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INVESTIGATING PLASMA-PHYSICAL PROPERTIES OF JETS IN NEARBY RADIO-BRIGHT AGN WITH KVN AND KaVA

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ABSTRACT

In this paper we introduce the *Plasma Physics of Active Galactic Nuclei* project, which is an ongoing experiment with Korean VLBI Network (KVN) and KVN and VERA Array (KaVA) to study multi-frequency polarimetric properties on parsec scales of active galaxies. The goal of the project is to improve our understanding of fundamental jet physics, especially evolution of the relativistic outflow coupled with the large-scale magnetic field. We selected six radio-loud AGN as our targets. So far we (i) detected resolved emissions regions at 86 and 129 GHz on VLBI scales, (ii) constructed 2D spectral index maps of the outflows, and (iii) found polarizations at 22 and 43 GHz for a few targets. Here we present spectral index distributions of 3C 120 between 22 and 43 GHz and a linear polarization map of BL Lac at 43 GHz obtained with KVN.

Key words: Galaxies: active, jets, magnetic fields — Radio continuum: galaxies — Techniques: interferometric, polarimetric

1. INTRODUCTION

Radio-loud Active Galactic Nuclei (AGN) are an interesting type subset of AGN populations due to their characteristic relativistic jets, which extend from the central few parsecs up to megaparsec scales. Such outflows are believed to be launched from the vicinity of central Supermassive Black Holes (SMBHs), where strong large-scale magnetic fields coupled with the spin of SMBHs with surrounding accretion disks play key roles in the processes (for the details, see Meier 2009; Boettcher et al. 2012 and references therein). To support existing theories or to develop a new model, detailed observations of the center of the jets on parsec scales is crucial. In particular, very high angular resolutions (≈ a few mas) achieved by Very Long Baseline Interferometry (VLBI) are powerful in detecting observable signatures predicted by the theories.

VLBA polarimetric observations by O'Sullivan & Gabuzda (2009a,b) show Rotation Measure (RM) and spectral index gradients along the downstream of jets in six blazars. The authors find helical configurations for pervading magnetic fields, properties of the sheath of plasma surrounding the jets, and several overdensity regions which are caused by either interaction of the outflows with the stationary interstellar medium (ISM) or in-situ particle re-acceleration. In addition, a recent study by Zamaninasab et al. (2014), which computed the fluxes of poloidal magnetic fields threading the jets for 76 sources monitored by VLBA, confirmed that the dynamical influence of the magnetic fields is more significant than previously assumed, even in the inner regions of accretion disks.

In this paper we introduce the *Plasma Physics of Active Galactic Nuclei* project, which is an observational study of nearby radio-loud AGN with spatially resolved jets of complex structures. Our goal is to study evolution of the jets with large-scale magnetic fields at high observing frequencies, e.g., from 22 to 129 GHz. We use two VLBI arrays – the Korean VLBI Network (KVN[1]) and the Korea and Japan joint array (KVN and VERA Array; KaVA[2]) – that have recently begun operation in the East Asia region. As preliminary results we show a spectral index map of 3C 120 at 22 and 43 GHz and a 43 GHz polarization map of BL Lac to illustrate our goal.

2. OBSERVATIONS AND DATA REDUCTION

We selected in total seven objects – 3C 111, 3C 120, 3C 84, 4C +01.28, 4C +69.21, BL Lac, and DA 55 – from a catalogue compiled by Kim & Trippe (2013). In case of KVN, each source is observed at frequencies of 22, 43, 86, 129 GHz for 10 hours using both LCP and

[1] See Lee et al. 2014 for its performance.
[2] See Niinuma et al. 2014 for continuum source imaging capability.

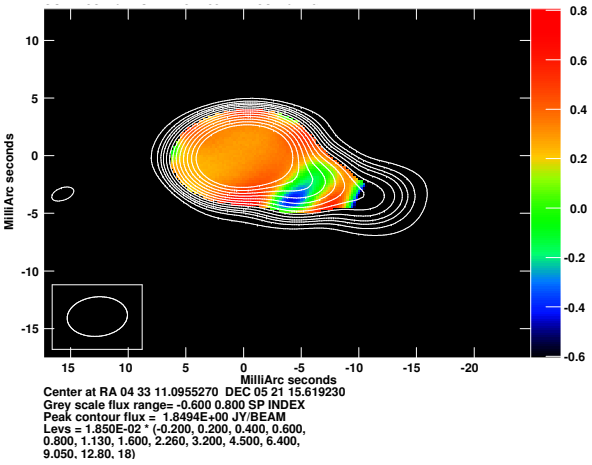

Figure 1. Spectral index distribution of 3C 120 made by using 22 and 43 GHz intensity maps. Texts describing peak contour flux and contour levels (in units of Jy/beam) are written in bottom of the main plot. Colorbar indicates corresponding spectral index values.

can feeds. In particular, with the special capability of KVN, we could perform observations at two frequencies simultaneously; either a combination of (a) 22 and 43 GHz or (b) 86 with 129 GHz at each epoch. With KaVA, we observed each source for six hours at 43 GHz with intensity measurements only.

The raw data taken from KVN and KaVA were correlated at the Korea-Japan Correlation Center (KJCC[3]). For post processing we primarily used `AIPS` and used `Difmap` for source imaging.

3. SPECTRAL INDEX DISTRIBUTIONS AND LINEAR POLARIZATIONS

Here we show only two results obtained from KVN observations.

In Fig. 1, we show the 22 – 43 GHz spectral index map[4] of 3C 120, which is a Seyfert 1 radio-loud active galaxy. The two intensity maps are aligned by 2D the cross correlation method implemented in the software developed by Kim & Trippe (2014). In the main plot, the gradient of the spectral index distribution over the jet downstream is evident. This indicates the complex particle density structure of the outflow. We also found a jump of the index value ($\approx$ 7 mas away from intensity peak) in the alternating spectral index patterns. A physical interpretation of such a feature is the next step of this study.

Fig. 2 shows the 43 GHz polarization properties of BL Lac, which is a Flat-Spectrum Highly Polarized Quasar. The upper and lower panels in the figure shows fractional polarization and polarization angles, respectively. The upper panel shows that the core region is polarized at most $\lesssim$ 10 percent, whereas the extended emission region is strongly polarized up to $\approx$ 40 percent even at 43 GHz. Indeed, the extended blob is quite strongly polarized. More interestingly, the two regions have different Electric Vector Position Angles (EVPAs). It is important to note that we still have not applied absolute EVPA calibrations here, but relative angle differences at the two regions may remain the same. Physically, these might originate from the combination of non-uniform magnetic field strengths and different levels of the field line ordering possibly due to internal shocks (e.g., Marscher & Gear 1985)

[3] `http://kjcc.kasi.re.kr/`.
[4] Here the index value is negative for the optically thin case.

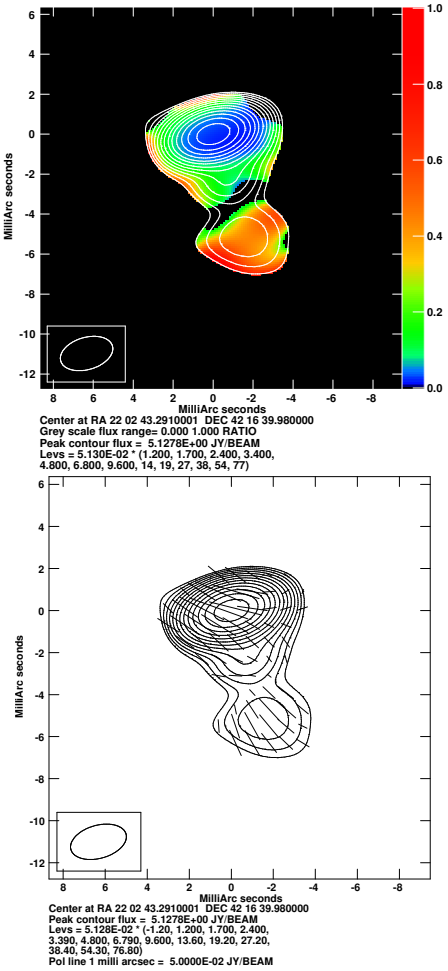

Figure 2. Polarization properties of BL Lac at 43 GHz. Please see the additional texts for contour peaks and contour level expressions. *Upper panel* : Fractional polarization of the source (1 corresponding to 100%). *Bottom panel* : Lengths of the lines indicate polarization intensities (1 mas = 50 mJy/beam) and the angles are EVPA. Please note that *here EVPA calibration is not performed yet.*

4. FUTURE PLANS

The project is currently ongoing with observations at KVN and KaVA during the 2014B season. For the next steps, we will derive physical properties of the sources based on results from 22 and 43 GHz observations. EVPA calibrations will be done with partially resolved and highly polarized quasars. We are currently analyzing KVN 86 and 129 GHz maps and KaVA 43 GHz maps for more detailed information about the sources. We expect more results from our study will be updated

soon.

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