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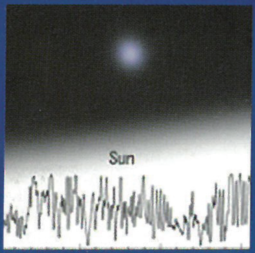
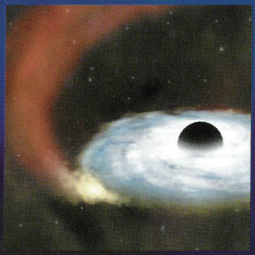
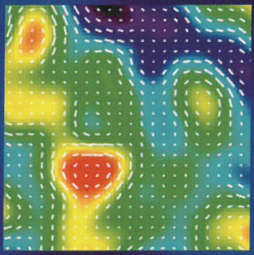
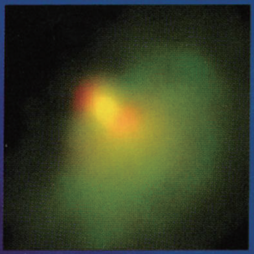


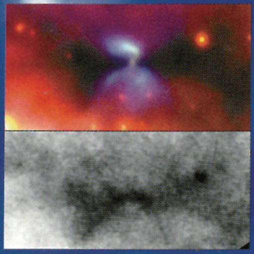
Annual Report of the National Astronomical Observatory of Japan

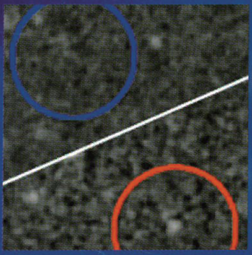
Volume 8 Fiscal 2005

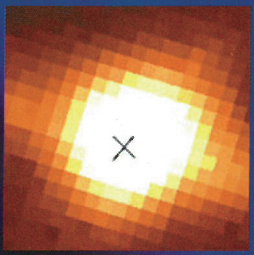


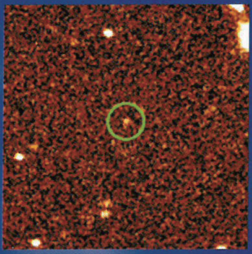












NAOJ
National Astronomical Observatory of Japan

Postscript

Editor Publications Committee
MIYOSHI, Makoto
IMANISHI, Masatoshi
UEDA, Akitoshi
OE, Masafumi
KUDO, Takahiro
SEKII, Takashi
SÔMA, Mitsuru
HANAOKA, Yoichiro

Publisher **National Astronomical Observatory of Japan**
2-21-1 Osawa, Mitaka-shi, Tokyo 181-8588, Japan
TEL: +81-422-34-3600
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Printer Meisei Kikaku Co., Ltd.
2-25-5 Enoki, Musashimurayama-shi, Tokyo 208-0022, Japan
TEL: +81-425-67-6233
FAX: +81-425-67-6230

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PREFACE

The National Astronomical Observatory of Japan (NAOJ) is pleased to release its 2005 Annual Report.

In fiscal year 2005, the second year since the incorporation of the national universities and inter-university research institutes, NAOJ started its real activities as an incorporated organization. First of all, the National University Corporation Evaluation Committee, organized by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), started the evaluation of incorporated organizations. At the end of June, institutes of the National Institutes of Natural Sciences (NINS), including NAOJ, submitted 2004 self-inspection reports to the committee, and had interviews with the officials in July. In September, the evaluation reports were released by the committee and it turned out most of the NAOJ activities were evaluated favorably. In this year, some effects of the incorporation became obvious; for example, in the salary system, NAOJ started making efforts to establish its original wage revision system, instead of following the recommendations of the National Personnel Authority as in the past.

One of the benefits brought by the incorporation is greater flexibility in the employment of contract employees. While there used to be strict regulations in hiring full-time contract employees, NAOJ is now able to hire them on its own responsibility, though the term of the employment contract is still limited to five years. The number of part-time contract employees such as postdoctoral fellows is also increasing. As of the end of 2005, NAOJ has 169 part-time contract employees and 33 special contract employees to 259 full-time employees. The contract employees are playing a large part of the organization. With these benefits by the incorporation, we assume greater responsibility as an incorporated organization. We should keep this firmly in mind and continue to take steps in the right direction.

NAOJ has adopted a project system since 2004. According to the Research Project Committee review, four "A" projects (exploratory projects) were launched this year; 4-Dimensional Digital Universe (4D2U) Project, Extrasolar Planet Detection Project, VWFI-HOP (Very Wide Field Imager for the Hubble Origins Probe) Project, and ELT (Extremely Large Telescope) Project. All of these projects are expected to grow larger and their activities are included in the annual report from this year. As for the two centers in NAOJ, the Public Relations Center was reorganized by integrating library, publication office, and astronomical information office into its functions. Outreach activities are continuously promoted by the new Public Relations Center. On the other hand, the Advanced Technology Center was also restructured to cover the optical infrared technology and millimeter/submillimeter development with the participation of the receiver development group of the ALMA project. With this reorganization, the NAOJ's technical basis is expected to be further reinforced. We believe the organizational reform should be continuously implemented to keep pace with the changing trends of new astronomy and break away from the conventional style when needed.

In the project week at the end of November, the Research Project Committee was held and intensive self-inspection and validation were conducted by each project or center, and by Division of Theoretical Astronomy. Implementation of self-inspection and validation is one of the objectives of the new project system. For budget allocation, hearings were conducted in the planning week in February 2006 to examine the performance and progress of each project, which were used as a basis for 2006 budget allocation plan. These systems of self-inspection/validation and budget allocation were highly evaluated by the National University Corporation Evaluation Committee of MEXT.

It has been five years since the start of open use of the Subaru Telescope and NAOJ Hawaii Observatory. In this opportunity, an international external review was held in August to check the results. Two foreign researchers and three Japanese researchers were invited as reviewers. The review was conducted for a wide-range of items; achievements of the Subaru Telescope, current situation of open use, personnel allocation, research development results of observation instruments, and education of graduate students. As a result of the review, the performance of the Subaru Telescope was valued highly for its outstanding achievements compared with other telescopes in the world, and it received special complimentary remarks saying that the first five years were a great success. It's especially gratifying that the early achievements of the Subaru Telescope, one of the most important observation instruments for NAOJ, was highly evaluated by the external review.

The ALMA (Atacama Large Millimeter/submillimeter Array) project, started last year, is making progress on its construction plan while overcoming various challenges it faces. The ALMA project is evaluated and inspected annually by the Council for Science and Technology Policy and by the Council for Science and Technology of MEXT. This year, the follow-up evaluation of the initial evaluation was held by the Council for Science and Technology Policy in May, and its report was released in August. In this evaluation also, the ALMA project was highly regarded, however, we still need to make an all-out effort for further development of this new project.

NAOJ is promoting exchange activities with the general public in various forms. In Mitaka area, NAOJ participates in "Mitaka Network University" from this year, and presents some interesting programs such as a series of public lectures, 4D theater, and astronomy pub where participants can have a pleasant chat with lecturers. In addition, "Star Party in Ishigaki Island" was co-hosted by Ishigaki island and NAOJ as in the last year. Unfortunately, the "Light Down" program (turning off the lights throughout the island) was cancelled off due to a typhoon, though, many of the islanders participated in the event. In Hawaii, `Imiloa Astronomy Center of Hawaii was opened near the NAOJ Hawaii Observatory to introduce the Hawaiian culture and astronomy. In the center, the 4-D Digital Universe Theater presented by NAOJ is gaining extraordinary popularity among visitors. We would like to continue these exchanges with the general public because we believe it is very important for NAOJ.

In closing, Dr. Norio Kaifu who had led NAOJ for six years as Director General resigned from his position upon the expiration of his term of office at the end of this fiscal year. Dr. Kaifu made great contributions to NAOJ, including promotion of radio astronomy at the Nobeyama Radio Observatory and other places, and construction of the Hawaii Observatory and the Subaru Telescope. Furthermore, he exercised strong leadership as Director General of NAOJ for the incorporation of NAOJ into NINS and introduction of the project system, as well as for the launch of the ALMA project. We would like to our deepest appreciation for his great effort.

Shoken Miyama

Shoken Miyama
Director General of NAOJ

I Scientific Highlights

(April 2005 - March 2006)

Numerous luminous buried AGNs in ultraluminous infrared galaxies

IMANISHI, Masatoshi
(Division of Optical and Infrared Astronomy, NAOJ)
DUDLEY, C. C.
(Naval Research Laboratory)
MALONEY, P. R.
(University of Colorado)

Ultraluminous infrared galaxies (ULIRGs) radiate very large luminosities ($L > 10^{12} L_{\odot}$) as infrared dust emission, and thus must possess extremely powerful energy sources hidden behind dust. The cosmic infrared background emission, the sum of dust-obscured activity in the universe, is dominated by high-redshift ULIRGs. Thus, distinguishing whether the energy sources of the ULIRG population are dominated by nuclear fusion inside stars (starbursts) or by active mass accretion onto supermassive blackholes with $M > 10^{7} M_{\odot}$ (AGN), is important to understanding the history of star formation and supermassive blackhole growth in the universe.

If luminous AGNs (=actively mass accreting supermassive blackholes) are present hidden behind dust in a torus geometry, their signatures are easily detectable thorough optical spectroscopy, because a large amount of AGN's radiation escapes along the torus axis and produces the so-called narrow line regions. However, since nuclear regions of ULIRGs are very dusty, AGNs resident in the majority of ULIRGs may be deeply buried in dust along all sightlines. Although such *buried* AGNs are elusive, it is fundamental to detect them and quantitatively determine their energetic importance. For these purposes, it is inevitable to observe at wavelengths of low dust extinction. One of such wavelengths is thermal infrared 3-4μm. Dust extinction at 3-4 μm is as low as that at 5-13μm. Furthermore, starburst and AGN emission are clearly distinguishable based on the spectral shapes; A starburst always shows strong 3.3μm Polycyclic Aromatic Hydrocarbon (PAH) emission, while if the equivalent width of the 3.3μm PAH emission is substantially smaller than that of a starburst, and strong dust absorption features are also detected, then a powerful buried AGN is required [1]. Finally, in a starburst, the energy sources and dust should be spatially well mixed, while the energy source is more centrally concentrated than the surrounding dust in a buried AGN. In the former case (starburst), there are upper limits to the optical depths of dust absorption features at 3-4μm, but they can be large in the latter case (buried AGN) [2].

We have performed systematic infrared 3-4μm spectroscopy, using Subaru IRCS, of nearby ULIRGs with no obvious AGN signatures in the optical, to search for elusive buried AGNs and determine their energetic importance (Fig. 1). We obtained the following main conclusions [3]. (1) Buried AGN signatures were found in roughy half of the observed ULIRGs, and in a much larger fraction of ULIRGs classified optically as LINERs than HII-regions. (2) Buried AGNs in ULIRGs showed larger dust extinction along our sightline than AGNs obscured by torus-shaped dust (optical Seyferts). Since the dust covering factor is larger in the former, this means that the total amount of nuclear dust around buried AGNs are systematically larger than that in optical Seyferts. (3) Buried AGN signatures were detected in ULIRGs with both warm and cool far-infrared colors. The larger amount of nuclear dust around buried AGNs (see above item 2) can naturally produce cooler far-infrared colors than AGNs surrounded by torus-shaped dust (which often show warm far-infrared colors).

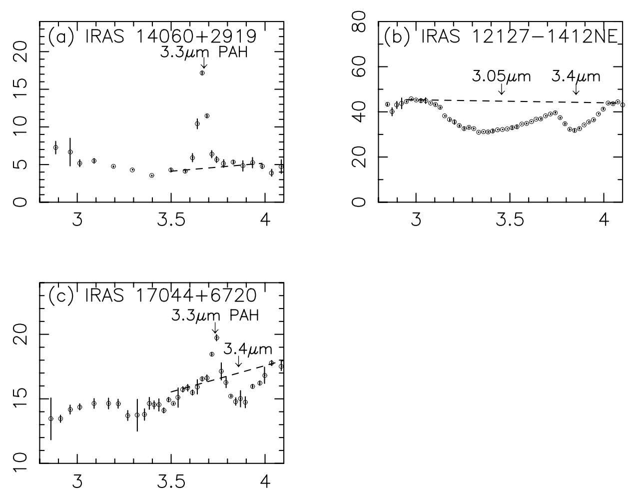

Figure1: Examples of infrared 3-4μm spectra of ULIRGs. The abscissa is observed wavelength in μm. The ordinate is flux in F_{λ} (10^{-16} W cm^{-2} μm^{-1}). (a) A ULIRG diagnosed to be starburst dominated, because of large equivalent width 3.3μm PAH emission. (b) A ULIRG dominated by a luminous buried AGN. No PAH emission and strong absorption features at 3.4μm by bare carbonaceous dust and at 3.05μm by ice-covered dust are found. (c) A ULIRG with starburst and buried AGN composite. A low equivalent width PAH emission and strong dust absorption features are detected.

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[3] Imanishi, M., et al.: 2006, *ApJ*, **637**, 114.

Photospheric and Chromospheric Vector Magnetograph Systems Installed into the Solar Flare Telescope

HANAOKA, Yoichiro, Flare Telescope Team
(Solar Observatory, NAOJ)

Active phenomena in the solar atmosphere are governed by the magnetic field, and therefore, the magnetic field information is critically important to study them. The photospheric vector magnetic field data have been used for this purpose, and the Solar Flare Telescope (Fig. 1) has carried out the imaging polarimetry observation of the photosphere since its construction. On the other hand, actual energy release sites in various active phenomena are in layers in the solar atmosphere much higher than the photosphere. Particularly, the information of the chromospheric vector magnetic field is very important to study the active phenomena as well as the photospheric one. However, polarization signals in the chromospheric lines, particularly lines formed in the middle and the upper chromosphere, are very weak. Therefore, it has been rather difficult to measure the vector magnetic field strengths in the middle/upper chromosphere.

To achieve high sensitivity in the polarization measurement to detect weak polarization signals, we need to reduce the crosstalk caused by the seeing effect, which is the largest source of spurious polarization signals, and also we need to integrate photons to reduce the statistical error. We have developed a polarimeter consisting of ferroelectric liquid crystals (FLC), which can be driven at high frequencies, and a high-speed CCD camera (about 500 frames s^{-1}). The combination of this polarimeter and the real-time data processing system enabled us to measure the polarization signals with the sensitivity of the order of 10^{-4}, which meets the requirement for measuring the chromospheric vector magnetic field.

We made two sets of the polarimeters, and installed them into the Solar Flare Telescope for the photospheric observation in the Fe I 6303 line and the chromospheric observation in the Hα line, respectively. The new polarimeter for the Fe I 6303 observation improved the sensitivity of the polarimetry for the photosphere very much, and furthermore, we started the regular chromospheric vector magnetograph observation in the Hα line. We have realized simultaneous observation of the vector magnetic fields in the photosphere and the chromosphere.

Sample polarization maps in Fe I 6303 and Hα are shown in Figure 2. Contours show the circular polarization signals, which correspond to the longitudinal magnetic field, and green sticks show the linear polarization signals, which correspond to the transverse magnetic field. Such data are now open on our WWW page.

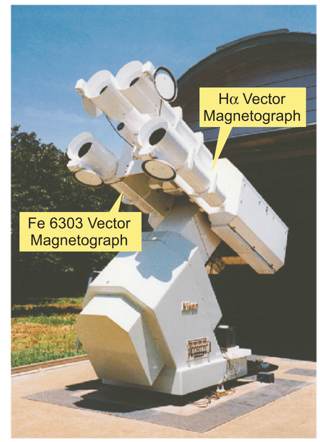

Figure1: The current configuration of the Solar Flare Telescope.

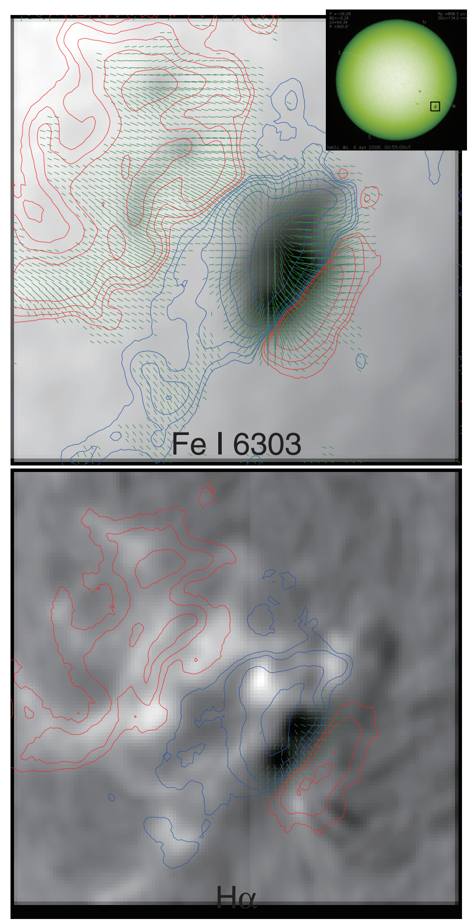

Figure2: Sample polarization maps taken in the Fe I 6303 line and the Hα line simultaneously. The position of the field of view is shown in the inset solar image at the top-right corner.

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Preflare Nonthermal Emission Observed in Microwaves and Hard X-Rays

ASAI, Ayumi, NAKAJIMA, Hiroshi*, SHIMOJO, Masumi
(Nobeyama Solar Radio Observatory, NAOJ)
WHITE, Stephen M. HUDSON, Hugh S., and LIN, Robert P.
(Maryland University) (UC Berkeley)

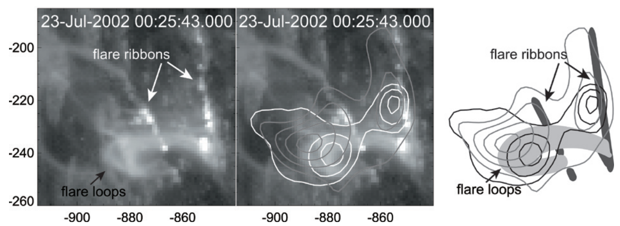

Figure1: Spatial distribution of the emission sources. The left and middle panels show a *TRACE EUV* (195 Å) image. The right panel shows the positions of the flare ribbons (*dark gray* regions) and the flare loops (*light gray*). The overlaid contour images are the NoRH 34 GHz brightness temperature (*white* in the middle and *black* in the right panels) and the RHESSI 25 - 40 keV intensity (*gray*).

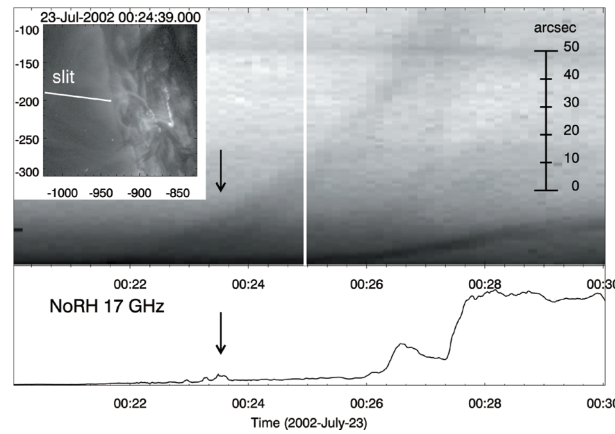

Figure2: *Top left*: a *TRACE* EUV image of the flare. The black solid line illustrates the position of the slit line. *Top right*: time slice image obtained with the *TRACE* images along the slit line. The horizontal and the vertical axes are time (UT), and the space along the slit, respectively. *Bottom*: NoRH 17 GHz light curve.

We examined in detail nonthermal emissions in the preflare phase of the X4.8 flare that occurred on 2002 July 23 spatially, temporally, and spectroscopically [1]. Nonthermal emissions, that are often observed in hard X-rays (HXRs), γ-rays, and microwaves at the beginning of a solar flare, are generated from accelerated particles, and are associated with intense energy release processes. Understanding of the particle acceleration mechanism has been one of the most important and the most difficult problems in solar physics. On the other hand, it is also interesting to study preflare activity, since this may hold the key for understanding how to trigger the catastrophic energy release of the flare. Even in the preflare stage of a solar flare, some energy release process is probably occurring at a low level, although the energy release is much milder. It is not widely accepted that nonthermal particles are present in significant numbers prior to the impulsive phase of a flare; rather, it is common to speak of preflare heating implying thermal behavior. Therefore, at least in terms of the explosiveness of energy release, the impulsive phase seems to be distinguished from the preflare phase.

We analyzed the flare, and found sufficient emissions both in HXRs and in microwaves that can be candidates for nonthermal emissions during the preflare phase. Especially, this is the first imaging observation of preflare nonthermal emission in microwaves. The microwave (17 GHz and 34 GHz) data obtained with NoRH[1] at Nobeyama Solar Radio Observatory and the hard X-ray data taken with *RHESSI*[2] clearly showed nonthermal features in the preflare phase. We focus on the nonthermal emissions of the preflare phase. First, the *GOES* temperature rapidly increases. This is often observed in a preflare phase, and the emissions are thought to be thermal. After some short delay, the microwave and HXR emissions starts to rise. In Figure 1 we present the spatial features during this phase. A microwave source appears at the top of the post flare loops that connect the flare ribbons. The spectral index of the microwave emission source (α) is about -3.0, which implies that this source is emitting nonthermal-gyrosynchrotron radiation. An HXR source also appears at this site, although apparently slightly higher than the microwave emission source. On the other hand, we can also see footpoint sources that are located on the *TRACE*[3] flare ribbons both in the microwaves and in the HXRs. The energy release probably occurs in the corona, some part of which is deposited at the footpoints to produce the EUV brightenings. The HXR emissions from the flare ribbon are thought to be generated by thick-target emission by nonthermal electrons. This is evidence for the existence of the nonthermal particles in this phase. Just after the phase, we found a faint ejection in the *TRACE* EUV images, which was followed by the fast energy release process occured in the impulsive phase (see Fig. 2).

Our results indicate that the process in the preflare phase, which leads to fast magnetic reconnection and a violent energy release, also releases enough amount of energy with the right conditions to accelerate particles to nonthermal energies. This suggests that the energy release mechanism in the preflare phase of a typical flare may be accompanied by particle acceleration, although it is much milder than that in the impulsive phase, and therefore hardly detected in flares smaller than this event.

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[1] Nobeyama Radioheliograph
[2] Reuven Ramaty High Energy Solar Spectroscopic Imager
[3] Transition Region and Coronal Explorer
*A former professor of NAOJ

The Unique Type Ib Supernova 2005bf: A WN Star Explosion Model for Peculiar Light Curves and Spectra

TOMINAGA, Nozomu, TANAKA, Masaomi, NOMOTO, Ken'ichi, UMEDA, Hideyuki
(School of Science, University of Tokyo)
MAZZALI, P. A. DENG, J. MAEDA, Keiichi
(Istituto Nazionale di Astrofisica-OATs) (NAOC) (Graduate School of Arts and Science, University of Tokyo)
MODJAZ, M., HICKEN, M., CHALLIS, P., KIRSHNER, R. P., WOOD-VASEY, W. M., BLAKE, C. H., SZENTGYORGYI, A., FALCO, E. E.
(CfA)
BLOOM, J. S. SKRUTSKIE, M. F.
(University of California) (University of Virginia)
INADA, Naohisa, MINEZAKI, Takeo, YOSHII, Yuzuru
(Institute of Astronomy, School of Science, University of Tokyo)
KAWABATA, Koji S. IYE, Masanori
(Hiroshima Astrophysical Science Center, Hiroshima University) (Optical and Infrared Astronomy Division, NAOJ)
ANUPAMA, G. C., SAHU, D. K., and PRABHU, T. P.
(Indian Institute of Astrophysics)

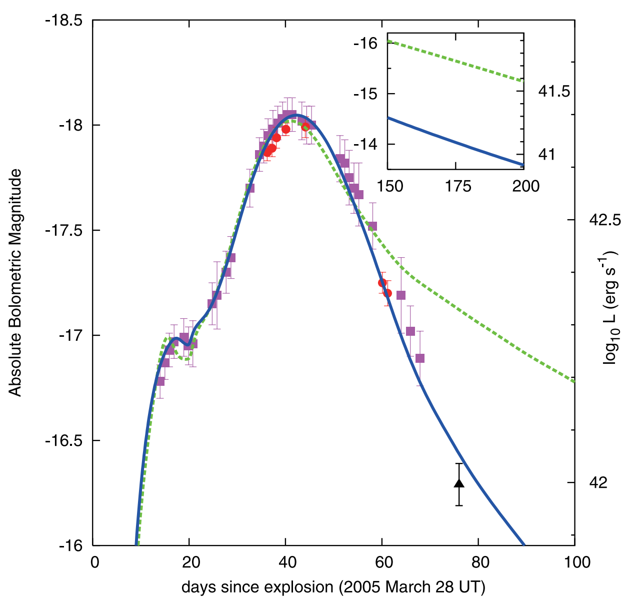

Figure1: The bolometric light curve constructed from *UBVRIJHK*-band LCs is compared with synthetic light curves are shown for normal (dashed) and enhanced γ-ray escape (solid) models.

We report a WN star explosion model for the unique type Ib supernova (SN) 2005bf that has peculiar light curves (LCs, Fig. 1) and spectra (Fig. 2) [1]. This event is an important SN to understand differences between Type Ib and Ic SNe.

This SN showed unique features: the LC had two maxima, and declined rapidly after the second maximum [2], while the spectra showed strengthening He lines whose velocity increased with time.

The double-peaked LC can be reproduced by a double-peaked ^{56}Ni distribution, with most ^{56}Ni at low velocity and a small amount at high velocity. The rapid post-maximum decline requires a large fraction of the γ-rays to escape from the ^{56}Ni-dominated region, possibly because of low-density "holes". The presence of Balmer lines in the spectrum suggests that the He layer of the progenitor was substantially intact. Increasing γ-ray deposition in the He layer due to enhanced γ-ray escape from the ^{56}Ni-dominated region may explain both the delayed strengthening and the increasing velocity of the He lines.

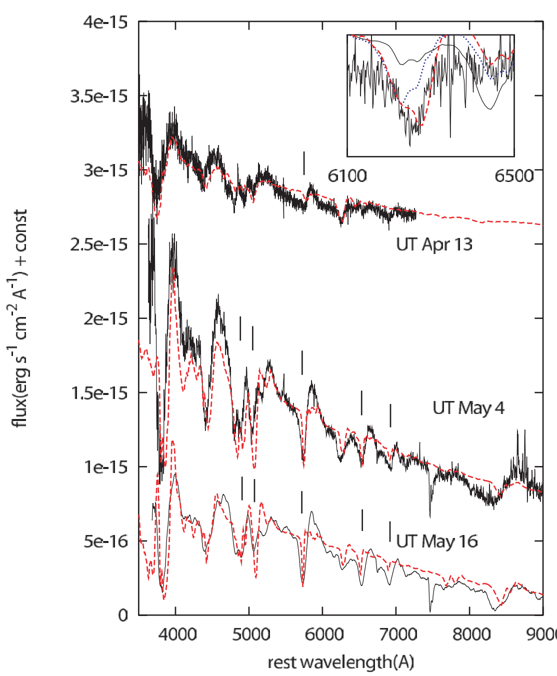

Figure2: Spectra of SN 2005bf (thick lines: 2005 April 13 - FLWO; May 4 - HCT; May 16 - Subaru Telescope) compared to the synthetic spectra (dashed lines) computed with the model that has ($M/M_\odot$, $E/10^{51}$erg) = (7, 1.3).

The SN has massive ejecta ($\sim 6-7M_\odot$), normal kinetic energy ($\sim 1.0-1.5\times10^{51}$ ergs), high peak bolometric luminosity ($\sim 5\times10^{42}$ erg s^{-1}) for an epoch as late as ~ 40 days, and a large ^{56}Ni mass ($\sim 0.32M_\odot$). These properties, and the presence of a small amount of H suggest that the progenitor was initially massive ($M \sim 25-30M_\odot$) and had lost most of its H envelope, possibly a WN star.

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Same-Beam Differential VLBI Technology Using Two Satellites of the SELENE Spacecraft

LIU, Qinghui, MATSUMOTO, Koji, KIKUCHI, Fuyuhiko, PING, Jinsong, ASARI, Kazuyoshi TSURUTA, Seiitsu, HANADA, Hideo, KAWANO, Nobuyuki
(RISE Project Office, NAOJ)

The Japanese SELENE project consists of a main satellite with a polar orbit of 100km, a relay sub-satellite (Rstar) with 2400-100 km, and a VLBI sub-satellite (Vstar) with 800-100 km. The high-degree lunar gravity field in the far side will be directly observed for the first time by 4-way Doppler tracking of the main satellite via Rstar, and the low-degree gravity fields especially near the rim will be more precisely observed by differential VLBI of the two sub satellites.

Rstar and Vstar only transmit three-pair carriers of 2212, 2218, 2287 MHz in S-band and one-pair carriers of 8456 MHz in X-band, and the difference in phase delay between Rstar and Vstar will be obtained from the relation between correlation phase and frequency of four carriers. In this case, the difference in correlation phase at each frequency has to be estimated without $2\pi n$ ambiguity, for which some strict conditions such as the error of correlation phase in S-band σ_s lower than 4.3° and the error of differenced total electron contents (ΔD_s) in ionosphere along the signal propagation paths less than 0.23 TECU are necessary.

In order to resolve the $2\pi n$ ambiguity problem, we propose a new VLBI technique, called same-beam differential VLBI, in which Rstar and Vstar are observed simultaneously by the same beam of the receiving antenna. In this case, the influence of atmosphere, ionosphere and receivers can be nearly canceled in the difference of correlation phases.

In this paper, we estimate the chance of same-beam differential VLBI observation by using simulating orbits of Rstar and Vstar, and find that it is about 80 percent paths of all. We also estimate the errors of atmosphere, ionosphere and receivers, and give methods for decreasing these errors. As shown in Table 1, phase errors in the receiver are lower than 1°. Phase fluctuations caused by thermal noise are 0.7° for S-band and 1.1° for X-band. Phase variations in main beam of receiving antenna can be compensated to 1.7° by using a formula determined by the least square method. Difference in delay time caused by measurement error of TEC in ionosphere is lower than 5 ps and D_s can be measured from X-and S-band correlation phases with an accuracy of 0.07 TECU. Difference in delay time caused by the measurement error of water vapor in atmosphere is less than 3 ps and phase fluctuations are less than 0.7° RMS for S-band and 2.8° for X-band estimated from the 26 m baseline VLBI observation results. Influence of phase characteristic of transmitting antenna and rotation of satellites can be reduced to 0.02° by using a low pass filter.

As shown in Table 2, we estimated that $\sigma_s < 3.1°$, $\sigma_x < 5.2°$, and $\Delta D_s < 0.1$ TECU by considering the influence of two satellites or two stations. In addition, the different error of the predicted geometric delay between Rstar and Vstar $\Delta\tau_s$ can be estimated with an accuracy of 1 ns by using range and Doppler measurements. The difference $\Delta\tau_x - \Delta\tau_s$ mainly originated in ionosphere and difference in positions of the S-band and X-band antennas is less than 0.0082 ns.

These results show that the conditions for removing $2\pi n$ ambiguity are satisfied by using the same-beam differential VLBI. Using this new technique, difference in delay time can be obtained with an accuracy of several ps, and the relative position between Rstar and Vstar can be determined with a very high accuracy of tens cm.

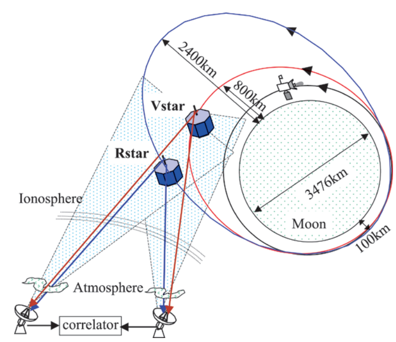

Figure1: Concept of the same-beam differential VLBI observation for SELENE project.

Error source	phase error σ_S(°)	phase error σ_X(°)
Receiver	1	1
Atmosphere	0.7	2.8
Receiving antenna	1.7	1.7
Thermal noise	0.7	0.7 , 1.1
Transmitting antenna	0.02	0.02
Root sum square	2.2	3.7

Table1: Errors of differences in correlation phase of S-band and X-band in the same-beam VLBI of SELENE.

ΔD_s	$\Delta\tau_s$	$\Delta\tau_x - \Delta\tau_s$	σ_s	σ_x
0.1 TECU	1 ns	0.0082 ns	3.1°	5.2°

Table2: ΔD_s, $\Delta\tau_s$, $\Delta\tau_x - \Delta\tau_s$, σ_s, σ_x in the same-beam VLBI of SELENE.

References

[1] Liu, Q., et al.: 2006, *IEICE*, **J89-B**, 602-617.

The Relation between the Two-Point and Three-Point Correlation Functions in the Nonlinear Gravitational Clustering Regime

KOYAMA, Hiroko (Waseda University)
YANO, Taihei (JASMINE Project Office, NAOJ)

We have studied the relation between the two-point and the three-point correlation functions in the nonlinear gravitational clustering regime. Under a scaling hypothesis for the bispectrum, as well as for the power spectrum, we have derived a new formula regarding the three-point correlation function, ζ, in the nonlinear regime as follows,

$$\zeta \sim \xi^{(3m+4w-2\varepsilon)/(2m+2w)} \tag{1}$$

where, ξ, m, w are the two-point correlation function, the power index of the power spectrum in the nonlinear regime, the number of spatial dimensions, respectively. The parameter ε, relatied with the information of the three-point correlation, is the minimum value of some power indexes for correlations of some waves, and one of which is the power index of the Fourier-phase correlation, α. The Fourier phase in the bispectrum is described as

$$< e^{i(\phi_{kt}+\phi_{k't}+\phi_{-kt-k't})} > \propto t^{-\alpha} < e^{i(\phi_k+\phi_{k'}+\phi_{-k-k'})} > \tag{2}$$

The value of α represents the vihaviour of the phase correlation. According to the value of α, there remain two characteristic possibilities for the evolution of the phases of the Fourier modes: they remain correlated (if $\alpha = 0$) or tend to become uncorrelated (if α positive) in the strongly nonlinear regime.

We have also checked the behaviour of the relation between the two-point and three-point correlation funcitons using numerical simulations in a one-dimensional Einstein de Sitter model.

Figure 1 shows the power spectrum in the nonlinear gravitational regime where we have chosen the initial power index 1. It can be fitted by $P(k) = \propto k^{-0.75}$. From the Fourier transform, the 2PCF obeys $\xi(r) \propto r^{-0.25}$. Figure 2 shows the bispectrum in the nonlinear regime when the power spectrum is expressed as in Figure 1. It is obvious that the bispectrum is well fitted by $B(k, 2k) \propto k^{-1.5}$. This value of the index, -1.5, is nearly equal to $2m \simeq 2 \times (-0.75) = -1.5$. Accordingly, $B(k, 2k) \propto k^{2m}$ coresponds to the expression (1) with the relation $\varepsilon = -m/2$. In other words, this result seems to agree with the hierarchical assumption $\zeta \propto \xi^2$.

References

[1] Koyama, H., Yano, T.: 2005, *ApJ*, **624**, 1.

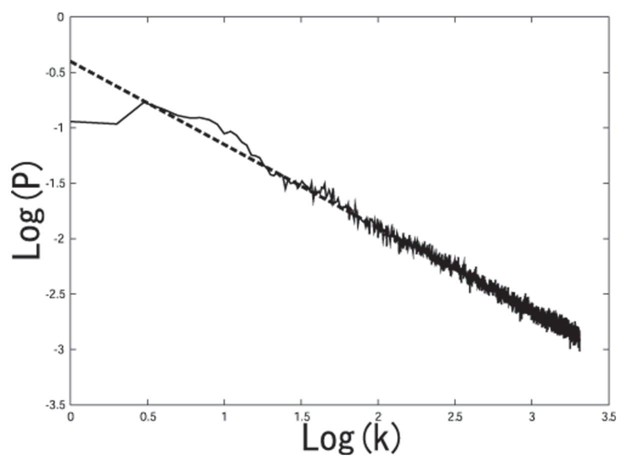

Figure1: Power spectrum $P(k)$. We have chosen the initial power spectrum as the power law with index $n = 1$ The power index of the power spectrum in the non-linear regime is fitted to -0.75.

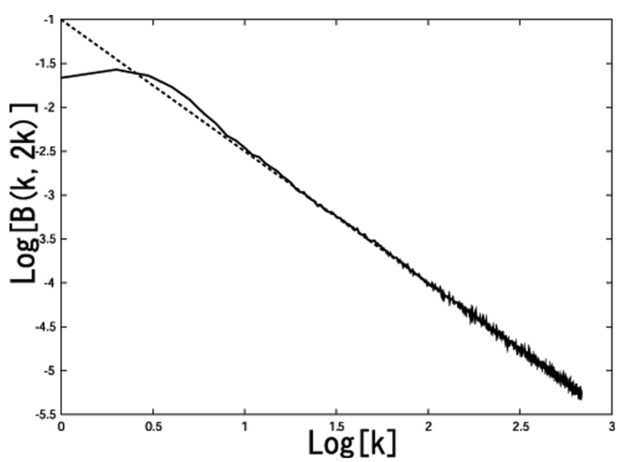

Figure2: The bispectrum in the nonlinear regime when the power spectrum is expressed as in Fig.1. The dashed line shows a power law with a power index of -1.5.

Observational Pursuit for Population III Stars

NAGAO, Tohru (NAOJ / INAF) MAIOLINO, R. (INAF–Roma) MOTOHARA, Kentaro (University of Tokyo)
MARCONI, A. (INAF–Arcetri) MURAYAMA, Takashi (Tohoku University) KASHIKAWA, Nobunari (NAOJ)
MALKAN, M. A. (UCLA) TANIGUCHI, Yoshiaki (Ehime University) OHTA, Kouji (Kyoto University)

Population III stars are the stars created by pristine gas with primordial elemental abundance ratios. Their properties have been extensively investigated theoretically, and now it is recognized that the initial-mass function of population III stars could extend up to a few hundreds $M_{\odot}$. Currently no population III stars have been discovered observationally so far, although massive population III stars likely contribute to the cosmic reionization and metal enrichment in the early universe. Therefore, we are now promoting a project aiming to discover massive population III stars in galaxies at high redshift ($z>6$), where the massive population III stars may still be in survival.

Galaxies hosting population III stars are expected to show an extremely large Lyα equivalent width and strong HeIIλ1640 emission, caused by hard ionizing radiation from population III stars. Therefore, efficient surveys for Lyα emitting galaxies (LAEs) with a large equivalent width are required. We thus developed a new selection method to select LAEs with a large equivalent width in a wide redshift range $6.0 < z < 6.5$ by utilizing broad-band and narrow-band photometric data. Applying this new method to the very deep and wide multi-band data of the Subaru Deep Field ([1], [2]), we selected some candidates and confirmed that three of them are indeed LAEs with a large rest-frame equivalent width (EW_0(Lyα) ≥ 100Å; z = 6.03, 6.04, 6.33; [3], [4]; Fig. 1).

In order to investigate whether such LAEs contain a significant number of massive population III stars or not, we tried to observe their redshifted HeIIλ1640 emission by using Subaru/OHS, that can achieve the deepest spectroscopic limiting flux in *JH*-band among any ground-based instruments (Subaru common-use program S05A-086). We carried out an ultra-deep *JH*-band spectroscopy for a LAE with EW_0(Lyα) = 130Å, with 42 ksec exposure time (Fig. 2). Although we obtained only an upper limit on the HeIIλ1640 flux, we found that the star-formation in this LAE is not dominated by population III stars and that this kind of observations can give some constraints on model parameters in theories of population III stars [5].

We are now carrying out additional observations for finding new high-z LAEs with a large Lyα equivalent width, selected by our new selection method (Subaru common-use program S06A-053). We are now also preparing additional near-infrared ultra-deep spectroscopic observations aiming to discover population III stars in such high-z LAEs through HeIIλ1640 emission.

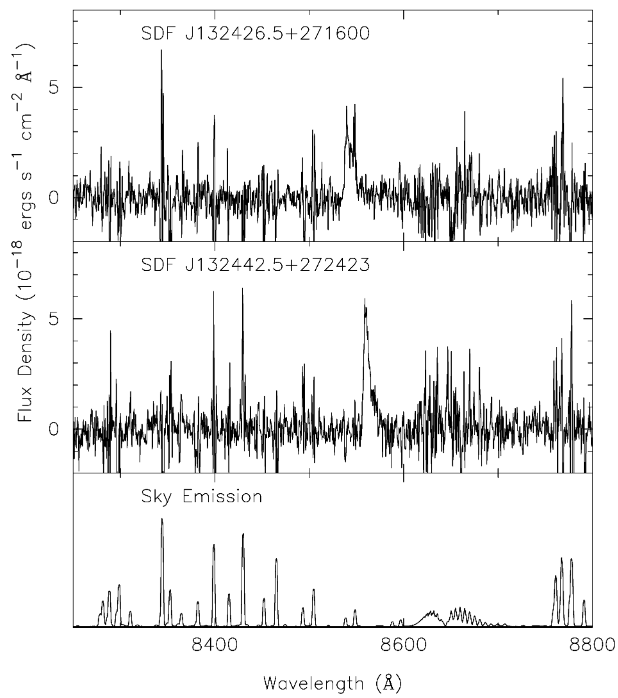

Figure1: Optical spectra of two LAEs selected by our new selection method to pick up LAEs with large Lyα equivalent width emission, obtained with Keck/DEIMOS [4]. Total exposure times are ~2 hours for each LAE. Thanks to high wavelength resolution R ~ 3600, an asymmetric profile that is expected for Lyα emission is clearly seen for each spectrum. Redshift and the rest-frame equivalent width are 6.03 and 6.04, and 94Å and 236Å, respectively. The latter is the LAE with the largest Lyα equivalent width spectroscopically confirmed so far.

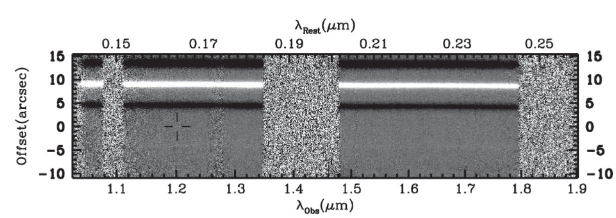

Figure2: *JH*-band spectrum of a LAE with EW_0(Lyα) = 130Å obtained by 42 ksec observation using Subaru/OHS [5]. The expected wavelength of the redshifted HeIIλ1640 emission of the target object is marked by the black cross. Three very strong continuum features (one is positive, and two are negative) are seen, which are the spectra of the reference star observed simultaneously with the main target.

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[1] Kashikawa, N., et al.: 2004, *PASJ*, **56**, 1011.
[2] Taniguchi, Y., et al.: 2005, *PASJ*, **57**, 165.
[3] Nagao, T., et al.: 2004, *ApJ*, **613**, L9.
[4] Nagao, T., et al.: 2005, *ApJ*, **634**, 142.
[5] Nagao, T., et al.: 2005, *ApJ*, **631**, L5.

Metallicity Evolution of Active Galactic Nuclei

NAGAO, Tohru (NAOJ / INAF) MAIOLINO, R. (INAF–Roma) MARCONI, A. (INAF–Arcetri)

Active galactic nuclei (AGNs) are very energetic objects releasing huge radiation from a compact region at a galactic center. Thanks to their high luminosity, we can observe them rather easily even at high-z universe. Since we can estimate gas metallicity of emission-line regions in AGNs through spectral analysis, AGNs have been investigated as a tracer of metallicity evolution of galaxies from high-z to the local universe. In particular, broad-line regions (BLRs) that reside at $r < 1$ pc from the nucleus have been intensively studied up to now. Such studies have revealed that the more luminous and/or the higher redshift AGNs tend to have the higher metallicity. However, we may see more luminous AGNs at higher redshift due to observational biases.

To solve this problematic situation, we analyzed >5000 spectra of AGNs taken from the SDSS database and examined them as independent functions of luminosity and redshift (Fig. 1). We then found that the BLR metallicity is strongly correlated with the AGN luminosity positively while that is independent of redshift at a given luminosity, at $2.0 < z < 4.5$ (Fig. 2, [1]). In order to interpret this result in terms of chemical evolutionary models of galaxies, it should be considered whether the BLR located very close to the nucleus really traces properties of whole of galaxies. We therefore investigated the dependences of metallicity on the luminosity and redshift also for narrow-line regions (NLRs; $r \sim 10^{1-3}$ pc). Although NLR metallicity is generally estimated by using NV emission, this emission line becomes too weak when the metallicity is low ($Z_{\rm NLR} < Z_\odot$) and thus only upper limits on the NV flux have been obtained for many high-z AGNs with NLR emission (type-2 AGNs). We thus developed a new metallicity diagnostic diagram that does not require the NV flux based on our intensive photoionization model calculations. Applying this new diagnostic diagram on available NLR data, we found that also the NLR metallicity strongly correlated with the AGN luminosity positively while that is independent of redshift at a given luminosity (Fig. 3, [2]). Since the spatial extent of NLRs is comparable with that of their host galaxies, our results are highly insightful to discuss the metallicity evolution of AGNs in terms of galaxy evolutionary models.

Now we are carrying out a new observational program to investigate NLR metallicity at higher redshift, $z > 3$, with VLT/FORS [30 hours (period 76, priority C) and 36 hours (period 77, priority 77) have been already allocated for this program]. We are also proposing a new observational project to Subaru, to investigate BLR metallicity of low-luminosity AGNs at high redshift. All of the observational insights should be summarized and discussed in terms of galaxy evolutionary models in order to understand the metallicity evolution of AGNs and galaxies. To conduct such a study, we are now preparing a hybrid model considering both galaxy chemical evolutionary models and photoionization models for emission-line regions [3].

References

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[2] Nagao, T., et al.: 2006, *A&A*, **447**, 863.

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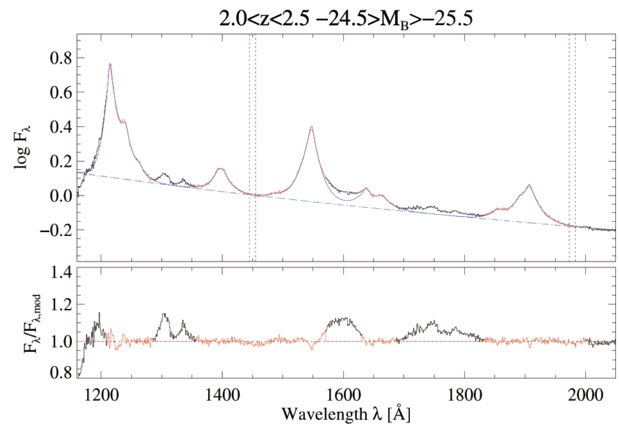


Figure1: Composite spectrum of AGNs made of 643 spectra at $2.0 < z < 2.5$ and with $-24.5 > M_B > -25.5$, taken from the SDSS Data Release 2 database [1]. Although the S/N of individual spectra is low, we can measure even weak emission lines accurately by using composite spectra.

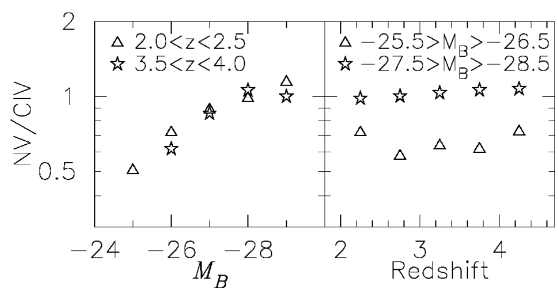


Figure2: BLR metallicity-sensitive flux ratio, NV/CIV, of SDSS AGNs as functions of the AGN luminosity (left) and of the redshift (right) [1].

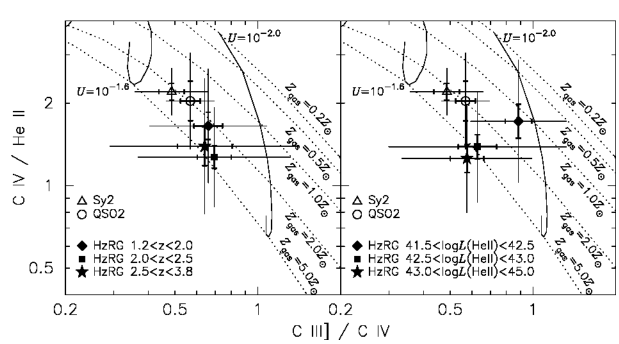


Figure3: New NLR metallicity diagnostic diagram developed by us [2]. Model grids shown here are for the $n_{\rm H} = 10^2 {\rm cm}^{-3}$ case. Although the models depend on the gas density and thus the absolute values of NLR metallicity cannot be estimated by this diagram, we can discuss the relative evolution or dependence of the NLR metallicity. The dependences of metallicity on the redshift and the AGN luminosity are examined in the left and the right panels, respectively. Thin bars denote the RMS's of the data distribution, and thick bars denote the estimated errors on the averaged values. A systematic shift of the data on the diagram is seen in the right panel.

One Solar Cycle Observations of Prominence Activities Using the Nobeyama Radioheliograph 1992-2004

SHIMOJO, Masumi, ASAI, Ayumi, NAKAJIMA, Hiroshi*, SHIBASAKI, Kiyoto
(Nobeyama Solar Radio Observatory, NAOJ)
YOKOYAMA, Takaaki
(University of Tokyo)

We developed a detection method for prominence activities based on 17 GHz images observed with NoRH, and applied the method to 12 yr of observations at NoRH. As a result, we detected 785 prominence activities, and found the following properties of the activities [1]:

1) The variation in the number of the prominence activities is similar to that of sunspots during one solar cycle. The prominence activities also have a dip around the solar maximum, like the sunspot number.

2) There are differences between the peak times of prominence activities and sunspots. The first peak of prominence activities is one year earlier than that of sunspots. The second peak time of prominence activities is delayed by one year from that of sunspots by one year.

3) The frequency distribution as a function of the magnitude of prominence activities in each phase of the solar cycle shows a power-law distribution. The power-law index of the distributions does not change, except around the solar minimum. At the solar minimum, the power-law index decreases from -2.6 to -3.7. The averaged power-law index is -2.8.

4) The number of prominence activities has a dependence on latitude, and numerous prominence activities occur in the active region belt. On the other hand, the average magnitude of prominence activities is independent of the latitude.

5) During the rise phase of the solar cycle, the locations of the high-latitude prominence activities migrate to the pole region. The poleward migration is similar to the motion of magnetic flux expanding from the active regions of early Cycle 23 to the pole region.

6) After the magnetic polarity reversal around the poles, the location of the prominence activities in the northern hemisphere slowly migrates to the equator. On the other hand, the prominence activities in the southern hemisphere continue at a high-latitude region until the decay phase of the solar cycle.

In this paper, we do not mention the difference between prominence eruption and prominence disappearance, since we do not classify the prominence activities based on the direction of the motion here. The future study is to measure the direction and the velocity of prominences, and to investigate the relationship between these phenomena and the solar cycle.

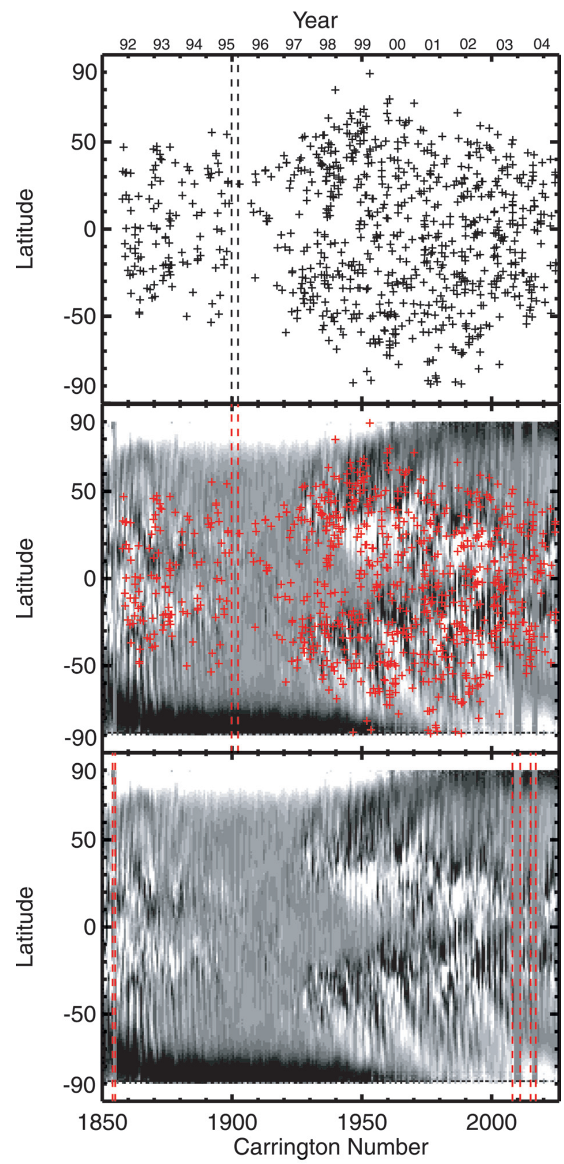


Figure1: Upper panel: Butterfly diagram of the prominence activities. The plus marks present the prominence activities. Lower panel: Gray scale shows the magnetogram observed by Kitt Peak Facilities, National Solar Observatory. Middle panel: The butterfly diagram of the prominence activities is plotted on the magnetogram. The black dashed lines on the upper panel and the red dashed line on the middle panel indicate the dormant period of the NoRH observation. The red dashed line on the lower panel presents dormant period for the changing system in Kitt Peak/NSO.

References

[1] Shimojo, M., et al.: 2006, *PASJ*, **58**, 85-92.

*A former professor of NAOJ

Discovery of an Extrasolar Planet HD149026 b with a Large Core

SATO, Bun'ei
(Okayama Astrophysical Observatory, NAOJ)
IDA, Shigeru
(Tokyo Institute of Technology)
TOYOTA, Eri
(Kobe University)
Debra, A. Fischer
(San Francisco State University)
Greg Laughlin
(University of California at Santa Cruz)
N2K Consortium

About 30 "hot Jupiters", extrasolar planets orbiting close to central stars, have been discovered by Doppler and Transit technique. Such short-period planets have high probability of transit, can be good tracers of multiple planet systems, and give deep insights into understanding of formation and evolution of extrasolar planets. Especially, transiting ones are highly important because they can provide rich information on radius, density, internal structure, and atmosphere of extrasolar planets. However, among 9 transiting planets currently known, only 3 of them were detected around bright enough ($V<10$) stars for high-precision photometry and spectroscopy.

Since 2004, we have established an international consortium (N2K) among Subaru (Japan), Keck (USA), and Magellan (Chile) aiming to search for hot Jupiters. We plan to survey 2000 solar-type stars for the next 3 years and to discover more than 60 hot Jupiters and several transiting ones. We have already screened about 750 stars, discovered 4 new hot Jupiters, and identified about 45 planet candidates.

HD149026 b is a "hot Saturn" discovered by Subaru and Keck observations [1]. Firstly Subaru/HDS found the star showing significant radial velocity variations and then Keck confirmed its orbital parameters to be $P=2.88$ days and $K_1=43.3\mathrm{ms}^{-1}$ (Fig. 1). After that, Fairborn observatory (USA) succeeded in detecting the transit of its orbiting planet (Fig. 2), whose radius is $0.73R_{JUP}$ (0.86 R_{SAT}), orbital inclination is 85°, and mass is 0.36 M_{JUP} (1.2 M_{SAT}). The mean density is derived to be about 1.7 times larger than that of the Saturn. Models for this planet suggest the presence of a 70 $M_{\oplus}$ (M_{EARTH}) core composed of elements heavier than hydrogen and helium (Fig. 3). Existence of such a large core prefers the "core accretion" scenario to the "disk instability" one as the formation mechanism of giant planets, although it may be difficult to form cores massive than $30M_{\oplus}$ within the conventional "core accretion" model. Several scenarios including a giant impact between two isolation-mass embryos are now being discussed [2].

References

[1] Sato, B., et al.: 2005, *ApJ*, **633**, 465.

[2] Ikoma, M., et al.: 2006, *ApJ*, **650**, 1150.

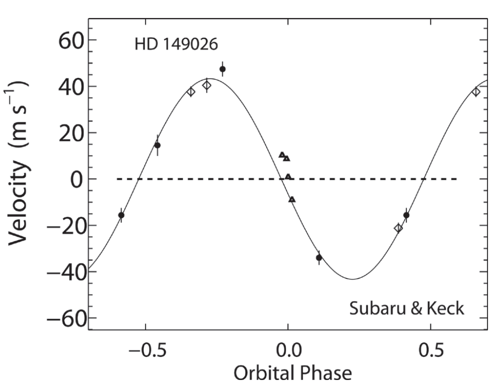


Figure1: Radial velocity variations in HD149026 detected by Subaru and Keck.

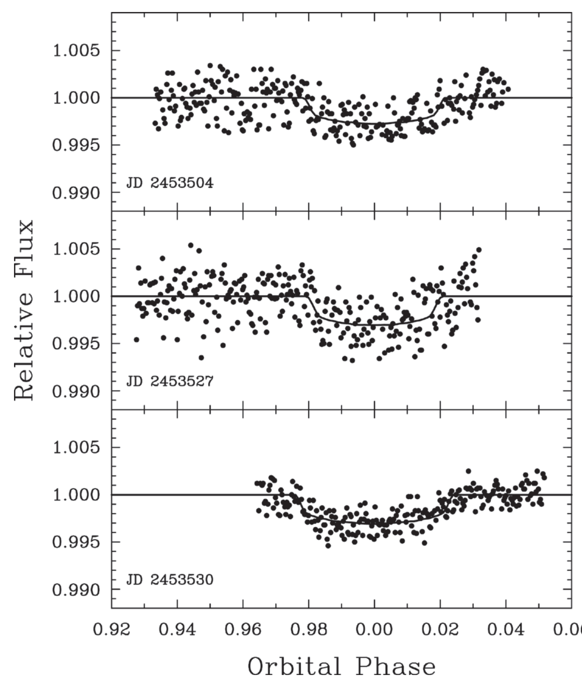


Figure2: Photometric transits of HD149026 detected by Fairborn Observatory.

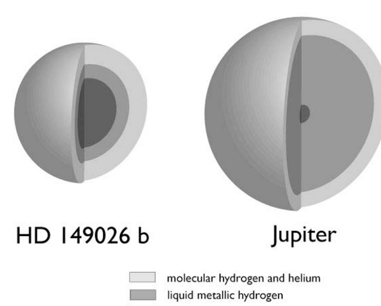


Figure3: Interior models of HD149026b (left) and Jupiter (right). Central dark grey regions express solid cores.

Local Gravity From Lunar Prospector Tracking Data: Results for Mare Serenitatis

GOOSSENS, Sander (NAOJ / DEOS)   VISSER, Pieter (DEOS)
HEKI, Kosuke (Hokkaido University)   AMBROSIUS, Boudewijn (DEOS)

Up to this date, the lunar gravity field has mainly been expressed by a global spherical harmonical representation, despite the lack of tracking data over the far side of the Moon. Such a representation requires regularisation, which greatly affects the complete final solution, for both the far and near side. To extract the wealth of information on the near side present in tracking data of the Lunar Prospector spacecraft, regional representations become of interest. Here, a high-resolution gravity anomaly solution for Mare Serenitatis, one of the large mascons on the near side, is presented [1]. The solution has been obtained by a complete and independent re-processing of Lunar Prospector tracking data, allowing for a comprehensive and accurate determination of local gravity fields on the Moon. The presented solution requires no regularisation.

Lunar Prospector tracking data are first processed using the GEODYN II software package. In this way, the reference orbit is determined and tracking data residuals with respect to the a priori gravity field model are generated. From these residuals, the local adjustments are estimated using a linear variational approach [2].

Figure 1 shows the new solution for Mare Serenitatis, using the latest state-of-the-art lunar gravity field model LP150Q as a priori model. The new solution is very similar to this model, which is also reflected in the small adjustment to the a priori model as shown in the top plot of Figure 2. Nevertheless, the ring of negative anomalies surrounding the mascon appears to be more continuous than in LP150Q, especially at the Southern border, suggesting that the high-frequency features have a physical reality.

The bottom plot of Figure 2 shows the adjustment when an older a priori gravity field model, GLGM-2, is used. This model does not contain Lunar Prospector data (whereas LP150Q relies heavily on these data). This plot clearly shows the power of the solution method to extract the high-frequency information from the residuals. There is a clear ring structure visible, which can also be seen in the differences between anomalies from the GLGM-2 and LP150Q models. Thus, using this local anomaly recovery method, a comprehensive and detailed local study of gravity on the lunar near side can be conducted.

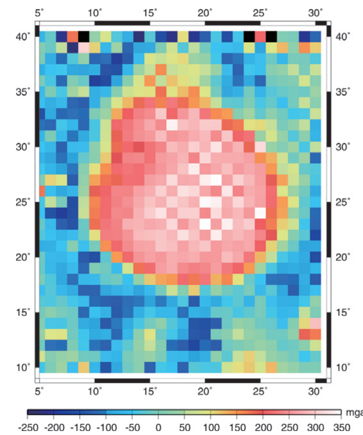
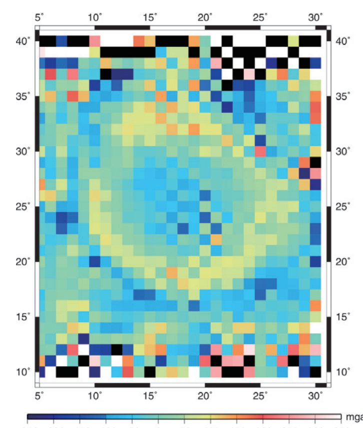
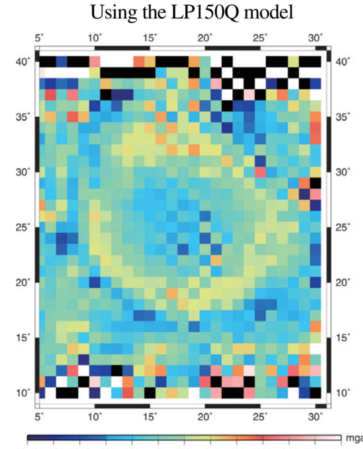


Figure1: New local solution for Mare Serenitatis.



Using the LP150Q model



Using the older GLGM-model

Figure2: Adjustments to the priori gravity field model. The top plot shows the adjustment to the LP150Q model, and the bottom plot shows the adjustment to the GLGM2 model.

References

[1] Goossens, S., et al.: 2005, *Earth, Planets and Space*, **57**, 1127-1132.
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Metal Abundances of Meteoroids in Meteor Showers: Leonids vs Geminid

KASUGA, Toshihiro
(RISE Project Office, NAOJ)
WATANABE, Jun-ichi
(Public Relations Center, NAOJ)
YAMAMOTO, Tetsuo
(Hokkaido University)
KAWAKITA, Hideyo
(Kyoto Sangyo University)
EBIZUKA, Noboru
(RIKEN)

Spectroscopy of a large scale activity of the 2002 Leonid meteor shower and a small scale activity of a 2004 Geminid meteor shower have been reported [1], [2].

High-definition TV spectra in the ultraviolet to visible region were obtained during the 2002 Leonid aircraft campaign. We analyzed 20 meteor spectra obtained from the 1767 (seven revolution) and 1866 (four revolution) trails on 2002 November 19 and identified neutral atoms, mainly Mg I, Fe I, Ca I, and Na I, in the observed wavelengths between 300 and 650 nm. The singly ionized atomic emissions, Ca II and Mg II lines, also appeared in the spectrum. The abundances of the metallic atoms, the electronic excitation temperature, and the electron density are obtained for each spectrum, assuming the Boltzmann distribution for the number at each energy level. The metallic abundances of Fe, Ca, and Na relative to Mg are slightly lower than solar abundances on average. We could not find any evidence of the solar heating effect on Leonid meteoroids between the 1767 and 1866 trails on orbit with their perihelion ($q \sim 1$AU). We can support the idea that silicate and carbon-mixed silicate are preserved in interplanetary space for at least several hundred years. Bands of CHON-related molecules, such as OH and CN, are not detected [1].

The results of Geminids suggest the possibility that the abundances of Geminid meteors are slightly different from solar abundances. Na/Mg $= 0.0036 \pm 0.0005$, which is much lower than other meteor showers. On the other hand, the Ni/Mg ratio is 0.078 ± 0.012, which is larger than solar abundance, and that of meteors of other showers. Extreme Na depletion, and moreover, excess Ni are derived for a Geminid meteor [2].

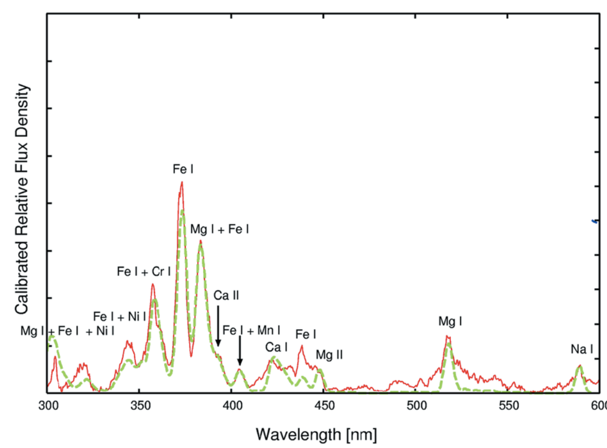

Figure1: A 2004 Geminid spectrum in Nobeyama Obs.

References

[1] Kasuga, T., et al.: 2006, *ApJ*, **638**, 1176.
[2] Kasuga, T., et al.: 2005, *A&A,* **438**, L17.

Observations of Star-forming Galaxies at z ~ 3 with ESO VLT: Escape Fraction of Ionizing Photons and Stellar Populations

IWATA, Ikuru
(Okayama Astrophysical Observatory, NAOJ)
INOUE, Akio K.
(Osaka Sangyo University)
DEHARVENG, J.-M., BURGARELLA, D., Buat, V.
(Laboratoire d'Astrophysique de Marseille)

The escape fraction of ionizing photons from star-forming galaxies is one of the most interesting and controversial parameters for galaxies in the early universe. Although it has been suggested that star-forming galaxies might be a major source of ionizing photons which have reionized the neutral hydrogen in the inter-galactic space sometime at $z>6$, current observational constraints on the escape fraction of ionizing photons are quite poor, even at the lower redshift ranges.

There are a few past works which investigated ionizing radiation emitted from galaxies at z ~ 3, and their results are inconsistent with each other; Steidel et al. reported that the escape fraction could be fairly high (~ 60%) [1], while Giallongo et al. placed much severe upper limits [2]. These studies are based on spectroscopic observations for limited number of galaxies. Since narrow-band imaging can achieve higher signal-to-noise ratio than spectroscopy at the same integration time, it is potentially quite effective way to explore the escape fraction of ionizing photons. With this idea, we have carried out narrow-band imaging observations using FORS1 attached to ESO VLT in 2003.

The target field is the Hubble Deep Field-South. We selected sample of galaxies with photometric redshift estimates around z ~ 3 based on the ultra-deep images in UV, optical and near-infrared, and executed the multi-object spectroscopy to determine redshifts of these galaxies, using VLT/FORS2. As a result, we have identified 5 new redshifts as well as confirmations of 6 redshifts [3].

The narrow-band imaging was made using an OII (373) filter. A total exposure time was 40,636 sec. There are two galaxies for which the filter can trace the wavelength range just shortward of Lyman-limit, at $z=3.170$ and 3.275. We carefully examined the reduced image and derived 3-σ limiting magnitude for positions of these objects to be 27.37 and 27.40 AB mag [4]. These limits correspond to the lower limits on the rate of non-ionizing UV flux density to ionizing one, F_{1400} / F_{900} of 15.6 and 10.2 (3-σ). Under the assumptions on the inter-galactic hydrogen absorption and the intrinsic SEDs, this result suggests that the escape fraction of ionizing photons are smaller than the high value reported by Steidel et al. Although in this work the number of sample objects are limited to two, we have verified that narrow-band imaging is a powerful method to explore the escape fraction for a specific redshift range. In order to reach a decisive conclusion on how much ionizing photons are emitted to inter-galactic space at high-redshift, we definitely need larger number of sample galaxies. Currently we are developing a narrow-band filter to trace ionizing photons at redshift around 3 for Subaru / Suprime-Cam, which has a field of view about 20 times wider than VLT / FORS. The observation with this filter should lead a drastic increase of sample objects.

We also investigated the stellar populations of these star-forming galaxies luminous in rest-frame UV wavelength. Star formation rates, ages, amount of dust attenuation and stellar mass were estimated by comparisons with template SEDs generated with a population synthesis code (Fig. 1). As a result, we found that they are fairly young (<200 Myr), actively star-forming ($10-100M_\odot$/yr) galaxies with small amount of dust ($E(B-V)<$ 0.3 in most cases) and stellar mass ($(0.5-5)\times10^{10}M_\odot$). We compared them with "distant red galaxies" (DRGs) in the same field, which are also estimated to be at z ~ 3 and have $J-K$ color redder than 1.3 AB mag. We found that, although DRGs have been suggested to be a passively evolving galaxies at high redshift, they would be in the actively star-forming phase with larger amount of dust and stellar mass compared to UV-luminous galaxies. DRGs could have large impact on the stellar mass density estimates at z ~ 3.

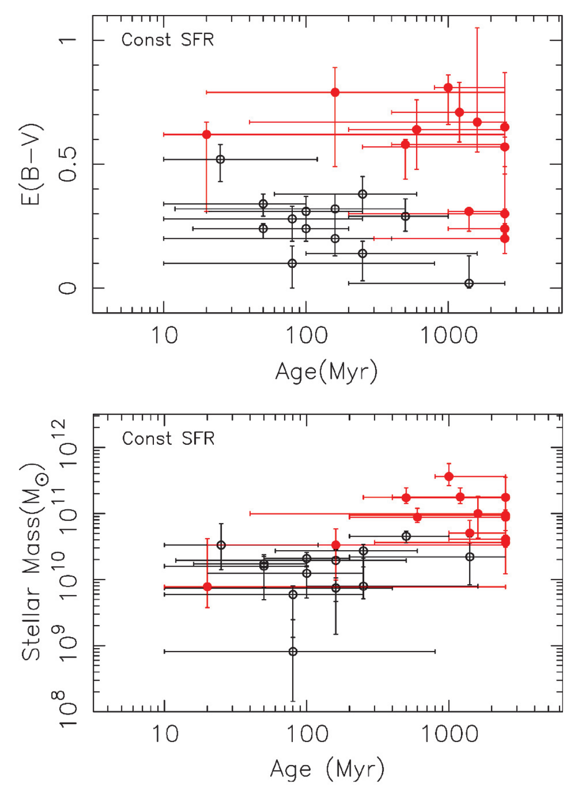

Figure1: Estimates of age versus dust attenuation (upper panel) and stellar mass (lower panel) for UV-luminous galaxies at z ~ 3 (open circles) and DRGs (filled circles).

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Three Dimensional Motion of Plasmas Associated with a Coronal Mass Ejection Observed with NOrikura Green-line Imaging System (NOGIS)

SUZUKI, Isao, SAKURAI, Takashi, ICHIMOTO, Kiyoshi

(Solar Observatory, NAOJ)

We present a Coronal Mass Ejection (CME) observation on 1999 May 7, in which NOGIS [1] revealed the motion of magnetic loops prior to the CME and of the CME itself [2].

NOGIS is installed on a 10cm coronagraph at the Norikura Solar Observatory, and has a unique capability of Doppler-shift measurements. NOGIS has a field-of-view covering from 1.03 $R_\odot$ to 1.33 $R_\odot$, which is suitable for observing CME source regions in the low corona.

In LASCO observation, the CME was ejected radially and eastward on 1999 May 7. Figure 1a and b show the CME source region (NOAA 8541) observed with NOGIS before the CME and MDI after the CME. This source region was basically bipolar, and showed two stet loop systems (a large loop 'L' and a small loop 'S'). If we assume that the photospheric magnetic fields were not significantly disturbed, nor were they changed by the occurrence of the CME, we might be able to infer the pre-CME magnetic configuration by using post-event magnetograms. Figure 1c and d show the current-free field lines [3] calculated from the photospheric magnetogram of May 11.

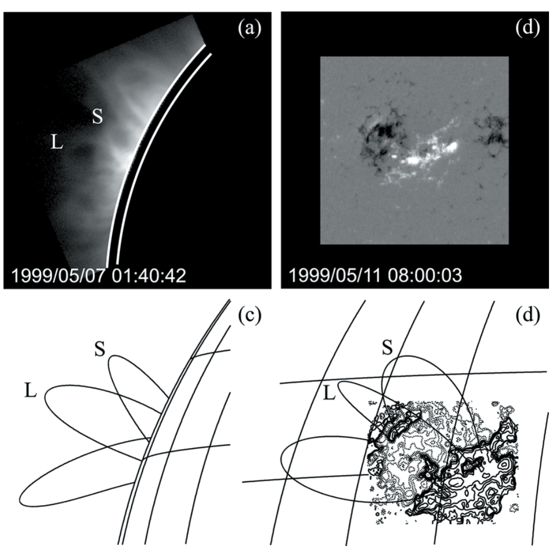

Figure1: (Top) Active region NOAA 8541 before and after the CME. (a) NOGIS intensity image and (b) MDI magnetogram. (Bottom) Current-free field lines calculated from the photosheric magnetogram of 1999 May 11.

These loop systems were initially static. However, around 02:00 UT (two and half hours before the CME) the southern footpoint of the small loop started moving gradually toward the southern footpoint of the large loop (Fig. 2a and b). The velocity of the motion in the plane of the sky was 0.2 km s^{-1}, which is a reasonable value for typical shearing motion in active regions. From the Doppler-shift measurements of NOGIS (Fig. 2c), the footpoint of the small loop showed a higher blue shift relative to the large loop. However, since the line-of-sight velocity (about 11 km s^{-1}) is much larger than the velocity in the plane of the sky and a downward plasma motion along the small loop was seen during the event, the measured Doppler shift might be explained by the downflow due to the projection effect.

The motion of the small loop toward the large loop lasted until it touched the southern footpoint of the large loop. The small loop apparently touched and destabilized the large loop, then mass ejection occurred. It was found in figure 2d that the mass was ejected with a red shift and south-eastward rather than radially. The line-of-sight velocity from the Doppler measurement was a few km s^{-1} with red shift on average.

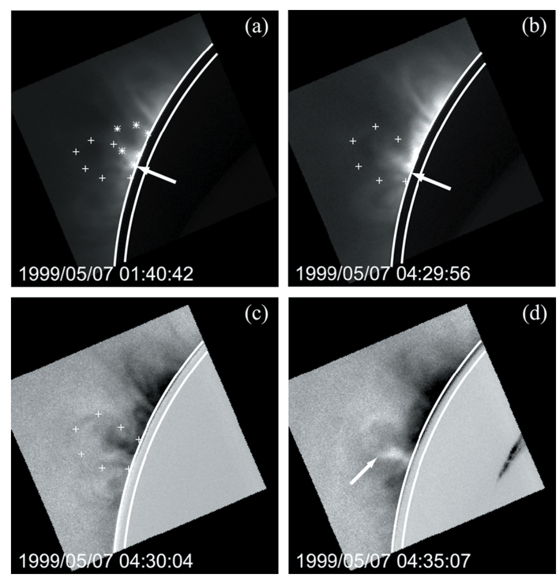

Figure2: (a－b) NOGIS intensity and (c) Doppler images before the CME. Symbols ＋ and ＊ indicate the large loop and the small loop, respectively. Arrows show the locations of the footpoint of the small loop. The dark (bright) regions in the Doppler image represent blue (red) shifts, respectively. (d) NOGIS Doppler image during the mass ejection. The arrow shows the mass ejection with red shift.

This CME was due to an interaction between the two approaching flux systems. The source region was not over the active region, but was at a lower altitude, at the footpoints of the two loops. The CME initially traveled non-radially until it reached the altitude of the LASCO field-of-view. The direction of mass ejection was therefore determined by the magnetic field configuration around the source region and the location of the initial energy release in the magnetic field structure.

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Three-Mirror Anastigmat Telescope Design for an ELT

NARIAI, Kyoji
(Meisei University)
IYE, Masanori
(Division of Optical and Infrared Astronomy, NAOJ)

The Ritchy-Cretien telescope design widely adopted for 8-10m class telescopes is a two-mirror system for removing the spherical and coma aberrations and providing a wide field of view. Its focal plane, however, is curved and the remaining astigmatism limits the useful field to about 6 arcmin in diameter (e.g. for Subaru Telescope).

The next generation extremely large telescopes (ELTs) with diameter exceeding 30m are expected to achieve diffraction limited imaging with the advent of advanced adaptive optics. Instruments for those ELTs inevitably become very large and difficult to exchange. A wide-field telescope optics with diffraction limited imaging performance, therefore, is beneficial in deploying multiple instruments.

Obvious solution is three-mirror anastigmat telescopes. A successful example is a Korsch three-mirror optics [1]. However, it is for long focal ratio optics and the central field is vignetted. Our newly designed optics [2] produces a flat focal-plane, diffraction-limited, 20 arcmin field-of-view, by removing spherical, coma, and astigmatism aberrations by a third aspheric mirror that reimages the pseudo image produced by the two-mirror system. An example of optical layout to secure vignetting free semi-circle field is shown in Figure 1. Figure 2 shows the spot diagram, demonstrating the image sizes are within the diffraction circle out to 8 arcmin in radius.

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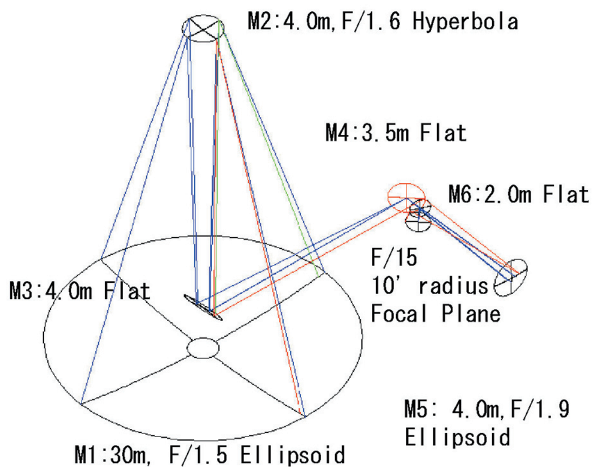

Figure1: Three-Mirror Anastigmat Layout.

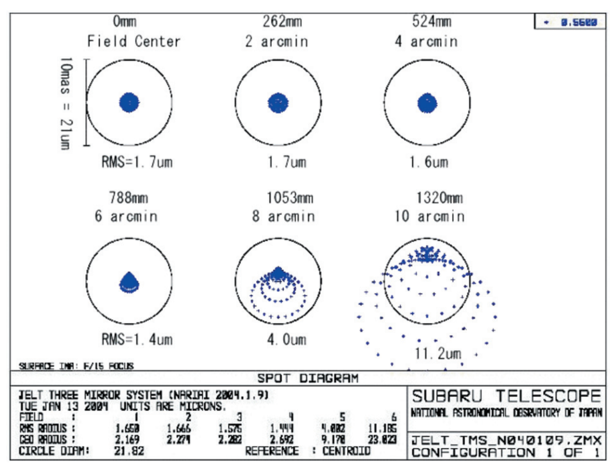

Figure2: Spot diagram with diffraction circles.

SMA Observations of Submm Bright Galaxies at High-z

IONO, Daisuke
(ALMA Project Office, NAOJ / Harvard-Smithsonian CfA)

Submillimeter surveys toward the deep universe have revealed the presence of galaxies that emit strongly in dust emission [1]. The problem with these surveys is that the angular resolution of JCMT is only 14", which is not high enough to identify the optical/NIR counterparts to the distant sub-mm bright galaxies. Up to the present, two of the common ways to identify the possible counterpart is to use 1.4 GHz radio [2] or 1.3 mm [3] interferometry. While the former is easily accessible using large scale interferometers such as the VLA, it is an indirect tracer that utilizes the radio-FIR correlation [4] and often biased toward $z < 2-3$ systems. The latter is a more direct tracer of the same dust emission, but the dust emission at 1.3 mm is often below the detection limit of existing mm instruments except for the brightest sources. With the advent of submm interferometers, we can now directly identify the optical/NIR counterparts to the submm bright galaxies.

Here we present Submillimeter Array (SMA) [5] observations toward two recently discovered submm bright sources, GN 20 and MIPS-J1428 [6]. GN 20 is a 20 mJy source discovered in the SCUBA image [7] of the GOODS North field [8]. MIPS-J1428 [9] is also a 20 mJy source, and it was discovered in the *Spitzer* MIPS images of the NOAO Deep Wide Field Survey [10]. The SMA is an 8-element submm interferometer operating primarily at 230 GHz (1.3mm) and 345 GHz (850μm) at the summit of Mauna Kea in Hawaii. The observed angular resolution is ~ 2" and the astrometric accuracy of these observation is ~ 0".1.

The SMA images along with their optical counterparts are shown in Figure 1. For GN 20, the IRAC 3.6μm image reveals a source centered < 0".5 west of the submm coordinates. Furthermore, the higher resolution *V*-band image obtained by the *HST* reveals a faint optical source 0".8 to the west. The analysis of available ACS images provides us a rough estimate of the probable redshift of the source and it is found to be $z \sim 3-4$. The offset between the submm coordinates and the *HST* galaxy is significant, and the submm emission may arise from part of a large galaxy where *V*-band emission is completely obscured by the foreground dust. It is also possible that GN 20 might be an interacting system where the optical galaxy is a companion to the dusty, more actively star forming galaxy.

As for MIPS J1428, the optical/NIR galaxy seen here is unambiguously the galaxy responsible for the extremely bright submm emission. The accurate astrometry provided by the SMA allows us to rule out fainter IRAC sources detected nearby [9] as possible counterparts. It is still possible that MIPS-J1428 could be strongly magnified by the foreground $z = 1.034$ galaxy, but the firm upper limit to the source size of < 1".2 (10 kpc at $z = 1.325$) given by the SMA rules out strong magnification.

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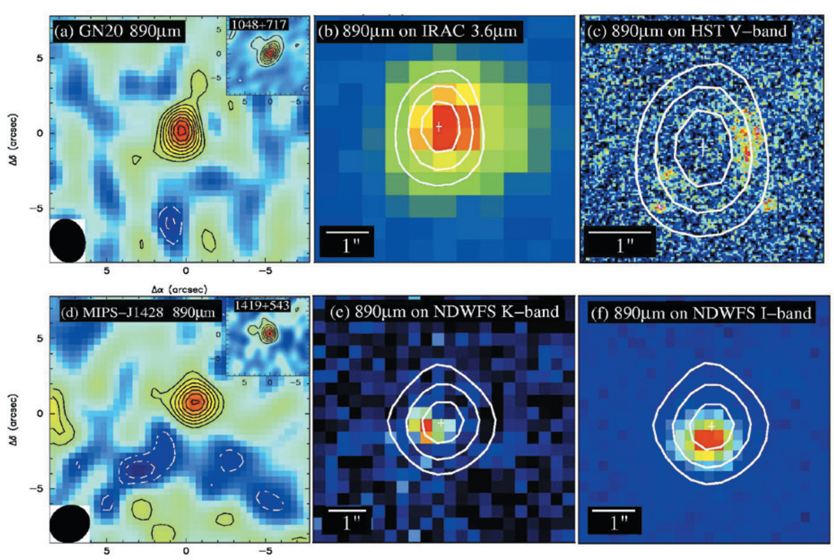

Figure1: (*a*) The SMA 890μm map of GN 20 and (*inset*) 1048 + 717. The lowest positive contours represent 2σ, and the contours increase by 1σ for GN 20, and by 2σ for 1048 + 717 which is our test QSO used to confirm our astrometric accuracy (see [6]). The SMA 890μm contours overlaid on the (*b*) *Spitzer* IRAC 3.6 μm image and over the (*c*) *HST* ACS *V*-band image, both obtained from the GOODS archive. The 4, 6, and 8 σ contours from (*a*) are shown, and errorbars near the center show the astrometric accuracy of the SMA image. (*d*) The SMA map of MIPS-J1428 and (*inset*) 1419 + 543. The contours are the same as in GN 20. The SMA 890μm map of MIPS-J1428 is shown overlaid on the NDWFS (*e*) *K*-band image and the (*f*) *I*-band image. The 3, 5, and 7 σ contours from (*d*) are shown, and errorbars near the center show the astrometric accuracy of the SMA image.

A Coronagraphic Search for Brown Dwarfs and Planets around Nearby Stars

NAKAJIMA, Tadashi, MORINO, Jun-Ichi, SUTO, Hiroshi, ISHII, Miki, TAMURA, Motohide
MIYAMA, Shoken, TAKAMI, Hideki, TAKATO, Naruhisa, OYA, Shin, HAYASHI, Saeko
(NAOJ)
TSUJI, Takashi (IoA, University of Tokyo) FUKAGAWA, Misato (Nagoya University) MURAKAWA, Kouji (MPIfR)
KUDO, Tomoyuki (GAUS) ITOH, Youichi OASA, Yumiko (Kobe University) OPPENHEIMER, B. R. (AMNH)

We have started a corongraphic search for brown dwarfs and planets around young nearby stars within 20 pc of the Sun, using the adaptive optics coronagraph, CIAO, on Subaru [1]. The dynamic range we have achieved is $\Delta K = 13$ at 2.″5 from the central star. For a typical target with $K = 7$ at 10 pc, the limiting absolute magnitude is $M_K = 20$. We apply two kinematical age criteria to select M and K dwarfs statistically younger than 350Myr. The first criterion is a small velocity deviation from the velocity of LSR. The second is a (U,V,W) velocity vector similar to a particular young moving group. The combination of the age and magnitude limits implies that the mass limit for giant planet detection is about $2M_J$ (Fig. 1). We show a sample image of a target field at 3 pc of the Sun with faint companion candidates (Fig. 2), to be followed up for the common proper motion test. Details of this work are published in [2].

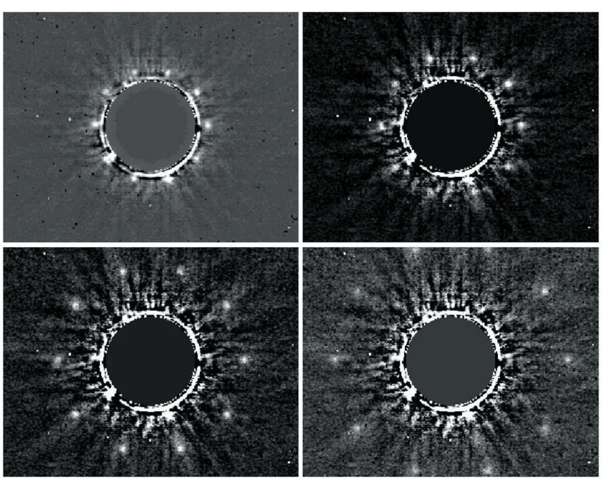

Figure1: Contrast estimation by simulated planets. To study the effects of speckle noise on dynamic range, simulated planet images of different magnitudes (small white dots) are placed at different radii on a PSF subtracted CIAO image of a real $K = 7$ star. Magnitudes and radii in arcsec of the simulated planets are (18,1.2), (19,1.5), (19.5,2.0), (20,2.5) for the panels at upper left, upper right, lower left, and lower right, respectively. At a given radius, the SNRs of ten simulated images range from 7 to 13.

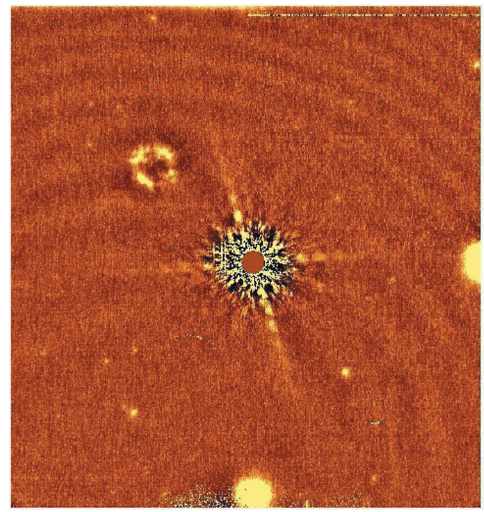

Figure2: An example of a target field. The target star is younger than 350 Myr and located at 3 pc of the Sun. The FOV is 60 × 60 AU and the minimum search radius is 6AU. The detection limit is $M_K = 22.6$.

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Morphological Classification of Galaxies using Photometric Parameters: the Concentration index versus the Coarseness parameter

YAMAUCHI, Chisato
(Subaru project Office, NAOJ / Institute of Space and Astronautical Science)
ICHIKAWA, Shin-ichi (Astronomical Data Analysis Center, NAOJ)
YAGI, Masafumi (Division of Optical and Infrared Astronomy, NAOJ)
DOI, Mamoru, YASUDA, Naoki, SEKIGUCHI, Maki, FUKUGITA, Masataka, OKAMURA, Sadanori
(University of Tokyo)
NAKAMURA, Osamu (University of Nottingham)
GOTO, Tomotsugu (Institute of Space and Astronautical Science)

We devised improved photometric parameters for the morphological classification of galaxies using a bright sample from the Sloan Digital Sky Survey (SDSS) [1].

With the advancement of digitized galaxy surveys, it is highly desirable to develop a fast, automated method of morphological classification applicable to large data samples, without loosing the accuracy of the traditional visual classification. The typical approaches employed for morphological classification are to apply artificial neural networks, and characterizations with simple surface photometric parameters [2], [3].

We focus on the photometric parameters for the morphological classification of galaxies using Sloan Digital Sky Survey.

Previous studies [4], [5] showed that the concentration index, calculated using circular isophotes as part of the standard SDSS pipeline reductions correlates fairly well with morphological type and can be used for classification into early and late galaxy types. The success rate of these approaches, with reference to visual inspection, is approximately 80%.

In this study, we use the SDSS First Data Release imaging data of 1421 galaxies selected from the SDSS Early Data Release and early commissioning data to improve the success rate of morphological classifiers by introducing additional photometric parameters, and evaluate the performance of them in comparison to the visually classified SDSS sample. First, we consider the performance of two types of concentration indices, using circular- and elliptical-apertures. We also introduce a new texture parameter to help our classification. Our texture parameter - coarseness - describes the structure of the outer galaxy isophotes, emulating the method employed in visual classification. The flux fluctuations are computed along elliptical circumferences in order to characterize the galaxy profile's departure from smoothness. The coarseness parameter is defined as the ratio of the range of fluctuations in surface brightness along the elliptic circumference to the full dynamic range of surface brightness of the galaxy.

We first examined the standard concentration index $C = r_{50}/r_{90}$ defined with the Petrosian flux in the circular apertures and found that the correlation with visual types is significantly affected by the axis ratio. We found that this effect is removed by defining the concentration index using elliptical apertures (C_e). The success rate of classifying galaxies into early and late types using C_e was 86.7% with respect to the reference visual classification. With the addition of the coarseness parameter (Y), we could achieve 88.1% of completeness. A reasonably high success rate (66.2%) was also attained in classifying galaxies into three types, early-type galaxies (E + S0), early- (Sa + Sb) and late- (Sc + Sdm + Im) type spiral galaxies. We could further improve the classification by considering 2-dimensional (using the C_e-Y plane) classification (Fig. 1). In the case of classification into two morphological types, this allowed us to attain a 89.4% completeness. For classification into three morphological types, the completeness was 68.1%.

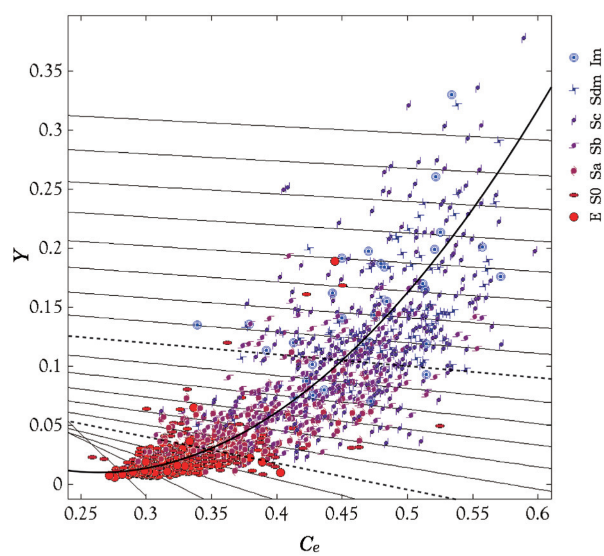

Figure1: The coarseness parameter Y of the 1421 galaxies in our sample versus the concentration index C_e. The quadratic function is the regression line by least-squares fitting to the average 2-vector of galaxies. The two dotted lines are the best classifiers into three types, E + S0, Sa + Sb and Sc + Sdm + Im on the 2-dimensional classification.

Our newly devised photometric parameter, coarseness, provides a mode of morphological classification as good as the traditionally used human-eye classification. Therefore, this new parameter has a potential to open new doors to detailed studies of galaxy morphology in current and future large CCD surveys.

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Dense and Warm Molecular Gas Observations of NGC 6240 with the Nobeyama Millimeter Array and the RAINBOW Interferometer

NAKANISHI, Kouichiro, OKUMURA, Sachiko K.
(Nobeyama Radio Observatory, NAOJ)
KOHNO, Kotaro
(Institute of Astronomy, University of Tokyo)
KAWABE, Ryohei
(ALMA Project Office, NAOJ)
NAKAGAWA, Takao
(Institute of Space and Astronautical Science, JAXA)

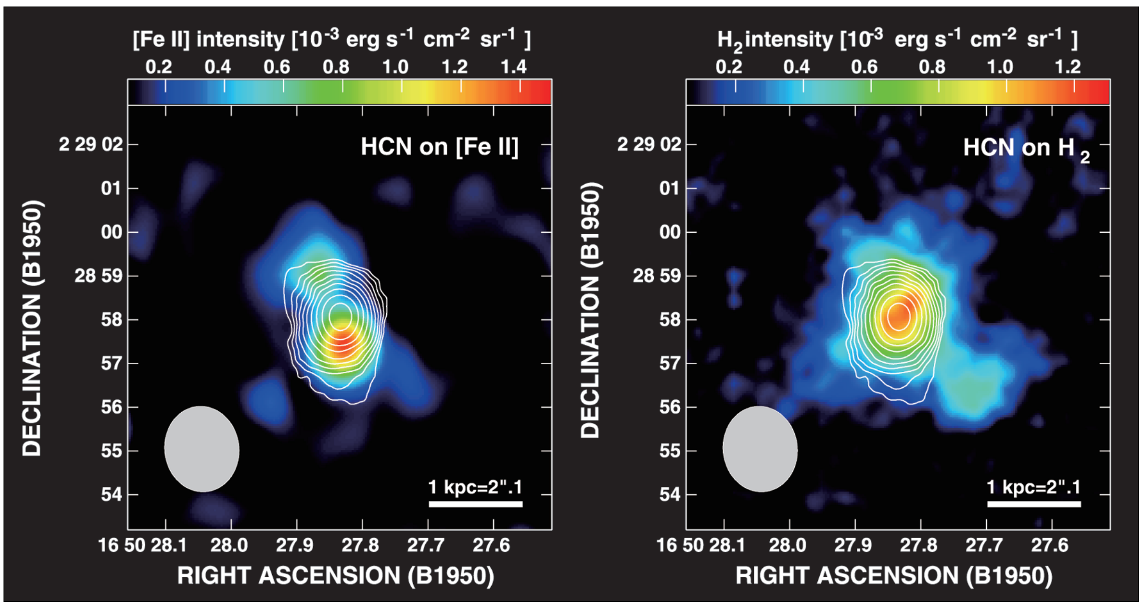

Figure1: HCN(1-0) integrated intensity map (contours) obtained with the NMA and the RAINBOW Interferometer [1] superposed on the near-infrared [Fe II] at 1.644μm (left panel) and H_2 ($v=1-0$ $S(1)$) at 2.121μm (right panel) emission line maps [2]. The figure clearly shows that the HCN peak (dense molecular gas) agrees well with the H_2 peak (hot molecular hydrogen excited by large-scale shock [3]) rather than the [Fe II] peak (supernova remnants, current massive star-forming regions).

Luminous infrared galaxies (LIRGs) are known to be huge molecular gas reservoirs [M (H_2) $> 10^9$ $M_\odot$]. The results of ^{12}CO(1 − 0) observations reveal that this molecular gas is usually concentrated at the center of LIRGs. However, the physical properties, namely the density and the temperature, of the molecular gas in LIRGs are still being studied.

NGC 6240 is one of the most well-known nearby LIRGs. This galaxy is a merger with clearly visible disturbed morphology and has double nuclei. High spatial resolution observations of the ^{12}CO(1 − 0), HCN(1 − 0), HCO$^+$(1 − 0), and ^{13}CO(1 − 0) molecular lines toward NGC 6240 have been performed using the Nobeyama Millimeter Array (NMA) and the RAINBOW Interferometer [1]. The RAINBOW Interferometer is a 7-element array combining the NMA with the NRO 45m telescope, providing higher spatial resolution and sensitivity than those of the NMA.

All of the observed molecular emission lines are concentrated in the region between the double nuclei of the galaxy. The distributions of both HCN and HCO$^+$ emissions, which are supposed to be dense molecular gas tracers, are not coincident with the current massive star-forming regions (see Fig. 1). The high HCN/^{12}CO line intensity ratio suggests that most of the molecular gas between the double nuclei is dense. A comparison of the observed high HCN/^{13}CO intensity ratio with the results from radiative transfer model calculations [4] suggest that the molecular gas is dense [n (H_2) $= 10^{4-6}$cm^{-3}] and warm ($T_{kin} > 50$ K).

The observed structure in NGC 6240 may be explained by time evolution of the molecular gas and star formation, which was induced by an almost head-on collision or very close encounter of the two galactic nuclei accompanied with the dense gas and star-forming regions.

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Clustering of Lyman Break Galaxies at z = 4 and 5 in The Subaru Deep Field: Luminosity Dependence of The Correlation Function Slope

KASHIKAWA, Nobunari
(Division of Optical and Infrared Astronomy, NAOJ)
and Subaru Deep Field team

The clustering strength of galaxies is one of the most fundamental measures in observational cosmology. The measurement of galaxy clustering and its evolution enable us to see the history of galaxy assembly, which is an essential process in the present-day standard paradigm of hierarchical galaxy formation. Recent numerical simulations suggest that some dark halos may harbor more than one Lyman break galaxies (LBGs). If this is the case, then clustering analyses made using a small FOV are biased to probe dominantly for galaxy pairs in the same halo and will tend to miss the halo-halo pair contribution, which has a distinct clustering strength at large scales.

We explored the clustering properties of LBGs at $z = 4$ and 5 with an angular two-point correlation function on the basis of the very deep and wide Subaru Deep Field data (Fig. 1). We confirmed the previous result that the clustering strength of LBGs depends on the UV luminosity in the sense that brighter LBGs are more strongly clustered. In addition, we found an apparent dependence of the correlation function slope on UV luminosity for LBGs at both $z = 4$ and 5 (Fig. 2). More luminous LBGs have a steeper correlation function. The bias parameter was found to be a scale-dependent function for bright LBGs, whereas it appears to be almost scale-independent for faint LBGs. Luminous LBGs have a higher bias at smaller angular scales, which decreases as the scale increases.

To compare these observational results, we constructed numerical mock LBG catalogs based on a semianalytic model of hierarchical clustering combined with high-resolution *N*-body simulation, carefully mimicking the observational selection effects. The luminosity functions and the overall correlation functions for LBGs at $z = 4$ and 5 predicted by this mock catalog were found to be almost consistent with the observation. The observed dependence of the clustering on UV luminosity was not reproduced by the model, unless subsamples of distinct halo mass were considered. That is, LBGs belonging to more massive dark halos had steeper and larger amplitude correlation functions. With this model, we found that LBG multiplicity in massive dark halos amplifies the clustering strength at small scales, which steepens the correlation function. The hierarchical clustering model could therefore be reconciled with the observed luminosity dependence of the correlation function if there is a tight correlation between UV luminosity and halo mass. Our finding that the slope of the correlation function depends on luminosity could be an indication that massive dark halos hosted multiple bright LBGs [1].

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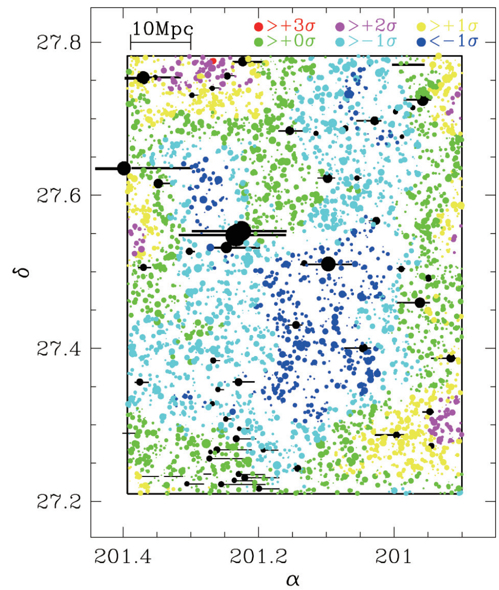

Figure1: Sky distribution of $z = 4$ LBG sample in the Subaru Deep Field. Larger circles denote brighter objects in total i'-band magnitude. The local overdensity, with the significance of each, is denoted by color as shown in the color legend. The black shaded areas are masked regions in which detected objects were rejected due to low *S/N*. North is up and east is to the left.

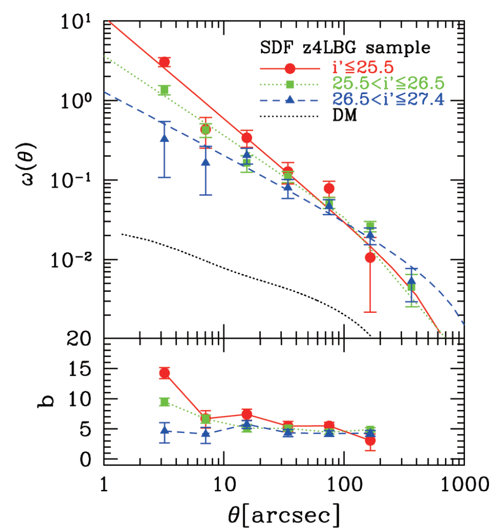

Figure2: Luminosity dependence of angular correlation functions (ACFs) in the $z = 4$ LBG sample. The ACFs of $i' \leq 25.5$, $25.5 < i' \leq 26.5$, and $26.5 < i' \leq 27.4$ are represented by symbols given in the legend. The dotted line is the nonlinear ACF of dark matter at $z = 4$ calculated with the same observational selection function. *Bottom*; Our defined bias parameter $b(\theta)$ for each luminosity subsample with the same symbol and color as indicated in the top panel.

Discovery of HE 1327-2326, the most iron-deficient star known

AOKI, Wako

(Division of Optical and Infrared Astronomy, NAOJ)

Measurements of chemical compositions for extremely metal-deficient stars have been providing constraints on the studies on formation and evolution of first generation stars, supernova explosion mechanism, early nucleosynthesis etc. For such purposes, surveys of extremely metal-poor stars have been made in the past few decades. Our group [1] conducted observations with the High Dispersion Spectrograph of the Subaru Telescope to measure the chemical compositions of candidate extremely metal-poor stars ([Fe/H]< -3) from 2003 to 2005. In this observing program, we found that HE 1327-2326, a star identified as a candidate metal-poor star by the Hamburg/ESO survey, is the most iron-deficient star known to date, and determined its detailed chemical abundance pattern [2], [3].

This star turned out to be a main-sequence or subgiant star from the photometric observations. Figure 1 shows a comparison of the spectrum of this object with that of CS 22876-032, the previously known most metal-deficient main-sequence star. The candidates of metal-deficient stars are selected from the strength of the Ca K line in the medium resolution spectra (upper panel). However, the high resolution spectrum of HE 1327-2326 shows that the contribution of interstellar absorption to this feature is significant, and the Ca abundance at the surface of this object is remarkably low. Indeed, the absorption features of other heavy elements like Fe are also extremely weak, and Fe abundance derived by the detailed abundance analysis is 250,000 times lower than the solar value. This is only about 60% of the Fe abundance measured for HE 0107-5240, the previously known most iron-deficient star (a red giant).

By way of contrast, a number of weak CH features are detected in the spectrum of this object, indicating that the carbon abundance of this object is not so deficient as Fe ([C/H] ~ -1.3). Detailed abundance analyses revealed the unique abundance pattern of this object that heavy elements (e.g. iron-peak elements) are extremely deficient while light elements (C, N, and α elements) are relatively rich. The low abundances of heavy elements suggest that this star well preserves the yields of the first generation stars. The nucleosynthesis of the first generation objects, and their mass function, are at present discussed based on the chemical composition of this star.

Moreover, the following two results for this objects were not expected before our observation: (1) The Li resonance line, which is detected in most main-sequence and subgiant stars at low metallicity, is not detected; (2) The heavy element Sr is overabundant ([Sr/Fe] $\sim +1$). These facts suggest the existence of unknown processes related to the formation of first generation stars and their nucleosynthesis. We note that a new spectrum of this object was obtained with ESO/VLT with longer exposure time, and new results including the determination of oxygen abundance [4] have been obtained.

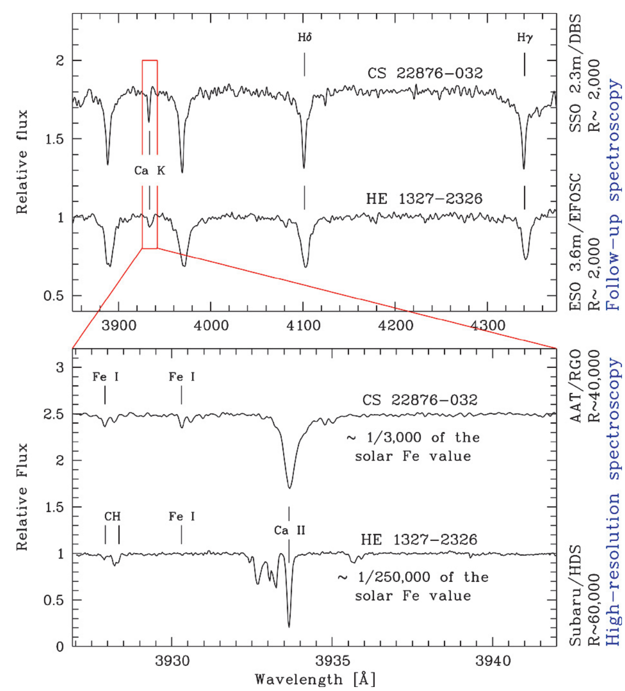

Figure1: A comparison of spectra of HE 1327-2327 and CS 22876-032 (the previously known most metal-deficient main-sequence star). The upper panel shows the medium resolution spectra, in which hydrogen Balmer lines as well as the Ca K line appear. The lower panel shows the high resolution spectra for the wavelength range near the K line. The Ca interstellar absorption is well separated from the stellar absorption line in the spectrum of HE 1327-2326. While no Fe absorption line is detected in this wavelength range for HE 1327-2326, weak absorption features of CH molecule are seen.

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[1] Followings are the members of this collaboration: W. Aoki, S. Honda, H. Ando, T. Kajino (NAOJ), M, Takada-Hidai (Tokai University), K. Nomoto, Y, Yoshii (University of Tokyo), M. Y. Fujimoto (Hokkaido University), J. E. Norris, A. Frebel, M. Asplund (Australian National University), T. C. Beers (Michigan State University), N. Christlieb (Hamburg University), S. G. Ryan, S. Tsangarides (Open University).

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Sulfur and Zinc Abundances of Galactic Disk/Halo Stars : Application of Extensive Detailed Non-LTE Calculations

TAKEDA, Yoichi (Division of Optical and Infrared Astronomy, NAOJ)
HASHIMOTO, Osamu, TAGUCHI, Hikaru (Gunma Astronomical Observatory)
YOSHIOKA, Kazuo (University of Air)
TAKADA-HIDAI, Masahide, SAITO, Yuji (Tokai University)
HONDA, Satoshi (Subaru Telescope, NAOJ)

Sulfur (S) and zinc (Zn) are of particular astrophysical importance because they are chemically "volatile". That is, they are difficult to condense into solids (unlike other "refractory" elements such as Mg, Si, Fe-group elements, etc.) and thus are considered to be hardly affected by depletion due to dust formation. Therefore, for the case of post-AGB stars in the late stage of stellar evolution, where atmospheric abundances of refractory elements have been more or less depleted because of condensation into dust coupled with mass-loss, [S/Zn] vs. [Zn/H] relation is often used as a substitute for [S/Fe] vs. [Fe/H], from which its original metallicity (or stellar population) may be inferred. In this sense, it is important as a prerequisite to understand the behavior of [S/Fe] and [Zn/Fe] with a change of [Fe/H] in metal-poor stars.

Unfortunately, however, these relations have not yet been firmly settled. Especially, we are still in a confusing situation concerning the case of S, for which two contradicting [S/Fe] trends toward a decrease of [Fe/H] (increasing vs. flat) are argued for very metal-poor stars ([Fe/H] < -2), depending on the lines (S I 8693/8694 and S I 9212/9228/9237) used for abundance determinations. On the other hand, the long-believed simple scaling of Zn with Fe ([Zn/Fe] $\simeq 0$) over a large range of metallicity has now become questioned based on recent analyses, which indicate a supersolar [Zn/Fe] toward an extremely metal-poor regime ([Fe/H] < -3) as well as a slight tendency even in galactic disk stars ($-1 <$ [Fe/H] $< +0.5$).

Here, it should be noted that all these analyses were done with the assumption of LTE (application of Saha-Boltzmann equation by using local temperature and density for calculating level populations), the validity of which has never been confirmed so far. Therefore, we decided to carry out extensive non-LTE calculations on neutral sulfur and zinc for the first time, in order to examine whether such a discrepancy on S or the observed trend in Zn may have something to do with the non-LTE effect, as well as to establish the non-LTE [S/Fe] vs. [Fe/H] and [Zn/Fe] vs. [Fe/H] relations. The results are shown in Figures 1 and 2, and summarized as follows:

We still encounter a serious difficulty in the [S/Fe] vs. [Fe/H] relation at the very metal-poor region of [Fe/H] < -2, in the sense that the [S/Fe] values derived from S I 8693/8694 (non-LTE effect is practically negligible) tend to rise progressively with a decrease of metallicity while those from S I 9212/9228/9237 (suffering considerably larger non-LTE effects) show a flat plateau or a sign of slight downward bending; the discordance amounts up to ~0.5 dex. Namely, the discrepancy seen in the LTE analyses is even exaggerated due to the application of non-LTE corrections.

For the studied Zn I 4722/4810/6362 lines, the non-LTE effect is generally small and insignificant. Inspecting the [Zn/Fe] vs. [Fe/H] relation resulting from our reanalysis, we almost confirmed the recently reported tendency, such as the gradual increase of [Zn/Fe] from [Zn/Fe] ~ 0 (at [Fe/H] ~ 0) to [Zn/Fe] ~ 0.2 (at

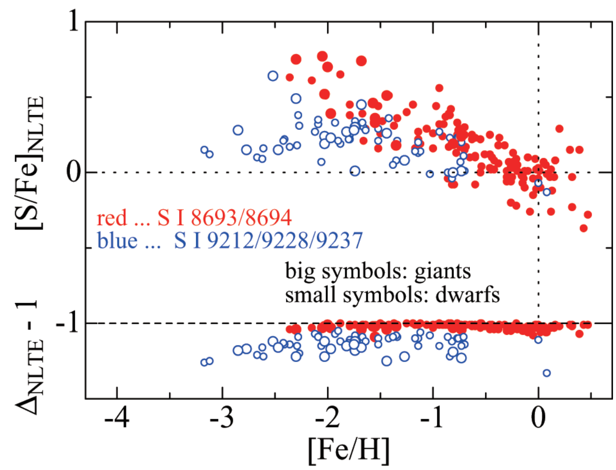

Figure1: Runs of $[S/Fe]_{NLTE}$ and Δ_{NLTE} (non-LTE correction) against [Fe/H].

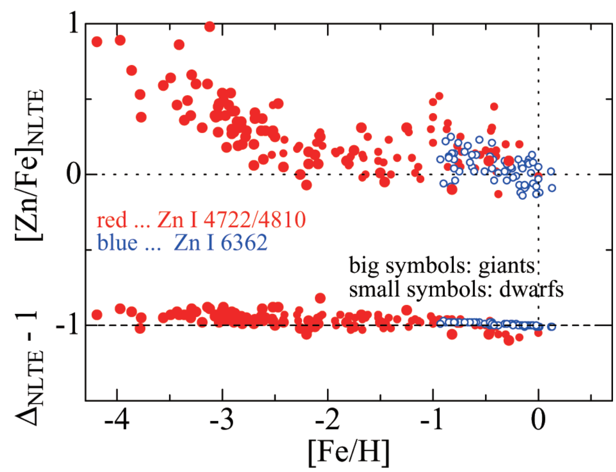

Figure2: Runs of $[Zn/Fe]_{NLTE}$ and Δ_{NLTE} (non-LTE correction) against [Fe/H].

[Fe/H] ~ -1), nearly constant [Zn/Fe] (i.e., without particular trend) over the region of $-2 <$ [Fe/H] < -1, and a beginning of rise at [Fe/H] < -2 continuing toward an extremely low-metallicity regime.

The details of this study are described in [1].

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Rotating Molecular Gas Associated with a Silhouette Disk at the Center of the Radio Galaxy 3C 31

OKUDA, Takeshi, KOHNO, Kotaro
(Institute of Astronomy, University of Tokyo)
IGUCHI, Satoru
(ALMA Project Office, NAOJ)
NAKANISHI, Kouichiro
(Nobeyama Radio Observatory, NAOJ)

The radio source 3C 31 is hosted by the D galaxy, which is the brightest galaxy in the Zwicky cluster 0107.5 + 3212 at a distance of about 70 Mpc. Very Large Array (VLA) images of radio wavelengths show bi-directional and twisting synchrotron jets with a size of approximately a few 100 kpc emanating from the center of the galaxy [1]. The Hubble Space Telescope (HST) observations reveal the presence of a silhouette disk with a diameter of about 6 arcsec or 2 kpc at a distance of 3C 31 [2]. The detection of abundant molecular gas has been reported in the course of the survey of ^{12}CO(J = 1 − 0) and ^{12}CO(J = 2 − 1) emissions toward 3C radio galaxies using the IRAM 30m telescope [3]. The proximity and the large apparent size of the disk of 3C 31 make it an ideal object to study the structure and the kinematics of molecular gas in a silhouette disk.

We report high angular resolution ^{12}CO(J = 1 − 0) observations of the radio galaxy 3C 31 using the Nobeyama Millimeter Array (NMA) and the RAINBOW Interferometer, which is a 7-element combined array between the NMA and the NRO 45m telescope that can achieve a very large collecting area and a high spatial resolution [4]. Our high-resolution (1."9 × 1."4 or 640 pc × 470 pc at D = 70 Mpc) ^{12}CO image shows a circularly rotating molecular gas disk, which closely coincides with a silhouette disk observed in the Hubble Space Telescope (HST) optical images.

The molecular gas mass (M_{gas}) of the disk is estimated to be $9.7 \times 10^8 M_\odot$ within a radius of 1 kpc, and the peak gas surface density Σ_{gas} is $4.0 \times 10^2 M_\odot$ pc^{-2} at 440 pc from the center, if a Galactic I(CO) to N(H$_2$) conversion factor (1.8×10^{20} [cm^{-2} (K km s^{-1})$^{-1}$]) is applied [5]. The rotation velocity of the disk is 460km s^{-1} at a radius of 1 kpc, giving an enclosed mass (dynamical mass) of $M_{dyn} = 5.0 \times 10^{10} M_\odot$ within this radius.

The ratio of gas mass to dynamical mass, $M_{gas} = M_{dyn}$ is less than 0.02 within a radius of 1 kpc. This ratio is smaller than those in typical star-forming/starburst galaxies by a factor of 3 or greater, implying that the molecular gas disk in the center of 3C 31 is gravitationally stable, and this is consistent with the fact that successive massive star formation does not occur there [6].

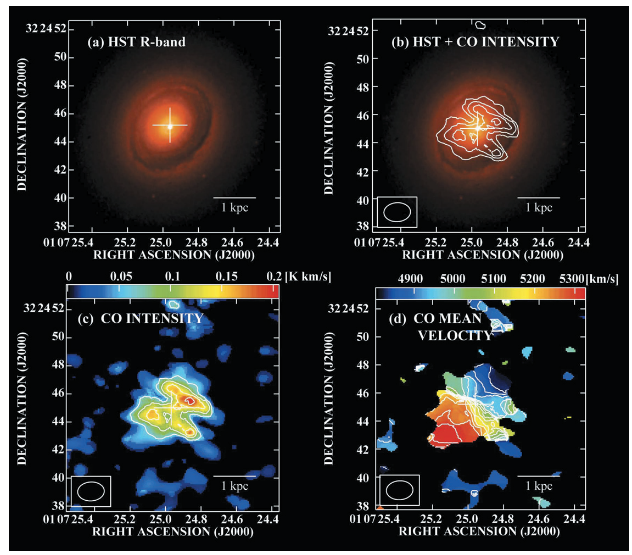

Figure1: The NMA and RAINBOW maps of ^{12}CO (J = 1 − 0) emission in the radio galaxy 3C 31. The central cross in figure (a), (b), (c), and (d) marks the peak of 8.4 GHz in the continuum. (a) HST R-band image of the center of 3C 31. The HST image was obtained from the data archive of the Multimission Archive at STScI. (b) Integrated intensity map (contour) of ^{12}CO (J = 1 − 0) superposed on an HST image (color). (c) Integrated intensity map of ^{12}CO (J = 1 − 0). (d) Intensity-weighted mean velocity map of ^{12}CO (J = 1 − 0).

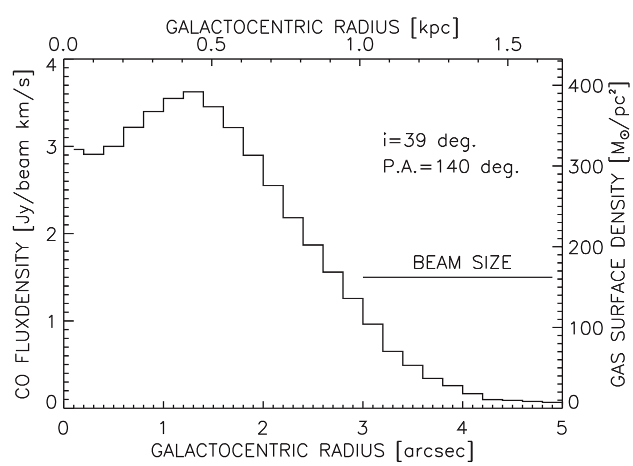

Figure2: Azimuthally averaged radial distributions of gas mass across the molecular disk in 3C 31.

References

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Installation of Seismic Attenuation System (SAS) to Gravitational Wave Detector TAMA300

FUJIMOTO, Masa-Katsu, KAWAMURA, Seiji, YAMAZAKI, Toshitaka
TAKAHASHI, Ryutaro, ARAI, Koji, TATSUMI, Daisuke, FUKUSHIMA, Mitsuhiro
SATO, Shuichi, TAKAMORI, Akiteru, and the TAMA Collaboration
(TAMA Project Office, NAOJ)

The development of Seismic Attenuation System (SAS) started from 1999 in cooperation with the LIGO group of USA. The experiments using SAS prototypes were finished by 2002. We started manufacturing and assembling of four SAS towers for TAMA300 from 2003. The first tower has been installed to the west-end room in September, 2005 (Fig. 1).

After the installation, we identified the natural frequencies of the inverted pendulum for horizontal isolation. The frequencies were decided as 154 mHz for X, 46 mHz for Y, and 542 mHz for rotation (θ) respectively. The horizontal modes (X and Y) were not degenerated at all. The natural frequencies of the Geometric Anti-Spring Filter for vertical isolation were 482 mHz and 919 mHz.

A full-digital system is introduced to control SAS for the first time in TAMA300. The system is handled by an all-purpose CPU (Penntium III/1.2 GHz) and a real-time OS. LabVIEW is available to program the controller. There are three acceleration sensors, three LVDTs, and three coil-magnet actuators for horizontal directions on the top of SAS. A LVDT and a coil-magnet actuator are used for vertical direction. Since acceleration sensors, LVDTs, and actuators are not put along the direction of identified mode (X, Y, and θ), three signals must be diagonalized to the directions of X, Y, and θ. Seven channels of acceleration sensor and LVDT are assigned to inputs (A/D converters) of the digital controller. Seven channels of diagonalized acceleration signal and actuator are assigned to outputs (D/A converters). Main process of the digital controller is diagonalization and filtering of input signals. The first, the diagonalization matrix was decided using natural modes which appear in the measured transfer functions from each actuator to each sensor. The second, optimal servo filters were designed using measured transfer functions from a diagonalized virtual actuator to a virtual sensor. The resonances of each mode were successfully damped by the designed servo system.

We added a digital controller for rotational motions (pitch and yaw) of the mirror in order to lock the 300 m cavity where one of mirror is suspended by installed SAS. A local optical lever was used as a angular sensor. A large resonant peak at 50 mHz due to the torsion mode was damped using complicated servo filters that it is difficult to construct by an analog controller. After the 300 m cavity is locked, the control signals are changed to more sensitive signals acquired by the Wave Front Sensing (WFS) method from the interferometer. Owing to this control, a stable lock of the 300 m cavity succeeded with SAS. We could change the control signals from optical lever to WFS successfully without lock lost.

The remains of a SAS tower will be installed as they become ready by autumn in 2006.

Figure1: Installation works for SAS in the west-end room.

Development of a laser interferometric high-precision angle sensor for the JASMINE satellite

ARAI, Koji (TAMA Project Office, NAOJ)
NIWA, Yoshito (Kyoto University / JASMINE Project Office, NAOJ)
SAKAGAMI, Masaaki (Kyoto University)
GOUDA, Naoteru, KOBAYASHI, Yukiyasu, YANO, Taihei (JASMINE Project Office, NAOJ)
YAMADA, Yoshiyuki (Kyoto University)

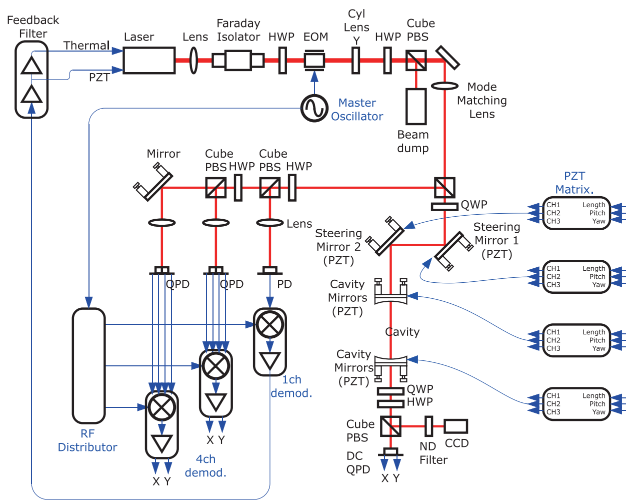

Figure1: Schematic diagram of the optical, electronic, and servo-control systems for the basic angle monitor.

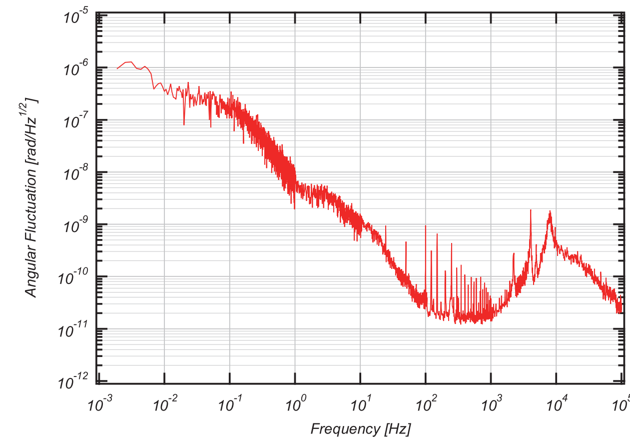

Figure2: Power spectral density of the measured differential angle fluctuation of the two mirrors forming Fabry-Perot cavity.

The JASMINE project proposes an astronomical satellite mission in near-infrared band. The goal of the project is establishment of astrometry by observing annual parallaxes and proper motions with precision of 10μarcsec for several hundred million stars in the galactic plane and the galactic bulge. Since it is difficult to control rotation of the satellite with such precision, a mirror called *beam mixing mirror* will be used to observe two largely-separated sky field simultaneously in order to distinguish the motion of stars from fluctuation of the satellite rotation. This angle separation, which is 99.5 degree for JASMINE, is called *basic angle*.

If the basic angle fluctuates more then 10μarcsec, the required observation precision would not be achieved. Therefore, the stability of the basic angle should be monitored by an high-precision angle sensor (basic angle monitor). Since 2004, JASMINE Project, with assistance of TAMA Project, started planning and development of a laser interferometer basic angle monitor.

This year, basic angle monitor using Wave Front Sensing technique[1], [2](WFS) was built. WFS is a technique to detect difference of optical axes between an optical cavity and an incident beam. In our instrument, the incident laser beam is accumulated in a Fabry-Perot cavity formed by two spherical mirrors. The reflected light is detected by quadrant photo detectors. Phase modulation is applied to the incident light so that the phase modulated light and the leakage intracavity light interferes on the quadrant photo detectors resulting in indication of the optical axis difference when the output signals are being demodulated. Using this instrument, differential fluctuation of the mirror angle, which affects the observation of JASMINE, is selectively detected, separated from other common-mode mirror angle fluctuation and incident beam fluctuation.

The characterization of our instrument was performed. The optical, electronic, and servo-control systems of the instrument were built (Fig. 1). The cavity length control establishes the state that the laser beam continuously resonates to the cavity. In this state, the angles of the two cavity mirrors were artificially actuated. From the response of the sensors, it was confirmed that the angle sensor linearly responds to the actuation and is 85 times more sensitive to the differential angle actuation, which we want to observe, than to the common-mode actuation. The differential angle fluctuation of the cavity mirrors were measured without any actuation (Fig. 2). It was found that the RMS fluctuation level above 1mHz with the current optical system is about 2500 times larger than the required level by JASMINE. This research resulted in the master degree of Niwa.

Our next step is proceed the experiment to fulfill the required level by JASMINE. Currently all of the optical system is placed under the atmospheric pressure. The fluctuation of the cavity by the air flow and the temperature change is to be considered by using vacuum systems and passive and active temperature stabilization systems.

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Velocity Drift of Water Maser Features of NGC 4258

YAMAUCHI, Aya
(Kyushu University / Nobeyama Radio Observatory, NAOJ)
SATO, Naoko
(Hokkaido University / Nobeyama Radio Observatory, NAOJ)
HIROTA, Akihiko
(University of Tokyo / Nobeyama Radio Observatory, NAOJ)
NAKAI, Naomasa
(University of Tsukuba)

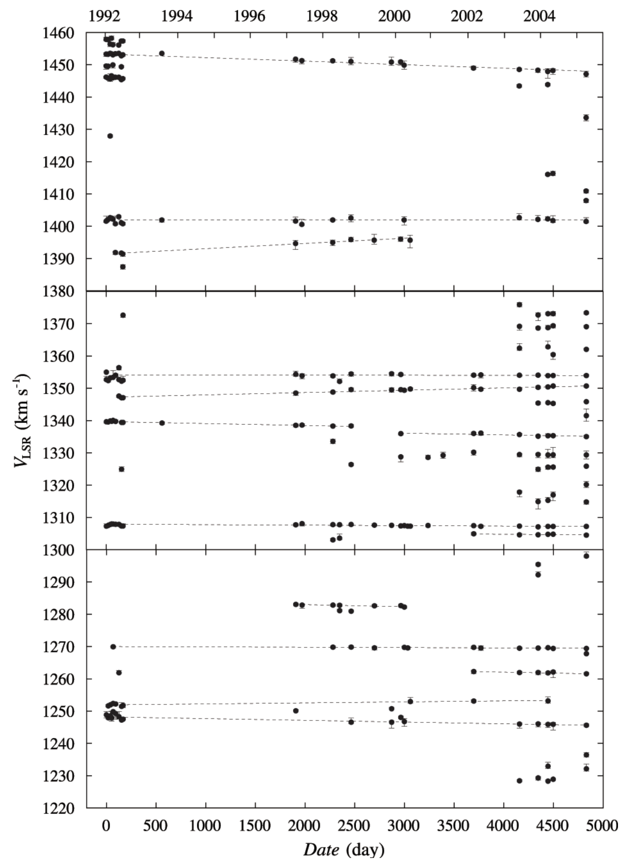

Figure1: Velocity variations of red-shifted features from 1992 January 12.

We monitored the velocities of high-velocity features for a H_2O megamaser, NGC 4258, using the 45-m telescope of the Nobeyama Radio Observatory (NRO) [1].

Water-vapor (H_2O) maser emission is a unique probe to investigate the structure and dynamics of active galactic nuclei (AGN) on the (sub-)parsec scale directly. NGC 4258 is the most studied megamaser. VLBI observations revealed the existence of a compact edge-on disk in Keplerian rotation and a massive black hole at the nucleus of the galaxy [2].

For most of megamasers, including NGC 4258, the intensities of blue-shifted features are weaker than those of red-shifted features. Maoz and McKee (1998) explained the asymmetry of the high-velocity features (i.e., red- and blue-shifted features) using a spiral shock model in masing disk [3]. In this model, it is expected that rotation of the spiral shock should lead to a velocity drift of high-velocity features. They predicted that red-shifted features have negative drift rates, and vice versa. To confirm this model, we measured the velocity drift rates of the high-velocity features of NGC 4258.

Observations of H_2O maser emission were made from 1992

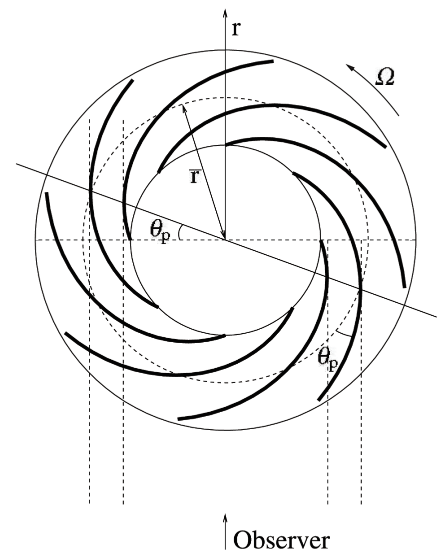

Figure2: An illustration of the spiral structure in a maser disk. $\bar{r}$ is the mean radius of the maser disk, and θ_p and Ω are the pitch angle and pattern speed of the spiral arms.

January through 2005 April. Figure 1 shows the velocity variations of the red-shifted features at $V_{LSR} = 1220$-1460km s^{-1}. We plot the features with peak intensities of $\geq 5\sigma$ for each observation. Using the data of 1992 − 2005, the drift rate was detected to be $\bar{a} = -0.036 \pm 0.007$km s^{-1} yr^{-1} on the average for 10 red-shifted features. The drift rate of a blue-shifted feature was $a = 0.20 \pm 0.10$km s^{-1} yr^{-1}. These results are consistent with a prediction that the observed line-of-sight velocities of red-shifted features decrease, and those of the blue-shifted increase, from the spiral shock model.

Assuming a logarithmic spiral (i.e., constant pitch angle of the spiral), we can calculate the pitch angle, θ_p, given by

$$\theta p = \tan^{-1}\left(-\frac{2a}{v\,\Omega}\right),$$

using an assumed pattern speed of the spiral arms, $\Omega = 2250$km s^{-1} pc^{-1}, and the rates of velocity drifts measured. The pitch angles of the spirals were obtained to be $\overline{\theta}_p = 2° \pm 1°$ on the average for the red-shifted features, and $\theta_p = 13° \pm 7°$ for the blue-shifted feature from the measured drift rates.

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Nobeyama Millimeter Array Observations of GRB 030329: a Decay of Afterglow with Bumps and Molecular Gas in the Host Galaxy

KOHNO, Kotaro, OKUDA, Takeshi, MURAOKA, Kazuyuki, ONODERA, Sachiko, SOFUE, Yoshiaki
(University of Tokyo)
TOSAKI, Tomoka
(Gunma Astronomical Observatory)
NAKANISHI, Kohichiro, KAMAZAKI, Takeshi, OKUMURA, Sachiko, KUNO, Nario, ISHIZUKI, Sumio
(Nobeyama Radio Observatory, NAOJ)
KAWABE, Ryohei (ALMA Project Office, NAOJ)
OHTA, Koji (Kyoto University)
KAWAI, Nobuyuki (Tokyo Institute of Technology, RIKEN)

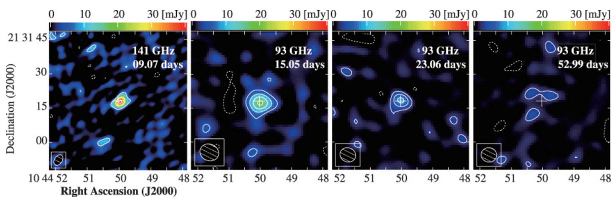

Figure1: Selected images of GRB 030329 afterglow at $\lambda = 2$ mm and 3 mm to depict fading afterglow emission. The observed frequency, time after the burst, and the synthesized beam are indicated. The central cross in each panel marks the position of the GRB 030329 optical afterglow. The contour levels are -3σ, 3σ, 9σ, and 15σ for the 141 GHz image, and the contour intervals are 2σ for 93 GHz images.

Nobeyama Millimeter Array was used to observe millimeter-wave afterglow of GRB 030329 at 93 GHz and 141 GHz from 2003 April 6 (8.23 days after the burst) to 2003 May 30 (61.97 days). A sensitive search for CO ($J = 1 - 0$) emission/absorption from the host galaxy of GRB 030329 was also carried out [1].

Unresolved millimeter continuum emission at the position of GRB 030329 was detected until 2003 April 21. We found a steep decline of continuum flux ($\propto t^{-2.0}$) during this period, in accord with a previous report. Moreover, our data implies that the decay was accompanied by possible plateaus phases on a time scale of several days. If they are caused by density fluctuations of surrounding ISM, the spatial scale of the structure corresponding to the time scale is about ~ 10^3 AU, supposing a relativistic expansion. From an integrated spectrum, produced by summing up the data from 2003 April 10 to 2003 May 30, we found a possible emission feature, which could be a redshifted CO ($J = 1 - 0$) line. Its position and redshift coincide well with those of GRB 030329, though further observations are required to confirm the detection. If the emission feature is real, the observed CO flux is 1.4 ± 0.52 Jy km s^{-1}, corresponding to a large molecular gas mass of $M(H_2) > 10^9 M_\odot$. This implies that the host galaxy, which is optically faint, is highly obscured due to a rich interstellar medium.

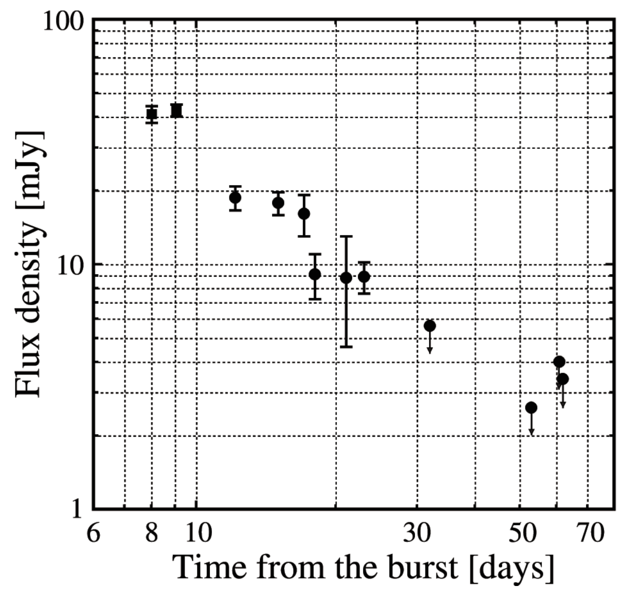

Figure2: Time variation of $\lambda = 2$mm (square) and 3mm (circle) continuum flux toward GRB 030329 observed with the Nobeyama Millimeter Array. The upper limits are 2σ.

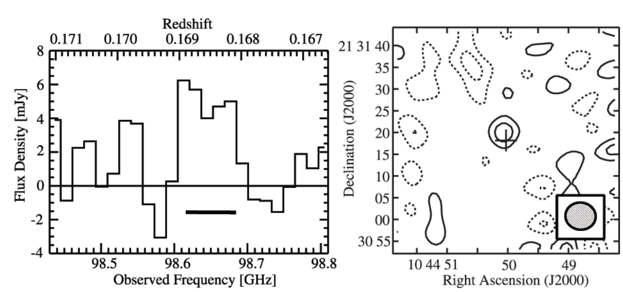

Figure3: (Left) Observed spectrum at the 98 GHz band toward GRB 030329, produced by summing up the 3 mm data from 2003 April 10 to 2003 May 30. The spectral resolution is 16 MHz or 48.6km s^{-1}, and the rms noise level is 3.8 mJy. (Right) A integrated intensity map of a possible CO emission line over a velocity width of 220km s^{-1}. The synthesized beam, shown in the right bottom corner, is $7''.0 \times 6''.3$ (position angle = 84°). The contour interval is 0.52 Jy^{-1} km s^{-1} (1σ).

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A 385-500 GHz Sideband-separating (2SB) SIS Mixer Based on a Waveguide Split-Block Coupler

KAMIKURA, Mamoru, TOMIMURA, Yu (University of Tokyo)
SEKIMOTO, Yutaro, ASAYAMA Shin'ichiro (NAOJ)
SHAN, Wenlei (NAOJ / Purple Mountain Observatory)
SATOU, Naohisa, IIZUKA, Yoshizo, ITO, Tetsuya, KAMBA, Toshiaki (NAOJ)
SERIZAWA, Yasutak (University of Tokyo)
NOGUCHI, Takashi (NAOJ)

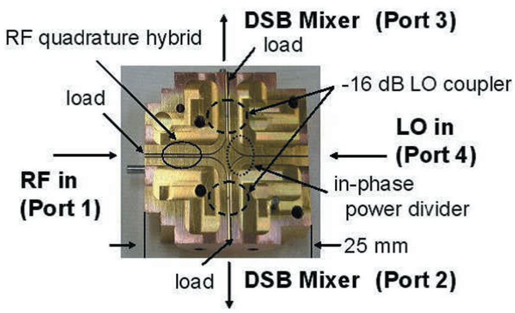

Figure1: Photograph of an RF/LO coupler. An RF/LO coupler contains an RF quadrature hybrid, two LO couplers, and an in-phase power divider.

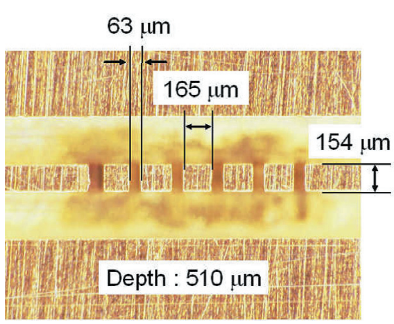

Figure2: Results of the mechanical measurements of the RF quadrature hybrid.

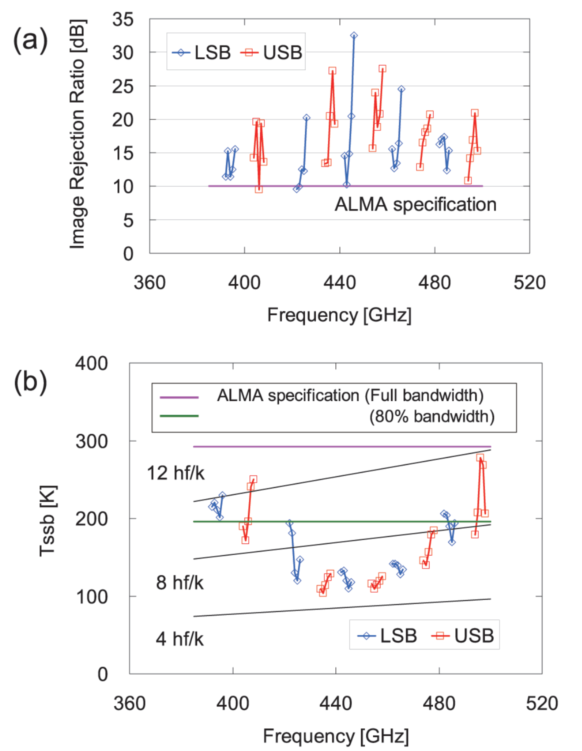

Figure3: (a) Image rejection ratio, (b) single-sideband (SSB) noise temperature of the ALMA Band 8 cartridge-type receiver [4] using the 2SB mixer.

We have developed a 385-500 GHz sideband-separating (2SB) SIS mixer, which is based on a waveguide split-block coupler [1]. The 2SB mixer is to be installed into the ALMA receiver for the Band 8 (385-500 GHz) frequency range. To reduce atmospheric noise, sideband separation is necessary. So far sideband-separating mixers have been designed and built at frequencies up to 370 GHz [2], [3]. This is a 2SB mixer at the highest frequencies at present.

For the 2SB mixer, we have developed and evaluated an RF/LO coupler, which contains an RF quadrature hybrid, two LO couplers, and an in-phase power divider (Fig. 1). We have machined the waveguide ($508\mu m \times 254\mu m$) on only one side to reduce the loss resulting from the misalignment of the two split blocks.

The dimensions of the RF/LO coupler were measured with a high precision (~$0.5\mu m$) scale. Amplitude and phase characteristics of the RF/LO coupler were also measured with a vector network analyzer. The simulated results from the mechanical measurements were almost consistent with the measured results with the vector network analyzer. The differences between these results were within 0.5 dB in amplitude, 10 degrees in phase, respectively.

The image rejection ratio (IRR) and the single-sideband (SSB) noise temperature of the ALMA Band 8 cartridge-type receiver [4] using the 2SB mixer were measured. The IRR was larger than 9.5 dB and typically 15 dB in the 385-500 GHz band (Fig. 3a).

The SSB noise temperature was around 5 times the quantum limit at 435 GHz, and less than 14 times the quantum limit in the 385-500 GHz band (Fig. 3b). We have achieved a broad-band and low-noise receiver which meets almost the ALMA specification. The SIS mixers in the receiver were developed by Shan et al. [5].

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Phoenicids in 1956 Revisited

WATANABE, Jun-ichi, SATO, Mikiya, KASUGA, Toshinori
(Public Relations Center, NAOJ)

The outburst of the Phoenicids observed in 1956 was investigated on the basis of the dust trail theory by using the newly linked orbit that was estimated from the asteroid 2003 WY_{25} and comet D/1819 W1 (Blanpain). We find that a bundle of the trails formed from late 18th through early 19th centuries came close to the Earth's orbit at the epoch of the outburst in 1956. According to similar calculations for 1950-2030, the situation in 1956 is proven to be the best epoch for the strong display in the Phoenicids. This result shows not only the definite association of the objects to the Phoenicids, but also the clear reason for the sudden outburst in 1956. Although the future activity is expected in 2014, it depends on the cometary activity of the parent object, because the related trails are expected to be relatively new. This is a new approach to explore the past history of cometary activities of relatively dormant objects by inspecting the activity of related meteor showers, with a help of the dust trail theory [2].

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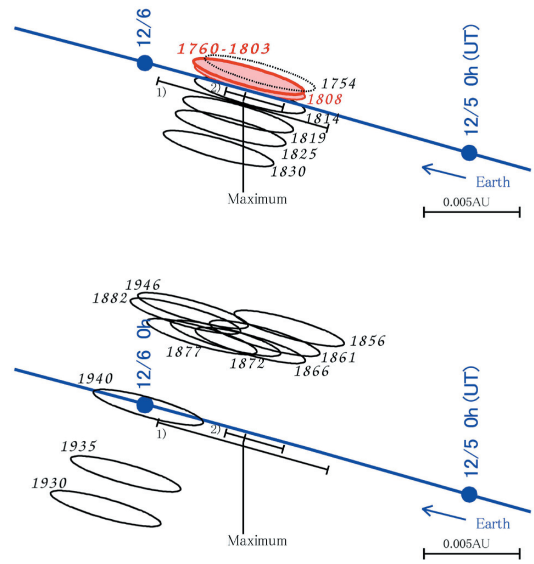

Figure1: The geometrical relation between the dust trails and Earth's orbit in 1956. Upper panel shows those trails formed before 1830, while the lower panel after 1856. Two lines indicate the duration of the outburst summarized by
1) Kronk
(http://comets.amsmeteors.org/meteors/showers/phoenicids.html, 2005) and
2) Huruhata and Nakamura [1],
including the epoch of the activity peak reported.

Size Distribution of Faint Jovian L4-Trojan Asteroids

YOSHIDA, Fumi, NAKAMURA, Tsuko
(NAOJ)

Jovian Trojans are asteroids located at a mean distance of 5.2 AU from the Sun. They share the orbit of Jupiter but lead or trail the planet by an angular distance of ~60°; they lie clustered around Jupiter's L4 and L5 Lagrangian points. It has been believed that they originated from planetesimals that formed near Jupiter and were captured into their current orbits, while proto-Jupiter was still growing. Therefor if there is some possibility that some information around Jupiter of early Solar system still remains till now, it may be on the Jovian Trojans. As a first step, we investigated the size distribution of the Trojans, in particular very faint members of them for getting some information of early Solar system.

We detected faint 51 Jovian Trojan asteroids in the L4 Lagrangian swarm in a wide-field survey near the ecliptic with the 8.2m Subaru telescope and Suprime-Cam [1]. The survey area was about 3 deg^2 and located ~ 30 deg in longitude ahead from the L4 point. The limiting magnitudes for our Trojan asteroids were $R=$ 24.4 mag. The size range of the detected Trojans is $0.7\mathrm{km}<D<12.3\mathrm{km}$ in diameter (D) (with an assumed albedo of 0.04 for each object, which is the mean albedo among known Trojans).

The mean slope of the cumulative size distribution, namely the power-law distribution index, was found to be 1.9 ± 0.1 for the Trojans with $2\mathrm{km}<D<10\mathrm{km}$. However, we noticed the slope changes around D ~ 5km. The separately best-fitted slopes for the size ranges of $2\mathrm{km}\le D<5\mathrm{km}$ and for $5\mathrm{km}<D\le10\mathrm{km}$ were 1.3 ± 0.1 and 2.4 ± 0.1, respectively. This changing nature of slope have also been found in the size distribution of km-to-subkm main-belt asteroids [2], it seems to be caused by collisional evolutions among the initial population having single power-law size distribution.

Using the size distribution of our Trojans and the spatial distribution model of the L4 Trojans proposed by [3], we estimated a total population number of the L4 Trojans with $D>$ 1km. We found that the total number of the L4 Trojans with $D>$ 1km (~ 6×10^5) is comparable to that of the main-belt asteroids with $D>1$km (~ 6.7×10^5, [4]).

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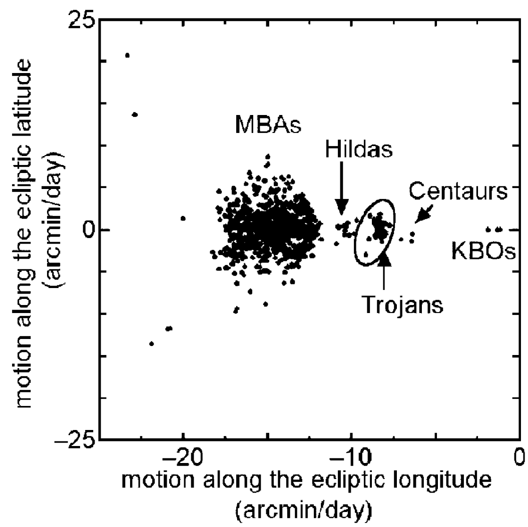

Figure1: Ecliptic longitude and latitude components of apparent motions for 1111 moving objects detected in this survey. There are 861 MBAs, 10 Hildas, 51 Trojans and others. This figure is the same as Fig. 4 of [1], [2].

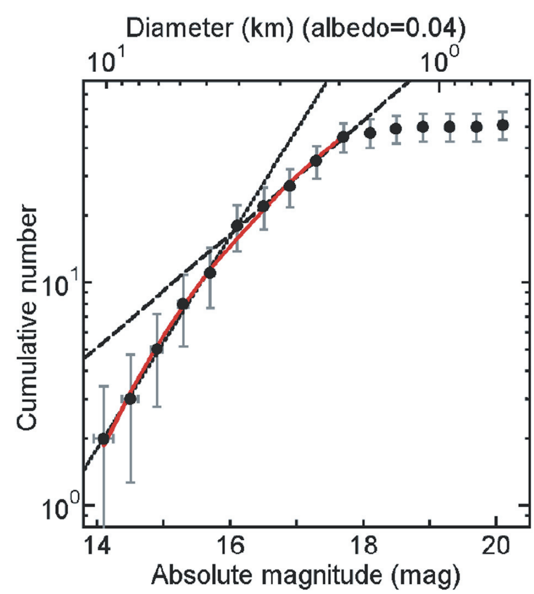

Figure2: The CSD of detected L4-Trojans (filled dots with error bars) and fitted curves. Our detection limit for Trojan asteroids lies in the $H=$ 17.7-bin. The dotted and dashed lines show the slope of 2.39 for asteroids with $D>5$km, and that of 1.28 for $D<5$km, respectively. We used the red solid line which connected smoothly between both slopes to estimate the number of the L4 Trojans with $D>1$km [1].

Near-Infrared Imaging Survey of Bok Globules: Density Structure

KANDORI, Ryo, NAKAJIMA, Yasushi, TAMURA, Motohide, TATEMATSU, Ken'ichi
(NAOJ)
AIKAWA, Yuri NAOI, Takahiro SUGITANI, Koji
(Kobe University) (JAXA) (Nagoya City University)
NAKAYA, Hidehiko NAGAYAMA, Takahiro, NAGATA, Tetsuya
(NAOJ) (Kyoto University)
KURITA, Mikio, KATO, Daisuke, NAGASHIMA, Chie, and SATO, Shuji
(Nagoya University)

We conducted a JHK_s imaging survey of Bok globules (isolated dense cores) using the infrared camera SIRIUS on the IRSF 1.4 m telescope in South Africa. On the basis of dust extinction ($A_V \propto$ column density) measurements of both starless and star-forming globules, we investigated their density structure using the Bonnor-Ebert model. We report important findings on the density structure, stability, and evolution of globules [1].

The Bonnor-Ebert sphere model ([2], [3]) describes a pressure-confined, self-gravitating isothermal gas sphere in hydrostatic equilibrium. The dimensionless radial parameter ξ_{max} determines the shape of a Bonnor-Ebert density profile as well as the stability of the equilibrium state, e.g., the solution of $\xi_{max} > 6.5$ is unstable to the gravitational collapse. The model well fits column density profiles of observed globules (Fig. 1), and physical properties including ξ_{max} of each globule were derived. We investigated the stability of globules on the basis of ξ_{max} for ten globules from our observations and four globules in the literature (Fig. 2). The sample consists of 11 starless and 3 star-forming globules. In addition to the near-infrared imaging, we have carried out radio molecular line observations toward the ten globules using the NRO 45 m telescope, and found that the globules are mostly dominated by thermal support.

(1) We found that more than half of the starless globules (7 out of 11 sources) are located near the critical state, $\xi_{max} = 6.5 \pm 2$. We suggest that a nearly critical Bonnor-Ebert sphere characterizes the typical density structure of starless globules, and it approximates the initial condition of gravitational collapse.

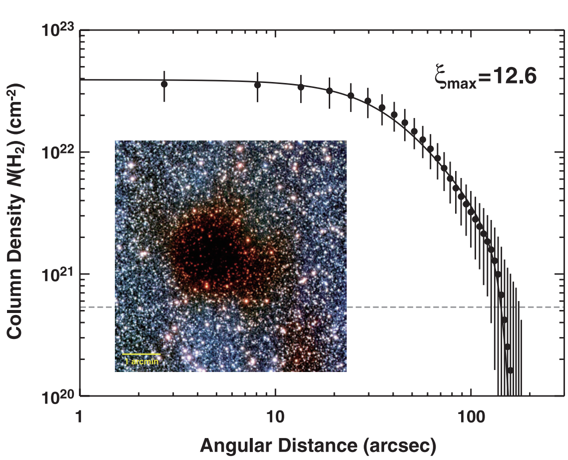

Figure1: Radial column density profile of the globule FeSt 1-457. The solid line denotes the best-fit Bonnor-Ebert profile which is convolved to the resolution of A_V map (33"). The broken line denotes 1 σ detection limit. Inset figure shows the JHK_s-composite image of the globule.

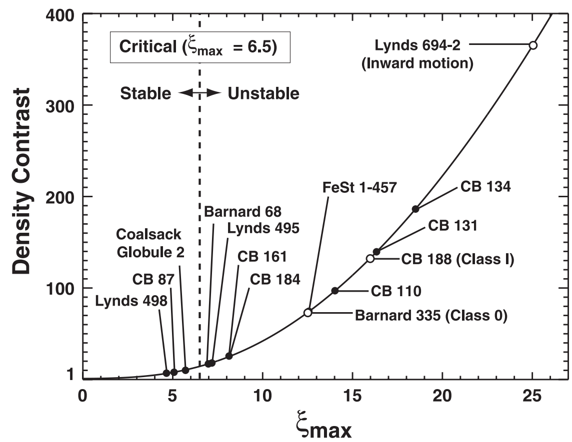

Figure2: The solid line shows the relationship between ξmax and density contrast (center-to-edge density ratio). Filled and open black circles denote starless and star-forming globules, respectively. The vertical dashed line denotes critical state of ξ_{max}=6.5.

(2) We found that four out of eleven starless globules show clearly unstable states ($\xi_{max} \gg 6.5$). Since unstable equilibrium states should not be long sustained, we expect that they are already collapsing toward higher central condensation or that extra force (e.g., magnetic and/or turbulent pressure) accounting for large ξ_{max} stabilizes the globules (e.g., [4]). It was also found that all three star-forming globules have unstable solutions, which is consistent with the fact that they have started gravitational collapse.

(3) We investigated the collapse of the Bonnor-Ebert sphere from a nearly critical state using the model calculation [5], and found that the column density profiles of the collapsing sphere mimic those of static Bonnor-Ebert spheres (unstable equilibrium solutions). By relating ξ_{max} to the collapsing sphere at a specific time, the evolutionary state of globules can be interpreted, and the detection probability of each ξ_{max} value can be predicted from the model calculation. Since the evolutionary timescale decreases with increasing density, the collapsing sphere resembles a marginally unstable Bonnor-Ebert sphere for a long time. It was found that the frequency distribution of ξ_{max} for the observed starless globules is consistent with that from model calculations of the collapsing sphere.

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Extremely high-velocity gas in a merginggalaxy Arp 220 revealed with ammonia absorption lines

TAKANO, Shuro, NAKANISHI, Kouichiro
(Nobeyama Radio Observatory, NAOJ)
NAKAI, Naomasa
(University of Tsukuba)
TAKANO, Toshiaki
(Chiba University)

We observed ammonia toward a merging galaxy Arp 220 with the Nobeyama 45-m radio telescope. We report detection of extremely wide absorption lines [1].

Arp 220 exists at ~ 77Mpc, and it is quite gas rich. It shows strong emission at far-infrared wavelength (~ 10^{12} solar luminosity). It is a prototypical ultraluminous infrared galaxy. At the center, two nuclei have been found, indicating that they are still in the process of merging two galaxies.

Observations were carried out with the Nobeyama 45-m radio telescope in May 2004. The receiver was equipped with cooled HEMT amplifiers for both circular polarizations. The four inversion transitions of $(J,K)=(1,1)$, (2,2), (3,3), and (4,4) at the 23.7-24.1 GHz region (rest frequency) in both polarizations were observed simultaneously. The spectra were obtained using acousto-optical spectrometers. The bandwidth of each spectrometer was 250 MHz.

The absorption lines were detected for all four transitions (Fig. 1, the (4,4) line is tentative). The (1,1) and (2,2) lines are overlapped each other, but the (3,3) line is not overlapped. The total width of the (3,3) absorption lineis extremely broad ~ 1800 km s^{-1} (approximate value obtained at the present signal-to-noise ratio). The widths of the (3,3) and (1,1) lines are extremely broad. Such extremely wide molecular absorption lines were detected for the first time in galaxies.

The rotational temperature of ammonia was calculated to be ~ 42K from the (1,1) and (2,2) absorption lines. The total column density obtained is ~ 2×10^{17}cm^{-2}. This is the highest value in external galaxies.

There are two remarkable points in the present study. First, the width, itself, is quite large. Second, the lines are observed in absorption. Absorption lines are formed by foreground gas only in front of the continuum emission. The size of the strong central continuum in Arp 220 is ~ 1". The wide absorption lines, therefore, indicate extremely high-velocity motion near the center. There are three possibilities to explain this extremely high-velocity motion. The first is that gas is rapidly rotating around the nuclear region. In such a case, the present situation may be partly similar to that of extremely high-velocity water masers at the active galactic nucleus in NGC 4258 ($\pm$1000 km s^{-1} offset from the central velocity). Using this maser emission, they found evidence for a massive black hole[2], [3]. In the aspect of velocity, the present results are similar to those in NGC 4258 suggesting the existence of an AGN in the central region. The second possibility is extremely high-velocity out flowing or inflowing gas at the nuclear region. In optical and X-ray observations the emissions from atomic gas were found to be extended. However, it is not sure whether the corresponding molecular gas exists. The third possibility is violent turbulence of gas, which may be caused near the colliding merging nuclei.

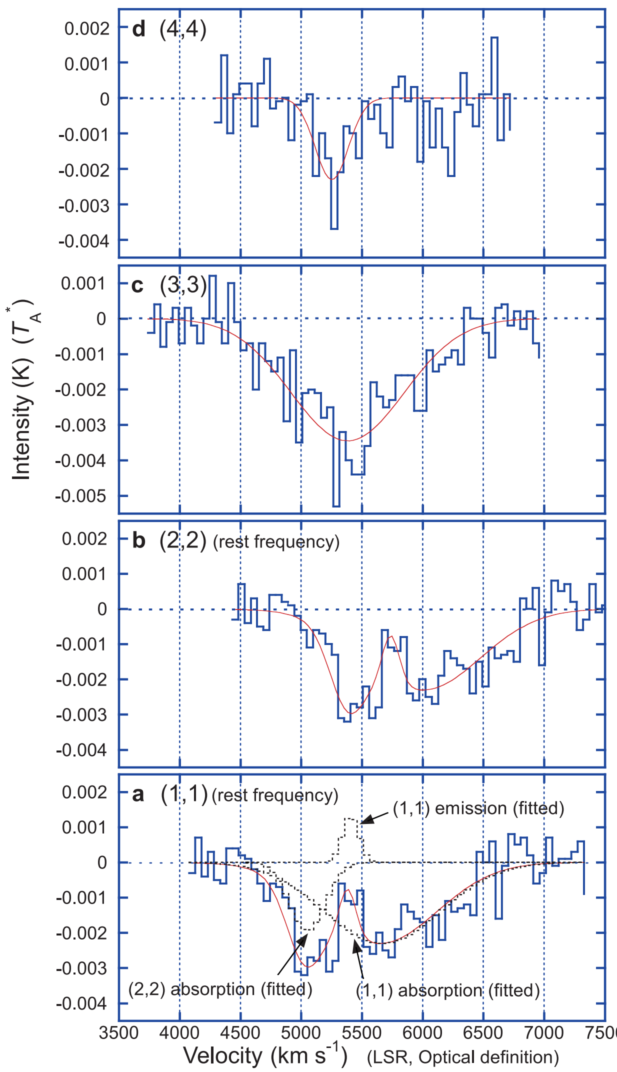

Figure1: Spectra of ammonia in Arp 220. The horizontal axis is velocity, and the vertical axis corresponds to intensity. Smooth curves are results of Gaussian fit.

References

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Discovery of Circumstellar Disk around a Massive Protostar by the Subaru Telescope

JIANG, Z., YANG, J. TAMURA, Motohide, SUTO, Hiroshi, ISHII, Miki
(Purple Mountain Observatory) (NAOJ)
FUKAGAWA, Misato HOUGH, J., LUCAS, P.
(University of Tokyo) (University of Hertfordshire)

The formation process for stars with masses several times that of the Sun is still unclear. The two main theories are mergers of several low-mass young stellar objects, which requires a high stellar density, or mass accretion from circumstellar disks in the same way as low-mass stars are formed, accompanied by outflows during the process of gravitational infall. Although a number of disks have been discovered around low- and intermediate-mass young stellar objects, the presence of disks around massive young stellar objects is still uncertain.

One of the best methods for distinguishing these two hypothesis is to directly detect a compact circumstellar disk around massive a YSO. However, massive stars are rarer than low-mass stars, and massive YSOs are distant in general. The nearest massive YSOs are situated at a distance of 450 pc, about three times farther than the typical nearest low-mass YSOs. Since the expected accretion disk has a scale of 100 to a few 100 AU, a spatial resolution of 0.1 arcsec is necessary.

Such a high resolution has not been achieved yet at submillimeter or millimeter wavelengths, while it is difficult to penetrate the heavy extinction in the star forming regions at optical wavelengths. Although adaptive optics (AO) observations on 8-m class telescopes can achieve ~ 0.1 arcsec resolution, the central massive YSOs are too bright for direct imaging to detect faint circumstellar nebula.

We have conducted high resolution (0.1 arcsec) near-infrared imaging polarimetry with the adaptive optics, an IR camera (CIAO), and its polarimeter on the Subaru telescope [1]. Figure 1 shows the polarization image of the BN object at 1.6μm [2]. The background shows a pseudo-color image of degrees of polarization, the red vectors correspond polarization angle and its degree, and the white contours show surface brightness.

While the surface brightness only show a circular structure near the central star except for the outer elongation, the polarization images clearly show the presence of an outflow/disk system around the Becklin-Neugebauer protostellar object, which has a mass of at least seven solar masses. Subsequent Monte-Carlo simulations well reproduce such structures. This strongly supports the theory that stars with masses of at least 7 solar masses form in the same way as lower mass stars.

High resolution polarimetry is thus proven to be a powerful tool to detect circumstellar disks around massive YSOs and can be used to test the accretion hypothesis for more massive (>10 solar masses) stars.

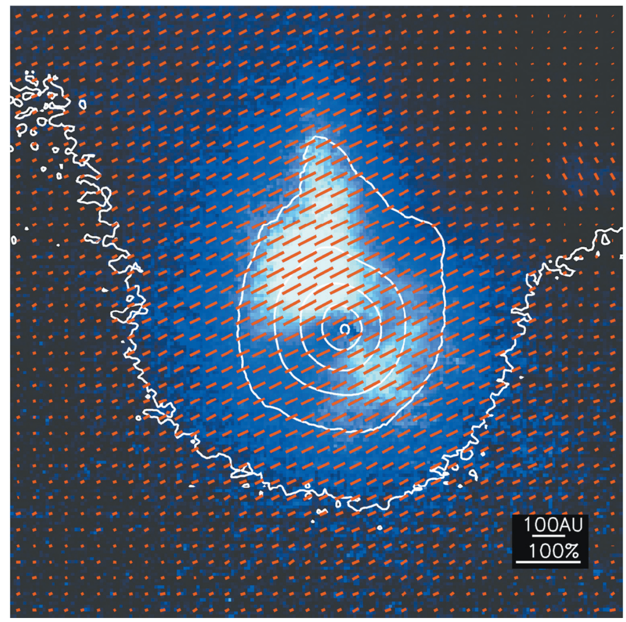

Figure1: Polarization image of the Orion BN object obtained with the Subaru telescope, adaptive optics (AO), IR camera (CIAO), and its polarimeter. The observed wavelength is 1.6μm (H band).

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Observations of Giant Silhouette Envelope Object M17-SO1

SAKO, Shigeyuki, MIYATA, Takashi, KAMAZAKI, Tsuyoshi
(Institute of Astronomy, University of Tokyo)
YAMASHITA, Takuya, FUJIYOSHI, Takuya, TERADA, Hiroshi
(Subaru Telescope, NAOJ)
KATAZA, Hirokazu, HONDA, Mitsuhiko
(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)
OKAMOTO, K. Yoshiko
(Institute of Astrophysics and Planetary Sciences, Ibaraki University)
JIANG, Zhibo
(Purple Mountain Observatory)
HANAWA, Tomoyuki
(Center for Frontier Science, Chiba University)
ONAKA, Takashi
(Department of Astronomy, University of Tokyo)

Circumstellar envelopes are the main source of mass supply to protoplanetary disks, which are cradles of planets, as well as to the central star. A mixture of dynamical forces induced by rotation, turbulence, magnetic field, and outflows will affect the envelopes forming protoplanetary disks [1]. Therefore, observational studies of these structures are crucial in understanding how each mechanism influences the disk formation processes to produce the variety of sizes and structures seen in protoplanetary disks [2].

Structures of envelopes extended to a few thousands of AU in radius around class 0/I protostars ($<10^5$ yr) have been observed with radio interferometers and infrared observations [3], [4]. However, the present radio interferometers do not posses sufficient spatial resolution to make it clear how mass is transferred from the envelope to the disk. Although scattered light around the central star is a better tool to study the structure at high resolution, whole area of the envelope cannot be traced with the scattered light alone because of its decreasing brightness away from the central star.

The problem with the scattered light can be resolved by using the silhouette of the envelope against a uniformly extended nebula since it provides a light source even in distant areas away from the central star. We focused on this merit and carried out survey observations at the Subaru telescope for silhouette objects in the M17 star-forming region. We used the 2.166-μm Brγ emission line as the background light and discovered a giant silhouette object M17-SO1 (Fig. 1) [5].

In follow up observations in the JHK bands, and at mid-infrared at the Subaru telescope and millimeter wavelengths at the Nobeyama millimeter array, M17-SO1 is revealed as an intermediate class I protostar of 2.5 to 8 solar masses. The silhouette image against the uniform background light source not only derives the exterior appearance but also the column density distribution. The envelope consists of two components - an inner dense part and an outer less dense part, whose masses are estimated to be 0.006 and 0.08 solar masses, respectively. The radial distribution of scale height of the envelope also indicates that the central star is heavier than 2.5 solar masses. Four dark arms are seen in the silhouette image. They tightly enclose the nebulosity due to scattering and are clearly separated from the flared structure of the envelope. The geometrical appearance suggests that the four arms are produced by bipolar outflows because this kind of structure is typical of systems associated with outflows.

The fact that the four arms are detached from the flared structure indicates that its scale height is determined not by the pressure from outflows but by the dynamical equilibrium between gravity of the central star and forces induced by pressure gradient, turbulence motion, and magnetic field. This suggests that the materials in the envelope fall to the centre not through direct path but through nearby disk mid-plane.

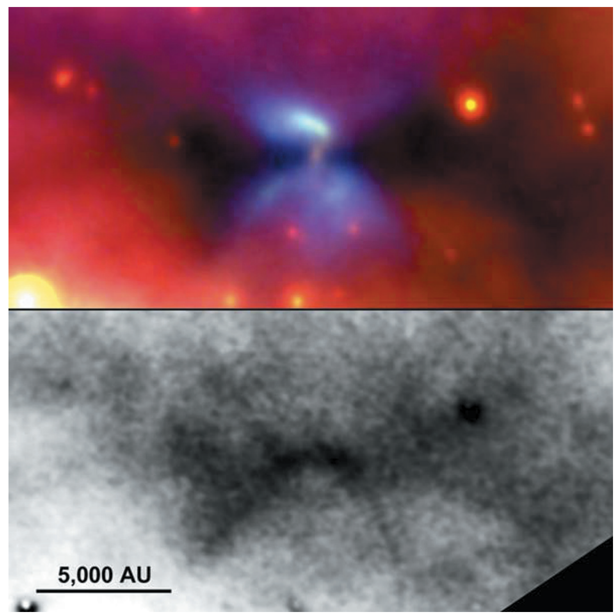

Figure1: (*top*) JHK pseudo-colour image of M17-SO1. This image was obtained by the IRCS with the adaptive optics system at the Subaru telescope on 15 Aug. 2003. The image area is 14.8 arcsec × 7.4 arcsec. (*bottom*) Silhouette image of M17-SO1 against the Brγ (2.166μm) emission. The image area is the same as in the top image.

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Forthcoming Launch of the SOLAR-B Spacecraft

KATSUKAWA, Yukio, ASAI, Ayumi, ICHIMOTO, Kiyoshi, KATO, Yoshihiro
KANO, Ryouhei, KUMAGAI, Kazuyoshi,SHIMOJO, Masumi, SUEMATSU, Yoshinori
TAMURA, Tomonori, TSUNETA, Saku, TONOOKA, Hideaki, NOGUCHI, Motokazu
NAKAGIRI, Masao, HARA, Hirohisa, MIYASHITA, Masakuni, WATANABE, Tetsuya
(NAOJ)
KOSUGI, Takeo, SAKAO, Taro, SHIMIZU, Toshifumi,
MATSUZAKI, Keiichi, KUBO, Masahito
(JAXA / ISAS)

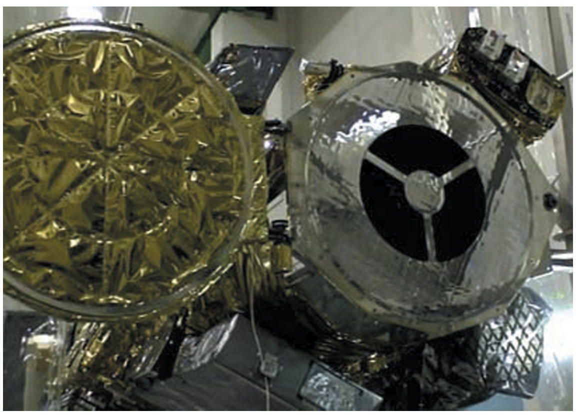

Figure1: SOLAR-B spacecraft when the front door of Solar Optical Telescope (SOT) was opened. SOT was located at the center, X-Ray Telescope (XRT) on the lower right, and EUV Imaging Spectrometer (EIS) on the upper left.

The Solar-B Project Office of the National Astronomical Observatory of Japan (NAOJ) contributes to system design and spacecraft-level performance testing of all the mission instruments, developments of the Optical Telescope Assembly (OTA) in the Solar Optical Telescope (SOT) and the CCD camera of the X-ray Telescope (XRT), and spacecraft-level contamination control in the SOLAR-B project with the Institute of Space and Astronautical Science of Japan Aerospace Exploration Agency (ISAS/JAXA). The office also plays a role of the interface between the spacecraft system and foreign partners in US and UK. After the electrical and mechanical interface testing in 2004, three mission instruments were disintegrated and were returned to institutes in charge. After fixing the problems found in the test, all the flight models were gathered in the clean room of ISAS in June 2005. The integration was performed so that the optical axes among three telescopes and sun-censors were aligned; the SOLAR-B spacecraft became a final form ready for launch (Fig. 1).

From August 2005, the electrical performance test was carried out for the three mission instruments and the spacecraft bus instruments, and it was completed without problems. The mechanical environment test was carried out in October 2005 to verify healthiness of the spacecraft against rocket launch environment. We confirmed that alignment among the telescopes and the electrical performance did not change during the mechanical environment test. The thermal vacuum test was performed in March 2006 at the ISAS space chamber (Fig. 2) where the thermal environment on orbit was simulated. In this test, we verified healthiness of the thermal design, function of temperature control systems, and electrical performance in the thermal vacuum environment. We completed all the environmental tests required for launch.

Figure2: SOLAR-B spacecraft at the ISAS space chamber just before the thermal vacuum test. The satellite was surrounded by aluminium frames equipped with test heaters to control outer temperatures.

In parallel with the spacecraft tests, Solar-B project office built Solar-B Science Center (SBSC) in NAOJ aiming to provide scientific analysis environment for researchers. We started development of analysis software and hardware in SBSC. We organized a SOLAR-B workshop in February 2006 for domestic researchers so that they would know what kind of data will be obtained by SOLAR-B.

In the next fiscal year, the final performance test is carried out until July 2006 in the clean room of ISAS, then the spacecraft is transported to Uchinoura Space Center (USC). The spacecraft launch operation starts at USC from August 2006. In the end of September, the SOLAR-B spacecraft will be launched by the M-V rocket, and installed to a sun-synchronous polar orbit of altitude about 680km.

Expanding Radio Lobe Revealed by VSOP Observations

ASADA, Keiichi, KAMENO, Seiji, INOUE, Makoto
(NAOJ)
SHEN, Zhi-Qiang (SAO)
HORIUCHI, Shinji (Swinburne University of Technology)
GABUZDA, Denise C. (University College Cork)

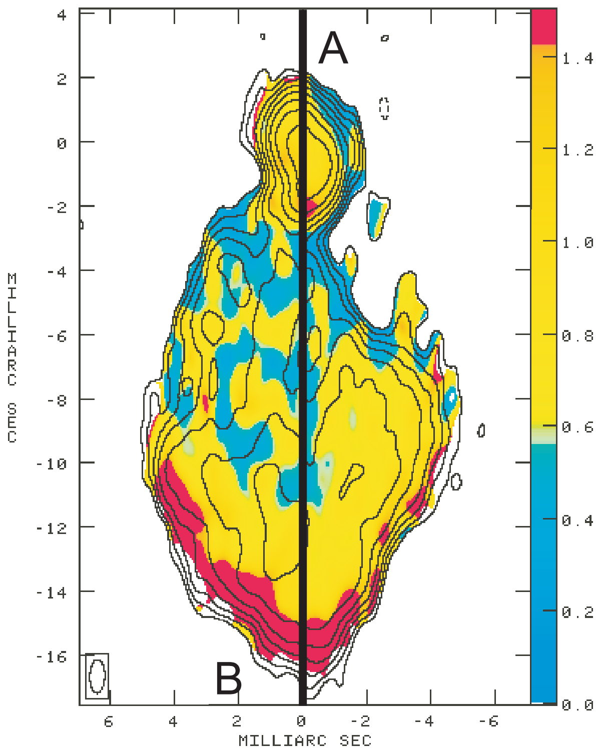

Figure1: The contours show the total intensity at second epoch and the color scale shows the distribution obtained by dividing of total intensity image at the second epoch by that of the first epoch. The increasing of the flux at the south edge in the second epoch clearly shows the expansion of the radio lobe.

We report the detection of the expansion of a young radio lobe associated with the bright radio source 3C 84 in the Seyfert galaxy NGC 1275 with VSOP observations [1].

Compact Symmetric Objects (CSOs) have similar structure to those of the classical double radio sources, but sizes of CSOs are 10^3 times smaller than those of the classical double radio sources. The compact structure of CSOs led a hypothesis at those are on a young stage of evolution to a large classical double radio lobe.

The compact radio source 3C 84, hosted by the Seyfert galaxy NGC 1275, is one of the strongest radio sources. Since it is a nearby ($z = 0.018$) source, 1 mas corresponds to 0.4 pc. Early VLBI observations revealed that 3C 84 had a complicated radio structure on parsec scales, consisting of a bright core with a flat spectrum and a complex structure of the southern radio lobe with a steep spectrum. Single dish observations of 3C 84 show that the outburst started at 1959, and total flux density showed several peaks in the mid-1980's and is now in a decay phase [2]. In order to reveal the evolution of radio lobe, we performed VSOP monitoring observations towards 3C 84.

As the results, we imaged well resolved structure of the southern radio lobe and detected its expansion (see Fig. 1, Fig. 2 left). If we assume that the southern radio lobe is expanding with constant velocity, the source size extrapolated back to zero at about the time of the 1956 and thus we estimated an expansion velocity of 0.50 ± 0.11 c. Then, this southern radio lobe is one of the youngest radio lobes with 40 yrs old. In addition, the epoch coincidentally corresponds to the beginning of the outburst event detected by single dish observations.

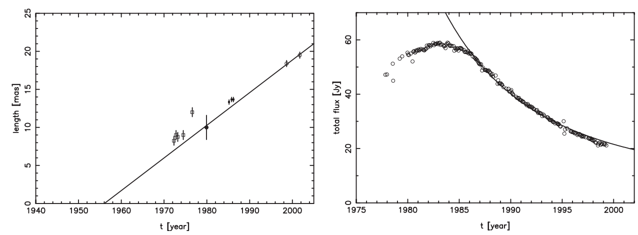

Figure2: (left) Size of the radio structure is plotted against time. Open circles represent our VSOP observations, and the others are obtained by previous VLBI observations. (right) The light curve of 3C 84 at 5 GHz observed by UMRAO with fitting results for adiabatic expansion.

In order to discuss the origin of the decay of the total flux density, we consider the efficiency of the expansion cooling and synchrotron cooling of the radio lobe. We found that the decay of total flux density can be naturally explained by an adiabatic cooling due to the expansion of the radio lobe, if we assume that the emitting region is the surface of the radio lobe and no injection of relativistic electron at the hotspot and jet components due to in-situ acceleration. It is consistent with the picture suggested by X-ray observations [3]. On the other hand, we ruled out the synchrotron cooling, because we need B> 48 mG to see such an effect and that is a little stronger than the equipartition magnetic field suggested for the radio lobes of CSO objects

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Near-infrared deep imaging of Subaru Supe Deep Field using Adaptive Optics

MINOWA, Yosuke, KOBAYASHI, Naoto, YOSHII, Yuzuru
(Institute of Astronomy, University of Tokyo)
TOTANI, Tomonori, MAIHARA, Toshinori, IWAMURO, Fumihide
(Kyoto University)
TAKAMI, Hideki, TAKATO, Naruhisa, HAYANO, Yutaka,
TERADA, Hiroshi, OYA, Shin, IYE, Masanori
(Division of Optical and Infrared Astronomy / Subaru Telescope, NAOJ)
Tokunaga, Alan T
(University of Hawaii)

We present a deep *K*'-band (2.12μm) imaging of the 1' × 1' Subaru Super Deep Field (SSDF) taken with the Subaru adaptive optics (AO) system [1]. AO compensates the disturbed wavefront by Earth's atmosphere and provides nearly diffraction-limited spatial resolution. Because the flux in the diffraction-limited core largely increases, it is expected to improve the sensitivity of detecting faint objects with AO. Total integration time of 26.8 hr results in the limiting magnitude of *K*'= 24.7 (5σ, 0''.2 aperture) for point sources, which is the deepest limit ever achieved in the *K*' band (Fig. 1). The average stellar FWHM of the co-added image is about 0''.18, which is comparable to or even smaller than that obtained with the Hubble Space Telescope in the near infrared.

We obtained the differential galaxy number counts down to *K*' ~ 25, which is more than 0.5 mag deeper than the previous data and then the faintest number count data ever obtained (Fig. 2). We found that the number count slope d log *N/dm* is about 0.15 at 22 < *K*' < 25, which is flatter than the previous data. This flatter slope at the faint-end (*K*' > 22) rejects earlier theoretical studies that predict further increase of the number counts beyond *K*' ~ 23 because of a large number of faint blue dwarf galaxies [2] or larger cosmic density at high-redshift than today [3].

The isophotal size distribution of the galaxies was obtained from the *K*'-band SSDF image down to the area size of less than 0.1 arcsec^2, which is less than half of that of the previous data in the *K*'-band. We compared the observed galaxy size vs. apparent magnitude relation with a simple pure luminosity evolution model allowing for intrinsic size evolution and found that a model with no size evolution gives the best fit to the data. It implies that the surface brightness of galaxies at high redshift is not much different from that expected from the size-luminosity relation of present-day galaxies.

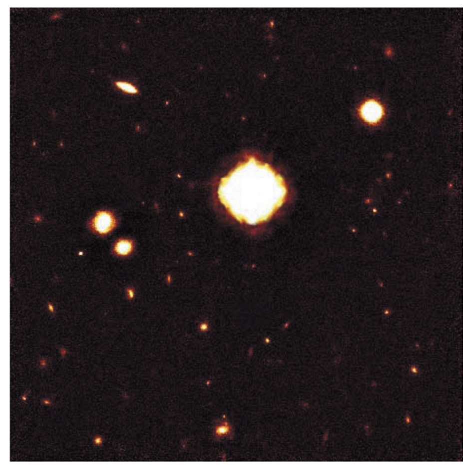

Figure1: IRCS+AO *K*'-band image of the SSDF. The field size is about 1' × 1'.

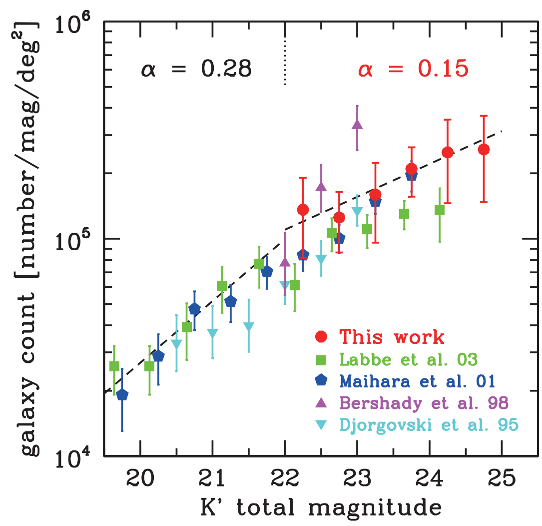

Figure2: Differential *K*'-band number counts of galaxies estimated from the SSDF. For purposes of comparison, the counts in the literature ([4],[5],[6],[7]) are also plotted.

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Reverberation Measurements of the Inner Radius of the Dust Torus in Nearby Seyfert 1 Galaxies

SUGANUMA, Masahiro (JASMINE Project Office, NAOJ) YOSHII, Yuzuru (University of Tokyo) KOBAYASHI, Yukiyasu (JASMINE Project Office, NAOJ)
MINEZAKI, Takeo (University of Tokyo) ENYA, Keigo (JAXA) TOMITA, Hiroyuki, AOKI, Tsutomu (University of Tokyo)
KOSHIDA, Shintaro (University of Tokyo / NAOJ) PETERSON, Bruce A. (Australian National University)

We carried out the intense monitoring observations in optical and near-infrared wavebands for nearby Seyfert 1 galaxies using MAGNUM telescope. Clear time-delayed response of the *K*-band flux variations to the *V*-band variations was detected for NGC 5548, NGC 4051, NGC 3227, and NGC 7469. The lag times can be interpreted as light-travel time between the central engine and the inner edge of the dust torus. Comparing our lag time measurements with other quantities (optical luminosity, central virial mass, and broad-line lag) based on our sample and others in the literature, we ensured next two important evidences [1].
1) The infrared lag time is tightly correlated with the optical luminosity according to $\Delta t \propto L_{\rm opt}^{0.5}$ in agreement with the expected relation of dust reverberation.
2) Infrared lags place an upper boundary on similar lag measurements of broad-emission lines in the literature, which not only supports the unified scheme of AGNs, but also implies a physical transition from the broad emission-line region (BLR) out to the dust torus that encircles the BLR.

The unified scheme of active galactic nuclei (AGNs) and radio-quiet quasars explains that Seyfert 1 nuclei with a broad emission-line region (BLR) would be classified as Seyfert 2 if high velocity clouds emitting broad emission lines are hidden by the dust torus that encircles such clouds [2]. However, the angular scale of inner dust torus even in the nearest AGN is too small to be spatially resolved with any current technology in optical and near-infrared imaging observations.

It is generally accepted that the near-infrared emission from Seyfert galaxies and quasars is thermally produced by hot dust heated to its sublimation temperature about 1500 K by UV radiation from the central engine. This model necessarily claims a dust distribution with a central hole. If we monitor their continuum fluxes in the UV/optical and near-infrared, a lag time would be expected that corresponds to the light-travel distance between the central engine and the hot dust region from which the bulk of near-infrared emission is radiated. The most successful case of similar technique is the reverberation mapping of the BLR carried out for many Seyfert 1 galaxies and quasars during the last decade (e.g., [3]). However, there have been only few cases where lag times for both BLR and dust torus were measured for the same AGN.

Over three years of observations, after the operation of the MAGNUM telescope started in early 2001, clear time-delayed response of the *K*-band flux variations to the *V*-band flux variations was detected for four galaxies including NGC 5548 (Fig. 1), after the first result in NGC 4151 [5]. We found that the lag time is tightly correlated with the optical luminosity as expected from dust reverberation ($\Delta t \propto L^{0.5}$), while only weakly with the central virial mass, which suggests that an inner radius of the dust torus around the active nucleus has a one-to-one correspondence to central luminosity. In the lag time versus central luminosity diagram (Fig. 2), the *K*-band lag times place an upper boundary on the similar lag times of broad-emission lines in the literature. This not only supports the unified scheme of AGNs, but also implies a physical transition from the BLR out to the dust torus that encircles the BLR.

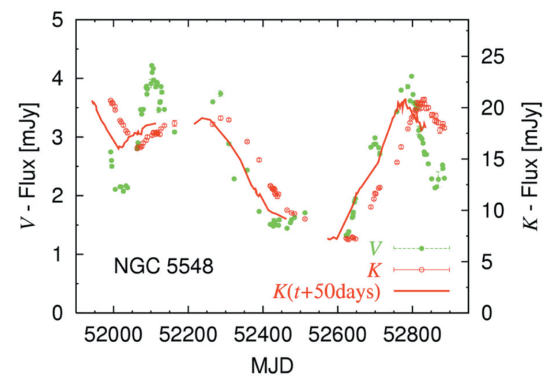

Figure1: Observed *V* and *K* light curves of NGC 5548 nucleus. Green and red circles correspond to *V* and *K*, respectively. The red line is the *K* light curve shifted backwards by 50 days [4].

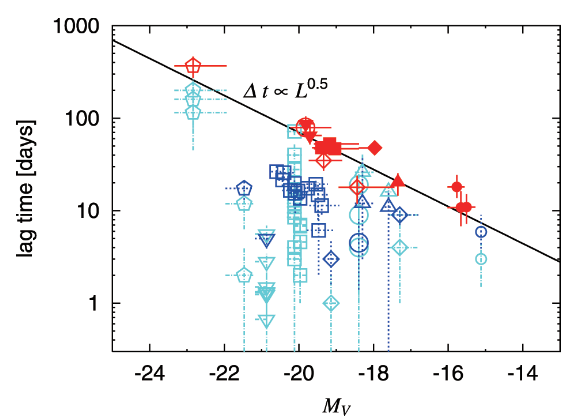

Figure2: Lag times plotted against the absolute *V* magnitude of AGNs. Red filled symbols show the infrared lags measured in this work, and red open symbols from a literature [5]. Blue (for Hβ lines) and light-blue (for other) symbols show the lag times of broad emission lines for the corresponding AGNs in the literatures.

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Compilation and Publication of Union Catalog for Books and Materials on Japanese Astronomy before Meiji Era

NAKAMURA, Tsuko, ITO, Setsuko

(Public Relation Center, NAOJ)

In conducting researches on the Japanese astronomy of the Edo era (1603-1868), the first step to be done is to know whereabouts of original books and materials on the discipline. For that purpose, it has been common that we use *Kokusho Somokuroku* (General Catalog of National Books before 1868) for consultation. However, because the main body of this catalog was compiled before WW-II, it is likely that a non-negligible fraction of the catalog entries has been destroyed by war-fires, or lost, or now belong to libraries different from those described in the catalog. Moreover, due to recent activities of local libraries, archives and museums in Japan for collecting and cataloging historical books and documents and their increased efforts to publicize such information via Internet services, we are in a position to havea much easier and better access to unknown historical sources newly acquired after WW-II.

With such background in mind, we started in 2002 as a team a project under governmental support to compile a general catalog of Japanese archives before 1870 on astronomy, land-surveying and relating disciplines. An interim report of this program, including the motivation and aims of this project, had already been made at a Commission-41 meeting of General Assembly of IAU in Sidney [1].

The four-year efforts, with 10 domestic and three overseas research members, to survey and inventorize Japanese astronomical books and materials preserved at 410 domestic and 24 overseas libraries and museums resulted in a book "General Catalog of Japanese Astronomical Books and Materials in the Pre-Meiji Era", published in February 2006 [2]; catalogs of such kinds including books preserved at overseas libraries have never been made before. This publication comprises about 6200 book titles, with whereabouts for each. This number outnumbers by about 50% that included in the Inventory Book for Survey, which was prepared as a basis of this survey at the start of this project [3]. With this catalog, we suppose that roughly 90% of the existing books and materials belonging to the above two disciplines are covered. Although this book also includes parts of books on Japanese mathematics (Wasan), navigation, physics and geosciences, etc. they are not so extensive and limited to those mainly relating to astronomy and land-surveying.

Here are some characteristics of our publication. First, we attempted as far as possible to contain in our catalog also the books and materials whose whereabouts are unknown but only cited in the literature. Second, we separated old every-year calendars such as Guchu-reki and Ise-goyomi from our main catalog into Appendices as an independent one; this will enhance both the systematic nature of this catalog and search ease.

The Japanese astronomy had heavily been affected by the Chinese culture from antiquity till the pre-modern times. After import-ban deregulation of foreign books by the eighth Shogun Tokugawa Yoshimune in 1720, the Japanese began to recognize the superiority of the European modern astronomy over the traditional Chinese one, and gradually learned understanding the western astronomical books without referring to the Chinese translation. Because of those reasons, this book also gives in Appendices the lists of the Chinese and western books that influenced the Japanese astronomy.

We expect that this book is of use, for an extended period of time, in researches in the fields of history of sciences, the western cultural transfer (Yogaku), as well as in the history of astronomy and land-surveying.

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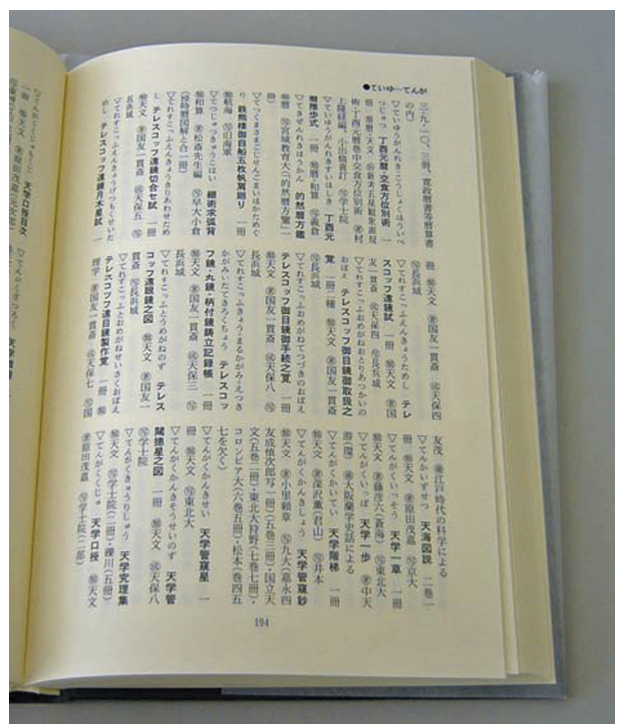

First Fringe Measurement of `OHANA

PERRIN, Guy
(Observatoire de Paris)
KOTANI, Takayuki
(Subaru Telescope, NAOJ / University of Tokyo)
GUYON, Olivier
(Subaru Telescope, NAOJ)
NISHIKAWA, Jun
(MIRA Project Office, NAOJ)
Other 31 Co-Authors

We report the success of the first interferometric observation of the `OHANA (Optical Hawaiian Array for Nanoradian Astronomy) project.

The `OHANA project aims at linking large telescopes on Mauna Kea, including Subaru, by using single-mode optical fiber to construct an infrared interferometer uniquely combining long baselines (up to 800-m) with large individual apertures [1]. The project was started in 2000. Figure 1 shows telescopes which will be used for `OHANA and possible baselines. As `OHANA utilizes existing telescopes equipped with Adaptive Optics, large and sensitive infrared array can be build easily. The sensitivity of `OHANA can be comparable with the next-generation infrared interferometer, VLTI (Very Large Telescope Interferometer) and Keck Interferometer, and its angular resolution is at least 4 times higher. `OHANA will give us critical information on the central region of YSO (Young Stellar Object) and AGN (Active Galactic Nucleus) by direct imaging [2]. The spatial resolution of `OHANA corresponds to 0.05 ~ 0.8 AU at the nearby star-formation region (150 pc), which enables us to observe the origin of jets, interaction between disk and star, and even stellar diameter. For nearby AGN (10Mpc), `OHANA can resolve 0.02 ~ 0.3 pc scale, which corresponds to the size of BLR (Broad Line Region) and inner region of dust torus.

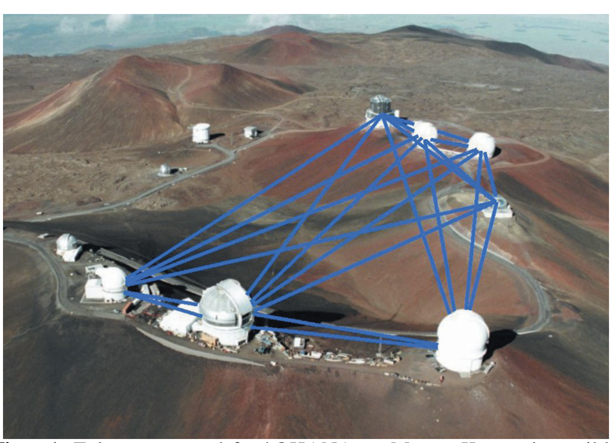

Figure1: Telescopes used for `OHANA on Mauna Kea and possible baselines.

We carried out the interferometric observation in June 2005 by connecting the two Keck telescopes (85-m baseline) with the 300-m K-band fibers which replaced bulk-optics beam train (i.e. mirrors to transport beams) [3]. The starlight was injected into the fibers near the AO focuses in the Nasmyth platform, and fibers were attached to the telescope structures and going down to the interferometric laboratory in the basement. The delay lines and beamcombiner of the Keck interferometer were used. The first fringes, shown in Figure 2, were obtained on the star 107 Her (A7V, K magnitude = 4.6). The apparent fringe contrast, i.e.

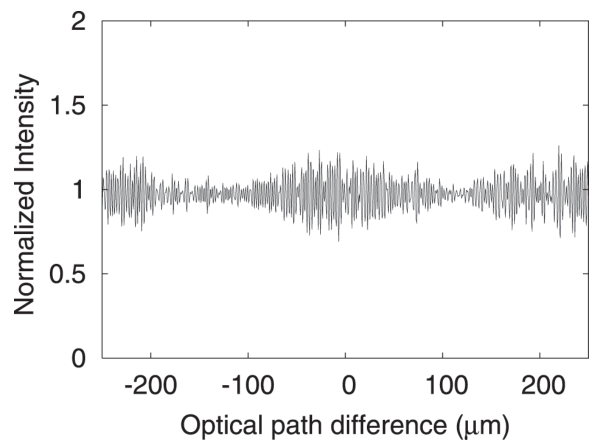

Figure2: Fringes on 107 Her (A7V, K magnitude = 4.6). Data is high-pass filtered in order to remove the effect of photometric fluctuation.

visibility was 0.26, which is rather low considering the almost unresolved angular diameter of 107 Her. Apparent fringe visibility is usually lower than the ideal value due to imperfect optics, mismatch of the polarization states, etc. For this observation, the degradation of visibility was caused by the chromatic dispersion arising from the different dichroich mirrors in the AO system of the two Keck telescopes. These dichroic mirrors can be easily replaced: we therefore expect to obtain much higher visibility for the next observations.

The light transmission of `OHANA was measured to be 0.5% but it is a lower limit because of the bad weather. In the clear sky condition, a 4% transmission is expected and can be increased up to 10% by improving optics. For comparison, Keck interferometer's transmission, with the more traditional beam transfer optics, is 1%. Therefore, `OHANA will be potentially much sensitive than the non-fiber configuration.

The success of this first `OHANA baseline demonstration is an important step toward a 800-m baseline interferometer with multiple baselines and large telescopes atop Mauna Kea. We will carry out our next step, the CFHT-Gemini interferometric observation, at the end of 2006. We also expect to combine the Subaru and two Keck telescopes within a few years.

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Combination of Nulling Interferometer and Modified Pupil for Observations of Exo-Planets

NISHIKAWA, Jun (MIRA Project Office, NAOJ)
KOTANI, Takayuki (Observatorie de Paris / University of Tokyo)
MURAKAMI, Naoshi, BABA, Naoshi (Hokkaido University)
ITOH, Yoichi (Kobe University)
TAMURA, Motohide (Division of Optical and Infrared Astronomy, NAOJ)

Very high dynamic range observations are required especially for the direct detection of extra-solar planets, which have a contrast of less than 10^{-9} at a distance of about 0.″1 from the central star. We proposed to use a nulling interferometer as pre-optics combined with a modified pupil telescope to achieve high performance coronagraph (Fig. 1 ; see [1] more details).

Nulling interferometry is one of the useful methods of achieving high dynamic range observations. Another method is the modified pupil, which suppresses the halo of the diffraction image of a point source relative to the core intensity, and others are the advanced nulling coronagraphs. The nulling interferometer can produce the total extinction for an on-axis point source but it transmits leakage light for a resolved star with off-axis rays. The residual wavefront is still flat and we consider it can be combined with the next high dynamic range method for a single telescope.

With the combination presented here, the effects of the nulling interferometer and the modified pupil are independent and they are multiplied, resulting in higher dynamic range than either method by itself.

For the source intensity reduction effect of the nulling interferometer (e.g. 10^{-3}) in the combination methods to reach the desired total dynamic range of 10^{-10}, the modified pupil is required to provide a lower contrast halo suppression (e.g. 10^{-7}) which is a welcome situation for helping exo-planet-finding telescopes to reduce the image core radius (e.g. $\leq 3\lambda/D$) by the modified-pupil and to increase throughput (Fig. 2).

The present combination is useful for the case where the diffraction image core radius of each element telescope is a few times smaller than the separation angle of the target exo-planet from the central star.

An example of the condition is a 600nm wavelength observation of a Sun-Earth-like system at a distance of 10 pc, with an apparent stellar diameter of 1 mas and a separation between the star and the planet of 100 mas, using a 3m baseline interferometer which is composed of two 3m sub-apertures with a diffraction limit of 41 mas extracted from a 6m telescope.

A nulling interferometer is shown to work as pre-optics which reduces the source intensity in front of any single telescope optics, just like the modified pupil method and the modern nulling coronagraph method. An additional nulling operation is applicable when the wavefront at the output pupil plane for each point of the resolved source has a uniform distribution after any previous nulling operation.

In analogy with the present concept, it is important to investigate various optical designs and combinations which have not yet been explored but have the potential to achieve higher dynamic range than that obtained by presently known methods and combinations. We are interested in making modifications to known methods including the proposals of the present paper in order to achieve high dynamic range with available optical components.

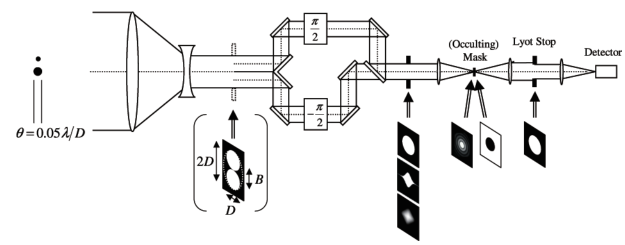

Figure1: Coronagraphic optics by pre-optics nulling interferometer combined with modified pupil method.

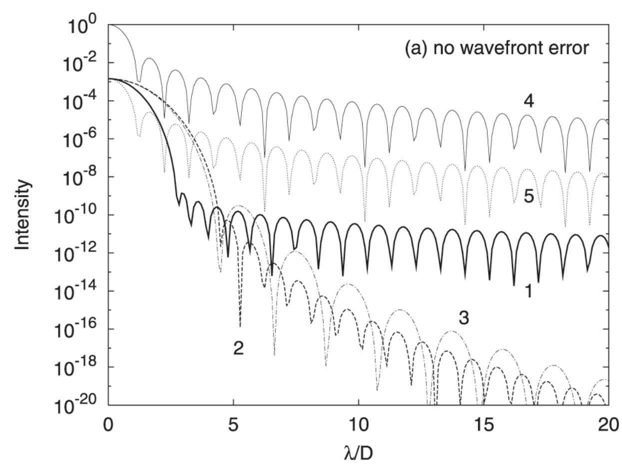

Figure2: Intensity profiles along the high-contrast axis for combinations of nulling interferometer with modified pupils. The profiles for three modified pupil under nulling interferometer destructive conditions are shown (1, 2, 3). In the case of the circular aperture we show both constructive condition (4) and destructive nulling condition (5).

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Development of ^{187}Re-^{187}Os nucleo-cosmochronometer for r-process in supernovae [1]

HAYAKAWA, Taketo (JAEA / NAOJ) SHIZUMA, Toshiyuki (JAEA) KAJINO, Toshitaka (NAOJ / UT / GUAS)
CHIBA, Satoshi, SHINOHARA, Nobuo, NAKAGAWA, Tsuneo (JAEA) ARIMA, T (University of Tohoku)

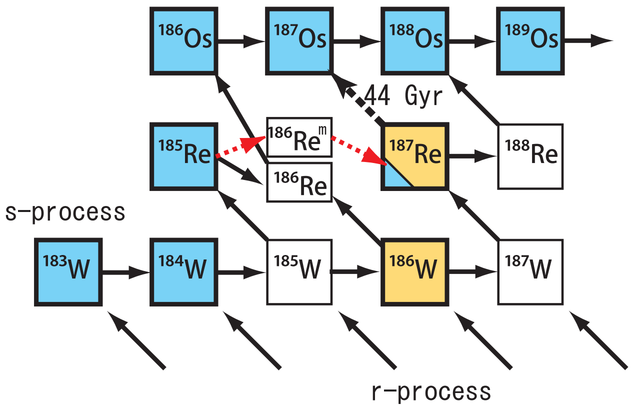

Figure1: A partial nuclear chart around a Re-Os region. Arrows are nucleosynthesis flows. The isotope ^{187}Re decays to ^{187}Os with a half-life of 44 Gyr. The nucleus ^{187}Re should be produced by a new s-process path though the ^{186}Re isomer (dot-line arrow).

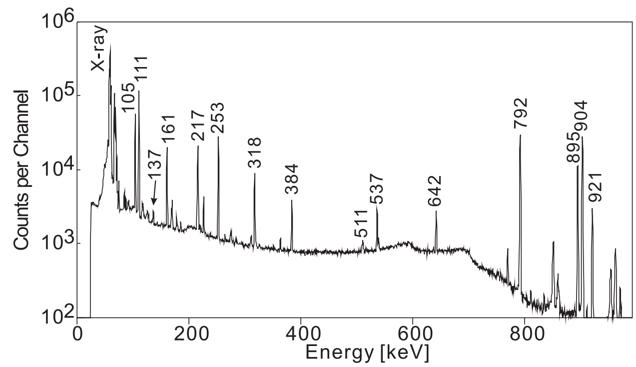

Figure2: A measured γ-ray spectrum from a sample after a neutron irradiation. Most γ-rays are irradiated from ^{184}Re. A γ-ray of 137 keV is most strong γ-ray from the ^{186}Re isomer.

Long-lived radioactive isotopes are used as nucleo-cosmochronometers, which are useful for an investigation of nucleosynthesis process and the solar system formation. The radioactive nuclei of cosmological significance are rare and only six chronometers with half-lives in the range of the cosmic age 1 ~ 100 Gyr were proposed. They are ^{40}K [2] and ^{87}Rb [3] for the s-process or explosive nucleosynthesis in supernovae, ^{176}Lu [4] for the photodisintegration reaction nucleosynthesis in supernovae, and ^{187}Re [3], ^{232}Th and ^{238}U [2] for the r-process. The nucleus ^{187}Re is dominantly synthesized by the r-process in supernovae but the s-process in low-mass AGB stars also contributes to the abundance of ^{187}Re as shown in Fig. 1 [5], [6]. We study a new s-process path through an isomer of ^{186}Re to improve the ^{187}Re chronometer.

First, we propose a new s-process path through a ^{186}Re isomer that contributes to the abundance of ^{187}Re and affect to ^{187}Re -^{187}Os chronology (see Fig. 1). The neutron-capture cross-section to the isomer with the experimental uncertainty has not been reported.

Second, we measure a ratio of neutron capture cross-sections of the isomer to the ground state of ^{186}Re at thermal neutron energy with neutrons provided from a nuclear reactor JRR-4. We measure the γ-rays from the ^{186}Re isomer as shown in Fig. 2. We obtain the ratio of $R_{th} = 0.54 \pm 0.11\%$. From this ratio we estimate the ratio of Maxwellian averaged cross sections at $kT = 30$ keV by using a statistical-model. The ratio is $R_{st} = 1.3 \pm 0.8\%$. We calculate the s-process contribution to ^{187}Re from the new path in a steady-flow model. The additional abundance of ^{187}Re is estimated to be $N_s = 0.56 \pm 0.35\%$ relative to the abundance of ^{186}Os.

Finally, we calculate the effect to a sample affected strongly by a single supernova such as pre-solar grains [7] using the ^{187}Re chronometer. We calculate the age of such samples in a sudden approximation under various conditions. The difference between the ages under the different conditions is at most ~ 2%.

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Sensitivity of R-Process Nucleosynthesis in Supernovae and GRBs to the Light-Element Nuclear Reactions [1]

SASAQUI, Takahiro (HITACHI High-Technologies Corporation)
KAJINO, Toshitaka (NAOJ / University of Tokyo / GUAS)
MATHEWS, Grant J. (University of Notre Dame)
OTSUKI, Kaori (University of Chicago)
NAKAMURA, Takashi (Tokyo Institute of Technology)

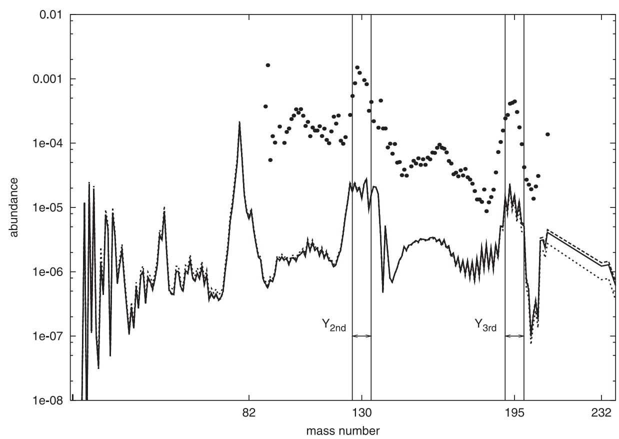

Figure1: Comparison of the final r-process abundances obtained with different α (αn, γ)^{9}Be reaction rates. Three lines are for the different rate adopted in literatures as summarized in ref. [1]. Y_{2nd} and Y_{3nd} indicate the typical r-process abundances of the 2nd peak and 3rd peak elements, respectively. The solar system r-process abundances from ref. [6] are shown by filled circles.

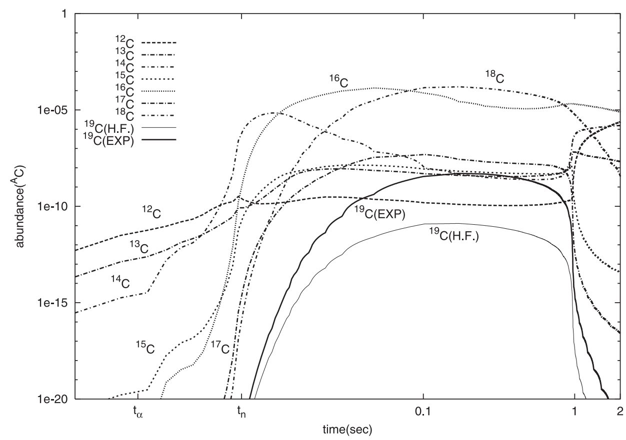

Figure2: Time evolution of carbon isotope abundances. Because of the large measured reaction cross section for ^{18}C(n, γ)^{19}C, the abundance of ^{19}C is increased compared with the abundance based upon the HF estimate. The accumulated abundance of ^{19}C rapidly photodisintegrates to ^{18}C due to the small neutron-separation energy.

We study the efficiency and sensitivity of r-process nucleosynthesis to the light-element nuclear reaction rates. We adopt empirical power-law relations [2] to parameterize the reaction sensitivities. We utilize two different hydrodynamic models for the neutrino-driven winds in order to study the dependence of our result on supernova wind models [3]. We also utilize an exponential model to approximate a wide variety of other plausible conditions for the r-process. We identify several specific nuclear reactions among light neutron-rich nuclei that play a critical role in determining the final r-process nucleosynthesis yields.

We also found a new concept of “semi-waiting” points among the light neutron-rich radioactive nuclei including lithium, boron, carbon, and oxygen isotopes. We show that not only neutron capture and β-decay, but also (α,n) reactions are important in determining waiting points along the r-process path.

Our numerical results from this sensitivity analysis serve foremost to clarify which light nuclear reactions are most influential in determining the final r-process abundances. We also quantify the effects of present nuclear uncertainties on the final r-process abundances. This study thus emphasizes and motivates which future determinations of nuclear reaction rates will most strongly impact our understanding of r-process nucleosynthesis.

We also studied extensively the dependence of the sensitivity on the expansion flow models. We adopted exponential flow models to simulate various expansion dynamics such as prompt and delayed supernova explosions, gamma-ray bursts central engines, binary neutron star or neutron star-black hole mergers, etc. [3], [4], [5]. The four important physical parameters which characterize the profile in the flow models are the dynamical timescale τ_{dyn}, the entropy per baryon *s/k*, the initial electron fraction Y_e, and the asymptotic temperature T_a. We found that the sensitivities depend most strongly on the dynamical timescale. Nuclear reactions and SN dynamics are thus complementary facets to understanding r-process nucleosynthesis. We believe that the present work provides a useful tool to elucidate which reactions are most important and also the synergy between the SN dynamics and nuclear reactions in r-process nucleosynthesis.

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Neutrino-Effects on R-Process Nucleosynthesis in Black-Hole Formation [1]

SASAQUI, Takahiro (HITACHI High-Technologies Corporation)
KAJINO, Toshitaka (NAOJ / University of Tokyo / GUAS)
BALANTEKIN, Akim Baha (University of Wisconsin)

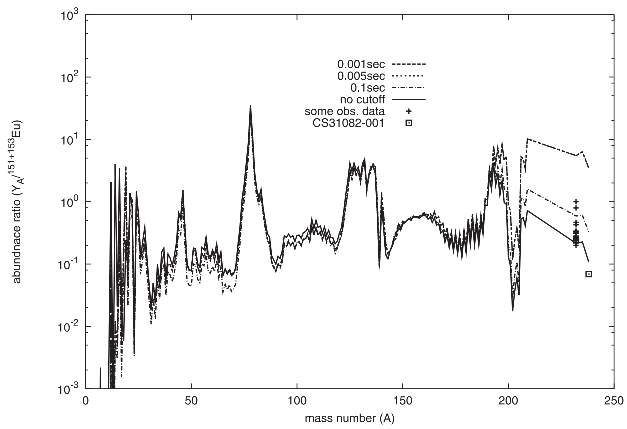

Figure1: Final abundance patterns as a function of mass number in the four cases of different neutrino cutoff times calculated in Otsuki flow model [2]. The cutoff times are set to be 0.001s (dashed line), 0.005 s (dotted line), 0.1 s (dash-dotted line), and ∞ (solid line). The points indicate recent observational data of abundance ratios ^{232}Th/(^{151}Eu + ^{153}Eu) and (^{235}U + ^{238}U)/(^{151}Eu + ^{153}Eu) of metal-deficient halo stars [3].

Massive stars $\geq 8M_\odot$ culminate their evolution by supernova (SN) explosions which are presumed to be most viable candidate for the astrophysical site of heavy r-process nucleosynthesis. If the models for the r-process are correct, then our nucleosynthesis results could also pose a significant constraint on the remnant of SN explosions, i.e. neutron star (NS) or black hole (BH).

In case of massive core collapse is thought to be formed a remnant stellar black hole. Intensive neutrino flux from the neutralized core and neutrino sphere might stop suddenly during the Kelvin-Helmholtz cooling phase because of the BH formation. It is another current interest in astrophysics and particle physics what kind of observable phenomena we could find from these SN neutrinos. In several theoretical studies of particle physics, it is discussed that even the neutrino mass is to be determined from the time delay of deformed neutrino energy spectrum after the cease of neutrino ejection (neutrino flux cutoff effect [4]).

We therefore studied expected theoretical response of the r-process nucleosynthesis to the neutrino cutoff effect in order to look for another independent observable of this phenomenon. We found a pretty sensitive response of the r-process yields, especially the heaviest end of r-process elements such as ^{232}Th and ^{238}U (actinides) as shown in Fig. 1. One obtains the biggest response if the neutrino cutoff occurs after the critical time when the expanding materials in the neutrino-driven wind drop out of the NSE. We found that actinide abundance profile can be fit by

$$z = z_{t\to\infty} + \frac{z_1}{1+(t/t_0)^\alpha} \tag{1}$$

or by the normalized form of

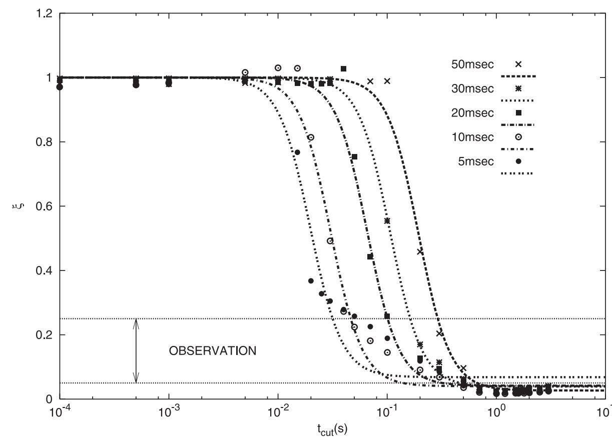

Figure2: Normalized abundance ratio $\xi = \frac{z-z_{t\to\infty}}{z_1} = \frac{1}{1+(t/t_0)^\alpha}$ vs. neutrino cutoff time t=t cut calculated in the exponential models which are characterized by the different dynamical expansion time scales τ_{dyn} = 5, 10, 20, 30, and 50 ms of the neutrino-driven wind, as indicated. Calculated data points are fit by universal curves. The parameter t_0, which corresponds to the time around which a drastic change of the final abundance occurs, is proportional to the dynamical timescale τ_{dyn}. Observed range includes both observational errors and dispersion from [3].

$$\xi = \frac{z \quad z_{t\to\infty}}{z_1} = \frac{1}{1+(t/t_0)^\alpha} \tag{2}$$

as displayed in Fig. 2 for many different SN expansion models with different τ_{dyn}. In these equations, $t = t_{cut}$, $z \equiv$ ^{232}Th/(^{151}Eu + ^{153}Eu), $z_{t\to\infty}$ means the abundance ratio of no neutrino cutoff, and $z_1 + z_{t\to\infty} (\equiv z_0)$ means the abundance ratio with no neutrinos, t_0 means the start of the drastic change of the ratio z , and α is a constant value. The quantity $\alpha = 3$ is model independent and the other quantities are model dependent.

The r-process nucleosynthesis changes maximally if the cutoff occurs during the r-process. Using this theoretical finding connected with future detection of the time-variation of SN neutrino spectrum, we are able to identify when the black hole formation occurs in the course of SN collapse and explosion.

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Primordial magnetic field constrained from CMB anisotropies

YAMAZAKI, Dai G. (University of Tokyo / NAOJ)
ICHIKI, Kiyotomo (University of Tokyo)
KAJINO, Toshitaka (NAOJ)
MATHEWS, Grant J. (University of Notre Dame)

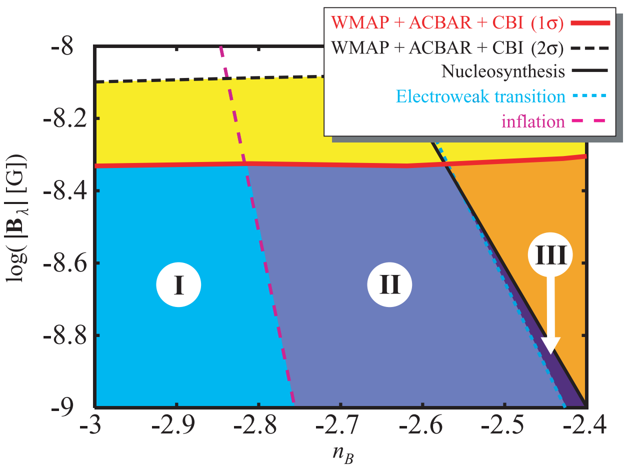

Figure1: Results of the MCMC method constrained by the WMAP, ACBAR, and CBI data [2]. Excluded and allowed regions at the 1σ (68%) C.L. and 2σ (95.4%) C.L. are shown in the two parameter plane of $|\mathbf{B}_\lambda|$ vs. n_B, where $|\mathbf{B}_\lambda|$ is the primordial magnetic field strength and n_B is the power-law spectral index. Solid and dotted curves are for $\Delta\chi^2 = 2.3$ and 6.17, respectively. The black-solid, skyblue-dotted, and pink-dashed lines are the upper limit of the produced PMF at the big-bang nucleosynthesis, the electroweak transiton, and the inflation epochs, respectively [3]. If the PMF is produced at the epochs of big-bang nucleosynthesis, the electroweak transition, or inflation, respectively, the region of I + II + III, II + III, or III on the right hand side are allowed by these constraints on the PMF for the galaxy cluster scale at the PLSS and the MCMC method with WMAP, ACBAR, and CBI data.

The primordial magnetic field (PMF) can strongly affect the cosmic microwave background (CMB) power spectrum and the formation of large scale structure. In this presentation, we calculate the CMB temperature anisotropies generated by including a power-law magnetic field at the photon last scattering surface (PLSS). We then deduce an upper limit on the primordial magnetic field based upon our theoretical analysis of the power excess on small angular scales. We have taken into account several important effects such as the modified matter sound speed in the presence of a magnetic field. An upper limit to the field strength of $|B_\lambda| = 7.7$ nG at the present scale of 1 Mpc is deduced. This is obtained by comparing the calculated theoretical result including the Sunyaev-Zeldovich (SZ) effect with recent observed data on the small scale CMB anisotropies from the Wilkinson Microwave Anisotropy Probe (WMAP), the Cosmic Background Imager (CBI) and the Arcminute Cosmology Bolometer Array Receiver (ACBAR). We discuss several possible mechanisms for the generation and evolution of the PMF in our study.

In order to constrain the PMF, we evaluate likelihood function of the WMAP TT, CBI, and ACBAR data in a wide range of parameter of the magnetic field strength $|B_\lambda|$ at 1 Mpc and the power-law spectral index n_B, along with six cosmological parameters, the Hubble parameter, the baryon and cold dark matter densities, the spectral index and the amplitude of primordial scalar fluctuation, and the optical depth, in flat Universe models, using the technique of the MCMC method.

For the first time we have studied scalar mode effects of the PMF on the CMB [2]. We have confirmed numerically without approximation that the excess power in the CMB at higher l can be explained by the existence of a PMF. For the first time a likelihood analysis utilizing the WMAP, ACBAR and CBI data with a MCMC method has been applied to constrain the upper limit on the strength of the PMF to be (Fig. 1)

$$|B_\lambda| < 7.7\text{nG} .$$

We have also considered three conditions on the generation and evolution of the cosmological PMF: 1) our result (Fig. 1); 2) the lower limit of the PMF from the magnetic field of galaxy clusters; and 3) the constraint on the PMF from gravity waves. Combining these, we find the following concordance region for the the PMF parameters;

$$1\text{nG} < |B_\lambda| < 4.7\text{nG} , \ -3.0 < n_B < -2.4 .$$

The PMF also affects the formation of large scale structure. For example, magnetic pressure delays the gravitational collapse. It is thus very important to constrain the PMF as precisely as possible. If we combine our study and future plans to observe the CMB anisotropies and polarizations for higher multipoles l, e.g. via the *Planck Surveyor*, we will be able to constrain the PMF more accurately, and explain the evolution and generation of the magnetic field on galaxy cluster scales along with the formation of the LSS.

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Supernova Neutrino Nucleosynthesis of Light Elements with Neutrino Oscillations

YOSHIDA, Takashi (Astronomical Institute, Tohoku University)
KAJINO, Toshitaka (Division of Theoretical Astronomy, NAOJ)
YOKOMAKURA, Hidekazu, KIMURA, Keiichi (Nagoya University)
TAKAMURA, Akira (Toyota National College of Technology)
HARTMANN, Dieter, H. (Clemson University)

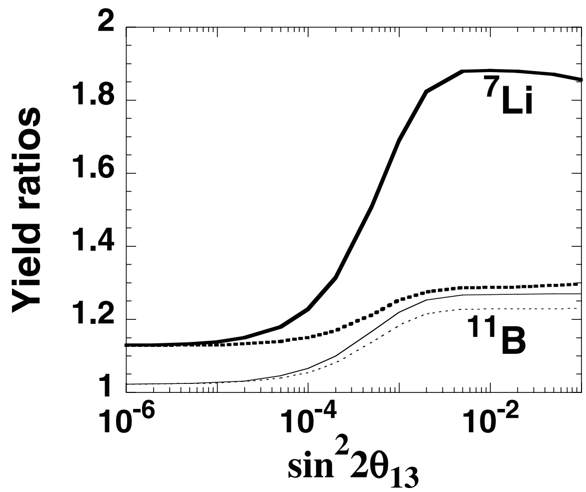

Figure1: The yield ratios of ^{7}Li and ^{11}B related to the mixing angle $\sin^2 2\theta_{13}$. Thick and thin lines indicate the yield ratios of ^{7}Li and ^{11}B, respectively. Solid lines and dotted lines correspond to normal mass hierarchy and inverted mass hierarchy.

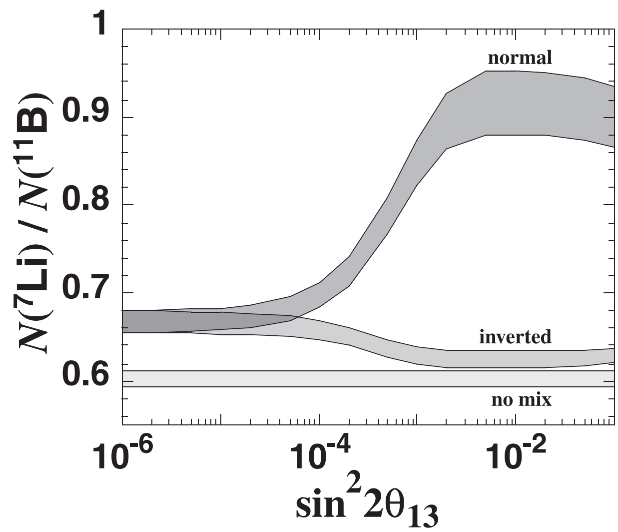

Figure2: The relation of the ^{7}Li/^{11}B abundance ratio with the mixing angle $\sin^2 2\theta_{13}$. The shaded ranges of ^{7}Li/^{11}B are due to the uncertainties in the neutrino temperatures and the total neutrino energy evaluated in [3].

We investigate the nucleosynthesis of light elements, ^{7}Li and ^{11}B, in supernovae taking account of neutrino oscillations [1]. Neutrinos emitted from the neutrino sphere change their flavors propagating in the surrounding stellar materials. The change of the neutrino energy spectra by the neutrino oscillations will change the yields of ^{7}Li and ^{11}B produced in supernovae.

We calculate detailed explosive nucleosynthesis using the supernova model of a 16.2 $M_\odot$ star [2] corresponding to SN 1987A. Parameter values of neutrino oscillations are adopted in accordance with the Large Mixing Angle solutions confirmed by recent neutrino experiments. However, whether mass hierarchy is normal or inverted has not been clarified and only upper limit of θ_{13} has been determined. We investigate the dependence of the ^{7}Li and ^{11}B yields on mass hierarchy and θ_{13}.

The relation between the yield ratios of ^{7}Li and ^{11}B and the mixing angle $\sin^2 2\theta_{13}$ is shown in Fig. 1. When we do not consider neutrino oscillations, the yields of ^{7}Li and ^{11}B are $2.36 \times 10^{-7}\ M_\odot$ and $6.26 \times 10^{-7}\ M_\odot$, respectively. One finds that both of the ^{7}Li and ^{11}B yields depend on $\sin^2 2\theta_{13}$. In a normal mass hierarchy and $\sin^2 2\theta_{13} \geq 2 \times 10^{-3}$, the ^{7}Li yield increases by a factor of 1.9. In an inverted mass hierarchy, the increase is smaller even relatively large $\sin^2 2\theta_{13}$ value. In the case of $\sin^2 2\theta_{13} \leq 2 \times 10^{-5}$ the yield ratio is about 1.1. On the other hand, the change of the ^{11}B yield ratio is smaller and the yield ratio is less sensitive to mass hierarchy. The ^{11}B yield ratio increase by a factor of 1.4 in a normal mass hierarchy and $\sin^2 2\theta_{13} \geq 2 \times 10^{-3}$.

The studies of Galactic Chemical Evolution (GCE) constrain the production of ^{11}B in supernovae. We have constrained the neutrino temperatures to reproduce the supernova contribution of ^{11}B during GCE [3]. However, the neutrino temperatures and the total neutrino energy still have uncertainties and the affected uncertainties of the ^{7}Li and ^{11}B yields make the effect by the neutrino oscillations ambiguous. Thus, we evaluate the dependence of the ^{7}Li/^{11}B abundance ratio on mass hierarchies and $\sin^2 2\theta_{13}$ taking into account uncertainties of the neutrino temperatures. The relation of the ^{7}Li/^{11}B ratio to mass hierarchies and $\sin^2 2\theta_{13}$ is shown in Fig. 2. When we do not consider neutrino oscillations, the ^{7}Li/^{11}B is about 0.6. In a normal mass hierarchy and $\sin^2 2\theta_{13} \geq 2 \times 10^{-3}$, the ^{7}Li/^{11}B is larger than 0.87. The ^{7}Li/^{11}B becomes larger by the neutrino oscillations. Therefore, a normal mass hierarchy and relatively large $\sin^2 2\theta_{13}$ might be constrained from the studies of light element synthesis in supernovae.

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II Publications, Presentations

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