CONTINUOUS SPECTRA OF CIRCUMSTELLAR ENVELOPES OF Be STARS

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Line emission in Be star spectra is accompanied by continuous emission both in the Balmer continuum and in the infrared spectral region, due to the same process that is responsible for Balmer line emission, i.e. to recombination radiation from ionized hydrogen in the extended circumstellar disks surrounding the hot central stars.

In the present study a grid of continuous spectra for model Be stars has been calculated. Computed model continua are then fitted to measured spectra, covering the wavelength range between 320 nm and 60 μm, for a total of 20 bright Be-type stars with spectral types between B0 and B7. For these stars, optical spectrophotometry in the wavelength range from λ = 320 nm to λ = 850 nm performed in 1981 or 1982 (Kaiser (1987), Dachs et al. (1989)) was combined with infrared broadband photometry in the J, H, K, L, M and N bands (λ 1.25...10.3 μm) obtained in 1982 (Dachs et al. (1988)) and with space-borne photometry collected in 1983 by the IRAS satellite at wavelengths 12 μm, 25 μm, and 60 μm (Beichman et al. (1988)). Measured Be star spectra were dereddened by applying the interstellar extinction curve taken from Cardelli, Clayton and Mathis (1989) and from Mathis (1990), and using appropriate values of the colour excess E^{is}_{B-V} of the interstellar reddening.

Model spectra were computed by adding continuous free-free and free-bound hydrogen recombination radiation from a circumstellar disk to photospheric fluxes from the central stars. Starting values for the effective temperatures, T_{eff}, and gravities g were assigned to program stars according to their MK spectral types as determined by Slettebak (1982), using the calibrations of Schmidt-Kaler (1982). Photospheric continuous fluxes for the central B stars were derived from the tables of Kurucz (1979) for wavelengths up to 20 μm. For $\lambda > 20$ μm, the central B star is assumed to radiate like a black body at temperature T_{eff}. The circumstellar disk is taken to be a rotating, isothermal plane-parallel slab with inner radius R_i equal to the stellar radius R_*, and with outer radius R_a, and to consist of pure hydrogen. Surface density N in the disk is assumed to decrease as $N \sim r^{-\alpha}$ with distance r from the central star.

Theoretical models were fitted to measured Be star spectra by varying the following fit parameters: T_{eff}, E^{is}_{B-V}, the fraction x_e of disk radiation

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to total (photospheric + disk) radiation at the normalization wavelength of $\lambda = 656.3$ nm, the electron temperature in the disk, T_e, using $T_e = 10000$ K as a starting value, the outer radius of the disk, R_a, in units of the stellar radius R_*, the optical depth τ_o of the emitting disk at the inner radius R_i for the wavelength of $\lambda = 656.3$ nm and for electron temperature T_e, and the exponent α of the radial density law in the disk.

Values of the stellar radius R_* are obtained for the program stars from the compilation by Schmidt-Kaler (1982) according to their MK spectral types. The inclination angle i was derived from the values of v sin i (Slettebak (1982)) under the assumption that Be stars rotate at a uniform velocity taken to be $\sim$ 450 km/s for B0...B1e stars and $\sim$ 350 km/s for B2...B7 stars. For shell-type spectra, partial absorption of continuous photospheric radiation by the circumstellar disk is taken into account. Important criteria for the goodness of fits are the height of the Balmer discontinuity and the slopes of continuous spectra in the ultraviolet, optical and infrared regions of the spectra.

Preliminary model fits obtained for the 20 program stars show that the fraction of continuous envelope radiation at λ 656.3 nm typically ranges between 1% and 24% of the total fluxes of the Be star systems. This causes circumstellar reddening of $E^{cs}_{B-V} = 0\overset{m}{.}00...0\overset{m}{.}09$. Electron temperatures of the models are found between 8000 K and 12000 K. Outer envelope radii range from 6 to 40 stellar radii and optical depths τ_o at λ 656.3 nm from 0.05 to 4.5, being about unity on the average. Stars with weak line emission from their envelopes (μ Cen, η Cen) seem to have extended disks with small optical depths τ_o. Exponents α of the power law of surface density in the disk range from 1.4 to 2.6, most often lying between 1.4 and 1.8. Volume emission measures EM defined by

$$EM = \int_{V_{envelope}} N_i(r) N_e(r) dV$$

(with V = volume of the circumstellar envelope) were also calculated for the best-fit models for program stars and found to range between $6.3 \cdot 10^{58}$ cm^{-3} and $1.3 \cdot 10^{61}$ cm^{-3}.

Close correlations exist for program stars between the several characteristic measures of the strength of continuous emission in Be star spectra, viz. the fraction x_e of disk to total continuous radiation at λ 656.3 nm, the colour excess E^{cs}_{B-V} caused by circumstellar excess radiation, the logarithm of volume emission measure, log EM, and the intensity of Balmer emission as given by Hα emission line equivalent widths, $W'_e(H\alpha)$.

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