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IMAGING CAPABILITY OF THE KVN AND VERA ARRAYS (KaVA)

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ABSTRACT

The Korean very-long-baseline interferometry (VLBI) network (KVN) and VLBI Exploration of Radio Astrometry (VERA) Array (KaVA) is the first international VLBI array dedicated to high-frequency (23 GHz (K-band) and 43 GHz (Q-band)) observations in East Asia. To evaluate the imagine capability of KaVA, we performed imaging observations of three bright active galactic nuclei (AGNs) known for their complex morphologies: 4C 39.25, 3C 273, and M87 by KaVA at K-/Q-band. Our KaVA images reveal extended outflows with complex substructure such as knots and limb brightening, in agreement with previous observations by other VLBI facilities. Angular resolutions are better than 1.4 and 0.8 milliarcsecond (max) at K-/Q-band, respectively. KaVA achieves a high dynamic range of ∼1000, more than three times the value achieved by VERA. We conclude that KaVA is a powerful array with a great potential for the study of AGN outflows, at least comparable to the best existing radio interferometric arrays.

Key words: techniques: interferometric — galaxies: active — galaxies: jets — radio continuum: galaxies

1. KVN AND VERA ARRAY (KaVA)

KaVA is a VLBI array that combines KVN and VERA, and its baseline lengths range from 305 to 2270 km (Figure 1, and Sawada-Satoh (2013)). Observing frequencies of 23 GHz (K-band) and 43 GHz (Q-band) are available. Table 1 summarizes the specifications of each array. As shown in this table, KVN has relatively short baselines (< 500 km), and so it can detect emission from extended structures but cannot see the detailed structure on the scale of a few max because it has insufficient angular resolution. VERA, on the other hand, has only long baselines (> 1000 km), and so it has high angular resolution but is less sensitive to extended emission. Therefore, because each array compensates for the weakness of the other, they are complementary, which makes KaVA a very promising VLBI facility. By improving the uv-coverage, KaVA is expected to offer significant advantages for the observing extended radio sources such as AGN jets.

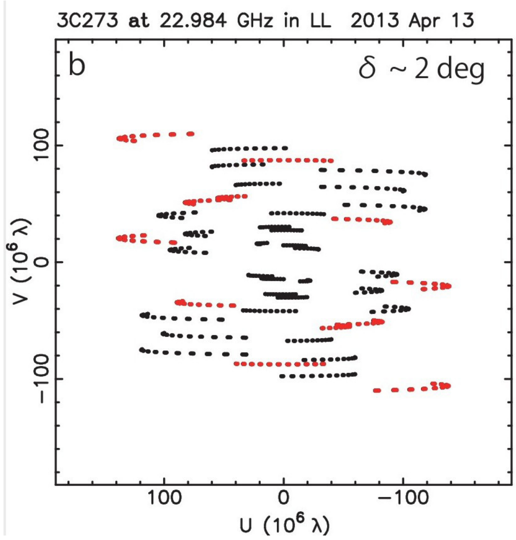

Figure 1. *uv*–coverage of 3C 273 (declination $\delta \sim 2^\circ$). Red plots show the one obtained by only VERA baselines, and black+red plots show the one obtained by KaVA baselines.

2. TEST OBSERVATIONS AND VLBI IMAGES

To evaluate the imaging capability of KaVA for extended sources, we carried out test observations for 4C 39.25 (relatively compact structure), 3C 273 (extended bright knotty jet structure), and M 87 (extended smooth jet structure) at both K-/Q-band with band-

Table 1
Summary of typical array specifications of each VLBI facility

	Array		
	KVN	VERA	KaVA
Baseline [km] (Shortest/Longest)	305/476	1019/2270	305/2270
Fringe spacing [mas] (K-/Q-band)	5.6/3.0	1.2/0.6	1.2/0.6

width of 32 MHz on 2013 April 13 and 14. Only 128 Mbps recording mode (bandwidth of only 32 MHz) allows us to conduct test observations in commissioning phase.

In these observations, we repeated 11 to 16 short-time scans (4 to 6 min/scan) for each source as follows: scan1 (source1) → scan2 (source2) → scan3 (source3) → scan4 (source1) → scan5 (source2) → scan6 (source3) → ···, to achieve good *uv*–coverages. Therefore, total on-source time for each source was approximately 1 hour. In Figure 1, we represent the *uv*-coverage of 3C 273 obtained by our test observation at K-band.

In the analysis procedure, we performed the calibraation of the observed visibility and VLBI image construction for each source in the standard manner, with the NRAO Astronomical Image Processing System (AIPS) software package (Greisen 2003) and the Caltech Difmap package (Shepherd 1997). To compare the imaging capabilities of KaVA with the ones of VERA, we made CLEAN images for each source. In Figure 2, we show three VLBI images for only 3C 273[1]; K-band image derived from only VERA baselines, K-band image derived from KaVA baselines, and Q-band image derived from KaVA baselines. Here we generated the VERA images by clipping the visibilities of VERA out of the AIPS-calibrated visibilities. As the imaging capability of KVN was recently evaluated by Lee et al. (2014), we focus on evaluating and comparing the imaging capabilities of KaVA and VERA in this paper.

3. EVALUATION OF THE IMAGING CAPABILITY OF KaVA

Based on the result of our analysis, we evaluated the quality of VLBI images and the morphological structures of each source obtained by KaVA observations. As shown in Figure 2, an extended jet structure in the KaVA images is well reproduced compared to the one in VERA image. In addition, the dynamic range of KaVA images for each target source were quite improved (Table 2).

KaVA can achieve a substantially high dynamic range, exceeding 1000, for sources having extended structures even with a bandwidth of only 32 MHz and on-source time of an hour, if we perform the observation to cover the spatial frequency uniformly within an hour angle spread ver a total observation time of 6-8 h. The dynamic range derived from KaVA observations is at least three times higher than only VERA observations. This imaging capability of KaVA has a great advantages for the statistical study of AGN jet science, such as discussing the jet kinematics effectively by observing many AGN jets as frequently as possible within a limited time.

[1] Please refer to Niinuma et al. (2014) on VLBI images of 4C 39.25 and M 87

Table 2
Comparison of image dynamic range between KaVA K-/Q-band and VERA K-band.

Source	KaVA K-band	KaVA Q-band	VERA K-band
4C 39.25	1768	1009	308
3C 273	1310	1064	363
M 87	1017	620	190

These values are adopted from Niinuma et al. (2014).

4. FUTURE PROSPECTS

Because KaVA has been verified by this work to offer superior imaging capability, we can discuss further AGN jet science as a large project of the KaVA AGN sub-working group. It is expected that not only the imaging capabilities of KaVA, but also the 1 Gbps recording mode in KaVA regular operation should be a very promising tool to study AGN jet physics.

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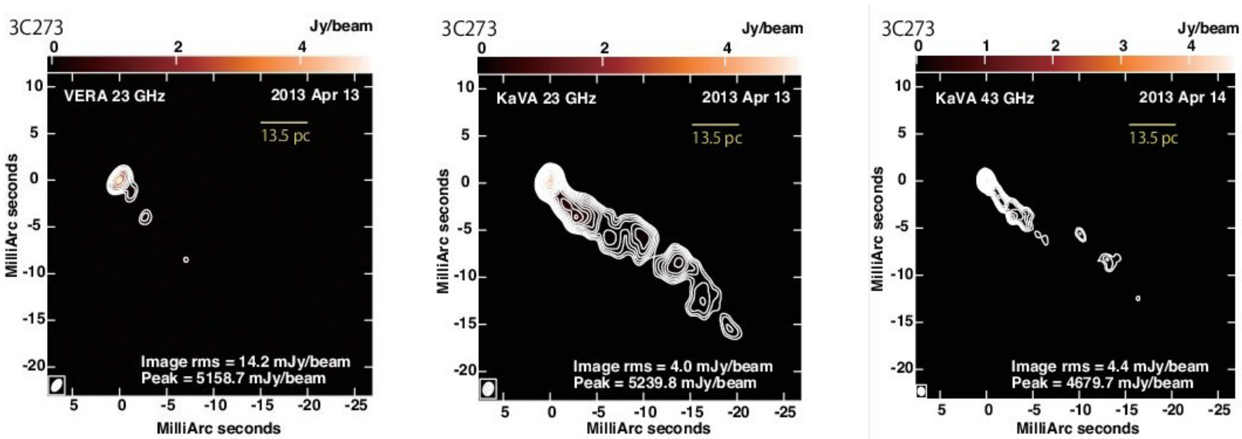

Figure 2. *Left*–, *middle*–, *right*–panels: VLBI images of 3C 273 observed by VERA at K-band and KaVA at K-/Q-bands, respectively. In each panel, peak intensities and image noise levels are indicated in the bottom-right corner and synthesized beams are also shown in the bottom-left corner in each image. In the top-right corner, the date and linear scale at the distance of each source are shown. Contours of each image begin at five times of image rms, and increase in $\sqrt{2}^n$ steps.