Bull. Astr. Soc. India (2000) **28**, 647-656

Indian Astronomical Observatory — High-altitude station for optical-infrared astronomy

1. Introduction

The Indian Astronomical Observatory (IAO) on Mt Saraswati ($32^{\circ}46'46''$ N latitude; $78^{\circ}57'51''$ E longitude; 4517 m above mean sea level), in Ladakh, is the high-altitude field station of the Indian Institute of Astrophysics (IIA) which has been established for pursuing optical and infrared astronomy. The observatory will operate a 2-m aperture remotely controlled optical-infrared telescope which has just been installed. A 0.5-m robotic photometry telescope is on the anvil. A 0.3 m site survey telescope, a 220GHz radiometer and an automated weather station are already operational at the site as a part of the continuing site characterization experiment. The site has an excellent potential for astronomical studies in the optical, infrared and sub-mm wavebands.

The site was selected as a precursor of the Himalayan Infrared Optical Telescope (HIROT) project to install a large aperture telescope for the country. Based on a detailed study of the meteorological data and satellite imagery, and site reconnaisance trips to six high-altitude sites in the Great Himalayan Ranges in 1993, the site at Hanle in the high-altitude cold desert of south-eastern Ladakh was chosen as the most prospective site. Site characterization studies, since 1995 January, have proved that the site is among the best high-altitude sites in the world.

Considering that the site is remote with minimal infrastructure facilities, it was decided to develop it with a 2-m aperture telescope and gain experience in remote operation capabilities before embarking on the project for a large national telescope. As of now, the infrastructure development is nearly complete. The 2-m telescope manufactured by M/s EOST, Tucson, has been installed and is being commissioned.

2. The site characteristics

The site characteristics of Hanle are summarized below :

- Good accessibility round the year
- Number of spectroscopic nights : 256 per year
- Number of photometric nights : 193 per year

- Precipitable water vapour : < 2 mm
- Annual precipitation of rain and snow : < 10 cm
- Low ambient temperature and very low humidity
- Low concentration of atmospheric aerosols
- Extinction in V band: ~ 0.1 mag / airmass
- Sky brightness : 23.2 (B); 21.5 (V) mag / arcsec^2
- Median Seeing : 1 arcsec; (< 0.8 arcsec for 25% of the time)
- Right Ascension advantage : Uniform distribution of useful nights round the year
- Longitudinal advantage ($78^{\circ}.5$ E)
- Latitudinal advantage ($32^{\circ}.8$ N)
- Low seismicity

3. Infrastructure

Though Hanle is connected to Leh by an all-weather road, it is essentially a remote site where the required infrastructure for the observatory needs to be specifically established. Considerable efforts have already been made in this direction and the observatory is at present self-sufficient for operating the 2-m telescope. Some of the main facilities are :

- Nearly 600 acres of land including the Digpa-ratsa Ri mountains and some flat area near its base have been transferred to IIA by the Jammu & Kashmir State.
- 8.5 km long motorable road between the Hanle monastery and Mt. Saraswati with a bridge across the Hanle river.
- The area near the top of Mt. Saraswati is levelled for future projects.
- Two Maruti Gypsy jeeps and a TATA 407 minitruck are available for transport of persons and material between Leh and Hanle, daily movement between the base and observatory area, and any medical emergencies at Hanle.
- Ten insulated shelters are available at the base of Digpa-ratsa Ri. These can accommodate 15-20 persons and provide space for office, dining, entertainment, kitchen, etc. Four shelters are provided at the observatory area as well. The ground floor of a permanent building at the base is complete, and the top floor will be completed in the summer of 2001.
- The power requirement of the observatory is met through solar and diesel power. Two 30 KWp SPV power plants are installed and commissioned at the observatory area. Two 63.5 KVA diesel generators are installed at the observatory area and one in the base station.

Another diesel generator is being procured for the base camp. One 1 KWp SPV power plant is installed at the base station. A 1KWp SPV power plant is also installed at Leh and there are plans to augment its capacity.

- Three underground storage tanks of 10,000 litres capacity each have been commissioned to store stock of diesel, petrol and kerosene.
- The water is currently being drawn from wells equipped with hand operated pumps. Borewells with electric pumps and storage tanks are being planned.
- A 5 lit/h capacity liquid nitrogen plant procured from M/s Stirling Cryogenics & Refrigeration, Netherlands, has been installed at the base station. Liquid nitrogen is routinely being produced for observations.
- The remote control of the telescope, instruments and dome, and downloading of data to the control facility at the Centre for Research and Education in Science and Technology (CREST) in Hosakote, near Bangalore, will be done with the help of two dedicated point-to-point satellite communication links utilising INSAT 3B (2 Mbps speed) and 2B (to be shifted soon to 2C; 128 kbps speed). A 3.8-m dish antenna and electronics have been installed at both the sites and the links are up. The INSAT 3B link is currently being used for data transfer. INTERNET facilities are also available at CREST.
- RABMN satellite links have been commissioned at Hanle and Leh to facilitate routine communications between Leh, Hanle, Bangalore and Kavalur. These links are also used to remotely log into the e-mail machine at Bangalore.
- The activities in Ladakh are coordinated by an astronomer and three engineers at the site, apart from personnel visiting from Bangalore. Minimal manpower has been provided for house-keeping and maintenance of the facilities.
- The enclosure for the 0.5 m telescope which was fabricated at the Vainu Bappu Observatory, Kavalur, has been erected.
- The 0.3 m telescope is already installed in the enclosure and is used as a seeing monitor. A 220-GHz radiometer is installed in a tower adjacent to this building, in a closed dome with a transparent slit. The computer controlled radiometer is operating continuously since December 1999.

4. The 2-m Telescope

The 2-m aperture optical-infrared telescope installed at the Indian Astronomical Observatory, Mt. Saraswati, Hanle saw the first technical light on September 27, 2000. The telescope, built by the EOS Technologies Inc., Tucson, Arizona, USA, and designed for remote operation is currently being fine-tuned and calibration tests are underway. The telescope will be remotely controlled via the 2Mbps satellite link from the CREST campus. Figure la shows the 2-m dome and telescope and Figure 1b shows a closer view of the telescope.

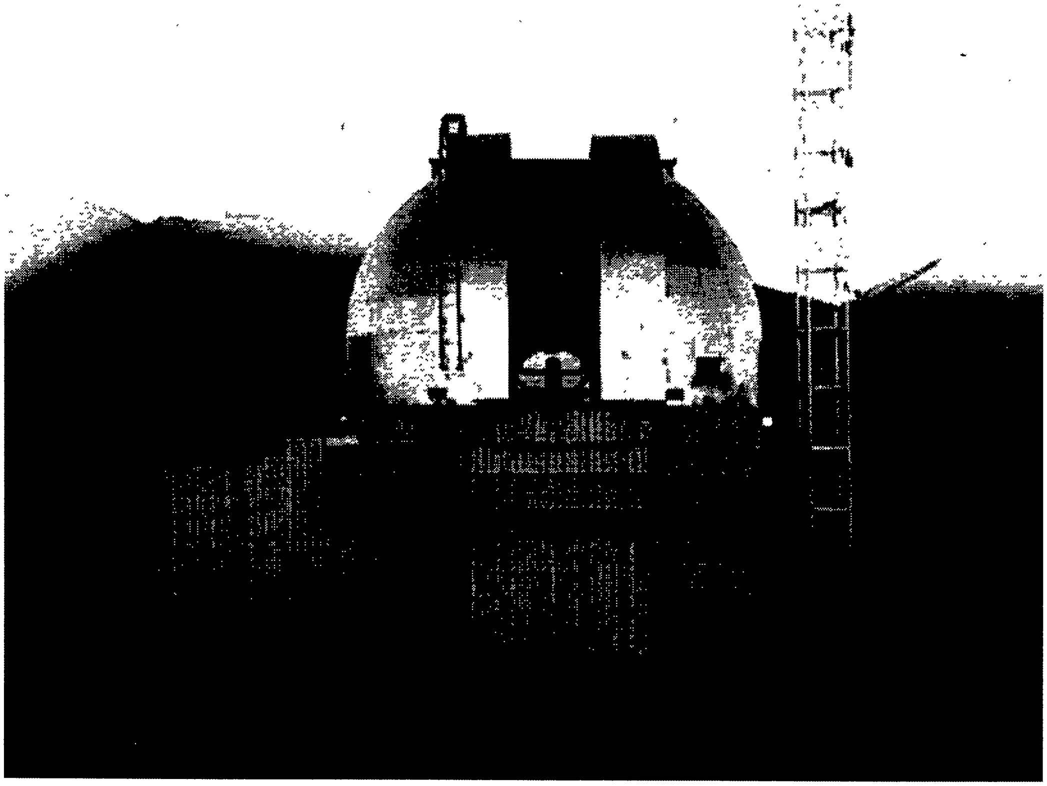

Figure 1a. The 2-m telescope enclosure with the microthermal tower in the foreground.

All data obtained from this telescope will be archived and made available through a web based public domain archive.

4.1 The telescope

The specifications of the telescope are summarized below :

Aperture	2.01 metres
Mirror Material	ULE
Optics	Ritchey-Chretien
Mount	Altitude over azimuth
Focus	Cassegrain; provision for Nasmyth
F-ratio	*f*/1.75 primary; *f*/9 Cassegrain
Image scale	11.5 arcsec/mm
Field of View	7 arcmin; 30 arcmin with corrector
Image quality (zenith)	80% power < 0.33 arcsec dia
Jitter & periodic errors	< 0.25 arcsec on each axis
Pointing Accuracy	< 0.45 arcsec over 17 arcsec move
	< 1.5 arcsec for > 10^{0} move
Tracking Accuracy	< 0.55 arcsec rms over 10 min
	< 0.3 arcsec with autoguider

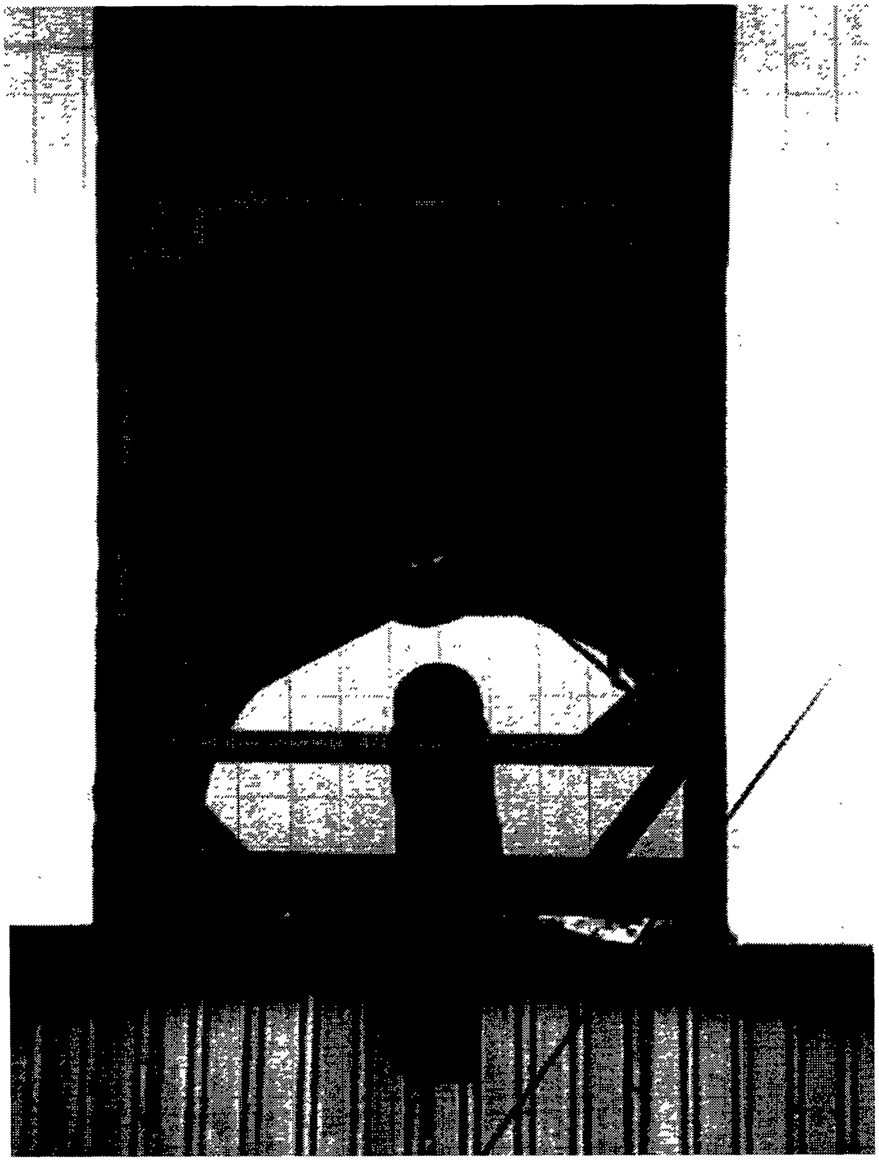

Figure 1b. View of the 2-m telescope seen through the slit in the dome.

Preliminary acceptance tests conducted during October 2000 showed that the specification on jitter and tracking accuracy without autoguider are fully met. The autoguider is yet to be implemented. A pointing accuracy of 6 arcsec was achieved for arbitrary movements over the sky, which need further refinement. The image quality was estimated to be < 0.70 arcsec dia (80% power) and needs to be monitored over a range of seeing values before estimating the value for zero seeing.

4.2 The focal plane instruments

The first generation instruments of the 2-m telescope will be mounted on an instrument mounting cube. This instrument cube has four side ports and one axial port with a mirror turret that permits mounting of instruments on all the ports and selecting them within a time of about one

Figure 2. The open star cluster NGC 2266 observed with the CCD imager through V filter. Field : 5.8 arcmin x 5.8 arcmin.

minute. The autoguider is mounted on one of the side ports, while the Shack-Hartmann sensor is mounted on another. Hence, two side ports and the on-axis port are available for science instruments. The first generation instruments are (1) a CCD imager, (2) an IR imager in the range 1.0 - 2.5 μm, and (3) an optical imager cum spectrograph. These instruments are described below. All instruments will be fully computer controlled and will have remote operation capability. The next generation instruments may include a camera-spectrograph in the IR region (1-5μm), a wide-field mosaic CCD camera, and a high resolution spectrograph in the optical. The total design weight of all the instruments mounted at a given time is limited to about 500 kg.

4.2.1 Optical imager

The first light optical imager is built in-house using a SITe 2K x 4K thinned, VISAR-coated ST-002AB CCD of 15μm pixel size. The pixel size of this CCD (0.17 arcsec at the Cassegrain Focus) and the format (5.9 arcmin x 11.8 arcmin) are ideally suited to exploit the on-axis field (7 arcmin diameter) of the telescope for sub-arcsecond resolution imaging. The large oversampling factor helps in image reconstruction to a resolution of 0.1 arcsec or better. Broadband and a few narrow band filters listed below will be available with this instrument which is currently being commissioned with broadband filters.

Filters available

- Broad band filters :
– Bessell *U BV RI, Z,* I_c (*I* filter with red cutoff)

- Narrow band filters (centre wavelength and (FWHM) in nm units):

372.7(5)	486.1(5)	500.7(5)
656.3(5)	664.3(10)	672.4(5)
680.4(10)	688.4(10)	696.4(10)
704.4(10)	712.4(10)	906.9(10)

Figure 2 shows the cluster NGC 2266 obtained with this instrument on October 21, 2000 in the *V* band.

4.2.2 Hanle Faint Object Spectrograph Camera (HFOSC)

The Hanle Faint Object Spectrograph Camera, an optical imager cum spectrograph, is being jointly built by the Copenhagen University Observatory (CUO) and the IIA.

The instrument is a focal reducer type of instrument i.e. by using a collimator with the same *F*-number as the telescope and a fast camera, the effective focal length of the telescope can be reduced. This allows a larger field coverage for a given detector, and also low and medium resolution grism spectroscopy with the insertion of dispersive elements between the collimator and the camera. It is possible to shift between these two modes in a few seconds.

The mechanical assemblies and the control system of HFOSC have been built at the CUO. The grisms are fabricated and supplied. The main optics has been designed and fabricated. The CCD dewar and controller are ready. Integration of the different units and tests are scheduled for November/December 2000.

The interface unit with narrowband filters and calibration sources is being designed by IIA and will be fabricated soon. The integrated instrument is expected to be installed at the telescope by January 2001.

Specifications :

Wavelength range : 350-900 nm

Detector : 2048 x 4096 CCD with 15 μm square pixels

Collimator focal length : 252 mm

Camera focal length : 147 mm

Reduction factor : 0.58

Resolutions : 0.30 arcsec/pixel. A set of 11 grisms allows a spectral resolution range of ~ 0.16 nm to 5 nm for a 1″ slit.

FOV : 14.2′ dia (optics)

Optical quality : 80% encircled energy within 0.3″

Efficiency of the collimator and camera : ~ 80% (400-1000 nm).

In a 10 minute exposure, we expect to be able to make a 3σ detection of a point source of $m_v \approx 25.5$ and an extended source of $\mu_V \approx 21.5$ mag/arcsec^2. In a 30 minute exposure, we expect to obtain a spectrum of a point source with $m_V = 18$ at R ≈ 150 and $m_V = 14$ at R ≈ 3600, with S/N = 50.

4.2.3 Near-IR imager

The near-infrared imager will be built around a 512 x 512 HgCdTe array of 18 μm pixel size. This will be sensitive to the wavelength range 0.8 – 2.5 μm which contains the *K* band which is of great importance in astrophysics. At Hanle, the median seeing in these bands is expected to be about 0.5 arcsec. The pixel size of 0.2 arcsec will help in subarcsec imaging and reaching out to fainter limits. The instrument will have two cameras that provide 1.8 arcmin x 1.8 arcmin field at 0.2 arcsec per pixel resolution, as well as 3.6 arcmin x 3.6 arcmin at 0.4 arcsec per pixel resolution. The instrument has been designed by M/s Infrared Laboratories, Tucson, and is being fabricated by them. It is expected to be available for observations by April 2001.

Filters available

- Broad band filters :
  – *J, H, K* and *K*-long (2.2-2.4 μm)
- Circular Variable Filter :
  – 1.29 to 2.3 μm quarter segment 1.5% average bandwidth
- Narrow-band Filters :
  – H_2 (2.122 μm) CO (2.295 μm) Br-γ (2.166 μm)

4.2.4 Science returns

The state of the art telescope, at the excellent site, is expected to provide high quality data to enable the study of diverse astrophysical problems related to stars and stellar systems. Some of the main thrust science programmes are listed below :

Follow up of γ-ray burst events

supernova search in galaxy clusters; studies of the temporal photometric and spectroscopic evolution of supernovae;

studies of galactic and extragalactic star-forming regions addressing the problem of dependence of the initial mass function (IMF) and star-formation rate (SFR) on the location, metallicity, structure of the background galaxy, gas dymnamical response to the structure and dynamics of the galaxy, the galaxy environment and interaction;

time variability of AGN; the starburst-AGN connection studies of interactions, mergers and activity in compact groups of galaxies; mass distribution and luminosity function in rich and poor clusters of galaxies;

a study of the chemical abundances, mass loss, chromospheric activity, etc of the post-AGB, hydrogen deficient and other chemically peculiar stars towards an understanding of the various stages of stellar evolution;

studies of the temporal evolution of novae during outburst; the binary components and circumstellar environment of novae (at quiescence) and symbiotic stars;

photometry of globular and galactic open clusters in order to obtain fundamental information such as the distance, age and chemical composition of the clusters using the colour-magnitude diagrams.

5. Antipodal Transient Observatory

The McDonell Centre for the Space Sciences of Washington University, St. Louis, USA and the IIA plan to operate two 50-cm F/10 Cassegrain telescopes for monitoring the Active Galactic Nuclei and other variable and transient sources. One of these telescopes will be at Hanle and the other in Arizona, USA. The two telescopes, 180^{0} apart in longitude, will together constitute the Antipodal Transient Observatory. The Washington University is providing the two telescopes and IIA is providing the CCD imagers. The enclosure, installation and operational expenses on site are borne by the individual observatories.

The CCD imagers already procured by IIA have 1K x 1K CCD detectors of 24 μm pixel size. This will provide for an image scale of about 1 arcsec per pixel and field of 17 x 17 arcmin^2. The telescope can thus function in robotic mode as well as in the remote observing mode.

The telescopes will be used for the continuous photometric monitoring of Active Galactic Nuclei for 70% of the time and the remaining time will be used for photometry of targets of opportunity and other programmes of interest.

The telescopes, manufactured by M/s Torus Precision Optics, Iowa, U.S.A., are being installed at the Weiner Mobile Observatory, Tucson, U.S.A., for testing. The enclosure structure for the telescope at Hanle is ready.

6. Other scientific projects at IAO, Hanle

The site of IAO, Hanle, is among the best high-altitude sites for ground-based astronomy in the near-ultraviolet to mm wavelengths and for atmospheric Cerenkov detection of high and ultra-high energy γ-rays. The site also provides a unique environment for many other scientific studies such as cosmic ray studies, geodynamics, geomagnetics, seismology, meteorology, and ionospheric and stratospheric research. With the infrastructure now developed for the IAO, the remoteness of the site is no longer a deterrent for initiating such projects. Apart from the 2-m and 50-cm telescopes to be operational soon, a few additional initiatives have already been undertaken towards research in various scientific paradigms in addition to astronomy.

A National Workshop on Science from Hanle was held at IIA in April 1999 and was attended by scientists in different disciplines from various research institutions across the country (Anupama 1999). Apart from astronomical programmes with the first generation instruments and proposals and telescopes to open up bands in the near-infrared to sub-mm region, the following additional experiments were suggested : solar studies including development of a multiwavelength solar radiometer; studies of atmospheric transparency at 220 GHz; optical imaging of mesospheric gravity waves; environmental monitoring of O_3, OH, aerosols, solar UV; magnetotelluric studies and broad-band seismology for delineating deep structure of the region and GPS geodesy to understand the kinematics and dynamics of continental deformation zones.

A few of the above mentioned experiments are already underway. Geodynamic studies have been undertaken periodically with a high accuracy GPS station, and a broadband seismograph has been installed. In addition, scientists from NPL have already made vists to Hanle to measure atmospheric water vapour, ozone, UV-B radiation, aerosol optical depth, Erythemal dose, etc. New opportunities are thus available at the Hanle site, not only for astronomy, but also in several other disciplines such as aeronomy, magnetotelluric studies and seismology.

References

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