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THE INFRARED EXCESS OF EARLY-TYPE STARS: MODELLING THE IRAS OBSERVATIONS

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ABSTRACT The IRAS satellite has observed some early-type stars in the infrared part of the spectrum. Most of this infrared radiation is due to free-free scattering in the dense stellar wind of these stars. We modelled this phenemenon by solving the equations of hydrodynamics as well as the radiative transfer equation (for a H and He mixture). This yields continuum fluxes at visible and infrared wavelengths which have been compared with the observations.

INTRODUCTION

Mass loss is an important and often unknown parameter of massive star evolution. Therefore, it is crucial to gain thorough understanding of the mass loss phenomenon. One aspect we study is the continuum radiation of these early-type stars. This continuum radiation differs significantly from what traditional atmosphere models (Kurucz, 1979) predict. Additional radiation is caused by free-free scattering in the material surrounding the star. The cross section for free-free scattering is proportional to the square of the wavelength. Hence, at larger wavelengths (infrared and radio) we see a larger radiating body.

We have modelled this radiation by superimposing a stellar wind model on the "classical" atmosphere model. For this stellar wind we solved the equations of hydrodynamics and of radiative transfer. The calculated continuum fluxes were compared with observations.

THE MODEL

Following the radiatively driven stellar wind theory (Castor et al., 1975; Abbott, 1982), we have solved the time independent equations of mass and momentum conservation for a spherically symmetric wind at constant temperature. This yields the dependence of velocity and density on radius. We have not solved the complete set of NLTE statistical equilibrium equations. Instead, we used LTE

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equations, taking into account however the geometrical dilution. Finally, we solved the equation of radiative transfer with electron scattering and free-free scattering by H and He as contributors to the opacity and emissivity. A classical Kurucz atmosphere provided the radiation input at the bottom of the wind.

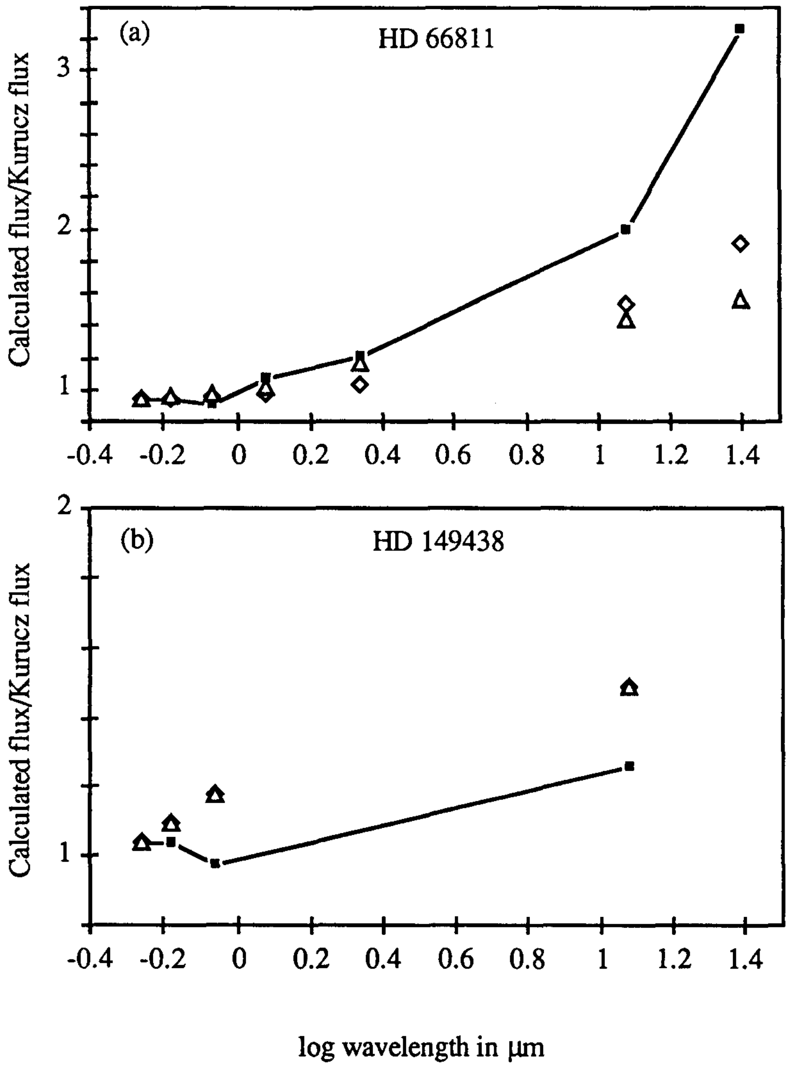

Fig. 1. Observed fluxes (▪) and model fluxes relative to the Kurucz flux at the same wavelength. Normal mass loss rates are indicated by a Δ, those three times higher by a ◇.

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RESULTS

We have applied our model to the O4If star ζ Pup (HD 66811). As a distance gauge, we assumed the distance of the star to be such that the theoretical flux equals the observed one for the V filter (0.555 μm). With the mass loss rate as predicted by the radiatively driven stellar wind theory (Kudritzki et al, 1989), we cannot fit the observations. Using a mass loss rate which is about 2.5 times higher we can model the radio fluxes fairly well.

Besides ζ Pup we also studied the following stars: HD 24912, HD 38771, HD 149438, HD 207198 and HD 218376. For these stars there are no radio observations. We have modelled their infrared fluxes, using both the mass loss rate predicted by the radiatively driven stellar wind theory and a mass loss rate which is 3 times higher, corresponding to what we needed to fit the radio observations for ζ Pup.

For some stars (HD 66811 - see fig.1a, HD 38771) observed fluxes are higher than the model fluxes, especially at larger wavelengths. There appears to be a problem with the distance gauge for some of the stars studied (e.g. HD 149438 - see fig.1b). Agreement between theory and observations would be a lot better if we had used the I filter (0.87 μm) instead of the V filter (0.555 μm).

CONCLUSIONS AND FUTURE WORK

The fact that calculated infrared fluxes are lower than the observed ones in some cases may point to additional mechanisms in the wind, e.g. shocks as proposed by Owocki et al. (1988). This is an important challenge to both the atmospheric and evolutionary theory : is there an inherent wind instability or are the shocks caused by non-radial pulsations at the base of the wind? The latter case would be relevant to the study of the stellar interior. However, detailed error analysis is required to judge the significance of the differences between observed and calculated fluxes.

In the near future, we shall extend the sample of stars and include the influence of the variation of temperature with radius. Furthermore, the contributions of bound-free transitions to the opacity and emissivity will be investigated. Finally, our code for calculating H and He in NLTE will be included in this model.

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