COMMISSION J: RADIO ASTRONOMY

Edited by Makoto Inoue

J1 Introduction

National Astronomical Observatory of Japan (NAOJ) has been promoting the Atacama Large Millimeter/Submillimeter Array (ALMA) project on behalf of Japanese astronomy community, collaborating with universities in Japan. Collaboration in ALMA has been discussed with Asian countries/observatories. In addition, collaboration of VLBI networks between a three-station VLBI network, under construction in Korea, and VERA of NAOJ are in progress. VERA is a four-station VLBI array for precise astrometry. Universities have been operating their own radio telescopes, e.g., NANTEN of Nagoya University has located in Chili, Mt. Fiji submillimeter telescope at the top of Mt. Fuji, a new array of Waseda University for pulsar search, etc.

Observations of millimeter and submillimeter regions have been made intensively for star forming regions and circumstellar disks, while the Nobeyama Radioheliograph has been operated routinely for almost 10 years. The major observing facilities and developments are first shown, and the scientific results and achievements are reviewed.

J2 New Instrumentation

J2.1 NRO 45-m Telescope and NMA

The 45-m telescope of Nobeyama Radio Observatory (NRO), NAOJ, has been operated at a frequency range of 20-150 GHz. In addition, a bolometer array, seven beams with 30-GHz bandwidth at 150 GHz, was installed. A 25-beam heterodyne receiver, BEARS, which can observe 5-by-5 sky positions simultaneously at 82-116 GHz, has been used for open use since 2000. The flatness of the azimuthal track (rail) of the telescope was improved to 0.7 mm (peak-to-peak) from 7.5 mm in 2000.

The Nobeyama Millimeter Array (NMA), which is composed of six 10-m antennas, has been operated at frequency ranges of 85-116 GHz and 126-152 GHz for past several years. In addition to these frequencies, the 230-GHz band was added in 1999. Some mirrors of the beam transmission of the antennas were repaired or replaced by new mirrors in 1999 and the aperture efficiency was improved to be 60%, 50%, and 31% at 92, 140, and 226 GHz, respectively. The RAINBOW interferometer, which connects NMA and the 45-m telescope to make an array with large gain, has been provided for open use since 2000.

(N. Nakai)

J2.2 Space VLBI VSOP

The HALCA satellite was launched in February 1997 by the Institute of Space and Astronautical Science (ISAS) as the main element of the VLBI Space Observatory Programme, VSOP [Hirabayashi et al. 2000a]. In the five years since launch, over 700 scientific observations have been carried out at 1.6 and 5.0 GHz. Of these, over 500 have been made as part of General Observing Time, for observing projects selected by international peer-review from open proposals submitted in response to Announcements of Opportunity. Most VSOP observations are made of extragalactic radio sources to study the compact cores and the parsec-scale jets, although observations of galactic hydroxyl masers and pulsars at 1.6 GHz have also been made. Approximately 175 observations have been made as part of the VSOP Survey program, a mission-led systematic survey of 289 active galactic nuclei at 5 GHz [Hirabayashi et al. 2000b]. In line with the ISAS-NASA Memorandum of Understanding, NASA ended its support of U.S. mission elements in February 2002. As a result, the mission is currently focusing on the VSOP Survey Program, with observations supported by the Usuda tracking station, the Mitaka correlator of NAOJ, the Penticton correlator (funded by the Canadian Space Agency), and telescopes in Australia, China, Europe, Japan, South Africa, and Russia.

(P.G. Edwards)

J2.3 VLBI Activities

Japanese VLBI Network (J-Net) consists of three telescopes, the 45-m telescope at Nobeyama, 10-m telescope at Mizusawa, and 6-m telescope at Kagoshima, operated at 22 GHz with the longest baseline of about 1300 km. Optionally the 34-m telescope of the Communication Research Laboratory (CRL) joins to increase sensitivity. VLBI observations have been conducted for water vapor masers in star-forming regions, late type stars and active galactic nuclei. In a high-mass star formation area in Orion KL, an enormous outburst of the 7.9 km/s water-maser feature was discovered [Omodaka et al. 1999]. The intensity reaches 3.5 million Jy at September 1998. The position of this velocity component was determined using the J-Net. A survey was conducted using J-Net to detect AGNs for the phase reference sources of VERA (see J2.8 below). In this survey, 267 VLBI candidates were observed to detect 51 new sources [Honma et al. 2000].

In VLBI technology area, remarkable achievement has been made. NAOJ and CRL have developed the Gbps VLBI systems. The NAOJ Gbps system has been developed for the VERA project, designed to acquire data from the VERA two-beam system (See J2.8). The data will be processed by Mitaka FX correlator. The CRL system has 1-Gbps recorder with a combination of Gbps samplers [Nakajima et al. 2001].

CRL, NAOJ, ISAS, and Nippon Telegraph Tele communication (NTT) have been carried out Asynchronous Transfer Method (ATM) based real-time VLBI observations since 1998. One-Gbps (1024-Mbps) real-time VLBI experiment was performed successfully to detect first fringes from Seyfert galaxies. Further, developments toward IP-based real-time VLBI and international real-time VLBI are in preparation.

(T. Omodaka & J. Nakajima)

J2.4 The 60-cm Telescope of the University of Tokyo

The radio astronomy group at the Institute of Astronomy of the University of Tokyo runs two 60-cm radio telescopes, called the Very Small Telescope (VST) 1 and VST2. The VST1 is located at Nobeyama and the VST2 at La Silla in Chile. They are identical with the 9-arcmin beamwidth. These telescopes are used for survey observations of the Galactic plane and nearby molecular clouds in CO (J=2-1) line [Handa et al. 1999]. The beam size of 9 arcmin enables us to make direct comparison with the 1.2-m telescope operated by Harvard Smithsonian Center for Astrophysics in CO (J=1-0) line, which gives density and temperature of molecular gas [Sakamoto et al. 1999]. An SIS receiver and a 2048-ch Acoust-Optical Spectrometer (AOS) with 500-MHz bandwidth were installed at VST1. A cooled Schotkey diode mixer receiver and a 2048-ch AOS with 1-GHz bandwidth were installed at VST2. The Telescope controlling system called ASTROS was extended to allow us remote operation available through the Internet.

Using VST2 molecular gas in the Galactic Center region was observed in ^{12}CO (J=2-1) and ^{13}CO (J=2-1) lines [Sawada et al. 1999]. Comparing with maps of ^{12}CO (J=1-0) observed by Calan 1.2-m telescope (Bitran et al. 1997), we show pressure distribution on *l*-v plane. It shows the pressure in the Sgr A molecular cloud is one-order of magnitude higher than in GMCs in the Galactic disk, but the pressure in the "Expanding Molecular Ring" is not so high.

(T. Handa)

J2.5 The 4-m Telescope of Nagoya University

The 4-meter radio telescope "NANTEN," which stands for southern sky in Japanese, has been operated by Nagoya University at Las Campanas Observatory in Chile since 1996 under mutual agreement with the Carnegie Institution of Washington. The main projects of the NANTEN telescope are (1) a full-mapping survey of molecular clouds in Large Magellanic Cloud (LMC) and (2) CO survey along the Galactic plane. The central area of 6° x 6° of the LMC has been covered at 2' grid spacing, and 168 molecular clouds are identified at the mass detection limit of ~40,000 solar masses. The cloud mass spectral index, -1.9, of the LMC is slightly steeper than that of our Galactic molecular clouds, suggesting the drastic dissipation of clouds due to high UV radiation from the young stellar clusters [Fukui et al. 1999, 2001; Yamaguchi et al. 2001]. The Galactic plane of $|b| < 9°$ and from $l = 230°$ to $l = 60°$ across the Galactic center has been covered at 4' or 8' grids [Fukui et al. 2001, see http://www.a.phys.nagoya-u.ac.jp/index.html]. More than 20 candidates of molecular super shells have been newly found, which provides unique samples for statistical studies of triggered star formation on the Galactic scale [e.g., Fukui et al. 1999; Yamaguchi et al. 1999; Matsunaga et al. 2001]. Two special issues on the NANTEN achievements were published in Publ. Astron. Soc. Japan Vol. 51, 1999 and Vol. 53, 2001.

(A. Mizuno)

J2.6 Arrays of Waseda University

Five spherical dishes were constructed to search pulsars and transient radio sources in Nasu Pulsar Observatory, 160 km north of Tokyo. The diameter of dishes is 20 m, and asymmetrical Gregorian sub-refrectors are used [Daishido et al. 2000, see J5.6]. The observed frequency is 1.4 GHz, and HEMT receivers with noise temperatures of 40 K are used. Extension to eight-element interferometer will be done in 2002.

On the roof of Waseda University we have a 64-element 2D interferometer from which we obtain spatial temporal cubic data of E(x, y, t) at 10.6 GHz. The 64 antennas have 128 A/D converters of 8 bits at 20 MHz, and the base band digital signals are transmitted by bit parallel optical fibers to the processor. Total bit rate is 2 Gbps. A Spatial Temporal FFT processor is operating at Nyquist rate to transform complex signals in real space to those in momentum space, i.e. E(x, y, t) --> E(k_x, k_y, f). The processor has capability to transform 16 x 16 x 256 complex data at Nyquist rate. LSIs of 512 Radix-4 butterfly designed by ASIC technology are used in the processor [Tanaka et al. 2000]. Due to optical fibers and phase calibration algorithm, phase stability in the interferometer was increased [Takeuchi et al. 2000].
(T. Daishido)

J2.7 Mt. Fuji Submillimeter Telescope

Mount Fuji Submillimeter-wave Telescope is the first radio telescope observing the submillimeter-wave radiation of celestial objects in Japan. The main reflector of the telescope has a diameter of 1.2 m with the surface accuracy of 10 μm, and is enclosed in a space frame radome which is transparent for submillimeter waves. With this telescope, we have been observing the spectral lines of the neutral carbon atoms toward various interstellar clouds since 1998. The observing frequencies are 492 GHz ($^3P_1 - {}^3P_0$) and 809 GHz ($^3P_2 - {}^3P_1$), which correspond to the wavelengths of 0.6 mm and 0.4 mm, respectively. Taking advantage of good observing conditions at the summit of Mount Fuji (3776 m above see level), more than 40 square degrees of the sky was already surveyed with the 492 GHz line [Aikawa et al. 1999], whereas several representative sources are mapped with the 809 GHz line [Yamamoto et al. 2001]. On the basis of the large area mapping observations, formation and evolution processes of molecular clouds are being studied in detail. This study is carried out in collaboration with researchers in several institutes including NAOJ and NASDA.

(S. Yamamoto)

J2.8 VERA Project

The Project VERA (VLBI Exploration of Radio Astrometry) that aims at high precision phase-referencing VLBI astrometry with expected accuracy of 10-μarcsec level was funded. Three VLBI stations out of planned four have completed, and the fourth station will be completed in 2002 [see http://veraserver.mtk.nao.ac.jp/index.html]. Each station is equipped with a 20-m telescope that makes it possible to observe two closely separated radio sources simultaneously, with angular separation up to 2°, by means of the newly developed dual-beam receiving system. The capability will effectively compensate the degrading phase fluctuations due to the turbulent troposphere. Receiving frequency covers 43-, 22-, 8- and 2-GHz bands with the longest baseline of the array being 2300 km. VERA will measure annual trigonometric parallax and proper motion of thousands of water and silicon mono oxide maser sources across the Milky Way Galaxy together with adjacent extragalactic continuum sources. Scientific targets of VERA include accurate determination of the Galactic constants (distance to the Galactic center and rotation speed at the solar neighborhood), reliable estimation of the dynamical mass of the Galaxy and hence the amount of the Galactic dark gravitating matter, revealing the dynamical structure of the Galaxy (central bar, spiral arms and warping), distance determinations to the star-forming regions and mass-losing evolved stars, direct calibration of the period-luminosity relation of Miras, phase-referenced VLBI imaging of 'radio-quiet' AGNs and extragalactic masers, ground support for future space VLBI missions, and some applications to geodesy and selenodesy. The whole VERA system is now intensively tested. The first VLBI fringe was obtained between Mizusawa and Iriki. Preliminary scientific observations mainly for testing the performance of the system will start in 2002 and the regular project observation is expected to start in 2004.

(T. Sasao)

J2.9 ASTE Project

The Atacama Submillimeter Telescope Experiment (ASTE) is an R&D program which is carried out by NRO of NAOJ in collaboration with Universidad de Chile, and with Japanese astronomers from universities (University of Tokyo, Nagoya University, Osaka Prefecture University, etc.). Technical and scientific purposes are to develop and evaluate a high precision 10-m telescope [Ukita et al. 2000; Ezawa et al. 2000; Ukita et al. 2001] under exposed conditions at a remote site, 4800 m in elevation, to develop and test low-noise submillimeter receivers [Sekimoto et al. 2001] and new SIS photon detectors [Matsuo et al. 2000], to test various techniques for submillimeter observations, and to explore the southern hemisphere at submillimeter bands.

(N. Ukita)

J2.10 ALMA Project

Large Millimeter and Submillimeter Array (LMSA) project had been promoted as the next big ground-based telescope project after SUBARU Telescope in Japan [Kawabe et al. 1999; Nakai 1999; Sakamoto et al. 1999; Kawabe et al. 2000]. Considering scientific benefit of combining three projects with similar objective and scale, i.e., LMSA in Japan, MMA in the United States, and LSA in Europe, NAOJ has started discussion with related institutes in US and Europe toward the possible cooperation and merger of the projects. These efforts resulted in funding for the research and development activities at NAOJ for FY2002-2003, with a prospect of Japanese participation in the construction of ALMA from FY2004.

Research and developments have been made for the key technical elements of the ALMA project with coordination with the North American and European partners. NAOJ has prepared the construction of Japanese 12-m prototype antenna for the joint evaluation of ALMA prototype antennas at Socorro in US. Its design study and technical developments have been made based on the new high precision 10-m antenna (ASTE antenna; see J2.9).

Development for receiver frontends included SIS mixers, frontend systems, and photonic local oscillator sources [Sekimoto et al. 2000, 2000; Lamb et al. 2001]. Novel types of Nb-based SIS junctions called Parallel Connected Twin Junction (PCTJ) and "Distributed Junctions" have been developed at NRO [Shi et al. 1999; Takeda et al. 2000; Noguchi et al. 2001; Matsunaga et al. 2001; Takeda et al. 2001]. PCTJ mixers are actually used for receivers at frequencies up to 500 GHz and their excellent performance has been demonstrated [Sekimoto 1999]. For frequencies above 600 GHz, SIS junctions with new materials such as NbTiN and NbN have been developed at NRO and CRL. A receiver system with a three-stage GM 4K-cryocooler was developed that is compatible with the cartridges for ALMA frontends. It will be installed at ASTE to test the prototypes of ALMA Band 8 (500 GHz) and Band 10 (900 GHz) frontend cartridges that are being built. Its copies can be used as test cryostats for other ALMA frontend cartridges being built in North America and Europe. A photonic LO source using an InP-InGaAs uni-traveling-carrier (UTC) photodiode was developed by NAOJ and NTT [Noguchi et al. 2001]. By illuminating it with lasers with wavelengths near 1.55 micrometers, they measured about 2 mW of output power at 100 GHz.

An FX-type correlator and a high speed sampler have been developed for the second generation ALMA correlator [Okumura et al. 2000, 2001]. A prototype FX correlator (2 GHz bandwidth and 131 x 10^3 frequency channels) and a 2-bit sampler with 4 G sample/sec were built and tested at NAOJ. Using NMA we successfully demonstrated the performance of this prototype system that covered a bandwidth of 2 GHz with 131 x 10^3 frequency channels to detect 19 spectral lines from Orion-KL in a single setting.

The characterization of ALMA site, the sector of Cerro Chascon was performed in collaboration with US and European groups. Among such activities are FTS measurement of atmospheric opacity in the sub-millimeter wavelength [Matsushita et al. 1999, 2000], soil condition study [Sakamoto & Sekiguchi 2001], and the study of health problems due to high altitude [Sakamoto et al. 1998].

Impact of the ALMA on studies of galaxy formation and planet formation was widely investigated and discussed in the Japanese astronomical community [e.g., Takeuchi et al. 2001, 2001].

(R. Kawabe and T. Hasegawa)

J3 Solar Radio Astronomy

Many solar dedicated satellites (YOHKOH, SOHO, TRACE, etc.) have been observing the solar activity together with ground based optical and radio telescopes. Nobeyama Radioheliograph (NoRH) is the major radio telescope for solar observations. Nobeyama symposium on "Solar Physics with Radio Observations" was held on October 1998 and the papers presented at the symposium were published as NRO Report No. 479 in 1999.

Imaging observations of flare-related very short pulses (shorter than one second) by NoRH were compared with hard X-ray observations [Altyntsev et al. 2000], and it was found that some of them are located very high in the corona [Altyntsev et al 1999]. Geometry of flaring loops was studied using the correlation of time variability of various parts of flaring sources [Hanaoka 1999], and the result confirmed the double-loop configuration of solar flares. Based on the results from NoRH and other observations, a new solar flare scenario was proposed [Shibasaki, 2001b]. Plasmas confined in a curved magnetic loop have free energy. This free energy will be converted to other forms explosively in case of high beta through localized quasi-interchange instability called "ballooning instability." Simultaneous observations of simple solar flares by NoRH (17 and 34 GHz) and BIMA (86 GHz) were compared [Kundu et al. 2000; Kundu et al. 2001]. The result showed that MeV-energy electrons are accelerated in single-loop configuration.

Prominence eruptions were extensively studied [Hori et al. 2000; Gopalswamy et al. 2000; Hanaoka and Shinkawa 1999]. The comparison with large field coronagraph observations by SOHO/LASCO showed that the erupted prominence observed by NoRH became the core part of the Coronal Mass Ejection phenomena [Hori 2000].

Three-minutes oscillation of sunspot-associated sources was detected [Gelfreikh et al. 1999a]. It was interpreted as the passage of upward propagating sound wave across the gyroresonance layer [Shibasaki 2001a]. The sound wave is generated at the temperature minimum layer in the sunspot umbra. The oscillation period is determined by the temperature at the temperature minimum layer.

Circular polarization degrees were used to measure magnetic field strength in active regions [Grebinskij et al. 2000]. A polarization reversal near the limb was detected and used to investigate magnetic field in the quasi-transverse region in the corona [Ryabov et al. 1999].

(K. Shibasaki)

J4 Solar System Radio Astronomy

The interplanetary scintillation (IPS) method can observe the dynamics and structure of the solar wind in three dimensions with a relatively short time cadence (< 1 day) using IPS radio sources distributed over the sky. Because of this advantage over in-situ measurements, we have been conducting the multi-station 327-MHz IPS observations at the Solar-Terrestrial Environment Laboratory (STE Lab). Using IPS observations, the origin of low-speed wind [Kojima et al. 1999b; Ohmi et al. 2001], solar cycle dependence of 3D solar wind structure [Kojima et al. 1999a, 2001], acceleration of the solar wind [Yokobe et al. 2000], and structure and dynamics of CME propagation [Tokumaru et al. 2000a, 2000b; Fry et al. 2001; Manoharan et al. 2000, 2001] have been studied.

The present IPS system at STE Lab observes several tens of IPS sources a day. To make solar wind observations with higher spatial and temporal resolution using the CAT method, we need more perspective views of the solar wind. Therefore, we are planning a new UHF antenna with a collecting area of 60 m x 120 m that will observe more than 100 IPS sources per day. The antenna is designed with a tolerance for radio noise interference and high aperture efficiency. Based on the successful development of the IPS CAT analysis, we are presently continuing a US-Japan cooperative project for space weather research between UCSD/CASS and STE Lab.

(M. Kojima)

J5 Galactic Radio Astronomy

J5.1 Galactic Center Region

Survey observations in CS (J=1-0) [Tsuboi et al. 1999] and SiO (J=1-0) [Deguchi et al. 2000; Miyazaki et al. 2001] were made in the central few-degree region with the 45-m telescope. Many SiO masers were found in the region. Statistical properties of the Galactic center molecular clouds were derived [Miyazaki and Tsuboi 1999, 2000]. Large-scale structure and kinematics of the molecular clouds were studied with the 60-cm telescope of University of Tokyo [Sawada et al. 1999a, 1999b, 2001]. The expanding shell interacted with the radio arc was studied, which probably activates the radio arc [Oka et al. 2001a]. The interacting point in the radio arc was studied with the 150-GHz NOBA bolometer [Reich et al. 2000]. A cloud collision-induced star formation was found in Sagittarius B2 [Sato et al. 2000]. A hyper-enegetic CO shell was found near the Galactic center [Oka et al. 2001b]. Flares at 100 and 150 GHz of Sgr A* were found with NMA [Tsuboi et al. 1999b; Miyazaki et al. 1999].

(M. Tsuboi)

J5.2 Star Forming Regions

A mapping in $H^{13}CO^+$, CO (J=1-0), and HCO^+ (J=1-0) toward OMC-2/3 revealed the existence of 18 dense cores and eight molecular outflows, and it was suggested that the dissipation of turbulence initiates the star formation [Aso et al. 2000]. A bright IRAS source 22134+5834 was observed with the 45-m telescope, leading to a detection of an outflow that is the most massive one so far [Dobashi et al. 2001b]. CO outflows (e.g., IRAS 21428+4732) were found toward a dark cloud complex near IC5146 with the 45-m telescope [Dobashi et al. 2001c]. A newly ejected extraordinarily compact protostellar jet, or a microjet was discovered from the class 0 protostar S106 FIR [Furuya et al. 2000]. The thermal emission line of SiO (v=0; J=2-1) was mapped toward the quadrupolar molecular outflow driven by the very cold far-infrared source IRAS 16293-2422 [Hirano et al. 2001]. Submillimeter CO emission from shock-heated gas was reported in the L1157 outflow [Hirano and Taniguchi 2001]. The ortho-to-para ratio of ammonia was measured in the L1157 outflow [Umemoto et al. 1999]. These studies gave us important results on the effect of outflow to the surrounding environment.

Evidence for a protostellar condensation that is very close to the moment of the formation of a protostellar core within a time scale of ~10^4 yr was discovered [Onishi et al. 1999a]. CS (J=2-1) interferometric observations were carried out with NMA toward a protostar (GH2O 092.67+03.07) in the Cygnus giant molecular cloud and a signature of an infalling and rotating disk, which could be the first clear detection of such motion around a young high mass star, was found [Bernard et al. 1999]. The maximum luminosity of protostars forming in molecular clouds has been investigated as a function of the parent cloud mass on the basis of a rich cloud sample searched for in the literature based on a sample of 499 molecular clouds [Dobashi et al. 2001a]. Small-scale structure of dust continuum sources was revealed in the Rho Ophiuchi A region through millimeter-wave interferometric study [Kamazaki et al. 2001]. Two millimeter continuum observations were made toward 15 bright-rimmed clouds (BRCs) associated with IRAS point sources and S140 with the Nobeyama Bolometer Array (NOBA) mounted on the 45-m telescope [Sugitani et al. 2000].

NANTEN telescope (see J2.5) has been revealing new views of molecular gas distribution of the southern sky. The first detection of a molecular supershell, Carina Flare, which is thought to be formed by multiple supernova explosions, was reported, and the clear evidence of triggering star formation by the supershell was found [Fukui et al. 1999]. Observations of the ^{13}CO and C^{18}O (J=1-0) emission toward the Southern Coalsack were made [Kato et al. 1999]. A ^{12}CO (J=1-0) survey for local molecular clouds was performed toward dark clouds in Aquila [Kawamura et al. 1999]. A ^{13}CO (J=1-0) survey for molecular clouds toward the Chamaeleon-Musca dark cloud complex was completed [Mizuno et al. 1998]. Dense cores and star-formation activities in the Chamaeleon dark-cloud complex were studied [Mizuno et al. 1999]. A filamentary massive dark cloud in Pipe Nebula showed a very low star-formation activity [Onishi et al. 1999].

Several observations towards star forming regions have been made: A large field of ~10 square degrees toward the two southern HII regions S35 and S37 [Saito et al. 1999]; an extensive search for molecular gas toward the Gum Nebula in the ^{12}CO (J=1-0) emission at 2.6 mm [Yamaguchi et al. 1999a]; new observations of the ^{12}CO, ^{13}CO, and C^{18}O (J=1-0) emission lines toward the Vela Molecular Ridge (VMR) [Yamaguchi et al. 1999b]; extensive ^{13}CO (J=1-0) observations toward southern 23 HII regions associated with bright-rimmed clouds [Yamagichi et al. 1999]; a search for molecular clouds toward the southern IRAS point sources at intermediate-to-high galactic latitude ($|b|$ = 10°) in ^{12}CO (J=1-0) emission [Yonekura et al. 1999]; and a C^{18}O survey for dense molecular cores in the Corona Australis (CrA) molecular cloud [Yonekura et al. 1999b].

(T. Onishi)

J5.3 Circumstellar Disks

Circumstellar disks are commonly found towards young stellar objects (YSOs). The disks are believed to be the precursors of planetary systems, i.e., protoplanetary disks, and are thought to be formed in disk-like envelopes around protostars. In the protostar stage, the specific angular momentum of the envelope gas plays a crucial role in the disk formation, and thus, observational studies of the kinematics of the envelopes have been extensively performed. The rotating and infalling motion of the envelopes was revealed around low-mass and intermediate-mass protostars with NMA and the 45-m telescope [Momose 1999; Saito et al. 1999, 2001; and Umemoto et al. 1999]. The signature of an infalling and rotating disk was also obtained around a young high-mass star with the NMA and the 45-m telescope [Bernard et al. 1999]. Furthermore, imaging of the water masers with the VLBI technique provides an excellent tool to probe the disk kinematics on subarcsecond scales. Actually, the velocity structure on 10-100 AU scales was successfully revealed [Imai et al. 1999; Slysh et al. 1999a, b].

The disk mass is one of the most important properties of the protoplanetary disks, which could drastically change the scenario for planet building. In order to determine accurately the disk mass, one must detect optically thin emission, such as thermal emission from dust in the disks at millimeter to submillimeter wavelengths. Dust continuum emission at 2 mm was detected from the disk of Haro 6-5B, which was imaged at visible and near-infrared with the HST, giving an accurate estimate of the disk mass [Yokogawa et al. 2001].
In the T Tauri stage after the protostar one, the disk formation has been completed and the disks evolve as accretion disks. The viscosity in the accretion disks is thought to be generated by some mechanisms, such as the MHD turbulence, where the magnetic field plays a key role. Submillimeter polarization was detected, for the first time, from T Tauri stars, showing that a toroidal component of the magnetic field is dominant in the disks [Tamura et al. 1999]. This result would put a constraint on the viscosity mechanisms. On the other hand, the evolution of molecular abundances in the accretion disks was theoretically investigated [Aikawa et al. 1999].

(Y. Kitamura)

J5.4 Stars

Stellar maser sources in the Galaxy have extensively been studied with the 45-m telescope. The radio observations using the SiO vibrationally excited lines around 43 GHz provide the radial velocities of the stars that are difficult to be observed at visible wavelengths due to interstellar extinction. The large scale surveys in SiO maser lines have revealed kinematics of stars in the Galaxy. By observing stars at the tip of the bulge bar, an appreciable number of stars at the bar tip was found to deviate from the circular motion of the Galaxy [Izumiura et al. 1999]. About 300 SiO maser stars were detected within 15° from the Galactic Center, which was found to present stellar streaming motions due to the bar structure of the bulge [Deguchi et al. 2000a, b]. Using a multi-beam receiver to survey SiO masers near the Galactic Center, we found a few strong SiO sources [Miyazaki et al. 2001]. Stars at the outer part of the Galaxy [Jiang et al. 1999a], and the high-galactic-latitudes [Ita et al. 2001] were studied. The southern IRAS sources were surveyed in SiO 86-GHz line with the Mopra 22-m telescope [Deguchi et al. 2001]. Up to now, approximately 1300 of SiO maser sources were detected in the sky [Deguchi et al. 1999, 2000c].

These IRAS/SiO stars were now identified with near-infrared array cameras [Deguchi et al. 1999, 2001]. Periods of light variations have been measured for these stars [Nakashima et al. 2000]. The near-infrared photometric data were useful to estimate better distances to these sources, to obtain an accurate rotation curve of the Galaxy, and to evaluate the streaming motions of stars in the bulge.

Individual sources were also studied in detail. VLBA mapping observations of SiO emission were made in IRC-10414, which exhibits unusual line-intensity ratio of the SiO (J=1-0) v=1 to v=2 transitions [Imai et al. 1999]. Strong SiO isotopic emission was found in TX Cam and other stars [Cho and Ukita 1998]. Interesting apparent-double SiO maser sources, in which a pair of sources is located within a 40” telescope beam, were studied [Deguchi et al. 1998].

(S. Deguchi)

J5.5 Interstellar Chemistry

One of current targets for interstellar chemistry is to understand the gas-dust interaction. The most important process is apparently the formation process of the hydrogen molecule on dust grain, which is the only effective process to produce the hydrogen molecule in interstellar clouds. This process was studied with the molecular dynamics calculation in detail and suggested that the hydrogen molecule is efficiently produced in its vibrationally excited states [Takahashi 2001]. Then, a possibility was proposed for detecting the infrared emission from the newly formed hydrogen molecule [Takahashi and Uehara 2001].

In addition to the hydrogen molecule, it is thought that some molecules are formed on dust grains. Cyclic-C_2H_4O and CH_3CHO were observed toward several massive star forming regions to found that their fractional abundances are higher by several orders of magnitude than those expected from the gas-phase chemical model calculations [Ikeda et al. 1999]. This indicates a possibility that these two organic species would be produced on dust grains and then be evaporated after onset of star formation. Another observational evidence for the gas-dust interaction comes from observations of the ortho-to-para ratio of NH_3 toward the star-forming region, L1157. The ortho-to-para ratio of 1.3–1.7 for NH_3 was derived, which is significantly higher than the statistical value of 1.0 [Umemoto et al. 1999a]. Such a high ratio can be understood when the NH_3 molecule is formed on cold dust grains.

In these years, the deuterium fractionation in molecular clouds has been studied in detail. The $HN^{13}C$ and DNC lines were surveyed toward a number of dense cores with the 45-m telescope, and it is founded that the degree of the deuterium fractionation is different from core to core [Hirota et al. 2001]. They found a possible correlation between the DNC/$HN^{13}C$ ratio and the NH_3/CCS ratio, and interpreted it in terms of the effect of chemical evolution of dense cores. The NH_2D line was detected toward many star-forming cores [Saito et al. 2000], and the NH_2D/NH_3 ratio was found to be large, 0.025 to 0.18, which is among the highest deuterium fractionation so far observed. This result suggests that a part of NH_3 in dense cores would originate from dust related reactions associated with energetic events, being consistent with the conclusion from the ortho-to-para ratio mentioned above.

The neutral carbon atom plays an important role in chemical and physical processes of molecular clouds. Large-scale mapping observations of the [CI] 492 GHz line have been carried out with several submillimeter-wave telescopes including the Mount Fuji submillimeter-wave telescope (see J2.7). For the first time the distribution of [CI] was delineated in the whole region of the HCL-2 region with the Mt. Fuji telescope, to find a unique cloud where the [CI] emission is very bright in spite of a relatively large visual extinction (Av > 6) [Maezawa et al. 1999]. They suggested that this [CI] rich cloud is in the early stage of molecular cloud formation. Observations of the Orion A molecular cloud with the [CI] 492 GHz line showed that the [CI] distribution well resembles the ^{13}CO distribution in a whole region. This result suggests a possible coexistence of the neutral carbon atom and the CO molecule, although its origin is still unclear [Ikeda et al. 1999].

It is important for astrochemistry to establish the chemical processes in protoplanetary disks. Recently, molecular observations of protoplanetary disks become possible, so that the reliable chemical model calculation, which can be compared with observations, is absolutely necessary. A landmark contribution in this area was reported [Aikawa et al. 1999]. They studied the chemical processes in the gas and solid phases of a protoplanetary disk considering its physical structure, and calculated the evolutionary variation of the molecular abundances. They critically compared the results with the molecular compositions of comets, and succeeded in explaining the coexistence of oxidized ice and reduced ice in the observed comets. Furthermore, they give some predictions for molecular observations of protoplanetary disks by radio telescopes.

(S. Yamamoto)

J5.6 Pulsars

In the pulsar timing project of CRL, PSR1937+21 has been observed every week since 1997 using the 34-m telescope at Kashima. The timing accuracy in the daily-averaged residuals is 2.65 microsec, and the frequency stability over one year is about 1 x 10-13 [Hanado et al. 2002]. These results confirm the feasibility of the 34-m telescope for the precise measurement of millisecond pulsars for timing observations. In the pulsar VLBI astrometry project of CRL, the two-station VLBI between the 34-m telescope at Kashima, Japan, and the 64-m radio telescope at Kalyazin, Russia, achieved highly positional accuracy in pulsar observations. Using the 7000-km baseline, they determined the celestial coordinates of five pulsars with the International Celestial Reference Frame (ICRF) at 1.4-2.2 GHz, and the accurate proper motion of PSR B0329+54 [Sekido et al. 1999]. The ionospheric delay, the most significant error source in pulsar VLBI observations, was corrected by the global ionospheric map produced from world wide GPS network observations. The time transfer system in order to link each atomic clock or celestial one has also been developed at CRL [Imae et al. 1999, 2001]. Gravitational delay in TOA due to MACHO eclipsing was theoretically investigated [Hosokawa et al. 1999]. Acceleration mechanism in radio and/or gamma-ray pulsars were deeply investigated [Hirotani & Shibata 2001].

In the Nasu Pulsar Observatory of Waseda University (see J2.6), five 20-m spherical dishes have been constructed and the total eight dishes will be built in 2002. A large outburst in Cyg X-3 was observed in Apr 20, 2000. A subreflector in each antenna is used to remove the spherical aberrations, and electromagnetic waves from the direction of five degrees from zenith are focused at a feed horn. Thus, each subreflector has asymetrical in shape and synchronously rotates around the azimuthal axis with each feed horn [Daishido et al. 2000].

(T. Daishido)

J6 Extragalactic Radio Astronomy

J6.1 Galaxies

Barred galaxies, NGC 3504 and NGC 253, have been fully mapped in CO with the 45-m telescope [Kuno et al. 2000; Sorai et al. 2000]. Ammonia NH_3 has been detected toward the center of Maffei 2, and its excitation temperature and orth-to-para ammonia ratio has been measured to be 30 K and 2.6, respectively [Takano et al. 2000].

The central region of the edge-on galaxy NGC 3079 has been imaged in CO with a spacial resolution of 1", using RAINBOW, and its rotation curve has been measured in detail [Sofue et al. 2001]. The ratio of HCN/CO has been investigated in the central regions of several Seyfert galaxies with the NMA. It has been statistically found from CO data of 20 barred and non-barred galaxies that molecular gas concentrates toward the central region of barred galaxies more than non-barred galaxies, due to barred potential [Sakamoto et al. 1999]. A large superbubble of molecular gas has been discovered in the starburst galaxy M82 and a middle mass black hole detected in X-ray is located in the molecular bubble, giving a suggestion of a formation mechanism of massive black hole [Matsushita et al. 2001].

(N. Nakai)

J6.2 Quasars and Active Galactic Nuclei

Following the discovery of a super massive black hole (SMBH), VLBI observations of H_2O masers toward NGC 5793 [Hagiwara et al. 2000; Hagiwara et al. 2001], NGC 3079 [Sawada-Satoh et al. 2000], and IC 2560 [Ishihara et al. 2001] resulted in possible detection of SMBHs.

A middle-scale ($M \sim 10^4$-10^6 solar masses) black hole was detected in a starburst galaxy M 82 with NMA [Matsushita et al. 2000], in collaboration with the Chandra X-ray observatory [Matsumoto et al. 2001]. The intermediate mass and the offset from the center of the galaxy by 170 pc suggest an evolving process to SMBH.

Accreting materials surrounding AGNs, which may feed SMBHs, have been unveiled with ground and space VLBI observations. Molecular OH [Hagiwara et al. 2000] and atomic hydrogen (HI) [Sawada-Satoh et al. 2000] absorption lines, and H_2O masers are powerful probe to investigate circumnuclear disks within sub-parsec scale. Multi-frequency continuum observations [Kameno et al. 2000; Kameno et al. 2001] illustrate sub-parsec scale plasma tori, where free-free absorption silhouettes background jets and radio lobes.

The space VLBI, VSOP, contributes progress of our knowledge on relativistic jets emanating from AGNs through detailed imaging. Its extreme resolution of ~0.3 milliarcsec triggered the discovery of tiny wiggles of straight jets in the acceleration region of NGC 6251 [Sudou et al. 2000]. Bending of straight jets was detected in Centaurus A [Fujisawa et al. 2000]. The rapid variability in flux density of OT 081 was indicated due to the variation of the jet viewing angle [Iguchi et al. 2000]. Based on the spectral peak and the size of jet components, the matter content of jets in 3C 345 was pointed out to be dominated by an electron-positron pair plasma, rather than a normal electron-proton plasma [Hirotani et al. 2000].

(S. Kameno)

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