VLBI activities in Japan and East Asia

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Abstract: We review the astronomy activity using VLBI technique in Japan and East Asia region. VLBI is the most accurate observation tool for astronomy. Then it has revealed many interesting phenomea in the univerve. And Japan, China and Korea have good activities in this field. These are supported the high techonoloy leve of each countries. We also show the impact of the technology of communication, information science and computing.

1. Introduction

Radio astronomy was started at 1931 by the discovery of the radio emission from a celestial object (Janskey,1932) He found a stable radio emission object with 4 minutes earlier rising than previous day, which is radio emission from the center of the Milky way galaxy. Generally the radio emission is caused by the gas objects. Afterward, radio astronomy has discovered many important objects and phenomena; pulsar, micro-wave back ground emission, black hole objects and gravitation wave.

Early time of radio astronomy, special resolution was around a few degrees, which was very bad to identify the celestial object. But the invention of radio interferometer made large progress for the spatial resolution of radio astronomy observations. Radio interferometer is a kind of interferometer, which makes combinations among the element telescopes. Usually radio astronomy observations use coherent frequency conversion, which is called heterodyne technique. It makes easier to make interference of received signals. By the diffraction limits, spatial resolution is limited to λ/D (λ: observing wavelength, D: size of aperture). For the interferometer, D is equivalent for the distance of element telescopes. Then shorter wavelength and larger separation between element telescopes make higher spatial resolutions. If received signals of the element telescopes are sent by using cables, the separation distance of the element telescope are limited. The maximum size of radio interferometer combined by calbes is 27 km, which is VLA(Very Large Array) in New Mexico of U.S.A. Typical special resolution of VLA is a few arc-seconds, which is almost same as optical observations. Spatial resolutions of optical observations are limited by the fluctuation of atmosphere.

2. VLBI Observations

In order to make higher spatial resolutions, longer distance between element telescopes are required. For it, VLBI(Very Long Baseline Intermeter) observation technique is invented in 1967 by Canadian and U.S.A. groups, individually. For the VLBI observations, wave form of received signals are recorded on magentic tapes and other media. They are shippped to one site and correlated each other. Then it is possible to make a interferometer between long separeted telescopes. For it, very accurate time synchronizations and stable frequency standard are needed. Nowadays GPS signals are used for the time synchronization and hydrogen maser oscillator is used for the frequency standard.

2. 1 Astronomy results by VLBI

From the invention of VLBI observation technique, many important results are obtained. VLBI observations has achieved a few mill-arc-second spatial resolution, which is 10 thousand times higher than human naked eyes. And VLBI has observed active galactic nuclus, which is thought as very massive black holes in the center of galaxies. And VLBI has showed the jet from active galactic nuclei has very fast jet, which appears as super luminal motions (Whitney, et al., 1971). It is caused by jet ejection with fast speed close to the light speed. And active jet phenomena was revealed. And VLBI has showed the evidence of black hole existence by measureing the mass of a celestial object (Miyoshi, et al., 1995). It measured the precise motions of a celestial object and obtained the dynamical mass. Because of high precision measurements by VLBI, these observations were realized. VLBI is the highest observation method at the point of spatial resolutions.

2. 2 VLBI observation system

For the VLBI observations, local oscillator for the frequency conversion must be locked to the frequecy standard at each site. Hydrogen maser oscillator has around 10^{-13} stability. Coherent time is usually around 100 to 10 seconds, which is mainly limited by the phase length fluctuations of atmosphere. Then it allows several hundred giga heltz observations. And GPS is used for the time synchronization with a few micro-second acuuracy. And digitized signals from the celestial objects are recorded on the magnetic tapes, hard disks and other medias. Currently highest recording rate is 1024 Mbps on tape and 4096 Mbps on disks. So VLBI observation technique requires modern technologies of digital and analog electronics.

Moreover data transimission by using optical fiber transmission began to be used. Optical fiber transmission has capability to tranfer much more data than tape recording and disk recording method. For example, 10 giga bit ethernet protocol becomes popular, which makes more than 5 Gbps rate. It is widest method for data transmission in usual applications. System development history and remarkable results are reviewed by B.G.Clark (2003).

2.3 History of Japanese activities

In Japan, RRL(Radio Research Laboratory, currently National Institute of Communication Information and Communication Technology) started the development of VLBI systems from 1974. They have developed K-1, K-2, K-3, K-4 and K-5 systems for data aquision and recording of VLBI. In 2003, K-5 system was developed, which has 1024 Mbps recording rate on hard disks with 2 or 1G sample per second samplig rate. In 1985, RRL group succeeded to detect of plate motion between Japan and Hawaii. These developments are used for the geodesy observations by Geographical Survey Institute of Japan.

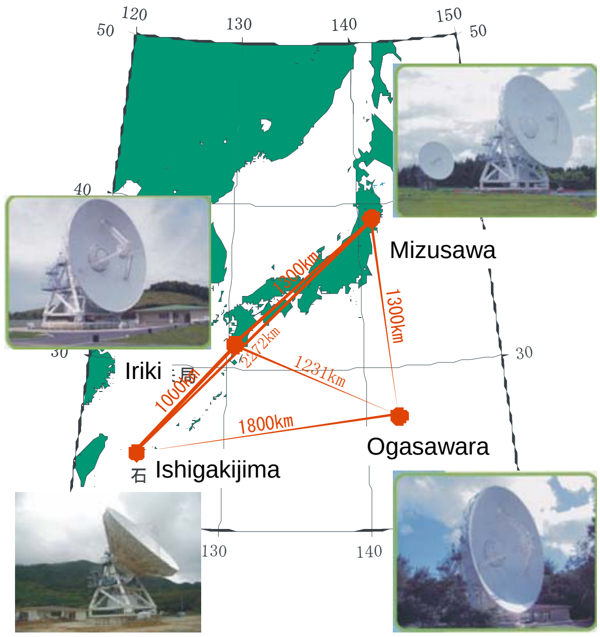
And Tokyo Astronomical Observatory(currently Nationa Astronomical Observatory of Japan) started the researches by using VLBI technique in 1981. Nobeyama 45-m radio telescope is a biggest millimeter-wave telecope in the world. Nobeyama group has joined millimeter-wave VLBI experiments with U.S.A and eupropian radio telescopes. Moreover Nobeyama group collaborated to develop the first space VLBI satellite (HALCA) and carry out the first space VLBI observations with Institute of Space and Astronautical Science. This satellite launched in 1997 with 8-m diameter deployable antenna and 128 Mbps data transmission. It revealed the fine structure of AGN jets , especially bending motions, and other important results were drawed down. And in 2000 NAOJ has stared the VERA project, which is the first phase referencing VLBI array for precise astrometry observations. It has reached highest accuracy to determine the position of celestila objects. Also NAOJ and ISAS group succeeded the VLBI observations with optical fiber transmission in 1996 under the collaboration with NTT(Nippon Telephone and Telegram). It has 256 Mbps data transmission rate on ATM network . And VERA and other Japanese VLBI stations established Japanese VLBI network in 2005. It has 9 VLBI stations in Japan. Four of them are connected by optical fiber networks with 2.4 Gbps data transmission.

3. Current Japanese Activities

As mentioned at 2.3, Japan has long history and good activities in the field of VLBI researches. Brief introductions of VERA , Japanese VLBI network and optical fiber linked VLBI projects are mentioned below. They are very unique and cutting-edge projects.

3.1 VLBI Exploration of Radio Astrometry(VERA) project

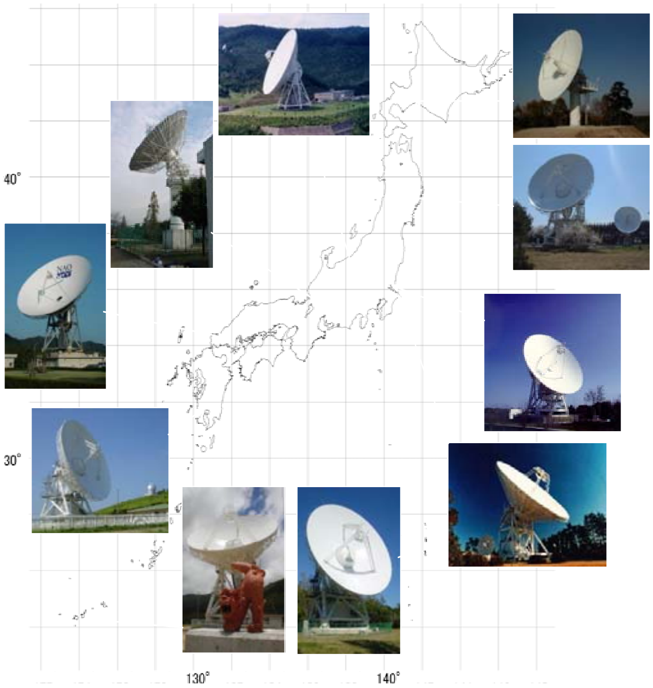
VERA aims astrometry observations using phase referencing VLBI techniques, whose goal is 10 micro−arc-second accuracy for trigonometric parallax measurements. VERA has four 20-m diameter VLBI radio telescopes in Japanese archipelago with the 2,300 km maximum baseline length. They are located on Mizusawa of Iwate prefeture, Iriki of Kagoshima Prefecture, Ogasawara of Tokyo metropolitan, and Ishigakijima of Okinawa prefecture (Figure 1). They have the two-beam observing system, which makes two-object simultaneous observations possible. It is first applications for actual astronomy observation system. Then it leads very accurate phase referencing VLBI observations. An important science goal is to make the 3-dimensional map of the Galaxy and reveal kinematical fields of the Galaxy. In order to it, VERA has 22GHz and 43GHz observing band for H_2O and SiO maser objects, respectively. Maser objects have compact structures and strong emissions. Then it is suit for astrometry observations. The fringe resolution of VERA is 2 milli-arc-second at 22 GHz and 1 milli-arc-second at 43GHz. In order to achieve a few micro-arc-second accuracy, around 1% of fringe resolution is required for the detemination of celestial objects. Then very precise calibration of path length are required. Around 4-mm accuracy was achieved for the path length calibration of the telescope and telescope positions. VERA has started the construction from 2000 and become operational from 2004. We have already measured annual parallaxes and proper motions for some galactic objects.



Figiure 1, VERA station distributions

3.2 Japanese VLBI network (J-Net)

Japan has 15 VLBI stations, which are used for astronomy and geodesy researches. In 2005, ten of them were organized as Japanese VLBI network. They consist of Tomakomai, Mizusawa, Kashima, Tsukuba, Usuda, Gifu, Yamaguchi, Iriki, Ishigakijima, and Ogasawara stations (Figure 2). One 64-m telescope, three 30-m class telescopes and four 20-m class telescopes are used, which is one of most sensitive VLBI arrays. Observing frequencies are mainly 8 and 22 GHz. Spatial resolutions of it are 10 milli-arc-second at 8GHz and 2 milli-arc-second at 22GHz. And observations sensitivity is around 10^7 K in brightness temperature. Current recording rate is 128 Mbps and will be extended to 1Gbps in near future. In this network, four research institutes and 5 universities are involved. And in 2008, two 32-m radio telescopes in Takahagi of Ibaraki prefecture and Ibaraki university will be involved.



Figire 2, Distrubition for J-Net

3,3 Optical fiber network of J-Net

Four telescopes of J-Net are connected by the optical fiber network. They are Kashima 34-m, Tsukuba 32-m, Gifu-10m and Yamaguchi 32-m radio telescopes. Data transmission rate is 2.4 Gbps for each telescope. This is the highest rate for this kind of applications. Data are transmitted to Mitaka, which is main campus of NAOJ, and correlated by a real-time VLBI correlator. It makes possible for very sensitive observations. Around 10^5K in brightness temperature is achieved. And in this year, Tomakomai 11-m telescope of Hokkaido prefecture will be connected. And test of L1 on demand connection will be started in this year, which is convenient to use common network. Because VLBI observation is carried out for around 10 days in a month and data transmission rate could be variable. Adopted data transmission observations due to the traffic of the network will be started for tests.

4. Other VLBI activities in East Asia

4.1 Korean VLBI Network (KVN)

Korean Astronomy and Space Science Institute (KASI) is constructing a new VLBI array, which has three 21-m radio telescopes at Seoul, Ulsan and Jeju (Figure 3). They will be operated at 22, 43, 86, and 126 GHz simultaneously.

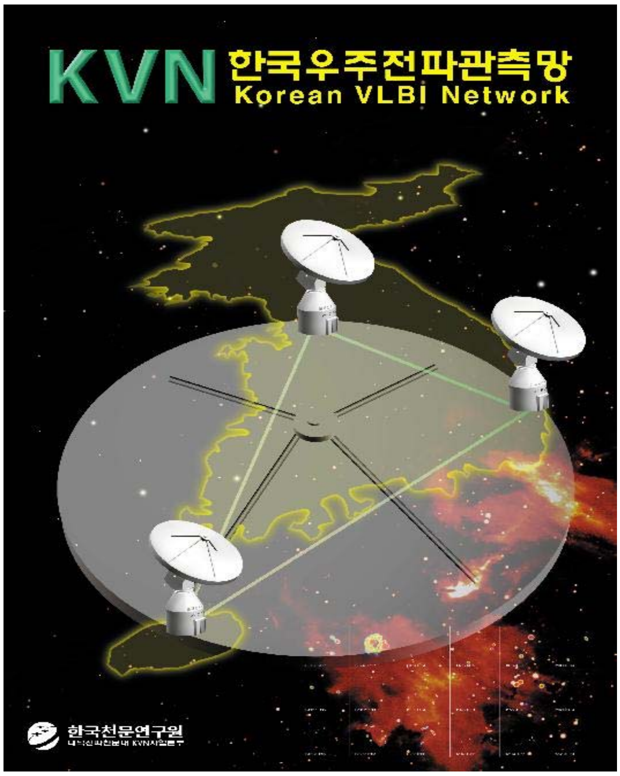


Figure 3 ; KVN telescopes array

It could make phase referencing observations. KVN will be most sensitive VLBI array at 3 millimeter wave length. It will be finished the construction in 2009.

4.2 Chinese VLBI Network (CVN)

China also has good activities of VLBI researches. There are four VLBI stations where Shanghai, Urumqi, Beijin, and Kumming (Figure 5). Main observation frequency is 2, 8, and 22GHz. New real-time and non-real-time correlators were constructed for the tracking of lunar satellite (Chang'E), which was launched in 2007. VLBI uses for the satellite navigations and orbit of Chang'E has determined after 30 minutes from observations.

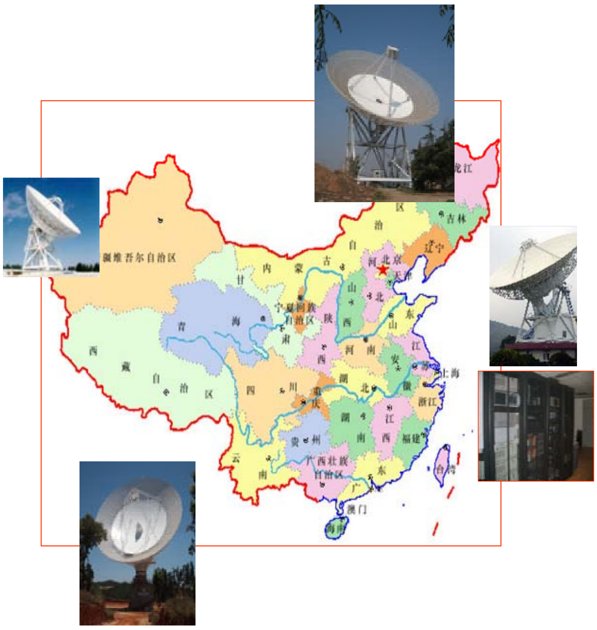


Figure 4, CVN station distributuion

4.3 East Asia VLBI network (EAVN)

East Asia VLBI network is organized as a combination of J-Net, KVN, and CVN (Figure 5). It has around 6,000 km and 40 km baseline length at maximum and minimum, respectively. And it has 18 stations, which is the largest number of VLBI array in the world. This network is organized under East Asia Core Observatory Associations (EACOA). Currently test observations with J-Net and CVN have started. It is expected as one of the major VLBI network. EAVN will have $10^{6\text{-}7}$K brightness temperature sensitivity. Then it will be a good astronomy observation facility for active galactic nuclei and other non-thermal

Figure 5; EAVN station distribution

emission object like pulsar, jet of star forming region and super nova remnants. And also it is expected as a ground array for VSOP-2. NAOJ and KASI started to develop a new correlation facility with 16 station input with 8Gbps each at Seoul.

5. Conclusion

The activities in Japan, Korea, and China at the field of VLBI research are introduced. They have unique and important activities. East Asia area has the largest number of radio telescopes in the world. These activities are based on the good status of electronics technologies in this area.

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