The evolutionary state and fundamental parameters of metallic A-F giants

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Abstract. Using Hipparcos parallaxes, we show that the metallic A-F giants found by Hauck (1986) on the basis of their high Δm_2 index in Geneva photometry are on average more evolved than their non-metallic counterparts. Their mass distribution, rate of binaries and $v \sin i$ are shown to be incompatible with those of Am stars, so that they cannot be descendants of the latter. They might be former normal stars going through a short metal-rich phase at the very end of their life on the Main Sequence.

Key words: Stars: fundamental parameters – Stars: chemically peculiar – Stars: rotation – Stars: evolution

1. Introduction

The metallic A-F giants, found by Hauck (1986) on the basis of their high Δm_2 index, have an abundance pattern similar to that of Am stars, except for Ca and Sc which have a more or less solar abundance (Berthet 1990, 1991). Their chemical anomalies closely resemble those of the δDel stars, which seem to be evolved Am stars (Kurtz 1976). Therefore, it appeared natural to consider the metallic A-F giants as evolved Am stars too. Indeed, the theory of radiative diffusion foresees that calcium, which had sinked to large atmospheric depths in the beginning of the star's life would be finally dredged up by the increasingly deeper outer convective zone as the star would reach the giant phase. This scenario was advocated by Berthet (1992).

Hereafter, we reconsider this question from a different standpoint and examine the evolutionary state of the metallic A-F giants in the light of the Hipparcos results.

2. Rotational velocity and rate of binaries

If metallic A-F giants were indeed evolved Am stars, they should share with them two essential characteristics: slow rotation and high rate of binaries. Since giants have a larger radius, they should rotate even more slowly than Am stars, merely by conservation of angular momentum. However, a glance at the distributions of the $v \sin i$ values of Am, metallic and non-metallic A-F giants suffices to cast serious doubts on the idea of an evolutionary link between Am and metallic giants (see Figure 11 of Künzli & North 1997): $v \sin i$ is uniformly distributed between 0 and 150 $\mathrm{km\,s^{-1}}$ for metallic giants, while it shows a maximum at 30-40 $\mathrm{km\,s^{-1}}$ and remains smaller than 100 $\mathrm{km\,s^{-1}}$ for Am stars. The rate of binaries has been examined using both data from the literature and observations done at Observatoire de Haute-Provence (CNRS), France, with the Aurélie spectrograph attached to the 1.52m telescope in 1994. For metallic A-F giants, the rate of binaries with orbital periods shorter than 1000 days is no more than about 23%, matching very well the figure (21.7%) found by Duquennoy & Mayor (1991) for G dwarfs. This figure is to be compared with the result of Abt & Levy (1985), who found 75% of binaries among Am stars. Here again, the metallic giants lack an essential characteristic of Am stars, namely a high rate of binaries (Künzli & North 1997).

If metallic A-F giants are not evolved Am stars, what are they? the simplest alternative scenario is that every A star goes through a short "metallic" phase at the end of its life on (or just beyond) the Main Sequence.

3. Evolutionary state and fundamental parameters

Practically all stars considered by Hauck (1986) have been measured by Hipparcos, and many of them are closer than 100 pc or have, in any case, a relative precision on the parallax better than $\sim 20\%$. The resulting HR diagram shows that the metallic giants tend to be more evolved on average than their normal counterparts, as confirmed by the cumulative distributions of the $\log g$ values. The $\log g$ values were obtained from the luminosities deduced from the Hipparcos parallaxes, from the $T_{\rm eff}$ deduced from Geneva photometry calibrated by Künzli et al. (1997) and from masses interpolated in the evolutionary tracks of Schaller et al. (1992). The KS test shows a very significant difference between the distributions of $\log g$ for metallic and normal giants. The mass distribution of the metallic giants is strongly peaked at 2 $\mathrm{M_\odot}$, while the mass distribution of Am stars is peaked at 1.5 $\mathrm{M_\odot}$ (North 1993). This difference alone does not completely exclude, however, any possible link between Am stars and metallic giants, because low mass Am stars would have evolved into giants with a $T_{\rm eff}$ cooler than the limit above which radiative diffusion still works.

4. Conclusions

There is a set of rather compelling arguments against the idea that metallic A-F giants would be evolved Am stars. On the other hand, the precise Hipparcos parallaxes allow for the first time to pinpoint these metallic giants in the HR diagram and to show that they all have $\log g \leq 3.8$. This seems to add some weight to the alternative idea that these giants have nothing to do with Am stars but may be former "normal" A stars going through a short phase where, for some as yet unclear reason, radiative diffusion is allowed to enhance the metallic abundance in their atmosphere.

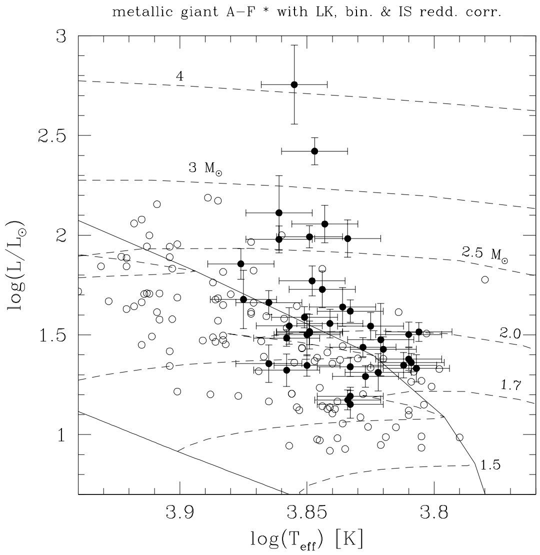

Figure 1. HR diagram of all giants considered by Hauck (1986). Full dots: $\Delta m_2 > 0.013$, open dots: $\Delta m_2 \leq 0.013$. ZAMS, TAMS and evolutionary tracks for $Z = 0.020$ are from Schaller et al. (1992).

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