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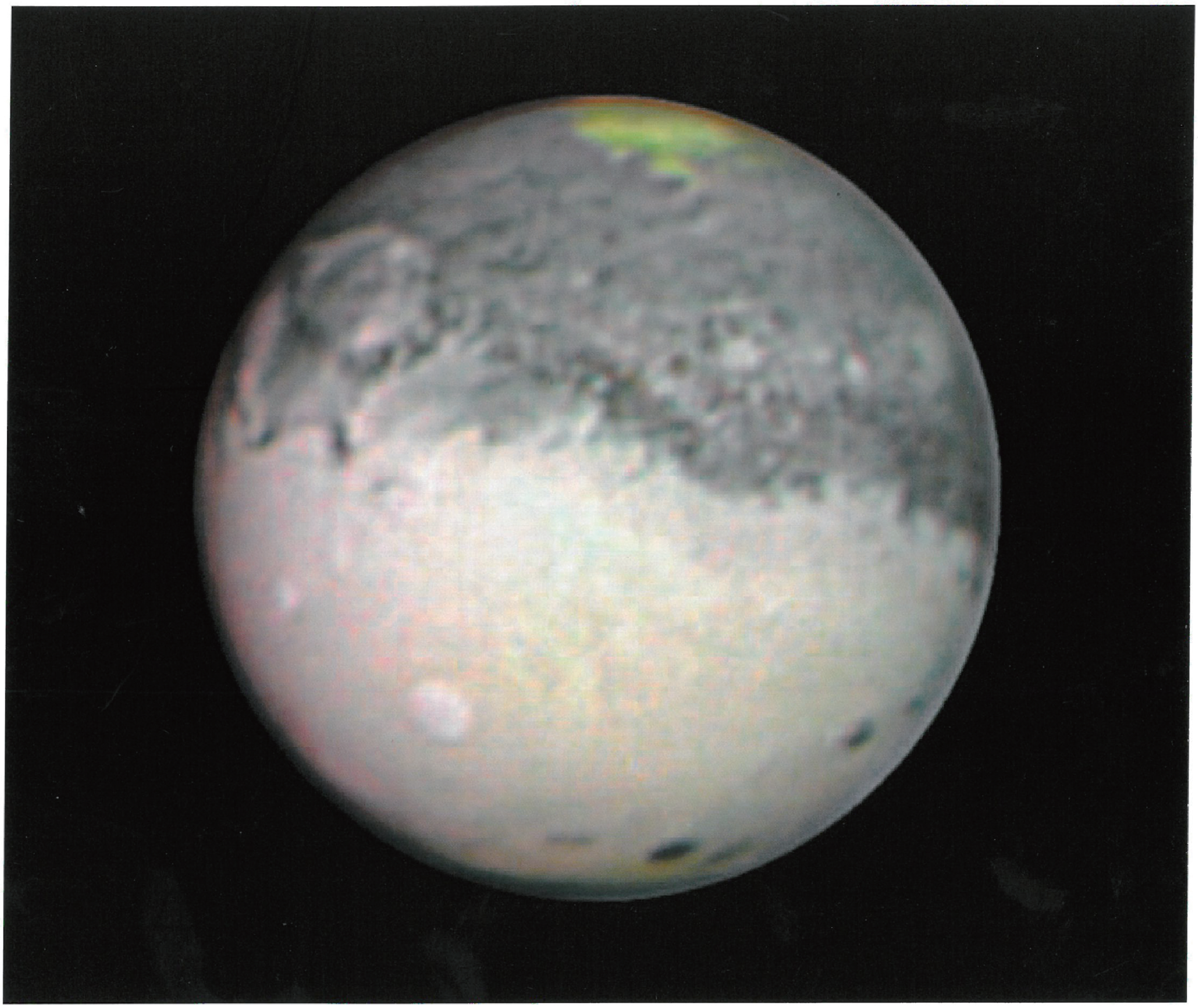

Volume 6 Fiscal 2003

Explanation of the cover photograph: A near-infrared image of Mars taken by the Subaru Telescope at the occasion of the closest approach to the Earth in the end of August, 2003. The observing instrument was the near-infrared spectrometer, IRCS, which has sensitivity at the wavelengths between 1 and 5 micrometers.

Postscript

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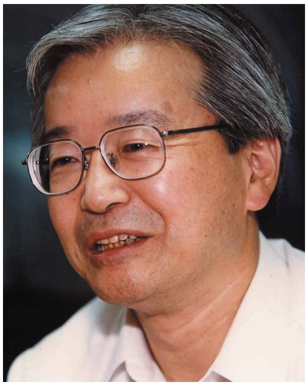
PREFACE



We present the annual report of achievements by NAOJ through the FY 2003.

Since its successful completion in 2000, the 8.2m aperture Subaru telescope at Mauna Kea, Hawaii has been released a number of remarkable observing results such as continuous renewal of record of the most distant galaxies ever observed, and detailed structure of proto-planetary disks, etc., as one of the leading ground-based optical/IR telescopes. The VERA (VLBI Experiment of Radio Astrometry) is accumulating observational test to achieve super-high spatial resolution for the long-term program which aims to map the whole our Galaxy by means of three-dimensional distance measurements of maser sources. The development of SOT, on-board SOLAR-B, a 50-cm aperture space optical telescope for observations of detailed solar surface structure which will be launched in 2006 by collaboration with JAXA, is approaching its final stage. The "Four-Dimensional Digital Universe" project which aims to open a novel means for education, PR and research is attracting a strong public interest. The NAOJ, a core national institute for astronomy in Japan, has been developing activities in wide areas based on its unique character as an inter-university research institute including all fields of ground based astronomy and related sciences : Details are presented in the text.

A big news in the FY 2003 is the allocation of the 8-year ALMA construction budget for NAOJ by the Government. From the FY 2004 Japan will join the world-scale cooperative construction of ALMA with Europe and North America toward the full operation from 2011 to open the unknown part of the universe. One of the important concepts of ALMA is a big jump in spatial resolution to achieve 0.01 arc-sec in sub-millimeter wavelength region which had been proposed and developed by Japanese radio astronomers' community for many years. The ALMA will conduct cutting-edge observations to reveal the process of planetary formation around a number of stars shining in the night sky, to develop our understanding of the material evolution throughout the history of expanding universe, and to find objects and phenomena which we never know without ALMA.

In 1982 NAOJ (the then Tokyo Astronomical Observatory, University of Tokyo) started the world-level mm-wave astronomy by establishing of the Nobeyama Radio Observatory equipped with the 45-m mm-wave telescope and the mm-wave interferometer. At the same time we started the discussion and development toward the next generation radio telescopes. The plan firstly based on the idea of large mm-wave interferometer with 30 element antennas (LMA), then had been developed to LMSA (Large MM- and Submm-wave Array) by emphasizing the astronomical importance of the sub-mm wave capability. Now the plan is going to be realized as a huge "world telescope" ALMA by global cooperation . We NAOJ will do our best for the successful completion and operation of this exciting project.

The NAOJ started its new history as a member institute of an inter-university research agency NINS (National Institutes of Natural Sciences) from April 2004. The NINS is a new research organization covering wide area of natural sciences; universe, energy, material, life and human physiology, and it aims to develop novel fields and activities in the science. Also such reorganization of research institutes in Japan to independent agencies from organizations directly belonging to the government aims to add more freedom to operational activities in those institutes for their scientific research of world level. Based on this viewpoint the NAOJ started serious discussion from 2001 aiming to construct new internal structure and operation system for our better activities as a research agency. After two years examination phase the proposal was accepted in September 2003 by the community through the comprehensive discussions, and the NAOJ started its new internal structure and operation system from April 1, 2004. The outlines of the new system are as follows.

1) Adoption of the project system. All observatories, facilities and groups in NAOJ except the theoretical astrophysics group are defined as "project" with various scales in size and term. Each project should make its mission, life and leadership clear, and all projects are reviewed yearly. This is to strengthen and heighten the moral, motives and efficiency for scientific achievements in each project under the limited resources of NAOJ. All the project should be built under the leadership of scientists(bottom-up). Small scale projects to develop novel methods/fields are also encouraged.

2) To ensure the above direction we strengthen the management structure to support director general, renew the personnel management system for research and engineering employee, and widen the acceptable position of the contracting staff members to make possible to invite a variety of talented people for projects, management, and support.

The NAOJ had achieved a number of successful developments and science in the past two decades, and had extended cooperative scientific activities with domestic and overseas communities widely. We continue our best efforts to reveal the universe we live, and to serve humankind in the field of science, technology, education and intellectual adventure.

Director General of NAOJ

I Scientific Highlights

(April 2003-March 2004)

Interferometer Gravitational Wave Detector TAMA300 Automatic Operation and International Collaboration Run

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A laser interferometer gravitational wave detector TAMA300 has performed nine times of data takings (DT) from 1999 up to now. In August 2000, the world's best sensitivity ($5 \times 10^{21}/\sqrt{\mathrm{Hz}}$ in strain) was achieved (M. Ando *et al*. 2001, *Phys. Rev. Lett*., **86**, 3950). The shot noise level has been reduced after the implementation of the power recycling in December 2001, according to which the total sensitivity of the detector is improved up to $2 \times 10^{21}/\sqrt{\mathrm{Hz}}$. The observable distance, at which neutron star binaries with $1.4M_\odot$ yield S/N=10, was extended from 33kpc to 73kpc. The strain sensitivity of the interferometer is shown in Figure 1. The sensitivity reached the shot noise limit at the frequencies higher than 1kHz.

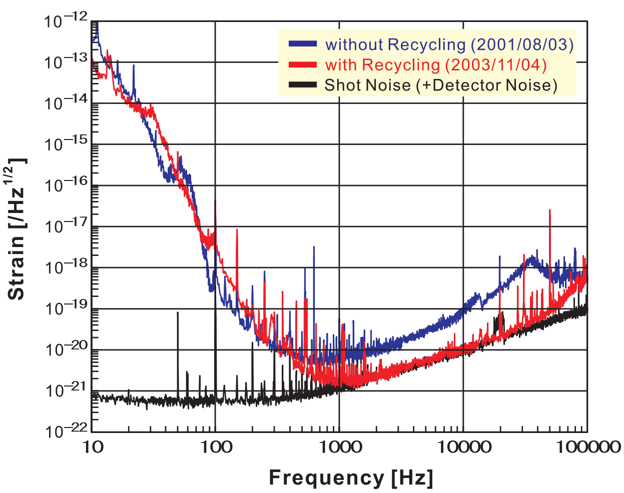

Figure1: Strain sensitivity of the interferometer.

Since gravitational wave signals are detectable through 24 hours, we had developed an automatic and crew-less operation system. The auto lock system recovers the servo loops to control the interferometer automatically. The programming language has been changed from C to National Instruments LabVIEW, which enabled to code a complicated sequence with multi-thread easily.

Figure 2 shows the operational status of the interferometer in DT9. This observation was placed as an international collaboration run. The period of the run was coordinated with the S3 run of LIGO in USA and GEO600 in Germany. Green lines indicate the period when the interferometer was operated and the analyzable data was taken. Total observation time was 558 hours.

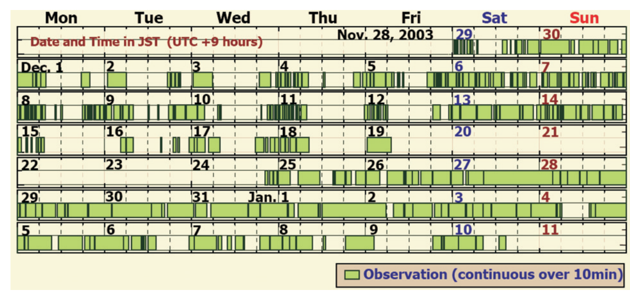

Figure2: Operational status of the interferometer in DT9.

In the first half of the run (Nov. 28–Dec. 19, 2003), the interferometer was operated only in the nighttime except weekends because of terrible vibrations caused by constructions around the site. The run was interrupted during Dec. 20–24 due to the power failure. In the latter half (Dec. 25, 2003–Jan. 10, 2004), three times of continuous operations longer than 24 hours were achieved (the longest time was 28 hours) owing to good environments in the New Year's holidays. The sensitivity was better than that in the first half, and such a sensitivity was kept up. As for the stability and the duty rate of the detector, the automatic operation system shows its ability with the newly complemented functions such as the automatic adjustment system for the interferometer, the emergency-call system to expert people via the mobile phone, the remote operation system, etc. In the case that the interferometer was not recovered automatically, the expert people called by the mobile phone confirmed the status of the interferometer through the internet and recovered the interferometer with the remote operation soon.

Solar-B/Optical Telescope Flight Model is Coming Up

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Integration of flight model Solar Optical Telescope (SOT) is nearly completing, which is to be carried aboard the JAXA/NAO solar observing satellite SOLAR-B (the launch is scheduled in the summer of 2006). The SOT is aiming at observing the solar atmospheric structures, especially solar magnetic structures, with a diffraction-limited resolution of 0.2 to 0.3 arcsec and polarization accuracy better than 10^{-3} which are difficult to keep during observation with ground-based instruments. The SOT consists of two separate optical structures: the Optical Telescope Assembly (OTA) being manufactured in Japan and the Focal Plane Package (FPP) by NASA, USA. The OTA is made of an aplanatic Gregorian telescope of 50 cm effective aperture and other indispensable auxiliary optical components such as a heat dump mirror, a secondary field stop-mirror, a collimataing lens unit, a polarization modulation unit and a tip-tilt mirror for image stabilization.

The integration of OTA-FM started in November, 2003, in a newly-built clean room of NAOJ. The framework of OTA was a truss of CFRP which had been used and proved in a proto-model OTA. Flight model optical components were individually examined and demonstrated optical performance better than allocated optical error budgets. Then, assembly and fine alignment of optical components on the truss were carried out by using the method well-established in the proto-model integration. As a result, the optical assembly was successful; OTA has small optical (coma and defocus) aberration enough to be acceptable for diffraction-limited performance in zero-gravity condition, which was estimated by the average of both measurements in OTA pointing upward and downward.

In the next, we are performing opto-thermal test in which OTA is put in a vacuum chamber and given temperature distributions expected on orbit. The purpose of this test is to confirm that additional wavefront error and defocus due to thermal deformation of structure are in acceptable ranges. Furthermore, end-to-end optical tests for OTA combined with FPP is planned in the summer of 2004 by actual sun observations. The sunlight can be fed to SOT in the clean room of NAOJ by a 90 cm heliostat installed on the roof in October, 2003.

Upon the integration, we have been much cautious in all the contaminant doubtful materials and spent considerable time in selection of low outgassing material, grease removing cleanings and baking out of most structure materials except for optical components, because contamination of optical surfaces and resulted degradation of photon through-put are one of the most crucial for the success of the telescope. Since assembly of deployment mechanisms for two doors (top-door at telescope entrance and side-door at heat dump window) and installation of heaters and temperature sensors are progressing satisfactorilly, final integration will be completed in the summer of 2004.

Figure1:OTA-FM is being hoisted out of an integration tower into another support frame for installation of heaters, temperature sensors, cables, and envelopes after the initial optical assembly and test (in the clean room of NAOJ).

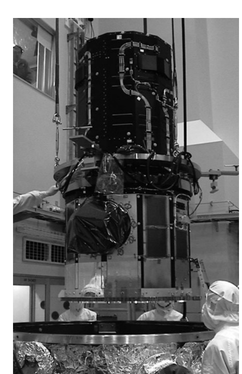

Figure2:Upside-down OTA-FM is being hoisted down to lower part of a vacuum chamber for opto-thermal test (in the clean room of NAOJ).

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Discovery of a Planetary Companion to the G-type Giant Star HD 104985

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We have carried out a precise Doppler survey of G-type giants in order to search for planets around intermediate-mass stars ($1.5 \sim 5M_\odot$) and to understand the formation and evolution of planetary systems around them. G-type giants are slow-rotators and have many sharp lines in their spectra and their surface activities are relatively low in contrast to their younger counterparts on the main-sequence, which would allow us to detect planets around them by precise radial velocity measurements. We are now monitoring about 300 G–K giants using HIgh Dispersion Echelle Spectrograph (HIDES) and an iodine absorption cell at Okayama Astrophysical Observatory. In this article, we report the first result from our survey, the discovery of a planetary companion around G-type giant star HD 104985 (G9III). This is the first planetary candidate around G-type giants and the third one around evolved giants.

The radial velocity of HD 104985 has been monitored since 2001 March, and it is found to show a large variation with a significant periodicity. The variability can be well fitted by a nearly circular orbit with a period $P = 198.2 \pm 0.3$ days, a velocity semiamplitude $K_1 = 161 \pm 2$ m s^{-1}, and an eccentricity $e = 0.03 \pm 0.02$ (Fig.1). Since HD 104985 is identified as a photometrically stable star from the Hipparcos measurements and the observed period is at least 2 orders of magnitude larger than expected in the case of radial pulsation, it is unlikely that rotational modulation or pulsation is the cause of the variability. Adopting a stellar mass of $1.6M_\odot$, we obtain for the companion a mass $m_2 \sin i = 6.3M_J$ and a semimajor axis $a = 0.78$ AU (Fig.2). A probable upper limit of 3 $M_\odot$ to the stellar mass yields $m_2 \sin i = 9.6\ M_J$, which still falls within the planetary mass regime. The estimated primary mass of 1.6 $M_\odot$ for HD 104985 corresponds to a progenitor with spectral type from early F to late A on the main sequence. The surrounding disks of such massive stars may have lifetimes shorter than those of lower mass stars, and the existence of gas giant planets around such stars would constrain the time scale and mechanism of giant planet formation.

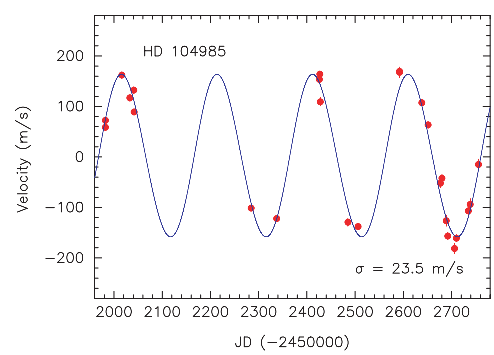

Figure1:Observed radial velocities of HD 104985 (*dots*). The Keplerian orbital fit is shown by the solid line. The rms deviation to the fit is 23.5 m s^{-1}.

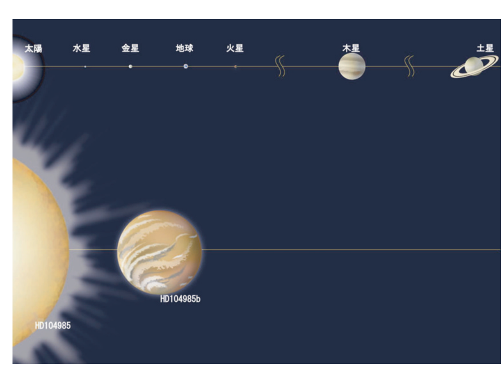

Figure2:Artist's concept of the planetary system around HD 104985 compared with the solar system.

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Discovery of a Large-Scale Structure at Redshift $\simeq 5$

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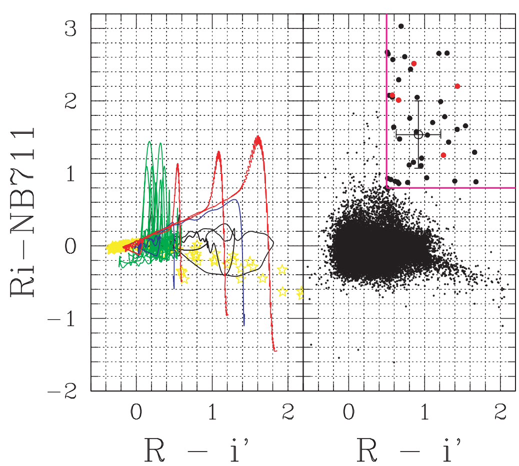

Figure1: Two-color diagrams for continuum color (R-i) and narrowband excess color (Ri-NB711), where $Ri \equiv (R + i)/2$ is a continuum magnitude. Left panel: Tracks of model galaxies at different redshifts. The red lines indicate model LAEs, while the other lines are for foreground galaxies ($z \leq 2$). The yellow star marks show Galactic stars. Right panel: Colors of the detected objects. The large circles indicate 43 LAE candidates, among which the red ones have spectroscopic observations while the small dots are for the other objects. Our LAE selection criteria are outlined by a pink line.

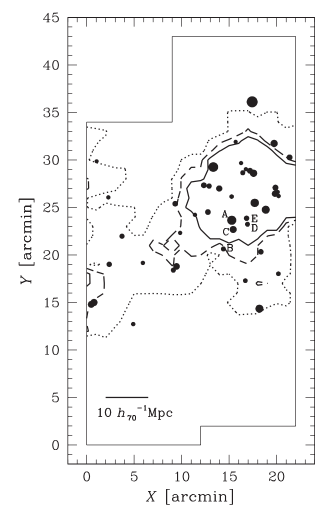

Figure2: Sky distribution of 43 LAE candidates. Areas of relatively poor quality have been trimmed. Brighter candidates are shown by larger circles. The dotted, dashed, and solid lines correspond to contours of a surface overdensity of 0, 1, and 2, respectively.Five objects with spectroscopic redshifts are marked with $A - E$.

The formation and evolution of the large-scale clustering of galaxies, as seen in the present-day universe, are central issues in cosmology. Observations of galaxy clustering in the distant universe give us great clues to this issue, including how galaxies were formed in the underlying dark matter.

Here we report the discovery of a large-scale structure of Lyman α emitting galaxies (LAEs [1]) at $z = 4.86$ based on wide-field imaging with Suprime-Cam on Subaru [2]. We observed a $30' \times 45'$ area of the Subaru Deep Field in a narrow band (NB711, λ_C=7126Å and FWHM=73Å) together with the R and i' bands. We isolate from these data 43 LAE candidates down to NB711 = 25.5 mag using color criteria (Fig.1). Follow-up spectroscopy of five of the 43 candidates suggests that the contamination by low-z objects is $\sim$ 20%.

We find that the LAE candidates are clustered in an elongated region on the sky of 20Mpc in width and 50 Mpc in length at z=4.86 (Fig.2), which is comparable in size to present-day large-scale structures (we adopt $H_0 = 70\mathrm{kms}^{-1}\mathrm{Mpc}^{-1}$, $\Omega_0 = 0.3$, and $\lambda_0 = 0.7$). This elongated region includes a circular region of 12Mpc radius of a higher surface overdensity ($\delta_\sigma = 2$), which may be the progenitor of a present-day cluster of galaxies.

Assuming this circular region to be a sphere with a spatial overdensity of 2, we compare our observation with predictions by Cold Dark Matter models. We find that an $\Omega_0 = 0.3$ flat model with $\sigma_8 = 0.9$ predicts the number of such spheres consistent with the observed number if the bias parameter of LAEs is as high as $b \simeq 6$. This value suggests that the typical mass of dark haloes hosting LAEs at $z \simeq 5$ is of the order of $10^{12} M_\odot$. Such a large mass poses an interesting question about the nature of LAEs.

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Buried AGNs in Ultraluminous Infrared Galaxies

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Ultraluminous infrared galaxies (ULIRGs), discovered with the *IRAS* all sky survey, radiate very large luminosities ($L > 10^{12} L_\odot$) as infrared dust emission, and thus possesextremely powerful energy sources hidden behind dust. High-redshift ULIRGs dominate the cosmic infrared background emission, and so have been used to trace the dust-obscured star formation rate, dust content, and metallicity in the early universe, by assuming that these ULIRGs are powered by starburst activity. However, the most important issue, namely, whether the dominant energy sources of ULIRGs are starbursts or dust-obscured AGNs, is still unclear.

If powerful AGNs are present and obscured by dust in a torus geometry, their signatures are easily detectable, because a large amount of AGN's radiation escapes along the torus axis. However, since nuclear regions of ULIRGs are very dusty, AGNs resident in the majority of ULIRGs may be deeply embedded in dust along all sightlines. It is fundamental to detect such *buried* AGNs and quantitatively determine their energetic importance. For these purposes, observations at wavelengths of low dust extinction are clearly a powerful way. One of such wavelengths is thermal infrared 3–4 μm. Extinction at 3–4 μm is as low as that at 5–13 μm. Furthermore, starburst and AGN emission are clearly distinguishable based on the spectral shapes; A starburst always shows strong 3.3 μm Polycyclic Aromatic Hydrocarbons (PAH) emission, while if the equivalent width of the 3.3 μm PAH emission is substantially smaller than that of a starburst, and strong dust absorption features are also detected, then a powerful buried AGN is required. Finally, in a starburst, the energy sources and dust should be spatially well mixed, while the energy source is more centrally concentrated than the dust in a buried AGN. In the former case (starburst), there are upper limits to the optical depths of dust absorption features at 3–4 μm, but they can be large in the latter case (buried AGN) [1].

Using these methods, we have succeeded in providing strong evidence for buried AGNs, which had previously been undetected with other methods, in several ULIRGs, and in quantitatively determining the energetic importance of buried AGNs (Figure 1). The presence of a powerful AGN in a bright ULIRG, UGC 5101, has been confirmed with subsequent X-ray observations (Figure 2), clearly-demonstrating the reliability of our 3–4 μm spectroscopic energy diagnostic method [2].

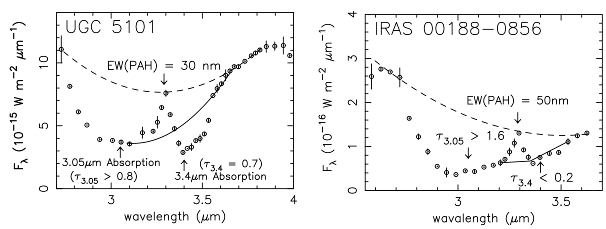

Figure1:3-4 μm spectra of two ULIRGs that show strong evidence of buried AGNs (UGC 5101 and IRAS 00188–0856). The equivalent widths of the 3.3 μm PAH emission is significantly weaker than those of starbursts, and 3.1 μm absorption by ice-covered dust (below the dashed continuum line) as well as 3.4 μm absorption by bare dust (below the solid continuum) are detected. The large optical depths of these absorption features are incompatible with a starburst, but favors a buried AGN. Since 3–4 μm continuum is dominated by hot dust with T $\sim$ 1000K at the innermost part of the surrounding dust, these optical depths probe dust column toward the buried AGNs.We found that the dereddened AGN luminosities could account for the bulk of the infrared luminosities of these ULIRGs.

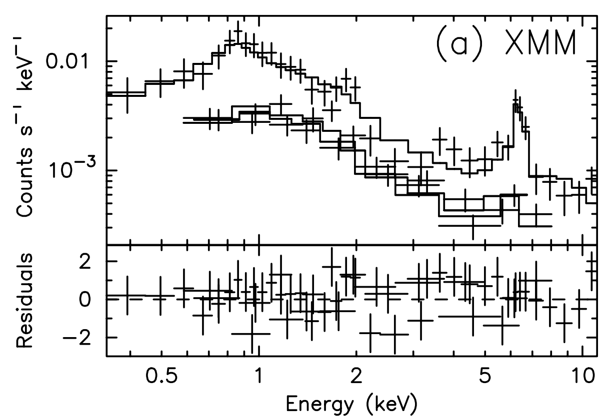

Figure2:X-ray spectrum of UGC 5101 obtained with *XMM*. In the upper panel, the higher and lower plots are EPIC PN and MOS spectra, respectively. Soft X-ray emission at 0.5–2 keV is dominated by thermal emission from starbursts. At >3 keV, a clear excess above the thermal emission is recognizable, which is interpreted as emission from a buried AGN. The absorption-corrected AGN luminosity is sufficiently large, as was estimated from the thermal infrared 3–4 μm spectrum.

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Compact Nuclear Starbursts in the CfA and 12 μm Seyfert 2 Galaxies

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According to the current unification paradigm of active galactic nuclei (AGNs), Seyfert 2 galaxies (which do not show broad optical emission lines) are believed to contain AGNs obscured behind dusty tori. Since the dusty tori are rich in molecular gas, they are plausible sites for starbursts to occur. However, the true nature of these starbursts is still unclear. To understand the properties of the compact (<300 pc in size) nuclear starbursts, by disentangling from extended star-formation activity in host galaxies, slit spectroscopy is effective.

In particular, 3–4μm slit spectroscopy can provide an excellent tool not only for detecting the compact nuclear starbursts, but also for making quantitative estimates of their luminosities. First, the 3.3μm polycyclic aromatic hydrocarbon (PAH) emission feature is detected only in starbursts and not in AGNs, making its luminosity a good measure of starburst activity. Second, the 3.3μm PAH emission from starbursts is intrinsically so strong that the signatures of even weak compact nuclear starbursts are detectable in normal (S/N $\sim$ 20) spectra. Third, the effects of dust extinction are much lower than at shorter wavelengths, and in a few selected Seyfert 2 galaxies, it has actually been confirmed that the magnitudes of the compact nuclear starbursts are reasonably quantifiable from the *observed* (not extinction-corrected) 3.3μm PAH luminosities [1].

We have applied this successful 3–4μm slit spectroscopy to 32 Seyfert 2 galaxies in the CfA and 12μm samples (Figure 1), and found the following main conclusions, based on this statistically meaningful sample number [2].

(1) The signatures of the nuclear starbursts were detected in one-third of the observed Seyfert 2 galaxies. However, in the majority of them, the equivalent widths of the 3.3μm PAH emission feature were much smaller than those observed in starburst galaxies, suggesting that the 3–4μm fluxes are dominated by AGNs and not by the nuclear starbursts.

(2) The 3.3μm PAH to infrared dust emission luminosity ratios were so small that the compact nuclear starbursts contribute only insignificantly to the infrared luminosities of Seyfert 2 galaxies.

(3) The 3.3μm PAH emission luminosities were statistically correlated with some indicators of AGN powers; *IRAS* 12μm and 25μm luminosities, and nuclear *N*-band (λ = 10.6μm) luminosities (Figure 2). These correlations are consistent with some theoretical models predicting that the presence of the nuclear starbursts in the torus can enhance the mass accretion rate onto a central supermassive blackhole, and thereby increase the AGN luminosity.

(4) Dust absorption features at 3.1μm (by ice-covered dust) and 3.4μm (by bare dust) were generally weak, suggesting that dust extinction toward the 3–4μm continuum emitting hot (1000K) dust at the innermost part of the torus is relatively modest, A_V <50-60 mag.

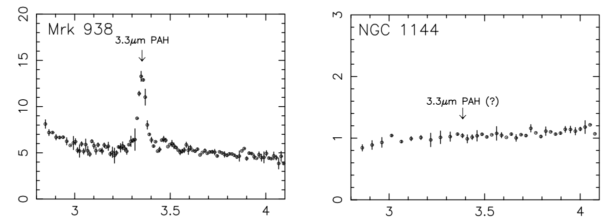

Figure1:Examples of 3–4μm spectra of Seyfert 2 nuclei. The abscissa is observed wavelength in μm, and the ordinate is F_λ in 10^{-15} W m^{-2} μm^{-1}. The left source shows a clear 3.3μm PAH emission feature, while the spectrum of the right source is nearly featureless, with no detectable 3.3μm PAH emission.

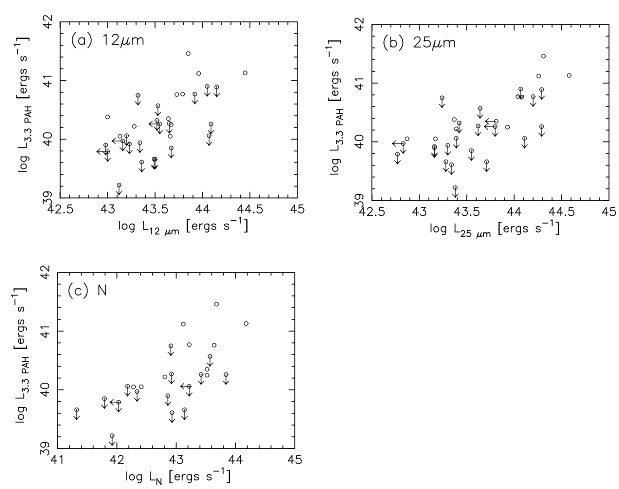

Figure2:The ordinate is the 3.3μm PAH emission luminosities measured in our slit spectra and reflects the absolute magnitudes of the compact nuclear starbursts. The abscissa is some luminosities that are thought to trace AGN powers. (a) *IRAS* 12μm luminosities. (b) *IRAS* 25μm luminosities. (c) Nuclear *N*-band luminosities measured with ground-based aperture (<10 arcsec) photometry. In all the plots, statistical correlations are found, suggesting that AGN and nuclear starbursts are physically closely related.

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X-ray Underluminous AGNs in Ultraluminous Infrared Galaxies

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Ultraluminous infrared galaxies (ULIRGs) radiate quasar-like luminosities ($>10^{12} L_{\odot}$) as infrared dust emission, and thus possess extremely powerful energy sources hidden behind dust. Estimating what fraction of the infrared luminosities are powered by starburst and AGN activity individually is important to understand the dust-obscured AGN–starburst connections.

To estimate an AGN contribution, an indicator which can trace AGN power, by disentangling from star-formation activity, is required. Two useful indicators currently known are (1) broad hydrogen emission lines in the optical and near-infrared domains and (2) X-ray emission at $E >$ 2keV. First, broad emission lines whose line widths are larger than 1500km s^{-1} in full-width at half maximum (FWHM) are believed to originate in high-velocity gas around an AGN, but are difficult to be produced with phenomena related to star formation. Next, 2–10 keV emission from an AGN is much stronger than star-formation. In many optically-selected dust-unobscured type-1 AGNs, the luminosities between 2–10 keV and broad line emission are correlated. If this correlation holds also for ULIRGs, then both of these indicators can be used to estimate the contributions from AGNs to the infrared luminosities of ULIRGs.

Although putative AGNs in the majority of ULIRGs are deeply buried in dust and gas, some fraction of ULIRGs happen to possess modestly dust obscured AGNs along our line-of-sight and show detectable near-infrared broad emission lines. If X-ray absorption is also modest ($N_{\rm H} < 10^{24}$ cm^{-2}) toward the AGNs in these ULIRGs, then we can detect direct 2–10keV X-ray emission from the AGNs and thus estimate absorption-corrected X-ray luminosities with sufficient accuracy. We have performed X-ray observations of ULIRGs with such modestly-dust-obscured AGNs (Figure 1) and compared their 2–10keV to broad line luminosity ratios with optically-selected type-1 AGNs [1]. We found that in ULIRGs the absorption-corrected 2–10keV luminosities are underluminous by an order of magnitude, with respect to the broad line luminosities (Figure 2). Based on some independent energy diagnostic methods, it is more likely that the AGNs in ULIRGs are underluminous in X-rays with respect to their overall spectral energy distributions, than that their broad lines are overluminous.

Possible reasons for the X-ray underluminosity include (1) at the dusty nuclear regions of ULIRGs, X-ray emission from AGNs is significantly suppressed for some reasons, (2) the detected 2–10 keV emission suffer from partial absorption by foreground compact (smaller than the X-ray emitting regions), clumpy, and Compton-thick ($N_{\rm H} > 10^{24}$ cm^{-2}) material, and (3) the 2–10 keV emission we detected is not directly transmitted components from the AGNs, but is scattered components by ionized gas. In any case, estimated AGN contribution from the observed 2–10keV spectra will substantially underestimate the actual AGN luminosities in ULIRGs. There are some ULIRGs, which are consistently suggested to be AGN-powered by some independent methods, but are argued to be starburst-powered from X-ray observations due to weak X-ray emission. This contradiction may come from the X-ray underluminosity from AGNs in ULIRGs.

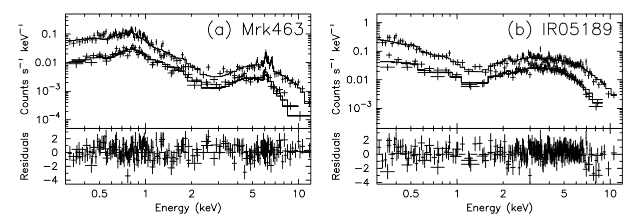

Figure1:X-ray spectra of two ULIRGs with detectable broad emission lines (Mrk463 and IRAS 05189−2524), obtained with XMM. In the upper panel, the upper and lower plots are EPIC PN and MOS data, respectively. In both sources, spectral excess at E $\gtrsim$ 2 keV is attributed to the X-ray emission from the AGNs, and absorption is estimated to be $N_{\rm H} < 3 \times 10^{23}$ cm^{-2}.

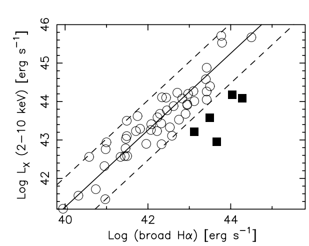

Figure2:Comparison between absorption-*corrected* 2–10keV X-ray luminosity (ordinate) and extinction- *uncorrected* broad optical Hα emission line luminosity (abscissa). Open circles are optically-selected type-1 AGNs. Filled squares are ULIRGs, whose locations are systematically at the lower-right side of the type-1 AGNs. For ULIRGs, the optical Hα luminosities are estimated with a conservative case-B theory, so that the actual positions should be even righter than the current plots. Additionally, while dust extinction of broad lines are negligible in type-1 AGNs, that may be significant in ULIRGs. If we correct for this dust extinction correction, the plots of ULIRGs will move even to the right, increasing their deviations from the type-1 AGNs.

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Hα Impact Polarization Observed in a Gradual Flare

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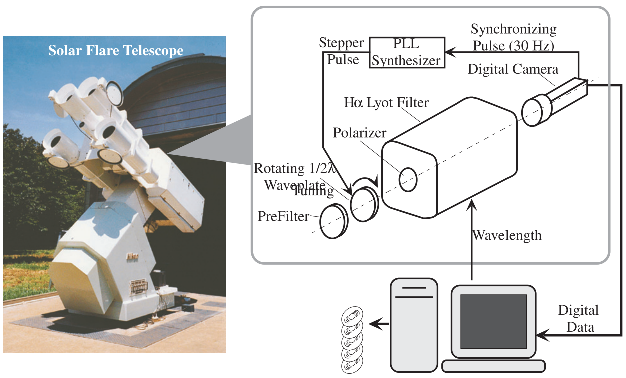

Figure1:The Solar Flare Telescope and the layout of the Hα polarimeter including the rotating waveplate modulator.

Linear polarization of chromospheric lines including the Hα line observed in solar flares is interpreted as impact polarization. The impact polarization is produced by accelerated high-energy particles, which precipitate into the chromosphere. Protons are preferable to produce the impact polarization, because they have heavy mass and easily penetrate into the chromosphere. Therefore, observations of impact polarization gives a rare chance to detect protons in solar flares, and have been considered to be very important for studying protons in solar flares.

There are some former observations of impact polarization. However, compared with the abundance of hard X-ray observations, polarization observations are few, and the behavior of protons in flares is not yet clear. Therefore, we installed a polarimeter into the Hα imager of the Solar Flare Telescope at Mitaka, which is operated by the Division of Solar Physics. As shown in Figure 1, a rotating $\lambda/2$ waveplate is placed just before the Hα Lyot filter. The images taken with the CCD camera are integrated in real-time, and polarization image sets are taken every 4s. Therefore, high-cadence imaging polarimetry in the Hα line became possible with this polarimeter. We started a regular observation with this polarimeter to obtain a number of samples of impact polarization observations in 2002 July. We carry out not only the polarimetry, but also the high-cadence imaging at the Hα center and the Hα off-band imaging for the Doppler velocity analysis.

Among the flares observed so far, a C5.8 flare on 2002 October 14 showed a particularly significant linear polarization [1]. This flare is a gradual one, which was accompanied by a filament eruption [Figures 2(a) and 2(b)]. The maximum degree of polarization of this flare exceeds 1%, and the orientation of the polarization is approximately perpendicular to the flare ribbons, as shown in Figure 2(c). These results can be explained with the assumption that the observed polarization is impact polarization produced by accelerated protons. Downward motion of the Hα emitting layer of the flare kernels, which is generally accepted as the reaction to the chromospheric evaporation, was also observed. Both the polarization and the downward motion show the tendency that they exhibit a significant signal during the rise phase of kernel brightenings. This fact suggests that not only the downward motion but also the polarization is closely related to the heating agent of the chromosphere. The hard X-rays observed by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) show a thermal component, which corresponds to the loop-top high-temperature source shown in Figure 2(b), but there is no detectable power-law component due to accelerated electrons. Therefore, protons are presumed to be not only the cause of the polarization, but also a possible candidate of the principal heating agent in this flare, which lacks high-energy electrons.

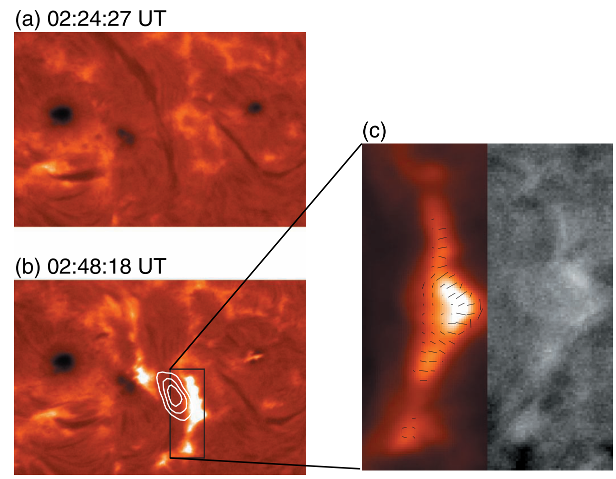

Figure2:Images of the flare on 2002 October 14 and a polarization map and a Dopplergram. (a) A pre-flare image showing the filament before the eruption. (b) The two-ribbon flare occurring after the filament eruption. The contours show the hard X-ray source observed with the RHESSI. (c) A polarization map (left-side) and a Dopplergram (right-side) of the region indicated by a rectangle in panel (b). Ticks in the polarization maps show the orientation and the degree of the polarization. In the Dopplergram, white patches in the flare ribbon correspond to the red shift.

Reference

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Correlation Tracking Image Stabilizer for Ground-Base Solar Observations

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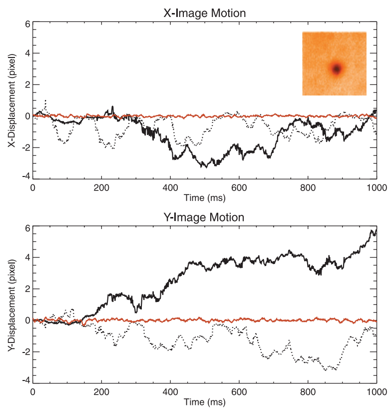

Figure1:Red line: Motion of the stabilized sunspot image (residual error of the correlation tracking) for 1000 frames, which corresponds to about 1s. Black lines: Motions of non-stabilized sunspot images. Two cases are shown with solid and dotted lines. Upper and lower panels show the motion along the x- and y-axes, respectively. The sunspot image used for the experiment is shown in the inset.

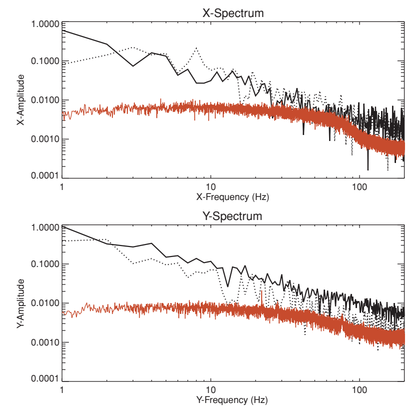

Figure2:Spectra of the motion of the sunspot in the stabilized (red lines) and the non-stabilized cases (black lines). The spectra of the x- and y-motions are shown in the upper and the lower panels.

Image stabilizers and adaptive optics systems are now under operation in many ground-base solar telescopes to remove the seeing effect. In both types of the systems, optical components are actively controlled on the basis of the image displacement signals.

In the solar observation, the image displacement should be calculated by the correlation calculation between the reference image and the live image. The live image is shifted step by step, and the displacement which gives the maximum correlation is searched. The huge amount of the correlation calculation was the biggest problem in the correlation tracking of the solar observation. However, personal computers (PCs) nowadays have enough performance to carry out the correlation calculation with a sufficiently high rate. Therefore, the combination of a PC and our real time software system for solar observation can realize the correlation tracking system.

We have developed a image stabilizing system based on the real-time correlation tracking with a high-speed CCD camera, of which the frame rate is 955 frames s^{-1}. In this system, the image displacement is calculated in every frame and a plane mirror attached on a piezo tilt-mount is controlled to cancel the displacement. An example of the comparison between the motion of the non-stabilized image for 1s and the (residual) motion of the stabilized image is shown in Figure 1. The striking effect of the image stabilization can be seen. The residual RMS fluctuation of the stabilized image is only 0.08 pixel (1pixel corresponds to 1 square-arcsec), while the non-stabilized image wobbles within several arcseconds. The spectra of the image motions are shown in Figure 2. The image motions up to several tens of hertz are suppressed by the image stabilization. Figures 1 and 2 show the behavior of the image stabilizer for only 1s, but our image stabilizing software can be used for the long-duration automatic tracking. The reference image is renewed every 10s, and in the case of troubles such as the cloud passing and the piezo mount reaching the limit, the mirror automatically returns to the origin and the tracking is resumed.

As mentioned above, the correlation tracking technique is common in the image stabilizer and the adaptive optics. Then we construct an experimental Shack-Hartmann sensor with the same CCD camera with 955 frames s^{-1} to evaluate the performance of a PC as the controller for the adaptive optics. Even though the PC used for the evaluation is not a new one (Pentium III 1.2 GHz), it can carry out the correlation tracking calculation for 4×4 subapertures of the Shack-Hartmann image with the rate of 955 frames s^{-1}. In the case of the half frame rate, the number of subapertures increases to 6×6. This result indicates that a low-order adaptive optics systems, which is under operation in some of the solar observatories, can be easily realized with our software system and a faster PC. Now we are developing an adaptive optics system for solar observations.

Detection of a Warm Molecular Wind in DG Tauri: a Milestone for Understanding the Mechanism of Mass Accretion and Ejection

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Jets/outflows in a variety of objects are associated with accretion disks. Among such objects ranging from X-ray binaries to quasars, young stellar objects (YSOs) provide the most easily observable examples. Indeed, many YSOs exhibit beautiful collimated jets at optical-IR wavelengths, and energetic molecular outflows at radio wavelengths. Understanding the mechanism of mass accretion and ejection in these systems is one of the fundamental open problems in contemporary astrophysics.

Accretion cannot proceed unless excess angular momentum is removed from surrounding materials, and there is growing evidence that the jet/outflow plays an important role for this process. Popular magneto-hydrodynamic models (magneto-centrifugal wind models) explain this physical link as follows; Magnetic and centrifugal forces act together to launch the jet/wind along magnetic field lines from the accretion disk, or interface between stellar magnetosphere and circumstellar disk. The magnetic field lines act as solid wires close to the star, and rotate together with the circumstellar disk. These accelerate the flow particles outwards and upwards in a `bead-on-a-wire' fashion. In this way angular momentum is channeled away from the disk through the outflow. This fascinating picture cannot easily be tested, since the process should occur on very small scales, which neither the *Hubble Space Telescope (HST)* nor adaptive optics on Subaru can resolve directly.

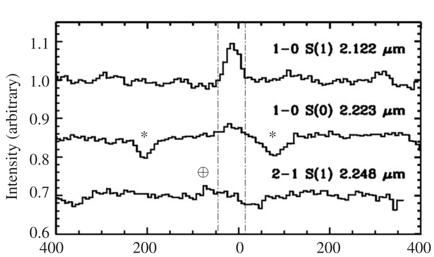

Figure1:Near-IR H_2 emission in DG Tauri observed at 8.2-m Subaru [1]. The emission features are blueshifted by 15 km s^{-1} from the systemic velocity, indicating that the observed emission is associated with outflowing gas. The asterisks indicate photospheric absorption features. Our seeing-limited observations show that the 1-0 S(1) emission is offset by 0''.2 from the star towards the extended jet, and a typical width of ~0''.6 perpendicular to the jet. Correcting the inclination to the line of sight, these indicate a flow length and width of ~40 and ~80AU, respectively. The line flux ratios indicate an excitation temperature of ~2000K.

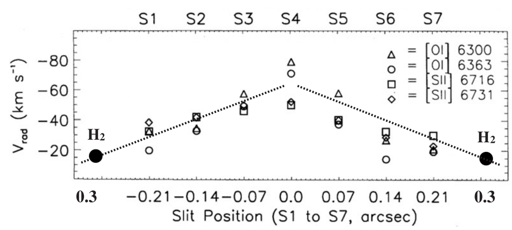

Figure2:Centroidal velocities of emission features observed across the DG Tau outflow. The data for forbidden line emission were obtained with the *Hubble Space Telescope* by Bacciotti et al.[2]. The dots for molecular hydrogen are based on our Subaru data. The figure suggests that the H_2 and forbidden line emission originate from different components of the same flow, i.e., a fast and partially ionised component near the axis and a slow molecular component surrounding it.

These models predict the presence of poorly collimated streamlines surrounding a well-collimated jet. In other words, a collimated jet observed at optical-IR wavelengths may be only a limited portion of the entire flow close to the outflow axis. The presence of an "unseen" wide-angled component has been suggested by the presence of a cavity in the molecular envelope, shock-heated molecular hydrogen along a cavity wall, a broad range of morphology of molecular bipolar outflows, and so on. Direct detection of such a flow component is desired to test the validity of the above models, and also understand the nature of molecular bipolar outflows.

The large diameter of Subaru and the high sensitivity of its infrared spectrograph (IRCS) allowed us to detect molecular hydrogen emission associated with a missing wide-angled wind. Fig. 1 shows the spectra of H_2 emission observed in DG Tauri, one of the most active T Tauri stars known. These emission lines exhibit a blueshifted line profile and spatial extension towards the extended jet, indicating that the emission is associated with outflowing gas. (Absence of redshifted emission is explained by obscuration of the counterflow by a circumstellar disk.) As shown in Fig. 2, the observed velocity and spatial scale are well explained if we regard this flow component as an outer extension of the kinematic structure observed in forbidden line outflow. This indeed agrees with model predictions of the magneto-centrifugal wind scenario.

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Universality in the Distribution of Caustics

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We numerically investigate the long–time evolution of density perturbations after the first appearance of caustics in an expanding cosmological model with one–dimensional ‘single–wave’ initial conditions. Focusing on the time–intervals of caustic appearances and the spatial distribution of caustics at subsequent times, we find that the time–intervals of caustic appearances approach a constant, i.e., their time–subsequent ratio converges to 1; it is also found that the spatial distribution of caustics at a given time features some universality rules, e.g., the ratio between the position of the nearest caustic from the center and that of the second nearest caustic from the center approaches a constant. Furthermore we find some rules for the mass distribution for each caustic. Using these universality constants we are in the position to predict the spatial distribution of caustics at an arbitrary time in order to give an estimate for the power spectral index in the fully–developed non–dissipative turbulent (‘virialized’) regime.

We have argued that the system of caustics displays some universality, after some time, with respect to regularity of time–intervals in the appearances of caustics, and the spatial distribution of caustics at subsequent times.

First, we have noticed the existence of a rule for the time–intervals of the appearances of caustics: the ratio of intervals quickly approaches 1, a fact that we have made plausible.

Second, we have found some rules hidden in the spatial distribution of caustics: the ratio between a position of the nearest caustic from the center and that of the second nearest caustic from the center $R_1 = X(N-1, N)/X(N-2, N)$ approaches a value of around 0.15, where $X(i, j)$ is the position of a caustic, as the i–th position of a caustic at the time when the j–th caustic appears.

Furthermore, the ratio between the nearest caustic from the center at the (N–1)th appearance of a caustic and that at the Nth appearance of a caustic $R_2 = X(N-1, N)/X(N-2, N-1)$ attains a value of around 0.3.

Third, we have found a rule for the mass distribution for each caustic, that is, we have derived the density distribution of a cluster. The mass distribution for each caustic can be fit to a line with the geometric progression of ratio 0.5.

Furthermore, using the above constants, we have found the smoothed density profile, and finally have evaluated the power index of the power spectrum in the ‘virialized’ regime to be -0.73. This value is different from -1 that is determined by the density profile around one singular point.

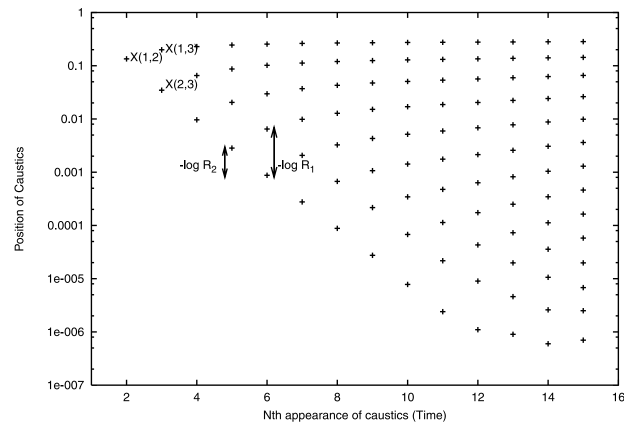

Figure1:Spatial positions of caustics at the N–th appearance of caustics.

The discovery presented in this research note, namely that there exist remarkable rules for the distribution of caustics, points towards several interesting theoretical implications for long–term properties of self–gravitating systems. As in studies of dynamical systems we here deal with a hierarchy of bifurcations. A fruitful way to explore universality properties further is to use renormalization group techniques similar to those developed for the Feigenbaum scenario of pitchfork bifurcations. With this note we have just provided a hint to the existence of universal constants. A detailed renormalization group and fixed point analysis is needed to support these findings. In this context an interesting question remains open: the existence of chaotic regimes.

Besides this theoretical interest we think that our results may be useful to check the accuracy of numerical simulations concerning their stability under long–time integration.

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r-Process Abundance Universality and Actinide Cosmochronology

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The heavy radioactive actinide nuclei, U and Th are generated by rapid neutron capture process (i.e., *r*-process). These nuclide have half lives $[t_{1/2}(^{238}\mathrm{U}) = 4.47 \times 10^9\,\mathrm{yr}, t_{1/2}(^{232}\mathrm{Th}) = 1.40 \times 10^{10}\,\mathrm{yr}]$ which are comparable to the cosmic age. The inferred abundance of U and/or Th can be used to estimate stellar ages. The stellar ages are given by;

$$\Delta T = 46.7\,(\log(\mathrm{Th/Eu})_0 - \log(\mathrm{Th/Eu})_T)\,\mathrm{Gyr},$$
$$\Delta T = 21.8\,(\log(\mathrm{U/Th})_0 - \log(\mathrm{U/Th})_T)\,\mathrm{Gyr},$$

where the index 0 denotes the initial production ratio, while the index T refers to the presently observed value.

Metal-deficient stars are believed to be the oldest stars in the Galaxy.Their age can be regarded as the Galactic age and a lower limit to the cosmic age. Dozens of observations of r-process elements in metal-deficient halo stars have been reported which show a $Z > 56$ abundance distribution pattern similar to the Solar-system r-process distribution (e.g.,[1]). This feature is called "the universality of the *r*-process". Because of this universality, it is believed that *r*-process elements for $Z > 56$ formed in the same ratio and their astrophysical origin is unique. The Th/Eu chronometer has applied for these metal-deficient stars and indicates reasonable ages(e.g.,[1]). However, the extremely *r*-process enhanced, metal-deficient star CS31082-001was reported to show quite high Th/Eu ratio [2]. Although it shows a similar abundance distribution for $56 < Z < 80$ elements, the Th/Eu ratio is higher than in the Sun. The Th/Eu chronometer shows this star is younger than the Sun in spite of its low metallicity ([Fe/H]∼−2.9). HDS group found two other metal-deficient stars which also show high Th/Eu ratio[3]. These observations imply that the heaviest r-process elements in these stars were generated with different production ratios and these elements could be formed in different nucleosynthesis environments.

We investigated *r*-process nucleosynthesis in various environments. For this study, we assume steady-state flow as a general model for the *r*-process nucleosynthesis environment. We calculated *r*-process nucleosynthesis in various combinations of the dynamical timescale τ_{dyn}, the entropy *S*, the electron fraction Y_e, and boundary temperature T_b. Differences in these parameters mean different density and temperature profiles, which results in different neutron-seed ratios and/or different paths of the *r*-process[4][5]. For details of our calculation, see [6].

The results are shown in Fig.1. Our results show that the abundance distribution for the $56 < Z < 80$ elements is almost independent of the nucleosynthesis environment as long as there are enough neutrinos to form 3rd peak elements. However, Th/Eu production ratio strongly depends upon the nucleosynthesis environment. In these calculations, the beta-decay flow into stable nuclei occurs after almost all neutrons have been depleted. Hence, the final abundance distribution was controlled by beta-delayed neutron emission rather than neutron-capture path. This seems to be the main reason of the universality between the peak elements which hold in theoretical calculations.

The observed universality does not mean a unique Th/Eu production ratio. This introduces an uncertainty into the use of the Th/Eu chronometer as a means to estimate the ages of the metal-deficient stars. On the other hand, the U/Th chronometer seems to be a good chronometer. We found the U/Th production ratio is almost independent of the nucleosynthesis environment if there were enough neutrons to reproduce the observed abundance distribution when they formed. Unfortunately, there are several uncertainties in the nuclear physics models. It is also difficult to detect U in metal-deficient stars. More experimental, observational, and theoretical studies for *r*-process nucleosynthesis are desired.

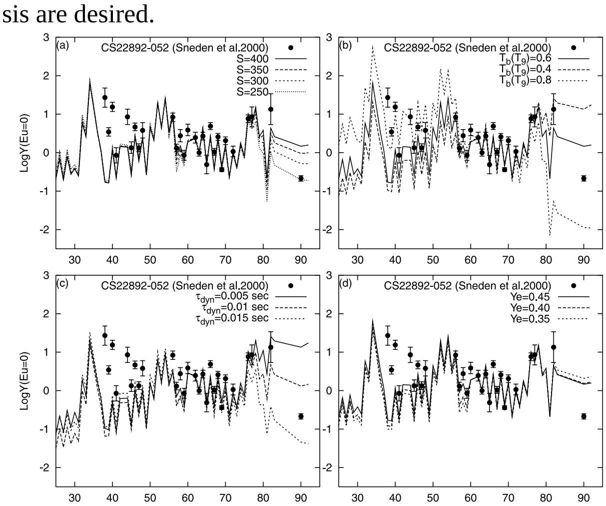

Figure1:Dependence of the nucleosynthesis yields upon various parameters of the astrophysical environment. Closed circles show observed elemental abundances in CS22892-052 [1].

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Subaru/FOCAS Spectropolarimetry of Type Ic Hypernova SN 2003dh/GRB 030329

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KASHIKAWA, Nobunari, TAKATA, Tadafumi, AOKI, Wako, KOMIYAMA, Yutaka
MIZUMOTO, Yoshihiko, NOUMARU, Junichi, OGASAWARA, Ryusuke
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We carried out spectropolarimetric observations of SN 2003dh/GRB 030329 in 2003 May and its properties are investigated through a comparison with spectra of the Type Ic hypernovae SNe 1997ef and 1998bw [1]. (Hypernovae being a tentatively defined class of SNe with very broad absorption features: these features suggest a large velocity of the ejected material and possibly a large explosion kinetic energy.)

It is shown that the spectrum of SN 2003dh obtained on 2003 May 8 and 9, i.e., 34–35 rest-frame days after the GRB (for $z = 0.1685$), are similar to those of SN 1997ef obtained $34 - 42$ days after the fiducial time of explosion of that SN. The match with SN 1998bw spectra is not as good (at rest 7300–8000Å), but again spectra obtained $33 - 43$ days after GRB 980425 are preferred. This indicates that the SN may have intermediate properties between SNe 1997ef and 1998bw. The time of explosion of SN 2003dh is then constrained to be between -8 and $+2$ days of the GRB, making this the first case to link the identity of GRB and hypernova both in space and in time. The Si and O P-Cygni lines of SN 2003dh seem comparable to those of SN 1997ef, which suggests that the ejected mass in SN 2003dh may match that in SN 1997ef. More recently, Mazzali et al. reported that the ejecta mass of SN 2003dh is found to be $\sim 8M_\odot$ which is somewhat less than in other two hypernovae [2].

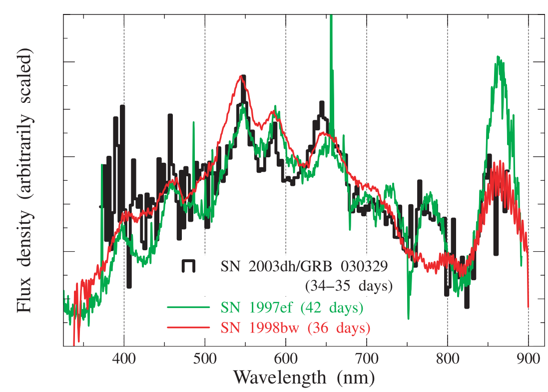

Figure1:Comparison of spectra of SNe 2003dh (black), 1997ef (green) and 1998bw (red).

Polarization was marginally detected at optical wavelengths and it is consistent with measurements of the late afterglow, implying that it mostly originated in the interstellar medium of the host galaxy. However, further spectropolarimetric observation of bright SNe of similar class is required to confim the interpretation.

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Late-time Spectroscopy of the Interacting Type Ia SN 2002ic: Evidence of a H-rich, Asymmetric CSM

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We obtained late-time optical spectroscopy of the Type Ia SN2002ic on 2003 June 27.6 UT [1] with the Faint Object Camera and Spectrograph on the Subaru Telescope. The spectrum has an epoch of ~ 222 rest-frame days after explosion[2].

The spectrum is shown in Figure 1 with line-identifications and compared with those of SNe 1997cy [3] and 1999E[4]. Strong H emission indicates an interaction between the expanding SN ejecta and an H-rich CSM (see [2] for early-time observations). The late-time spectrum of SN 2002ic resembles those of SNe 1997cy and 1999E, though the latter were originally classified as Type IIn SNe. The three SNe also have similar luminosities, suggesting that they are the same phenomenon and that the CSM is also similar. We proposed a new classification, Type IIa SNe, for these events.

The observed line profiles and line ratios were analyzed within the ejecta-CSM interaction scenario. The emission in H Balmer, [O III], and He I lines, and in permitted Fe II blends, resembles the spectra of the Type IIn SN 1987F [5] and of Seyfert 1 galaxies. A high-density, clumpy CSM is inferred. Strong, very broad [CaII]/Ca II and [O I]/O I emissions imply that not all the outer SN ejecta were decelerated in the interaction, suggesting that the CSM is aspherical. This asymmetric scenario is consistent with spectropolarimetical observations [6].

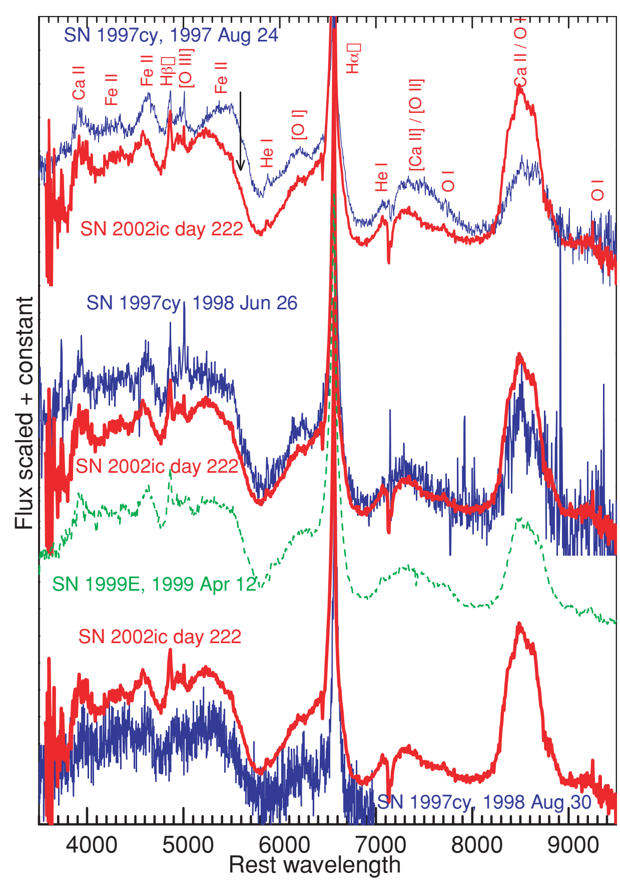

Figure1:Spectrum of SNe 2002ic (*red thick lines*;~ 222 days) compared with those of SNe 1997cy (*blue thinlines*) and 1999E (*green dashed line*)

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SUBARU Deep Spectroscopy of the Very Extended Emission-Line Region of the Seyfert Galaxy NGC 4388

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Recently, Yoshida et al.[1] found a very large region of ionized gas extending around a Seyfert 2 galaxy in the Virgo Cluster, NGC 4388. This very extended emission-line region (VEELR) has a size of 35 kpc and is located preferentially toward the northeastern side of the galaxy. Here we report the results of deep optical spectroscopy of the VEELR of NGC 4388 using FOCAS of the Subaru Telescope[2].

The Hα radial velocities of most of the filaments of the region are highly blueshifted with respect to the systemic velocity of NGC 4388. The velocity field is complicated, and from the kinematic and morphological points of view, there seems to be several streams of filaments: low-velocity filaments, with radial velocities v relative to the systemic velocity of the galaxy of roughly -100 km/s; high-velocity ($v \sim -300$ km/s) filaments; and a very high velocity ($v \sim -500$ km/s) cloud complex (Fig.1).

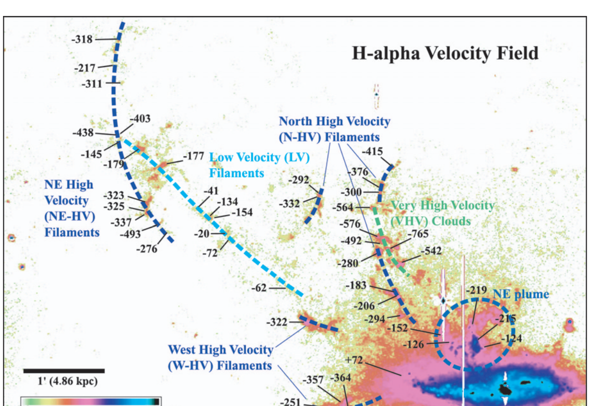

Figure1:Velocity field of the VEELR of NGC 4388 overplotted on the Hα+[N II] image. Schematic lines indicating individual groups of filaments/clouds are overlaid.

The emission-line intensity ratios of the VEELR filaments are well explained by power-law photoionization models with solar metal abundances, suggesting that the Seyfert nucleus of NGC 4388 is the dominant ionization source and that the VEELR gas has moderate metallicity. In addition to photoinozation, shock heating probably contributes to the ionization of the gas. In particular, the filaments outside the ionization cone of the Seyfert nucleus are mainly excited by shocks. The predicted shock velocity is $200 - 300$ km/s, which is comparable to the velocities of the filaments.

We conclude that the VEELR was formerly the disk gas of NGC 4388, which has been stripped by ram pressure due to the high-speed (~ 2000 km/s) collision between the hot intracluster medium (ICM) and the galaxy. The velocity field and the morphology of the VEELR closely resemble snapshots from some numerical simulations of this process. In the case of NGC 4388, the ram pressure stripped gas, which is normally seen as extended HI filaments, happens to be exposed and ionized by the power-law radiation from the Seyfert nucleus, and so can be seen as optical emission-line gas (Fig.2). The ram pressure probably caused active star-formation in the disk of the galaxy, also. Interaction between the outflow induced by the disk star-formation and the ram pressure stripped gas stream well explains the properties of extended radio emission and the morphology of faint Hα filaments.

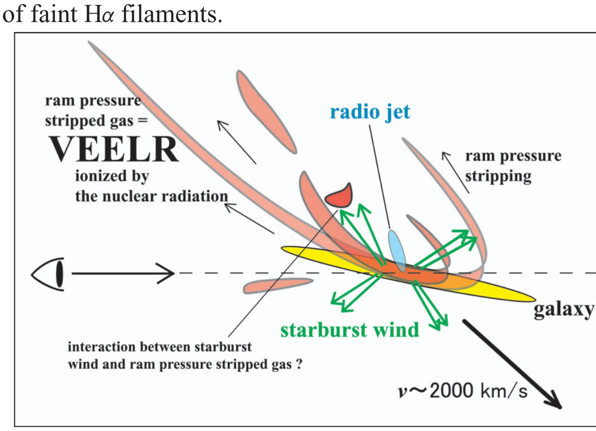

Figure2: Schematic draw of the structure of the emission-line regions around NGC 4388.

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VERA Observations of the W49N H_2O Maser Outburst

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NAKASHIMA, Kouichirou, NAGAYOSHI, Riiko, OMODAKA, Toshihiro
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We report on a strong outburst of the W 49N H_2O maser observed with VERA in 2003 October[1].

As a part of VERA's phase-referencing performance test [2], observations of the W 49N and OH43.8-0.1 H_2O maser pair were performed with an interval of about one month. During the course of the observations, a strong maser outburst has occurred in W49N, and we have successfully detected this outburst with VERA. Figure 1 shows the spectral evolution of W49N H_2O maser at 22 GHz, with a strong outburst around day of year 281 and 294 at $V_{\rm LSR} = -30.7$ km/s. The peak intensity was 7.9×10^4 Jy, being one of the strongest outbursts observed in W49N so far.

We have also mapped the W49N H_2O maser using VERA array on the day of year 294, and successfully identified the outburst maser spot. Figure 2 shows the maser spot distribution in W49N, and the arrow on the right map shows the location of the outburst spot. Interestingly, the spot is on the arc-like structure, which is likely to be a shock front powered by forming stars, indicating possible link between the maser outburst and shock phenomenon.

Further monitoring observations of the spot motions in the arc-like structure will allow us to understand more deeply the mechanism of maser outburst. Also, we are performing astrometric measurements of the separation of the two sources (W49N and OH43.8-0.1), and further observations will allow us to evaluate astrometric capability of the VERA system.

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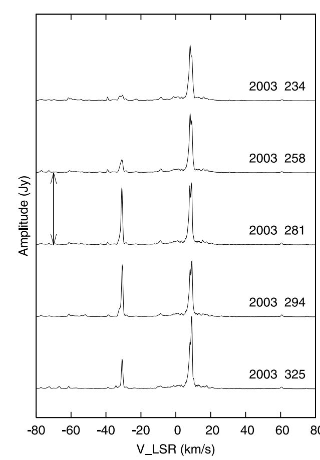

Figure1:Spectral evolution of W49N H_2O maser. Vertical arrow corresponds to 10^4 Jy. Dates of observations (day of year) are also indicated.

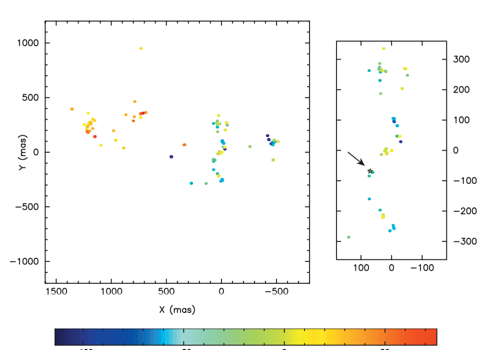

Figure2:Maser spot distribution in W49N on day of year 294 in 2003. Right panel shows the extended map of the central maser cluster, and the arrow indicates the position of outburst spot.

Meteoroid Clusters in Leonids: Evidence of Fragmentation in Space

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During the recent Leonids storm, several short-duration "outbursts" in which more than 20–40 meteors appeared in a few seconds, have been reported[1][2]. The meteors in these events were extremely localized within a few hundred km, which should be caused by clusters of meteoroids. The existence of such clusters indicates the fragmentation of meteoroids during orbital motion in interplanetary space. Considering the extent of the spatial distribution, the fragmentation should have occurred at around the perihelion passage of the meteoroids just before encountering the Earth. This may cause a possible enhancement of smaller meteoroids, even in old dust trails. A possible example of similar clusters in the past meteor storm of Giacobinids is also noted. Such phenomena may be generally observed in strong meteor storms.

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Figure1:The Leonid meteor storm in 2001 over Japan. Photo by M. Tsumura.

The Distribution of Star-Forming Regions in Luminous Infrared Galaxies

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We performed Hα imaging observations of 22 luminous infrared galaxies (LIRGs) to investigate how the distribution of star-forming regions in these galaxies is related to galaxy interactions and global star-forming properties[1]. Observations were made with the Kyoto tridimensional spectrograph I attached at the Cassegrain focus of the Okayama Astrophysical Observatory 188cm telescope.

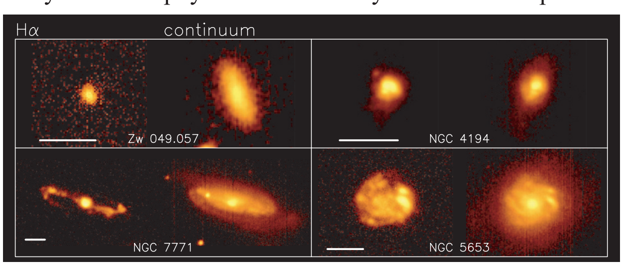

Figure1:Examples of Hα and continuum images. The scale bar represents 5 kpc.

Based on correlation diagrams between Hα flux and continuum emission for individual galaxies (figure 2), a sequence for the distribution of star-forming regions was found: very compact (∼ 100pc) nuclear starbursts with almost no star-forming activity in the outer regions (type 1), dominant nuclear starbursts $\lesssim$ 1kpc in size and a small-contribution from the outer regions (type 2), nuclear starbursts $\gtrsim$ 1kpc in size and a significant contribution from the outer regions (type 3), and extended starbursts with relatively faint nuclei (type 4).

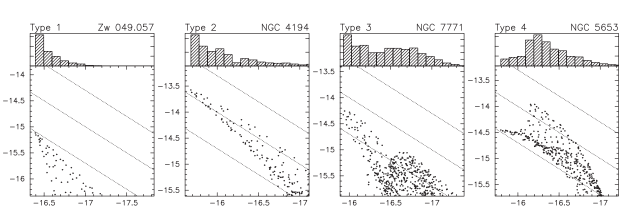

Figure2:The ordinate represents log Hα surface brightness (ergs ^{1}cm ^{2}arc sec ^{2}) and the abscissa log continuum surface brightness (ergs ^{1}cm ^{2}Å ^{1}arc sec ^{2}). The continuum surface brightness increases leftward, so the galaxy nucleus corresponds to the left edge of the diagram. The small dots represent Hα and continuum surface brightness measured at each position. In the top panel of each diagram, the distribution of integrated Hα flux from each continuum surface brightness bin is shown.

These classes of star-forming region were found to be strongly related to global star-forming properties such as star-formation efficiency, far-infrared color, and dust extinction (e.g., figure 3). There was a clear tendency for the objects with more compact distributions of star-forming regions to show a higher star-formation efficiency and hotter far-infrared color.

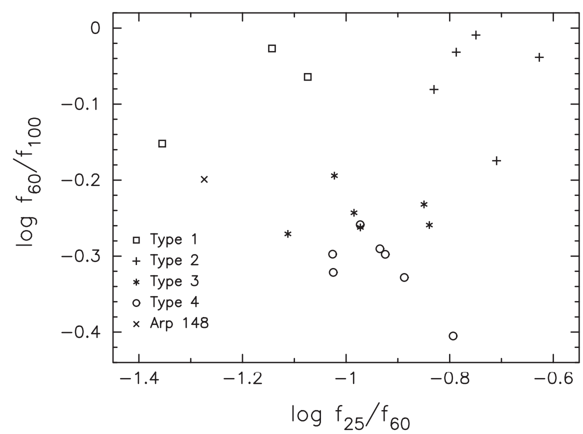

Figure3:*IRAS* color-color diagram for the sample objects. The different types of objects show different flux ratios.

We also found that the distribution of star-forming regions was weakly but clearly related to galaxy morphology: severely disturbed objects had a more concentrated distribution. The sequence of the distribution of star-forming regions and its relation to morphological properties suggest that, as the interaction proceeds, star formation in outer regions fades out and nuclear starburst becomes dominant. It is also notable that an appreciable fraction of the sample objects were dominated by extended starbursts (type 4), which is unexpected in the standard scenario of interaction-induced starburst galaxies. Therefore, it may be crucial to determine the triggering mechanism of star-formation in these objects in order to better understand star-forming activity in LIRGs.

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Near-Infrared Coronagraphic Imaging of Herbig Ae Star HD 150193A

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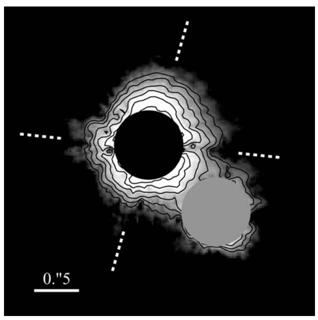

Figure1:Circumstellar disk around HD 150193A. The scattered light by dust grains was detected in the *H*-band. The occulting mask has a diameter of 0.''5 but inner 0.''8 region (black circle) is photometrically unusable. A gray filled circle represents the T Tauri companion star located at 1.''1 from the primary. The contours are overplotted starting from 64 to 6.4 mJy arcsec $^{-2}$ in steps of 0.5 magnitude. Dotted lines indicate the directions of secondary spider pattern.

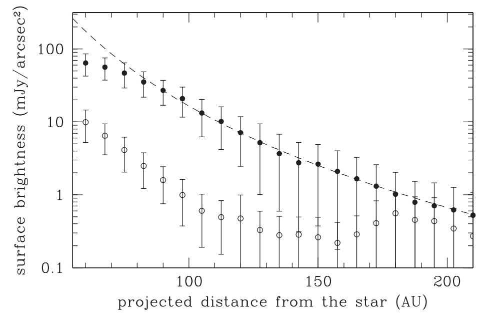

Figure2:Azimuthally averaged radial profile of the circumprimary disk around HD 150193A (filled circles). The profile is averaged along the elliptical path with P.A. = 358° and ellipticity = 0.79, assuming that the disk is circular. The profile is well fitted by a power-law with the index of − 4.6 (dashed line). Profile around the companion is also shown (open circles), azimuthally averaged in the southern half region.

We report the near-infrared imaging of pre-main-sequence (PMS) star HD 150193A with the stellar coronagraphic camera and the adaptive optics (AO) on the Subaru 8.2-m Telescope [1].

The disk structure is now ubiquitous around low-mass T Tauri stars and intermediate-mass Herbig Ae stars. In order to understand the formation process of extra-solar planetary systems, it is important to study the spatial structure of disks where planets are most likely formed as a by-product of star formation process. However, few disks have been spatially resolved so far because of the observational difficulty: both high-resolution and high-contrast are required to image the small and faint structure in the vicinity of the central bright star. Therefore, we have initiated AO imaging of PMS stars with the coronagraphic camera CIAO on the Subaru Telescope, which is one of the most suitable instruments for direct imaging of disks.

HD 150193A is a relatively old Herbig Ae star with its mass of $\sim 2M_\odot$ and its age of 6 Myr. Previous observations suggest the presence of abundant circumstellar dust around HD 150193 which led us to observe this nearby (d = 150 pc) source: the circumstellar dust mass was estimated to be 0.01 $M_\odot$ in the submilliter observations [2], and [3] marginally resolved HD 150193A with 2 μm speckle holography. It is also notable that HD 150193 is a binary with a T Tauri companion star HD 150193B, which enables us to investigate the disk properties in the multiple system.

The H-band (1.65 μm) observations were carried out in 2002 July. The AO was utilized, giving the spatial resolution of 0.''1. We occulted HD 150193A with a mask whose diameter was 0.''5. In order to detect the faint structure, we observed the reference star without any circumstellar material using the same AO and coronagraphic configurations, then subtracted the reference star image from each of HD 150193A and B.

We detected the disk around HD 150193A extending from the edge of the coronagraphic mask at 50 AU to about 190 AU. The surface brightness and size of the disk are similar to those of other resolved disks around Herbig Ae stars. While, no circumstellar matter was detected around the companion star. This is consistent with the observational trends that the circumprimary disk have larger mass than that of the circumsecondary disk, and that the properties of circumprimary disks in wide binary systems are comparable to those of the disks around single stars [4]. Further detailed study of this typical binary HD 150193 could contribute the understanding of disk evolution and planet formation in binary systems.

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The Collapse and Fragmentation of Magnetized Molecular Cloud – MHD Nested Grid Simulation –

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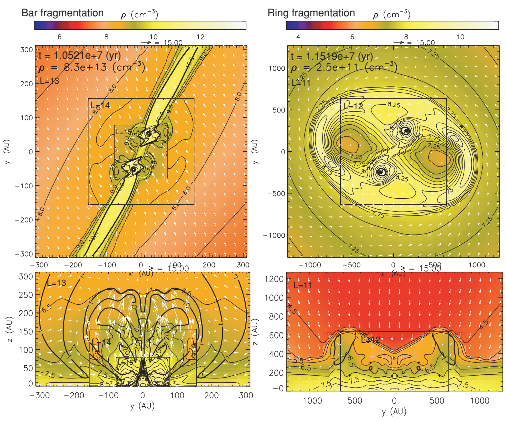

Figure1:Two typical models of the adiabatic core are plotted (bar:left, ring:right). Density (contour and false color) and velocity vectors (arrows) are plotted on *x*=0 plane (lower panels) and on the *z*=0 plane (upper panels). The elapsed time, the maximum density, grid level and scale length are also plotted. Thick lines in the upper panels denote the contour line of the adiabatic core, while those in the lower panels mean the isovelocity curves representing the outflow region.

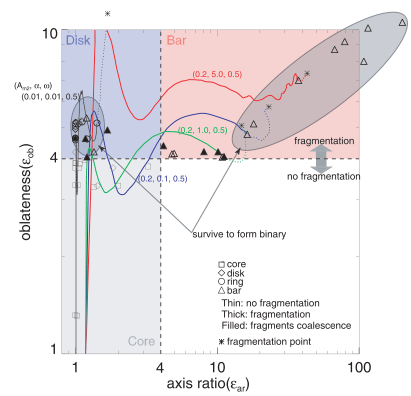

Figure2:The axis ratio and oblateness are plotted when the gas at the cloud center becomes adiabatic. The abscissa indicates the axis ratio and the ordinate is the oblateness. Fragmentation occurs above the horizontal dashed line (oblateness> 4). The domains in large circles mean that fragmented cores survive to form binary or multiple stars. The solid(dotted) lines represent the evolutional tracks for some typical parameters. The symbols denote the shape of the adiabatic core when the fragmentation occurs or the calculation ends. Thick-line and filled symbols represent the cores which experience fragmentation.

Collapse and fragmentation of the rotating magnetized molecular cloud is studied by using 3D MHD Nested Grid simulations[1].

To study the evolutional processes of the molecular cloud, we assume a cylindrical gas cloud with rotation axis and magnetic field being parallel to the cylindrical axis and add the axisymmetric and non-axisymmetric perturbation for collapse and fragmentation of cloud. For adopting the Nested Grid method, we calculate the cloud evolution with 15 orders of magnitude for density ($10^2 - 10^{17}\,\mathrm{cm}^{\ 3}$) and 5 orders of magnitude for spatial scale($10^6 - 10\,\mathrm{AU}$). We parameterize the magnetic field strength, rotation speed and the amount of initial non-axisymmetric perturbation. We calculated 51 different models by vector parallel supercomputer VPP5000 at Astronomical Data Analysis Center, National Astronomical Observatory of Japan.

As a result, the cloud evolutions are classified into the following three types: (1)Core, (2)Bar Fragmentation, and (3)Ring Fragmentation. Figure 1 shows the final state of the typical Bar Fragmentation (left panels) and Ring Fragmentation (right panels) models. When the elongated bar is formed in the isothermal collapse phase, fragmentation occurs in the adiabatic accretion phase. In Bar Fragmentation models, the fragments are easy to merge owing to their small orbital angular momenta, while strong outflows are driven by their large spin angular momenta. On the other hand, when the axisymmetric disk is formed and the non-axisymmetry does not grow sufficiently in the isothermal collapse phase, the disk deforms into a ring and fragments in the adiabatic accretion phase. The fragments formed by Ring Fragmentation have large orbital angular momenta but small spin one. For this reason, they seem to become a binary system, although the weak outflows are driven.

Figure 2 shows the axis ratio (x-axis:degree of the bar at z=0 plane), oblateness (y-axis:degree of the disk) and core shape at the final state. Four thick (dotted) lines indicate the evolutions of the cloud shape in the isothermal collapse (adiabatic accretion) phase. From these lines, we found that (i)disk forms early in the model with initial large rotation speed and strong magnetic field, (ii)the non-axisymmetry evolves only after the disk formation. From distribution of symbols in Figure 2, we found that the binary formation conditions are (i) the sufficiently thin disk is formed (oblateness >4) and (ii) the central region has the small axis ratio (<1) or sufficiently large axis ratio (>10) in the isothermal collapse phase.

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An Optical and NIR Search for Brown Dwarfs in the Pleiades Cluster

NAGASHIMA, Chie, NAKAJIMA, Yasushi, TAMURA, Motohide, NAKAJIMA, Tadashi,
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We report discovery of four new brown dwarf (BD) candidates including three L-type from a brown dwarf search in the Pleiades open cluster in five optical and near infrared (NIR) bands [1].

In the Pleiades cluster which is one of the best clusters for a BD search, about 20 M-type BDs have been identified by optical surveys, however, there is only one known L-type BD (Roque25; [2]). L-type BDs are too cool to detect in optical wavelengths. So we have carried out a BD survey in both the optical and NIR of an area of $14' \times 23'$ of the central region of the Pleiades cluster, which has not yet been surveyed because of the existence of large extinction. The NIR survey was made with SIRIUS on the UH 2.2 m telescope and the optical survey was made with Wide Field Camera on the Isaac Newton Telescope.

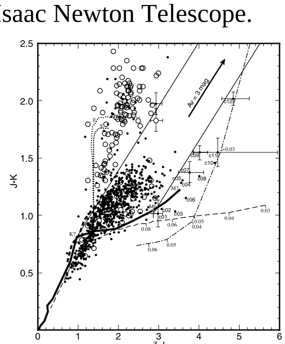

Figure1:The $J - K$s, $i' - J$ colour-colour diagram for all detected objects. Small dots are point sources and open circles are extended sources. The thick solid and dashed curves are the loci of main sequence and red giant stars. The thin dashed and dot-dashed lines are the 125 and 120 Myr isochrones of the NextGen model (inappropriate for L-type) and Dusty model (inappropriate for early M-type), respectively. Numbers with tick marks denote masses in solar mass units.

In Fig. 1, most objects are concentrated in the region of reddened main sequence (reddening band), and a number of extended sources spread upward and some point sources exist on the right hand of the reddening band. Objects spread upward are likely to be galaxies reddened with extinction and K-corrections (dotted lines). Because the theoretical isochrones for BDs extend toward right hand of the reddening band, 12 objects (c01 ∼ 12) in this region are selected as candidates. Among them, four objects lie on the theoretical isochrones in the colour-magnitude diagram (In Fig. 2), so we identified them as Pleiades BD candidates (PL-1∼ 4). The estimated mass of faintest one, PL-4, is around 0.028 $M_{\odot}$, which is maybe the lowest mass object found so far in the Pleiades cluster.

The SED of PL-1 is consistent with a mid to late-M spectral type, PL-2 and PL-3 with late-M to early L types, and PL-4 with an early-mid L type (fig. 3). The result of this work shows that the combination of optical and NIR survey is effective for a L-type BD search.

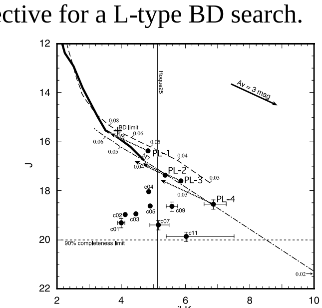

Figure2:The $J, i' - K$ colour-magnitude diagram. Filled circles are BD candidates and dotted arrows are estimated maximum reddening vectors. Other symbols are as in Fig. 1.

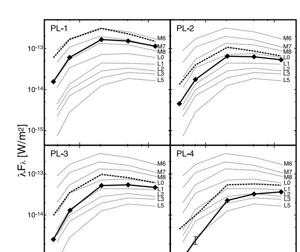

Figure3:The SEDs for four BD candidates. Solid and dashed lines represent the SEDs with no extinction and with possible maximum extinction, respectively. Dotted lines are SED templates made from field BDs.

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Evolution of DLA Systems From Hierarchical Galaxy Formation Models

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We investigate evolution of Damped Lyman α(DLA) systems in the hierarchical structure formation scenario[1]. DLA systems, which have been associated with cold gas (HI column densities $N_{\mathrm{HI}} > 2 \times 10^{20}\,\mathrm{cm}^{-2}$) in protogalactic disks, provide some advantages in the investigation of various characteristics of primordial galaxies. Recent measurements of metal abundance unaffected by dust depletion can provide good evidence for understanding the processes of metal pollution and revealing the connection between DLA systems and galaxies. For example, the metallicities is typically $Z_{\odot}/10$ and it exhibits milder evolution at redshift $1 < z < 4$. Furthermore, DLA systems have other observational properties that the HI column density distributions follow a single-power law.

We here investigate the evolution of DLA systems in our semi-analytic model taking into account merging processes of dark halos, star formation processes and so on.

We can consistently show the metallicity evolution and the column density distribution for reasonable models which also reproduce fundamental properties of local galaxy population[2]. This result suggests that the chemical evolution of DLA systems can be consistently reconciled with the observational features of typical galaxies. We conclude that DLA systems primarily consist of sub-L^{*} and/or dwarf galaxies (e.g., B-band magnitude $M \sim -17$ mag, HI-gas mass $\sim 10^{9} M_{\odot}$, circular velocity $V_{c} \sim 90$ km/s). This picture shows strong conflict with the classical one in which DLA systems are relatively massive galaxies like our Galaxy. We also compare our results with other theoretical studies and discuss some advantages in the investigation of DLA systems[1].

Based on this study, we proceed to investigate the evolution of DLA systems as follows.

(1) DLA systems at low redshifts. Recently, ground-based and HST images have revealed various properties of host galaxies of DLA systems (DLA galaxies) especially at redshift $z < 1$. We focus on the low-redshift DLA systems. As a result, DLA galaxies primarily comprise low surface brightness (LSB) dwarf galaxies(surface brightness $22 - 27$ mag arcsec^{-2}, size ~ 3 kpc, star formation rate $\sim 10^{-2} M_{\odot}$/yr)[3].

(2) Radio observations of DLA systems. Recent radio observations reveal new properties of DLA systems such as abundance of hydrogen molecules. We explore some possibilities for studying DLA systems by radio observations based on radio properties which agree well with our results[3].

(3) DLA-galaxy surveys at high redshift. Recent surveys of DLA galaxies at redshift $z > 3$ presented that DLA galaxies exhibit fundamental properties of Lyman-break galaxies[4]. In autumn 2004, we have a plan to observe DLA galaxies at high redshifts with ESO investigators and to clarify the connection between DLA galaxies and Lyman-break galaxies.

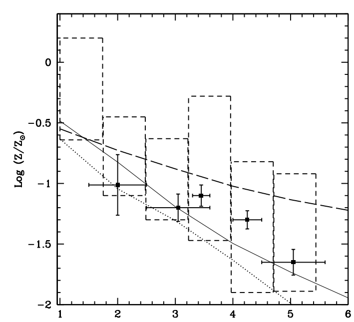

Figure1:Metallicity of cold gas in DLA systems as a function of redshift (soild line: best model)

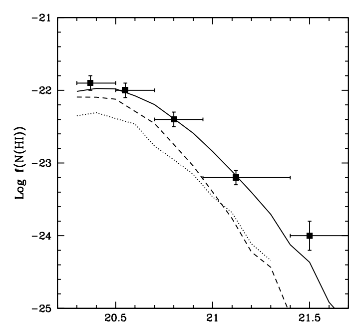

Figure2:DLA column density distribution (solid line:best model)

References

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Toward General Relativistic Gauge Invariant Nonlinear Perturbation

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This research is concerning about general framework of general relativistic nonlinear perturbation theory, which will have many physical applications. We report the part[1] of this research.

General relativity is based on the concept of general covariance. Intuitively, general covariance states that there is no preferred coordinate system in nature. This is based on the philosophy that the choice of coordinate system have nothing to do with natural phenomena. If we choose one coordinate system, we can observe the natural phenomena in terms of this coordinate system, and if we choose another coordinate system, we observe the same phenomena by different way.

On the other hand, the Einstein equation in general relativity is a set of nonlinear equations, but many exact solutions to this equation are known[2]. However, these exact solutions are most often too idealized to properly represent the realm of natural phenomena. In such situations, the perturbative approach is one of the powerful techniques to investigate physical systems and is one of the popular techniques in any theory of physics. In general relativistic perturbations, *gauge freedom*, which is unphysical degree of freedom, arises due to general covariance. To obtain physically meaningful results, we have to fix these gauge freedom or to extract *gauge invariant part of perturbations*.

In linear perturbation theory, this "gauge freedom" is regarded as the freedom of the infinitesimal coordinate transformation. This understanding of "gauge freedom" is correct when we concentrate only on the linear order. However, it is known that this understanding of gauge freedom is not enough in nonlinear perturbations.

To explain the notion of "gauge freedom", we have to remind what we are doing in the perturbation theory. In perturbation theory, we always treat two spacetime manifold. One is the "physical spacetime" which we try to describe by perturbation theory and another is the "background" which is prepared for perturbations. Further, in perturbation theory, we always write the equation in the form

$$Q\,(\text{“}p\text{”}) = Q_0\,(p) + \delta Q\,(p). \qquad (1)$$

This gives the relation between the variable Q on the physical spacetime and its background value Q_0 and the variable δQ on the background. δQ is called the perturbation of Q from Q_0.

However, through Eq. (1), we are implicitly assuming that there exists a point identification map between the physical spacetime and the background. This is called a "gauge choice" in perturbation theory [3]. Namely, Q in Eq. (1) is a field on the physical spacetime and the point "p" is on this spacetime. On the other hand, the background value Q_0 of Q and its deviation δQ from Q_0 in Eq. (1) are

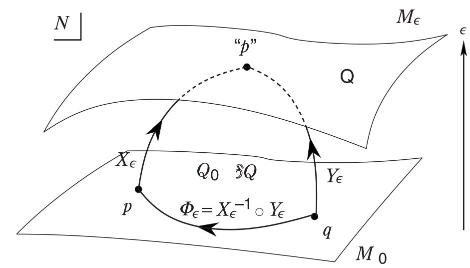

Figure1:The "physical spacetime" M_ϵ is described by the perturbation on a "background" M_0 with an infinitesimal parameter ϵ. The correspondence of the points of these two spacetime manifold is arbitrary and this is "gauge freedom".

fields on the background and the point p is on this background. Since we regard that Eq. (1) is for fields, the points "p" and p should be same.

If there is a preferred coordinate system on both these spacetimes, we can accomplish this identification using this preferred coordinate system. However, there is no such coordinate system due to general covariance and the gauge choice is not unique when we consider theories in which general covariance is imposed. This arbitrariness is just "gauge freedom" of perturbations. This freedom is arisen by the relation between the physical spacetime and the artificial background. Hence, this gauge freedom should have nothing to do with physical quantities which appear in observations or in experiments. Actually, some linear order variables which is independent of this gauge freedom relate variables in observations. These are called gauge invariant variables.

Based on this understanding of "gauge freedom", we propose the systematic procedure to find gauge invariant variables for gravitational field in nonlinear perturbation theory with two infinitesimal parameters. Further, we have shown that we can always find the gauge invariant quantities for nonlinear perturbations of an arbitrary physical variables by using gauge variant part of the spacetime metric. In our proposal, we do not specify anything about the background nor physical meaning of parameters for perturbations. This implies that our proposal is applicable to any theory in which general covariance is imposed and has many applications. One of applications is already published in literature[4].

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Discovery of Star Formation in Extended HI Gas around NGC 6822

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The Local Group dwarf irregular galaxy NGC 6822 is located at about 500 kpc from our Galaxy and is a well-studied galaxy in an isolated environment. Similar to many dwarf irregular galaxies, it is also embedded in an HI gas envelope which is more extended than the main stellar body of the galaxy observed in the optical wavelength [1] (see Fig. 1). However, the star formation activity in the gas envelope has not been studied extensively so far. We therefore carried out an observation with Subaru Prime Focus Camera (Suprime-Cam) to cover the entire gas envelope down to unprecedented depth [2].

Since stars are well resolved by Suprime-Cam beyond the limiting magnitude of existing surveys, the data enable us to investigate the spatial distribution of each stellar population over a very wide field of view. The old stellar population is distributed in a nearly circular area out to $\sim 15'$ and comprises the main stellar body of the galaxy as seen in Fig. 1. On the other hand, blue young stellar population traces the HI gas envelope very well, suggesting that the star formation activity had also occurred in the gas envelope (Fig. 2). The age of the blue stellar population is estimated to be $\sim$ 180 Myr from the color-magnitude diagrams for SR-1,2 regions (shown in Fig. 2). The age is consistent with the time of the onset of the recent star formation observed in the central region of the galaxy.

Since the surface brightness of the blue stellar population in the gas envelope is 27 mag arcsec ^{2} even at the brightest region, it is first discovered by Suprime-Cam which has wide and deep observation capability. To make use of the capability of Suprime-Cam, we are planning to observe several nearby dwarf irregular galaxies, aiming to reveal; whether the star formation activity in the extended gas envelope is universal for all dwarf irregular galaxies or not, how the star formation activity in the extended gas envelope affects the evolution of dwarf irregular galaxies, what the origin of the gas envelope around dwarf irregular galaxies is.

References

[1] de Blok, W. J. G., & Walter, F.: 2000, *ApJ*, **537**, L95.

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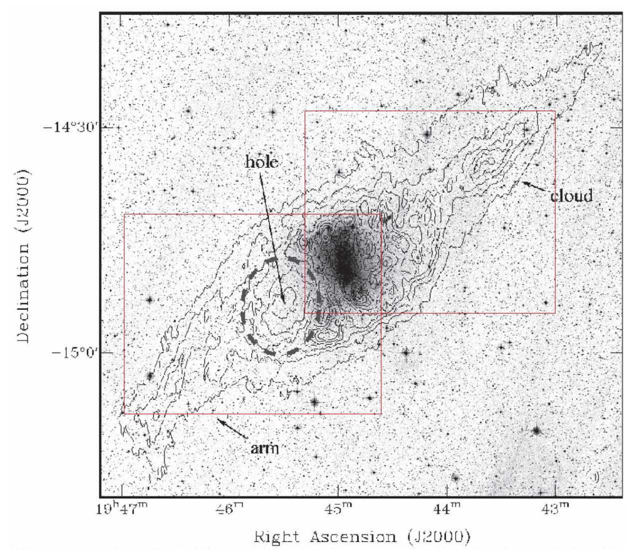

Figure1:The HI density map taken from de Blok & Walter (2000) overlaid on the Digitized Sky Survey image. The HI gas envelope is more extended than the stellar body of the galaxy and has complicated structures such as arm, hole and cloud. Our survey fields are represented by red lines.

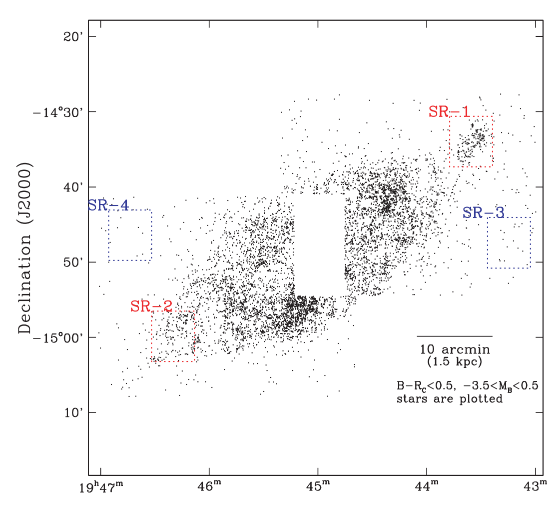

Figure2:Distribution of blue stellar population ($B - R_C < 0.5$, $-3.5 < M_B < 0.5$; mainly B- to A-type main sequence stars). The area is the same as Fig. 1. Note that the central part of the galaxy, where stars are crowded, is excluded from present analysis (hence the center of the figure is blank).

Magnetic Properties at the Footpoints of Hot and Cool Loops

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The solar corona consists of ubiquitous loops representing magnetic fieldlines. Recent observations with Yohkoh, SOHO, and TRACE have revealed that individual coronal loops have different temperatures ranging from 1 to 5 MK. Hot ($T = 2 - 5$ MK) loops seen in Yohkoh/SXT images and cool ($T \sim 1$ MK) loops seen in SOHO/EIT and TRACE images have different appearances and do not coincide in position. We investigate what kind of magnetic properties in the photosphere makes such a difference in the coronal temperature.

Since the heating energy is supplied from the footpoints of the coronal loops along magnetic field lines, it is critically important to investigate magnetic properties at and around the footpoints of the coronal loops. However, it is difficult to identify footpoint positions unambiguously with the SXT because the hot SXT loops are diffuse and dark near their footpoints. We overcome the difficulty by using moss structure observed with the TRACE, which is low-lying EUV structure located at the base of the hot loops. It is necessary to use measurement of photospheric magnetic fields as precise as possible because the heating of the corona does not depend on the magnetic flux alone (e.g. sunspot umbrae). We employ the Advanced Stokes Polarimeter (ASP) at the National Solar Observatory (NSO).

The photospheric magnetic parameters (field strength, inclination, and magnetic filling factor) in the moss regions (i.e. footpoints of the hot SXT loops) are compared with those in the footpoint regions of the cool TRACE loops. The footpoints of the both loops have magnetic fields whose strength is 1 – 1.5 kG and the orientation is nearly vertical to the surface. The most significant difference is discovered in the magnetic filling factor, which is defined by the fraction of an ASP pixel filled with a magnetized atmosphere. The moss regions, i.e. the footpoints of the hot loops, have significantly lower filling factor than the footpoints of the cool loops.

Magnetic fields are not uniformly distributed in the photosphere, but are clusters of strong and fine magnetic elements. If we assume that the magnetic elements have the same field strength and spatial size, the observed magnetic filling factor can be interpreted to be proportional to the surface number density of the magnetic elements. Low filling factor observed in the moss regions corresponds to a low number density of the magnetic elements. The lower number density with larger photospheric motion would provide enhanced coronal heating by efficient braiding of coronal magnetic fields, and leading to the hot loops. On the other hand, concentrated magnetic elements with smaller velocity fields may not allow efficient braiding, resulting in less heating for the cool loops.

References

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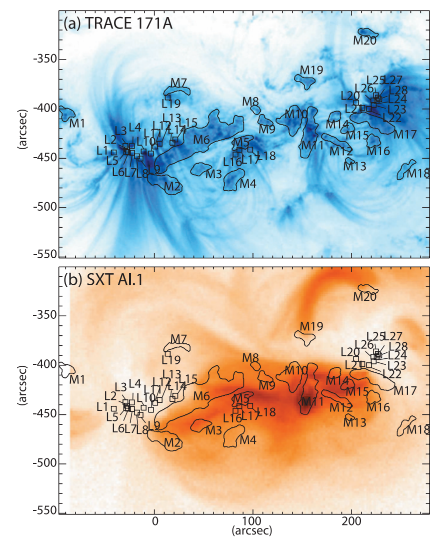

Figure1:(a)Cool (1MK) corona observed with TRACE, and (b) the hot (>2MK) corona observed with Yohkoh/SXT.

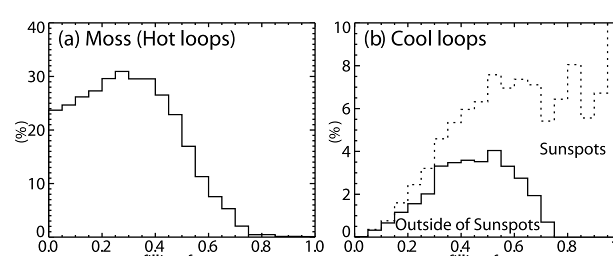

Figure2:Percentage of the area covered by (a) the moss (hot loops)and (b) the footpoints of the cool loops as a function of the magnetic filling factor.

High Resolution Lunar Gravity Anomaly Maps

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Gravity data of the planets and satellites are provided by radio tracking of spacecraft. In the case of the Moon, however, the gravity studies have a difficulty, that is, direct tracking data are unavailable at farside because of the lunar synchronous rotation. The Lunar Prospector (LP) carried out detailed gravity measurement in average altitude of 30 km at the end of the mission. Though the gravity data have a potential of deriving high resolution gravity map, previous works such as LP165 gravity model [1], which adopted spherical harmonic expansion, could not achieve it because of the farside gravity data gap.

In this study, we have made lunar nearside free-air gravity anomaly map through direct inversion of LP LOS (Line-of-Sight) acceleration data (Fig. 1a) [2]. We also perform terrain correction directly for the LOS data using Clementine grid topography data, and the corrected data are processed with same procedure as the free-air gravity anomaly in order to obtain Bouguer gravity anomaly map (Fig. 1b). These two maps achieve 24 km resolution at lunar surface, and are the highest resolution lunar gravity maps at present.

To take advantage of the high-resolution, we investigate compensation state of craters and mascons in detail. Among these gravity anomaly maps, the Bouguer gravity anomaly is useful to study relatively shallow interior since it is supposed to be free from gravity signals of the surface topography. The compensation state mainly controlled by two factors, (1) size of the crater, and (2) elastic thickness of lithosphere. Thus, the compensation state inferred from the Bouguer gravity anomaly map enable us to estimate the thickness of lithosphere at the time of crater formation.

The compensation states of craters and mascons are evaluated as a mass deficit. Figure 2a shows mass deficits of medium-sized craters, 60 – 300km in diameter. It represents the mass deficits are almost zero; the lithosphere was enough rigid to support these medium-sized craters. Next, we calculate mass deficits of large impact basins, 200 –1,000 km in diameter, and compared the results with Moho topography model for the purpose of estimating lithospheric thickness beneath them. It is found from Fig. 2b that the lunar lithosphere was as thick as 20 – 60 km at the time of the mascon formation.

These results will be an important constraint for thermal history of the Moon, because the thickness of lithosphere notably depends on the temperature.

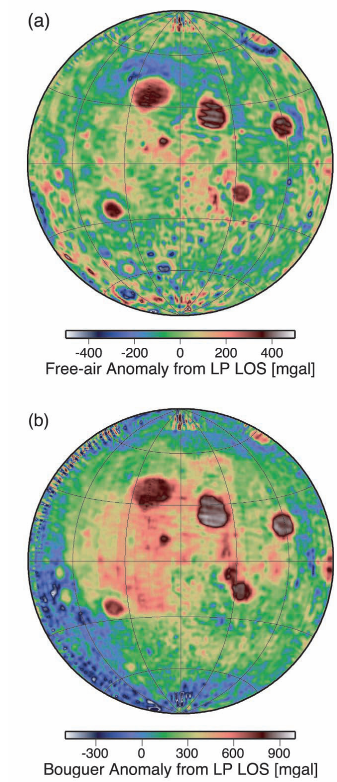

Figure1:The free-air (a) and Bouguer (b) gravity anomaly maps from direct inversion of the LP LOS data. Resolution of these maps are 24km.

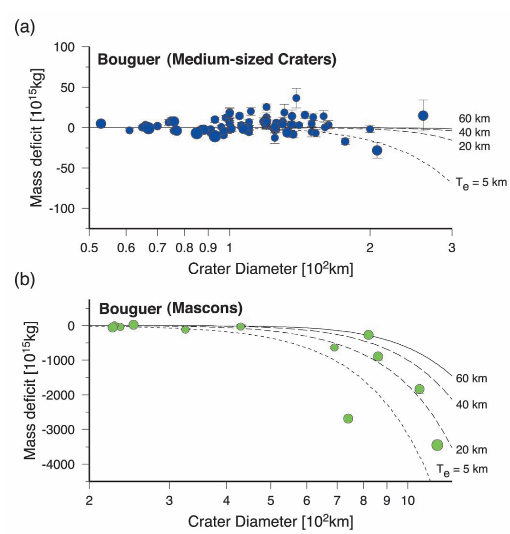

Figure2:Observed (circles) and calculated (curves) mass deficits associated with medium-sized craters (a) and mascons (b) from Bouguer anomaly. Thickness of the lithosphere, Te, was 20 – 60 km at the time of mascon formation.

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Observational Impact of Scattered Light from the Laser Beam of a Laser Guide Star Adaptive Optics

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MINOWA, Yosuke
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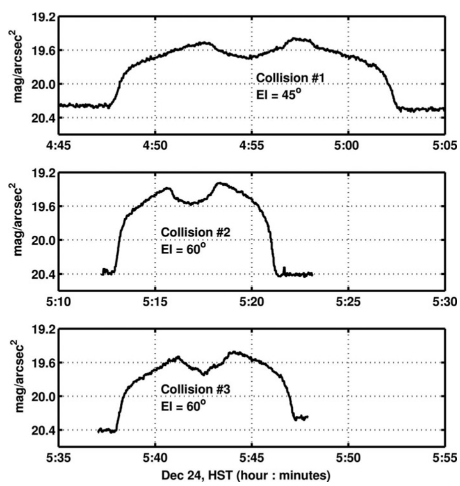

Figure1:Measured surface brightness profiles of the scattered light during three observed transits of the Keck II laser beam. We estimated the surface brightness of the scattered light by calculating the total flux at the pupil plane normalized by the area size of field stop. This is equivalent to the surface brightness at the telescope focal plane. While the sky background is to 20.4 mag/arcsec^2, the surface brightness increases to 19.5 mag/arcsec^2 when the laser beam collides with Subaru Telescope beam. The dip in the middle of the light curve is due to the vignetting of secondary mirror.

We report our measurement whose purpose was to evaluate the observational impact of the scattered light from the laser beam on other telescopes whose field of view happens to cross the laser beam[1].

The scattered light from the sodium laser beam at the wavelength of 589 nm (D2 line) projected from the Keck II telescope towards 70 arcsecond north of the star, SAO99809, was measured using the wavefront sensor of Subaru Adaptive Optics[2] on December 24, 2001 (Hawaii Standard Time). The projected laser power was 17 W and beam diameter was 48 cm. The actual flux level measured when the Subaru Telescope was pointing at elevation angles of 45 and 60 degrees was roughly equivalent to 19.5 magnitude per square arcsecond calibrated by a standard star magnitude in R band (See figure 1).

The results of measurements were shown to be consistent within a factor of 2 with theoretical estimation based on the laser beam flux and the efficiency of Rayleigh scattering due to molecules and Mie scattering of aerosols in the atmosphere, which was evaluated by the combination of AERONET database[3] of Mauna Loa Observatory and our measured data of dust counter at the Subaru Telescope. We also found that about 90 % of the scattered light was due to Rayleigh scatter, since the number density of aerosol is quite stable and small. Our measurement, for which the scattered height is about several hundred meters, shows that the surface brightness of the laser beam is no brighter than the sky background 45 degrees away from the full moon[4]. Although the impact of this scattered light depends on the type of observation, many observations could be performed without significant deterioration.

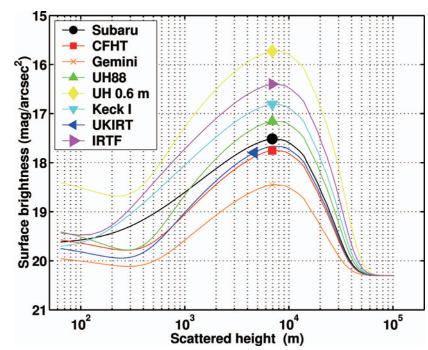

Figure2:Calculated surface brightness of other telescopes at Mauna Kea in the case of the first collision of our measurement. The surface brightness becomes larger when the telescope diameter is smaller. This is because that the surface brightness increases linearly with the telescope diameter while the sky background increases by the square of telescope diameter. Also the surface brightness becomes larger for the closer telescope from Keck II, because the overlapped laser beam with the telescope beam is getting longer.

We also estimate the effect of scattered light for other telescopes at Mauna Kea (See figure 2). The disturbance to astronomical observations could be most significant, when the optical axis of the telescope and the center of the laser beam collide at an altitude of around 8 kilometers.

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The Discovery of Two Lyman α Emitters beyond Redshift 6 in the Subaru Deep Field

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KASHIKAWA, Nobunari and Subaru Deep Field team
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Probing the star-formation activity in galactic or sub-galactic systems in the early universe is important for understanding both the history of galaxies and the origin of cosmic reionization. Recent advances in deep optical imaging capability with 8-10m class telescopes enabled new searches for star-forming galaxies beyond redshift 5. The surveys for emission-line galaxies with narrow-band filters have an intrinsic limitation in redshift coverage, and hence the survey volumes are often not large enough to ensure sufficient robustness for success. In order to increase the survey volumes and to reach the faint limiting magnitude, we need wide-field CCD cameras on 8-10m class telescopes. Suprime-Cam mounted at the prime focus of the 8.2m Subaru Telescope, provides a unique opportunity for wide-field (a $34' \times 27'$ field of view), narrow-band imaging surveys for emission-line objects at high redshift.

We performed a deep optical imaging survey using a narrow-band filter (NB921) centered at $\lambda = 9196$ Å together with i' and z' broadband filters covering an $814\,\mathrm{arc\,min}^2$ area of the Subaru Deep Field. Although the help of any gravitational lensing is highly useful for investigating faint high-z objects, it is also important to search for high-z LAEs in a so-called blank field for an unbiased study.

We obtained a sample of 73 strong NB921-excess objects based on the following two color criteria: $z' - NB921 > 1$ and $i' - z' > 1.3$. We then obtained optical spectroscopy of nine objects in our NB921-excess sample, and identified at least two Lyα emitters at $z = 6.541 \pm 0.002$ and $z = 6.578 \pm 0.002$, each of which shows the characteristic sharp cutoff together with continuum depression at wavelengths shortward of the line peak. The latter object is more distant than HCM-6A at $z = 6.56$, which is the most distant known object that has been found so far.

These new data allow us to estimate the first meaningful lower limit of the star-formation rate density beyond redshift 6; $\rho_{SFR} \sim 5.2 \times 10^{4} M_{\odot}\mathrm{yr}^{1}\,\mathrm{Mpc}^{3}$. Since it is expected that the actual density is several times higher than this value, our new observation reveals that a moderately high level of star formation activity already occurred at $z \sim 6.6$.

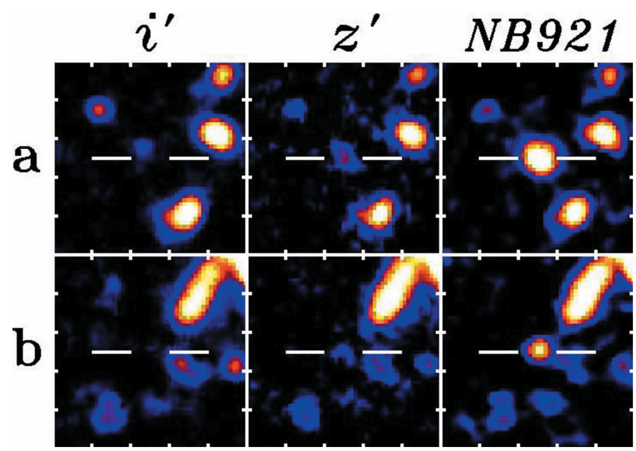

Figure1:Thumbnail images of the two well-defined LAEs, (a) SDF J132415.7 + 273058 and (b) SDF J132418.3 +271455. The size of each image is $10'' \times 10''$, and north is up and east is to the left.

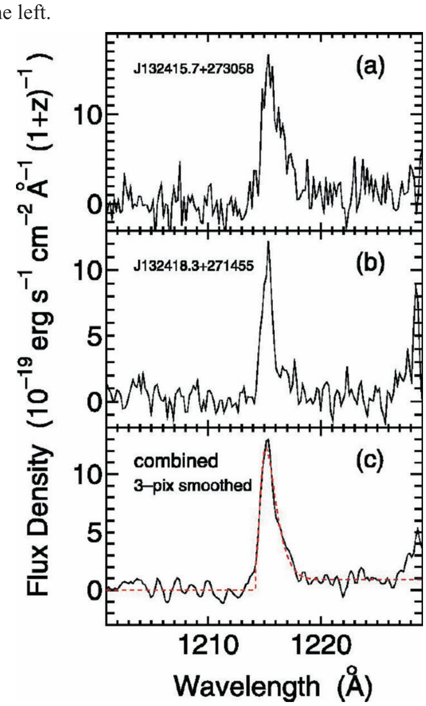

Figure2:Rest-frame UV spectra of two LAE candidates between 1200Å and 1230Å. The spectra of SDF J132415.7 + 273058 and SDF J132418.3 + 271455 are shown in panels (a) and (b), respectively. The combined spectrum of these two LAEs is shown in panel (c). A trial of the profile fitting with a combination between emission and absorption is shown by the red line.

References

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New Methods to Monitor a Satellite-to-Satellite 4-way Link

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TAKANO, Tadashi[2], KAWANO, Nobuyuki[1]
1:National Astronomical Observatoy, 2:Japan Aerospace Exploration Agency

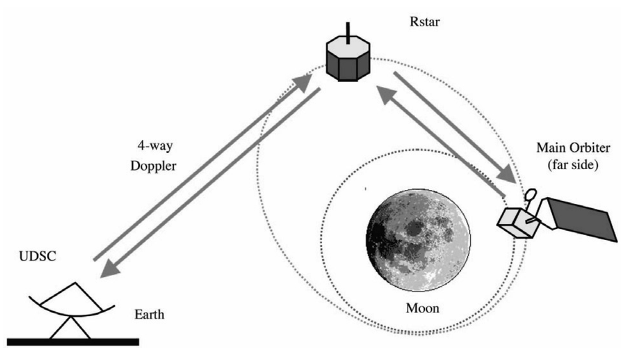

Figure1:4-way Doppler measurement system.

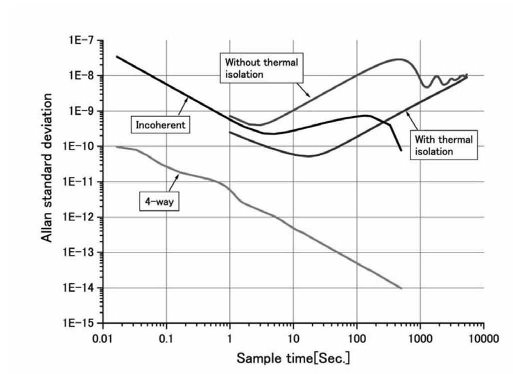

Figure2:Allan standard deviation.

We proposed new methods to monitor a satellite-to-satellite 4-way link to make the first direct measurement of Doppler frequency above the lunar far-side [1].

The Japanese lunar explorer SELENE will be launched in 2006. It consists of 15 mission instruments, and will make various observations all over the Moon. The lunar gravity field in the far-side will be directly measured for the first time. It is achieved by relaying a stable frequency signal between a ground station and the main orbiter by a relay satellite when the main orbiter is above the far-side.

This method is called “4-way Doppler method” since the stable frequency signal travels on four paths between the ground station and the main orbiter via the relay satellite [2]. The relay satellite has the high orbit with peri-lune height of 2,400 km, while the height of the main orbiter is 100 km. The orbit of the main satellite is affected by the small irregularity of the lunar gravity field. On the contrary, the irregularity changes the orbit of the relay satellite little because of its high orbit. Thus, the high order and degree gravity coefficients are estimated by 4-way Doppler measurements.

In order to perform a 4-way measurement, the frequency signal transmitted from every satellite has to be coherent with the transmitted stable frequency signal from the ground station. For this reason, all the satellite has a PLL (phase locked loop). However, the relay satellite cannot relay telemetry signals since the weight and electric consumption of the satellite is quite limited.

We can not know directly the PLL status onboard the main orbiter from the telemetry signal when the main orbiter is above the far-side. Thus, the new methods to monitor a satellite to satellite 4-way link are required. There are some methods other than telemetry to know the PLL status from the down-link signal. We noticed that the frequency stability of the down-link signal depends on the PLL status. The down-link signal is highly stable when the PLL is locked. On the other hand, its stability is two orders worse than that of the locked down-link signal when the PLL is unlocked. We compared the advantages of these methods mutually by the simulation of Doppler frequencies when the PLL is locked or un-locked. We propose the following new methods to monitor a satellite-to-satellite 4-way link.

(1) To calculate Doppler frequency variation of the returned signal. When the variation exceeds a certain level, the PLL is decided to be un-locked.

(2) To calculate Doppler rate variations of the returned signal. When the variation exceeds a certain level, the PLL is decided to be un-locked.

(3) The grand station periodically sweeps the frequency of the transmitting signal. When the spectrum at the sweep period exceeds a certain level, the PLL is decided to be locked. These three method can be easily performed for a few tens seconds without any prediction of Doppler frequency and its rate.

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Development of Ultra Light Weight Mirror for Space and Ground Based Telescopes

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We report on the development of the light weight mirror by employing the Carbon-fiber-reinforced Carbon composite material (hereafter referred to as C/C). Future large aperture optical-IR telescopes require very light-weight primary mirror. While the lightweight mirrors are being developed around the world, the technology appears not to be mature enough for the optical and near infrared wavelengths.

We choose C/C, which has such attractive properties as high specific rigidity, almost zero-CTE thermal expansion, and no dimensional change due to moisture-absorption. We stress that the light-weight honeycomb sandwich panel has been already developed for C/C. Our finite element analysis indicates that a 3.5m diameter C/C mirror for the optical telescope can be built with total weight under 200kg.

Reflective surface with optical quality is developed on the C/C surface by depositing a thick (about 100 micrometer) electroless nickel plating layer (Kanizen) with high-precision cutting and polishing. Figure 1 shows the 15cm aperture C/C spherical mirror, which is made to establish the fabrication process of the curved C/C mirror. The figure error (deviation from sphere) of the substrate before plating reaches 7 micron rms.

Given the complex structure of the C/C mirror, we measure the figure change with temperature. The mirror is located in the temperature oven for measurement with an interferometer located outside. Figure 2 shows the thermal deformation. Top panel is the wavefront error (WFE) map with 50 degree C subtracted by that with 23.6 degree C. This WFE map is then divided into three components with different spatial frequency (bottom panels).

Two significant improvements are made based on the maps. First, we succeed to reduce the thermal deformation of the high spatial frequency (period~ 2mm), which is due to the braiding of the carbon-fiber bundles by employing thinner fiber bundles. Second, the thermal deformation of the middle spatial frequency (honeycomb pattern, period ~ 6mm) is also reduced by adopting the thicker (3mm) substrate [1].

We believe that this is the first attempt to make the ultra light weight mirror with C/C. Further improvement is being pursued.

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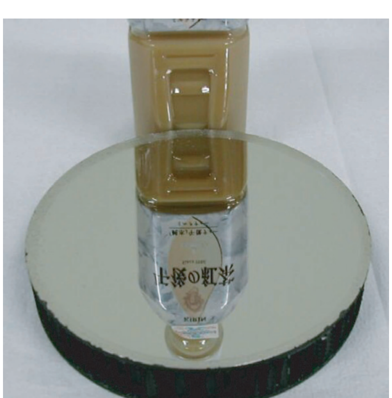

Figure1:C/C spherical mirror (15cm aperture).

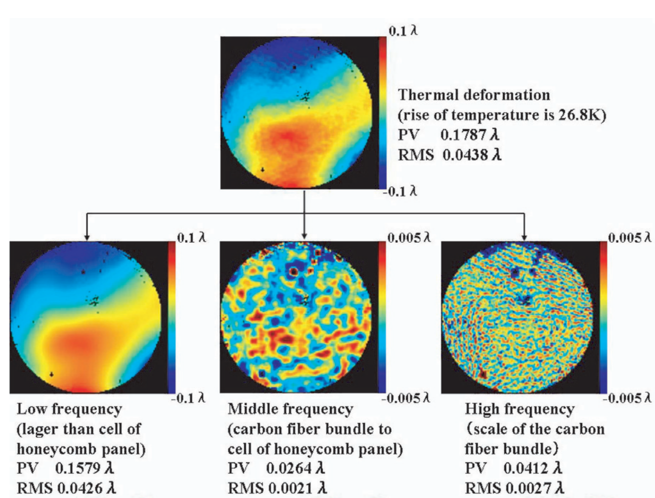

Figure2:Thermal deformation of C/C spherical mirror (evaluation area is 5.6cm aperture, λ =633nm).

Observation of Solar Flare Hard X-ray Spectra Using CdTe Detectors

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Most solar flares are accompanied by signatures of highly accelerated electrons, yet the acceleration process and its role in flares remains a mystery. In many flares these nonthermal electrons are shown to contain enough energy to drive the entire flare. Yet a significant minority of flares show little or no evidence for nonthermal electrons, suggesting the existence of alternative energy release and transport mechanisms. We report an observation of a solar flare where neither hard X-ray nor radio emission shows any sign of accelerated electrons [1].

The flare was observed by a balloon-borne hard X-ray spectrometer [2,3] newly developed at NAOJ. This instrument is composed of sixteen $10 \times 10 \times 0.5$mm cadmium telluride (CdTe) semiconductor detectors, and has an energy range of $15 - 120$keV with an energy resolution of 3keV at 60keV.

The flare occured at 06:41 UT on 24 May 2002 in the on-disk active region NOAA 9963. It was also observed by the Nobeyama Radio Polarimeters (NORP), and partially by the RHESSI satellite. The observed light curves are shown in figure 1.

The observed HXR spectra was fitted to two models, a single-temeprature thermal model and a pure power law spectrum (figure 2). While both models are consistent with the data, the best fit spectral index of the nonthermal (power law) model is an unusually high values, e.g. 8.3 for the 06:41:50—06:43:30 time interval. The temperature of the best-fit thermal models are in a more reasonable range, e.g. 37.8MK for the same time range. The RHESSI spectrum for the same time period was also analyzed, and the result was shown to be inconsistent with the nonthermal model and consistent with the thermal model.

The NORP data shows two features, the impulsive emission in the 3.75GHz band and more gradual emission in 9.4 and 17GHz bands. The impulsive feature was successfully modeled as thermal gyrosynchrotron from the thermal component seen in the HXR data. The gradual component was also successfully modeled from GOES SXT data, using the source size obtained by SOHO EIT. Therefore the radio and X-ray data are consistent if all observed emission are assumed to be thermal. Furthermore, we calculated the energy of an unseen nonthermal component assuming it just below the detection threshold throughout the flare. This was found to be less than the peak thermal energy content of the SXR source. This shows the nonthermal electrons cannot be the sole energy source for creating the SXR source.

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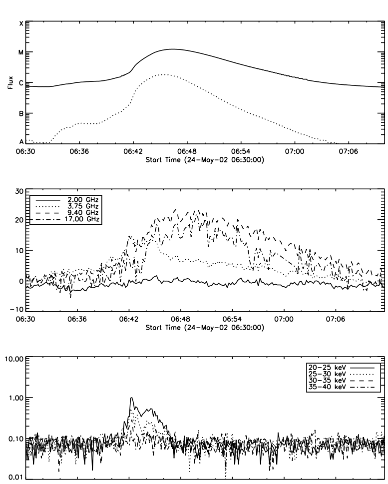

Figure1:Top: GOES soft X-ray light curve. *Middle:* Nobeyama Radio Polarimeters (NORP) lightcurves. *Bottom:* balloon HXR light curve.

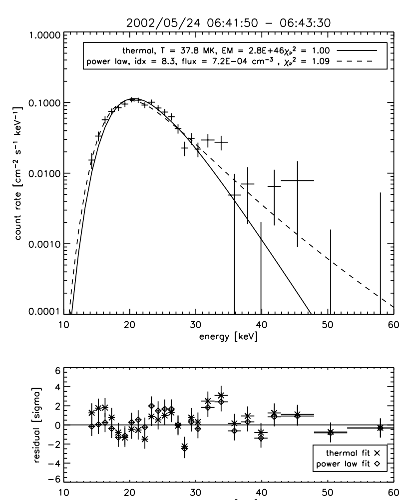

Figure2:Balloon HXR spectrum integrated over 06:41:50—06:43:30 (size of crosses indicate 1σ error bars), and fit results to purely thermal spectrum (solid line) and power law spectrum (dashed line).

Hard X-ray Surveys of AGNs : Revealing Formation History of Massive Black Holes in Galaxies

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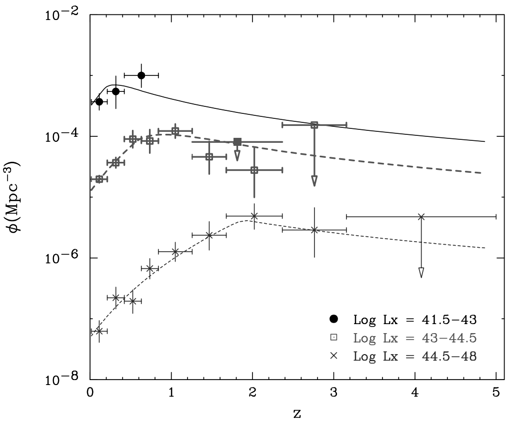

Figure1:Cosmological evolution of number density of AGNs in each luminosity bin. The points with error bars represent the results, and the lines indicate results of fitting for the data points with the luminosity-dependent density evolution model.

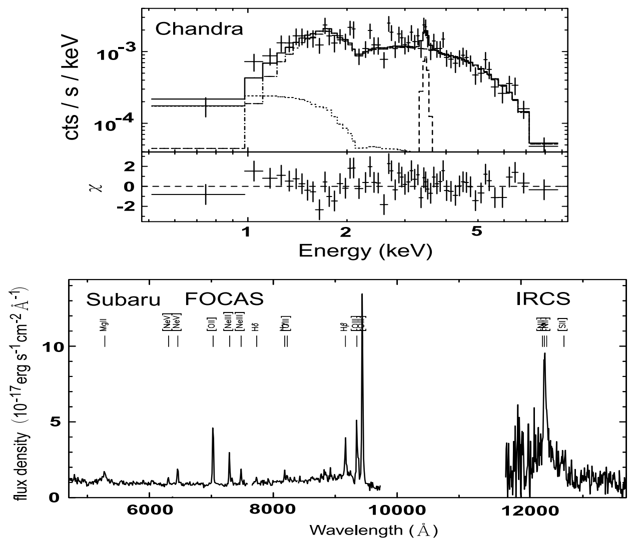

Figure2:X-ray spectrum of an obscured QSO, AXJ08494+4454, obtained with *Chandra* (Upper). Optical and near-infrared spectra of the QSO taken with Subaru/FOCAS and IRCS (Lower). The near-infrared observation revealed strong broad Hα emission line.

Understanding the evolution of the Active Galactic Nuclei (AGN) population is a crucial key to reveal the formation history of massive black holes found at the centers of nearby galaxies. Hard X-ray survey of AGNs is less affected by absorption to the nucleus, thus useful to reveal the whole population of AGNs and examine their cosmological evolution.

We conducted optical follow-up observations of hard X-ray sources found by X-ray satellite, *ASCA*, mostly using University of Hawaii 2.2m telescope and Kitt Peak 2.1m telescope, and with Subaru telescope for faintest objects. We revealed natures and redshifts of optical counterparts of almost all of the hard X-ray sources [1][2]. Combining the high-completeness hard X-ray AGN sample with an AGN sample obtained by the *Chandra* deep survey, we examined the fraction of obscured AGN as a function of luminosity and the cosmological evolution of the AGN luminosity function [3]. The fraction of obscured AGN decreases with increasing luminosity. For AGNs with luminosity comparable to Seyfert galaxies, the fraction of the obscured AGNs is about 60%, but for more luminous AGNs, i.e. QSOs, the fration is 30%. If we explain the results based on the unified scheme of Seyfert galaxies, the opening angle of the dust torus of QSOs is larger than that of Seyfert galaxies on average. The AGN number density in each luminosity bin which derived from cosmological evolution of AGN luminosity function shows that the number density of QSOs peaks at redshift of 2, which is consistent with the results from optical QSO surveys, but that of Seyfert galaxies peaks at lower redshift, ~1 (Figure 1). This may indicate that larger black holes are formed at higher redshift.

We also conducted near-infrared spectroscopic observation of an obscured QSO found in the *ASCA* surveys with Subaru/IRCS. Although the amount of X-ray aborption is large, the near-infrared spectrum shows strong broad Hα emission line [4] (Figure 2). Near-infrared imaging observations of *ASCA* AGNs with UH 2.2m telescope also revealed that the optical to near-infrared colors of X-ray obscured AGNs are not so red [5]. These results indicate the dust extinction observed in the optical is not as large as that expected from the amount of the X-ray absorption. The gas and dust composition around the nucleus can be different from that of inter-stellar matter in the Galaxy.

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Nucleosynthesis of Light Elements and Heavy *r*-Process Elements through the ν-Process in Supernova Explosions

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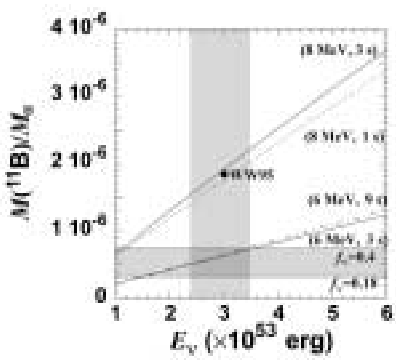

Figure1:The dependence of neutrino parameters on the ejected ^{11}B mass. Horizontal and vertical axes indicate the total neutrino energy and the ejected ^{11}B mass. The energy (MeV) and the time (s) in parenthesis are the temperature of $\nu_{\mu,\tau}$, $\bar{\nu}_{\mu,\tau}$ and the decay time of the neutrino flux. The horizontal shaded region is the range evaluated from Galactic chemical evolution models of the light elements. The vertical shaded region is the range evaluated from the gravitational energy of a neutron star.

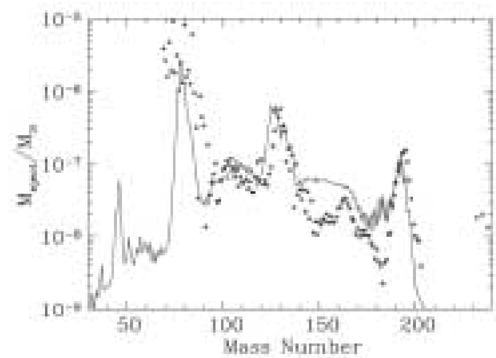

Figure2:The *r*-process abundance pattern in the case of $T_{\nu_{\mu,\tau},\bar{\nu}_{\mu,\tau}} = 6$ MeV and $E_\nu = 3\times10^{53}$ ergs, $\tau_\nu = 9$s. Stars indicate the observed abundance pattern of the *r*-process elements[4]

We investigate the dependence of the supernova neutrinos emitted during supernova explosions on the ejected masses of the light elements such as ^{7}Li and ^{11}B and the heavy *r*-process elements[1]. We adopte a common neutrino luminosity model for the light element and *r*-process element synthesis. The total neutrino energy E_ν and the decay time of the neutrino flux τ_ν are adopted as parameters. The energy spectra of the supernova neutrinos are assumed to obey Fermi distribution. The temperature of $\nu_{\mu,\tau}$ and $\bar{\nu}_{\mu,\tau}$, $T_{\nu_{\mu,\tau},\nu_{\mu,\tau}}$ is set to be 8 MeV and the temperatures of ν_e and $\bar{\nu}_e$ are set to be 3.2 MeV and 5.0 MeV.

We used the supernova explosion model of a 16.2 $M_\odot$ star corresponding to SN 1987A [2]. The obtained ejected masses of ^{7}Li and ^{11}B are roughly proportional to the total neutrino energy and scarcely depend on the decay time of the neutrino flux (see Fig. 1). The *r*-process nucleosynthesis was calculated using the neutrino driven wind models of a 1.4 $M_\odot$ neutron star [3]. The obtained *r*-process abundance pattern mainly depends on the peak neutrino luminosity which is proportional to E_ν/τ_ν. A small peak neutrino luminosity is favorable for the reproduction of the *r*-process abundance pattern of the solar system composition.

There is an overproduction problem of ^{11}B in the Galactic chemical evolution: the supernova contribution of ^{11}B evaluated from the supernova nucleosynthesis theory is overproduced by a factor of 2.5 to 5.6 compared to the Galactic chemical evolution models [5][6]. On the other hand, the total neutrino energy is almost equal to the gravitational energy of a typical neutron star, i.e., about 3×10^{53} ergs. We reproduce the ejected mass of ^{11}B evaluated from the Galactic chemical evolution models when we decrease the neutrino temperature $T_{\nu_{\mu,\tau},\nu_{\mu,\tau}}$ from 8MeV to 6MeV and set the decay time of the neutrino flux τ_ν as 9s. The *r*-process abundance pattern has been also well reproduced with the same supernova neutrino model. Small neutrino temperature about 6MeV can reproduce the Galactic chemical evolution of both of the light element and the *r*-process element synthesis.

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Oscillations in the Coronal Green-Line Intensity Observed at Lomnický Štít and Norikura Nearly Simultaneously

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The heating mechanism of the solar corona is not yet fully understood, but so far two competing models have been proposed. One is the microflare hypothesis, and the other is the wave hypothesis. In the framework of the wave model, it is crucially important to know what kind of waves exist in the solar corona.

The observations of waves in the corona have been made in two ways. One is to observe the Doppler shift in coronal emission lines, and the other is to observe the intensity of either the emission lines or of the electron scattering continuum. Although it is easier to measure the intensity than the Doppler shift, the intensity observation is subject to variations in sky conditions. So far many reports appeared claiming the detection of oscillations in line or continuum intensities, but they are not truly believed.

In the present analysis, we combined the data of the coronal emission line at 5303Å (the so-called coronal green line) from the Lomnický Štít observatory in Slovakia (altitude 2632m) and from the Norikura Solar Observatory (altitude 2876m), NAOJ. The Lomnicý Štít data were obtained with a 20cm aperture coronagraph with a photoelectric photometer. The 25cm aperture coronagraph with a spectrograph at Norikura was used to obtain the spectra (and therefore the Doppler shift and line intensity) of the green line. The joint observation was carried out on 2000 October 24, with a time difference of two hours.

The background sky intensities from Slovakia and from Norikura showed different power spectra, indicating differing sky conditions at the two sites. The line intensity data from the two observatories, however, showed a similar peak in power spectra, centered around a period of 3–5 minutes. The Doppler shift data from Norikura also showed a similar behavior. Therefore, the existence of intensity oscillation was of no doubt. However, the intensity variations showed coherence over a large spatial scale which is hard to interpret.

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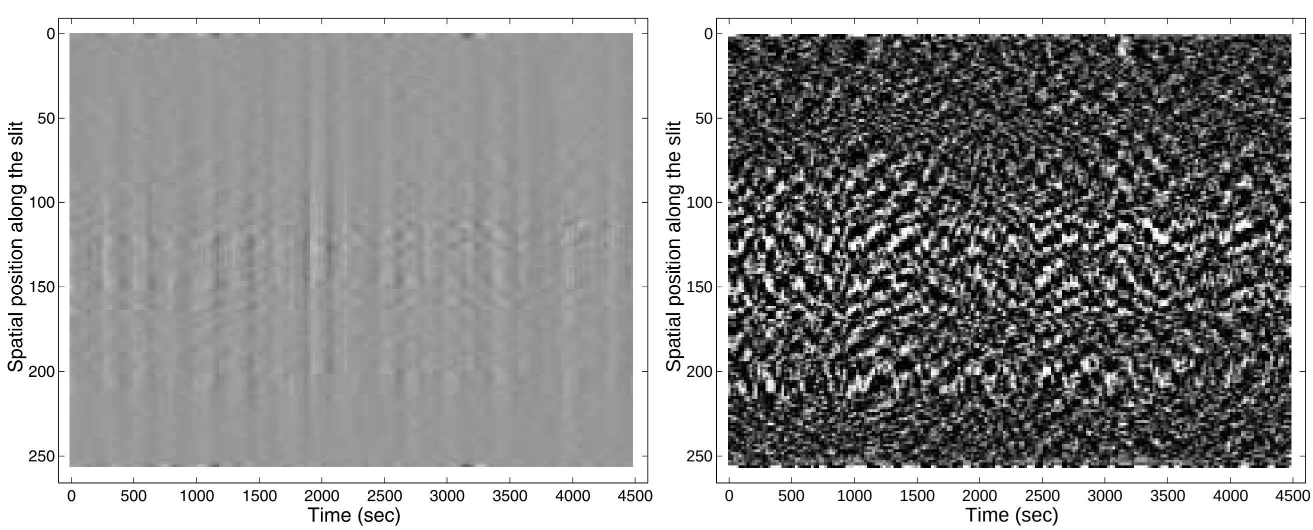

Figure1:The intensity variation of the coronal green line observed at Norikura. The abscissa is time and the ordinate is the coordinate along the slit of the spectrograph. The left-hand-side panel is the raw data, and the right-hand-side panel shows low-pass filtered data in which short time-scale phenomena are enhanced.

New Clean Room for Space Instrumentation

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1. Introduction

New clean room (192m^2) was completed in the Advanced Environment Test building on the spring of 2003. The clean room is equipped with the checkout room on the second floor looking over the clean room to generally support the activities in the clean room. The nominal cleanliness is 100,000. The class indicates the number of particles with size larger than 0.5 μm per cubic feet. We extensively clean up the clean room and equipment to be brought into the clean room immediately after its completion. The clean room turns out to have performance of approximately class 100 with 10 personnel working in the clean room.

On February 2003, the heliostat (Fig. 6) was completed on the roof top of the building, and we can introduce the light from the sun and stars into the clean room through the glass window on the ceiling without breaking the cleanliness. Since May 2003, this clean room has been heavily used to construct and test the Optical Telescope Assembly to be aboard the Solar-B satellite. The beam size is approximately 50 cm. This is a unique feature of the NAO clean room.

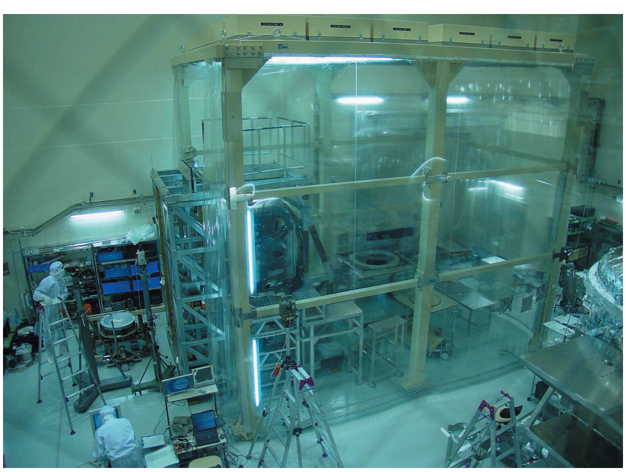

Figure1: Clean Room.

2. Environmental maintenance of the clean room

Needless to say, dusts and organic materials (gas) are extremely hazardous for space optical hardware. We are taking the following precautions to maintain the clean environment:

(1) continuous monitoring of number of floating particles in air (particle contamination),
(2) regular monitoring of molecular contamination with witness glass located on the walls of the clean room,
(3) control of the temperature and humidity (20 ± 0.2℃, 45 ± 2%),
(4) folding (accordion) booth for carrying-in equipment and unpacking,
(5) maintenance of air condition system including the addition of the high-performance particle filters for air coming from outside to maintain the positive pressure of the clean room,
(6) cleaning and dust check of equipment carried into the clean room with black light,
(7) regular cleaning of the floor and prompt exchange of the filled garbage boxes in the clean room.

Regarding (4), the clean room is unfortunately not equipped with a dedicated room for unpacking. Thus, we developed the foldable booth located inside of the entrance door, and the carry-in procedure is as follows: We open the entrance door, and bring containers inside. The area connected to the door is separated from the clean room with the unfolded booth with curtain. We clean the hardware after closing the door in the booth. The booth is then folded to the width of 1m not to dominate the area of clean room, and instruments are moved into the clean room. This sequence enables us to completely separate the dirty outside from the clean room.

Regarding (5), when the air condition system had to be turned off for the critical measurement such as the measurement with an interferometer to eliminate the effect of vibration, cleanliness class more than 100,000 was recorded. This was due to the air that was introduced from outside through the built-in filter, whose performance is apparently not acceptable. In order to improve the quality of the air, we installed the HEPA filter, resulting in a significant improvement with cleanliness class<200 (0.3 μm particles).

With these efforts, we can usually achieve class 100 (0.3 μm particles). Furthermore, Optical Telescope Assembly has been kept in the clean booth (27m^2) located in the clean room. The cleanliness class in the clean booth is less than 50 when there are several workers inside the booth and 0 when there are no personnel inside.

3. Monitoring the cleanliness

The number of floating particles is being measured by particle counters. Fig. 2 shows the time variation of number density of >0.3μm particles in the clean booth, and Fig. 3 shows that of >0.5μm particles for the period when optical alignment of Solar-B optical telescope assembly is done from 6 May to 26 May 2004. From these data, periodic day-night variation can be read. Sometimes over 1,000 was recorded, because the air conditions of the clean booth was turned off to remove the effect of vibration during interferometer measurement. Some of these peaks corresponds to the timing when containers were brought from outside. Fig. 4 shows the histogram of 0.5μm particles, and indicates that for 90% of the time cleanliness class was less than 5. Even when approximately 10 persons were working in the clean room, the class was almost less than 10. Fig. 5 shows the long-term monitoring on the number of 0.3μm particles. Although the cleanliness factor was sometimes close to 100,000 for short duration as mentioned previously, it is usually about 100. (From the end of January to the beginning of February 2004, the particle counter was out of order so there is no data for the period.)

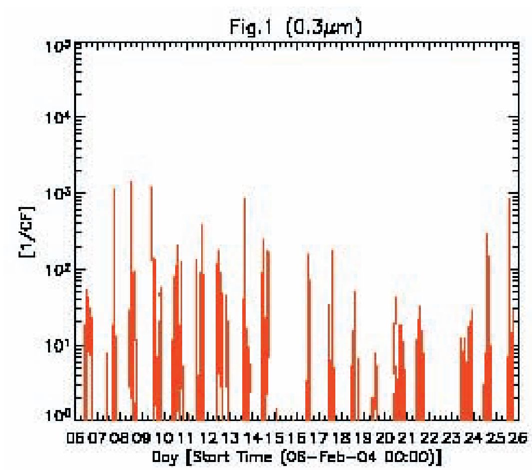

Figure2: Time variation of the number density (0.3μm particles).

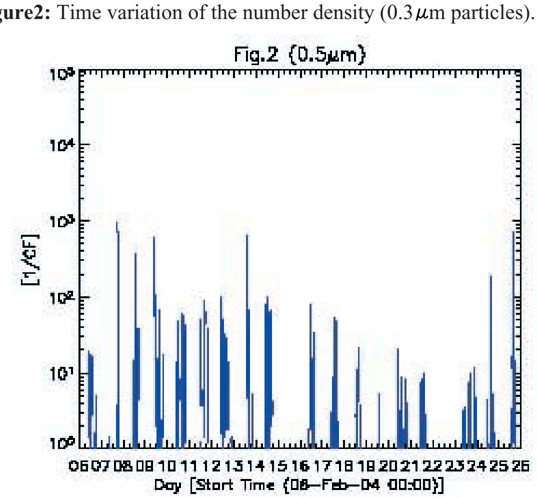

Figure3: Time variation of the number density (0.5μm particles).

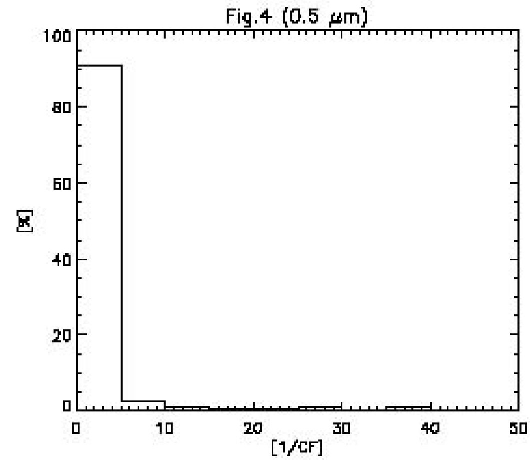

Figure4: Histogram of the number density (0.5μm particles).

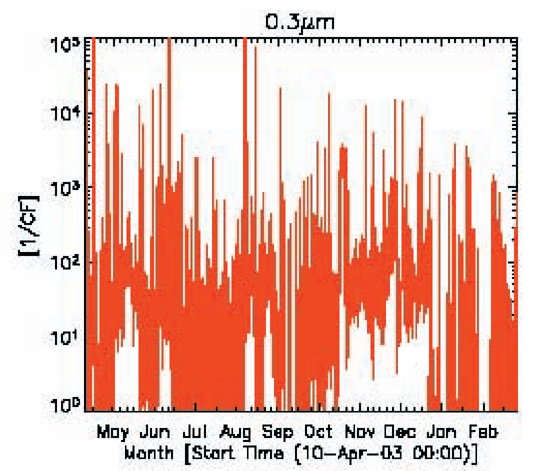

Figure5: Long-time variation of the number density (0.3μm particles).

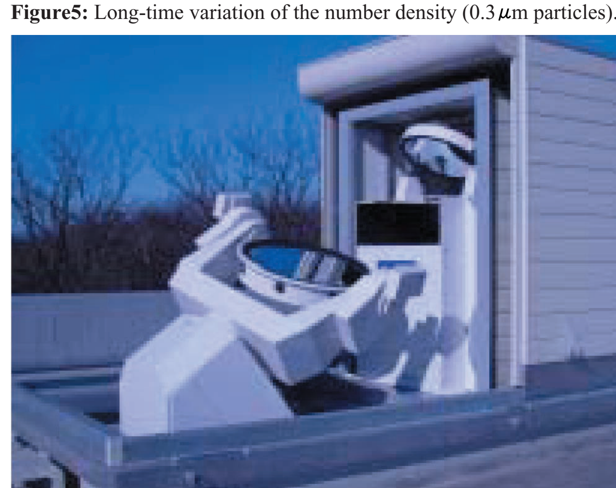

Figure6: Heliostat

Oscillatory Orbits in the Standard Mapping

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Chazy introduced oscillatory solutions of the gravitational three–body problem as a logical consequence in the classification of final motions. Sitnikov proved the existence of this type of motion in the three-dimensional restricted three–body problem with masses $m_1 = m_2 \neq 0$ and $m_3 = 0$. The demonstration of this existence was named the Sitnikov problem.

Sitnikov considered the situation in which two bodies with equal mass move in elliptic orbits in the x-y plane. The center of mass is located at the origin. The third body moves along the z axis. Sitnikov proved that there is a set of initial conditions whose orbits survive the first ejection after the first syzygy (the line connecting two primaries) crossing (that is, the orbits do not escape), there is a subset of initial conditions whose orbits survive the second ejection, and so on, and that there are orbits whose ejection distances grow indefinitely. He proved that there exist initial conditions such that the distance $r(t)$ of the third body from the origin does not grow monotonically although its supremum increases without bound. These conditions are those of an oscillatory orbit. The Sitnikov problem has been extended by Alekseev, Easton and McGehee. The existence of oscillatory orbits in other three-body systems was verified with the aid of numerical integration. Many references are in Ref[1].

The orbits of the accelerator mode[2] in the standard mapping corresponds to escape orbits in three–body problems. The accelerator mode appears as soon as the last Kolmogorov–Arnold–Moser curve disintegrates. In the vicinity of an orbital point of the accelerator mode, there exist points of non–Birkhoff periodic orbits which, in the language of the three–body problem, are ejected to various distances. Therefore we hypothesize the existence of oscillatory orbits if orbits of the accelerator mode exist. We prove that this hypothesis is correct. The detailed proof is contained in Ref[3].

The standard mapping we consider is defined on a cylinder:

$$y_{n+1} = y_n + a \sin x_n,\ x_{n+1} = x_n + y_{n+1} \ (\mathrm{mod}\ 2\pi),$$

where a is a positive parameter.

Here we show briefly the procedure of our proof. We take any accelerator mode from the dynamical order relation obtained in Ref[2]. Next we prove the existence of the non–Birkhoff type doubly symmetric periodic orbits in the vicinity of this accelerator mode. These orbits go together with the accelerator mode but return back. The initial point of the oscillartoy orbit is obtained as the accumulation point of these orbits.

The system containing oscillatory orbits seems to have the following characteristic property. There is a point z_0 such that the orbit starting at this point goes to infinity as t goes to infinity; that is, an escape orbit exists. Further there exists an initial point z'_0 in a neighborhood of z_0 such that the orbit starting from z'_0 goes far from z'_0 but eventually comes back to z'_0. The initial point of an oscillatory orbit is located in the vicinity of z_0 and z'_0. It is important to make clear the necessary and sufficient conditions for the existence of oscillatory orbits. This is a future problem.

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Subaru/HDS Studies of Eu Isotope Abundances in Metal-Deficient Stars

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Chemical composition of metal-deficient stars provide with a unique opportunity to study the nucleosynthesis processes in the early Galaxy. Analyses of isotope abundances, in addition to elemental abundances, in these stars are expected to make a significant progress in the understanding of details of the processes. As the first step of this challenge, we have obtained high-resolution ($R \sim 10^5$) spectra of several metal-deficient stars with Subaru/HDS, and made analysis of the Eu II lines, which show relatively large isotope (^{151}Eu and ^{153}Eu) splittings.

(1)The ^{151}Eu fraction in r-process-enhanced stars is slightly smaller than 50% (left figure), in agreement with that in solar system material. The elemental abundance pattern of heavy nuclei in these stars are well known to agree with that of the solar-system r-process component, and the agreement has been confirmed in isotopic level for Eu [1].

(2)The ^{151}Eu fractions in two stars with s-process element-excesses are 55-60% (left figure)[2]. While more than 90% of Eu in solar-system material originates from the r-process, the majority of Eu in these stars is estimated to be yielded by the s-process from the abundance patterns of heavy elements. The present analysis derived, for the first time, an observational constraint on the Eu isotope ratio produced by the s-process. Since the Eu isotope is significantly affected by the branching at ^{151}Sm, the isotope ratio can be a probe to investigate the temperature and neutron density in the s-process site. Our model calculation of the s-process, adopting the recent nuclear reaction rate shows that the observed Eu isotope ratio can be well explained by neutron density of 10^{7-9} cm^{-3} and temperature of $kT = 10 - 30$ keV (right figure). Future progress in the quality of the observational data and nuclear reaction rates will enable us to study the condition of the s-process in evolved intermediate-mass stars (AGB stars), i.e., to estimate the contribution of the process during the thermal pulse (high temperature and high neutron density) and that between the pulses (low temperature and low neutron density). The present study shows that detailed analyses of Eu isotope ratio will provide a new observational constraint on the recent complicated s-process and AGB models.

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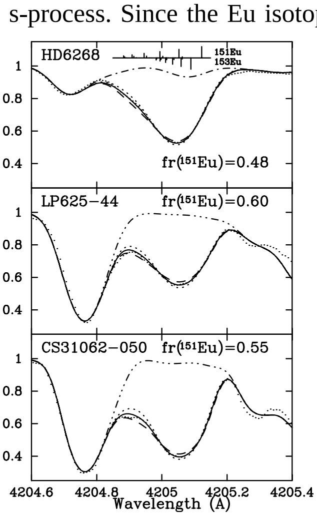

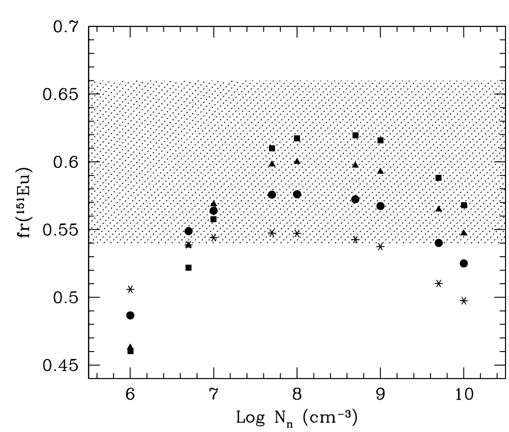

Figure1: left: A Eu II line of the r-process-enhanced star HD6268 (upper panel) and those of the s-process-enhanced stars LP625-44 and CS31062-050. Solid lines show synthetic spectra calculated assuming the best-fit Eu isotope ratios, and dotted and dashed lines indicate the ones assuming 10% differences of ^{151}*Eu* fraction. **right:** ^{151}Eu fraction as a function of neutron density calculated by the s-process model for 30keV(squares), 20keV(triangles), 15keV(circles), and 10keV(asterisks). The observational result for LP625-44 is shown by the hatched area.

A New Precession Formula

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Modifying J. G. Williams' formulation [1], we developed a new scheme to express the precession and nutation in an arbitrary inertial frame of reference. It gives the precession-nutation matrix as the product of four rotation matrices as

$$NP = R_1(-\epsilon) R_3(-\psi) R_1(\bar{\varphi}) R_3(\bar{\gamma})$$

and the precession one similarly as

$$P = R_1(-\bar{\epsilon}) R_3(-\bar{\psi}) R_1(\bar{\varphi}) R_3(\bar{\gamma}).$$

Here (1) $\bar{\varphi}$ and $\bar{\gamma}$ are the angles to specify the location of the ecliptic pole of date in the given inertial frame, (2) ψ and $\bar{\psi}$ are the true and mean ecliptic angles of precession around the ecliptic pole of date and counted clock-wise from the direction to the z-axis of the given inertial frame, respectively, and (3) ϵ and $\bar{\epsilon}$ are the true and mean obliquities of the ecliptic with respect to the $x-y$ plane of the given inertial frame, respectively. Note that $\psi \equiv \bar{\psi} + \Delta\psi$ and $\epsilon \equiv \bar{\epsilon} + \Delta\epsilon$, where $\Delta\psi$ and $\Delta\epsilon$ are the usual nutations in longitude and in obliquity, respectively.

As a result, reference frames referred to the true or mean equator and equinox of date are explicitly described in the ICRF by using the newly introduced precession angles and the usual nutation angles. Although the expression of nutation matrix is unchanged as

$$N = R_1(-\epsilon) R_3(-\Delta\psi) R_1(\bar{\epsilon}),$$

we recommend the usage of the above form of NP instead of preparing P and N separately because of faster evaluation. The formulation is robust in the sense it avoids a singularity caused by finite pole offsets near the epoch. Facing the singularity is inevitable in the pre-2003 IAU formulation.

By using the new formulation, we created a new set of precession formulas [2]. First, we adopted a numerical determination of the motion of ecliptic in DE405 [3] to specify the polynomial expressions of $\bar{\gamma}$ and $\bar{\varphi}$ in the inertial sense. Next, we selected a recent theory of the forced nutation of the non-rigid Earth, SF2001, [4], to express $\Delta\psi$ and $\Delta\epsilon$ in a compact and precise trigonometric series expansion. Then we converted the true pole offsets observed by VLBI for 1979-2000 to the offests in the two precession angles, $\bar{\psi}$ and $\bar{\epsilon}$. As their first approximation, we used η_A and ε_A of Williams (1994). From the converted offsets, we determined the best-fit polynomial expressions of the corrections to the approximations as well as the equinox correction. We judged from a weighted least square method that linear corrections are sufficient. Thus we determined the polynomial expressions of $\bar{\psi}$ and $\bar{\epsilon}$ as well as the equinox correction E to the IAU 1976 formulation. Combining these with the above formulas of planetary precession, we determined the mean celestial pole offset at J2000.0 as

$$\bar{X}_0 = -(17.12 \pm 0.01)\,\text{mas}, \bar{Y}_0 = -(5.06 \pm 0.02)\,\text{mas}.$$

By shifting the base reference frame from the ICRF to the mean equator and equinox at J2000.0, we derived the best-fit polynomials of the classic precession quantities, $\sin\pi_A \sin\Pi_A$, $\sin\pi_A \cos\Pi_A$, π_A, Π_A, p_A, ψ_A, ω_A, χ_A, ϵ_A, ζ_A, z_A, and θ_A. They are provided in Table 1 of Fukushima (2003) as well as all the existing formulas given in the literature.

As a by-product, we estimated the speed of general precession in longitude at J2000.0 as

$$p = (5028.7955 \pm 0.0003)'' \,/\text{Julian century},$$

the mean obliquity at J2000.0 in the inertial sense as

$$(\epsilon_0)_I = (84381.40621 \pm 0.00001)'',$$

and that in the rotational sense as

$$(\epsilon_0)_R = (84381.40955 \pm 0.00001)''.$$

Also, by adopting a best estimate of the theoretical value of the geodesic precession,

$$p_g = (1.9196 \pm 0.0003)''/\text{Julian century},$$

we determined the dynamical flattening of the Earth from the precession constant as

$$H_d = (3.2737804 \pm 0.0000003) \times 10^{3}.$$

From the classic polynomial expressions derived in the above, we evaluated the effect of the sense in defining the ecliptic. The resulting polynomial forms of the new precession angles in both the rotational and inertial senses are, as well as the derived classic precession quantities, summarized in [4]. These constitute a new set of the fundamental expressions of the precession quantities.

If the concern is the minimization of modification of the pre-2003 IAU formulation, the readers may use the updated classic quantities as well as the frame adjustment at the epoch.

Note that, although we have called $\bar{\psi}$ and $\bar{\epsilon}$ the lunisolar precession in this article, they are meant to include the effect of the geodesic precession. In spite of our presentation of precession quantities in both senses, one should understand that those in the inertial sense are of primary nature and the expressions in the rotational one were derived from them.

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Formation of the First Stars by Accretion

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The process of star formation from metal-free gas is investigated by following the evolution of accreting protostars with emphasis on the properties of massive objects. The main aim is to establish the physical processes that determine the upper mass limit of the first stars. Although the consensus is that massive stars were commonly formed in the first cosmic structures, our calculations show that their actual formation depends sensitively on the mass accretion rate and its time variation. Even in the rather idealized case in which starformation is mainly determined by $\dot{M}_{\rm acc}$, the characteristic mass scale of the first stars is rather uncertain. We find that there is a critical mass accretion rate $\dot{M}_{\rm crit} \simeq 4 \times 10^{\ 3} M_{\odot}\,{\rm yr}^{\ 1}$ that separates solutions with $\dot{M}_{\rm acc} < \dot{M}_{\rm crit}$ in which objects with mass $\gg 100 M_{\odot}$ can form, provided there is sufficient matter in the parent clouds, from others ($\dot{M}_{\rm acc} > \dot{M}_{\rm crit}$) where the maximum mass limit decreases as $\dot{M}_{\rm acc}$ increases. In the latter case, the protostellar luminosity reaches the Eddington limit before the onset of hydrogen burning at the center via the CN-cycle. This phase is followed by a rapid and dramatic expansion of the radius, possibly leading to reversal of the accretion flow when the stellar mass is about 100 $M_{\odot}$.

Under a realistic time dependent accretion rate that starts at high values ($\sim 10^{\ 2} M_{\odot}\,{\rm yr}^{\ 1}$) and decreases rapidly in the high mass regime ($M_{*} > 90 M_{\odot}$), the evolution follows the case of $\dot{M}_{\rm acc} < \dot{M}_{\rm crit}$ and accretion can continue unimpeded by radiation forces. Thus, the maximum mass is set by consideration of stellar lifetimes rather than by protostellar evolution. In this case, the upper limit can be as high as $\sim 600 M_{\odot}$.

We consider also the sensitivity of the results to the presence of heavy elements with abundances in the range $Z = 5 \times 10^{\ 5} Z_{\odot}$ to $5 \times 10^{\ 3} Z_{\odot}$. The main evolutionary features of protostars are similar to those of metal-free objects, except that the value of $\dot{M}_{\rm crit}$ increases for metal-enriched protostars. Since the accretion rate is lower in a slightly polluted environment, the condition $\dot{M}_{\rm acc} < \dot{M}_{\rm crit}$ is expected to be more easily met. We find that for metallicities below $\sim 10^{\ 2} Z_{\odot}$, where radiation forces onto dust grains in the flow are negligible, a slightly metal-rich gas favors continued accretion and the formation of very massive stars.

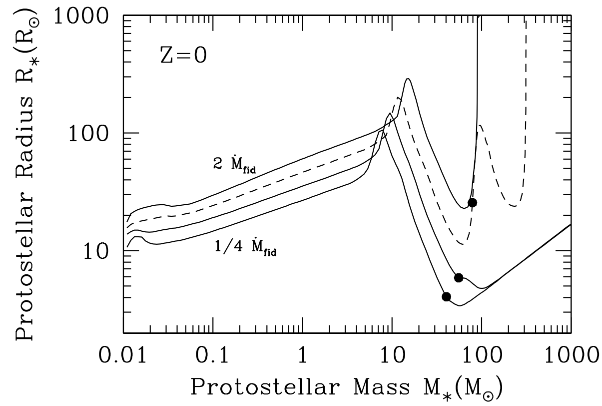

Figure1:Mass-radius relations for metal-free protostars evolving with an accretion rate $\dot{M}_{\rm acc} = 1/4, 1/2, 1, 2\dot{M}_{\rm fid}$ (from top to bottom). The dashed line is for $\dot{M}_{\rm acc} = \dot{M}_{\rm fid}$, where the fiducial value is $\dot{M}_{\rm fid} = 4.4 \times 10^{\ 3} M_{\odot}\,{\rm yr}^{\ 1}$. The filled circles indicate the onset of H-burning via the CN-cycle.

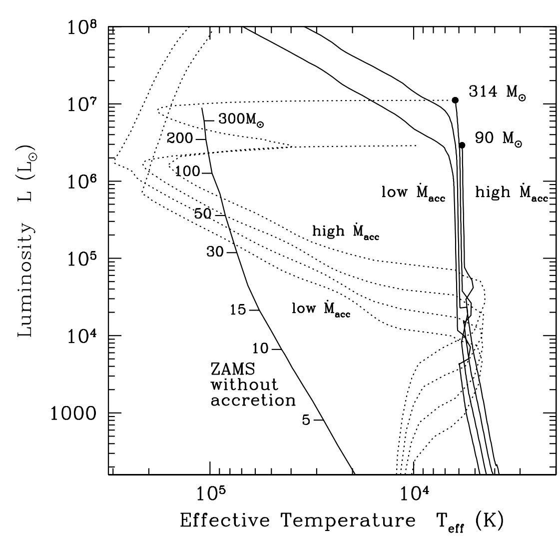

Figure2:HR diagram for primordial protostars. For comparison, we also show the locus of the metal-free ZAMS stars as computed by Marigo et al. [3] for $M_{*} < 100 M_{\odot}$ and by Bromm et al. [2] for higher masses. The dotted lines show the temperature and luminosity at the stellar surface.

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The Mass Spectrum of Metal-free Stars Resulting from Photodissociation Feedback: A Scenario for the Formation of Low-mass Population III Stars

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The initial mass function (IMF) of metal-free stars that form in the initial starburst of massive (virial temperatures $> 10^4$K) metal-free protogalaxies is studied. In particular, we focus on the effect of H_2 photodissociation by pre-existing stars on the fragmentation mass scale, presumedly determined by the Jeans mass at the end of the initial free-fall phase, i.e., at the so-called "loitering phase," characterized by the local temperature minimum. Photodissociation diminishes the Jeans mass at the loitering phase, thereby reducing the fragmentation mass scale of primordial clouds. Thus, in a given cloud, far ultraviolet (FUV) radiation from the first star, which is supposedly very massive ($\sim 10^3 M_\odot$), reduces the mass scale for subsequent fragmentation. Through a series of similar processes the IMF for metal-free stars is established. If FUV radiation exceeds a threshold level, the star-forming clumps collapse solely through atomic cooling. Correspondingly, the fragmentation scale drops discontinuously from a few times $10 M_\odot$ to sub-solar scales. In compact clouds (< 1.6 kpc for clouds of gas mass $10^8 M_\odot$), this level of radiation field is attained, and sub-solar mass stars are formed even in a metal-free environment. Consequently, the IMF becomes bi-modal, with peaks at a few tenths of $M_\odot$ and a few times $10 M_\odot$. The high-mass portion of the IMF, $\xi_{\rm high}(m_*)$, is found to be a very steep function of the stellar mass m_*, $\xi_{\rm high}(m_*) \propto m_*^{\ 5}$. Therefore, the typical mass scale of metal-free stars is significantly smaller than that of the very first stars. In the Appendix we study the thermal instability in collapsing primordial prestellar clumps, and discuss why the thermal instability occuring during the three-body H_2 formation does not appear to manifest itself in causing further fragmentation of such clumps.

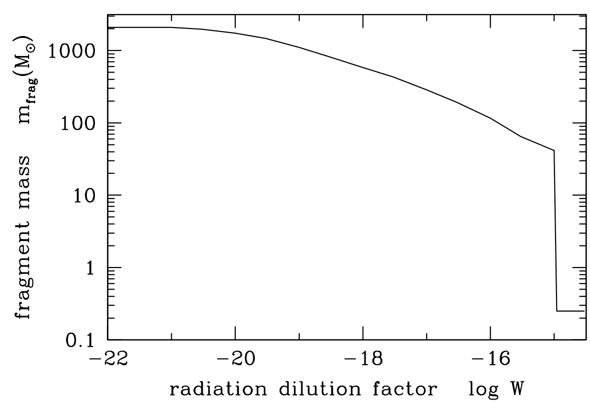

Figure1:The fragmentation mass scale as a function of the dilution factor W, which parametrizes the FUV radiation density.

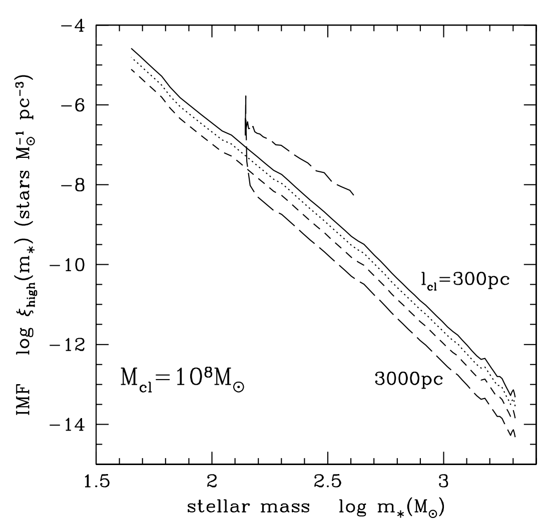

Figure2:The initial mass function of metal-free stars in clouds of $M_{\rm cl} = 10^8 M_\odot$. Shown are the results for the cloud length scale of 300pc (solid line), 500pc (dotted line), 1000pc (short-dashed line), and 3000pc (long-dashed line).

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An S0-like Galaxy Found at Redshift 1.5

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The first light imaging observation of a cluster of galaxies A851(CL0939+4713) at redshift 0.4 with the Subaru SuprimeCam revealed its superb imaging capability with limiting magnitude R=28 in 1 hour exposure [1]. A remarkable ERO (Extremely Red Object) found in this observation, ERO J094258+4659.2 with R–K=7.5, was originally considered to be a gravitationally lens stretched image of a background elliptical galaxy as the major axis of this image is aligned with the equipotential surface of the lensing cluster.

However, following detailed imaging and spectroscopic studies have shown that this is an S0-like galaxy with exponential luminosity profile, rather than a lensed elliptical with de Vaucouleurs' law, without recent star forming activity and located in a field environment at redshift 1.5 [2].

Although this is a single case of finding an S0-like galaxy at such a high redshift, this finding places an important constraint on the galaxy formation scenario as ERO J094258+4659.2 is likely to be a galaxy with dynamically relaxed disk component of evolved stars without a conspicuous young population. The ordinary scenario of tidal stripping of disk galaxy to form an S0 in a cluster environment cannot explain the origin of ERO J094258+4659.2, as it is in a field environment at redshift 1.5. Usual CDM scenario shows the formation of massive galaxies takes place at redshift < 1 by successive merging of tiny galaxies. However, the lack of spectroscopic evidence of recent star forming activity in this galaxy and the very well relaxed luminosity profile of this galaxy imply that such a major merger event, if any, should have taken place long ago in this galaxy, meaning the epoch of formation of this galaxy much earlier than redshift 1.5.

HST proposal to observe this galaxy was granted for cycle 13.

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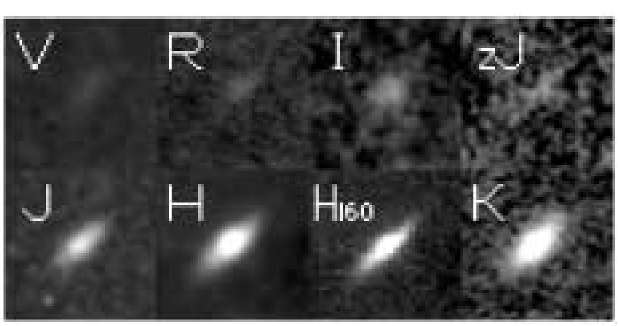

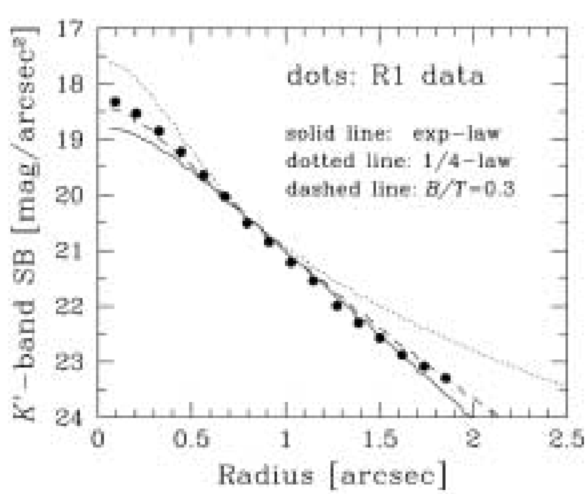

Figure1: Multi band images of ERO J094258+4659.2(left) and its exponential luminosity profile(right)

Disappearing Dark Matter in Brane World Cosmology: New Limits on Noncompact Extra Dimensions

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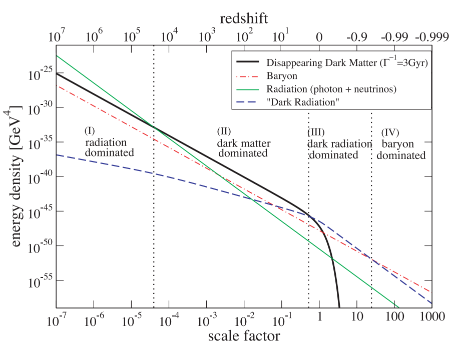

figure1: Illustration of the energy densities with scale factor in models with dark-matter decay into the extra dimension.

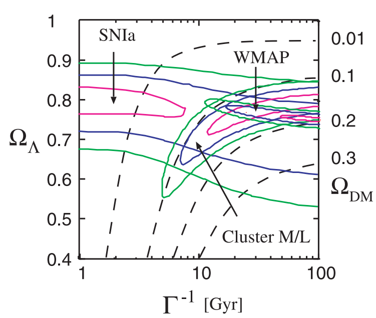

figure2: Contours of constant χ^2 in the Γ^{-1} vs. Ω_Λ plane. Lines drawn correspond to 1, 2, and 3σ confidence limits for fits to the magnitude-redshift relation for Type Ia supernovae, the mass-to-light ratios of galaxy clusters, and constraints from the CMB. The dashed lines indicate contours of constant Ω as labeled. The dark radiation contribution can be deduced from the figure, via $\Omega = 1 - \Omega_\Lambda - \Omega - \Omega_B$

We consider a brane-world cosmology whereby the universe is described as a three-brane embedded in a five-dimensional anti-de Sitter (AdS_5) bulk spacetime, and explore cosmological implications of dark matter as massive particles trapped on a brane. It is an unavoidable consequence of this cosmology that massive particles are metastable and can disappear into the bulk dimension. Here, we assume that a massive dark matter particle (e.g. the lightest supersymmetric particle) has the shortest lifetime Γ^{-1} for disappearing into the bulk. The energy flow of dark matter particles into the bulk induces a back reaction from the background gravitational field in the bulk and generates the "dark radiation" on the brane. As an example, Figure 1 illustrates the evolution of a a simple flat, $\Lambda_4 = k = 0$, disappearing dark matter cosmology with $\Gamma = 3$ Gyr. This cosmology separates into four characteristic regimes identified on Figure 1. These are: I) The usual early radiation dominated era; II) a dark-matter dominated era; III) a late dark radiation dominated era ; and IV) Eventually, a baryon-dominated regime also exists.

This new paradigm will change the standard thermal history of the universe mainly in two ways. First, more dark matter particles in the past change the expansion history of the universe and lead the stronger decelerating expansion in the early universe. Second, the disappearance of dark matter particles results in the increasing ratio of dark matter density to that of baryon with look back time to the past. We examine cosmological constraints on this new paradigm and show that disappearing dark matter is consistent (at the 95% confidence level) with all cosmological constraints, i.e. present observations of Type Ia supernovae at the highest redshift, trends in the mass-to-light ratios of galaxy clusters with redshift, the fraction of X-ray emitting gas in rich clusters, and the spectrum of power fluctuations in the cosmic microwave background. The result of our standard χ^2 goodness of fit to the data sets are depicted in Figure 2. In this figure, Ω_Λ means the energy density in cosmological constant (Λ) in critical density units, for example. We find a minimum χ^2 per degree of freedom of $\chi_r^2 = 0.61$ for $\Gamma^{-1} = 34$ Gyr for Cluster M/L data, which is an improvement over the fit with a fixed M/L (assumed in standard cosmology) for which $\chi_r^2 = 0.67$. The Type Ia SN implies $\chi_r^2 = 0.94$ for $\Gamma^{-1} = 0.3$ Gyr, which is to be compared $\chi_r^2 = 0.96$ for a standard ΛCDM cosmology. Combining recent cosmic microwave background measurements by WMAP, a best 2σ concordance region is identified corresponding to a mean lifetime for dark matter disappearance of $15 \leq \Gamma^{-1} \leq 80$ Gyr. Should the dark-matter mass m_0 ever be known, this would give a new limit on the five dimensional Planck mass to $(M_5/M_4) \approx 4\,(m_0/\mathrm{TeV})^{1/2}(\Gamma^{-1}/15\text{~Gyr})^{1/6}$.

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II Publications, Presentations

1. Refereed Publications

Abazajian, K., Adelman-McCarthy, J. K., Agueros, M. A., Allam, S. S., Anderson, S. F., Annis, J., Bahcall, N. A., Baldry, I. K., Bastian, S., Berlind, A., Bernardi, M., Blanton, M. R., Blythe, N., Bochanski, J. J. Jr., Boroski, W. N., Brewington, H., Briggs, J. W., Brinkmann, J., Brunner, R. J., Budavari, T., Carey, L. N., Carr, M. A., Castander, F. J., Chiu, K., Collinge, M. J., Connolly, A. J., Covey, K. R., Csabai, I., Dalcanton, J. J., Dodelson, S., Doi, M., Dong, F., Eisenstein, D. J., Evans, M. L., Fan, X., Feldman, P. D., Finkbeiner, D. P., Friedman, S. D., Frieman, J. A., Fukugita, M., Gal, R. R., Gillespie, B., Glazebrook, K., Gonzalez, C. F., Gray, J., Grebel, E. K., Grodnicki, L., Gunn, J. E., Gurbani, V. K., Hall, P. B., Hao, L., Harbeck, D., Harris, F. H., Harris, H. C., Harvanek, M., Hawley, S. L., Heckman, T. M., Helmboldt, J. F., Hendry, J. S., Hennessy, G. S., Hindsley, R. B., Hogg, D. W., Holmgren, D. J., Holtzman, J. A., Homer, L., Hui, L., **Ichikawa, S.**, Ichikawa, T., Inkmann, J. P., Ivezic, Z., Jester, S., Johnston, D. E., Jordan, B., Jordan, W. P., Jorgensen, A. M., Juric, M., Kauffmann, G., Kent, S. M., Kleinman, S. J., Knapp, G. R., Kniazev, A. Y., Kron, R. G., Krzesinski, J., Kunszt, P. Z., Kuropatkin, N., Lamb, D. Q., Lampeitl, H., Laubscher, B. E., Lee, B. C., Leger, R. F., Li, N., Lidz, A., Lin, H., Loh, Y., Long, D. C., Loveday, J., Lupton, R. H,. Malik, T., Margon, B., McGehee, P. M., McKay, T. A., Meiksin, A., Miknaitis, G. A., Moorthy, B. K., Munn, J. A., Murphy, T., Nakajima, R., Narayanan, V. K., Nash, T., Neilsen, E. H. Jr., Newberg, H. J., Newman, P. R., Nichol, R. C., Nicinski, T., Nieto-Santisteban, M., Nitta, A., Odenkirchen, M., Okamura, S., Ostriker, J. P,. Owen, R., Padmanabhan, N., Peoples, J., Pier, J. R., Pindor, B., Pope, A. C., Quinn, T. R., Rafikov, R. R., Raymond, S. N., Richards, G. T., Richmond, M. W., Rix, H., Rockosi, C. M., Schaye, J., Schlegel, D. J., Schneider, D. P., Schroeder, J., Scranton, R., Sekiguchi, M., Seljak, U., Sergey, G., Sesar, B., Sheldon, E., Shimasaku, K., Siegmund, W. A., Silvestri, N. M., Sinisgalli, A. J., Sirko, E., Smith, J. A., Smolcic, V., Snedden, S. A., Stebbins, A., Steinhardt, C., Stinson, G., Stoughton, C., Strateva, I. V., Strauss, M. A., SubbaRao, M., Szalay, A. S., Szapudi, I., Szkody, P., Tasca, L., Tegmark, M., Thakar, A. R., Tremonti, C., Tucker, D. L., Uomoto, A., Vanden Berk, D. E., Vandenberg, J., Vogeley, M. S., Voges, W., Vogt, N. P., Walkowicz, L. M., Weinberg, D. H., West, A. A., White, S. D. M., Wilhite, B. C., Willman, B., Xu, Y., Yanny, B., Yarger, J., **Yasuda, N.**, Yip, C., Yocum, D. R., York, D. G., Zakamska, N. L., Zehavi, I., Zheng, W., Zibetti, S., and Zucker, D. B.: 2003, The First Data Release of the Sloan Digital Sky Survey, *Astron. J.*, **126**, 2081-2086.

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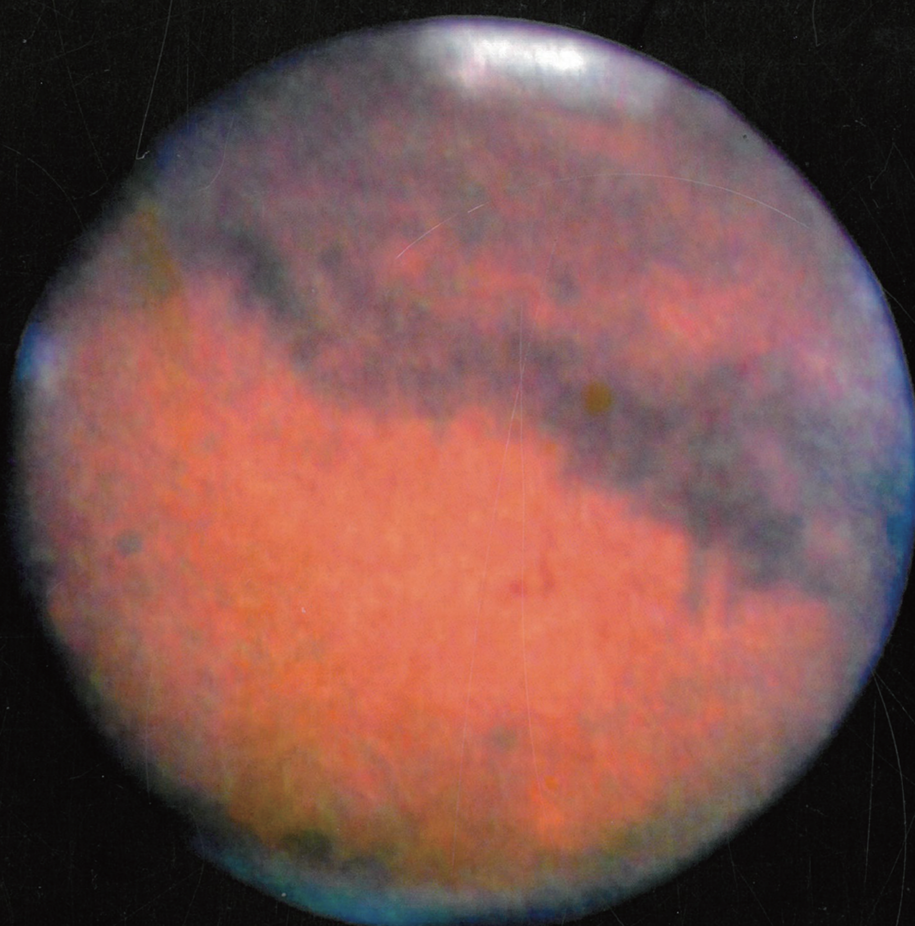
Explanation of the back cover photograph: An optical image of Mars taken by the Subaru Telescope at the occasion of the closest approach to the Earth in the end of August, 2003. The observing instrument was the Hi-vision camera of NHK (Japan Broadcasting Corporation). The image has been synthesized from the movie frames.



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