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Stellar astronomy with VBT

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Abstract. Some of the current observational programmes with VBT regarding the galactic astronomy are reviewed.

Key words : stellar physics—CCD imaging—spectroscopy—photometry

1. Introduction

The 2.34 metre Vainu Bappu Telescope (VBT) has been operating as a national facility for the last 3-4 years. Although the prime focus operations were going on for some time the observations with the cassegrain focus only started from December 1990. The astronomical programmes being done are essentially dictated by the backend instrumentation developed at the observatory or brought by the visiting astronomers. The instruments which have been used more routinely are the following :

CCD imaging Camera System Astromed with various filters containing a GEC chip. The system is used with a Wynne Corrector at the prime focus (scale—27 arc sec/mm). Operations and data acquisition are done through a PC. This is the main instrument that is used with the prime focus. At cassegrain focus the main instruments include a Boller and Chivans (B & C) spectrograph attached to a 6-inch camera with Astromed CCD system as a detector. In addition the other commonly used instruments are the UBVRI polarimeter of PRL (Deshpande *et al.* 1985) and a two star photometer of ISRO (Marrar *et al.* 1993). Several other instruments like Fabry-Perot spectrometer, a speckle camera, etc. have also been used on occasions.

2. Research programmes

Now I would like to describe a few programmes using the prime focus CCD imaging system. The studies of star clusters is one of the main programmes underway. This includes clusters containing objects of special interest like planetary nebulae, supergiants, etc., as well as clusters selected with a view to study the star formation processes, initial mass function and stellar evolutionary aspects (e.g. convective core overshooting, etc.) (the later programs are being pursued by Ram Sagar and A. Subramaniam). In this respect study of the cluster NGC 2818 containing the planetary nebulae NGC 2818 by Surendiranath *et al.* (1990) is of particular interest. Their main interest was to study the properties of the central star of this planetary nebula (CSPN) like the age, distance, etc., through the study of the cluster. Since the radial velocity of the nebula (-1 ± 3.0 km s^{-1} by Ackers *et al.* 1992) and that of the

cluster ($+3 \pm 20$ km s^{-1}) agree, the cluster-membership of the PN is more likely. The present study using the CCD observations in VRI filters down to a magnitude limit of $V = 21$ mag in the central regions of the cluster, defined the cluster main sequence much better than earlier studies (5 mag fainter than the turnoff). From the V vs $V - I$ diagram, the $(m - M)_0 = 12.9 \pm 0.1$ and a distance of 3.8 ± 0.1 kpc have been estimated. Assuming solar metalicity (as indicated from the elemental abundances of the PN—Dufour 1984), the estimated age is $5 \pm 1 \times 10^8$ yrs from the isochrones by Vandenberg, suggesting a mass to the main sequence progenitor of PN $\geq 2.58\ M_\odot$. The luminosity of the CSPN is estimated to be $\sim 10^3\ L_\odot$ and the radius = $0.04\ R_\odot$. However, in an independent study of the cluster Pedreros (1989) estimates the [Fe/H] as –0.34. An independent check of the cluster metalicity either spectroscopic or Stromogren photometric indices is necessary for a better estimate of the physical properties of the CSPN.

Deep CCD imaging of planetary nebulae and post AGB star fields in various narrow and wide band filters are also being actively pursued to detect the presence of nebula and their morphological studies. In regard to solar system objects, imaging of the comets (e.g. Swift-Tutle) and planetary environment are some of the other programmes of interest.

The spectroscopic programmes are more varied. Prabhu has already described the programmes regarding novae and supernovae. Other major programmes include the study of hydrogen deficient stars, particularly the stars classified as WC 11 and their relationship with other cooler hydrogen deficient stars. The WC 11 stars are a group of cool Wolf Rayet stars which forms an extension to the WC class and show lines of CIII, CII, CI, He I, etc. In addition, their spectra also show low excitation nebular lines like [O II], [S II], [N II], etc. They also possess large infrared excesses. Some (if not all) are thought to be hydrogen deficient. Their evolutionary state is very uncertain. Two possible scenarios are a proto-planetary nebula on the way to become a central star of a planetary nebula and later to a white dwarf or an object which has experienced a last thermal pulse (helium shell flash) and as a result coming back to become an AGB star for a second time. To distinguish these two possibilities these objects are being studied as a group, particularly with a view to estimate the nebular properties like electron density (n_e), electron temperature, abundances, photon flux from the star (whether it is sufficient to photoionize the present nebula and the IR excess present or not), the mass loss (and the ejected mass), the expansion velocity (age) etc. It has also been suggested that some of these objects might have binary companions : a possibility which is yet to be confirmed. Spectroscopic studies in various wavelength regions from UV to IR are needed to study the various properties mentioned above, mainly because the diagnostic lines occur in different wavelength regions. Most often the nebular emission lines are blended with stellar emission lines requiring higher spectral resolution and nebular modelling in estimating these properties.

We have been obtaining spectra mainly of He 1044, M4-18, CpD – 56° 8032, (see figure 1 for the display of the spectrum) and V 348 Sgr. No trace of a binary companion can be seen. Although light variability is detected in CpD – 56° 8032, its behaviour is similar to R Cr B stars like MV Sgr and DY Cen suggesting their kinship. Using the photoionisation models by Surendiranath (these proceedings) we are presently analysing these objects.

Another programme of interest is about the diffuse interstellar bands (DIBs). Although more than 100 DIBs are known so far, since their discovery in 1934, no proper identification of their carrier(s) is known. It is not even clear whether they are due to complex gas molecules or dust features and whether more than one carrier is involved. They have been

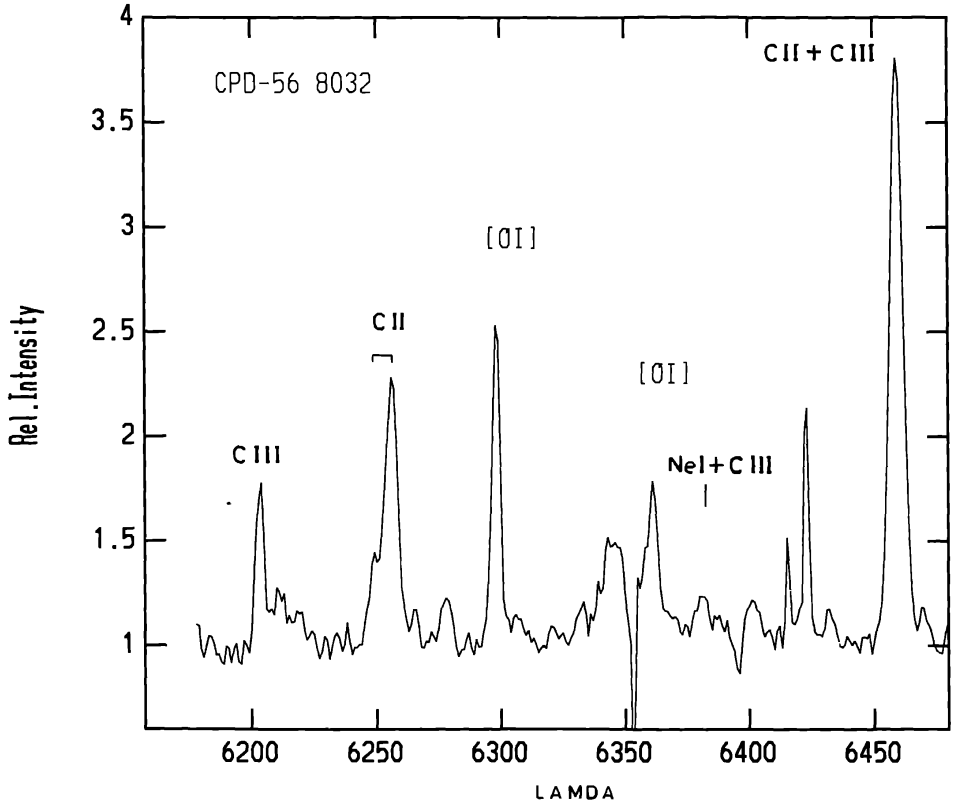


Figure 1. Spectrum of CpD – 56° 8032 obtained with B and C spectrograph.

classified into a few families depending on their behaviour. It was proposed by Cohen & Jones (1987) that five DIBs which occur strongly in the spectrum of the WC 11 star IRAS 21282 + 5050 are of circumstellar origin and they also point out that the infrared features at 7.7 μ, 11.3 μ, etc. are also enhanced in the star as such the carrier could be a Polycyclic Aromatic Hydrocarbon (PAH) molecule. Since the carbon-rich environment seems to be indicated for the presence of some DIBs, it was proposed to survey the other WC 11 stars and related objects in a systematic way both hydrogen deficient carbon stars and the normal stars as well. The B and C spectrograph with 1200 grs/mm grating gives a resolution of 1.3 Å per pixel and can cover about 15 DIBs at one setting. Spectra of stars $V \sim$ 14-14.5 can be obtained with good S/N in about one hour exposure (see figure 2). Recently a set of diffuse emission bands corresponding to some DIBs have been seen in the R CrB star V 854 Cen at minimum by Rao & Lambert (1993) (similar bands have been seen earlier only in HD 44179, the central star of Red Rectangle) suggesting hydrogen deficient carbon star might be one of the contributors of these band to the ISM.

For other spectroscopic programmes currently in progress are the study of AGB and proto PN candidates by Parthasarathy and Eswara Reddy, members of star clusters for the study of their metalicity and membership by Ram Sagar and A. Subramaniam, and spectra of comets on occasion.

Some of the photometric programmes being carried out at the cassegrain focus are the polarimetric studies mainly using PRL Polarimeter of a variety of stars having large infrared excesses, like R CrB type and other HdC stars, RV Tauri stars and premain-sequence objects.

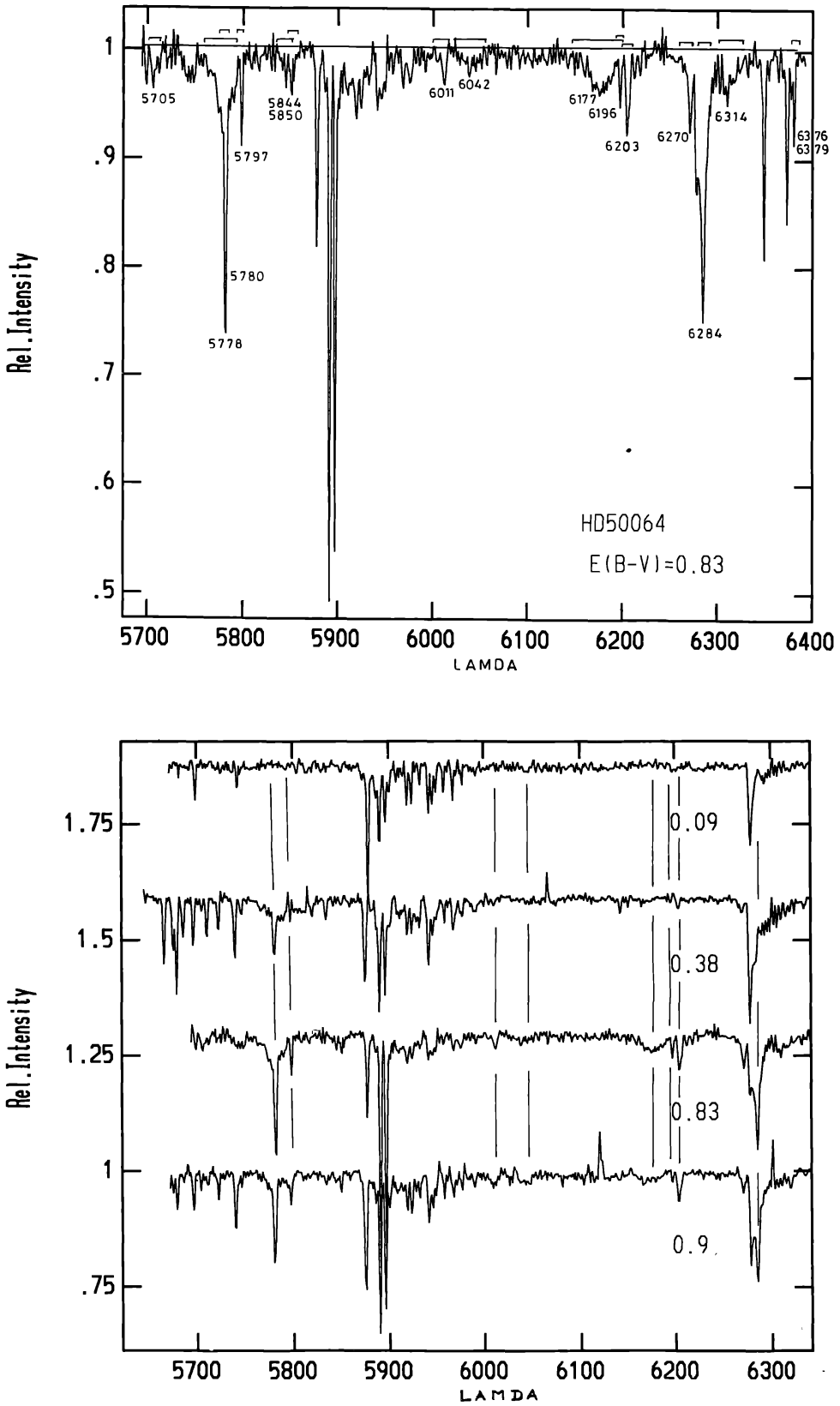
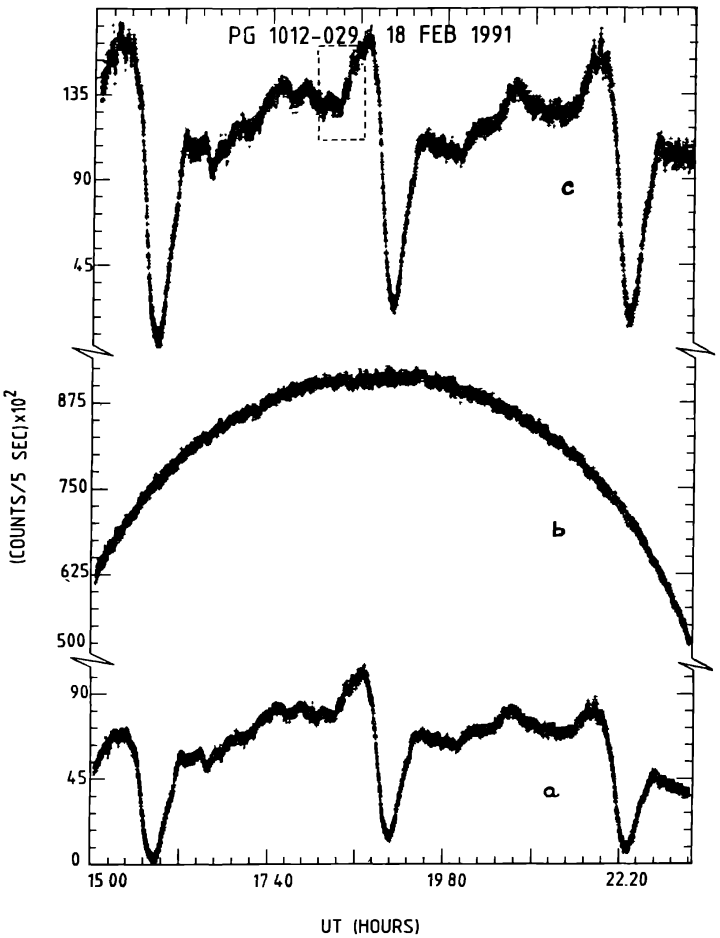


Figure 2a&b. Spectra of stars illustrating the DIBs and their variation with $E(B - V)$.

The recent study of the linear polarization changes in the R CrB star V 854 Cen during the minimum as well as maximum suggested that the dust ejections in the star (which causes the major brightness drops) occur roughly in the same plane and a scattering region almost perpendicular to the plane of ejection of dust is seen during the deep minimum (Rao & Raveendran 1993). Similar bipolar geometry is also indicated in the RV Tauri star AR Pup from its sudden changes in position angle by 90° in U and B bands (less in other bands) on a few occasions.

Another major photometric programme which is being pursued by T. M. K. Marrar and his group from ISRO is the high speed photometric monitoring of cataclysmic variables (CV) and pulsating white dwarfs using a two star photometer. The main interest in the study of CVs is to obtain their orbital parameters and accretion phenomenon around the compact object. Objects brighter than $V \sim 15$ are being observed. The recent observations of the star PG 1012-029 (B = 14.8), which has a period of $3^h\ 14^m\ 59^s$ and depth of 1.9 mag in B, have been used to refine both the period and its derivative, as well as it led to the discovery of



PG 1012-029 OBSERVED OVER A FULL NIGHT WITH THE VBT USING A TWO STAR PHOTOMETER
a. The sky subtracted light curve of the star in white light
b. The sky subtracted light curve of a field star
c. The extinction corrected light curve

Figure 3. Light curve of PG 1012-029 by T. M. K. Marrar and collaborators.

the presence of two short periods outside the eclipse. The study of the white dwarf pulsations is a part of the global network (the Whole Earth Telescope programme) to study the various frequencies and their splitting. For example, their study of PG 1159 has not only showed the luminosity variations due to nonradial g-modes, but also allowed them to estimate the mass of the object as 0.586 $M_{\odot}$, and a rotation period of 1.38 days with a magnetic field of 6000G. It also suggested that the outer layers are compositionally stratified.

In the above account I tried to illustrate some of the programmes being pursued presently with VBT, and some results yielded. I would like to thank many of my collaborators and other users of VBT for the information and results mentioned here.

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