# INFRARED SPECTROSCOPY OF Be STARS*

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## 1. Introduction

FeII emission lines are present in a variety of astrophysical objects and, in particular, in Be stars, where in some situations they can also be seen in absorption. Selvelli & Araujo (1984) studied a sample of classical Be stars that have FeII emission lines in the optical region. The analysis of IUE spectra of those stars revealed that, for the majority of the objects, neither absorption nor emission FeII features were present in the UV. The conclusion was that their data could not support excitation of FeII by continuum fluorescence. On the other hand, FeIII of circumstellar origin is often seen in absorption in the UV spectra of Be stars (Snow & Stalio 1987 and references therein). This could be an indication that the optical FeII emission lines are originated from recombination and cascade. However, Selvelli & Araujo (1984) argued that, since the multiplet UV 191 of FeII does not appear in emission, that mechanism is probably not relevant. In the present work we report new spectroscopic observations in the near infrared of a sample of 60 Be stars, including the prominent FeII 999.7 nm emission line. This line is also present in the spectra of superluminous B stars for which mass loss rates have recently been estimated (Lopes, Damineli-Neto & Freitas Pacheco 1992). We derived mass loss rates from the infrared line luminosities, in agreement with those derived by other methods. We also found a new evidence of the Be envelope flattening through the FeII/Pa$\delta$ line ratio.

## 2. Observations and Results

Most of the observations were carried out at the National Laboratory for Astrophysics (Brasópolis – Brazil), using the 1.6-m telescope. Observations cover the period from 1988 May to 1992 December. The Coudé spectra covered a range of 23 nm in our CCD, encompassing the FeII 999.7 nm and Pa$\delta$ (HI 1004.9 nm) lines with a resolution of $\lambda/\Delta\lambda \sim 10000$. Some data for northern objects were obtained at the Bologna Astronomical Observatory

* Based on observations made at the Laboratório Nacional de Astrofísica (Brasópolis, Brazil) and at the Osservatorio Astronomico di Bologna (Loiano, Italy)



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(Italy) from 1989 September until 1990 January, using the 1.52-m telescope. These spectra have $\lambda/\Delta\lambda \sim 2000$ resolution.

The most important result from our data is the strong correlation between the line luminosity of FeII 999.7 nm and that of Paschen-delta. The best fit equation represents also quite well the superluminous B stars data. The FeII 999.7 nm line is probably excited by Ly$\alpha$ photons (Johansson 1984) and our data suggest that such a mechanism may be operative in both classes of stars. We found, from our previous work (Lopes, Damineli-Neto & Freitas Pacheco 1992), that the mass loss rates from superluminous B stars are strongly correlated with the luminosity in the FeII 999.7 nm (or, equivalently, in the Pa$\delta$) line. From our data we obtained the relation

$$\log\,(\mathrm{d}M/\mathrm{d}t) = -5.57 + 0.71 \log\,[L(\mathrm{FeII})/L_\odot], \tag{1}$$

where mass loss rates are in solar masses per year. If such a relation can be extrapolated to lower luminosities, where classical Be stars are found, then the mass loss rate interval for the objects in this class is

$$-7.7 < \log\,(\mathrm{d}M/\mathrm{d}t) < -6.3. \tag{2}$$

This range is in quite good agreement with previous analyses (see, e.g., Damineli-Neto & Freitas Pacheco 1982) and with the theoretical predictions of asymmetric wind models of Araujo & Freitas Pacheco (1989).

We have also distributed the stars of our sample into bins of 50 km s$^{-1}$ projected rotational velocity and averaged the corresponding FeII 999.7/Pa$\delta$ ratio in each bin. There is a net correlation between this line ratio and $V \sin i$ (i.e., and the aspect of the equatorial region), indicating a polar flattening of the classical Be envelopes, as suggested by other methods. The observed correlation can probably be explained in terms of optical depth effects in the Pa$\delta$ line, as the envelope seems to be optically thin to the FeII 999.7 line. An increasing line opacity from the pole towards the equator by a factor of 2.0 – 2.5 may explain quite well the observed behaviour.

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## References

Araujo, F.X. and Freitas Pacheco, J.A. de: 1989, *MNRAS* **241**, 543.
Damineli-Neto, A. and Freitas Pacheco, J.A. de: 1982, *MNRAS* **198**, 659.
Johansson, S.: 1984, *Phys. Scr.* **T8**, 63.
Lopes, D.F., Damineli-Neto, A. and Freitas Pacheco, J.A. de: 1992, *A & A* **261**, 482.
Selvelli, P.L. and Araujo, F.X.: 1984, *Proc. 4th European IUE Conf.*, ESA SP-218, p. 301.
Snow, T.P. and Stalio, R.: 1987, *Exploring the Universe with the IUE Satellite*, ed. Y. Kondo, p. 183.