A modern 3.6 meter new technology optical telescope as a major national initiative in Astrophysics

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Abstract

The scientific development in the field of observational astronomy in India has been quite significant in the recent past. India has three 2-meter class and six 1-meter class optical and near infrared telescopes. These telescopes are mainly used for photometric and low-to-medium resolution spectroscopic observations of Galactic and extra-galactic sources. In order to complement these observing facilities, the Department of Science and Technology, Govt. of India plans to install a 3.6-m modern state-of-the-art optical telescope at Devasthal near Nainital in the central Himalayan range. ARIES, Nainital, taking a lead role in the installation of the optical telescope during the next five years with national and international collaborations.

(**Keywords** : Optical astronomy/telescopes/multi-wavelength astronomy)

Preamble

India has a rich heritage in theoretical, computational, and observational astronomy. In recent years, considering the importance of multi-wavelength astronomy in the present era, the observational facilities in India are taken to a greater height and made internationally competitive at radio (Giant Meter-wave Radio Telescope (GMRT) near Pune), infrared (TIFR balloon-borne telescope, Gurusikhar infrared telescope), ultra-violet and X-rays (First Indian Multi-wavelength Astronomical satellite. ASTROSAT, to be launched in 2008-09) and Gamma rays (TACTIC, Mt Abu, Hager and MACE at Hanle) wavelengths. In the optical and near-infrared regions, to complement the existing Indian observing facilities (three 2-m class namely Himalayan Chandra Telescope (HCT) at Hanle, Vainu Bappu Telescope at Kavalur and IUCAA Girawali telescope near Pune and six 1- meter class optical telescopes) and also make it globally competitive, a modern 3.6 meter new technology optical telescope, the largest in India, is being installed at Devasthal, Nainital in Uttarakhand as a major national observing facility. For this, Aryabhatta Research Institute of Observational Sciences (acronym ARIES), an autonomous research institute under the Department of Science and Technology (DST), Government of India, has taken lead in collaboration with Indian Institute of Astrophysics (IIA), Bangalore and Tata Institute of Fundamental Research (TIFR), Mumbai within the country and with Russia and Belgium from abroad. The telescope will be installed at Devasthal located about 50 km by road and east of Nainital. The site has been identified after an extensive survey carried out in the central Himalayas during 1980-2001[1–3]. The annual air temperature at Devasthal varies between –5 to +22°C. The seeing defined as amount of blurring of a point source due to the earth's atmosphere has been quantified using extensive measurements taken with modern instruments namely differential image motion monitor installed around 2-m above the ground level[2,3]. These observations along with micro thermal fluctuation measurements[1] carried out at 2, 6 and 12 m above the ground indicate that the sub arc second (~ 0.7) seeing can be obtained at Devasthal if the telescope is installed about 8 m above the ground. These coupled with the number of yearly spectroscopic nights (~ 210), darkness of the per square arc sec sky (V ~ 21.8 mag) and other atmopsheric parameters for Devasthal make this site competitive with the best international sites located in Chile and La Palma. The site (Latitude: 29 deg 39 min North, Longitude : 79 deg 68 min East, Altitude: 2540 m) thus has a unique advantage of the geographical location conducive for astronomical observations of those optical transient and variable sources which require 24 h continuous observations and can not be observed either from east in Australia or west in La Palma due to day light. A long distance view of the top of Devasthal site is shown in Fig.1.

Technical Parameters and Science Drivers of the 3.6-m New Technology Optical Telescope

The fundamental telescope optics parameters are a primary mirror of diameter 3.6 m, F/2 primary, F/9 effective focal ratio, Ritchey-Chretien configuration with a back focal distance of 2 m. The telescope performance is set to have eighty percent energy within 0.45 arc sec diameter in 30 arc min field over 350 to 3000 nm wavelength range. The primary mirror will have a meniscus shape with a thickness to diameter ratio of about 1 to 20 and the total weight of the machined mirror after a Cassegrain hole of about 600 mm will be around 4000 kg. The secondary mirror will have a diameter of about 900 mm. The primary and secondary mirror surfaces will be polished with a typical wavefront accuracy of 30 nm RMS at 600 nm. For a telescope with these dimensions, it becomes essential to have active mount for the primary mirror which is required to keep both the mirrors primary and secondary aligned all the time within the requirements under varying telescope positions and thermal environment. The telescope will have a Alta-Azimuth mounting with a zenith blind spot of less than 5 degree. Fig. 2 shows optical layout and a sketch of the 3.6 meter optical telescope. The project cost is around 120 crore rupees. First light for the telescope is proposed in 2012.

Investigating pulsational characteristics and magnetic field structure of stars would be one of the prime science goals. In addition, the near-infrared spectroscopy and narrow-band imaging will be used to study galactic HII regions, debris disks around stars, cataclysmic variables, asymptotic giant branch stars, X-ray binaries and active

Fig. 1- A long distance view of the top of Devasthal site.

galactic nuclei. The scientific objective of this telescope also includes studies of Doppler imaging and stellar magnetism in active and late type stars, astero-seismological studies of white dwarfs, chemically peculiar magnetic stars, etc. Back-end instrumentation techniques such as imaging, spectroscopy and hitherto less explored spectro-polarimetry will be used to achieve these aims. Further details of the science drivers are given elsewhere[4].

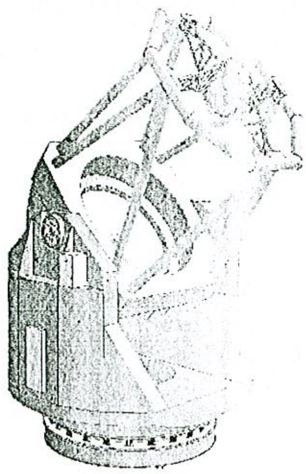

Fig. 2– A sketch of the 3.6 m optical telescope along with optical layout.

First Generation Back-end Instruments

As a first generation instrument, it is proposed to have a high resolution spectrograph, a faint object spectrograph and camera and a near-infrared imaging camera, all mounted at the Cassegrain end of the telescope.

High Resolution Spectrograph : Echelle spectropolarimetric device for the observations of stars is a new generation instrument for the study of stellar spectro-polarimetry. It is designed to obtain the complete optical spectrum from 370 to 1050 nm in a single exposure. The instrument is being developed by IIA, Bangalore. The maximum spectral resolution achieved is around 80,000. The instrument can measure all polarization components of the stellar light (linear and circular). The combined throughput of the instrument and the telescope is about 20 percent at peak, highest achieved so far for any astronomical spectrograph. The proposed 3.6 m optical telescope shall thus provide as complementary facilities to the existing Indian optical telescopes which are being heavily used for photometry and low resolution spectroscopic work. The proposed instruments coupled with the 3.6 m telescope would be capable of measuring spectrum with a signal to noise ratio of 100 for an integration time of one hour for a star of V = 14 mag. It can also detect complex magnetic field in the stellar environment for a star of V = 13 mag with on uncertainty of 10 gauss. The spectral stability of this instrument ensures a measurement of radial velocity variation of about 10 m/s.

Low Resolution Spectroscopic Camera : The low resolution spectrograph and Camera is a very useful instrument and is proposed to work in low resolution (~500 to 1000) spectroscopic and imaging mode. It is a focal reducer instrument and in imaging mode it will be able to image 10′x10′ field in broad and narrow band filters in the wavelength range 350 to 1000 nm. It is proposed to have a 4kx4k CCD with 15 micron pixel size. When coupled with the 360-cm telescope, it will have a 3σ- detection of 25 mag in V band.

Near Infrared Imaging Camera : A general purpose near-infrared imaging camera with limited spectroscopic capability is proposed for observations in the near-infrared bands between 1 to 2.5 micron. It is being developed by TIFR, Mumbai. It will use a 1024x1024 pixel Hawaii HgCdTe detector array manufactured by Rockwell International USA and will have flexible optics and drive electronics that will permit a variety of observing configurations. The array will have a pixel size of 40 microns, read-noise of about 30 e/pixel, dark current of less than 0.2 e/sec/pixel and a gain of 10 e/adu. The primary aim of this instrument would be to obtain broad and narrow band imaging of the fields as large as 4′x4′ and also to use it as a long-slit spectrometer with moderate resolving power

(~ 400) when attached to the telescope. The proposed near-infrared imaging camera at the 3.6 m telescope is expected to reach the 5 σ detection of 22.5 mag in J, 21.5 mag in H and 21.0 mag in K with one hour integration.

Summary

Modern national observational facilities in optical and near-infrared astronomy are being established at Devasthal, Nainital located in central Himalayas. The 3.6 m, *f*/9 reflector shall be used mainly in the spectroscopic mode at optical band (370 to 1050 nm) and imaging at near-infrared (1000 - 3000 nm) bands. A high signal spectro-polarimetric observations of object up to V = 14 mag and a 5-sigma detection of 21 magnitude object at K band can be easily achieved. This will increase the observing capacity of Indian astronomers many fold.

Reference

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