GROUND-BASED OPTICAL ASTRONOMY IN INDIA

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Abstract

There is considerable progress in the ground based optical astronomy in India during the last 25 years. During the period 1965 to 1995 four one meter class telescopes and one 2.3m telescope have come into operation. The number of users of these facilities has increased considerably. The existing optical telescpes in India are heavily over-subscribed and are not large enough for observing fainter stars and faint and distant galaxies .

There is an urgent need to set up at good sites in India 4m class new technology telescopes and a few 1m and 2m class telescopes equipped with upto date auxiliary instruments.

1 Introduction

During the last 30 years, a number of telescopes have become available in India for astronomical observations over different regions of the electromagnetic spectrum ranging from Gamma-rays, X-rays, optical, infrared and radio wavelength regions. In this paper the existing facilities for ground-based optical astronomy in India are described. The research work in optical astronomy in India and future plans to set up new 2m to 4m class telescopes are also described.

There are five major existing optical telescopes in India: (i) a 1m Carl-Zeiss telescope at Naini Tal, (ii) a 1.2m Baker reflector at Rangapur near Hyderbad, (iii) a 1m Carl-Zeiss telescope and a 2.3m Vainu Bappu Telescope (VBT) at Kavalur, (iv) a 1.2m infrared telescope at Gurusikhar near Mount Abu. There are also three main solar observatories in India at Kodaikanal, Udaipur and Naini Tal. The above facilities and the institutions engaged in optical astronomy are described below.

2 Vainu Bappu Observatory, Kavalur, Indian Institute of Astrophysics

Kavalur Observatory (longitude 78^{o} $49^{'}$ $54^{"}$ E, latitude 12^{o} $34^{'}$ $32.2^{"}$ N) was set up in 1968 as a part of the Kodaikanal Observatory. In 1971 the Kodaikanal Observatory was made into the Indian Institute of Astrophysics with its headquarters

at Bangalore. In 1986 the Kavalur Observatory, as well as the 2.3m telescope at Kavalur were named after the founder, M.K.Vainu Bappu.

2.1 Telescopes and Instruments at Kavalur

There are five telescopes at Kavalur: (i) 2.3m telescpe (VBT), (ii) 1m Carl-Zeiss telescope, (iii) 75cm telescope, (iv) 45cm Schmidt telescope, (v) 34cm photometric telescope.

2.1.1 2.3m Telescope

The 2.3m telescope has two foci: an f/3.25 prime focus, and an f/13 Cassegrain focus in use. It is having provision for an f/30 coude focus. The prime focus (scale : 27 arcsec mm^{-1}) is used with Wynne corrector system which provides a field of 20 arcminute diameter. This arrangement is used for imaging through standard broad-band filters such as UBVRI and also through narrow-band filters such as H-beta, [OIII] 5007$\AA$, H-alpha, [NII] etc. The detector system is a liquid nitrogen cooled CCD camera system with a GEC chip of 385 X 576 pixels. It is operated through a PC based data acquisition system. This set up is being used for obtaining the CCD imges and photometry of galaxies, star clusters, planetary nebulae, post-AGB objects and IRAS sources etc.

At the Cassegrain focus of the 2.3m telescope the main instrument in operation is a Boller & Chivens spectrograph with a CCD camera (Astromed CCD). Several gratings are available to obtain spectra from 4000$\AA$ to 10,000$\AA$ with spectral resolutions ranging from 2.7$\AA$ to 10.8$\AA$. This spectrograph is being used to obtain spectra of post-AGB stars, planetary nebulae, novae, supernovae, optical candidates of IRAS sources, A and F stars with dust shells, Be stars and X-ray binaries etc.

Several other instruments are brought by visiting astronomers and are used at the 2.3m telescope. These include an automated polarimeter, an infrared photometer, a Fabry-Perot spectrometer. These three instruments were developed by the astronomers at the Physical Research Laboratory (PRL). A two-star high-speed photometer built by Indian Space Research Organization (ISRO) is being used with the 2.3m telescope by ISRO astronomers.

2.1.2 1m Carl-Zeiss Telescope at Kavalur

The 1m Carl-Zeiss telescope is a Ritchey-Chretien Cassegrain f/13 reflector. The scale is 16 arcsec mm^{-1} in the f/13 configuration. Focal reducers are available to obtain f/6 and f/2 beams also. The coma-free field is 40 arcminute diameter. An f/30 coude focus is also available. The auxiliary instruments presently available at the 1m telescope are :

Direct imaging cameras with plate holders at f/13 and f/6 focus are available. The entire 40 arcmin diameter coma-free field of the Cassegrain focus can be cov-

ered with the Zeiss plate holder using a 16cm X 16cm photographic plate and standard UBVRI filters of 16cm X 16 cm size. The f/6 and f/2 focal reducers also give 40 arcmin field with image scales of 33 and 100 arcsec mm^{-1} respectively. Currently for imaging a Photometrics CCD system is being used. The CCD used is a Thomson chip of 576 X 384 pixels. A dedicated computer is used for data acquisition. The BVRI images of galaxies, star clusters etc are being studied using this CCD system at the 1m telescope.

The low and medium resolution spectra are obtained with a Zeiss Universal Astronomical Grating Spectrograph (UAGS) adapted with a 25cm camera. With the CCD system described above spectra with resolutions ranging from 11$\AA$ to 2.5$\AA$ can be obtained by using appropriate gratings. This spectrograph is in regular use to obtain spectra of novae, supernovae, post-AGB stars, planetary nebulae, Be stars, X-ray binaries and bright galaxies.

The other instruments in regular use at the Cassegrain focus are a UBVRI polarimeter for linear polarization studies., a single-channel UBVRI photoelectric photometer.

A high resolution echelle spectrograph is in regular use at the f/30 coude foucs of the 1m telescope. The spectrograph contains a 76 lines mm^{-1} R2 echelle with a 150 lines mm^{-1} cross disperser grating and a 25cm camera coupled with a Photometrics CCD system. This spectrograph is being used to study the spectra of late type supergiants, light elemental abundances in bright F and G stars, A and F stars with dust shells and Be stars.

2.1.3 75 cm Telescope

The 75 cm telescope is a f/13 Cassegrain system with a UBVRI photometer. An InSb infrared JHKL photometer is also available for infrared photometric observations with this telescope.

2.1.4 45 cm Schmidt Telescope

The 45 cm Schmidt Telescope consists of 60cm f/2.245 primary and a 45cm corrector plate. A field flattener is placed in front of the focal plane to obtain a flat field of 3^o X 4^o with a plate scale of 150 arcsec mm^{-1}.

2.1.5 34 cm Photometric Telescope

The 34 cm Telescope is having a UBV photoelectric photometer. It is being used to monitor the light variations of RS CVn stars, binary stars and several types of varibale stars.

2.2 Research with the above facilties

A wide variety of observational programmes are being carried out using the above mentioned telescopes and instruments at Kavalur. The main research areas are

: post-AGB stars, Chemical composition of stars, R Cr B stars, RV Tau stars, color-magnitude diagrams of star clusters, planetary nebulae, novae & supernovae, Be stars, RS CVn stars, binary stars, late type supergiants, stellar chromospheric activity, star clusters in the Large Magellanic Cloud, early type galaxies, extra-galactic supernovae, AGN etc. The solar system objects also get their share of attention.

3 Nizamiah and Japal-Rangapur Observatories and Department of Astronomy, Osmania University, Hyderabad

3.1 1.2m Telescope

A 1.2m Fecker reflector was set up at Japal-Rangapur (longitude 76^{o} $13^{'}$ $39^{"}$ E and latitude 17^{o} $05^{'}$ $54^{"}$ N) near Hyderabad. The 1.2m telescope is having f/3.5 prime focus and f/13.7 Nasmyth focus. At the prime focus with a Baker corrector a wide field of 3^{o} X 3^{o} is obtained. The instruments that are being used are : (i) a two channel photoelectric photometer with a photon counting system, (ii) a Meinel spectrogaph with gratings yielding dispersions of 132, 66, and 33 $\AA$ mm^{-1} , (iii) a scanning spectrometer.

3.2 38cm Telescope

The 15-inch (38cm) f/13 Grubb refractor is now at the Osmania University campus. It is equipped with a photoelectric photometer and is used to study the eclipsing binaries, RS CVn stars etc.

3.3 20cm Astrograph

The 8-inch (20cm) astrograph is a f/15 refractor with a 10-inch refractor as a guide telescope.

3.4 Research

A number of eclipsing binary stars have been observed in UBV with the 1.2m telescope. Light curves were obtained for several Algol type and RS CVn type binary stars. The spectroscopic studies of A and Am stars, classification of Am stars, radial velocity curves of spectroscopic and eclipsing binary stars, comets etc are some of the observing programs that are being carried out with the 1.2m telescope.

A number of collaborative programmes are being carried out using the 1.2m telescope. These include X-ray binary stars, planetary nebulae, near-earth asteroids etc.

4 Uttar Pradesh State Observatory (UPSO), Naini Tal

4.0.1 1m Carl Zeiss Telescope

A 1m Carl Zeiss telescope was installed in 1972 at Manora Peak near Naini Tal (altitude 1950m) (longitude : $79^o\ 27'\ 24"$ E, latitude: $29^o\ 21'\ 36"$). A number of instruments are available for use at the Cassegrain focus of the 1m telescope. Some of the instruments are: (i) photoelectric photometers, (ii) a Cassegrain spectrograph giving a dispersions of 30 to 150$\AA$ mm^{-1}, (iii) a grating spectrometer with a 1024 element reticon array, (iv) a CCD camera with a Thomson chip of 576 X 384 pixels, (v) a 1024 X 1024 Tektronics CCD camera etc.

4.0.2 56cm Telescope

The 56cm reflector is provided with two objective prisms and a Baker corrector for photography at the Newtonian focus. There is also a photometer at the folded Cassegrain focus.

4.0.3 38cm Telescope

The 38cm reflector is equipped with a photoelectric photometer.

4.1 Research

UBV photometry of eclipsing binary stars, variable stars, star clusters, Be stars, late type stars and galactic structure are some of the observational programs that are being carried out with the above facilties. Solar system objects also get their share of attention.

5 Infrared Telescope at Gurushikhar, Mt Abu and Physical Research Laboratory, Ahmedabad

The Gurushikhar Observatory , Mount Abu in south Rajasthan (longitude: $72^o\ 46'\ 47.5"$ E and latitude : $24^o\ 39'\ 08.8"$ N, altitude : 1680m) is a part of the Physical Research Laboratory, Ahmedabad. Gurushikhar is located 225 km north of Ahmedabad at an altitude of about 1700 meters and offers more than 200 clear nights per year. The preciptable water vapour is usually around 1 - 2 mm in winter,

which makes Gurushikhar a good observing site for infrared window. The 1.2 m infrared telescope has been successfully put into operation in December 1994.

5.1 1.2 m Gurushikhar Infrared Telescope (GIRT)

The 1.2 m telescope is mainly designed for infrared observations, however, the surface accuracy of all the optical components has been achieved for observations at 5000$\mathring{A}$. Hence the telescope can also be used for optical observations. The primary mirror has an aperture of 1.22m with f/3 beam. The entire telescope can be nodded with a frequency of 1 Hz for chopping the signal. Two secondary mirrors have been provided for observations at the Cassegrain focus. One of them is a vibrating secondary morror with f/45 beam. The vibration is to chop the signal so that the fainter objects can be detected. The secondary mirror has f/13 beam and operates in a non-vibrating mode and is used for observations at the Cassegrain focus. Provision is also made for a coude system (f/45 beam) so that observations with heavy instruments can be made. The telescope is fully computer-controlled.

5.2 Instruments

The instruments that are being used with the 1.2 m telescope infrared telescope are: (i) High speed near infrared photometer for lunar occultations, (ii) imaging Fabry-Perot spectrometer, (iii) optical and near infrared CCD cameras, (iv) an infrared camera with HgCdTe detector, (v) optical and near infrared polarimeters.

5.3 Research

Some of the research programmes that are being carried out by the PRL astronomers using their infrared telescope and also using the facilities at other observatories in india are: planetary nebulae, HII regions, polarization measurements of stars with dust shells, active galactic nuclei, giant elliptical galaxies, infrared photometry, observations of lunar occultation of bright infrared sources in the infrared.

6 Inter University Centre for Astronomy and Astrophysics (IUCAA), Pune

IUCAA was set up by the University Grants Commission in 1988 as a research and training centre for students and teachers in the universities. Extragalactic and stellar astronomy observing programms are being carried out using national and international facilities. IUCAA is in the process of acquiring a 1.5m telescope. They also have plans to set up small (35cm) automated photometric telescopes in university groups.

7 Tata Institute of Fundamental Research, Bombay

Some of the research programms that are being carried out using the various ground based optical telescopes in the country are: optical studies of X- ray emitting stars, elliptical galaxies, star forming regions, Be stars, infrared photometry and imaging etc.

8 Patiala University, Punjab

Recently a 60cm optical telescope has been set up in the Patiala University. It is being used at present primarily for teaching.

9 Future Plans

In India there is a growing need to build a large telescope which will serve as a national facility, which will enable the Indian astronomers of coming decades to carry out front rank research work in several fields in astrophysics. There is also a need to build several 2m class telesopes for the rapid growth of ground based optical astronomy in India. Now there are plans to build 1.5m to 2m class optical/infrared telescopes. Site survey has been initiated in the Himalayan region to find a suitable site to set up 4m to 2m class infrared and optical telescopes. Site survey is being carried out at Hanle (latitude 32^{o} $47^{'}$ N, longitude 78^{o} $57.5^{'}$ E, altitude 4517 metres). Hanle can be accessed by road from Leh. Initial site survey data indicates that Hanle is a good site for optical/infrared telescopes.

10 Facilities for solar research

10.1 Kodaikanal Observatory, Indian Institute of Astrophysics

Kodaikanal observatory was established in 1899 as a solar physics observatory (longitude 77^{o} $28^{'}$ $07^{"}$ E, latitude 10^{o} $13^{'}$ $50^{"}$ N, altitude 2343m). It is now a field station of the Indian Institute of Astrophysics. The facilities are: (i) a 15cm aperture refractor serves as a photoheliograph yielding a 20cm diameter white-light image of the sun, (ii) twin spectroheliographs giving 6cm diameter images of the sun in Ca II K line and hydrogen H-alpha line, (iii) a tunnel telescope consists of a 60cm diameter two mirror coelostat that directs light via a flat mirror to a 38cm aperture, f/90 achromat which forms a 34cm diameter solar image at the focal plane. A littrow spectrograph and a spectroheliograph are available for use with tunnel telescope. These provide high spatial resolution (5.5 arcsec mm^{-1})

and spectral resolution (9mm/Å) for solar observations. A spectropolarimeter for measuring all three components of the solar magnetic field was built in 1992.

Some of the observational solar research programms that are being carried out are: solar chromospheric activity and rotation, supergranular cells, magnetic fields, flares, Sun as a star, five-minute oscillations, spectropolarimetry, total solar eclipses, etc.

10.2 Udaipur solar observatory

The Udaipur solar observatory (longitude 73° 42′ 45″ E , latitude 24° 35′ 08″ N, altitude 300m) was set up in 1975. It is located on an island in the Fatehsagar lake in Udaipur. The Udaipur solar observatory is now attached to the Physical Research Laboratory, Ahmedabad.

The facilities are : A 10 foot spar telescope with a 25 cm aperture objective lens for taking H-alpha chromospheric images. Also, a 15cm aperture telescope has been mounted on the spar for taking white light pictures of the solar disc. A coude 15 cm aperture telescope with a Littrow spectrograph is available for taking multislit spectrograms of flares, prominences ,etc.

The Udaipur solar observatory is engaged in helioseismological study, through its participation in the international programme of Global Oscillation Network Group (GONG). Monitoring and study of the solar chromospheric activity is one of the major research programmes that are being carried out. The Udaipur solar observatory has participated in a number of international solar observations programmes.

10.3 Uttar Pradesh State Observatory (UPSO), Naini Tal

The UPSO has several facilities available for solar research. Some of them are: (i) a 9m focus, Czerney-Turner type horizontal spectrograph with a dispersive power of 1.2Å mm^{-1} in the first order. It is coupled with a 45cm coelostat and a 25cm f/66 off-axis skew Cassegrain telescope. (ii) there are facilities for obtaining white light photographs and H-alpha and CaII filtergrams, etc.

Monitoring the solar activity is one of the major solar research programme. Obseravtions and analysis of solar flares, surges, prominences are being carried out. Relationships between coronal holes, coronal mass ejections and solar flares are being studied.

11 Conclusions

There is considerable progress in the ground based optical astronomy in India during the last 25 years. During the period 1965 to 1995 four one meter class telescopes and one 2.3 meter telescope have come into operation. The number of

users of these facilities, the number of research papers published in refreed journals has increased considerably over the years. Stellar and solar and solar systems objects were major areas of research with these facilties until recently. The four major optical facilities in India have now acquired CCD cameras, spectrographs, IR photometers, polarimeters , computers, etc. The research areas that are now being carried out using the digital detectors have expanded and there is considerable progress in the study of stellar, galactic and extragalactic objects.

The existing optical telescopes in India are heavily over-subscribed and are not large enough for observing fainter galactic objects and faint and distant galaxies. There is an urgent need to set up at a good site in India a 4m class new technology telescope and a few 1m and 2m class telescopes.