Radio and Gamma Properties of the 2 cm Survey and MOJAVE Samples

Eduardo Ros for the MOJAVE collaboration
Departament d’Astronomia i Astrofísica, Universitat de València, E-46100 Burjassot, Spain
Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

The 2 cm VLBA Survey observed since 1994 a set of ~170 Quasars, BL Lac objects, and radio galaxies, selected to be representative of the compact AGN radio population. This effort was continued as the MOJAVE project, where a statistically complete set of radio sources being monitored was defined. A comparison of the gamma-detection rates between the members of both samples shows that the MOJAVE-I sources, hosting generally faster jets, have a much higher detection rate than the sources not belonging to this sample. BL Lac objects are more favourably detected than QSOs in gamma-rays, in the same rate for both samples.

1. Background

The 2 cm Survey observed from 1994 to 2002 a set of 171 Quasars, BL Lac objects, and radio galaxies, selected to be representative of the compact AGN radio population (see e.g., [1]; images in [2] and [3]; kinematical results of the parsec-scale jet features in [4] and [5]). This sample was redefined to include 135 objects (two thirds from those belonging to the 2 cm Survey sample) and to be statistically complete with continued monitoring observations from 2002 with the name of the MOJAVE-I program (see [6] for a description of the images, and [7] for kinematical results).

The Large Area Telescope (LAT, see [8]) on board the Fermi Gamma-ray Space Telescope has detected a big fraction of the AGN present in these samples. Furthermore, [9] has shown that the majority of the Fermi blazars are radio-loud and show a core-jet structure at parsec scales.

First results on the gamma-radio relationship were published for the statistically complete sample, in a first instance for the LAT Bright AGN Source (LBAS) 3-month list (see [10, 11, 12, 13] for the MOJAVE results, and [14] for the LBAS). The results presented in this conference are based on a preliminary 11-month list of Fermi/LAT detections as of early November 2009, at the time of the Fermi Symposium 2009.

From the 2 cm Survey sample, 79 prominent AGN are not members of the statistically complete sample (MOJAVE-I), and their radio properties can be as well compared to the Fermi/LAT findings (19 of those are detected at the preliminary 11-month list).

2. Observations

Kinematic values of the AGN jets were obtained from the intensive monitoring survey being performed since 1994. Generally, the Very Long Baseline Array (VLBA) observed each AGN for a total time of 50–60 min in scans of several minutes spread over 8 hr, providing an almost full interferometric track. Each source was observed over several epochs during those years, with a time sampling of at least one observation per year. Additional, high-quality VLBA archival epochs were added to the data base.

After (semi-automatic) imaging of the VLBI observations, the features observed in the jets were modeled by Gaussian functions fitted to the interferometric visibilities. Those features were identified over several epochs, and the measurement of their relative positions provided kinematical values from which further statistical studies can be performed, as well as individual source studies (see [15] for a description of the imaging process and [6, 7] and references therein for kinematic results of the MOJAVE-I sample, and [14] for the kinematic analysis of the 2 cm Survey sample.). Here we compare these results with the Fermi/LAT detections.

3. Results

Figure 1 shows a chart counting the members of the 2 cm Survey and the MOJAVE-I samples, divided by...
Table I Fermi/LAT detection rate for the 2 cm Survey and the MOJAVE-I Samples (based on a preliminary LAT 11-month catalog, see text)

| Set                        | Total | LAT detected | LAT Frac. QSO | LAT Frac. BL Lac | LAT Frac. Radio Gal. |
|----------------------------|-------|--------------|---------------|------------------|----------------------|
| MOJAVE-I                   | 135   | 85           | 60%           | 86%              | 38%                  |
| 2 cm Survey                | 171   | 82           | 46%           | 79%              | 21%                  |
| MOJAVE-I and 2 cm Survey   | 96    | 63           | 65%           | 84%              | 38%                  |
| MOJAVE-I not 2 cm Survey   | 38    | 22           | 52%           | 100%             | --                   |
| 2 cm Survey not MOJAVE-I   | 79    | 19           | 22%           | 67%              | 8%                   |

Figure 2: Redshift distribution and Fermi/LAT detection rate for the MOJAVE-I (top) and the 2 cm Survey (not included in MOJAVE-I) samples. Transparent colours represent non-detections, whereas full colour correspond to LAT detections. Notice that the used list of gamma-detections is preliminary.

optical class, with fill colour for the sources detected at the preliminary 11-month Fermi/LAT list and transparent colour for the non-detected one. Those are shown numerically in Table I.

Figure 2 shows the distribution of redshifts and the differences between the statistically complete sample (top) and the sources from the 2 cm Survey not belonging to this (bottom). With a smaller number of sources, the fraction of moderate redshift QSOs is larger for the sources not included in MOJAVE-I. Again, the detection rate is very low for radio galaxies and quasars.

Figure 3 shows the distribution of the maximum jet speeds for both sets of sources. Notice that the faster jets (above 10c) belong favourably to sources detected by LAT, and that in general all sources from the 2 cm Survey not contained in MOJAVE have slower jets. From those, the high speed ones are not detected by LAT. As it was preliminarly presented by [10] and will be shown by [15], sources with faster jets tend to be favourably detected by LAT.
4. Discussion and Conclusions

The gamma detection rate of the MOJAVE sample is much higher than for the sources of the 2 cm Survey not belonging to the complete sample. The latter sources have in general slower jets. Notice that the MOJAVE-1 sample is selected on the base of compact, beamed (VLBI) emission, and that the gamma-ray emission is correlated with compactness [11].

BL Lacs (seen with beamed jets) are more favourably detected than QSOs by Fermi/LAT, in the same rate for both samples.

The speeds for gamma-detected sources at the MOJAVE-1 sample are higher than for the non-detected ones, especially in the case of the QSOs. Notice that the faster the jets are, the more sources have been gamma-detected (9 out of 10 for $v > 24c$).

A 70% of the quasars of the 2cm Survey not belonging to MOJAVE-I were not detected in gamma-rays, which shows a big difference in the parent population from the statistically complete sample and the additional sources. Notice as well that the MOJAVE-1 sample was selected from active sources since the mid 1990s. Sources which were active before and not at present would emit in gamma-rays less likely.

The kinematic results from the sources belonging to the 2 cm Survey and not belonging to the statistically complete sample, and a discussion on the Fermi/LAT detections from the newer gamma-catalog to be released in a near future will be presented in [4]. In a mid-term, the excellent results to be provided by Fermi, including gamma luminosities and variability will be tested in the near future together with the radio properties, yielding unprecedented information about the nature of the AGN phenomenon and the emission processes involved.

Acknowledgments

In the framework of the MOJAVE collaboration we thank especially Christian M. Fromm for support in the kinematic analysis and Chin-Shin Chang for analysis from the Fermi/LAT detection list. We thank the Fermi/LAT collaboration for providing preliminary gamma-catalog data (11-month list) for the production of this contribution. The Very Long Baseline Array is operated by the USA National Radio Astronomy Observatory, which is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. The MOJAVE project is supported under USA National Science Foundation grant 0406923-AST.

References

[1] K.I. Kellermann et al., “Sub-Milliarcsecond Imaging of Quasars and Active Galactic Nuclei. III. Kinematics of Parsec-scale Radio Jets”, ApJ, 609, 539, 2004.
[2] K.I. Kellermann et al., “Sub-Milliarcsecond Imaging of Quasars and Active Galactic Nuclei”, AJ, 115, 1295, 1998.
[3] J.A. Zensus et al., “Sub-milliarcsecond Imaging of Quasars and Active Galactic Nuclei. II. Additional Sources”, AJ, 124, 662, 2002.
[4] E. Ros et al., “Sub-Milliarcsecond Imaging of Quasars and Active Galactic Nuclei. V. Extending and exploring the sample.”, A&A, in preparation.
[5] M.L. Lister et al., “MOJAVE: Monitoring of Jets in Active Galactic Nuclei with VLBA Experiments. V. Multi-Epoch VLBA Images”, AJ, 137, 3718, 2009.
[6] M.L. Lister et al., “MOJAVE: Monitoring of Jets in Active Galactic Nuclei with VLBA Experiments. VI. Kinematics Analysis of a Complete Sample of Blazar Jets”, AJ, 138, 1874, 2009.
[7] D.C. Homan et al., “MOJAVE: Monitoring of Jets in Active Galactic Nuclei with VLBA Experiments. VII. Blazar Jet Acceleration”, ApJ, 706, 1253, 2009.
[8] W.B. Atwood et al., “The Large Area Telescope on the Fermi Gamma-Ray Space Telescope Mission”, ApJ, 697, 1071, 2009.
[9] Y.Y. Kovalev, “Identification of the Early Fermi/LAT Gamma-Ray Bright Objects with Extragalactic VLBI Sources”, ApJ, 707, L56, 2009.
[10] M.L. Lister et al., “A Connection Between Apparent VLBA Jet Speeds and Initial Active Galactic Nucleus Detections Made by the Fermi Gamma-Ray Observatory”, ApJ, 696, L22, 2009.
[11] Y.Y. Kovalev et al., “The Relation Between AGN Gamma-Ray Emission and Parsec-Scale Radio Jets”, ApJ, 696, L17, 2009.
[12] A.B. Pushkarev et al., “Jet opening angles and gamma-ray brightness of AGN”, A&A, 507, L33, 2009.
[13] T. Savolainen et al., “Relativistic beaming and gamma-ray brightness of blazars”, A&A, in press, 2010 (arXiv:0911.4924).
[14] A.A. Abdo et al., “Fermi/Large Area Telescope Bright Gamma-Ray Source List”, ApJS, 183, 46, 2009.
[15] A.B. Pushkarev et al., “Kinematic Properties of Fermi/LAT detected sources”, A&A in preparation.