# A Hard X-ray Survey of Radio-Selected Blazars


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## Abstract

The MOJAVE program has been monitoring a statistically complete sample of 135 radio-loud active galactic nuclei (AGN) of the northern hemisphere using the Very Long Baseline Array (VLBA). This sample, dominated by low-peaked blazars, is here characterized for the first time in the hard X-ray regime by the use of *Swift*/BAT. Here, we present the hard X-ray flux and luminosity distributions and discuss a partial correlation of (beamed) radio and X-ray fluxes as well as their luminosities. Previous *Swift*/BAT surveys revealed 49 hard X-ray emitting blazars all over the sky. MOJAVE-1, extended by the blazar list of the southern VLBI program TANAMI, exhibits a large portion of hard X-ray emitting blazars (127 out of 169), more than doubling the known population in this energy regime.


## Motivation

The spectral energy distribution (SED) of blazars is typically characterized by a synchrotron and possibly inverse-Compton peak stretching from the radio regime up to TeV energies. Thousands of blazars have been discovered in various surveys. However, they are notoriously difficult to study in the hard X-ray domain, if detected there at all. Just **49** out of **1210** sources in the recent 70-month *Swift*/BAT catalogue (Baumgartner et al., 2012) have been classified as blazars, whereas *Fermi*/LAT detected about 1800 sources (Nolan et al., 2012) with the fraction of blazars above 40%.

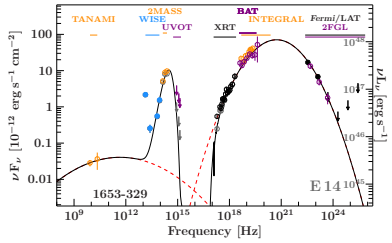


Fig.1: SED of blazar 1653-329 (Krauss et al., 2014)

## The Radio-Selected Sample

The **MOJAVE** program (Monitoring Of Jets in Active galactic nuclei with VLBA Experiments) provides continuous interferometric measurements of the radio-brightest AGN in the northern hemisphere (Lister et al., 2009) conducted at 15 GHz by the Very Long Baseline Array (VLBA).

We concentrate on the flux-limited MOJAVE-1 sample, consisting of **135 sources** and dominated by low frequency-peaked blazars (LBLs).
This flux-density limited sample can be regarded as **statistically complete**. The Mojave-1 sample can be extended by the blazar sample observed by the VLBI program **TANAMI** in the southern hemisphere (Ojha et al., 2010), adding 76 new sources.


Fig.2: The VLBA. Image credit: NRAO.

## Results

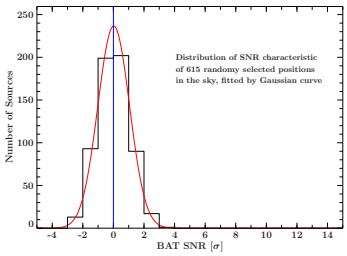


Fig.3: SNR distribution of blank sky survey.

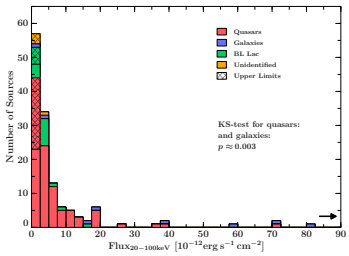


Fig.5: Hard X-ray flux distribution for MOJAVE-1 sample

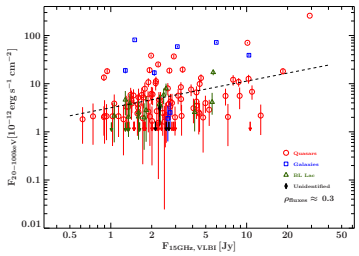


Fig.7: Correlation of BAT and 15 GHz flux.

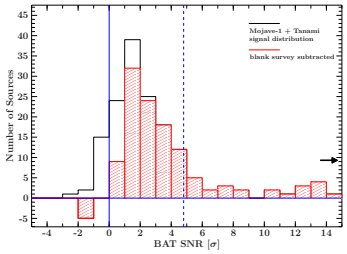


Fig.4: MOJAVE-1 and TANAMI significance distribution.

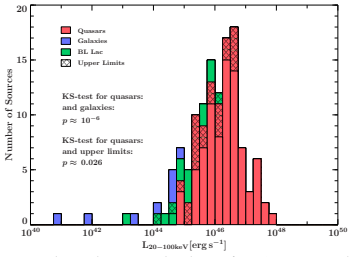


Fig.6: Hard X-ray luminosity distribution for MOJAVE-1 sample

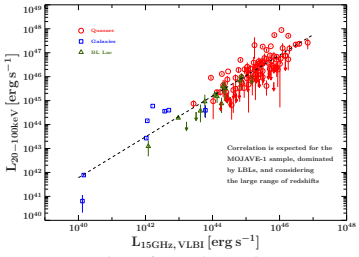


Fig.8: Correlation of BAT and 15 GHz luminosity.

**Newly detected sources: Mojave + Tanami (> 1 Jy)**

- Estimating the **number of detections** by subtracting a renormalized blank sky distribution from the blazar significance distribution.
- **At least 127** out of 169 sources are detected, **more than doubling** the number of hard X-ray emitting blazars registered by BAT.
- Previous *Swift*/BAT catalogues featured a detection threshold of 4.8 $\sigma$. We derive fluxes for sources with SNRs $\gtrsim 1\,\sigma$.
- In order to **determine fluxes**: fit power law distribution to bright sources and use template spectrum for very faint sources.

**X-ray emission characteristics: Mojave**

- Significant (partial) correlation between radio and X-ray flux as well as their luminosities (Fig. 7 and 8).
- Significant difference in X-ray flux distribution for radio galaxies and quasars due to **distance** and in luminosity likely due to **orientation** and **beaming** (Fig. 5 and 6).
- The luminosity distribution differs noticeably for weakly detected blazars and the rest of the sample (KS-test, $p \approx 0.026$).

## Conclusions

**Until now only very few blazars, especially LBLs, have been detected in the hard X-rays. This new sample doubles the known number. About half of the sample is still too faint for spectral fitting. In order to estimate fluxes for faint sources, template spectra are applied.**
**The obtained properties for the various AGN types will become important for further research regarding broadband SED modelling, the blazar sequence or classification issues of single sources.**

## References


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