

2.4 Operations and Results of J-Net (Japanese Domestic VLBI Network)

By

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ABSTRACT

J-Net (Japanese VLBI Network) is the only VLBI network available for common use in Japan. It consists of three antennas belonging to the National Astronomical Observatory (NAO) of Japan (45-m antenna at Nobeyama Radio Observatory, 10-m antenna at Mizusawa Astrogeodynamics Observatory, and 6-m antenna at Kagoshima) and one antenna of the Communications Research Laboratory (34-m antenna at the Kashima Space Research Center) that participates as a base for joint research with NAO. The J-Net started common-use observations in the 22-GHz band in 1994. It has been used mainly for imaging VLBI observations of water vapor masers in star-forming regions and late-type stars with resolutions of several milliarcseconds. The contributions of J-Net to Japanese VLBI activity have been extensive.

Keywords: J-Net, Common use, Imaging VLBI, Water vapor maser, KNIFE

1. Introduction

The Japanese Domestic Very Long Baseline Interferometry (VLBI) Network known as “J-Net” is the only VLBI network available for common use in Japan. It features three antennas of the National Astronomical Observatory (NAO) and one of the Communications Research Laboratory (CRL). The former group consists of the 45-m antenna at the Nobeyama Radio Observatory, the 10-m antenna at the Mizusawa Astrogeodynamics Observatory, and the 6-m antenna at Kagoshima. The latter is the 34-m antenna at the Kashima Space Research Center, and this antenna participates in the network as a base for joint research with NAO. The J-Net began operations in 1994 and has been providing common-use observations in the 22-GHz band. It has been mainly used for imaging water maser sources in star-forming regions and late-type stars at resolutions of several milliarcseconds. These J-Net observations have been making major contributions to Japanese VLBI research.

2. J-Net Background and Performance

As described above, J-Net, the Japanese Domestic VLBI Network, consists of three NAO antennas and one CRL antenna to form the only VLBI network for common use in Japan. The NAO antennas are the 45-m antenna at the Nobeyama Radio Observatory, the 10-m antenna at the Mizusawa Astrogeodynamics Observatory, and the 6-m antenna at Kagoshima. The CRL antenna is the 34-m antenna at the Kashima Space Research Center that participates in J-Net as a joint-research base. The first fringe output in the 22-GHz band was achieved in

1993 and common-use observations began in 1994.

Before J-Net, VLBI observations in the 22- and 43-GHz bands had begun in the latter half of the 1980's on the baseline between Kashima and Nobeyama known as the Kashima Nobeyama InterFERometer (KNIFE). These observations used the 34-m antenna at the Kashima Space Research Center and the 45-m antenna at the Nobeyama Radio Observatory. They produced landmark results, clarifying, for example, the physical state of the periphery of late-type stars and the excitation mechanism of silicon-monoxide masers⁽¹⁾, and the size of high-velocity components of extragalactic water maser sources⁽²⁾. Observations of continuum emission from active galactic nuclei were also performed. For example, Matsumoto et al. carried out a radio-source survey in the 22- and 43-GHz bands with the aim of finding radio sources for future shortwave geodetic VLBI⁽³⁾. Kamenno et al., moreover, researched continuum spectra including 18 compact-steep-spectrum (CSS) radio sources in the 22- and 43-GHz bands, and have shown that CSS can be explained by a core having a flat spectrum combined with a radio lobe having a steep slope⁽⁴⁾.

On entering the 1990's, a 10-m high-accuracy VLBI antenna was constructed at NAO's Mizusawa Astrogeodynamics Observatory to provide an additional antenna that could make millimeter-wave observations. Also, as a result of this development, a 6-m antenna that had been moved to the Nobeyama Radio Observatory and used for geodetic VLBI observations was upgraded for use in shortwave VLBI, and then moved again to Kinkowan Park in Kagoshima City. This antenna was placed under the operation of Kagoshima University

making common-use observations a possibility⁽⁶⁾. Around this time, VLBI observations also began at the Usuda Deep Space Center of the Institute of Space and Aeronautical Science (ISAS) using a 64-m antenna.

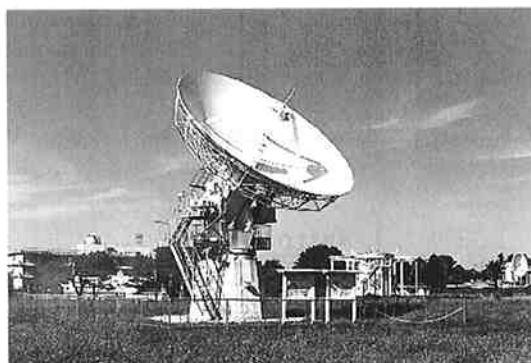
Against the above background, expectations were high at the 1993 VLBI Symposium that the three stations then owned by NAO could be used to perform VLBI observations together with CRL's 34-m Kashima antenna participating as a joint-research base. A decision was consequently made in the fall of 1994 to begin common-use observations with NAO's three stations. This decision was significant since the only chance to perform domestic shortwave VLBI up until then was through the two stations and one baseline configuration of KNIFE, which presented a problem in terms of imaging performance. The 4-station, 6-baseline configuration of J-Net, however, provided a system with remarkably improved imaging performance. Photographs of the four J-Net stations are shown in Fig. 1.

Table 1 summarizes the performance of each station. At first, a 16-channel K-4 system with a bandwidth of 2 MHz was used as a backend. In subsequent years, however, progress was made in VLBI Space Observatory Program (VSOP) backends, and at present, the stations use a 4-channel VSOP terminal with a bandwidth of 16 MHz capable of recording 128 Mbit/s (and even 256 Mbit/s). This enhancement means a marked improvement in detection sensitivity for radio continuum.

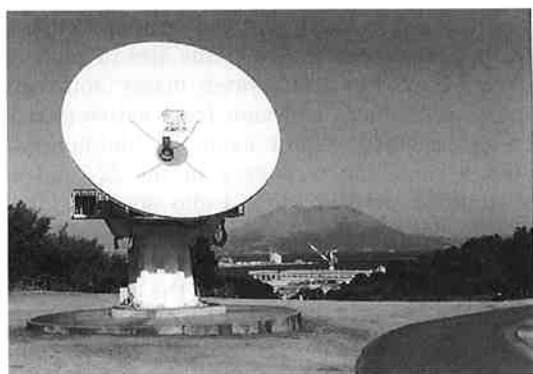
Table 2 gives fringe interval and detection sensitivity for each of the baselines formed by the four observation stations. The Nobeyama-Kashima baseline (shortest at a length of 200 km) has the highest detection sensitivity and the largest fringe interval, while the Mizusawa-Kagoshima baseline (longest at a length of 1300 km) has the lowest detection sensitivity and the smallest fringe interval. As a consequence, J-Net has high-performance capabilities and can image celestial bodies of a size no more than several mas.



(a) Nobeyama 45-m antenna



(b) Mizusawa 10-m antenna



(c) Kagoshima 6-m antenna



(d) Kashima 34-m antenna

Fig. 1

Table 1 Performance of J-Net participating stations

Station	Nobeyama 45m	Mizusawa 10m	Kagoshima 6m	Kashima 34m
Diameter	45m	10m	6m	34m
Beam size	1.'2	5.'2	9.'5	1.'6
Aperture efficiency (%)	63	36	40	57
Frequency range (GHz)	20.0 — 24.0	19.5 — 25.0	19.5 — 25.0	21.9 — 22.4 23.5 — 24.0
Tsys (K)	180	200	200	200
Trec (K)	<100	80	50	90
Antenna drive speed AZ, EL (deg/s)	0.3, 0.3	3, 3	1.5, 0.75	0.75, 0.67
AZ drive range (deg)	−90 — 450	−90 — 450	−90 — 450	−270 — 270
EL drive range (deg)	11 — 80	3 — 88	10 — 88	7 — 88
Backend	VSOP	VSOP	VSOP	VSOP
Frequency standard	H maser	H maser	H maser	H maser
Polarization	R/L switching	R/L switching	R/L switching	R/L switching
Antenna location	Minamimaki, Nagano prefecture	Mizusawa, Iwate prefecture	Kagoshima, Kagoshima prefecture	Kashima, Ibaraki prefecture
X (m)	−3871023.49	−3857236.03	−3537007.89	−3997649.22
Y (m)	3428106.80	3108803.31	4140258.02	3276690.83
Z (m)	3724039.50	4003883.12	3309951.07	3724278.89

Table 2 Sensitivity and fringe interval of each J-Net baseline

(a) For 22-GHz radio sources

Baseline	Minimum Fringe Interval (mas)	Correlation Flux Density (Jy)	Minimum brightness temperature (K)
Nobeyama-Mizusawa	6.6	0.27	5.8×10^6
Nobeyama-Kagoshima	3.1	0.45	4.0×10^7
Mizusawa-Kagoshima	2.2	2.75	5.3×10^8
Kashima-Nobeyama	14.2	0.05	2.9×10^5
Kashima-Mizusawa	7.8	0.48	7.2×10^6
Kashima-Kagoshima	2.6	0.63	8.5×10^7

(b) For 22-GHz water maser sources (velocity resolution: 0.84 km/s)

Baseline	Minimum Fringe Interval (mas)	Correlation Flux Density (Jy)
Nobeyama-Mizusawa	6.6	4.4
Nobeyama-Kagoshima	3.1	7.1
Mizusawa-Kagoshima	2.2	4.4
Kashima-Nobeyama	14.2	1.1
Kashima-Mizusawa	7.8	7.8
Kashima-Kagoshima	2.6	10.4

3. J-Net Operating Organization

In conjunction with J-Net operation, representatives from the observation stations making up the network attend monthly or bimonthly meetings chaired by Professor Toshihiro Omodaka of Kagoshima University. These meetings are held to review the status of each station, decide on J-Net project-oriented observations, and discuss related business. In actual charge of J-Net operation is the VLBI Expert Group (VEG) which manages observation schedules, regulates operations, and executes observations. There is also a technical screening process for common-use observation proposals that have been received, and proposals that pass this screening are then turned over to a referee for scientific appraisal (the same as for an ordinary observation proposal with the 45-m antenna). Then, by way of the program committee, a radio expert committee finalizes the observation proposal to be employed for common use.

A correlation station established on NAO's Mitaka campus performs J-Net correlation processing⁽⁷⁾. A major task of this station is to support VLBI observations associated with VSOP satellites, and it therefore uses other VSOP recording equipment associated with international VLBI observations to carry out correlation processing of recorded data. First, however, the correlation station sends out magnetic tapes to each observation station once J-Net observation schedules and the required number of tapes for each station have been decided. The stations then perform the observations according to schedule, and on completion, return the tapes to the correlation station. In this process, observation schedules prepared by the observers in question are checked and modified as needed by VEG, and once finalized, are stored on a server on the computer system of the Mitaka correlation station. The observation manager at each station then downloads the observation schedule for his site by File Transfer Protocol (FTP), and each station proceeds to make its observations in an independent manner. On completion, the observation manager at each station uploads the site's observation log by FTP to the server at the Mitaka correlation station. Correlation processing can now be performed at the correlation station using information from the observation schedules and observation logs stored on the server. Finally, correlation data resulting from correlation processing is recorded on magnetic tapes in Flexible Image Transport System (FITS) format for each observation item and handed over to the observers. The observers, in turn, determine the images and positions of celestial bodies using analysis software like the Astronomical Image Processing System (AIPS).

Before the deployment of the Mitaka correlation station in 1996, correlation processing was performed one baseline at a time by the New Advanced One-unit Correlator (NAOCO) set up at NAO's Mizusawa Astrodynamics Observatory⁽⁸⁾. At that time, data resulting from correlation processing was not processed directly by AIPS or the like but rather analyzed by software created by each observer at his own expense.

4. J-Net Achievements and Common Use

J-Net is engaged in project-oriented observations and common-use observations. An example of the former is the monitoring of water maser sources in high-mass star formation areas like Orion-KL and in late-type stars. In this monitoring of water maser sources in Orion-KL, VLBI observations are performed over a short span of one to two months and maser spots having a velocity width of about 100 km/s are traced. In December 1997, right in the middle of such observations, a velocity component with $V_{lsr}=7.9$ km/s gave rise to an outburst reaching 3.5 million Jy by September 1998. The position of this velocity component was determined within one arc second using J-Net⁽⁹⁾. In conjunction with this research, it was found that 46% at maximum of this velocity component was linearly polarized⁽¹⁰⁾.

Main results of common-use observations are as follows. First, with regards to results of KNIFE and early J-Net, the velocity distribution of a water maser associated with protostar IRAS1693-2422 led to the discovery of a molecular gas disk that was rotating around and falling into the protostar⁽¹¹⁾. Next, it was found that line-of-sight velocities in water maser spots around late-type star RT-Vir change linearly⁽¹²⁾. This was not well understood in the period before this discovery since other maser spots that would happen to have the same velocity could not be resolved by a single telescope. With VLBI, however, the resolving of individual maser spots made it possible for the first time to trace changes in velocity. Also, in the course of VLBI observations of maser spots around late-type stars, compact components of maser spots that cannot be resolved by a 1300-km baseline were detected⁽¹³⁾. (For details on these results of common-use observations, please see the article by Hiroshi Imai in this special edition.) Other J-Net research that should be mentioned is that associated with the VLBI Exploration of RadioAstrometry (VERA) project now under construction by NAO. This project aims to apply a relative VLBI technique to use the positions of active galactic nuclei like quasi-stellar objects (QSOs) as reference points and measure the positions of maser sources within the Milky Way Galaxy to a precision of 10 microarcseconds. It also aims to determine trigonometric parallax and proper motion so as to investigate the distribution of maser sources in the Galaxy⁽¹⁴⁾. Here, however, if no VLBI continuous radio sources like QSOs can be found near maser sources, the number of maser sources in the Galaxy that can be measured will be limited. For this reason, a survey of VLBI radio sources was conducted using J-Net⁽¹⁵⁾. In this survey, 267 candidate sources were measured and fringes with $S/N > 5$ were detected in 93, and among these, 51 turned out to be sources for which fringes were again confirmed. In this kind of survey, ongoing observations are necessary, and in actuality, observations continue. Finally, a brief note on J-Net contributions that might not be readily apparent should be made here. J-Net has contributed to the realization of the VLBI Space Observatory Program (VSOP) through the development of ground observation facilities

applicable to VSOP and through trial observations and experiments using such developed VLBI equipment. And in the future, the importance of J-Net should increase all the more as it becomes a ground-based VLBI observation network for the VSOP2 project targeting shortwave deep-space VLBI.

5. Summary

As a Japanese domestic VLBI network for common use, J-Net has contributed to advances in VLBI astronomy elucidating in particular the structure of water maser sources in star-forming regions, late-type stars, and active galactic nuclei, and the physics of active galactic nuclei. The J-Net has also contributed to the nurturing of VLBI researchers in Japan. For the future, we can expect J-Net to function as an important VLBI network with a solid foundation in Japan, and to enter a whole new era when the VERA project now under construction by NAO becomes available for common use.

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