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JAPAN 8M TELESCOPE: SUBARU PROJECT

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ABSTRACT

An updated project status review of the Japan 8m telescope, Subaru, scheduled for its first light in the second quater of 1998 atop Mauna Kea is given.

Key Words : optical/infrared telescope, active/adaptive optics, instrumentation

I. PROJECT STATUS

An 8.2m optical and infrared telescope, Subaru, is under construction atop Mauna Kea, Hawaii, by the National Astronomical Observatory, Japan[1]. The feasiblity studies of the project started back in 1984. The actual construction budget was granted since the fiscal year 1991. The first light of this telescope is scheduled in the 2nd quarter of 1998. The main scientific objectives are to make advances in the observational cosmology and in the studies of star formation.

(a) Thin Meniscus Primary Mirror with Active Optics

In order to reduce the weight and the cost of the telescope and enhance the flexibility to attain high optical performance, it was decided to adopt a thin meniscus primary mirror with an active support system in the early phase of the project definition. A small scale active optics experiment was carried out in 1988 to demonstrate the feasibility of the concept[2]. Corning Ultra Low Expansion glass ULE^{TM} was chosen for the primary mirror blank and the 8.3m blank was successfully casted and sagged down at the Corning Canton plant by the summer of 1994. It was then transferred to an underground optical shop constructed by Contraves USA near Pittsburg for figuring and polishing and is now in the final stage of figuring the back surface to drill 261 pockets to house the support actuators. We expect to finish polishing the mirror by the 3rd quarter of 1997[3].

(b) Enclosure

The Subaru telescope is housed in a corotating enclosure set on a fixed building. The five storied cylindrical enclosure was designed to attain the best local seeing condition by operating the front, rear, and side vanes to regulate the flushing wind flow. Inside this enclosure is a top unit exchange system, with which prime focus instruments and the secondary mirrors are exchanged and stored at the top unit floor. The Nasmyth floor has two platforms of 6m x 6m space to house the massive instruments, HDS and OHS. There are storing spaces where a few Cassegrain instruments can be kept at stand by condition. Exchanging the Cassegrain

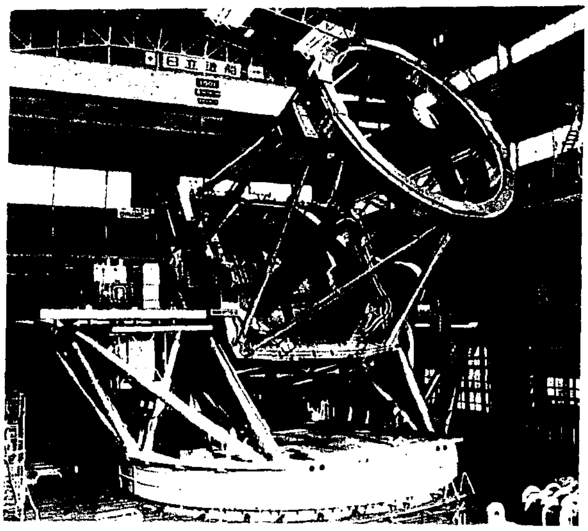

Fig. 1.— Subaru telescope under assembling test at a factory in Osaka, Japan

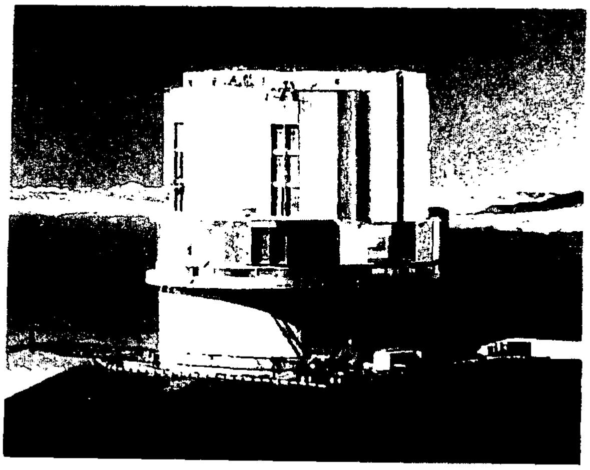

Fig. 2.— Subaru enclosure near completion atop Mauna Kea, Hawaii

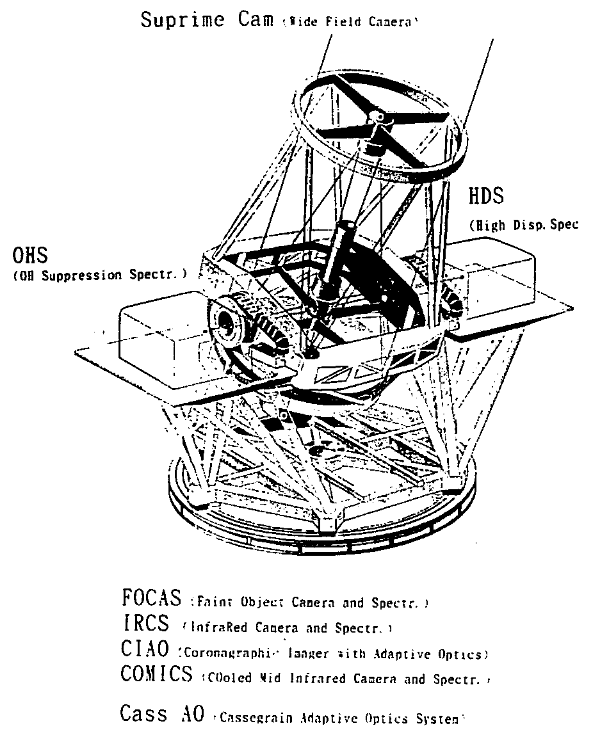

Fig. 3.— Scientific Instruments of the 8m Subaru Telescope

instrument can be done with an aid of the Cassegrain exchanging system within a reasonable time to realize a flexible scheduling of observations. Flushing floor beneath the Cassegrain floor is a space to allow the wind flow to keep the thermal environment inside the enclosure as close as that of the exterior field. At the base floor of the lower building, a 10m aluminizing plant, a mirror cleaning plant, and mirror handling tools will be located. The primary mirror will be lowered by the 80-ton capacity crane through the mirror hatch of the Cassegrain floor in case of re-aluminizing operation. The telescope and the enclosure will be controlled from the annex control building connected to the enclosure by an underground corridor.

II. INSTRUMENTATION

Three baseline programs run by the project office for the Subaru instrumentation are 1) development and procurement of 4k x 2k thinned CCDs and infrared arrays, 2) construction of a Cassegrain Adaptive Optics System optimized for infrared applications, and 3) construction of Mid InfraRed Test Observation System.

In addition to these baseline programs, the Subaru Instrumentation Committee and the Subaru project office approved the following seven scientific instruments for construction[4,5] (cf. Figure 3). 1) Faint Object Camera And Spectrograph (FOCAS), 2) InfraRed Camera and Spectrograph (IRCS), 3) COoled Mid Infrared Camera and Spectrograph (COMICS), 4) Coronagraphic Imager with Adaptive Optics (CIAO), 5) High Dispersion Spectrograph (HDS), 6) OH airglow suppression Spectrograph (OHS), and 7) Subaru Prime-focus Camera (Suprime-Cam). Instruments 1-4) are for the Cassegrain focus. Instruments 5-7) are for the optical Nasmyth, the infrared Nasmyth, and the primary focus, respectively.

The main budgets for constructing these instruments are available for the fiscal years 1996-1999. The first lights of these instruments are expected to take place successively from the summer of 1998 till the spring of 2000. Actual assignment of instrument verification runs on the telescope will be made in the near future by reviewing the progress of construction of the above instruments.

For testing purposes, a 1.6m infrared telescope, a common use Cassegrain simulator, and a Nasmyth simulator were installed at the Mitaka campus. Cassegrain and Nasmyth simulators of identical design will be installed at the Hilo base facility in Hawaii by 1997. The telescope software group is defining the framework for developing the instrument control softwares run on a network system. Individual group is responsible for developing the instrument control software and the data reduction software package.

(a) CCD

The standard CCDs to be used in optical instruments, FOCAS, HDS, and Suprime-Cam should have 4000×2000 pixels of $15m \times 15\mu m$ pixel in size on a 3 side buttable package. The FOCAS, HDS, and Suprime-Cam will use 2, 2, and 10 such CCDs, respectively, in mosaiced configurations. These CCDs should be thinned, backside illuminated devices with appropriate anti reflection coatings deposited on their surface. NAOJ has been participating in the MIT/LL consortium to develop large format CCDs. In paralell to this effort, NAOJ and Hamamatsu Photonics Co. have been collaborating to develope large format thinned CCDs with AR coatings[6] and has evaluated sample CCDs provided by Loral, MIT/LL, EEV, and Hamamatsu.

(b) FOCAS

Faint Object Camera And Spectrograph (FOCAS) is a Cassegrain instrument with an all-refractive optics of high throughput optimized for the wavelength region of 365-900 nm. The instrument has an unvignetted field of view of 6 arcmin in diameter at 0.1 arcsec/pixel sampling. FOCAS will have direct imaging mode, long slit spectrographic mode, multi slit spectrographic mode, polarimetric imaging and spectrographic modes. The spectral resolution of $R = 500 - 2000$ will be realized for a slit width of 0.4 arcsec. These modes are easily selected by changing the optical elements mounted on a few rotating turrets or on a sliding mount. The entire instrument is suspended from the Cassegrain mechanical flange at a circular ring on a plane containing the center of gravity of the instrument by 12 CFRP trusses. This support structure is designed to reduce the translational shift of the optics keeping the parallelism to the telescope main optics so that the resulting image motion at the detector should be within an acceptable level. A prototype aperture mask exchanging unit was constructed at NAOJ. An off-line, stand-alone YAG laser cutting system is designed to make aperture masks for the FOCAS.

(c) HDS

High Dispersion Spectrograph (HDS) is a Nasmyth echelle spectrograph with a quasi Littrow configuration. A catadioptric camera with a triplet corrector is used to cover the wide wavelength region of $0.3 - 2.3\mu m$. Two echelle gratings with $tan\theta = 2.8$ on a mosaic mount will be used as the primary dispersive element. Each of the cross dispersing gratings optimized for the blue and the red regions are also on a mosaic mount. As for the infrared, a flat mirror and an order sorting filter will be used to record a small portion of a single order of the spectrum on an HgCdTe array. The HDS is designed to give a spectral resolution of R = 100,000 with a 0.4 arcsec wide slit which projects on $45\mu m$, or 3 pixels, of the CCD. With the use of an image slicer and future CCDs with smaller pixel size, one can increase the resolution upto R = 300,000, since the optics are designed to give spot diagrams generally as small as $10\mu m$ in diameter.

(d) Suprime-Cam

Suprime-Cam, covering 30 × 24 arcmin field of view of which the unvignetted area is 30 arcmin in diameter, will be operated in the staring mode. The TDI mode, or drift scan mode, is abandoned because of the field distortion introduced by a specially designed prime focus triplet corrector with a built-in atmospheric dispersion corrector. Suprime-Cam will have an automatic filter exchanger which can hold up to 10 filters and a shutter which makes an exposure time as short as one second possible. The detectors will be cooled by means of refrigerators. Since the provision of the prime focus will be scheduled behind the Cassegrain focus, Suprime-Cam will see its first light at the Cassegrain focus, where it gives an field of view of 5 x 4 arcmin with the resolution of 0.03 arcsec/pixel.

(e) Adaptive Optics

The Cassegrain Adaptive Optics (AO)[7] is optimized for use at K-band. Two among the four Cassegrain instruments will use this AO system. A bimorph deformable mirror driven by 36 electrodes is used to compensate the wavefront aberration. A curvature wavefront sensor with 36 avalanche photodiodes operated in photon-counting mode is manufactured. The wavefront sensing beam is devided and led to the 36 photodiodes through a custom designed microlens array to match the distribution of electrodes in the bimorph mirror. An oscillating membrane is used to generate necessary offsets of the pupil image just in front of and behind the detector array. The wavefront sensor is mounted directly on the science instrument to minimize the relative flexture between the WFS and the science instrument. The unvignetted field of view of the AO system is 120 arcsec in diameter. By inserting the retractable feed mirror in front of the Cassegraing focal plane, one can easily switch from the ordinary mode to the AO mode without changing the focal position of the instruments and keeping the F-ratio of the incident beam. The total bandwidth will be over 100Hz. The usage of a laser guide star is foreseen in the future.

(f) Infrared Camera and Spectrograph

IRCS is a general purpose $1 - 5\mu m$ infrared instrument for imaging and spectroscopy using the adaptive optics and the tip-tilt secondary mirror of the telescope. It is optimized at $2.2\mu m$ where the deepest observation is targetted with cooled optics and InSb arrays. The spectral resolving power of 20,000 will be provided. It is designed and manufactured at University of Hawaii and will consist of a fore optics, with a beam-splitter which feeds the light shortward of $1\mu m$ to the wavefront sensor mounted directly on IRCS, a spectrograph optics, and an imaging camera optics.

(g) Coronagraphic Imager with Adaptive Optics

CIAO is an imager using the adaptive optics to observe faint objects around a bright central point source. It will have an occulting mask to block the light from the central point source and an apodizing mask to reduce the diffracted light due to the structural components of the optics. A focal reducing optics with dispersive grism will also be available to make low resolution spectroscopy of quasar host galaxies and protostellar disks.

(h) OH Airglow Suppression Spectrograph

This is a unique two stage spectrograph to attain deep imaging and low resolution spectroscopy of very faint objects in the near infrared and will be manufactured by Kyoto University[8]. The first stage spectrograph with spectral resolution above 5,000 produces a high resolution spectrum on a curved mirror surface, where a mask is placed to remove many of narrow sections of the spectrum containing strong atmospheric OH emission. The reflected light, which is free from the OH emission, is reimaged in white light to allow deep imaging or further can be fed into the second stage low resolution spectrograph.

(i) Cooled Mid Infrared Camera and Spectrograph

COMICS is a dual beam instrument for $10\mu m$ and $20\mu m$ diffraction limited imaging and medium resolution long-slit spectroscopy. The spectrum will be covered by 6 Si:As BIB array detectors. The tip-tilt correction using the secondary mirror of the telescope will be incorpolated to enhance the spatial resolution.

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