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Characterization of sites for Indian Large Optical Telescope Project

Characterization of sites for Indian Large Optical Telescope Project

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Abstract.
Growing Indian astronomical community require access to large observing facility preferably located within the country. Site surveys carried out in the post indicates that the best sites for optical-NIR astronomy can better be found in Indian part of trans-Himalayan region. This very high-altitude, extremely dry and cold region is far from any artificial light pollution having low atmospheric aerosols, not much affected by monsoon and has got clear sky all through year. In the year 2000, as a pathfinder to large telescope, one 2m size optical telescope was commissioned at Indian Astronomical Observatory(IAO) Hanle Ladakh. However, before initiating a project to install a large 8-10m size Optical-NIR telescope it is essential to thorough characterize few candidate sites in and around IAO. Keeping this in consideration, once again we have started a detailed site survey program. In this paper, we will briefly present our effort to indigenously develop site survey instruments as well as results obtained by using them.

1. Introduction

While great strides have been made in observational astronomy all over the world, the Indian astronomers have to solely rely on 2 m class telescopes in all these years. To keep up with the emerging trends and explore the new horizons in astronomy, there is proposal by Indian astronomical community to install a modern, state-of-the-art 8-10m class telescope some where in India. In eighties, its was found by Indian astronomers that the best place for optical NIR observation can only be found in Himalayan region. A national project headed by A Bhatanagar was initiated to search for sites in in Ladakh region. The survey carried out during 1984-1989 near Nimmu (4100 m above msl) on Leh-Kargil road northwest of Leh found this place very suitable for astronomy, except relatively less number of clear nights. Few year later, under separate initiative to identify suitable sites for large Optical-NIR observatory, Indian Institute of Astrophysics (IIA) started surveying Himalayan and trans-Himalayan regions. By making use of available topographical maps, weather data and satellite imagery, six potential sites all more than 4000m above from mean sea level were identified. Based preliminary survey carried out at sixes places, Digpa-ratsa Ri, Hanle (mount Saraswati), was chosen for further detailed studies. Hanle is a high-altitude, extremely dry and cold place. This place is far from any artificial light pollution having low atmospheric aerosols, not much affected by monsoon and has got clear sky all through year. This place provides an excellent opportunity for developing astronomical facilities at a variety of frequency and an initiative has already been taken to establish astronomical facility over there. As a pathfinder to large telescope, one moderate

Table 1. Three candidate sites for the NLOT

Place	Altitude(M) (M)	Longitude (HH:MM:SS)	Latitude (DD:MM:SS)	Wind speed(night) (m/s)	RH %	Extreme Temp (C)
IAO Hanle	4500	78:58:29	32:46:48	4.0	33	-25.0/26.0
Kalak-Tartal	5486	79:00:44	32:38:23	6.2	45	-23.8/18.7
Randog	5055	78:55:20	32:50:46	7.2	50	-27.7/17.9

size Optical telescope was installed during 2000 at one of the peak called mount Sarswati in Hanle. Since then, slowly all required infra-structure is being created. More than a decade long observing experience with 2m size telescope, it has been found that Hanle region thus has the required characteristics of a good astronomical site and could be a natural candidate site for any future large aperture Indian optical-infrared telescope (Cowsic et. al. 2002). However, setting up 8-10 meter size telescope requires huge amount of investment and the manpower, therefore, a thorough understanding and characterization of the intended sites are necessary. In the year 2007-08, a detailed site survey program was initiated to characterize the site where current 2m telescope is installed as well few more potential sites within few km from it. In this paper we present our effort being carried out in this regards.

2. Meteorological Data

In order to record meteorological parameters, several weather stations have been installed at different candidate sites. Weather installed at IAO is continuously used to collect data over more than 18 years. Whereas, weather stations in other two peaks are operating since 2007. These weather station records, wind speed and direction, relative humidity, ground and air temperature, rainfall and solar irradiation. Table 1 provides statistics of meteorological data collected for three sites over a very long period.

3. Cloud Monitors

The most important parameter for any astronomical sites is availability of large number of clear nights well distributed over all through the year. Therefore, monitoring local sky for the cloud is the first task before setting-up a new observatory. There are different methods adopted to monitor sky conditions. In the classical method, the whole sky is divided in eight equal parts and cloud is visually looked at in these sky regions. At IAO site, sky is being manually monitored over more than 18 years. In addition to this satellite imagery data can also be used to get qualitative estimates of clear sky. However, the best and more reliable method is to make use of all sky optical and/or IR camera, which captures whole sky on very regular basis.

3.1. CCD based All Sky Camera

CONCAM stands for CONtinuous CAMera, designed and built by Robert Nemiroff and his team at Michigan Technical University (Pereira 2003). CONCAM consists of a fish-eye lens that projects the night sky onto an SBIG CCD camera. Some time in 2004, one of CONCAM unit was installed at IAO Hanle and since then it is continuous working. The camera switches itself on during evening twilight and stops at the end of the night. Images are taken every four minutes of interval and they are immediately corrected for bias and flats. The reduced data is archived as well as made available on real time through Web. Over ten years of operation more than a million all sky night images are collected.

3.2. IR scanning cloud Monitor

A CCD camera based all sky monitor is an inexpensive tool, however, appearance of clouds in the optical images is very deceptive due to its strong dependency on apparent optical sky brightness which in turn depend on phases of the Moon, local light pollution and other atmospheric variables. Automated tools developed to derive a quantitative information of cloudiness from all sky images, usually fails to reliably extract cloud information and results are often found to be inconsistent with other methods. All Sky Scanning Cloud Monitor is one of the instrument what we have developed for the purpose of surveying potential sites. The instrument works on the principle of detection of the Infrared radiations from the clouds (Clay et al. 1998). A number of thermopile sensors are arranged in the form of a circular array and whole sensor array is rotated in azimuth to cover the full sky. The device has got high sensitivity, provides radiometric output, cover whole sky, works in fully automated mode and also very cost effective. The IR scanning cloud monitor has been calibrated and tested in IIA Bangalore then after recently it has been installed at IAO Hanle.

The analysis of cloud data indicates that as for as availability of number of clear nights is concern, IAO Hanle is not to different from Mauna Kea. Usable nights are more than 80%, whereas, number of spectroscopic nights are found to be about 70%. Even during peak Monsoon season, when rest of India is severely affected by cloud, one can expect about 35-50% clear nights at IAO Hanle.

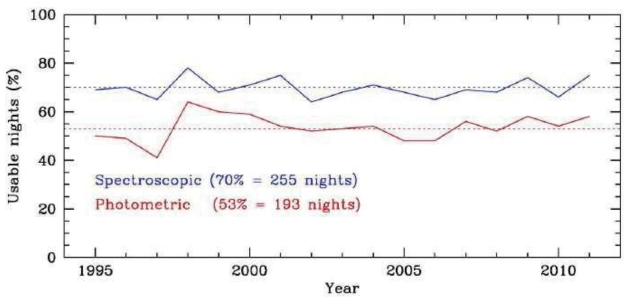

Figure 1. Automated extinction monitor

4. Extinction monitor

Quality of the nights whether it is photometric or spectroscopic is primarily judged by cloud coverage. Cloud free sky is usually considered to be photometric, whereas, partially cloudy sky is designated as spectroscopic. However, in practice, it has been noticed that even cloud free nights can have variable atmospheric transparency linked with change in atmospheric aerosol and absorption by water molecules. By doing photometric observations of stars, atmospheric extinction can be precisely measured. The best way to generate accurate statistics of photometric nights over longer run is to operate an automated extinction monitor (AEM). Our AEM is a standalone semi-robotic instrument designed to measure any small variation in the atmospheric transparency in one of optical band. The instrument comprises a wide field telephoto lens Nikon 300m F/4, an yoke mount equatorial tracking system, and a thermo-electrically cooled large format U32 Apogee CCD camera. The whole device is kept inside a tilted sliding roof enclosure which is again motorized and computer controlled. The key idea behind developing this instrument is to observe few hundred stars, brighter then 12th magnitude, over varying range of airmass. And make use of the brightness measurements of all stars to determine atmospheric extinction with very high accuracy. The same device can also provide sky brightness in one of photometric bands. The Extinction monitor was installed at Hanle during end of 2012, initial few months required to test the data quality of the device and also in improving its hardware . Then after device is being used almost on regular basis. We have collected more than 100 nights data which has not been completely analyzed. Initial test indicates that device works very precisely and extinction measured using AEM closely matches with 2m HCT observation.

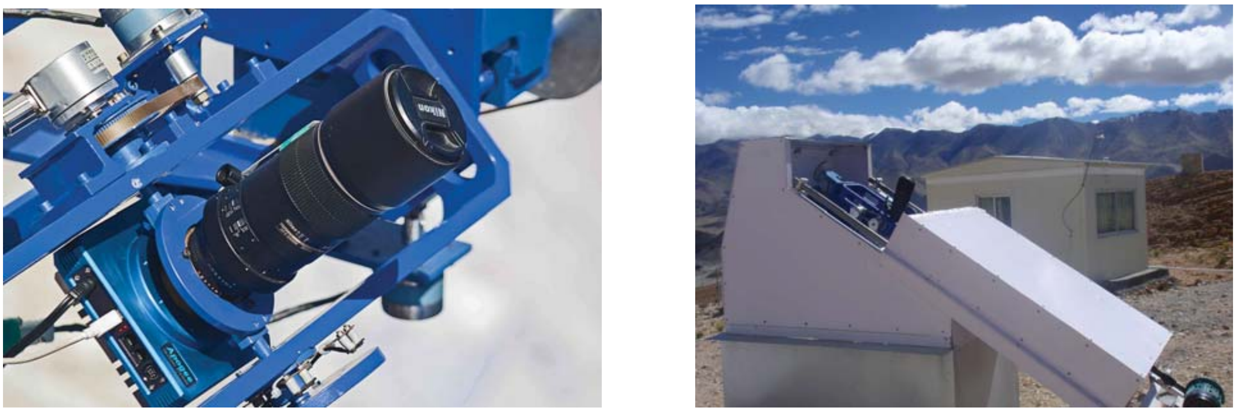

Figure 2. Automated extinction monitor

5. DIMM Seeing Monitor

The most essential instrument for any site survey program is an automated seeing monitor. A new DIMM seeing monitor was developed using 14” Meade LX200 GPS telescope. It uses a U2000 CCD camera from Apogee which can have very short exposure and support fast read out, a prism as well as a mask with two holes. In order to make the device fully automated, we have incorporated, external limits switches into RA and Dec drives, day-night light and cloud detectors, a micro-controller driven power supply and a vertically sliding enclosure. Since the Meade telescope has got poor pointing accuracy, so we added a small finder attached with the web camera, which covers 1.5x2.0 degree FoV and automatically center the star. The instrument control and analysis software have been developed using C++ programming language. Images acquired by seeing monitor is archived and also processed in real time. The seeing monitor was installed at 4m high tower at IAO Hanle during September 2011. Since then it is in regular use and more than 180 nights seeing data have been collected. It was noticed that due to wind sake images acquired at higher wind speed were found to be elongated and such data points are excluded while computing the seeing values. The mean and median seeing value at Hanle is found to be 1.37±0.50 arc-sec as well as 1.27±0.31 arc-second respectively. Whereas, in the past seeing measured using old seeing monitor over less number of nights, shows median seeing value about 1.0 arc-sec. One way to interpret the differences, is the new seeing values which has been mostly collected during winter season. Whereas, it has been found from images collected using science camera of 2m HCT telescope that seeing is found to be usually very poor in winter season. Therefore, we expect better median seeing values, once we collect data equally spread all through year. Analysis of nightly seeing data show different behaviors/pattern. There are nights in which seeing values are considerably high all through night. Whereas, is in some night, seeing is found to be stable and exceptionally good. There are nights in which seeing may be large at the start of observations but later it improves or vice-versa.

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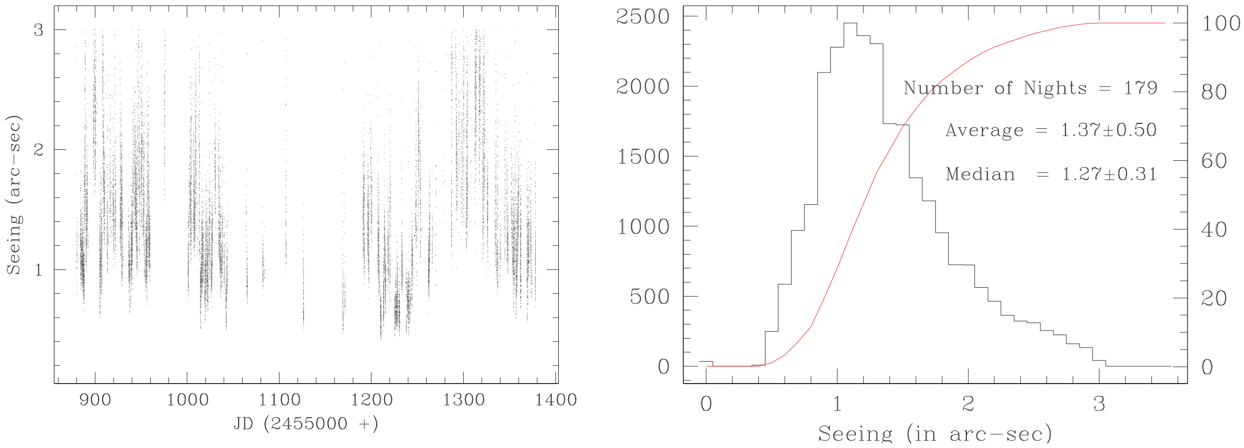

Figure 3. Distribution of seeing values collected during September 2011 to March 2013.

6. Lunar Scintillometer

Ground layer turbulence is one of the important site characterization parameters used for assessing the quality of an astronomical site. Lunar Scintillometer (LuSci) is a simple, yet an effective site-testing device for measuring the ground layer turbulence. The instrument consists of a linear array of photo-diodes which record the variations in moon's intensity caused by the lower layers of the Earth's atmosphere. The co-variance between all possible pairs of photo-diodes can be used to reconstruct the ground layer turbulence profile starting from the ground up-to a maximum height roughly determined by the distance between the furthest pair of detectors. Our 6-channel LuSci is close replica of turbulence profillometer recently built by the team led by Andrei Tokovinin of CTIO, Chile (Tokovinin et. al. 2010) A web-cam is used to ensure that the instrument is pointed to the moon. The whole assembly goes as piggyback on a small 12" Meade LX200 telescope which facilitate to point and track the Moon. Instrument control software which handles, Lusci, web camera and a Meade telescope has been developed using LabView. After testing the device in the laboratory as well as with the Moon, device was finally installed at IAO Hanle in September 2013. Then after Lusci data has been collected in more than 25 nights over several observing campaign. The average ground layer integrated seeing up to 784 meter high from telescope is found to be 0.38±0.28 arc-second, wheres as median values is 0.32±0.16 arc-sec. Most of the time it was found that the first two layers from device (3m and 12m) appears to contributing most. However there were instances when turbulence shifted from one layer to other during course of observations.

7. Other Survey Devices

7.1. 220Hz Radiometer

A 220-GHz (1.36 mm wavelength) Radiometer was jointly developed by Indian Institute of Astrophysics, Raman Research Institute and the University of Tokyo. The device was installed at IAO Hanle some time in 1999, since then it is continuously working. Radiometer works in scanning mode and measured opacity at 1.36mm wavelength. Opacity measurements carried out by this instrument over several years show that the absorption at this frequency is less than 0.1 for 70% of the time in winter months. This shows that at least during winter months IAO site is better than at Mauna Kea. However, annual average opacity has been found to be same for both the sites.

7.2. MASS-DIMM

The MASS-DIMM is one of very important site survey device which gives atmospheric turbulence profile, starting from 500m to 16km (Tokovinin & Kornilov 2007). We have got an MASS-DIMM from TMT USA as a loan for two years. MASS-DIMM instrument require a very sturdy telescope which is not affected by wind gust and can provide reliable seeing measurement at higher wind speed. Instead of using commercially available telescope which usually fails to meet this requirements, we have been developing a light weight, but stiff telescope driven by direct drive motors. The MASS-DIMM software originally developed by TMT also requires considerable changes before we can make use of it.

7.3. Micro-Thermal Seeing Measuring Device

In between ground and inversion layer there is strong convection which introduces micro-thermal fluctuations causing inhomogeneities in refractive index. By making use of accurate and fast temperature recording sensor, one can measure fluctuation in temperature and hence refractive index structure constant. A micro thermal measuring device is being developed at IIA.

Acknowledgment

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