The new 130-cm optical telescope at Devasthal, Nainital

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A modern Ritchey–Chretien Cassegrain 130-cm diameter optical telescope has been successfully installed at Devasthal, Nainital in the central Himalayan region. This location was chosen after carrying out extensive site surveys. The first images obtained with the telescope indicate that atmospheric seeing and sky darkness at Devasthal are nearly at values as measured during the site survey. The values of seeing and sky darkness are comparable to some of the best astronomical sites in the world. The 130-cm telescope is functional and observations can be carried out from the control centre at Devasthal or from the Manora Peak in Nainital. This telescope has started providing valuable data for a number of research projects and is expected to help meet part of the national requirement in optical observational astronomy from small-aperture ground-based telescopes.

Keywords: Astronomical sites, atmospheric seeing, optical telescope, sky darkness.

THE Aryabhatta Research Institute of Observational Sciences (acronym: ARIES), an autonomous research institute under the Department of Science and Technology (DST), Government of India, has successfully installed a 130-cm optical telescope at Devasthal, Nainital, in the central Himalayan region. The institute so far had only a 104-cm telescope installed in 1972 as the main observational facility. This new telescope will meet part of the optical observational requirements from the astronomers in ARIES and the country. The telescope is equipped with low noise and fast modern charge-coupled devices (CCD) detectors and high transmission filters. Although the aperture of this telescope is small in the present international context, the darkness and sub-arcsec seeing available at the Devasthal site, and being equipped with extremely sensitive detectors makes it a versatile equipment for carrying out valuable astronomical research. The relevance of such small-aperture telescopes in the present era is well documented in the literature[1,2] in terms of scientific output against per unit capita of investment. The site also has an added advantage of being in the zone of a crucial geographical location on the globe for a number of time-critical observations of cosmic events. There are only a few modern optical observing facilities between Australia in the East and Canary islands in the West spanning nearly 180° in longitude. This telescope is expected to serve the needs of optical identifications and follow-up observations of many new sources to be discovered with the upcoming X-ray/UV space telescope, ASTROSAT and the already operational radio telescope, GMRT. A brief description of the site, the telescope and its capabilities along with the first images obtained are presented in this article.

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Devasthal site

Devasthal (meaning 'abode of God') is a mountain peak near Nainital (60 km away) at 79.7°E long., 29.4°N lat., and at an altitude of ~2450 m amsl. The geographical location is shown in Figure 1. The site is away from major urban settlements in the region. Its line-of-sight distance from the Manora Peak at Nainital is nearly 22 km. It was chosen after an extensive site characterization conducted during 1980–2001 in the central Himalayan range. Details of the site characterization are published in the literature[3–5]. The main advantages of Devasthal site are in its dark skies, sub-arcsec seeing, low extinction and at the same time being easily accessible and manageable. The 'seeing' is a measure of atmospheric blurring caused by turbulence in the air. The seeing affects sharpness of the celestial images and is of paramount importance for locating a site for optical astronomy. Such characteristics of an astronomical site for locating modern optical telescopes cannot be ignored in order to get maximum research output with minimal expenditure in running an observatory.

Infrastructure development has been carried out extensively at Devasthal site. The nearest village Kulauri-Jadapani, 3 km away from the Devasthal peak, provides a state road connectivity from Nainital and other major places in the region. The institute has built a 4-m wide road up to the peak from the state road. There is an 18 Mbps microwave link providing data connectivity between Manora Peak and Devasthal. A three-phase dedicated feeder of 11 kV high-tension power transmission line has been provided to Devasthal by the Uttarakhand Power Corporation Limited. The requirement of water is currently met by a deep borewell and through rainwater recharging pits. There are sufficient rooms in the guest house at the site to accommodate visitors.

The 130-cm optical telescope

The main objective for setting up of a 130-cm optical telescope at Devasthal was to meet the observational requirements for the institute's scientific programmes, which were so far being carried out using a nearly 40-yr-old 104-cm Sampurnanand telescope. The duty cycle of observations with the 104-cm telescope has limited capabilities due to its manual operation. This old system also does not provide a testbed for carrying out developmental activities for emerging observing techniques such as robotic and software-based operation, and improving image quality through fast imaging or adaptive optics. The institute's main scientific programmes such as monitoring of transients (gamma ray bursts (GRB); supernovae explosions), variability of stars in the Milky Way and of active nucleus in external galaxies require an automated telescope for efficient observations[6]. Other programmes such as imaging of star clusters require wide-field imaging capabilities. Keeping in mind the current and future observational and technical developmental requirements, a wide-field 130-cm telescope was proposed in 2005. The installed 130-cm telescope at Devasthal is able to fulfil most of these requirements.

The telescope has been fabricated by DFM Engineering Inc., USA. The telescope uses a modified Ritchey–Chretien Cassegrain design, which means it has three optical components, namely primary mirror, secondary mirror and a corrector or field flattener. The focal length-to-diameter ratio (focal-ratio) of the overall optics was kept at 4, making it a fast system providing 40 arcsec view of the sky in 1 mm scale at the focal plane. A single-element corrector provides a nearly flat field view of the sky up to 66 arcmin in diameter. The mirrors are made of Corning's ultra low expansion glass/ceramic material. The mirrors are polished to optical wavelength accuracies and coated with aluminium to obtain high reflectivity at visible wavelengths.

A photograph of the telescope after installation at Devasthal is shown in Figure 2. The tube of the 130-cm telescope is of open truss, allowing the telescope to cool faster in the ambient. The telescope mount is of fork-equatorial-type, which requires only one axis of rotation while tracking celestial sources. The mechanical structure of the telescope is made up of steel and aluminium. There is also a provision through Invar rods and bimetallic materials for automatic compensation of focus variation brought from expansion or contraction of optical tube due to changes in the ambient temperature. The focus can be

Figure 1. Geographical location of Devasthal in the map of Uttarakhand (courtesy: ISRO).

Figure 2. A view of the 130-cm optical telescope installed at Devasthal. The fork structure is painted yellow and the optical tube structure is painted white (outer) and black (inner).

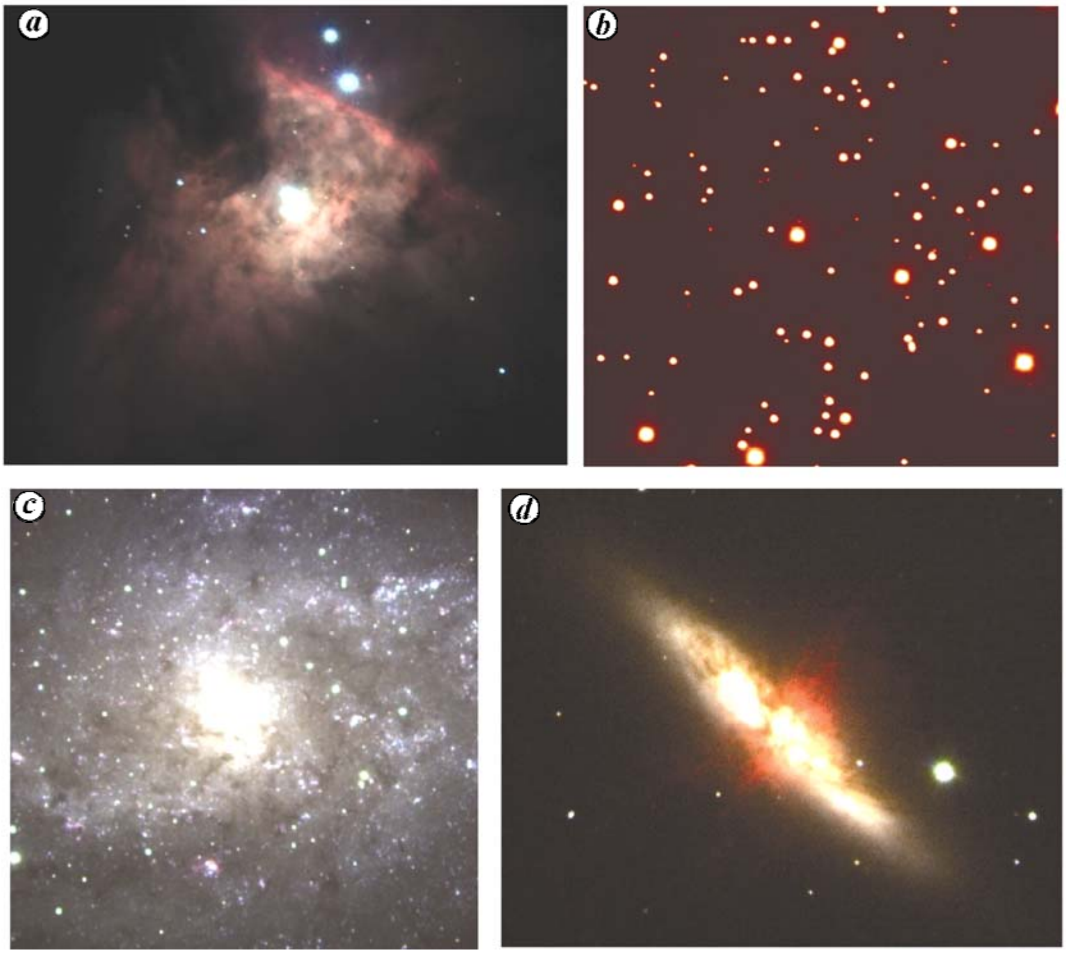

Figure 3. Images taken using the 130-cm telescope. ***a***, Broadband BVR colour composite image of the Orion nebula. ***b***, Central portion of M67 star cluster in white light. ***c***, BVR colour composite image of the central portion of the galaxy NGC598. ***d***, Starburst galaxy M82 showing ionized gas in H-alpha (red colour).

adjusted using a five-axis (tip, tilt and three-axis translation) controller on the secondary mirror. The telescope uses friction drives to control motions in right ascension and declination axes. The friction drives provide smooth and accurate pointing without any backlash. The encoders to register the position of the drives are absolute in 25-bit. The telescope can be pointed to a celestial object with an accuracy of 10 arcsec rms. The mechanical system provides a tracking accuracy at nearly 0.5 arcsec rms over 10 min without any external guider.

The telescope is controlled using dedicated softwares. The control system is capable of operating the telescope automatically. The system can also be interfaced with the standard sky-viewing software such as TheSky, eliminating the need for any finding chart. The system maintains an accurate time standard using the Global Positioning System satellites. There is also an onsite weather monitoring system to keep a watch on the outside weather. The telescope is housed in an open roll-of-roof-type structure again to help it cool faster in the ambient. The roof has been designed and constructed by the institute.

Three CCD cameras are currently available with the telescope for obtaining images of the celestial sky. These are: (1) 2048×2048 pixels, 13.5 μm pixel size conventional back-illuminated, deep thermoelectrically cooled (–80°C) CCD; (2) 512×512 pixels, 16 μm pixel size, electron multiplying frame transfer back-illuminated, deep thermoelectrically cooled (–90°C) CCD; (3) 3326×2504 pixels, 5.4 μm, front illuminated, thermoelectrically cooled (–30°C) conventional CCD. The first two cameras use high quantum efficiency E2V chip, assembled by ANDOR with low read noise electronics. The third camera is from SBIG using Kodak chip. More details of the telescope system and cameras are provided elsewhere (Omar *et al.*, in preparation).

The telescope was inaugurated by T. Ramasami, DST, India on 19 December 2010. The images obtained with the telescope show best FWHM at nearly 1 arcsec. The atmospheric extinction at Devasthal was measured as 0.24 mag in B (Blue), 0.14 mag in V (Visual) and 0.08 mag in R (Red) band on the first week of December 2010. The extinction can vary significantly from one night to another over the seasons. The sky brightness is measured as 21.2 mag/arcsec^2 in the V band on moonless night. The sky brightness varies with the phase of the moon. These values are comparable to those of other major national and international optical observing sites. The telescope is equipped with a motorized filter changer, design and developed at the institute. Currently, broad-band (BVRI), (u, g, r, i, z) and narrow-band interference filters for O[III], S[II] and H-alpha line observations are available. The telescope is now being used for photometric observations of star clusters, galaxies and monitoring extrasolar planets, transients such as GRB and supernovae.

Some of the first light images are shown in Figure 3. Figure 3 *a* is a broad-band BVR colour composite image of the famous Orion star-forming region, also known as 'mrigshirsha nakshatra'. Figure 3 *b* is an image of M67 open star cluster in white light, while Figure 3 *c* shows image of the galaxy NGC598 in BVR broad-band colour. Figure 3 *d* shows ionized gas seen in H-alpha (red colour) in a starburst galaxy M82. The typical exposure time in these images was 5 min in each colour for broad-bands and 15 min for the H-alpha band. The image quality in terms of FWHM varied between 1″ and 1.8″ in the images shown here. The stars of 20 mag are detected with S/N ratio of 5 in nearly 1 min of observation in the V and R bands. The limiting sensitivity is therefore expected to be between 24.0 and 24.5 mag in the V and R bands in nearly 30 min of observation in good seeing (<1.5″) conditions. The surface brightness sensitivity in unbinned pixels is currently achieved at ~22.3 mag/arcsec^2 in the V and R bands in nine co-added frames of 50 s exposure each. These observational numbers are consistent with the simulation results reported by Sagar *et al.*[7].

Future developments

Devasthal is an emerging observatory for optical astronomy in the country. Several new facilities have been proposed at the site in the next 2–3 years. These include a 360-cm, the largest in the country, optical telescope to be installed in 2012. This telescope will have several new technologies being built in collaboration with Belgium[7]. It will complement the observing capabilities of the 130-cm telescope, as the 360-cm telescope will be mainly used for spectroscopic observations. Thus the optical telescopes installed at Devasthal will increase the observing capabilities of the Indian astronomical community by manifold in the near future.

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ACKNOWLEDGEMENTS. We thank G. Srinivasan, and members of the project management board – D. Bhattacharya, A. Pati, S. Chandrasekhar, S. K. Ghosh and P. Sreekumar, for their encouragement. We acknowledge the support from the Chairman, ARIES Governing Council and The Secretary, DST, New Delhi, for ensuring that the project runs smoothly. We also thank the staff of ARIES for providing support during all phases of the project.

Received 9 January 2011; revised accepted 22 August 2011