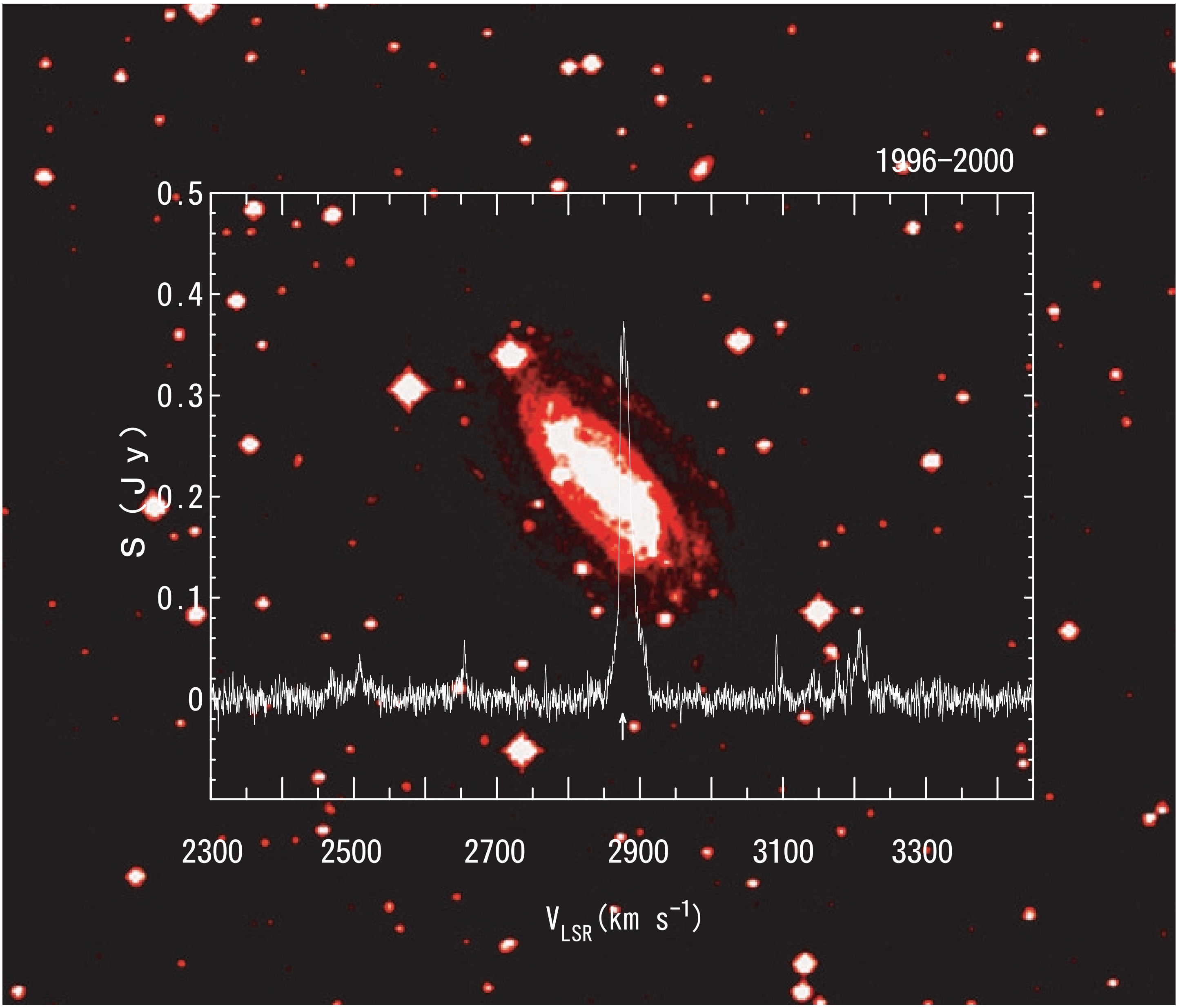
ISSN 1346-1192

ANNUAL REPORT OF THE NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN



Volume 4 Fiscal 2001

Explanation of the cover photograph: A spectrum of water-vapor maser emission from the nucleus of a type 2 Seyfert galaxy, IC 2560 (optical photograph). In addition to the known strong features around the systemic velocity (2876 km/s), weaker high-velocity features offset from the systematic velocity up to ±420 km/s has been newly detected. Analysis has shown that a super massive black hole sits at the nucleus from analyzing the data (2001; PASJ, **53**, 215). The optical image is taken from Digitized Sky Survey (UK Schmidt).

Postscript

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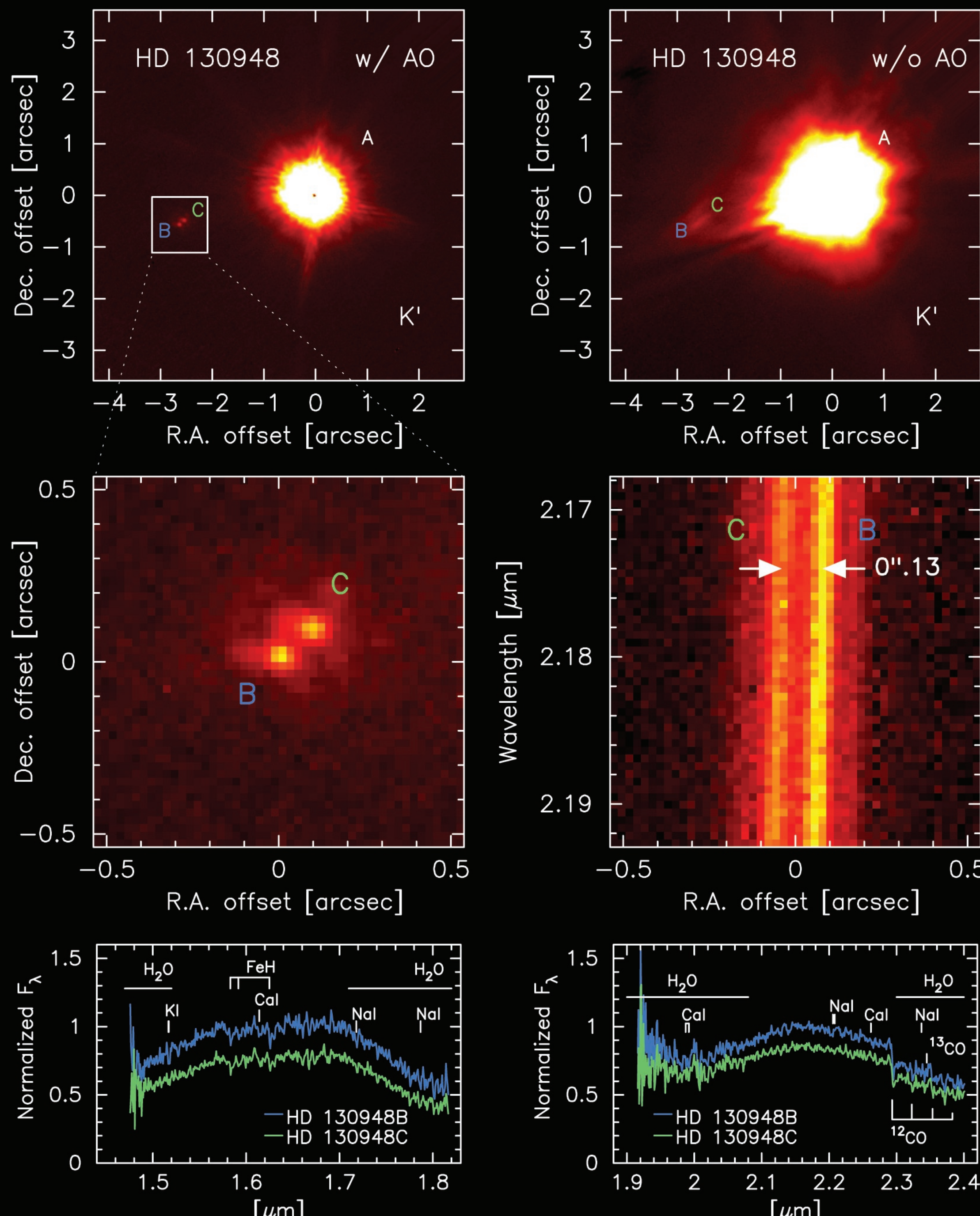
YAMASHITA, Yoshiko
YASUDA, Naoki

Publisher **National Astronomical Observatory of Japan**

Osawa 2-21-1, Mitaka-shi, Tokyo 181-8588, Japan
TEL: +81-422-34-3600
FAX: +81-422-34-3690
http://www.nao.ac.jp/

Printer Kyoshin Co., Ltd.

1-20-19, Miyamae, Suginami-ku, Tokyo 168-0081, Japan
TEL: +81-3-3331-0950



Subaru IRCS view of binary brown dwarfs HD 130948B and HD 130948C.
With adaptive optics, IRCS delivers images and spectra with diffraction-limited resolution.
In this image, a close binary with a 0.13 arcsecond separation is clearly resolved.

National
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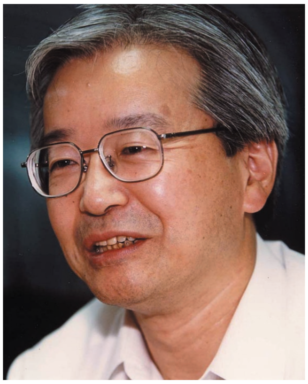
Table of Contents

PREFACE



The NAOJ is promoting manifold fields of astronomy and astrophysics such as the optical/IR astronomy, radio astronomy, solar physics, theoretical astronomy/astrophysics, VLBI astrometry/geodesy, gravitational wave detection by operating top-level large facilities in each field. Among excellent institutes for astronomy and astrophysics in the world which are specialized in the individual fields such as optical/IR, radio or theory, the NAOJ is a unique institute for astronomy and astrophysics as a whole. The role of the NAOJ is also to provide top-level facilities for university scientists and to represent the Japanese astronomy and astrophysics as an inter-university national research institute.

Under above characteristics and status the NAOJ has been developing new projects such as the VERA, Subaru, TAMA-300 and ALMA to promote the research and education, and tried to respond to the strong public interest about the world we are living. Here I make a very brief review of our achievements during the financial year 2001, and the details are reported in the following text sections.

The Subaru Telescope, an 8.2m aperture optical/IR telescope has been in excellent condition through the open operation started last year. Five observing instruments among seven were already opened for the operation. Remaining two instruments and adaptive optics system are to be in operation from 2002. Refer to the highlight papers in the text for the scientific results from the Subaru Telescope.

The construction of a 20m antenna in Ishigaki Island, Okinawa was finished. This is the 4-th and final of dual-beam 20m antennas for the VERA project. The test observations with the max. 2300km baseline VLBI network (connecting the Mizusawa, Kagoshima, Chichi-Jima and Ishigaki stations) to measure the distance to radio stars aiming to produce the three-dimensional map of the whole Galaxy will start next year.

The gravitational wave detector TAMA-300, an advanced collaboration project with the University of Tokyo and KEK, had succeeded in the long-term operation for the first time in the world. The sensitivity was also in the highest level. The data reduction and further stabilization of operation are in progress.

In the Nobeyama Radio Observatory the BEARS, a new 85-115 GHz 25-beam receiver for the 45m telescope, has been operated with satisfactory performance through the year. The observations of molecular clouds have been made extensively by using the huge mapping capability of the BEARS. The RAINBOW, a combination of the 45m telescope and six 10m antennas of the NMA (Nobeyama Millimeter Array) has been operated successfully as one of the most sensitive interferometer in the mm-wavelength region. The Nobeyama Radio Heliograph and the solar magnetograph in Mitaka Campus have actively produced data which provided new understandings of the solar activity.

The progress worthy of special mention in 2002 was the promotion of the collaboration with universities in radio astronomy. The Hokkaido University, Gifu University, Yamaguchi University and Kagoshima University have started the building-up of a new radio astronomy group by using the 11m to 32m aperture antennas with VLBI capabilities under the close cooperation with

NAOJ. Another remarkable activity was made in the field of public relation and education. The Public Relation Center has successfully developed a number of excellent tasks like very popular event “Your Four Days as an Astronomer” for high school students. Also various public activities were made in the local NAOJ facility areas including Hawaii and VERA sites, and the NAOJ is now acting an important role in the science education for the public and students.

The most important ongoing project of the NAOJ is realization of the ALMA, which is an international large mm wave and sub-mm wave interferometer to be constructed in northern Chile. Japanese participation to the ALMA, especially with its sub-mm wave technology and experience, is essentially important to this epoch-making big project. The reorganization of all national universities/institutes to be independent agencies aiming for operation from FY2004 is another major subject for NAOJ. Intensive discussions are ongoing to create a flexible organization for powerful basic research.

Norio Kaifu
Director General
National Astronomical Observatory of Japan

I Scientific Highlights

(2001 Apr. - 2002 Mar.)

The Mechanical Test Model of the Solar-B spacecraft mounted on the shaking machine of the ISAS environmental test facility.
The healthiness of the structure against the launch condition was confirmed.

Development of the Solar-B Spacecraft

TSUNETA, Saku, ICHIMOTO, Kiyoshi, SUEMATSU, Yoshinori, SHIMIZU, Toshifumi
HARA, Hirohisa, KANO, Ryohei, NAGATA, Shin'ichi, TAMURA, Tomonori
NAKAGIRI, Masao, NOGUCHI, Motokazu, KATO, Yoshihiro
(Solar Physics Division, NAOJ)
WATANABE, Tetsuya, HANAOKA, Yoichiro, SAWA, Masaki
(Radio Astronomy Division, NAOJ)
OTSUBO, Masashi
(Advanced Technology Center, NAOJ)
KOSUGI, Takeo, YAMADA, Takahiro, SAKAO, Taro
MATSUZAKI, Keiichi, MINESUGI, Kenji, ONISHI, Akira
(ISAS)
KATSUKAWA, Yukio, KOBAYASHI, Ken, KUBO, Masahito
(Tokyo University)

The Solar-B spacecraft, currently under development toward the launch in summer of 2005, consists of the Solar Optical Telescope (SOT) to make a precise measurements of magnetic fields of solar photosphere with a high spatial resolution, the X-Ray Telescope (XRT) to observe the dynamics of the high temperature corona, and the EUV Imaging Spectrometer (EIS) to observe plasma motions in transition region and corona. The aim of the Solar-B is to investigate the physical coupling between the photosphere (engine) and the corona (dissipater) to ultimately understand the coronal heating mechanism. The magnetic field maps with 0.2" resolution, the images of high temperature corona with 1" resolution, and the precise coronal velocity maps provided by these telescopes are all new and unprecedented scientific outcome are expected.

These advanced instruments are being developed under close collaboration between Japan (ISAS/NAOJ), the United State (NASA), and the United Kingdom (PPARC). Regarding the SOT, the largest of the three telescopes, the 50cm ϕ optical telescope (OTA) is developed by Japan and the Focal Plane Package (FPP) is developed by NASA. Regarding the XRT, NASA is in charge of the X-ray optics and Japan is in charge of the X-ray CCD camera and observation control system. EIS is developed mainly by US and UK. In this collaboration, the primary responsibility of NAOJ is the fabrication of the OTA and the X-ray CCD camera. NAOJ, in collaboration with ISAS, is also playing a role in designing and testing the interface between each instrument and the spacecraft and in developing the Mission Data Processor which is one of the key components of the Solar-B mission.

After extensive study and design work under the strict constraints of mass, size, cost, time and environmental conditions, the Mechanical Test Model (MTM) of the spacecraft was completed in May 2002. The MTM is used to verify the mechanical validity of the spacecraft and each instrument against the launch condition, and, in case of Solar-B, its fidelity to the flight model is quite high. Figure 2 shows the Solar-B MTM mounted on the ISAS vibration test facility. The cubic box in the bottom is the bus module which contains common electrical devices including the attitude control system. Mounted on both sides of the bus are the solar array panels, each of which will be expanded to 4.5m in orbit (Figure 1). The cylindrical Optical Bench Unit (OBU) made of a low expansion CFRP with 1m diameter and 1m height is attached on the bus module. The OTA is installed inside the OBU. The FPP, which is a rectangular box, is mounted on the side of OBU. The XRT and EIS, which are also mounted on the side of OBU, are so long (−3m) that they extend to the bottom of the spacecraft through the side of the bus module.

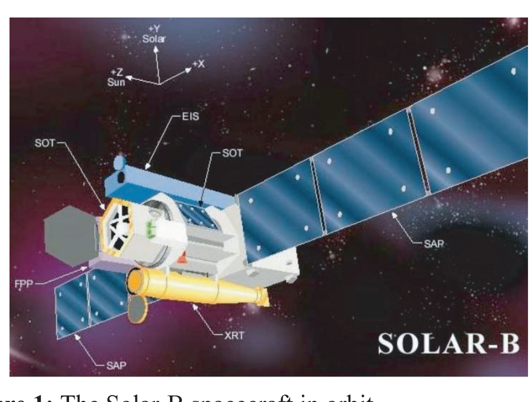


Figure 1: The Solar-B spacecraft in orbit

Figure 2: The Solar-B Mechanical Test Model mounted on the ISAS vibration test facility.

By using the cylinder-shaped OBU, the 4 scientific instruments were compactly mounted on the spacecraft. It is noted however that the Solar-B is one of the largest scientific satellite in Japan with its total size of 1.5m × 1.5m × 3.8m.

The status reports of OTA are given in other highlights by Suematsu and Nagata of this annual report of NAOJ. The status of XRT is briefly described here. The mechanical/thermal test model of the X-ray CCD camera is shown in Figure 3. The 2K × 2K back-side illuminated X-ray CCD is cooled down to −45˚C ~ −70˚C using radiator, and its position can be controlled in a range of ± 1mm to accommodate any change of focus of the 3m long telescope and to optimize the focus position for various fields of views of observation program. NAOJ has been performing the calibration and evaluation of the CCD camera using the medium-size vacuum chamber and X-ray monochromator installed in the Advanced Technology Center. The extensive activities for fabrication and testing of the flight CCD camera will continue until its completion in March 2003. The CCD will then be delivered to the US to be combined with the X-ray telescope at NASA and after final testing the XRT will be delivered back to Japan to be installed to the Solar-B spacecraft in January 2004.

Though the CCD and the grating of EIS are under fabrication in UK and US, it is noted that a significant contribution from Japanese technology was made to improve their performance in resolution and sensitivity.

The system level mechanical test (2002.5-7) will be followed by the system level thermal vacuum test in October 2002. The integration of the flight OTA will start in April 2003. The integration and optical performance tests of the flight model OTA will be performed in the large clean room of the environment test facility newly constructed in NAOJ. After electrical/mechanical interface check starting in January 2004 and the final integration testing, the Solar-B is planned to be launched in summer of 2005.

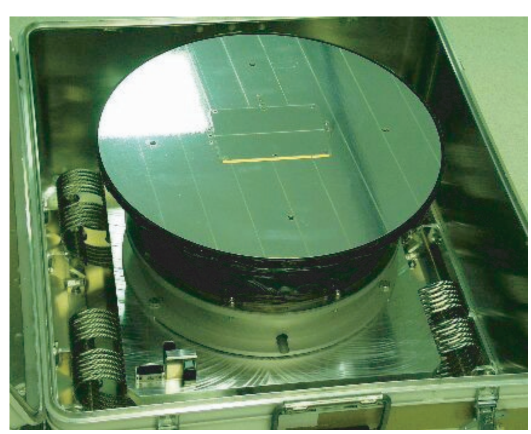


Figure 3: Mechanical/thermal test model of the X-ray CCD camera

Development of Solar-B Solar Optical Telescope

SUEMATSU, Yoshinori, ICHIMOTO, Kiyoshi, SHIMIZU, Toshifumi, NAGATA, Shin'ichi, TAMURA, Tomonori, TSUNETA, Saku, NOGUCHI, Motokazu, KATO, Yoshihiro, NAKAGIRI, Masao
(Division of Solar Physics, NAOJ)
OTSUBO, Masashi (Advanced Technology Center, NAOJ)
HANAOKA, Yoichiro (Division of Radio Astronomy, NAOJ)
KATSUKAWA, Yukio, KOBAYASHI, Ken, KUBO, Masahito
(Univ. of Tokyo)

The solar optical telescope (SOT) to be carried aboard the 22nd ISAS science satellite Solar-B (to be launched in the summer, 2005) consists of the optical telescope assembly (OTA) made of 50 cm aperture Gregorian telescope and the focal plane package (FPP) consisting of the filtergraph and spectrograph.

The OTA (Figures 1 and 2) and the FPP (Figure 3) are designed and manufactured in Japan and the United States, respectively, to achieve a near diffraction-limited optical performance in collaboration with each other. The project is going very well thanks to intimate communications between Japanese and US teams. We have had ten J-US joint design meetings (about fifty days in total) to work out the sophisticated mechanical, optical and thermal interface since the project started two and half years ago. We have also performed joint tests for a total of three months.

We here briefly describe the OTA structure shown in

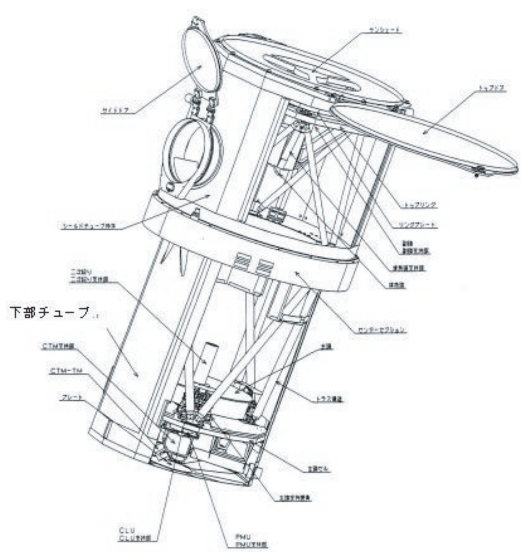


Figure 1: Layout of the Optical Telescope Assembly (OTA).

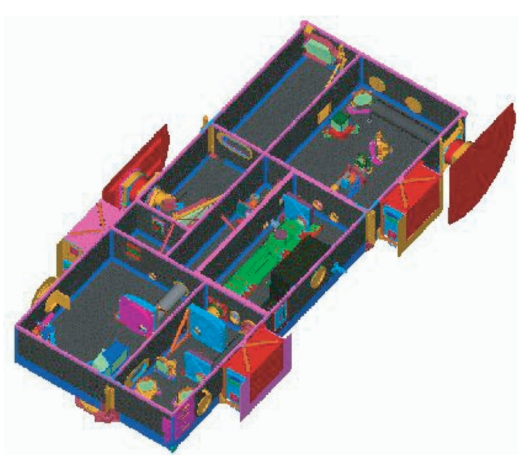


Figure 3: Layout of Focal Plane Package (FPP).

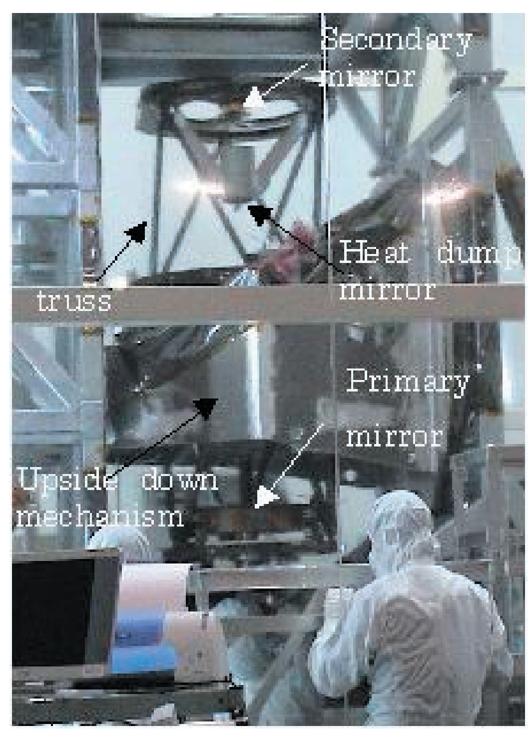


Figure 2: OTA integration in clean booth.

Figure 1. The OTA framework is composed of truss of CFRP (carbon-fiber reinforced composite material), and is an adhesively bonded structure. The primary mirror (Figure 1), which is only 14 kg weight, and the secondary mirror are made of lightweight ULE like the SUBARU telescope. An aberration-free collimator lens unit (CLU, Figure 5) is located

Figure 4: Primary mirror of OTA.

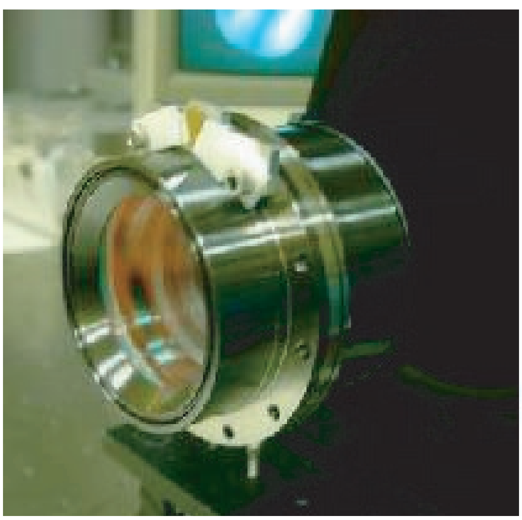


Figure 5: Flight model of Collimator Lens Unit (CLU).

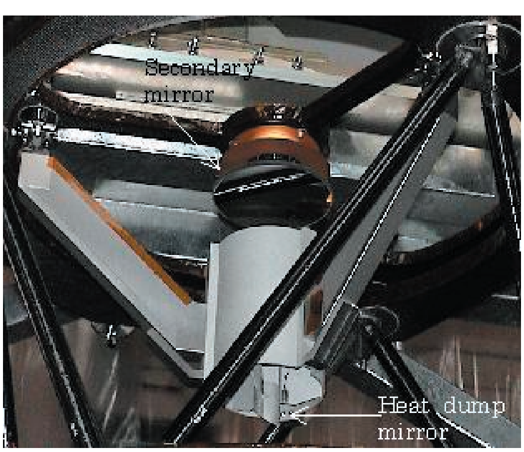


Figure 6: Secondary mirror and heat dump mirror (HDM) of OTA

on the secondary focus in order to transfer a collimated beam to the FPP. A heat dump mirror (HDM, Figure 6), which is made of aluminum, is located at the primary focus and dumps most unnecessary solar light to the space. SOT has image stabilization system (see a highlight article by Nagata et al. in this volume) and a tip-tilt mirror for this system is located inside of the OTA.

An integration of OTA proto model, an alignment of its optical components and random vibration/shock test have been carried out with ISAS facility from August, 2001 through April, 2002. We prepared in advance necessary equipments for the integration and test such as a high surface accuracy flat mirror of 60 cm diameter (rms wavefront error of 15 nm), a booth of cleanliness class 100, a tower for the OTA integration and optical test (Figure 7), a high-speed laser interferometer, a large optical bench, and a six-axes drive stage.

In order to perform the optical test, the OTA proto model was integrated with actual optical components quite similar to flight ones except for their wavefront error accuracies; the flight model CFRP truss was used. The proto model primary and secondary mirrors are also intended as backups for the flight by re-polishing in a contingency case. Proto model CLU consists of two-group two-lens to give an optimal performance in test wavelength of 632.8 nm (flight model CLU

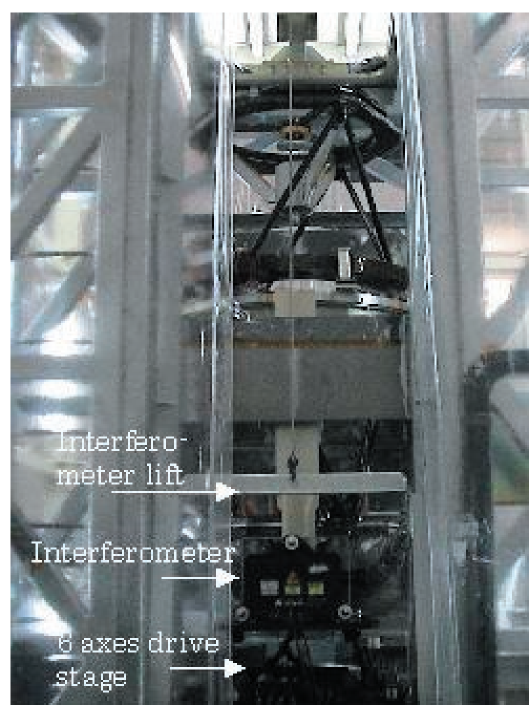


Figure 7: A scene of optical test of OTA

is made of six-group six-lens). The tip-tilt mirror is made of ULE glass supported and tilt adjusted by three piezo actuators for image stabilization. All the optical components of OTA are fixed at their best optical performance positions during the integration and test phase, since the OTA has no adjustment mechanism on orbit; only focus adjustment is made with a re-imaging lens of FPP.

The telescope structure therefore plays a key role in giving the diffraction-limited performance; mounting mechanism of optical components, especially of the primary mirror, should not degrade their optical qualities and truss should maintain the separation between the primary and secondary mirror in the accuracy of five microns. It is necessary to verify by testing that no misalignment of the OTA optical component is caused by the satellite launch condition.

The alignment of OTA by using interferometer was verified in the beginning of the test; coma aberration due to decenter and tilt misalignment of secondary mirror and defocus due to its despace misalignment can be made negligibly small. This first measurement is affected by the deformation caused by the gravity. We then carried out wavefront error measurements in both upward (+1G) and downward (−1G) pointing telescope configuration to estimate a zero gravity despace position. Based on these measurement, the secondary mirror was adjusted to the zero gravity focus position. The integration and optical tests were made using the tower (3.2 m high) which is capable to mount the OTA, orienting it upside down and to set the 60 cm flat mirror at the top or bottom depending on the OTA orientation. To prevent the OTA from being contaminated, all these activities were done in class 100 clean rooms by workers wearing clean clothes, hood and gloves for class 100.

In addition to static misalignment, dynamic misalignment of OTA optics was a more important concern. To check the healthiness of optics against the satellite launch, the most violent mechanical environment, the random vibration and shock test simulating the launch condition was performed using the ISAS facility. By comparing the wavefront errors of OTA before and after the test, it was demonstrated that the change of coma and defocus aberration of OTA is within the budget to achieve the diffraction-limit. This was one of the most important milestones for the flight model.

SOT team of NAOJ is contributing to not only system-level test but also component-level test. For example, all the contaminant doubtful material of OTA is quantitatively tested for out-gassing using a medium-sized vacuum chamber in the Advanced Technology Center, NAOJ, because contamination of optical surfaces and resulted degradation of photon through-put are one of most crucial points for the success of SOT. NAOJ is performing, using HDM coating samples, a thermal cycling test and a heat load test by focusing 1000 times strong solar light on its surface. For the CLU, we performed opto-thermal tests (optical performance test in varied space thermal condition) and chromatic aberration measurements using a MTF measurement system of NAOJ. A J-US combination test of image stabilization system (CTM, the correlation tracker and tip-tilt mirror package) proto model was successfully completed in April of 2002 in NAOJ (see Nagata et al.).

Finally, we will perform an opto-thermal test with the OTA proto model, because the OTA has non-uniform temperature distribution on orbit. For this test, a large vacuum chamber of 2m diameter and 4.2m tall has been manufactured (Figure 8). The chamber contains two separate shrouds; upper and down side apart, and can control OTA thermal condition similar to that on orbit (−40 degC to 50 degC). The wavefront error of OTA will be measured in the varied thermal condition of the space to confirm that the thermal deformation and misalignment of OTA optics is within the budget for the diffraction-limit. This opto-thermal test is scheduled in January of 2003 and then the flight model integration and test will start in April of 2003.

Figure 8: Vacuum chamber for opto-thermal test of OTA.

Development of Image Stabilization System for Solar Optical Telescope onboard Solar-B satellite

NAGATA, Shinichi, SHIMIZU, Toshifumi, ICHIMOTO, Kiyoshi, TSUNETA, Saku
(Solar Physics Division, NAOJ)
MATSUZAKI, Keiichi
(ISAS)
KOBAYASHI, Ken
(Univ. Of Tokyo)

The primary objective of the Solar Optical Telescope (SOT) onboard Solar-B spacecraft, which is to be launched in summer of 2005, is to obtain high resolution magnetic field images of solar surface with the telescope's diffraction-limit resolution (0.2″). Since the attitude control system of the spacecraft cannot satisfy the scientific requirement to stabilize the SOT pointing to its sub-pixel size[1] (~ 0.02″), the SOT incorporates a closed-loop image stabilization system. This digital servo system consists of correlation tracker, tip-tilt mirror[2] (figure 1), and tip-tilt mirror controller (figure 2). The correlation tracker, provided by NASA, takes the solar granulation images with frequency of 580 Hz and generates the SOT pointing error signal for tip-tilt mirror control by the correlation analysis of the images. The tip-tilt mirror and its controller that is responsible for the closed-loop control is provided by NAOJ. A 64 bits CPU, which is newly developed by NASDA for space application, is used for this controller. The closed-loop control is implemented by the software of this controller. Since the main purpose of this system is to suppress the low frequency disturbance (target cross over frequency is 14 Hz), the software basically works as integration controller. In addition to this basic function, the software has the capability to diagnose the system transfer function by giving reference signal to the system and monitoring the system response to this reference signal. This software also has the capability to insert three optional filters in the closed-loop calculation.

The performance of the proto model image stabilization system was evaluated February-April 2002 and it was shown that the closed-loop system worked perfectly. We confirmed that the system satisfied the requirement for jitter reduction (20 dB at ~ 1 Hz, cross over frequency is set to 14 Hz), and the control error due to the instrument is as low as ~ 0.0002″.

The optical configuration of the test is shown in figure 3. The light through the granulation simulator, which can be

[1] The spacecraft pointing is always drifted with a few arcseconds amplitude due to the reaction of moving component such as momentum wheel, gyro scope, filter wheel and scan mirror of telescope and so on.

[2] The lifetime test for commercial PZTs, which is used to actuate the tip-tilt mirror, have been performed since November of 2000.

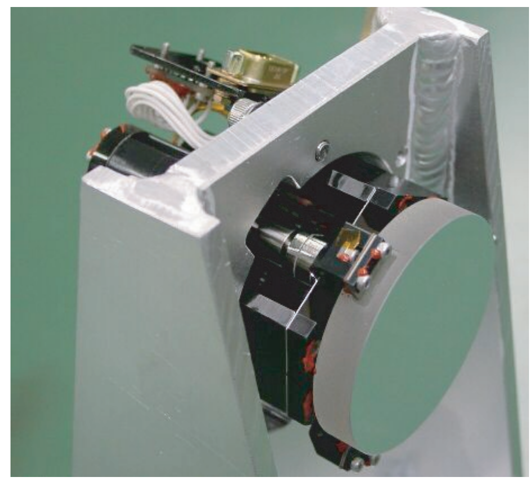


Figure 1: Tip-Tilt mirror

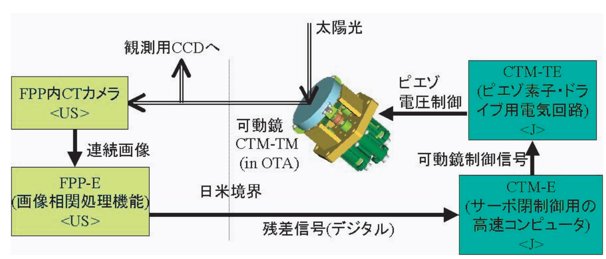


Figure 2: Image stabilization system

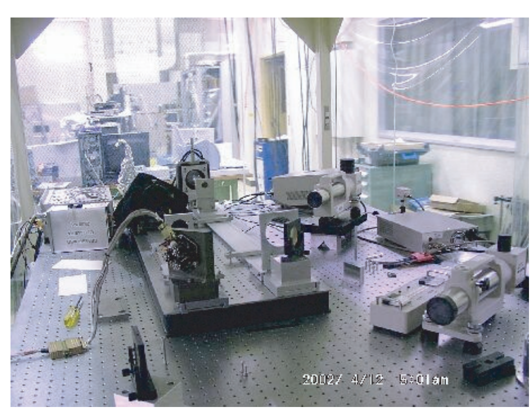


Figure 3: Optical configuration of the test

actuated to generate pointing errors, is reflected by the tip-tilt mirror and delivered to the CCD camera. Jitter reduction performance test, evaluation of diagnostics capability, and evaluation of system control error were performed.

A comparison of system transfer function obtained by the diagnostic capability and the designed one is shown in figure 4. The measurement curve shown by diamonds agrees well with designed curve shown by solid line. The gain curve can be approximated by software integration controller($|G(\omega)| \sim k2\pi/\omega$)[3], and the phase curve can be approximated by the delay time of digital processors ($\angle G\omega) \sim \tau\omega$)[4].

In figure 5, an example of jitter reduction performance measurement is compared with a model deduced from the system transfer function measurement. The measurement is shown by diamonds and the model is shown by solid line. This comparison was performed several times with varying the parameters of the controller software. The both data agreed well with each other in all the cases, and we confirmed that diagnostic capability can be used to evaluate and adjust the closed-loop performance in orbit.

The power spectrum of pointing error signal taken by both servo loop closed and opened are shown in figure 6; the low frequency disturbance is greatly reduced as expected from the jitter reduction shown in figure 5. In this measurement, the RMS of the pointing error with servo loop closed is $0.0002''(1\sigma)$.

The proto model phase was successfully closed by these fruitful test results.

The image stabilization performance in orbit will be ultimately evaluated by using the closed-loop characteristics obtained in this test and the SOT pointing properties measured in the spacecraft mechanical model test scheduled in July of 2002. The flight model fabrication will start after this performance evaluation. The flight model performance test is scheduled May-July of 2003 in USA.

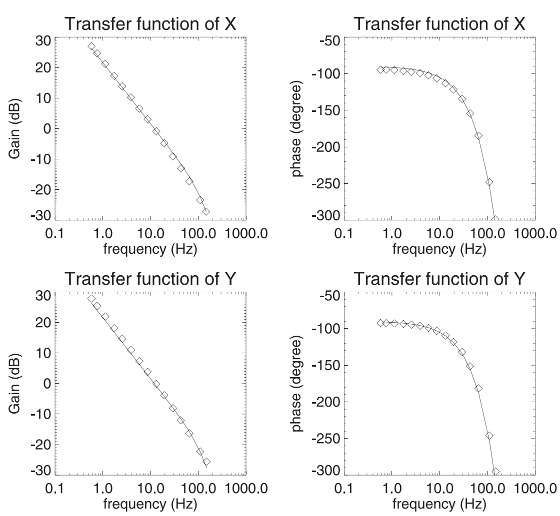


Figure 4: System transfer function (upper panel for X direction, lower panel for Y direction).

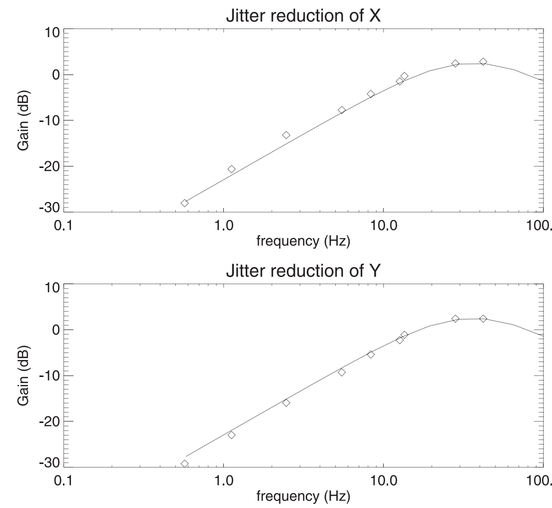


Figure 5: Jitter reduction (gain only).

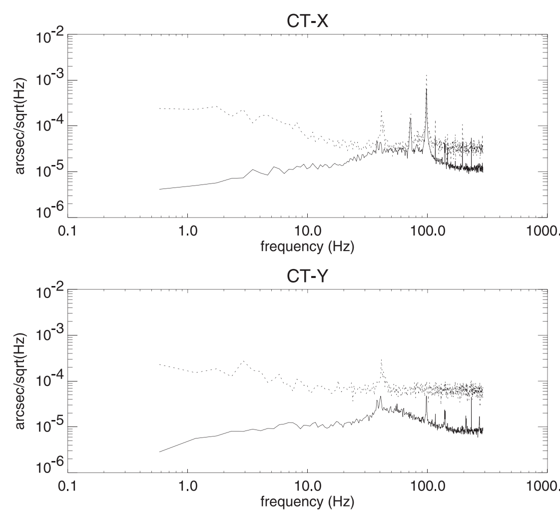


Figure 6: Power spectrum of error signal taken by servo loop closed (solid line) and opened (dotted line); upper panel for X and lower panel for Y direction.

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[3] k is an integration gain
[4] τ is delay time

Completion of VERA Ishigakijima Station

MIYAJI, Takeshi, IWADATE, Kenzaburo, KAMEYA Osamu
HONMA, Mareki, KOBAYASHI, Hideyuki, SASAO, Tetsuo
(VERA Promotion Office, NAO)
and VERA Project Team

Following the construction of three stations of VERA (Mizusawa, Iriki and Ogasawara) approved in the Supplementary Budget in 1999 fiscal year, the establishment of Ishigakijima Station was approved in the Supplementary Budget in 2000 fiscal year. The construction started in the summer of 2001 and completed in March, 2002.

A station at Ishigakijima is indispensable for VERA(VLBI Exploration of Radio Astrometry) Project in order to achieve the measurement goal of 10 μ-arcsecond level astrometric accuracy. The addition of the new station to the preceding three has almost doubled the maximum baseline length from 1,300 km to 2,300 km and the number of baselines from 3 to 6. The array enhancements, combined with the phase-compensation capability of VERA and the triangulation using the Earth's Revolution around the Sun (annual parallax method), will enable VERA to realize 100 times improvement in the accuracy of position and distance measurements in astronomy.

In the foundation work at Ishigakijima, a special attention was paid to increase the strength of the foundation since the land was reclaimed. 16 piles with 1.5 meter diameter were used compared with 12 in three other stations. In constructing the 20 m antenna, the experience gained in the construction of three preceding stations were fully utilized. To avoid possible delay in the work schedule due to typhoons, a large 200 ton crane was used for effective construction. The construction accuracy was measured from midnights to early mornings to minimize the heat effects due to the sunshine in the subtropical island. The novel receiving and recording systems are installed and tested in Ishigakijima where many improvements were applied based on the experience in three other stations.

The Opening Ceremony of the station was held in Ishigaki City in May 25, 2002, where the City Mayor Mr.Ohama made a heartful welcome speech for the VERA station. Local people and amateur astronomers showed a great interest to the new scientific facility in the island. 280 people attended in the public astronomy lecture organized by NAO. 1500 people visited the antenna site in the openhouse held in May 26. 250 people gathered in the star watching event and 150 people visited the photoexhibition titled 'Universe viewed by Subaru Telescope'.

Test and calibration observations are now conducted in Mizusawa, Iriki and Ogasawara stations where initial setups and performance tests of the telescope system are almost completed. The first VLBI fringe was detected between Mizusawa and Iriki. Simultaneous tracking of two radio sources was successfully demonstrated. Test VLBI observations started in three stations including Ogasawara. Test VLBI observations with the full four-station array will start within this academic year. Through the test and calibration observations, we expect to soon realize the 10 μ-arcsecond level astrometric accuracy.

Figure 1: Top : 20 m antenna under construction with 200 ton crane (Autumn, 2001), bottom: Visitors looking at the moving telescope in the openhouse held in the day after the Opening Ceremony

Interferometric Gravitational Wave Detector TAMA300: 1,000 hours Observation and Recycling Experiment

FUJIMOTO, Masa-Katsu, KAWAMURA, Seiji, YAMAZAKI, Toshitaka, TAKAHASHI, Ryu-taro
ARAI, Koji, TATSUMI, Daisuke, FUKUSHIMA, Mitsuhiro, ZHU, Zong-Hong
BEYERSDORF, Peter, SATO, Shuichi
(Division of Astrometry and Celestial Mechanics, NAOJ)
ANDO, Masaki (University of Tokyo) TAGOSHI, Hideyuki (Osaka University) KANDA, Noriyuki (Miyagi University of Education)
and the TAMA Collaboration

Data from the observation using the interferometric gravitational wave detector TAMA300 was taken six times from 1999 up to now. In the event search using the data of Data Taking 2, an observational limit to event rate of gravitational waves due to inspiraling neutron star binaries was obtained for the first time (H. Tagoshi, *et al.*: *Phys. Rev.* D63, (2001) 062001). In August 2000, the world top sensitivity ($5 \times 10^{-21}/\sqrt{\mathrm{Hz}}$ in strain) was achieved (M. Ando *et al.*: *Phys. Rev. Lett*. 86, (2001) 3950). Afterwards the sensitivity around 100 Hz was also improved by modifications of the vibration isolation system. S/N to black holes with $10M_\odot$ in distance of 10 kpc was largely improved from 15 to 35 by this improvement. S/N to neutron stars with $1.4M_\odot$ did not change (~ 35).

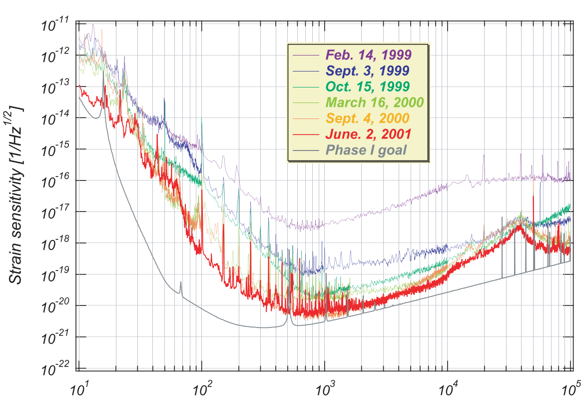

Figure 1: History of the sensitivity improvement in TAMA300. The sensitivity around 100Hz was improved about 10 times in 2001.

In Data Taking 6 accomplished 2001 summer (50 days), observation time more than 1,000 hours was achieved and preeminent stability with duty cycle of 86% was obtained. In this observation, newly developed automatic locking system of the interferometer makes automatic operation of over 50 control loops succeed. Figure 2 shows integrated observation time. Histogram shows observation time in each shift (8 hours). A line shows total observation time. Observation time is disturbed at points where histogram falls in due to mainly environmental disturbance like a typhoon and laser trouble. The result that event rate of inspiraling neutron star binaries inside Galaxy was less than 0.0095 event/hour (90% C.L.) was obtained from an analysis of the observation data.

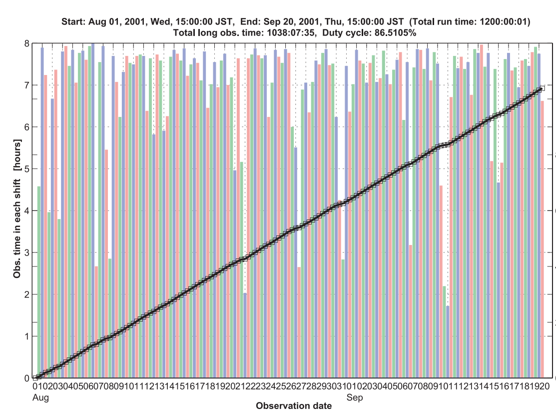

Figure 2: Integrated observation time in Data Taking 6. Fall-in on the 22th August and the 11th September shows typhoon attacks to Tokyo.

We began recycling experiment after Data Taking 6. The recycling technique makes light power inside the interferometer increase and shot noise level decrease. Therefore more improvement of the sensitivity is expected. Although control of the whole interferometer became difficult by introducing recycling mirror, the operation has been already succeeded in December 2001. The sensitivity also was recovered almost the same degree before introduction (improved partially).

Eleven-Year Solar Cycle Periodicity in Sky Brightness Observed at Mt. Norikura

SAKURAI, Takashi
(Norikura Solar Observatory, NAOJ)

We analyzed the brightness of the sky observed with a coronagraph at Mt. Norikura in the period of 1951-1997 [1]. The coronagraph is a telescope designed to observe the solar corona without eclipse, by artificially occulting the sun with a metal disk in the telescope. In the process of measuring the intensity of coronal emission, the sky background brightness has also been measured in order to subtract it from the coronal emission. The sky background is due to scattering by aerosols in the upper atmosphere.

The power spectrum analysis shows that the strongest signal is from annual variations; generally the sky is brighter in spring because of dust from the China continent. However, we have discovered that the power spectrum also shows a clear eleven-year periodicity of solar activity cycle. The peaks in the eleven-year component are found in the declining phase of activity, 2-4 years after the sunspot number maximum. The amplitude of this component is about 20% of the mean. A possible interpretation is that the solar activity (probably the UV radiation) modulates the contents of aerosols in the upper atmosphere of the earth, thus producing variations in scattering of sunlight.

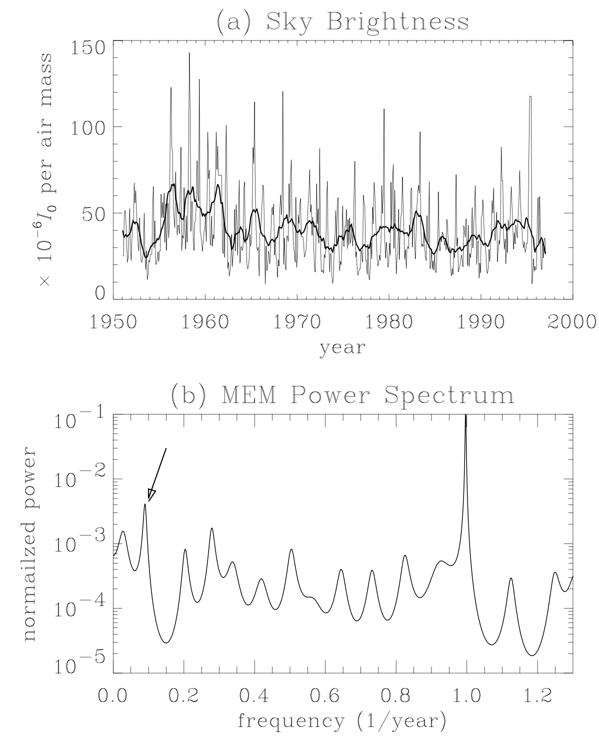

Figure 1: (a) The brightness of the sky observed at Mt. Norikura in the period of 1951-1997. The thin line shows monthly data, and the thick line is a one-year running mean. (b) The power spectrum of the sky brightness by the maximum entropy method. The eleven-year peak is indicated by the arrow.

Reference

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Near Infrared Adaptive Optics Spectroscopy of Binary Brown Dwarf

GOTO, Miwa, KOBAYASHI, Naoto, TERADA, Hiroshi, GAESSLER, W.
KANZAWA, Tomio, TAKAMI, Hideki, TAKATO, Naruhisa
KAMATA, Yukiko, IYE, Masanori, SAINT-JACQUES, D. J.
(NAOJ)
TOKUNAGA, A. T., POTTER, D., CUSHING, M.
(University of Hawaii)

We report the first near infrared spectroscopy assisted by the Subaru adaptive optics (AO) system [1].

HD 130948 is a triple system discovered by [2] in the course of an imaging survey of low-mass companions to nearby young stars. The HD 130948 system consists of a bright primary star (V = 5.9) with a faint companions at a separation of 2".63. The goal of the present observation is to confirm the substellarity of the faint binary companions. The binary companions are separated by only 0".13.

Close binary brown dwarfs are important in terms that the dynamical mass is obtained without depending on any stellar model. The mass of brown dwarfs has been determined by comparing the optical properties such as luminosity and spectrum with an evolutional model of low mass stars. If the dynamical mass of the stars which is independent from optical properties is available, the stellar models are then tested in turn.

Suppose the mass is same, the smaller the radius of the orbit of the system, the shorter the orbital period. To determine the dynamical mass of brown dwarfs in realistic time scale, the separation of the binary companions should be 1-2 AU or smaller. It corresponds to 0".1 to 0".2 in projection at ~10pc away from us. The assistance of the adaptive optics system is integral for the observation from the ground.

We need the spectra of both binary components separately to compare it with existing photosphere models, which means

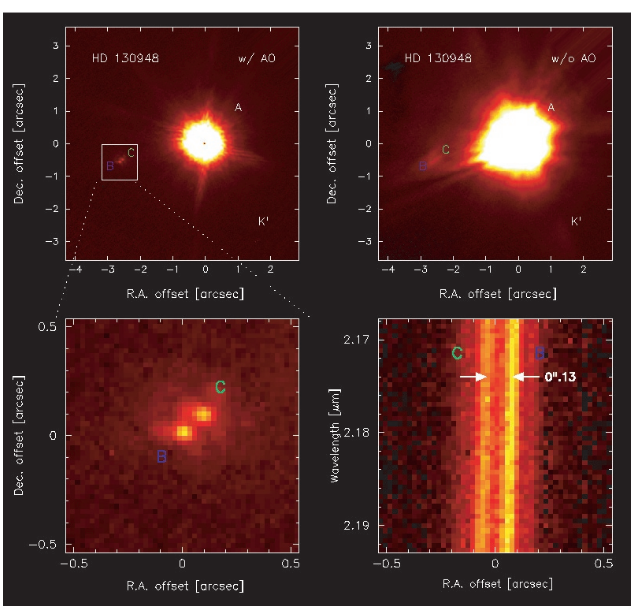

Figure 1: Counter clockwise from the upper right: K-band (2.2 μm) image of HD 130948 without adaptive optics system and with adaptive optics system. A blow up of faint companions, a spectrogram at around 2.1 μm.

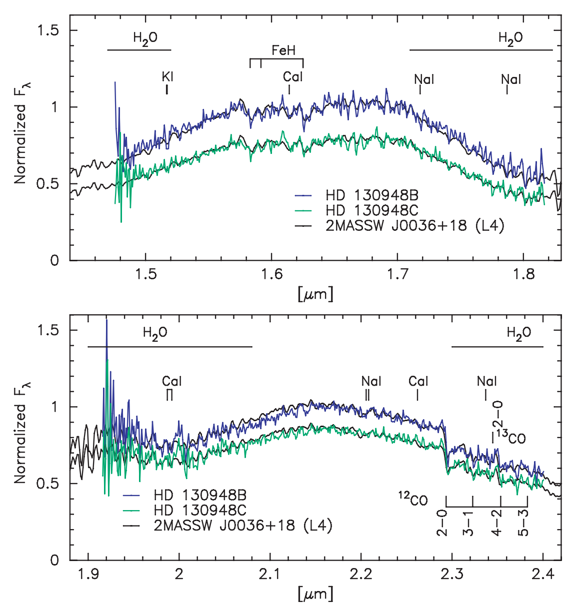

Figure 2: H-(1.48 - 1.82 μm) and K-band (1.90 - 2.40 μm) spectra of HD 130948 B and C. The water vapor absorption is conspicuous at the both ends of the bands, which ensures the low mass nature of the stars.

that the observation needs both high spatial resolution and spectroscopic capabilities. Subaru AO with infrared camera and spectrograph (IRCS) provides one of a few solutions that satisfies the requirements.

We successfully delivered the spectra of both components HD 130948 B and C with clear separation. The water vapor absorption features at the both ends of the *H*- and *K*- bands clearly manifest that low mass nature of the companions. The absorption strength indicates the effective temperature of the HD 130948 B and C are about 1900 K. The age of the primary HD 130948 A is estimated to be 0.3 to 0.8~Gyr based on the rotation period, X-ray activity, and possible attribution to a group of young stars Ursa Major Stream. Assuming the coevality of the triple system the mass of HD 130948 B and C has been derived to be in between 0.040 $M_{\odot}$ and 0.065 $M_{\odot}$ with the evolutional model of the effective temperature [3]. The substellarities of the both binary companions are confirmed that they are lighter than the limit of the sustainable hydrogen burning.

The monitoring observation of the binary brown dwarfs to determine the orbital is in progress by the collaborators at University of Hawaii.

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[3] Baraffe, I., et al.: 1998, *A&A*, **337**, 403.

Galaxy Number Counts in the Hubble Deep Field as a Strong Constraint on a Hierarchical Galaxy Formation Model

NAGASHIMA, Masahiro, TOTANI, Tomonori
(Division of Theoretical Astrophysics, NAOJ)
GOUDA, Naoteru
(Division of Astrometry and Celestial Mechanics, NAOJ)
YOSHII, Yuzuru
(Institute of Astronomy, University of Tokyo)

We re-analyzed number counts of galaxies using a semi-analytic model (SAM) of galaxy formation based on the hierarchical clustering scenario[1]. The main results are shown in Figure 1. We have determined the astrophysical parameters in the SAM that reproduce observations of nearby galaxies, and used them to predict the number counts and redshifts of faint galaxies for three cosmological models for (1) the standard cold dark matter (CDM) universe (SCDM; red lines), (2) a low-density flat universe with nonzero cosmological constant (LCDM; green lines), and (3) a low-density open universe with zero cosmological constant (OCDM; blue lines). The novelty of our SAM analysis is the inclusion of selection effects arising from the cosmological dimming of surface brightness of high-redshift galaxies, and also from the absorption of visible light by internal dust and intergalactic HI clouds. Contrary to previous SAM analyses which do not take into account such selection effects, we find, from comparison with observed counts and redshifts of faint galaxies in the Hubble Deep Field (HDF), that the standard CDM universe is not preferred, and a low-density universe either with or without cosmological constant is favorable, as suggested by other recent studies. The importance of the selection effects are also shown in the Figure 1, as the difference between the thick and thin lines. Moreover, we find that a simple prescription for the time scale of star formation (SF), being proportional to the dynamical time scale of the formation of the galactic disk, is unable to reproduce the observed number-redshift relation for HDF galaxies, and that the SF time scale should be nearly independent of redshift, as suggested by other SAM analyses for the formation of quasars and the evolution of damped Ly-α systems.

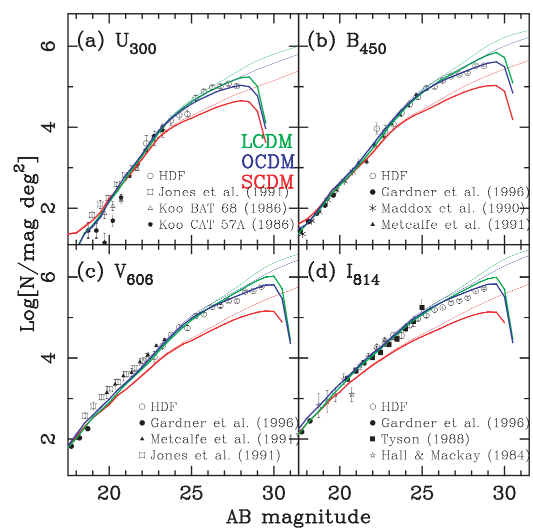

Figure 1: *N*–*m* relation. The green, blue and red lines denote the predicted galaxy counts in a Λ-dominated flat Univese (LCDM), an open Universe (OCDM), and the standard CDM model (SCDM), respectively. The thick and thin lines indicate models with and without the selection effects, respectively.

Reference

[1] Nagashima, M., Totani, T., Gouda, N., and Yoshii, Y.: 2001, *Astrophys. J.*, **557**, 505–518.

Photoionization effect of the UV background on the colour-magnitude relation of elliptical galaxies

NAGASHIMA, Masahiro
(Division of Theoretical Astrophysics, NAOJ)
GOUDA, Naoteru
(Division of Astrometry and Celestial Mechanics, NAOJ)

We examined effects of the ultraviolet background radiation (UVB) on the colour-magnitude relation (CMR) of elliptical galaxies in clusters of galaxies in the hierarchical clustering scenario by using a semi-analytic model of galaxy formation [1]. In our model the UVB photoionizes gas in dark haloes and suppresses the cooling of the diffuse hot gas onto galaxy discs. By using a semi-analytic model without the effect of the UVB, Kauffmann & Charlot [2] found that the CMR can be reproduced by strong supernova heating because such supernova feedback suppresses the chemical enrichment in galaxies especially for small galaxies as shown in Figs. 1a and 1b. We find that the CMR also becomes bluer by the UVB in a different way from the supernova feedback as shown in Fig. 1c. Thus there is a degeneracy between the supernova feedback and the UVB on the CMR.

While the supernova feedback suppresses the chemical enrichment by a similar mechanism to galactic wind, the UVB suppresses the cooling of the hot gas as schematically shown in Fig.2. This fact induces the suppression of the metallicity of the intracluster medium (ICM). In our model we find that the existence of the UVB is plausible to account for the metallicity of the ICM in observations that is nearly equal to 0.3 times the solar value, and that in this case we can reproduce the CMR and the metallicity of the ICM simultaneously.

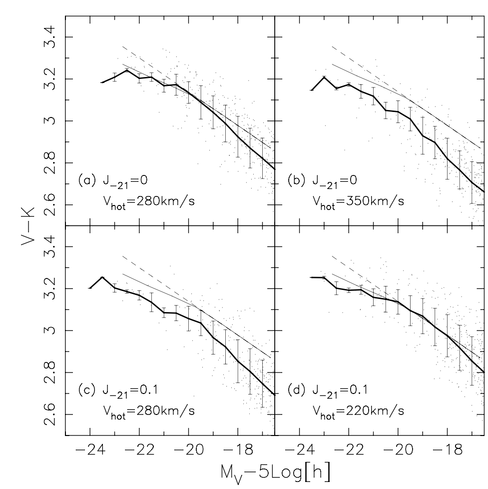

Figure 1: Color-magnitude relations. The lines denote the observed Coma CMRs with and without aperture correction, respectively. The curves indicate the model predictions.

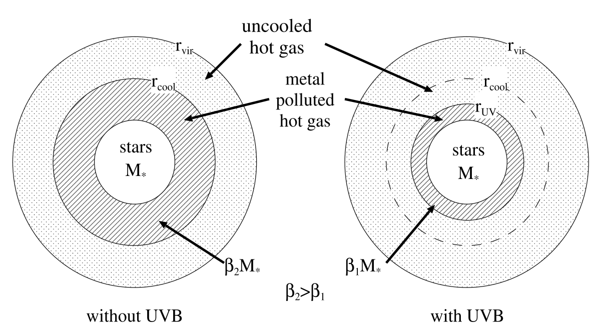

Figure 2: Schematic descriptions of ellipticals in dark haloes. These two galaxies have the same masses of dark matter and stars. r_{vir} denotes the virial radius of the haloes. The mass of the reheated, metal-polluted hot gas is βM_*. The right model has weaker supernova feedback than the left model because of the UVB.

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A Solution to the Missing Link in the Press-Schechter Formalism

NAGASHIMA, Masahiro
(Division of Theoretical Astrophysics, NAOJ)

The Press-Schechter (PS) formalism for mass functions of the gravitationally collapsed objects is reanalyzed[1]. It has been suggested by many authors that the PS mass function agrees well with the mass function given by *N*-body simulations, while many too simple assumptions are contained in the formalism. In order to understand why the PS formalism works well we consider the following three effects on the mass function: the filtering effect of the density fluctuation field, the peak ansatz in which objects collapse around density maxima, and the spatial correlation of density contrasts within a region of a collapsing halo because objects have non-zero finite volume. According to the method given by Yano, Nagashima & Gouda (YNG) [2] who used an integral formula proposed by Jedamzik [3], we resolve the missing link in the PS formalism, taking into account the three effects. While YNG showed that the effect of the spatial correlation alters the original PS mass function, in this paper, we show that the filtering effect almost cancels out the effect of the spatial correlation and that the original PS is almost recovered by combining these two effects, particularly in the case of the top-hat filter. The mass functions in the case of a ΛCDM model are shown in Fig.1. Our prediction (the dash-dotted curve) well agrees with *N*-body results (crosses). On the other hand, as for the peak ansatz, the resultant mass functions are changed dramatically and not in agreement especially at low-mass tails in the cases of the Gaussian and the sharp *k*-space filters. We show that these properties of the mass function can be interpreted in terms of the kernel probability $P(M_1|M_2)$ in the integral formula qualitatively.

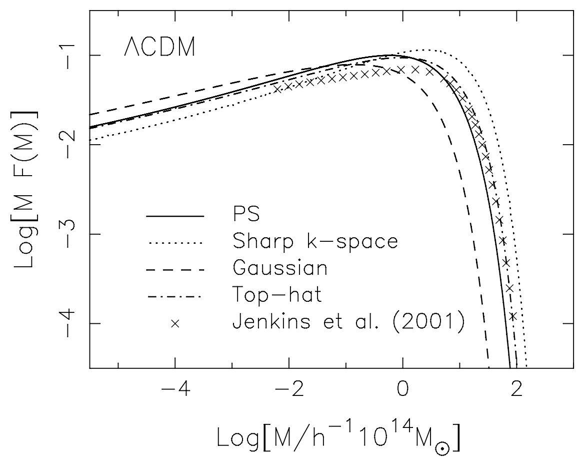

Figure 1: Differential multiplicity functions *F(M)* with the effect of the spatial correlation in a ΛCDM model. The solid, the dotted, the dashed and the dash-dotted lines denote *F*(*M*) for the PS, the sharp *k*-space, the Gaussian and the top-hat filters. The crosses indicate the mass function given by Jenkins et al. (2001), which was obtained by fitting their *N*-body simulation.

References

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[3] Jedamzik, K.: 1995, *Astrophys. J.*, **448**, 1.

Spectropolarimetric Evidence of Asymmetric Outburst in the Fast Nova V1494 Aquilae

KAWABATA, Koji S.
(Division of Optical and Infrared Astronomy, NAOJ)
AKITAYA, Hiroshi, IKEDA, Yuji, ISOGAI, Mizuki, NAKAYAMA, Satoru, SEKI, Munezo
(Tohoku University)
KONDOH, Masahiro
(Fukushima University)
KARUBE, Tomokazu, OKAZAKI, Akira
(Gunma University)
HIRATA, Ryuko
(Kyoto University)
MATSUMURA, Masafumi
(Kagawa University)
HIRAKATA, Nobuyuki
(Takeo High School)

We reported our extended polarimetric observations of a fast nova from the pre-maximum to transition stages [1]. The observations were made for V1494 Aquilae (= Nova Aql 1999 No.2) at the Dodaira Observatory of NAOJ between 1999 December 2 and 2000 March 29 (UT). (The Dodaira Observatory was closed on the end of 2000 March and March 29 was the final observation day at the observatory.) We discovered that the light from the nova had already been intrinsically polarized in the pre-maximum stage and that the intrinsic polarization took a local maximum at visual maximum light. For the next six days a nearly orthogonal polarization component gradually increased. This component was later accompanied and finally replaced by rapidly oscillating components. These observations provide direct evidence that an asymmetric geometry was present even prior to maximum brightness. The principal geometry of the wind projected onto the sky appears nearly constant, at least, from shortly after visual maximum to transition stages, but clumping of the ejecta appears to become significant in the later stages. The nearly orthogonal rotation of the position angle seen around the maximum light could be interpreted in terms of the optical depth effect, as seen in the prolate density distribution model of the scattering dominated photosphere [2].

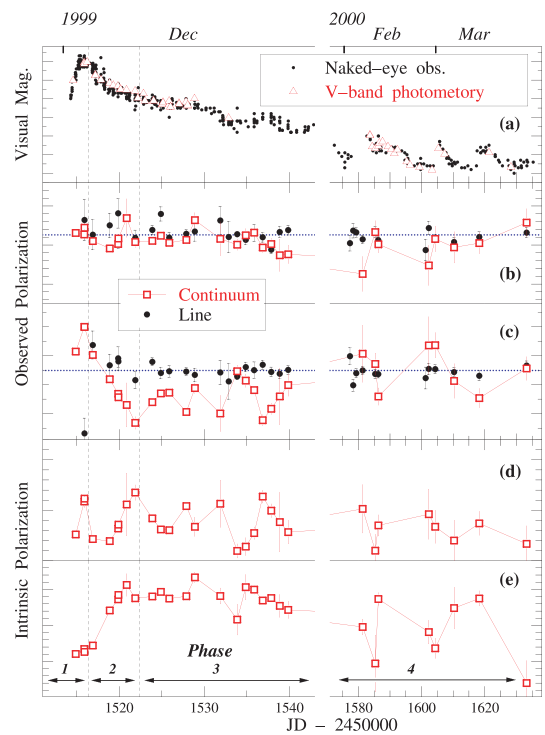

Figure 1: Time variations of the continuum and line polarization. We show (a) visual light curve from VSNET, (b, c) level and position angle of the observed polarization, respectively, and (d, e) those of the intrinsic polarization. The open squares and filled circles represent the data averaged for the line-free continuum areas and for strong emission lines (Hα, Hβ and OI λ8446), respectively. In panels (b) and (c), the estimated interstellar component at Hα is shown by horizontal dotted lines. The error bars represent 1σ observational error.

References

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High-speed Hα camera for solar flare observations

HANAOKA, Yoichiro
(Division of Radio Astronomy, NAOJ)
NOGUCHI, Motokazu, ICHIMOTO, Kiyoshi, SAKURAI, Takashi
The Solar Flare Telescope Team
(Division of Solar Physics, NAOJ)

To resolve individual spikes (elementary bursts) of impulsive solar flares requires a time resolution within 1 sec and a spatial resolution of about 1 arcsec. However, it is difficult to realize such high temporal and high spatial resolutions simultaneously with the hard X-ray instruments. On the other hand, it is easy to obtain one-arcsec resolution images with the video rate in the Hα flare observations. High-cadence Hα observations of solar flares are strongly required during this solar maximum, because we have plenty of hard X-ray data provided by the Yohkoh satellite and RHESSI. Then, we have developed a high-speed Hα camera, which is a new digital imaging system for the Hα imager of the Solar Flare Telescope at Mitaka, for the high-cadence observations of solar flares.

Figure 1 shows a schematic view of the system. A high-speed digital camera was installed in the Solar Flare Telescope, and data from the camera are processed with a PC. Generally, observations with high resolutions produce huge amount of data. It has been difficult to handle such a flood of data, but the recent advance of the computer technology enables us to handle vast data with a small computer. We constructed a framework of the general purpose real-time data processing system for solar observations, and the high-speed Hα camera is an application of this system. To install a new application, for instance a real-time frame selector instead of the high-speed Hα camera, we just need to replace the image processing functions, as if to replace a 'building block'.

In the actual operation of the high-speed Hα camera, images taken in every 30 sec are kept as context data. High-cadence images with a 0.5 sec cadence are recorded in parallel. After the daily observation, flares are searched automatically, and the high-cadence data of the time periods of the detected flares are cut out and recorded on CD-Rs. Quick-look images and movies, and daily Hα images and movies, lists of the observation time periods and detected flares are also produced automatically, and they are open on the WWW page of the Division of Solar Physics, NAOJ. During the period from 2001 July through 2002 April, the observation was carried out on 215 days, and 290 flares were recorded.

We are planning to replace the white-light imager of the Flare Telescope with a similar system, and to introduce a polarimeter system to measure the linear polarization in the Hα line.

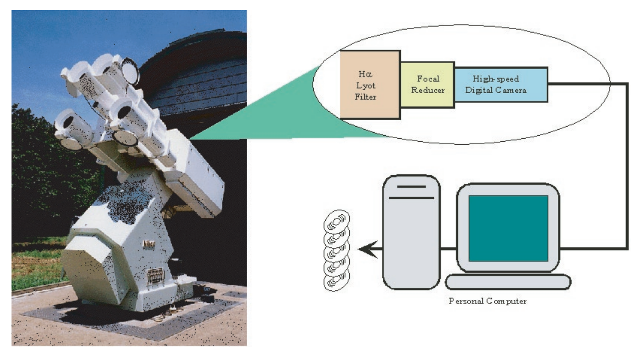

Figure 1: Schematic drawing of the high-speed Hα camera system.

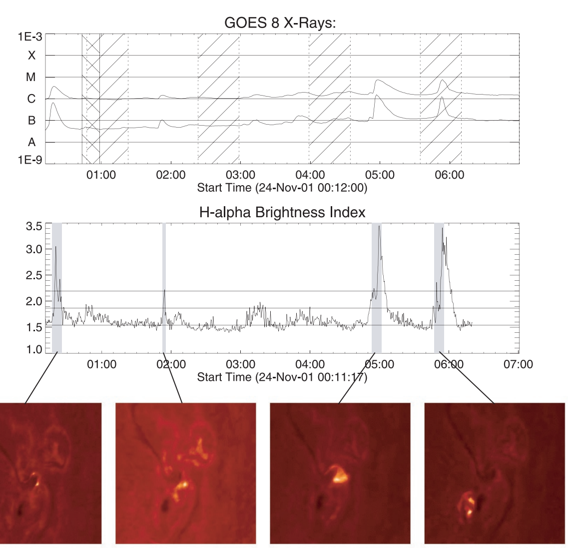

Figure 2: Plot of Hα brightness index on 2001 Nov. 24 (lower panel) along with a plot of soft X-ray intensity (upper panel). Four flares were detected automatically and high-cadence data of the shadowed periods are recorded. Sample images of the flares are also shown.

A Large-Scale CO Mapping of the Central Region of W51

OKUMURA, Shin-ichiro
(Earth Observation Research Center, NASDA)
MIYAWAKI, Ryosuke
(Fukuoka University of Education)
SORAI, Kazuo
(Hokkaido University)
YAMASHITA, Takuya
(Subaru Telescope, NAOJ)
HASEGAWA, Tetsuo
(ALMA Project Office, NAOJ)

W51 is one of the most luminous star-forming regions in the Galaxy. During the past two or three decades, G49.5-0.4, the brightest H II region complex in W51, has been subject to detailed observational studies as an example of massive star-forming regions. Near-infrared observations of the entire region of G49.5-0.4 revealed that the region is separated into four subgroups according to their ages, and that 17 O stars in the youngest group were born in the last 0.8 Myr [1]. We have obtained a high-resolution (16″) ^{13}CO (J = 1−0) map of the entire region of G49.5-0.4 to determine the relationship between the morphological and kinematical features of the molecular clouds and the massive star-formation activity [2].

Observations in the ^{13}CO (J = 1−0) line were made with the 45 m telescope at Nobeyama Radio Observatory. We mapped an area of about 15′.3 × 16′.7 centered near W51 IRS 2, with a 17″ grid spacing.

Figure 1 shows position-velocity maps for ^{13}CO cut along three different axes. Here, four discrete molecular clouds were identified toward G49.5-0.4, as shown on the figure. We also found the peculiar morphological feature of each cloud [2]. They are too complicated for us to describe their evolution.

We think that the 60 km s^{-1} cloud was sandwiched between the 56 km s^{-1} cloud and the HV stream, resulting in a “pileup”of the molecular clouds and such a peculiar morphological feature. An abundance of massive stars in W51 IRS 1 also seems to have resulted from the “pileup.”

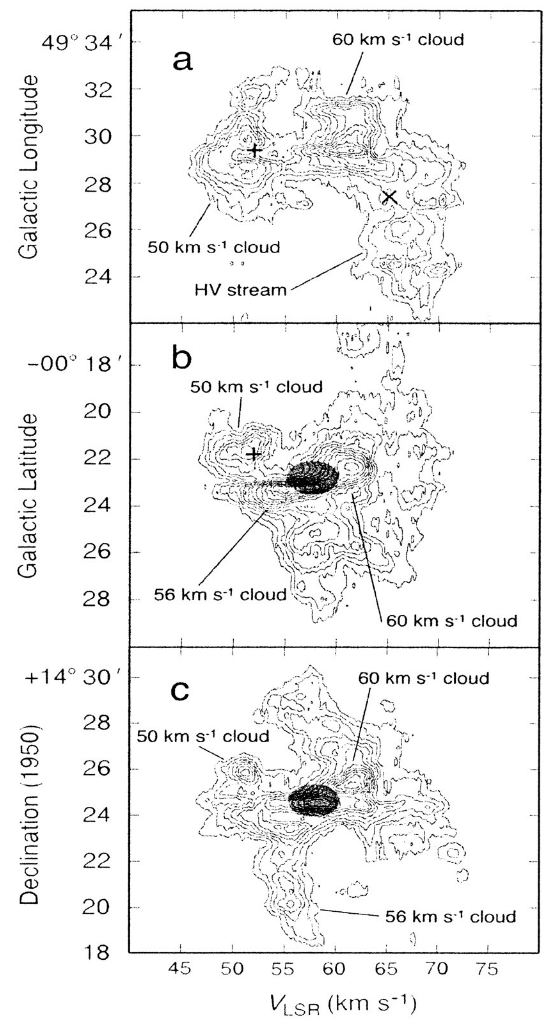

Figure 1: Position-velocity map for ^{13}CO cut along (a) b=−00°22'0, (b) l=49°29'5, and (c) α_{1950}=19^{h}21^{m}24^s. The pluses and the cross indicate the positions of W51 IRS 2 (W51d) and W51b (see [1] and references therein), respectively, and the shaded areas show the positions of W51 IRS 1 (W51e). The labels in the figures show each cloud system identified here.

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Near-Infrared Spectroscopy of the Compact HII Region W51 IRS 2

OKUMURA, Shin-ichiro
(Earth Observation Research Center, NASDA)
MORI, Atsushi, WATANABE, Etsuji
(Okayama Astrophysical Observatory, NAOJ)
NISHIHARA, Eiji
(Gunma Astronomical Observatory)
YAMASHITA, Takuya
(Subaru Telescope, NAOJ)

Massive stars are born in giant molecular clouds and form HII regions around them. Young HII regions are in a state of rapid expansion, therefore, compact/ultracompact HII regions represent very early stages in the lives of massive stars. They provide information on the process of massive-star formation in the clouds in which they form. Most of them are luminous in the infrared and radio wavelength, whereas masked in the visual by extinction. It means that they must be studied in the infrared or longer wavelength.

Medium-resolution (R ~ 460) spectra of the compact HII regions W51 IRS 2 EAST (hereafter IRS 2E) and W51 IRS 2 WEST (hereafter IRS 2W) have been obtained in the *K* window, using a near-infrared camera and spectrograph, OASIS [1]. Brγ, HeI, [FeIII], molecular hydrogen (H_2) lines, and an unidentified line at 2.288 μm were detected [2].

We have measured three [FeIII] transitions and compared the line ratios with the model calculations. The observed line ratios are consistent with the values predicted for $n_e \sim 10^5$–10^6 cm^{-3}. From the observed line ratio of [FeIII] 2.22 μm to Brγ emission, we also derived an average gas phase abundance of log (Fe^{++}/H^+)=−6.3.

We have detected emission in 7 transitions (IRS 2E) and 5 transitions (IRS 2W) of H_2. The rotational and vibrational excitation temperatures, and the ortho-to-para ratios of H_2 were calculated from the observed line ratios. Our results indicate that the excitation of H_2 in both IRS 2E and IRS 2W is dominated by fluorescence, rather than shocks.

The unidentified line at 2.288 ± 0.001 μm was detected with ~ 2% of the intensity of Brγ in both IRS 2E and IRS 2W. There is a possibility that the line is identified as the H_2 3−2 S(2) line at 2.287 μm. However, in IRS 2E, the intensity of the 2.288 μm line is comparable to that of the H_2 1−0 S(1) line, and furthermore in IRS 2W, it is three times larger than that of the 1−0 S(1) line. The observed intensity ratios are hard to be explained by any of the H_2-radiation models. Therefore, we came to the conclusion that this emission is not due to H_2 and it remains unidentified.

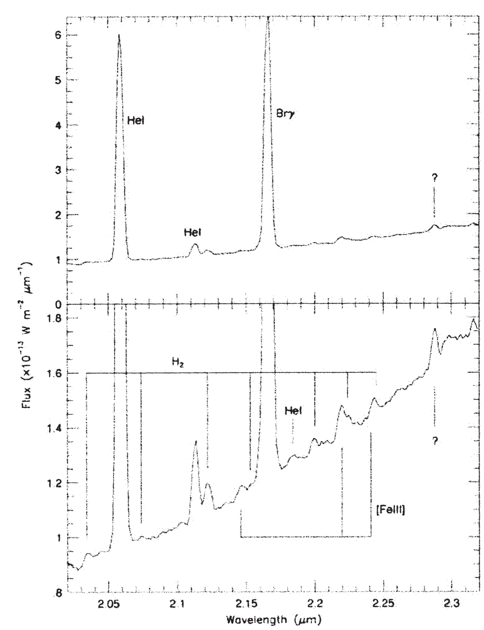

Figure 1: Spectrum of W51 IRS 2E showing bright hydrogen and helium recombination lines (upper) and many other weaker lines (lower).

References

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Acceptance and adaptation of octants and sextants in Japan during the 18th and 19th centuries

NAKAMURA, Tsuko
(Division of Optical and Infrared Astronomy, NAOJ)

This work overviews the introduction, acceptance and adaptation of octants and sextants in Japan during the 18th and 19th centuries. Octants first appear in the Japanese literature in the 1770s. In 1783 Motoki Ryoei, a well-known interpreter and scholar, first translated a Dutch book on octants (1749) by Cornelis Douwes. From that date, octants continued to attract wide interest from Japanese professional and amateur astronomers and land surveyors, and a considerable number of books on octants and sextants were published up to the 1860s. In this study we made clear that C. Douwes played an important role in translating into Dutch the eminent book "Astronomie" by the French astronomer J.J.F. de Lalande, through which the Japanese recognized the decisive superiority of the Western astronomy over the traditional one of Chinese origin. We also found out that, around 1806, an octant was made for the first time by Michikata Kume, the low-ranking vassal of a Daimyo lord in Shikoku. Owing to the strict seclusion policy adopted by the Tokugawa shogunate during the Edo period, the Japanese adapted octants as a convenient instrument for land surveying rather than for navigation, and even unique range finders were also invented as a modification. It was not until after the mid-1850s that octants were used for marine navigation.

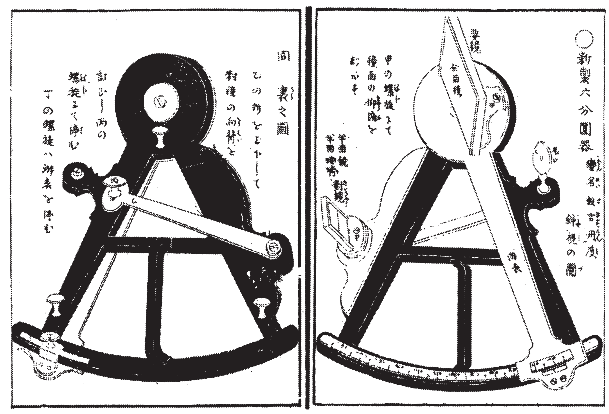

Fig. 1: Sextant designed for land-surveying (from "Rokubungi Ryochi Tebikiso" published in 1852 by Murata Sajuro). Note that there are no sun-glasses.

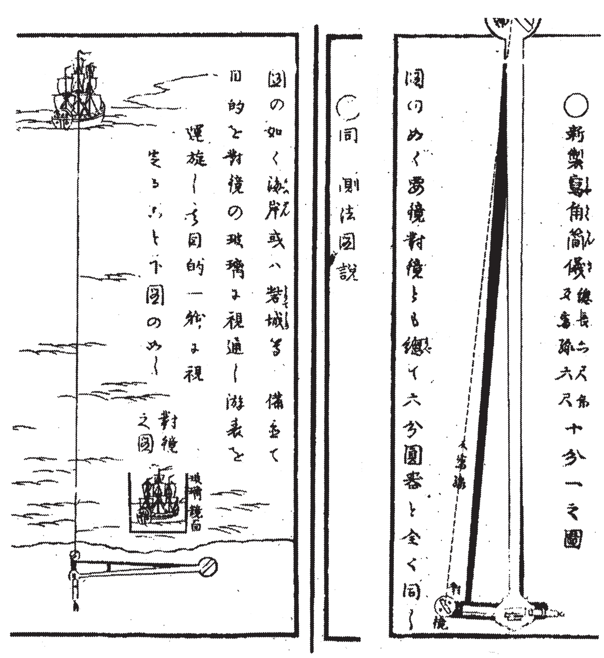

Fig. 2: Range-finder called "Shakaku Kangi" (from "Rokubungi Ryochi Tebikiso").

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[1] Nakamura, T.: 2002, *J. Astron. History and Heritage*, **5**, in press.

Dense Plasma Torus around the Nucleus of NGC 1052

KAMENO, Seiji, INOUE, Makoto
(Division of Radio Astronomy, NAOJ)
SAWADA-SATOH, Satoko, SHEN, Zhi-Qiang, WAJIMA, Kiyoaki*
(The Institute of Space and Astronautical Science)

Some galaxies host Active Galactic Nuclei (AGNs) which emit tremendous power of ~ $10^{35} - 10^{41}$ W. The origin of the power is considered to consist of a massive black hole with accreting matter onto it. Here, we introduce radio observations unveiling 'fuel reserver' associated with an AGN in NGC 1052 at the distance of 60 million light year.

Figure 1 shows the trichromatic radio image of NGC 1052 obtained with the VLBA[1]. Twin jets emanating from the nucleus are symmetric at 15.4 GHz, while the receding jet is fainter than the approaching one at 2.3 GHz as drawn by blue color. Spectral analysis indicates that free-free absorption (FFA) is working towards the receding jet.

FFA is a radiative transfer process that cold dense plasma diminishes radio emission. Its opacity indicates electron density, electron temperature, and path length of the absorbing plasma.

Figure 2a illustrates the distribution of the FFA opacity calculated from the trichromatic images. The opacity along the jet (figure 2b) rapidly decreases towards the approaching jet, while it covers ~ 2 light year towards the receding jet. The asymmetric opacity profile is suggestive of a dense plasma torus perpendicular to the jet (figure 2c), which can be a 'fuel reserver' of AGN. We also found diffuse ambient absorber surrounding the torus, drawn by green curve in figure 2b.

It is remarkable that the spherically symmetric distribution coexists with the torus. The latter should be supported by the centrifugal force by rotation around the nucleus, while the former is supported by the thermal pressure. Our results suggest transition from the radial accretion to rotational accretion.

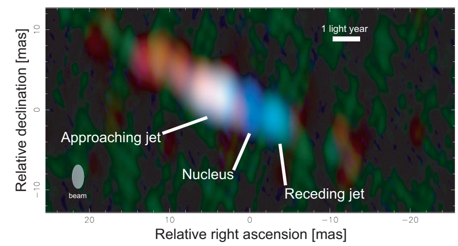

Figure 1: Trichromatic radio image of NGC 1052. Images at 15.4, 8.4, and 2.3 GHz are drawn in blue, green, and red channels, respectively. The western receding jet shows blue color, which indicates absorption at lower frequencies.

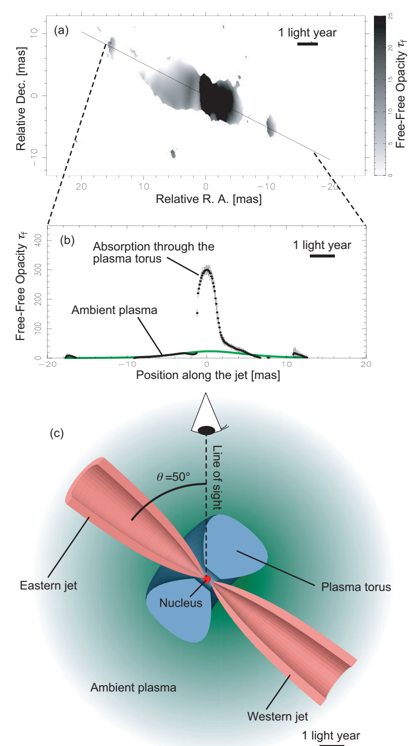

Figure 2: (a): A grayscale distribution of the free-free absorption opacity. (b): The opacity profile along the jet. It peaks at the nucleus and tails towards the receding jet, but rapidly decreases towards approaching jet. (c): A schematic diagram of NGC 1052. A plasma torus perpendicular to the jet is the free-free absorber, which covers the receding jet but does not the approaching one. That is why the opacity distribution is asymmetric.

Reference

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*: Present position: NAOJ

[1]: The VLBA is a facility of the National Radio Astronomy Observatory in U.S.A.

Near-IR study of M16 (SIRIUS first light observations)

SUGITANI, Koji
(Insitute of Natural Sciences, Nagoya City University)
TAMURA, Motohide
(Division of Optical and Infrared Astronomy, NAOJ)
NAKAJIMA, Yasushi, NAGASHIMA, Chie, NAGAYAMA, Takahiro, NAGATA, Tesuya, SATO, Shuji
(Department of Astrophysics, Nagoya University)
PICKLES, Andrew J.
(Institute for Astronomy, University of Hawaii)
NAKAYA Hidehiko
(Subaru Telescope, NAOJ)
FUKUDA, Naoya
(Department of Physics, Chiba University)
OGURA, Katsuo
(Kokugakuin University)

SIRIUS (Simultaneous three-color InfraRed Imager for Unbiased Surveys) has been constructed under the collaboration between Nagoya University, NAOJ, Nagoya City University, and others [1]. We have performed its first light observations in August and October, 2000, on the University of Hawaii 2.2 m telescope. Here we present JHKs imaging study of M16 that were obtained with SIRIUS.

In contrast to optical images, the infrared images show that the Eagle Nebulas pillars have head-tail structures, with the heads faced toward the central part of the star cluster NGC 6611 and the tails trailed toward the opposite side (Fig. 1). We have found a number of previously unreported young stellar object (YSO) candidates associated with these head-tail pillars [2]. In particular, the youngest YSOs are located at the tips of the pillars or globules, facing toward the central part of NGC 6611. Some are associated with near-infrared jets or cometary reflection nebulae, with indications of a circumstellar disk. This YSO distribution and the cloud structures suggest that the most recent star formation is taking place following the interaction with UV light from the OB stars in NGC 6611.

This image was also used for the paper of NMA observation of M16 [3].

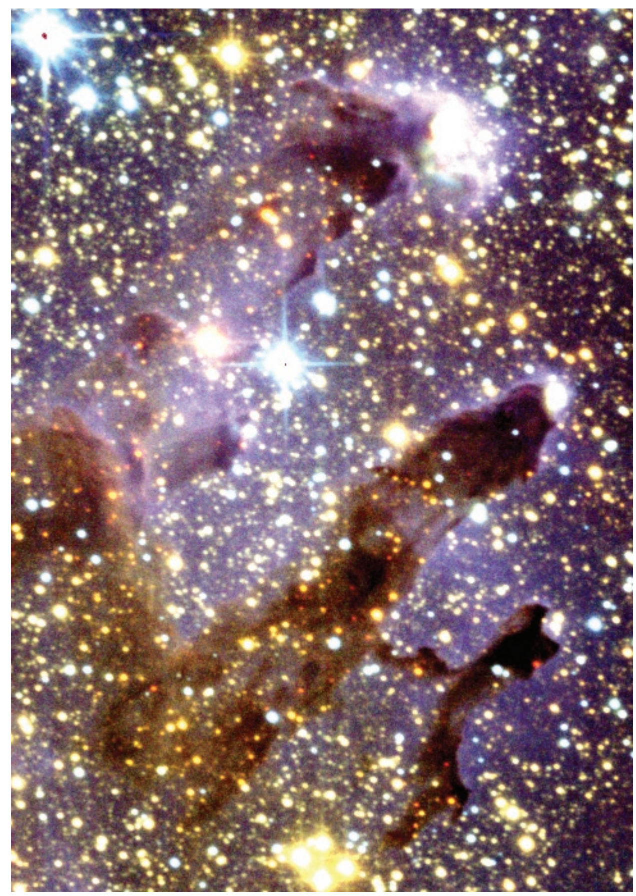

Figure 1: JHKs three-color composite image of M16 (J: blue; H: green; Ks: red) obtained by SIRIUS, which was mounted on the UH 2.2 m telescope. North is up, and east is to the left.

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2 Millimeter Dust around NGC 7538-IRS 1, 2, and 3. I. Unifilled structure of dust

AKABANE, Kenji*, MATSUO, Hiroshi, KUNO, Nario
(Nobeyama Radio Observatory, NAOJ)
SUGITANI, Koji
(Institute of Natural Science, Nagoya City University)

A 2mm continuum mapping observation around NGC 7538-IRS1, 2, and 3 was made by the Nobeyama Bolometer Array (NOBA) with a spatial resolution of 12″. An extended source of ~ 32″ × 44″ ($\Delta\alpha \times \Delta\delta$), having a hardly resolved central core structure, was observed [1]. The core gives flux density of 3.1Jy ± 1Jy and is clearly identified with that from the compact free-free emission region. A smooth and extended source (figure 1) gives an integrated flux density of 5Jy ± 1.5Jy, and an intensity spectrum of $\nu^3 \sim \nu^{3.5}$ in the millimeter wave region. The fitting of a gray body function to the observational data shows that an absorption index β, of 1.8 ~ 2.0, filling factor η, of 0.3 ~ 0.5, and the dust temperature, T_d of 34K ~ 45K are of reasonable parameters for this 2mm extended dust (figure 2, table 1). Astronomical silicate grains were examined for the dust model. The total mass and luminosity were obtained as $M_d = 0.85 \times 10^2\ M_\odot$ and $L_d = 2.2 \times 10^5\ L_\odot$, respectively. The extent of 2mm dust emission partly coincides with those of the 100μm map, of the 57μm map, and of the total intensity of the wing parts of the CO(J=1−0) line emission of the region (figure 1)[2].

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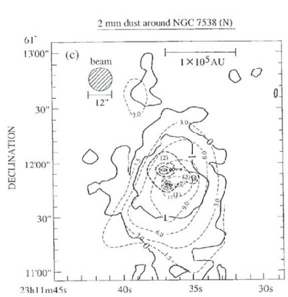

Figure 1: Overlap of the distribution of the both wing parts of CO(J=1−0) line (dashed line)[2] on the present result of 2mm dust (full line)[1].

Table 1: A gray body fitting result

Parameter	
T_{dust}(K)(1)	42
$2r_c$ (pc)(2)	~0.5
β(3)	2.0
Ω_0 (sr)(4)	2.6×10^{-8}
Ω_e (sr)(5)	1.08×10^{-8}
η(6)	0.42
A_e (= $R^2\Omega_e$ m^2)(7)	8.03×10^{31}

(1) Temperature of the dust grain.
(2) Full size of the distributed dust clumps.
(3) Absorption index of dust grains.
(4) Solid angle of the dust clumps.
(5) Total of net solid angle of the dust emission area.
(6) Filling factor of the dust clumps.
(7) Total of net projective area of the dust emission.

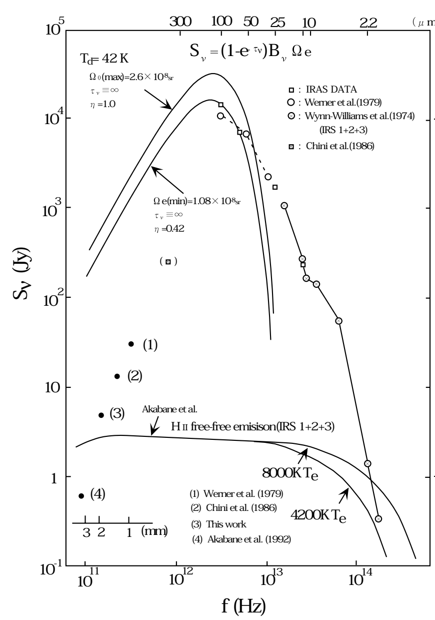

Figure 2: Spectral feature of the sources in the region of NGC 7538(N). Reported mm, sub-mm, far-IR, and mid-IR data of the region are plotted with the referred black body emission profiles[1].

*Professor Emeritus, Tokyo Astronomical Obseravtory, University of Tokyo

Buried AGNs in LINER type ultraluminous infrared galaxies

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

Ultraluminous infrared galaxies (ULIRGs) radiate most of their quasar-like luminosities (> $10^{12}L_{\odot}$) as infrared dust emission. Since the cosmic submillimeter background emission, which reflects the total amount of the cosmic activity hidden by dust, is dominated by discrete sources, similar to ULIRGs, ULIRGs have been used to trace the star formation rate, dust content, and metallicity in the early universe. However, the most important question of whether ULIRGs are powered predominantly by starburst activity or an AGN buried in a thick dust shell is energetically required remains unanswered.

In order to detect the putative buried AGNs and properly evaluate their energetic importance in ULIRGs, it is essential to observe at wavelengths where dust extinction is low. At 3−4 μm, dust extinction is as low as that at 7−8 μm [4], and we can quantitatively distinguish between starbursts and buried AGNs, by using the 3.3 μm PAH emission and 3.4 μm carbonaceous dust absorption (Figure 1). Recent detailed studies have shown that the bulk of the infrared luminosities of ULIRGs originate in compact (< a few 100 pc) nuclear regions and not extended regions [6]. Thus, ground-based slit spectroscopy is better suited than space-based large aperture spectroscopy to find evidence for the putative buried AGNs at the nuclei of ULIRGs, by minimizing the contamination from extended emission.

Theoretically, buried AGNs produce LINER-type optical spectra because an X-ray dissociation region dominated by emission from neutral and singly-ionized species develops around them [5]. We thus performed 3−4 μm spectroscopy of three bright ULIRGs classified optically as LINERs, and found strong evidence for energetically important buried AGNs in two out of the three observed LINER ULIRGs (IRAS 08572+3915 and UGC 5101; see Figure 1). Based on the comparison of the optical depth of the 3.4 μm carbonaceous and 9.7 μm silicate dust absorption, it was also suggested that dust has a strong temperature gradient [1], which favors the presence of a compact energy source, that is, an energetically importance buried AGN. Our result contradicts the widely-held view that LINER ULIRGs are starburst powered. We plan to extend this study to fainter LINER ULIRGs to clarify more unambiguously the energetic importance of buried AGNs in LINER ULIRGs in general.

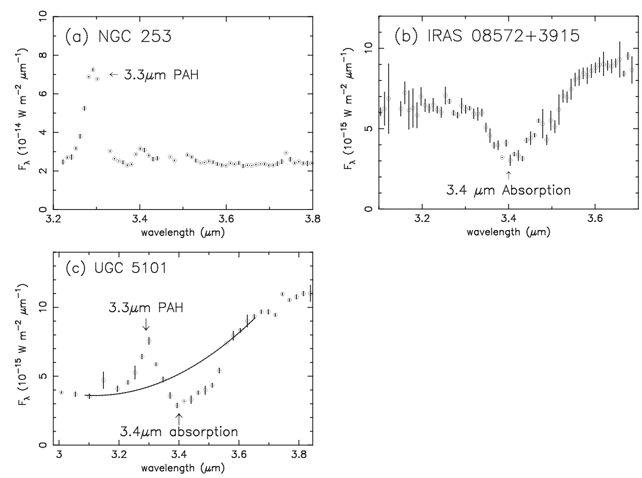

Figure 1: (a) A 3−4 μm spectrum of a starburst powered galaxy (NGC 253) Since the equivalent width of the 3.3 μm PAH emission is, by definition, robust to dust extinction, strong 3.3 μm PAH emission should be always seen regardless of dust extinction of starbursts. (b) A LINER ULIRG powered by a buried AGN (A_V ~ 150 mag), with undetectable starburst activity (IRAS 08572+3915). It shows a strong 3.4 μm carbonaceous dust absorption feature, with no detectable 3.3 μm PAH emission. (c) A LINER ULIRG powered both by an energetically important buried AGN and detectable starburst activity (UGC 5101). The solid line is the adopted continuum level. It shows both the 3.4 μm carbonaceous dust absorption and the 3.3 μm PAH emission, but the equivalent width of the PAH emission is significantly lower than in starburst galaxies. Based on the optical depth of the 3.4 μm dust absorption after subtracting the contribution from starbursts to the observed 3−4 μm fluxes, we can estimate dust extinction *toward the buried AGN* (A_V > 100 mag in this source), and found that the dereddened dust emission luminosity produced by the buried AGN can account for >70% of the infrared luminosity of UGC 5101. Adopted from [2] and [3].

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A list of all integrable two-dimensional homogeneous polynomial potentials with a polynomial integral of order at most four in the momenta

NAKAGAWA, Katsuya
(Graduate University for Advanced Studies/NAOJ)

YOSHIDA, Haruo
(Division of Astrometry and Celestial Mechanics, NAOJ)

A Hamiltonian system with two degrees of freedom is integrable if the system has a first integral which is independent of the Hamiltonian. The purpose of this study is to investigate the conditions for which a Hamiltonian system with a two-dimensional *homogeneous polynomial* potential, defined by

$$H = \frac{1}{2}(p_x^2 + p_y^2) + V(x,y), \tag{1}$$

possesses an additional *polynomial* first integral. The homogeneity of potentials is assumed from the following two reasons:

- The integrability of a non-homogeneous potential depends on the integrability of each of its lowest-degree part and highest-degree part, which means that a study of integrability for homogeneous potentials is the basis of considering integrability for non-homogeneous potentials.
- The system with a homogeneous potential is invariant under a scale transformation, which leads to the weighted-homogeneity of first integrals. As a result, we can simplify the form of first integrals.

Let a polynomial $\Phi(x, y, p_x, p_y)$ be a first integral of the system. Then, the Poisson bracket of Φ and H vanishes identically, which gives an identity for x, y, p_x, p_y. Then, we have simultaneous algebraic equations for the coefficients of the potential and the first integral.

By solving these simultaneous algebraic equations, we can find

$$V = r^k = (x^2 + y^2)^{k/2} \qquad (k = \text{even}) \tag{2}$$

with an additional polynomial first integral {\em linear} in the momenta, and

$$V = \frac{1}{r}\left[\left(\frac{r+x}{2}\right)^{k+1} + (-1)^k \left(\frac{r-x}{2}\right)^{k+1}\right] \tag{3}$$

$$V = Ax^k + By^k \tag{4}$$

with an additional polynomial first integral *quadratic* in the momenta. The potentials (2), (3), and (4) are *separable in polar, parabolic, and Cartesian coordinates,* respectively. In the early 1980s, the following three potentials were discovered with an additional polynomial first integral which is *genuinely quartic* in the momenta.

$$V = x^3 + \frac{3}{16}xy^2 \tag{5}$$

$$V = x^3 + \frac{1}{2}xy^2 + \frac{\sqrt{3}\,i}{18}y^3 \tag{6}$$

$$V = x^4 + \frac{3}{4}x^2y^2 + \frac{1}{8}y^4 \tag{7}$$

According to Hietarinta (1983), these three potentials are the only ones that admit an additional polynomial first integral genuinely cubic or quartic in the momenta if the degree of homogeneous potentials is {\em five or less}.

In this paper [1], the case for homogeneous potentials of an *arbitrary* degree is investigated. As a result, the following theorem is obtained.

Theorem ([1]) *If the degree of the homogeneous potential is five or more, then the system can not have an additional polynomial first integral which is genuinely cubic or quartic in the momenta.*

This theorem, together with the result of Hietarinta (1983), brings a list of all integrable two-dimensional homogeneous polynomial potentials with an additional polynomial first integral of order at most four in the momenta:

- A first integral linear in the momenta: (2)
- A first integral quadratic in the momenta: (3), (4)
- A first integral cubic in the momenta: —
- A first integral quartic in the momenta: (5), (6), (7)

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Submillimeter Imaging Polarimetry of the NGC 7538 Region

MOMOSE, Munetake
(Institute of Astrophysics and Planetary Sciences, Ibaraki University)
TAMURA, Motohide (Division of Optical and Infrared Astronomy,NAOJ)
KAMEYA, Osamu (Division of Earth Rotation, NAOJ)
GREAVES, Jane S. (Joint Astronomy Centre)
CHRYSOSTOMOU, Antonio, HOUGH, Jim H. (Department of Physical Sciences, University of Hertfordshire)
MORINO, Jun-Ichi (Subaru Telescope, NAOJ)

Imaging polarimetry of the 850μm continuum emission in the NGC 7538 region was carried out using the SCUBA Polarimeter. The polarization map is interpreted in terms of thermal radiation by magnetically aligned dust grains. Two prominent cores associated with IRS 1 and IRS 11, IRS 1(SMM) and IRS 11(SMM), are found in the surface brightness map. Although these cores look similar in surface brightness, their polarization shows striking differences. In IRS 11(SMM), the polarization vectors are extremely well ordered, and the degrees of polarization are quite high with an average of ~3.9%. In IRS 1(SMM), on the other hand, the directions of polarization vectors are locally disturbed, and the degrees of polarization are much lower (1.6% in average) than those of IRS 11(SMM). These differences suggest that small scale fluctuations of the magnetic field are more prominent in IRS 1(SMM). This can be interpreted in terms of the difference in evolutionary stage of the cores. Inside IRS 1(SMM), which seems to be at a later evolutionary stage than IRS 11(SMM), substructures such as subclumps or a cluster of infrared sources have already formed. Small scale fluctuations in the magnetic field could have developed during the formation of these substructures. The distribution of magnetic field directions derived from our polarization map agrees well with those of molecular outflows associated with IRS 1(SMM) and IRS 11(SMM). Comparisons of energy densities between the magnetic field and the outflows show that the magnetic field probably plays an important role in guiding the directions of the outflows.

This work [1] was supported in part by the Grant in-aid for Scientific Research of Ministry of Education, Science, Sports and Culture, and by the Japan Society of the Promotion of Science.

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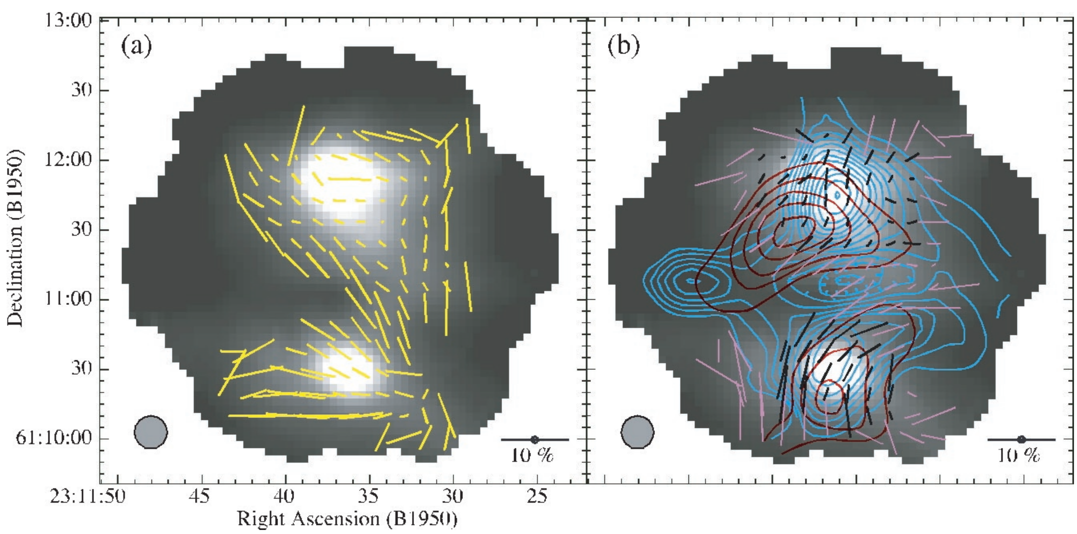

Figure 1: (a) Polarization E vectors of the 850μm continuum emissions (green lines) superposed on the surface brightness map (gray scale). The length of each line is proportional to the polarization degree. (b) Magnetic field directions derived from the polarization vectors in (a) (black and violet lines) superposed on the distribution of CO(J=3−2) high-velocity outflows [2] (contours). The black lines indicate field directions inside the regions where the flux density is higher than 10 % of the IRS 1(SMM) peak while the violet lines indicate those outside the regions. The blue and red contours show the distribution of the CO(J=3−2) emissions integrated over V_{LSR} = −74 to −64 km s^{-1} and V_{LSR} = −54 to −44 km s^{-1}, respectively.

The Spin Temperature of NH_3 in Comet C/1999S4 (LINEAR)

KAWAKITA, Hideyo (Gunma Astronomical Observatory)
WATANABE, Jun-ichi (Public Information Office, NAOJ)
ANDO, Hiroyasu, FUSE, Tetsuharu, OKITA, Kiichi, USUDA, Tomonori
(Subaru Telescope, NAOJ)
AOKI, Wako, HONDA, Satoshi, KAJINO, Toshitaka, NOGUCHI, Kunio, KAWANOMOTO, Satoshi
(Division of Optical and Infrared Astronomy, NAOJ)
IZUMIURA, Hideyuki, WATANABE, Etsuji, YOSHIDA, Michitoshi
(Okayama Astrophysical Observatory, NAOJ)
SATO, Bun'ei
(Okayama Astrophysical Observatory, NAOJ, Department of Astronomy, School of Science, University of Tokyo)
KAMBE, Eiji (Department of Earth and Ocean Sciences, National Defense Academy)
SADAKANE, Kozo (Astronomical Institute, Osaka Kyoiku University)
TAKADA-HIDAI, Masahide (Liberal Arts Education Center, Tokai University)
TAKEDA, Yoichi (Komazawa University)

A high dispersion spectrum of Comet C/1999 S4 (LINEAR) was obtained in the optical region using the high dispersion spectrograph (HDS) on the Subaru telescope when the comet was 0.863 astronomical units (AU) from the Sun before its disintegration. We obtained high signal-to-noise ratio emission lines of the cometary NH_2 bands from which an ortho-to-para ratio (OPR) of 3.33±0.07 was derived on the basis of a fluorescence excitation model. Assuming that cometary NH_2 mainly originates from ammonia through photodissociation, the derived OPR of NH_2 molecules should reflect that of ammonia, which provides information on the environment of molecular formation or condensation and of the thermal history of cometary ices. It can be safely assumed that the OPR of ammonia in comets was unchanged in the nucleus. If the OPR equilibrated to the temperature of icy dust mantle in the solar nebula, the derived OPR suggests the temperature of about 28 K. This may indicate a formation region of the cometary ammonia ice between the orbit of Saturn and that of Uranus in the solar nebula [1].

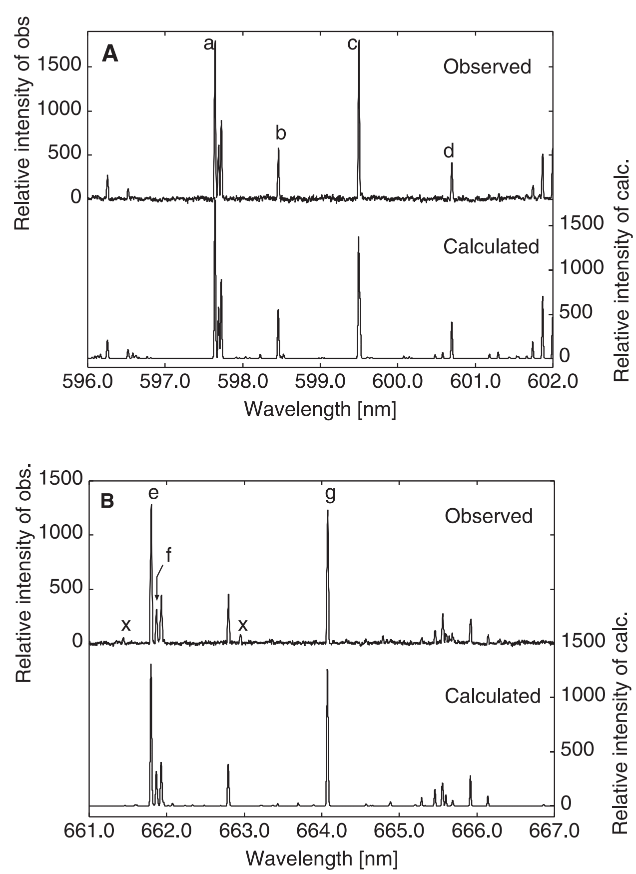

Figure 1: Spectra of NH_2 $\tilde{A}$ (0, 9, 0) and $\tilde{A}$ (0, 7, 0) bands in comet C/1999 S4 (LINEAR) and the synthetic spectrum based on the fluorescence equilibrium calculation.

Reference

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Wide-Field TV Observation of the Leonid Meteor Storm in 2001: Main Peak over Japan

WATANABE, Jun-ichi
(Public Relations Center, NAOJ)
SEKIGUCHI, Tomohiko
(Division of Radio Astronomy, NAOJ)
SHIKURA, Masato
(Departmernt of Physics, Science University of Tokyo)
NAITO, Seiichiro
(Department of Astronomy, School of Science, The University of Tokyo)
ABE, Shinsuke
(The Institute of Space and Aeronautical Science)

The world-wide campaign of the Leonid meteor shower performed until 2000 resulted in great success. One of the important advances in meteor science is on the structure of the spatial distribution of meteoroids in the meteor stream, which consists of several narrow dust trails. Each trail was formed by meteoroids ejected at a particular return of the parent comet. Based on this concept, several researchers performed a detailed calculation, which resulted in great success for reproducing the observed time profile of the Leonids activity.

According to these so-called "dust trail" theories, the Leonid meteor shower was expected to show a strong display between 17h 00m and 18h 30m UT in 2001 November 18 by two dense dust trails of 1699 and 1866. These predictions suggested that Japan would be one of the best observational site.

As same as our observations in 1998[1] and 1999[2], we carried out a wide-field TV observation at Iwaki city, Fukushima prefecture, from 17h17m UT through 20h20m UT on 2001 November 18[3]. We used a lens with the shortest focal length (f = 3.8 mm, F0.8, HG3808AFCS-HSP, CBC Co.). The combination of the back-up camera with this lens giving a wide field of view of 80˚.6 × 65˚.0, along with a limiting magnitude of 3.5. We detected 869 Leonid meteors, along with 32 non-Leonids. A broad main-peak of the activity was recognized at around 18h25m UT, when the peak influx rate of meteoroids was 1.4 × 10^{-5} km^{-2} s^{-1} (mag ≤ +3). The activity of this main peak was comparable to that of a storm observed in 1999 over Europe.

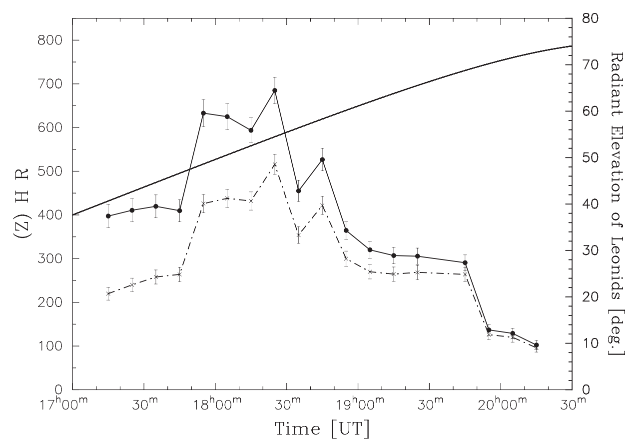

Figure 1: Time variation of the number of Leonid meteors detected in our TV observation on 2001 November 18. The dash-dotted line is the hourly rate of the number of meteors observed in a 15 min interval, and the solid line is the number after a correction for the radiant-point elevation. The solid curve is the elevation of the radiant point.

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Optical Follow-up of the GRB 010222 Afterglow by Subaru Telescope

WATANABE, Jun-ichi
(Public Relations Center, NAOJ)
KINOSHITA, Daisuke
(Graduate University for Advanced Studies/NAOJ)
KOMIYAMA, Yutaka, FUSE, Tetsuharu
(Subaru Telescope, NAOJ)
URATA, Yuji
(Departmernt of Physics, Science University of Tokyo)
YOSHIDA, Fumi
(Graduate School of Science and Technology, Kobe University)

Gamma Ray Bursters (GRBs) are thought to be the most violent phenomena in the universe. Follow-up observations at various wavelength are necessary to reveal the nature of GRBs. However, the difficulty of such a follow-up still remains mainly concerning the unexpected nature of the time and position of GRBs. Therefore, some coordinated cooperations should be necessary for the follow-up of the GRBs by many researchers including those in the other field.

When we were performing a deep survey observation for the Edgeworth-Kuiper belt objects on 2001 February 21 using the Suprime-Cam of the Subaru telescope at Mauna Kea, we received an alert concerning the appearance of Gamma Ray Bursts (GRB 010222), which appeared on Feb. 22, 07:23:30 U.T. The message also stated that this GRB 010222 was a very bright GRB, possibly the brightest ever observed by BeppoSAX [1]. We decided to dedicate a part of our telescope time to observe the optical afterglow of GRB 010222[2]. The obtained *R*-band magnitude was 18.59 ± 0.04 at February 22.51 UT, 18.99 ± 0.04 at February 22.65 UT, and 21.76 ± 0.03 at February 25.64 UT. The light curve made from all data reported so far shows the decay of the brightness with a broken power law, of which the indices are −0.92 ± 0.01 before and −1.27 ± 0.01 after the break. The break point of the light curve is 0.73 ± 0.02 d after the burst, which is the earliest example ever observed.

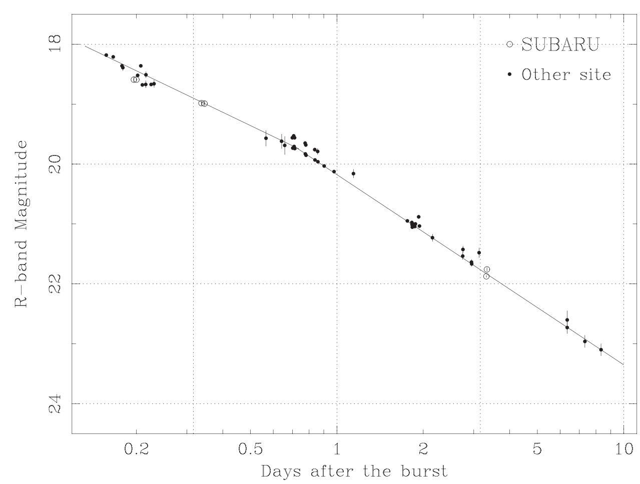

Figure 1: Time variation of the brightness of GRB 010222. Time is counted by day from 22.308 UT. The open circles are our data, while others are data taken by GCN circulars (GCN967 A. Henden et al., GCN 970 K. Z. Stanek et al., GCN 973 P. A. Price et al., GCN 975 J. P. U. Fynbo et al., GCN 983 K. Z. Stanek et al., GCN 985 N. Masetti et al., GCN 990 A. Oksanen et al., GCN 991 K. Z. Stanek & E. Falco, GCN 992 G. Valentini et al., GCN 998 & 1000 C. Veillet, GCN 1002 S. Holland et al.). The light curve was fitted by a power law together with a break at 0.73 d after the burst.

References

[1] Piro, L.: 2001, *GCN Circ.*, 959.

[2] Watanabe, J., Kinoshita, D., Komiyama, Y., Fuse, T., Urata, Y., Yoshida, F.: 2001, *Pub. Astron. Soc. Japan*, **53**, L27–L31.

Development of a new GPS device for precise timing measurements

SÔMA, Mitsuru
(Division of Astrometry and Celestial Mechanics, NAOJ)
HAYAMIZU, Tsutomu
(Sendai Space Hall),
GESHIRO, Hiroyuki
(Oishikogen Astronomical Observatory)

The Japanese shortwave JJY time signals were shut down on 2001 March 31st. Instead the longwave time signals are now emitted at 40 and 60 kHz, and inexpensive clocks and watches controlled by those signals are on the market. However according to our measurements those radio-controlled clocks have typically delays of 0.1s to 0.3s, and therefore they cannot be used for precise timing observations [1].

The longwave JJY time signals have only a carrier wave of 40 kHz or 60 kHz and by changing the length of the carrier signal of each second they provide binary codes of the date, time, etc. In the case of the longwave WWVB time signals the binary codes are provided by different reduction percentage of the amplitude of the carrier. Both of JJY and WWVB have no audio component, and we understand that most of the longwave time signals in the world are of the same kinds. Therefore, in order to make the signals audible, it is needed to use the CW mode of the receivers and a filter of about 500 Hz, which can cause a delay of about several tens of milliseconds. This fact demonstrates that it is very hard to get a precise pip sound at each second like the shortwave time signals.

As seen above there was no simple way of using the longwave time signals for precise timing measurements. Accordingly we designed equipment, called the GHS clock, that can be used with inexpensive GPS receivers to produce both an LED flash and a pip sound at the beginning of each second [2][3]. GHS stands for Geshiro-Hayamizu-Sôma, which comes from the names of the authors of the equipment. According to the GPS receiver manual, this device has an accuracy better than 500 nano-seconds, and our tests show that it usually has an accuracy better than 200 nano-seconds. A brief description of the GHS clock is also given in [4].

The GHS clock provides both a shortwave JJY like pip sound and an LED flash at each second, so that it can be used by those who have used the shortwave JJY time signals and it can also be used by video observers who want to get precise timing measurements of astronomical phenomena.

The users can make their own GHS clocks according to their elaborate plans. Fig. 1 shows an example of a microcomputer-installed GHS clock, which can display the date, the time, the geodetic coordinates of the station, the true local solar time, the local sidereal time, and the hour angle of Polaris on the liquid crystal screen.

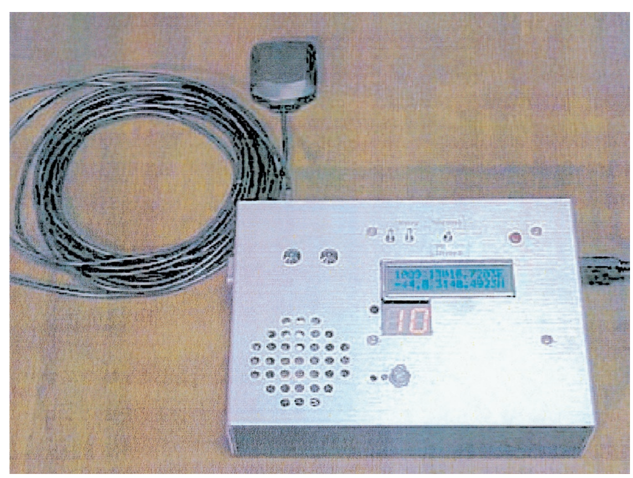

Figure 1: Microcomputer-installed GHS clock

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[2] Hayamizu, T., Geshiro, H., and Sôma, M.: 2000, *The Astronomical Herald*, **93**, 720–727 (in Japanese).
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[4] Nugent, R.: 2000, *Occultation Newsletter*, **8** (2), 3–5.

High-beta Disruption in the Solar Atmosphere

SHIBASAKI, Kiyoto
(Division of Radio Astronomy, NAOJ)

The outer layers of X-ray loops in solar flares are known to be more active: they are hotter than the lower loops and above-the-loop-top hard X-ray sources are formed there. These phenomena are interpreted as the result of the reconnection above the loop, which convert magnetic energy into thermal and non-thermal energy of plasma. However, little direct evidence for the reconnection has been presented so far. This paper interprets the activity in the outer layer of flaring loops on a different scenario. Coronal loops filled with hot and dense plasma (high beta) or with fast plasma flow, surrounded by the low-beta corona, are unstable at their outer boundary where the curvature is convex outward and the density gradient is inward. The centrifugal force acting upward on the plasma in the loop can exceed that of gravity. This condition is favorable for localized interchange instability called "ballooning instability" and the plasma in the loop is ejected when the instability has developed into non-linear phase ("high-beta disruption"). This is a natural consequence of the high-beta (and/or the high velocity) plasma confined in a curved coronal loop. The high-beta disruption has many elements common to solar flares. In this paper, importance of the high-beta plasma is stressed, which is a neglected part of the solar activity so far.

Reference

[1] Shibasaki, K.: 2001, *Astrophys. J.*, **557**, 326.

Sunspot Magnetic Fields Observed with a Large-Format Infrared Array

SAKURAI, Takashi
(Solar Physics Division, NAOJ)
YANAGISAWA, Kenshi
(Okayama Astrophysical Observatory, NAOJ)
KOBIKI, Toshihiko
(Norikura Solar Observatory, NAOJ)
KASAHARA, Shouichi
(Faculty of Science and Technology, Meisei University)
NAKAKUBO, Kayoko
(Suginami Science Center, Tokyo)

Magnetic fields on the sun are usually measured by the Zeeman effect of spectral lines. The sensitivity of magnetic field measurement depends on the width of spectral lines and the magnitude of the Zeeman splitting. The former increases linearly in wavelength, while the latter increases in proportion to the square of the wavelength. For example, in the *H*-band region (1.5-1.8 μm) in the infrared, we can achieve a three-times higher sensitivity compared to the visible wavelengths near 5000 Å.

We have carried out spectro-polarimetric observations of sunspots by using a PtSi near-infrared camera (KONIC) of Kiso Observatory, The University of Tokyo, in November 1999. The detector has a format of 1040 × 1040 pixels. The camera was attached to a spectrograph of the Domeless Solar Telescope at Hida Observatory, Kyoto University. Because the quantum efficiency of the PtSi detector is low (about 2%), the exposure time was a few seconds with a dispersion of 1.4 Å/mm.

We observed the absorption lines of Fe I at 15648.5 Å (Landè factor $g_L = 3$) and derived the distribution of the magnetic field strengths and inclination angles across the sunspots. Figure 1 shows completely split Zeeman components from a sunspot whose field strength was 2400 Gauss.

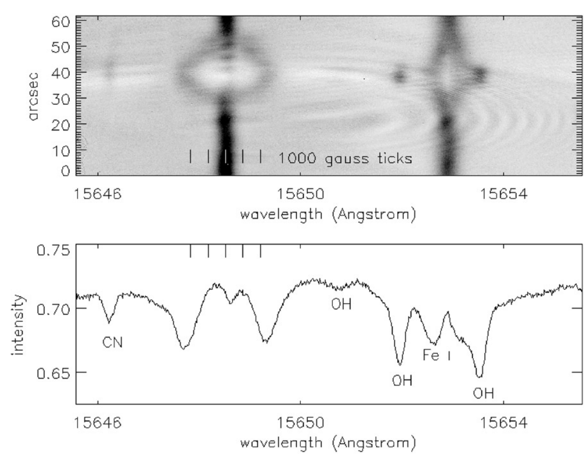

Figure 1: The spectra of a sunspot (NOAA region 8747, 1999 November 3). The spectrum at the top panel has been divided by the intensity integrated over the wavelength, so that the sunspot does not show up dark, but the location of the spot is readily inferred by the large Zeeman splitting. The bottom panel is a profile of the upper panel through the umbra. The tick marks shown at the Fe I 15648.5 Å (g_L = 3) line on the left indicate a Zeeman splitting of each 1 kG. The line on the right is Fe I 15652.9 Å (g_L = 1.53).

Reference

[1] Sakurai, T., et al.: 2001, *Publ. Astron. Soc. Japan*, **53**, 923.

Flexible Prism Used as an Image Stabilizer

SAKURAI, Takashi
(Solar Physics Division, NAOJ)
NOGUCHI, Motokazu, SHINODA, Kazuya, TANAKA, Nobuyuki
(Norikura Solar Observatory, NAOJ)

The image motion due to atmospheric turbulence (seeing) or vibration of a telescope degrades the quality of observed images. An image stabilizer made of a small 'tip-tilt' mirror is often used to compensate for the image motion. An inconvenient aspect of the tip-tilt mirror is that it bends the optical path. Unless it is planned from the beginning, the existing optical system has to be modified considerably to incorporate the tip-tilt mirror.

We have developed a new image-stabilizing scheme by using a flexible prism [1]. This kind of prism is now widely used as an anti-vibration scheme in hand-held video cameras. An advantage of this scheme is that we simply put the prism into the existing optical path to correct for the image motion.

The prism we use as an image stabilizer is manufactured by Canon (the registered brand name is 'vari-angle prism'). Canon produces a vibration-stabilized binocular equipped with this prism. The aperture is 40 mm, and it responds to frequencies up to 20 Hz.

Figure 1 shows the prism. The prism is made of two plates of glass whose peripheries are connected by a bellows. In the volume sealed by two glass plates and the bellows is contained a liquid, so that the glass plates can be tilted. The tilt axes of the two glass plates are oriented 90˚ from each other, so that by properly tilting both glass plates, the light beam can be deflected to any direction within a few degrees. The tilt of the prism is driven by two solenoid coils.

Figure 2 shows the performance of the prism tested on the Solar Flare Telescope at Mitaka. Although the response speed of 20 Hz is not fast enough to fully compensate for the seeing effect, it is effective in removing low frequency vibration of the telescope due to winds. The prisms have been equipped on the Solar Flare Telescope since 1995.

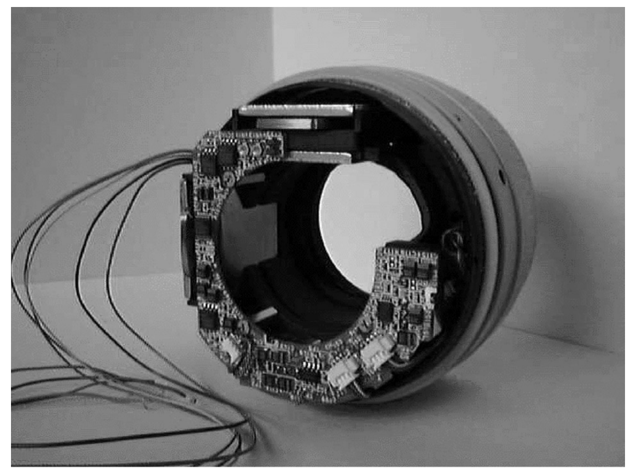

Figure 1: The prism. The aperture is 40 mm.

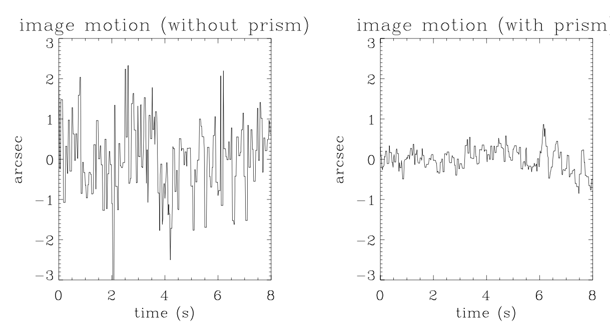

Figure 2: Positions of the solar image from the telescopes without (left) and with (right) the prism, observed simultaneously. The image motion was suppressed to less than 1″ by the prism.

Reference

[1] Sakurai, T., et al.: 2001, *Solar Phys.*, **205**, 201.

Interpolation of One- and Two-Dimensional Images with Pixelwise Photon Number Conservation

SAKURAI, Takashi, SHIN, Junho
(Graduate University for Advanced Studies/NAOJ)

The interpolation of one- and two-dimensional images is considered. The usual linear or cubic-spline interpolations try to connect given data points. On the other hand, image data give area integrals of the radiation intensity (i.e. photon counts) over pixels. Our problem in one-dimensional case is to find an interpolating function $y(x)$ which, after integration over pixels, gives the prescribed photon counts.

We adopted the variational principle in which the linear and cubic-spline interpolations, respectively, minimize the energy of tension and bending. When the constraint of prescribed photon counts is added by using the Lagrange's multiplier, we obtain the quadratic and fourth-order polynomials, respectively, as extensions of linear and cubic-spline interpolations. A similar technique has been developed for two-dimensional data. These methods were tested on some simple examples and showed satisfactory results [1].

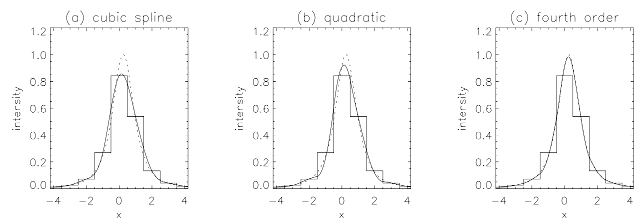

Figure 1: The dotted curves represent the original data, and the step functions indicate the sampled data with an image detector. If one uses a simple cubic-spline interpolation (left), the difference between the original function and the interpolated curve is large. The quadratic (middle) and fourth-order (right) interpolations recover the observed photon counts (represented by step functions) exactly. The difference between the original function and the interpolated curves is small.

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[1] Sakurai, T., and Shin, J.: 2001, *Publ. Astron. Soc. Japan*, **53**, 361.

Chromospheric Magnetic Field of Solar Active Regions

CHOUDHARY, Debi Prasad
(Udaipur Solar Observatory, India)
SAKURAI, Takashi
(Solar Physics Division, NAOJ)

The three-dimensional structure of magnetic field of 137 solar active regions is studied by comparing the observed and computed chromospheric field. The data used are magnetograms of the photosphere and the chromosphere obtained at NSO Kitt Peak. Chromospheric magnetograms are obtained by observing the Ca II 8542 Å line, which is formed 800 km above the photosphere. We computed the potential magnetic field at this height by using the observed photospheric field as the boundary condition, and compared it with the observed chromospheric field.

In the low field range, within ± 300 G, most of the observed field is close to the potential field. For field values greater than ± 500 G, we frequently found large deviations from the potential field. The long-lived active regions, which make multiple disk passages, show marked non-potentiality during their initial phase. During the decaying phase they converge to potential field configuration.

The deviation of the observed chromospheric field from the computed potential field extrapolated from the photosphere can be a good indicator for flare productivity of the region. This property can be useful in the framework of space weather forecast and flare prediction.

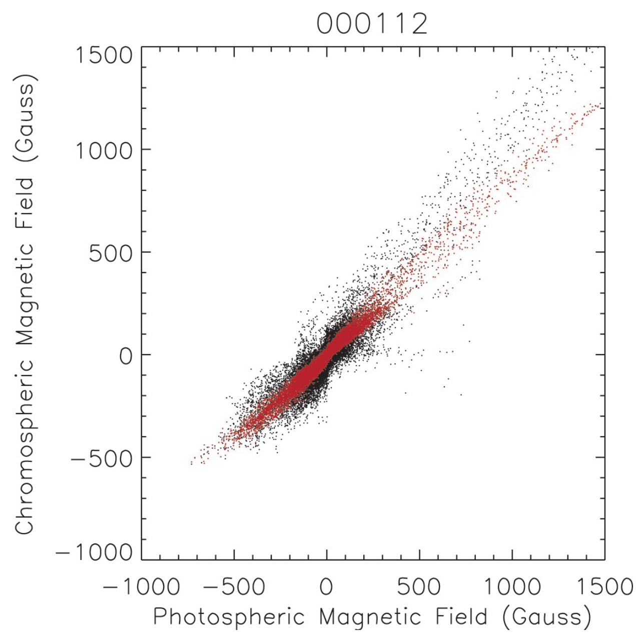

Figure 1: The scatter plot of the photospheric (abscissa) and chromospheric (ordinate) magnetic field strengths in active region NOAA 8821 on 12 January 2000. The black and red dots are the observed and computed chromospheric fields, respectively.

Reference

[1] Choudhary, D. P., Sakurai, T., and Venkatakrishnan, P.: 2001, *Astrophys. J.*, **560**, 439.

Radial distribution of molecular gas in galaxies

NISHIYAMA, Kota, NAKAI, Naomasa, KUNO, Nario
(Division of Radio Astronomy, NAOJ)

We have studied the distribution and dynamics of molecular gas in galaxies by observing CO emission mainly along the major and minor axes of 28 nearby spiral galaxies with the 45-m telescope of the Nobeyama Radio Observatory. The observations showed that the surface density of molecular gas indicates an exponential distribution in the region of the flat (differential) rotation curve for all the galaxies. This could be because the radial distribution is determined by gas inflow due to the viscosity of molecular clouds. The surface density of molecular gas in barred galaxies also shows a characteristic distribution in the region of the bar, suggesting gas inflow along the bar by the bar potential and perpendicular to the bar by viscosity. Such a transfer of molecular gas increases the gas density in the central region, probably causing the evolution of the rotation curve, which is determined by the mass distribution, on the time scale of the galaxy age. We compared the radial distribution of the surface density of HI with that of H_2, and found same scale length of the exponential distribution in the Virgo galaxies and a much larger scale length in field galaxies for HI. This could be due to a difference in the viscosity coefficient of the HI gas.

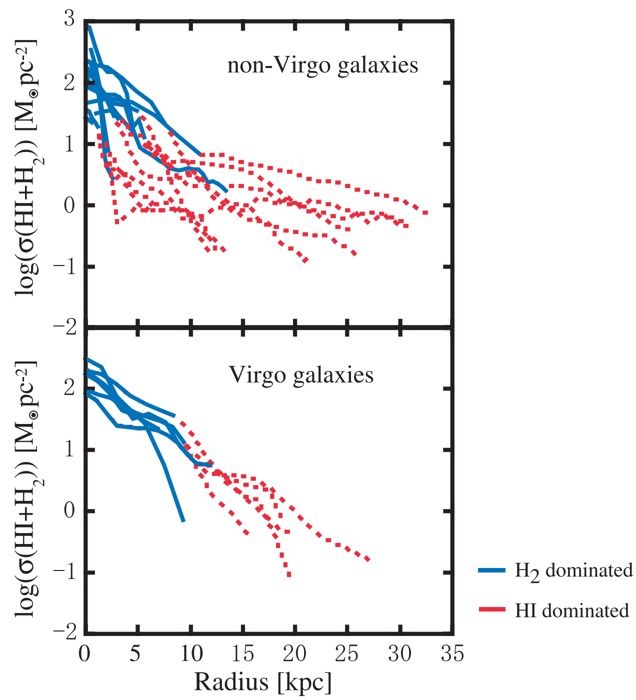

Figure 1: Radial distributions of the total gas (H_2 + HI) of molecular and atomic gas in non-Virgo galaxies (upper) and Virgo galaxies (lower). The blue and red lines indicate the H_2- and HI-dominated regions, respectively.

References

[1] Nishiyama, K., and Nakai, N.: 2001, *PASJ*, **53**, 713.
[2] Nishiyama, K., Nakai, N., and Kuno, N.: 2001, *PASJ*, **53**, 757.

Discovery of a water megamaser in a starburst galaxy NGC 6240

NAKAI, Naomasa (Division of Radio Astronomy, NAOJ)
SATO, Nahoko (NAOJ/Hokkaido University)
YAMAUCHI, Aya (NAOJ/Kyushu University)

We detected a water-vapor maser emission in a prototypical ultraluminous FIR galaxy with an AGN, NGC 6240. The flux density of the detected maser line was *S*=96 mJy at a distance of 100 Mpc, which is typical for water megamaser. The maser line was redshifted by 204 km/s relative to the systemic velocity of the galaxy, while no systemic velocity feature was detected. The previous observed upper limits were at a level lower than the present flux density, indicating that the water maser in NGC 6240 flared up by more than a factor of 5 in 2001.

References

[1] Braatz, J. A., Wilson, A. S., and Henkel, C.: 1996, *ApJS*, **106**, 51.
[2] Claussen, M. J., and Lo, K.-Y.: 1986, *ApJ*, *308*, 592.
[3] Henkel, C. et al.:1984, *A&A*, **141**, L1.
[4] Nakai, N., Sato, N., and Yamauchi, A.: 2002, *PASJ*, **54**, L27.

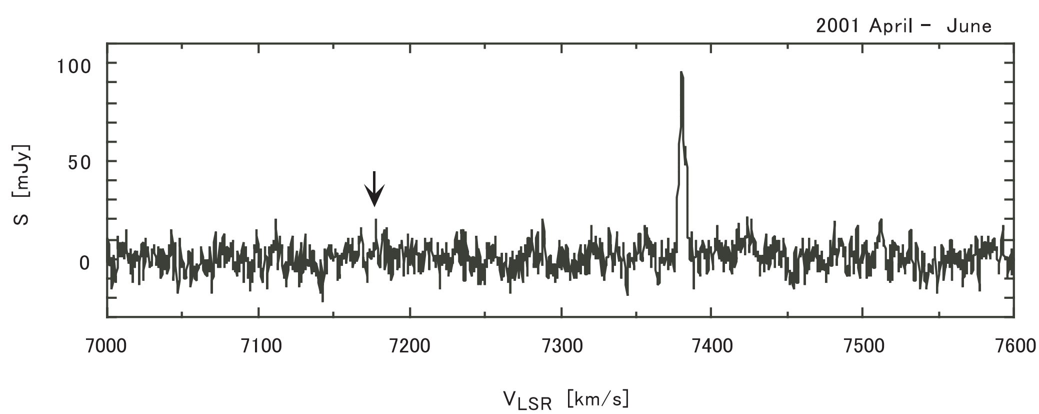

Figure 1: Water-vapor maser spectrum of NGC 6240 measured with the 45-m telescope of the Nobeyama Radio Observatory. The arrow indicates the systemic velocity of the galaxy.

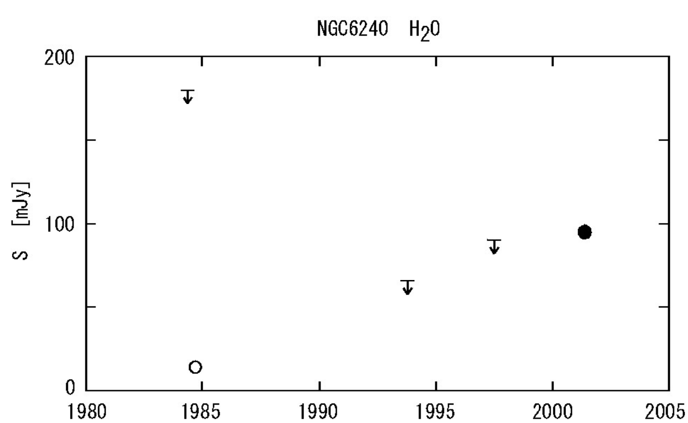

Figure 2: Peak flux densities of the water-vapor maser emission from NGC 6240 measured until 2001. [1] [2] [3] [4] The unfilled circle indicates a possible detection in 1984 September [3] and the filled circle the present result. The upper limits are 3 rms.

Spectroscopic Studies of r-Process Elements in Extremely Metal-Poor Stars with Subaru HDS and Cosmochronometry

HONDA, Satoshi, AOKI, Wako, ANDO, Hiroyasu, NOGUCHI, Kunio
(Division Optical and Infrared Astronomy, NAOJ)
KAJINO, Toshitaka
(Theoretical Astrophysics Division, NAOJ)

We obtained high resolution (R = 50,000 ~ 90,000), high quality (S/N = 50 ~ 400) spectra of 22 metal-poor stars for precise abundance studies with High Dispersion Spectrograph (HDS) fabricated for the Subaru Telescope.

We found that Mg, Si, Ca, and Ti show overabundances compared with Fe, and the abundances of iron-peak elements show small dispersion. Compared with the abundances of these elements, those of neutron-capture elements show large dispersion as found by previous studies. The dispersion can be interpreted as a result of incomplete mixing of the interstellar medium at the beginning of the Galaxy formation.

The Ba to Eu ratios in metal-poor stars observed in our program are nearly equal to that of the solar system r-process component. This result proves that these elements are primarily synthesized by r-process. The abundance patterns of the heavy neutron-capture elements ($56 \le Z \le 69$) in seven objects with excesses of the neutron-capture elements are similar to that of the solar system r-process component. However, the abundance patterns of neutron-capture elements ($56 \le Z \le 69$) in two of them show significant deviation from that of the solar system r-process component, which can not be explained only by the uncertainty of the analysis. This result suggests that s-process nucleosynthesis contributes to the production of neutron-capture elements in these objects, or small variation exists in the abundance pattern of elements produced by the r-process in the range of $56 \le Z \le 69$. On the other hand, the abundance ratios of light neutron-capture elements ($38 \le Z \le 46$) to heavier ones ($56 \le Z \le 69$) show a large dispersion. This result supports previous suggestions that the light neutron-capture elements have been produced in the different sites from those for heavy ones.

The abundance ratio of the radio-active element Th (Z = 90) to stable one (e.g., Eu) in very metal-poor stars has been used as a cosmochronomter in some previous works. Th is detected in seven stars in our sample. The Th/Eu abundance ratios ([Th/Eu]) distribute from −0.30 to −0.67. These values correspond to the ages of only a few or zero Gyrs, when we assume the initial Th/Eu abundance ratio is the same as that of the solar system. These are too short as the ages of very metal-poor stars, which are believed to be formed in the early Galaxy. This result means that the universality of the abundance pattern of the neutron-capture elements can not be extended to Th (Z = 90) by using the solar system r-process component. Th/Eu is not a good chronometer for metal-poor stars.

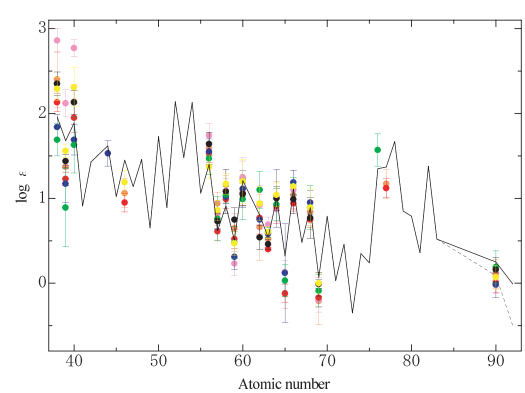

Figure 1: Scaled abundances in our objects compared with the solar system r-process compornent.

Small Fluctuation of Coronal X-Ray Intensity : Possibility of Nanoflare Heating

KATSUKAWA, Yukio
(University of Tokyo/NAOJ)

TSUNETA, Saku
(Solar Physics Division, NAOJ)

Small flare ("nanoflare") is one of the possible mechanisms to heat the solar corona, in which many energetically small transient events continuously occur and heat the corona. A simple method to probe the nanoflare heating scenario is counting of transient events such as flares and microflares observed in X-rays and EUV. Energy of each event and occurrence rate give total heat input into the corona by such events. Many works have been performed until now, and showed that events which can be identified as discrete ones (energy ranges from 10^{24} to 10^{33} erg) do not supply enough energy to heat the corona. Thus, it is important to investigate whether much smaller energy events occur more frequently. However, such tiny events may be unable to be identified as discrete events, and new approaches are required.

In this work, we suggest a new but simple approach to analyze time variation of the corona. We extract persistent component in time profiles of X-ray intensity, and calculate mean intensity. Then, we make histograms about deviation from the mean intensity. Fluctuation of the X-ray intensity can be characterized quantitatively by the width of the histograms. If the histograms are broader than noise distribution, it means that X-ray intensity fluctuates and tiny events are occurring in the corona.

We use images of an active region obtained by *Yohkoh* Soft X-ray Telescope (SXT)(Figure 1) in this analysis. The histograms mentioned above are made for different intensity levels (Figure 2). The histograms are found to consist of two components; Gaussian-like distribution around the center, which corresponds to random fluctuation around the mean intensity, and wing component, which corresponds to systematic time variation of X-ray intensity. Since we are here interested in small fluctuation around the mean intensity, we extract the central Gaussian-like component, and measure the width of the histograms. Of course, noises of SXT cause false fluctuation. We evaluate all noise sources accurately, and compare the observed histogram width with the predicted noise level.

In dark regions (Figure 2[a]), the fluctuation of X-ray intensity is almost due to the noise. On the other hand, the histogram in bright regions (Figure 2[b]) is found to be broader than the predicted noise distribution. This means that some fluctuating sources exist in the solar corona. We attribute the observed small fluctuation to the signature of nanoflares. We also estimate the energy of nanoflares from the observed fluctuation of X-ray intensity. The estimated energy is about 10^{20} erg, and is much smaller than the energy of theoretically predicted nanoflares (10^{24} erg).

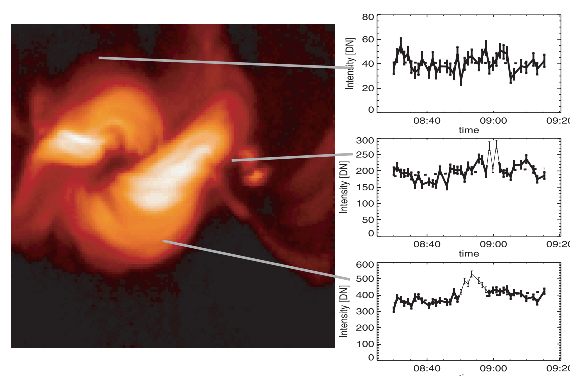

Figure 1: Soft X-ray image of an active region obtained by Yohkoh (left), and sample light-curves of the X-ray intensity (right).

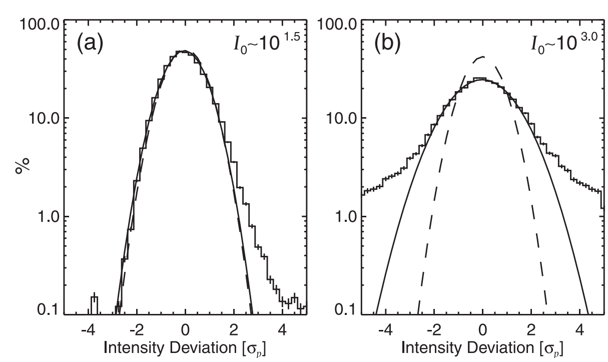

Figure 2: Histograms of the X-ray intensity. (a) is for dark regions, and (b) is for bright regions. The dashed curves show the predicted noise distribution.

Reference

[1] Katsukawa, Y., and Tsuneta, S.: 2001, *ApJ*, **557**, 343.

Lithium isotopic ratio in interstellar media

KAWANOMOTO, Satoshi, ANDO, Hiroyasu
(Division of Optical and Infrared Astronomy, NAOJ)
SUZUKI, Ken, Takeru
(University of Tokyo/Division of Theoretical Astrophysics, NAOJ)
KAJINO, Toshitaka
(Division of Theoretical Astrophysics, NAOJ)

Although most of metals in the universe are synthesized by nuclear reactions in the interior of stars, the light elements like Lithium are synthesized by Big-Bang nucleosynthesis, spallation reactions in interstellar media, nova nucleosynthesis, and supernova nucleosynthesis. Light elements are destroyed easily inside stars. Therefore Lithium is the most important element for studies of the Big-Bang theory, the Galactic chemical evolution, and structure of stars. It should be noted that there are two stable isotopes ^{7}Li and ^{6}Li with different characters. ^{7}Li is synthesized by the Big-Bang nucleosynthesis, but ^{6}Li is rarely created in Big-Bang. Because of this difference, the isotopic ratio of Litnium varies depending on the location and time. We tried to observe interstellar absorption lines in order to derive the isotopic ratio.

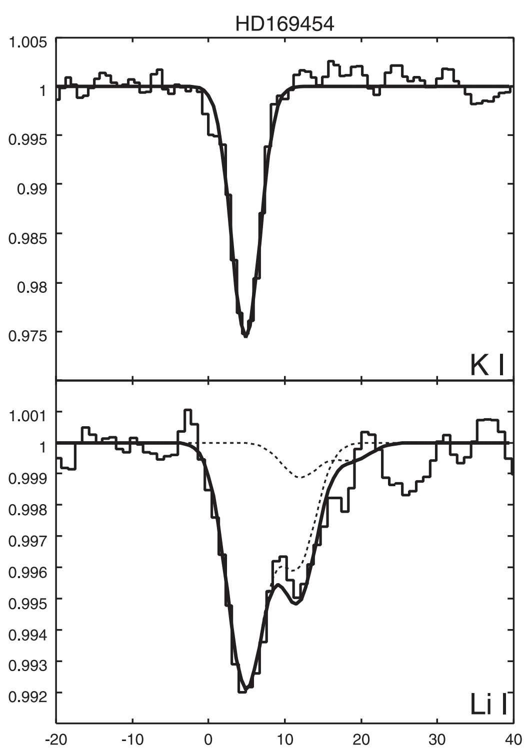

Figure 1: Sample spectrum of HD169454 Li I and K I.

In the early observations of Subaru-HDS (High Dispersion Spectrograph), we obtained some spectra of interstellar absorption lines including λ =6708Å Lithium lines as a test observation for high spectral dispersion and high signal-to-noise ratio. From these data and additional data obtained at Okayama Astrophysical Observatory, we derived the lithium isotopic ratio for directions of three stars, χ^2–Ori, HD169454, HD250290. A sample spectrum is shown in Figure 1. Distances of these stars are about 1.5kpc. We derived the lithium isotopic ratio for these stars.

On the basis of our results together with the data of ^{7}Li/^{6}Li so far reported for the local ISMs in the solar neighborhood, we attempted to determine the primordial ^{7}Li abundance by using the GCE model, taking into account its galactocentric distance dependence. In Figure 2, we show the galactocentric distance dependence of ^{7}Li/^{6}Li. Using these data, we obtained the upper limit of primordial lithium abundance, ^{7}Li/H $< 8 \times 10^{-10}$. This is the first result of primordial lithium abundance determined without using observations of population II stars.

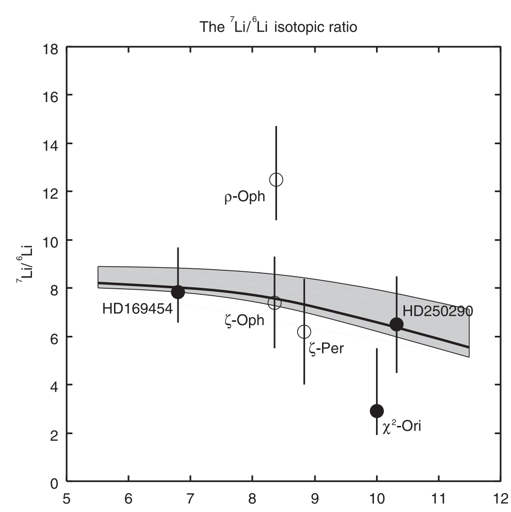

Figure 2: Plot of ^{7}Li/^{6}Li vs. galactocentric distance of background stars with best fit model calculation. Our new data (filled circle), previously reported data (open circle), and a model calculation (solid line) with error region (shaded area) are shown.

Revision of Ephemeris Yearbook (Rekishoh-Nenpyoh)

FUKUSHIMA, Toshio, NAKAI, Hiroshi, ITO, Setsuko
(Public Relations Center, Ephemeris Computation Office)

The Ephemeris Computation Office of the Public Relations Center, NAOJ, has conducted the computation of a Japanese civil almanac named Ephemeris Yearbook, or Rekishoh-Nenpyoh in Japanese. The Yearbook contains the date of vernal and autmunal equinoxes, the apparent positions of the Sun, the Moon, and major planets, the information on the solar and lunar eclipses and planetary phenomena, and other ephemeris issues. This work is to comply with the preparation of ephmerides, one of the legal missions charged to the observatory.

Since the last major revision on 1985, the advent of observational techniques and the rapid increase of observational data both in quality and in quantity have spurred the creation of better lunar/planetary ephemerides as well as the latest nutation theories. Also it has been well acknowledged that the Tokyo Datum, the basic set of Japanese geodetic system used since the Meiji era, has non-negligible difference from the so-called world geodetic systems thanks to the GPS and other precision measurement techniques in space geodesy. Then the Japanese Government recently replaced the Datum by a new one based on a recent ITRF by modifying the law of surveying, which automatically requires the adopted values of latitude and longitude of some representative positions listed in the Ephemeris Yearbook. Accounting these situation and requirements, we have updated the basic theories of the Ephemeris Yearbook from the year of 2003. The major revi-

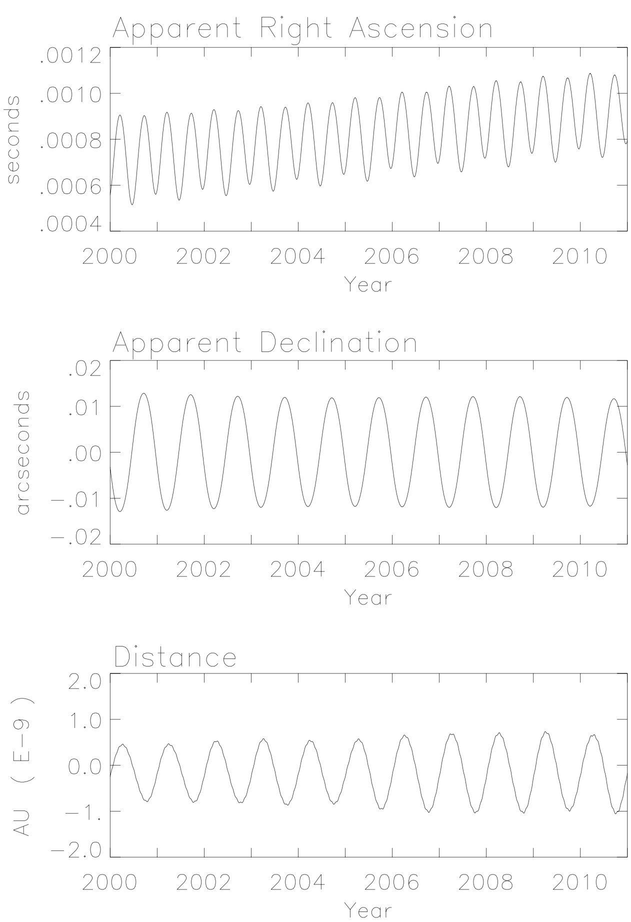

Figure 1a: DE405−DE200 (Sun)

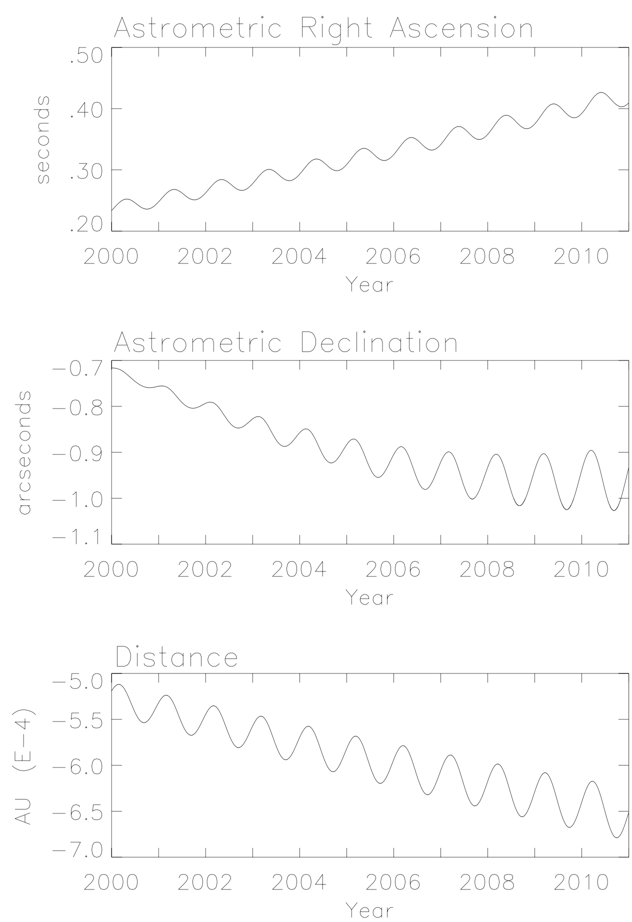

Figure 1b: DE405−DE200 (Pluto)

sions are as follows.

1. Revision of Lunar/Planetary Ephemeris

As for the position and velocity of the Sun, the Moon, and major planets, we replaced the current basis, DE200/LE200 of NASA/JPL, by its latest version, DE405/LE405 (Standish 1998). The accuracy of the latter is estimated as small as 1 mas for the apparent position of inner planets. At the same time, the fundamental reference frame of the Yearbook was changed from the classic one, that based on the mean equinox and equator at J2000.0, to the International Celestial Reference Frame, the IAU official reference frame defined by the set of positions of quasars. Also the system of astronomical constants has been changed to that adopted in DE405/LE405, which is quite close to the IAU 2000 Best Estimates of Astronomical Constants. This change introduced some small differences as shown in Figs. 1a and 1b. The figures illustrate the differences in the right ascension, the declination, and the geocentric distance of the Sun and Pluto between DE405 and DE200.

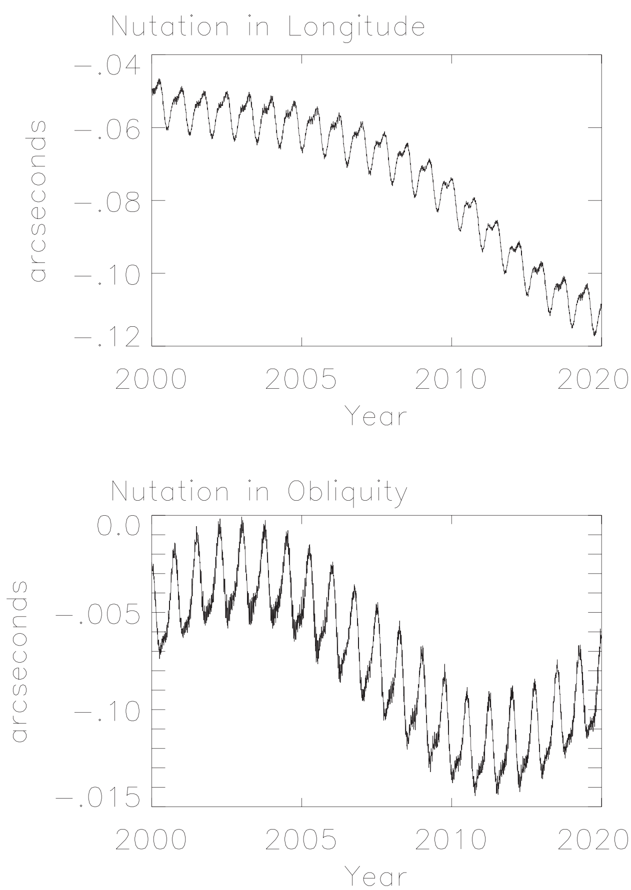

Figure 2: SF2001−IAU1980

2. Revision of Nutation Theory

As for the nutation theory, we replaced the IAU 1980 theory to SF2001 (Shirai and Fukushima 2001). The latter was created by fitting to the VLBI observations of the Earth pole offsets in the last 20 years and includes a correction to the IAU 1976 precession formula. Fig.2 shows the difference of the IAU 1980 nutation theory and SF2001. The difference of SF2001 from the other latest nutation theories such as IAU2000A are small as less than 1.5mas in longitude and 0.6 mas in obliquity for the forthcoming 20 years.

3. Revision of Geodetic System

To be conformal with the modification of the laws of the surveying and the hydrographic duties adopted by the Congress in June, 2001, and enforced on April 1st, 2002, we revised the data of geodetic system such as the radius and the flattening factor of the Earth and the longitude and latitude of many landmarks in Japan.

4. New Form of Expression

In order to enable to obtain more precise values of the nutations and the equation of equinox, we changed their tabulation stepsize from 10 days to 4 days.

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When did the Hubble Sequence Appear ?

YAMADA, Toru
(Division of Optical and Infrared Astronomy, NAOJ)

KAJISAWA, Masaru
(NAOJ / Tohoku University)

We are conducting observational study to reveal overall history of structure formation in the universe. In this year we worked on the Subaru deep NIR data as well as HST archived data of the Hubble Deep Field North [1][2].

First, with the HST NICMOS deep imaging data, we construct a volume-limited complete sample of galaxies up to $z = 2$ with $M\mathrm{v} < -20$ and investigated their evolution. We found that (i) there are about 100 galaxies with $M\mathrm{v} < -20$ and $z < 2$ in HDF-N, (ii) the commoving density of bulge-dominated galaxies rapidly decrease above $z = 1$, and (iii) rest-optical flux of disk galaxies at $z > 1.5$ is completely dominated by the young stars formed in on-going star formation. The Hubble sequence clearly appears up to $z = 1$ but conspicuously changes above the redshift.

We then conducted extremely deep NIR imaging with Subaru to study the rest-frame optical properties of the galaxies at $z > 2$. We found that many galaxies at $z > 2$ in HDF-N (i) have no clear morphological sequence, (ii) have stellar mass significantly smaller than the typical L* galaxies at $z = 0$, and (iii) rest-optical flux is dominated by young stars.

In HDF-N, massive galaxies which form the Hubble sequence have not been formed yet and they appeared as they are around $z \sim 1$. Using the upcoming data taken for the Subaru Observatory project, we will study how these are general trend in the universe.

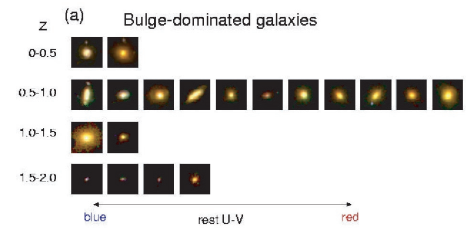

Figure 1: A complete sample of bulge-dominated galaxies at $z < 2$

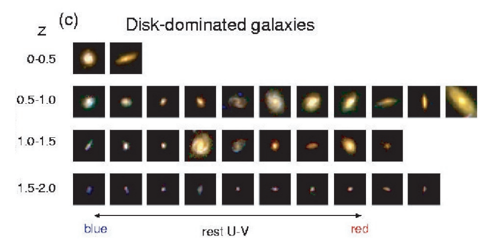

Figure 2: A complete sample of disk-dominated galaxies at $z < 2$

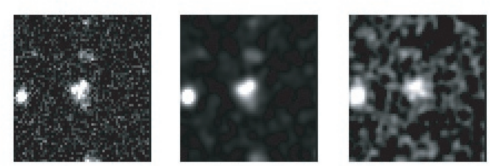

Figure 3: (left) Rest-UV morphology of a galaxy at $z = 3.4$ with HST. (right) Rest-optical morphology of the galaxy with CISCO

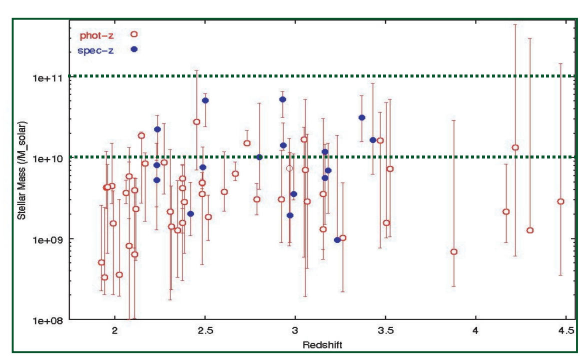

Figure 4: Observed stellar mass distribution of galaxies at $z > 2$

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Bicolour Lightcurve of TNO 1996 TO66 with the ESO-VLT

SEKIGUCHI, Tomohiko
(Division of Radio Astronomy, NAOJ)

BOEHNHARDT, Hermann
(Eouropean Southern Observatory)

HAINAUT, O. R.
(Eouropean Southern Observatory)

DELAHODDE, C. E.
(Institut d'Astrophysique de Marseille)

Abstract

We performed high resolution imaging of 1996 TO66 in *V* and *R* band to verify and monitor the lightcurve change, to address a colour change over a rotation and to search for a cometary activity. No activity was detected at the 29 mag/sq.arcsec level with 5400s integration time with the ESO-VLT. Combining the data in Nov. and Dec. 1999, we obtained a complete rotation period coverage. The lightcurve was a single-peaked, with an amplitude of 0.21 mag in *R*. The $(V-R)$ colour displays the inhomogeneity of TNO surface. TNO's patchy surface may be caused the intensity change of water absorption feature in near-IR spectra. These observations can be the starting points for a challenging work of surface mapping of TNOs.

Summary

The main results of this study are the following:

- 1996 TO66 is one of the largest TNO. The derived diameter is 600−700 km assuming 0.04 albedo.
- Our data are consistent with the 6.25 hr rotation period.
- No resolved coma was detected down to 29 mag/sq.arcsec on a 5400s composite *R* exposure.
- The $(V-R)$ colour of 1996 TO66 has neutral colour over a rotation in general but a small bump around the rotation phase of 0.4 may indicate a change in the colour gradient of the surface material. This supports the inhomogeneous surface material and reflectivity as reported by Brown et al. (1999) and Hainaut et al. (2000).

These results come to the starting points for a work of surface mapping of TNOs as Pluto.

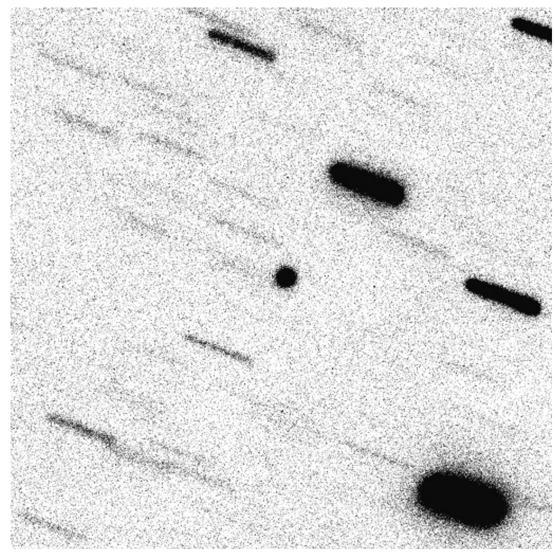

Figure 1: The *R*-band images of 1996 TO66 in November, 1999, with an effective integration time of 5400s. 1996 TO66 in the center and the star appear trailed because the images have been shifted to cancel out the motion of the TNO. 51" × 51".

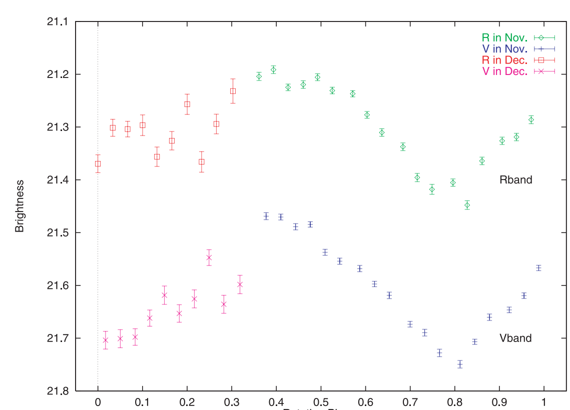

Figure 2: Phased lightcurve of 1996 TO_{66} in *V* and *R*-band folded with 6.25 h period.

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Probing Dark Matter Substructure in Lens Galaxies

CHIBA, Masashi
(Division of Astrometry and Celestial Mechanics, NAOJ)

The cold dark matter (CDM) scenario for structure formation in the universe has been quite successful in explaining a wide variety of observational results, including characteristic fluctuations of the cosmic microwave background and large-scale structure of galaxies on scales larger than ~ 1 Mpc. The currently best world model, which accords with the results of many cosmological observations, consists of approximately 30 % CDM and 70 % vacuum energy or quintessence. However, the recent advent of high-resolution *N*-body simulations on CDM-based structure formation has enabled to highlight various discrepancies with existing observations on scales smaller than ~ 1 Mpc. One of the most serious issues is that CDM models predict the existence of several hundred clumps or “subhalos” in a galaxy-sized halo, in sharp contrast to the observed number of about dozen Milky Way satellites.

To assess the existence of such numerous CDM subhalos in a galaxy-sized halo, we investigate their effects on the events of strong lensing. Lens galaxies are represented by a smooth ellipsoid in an external shear field and additional CDM subhalos taken from Monte Carlo realizations which accord with recent *N*-body results. We also consider other possible perturbers, globular clusters and luminous dwarf satellites, for comparison. We then apply the models to the particular lens systems with four images, B1422 + 231 and PG1115 + 080, for which smooth lens models are unable to reproduce both the positions of the images and their radio flux ratios or dust-free optical flux ratios simultaneously. We show that the perturbations by both globular clusters and dwarf satellites are too small to change the flux ratios, whereas CDM subhalos are most likely perturbers to reproduce the observed flux ratios in a statistically significant manner (Figure 1). This result suggests to us the presence of numerous subhalos in lens galaxies, which is consistent with the results of cosmological *N*-body simulations.

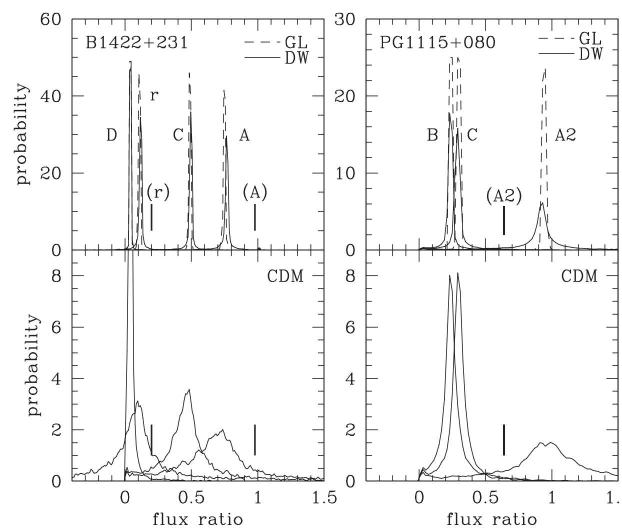

Figure 1: The probability distributions of the flux ratios for B1422 + 231 (left panels, in units of flux B) and for PG1115 + 080 (right panels, in units of flux A1). Upper panels show the cases of globular clusters (dashed lines) and dwarf satellites (solid lines) as perturbers, whereas lower panels show the case of CDM subhalos. Solid bars denote the observed flux ratios of A/B and $r \equiv (A+B+C)/(|A|+|B|+|C|)$ for B1422 + 231 and A2/A1 for PG1115 + 080.

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Sensitivity of an imaging space infrared interferometer

NAKAJIMA, Tadashi
(Division of Optical and Infrared Astronomy, NAOJ)
MATSUHARA, Hideo
(ISAS)

Early in the 21st century space infrared observatories such as ASTRO-F, SIRTF, FIRST, and SPICA are planned to study the formation of planets, stars, and galaxies. The improvement in sensitivity is so great that the source-detection limits of these space observatories are expected to be set by source confusion, especially in the far infrared. To improve further the source detection limits, individual sources need to be resolved by an infrared interferometer. Therefore it is important to quantify the sensitivity of a space infrared interferometer for the purpose of aperture synthesis imaging.

Following the observatories, space infrared interferometers such as TPF and Darwin are considered, with an emphasis on the detection of terrestrial planets around nearby stars. TPF and Darwin will consist of several radiation cooled apertures and will be capable of synthesis imaging as well as planet detection by nulling interferometry. The detection limits of these interferometers for general purpose imaging are of great interest. Among many applications of synthesis imaging with space infrared interferometer, we are interested particularly in deep galaxy count by which the history of galaxy formation can be studied. We discuss how a TPF like interferometer operated in the far infrared can improve the number count data of high-redshift galaxies.

We first formulate the signal-to-noise ratios of infrared images obtained by aperture synthesis in the presence of source shot noise, background shot noise, and detector read noise. We consider the case in which n beams are combined pairwise at $n(n-1)/2$ detectors and the case in which all the n beams are combined at a single detector.

We obtain the detection limits of separated spacecraft interferometers such as the TPF and Darwin in the presence of the natural thermal background as functions of wavelength. The comparison of a TPF-like interferometer with NGST, SPICA, and FIRST reveals that at $\lambda > 100\,\mu$m, an interferometer is more sensitive than SPICA or FIRST. This is true with only radiation cooling of the apertures.

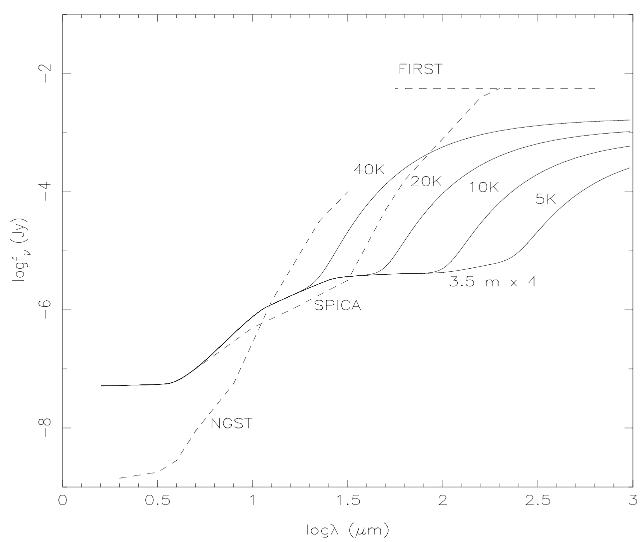

Figure 1: Comparison with monolithic observatories. The sensitivity of an interferometer composed of four 3.5-m apertures is plotted for telescope temperatures of 5, 10, 20, and 40 K with an emissivity of 5%. The maximum baseline length is assumed to be 100 m. The dashed curves denote the sensitivities of NGST, SPICA, and FIRST that are given for comparison.

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CCD Photometry of the MUSES-C Mission Target: Asteroid (25143) 1998 SF36

DERMAWAN, Budi

(School of Science, Univ. of Tokyo)

NAKAMURA, Tsuko, FUKUSHIMA, Hideo, SATO, Hideo, YOSHIDA, Fumi

(Division of Optical and Infrared Astronomy, NAOJ)

SATO, Yusuke

(Graduate School of Education, Tokyo Gakugei Univ.)

We conducted extensive photometric observations using 0.5-m telescope equipped with CCD camera of 1152 × 770 pixels at NAO-Mitaka from 2001 February 15 until March 19, covering phase angle (α) of 20.7°–36.5°, to obtain the physical properties of Near-Earth Asteroid (25143) 1998 SF36. The asteroid is now planned as the target for the Japanese MUSES-C sample return mission, so that detailed knowledge of physical characteristics of this asteroid is very essential for the success of this mission. Photometric data (*I*-band) were successfully taken for 13 nights, while colorimetric observation was attempted on March 18 using *BVRI* bands.

We revealed several physical properties such as asteroid's colors, rotation period, phase curve, and lightcurves. We obtained the asteroid's colors (without solar colors substraction): $(B-V) = 0.902 \pm 0.042$, $(V-R) = 0.475 \pm 0.039$, and $(V-I) = 0.725 \pm 0.012$. This implies that the type of this asteroid is close to the S-type, though it does not seem to be a typical S-type, judging from its location of the color diagram shown in figure 1. In order to find the rotation period of this asteroid, we employed the Phase Dispersion Minimization technique and the Fourier-transform method. A resulting spin period of this asteroid is found to be 12.13 ± 0.02 hr. We also calculated the asteroid absolute magnitude (H) and the slope (G) for the two-parameter magnitude system derived from the asteroid's phase curve. We thus obtained $H = 18.61 \pm 0.18$, $G = 0.29 \pm 0.14$, and the estimated albedo is to be $0.29^{-0.08}_{+0.09}$. We suggest that this albedo may be higher than that for the typical S-type asteroids. After employing the phase-angle dependence on the light-curve, we could eventually make a composite light-curve by applying the Fourier analysis method shown in figure 2 for $\alpha = 20.8°$. We made clear that the peak-to-peak amplitude at zero phase angle A (0°) ≃ 0.49 mag, which implies that the minimum ratio of the longest and intermediate axes is 1.6.

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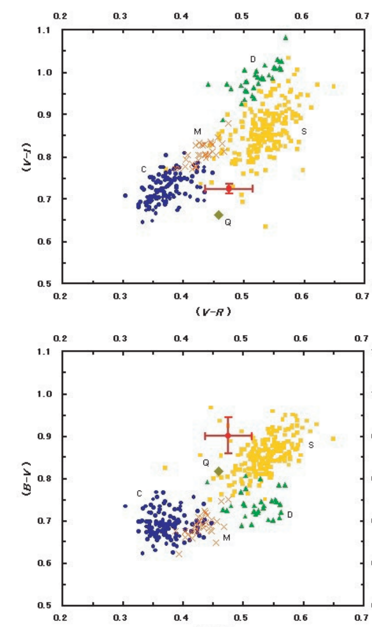

Figure 1: Obtained asteroid colors (marked with error bars) in color diagrams $(V-I)$ vs $(V-R)$ on the upper panel and $(B-V)$ vs $(V-R)$ on the lower one. The letters denote the asteroid's type. The asteroid data are taken from the Eight-Colors Asteroid Survey (ECAS).

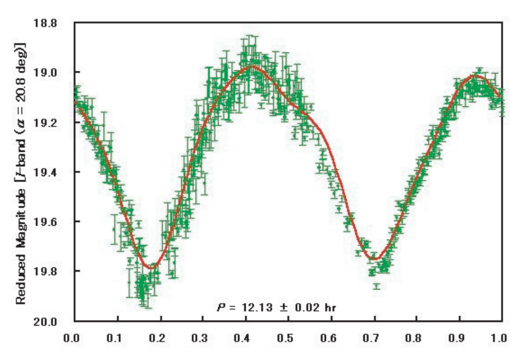

Figure 2: Composite light-curve of the asteroid at $\alpha = 20.8°$. The observed data points are given with error bars and folded into the rotational phase with the period of 12.13 hr based on 2001 February 15.56588.

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