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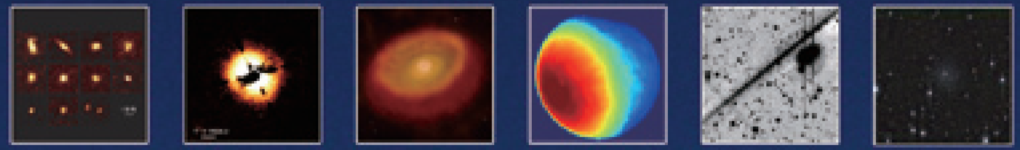

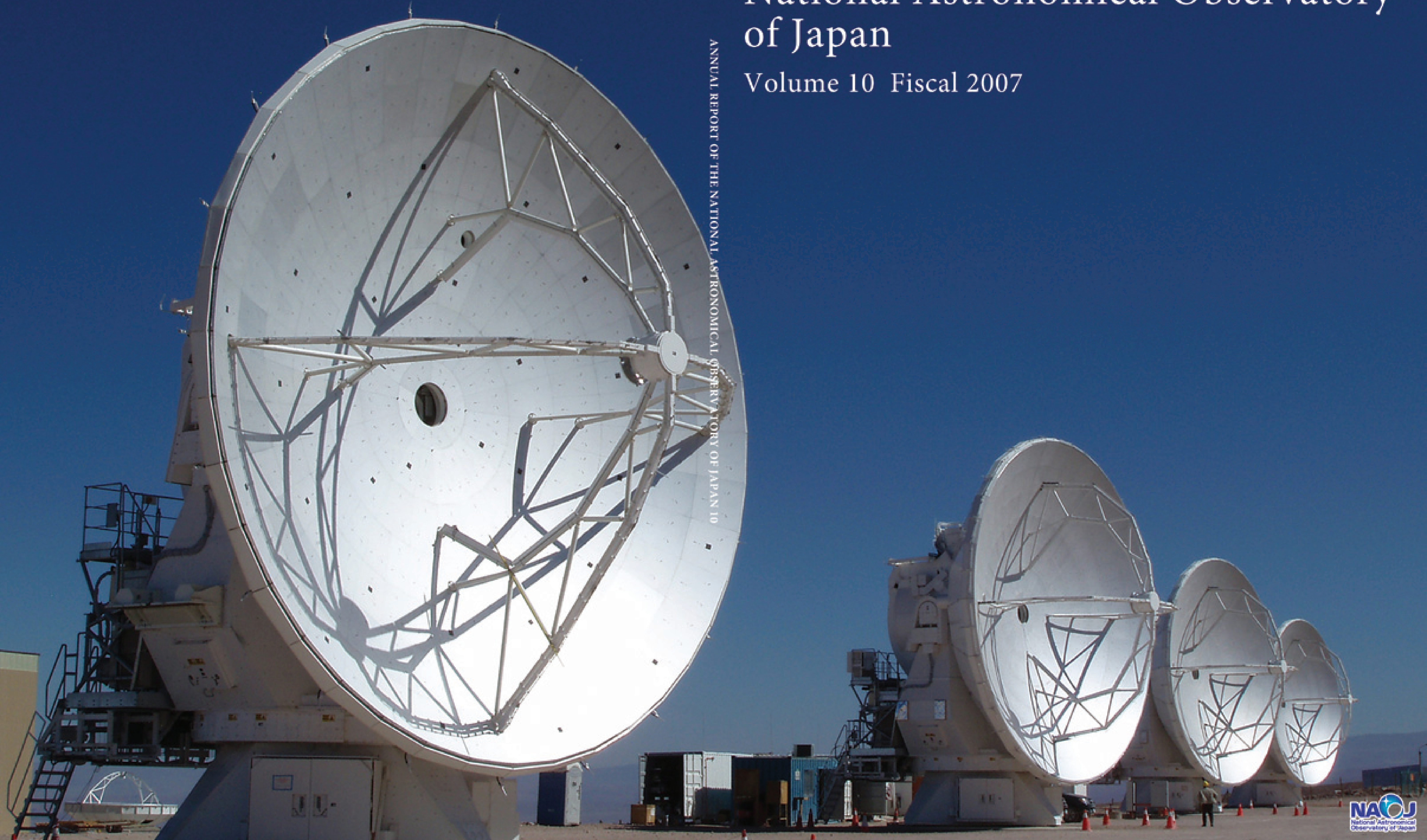

ANNUAL REPORT OF THE NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN 10

Annual Report of the National Astronomical Observatory of Japan
Fiscal 2007

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Annual Report of the
National Astronomical Observatory of Japan
Fiscal 2007

Shoken MIYAMA
Director General of NAOJ

P R E F A C E

I am pleased to present the Annual Report of the National Astronomical Observatory of Japan (NAOJ) for fiscal 2007. In the preface, I would like to focus on the activities and achievements related to one of the key topics of today's astronomy as the status of NAOJ activities are provided in each section of this report.

Using numerous telescopes, NAOJ has been observing astronomical phenomena in the universe including stars, planet systems, galaxies, clusters of galaxies, and cosmic large-scale structure (the entire structure of the universe). Recent studies have revealed that these astronomical materials which are visible with telescopes (starts and galaxies) account for only 4% of the total mass in the universe, indicating that most of the universe mass is made up of invisible materials named "dark matter" and "dark energy", 20% and 75% respectively. The presence of these invisible materials became known because of the gravitational effects they have on visible objects.

The dark matter was suggested as a gravitational source (not a gravity of a regular material like fixed stars) by a phenomenon called flat rotation where the orbital velocity of stars is maintained evenly regardless of the distance between the stars and the center of our galaxy. In addition, nothing seems more persuasive than the dark matter when it comes to explaining why high temperature gas in galaxy clusters can remain bound to the cluster and why lights are inflected more greatly than by the gravity of the galaxy (gravitational lens effect).

It gradually became known that the dark energy must exist, as universal repulsion, three times the mass of the gravitational sources in the universe. This is derived from the fact that the expansion velocity of the universe is increasing at an accelerated pace, while gravitational sources are present in the universe (materials and dark matter).

The dark matter and dark energy have not yet been identified exactly but posed an enormous challenge to basic science (elementary particles theory and high-energy physics) with the findings obtained in the fields of astrophysics and astronomy (observational and theoretical astronomy). A fundamental concept of astrophysics has been, so far, to grasp a reasonable picture of the universe based on basic science. However, it may be changed by new emerging forces like the dark energy which can be a trigger requiring a new approach to the science of the 21st century.

In the new phase of cosmology, NAOJ's observational instruments are playing a significant role, including VERA (VLBI Exploration of Radio Astrometry) of Mizusawa VERA Observatory which has succeeded in determining the distance of the farthest star ever observed in our galaxy by the triangulation. This achievement allowed NAOJ to investigate in detail stars moving at a constantly high velocity in our galaxy. NAOJ will observe the distance and orbital velocity of more stars, trying to determine the distribution of the dark matter.

The 8-m Subaru Telescope remarkably contributes to development of observational cosmology, with its spectrograph and wide-field imager that is the only camera mounted among similar-sized telescopes to Subaru. To investigate the dark energy and dark matter more closely, we started a project to fabricate Hyper Suprime-Cam, a camera with an even wider view filed than the current imager. This project, in collaboration with Princeton University of the United States and Academia Sinica Institute of Astronomy and Astrophysics of Taiwan, is so comprehensive that it requires the upgrade of the Subaru Telescope itself as well. This camera is expected to dramatically accelerate the advancement of observational cosmology. In addition to the implementation of the project, we successfully completed a new adaptive optics with near-diffraction-limit resolution for images obtained by ground-based telescopes as well as a laser-guide star system which artificially creates reference objects for the adaptive optics. The both satisfied the projected performance.

Computation simulation, which is of significance for the studies of cosmology, revealed what type of dark matter is necessary to form the cosmic large-scale structure. To analyze observational data, software and hardware for data analysis need to be regularly maintained and upgraded. Thanks to the support from many people concerned, the computer system and instruments of NAOJ have been fully replaced, which are used for shared use, advance theoretical study, analyze and establish database.

Atacama Large Millimeter/submillimeter Array (ALMA), an international project with Europe and North America, is expected to benefit the advancement of the astronomical studies. ALMA is an array consisted of eighty antennas (7-m and 12-m antennas) including sixteen Japanese antennas and has been under construction in Chile. NAOJ has delivered four 12-m antennas to the site in Chile ahead of the other two partners and took images of the moon in radio spectrum with one of the antennas. The Japanese correlator was installed at the site and will combine signals transmitted from the Japanese sixteen antennas. The development and fabrication of the receivers for the antennas are steadily going on.

On top of the subjects mentioned above, there are more challenging subjects of today's astronomy: the discovery of extrasolar planets; the exploration of extraterrestrial life; the advancement of solar science; the explanation of undefined celestial materials like black hole; the ascertainment of the structure of galaxies; and the unravelment of the forming process of galaxies, stars and planets. To explore these unanswered mysteries, the following activities have been continuously conducted: the development of the Subaru Telescope and its new device; Hinode, the observational satellite to study the sun; Kaguya, the moon exploration satellite which provides the new information on the moon; VSOP-2 (VLBI Space Observatory Programme-2) whose operation has actually started; Nobeyama Millimeter Array; and Okayama Astrophysical Observatory.

MIRA Project which was ranked as "A project" (projects in the early developmental stage) ended at the end of fiscal 2007 as the external review committee decided the continuous study by MIRA in Mitaka was not feasible. The other "A project," 4-Dementional Digital Universe (4D2U) Project also ended in fiscal 2007, while the development of its contents and public outreach activities will be continued, by Center for Computational Astrophysics and by Public Relations Center respectively.

Our public outreach activities have intensely been promoted to provide the public with the information on the astronomical achievements. The official website of NAOJ has been successful with 50 million hit counts a year. Astronomy-related questions asked of NAOJ were answered in a more effective way, and the special open day events at the observatories attracted more visitors than previous years.

Following the adoption of adjusting cost for the promotion of science and technology from Ministry of Education, Culture, Sports, Science and Technology, Scientific Culture Formation Unit was established in collaboration with Mitaka City in fiscal 2007. The Unit provides educational programs for those who have been recruited and will promote scientific culture taking advantage of NAOJ's scientific resources and achievements. Scientific Culture Formation Unit has started to support the students who try to establish new business on their own.

In terms of education, great efforts have been made to provide excellent graduate education, nurture young researchers, and improve academic research environments. In such environments of NAOJ, 50 and more graduate students and researchers engaged in research activities. We will continuously make further efforts to educate and support young researchers.

Shoken Miyama

Shoken MIYAMA
Director General of NAOJ

I Scientific Highlights

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Detection of coronal Alfvén waves in a solar prominence with *Hinode*

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It is well known that a bright structure is often seen in Hα line above the solar limb. It is called prominence (or filament if seen on the disk), which is cool plasma (~10,000 K) supported by coronal magnetic fields in the hotter corona (~1 MK). Detailed properties of prominence have remained unclear.

The new Japan/US/UK solar physics satellite *Hinode* enables the highest resolution imaging of prominences as yet seen with a temporal uniformity that allows long hours of diffraction-limited movies, a feat that is impossible by ground-based observations. We investigate fine structures of active region prominences with *Hinode* Solar Optical Telescope (SOT) observations.

To investigate fine structures and coronal magnetic property of an active region prominence, we obtained over 1 hour of continuous SOT images of active region NOAA AR 10921 on the west solar limb on 2006 November 9. The prominence is located 10,000–20,000 km above the visible limb (Fig.1), and exhibits a very complex fine structure with predominant horizontal thread-like features. These threads have continuous horizontal flows with a typical speed of about 40 km s^{-1}, and also vertical oscillations in the plane of the sky with periods of several minutes (Fig. 2). The oscillatory motion is most likely due to propagating or standing Alfvén waves on the horizontal magnetic field lines that form the prominence. This represents the first direct detection of Alfvén waves along coronal magnetic field lines [1].

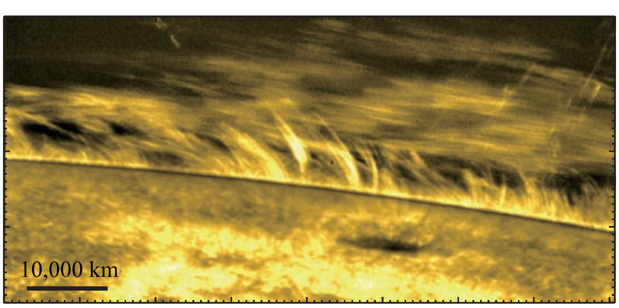

Figure 1: A prominence over the solar limb with the *Hinode* Solar Optical Telescope (SOT). The prominence consists of fine thread structures. We can also see a sunspot, spicules, and so on.

We cannot distinguish the time difference at the minimum and maximum amplitudes all along the thread because the wavelength of the Alfvén waves seems to be much longer than that of the threads. From the fact, we estimate the wavelength and speed to be more than 250,000 km and 1,050 km s^{-1}, respectively. If we assume that the plasma density is 10^{10} cm^{-3}, the implied magnetic field strength is ~50 Gauss for the propagating Alfvén wave, in agreement with measurements and models of active region prominence magnetic fields. The Poynting flux of the observed Alfvén waves is sufficient to heat coronal loops, so the Alfvén waves may play an important role in the coronal heating.

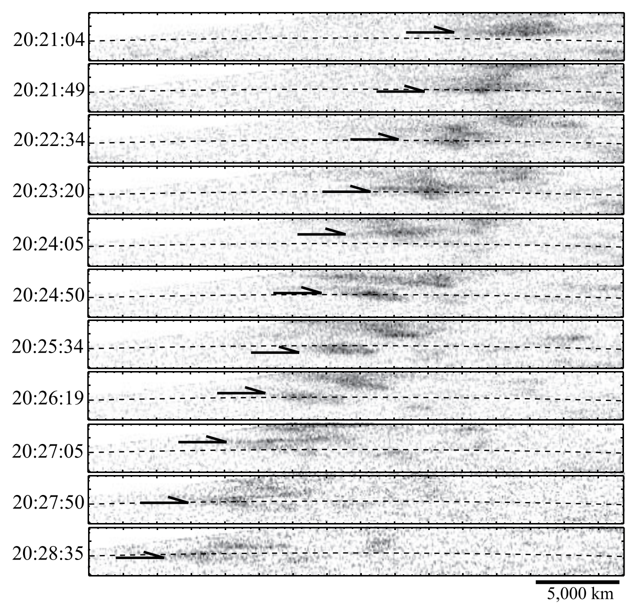

Figure 2: Example of a vertical oscillation of a single prominence thread. A small field of view is extracted from the larger field shown in Figure 1 and shown in negative contrast. The dashed line in each panel indicates an approximately constant height above the photosphere.

Reference

[1] Okamoto, T. J., et al.: 2007, *Science*, **318**, 1577.

Small-Scale Jetlike Features in Penumbral Chromospheres

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The Solar Optical Telescope (SOT) on *HINODE*, which was successfully launched in September 2006, has provided dynamic nature of the solar chromosphere by unprecedented high resolutional observations from space. It is discovered that small-scale jetlike activities frequently happen in penumbral chromospheres (Fig.1) [1]. The jet-like features newly discovered with SOT have length of 1000–3000 km and width of 300–400 km. It is remarkable that their duration is mostly shorter than 1min. The spatial and temporal scales are much smaller than chromospheric activities ever known, and existing ground-based observations could not resolve them. An apparent velocity of the jetlike activities is 50–100 km/s, but sometimes reaches over than 100 km/s. The velocities are much faster than the acoustic velocity in the chromosphere that is about 10 km/s. The jetlike activities in penumbral chromospheres are referred to as "penumbral microjets" according to their small scales.

Penumbral microjets are a ubiquitous phenomenon in the penumbral chromosphere. But there is a tendency about the occurrence site of penumbral microjets. The footpoints are always located between two dark penumbral filaments. There are nearly horizontal magnetic fields along the dark filaments, and relatively vertical fields are there between the dark filaments. The penumbral microjets are structures brightened along the vertical field lines. In addition, the penumbral microjets are found to occur frequently near penumbral grains moving inward with velocities of about 0.7 km/s.

There are complex magnetic configuration, called uncombed magnetic structure, in a penumbra as mentioned above. A penumbra consists of two magnetic components, one is nearly horizontal flux tubes and the other is relatively vertical background fields. The two magnetic field components are interlaced each other with spatial scale of about 1000 km. Strong discontinuities and electric currents are naturally generated between the two different magnetic fields, and magnetic energies are supposed to be sporadically released through magnetic reconnection. The energy release most probably causes brightening in the chromosphere, and is observed as a penumbral microjet. It is expected to have an outflow with Alfvén velocity when magnetic reconnection happens. The observed apparent velocity of penumbral microjets is roughly consistent with the Alfvén velocity in the chromosphere, which strongly supports the possibility of magnetic reconnection.

We can make rough estimation of an energy content of each penumbral microjet by assuming its temperature and density in the chromosphere. The estimated energy is about 10^{23} erg per each microjet, which are comparable to an energy of a microflare (or nanoflare) in coronae. Because the penumbral microjets are a ubiquitous activity in a sunspot penumbra, they might contribute to heating of chromospheres and coronae.

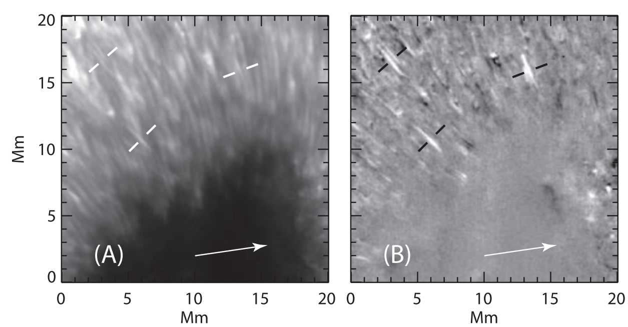

Figure 1: Penumbral microjets in the sunspot chromosphere discovered with *HINODE* SOT. (A) A sunspot image taken through the Ca II H filter of SOT, and (B) its brightness difference from a previous frame 30 sec before. Penumbral microjets are clearly identified in the difference image.

Reference

[1] Katsukawa, Y., et al.: 2007, *Science*, **318**, 1594.

Behavior of Lithium Abundances in Solar-Analog Stars

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Since lithium atoms are destroyed when they are conveyed into the hot stellar interior ($T > 2.4 \times 10^6$ K), the surface Li abundance (A_{Li}) can be used as a probe for diagnosing the past history of envelope mixing. For example, the fact that the current solar A_{Li} value is considerably reduced (by a factor of ~100) as compared to the solar system composition (primordial value) may be interpreted as a result of long-proceeding gradual depletion caused by mixing due to the deep convection zone. Curiously, however, when we pay attention to other solar type stars (early G-type main-sequence stars), we see a remarkably large diversity of A_{Li} amounting to more than ~2 dex (among which the Sun's A_{Li} is definitely low). Why such a large difference is produced for stars with similar parameter values?

In order to contend with this problem, we carried out a comprehensive statistical study on 118 selected solar analogs based on the high-dispersion spectra obtained with the 188 cm reflector and the HIDES spectrograph at Okayama Astrophysical Observatory. The atmospheric parameters were determined spectroscopically from Fe I and Fe II lines, the mass and age were evaluated from the positions on the HR diagram with the help of stellar evolutionary tracks, the macrobroadening velocity ($v_{\mathrm{r+m}}$) was established by spectrum-fitting analyses in the 6080–6089 Å region, and the Li abundance (A_{Li}) was evaluated from the Li I 6708 line feature. The resulting A_{Li} vs. T_{eff} and A_{Li} vs. $v_{\mathrm{r+m}}$ plots are depicted in Figures 1a and 1b, respectively, from which we can draw the following conclusions (see [1] for more details).

— (1) A close connection exists between the macro-broadening velocity ($v_{\mathrm{r+m}}$; a combination of the projected rotational velocity $v_{\mathrm{e}} \sin i$, and the macroturbulence v_{macro}) and the surface Li abundance, in the sense that A_{Li} progressively grows with an increase in $v_{\mathrm{r+m}}$ (Fig. 1b). Since the macroturbulence (essentially the granular motion of stellar convection origin) is unlikely to vary much among stars of similar parameters, we may regard that the diversity of $v_{\mathrm{r+m}}$ simply reflects the difference in $v_{\mathrm{e}} \sin i$. Accordingly, we may state that "a lowering of stellar rotation leads to an enhanced envelope mixing (i.e., decrease in A_{Li})". (This kind of mechanism was once proposed from the theoretical side; e.g., [2]).

— (2) The A_{Li} values of five planet-host stars situate in the lower envelope of the distribution (Fig. 1a), which confirms the recent argument that the photospheric Li abundances in planet-host stars tend to be lower than those in non-planet-host stars (e.g., [3, 4]). Considering the $v_{\mathrm{e}} \sin i$-dependence of A_{Li} mentioned above, we may speculate from this fact that the decrease in the stellar angular mumentum caused by the existence/formation of planets may have lowered the surface Li abundance via the enhanced mixing.

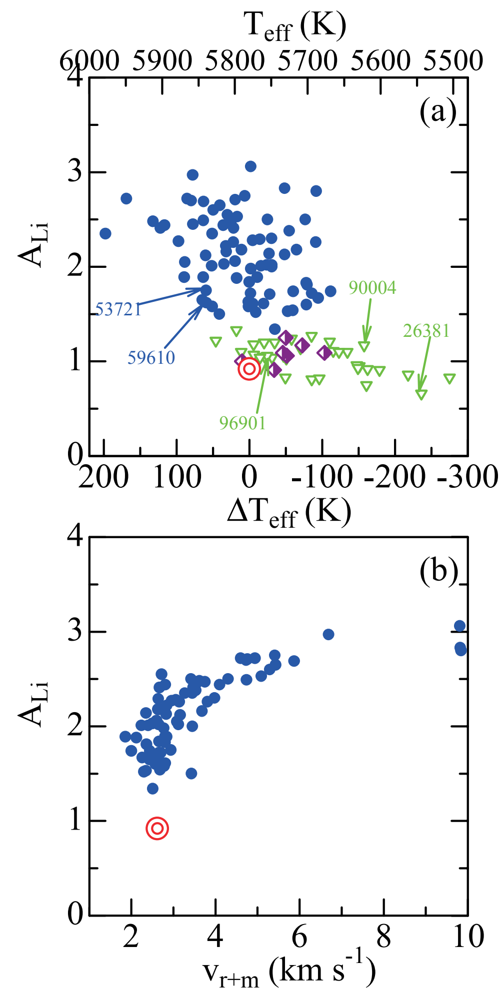

Figure 1: (a) Relation between the surface lithium abundance (A_{Li}) and the effective temperature (T_{eff}). Filled circles (blue): reliable A_{Li} values. Dianmonds (purple): unreliable A_{Li} values at the detection limit. Inverse triangles (green): upper limit A_{Li} values (for the case of invisible Li line). The double circle (red) represents the solar value. The five planet-host stars are indicated by their HIP numbers. (b) Relation between the surface lithium abundance (A_{Li}) and the macrobroadening velocity ($v_{\mathrm{r+m}}$).

References

[1] Takeda, Y., et al.: 2007, *A&A*, **468**, 663.
[2] Martín, E. L., Claret, A.: 1996, *A&A*, **306**, 408.
[3] Israelian, G., et al.: 2004, *A&A*, **414**, 601.
[4] Takeda, Y., Kawanomoto, S.: 2005, *PASJ*, **57**, 45.

Fine Structures of Solar X-Ray Jets Observed with the X-Ray Telescope aboard Hinode

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The X-Ray Telescope (XRT) aboard Hinode has revealed the fine structure of solar X-ray jets [1]. One of the fine structures observed by XRT is an expanding loop. The loop appears near the footpoint of the jet when the footpoint brightening is observed. Additionally, we have found that the X-ray jets begin just after the expanding loop 'breaks'. Other fine structures discovered by XRT are thread-like features along the axis of the jets. XRT has shown that these thread structures compose the cross-section of jets. The fine structures and their motions strongly support the X-ray jet model based on magnetic reconnection, and also suggest that we must consider the threedimensional configuration of magnetic field to understand jet phenomenon.

We investigated also the reverse jet associated with the Xray jet in the quiet sun, and propose that the reverse jet is produced by heat conduction or a MHD wave subsequent to the main jet.

Reference

[1] Shimojo, M., et al.: 2007, *PASJ*, **59**, S745.

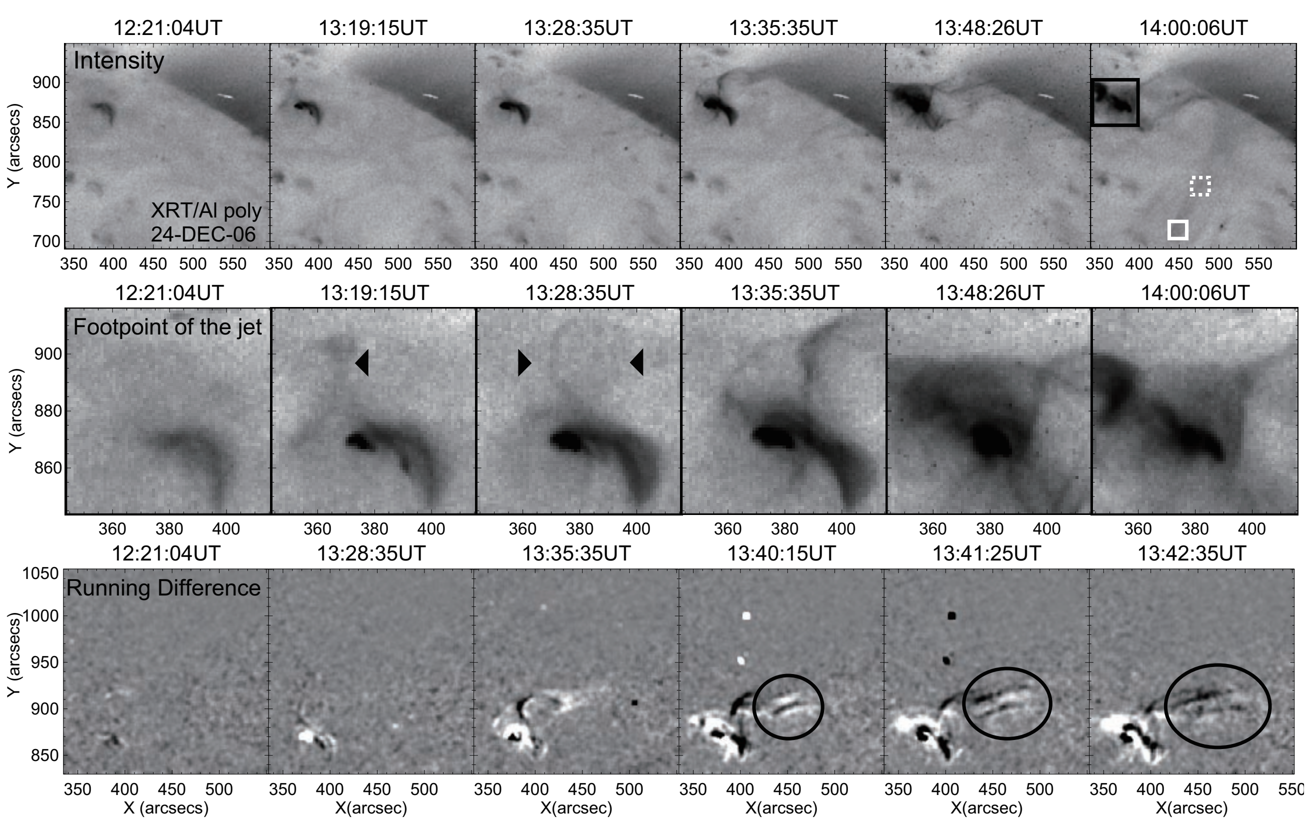

Figure 1: A solar X-ray jet in quiet sun. Upper row: The X-ray intensity maps with the wide field of view (Negative images). Middle row: The X-ray intensity maps around the foorpoint (Negative images). The triangle symbols indicate expanding loops. Lower row: Running difference images are shown for the jet (Positive Images). The black circles indicate the thread-pattern movement for the jet.

First Results from the Hinode/SOT Helioseismology Programme

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Results from initial helioseismic observations by the Solar Optical Telescope (SOT) on Hinode are reported.

SOT has been providing us with excellent stable high-resolution images of the Sun in various wavelengths since it was launched in September, 2006. As an attempt to exploit this capability for helioseismology, we examined intensity oscillation data in Ca II H line and the G band from the Broadband Filter Imager (BFI).

The power spectra (k–ω diagrams) and the corresponding time-distance cross-correlation diagrams were obtained for data from a 12-hour observation of a quiet region [1]. In these basic diagnostic diagrams, we saw components of much higher frequencies and wavenumbers than had been observed before, indicating great potential for high-resolution helioseismic observation by Hinode/SOT. In our initial time-distance analysis, we observed subsurface supergranular patterns clearly (see Fig. 1), which were found to be coherent over the depth range of a few Mm.

In [2] we reported a cross-spectral analysis of solar oscillations observed in intensity signals from two different layers. We found that below the acoustic cutoff frequency there is no phase shift in the cross phase spectrum along the f-mode ridge, but along the p-mode ridges the phase shift has strong peaks. If the absence of the phase shift is due to the standing wave nature, the phase shift along the p-mode ridges must also be zero. Why the p modes and the f modes behave differently is still a puzzle.

Oscillations within sunspots have been observed by SOT [3, 4]. In local-helioseismological techniques, we examine how acoustic waves propagate so that we can study subsurface structures. Furthermore, to reveal the mechanism of how sunspots evolve and dissipate by local helioseismology, we need to know how the acoustic waves interact with magnetic fields in detail. Therefore, sunspot oscillations are important scientific targets.

We investigated the spatial distribution of the power spectral density of the oscillatory signal in and around a sunspot [3]. In Ca II H intenstiy 5.5-mHz oscillations in the umbra were prominent. These are due to so-called ‘umbral flash’, patchy transient brightening seen in the chromosphere of the sunspot umbra. The Ca II H power is enhanced throughout most of the umbra, but in the region within about 3 arcsec from the center of the umbra the power was suppressed (See Fig. 2). This kind of fine structure cannot easily be explained by the field-guided upward-propagating shock-wave model for the umbral flash proposed so far.

We also reported observations of sunspot oscillations excited by a solar flare [4]. Since these oscillations appeared in the sunspot umbra and inner penumbra, they might represent magnetohydrodynamic oscillatory modes and may provide us with useful information about the flare mechanism.

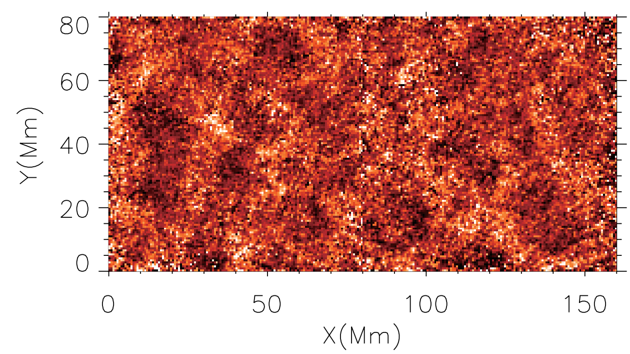

Figure 1: An outward-inward travel time difference map from 12-hr Ca II H data over the surface distance of 14.86Mm, indicating flow divergence due to supergranulation [1].

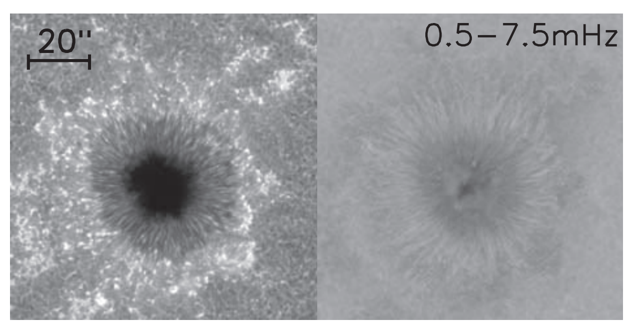

Figure 2: Intensity map (left) and power map (right) from the Ca II H data of the active region NOAA 10935 [3].

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[1] Sekii, T., et al.: 2007, *PASJ*, **59**, S637.
[2] Mitra-Kraev, U., Kosovichev, A. G., Sekii T.: 2008, *A&A*, **481**, L1.
[3] Nagashima, K., et al.: 2007, *PASJ*, **59**, S631.
[4] Kosovichev, A. G., Sekii, T.: 2007, *ApJ*, **670**, L147.

Dynamic formation of the magnetic structure of a solar prominence

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Solar filaments, or prominences observed at the solar limb, are one of the prominent objects showing floated structure on the Sun. The gas density in a filament is significantly higher than its surroundings, and now it is widely believed that the mass of a filament is magnetically supported against gravity (Fig. 1; see [1], [2]). The magnetic field has a significant effect on the dynamic and thermodynamic states of filaments via the Lorentz force and thermal conduction along magnetic field lines, so the structure of magnetic field in filaments has been an important issue for the study of the nature of filaments [3].

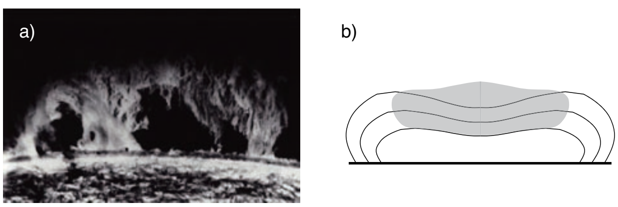

Figure 1: a) A solar prominence, b) A two-dimensional, static model of a prominence.

We reported a result that the emergence of subsurface magnetic field naturally reproduces the feature of the global magnetic configuration observed in solar filaments. This is obtained by performing three-dimensional simulation of a twisted flux tube that emerges in the shape of multi-loop in a highly stratified solar atmosphere extending from the subsurface layer to corona (Fig. 2. from [4]). A key finding is that a kinking of the twisted flux tube occurs at the site of a linkage between adjacent -loops. This develops a magnetic structure that has remarkable similarities to the structure of a filament in that the inner part of the twisted flux tube can be applied to the main body of a filament while the outer part is reminiscent of observations of filament feet and a coronal arcade overlying the main body of a filament. Based on the result we concluded that geometric features of filaments observed on the Sun may have the origin in the handedness of twisted magnetic field below the solar surface, i.e., a flux tube with a left- (right-) handed twist produces a dextral (sinistral) filament. This research was supported by a Grant-in-Aid (19740101, PI: T. Magara) from the Ministry of Education, Culture, Sports, Science and Technology.

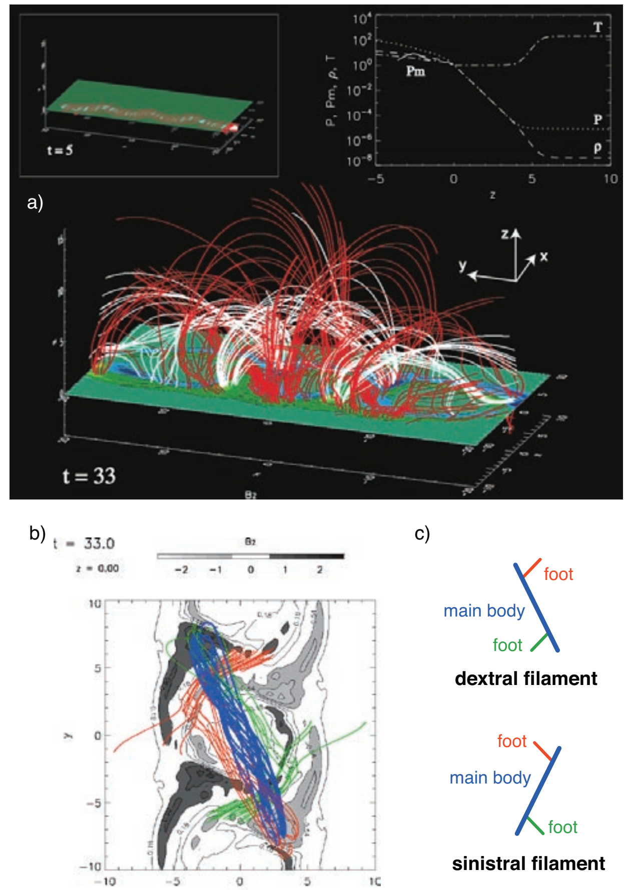

Figure 2: a) Magnetic structure of a solar prominence obtained by a 3D MHD simulation b) Distribution of photospheric magnetic field and the field lines formed above the photospheric field. c) Geometric features of dextral and sinistral filaments.

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[2] Kuperus, M., Raadu, M. A.: 1974, *A&A*, **31**, 189.
[3] Tandberg-Hanssen, E.: 1995, *Astrophysics and Space Science Library*, 199.
[4] Magara, T.: 2007, *PASJ*, **59**, L51.

Supernova Mixtures Reproducing Isotopic Ratios of Presolar Grains

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Primitive meteorites contain very small (nm ~ μm sized) grains indicating huge isotopic anomalies. These isotopic anomalies are not explained by physical and chemical processing in the solar-system formation, and are considered to indicate evidence for nucleosynthesis in stars and the Galactic chemical evolution. Therefore, these grains are called as presolar grains (e.g., [1]).

Silicon carbide type X (SiC X) and low density graphite are considered to originate from supernovae. The excesses of ^{28}Si and the original presence of short lived nuclei ^{44}Ti are strong evidence for their origin. However, their isotopic and elemental features are different from those of bulk composition of supernova ejecta. Therefore, their features are considered to be evidence for large heterogeneous mixing of supernova ejecta.

In this study, heterogeneous supernova mixtures reproducing isotopic ratios of individual single grains as many as possible are sought. The isotopic features and mixing ratios of the mixtures are also investigated. From the obtained mixtures, the elemental compositions and the formation condition of the presolar grains from supernovae are discussed [2].

The isotopic ratios ^{12}C/^{13}C, ^{14}N/^{15}N, ^{26}Al/^{27}Al, ^{29}Si/^{28}Si, ^{30}Si/^{28}Si, ^{44}Ti/^{48}Ti of 18 SiC X and 26 low density graphite (and ^{16}O/^{17}O and ^{16}O/^{18}O for low density graphites) are adopted for comparison. The abundance distributions of the supernova ejecta of 3.3, 4, 6, and 8 $M_\odot$ He star models corresponding to the advanced stages of 13, 15, 20, and 25 $M_\odot$ ZAMS stars [3] are used to investigate supernova mixtures. The supernova ejecta are divided into seven layers; the Ni, Si/S, O/Si, O/Ne, C/O or O/C, He/C, and He/N layers in accordance with their main compositions.

Figure 1 shows six isotopic ratios of SiC X KJGM2-243-9 and three supernova mixtures. These mixtures reproduce five isotopic ratios except ^{14}N/^{15}N. In this study, the mixtures reproducing isotopic ratios of individual grains are classified into three groups. The above mixtures are classified into group C. The ones reproducing except ^{12}C/^{13}C are classified into group N. The ones reproducing both C and N isotopic ratios but except one ratio are classified into group CN. In the case of low density graphites in which ^{44}Ti/^{48}Ti was not measured, the mixtures reproducing six isotopic ratios in seven ratios are found. They are also classified into the three groups.

The mixing ratios of the mixtures depend on reproduced isotopic ratios. In group C, the main component is the He/N layer. The C/O, He/C, and Ni layers are added with small fractions. In group N, the main component is the He/C layer. The C/O, He/N, and Ni layers are additionally contained. In group CN, the innermost Ni layer is the main component and the He/N layer is the second main component.

The elemental composition of the supernova mixtures is important from the viewpoint of the grain formation. Silicon carbide and low density graphite are formed in carbon-enriched material rather than oxygen. In this study, most of the mixtures indicate the C/O ratio in the range of 1 ~ 2. On the other hand, the mixtures of group CN for SiC X indicate very small C/O ratio (~ $O(10^{-3})$). TiC subgrains in some graphite suggest that graphite grains are formed in Fe-enriched environment rather than Si. The mixtures obtained in this study have a correlation between Fe/Si and Fe/C. The mixtures in group CN for low density graphite show Fe/Si ~10^4, which is favorable for the formation of TiC subgrains.

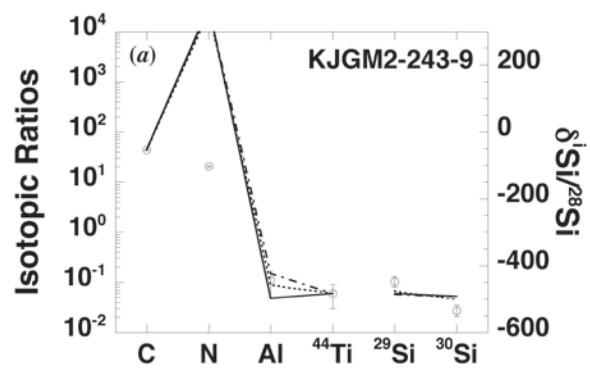

Figure 1: Isotopic ratios of SiC X grain KJGM2-243-9 and supernova mixtures. Circles indicate the isotopic ratios of KJGM 2-243-9. Solid, dotted, and dash-dotted lines correspond to the supernova mixtures for 3.3, 6, and 8 $M_\odot$ models.

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[2] Yoshida, T.: 2007, *ApJ*, **666**, 1048.
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ν-Process Nucleosynthesis in Population III Core-Collapse Supernovae

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Recent observations of metal-poor stars with $-4 <$ [Fe/H] < -2 indicated that the average abundance ratios to Fe [X/Fe] are in the range ±0.5 dex for most observed elements [1] ($[X/Y] \equiv \log(N_X/N_Y) - \log(N_X/N_Y)_\odot$ where N_X and N_Y are the abundances of elements X and Y). The abundance ratios observed in extremely metal-poor (EMP) stars and those in very metal-poor stars are in agreement with the yields produced in Population III hypernovae and both contributions from Population III supernovae and hypernovae [1]. On the other hand, the supernova and hypernova yields for N, K, Sc, Ti, Mn, and Co are too small to explain the observed abundance ratios.

We investigate the contribution of the ν-process in the nucleosynthesis of Population III supernovae and hypernovae. We focus on the production of odd-Z iron-peak elements. We investigate the dependence of the yields of Sc, Mn, and Co on the neutrino irradiation of the supernova ejecta. Then, we indicate whether the abundance ratios of these elements observed in EMP stars are reproduced by supernovae and hypernovae with the effects of the ν-process [2].

In the case without the ν-process, most of Sc and Mn are produced during incomplete Si burning. Most of Co is produced in complete Si burning region. On the other hand, when the ν-process is considered, the Sc amount produced in complete Si burning region increases. In the regions of complete and incomplete Si burning, ^{55}Co as well as neutrons and protons are produced from ^{56}Ni, which has been produced in NSE and QSE, through the ν-process. The produced ^{55}Co decays to ^{55}Mn. The neutrons and protons are captured by ^{44}Ti and ^{58}Ni to produce ^{45}V, ^{59}Cu, and ^{59}Ni. They change to ^{45}Sc and ^{59}Co through β^+-decays and electron captures.

Figure 1 indicates the abundance ratios of Population III 15 $M_\odot$ supernova and 25 $M_\odot$ hypernova with the relation of the total energy released by neutrinos E_ν . The abundance ratios of the 25 $M_\odot$ supernova are similar to those of the 15 $M_\odot$ supernova. The abundance ratios of Sc, Mn, and Co in the supernovae increase owing to the contribution from the ν-process. The abundance ratios of Sc and Mn in the hypernova are also enhanced by the ν-process but the Co abundance ratio is not.

Supernova models with the ν-process well reproduce the Mn/Fe ratio observed in EMP stars. The neutrino energy released from the supernovae should be (3–9) × 10^{53} erg to reproduce the Mn/Fe ratio of the EMP stars. On the other hand, in order to reproduce the Sc/Fe and Co/Fe ratios observed in the EMP stars, stronger neutrino irradiation is necessary for the supernova and hypernova models.

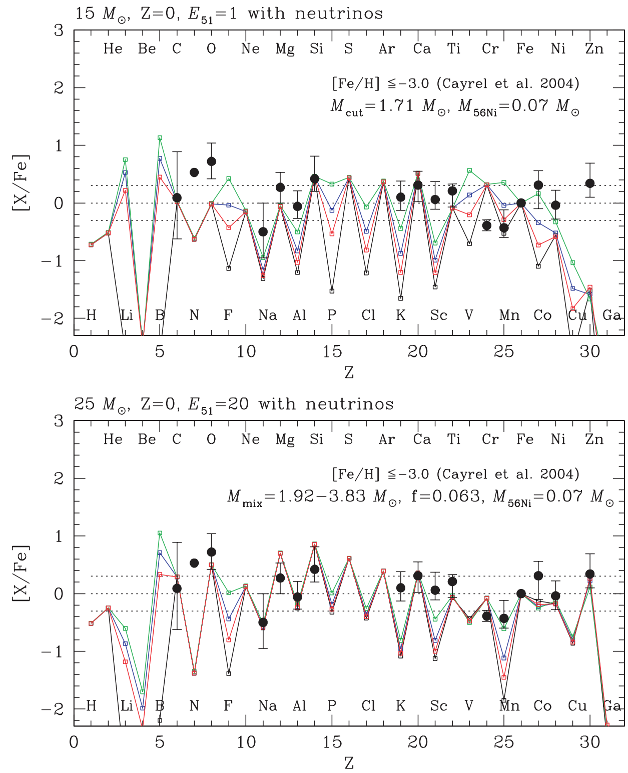

Figure 1: Abundance ratios [X/Fe] for Population III 15 $M_\odot$ supernova (upper panel) and 25 $M_\odot$ hypernova (lower panel). Black, red, blue, and green lines correspond to the case without the ν-process, the cases with the ν-process and $E_\nu = 3 \times 10^{53}$, 9×10^{53}, 3×10^{54} ergs. Circles indicate the abundance ratios of averaged over 22 EMP stars [3].

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[1] Tominaga, N., Umeda, H., Nomoto, K.: 2007, *ApJ*, **660**, 516.
[2] Yoshida, T., Umeda, H., Nomoto, K.: 2008, *ApJ*, **672**, 1043.
[3] Cayrel, R., et al.: 2004, *A&A*, **416**, 1117.

The Habitat Segregation between Lyman Break Galaxies and Lyman α Emitters around a QSO at $z \sim 5$

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We carried out a target survey for Lyman break galaxies (LBGs) and Lyman α emitters (LAEs) around QSO SDSS J0211-0009 at z = 4.87. The deep and wide broadband and narrowband imaging simultaneously revealed the perspective structure of these two high-z populations. The LBGs without Lyα emission form a filamentary structure including the QSO, while the LAEs are distributed around the QSO but avoid it within a distance of ~4.5 Mpc (Fig. 1). On the other hand, we serendipitously discovered a protocluster with a significant concentration of LBGs and LAEs where no strongly UV ionizing source such as a QSO or radio galaxy is known to exist (Fig. 2). In this cluster field, two populations are spatially crosscorrelated with each other. The relative spatial distribution of LAEs to LBGs is in stark contrast between the QSO and the cluster fields. We also found a weak trend showing that the number counts based on Lyα and UV continuum fluxes of LAEs in the QSO field are slightly lower than in the cluster field, whereas the number counts of LBGs are almost consistent with each other. The LAEs avoid the nearby region around the QSO where the local UV background radiation could be ~100 times stronger than the average for the epoch. The clustering segregation between LBGs and LAEs seen in the QSO field could be due to either enhanced early galaxy formation in an overdense environment having caused all the LAEs to evolve into LBGs, or local photoionization due to the strong UV radiation from the QSO effectively causing a deficit in low-mass galaxies like LAEs [1].

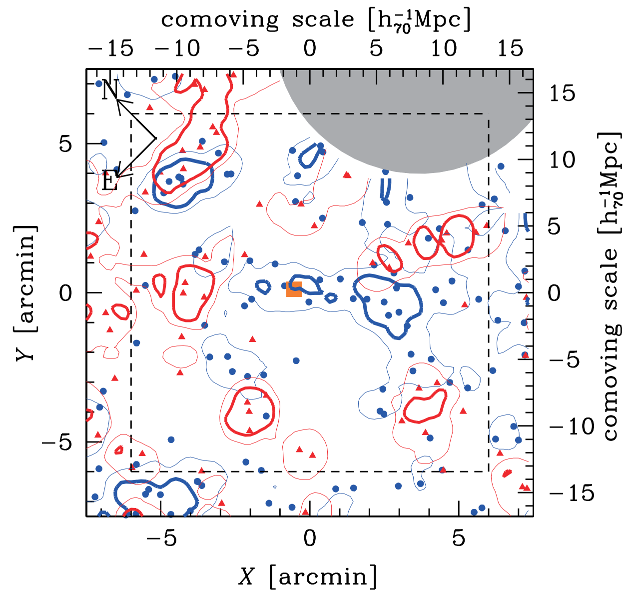

Figure 1: The LBG (blue circle)/LAE (red triangle) distribution and its surface number density contours (blue for LBGs and red for LAEs) in the QSO field around SDSS J0211-0009 (central orange square). The thin and thick contours denote 1σ and 3σ excess from the mean local density.

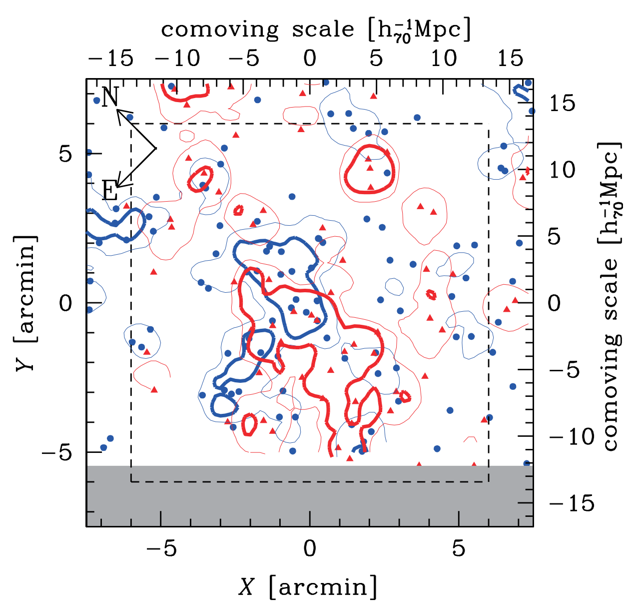

Figure 2: Same as Figure 1 but for the cluster field.

Reference

[1] Kashikawa, N., et al.: 2007, *ApJ*, **663**, 765.

First Measurement of Meteoroid Tunnel Size in Earth's Atmosphere

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Subaru Telescope, focused to infinity, records defocused images of nearby meteors and artificial satellites (Fig. 1). Meteors and artificial satellites can be distinguished by their angular width of defocused images (Fig. 2). Imaging observations of Andromeda galaxy for 19 hours during August 12-15, 2004, recorded 57 tracks, of which 44 were artificial satellites and 13 were meteors. Although the observing run was just after the peak of Perseids meteor shower, most were sporadic meteors and only one was confirmed to be Perseids. Among the 44 tracks of artificial satellites, 17 were identified to specific satellites catalogued in the public data base.

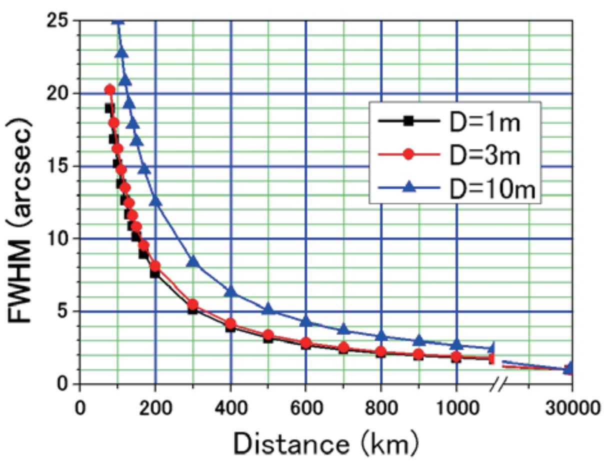

Figure 1: Calculated angular size of an object with diameter D [m] at a distance of d [km] as seen by Subaru Telescope.

The main scientific achievement of the present paper was the first measurement of the size of shining column of meteors based on a physical assessment. The width of meteor tracks were unresolved so far and the size of the shining column was known to be smaller than about 1m, corresponding to the size spanning 0.5 arcsecond at 110 km height. The current team used the fact that the forbidden line photons emitted at 558 nm by neutral oxygen atoms are produced by collisional excitation (Fig. 3). If one can evaluate the total number of this forbidden line photons $N_{[OI]}$ emitted in a unit time, it should be equal to the total number of collisional excitation events that took place in the same time. As the number density of neutral oxygen atoms n_{OI} at 110 km altitude and the track length L traversed by the meteor in a unit time are known, one can derive the cross section S of the collision column from the following equation

$$S = N_{[OI]} / (n_{OI} L). \qquad (1)$$

Analysis of four meteors observed through the V-band filter covering the 558nm forbidden line photons yielded the column diameter in the range 2–10 mm. This size turned out to be about 10 times the size of a few–few tens of μg meteoroids, that were estimated from their luminosity. This paper eventually yielded scientific results for the nearest object ever studied by Subaru Telescope [1].

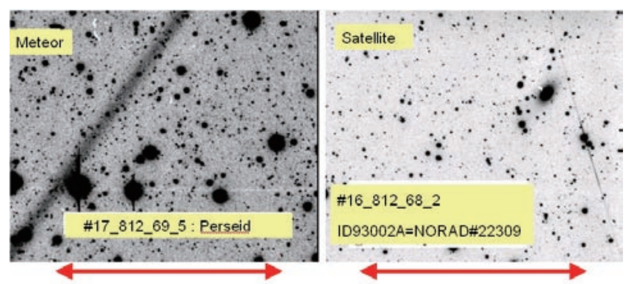

Figure 2: Typical images of a meteor (left) and an artificial satellite (right). Meteors at 110 km altitude are much more defocused than satellites at 500–20,000 km altitude. Arrows indicate 5 arcmin span. Images are shown in negative prints.

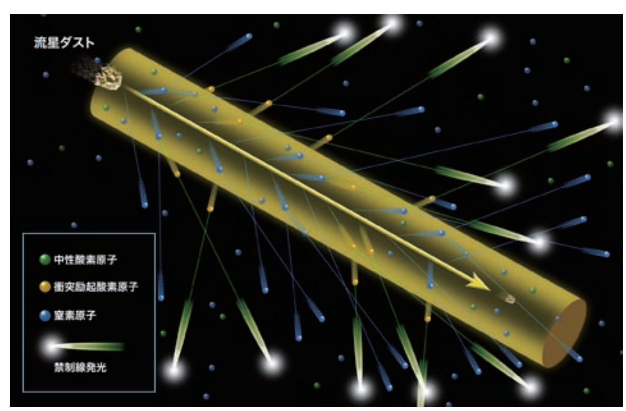

Figure 3: Neutral oxygen atoms directly hit by the meteoroid or by accelerated nitrogen or oxygen atoms are collisionally excited. Excited atoms return to ordinary state by emitting a 558-nm forbidden line photon. By counting the number of these special photons, one can calculate the width of the collision tunnel bored by the meteoroid. (Illustration by N. Ishikawa)

Reference

[1] Iye, M., et al.: 2007, *PASJ*, **59**, 841.

Active supermassive blackholes buried in ultraluminous infrared galaxies, unveiled through Spitzer infrared spectroscopy

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Ultraluminous infrared galaxies (ULIRGs) radiate the bulk of their large luminosities (>$10^{12}L_\odot$) as infrared emission. This means that (1) very luminous energy sources are present hidden behind dust, (2) the bulk of the energetic radiation from the hidden energy sources is once absorbed by the surrounding dust, and (2) the heated dust emits strong infrared radiation. The energy source can be nuclear fusion inside rapidly formed stars (starburst) and/or active mass accretion onto a central supermassive blackhole (AGN). Distinguishing the hidden energy sources of ULIRGs is indispensable not only to understand the true nature of the ULIRG population, but also to unveil the history of star-formation and supermassive blackhole growth in the dust-obscured side of the universe.

Identifying the hidden energy sources of ULIRGs is difficult because highly-concentrated nuclear dust can easily bury (= obscure in all directions) the putative AGNs. Unlike an AGN surrounded by torus-shaped dust, which is easily detectable through optical spectroscopy, such *buried* AGNs are very difficult to find. However, detecting *buried* AGNs and estimating their energetic role are the most important issue in the current ULIRG study. For this purpose, observations at wavelengths of low dust extinction are necessary, and infrared 5–35 μm spectroscopy is an effective means. First, PAH (polycyclic aromatic hydrocarbon) emission features, found at 3–25 μm, are detected in starburst galaxies, but not in AGNs, because of the destruction of PAHs. Hence, the presence or absence of the PAH emission can be used to identify the energy sources. Next, in a normal starburst, where the stellar energy sources and dust are spatially well mixed (Fig. 1, left), there is an upper limit for the optical depth of the 9.7 μm silicate dust absorption feature, while it can be arbitrarily large in a buried AGN, where the energy source is more centrally concentrated than the surrounding dust (Fig. 1, right) [1].

Using the IRS spectrograph onboard the Spitzer infrared satellite, we observed 48 ULIRGs with no obvious AGN signatures in the optical, by combining data taken through our Cycle-1 program and archival data. We have obtained low resolution (R < 100) infrared 5–35 μm spectra of the complete sample of optically non-AGN ULIRGs at $z < 0.15$ (Fig. 2), and found signatures of luminous buried AGNs in roughly half of the observed ULIRGs [1]. Our results strengthen our previous argument, based on Subaru infrared 3–4 μm spectroscopy [2], that luminous buried AGNs are common in the ULIRG population.

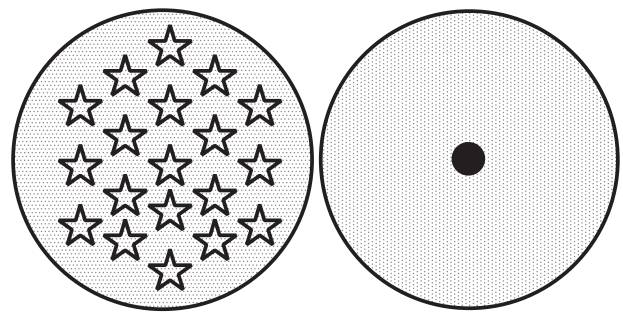

Figure 1: Geometry of energy sources and dust. (*Left*): Normal starburst. Stellar energy sources (open stars) and dust are spatially well mixed. (*Right*): Buried AGN. The energy source (= a mass accreting supermassive blackhole; filled circle) is spatially very compact and is more centrally concentrated than the surrounding dust.

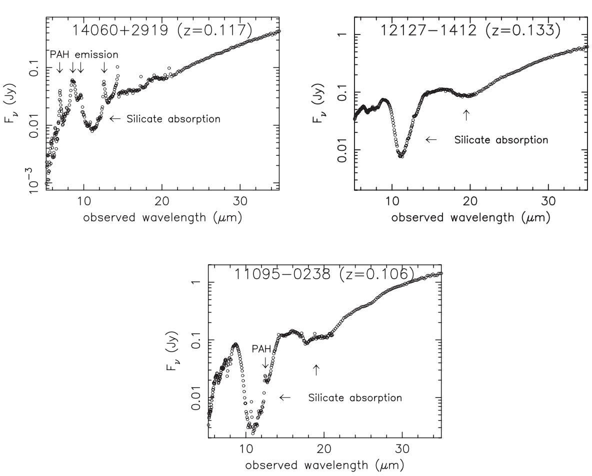

Figure 2: Examples of Spitzer infrared 5–35μm spectra of ULIRGs. (*Upper left*): Starburst-dominated ULIRG. PAH emission is strong. (*Upper right*): ULIRG dominated by a buried AGN. No PAH emission and strong silicate dust absorption are detected. (*Lower*): ULIRG with starburst and buried AGN composite. PAH emission is seen, but its strength is weak.

References

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Nobeyama Millimeter Array HCN(1–0) and HCO^+(1–0) observations of luminous infrared galaxies

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Luminous infrared galaxies radiate very large luminosities (>10^{11} $L_\odot$) as infrared dust emission, suggesting that powerful energy sources are present, surrounded by dust. The energy sources are star-formation (nuclear fusion inside stars) and/or active galactic nuclei (AGNs; active mass accretion onto a central supermassive blackhole with mass >10^6 $M_\odot$). Unlike AGNs obscured by torus-shaped dust, putative AGNs in LIRG's nuclei are likely to be obscured by a large amount of nuclear dust and gas in all directions (= buried), making the identification of AGNs difficult.

An AGN has the following remarkable properties, compared to star-formation. First, strong X-ray (E > 2 keV) emission is produced in the close vicinity of the accretion disk around a central supermassive blackhole, through the inverse Compton process. Second, emission surface brightness of an AGN is so high that the surrounding dust can be heated to high temperature and the hot dust can produce strong mid-infrared (5–20 μm) emission. In the case of a buried AGN at a LIRG's nucleus, direct detection of these AGN's properties is not easy, because of large extinction/absorption. However, we may be able to detect buried AGN signatures, through the effects of the AGN to the surrounding gas.

HCN(1–0) and HCO^+(1–0) emission are proposed to be a useful tool to probe such AGN effects. Observationally, AGN-dominated galaxy nuclei show high HCN(1–0) to HCO^+(1–0) ratios in brightness temperature ($\propto$ flux × λ^2), while starburst galaxies display low ratios. We have systematically investigated the HCN(1–0)/HCO^+(1–0) brightness-temperature ratios in a large number of LIRGs [1]. Our main results are that LIRGs with luminous buried AGN signatures in our previously taken infrared spectra tend to show large HCN(1–0)/HCO^+(1–0) brightness-temperature ratios, as seen in AGNs, while LIRGs without luminous AGN signatures in the infrared tend to show low ratios (Fig. 1 and 2). Namely, in many LIRGs, this HCN(1–0)/HCO^+(1–0) method agrees with our infrared energy diagnostic, confirming the effectiveness of this HCN/HCO^+ method.

The high HCN(1–0)/HCO^+(1–0) brightness-temperature ratios found in AGNs could be explained by the following scenarios. First, if the HCN abundance in the gas close to the AGN is enhanced, relative to HCO^+, due to AGN's chemical effects, then the HCN brightness-temperature can be high. Some theoretical calculations also predict that HCN abundance can be high, compared to HCO^+, in some reasonable parameter range for gas around buried AGNs in LIRG's nuclei. Alternatively, HCN molecule can be excited by absorbing mid-infrared photons, because HCN has a line at 14 μm. Since mid-infrared 14 μm emission is strong in an AGN, this radiative excitation can work effectively in an AGN, and can produce strong HCN(1–0) emission in the millimeter wavelength range, through a cascade process. We need detailed comparison with sophisticated theoretical models which realistically incorporate the structure of gas at LIRG's nuclei.

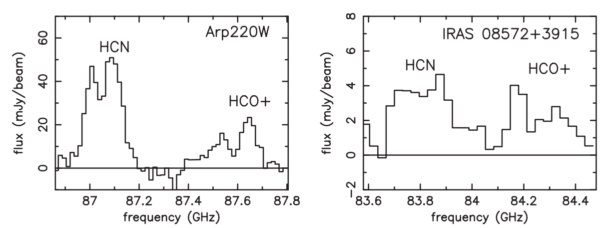

Figure 1: Example spectra of LIRGs obtained with Nobeyama Millimeter Array. HCN(1–0) emission is strong.

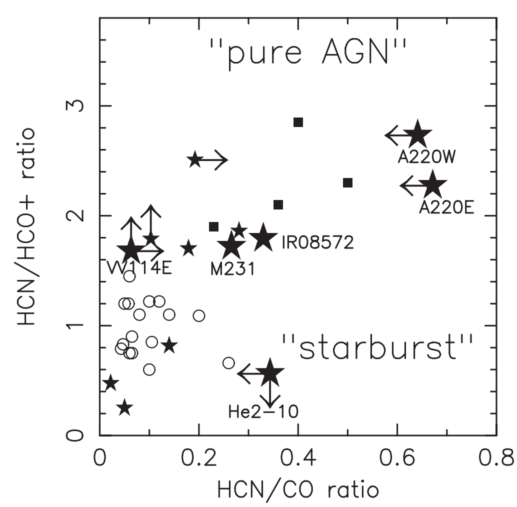

Figure 2: Filled squares: AGN-dominated galaxy nuclei. Open circles: starburst galaxies. AGNs distribute at the upper part, compared to starbursts. Filled stars: LIRGs. Large filled stars with objects name: LIRGs observed this time. LIRGs with luminous AGN signatures at other wavelengths tend to distribute at the upper part occupied by AGN-dominated galaxy nuclei.

Reference

[1] Imanishi, M., et al.: 2007, *AJ*, **134**, 2366.

Observations of Circumstellar Disks around Massive Protostars by the Subaru Telescope

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The formation process for stars with masses several times that of the Sun is still unclear. The two main theories are mergers of several low-mass young stellar objects, which requires a high stellar density, or mass accretion from circumstellar disks in the same way as low-mass stars are formed, accompanied by outflows during the process of gravitational infall. Although a number of disks have been discovered around low- and intermediate-mass young stellar objects, the presence of disks around massive young stellar objects is still uncertain. One of the best methods for distinguishing these two hypothesis is to directly detect a compact circumstellar disk around a massive YSO. However, massive stars are rarer than low-mass stars, and massive YSOs are distant in general. Since the expected accretion disk has a scale of a few 100 AU, a spatial resolution of 0.1 arcsec is necessary.

We have conducted high resolution (~0.1 arcsec) near-infrared imaging polarimetry with the adaptive optics, an IR camera (CIAO), and its polarimeter on the Subaru telescope. High resolution polarimetry is thus proven to be a powerful tool to detect circumstellar disks around massive YSOs and can be used to test the accretion hypothesis for more massive (>10 solar masses) stars. We have detected such a disk around BN and reported in Nature in 2005. We also observed 4 additional objects (S140 IRS1, S255 IRS1, NGC7538 IRS1, IRAS23033+5951) and found evidence for disks around 3 objects (Fig. 1) [1]. These are considered to be 10–30 solar mass objects.

These results strongly support the theory that stars with masses up to 30 solar masses form in the same way as lower mass stars. We could not detect such evidence in NGC 7538, however. We hope to study more massive stars with the new instrument HiCIAO, to test the accretion hypothesis for more massive stars.

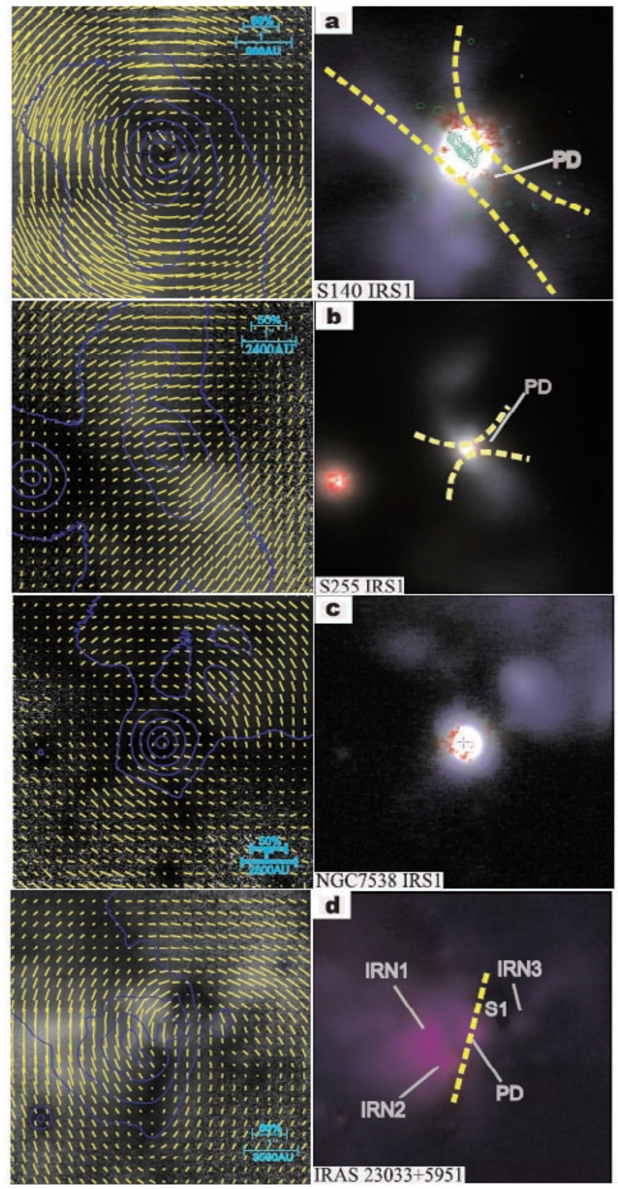

Figure 1: (left) Polarization vector (yellow) and polarization degree (gray-scale) maps. Blue contours show surface brightness. (right) surface brightness. (red) and polarized intensity (blue) maps. Contours in (a) show ionized disk.

Reference

[1] Jiang, J., et al.: 2008, *ApJ*, **673**, L175.

Infrared Imaging Polarimetry of the NGC 2071 Star-Forming Region with SIRPOL

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SIRPOL is the polarimetry mode of the *JHKs* band simultaneous infrared (IR) camera SIRIUS mounted on the 1.4 m IRSF survey-dedicated telescope in South Africa, which has been available since 2005 December. The instrument is the first to provide deep and wide-field infrared polarimetric images, and can in principle measure polarizations of all 2MASS-detected sources within a field-of-view of 7.′7 × 7.′7 in the *JHKs* bands simultaneously with 1% polarization accuracy. Such a capability is unique and has broad applications in many fields of astronomy, including efficient detection of circumstellar material that produces scattering, and delineating magnetic field structures in molecular clouds and in galaxies, through dichroic polarization.

We conducted deep *JHKs* imaging polarimetry of the NGC 2071 star-forming region (Fig.1). Our polarization data revealed various infrared reflection nebulae (IRNe) associated with the central IR young star cluster NGC 2071IR and identified their illuminating sources. There are at least 4 IRNe in NGC 2071IR, and several additional IRNe were identified around nearby young stars. Each illuminating source coincides with a known near-IR source, except for IRS 3, which is only a part of IRN 2 and is illuminated by the radio source 1c. Aperture polarimetry of the other point-like sources within the field was conducted in this region for the first time. The magnetic field structures (from 1 pc down to 0.1 pc) were derived using both aperture polarimetry of the pointlike sources (Fig. 2) and imaging polarimetry of the shocked H_2 emission; both are of dichroic origin and the derived field directions are consistent with each other. The magnetic field direction projected on the sky is running roughly perpendicular to the direction of the largescale outflow. We argue that the field strength is too weak to align the outflow in the large-scale field direction via magnetic braking [1].

Reference

[1] Tamura, M., et al.: 2007, *PASJ*, **59**, 467.

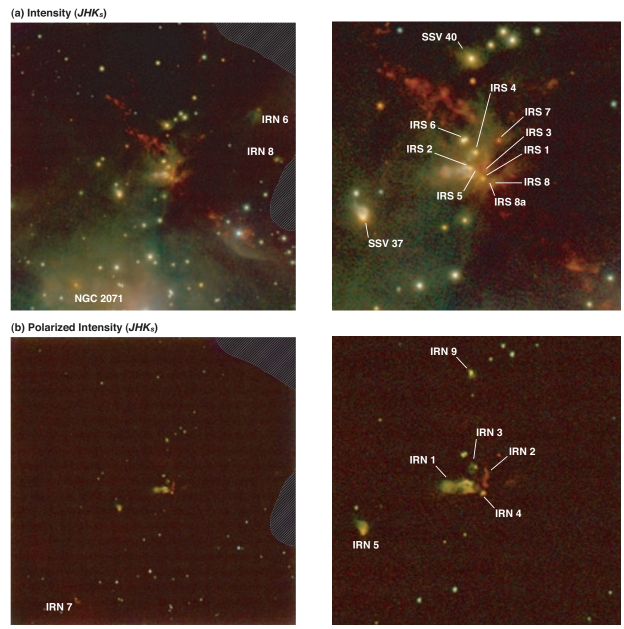

Figure 1: *JHKs* color composite images of intensity (a) and polarized intensity (b) of the NGC 2071 region. Field-of-view is 7.′7 × 7.′7 in the left images, while it is 40″ × 40″ in the right images.

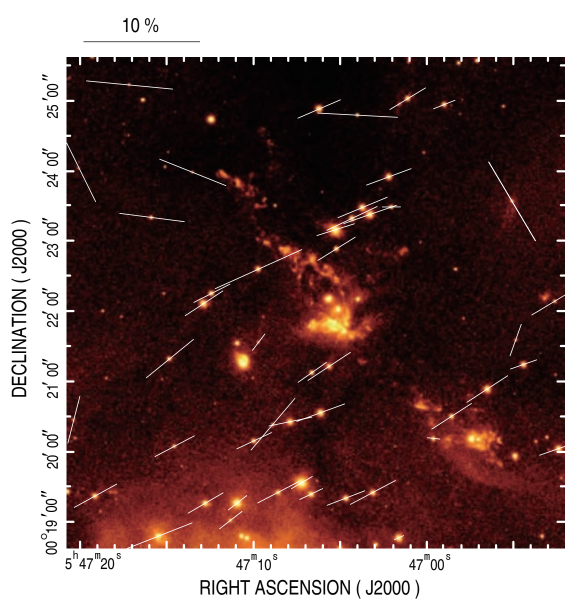

Figure 2: *Ks* band polarization map of point-like sources superposed on the intensity image. Note that the polarization of the central source of IRN 6 seen in the northwest has a clear intrinsic polarization.

UKIDSS searches of ultracool dwarfs: 1

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It has been established that the dwarf temperature sequence goes beyond the M stars from the observations in 1980–90s, and they are now recognied as L stars and T stars. The temperatures for M stars are 3800–2100K, corresponding to young brown dwarfs and low-mass stars. Those for L stars are 2100–1300K, while they are less than 1300K for T stars. L/T stars are brown dwarfs whose masses are less than 0.075 $M_{\odot}$.

In retrospect, the first L dwarf was discovered in 1988, and the first T dwarf was discovered in 1995. About 500 L dwarfs and about 60 T dwarfs have been known before 2007. These numbers can be significantly increased by recent deep and wide-area surveys. It is expected that UKIDSS survey using UKIRT 3.8 m telescope and WFCAM IR camera can detect many faint objects that cannot be observed with 2MASS/SDSS surveys. Furthermore, ultracool dwarfs, too cool to be detected with previous surveys, can be detected. Such ultracool dwarfs are called Y dwarfs; its spectra are expected to be very similar to that of Jupiter.

Our UKIDSS consortium has first used Early Data Release (EDR) and developed a method to select good candidates for ultracool dwarfs with UKIDSS/SDSS colors (Fig.1). We then made extensive follow up observations such as methane imaging and spectroscopy with Subaru/Gemini telescopes (Fig. 2).

As a result, from the EDR and First Data Release 1, we have discovered 13 T dwarfs down to T8.5 [1, 2]. We are close to the first Y dwarf detection and its statistical discussion.

References

[1] Kendall, T. R., et al.: 2007, *A&A*, **466**, 1059.
[2] Lodieu, N., et al.: 2007, *MNRAS*, **379**, 1423.

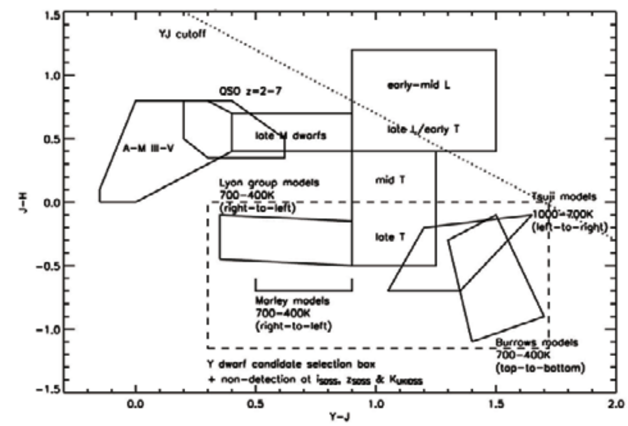

Figure 1: *J–H*, *Y–J* 2-color diagram for sources we expect in the UKIDSS. The location of A-M (III-V) stars, late M, L, and T dwarfs and z = 2 QSOs have been determined using colors synthesized from variable spectroscopy. Expected Y dwarf colors have been synthesized from the latest theoretical model spectra.

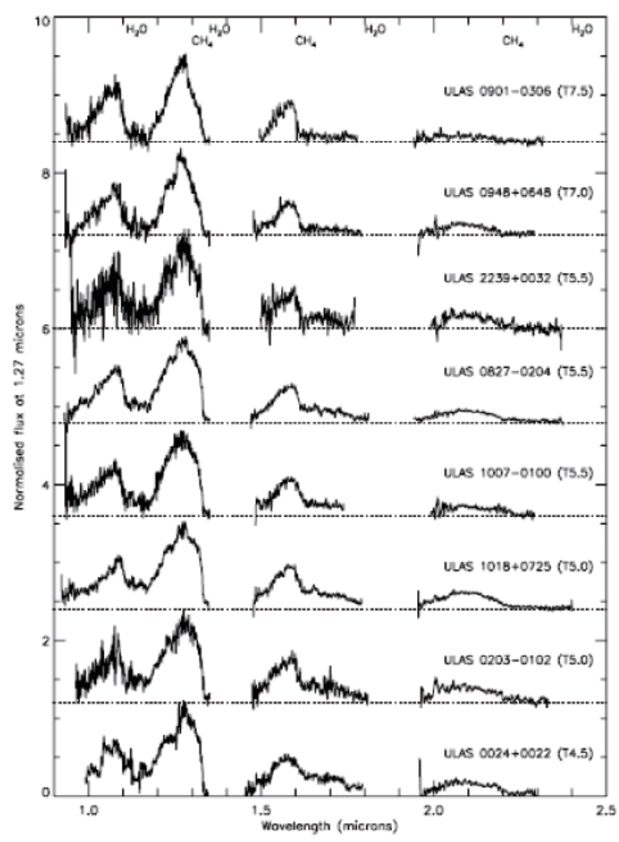

Figure 2: Example of spectroscopic library of UKIDSS T dwarfs (T4.5–T7.5). The spectra are from Gemini/GNIRS.

Velocity of coronal jets measured by EIS/*Hinode*

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Hinode spacecraft [1] has found a lot of jets in a polar coronal hole, where used to be thought quiescent. These ubiquitous phenomena are essential for understanding the coronal heating and solar wind acceleration in coronal holes. The X-Ray Telescope (XRT; [2]) allowed to examine the evolution of fine structures in jets. Detailed analysis indicates that the movements of thread in a jet is consistent with the X-ray jet model based on magnetic reconnection [3]. In addition to the apparent motion of the jets, line-of-sight velocity must be measured to study their dynamics.

Thanks to the high throughput and resolution of the EUV Imaging Spectrometer (EIS; [4]), Doppler shift of Fe XII λ195.12 emission line has been measured in a polar coronal hole [5]. Figure 1 shows radiance and velocity maps in the Fe XII λ195.12. Elongated jets are found above bright tiny loops in the coronal hole. Assuming one component plasma flow, Doppler shift of −30 km s^{-1} was derived in the most prominent jet. Blueshifts in jets are interpreted as upward flow in the corona. The actual upflow velocity could exceed 200 km s^{-1} if projection effect is taken into account. The observation implies that these jets are persistent flows rather than transient events, since it took about two hours to complete the raster scan. It is interesting to note that these jets are much weaker in radiance than bright loops in corona and they may not be clearly detected by a imaging telescope. Spectroscopic observations provide essential data for studying coronal dynamics, which are complementary to imaging observation.

It is important to understand the role of magnetic fields in view of energy release in the corona. Another observations including Solar Optical Telescope (SOT) are being investigated to examine magnetic fields in coronal holes.

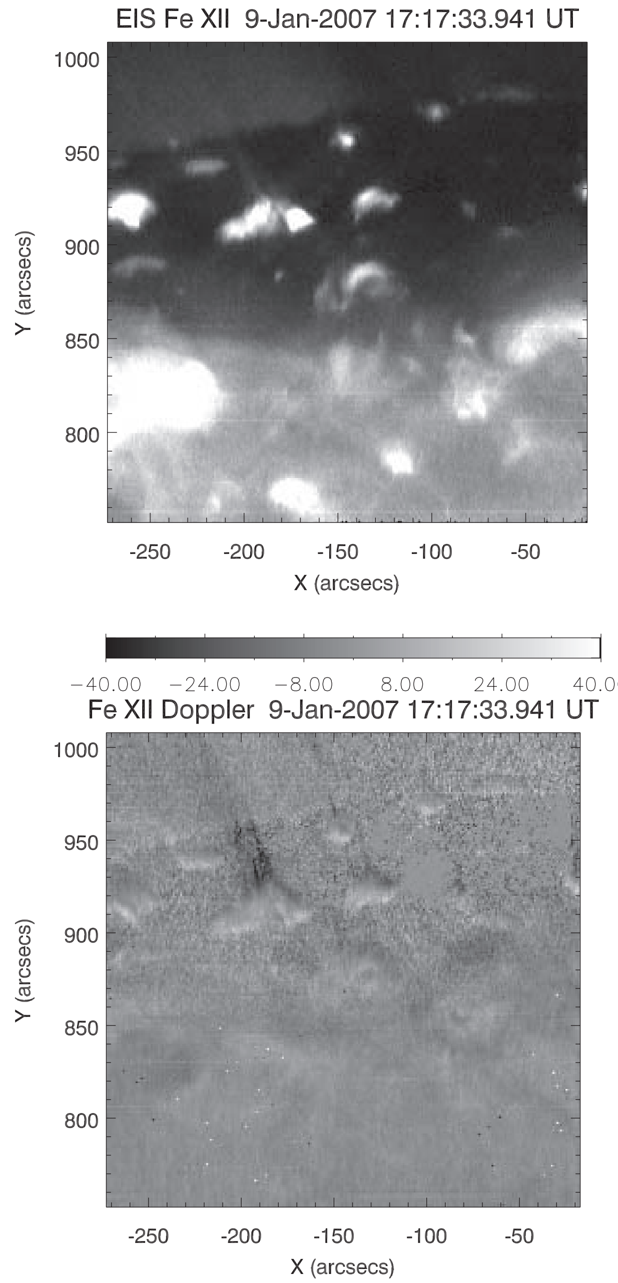

Figure 1: *Top*: Radiance map in Fe XII λ195.12. Coordinates indicate positions with respect to the Sun center. Bottom: Doppler velocity in the range of −40 to +40 km s^{-1}. Positive and negative velocities correspond to blue and red shifts, respectively.

References

[1] Kosugi, T., et al.: 2007, *Sol. Phys.*, **243**, 3.
[2] Golub, L., et al.: 2007, *Sol. Phys.*, **243**, 63.
[3] Shimojo, M., et al.: 2007, *PASJ*, **59**, 745.
[4] Culhane, L., et al.: 2007, *Sol. Phys.*, **243**, 19.
[5] Kamio, S., et al.: 2007, *PASJ*, **59**, 757.

Magnetic Feature and Morphological Study of X-Ray Bright Points with Hinode

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We observed X-ray bright points in a quiet region of the Sun with the X-ray Telescope (XRT) aboard the Hinode satellite from 11 UT to 24 UT on 19 December 2006.

There are two primary results of our investigation: first we identify four distinct shapes of XBP in the XRT observations; second we identify several XBPs that appear to be inconsistent with the flux cancellation model based on simultaneous SOT/NFI line-of-sight magentograms and XRT images.

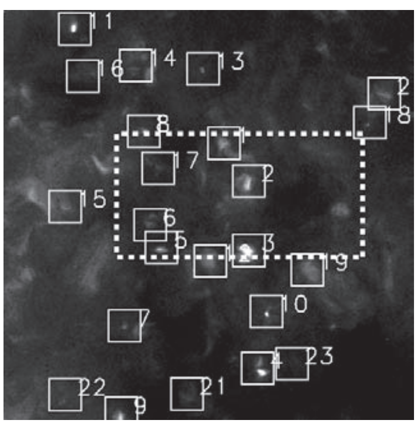

Figure 1: A snap shot of the quiet region of the Sun taken with the XRT on 19 Dec 2006. Small white squares with reference numbers represent areas of identified XBPs. The large dashed rectangle shows the field of view of SOT NFI.

High resolution X-ray images revealed that many XBPs have complicated structure and vary dramatically with time. Almost all of the dynamic eruptions in the quiet region were composed of XBPs and they have either loop or multiloop shapes, as is observed in larger flares. We classified the morphology of the XBPs into four types as shown in Figure 2.

In this observation sequence, the brightening XBPs have strong magnetic fields with opposite polarities near their footpoints. Several theoretical models of XBPs have recently been proposed, most of which include magnetic reconnection for generating the X-ray sources. While we have found a possible example of associated magnetic cancellation, at least for some XBPs, their Xray variation did not seem to be associated with magnetic cancellation. According to converging flux model proposed by Priest 1994 [1], cancelling magnetic features at the photosphere are correlated with their accompanying XBPs in the corona. However, X-ray intensity changes of XBPs did not seem to depend on their magnetic footpoint behavior. In other words, foot-point magnetic field does not directly affect the upper coronal behavior [2].

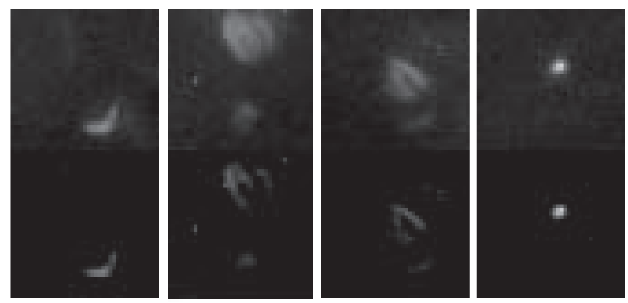

Figure 2: Typical morphologies of XBPs. Raw images (top) and unsharp masked images (bottom). From left to right, images represent loop, multiple loop, cusp and point-like structures.

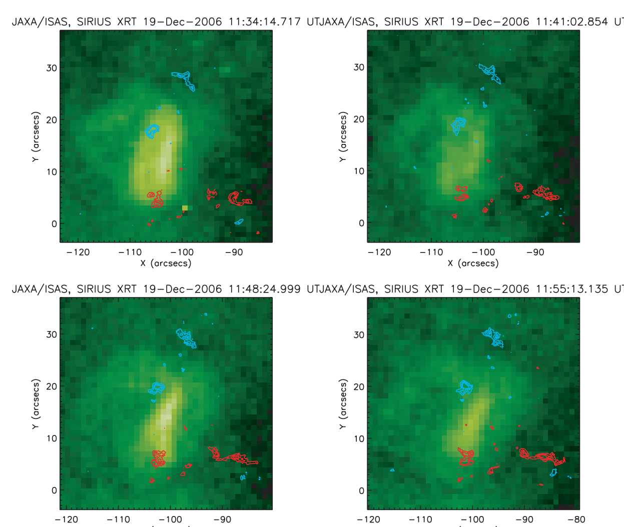

Figure 3: X-ray images taken with XRT are overlaid with the contours of the line-of-sight magnetograms taken with SOT. The contour levels correspond to the polarized degrees for both plus (red) and minus (cyan).

References

[1] Priest, E. R., et al.: 1994, *ApJ*, **427**, 459.
[2] Kotoku, J., et al.: 2007, *PASJ*, **59** 735.

Emergence of a helical flux rope associated with prominence formation

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NAGATA, Shin'ichi, SHIBATA, Kazunari (Kyoto University)

KUBO, Masahito, LITES, Bruce W.
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TARBELL, Theodore D., SHINE, Richard A., BERGER, Thomas E., TITLE, Alan M.
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Solar prominences are cool material (10^4 K) floating in the corona (10^6 K). It is known that prominences are supported by coronal magnetic fields against gravity and located along polarity inversion lines (PILs). Moreover, based on previous quantitative studies, it is often thought that magnetic fields in prominences have helical structures.

How is such a helical magnetic field created in association with prominences in the corona? Two theories have been discussed: flux rope models and sheared arcade models. In the former model, an originally twisted flux rope emerges from below the photosphere into the corona. In the latter one, potential fields in the corona are sheared by the photospheric motion along PILs. As a result, magnetic reconnection occurs among the sheared fields, and then helical fields are constructed in the corona. However, we have no clear observational evidence to support either model. To clarify the formation process of magnetic fields in a prominence, we have to investigate the relationship between the evolution of its associated magnetic fields on the photosphere and the overlying prominence.

The *Hinode* satellite was tracking a sunspot in active region NOAA 10953 from 2007 April 28 to May 9. Figure 1 shows an Hα filtergram, and a vector magnetogram of the active region taken or scanned. At the beginning of this observation, the prominence was so unstable that it disappeared and reappeared repeatedly. However, at some point, the prominence became stable. Focusing on this change, we analyze the time evolution of photospheric vector magnetic fields. As a result, we found four features:

1. The abutting opposite-polarity regions on the two sides along the PIL first grew laterally in size and then narrowed.
2. These abutting regions contained vertically-weak, but horizontally-strong magnetic fields.
3. The orientations of the horizontal magnetic fields along the PIL on the photosphere gradually changed with time from a normal-polarity configuration to a inverse-polarity one.
4. The horizontal-magnetic field region was blueshifted.

These indicate that helical flux rope was emerging from below the photosphere into the corona under the preexisting prominence [1]. We suggest that this supply of a helical magnetic flux into the corona is associated with formation and evolution of active-region prominences.

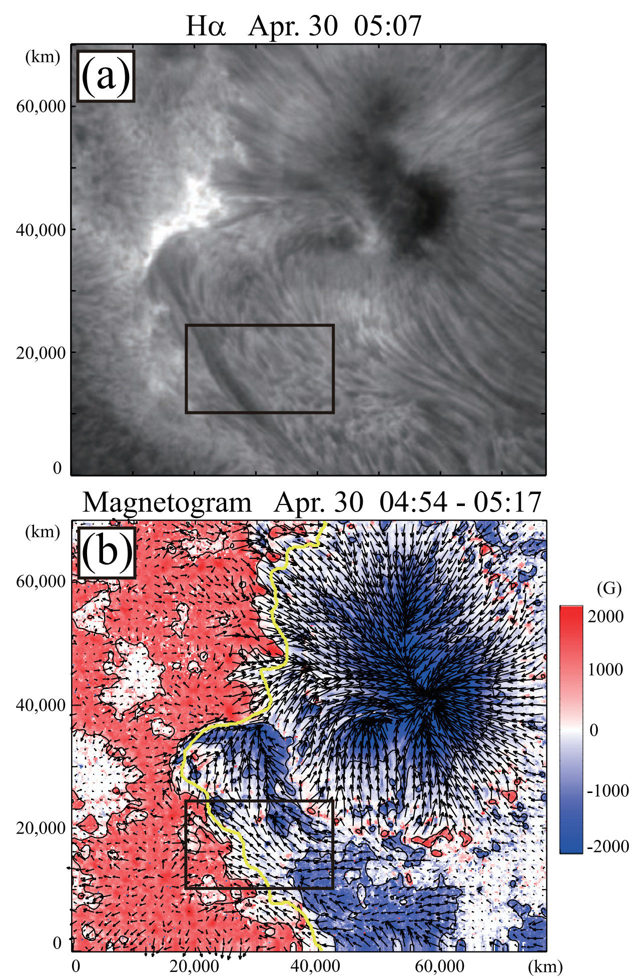

Figure 1: (a) Hα image. (b) Magnetogram. Color contour indicates the strength of vertical magnetic fields; red is positive and blue is negative. Arrows show the strength of horizontal magnetic fields. The yellow line is PIL.

Reference

[1] Okamoto, T. J., et al.: 2008, *ApJ*, **673**, L215.

Discovery of long, narrow, and straight HII gas in the Coma Cluster

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We observed the Coma Cluster in broadband and Hα narrowband with the Suprime-Cam mounted on the Subaru Telescope. In the data, we discovered a long, narrow and straight ionized hydrogen structure from the center of a poststarburst galaxy, D100 (Fig. 1) [1]. The follow-up spectroscopy confirmed that the structure has almost the same redshift as D100, and is emitting strong Hα (Fig. 2). If we assume the distance to the Coma Cluster to be 100 Mpc and the structure is observed as edge-on, the size of the structure is 60 × 2 kpc.

If we assume that the morphology of the gas is homogeneous cylinder, the mass of the ionized gas is ~2 × 10^8 $M_\odot$. The mass is comparable to a whole gas mass of a dwarf galaxy. Since the structure was not detected in previous HI observation, the gas is almost fully ionized.

The questions are the origin of the gas, the mechanism to form the long, narrow, and straight structure, and the ionizing source. Such long, narrow and straight ionized gas features were discovered in other clusters by previous studies, and they were jets from AGN. D100, however, shows no AGN. Neither X-ray nor radio, which often associate with jets, was detected around the region. Moreover, the emission line ratio implies that the ionizing source is not an AGN, but rather UV photon from HII regions or shock excitation. We presented two possible hypotheses to explain these results;

1. A gas rich dwarf is elongated by tidal force during infall to D100
2. The disk of D100 is stripped by ram pressure of the cluster gas.

Each hypothesis has problems, though. The former cannot explain the large dispersion of recession velocity in the structure. Also, the latter hypothesis requires special configuration that the edge of the tidal structure should be on at the line of sight to D100, and the orbit of the dwarf should be edge on, which is very rare. The latter, on the other hand, cannot explain why the structure is so narrow and straight. It is a future task to construct a consistent model.

Regarding the ionizing source, we proposed three possible ideas, since there are no AGN nearby;

1. interaction with cluster gas,
2. ionizing photon from star-forming region of D100,
3. the UV from hot cluster gas,

We now have data showing that the current star-formation of D100 is too weak to excite the structure, and 2. is denied.

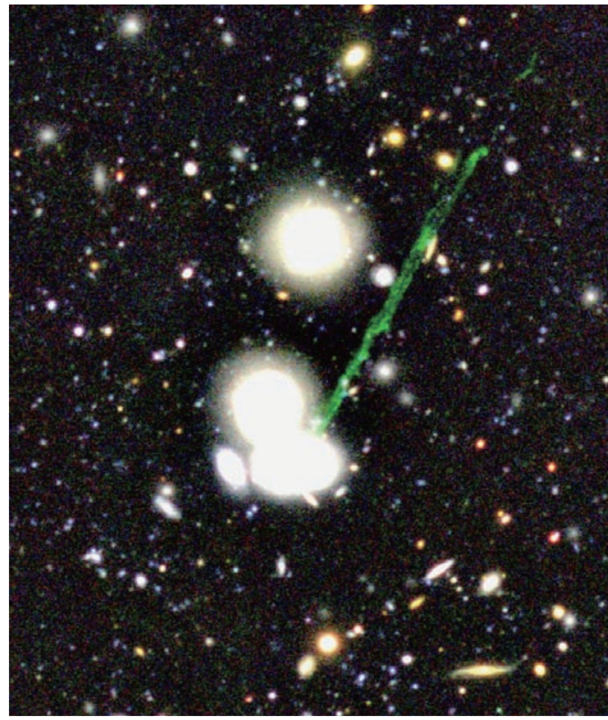

Figure 1: B(B), G(Hα), R(i) pseudo-color image. Ionized gas is seen as green.

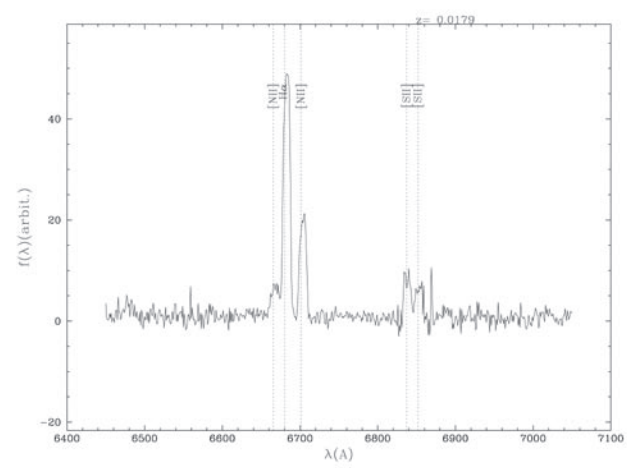

Figure 2: Spectrun of the gas near the center of D100.

Reference

[1] Yagi, M., et al.: 2007, *ApJ*, **660**, 1209.

Performance improvement of gravitational wave detector TAMA300 with a low frequency vibration isolation system

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We have been working on the new vibration isolation system, called "Seismic Attenuation System" (SAS), since 2005. The sensitivity of gravitational wave detector TAMA300 at around 100 Hz was previously limited by coupling of alignment sensing noise. In order to improve the sensitivity of TAMA300 in the low frequency band, the control bandwidth of the alignment control should have been reduced. For this purpose, we replaced the previous vibration isolation system to the SAS for all of four test masses. The installation and the tuning were completed in the summer of 2007.

The vibration isolation performance of the SAS essentially relies on low resonant frequencies of the mechanical systems. The SAS has a multiple-stage structure with a total height of about 2.5 meters, to realize seismic filtration from the low frequency such as 50 mHz. In order to suppress the excited motion of the low frequency resonances, three active local controls, an inverted pendulum control, a torsion mode control, and a test mass control, are applied. All of these control servos are realized by digital control systems based on LabVIEW. With the intrinsic vibration isolation performance of the SAS and these local control systems, test mass motions are well stabilized in all frequency band [1]. The longitudinal fluctuation of the 300-m Fabry-Perot cavity was measured by a cavity length correction signal. The displacement spectrum below 10 Hz is shown in Figure 1. By comparison with the spectrum with the previous suspension system, significant improvement of the length fluctuation with the SAS above 0.2 Hz was confirmed.

After the shaking down and tuning of the SAS, the power recycled operation of the 300-m Fabry-Perot Michelson interferometer has been recovered [1]. For the lock acquisition of the arm cavity, a digital control with TMS320C6713 DSP based system with a sampling rate of 200 kHz is newly employed. This achieves control bandwidth of about 800 Hz. Increasing use of digital filters makes the interferometer operation flexible and easier. Digital filters, however, have 100 to 1000 times worse noise levels compared to well-designed analog circuits. In order to avoid coupling of these noises to the interferometer sensitivity, analog frontend system before and after the digital filters were carefully designed.

The current sensitivity of TAMA300 is shown in Figure 2. Sensitivity improvement up to 200 Hz was confirmed although further tuning of the interferometer system is needed for the higher frequency band. Further improvement is expected by employing fast wave front sensing servos for mirror angular control.

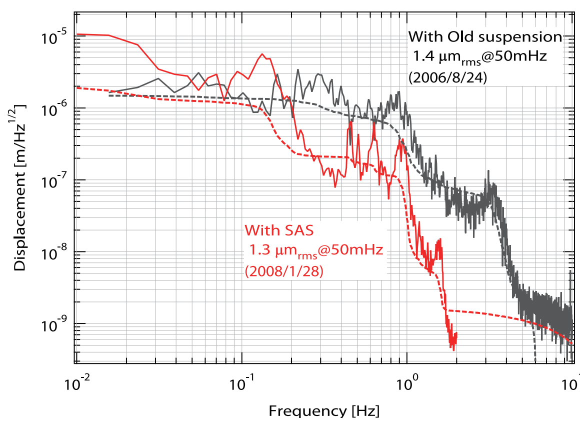

Figure 1: Length fluctuation of the 300-m cavity with the SAS and with the previous suspension system.

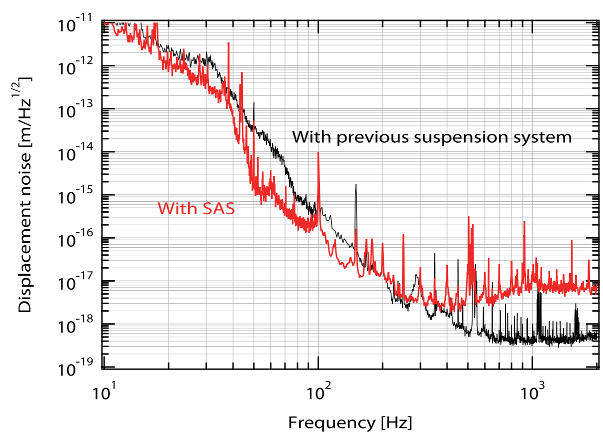

Figure 2: Current strain sensitivity of TAMA300 (red). The previous best sensitivity (black) is also shown.

Reference

[1] Takahashi, R., et al: 2008, *Class. Quamtum Grav.*, **25**, 114036.

Project Milkyway

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The aim of "Project Milkyway" is to reveal the formation process of galaxies, especially that of the Milkyway galaxy, by the state-of-the-art simulations. For this purpose, we have developed (i) PC-clusters whose computational nodes consist of ordinary CPUs (AMD Opteron) and special purpose computers, GRAPEs, which accelerate the calculation of gravity, and (ii) a parallel tree SPH code *ASURA* that utilizes GRAPEs.

We first performed high-resolution simulations of the ISM in order to investigate feasible modelling of star formation in high-resolution simulations [1]. From our simulations, we found that simulations which adopt a high-n_{th} model, where stars are formed from dense regions (n_H > 100 cm^{-3}), reproduce observational properties of global star formation such as star formation histories and surface gas density-surface star formation rate relations. Previous low-resolution simulations which adopt the isothermal ISM with a low-n_{th} model (n_{th} = 0.1 cm^{-3}), which is usually used in cosmological simulations of galaxy formation, also reproduce these properties. However, only high-n_{th} models can reproduce the inhomogeneous structure of the ISM and the vertical structure of gas and stars. It is remarkable that the use of a high-n_{th} criterion for star formation in high-resolution simulations makes numerical models fairy insensitive to the assumed values of the local star formation efficiency.

We next applied the high-n_{th} model to the evolution of interacting galaxies. We simply considered a collision of an equal mass, gas rich galaxies with a parabolic orbit.

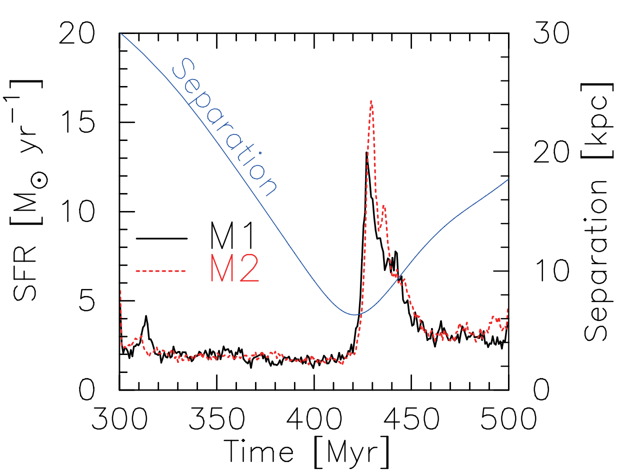

Figure 1: Star formation rate as the function of time (Myr). Black-solid and red-dotted lines indicate global star formation rate for two different mass resolution runs. Blue-solid line indicates the separation distance of galactic cores.

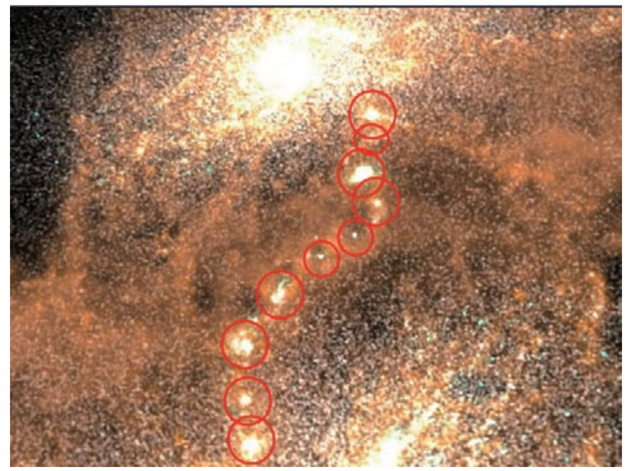

Figure 2: "Starburst" occurs in the "giant filament" during the first encounter. A number of star clusters are formed in the giant filament at the starburst phase. Brown, white and green points indicate gas, disk stars, and young stars, respectively. Red circles represent the star clusters which is self-bound. We thank Takaaki Takeda, who created this beautiful picture.

We use a total of 1.5 × 10^7 particles to represent two progenitor galaxies. From our simulations, we found that (I) a "giant filament" is formed at the collision interface and the burst of star formation occurs in the filament (see Fig. 1), and (II) a number of star clusters are formed in the giant filament at the starburst phase (see Fig. 2). These are consistent with observed properties of interacting galaxies and none of previous simulations reproduce these properties.

High-resolution with a realistic star formation model, such as our high-n_{th} model, allows us to study both quiescent star formation and starburst modes in *N*-body/SPH simulations. We are now tackling cosmological simulations of galaxy formation.

Reference

[1] Saitoh, T. R., et al.: 2008, *PASJ*, **60**, 667-681.

Common-Path Spectropolarimetric Differential Imager Using Variable Channeled Spectrum

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Various concepts of a high-contrast imager have been proposed for direct detection of exoplanets. In particular, a four-quadrant phase mask (FQPM) coronagraph can eliminate stellar light efficiently [1]. However, stellar speckle noise due to imperfections of optical surfaces prevents from observing the exoplanets. For suppressing the residual speckle noise, a spectral differential imager (SDI) or a polarization differential imager (PDI) has been proposed [2, 3]. The differential imagers acquire two images of different wavelengths or two orthogonal polarizations, and subtract one image from another one to cancel out the speckle noise. However, non-common-path aberration will be a serious problem because it causes remnant speckle noise in the differential images.

We propose a novel common-path differential imager, which can obtain both spectral and polarization differential images. Figure 1 shows the principle. The SDI-part is composed of two polarizers (P1 and P2), a variable retarder (VR1), and an interference filter (IF). By adjusting the retardation of VR1 and transmittance of IF properly (Δ_0 and T_0, respectively), a spectral transmittance of the optical system can be written as $T_0 \cos^2(\Delta_0/2)$, which acts as a bandpass filter with a central wavelength of λ_1, as described in Figure 1a. When the retardation is set to $\Delta_0 + \pi$, the transmittance becomes $T_0 \sin^2(\Delta_0/2)$ and also acts as a bandpass filter of λ_2, (Fig.1b). A spectral differential image can be obtained by subtracting two images acquired by these bandpass filters. The PDI-part is easily realized by inserting an additional variable retarder (VR2). Two images of 0°- and 90°- linearly polarizations can be obtained when the retardation of VR2 is set to 2π and π, respectively. Thus, a polarization differential image can be obtained by subtracting these two images.

We carry out numerical simulations of the proposed method (only the SDI-mode) equipped with an achromatic FQPM coronagraph. We simulate observations of a methane absorption feature in the H band. Note that, in practice, the variable retarder VR1 must be separated into a fixed retarder with large retardation and a variable retarder with small one, because it is difficult to reach large enough retardation with a single variable retarder. As the fixed and variable retarders, we assume a quartz retarder with a thickness of 1.8mm and an achromatic variable retarder, respectively. The central wavelength and bandwidth of the assumed interference filter are λ_0 = 1610 nm and $\Delta\lambda$ = 85 nm, respectively. As a result, the simulated optical system has two specific central wavelengths (λ_1 = 1580 nm, λ_2 = 1635 nm). Figure 2 shows the simulated FQPM-coronagraphic images with and without the SDI. As a result, a model exoplanet, which is 2×10^{-8} times fainter than a model star can be clearly observed at 5.0 λ/D (a white arrow).

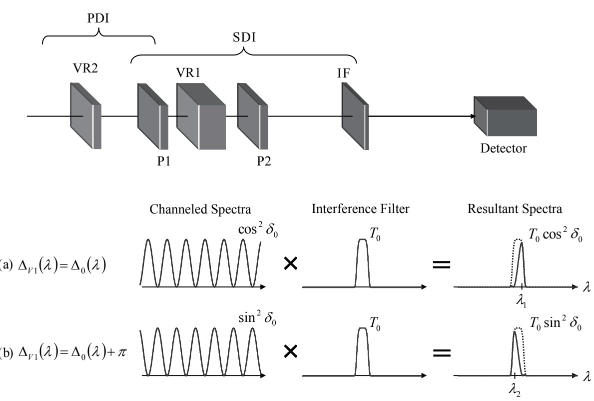

Figure 1: Principle of a common-path spectropolarimetric differential imager.

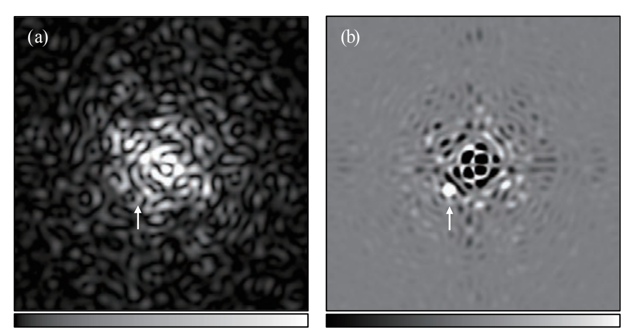

Figure 2: Numerical simulations of FQPM-coronagraphic images (a) without and (b) with the SDI.

References

[1] Rouan, D., et al.: 2000, *PASP*, **112**, 1479.
[2] Racine, R., et al.: 1999, *PASP*, **111**, 587.
[3] Baba, N., Murakami, N.: 2003, *PASP*, **115**, 1363.

Wide-Field Survey of the Local Group Dwarf Spheroidal Galaxy Leo II

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NAKATA, Fumiaki, OKADA, Norio, YAGI, Masafumi
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We carried out a wide-field imaging survey of the Local Group dwarf spheroidal galaxy Leo II using Subaru Prime Focus Camera (Suprime-Cam) (Fig. 1). The extensive field coverage of Suprime-Cam enabled us to investigate the extent of Leo II and the variation of the properties of stars within the galaxy. In particular, since Leo II is located so close (230 kpc), we can measure the position and the brightness of each star in the galaxy very accurately. By comparing these measurements and the evolution theory of stars, we can investigate the evolution of the galaxy, as an assembly of stars in the galaxy, in detail.

We first investigated the extent of Leo II by counting the number of red giant stars, which were selected from the color-magnitude diagram of Leo II, as a function of the radius; over a dozen red giant stars were found to exist beyond the tidal radius. To investigate how these extra-tidal stars are distributed, we made the surface brightness map determined by the stars that belong to Leo II (Fig. 2). As seen in this picture, a knotty structure, whose surface brightness is as faint as about 31 mag/arcsec^2, was discovered on the east (left) side of Leo II. The stars belonging to the structure are relatively old and their properties are similar to that of the stars located within the main body of the galaxy. We suggest that this structure could be a small globular cluster being disrupted by the tidal force of the galaxy; however, further observation is required to give a definite answer.

We also investigated distributions of red giant stars, horizontal branch stars and sub-giant branch stars located in the inner part of the galaxy. We showed that the property of the stars is different throughout the galaxy; the younger stars are found in the inner portions while old stars are found all through the galaxy. We conclude that star-forming activity occurred more than 8 Gyr ago throughout the galaxy, and the star-forming region gradually shrank from the outside toward the center [1]. The formation of stars ceased approximately 4 Gyr ago, except for the galactic center, where a small population younger than 4 Gyr is present.

Figure 1: False-color image of Leo II (composed from V and Ic band images). The field of view is 26.67 arcmin, covering much wider area than the tidal radius of Leo II (8.6 arcmin).

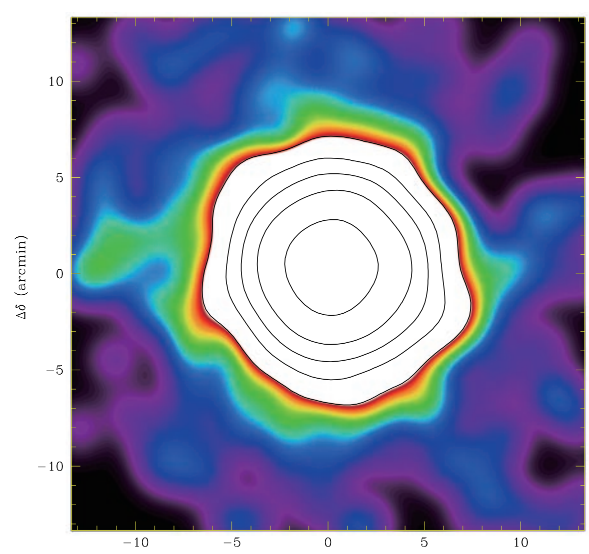

Figure 2: The surface brightness map of Leo II. From this figure, very faint knotty structure (shown in green to the east (left) of Leo II) was discovered.

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[1] Komiyama, Y., et al.: 2007, *AJ*, **134**, 835.

Activities of parent comets and related meteor showers

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The activity of a meteor shower is thought to be proportional to the activities through time of the parent comet. Recent applications of the dust trail theory provide us not only with a new method to forecast the occurrences and intensities of shower activities, but it is also offers a new approach to explore the history of past activities of the parent comet by retro-tracking its associated meteor showers. We introduce the result of an effort for relating meteor shower activities to the parent comet activities for which we chose the Draconids and comet P/Giacobini-Zinner in this paper [1].

Figure 1: Comet 21P/Giacobini-Zinner taken on October 2 with the 50cm telescope at the Mitaka of National Astronomical Observatory of Japan. The image is a composite of separate exposures of three filters ofdifferent color bands.

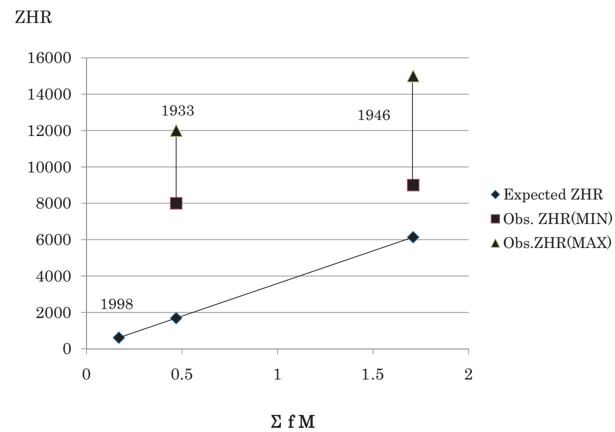

Figure 2: The relation between the ZHR and *fM* value. The solid line is the expected relation when normalized to the 1998 outburst. The vertical lines are the range of the observed ZHR. Both the 1946 and 1933 storms are higher than expected.

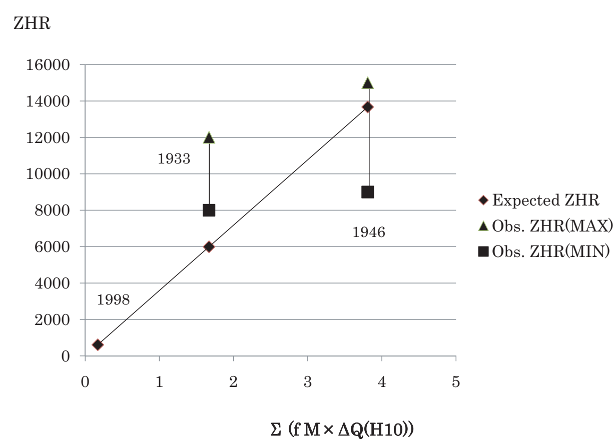

Figure 3: Same as figure 1, but the "corrected" *fM* value by the absolute magnitude of the parent comet. The 1933 and 1946 storm activities are well within the expected level of the 1998 activity case.

Reference

[1] Watanabe, J., Sato, M.: 2008, *Earth, Moon, and Planets*, **102**, 111.

Three-dimensional simulations of molecular cloud fragmentation regulated by magnetic fields and ambipolar diffusion

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We employ the first fully three-dimensional simulation to study the role of magnetic fields and ion-neutral friction in regulating gravitationally-driven fragmentation of molecular clouds [1]. The cores in an initially subcritical cloud develop gradually over an ambipolar diffusion time while the cores in an initially supercritical cloud develop in a dynamical time (Fig. 1). The infall speeds on to cores are subsonic in the case of an initially subcritical cloud (Fig. 2), while an extended (≥ 0.1 pc) region of supersonic infall exists in the case of an initially supercritical cloud. These results are consistent with previous twodimensional simulations. We also found that a snapshot of the relation between density (ρ) and the strength of the magnetic field (B) at different spatial points of the cloud coincides with the evolutionary track of an individual core (Fig. 3). When the density becomes large, both relations tend to $B \propto \rho^{0.5}$.

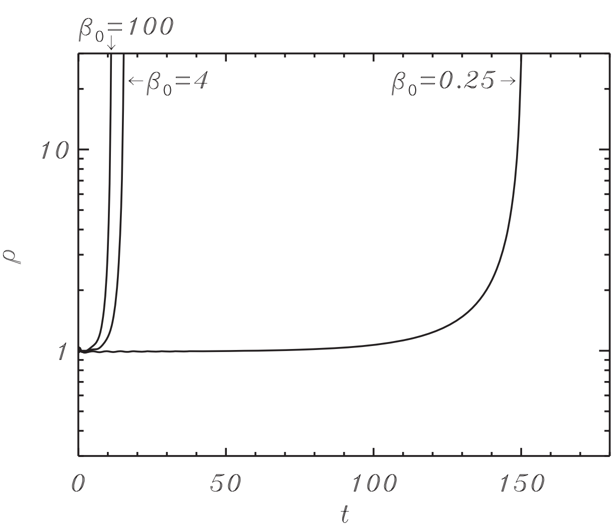

Figure 1: The time evolution of the density at the location where the density reaches its maximum value in each simulation. Each line shows a case of different initial plasma β (β_0). When $\beta_0 < 1$, the cloud is subcritical. The unit of time is ~ 2.5×10^5 yr.

Reference

[1] Kudoh, T., et al.: 2007, *MNRAS*, **380**, 499.

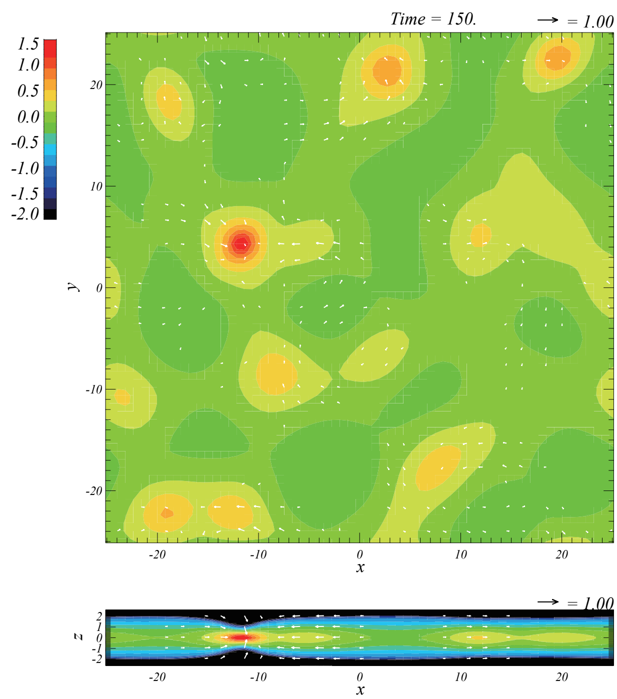

Figure 2: The logarithmic density contours for $\beta_0 = 0.25$ at $t = 150$. Arrows show velocity vectors on each cross section. The unit of the velocity vector is the sound speed (~0.2 km/s) at $z = 0$. Upper panel shows the cross section at $z = 0$, and the lower panel shows the cross section at $y = 4.3$.

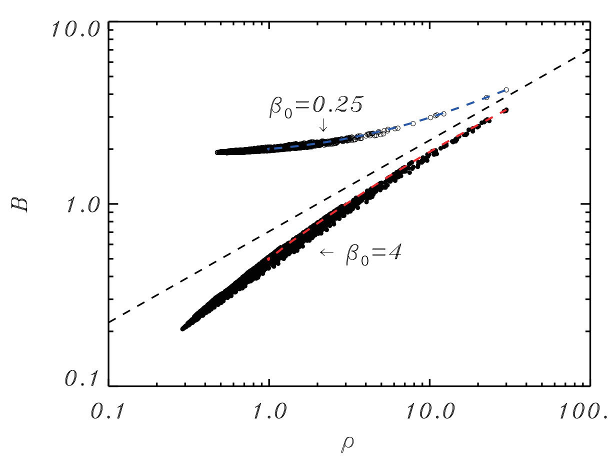

Figure 3: Open circles show the magnetic field strength as a function of density along $z = 0$ at $t = 150$ for the model with $\beta_0 = 0.25$. Filled circles are the same for $\beta_0 = 4$, at $t = 15.3$. The blue line shows the evolutionary track of the point at which the density achieves its maximum value for the model with $\beta_0 = 0.25$. The red line is the same for $\beta_0 = 4$. The dashed line shows $B \propto \rho^{0.5}$. The unit of the magnetic field strength is ~10 μG.

Vertical Temperature Structures of the Solar Corona derived with the Hinode X-Ray Telescope

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We obtain temperature structures in faint coronal features above and near the solar limb with the X-ray Telescope (XRT) on board the Hinode satellite by accurately correcting the scattered X-rays from surrounding bright regions with occulted images during the solar eclipses [1]. Figure 1 shows the temperature and emission measure maps taken at the eclipse on February 17, 2007, in which the Moon passed the southern part of the solar corona and occulted a polar coronal hole. Our analysis yields the polar coronal hole temperature of about 1.0 MK and emission measure in the range of $10^{25.5}$–$10^{26.0}$ cm^{-5}. The derived temperature is almost consistent with past studies by emission lines, but inconsistent with the SXT result. It is probably because SXT has almost no response to 1 MK plasma. Above the coronal hole some radial plume-like structures were seen. The temperature profiles along them as a function of height are shown in Figure 2. They appear to have increasing temperature with height during the first 100 Mm and constant temperatures above 100 Mm. We discussed the possibility of heating by Alfvén waves with periods of 3–5 minutes, and ruled out such the heating at last.

In addtion, we analyzed diffuse quiet Sun region at mid-latitudes by the eclipse on March 19, 2007, and found for the diffuse quiet-Sun region the temperatures are the highest just above the limb and appear to decrease with height. The difference with the temperature along plume-like structures may be due to different magnetic configurations.

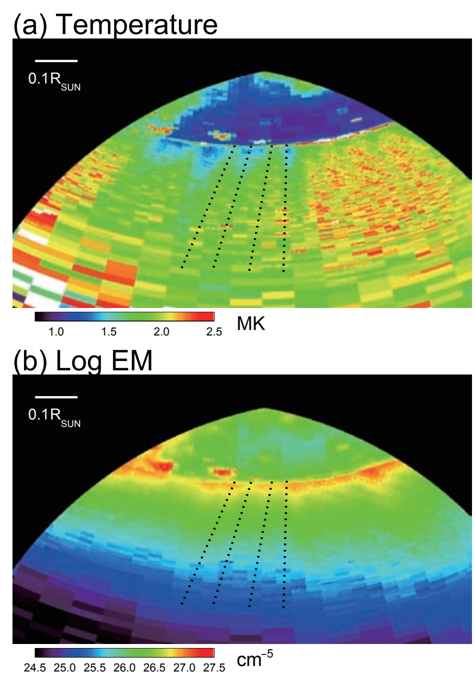

Figure 1: (a) Temperature and emission measure maps derived with the filter-ratio method of Hinode/XRT. We accurately estimated scatterred X-rays from surrounding corona in lunar shades, and analyzed the coronal temperature in it.

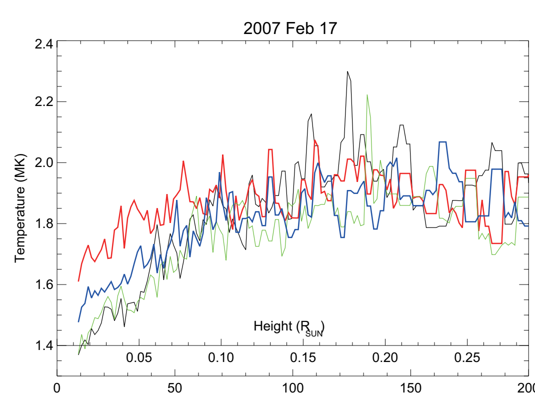

Figure 2: Temperature profiles along some plume-like structures which were seen above the southern coronal hole (thin dot lines in Figure 1).

Reference

[1] Kano, R., et al.: 2008, *PASJ*, **60**, 827.

Radial Velocity Variations of Procyon: Detection of Oscillations and Long-Term Variations

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and 14 authors

Small uncertainties in physical processes in stars, such as convection, rotation, and material diffusion, have often large consequences for the evolution of stars. The goal of asteroseismology is to improve the description of interior physics of stars to such a level that cannot be reached with conventional observations. The asteroseismology of solar-type stars become active than ever, as an application of helioseismology, as a probe of planet-harboring stars, and stimulated by developments of sophisticated observing methods.

After Bedding et al.'s convincing detection of solar-type oscillations in β Hyi in 2001, asteroseismology is now applied to several main-sequence stars like α Cen A. Despite formidable challenges by many researchers for the past few decades, however, features of oscillations in Procyon have not been uncovered yet. One of reasons of this inability is that the star, almost departing its main-sequence phase, has already lost its simple oscillation pattern in the periodogram. Therefore, to firmly obtain its oscillation frequencies, we conducted a big observing campaign of Procyon in Jan. 2007 (P.I. Tim Bedding), connecting 10 observatories around the globe.

We, Japanese group, developed an iodine cell for the HIDES at Okayama Astrophysical Observatory in 2000, and have tried to improve our radial-velocity extraction software since then. In fact, for iodine cell observations, it is crucial to remove influences of temporally variable instrumental profile of the spectrograph on the stellar radial velocity. In the 2007 campaign, we can reach the precision of 2 m s^{-1} [1].

Owing to such high precision, we could see the oscillation signal in real temporal domain at Okayama (Fig. 1). More interestingly, in comparison to simultaneous observations with AAT we can clearly detect slow variations on time scale of hours to weeks in the star. These are probably due to granules and spots in the star, indicating similar activities occurring in Procyon to those seen in our sun. We are now examining properties of the oscillations and the slow variations by combining all campaign data.

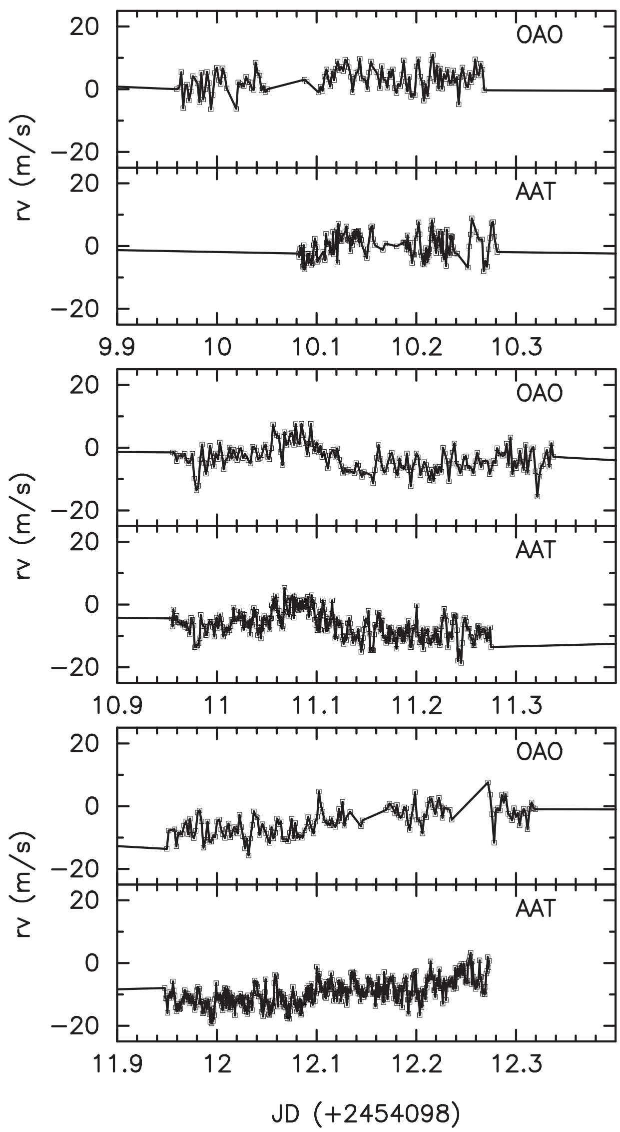

Figure 1: Radial velocity variations in Procyon during 2007 campaign. Not only oscillation signals, but also slow variations are clearly seen both in OAO and AAT data.

Reference

[1] Kambe, E., et al.: 2008, *PASJ*, **60**, 45.

Physical and Chemical Properties of Massive Clumps in the AFGL 333 Cloud

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A far-infrared source, AFGL 333, is located in the W 3 giant molecular cloud at a distance of 1.95 kpc [1]. AFGL 333 itself is a compact HII region generated by a B0.5 type star [2]. Recently, we have mapped the AFGL 333 region in the C^0 $^3P_1$–$^3P_0$ line and the CO J = 1–0 isotopomer lines ([3]; Paper I). From the $C^{18}O$ J = 1–0 observation, we have found two massive clumps in the AFGL 333 cloud: Clump A (2.3×10^3 $M_\odot$) and B (1.4×10^3 $M_\odot$) (Fig.1a). Although their masses are comparable to those for on-going massive star-forming clumps, no IRAS and NVSS sources are associated with Clump A and B. In addition, we have found in Paper I that the $[C^0]/[CO]$ and $[CCS]/[N_2H^+]$ ratios are higher in the AFGL 333 cloud than in the W 3(OH) cloud. From these results, we have suggested that these massive clumps are in an early stage of massive star formation. In this paper, we have further investigated their physical and chemical properties in detail.

We have mapped the N_2H^+ J = 1–0, CCS J_N = 4_3–3_2, HC_3N J = 5–4 toward two massive clumps in the AFGL 333 cloud by using the Nobeyama Radio Observatory 45 m telescope (Fig.1b–d). The distributions are found to be different from molecule to molecule. The N_2H^+ emission comes from the both clumps, whereas the CCS and HC_3N emissions mainly come from Clump B. We found that the $[CCS]/[N_2H^+]$ and $[HC_3N]/[N_2H^+]$ ratios tend to be higher in Clump B than Clump A. These results may indicate that Clump B is chemically younger than Clump A.

In Fig.1e, we plot 2MASS sources as diamonds. Several 2MASS sources with $H–K > 2$, which are expected to be YSO candidates, are associated with Clump A. In contrast, such sources are not found in the central part of Clump B. These results indicate that Clump B is in an earlier evolutionary stage than Clump A.

Figure 1f shows the 1.3 mm continuum contour map observed by [4]. It appears that each clump contains four cores (MMS 1a–d in Clump A and MMS 2a–c and 3 in Clump B). In the Spitzer 24 μm image (Fig.1g), dark patches correspond to MMS 2a–c, implying that MMS 2a–c are still starless or in a very early stage of star formation. We suggest that MMS 2a, which is the most massive core in Clump B, might be a starless core in which high- or intermediate mass stars will be formed there in the near future. Such a core is an important target to understand the initial condition of high- or intermediate-mass star formation. Details of this study are described in [5].

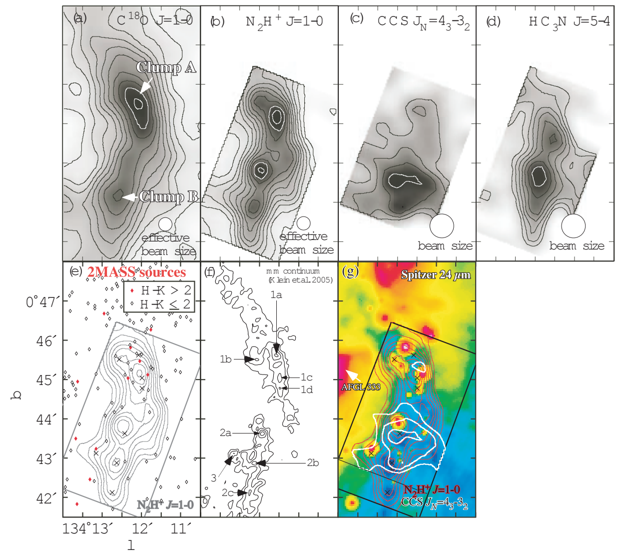

Figure 1: Integrated intensity maps of $C^{18}O$ J = 1–0 (a), N_2H^+ J = 1–0 (b), CCS J_N = 4_3–3_2 (c), HC_3N J = 5–4 (d). (e) Distribution of the 2 MASS point sources. (f) 1.3 mm continuum contour map observed by [4]. (g) Spitzer 24 μm image.

References

[1] Xu, Y., et al.: 2006, *Science*, **311**, 54.
[2] Hughes, V. A., Viner, M. R.: 1982, *AJ*, **87**, 685.
[3] Sakai, T., Oka, T., Yamamoto, S.: 2006, *ApJ*, **649**, 268.
[4] Klein, R., et al.: 2005, *ApJS*, **161**, 361.
[5] Sakai, T., Oka, T., Yamamoto, S.: 2007, *ApJ*, **662**, 1043.

Three Dimensional Line Transfer Study of Molecular Gas at the Centers of Active Galaxies

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Molecular gas in external galaxies is a subject of crucial importance for observational and theoretical studies of galaxy formation. Among the interstellar medium (ISM) in external galaxies, compact molecular gas around an active galactic nuclei (AGN) is expected to be an energy budget from AGN and/or the central starburst. Recent observations suggest line ratios in millimeter and submillimeter band may be a good tool to reveal the longstanding question on the origin of activity – AGN or nuclear starburst [1]. In spite of numerous observational studies towards the compact molecular gas or AGN torus at the center of external galaxies, current instruments have not succeeded in resolving internal hydrodynamical and/or thermal structures [2, 3].

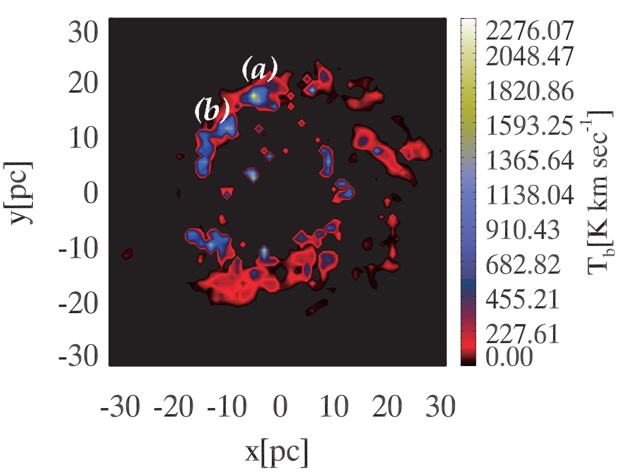

Figure 1: The integrated intensity distribution of HCN(1–0) line of our simulation in face-on view.

In order to study the internal structures of compact molecular gas at the center of an active galaxy, we performed line transfer calculations of HCN, and HCO^+ rotational lines along with high resolution hydrodynamic simulation [2]. Figure 1 shows an integrated intensity distribution of HCN(1–0) line. It presents inhomogeneous intensity distribution caused by highly clumpy density and temperature structures of the molecular gas. The typical size of bright spots appearing in Figure 1 is about 10 pc, or 0″.1 if the galaxy is located at distance of 20 Mpc. The forthcoming high resolution observation with Atacama Millimeter/submillimeter Array (ALMA) can resolve such tiny structures. In this mean, our line transfer simulation method is capable of direct simulation of high quality mm./submm. observations in ALMA era.

These results demonstrates that when inhomogeneous ISM is subthermally excited and marginally thick ($\tau_0 \approx 1$), interpretation of observational results should be done carefully. Figure 2 shows the density and optical depth increment distributions along two lines of sight labelled as (a) and (b) in Figure 1. At the point (a) the stimulated emission dominates the intensity due to weak inverted population, though, such an amplification does not appear at the point (b). These results emphasize the ability and applicability of our approach, that is, the compilation of hydrodynamic simulations and three-dimensional radiative transfer calculations.

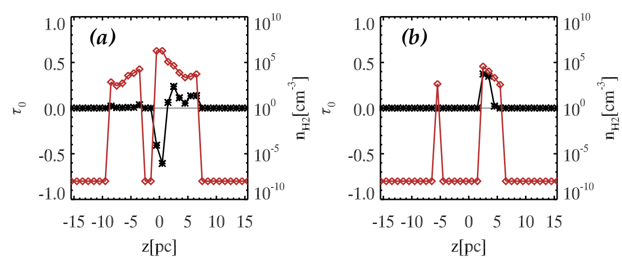

Figure 2: Density and optical depth increment distribution along two lines of sight at the points labeled (a) and (b) in Figure 1. Red lines denote density, and black lines do optical thickness increment, respectively. These correspond different circumstances, due to inhomogeneous torus structure and excitation condition.

Our results of excitation temperatures show that line ratio $R_{HCN/HCO^+} > 1$ is quite difficult to achieve unless fractional abundance of HCN is much greater than that of HCO^+, namely $y_{HCN} \geq 10 \times y_{HCO^+}$ or more (where y is molecular abundance compared with hydrogen molecule). Realistic simulation with chemical evolution models will reveal the validity of HCN/HCO^+ diagnostics of active galaxies.

References

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[2] Yamada, M., Wada, K., Tomisaka, K.: 2007, *ApJ*, **671**, 73.
[3] Wada, K., Tomisaka, K.: 2005, *ApJ*, **619**, 93.

Subaru Near-Infrared Multicolor Images of Class II Young Stellar Object, RNO 91

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RNO91 is known as a source of complex molecular outflows. Previous studies suggested that RNO91 was associated with a reflection nebula [1, 2, 3], a CO outflow [4], shock-excited H_2 emission [5], and a disk type structure [3]. However, geometry of RNO91, especially its inner region, is not well confirmed yet. High resolution imaging is needed to understand the nature of RNO91 and its interaction with outflow.

Thus, we conducted sub-arcsecond near-infrared imaging observations of RNO91 with CIAO mounted on the Subaru 8.2 m telescope. We present our *JHK* band data along with optical images, which are the highest resolution images of RNO91 ever taken (Fig.1) [6]. We examined the colors of associated nebula and compared the geometry of the outflow/disk system suggested by our data with that already proposed on the basis of previous studies. The main conlusions are as follows [6]:

1. Our *K*-band image shows bright circumstellar nebulosity detected within ~2″ around the central source while it is less conspicuous at shorter wavelengths. At all wavelengths, radial profile of the surface brightness showed a change of slope at ~2″(300AU) from the central peak, suggesting a morphological difference beyond this point. P.A. and size of this red color nebulosity agree with those of the previously detected polarization disk. These data agreement indicates that this bright nebulosity region which follows the reddening law might be attributed to a disk-like structure.
2. At *J* and optical wavelengths, several blue knot-like structures are detected. Each of these structures has a few of 10 AU scales and randomly distributed around and beyond the bright circumstellar disk. We suggest that these knotty reflection nebulae may represent disintegrating fragments of an infalling envelope. The complex distribution of reflection nebulosity seen around RNO91 appears to confirm the interpretation of this source as an object dispersing its molecular envelope while transitioning from protostar to T Tauri star.
3. Our image has the appearance of arc-shaped nebulosity. We interpret these structures as being roots of a bipolar cavity opening toward the northeast and the southwest.

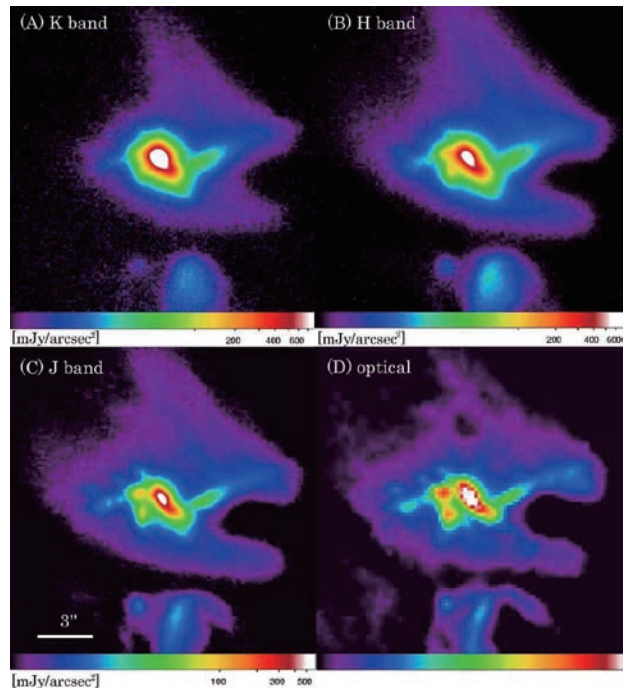

Figure 1: *J*, *H* and *K* band images of RNO91 with an *HST* optical image (F606W). Field of View (FOV) is 17″ × 17″.

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Parallax measurement of star-forming region S269 with VERA

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KAMEYA, Osamu, KAMOHARA, Ryu-ichi, KAN-YA, Yukitoshi, KAWAGUCHI, Noriyuki
KOBAYASHI, Hideyuki, KUJI, Seisuke, KURAYAMA, Tomoharu, MANABE, Seiji, MIYAJI, Takeshi
OYAMA, Tomoaki, SAKAI, Satoshi, SATO, Katsuhisa, SHIBATA, M. Katsunori, TAMURA, Yoshiaki
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S269 (Sharpless 269) is a massive star forming region toward constellation Orion, and a bright H_2O maser source is associated with S269. We have performed highprecision astrometry of the H_2O maser in S269 with VERA, and detected the annual modulation in the eastwest position offset as shown in Figure 1. From the amplitude of the position modulation, the trigonometric parallax of S269 is determined to be 189 ± 8 μas. This corresponds to the source distance of 17250 light-year, being one of the largest ditances ever measured by means of trigonometric parallax.

The proper motions of S269 have also been measured based on the VERA observations. The relative motion of S269 with respect to the LSR (the Local Standard of Rest) is found to be 0.2 mas yr^{-1}. Such a small proper motion can be explained if the velocity vectors of S269 and the Sun are similar to each other and cancelled out in the relative measurements. Based on this fact combined with the parallax measurement of S269, the Galactic rotation velocity at the position of S269 is also determined precisely. The result indicates that the difference of rotation velocities at the Sun and at S269 (which is 13.1 kpc away from the Galaxy's center) is less than 3 %. This gives the strongest constraint on the flatness of the outer rotation curve as shown in Figure 2, and provides a direct confirmation on the existence of large amount of dark matter in the Galaxy's outer disk.

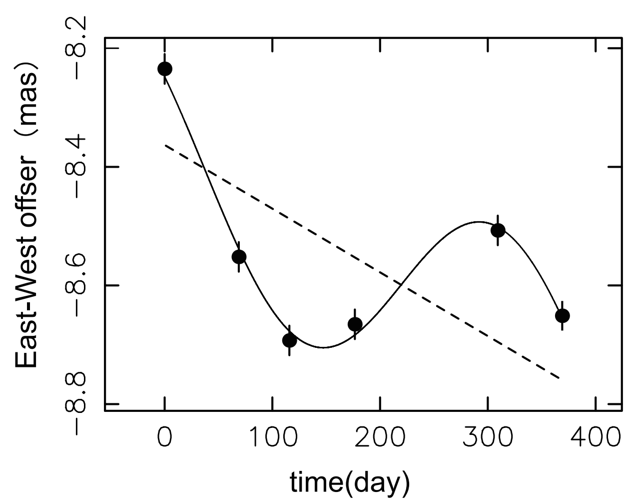

Figure 1: East-West motion of the maser source in S269 observed with VERA. The annual modulation caused by the parallax (π = 189 ± 8 μas) is clearly seen.

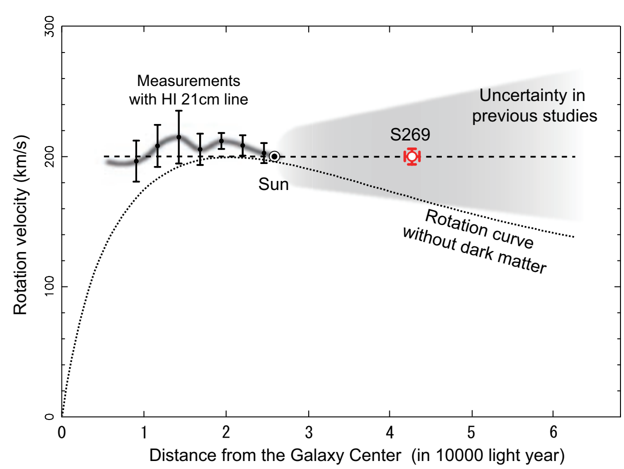

Figure 2: Rotation curve of the Galaxy obtained by previous studies as well as the rotation velocity at S269 obtained with VERA. Our observations suggest that the rotation curve is likely to be flat out to ~40000 light year from the Galaxy's center.

Reference

[1] Honma, M., et al.: 2007, *PASJ*, **59**, 889.

Dense molecular gas arc in supergiant HII region NGC 604

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(1 NAOJ, 2 University of Tokyo)

Giant or supergiant HII regions (hereafter referred to as GHRs) are one of the most prominent objects in star-forming galaxies at the optical wavelength (Kennicut 1984). Central star clusters in GHRs appear to have formed during the initial stages of the formation of GHRs, and are expected to have a strong impact on their natal molecular clouds due to their strong UV radiation, stellar wind, and supernova explosion. Therefore, GHRs provide us with an ideal environment to understand the clustered OB star formation process, and their impact on the ambient interstellar medium (ISM). These physical processes are also crucial in the evolution of starburst in galaxies.

To address this issue, we present the ^{12}CO(3–2) and ^{12}CO(1–0) observations of NGC 604 in the nearest faceon spiral galaxy M 33 using the Atacama Submillimeter Telescope Experiment (ASTE) 10-m and the Nobeyama Radio Observatory (NRO) 45-m telescopes [1].

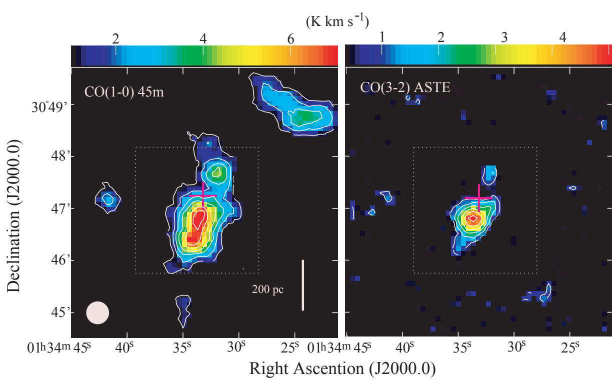

Figure 1: Total integrated intensity maps of ^{12}CO(1–0) (left panel) and ^{12}CO(3–2) (right panel). the position of the central star cluster of NGC 604 indicated as cross.

We found a high ^{12}CO(3–2)/^{12}CO(1–0) ratio gas with an arc-like distribution ("high-ratio gas arc") surrounding the central star cluster of the supergiant HII region NGC 604. The discovered "high-ratio gas arc" extends to the south-east to north-west direction with a size of ~ 200 pc. The western part of the high-ratio gas arc closely coincides well with the shells of the HII regions traced by Hα and radio continuum peaks. The CO(3–2)/CO(1–0) ratio, $R_{3-2/1-0}$, ranges between 0.3 and 1.2 in the observed region, and the $R_{3-2/1-0}$ values of the high-ratio gas arc are around or higher than unity, indicating very warm ($T_{kin} \geq$ 60 K) and dense ($n_{H_2} \geq 10^{3-4}$ cm^{-3}) conditions of the high-ratio gas arc. We suggest that the dense gas formation and second-generation star formation occur in the surrounding gas compressed by the stellar wind and/or supernova of the first-generation stars of NGC 604, i.e., the central star cluster of NGC 604. Thus, NGC 604 is an example of a large-scale sequential star formation.

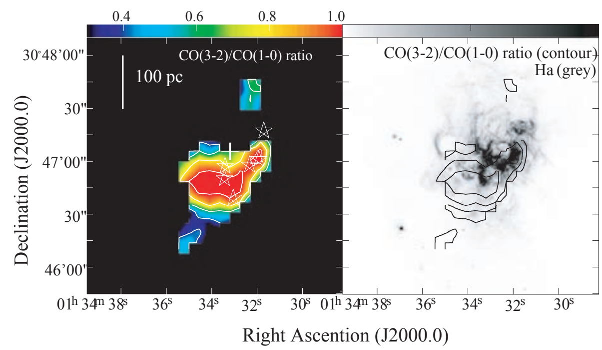

Figure 2: Maps of the ratio of ^{12}CO(3–2) to ^{12}CO(1–0) (left panel) and the Hα emission by HST (right panel; from the HST archive). The contour levels are 0.4, 0.6, 0.8, and 1.0. The crosshairs in the center indicate the position of the central star cluster of NGC 604, while the stars represent the peak positions of the HII regions detected by λ 3.6-cm radio continuum emission.

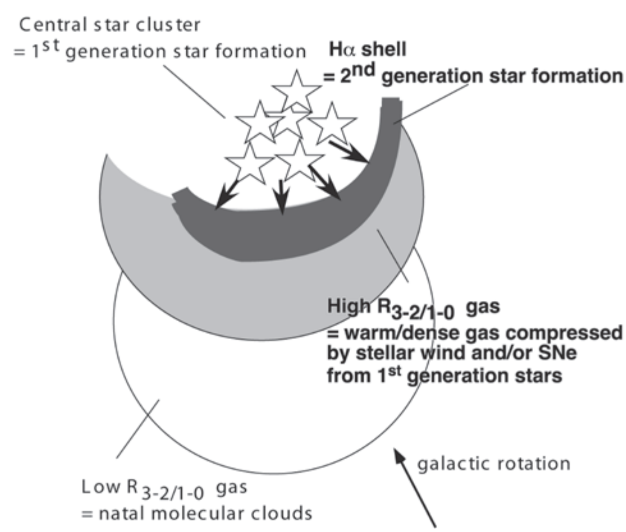

Figure 3: Scematic view of NGC 604.

Reference

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Near-Infrared Imaging Polarimetry of the Star Forming Region NGC 2024

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We present near-infrared polarimetric studies of NGC 2024, a massive star-forming region in the Orion B giant molecular cloud [1]. Observations were made using the near-infrared imaging polarimeter SIRPOL (polarimeter: [2], camera: [3]) on the IRSF 1.4-m telescope in South Africa. IRSF/SIRPOL is the first instrument to provide deep (J = 19.2 mag, S/N = 5) and wide-field (7.′7 × 7.′7) polarization images at *JHK*s simultaneously. Such capability is particularly useful to trace extended polarized emission by dust scattering, i.e., infrared reflection nebulae (IRNe), and to delineate magnetic field structure through dichroic polarization.

In Figs. 1 and 2, we show composite *JHK*s intensity (I) and polarized intensity (PI) images, respectively. On the largest scale, we found an extensive IRN extending over the entire FoV in Fig. 2. Though the IRN can be responsible for massive star(s) exciting the HII region, source identification studies reported so far are still unclear because of heavy obscuration of the nebula by foreground dust lane. We directly constrained the position of illuminating source through the analysis of polarization vectors; a massive O8–B2 type star IRS 2b, located in the center of centrosymmetric polarization vector pattern, is most likely to be the source illuminating the nebula.

For smaller-scale nebulae, we discovered five IRNe associated with YSOs in our polarization images (Fig. 2). The pattern of polarization vector around the YSOs appears centrosymmetric, indicating that these IRNe are illuminated by each central star and are responsible for the structure of circumstellar material that produces strongly polarized light through dust scattering. The polarized intensity of each IRN shows a butterfly-shaped emission pattern extending over 5000–10000 AU, which agrees well with the picture of disk/envelope system around young stars.

We performed software aperture polarimetry of the 211 point-like sources detected on the *JHK*s intensity images. We found 64 highly polarized sources (HPS), which show larger polarizations than estimated from dichroic extinction. The large polarization of HPSs indicates that they are accompanied by unresolved IRNe. By comparing our polarimetry with recent spectro-photometric results [4], we found five brown dwarfs with highly polarized integrated emission. These sources serve as direct evidence of (compact) circumstellar structure around young brown dwarfs.

We investigated the magnetic field structure of NGC 2024 through dichroic polarization. The average position angle of projected magnetic fields across NGC 2024 is 110°. We found a good consistency in magnetic field structures obtained using near-infrared dichroic polarization and sub-mm/far-infrared dust emission polarization [5, 6], indicating that the dichroic polarizations at near-infrared wavelengths trace magnetic field structures inside dense molecular clouds.

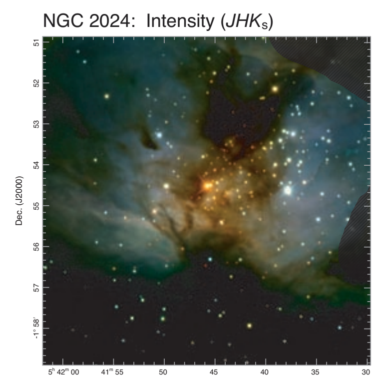

Figure 1: Three color composite of *JHK*s intensity (I) images toward NGC 2024. The image is in logarithmic scale.

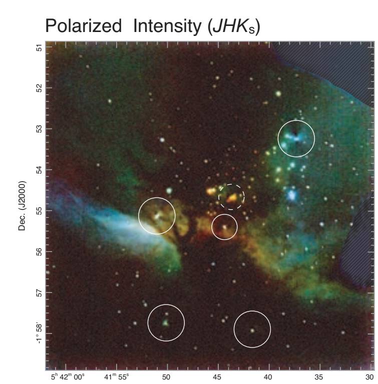

Figure 2: Three color composite of *JHK*s polarized intensity (PI) images. Newly found five small IRNe are enclosed by circles. A nebula enclosed by broken line is the previously known IRN associated with the source FIR 4. The image is in logarithmic scale.

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Water Maser and Ammonia Survey toward IRAS Sources in the Galaxy. : H_2O Maser Data

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We have completed a sensitive survey of IRAS sources in the H_2O maser and NH_3 emission with the Nobeyama 45 m telescope.

The H_2O masers are believed to be one of the best tracers to investigate the earliest phases of low- to highmass star formation. In addition, the NH_3 emission is another good tracer to investigate the earliest phases of low- to high-mass star formation. They often trace dense cores with sizes of ~0.1 pc, which are thought to be the sites of star formation [1]. Consequently, our combined survey of H_2O maser and NH_3 emission is most likely to provide a useful database to reveal the earliest phases of star formation. The other goal of our study is to investigate the excitation conditions of the H_2O masers and its relation to the evolution phase of the YSOs. An additional goal of our survey is to detect new H_2O maser sources and to increase the number of known masers.

Our target sources mainly consist of the cold IRAS point sources with strong CO emission catalogued by [2]. They selected the YSO candidates with color indices of $\log(F12/F25) \leq -0.4$, and $\log(F25/F60) \leq -0.4$ or $\log(F12/F60) \leq -0.4$ from the IRAS point source catalogue, and carried out a CO(1–0) survey toward them. They made a catalogue of 1331 YSOs with the significant CO emission. Furthermore, we picked up other YSO candidates from the catalogues of outflow sources [3], embedded clusters [4], and low-mass stars [5]. Finally, we selected 1563 sources for our survey.

This survey has a 1σ noise level as small as 0.24 Jy, resulting in one of the most sensitive water maser surveys. The maximum distance of the masers to be detected by our survey is estimated to be 3 kpc for the sources with $F_{\nu,1\mathrm{kpc}} < 10$ Jy and 10 kpc for 10 Jy $\leq F_{\nu,1\mathrm{kpc}} < 100$ Jy, where $F_{\nu,1\mathrm{kpc}}$ is the maser flux density converted at the distance of 1 kpc. For the strong masers with $F_{\nu,1\mathrm{kpc}} \geq 100$ Jy, our survey can detect all the sources in the Galaxy.

We carried out a total of 2229 observations toward 1563 sources and detected water maser emission toward 222 sources. Our survey newly found the masers from 75 of the 222 sources. Among these 75 masers, two are associated with the low-mass stars L1551 IRS 5 (Fig.1) and IRS 43. Furthermore, we discovered an extreme high velocity component with $V_{\mathrm{LSR}} = -146$ km s^{-1} toward the well known source, NGC 7538 IRS 11. For the three sources of NGC 1333 IRAS 4A/B, IRAS 05329-0512, and 06053-0622, we succeeded in spatially separating multiple velocity components.

Details of the obsered sources, the maser spectra of the new sources, and the line parameters of all the detected sources are described in [6].

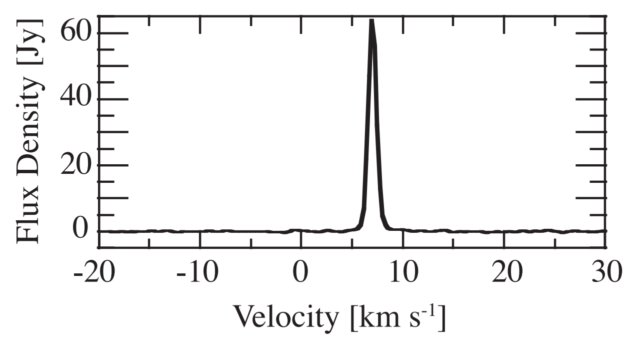

Figure 1: New H_2O maser emission from L1551 IRS 5.

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Characteristics of Anemone Active Regions Appearing in Coronal Holes Observed with the Yohkoh Soft X-Ray Telescope

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Among many findings achieved by the Soft X-ray Telescope (SXT) aboard *Yohkoh*, one of the interesting discoveries is "sea-anemone" like structure. This phenomenon is characterized by radially aligned coronal loops as shown in Fig. 1a. These active regions (ARs) are thought to often appear in coronal holes (CHs) that consist of global open magnetic field, and they are called *anemone ARs* [1]. The situation of the magnetic reconnection between the emerging flux and the surrounding field in forming an anemone AR is suitable to generate Xray jets, and indeed, many associated jets have been observed. Attentions to the relation between anemone ARs and fast solar winds have also been paid, and therefore, the understandings physical and morphological characteristics of anemone ARs are important for space weather studies. However, how frequently such an asymmetric magnetic configuration occurs in CHs, and the features have not been well understood.

We statistically examined the features of anemone ARs observed by *Yohkoh*/SXT [2]. First, we surveyed 49 ARs whose births were observed with SXT from 1991 November to 1992 May, and found; (1) About one-forth of all newly emerged ARs were anemone ARs. Moreover, almost all anemone ARs appeared within CHs, and the ARs that appeared in quiet regions did not show anemone structure. We also confirmed that anemone ARs usually generate X-ray jets. Next, we examined 28 anemone ARs observed between 1991 November and 1993 March, and found the following features; (2) About 71 % of all anemone ARs appeared in the northern hemisphere, while the sunspot number was larger in the southern hemisphere, in this period. This means that the number of anemone ARs has a feature of the anti-solar activity. Furthermore, almost all anemone ARs were not located on or near the global neutral line where active longitudes were situated, (3) Among the anemone ARs in the northern hemisphere, about 80 % had the characteristics that magnetic polarity of the preceding spots was negative, which is consistent with the Hale-Nicholson's polarity law. It is opposite to that of surrounding CHs, since almost all the surrounding CHs in the northern hemisphere had the positive magnetic polarity during this period. (4) Anemone ARs showed more or less following-preceding (east-west) asymmetry in SXR intensity distribution. The features (1), (2), and (3) suggest that the anemone ARs have simpler (less sheared) magnetic structure than other ARs. The "anemone" shape itself shows a potential like magnetic configuration, that is, the lowest energy state. This is also consistent with the facts that α- β-type spots, which are less active ARs, are observed at the center of anemone ARs. Moreover, the observed anemone ARs showed the preceding-spotdominant magnetic structure clearer than those appearing in other regions. The feature (4) showed that the following-preceding asymmetry in SXR intensity distribution depends on the order of the magnetic polarities of anemone ARs and CH.

More detailed examinations of anemone ARs and structure of the emerging fluxes, by using data that have higher spatial resolution and sensitivity are required to answer these questions. For example X-Ray Telescope on board *Hinode* have observed many similar (and smaller) features, and analyzing them will be appropriate.

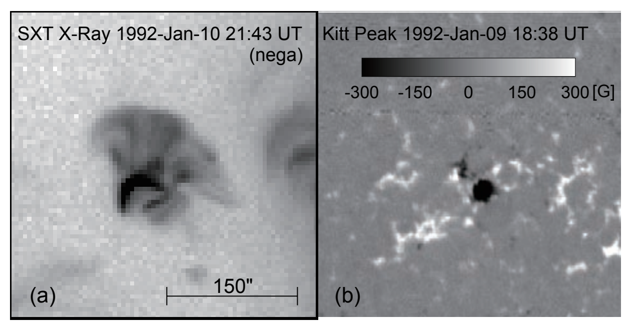

Figure 1: Typical example of the anemone AR observed on 1992 January 10 (NOAA AR 7001). (a) SXR image taken with the *Yohkoh* SXT. (b) Magnetogram taken at Kitt Peak.

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Discovery of a Scattering Disk around the Low-Mass T Tauri Star FN Tauri

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Investigation of protoplanetary disks is important to understand the origin of the Earth and our solar system. In particular, direct imaging of circumstellar disks provides hard-and-fast proof of its existence and enables us to derive properties such as radius, inclination, and the surface brightness distribution. However, the number of resolved disks around T Tauri star is not large enough to discuss the morphological diversity and evolutionary sequence. Therefore, we have conducted deep coronagraphic imaging of T Tauri stars using the Coronagraphic Imager (CIAO) with the adaptive optics system (AO) on the Subaru telescope.

FN Tau is classified as a single, classical T Tauri star with a spectral type of M5. This star is associated with the Taurus molecular cloud at a distance of ~140 pc. The stellar mass is estimated to be ~0.1 $M_\odot$ [1].

We have discovered an optically thick disk as far as ~260 AU from the central star (Fig.1) [2]. The surface brightness of disk decreases as a power-law of $r^{-2.5}$, suggesting that the disk is flared. The disk morphology appears to be relatively featureless except for an azimuthal asymmetry in the surface brightness, indicating that the disk is not perfectly face-on but is slightly tilted. The disk mass, derived from a simple disk emission model with previous photometry at optical to millimeter wavelengths, is ~0.007 $M_\odot$, 6 % of the mass of the central star (Fig. 2).

FN Tau disk has sufficient mass to produce several Jupiter-mass planet. However, the predicted surface density distribution seems to be too small [3]. The final mass of possible proto-planet is estimated to be ~1 Earth mass. Our result is a first direct imaging of disks around M type T Tauri stars. . The FN Tau disk is one of the best targets for disk and planet formation studies around M stars.

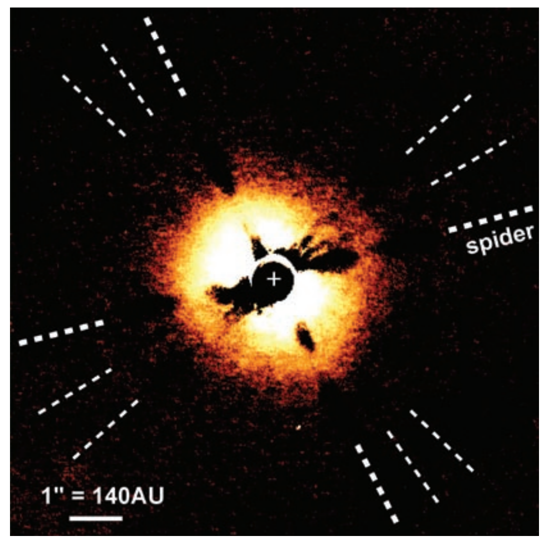

Figure 1: *H*-band (1.65 μm) coronagraphic image of FN Tau disk. Diameter of the occulting mask is 0.8 arcsec. The cross mark indicates the stellar position. The directions of the spider patterns are indicated by white dash lines.

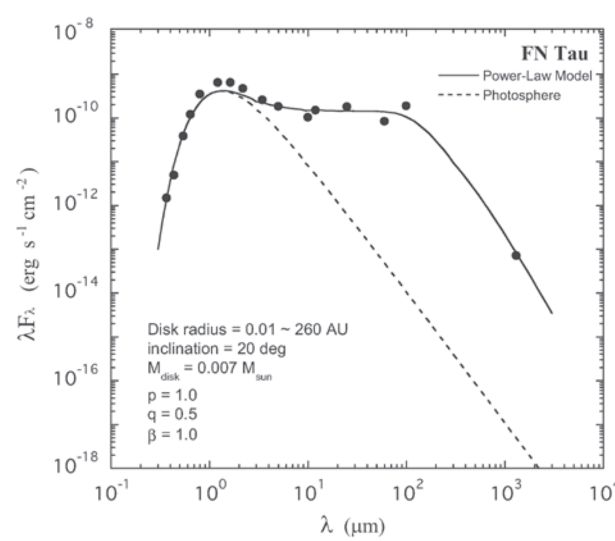

Figure 2: Spectral energy distribution (circles) and its disk model for FN Tau. The dashed line is a blackbody for the central star (3240 K). The solid line is sum of the stellar and disk fluxes.

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Supernova Nucleosynthesis and Neutrino Oscillation with Improved Reaction Rates

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Quantum states of three-flavor neutrinos admix with one another, which induces flavor oscillation. Mixing angle θ_{13} and mass hierarchy are still unknown among neutrino oscillation parameters. Our proposed astronomical method to determine these unknown parameters is to make use of the neutrino matter effect (MSW effect) on the abundance ratio of the elements like $^{7}Li/^{11}B$ produced in supernova (SN) nucleosynthesis [1, 2].

Absolute yields however depend strongly on the Hamiltonians which were used in the theoretical calculations of the neutrino-induced reaction cross sections in this method. Based on the recent advances in nuclear shell model calculations in *p*-shell and *fp*-shell nuclei, we studied neutrino reactions on ^{12}C and ^{4}He as well as Fe and Ni isotopes quantum mechanically [1]. The charge-exchange reaction cross sections based on new shell model Hamiltonians are found to be enhanced compared with previous calculations. It was also found that more neutrons are knocked-out by SN neutrinos from more neutron-rich Ni isotopes. We clarified that the Hamiltonian dependence of the cross sections offsets each other by taking the abundance ratio $^{7}Li/^{11}B$. Our proposed astronomical method to determine the unknown neutrino oscillation parameters thus turns out to be a very precise one [1, 3].

In the *fp*-shell, recently proposed shell model Hamiltonian (GXPF1 [4]) leads to a good description of heavy mass nuclei. We show calculated results of the DAR (decay-at-rest) neutrino-induced reaction ^{56}Fe (ν_e, e^-) ^{56}Co in Fig.1. They include both GT (Gamow-Tellar) and IAS (isobaric analog state) transitions. The GT strength distribution in ^{58}Ni is very well reproduced with the GXPF1J Hamiltonian. Calculated cross section for the GT and IAS transitions for GXPF1J is $\sigma = 2.29 \times 10^{-40}$ cm^2 while the experimental value obtained by the KARMEN collaborations [5] is $\sigma = 2.56 \pm 1.08 \pm 0.43 \times 10^{-40}$ cm^2 [6], that includes also the contributions from the spin-dipole transitions.

We also investigated the ^{56}Fe (ν_e, e^-) ^{56}Co reaction induced by the SN neutrinos. Calculated results of the GT transitions for the GXPF1J Hamiltonian are shown in Fig. 2 for the neutrino temperature of T = 2~12 MeV, comparing with previous calculations [6, 7]. The present results, which include contributions other than the GT transition, would get larger than those of ref. [6] for $T \leq$ 8 MeV but still smaller than those of ref. [7]. This is also true for the calculated results for the ^{56}Ni (ν_e, e^-) ^{56}Cu reaction cross sections.

Branching ratios to neutron, proton and α-particle knock-out reactions were calculated in the Hauser-Feshbach theory. Protons are mainly emitted after the (ν_e, e^-) processes while neutron emission is the dominant channel for the ^{56}Fe ($\bar{\nu}_e$, e^+) ^{56}Mn reaction. For the ($\bar{\nu}_e$, e^+) reaction, calculated B(GT) value, 2.9 for the GXPF1J Hamiltonian, is close to the experimental value of 2.8 ± 0.3 [8]. We find that neutron emission cross sections increase as the neutron excess gets larger for the (ν_e, e^-) reactions. We expect more neutrons emitted from the neutron-rich nuclei for the improved new Hamiltonian, GXPF1, compared to conventional ones. Extended study on the roles of these neutrons in the SN nucleosysnthesis is now underway.

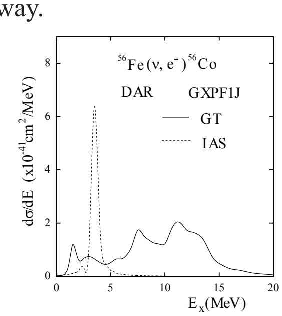

Figure 1: Calculated reaction cross sections for ^{56}Fe (ν_e, e^-) ^{56}Co induced by DAR neutrinos.

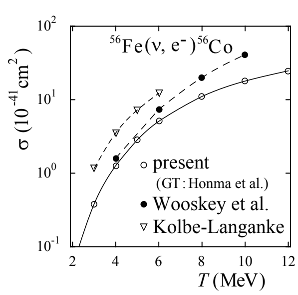

Figure 2: The same as in Fig.1 for supernova neutrinos with temperature T.

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Transient horizontal magnetic fields in solar plage regions

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Magnetic fields on the Sun appear to be essentially vertical in the quiet Sun and in active regions due to buoyancy, (Exceptions are penumbra and emerging flux region.), and the classical concept about solar magnetic fields was dominated by sub-arcsecond vertical kG magnetic flux tubes as well as sunspots and pores. However, the Solar Optical Telescope aboard Hinode completely change the paradigm that the quiet Sun is dominated by vertical magnetic fields; Hinode discovered prevalent existence of small-scale horizontal hG magnetic fields in the quiet Sun at unprecedented small scales [1, 2, 3].

Our Spectro-polarimetric observations reveal widespread occurrence of transient, spatially isolated horizontal magnetic fields in a plage region as well as in the quiet Sun [4]. Figure 1 shows an example of them. These events are not associated with existing long-lived magnetic fields forming the active region, and appear in a region of insignificant vertical fields. A remarkable feature is that the horizontal magnetic structure first appears inside the (bright) granule, subsequently moves to the (dark) inter-granular lane, and finally disappears in the inter-granular lane. The horizontal magnetic structure continues to be smaller than or at most as large as the size of the granule where it appears. These transient horizontal magnetic fields which we detect are granular-sized (~1″), and transient with a lifetime less than ~10 minutes, which are comparable to the lifetime of granules. The lifetime, the size, and the Stokes profiles show that these horizontal magnetic fields are tossed about by granular motion. These properties are in contrast to those of the more well-known emergence driven by magnetic buoyancy, which we also report in this paper (See [4] for more details.). Our finding suggests that the granular convection in the plage regions is characterized by a high rate of occurrence of granular-sized transient horizontal fields.

These ubiquitous transient horizontal fields raise two curious questions. One is about their origin; they may come from the local vertical fields and/or the global magnetic fields or they may be generated by a local dynamo process. Another one is about their influence on chromosphere and corona; do horizontal magnetic fields which dominate the Sun on the photosphere have any consequence on upper atmosphere? These transient horizontal fields would provide new insights on solar daynamo process and chromospheric and/or coronal heating.

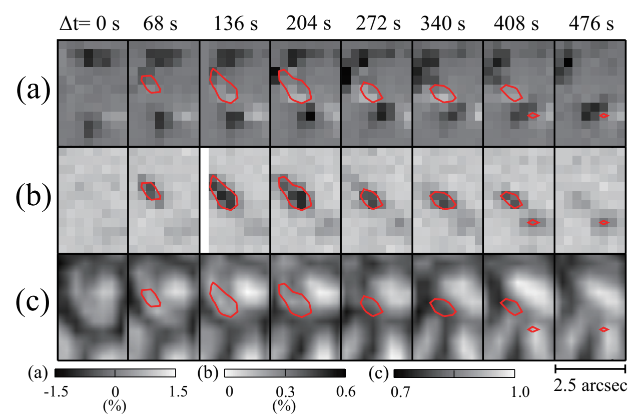

Figure 1: The evolution of physical quantities of transient horizontal fields for the plage region: (a) *CP* (vertical magnetic field), (b) *LP* (horizontal magnetic field), (c) *Ic*. The region where *LP* is larger than 0.3% is enclosed by red lines.

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Direct and semi-direct neutron capture of neutron-rich Tin isotopes and its implications for the r-process nucleosynthesis

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The neutron capture reaction rates on neutron-rich unstable isotopes far from the β-stability line are essential for understanding the rapid neutron capture nucleosynthesis (r-process), considered to occur in supernova explosions. The neutron magic numbers N = 50, 82, 126 *etc*. affect the final mass distribution of products in the r-process, where the capture cross sections have minima. As a matter of fact, astronomical observations of metal-deficient stars reported a “universal” abundance distribution of the r-nuclei in a certain mass region but that relative abundances between different mass regions separated by the neutron magic number N = 82 are different [1]. Therefore, an unstable double-magic nucleus ^{132}Sn (N = 82) takes the key for understanding the r-process.

We carry out a systematic calculation of both direct and semi-direct (DSD) cross sections to improve the prediction of the neutron capture reaction rates of the Tin isotopes. A single-particle potential (SPP) is adopted which gives a good reproduction of the known singleparticle energies over a wide mass region, namely the Koura-Yamada potential (KY-SPP) [2]. We also perform Hauser-Feshbach (HF) model calculations and investigate whether the inversion of the HF and direct cross sections occurs or not at the neutron-rich isotopes [3].

The levels calculated by KY-SPP exhibit somewhat narrow gap at N = 82 compared to an experimental value, but the single-particle energies of the unfilled levels are reproduced with an accuracy of about 300 keV on the average. It is especially important to predict the energy and presence of $3p_{3/2}$ and $3p_{1/2}$ states that can couple to the s-wave of the incoming scattering wave, that gives a dominant contribution to the low-energy direct capture cross section relevant to the r-process.

The DSD and HF neutron capture cross sections are calculated for a series of even-even Tin isotopes at 30 keV, which are shown in the Figure 1. The HF cross section decreases as the mass number increases, and shows a drastic decrease when going from ^{130}Sn to ^{132}Sn. This trend is correlated with a change in the neutron separation energies. On the other hand, the DSD cross section decreases only modestly, and it exceeds the HF cross section at ^{132}Sn and beyond. Therefore, we see that the inversion of the HF and DSD cross section indeed occurs at the border of the N = 82 magic for the neutron-rich Tin isotopes (and probably its vicinity). The gradual decrease of the DSD cross sections in our calculation is different from a more-rapid mass-number dependence of the direct capture cross section calculated by Rauscher et al. [4] due, probably, to the stability of the single-particle energies calculated with KY-SPP. The cross symbol denotes a result calculated by Rauscher et al. [4] by using experimental level energies as their best estimate of the direct (n, γ) cross section of ^{132}Sn. Our result, without adjustment, is in a fair agreement with this value.

The r-process abundance of ^{132}Sn isotope is calculated with the HF (n, γ) rate alone and both the HF + DSD rates. We notice that the difference in these reaction rate gives rise to a difference of more than a factor of 3 in the initial abundance of ^{132}Sn, but the difference diminishes as time passes, indicating a presence of unknown mechanism that brings about universality.

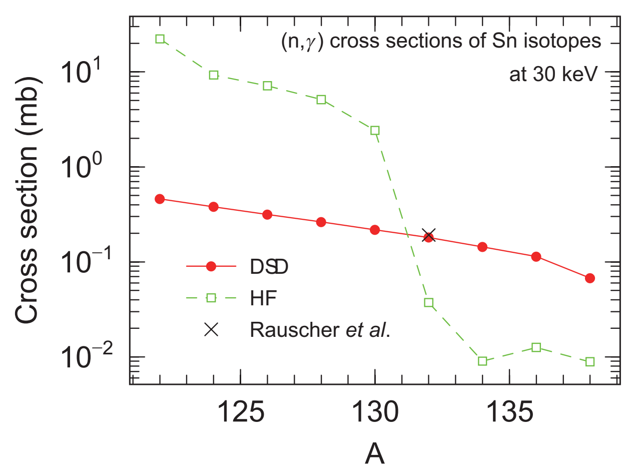

Figure 1: Calculated DSD and HF cross sections for a series of even-even Tin isotopes at 30 keV.

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Effects of primordial magnetic field and background gravitational wave on low and high multipoles of the cosmic microwave background

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Magnetic fields in clusters of galaxies have been observed with a strength of 0.1–1.0 μG. The existence of a primordial magnetic field (PMF) of order 1 nG whose field lines collapse as structure forms is one possible explanation for such magnetic fields in galactic clusters. The origin and detection of the PMF is, hence, a subject of considerable interest in modern cosmology. Moreover, the PMF could influence a variety of phenomena in the early universe such as the cosmic microwave background (CMB) [1, 2, 3], or the matter density field [4]. Temperature and polarization anisotropies in the CMB provide very precise information on the physical processes in operation during the early universe. Recent experiments, however, has indicated a potential discrepancy between these observations at higher multipoles $l \geq 2000$ and the best-fit cosmological model. This discrepancy is difficult to account for by a simple retuning of cosmological parameters or by the Sunyev-Zeldovich effect. The PMF provides a plausible explanation for such the possible disparity between observations and theoretical fits to the CMB power spectrum [1, 2, 3]. Here we report on calculations of the numerical CMB polarization anisotropies from the PMF. We then deduce a precise estimate of the PMF effect on a BB mode of perturbations.

The introduction of the PMF leads to a better fit to the CMB power spectrum for the higher multipoles, and the fit at lowest multipoles can be used to constrain the correlation of the PMF with the density fluctuations for large negative values of the spectral index. Our prediction for the BB mode for the PMF average field strength $|B_\lambda|$ = 4.0 nG is consistent with the upper limit on the BB mode deduced from the latest CMB observations. We find that the BB mode is dominated by the vector mode of the PMF for higher multipoles and by a gravitational-wave background (GWB) for lower muotipoles (Fig.1). We also show that by fitting the complete power spectrum one can break the degeneracy between the PMF amplitude and its power spectral index. Furthermore, there is no discrepancy at higher l between observations and theories of the CMB polarization for models with the PMF. We also show clearly that the power spectral index of the PMF, n_B, is effectively constrained from CMB observations for higher l. The models with higher n_B give better fits to the observations than those with lower n_B for the lower l regions of the BB modes [3].

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

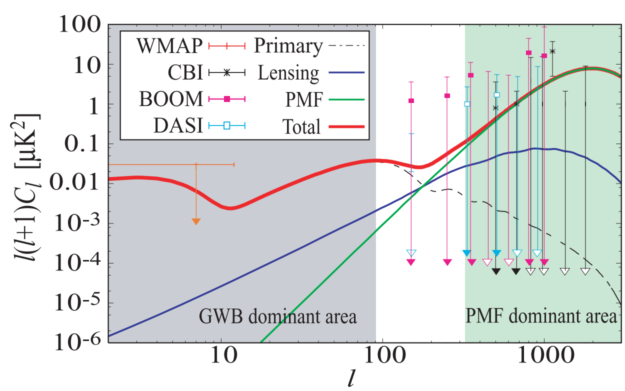

Figure 1: CMB polarization anisotropies (BB mode) from the PMF . This figure shows a comparison of the computed total power spectrum with the observed CMB spectrum for models with B_λ = 4.0 nG and $n_B = -2.5$. All Lines in the figure are plotted in the absolute value. Downward arrows for the error bars indicate that the data points are positive and the lower error negative. Green and gray areas show the PMF and the GWB dominant areas.

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Simultaneous Solution to the Big-Bang Li Problems from a Long-lived Negatively Charged Particle

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Recent spectroscopic observations of metal poor halo stars (MPHSs) have indicated that both ^{7}Li and ^{6}Li have abundance plateaus with respect to the metallicity. Abundances of ^{7}Li are about a factor of three lower and those of ^{6}Li are about 1000 times higher than the primordial abundances predicted by standard big-bang nucleosynthesis (SBBN). ^{6}Li, therefore, might have another cosmological or Galactic origin than the SBBN.

We calculated big-bang nucleosynthesis (BBN) assuming existence of a negatively-charged massive particle X^- in the early universe that binds to the light nuclei A produced in BBN and makes bound states A_X, but would have decayed long before it could be detected [1, 2]. We found that the ^{7}Be$_X$ (p, γ) reaction through the atomic ground state ^{8}B$_X$ between a X^- particle and a 1^+, E^* = 0.770 MeV nuclear excited state of ^{8}B could possibly contribute to destruction of ^{7}Be$_X$ [1]. But we concluded that this channel would not be important from the estimate of realistic binding energies of A_X [2]. We integrated Boltzmann equations including terms for the recombination and ionization of X^- particles by normal and X-bound nuclides as well as many possible nuclear reactions among them. Parameters are the life time τ_X and the abundance ratio of X^- to baryon $Y_X \equiv n_X/n_b$.

We perform the BBN calculation in which X^- particles are included at 10 % of the total baryon number, i.e., $Y_X = 0.1$ (Fig.1). The decay of X^- is not considered, corresponding to the case of $\tau_X = \infty$. The recombinations occur at temperature of $T_9 \equiv T/(10^9\text{K}) \sim 0.3$ for ^{7}Li and $T_9 \sim 0.5$ for ^{7}Be. ^{7}Be$_X$ abundance increases accordingly. At $T_9 \sim 0.1$, the X^- particles are captured onto ^{4}He. The reaction ^{4}He$_X(d, X^-)$ [3], then, produces ^{6}Li. ^{7}Be is destroyed by the nuclear reaction after the recombination ($T_9 \sim 0.3$), i.e., ^{7}Be$(X^-, \gamma)^7$Be$_X(p, \gamma)^8$B$_X$ [4]. Figure 2 shows Li abundances relative to the observed values, i.e., $d(^A\text{Li}) = {}^A\text{Li}^{\text{Calc}}/{}^A\text{Li}^{\text{Obs}}$ in the Y_X vs. τ_X plane. We find a simultaneous solution to both of the ^{7}Li overproduction problem and the ^{6}Li underproduction problem in the parameter region of $Y_X \geq 0.2$ and $\tau_X \sim (1\text{–}3) \times 10^3$ s.

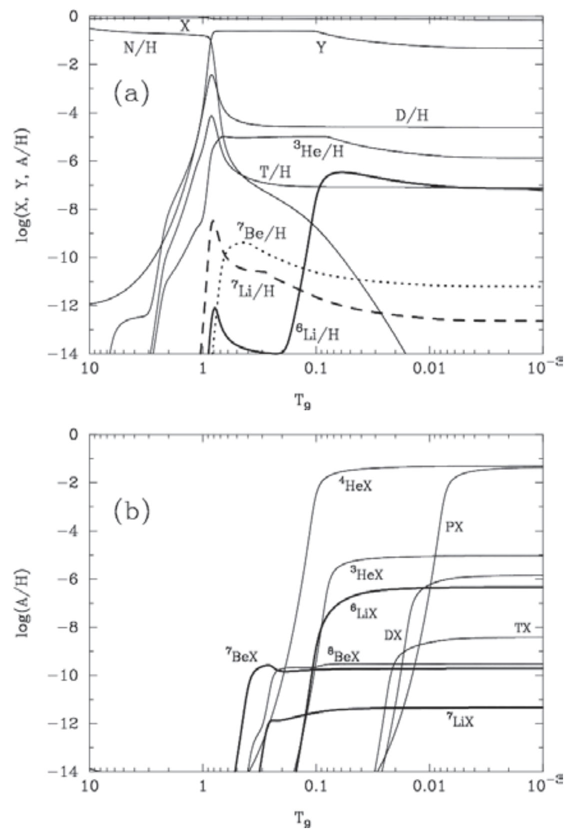

Figure 1: Abundances of normal nuclides (a) and X-bound nuclides (b) as a function of T_9. The parameters are set to be $Y_X = 0.1$ and $\tau_X = \infty$. This figure is reprinted from [2].

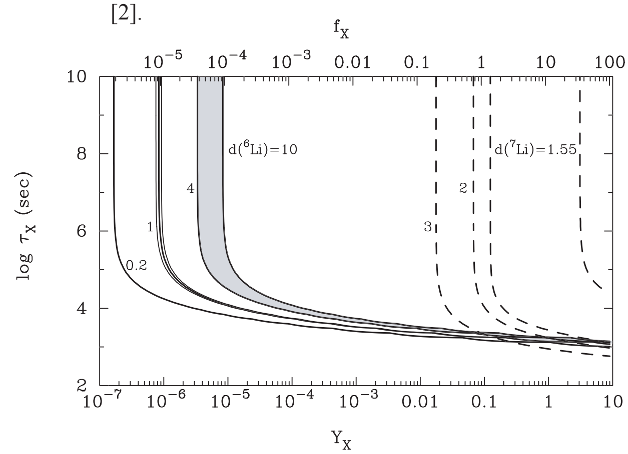

Figure 2: Contours of constant lithium abundances relative to the values observed in MPHSs, i.e., $d(^6\text{Li}) = {}^6\text{Li}^{\text{Calc}}/{}^6\text{Li}^{\text{Obs}}$ (solid curves) and $d(^7\text{Li}) = {}^7\text{Li}^{\text{Calc}}/{}^7\text{Li}^{\text{Obs}}$ (dashed curves). In the gray region, the condition $d(^6\text{Li}) > d(^7\text{Li})$ is satisfied. This figure is reprinted from [2].

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II Publications, Presentations

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