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Japanese radio astronomy—Past, present, and future

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Abstract. The past, present and future of radio astronomy in Japan are described from the author's personal view point. The radio astronomy in Japan is quickly growing in terms of the telescope size, the budget scale, and the total number of researchers in the country. Profiles of pioneers and predecessors in radio astronomy in Japan are briefly mentioned. Fields of researches pursued in the major radio-astronomy institutions with small and large radio telescopes are also described. The status of the major future projects such as VSOP, VERA, LMSA, and the submillimeter-wave telescope at Mt. Fuji is reviewed.

Key words : radio astronomy—future projects

1. Introduction

Radio astronomy in Japan is now rapidly expanding in terms of the number of researchers, the budget, the research fields. This tendency has been created since 1980 by the efforts of predecessors in Japanese radio astronomy, partly owing to an economic success of the Japanese industry. These predecessor's works are based on the previous efforts of pioneers of radio astronomy in this country during and after the World War II (for the early history, see Tanaka 1984).

One of the most famous pioneers in this field was Shuji Yagi, an inventor of Yagi Udagawa antenna, a founder of the Engineering school of Tohoku University, president of the Tokyo Institute of Technology, and a member of the House of Councilors after World War II. As early as in 1936, soon after the discovery of cosmic radio signals by Carl Jansky in 1933, he made a recommendation to the Ministry of Education, Science and Culture, Japan, to develop radio-wave observation facilities in Tokyo Astronomical Observatory of the University of Tokyo (former National Astronomical Observatory).

One of the pioneers in the other stream was Minoru Oda, a founder of X-ray astronomy. Soon after World War II, he built a radio telescope to detect radio emission from the sun at 3.3 GHz in Osaka University. Since he quickly shifted his interest to X-ray astronomy and became a founder of X-ray astronomy in U.S. and Japan with his modulation collimator, the radio astronomy was pursued by his collaborator, Tatsuo Takakura, working in the same university at that time who later became a professor in Tokyo Astronomical Observatory. Further, this stream of solar radio astronomy had been expanded by Keizo Kai, who founded the Nobeyama Solar Radio Observatory in 1970. It is a pity that Kai did not live to see the completion of the 17 GHz radio heliograph.

Another stream of pioneers in Japan was created after the World War II by Takeo Hatanaka, a professor of the Department of astronomy, University of Tokyo. In collaboration with Kenji Akabane, he made the 24-m spherical ground-fixed telescope to observe the HI 21 cm line in the Galaxy. His death at the age of 49 by a heart-attack shrunk the cosmic radio field and funding. The real start of observational cosmic radio astronomy at mm-wavelengths in Japan had to wait till the construction of the 6-m mm-wave telescope in 1969 by Kenji Akabane, Masaki Morimoto and Norio Kaifu. Though the 6-m mm-wave telescope could not facilitate very sensitive receivers and also suffered from a heating problem by sun light, it gave a number of fruits as detections of several interstellar molecules such as CH_3NH_2 and para-H_2CO at around 70 GHz region for the first time in the world. These discoveries lead to ripen the science of molecular radio astronomy in this country. Strong characters of M. Morimoto and N. Kaifu were enough to attract a number of young scientists to be involved in this field and to obtain funds to build the 45-m radio telescope and the five element mm-wave interferometer (FEMIN) in Nobeyama. The first director of Nobeyama Radio Observatory, Haruo Tanaka, was also the other pioneer of radio astronomy coming from Toyokawa Research Institute of Atmospherics, University of Nagoya. Unfortunately he died soon after his retirement of the directorship at Nobeyama Radio Observatory. One of his unpublished works was the detection of the cosmic background radiation prior to that of Penzias and Wilson in 1965 (see the article in Tanaka 1984).

Radio astronomy was one of the minor fields in astronomy in Japan before 1980. The total number of radio astronomers in Japan was less than 20 when Nobeyama Radio Observatory was created. Nobeyama was funded in 1979, and was separated from the University of Tokyo in 1988. It then became a branch of the National Astronomical Observatory which was created at the same time from the former Tokyo Astronomical Observatory. This is a major centre of radio astronomy in Japan.

2. Present status

At present, about 50 radio astronomers occupy research and teaching positions in Japan. About 4 graduate schools offer a Ph. D. course in radio astronomy: Advanced University (Nobeyama Radio Observatory), University of Tokyo (Institute for Astronomy), University of Nagoya (Department of Astrophysics), Ibaraki University (Physics Department). Also it is possible for students from other universities to study radio astronomy by staying temporarily in the above-mentioned graduate schools. They can earn Ph. D. degrees (with an agreement from their home institutions). Table 1 and Fig. 1 summarize the major radio astronomy groups and telescopes in Japan. Various fellowships and scholarships are provided for foreigners to perform research in these institutions by the Ministry of Education, Science and Culture, Japan Society for Promotion of Sciences, and the other private foundations several times a year (the contact must be made through host scientists; note that Japanese academic year starts from April).

Radio astronomy in Japan is heavily tilted towards molecular radio astronomy at mm-wave lengths for historical reasons, but the other areas of radio astronomy such as the cm- and m-wavelength astronomy, planetary radio astronomy, pulsar radio astronomy, and radar astronomy, have almost been neglected. This tendency seems to be created because most of the professional radio astronomers were graduates of the University of Tokyo (and Nobeyama) school of radio astronomy where prime emphasis was laid on the molecular radio astronomy.

Nobeyama Radio Observatory (Fig. 2) was separated from University of Tokyo in 1988 and became one of the branches of National Astronomical Observatory, directly operated by Ministry of Education, Science, and Culture. Nobeyama is the biggest radio astronomy group in Japan in terms of the budget, telescopes, and the number of researchers. This observatory involves approximately 25 research astronomers, 5 post-doctoral research fellows, 15 graduate students, and 10 engineers. The fields of researches being pursued here are searches of new interstellar molecules, study of star forming regions with molecular lines, high spatial resolution observations of circumstellar envelopes of evolved stars, study of active galaxies by CO lines, and theoretical studies of the magnetic fields in star forming regions. Nobeyama Radio Observatory has also a big engineering group, which is developing SiS mixers in a tight collaboration with Japanese industry.

Nobeyama Radio Observatory is an inter-university research institute. This means that the observatory is a service institute to provide facilities for researchers in universities as well as to pursue their own sciences in radio astronomy. About 2000 hours of telescope time per year are shared by all researchers who apply for the observing time. Proposals are examined by 7 referees under the auspices of the telescope committee. The proposals are accepted twice a year (deadlines are normally June and October) for the 45-m telescope and once a year (in August) for millimeter-wave array. Normally they are oversubscribed by a factor of three. About 20-30 per cent of the proposals come from foreign countries: U.S., European countries, China and Korea.

The other activity of the Nobeyama Radio Observatory is to participate in the VLBI Network, called KNIFE (Kashima-Nobeyama Interferometer). It consists of the Nobeyama 45-m telescope and Kashima 26-m antenna with the east-west baseline of separation of about 200 km. Observations at 1.3 cm and 7 mm, respectively, have successfully mapped the distributions of H_2O and SiO maser spots in evolved stars and galaxies. Mizusawa Latitude Observatory is the other centre for the VLBI study of the earth rotation and astrometery. They have a 10-m telescope and work in positional astronomy at S (~ 2 GHz) and X (~ 8 GHz) bands with U.S. network IRIS-A and Deep Space Network in NASA.

Table 1. Major Radio telescope facilities in Japan.

Institution (Organization)	Radio Telescope (Director, approximate number of astronomers)
Nobeyama Radio Observatory (National Astronomical Observatory)	45-m mm-wave telescope, 10-m six element mm-wave interferometer (M. Ishiguro, 50)
Nobeyama Solar Radio Observatory (National Astronomical Observatory)	Radio Heliograph (70-cm 80 elements) (S. Enome, 5)
Mizusawa Latitude Observatory (National Astronomical Observatory)	10-m radio telescope (dedicated to VLBI) (T. Sasao, 10)
Usuda Deep Space Station (Institute for Space and Astrophysical Sciences)	64-m Deep Space Antenna (H. Hirabayashi, 5)
Institute for Astronomy (University of Tokyo)	Two 60-cm submillimeter-wave telescopes (T. Hasegawa, 5)
Department of Astrophysics (University of Nagoya)	Two 4-m mm-wave telescopes (Y. Fukui, 5)
Centre for Sun and Earth Environment (University of Nagoya)	UHF radio telescope (M. Kojima)
Department of Physics (University of Kogoshima)	6-m mm-wave telescope (dedicated to VLBI) (T. Omodaka, and M. Morimoto)
Department of Electronic engineering (Kyushu Tokai University)	11-m radio telescope (K. Fijishita)
Kashima Space Communication Centre Ministry of Post and Telecommunications	34-m radio telescope (H. Takaba)
School of Education (Waseda University)	Wide Field Digital Radio Camera (T. Daishido)
Sugadaira Space Radio Observatory (University of Electrocommunications)	Solar wind scintillation antenna (100-m) (T. Yoshino)
Physics Department (Hyogo Medical University)	Decameter wave facility for Jupiter (K. Maeda)
Department of Physics (Ibaraki University	.... (T. Amano, 3)
Department of Education (Utsunomiya University)	.... (H. Tabara, 2)
Department of Astronomy and Earth Sciences (Tokyo Gakugei University)	.... (F. Sato, 2)

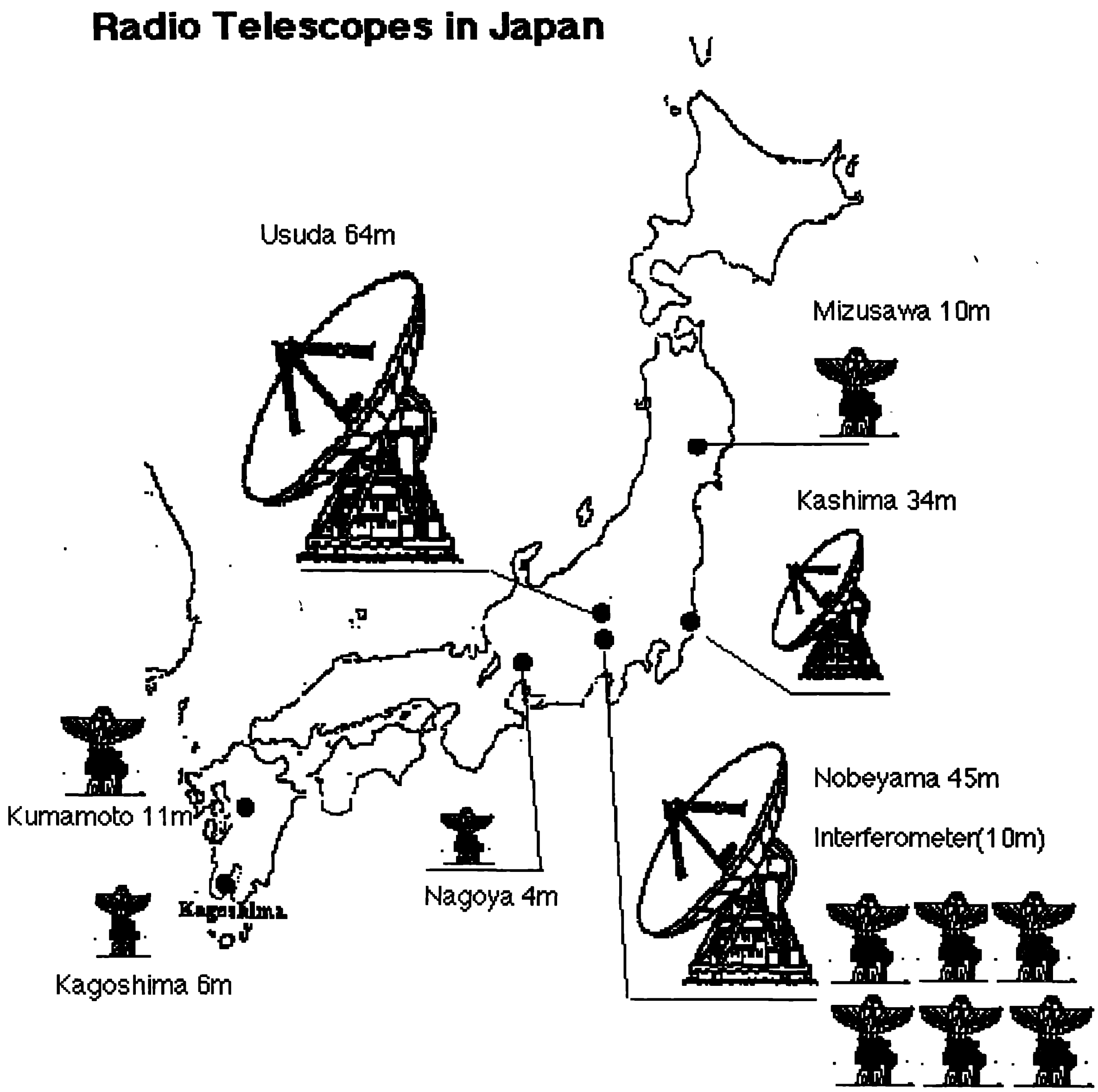
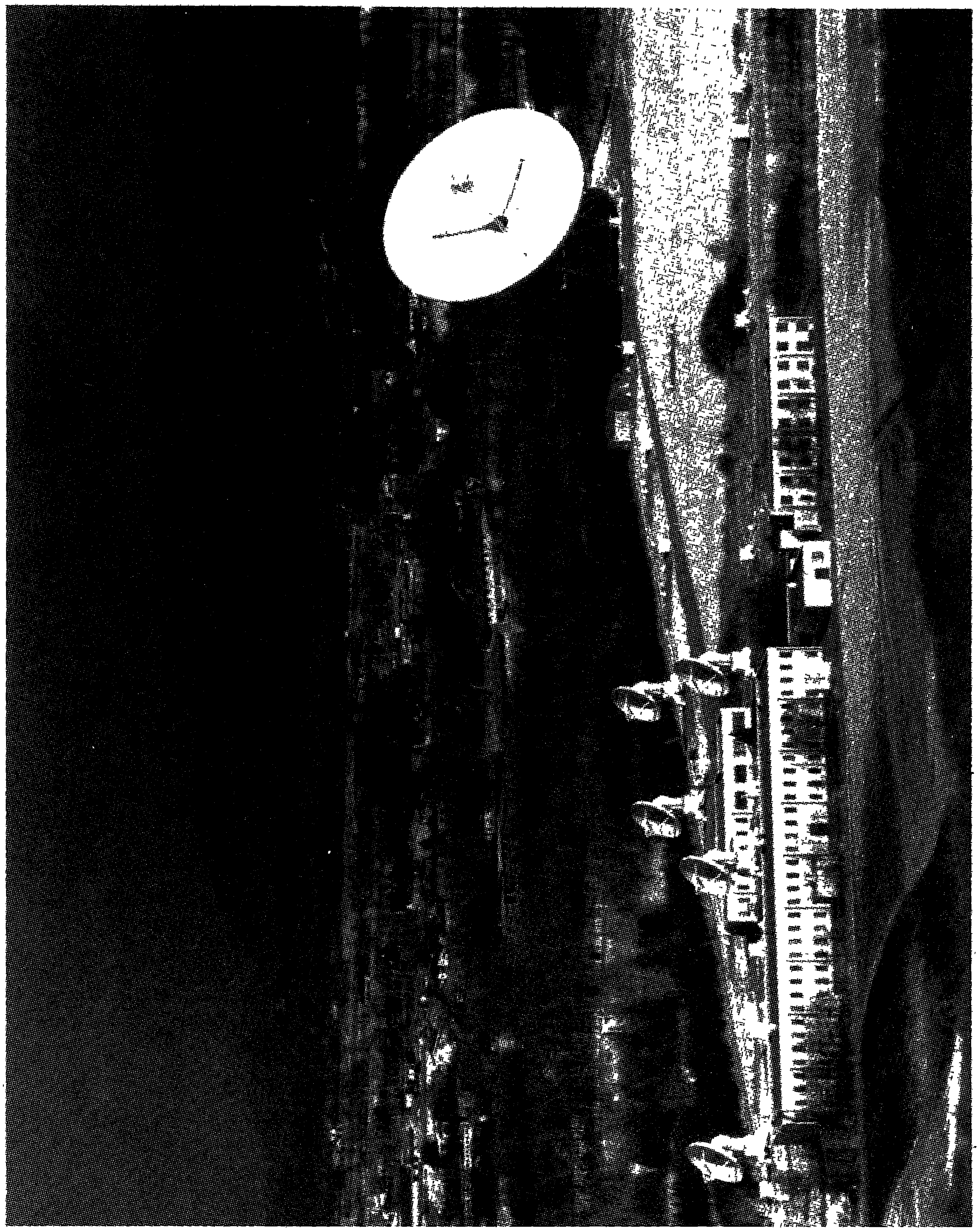

Radio Telescopes in Japan
Usuda 64m
Mizusawa 10m
Kashima 34m
Nobeyama 45m
Interferometer(10m)
Kumamoto 11m
Nagoya 4m
Kagoshima 6m

Figure 1.



Nobeyama Radio Observatory · Photo by Takizawa

One of the biggest groups in radio astronomy outside Nobeyama is in the Institute for Astronomy, University of Tokyo, directed by Prof. Yoshiaki Sofue. Dr. T. Hasegawa has operated the 60 cm offset-Cassegrain-focus telescope with a beam of about 20', mapping the CO J = 2-1 emission in the Galactic plane at 230 GHz. It is intended to be complimentary to the Columbia survey of the galactic plane by the CO J = 1-0 transition with the 1.2-m telescope. They have another copy of the 60-cm telescope in European Southern Observatory at La Silla, Chile, and are now trying to start observations of the Galactic plane in the Southern hemisphere. Another group in this institute is working on evolved stars. This group, directed by Prof. Takashi Tsuji, is trying to establish a unified view of the circumstellar matter of evolved stars by combining the radio data from the 45-m telescope and interferometric observations with the infrared spectra taken by IRAS and possible future data with the Infrared Space Observatory.

The other radio astronomy group is in the Department of Astrophysics, Nagoya University, directed by Prof. Yasuo Fukui. This group has two 4-m single-dish telescopes (not interferometer) for mapping the molecular clouds by ^{12}CO and ^{13}CO J = 1-0 lines. They have detected a number of bipolar objects in molecular clouds in Orion-Monoceros regions. This group plans to ship one of their 4-m telescopes to the European Southern Observatory, Chile.

The group in the Department of Physics, Ibaraki University, is recently created, and it is directed by Prof. Takayoshi Amano, a molecular spectroscopist, who has been transferred from the Herzberg Institute of Astrophysics, Canada. The department has started a new Ph. D. course from this year. Dr. Masato Tsuboi and Ken'ichi Tatematsu of this university are working on the Galactic centre region and the Orion Nebula.

In addition a few radio astronomers are also working in rather small departments of educational colleges, e.g. 2 in Utsunomiya University, 2 in Tokyo Gakugei University, and 1 in Waseda University. Though these colleges are not for pursuing researches in radio astronomy, their levels of research are quite high. Prof. Hiroto Tabara and Dr. Tatsuji Kato in Utsunomiya University are working on the continuum radiation from QSO and AGN. Prof. Fumio Sato and Dr. Hideyuki Izumiura in Tokyo Gakugei University are working on HI in molecular clouds and the circumstellar envelopes of evolved stars. Prof. Tsuneaki Daishido of Waseda University is using his survey telescope for studying transient objects. The other group in Kagoshima University was created recently by Prof. Masaki Morimoto, Prof. Toshihiro Omodaka, and Dr. Masatoshi Kitamura. They have rebuilt the 6-m telescope which was originally made in Tokyo Astronomical Observatory in 1969. They are working with VLBI at 1 cm on the Nobeyama-Kagoshima baseline.

3. Japanese style of scientific research

Search for new interstellar molecules

A group of radio astronomers and molecular spectroscopists, lead by Prof. Norio Kaifu (now in charge of SUBARU 8.3-m optical telescope project at National Astronomical Observatory) and Prof. Shuji Saito in Institute of Molecular Sciences, are interested in a molecular line survey.

They are working in the frequency ranges around 22 GHz, 45 GHz, and 80-110 GHz. They have completed the line survey in TMC-1 (a dark cloud), Sgr B2 (Molecular cloud near the galactic centre) and IRC + 10216 (a carbon star) and found about 300 unidentified lines. Utilizing a high spectral resolution of acousto-optical spectrometers available at Nobeyama (40 kHz per channel), they first concentrated their effort on the dark cloud, TMC-1, which has a typical velocity width of less than 1 km s^{-1}. They have identified a number of new molecules such as CCS, C_6H and HCCNC. The chemistry of carbon chain molecules in dark cloud has been revealed by these discoveries. However, their effort was stunted by the death of Dr. Hiroko Suzuki, a member of this group, by a car accident in 1987 (Suzuki 1989). Her effort was succeeded by Dr. Kentaro Kawaguchi and Dr. Yamamoto, resulting in discoveries of molecules such as C_3H, vibrationally excited C_4H, CCO, MgNC in the carbon star IRC + 10216 (see Fig. 3).

Study of SiO maser sources

One of the advantages of the Nobeyama 45-m telescope is that it is very sensitive in the frequency region of 45 GHz including the SiO $J = 1\text{-}0$ $v = 1$ and $v = 2$ transitions at 43.122 and 42.821 GHz. This frequency range is less influenced by climate and pointing errors (because of 41" beam at 43 GHz). Dr. H. Izumiura of Tokyo Gakugei University, in collaboration with Nobeyama and University of Tokyo groups, has made a large SiO maser survey of the Galactic bulge IRAS sources and detected SiO in 194 of the 313 observed sources. This database of SiO sources in the galactic bulge revealed that the average radial velocity of the bulge stellar system is negative by about -20 ± 8 km s^{-1}. This observation indicates that the local standard of rest is moving toward the galactic centre by that velocity, and that there exists a stellar streaming motion in the bar-like bulge (see Fig. 4). They also found that the radial velocity of northern bulge sources are systematically shifted to the radial velocity of the southern bulge sources, indicating a tilt of about 8° of the bulge rotation axis. The other important research in this field is the discovery of silicate carbon stars. Dr. Y. Nakada (Kiso Observatory, Univ. Tokyo) detected H_2O maser emission from the carbon star, V778 Cyg, establishing that the circumstellar envelope of the silicate carbon star is really oxygen-rich. The position of H_2O masers in V778 Cyg, which is measured by Nobeyama millimeter-wave array, was confirmed to coincide with the optical star within an accuracy of 1" (see review by Deguchi 1992).

Search for gas-dust disk in young stars

Stars must be formed in interstellar molecular clouds. An accrection of the gas with angular momentum naturally forms a disk around young stars, resulting in the much larger bipolar outflowing jets in the molecular cloud. In 1984, Prof. Norio Kaifu detected an elongated component in the CS J = 1-0 transition in L1551, which is oriented perpendicularly to the well known CO bipolar flow in this source. This discovery lead to the belief that we can detect the accretion disks of young stars by the CS lines. Contrary to this belief, accretion disks around young stars had not been confirmed for a decade. Prof. T. Omodaka of Kagoshima University predicted that a T-Tauri star, GL Tau, should have a disk around the central star and should be detectable in the CO J = 1-0 transition. This prediction was made at the open conference in the

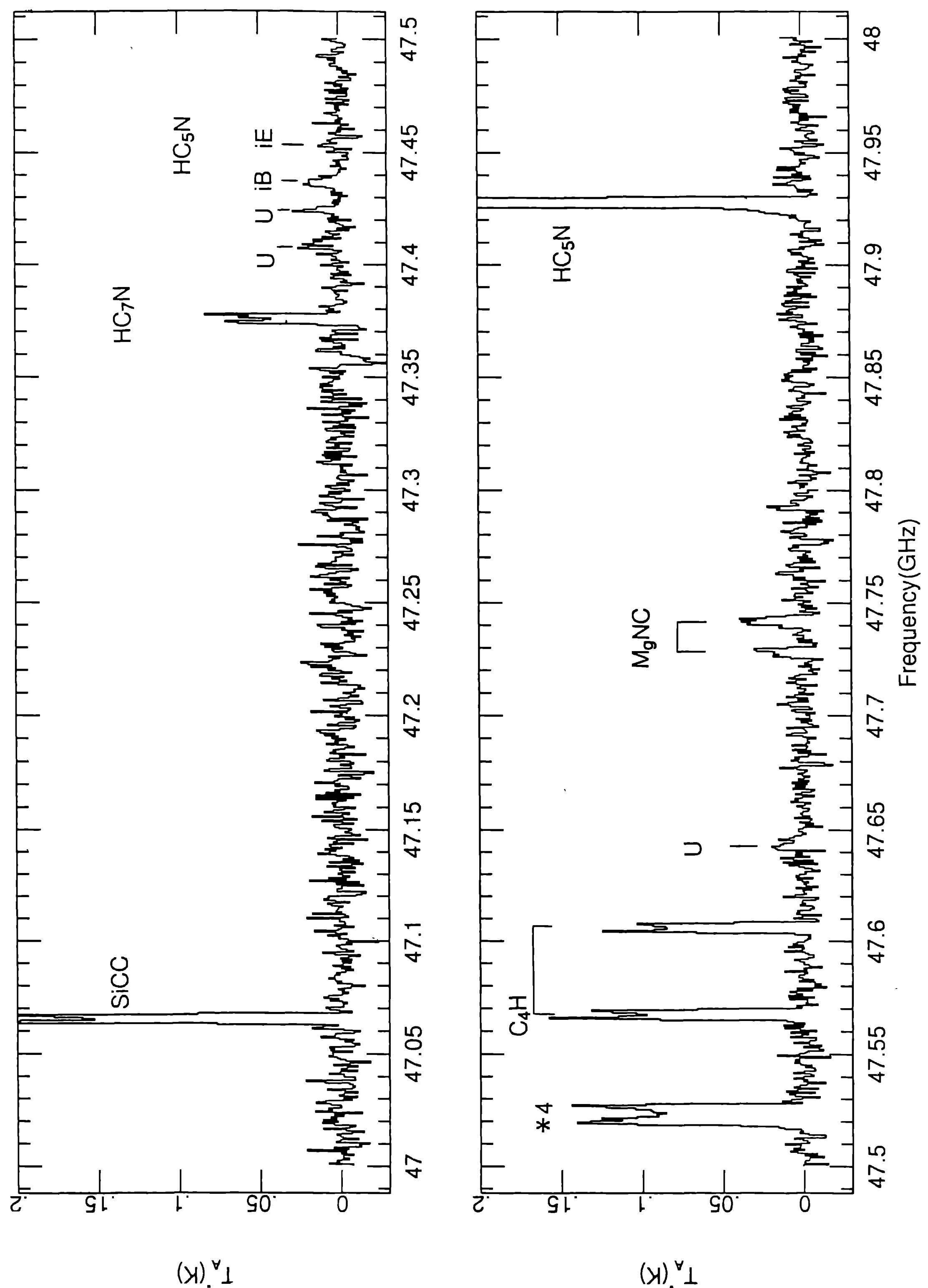


Figure 3. Spectral lines in IRC + 10216 between 47 and 48 GHz. A number of lines from carbon bearing molecules and unidentified lines (U) are seen. MgNC is one of the interstellar/circumstellar molecules detected recently at Nobeyama.

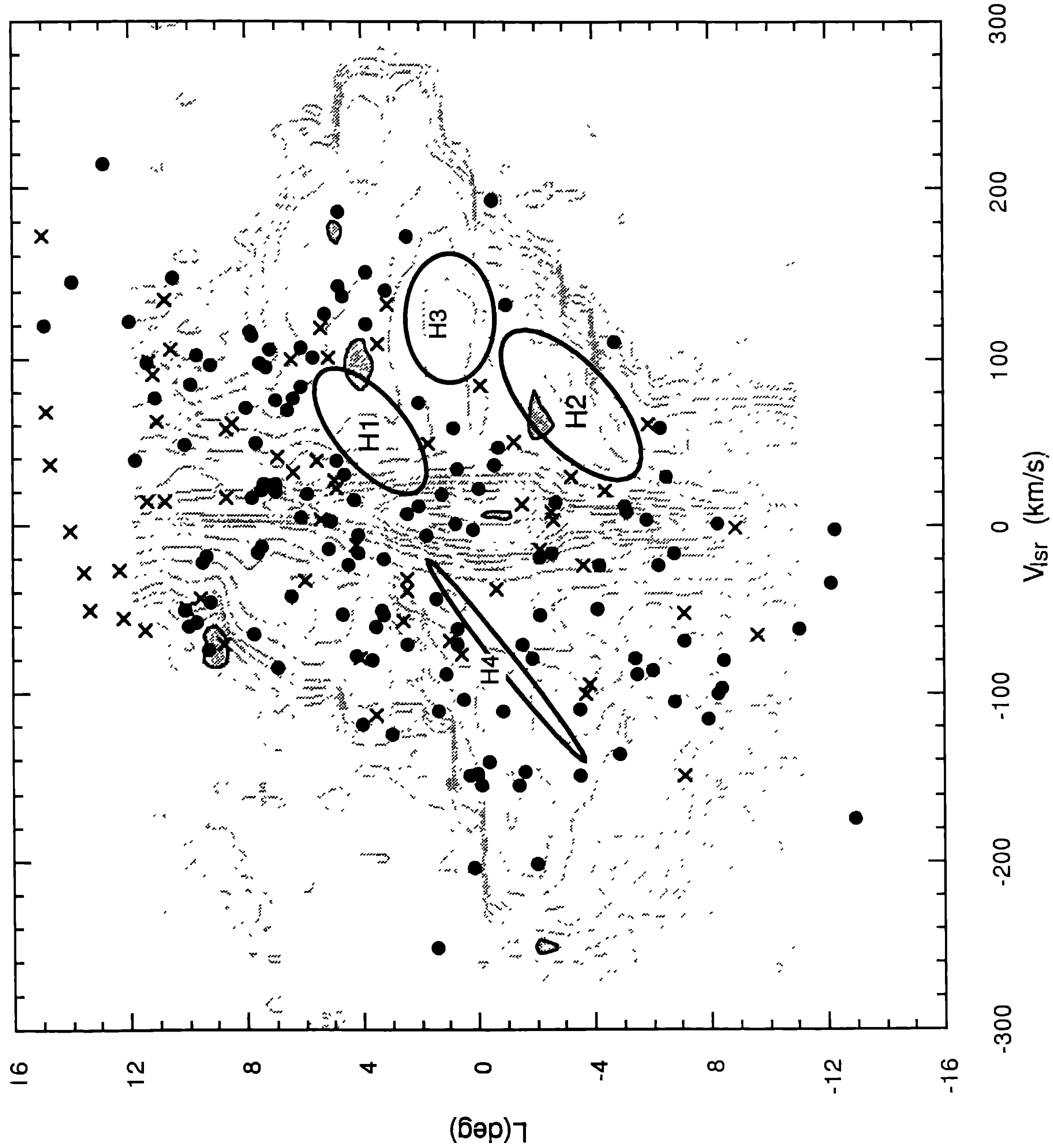


Figure 4. The overlay of the SiO maser longitude-velocity map on the HI map (taken from Burton & Liszt 1976) at the Galactic bulge. The contour dips in the HI map are hatched. The filled circles are the bulge sources and the crosses and the disk sources. The SiO holes, H1-H2, are quite close to the basin of the HI contours around (90 km s−1, 4.2°) and (60 km s−1, −2.3°) (hatched area). The presence of holes named H3 and H4 are less clear.

selection of long-term projects at Nobeyama in 1991 (the long term project will be given about 200 hours of telescope time in one year). Since this project failed to obtain the observation time in that term of the year, another group of people observed this source (which was not initially included in their proposal), and detected a narrow ^{13}CO feature in this source (with two peaks broadened by rotation). This caused a turmoil in claims for priority between the two proposers and the proposal selection procedure at Nobeyama was questioned. This discovery indicates that the gas accretion disks around young stars can also be observed in mm-wavelength lines. High-spatial resolution observations revealed that the CO distribution is concentrated within a few arc seconds of the central star.

Study of galaxies by molecular lines

The Nobeyama mm-wave array (NMA) has a spatial resolution of about 4" at 115 GHz. Dr. Kawabe and his group have been mapping spiral and irregular galaxies by the CO J = 1-0 line. They have confirmed that the position of highly redshifted (z = 2.286) J = 3-2 CO line in the highly infrared luminous galaxy, IRAS F10214 + 4724, coincides with the optical position of the galaxy within 9" and that the line profile of the CO J = 3-2 transition is slightly different from the profile which was first detected at NRAO. Dr. Nakai and collaborators found the extreme high velocity components of about 1000 km s^{-1} in the H_2O masers from the nucleus of a spiral galaxy, NGC 4258, with the 45-m telescope. The VLBA observations by Dr. Makoto Miyoshi and others leads a model of fast rotating disk surrounding the central black hole at the nucleus of NGC 4258.

These innovative researches are mainly in molecular radio astronomy field. The absence of a large optical telescope in Japan made radio astronomers being reluctant to perform multi-wavelength study of radio sources. However, this situation will be improved by the construction of SUBARU 8.3m telescope in Hawaii and by collaboration with Infrared Space Observatory by Europeans in near future. Traditions play an important role in the scientific research as well as in real life. In this sense, aggressiveness is suppressed in social life in Japan. Contrary to this tradition, radio astronomers in Japan behave in an opposite sense somewhat, inevitably for their survival in the field which was a minor science till 1980.

4. Future projects

Because of the budget and man-power limitations, most of the big radio astronomy projects have been planned mainly at the Nobeyama Radio Observatory, the National Astronomical Observatory and in some part at the Institute for Space and Astrophysical Sciences (ISAS). This tendency may not easily change in the near future, but several smallscale projects are also planned at various departments in different Universities which are mentioned somewhat above. At present, we have one running project already funded (VSOP) and several big projects under discussions in Nobeyama Radio Observatory.

VLBI Space Observatory Programme (VSOP)

This project has been funded since 1993 and running at the Institute of Space and Astrophysical Sciences (ISAS) directed by Prof. Hisashi Hirabayashi in cooperation with the National Astronomical Observatory (by Prof. Makoto Inoue). The radio astronomical satellite Muses-B with a (folding) 8-m dish for VLBI will be launched in early 1997 with the new M-CV rocket of ISAS (Fig. 5). The life time of this satellite is about 1.5 years and the observable wavelengths are 1.3, 6 and 18 cm. The weight of the satellite is about 400 kg and will be controlled from the Usuda Space Station, Nagano-prefecture, 30 km north of Nobeyama. The satellite orbit has an inclination of 31 degrees with the apogee of 2200 km, the perigee of 1000 km and the period of 6 hours. It is planned that the U.S. VLBA network, Australian Telescope in Southern hemisphere intensively coordinate with this satellite during the flight. The coordination with the other existing antennas in Japan is also essential. Both continuum and line observations are planned. The study of proper motions of water maser spots at 1.3 cm is one of the main target of this project. Further the 18 cm OH masers and the 6 cm H_2CO absorption/emission lines will also be observed. Continuum radiation from the accretion disk in active galactic nuclei is also one of the targets. The longest baseline reaches about 30,000 km and the resolution at a wavelength of 1 cm will be 0.01 milliarcsec. The data received by satellite are transferred to the 5 ground stations (3 DSN stations, Green Bank, and Usuda) with a bandwidth of 64 MHz at the rate of 128 Mbps and recorded on the magnetic tapes. The correlators are now being prepared at National Astronomical Observatory at Mitaka.

Large Millimeter and Submillimeter-wave Array (LMSA)

This project is now under discussion in Nobeyama Radio Observatory. The plan is to build an interferometric array with the 30 10-m dishes working at millimeter and submillimeter wavelengths. This is an expanded version of the present 6-element millimeter-wave array at Nobeyama. The altitude of Nobeyama is about 1300-m from the sea level and the water vapour pressure is not low enough at this level to expand the array to observe at wavelengths below 1.3 mm. The possible array site is Mauna Kea in Hawaii, or Atacama desert in Chile. A lot of arguments are now going on as to which group should be a partner of LMSA : the Smithsonian group of the Submillimeter Array at Mauna Kea which is now under construction, the NRAO group of Submillimeter Array in Mauna Kea, or the European group in Chile. The science to be pursued will be to detect submillimeter radiation from the highly redshifted galaxies, from the protoplanets in young stars, and from hot dust envelope of evolved sars. The completion of this array is expected to be around 2010 when the Japanese economy will hopefully be in a good shape.

VLBI for the Earth Rotation study and Astrometry (VERA)

This project is planned by Prof. Tetsuo Sasao, a relativist at the Mizusawa Latitude Observatory of the National Astronomical Observatory. It consists of two VLBI stations with four 15-m (or 25-m) dishes separated by 2300 km in the northern and southern parts of Japanese islands (Fig. 6). The VLBI is devoted for the study of the earth rotation, astrometry, and radio astronomy. It is planned to measure the baseline length with a relative field-of-view

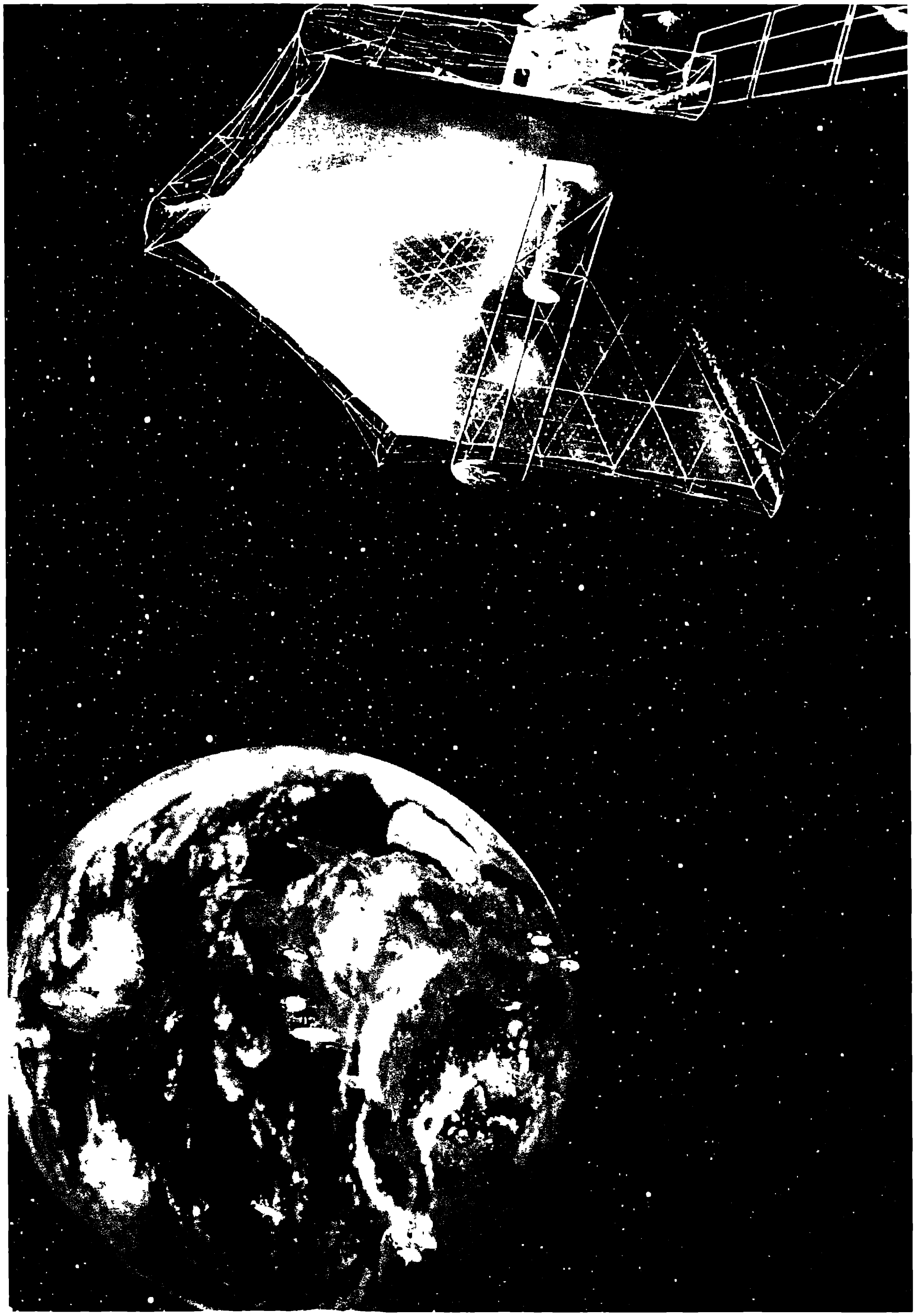


Figure 5. Project VSOP.

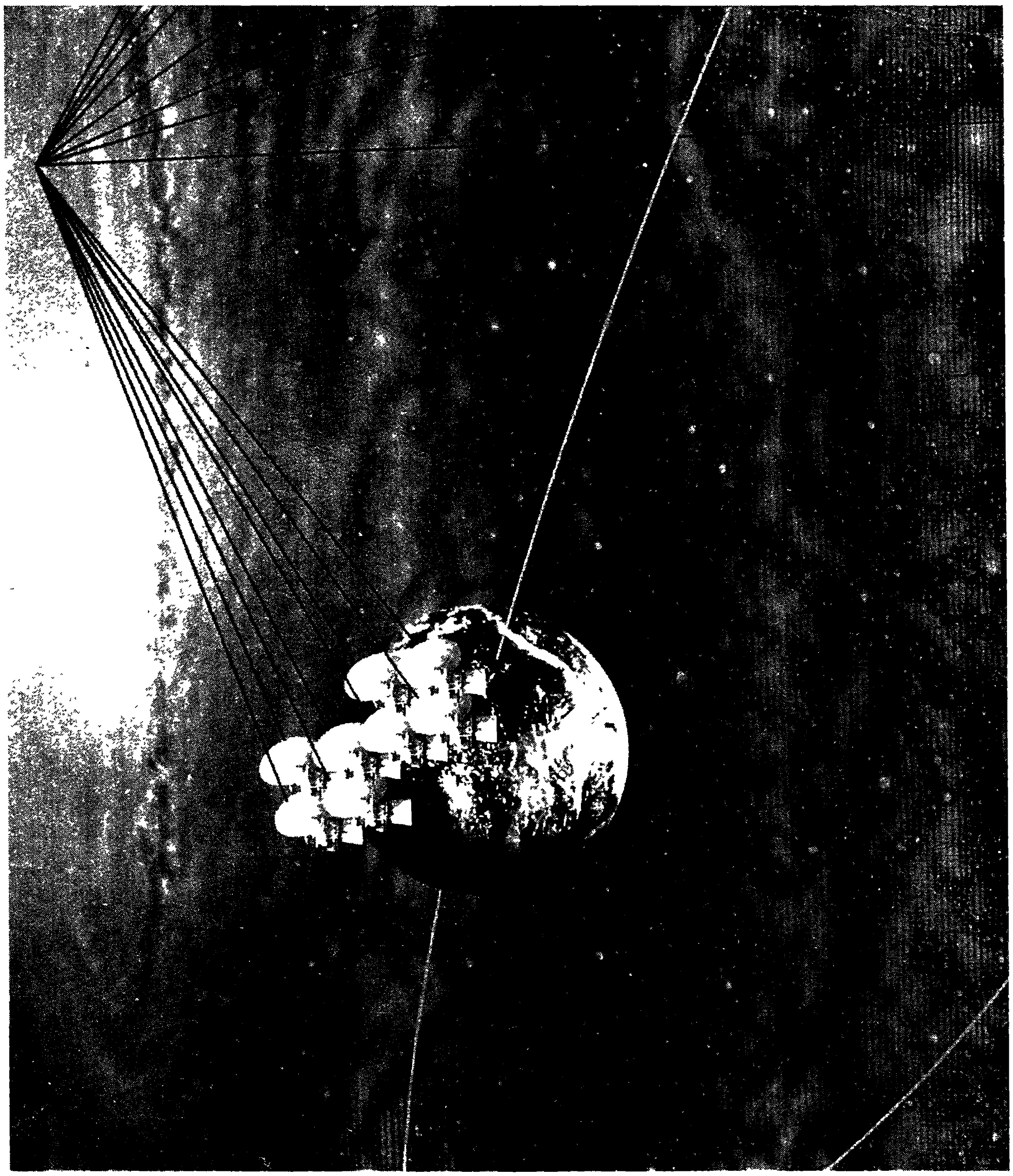


Figure 6. Project VERA.

method at the wavelengths between 7 mm and 15 cm. The positions of radio sources are measured relative to each other. To minimize the phase noise due to atmosphere by pointing two sources at their separate positions, the slewing speed of the telescope is set to a high value of more than 6 degree/sec. It is planned to observe 180 radio sources/day per baseline and 920 sources/day in 4 baselines. The bandwidth is about 80 MHz per channel and there are 10 channels. The recorder speed is planned to be 1 Gbps. The science pursued with this interferometer consists of the irregular variation of the earth's rotation by measuring nutation period with an accuracy of the position measurement of about 0.05 mas.

Submillimeter-wave telescope at Mt. Fuji

This project is to build the 2-m submillimeter-wave telescope, and was planned by Dr. Satoshi Yamamoto, a molecular spectroscopist, at the Department of physics, University of Tokyo, in cooperation with Prof. Shuji Saito at the Institute for Molecular Science and Dr. Masatoshi Ohishi at the Nobeyama Radio Observatory. Mt. Fuji is the highest mountain in Japan (3776 m from the sea level), but it is not necessarily a good site for astronomy because of severe climate. The high water vapour pressure prohibits to operate the telescope in summer at submillimeter wavelengths. On the other hand, the snow in winter at Mt. Fuji prohibits the engineers to attend to operational needs of the telescope. Therefore, the telescope is planned to be remotely operated from the mountain foot. They plan to survey the entire sky by using CI fine structure line at 492 GHz.

4. Conclusions

The financial situation in performing scientific research has completely changed in the last 10 years in Japan. Experimental sciences have ripened with the support from industry. Twenty years ago, all scientists were against any levels of cooperation of universities with industries. Nowadays, it is totally opposite; all scientists in any research institute welcome the financial support from industry.

These dramatic changes of social and cultural conditions in Japan in the last 20 years forced radio astronomers to behave more boldly to plan ambitious and expensive projects such as the VLBI Space Observatory Program (VSOP) and the Large Millimeter-Submillimeter Array (LMSA). However, these projects are planned with a weight on the engineering aspects of the telescope and not much on considerable astronomy involved. The other weak point common to most of the Japanese projects is that these are managed only by Japanese, and more experienced radio astronomers of the Western community are, at best, marginally involved, and, in normal case not involved at all, even for several-hundred-million-dollar projects. Even at present, no permanent position is offered to aliens in the National Astronomical Observatory where about 150 civil servants work. One excuse for this situation is obviously a language barrier. It is difficult for Westerners or Asians to use Japanese skillfully.

The success of the big Japanese projects seems to depend on the personal sacrifices from the scientists. As mentioned before, four radio astronomers, T. Hatanaka, H. Tanaka, H. Suzuki, and K. Kai have lost their lives at the peak of their careers. The sacrifices are not limited to the top project managers but are also forced on the young graduate students and post-doctoral research fellows, who are more often than not underpaid or not paid at all. However, one aspect of these sacrifices for young researches in this country is that from these severe social conditions for performing sciences in the past emerged a basic political power to strengthen the scientists and to motivate them to build large telescopes with a handful of politically and scientifically skilled organizers.

Even so, the Japanese radio astronomy and it's community are in a state of healthy growth at present and hopefully will continue to do so in future. The isolation from Western scientific community is now being overcome by the use of computer networks and E-mails and by frequent jet travels. The geographical handicap of Japanese community is somewhat lessened by these advanced tools though the language barrier remains. The scenario of radio astronomy in Japan may change drastically in future and the radio astronomical facilities may be set up on foreign sites as well.

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