COMMISSION J: RADIO ASTRONOMY

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J1 Introduction

Several new observing systems have been operational, particularly in Universities. We formally participated in the ALMA project and began construction. A space mission is waiting for the launch to the Moon, and the second Space VLBI project has been proposed. The organization system of National Universities and Institutes was largely changed to agencies, and the effects are not yet understood.

In J2, instrumentations and observing facilities of newly built or developed ones are shown, followed by the progress of individual research fields in terms of scientific target: the Solar Radio Astronomy in J3, and then starting from the Solar System in J4 to Quasars and Active Galactic Nuclei in J6 by the order of distance from us.

J2 New Instrumentation

J2.1 ALMA

The National Astronomical Observatory of Japan (NAOJ) and the radio astronomy research community in Japan promoted the Atacama Large Millimeter/submillimeter Array (ALMA) project. The construction project of the Japanese part of ALMA has started in 2004 April with an approval of the funding.

Based on the resolution between the ALMA Coordination Committee (ACC) and NAOJ concerning the Partnership for Planning the Atacama Large Millimeter/submillimeter Array (ALMA) signed on 2001 April by the European and North American delegates of ACC and the Director General of NAOJ, NAOJ made a funding request for ALMA construction starting from FY2002. Although this initial request was not successful in getting the construction fund, NAOJ was given a fund for FY2002 and FY2003 for the research and development of key technologies of large millimeter/submillimeter arrays, i.e., precision reflector antennas, the millimeter/submillimeter receiver front-ends, and wide-band digital spectro-correlators. The European and North American partners successfully acquired the construction funding starting from 2002, and the construction of ALMA was started with a bilateral agreement between them. In 2003 and 2004 NAOJ continued negotiation with the European and North American partners for the participation in the ALMA construction. In March 2004 the Japanese construction fund starting from FY2004 was approved, and the Agreement Concerning the Construction of the Enhanced Atacama Large Millimeter/submillimeter Array

(ALMA) was signed in 2004 September between the European Organization for Astronomical Research in the Southern Hemisphere, the National Science Foundation of the United States and the National Astronomical Observatory of Japan. The Japanese deliverables defined in the Agreement included the Atacama Compact Array (ACA) system and three new receiver bands: the ACA system consists of twelve 7-m antennas, four 12-m antennas and a dedicated ACA correlator, and will take short-baseline and total-power data to be combined with the data from the 64-element 12-m antenna array built by the European and North American partners. Eighty receiver front-end cartridges for each of the new receiver bands (Band 4: 125–163 GHz, Band 8: 385–500 GHz, Band 10: 787–950 GHz) will be built and integrated into the front-end subsystems at the Cassegrain foci of all ALMA antennas, along with the four bands built by the European and North American partners.

NAOJ conducted the design and development of the ALMA antenna by building a prototype 12-m antenna and evaluating it at the ALMA Test Facility (ATF) in Socorro, USA. The prototype antenna met the major specifications that were verifiable at ATF, and the technical feasibility was demonstrated [Ukita et al. 2004]. The development of the receiver front-end was made as collaboration among NAOJ, Osaka Prefecture University, Nagoya University, and Toyota National College of Technology. It included design and development of wide-band sideband-separating SIS mixers without mechanical tuners, prototyping of receiver cartridges for Band 4, 8, and 10 and field-testing them, refinement of the cartridge concept of the cryostat, and design and production of cartridge test cryostats [Andoh et al. 2003; Asayama et al. 2003a, 2003c, 2004; Ogawa et al. 2003; Sekimoto et al. 2003a; Sugimoto et al. 2003a, 2003b; Yokogawa et al. 2003a]. A photonic scheme for the local oscillator signal generation was developed, and a research on the photomixers was made as collaboration between NAOJ and NTT [Ishiguro et al. 2002; Ito et al. 2002; Noguchi et al. 2001; Sekimoto et al. 2003a; Ueda et al. 2003a, 2003b]. NAOJ built a single-baseline test FX correlator and evaluated its performance with an actual observation of the astronomical signal at Nobeyama, confirming the technical feasibility of large scale FFT processing [Okumura et al. 2002, 2003]. A prototype A/D converter with 4 Gsps in 2 bits was developed and successfully evaluated [Okiura et al. 2002]. Numerical simulations were made to assess the importance of ACA in wide-field imaging by ALMA and to identify the critical technical requirements that make ACA meaningful [Tsutsumi et al. 2004]. The characterization of the ALMA site was continued, and the methods to compensate the atmospheric phase fluctuation were studied [Matsushita et al. 2002; Sakamoto 2002b, 2003c, 2003d, 2004a, 2004b, 2004c; Watanabe 2004]. The organizational structure to manage the Japanese part of the construction project was developed in NAOJ in harmony with the “bilateral” management structure. Computing was identified as one of the areas that require joint development by a unified team with members from the three partners, and a plan was made for such a scheme. Astronomers in China/Nanjin and China/Taipei expressed their interests in collaboration in construction and/or operation of ALMA, and discussion started between NAOJ and their institutes. (T. Hasegawa)

J2.2 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. A 25-beam SIS receiver at 82-116 GHz, BEARS, and a 6-beam SIS receiver at 40-50 GHz are available on the telescope. In addition, a bolometer array, seven beams with 30-GHz bandwidth at 150 GHz, is also available. New encoder system for the telescope is under construction. The Nobeyama Millimeter Array (NMA), which is composed of six 10-m antennas, has been operated at 85-116, 126-152, and 220-240 GHz. The RAINBOW interferometer, which connects NMA and the 45-m telescope to make an array with large gain, has been provided for open use. (M.Tsuboi)

J2.3 ASTE

The Atacama Submillimeter Telescope Experiment (ASTE) is a project to operate a 10-m submillimeter telescope at a high altitude site (4,800 m) located in Atacama Desert in Northern Chile. The project aims to explore the southern sky with a submillimeter region at 300-900 GHz, as well as to study and develop instruments or methods for submillimeter observations. The telescope was shipped to Chile in 2002. Following the evaluation and testing phase including detection of CO (J=7-6) emission at 807 GHz, we have started the spectroscopic observations mainly at 345 GHz band to detect various emission lines including CO(J=3-2) or CS(J=7-6) through numbers of astronomical objects.

The 10-m antenna has an excellent performance with its surface accuracy adjusted within 19 microns rms, which is realized utilizing the motorized actuators supporting the 205 panels which consists the surface of the main reflector. Several receivers were tested on board in early phase operation in Chile: SIS receivers at 100 GHz to 800 GHz, and a bolometer system at 350 GHz to 850 GHz. These receivers provided the first chance to observe astronomical radio waves with 800 GHz band at the Atacama site. Currently the SIS receiver at 345 GHz with cartridge type plug-in cryogenics is in operation, which is presenting an excellent performance with system noise temperature within 130 K to 200 K. The spectrometer is an array of 4 XF type digital auto-correlators, each with spectral channels of 1024 and frequency resolution of 31.25 kHz. The bandwidth can be either 512 MHz or 32 MHz for each auto-correlators which may cover 750 km/s at 810 GHz. The control system is designed to enable operating the telescope remotely through the network connection. The connections are via satellite link from the telescope site to San Pedro de Atacama (alt. 2400 m) and Universidad de Chile in Santiago, with further connection to Japan through the internet. The telescope site is powered by two sets of generators, as well as several safety equipments including oxygen compressors and satellite phones. (H. Ezawa)

J2.4 NANTEN 4-m Telescope of Nagoya U

The NANTEN telescope, a 4-m millimeter-submillimeter telescope, was installed at the Las Campanas Observatory in Chile under a mutual agreement between Nagoya University and the Carnegie Institution of Washington. The observations were carried out mainly in the 12CO, 13CO, and C18O (J=1-0) emissions at a beam size of 2.7 arcmin. The molecular cloud survey toward LMC and SMC has been completed and resulted in a detection of ~260 Giant Molecular Clouds. The survey toward the Galactic plane in 12CO almost covers 60° > l > 240°, -10° < b < 10° with grid spacings of 4 arcmin for |b| < 5° and of 8 arcmin for the rest. This resulted in a number of detections of Giant Molecular Clouds (GMCs) as well as candidates for supershells along the galactic plane. Detailed studies of interacting clouds with HII regions and/or SNRs are also carried out. The physical properties of the molecular gas toward GMCs, dark clouds, and high latitude clouds in the Galaxy are studied. These results are described in a section of "Star Formation".

The NANTEN telescope had stopped its operation in October of 2003, and the upgrade for sub-millimeter observations started from the period [NANTEN2 project]. The telescope is installing at Pampa la Bola in Chile at an altitude of 4,800m to realize a large-scale survey at submm wavelengths. In this new project, we will make large-scale surveys toward the Galaxy and nearby galaxies including the Magellanic Clouds by using mainly CO and [CI] lines in a 100-800 GHz range. The purpose is an elucidation of evolution of interstellar matter and the mechanism of star formation in the local group by revealing the distribution, kinematics, and physical conditions of interstellar gas in the atomic-molecular phases with the thorough extensive survey. This project is collaboration between Universities in Japan (Nagoya University and Osaka Prefecture University), Germany (University of Cologne and University of Bonn), South Korea (Seoul National University), and Chile (University of Chile). The telescope is enclosed in a dome with a shiftable membrane to prevent perturbations such as strong wind and sunlight. The installation started at the beginning of 2004. The highest observing frequencies will be covered by the KOSMA SMART receiver, a dual-frequency, 2 x 8 pixel array receiver operating between 460 and 880 GHz, and KOSMA array Acousto Optical Spectrometers as backends. (T. Onishi)

J2.5 Mt. Fuji Submillimeter Telescope

Mount Fuji submillimeter-wave telescope is operated by Yamamoto Group of Department of Physics, The University of Tokyo, in collaboration with Nobeyama Radio Observatory. It is a 1.2-m telescope enclosed in the space frame radome with GoreTex membrane, and is used exclusively for survey observations of the fine structure lines of the neutral carbon atom ([CI] 492 GHz and 809 GHz). With this telescope, more than 40 square degree areas of nearby molecular clouds have been observed in the 492 GHz CI line, and several representative sources have been mapped in the 809 GHz CI line. Among them, Kamegai et al. (2003) presented the large-scale CI (492 GHz) map toward rho-Ophiuchi molecular cloud. The CI emission peak is found to exist behind dense cores with respect to the excitation star (HD147889), suggesting that the peak is in the early stage of chemical evolution. Oka et al. (2004), on the other hand, studied the CI (492 GHz) distribution in the NGC1333 region. Again the CI peak is located behind dense cores with respect to the excitation stars. With the aid of chemical model calculations, they showed that it is essentially important to consider the chemical evolutionary effect in interpretation of the CI distribution.

Unfortunately, Mount Fuji submillimeter-wave telescope will be closed in August 2005. This is because the electricity supply from the meteorological weather station becomes unavailable due to shut down of the weather station. (S. Yamamoto)

J2.6 The 60-cm Telescope of the U. Tokyo

The radio astronomy group at Institute of Astronomy in the University of Tokyo runs a 60-cm radio telescope, called the Very Small Telescope 1 (VST1) located at Nobeyama with support of Nobeyama Radio Observatory. The telescope is designed for survey observations of the Galactic plane and nearby molecular clouds in CO (J=2-1) and other lines near 230 GHz. The beam size of 9 arcmin enables us to make direct comparison with the CO (J=1-0) line obtained using the 1.2-m telescope operated by Harvard Smithsonian Center for Astrophysics, which gives density and temperature of molecular gas. To improve observation efficiency we have upgraded the telescope system since 2003 with cooperation of radio astronomy groups in Osaka Prefecture University and Tokyo Gakugei University. The receiver has replaced to sideband separating receiver (2SB), which can simultaneous observations in both side bands. Using the 2SB receiver we plan to make observations in both 12CO and 13CO at once. For the dual IF signals obtained by the 2SB receiver, we have designed and installed two sets of 2048-channel Acousto-Optical Spectrometers (AOS) with a 250-MHz bandwidth. The telescope controlling system has been revised from DOS based to Linux based. The new system called UltraASTROS is improved for easy accessibility through the Internet and is designed to make automated observations. The new telescope system was performed the first engineering observations in 2005. (T. Handa)

J2.7 Arrays of Waseda University

Transient radio source survey and EGRET Gamma-ray source identification program has been started at Nasu Pulsar Observatory of Waseda University. A spherical dish array of 8 x 20-m elements is operated at 1.4 GHz, covering between 32° to 42°. in Declination. During early observations, a large outburst was detected at April 20, 2000. (T. Daishido)

J2.8 VERA and VLBI Activities

J2.8.1 VLBI Networks

VLBI Exploration of Radio Astrometry (VERA) aims to determine the distance to celestial objects in our Galaxy by measuring annual parallaxes and to investigate the structure of our Galaxy. VERA consists of four 20-m radio telescopes around the Japanese Archipelago (at Mizusawa, Iriki, Ogasawara, and Ishigakijima). VERA has a dual-beam observing system for the phase referencing VLBI observations. VERA will observe around one thousand objects to make a three-dimensional map of our Galaxy. The dynamic structure of our galaxy will be revealed by measuring the motions of these objects. At 2004, VERA developed a central control system and became regular operation phase. The accuracy of astrometry has reached around 100 micro-arcsecond. VERA has endeavored more accurate calibration procedures for the improvement of the accuracy.

At 2004, the new Japanese VLBI network was organized, which consists of 10 VLBI stations: VERA 4 stations, Tomakomai 11-m telescope, Kashima 34-m telescope, Tsukuba 32-m telescope, Usuda 64-m telescope, Gifu 11-m telescope and Yamaguchi 32-m telescope. Since December 2004, observations were started at 8GHz, achieving the mapping dynamic range of 1500. So possibilities of high dynamic range observations were demonstrated. Regularly it has been operated around 20 hours per month.

At the 6th East Asian Astronomy Meeting held at Seoul in October 2004, East Asia VLBI consortium was organized. It aims to organize the East Asia VLBI network, which consists of current and constructed VLBI stations in China, Japan and Korea. Especially this area will have more than fifteen VLBI stations within 2,000-km in diameter, the distribution of the network is the most dense in the world. At 2004, Sheshan station of China was joined to Japanese VLBI network observations at 22 GHz and gave good fringes.

J2.8.2 VLBI Activities in Institutes and Universities

National Astronomical Observatory of Japan (NAOJ) has two projects related to VLBI activities. One is the VERA project and the other is a Space VLBI project. NAOJ has 7 VLBI stations. Four of them are VERA stations and others are Nobeyama 45-m, Yamaguchi 32-m and Kagosima 6-m radio telescopes. VERA project has been developing optical fiber link VLBI system. Tsukuba 32-m, Kashima 34-m, Usuda 64-m and Gifu 11-m telescopes are combined with optical fiber links, which makes it possible to transmit data with 2-Gbps from each station. It is a unique operation VLBI array with optical fiber link in the world. A new Space VLBI project VSOP-2, next to HALCA/VSOP, has been proposed to the Institute of Space and Astronautical Science (ISAS), collaborating with the Space VLBI group in ISAS, and other groups.

National Institute of Information and Communication Technology (NICT) is operating 34-m and 11-m radio telescopes at Kashima and another 11-m radio telescope at Koganei. They are mainly used for geodetic and astronomical VLBI observations and pulsar timing observations. As one of the Technical Development Centers of International VLBI Service for Geodesy and Astrometry (IVS), NICT has been developing Gbps-class VLBI observing systems to enhance the sensitivity of the VLBI observations [Nakajima et al. 2001], and the K5 VLBI system to realize e-VLBI in real-time over the shared IP networks [Kondo et al. 2002; Koyama et al. 2002]. Software correlator programs which run on multiple PC systems for distributed processing are under development as the correlator part of the K5 system. By using the K5 system, rapid turnaround estimation of UT1-UTC as short as 4.5 hours was demonstrated in June 2004 with a baseline between Kashima and Westford (Haystack Observatory) VLBI stations [Koyama et al. 2003]. The K5 system is also being used for investigations about precise orbit determination of spacecrafts. Nozomi and Hayabusa spacecrafts were observed by differential VLBI technique to improve the accuracy of the position of these spacecrafts [Kondo et al. 2002]. Theoretical investigations to improve the VLBI measurements are also carried out, such as ionospheric delay modeling [Sekido et al. 2003a] and relativistic VLBI delay model for finite distance radio sources [Sekido et al. 2003b].

Geographical Survey Institute (GSI) has a VLBI network of Tuskuba 32-m, Shintotugawa 10-m, Chichijima 10-m, and Aira 10-m radio telescopes. Japan domestic geodesy VLBI experiments are carried out using them every month, which is called as JADE. Some other stations of other institutes were joined in JADE to determine their positions. GSI carries out UT1 experiments between Tsukuba, Wetzell in Germany, and/or Onsala more than 100 times per year. Tsukuba 32-m telescope participates in the IVS observations regularly.

Institute of Space and Astronautical Science (ISAS) became a department of Japan Aeronoautical Exploration Agency (JAXA). It carried out a space VLBI mission VSOP. Usuda 64-m antenna is used for the Japanese VLBI network observations. ISAS has developed a satellite orbit determination system using VLBI technique. Kagoshima 34-m antenna was installed a VLBI terminal system and is also used for the satellite navigation experiments.

Universities in Japan recently have their own radio telescopes and form optionally the Japanese VLBI network with VERA and other telescopes in Institutes. Hokkaido University has an 11-m radio telescope at Tomakomai, operated at 22 GHz. It is mainly used for the galactic plane survey by NH3 as a single dish. It has also a VLBI terminal system and joins to Japanese VLBI network observations. Gifu University has an 11-m radio telescope at Gifu, operated at 2 and 8 GHz. It is mainly used for geodetic VLBI experiments and e-VLBI experiments. Yamaguchi University cooperates in the operation of Yamagauchi 32-m radio telescope with NAOJ. It is used as a station of Japanese VLBI network. The group of the Yamaguchi University has carried out methanol maser survey observations as a single dish. They discovered some new sources. Kagoshima University cooperates in the VERA project of NAOJ. Iriki station, one of four VERA stations, is operated by the group of Kagoshima University. (H. Kobayasgi)

J2.9 Space VLBI VSOP

The VLBI (Very Long Baseline Interferometry) Space Observatory Programme (VSOP) was realized with the launch of the radio astronomy satellite HALCA by the Institute of Space and Astronautical Science (ISAS) in February 1997. HALCA exceeded its nominal five year lifetime, conducting almost 800 observations at 1.6 and 5.0 GHz to study the compact cores and the parsec-scale jets of extragalactic radio sources and other objects. In addition to open General Observing Time, observations were undertaken at 5 GHz for the VSOP Survey program, a mission-led survey to study the statistical properties of the bright, flat-spectrum of active galactic nuclei, with results for the first 102 sources published last year [Scott et al. 2004]. One of HALCA's four reaction wheels stopped operating in October 1999, and a second has not been able to be restarted after a loss of attitude control in October 2003. HALCA is being monitored during one tracking pass per week, with the VSOP team's efforts now being focused on improving access to the VSOP data archive, and on preparations for the submission of a proposal for a next generation mission, VSOP-2, which will provide gains in sensitivity and angular resolution of an order of magnitude compared with VSOP. (P.G. Edwards)

J2.10 Lunar exploration

Two radio-metric experiments are planned in Japanese SELENE (Selenological and Engineering Explorer) mission. One is a 4-way Doppler experiment using a relay sub-satellite. The second is a differential VLBI experiment with the two sub-satellites which transmit three carrier waves at S band and one carrier wave at X band. Both experiments are to measure the precise lunar gravity field. SELENE is scheduled to be launched in 2007. The PFM integration test has already begun in late 2004. The VLBI recording system was equipped to all of VERA antennas and to three stations in China and Europe, except one for Germany. (N. Kawano)

J3 Solar Radio Astronomy

Nobeyama Radioheliograph (NoRH) is a radio interferometer dedicated for solar observations. It has been operating since 1992 and has completed one solar cycle observation. Due to the uniform date set of microwave full disk images of the Sun for one solar cycle or more, statistical studies of solar activity over solar cycle can be done. On this occasion, an international symposium "Solar Physics with Nobeyama Radioheliograph" was held on October 2004 to summarize science outputs from NoRH and to discuss future researches.

High-cadence imaging capability (0.1 second) of NoRH made it possible to detect directly high-energy electron streams along a large coronal loop. The electrons are accelerated or injected at one of the footpoints of the large loop. The projected speed of the stream is one-third of the light speed. Taking into account the gyration of electrons around magnetic field and the angle between the loop and the line-of-sight, actual speed of electrons is close to the light speed and this is consistent with the fact that the steaming electrons generate microwave emission through gyro-synchrotron mechanism [Yokoyama et al. 2002].

Properties of extended non-thermal flaring loops have been studied. These loops do not necessarily associate with high-temperature and high-density plasma that emit soft X-rays. Microwaves are emitted by interaction of high-energy electrons with magnetic field, hence, microwaves cover the whole loop. They are clearly observed when the loops sizes are large enough to be resolved by the beam of NoRH. Recent studies show that, many of these loops have brighter loop top compared to loop legs or footpoints [Melnikov et al. 2002a]. Gyro-synchrotron emission is known to be very sensitive to magnetic field strength. Model calculations show that loop footpoints are brighter than loop tops. However, observations show opposite. This is interpreted by large pitch angle distribution of accelerated electrons. This is a very strong constraint to acceleration mechanism of high-energy electrons in solar flares. Oscillations of flaring non-thermal loops were reported and the oscillation mode is identified [Melnikov et al. 2004, Stepanov et al. 2004]. Based on oscillations, diagnostic method of flaring loops has been developed.

After the launch of RHESSI (Ramaty High Energy Spectroscopic Imager) satellite in 2002, many strong flares were observed simultaneously by RHESSI and NoRH. Some of the analysis of these events are reported [Kundu et al. 2004, and White et al. 2003]. Due to hard X-ray and gamma-ray spectroscopy of RHESSI together with imaging capability, studies of high-energy particle acceleration will be greatly enhanced by combining with two-frequency imaging capability of NoRH. However, the acceleration mechanisms are not yet conclusive. (K. Shibasaki)

J4 Solar System Radio Astronomy

Tohoku University has established a meter to decimeter wave range radio telescope, named IPRT (Iitate Planetary Radio Telescope), in 2001 at Iitate, Fukushima, Japan. The antenna of the radio telescope is a fully steerable offset-parabola type with the physical aperture area of 1023 m2, and composed of a pair of same-shaped parabolic rectangular sections (16.5 m x 31 m) installed on one alt-azimuth mount. The radio telescope has been dedicated for exclusive and regular observation of planetary radio emissions to investigate electromagnetic environment of planets, particularly Jupiter's inner magnetosphere [Tsuchiya et al., 2002, Tsuchiya et al., 2003; Misawa et al., 2003].

Jovian synchrotron radiations (JSR) emitted from relativistic electrons trapped in the Jupiter's radiation belt were observed during a rarely strong solar event on October 28 and 29, 2003 by Tsuchiya et al. (2004). The observations were made by using IPRT at Iitate Observatory during the period from October 16 to November 20, 2003. They compared the variation of JSR intensity with the solar F10.7 flux and found that JSR showed an unusual increase of its magnitude by about 50% during the period of solar flux enhancement, and subsequent rapid decrease after the solar event with the decay rate of about 0.3 Jy/day. (A. Morioka)

The interplanetary scintillation (IPS) method can observe the dynamics and structure of the solar wind in three dimensions with a relatively short time cadence using IPS radio sources distributed over the sky. Because of this advantage over in-situ measurements, the Solar-Terrestrial Environment Laboratory (STEL) has been conducting the IPS observations at a frequency of 327 MHz using four-station system.

To make solar wind observations with higher spatial and temporal resolution using the tomographic method, the project to build a new large UHF antenna, Solar Wind Imaging Facility (SWIFT), has been commenced. The antenna will have a collecting area of 40 m x 106 m which consists of two cylindrical parabolic reflectors with 20 m width (EW) and 106 m length (NS). The antenna is designed with a tolerance for radio noise interference and high aperture efficiency. The SWIFT will observe meridian-passage radio sources by changing direction of beam from S60 to N30.

A solar wind prediction experiment is being carried out under collaboration between CASS/UCSD and STEL by using computer-assisted tomography (CAT) analysis. In this experiment, speed and density variations in the near-earth solar wind are predicted from IPS measurements in quasi real time via STEL and UCSD web servers (http://cassfos02.ucsd.edu/solar/forecast/index.html, http://stesun5.stelab.nagoya-u.ac.jp/forecast/).

The elucidation of three-dimensional (3D) structure and propagation characteristics of coronal mass ejections (CME) is an important subject in solar weather research. In particular, our knowledge on the 3D properties of CMEs in the interplanetary space (i.e., beyond the field of view of the coronagraph) is limited due to the shortage of global observations. We have been studying the 3D structure and propagation characteristics of ICMEs, using IPS observations. However, there has been a difficulty in investigating 3D properties of ICMEs precisely from IPS data because of line-of-sight (los) integration effects. Recently, we have developed the model fitting analysis method, which allows us to remove the los integration effects and to retrieve the 3D structure of ICMEs from IPS data. Using this revolutionary technique we have studied the structure and dynamics of ICMEs [Ananthakrishnan et al., 2002; Tokumaru et al., 2003a, b; Yamashitaet al., 2003; Jackson et al., 2003; Kuwabara et al., 2004; Tokumaru et al., 2005].

Various kinds of coronal holes produce various speed of solar wind and construct 3D structures of the solar wind. We have investigated the relation between solar wind velocity and physical properties of the corona holes. The relations among a solar wind velocity (V), coronal hole scale size, a magnetic flux expansion rate (f) and photospheric magnetic field (B) are examined, and the highest correlation was found between V and B/f [Kojima et al., 2004b] and small coronal holes were found to be sources of the slower solar wind [Ohmi et al., 2003a, b; Ohmi et al., 2004]. (M. Kojima)

J5 Galactic Radio Astronomy

J5.1 Galactic Center Region

The Nobeyama Radio Observatory 45-m telescope (RT45) Galactic Center CO survey indicated that all the clouds in the GC are in equilibrium with high pressure in the GC environment (Oka et al.2001, Oka and Hasegawa 2003). Mapping observations of SiO maser sources near the GC were made with RT45 at 43 GHz, resulted over 200 detections of SiO sources (Deguchi et al. 2002, 2003 Imai et al.2003). The 7-years monitoring observations of Sagittarius A* at 100 and 140 GHz with Nobeyama Millimeter Array (NMA) found intraday variation of Sgr A* (Miyazaki et al. 2004). VLBA observation revealed a radio intraday flare of Sgr A* at 43 GHz (Miyoshi et al. 2003). Aperture synthesis observations of Sagittarius B2 Main in the FeO (J=5-4) line using NMA confirms the detection of this line in absorption (Furuya et al. 2004). A comparison between CO and OH data derived the molecular face-on view of the GC (Sawada et al.2003). Circular polarization of Sgr A* with RT45 at 100 GHz was measured to be less than 0.5% (Tsuboi et al.2003). (M. Tsuboi)

J5.2 Star Forming Regions

A number of high-density molecular cores were observed in nearby low-mass star forming regions in order to pursue the initial conditions of low-mass star formation. H13CO+ (J=1-0) observations in Taurus gave us detailed information of dense cores just before star formation with a nearly complete sample of 55 high density cores in the region [Onishi et al. 2002]. Physical properties of 179 C18O cores were summarized [Tachihara et al. 2002], and 8 cores in Taurus were mapped in the line of N2H+ (1-0) [Tatematsu et al. 2004] to investigate the evolutionary status of the dense cores. Several molecular lines were used to investigate the chemical evolution of several pre-protostellar cores [Hirota e tal. 2003; Lee et al.2003; Hirota et al. 2004]. Coalescence processes of small clumps are suggested to be likely to play an important role in forming protostars inside cores with a high spatial resolution observation by using NMA toward two dense cores [Takakuwa et al. 2003].

Observational study of low-density gas revealed important features to constrain theoretical models of molecular cloud formation. Large velocity dispersion in a small spatial scale of ~0.01 pc was detected toward high latitude clouds and a Taurus cloud, suggesting the structure formation of molecular clouds through thermal instability [Sakamoto 2002; Sakamoto and Sunada 2003]. A large scale survey toward galactic high-latitue region detected a few hundred molecular clouds, and the evolutionary status was investigated by comparing molecular data with infrared and HI data [Onishi et al 2001; Yamamoto et al. 2003].

Ten massive star-forming regions were studied in the lines of 13CO, C18O(J=1-0) and CS(J=2-1) [Ao et al. 2004]. An interferometric and single-dish study of G24.78+0.08, a region associated with high-mass star formation, strengthened the proposed scenario star formation would occur from inside-out collapse of the parsec-scale clump, followed by infall reversal due to outflows powered by the newly formed massive stars [Cesaroni et al. 2003]. Evolutional sequence of high-mass protostars is studied though high angular resolution observations at millimeter wavelengths of the high-mass star forming region G24.78+0.08 [Furuya et al. 2002]. Heads of two molecular pillars in the Eagle Nebula were observed by using the Nobeyama Millimeter Array with a spatial resolution, and propagation of star formation was suggested in the region [Fukuda et al. 2002].

NANTEN telescope has been revealing new views of molecular gas distribution of the southern sky. The new sensitive survey of giant molecular clouds (GMCs) in the LMC tripled the number of the GMCs from 55 to 168 [Fukui et al. 2001]. Catalog of GMCs in the LMC for the first survey was presented [Mizuno et al. 2001] and the result of the GMC survey toward the SMC was presented [Mizuno et al. 2001]. The effect of supergiant shells on the formation of molecular clouds and stellar clusters was studied [Yamaguchi et al. 2001] and the evolutional sequence of GMCs was elucidated by using the NANTEN LMC data [Yamaguchi et al. 2001]. Eight molecular supershells were detected from the NANTEN galactic plane survey [Matsunaga et al. 2001] and the effect of supernova to molecular clouds were studied toward the Vela supernova remnant [Moriguchi et al. 2001]. The most massive C18O molecular complex was found in Centaurus region [Saito et al. 2001], and a large scale study of H13CO+ and C18O (J=1-0) was carried out toward a GMC Orion B [Aoyama et al. 2001]. Star formation in IC 2218 in the Orion-Eridunus Bubble was investigate to reveal the effect of massive stars to the star formation in it [Kun et al. 2001]. Large scale 12CO(J=1-0) surveys toward nearby low-mass star forming regions were carried out toward Chamaeleon [Mizuno et al. 2001] and Lupus [Tachihara et al. 2001]. Molecular clouds at Galactic high-latitude were surveyed extensively toward Aquila [Kawamura et al. 2001] and toward the infrared excess clouds [Onishi et al. 2001]. The correlation between CO column density and extinction was investigated for molecular clouds in Chamaeleon II-III complex.

CO molecular outflows are searched toward the cloud A and B2 of the Rho-Ophiuchi star-forming region and all the newly discovered outflows are likely to be driven by Class II sources or near-infrared sources, and none of them is associated with the cold submillimeter-millimeter sources without infrared counter parts [Kamasaki et al. 2003]. High-resolution millimeter imaging was carried out toward the R Coronae Australis IRS 7 region, and three compact objects located within 4" (700 AU) of IRS 7A [Choi and Tatematsu 2004]. Millimeter wavelength observations are presented toward NGC 1333 IRAS 4, a group of highly embedded young stellar objects in Perseus, that reveal motions of infall, outflow, rotation, and turbulence in the dense gas around its two brightest continuum objects, 4A and 4B [Di Francesco et al. 2001]. Result of multiepoch 22 GHz H2O maser survey mainly toward 142 low-mass young stellar objects using the Nobeyama 45 m telescope and the Very Large Array was compiled together with their H2O maser activity [Furuya et al. 2003]. Molecular gas toward the supernova remnant (SNR) W44 (G34.7-0.4) was extensively mapped in CO J=1-0 emission with the 17" beam of the Nobeyama 45 m radio telescope, detecting high-velocity (> 25 km s-1) CO line wings [Seta et al. 2004]. (T. Onishi)

J5.3 Circumstellar Disks

Low- and intermediate-mass pre-main-sequence (PMS) stars are usually found to be accompanied by circumstellar disks of gas and dust. Our solar system and the exoplanets being discovered since 1995 are believed to form in the disks, and thus, the disks are called protoplanetary ones. The physical and chemical properties of the disks are theoretically thought to determine the key characteristic of a newborn planetary system. One of the major causes of the diversity of the exoplanets is the radial distribution of the disk surface density. An extensive imaging survey of the disks around T Tauri stars with the Nobeyama Millimeter Array (NMA) has revealed the diversity of the surface density distribution [Kitamura et al. 2002]: the power-law index of the distribution is 0-1 in most cases, smaller than 1.5 in the Hayashi model, the standard one for the origin of our solar system. Furthermore, the survey has discovered the radial expansion of the disks as an accretion disk, which means that the physical properties of a disk just at the end of the accretion stage are the initial conditions for planet building.

Another important factor for understanding the exoplanet diversity is the chemical nature of the disks. However, there exist only a few sources for which interferometer images were obtained with various molecular lines. For the disk around LkCa 15, the NMA has marginally resolved the spatial distribution of formaldehyde [Aikawa et al. 2003]. It is found that the column density of formaldehyde is one order of magnitude larger than that predicted by theoretical models of disk chemistry, while the formaldehyde intensity is less centrally peaked than that of CO, consistent with the models.

The observational studies of the protoplanetary disks have been performed mainly for young stellar objects (YSOs) in the Taurus molecular cloud, a typical site for low-mass star formation. To understand the diversity of planetary systems, however, it is crucial to study the disk properties in other clouds and to reveal region-to-region variations. Another sample of the nearest star-forming regions is MBM 12, whose distance is considered to be 65-360 pc. The NMA has succeeded in detecting the dust thermal emission from three YSO disks [Itoh et al. 2003]. The conclusion of this study is that the disks in MBM 12 have masses and IR excesses similar to those in Taurus. (Y. Kitamura)

J5.4 Stars

Masers in evolved stars have extensively been studied with Nobeyama 45-m telescope. The J=2-1 v=1 and 2 transitions of SiO around 43 GHz are easily detectable with this telescope with the SiS mixer receiver using acousto-opto spectrometers. The high sensitivity due to large aperture of this telescope enables us to detect the objects at 10 kpc away. Deguchi et al. (2001) detected a number of new SiO maser sources within a few pc of the Galactic center. Furthermore, a targetted survey of the ~400 large-amplitude variables within 30 pc of the Galactic center (Imai et al. 2002b; Deguchi et al. 2003a) yielded about 200 detections in the SiO maser lines. With these systematic surveys by SiO maser lines, dynamics of the intermidiate-mass stars around the Galactic center black hole was revealed. Furthermore, surveys of about 400 IRAS sources in the Galactic disk were performed by SiO maser lines (Nakashima & Deguchi 2003ab), resulting 250 new detections in SiO. Some of them were turned out to be very interesting objects (Nakashima et al. 2004; Deguchi et al. 2004) from the view point of stellar evolution. High-spatial resolution observations with millimeter-wave interferometers (BIMA & NMA) of these objects were also performed, clarifying the bipolar outflow structure (Nakashima & Deguchi 2004). The radial velocities of stars, which were accumulated with these SiO survyes, can be used to obtain the pattern speed of the Galaxy (Deguchi et al. 2004b). (S. Deguchi)

J5.5 Interstellar Chemistry

Deuterium fractionation is an important problem in astrochemistry. It is deeply related to the chemical evolution and the depletion of molecules onto dust grains. Saito et al. (2002) proposed that the deuterium fractionation ratio can be used as an indicator of the chemical evolution of dense cores on the basis of the DCO+/H13CO+ data toward TMC-1 and chemical model calculations. Hirota et al. (2003) mapped the DNC (J=1-0) and HN13C (J=1-0) lines toward several dense cores, and found that the chemical fractionation ratio does not vary within each cloud even in L1544, where heavy depletion of molecules has been reported. This means that the DNC/HN13C ratio is not very sensitive to the depletion factor unlike the DCO+/HCO+ ratio. Since the time scales of chemical evolution, depletion, and physical evolution are comparable to one another, these three factors should be considered for detailed interpretation of deuterium fractionation data. In this relation, an important contribution from the laboratory microwave spectroscopy has been made by Hirao and Amano (2003). They measured the accurate transition frequency of the 1{10}-1{01} transition of D2H+ at 691 GHz in the laboratory. Immediately after the laboratory study, Vastel et al. (2004) detected this line toward IRAS16293-2422, where various deuterated molecules have been detected. According to the model of deuterium fractionation, D2H+ is expected to be abundant in a cloud with high depletion. The detection of D2H+ clearly confirms this effect.

In relation to the chemical evolution of dark cloud cores, Aikawa et al. (2003) studied the distribution of CCS and other molecules in L1544, considering the effects of the chemical evolution and the depletion. It is confirmed that the CCS distribution shows a hole at the central part of the core in the late stage, where HN2+ becomes abundant. On the other hand, Hirota et al. (2002) found a unique core, L1521E. In this source, the carbon-chain molecules like CCS are very abundant, whereas NH3 and HN2+ are deficient. Furthermore it shows a very low deuterium fractionation ratio. On the basis of these results, they concluded that L1521E should be in a very early stage of chemical evolution. Later Tafalla and Santiago (2004) reported that this cloud shows little depletion, confirming its youth. Hirota et al. (2004) further reported two more clouds which are similar to L1521E. These young clouds would be important to understand the initial conditions of star formation.

A big progress has been achieved in the field of grain surface chemistry. It is well known that the highly saturated molecules like CH3OH cannot be produced in the gas phase efficiently. Although the formation of CH3OH on dust grains due to reactions of CO and H is proposed, its detailed mechanism and reaction rates has still been controversial. Watanabe and Kouchi (2002) succeeded in characterizing these surface reactions by using the H atom source with calibrated intensity. This and related beautiful experiments (Watanebe et al. 2003, Hidaka et al. 2004) have opened a new window on laboratory studies of grain surface reactions, and they would provide more sound basis of the rates of the reactions to chemical model calculations of molecular clouds and protoplanetary disks.

As for the extragalactic sources, Takano et al. (2002) reported observations of NH3 toward NGC253 and M82, and discussed the origin of the source-to-source variation of the NH3 abundance. On the other hand, Oike et al. (2004) studied the abundances of C3H2 toward the same sources. (S. Yamamoto)

J5.6 Pulsars

There are many progresses in theoretical researches. Following results are obtained on the emission mechanism. The outer gap electrodynamics of the pulsar magnetosphere is solved in two-dimension for the first time by Takata, Shibata and Hirotani (2004). Contradicting the previous picture, it has been shown that the magnetic field in pulsar wind nebulae is turbulent (disordered) significantly, requiring a change in the theoretical model [Shibata et al. 2003]. Other studies on this issue are; the screening of the electric field in the pulsar polar cap [Asano et al. 2004], the estimation of the fluxes of neutrinos and gamma rays [Nagataki, 2004], the model to the PSR1259-63/Be star system [Murata et al. 2003], the propagation and transmission of Alfven waves [Kojima 2004], and the counterstreaming instability in magnetized pair plasma [Saito 2004]. In addition, there are some papers on other issues such as simulations on the core collapses [Kotake et al. 2004 and Takiwaki et al. 2004] and acceleration analyses by using magnetohydrodynamic process [Okamoto 2002, 2003]. The investigation on the gravitational delay of pulsar TOA is conducted in NICT, NAOJ and Nagano NCT. Some presentations on this subject have been done in Japan Applied Physics Society Meetings in 2004.

As for the observation activities, a 30-m spherical dish has been built in Nasu Pulsar Observatory of Waseda University. Tracking observation is possible with Az-El Feed Horn system synchronized to Gregorian subreflector. RF frequency is 1.4GHz and a 2bit 400 MHz/1 bit 800 MHz complex Nyquist sampler is tested for dispersion removing in voltages. Kashima 34-m telescope in CRL (renamed to NICT since 2004) has been observing the timing of millisecond pulsars almost every week since 1997 [Hanado et al. 2002]. The observation results at Kashima show good agreement with other reports [Hanado et al. 2004]. From the simultaneous timing observation with Kalyazin 64-m telescope at in Russia, a long-term DM variation of PSR1937+21 is found [Ilyasov et al. 2004]. The collaboration between Kalyazin 64-m telescope and Kashima 34-m telescope has been continued in pulsar VLBI [Rodin et al. 2002]. (Y. Hanado)

J6 Extragalactic Radio Astronomy

J6.1 Galaxies

The distribution and dynamics of molecular gas in galactic disks have been studied with the 45-m telescope and the Nobeyama Millimeter Array of the Nobeyama Radio Observatory: NGC 3079 shows central massive core of the molecular gas (Koda et al. 2002). The molecular gas in the central regions of the non-barred Seyfert galaxies, NGC 4501 (Onodera et al. 2004) and NGC 5033 (Kohno et al. 2003a), were mapped in CO. Properties of molecular clouds were examined in the spiral arm of M51 (Tosaki et al. 2002) and in the interarm of NGC 5055 (Tosaki et al. 2003). The dense molecular gas traced by HCN was well studied in many galaxies, NGC 253 (Paglione et al. 2004), NGC 1097 (Kohno et al. 2003b), NGC 4527 (Shibatsuka et al. 2003), NGC 5195 (Kohno et al. 2002), lenticular galaxies (Kuno et al. 2002), and CO bright galaxies (Sorai et al. 2002), in relating to star formation and Seyfert activity. Multitransitions of CO in the Antennae, archetypical interacting galaxy pair, were fully mapped for their disks to know the relation to starbursts (Zhu et al. 2003), while observations of ammonia (Takano et al. 2002) and cyclopropenylidene (Cyclic-C3H2) (Oike et al. 2004) in M82 and

NGC 253 quantitatively revealed physical and chemical properties of the archetypical starburst galaxies. Rotation curves in the inner disks of Virgo galaxies were determined from the high resolution CO mapping (Koda and Wada 2002, Sofue and Rubin 2001, Sofue et al. 2003a, 2003b, 2003c).

High-resolution observations of CO emission from the z = 4.7 QSO BRI 1202-0725 and the z = 4.4 QSO BRI 1335-0417 using the Very Large Array show that CO is spatially resolved into two components separated by 1" and 4", with substructure on scales ~0.2"-0.5" (Carilli et al. 2002). The Sunyaev-Zel'dovich (SZ) effect was successfully detected on a distant galaxy cluster, RX J2228+2037, at z = 0.421 (Pointecouteau et al. 2002) and on eight galaxy clusters from z = 0.18 to 0.55 (Tsuboi et al. 2004) at 21 GHz and 43 GHz, respectively, and the physical state of the cluster or the Hubble constant is determined. A gamma-ray burst, GRB 030329, was detected at 23 GHz, 43GHz, and 90 GHz with the 45-m telescope, and time variations of the flux densities were consistent with the expectation from the fireball model (Kuno et al. 2004). (N. Nakai)

J6.2 Quasars and Active Galactic Nuclei

Active Galactic Nuclei (AGNs) are considered to consist of a super massive black hole (SMBH) and an accretion disk rotating around it. Relativistic jets often emanate from the disk.

The footpoint of the jet was monitored in the radio galaxy 3C 66B and an orbital motion of the SMBH-disk system was discovered, implying a SMBH binary. The discovery gives a clue to the SMBH formation mechanism [Sudou et al. 2003].

Various observations have unveiled fuel reservoirs around the central engine of AGN. NMA imaged CO (J=1-0) gas associated with a dust disk of 1 kpc in the radio galaxy 3C 31 [Okuda et al. 2005]. HCN (J=1-0) and CO (J=3-2) lines trace denser gas concentrated in the 100-pc region in AGNs such as NGC 1097 [Kohno et al. 2003a] and M 51 [Matsushita et al. 2004]. Starburst sometimes happens in such reservoirs and may cause mass accretion into the central engine. An imaging survey of molecular lines was conducted for 20 nearby Seyfert galaxies using the NMA and proposed a diagnostics of starburst. Seyfert galaxies without starburst show significantly higher HCN-to-CO and HCN-to-HCO+ intensity ratios than those with starburst does [Kohno et al. 2003b]. In the central sub-pc region, these matters are partially ionized to be probed via free-free absorption [Kameno et al. 2003] and polarization properties [Mutoh et al. 2002].

VLBI polarimetry of 3C 273 has revealed a gradient of Faraday rotation measure across the jet, which infers a helical magnetic structure winding up the jet [Asada et al. 2002], predicted by a MHD (Magneto-Hydro Dynamics) collimation and acceleration mechanism. (S. Kameno)

Acknowledgements

The editor thanks T. Daishido, S. Deguchi, P.G. Edwards, H. Ezawa, Y. Hanado, T. Handa, T. Hasegawa, S. Kameno, N. Kawano, Y. Kitamura, H. Kobayashi, M. Kojima, A. Morioka, N. Nakai, T. Onishi, K. Shibasaki, M. Tsuboi, and S. Yamamoto for their collaboration in preparing this review article.

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