Bull. Astr. Soc. India (1995) **23**, 351–355

Astronomy with Vainu Bappu Telescope

N. Kameswara Rao

Indian Institute of Astrophysics, Bangalore 560 034, India

The on-going programmes with Vainu Bappu Telescope (VBT), essentially, reflect the optical astronomy currently being done in the country, since VBT as a national facility and as the biggest telescope available in the country – attracts proposals from major astronomical centres in the country. I suppose that is the reason why the organisers of this meeting selected this topic for me. Before discussing the astronomy being done with VBT, let me briefly describe some of the historical developments which led to the realisation of this 2.34m telescope in the country.

As early as in 1945 the committee for the post-war development of astronomy, chaired by Meghnad Saha, pointed out that to pursue the night time astronomy the country needs "an astronomical observatory provided with a large sized telescope for special stellar work". Based on this recommendation, A.K. Das, in 1957, proposed a telescope of 100 inch size to be located on a suitable site in central India (Das 1960). However, it was Vainu Bappu who really initiated a serious effort towards building an observatory for night time astronomy soon after he joined Kodaikanal Observatory in 1960. A site-survey was conducted in south India with a view to study the galactic centre and the Magellanic clouds (the main attractions at that time). The Kavalur-site in Javadi hills of Tamil Nadu was selected in 1962 where a Carl Zeiss 1 meter telescope was installed during 1965-72.

Soon after the formation of the Indian Institute of Astrophysics (IIA) in April 1971, Bappu revived the idea of the large telescope project and in September 1971 presented to the IIA council the need for such a telescope to specifically study three main topics : (1) to study (trace) the spiral structure of the galaxy; (2) for the study of stellar chromospheres principally by the method of stellar spectroscopy; (3) for the study of the morphological aspects of the external galaxies, the chemical composition parameters in these aggregates and their bearing on stellar evolution. He also proposed to build the telescope indigenously. The proposal was accepted and the glass blank of 93-inch size arrived in March 1974 from Schott Glass Works. After the concept report for a 90-inch telescope was presented, a formal green signal for the project was given by IIA Council – 31 years after the Saha committee recommendation—finally resulting in the formal inauguration of the telescope on 19 January 1986 by Rajiv Gandhi, the then Prime Minister of India. He also named the telescope as Vainu Bappu Telescope (see

Bhattacharyya & Rajan 1992 for a detailed account). The telescope initially started operating with a f/3.25 prime focus and later in November 1989 the f/13 Cassegrain focus came into operation.

The programmes that could be carried out at the telescope are dictated by the available backend instrumentation. The backend instruments that have been used mainly are the following : (1) A CCD imaging camera with various filters (UBVRI etc). The CCD dewar with a GEC p8603 chip of 385 x 578 pixels of 22 microns (of Astromed Inc.) is the main detector unit. A dewar with a Thompson 1024 x 1024 pixel chip is in the process of getting installed. This imaging camera system mainly operates at prime focus (a field of 4 arcmin x 5 arcmin with GEC chip). (2) A Boller and Chivans spectrograph attached with the CCD camera operating at Cassegrain focus provides facility for intermediate resolution spectroscopy with various gratings. (3) Polarimeter developed (and used) by PRL group operating at Cassegrain focus. (4) A three (two) star photometer built by the ISRO group for fast photometry. In addition other instruments like speckle camera, a Fabry-Perot spectrometer, IR (InSb) photometer were also used on occasions. Now let me present to you some of the astronomical programmes that are currently being done with VBT (see Rao 1993; Prabhu 1993; Kembhavi 1994 for an account of the earlier work).

Galactic astronomy

(i) Stars and stellar systems : One of the main programmes being done at the prime focus is the study of star clusters in various filters (particularly in UBVRI). Star clusters that contain objects of special astrophysical interest like, planetary nebulae (PN) or supergiants etc. are being studied to investigate their association and also to establish the physical parameters of these objects and their stellar evolutionary implications. Clusters that are associated with PN are of particular interest. In continuation of the earlier studies (eg. NGC 2818 – Surendiranath *et al.* 1990), the recent study of the cluster NGC 2453 containing the PN NGC 2452 has brought out significant new information (Mallik *et al.* 1995). Earlier the physical association of the PN with the cluster was under considerable doubt. Although one yellow giant member of the cluster has the same radial velocity (representing the cluster : +67 ±14 km/s) as that of the PN (+68 km/s), the distance of the cluster from various estimates ranged from 1.5 to 5 kpc, as opposed to the extinction distance of the PN of 3.5 ± 0.5 kpc. The study by Mallik *et al.* with VBT, where they could observe stars 5 magnitudes fainter than the earlier studies (~ 20th mag.) led them to fix the main sequence of the cluster well and thus to estimate the photometric distance of the cluster accurately as 5.9 ± 0.3 kpc – quite different from the PN's 3.5 kpc. Thus they conclude that the physical association of the PN with the cluster is very doubtful.

The other interests in cluster studies are the following : a systematic investigation of the physical properties of the cluster with respect to the galactocentric distance, the star formation process, initial mass function and other aspects of stellar evolution. Such studies are being pursued by Ram Sagar and his associates.

Imaging of planetary nebulae (in various filters), cometary globules in dark clouds and post-AGB objects are being carried out by various groups.

Studies of AGB and post-AGB stars is of particular interest at IIA. Medium and low resolution spectroscopy of these objects with B & C spectrograph is actively pursued in this regard. The group of post-AGB objects like the hydrogen deficient stars of R CrB type not only provide an opportunity to study the dust formation in the atmospheres of stars but also provide clues to the possible identification of the carriers of the diffuse interstellar bands (DIBs). Some of these stars in faint phase show emission bands that correspond to the famous DIBs which lack the identifications since their discovery some 60 years back. The study of these bands in the peculiar hydrogen deficient carbon rich environment of these stars might give clues to their parent species. With these views, intensive spectroscopic monitoring of these objects is being pursued. Post-AGB stars like some carbon rich RV Tauri stars show gas which is depleted in elements that could be locked up in grains. Such stars are also being spectroscopically monitored. The prospective proto-planetary candidates (mainly discovered from IRAS surveys) are also being investigated spectroscopically to study their evolutionary characteristics.

The evolution of the spectra of novae is one of the traditional topics which is being pursued at IIA. The tradition of study of novae goes back to the times of Pogson (who studied objects like U Sco, U Gem etc. at Madras during 1860–93). Prabhu and Anupama have been monitoring novae with VBT to study not only the physics of the ejecta and mass loss but also to estimate their elemental abundances. The latest candidate which they are monitoring is the nova Cas 1993 which they were able to monitor for about 2 years.

The polarimetric programmes at the Cassegrain focus include the study of R CrB stars, RV Tauri stars and pre-main-sequence objects. Particularly interesting is the study of some carbon rich RV Tauri stars like AR Pup which show changes in the position angle by 90 degrees at different times, revealing peculiar geometries for the scattering dust envelope (Raveendran & Rao 1992).

One of the important photometric programmes being done with the three star photometer at the Cassegrain focus of VBT is the study of white dwarf oscillations (in objects like PG 1159, BG CMi) and cataclysmic variables by T.M.K. Marar and his associates sometimes as part of the whole-earth telescope campaign. In their latest investigation of the unique intermediate polar object discovered by ROSAT, they discovered a 13.9 minute period colour dependent variation (x-ray period is also 13.9 minutes) – associated with the rotation period of the magnetic white dwarf in this system of orbital period of 5.5–6 hours.

Solar system studies

Studies of comets is a long standing tradition at IIA going back to the time of Evershed. VBT is used in the imaging studies of several recent comets including Swift–Tuttle which revealed the rotation of the nucleus (and the jets) with a period of 2.7 days. The latest study in this direction is the monitoring of the spectacular crash of the fragments of the comet Shoemaker – Levy 9 on Jupiter. Images of the comet have been obtained soon after its discovery (from 27th May 93 onwards) and were utilised in improving the positions and the trajectories of the fragments by Vasundhara Raju and her associates. The VBT was particularly used to obtain the intermediate resolution spectra of the crash site of the fragments and surroundings. The spectra showing CH4 emissions are prominent in the crash areas relative to the adjacent sites. The spectra are being studied in detail (Chakraborty & Vasundhara Raju). The other major programme which has been initiated with VBT is the study of the near-earth asteroids.

Extragalactic studies

Most of the extragalactic studies with VBT utilise the CCD imaging camera at the prime focus. Studies ranging from individual galaxies to clusters of galaxies are being pursued.

The star-forming regions in galaxies and the starburst galaxies are being systematically studied to investigate the population content and the distribution of gas and dust and interactions with the neighbouring galaxies. In a recent study of the irregular edge-on galaxy NGC 4656, Mayya could find extraplanar ionized structures, at vertical heights of 1 – 2 kpc from the disk and warps at the edges from H-alpha, VRI band images which he interprets as a result of an encounter with the companian galaxy NGC 4631.

Surface brightness distribution studies of various types of spirals are being pursued by several groups (Prabhu, Kembhavi, Singh, Bhat *et al.*) systematically.

Clusters of galaxies are being observed both for morphological studies as well as to locate and study gas flows (cooling). Anupama and Valluri have imaged the compact group HCG 62 (which has an X-ray halo) in H-alpha, R and other filters to locate the gas. They find excess H-alpha emission in the centres of the galaxies, which is attributed to cooling flows. The total emission flux in each galaxy is estimated as 10^{39} erg/s and the ionized mass as about 10^4 $M_\odot$.

Polarimetric monitoring of active galactic nuclei and BL Lac objects is a major programme being pursued at the Cassegrain focus by the PRL group (Deshpande *et al.*). The aim is to search for smallest time variations both in light and polarization which can distinguish various models proposed as well as provide an estimate for the source size. Deshpande & Joshi's (1993) observation of Mrk 421 showed variations in polarization (and light) in the time scale of 19.5 minutes. Their recent studies show variations in polarization in OJ 287 with a period of 6.3 minutes. This group is also studying variation in polarization with different apertures of several Seyfert galaxies (the smaller the aperture the less will be the contribution from the galaxy light to the nucleus) which seem to suggest that nuclear regions are dominated by synchrotron radiation.

In a similar study the light variability in optically selected radio quiet QSOs is being pursued by Gopalkrishna, Ram Sagar & Witta (1993 a, b; 1995) using the prime focus CCD system. Their aim is to study the microvariability as a guide to discern various models. In a sample of a dozen or so objects they studied (Mv << – 23) intensively, some (about five) do fluctuate in optical on a very short time scale. If radio quietness is attributed to lack of jets then the microvariability is attributed to accretion disk activity. In an impressive study of the BL Lac object 0716 + 714, this group could monitor the light variability for 22 nights almost continuously (also using other telescopes) in BVRI filters to study the simultaneous variability in different wave bands to constrain the models proposed and also the size of the source.

One of the significant programmes being pursued spectroscopically (mainly) with VBT is the study of supernovae. The recent monitoring of SN 1993 J in M 81 is a major effort in this direction. VBO (Kavalur) is probably the only place where both SN 1987 A in LMC (dec = –69°) and of SN 1993 J in M 81 (dec = +80) could be monitored (the advantage of an equitorial site). The spectroscopic monitoring of SN 1993 J by Prabhu and colleagues (Prabhu *et al.* 1995) not only showed the evolution and kinematic behaviour of the SN envelope but also showed a similar phenomenon noticed (by us) earlier in SN 1987 A (Ashoka *et al.* 1987) namely the outer layers of the progenitor star were mixed with CNO-processed material i.e. nitrogen enhanced gas. Another significant result is that the application of Baade – Wesslink method resulted in a distance estimate to the galaxy of 4 Mpc consistent with the distance estimated from cepheids using HST.

In the above account, I have tried to give a brief description of various astronomical activities underway with VBT using its very limited backend instruments. However one of the strong inadequacies and also future thrust is the development of sophisticated backends. One of the immediate needs of VBT is the facility for high resolution spectroscopy. In this direction we have been planning to build a fibre linked echelle spectrograph to be located in the coude laboratory. A high resolution echelle grating has already been procured and plans are afoot to complete the spectrograph in the immediate future. Hopefully other institutions in the country would soon start building state of the art backend instrumentation for VBT to make it more effective. I hope such efforts get ample encouragement.

Acknowledgements

I would like to thank many colleagues and friends for their generosity in supplying me their results obtained with VBT, some of which are unpublished.

References

Ashoka B.N., et al. 1987, JA&A 8, 195.
Bhattacharyya J.C., Rajan K.T., 1992, BASI, 20, 319.
Das A.K., 1960, Modemisation of the Astrophysical Observatory, Kodaikanal, IMD.
Deshpande M.R., Joshi U.C., 1993, BASI, 21, 455.
Gopal Krishna, Ram Sagar, Witta P.J., 1993a, MNRAS, 262, 963.
Gopal Krishna, Ram Sagar, Witta P.J., 1993b, BASI, 21, 441.
Gopal Krishna, Ram Sagar, Witta P.J., 1995, IAU Symp. 159; MNRAS (Submitted).
Kembhavi A., 1994, (ASI meeting, Bombay).
Mallik D.C.V., Ram Sagar, Pati A.K., 1995, A&A (Submitted).
Prabhu T.P., 1993, BASI, 21, 225.
Prabhu T.P., et al. 1995, A&A, 295, 403.
Rao N.K., 1993, BASI, 21, 267.
Surendiranath R., et al., 1990, J.A.&A., 11, 151.