UPPER LIMITS FOR THE EFFECTIVE TEMPERATURE OF WOLF-RAYET STARS FROM THE PRESENCE OF HE I

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ABSTRACT. A recently developed non-LTE code for realistic semi-empirical models of Wolf-Rayet atmospheres is used to calculate synthetic helium lines. From the resulting line strenghts it can be concluded that if He I lines are present, the effective temperatures of these stars have to be less than an upper limit. This limit depends on the stellar radius and is approximately 40kK for $R_* = 20\ R_\odot$ to 60kK for $R_* = 5\ R_\odot$.

1. Introduction

The basic stellar parameters of the Wolf-Rayet stars are still essentially unknown though much effort has been invested in this subject. In particular, the published values of the effective temperature strongly disagree: for the subclass WN5, e.g., the temperatures range from 29kK (Underhill, 1983) over 41kK (Nussbaumer et al., 1982) to 90kK (Cherepashchuk et al., 1984).

Our new approach to the temperature problem is based on semi-empirical model calculations. It is demonstrated that the He I / He II line ratio may be used as a sensitive temperature indicator.

2. Non-LTE model calculations for WR atmospheres

The calculations are performed as described by Hamann (1985, 1986) and Hamann and Schmutz (1986). In order to avoid high electron temperatures in the envelope the temperature law was forced to approach to 8kK at great distances from the star, in contrast to the temperature structure adopted by Hamann and Schmutz (1986).

In Fig. 1 line profiles of He I λ5876 and He II λ4686 are presented for several star temperatures, while the remaining parameters characterizing the model are kept fixed at $R_* = 20\ R_\odot$, $\dot{M} = 4\ 10^{-5}\ M_\odot/\mathrm{yr}$, V_{max} = 2100 km/sec, $\beta = 1$, and $\log(g_{eff}) = 3.5$. The line strengths as well as the profiles depend also on the other model parameters: the stellar radius, the mass-loss rate, the velocity law and the temperature stratification in the wind. Next to the effective temperature, the stellar radius has the largest influence on the line strength.

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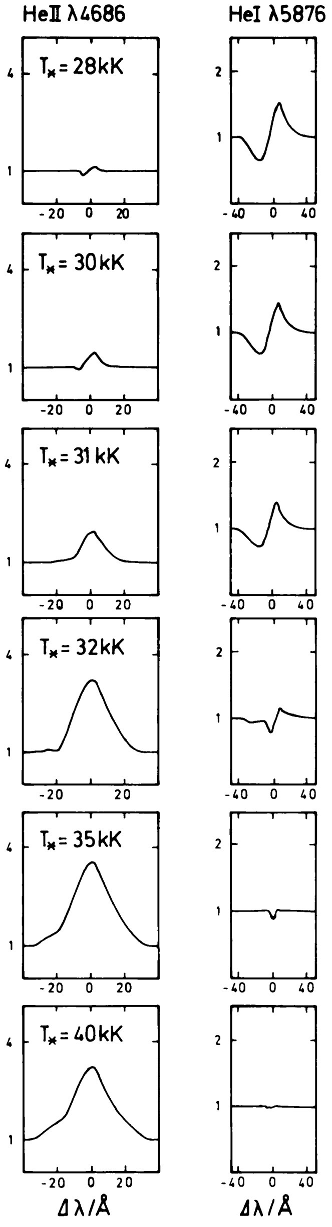

Figure 1.
Synthetic line profiles of He I λ5876 and He II λ4686 calculated for different star temperatures.

In the temperature sequence shown in Fig. 1, He I λ5876 would not be observable for temperatures higher than about 35kK. It is obvious that the presence of He I lines in a Wolf-Rayet spectrum gives an upper limit for the effective temperature of the star. Varying parameters other than temperature and radius may influence the line strengths up to a factor of two or three. Taking into account other parameter combinations, it can be stated that the He I lines vanish for temperatures higher than 40kK for $R_* = 20\ R_\odot$ to 60kK for $R_* = 5\ R_\odot$.

3. Conclusions

He I lines are observed in the spectra of the Wolf-Rayet subtypes WN5 or later and WC7 or later. From the upper temperature limit derived above these Wolf-Rayet stars are clearly below the temperature threshold, for which He^{++} recombines in the outer envelope (Schmutz and Hamann, 1986). It is therefore certain that these stars have He^{+} and not He^{++} as the dominating ion in the radio-emitting region. Therefore, the mass-loss rates hitherto published have to be corrected as given by Schmutz and Hamann (1986). On the whole the mean mass-loss rates of the Wolf-Rayet stars are of the order of $4\ 10^{-5}\ M_\odot/yr$, rather than $2\ 10^{-5}\ M_\odot/yr$ as given by Abbott et al. (1986).

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