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An Introduction to the Indian Astronomical Observatory, Hanle

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Abstract.

Situated in the high-altitude cold desert of Changthang Ladakh bordering Himachal Pradesh and Tibet, Indian Astronomical Observatory, Hanle (32°46′46″N, 78°57′51″E; 4500 m above msl), provides excellent opportunities for developing astronomical facilities at a variety of frequencies. In addition, it provides environment and logistics for a range of scientific experiments which benefit from its unique location.

Indian Institute of Astrophysics has built this observatory around a modest 2-m aperture optical/infrared telescope. A 0.5 m telescope will soon be added. A larger facility (6.5-8.5 m class infrared/optical telescope) is under consideration.

A 2-m telescope of new advanced technology design has been installed at the observatory in what probably is a record in the speed of execution. The site development, fabrication and installation of the telescope has been accomplished in just about 3 years. The telescope saw its first light on the night of September 26/27 2000 and has been operating with a CCD imager. A larger CCD imager, a faint object spectrograph camera, and a JHK imager are under fabrication. A 1-5 micron imager spectrograph is planned as the next generation instrument. The telescope will be remotely operable from the Centre for Research and Education in Science & Technology of IIA at Hosakote near Bangalore over the next few months. All the necessary infrastructure including 20 kw/h power through generators, 1 Mbps dedicated satellite communication link (to be upgraded to 2 Mbps and a 128 kbps redundant link to be established), liquid nitrogen plant, etc. have been already developed. The Government of Jammu & Kashmir has transferred over 600 acres of land to the observatory. The infrastructure developed for the observatory is already being used for other scientific experiments by national and international institutions. The experiments include determination of atmospheric opcaity at mm wavelengths, geodynamic and seismological experiments, aerosol background and other aeronomical experiments.

1. Introduction

Clear skies free of clouds, atmosphere without pollen, dust or aerosols, a location far removed from city lights, and with laminar airflow are needed for making astronomical observations of high quality in the optical band width. If we are interested in extending the observations to longer wavelengths, then the airmass above the telescopes should not have much precipitable water vapour. Thus the question which was the concern of the Indian astronomers was whether such a site could be found in India subject to the two monsoons. The Indian Institute of Astrophysics in the year 1992 decided to make an all out effort to search for such a site in India. The main strategy for the search was provided by the idea that the monsoon winds would be effectively stopped by the high Himalayan mountain ranges and that in the rain shadow regions of Ladakh we may find a suitable site. It would have the added advantage of a high elevation, leaving behind much of water vapour which has a scale height of $\sim$ 1.5 km in the atmosphere. Also the overburden of air being thinner and smaller, we may expect considerable improvement in "seeing" with respect to sites at lower elevations. Encouraged by these thoughts and supported by the Department of Science and Technology, the Indian Astronomical Observatory became a reality just about a year ago. The saga of this effort in setting up this observatory has been described in several places. The present report is taken essentially from our presentation to the ASP Conference Series (Cowsik et al 2001C).

IIA looked at the available topographical maps, weather data, and satellite imagery in 1992–93 to identify possible sites in the Himalayan and trans-Himalayan regions. In August 1993, teams from the Institute travelled to six prospective sites all above 4000 m altitude and carried out reconnaisance simultaneously to identify the one that provides the best conditions which could then be chosen for further site characterization. As one would expect, the high-altitude cold desert of Ladakh, being in the rain-shadow of the tall mountains of the Himalayan regions, provides the largest number of clear nights as well as dry and cold conditions suitable for infrared and sub-mm observations. Among the two sites shortlisted in this region (mountains near the brackish lake Tso Moriri, and the Digpa-ratsa Ri range at the centre of Nilamkhul Plain, Hanle), the site at Hanle was selected for further characterization based on its local topography conducive to streamlined wind flow and better seeing.

IIA set up a site survey camp in the Nilamkhul Plan at the end of 1994. A continuous monitoring of cloud cover, ambient temperature and relative humidity for an year confirmed that the site had an excellent potential (HIROT Team, 1996). Hence it was decided in 1996 to develop the site into an observatory beginning with a telescope of 2-m aperture, operated remotely in the optical and infrared wavelength bands. The financial sanction of the Government of India was obtained during the second half of 1997. An order for the 2-m telescope was placed with M/s Electro Optic Systems Pty Ltd, Australia and the development of necessary infrastructure at the site was initiated. The observatory was ready for the telescope in three years. The telescope, fabricated by M/s EOST, Tucson, was received at Mumbai port in July 2000, reached the site in a few weeks and saw its first light on 26/27 September 2000 which heralded the birth of the Indian Astronomical Observatory (IAO) (see Anupama 2000). It is currently undergoing acceptance tests while a few observations of targets of opportunity were also undertaken (e.g., Cowsik et al. 2001a).

2. The site and its characteristics

The gateway to Ladakh is through Leh, which is at an altitude of 3200 m above mean sea level, and is connected all through the year to Delhi, Srinagar, Jammu and Chandigarh by regular commercial flights. On the other hand, the surface access to the mainland south of Himalayas is either through Srinagar and Jammu or through Manali, and is possible only in summer months due to heavy snowfall in the Himalayas durint winter months.

Mt Saraswati, Digpa-ratsa Ri, is located in the Ladakh highlands of Jammu & Kashmir state of India at longitude 78°57′51″ E and longitude 32°46′46″ N. The peak of the isolated hill range is at 4517 m above mean sea level, 200 m above the surrounding Nilamkhul Plain. Changthang is a high-altitude plateau at a mean level of 4200 above msl with hills and mountains rising above the plateau. The site can be reached by an all-weather road from Leh, the biggest township in Ladakh. The road coasts along the banks of Indus for the first 200 km after which it turns south and hugs the banks of a tributary, the Hanle river for a further 50 km. The base camp of IAO is 5 km from the Hanle village and a 5 km road links it to the observatory peak.

IIA has manned Hanle since 1994 December and the site characterization has been a continuous process. A weather station was installed in 1996 July. Precipitable water vapour was measured through a sun-spectrophotometer in April 1995 and using a 220 GHz radiometer in November 1996. A 220 GHz radiometer was installed for continuous operation in December 1999 (Ananthasubramanian, Yamamoto & Prabhu 2001). Seeing was estimated with a Differential Image Motion Monitor set up at the peak in July 1998. The site characteristics, based on the observations collected so far, are listed in Table 1.

Table 1. Site Characteristics of Mt. Saraswati

Accessibility	around the year
Number of spectroscopic nights	260 per year
Number of photometric nights	190 per year
Precipitable water vapour	≤ 2 mm
Annual precipitation of rain and snow	< 7 cm
Extinction in V band	~0.1 mag/ air mass
Sky brightness	$\mu_V = 21.5$ mag/arcsec^2
Median Seeing	0.8 arcsec
Distribution of useful nights	uniform round the year
Median temperature	$-2°$ C at night (minimum $-24°$ C)
Median relative humidity	30% at night (minimum $< 10\%$)
Median windspeed	2.2 m/s (8 kmph) at night
Wind direction	Prevailing south-south-westerly

The number of spectroscopic and photometric nights were estimated from the hourly log of number of octas of cloud coverage. Fig. 1 shows their monthly distribution over the years 1996–99.

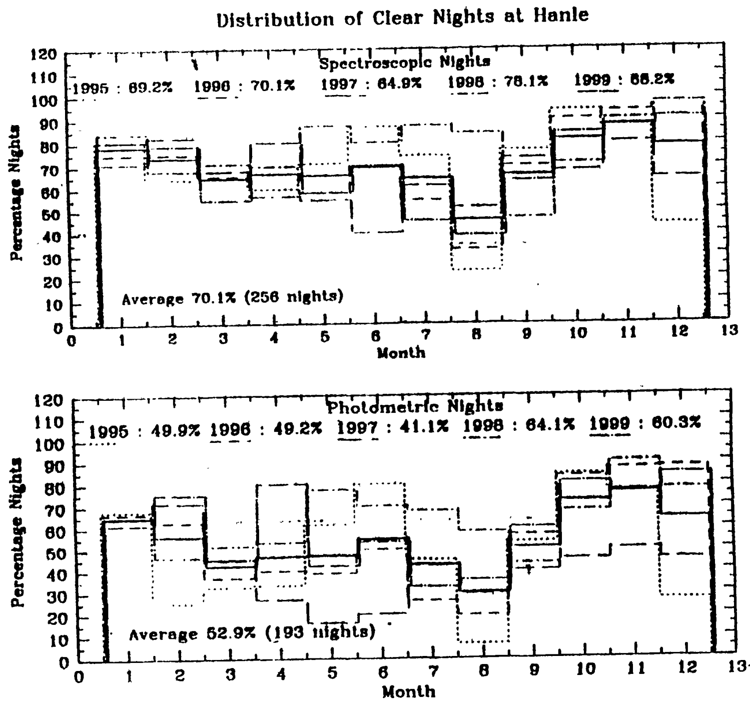

Figure 1. Distribution of usable nights at Mt. Saraswati

3. The infrastructure

Nilamkhul Plain is inhabited and has a population of about 1000 persons living in a few hamlets sprinkled several kilometres apart. The community survives mainly on scanty agriculture during the summer months and is capable of providing very little support for the operation of the observatory except for a small labor force. The region is connected to Leh by a weekly public bus. The supply of electricity is extremely limited, and the source of water is restricted to a few small streams which flow in the summer at the foot of Digpa-ratsa Ri. IIA had to develop all the infrastructure required for the observatory. The permanent camp was initially set up in a hut provided temporarily by a government department. A plywood and glass hut was fabricated in IIA workshop, and erected at the foot of Digpa-ratsa Ri in November 1996. Additional huts made of fiber-reinforced plastic were procured and erected during the next summer. Permanent laboratory builidng with some guest rooms has been constructed recently.

Work on laying an unpaved road from the base station to the peak commenced the same year and was jeepable by the end of summer of 1997. Two solar photovoltaic (SPV) power plants of 30 kWp capacity each were installed during the summers of 1998 and 1999. There are also two diesel generator sets of 62.5 kVA capacity for backup at the observatory and similar units at the base camp. A 1 kW SPV power plant was installed at the base for lighting and communication equipment.

The early communication was through a satellite communication link on a shared hub with a bandwidth of 1200 baud which was later upgraded to 9600-

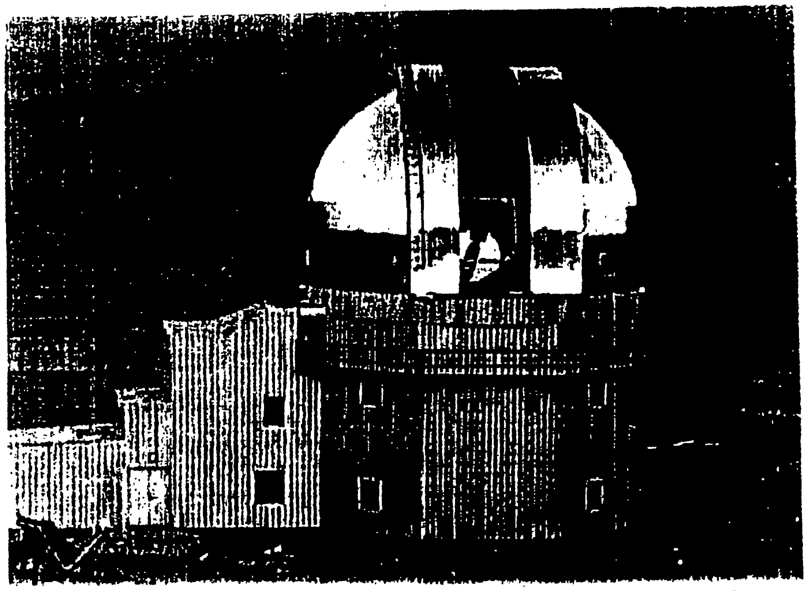

Figure 2. The 2-m telescope in its enclosure at IAO, Hanle

band. This helped in communicating with the external world through electronic mail since no other communication facilities were available at the site. Work on setting up a 128 kbps point-to-point satellite communication link between Hanle and the Centre for Research and Education in Science & Technology (CREST) campus of IIA at Hosakote near Bangalore was also initiated in 1997. Currently, the observatory is connected to CREST through a 1 Mbps satellite link.

A liquid nitrogen plant of 5 lit/h capacity was procured from M/s Stirling Cryogenics Ltd, Netherlands, and installed at the site in 1999. The enclosure of the telescope was built over three working seasons: the pier in 1998, the main structure in 1999 and the dome and cladding in 2000 just prior to the arrival of the telescope.

Apart from this, additional facilities are being created as and when needed for a variety of projects. The site characterization building houses a Meade 1?-inch telescope used as a DIMM and the 220 GHz radiometer. A 50-cm telescope enclosure is ready and awaits the telescope. All the facilities are interconnected by cables for the distribution of electrical power, telephones and for computer LAN signals. The telephone exchange and computer network are connected to the CREST campus through satellite communication links.

The staff for the maintenance of the observatory consists largely of engineers, technicians and support personnel hailing from the Ladakh region itself (altitudes > 3000 m) who can work well continuously at high altitudes. The observatory has thus become self-sustained for routine operations.

4. The 2-m Telescope

The 2-m aperture optical-infrared telescope is compact, and completely computer-controlled telescope. The basic specifications are listed in Table 2. The telescope will be remotely operated from the CREST campus of IIA, to the north of Bangalore using a 1 Mbps (to be upgraded to 2 Mbps when the demand increases) dedicated point-to-point communication link through the INSAT satellite. The telescope, dome and a CCD camera are already being operated in this mode. The integration of different software components will be initiated in 2001 August, after the installation of an autoguider.

Table 2. Basic specifications of the 2-m telescope

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° move
Tracking Accuracy:	$<$ 0.55 arcsec rms over 10 min
	$<$ 0.3 arcsec with autoguider

5. The focal plane instruments at the 2-m telescope

The first generation instruments are described below. 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 band. The instrument mounting cube of the 2-m telescope has four side ports and one axial port with a mirror turret that permits selecting an instrument from any port within a minute. One of the ports will be used for autoguider and hence four ports will be available for instruments. The telescope design limits the total weight of all the instruments mounted at a given time to about 500 kg.

5.1. Optical Imager

An optical imager is built in-house using a SITe ST-002AB 2k $\times$ 4k CCD chip of pixel size 15μm $\times$ 15μm, thinned and VISAR-coated. The pixel size (0.17 arcsec at the Cassegrain Focus) and the format (5.9 arcmin $\times$ 11.8 arcmin) are ideally suited to fully exploit the available on-axis field (7 arcmin diameter) of the telescope and carry out subarcsecond-resolution imaging from the site that offers excellent seeing. The large oversampling factor helps in image reconstruction to a resolution of 0.1 arcsec or better. The filter wheel unit has been designed and fabricated in-house. The imager is being fine tuned in the laboratories of IIA. Apart from $UBVRII_cZ$ filters, some narrowband filters will also be available.

5.2. Hanle Faint Object Spectrograph Camera (HFOSC)

Hanle Faint Object Spectrograph Camera is an optical imager cum spectrograph built collaboratively at the Copenhagen University Observatory. It is expected to be commissioned in 2001 August. The instrument is a focal reducer type of instrument, i.e., by a 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 size. It is also possible to carry out low and medium resolution grism spectroscopy by inserting dispersive elements between the collimator and camera. The time taken to shift between these two modes is only a few seconds. The specifications of the spectrograph are listed in Table 3.

Table 3. Specifications of HFOSC

Wavelength range	350–900 nm
Detector	2048 × 2048 CCD; 15 μm^2 pixels
Collimator focal length	252 mm
Camera focal length	147 mm
Reduction factor	0.58
Spatial resolution	0.30 arcsec/pixel
Spectral resolution	$\sim$ 0.16 nm to 5 nm for a 1″ slit
FOV	10.1 × 10.1 arcmin^2
Optical quality	80% EE 0.3″ dia
Efficiency of optics	$\sim$ 80% (400–1000 nm)

5.3. Near-IR Imager

The near-infrared imager is built around a 512 × 512 quadrant of a HAWAII HgCdTe array of 18 μm × 18 μm pixel size. The instrument will have two cameras that provide 1.8 arcmin × 1.8 arcmin field at 0.2 arcsec per pixel resolution (for seeing-limited imaging), as well as 3.6 arcmin × 3.6 arcmin at 0.4 arcsec per pixel resolution for wider field coverage. The instrument was designed and fabricated by M/s Infrared Laboratories, Tucson, and is expected to be installed by October 2001. Apart from the JHK broadband filters, a K-long (2.2–2.4 μm) filter will be available to take advantage of low thermal background in cold winter nights. A circular variable filter between 1.29 to 2.3 μm with 1.5% average bandwidth will be available in parallel beam to simulate intermediate bands. Following narrow-band filters will also be available: H_2 (2.122 μm), CO (2.295 μm), Br-γ (2.166 μm), Fe II (1.644 μm), and continuum filters for Fe II and K band.

6. Other Scientific Projects at IAO

Hanle was identified as a part of the proposal to develop a large infrared-optical telescope in India. The efforts towards the latter will continue, with possible participation of other interested countries. Apart from being one of the best high-altitude sites for ground-based astronomy in the near-ultraviolet to mm wavelengths and for detection of high and ultra-high energy γ-rays using the atmospheric Cerenkov technique (Cowsik et al. 2001b), Hanle 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 telescope expected to be operational soon, and the large infrared optical telescope envisaged as the second step in the development of IAO, a few additional initiatives have already been undertaken towards research in various scientific paradigms including astronomy (cf., Anupama 1999).

6.1. Ground-based gamma-ray observatory

Recently Indian Astronomical Observatory has been set up at Hanle (32°46′46″N, 78°57′51″E, 4515m amsl) situated in the high altutude cold desert in the Himalayas. The Observatory has 2-m aperture optical-infrared telescope, recently built by the Indian Institute of Astrophysics.

We have carried out systematic simulations for this observation level to study the nature of Cerenkov light pool generated by gamma ray and proton primaries incident vertically at the top of the atmosphere. The differences in the shape of the lateral distributions of Cerenkov light with respect to that at lower altitudes is striking. This arises primarily due to the proximity of the shower maximum to the observation site. The limited lateral spread of the Cerenkov light pool and near 90% atmospheric transmission at this high altutude location makes it an ideal site for a gamma ray observatory. This results in a decrease in the gamma ray energy threshold by a factor of 2.9 compared to that at sea-level. Several parameters based on the density and timing information of Cerenkov photons, including local and medium range photons, including local and medium range photon density fluctuations as well as photon arrival time jitter could be efficiently used to discriminate gamma rays from more abundant cosmic rays at tens of GeV energies.

6.2. The Antipodal Transient Observatory

IIA and McDonnell Center for the Space Sciences of Washington University, St. Louis, plan to operate two 50-cm F/10 Cassegrain telescopes for monitoring 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° apart in longitude, will together constitute the Antipodal Transient Observatory. The telescopes manufactured by M/s Torus Precision Optics, Iowa, are undergoing acceptance tests. The enclosure of the telescope at Hanle has been erected.

6.3. Geodynamic Deformation Field over the Indian Continent

As a part of the national GPS network to model the dynamics of the Indian continent, a permanent GPS station has been established at Hanle together with ten other GPS sites in Ladakh to determine the annual displacement and strain fields in the Indian territory southwest of the Karakoram fault. The study provides the station coordinates with reference to WGS 84 with sub-cm accuracy and also yields strain rates suffered by the region to elucidate the nature and extent of the continental deformation in Ladakh in the wake of the Indo-Eurasian convergence of 51 mm/yr (Jade et al., 1999). A continuously operating broadband seismograph was also installed at Hanle in October 2000. This will provide an important seismic station in a significant arena of Himalayan geodynamics.

6.4. Aerosol Content at Leh and Hanle

Measurements of atmospheric parameters at remote and high altitude areas are scanty. As these areas are free from the influence of man-made sources, measurements at these locations will serve as background values of the parameters. As a part of the proposed aerosol and trace gases measurement programme, the Indian Institute of Tropical Metorology carried out Aitken nuclei measurements at Leh and Hanle during October 1999. The study found that the concentration of Aitken nuclei at Hanle were exceptionally low, reaching 100 cm^{-2} at night. The Aitken nuclei are aerosol particles of size < 1 μm. They form an active component of the earth's atmosphere, and respond quickly to changes in relative humidity, absorbing and releasing moisture. They are of interest in astronomy since their concentration determines the formation of haze. They also adhere easily to optics. Thus, their low concentration at Hanle indicates that the site has excellent quality of photometric nights, low atmospheric absorption and infrared emission from aerosols, as well as low deposition of aerosols on optics.

6.5. 220 GHz Radiometer

The University of Tokyo, Raman Research Institute (Bangalore), and IIA are collaborating to characterise Hanle for mm and sub-mm astronomy. Towards this end, a 220 GHz tipping radiometer was installed in December 1999. A description of the system and some preliminary results are provided in this volume by Ananthasubramanian, Yamamoto & Prabhu (2001).

Acknowledgments. A project of this magnitude could not have been completed in such a short time without active participation of a large number of scientists, engineers and other staff members of the Institute. Space does not permit listing every name, but their contributions are gratefully acknowledged.

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