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IV. RELATED RESULTS AND ACTIVITIES IN WESTERN PACIFIC VLBI NETWORK

IV.4 RADIO ASTRONOMY WITH THE KASHIMA 34 M ANTENNA

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ABSTRACT

CRL's 34 m antenna at Kashima which is equipped with low noise receivers which operate from 1.5 GHz to 43 GHz, covers most of the radio astronomical bands in this frequency range. The antenna has extremely accurate surface panels and is highly efficient even on the millimeter wavelength. Many kinds of single dish observations and radio astronomical VLBI observations have been performed. Domestic VLBI experiments between the Kashima 34 m and the Nobeyama 45 m antennas are called KNIFE and are highly sensitive on the short centimeter and millimeter wavelengths. VLBI experiments between the Usuda 64 m and the Kashima 34 m antennas were called UKAI and are highly sensitive on the 2 GHz and 8 GHz bands. This paper reviews published work on radio astronomy by using data obtained from the 34 m antenna at Kashima. The results of observations of astronomical masers, extragalactic radio continuum sources, pulsars, and interplanetary scintillation (IPS) observations are presented.

Keywords: radio astronomy, antenna, VLBI, time and space

1. Introduction

The Kashima 34 m antenna (Fig. 1) was built in 1988 as the central station for the Western Pacific VLBI network. The antenna is equipped with low noise receivers cooled with gas-helium refrigerators and has a band range from 1.5 GHz to 43 GHz. The surface accuracy is 0.17 mm (rms) at 45 degree elevation. The pointing accuracy of 0.002 degree (rms) enables the antenna to perform well on the millimeter wavelengths. Details of the 34 m antenna were described by Takaba et al. (1990)[1]. Although the original antenna had 300 MHz and 600 MHz feeds at the prime focus, we removed them in 1993 because it was very difficult to use these bands due to the effect of the strong interference signals. In addition we wanted to maximize the antenna's short wavelength efficiency.

Radio astronomy is one of the newest fields in astronomy and celestial radio waves from our galaxy were first detected in 1932. In recent years, the technology to construct large antennas and the

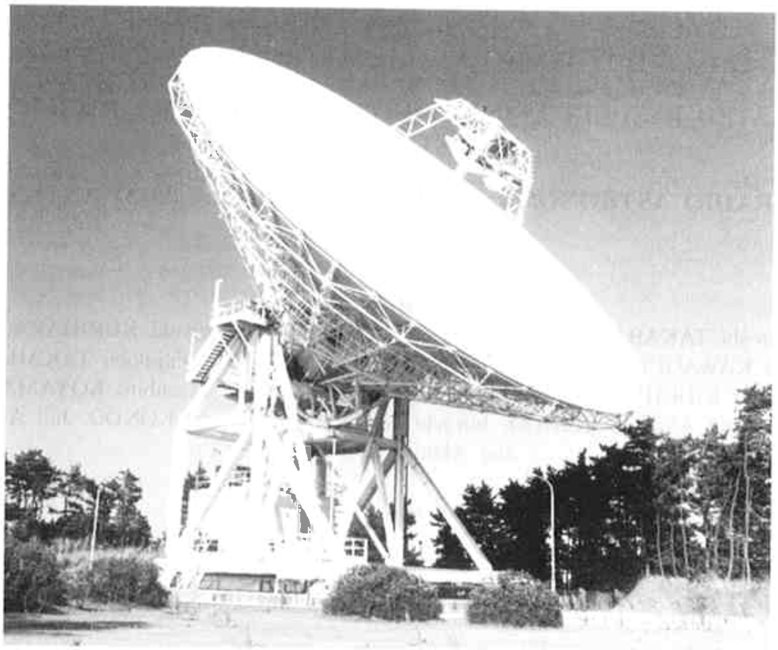


Fig. 1 CRL's 34 m antenna at Kashima Space Research Center

devices necessary to make low noise receivers has been developed, and our ability to detect very faint celestial signals has increased dramatically. Many new phenomena have been discovered and the study of the universe has been improved by the use of radio astronomy. Also, many new sources have been found, such as quasars which are very compact and emit very strong signals, pulsar which emit very accurate pulse-like signals, and other sources which have very strong maser lines. Besides their importance for radio astronomy, these objects are also very important because they are related to the measurement of time and space. This paper also introduces some of the applications of radio astronomy for antenna measurements, time keeping, and for solar-earth science.

2. Maser Observations

The first maser phenomena was found in 1966 and it was the astronomical maser observed in the dense gas around the regions where massive stars are formed. This discovery led to the study of artificial maser and laser physics. Details of astronomical masers were reviewed by Elitzur (1992)[(2)].

More than 100 interstellar molecules and ions have been discovered so far and of those about 10 molecules have maser transitions. Observations of such the interstellar molecular lines in the radio range provides us with data concerning the invisible dense gas in dark clouds, the mass losing red giants, the very young stars, and the centers of the galaxies.

The CRL 34 m antenna is capable of observing OH masers at 1.6 GHz, H_2O masers at 22 GHz, and SiO masers at 43 GHz bands. Maser comes from very small regions that are only measured by VLBI observations and they are considered to be point sources. Also, some maser sources are detected more than 100 K antenna temperatures by the large antennas. These maser sources can be

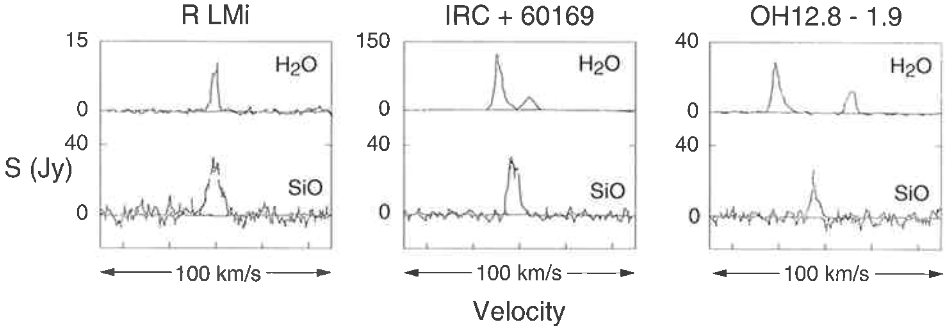


Fig. 2 (a) H_2O (upper) and SiO (lower) maser spectra in a Mira Variable, (b) an IRC/AFGL object, and (c) an OH/IR star. The data was obtained after 10 minutes integration by the 34 m antenna at Kashima using AOS.

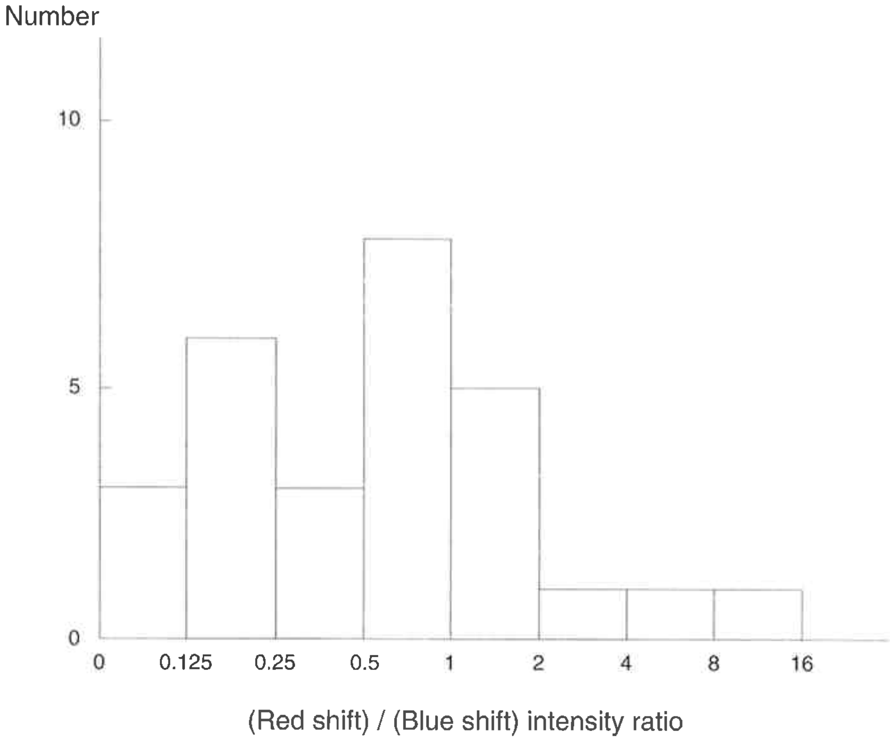
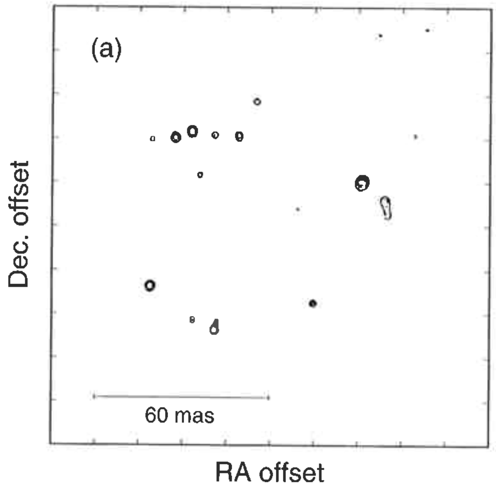


Fig. 3 Number distribution of the (Red-shifted)/(Blue-shifted) integrated intensity ratio for H_2O maser sources with separated peaks.

used to calibrate the pointing of the large antennas. By observing H_2O maser sources on the 22 GHz bands, Takaba (1991)[3] obtained the pointing parameters of the 34 m antenna within an accuracy of 0.002 degree (rms).



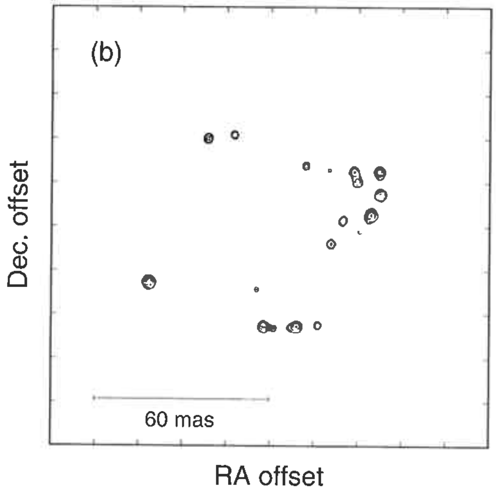


Fig. 4 Spatial distribution of SiO maser emission for W Hya for (a) the J = 1 – 0, v = 1 and (b) the J = 1 – 0, v = 2 transitions.

Single dish maser observations are done using an acousto-optical spectrometer (AOS) developed in Nobeyama and the 34 m antenna at Kashima. The H_2O maser survey at 22 GHz was started in 1991, and of the almost 900 infrared sources observed, 200 sources had H_2O maser emission, and about 50 sources were new detections(4). By comparing the 22 GHz H_2O maser and 43 GHz SiO maser emissions of almost 300 known late type stars, Takaba et al. (1994)(5) found a systematic change in the H_2O maser spectra which can be used to trace the evolution of the late type stars (Fig. 2). These spectral changes can be explained by the collisional excitation of the H_2O molecules and the beaming effect taking into consideration the velocity fields of the gas surrounding the late type stars. The authors also found that the blue shifted emission was stronger than the red shifted emission in most sources which exhibited double peaked H_2O maser emissions (Fig. 3), and proposed the blocking effect with their beaming model. VLBI observations between the Kashima 34 m and the

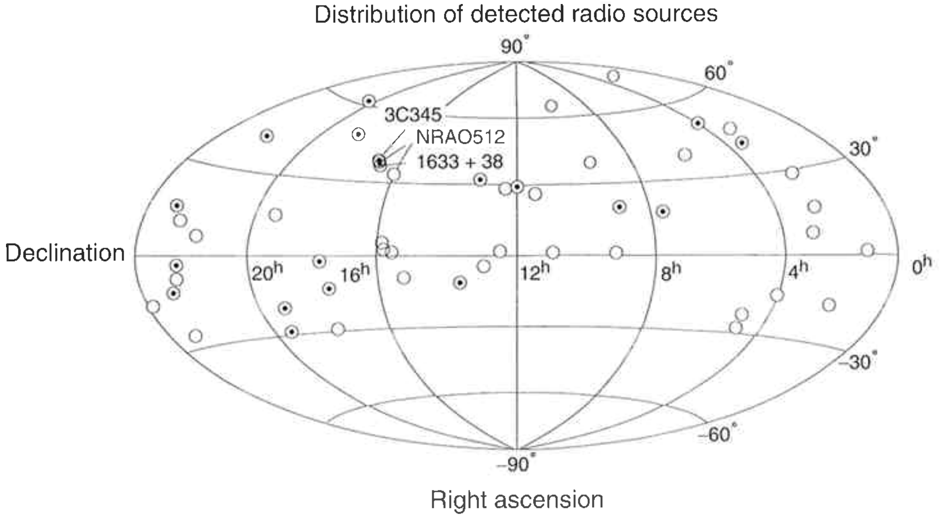


Fig. 5 Sky distribution of strong radio sources detected with KNIFE. Open circles represent the sources detected at 22 GHz, and dotted circles represent those detected at 43 GHz.

Nobeyama 45 m antennas are called KNIFE. Observations of H_2O maser in late type stars using KNIFE[6] show that the red shifted emission is highly resolved compared to the blue shifted emission. This result supports the idea of the blocking model.

Miyoshi et al. (1993[7], 1994[8]) observed SiO maser in late type stars using KNIFE. Two different transitions SiO(J = 1 − 0, v = 1) and SiO(J = 1 − 0, v = 2) were observed simultaneously and the results show that the two maser lines come from almost the same region (Fig. 4) which suggest the collisional excitation model. Since the two lines are about 300 MHz apart, we may use the band synthesis method by observing the two lines simultaneously. Then we may be able to obtain the absolute position in milli-arcsecond resolution. If this is true, we should be able to trace the galactic rotation by observing late type stars in our galaxy.

Strong H_2O masers are also found in star forming regions. Iwata et al. (1993)[9] reported the results of VLBI experiments using KNIFE. The maser emitting regions are found to be very close to the infrared source in dense molecular clouds.

3. Radio Continuum Observations

Quasars are very compact strong radio sources which are far from our galaxy. Recent studies indicate that quasars are the proto-galaxies which was created at the first stage of the universe and that they have massive black holes at their centers. There is considered to be a dense gas disk surrounding the black hole and some infall gas accelerating outwards, while its large gravitational energy is released. The mechanism is still unclear and the study of quasars is considered to be of major importance in order to investigate the evolution of the universe. Some quasars eject jet-like components from their cores and superluminal motions were detected in several sources. Strong quasars tend to have large time variation and it is thought that in such quasars the disk is face on to us and that the coming jets have strong radio intensities which peak at the millimeter wavelengths.

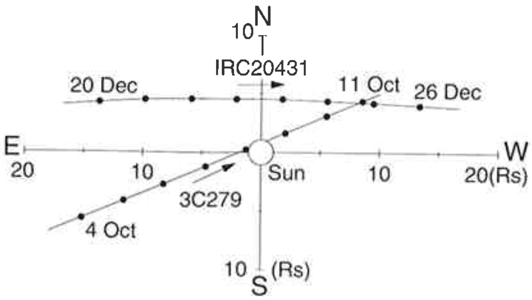


Fig. 6 The position of the radio sources, 3C279 and IRC 20431 relative to the sun as seen from the earth. 3C279 was observed at 2/8 GHz. IRC 20431 is an H_2O maser source and was observed at 22 GHz.

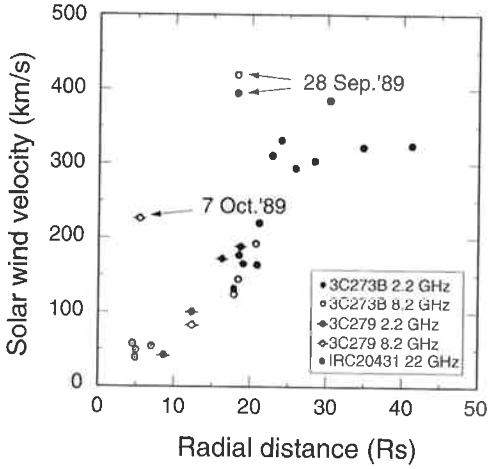


Fig. 7 The estimated solar wind velocity from the scintillation observations versus the radial distance from the sun.

Compact steep spectrum (CSS) objects are quasars with radio quiet spectrum(10). Kameno et al. (1993)(11) and (1994)(12) observed CSS objects by KNIFE and reported the existence of the flat spectrum component at the central core of the sources. These results indicate that active cores also exist at the center of the CSS objects.

VLBI experiments for geodesy need wide bandwidths to obtain more accurate time delays. The ordinary geodesy VLBI experiments are carried out on the 2 and 8 GHz bands because those two bands are installed in most of the large antennas which use satellite communications. To obtain a wider bandwidth, higher frequency VLBI is required. The 22 GHz band should be the candidate frequency for wide bandwidth VLBI observation. Matsumoto et al., (1994)(13) surveyed strong radio continuum sources on the 22 GHz and 43 GHz bands using KNIFE and selected candidates for the geodetic VLBI on the 22 GHz band. The sky distribution of the strong radio sources on the 22 GHz and 43 GHz bands is found to be almost uniform (Fig. 5).

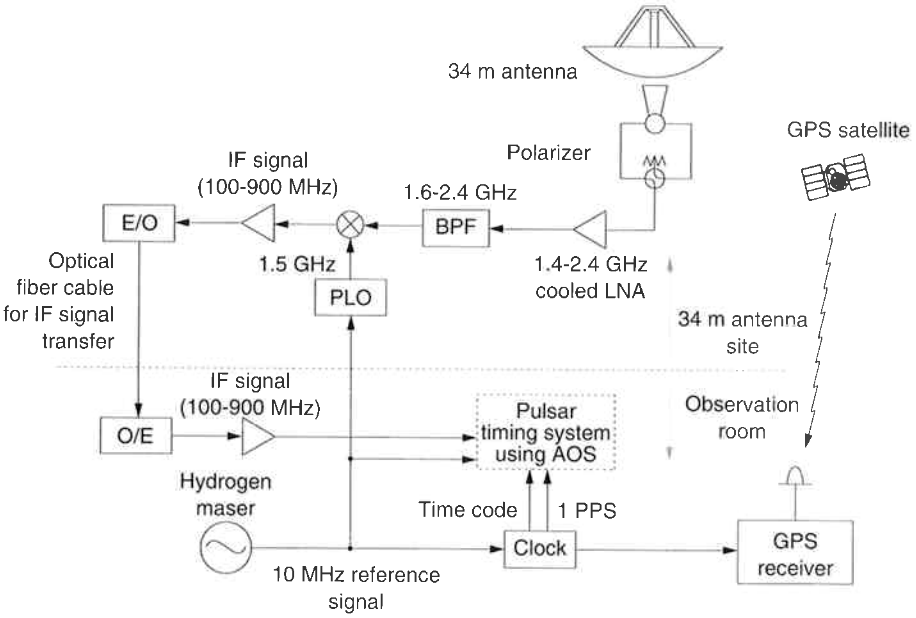


Fig. 8 New pulsar timing observation system developed by CRL. GPS receiving system and Hydrogen maser are used for precise time comparison.

4. Interplanetary Scintillation Observations

Quasars and maser sources are strong point sources in radio wavelengths and if we observe the intensity changes of the sources, we can determine the physical parameters of the interstellar medium. Interplanetary scintillation observations use sources which are distributed near the elliptic and observe the scintillation when the sun passes close to the sources.

By using the 34 m antenna, Tokumaru et al., (1991)[14] observed quasars on the 2 and 8 GHz bands, and H_2O maser sources at 22 GHz band (Fig. 6). The results show that there is a good correlation between the distance from the sun and the scintillation index. The derived solar wind velocity correlates well to the radial distance from the sun (Fig. 7). Also, some fluctuation in the acceleration near the sun is found. The observations are being continued for one solar activity cycle (11 years) and will produce new evidence that can be used to study the solar wind acceleration mechanism.

5. Pulsar Observations

Pulsars are rotating neutron stars and emit pulse-like signals. The newly discovered pulsars called millisecond pulsars have very stable pulse periods, in the order of milliseconds.

Most of the pulsars lose the rotation kinetic energy due to their interaction with the magnetic fields and the periods become longer. However, the millisecond pulsars are found to be the binary system and had been accelerated by obtaining the angular momentum from the companion star in the mass accretion process.

The millisecond pulsars are very old pulsars (they are thought to be more than 10 million years old) and the stellar systems are very stable, which results in very precise periods of rotation[15]. According to recent observations, the long-term stability of the millisecond pulsars is considered to be as stable as the atomic clocks on earth[16], and they may be even more stable than atomic clocks over longer time-scales (longer than 10 years). CRL has started pulsar timing observations in order to establish universal time keeping by using the millisecond pulsars[17].

The pulsar timing observation system developed at CRL is described by Hanado et al. (1994)[18]. This new system uses an acousto-optical spectrometer (AOS) to obtain a wide bandwidth (Fig. 8). Pulsars are also point sources, and they are good targets for VLBI observations. Hama et al., (1994)[19] reported the results of the pulsar VLBI observations between the Kashima 26 m and the Usuda 64 m antennas. The data obtained from pulsar VLBI observations will be useful for studying the physical characters of pulsars and also for radio astrometry because they are distributed throughout our galaxy.

6. Conclusion

Radio astronomical observations using the CRL's 34 m antenna are summarized. Maser observations, radio continuum observation, interplanetary scintillation observations, and pulsar observations are shown. These results show that in addition to the single dish observations, the contributions of the VLBI observations are very important for the study of radio astronomy and the application of radio astronomy for time and space measurements.

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