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KVN PHASE REFERENCING OBSERVATIONS OF THE VIRGO CLUSTER

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ABSTRACT

By probing nuclear regions and the overall properties of AGN hosts as a function of their environments, we aim to observationally examine how AGN activities are related to their surroundings. We have selected a representative sample of AGN hosts in the Virgo cluster. The selected galaxies are located in a range of density regions showing various morphologies in 1.4 GHz continuum emission. High-resolution observations with the Korean VLBI Network (KVN) allow us to access the inner region of the AGN without suffering from dust extinction and synchrotron self-absorption. Since a number of our targets are too weak to be detected at K-band (22 GHz) within their coherence time, we applied phase referencing to calibrate fast atmospheric phase fluctuations.

Key words: atmospheric effects - galaxies: active - galaxies: clusters - instrumentation: interferometers - galaxies: nuclei

1. INTRODUCTION

AGN activity and its feedback can affect galaxy evolution. The growth of black holes and the frequency of AGN activity are controlled by how frequently and quickly the feedback process takes place and how the accretion energy is converted to heat in the ambient interstellar medium (ISM), which may change with surroundings. AGN properties such as the feedback frequency and strength are dependent on the truncation radius, beyond which gas stripping is assumed to be effective (Shin et al., 2012).

Feedback from AGNs is required to explain the galaxy stellar mass function and star formation histories. The power and frequency of AGN outbursts are linked to the black hole environment, and it is unclear whether mechanical energy or radiative processes can affect galaxy evolution more, whether the AGN frequency and/or strength are related to the environment, and if so, how.

We therefore attempt to provide an observational approach to determine how these activities are related to the intra-cluster medium (ICM) density by probing the properties of the central part of AGN hosts with respect to their surroundings. Considering that an AGN is a cyclic event and individual AGN power, and hence the strength of the outflow, is likely to change with time, we have selected only those systems where extended signatures are present so that we can study how the AGN feedback interacts with ICM.

2. SAMPLE SELECTION AND DATA

We have selected a representative sample of AGN hosts in the Virgo cluster. Virgo, as the nearest rich galaxy cluster (16.5 Mpc, Mei et al., 2007), is an ideal place to study the detailed properties of individual galaxies. In this study, we particularly focus on early type galaxies located in a range of density environments and showing extended features at low radio frequencies, i.e. outflowing jets indicative of AGN feedback. We have selected eight galaxies, including seven cluster members (M49, M60, M84, M87, NGC 4435, NGC 4526, NGC 4636) and one galaxy that is likely to be in the background (NGC 4261) but still close enough to be studied in high resolution. The selected galaxies are located in a range of density regions showing various morphologies in the 1.4 GHz continuum from the VLA FIRST survey. The distribution of our targets in the Virgo cluster is shown below in Figure 1. The FIRST images where the extended jets can be seen and our K-band maps obtained using the Korean VLBI Network (KVN) which show deeper into the center of each source are also presented.

3. PHASE REFERENCING

Fundamentally, phase referencing (PR; Shapiro et al., 1979; Alef, 1988) uses the fringes of the calibrator to estimate the antenna based complex gains. These gains are time interpolated to the target observations resulting in calibrated target visibilities.

Our target list provides an excellent sample to prove the phase referencing capability of our combined net-

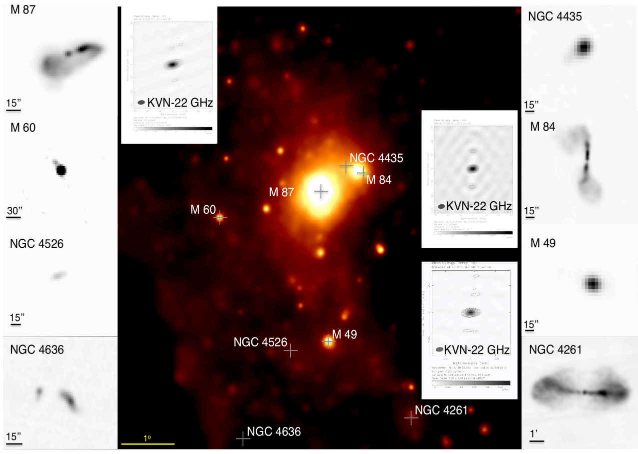

Figure 1. The sample of this study and its distribution along the Virgo Cluster. The background is the ROSAT X-ray image showing the ICM distribution. The FIRST survey, 1.4 GHz continuum images of our sample are also plotted in different scales. The KVN maps at 22 GHz for three detected sources result from this work.

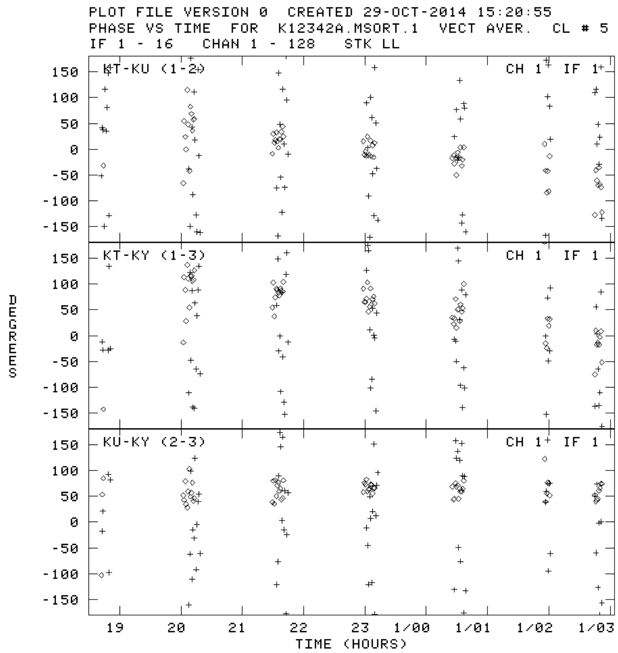

Figure 2. The phase solutions as a function of time of M84 are presented for each baseline before (cross sign) and after (diamond sign) applying the phase correction of the phase calibrator M87. In the latter case the phases are converged and averaged, where they can be used for the mapping.

work, the KVN (Kim et al., 2004), since they (both calibrators and targets) have various separation angles (1 ∼ 4.8 degrees) and their fluxes range from tens of mJy to tens of Jy in K/Q band. The detection rate for our targets (3 out of 8 targets were detected), as shown in Figure 2, is impossible without using rapid source switching. As shown with one example (M84) in Figure 2, the phases of the source are widely distributed over time. After applying phase referencing the phase solutions converge and can be integrated in order to produce the radio map, where the relevant intensity and radio morphology can be studied.

4. SUMMARY & DISCUSSION

In this study we have presented high frequency radio observations of eight AGN candidates in the Virgo cluster. The current results primarily focus on fringe detection tests with the "source switching phase referencing observation" of KVN.

In particular, our phase referencing method with KVN at 22 GHz and its detection capabilities have been discussed. Observing calibrators and targets with various separations (1 ∼ 4.8 degrees) and radio brightness (a few tens of mJy to several tens of Jy), we have demonstrated the capabilities of phase referencing at K-band. The fast slewing time of KVN antennas (∼3 degrees/sec) allowed us to minimize the source switching time between the target and the calibrator and thus good calibration results can be achieved (e.g. NGC 4261 has a separation angle from its calibrator of ∼3.5 degrees). The marginal detection of four targets was challenging, since the visibility phases did not converge after applying the calibrator phase solutions. However, with the detected phase visibilites, we obtained the 22 GHz fluxes. We did not see any visibility phases in NGC 4526, which has the largest separation angle (∼4.75 degrees) from its calibrator of our target list.

This fringe detection test allowed us to confirm the high possibility of the detection of our Virgo samples with the KVN and provided very good candidates for capability testing for the phasing referencing technique in the near future, combining both (KaVA) KVN and VLBI observation with VLBI Exploration of Radio Astrometry (VERA).

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REFERENCES

Alef, W., 1988, in IAU Symposium, The Impact of VLBI on Astrophysics and Geophysics, ed. M. J. Reid & J. M. Moran, 129, 523

Kim, H. -G., Han, S. -T., Sohn, & B. W., et al., 2004, Construction of the Korean VLBI Network (KVN) in European VLBI Network on New Developments in VLBI Science and Technology, ed. R. Bachiller, F. Colomer, J. -F. Desmurs, & P. de Vicente, 281

Mei, S., Blakeslee, J. P., Côté, P., et al. 2007, The ACS Virgo Cluster Survey. XIII. SBF Distance Catalog and the Three-dimensional Structure of the Virgo Cluster, ApJ, 655, 144

Shapiro, I. I., Wittels, J. J., Counselman, III, C. C., et al., 1979, Submilliarcsecond Astrometry via VLBI. I - Relative Position of the Radio Sources 3C 345 and NRAO 512, AJ, 84, 1459

Shin, M. -S., Ostriker, J. P., & Ciotti, L. 2012, Environmental Effects on the Growth of Supermassive Black Holes and Active Galactic Nucleus Feedback, ApJ, 745, 13