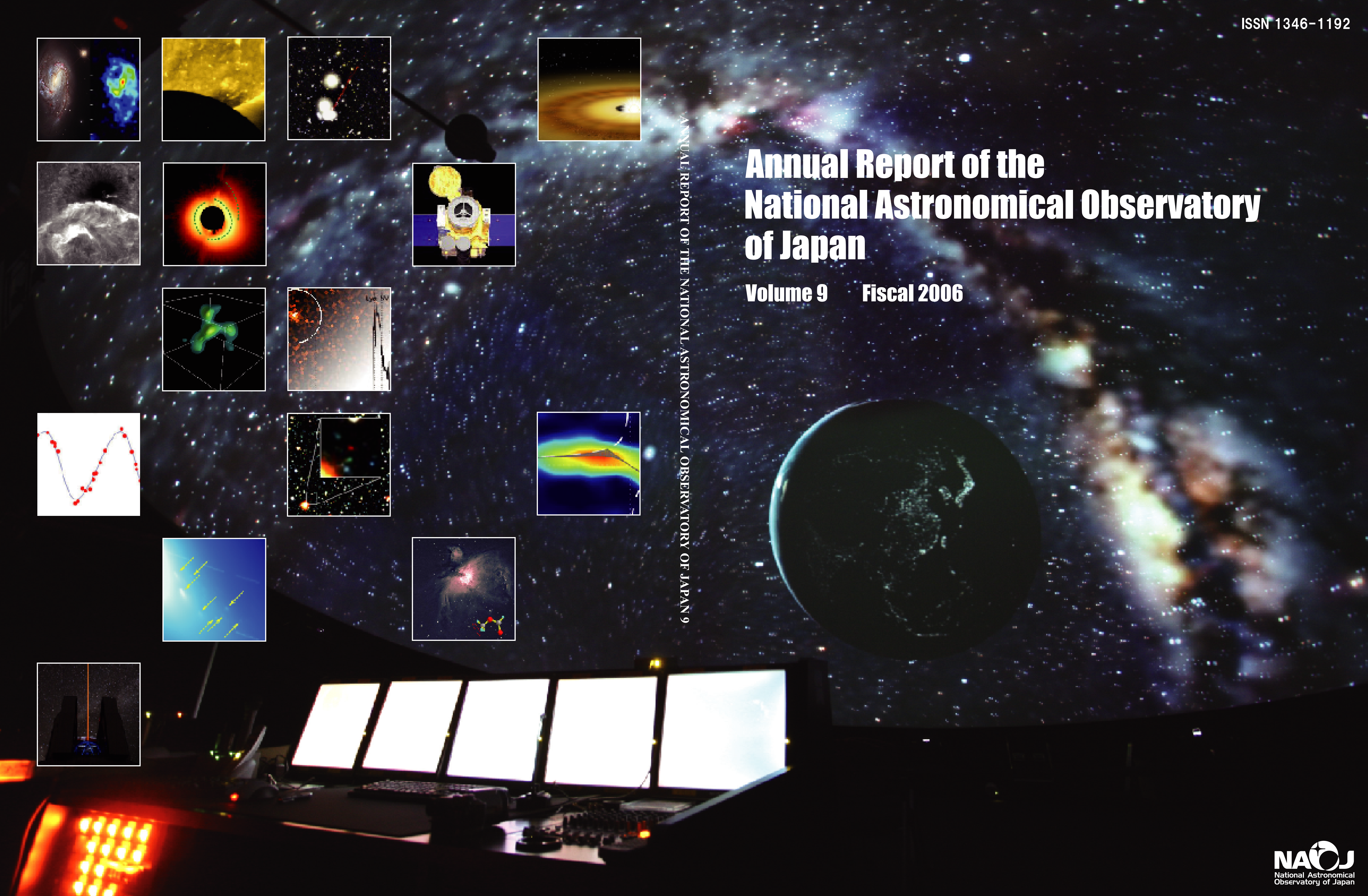

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ANNUAL REPORT OF THE NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN 9

NAOJ
National Astronomical
Observatory of Japan

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Preface — Shoken MIYAMA
Director General
National Astronomical Observatory of Japan

PREFACE

I am pleased to present the Annual Report of the National Astronomical Observatory of Japan (NAOJ) for fiscal 2006. This is the first annual report that I present as Director General of NAOJ.

Three years have passed since the national universities and inter-university research institutes were incorporated. This year, NAOJ had the second annual evaluation by the National University Corporation Evaluation Committee, and I think our activities were highly evaluated. From now on, we will make the most of the increased freedom given to the independent corporations and apply it for researches and activities as an inter-university research institute. For evaluations of each project and center, we organized the Planning and Reviewing Committee, in which external committee members are half of the members in number. We have utilized the feedbacks from the committee for the improvement of our activities.

Also, international evaluations were conducted for two “A projects” (projects in the early developmental stage), 4-Dimensional Digital Universe (4D2U) Project and MIRA Project, to judge the project activity level and discuss the continuance of these projects. The future vision of these projects will be defined next year based on the result of this international evaluation as well as the evaluation result presented by the Planning and Reviewing Committee.

As for the achievements in research field, the Subaru Telescope at NAOJ Hawaii Observatory has been continuously achieving many results, such as the success of the first measurement of the spatial distribution of dark matter in the universe, and the establishment of a new world record for the most distant galaxy observation. It is noteworthy that nine from the ten of most distant galaxies have been discovered by the Subaru Telescope. However, if we are content to the current achievements of the Subaru Telescope, we will soon lag behind other research institutes in the world. To avoid such situation, it is important to advance research and development (R&D) of new observation instruments. In 2006, as a part of our R&D efforts, a new adaptive optics AO188 was completed. In this new adaptive optics, wavefront compensation has been remarkably improved by increasing the number of segmented mirrors several times, and thereby near-diffraction-limit resolution has been achieved. Further development is expected by combining this with a newly-completed laser-guide star system which artificially creates reference objects for AO. Furthermore, we have also been developing HiCIAO, the successor to the current stellar coronagragh CIAO, and HiperSurprimeCam, the successor to the current wide-field imager SurprimeCam. We will continuously work hard on the equipment development for the Subaru Telescope.

In October 2006, we succeeded in launching the SOLAR-B satellite, which had been a long-held wish of astronomers involved in solar observation. This astronomical observation satellite named “HINODE” is successfully sending us brilliant initial images, and it has been confirmed that the optical telescope integrating the observation instrument for launch, which was assembled in the NAOJ Advanced Technology Center, is producing results as expected. The moving images of the Sun’s surface captured with unprecedentedly high angular resolution show us the activities on the Sun’s surface in great detail. By analyzing these images, a new picture of solar physics will be unveiled.

In addition to what has been mentioned above, many other results have been achieved such as: a creation of a radio map catalog of near-by galaxies using the multi-beam receiver at Nobeyama Radio Observatory; a discovery of a planet around a giant star by Okayama Astrophysical Observatory; and a success of distance measurement of a Galactic maser object by Mizusawa VERA Observatory. Further detailed observation, measurement of distance and proper motion of many maser sources are expected in future.

ALMA (Atacama Large Millimeter/submillimeter Array) Project, which is under construction in international cooperation, has entered the 3rd year in the 8-year plan. The construction of the antenna and development of the receiver and the correlator are about to enter the most important phase. The antennas are scheduled to be shipped to Chile in 2007, and their tentative assembly is now going on in Japan. As for the ALMA Board, the top decision-making body of ALMA, it was authorized that the number of delegates from NAOJ shall be increased from 1 to 3, after discussions from various viewpoints. As a result, the board will be operated in a manner which is approximately consistent with the contribution ratio to ALMA: with 4 members from North America, 3 from Europe, 3 from East Asia, and 1 from Chile.

In October 2006, there was an earthquake in the sea around the Island of Hawaii, and the Subaru Telescope and other observation facilities were damaged. Fortunately, we could escape from fatal damages to the facilities by conducting prompt investigations and making emergency action plans, and could restore them to the normal operation status after nearly one-month operation halt. Although there were some remaining actions in the following year, most of them have already been completed. In addition to this, there were some powerful typhoons in this year. Ishigakijima Astronomical Observatory, VERA Ishigaki Station, and VERA Chichijima Station were damaged by typhoon. In particular, Ishigakijima Astronomical Observatory were suffered strong gusts of wind of the powerful typhoon, which blew off both of the two dome slits, and the inside of the dome was exposed to heavy wind and rain and severely damaged. As the wind speed was higher than expected, we conducted a detailed investigation of the damages. Restoration of the facilities had almost been completed by the end of the year after operation halt of more than 6 months. The costs for restoring the facilities affected by the earthquake and typhoon were covered by the natural disaster relief expenditure from the government, nonlife insurance, and NAOJ contingency fund. These events taught us that it is necessary to take various measures in the event of natural disasters.

Also in this year, we made a lot of effort for graduate education. Once in several months, we held an informal gathering for discussion between students at the Graduate University for Advanced Studies and the faculty including the Academic Dean (NAOJ Director General) and Associate Dean to have a lively exchange of opinions. By using the teleconference system, students at remote campuses could also participate in the discussion. We will continuously facilitate close interactions with students.

Public outreach activities have also been intensely promoted to introduce the latest astronomical research development to the public. One of the outstanding accomplishments in this year is the completion of the four-dimensional dome theater (4D2U Dome Theater) at the end of the year, which was developed by the 4D2U project mentioned above. This dome theater can project the image of outer space seamlessly on the screen of the 10-meter planetarium dome with 13 projectors, unlike the old theater with just 3 flat screens. And the method of stereoscopic viewing has also been changed from the conventional polarization-based method to the wavelength multiplex imaging method using interference filters, which allows freedom of choice in the selection of screen materials and reduces eye's fatigue of the viewers. The dome theater will enable us to provide a wider range of contents produced by NAOJ for the public.

Another event to be mentioned is the decision on the main building of the former international latitude observatory in Mizusawa campus. We canceled the demolition of the building according to the request from local residents, and decided to assign it to Oshu city where the observatory was located, as a result of a selection. The renovation will be completed in 2007 at the expense of Oshu city, and the renovated building will be shared by the citizens as a historical property in tribute to Dr. Hisashi Kimura and "Kaze no Matasaburo" (Matasaburo of the Wind - one of the major works of Kenji Miyazawa), and will be used as a building to provide opportunity for the citizens to become familiarized with Astronomy.

Shoken Miyama

Shoken Miyama
Director General of NAOJ

I Scientific Highlights

(April 2006 - March 2007)

Discovery of the most distant galaxy at a redshift 6.96 : Probing the epoch of cosmic reionization

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The Universe began with a fireball 13.7 Gyr ago. Quick expansion and cooling made it filled with neutral hydrogen by 0.38 Myr after the big bang. The first generation of galaxies were born a few 100 Myr later and UV radiation of newly formed massive stars ionized the interstellar gas producing characteristic Lymanα line emission. The current group made Suprime-Cam survey with a special filter developed for isolating galaxies with Lyman α emission line at redshift 7.0 in the Subaru Deep Field. FOCAS spectroscopy of two targets selected by their color out of 41,533 objects studied, led to the finding of the most distant galaxy at a redshift 6.96 (Figs. 1, 2, and 3; Table 1), IOK-1, at 12.88 billion light years away [1]. We are looking at this galaxy at 780 Myr after the big bang. The number of galaxies at redshift 7.0 appears to be significantly smaller than that at redshift 6.6, about 60 Myr later. This decrease could be interpreted that we are stepping into the era of cosmic re-ionization.

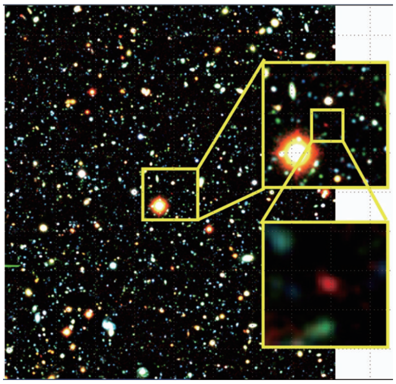

Figure 1: The most distant galaxy IOK-1 found.

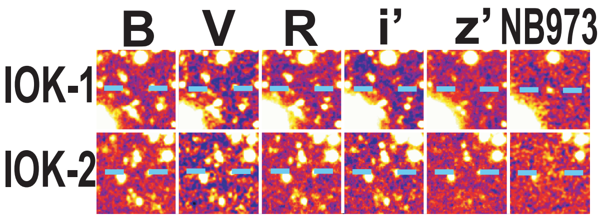

Figure 2: Two candidates visible only in NBF973.

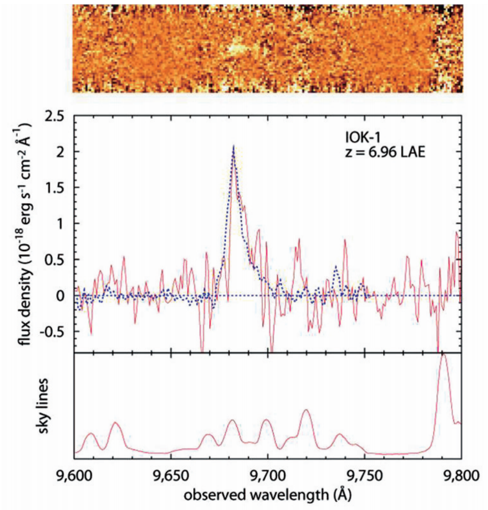

Figure 3: Lyman α emission line at rest wavelength of 121.5nm was seen at 968nm, corresponding to a redshift 6.96.

Table 1: Top 10 most distant galaxies as of Sep. 2006.

No	ID	z	distance[#]	date
1[&]	IOK-1	6.964	128.8	2006.9
2	SDF 1004	6.597	128.2	2005.2
3	SDF 1018	6.596	128.2	2006.4
4	SDF 1030	6.589	128.2	2006.4
5	SDF 1007	6.580	128.2	2005.2
6	SDF 1008	6.578	128.2	2005.2
6	SDF 1001	6.578	128.2	2003.4
8*	HCM-6A	6.560	128.2	2002.4
9	SDF 1059	6.557	128.2	2006.4
10	SDF 1003	6.554	128.2	2005.2

[#] For a standard cosmology model with age 13.66 Gyr.
* Discovered by Hu et al. with Keck telescope.
[&] The most distant galaxy found by the present study.
Note that a few other gravitationally lensed galaxies are claimed to be at redshift around 7 from their colors but lacking spectroscopic confirmation.

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CCD Centroiding Experiment for Correcting the Distorted Image on the Focal Plane

YANO, Taihei, ARAKI, Hiroshi, GOUDA, Naoteru, KOBAYASHI, Yukiyasu,
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INTRODUCTION

JASMINE will measure trigonometric parallaxes, positions and proper motions of stars with the precision of 10 microarcsec. ILOM will also measure the positions of stars in order to obtain the lunar physical libration and the free librations directly from the lunar surface.

Both projects use a common astrometric technique to obtain precise positions of stars. In order to accomplish this goal, we must determine the accurate centroid of star images on the detector.

We have demonstrated the measurements of the positions of artificial star images on the CCD plane with 1/300 pixel precision in a laboratory experiment [1]. In the experiment, we have just measured the positions of stars on the CCD focal plane, in other words, we do not care about the possible distortion of the image due to optical aberration. Here we also consider the correction for the distortion from the strongly distorted optical image.

ALGORITHM

In order to estimate the distance between two point sources from distorted image frames, the following algorithm is proposed. First of all, we pick up two stars to measure the distance. Next we seek the pixel in which a number of photons is maximum in each star. Then we pick up a square subset of 5×5 pixels around the peak pixel of each star image. Accordingly, the number of photons is the maximum values at the center of pixels in both two stars. Only the pixel values of the two subsets are used to measure the distance of the two stars. The photon weighted means (x_c, y_c) are different from the centers of the stars. Here, we assume that the difference between the photon weighted mean and the center of the star is proportional to the deviation of the photon weighted mean from the center of the pixel.

$$x_a - x_c = kx_c , \qquad y_a - y_c = ky_c \tag{1}$$

where (x_a , y_a) is the center of a star from the center of the pixel,

We assume that the value of distortion at a certain point on the focal plane is proportional to the cube of distance from the position of the optical axis on the focal plane,

$$\delta\boldsymbol{r} = \epsilon r^3 \hat{\boldsymbol{r}} , \tag{2}$$

where $r = \sqrt{(x - x_{\mathrm{center}})^2 + (y - y_{\mathrm{center}})^2}$ is the distance of a star from the position of the optical axis on the focal plane, ϵ is a constant, and $\hat{\boldsymbol{r}}$ is the unit vector of $\boldsymbol{r}$. Then we utilize a least square method to obtain the distance of two stars.

RESULTS

Because of the distortion of an image on the focal plane in addition to the deviation of the photon weighted means from the center of stars, distances of two stars are spread to about 0.5 pixels. By correcting the distortion of images and the deviation of the photon weighted means from the centers of stars, the dispersion of the errors becomes smaller than 1/100 pixels.

This result indicates that the distortion of the image on the CCD array is well fitted by the third order correction. Furthermore, uncontrolled random deviation from the optics or the CCD array is very small. The other unexpected deviation from the other origin is also small. Therefore there is high potential for measuring the positions of stars with high precision by using a CCD array and the algorithm proposed in this paper for our projects.

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[2] Yano, T., et al: 2006, *PASP*, **118**, 1448.

An Interpretation of Flat Density Cores of Clusters of Galaxies by Degeneracy Pressure of Fermionic Dark Matter: A Case Study of A1689

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Flat density cores have been obtained for a limited number of clusters of galaxies by strong gravitational lensing. Using a phenomenological equation of state (EOS) describing the full-to-partial degeneracy, we integrate the equation of hydrostatic equilibrium [1]. The EOS is based on an assumption that the local kinetic energy of a classical particle induced by the gravity dissolves the quantum statistical degeneracy. The density profile is uniquely determined by four parameters, the central density, $\rho(0)$, the properties of a fermion, namely, the mass, m, and statistical weight, g, and the ratio of the total matter density and fermion density, δ. As a case study, we model the column density and 2D encircled mass profiles of A1689, whose column density profile has been observationally obtained by Broadhurst et al., using gravitational lensing. The column density and 2D encircled profiles at the core, are reasonably reproduced for models with a limited range of particle properties. In the case that previously unknown fermions with spin 1/2 dominate the dark matter, the acceptable particle mass range is between 2 and 4 eV. In the case that the dark matter consists of the mixture of degenerate relic neutrinos and classical collisionless cold dark matter particles, the mass range of neutrinos is between 1 and 2 eV, if the ratio of the two kinds of dark matter particles is fixed to its cosmic value. Both the pure fermionic dark matter models and neutrino-CDM-mixture models reproduce the observations equally well (Table 1, Figures 1, 2).

Table 1: Solutions for the Mixture of Neutrinos and Nondegenerate Cold Dark Matter.

$\rho(\mathrm{B})/\rho(\mathrm{DM})$	Particle Type	g	(m, r_t) eV, kpc
0.2	$\nu + \bar{\nu}$	6	(1.6,106) ~ (2.1,73)
0.5	$\nu + \bar{\nu}$	6	(1.1,106) ~ (2.4,73)

References

[1] Nakajima, T., Morikawa, M.: 2007, *ApJ*, **655**, 135.

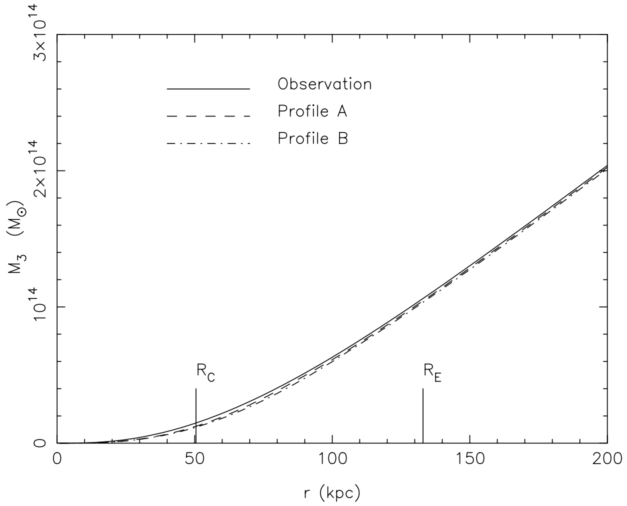

Figure 1: Volume density profiles. Profile A corresponds to the highest density model and profile B is the lowest density model and other model profiles lie between the two extremes. R_C and R_E denote the radius of the radial critical curve and that of the tangential critical curve (or the Einstein radius), respectively.

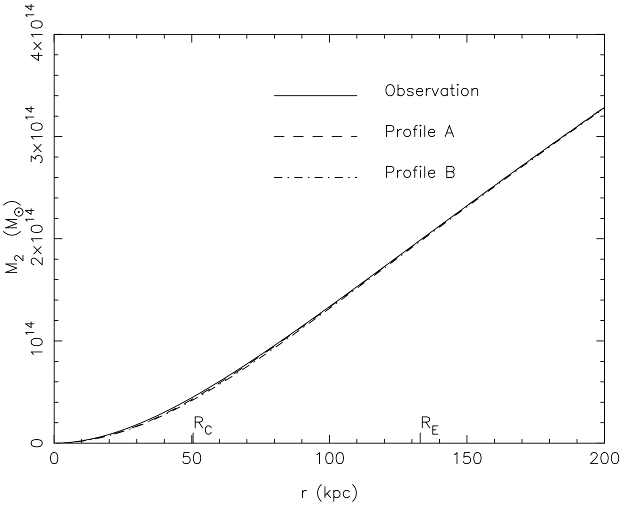

Figure 2: 2D encircled mass profiles for general fermionic dark matter. The observed profiles and model profiles A and B are indistinguishable.

Zenith-Distance Dependence of Chromatic Shear Effect: A Limiting Factor for an Extreme Adaptive Optics System

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Consider a perfect AO system with a very fine wavefront sampling interval and a very small actuator interval. If this AO system senses wavefront at a wavelength, λ_{WFS}, and does science imaging at another wavelength, λ_{SCI}, the light paths through the turbulent atmosphere at these two wavelengths are slightly different for a finite zenith distance, z. The error in wavefront reconstruction of the science channel associated with this non-common path effect, or so-called chromatic shear, is uncorrectable and sets an upper bound of the system performance. We evaluate the wavefront variance, $\sigma^2(\lambda_{\mathrm{WFS}}, \lambda_{\mathrm{SCI}}, z)$ for a typical seeing condition at Mauna Kea and find that this effect is not negligible at a large z [1]. If we require that the Strehl ratio be greater than 99 or 95%, z must be less than about 50 or 60º respectively, for the combination of visible wavefront sensing and infrared science imaging (Fig. 1).

It is well known that a high-performance adaptive optics system with a Strehl ratio well over 90% is required for the direct detection of an exoplanet from the ground especially in reflected light. Such an adaptive optics system is often called an extreme AO system (ExAO), because of its high level of sophistication in instrumentation. The ExAO has strict requirements on guide stars and wavefront sensors. Fine wavefront sampling is achieved by many pixels in the wavefront sensor, each of which corresponds to the length scale less than cm. Fine temporal sampling is also required along with the fine spatial sampling. Therefore, a large number of photons are required for a tiny area on the wavefront for a short period of time. So an AO guide star must be very bright. Another requirement on the guide star is that it must be regarded as a point source, even after the AO correction, and a presently available laser guide star, located at a finite altitude with a finite angular extent, is not fitted for this purpose, even if the problem of brightness or laser power is overcome. If the Strehl reduction due to the finite extent of the laser guide star is inevitable, there is no point of sampling the wavefront so finely, in other words, there is no use of an ExAO. For the same reason, a stringent requirement on isoplanicity will result in a small field of view. For these reasons, the major application of an ExAO requires a very bright natural guide star and the high Strehl ratio is achieved only for a small field of view. All things considered, an exoplanet search around bright nearby stars, will remain the primary scientific goal for an ExAO project.

There are many sources of errors that can cause the reduction of the Strehl ratio, but most of them are in principle controllable by sophisticated instrumentation. However, there are also some errors which are in principle uncorrectable. Here we focus on one of the major uncorrectable errors: atmospheric chromatic non-commonpath error, or "chromatic shear (CS)", associated with the different paths through the turbulent atmosphere of the light beams incident on the visible wavefront sensor and the infrared science imager, when the target star is at a finite zenith distance.

In actual astronomical observations, total observing time for an object is finite and the object never stays at the zenith. Moreover, it often happens that an object needs to be observed at a large zenith distance, due a large difference between the declination of the object and the latitude of the observatory. In order to secure a significant amount of observing time for an exoplanet search, it is inevitable to observe a target star with a finite zenith distance.

Most of the current AO systems sense wavefront at visible wavelengths and image the target at near-infrared wavelengths. This is partly due to the higher availability of a visible detector such as a CCD for a wavefront sensing camera. However, if the CS effect is a significant limiting factor for the next-generation extreme AO systems whose scientific justification is direct exoplanet detection, the choice of the combination of λ_{WFS} and λ_{SCI}, may need to be reconsidered.

In this paper, we quantify the magnitude of this CS effect, in terms of wavefront variance associated with it.

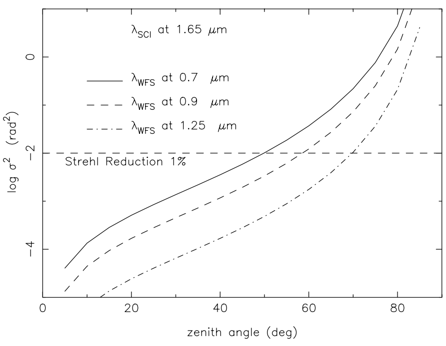

Figure 1: Wavefront variance due to atmospheric noncommon path effect. $\lambda_{SCI} = 1.65\ \mu$m. Assumed seeing condition is $r_0 = 0.2$m at $\lambda = 0.5\ \mu$m. The variance for an arbitrary r_0 can be obtained by shifting each curve vertically by (5/3) $\log_{10}(0.2/r_0)$.

References

[1] Nakajima, T.: 2006, *ApJ*, **652**, 1782.

A Nobeyama Millimeter Interferometric Search for Buried Supermassive Blackholes in Luminous Infrared Galaxies

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Luminous infrared galaxies (LIRGs) radiate large luminosities ($L > 10^{11}L_\odot$) as infrared dust emission. The large infrared luminosities mean that: (1) powerful energy sources are present hidden behind dust; (2) energetic radiation from the energy sources is absorbed by the surrounding dust; and (3) the heated dust grains re-emit this energy as infrared thermal radiation. To understand the nature of LIRGs, it is essential to distinguish whether the hidden energy sources are starbursts and/or active galactic nuclei (AGNs; mass accreting supermassive blackholes). If luminous AGNs are present and obscured by dust in a *torus* geometry, such obscured AGNs are easily detectable through optical spectroscopy, because AGN's ionizing radiation can escape along the torus axis direction. However, since the nuclear regions of LIRGs are very dusty, most of putative AGNs in LIRGs are likely to be obscured by dust along all sightlines. It is fundamental to evaluate the energetic contribution from such *buried* AGNs to LIRGs.

In an AGN, much stronger X-ray emission than a starburst is produced in the close vicinity of an accretion disk around a central supermassive blackhole. Hence, detection of a strong X-ray emitting source can be strong evidence for the presence of a luminous AGN. Unfortunately, the bulk of buried AGNs in LIRGs are likely to suffer from Compton thick ($N_{\mathrm{H}} > 10^{24}\ \mathrm{cm}^{-2}$) absorption, so that detection of directly transmitted X-ray emission is difficult with the existing X-ray satellites, except a few nearby, bright LIRGs. However, a luminous X-ray emitting buried AGN can make chemical and physical effects to the surrounding gas and dust, and can produce the X-ray dissociation regions (XDRs). If XDRs show different flux ratios of emission lines from photo-dissociation regions (PDRs) usually found in a starburst, they are distinguishable. We have observed several bright LIRGs at the HCN (J=1–0) and HCO$^+$ (J=1–0) lines at ~3.4 mm (89 GHz), using the Nobeyama Millimeter Array (Figure 1), and found that LIRGs which are diagnosed to be AGN (starburst)-powered from our previous infrared spectroscopy tend to show HCN/HCO$^+$ brightness temperature ratios found in AGNs (starbursts) (Figure 2). Since dust extinction is negligible in the millimeter wavelength range, this millimeter method can potentially be a powerful tool to unveil luminous buried AGNs in LIRGs in the ALMA era [1], [2].

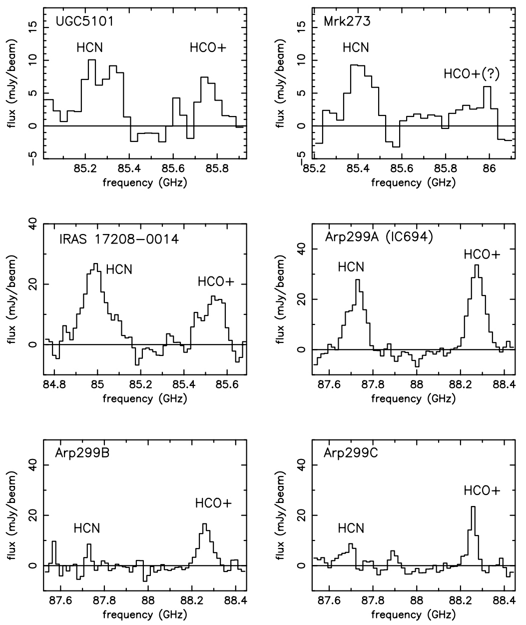

Figure 1: HCN and HCO$^+$ spectra of LIRGs obtained with the Nobeyama Millimeter Array.

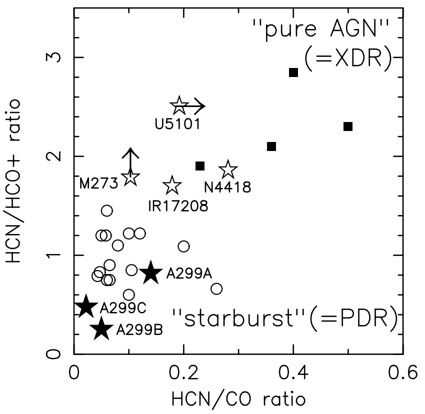

Figure 2: Millimeter interferometric energy diagnostic method [3]. The abscissa is HCN/CO ratio and the ordinate is HCN/HCO$^+$ ratio in brightness temperature ($\propto$flux $\times$ λ^2). LIRGs diagnosed to be AGN (starburst)-powered through infrared spectroscopy tend to distribute in the AGN (starburst) range in this millimeter-based diagram.

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Effects of Phase Characteristics in Main Beam of Telescopes on Same-Beam VLBI

LIU, Qinghui, KIKUCHI, Fuyuhiko, TSURUTA, Seiitsu, MATSUMOTO, Koji, HANADA, Hideo
KAMEYA, Osamu, TAMURA, Yoshiaki, ASARI, Kazuyoshi, KAWANO, Nobuyuki
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The Japanese SELENE project to be launched in 2007 consists of a main satellite, a relay sub-satellite (Rstar), and a VLBI sub-satellite (Vstar). The differential phase delay between Rstar and Vstar will be obtained for the first time with a very high accuracy of several pico seconds. Rstar and Vstar only transmit three carriers at frequencies of 2.212, 2.218, and 2.287 GHz and one carrier at a frequency of 8.456 GHz. The absolute difference in the correlation phase at each frequency has to be estimated without 2π ambiguity when obtaining the differential phase delay. This requires the rms error of the differential correlation phase at S-band to be lower than 0.075 radians.

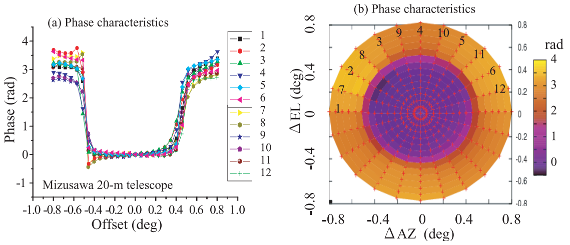
To resolve the 2π-ambiguity problem, we will use same-beam differential VLBI, in which Rstar and Vstar are observed simultaneously using the main beam of each telescope [1]. Because the propagation paths of the radio waves from Rstar and Vstar are nearly the same, the influence of the instrument, the atmosphere and the ionosphere can nearly be canceled out. However, phase characteristics across the main beam of the telescopes must not be neglected. Accurate measurement and correction for phase characteristics of the telescopes are thus key techniques for achieving same-beam differential VLBI.

We measured the phase characteristics at S-band of the Mizusawa 20-m and 10-m telescopes by using geostationary satellites [2]. In the measurement, one telescope tracks the satellite with a zero-offset angle, and the other scans for 12 paths as shown in Fig. 1(b). The phase characteristics of the telescope under test was obtained using the phase difference between the signals received by the two telescopes. The phase characteristics were measured stepped radially with 29 points along each path. The measurements were made in 1 minute for every point. The zero-offset point of the telescope under test was observed repeatedly every 8 minutes to correct the time variation of the phase in the system itself.

Figure 1 shows the measured phase characteristics of the 20-m telescope for paths 1–12 measured at a freqency of 2.2807 GHz and an EL of 44.8 degrees. They are nearly constant up to an offset angle of about 0.4 degrees, where they jump by about π. Figure 2(a) shows the phase characteristics in the main beam of the 20-m telescope. To correct the phase characteristics across the main beam, we fitted the measured results over all 12 paths to a single quadratic in both AZ and EL. The results after correction are shown in Fig. 2(b). Within ±0.3 degrees in both axes there is a significant improvement. Before correction, the phase characteristics lie between ±0.1 radians with an overall rms of 0.06 radians. After correction, the phase characteristics lie between ±0.05 radians with an overall rms of 0.03 radians.

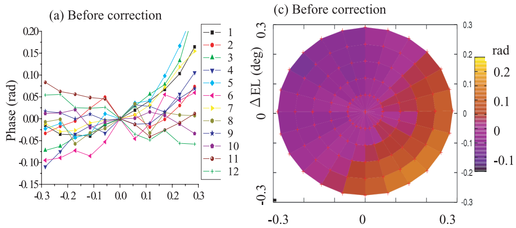
Figure 2(c) and (d) show the two-dimensional phase characteristics in the main beam of the 20-m telescope. The phase characteristics shown in the upper left part of Fig. 2(c) is negative, whereas the phase characteristics in the lower light part are positive. After correction, the residual phase characteristics are random. We also measured the phase characteristics at an EL of 30 degrees, the results are similar for an EL of 44.8 and 30 degrees.

The phase characteristics were measured to an error of about 0.04 radians rms. The phase characteristics in the main beam after correction is less than 0.03 radians rms for the 20-m and 0.04 for the 10-m telescopes. This satisfies the 0.075 radians rms required to resolve the 2π ambiguity problem, and confirms the effectiveness of the same-beam differential VLBI technique for the VLBI observations of SELENE.

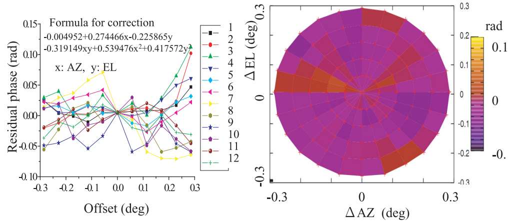

(a) Phase characteristics

(b) Phase characteristics

Figure 1: Phase characteristics of 20-m telescope.


(a) Before correction

(c) Before correction


(b) After correction

(d) After correction EL=44.8 deg

Figure 2: Phase characteristics in main beam of 20-m telescope (a)(c) before correction and (b)(d) after correction by quadratic formula.

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A Search for CO ($J = 3 - 2$) Emission from the Host Galaxy of GRB980425 with the Atacama Submillimeter Telescope Experiment

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We report on a deep search for CO(3–2) line emission from the host galaxy of GRB980425 with the Atacama Submillimeter Telescope Experiment (ASTE) [1].

Long-duration gamma-ray bursts (GRBs) are considered to be due to the death of massive stars. Therefore, GRBs are closely associated with the star formation of host galaxies. Since GRBs can be detected at cosmological distances, they are expected to be probes of the star formation history of the Universe. In order to determine the use of GRBs, it is essential to understand the star formation of their hosts. Multi-wavelength observations have shown that the star formation rates (SFRs) of GRB hosts derived from submillimeter/radio observations are generally higher than those from optical/UV observations [2], [3]. This implies that GRB hosts have a large amount of molecular gas and massive star formation obscured by dust. In order to solve this problem, it is necessary to derive the SFRs in a method which is independent of existing methods and not affected by dust extinction.

We searched for CO(3–2) toward the host galaxy of GRB980425 with the ASTE. This galaxy is the nearest GRB host known to date ($z = 0.0085$), and the proximity makes it the best target to detect CO emission. We observed five points of the galaxy covering the entire region. After combining all of the spectra, we obtained a global spectrum with the rms noise level of 3.3 mK in $T_{\rm mb}$ scale at a velocity resolution of 10 km s^{-1} (Fig. 1). No significant emission was detected, though we find a marginal emission feature in the velocity range corresponding to the redshift of the galaxy. We derive 3 σ upper limits on the global properties: the velocity-integrated CO(3–2) intensity of $I_{\rm CO}(3\text{–}2) < 0.26$ K km s^{-1} by adopting a velocity width of 67 km s^{-1}; the H$_2$ column density of $N({\rm H_2}) < 3 \times 10^{20}$cm^{-2}; the molecular gas mass of $M({\rm H_2}) < 3 \times 10^8\ M_\odot$, by assuming a CO line luminosity to H$_2$ molecular gas mass conversion factor of $X_{\rm CO} = 5.0 \times 10^{20}$ cm^{-2} (K km s^{-1})$^{-1}$; and the star formation rate of SFR $< 0.1\ M_\odot$ yr^{-1}, based on the Schmidt law. The SFR is consistent with the previous results of Hα and mid-IR observations, thereby suggesting that there is no significant obscured star formation in this galaxy.

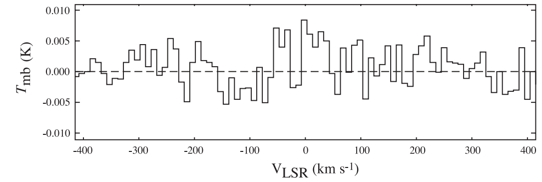

Figure 1: Global spectrum at a velocity resolution of 10 km s^{-1}. This exhibits the global property of the host galaxy of GRB980425. The rms noise level is 3.3 mK in $T_{\rm mb}$ scale.

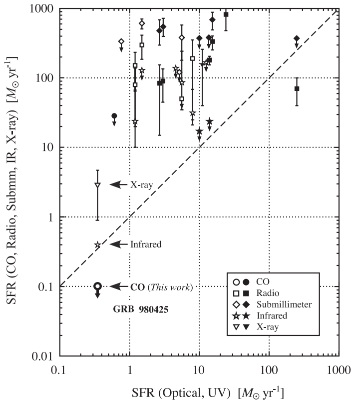

Figure 2: Comparison of the SFRs of GRB hosts determined by various observational methods. The ordinate is the SFR derived by extinction-free methods, and the abscissa is the SFR from optical and UV. The open symbols are the SFRs that are corrected for extinction in the host galaxies, and the solid symbols are those that are not corrected.

Figure 2 shows the SFRs of GRB hosts derived by several methods (see [4] and references therein). The ordinate is the SFR determined from extinction-free wavelengths, such as the CO line, radio/submillimeter continuum, IR, and X-rays. The abscissa is the SFR determined from optical and UV. The majority of the GRB hosts are located above the diagonal, implying that they have a large amount of molecular gas and massive star formation obscured by dust. This tendency is observed in LIRGs, ULIRGs, and submillimeter galaxies but not in normal spiral galaxies. On the other hand, our study shows that the host galaxy of GRB980425 shows a different trend. This suggests that various GRB hosts exist in terms of the presence of obscured star formation.

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Origins of Carbon-Enhanced Metal-Poor Stars

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An important fact found by the surveys of metal-poor stars is that the fraction of Carbon-Enhanced Metal-Poor (CEMP) stars is significantly high in the low metallicity range. At the solar metallicity, carbon-enhanced Asymptotic Giant Branch (AGB) stars, which are evolved low- and intermediate-mass stars, are known but their fraction is at most 1%. On the other hand, the fraction of CEMP among metal-poor stars (e.g. [Fe/H]< –2) is estimated to be 10–20%. This class of stars includes the two objects having the lowest abundances of heavy elements known to date ([Fe/H]< –5), indicating the importance of CEMP stars for understanding of the star formation and nucleosynthesis in the very early Universe. In order to investigate the origins of CEMP stars, we have been conducting measurements of chemical abundances for a large sample of these objects since 2000 using Subaru Telescope High Dispersion Spectrograph. A summary of our work is given by Aoki et al. (2007)[1], in which following observational facts are reported:

(1) About 80% of the sample (64 CEMP stars) show large excesses of Barium (Ba), indicating the source of high abundances of carbon as well as heavy elements is the nucleosynthesis in AGB stars. Hence, the most important origin of carbon-excesses in CEMP stars is AGB stars. However, since the objects we are now observing are not at the AGB stage, we should be observing the companion object that has received significant mass from the primary AGB star that has already evolved to faint white dwarfs.

(2)The fraction of Ba-enhanced objects among CEMP stars is dependent on metallicity: the fraction of Ba-normal objects increases in the metallicity of [Fe/H]< –2.6 (Figure 1). The two objects with [Fe/H]< –5 should be the extreme examples of this class. The existence of such objects at lower metallicity is the second reason for the high fraction of CEMP stars, though their origins are still very unclear (see below).

(3) A majority of Ba-enhanced stars have carbon abundances similar to, or slightly lower than, the solar value (–1 <[C/H]≲ 0), and a clear cutoff exists at [C/H]~ 0. This suggests that AGB stars yield carbon abundances similar to the solar value ([C/H]~ 0), which is mostly independent of the metallicity, and the yields are now observed at the surface of the secondary star without significant dilution.

Such recent work revealed the classification of CEMP stars, while the detailed understanding for each group is the ongoing and future work. The detailed abundance patterns of heavy elements in Ba-enhanced stars, whose carbon is believed to be provided by AGB stars, give strong constraints on the models for the s-process in AGB stars. Some CEMP stars are already known to show abundance patterns that cannot be explained by the current s-process models [2]. Such objects are important target to study the origins of heavy elements in the universe. The Ba-rich CEMP stars are believed to belong to binary systems, but that should be confirmed by a long term monitoring of radial velocities.

Several CEMP stars having normal Ba-abundances show excesses of α-elements compared to other metal-poor stars, suggesting these stars are produced from the material polluted by unusual supernovae that yields high C/Fe ratios. These are important objects to investigate the nucleosynthesis in the first generations of stars. Other Ba-normal CEMP stars show no abundance anomaly except for carbon and nitrogen. Understanding of such objects remains as a future work.

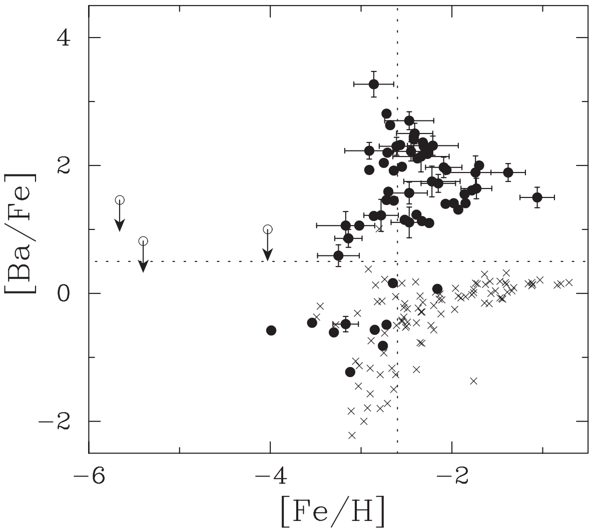

Figure 1: Ba abundance ratios ([Ba/Fe]) as a function of iron abundances ([Fe/H]) for CEMP stars (filled circles). The symbols with error bars indicate the results reported by Aoki et al. [1]. The open circles show the upper limit of Ba abundances for CEMP with [Fe/H]≤ – 4. Normal stars (with no excess of carbon) are shown by crosses for comparison purposes. All but one CEMP stars with [Fe/H]> –2.6 show excesses of Ba ([Ba/Fe]> +0.5), while Ba-normal CEMP stars appear in the lower metallicity range.

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Where did starburst occur and from where did it terminate in E+A galaxies?

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We investigated stellar population in E+A galaxies by slit spectrometry.

E+A galaxy is a galaxy with strong Balmer absorption and no emission lines. They are thought to be a poststarburst galaxy; experienced a strong starburst in 1 Gyr and terminated it abruptly. How the starburst started, and how it stopped is not understood so far.

To answer the questions, we observed 3 E+A galaxies from unbiased E+A sample [1] selected from SDSS catalog with the Apache Point 3.5m telescope, and investigated the distribution of young stellar population [2]. Spatially resolved spectra were obtained by taking several apertures along the slit. Assuming that the light distribution of the galaxies follow Sersic function, we deconvolved the PSF, and showed that the extension of poststarburst region is not confined in the core but rather extended in whole galaxy. We also showed that required mass of starburst is only ~5% of old population to reproduce the observed spectra.

Our second study[3] is based on slit spectroscopy using faint object camera and spectrograph (FOCAS) at the Subaru telescope. A nearby E+A galaxy (SDSS J161330.18+510335.5; Fig 1) shows a tidal feature(plume), and is apparently interactiong with its neighbour(Fig1, Red). We confirmed that the two galaxies have almost the same redshift, and they are a phisically interacting pair. We also discovered that poststarburst signature, strong Balmer absorption without any sign of starformation, exist not only in its core but also at 4 kpc from the core (Fig 2). It means that there had been a strong starburst in the plume and the burst suddenly stopped. Then, we made model spectra using a stellar synthesis model (BC2003), assuming that the progenitor of the E+A is mildly starforming galaxy. Investigating the models and the observed spectra in $H\delta$ vs 4000Å break (D4000) plane, we found that the age of young population can be decoupled from the metal and the burst-strength (mass ratio of young population to old one) when the luminosity of young population is much stronger than that of old population. It enable us to estimate the age since the end of the burst approximately. Applying this method to the observed data, we found the sign that the end of the starburst is relatively later at the center than the outer part (in the plume) in this galaxy. This result is consistent with the fact that CaH-K ratio is larger at the center(x=0). We concluded that the end of starburst propagated inward in this galaxy.

More detailed study on this E+A, kinematics study and metallicity distribution, is ongoing.

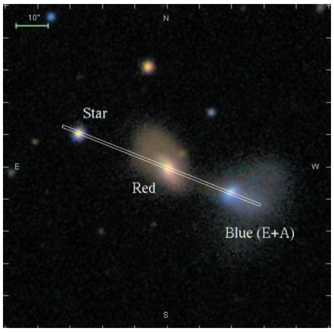

Figure1: Image taken from SDSS archive around SDSS J161330.18+510335.5 ("Blue E+A"). Slit position is overplotted [3]. Tidal plume is extended to the bottom right.

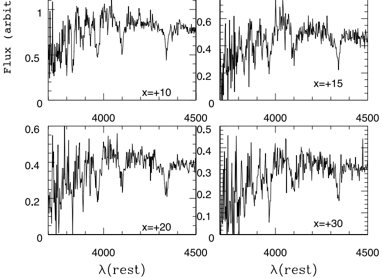

Figure 2: Spatioally resolved spectra of E+A in Fig.1 [3]. H_δ at ~4100Å (rest) and H_γ at ~4350Å (rest) are obvious. The unit of x is [pixel], and x=+30 corresponds to ~ 4kpc, since the scale is 0.13 kpc/pixel at this galaxy.

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First light of the Laser Guide Star Adaptive Optics System: 10 times clearer vision for Subaru Telescope

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COLLEY, Stephen, ELDRED, Michael, DINKINS, Mathew, GOLOTA, Taras
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Even though the theoretical diffraction limit of an 8m class telescope is 0.06 arcsec in the near infrared K-band, practical average seeing at Mauna Kea is about 0.6 arcsec, 10 times poorer than the ideal limit. Adaptive Optics is an innovative technology to measure the wavefront errors due to the turbulent atmosphere and correct them in real time to retrieve the diffraction limited imaging capability. The current group developed (1) an advanced adaptive optics system with 188 control elements based on their experiences in constructing the 36-element AO system and (2) a laser guide star generating facility for the Subaru Telescope. The project was supported by the grant in aid for specially promoted research on "High resolution near infrared observations of distant universe by a laser guide star adaptive optics system" led by M.Iye during the fiscal years 2002-2006. The left panel in Figure 1 shows the first light image of Trapezium region in the Orion nebula taken by the 188-element AO system on October 9, 2006. The breathtaking resolution is evident when the image is compared with the image on the right panel of Figure 1 obtained in 1999 using a classical infrared camera during the first light epoch of Subaru Telescope.

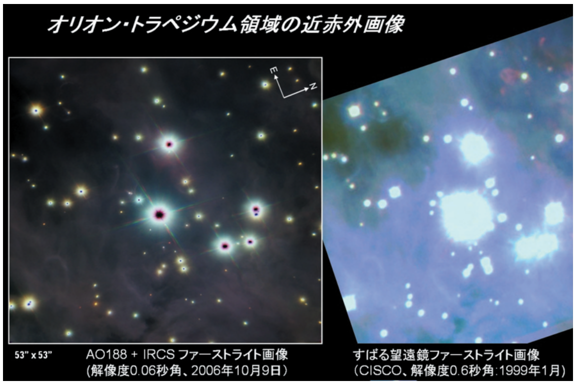

Figure 1: 188 AO image(left) and non-AO image(right) of the trapezium region in the Orion nebula.

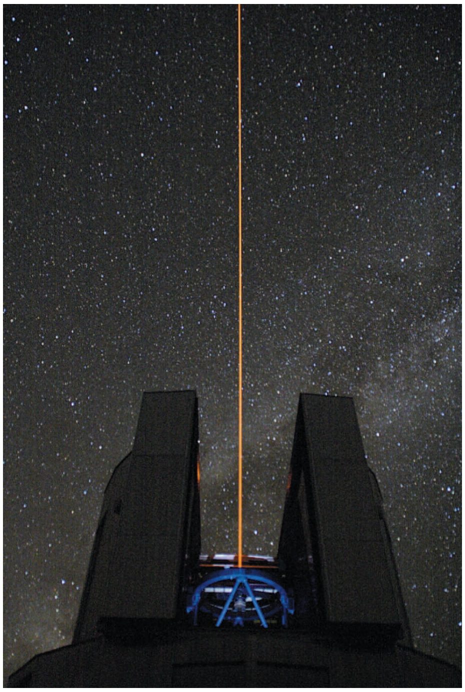

Figure 2: The first launching of the laser beam from Subaru Telescope.

Figure 2 shows another impressive picture when the powerful laser beam was launched for the first time from Subaru Telescope to generate an artificial guide star at about 100km above the site on October 12, 2006. These successful results ensure that diffraction limited imaging observations will become reality with Subaru Telescope even for target fields where no bright natural guide star is available for the driving the AO system. A series of papers reporting these achievements are published in [1]- [9].

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High-Dispersion and High-S/N Spectrum Atlas of Vega

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Vega has long been known for its low projected rotational velocity ($v_e \sin i$ of ~ 20 km s^{-1}), which is rather unusual for such early-type stars (A0 V). However, the discovery of anamolous "flat-bottomed" shape of weak lines, which was revealed for the first time by the ultrahigh S/N (> 2000) Reticon spectrum obtained at Dominion Astrophysical Observatory [1], presented a new picture that the apparently sharp-lined Vega is actually a rapid rotator seen nearly pole-on and the peculiar line profile may be interpreted as due to the rotation-induced latitude-dependent variation of stellar surface properties [2, 3]. In fact, this view has got support at least qualitatively from a recent interferometric observation of Vega's surface brightness distribution [4].

This does not mean, however, that we already have a fully satisfactory understanding of this star. As a matter of fact, from a quantitative point of view, any consensus has not yet been accomplished regarding the nature of Vega's rotation, as the best solutions of (v_e, i) suggested from these studies appreciably differ from each other: (245 km s^{-1}, 5°.1; [2]), (160 km s^{-1}, 7°.9; [3]), and (274 km s^{-1}, 4°.5; [4]). It is evident that much more work remains to be done in this field.

Unfortunately, the ultra-high-S/N spectrum obtained at Dominion Astrophysical Observatory [1], which has been exclusively invoked so far [2, 3], is not placed in the public domain. We therefore decided to collect such similar high-quality spectral data of Vega based on our own observations at Okayama Astrophysical Observatory, and to publish them as a digital spectrum atlas.

The spectroscopic observations were carried out on 2006 May 1–4 by using the HIDES Spectrograph attached to the 188 cm reflector at Okayama Astrophysical Observatory (OAO), which enabled us to obtain the data at four wavelegth regions (region "b" of ~3900–5100 Å, region "g" of ~5000–6200 Å, region "r" of ~6000–7200 Å, and region "i" of ~7600–8800 Å). The data reduction was performed with IRAF in the standard manner. The resolving power of the finally resulting spectra is R ~100000 (corresponding to the slit width of 100 μm), and their typical S/N ratios are ~1000–2000 on the average as shown in Figure 1.

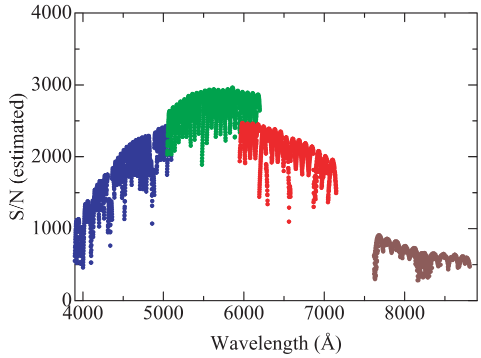

Figure 1: Estimated S/N ratios vs. wavelwength.

We have made these very high-quality digital spectra of Vega freely available via on-line, the details of which are described in [5]. The actual data are given in the form of electronic tables to this paper, though also downloadable from the FTP site of the Astronomical Data Center of NAOJ: ftp://dbc.nao.ac.jp/DBC/ADACnew/J/other/PASJ/59.245/ In addition, the theoretically simulated spectra based on the spectrum synthesis, the list of lines predicted to have appreciable strengths, and the spectra of a rapid rotator (α Leo) for the removal of telluric lines, are also appended to increase the usability of the atlas.

An example of comparison between our spectra and two other published spectra [6, 7] is presented in Fig. 2, where we can recognize that our data are of so high quality as to reveal the peculiar/characteristic profile shape seen in very weak lines.

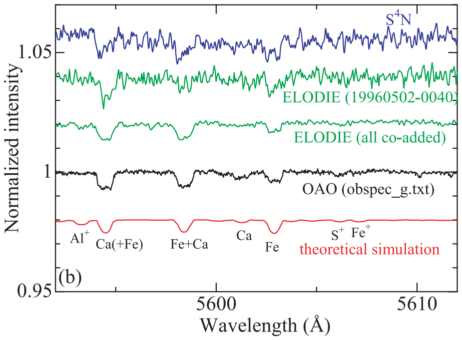

Figure 2: Comparison with other published spectra.

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ASTE Observations of Warm Gas in Low-mass Protostellar Envelopes: Different Kinematics between Submillimeter and Millimeter Lines

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We report the first results of mapping observations of low-mass protostellar envelopes in submillimeter CS (J=7–6; 342.9 GHz) and HCN (J=4–3; 354.5 GHz) lines with ASTE [1]. ASTE is the first Japanese large (= 10 m) submillimeter single-dish telescope at the Atacama Dessert, northern Chile, where ALMA will be constructed [2]. Observational studies with ASTE should provide us with invaluable insight for future studies with ALMA.

In Figure 1, we show total integrated intensity maps in the HCN (J=4–3) and CS (J=7–6) lines toward one of the low-mass protostars, L483, observed with ASTE. There appears a western extension both in the HCN and CS emissions, and the structures traced by these submillimeter emissions are resolved with ASTE. The deconvolved size of the HCN emission measured from a 2- dimensional Gaussian fitting to the image is 5500 × 3700 (AU) (P.A. = 78º), while in the CS emission only the major axis is resolved (~ 2300 AU). This result suggest that these submillimeter emissions, which should trace gas temperatures above ~ 40 (K) and densities above ~ 10^7 cm^{-3}, can be more extended than ~ 2000 AU in the low-mass protostellar envelope.

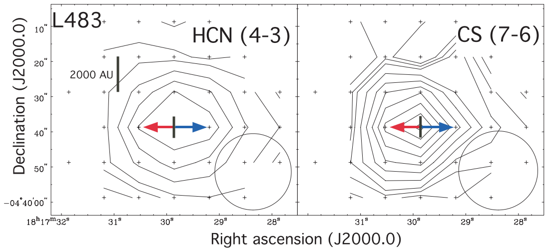

Figure 1: Total integrated intensity maps (integrated velocity range 4.2 - 6.9 km s^{-1}) of the HCN (4–3) (left) and CS (7–6) (right) emission in L483, taken with ASTE. Contour levels are 2, 4, 6 σ, and then 10 σ in steps of 4 σ (1 σ = 0.0733 K km s^{-1}). The highest contour in the HCN map is 18 σ and that in the CS map 34 σ. Crosses indicate observed positions, and open circles at the bottom right corner beam sizes. Red and blue arrows show the direction of the redshifted and blueshifted molecular outflow, respectively, and he roots of the arrows indicate the protostellar position.

Figure 2 presents the velocity structure traced by the submillimeter CS line in L483. Along the axis of the associated molecular outflow, the CS (7–6) line is redshifted at the west of the protostar and blueshifted at the east. The same velocity gradient is also found in the HCN (4–3) line. Interestingly, this trend of the velocity gradient is opposite to that of the molecular outflow, and that in the 3-mm counterpart of the CS (2–1) line and other 3-mm lines such as N_2H^+ (1–0) [3]. The same results are also seen in another low-mass protostellar envelope around B335 (Figure 3). These results suggest that the submillimeter emissions have different origin from that of the millimeter lines.

In summary, submillimeter molecular lines can be more extended than expected, and trace different gas components from those by millimeter lines in lowmass protostellar envelopes. Detailed observations with ALMA should unveil the origin of these submillimeter emissions in low-mass protostellar envelopes.

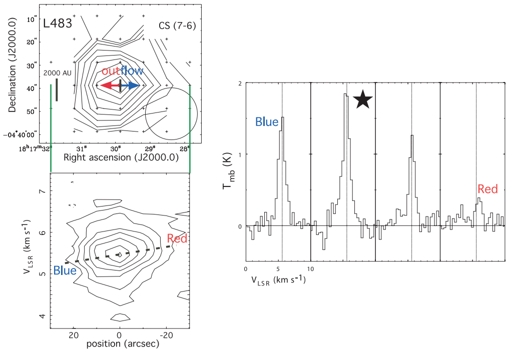

Figure 2: ASTE results of the velocity structure traced by the submillimeter CS (7–6) line in L483. (upper left) Total integrated intensity map of the CS (7–6) emission in L483, shown in Figure 1. (lower left) Position-Velocity diagram of the CS (7–6) line along the axis of the associated molecular outflow in L483. Contour levels are from 2 σ in steps of 2 σ (1 σ = 0.133 K). A dashed line delineates the detected velocity gradient. (right) CS (7–6) line profile map at a grid spacing of 10″ along the outflow axis in L483. A star mark indicates the position of the protostar.

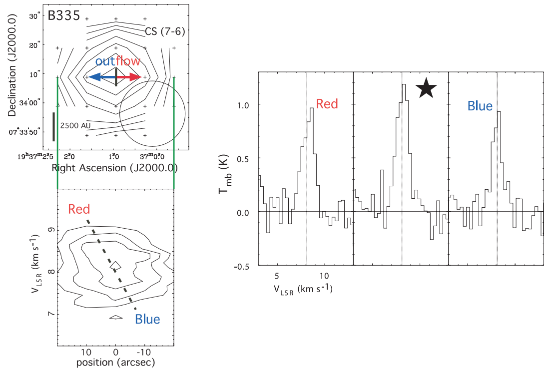

Figure 3: Same as Figure 2 but for another protostar of B335.

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Atomic Carbon in the AFGL 333 Cloud

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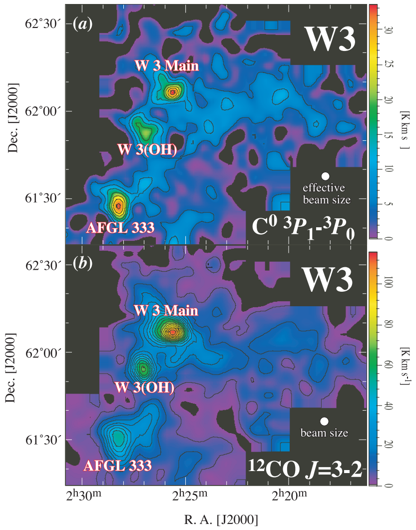

Figure 1: Integrated intensity maps of the C^0 $^3P_1 - {}^3P_0$ emission (a) and the ^{12}CO J=3–2 emission (b) observed toward the W 3 giant molecular cloud.

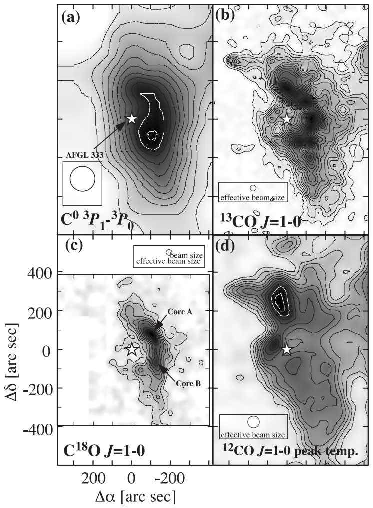

Figure 2: Integrated intensity maps of the C^0 $^3P_1 - {}^3P_0$ emission (a), the ^{13}CO J=1–0 emission (b), and the $C^{18}O$ J=1–0 emission (c) in the AFGL 333 cloud, and a peak temperature map of the ^{12}CO J=1–0 emission in the same region (d).

The W 3 giant molecular cloud (W 3 GMC) is an active star-forming site lied on the Perseus arm. It involves three star forming clouds; W 3 Main, W 3(OH), and AFGL 333. The three clouds exhibit different starforming activities in spite of their similarity in size and mass. The ratio of the infrared luminosities inW3 Main, W 3(OH) and AFGL 333 is 1.0:0.25:0.07 [1], suggesting that AFGL 333 is less active than W 3 Main and W 3(OH). The W 3 Main and W 3(OH) regions have been studied extensively with observations at various wavelengths. In contrast, little attention has been paid on the AFGL 333 region, probably because of its weaker star-formation activity.

We have mapped the W 3 GMC in the C^0 $^3P_1$–$^3P_0$ ([CI] 492 GHz) and ^{12}CO J=3–2 emission lines with the Mount Fuji Submillimeter-wave Telescope. We found that the [CI] intensity is notably strong in the AFGL 333 cloud (Fig. 1a), whereas the ^{12}CO J=3–2 intensity, which traces warm gas, is relatively weak (Fig. 1b). In order to investigate an origin of the bright [CI] emission toward the AFGL 333 cloud, we have mapped the cloud in the CO J=1–0 isotopomer lines by using the Nobeyama Radio Observatory (NRO) 45 m telescope.

Figure 2 shows the integrated intensity maps of the [CI] and CO isotopomer lines and the peak temperature map of ^{12}CO J=1–0 toward the AFGL 333 cloud. We found that the [CI] emission mainly arises from the molecular cloud traced by the ^{13}CO and $C^{18}O$ lines. The C^0 column density is found to be linearly correlated with the C0 column density. In addition, the [C^0]/[CO] ratio tends to be higher in the AFGL 333 cloud than in the W3(OH) cloud. These results suggest the chemical youth of the AFGL 333 cloud relative to the W3(OH) cloud.

If the chemical youth of the AFGL 333 cloud is responsible for the high $N(C^0)/N(CO)$ trend, it should also be reflected in the chemical composition of dense cores. From this motivation, we observed the CCS and N_2H^+ lines with the NRO 45 m telescope (CCS is abundant in the early stage of chemical evolution, while N_2H^+ is abundant in the late stage). The CCS line was detected only in the AFGL 333 cloud, and we found that the [CCS]/[N_2H^+] ratio is higher in the AFGL 333 cloud than in the W3(OH) cloud. This result along with the higher [C^0]/[CO] ratio in the AFGL 333 cloud indicates the chemical youth of the AFGL 333 cloud relative to the W3(OH) cloud. Since there is no IRAS and cm sources toward the two clumps in the AFGL 333 cloud (see Fig. 2c), the clumps are chemically and physically young. These clumps would be important targets to study the early stage of massive star formation. Details of this study are described in [2].

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Nobeyama CO Atlas of Nearby Spiral Galaxies: Distribution of Molecular Gas in Barred and Nonbarred Spiral Galaxies

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We made a CO(1 – 0) mapping survey of 40 nearby spiral galaxies with the Nobeyama 45-m telescope. The criteria of the sample selection were (1) RC3 morphological type in the range Sa to Scd, (2) distance less than 25 Mpc, (3) inclination angle less than 79º (RC3), (4) flux at 100 μm higher than ~ 10 Jy, (5) spiral structure is not destroyed by interaction. The maps of CO cover most of the optical disk of the galaxies. Using these data we have compared the distribution of molecular gas in barred and non-barred spirals and investigated the influence of the bar. We confirmed that the degree of the central concentration of molecular gas within the radius of the order of a bar length ($f_{\rm in}$) in barred spirals is significantly higher than that in non-barred spirals (Figure 1). This is contrast with the degree of the concentration of the total molecular gas mass within the radial distances of the order of the bar ($f_{\rm out}$), which is similar for both barred and non-barred spirals (Figure 2). This implies that the bars appear to be efficient in driving gas that lies within their radial scales toward the center of the host galaxies, but that they play quite a smaller role at larger spatial scales on the disks. Thus the characteristic feature of the radial distribution of molecular gas seen in barred spirals, i.e. the strong intensity peaks at their centers, the shallow gradients within the bar regions or/and the secondary peaks at the radius of the bar-ends, can be explained by the accumulation of molecular gas within the bar regions. The accumulated gas by bars accounts for about half of molecular gas within the central region. We also found a correlation between the degree of central concentration of molecular gas, $f_{\rm in}$, and the bar strength. Galaxies with stronger bars tend to have higher central concentrations. A correlation between the degree of central concentrations of molecular gas and the abundance gradient of heavy elements was also found. Galaxies with higher $f_{\rm in}$ have shallower abundance gradient. These results indicate that stronger bar accumulate molecular gas toward the center more efficiently. The correlation between the degree of central concentration of molecular gas and the strength seem to be consistent with long-lived bars rather than short-lived ones which are destroyed by the gas accumulation toward the center many times in the Hubble time.

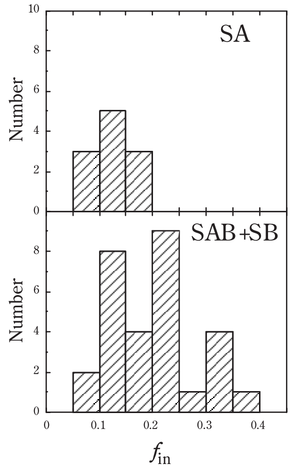

Figure1: Histgrams of $f_{\rm in}$ for SA and SAB+SB galaxies.

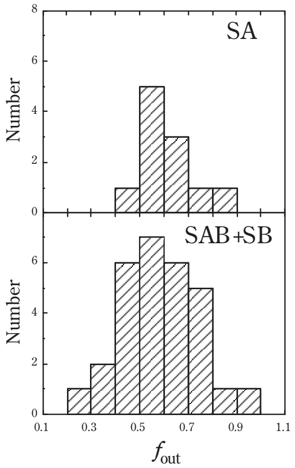

Figure2: Histgrams of $f_{\rm out}$ for SA and SAB+SB galaxies.

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Luminosity Dependent Evolution of Lyman Break Galaxies : UV Luminosity Functions from redshift 5 to 3

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The development of large ground-based telescopes and sensitive large format detectors, as well as the develepment of various techniques for the selection of high-z galaxies enabled us to construct large samples of galaxies in the early universe. The next major step for the comprehensive understanding of galaxy evolution would be to explore the relationship of galaxies selected with different criteria at different epochs and find links between them. Here we focus on the evolution of Lyman break galaxies, which are thought to be actively star-forming galaxies with relatively small amount of dust attenuation. The properties of Lyman break galaxies (LBGs) at z~5 obtained by deep and wide blank field surveys are presented, and through the comparison with samples at lower redshift ranges (z=4 and z=3) we discuss the evolution of star-forming galaxies in the early universe.

Our z~5 LBG sample is based on surveys for the two independent blank fields (the region including the Hubble Deep Field - North and the J0053+1234) obtained with the Suprime-Cam attached to the 8.2m Subaru Telescope. The total effective area after masking bright objects is 1,300 arcmin^2, and deep V , I_c and z'-band imaging enabled us to securely select V - dropout objects down to z'_{AB}=26.5 mag (for the HDFN region) or 25.5 mag (for the J0053+1234 region). The number of z~5 LBG candidates in our sample is 850. It should be emphasized that the area coverage of our survey is more than 100 times wider than the ACS field of the Hubble Ultra Deep Field and more than 4 times wider than the total area covered by the GOODS, and this wide field coverage has a crucial importance for reliable determination of the abundance of luminous objects. Thus our survey is able to explore both bright and faint parts of the LF reliably. The redshifts of a number of our LBG candidates have been spectroscopically determined, and the validity of our color selection criteria have been confirmed.

In figure 1 we show the UV luminosity function (LF) of LBGs at $z \sim 5$ derived from our sample with filled circles and a solid line [1]. In this figure we also show the UVLF of LBGs at $z \sim 4$ and 3 based on the very deep survey (Keck Deep Fields; [2]). We found that in the luminous end of the UV LF there is no significant evolution from $z \sim 5$ to 3 (≈1 Gyr), while in the fainter part, the gradual increase of number density is observed. This clear contrast in the UV LF suggests that the evolution of the LBGs is *differential*, depending on UV luminosity.

In spectroscopic follow-up observations we also found that equivalent widths of Ly-α emission for star-forming galaxies at z = 5–6 show a strong dependence on UV luminosity [3]: UV luminous objects have weak or no Ly-α emission, suggesting that they are either in relatively dusty environment or are enshrouded by massive HI gas haloes. We suggest that the evolution of star-forming galaxies in the first 2 Gyr of the universe could be well described with the biased evolution scenario: a galaxy population hosted by massive dark haloes start active star formation preferentially at early time of the universe, while less massive galaxies increase their number density later. To understand the origin of this differential evolution would be an important clue to clarify the star formation process in the early universe.

The details of this work can be found in [1] and [3].

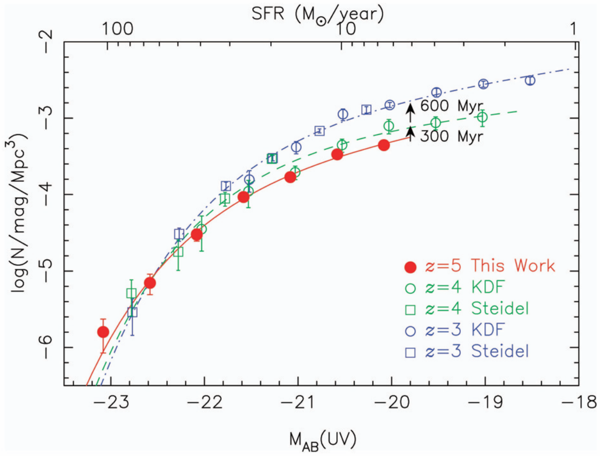

Figure 1: LBG UV luminosity function from z=5 to 3. Data for z=3 and 4 are taken from [2] and [4].

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First Infrared Imaging Polarimetry of β Pictoris

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One of the most exciting news from IRAS launched in 1983 was that some main-sequence stars were associated with large infrared excesses (IRE). This was interpreted as the presence of circumstellar dust which is considered to be debris of planetary formation. As a consequence of follow-up observations from the ground, Smith and Terrile discovered the dust disk around β Pic [1]. This result is regarded as one of the most important discoveries in witnessing a phase of planetary formation.

A number of main-sequence stars with similar IRE have been discovered, and they are known as Vega type stars. At present, those disks are not regarded as the "debris" of protoplanetary disk but are rather secondary; they are due to collisions of smaller bodies. (Thus, they are indeed a kind of "debris").

However, the progress of direct observations of such debris disks has been slow since the β Pic, especially at optical and near-infrared wavelengths. Although there are some observations with the Hubble Space Telescope and the adaptive optics on the 4-m class telescopes, no near-infrared polarimetry or no observations with 8-m class telescopes have been conducted yet. This is because the central stars of Vega-like stars are too bright to directly observe their circumstellar structures (β Pic is a 4th magnitude star at a distance of 19 pc).

In order to resolve this contrast problem and to observe structures near bright stars, we have observed β Pic with the Subaru 8-m telescope, adaptive optics, coronagraph, and a polarimeter (Figure 1) [2]. This is the first case that combined adaptive optics, coronagraph, and polarimetry, simultaeously.

Our main results are summarized as follows [3]:

- Polarization of ~10% is detected out to r~120 AU with a centrosymmetric vector pattern around the central star, confirming that the disk is seen as an infrared reflection nebula.
- We have modeled our near-infrared and previous optical polarization results in terms of dust scattering in the disk and argue that the observed characteristics of the disk dust are consistent with the presence of ice-filled fluffy aggregates consisting of submicron grains in the β Pic system.
- Our results are indicative of the presence of multiple planetesimal belts.

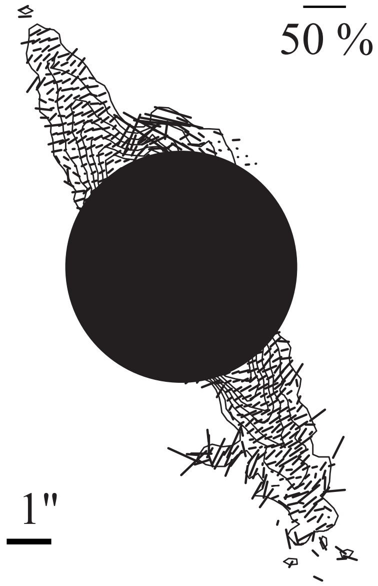

Figure 1: Polarization vector map in *K* band, overlaid with intensity contours. The intensity contours are created from the Stokes I parameter.

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Infrared Imaging Polarimetry of the Orion Nebula

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SIRPOL is the polarization mode of the three-band simultaneous camera SIRIUS [1] on the 1.4-m telescope, IRSF, situated in SAAO, South Africa. The development of the polarimeter started in FY2005 and the linear polarization mode had its first light in 2005 December [2] and the circular polarization mode in 2006 December.

Near infrared imaging polarimetry is important to study dusty star forming regions and late-type stars as well as the Galactic center and star forming galaxies by revealing the dust scattering and absorption. In particular, it provides crucial information on illuminating YSOs which form infrared reflection nebulae, thus enabling us to understand the "geometry" of the regions. We can also obtain information of magnetic fields by observing background stars.

However, in spite of its usefulness, the "wide-field" infrared polarimetry has been scarcely conducted because of the lack of the appropriate polarimeter. Even toward the most famous Orion star forming cloud, the regions studied with polarimetry was very limited.

Figure 1 (left) shows *JHK*s color composite images of M42. It was reproduced from the Stokes *I* parameter obtained with SIRPOL. Figure 1 (right) shows the same but in polarized intensities (intensity $I \times P$). One could easily notice the prominent difference between the two. Even this one-field data is the widest infrared polarization image.

Our main results from the polarization data are summarized as follows [3]:

- We detected various circumstellar structures as infrared reflection nebulae (IRNe) around young stellar objects (YSOs), both massive and low mass. We found the IRN around both IRc2 and BN to be very extensive, suggesting that there might be two extended bipolar/monopolar IRNe in these sources.

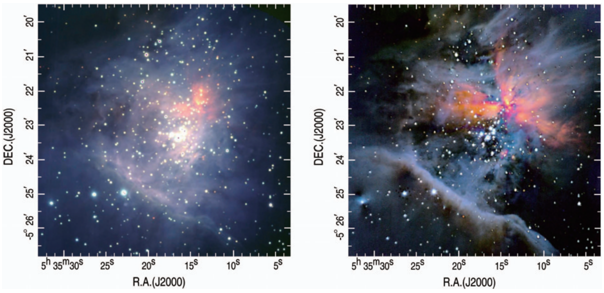

Figure 1: Near-infrared three-color composite images of the Orion Nebula (M42) in intensity (left) and in polarized intensity (right). North is up, and east is to the left. The images are in logarithmic scale.

- We discovered at least 13 smaller scale (~0.01 to 0.1 pc) IRNe around less massive YSOs, including the famous source θ^2 Ori C.

- We also suggest the presence of many unresolved (<690 AU) systems around low-mass YSOs and young brown dwarfs showing possible intrinsic polarizations.

Wide-field infrared polarimetry is thus demonstrated to be a powerful technique in revealing IRNe and hence potential disk/outflow systems among high-mass to substellar YSOs. The information of the magnetic fields will be discussed elsewhere.

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Development of a multi-Fourier-transform interferometer: fundamentals

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We report the fundamentals of Multi-Fourier Transform interferometer(MuFT). MuFT is an aperture synthesis interferometer using direct detector in millimeter and sub-millimeter bands. We report Fundamentals of observation by MuFT in this article[1].

MuFT is a kind of bolometric interferometer applying Fourier transform spectroscopy in aperture synthesis technique. This idea was researched for Double-Fourier system in near-infrared from the end of 1980s[2][3]. In this addition, MuFT is also able to measure polarimetry, as follow. This is a reason of call this system 'Multi- Fourier'. Figure 1 is simplified schematic diagram of a MuFT. Light from the object is been wavefront division. These beams are recombined after modulation of one of the light path lengths to make an internal time lag. Modulation signal is detected by a direct detector system. This signal is expressed as a mutual coherence function of the apertures position (baseline vector) and an internal time lag. However this function is real function, Fourier transformed function to the time lag is expressed as a baseline vector and frequency. This function has phase information except at spectra. A physical explanation of the observability of complex visibility by the MuFT is given.

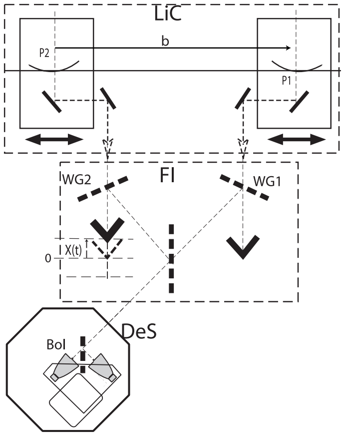

Figure 1: Simplified schematic diagram of a MuFT. Wavefront division of the source light is performed by the LiC. The divided waves are combined by the FI through optical systems. The interferogram is measured by the DeS. Bol is Bolometer.

A wire grid polarizer (WG) is used as a beam splitter in this system. So the wavelength dependence of the reflectivity and transmissivity of a WG is small and is suitable for a wide-band measurement system. The wire grid makes polarization light that an orthogonal electric field element penetrates in the direction of the wire, and a parallel electric field element reflects. In these reason, MuFT has two advantages. First, MuFT performs wideband imaging and spectroscopy. Second, by combining WGs adequately, source intensity distributions of four Stokes parameters can be acquired in a wide band as equation (1),

$$
\begin{aligned}
I_{\mathrm{Op1}} &= \frac{1}{4}\int_{\Omega} \mathrm{d}^2\theta \int \mathrm{d}\nu A_{\nu}(\theta) \frac{I(\theta,\nu) \pm Q(\theta,\nu)}{2} \\
&\quad \left[1 + \cos 2\pi \frac{\nu}{c}\left(\mathbf{b}\cdot\boldsymbol{\theta} - 2x\right)\right], \\
I_{\mathrm{Op2}} &= \frac{1}{2}\int_{\Omega} \mathrm{d}^2\theta \int \mathrm{d}\nu A_{\nu}(\theta) \frac{1}{2}\Bigg[I(\theta,\nu) \\
&\quad + \Bigg(\mathcal{U}(\theta,\nu)\cos\left[2\pi\frac{\nu}{c}\left(\mathbf{b}\cdot\boldsymbol{\theta} - 2x\right)\right] \\
&\quad \pm \mathcal{V}(\theta,\nu)\sin\left[2\pi\frac{\nu}{c}\left(\mathbf{b}\cdot\boldsymbol{\theta} - 2x\right)\right]\Bigg)\Bigg],
\end{aligned}
\tag{1}
$$

equations (1) are interference signal in each optical option, I, Q, $\mathcal{U}$, $\mathcal{V}$ is Stokes parameter, θ is 2D position, and x is distance of moving mirror.

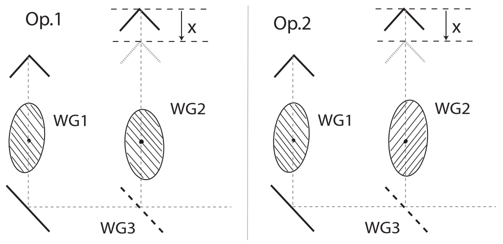

Figure 2: Two basic configurations of wire grid 1 and 2. Left figure is Option.1 (WGs are parallel) and right figure is Option.2. Gray lines are light path (WGs are perpendicular).

We already in acquiring the mutual coherence signal for an extended source in broadband at laboratory experiment. 2D source images for each frequency from 5 cm^{-1} (150 GHz) to 35 cm^{-1} (1.05 THz) with a wavenumber interval of 0.4 cm^{-1} (12 GHz) were successfully extracted[4]. The test astronomical observation using MuFT is in progress at Nobeyama Astronomical observatory.

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Neutrino-Nucleus Reactions based on New Shell Model Hamiltonians

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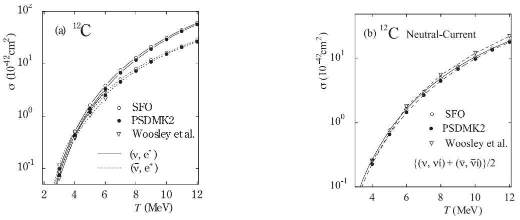

Figure 1: Calculated cross sections for neutrino ^{12}C reactions induced by supernova neutrinos with temperature T obtained by using the SFO and PSDMK2 Hamiltonians. Both (a) the charge-exchange reactions and (b) the neutral current reactions are treated. Previous calculations of Ref. [9] are also given.

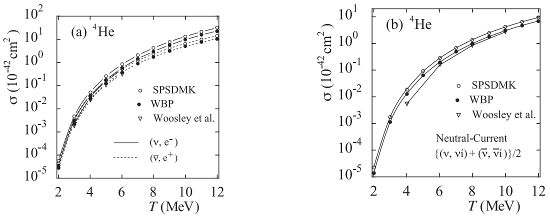

Figure 2: Calculated (a) charge-exchange and (b) neutral current reaction cross sections for ν-^{4}He reactions obtained by using the WBP and SPSDMK Hamiltonians. Previous calculations of Ref. [9] are also shown.

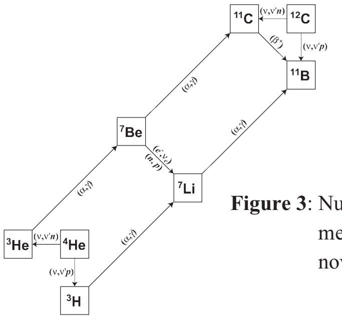

Figure 3: Nucleosynthesis path of light elements ^{7}Li and ^{11}B during supernova explosion [10].

A new shell model Hamiltonian for p-shell nuclei [1] which properly takes into account important roles of spin-isospin interactions is used to obtain cross sections of neutrino-^{12}C reactions induced by decay-at-rest (DAR) neutrinos as well as supernova neutrinos [1].

Our new shell model Hamiltonian (SFO) can describe well the exclusive Gamow-Teller transitions in ^{12}C as well as magnetic moments of p-shell nuclei [2]. It is shown to have proper tensor components, which have attractive (repulsive) nature for the monopole matrix elements with $j_1 = j_>$ and $j_2 = j_<$ ($j_1 = j_2 = j_>$ or $j_1 = j_2 = j_<$).
This is consistent with the general robust nature of the tensor interaction [3]

Charge-exchange and neutral current neutrino nucleus reaction cross sections for ^{12}C induced by the DAR neutrinos [4-6] are shown to be well reproduced by our new shell model Hamiltonian. The exclusive reaction is induced by the Gamow-Teller transition, which is well described by the SFO Hamiltonian. For the inclusive reaction, a large quenching is needed in the spin-dipole transitions with J=2$^-$ to explain the data, which is consistent with the observations in electron scaterings [7].

Reactions induced by supernova neutrinos are also investigated (see Fig. 1). Branching ratios to various decay channels, including neutron and proton knock-out processes, are calculated by the Hauser-Feshbach theory. Neutrino -^{4}He reactions are also investigated by using recent shell model Hamiltonians such as WBP [8]. The reaction cross sections are found to be enhanced for both ^{12}C and ^{4}He compared with previous calculations [9](see Figs. 1 and 2).

As an interesting consequence of this enhancement in the cross sections, a possible enhancement of the production yields of light elements, ^{7}Li and ^{11}B, during supernova explosions is pointed out. The neutral current reactions, ^{12}C (ν, ν'p) ^{11}B and ^{12}C (ν, ν'n) ^{11}C, are important for the production of ^{11}B. The enhancement of these cross sections lead to those of the abundance of ^{11}B. The reactions, ^{4}He (ν, ν'p) ^{3}H and ^{4}He (ν, ν'n) ^{3}He are important for the production of ^{7}Li through ^{3}H (α, γ) ^{7}Li and ^{3}He (α, γ) ^{7}Be (e$^-$, ν_e) ^{7}Li processes. When the ν- ^{4}He reaction cross sections are enhanced, the abundances of both ^{7}Li and ^{11}B are increased as the abundance of 11B is affected by that of ^{7}Li through ^{7}Li (α, γ) ^{11}B etc. Compared to the case by previous cross sections (HW92), the abundances of ^{7}Li and ^{11}B are found to be enhanced by a factor of 1.30 and 1.19, respectively, for WBP+SFO.

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Nonlinear Hydromagnetic Wave Support of a Stratified Molecular Cloud. II. a Parameter Study

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We have performed 1.5-dimensional numerical simulations of nonlinear MHD waves in a gravitationally stratified molecular cloud that is bounded by a hot and tenuous external medium [1].

Using the same basic model as presented in Paper I [2], we have carried out a parameter survey by varying the frequency of the driving force and the magnetic field strength of the cloud. Under the influence of a driving source of Alfvénic disturbances, a cloud shows significant upward and downward motions, with an oscillation time scale that is comparable to the cloud crossing time. We found that the key parameter for the evolution of the cloud is the Alfvén wavelength of the driving force. If the wavelength is larger than the size of the cloud, the cloud is affected less by the waves. The wavelength that is the same order of the cloud size is the most effective in expanding the cloud (Fig.1).

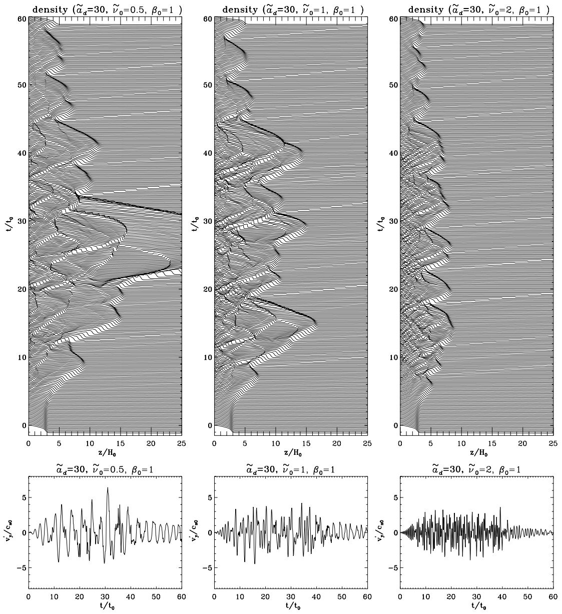

Figure 1: The time evolution for different frequencies ($\tilde{\nu}_0 = 0.5$, $\tilde{\nu}_0 = 1$, $\tilde{\nu}_0 = 2$) with the same parameters of $\tilde{\alpha}_d = 30$ and $\beta_0 = 1$. The upper panels show the time evolution of density. The density profile at various times are stacked with time increasing upward in uniform increments of $0.2t_0$. The lower panels show the time evolution of v'_y at $z = 0$.

This means that turbulent expansion is different than the usual notion of expansion due to a "turbulent pressure" in which the wavelengths need to be much smaller than the cloud size.

The line-width–size relation [3],

$$\langle \sigma^2 \rangle_t^{1/2} \propto \langle z \rangle_t^{0.5}, \tag{1}$$

is obtained by an ensemble of clouds with different physical parameters which are individually in a time-averaged self-gravitational equilibrium state (Fig.2). The largest amplitude random motions occur in the outer low density regions of a stratified cloud.

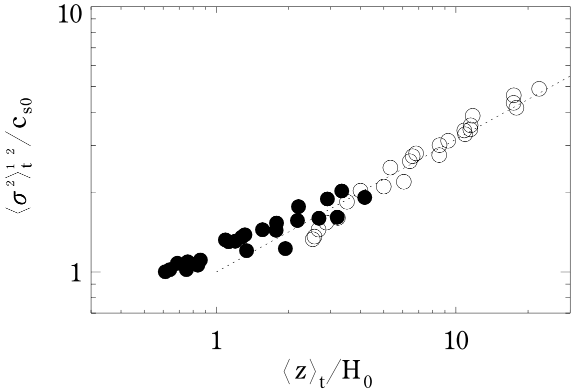

Figure 2: Time averaged velocity dispersions ($\langle \sigma^2 \rangle_t^{1/2}$) of different Lagrangian fluid elements for different parameters as a function of time averaged positions ($\langle z \rangle_t$). The open circles correspond to Lagrangian fluid elements whose initial positions are located at $z = 2.51H_0$, which is close to the edge of the cold cloud. The filled circles correspond to Lagrangian fluid elements whose initial positions are located at $z = 0.61H_0$, which is approximately the half-mass position of the cold cloud. The dotted line shows $\langle \sigma^2 \rangle_t^{1/2} \propto \langle z \rangle_t^{0.5}$.

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ASTE CO(3-2) Observations of the Barred Spiral Galaxy M 83

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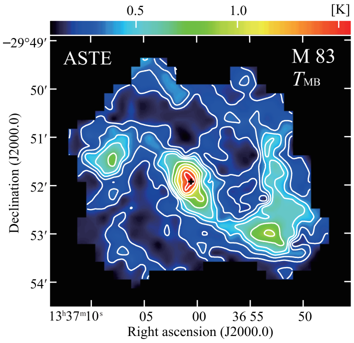

Figure 1: A contour map of the CO(J = 3–2) peak brightness temperature. Countours are at 0.2, 0.3, 0.4, 0.5, 0.7, 0.9, 1.1, 1.3, 1.5 K, and the peak is 1.53 K. Major structures, i.e., the nucleus, bar, and inner spiral arms are clearly resolved.

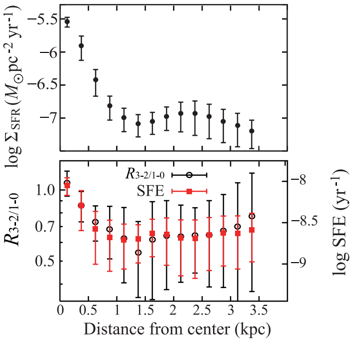

Figure 2: (top) Azimuthally averaged Star formation rate as a function of the galactocentric radius of M 83. (bottom) Azimuthally averaged Star formation efficiency and $R_{3\text{–}2/1\text{–}0}$ as a function of the galactocentric radius of M 83.

We report wide-area observations of CO(J = 3–2) line emission using the Atacama Submillimeter Telescope Experiment (ASTE) towards the whole inner disk of M 83 (NGC 5236) [1].

The CO(J = 3–2) emission can trace the dense component of molecular clouds ($n_{\rm H_2} \sim 1 \times 10^4$cm^{-3}), which is directly linked to star formation.

M 83 is a nearby, face-on, barred spiral galaxy hosting an intense starburst at its center. The distance to M 83 is estimated to be 4.5 Mpc; so 1″ corresponds to 22 pc. The inclination of M 83 is 24º. Its proximity and face-on view enable us to resolve its major structures such as the nuclear starburst region, bar, and inner spiral arms even by single-dish observations at millimeter or submillimeter wavelength. Therefore, M 83 is the best target to investigate the spatial variations of star formation effi- ciency (defined as star formatino rate per unit gas mass; hereafter SFE) and the physical state of the molecular gas between the nuclear region and the disk region.

Figure 1 shows a peak temperature map of the CO(J = 3 – 2) emission of M 83. Significant emission was detected at the nucleus, bar, and inner spiral arms. We successfully resolved these structures at a resolution of 22″. This is the first map that clearly depictsthe distribution of CO(J = 3 – 2) emission in the disk region of M 83 including spiral arms However, no significant emission lines were detected in the inter-arm region.

Figure 2 shows azimuthally averaged star formation rate, SFE, and CO(J = 3 – 2)/CO(J = 1 – 0) ratio ($R_{3\text{–}2/1\text{–}0}$) as a function of the galactocentric radius of M 83. The average $R_{3\text{–}2/1\text{–}0}$, at the 22″ resolution was ~ 1 at the center of M 83 (r < 0.5 kpc). The ratio drops to a constant value, 0.6–0.7, through the disk region (0.5 < r < 3.5 kpc). This implies that molecular gas is denser at the nucleus than disk region. The radial pro- file of the SFE, determined from 6 cm radio continuum and the CO(J = 1 – 0) emission, shows the same trend as $R_{3\text{–}2/1\text{–}0}$; i.e., the SFE shows a strong peak at the nucleus (r < 0.25 kpc), whereas it drops to a constant value in the disk region (0.5 < r < 3.5 kpc).

At the bar-end of M 83 (r ~ 2.4 kpc), the amounts of molecular gas and the massive stars are enhanced, whereas there is no excess of $R_{3\text{–}2/1\text{–}0}$ and SFE in that region unlike its center. This means that the presence of nuclear starburst is not only due to the enhancement in the gas mass but also due to the enhancement in the ef- ficiency of star formation. In other words, a simple summation of the star forming regions at the bar-end (and the disk region) cannot reproduce the nuclear starburst of M 83. These results could suggest that the spatial variation of the dense gas fraction traced by $R_{3\text{–}2/1\text{–}0}$ governs the spatial variation of SFE in M 83.

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ASTE Observations of Nearby Galaxies : A Tight Correlation between CO(J = 3–2) Emission and Hα

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Star formation rates (SFRs) obtained via extinction corrected Hα are compared to dense gas as traced by ^{12}CO(J = 3–2) emission at the centers of nearby galaxies, observed with the ASTE telescope.

The present knowledge of star formation on galactic scales in relation with its precursor gas is generally expressed by the Schmidt law, $SFR \propto \rho^{N}$ where SFR is the star formation rate, ρ the gas density, and N the Schmidt law index, expressing the efficiency of star formation from gas. Often written also in terms of surface averaged quantities (e.g., [1]), the equation above relates two physical values SFR and ρ which are generally spatially decoupled when observed locally, and connected in a spatially averaged sense. The connection between the two values also have a time averaged nature, namely the formation timescale of massive stars. Therefore, in order to obtain valid physical suggestions from the Schmidt law, we must derive these two values based on measurements which express conditions that are spatially and temporally connected as much as observations allow.

The main objective and result of this paper is to examine the correlation between ^{12}CO(J = 3–2) tracing warm dense gas (typically ~ 30K), and *extinction corrected* Hα luminosity tracing accurately the SFR, both in surface averaged densities.

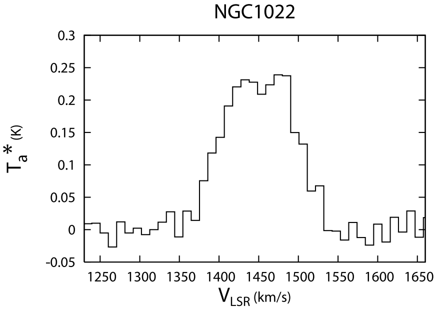

Figure 1: ^{12}CO(J = 3–2) spectra of NGC 1022 observed at ASTE.

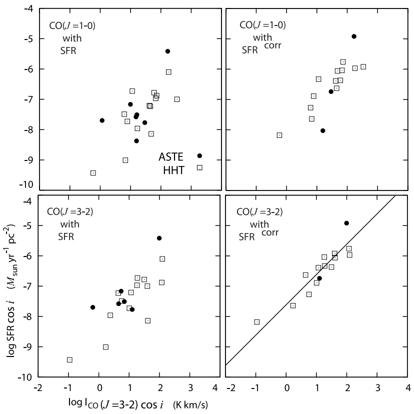

Figure 2: The obtained Schmidt law for the sample galaxies, using combinations of gas (^{12}CO(J = 1–0) and ^{12}CO(J = 3–2), and SFR with and without internal extinction correction. The lower right hand panel is best correlated, with N = 1.0 shown as the best fit line.

Observation of the ^{12}CO(J = 3–2) at 345GHz was conducted using the Atacama Submillimeter Telescope Experiment (ASTE), a 10m single dish located in the Atacama desert of altitude 4800m in Pampa La Bola, Chile. Figure 1 shows a spectra from one of galaxies observed at ASTE. A total of 9 galaxies were observed towards 14 pointings.

Figure 2 shows the obtained Schmidt law between extinction corrected Hα and ^{12}CO(J = 3–2). For comparison, we also show the relation between ^{12}CO(J = 1–0) and Hα. ^{12}CO(J = 1–0) data are taken from similar resolution (16″ or 22″) surveys ([2] and references therein). Apparently, a combination of extinction corrected SFR and dense gas gives a better correlation.

Interpreting this result in a qualitative manner is easy. Assuming that star formation occurs where gas density exceeds a certain value, we can expect that ^{12}CO(J = 3–2) is more spatially and temporally connected to star formation compared to ^{12}CO(J = 1–0). By using Hα as a SFR tracer, the spatial connection (resolution) and temporal connection (traces SF over 10^6 years) are even more improved. This improvement should show up in terms of the Schmidt law. The best fit slope of N = 1.0 suggests that dense gas observed here traces and counts the individual units of star formation sites., as implied by [3].

References

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Neutrino Oscillation Effects on Supernova Light-Element Synthesis

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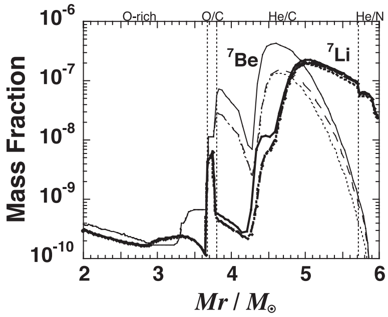

Figure 1: Mass fraction distribution of ^{7}Li in the normal mass hierarchy as a function of the mass coordinate in units of $M_\odot$. Thick lines and thin lines correspond to the mass fractions of ^{7}Li and its isobar ^{7}Be, respectively. Solid lines and dashed lines correspond to the cases of $\sin^2 2\theta_{13} = 1 \times 10^{-2}$ and 1×10^{-6}. The mass fractions calculated without neutrino oscillations are indicated by dotted lines.

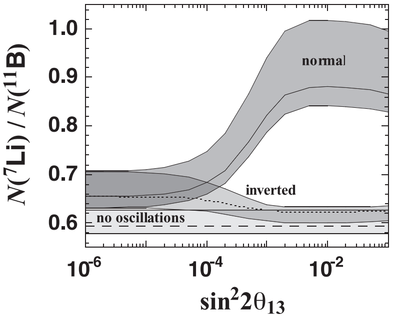

Figure 2: Dependence of the ^{7}Li/^{11}B abundance ratio on $\sin^2 2\theta_{13}$. The dark- and medium-shaded regions indicate the ranges of the ^{7}Li/^{11}B in the normal and inverted mass hierarchies. The abundance ratio without oscillations is indicated by the light-shaded region. These regions are obtained including uncertainties of neutrino temperatures (see [1] for details).

We study the supernova light-element nucleosynthesis considering neutrino oscillations and investigate the dependence on neutrino oscillation parameters such as mass hierarchies and a mixing angle θ_{13} [1].

We adopt the supernova model of a 16.2 $M_\odot$ star corresponding to SN 1987A, as the same in the previous study [2]. We use a Large Mixing Angle (LMA) solution for neutrino oscillation parameters. Since mass hierarchies have not been clarified from neutrino experiments and only an upper limit of the mixing angle θ_{13} has been obtained, we parameterize these quantities.

The mass fraction distribution of ^{7}Li is shown in Fig. 1. Most of ^{7}Li is produced as ^{7}Li and its isobar ^{7}Be in the outer He layer. Neutrino oscillations raise the mass fractions of ^{7}Li and ^{7}Be. Especially, the ^{7}Be mass fraction increases in the case of the normal mass hierarchy and $\sin^2 2\theta_{13} = 1 \times 10^{-2}$.

The main production process of ^{7}Li and ^{7}Be in the He layer is ^{4}He(ν, $\nu' p$)^{3}H(α, γ)^{7}Li and ^{4}He(ν,ν' n)^{3}He(α, γ)^{7}Be. When neutrino oscillations are considered, the contribution from ^{4}He(ν_e, $e^- p$)^{3}He and ^{4}He($\bar{\nu}_e$, $e^+ n$)^{3}H becomes also important. As a result, ^{3}He and ^{3}H are produced more effectively, and therefore, the abundances of ^{7}Be and ^{7}Li increase. The temperatures of ν_e and $\bar{\nu}_e$ are smaller than those of $\nu_{\mu,\tau}$ and $\bar{\nu}_{\mu,\tau}$ just above the neutrino sphere. Then, the temperatures of ν_e and $\bar{\nu}_e$ increase in the O/C layer due to the transitions of $\nu_e \leftrightarrow \nu_{\mu,\tau}$ and $\bar{\nu}_e \leftrightarrow \bar{\nu}_{\mu,\tau}$. The transition of ν_e and $\nu_{\mu,\tau}$ becomes most effectively in the normal mass hierarchy and large $\sin^2 2\theta_{13}$ value.

We propose a possibility for constraining neutrino oscillation parameters from the supernova light-element synthesis. The dependence of the ^{7}Li/^{11}B abundance ratio on $\sin^2 2\theta_{13}$ is shown in Fig. 2. Each shaded region is obtained including the uncertainties in the supernova neutrino temperatures (see [1] for details). The ^{7}Li/^{11}B is about 0.6 without neutrino oscillations. On the other hand, it is larger than 0.83 in the case of the normal mass hierarchy and $\sin^2 2\theta_{13} > 0.002$. Future observations of ^{7}Li/^{11}B ratio in stars having a trace of supernovae or supernova originating presolar grains combined with the evaluation of supernova nucleosynthesis models may constrain neutrino oscillation parameters.

New neutrino-nucleus reaction cross sections of ^{4}He and ^{12}C have been calculated recently as a function of the neutrino energy [4]. The abundances of ^{7}Li and ^{11}B as well as the dependence on oscillation parameters will be evaluated more precisely with the new cross sections.

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The Distance to the Galactic Center

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We report the determination of the distance to the center of our Galaxy using the Bulge red clump giants [1]. Derived distance modulus is $(m - M)_0 = 14.38 \pm 0.03$ (stat) ± 0.10 (sys), which corresponds to the distance $R_0 = 7.52 \pm 0.10 \pm 0.35$ (sys) kpc.

Red clump (RC) giants have been recently claimed to be a very accurate distance indicator. They are the equivalent of horizontal-branch stars for a metal-rich population, and have narrow distributions in luminosity and color, and consequently occupy a distinct region in the color magnitude diagram (CMD). The *Hipparcos* catalog allows us an exact calibration of RC absolute magnitudes, and therefore RC stars can be used as a reliable standard candle.

About 100 × 3 (J, H, K_S) images were obtained over $| l |< 1^{\circ}.0$ and $| b |< 1^{\circ}.0$ using the near-infrared camera SIRIUS on the IRSF telescope. The averages of the 10σ limiting magnitudes were $H = 16.6$, and $K_S = 15.6$.

To analyze the magnitude distribution of RC stars, we define the extinction-free magnitude

$$K_{H-K} \equiv K_S - \frac{A_{K_S}}{E(H-K_S)} \times \left\{ (H-K_S) - (H-K_S)_0 \right\}$$

where we use the reddening law $A_{K_S} / E(H - K_S) = 1.44$ [2], and the intrinsic $H - K_S$ color of RC stars $(H - K_S)_0 = 0.07$. K_{H-K} is thus defined so that if $A_{K_S} / E(H - K_S)$ is independent of location, then K_{H-K} is independent of extinction for any particular star. We then construct K_S vs. $H - K_S$ CMD and extract the stars in the region of the CMD dominated by RC stars. The extracted stars are used in turn to make a K_{H-K} histogram (luminosity function, Fig. 1). The histogram has a clear peak and is fitted with the sum of exponential and Gaussian functions (*thick curve* in Fig. 1).

By fitting the luminosity function of the extracted stars at $| l |< 1^{\circ}.0$ and $0^{\circ}.7 <| b |< 1^{\circ}.0$, we obtained the center of the RC peak as $K_{H-K} = 12.855 \pm 0.005$. The distance modulus to the Galactic center is given by $(m - M)_0 = K_{H-K} - M_{K_S} + \Delta M_K$, where M_{K_S} is the absolute K_S magnitude of local RC stars, and ΔM_K is population correction calculated from theoretical stellar evolution models. Here we adopt $\Delta M_K = -0.07$ and $M_{K_S} = -1.59$. Hence we obtain $(m-M)_0 = 14.38 \pm 0.03$ (stat), which corresponds to $R_0 = 7.52 \pm 0.10$ (stat) kpc. Systematic errors are summarized in Table 1, and estimated to be ±0.35 kpc.

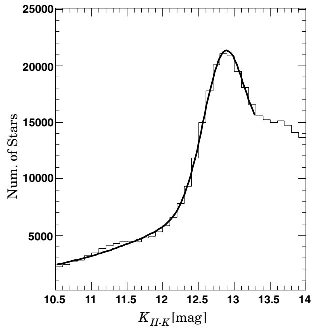

Figure 1: Histogram of the dereddened K_{H-K} magnitude for all the stars in the RC dominated region at $| l |< 1^{\circ}.0$ and $0^{\circ}.7 <| b |< 1^{\circ}.0$. Exponential and Gaussian functions are used to fit the histograms (*thick curve*).

Table 1: Systematic Error Budget

Error	Estimation (mag)
fitting the RC peak	0.03
extinction law	0.05
zero-point uncertainty	0.04
population correction	0.07
system transformation	<0.01

Our result, $R_0 = 7.52 \pm 0.10$ (stat) ± 0.32 (sys) kpc, is in excellent agreement with 7.62 ± 0.32 kpc [3] which is determined geometrically with the star S2 orbiting the super massive black hole in the Galactic center. When the population effect of RC stars is taken into account, the distances obtained in previous RC studies are consistent with this result.

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Search for Herbig Ae/Be Stars in the Magellanic Bridge

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We have found Herbig Ae/Be star candidates in the western region of the Magellanic Bridge [1].

A number of HI surveys have revealed a continuous bridge of gas between the SMC and LMC, now known as the Magellanic Bridge (MB). The MB is the closest bridge (~60kpc) among a number of known intergalactic bridges situated in groups of galaxies, and the mechanism responsible for the formation of the MB is widely considered to be gravitational influence of the LMC. The MB can thus provide us with insights into the role of external dynamical interactions in stimulating star formation. In addition, the very low metallicity of the MB was found to be ~1.1 dex lower than our Galaxy. Because of their metallicity and vicinity, the pre-main sequence (PMS) stars in the MB offer a good opportunity to study in detail the formation and evolution of individual young stars in different environments.

We surveyed about 3.°0 × 1.°3 (24° < α < 36°, –75.°0 < δ < –73.°7) in the near-infrared J,H, and K_S bands with IRSF/SIRIUS, and have detected ~ 20,000 stars in the three bands with photometric errors of 0.1 mag. Herbig Ae/Be stars show strong excess radiation at infrared wavelengths, and thus one can find them in a color-color diagram, such as $J - H$ versus $H - K_S$ diagram (Fig. 1). We selected Herbig Ae/Be candidates with the following criteria: (1) $J - H \leq 0.2$, (2) $J \geq 13.4$, (3) more than 0.1 mag apart from the OB locus, and (4) located under the line $J - H = 4.2 \times (H - K_S) - 0.23$ (see Fig. 1). As a result, we found 203 Herbig Ae/Be star candidates. A concentration of the candidates associated with a star cluster NGC796 is found, but we cannot find any other concentrations.

There could be three populations in the region where our Herbig Ae/Be candidates are distributed: Herbig Ae/Be stars, classical Be (CBe) stars, and dwarfs of O to F5 spectral type. To confirm whether Herbig Ae/Be stars exist in the MB or not, the number of contamination by them was estimated. The estimates suggest that about 60% of the 203 candidates could be contaminated by the dwarfs and CBe stars. We therefore conclude that 81 of them are Herbig Ae/Be stars after eliminating the possible contaminating sources. However, the contamination of the CBe stars depends on the frequency of the CBe stars among B-stars (see [1] for more details), and the frequency is still controversial. Therefore a more precise determination of the CBe frequency or observations to differentiate between the Herbig Ae/Be stars and CBe stars are required.

The luminosity of the candidates implies that the formation process of the Herbig Ae/Be stars in the MB is different from those in our Galaxy. Assuming that our candidates are the group III Herbig Ae/Be stars defined by Hillenbrand et al.[2], the J band magnitudes show that the candidates have masses in the range of ~10 to more than 30 $M_{\odot}$. If they are members of the group I/II, the mass range is ~ 3 to more than 20$M_{\odot}$. Higher mass PMS stars are not expected to be visible before they reach the zero-age main sequence due to obscuration by circumstellar dust envelope/disk, but the visibility may depend on the environmental condition such as metallicity. Hence our result may suggest that the environmental effect of low metallicity can be seen for the Herbig Ae/Be stars in the MB.

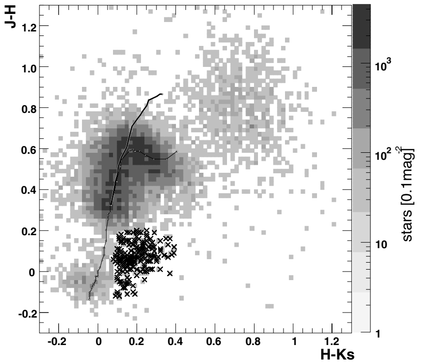

Figure 1: $J - H$ versus $H - K_S$ color-color diagram for the point sources detected in all bands with photometric error less than 0.1 mag (grayscale). *Crosses* represent Herbig Ae/Be candidates. The thin and thick curves are the loci of dwarfs and giants, respectively.

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Distribution of dust clouds around the central engine of NGC 1068

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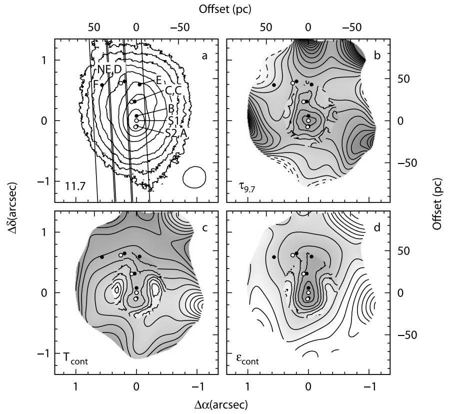

Figure 1: MIR image and grey body parameters in eq. 1. Locations of the 5 GHz sources [open circles][2] and the [O III] clouds [filled circles][3] are indicated. (a) 11.7 μm image. The straight lines show positions and widths of the three *L*-band slits. (b) $\tau_{9.7}$ map. Solid contours and darker grey scale show $\tau_{9.7} > 0$ (absorption) up to 1.5 while dashed contours and lighter grey scale shows negative $\tau_{9.7}$. (c) $T_{\rm cont}$(MIR) between 160 K (dark) and 280 K (light). (d) $\varepsilon_{\rm cont}$ shown with five contours in each dex between $10^{-1.4}$ (dark) and $10^{-3.8}$ (light). The fit for the outer region is performed on images convolved with a Gaussian of FWHM same as the original PSF (the circle in panel *a*).

We studied the distribution of dust clouds around the central engine of NGC 1068 based on shifted-and-added 8.8 – 12.3 μm (MIR) multi-filter images and 3.0 – 3.9 μm (*L*-band) spectra obtained with the Subaru Telescope [1].

From the MIR multi-filter images and the *L*-band spectra, we successfully constructed maps of color temperatures, emissivities, and optical depths of silicate and carbonaceous dust in absorption and emission in a region of 100 pc ($1''.4$) around the central peak (Fig. 1). The MIR parameters are derived with fitting the observed data to a grey body model:

$$F(\lambda) = \varepsilon_{\rm cont}\left(\frac{\lambda}{10\mu{\rm m}}\right)^{-1.6} B(T_{\rm cont},\lambda)\times e^{-\tau 9.7\times k(\lambda)}, \qquad (1)$$

where $k(\lambda)$ is the optical depth of the silicate feature obtained from the IR excess [4] and normalized at 9.7 μm. The *L*-band parameters area derived with assuming straight continuum at each position. The reconstructed parameters show the following characteristics.

First, color temperature of the MIR continuum scatters around the thermal equilibrium temperature with the central engine as the heat source while that of the *L*-band continuum is higher and independent upon distance from the central engine. Figure 2 shows the continuum temperatures at different distances.

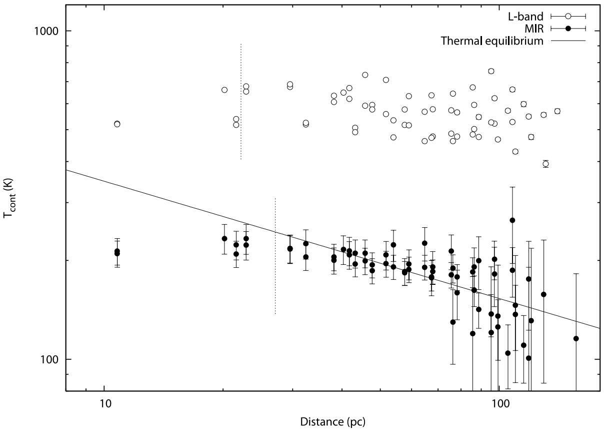

Figure 2: Color temperatures of continua measured in MIR (filled circles) and in the *L*-band (empty circles). Horizontal axis shows projected distance on the sky from the central engine. The solid line shows thermal equilibrium temperature of dust with emissivity proportional to $\lambda^{-1.6}$ and heated by a UV source of $L = 2.2 \times 10^{11} L_\odot$ [5]. The spatial resolutions of the data and contamination of light from the peak limit the color temperatures to be accurate only to the right of the vertical dotted lines.

Second, the peak of the 9.7 μm silicate absorption feature is shifted to a longer wavelength at some locations.

Third, the ratio of the optical depths of the silicate absorption feature and the absorption feature by carbonaceous dust is different from the Galactic values and show complicated spatial distribution.

Fourth, there is a pie-shaped warm dust cloud as an enhancement in the emissivity of the MIR continuum extending about 50 pc to the north from the central engine (Fig. 1d). We speculate that material falls into the central engine through this cloud.

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Abundances of metal-poor star HD 122563

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The chemical composition of metal-poor stars is expected to reflect the yields from a quite small number of nucleosynthesis events (or possibly a single event). Many observational studies for metal-poor stars have shed light on the understanding individual processes in the universe. However, mechanism and astrophysical sites of the r-process, which synthesizes elements heavier than the iron, is still not well known. Previous observations have shown that the abundance patterns of the heavy neutron-capture elements ($Z \geq 56$) agree well with the solar-system r-process pattern [1], but this is not the case for lighter ones; that is, a large abundance scatter exists in such elements [2].

Our recent observations revealed that a correlation exists in light neutron-capture element Sr (Z=38) and heavy neutron-capture element Ba (Z=56) [3]: There is no Ba-rich star having very low Sr abundance, while a large scatter of Sr abundances is only found in Ba deficient stars. This result suggests the existence of a process mainly yielding Sr (we here call this “weak-r process” [4]), which is separated from the “main r-process” that yields Sr and Ba in similar proportions.

In order to clarify the weak r-process observationally, we observed a star having high Sr/Ba ratio with the Subaru/HDS, which presumably reflects the weak r-process strongly, to investigate neutron-capture elements in detail [5]. We selected the bright metal-poor star HD 122563 ([Fe/H]=–2.8) to obtain the near-UV spectrum (3070–4780Å) where many lines of neutron-capture elements exist. Though observing this range with ground-based telescopes is difficult, the S/N ratios of our spectra are 480 at 3500Å and 1300 at 4500Å with resolving power of about 90,000.

We have determined abundances of 19 neutron-capture elements, and upper limits for five other elements. Nb, Mo, Ru, Pd, Ag, Pr, and Sm are detected for the first time for this object by this observation. A comparison of the derived abundance pattern with the r-process pattern of solar-system (Figure 1) reveals that the light neutron-capture elements (Sr- Zr) show very large excesses compared to heavy ones like Ba, La, and Eu. The abundances of elements with intermediate mass (Z = 41 ~ 47), which are determined by our study for the first time, show a continuous decrease with increasing atomic number. This trend is not expected from usual r-process models in which a rapid drop of abundances from Zr to heavier elements reflecting the nature of neutron magic number. Further theoretical work is required to reproduce the observed abundance pattern.

Such a decreasing trend of the abundances with increasing atomic number is also seen in the heavier elements than Ba. This differs from the abundance pattern found in r-process rich metal-poor stars so far, possibly reflecting the process that produced light neutron-capture elements abundance in the early Galaxy.

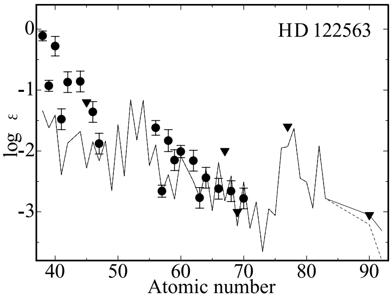

Figure 1: Abundances of HD 122563 compared to the scaled solar system r-process pattern (normalized at Eu).

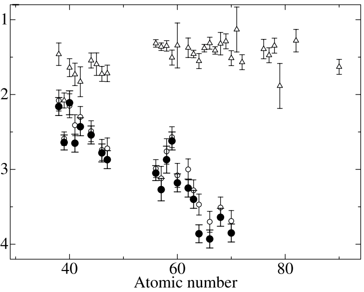

Figure 2: Logarithmic differences from the solar system r-process pattern. The open triangles mean the abundances of r-rich star CS 22892-052, while the open and filled circles mean those of HD 122563 and HD 88609, respectively. The difference of the abundance patterns of HD 122563 and HD 88609 from the solar r-pattern become larger with increasing atomic number.

A similar abundance pattern is recently found in another metal-poor star [6], indicating that HD 122563 is not a unique object, and that the observed abundance patterns give strong constraints on the future modeling.

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Project “Origin of Milkyway”

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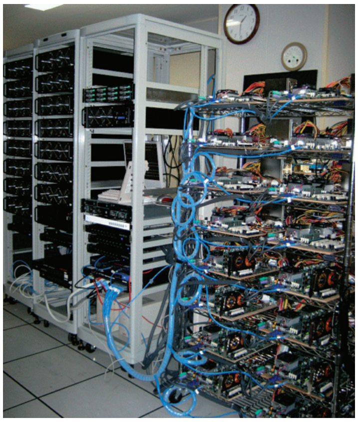

Figure 1: Photo of our clusters. Left side two 19-inch racks hold 16 nodes, where each node consists of an Opteron 250 CPU and a GRAPE-7. The aluminum rack in the right side holds other 16 nodes, where each node consists of two Opteron 244 CPUs without any GRAPEs. Gateway, file server, network switches are installed between the two clusters.

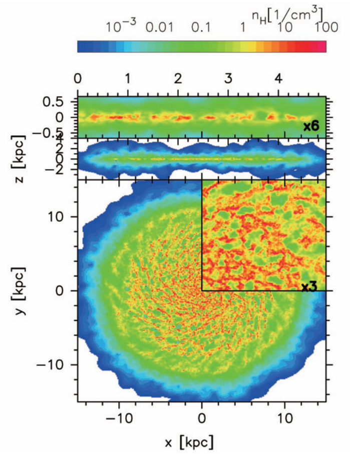

Figure 2: Gas density map. Advanced numerical resolutions and more realistic and acceptable star formation conditions allow us to observe complex structures in our interstellar matter. Previous simulations on galaxy formation can not resolve such a fine structures in their models.

The scientific goals of the project “Origin of Milkyway” are to reveal (1)the formation processes of the stereostructure of Milkyway, (2)the origin of variety in the morphology of galaxies, and (3)the origin of the correlation between super massive BHs and their host galaxies, using ultra high resolution simulations of galaxy formation including small scale physics. In order to archive the state-of-the-art simulations, we adopt special purpose computers, namely GRAPEs, and we develop a special simulation code which brings out the performance of GRAPEs. See [1] for more details.

In previous numerical simulations on galaxy formation, special resolution is ~kpc and mass resolution is ~ $10^{5-6} M_\odot$. Number of mass elements in a galaxy is only ~ 10^4. As a result, it is difficult to reproduce exact mass-assembly histories with the bottom up nature in currently favored cosmology and fine structures appeared in interstellar matter. The only way to reveal complex formation processes on galaxy formation is to increase number of mass elements in a galaxy.

Until now, we have developed two PC-clusters: *Amanogawa Zerogo-ki* (Intel Xeon 3.6 GHz dual × 4) and *Amanogawa Syogo-ki* (AMD Opteron 250 single 2.4GHz ×16 + Opteron 244 dual × 16 + GRAPE-7 × 24). We are developing and testing our parallel simulation code on these clusters.

We investigate a new set of star formation conditions suitable for high-resolution simulations to resolve molecular clouds. The results of simulations are summarized as follows:

1. A thin gas disk with inhomogeneous, multiphase structures is successfully formed.
2. Our models reproduce observational relation, that is Kennicutt-Schmidt relation. The choice of the star formation efficiency has a minor effect on the star formation in our models.
3. The time scale of the mean mass transfer from diffuse region to dense region is very slow, and it determines global star formation rate.

We are now preparing new simulations of galaxy formation with our new star formation recipe.

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Periodic Vortex Shedding from a 12-m Antenna

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Figure 1: Three ALMA prototype 12-m antennas (front) at the NRAO VLA site. The NAOJ antenna (left) was used for the measurements. Two 25-m antennas (back) are element antennas of the VLA.

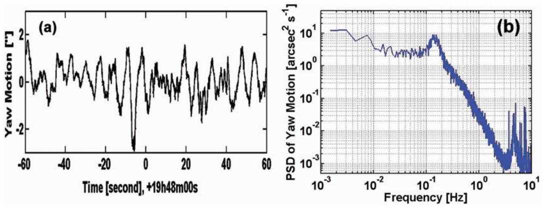

Figure 2: (a) A time history of yaw motion of the elevation axis for two minutes in the wind of 9 m s^{-1}. (b) A mean PSD of yaw motion of the elevation axis for three hours shows an enhanced component near 0.15 Hz.

The von Karman vortex sheet is a famous flow pattern which forms in the wake of a rough body for a given range of Reynolds numbers. In nature, this pattern shows up wonderfully on oceanic stratocumulus cloud decks in the wake of an isolated island as shown in pictures taken from satellites. A similar turbulent flow has been found to take place around the NAOJ 12-m parabola antenna for the ALMA project during performance tests carried out at the NRAO VLA site (Fig. 1).

Figure 2a shows a time history of yaw motion of the elevation axis derived from the displacement of the bearing housings measured with linear gauges mounted on a reference frame structure built in each side of the yoke. The measurements were made in the wind of 9 m s^{-1}, and the Reynolds number was 6×10^6. Figure 2b displays a power density spectrum (PSD) of the yaw motion in which an enhanced component is discernible at 0.15 Hz. The same periodicities have also been observed in both the wind direction and wind velocity measured with a 3D ultrasonic anemometer in the wake downstream of the antenna (Fig. 3). Such periodicities have been seen in neither rotation of the elevation axis nor vertical wind velocity. These observations suggest that there is a large scale, periodic flow pattern in the wake, possibly a large eddy, and that the oscillatory lateral force by shedding vortices exerts on the antenna to make the yaw motion.

Our field measurements have determined some basic wind engineering parameters for a parabola antenna. From measured periodicity, the Strouhal number has been determined to be 0.19, which is comparable to those of cylinder, inverse triangle, and other similar geometric shapes. From an observed amplitude of yaw motion and torsional rigidity of the yoke structure, an amplitude of torque variation has been estimated to be 2,100 Nm. We have found that oscillatory lateral force per unit area on the antenna is equal to the stagnation pressure of the upstream wind, namely the shape coefficient, C_k , is 1. It is interesting to note that the C_k for a cylinder is also 1 for a wide range of the Raynolds number, $10^2 – 10^{-7}$.

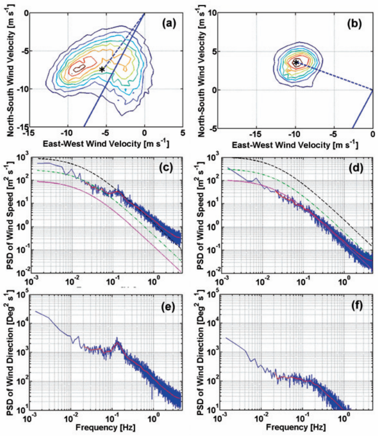

Figure 3: Wind velocity vector distributions, mean PSDs of wind speed, and wind direction in the wake downstream of the antenna (a), (c), (e), and in the undisturbed wind, (b), (d), and (f). Star marks (*) indicate mean wind velocities, broken lines the wind directions, thin lines the directions of the antenna from the anemometer. Solid lines in (c) and (d) indicate a PSD of Simiu wind model of 9 m s^{-1} for an open terrain, dashed line for 3*Simiu, and broken lines for 10*Simiu.

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Discovery of Hα Absorption in the Broad Absoprtion Line Quasar SDSS J0839+3805

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During our search for low ionization broad absorption line quasars and iron low ionization broad absorption line quasars by visual inspection of ~ 4800 spectra between redshifts of 2.1 and 2.8 in the Sloan Degital Sky Survey (SDSS), we found an unusual BAL quasar, SDSS J0839+3805. Figure 1 shows its rest UV spectrum from SDSS data. It shows many absorption lines from Fe II, Zn II, Cr II, and Si II. Since the Lyα emission line is narrow and there are no broad emission lines in the rest UV spectrum of SDSS J0839+3805, we carried out nearinfrared spectroscopy in order to examine properties of the Hβ and Hα emission lines.

We discovered Hα absorption in the broad Hα emission line (Fig. 2) through near-infrared spectroscopy with the Cooled Infrared Spectrograph and Camera for OHS (CISCO) on the Subaru telescope [1]. The presence of non-stellar Hα absorption is known only in the Seyfert galaxy NGC 4151 at that time [2]; thus, our discovery is the first case for quasars. The Hα absorption line is blueshifted by 520 km s^{-1} relative to the Hα emission line, and its redshift almost coincides with those of UV low-ionization metal absorption lines. The width of the Hα absorption (~ 340 km s^{-1}) is similar to those of the UV low-ionization absorption lines. These facts suggest that the Hα and low-ionization metal absorption lines are produced by the same low-ionization gas, which has a substantial amount of neutral gas. The column density of the neutral hydrogen is estimated to be ~ 10^{18} cm^{-2} by assuming a gas temperature of 10,000 K from the analysis of the curve of growth.

Furthermore, the UV spectrum of SDSS J0839+3805 shows a remarkable similarity to that of NGC 4151 in its low state, suggesting that the physical condition of the absorber in SDSS J0839+3805 is similar to that of NGC 4151 in the low state. As proposed for NGC 4151, SDSS J0839+3805 may also be seen through the edge of the obscuring torus.

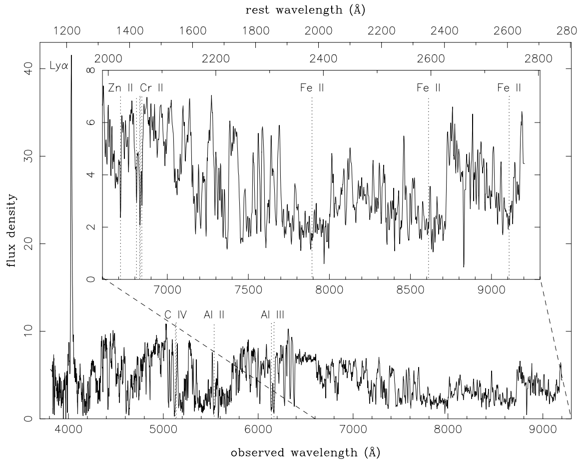

Figure 1: Observed spectrum of SDSS J0839+3805 in the SDSS. Ordinate is a flux density, and abscissa is the observed wavelength. The rest wavelength is given along the top axis. Dotted lines show the wavelengths of the absorption lines.

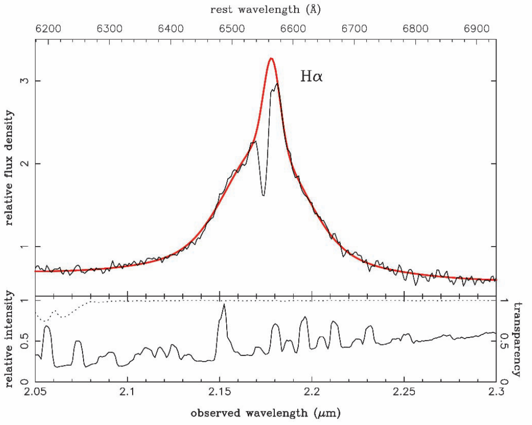

Figure 2: Top: K-band spectrum of SDSS J0839+3805. Ordinate is a relative flux density, and abscissa is the observed wavelength. The rest wavelength is given along the top axis. The Hα emission is fitted with three Gaussians. The best fit is shown as a red solid line. Bottom: The sky emission spectrum (solid line) and the atmospheric transmission curve (dotted line).

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Polarization Differential Objective Spectroscopy with a Nulling Coronagraph

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Direct detection of exoplanets is very challenging in that it simultaneously requires extremely high dynamic range, high spatial resolution, and high sensitivity. For high-contrast imaging, the light from a parent star must be suppressed so that a planetary signal can be distinguished from the undesirable stellar noise. A nulling stellar coronagraph with a four-quadrant phase mask (FQPM) is one of the most promising concepts [1]. To achieve achromatic deep nulling, we proposed a polarization interferometric stellar coronagraph using a four-quadrant polarization mask (FQPoM), and have successfully demonstrated over a broad wavelength range [2]. In principle, the FQPoM coronagraph has the ability to realize perfect elimination of the stellar light. However, various factors (manufacturing errors in the FQPoM, finite angular size of a star, surface roughness of optical elements etc.) generate residual stellar noise. For further suppressing the residual noise, we also proposed a polarization differential imaging (PDI), which extracts a partially polarized planetary signal from unpolarized residual stellar noise [3].

We report the laboratory demonstrations of spectroscopic observations using the FQPoM coronagraph and the PDI testbed. Figure 1 shows an optical setup. The light from a halogen lamp (planet model) is made to produce an artificial absorption line by using the reflection from an interference filter. Three tilted glass plates are used to simulate a partially polarized planetary signal. The light beams of the stellar and planetary models are led to the polarization modulator (liquid-crystal variable retarder, LCVR) for the PDI, FQPoM coronagraph, and objective spectrometer.

Figure 2 shows the experimental results. The planet/star intensity ratio is 8×10^{-5}, and their angular separation is 3.2 λ/D. A degree of polarization of the planet model is about 50%. The images on the left are the FQPoM coronagraphic images (a,b) before and (c) after the differentiation. The graph on the right shows their objective spectra recorded at the position of the planet model. In this graph, the dip caused by the artificial absorption can be seen around λ = 630 nm. Plot (d) is the differential spectrum created by using only the planet model (ideal differential spectrum of the planet model). The deviation from the ideal spectrum can be observed in particular in the short-wavelength (λ < 560 nm) and long-wavelength (λ > 650 nm) regions. This is because the residual stellar noise contaminates these spectral regions. We suppose that the residual noise is mainly caused by the slight displacement of the image (estimated to be about 0.01 λ/D) when modulating the polarized light using the LCVR.

The obtained differential spectrum ideally corresponds to the Stokes $Q(\lambda)$ parameter. We expect that observations of accurate $Q(\lambda)$ [and $U(\lambda)$] parameters of exoplanets will enable us to obtain a clearer knowledge of planetary atmospheres.

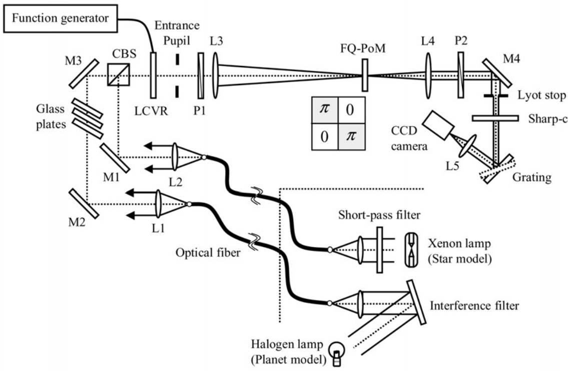

Figure 1: Optical setup for polarization differential spectroscopy with FQPoM coronagraph.

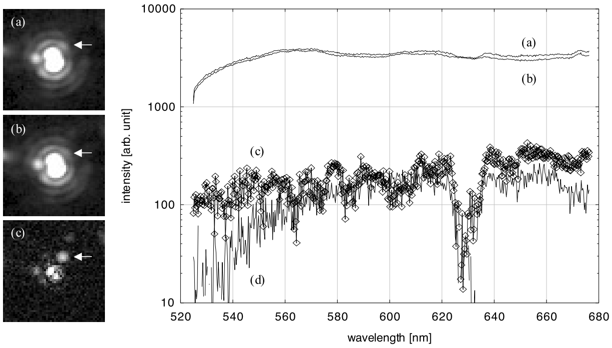

Figure 2: (Left) Acquired coronagraphic images (a,b) before and (c) after differentiation. (Right) Objective spectra of these coronagraphic images at the position of the planet model.

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High-Resolution Studies of the Dense Molecular Cores toward Massive Star-Forming Regions

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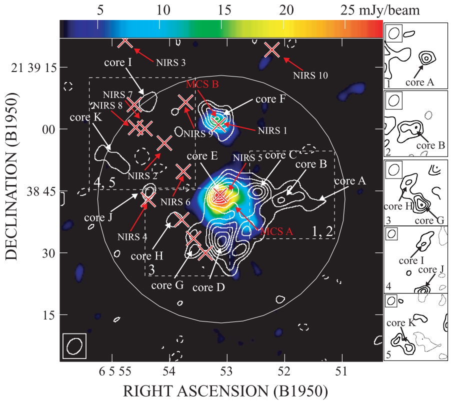

Figure 1: Color images of the 110 GHz continuum emission overlaid with contours of $C^{18}O$ (J=1–0) emission. Contour levels are from 3 σ in steps of 2 σ. 1 σ noise levels are 13 mJy. Three dashed squares denote the area of five right panels. Five right panels: (1, 3, 4, 5) 1 σ = 30 mJy, (2) 1 σ = 20 mJy). The integrated velocity ranges are (1,3) 3.0–4.0 km s^{-1}, (2) 4.0–5.5 km s^{-1}, and (4) 1.6–2.6 km s^{-1}.

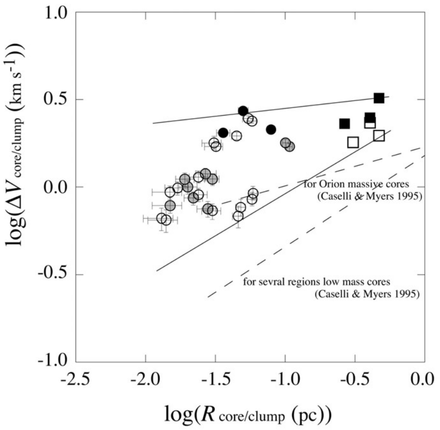

Figure 2: The correlation between the radius and the line width of the cores. The circles and squares are the cores and the clumps identified by [1], respectively. The black and grey filled marks are the objects with massive star formations and NIR sources, respectively. The solid lines are the maximum and minimum index of the line width-radius relation, respectively.

We report the results of an imaging of dense molecular cores in three cluster-forming regions, IRAS 02461+6147, IRAS 03035+5819, and IRAS 06058+2138, by the Nobeyama Millimeter Array.

In these cluster-forming regions, there are massive (proto)stars with the high luminosity of 1–5 × $10^4 L_\odot$ and the massive dense clumps, which have a mass of ~ $500 M_\odot$, a radius of ~ 0.3 pc, and a line width of ~ 2.5 km s^{-3}, are identified by [1]. The goal of the present observation is to reveal the inner structure of the dense gas in the clumps with the cluster formation including massive (proto)stars.

Most of the recent observations toward the massive star-forming regions have focused on the identification of hot cores, which have a luminosity larger than $10^4 L_\odot$ and temperatures of 100 K or higher [2]. Due to these characteristics, it has been suggested that hot cores contain massive (proto)stars. However, hot cores are unlikely to keep a physical feature of the earlier stage of evolution, just before the formation of massive (proto)stars, i.e., a cold core. It is therefore important to identify and study cold cores in appropriate molecular lines.

We have observed toward three cluster-forming regions using the $C^{18}O$ molecular line, which can detect the cold cores, and we have identified 28 dense cores and four thermal dust millimeter continuum sources (MCSs) (Fig. 1). The mass, effective radius, and line-width of these cores range from 2.1 to $29 M_\odot$, from 0.013 to 0.108 pc, and from 0.7 to 2.7 km s^{-1}, respectively.

Sevral cores with various line widths exist in one clump, and we found that the index of the radius–line width relation is difference form cores to cores in one clump (Fig. 2). In addition, we divide the $C^{18}O$ cores into two types, a turbulent core and a non-turbulent core. The non-turbulent cores are similar to the typical cores in the low-mass star-forming regions. On the other hand, the turbulent cores have a higher average H_2 density than those of the non-turbulent cores and the external pressure of these cores is 100 – 1000 times higher than that of low-mass star-forming regions. In particular, three of the turbulent cores are associated with massive protostar candidates and the intensity peak of MCS. From these results, we suggest that massive stars are formed from the turbulent cores which are gravitationally bound. This suggestion is consistent with the theoretical suggestion by [3]. In addition, in order to form such a turbulent core in a molecular cloud, the molecular must has a large kinetic motion and a large mass.

The observation of the cores in the clump with the cluster formation is in progress by the Nobeyama Millimeter Array.

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Improvement of Gravitational Wave Detector TAMA300 by the Seismic Attenuation System (SAS)

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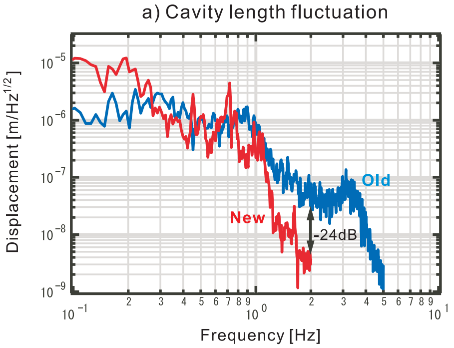
We started installation of the Seismic Attenuation System (SAS) in 2005 in order to improve the vibration isolation system in the interferometer gravitational wave detector TAMA300. The second SAS, which was installed at the east-west front (NM1) in June, 2006, formed a 300-m cavity with the SAS at the west end (EM1) installed in 2005. Length fluctuation of the cavity measured by feedback signals to lock the cavity showed the improvement of –24dB at 2 Hz as compared with old suspensions (Fig. 1a). We confirmed the improvement of –25dB at 3 Hz on angular fluctuations too (Fig. 1b). As a result, we expect the bandwidth of the alignment control feedback is set to be lower than 5 Hz. This will result reduction of the noise due to the alignment control system which limited the former sensitivity of TAMA300. Then followed the installation of two SASs to the north-south arm in October and November. We could lock the interferometer with four SASs in March, 2007 successfully. There the east-west arm cavity was locked by actuating the laser frequency for stabilization of the light source, while the north-south arm cavity was locked to this stabilized light by actuating the mirror of the north-south front (NM2). The basic behavior of the interferometer with SASs was confirmed.

The natural frequencies of the inverted pendulum (IP), which characterize quality of each SAS, are shown as follows. Most of the horizontal modes (X and Y) were tuned to be lower than 100mHz except for EM1 in which asymmetry of elastic spring components of the IP caused the large splitting of the modes. Frequencies of rotational mode (θ) are about 0.5 Hz.

	X [mHz]	Y [mHz]	θ[Hz]
NM1	50	60	0.50
EM1	150	50	0.54
NM2	30	60	0.52
EM2	50	70	0.50

There are two kinds of control system for the SAS. Each system is handled by a digital instrument using an all-purpose CPU (Pentium) + RTOS. One is the IP control system which feeds back signals of acceleration sensors and LVDTs (position sensors) on the top of SAS to actuators for the IP. Scince the lower stage is suspended by a single wire from the IP, it has a torsion mode at ~ 50 mHz. The system also damp this torsion mode using a differential photo sensors and the actuators for the IP. The other is the PF-TM control system which feeds back signals of mirror rotation (Pitch and Yaw) detected by local optical levers to actuators for the mirror. After the 300-m cavity is locked, the sensing signals are changed to global signals acquired by the Wave Front Sensing (WFS) method from the interferometer.


a) Cavity length fluctuation

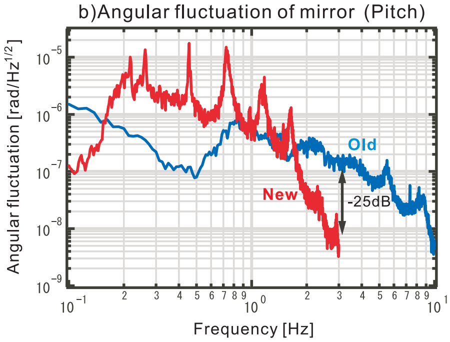

b)Angular fluctuation of mirror (Pitch)

Figure 1: Improvement of the vibration isolation system. Old suspension and New SAS are shown.

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Giant Molecular Association in Spiral Arms of M 31: Evidence for Dense Gas Formation via Spiral Shock Associated with Density Wave ?

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We present the observations of ^{12}CO(J = 1 – 0), ^{13}CO(J = 1 – 0) and ^{12}CO(J = 3 – 2) emissions toward a GMA in the southern spiral arm of M 31 using Nobeyama 45-m and ASTE 10-m telescopes [1].

Spiral arms are the most striking structures in disk galaxies and a major site of massive star formation. Spiral arm, i.e., density waves, seem to enhance the star and dense gas formation due to the accumulation and/or compression of gases. On the other hand, it is well established that molecular gases in spiral arms show very large structures, which are often referred to as Giant Molecular Associations (GMAs). Observational studies of GMAs in galaxies provide us with invaluable clues on the physics that governs the large scale star formation in the disk regions of galaxies.

It is difficult to achieve this by observations of rather “distant” galaxies using current mm-wave facilities due to their limitation on the angular resolutions and sensitivities. The best method of overcoming this limitation is make very wide-area observations of molecular lines in very nearby galaxies; M 31, the nearest massive spiral galaxy at a distance of 0.69 Mpc, is a suitable target for this purpose.

The observed region is 3′ × 4′ (0.6 kpc × 0.8 kpc) with resolutions of 16″ – 17″ for ^{12}CO(J = 1 – 0) and ^{13}CO(J = 1 – 0). We obtained a 1.′2 × 1.′4 wide ^{12}CO(J = 3 – 2) map with a resolution of 23″. The GMA has a size and mass of a few 100 pc and $5.6\times10^6 M_\odot$, respectively. The ^{12}CO(J = 1 – 0) to ^{13}CO(J = 1 – 0) integrated intensity ratio ($R_{12/13}$) and the ^{12}CO(J = 3 – 2) to ^{12}CO(J = 1 – 0) integrated intensity ratio ($R_{3-2/1-0}$) averaged over the entire region of the GMA are ~ 10 and 0.3, respectively. These line ratios suggest gas densities of (3 – 6) × 10^2cm^{-3} at a temperature of 15 – 25 K, which are similar to or slightly larger than those of GMCs in Galactic disk. We found a radial gradient of $R_{12/13}$ within the GMA, over a range from 6 at the center of the GMA to 14 at the edges of the GMA. The distribution of $R_{12/13}$ shows a smooth structure with an overall density gradient.

The GMA consists of two velocity components, blue (~ –505 km s^{-1}) and red (≥ –490 km s^{-1}). In Both the ^{12}CO(J = 1 – 0) and ^{13}CO(J = 1 – 0) profiles, the blue component shows a strong peak intensity and narrow velocity width, while the red component is weaker and wider. $R_{12/13}$ of the red components is 5, which is smaller than that of the blue one (16), indicating the red component has a higher gas density. By considering the direction of galactic rotation in this region, we suggest that the red component is the “post-shock” dense gas decelerated by shock due to the density wave.

References

[1] Tosaki, T., et al.: 2007, *PASJ*, **59**, 33.

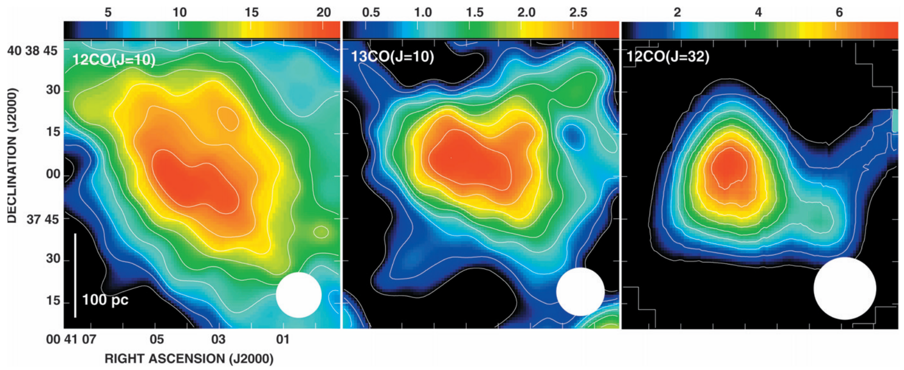

Figure 1: Integrated intensity maps of ^{12}CO(J =1–0) (left) and ^{13}CO(J =1–0) (middle) by NRO 45-m telescope, and ^{12}CO(J =3–2) (right) by ASTE.

MOIRCS Deep Survey : DRG Number Counts

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MOIRCS GTO team is carrying out a deep imaging survey with Subaru/MOIRCS in the GOODS-North region. Our main objectives are 1) to search LBGs and Lyα emitters at $z > 7$ and 2) to investigate the histories of star formation and mass assembly of galaxies at $1 < z < 4$. Here we present the result of the study of the number counts of Distant Red Galaxies (DRGs) with $J - K$(Vega)> 2.3 down to $K = 23$ [1].

We observed one field of view of MOIRCS (4 × 7 arcmin^2) in the GOODS-North region. Our data reached J =24.6, H = 22.8 and K =23.2 (5σ limit, Vega system) with the FWHM of 0.42 arcsec for the point source. We used the deep J and K-bands images to investigate the number counts of DRGs. About 90 DRGs were detected in our field of ~24.3 arcmin^2.

Figure 1 shows the number counts of DRGs in our field. The number counts of DRGs turn over at $K \sim 22$, while the number counts of all K-selected objects continue to increase to at least $K \sim 23$. The number counts of DRGs in our field agree well with those in other general fields at $K < 22$ (the bottom panel). The dashed line in the figure shows the result of the linear fit for the counts of DRGs at $K < 22$ in our and other general fields. When we extrapolated this linear line to $K \sim 23$, the surface density of the faint DRGs with $K > 22$ in our field was clearly deficient. The density in the $22.5 < K < 23$ bin is about a factor of three lower than that expected from the number counts at a brighter magnitude.

At $K > 22$, only HDF-South data [2] have a sufficient depth and can be used for a comparison with our data. The number counts in HDF-South do not show a decrease at $K > 22$, but are still consistent with our results within the uncertainty. Since DRGs show a strong angular clustering (Fig. 2), however, the small survey areas of the HDFs could introduce large uncertainty and a wide area survey is essential for these galaxies.

While the number density of DRGs at $2 < z < 4$ decrease at $K > 22$, bluer galaxies with $J - K < 2.3$ at the same redshift range do not show a similar decrease but continue to increase to $K \sim 23$ [1]. These results suggest that the mass-dependent color distribution, where most of the low-mass galaxies are blue, while more massive galaxies tend to have redder colors, had already been established at that epoch.

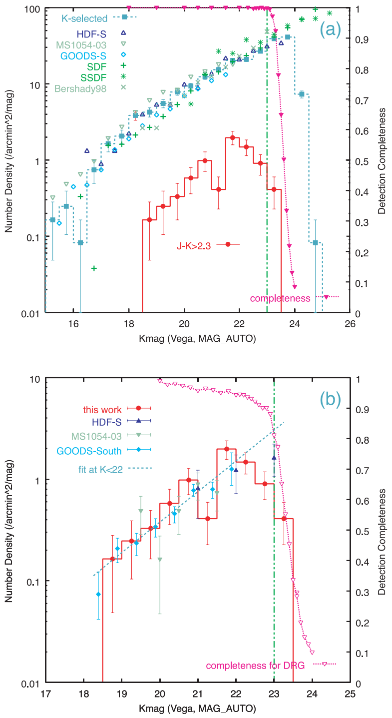

Figure 1: Number counts of DRGs in MOIRCS Deep Survey field. Top: the number counts of all K-selected objects (green squares) and DRGs with $J - K > 2.3$ (red circles). Bottom: comparison of DRG number counts with other general fields. Dashed line shows a linear fit for the data points at $K < 22$.

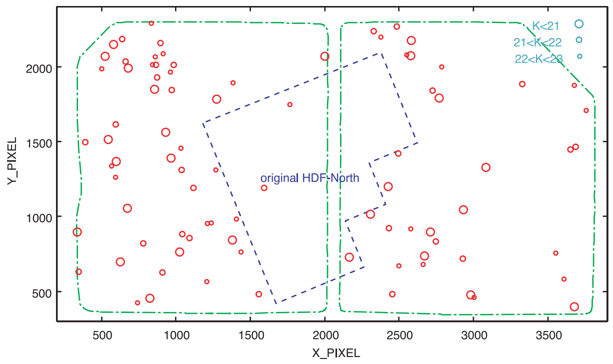

Figure 2: Spatial distribution of DRGs in MOIRCS Deep Survey field. The size of symbols is scaled according to apparent K-band magnitude. The dashed line show the region of the original HDF-North.

Reference

[1] Kajisawa, M., et al.: 2006, *PASJ*, **58**, 951.
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Protocluster Search around Radio Galaxies at $z \sim 2.5$ with Subaru/CISCO

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We report the discovery of protocluster candidates aroundhigh-redshift radio galaxies at $z \sim 2.5$ on the basis of clear statistical excess of color-selected galaxies around them seen in the deep near-infrared imaging data obtained with Subaru/CISCO [1].

From many previous studies, it appears that major star formation in bright cluster galaxies was virtually completed by $z \sim 2$. Therefore it is important to search protoclusters up to $z > 2$ in order to directly see the forming phase of these galaxies. It is not an easy task, however, since it requires a large volume to survey in order to find such rare objects.

We performed the *JHK*-bands imaging observations of the fields of the six radio galaxies at z~2.5 with Subaru/CISCO. High-z radio galaxies are expected to point us towards protoclusters, since they are among the most massive galaxies at any redshift, and in fact powerful radio galaxies at intermediate redshift tend to inhabit rich environment. We make use of our NIR multicolor photometric data in order to effectively pick up plausible protocluster members at $z \sim 2.5$ associated with the central radio galaxies. In addition to $J - K > 2.3$ (DRG selection), we apply a new color cut of $J - K > 2.5 \times (H - K) + 0.5$ & $J - K > 1.5$, using *JHK*-bands data (Fig. 1). This two-color-based selection has several advantages over DRG selection: (1) younger or star-forming galaxies with relatively bluer $J - K$ color at $z \sim 2.5$ can also be sampled, (2) this selection isrobust against dust extinction, (3) most of cool M, L and T dwarfstars can be excluded.

Over the range of $19 < K(\text{Vega}) < 21.5$, we see a significant excess of these color-selected galaxies by a factor of about 2 (for DRGs) or 3 (for *JHK* selection) around the radio galaxies fields compared to those found in the general field of GOODS-South (Fig. 2). In particular, two radio galaxies (4C –00.62 & 4C +23.56) fields show very strong density excess (factor of 5 excess of *JHK*-selected galaxies, see right panel of Figure 2), and these are likely to be protoclusters associated with the radio galaxies.

Figure 3 shows $J - K$ versus K CM diagrams of the 4C – 00.62 field. The *JHK*-selected galaxies in this field tend to be relatively bluer than the expected CM relation (red line in the figure) calculated from the passive evolution (0.1 Gyr single burst) model with $z_{\text{form}}=5$. These galaxies might have been shifting from the actively star-forming phase to passively evolving phase at the observed epoch. Using such a useful NIR color-selection technique, we expect to be able to understand how the CM relation of galaxies formed in protoclusters in the early universe.

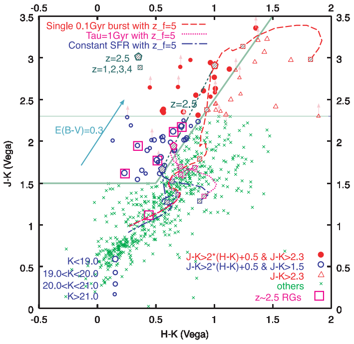

Figure 1: Combined *J–K* vs *H–K* color-color diagram of all the six radio galaxies fields. The thick line and horizontal thin line shows the boundaries of our two-color selection with *JHK*-bands and DRG selection, respectively. Different symbols correspond to our different color selections (Circles show *JHK*-selected galaxies, and their red and blue colors represent their *J–K* colors).

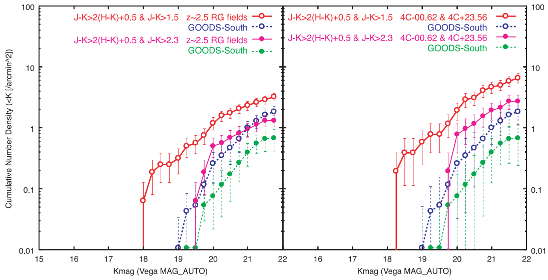

Figure 2: Combined cumulative number counts of *JHK*-selected galaxies in the radio galaxies fields (red) and those in a controlled field GOODS-South (blue). Solid symbols show red *JHK*-selected galaxies with *J–K*>2.3. (left): for all the six radio galaxies fields. (right): for only the two most plausible protoclusters of 4C – 00.62 & 4C +23.56.

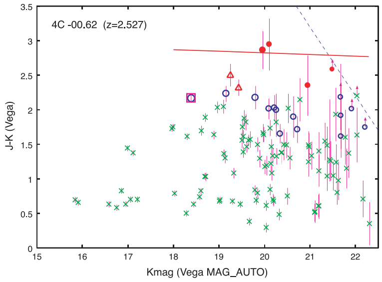

Figure 3: *J–K* vs *K* CM diagram of 4C –00.62 field. Different types of symbols differentiate the adopted color selections as indicated in Figure 1. The red line shows the expected CM relation at z~2.5 calculated from the 0.1 Gyr single burst model $z_{\text{form}}=5$.

Reference

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^{12}CO(J =3–2) Line Observation of Elliptical Galaxies

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We report ^{12}CO(J =3–2) observations of 15 nearby elliptical galaxies carried out with the ASTE telescope[1].

Cold interstellar medium (ISM) is a minor component of elliptical galaxies. ISM present in ellipticals is thought to result from stellar mass loss or accretion from outside. It is difficult to study such mechanisms from ISM observations for spiral galaxies because they contain much ISM from early stages of galaxy formation. Cold ISM observation for elliptical galaxies is crucial for such a study.

Several surveys have been made using the CO(1–0) and CO(2–1) lines (e.g., [2]). However, all of these studies have concentrated on ellipticals which are detected at 100 microns by IRAS, and are therefore biased. This study examines whether there is a difference in results, selecting objects without regard to the presence of other tracers of cold interstellar matter.

The observed galaxies were 13 elliptical galaxies lying in the right ascension range 22h – 7h and between declinations of –30 degrees - +20 degrees, and having recession velocities less than 5000 km s^{-1}. No other criterion was used for thirteen of the galaxies, so they are unbiased. In addition, NGC 855 and NGC 2328 were observed to compare with CO(1–0) and CO(2–1) data. Fifteen ellipticals were observed.

We carry out observations with the ASTE, 10m antenna located in the Atacama Desert in Chile on August 21–24 2006. Observed line was ^{12}CO(J =3–2) (345GHz). The spectra were smoothed by 46 channels to a velocity resolution of 19.8 km s^{-1}. The typical rms noise levels, $\Delta T_{\rm MB}$, for the smoothed spectra were 8 mK.

The spectra for fifteen observed galaxies are shown in figure 1. We detected CO(3–2) emission from three galaxies, all for the first time. Two of them are undetected by IRAS at 100 microns.

Comparisons with CO(2–1) and CO(1–0) data give line ratios of CO(3–2)/(1–0)=0.5 and CO(2–1)/(1–0)=0.8. We calculated line ratios using the Large Velocity Gradient (LVG) model, and found that H$_2$ density was $3\times 10^2 - 1\times 10^3$ cm^{-3} in the temperature range of 15 – 100 K. The molecular gas masses were estimated to be $2.2\times 10^6 - 4.3 \times 010^8$ $M_\odot$. These values are consistent with former researches (e.g., [2])

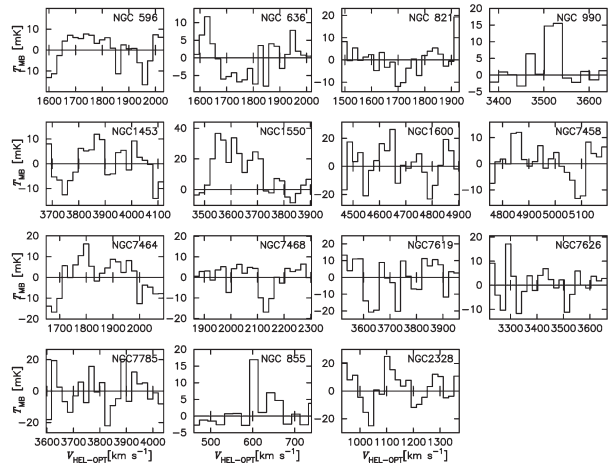

Figure 1: CO Spectra of the observed elliptical galaxies.

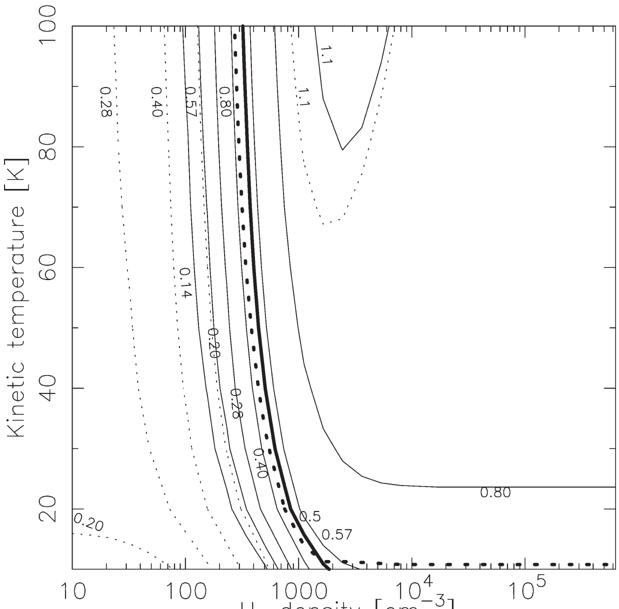

Figure 2: Relationship among density, temperature and line ratios derived by LVG calculations. The solid and dotted lines denote R_{31} and R_{21}, respectively. The thick lines denote values for NGC855.

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Torsionally Excited Methyl Formate in Orion KL

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Methyl formate ($HCOOCH^3$) is one of the molecules with dense rotational spectral lines, and more than 500 lines in the ground state have been detected in space [1]. It has an internal rotation of the methyl group ($-CH_3$) as shown in Figure 1.

Large saturated organic molecules like methyl formate are often found in hot cores in massive star-forming regions. In such hot regions, it is probable that torsional motion of the methyl group is excited, because the energy of the tortional motion is generally not large. Rotational transitions in the torsionally excited state have already been detected for methanol (e.g., [2]).

There are many radio signals whose origin is unknown and efforts to identify these signals are under progress. Recently researchers in the University of Toyama succeeded to assign laboratory spectra of methyl formate in the first torsionally excited state [3,4]. This success made it possible to compare with the data observed with radio telescopes.

This time we report a successful assignment of unidentified lines in Orion KL to the first torsionally excited methyl formate [5]. We have assigned 7 unidentified lines from previous line surveys around 97 GHz with Nobeyama 45 m radio telescope [6] to this excited state. In addition, at least 13 lines from other line surveys were also identified.

The temperature and the column density in the first torsionally excited state of this molecule were calculated to be 44±10 K and (8.6±3.2) $\times 10^{14}$ cm^{-2}, respectively, using a rotation diagram method. The temperature obtained is similar to those of the ground state, but our column density is rather high, considering that methyl formate is in the first torsionally excited state. The diagram is shown in Figure 2.

It is quite likely that many remaining unidentified lines can be explained by this kind of organic molecules in the torsionally excited states.

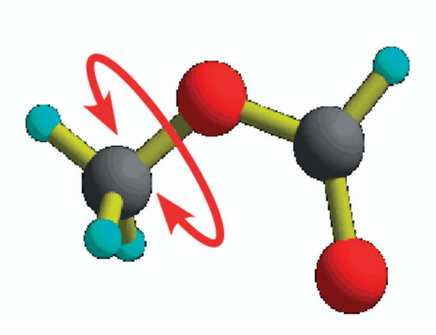

Figure 1: Molecular structure of methyl formate is schematically shown. The internal rotation of the methyl group ($-CH_3$) is indicated with a red arrow.

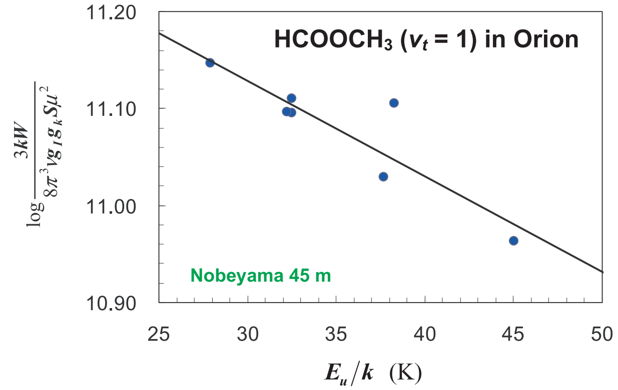

Figure 2: Rotational diagram for methyl formate in its first torsionally excited state. The data used are obtained with Nobeyama 45 m radio telescope [6]. The upper-state energy E_u/k was set to relative value to the lowest rotational state of methyl formate in this excited state.

References

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Universality of the γ-process in core-collapse supernovae

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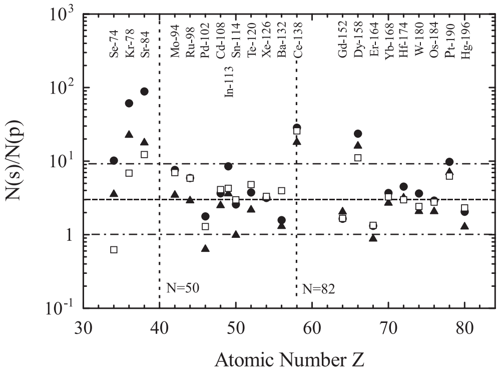

Figure 1: Calculated ratios of an s-nucleus to a p-nucleus, $N(\mathrm{s})/N(\mathrm{p})$. The s-nucleus is two neutrons heavier than the p-nucleus with the same atomic number. The filled circles are the calculated ratios in the model with $M = 40\ M_\odot$, $Z = Z_\odot$ and $E = 10^{51}$ erg. The triangles are those in the model with $M = 25\ M_\odot$, $Z = Z_\odot$ and $E = 20 \times 10^{51}$ erg. The square are those in the model with $M = 25\ M_\odot$, $Z = 0.05\ Z_\odot$ and $E = 10^{51}$ erg. The dashed line is $N(\mathrm{s})/N(\mathrm{p}) = 3$. The dot-dashed lines are 1 and 9. The dot lines show the atomic number corresponding to the neutron magic numbers of N=50 and 82. All the calculated ratios in the region of $N > 50$ are almost centered around a specific number of 3.

The origin of the *p*-nuclei has been studied by theoretical and experimental methods over the last 50 years [2-7]. The *p*-nuclei are on the neutron-deficient side of the β-stability line and their isotopic fractions are small (typically 0.1 ~ 1 %). In our previous paper [4], we reported the scaling in the solar system abundances, which are the evidence that the most probable origin of the pnuclei is the γ-process, which is photodisintegration reactions in supernova explosions [2], [3]. There are 22 *p*-nuclei associated with almost pure *s*-nuclei that have two more neutrons than the *p*-nuclei. We found the scaling that the abundance ratios of $N_\odot(\mathrm{s})/N_\odot(\mathrm{p})$, where $N_\odot$ is each solar abundance, are almost constant within a factor of 3 over a wide range of atomic number. This scaling leads a novel concept of “the universality of the γ-process” that the $N(\mathrm{s})/N(\mathrm{p})$ ratios of nuclei produced in individual supernovae are almost constant over this wide range [4]. However, the reason why the scaling and universality appear in the solar abundances has remained an open question.

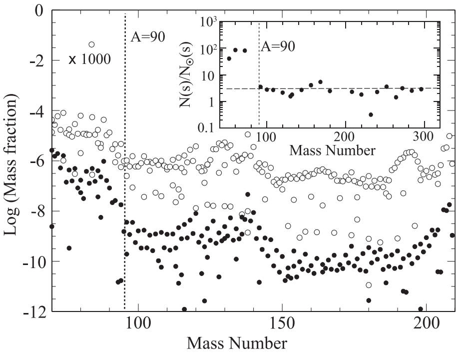

Figure 2: The abundance distribution of the seed nuclei for the p-process after the weak s-process (filled circles), and as the initial composition (open circles) in a model with $M = 25\ M_\odot$, $Z = Z_\odot$. The open circles have been multiplied by 1000. The inset displays the abundance ratios of the s-processed nuclei to the initial compositions for 22 nuclei, which are members of the scaling.

We calculated the γ-process in oxygen-neon layers in core-collapse supernovae under various conditions [1]. Figure 1 shows the calculated results, which are constant over a wide range of the atomic number. These results show that the $N(\mathrm{s})/N(\mathrm{p})$ ratios of nuclei produced by individual supernovae are independent of the astrophysical conditions. We calculated the change of the abundance distributions of the initial seeds (Fig. 2).

We conclude that three mechanisms contribute to this universality. The first is that both β^+ decay and direct (γ,n) reactions contribute to the constant $N(\mathrm{s})/N(\mathrm{p})$ ratios. The second is a weak *s*-process before supernovae, which is the reason that the *p*-nucleus abundances are proportional to the *s*-nucleus abundances. The third is the shift of γ-process layers, of which the peak temperature is almost constant. Our calculations further suggest an extended universality that the s/p ratios in the γ- process layers are not only constant but also centered around a specific value 3 (Fig. 1). To verify this, we propose an astronomical observation of Indium isotopic abundance fractions.

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Removal of Central Obscuration and Spider Arm Effects with Beam-Shaping Coronagraphy

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In this paper, we describe a pre-optics system designed for high contrast imaging. It is commonly said that high contrast imaging instruments, like coronagraphs, should be used on off-axis telescopes. The reason is that most coronagraphs are sensitive to the central obstruction pattern, as well as supporting spider arms. This kind of pupil geometries usually create unwanted light distribution (diffracted light) in the Lyot plane, thus limiting the performance of coronagraphs.

We propose to use a well suited combination of a small diffraction mask, associated with a complex amplitude filter in the conjugated pupil plane (the beam shaping filter), to shape the output light beam (both in amplitude and phase), and especially remove the central obstruction and spider arms [1]. The diffraction mask produces a well defined diffraction pattern in the pupil plane and sends light at the central obstruction and spider arms locations, so that coherent light is present in pupil areas where it didn't exist before (the original entrance pupil). By correctly modifying the amplitude and phase of the light in these areas (i.e. to perform a beam shaping), we can virtually produce any kind of output pupil shape: e.g. flat or apodized [2]. The optical scheme is shown on Fig. 1. Note that this diffraction mask is different from the coronagraphic mask: an independent coronagraph is used *after* this pre-optics setup.

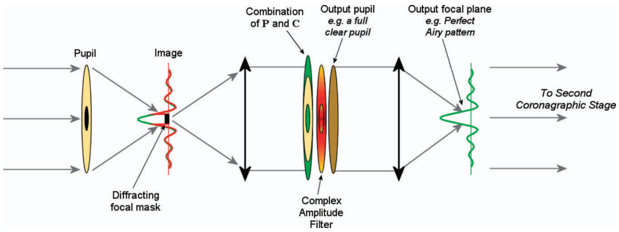

Figure 1: Schematic of the beam-shaping coronagraphy. The diffraction effect of a focal mask in the re-imaged pupil naturally fills the central obstruction and spider arms structures with coherent light. A special complex amplitude filter is placed in this pupil in order to shape the beam as needed for a downstream coronagraph.

We considered two types of focal plane diffraction masks: simple occulters (circular masks, Lyot type) and π phase-shifting mask (like in Roddier coronagraphy). These diffraction masks produce different amplitude distributions in the pupil plane. We studied the optimal combination of such masks and beam shaping filters (in the pupil plane) so that we can maximize the throughput of the system (which also depends on the desired output pupil amplitude distribution). For a flat (phase and amplitude) output pupil, the throughput with occulting diffraction masks can be about 60% with a mask as small as 1.2 λ/D in diameter. For Lyot type occulting masks, the complex amplitude filter always need to apply a π phase-shift at the central obstruction and spider arms. If we use π phase-shifting masks as diffracting masks in the focal plane, there is sometimes no need to perform other π phase-shifts in the pupil plane, meaning that the complex amplitude filter can be amplitude-only.

The phase or amplitude transitions for the complex amplitude filter are ideally sharp transition, in other words discontinuities. We studied possible realizations of such pre-optics system by considering unperfect transition areas. We conclude, as shown in Fig. 2, that our system offers a significant gain, with no huge loss in transmission due to the complex amplitude filter.

Liquid crystal amplitude and phase modulators (Spatial Light Modulators) are possible candidates for the complex amplitude filter. Our technique has some chromatic issues that we did not fully address in this paper, but we point out some technological solutions that could allow broader band setups.

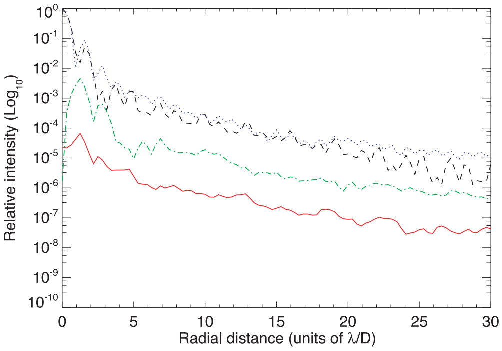

Figure 2: Performance of our system combined with a four quadrant phase mask (FQPM) coronagraph with a Subaru/VLT-like pupil shape. The curves correspond to the reference image without coronagraphic mask but with Lyot stop and without beam-shaping (dotted), the reference image without coronagraphic mask but with Lyot stop and with beam-shaping (dashed), the coronagraphic FQPM image without beam-shaping (dash-dotted green), the coronagraphic FQPM image with beam-shaping (continuous red).

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Imaging Spectroscopy of a Gradual Hardening Flare on 2000 November 25

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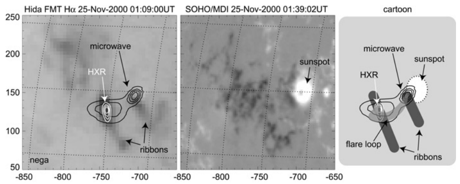

Figure 1: Spatial distribution of the emission sources. *Left*: Hα image of the flare. A microwave and a HXR image are overlaid with the *black* and *white* contours, respectively. *Middle*: Magnetogram of the active region. *Right*: Cartoon which shows the geometrical features of the flare. The *light gray* shade shows the flare loop seen in soft X-rays.

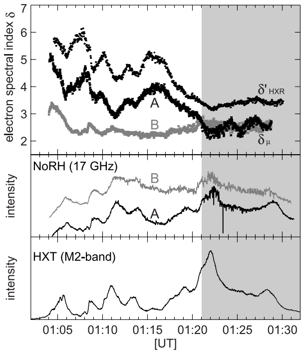

Figure 2: Temporal variation of the spatially-resolved physical parameters of each emission source. *Top*: electron energy spectral index derived from the HXR emission δ_{HXR}, and those derived from the microwave $\delta\mu$ for emission sources, A and B. *Middle*: microwave (in 17 GHz) light curves integrated over each emission source (scaled arbitrarily). *Bottom*: light curve of the total HXR intensity.

We examined nonthermal emissions of an M8.2 long duration flare that occurred on 2000 November 25 [1]. This flare showed the peculiar hardening features in microwaves obtained with NoRH[1] and NoRP[2] at Nobeyama Solar Radio Observatory, and in hard X-rays (HXRs) obtained with *Yohkoh*/HXT[3]. In these flares it has been thought that the magnetic trapping works extremely efficiently. We performed a detailed imaging spectroscopic analysis of nonthermal emission sources for a gradual hardening flare.

We can see a two-ribbon structure (see Fig. 1). A compact HXR source appeared on the eastern flare ribbon, while a dominant microwave source (source A) appeared on the western flare ribbon and showed no counterparts for the HXR source in the eastern ribbon. The microwave source A is located near the sunspot, and therefore, has strong magnetic field. We also identified an extended microwave emission source (source B) which is located between the two flare ribbons. In the soft X-ray images, we can see a faint loop structure which connects the flare ribbons. The source B just lies along the faint flare loop. We performed the imaging spectroscopic analyses for these microwave sources A and B and the HXR source (see Fig. 2). The temporal evolutions of the flux and the spectral index of the source A are quite similar to those of the HXRs, and both clearly showed gradual hardening tendencies in their spectra. Therefore, we concluded that almost all of the accelerated electrons are trapped and dripping to generate the footpoint microwave source and the HXR source. However, there is a constant gap between the electron spectral index derived from the source A and that from the HXR source. On the other hand, the source B does not show any similarity to the HXR and microwave footpoint sources, while its observational features such as gradual time profile and very hard spectrum show that this source is also generated by trapped electrons. This is probably because the effective energy of the trapped electrons that emit the gyrosynchrotron emission at the loop top (source B) should be larger than about 1 MeV.

From these observational results, we suggest that almost all of the accelerated electrons are trapped in the loops and dripping into the footpoints. The microwave source A is generated by dripping of the trapped electrons, and most of the electrons are reflected by mirror effect due to strong magnetic field and precipitate into the HXR footpoint source. On the other hand, the source B just reflects the trapped electrons. The gap of the indices is thought to be essential in this flare, and the energy spectrum show a breakup feature in nature if we consider that effective energy of electrons which contribute to the source A is higher than that in the HXR source. Since the magnetic loop is quite asymmetric, the anisotropic pitch angle distribution could be required for the forcible trapping effect in such an asymmetrical magnetic loop. These results could show that properties of the gradual component must be produced by a different acceleration mechanism from that of the impulsive phase, and that the additional acceleration in the shrinking magnetic loops could be a candidate.

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[1] Nobeyama Radioheliograph

[2] Nobeyama Radio Polarimeters

[3] Hard X-ray Telescope

Solar Heating Effect on Meteoroids in Meteor Showers

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The observed sodium abundance of meteoroids in meteor showers might differ from the original abundance because of processing in interplanetary space after ejections from their parent bodies. Among various processes, thermal alteration of alkali silicate is most likely the major process of Na depletion [1], [2], [3].

Aim is for clarifying at which perihelion distances the thermal desorption alters the Na content of meteoroids that are observed as meteor showers. Method is compilation Na abundances of meteoroids in meteor showers at each perihelion distance and compare them to the sublimation temperatures of alkali silicates. Results are that Na abundances of meteoroids do not depend on their perihelion distances at $0.14 \le q \le 0.99$AU. No Na depletion in these distances constrains the temperature of meteoroids at $q = 0.14$AU to be lower than the sublimation temperature of alkali silicates ~ 900 K. We conclude that meteoroid particles are characterized as large, compact, blackbody - like particles. On orbit with perihelion distances $q < 0.1$AU, meteoroids would show evidence of thermal desorption of metals, in particular, Na [3].

Solar heating effect on their parent bodies is also possible event. Asteroid 3200 Phaethon is suggested for a candidate of the direct Impact research. The object is considered to be the dormant comet and the parent of the Geminid meteor shower. Instead, one could say that there are some possible arguments for a space impact mission, and then show the additional interesting possibility of artificially generated meteor showers. Dust trail theory can calculate a bundle of trails' distribution and be used to show in which years artificial meteors would be expected. Results indicate that meteor showers are seen on Earth about 200 years later from the event on 12 April in 2022 [2].

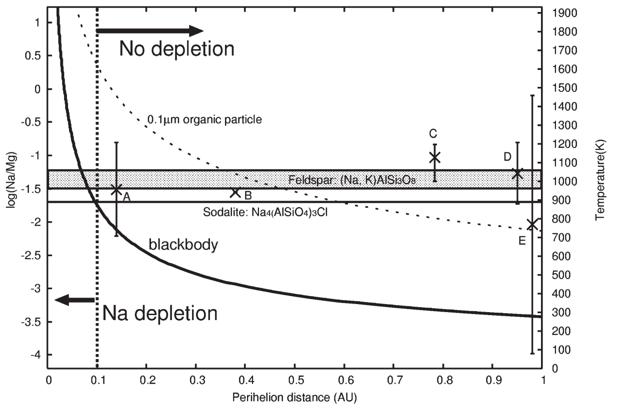

Figure 1: Temperatures of dust particle as a function of the perihelion distance. Also plotted are the averaged Na/Mg ratios deduced from data. Sublimation temperature of sodalite is shown by the horizontal line (the right axis). The stripe band shows solar Na/Mg ratio (the left axis) and sublimation temperature of feldspar (the right axis). The perihelion distances of meteor showers are $q \sim 0.14$AU (A) for Geminid, 0.38AU (B) for Taurid, 0.78AU (C) for Andromedid, 0.95AU (D) for Perseid, 0.98-0.99AU (E) for Leonid, Cygnid and Draconid.

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Li Production by the Radiative Decay of Long-Lived Particles

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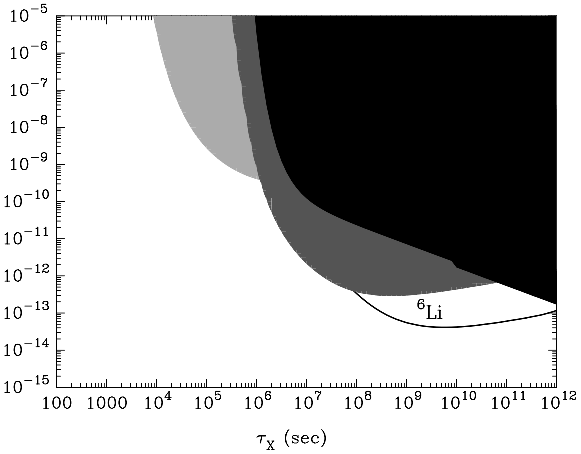

Figure 1: Gray regions are the excluded area in the parameter space (τ_X, ζ_X) for models with a fixed baryon to photon ratio of η =6.1 × 10^{-10}. The dark gray region is excluded by an overabundance of ^{3}He, whereas the light shaded region is mostly excluded by an underabundance of deuterium. The black shaded region is excluded by the CMB blackbody energy spectrum. The curved line identifies the contour of ^{6}Li/H = 6.6 × 10^{-12} , the abundance of ^{6}Li observed in MPHSs. The region above the contour and below the nucleosynthesis and CMB constraints is allowed and abundant in ^{6}Li.

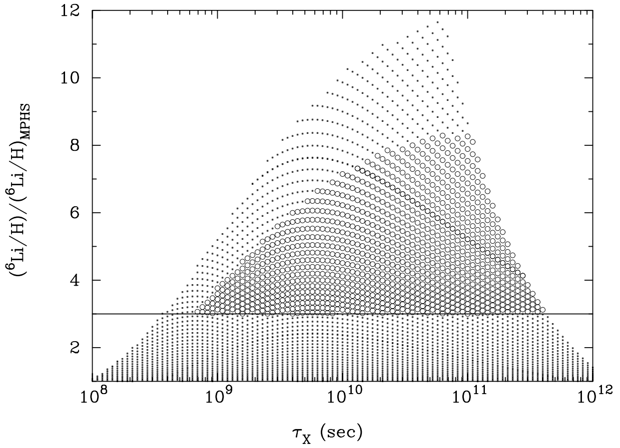

Figure 2: Ratio of calculated ^{6}Li/H abundances to the observed abundance in MPHSs as a function of τ_X. Results in the allowed parameter region of (τ_X , ζ_X) producing ^{6}Li/H larger than the value found in MPHSs, or the marked region " ^{6}Li " in Fig. 1 are plotted by small squares. The horizontal line indicates a factor of three overproduction of ^{6}Li. The large circles denote values in the allowed region with abundances of ^{3}He/H=1.3–2.5×10^{-5} and ^{6}Li/H $\geq 3 \times 6.6 \times 10^{-12}$.

Recent spectroscopic observations of metal poor stars have indicated that both ^{7}Li and ^{6}Li have abundance plateaus with respect to the metallicity~[2]. Abundances of ^{7}Li are about a factorthree lower than the primordial abundance predicted by standard big-bang nucleosynthesis (SBBN), and ^{6}Liabundances are ~ 1/20 of ^{7}Li, whereas SBBN predicts negligibleamounts of ^{6}Li compared to the detected level. Thesediscrepancies suggest that ^{6}Li has another cosmological or Galacticorigin than the SBBN. Furthermore, it could appear that ^{7}Li (andalso ^{6}Li) has been depleted from its primordial abundance by somepost-BBN processes [3]. We study the possibility that the radiative decay of long-lived particleshas affected the cosmological lithium abundances. We calculate thenon-thermal nucleosynthesis associated with the radiativedecay, and explore the allowed region of the parametersspecifying the properties of long-lived particles X, i.e. a lifetime τ_X and $\zeta_X = (n_X^0/n_\gamma^0)E_{\gamma 0}$, where (n_X^0/n_γ^0) is equal to a number ratio of X to photon before X-decay and $E_{\gamma 0}$ is the emitted photon energy in theradiative decay. We also impose constraints from observations of the CMB energy spectrum. It is found that non-thermalnucleosynthesis produces ^{6}Li at the level detected in metal poor halostars (MPHSs) , when the lifetime of the unstable particles is of the order ~ 10^8 – 10^{12}s and their initial abundance with respect to that of thephotons is ~ (10^{-13} – 10^{-12} ~ GeV)/ $E_{\gamma 0}$ (Fig. 1, 2).

We conclude that a combination of two different processes could explain thelithium isotopic abundances in MPHSs. First, a non-thermal cosmological nucleosynthesis associated with theradiative decay of unstable particles; and second, about the same degreeof stellar depletion of both primordial lithium isotopic abundances. If MPHSs experience ^{6}Li depletion of factor much greater than ~3, the simple radiative decay process can not be the cause of large ^{6}Li abundances in MPHSs.

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