Active OB stars: structure, evolution, mass loss, and critical limits
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Mass loss in 2D rotating stellar models

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Abstract. Radiatively driven mass loss is an important factor in the evolution of massive stars. The mass loss rates depend on a number of stellar parameters, including the effective temperature and luminosity. Massive stars are also often rapidly rotating, which affects their structure and evolution. In sufficiently rapidly rotating stars, both the effective temperature and surface flux vary significantly as a function of latitude, and hence mass loss rates can vary appreciably between the poles and the equator. In this work, we discuss the addition of mass loss to a 2D stellar evolution code (ROTORC) and compare evolution sequences with and without mass loss.

Keywords. stars: evolution, stars: mass loss, stars: rotation

1. Introduction

Many massive stars are known to be rotating, and this causes a variation in temperature from pole to equator. Since radiatively driven mass loss depends sensitively on the temperature and local flux, these differences can affect the distribution of mass lost. These differences can cause small changes in the structure of a star, which can accumulate over the course of the evolution. In this paper, we investigate the 2D mass loss of rotating stars.

2. Models

We calculate mass loss rates for 2D stellar structure models calculated using `ROTORC` (Deupree 1990, Deupree 1995). To calculate the mass loss, we use the local effective temperature and luminosity at each surface zone. The mass loss rates are calculated using the prescription of Vink *et al.* (2001). The mass loss rate in each zone is weighted by the area of the zone to calculate the mass lost. Mass loss can also be calculated using the overall effective temperature and luminosity of the model, giving a pseudo-1D mass loss calculation. In this case, the mass lost is divided evenly among the angular zones.

3. Mass Loss

The 2D mass loss rates were compared to a pseudo-1D calculation based on the overall effective temperature and luminosity of the star. In both cases, the total amount of mass lost is the same. The 2D calculation, using the local temperature and luminosity has a much higher mass loss rate at the pole than the 1D case, while the mass loss rate at the equator is lower.

We have also compared the calculated variation in mass loss rates as a function of angle to that predicted using Castor, Abbott & Klein (1975, hereafter CAK) mass loss

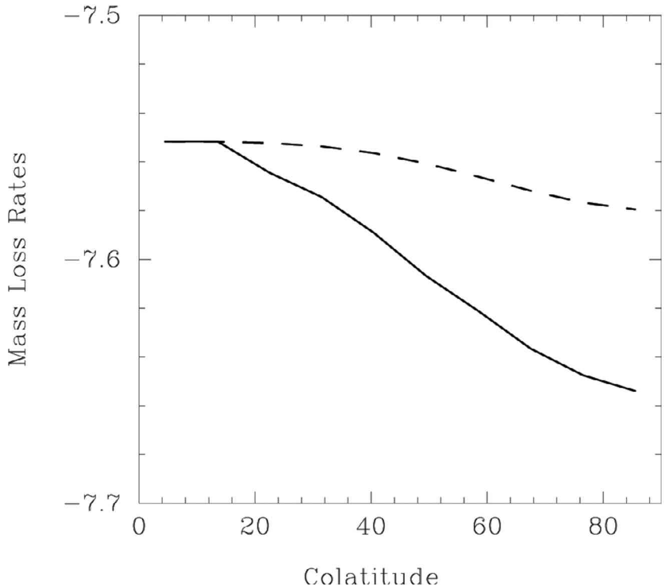

Figure 1. Calculated mass loss rates for a 20 $M_\odot$ rotating at 275 km/s for the 2D case (solid) and the CAK predictions (dashed). The mass loss rates in the 2D calculation decrease towards the equator much more rapidly than the CAK predictions.

rates and assuming a von Zeipel (1924) gravity darkening law. The CAK mass loss rates are normalized to be the same as the Vink mass loss rates at the pole. As shown in Figure 1, our calculated mass loss rates are considerably lower at the equator than the CAK predictions. Work is in progress to determine how much of this difference arises from the models, and how much arises from the different mass loss rates.

We have compared the interior structure of models that have had mass removed by both the 2D calculation and the pseudo 1D calculation. As discussed above, the type of calculation does not affect the total amount of mass removed, merely the distribution of this mass. A comparison of the 1D and 2D mass loss distributions results in differences in the core density of approximately 3.5%.

4. Conclusions

Preliminary results indicate that a full 2D calculation of mass loss using the local effective temperature and luminosity can significantly affect the distribution of mass loss in rotating main sequence stars. More mass is lost from the pole than predicted by 1D models, while less mass is lost at the equator. This change in the distribution of mass loss will affect the angular momentum loss, the surface temperature and luminosity, and even the interior structure of the star. After a single mass loss event, these effects are small, but can be expected to accumulate over the course of the main sequence evolution.

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