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THE LATEST RESULTS FROM SUBARU TELESCOPE

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ABSTRACT

The latest scientific highlights obtained with the Subaru telescope are given together with its current status and on-going instrumentation. We have been successfully operating the telescope and 8 observatory instruments (including an adaptive optics system) since January 1999, when the first light was accomplished. Open-use of Subaru began in December 2000. Subaru has a unique capability of its prime focus among other 8–10 meter class telescopes and has an excellent imaging performance as a result of its sophisticated active optics combined with the high stability of the sky at Mauna Kea. Scientific highlights are given on the discoveries of the most distant galaxies, spiral structure on a protoplanetary disk around AB Aur, and planetesimal belts in the debris disk around β Pic. Brief summaries are given for three new instruments: the Multi-Object Infrared Camera and Spectrograph (MOIRCS), 188 element adaptive optics system, and Fiber Multi-Object Spectrograph (FMOS)

Key words : telescopes

I. CURRENT STATUS

Subaru is an 8.2 m optical-infrared telescope located atop Mauna Kea, Hawaii. It was constructed by the National Astronomical Observatory of Japan with funding from the Japanese government. The construction began in 1993 and finished in 1999. We received the first light of the telescope in January 1999 and successively commissioned seven observatory instruments and an adaptive optics system thereafter.

Open-use of the Subaru telescope started in December 2000 and ~120 nights per semester are currently open to any researchers, although the oversubscription rate is high (5–6). The rate of successful observations are 70 % with 25 % and 5 % for weather and hardware downtimes, respectively. The number of papers published in refereed journals was ~60 in 2004, reaching the levels of other 8–10 m class telescopes.

The performance of Subaru Telescope was found to be satisfactory. Figure 1 shows that the seeing is better than 0.″6 for ~45 % of observable time. The best natural seeing of 0.″2 was attained in June 1999 at the K band, demonstrating that the active primary mirror support system works well under the stable atmosphere of Mauna Kea.

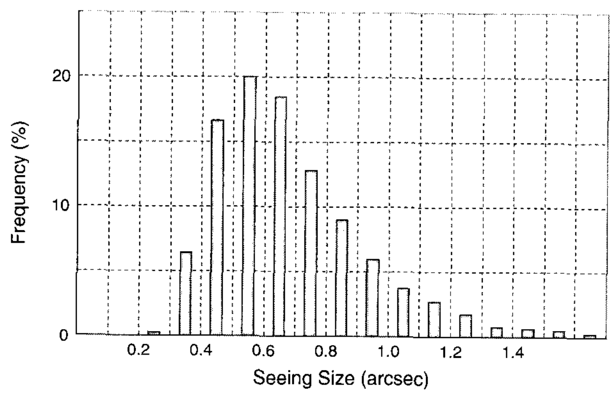

Fig. 1.— Frequency distribution of the Subaru Telescope seeing size (FWHM) at the R-band corrected to the zenith. (compiled by A. Miyashita)

II. SCIENCE HIGHLIGHTS

(a) The Most Distant Galaxies

The unique feature of the Subaru telescope is its prime focus, where the Suprime-Cam (Subaru Prime Focus Camera) covers the field of view of 34′×27′ with its ten 4 K×2 K CCDs. The Suprime-Cam is mainly used for wide field surveys ranging from solar system research to the quest of the farthest reaches of the universe.

Figure 2 shows the Lyman α emission spectra from the most distant galaxies discovered in the Subaru Deep Field Survey (Kodaira et al. 2003; Taniguchi et al. 2005). The skewed line profiles and high S/N ratio of the emission lines give clear evidence that they are indeed the Lyman α lines emitted by the most distant galaxies. Current ranking of the most distant galaxies is shown in Table 1, where the majority was discovered by the survey with the Subaru Telescope.

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TABLE 1.
CURRENT RANKING OF THE MOST DISTANT GALAXIES

	OBJECT	RED SHIFT	TELESCOPE	REFERENCE*
1	ABELL 1835 IR1916	z=10	VLT	A
2	LENSED GALAXY TOWARD ABELL 2218	z~7	HST/KECK	B
3	SDF ID1004	z=6.59	SUBARU	C
4	SDF ID1005	z=6.583	SUBARU	C
5	SDF ID1007	z=6.58	SUBARU	C
6	SDF 132418	z=6.578	SUBARU	C
7	HCM-6A	z=6.56	KECK/SUBARU	D
8	SDF ID1003	z=6.55	SUBARU	C
9	SDF ID1002	z=6.55	SUBARU	C
10	SDF 132415	z=6.541	SUBARU	C
11	SDF ID1010	z=6.54	SUBARU	C

* A: Pello et al. (2004), B: Kneib et al. (2004), C: Kodaira et al. (2003) & Taniguchi et al. (2005), D: Hu et al. (2002)

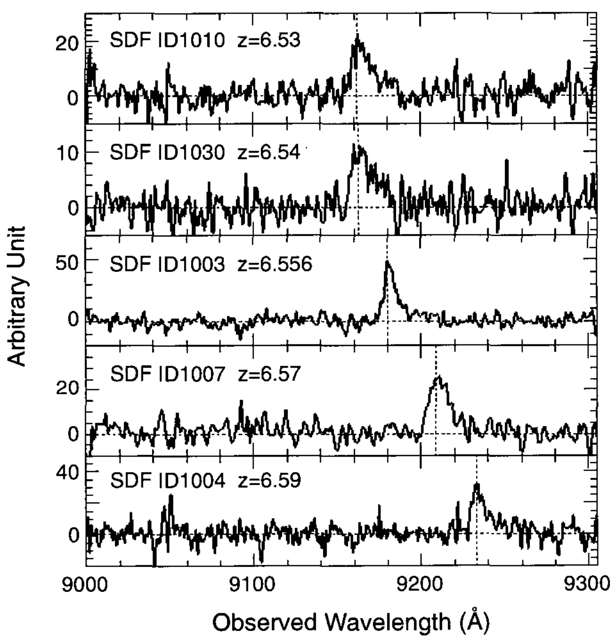

Fig. 2.— Lyman α emission lines from the farthest galaxies discovered by a deep survey with Suprime-Cam (Taniguchi et al. 2005)

(b) Disks around Young Stars

Figure 3 shows an *H* band image of a protoplanetary disk around the Herbig Ae star AB Aur (Fukagawa et al. 2004). A well-resolved double spiral pattern is seen at $r = 200-450$ AU. The spiral arms are trailing if the brighter southeastern part of the disk is the near side. The spiral structure may be excited by the weak gravitational instability, which may be maintained for millions of years by continuous mass supply from the envelope of the star. The presence of such an instability suggests that the disk mass to stellar mass ratio is significantly larger than that of the primordial solar nebula.

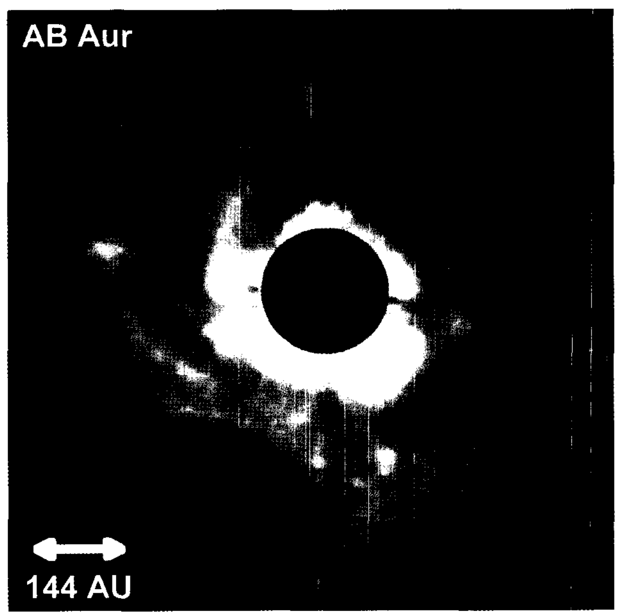

Fig. 3.— *H* band image of the disk around AB Aur. Up is north and left is east. (Fukagawa et al. 2004)

Another interesting result obtained with Subaru is the discovery of 'planetesimal belts' in the debris disk around β Pic (Okamoto et al. 2004). Figure 4 shows two representative 10 μm spectra taken at the center (left) and at $0\farcs33$ southwest of it (right) in the disk. Each emission spectrum above the fitted power-law continuum was decomposed to the three spectral features: crystalline forsterite (solid curve), amorphous silicate with a radius of 2.0 μm (broken curve) and amorphous silicate with a radius of 0.1 μm (dash dotted curve). By analyzing the spatial variation of the relative strength of the three features, Okamoto et al. (2004) found that the distribution of submicron-size

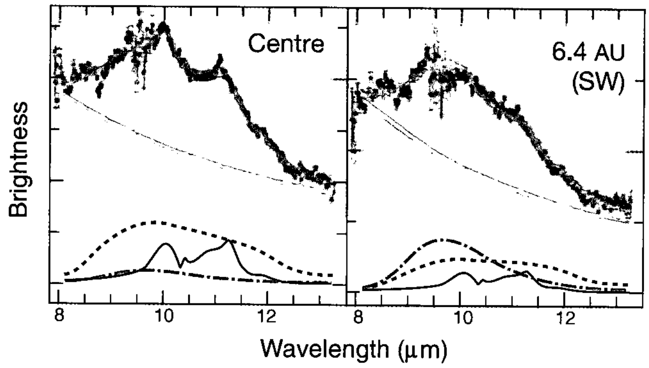

Fig. 4.— 10 μm spectra at the center (left) and 6.4 AU (0.″33) southwest of it (right) toward β Pic obtained with a 0.″33 wide slit of COMICS. Solid, broken and dash dotted lines show fitted decomposed spectra of crystalline forsterite, 2.0 μmm radius amorphous silicate, and 0.1 μmm radius amorphous silicate, respectively. Grey line shows the power-law continuum. (Okamoto et al. 2004)

grains in the debris disk has peaks at 6, 16 and 30 AU from the star, whereas the crystalline and micron-size amorphous silicate grains are concentrated at the center. Because submicron grains are quickly blown out from the system by radiation pressure from the star, the peaks indicate the locations of ongoing dust replenishment, which originates from ring-like distributions of planetesimals.

III. FUTURE INSTRUMENTATION

The Multi-Object Infrared Camera and Spectrograph (MOIRCS) has been under testing on the telescope since September 2004. It is equipped with two 2 K × 2 K HgCdTe (HAWAII-2) arrays covering a field of view of $7' \times 4'$ at the Cassegrain focus. It has an imaging capability at z, J, H and K bands. The MOIRCS can hold 24 masks in the cryostat with up to 50 slits cut in each mask. The slit masks are kept cooled in the cryostat and can be placed at the focal plane without being warmed.

Subaru's current adaptive optics (AO) is a natural guide star system with 36 correction elements used with near infrared instruments (IRCS and CIAO). In order to enhance the sky coverage and strehl ratio, the AO team at the Subaru Telescope is fabricating a new AO with 188 correction elements. It will be placed at the Nasmyth platform and used with (or without) a laser guide star. It will achieve a Strehl ratio of 0.8 in the K band with the sky coverage of >40%. Although not sufficient for optical observations, it can also be used in the visible red wavelength to obtain the image size of 0.″033 (FWHM). A brief summary of the new AO is given in Table 2.

The Fiber Multi-Object Spectrograph (FMOS) is being fabricated under collaboration with the Kyoto University, Anglo-Australian Observatory and Particle Physics and Astronomy Research Council (UK). It will be mounted at the prime focus utilizing the wide field capability of the Subaru telescope. Four hundred optical fibers are distributed in the field of view of 30′ and are pointed at their targets in 10 minutes. The spectra are fed to two spectrographs equipped with OH-airglow suppression systems. Testing of the FMOS will start from 2006.

TABLE 2.
COMPARISON OF CURRENT AND NEW ADAPTIVE OPTICS SYSTEMS

	Current AO	New AO
System	NGS 36	LGS/NGS 188
Sky coverage	~2%	>40%
Focus	Cassegrain	Nasmyth
Strehl Ratio (K)	0.3	0.8
R-band performance	N/A	SR~0.04 FWHM=0.″033
Commissioning	2000	2006

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