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Spectrophotometry of chemically peculiar stars with a moderate size telescope

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1. Introduction

Most stars which are categorised as chemically peculiar, display some spectral peculiarities superimposed on the spectra of otherwise apparently normal stars. Historically, some A type stars were the first such stars to be noticed and they were called the peculiar A stars, or in short as the Ap stars. They showed varying amounts of overabundances of several elements like Si, Hg, Mn, Sr, Cr and so on besides many rare earths.

A study of such peculiar A stars was taken up by Babu (1971, 1972, 1976, 1977), Babu and Sinhval (1972), Babu and Rautela (1978), Rajamohan and Babu (1978) and Babu and Shylaja (1978, 1981a, 1981b, 1982, 1983, 1986, 1992), using moderate size telescopes at the U.P. State Observatory, Nainital and at the Vainu Bappu Observatory of the Indian Institute of Astrophysics, Kavalur.

These chemically peculiar A stars are generally bright enough to be listed in the Bright Star catalogue (Hoffleit and Jaschek, 1982; Hoffleit et al., 1983) and therefore the telescopes of 0.5 to 1 meter size would be just the appropriate instruments for carrying out most of their photometric observations. In fact, the larger telescopes will be unsuitable for such observations of these stars. However, observations involving high resolution spectroscopy would require larger size telescopes, in any case.

2. Instrumentation and observations

The 0.5 and 1 meter telescopes at the U.P. State Observatory, Nainital, and the 1 meter telescope at the Vainu Bappu Observatory of the Indian Institute of Astrophysics, Kavalur have been used by us for the observations of these Ap stars. At both places, photoelectric spectrophotometers, which are popularly known as scanners, were employed for measuring the light intensity of the star at the given wavelengths.

At UPSO, a Hilger and Watts monochromator was incorporated into a photoelectric spectrophotometer designed by the then Director, Dr. S.D. Sinhval and then Chief of the mechanical workshop, Mr. Nicholson Dass along with the author in 1970. A set of diaphragms of various sizes were made on a wheel, which in turn was placed at the entrance of the monochromator after removing the original entrance slit. This was done in order to allow the entire star light onto the F/13 collimating mirror of the monochromator. The 600 lines/mm reflection grating of the monochromator gave rise to a dispersion of 70 Å/mm and the exit slit was fixed at a width of 1mm. A mechanical drive was arranged to rotate the grating on its axis and the instantaneous position of the grating was noted from a counter which is periodically calibrated with the help of a mercury source in the laboratory. The dispersed light of the star was received by a peltier cooled EMI 9558R photomultiplier. The d.c. signal was appropriately amplified and recorded on a Honeywell Brown Recorder.

A fully automated scanner arrangement, designed by the then Director, the late Prof. M.K.V. Bappu, was available at VBO in 1977 (Bappu, 1977). In this instrument, the monochromator part was specifically designed and fabricated at the observatory workshop. The grating in this case, was rotated by a stepper motor, which in turn was controlled by a TDC-12 computer. The dry-ice cooled EMI 9558R photomultiplier was employed to receive the signal which was recorded by a similar Brown recorder. Later on, the recording facility got graduated to a pulse counting system.

The classical procedure was used for reducing this type of data, in which the correction for the atmospheric extinction was applied in the usual manner. The energy distribution curves of the Ap stars were finally obtained after applying the system calibration which was derived from the observational data of the standard stars. Spectrophotometric observations of more than 150 Ap stars have so far been obtained by using these moderate size telescopes and it is presently an on-going programme at VBO.

However, presently the CCD facility at the 1 meter telescope of VBO is being used with the Universal Astro-Grating Spectrograph for obtaining the spectrophotometric observations of the Ap stars. For this purpose, a 150 lines/mm grating is used in the UAGS, which provides a low dispersion spectrum covering from about 4000Å to about 7000Å in a single frame of 380×570 pixels. The reduction of this data is carried out by the IRAF software programmes. An upgradation of the CCD chip size to say, 1024×1024 pixels, with an appropriate wavelength sensitivity, will indeed enable us to cover a much larger wavelength region of the energy distribution curve of the given stars.

3. Discussion

The peculiar characteristics of these stars have generally been found to be causing a blanketing effect in the UV and the short wavelength region of the respective spectra. Gerbaldi (1974) showed that the Balmer discontinuity in Ap stars is affected by the particular character of the star. Megessier (1988) found that the Ap stars have less UV flux and a larger visible flux with a smaller Balmer jump as compared to the normal stars of the same effective temperature. Kroll (1987) and Kroll et al. (1987) indicated that the Ap stars behave like main sequence objects and hence like black bodies in the near IR, where they are not affected by the chemical peculiarities.

The problem of blanketing has been discussed by Chandrashekar (1936) and by Munch

(1946) under certain simplifying assumptions regarding the nature and distribution of the line absorption. Code (1950) pointed out that the line absorption is generally of importance in the outer layers of the atmosphere and acts to reduce the boundary temperature. The flux that is thrown back into the atmosphere at first increases the gradient, while at optical depths of the order of unity in the continuum the gradient approaches that of a gray atmosphere. The temperature, however, is somewhat higher than that at the corresponding depth in an unblanketed atmosphere.

Leckrone (1975), while reviewing the properties of Ap stars in the UV, showed that these stars are consistently flux deficient in the ultraviolet, compared to normal stars, whose Balmer jumps and Paschen slopes they match well. Such data suggest the presence of greatly enhanced opacity sources, essentially giving rise to an effect that is akin to blanketing, in the UV region of Ap stars, distributed more or less uniformly over the entire region of the Balmer continuum. These stars typically show enhanced line strengths in the visible, for example in the iron-peak elements and the rare earth species. Leckrone, Fowler and Adelman (1974) through their numerical experiments with heavily line-blanketed model atmospheres showed that the greatly enhanced opacities remove flux from the ultraviolet and redistribute it through backwarming into the visible, making a Si star for example, appear bluer in B-V, brighter in absolute visual magnitude and hotter at depth in its atmosphere than a normal star of similar effective temperature. And it is clearly seen in the models that the UV flux is emerging from higher and cooler atmospheric regions in the enhanced opacity model than it does in the model with unenhanced UV line opacities.

In several of the chemically peculiar stars observed by us, the energy distribution curves showed a clear blanketing effect in the shorter wavelength region, indicating enhanced opacities in the ultraviolet-violet region and possible backwarming in the blue-green region of the spectrum. Thus in such cases, the shorter wavelength parts of even the visible region were avoided and only the longer wavelength region of the energy distribution curves were employed for comparing with the Balmer-line blanketed theoretical models (Mihalas, 1966; Kurucz, 1979) for estimating their respective effective temperatures.

Then, using the observed and the matching theoretical fluxes of the Ap stars, we obtained their respective radii R/R(sun) with the following relation (Gray, 1967),

$$R/R(sun) = 44.33 \times 10^6 (F_\upsilon / \mathcal{F}_\upsilon)^{1/2}. 1/p$$

where p is the parallax, while F_ν and $\mathcal{F}_\nu$ are the observed and the corresponding theoretical monochromatic fluxes (in erg/sec/cm^2/Hz).

Further on, using the estimated effective temperatures and the corresponding radii of the Ap stars, their bolometric magnitudes M(bol) were obtained form the relation (Allen 1973)

$$M(bol = 42.36 - 10 \log T(eff) - 5 \log R/R(sun).$$

Finally, with the available data of m(vis) and parallax, the absolute magnitudes M(vis) were computed and hence the bolometric corrections. However, the uncertainties in these estimations are expected to be of the order of 20-30%, which is essentially due to the inherent errors involved in the parallax measurements.

A relation between the T(eff) and the M(bol) of these stars (Fig.1) shows that they are generally located around the upper edge and slightly above the main sequence band. This indicates that these chemically peculiar stars are probably transiting towards the yellow giant region and are presently in the hydrogen shell burning phase.

The same energy distribution curves have further been analysed to study the periodic variations in the broad spectral features around 4200 Å and 5200 Å, which are readily noticed in some of the observed stars. The equivalent widths of these features are found to be varying with the same periodicities as those of the light variations, magnetic field variations, etc. of the given chemically peculiar star. Such variations observed in the above mentioned broad spectral features have been interpreted as due to the surface inhomogeneities of these stars having large sized patches of certain predominant chemical compositions (Pavlova et al., 1977; Shylaja and Babu, 1986; Hatzes, 1993; Wehlau and Rice, 1993).

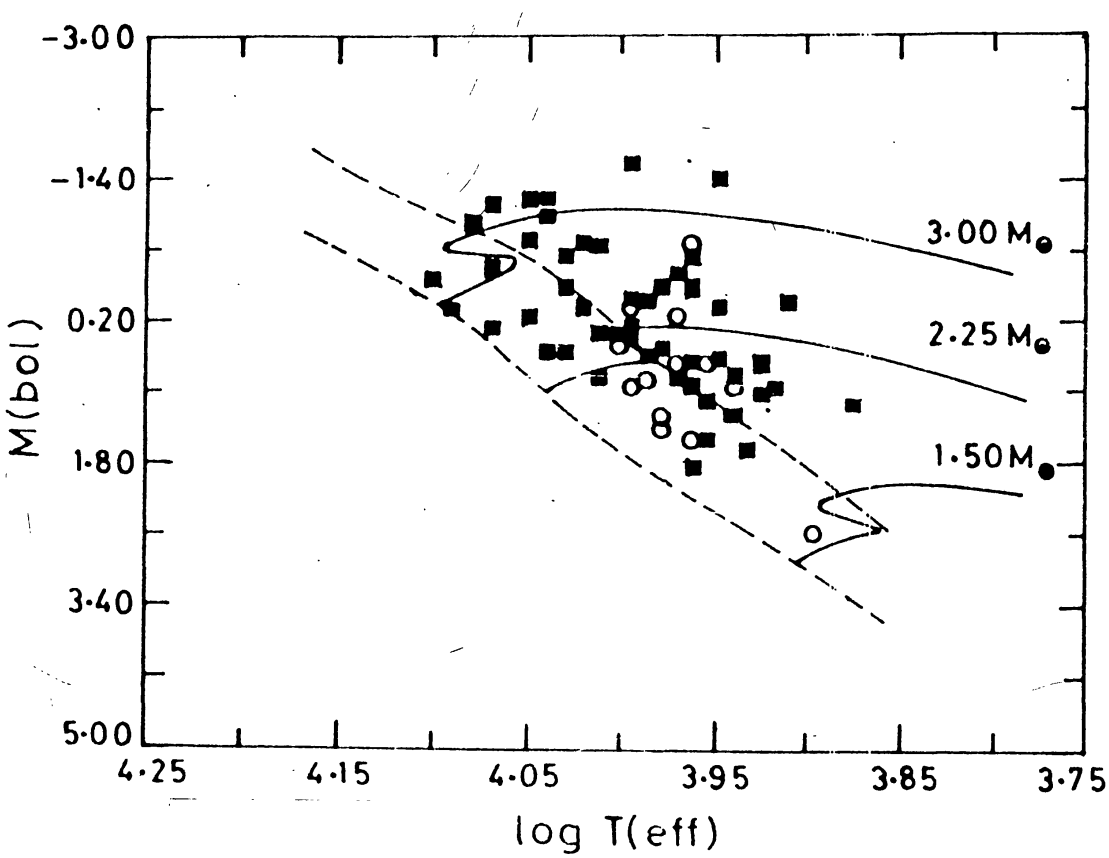

Figure 1. Relationship between effective temperatures and bolometric magnitudes of Ap and normal A stars. The filled squares denote the Ap stars, while the circles represent the normal A Stars. The dashed lines are the boundaries of the main sequences band and the solid lines are the evolutionary tracks.

4. Conclusion

The stars classified as the chemically peculiar A stars (or the Ap stars) are just about the right order in brightness (brighter than about 9 mag) to be observed with moderate size telescopes. Thus telescopes of 0.5 to 1 meter size would be just the appropriate instruments for carrying out most of their photometric observations, while the larger telescopes will make the images too bright and the detectors placed at their focal planes will become over-exposed. However, observations involving high resolution spectroscopy of these stars would require larger size telescopes, in any case.

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