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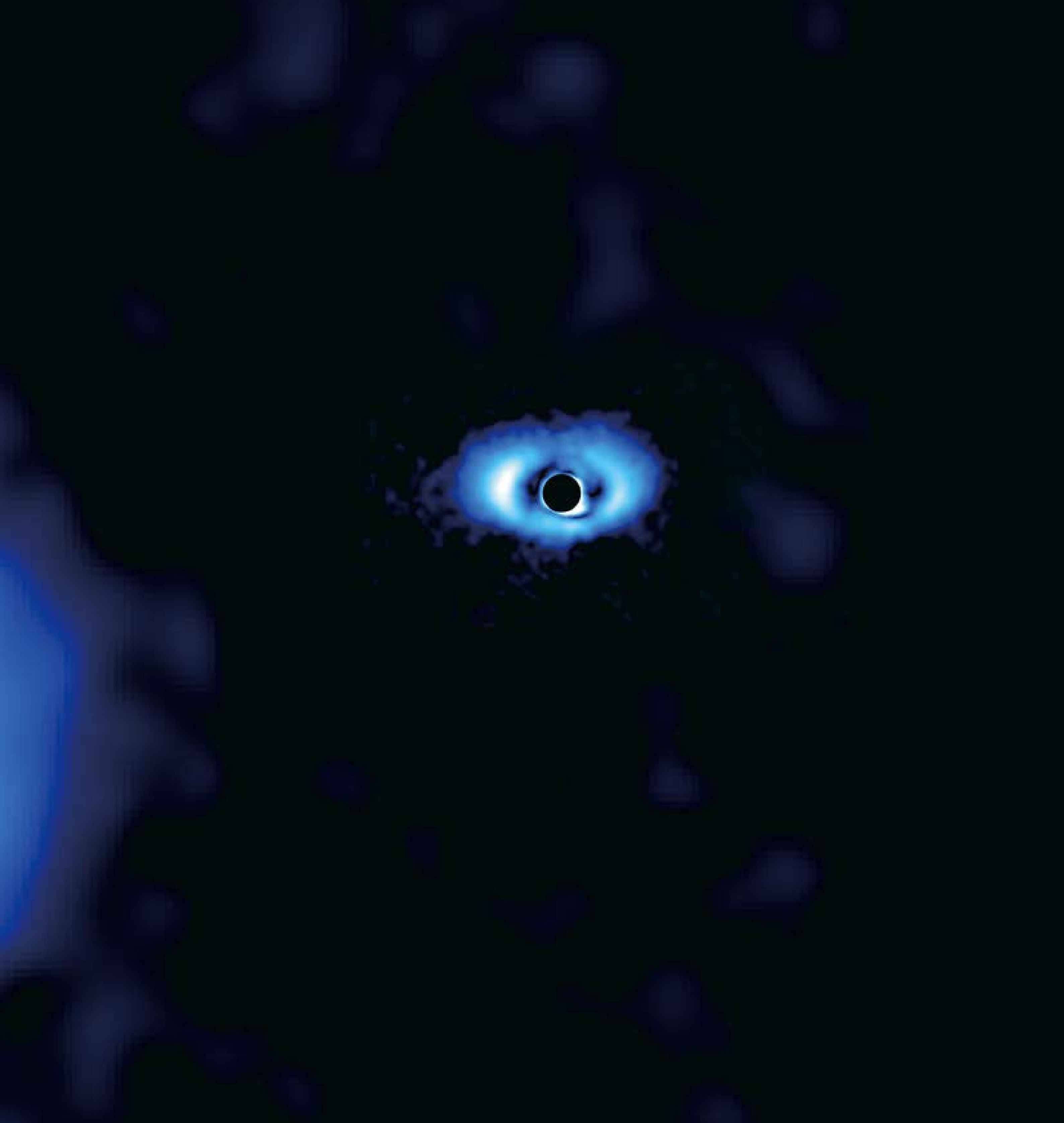

Cover Caption

Near-infrared (wavelength of 1.6 μm) image of young solar-type star PDS 70 (age of 10 million years) observed in the Subaru telescope. One of the largest gap in the protoplanetary disk around PDS 70 was observed for the first time among solar-type stars.

Postscript

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Fiscal 2012

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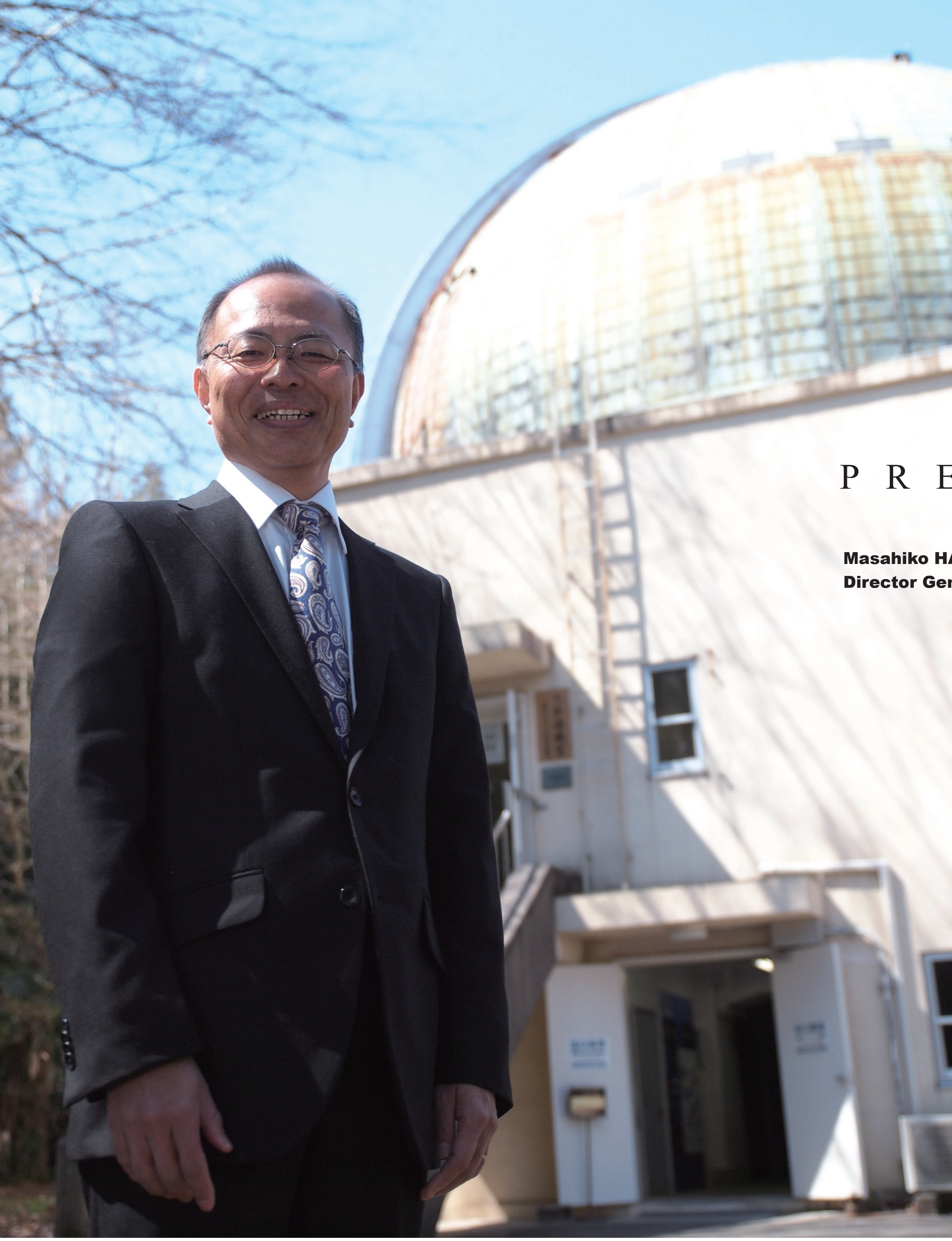

PREFACE

Masahiko HAYASHI
Director General of NAOJ

It is my pleasure to present our Annual Report for the fiscal year 2012.

FY 2012 celebrated the inauguration of ALMA, which has almost finished the installation of the total 66 antennas, and acceptance/commissioning of the receivers and correlators. The inauguration ceremony was held at the Operations Support Facility (OSF) at an altitude of 2900 meters on March 13, 2013 with the attendance of over 400 guests including President Pinera of Chile. From Japan, more than 50 people attended the ceremony. Teru Fukui, Senior Vice Minister of Education, Culture, Sports, Science and Technology, made a speech expressing continued strong support of the Japanese government to ALMA. On the following day, most of the guests visited the Array Operations Site (AOS) at 5000 meters.

ALMA started its open-use early science observations (Cycle 0) with 16 antennas from 2011, and began to deliver its early results from the second half of FY 2012. Although the current angular resolution of ALMA is only 1 arcsec (1/3600 of one degree), ALMA has already achieved overwhelmingly high sensitivity. ALMA revealed a totally unexpected spiral structure of gas around a low-mass star (similar to the Sun) which is emitted at the end of its life before evolving to a white dwarf. This is a whole new picture of the universe that we have never seen before. We are excited to see what will be discovered by ALMA with further improved resolution and sensitivity.

On the other hand, we had very sad news of the accidental death of Professor Koh-Ichiro Morita in Santiago, a leading scientist in the field of radio interferometer who worked for the realization of Japan’s participation to ALMA by proposing the enhancement of the array with the Atacama Compact Array (ACA). In honor of the late Professor Morita, the ALMA Board gave the name of “Morita Array” to the ACA. We always remember his achievement seeing the array with his name, which brings us small comfort and relief. I believe the only thing we can do is to devote ourselves toward the achievement of maximum scientific results with ALMA.

Meanwhile, Subaru Telescope started test observations with new Hyper Suprime-Cam, a next-generation prime-focus camera with a field of view about 10 times wider than the old one. This “hyper” camera has newly-developed 116 wideband CCDs for astronomical observations and 900 million pixels in total. It will be a powerful tool not only in the search for distant unknown objects where Subaru telescope demonstrates unparalleled strength but also in the high-sensitivity survey of a wide field to study the distribution of dark matter and dark energy which is yet to be explored.

Remarkable scientific results on exoplanets with Subaru Telescope should also be mentioned. Its improved function enabled direct imaging of Jupiter-like gaseous planets and revealed the existence of a giant gaseous planet in a place far from the central star, equivalent to the distance between the Sun and Pluto in the solar system. Also, Subaru successfully imaged a number of protoplanetary disks, many of which have a spiral or ring structure. It is expected that further study using ALMA observation data as well will enhance the understanding of planetary formation.

The Thirty Meter Telescope (TMT) is making steady progress in the preparation for the construction. TMT is an optical-infrared telescope to be built on the summit of Mauna Kea in international partnership of National Astronomical Observatory of Japan (NAOJ), California Institute of Technology (Caltech), University of California (UC), Department of Science and Technology of India, Association of Canadian Universities for Research in Astronomy (ACURA), and National Astronomical Observatories of the Chinese Academy of Sciences. We still have a lot to discuss about the share of contribution to the construction among partners and how to ensure each partner’s budget acquisition as planned, etc. This kind of collaborative work is inevitable for a large-scale international project. In spite of various difficulties to overcome, we are pleased to have the opportunity to lead a global project and take the initiative in building a strong organization for TMT construction.

FY 2012 celebrated the 30th anniversary of Nobeyama Radio Observatory and we held a commemoration ceremony in September. The NRO 45-m Telescope has produced significant results such as the discovery of many kinds of new interstellar molecules and finding of evidence for the existence of a massive black hole in the center of a galaxy. Although its aging deterioration is not avoidable, it will still be a front-line telescope with overwhelmingly improved receiver sensitivity.

Also, FY 2012 marks the 10th anniversary of the completion of VERA at the Mizusawa VLBI Observatory for which a commemoration ceremony was held in Oshu, Iwate. VERA provides accurate measurement of the distance and the motion of astronomical objects thousands of light years away from the Sun, thereby revealing detailed kinematics and structure of the Galaxy. A recent result shows that the Sun orbits the Galaxy at a rate 10% faster than previously believed.

The Center for Computational Astrophysics relocated the supercomputer from Mitaka campus to Mizusawa VLBI Observatory at the renewal of the lease. The new supercomputer, named Aterui in tribute to a hero in the Tohoku region where Iwate prefecture is situated, will start operation from FY 2013.

In this time of dynamic change, rapid development is required also in astronomy. While new telescopes are planned and realized one after another, once the most advanced telescopes become soon out of date. In this rapidly changing world, we reaffirm our mission to keep up with global scientific advances and continuously provide frontier facilities for world-wide researchers in order to return the results of research to society as an institute of the Inter-University Research Institute Corporations.

Masahiko HAYASHI
Director General of NAOJ

I Scientific Highlights

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Three-Dimensional Structure of Supernovae Studied by Spectropolarimetric Observations

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Massive stars are thought to end their lives as supernova explosion. However, the explosion mechanism is not yet clear. Recent numerical simulations suggest that multi-dimensional effects are critical for successful explosions. In contrast, it is not easy to study the multi-dimensional shape of supernovae observationally, since supernovae in external galaxies are point sources (Figure 1).

In this study, we focus on spectropolarimetric observations, which are sensitive to multi-dimensional shape of the sources. We have performed multi-dimensional radiative transfer simulations and found following. (1) If the supernova explosion is completely axisymmetric, the spectropolarimetric data should align in the Stokes *QU* diagram. (2) If the supernova explosion has a 3D, clumpy structure, the data in the *QU* diagram show a loop. Based on these expectations, we have performed spectropolarimetric observations of extragalactic supernovae using Subaru/FOCAS.

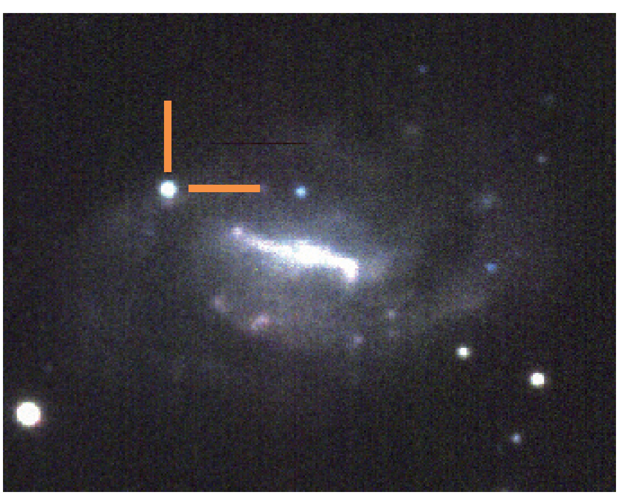

Figure 1: Optical image of SN 2009mi in IC 2151 (the position of the supernova is pointed by the lines).

As a result of spectropolarimetric observations [1], we found that the data show a loop in the *QU* diagram as shown in Figure 2. This is consistent with the expectation of a 3D, clumpy explosion. By combining our new results with our past observations [2,3] and the data taken by other groups, we found 5 supernovae out of 6 objects show a similar pattern. This indicates that supernova explosion generally has a 3D, clumpy structure. Such a structure may be formed by the convection during the explosion. Our results can be an important key to understand the explosion mechanism from actual observations.

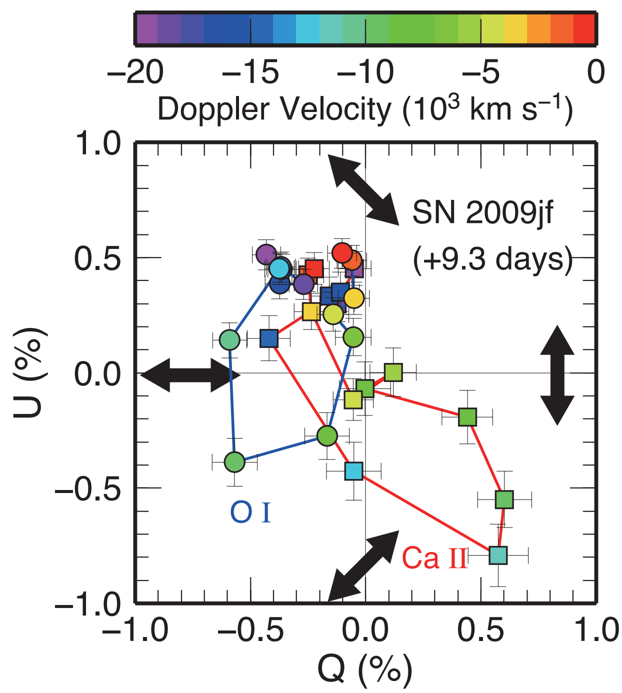

Figure 2: Spectropolarimetric data of SN 2009jf taken with Subaru/FOCAS. The data are plotted in the Stokes *QU* diagram. Different colors represent different wavelength (Doppler velocities). The observed data suggest 3D, clumpy structure of supernova ejecta.

References

[1] Tanaka, M., et al.: 2012, *ApJ*, **754**, 63.
[2] Tanaka, M., et al.: 2008, *ApJ*, **689**, 1191.
[3] Tanaka, M., et al.: 2009, *ApJ*, **699**, 1119.

Infrared Observations of "Middle-Aged" Supernovae Filling the Gap between Supernovae and Supernova Remnants

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Observational studies of supernovae can be divided into two categories: (1) young supernovae (within a few years after the explosion) in external galaxies, and (2) supernova remnants in our Galaxy (older than a few hundred years old). Extragalactic supernovae can be observed only for a few years since they get fainter. On the other hand, probability to have a young supernova in our Galaxy is extremely low (about once in a century). Therefore, we don't have any observational example in the gap of these two phases, except for SN 1987A in the Large Magellanic Cloud. Thus, it was basically impossible to observationally study the long-term evolution from supernova to supernova remnant.

In order to detect supernovae in this gap, so called "middle-aged" supernovae, we searched supernovae in the images of nearby galaxies taken with AKARI satellite. As a result, we discover infrared emission from SN 1978K in NGC 1313 [1] (Figure 1). This is the emission at 28 years after the explosion, and the second example of middle-aged supernovae after SN 1987A.

The spectral energy distribution (SED) is quite intriguing. It is similar to the SED of Galactic supernova remnant Cassiopeia A (about 300 years old). In addition, from the analysis of the SED and model calculations, we found that (1) SN 1978K is associated with 1×10^{-3} $M_{\odot}$ of silicate dust, and (2) the emission is caused by the circumstellar dust heated by the shock wave of the supernova. These results indicate that at least this supernova already radiates by the interaction between supernova ejecta and surrounding medium as in supernova remnants. This observation provides a unique example to understand the long-term evolution from supernova to supernova remnant.

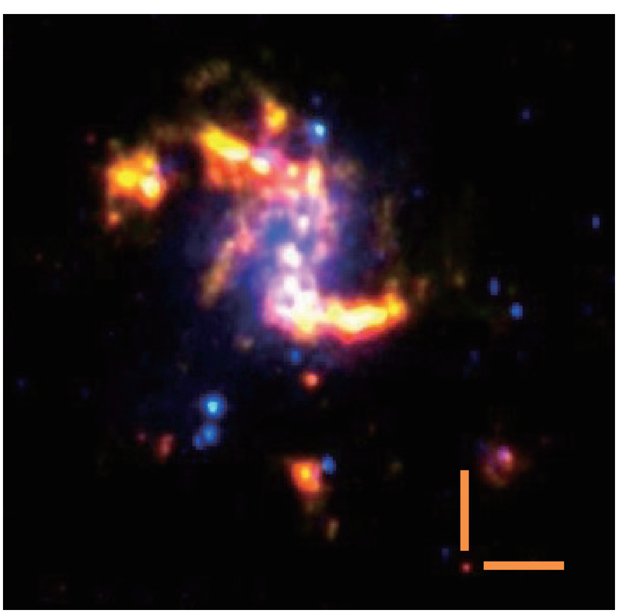

Figure 1: Infrared image of SN 1978K in NGC 1313 at 28 yr after the explosion (the position of the supernova is pointed by the lines).

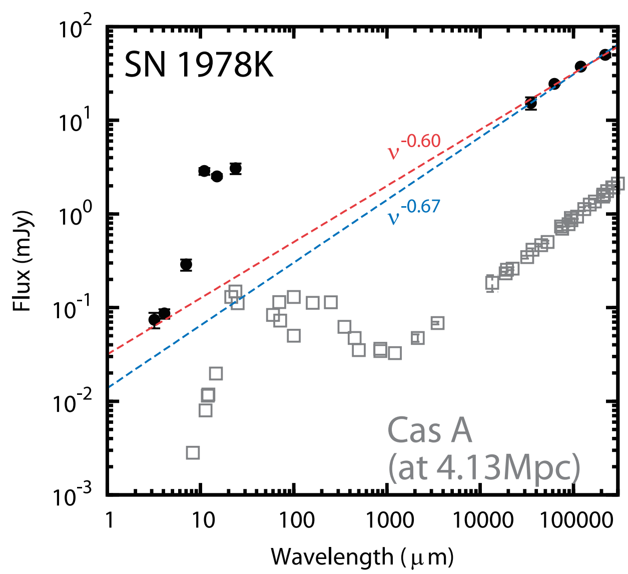

Figure 2: Infrared-to-radio SED of SN 1978K (black), compared with that of Cassiopeia A (gray). Both objects show synchrotron emission at radio wavelengths and infrared excess by the dust emission. The infrared emission from SN 1978K is reproduced by 1×10^{-3} $M_{\odot}$ of silicate dust.

Reference

[1] Tanaka, M., et al.: 2012, *ApJ*, **749**, 173.

Near-Infrared Circular Polarization Images of NGC 6334-V

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We present results from deep imaging linear and circular polarimetry of the massive star-forming region NGC 6334-V (Figure 1). These observations show high degrees of circular polarization (CP), as much as 22 % in the K_S band, in the infrared nebula associated with the out ow. The CP has an asymmetric positive/negative pattern and is very extended (~80″ or 0.65 pc). Both the high CP and its extended size are larger than those seen in the Orion CP region (Figure 2). Three-dimensional Monte Carlo light-scattering models are used to show that the high CP may be produced by scattering from the infrared nebula followed by dichroic extinction by an optically thick foreground cloud containing aligned dust grains. Our results show not only the magnetic eld orientation of around young stellar objects, but also the structure of circumstellar matter such as out ow regions and their parent molecular cloud along the line of sight. The detection of the large and extended CP in this source and the Orion nebula may imply the CP origin of the biological homochirality on Earth [1].

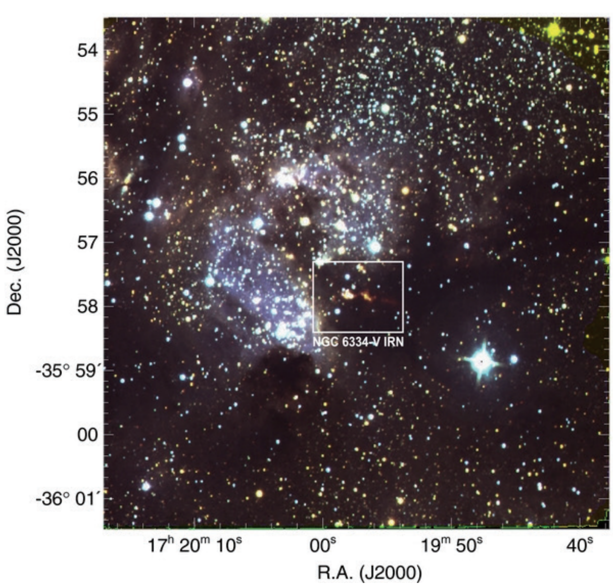

Figure 1: Color composite Stokes I image of the NGC 6334-V region in the J (blue), H (green), and K_S (red) bands from the IRSF/SIRPOL (CP) observations.

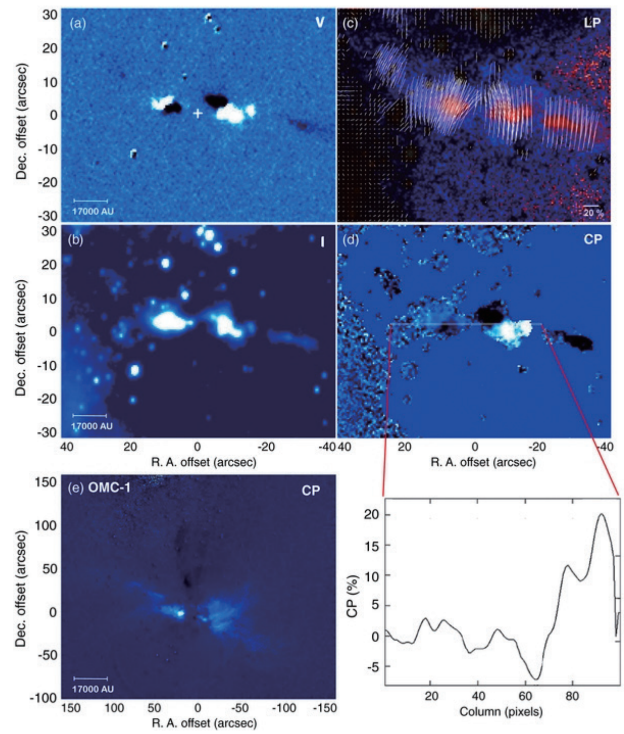

Figure 2: ((a) and (b)) Stokes V and I images of NGC 6334-V IRN in the K_S band, respectively. The white cross shown in (a) is the location of the illuminating star. (c) K_S polarization vector map of NGC 6334-V IRN superposed on the LP image. (d) CP image in the Ks band and a plot line indicated a white box and columns of the sub-CP image smoothed by 3 pixels of NGC 6334-V IRN. For making the CP image, I image was masked with a threshold of 2σ of approximate sky value. (e) CP image of OMC-1 in the K_S band.

Reference

[1] Kwon, J., et al.: 2013, *ApJ*, **765**, L6.

Detection of Low-Level Activities in Solar-Analog Stars from the Emission Strengths of Ca II 3934 Line

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There have been several arguments regarding the status of solar activity among similar Sun-like stars. This began with the implication of Baliunas and Jastrow [1] based on their Mt. Wilson HK survey that a considerable portion (~1/3) of solar-type stars have activities significantly lower than the present-day Sun, which they called "Maunder-minimum stars." However, their conclusion could not be confirmed by Hall and Lockwood's follow-up study [2], and Wright [3] criticized the reality of such low-active solar-type stars by pointing out that most of them are not so much dwarfs as evolved subgiants.

Given this controversial situation, we decided to contend with this problem by ourselves based on carefully selected sample of 118 solar-analogs sufficiently similar to each other (which we already investigated their stellar parameters as well as Li/Be abundances in a series of papers; cf. [4,5,6]), with a special attention being paid to reliably evaluating their activities down to a considerably low level.

Practically, we measured the emission strength at the core of Ca II 3933.663 line (K line; cf. Figure 1) on the high-dispersion spectrogram obtained by Subaru/HDS, where we gave effort to correctly evaluating the pure emission component by removing the wing-fitted photospheric profile calculated from the classical solar model atmosphere to obtain $R'_{\rm Kp}$ (ratio of chromospheric core emission flux to the bolometric flux). This enabled us to detect low-level activities down to log $R'_{\rm Kp} \sim -5.5$.

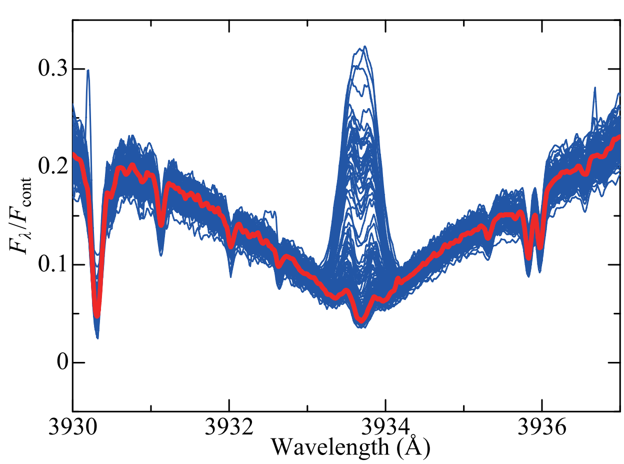

Figure 1: Observed spectra at the Ca II K line core for the 118 program stars (blue) and Vesta/Sun (red).

From the distribution histogram of log $R'_{\rm Kp}$ (Figure 2), we could recognize a clear Vaughan–Preston gap between two peaks at ~ -5.3 and ~ -4.3. Our result of log $R'_{\rm Kp,\odot} = -5.33$ manifestly suggests that the Sun belongs to the group of the former peak and has a distinctly low-active nature among solar analogs. Actually, the fraction of stars satisfying the condition of log $R'_{\rm Kp} \leq$ log $R'_{\rm Kp,\odot}$ is only ~10 %. This consequence exclude the possibility for the existence of a considerable portion (e.g., ~1/3) of "Maunder-minimum stars" such that having activities significantly lower than the current solar-minimum level as once suggested by Baliunas and Jastrow ([1]). This consequence also implies that the Sun is a distinctly low-active star even within the group of solar-analog stars. See [7] for more details of this study.

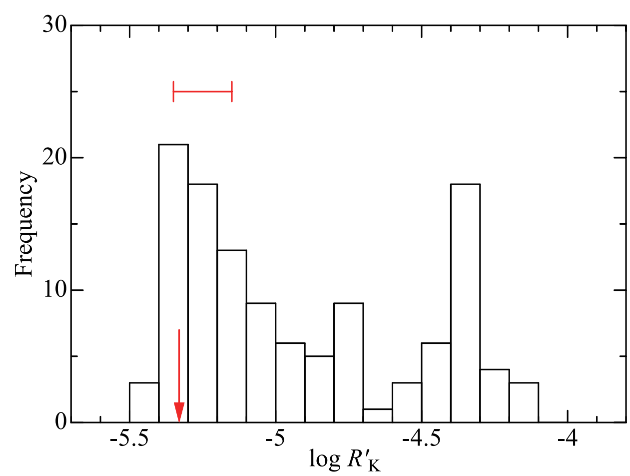

Figure 2: Distributions of log $R'_{\rm Kp}$. The arrow shows the position for the Sun, and its expected minimum–maximum range is also indicated.

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The Galaxy Luminosity Functions down to $M_R = -10$ in the Coma Cluster

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The galaxy luminosity function (LF) is a useful measure to describe fundamental statistical properties of galaxy populations and serves as a clue to study the history of galaxy formation and evolution. However, our knowledge of the faint part of the LF ($M_R > -19$), which is dominated by dwarf galaxies, is still very limited. The aim of the present study is to investigate the properties of the very faint dwarf population and their possible environmental dependence, if any, in terms of LF, color, and surface brightness.

We construct the LFs at three fields ocated at the center, intermediate, and outskirt in the Coma Cluster [1]. Deep and wide images are obtained with the Suprime-Cam mounted on the Subaru Telescope. Contamination from background galaxies is subtracted statistically using the number counts of galaxies in a blank field, the Subaru Deep Field.

The LF ($-19 < M_R < -10$) shows no significant differences among the different three fields in this cluster (Figure 1). It shows a clear dip at $M_R \sim -13$, and is composed of two distinct components of different slopes; the bright component with $-19 < M_R < -13$ has a flatter slope than the faint component with $-13 < M_R < -10$ which has a steep slope. The bright component ($-19 < M_R < -13$) consists of mostly red extended galaxies including few blue galaxies whose colors are typical of late-type galaxies. On the other hand, the faint component ($-13 < M_R < -10$) consists of largely PSFlike compact galaxies (Figure 2). We found that both these compact galaxies and some extended galaxies are present in the center while only compact galaxies are seen in the outskirt. In the faint component, the fraction of blue galaxies is larger in the outskirt than in the center. We suggest that the dwarf galaxies in the Coma Cluster, which make up the two components in the LF, are heterogeneous with some different origins.

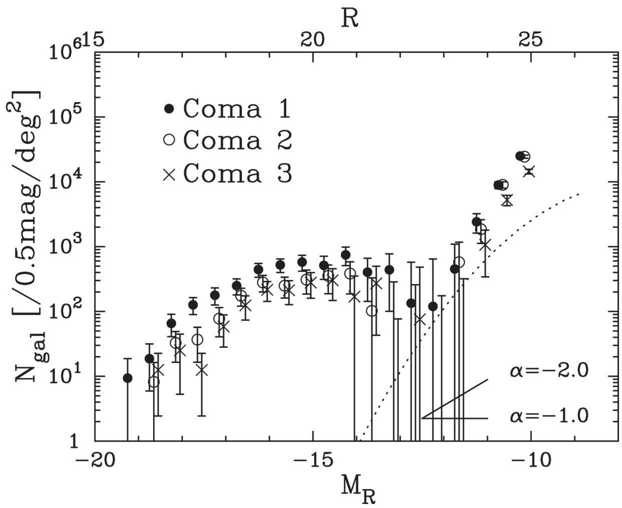

Figure 1: The *R*-band LFs of the center (Coma 1), intermediate (Coma 2) and outskirt (Coma 3) fields, respectively. The error bars are based on Poisson statistics. The broken curve indicates the LF of globular clusters in the Coma 1 field calculated using the previous results of [2] and [3].

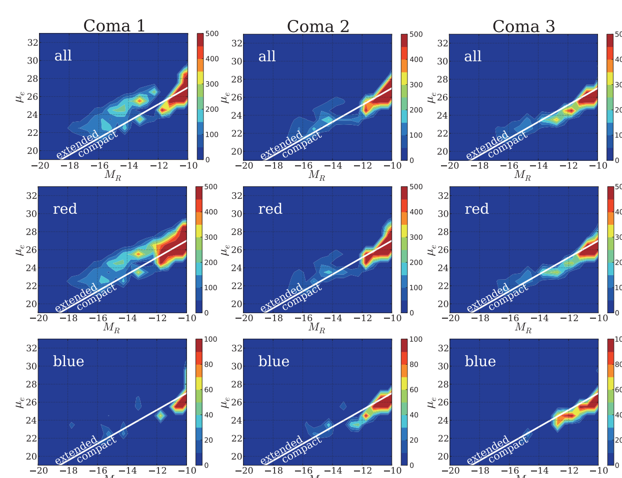

Figure 2: The color-coded number density contours of estimated member galaxies (all galaxies: *top row*, red galaxies: *middle row*, blue galaxies: *bottom row*) in the *R* absolute magnitude versus effective surface brightness plane. The white solid line indicates the discrimination between the extended (*upper*) and the compact (*lower*) objects.

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Kinematic Imprint of Clumpy Disk Formation on Halo Objects

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Clumpy disk galaxies in the distant universe, at redshift of $z \gtrsim 1$, have been observed to host several giant clumps in their disks [1]. They are thought to correspond to early formative stages of disk galaxies [2]. On the other hand, halo objects, such as old globular clusters and halo stars, are likely to consist of the oldest stars in a galaxy (age $\gtrsim$ 10 Gyr), clumpy disk formation can thus be presumed to take place in a pre-existing halo system.

Giant clumps orbit in the same direction in a premature disk and are so massive that they may be expected to interact gravitationally with halo objects and exercise influence on the kinematic state of the halo. Accordingly, I scrutinize the possibility that the clumps leave a kinematic imprint of the clumpy disk formation on a halo system.

I perform a restricted *N*-body calculation with a toy model to study the kinematic influence on halo objects by orbital motions of clumps and the dependence of the results on masses (mass loss), number, and orbital radii of the clumps. My result shows that halo objects can be rotated by clump motions and acquire disky rotation in a dynamical friction time scale of the clumps, ~0.5 Gyr (the top panel of Figure 1). The influence of clumps is limited within a region around the disk, while the halo system shows vertical gradients of net rotation velocity and orbital eccentricity (the bottom panel of Figure 1). The signicance of the kinematic influence strongly depends on the clump masses; the lower limit of postulated clump mass would be $\sim 5 \times 10^8 M_\odot$. The result also depends on whether the clumps are subjected to rapid mass loss or not, which is an open question under debate in recent studies. The existence of such massive clumps is not unrealistic. I therefore suggest that the imprints of past clumpy disk formation could remain in current galactic halos. This result has already been published in a refereed journal [3].

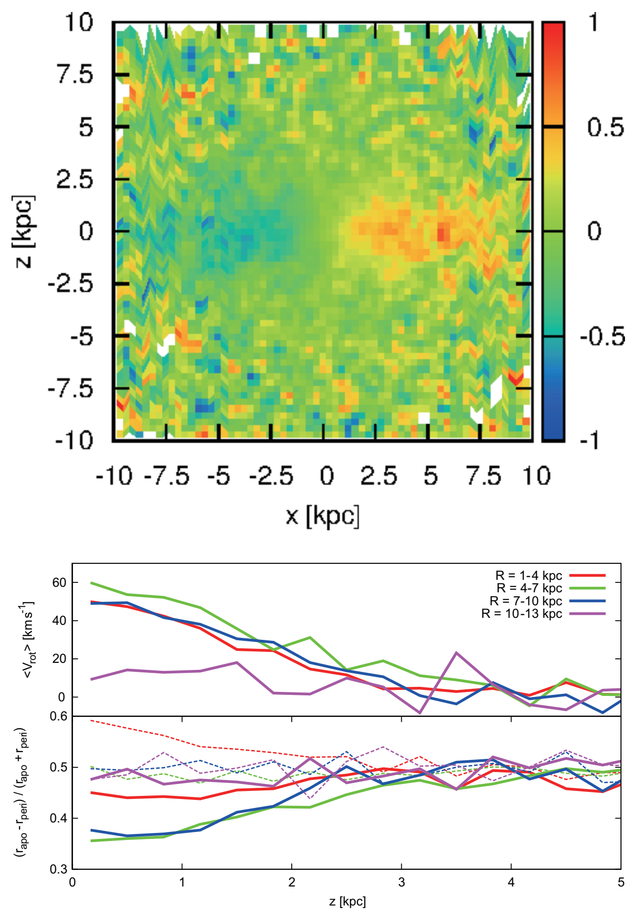

Figure 1: Map of mean line-of-sight velocity from the edge-on view (top). The values are normalized by the line-of-sight velocity dispersion inside r_0 = 4 kpc, which is 106 km s^{-1}. The mean azimuthal velocity and orbital eccentricity, $e \equiv (r_{apo} - r_{peri})/(r_{apo} + r_{peri})$, of the halo objects as functions of distance from the clump orbital plane (bottom), where r_{apo} and r_{peri} are apo- and peri-center distances, respectively. Each line indicates a radial range in cylindrical coordinate, *R*. In the bottom panel, the halo objects rotating prograde and retrograde are separately plotted; the thick and thin lines correspond to prograde and retrograde ones, respectively.

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Astrometric Mock Observations for Determining the Local Dark Matter Density

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To determine the local dark matter density (LDMD) around the solar system is a classical problem in astronomy since [1]. In recent years, dedicated searches for candidates of dark matter (DM) particles have intensified. Experiments aiming at direct detection of the DM particles look for signals from recoil of DM particles with nuclei inside the detector. Thus, the event rates of the direct detection are clearly proportional to the LDMD around the solar system. This is why the problem of determining the LDMD at the solar position has recently been attracting a great deal of attention.

Recently, Garbari et al. [2,3] have devised a novel method to determine the LDMD from stellar distribution and vertical velocity dispersion profiles perpendicular to the Galactic plane, which they named a minimal assumption (MA) method. Their method has the advantages of abolishing conventional approximations and using only a few assumptions. Their determinations preferred higher dark matter densities than conventional values although the previous results are within their quoted errors.

This study is aimed at carefully scrutinizing the MA method and examining influence on the LDMD determination with the MA method by observational uncertainties. We discuss how the determinations of the LDMD vary with observational precisions on parallax, proper motion and line-of-sight velocity measurements. For these aims, we create mock observation data for stars being dynamical tracers based on an analytical galaxy model and apply parametrized observational errors to the mock data. We evaluate the accuracy of determining the LDMD by applying the MA method to the mock data. In addition, we estimate a sample size and observational precision required to determine the dark matter density with accuracy.

We find that the MA method is capable of determining the LDMD with accuracy if the sample size and observational precisions are satisfactory. The sample size required is approximately 6,000 stars. The random errors of parallaxes and proper motions can cause systematic overestimation of the dark matter density. We estimate the required precisions of the parallax measurements to be approximately 0.1–0.3 milliarcseconds at 1 kpc away from the sun; the proper motion precisions do not seem to be as important as the parallaxes. Also, we find that the line-of-sight velocity errors can cause either under-estimation or overestimation of the dark matter density, which is contingent on distance-dependence of the errors.

From these results, we expect that use of the *Hipparcos* catalog would overestimate the LDMD because of the imprecise parallax measurements if the MA method is applied; however, we emphasize the capability of their method. [2] was making use of the *Hipparcos* catalog which might lead to their high LDMD. We expect that *Gaia* will provide data precise enough to determine the LDMD.

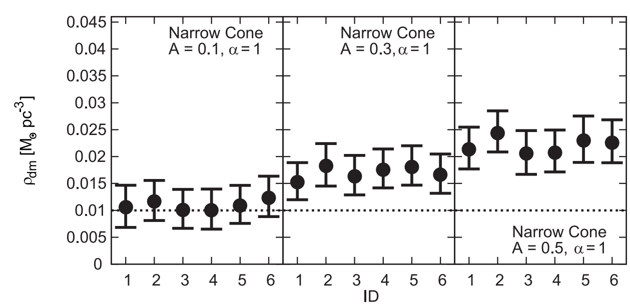

Figure 1: Influence of the astrometric distance errors on determining the LDMD. The panels from the left to right indicate the results of adopting A = 0.1 0.3 and 0.5, respectively, where A is parallax measurement precision at 1 kpc away from the sun. In each case, we conduct the same computation with different tracer samples generated in the same conditions (ID = 1–6) with 24,000 sample stars. The horizontal dotted line indicates the true LDMD assumed in our model.

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Spacecraft Observation of a Central Engine of Magnetic Reconnection

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Magnetic reconnection is a driver of explosive events in space and astrophysical plasmas. It has been thought that the reconnection process is controlled by magnetic dissipation physics in a small-scale region near the reconnection point (X-line). In other words, the dissipation region plays a role as a central engine of magnetic reconnection. Although it was not clearly defined before, recent theory suggests that the dissipation region is best identified by a frame-independent dissipation measure [1].

In the Earth's magnetosphere, spacecrafts have observed reconnection events for many years. Such "in-situ" measurements have provided key information for reconnection theories. So far, there has been no clear observation of the dissipation region, mainly because the present instruments can hardly resolve the small dissipation region whose typical size is 1000 km × 100 km.

The Geotail spacecraft, developed by JAXA/ISAS in collaboration with NASA, has been observing the Earth's magnetosphere since 1992. On 15 May 2003, it encountered a reconnection event in the night side of the magnetosphere [2]. This is the best reconnection event in 20 years of Geotail observation. The top panel in Figure 1 shows selected Geotail data during the event [3]. Both an ion flow (blue) and an electron flow (red) reverse their directions, and electrons are outrunning ions. This is a signature of reconnection jets from the X-line. The gray histogram shows an approximate form of the energy dissipation,

$$D_e^* = j_x(\vec{E} + \vec{v}_e \times \vec{B})_x + j_y(\vec{E} + \vec{v}_e \times \vec{B})_y, \quad (1)$$

which is useful in this specific configuration [3]. As indicated by the arrow, there is a characteristic structure with energy dissipation at the plasma jet reversals. The picture is qualitatively similar to one in a kinetic simulation, as shown in the bottom panel in Figure 1.

We extensively check our dataset, including raw instrumental data of the electric field. We confirm that several possible factors such as an offset in E_x do not change the picture around the jet reversal. Therefore, although our resolution is quite limited, we are convinced that the Geotail encountered the dissipation region. To our knowledge, this is the first clear detection of the dissipation region of magnetic reconnection in the planetary magnetotail.

In 2014, NASA will launch magnetospheric multiscale (MMS) satellites to directly probe reconnection sites with ultra-high-resolution instruments on four spacecrafts. When the spacecrafts will encounter the dissipation region, we will hopefully be able to identify it by using our diagnosis. The high-resolution data of the dissipation region will be transferred to the ground with the highest priority, and then it will provide key information about the breaking mechanism of magnetic field lines.

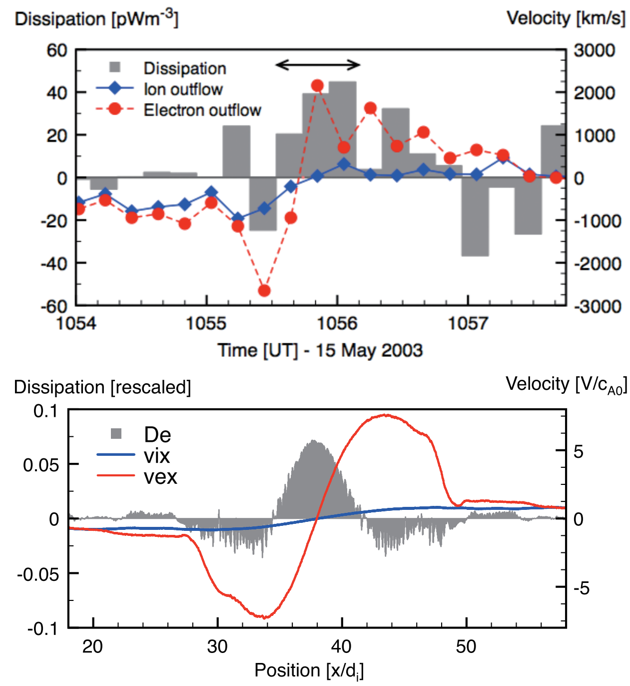

Figure 1: (Top) Geotail observation from 1054:00 UT to 1057:45 UT on 15 May 2003. The outflow component of the perpendicular ion (blue) and electron (red) velocities, and the approximate dissipation measure D_e^* (Eq. 1) are presented. (Bottom) The same quantities in a 2D kinetic simulation. 1D cut along the outflow direction.

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Accurate Measurements of the Brightness of the White-Light Corona at the Total Solar Eclipses on 1 August 2008 and 22 July 2009

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The total eclipses are good chances to observe the white-light corona from just above the solar limb to as far as several solar radii. We measured the brightness of the white light corona at the total solar eclipses on 1 August 2008 and 22 July 2009 during the deep solar minimum, when solar activity was at its lowest in one hundred years [1]. After careful calibration, the total brightness of the corona in both eclipses was evaluated to be approximately 0.4×10^{-6} of the total brightness of the Sun. The measured value is lower than those measured in the former minima [2]. The total brightness of the white-light corona corresponds to the total amount of the coronal material. Therefore, the low brightness of the corona shows that the amount of the coronal material was particularly small when the magnetic activity on the solar surface became quite low.

Furthermore, we compared the total brightness of the K + F-corona beyond $3\,R_\odot$ in both eclipses to the formerly measured brightness of the F-corona only (Figure 1). The measured results of the F-corona show some scatter, because it is generally difficult to isolate the F-corona from the K+F-corona. Our results show that the K + F-corona brightness values at the two eclipses are lower than some of the F-corona only brightness values previously measured. Due to the low solar activity, the K-corona brightness beyond $3\,R_\odot$ is quite low at the two eclipses, and our measurements give the reliable upper limit of the F-corona brightness on the basis of the high-accuracy calibration.

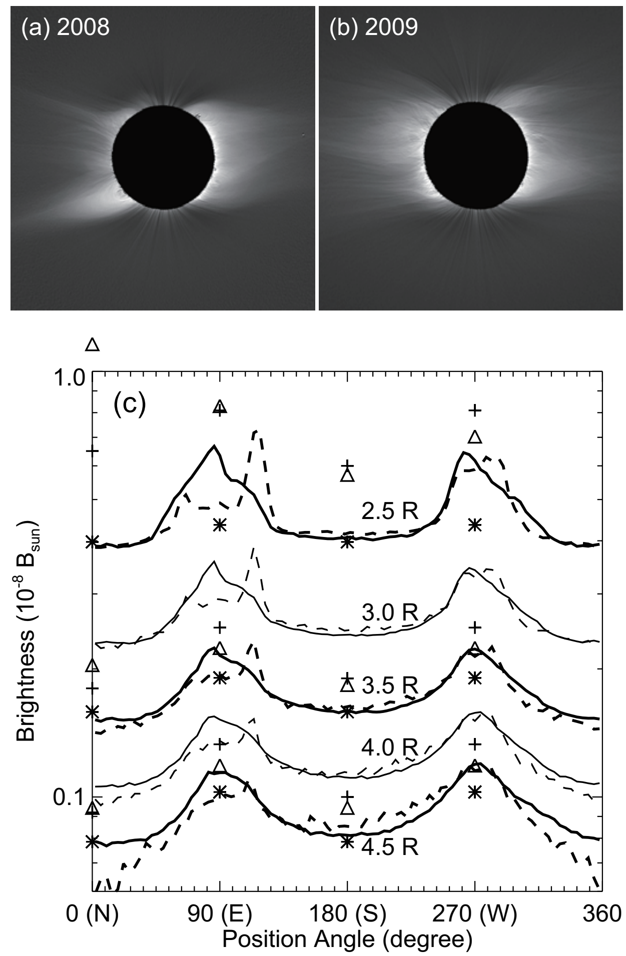

Figure 1: (a) Stacked images of the white-light corona taken in the 1 August 2008 eclipse and (b) the 22 July 2009 eclipse. To show the fine structures in the corona clearly, radial brightness decrease is suppressed, and structures of the coronal streamers are enhanced. The solar north is to the top. (c) Tangential coronal brightness distributions in the 2008 (dashed curves) and the 2009 (solid curves) eclipses at radii of 2.5, 3.0, 3.5, 4.0, and 4.5 $R_\odot$. Formerly measured brightness values of the F-corona [3,4,5] for radii 2.5, 3.5, and 4.5 $R_\odot$ are also shown by triangles, plus signs, and stars. Our results for these radii are shown in thick curves.

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Early Thermal X-Ray Emission from Long Gamma-Ray Bursts

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Gamma-ray bursts (GRBs) are sudden appearance of gamma-ray point source on the celestial sphere. GRBs are divided into two groups, short and long bursts. Bursts with the duration longer (shorter) than 2 sec are classified as long (short) GRBs. Short GRBs are currently considered to originate from the merger of two neutron stars in a closed binary. Long GRBs are produced by an ultrarelativistic jet that launches as a result of the gravitational collapse of the iron core of massive stars, which is observationally confirmed by temporal and spacial coincidence between a special class of type Ic supernovae and long GRBs. Many problems, such as, radiation mechanisms of gamma-rays, jet injection, and so on, remain unsolved and discussed by a lot of researchers.

In this research [1], the dynamical evolution of an ultrarelativistic jet injected into the core of a massive star is investigated by two-dimensional relativistic hydrodynamic code developed by one of the authors (Figure 1). As a progenitor model, we adopted a Wolf-Rayet star with the mass of 14 $M_\odot$ and the radius of 4 $\times 10^{10}$ cm. Especially, we focus on the circumstellar medium (CSM) of the progenitor. Wolf-Rayet stars are considered to experience violent mass losing process prior to the gravitational collapse. Then, we calculate models with steady wind with the mass-loss rates 10^{-7}, 10^{-6}, 10^{-5}, 10^{-4}, and 10^{-3} $M_\odot$ yr^{-1} to investigate effects of the presence of dense CSM on the dynamics of the jet. In Figure 2, radial profiles of the velocity, the density, and the pressure along the inclination angle of 45° are compared for models with the mass-loss rates of 10^{-7} and 10^{-3} $M_\odot$ yr^{-1}. In the dense CSM model, the reverse shock is formed and propagates in the ejecta. On the other hand, in the dilute CSM model, the rarefaction wave propagates in the ejecta.

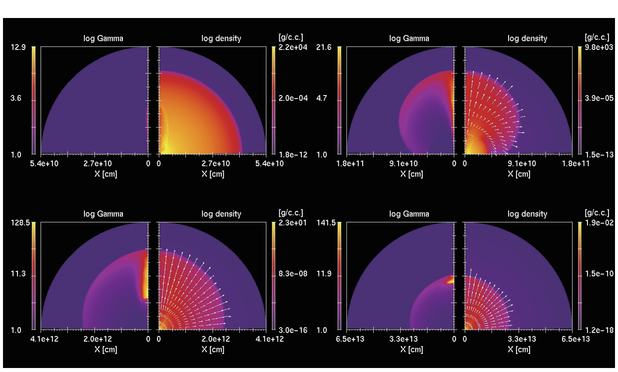

Figure 1: Results of relativistic hydrodynamical simulation of an ultrarelativistic jet emanating from a massive star.

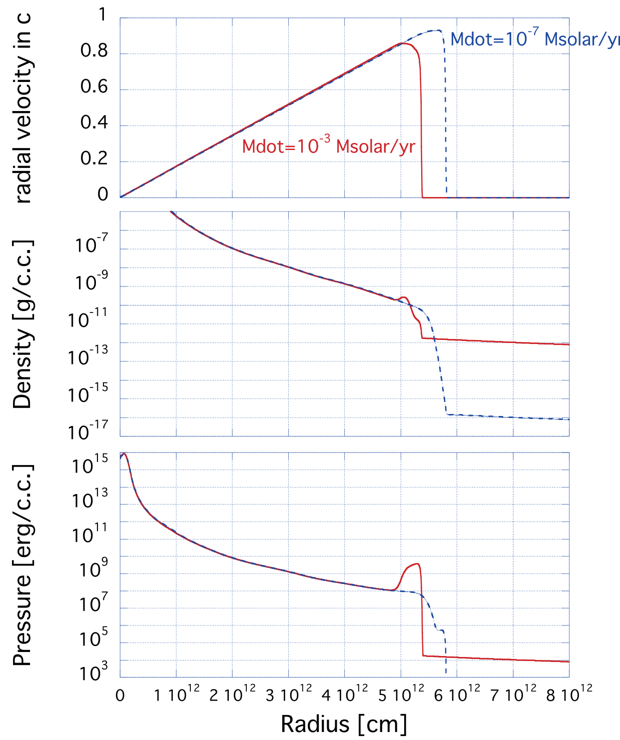

Figure 2: Radial profiles of the velocity (top), density (middle), and pressure (bottom) of the ejecta along the inclination angle of $\theta = 45°$. Solid and dashed lines correspond to dense and dilute CSM models.

Calculating the photospheric emission from the ejecta for each model, we found that the photospheric emission can explain properties of recently discovered thermal Xray emission from GRBs [2]. It may be possible that the circumstellar environment of massive stars that end their lives as GRBs can be probed by observing thermal X-ray emission.

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Recalibration of the Photometric Zero Point of SDF/SXDS Catalogs

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As products from Subaru Observatory Projects, Subaru Deep Field (SDF) and Subaru XMM-Newton Deep Survey (SXDS) public catalogs [1,2] are publicly available. Recently, [3] reported that B-R color distribution was inconsistent between SDF and SXDS. We therefore recalibrated the B, V, R, i, and z magnitudes of SDF and SXDS against the Sloan Digital Sky Survey (SDSS) [4].

We first constructed color conversions from the SDSS filter system [5] to the Suprime-Cam filter system. The model calculation by ATLAS9 [6] and Yonsei-Yale isochrone [7,8] was used to construct a set of spectral energy distributions (SED) of stars. The transmittance of SDSS and Suprime-Cam were multiplied to the SEDs to calculate the magnitudes, and polynomial function was fitted to the SDSS color vs SDSS-Suprime colors.

Then, possible error sources, such as the mass and temperature of the star, metallicity, recession velocity, Galactic extinction, and atmospheric absorption in the observation were examined. The color constraint of SDSS color in which the variation by these factors is small enough (no more than 0.04 mag) was calculated. The conversion was tested with empirical stellar spectral libraries (BPGS [9], HILIB [10], STELIB [11], CFLIB [12]), and it also worked well within the error.

We selected r~20 mag stars in SDSS, converted them into AB magnitude, converted to Suprime-Cam magnitude, and compared with the SDF/SXDS catalogs. Some data showed an offset larger than 0.1 mag (Table 1). If we correct the offset, the color distribution of R~24 objects in SDF and SXDS became consistent, which were inconsistent if we used the original catalog values (Fig. 1). Since the offset around 20 mag corrected the data around 24 mag, it should be an offset of the zero point.

band	SDF	SXDS-C	SXDS-N	SXDS-S
B	−0.12	0.00	0.02	0.01
V	−0.03	−0.02	−0.02	−0.01
R	−0.05	−0.04	−0.05	−0.05
i	−0.11	−0.10	−0.11	−0.16
z	−0.06	−0.13	−0.14	−0.12

Table 1: Part of the offset of zero point between SDF/SDXS and SDSS. Significant difference is in red.

The origin of the offset was partly explained by relatively higher metallicity of model stars which were used for color calibration of SDF B-band. Also, the calibration of the spectrophotometric standard star SA95-42 [13] which was used for i-band calibration was doubtful. The origin of other offsets remained unclear.

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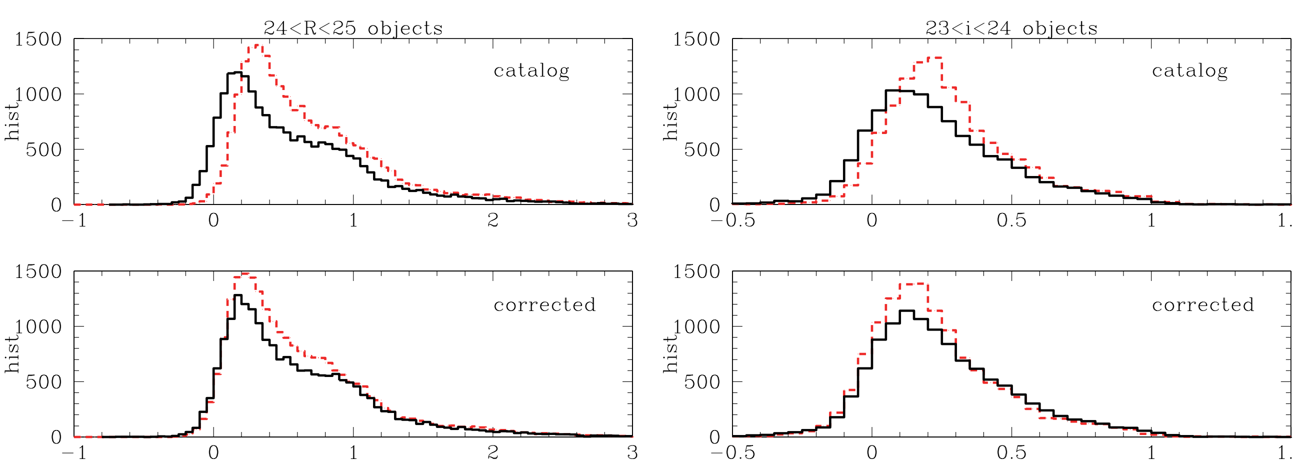

Figure 1: Color distribution of faint objects in SDF (black) and SXDS (red). Top panel uses the catalog values, and bottom panel is after zero point correction. Left panels show B-R color distribution of 24<R<25 magnitude, and right ones show i-z color distribution of 23<i<24 objects.

Crosstalk Analysis of New CCDs of Suprime-Cam

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The detectors of Suprime-Cam were replaced in 2008/07 to full-depleted back illuminated CCDs [1]. The new CCDs show a crosstalk features between channels (Figure 1 top). Such crosstalk was reported in multichannel CCDs in other observatories [2,3,4,5,6].

In Suprime-Cam, one of the three crosstalk shadows moves parallel to the source. Default dithering sequence of Suprime-Cam does not change the position angle, and the shadow of the same parity gains S/N after coadd (Figure 2). It causes problem especially in two cases: a narrow band imaging with low sky background, and deep imaging with lots of exposures. In either case, the crosstalk affects the result, it is important to formalize the effect and correct it appropriately.

In this study, I used cosmic rays in dark frames (exposures with shutter closed). Detecting cosmic rays and compare the data at corresponding pixels in other channels, the crosstalk can be formalized. Moreover, as the dark current is very low in the new CCDs, the difficulties of background subtraction is avoided.

The results of the analysis are as follows; 1) The crosstalk of the Suprime-Cam new CCDs is a decrease of the bias level. It is proportional to the input signal in a channel (Fig. 3), and the coefficient is typically 10^{-4}. It is comparable to other observatories [2,3]. 2) No crosstalk between chips is detected. 3) The strength of crosstalk depends on the pair of channels. The central two channels shows significantly weak crosstalk. This asymmetry implies that the crosstalk is a phenomenon around on-chip amplifiers (amps). 4) The strength shows no difference among chips. It only depends on the distance between the channels. 5) Crosstalk does not change by a change of the gain of on-chip amp. It implies that the crosstalk is not an interaction of charges but an interaction of signals. 6) Crosstalk is recognized not only at the corresponding pixel but 2 pixels read after the pixel.

A correction formula is derived from the analysis of the dark frames. The correction also works well for other data frames (Fig. 1 bottom) [7], and the tool is provided to the public.

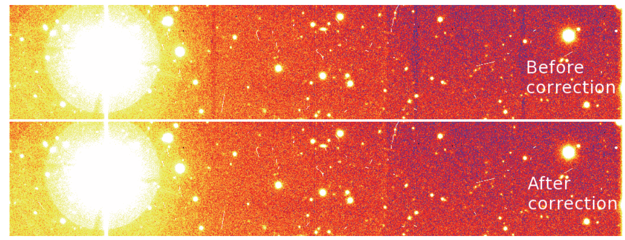

Figure 1: Example of crosstalk. (Top) before correction. (Bottom) after correction.

Figure 2: Schematic figure of coadd of dithered data.

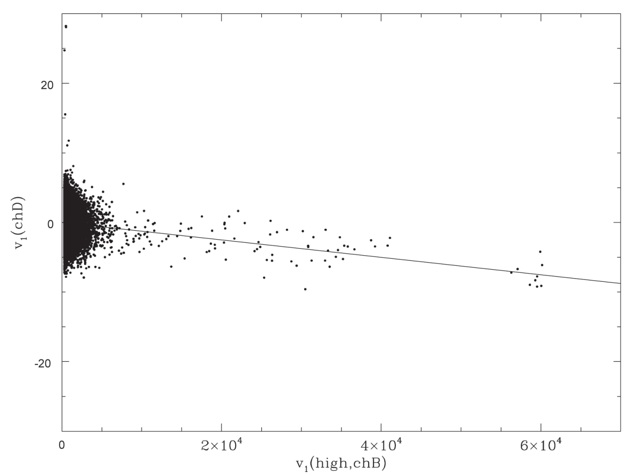

Figure 3: Correlation between input signal and crosstalk signal in chip0 ch-B and ch-D. The solid line shows the best-fit regression.

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Astrometric Goal of Small-JASMINE

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JASMINE Working Group

Small-JASMINE [1] is the astrometric satellite, which will observe the central region of the Galactic bulge, measuring the parallax and the proper motion with high accuracy using the near infrared wavelength (1.1 μm~1.7 μm). The mission time is required to continue for around 1~3 years. Three-year observation will produce the astrometric data of the parallax with an accuracy of about 10 micro-arcseconds and the proper motions with that of about 10 micro-arcseconds per year at Hw=11.5 mag. The region with the above accuracies is at the center of the observing region of 0.3×0.3 square degrees. On the other hand, observing region covers a field of about 3×3 square degrees. The parallax with an accuracy of about 70 micro-arcseconds and the proper motion with that of about 70 micro-arcseconds/yr will be obtained within the region of 3×3 square degrees. These accuracies of the parallax and proper motion are summarized in maps shown in Fig. 1 and Fig. 2, respectively [2].

After the one year observation has passed, we obtain the parallax with an accuracy of 28 μas and the proper motion with an accuracy of 55 μas/yr at Hw=11.5 mag. In this case, we cannot derive the distance of the bulge stars with high accuracy. However, in the case of Hw=10 mag, we obtain the parallax with an accuracy of 14 μas and the proper motion with an accuracy of 23 μas/yr by one year observation. In this case, bulge stars can be obtained distances with high accuracy.

Kinematical and dynamical information on the Galactic bulge stars will be obtained after the observing period of about 1~3 years. Accordingly it is expected that our understanding of the dynamical structure of the Galactic bulge will be greatly improved. Furthermore, we may have the chance to observe the different region which has scientifically interesting target in winter or summer seasons. For example, Cygnus X-1 is one of the observing candidates. If we successfully observe the object during a few weeks, the orbital elements of the star accompanying Cygnus X-1 can be resolved by Small-JASMINE.

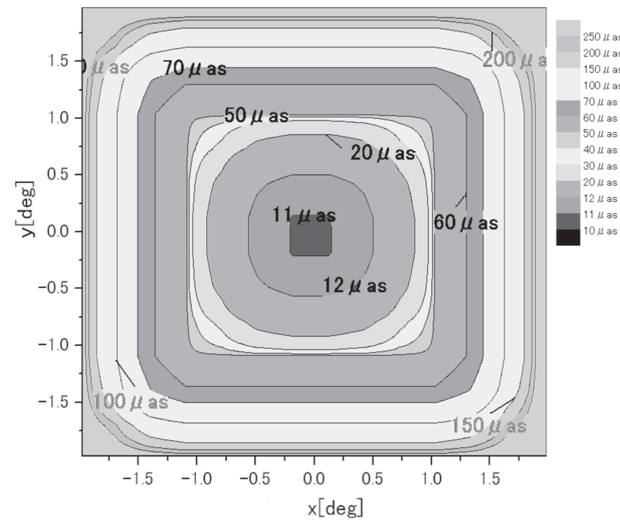

Figure 1: Accuracy map of the parallax.

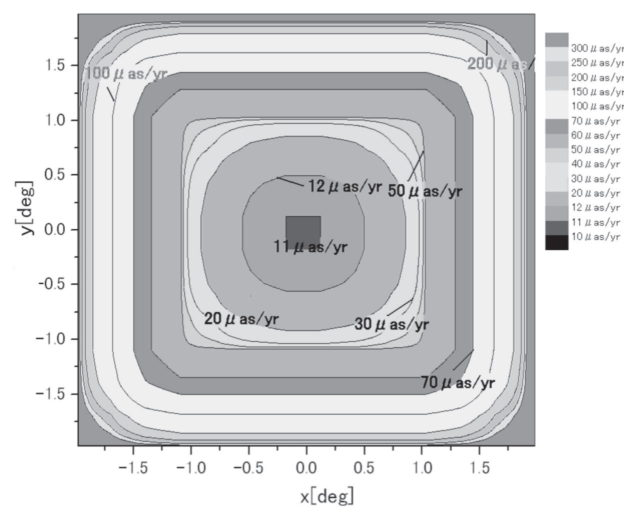

Figure 2: Accuracy map of the proper motion.

References

[1] Yano, T., Gouda, N., Kobayashi, Y., Tsujimoto, T., Hatsutori, Y., Murooka, J., Niwa, Y., Yamada, Y.: 2011, *EAS Publications Series*, **45**, 449.
[2] Yano, T., Gouda, N., Kobayashi, Y., Tsujimoto, T., Niwa, Y., Yamada, Y.: 2012, *Advancing the Physics of Cosmic Distances, Proc. IAU, IAU Symp.*, **289**, 433.

Astrometric Error Caused by Gravitational Microlensing Effect in the Galactic Bulge Stars

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We have investigated an expected deviation of the positions or the proper motions of stars as the cosmic error caused by the gravitational microlensing effect [1]. In observing stars in the Galactic bulge region, we obtain an expected deviation of a star positions by gravitational microlensing effect of about 7 μas. We have also estimated the expected deviation of the proper motions of stars in the Galactic bulge caused by the gravitational microlensing effect. The expected deviation of the proper motions is mainly caused by the lens object located at the nearest angular distance from the source star. Each deviation of the proper motion has a value of less than 0.02 μas/yr for 99 % of the sources.

In estimating the the expected deviations of positions of stars and those of proper motions of stars in the Galactic bulge region, we assume that the optical depth, τ, is about 1×10^{-6}. The typical relative proper motion between a bulge star and a lens object can be estimated as several mas/yr using the Oort constants, solar motion, and velocity dispersion. Accordingly we assume that the proper motion is about 5 mas/yr.

We have investigated the correlation of the deviation of Galactic bulge stars caused by the gravitational microlensing effect. In order to estimate the correlations of these deviations of two sources, we define the correlation between deviations of source A and source B, ρ_{AB}, as follows,

$$\rho_{AB} = \frac{\langle \boldsymbol{\delta_A} \cdot \boldsymbol{\delta_B} \rangle}{\sqrt{\langle \delta_A^2 \rangle \langle \delta_B^2 \rangle}}, \tag{1}$$

where δ_A and δ_B are positional deviations of source A and source B, respectively. The correlation ρ has a value between −1 and 1. If the value is around 1, deviations of two sources are strongly correlated. On the other hand, if the value is 0, deviations are not correlated.

Here we define the dimensionless correlation angle at which the value of the correlation is equal to 0.5. Then we can say that the deviations of two sources, separated with an angle smaller than correlation angle, are correlated. And if not, uncorrelated.

The value of the correlation angle of the positional deviation is estimated to be about 1 arcmin. In the same way, we have estimated the correlation angle of the deviation of the proper motions. The angle is estimated to be about 1 arcsec. The following difference distinguishes the deviation of the position and that of the proper motion. The positional deviation is affected not only by lenses near the source but also by the lenses far from the source. On the other hand, the deviation of the proper motion by microlensing is mainly only caused by the nearest lens from the source. This difference causes that of the correlation angle.

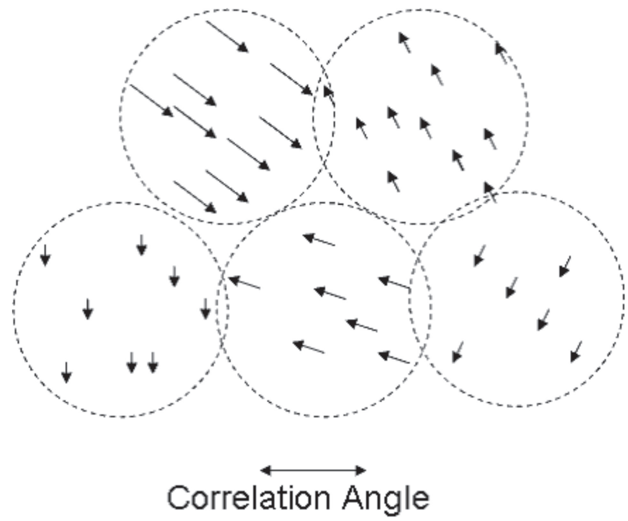

Figure 1: Schematic of the deviations and correlation angle.

Upcoming observation by an astrometric satellite like Gaia or JASMINE [2] will provide the catalogue with the accuracy of about 10 μas. Then the typical deviation with the value of 7 μas is less than the value of the observing accuracy by the forthcoming astrometric satellites. Therefore it is not a crucial problem for astrometry missions such as Gaia or JASMINE. However it will be a serious problem for the next generation of astrometry missions with the accuracy of 1 micro-arcsecond level.

References

[1] Yano, T.: 2012, *ApJ*, **757**, 189.
[2] Yano, T., Gouda, N., Kobayashi, Y., Tsujimoto, T., Hatsutori, Y., Murooka, J., Niwa, Y., Yamada, Y.: 2011, *EAS Publications Series*, **45**, 449.

AKARI/AcuA Physical Studies of the Cybele Asteroid Family

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We present a study of 107 Cybele asteroids based on the archival data base "Asteroid Catalog Using *AKARI* (AcuA)" taken by the infrared astronomical satellite. The data base provides diameters $D > 10$ km, geometric albedos and taxonomic informations (75 %) of the Cybeles. We find taxonomic diversity (mainly C-, D- and P-type) in the population of seventy-eight small Cybeles with diameters 10 km < D < 80 km. Their cumulative power-law size distribution index shows a shallow value of 0.86 ± 0.03. By contrast, twenty-nine large Cybeles with $D > 80$ km are mostly classified as C- or P- types (90 %), having a power-law index of 2.39 ± 0.18. The total mass of Cybele asteroids is estimated to be ~10^{-5} M_{Earth}. We also discuss the origin and formation process of Cybele asteroid family. See [1] for more details.

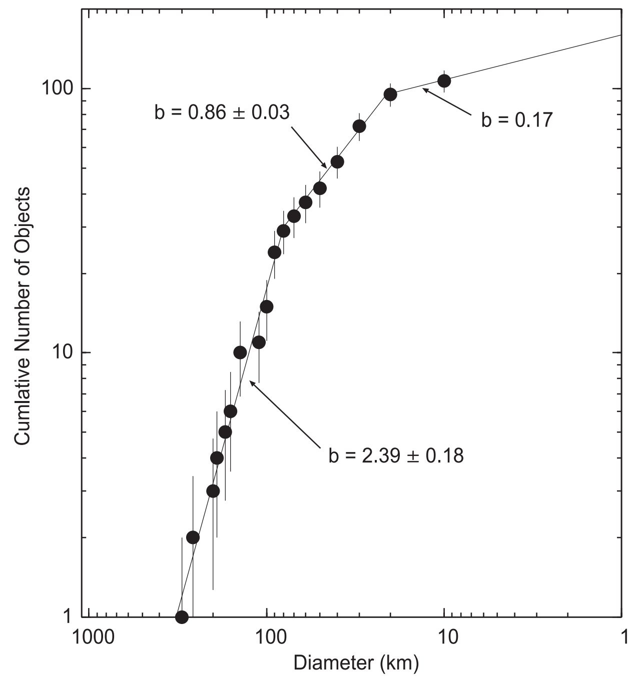

Figure 1: Cumulative size distribution of 107 Cybele asteroids. The derived power-law indexes are $b = 0.17$ (10 km < D < 20 km), 0.86 ± 0.03 (20 km < D < 80 km) and 2.39 ± 0.18 ($D > 80$ km).

Reference

[1] Kasuga, T., et al.: 2012, *AJ*, **143**, 141.

Measurements of Stellar Inclinations for Kepler Planet Candidates

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The origin of close-in giant planets (so-called "hot Jupiters") has been the most enduring problem since the discovery of the first extrasolar planet. Measurements of the spin-orbit angle (the relation between the stellar spin axis and planetary orbital axis) are a promising tool to uncover the formation and evolution (migration) history of exoplanetary systems. This is because different evolution models predict different distributions for the spin-orbit angle and measurements of the angle provide us an insight into the origin of exoplanets.

So far, the Rossiter-McLaughlin (hereafter RM) effect for transiting exoplanets has been the major channel to measure the spin-orbit angle. However, the RM effect is only applicable to giant planets orbiting at the proximity of their host stars. When the size of planet is small, the RM signal becomes weaker, which makes the measurement unreliable. In order to measure the spin-orbit angle for a smaller and distant exoplanet, we focused on the measurements of stellar inclinations I_s (see Figure 1). In a transiting exoplanetary system, where the planetary orbit is edge-on from our direction, the stellar inclination I_s is a useful indicator of the spin-orbit alignment/misalignment; when I_s turns out to be deviated from 90° through observations, it suggests a spin-orbit misalignment along the line-of-sight. This method to constrain the spin-orbit angle can be applied regardless of the size and orbital distance of the transiting planet.

In order to measure stellar inclinations for transiting systems, we focused on the *Kepler* photometry. Among the planet-hosting stars detected by *Kepler*, some show periodic flux variations due to starspots. A period analysis of such a periodic flux variation will give us the rotational period P_r of the star. Meanwhile, the projected rotational velocity $V \sin I_s$ could be obtained via spectroscopy. Combining these measurements along with the stellar radius estimated from spectroscopy, one can put a constraint on the stellar inclination I_s.

We picked up about 10 systems among the "Kepler Object of Interest (KOI)" list, all of which show periodic flux variations, and conducted spectroscopic observations with Subaru/HDS. Figure 2 shows the projected rotational velocity $V \sin I_s$ as a function of the rotational velocity at the stellar equator ($V_{\rm eq}$). The equatorial rotational velocity were estimated by combining the rotational periods P_s from the *Kepler* photometry with the stellar radii from the Subaru spectroscopy. While most of the systems are along the solid line (I_s = 90°), suggesting spin-orbit alignments, at least one system, KOI- 261, significantly deviates from the solid line. This most likely implies a spin-orbit misalignment along the line-of-sight. We note that all the systems shown in Figure 2 have Earth-sized or Neptune-sized exoplanets (no Jovian one), providing us a unique opportunity to discuss the evolution history of smaller exoplanets [1].

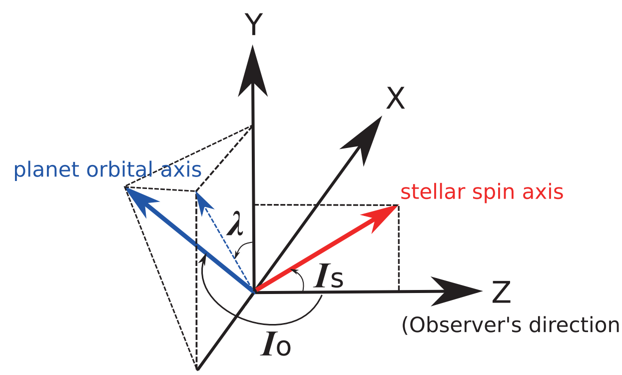

Figure 1: Schematic figure for the spin and orbital axes. The stellar inclination I_s is defined as the angle between the stellar spin axis (red) and line-of-sight.

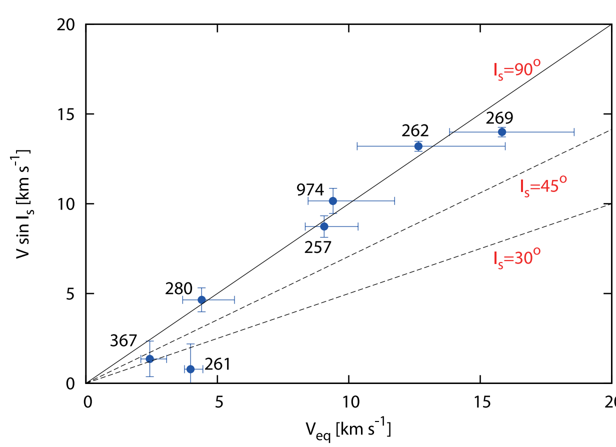

Figure 2: The estimated $V_{\rm eq}$ and $V \sin I_s$. The solid line indicates the case that our line-of-sight is vertical to the stellar spin axis.

Reference

[1] Hirano, T., Sanchis-Ojeda, R., Takeda, Y., Narita, N., Winn, J. N., Taruya, A., Suto, Y.: 2012, *ApJ*, **756**, 66.

Planet-Planet Eclipse and the Rossiter-McLaughlin Effect of a Multiple Transiting System

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TAKEDA, Yoichi, AOKI, Wako, TAMURA, Motohide (NAOJ) SUTO, Yasushi (University of Tokyo)

Transiting exoplanetary systems provide us a unique opportunity to measure the stellar obliquity with respect to the planetary orbital plane. When we observe radial velocities (hereafter RVs) during a planetary transit, an anomalous RV variation is manifested in addition to the normal sinusoidal RV variation inspired by the Keplerian motion of the planet. This phenomenon, called the Rossiter-McLaughlin (RM) effect, has been exploited to measure the sky-projected angle between the stellar spin axis and planetary orbital axis (the spin-orbit angle). Measurements of the spin-orbit angle provide an important observational clue to distinguish among the possible scenarios for the formation and evolution of exoplanetary systems.

So far, the RM effect has been measured for single transiting systems. Since the *kepler* space telescope was launched in 2009, however, many multiple transiting systems are now available, and their origin and evolution history are of primary interest. In order to discuss the spin-orbit angle for multiple transiting systems, we focused on “KOI-94,” one of the planet-hosting candidate detected by *Kepler*. KOI-94 is comprised of four planet candidates with relatively packed orbits. As a result of conducting the measurement of the RM effect for KOI-94.01 (the largest candidate among the four), we obtained Figure 1 and the RV anomaly due to the RM effect shows that the planetary orbital axis is well aligned with the stellar spin axis [1].

In addition to the measurement of the RM effect, we discovered a very unique astronomical event for this multiple transiting system, which we call a “planet-planet eclipse.” Figure 2 indicates the archived data of the KOI-94 light-curve, delivered by Kepler. This clearly shows a double transit event, in which the two planets (KOI-94.01 and 94.03) transit the host star simultaneously. Interestingly enough, there is a bump around the bottom of the double transit. This bump most likely represents an overlapping event of the two transiting planets on the stellar disk (“planet-planet eclipse”). The planet-planet eclipse is not only an astronomically rare event, but also provides us a unique opportunity to put a tight constraint on the “mutual inclination” between the two planetary orbits. From the timing and size of the bump in Figure 2, we showed that the two planetary orbits (of KOI-94.01 and 94.03) are well aligned at least in the sky.

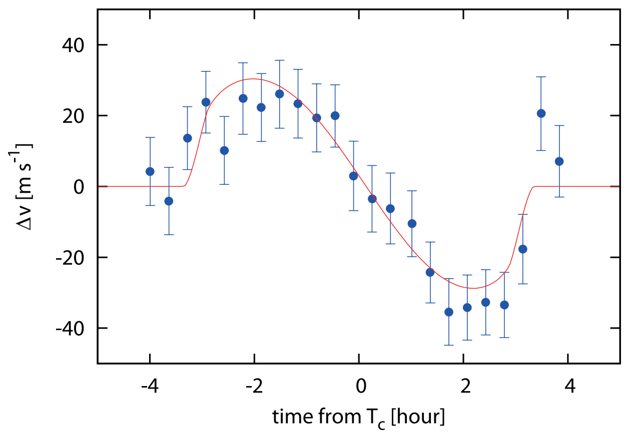

Figure 1: RV variation of KOI-94 during the transit of KOI-94.01.

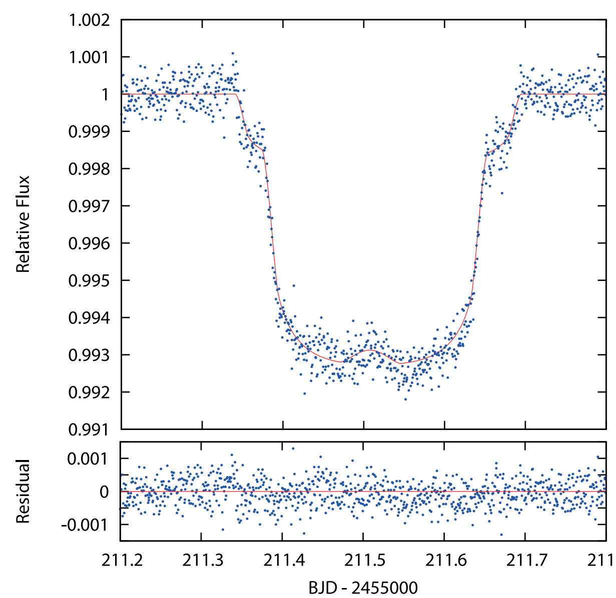

Figure 2: A part of the public light-curve delivered by the Kepler space telescope.

Reference

[1] Hirano, T., Narita, N., Sato, B., Takahashi, Y. H., Masuda, K., Takeda, Y., Aoki, W., Tamura, M., Suto, Y.: 2012, *ApJ*, **759**, L36.

The Source Counts of Submillimetre Galaxies Detected at $\lambda = 1.1$ mm

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KOHNO, Kotaro[5], TAMURA, Yoichil[5], HATSUKADE, Bunyo[6], KAWABE, Ryohei[7], OSHIMA, Tai[7]
EZAWA, Hajime[7], NAKANISHI, Koichiro[7], CHAPIN, E. L.[8], HALPERN, M.[8], SCOTT, Duglous[8]
DUNLOP, J. S.[9], SANDERS, Dave[10], SCOVILLE, Nick Z.[11], KIM, S.[12], LOWENTHAL, J. D.[13]

1: National Radio Astronomy Observatory, 2: University of Massachusetts, 3: INAOE, 4: University of Colorado, 5: University of Tokyo, 6: Kyoto University, 7: NAOJ, 8: University of British Columbia, 9: University of Edinburgh, 10: University of Hawaii, 11: Caltech, 12: Sejong University, 13: Smith College

The source counts of galaxies discovered at submillimetre and millimetre wavelengths provide important information on the evolution of infrared-bright galaxies. We combine the data from six blank-field surveys carried out at 1.1 mm with AzTEC (Table 1), totalling 1.6 deg^2 in area with root-mean-square depths ranging from 0.4 to 1.7 mJy, and derive the strongest constraints to date on the 1.1 mm source counts at flux densities $S_{1.1\,\mathrm{mm}} = 1-12$ mJy (Figure 1). Using additional data from the AzTEC Cluster Environment Survey to extend the counts to $S_{1.1\,\mathrm{mm}} \sim 20$ mJy, we see tentative evidence for an enhancement relative to the exponential drop in the counts at $S_{1.1\,\mathrm{mm}} \sim 13$ mJy and a smooth connection to the bright source counts at > 20 mJy measured by the South Pole Telescope; this excess may be due to strong-lensing effects.

We compare these counts to predictions from several semi-analytical and phenomenological models and find that for most the agreement is quite good at flux densities ≥ 4 mJy; however, we find significant discrepancies ($\geq 3\sigma$) between the models and the observed 1.1 mm counts at lower flux densities, and none of them is consistent with the observed turnover in the Euclideannormalized counts at $S_{1.1\,\mathrm{mm}} \leq 2$ mJy. Our new results therefore may require modifications to existing evolutionary models for low-luminosity galaxies. Alternatively, the discrepancy between the measured counts at the faint end and predictions from phenomenological models could arise from limited knowledge of the spectral energy distributions of faint galaxies in the local Universe [1].

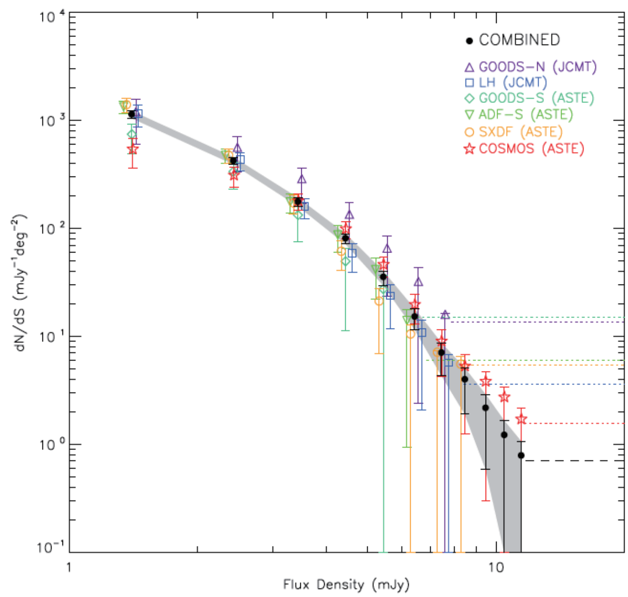

Figure 1: Differential source counts derived from six blank-field surveys carried out with AzTEC on JCMT and ASTE. The shaded region highlights the 68 % confidence range on the combined counts from all six surveys.

Table 1: Summary of AzTEC blank-field surveys.

Field	Telescope	Area (deg^2)	Num. of sources	Ref.
GOODS-N	JCMT	0.08	50	[2]
LH	JCMT	0.30	180	[3]
GOODS-S	ASTE	0.08	66	[4]
ADF-S	ASTE	0.20	279	[5]
SXDF	ASTE	0.21	271	[5]
COSMOS	ASTE	0.72	230	[6]
Total:		1.60	1076	

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[1] Scott, K. S., et al.: 2012, *MNRAS*, **423**, 575.
[2] Perera, T. A., et al.: 2008, *MNRAS*, **391**, 1227.
[3] Austermann, J. E., et al.: 2010, *MNRAS*, **401**, 160.
[4] Scott, K. S., et al.: 2010, *MNRAS*, **405**, 2260.
[5] Hatsukade, B., et al.: 2011, *MNRAS*, **411**, 102.
[6] Aretxaga, I., et al.: 2011, *MNRAS*, **415**, 3831.

Spiral Structures in the Protoplanetary Disk around SAO 206462

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1: Kogakuin University, 2: Goddard Space Flight Center, 3: The University of Tokyo, 4: Osaka University, 5: University of Louisville, 6: University of Cincinnati, 7: The Aerospace Corporation, 8: Universidad de Valparaso, 9: University of Toronto, 10: NAOJ, 11: Ibaraki University, 12: Kanagawa University, 13: Nagoya University, 14: Tokyo Institute of Technology, 15: Princeton University, 16: Observatoire de la Côte d'Azur, 17: Max Planck Institute for Astronomy, 18: College of Charleston, 19: University of Hawaii, 20: Kyoto University, 21: The Graduate University for Advanced Studies, 22: Hiroshima University, 23: Instituto Nacional de Técnica Aeroespacial, 24: Jet Propulsion Laboratory, 25: TMT Observatory Corporation, 26: Academia Sinica, 27: University of Amsterdam, 28: Hokkaido University, 29: University of Oklahoma, 30: Tohoku University

Understanding physical properties of protoplanetary disks is important in understanding planet formation processes.

We report the results of observations, conducted under SEEDS project, of the disk around SAO 206462 (HD 135344B, F4V, d = 140 pc [1]). We clearly detected the disk in scattered light at *H*-band. The most interesting features were the spiral structures (Fig. 1).

Assuming that the spirals were a part of density wave, we constructed the model equation for the spiral structures using spiral density wave theory. As a result, it was indicated that such spirals were able to exist in disks with the temperature profiles that were consistent with other observations. It was also hinted that the launching point (corotation radius) of the spirals might exist in the outer part of the disk.

It is expected that dynamically active disks ubiquitously harbor small-scale spirals. Future observations by large telescopes (ALMA, TMT, etc.) with better spatial resolution will deepen our understanding of protoplanetary disks and planet formation processes.

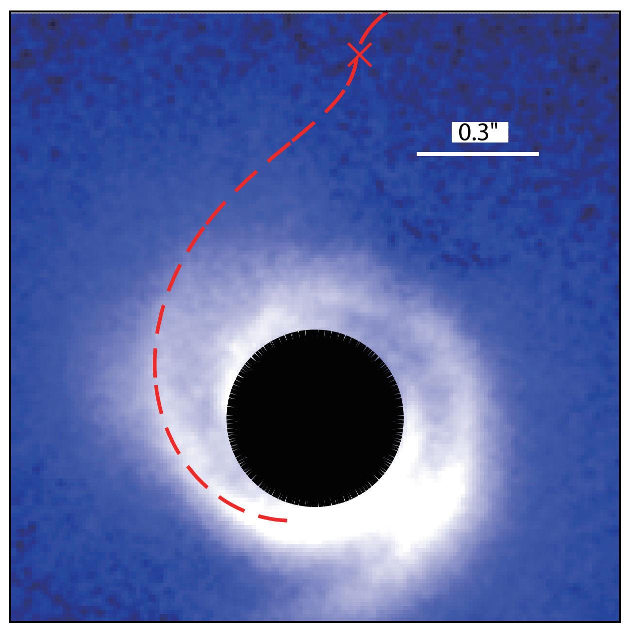

Figure 1: *H*-band polarized intensity map of the disk around SAO 206462. The central region (r ≤ 0.2 asec) is covered. The red dashed and the red cross indicate the best-fit for the spiral structure and the launching point. This figure is adopted from the front page of *Astronomical Herald* 2013 March issue.

Reference

[1] Muto, T., et al.: 2012, *ApJ*, **748**, L22.

Outer Rotation Curve of the Galaxy with VERA I : Trigonometric Parallax of IRAS 05168+3634

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Precise structure and dynamics of the Milky Way Galaxy are still relatively ambiguous due to difficulties of precise distance measurements. In particular, for the outside of the solar circle region, distance measurements have large uncertainties since the tangent velocity method can not be used in the place (e.g., [1]). To overcome the distance uncertainties, we have been using VERA (VLBI Exploration of Radio Astrometry) to measure parallactic distances and proper motions of starforming regions located at the outer region (outside the solar circle). Our results can be used to understand not only precise structure of the Milky Way Galaxy (e.g., spiral arm location), but also mass distribution of the Galaxy. In this paper, we report one of our results for IRAS 05168+3634 as a high-mass star-forming region [2].

Eleven VLBI observations with VERA obtained between October 2009 and May 2011 yielded the trigonometric parallax and proper motion of IRAS 05168+3634. The parallax is 0.532 ± 0.053 mas, corresponding to a distance of $1.88^{+0.21}_{-0.17}$ kpc. The proper motion components are $(\mu_\alpha \cos\delta, \mu_\delta) = (0.23 \pm 1.07, -3.14 \pm 0.28)$ mas yr^{-1}. Our result places the source in the Perseus arm. Combining the distance and proper motion with the systemic velocity results in a rotation velocity of 227^{+9}_{-11} km s^{-1} at the source, assuming $\Theta_0 = 240$ km s^{-1}. The result corresponds to marginally slower rotation with respect to the flat Galactic rotation curve, $\Theta(R) = \Theta_0$. In addition, the slower rotation is almost consistent with previous VLBI results in the Perseus arm (see Fig. 1).

Fig. 1 shows the peculiar (non-circular) motions based on VLBI observations of the Perseus arm after subtractions of the Galactic rotation and the solar peculiar motions. Note that a flat Galactic rotation curve —$\Theta(R) = \Theta_0$— was assumed to derive the peculiar motions. Obviously, almost all sources in the Perseus arm are moving systematically toward the Galactic Center, and lag behind the Galactic rotation. These motions are consistent with the prediction of the density wave theory which showed that large peculiar motions, toward Galactic center and counter to the Galactic rotation, are occurred at the inner edge of the spiral arm in the case of inner co-rotation radius [3].

We have been observing Galactic star-forming regions with VERA, which will allow us to understand not only the mass distribution of the Galaxy (as part of the VERA outer rotation curve project), but also whether the density-wave theory is correct or not in the near future.

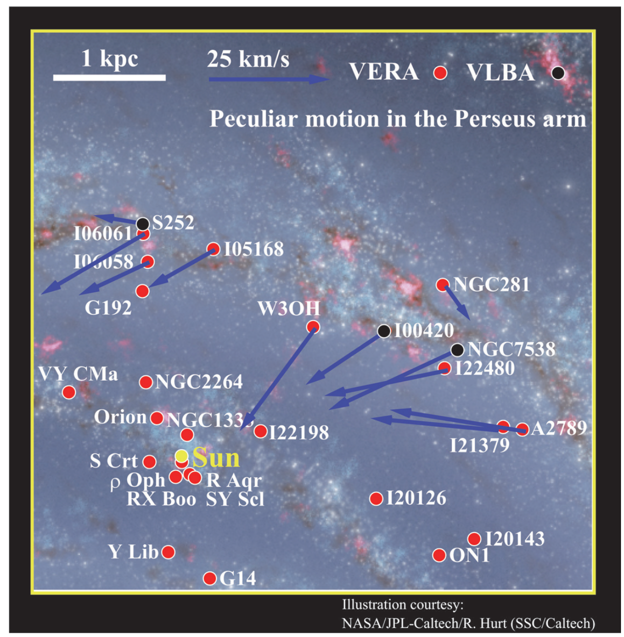

Figure 1: Peculiar motions in the Perseus arm. The arrows represent peculiar motions for the sources located in the Perseus arm based on VLBI observations. Note that a at Galactic rotation curve —$\Theta(R) = \Theta_0$— was assumed to derive the peculiar motions. Based on the figure, almost all sources in the Perseus arm are moving systematically toward the Galactic Center and lag behind the Galactic rotation.

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[3] Mel'nik, A. M., et al.: 1999, *Astron. Lett.*, **25**, 518.

Polarimetric Imaging of Large Cavity Structures in the Pre-Transitional Protoplanetary Disk around PDS 70: Observations of the Disk*

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SUZUKI, Ryuji[1], SUTO, Hirohi[1], TAKAHASHI, Yasuhiro[1], DONG, Ruobing[2], ZHU, Zhaohuan[2], BRANDT, Timothy[2]
JANSON, Markus[2], KNAPP, Gillian[2], TURNER, Edwin[2], KUDO, Tomoyuki[1], USUDA, Tomonori[1], EGNER, Sebastian[1]
TERADA, Hiroshi[1], TOMONO, Daigo[1], TAKAMI, Hideki[1], GUYON, Olivier[1], HAYANO, Yutaka[1], HAYASHI, Saeko[1]
ISHII, Miki[1], NISHIMURA, Tetsuo[1], PYO, Tae-Soo[1], TAKATO, Naruhisa[1], HONDA, Mitsuhiko[3], MCCLURE, Melissa[4]
MUTO Takayuki[5], WISNIEWSKI, John[6], ABE, Lyu[7], HENNING, Thomas[8], BRANDER, Wolfgang[8], FELDT, Markus[8]
CARSON, Joseph[9], FUKAGAWA, Misato[10], GOTO, Miwa[11], MCELWAIN, Michael[12], GRADY, Carol[12]
HODDAP, Klaus[13], MATSUO, Taro[14], MAYAMA, Satoshi[15], MIYAMA, Syoken[16], MORO-MARTIN, Amaya[17]
SERABYN, Eugene[18], TAKAMI, Michihiro[19], THALMANN, Christian[20], WATANABE, Makoto[21], YAMADA, Toru[22]

1: NAOJ, 2: Princeton University, 3: Kanagawa University, 4: The University of Michigan, 5: Kogakuin University, 6: University of Washington, 7: University of Nice, 8: Max Planck Institute for Astronomy, 9: College of Charleston, 10: Osaka University, 11: Universitatssternwerte Munchen, 12: Goddard Space Flight Center, 13: University of Hawaii, 14: Kyoto University, 15: The Graduate University for Advanced Studies, 16: Hiroshima University, 17: CAB-CSIC/INTA, 18: Jet Propulsion Laboratory, 19: Institute of Astronomy and Astrophysics, 20: University of Amsterdam, 21: Hokkaido University, 22: Tohoku University

Protoplanetary disks are believed to be the birthplaces of planets [1]. Among them, disks which have substantial infrared excesses but reduced uxes at wavelengths < 20 μm, i.e., transitional disks [2], could be related to the early phases of planet formation [3] and are therefore particularly important for understanding how, where, and when planets form. For many transitional disks, partial inner holes or partial gaps have been directly resolved by interferometry at (sub)millimeter wavelengths [4]. However, gap formation mechanism is still unclear.

One good candidate to investigate the inner hole/gap region at tens AU is a weak-lined T Tauri star PDS 70 (K5 type; 0.82 $M_\odot$; < 10 Myr; [5]; [6]; [7]). A scattered light disk with a radius at 14 to 140 AU was detected by *Ks*-band imaging [6]. Thus, we have observed PDS 70 with *H*-band polarized imaging and *L′*-band imaging [8].

As results of observations, a giant inner gap is clearly resolved for the first time, and the radius of the gap is ~70 AU. Our data show that the geometric center of the disk shifts with ~6 AU toward the minor axis. We confirm that the brown dwarf companion candidate to the north of PDS 70 is a background star based on its proper motion. As a result of SED fitting by Monte Carlo radiative transfer modeling, we infer the existence of an optically thick inner disk at a few AU. Combined with our observations and modeling, we classified the disk of PDS 70 as a pre-transitional disk. Furthermore, based on the analysis of *L′*-band imaging data, we put an upper limit mass of companions at ~30 to ~50 M_J within the gap. Taking account of the presence of the large and sharp gap, we suggest that the gap could be formed by dynamical interactions of sub-stellar companions or multiple unseen giant planets in the gap.

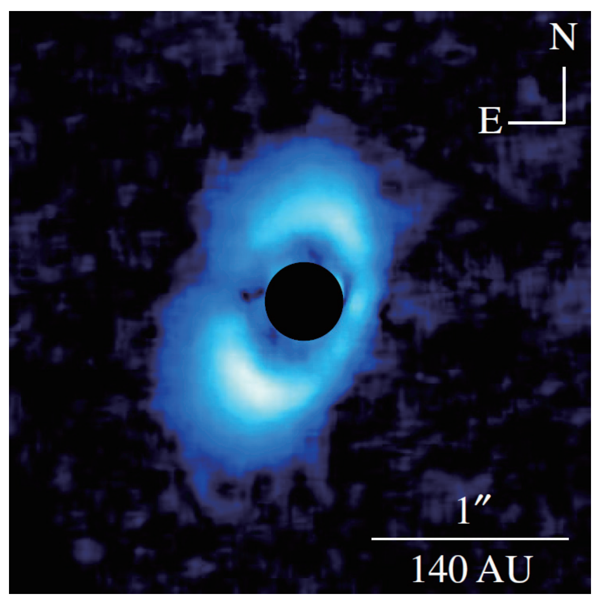

Figure 1: *H*-band polarized intensity image of PDS 70 with a software mask with 0.″4 diameter. The FOV is 3.″0 ×3.″0 with a convolution of a spatial resolution.

* Based on data collected at the Subaru Telescope, which is operated by the National Astronomical Observatory of Japan.

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Molecular Gas Distributions of Interacting Galaxies in Early and Mid Stage Using $^{12}CO(J=1-0)$ Mapping Observations

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Galaxies frequently interact with other galaxies and give an influence of strong gravity on each other. Those celestial objects whose distributions and kinematics of stars and gas are changed by the gravity are called as interacting galaxies. Interacting galaxies have an important features of active star formation which have known from about 30 years ago. Although many studies have been done, a precise mechanism of active star formation in interacting galaxies is an open question. Since stars are made from molecular gas, it is necessary to understand the properties of molecular gas in interacting galaxies for clarifying the mechanism of bursts of star formation. Most of previous observations aimed only at the centre of galaxies where emission from molecular gas tends to be strong, distributions of molecular gas is unknown. Even more, the most targets of observational studies are interacting galaxies in late stage whose star formation activity is already enhanced. Thus, the properties of molecular gas in interacting galaxies in early stage are scarcely investigated. Although interacting galaxies in late stage can be used to investigate the "results" of an enhancement of star formation, its "cause" can not be understood without observing interacting galaxies in early stage.

In order to understand how star formation activity is enhanced through galaxy interactions, we performed $^{12}CO(J=1-0)$, which is a good tracer of diffuse molecular gas, mapping observations using NRO 45-m radio telescope and revealed the distributions of molecular gas of four interacting galaxies in early and mid stage: Arp 84, VV 219, VV 254, Arp 244 (Fig. 1). The distributions of molecular gas greatly differ from both atomic gas and old stars whose data are already obtained with other telescopes. These discrepancies imply that the effects by the interaction on each medium are different and physical properties should be also changed from isolated galaxies. We derived the degree of central concentration of molecular gas and found that molecular gas in interacting galaxies in early and mid stage are less concentrated than that in isolated galaxies. This result is opposite to the fact that molecular gas in interacting galaxies in late stage is highly concentrated toward the centre of the galaxy and numerical simulations which suggest gas inflow occurs when two galaxies collide. We obtained a picture that the interaction does not proceed through a direct infall of molecular gas to a galactic centre but through complicated processes such as an off-centre and/or wide distributions of molecular gas in the beginning of the interaction.

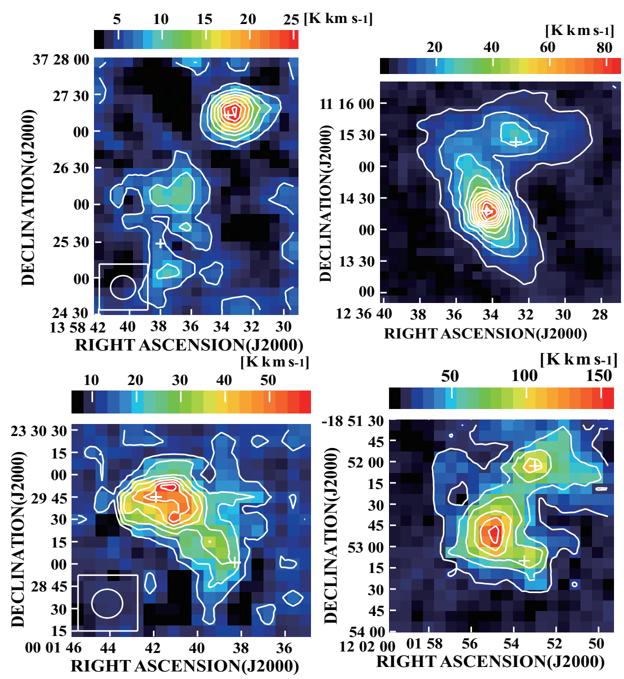

Figure 1: Integrated intensity maps of $^{12}CO(J = 1-0)$. Arp 84 (top-left), VV 219 (top-right), VV 254 (bottom-left), Arp 244 (bottom-right).

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Detailed Density and Velocity Structures of the Protostellar Core B335

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In order to understand physical processes of low-mass star formation, it is important to investigate the properties of dense (~10^5 cm^{-3}) cores in molecular clouds. Such compact (~0.1 pc) cores supply material to newly forming stars through dynamical gravitational collapse, nevertheless detailed physical processes are still uncertain. One of the investigative approaches is to derive the detailed density and velocity structures from observations of protostellar cores which are expected to retain information on the initial conditions of collapse.

The Bok Globule B335 is an isolated low-mass star-forming region harboring a low-mass Class 0 source, which is a suitable target for the study of low-mass star formation. We carried out the observations with the Nobeyama 45 m telescope and the Nobeyama Millimeter Array (NMA) in the $H^{13}CO^+(J=1-0)$ line emission. We performed combined imaging of interferometer and single-dish data in the Fourier domain (*u*–*v* domain), and applied the data optimizations to sensitivities and relative weights between 45 m and NMA data [1]. We finally obtained a combined image of B335 in the $H^{13}CO^+$ line emission with a synthesized beam size of 5″.6 × 4″.4.

Our analysis using a combining technique of singledish and interferometer data revealed the structure of the inner dense envelope within the core with a high spatial resolution of ~750 AU. Using the 45 m and combined data, we determined the radial column density profile of the B335 core. We found a reliable difference in the power-law indices of density profile between the outer and inner regions of the core; $n(r) \propto r^{-2}$ for $r \geq$ 4000 AU and $n(r) \propto r^{-1.5}$ for $r \leq$ 4000 AU. Our derived density profile is better explained, both qualitatively and quantitatively, in the picture of Shu's self-similar solution than in that of the Larson–Penston solution. Moreover, we performed simple model calculations of position–velocity diagrams to investigate the kinematics in the core. The model calculations successfully reproduce observational results, while suggesting a central stellar mass of ~0.1 $M_\odot$ and a small inward velocity of ~0 km s^{-1} in the outer region of the core ≥ 4000 AU.

From quantitative comparisons of density and velocity structures from the observational results with theoretical models, we concluded that a picture of Shu's solution or an isothermal collapse of a marginally stable Bonnor–Ebert sphere is suitable for the gravitational collapse of the B335 core. This result is published in [2].

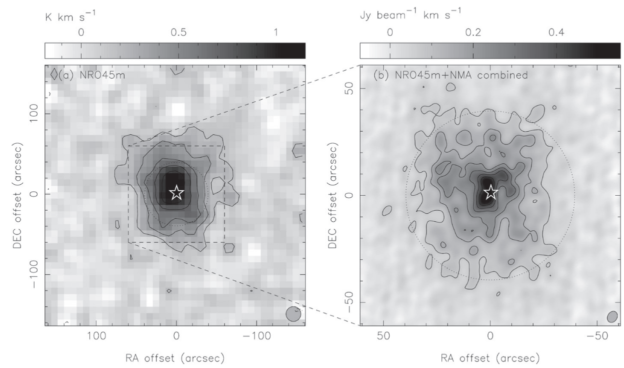

Figure 1: Total integrated intensity maps of B335 in the $H^{13}CO^+$(J = 1–0) line emission obtained with the 45 m telescope (left) and by combining the 45 m telescope and NMA data (right). The open star in each map is the peak position of the 87 GHz continuum emission observed with the NMA. The beam size for each map is shown as a filled circle or filled ellipse at the bottom right corner. Dotted circle in the combined image indicates the field of view, i.e., FWHM primary beam size of the NMA observations.

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Explicit-Implicit Scheme for Relativistic Radiation Hydrodynamics

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Relativistic flows appear in many high-energy astrophysical phenomena in which the magnetic field has a crucial role in dynamics. For example, magnetic fields connecting an accretion disk with a central star, or, different points of accretion disks are twisted and amplified due to the differential rotation, launching jets. Also magnetic fields play an important role in accretion disks to transport the angular momentum outward, leading to the mass accretion.

Not merely the observational point of view, but the radiation field is also an important ingredient in the dynamics of relativistic phenomena. The radiation pressure force would play a key role in jet acceleration. Recently, Takeuchi, et al. [1] showed a formation of radiatively accelerated and magnetically collimated jets using non-relativistic radiation magnetohydrodynamic (RMHD) simulations. These magnetic and radiative forces would accelerate jets and outflows to the relativistic speed. But, due to the lack of numerical techniques, RMHD simulations consistently including relativistic effects have not been performed.

The radiation field is described by the radiation transfer equation, which represents time evolutions of the intensity. But it is hard task to solve the transfer equation coupling with the hydrodynamic code due to its complexity and high computational costs. Recently, Farris, et al. [2] proposed numerical schemes to solve general-relativistic radiation magnetohydrodynamic equations. They solved radiation moment equations instead of solving the radiative transfer equations

$$\frac{1}{c}\frac{\partial E_r}{\partial t} + \frac{\partial F_r^j}{\partial x^j} = -G^0, \quad (1)$$

$$\frac{1}{c^2}\frac{\partial F_r^i}{\partial t} + \frac{\partial P_r^{ij}}{\partial x^j} = -G^i, \quad (2)$$

where E_r, F_r^i and P_r^{ij} are the radiation energy density, flux, and stress, respectively.

The radiation and fluids interact each other through absorption and scattering processes. These processes are described by radiation four force G^μ. In their treatment, G^μ is numerically integrated using explicit scheme. Then, a numerical time step Δt should be restricted being shorter than their typical timescales ($\Delta t < \min[t_{ab}, t_{sc}]$) to ensure the numerical stability. Therefore, high computational costs prevent us from studying long term evolutions when the gas is optically thick.

In this paper [3], we propose an numerical schemes to overcome this problem. Governed equations are integrated in time using both explicit and implicit schemes. The former solves an hyperbolic term and latter one treats the gas-radiation interactions through absorption and scattering processes. This method allows us to take a larger time step $\Delta t > t_{ab}$, t_{sc} than that of the explicit scheme.

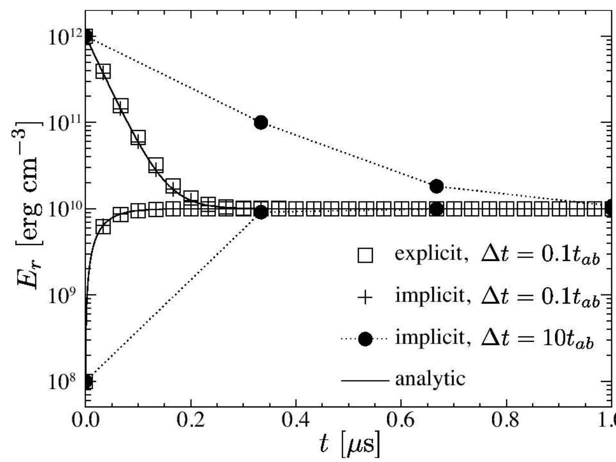

Figure 1: Thermal evolution of radiation energy E_r. Crosses and squares respectively denote results of explicit and implicit schemes, while solid curves do analytical solutions. Filled circles with dotted curves show the results of the implicit scheme with a larger time step of $\Delta t = 10\,t_{ab}$.

In figure 1, we show numerical results that the radiation field approaches to the local thermodynamic equilibrium (LTE) state. We can see that the implicit scheme guarantees that the radiation field stably approaches to LTE with a larger time step Δt. Thus, our scheme drastically reduce computational costs. We believe that our scheme can be applicable to more realistic high-energy astrophysical phenomena.

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Effects of Power Law Primordial Magnetic Field on Big Bang Nucleosynthesis

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Big bang nucleosynthesis (BBN) is affected by the energy density of a primordial magnetic field (PMF) [1,2]. For an easy derivation of constraints on models for PMF generations, we assume a PMF with a power law (PL) distribution in wave number defined with a field strength, a PL index, and maximum and minimum scales at a generation epoch. We then show a relation between PL-PMF parameters and the scale invariant (SI) strength of PMF for the first time. We perform a BBN calculation including PMF effects, and show abundances as a function of baryon to photon ratio η. The SI-PMF strength is constrained from observational constraints on ^{4}He and D. The minimum abundance of ^{7}Li/H as a function of η slightly moves to a higher ^{7}Li/H value at a larger η value when a PMF exists during BBN. We then discuss degeneracies between the PL-PMF parameters in the PMF effect. We also assume a general case in which both the existence and the dissipation of PMF are possible. It is then found that an upper limit on the SI-PMF strength can be derived from a constraint on ^{4}He abundance, and that a lower limit on the allowed ^{7}Li abundance is significantly higher than those observed in metal-poor stars.

We investigated constraints on parameters of the PL-PMF from the light elements abundance up to Li produced in BBN [3]. We showed respective and combined constraints on the parameters. As a result, we obtained upper limits on the SI-PMF strength, i.e., $B_{\rm SI}^{Y_{\rm p}+D} \leq 1.45 - 1.95\,\mu$G from abundances of ^{4}He and D for the 2σ region of η values by the WMAP 7yr data (Fig. 1).

We assume a PMF characterized by the power spectrum of a PL in wave number. Parameters of this PL-PMF are a field amplitude B_λ, a PL index $n_{\rm B}$, and maximum and minimum scales at a generation epoch $k_{[\rm max]}$ and $k_{[\rm min]}$, respectively. We then show a relation between PL-PMF parameters and the scale invariant (SI) strength of PMF for the first time as follows:

$$B_\lambda = B_{\rm SI}\sqrt{\frac{\Gamma\left(\frac{n_{\rm B}+5}{2}\right)}{\left(k_{[\rm max]}^{n_{\rm B}+3} - k_{[\rm min]}^{n_{\rm B}+3}\right)\lambda^{n_{\rm B}+3}}}. \quad (1)$$

Using this relation, we discuss the degeneracy of the PL-PMF parameters in effects on BBN and showed some possibility of constraining models of PMF generations by combining constraints on the SI field strength from light element abundances to the relation between PL-PMF parameters and the SI field strength.

In addition, we consider a general case in which the existence and energy dissipation of the PMF are allowed. Based on our result of the BBN calculation (Fig. 1), it was found that an upper limit on the strength of the PMF can be derived from a constraint on ^{4}He abundance. A lower limit on ^{7}Li abundance is also derived, and it is significantly higher than those observed in metal-poor stars. We then conclude that it is impossible to solve the ^{7}Li problem by the PMF energy density, even if we consider that part of the PMF energy is dissipated and transferred to the radiation energies.

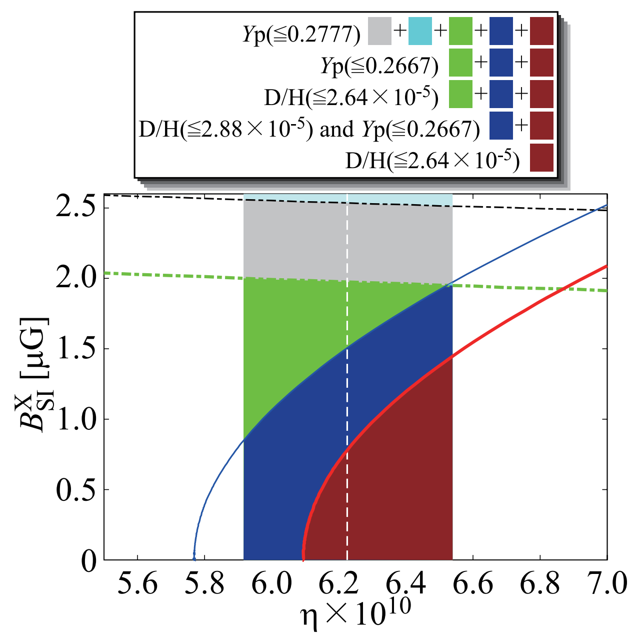

Figure 1: Constraints on the field strength $B_{\rm SI}^{\rm X}$ We use the following upper limits on the abundances: $Y_{\rm p} = 0.2667$ (thick solid line) and 0.2777 (thin solid line), D/H = 2.88×10^{-5} (thick dot-dashed line) and 2.64×10^{-5} (thin dot-dashed line), and ^{7}Li/H = 2.35×10^{-5} (dotted line). The vertical painted band is the limit on the baryon to photon ratio from WMAP 7yr data [4]. The white dashed line indicates the best value. Painted regions in this figure are as indicated in the legend box at the top.

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A Starbursting Proto-Cluster in Making Associated with a Radio Galaxy at $z = 2.53$ Discovered by Hα Imaging

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Galaxy clusters in the local Universe are dominated by early-type galaxies evolving passively, in contrast to general fields where late-type galaxies with active star formation are preferentially found [2]. However, it remains unknown when and how the environmental dependence of galaxy properties appeared. Proto-clusters at $z \gtrsim 2$ are ideal targets to address the issues, because approaching the formation epoch means that we can directly witness present-day cluster galaxies being vigorously growing.

Here, we show a discovery of a starbursting proto-cluster around a radio galaxy USS 1558-003 at $z = 2.53$ where there are a lot of cluster galaxies forming stars. The field surveyed has been known as an over-dense region of distant red galaxies (DRGs) [3]. Using NB2315 filter in MOIRCS on Subaru Telescope, which is perfectly matched to detect Hα emissions from galaxies at $z = 2.53$, a panoramic survey of Hα emitters (HAEs) is conducted in the proto-cluster. We have then succeeded in mapping out the 2-dimensional structure of the proto-cluster, and investigating the star forming activities and the stellar mass content of this forming cluster. The three main results we have found are summarized below (see also figure 1, and our paper [1] for more details).

(1) The proto-cluster is composed of three conspicuous groups of galaxies. One of them is surrounding the radio galaxy, and another is about 1.5 Mpc (physical scale) away from the radio galaxy to the south-west, and the other is in between the two clumps. These groups show significant excess in the number densities of both HAEs and DRGs. Their close separations suggest that they would merge together in the near future and grow to a single, more massive galaxy cluster at later times.

(2) A large fraction of the HAEs in this proto-cluster have star formation rates (SFRs) higher than $100\,M_\odot\,\mathrm{yr}^{-1}$, indicating that at $z \sim 2.5$, the progenitors of cluster early-type galaxies are vigorously forming in the biased high density regions. Star formation activity is high everywhere irrespective of environment within the proto-cluster region, and the properties of individual HAEs show little environmental dependence, except that the HAEs in the densest clump may have slightly higher SFRs compared to those in other regions.

(3) Most of the HAEs have blue colors, but some emitters have very red colors comparable to DRG. The red HAEs tend to be clustered in the three highest density clumps in contrast to lower-z clusters where similar red emitters are avoiding the cluster cores and preferentially located in the medium density regions or the outskirts of the clusters. Since the red emitters are likely to be dusty starburst galaxies in the transitional phase, this result may indicate that some environmental effects, such as galaxy-galaxy interaction, are at work on galaxies in the dense proto-cluster core at $z = 2.53$ and they are just changing their properties rapidly.

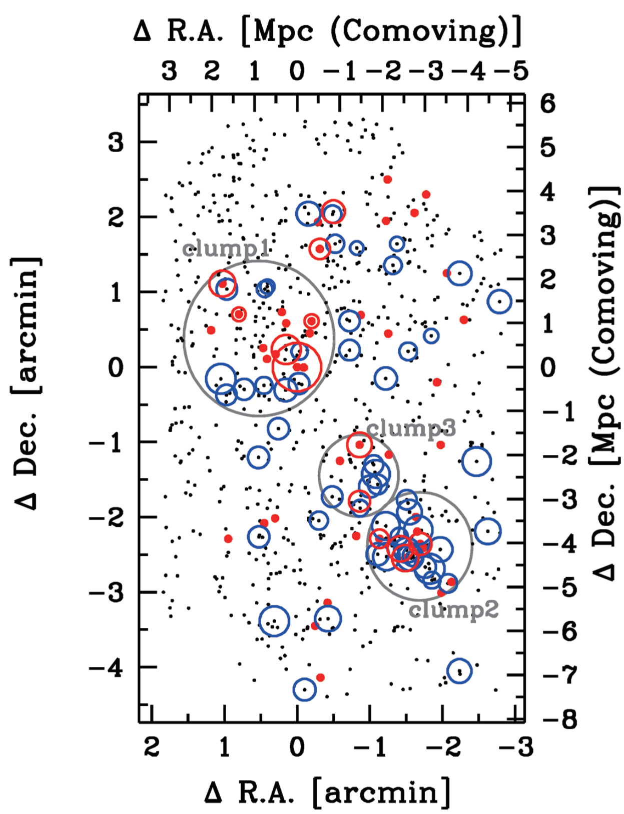

Figure 1: The spatial distribution of HAEs at $z = 2.53$ shown by blue open circles with the size scaled with SFR, i.e., larger symbols mean higher SFRs [1]. Gray open circles show three clumps where HAEs are strongly clustered. The red HAEs with $J - Ks > 1.38$ are also specified with red open circles. The red filled dots show DRGs, while the black dots show all galaxies detected in the field.

* belonged to NAOJ when the paper [1] was published.

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In-House Manufacturing of ALMA Receiver Parts

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At the Mechanical Engineering Shop (ME Shop) in Advanced Technology Center, we have been working on in-house manufacturing (mass production processing) of four critical parts for the ALMA receiver cartridges. We are pleased to announce that we have successfully completed the target production volume (73 units) in March 2013. Including prototyping, it took four years period to complete manufacturing. The aims of in-house manufacturing were twofold: in budgetary terms, we wished to achieve cost savings, and in technological terms, to establish high-precision processing in 'mass production'. We have mostly been successful to achieve both of these. The products' details and our approach to making these are outlined below.

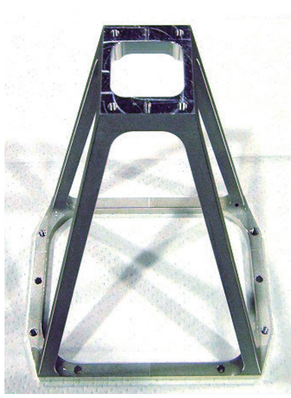
The following two points required particular attention in mass production. (1) Until this project, the ME Shop had been principally involved in manufacturing one-off processing pieces such as in prototyping manufacturing, and the current project was the first attempt at mass production over a relatively long period. (2) Responding to machining request for upcoming common use programs other than ALMA. After detailed discussion with the ALMA receiver development team, dedicated machinery for mass production was selected, 50 % of machinist manpower was allocated, and the ME Shop took charge of machining the following four parts for mass production.

(a) Band 4 Cold Optics Support Structure
(b) Band 4 Warm Optics Frame
(c) Band 4 Warm Optics Elliptical Mirror
(d) Band 8 Cold Optics

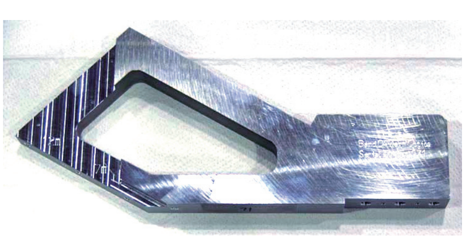
All these products were fully machined from aluminum blocks. Each produce has strict tolerance on its key geometries. The following plans were taken to meet these demanding requirements.

- Dedicated processing staffs.
- Use of dedicated processing machinery and thorough environmental control, such as air temperature.
- Use of materials with quality certificates attached.
- Final machining process after feedback to the machinery setting from the precision measurement using a three-dimensional profiler etc.

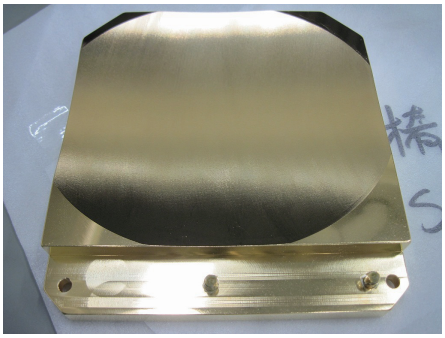
Including the prototyping manufacturing, Mr. Tetsuo Nishino was in charge of all processing of (a) and (b), and Mr. Takeo Fukuda was in charge of (c) and (d). The 73 final products all passed inspection for ALMA specification.

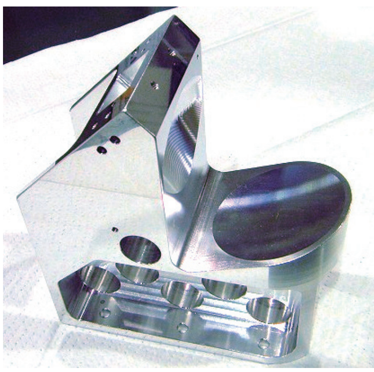


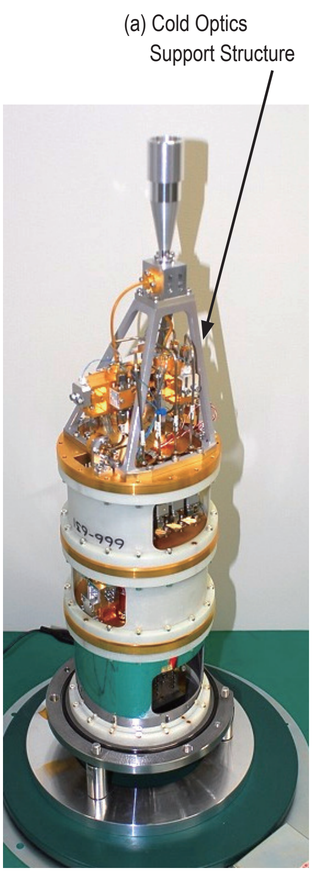
Product Name	(a) Band 4 Cold Optics Support Structure
Materials	A6061 (aluminum alloy)
Materials Block Size	100 × 113 × 130 (mm)
Product Dimensions	90 × 109 × 121 (mm)
Processing Machinery Used	Wire electrical discharge machine, milling machine
Accuracy Required	Height ± 0.05 (mm) Parallelism between upper and lower surface 0.015 (mm) Positional tolerance between base location holes and upper surface pins Φ 0.05
Average Processing Period	2.5 months for 1 lot (10 units)



Product Name	(b) Band 4 Warm Optics Frame
Materials	A5083 (aluminum alloy)
Materials Block Size	25 × 260 × 390 (mm) (1 pair)
Product Dimensions	25 × 135 × 320 (mm)
Processing Machinery Used	Wire electrical discharge machine, milling machine
Accuracy Required	Angular accuracy in each of the three surfaces for mirror attachment is ± 0.01 degrees
Average Processing Period	2.5 months for 1 lot (12 units)

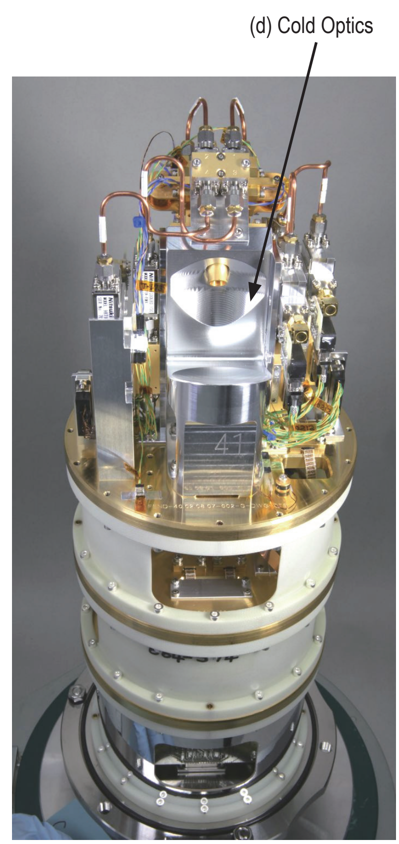
	Product Name	(c) Band 4 Warm Optics Elliptical Mirror
	Materials	A5083 (aluminum alloy) + gold plating after processing
	Materials Block Size	21.5 × 151 × 163 (mm) (6-surface milled)
	Product Dimensions	21.5 × 151 × 163 (mm)
	Processing Machinery Used	Milling machine, machining center
	Accuracy Required	Surface contour 0.02 (mm)
	Average Processing Period	1 month for 1 lot (10 units)

	Product Name	(d) Band 8 Cold Optics
	Materials	A6061 (aluminum alloy)
	Materials Block Size	55 × 115 × 130 (mm)
	Product Dimensions	52 × 112 × 122.654 (mm)
	Processing Machinery Used	Milling machine, machining center
	Accuracy Required	Gradient of horn attachment surface 0.02 (mm) Reference point of horn attachment location ± 0.015 (mm)
	Average Processing Period	2 months for 1 lot (5 units)



Band 4 Cartridge

Band 4 Warm Optics Arrangement Diagram



Band 8 Cartridge

Giant Molecular Cloud Evolutions in the nearby Spiral Galaxy M33

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We present a giant molecular cloud (GMC) catalog of the nearby spiral galaxy M33, containing 71 GMCs in total, based on wide-field (121 arcmin^2 in total) and high-sensitivity (1σ =16–32 mK in $T_{\rm mb}$ for a velocity resolution of 2.5 km s^{-1}) CO(J = 3–2) observations with a spatial resolution of 100 pc using the ASTE 10 m telescope (Fig. 1) [1]. Employing archival optical data, we also generate a complementary new catalog of young stellar groups (YSGs) from the excess of the surface stellar density, and estimate their ages by comparing with stellar evolution models. The physical parameters of YSGs are comparable to those of typical OB associations.

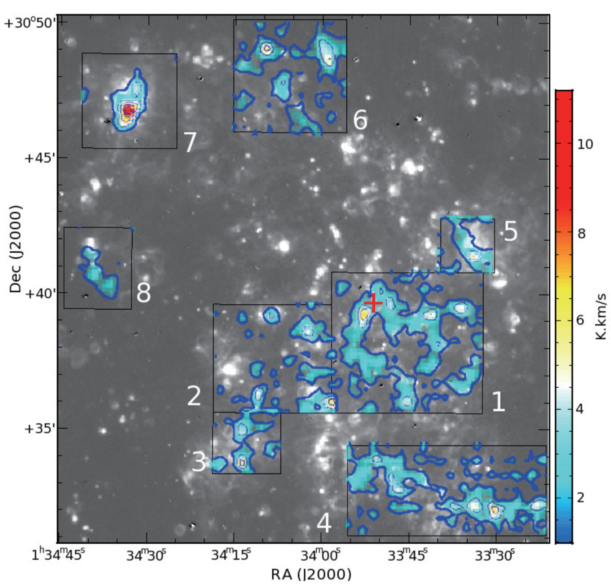

Figure 1: CO(J = 3–2) integrated intensity map with 100 pc resolution, overlaid on the Hα image. The rectangular boxes the eight observed regions with labels. The cross symbol is the galaxy center.

A spatial comparison among the identified GMCs, YSGs, and H II regions from a compilation in the literature enable us to classify GMCs into four categories: Type A, showing no sign of massive star formation (SF); Type B, being associated only with H II regions; Type C, with both H II regions and < 10 Myr old YSGs; and Type D, with both H II regions and 10–30 Myr YSGs (Fig. 2a). Out of 65 GMCs (discarding those at the edges of the observed fields), 1 (1 %), 13 (20 %), 29 (45 %), and 22 (34 %) are Types A, B, C, and D, respectively. We interpret these categories as stages in a GMC evolutionary sequence. Assuming that the timescale for each evolutionary stage is proportional to the number of GMCs, the lifetime of a GMC with a mass > $10^5 M_\odot$ is estimated to be 20–40 Myr. In addition, we find that the dense gas fraction as traced by the CO(J = 3–2)/CO(J = 1–0) ratio is enhanced around SF regions (Fig. 2c). This confirms a scenario where dense gas is preferentially formed around previously generated stars, and will be the fuel for the next stellar generation.

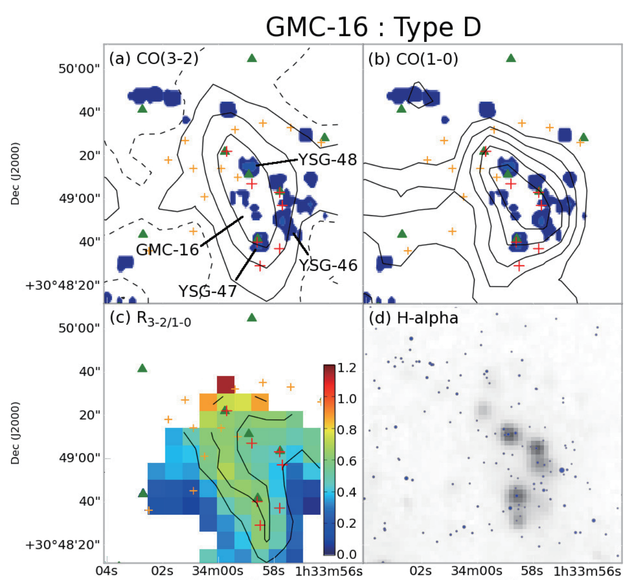

Figure 1: An example of Type D GMC with (a) CO(J = 3–2), (b) CO(J = 1–0) integrated intensity map, (c) CO(J = 3–2)/CO(J = 1–0) ratio, and (d) Hα image. Color contours indicate the surface density of young stars.

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Suzaku/WAM and RHESSI Observations of Non-Thermal Electrons in Solar Microflares

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The maximum energy up to which electrons are accelerated in microflares is not well understood. While microflares frequently show softer/steeper spectra than regular flares [1], some also show spectra comparable to the hardest/flattest flare spectra. Because of the rather short durations of non-thermal HXR microflares (typically < 1 minutes [2]), a large effective area is essential for the detection of high-energy photons from microflares. The Wide-band All-sky Monitor (WAM [3,4]), which is a part of the Hard X-ray Detector (HXD [5]) onboard the Suzaku satellite [6], is a HXR and γ-ray all-sky monitor with the highest effective area among the instruments presently observing the Sun. We reported on hard X-ray spectroscopy of solar microflares observed by Suzaku/WAM and by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) [7].

The WAM solar flare list contains 6 GOES B-class microflares that were simultaneously observed by RHESSI between the launch of Suzaku in July 2005 and March 2010. At 100 keV, the detected WAM fluxes are more than ~20 times below the typical RHESSI instrumental background count rates (An example of WAM and RHESSI joint spectrum is shown in Fig. 1). The RHESSI and WAM non-thermal spectra are in good agreement with a single power-law with photon spectral indices between 3.3 and 4.5. In a second step, we also searched the RHESSI microflare list for events that should be detectable by WAM assuming the non-thermal power-law emission seen by RHESSI extends to > 50 keV. From the 12 detectable events between July 2005 and February 2007, 11 were indeed seen by WAM. This shows that microflares, similar to regular flares, can accelerate electrons to energies up to at least 100 keV.

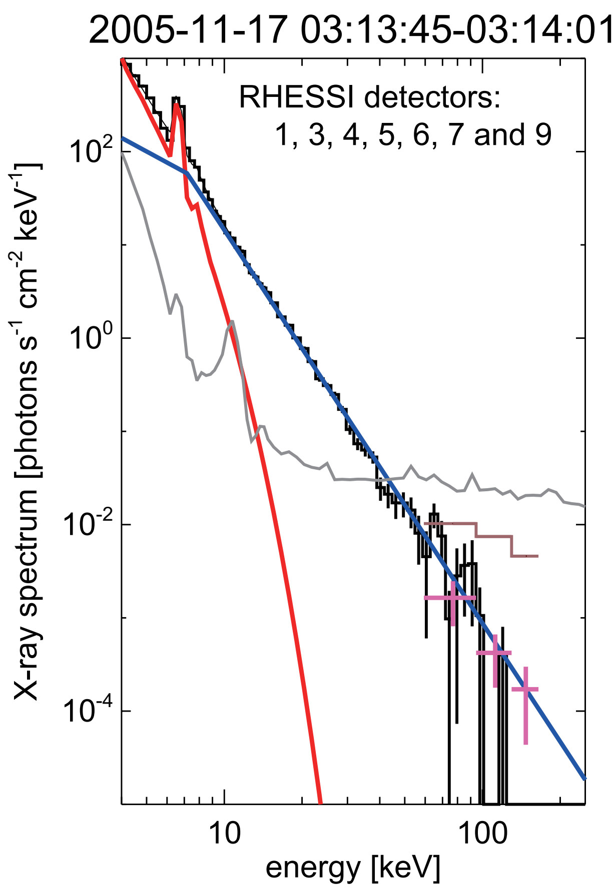

Figure 1: WAM and RHESSI joint spectrum of an example of the microflares in this research. The black line with the errorbars and magenta points are RHESSI and WAM data, respectively. The gray curve gives the RHESSI background spectrum, and the brown line gives the WAM background. The red curve and blue line are thermal bremsstrahlung and non-thermal power-law components obtained by fitting the RHESSI data.

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Magnetically Confined Interstellar Hot Plasma in the Nuclear Bulge of Our Galaxy

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The origin of the Galactic center diffuse X-ray emission (GCDX) is still under intense investigation. In particular, the interpretation of the hot ($kT \approx 7$ keV) component of the GCDX, characterised by the strong Fe 6.7 keV line emission, is problematic. Two main ideas have been suggested to account for it : a truly diffuse plasma that bathes the emitting region (e.g., [1]); and a superposition of a large number of unresolved point sources (e.g., [2]).

In Nishiyama et al. 2013 [3], we show that the spatial distribution of the GCDX does *not* correlate with the number density distribution of an old stellar population traced by near-infrared (NIR) light. The longitudinal and latitudinal profiles of the 6.7 keV line emission measured by *Suzaku* clearly show an excess over the stellar number density profiles, strongly suggesting a significant contribution of the diffuse interstellar plasma. Contributions of the old stellar population to the GCDX are estimated to be ~50 % and ~20 % in the nuclear stellar disk and nuclear star cluster, respectively.

The most puzzling aspects of the GCDX is its high temperature. Since the $kT \approx 7$ keV plasma is too hot to be gravitationally bound, it requires a huge energy source *without* a confinement mechanism of the plasma. One idea to address this energetics issue is the confinement of the plasma by magnetic fields [4].

We have carried out NIR polarimetric observations for the central $|l| < 1^\circ.5$ and $|b| < 1^\circ.0$ region, and we obtain polarization originating from magnetically aligned dust grains in the Galactic center (for more detail, see [5]). The polarized angle traces the Galactic center's MF direction projected onto the sky. The obtained polarization map (Fig. 1) suggests that the GCDX region is permeated by a large scale, *toroidal* magnetic field, indicating a magnetic confinement of the hot plasma.

If the plasma were not confined, it would be rushing out of the Galactic plane vertically as a galactic wind. Assuming the gas flows out from the X-ray emitting region at the sound speed, the escape timescale is $\sim 4 \times 10^4$ yr. This requires a huge energy input to sustain the hot plasma; e.g., an unreasonably high supernova rate of $\sim 5 \times 10^{-3}$ yr^{-1}. If the plasma is magnetically confined, and there is no other cooling mechanism, the hot plasma only cools by radiation with a timescale of 10^7–10^8 yr, several orders of magnitude longer than the escape timescale. This would reduce the required energy input by several orders of magnitude and thus relax the energetics problem.

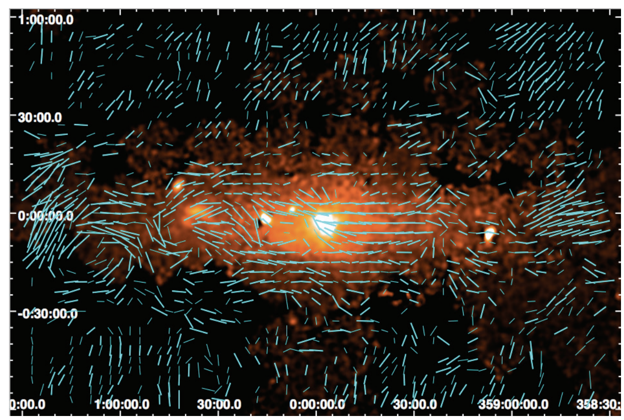

Figure 1: Polarimetry results covering $3^\circ.0 \times 2^\circ.0$ in the Galactic coordinate, together with an intensity map of 6.7 keV line emission [6]. The cyan vectors show the inferred magnetic field direction, and the lengths are proportional to polarization percentage.

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Young, Massive Star Candidates Detected throughout the Nuclear Star Cluster of the Milky Way

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Nuclear star clusters (NSCs) are ubiquitous in galaxies and appear as compact clusters at the dynamical centers of their host galaxies [1]. They show mixed stellar populations and their spectra indicate recent events of star formation. However, it is impossible to resolve external NSCs in order to examine the relevant processes. The Milky Way NSC, on the other hand, is close enough to be resolved into its individual stars and presents therefore a unique template for NSCs in general.

Young, massive stars have been found by AO assisted, systematic spectroscopic studies at projected distances $R < 0.5$ pc from the supermassive black hole Sgr A* (e.g., [2]). In recent years, increasing evidence has been found for the presence of young, massive stars also at $R > 0.5$ pc (e.g., [3]). Our goal is a systematic search for young, massive star candidates throughout the entire region within $R \sim 2.5$ pc of the black hole.

We present the results of a systematic search for young, massive stars within $R \approx 2.5$ pc of Sgr A* via nearinfrared (NIR) imaging observations with VLT/ISAAC [4]. Our method is a narrow-band seeing-limited imaging, using the CO-band absorption of late-type stars to distinguish between young, massive, early-type stars and late-type giants in the central $\sim 6 \times 6$ pc. Recurrence to seeing-limited observations allow us to probe a significantly larger FoV than what would be possible in comparable time with AO imaging.

We have found 63 early-type star candidates at $R < 2.5$ pc, with an estimated erroneous identification rate of only about 20 %. Considering their K-band magnitudes and interstellar extinction, they are candidates for Wolf-Rayet stars, supergiants, or early O-type stars. Of these, 31 stars are so far unknown young, massive star candidates, all of which lie at $R > 0.5$ pc. The surface number density profile of the young, massive star candidates can be well fit by a single power-law ($\propto R^{-\Gamma}$), with $\Gamma = 1.6 \pm 0.17$ at $R < 2.5$ pc, which is significantly steeper than that of the late-type giants that make up the bulk of the observable stars in the NSC. Intriguingly, this power-law is consistent with the power-law that describes the surface density of young, massive stars in the same brightness range at $R < 0.5$ pc.

The finding of a significant number of newly identified early-type star candidates at the Galactic center suggests that young, massive stars can be found throughout the entire cluster which may require us to modify existing theories for star formation at the Galactic center. Follow-up studies are needed to improve the existing data and lay the foundations for a unified theory of star formation in the Milky Way's NSC.

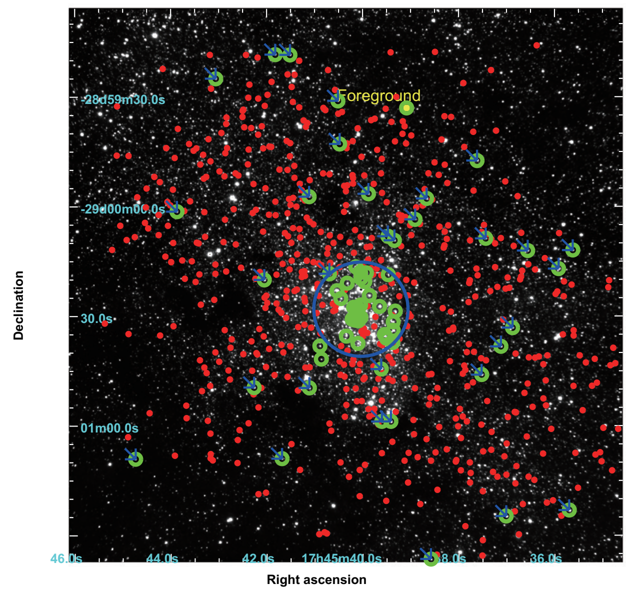

Figure 1: Spatial distribution of the early-type star candidates (green circles). The candidates which have been unknown so far are indicated by blue arrows. Red giants identified by our analysis are marked by red circles. The large blue circle delimits a region within 0.5 pc (12″.9) in projection from Sgr A*. We have identified about 30 new candidates outside the 0.5 pc region.

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Asymmetric Dust Jets and Extended Structure of 22P/Kopff Observed during 2009 Appearance

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We observed the short-period comet 22P/Kopff during the 2009 appearance with MITSuME 3-color simultaneous imaging CCD cameras of Ishigakijima astronomical observatory and a 2kCCD camera of Kiso observatory from 2009 August to December after the perihelion passage on 2009 May [1].

In the observation, we confirmed the diffuse coma structure around the nucleus and the asymmetric fanshaped jet structure toward the south (Fig. 1). In addition, the dust trail was detected on the project orbit of the comet, while the obvious neck-line structure could not be confirmed.

With the observational data of the asymmetric jet, we deduced the direction of the rotational axis. We analyzed the time evolution for the position angle of the rotational axis and obtained the pole orientation of $(\alpha_{pl}, \delta_{pl}) = (302° \pm 30°, 62° \pm 10°)$ or $(\alpha_{pl}, \delta_{pl}) = (122° \pm 30°, -62° \pm 10°)$.

Then, we modified the theoretical model of the dust ejection [2] in order to explain the dust trail and the asymmetric jet, and performed the numerical simulation (Fig. 2). As a result, we found the observed dust structure can be well reproduced by the dust emission near the south polar region (Fig. 3).

This means that the polar region of the comet is still active, while most of the surface is becoming dormant.

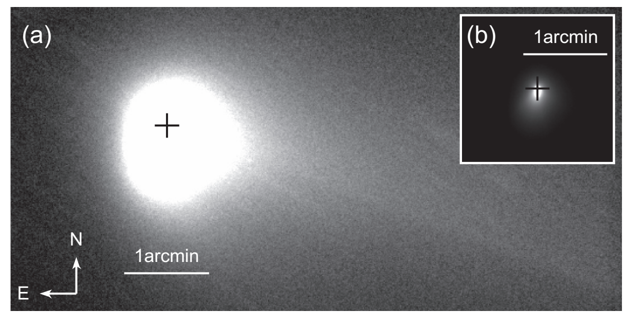

Figure 1: Images of 22P/Kopff on 2009 August. (a) shows the diffuse dust structure, including a linear tail. (b) shows the fan-shaped jet structure around the comet nucleus.

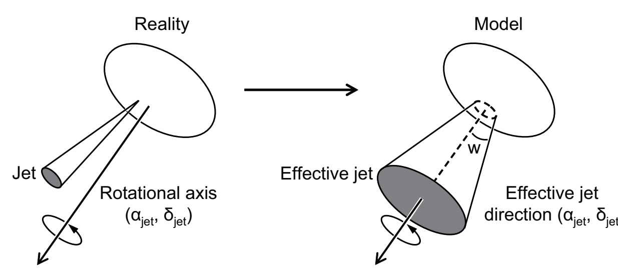

Figure 2: Image of the cone-shaped dust jet influenced by rotation of the comet nucleus.

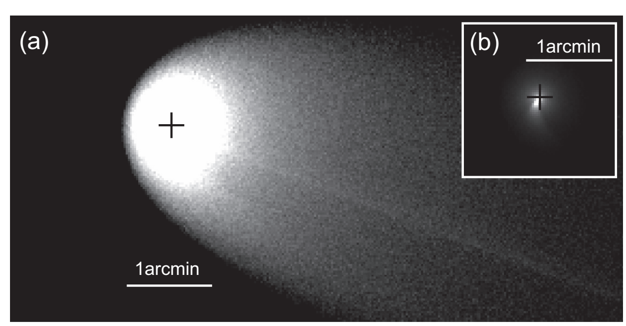

Figure 3: Images of the numerical simulation of 22P/Kopff based on the dust ejection model considering the asymmetric jet.

References

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Production of High Temperature Plasmas During the Early Phases of a C9.7 Flare. II. Bi-Directional Flows Suggestive of Reconnection in a Preflare Brightening Region

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The 2007 June 6 16:55 flare was well observed with high time-cadence sparse raster scans by the EUV Imaging Spectrometer (EIS) on board the Hinode spacecraft. The observation covers an active region area of 240″×240″ with the 1″ slit in about 160 seconds [1].

A preflare brightening to this flare, which started ~9 minutes prior to flare-ribbon onset, looks like two small loops apparently having a cusp-shape structure about 40″–50″ west of the main flaring loops. This interaction shows dyanamic behavior in velocity during the early phases of the flare: The HeII line at 256.32 Å shows the existence of a bi-directional flow along the Earth-Sun line of sight of about −70 and +100 km s^{-1}. On the other hand, the FeXVI line at 262.98 Å formed at higher coronal temperatures shows only a slight increase in intensity at the location of these loops, and the FeXXIII line at 263.76 Å barely appears. Electron density at the site derived from the intensity ratios of the FeXIV line pair at 264.78 Å and 274.20 Å is lower than the average of $10^{9.3}$ cm^{-3} in other parts of the active-region outskirts.

The FeIX images taken on Stereo-A/B reveal that two tiny loops may merge at first around 17:14:24 UT, and move south- or southwest-wards. A bright point located at the junction of the loops seen in the images taken at 17:19:24 UT may be considered as a candidate location where magnetic reconnection took place, triggered by the preceding interaction of these two loops. The S-E side loop exhibits more dynamic plasma motions via this energy deposition.

From these observations, the preflare-brightening region may be heated via magnetic reconnection taking place as a result of loop-loop interaction [2].

A similar type of transient phenomena is explosive events constantly occurring in the quiet-sun network, which are thought to be a manifestation of magnetic reconnection [3]. These phenomena appear as bi-directional jets in transition-region (TR) lines. Although the characteristics of flows in the event studied here are observed to be similar to those of TR explosive events, this event is associated to the occurrence of a major flare (C9.7), and plasmas are produced around the region heated more than 10 MK. The length of brightening loops are much larger than those of explosive events, and the locations of up- and down-flows in the TR are better spatially-resolved in these interacting coronal loops.

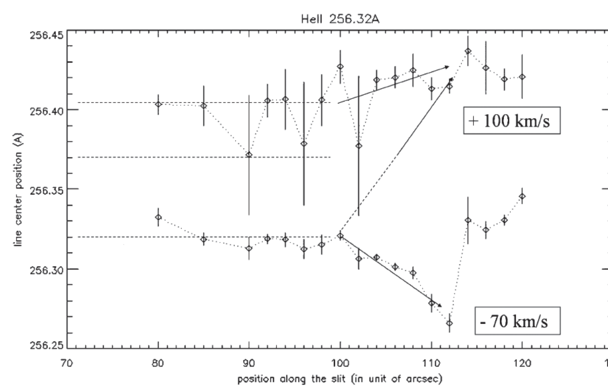

Figure 2: Line-center wavelengths of the two components in the HeII line window. Bars indicate the ranges of fitting errors. Horizontal dotted lines indicated the wavelengths of HeII λ256.32, SiX λ256.37, and FeX/XII λ256.405.

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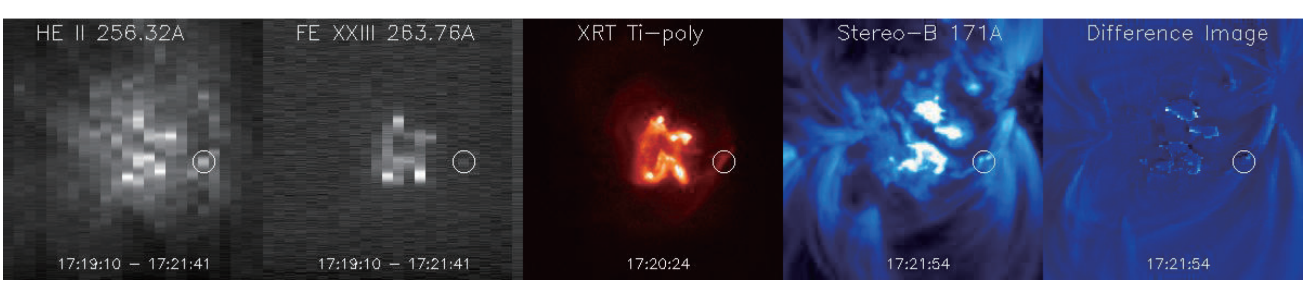

Figure 1: Coalignment among the EIS (HeII and FeXXIII), XRT (Ti-Poly), and EUVI-171 Å on STEREOB, and its difference of image to that of STEREO-A (top panels).

The Image Slicers for the Subaru Telescope High Dispersion Spectrograph

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The High Dispersion Spectrograph (HDS) on Subaru Telescope can achieve a very high resolving power, up to 150000, by applying a very narrow slit. When a slit of 0″.3 (150 μm) width is applied, the resolving power is 115000. The throughput at the slit is, however, as low as 45 % for the typical seeing size of the telescope at Mauna Kea in Hawaii (~0″.6). In order to improve the efficiency of the spectrograph for observations with very high resolution, we installed a Bowen-Walraven type image slicer [1]. This type of image slicer traps incident light in a thin plate by total internal reflection, and slices the image by sending the light at every second reflection to a glass prism inclined with an appropriate angle (see figure 1). After designing the instrument in late 2008, it was constructed in 2009 and installed in 2010. The instrument was opened for common use of HDS from 2011 August.

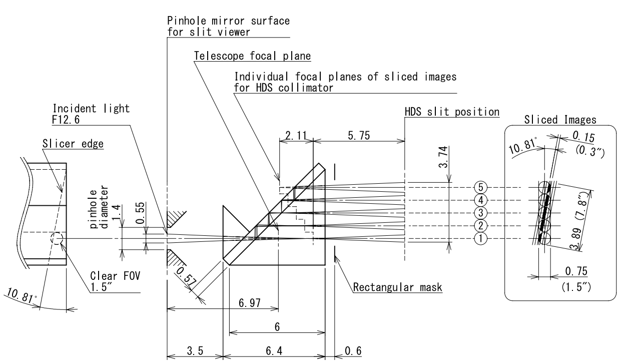

Figure 1: Optical design of IS#1.

The Bowen-Walraven type image slicer that we installed is optimized for the two following prime requirements. The first requirement is to maximize the energy from point sources under the typical seeing of 0″.6 on Mauna Kea. Therefore, the clear aperture should be up to 1″.5 (corresponding to 0.75 mm on the focal plane of Subaru Telescope). The second requirement is a spectral resolving power as high as R ~110000. Therefore, the width of the sliced images should be 0″.3 (0.15 mm). In order to fill these two requirements, the image slicer is designed to transform a 1″.5 × 1″.5 field of view into five sliced images of 0″.3 width, as shown in figure 1. The five sliced images (hereafter "slices") are numbered from 1 to 5 along the optical path, as shown in the figure. We note that since observing targets of this instrument are assumed to be bright stars, no slice is dedicated to obtain a background-sky spectrum.

The gain of photons expected by using the image slicer, that is, the ratio of the fraction of light entering the spectrograph with the image slicer to that with the 0″.3 slit, is higher than unity for a seeing size larger than 0″.3, and reaches two at 0″.8 (see black lines in figure 2). Hence, to obtain spectra with resolution as high as R = 110000, a higher S/N is expected by using the image slicer under any seeing condition at Mauna Kea. Science results using this instrument on, e.g., metal-poor binary stars and an extrasolar planet have been published [2,3].

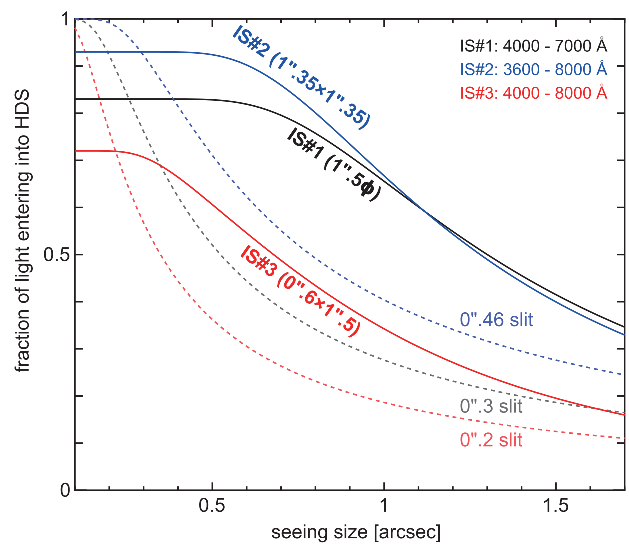

Figure 2: Efficiencies of image slicers and corresponding slits.

In addition to this first image slicer (IS#1), we developed two more similar ones. The second one (IS#2), which achieves R = 85000 with the 0″.46 × 3 format, was opened for common use of HDS from 2012 August. Its spectral resolution is adjusted to the one used the most frequently in HDS observations. The third one (IS#3) has the highest spectral resolution R = 165000 with the 0″.2 × 3 format. Among the 8–10 meters telescopes in the world, HDS with the IS#3 must be the unique instrument to realize efficient observations with such highest spectral resolution. This IS#3 is also going to be opened for common use in 2013.

References

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MKID 102 Pixel Millimeter-Wave Camera Development

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A 1000 pixel millimeter and terahertz camera with superconducting MKID (Microwave Kinetic Inductance Detector) is being developed for LiteBIRD which detects CMB B-mode polarization and for Antarctica Dome Fuji telescope which observes distant galaxies with wide field of view, in collaboration with KEK, Riken, Tsukuba University, Saitama University, and Okayama University [1]. We developed 220 and 440 GHz imaging array in 2012 fiscal year.

The MKID was invented by Caltech/JPL group (P. Day et al. 2003). Superconducting resonators in MKID senses surface impedance determined by a number of quasi-particles which incoming photons generate by destroying cooper pairs. It has larger dynamic range than TES (transition-edge sensors). The resonant frequencies among 2–12 GHz are sensed by frequency comb generated by DAC (Fig. 3). MKID has a simple structure named CPW (co-planar waveguide), so a higher yield is expected.

To detect submillimeter-waves efficiently, the camera combined lens array with superconducting planar antenna. Although silicon is an ideal material for millimeter-wave lens in the aspects of low loss and large refractive index, it was not available for this lens, because it was difficult to fabricate millimeter-wave lens array. Recently, ATC ME shop succeeded in fabricating millimeter-wave Si lens array by a sealing process with a high-speed spindle and small diameter end-mills.

We have demonstrated symmetrical and low side-lobe beam pattern of this camera with the Si lens array (Fig. 2) [2]. Although it is necessary to apply anti-reflection coating on the lens surface due to a large refractive index of Si, the anti-reflection coating was not applied at the measurement.

T. Noguchi et al. have been developing high quality superconducting film to reduce imaginary part of the gap energy and to decreases the noise and the loss [3]. For this purpose, an MBE instrument has been introduced. Al (111) epitaxial film was fabricated on Si (111) substrate [4]. This Al MKID achieved an extremely low noise of electrical NEP 6×10^{-18} W Hz$^{-1/2}$ (Fig. 2) [4,5].

A test system for noise and beam measurements has been developed with 0.1 K dilution refrigerator (Fig. 3) [6]. A readout circuit with a complex FFT has been also developed for frequency multiplexed MKIDs (Fig. 3). It has been demonstrated to read the 100 pixel Al-MKIDs simultaneously [1].

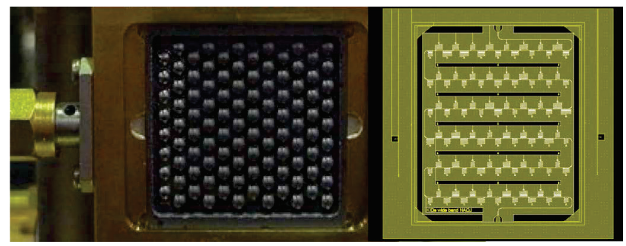

Figure 1: Antenna coupled Al-MKID 102 pixel camera [2]. (left) 102 pixel Si lens array fabricated by ATC ME shop. (right) Al CPW pattern of 102 pixel camera. The size of the camera is 24×22 mm^2.

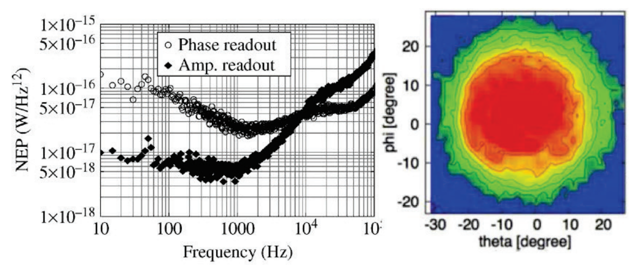

Figure 2: (left) Dark NEP of Al MKID [5]. Amplitude noise of NEP was 6×10^{-18} W Hz$^{-1/2}$. Phase noise was larger by an order of magnitude. (right) Beam pattern of a pixel of Al-MKID camera was measured at 220 GHz [2].

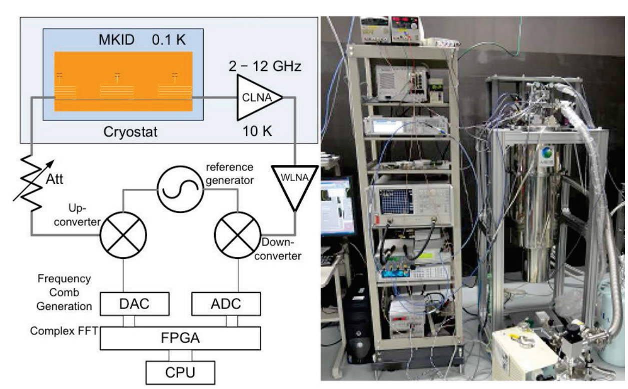

Figure 3: (left) Schematic drawing of MKID and its readout electronics. (right) Al-MKID camera and 0.1 K cryogenic system [6] .

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Discovery of Superhumps during a Normal Outburst of SU UMa

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Here we report on simultaneous g’, Rc, and Ic photometry of SU UMa (a prototype of SU UMa-type dwarf novae) using OAO/MITSuME 50 cm telescope.

SU UMa-type dwarf novae are a subclass of dwarf novae. Their orbital periods range 1–2 hours. SU UMa-type dwarf novae show two types of outbursts. One is normal outburst, whose duration is about a few days. The other is superoutburst, whose duration is about two weeks. During the superoutburst, a tooth-like modulations called superhumps are observed. The superhump period is a few percent longer than the orbital period of the system. This is understood by phase-dependent tidal dissipation of a precessing accretion disk.

Long-term behavior of SU UMa-type dwarf novae are well explained within the framework of the thermal-tidal instability model [1]. According to this model, the radius of the accretion disk increases when a normal outburst occurs. When the radius of the accretion disk reaches the 3:1 resonance (at which the tidal instability sets in), a superoutburst is triggered. In other words, the radius of the accretion disk is below the 3:1 resonance radius outside the superoutburst.

Recently, [2] reported that superhumps are detected superhumps during a normal outburst just before the superoutburst. [3] further reported that superhumps persist during a normal outburst just after the superoutburst. These observations suggest that a reform of the thermal-tidal instability model is required.

In the present observations, we report on the detection of superhumps during an *isolated* normal outburst of SU UMa (see figure 1). Our result suggests that the radius of the accretion disk is already reaches the 3:1 resonance radius even in the middle of the cycle of the superoutbursts. Our result also raises a question why a superoutburst is suppressed, despite the accretion disk reaching the 3:1 resonance radius. This should be elucidated in future observations of other SU UMa-type dwarf novae.

More detailed discussion is given in the published letter [4].

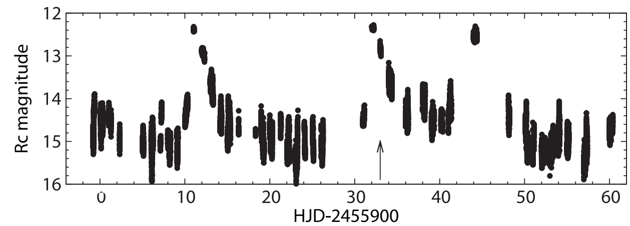

Figure 1: Rc band light curves of SU UMa. During the normal outburst marked with an arrow, we detected superhumps. This is the first case that superhumps are observed during an isolated normal outburst.

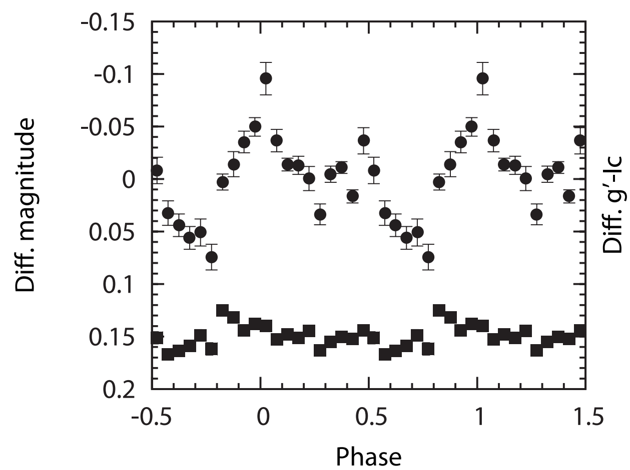

Figure 2: top: Phase-averaged Rc light curve folded with 0.07904 d. This periodicity is identical with that reported by [5]. bottom: g’-Ic color variations folded with the same period. A phase discordance between the magnitude and color is often observed during superhumps.

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NIR Spectroscopy of Star-Forming Galaxies at z~1.4 with Subaru/FMOS

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The gas-phase metallicity (hereafter metallicity) is one of the important parameters in understanding the galaxy evolution. It is known that the metallicity of galaxies correlates well with the stellar mass at the local universe. The mass-metallicity relation at higher redshifts still remains unclear because of the small sample size. We carried out the NIR spectroscopic survey of star-forming galaxies at z~1.4 by using FMOS (Fibre Multi Object Spectrograph) [1] on the Subaru Telescope.

We observed ~320 galaxies with $K < 23.9$ mag (AB), $1.2 < z_{ph} < 1.6$ ($z_{med} \sim 1.4$), $M_{*\odot} > 10^{9.5} M_{\odot}$, $F(H\alpha)^{expected} > 5\times10^{-17}$ erg s^{-1} cm^{-2} in the SXDS (Subaru XMM-Newton Deep Survey) field during the FMOS/GTO. The data reduction was done with the FMOS standard pipeline [2], and the spectral fitting including the effects of OH-masks was carried out. For 71 objects, Hα emission lines are detected significantly.

The metallicity is derived from the obtained [NII]/Hα line ratio. The stacking analysis is also done by dividing the sample into three stellar mass bins. The distribution of the metallicity and the stellar mass with the result from the stacking analysis is presented in Figure 1. It is shown that the mass-metallicity relation at z~1.4 is located between those at z~2.2 and z~0.8 with a smooth evolution from z~3 to z~0.1.

It is known that there exists an intrinsic scatter significantly larger than the observational error in the mass-metallicity relation at z~0.1. The origin of the scatter, in other words, the dependence of physical parameters on the mass-metallicity relation, is a key to understand the galaxy evolution. At higher redshift, however, it is still unclear whether there is a scatter in the mass-metallicity relation or not, again, partly due to the small sample size.

By using the large NIR spectroscopic sample at z~1.4, we examined the scatter of the mass-metallicity relation and the dependence of other physical parameters. The resultant mass-metallicity relation at z~1.4 shows an intrinsic scatter of ~0.1 dex after subtracting the observational error, which is similar to that at z~0.1. We find that the dependence of dust corrected SFR and the galaxy size (half light radius) on the mass-metallicity relation: At a fixed stellar mass, galaxies with lower SFR (smaller size) tend to show larger metallicity [3]. The sample size, however, is still limited, and further observations are desirable for more detailed discussions.

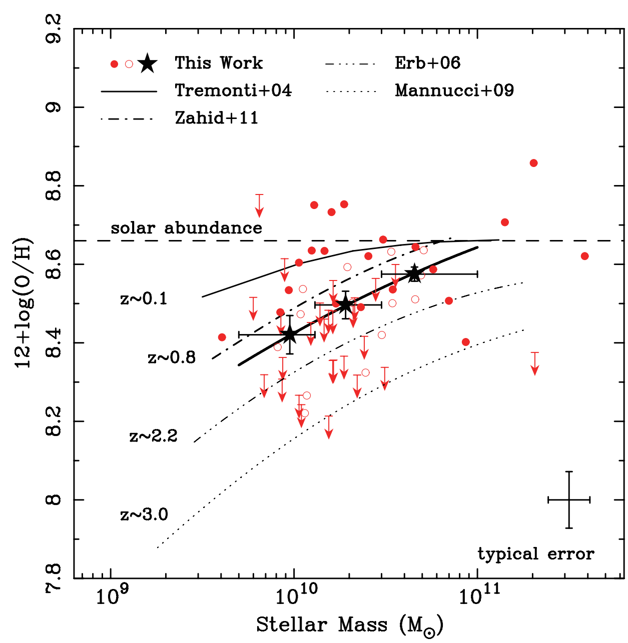

Figure 1: The mass-metallicity relation at z~1.4. Objects with the [NII] SN ratio of ≥3.0 and 1.5–3.0 are indicated by filled and open circles, respectively. Objects with the SN ratio of <1.5 are shown by arrows as upper limits. Results from the stacking analysis are shown by filled stars with error bars. Previous results at z~0.1–3 in the literature are also presented. The typical error for an individual object is presented on the bottom-right corner.

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Giant Molecular Clouds and Star Formation in the Tidal Molecular Arm of NGC 4039

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MATSUSHITA, Satoki[2/4], TREJO, Alfonso[4], CHAPILLON, Edwige[4], TAKAHASHI, Satoko[4], SU, Yu Nung[4]
KAWAMURA, Akiko[1], AKIYAMA, Eiji[1], HIRAMATSU, Masaaki[1], NAGAI, Hiroshi[1], MIURA, Rie E.[1]
KURONO, Yasutaka[1], SAWADA, Tsuyoshi[1/2], HIGUCHI, Aya[1/2], TACHIHARA, Kengo[1/2]
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The properties of tidally induced arms provide a means to study molecular cloud formation and the subsequent star formation under environmental conditions which in principle are different from quasi stationary spiral arms. We report the properties of a newly discovered molecular gas arm of likely tidal origin at the south of NGC 4039 and the overlap region in the Antennae galaxies, with a resolution of $1''.68 \times 0''.85$, using the Atacama Large Millimeter/submillimeter Array science verification CO(2–1) data (Fig. 1) [1].

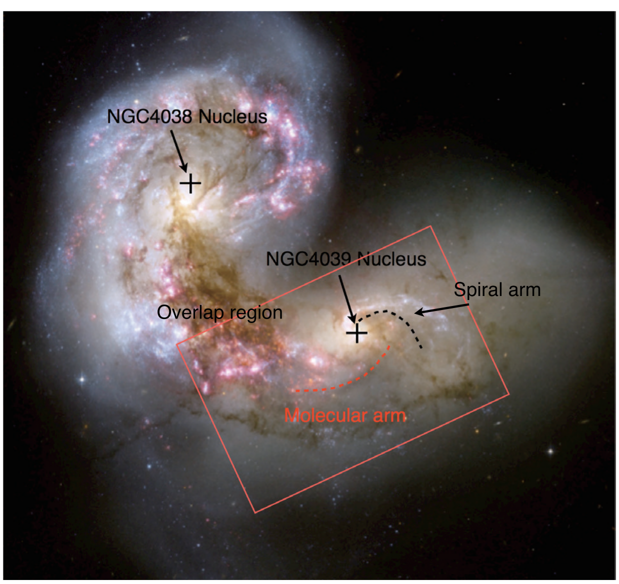

Figure 1: HST Optical composite image of Antennae galaxy indicating the positions of the NGC 4038/9 nuclei, the overlap region, NGC 4039's spiral arm, and the molecular arm of tidal origin that we study in [1]. The rectangle indicates the mosaic covered by ALMA observations.

The arm extends 3.4 kpc (34″) and is characterized by widths of $\lesssim$ 200 pc (2″) and velocity widths of typically $\Delta V \simeq$ 10–20 km s^{-1} (Fig. 2). About 10 clumps are strung out along this structure, most of them unresolved, with average surface densities of $\Sigma_{\rm gas} \simeq$ 10–100 $M_\odot$ pc^{-2}, and masses of (1–8)$\times 10^6$ $M_\odot$. These structures resemble the morphology of beads on a string, with an almost equidistant separation between the beads of about 350 pc, which may represent a characteristic separation scale for giant molecular associations.

We find that the star formation efficiency at a resolution of 6″ (600 pc) is in general a factor of 10 higher than in disk galaxies and other tidal arms and bridges. This arm is linked, based on the distribution and kinematics, to the base of the western spiral arm of NGC 4039, but its morphology is different to that predicted by high-resolution simulations of the Antennae galaxies.

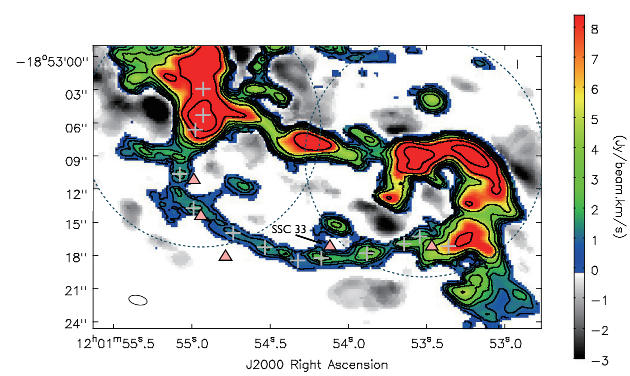

Figure 2: Integrated intensity map, emphasizing the tidal molecular arm to the South. The triangle signs show the location of super stellar clusters along the molecular arm.

Reference

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Disentangling the Circumnuclear Environs of Centaurus A: Gaseous Spiral Arms

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We report the existence of spiral arms in the recently formed gaseous and dusty disk of the closest giant elliptical, NGC 5128 (Centaurus A), using high resolution ^{12}CO(2–1) observations of the central 3′ (3 kpc) obtained with the Submillimeter Array (SMA) [1]. This provides evidence that spiral-like features can develop within ellipticals if enough cold gas exists.

We elucidate the distribution and kinematics of the molecular gas in this region with a resolution of 4″.4 × 1″.9 (80 pc × 40 pc). From the ^{12}CO(2–1) emission distribution in Fig. 1, we confirm that the molecular gas is preferentially located along two filamentary structures resembling spiral-arm-like features to the SE and NW of the circum-nuclear gas (< 200 pc). The larger field of view of our observations demonstrates that these filamentary structures extend at least 1″.0, and they are curved toward the NE and SW. The general properties of the arms are similar to those in spiral galaxies: they are trailing, their width is ~500 ± 200 pc, and the pitch angle is ~20°.

A consequence of the compression produced by these spiral arms is that it is expected to trigger star formation (SF) on the leading edge. This is consistent with abundant SF traced by Paα, coincident at least with the southern molecular spiral arm (nearest part and thus likely the least obscured). The spiral features seen in the ^{12}CO emission is also associated with the distribution of certain tracers observed in poorer angular/spectral resolution maps, such as the SCUBA 450 μm emission map as well as the pure rotational line of molecular hydrogen H_2 ($J = 2$–0) S(0) (28.22 μm) emission observed with Spitzer/IRS [2]. The molecular hydrogen transition H_2 ($J = 2$–0) S(0) indicates the presence of gas with T ~ 200 K, which is likely tracing photodissociation regions associated with abundant SF.

A small perturbation could have triggered this spirality, such as a non-axisymmetric weak potential [3] or a minor merger after the disk was relatively well settled. From the HI structure and kinematics [4] we infer that the formation of spiral arms took place in less than 0.3 Gyr, which is likely the most accurate measure of time at our disposal since HI is one of the most sensitive components of interaction. Simulations of gas fueling in the deep potentials of giant ellipticals are needed to investigate the response of the gas under these conditions.

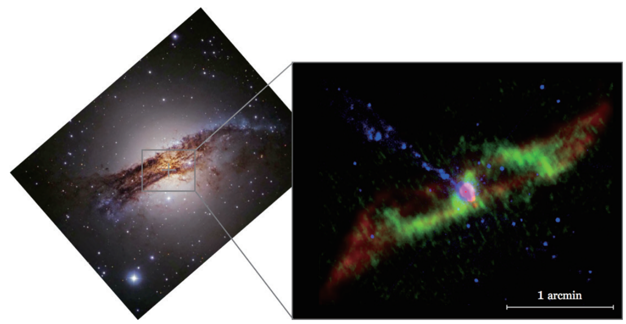

Figure 1: Left) Optical image of Centaurus A, showing its prominent dust lane. Right) The molecular gas as traced by our SMA CO(2–1) observation (green), PAH and dust emission at 8 μm observed by Spitzer (red, [5]), and the Chandra X-ray observations of the jet (blue). Note that the spiral and the 8 μm emission in this panel are within the optical dust lane visible in the left panel. The most prominent features of the ^{12}CO(2–1) emission are consistent with those of the 8 μm emission, but the CO shows the spiral arms.

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A Large Scale Structure Traced by [OII] Emitters Hosting a Distant Cluster at $z = 1.62$

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It is widely known that the formation and evolution of galaxies strongly depend on their surrounding environments [1]. Clusters and their surrounding regions serve as ideal sites for studying the roles of galaxy environment on galaxy formation and evolution. We have conducted a narrow-band survey of [OII] emitters in and around the ClG J0218.3–0510 cluster at $z = 1.6$, which is one of the most distant cluster, using Suprime-Cam on Subaru. The observation with z_R filter was newly carried out to measure the continuum at the same wavelength as the narrow-band filter (NB 973).

On the basis of narrow-band excesses and photometric redshifts, our survey provides a sample of 352 [OII] emitters over a 830 arcmin^2 area [2]. The FMOS near-infrared spectroscopic observations have confirmed 31 [OII] emitters at $z \sim 1.6$ by the presence of Hα or [OIII] lines at the expected wavelengths. The [OII] emitters constitute a large scale structure at $z = 1.62$ in which the ClG J0218.3–0510 cluster is embedded (Figure 1). Also, we find that many star-forming [OII] emitters are located even in the cluster core (r < 0.4 Mpc in the physical scale) and in the surrounding clumps, and show a very high overdensity by a factor of 40 compared to the field region. This trend is consistent with our previous studies in the distant cluster at $z = 1.47$ [3,4], suggesting that the integrated star formation activity per unit volume is activated in cluster regions.

Also, we obtain a large fraction of [OII] emitters even in the cluster core, showing that the star forming activity in the cluster core is elevated substantially compared to the local clusters where there are little star-forming galaxies in their cores. There is no longer a environmental dependence in the relative fraction of [OII] emitters in the all population, and the well known SFR-density relation in the present-day Universe no longer exists within errors. Furthermore, the properties of the individual [OII] emitters, such as star formation rates, stellar masses and specific star formation rates, do not depend on the local density, either. These results suggest that the [OII] emitters in the high density regions are just in the transition phase from a star-bursting mode to a quiescent mode due to some environmental effects and the star formation rates in these systems may be rapidly declining.

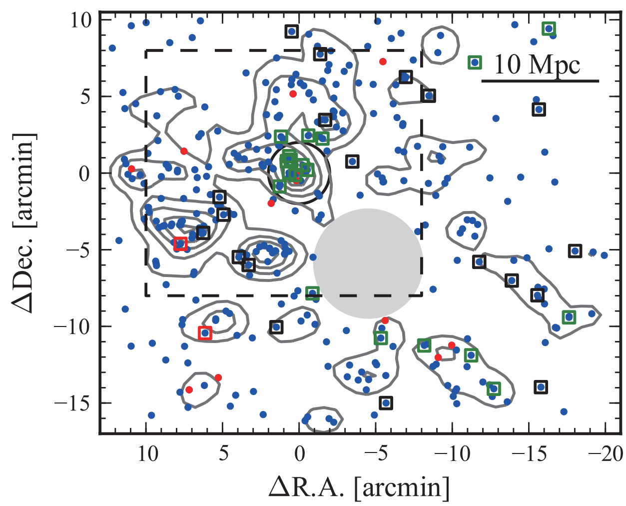

Figure 1: The 2-D distributions of 352 [OII] emitters. Blue and red filled circles show star-forming and red [OII] emitters, respectively. Squares indicate the spectroscopically confirmed objects with $1.590 \le z_{spec} < 1.620$ (black), $1.620 \le z_{spec} \le 1{:}630$ (green) and $1.630 < z_{spec} \le 1.644$ (red). Contours denote the local number density of [OII] emitters. A gray filled circle is a masked region near a bright star.

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Discovery of a Protocluster at $z \sim 6$

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Exploring the structure formation and evolutionary history of the early universe is an issue of strong current interest in astronomy. In the cold dark matter model, clusters of galaxies form in the densest peaks of dark matter in the early universe. These grow by merging and by accreting material from surrounding low-density regions [1]. Theoretical models predict that galaxies lying inside these high-density regions may have formed earlier and/or evolved more rapidly, compared with their surroundings [2]. Clusters of galaxies are thus the noteworthy site of dark matter structure formation and galaxy evolution. Protoclusters in the early universe would provide a great deal of information on the primordial conditions of clusters at their birth.

We used the deep and wide field of the Subaru Deep Field. These images were constructed by stacking all the data taken from 2001 to 2008, containing almost 30 hours worth of integration time in total. We selected 258 $z \sim 6$ galaxy candidates using Lyman break technique. Figure 1 shows the sky distribution of the 258 $z \sim 6$ galaxy candidates. We found an apparently overdense region, centered in the southern part of the field. To determine the overdensity significance quantitatively, we estimated the local surface number density. We found that our region of interest appeared overdense at the 6σ significance level beyond the mean surface number density at the peak.

We carried out follow-up spectroscopy on the overdense region, using FOCAS on the Subaru telescope. We spectroscopically confirmed 15 $z \sim 6$ galaxies in the overdense region. Eight galaxies of them are apparently concentrating at $z \sim 6.01$ ($\Delta z < 0.05$). The redshift concentration at $z \sim 6.01$ is about seven times higher than the number density expected from a uniform distribution. Thus, this region is almost certain to be a galaxy protocluster at $z \sim 6.01$. If true, this protocluster would be the highest redshift large scale structure probed by the unique wide-field imaging capability of SuprimeCam.

The velocity dispersion of the eight protocluster members is 647 ± 124 km s^{-1}, which is about three times higher than that predicted by the standard cold dark matter model. From the three-dimensional distribution, we proposed two possible explanations for this discrepancy: either the protocluster is already mature, with old galaxies at the center, or it is still immature and composed of three subgroups merging to become a larger cluster. Further deep spectroscopic observations or multi-wavelength imaging to trace the rest-frame optical wavelengths would provide a clearer picture of the protocluster structure, as well as providing constraints for the galaxy/stellar populations of protocluster members [3].

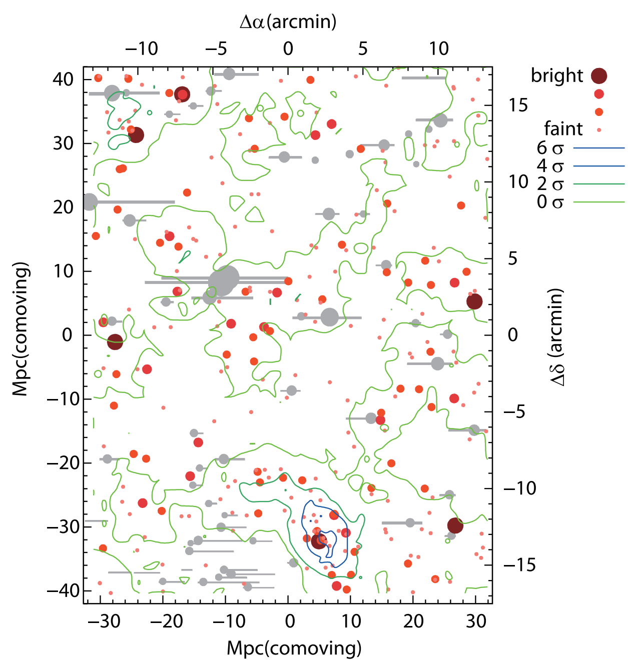

Figure 1: Sky distribution of 258 $z \sim 6$ galaxy candidates, with surface number density contours. The $z \sim 6$ galaxy candidates are represented by filled circles whose size is proportional to the z'-band magnitudes. The lines correspond to contours of surface overdense significance from 6σ to 0σ with a step of 2σ. The overdense region can be clearly seen at the southern edge of the plot.

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Direct Imaging Discovery of a ‘Super-Jupiter’ around the Late B-Type Star κ And

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Stellar mass is emerging as one of the most important parameters in determining the properties of planetary systems, along with stellar metallicity. Radial velocity surveys have indicated that the frequency of giant planets increases with the mass of the stellar host [1], and many of the roughly dozen exoplanets that have been directly imaged so far have had A-type stellar hosts [2,3], despite such large stars being in the small minority of surveyed targets. The increase in planet frequency with host star mass can be readily explained theoretically, through the consideration that more massive stars are likely to have more massive disks [4]. On the other hand, massive stars also feature anl increased intensity of high-energy radiation, which may significantly shorten the disk lifetime due to photo evaporation, and thus decrease the time window in which giant planets are allowed to form. This raises the question whether there is a maximum stellar mass above which giant planets are unable to form.

We present the direct imaging discovery of an extrasolar planet, or possible low-mass brown dwarf, at a projected separation of 55±2 AU (1.″058±0.″007) from the B9-type star κ And [5]. The planet was detected with Subaru/HiCIAO during the SEEDS survey, and confirmed as a bound companion via common proper motion measurements. Observed near-infrared magnitudes of J = 16.3±0.3, H = 15.2±0.2, K_S = 14.6±0.4, and L' = 13.12±0.09 indicate a temperature of ~1700 K. The host star is a member of the Columba association, implying a corresponding age of 30^{+20}_{-10} Myr. The system age, combined with the companion photometry, points to a model-dependent companion mass ~12.8 M_{Jup}. The host star’s estimated mass of 2.4–2.5 $M_\odot$ places it among the most massive stars ever known to harbor an extrasolar planet or low-mass brown dwarf. While the mass of the companion is colse to the deuterium burning limit, its mass ratio, orbital separation, and likely planet-like formation scenario imply that it may be best defined as a ‘Super-Jupiter’ with properties similar to other recently discovered companions to massive stars radial velocity surveys.

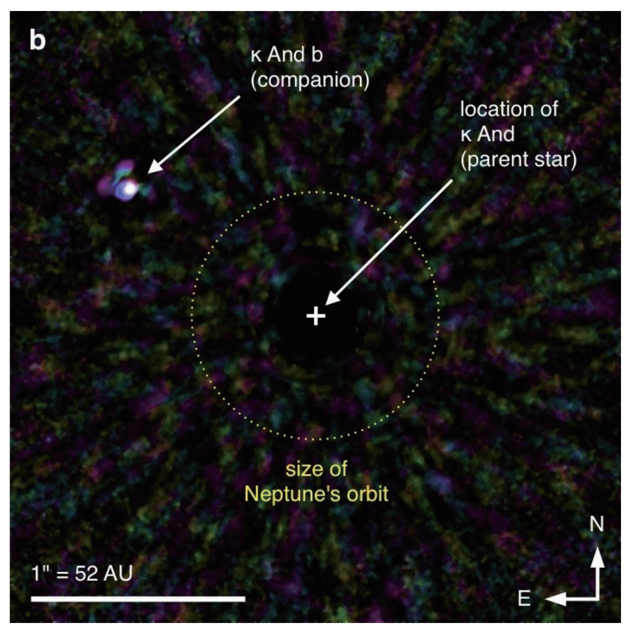

Figure 1: Signal-to-Nise map of κ And b after LOCI/ADI data reduction. The S/N is calculated in concentric annuli around the star.

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High-Contrast Near-Infrared Polarization Imagin of MWC 480

KUSAKABE, N.[1], GRADY, C.[2], SITKO, M.[3/4], HASHIMOTO, J.[1], KUDO, T.[1], FUKAGAWA, M.[5], MUTO, T.[6/7] WISNIEWSKI, J.[8], MIN, M.[9], MAYAMA, S.[10], WERREN, C.[3], DAY, A.[3], BEERMAN, L.[3], LYNCH, D.[11] RUSSELL, R.[11], BRAFFORD, S.[12], KUZUHARA, M.[13], BRANDT, T.[14], ABE, L.[15], BRANDNER, W.[16] CARSON, J.[17], EGNER, S.[18], FELDT, M.[16], GOTO, M.[19], GUYON, O.[18], HAYANO, Y.[18], HAYASHI, M.[20] HAYASHI, S.[18], HENNING, T.[16], HODAPP, K.[21], ISHII, M.[20], IYE, M.[1], JANSON, M.[14], KANDORI, R.[1] KNAPP, G.[14], MATSUO, T.[22], MCELWAIN, M.[23], MIYAMA, S.[1], MORINO, J.[1], MORO-MARTIN, A.[14/24] NISHIMURA, T.[18], PYO, T.[18], SUTO, H.[1], SUZUKI, R.[1], TAKAMI, M.[25], TAKATO, N.[18], TERADA, H.[18] THALMANN, C.[26], TOMONO, D.[18], TURNER, E.[14/27], WATANABE, M.[28], YAMADA, T.[29], TAKAMI, H.[18] USUDA, T.[18], TAMURA, M.[1]

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For the vast majority of protoplanetary disks, modeling of the IR spectral energy distribution (SED) has been the principal tool for characterizing the properties of the dust disk. Some higher mass analogs to T Tauri stars, The Herbig Ae stars, exhibit striking variability in the IR SED, which has been interpreted as reflecting changes in the scale height of the dust disk at or near the sublimation radius [1]. One of the key predictions of modeling from the IR excess of Herbig Ae stars is that for protoplanetary disks, where significant grain growth and settling has occurred, the dust disk has flattened to the point that it can be partially or largely shadowed by the innermost material at or near the dust sublimation radius. When the self-shadowing has already started, the outer disk is expected to be detected in scattered light only in the exceptional cases when the scale height of the dust disk at the sublimation radius is smaller than usual. Hight-contrast imaging combined with the IR spectral energy distribution allow us to measure the degree of flattening of the disk, as well as to determine the properties of the outer disk.

We present polarimetric differential imaging in the *H* band obtained with Subaru/HiCIAO of MWC 480 [2]. The HiCIAO data were obtained at a historic minimum of the NIR excess. The disk is detected in scattered light from 0″.2 to 1″.0 (27.4–137 au). Together with the marginal detection of the disk from 1998 February 24 by Hubble Space Telescope/NICMOS [3], our data constrain the opening half-angle for the disk to lie between $1^{\circ}.3 \leq \theta \leq 2^{\circ}.2$. When compared with similar measures in CO for the gas disk is a factor of 5–7 flatter than transitional disks, which have structural signatures that giant planets have formed.

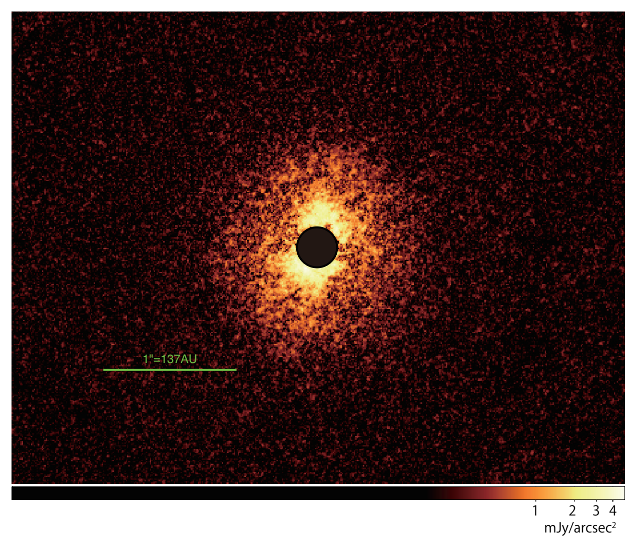

Figure 1: *H*-band Polarization Intensity image of MWC 480. Central black circle shown the occulting mask (r=0″.15).

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Optics Design and Optimizations of the Multi-Color TES Bolometer Camera for the ASTE Telescope

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LEE, Adrian T.[5], HOLZAPFEL, William L.[5], TAMURA, Yoichi[3], HIROTA, Akihiko[2],
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Wideband mm/submm continuum observations provide great opportunities to explore the cosmic history of star-formation across the Hubble time via observations toward submm galaxies and nearby galaxies, as well as the clusters of galaxies through the Sunyaev-Zel'dovich effect. To promote such studies, a new TES (Transition Edge Sensor) bolometer camera for the ASTE 10-m telescope has been developed. The observing bands are carefully selected at 1100, 850, and 450 μm. In this study, we design the re-imaging optics to realize multi-pixel, wide field of view, and multi-color system under the limitation of the Cassegrain system of ASTE.

The optics is designed using the ray-trace method. Figure 1 and 2 show the designed cabin optics and cold optics. The optics has capabilities of the two-color observation and the 7.5 arcmin field of view. The pixel numbers are optimized to be 169, 271, and 919 for the 1100, 850, and 450 μm bands, respectively. The imaging qualities of the designed optics is enough better to achieve diffraction limit at the shortest wavelength.

The designed optics is simulated by physical optics to evaluate the influence of diffraction. The beam properties are calculated by tracing the propagations of the electro-magnetic wave radiated from conical horns. Consequently, the aperture efficiencies are ~35 %, 35 %, and 32 %, and the beam sizes (FWHM) are ~28″, 22″, and 12″ for the 1100, 850, and 450 μm bands, respectively. Thus we demonstrate the designed optics can achieve sufficient optical performance at the observing bands.

Based on the optics design, the bolometer camera were fabricated and evaluated. The first on-site installation was performed in May 2012. The upcoming scientific runs expected to create new scientific achievements for understandings of the formation history of the Universe.

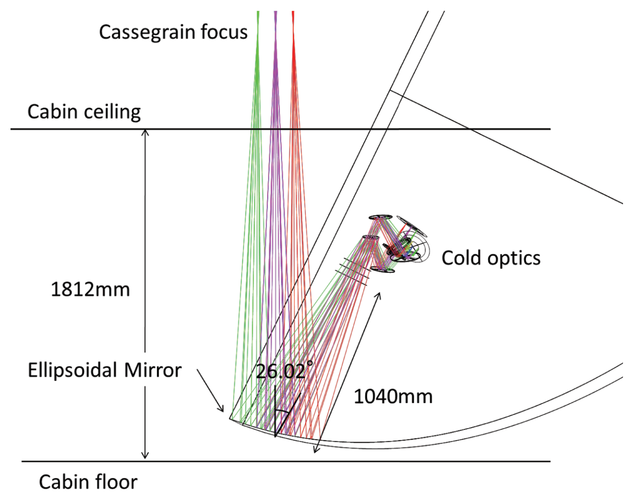

Figure 1: Receiver cabin optics. The rays reflected by the main- and sub-reflectors focus near the ceiling of the receiver cabin, and go into the receiver cabin. A modified ellipsoidal mirror optimized by adding fifth-ordered polynomials to reduce aberration is located near the bottom of the cabin to refocus the outspreading rays into the camera cryostat.

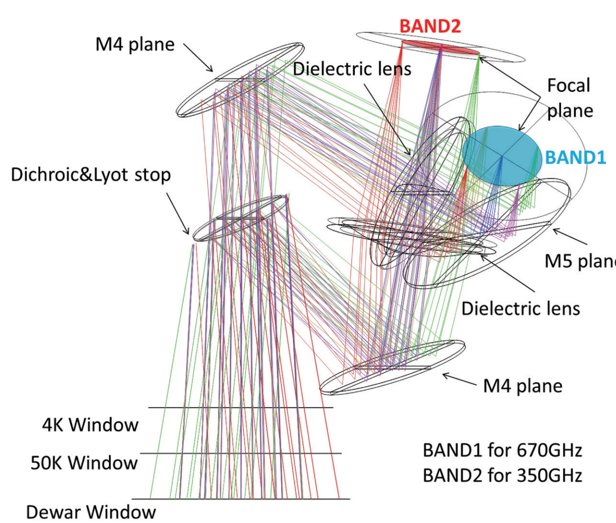

Figure 2: Cold optics. The rays reflected by the ellipsoidal mirror go through a cryostat window. The dichroic filter divides incoming rays into two bands. Each ray is focused at the focal plane after a flat mirror and a high density polyethylene lens, and couples with a conical horn.

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Three-Dimensional Hydrodynamic Core-Collapse Supernova Simulations for an 11.2 $M_\odot$ Star with Spectral Neutrino Transport

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Core-collapse supernovae have long drawn the attention of astrophysicists because they have many aspects playing important roles in astrophysics. They are the mother of neutron stars and black holes; they play an important role for acceleration of cosmic rays; they influence galactic dynamics triggering further star formation; they are gigantic emitters of neutrinos and gravitational waves. They are also a major site for nucleosynthesis, so, naturally, any attempt to address human origins may need to begin with an understanding of core-collapse supernovae.

Ever since the first numerical simulation of Colgate & White (1996), the neutrino-heating mechanism, in which a stalled bounce shock is revived by neutrino energy deposition to trigger explosions, has been the working hypothesis of supernova theorists for these ~50 years. However, one important lesson we have learned from the pioneering simulations that implemented the best input physics and numerics to date, is that the mechanism fails to blow up canonical massive stars in spherical symmetric (1D) simulations. Pushed by mounting supernova observations of the blast morphology, it is now almost certain that the breaking of the spherical symmetry is the key to solve the supernova problem.

In fact, the neutrino-driven explosions have been obtained in the following state-of-the-art two-dimensional (2D) simulations. Using the MuDBaTH code which includes one of the best available neutrino transfer approximations, Buras et al. (2006) firstly reported explosions for a non-rotating low-mass (11.2 $M_\odot$) progenitor of Woosley et al. (2002), and then for a 15 $M_\odot$ progenitor of Woosley & Weaver (1995) with a moderately rapid rotation imposed by Marek & Janka (2009).

To go up the ladders beyond 2D simulations, we explore in this study possible 3D effects in the supernova mechanism by performing 3D, multigroup, radiation-hydrodynamic core-collapse simulations. For the multigroup transport, the IDSA scheme (Liebendörfer et al. (2009)) is implemented, which can be done rather in a straightforward manner by extending our 2D modules to 3D.

We focus here on the evolution of the 11.2 $M_\odot$ star. By comparing with our 1D and 2D results, we study how the increasing multi-dimensionality could affect the postbounce supernova dynamics.

In agreement with previous study, our 1D model does not produce explosions for the 11.2 $M_\odot$ star, while the neutrino-driven revival of the stalled bounce shock is obtained both in the 2D and 3D models. Their result indicates that violent convective matter motions promote the neutrino heating for successful explosions.

For detail, see the original paper of Takiwaki et al. (2012).

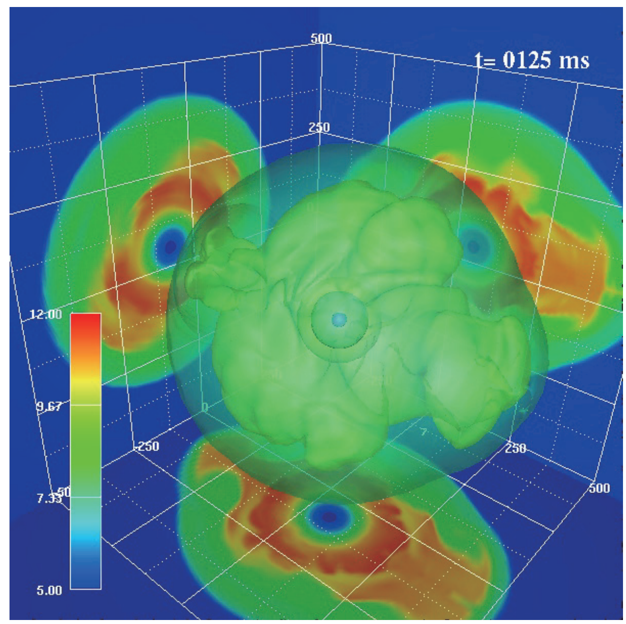

Figure 1: Time snapshot of the 3D model. The surfaces of constant entropy are depicted in the center and cutted colour contour of entropy is pasted on the side walls.

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Fundamental Structure of the Galaxy Determined with VERA

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We have determined fundamental structure of the Milky Way Galaxy based on the results of highly-accurate astrometry carried out by VERA and other VLBI arrays. VERA (VLBI Exploration or Radio Astrometry), being operated by NAOJ in collaboration with Kagoshima University, has been conducting astrometry of Galactic maser sources with an aim to reveal the three-dimensional structure of the Milky Way Galaxy based phase-referencing VLBI technique, and similar projects are also on-going using VLBA, EVN and so on.

In the present study, we have compiled astrometric results (distances and 3-d motions) of 52 star-forming regions obtained by VERA and other arrays, and used them to determine the fundamental structure of the Milky Way Galaxy. Figure 1 shows the distribution of the 52 sources in the Galaxy, with vectors showing their motions in the Galactic plane. Clearly Galactic rotation can be seen, and from their motions even the position of the rotation center can be estimated. In the present study, we have utilized MCMC (Markov-chain Monte Carlo) method to obtain the best model to reproduce the positions and motions of the maser sources, with model parameters such as the Galactic center distance, R_0, and Galactic rotation velocity at the Sun, Θ_0.

The Galaxy center distance is obtained to be $R_0 = 8.05 \pm 0.45$ kpc. This is consistent with the recent results and the IAU standard (R_0 of 8~8.5 kpc). On the other hand, the Galactic rotation velocity is determined as $\Theta_0 = 238 \pm 14$ km s^{-1}, which is roughly 10 % larger than the IAU standard of 220 km s^{-1}. This result indicates that the mass of the Galaxy is higher than previously expected, which impacts not only on the Galactic structure but also on dark mater search in the Galaxy.

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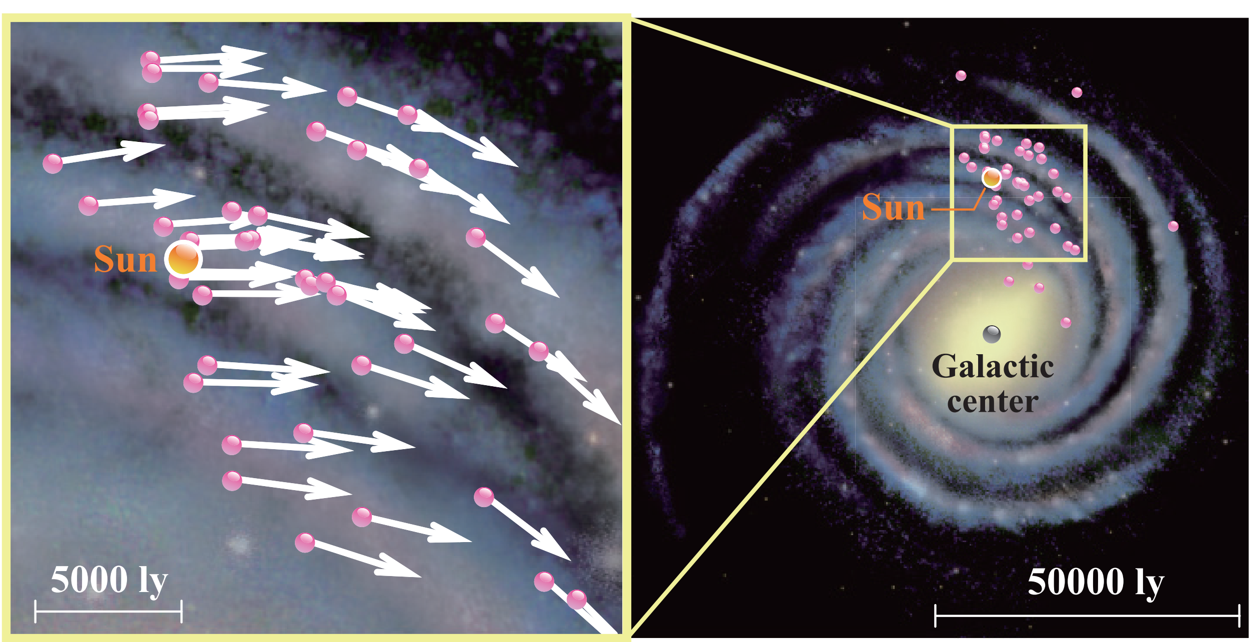

Figure 1: Galaxy-scale distribution and motion of the 52 star-forming regions, for which accurate astrometric results have been obtained.

NRO M33 All-Disk Survey of Giant Molecular Clouds (NRO MAGiC): II. Dense Gas Formation within Giant Molecular Clouds in M33

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We have conducted observations of the ^{12}CO(J=1–0) and ^{12}CO(J=3–2) line emission of 74 major giant molecular clouds (GMCs) within the galactocentric distance of 5.1 kpc in the Local Group galaxy M33 [1]. The observations are part of the Nobeyama Radio Observatory M33 All-disk survey of Giant Molecular Clouds project (NRO MAGiC [2]). The spatial resolution is 100 pc.

We detect ^{12}CO(J=3–2) emission of 65 GMCs successfully. The ^{12}CO(J=1–0) and ^{12}CO(J=3–2) integrated intensity ratio $R_{3-2/1-0}$ is spread over a wide range from less than 0.1 to 0.74, having a weighted mean of $R_{3-2/1-0}$ = 0.26. This weighted mean is slightly smaller than that of the quiescent disk region of the Milky Way. Furthermore, we find that the correlation between the surface density of the star formation rate ($\Sigma_{\rm SFR}$), which is derived from a linear combination of Hα and 24 μm emissions, and the ^{12}CO(J=3–2) integrated intensity still holds at the scale of 100 pc (Figure 1), although the correlation between $I_{\rm CO(1-0)}$ and $\Sigma_{\rm SFR}$ is not obvious, as we have already shown in the preceding paper [3]. This result show that the star-forming activity is closely associated with warm and dense gases that are traced with the ^{12}CO(J=3–2) line, even in the scale of GMCs.

We also find that the GMCs with a high star-forming activity tend to show a high value of $R_{3-2/1-0}$. Moreover, we also observe a mass-dependent trend of $R_{3-2/1-0}$ for the GMCs with a low star-forming activity (Figure 2). From these results, we speculate that the $R_{3-2/1-0}$ values of the GMCs with a low star-forming activity mainly depend on the dense gas fraction and not on the temperature, and therefore, the dense gas fraction increases with the mass of GMCs, at least in the GMCs with a low star-forming activity.

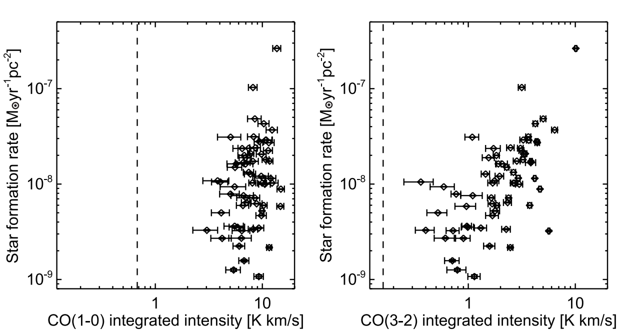

Figure 1: The surface density of SFR ($\Sigma_{\rm SFR}$) versus $I_{\rm CO(1-0)}$ and $I_{\rm CO(3-2)}$ at the $T_{\rm CO(1-0)}$ peak position in each GMC. The dashed lines indicate the sensitivity limits for each CO line. Correlation coefficients are 0.22 and 0.68, respectively.

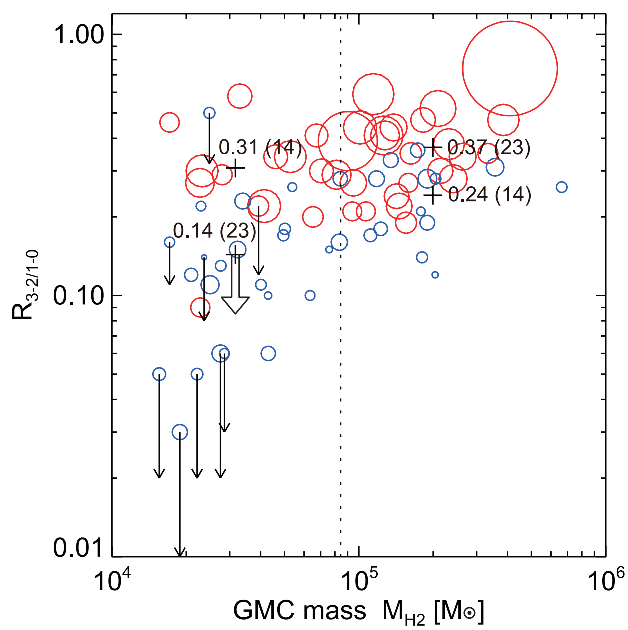

Figure 2: GMC mass versus $R_{3-2/1-0}$. The area of the circles is set proportionally to $\Sigma_{\rm SFR}$ at the $T_{\rm CO(1-0)}$ peak position of each GMC. The red circles represent GMCs with $\Sigma_{\rm SFR} > 1\times10^{-8} M_\odot\,{\rm pc}^{-2}$, and the blue ones indicate those with $\Sigma_{\rm SFR} < 1\times10^{-8} M_\odot\,{\rm pc}^{-2}$. The dotted line indicates the criterion of $M_{\rm H2} = 8.4\times10^4 M_\odot$. The black crosses and the numbers next to them stand for the averaged $R_{3-2/1-0}$ values in each mass-bin, which are taken for GMCs with higher and lower star-forming activity, respectively. The numbers in the bracket are the numbers of the GMCs used for averaging. For GMCs whose ^{12}CO(J=3–2) emissions are not detected, $R_{3-2/1-0}$ is shown as the upper limit, with an arrow whose length is the rms value of $R_{3-2/1-0}$.

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The Origin and Maintenance of a Retrograde Exoplanet

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NAGASAWA, Makiko[4], ABE Lyu[5], BRANDNER, Wolfgang[6], BRANDT, Timothy, D.[7], CARSON, Joseph[8]
EGNER, Sebastian, E.[1], FELDT, Markus[6], GOTO, Miwa[9], GRADY, Carol, A.[10], GUYON, Olivier[1]
HASHIMOTO, Jun[1], HAYANO, Yutaka[1], HAYASHI, Masahiko[1], HAYASHI, Saeko, S.[1], HENNING, Thomas[6]
HODAPP, Klaus, W.[11], ISHII, Miki[1], IYE, Masanori[1], JANSON, Markus[7], KNAPP, Gillian, R.[7]
KUSAKABE, Nobuhiko[1], KWON, Jungmi[3], MATSUO, Taro[12], MAYAMA Satoshi[3], McELWAIN, Michael, W.[10]
MIYAMA, Shoken[13], MORINO Jun-Ichi[1], MORO-MARTIN, Amaya[14], NISHIMURA, Tetsuo,[1] PYO, Tae-Soo[1]
SERABYN Eugene[15], SUTO, Hiroshi[1], TAKAMI Michihiro[16], TAKATO, Naruhisa[1], TERADA, Hiroshi[1]
THALMANN, Christian[17], TOMONO, Daigo[1], TURNER, Edwin, L.[7/18], WATANABE, Makoto[19]
WISNIEWSKI, John, P.[20], YAMADA, Toru[21], TAKAMI, Hideki[1], USUDA, Tomonori[1], TAMURA, Motohide[1]

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We previously discovered the first evidence of a retrograde orbit of an extrasolar planet, HAT-P-7b (Narita et al. 2009) [1]. Although retrograde planets, which have orbits that run counter to the spin of their central stars, are absent in our Solar System, they occur in other planetary systems in the Universe. However, astronomers and planetary scientists did not know how such retrograde planets formed.

Generally speaking, planetary orbits are considered to be well aligned with the host star's rotation, at least at the initial stage. Thus in a retrograde planetary system, it is expected that other bodies in the planetary system had altered the orbit of the retrograde planet.

We used the HiCIAO and HDS instruments of the Subaru telescope to search for such other massive bodies in the HAT-P-7 system. Consequently, we found a binary low-mass stellar companion at over 1000 AU, and another giant planet at over 5 AU in this system.

Then, how did the retrograde orbit of the planet develop? We consider that the existence of the companion star (HAT-P-7B) and the newly confirmed outer planet (HAT-P-7c) are likely to play an important role in forming and maintaining the retrograde orbit of the inner planet (HAT-P-7b) via the Kozai mechanism, a longterm process during which a more massive object has an effect on the orbit of another.

In the case of HAT-P-7b, we posited so-called "sequential Kozai migration" as an explanation of this retrograde planet. It suggests that the companion star (HAT-P- 7B) first affected the orbit of the newly confirmed outer planet (HAT-P-7c) through the Kozai mechanism, causing it to tilt. When the orbit of that planet inclined enough, HAT-P7c altered the orbit of the inner planet (HAT-P-7b) through the Kozai mechanism, so that it became retrograde. This sequential orbital evolution of the planet is one of the scenarios that could explain the origin of retrograde/tilted/eccentric planets.

We have demonstrated the importance of this kind of follow-up observations for retrograde planetary systems to check for the presence of outer massive bodies, which may play an important role in understanding the entire picture of planetary migration. The findings provide important clues for understanding the origin of a variety of planetary systems, including those with highly tilted and also eccentric orbits [2].

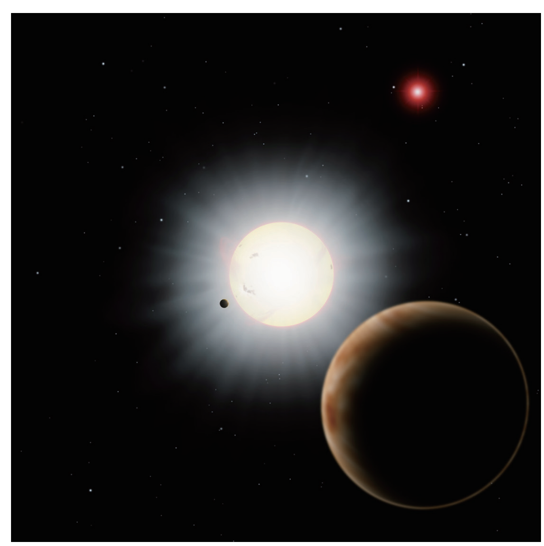

Figure 1: Artist's rendition of the HAT-P-7 system. We used the Subaru Telescope to discover the retrograde planet (nearest the central star), another giant planet (in the foreground), and a companion star (upper right) in this system.

References

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3D Dissipation Mechanism in Fast Magnetic Reconnection

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Magnetic reconnection is a promising process which provides efficient energy release in solar flares and geomagnetospheric substorms. The process is also considered be important in fusion devices because it can disturb the plasma confinement due to the magnetic field. The efficient energy release of the magnetic field requires a locally intense electric resistivity. However, the generation mechanism of the resistivity has been poorly understood in collisionless reconnection. The difficulty in understanding the dissipation processes is attributed to the nonlinear and multi-scale nature of magnetic reconnection. The dissipation takes place in a microscopic region where the plasma kinetics is significant, while it can have an impact on large-scale processes in macroscopic region where the fluid approximation is valid. On the other hand, large-scale field line topology also affects the kinetic processes in the microscopic region. Therefore, in order to reveal the dissipation mechanism in magnetic reconnection, it is necessary to describe self-consistently both the kinetic process in microscopic region and the fluid dynamics in macroscopic region.

It has been demonstrated that 2D magnetic reconnection is supported by an effective resistivity termed the inertia resistivity which is caused due to the electrons accelerated in a finite time near the x-line. However, the *in-situ* observations in the geomagnetosphere and laboratory experiments have indicated that the current layer is not so thin as expected in the 2D model, and have detected active electromagnetic (EM) waves, which implys the importance of the anomalous dissipation (e.g., [1]).

The present study has investigated the 3D dissipation mechanism in a fast magnetic reconnection by using the large-scale particle-in-cell (PIC) simulations. The PIC model in this study employs the adaptive mesh refinement (AMR) [2]. The ion-to-electron mass ratio is 100. The number of the particles used reaches 10^{11} totally, and the maximum spatial resolution is $4096 \times 512 \times 4096 = 10^{10}$ [3]. Figure 1 shows a 3D snapshot around the x-line during the fast reconnection. It is found that an EM mode is excited around the x-line and kinks the electron current layer. The linear analysis indicates that the mode is a new-type shear mode excited due to the velocity shear across the current layer rather than the classical drift mode driven by the ion-electron relative velocity. Furthermore, it is confirmed that the mode is unstable even for the realistic mass ratio.

Figure 2 shows the anomalous momentum transport of the electrons due to the EM turbulence. One can see that the anomalous transport due to the shear driven mode is dominant in the localized region around the x-line. Since the reconnection electric field is $E_y \approx 0.1$, the estimated contribution to the magnetic dissipation of the anomalous transport is about 50 % in the fast magnetic reconnection. In particular, it is found that the anomalous transport is enhanced in association with the plasmoid (flux rope) formations.

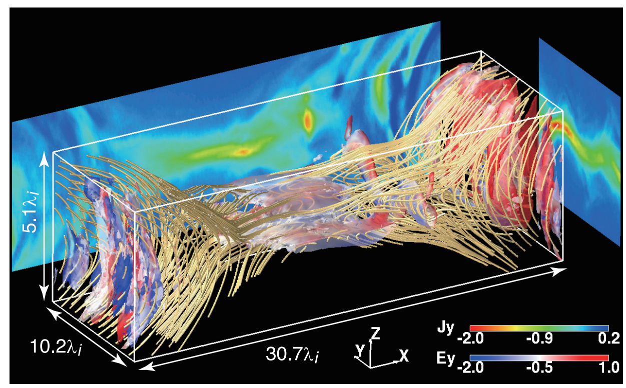

Figure 1: 3D snapshot around the x-line during the fast magnetic reconnection of an isosurface for $|J|/en_0V_A = 0.4$ colored by Ey with the magnetic field lines in yellow curves and 2D profiles of J_y.

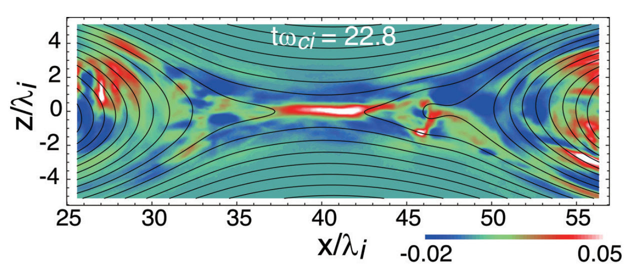

Figure 2: Anomalous momentum transport of the electrons due to the EM turbulence $\langle \delta(n_e\vec{V}_e) \times \delta\vec{B} \rangle / \langle n_e \rangle$, where $\langle \cdot \rangle$ indicates the average over y axis.

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Power Spectral Analysis of the Magneto-Convection on the Solar Surface with HINODE SOT

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Interaction between the thermal convection and magnetic fields creates structures over various spatial scales, such as sunspots (10^4–10^5 km) and fine magnetic flux tubes (~100 km). It is quite important to investigate the transfer of kinetic and magnetic energies among the convection and magnetic fields at various spatial scales for understanding how the magnetic structures are created on the solar surface. In order to quantify it, we performed power spectral analysis of surface temperatures, velocities, and magnetic fields, using spectro-polarimetric data taken with the HINODE Solar Optical Telescope (SOT). Because of the stable image quality as well as accurate polarimetric measurements, we could successfully obtain power spectra of the surface convection at the spatial scale smaller than granules with enough reliability for the first time by characterizing influence of the telescope's angular resolution and noises.

The kinetic (temperatures' and velocities') power spectra have a prominent peak at the granular scale (~1000 km, Fig. 1 top), which indicates injection of the kinetic energy occurs at that scale. At the spatial scale smaller than granules, the power spectra show power-law like spectra whose power-law indices are −4 – −3. The spectra are significantly steeper than the Kolmogorov's −5/3 for isotropic turbulences. It has not been understood why the slope is so steep on the solar surface.

The magnetic power spectra are created in low magnetic flux regions (Fig. 1 top) and high flux regions (Fig. 1 bottom), separately. In the low flux regions (< 10 gauss), the magnetic spectra exhibit a peak at around the granular scale (~800 km) and power-law like spectra whose indices are about −1.3 at the sub-granular scale. A MHD numerical simulation of the surface magneto-convection suggests that small-scale magnetic fields are created at the scale smaller than the HINODE resolution by local dynamo action, and they have more impacts on the overall magnetic energy budgets than the magnetic fields resolved with HINODE. The power spectra based on the Hinode observation imply, on the other hand, that magnetic energies coming from the granular-scale structures are more important than the structures of the unresolved scale. The magnetic spectra are less steep than the kinetic ones at the sub-granular scale, and the power-law indices differ by about 2, which can be interpreted that magnetic structures are created by velocity shear of the surface convection. In the high flux regions (> 50 gauss), the power-law indices of the kinetic and magnetic power spectra become similar. This is probably due to strong coupling of the convection and magnetic fields at each spatial scale. Comparison with MHD numerical simulations of the surface magneto-convection is expected to provide deeper insights on how the magnetic structures are created as a next step.

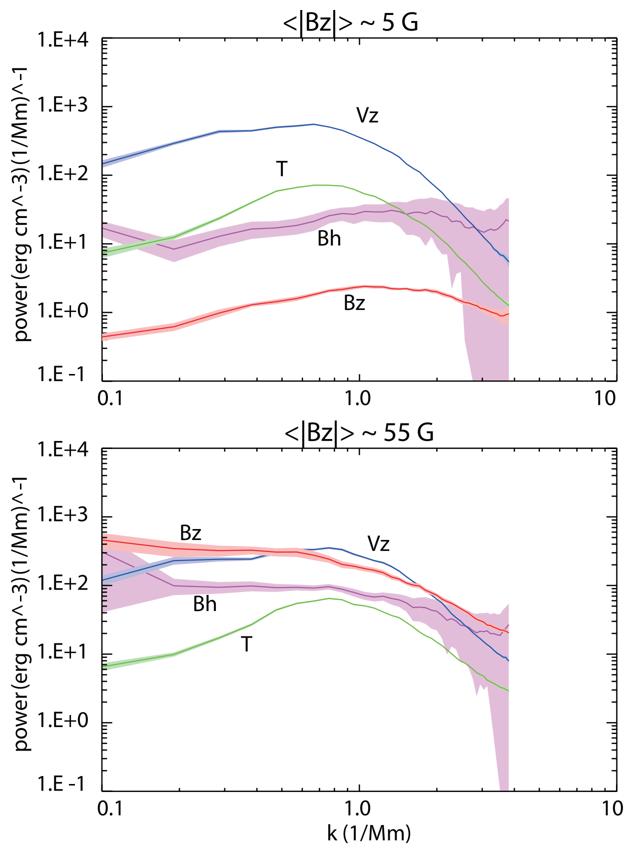

Figure 1: Kinetic and magnetic power spectra of the granular convection on the solar surface derived with HINODE SOT in low and high flux regions (top and bottom, respectively).

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Astrophysical Impact of New β-decay Half-lives on *r*-process Nucleosynthesis [1]

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Rapid neutron capture process (*r*-process) is responsible for the origin of approximately half of the elements heavier than iron. Despite of several decades of theoretical studies and observational progress, the astrophysical sites for *r*-process nucleosynthesis are unknown.

Physical conditions for the *r*-process are well constrained. It is evident that the *r*-process occurs via a sequence of rapid neutron captures on neutron-rich isotopes far from stability. The relative abundance of *r*-process elements is then determined by the relative β-decay rates along this *r*-process path, i.e., slower β-decay lifetimes result in higher abundances.

In this context, it is of particular interest that β-decay half-lives of 38 neutron-rich isotopes including ^{100}Kr, $^{103\text{–}105}$Sr, $^{106\text{–}108}$Y, $^{108\text{–}110}$Zr, ^{111,112}Nb, $^{112\text{–}115}$Mo, and ^{116,117}Tc have been measured at the recently commissioned radioactive isotope beam factory (RIBF) facility at the RIKEN Nishina Center [2]. Newly measured lifetimes are an improvement on existing measurements and a number of them were measured for the first time.

We performed nucleosynthesis calculations for ejecta from the MHD supernova model [3] with the three different reaction networks. These are extensions of the basic network described in [3,4]. First, we adopt FRDM theoretical rates [5] from the REACLIB compilation [6] as standard. The other two (RIBF and RIBF+) utilize the new experimental β-decay half-lives and two versions of the theoretical FRDM β-decay rates for the other isotopes. The RIBF network replaces the FRDM rates with the new measured ones where possible. The network (RIBF+) is based on the RIBF network and FRDM rates with modified Q values for (n, γ) for $A = 97\text{–}115$ isotopes based on the new suggested masses.

Figure 1 shows the final abundance distribution with the solar system abundances [7]. The newly measured β-decay rates in this mass region might shift the β-flow equilibrium thereby filling in the low abundances near $A \sim 120$. The abundances in the $A = 110\text{–}120$ region however are only slightly enhanced. Although the new rates provide a little assistance in enhancing the abundances near the valley, they do not alleviate this problem.

We note that the *r*-process ow moved farther away from stability and proceeded faster in the RIBF+ network in which the (n, γ) Q values were systematically enhanced for isotopes with $A = 104\text{–}115$. This helped to fill in the abundances in the higher mass region with $A \geq 115$. Thus, it is important to measure the masses and/or neutron separation energies in this region.

Furthermore, our results suggest that nucleosynthesis in the LEPP (light-element primary process) elements with $A \leq 120$ observed in some ultra-metal-poor stars [8], also is sensitive to the nuclear physics uncertainty from β-decay rates in this region. Hence, further studies on both the nuclear physics and astrophysics of the synthesis of elements with $A \sim 110\text{–}120$ are warranted.

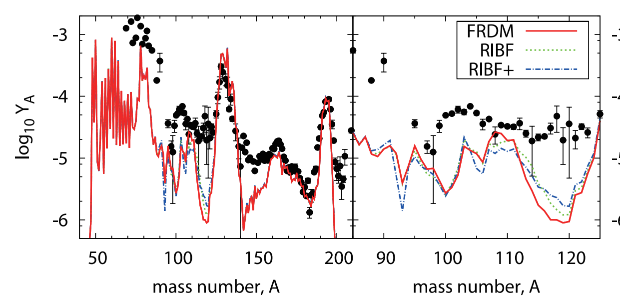

Figure 1: Total final abundance distributions of *r*-process elements from the adopted MHD supernova model with observed solar system abundances (black dots, taken from [7]). Red solid, green dotted, and blue dashed lines correspond to results from using the FRDM (standard), RIBF, and RIBF+ rates, respectively.

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Solution to Big-Bang Nucleosynthesis in Hybrid Axion Dark Matter Model

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The primordial ^{7}Li abundance predicted in standard big bang nucleosynthesis (BBN) model for the baryon-to-photon number ratio η determined from the cosmic microwave background observations is significantly more than those observed in old halo stars [1,2]. Recently a new solution to the lithium puzzle was proposed, which is a mechanism for the cooling of photons in the epoch between the end of BBN and the last photon scattering. An axion, one of candidates for the dark matter could form a Bose-Einstein condensate (BEC) and may have cooled the photons in the epoch [3]. The baryon-to-photon ratio would then be smaller in BBN epoch ($\eta = 4.6\times10^{-10}$ [3]) than that measured by WMAP ($\eta = 6.2\times 10^{-10}$ [4]). In the cooling model, however, the deuterium (D) abundance and the effective number of neutrinos are too high although the ^{7}Li abundance agrees with observations.

Nonthermal photons can be generated through electromagnetic energy injections by the radiative decay of long-lived particles after the BBN epoch. Long-lived particles are motivated by particle physics beyond the standard model. These nonthermal photons can photodisintegrate background light elements. Effects of energy injection depend on two parameters. One is $\zeta_X = (n_X^0/n_\gamma^0)E_{\gamma0}$ where (n_X^0/n_γ^0) is the number ratio of the decaying particle X and the background radiation before the decay of X, and $E_{\gamma0}$ is the energy of photon emitted at the radiative decay. The other is τ_X, the lifetime of X.

We calculated BBN in a hybrid axion and decaying exotic relic particle model in which the axion cools the photons and the particle produces nonthermal photons to eliminate the high D abundance in the original axion BEC model. We compared results with observational constraints on primordial nuclear abundances.

We also utilize a limit on the sum of primordial abundances of D and ^{3}He taken from an observational abundance for the protosolar cloud, i.e., (D+^{3}He)/H=$(3.6\pm0.5)\times10^{-5}$ [5]. This abundance can be regarded as constant at least within the standard cosmology since it is not affected by stellar activities significantly despite an effect of D burning into ^{3}He via ^{2}H(p, γ)^{3}He would exist [6]. We thus showed that the constraint on (D+^{3}He)/H abundance excludes the original axion BEC model.

We found a narrow parameter region in which calculated abundances of all nuclides including D and ^{7}Li are simultaneously in ranges of adopted observational constraints. We conclude that the present model eliminates the main drawback of the original axion BEC model by reducing primordial D abundance via ^{2}H(γ, n)^{1}H reaction, where γ's are nonthermal photons. We note that the decaying X particle model with the WMAP η value cannot resolve the ^{7}Li problem by itself [7].

Figure 1 shows a result of a BBN calculation in our hybrid model [8]. The small difference at $T_9 \gtrsim 0.06$ observed between solid and dashed lines is caused by difference between initial η values. At $0.06 \gtrsim T_9 \gtrsim 7\times10^{-3}$, effects of ^{2}H($\gamma$, n)^{1}H are seen in the decrease of D and the increase of n abundances. We find a slight decrease in ^{7}Be abundance caused through reactions ^{7}Be(γ, ^{3}He)^{4}He, ^{7}Be(γ, p)^{6}Li, and ^{7}Be(γ, 2pn)^{4}He. The second reaction increases the ^{6}Li abundance. Finally, at $T_9 \lesssim 7\times10^{-3}$, when the abundance of long-lived X particle is already less than 3 % of the initial abundance, effect of ^{4}He photodisintegration is to increase ^{3}H and n abundances.

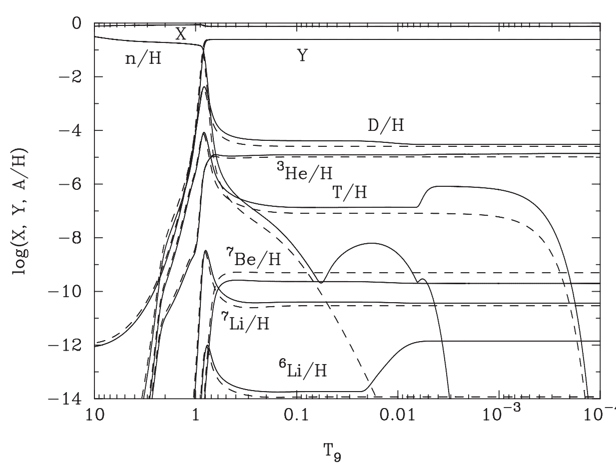

Figure 1: Mass fractions of H and ^{4}He (X_p and Y_p, respectively) and number ratios of other nuclides relative to H as a function of $T_9 \equiv T/(10^9\,\mathrm{K})$. Solid lines show the abundances in the hybrid model with the parameters $(\tau_X, \zeta_X)=(10^6\,\mathrm{s}, 2\times10^{-10}\,\mathrm{GeV})$ which predict primordial abundances consistent with all observations. The dashed lines show the standard BBN prediction. This is reprinted from [8].

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Supernova-, Solar- and Reactor-Neutrino Detection and Precise Theoretical Calculation of Neutrino Capture Cross Section on ^{13}C [1]

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The natural abundance of ^{13}C is 1.07 % in carbon isotopes. As the threshold for charged-current reactions on ^{12}C is slightly more than 13 MeV, ^{13}C is an attractive target to detect very low-energy neutrinos. The background is from supernova and ^{8}B solar neutrinos. In scintillator-based experiments, ^{13}C may be useful to sort out uxes of various avors from supernovae.

A new shell-model Hamiltonian for p-shell nuclei, SFO [2], is used to evaluate neutrino cross sections on ^{13}C. With this new Hamiltonian the magnetic properties of p-shell nuclei are considerably improved compared to conventional Hamiltonians such as Cohen-Kurath (CK) Hamiltonian [3]. Here, we study neutrino-nucleus reactions, which are induced mainly by excitations of Gamow-Teller and spin-dipole states as well as isobaric analog states. The SFO Hamiltonian, which was constructed for use in the p-sd shell configurations including up to 2–3 $\hbar\omega$ excitations, can describe well the magnetic moments of p-shell nuclei systematically and Gamow-Teller (GT) transitions in ^{12}C and ^{14}C with a small quenching for spin g-factor and axial-vector coupling constant: i.e., $g_A^{eff}/g_A = g_s^{eff}/g_s = 0.95$. In case of CK, where configuration space is restricted to within p-shell, a large quenching factor of $g_A^{eff}/g_A = 0.69$ is used. The exclusive cross sections, ^{12}C (ν_e, e^-) ^{12}N ($1^+_{g.s.}$), obtained by shell-model calculations with SFO and CK are are shown in Fig. 1 together with the experimental values. The SFO is found to reproduce the experimental values very well. The cross sections for SFO are enhanced compared with those for CK.

The charged-current cross sections leading to various states in the daughter ^{13}N and the neutral-current cross sections leading to various states in the daughter ^{13}C are obtained with the use of SFO [1]. Simple polynomial fits to those cross sections are also provided for quick estimates of the reaction rates (see Ref. [1]). In Fig. 2, cross sections induced by Gamow-Teller and isobaric analog transitions are compared between SFO and CK. The SFO give larger cross sections compared with CK [4].

One possible application of these cross sections could be to search for electron neutrino appearance in the reactor antineutrino ux and determine the mass hierarchy [5], being free from supernova and solar neutrino background. Ideally one would like to be as close to the reactors as possible much like experiments searching for the neutrino magnetic moment. However, in this case reactor neutrino ux uncertainties can be sizable. This is also true for the energy-integrated count rate, which is between 5.2 and 13.0 MeV. One possible way to reduce such uncertainties is to use much more abundant electron antineutrinos to estimate the reactor flux. This can be achieved using neutral-current scattering.

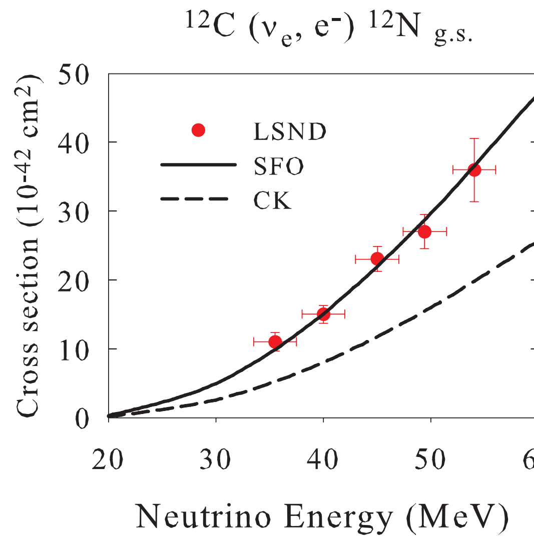

Figure 1: The exclusive cross sections for ^{12}C (ν_e, e^-) ^{12}N ($1^+_{g.s.}$) in shell-model calculations with SFO and CK.

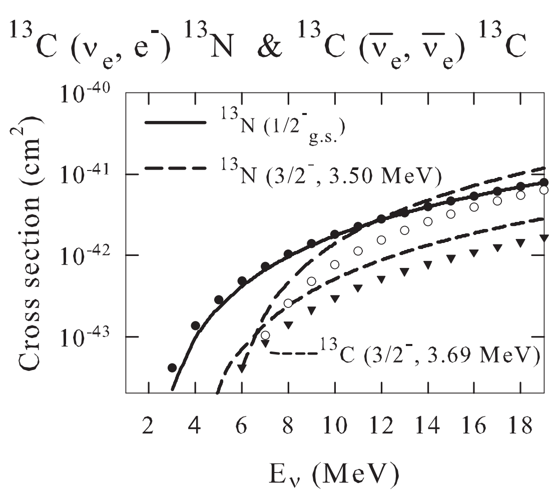

Figure 2: Calculated charged-current cross sections for ^{13}C (ν_e, e^-)^{13}N to the ground ($1/2^-$) and $3/2^-$ (3.502 MeV) states and neutral-current cross sections for ^{13}C ($\bar{\nu}_e$, $\bar{\nu}_e$')^{13}C to $3/2^-$ (3.685 MeV) state with SFO. Calculations with CK are indicated by circles anf triangles.

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Subaru Imaging of Asymmetric Features in a Transitional Disk in Upper Scorpius

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We report high-resolution (0.07 arcsec) near-infrared polarized intensity images of the circumstellar disk around the star 2MASS J16042165-2130284 obtained with HiCIAO mounted on the Subaru 8.2 m telescope [1]. We present our *H*-band data, which clearly exhibits a resolved, face-on disk with a large inner hole for the first time at infrared wavelengths (Figure 1). We detect the centrosymmetric polarization pattern in the circumstellar material as has been observed in other disks. Elliptical fitting gives the semimajor axis, semiminor axis, and position angle of the disk as 63 AU, 62 AU, and −14°, respectively. The disk is asymmetric, with one dip located at position angles of ~85°. Our observed disk size agrees well with a previous study of dust and CO emission at submm wavelength with SMA. Hence, the near-infrared light is interpreted as scattered light reflected from the inner edge of the disk. We discuss the possibility that the asymmetric features which we have observed may be related to the existence of unseen bodies within the disk.

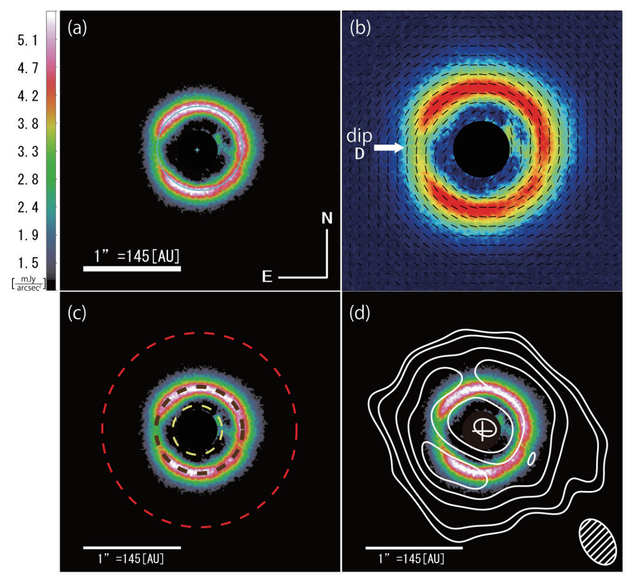

Figure 1: *H*-band HiCIAO images of J1604-2130. The saturated central area (radius = 0″.2) is masked in black. (a): the *PI* image of J1604-2130. The field of view (FOV) is 2″.9 ×2″.9. The unit of the color bar is mJy/arcsec^2. The light blue ellipse and plus sign are the best fit result of our elliptical disk model and the ellipse center. (b): *H*-band polarization vectors super-posed on the *PI* image. The vector directions indicate angles of polarization. The plotted vectors are based on 7 [pixel] × 7 [pixel] binning corresponding to the spatial resolution. The FOV is 2″.0×2″.0. The vector's lengths are arbitrary. (c): Red (r = 145 AU), brown (r = 63 AU), and yellow (r = 33 AU) circles superimposed on the *PI* image. (d): SMA 880 μm continuum map [2] superimposed on the *PI* image. White color contours indicate 2, 3, 6, 9, and 12σ intensity (1σ = 1.3 mJy/beam). The ~0″.5×0″.3 beam of SMA is shown in the bottom right.

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The Detection of C_{60} in the Well-Characterized Planetary Nebula M1-11

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We performed multiwavelength observations of the planetary nebula (PN) M1-11 and we obtained its elemental abundances, dust mass, and the evolutionary status of the central star.

Using Subaru/HDS, OAO/ISLE, and *Spitzer*/IRS spectra, we detected over 220 emission lines and we detemined the eleven elemental abundances. Our determined elemental abundances are in excellent agreement with a nucleosynthesis model for initially 1.5 $M_\odot$ stars with the metallicity $Z = 0.004$.

The *AKARI*/IRC, VLT/VISIR, and *Spitzer*/IRS spectra show features due to carbon-rich dust, such as the 3.3, 8.6, and 11.3 μm features due to polycyclic aromatic hydrocarbons (PAHs), a smooth continuum attributable to amorphous carbon, and the broad 11.5 and 30 μm features often ascribed to SiC and MgS, respectively. We also reported the presence of an unidentified broad feature at 16–22 μm, similar to the feature found in Magellanic Cloud PNe with either C-rich or O-rich gas-phase compositions. We identified for the first time in M1-11 spectral lines at 8.5 (blended with PAH), 17.3, and 18.9 μm that we attribute to the C_{60} fullerene (Fig. 1). Using the detected C_{60} lines, we determined the C_{60} mass (2.75 $\times 10^{-8}\ M_\odot$) and temperature (399 K) in M1-11.

Using the radiative transfer code Cloudy, combined with a modified blackbody, we have fitted the ~0.1–90 μm spectral energy distribution (SED) and determined physical properties of the central star and the ionized gas and dust masses (Fig. 2). Our chemical abundance analysis and SED model suggest that M1-11 is perhaps a very young C-rich PN (~1000 yrs), and that it evolved from a ~1.5 $M_\odot$ star.

The obtained values in M1-11, namely, the C_{60} mass and temperature, the elemental composition of the gas in the nebula, the mass of the progenitor star, and the evolutionary status, are very similar to those seen in other C_{60} containing PNe.

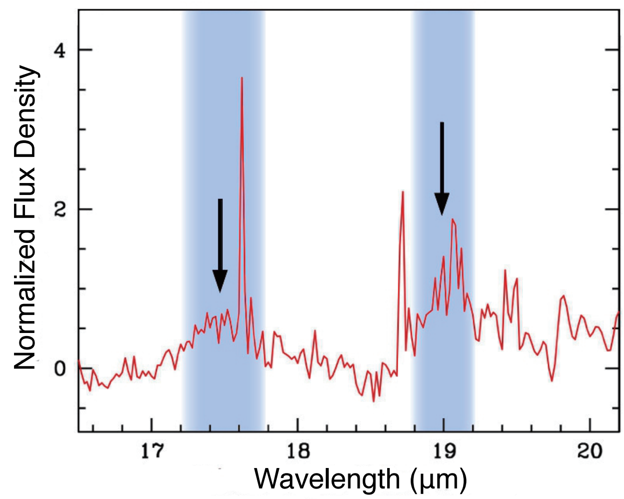

Figure 1: Detection of C_{60} bands in M1-11. Arrows indicate the positions of the 17.3 μm and 18.9 μm C_{60} bands.

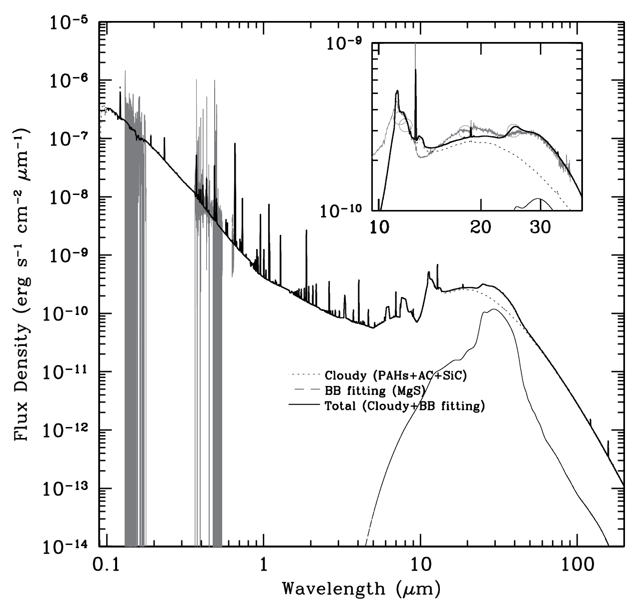

Figure 2: The fitted SED from the Cloudy modeling (dots) and the modified blackbody fitting (long dash) and the resultant SED (thick black line). The gray circles and lines are the observed data. In the Cloudy model, we considered PAHs, amorphous carbon (AC), and SiC. The modified blackbody fitting is performed for MgS only. The close-up feature of the observed and fitted SEDs around 10–40 μm are presented in the inner box.

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Exploring the Neutrino Mass Hierarchy Probability with Meteoritic Supernova Material, ν-Process Nucleosynthesis, and θ_{13} Mixing [1]

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Oscillations in the three-neutrino flavor mixing scenario are described by three angles θ_{12}, θ_{23}, and θ_{13} plus a CP-violating phase δ_{CP}. Solar, atmospheric, and reactor neutrino oscillation measurements have provided information on the neutrino mass differences, i.e $\Delta m_{12}^2 \equiv |m_1^2 - m_2^2| = 0.000079\,\mathrm{eV}^2$ and $\Delta m_{13}^2 \approx |\Delta m_{23}^2| \approx 2.4 \times 10^{-3}\,\mathrm{eV}^2$. These measurements, however, are unable to determine the mass hierarchy, i.e. whether $\Delta m_{23}^2 > 0$ (normal) or $\Delta m_{23}^2 < 0$ (inverted) is the correct order. Also, solar, atmospheric and reactor neutrino oscillation experiments have determined θ_{12} and θ_{23} to reasonable precision. However, only recently have measurements of θ_{13} become available. The best current measurements [with $\delta_{CP} = 0$ and $\theta_{23} = \pi/4$] is from the the Daya Bay experiment that has reported $\sin^2 2\theta_{13} = 0.092 \pm 0.016(\mathrm{stat}) \pm 0.005(\mathrm{syst})$ [2], This is also consistent with the previously reported lower limit and upper limits to θ_{13} from the T2K collaboration [2] of $0.03(0.04) < \sin^2 2\theta_{13} < 0.28(0.34)$. These results, however, do not yet determine whether the normal or inverted hierarchy is the correct ordering of mass eigenstates.

In this context it is noteworthy that the synthesis of ν-process elements ^{7}Li and ^{11}B in core collapse supernovae is sensitive to the neutrino mass hierarchy and θ_{13}. Previous studies [3] pointed out that for a finite mixing angle $\theta_{13} > 0.001$ the relative synthesis of ^{7}Li and ^{11}B in the ν-process is sensitive to the mass hierarchy. Since $\theta_{13} > 0.001$ is indeed implied by the Daya Bay +RENO + Double Chooz results to better than the 5σ C.L., we could reconsider the supernova ν-process as a means to constrain the neutrino mass hierarchy. The width of the shaded region of Figure 1 shows the current constraints on the θ_{13} mixing compared with the extended results of ^{7}Li and ^{11}B nucleosynthesis from [3].

Moreover, there has also been a recent possible discovery [4] of ν-process ^{7}Li and ^{11}B supernova material in SiC X grains from the Murchison meteorite. The top of the shaded region on Figure 1 shows the 1σ upper limit to the ^{7}Li/^{11}B ratio from that study. The goal of this paper was to examine the likelihood of one neutrino mass hierarchy over another in a Bayesian statistical analysis that took proper account of all of the supernova model uncertainties as well as the measurement uncertainties of the SiC X grains and the θ_{13} limits. In our five dimensional Bayesian analysis we found that there is a preference for an inverted hierarchy at the level of 74 %/26 % compared to a prior expectation of 50 %/50 %.

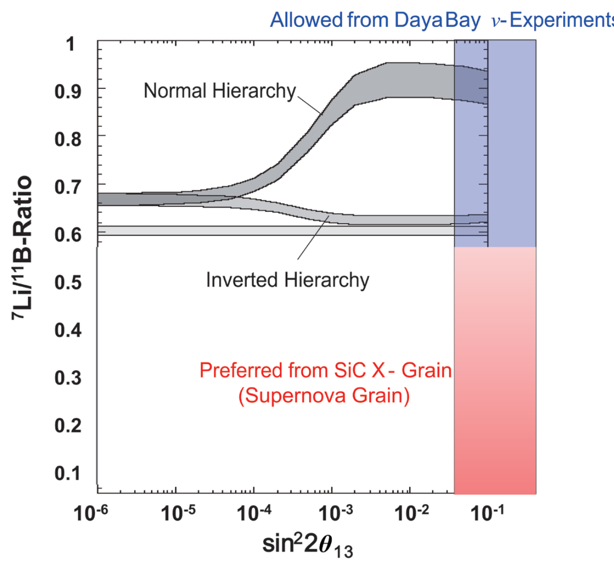

Figure 1: Produced ^{7}Li/^{11}B abundance [3] as a function of mixing angle for both a normal and inverted neutrino mass hierarchy. This ratio varies in models with different neutrino temperatures in the range indicated by the lower and upper solid lines. The width of the blue shaded region indicates the 2σ confidence limits to $\sin^2(2\theta_{13})$ from the Daya Bay result [2]. The red shaded region is the 1σ upper limit on the observed ν-process ^{7}Li/^{11}B ratio as deduced here from the SiC X grains. This is reprinted from [1].

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Substellar-Mass Condensations in Prestellar Cores

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We present combined Submillimeter-Array (SMA) + single-dish images of the (sub)millimeter dust continuum emission toward two prestellar cores SM1 and B2-N5 in the nearest star cluster forming region, ρ Ophiuchus. Our combined images indicate that SM1 and B2–N5 consist of three and four condensations, respectively, with masses of 10^{-2}–$10^{-1}\,M_{\odot}$ and sizes of a few hundred AU. The individual condensations have mean densities of 10^{8}–$10^{9}\,\mathrm{cm}^{-3}$ and the masses are comparable to or larger than the critical Bonner-Ebert mass, indicating that the self-gravity plays an important role in the dynamical evolution of the condensations. The coalescence timescale of these condensations is estimated to be about 10^{4} yr, which is comparable to the local gravitational collapse timescale, suggesting that merging of the condensations, instead of accretion, plays an essential role in the star formation process.

These results challenge the standard theory of star formation, where a single, rather featureless prestellar core collapses to form at most a couple of condensations, each of which potentially evolves into a protostar that is surrounded by a rotating disk where planets are created.

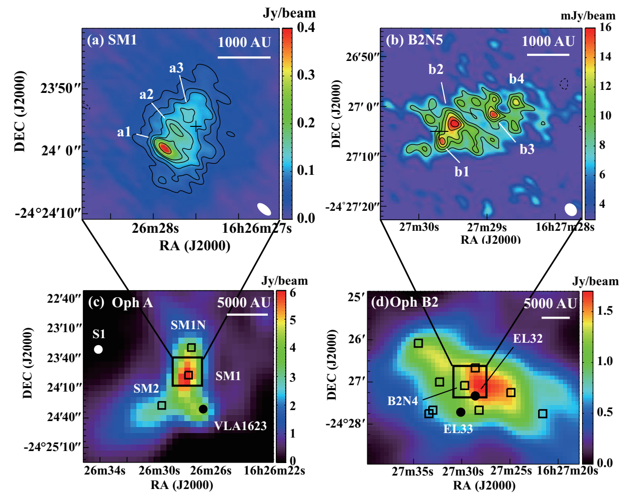

Figure 1: (a) Combined SCUBA and SMA image toward SM1. The contour levels are −20, 60, 80, 100, 130, 160, and 320 mJy/beam. The cross is the position of SM1 identified by Motte et al. (1998). The alphabets designate the identified condensations. (b) Combined AzTEC/ASTE and SMA image toward B2–N5. The contour levels are −3, 8, 10, 12, 14, and 16 mJy/beam. The cross is the position of B2-N5 identified by Friesen et al. (2010). (c) the SCUBA 850 μm continuum image toward the Oph A region (Johnstone 2000). The white and black filled circles are the B star, S1, and the prototypical Class 0 YSO, VLA 1623, respectively. The positions of some submillimeter continuum sources are indicated by the squares (Motte et al. 1998). (d) the AzTEC/ASTE 1.1 mm continuum image toward the Oph B2 region. The black filled circles are the positions of Class I YSOs, EL32 and EL33. In panels (a) and (b), the synthesised beams are shown in the lower right of the panels.

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Early Galactic Chemical Evolution and *r*-Process Nucleosynthesis in Black-Hole Forming Supernovae [1]

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Extremely metal-poor (EMP) halo stars are early generations of stars whose elemental abundances reflect the interstellar gas compositions of the early Galaxy. Compilations of abundances of neutron-capture elements in EMP stars indicate that Sr and Ba show a clear cutoff in the distribution of [Sr/Ba] at [Fe/H] ~ −3.6 and an upper bound as a function of [Fe/H] as well as a lower bound at [Sr/Ba] ~ −0.5 as shown in the upper Fig. 1 [2].

Our recent model [3] was developed in which the collapses of type II supernovae (SNe) are found to reproduce many of these features seen in the data. We point out that the cutoff at [Fe/H] = −3.6 for [Sr/Ba] > 0.0 data can be explained by the truncated r-process, that is, by the collapses to black holes over a fairly wide mass range of progenitor stars. Furthermore, the results of our GCE calculations can predict the upper bound in [Sr/Ba] in these data. Effects of turbulence in an explosive site have also been simulated, and are found to be important in explaining the large scatter observed in the [Sr/Ba] data [1]. See the lower Fig. 1.

A fascinating aspect of this work is the possibility that observed minima in [Ba/Fe], [Sr/Fe], and [Sr/Ba] may be directly related to the stiffness of the nuclear EOS. The lower limit of [Ba/Fe] as a function of metallicity predicted in our model can be reproduced in a GCE model assuming a contribution to r-process elements from black holes produced in fallback SNe. The softer the equation of state (EOS), the lower the calculated [Ba/Fe] as a function of [Fe/H]. Thus the observed lower limit in [Ba/Fe] as a function of metallicity appears to constrain the lower limit of the stiffness of the EOS.

While astronomical observations of neutron star masses are able to predict a lower limit of the stiffness of the EOS, this model suggests a new method of determining the upper limit [4].

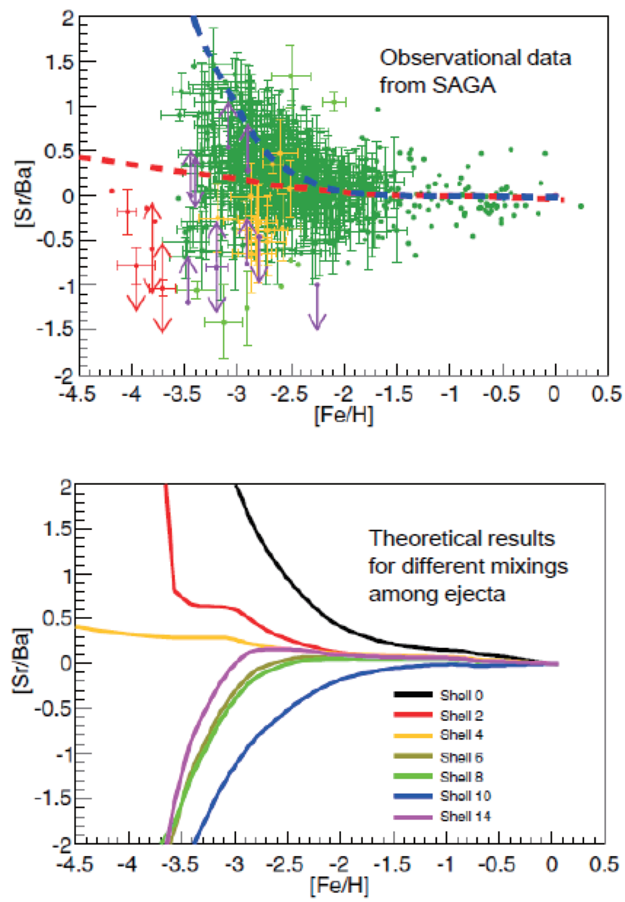

Figure 1: Upper: The calculated results for [Sr/Ba] assuming a truncated black-hole forming r-process. The red dashed line corresponds to a GCE model without production in a truncated r-process, while the blue dashed line corresponds to a GCE model with a primary production from this r-process for all stars with $M \geq 20\,M_{\odot}$. Lower: The GCE results for single-site truncated rprocess production for turbulent ejection of specific shells assuming only those shells are ejected. From shell 0 toward shell 14, each colored line indicates calculated [Sr/Ba] with the mixing for deeper shell.

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High-Lying Excited States in Gamow Teller Strength and Their Roles on Neutrino Reactions

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The Gamow Teller (GT) transition strengths deduced from charge exchange reactions (CEXRs) are very helpful for understanding the nuclear reaction induced by the solar neutrino. For further study of supernovae (SNe) neutrinos in the cosmos, one needs to study high-lying GT states around a few tens of MeV region as well as other multipole transitions because of the high energy tail in the neutrino spectra emitted from the neutrino sphere. In this report, we address the importance of the high-lying GT excited states, which data now become available from various CEXR experiments. For example, the GT(±) strength up to 70 MeV are successfully extracted by ^{90}Zr(n, p) and ^{90}Zr(p, n) reactions [1].

Our discussions are extended to investigate roles of the high-lying states beyond a few low-lying states known in the old experiment on the reaction induced by SNe neutrinos particularly on ^{40}Ar target. The nucleus was originally exploited to identify the solar neutrino emitted in the pp-chain, and now lots of applications for more energetic neutrino detection are under progress. Expected large difference between the cross sections of ν_e and $\bar{\nu}_e$ reactions on ^{40}Ar, which difference were anticipated because of the large Q value in the $\bar{\nu}_e$ reaction, is significantly diminished compared to previous results. Our calculations are carried out by the Quasiparticle Random Phase Approximation (QRPA), which takes the neutron-proton pairing into account to the standard proton-neutron QRPA (pnQRPA) where only proton-proton and neutron-neutron pairing correlations are considered.

First, we compare our theoretical results to recent experimental GT(∓) strength distribution data [1] which were deduced by the multipole decomposition (MD) technique from ^{90}Zr(p, n) at the bombarding energy 295 MeV and ^{90}Zr(n, p) at 293 MeV reactions. In such a high energy region, the $\Delta L = 0$ contribution from the isovector spin monopole (IVSM) can be included around 35 MeV region in the GT strength. By extracting $\Delta L = 0$ IVSM contribution with the MD technique, they succeed to obtain the ISR value about 90 %.

In Fig. 1, we show the GT strength distributions and their running sums by the the QRPA. The GT strengths are clearly redistributed by the np pairing in the QRPA. If we compare to the experimental data [1], two peak positions around 3(9) and 10(16) MeV regions w.r.t ^{90}Nb (^{90}Zr) are well reproduced in the QRPA. This result is also consistent with previous results by the Dressed RPA. Also the quenching factor data related to total running sums, $Q = (S_- - S_+)/(3(N-Z)) = 0.90 \pm 0.05$ or 0.88 ± 0.06 [1], are almost reproduced by our results 0.96, although strength shapes are a bit different from the experimental data. Since only the GT states are considered in this work, our results beyond 20 MeV are not presented in Fig. 1. Detailed discussion are done at Ref. [2].

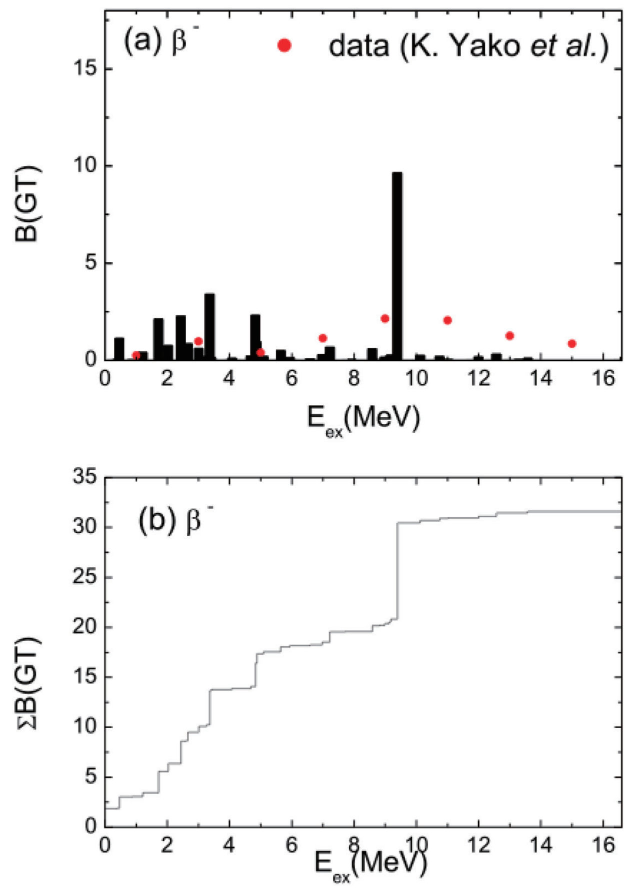

Figure 1: GT(−) strength distributions and their running sums for ^{90}Zr by the QRPA. Experimental data [1] are denoted as red points by subtracting the experimental Q value between ^{90}Zr and ^{90}Nb.

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Neutrino Induced Reactions Related to the ν-Process Nucleosynthesis of ^{92}Nb and ^{98}Tc [1]

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The neutrino (ν) process involves ν-induced reactions on various nuclei during core collapse supernovae (SNe). Huge numbers of neutrinos are emitted from a proto-neutron star in early phase of the SN. Most neutrinos escape into the space, but a small fraction of neutrinos transfer their energy to materials in outer layer of star by neutrino-nucleus interactions. This process has been proposed as the origin of some rare isotopes of light and heavy elements.

Among the many heavy elements, only the two isotopes ^{138}La and ^{180}Ta are currently thought to be synthesized primarily by the ν-process [1]. These two isotopes have similar features: they cannot be produced by either β^+, EC, or β^- decays because they are shielded against these decays.

In principle, any nuclide can be synthesized by the ν-process in SN explosions. The produced abundances, however, are usually negligibly small because of the weak interaction. Thus, the ν-process can only play a dominant role in the case of very rare isotopes that cannot be produced by other means.

In a recent work [2], we pointed out that the nuclear chart around ^{92}Nb and ^{98}Tc is quite similar to that of ^{138}La and ^{180}Ta. Although both nuclei are unstable, their half-lives are long enough to be observed on stellar surfaces or to be incorporated into meteorites.

The isotopic abundance ratio of ^{92}Nb/^{93}Nb is known to be ~ 10^{-3}–10^{-5}. This is comparable to the isotopic rations for ^{138}La/^{139}La and ^{180}Ta/^{181}Ta. An evidence of the extinct unstable isotopes of Tc has been investigated, but it has not been found yet. This suggests the abundance of ^{98}Tc is small compared with a detection limit. Therefore, it has been proposed that the two nuclei ^{92}Nb and ^{98}Tc may have a ν-process origin.

The nuclear structure of ^{92}Nb and ^{98}Tc are key ingredients for this calculation. Our scheme for describing such excited states makes use of the standard quasi-particle random phase approximation (QRPA). For the NC reactions, we generate the ground and excited states of the odd-even target nuclei, ^{93}Nb and ^{99}Ru, by applying the quasi-particle operators to the even-even nuclei, ^{92}Zr and ^{98}Ru, which are treated as the BCS ground state.

In table 1, we tabulated main relevant neutrino-induced reactions and averaged cross sections for the typical (averaged) neutrino energy given by the ν temperature used in our calculations of nucleosynthesis [2].

Reactions	$< E_k >$ [MeV]	T [MeV]	$< \sigma >$
^{98}Mo$(\nu_e, e^-)^{98}$Tc	10.08	3.2	7.77
^{98}Mo$(\nu_e, e^- p)^{97}$Mo	10.08	3.2	1.90
^{98}Mo$(\nu_e, e^- n)^{97}$Tc	10.08	3.2	0.09
^{99}Ru$(\bar\nu_\mu, \bar\nu'_\mu)^{99}$Ru	18.90	6.0	78.5
^{99}Ru$(\bar\nu_\mu, \bar\nu'_\mu n)^{98}$Ru	18.90	6.0	14.6
^{99}Ru$(\bar\nu_\mu, \bar\nu'_\mu p)^{98}$Tc	18.90	6.0	1.70
^{99}Ru$(\bar\nu_e, \bar\nu'_e)^{99}$Ru	15.75	5.0	52.1
^{99}Ru$(\bar\nu_e, \bar\nu'_e n)^{98}$Ru	15.75	5.0	10.5
^{99}Ru$(\bar\nu_e, \bar\nu'_e p)^{98}$Tc	15.75	5.0	0.92
^{92}Zr$(\nu_e, e^-)^{92}$Nb	10.08	3.2	8.92
^{92}Zr$(\nu_e, e^- p)^{91}$Zr	10.08	3.2	2.32
^{92}Zr$(\nu_e, e^- n)^{91}$Nb	10.08	3.2	0.42
^{93}Nb$(\bar\nu_\mu, \bar\nu'_\mu)^{93}$Nb	18.90	6.0	46.8
^{93}Nb$(\bar\nu_\mu, \bar\nu'_\mu n)^{92}$Zr	18.90	6.0	1.04
^{93}Nb$(\bar\nu_\mu, \bar\nu'_\mu p)^{92}$Nb	18.90	6.0	4.90
^{93}Nb$(\bar\nu_e, \bar\nu'_e)^{93}$Nb	15.75	5.0	30.0
^{93}Nb$(\bar\nu_e, \bar\nu'_e n)^{92}$Zr	15.75	5.0	0.60
^{93}Nb$(\bar\nu_e, \bar\nu'_e p)^{92}$Nb	15.75	5.0	3.92

Table 1: Averaged cross sections in units of 10^{-42} cm^2 for ^{98}Mo via CC and ^{99}Ru via NC, and ^{92}Zr via CC and ^{93}Nb via NC with the particle emission.

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Pulsar Kick Induced by Asymmetric Emission of Supernova Neutrinos[1]

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We studied the supernova neutrino scattering and absorption processes in strongly magnetized proto-neutron stars at finite temperature and density. We used a fully relativistic mean field theory [2] for the hadronic sector of the equation of state including hyperons. We solved the Dirac equations for all constituent particles, p, n, Λ, e, and ν, for a poloidal magnetic field with $B \sim 10^{17}$ G. We then applied the solutions to obtain a quantitative estimate of the asymmetry that emerges from the neutrino-baryon collision processes. We included the effects of distortion of the Fermi spheres made by magnetic field that implies asymmetric neutrino scattering and absorption cross-sections.

We found that the differential neutrino scattering cross sections are slightly enhanced in the arctic direction parallel to the poloidal magnetic field B in both cases with and without Λ's (Fig. 1a, c), while the differential absorption cross-sections are suppressed (Fig. 1b, d). The differential cross-sections were integrated over the momenta of the final electrons for absorption, and over the momenta of initial neutrinos for the scattering, respectively. Quantitatively, when $B = 2 \times 10^{17}$ G, the reduction for the absorption process results in about 2 %, and the enhancement for the scattering process about 1 % in the forward direction along the direction of B.

Using these cross-sections, we calculated the neutrino mean-free-paths (MFPs), and then applied to a calculation of pulsar-kicks in core-collapse supernovae. We solved the Boltzmann equation using a one-dimensional attenuation method. Our estimated pulsar-kick velocities are v_{kick} = 610 km s^{-1} or 580 km s^{-1} with or without Λ's, at T = 20 MeV. These values are in reasonable agreement with the observed average pulsar-kick velocity of v_{kick} = 400 km s^{-1}.

Realistic 3D simulation [3] of rotational magnetized proto-neutron star suggests that not only poloidal but toroidal magnetic fields are induced. We currently study the effect of of neutrino-asymmetry in spin-down phenomena of the proto-neutron star [4].

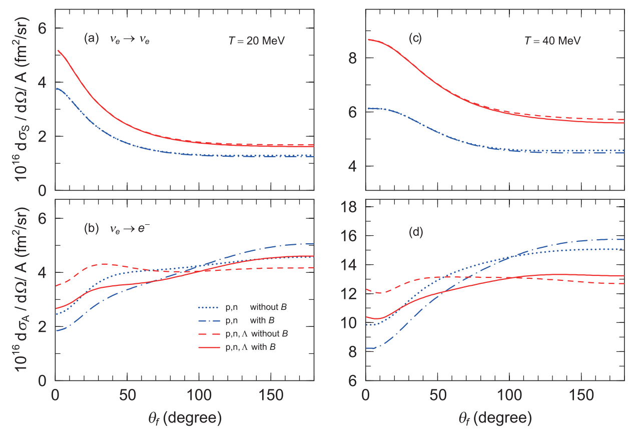

Figure 1: Effects of magnetic fields on the differential cross sections $d\sigma = d\Omega$ = A for neutrino scattering $\nu_e \to \nu_e$ (a and c), and for neutrino absorption $\nu_e \to e^-$ (b and d). Each line is for the different case as indicated.

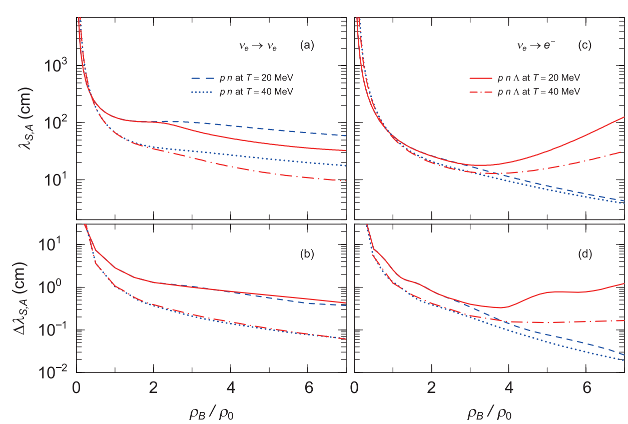

Figure 1: Upper panels show the neutrino MFP for scattering (a) and absorption (c) without magnetic field. Lower panels (b) and (d) show the magnetic contribution to the MFP for scattering (b) and absorption (d). Each line is for the different case as indicated.

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