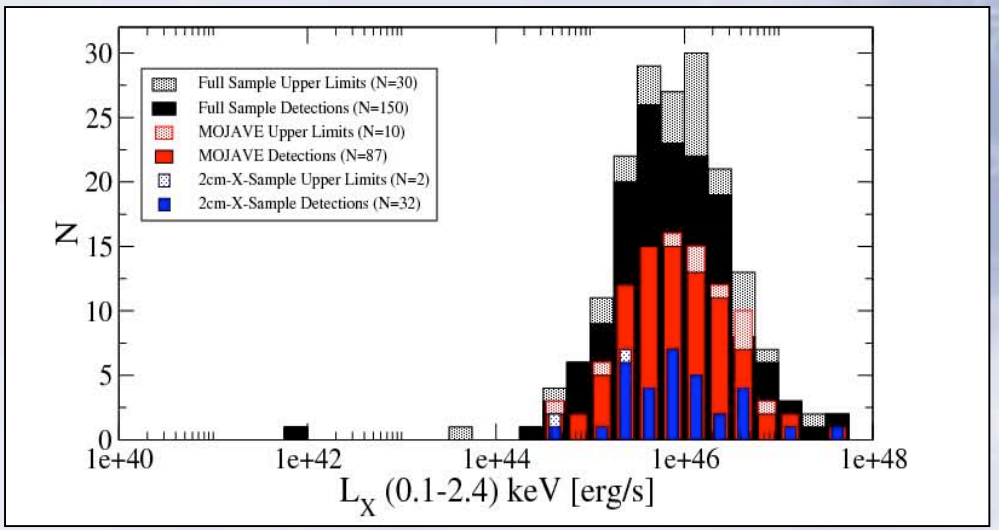
- 15 sources exhibit a soft-excess component.

Kadler et al. in prep.

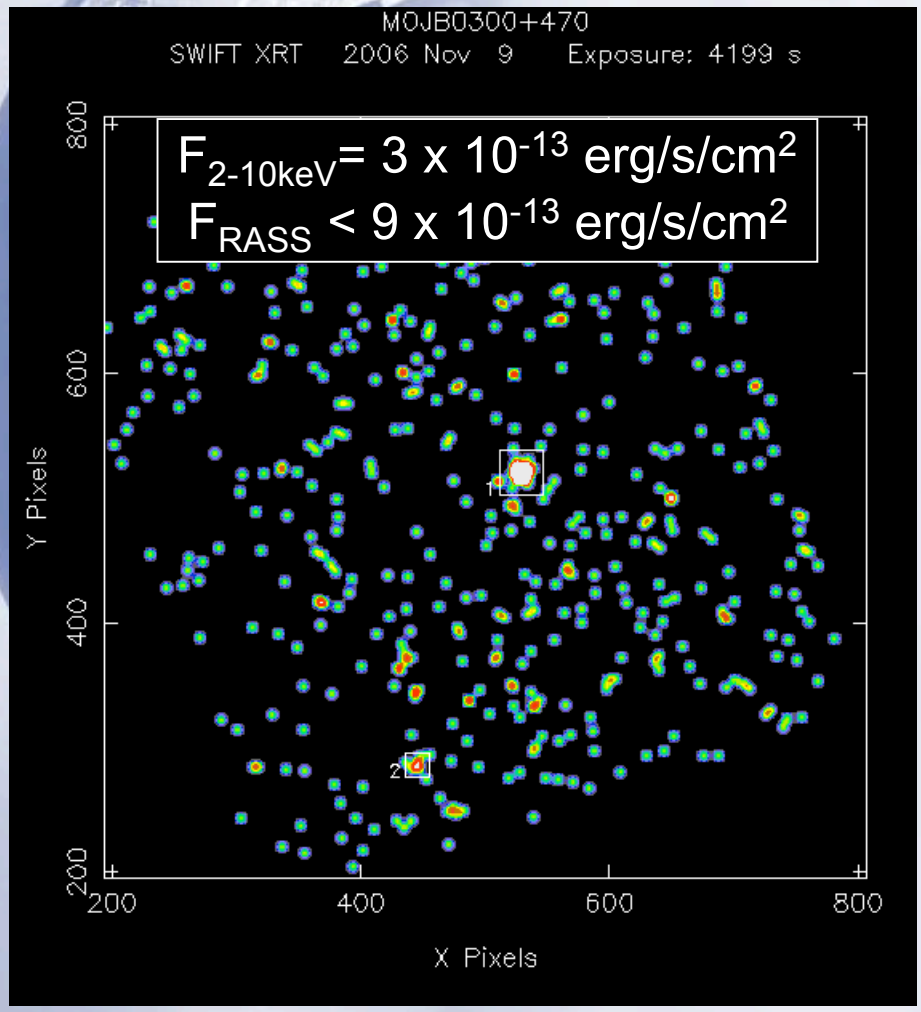
# *The 2cm-X-Sample is representative of MOJAVE, but…*



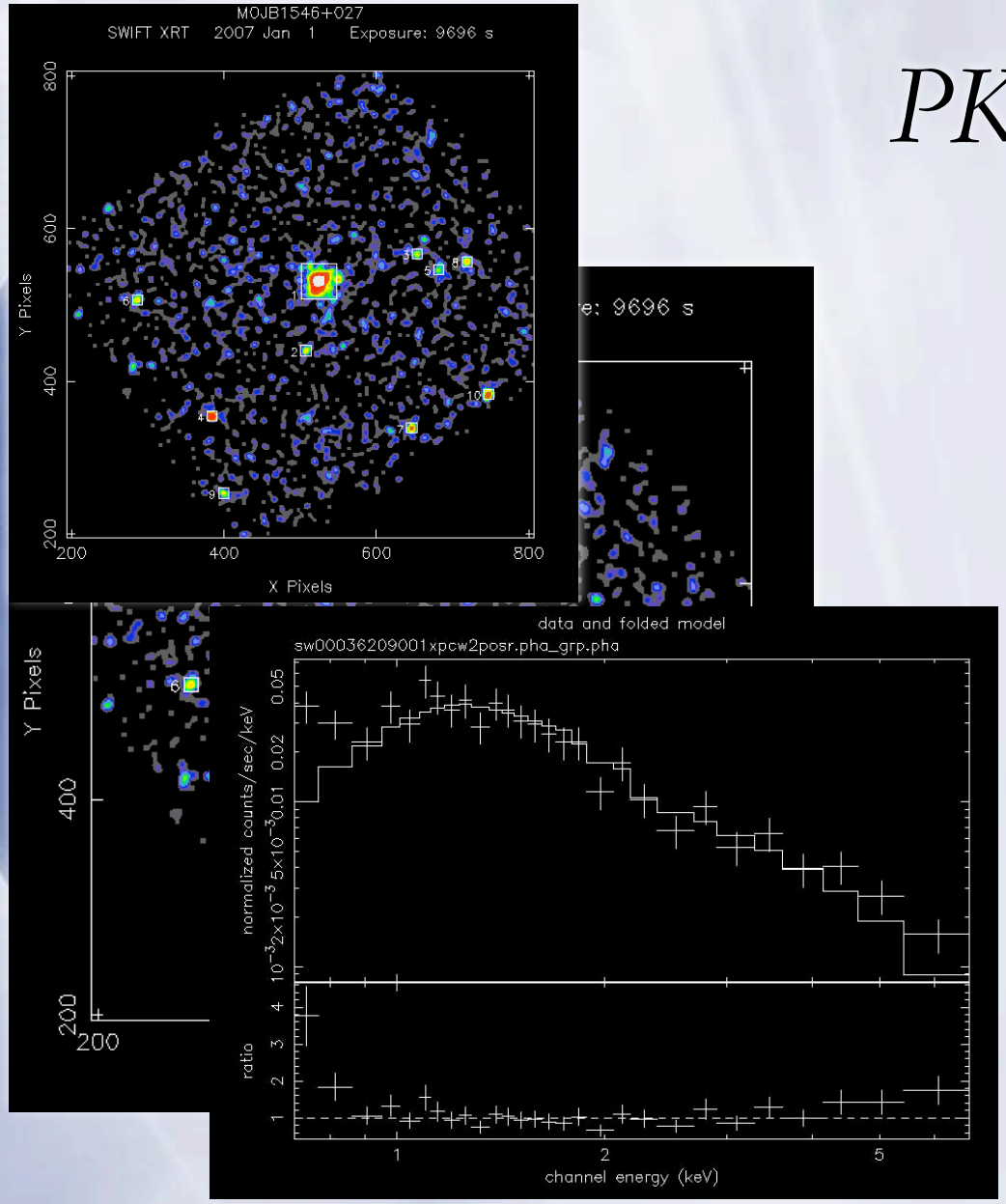

- …only 50 sources for statistics
- …many interesting objects have never been observed at 0.2-10 keV
- …mostly non-simultaneous data and incomplete SEDs
- …non-uniform data quality



# *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



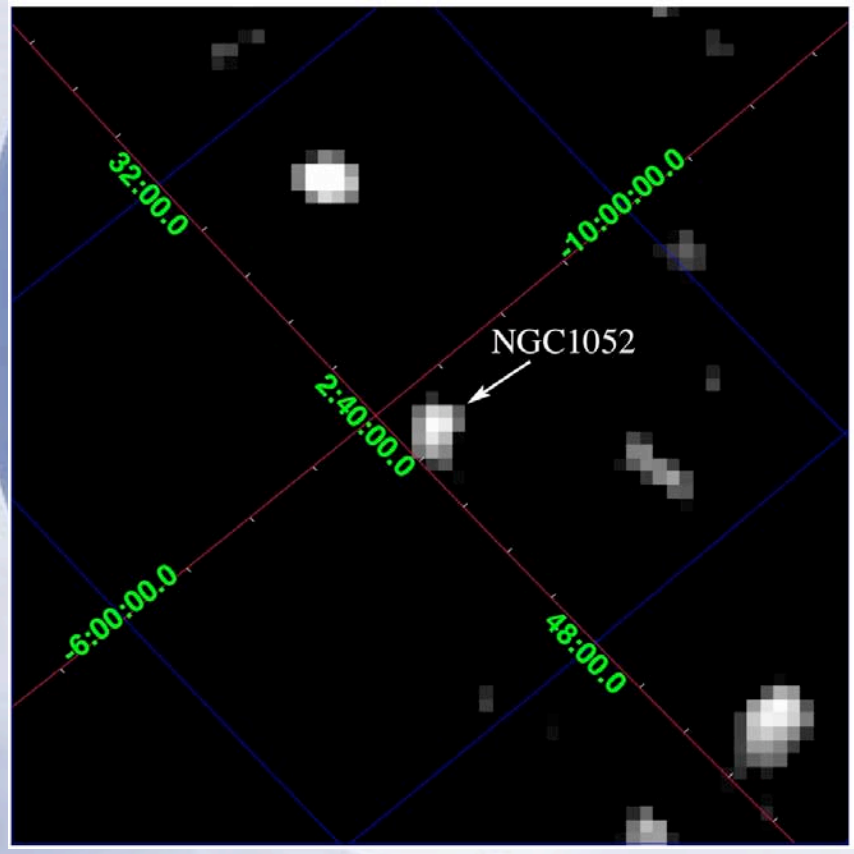

# *PKS B1546+027*

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

# *Current Status*

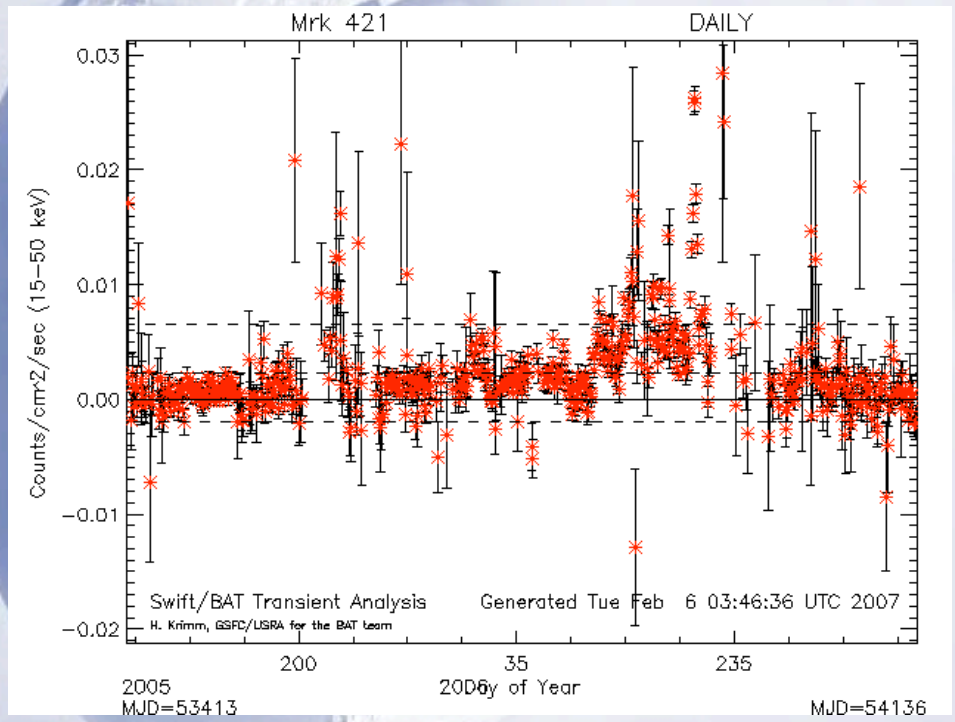
- 25 observations completed (~10kec)
- 17 observations begun
- All targets detected so far with the XRT
- Contemporaneous radio spectra from RATAN-600 program for all XRT/UVOT measurements
- From March 2007 on quasi-simultaneous Swift/VLBA observations

# *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 light curve; BAT daily averages; Courtesy of H. Krimm and the BAT team (see: http://swift.gsfc.nasa.gov/docs/swift/results/transients)

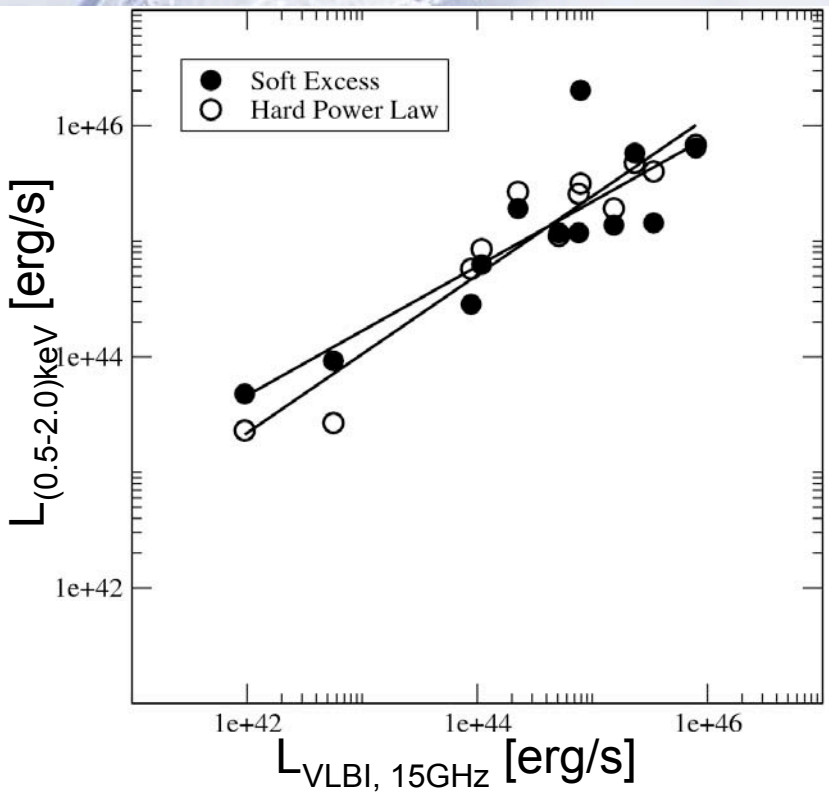
- Hard X-ray flares can be detected by BAT
- See, e.g., Mrk421
- From February 2007 on: BAT monitoring of all MOJAVE sources

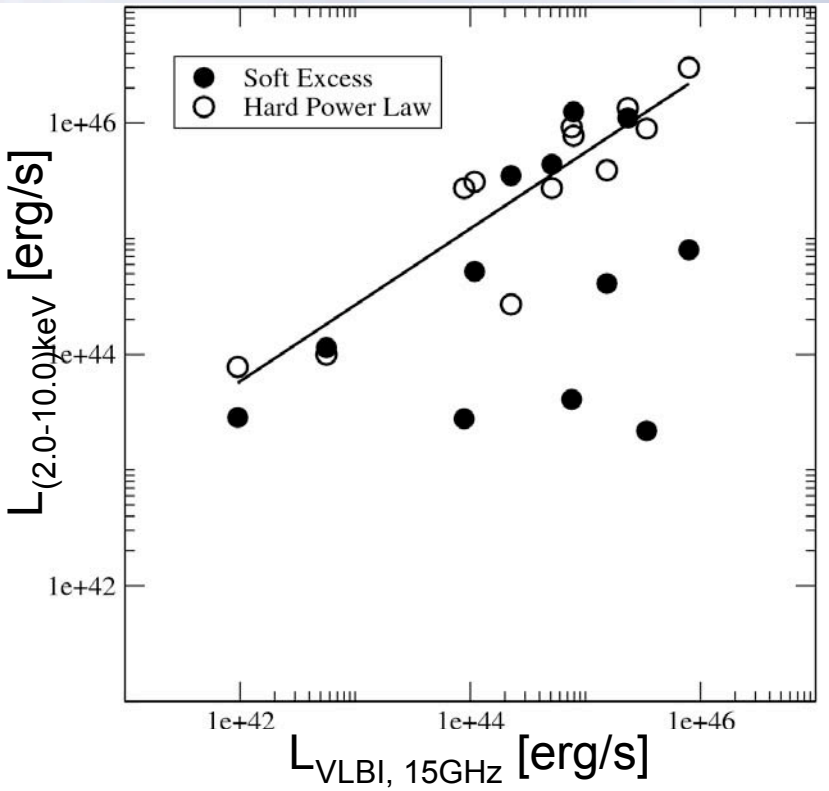
**_VLBI in the GLAST Era_:**
Workshop to be held at GSFC on April 23/24, 2007

# *Summary*

- MOJAVE is monitoring the radio- and γ-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*



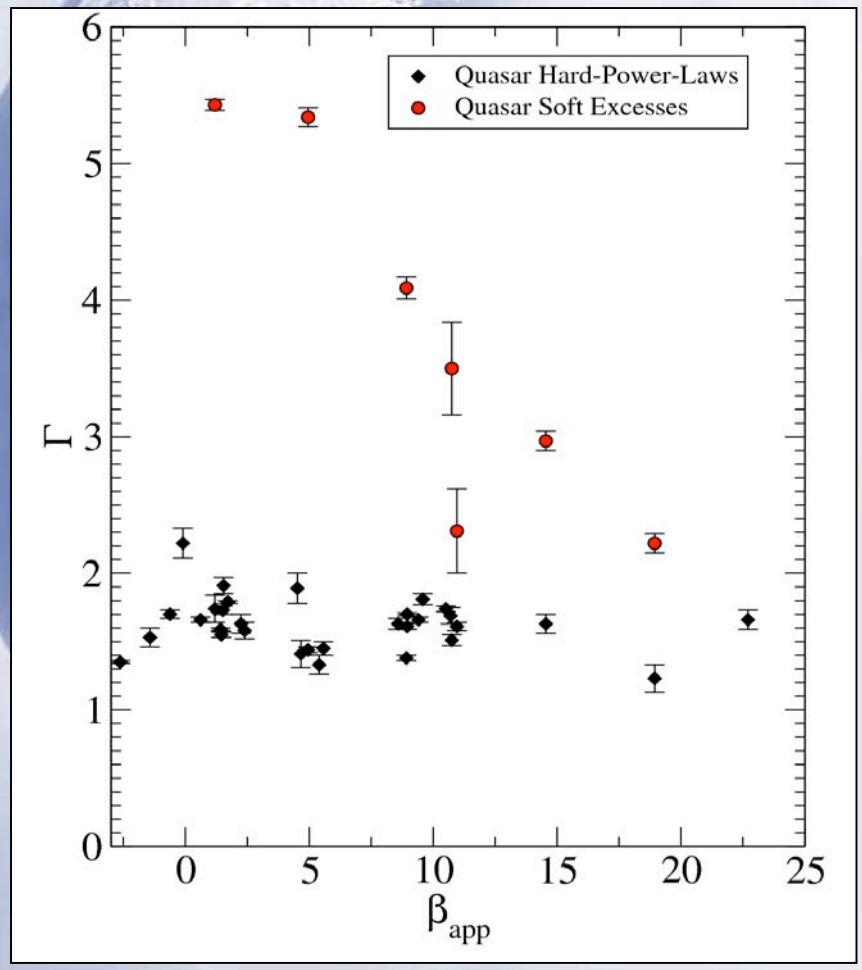

Soft X-rays (0.5keV - 2keV):

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 $\beta_{app}$
- Soft-excess power law photon indices correlate with $\beta_{app}$
- 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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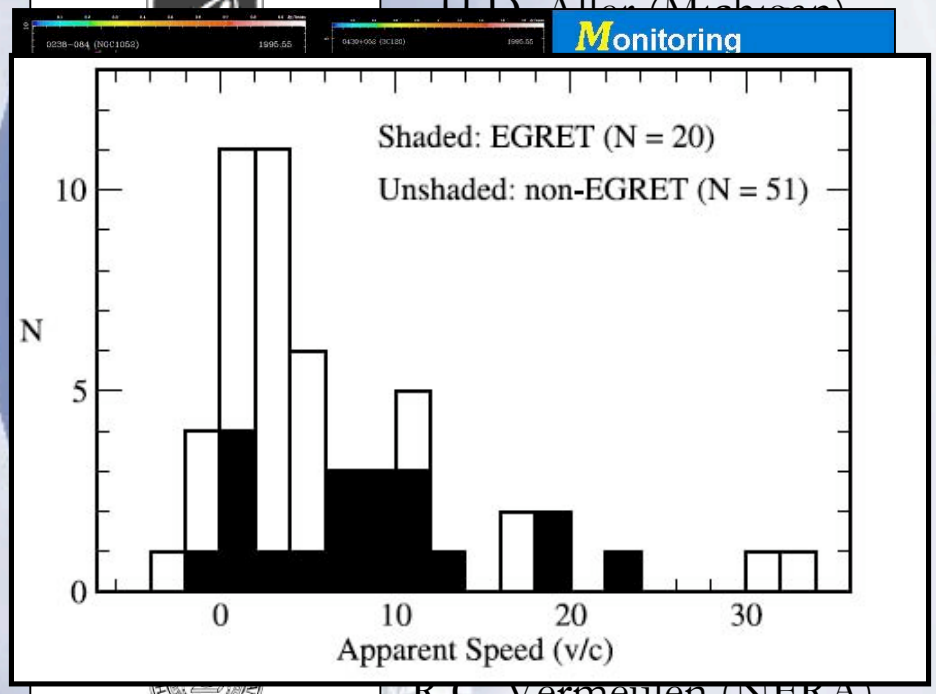


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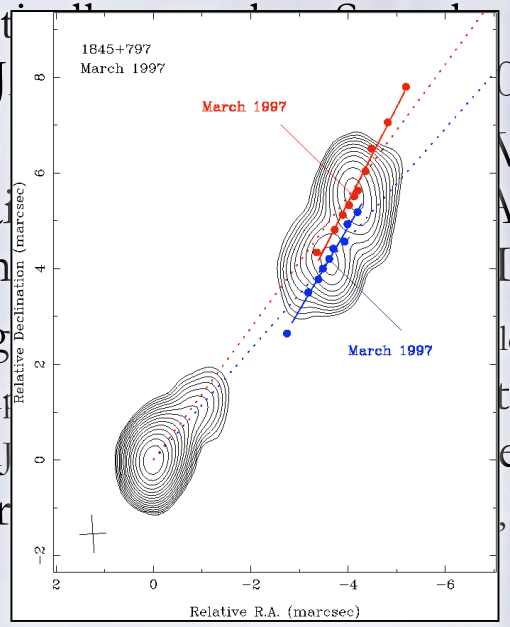


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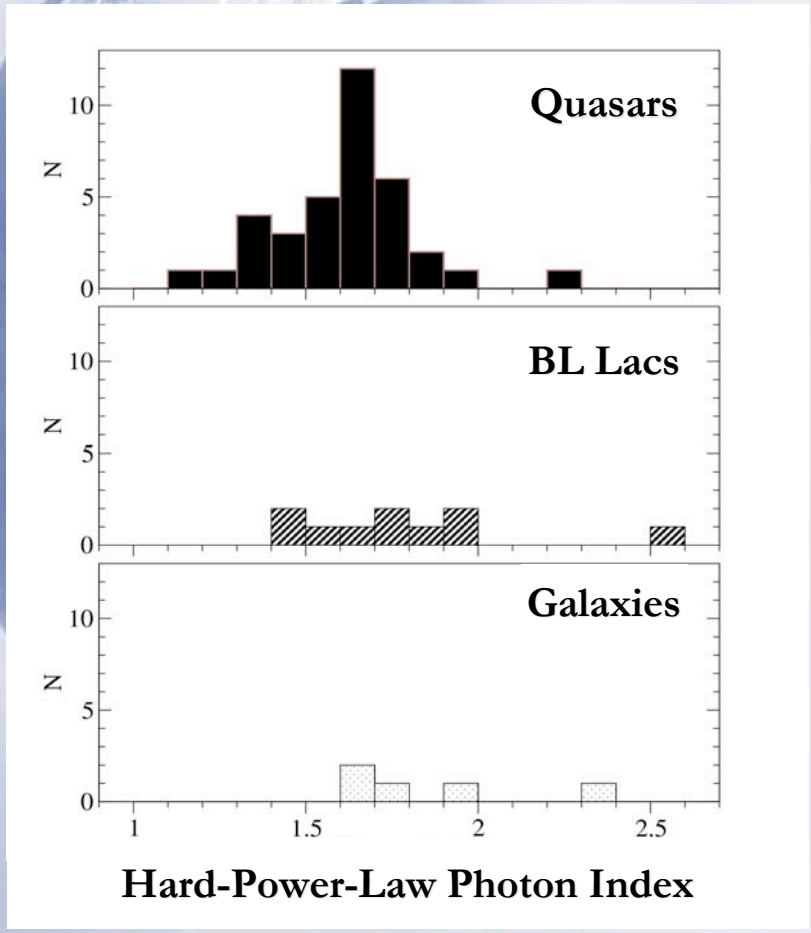
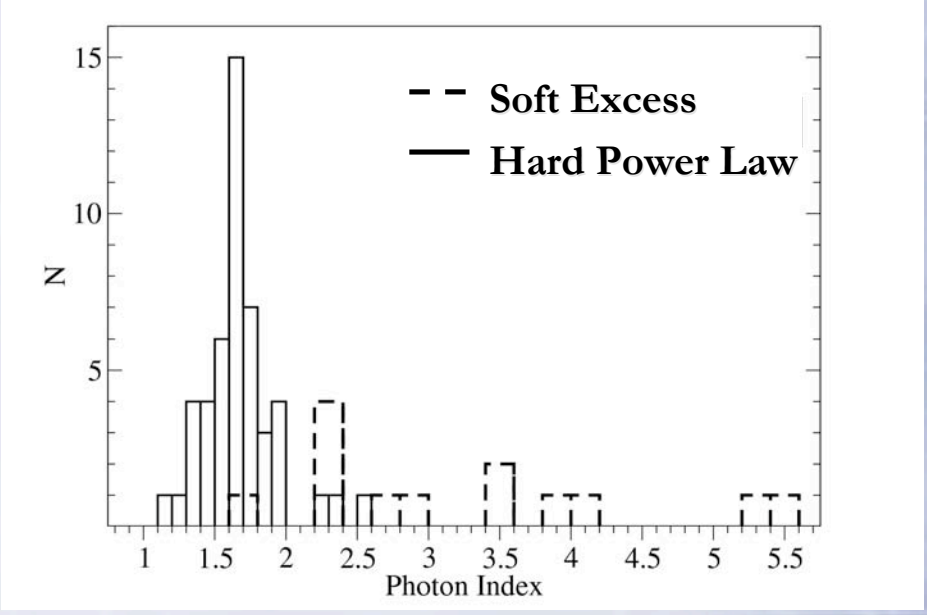
# *Distribution of Photon Indices*



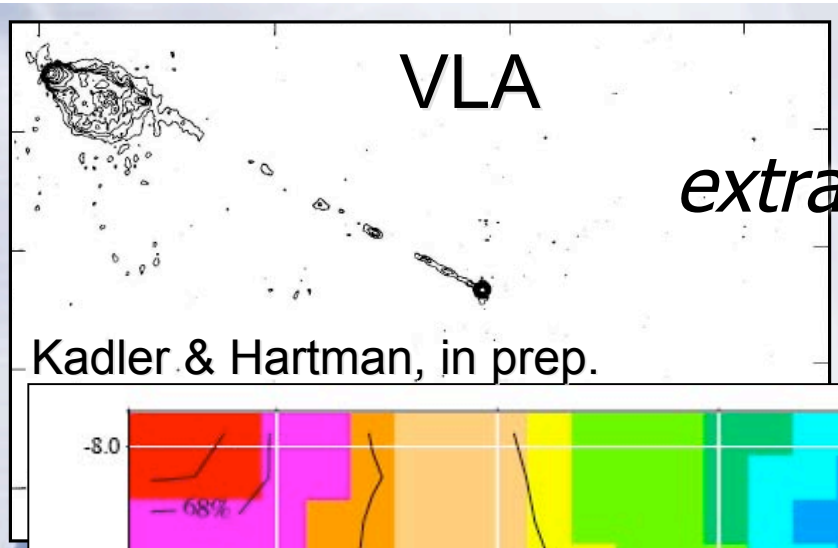

- Narrow distribution of hard power law photon indices:
  $\Gamma = 1.68$, $\sigma = 0.26$

⇒ Flatter than radio-quiet AGN spectra (e.g., Reeves et al. 2000)

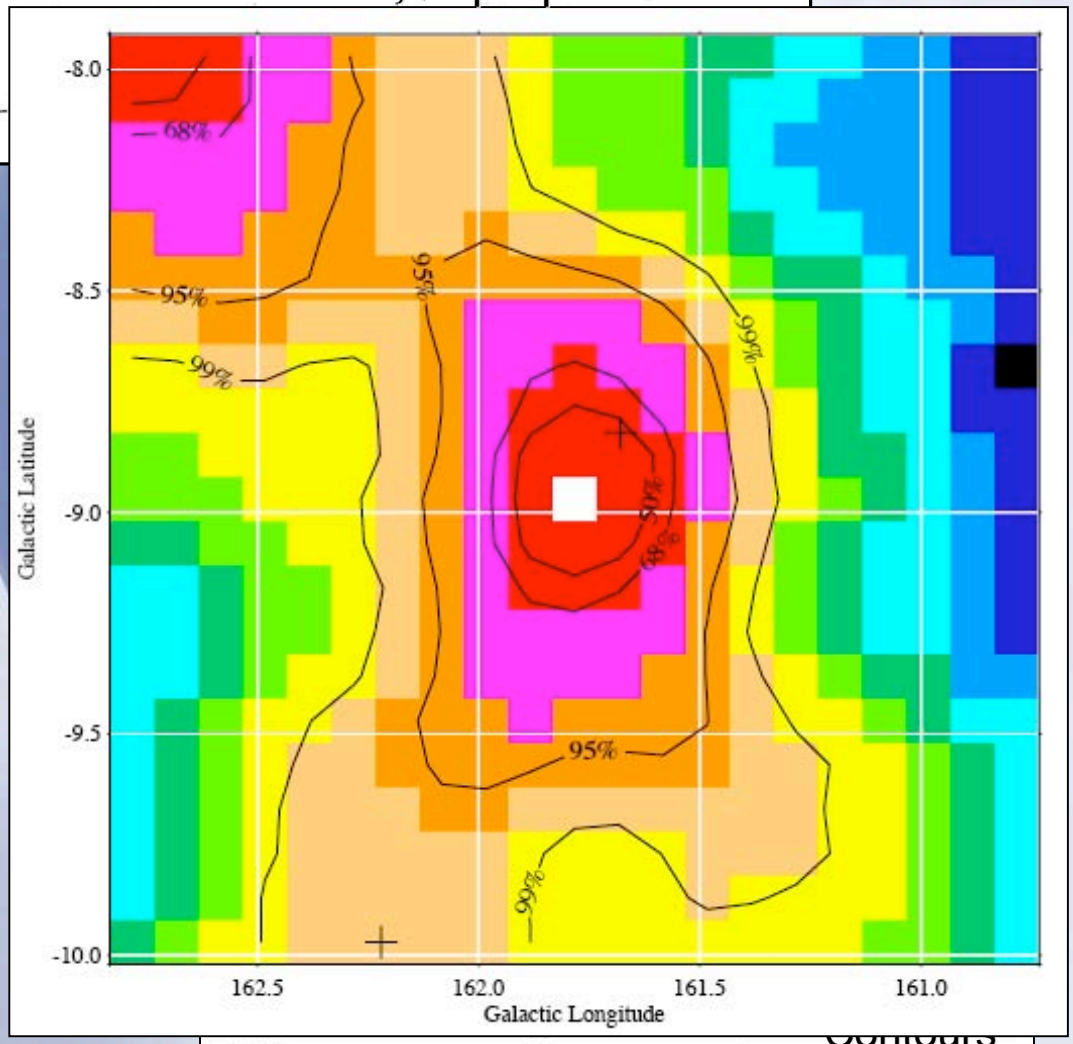
- Broad range of soft-excess power law photon indices up to 5.5

⇒ Various mechanisms? Spectral curvature?

# *...and blazars are not the only extragalactic γ-ray sources, either - Example: 3C111*




Kadler & Hartman, in prep.




- 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 >1GeV 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)
- Stratified Jets? (Ghisellini et al. 2005, A&A, 432, 401)