A Polarization Study of the University of Michigan BL Lac Object Sample

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Abstract

Twenty one BL Lac objects from the University of Michigan sample were observed with the VLBA at 5, 8 and 15 GHz in December 1999. Our analysis of these data is ongoing and we present our first results here. Total-intensity and linear polarization images are presented for several individual sources as examples. The polarization of each object at the different frequencies and the rotation in the polarization angle between the frequencies (Faraday rotation) are considered, together with the general structure and spectral-index distributions of the sources. The sample includes 1413+135, which is interesting in being the only source showing a two sided jet structure.

Introduction

BL Lacertae, discovered in 1929, was originally classified as a faint variable star, but later realized to be an Active Galactic Nucleus (AGN). It is a prototype of the class of "BL Lac Objects," distinguished by an absence of strong optical emission lines.

The radio emission of BL Lac objects is believed to be synchrotron radiation. In the standard picture, BL Lac objects (and other compact radio-loud AGNs) eject two relativistic jets in opposite directions, one of which points roughly in the direction of the observer and is therefore highly Doppler boosted. The polarization of the radio emission can tell us about the degree of ordering of the magnetic field associated with the synchrotron radiation and the density of the thermal electrons in the path from the radio source to the observer.

The observed synchrotron radiation usually follows a power law spectrum in optically thin regions, $S \propto \nu^{\alpha}$, where α is the spectral index. This turns over at lower frequencies due to synchrotron self absorption (the plasma of spiralling relativistic electrons becomes opaque to it's own radiation).

BL Lac objects show the following characteristics:

- A smooth optical continuum, which originates in an unresolved source.
- Luminosities can change by up to 30% in 24 hours and can vary by a factor of 100 over a longer time period.
- Strong, variable, polarized radio emission.
- Emission and absorption lines that are weak, relative to the continuum; when lines are detected, the redshifts tend to be low (compared to those of quasars).
- Highly variable optical polarization that can reach rather large values.

A sample of approximately 40 BL Lac Objects with radio fluxes greater that 400 mJy has been observed at the University of Michigan since the late 1970's (e.g. Aller et al. 1999). These sources are being monitored at 2 cm (15 GHz), 4 cm (8 GHz) and 6 cm (5 GHz) in total intensity and polarization. Gabuzda et al. obtained VLBI polarization data at these wavelengths for roughly half the sample as part of a separate study. We are now analysing analogous data for the twenty-one of the University of Michigan BL Lac objects which are not included in the sample studied by Gabuzda et al. Our long term goals are to determine the VLBI total intensity and polarization structure at wavelengths monitored at University of Michigan and to look for correlations between the VLBI properties and integrated variability characteristics.

Observations and Reduction

Polarization observations of 21 objects in the University of Michigan BL Lac sample were obtained on the Very Long Baseline Array (VLBA) in December 1999 at 2 cm, 3.6 cm and 6 cm. The observations were carried out in a "snapshot" mode, resulting in a total on-source time of approximately 30 minutes per wavelengths. The calibration and imaging were carried out in AIPS using standard techniques.

Results and Discussion

All the total intensity and polarization images have been made, and are in the process of being analysed. We present here results for several individual sources as examples of the tendencies observed and the type of information that can be extracted from the data.

1413+135

1413+135 is an interesting and unusual BL Lac object because it shows a two-sided jet structure. Figure 1 shows the total-intensity maps of this source at 5, 8 and 15 Ghz together with the 5-8 Ghz spectral-index map. The source is only weakly polarized, for reasons that are not yet clear. The spectral-index distribution clearly shows a flat-spectrum core and the two optically thin jets. The presence of the counter-jet suggests that the jets make a relatively large angle to the line of sight.

1413+135 (cont.)

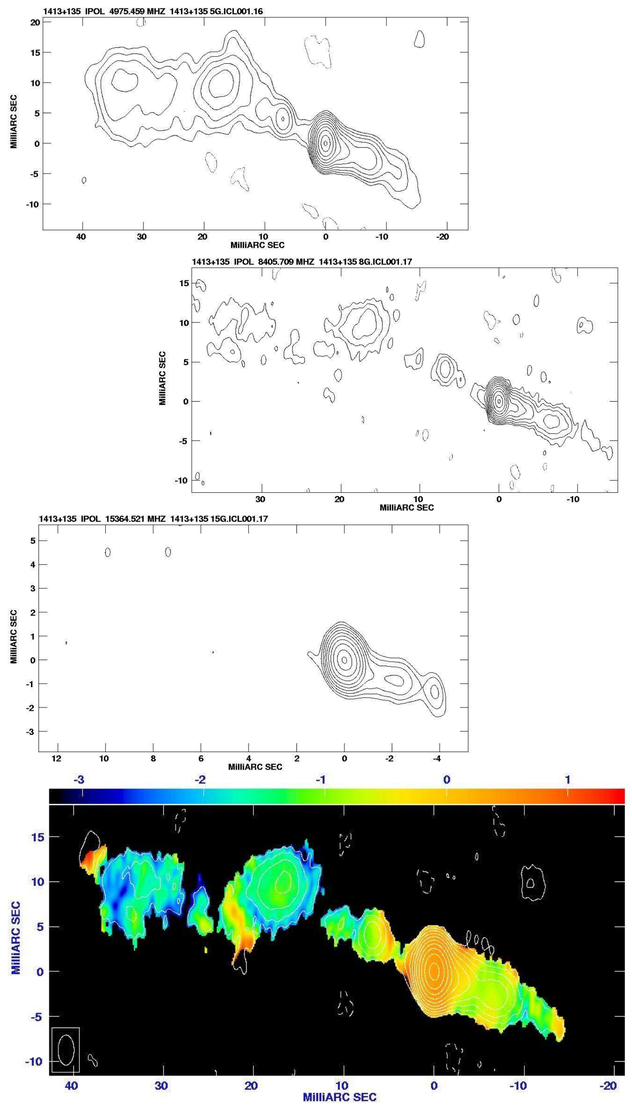


Fig 1. Polarization maps and spectral index maps of 1413.135.

0754+100

The core polarization angles of 0754+100 at each of the three frequencies are quite different; this is true in the jet as well, though to a lesser extent. This suggests the action of Faraday rotation: as linearly polarized light passes through a medium with free electrons and a magnetic field, the plane of polarization is rotated. The action of Faraday rotation can be identified by its characteristic linear dependence on the square of the observed wavelength.

The rotation measure of the core is approx +270 Rad m^{-2}, while that in the jet is approx +120 Rad m^{-2}, indicating a likely enhancement in the density of free electrons in the core region. The jet of this source may also show transverse RM gradients, possibly indicating the presence of a helical **B** field associated with the jet (see the poster by

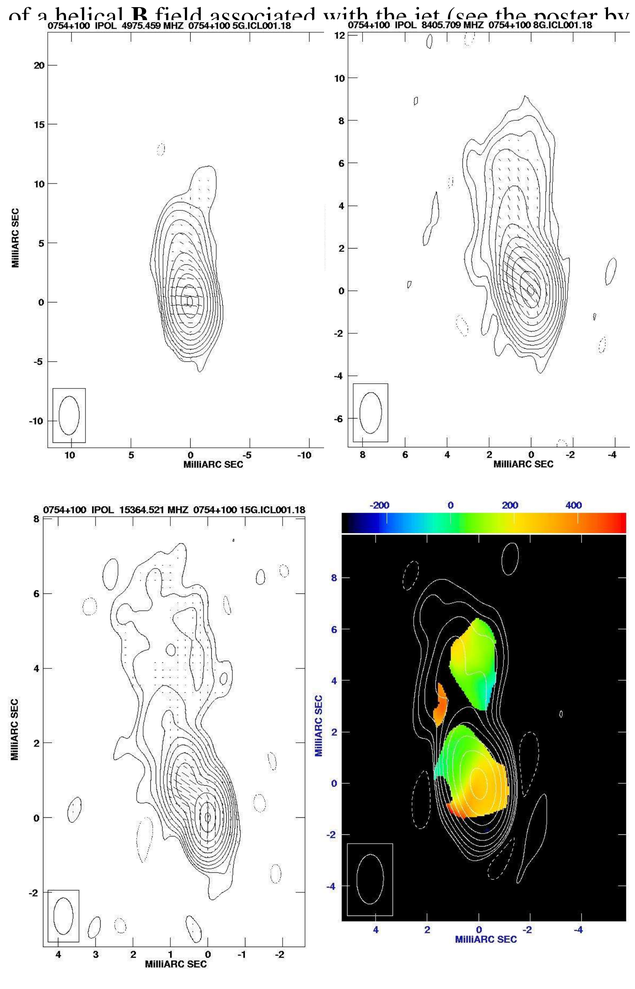


Fig 3. Polarization maps of 0754+100 and the rotation measure map made using all three wavelengths, convolving the 6cm and 2cm maps with the 4cm beam.

0818-128

The spectral image of 0818-128 (Fig. 2) shows a clear distinction between the optically thick core and optically thin jet. In addition, the core polarization angles show evidence of Faraday rotation, while the jet polarization angles are nearly the same at all three wavelengths (e.g. See the jet region about 7.5 mas from the core, visible in all three maps). If the emitting region is optically thin, the magnetic field is perpendicular to the observed plane of polarization, so that the inferred jet B field is approximately perpendicular to the jet direction, as is often the case for BL Lac objects.

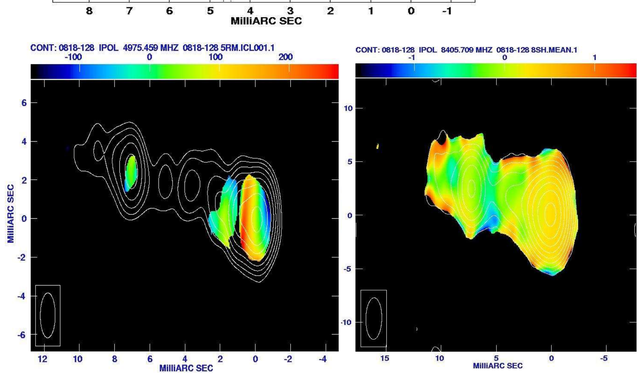
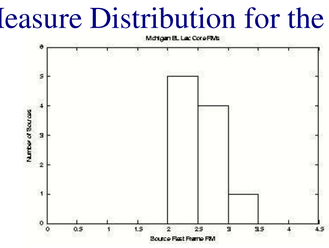


Fig 2. Polarization maps at 5, 8 & 15 Ghz, rotation measure map (left) and spectral index (right) map of 0818-128.

Rotation Measure Distribution for the Sample



This histogram presents the distribution of the core Faraday rotation measures for the subset of the twenty-one sources for which core polarization was detected at all three wavelengths and for which redshifts are available. The observed rotation measures have been reduced to the source rest frame by multiplying by a factor of $(1+z)^2$. This histogram is virtually identical to the corresponding rotation-measure distribution for a sample of 1 Jy radio BL Lac objects presented in the poster by Pashchenko & Gabuzda, demonstrating that these slightly weaker BL Lac objects have the same characteristic core rotation measures.

Further analyses of the characteristic VLBI properties of the University of Michigan BL Lac object sample are under way. Our future work also includes a comparison of the VLBI properties and integrating monitoring characteristics of the sources.

Acknowledgements

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