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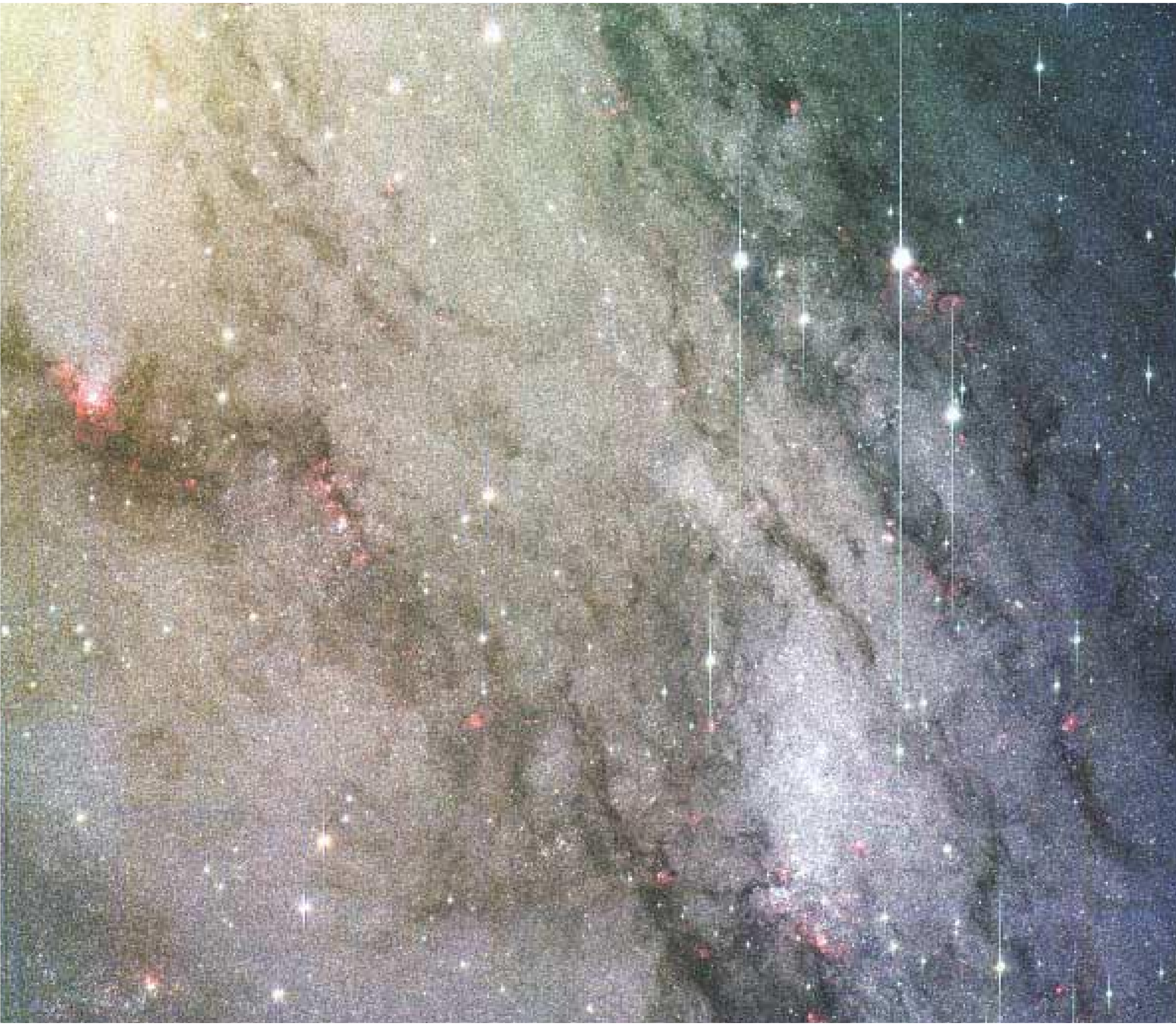
ANNUAL REPORT OF THE NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN



Volume 3 Fiscal 2000

Explanation of the cover photograph : — **Sister Star World 2.5 Million Light Years Away** —

Shown is a new color image of the southwest region of Andromeda Galaxy taken with Subaru's prime focus camera "Suprime‐cam". Stars of the galaxy are seen as a great many small white dots. Many of the stars, clusters and nebulae have been resolved for the first time in this image.

Postscript

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Table of Contents

PREFACE

As the first page of the NAOJ Annual Report ○ briefly review the FY2000 (April 2000 to March 2001) and try to clarify where we are standing after this fruitful year.

First, regarding important achievements in the last financial year, we started the operation and open-use of the 8.2m optical/IR telescope Subaru with excellent imaging performance and scientific capability. The TAMA-300, an interferometer-type gravitational wave detector built in Mitaka campus achieved the highest sensitivity ever reported through the long-term observing run. The VERA, a high-accuracy VLBI network dedicated to direct distant measurements of maser stars throughout our Galaxy successfully started the construction of all four stations. The three partite joint construction scheme of ALMA, a very large millimeter and submillimeter array project in Chile, was agreed by ESO, NSF and NAOJ. The Subaru operation and ALMA construction are the main stream for the NAOJ as a national central institute for astronomy. On the other hand remarkable progress of variegated projects in wide field of astronomy such as gravitational waves, astrometry, solar physics, theoretical astrophysics etc. is essentially important also for the future of astronomy. Many active young astronomers and new ideas of science have grown through those projects.

Second, as for the scientific results, more than 20 papers have already been published by using the Subaru telescope through its test run and early-phase operation. The detection of huge number of extremely low mass stars is an example of excellent results from Subaru. Another one is the discovery of very strong excess background IR emission after the subtraction of the estimated IR emission of all observable galaxies (A model tells that 90% of them have already been resolved by the Subaru telescope). The Nobeyama 45-m mm-wave telescope discovered a 2.8 million Solar mass black-hole in the center of a galaxy IC2560. Significantly it is the second confirmation of a very massive black-hole since the detection in the center of NGC4258 also made by the Nobeyama 45-m telescope several years ago. In addition many results including remarkable images from the VSOP (a Japanese launched space VLBI), start of the extra-solar planets search program in the Okayama Astrophysical Observatory etc. are included in the Highlights chapter of this Annual Report.

The promotion of the astronomical engineering and technology is one of the most important programs of NAOJ. As readers would find in this Annual Report the technological developments and engineering programs are now very active throughout all fields of astronomy in NAOJ: mm- and submm-wave technology in Nobeyama and ALMA, activities in the Advanced Technology Center related to the Subaru and other projects, the advanced technology for the gravitational wave detection, space missions like Solar-B and SELENE, and computer science, etc. The human resources and infrastructure for the engineering and technology in NAOJ, however are still poor compared with the level which modern astronomy requires us. This is among essentially important points which we need further considerations.

Another important progress I like to point out is those in the public relation program of NAOJ. The interest from public caused by the successful completion of the Subaru telescope was enormous. On the other hand various activities such as the educational program 'Four Days You become an Astronomer', which is now very popular among the high-school students, the daily opening of the observatory campus at Mitaka and monthly star-gazing program etc. have been carried out successfully by the Public Relation Center with help of many volunteers. One of the important functions of national research institutes is to promote the public understanding of science for the future of human beings, and we plan to promote activity in this field farther.

Norio KAIFU
Director General
National Astronomical Observatory of Japan

I　Scientific Highlights

(2000 Apr. | 2001 Mar.)

VERA Ogasawara Station

Completion of three stations of VERA

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Hideyuki KOBAYASHI (Division of Radio Astronomy, NAOJ)
Noriyuki KAWAGUCHI, Seiji MANABE (Division of Earth Rotation, NAOJ)
Tetsuo SASAO (Division of Earth Rotation, NAOJ)
VERA group

We have completed the construction of three stations of the VERA (VLBI Exploration of Radio Astrometry) project. The VERA array consists of four 20m-diameter radio telescope spread over Japan (Mizusawa, Iriki, Ogasawara, and Ishigaki-jima), aiming at astrometry of the whole Galaxy with an accuracy of 10-microarcsec level.

In order to achieve such a high accuracy, VERA utilize the phase-referencing technique to remove the atmospheric fluctuation. For that purpose, we have developed so-called `dual-beam antenna', with which one can observe two adjacent sources simultaneously. VERA's dual-beam antenna has two receivers at its Cassegrain focus that are fully steerable with separation ranging from 0.5 degree to 2 degree. Such a dual-beam antenna has been constructed for the first time, and is expected to open a new stage in phase-referencing VLBI astrometry. In addition to dual-beam antenna, we have also developed new instruments for VERA such as receivers and digital backends. In particular, the data recorder has the recording rate of 1 Giga-bit per second, which is the highest among the existing digital recorders in the world.

After the completion of three stations, we have been conducting the examination of system performance including antenna, receivers, digital backends, correlator, and so on. Construction of the fourth station (Ishigaki-jima) has also started in 2001, and will be completed by the end of fiscal year 2001. We are also expecting to have a first fringe (as a single-beam VLBI array) by the end of fy 2001, and in 2002 we will start phase-referencing observation with dual-beam system.

Fig. 1. View of VERA Mizusawa station. Left is the VERA 20m telescope, and right is the VLBI 10m telescope.

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1) Honma, M., Kawaguchi, N., Sasao, T.: 2000, *proc. of SPIE* **4015**, 624.
2) Honma, M.: 2001, *proceeding of IAU Symp*.186, in press

Fig. 2. Dual-beam platform system. Two receivers will be mounted on two platforms that are sustained by six arms.

Fig. 3. Dual-beam receivers mounted on the dual-beam platform. Each receiver has two horns for 22 GHz and 43 GHz. Two boxes on the left are local oscillator and electro-optical transformer.

Fig. 4. Digital backends and their PC systems installed in the control room.

Subaru Telescope High Dispersion Spectrograph (HDS) First Light

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(Tokai University)
Yoichi TAKEDA
(Komazawa University)

The High Dispersion Spectrograph (HDS, Fig. 1.) was constructed as a first-generation instrument for the Subaru telescope, and is located at one of the Nasmyth foci (optical Nasmyth). The spectrograph was assembled at the summit of Mauna Kea in March 2000, and achieved first-light in July 2000 (Fig. 2.). The performance of the instrument was confirmed by the subsequent test observing runs.

HDS is a so-called echelle spectrograph, which uses higher orders of an echelle grating. Strong points of echelle spectrograph are its high resolving power and wide wavelength coverage. The resolving power about 90,000 (3.3km/s) is achieved by the standard setup with 0.4 arcsec slit width (near the seeing size possible by the Subaru Telescope). Even higher resolution up to 150,000 is possible by narrower slit. The resolving power of HDS is highest in those with spectrographs of 8-10m telescopes in the world. The wavelength coverage is 1500-2000 Å, thanks to the mosaic of two large CCDs (4100 × 2048 pixels). The efficiency of the spectrograph (including the throughput of the telescope) was measured in the test observing runs using standard stars. As shown in Fig. 3., the efficiency is about 13% in 5000-6000 Å, which is near the expected value. The efficiency in blue region is relatively high, reflecting the high efficiency of the detectors in this region.

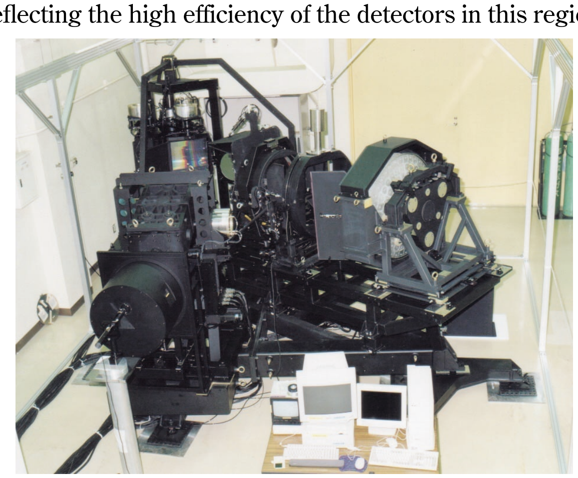

Fig. 1. HDS during the test in Mitaka (Tokyo)

After the first light, test observations have successfully been carried out, and some observing modes are tested for a variety of objects. HDS is now opened to common-use (from April 2001), and scientific observation has started.

Fig. 2. The twilight spectrum obtained with HDS. The dispersion direction is top-bottom. The right-bottom is corresponding to the shortest wavelength range, and left-top is to the longest one.

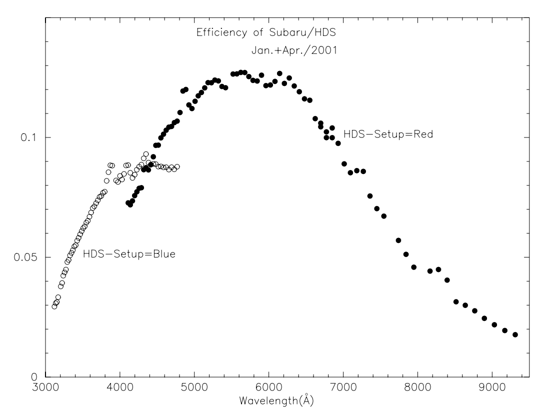

Fig. 3. Efficiency of HDS including the throughput of the telescope. The filled circles indicate the efficiency of blue setup, and open circles do that of red setup.

Development of laser altimeter (LALT) on board SELENE orbiter

Tsuneya TSUBOKAWA, Hiroshi ARAKI, Seiichi TAZAWA, Kazuyoshi ASARI, Nobuyuki KAWANO
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Lunar laser altimeter (LALT) on board SELENE orbiter has been developed by the RISE group. The manufacture of Proto-type model of LALT (LALT-PM) was finished in December 2000. LALT is one of nine instruments aboard the SELENE lunar orbiter to be launched in 2004.

LALT transmits laser pulses, determines their round trip times to the surface of the moon using a time interval counter, and measures ranges between SELENE orbiter and the lunar surface in the nadir direction with 5m accuracy every 1 second for 1 year mission period. The acquired range data are transformed to the topography of the moon with the aid of position and attitude data of the SELENE orbiter obtained from the ground-based tracking and on board star sensor respectively. Distances between ranged positions in the equatorial region will be less than 3km while mean distances are expected to be about 700m. In the polar region the maximum distance of ranged position will be reduced to 300m while mean distance will be about 100m. The number of range data from LALT is expected to be two orders of magnitudes larger than that by the Clementine-LIDAR.

Primary missions of LALT are determining global figure of the moon (spherical harmonics expansion of the lunar figure) and making lunar topographic maps including polar region more accurately. These products will play a significant roll for the investigation of internal structure of the moon with the new and precise gravity data from the Doppler and Differential VLBI tracking of main and sub-satellites of SELENE. They are also indispensable to search for the site of deployment of ILOM (In-situ Lunar Orientation Measurement) telescope that is now under investigation.

LALT utilizes a laser diode (LD) pumped Q-switched Nd:YAG laser that has a wavelength of 1064nm, a pulse width of <15ns, one pulse energy of 100mJ. The output beam divergence is improved to 0.3mrad from 3mrad by Galileo refractor-type collimator whose aperture is 7.5cm, which resulted in a moon surface spot size (foot print) of 30m. The return pulses are captured by Cassegrain-type reflector whose aperture is 11cm and detected by Si-APD detector. We have developed the LALT-PM to confirm the basic design performances toward a real flight model. All environmental tests required for the LALT have carried out and ground based ranging test, data acquisition system check and EMC test are now being continued.

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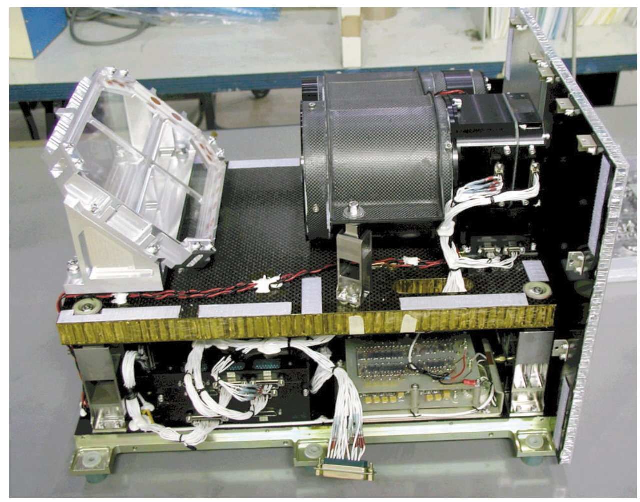

Fig. 1. Internal structure of LALT-TR

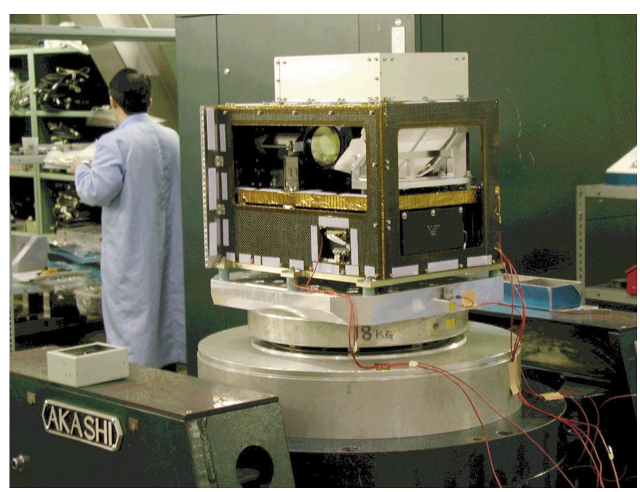

Fig. 2. Vibrations test of LALT-TR

First Light of the JHKs-band simultaneous infrared camera - SIRIUS

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(Division of Optical and Infrared Astronomy, NAOJ)
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Koji SUGITANI (Nagoya City College)
Andrew PICKLES (University of Hawaii)
Yumiko OASA (University of Tokyo)
Kenshi YANAGISAWA (Okayama Astrophysical Observatory, NAOJ)
Tomoyasu YAMAMURO (Jenesia, Inc.)

We have developed an infrared camera suitable for large-scale surveys at near-infrared wavelengths, called SIRIUS (Simultaneous-color Infrared Imager for Unbiased Surveys), with fund from Monbu-Kagaku-syo for Scientific Research on Priority Areas "A Through Study of Magellanic Cloud" (headed by Prof. T. Hasegawa; 1998-2001). SIRIUS is equipped with three science-grade HgCdTe arrays of 1024×1024 pixels and enables us to make simultaneous JHKs imaging of the same field of the sky. The pixel scales are 0.45 and 0.28″/pixel and the field-of-views are about 8′ and 5′ on the Nagoya 1.4-m telescope (IRSF) in South Africa and on the University of Hawaii 2.2-m telescope (UH88) in Hawaii, respectively. SIRIUS fills the gap between the 2MASS/DENIS and the large telescopes such as the Subaru: the former covers the whole/half sky with a low resolution and medium sensitivity, while the latter has a high resolution and very high sensitivity but with limited sky coverage. SIRIUS is almost hand-made except for the infrared arrays, thanks to the help of the machine shop at Physics Lab. of Nagoya University.

The development of SIRIUS went well and we had a successful first light on the UH88 in August, 2000, confirming that the specification on the telescope was as designed. The typical image quality is 0.7″ FWHM, thanks to the adoption of the Offner optics. The limiting magnitude is as high as 18.7 magnitudes in H-band (9 minutes integration time, 10 sigma). We have already started the SIRIUS observations at IRSF from December, 2000. Several projects including a deep survey of the "whole" Large Magellanic Cloud (LMC), monitoring of evolved stars in LMC, and deep surveys of star-forming regions for IMF studies are currently in progress.

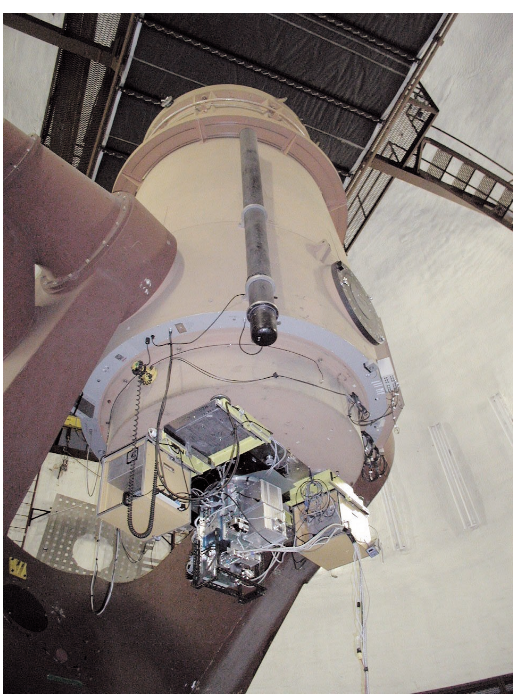

Fig. 1. SIRIUS mounted on the University of Hawaii 2.2-m telescope.

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1) Nagayama, T. et al.: 2000, *in The New Era of Wide Field* Astronomy (Preston, UK)
2) Nagashima, C. et al.: 1999, *Star Formation* 1999, 397.

Fig. 2. Three-color composite images (made from SIRIUS JHKs images) of star-forming regions. Left: Cep A obtained with SIRIUS+UH88, Right: NGC 3603 obtained with SIRIUS+IRSF.

Observed annual gravity variation and the effect of sea surface height variations

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Yuichi AOYAMA, Herbert McQUEEN (The Australian National Univ.)
Kazuo SHIBUYA (National Institute of Polar Research)
Yoshiaki TAMURA, Kazuyosi ASARI, Masatsugu OOE (Division of Earth Rotation, NAOJ)

Japanese superconducting gravimeter (SG) group is operating an international observation network with SGs that is called GGP-Japan Network, which consists of seven sites and covers wide latitude from 79 deg north (Ny-Alesund) to 69 deg south (Syowa) including a station near the equator (Bandung).

Through the changes in currents and ocean bottom pressure, the oceans have a significant impact on many global geophysical processes such as the Earth orientation parameters, the Earth's gravity field and the motion of Earth's center-of-mass. Sato et al.1) discussed the effect of sea surface height (SSH) variations on the SG observations made at the three different sites of the network, namely Esashi, Canberra and Syowa, and they found that, at all of the three sites, a good agreement between the observed annual gravity variations and the predicted values which are taken into account the SSH data. The results (Fig.1 and 2) from both data sets of an ocean model (POCM[2]) and TOPEX/Poseidon show the significance of the SSH effect and of the correction for thermal steric changes in SSH variations that would have no gravitational signals. The present results also suggest that the GGP-Japan network may give a useful data set that can be used for the comparison and/or the combination with the data obtained from the satellite gravity missions such as CHAMP, GRACE and GOCE.

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1) T. Sato et al.: 2001, *Physics of the Earth and Planetary Interiors*, **123**, 45-63.
2) Semtner & Chervin: 1992, *J. Geophys. R.*, **97**, 5493-5550.

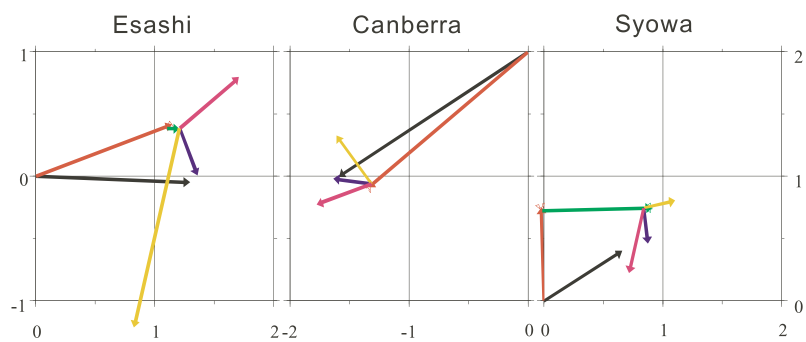

Fig.1. Vector plots of the observed annual components and predicted ones. The horizontal and vertical show real and imaginary parts in unit of microGals, respectively. The observation, the polar motion effect and the effect of solid tide are displayed with three vectors of black, red and green, respectively. The three vectors of yellow, blue and pink show the effect of SSH variations evaluated from the POCM data using the steric coefficients of 0.0×10^{-2} m/deg, 0.60×10^{-2} m/deg and 1.0×10^{-2} m/deg, respectively. It may be worth to note that the value of 0.60×10^{-2} m/deg was estimated using the SSH data and the sea surface temperature data.

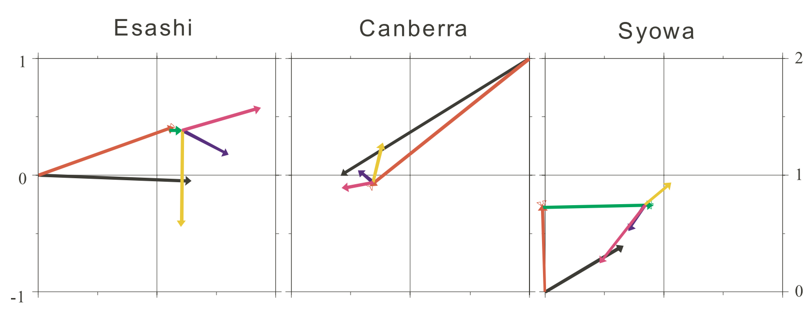

Fig. 2. Similar plots as Fig. 1, but the SSH vectors evaluated from the TOPEX/Poseidon data are displayed.

Estimation of the Lunar Gravitational Fields and Density of the Lunar Core by VLBI Radio Source Mission in SELENE

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(NASDA)

Internal structure of a planet and whether it has a metallic core or not can be estimated from orbits of an artificial satellite passing near the planet. It is not known if there is a metallic core in the Moon although it is the nearest object from the earth. This is partly because the moment of the Moon is about 0.39 which is closer to 0.4 and suggests a small core if present, and because there possibly be a systematic error larger than an internal error in the value of it.

Although accuracy of the moments of inertia of the moon is apparently high due to the highly precise Stokes coefficients and the libration parameters, it is pointed out that it has a systematic error exceeding about 1%. If there is systematic errors in the Stokes coefficients, this can be a cause of the possible systematic error in the moments of inertia.

In SELENE project, differential VLBI measures relative position of two radio sources which are on board two sub-satellites orbiting the Moon. This can not only improve the accuracy of the lunar gravitational fields but also improve the quality of the observations because it makes up a three dimensional tracking of the orbits, one from Doppler and the other two from differential VLBI. Furthermore, combination of the different kinds of observations is hard to introduce any systematic error, because Doppler and VLBI observations supplement to each other both in the sensitivity and the coverage. For example, Doppler observation is highly sensitive in the orbit near the longitude of 0 degree and less sensitive for 90 degrees, and VLBI, on the other hand, is highly sensitive for the region where Doppler observation is less sensitive in the case of the estimation of C20, which means that these observations can determine the Stokes coefficients of low degrees by using the data not from a part of the Moon but from all over the Moon. It is expected that the systematic error should be less than 0.1% by these observations.

We investigate how the moment of inertia can constrain core density by using a three-layer model. There will be no limit to core density without any information of crustal or mantle density even if accuracy of the moment of inertia is very high. It becomes possible to constrain core density by adding some assumptions. The core density can be estimated with an accuracy of about 15% if we can know the crustal density as 2.9 ～ 3.1g/cm^3, depth of the crust-mantle boundary 55km (near the minimum value) and core radius 450km through seismological, mineralogical and gravity observations as shown in Fig. 1.

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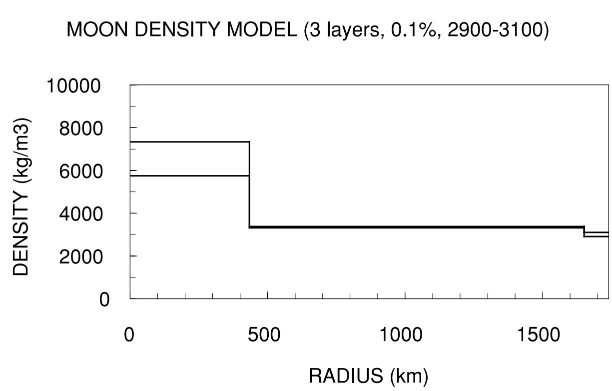

Fig. 1. A three-layer density model of the moon constrained by moment of inertia of 0.1% accuracy. Crustal density, crustal depth and core radius are supposed to be 2.9g/cm^3～ 3.1g/cm^3, 55km and 450km, respectively.

Achievement of the world's best sensitivity and 160 hours operation with the interferometric gravitational wave detector TAMA300

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Nobuyuki KANDA (Miyagi University of Education)
Hideyuki TAGOSHI (Osaka University)
and the TAMA Collaboration

The interferometric gravitational wave (GW) detector, TAMA300, has been operated from the summer of 1999 with full configuration except for the power-recycling technique. After the first operation, noise investigation and preparations for long stable operation were made. In the September of 2000, we achieved the world's best sensitivity of $h \sim 5 \times 10^{-21}/\sqrt{\mathrm{Hz}}$ as shown in Fig. 1.

With this sensitivity, our detector has a sufficient detection capability for gravitational wave from inspiraling binaries at Galactic Center as shown in Fig. 2, assuming optimally-polarized GWs from an optimal direction for the detector. The signal-to-noise ratio (SNR) is about 30 in the case of neutron stars ($1.4M_\odot + 1.4M_\odot$) binary at 10kpc distance.

The interferometer was operated for over 160 hours from August 21 to September 3, 2000. Duty ratio of 94.8% was obtained in the total run time. The observation was performed in the night time for the efficient collection of high-quality data. The main causes of losing operation were large seismic disturbances including earthquakes, and common mode drift of two arm cavities (δL_+).

The stability of the detector sensitivity was evaluated. The noise floor-level drift was kept within 3dB for about 90% of the total operation time. In addition, the Gaussianity of the noise level was evaluated every 30 seconds. We observed about 10 non-Gaussian periods per hour in this observation run. The non-Gaussian noise will be partly removed by veto analysis using other channels, such as seismic motion, laser intensity noise, contrast fluctuation, and a δL_+ signal.

After the above data-taking, installation of additional seismic isolation systems and improved mirror suspensions has been performed for each arm cavity mirrors. As a result, noise level around 100 Hz was reduced by one order of magnitude as shown in Fig. 1. Consequently, sensitivity for massive star binaries was drastically improved as shown in Fig. 2. Because an orbitary frequency of the massive star binaries ($\geq 20\ M_\odot$) cannot reach 50 Hz before making coalescence, only low frequency noise level is significant for GW signals from the massive star binaries.

The above sufficient sensitivity to detect GWs emission from Galactic Center and stable long-time (over 100 hours) operation of the TAMA detector are significant advancements for the first detection of gravitational wave signal.

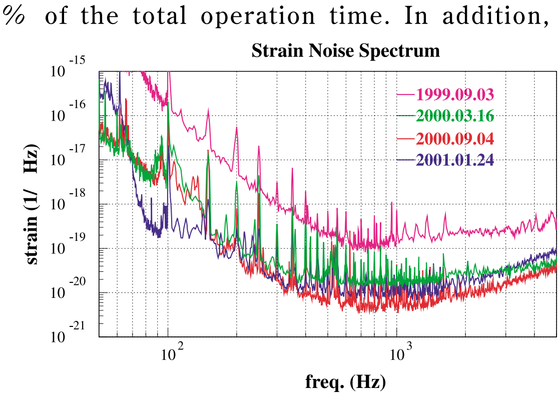

Fig. 1. The noise sensitivity of the GW detector TAMA300. The curve "2000.09.04" indicates our best sensitivity, that is the world's best sensitivity. The curve "2000.01.24" is obtained after installations. The noise level around 100Hz was improved by one order of magnitude.

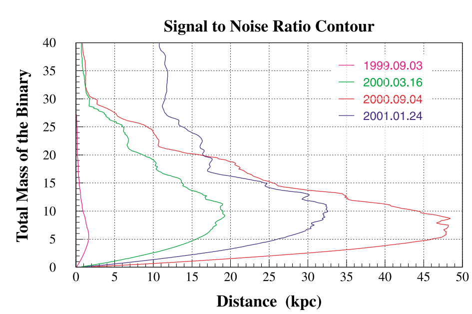

Fig. 2. Contour plot of signal-to-noise ratio (SNR) expected to be 10 for GWs from inspiraling compact binaries with equal mass. Optimally-polarized GWs from an optimal direction for the detector are assumed. TAMA has the sensitivity to detect $1.4M_\odot + 1.4M_\odot$ binary coalescence at Galactic Center with SNR of 30. After installation of additional seismic isolation systems and improved mirror suspensions has been performed, sensitivity for massive star binaries were drastically improved.

A Comparison of the Spatial Distribution of $H^{13}CO^+$, CH_3OH, and $C^{34}S$ Emission and its Implication in Heiles Cloud 2

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Masao SAITO
(C. f. A.)
Naomi HIRANO*
(Graduate University for Advanced Studies)

We have mapped the Heiles Cloud 2 region in the Taurus molecular cloud complex with $H^{13}CO^+$, CH_3OH, and $C^{34}S$ lines, using the Nobeyama Radio Observatory 45 m telescope. We found chemical difference between the molecular cloud cores with and without protostars, which indicate the link between physical and chemical evolution of molecular cloud cores.

In Figure 1, we show our observational results. We took advantage of the ability of the 45 m telescope and received all the three lines simultaneously. Thus, there is no pointing error among the three lines, making it possible to compare the distribution of the three lines directly. The $H^{13}CO^+$ emission is intense toward the protostars (cross marks in Figure 1) and traces well molecular cloud cores associated with the protostellar formation. On the other hand, the CH_3OH emission is weak toward the protostellar positions, and the emission does not trace the protostellar cores. Interestingly, there are some strong CH_3OH condensations without protostars, like the one at the northern-most part of TMC-1. The $C^{34}S$ emission is much weaker than the $H^{13}CO^+$ or CH_3OH emission, but the detailed comparison tells us that the distribution of the $C^{34}S$ emission is different from that of the $H^{13}CO^+$ and CH_3OH emission. Our excitation analyses of these molecular lines show that the observed difference of the molecular line distribution is due to the relative abundance variation of the molecules, and that the difference of the relative abundance ratio of $H^{13}CO^+$ to CH_3OH is more than a factor of 10 between the protostellar and starless cores.

Why does the chemical difference between starless and protostellar cores take place ? According the chemical evolutional model of molecular cloud cores, the $H^{13}CO^+$ abundance increases toward the later stages of the chemical evolution, while the CH_3OH abundance takes its maximum at the earlier stage of the chemical evolution and decreases greatly toward the later stage. On the other hand, molecular cloud cores evolve to the protostellar formation, thus protostellar cores are more evolved than starless cores in the physical point of view. Therefore, toward the protostellar cores $H^{13}CO^+$ is more abundant while CH_3OH is less abundant, and in the starless cores CH_3OH is more abundant than $H^{13}CO^+$. Our observational results suggest the link between the physical and chemical evolution of molecular cloud cores. We should study molecular cloud cores in both physical and chemical aspect, in order to truly understand the evolutional process of molecular cloud cores.

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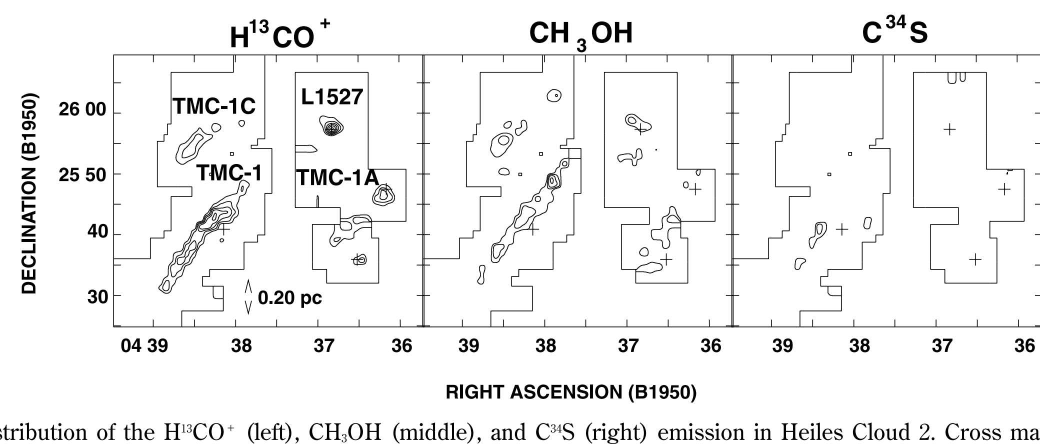

Fig. 1. Distribution of the $H^{13}CO^+$ (left), CH_3OH (middle), and $C^{34}S$ (right) emission in Heiles Cloud 2. Cross marks indicate the position of protostars.

* Present Address : ASIAA

Non-existence of the Modified First Integral by Symplectic Integration Methods

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Symplectic integration methods have good property for conservation of energy. In general an n-th order symplectic method keeps the error of energy within the order of $O(\tau^n)$ for an exponentially long time interval, where τ is the step size. This is guaranteed by the existence of the **modified Hamiltonian** $\tilde{H}$, which is an exact conserved quantity of the integration method. For the first order method, $\tilde{H}$ is given by the series

$$\tilde{H} = H_0 + \tau H_1 + \tau^2 H_2 + \cdot\cdot\cdot\cdot\cdot$$

In case that the system has an additional first integral, it is often observed that this integral is also well conserved by symplectic methods. However, this is not always the case. In super-integrable 2D systems, in which all bounded orbits are periodic, the 3rd first integral is not well conserved even by symplectic methods. For this integral, it is shown that the **modified first integral** of the form,

$$\tilde{\Phi} = \Phi_0 + \tau \Phi_1 + \tau^2 \Phi_2 + \cdot\cdot\cdot\cdot\cdot$$

which is defined to be an integral for the modified Hamiltonian, does not exist in general.
As a simple example, consider a 2D harmonic oscillator with the frequency ratio of 1:2

$$H = H_0 = \frac{1}{2}(p_1^2 + p_2^2) + \frac{1}{2}(q_1^2 + \frac{1}{4} q_2^2)$$

When the first order symplectic method is applied, the modified Hamiltonian is given by

$$H_1 = \frac{1}{2} p_1 q_1 + \frac{1}{8} p_2 q_2 ,$$

$$H_2 = \frac{1}{12}(p_1^2 + q_1^2) + \frac{1}{48}(p_2^2 + \frac{1}{4} q_2^2)$$

etc. On the other hand, for the first integral

$$\Phi = \Phi_0 = p_1(4p_2^2 - q_2^2) + 4 q_1 p_2 q_2$$

the first order term of the modified first integral is given by

$$\Phi_1 = p_1 p_2 q_2 + 2 p_2^2 q_1$$

but it is proved that the second order term Φ_2 cannot be a differential polynomial of H and Φ. This implies the non-existence of the modified first integral. In correspondence with this fact, Φ is not well conserved by the symplectic method and the super-integrability is violated (Fig.1). On the other hand, it is shown that for the oscillator with the frequency ratio of 1:1, the modified integral does exist and periodicity of the solution is well conserved numerically (Fig.2).

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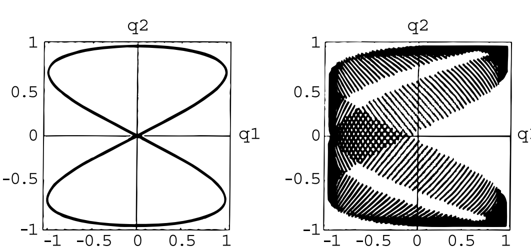

Fig. 1. Exact solution (left) and numerical solution (right) for the oscillator with freq. Ratio 1 : 2

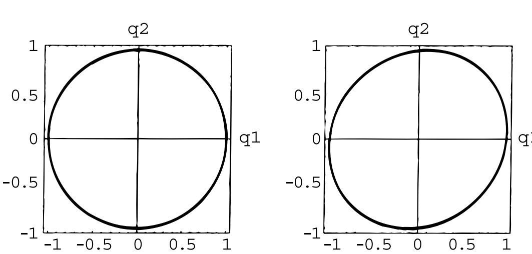

Fig. 2. Exact solution (left) and numerical solution (right) for the oscillator with freq. Ratio 1 : 1

A Necessary Condition for the Integrability of Homogeneous Hamiltonian Systems with Two Degrees of Freedom

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It is a fundamental problem in celestial mechanics to determine whether a given Hamiltonian system is integrable or not. At present, however, we do not know any algorithm that enables us to solve this problem. The strongest criterion for integrability of Hamiltonian systems with a two-dimensional homogeneous potential of an integer degree,

$$H = \frac{1}{2}\left(p_1^2 + p_2^2\right) + V(q_1, q_2) \qquad (1)$$

is due to Morales-Ruiz and Ramis. They obtained a necessary condition for integrability from their own theorem based on the differential Galois theory. The necessary condition was obtained from the following three facts.

(I) The variational equation around a straight-line solution of equations of motion is transformed into a Gauss hypergeometric equation.

(II) If the system is integrable, then the Gauss hypergeometric equation is solvable in the sense of the differential Galois theory, i.e. the solution is obtained only by a combination of algebraic functions, quadratures and exponential of quadratures.

(III) A necessary and sufficient condition for solvability of Gauss hypergeometric equations is given by Kimura's theorem.

Yoshida [1] gave a direct and independent proof of the fact (II). We proved [2] that the proof of Yoshida [1] can be easily extended and applied to the more general Hamiltonian system

$$H = T(p_1, p_2) + V(q_1, q_2), \qquad (2)$$

where T and V are homogeneous functions of integer degrees m and k, respectively.

The fact (I) remains true for the system (2) and we obtain the Gauss hypergeometric equation

$$z(1-z)\frac{d^2\xi}{dz^2} + [\gamma - (\alpha+\beta+1)z]\frac{d\xi}{dz} - \alpha\beta\xi = 0$$

with the parameters

$$\alpha + \beta = \frac{1}{m} - \frac{1}{k}, \quad \alpha\beta = -\frac{\mu\lambda}{mk}, \quad \gamma = 1 - \frac{1}{k}$$

Here, μ and λ are parameters determined by T and V, respectively. If the system (2) is integrable, then the solution of the Gauss hypergeometric equation is given by

$$\xi = \exp\left[\int \zeta(z)\, dz\right],$$

where $\zeta(z)$ is an algebraic function. This means that the solution of the Gauss hypergeometric equation can be obtained only by a combination of algebraic functions, quadratures, and exponential of quadratures. Applying Kimura's theorem to the Gauss hypergeometric equation, we can obtain a necessary condition for the integrability of the system (2). For example, if the system (2) is integrable for general values of m and k, then the product of μ and λ must satisfy the following condition.

$$\mu\lambda \in \{(jm-1)(jk-1)\} \cup \{(jm+1)(jk-1)+1\}$$

Here, j represents an arbitrary integer.

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Spectroscopic Evidence for the dusty tori in the close vicinity of AGNs

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Active Galactic Nuclei (AGNs) consist of type-1 AGNs (which show broad optical emission lines) and type-2 AGNs (which do not). According to the current AGN unification paradigm, both types of AGNs are intrinsically the same, but the nuclei of type-2 AGNs are obscured by the dusty tori in the close vicinity of the AGNs, while those of type-1 AGNs are not. If such dusty tori actually exist in the close vicinity of the AGNs, strong dust emission from the dusty tori should be detected in the thermal infrared wavelength range. However, its detection has not yet been achieved[1]. Currently, a different model has been proposed: dust in the host galaxies with a 100 pc scale rather than in the dusty tori plays an essential role to differentiate between type-1 and type-2 AGNs[2]. Thus, observational confirmation of the presence of the dusty tori is important to understand the nature of AGNs.

Although the putative dusty tori are so small in size that they have not been found with direct imaging observations, it is possible to spectroscopically confirm the presence of the dusty tori. As shown in Figure 1, when the dusty tori are actually present in the close vicinity of the AGNs, dust has a strong temperature gradient, with the temperature of the dust decreasing rapidly with increasing distance from the central AGNs. In the case of blackbody radiation, continuum emission at 3-4 μm (10 μm) is dominated by dust at ~1000 K (300 K). Since dust at 1000 K is located deeper inside, dust extinction toward the 1000 K dust estimated using the 3-4 μm data should be larger than that toward the 300 K dust estimated using the 10 μm data. In the case of dust in the host galaxies (100 pc away from the central AGNs), such a strong temperature gradient should not occur and thus the above relation is not expected to be present.

Based on this logic, we detected the sign of a strong temperature gradient in general type-2 AGNs whose host galaxies are not seen from an edge-on direction, and thus concluded that the dusty tori are responsible for the nuclear obscuration[3]. Our observational study supports the conventional AGN unification paradigm.

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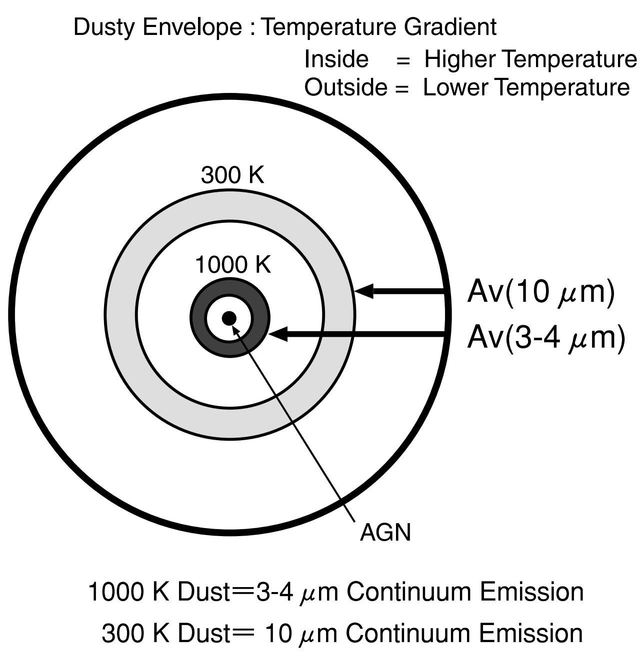

Fig. 1. A top view of a dusty torus. We are at the right side. Thermal emission from 300 K dust at the further side contributes little to an observed flux because of much larger dust extinction than that at the nearer side.

A Near Infrared Imaging Survey of the Lupus 3 Dark Cloud

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We present the first report on results of a near-infrared imaging survey of the Lupus 3 dark cloud. This cloud is known to be associated with a modest cluster of T Tauri stars from a previous optical H α emission-line star survey. We aim at discovering embedded cluster members and low-luminousity sources with this survey.

The survey was done with the Du Pont 2.5-m telescope at Las Campanas observatory, Chile. The survey covers $7' \times 11'$, which corresponds to a projected area of ~0.35 pc × 0.55 pc at a distance of 150 pc. Mapping was carried out at J(1.27 μm), H(1.65 μm), and *Ks*(2.16 μm), to a 10 σ limiting magnitude of J=17.0, H=16.5, and Ks=15.5. The number of the sources is 229 which are detected at all bands and brighter than $Ks < 15.8$; 90% completeness limit. Ten out of them are candidates of Lada's class II pre-main-sequence stars, as they have color excess which cannot be explained by reddening by interstellar dust. We also identified 11 class I-like objects which were not detected at J and have large color-excess, $H-Ks \geq 2$. The color excess is not likely explained by extinction due to the Lupus dark cloud. There are 3 sub-clusters in this survey area. Two of them are embedded ones which mainly consist of the class I-like sources. We estimate masses of the class II candidates with an aid of an evolutionary model of pre-main-sequence star. Ten of them have masses less than 0.08 $M_{\odot}$, if we assume their age to be 10^6 yr. We consider them as candidates of young brown dwarfs.

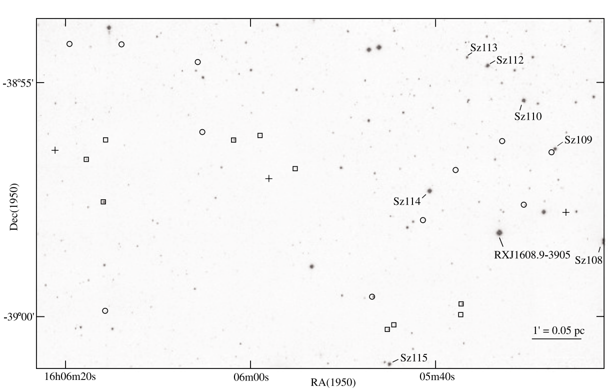

Fig. 1. Ks band mosaic image is shown as a reversed image. PMS candidates are indicated by open circles and open squares for Class-II and Class-I sources, respectively. IRAS 16054-3857, IRAS 16059-3857, and IRAS 16063-3856 are indicated by crosses. Schwartz's emission-line objects and a weak-line T Tauri star found by ROSAT are also indicated with their names.

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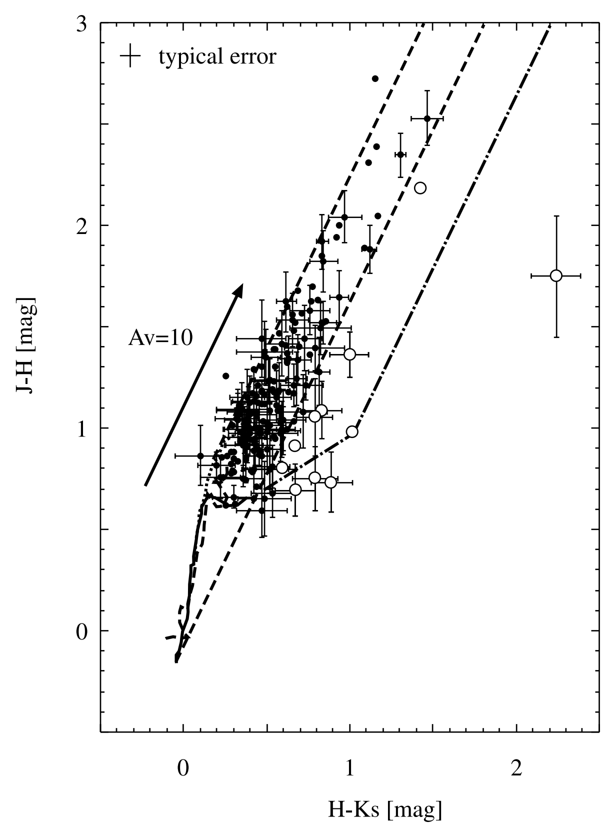

Fig. 2. A color-color diagram for the JHK-sources is shown. Candidates for background and PMS stars are indicated by filled and open circles, respectively.

Distribution and Kinematics of Molecular Gas in Barred Spiral Galaxies I. NGC 3504

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Many numerical simulations have been performed till present to study the distribution and dynamics of the interstellar medium in barred spiral galaxies. However, observational data are still insufficient to compare with the numerical simulation results. The combination of the Nobeyama 45-m telescope and the 2×2-beam SIS focal plane array receiver is suitable for such observations that require high angular resolution and high mapping performance. We made CO mapping observations of barred spiral galaxies with the instrument.

We present the results of one of our sample, NGC 3504. The results show that there are ridges of molecular gas along the leading edge of the bar (fig. 1.). The ridges coincide with the HII regions. The velocity perpendicular to the bar decreases abruptly at the ridge. The velocity change implies that the molecular gas changes the direction of its motion to parallel to the bar at the ridge.

The pattern speed of the bar is important factor to study the relation between resonances and structures of galaxies, such as ring structure often seen in barred spirals and central condensations of gas. Moreover, the measurement of the pattern speed of the bar is important to give constrains on the dark matter content, because dynamical friction from a dark matter halo should slow the pattern speed of the bar. Since the position angle of the major axis of the bar and the line of nodes are almost the same in NGC 3504, an upper limit to the pattern speed of the bar can be derived directly from the radial velocity. The resultant upper limit is 41 km s^{-1} kpc^{-1} which is much smaller than that derived with an assumption that the corotation radius is located at the end of the bar (77 km s^{-1} kpc^{-1}).

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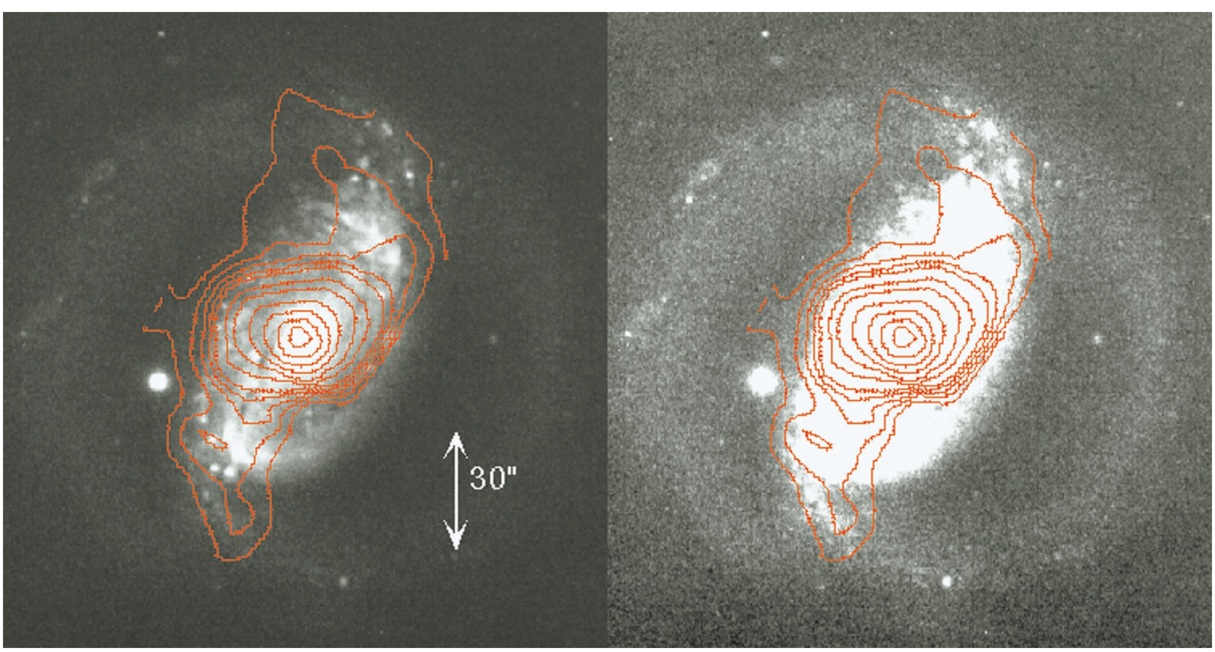

Fig.1. CO integrated intensity map of NGC3504 (contour) overlaied on optical images.

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Distribution and Kinematics of Molecular Gas in Barred Spiral Galaxies II. NGC 253

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The large scale mapping of the disk of a nearby barred galaxy, NGC 253 in CO ($J=1-0$), was made with an angular resolution of 16″ with the 45-m telescope of the Nobeyama Radio Observatory. Figure 1 shows a map of the integrated intensity, $I_{\rm CO} \equiv \int T_{\rm MB}({\rm CO})\, dV$, of the CO line emission. Molecular gas concentrates in the nuclear region and the large-scale bar seen in near-infrared images.

Fig. 2 shows the radial distribution of CO emission converted to the surface density of molecular gas using the conversion factor $X=1\times10^{20}\,{\rm cm}^{-2}\,({\rm K\ km\ s}^{-1})^{-1}$ and correcting the inclination angle of the galactic disk. The radial distribution of molecular gas indicates a secondary peak, whose radius agrees with that of the Hα ring and the ends of the bar, as well as a central strong peak. The radial distribution is well fitted by an exponential function or a power law outside the secondary peak. A rotation curve is rising in the inner region and changes to flat at the ring. These facts suggest that molecular gas infalls from the outer disk by losing angular momentum due to gaseous viscosity in the region of the differential rotation, and accumulates at the ring. In the bar region (and within the corotation radius), molecular gas again loses its angular momentum due to the bar potential, and is infalling toward the nuclear region.

An isovelocity contour maps of CO shows heavy crowding of velocity contours in leading sides of the bar, which indicates strong non-circular motion due to the bar, i.e., velocity vectors suddenly change after passing the bar. The upper limit of the noncircular motion along the major axis of the bar in the leading edge of the bar is $\approx 70-130$ km s^{-1} in the rest frame of the bar, with the assumption that molecular gas moves roughly along the bar major axis in its leading side and the pattern speed of 52 km s^{-1} kpc^{-1}.

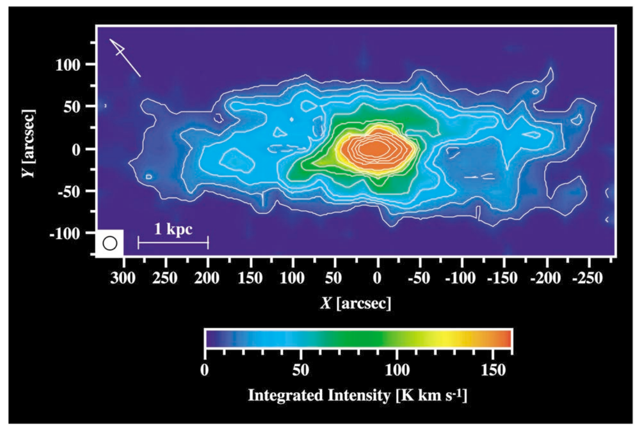

Fig.1. Map of integrated intensity of CO. A color bar presents the integrated intensity in K km s^{-1} unit. The arrow in the upper left corner indicates the direction toward the north. The circle at the bottom left corner presents the telescope beam size of 16″.

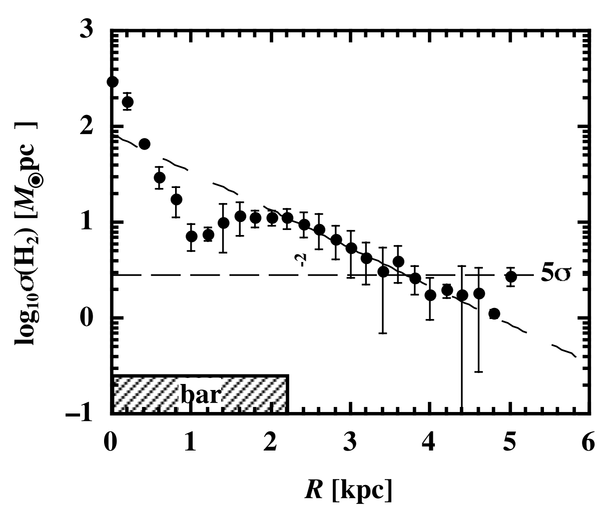

Fig.2. Radial distribution of the surface density of molecular gas. Error bars mean standard deviations of the density contributed to each annulus. Inclined dashed line is an exponential fitting in the range of $2.2 \leq R \leq 3.6$ kpc. The horizontal dashed line is the 5σ noise level under which the data are not used for the fitting. The shaded bar in the bottom indicates the semimajor axis of the bar.

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Development of Iodine Absorption Cell for the OAO-HIDES

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For the purpose of detecting small radial velocity variations of stars due to reflex motion caused by planets or due to various types of stellar oscillations, we have developed an iodine absorption cell (I_2 cell) for the High Dispersion Echelle Spectrograph (HIDES) at the 188 cm reflector of Okayama Astrophysical Observatory, NAOJ (OAO). By placing the I_2 cell in front of the entrance slit of the spectrograph, numerous absorption lines of iodine molecules are superimposed on the spectrum of the target star. The iodine lines experience the same instrumental shifts and distortions as the stellar spectrum. Therefore, by measuring the variation of line positions of the star relative to those of the iodine, we can correct these instrumental errors and determine the stellar radial velocity at a precision of a few m s^{-1}.

The design of I_2 cell for HIDES is almost the same as that adopted for the spectrograph HDS on SUBARU. The shape of the cell itself is a cylinder whose diameter is about 55 mm and height is about 38 mm. The cell is enclosed in a vacuum case mounted on a slide stage in front of the slit unit of HIDES, and can be inserted in the telescope beam through GUI (Fig.1). The cell temperature is controlled at 55°C, which ensures that almost all iodine is vaporized. The overall depth of the iodine absorption lines is optimized for determining the radial velocity of solar-type stars.

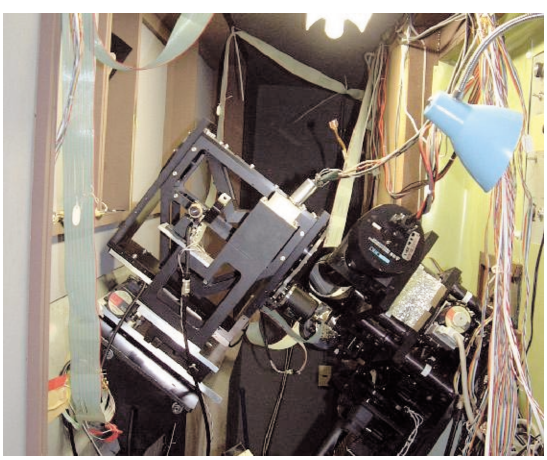

Fig. 1. I_2 cell in the coudé room of 188 cm reflector at OAO. The small black box in the foreground in the middle of the picture is the vacuum case enclosing the cell. The Image Rotator is mounted on the same stage. The starlight comes into the cell from the upper left (telescope) and goes out to the lower right (spectrograph).

A spectrum taken through the I_2 cell can be modeled as the product of the intrinsic stellar spectrum and the iodine spectrum, which is further convolved with the instrumental profile of the spectrograph. The intrinsic stellar spectrum is shifted relative to the iodine spectrum so as to fit to the observed spectrum. We have also developed a computer code for this analysis.

We observed the solar-type star υ And for 3 days in 2000 October, which has been reported to have three planets and its main Doppler velocity periodicity is about 4.6 day with amplitude 75 m s^{-1}. Our data successfully reproduced the expected radial velocity curve and achieved a relative precision of 5 m s^{-1} (Fig.2).

Now, we are planning a search for extra-solar planets around giant stars and a search for solar-like oscillations of stars using HIDES and the I_2 cell, while aiming at a much higher precision to a level of < 1 m s^{-1}.

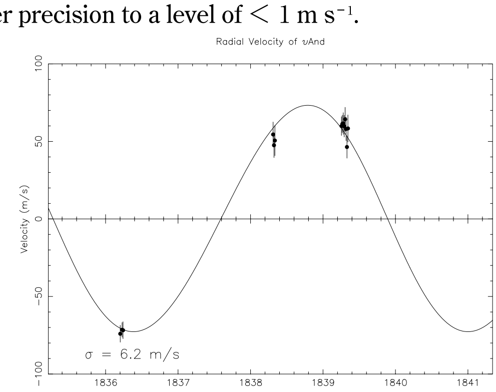

Fig. 2. Radial velocity variation of υAnd observed with HIDES and the I_2 cell. The solid curve is the expected radial velocity curve calculated with the published orbital elements.

Clear Evidence of Reconnection Inflow of a Solar Flare

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We found an important piece of evidence for magnetic reconnection inflow in a flare on March 18, 1999. The flare occurred on the north-east limb, displaying a nice cusp-shaped soft X-ray loop and a plasmoid ejection typical for the long-duration-events. The EUV observation of the same flare shows us a bubble-like void ejection. The core of this EUV void corresponds to the soft X-ray plasmoid. Moreover, as this void is ejected, magnetic reconnection occurs at the disconnecting point. A clear ingoing pattern toward the magnetic X-point is seen. The velocity of this apparent motion is about 5 km sec^{-1}, which is an upper limit on reconnection inflow speed. Based on this observation, we derive the reconnection rate as $M_A = 0.001 - 0.03$, where M_A is a Alfvén Mach number of the inflow.

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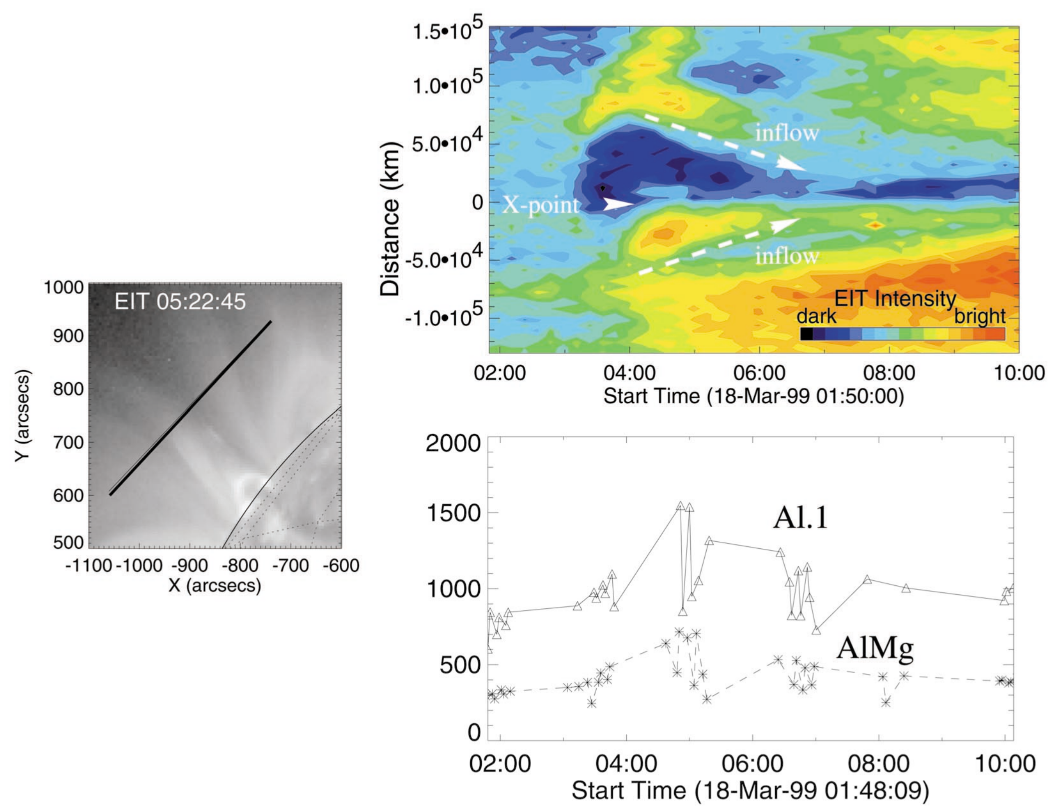

Fig. Evolution of 1-dimensional plot of EIT data nearly across the X-point. (left) A snap shot of EUV (Fe 195 Å) image by SOHO/EIT. The field-of-view size is 500 arcsec × 500 arcsec (≈350,000 km × 350,000 km). (upper right) Time evolution of 1-dimensional distribution of EUV intensity along the thick solid line in the left panel. (bottom right) Soft X-ray light curves by Yohkoh/SXT in arbitrary units.

Extragalactic Background Light versus Deep Galaxy Counts in the Subaru Deep Field : Missing Light in the Universe?

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We have completed a careful analysis of a very deep image taken at near-infrared wavelengths. The "Subaru Deep Field" (SDF) was observed soon after the first light of Subaru Telescope, and subsequent study has revealed that the galaxies detected in the image account for more than 90% of all the galactic light in the Universe. This is a higher fraction than that of the optical Hubble Deep Field images, and the SDF is therefore the deepest image of the Universe ever taken.

The SDF was imaged at a wavelength of 2.1 microns, and detected some of the faintest galaxies ever observed, down to a magnitude of 24.5. The team used their models of galaxy evolution to predict how many faint galaxies would be missed in deep images, and discovered that the galaxies they detected in the SDF image accounted for more than 90% of the total near-infrared light from all the galaxies in the Universe along this line of sight (Fig. 1). Subaru is now seeing almost to the edge of the Universe and very little extra light from fainter galaxies would be seen using more sensitive observations.

Although the Subaru observations can account for almost all of the light emitted by galaxies in the Universe, measurements from satellites have revealed that the total amount of extragalactic background light is 3 times larger. It was previously believed that all the near-infrared extragalactic light came from discrete galaxies; but these latest observations reveal that there is a great deal of light unaccounted for, which cannot be due to normal galaxies. Resolving this discrepancy will be an important challenge for future astronomy.

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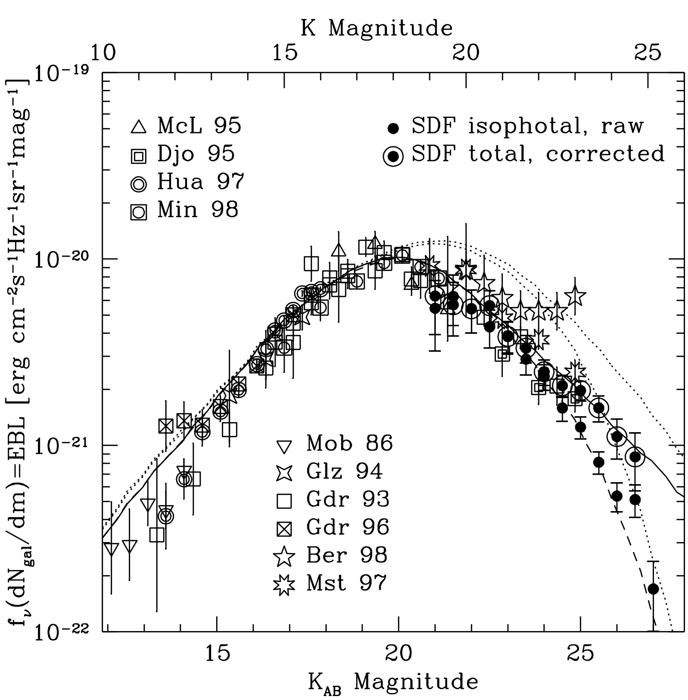

Fig.1 Contribution to the extragalactic background light in the K band from galaxy counts multiplied by flux. The data indicated as SDF are the Subaru data. It is evident that contribution to EBL is rapidly decreasing beyond K = 20 mag.

SiO Emission in the Multi-lobe Outflow Associated with IRAS 16293-2422

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We have mapped the thermal emission line of SiO (v = 0; J = 2-1) associated with the quadrupolar molecular outflow driven by the very cold far-infrared source IRAS 16293-2422. The SiO emission is significantly enhanced in the northeastern red lobe and at the position ∼50″ east of the IRAS source (Fig. 1). Strong SiO emission observed at ∼ 50″ east of the IRAS source presents evidence for a dynamical interaction between a part of the eastern blue lobe and the dense ambient gas condensation, however, such an interaction is unlikely to be responsible for producing the quadrupolar morphology. The SiO emission in the northeastern red lobe shows the spatial and velocity structure similar to those of the CO outflow, suggesting that the SiO emission comes from the molecular outflow in the northeastern red lobe itself. The observed velocity structure is reproduced by a simple spatio- kinematic model of bow shock with a shock velocity of 19-24 km s^{-1} inclined by 30-45° from the plane of the sky. This implies that the northeastern red lobe is independent of the eastern blue lobe and that the quadrupolar structure is due to two separate bipolar outflows.

The SiO emission observed in the western red lobe has a broad pedestal shape with low intensity. Unlike the SiO emission in the northeastern red lobe, the spatial extent of the SiO emission in the western red lobe is restricted to its central region. The spatial and velocity structures and the line profiles suggest that three different types of the SiO emission are observed in this outflow; the SiO emission arises from the interface between the outflowing gas and the dense ambient gas clump, the SiO emission coming from the outflow lobe itself, and the broad SiO emission with low intensity observed at the central region of the outflow lobe.

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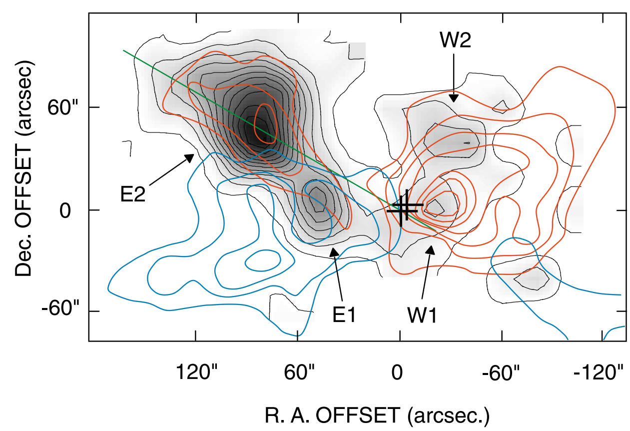

Fig. 1. Integrated intensity map of the SiO J = 2-1 emission (V_{LSR} = 2-20 km s^{-1}, *gray scale*) superposed on the CO J= 1−0 outflow map (V_{LSR} = −10−2 km s^{-1}, blue contours and V_{LSR} = 6−20 km s^{-1}; red contours) presented by Mizuno et al. (1990). The contours of the SiO J=2−1 map are drawn every 1.0 K km s^{-1} (3σ) with the lowest contours of 1.0 K km s^{-1} (3σ). Two crosses indicate the positions of the I16293 binary protostars.

Water-Vapor Maser Emission from the Seyfert 2 Galaxy IC 2560 : Evidence for a Super-Massive Black Hole

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We present an H_2O maser emission study of the Seyfert galaxy IC 2560 based on single-dish and VLBI observations. The maser emission was detected in multiple velocity ranges: one around the systemic velocity, one blue-shifted from the systemic velocity by 220−420 km/s, and one red-shifted by 210−350 km/s. This was the first detection of high-velocity features in this galaxy. The velocity of the systemic features drifts at a mean rate of 2.62±0.09 km/s/yr. Assuming a compact Keplerian disk at the nucleus, the inner and outer radii of this disk are 0.07 and 0.26 pc, respectively. The central mass confined within the disk inner radius is $2.8\times10^6\ M_\odot$, and its density is at least $2.1\times10^9\ M_\odot/\mathrm{pc}^3$. Such a high density strongly suggests the existence of a black hole at the nucleus. The 2−10 keV luminosity based on ASCA data is 1.0×10^{41} erg/s, which makes IC 2560 one of the low-luminotisy AGNs. Adopting the standard accretion model, the mass-accretion rate needs to be $2\times10^{-5}\ M_\odot$/yr in order to explain the X-ray luminosity.

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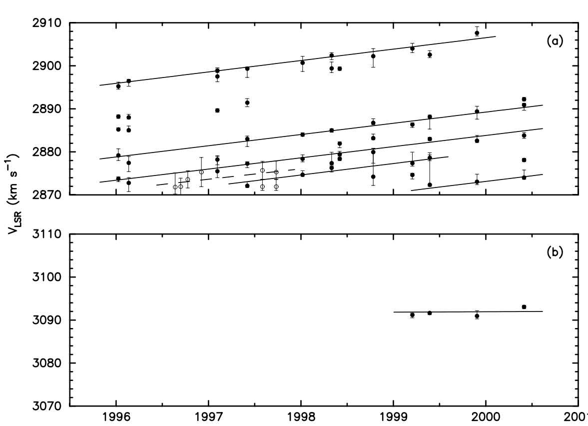

Fig. 1. Velocity variations of (a) systemic features and (b) a red-shifted feature of H_2O maser in IC 2560.

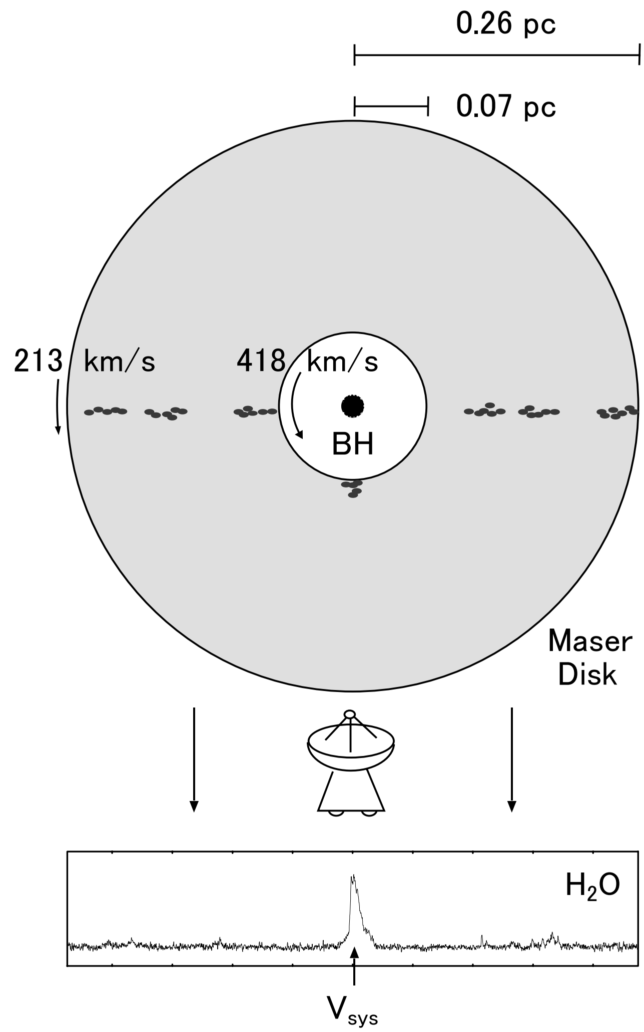

Fig. 2. Picture of a compact rotating disk with masers.

Spectropolarimetry of Nova Sgr 1999

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Variable, intrinsic component of linear polarization has been found in more than ten novae. The proposed mechanisms of the intrinsic polarization in the outburst phase can be roughly divided into two kinds of light scattering: one is due to free electrons and the other is due to dust particles. However almost all of the past polarimetry of novae used wideband filters, and the contamination of possibly unpolarized emission lines would not allow for complete understanding of the wavelength dependence of polarization.

We carried out spectropolarimetry of Nova Sgr 1999 (= V4444 Sgr) on four nights in the interval between 1999 April 29 and 1999 May 7, using a low-resolution spectropolarimeter, HBS. Three of the four observations were made with the 0.91m telescope at the Dodaira Observatory of NAOJ, and the remaining one (May 7) was made with the 1.88m telescope at the Okayama Astrophysical Observatory of NAOJ. The observations show three distinctive properties of polarization for this nova: (1) the observed polarization level increases towards shorter wavelength; (2) there is no apparent change at the wavelengths of the strong emission lines in either the polarization level or its position angle; (3) the polarization properties remain almost constant during the 10 day period of the observations.

The data shown in Stokes QU diagram are almost along a line with slope of PA=37degs and range systematically with wavelength from the upper right to the lower left. We separate the interstellar polarization component from the observed polarization by assuming that the component intrinsic to this nova has a power-law-type function of wavelength. The decomposed intrinsic polarization can be explained by scattering due to small grains (radius <0.08 μm) of which the amount is almost equal to, at least, that of dust formed in one typical nova event. These results suggest the preexistence of the dust cloud in the vicinity of the nova, at least several dozens of AU from the central star.

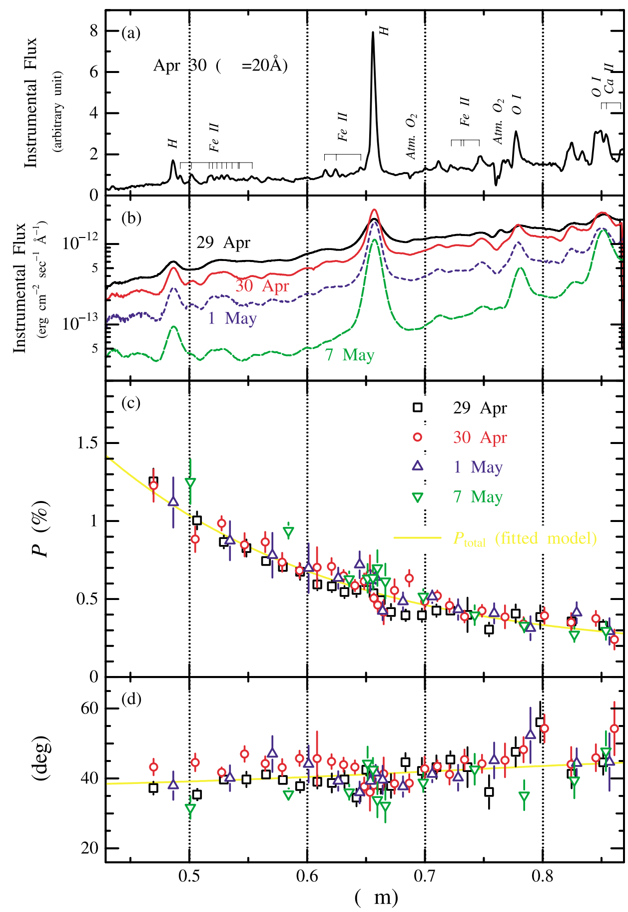

Fig. 1. HBS observations of V4444 Sgr. We show (a) higher resolution ($\Delta\lambda = 0.002\,\mu$m) spectrum obtained on 1999 April 30, (b) the unbinned instrumental flux, (c) the polarization level, and (d) the position angle as a unction of wavelength. The observational errors (1σ) are also shown in (c) and (d). Both fluxes are calibrated not for the air mass effect but only for the instrumental responce. The polarization data have been properly binned to a constant error of 0.02% in photon statistics. The curves in (c) and (d) show an example of decomposed polarization model.

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Ionization in W51IRS2 Ultracompact HII Region Probed with Mid-Infrared Fine Structure Line Emissions

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Massive stars are formed in cocoons of dense dust and gas, and manifest themselves as ultracompact HII regions when their UV radiation becomes strong enough. One of the most basic parameters is masses of their ionizing stars. However, the ionizing stars cannot be observed directly because most of their photospheric emission is absorbed by surrounding dust. Their masses are usually estimated from the total ionizing photon numbers derived from the radio continuum fluxes and/or the total luminosities derived from the far-infrared observations assuming a single star or a stellar mass function. In contrast, mid-infrared ionic lines of different ionizing potentials probe the masses through UV color of the ionized regions. Fine structure lines of [NeII] 12.8 μm, [ArIII] 8.99 μm, and [SIV] 10.51 μm, are observed in the N-band. The ionization potentials to form Ne^{+}, Ar^{2+}, and S^{3+} are 21.56eV, 27.63eV, and 34.83eV, respectively.

In this research, we observed massive star forming region W51IRS2 to investigate their ionization status. N-band imaging and low-resolution spectroscopy were made with 1″ spatial resolution. IRS2 was resolved into seven sources based on the continuum and the emission line maps. The nature of these sources were investigated using their thermal dust emission, the 9.7 μm absorption feature, and/or three fine structure emission lines of [NeII] at 12.8 μm, [ArIII] at 8.99 μm, and [SIV] at 10.51 μm. Four of the sources were identified as ultracompact HII regions and one as an embedded protostar candidate. To estimate the spectral types of the ionizing stars, we made a line flux ratio diagram (Figure 1). On the diagram, we compared the ratios with model prediction for each region ionized by a single massive star. (The model used recent stellar atmosphere model taking into account of non-LTE and stellar wind.) The spectral types of the ionizing sources for W51IRS2 ultracompact HII regionsare derived from the diagram to be all around O9, which is much later than those (O5.5 and O7.5) derived from the radio continuum fluxes. The observed line ratios of (ultra)compact HII regions in IRS2 and in literature follow a single excitation track but it is different from that predicted from the model. We propose two possibilities to resolve the discrepancy: (1) the employed models for the stellar atmosphere are not sufficiently correct in the UV range, or (2) the (ultra)compact HII regions are ionized by stellar clusters. Also the ratios do not show good correlation withthe spectral types estimated from the radio continuum fluxes. It questions the usual mass estimate using the radio continuum.

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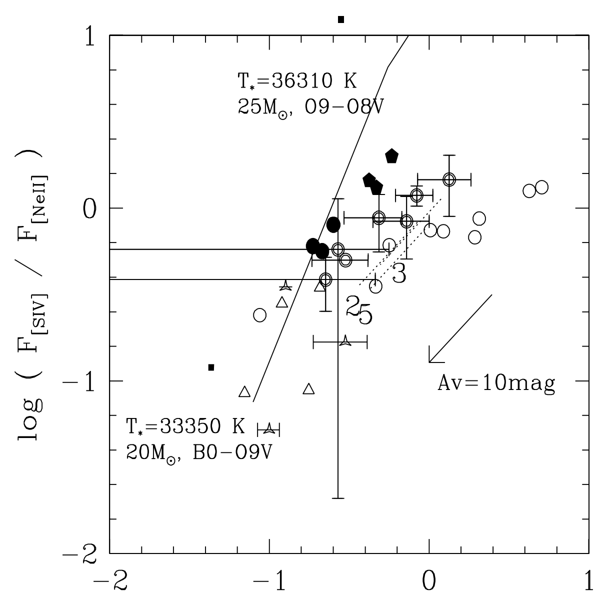

Fig. 1. Line flux ratios for (ultra)compact HII regions. Filled circles and pentagons connected with dotted lines indicate the ultracompact HII regions in W51IRS2. Each filled squares connected with solid lines indicate model prediction for an ultracompact HII region ionized by a single star. The other symbols indicate the observed ratios of other ultracompact HII regions in literature (Open and doubled circles indicate the objects for which both ratios are available, starred triangles those for which only upper limits are given for F([SIV])/F([NeII]), and the open triangles those for which both ratios are upper limits.)

TV Observation of the Leonid Meteor Shower in 1999: Secondary Peak over Japan

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Since the parent comet 55P/Tempel–Tuttle returned in 1998, the Leonid meteor shower was expected to show a higher than usual activity in 1998-2001. In 1999, the maximum of the activity was expected at around 02h UT on November 18, many expeditions, including NASA's Leonids Multi-Instrument Aircraft Campaign, were performed mainly in Europe and northern Africa.

In order to monitor the activity of the Leonid in 1998, we used a high-sensitivity TV camera system (Watanabe et al. 1999). However, the number of Leonid meteors we detected was only 58. This was not only due to the low activity, but also due to the narrow field of view of the camera system. In 1999, we concentrated on the detection of right meteors, and a new camera system was applied in order to cover a wide field of view. This camera comprised a high-sensitivity monochromatic CCD camera (WATEC Co., type WAT-902H) along with a C-mount camera lens ($f=12.5$ mm $F1.3$, CCML-1253, Fit Co.). This system gives a field of view of 37.0×50.6 degrees, along with a limiting magnitude of 5 under the best sky condition. This field of view is by about 9.5 larger than that realized by the camera system used in 1998. Using this new camera system, we carried out a TV observation of the Leonid meteor shower at the Nobeyama Radio Observatory, from 12h30m UT through 20h15m UT on 1999 November 18. As a result, we detected 428 Leonid meteors, along with 55 sporadic meteors. A gentle peak of the activity was recognized at around 17h UT, when the peak influx rate of meteoroids was 1.1×10^{-6} km^{-2} s^{-1} (mag $< +5$). This secondary peak was at least by one order smaller than the main peak of the Leonid storm observed at 02h UT over Europe.

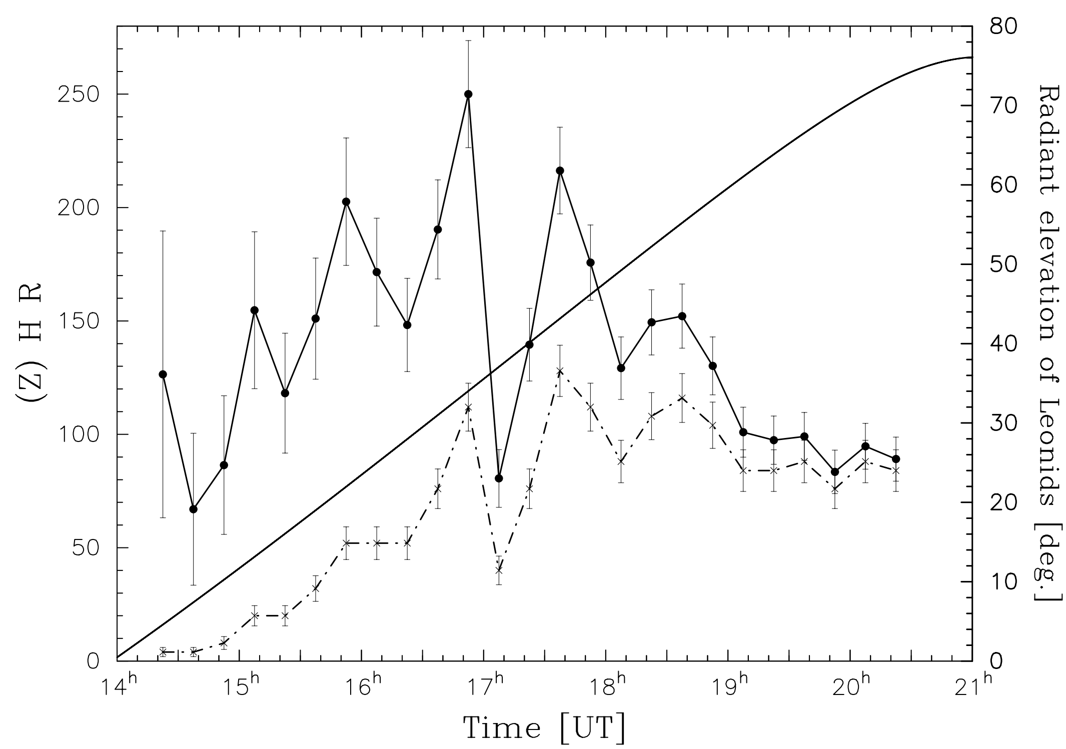

Fig. 1. Time variation of the number of Leonid meteors detected in our TV observation on 1999 November 18. The dash-dotted line is the hourly rate of the number of meteors observed in 15 min interval, and the solid line is the number after a correction for the radiant-point elevation. The solid curve is the elevation of the radiant point.

High-Dispersion Spectra of NH_2 in the Comet C/1999S4 (LINEAR) : Excitation Mechanism of the NH_2 Molecule

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We carried out a high-dispersion spectroscopic observation of the comet C/1999S4 (LINEAR) on 2000 July 8.75 (UT). The NH_2 $\tilde{A}$ (0,10,0) $-\tilde{X}$ (0,0,0) and $\tilde{A}$ (0,9,0) $-\tilde{X}$ (0,0,0) bands were extracted from the observed spectrum and compared with the modeled spectra. We developed a fluorescence equilibrium model for the NH_2, in which $\tilde{A}$ (0, v'_2,0) $-\tilde{X}$ (0,0,0) transitions and the radiative relaxation among the rotational levels in $\tilde{X}$ (0,0,0) were considered. The rotational structure of the spin doublet (F1 and F2 levels) and the Swings effect were considered in the model. The modeled spectra are consistent with the observed spectra of the $\tilde{A}$ (0,10,0) and $\tilde{A}$ (0,9,0) bands. Our results show that the fluorescence excitation and the radiative relaxation processes are dominant for NH_2 in a coma of the comet at ~ 1 AU from Sun. The fluorescence efficiencies of NH_2 calculated form our model are important for the future study on the NH2 abundance in the comets because the ammonia abundance in comets can be derived from NH_2.

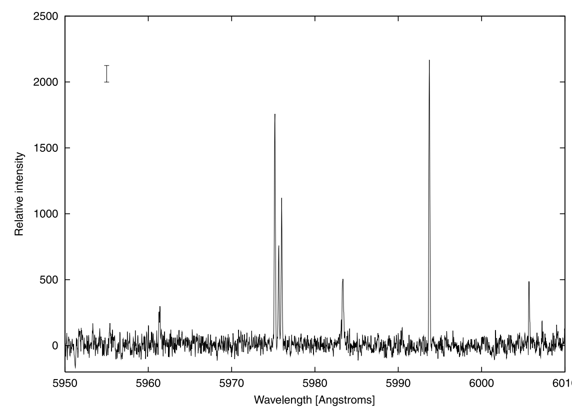

Fig. 1. NH_2 $\tilde{A}$ (0,9,0) band spectrum in comet C/1999S4 (LINEAR) on 2000 July 8.75(UT) using the high-dispersion (R=50000) echelle spectrograph attached to the 1.9 m telescope. Most of the emission lines stronger than 3 σ error-bar (shown at the top-left of the figure) belong to the NH_2 $\tilde{A}$ (0,9,0) band.

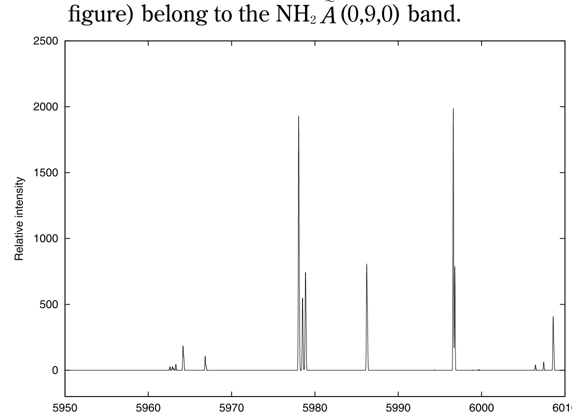

Fig. 2. The NH_2 $\tilde{A}$ (0,9,0) band spectrum based on the fluorescence equilibrium model. The model result is well fitted to the observation within the errorbar (figure 1). Observed spectrum was shifted in the wavelength due to the cometary motion relative to the Earth.

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CIAX: Cassegrain Instrument Auto eXchanger for the Subaru Telescope

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The Cassegrain Instrument Automatic eXchanger "CIAX" system for the 8.2 meter Subaru Telescope moves instruments between the Cassegrain mounting flange and stand-by flanges without manual intervention. Subaru Telescope has five Cassegrain common instruments including CIAX-3 sub-system that swaps three small instruments (approximately 300 or 150 kgf each) automatically in 10 minutes on the telescope. Observation efficiency improves not only because of quick exchanges, scheduled or emergency, but also because of increased flexibility in selecting an optimum instrument for weather conditions or observation goals.

Instrument Exchange System

Interfaces to the telescope flange are standardized for all five Cassegrain instruments (approximately 2000 kgf each and 2×2×2 m^3 size) currently in use.

CIAX cart that transports these instruments between the telescope and the stand-by flanges in about 15 minutes is using wireless LAN for remote control. Since the cart has no external cables, four automobile batteries supply the power. They are automatically charged at the two park positions in each stand-by room. Four stand-by flanges are located in two rooms of the dome. Two are fixed type and the other two are movable to make space for the route of the cart. Their mechanical and connector interfaces are identical to those of the telescope flange. Reliable and safer instrument exchanges are achieved by the precision mechanical positioning system (less than 0.5 mm) and automatic connector system for electrical cables, optical fibers and fluid lines.

Automatic connectors

The automatic connector system consists of four units: two are for optical fibers, one for electrical and the fourth for uid lines. At the fiber line, networks for the instrument and fiber lines for exclusive non-network use are connected for its control and data sending. At the fluid lines, ethylene glycol is supplied for cooling instruments, compressed gas is supplied for controlling pneumatic actuators and cleaning the optics and helium gas is also supplied for cooling infrared instruments. When the instrument is pulled up onto the flange, all automatic connectors are also connected.

Control Networking

The CIAX control system consists of one UNIX WS, four PCs and four Programmable Logic Controllers (PLCs). Each PLC is connected to and controlled by computers through RS-232C. The two PCs running by Windows NT are used for controlling of the cart & stand-by flanges by file sharing. Interlocks between the flanges and the cart are provided locally by the PCs. Other two LINUX PCs control automatic doors of the stand-by rooms, lighting, and power supply to instruments through I/O relays. They also check the proximity of the top of an instrument to the standby flange with potentiometers. The main computer of the CIAX system (CIAX-WS) communicates with all PCs and control all CIAX instruments including the Cassegrain Jack Bolts and Instrument Rotator. Moreover it checks all statuses and interlocks of whole system.

We installed several CCD cameras, Internet cameras and microphones for safety check. An Internet camera is placed on the cart and sends images of the surroundings. CCD cameras installed on all automatic connector systems and stand-by rooms are used to check whether obstructions exist and whetherthe connection is complete.

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Fig. 1. Cart and CIAX3 at Cassegrain focus

Light Pollution and Its Energy Loss

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For optical astronomical observations, light pollution is a severe problem not only to request the longer exposure time but also to reduce its limiting magnitude. Its condition becomes worse and worse depending on expansion of city areas and increase of unproper lighting fixtures, and therefore it has brought a big damage for activities of amateur astronomers and for astronomical education.

In an area having light pollution, a light fixture dose not illuminate properly its target object but ejects much light to space which is now energy loss. Light pollution disturbs an important occasion for people to understand our universe and also causes a loss of finite energy resources.

Since 1972, US meteological satellite program have been producing data of brightness distribution on a terrestrial surface. From 1993, The US National Geographic Data Center started to distribute those digital data and now one can obtain those absolute values at different points. We are continuously ovservating those light energy loss using the data and try to find its time dependeces at different cities which show rearly those increases.

For cases of 1998, each Japanese electric supply company kindly provided us values of the total electric energy supply at times when our data are available. Figure 1 shows a relation between the total electric energy supply and light energy detected by the DMSP at different times. Unfortunately, we could not obtain enough number of data points because of some constraints of weather conditions and low priority of this find of observations under US Air Force. However, there is a good corelation except for cases of D electric company and J electric company. 0.1 to 0.2 % of the total electric energy supply is ejected to space in a form of light energy loss.

For a case of D electric supply company, light ejected to downwards effectively reflected upwards by snow covered surface. For a case of J electric supply company, light ejected from US Army base was added. Therefore, those areas show highter light energy loss to space.

One can see an interesting distribution of one carefully watches each distribution if data for case A, B and C electric companies. The point of each corelation line cross at non-zero value of light energy loss for zero value of the total electric supply. Since number of data is not large enough we can not definitely say following result. That is, there are some other light sources such as head light cars.

We started this study to protect light pollution for good astronomical observation sites. However, now we have now a possibility to provide data relating to problems of energy conservation and environmental problems which are getting much global concern.

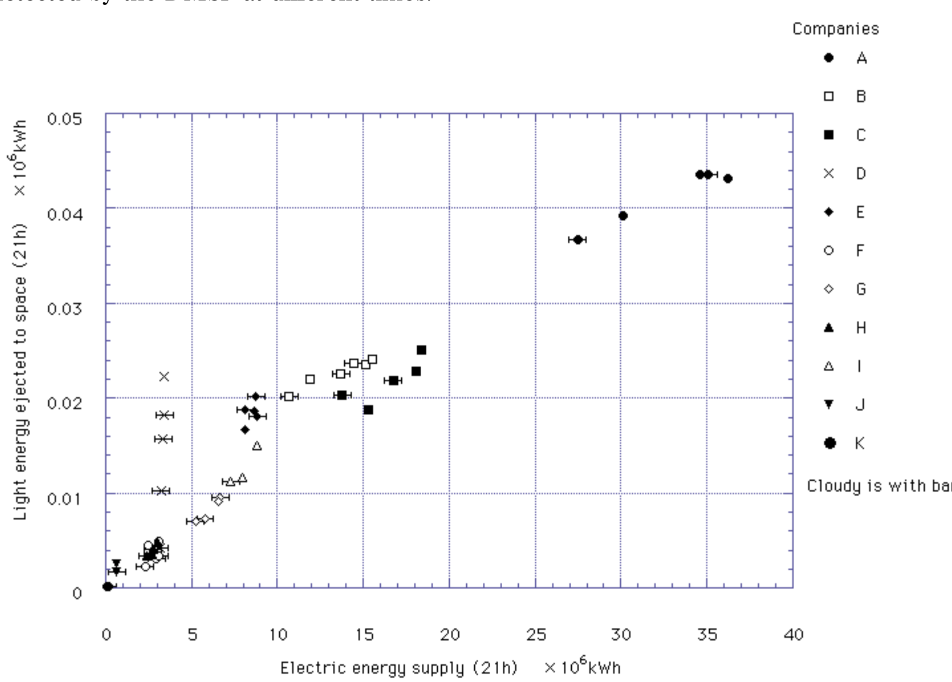

Fig. 1. Light Energy Loss.

Development of a New SPH Scheme for Shear Flows and Its Astrophysical Application

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Smoothed Particle Hydrodynamics (SPH) is one of the computational methods to study the fluid dynamics and is widely used to investigate the astrophysical problems. However, SPH technique cannot describe accurately the long-term evolution of shear flows, which prevail, for example, in protoplanetary disks. As the calculation proceeds, density errors increase up to $\Delta\rho \gtrsim \rho$ (See Fig.1). The time scale of the error emergence is of the order of dynamical time scale. We demonstrate that these errors are originated from the definition of density of SPH. Therefore, we reformulate the SPH method and find the expression of consistent velocity field in terms of the particle velocities to satisfy the continuity equation. We should distinguish the particle velocity and the fluid velocity throughout the calculation. Particle positions should be updated by the particle velocities. The difference of the particle velocity and the fluid velocity is very small, of the order of h^2, where h corresponds to the spatial resolution in SPH. Although this is the second order difference, it brings the large density errors when we follow the long-term evolution of shear flows. We demonstrate that the accurate calculation can be made with our newly improved SPH method (See Fig.2).

We apply our method to the binary - circumbinary-disk interaction problem. When the orbit of binary is eccentric, we cannot use any rotating frame of reference to reduce the complexity of the problem, and it is difficult to study the eccentric binary case with the grid-based calculation. Thus, we have calculated this problem with our newly devised SPH scheme for shear flows, and have found that highly eccentric binary makes the m=1 density structure on the circumbinary disk (See Fig.3). This is a standing wave in the inertial frame. The existence of this m=1 density structure in the gaseous disk system is not previously reported in the literature. The excitation of m = 1 mode can be explained analytically, and the location of the density enhancement is simply understood in terms of the orbits of fluid elements. We also compare this result with observations and discuss the astrophysical implication.

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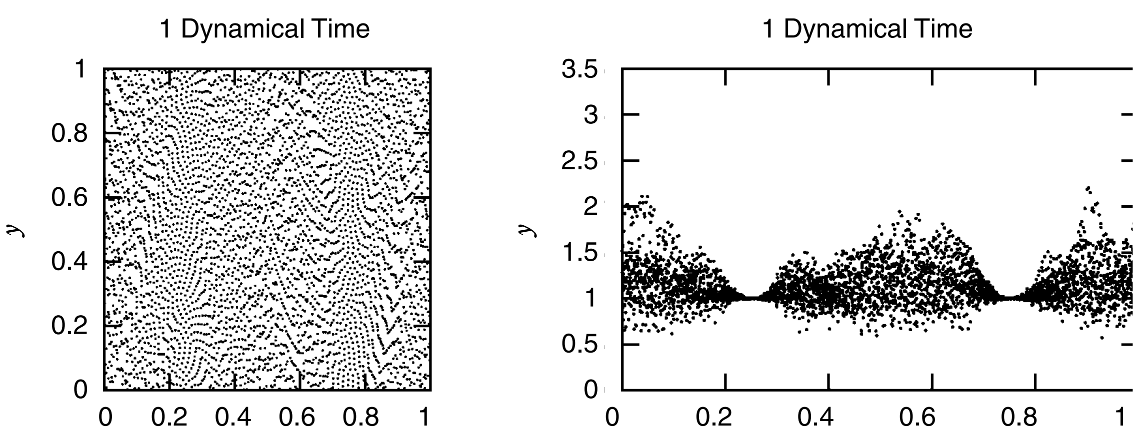

Fig. 1. Two-dimensional shear flow test with standard SPH. The position of SPH particles and the surface density at the particle position after one dynamical time are shown. Initially, the constant density of unity and the shear flows of $v_x=0$, $v_y=\sin(2\pi x)$ are considered. The computational domain is 1×1 and the cyclic boundary conditions are considered. The large density errors of $\Delta\rho \gtrsim \rho$ emerged in the SPH result although the density should be kept as $\rho(x)=1$.

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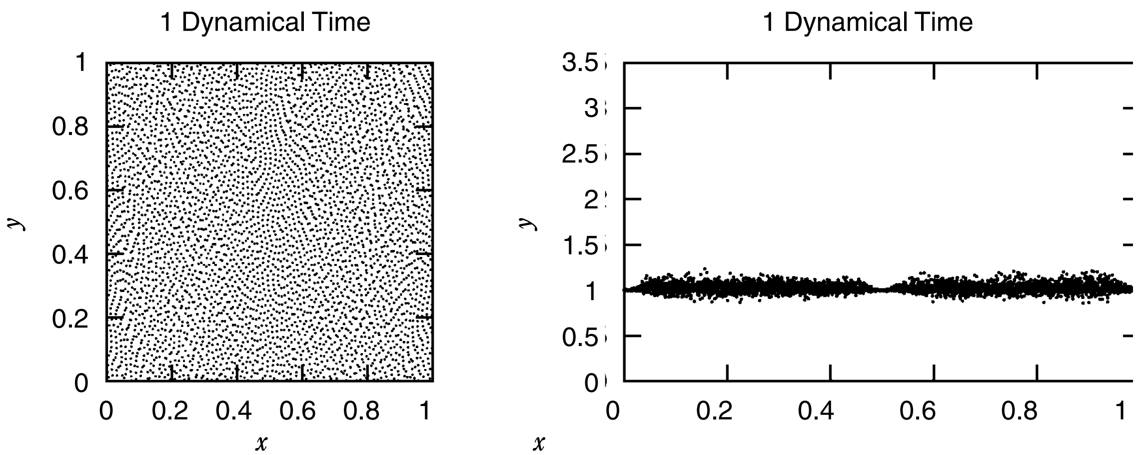

Fig. 2. Same as Fig.1 but our improved SPH scheme is applied. The error is dramatically reduced and the accurate long-term evolution can be performed.

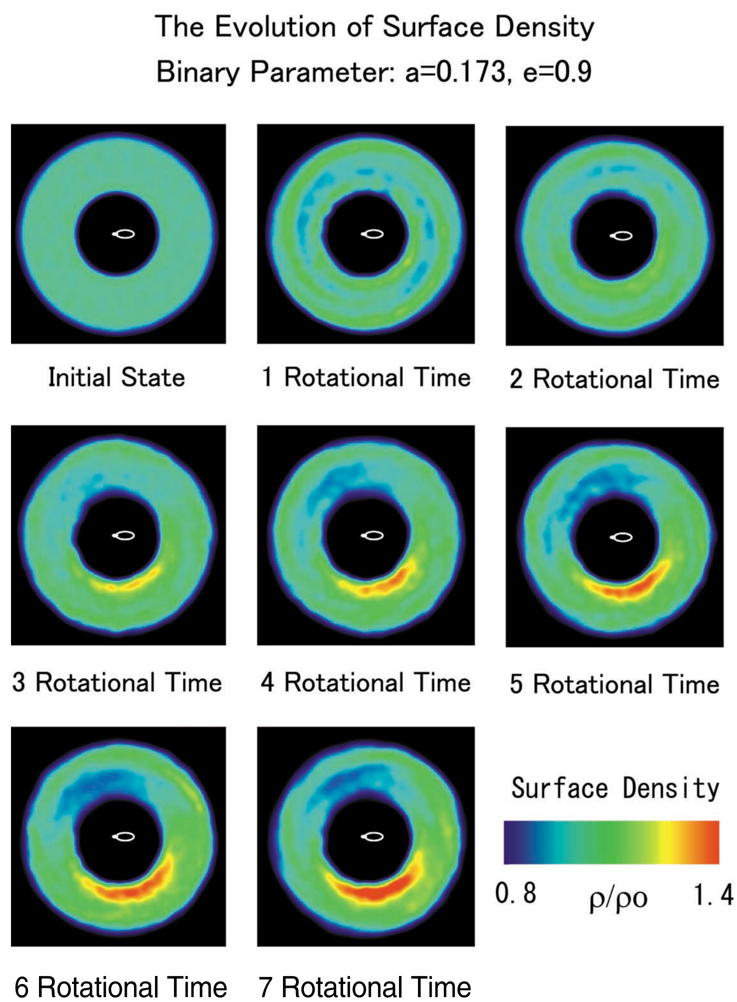

Fig. 3. The evolution of the surface density of circumbinary disk with $e=0.9$ binary. The mass ratio is 4:1. Time is measured at the middle of the circumbinary disk, $r=1$.The white circles represent the orbits of the binary. The semimajor axis of the binary is roughly three times as small as the inner edge of the circumbinary disk. As the time proceeds, $m=1$ standing wave emerges on the circumbinary disk.

Dense Cores and Molecular Outflows in the OMC-2/3 Region

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Takenori Nakano, Katsuji Koyama (Kyoto University)
Satoshi Yamamoto (University of Tokyo)

To understand how stars from, it is essential to know the properties of dense cores, which serve as the initial condition for star formation, and the properties of outflows, which might be deeply related to the mass infall onto protostars or protostars' growth. The OMC-2/3 region in the Orion giant molecular cloud has been extensively studied recently, and data at various wavelengths are available. We have observed this region in the $H^{13}CO^+$ (1−0), HCO^+(1−0), and CO(1−0) lines by using the Nobeyama 45 m radio telescope. We have identified 18 dense cores in $H^{13}CO^+$(1−0) and eight molecular outflows in CO and HCO^+(1−0) in OMC-2/3. Four of these outflows are newly found. The line widths of the $H^{13}CO^+$(1−0) cores in OMC-2/3 are twice as large as those in dark clouds, and the momentum fluxes of the outflows in OMC-2/3 are approximately 2 orders of magnitude larger than those of outflows in dark clouds. We found that the mass-loss rate of the outflow is proportional to the third power of the core velocity dispersion, which suggests that the outflow mass-loss rate is proportional to the mass infall rate onto the protostar. From a comparison between the properties of cores associated with protostars and those without protostars, we suggest that the dissipation of turbulence initiates star formation.

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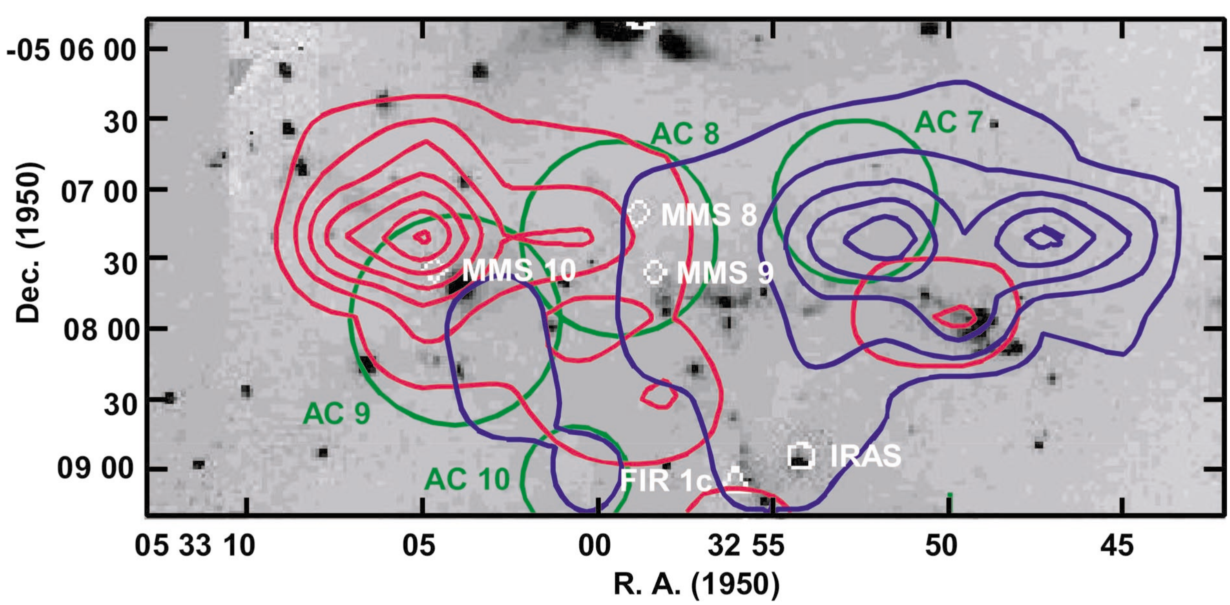

Fig. 1. Map of the outflow from the protostar MMS9 in CO (1-0) superimposed on the image of H_2 emission (Yu et al. 1997). The blue and red contours represent the distribution of the blueshifted and redshifted gas of the outflow, respectively. The green circle represents the position and size of the dense core.

Temperature Measurement of Sunspot by Radio Observation

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Detection of umbral oscillation of sunspot by Nobeyama Radioheliograph at 17 GHz has already been reported (Ref. 1). Further study showed that the oscillation is caused by sound wave propagating upward through the gyroresonance layer (2000 Gauss iso-Gauss layer, 3 rd harmonics at 17 GHz). Temperature and density fluctuation due to the sound wave causes radio brightness variation. In the present work, we found that the oscillation frequency is determined by the temperature around the temperature minimum region in the umbra. We can measure the sunspot temperature by spectral analysis of the umbral oscillation (Ref. 2).

In the hydrostatic atmosphere with uniform temperature, the sound wave propagating upwards has a lower cutoff frequency. At the upper side of the atmosphere, waves at the cutoff frequency are preferentially excited. In the sunspot umbra, atmosphere is in hydrostatic equilibrium due to the strong magnetic field that acts as a solid wall. Around the temperature minimum region, temperature is uniform. Due to these conditions inside the umbra, we can expect that the atmosphere has a lower cutoff frequency. The frequency is determined by the gravity acceleration and the temperature: $f \sim 12.0 / \mathrm{sqrt}(T)$, where f is the frequency in milli-Herz and T is the temperature in thousand Kelvin. The observed 6 mHz (about 3 min.) corresponds to 4,000 K.

So far, the 3-minutes oscillation has been interpreted as a result of cavity resonance between temperature minimum region and transition region. In the cavity between these sharp boundaries, waves are trapped and are standing waves.

But our observations show that waves are propagating and no harmonics are detected that is expected in the case of cavity resonance. Five minutes oscillations at the photosphere in the sunspot umbra are not observed at the chromosphere and above. These phenomena are easily be understood by our new interpretation but it is hard to understand by the existing resonance interpretation. Moreover, based on the new interpretation, we can measure sunspot temperature. Many studies can be done: relation between temperature and sunspot type, age, etc., relation between the solar activity and sunspot temperature. Studies of sunspot structure and of sunspot generation regions could be done using temperature structures and variations.

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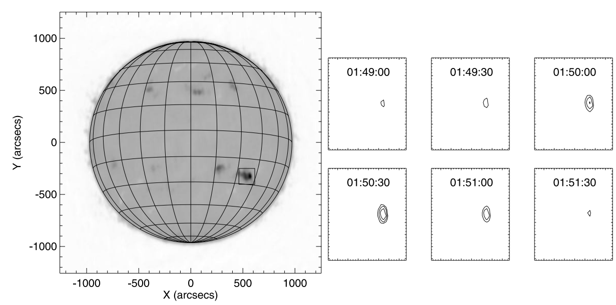

Fig. 1. Full disk image and partial frame images.
The contours are from 32,000 K and the contour step is 2,000 K.

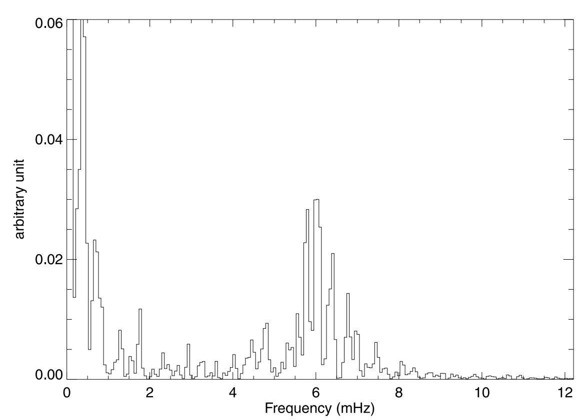

Fig. 2. Frequency spectrum of 3-min oscillation

Development of the Image Rotator for the Coudé Focus of the OAO 188cm Telescope

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In the observations with the High Dispersion Echelle Spectrograph (HIDES) at the coudé focus of OAO 188cm telescope, observers thus cannot freely specify the observing slit position angle on the focused image. Furthermore, the image rotation caused by diurnal motion of the observing object smears the spatial information along the slit when the exposure time is substantially long. It is therefore difficult to observe spatial structure of extended sources with the coudé spectrograph.

In order to overcome this situation, we have developed an image rotator for the coudé focus of the OAO 188cm telescope. The image rotator consists of three flat mirrors placed in a special configuration. Rotating this optics around the optical axis of the coudé beam, observers can take any slit position angle and cancel the effects of image rotation by diurnalmotion. The rotator has a 4 arcminutes field of view, which corresponds to that of the wide field acquisition camera of the coudé focus. This wide field enables to perform offset-guiding during exposures of spatially extended objects with no central bright point source. This instrument is mounted on a slide stage in front of the coudé slit unit and easily be controlled through GUI.

In the case of HIDES, the maximum slit length projected on the sky is limited to about 15 arcseconds (around H α) because of the closely lying adjacent diffraction orders of the echellogram. In order to realize a much longer slit length we plan to use a narrow band filter of about 50 Å FWHM to extract a single diffraction order of the echellogram. For point-like objects, the influence of atmospheric dispersion can be avoided by this instrument, keeping the slit position angle parallel with the zenith direction. When HIDES is equipped with a mosaic-ed CCD camera in order to observe much wider wavelength region by one exposure, the image rotator will also be useful as a practical atmospheric dispersion compensator.

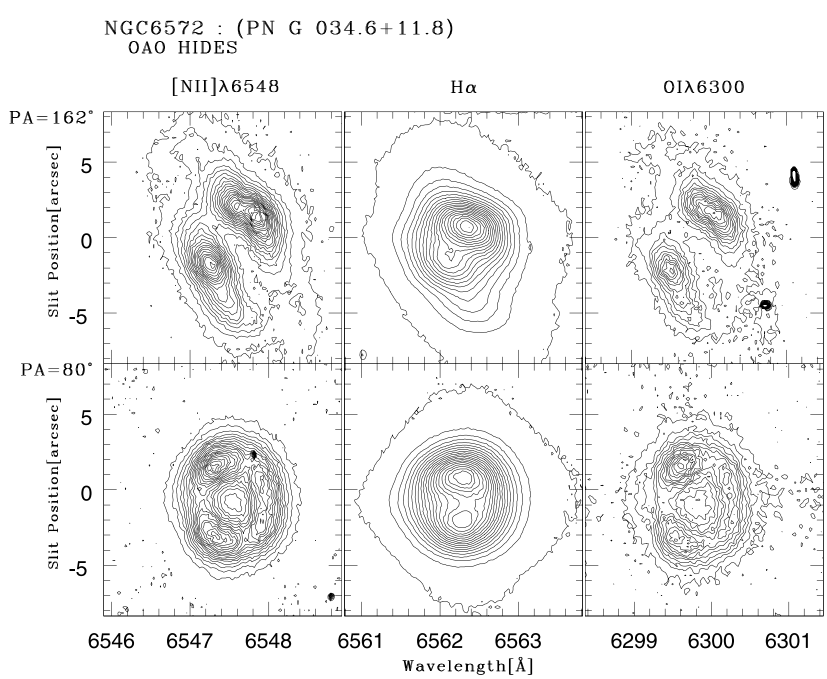

Fig.1. Position-velocity contour maps of a planetary nebula NGC6572 observed by HIDES & image rotator. The uppers are countours of [NII] λ6548, Hα, OIλ6300 (left to right) observed at P. A.=162° (the vertical axis presents spatial distribution, and the horizontal presents wavelength). The bottoms are same ones observed at P. A. = 80°.

Long-Term Integration Error of Kustaanheimo-Stiefel Regularized Orbital Motion

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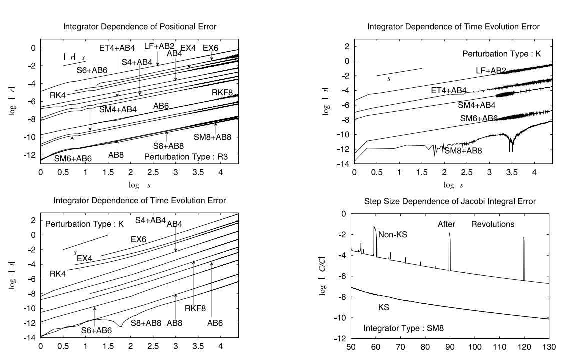
In studying celestial mechanics, numerical integrations are the strong tools for investigating the long-term behavior of dynamical systems, constructing high-precision ephemeris, and so on. Until now, developing the highly accurate integration schemes such as the symplectic integrator and the symmetric multistep method, has devoted to an reduction of integration error.

However we showed that it is effective to transform equations of motion (EOM) into the regular and linear form by KS (Kustaanheim-Stiefel) regularization and we can reduce the integration error. The KS regularization has been used properly to avoid the accumulation of error at the close approach among the celestial bodies. The KS transformation contains both the space and time transformations then the EOM is rewritten in the form of perturbed harmonic oscillators. In this case, the independent variable is not the time but the fictitious time s. Adopting the linearized EOM, we found that the error growth of the position is proportional to s. This properly does not depend on the types of perturbation, the integrator used, nor the nominal eccentricity. In the KS regularization, the physical time must be calculated by the integration because of time transformation. The error of physical time grows linearly when the harmonic oscillator parts of EOM are integrated by the time symmetric integrators ; the leapfrog or symmetric multistep method, while proportional to s^2 integrating the same parts by the traditional ones. Further we discovered that the KS regularization evades the stepsize resonance/instability of symmetric multistep method for the special second order ordinary differential equations (ODEs) in integrating the Kepler problem, and we indicated that the harmonic oscillator potential can only avoid the resonance/instability. Therefor we can perform the fast and highly accurate integration in the condition, $\Delta x \propto t$ by KS transformation. Nevertheless, the KS regularization have limits ; the symmetric multistep method for special second order ODEs cannot deal with the acceleration depending on velocity v and the symmetric multistep method for general first order ODEs often faces the numerical instability. To find a scheme applicable to a general perturbation and reduce the integration error of physical time t, we considered the application of the method of variation of parameter (MVP) to the KS regularizaton. Since the EOM in KS regularization is expressed in the form of harmonic oscillator, we can define the KS elements as the amplitudes and phases. We confirmed that the MVP reduces the integration error of both the position and physical time and it grows only linearly with respect to s. The KS elements were first introduced by Stiefel et al. [3] and modified by Stiefel & Scheifele [4]. Stiefel's KS elements are not complete in the sense that the element of physical time is not given. Thus we introduced a time element and obtained the third set of KS elements. Unfortunately, the good property of KS regularization and its MVP fail in the general N-body problem because the fictitious time is proper to each body.

Therefore KS regularization including its MVP is effective to study the long-term behavior of perturbed two body problems; especially the dynamics of comets, minor planets, the Moon, and natural/artificial satellites.



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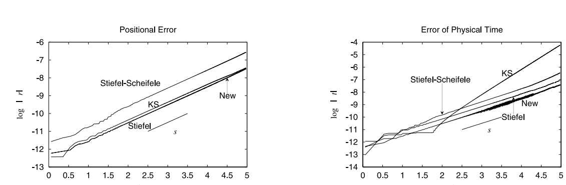

Detecting Astrometric Microlensing with VERA

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Astrometric gravitational microlensing is a new type of microlensing that is detected through the positional shift of the lensed image. We have investigated the possibility to detect such an astrometric microlensing event with VERA (VLBI Exploration of Radio Astrometry), which is an new VLBI array promoted by NAOJ aiming at high-precision astrometry, and have revealed that VERA can be a new tool to study astrometric microlensing caused by both stars in the Galaxy's disk and MACHOs in the Galaxy's halo.

First we have calculated the probability of astrometric microlensing of distant radio sources (QSOs and radio galaxies) due to MACHOs in the Galaxy's halo. We have found that 2-3% of radio sources are always being lensed by MACHOs, assuming a typical parameter of Galaxy's halo structure. Typical event duration is also found to be 15 yr. These results imply that if one monitor a few hundred sources, an astrometric event should be detected with VERA within 20 yr. We also found that if one detect such an event with VERA, one can strongly constrain the lens mass even when the lens distance and source distance are unknown, indicating that VERA can be a new tool to investigate the nature of MACHOs.

Moreover, we have also investigated the possibility to detect an astrometric microlensing due to stars in the Galaxy's disk. Our calculations have shown that around 10% of radio sources behind the Galactic plane are always being lensed by the disk stars. This event probability is 15 times larger than that for star-star lensing (both lens and source are Galactic disk stars). Furthermore, the event duration for distant sources (case for VERA) is around 7 yr, while the event duration for star-star lensing (corresponding to astrometric lensing event detectable with space astrometric missions like SIMA and GAIA) is around 15 yr. Thus, it is relatively easier to find an astrometric microlensing with VERA than with SIM or GAIA.

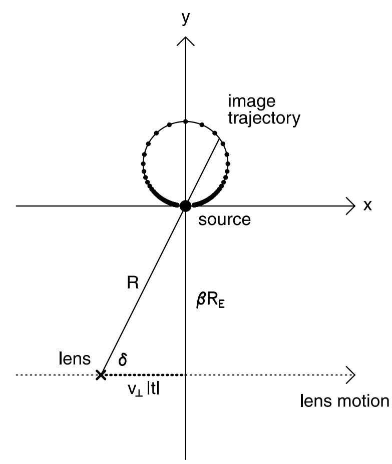

Fig. 1. Schematic view of astrometric gravitational microlensing event. Usually the image trajectory becomes a circle.

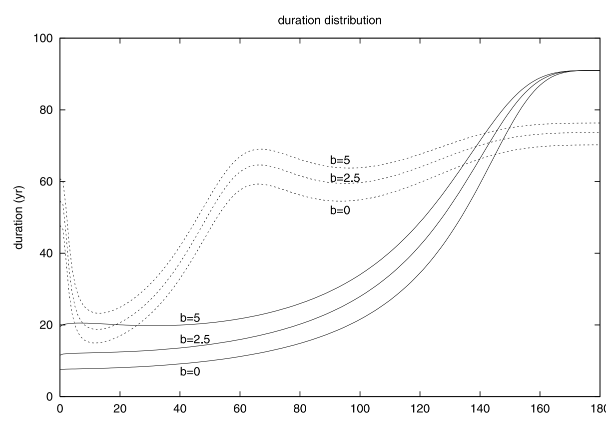

Fig. 2. Event duration for various galactic longitude and latitude. Thick lines are for VERA cases (QSO for source), and dashed lines are for SIM and GAIA cases (disk stars for both source and lens).

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MM-Wave Interferometric Study of the ρ-Ophiuchus A Region I. Small-Scale Structures of Dust Continuum Sources

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We performed 3 mm continuum and ^{12}CO (J=1-0) line observations of the ρ Ophiuchus A region using the Nobeyama Millimeter Array. The high resolution dust continuum map reveals that the two submillimter sources (SM1 and SM1N), which are considered to be pre-protostellar cores, consist of smaller scale fragments of 600 - 1100 AU in size. The small fragments are lying along two filamentary features that cross each other at the position close to SM1, with a typical projected separation of 1200 AU. This is the first detection of such small-scale fragments in pre-protostellar cores from dust continuum observations. The masses and densities of the small fragments are estimated to be 0.054−0.14 $M_{\odot}$ and (2.0−15) × 10^7cm^{-3}, respectively, and they appear to be gravitationally bound.

From our CO observations, we have discovered a previously unknown CO outflow whose axis is almost parallel to that of the nearby outflow associated with VLA1623. However, the center of this outflow is likely to be the near-infrared source GY30, and does not coincide with any of the small fragments. All small fragments except one show no sign of protostellar activities such as CO outflow and centimeter radio continuum emission, suggesting that they are in the evolutionary stage prior to form protostars with outflow activities. On the other hand, the small fragment with the largest mass is likely to be associated with 6 cm continuum emission, which is thought to be free-free emission. This implies the possibility that the protostellar formation has already occured in the fragment. The presence of small scale fragments with and without protostellar activities suggests that star formation in this region occur in such a small fragment or through coalescence of several small fragments.

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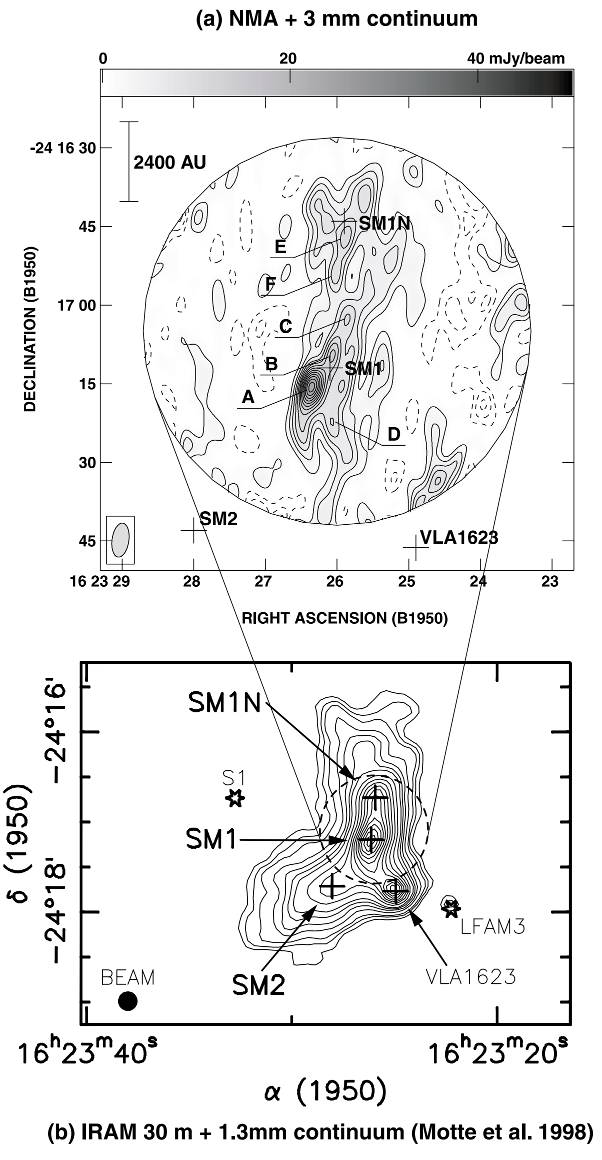

Fig.1 (a) 3 mm continuum map with the NMA. Plus signs are submillimeter continuum sources, SM1, SM1N, SM2 and VLA 1623, identified by Motte et al. (1998). The labels ("A" − "F") indicate the small cores identified by us. (b) 1.3 mm continuum map with the IRAM 30 m telescope by Motte et al. (1998). Dashed circles indicate our observational field. Cross marks are same submillimeter continuum sources as Fig. 1a.

Highly Polarized Burst of a Water Maser in Orion-KL

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The star-forming region Orion-KL is known to have once had a spectacular water-maser burst event accompanied by very high fractional polarization up to 70% in the 1980's. In 1997 December, it was discovered that the Orion-KL water maser had again started to burst. The total flux density of the spectral feature at a velocity of Vlsr=7.9km/s appeared to increase exponentially, and reached values as large as 3.5 million Jy in 1998 September. The position of the present burst coincides with that of the previous event to an accuracy of 1''. Because the present event is the only second known in this region, we can not judge the periodicity.

We measured the linear polarization of the maser after the burst, during a phase of rapid flux density decrease. The observations of the Orion-KL burst maser were made on 1998 December 21, 1999 January 22, 27, and 28, February 22, March 1, and June 8 using the Mizusawa 10m radio telescope. We found that the total flux density of 2.4 million Jy exhibits about 46% linear polarization. Over the next six months we found that the total intensity decrease by about two order of magnitude, while the fractional linear polarization gradually fell to 30%. These results suggest that the present bursting phenomenon has an origin similar to the super-maser event starting in 1979, and that the phenomenon of the extremely bright masers in this region is geometric in nature and related to a strong magnetic field.

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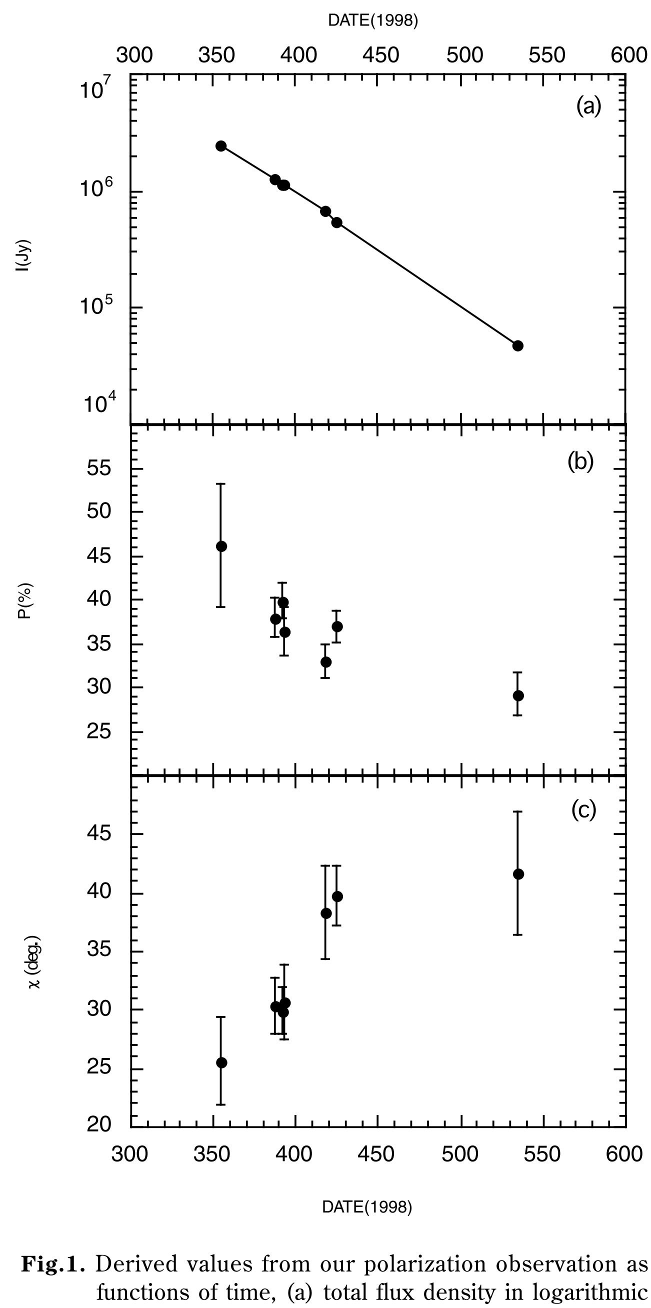

Fig.1. Derived values from our polarization observation as functions of time, (a) total flux density in logarithmic scale, (b) polarization degree, (c) polarization angle.

CO Line Observations of the Radio Lobe Galaxy NGC3079 with Rainbow Interferometer

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Judith A. IRWIN
(Department of Physics, Queen's University)

We have performed high-resolution ($\sim$ 1") aperture synthesis observations of the ^{12}CO(J=1−0) line emission from a radio lobe galaxy NGC 3079 using the Rainbow interferometer (Nobeyama Millimeter Array+the 45m Telescope). The CO distribution of NGC 3079 shows [1] nuclear molecular disk (NMD) of about $3\times10^9\ M_\odot$ in 750 pc radius. [2] spiral arm structure on the NMD, [3] ultra-high-density core (UHC) of about $3\times10^8\ M_\odot$ in 150 pc radius. The UHC is an order of magnitude more massive than that in the same area of the Galactic center, and the mean density is as high as $\sim 3\times10^3$ H_2 cm^{-3}. A position-velocity diagram along the major axis indicates that the rotation curve already starts at a finite velocity exceeding 300 km s^{-1} at least in the resolution $\sim$ 150 pc. The dynamical mass within 150 pc radius is then estimated to be $M_{\rm dyn}=V_{\rm rot}^2\ R/G\sim 2\times10^9\ M_\odot$, assuming pure circular rotation of the UHC. The UHC is trapped in that deep potential of the galactic center.

We consider the reason why the UHC could have survived in the gas phase without suffering from current star formation. The Jeans time in the UHC is an the order of $t_J\sim 10^6$ yr. On the other hand, the dynamical timescale for a cloud to be torn off by the Coriolis force and differential rotation is $t_D\sim dV/dR-\omega\sim 2.5\times10^5$ yr (V, R and ω are the rotation velocity, radius and angular velocity). $t_J > t_D$ may indicate that clouds cannot collapse to form stars, but are kept gravitationally stable and stretched azimuthally along the orbits by the rapid differential rotation due to the deep potential.

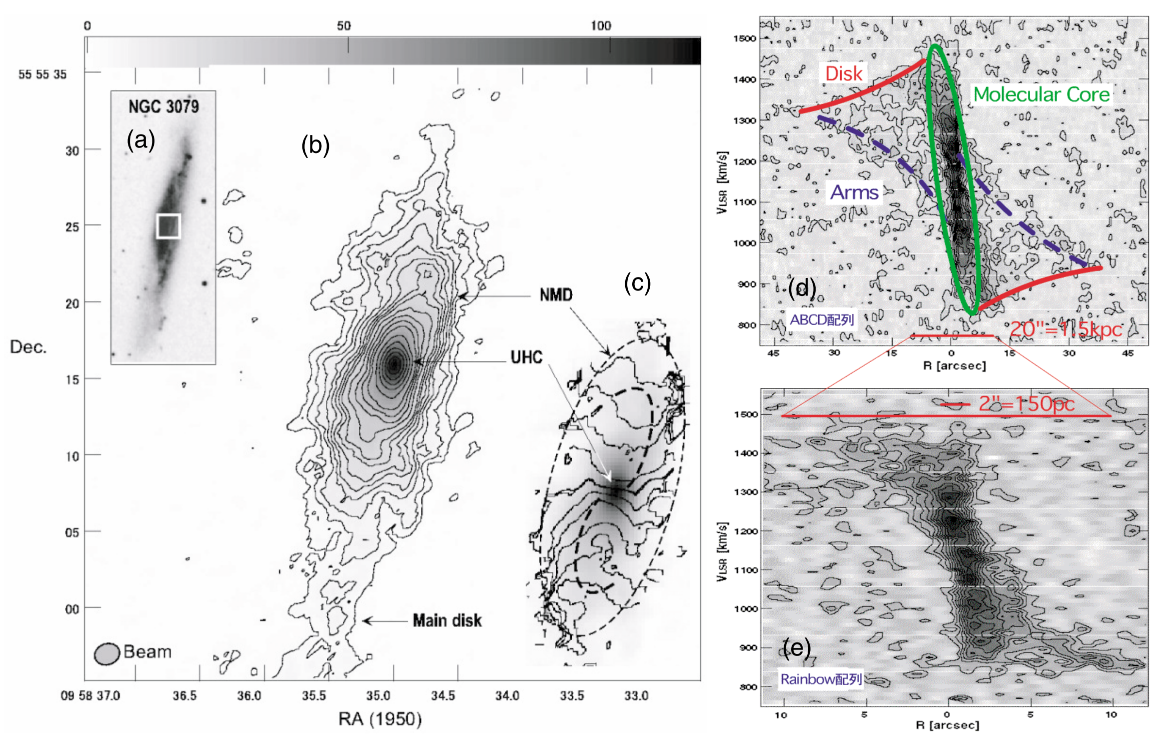

Fig.1. (a) Optical image of NGC3079, (b) CO(J=1−0) integrated intensity map, (c) CO mean velocity field. (d) Position-velocity diagram from Nobeyama Millimeter Array, (e) Position-velocity diagram from Rainbow Array.

First Fringe at Submillimeter Wavelengths (350 GHz band) using the Nobeyama Millimeter Array

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Seiichi SAKAMOTO, Ryohei KAWABE
(ALMA Project Office, NAOJ)

We develop an experimental interferometer system at submillimeter wavelengths (350 GHz band), which consists of three antennas of the Nobeyama Millimeter Array (NMA). Here we report the detection of the first fringe at 350 GHz using two elements of the NMA which were equipped with 350 GHz SIS receivers.

The mixer of each 350 GHz receiver is the parallel-connected twin junction (PCTJ), developed at Nobeyama Radio Observatory. The LO source was composed of a frequency tripler and a Gunn oscillator at 110 GHz band. The LO signal was coupled with the RF (350 GHz band) signal using a free standing tungsten wire grid with a diameter of 20 μm and a pitch of 80 μm. The receiver noise temperatures measured with the hot − cold method using LN_2 were not good (Y-factor was about 2 dB in DSB), but we will improve the performance of the receivers soon by fixing some problems, which are mainly located on receiver optics. IF signal at 4.5 − 7 GHz band is transformed to optical signal and transmitted to the interferometer building where A/D and spectro-correlator system is placed.

We installed the 350 GHz receivers to the antennas from December 26 to December 28, 2000. Each dewar of the NMA has three receiver ports (100, 150, and 230 GHz bands). We removed a 150 GHz receiver, and then a 350 GHz receiver was installed there. We substituted a wide band receiver covering a frequency range of 86 − 150 GHz developed by Iwashita et al. for the existing 100 GHz receiver in order to make 150 GHz band observations as well. Using the 345 GHz receivers, we observed the Moon, Mercury, and Jupiter to adjust a focus of the optics and pointing offset. Then we made interferometric observations of the Jupiter and successfully obtained the first fringe at submillimeter wavelengths from the Jupiter. The baseline length was 47 m, and the zenith opacity at 350 GHz band was about 0.7 during the observations. The aperture efficiency of the two 10 m antennas (antenna D and F) were about 10〜15% determined from single dish observations of the Jupiter. We will try to make aperture synthesis observations at 350 GHz band using three elements of the NMA in the coming observing season. The performance of the NMA at 350 GHz band will also improved by fixing the problem at 350 GHz receivers and adjusting the main reflector panels with holographic measurements.

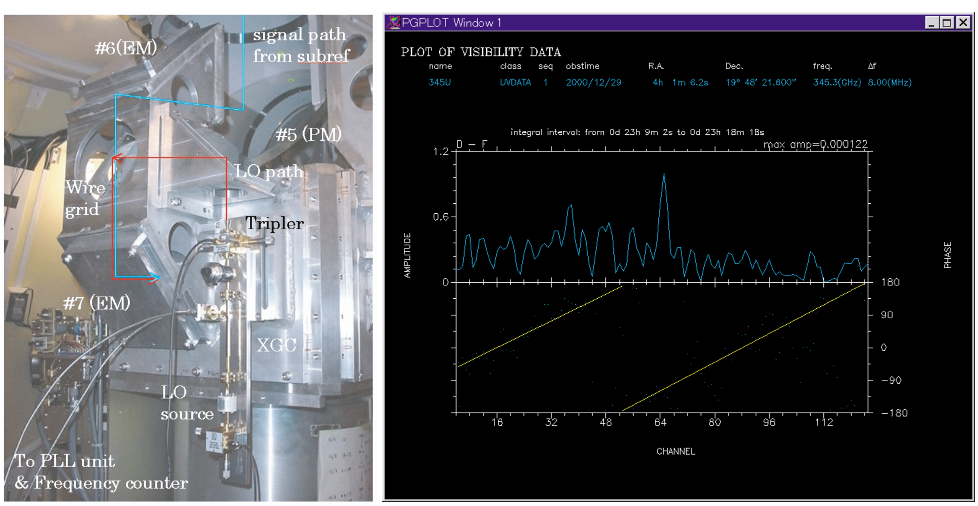

Fig.1. Left: The 350 GHz receiver system installed in the receiver cabin of the antenna F. Right: The first fringe at 350 GHz band obtained with the interferometric observations of the Jupiter. The upper panel shows the visibility amplitude (arbitrary unit), and the lower panel shows the visibility phase (from −180° to +180°) as a function of the channel number (or frequency).

Analysis of short period variations of Doppler frequency caused by the spin of Mars spacecraft, NOZOMI

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Integrated Doppler tracking measurement of a satellite around the moon or a planet is one of the major methods to estimate the gravity field of the Moon or a planet. SELENE is a Japanese lunar mission which has been planned for launching in 2004. A global coverage of Doppler measurements of satellites of SELENE with the precision of 0.1mm/s of range rate (1mHz of Doppler frequency at S-band) with every 10 second integration will ensure to improve the lunar gravity model. In Doppler tracking measurements for a spin-stabilized satellite, the nonlinear phase characteristics of the satellite-borne receiving/transmitting antenna should introduce the oscillating errors into Doppler frequency data, and into the range rate measurements [1]. In order to identify this phenomenon in the actual tracking data, and to study the methods for removing these effects, we analyzed the integrated Doppler frequency data of a spin-stabilized satellite, NOZOMI observed at the Kagoshima space center. After a removal of long period variations caused by oribiting of NOZOMI, the effects of phase characteristics of the antenna on the Doppler frequency has been identified (Fig. 1). A method to remove above effects is proposed. By using the method, the effects can be removed (Fig. 2). In these analyses, a condition for spin period of satellite has also been found to remove the above effect [2].

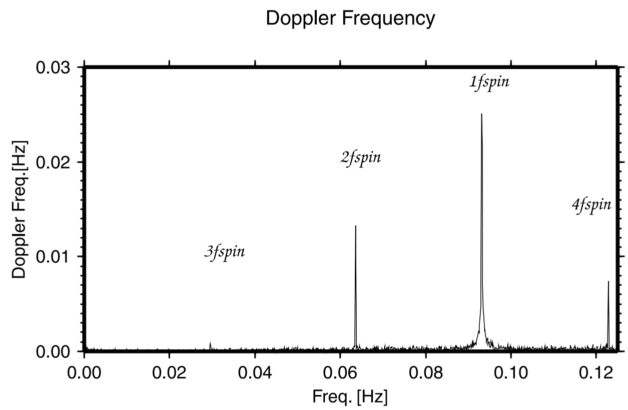

Fig.1. Spectrum of residual of Doppler frequency after subtracted by 5-order polynonials. We detect the four peaks in this specturm.

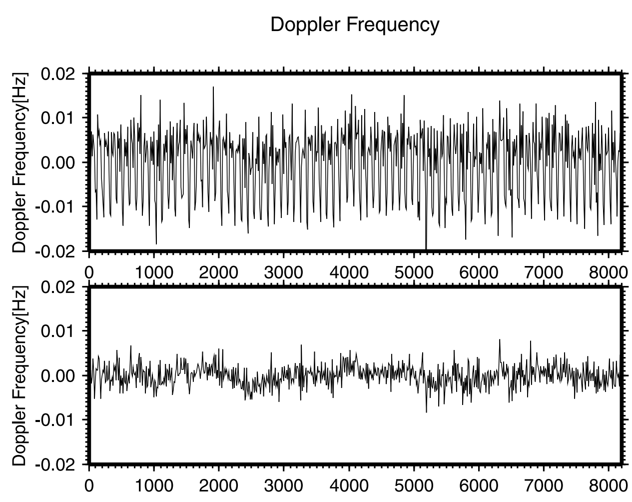

Fig.2. The Doppler frequency variations converted to 12 second sampling data. Upper figure: before filtering, Lower figure:after filtering

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An Origin of "Turbulence" in Interstellar Clouds

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The propagation of a shock wave into an interstellar medium is investigated by two-dimensional numerical hydrodynamic calculation with cooling and thermal conduction. We present results from the first high resolution two-dimensional calculations ever to follow the fragmentation due to thermal instability in shock-compressed layer. We use realistic thermal conduction coefficient to resolve "Field length" that is the critical wavelength for thermal instability.

We find that geometrically thin cooling layer behind the shock front fragments into small cloudlets. The cold clumps have considerable translational velocity dispersion. The typical velocity dispersion is about several km/s. The linear analysis predicts that perturbation with sufficiently long wavelength grows exponentially. However, the velocity of the non-linearly developed perturbation has the upper limit that is the sound speed of the warmer medium (≈10km/s), because the driving force of the instability is the pressure of the less dense warmer medium. This non-linearly developed perturbation produces the translational velocities of the cold clumps. These velocity on the order of the sound speed of the WNM is highly supersonic with respect to the sound speed of cold gas. Thus we can understand why the supersonic velocity dispersion of the cold medium is comparable to the sound speed of the WNM.

From these results we demonstrate that the role of thermal instability behind the shock front is one of the most important processes in the evolution of interstellar shocked layers.

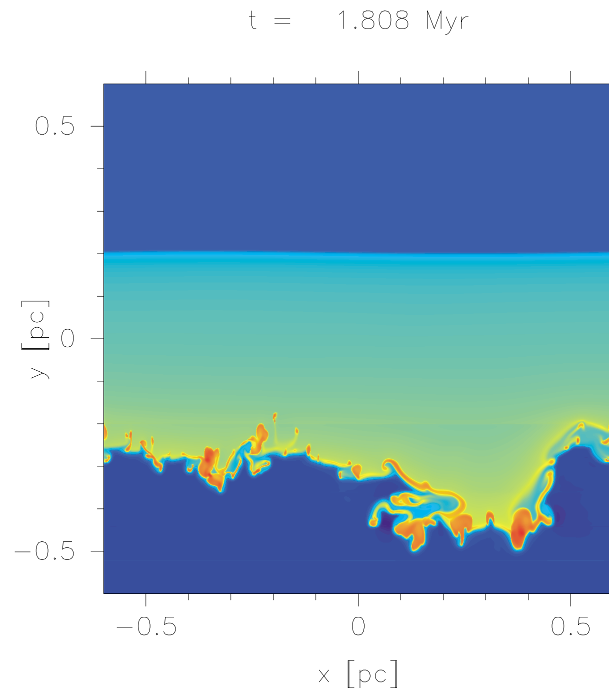

Fig.1. Density distribution of the shock-compressed layers. The panel shows the calculation at t =1.808 Myr.

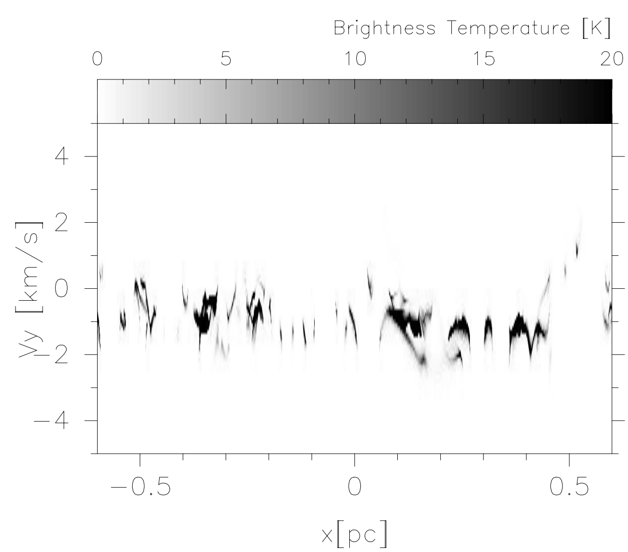

Fig.2. The panel shows the position-velocity (P-V) diagram of the ^{12}CO J=1−0 emission obtained from the calculation at t =1.808 Myr (see Figure 1). We assume 5.8 % of the carbon is CO.

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Molecular Superbubble around Intermediate Mass Black Hole in M82

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M82 is known as one of the nearest starburst galaxies. It is bright in all the wavelengths and has been studied by many authors, and therefore it is suitable for the case study of starburst phenomena. The recent upgrades of the antenna mirrors, receivers, and correlators for the Nobeyama Millimeter Array make us possible to observe M82 with five times higher sensitivity than the past observations. The newly obtained ^{12}CO(1−0) image shows diffuse spurs spread toward the minor axis direction of the galaxy, in addition to the previously identified three prominent peaks (Fig.1a). These spurs trace the optical dark filaments, and maybe connected to the kpc-scale outflows which can be seen in many wavelengths. We have also successfully imaged an expanding molecular superbubble, which is about 140 pc offset from the nucleus and has a radius of about 100 pc. The dynamics of the molecular gas superbubble is very similar to those of atomic gas superbubbles in other galaxies. The energy of the molecular gas superbubble is, however, about 10^{55} erg (corresponds to 10^3-10^4 supernovae), an order of magnitude or more larger than those of the atomic gas superbubbles.

On the other hand, the high-resolution X-ray observations with Chandra revealed that there is an intermediate/high mass ($>700\ M_\odot$) black hole (BH) located inside the superbubble. In addition, there is also a 2.2 μm secondary peak (a star cluster dominated by red supergiants. Primary peak corresponds to the nucleus), and therefore it seems reasonable to suppose that these objects are related each other (Fig.1b). Hence, we will discuss the possibility that the starburst at the star cluster produces the superbubble and the BH. We first calculated the stellar population of this cluster with considering an initial mass function and the age of the superbubble, and the result suggests that a large number of supernova explosions which are enough to make the superbubble had occurred in the cluster. Furthermore, if we assume that the density distribution of the cluster is similar to that of a globular cluster, it maybe possible to form a $10^2-10^3\ M_\odot$ black hole with stellar-stellar or BH-BH mergers at the very center of the cluster. Hence, this BH should have an intermediate mass between stellar mass BHs and supermassive BHs.

Since this intermediate mass BH is located offset from the dynamical center, it may sink down to the nucleus with dynamical friction. There is a vast amount of matter toward the nucleus, so it is possible to feed matter to this BH, and thus it will grow to be a supermassive BH. Many authors have discussed the relationships between starbursts and AGNs in the past. Recent HST quasar host images show that some of the quasars are embedded in interacting (and therefore active star forming) galaxies. Our results may suggest that starburst phenomena are closely related to the formation of supermassive BHs, which power the quasars and AGNs.

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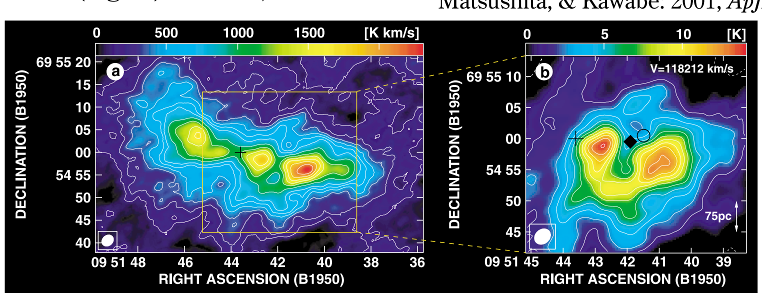

Fig.1. (a) ^{12}CO (J = 1−0) integrated intensity image of the central region of M82 (The contour levels are 5, 10, 15, 20, 25, 30, 40, 50, ・・・, 90 σ). The + mark indicates the galactic nucleus, and the synthesized beam is shown at the bottom-left corner. (b) ^{12}CO (J=1−0) superbubble image, which is made with binning over the velocity range of 118−212 km s^{-1}. The +, ◇, and ○ marks indicate the nucleus, the 2.2 μm secondary peak, and the intermediate mass black hole, respectively.

1.3–4.2 μm spectroscopy of dust in the Taurus dark cloud — Water ice distribution in molecular cloud —

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In molecular cloud, water ice is a key material for the investigation of dust properties such as chemistry and evolution of dust. Previous works have shown (1) water ice can survive inside the cloud because it is easily broken by the interstellar UV field at outside the cloud and (2) about 10% of atomic oxygen is consumed as water ice. The former varies cloud to cloud while the latter doesn't.

In order to investigate the water ice distribution in a molecular cloud, we have conducted near infrared spectroscopy of 61 background stars toward Heiles Cloud 2 in the Taurus molecular cloud complex (Murakawa et al. 2000). We used a low dispersion spectrometer, PASP2, which can simultaneously obtain the spectrum with a wavelength coverage between 1.3 and 4.2μm and produces a spectral resolution of $\lambda/\Delta\lambda \sim 40$. For 56 out of 61 objects, the visual extinction (Av) and the optical depth of water ice at $\lambda = 3.1\mu m$ (τ_{ICE}) have been estimated: for 50 out of 56 objects, these were systematically estimated from our data only. We have constructed a "water ice map" in which τ_{ICE} is plotted at the position of each object. The water ice map is then compared with the $C^{18}O$ (J=1−0) map obtained by millimeter observations (Sunada & Kitamura, 1998). We find that the distribution of water ice is closely correlated with that of $C^{18}O$. Strong water ice absorption is seen only toward the dense $C^{18}O$ clumps, while less water ice absorption is detected toward the outer region of the cloud. There is an Av threshold for the positive ice detection (A_{V0}), as suggested by previous observations, but with a significant scatter; $A_{V0}=2-5$ mag. The scatter might be caused by the different contribution of the inner water-containing portion of the cloud along the line of sight. The value of τ_{ICE} increases with increasing of Av and the slope of $\Delta\tau_{ICE}/\Delta A_V$ is 0.067, consistent with the previously observed values for the Taurus molecular cloud.

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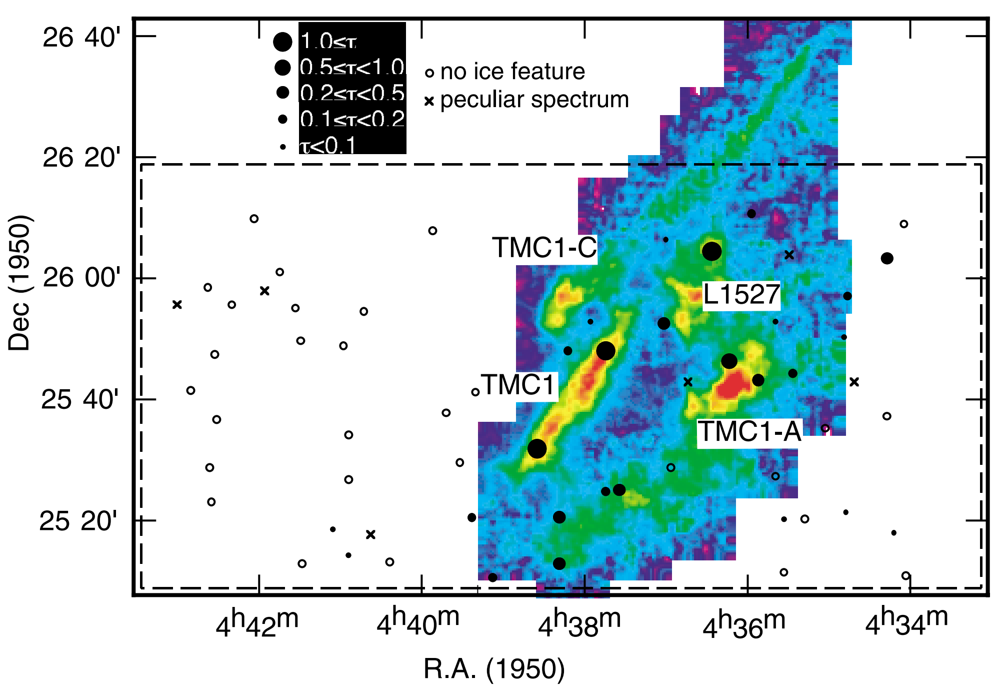

Fig.1. Water ice map overlaid on $C^{18}O$ map. The $C^{18}O$ map was from sunada & Kitamura (1998). Both filled and open circles shows the position of observed field star and the diameter of filled circles is proportional to the value of τ_{ICE}. The large dashed-line rectangle is the surveyed region.

Magnetic Separatrix and Loop Heating in the Solar Corona

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The solar corona is made of magnetic loops. It is now believed that the high temperature (typically 2×10^6 K) of the corona is due to magnetic fields. The corona is generally hotter and denser where the magnetic field is stronger. However, in high-field regions, some field lines show up as bright loops and other field lines do not. This means that the heating depends not only on the field strength but also on some additional factors.

We studied the coronal loops observed by the soft X-ray telescope of Yohkoh and the surface magnetic fields observed with the Solar Flare Telescope at Mitaka. We paid attention to the so-called ‘separatrix’ of field lines. The separatrix divides field lines into groups and each group shares the same connectivity of field lines.

We found that the field lines lying in the separatrix generally show up as bright loops. Field lines situated near the separatrix, starting from two nearby points, tend to separate far apart at the end of the field lines. This means that the fluid motions at two distant points (which are necessarily uncorrelated) are mapped to two nearby points, and a discontinuity may be created across the field lines. The fact that the field lines in the separatrix are heated indicates that a discontinuity in the field, namely a current sheet, may be a key ingredient in heating the coronal loops.

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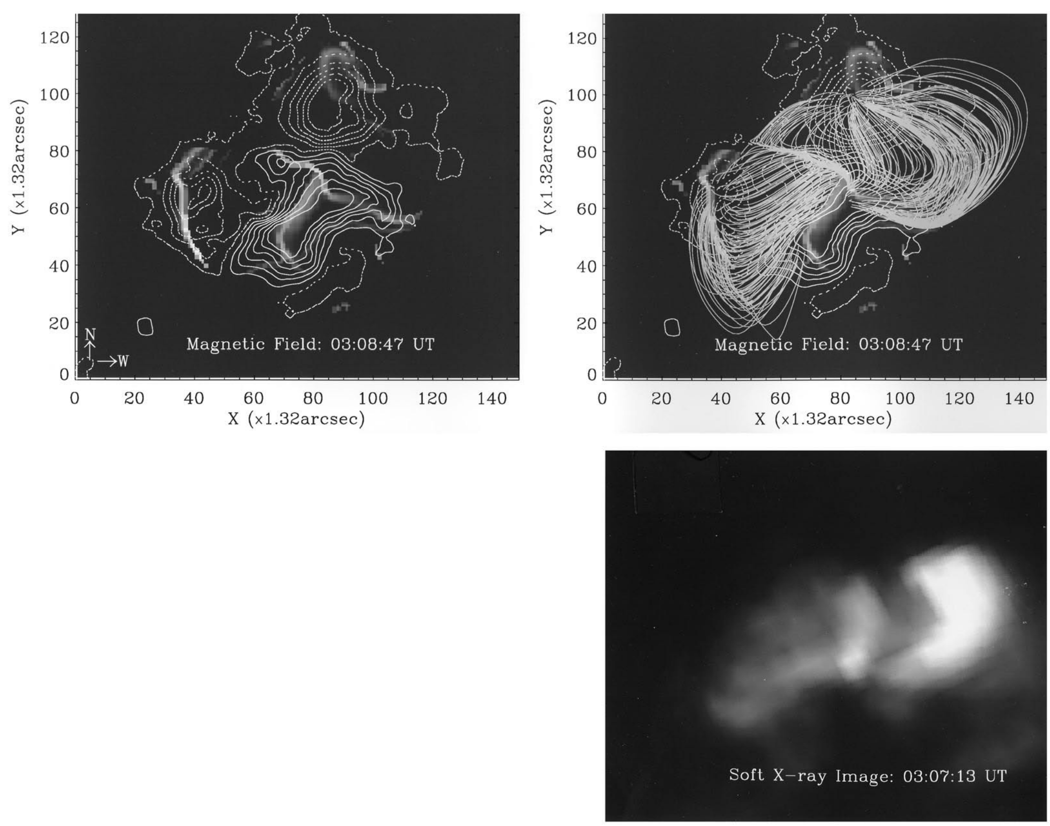

Fig. 1. Top left: The cross-section of the separatrix at the solar surface in gray scale. Contours indicate the line-of-sight component of magnetic fields (solid=positive, dotted=negative polarities). Top right: Field lines starting from the separatrix. The overall shape of the volume filled with those field lines matches the shape of coronal X-ray loops (bottom right).

Importance of Magnetic Shear in Flare Activity Inferred from Vector Magnetograph Observations

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Solar flares are caused by excess magnetic energy, or magnetic shear, stored in the corona. Although currently we can measure the magnetic fields only at the solar surface (photosphere), a sheared state of the coronal field will reflect itself in the measured surface field configuration. Therefore we expect that the shear will develop before a flare, and it will be reduced after the flare. There were in fact such ideal examples, but there were also contradictory examples.

We studied eight flare events observed with the Solar Flare Telescope at Mitaka. The instrument measures the magnetic field vector at the photosphere. We found that, five among eight events did not show significant decrease in magnetic shear. In these flares, the shear in the flaring regions was moderate, and the regions were accompanied with vigorous emergence of magnetic flux. Under such circumstances, the emerging flux brings not only the energy but also disturbances to the system and destabilizes the magnetic configuration. Therefore, the region ignites a flare before significant shear is stored.

On the other hand, the remaining three flares were characterized by very high shear, and after the flare the shear clearly decreased. In this latter class of flares, somehow the emerging flux activity was low, and the magnetic configuration could reach a critical state with high magnetic shear.

The ratio of flares with 'moderate shear' and 'high shear' was five to three in the present study. We need more data to further quantify the characteristics of flares and magnetic shear.

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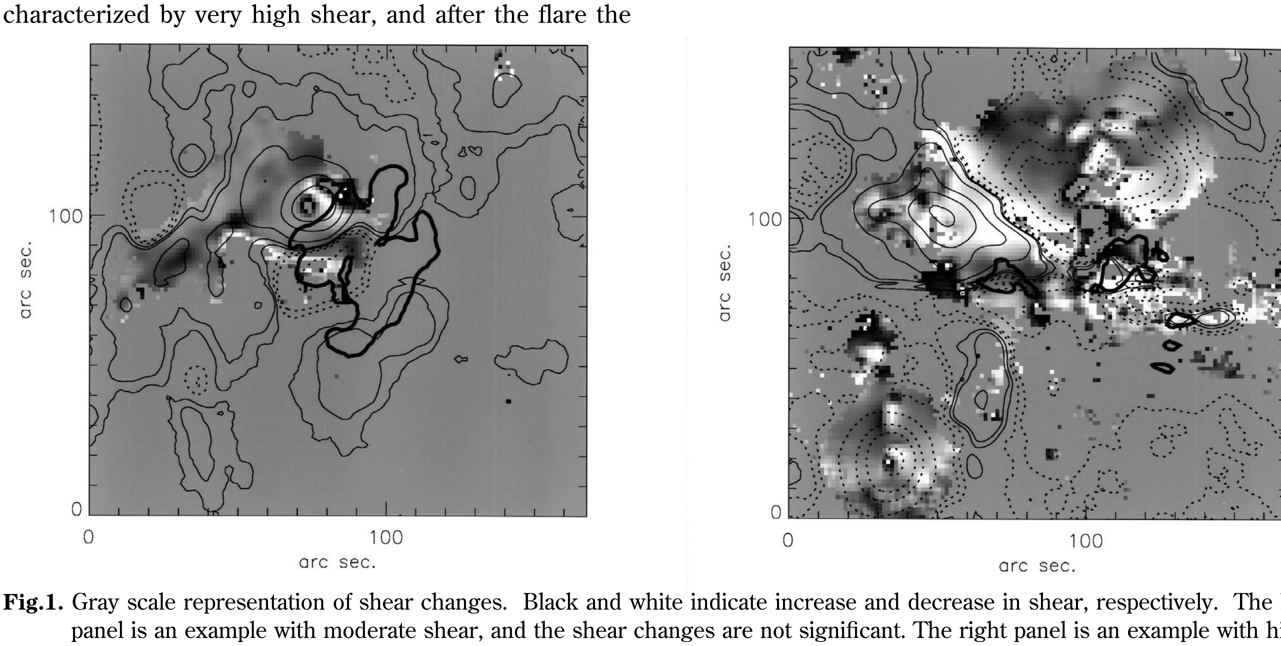

Fig.1. Gray scale representation of shear changes. Black and white indicate increase and decrease in shear, respectively. The left panel is an example with moderate shear, and the shear changes are not significant. The right panel is an example with high shear, and definite shear decrease was detected. Contours indicate the line-of-sight component of magnetic fields (solid＝positive, dotted＝negative polarities), and thick contours show the location of the flare activity.

Precise Lunar Limb Profile Data Obtained from Video Observations of Lunar Occultations

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Until a few decades ago, lunar occultations were used to investigate the lunar motion, the Earth's rotation (ET − UT), and positions of isolated islands, but now they can be investigated much more precisely from modern technique, such as lunar laser ranging, satellite laser ranging, VLBI, atomic clocks, etc. The current value of lunar occultation observations can be summarized as follows:

1. To provide limb profile data of the Moon. The lunar topographic features were observed by the Clementine lunar mapping mission in 1994, but the Clementine laser altimeter data are too sparse to replace Watts' (1963) limb profile charts, and the Clementine data are not very accurate (about 50 m at best). Combining the limb profile data from lunar occultations and the solar eclipse observations, we can detect the solar diameter variation.
2. To detect the errors of the proper motion system of the Hipparcos Catalogue. The Hipparcos Catalogue was released in 1997 and the Hipparcos team claims that the Hipparcos reference frame is linked to the ICRS (International Celestial Reference System) with the accuracy of 0.6 mas (milliarcsecond) in orientation and 0.25 mas/year in spin. But the direct comparison of the proper motions between Hipparcos and FK5 gave inconsistent results with the precession error of about −3 mas/year of FK5. Therefore it is possible that the proper motion system of the Hipparcos frame has considerable errors. Since the lunar & planetary ephemeris of JPL of the U.S.A. (the latest one is DE405/LE405) is already on ICRS within 1 mas, the problem will be resolved by analyzing lunar occultations using the Hipparcos Catalogue and the DE405/LE405 ephemeris.

Observations of total occultations are especially useful if they are observed by video because video observations have no personal equations. Occultations of the first magnitude stars can be observed easily by camcorders without telescopes or binoculars. One video observation of lunar occultation with a 30 ms accuracy gives the height of the lunar limb features with the accuracy of about 30 m, which is more accurate than the laser altimeter observations by Clementine.

Occultations of the first magnitude stars Aldebaran and Regulus occurred in 1998 and 1999. We had a campaign of video observations of them all over Japan. In total we obtained 74 contacts of the occultations. Each of the observed limb data has an accuracy of about $\pm 0''.015$. It should be emphasized that the mountains and valleys near Watts Angle of 115°, which had not been shown in Watts' charts, were newly detected from the Aldebaran occultation of 1999 Feb.23, as shown in Fig. 1

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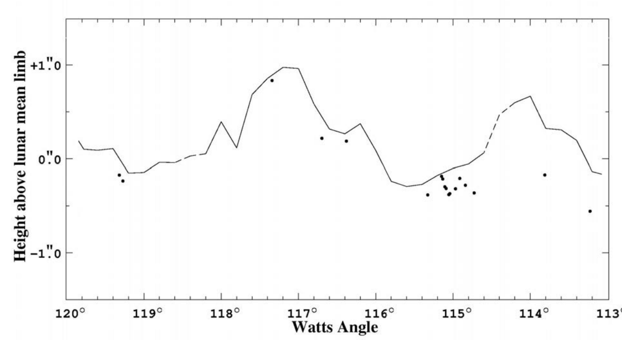

Fig. 1. Sample of the obtained lunar limb profile data. The dots represent the obtained data, while the solid line shows limb features from Watts' charts. The lunar librations at the time were $l = +1°.51$, $b = +6°.81$.

Observations of Ammonia in External Galaxies. II. Maffei 2

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The ammonia (J, K) = (1,1), (2,2), (3,3), and (4,4) transitions in the 23.7−24.1 GHz region were searched in a nearby galaxy, Maffei 2, to study the relation between the molecular abundances and the physical conditions in galaxies. The observations were carried out with the 45 m radio telescope at Nobeyama Radio Observatory. The (1,1), (2,2), and (3,3) emission lines were clearly detected. However, the (4,4) line is only marginally detected. The net integration time toward the source was about 32 hours. The obtained rotational temperatures and ortho-to-para abundance ratios are about 30 K and about 2.6, respectively.

The ratio is different from the statistical value of 1 (high-temperature limit), and it corresponds to the ratio at a temperature of about 13 K for distribution between ortho and para states. This low temperature cannot be realized, if ammonia is formed by gas-phase reactions. Thus ammonia formation is possibly related to grain. The abundance of ammonia relative to H_2 in Maffei 2 was obtained to be 1×10^{-7}; the largest abundance among galaxies where ammonia has already been detected, and the abundance in Maffei 2 is more than an order of magnitude larger than the already reported upper limit in M 82.

We have reported that molecular abundance in M 82 is systematically peculiar regarding the formation mechanisms of molecules (ref. 2, 3). Hence, in addition to this new result of ammonia in Maffei 2, we further confirmed this peculiarity in M 82.

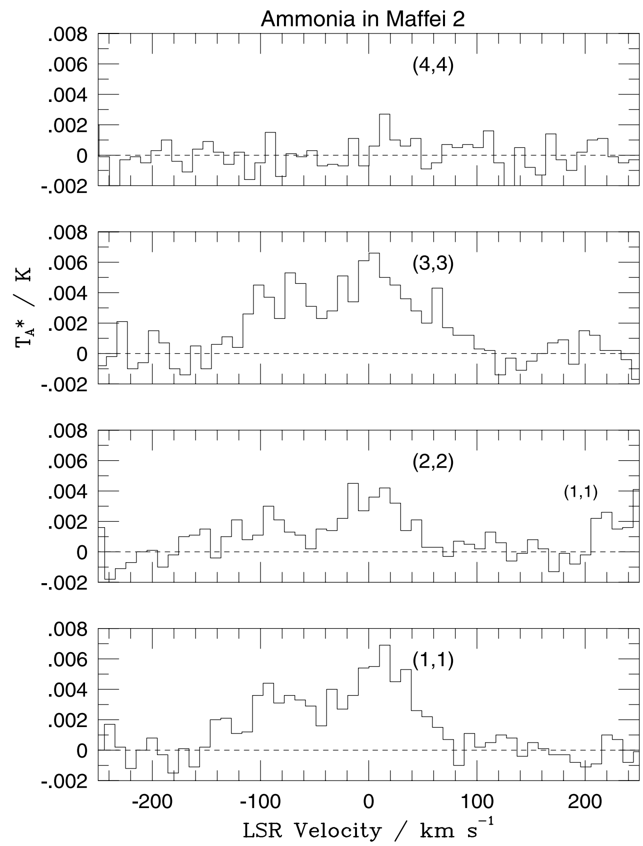

Fig.1. Ammonia spectra in Maffei 2. Frequnecy regions for the four transitions (J, K) = (1,1), (2,2), (3,3), and (4,4) were shown in velocity with respect to the local standard of rest. The ordinate corresponds to intensity of the emissions. The (1,1), (2,2), and (3,3) transitions are clearly detected. The lines show double peak structure at about 0 km s^{-1} and −100 km s^{-1} due to gas motion in this galaxy.

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Development of Photonic Local System for ALMA Type Receiver

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New technologies in optics and photonics are required in the giant radio telescope ALMA (Atacama Millimeter / Submillimeter Array) which is planned to be constructed at a 5000-m site in Chilean Andes. We are developing a photonic local oscillator with a UTC-PD (Uni-Traveling - Carrier Photo Diode) for the ALMA. A signal at millimeter and submillimeter wavelengths are produced with the UTC-PD by mixing two laser signals at different frequencies[1]. We have designed a W-band wave guide (75−110 GHz) photo mixer for the UTC-PD. The output signal from wave guide is shown in Fig-1. The output power is measured by use of a harmonic mixer and a spectrum analyzer(HP8563). The output power is as large as −1.5 dBm at 100 GHz that is highest power reported so for. The photo mixer shows wide frequency range. Frequency characteristics of the photomixer is shown in Fig-2. Change of the relative output power from wave guide is as small as 3dB for the frequency range of W-band.

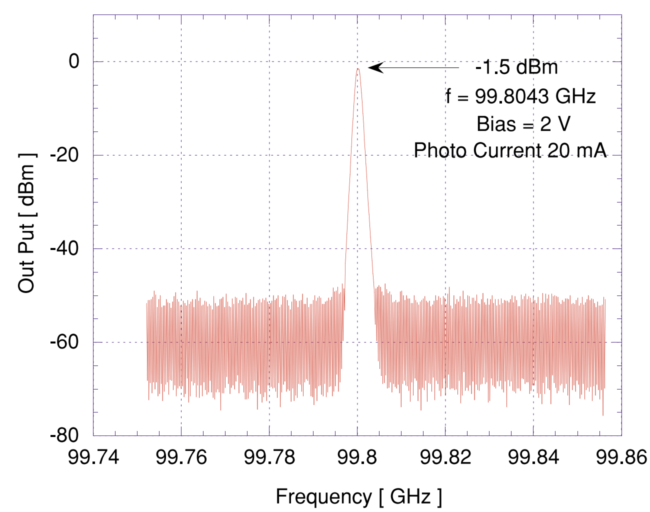

Fig.1. Output power of the photomixer. The output power is as large as −1.5 dBm from W-band wave guide.

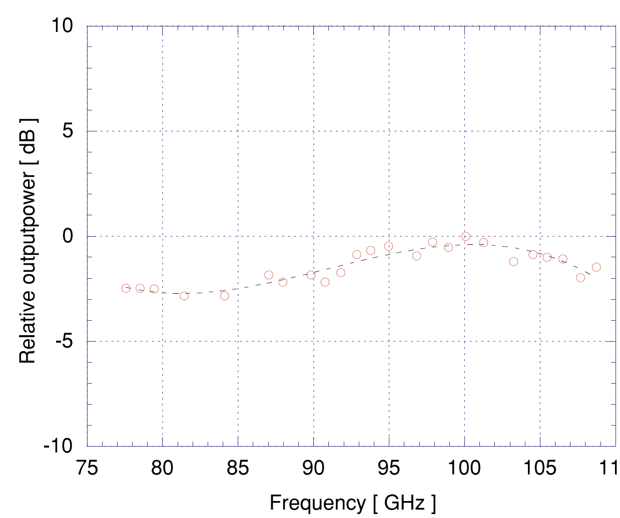

Fig.2. Frequency characteristics of the photomixer. Change of the relative output power is less than 3dB.

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Millimeter Continuum Image of the Circumstellar Disk around the Young Star Haro 6-5B

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Aperture synthesis observations of dust continuum emission at 2 mm from the class I object Haro 6-5B, made with the Nobeyama Millimeter Array, are presented. A disk like structure that coincides with the dark lane in the visible and near-infrared images is clearly resolved with a small synthesized beam of 1″.33×1″.21 with its position angle (P. A.) of 134°. The beam-deconvolved size of the disk is 2″.33×0″.97 at P. A. = 138°, and the total flux density is 36.7±2.6 mJy. The radius and inclination angle of the disk derived from the image are 309±18 AU and 67±5°, respectively. By model fitting of the spectral energy distribution of Haro 6-5B with theses values, the power-law index of the dust opacity, β, is derived to be 1.05±0.04 and the disk mass is calculated to be 0.021 ± 0.002 $M_{\odot}$. No extended emission with 1000AU scale is detected, suggesting that the envelope around Haro 6-5B has been almost dissipated and that the object is a transient source from the protostar stage to the T Tauri stage.

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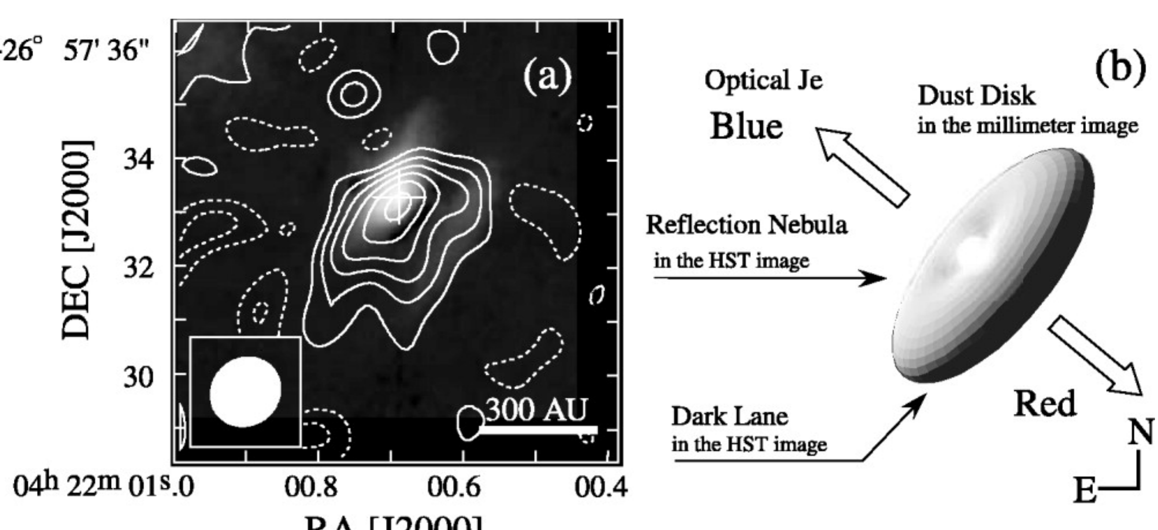

Fig.1. (a) Contour map of 2 mm continuum emission around Haro 6-5B with AB+D configurations of the NMA superposed on the NIR image in gray scale taken by the HST / NICMOS (Padgett et al. 1999). The white circle at the bottom left-hand corner is the synthesized beam. The contour intervals are 1 σ starting at ±1 σ (1 σ =2.6 mJy /beam). Negative contour are shown as dashed lines. (b) Schematic illustration of the circumstellar disk around Haro 6-5B.

Development of Multi-band Imaging Camera for the Japanese Asteroid Sample Return Mission MUSES-C

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The MUSES-C is the Japan-US joint asteroid sample return mission whose spacecraft is now under development by the ISAS. The launch is planned around the end of 2002 and the whole mission period till sample retrieval on Earth will be approximately five years. In this report we present current development status of our Asteroid Multi-band Imaging CAmera (AMICA) for the MUSES-C and relating sciences.

The MUSES-C target is the asteroid 1998SF36, one of the Amor-type asteroids. Since the size of the target is found to be much smaller (about 500m in diameter) than some asteroids so far measured by the US spacecraft (many kilometers in size), we may expect qualitatively different results (due to the low surface gravity) from those for the past US asteroid missions.

The AMICA is equipped with a cosmic-radiation-resistant CCD chip of MPP-type (1000×1000 pixels) whose dark noise is a few hundred times smaller than that for traditional non-MPP CCDs. The AMICA is characterized by that it adopts the ECAS standard filters; such an approach has never been attempted before. The ECAS is the multi-band photometric system specially designed for asteroid taxonomic classification (Tedesco et al. 1982), so that AMICA data in combination with inflight calibration using the ECAS standard stars will open up a way to compare the surface colors of the MUSES-C target directly with the abundant ECAS database which stores more than 700 asteroid data. The AMICA-obtained color map of the asteroid is also very important, to interpret how materials determined from laboratory analysis of returned samples distribute over the surface of the target asteroid.

AMICA has four position-angle glass polarizers. They are located on one edge of the CCD chip (200×200 pixels), immediately in front of it. The in-situ polarimetric observations are expected to provide optical property, size distribution of regolith particles on the asteroid surface. Other planned sciences are construction of shape and spin model for the asteroid, search for possible satellite(s), uninterrupted long-term lightcurve observations, and so on. Such a variety of AMICA sciences will allow us to infer the origin and subsequent evolution of the asteroid 1998SF36.

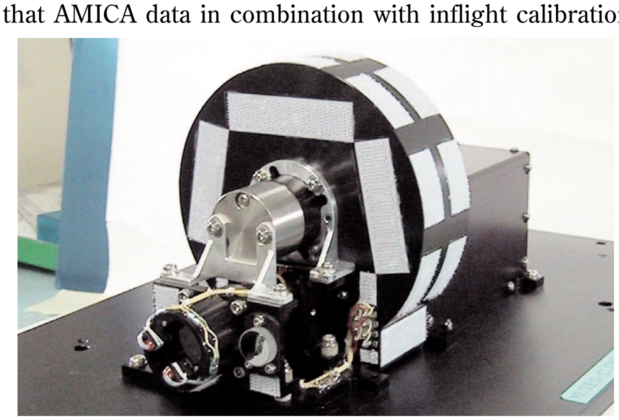

Fig.1. Photo of the AMICA proto-model assembly. The black tube in the lower front part is the refractor telescope. Two small protrusions are lamps for flat-fielding.

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Fig.2. Eight-position filter wheel and ECAS filters. Each filter is sector-shaped and placed closely side by side on the edges, so that this prevents us from becoming blind when the filter wheel stops by accident at an unexpected position.

First Subaru Observations of Sub-km Main Belt Asteroids

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Sub-km objects in the main asteroid belt had never been observed before due to their faintness, at least except for serendipitous detections. Recent advent of 8-10m gigantic telescopes with the wide field-of-view like Subaru, however, enabled us to access sub-km main belt asteroids (MBAs) systematically for the first time. The study of sub-km MBAs is very important mainly from the following two viewpoints: 1) the majority (nearly 70%) of near-Earth asteroids which are supposed to originate from the main asteroid belt are sub-km-sized, and 2) this size region lies near the border-line size separating the two catastrophic impact mechanisms, namely those in the strength regime and the gravity regime.

This is a report on the first attempt to obtain the size distribution of sub-km MBAs using Subaru images by means of a statistical analysis. We made observations of sub-km MBAs with the prime-focus mosaic CCD camera (Suprime-Cam) for the Subaru telescope. We have detected 27 moving objects in a single image of the sky (field of view: 27'×27'), whose location was 41 deg off opposition. From their positions and projected motions on the sky, all the detected objects were found to be new and consistent with the characteristic of MBAs. The V-magnitudes of the discovered asteroids range approximately from 19 to 24. Under some simple but reasonable assumptions, we estimated the cumulative size distribution for the asteroids. This is the first statistics for sub-km MBAs (the minimum diameter corresponds to about 0.6km). It is found that the slope of the cumulative size distribution for the observed asteroids is 1.0 with an error of about 0.3. We note that our slope is fairly smaller than that obtained in the past survey observations for asteroids larger than a few kilometers (about 1.75), implying considerable depletion of sub-km members among the MBAs probably due to formation of "rubble piles".

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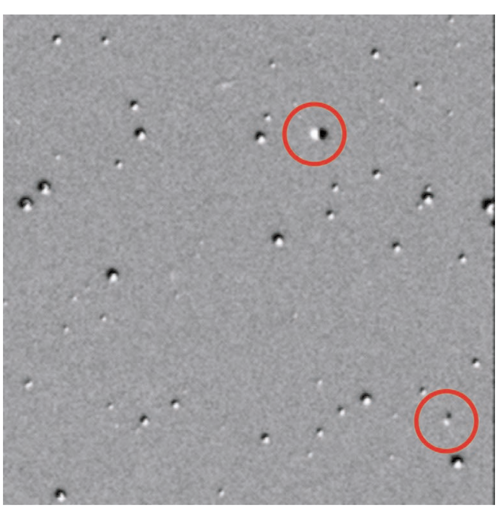

Fig.1. Two detected asteroids from the Subaru Suprime-cam observations. Moving objects appear as pairs of black-and-whites dots, since this image was produced by subtracting the second image from the first one.

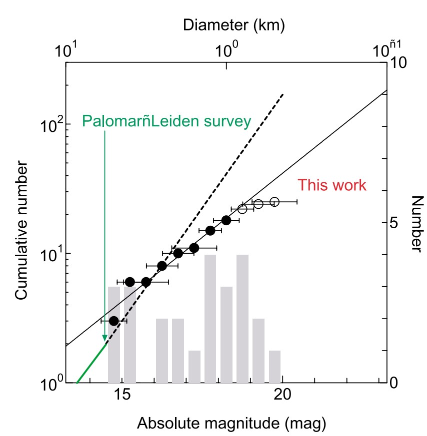

Fig.2. The differential (white-box histogram) and cumulative (black and white dots) *H*-mag distributions for our observed asteroids. The diameter (logarithmic) scale in the upper abscissa is calculated from an empirical relation: $\log D = 3.65 - 0.2H$. The solid line is least-squares-fitted to the black dot points. The dashed line is drawn only to represent the slope for the past systematic surveys (the Palomar-Leiden and Spacewatch).

VSOP Clarified Kinematics of the Quasar 3C 380's Jets

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The quasar 3C 380 at the redshift of 0.692 (distance of 6 billion light years) is known to be a strong radio source with relativistic jets, which show an apparent superluminal motion and a bent rigde line. VSOP observations, with a high spatial resolution of sub-milliarcsec, have potential to measure the motion of jet components precisely. By tracing the motions, we expect to clarify which causes the bending jet: interactions with external matterial or ballistic motions from a precessing nozzle. This is our aim to observe 3C 380 with the VSOP at λ 6 cm on July 4, 1998.

Figure 1 shows the radio image with a resolution of 0.74 $\times$0.36 mas, or 14$\times$6.8 light years. Components C1, C2, A, D, and F are identified along the jet emanating from component C. VSOP have resolved component C for the first time, whose size is 0.70$\times$0.21 milliarcsec. We derived the brightness temperature of $T_b = 4.1\times10^{11}$ K, which is attainable without any Doppler beaming effect. This suggests that component C is the stational core.

On the contrary, components C2, A, and F show constant apparent speed for more than a decade with respect to component C (see Fig. 2). These components also show constant position angles of the motion vectors, indicating ballistic expansion centered on the core. The apparent opening angle of the jet is 26°.8 between the ridge lines along C2 - A and D - F. Our results suggest that the nozzle direction changed at 60 to 40 years ago.

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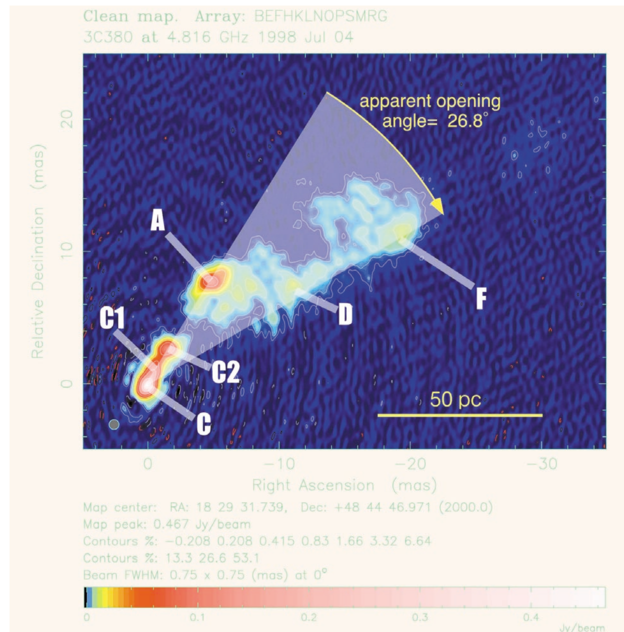

Fig. 1. A VSOP image of 3C 380 at λ6 cm.

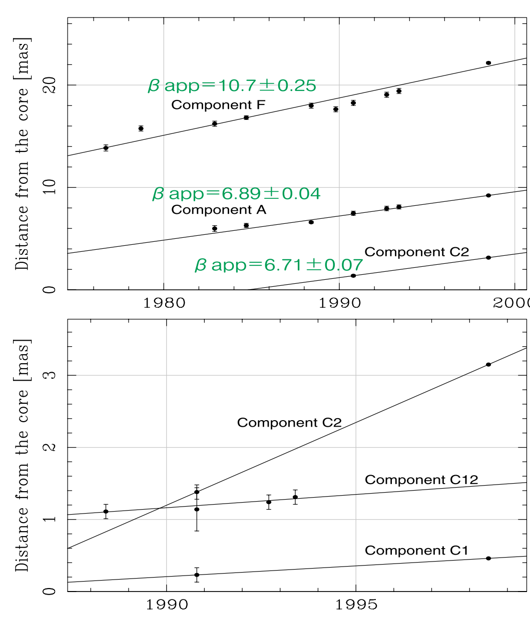

Fig. 2. Angular distances from the core versus observation epochs. Inclinations of the linear fit corresopond to the apparent velocities of 10.7, 6.89, and 6.71 times the speed of light for components F, A, and C2, respectively.

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Superclustering of Faint Galaxies and QSOs at z~1.1

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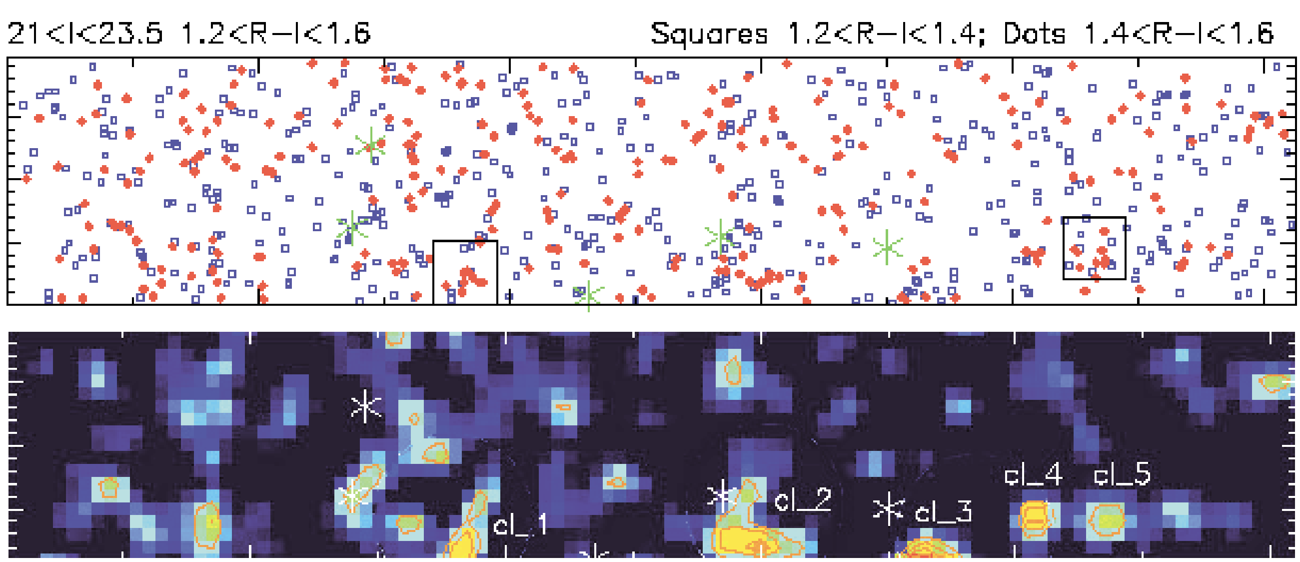
Supercluster is a loose aggregation of several clusters and groups, and is the recognizable largest scale structure in the Universe. Its total extent is typically several tens of Mpc to even ~200 Mpc. Such large-scale structures are not only valuable as the constraints for the cosmological models, but also important as the laboratory for studying how the formation and the growth of a cluster affect the evolution of galaxies in it.

In the Feb.1st issue of *the Astrophysical Journal* we have reported the detection of the signature of a supercluster at highest redshift ever known. The supercluster is detected through the analysis of our quite homogeneous data with the extent of nearly the twice of the full moon, and is apparently traced by the group of five QSOs at the redshift of $z=1.1$. For reference, most of currently known superclusters are at the local Universe; only a few superclusters are ever known at $z>0.5$.

The figures shown below show the detected signature of the supercluster in our observed area of 48'×9', which is taken at the Apache Point Observatory, U.S.A. From the raw catalog we extract the galaxies that show 1) very red color that are typical of the cluster galaxies, 2) consistent magnitude with galaxies at the redshift of the group of QSOs, and construct the density map of these galaxies. The upper panel is the position of galaxies that satisfy the above criteria. Red marks are more likely be the galaxies at the QSOs. The lower panel is its smoothed density-map expression. Yellow regions show more prominent excess. In both figures, the asterisks are the position of the QSOs. It is clearly seen that the clustering regions are mostly lie at the lower-half of the area, where four of five QSOs exist. Namely, the excess of QSOs is associated by the excess of galaxies whose colors and magnitudes are consistent with those at the QSO redshift. We have also confirmed this by angular correlation function analysis, and have shown that the clustering signal extends across the whole 48-arcmin-extent of the lower-half area. This scale corresponds to ~20 Mpc at the QSO redshift of $z=1.1$.

We already have taken the new data using the Subaru Telescope at the end of last March. The size of the new data is more than 6 times larger than the APO data. The data will enable us to figure out the most distant super-large scale (>60 Mpc) structure ever known at $z>1$, and also provide the sample of a number of clusters at $z>1$ that are essential for the study of the evolution of galaxies in cluster environment.



Constraints on Neutrino Degeneracy from BBN and the Cosmic Microwave Background

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We analyze the cosmological constraints on the existence of a net universal lepton asymmetry and neutrino degeneracy. We show that neutrinos can begin to decouple at higher temperatures than previous estimates due to several corrections which diminish the neutrino reaction rate. For sufficiently large degeneracy, neutrino decoupling can occur before various particles annihilate and even before the QCD phase transition. These decoupled neutrinos are therefore not heated as the particle degrees of freedom change. The resultant ratio of the relic neutrino-to-photon temperatures after $e^{\pm}$ annihilation can then be significantly reduced by more than a factor of two from that of the standard nondegenerate ratio. This changes the expansion rate and subsequent primordial nucleosynthesis, photon decoupling, and structure formation. In particular we analyze physically plausible lepton-asymmetric models with large ν_μ and ν_τ degeneracies together with a moderate ν_e degeneracy. We show that the nucleosynthesis by itself permits very large neutrino degeneracies $0 \leq \xi_\mu$, $\xi_\tau \leq 40$, $0 \leq \xi_e \leq 1.4$ together with large baryon densities $0.1 \leq \Omega_b h_{50}^2 \leq 1$ as long as some destruction of primordial lithium has occurred. We also show that structure formation and the power spectrum of the cosmic microwave background allows for the possibility of an $\Omega = 1$, $\Omega_\Lambda = 0.4$, cosmological model for which there is both significant lepton asymmetry ($|\xi_\mu| = |\xi_\tau| \approx 11$) and a relatively large baryon density ($\Omega_b h_{50}^2 \approx 0.2$).

We analyze the cosmological constraints on the existence of a net universal lepton asymmetry and neutrino degeneracy based upon the latest high resolution CMB sky maps from BOOMERANG, DASI, and MAXIMA-1. We compute likelihood functions for ($\Omega_b h^2$, Ω_Λ, h, n, $\xi_{\mu,\tau}$) in flat cosmological models with and without degenerate neutrinos. We adopt priors on the degeneracy parameters ξ_e, $\xi_{\mu,\tau} = \xi_\mu = \xi_\tau$ and $\Omega_b h^2$ based upon light-element constraints on promordial nucleosynthesis. We also adopt the prior of $h = 0.72 \pm 0.08$ from the Hubble Key Project results. Our neutrino-degenerate CMB models include a correction for that change in neutrino decoupling temperature with degeneracy. The marginalized likelihood functions show a slight preference for degeneracy parameters $\xi_{\mu,\tau} \approx 1 \pm 1$, $\xi_e \approx 0.1$, and $\Omega_b h^2 \approx 0.021$. This implies an upper limit on possible neutrino degeneracy of $\xi_{\mu,\tau} \leq 2$.

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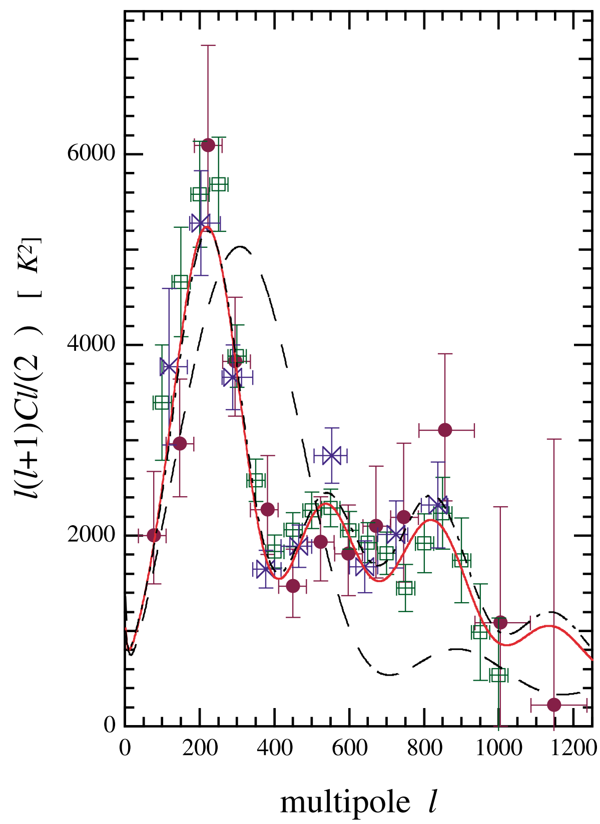

Fig.1. Power spectrum of fluctuations in the CMB for a best non-degenerate model ($\xi_{\mu,\tau}, \Omega_\Lambda$) = (0,0.7) [dot-dashed line] and optimum neutrino-degenerate models with ($\xi_{\mu,\tau}, \Omega_\Lambda$) = (2,0.7) [solid line], (11,0.4) [dotted line]

The R-Process in Supernovae

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We present calculations of r-process nucleosynthesis in neutrino-driven winds from the nascent neutron stars of core-collapse supernovae. A full dynamical reaction network for both the α-rich freezeout and the subsequent r-process is employed. The physical properties of the neutrino-heated ejecta are deduced from a general relativistic model in which spherical symmetry and steady flow are assumed.

In this study, we explore three specific models of the neutrino-driven winds based upon combinations of two parameters, the mass (M) and radius (R) of the neutron star: A) $(M, R) = (1.4\ M_\odot,\ 10\ \mathrm{km})$; B) $(M, R) = (1.4\ M_\odot,\ 7\mathrm{km})$; and C) $(M, R) = (2.0\ M_\odot,\ 10\mathrm{km})$. The difference between models A and B is the compaction ratio GM/c^2R, while neutron star mass is the same. On the other hand, effects of general relativity are manifest through the compaction ratio. Models B and C therefore involve different masses and radii, while the compaction ratio is the same.

Our results suggest that proto-neutron stars with a large compaction ratio (models B and C) provide the most robust physical conditions for the *r*-process. The third peak of the *r*-process is well reproduced in the winds from these "compact" proto-neutron stars even for a moderate entropy, $\sim 100-200\ N_A k$, and a neutrino luminosity as high as $\sim 10^{52}$ erg s^{-1}. This is due to the short dynamical timescale of material in the wind. As a result, the overproduction of nuclei with $A \lesssim 120$ is diminished (although some overproduction of nuclei with $A \approx 90$ is still evident). The abundances of the *r*-process elements per event is significantly higher than in previous studies. The total-integrated nucleosynthesis yields are in good agreement with the solar *r*-process abundance pattern. Our results have confirmed that the neutrino-driven wind scenario is still a promising site in which to form the solar *r*-process abundances.

However, our best results seem to imply both a rather soft neutron-star equation of state and a massive proto-neutron star which is difficult to achieve with standard core-collapse models. We propose that the most favorable conditions perhaps require that a massive supernova progenitor forms a massive proto-neutron star by accretion after a failed initial neutrino burst.

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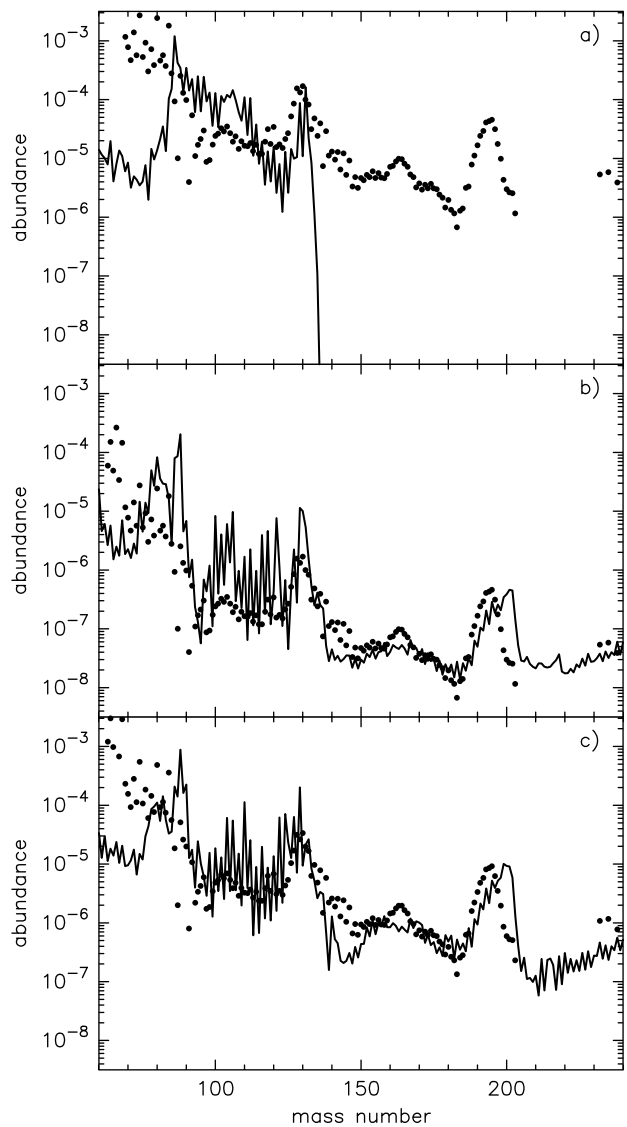

Fig. 1 The mass-weighted integrated yields for models A (a), B (b), and C (c) as functions of mass number (lines). Also denoted are the scaled solar r-abundances (points).

Abundances and Evolution of Lithium in the Galactic Halo and Disk

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Lithium is a valuable diagnostic of stellar and Galactic evolution. As the only metal synthesized in the big bang, 7Li provides a rare constraint on the baryon density of the universe. Secondly, it is destroyed inside stars, so its survival at the stellar surface indicates the degree of mixing via convection, diffusion and other processes. Thirdly, as a product of spallation and stellar sources, it provides a measure of the chemical evolution of the Galaxy.

In the quest for the primordial lithium abundance, observers have studied progressively more metal-poor stars, but had neglected those at [Fe/H] ~ -1.5, which formed later in the evolution of the Galaxy and reflect intermediate stages of its evolution. Therefore, we set out to observe and analyse a sample of more metal-rich ($-2 \lesssim$ [Fe/H] $\lesssim -1$) halo stars than had been targeted previously. We obtained new data on 14 stars which we combined with existing observations, and used this to examine the chemical evolution of the Galaxy as revealed by Li.

Our observations showed that the Galactic lithium abundance increased by a factor of two from the primordial level to the value found in the last halo stars to form at the end of the halo-building epoch ([Fe/H] $= -1.0$). We compared the observations with several GCE calculations including existing one-zone models and a new model developed by some of us in the framework of inhomogeneous evolution of the Galactic halo. We showed that Li evolved at a constant rate relative to iron throughout the halo and old-disk epochs, but during the formation of young-disk stars, the production of Li relative to iron increased significantly. These observations can be understood in the context of models in which post-primordial Li evolution during the halo and old-disk epochs is dominated by Galactic cosmic ray fusion and spallation reactions. However, the onset of more efficient Li production (relative to iron) in the young disk is a major challenge to the models. Although the onset of Li production in this epoch of Galactic history coincides with the appearance of Li from novae and AGB stars, the quantity of Li produced by models of these sources is currently inadequate to explain the observations. We have been led to speculate that cool-bottom processing (production) of Li in low-mass stars may provide an important late-appearing source of Li to explain those productions in the young disk.

One result emerging from the more successful modelling of the halo phase of evolution was the finding that several models could broadly fit the halo data, including the classical and the inhomogeneous models. However, the inhomogeneous models, the topic of much recent research by our group and others, predicts slightly different rates of evolution and a growing *range* in enrichment rates in different stars born at the same epochs. We will pursue improved Li observations to help break the degeneracy which exists in confronting current models with the data.

While none of these models presents a *perfect* fit to *all* epochs of Galactic evolution, the match between the models and data is sufficiently good to believe that current thinking provides viable descriptions of Galactic chemical evolution, albeit not uniquely so. The primary remaining challenge is to reproduce the efficient production of Li during late stages of disk evolution.

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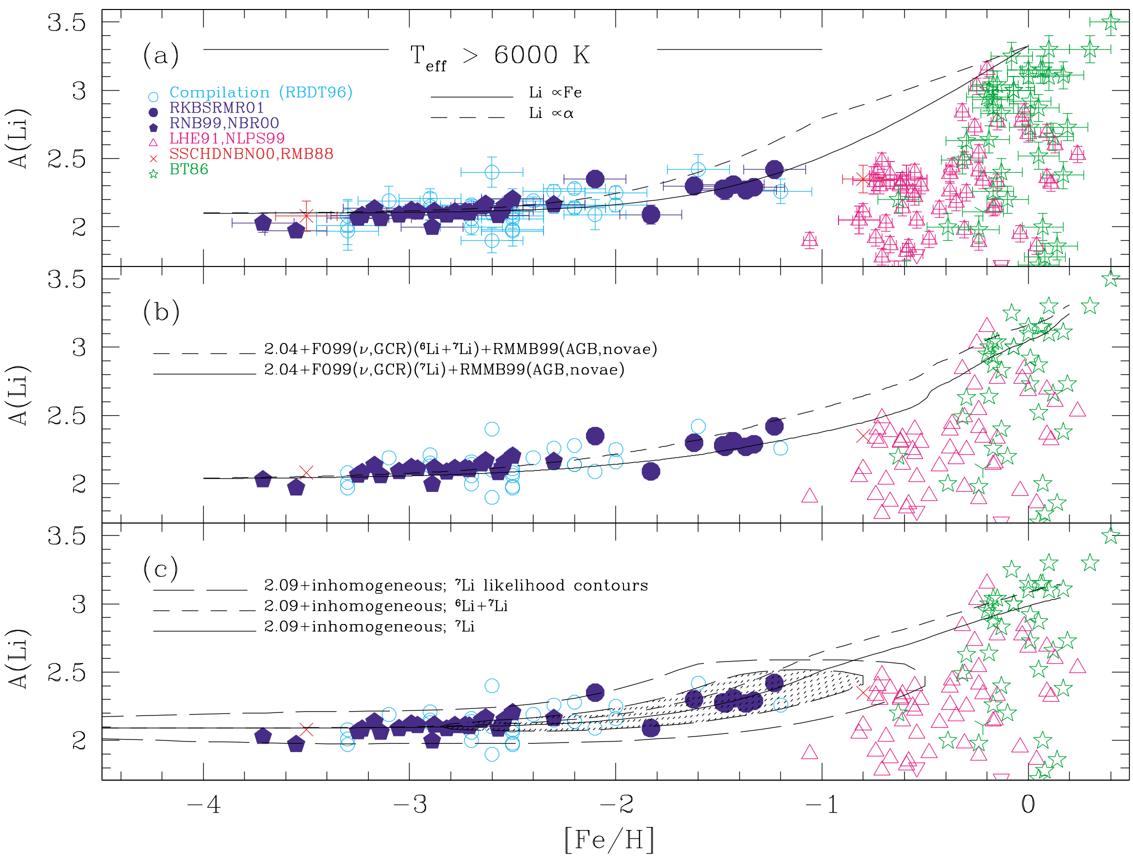

Fig.1. —Comparison of halo, old disk and young disk star observatios with theoretical models. (a) Simple two-component model. Solid curve: assumes Li production scales with iron; dashed curve: assumes Li production scales with the α-elements. (b) Hybrid model based on Primordial, GCR, and ν-process model of Fields & Olive (1999a,b; Ryan et al. 2000) plus the AGB star and novae contributions from Romano et al. (1999). Solid curve: ^{7}Li only; dashed curve: includes ^{6}Li. (c) Inhomogeneous model. The two longdashed contour lines, from the inside outwards, correspond to the (error-convolved) frequency distribution of long-lived stars of constant probability density 10^{-4} and 10^{-8} in unit area of $\Delta[\mathrm{Fe/H}]=0.1\times\Delta A(\mathrm{Li})=0.002$. (The inner contour is shaded for clarity.) Solid curve: evolution of the ^{7}Li gas abundance. Short-dashed curve: ^{6}Li+^{7}Li abundance.

II Publications, Presentations

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