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THE EVOLUTION OF IRON WHITE DWARF STARS

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RESUMEN

Las recientes mediciones hechas con el satélite *Hipparcos* muestran una fuerte evidencia observacional sobre la existencia de algunas estrellas enanas blancas con interiores ricos en hierro. Aquí estudiamos la evolución de enanas blancas ricas en hierro, para las cuales el enfriamiento está notablemente acelerado si las comparamos con enanas blancas estándares, ricas en carbono-oxígeno.

ABSTRACT

Recent measurements by *Hipparcos* provide strong observational evidence supporting the existence of white dwarf stars with iron-rich core composition. Here we examine the evolution of iron-rich white dwarfs, for which the cooling is substancially accelerated as compared with the standard carbon-oxigen white dwarfs.

Key Words: **STARS: EVOLUTION – STARS: WHITE DWARFS**

1. INTRODUCTION

White dwarf (WD) stars are the most useful objects for testing the theory of electron degeneracy. Because of the great importance of the theory of electron degeneracy in several astrophysical circumstances, great effort has been devoted to improving our knowledge of the mass-radius relation for WD stars. In this context, recent observations carried out by the astrometric satellite *Hipparcos* have allowed Provencal et al (1998) to substantially improve the mass and radius determination for 20 WDs. From very accurate parallaxes, these authors determined precise mass and radius values, without invoking mass-radius relations, thus making these WDs excellent targets for testing stellar degeneracy directly. In particular, the results of Provencal et al. present strong evidence that at least three objects of their WD sample appear to have an interior chemical composition consistent with iron. Indeed, GD 140, EG 50 and Procyon B have stellar radii that are significantly smaller than those corresponding to a carbon-oxigen (CO) interior for their observed masses. Needless to say, such results are clearly at odds with the standard theory of stellar evolution, which predicts a CO interior for intermediate mass WDs. The aim of the present work is to perform an exploration of the structure and evolution of such objects, by means of a detailed WD evolutionary code.

2. EVOLUTIONARY RESULTS

We computed the evolution of iron WD models with stellar masses of M = 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, and 1.00 $M_{\odot}$. The calculations were carried out with the same volutionary code as described in Althaus & Benvenuto (1997) (see also Althaus 2001; these proceedings). In particular, opacities and neutrino energy release rates for iron composition were taken from the works of Itoh and collaborators, a description of which is given in Panei, Althaus & Benvenuto (2000).

The main results of our calculation are shown in Fig. 1*a*, *b*. We evolved iron WD models with masses ranging from 0.4 $M_{\odot}$ to 1.0 $M_{\odot}$. The evolutionary sequences were computed down to $\log L/L_{\odot} = -5$. To derive the radius of each model at some given T_{eff}, we performed an interpolation in each evolutionary track to a fixed value. Mass-radius relation for ^{56}Fe are presented in Fig. 1*a* for T_{eff} ranging, from bottom to

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top, from 5,000 °K to 55,000 °K with steps of 10,000 °K, and from 70,000 °K to 145,000 °K with steps of 15,000 °K. To explore the sensitivity of our results to a hydrogen envelope, we considered two extreme values: $M_H/M_* = 10^{-5}$ and $M_H/M_* = 0$.

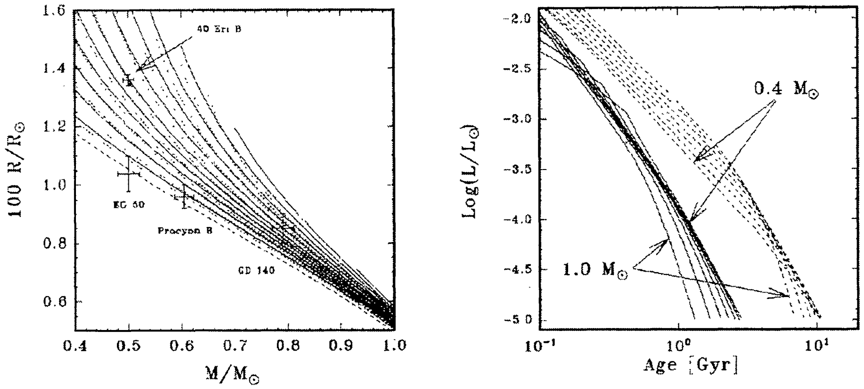

Fig. 1. (*a*) Mass-Radius relation for iron WD models with different T_{eff} values. Solid and dashed lines represent models with and without a hydrogen envelope, respectively. For the sake of comparison, we also show the zero temperature Hamada & Salpeter (1961) models. (*b*). Stellar luminosity versus age relation corresponding to iron (solid lines) and CO (dashed lines) WD models with different stellar masses.

In Figure 1.(*b*) we show the time spent to cool down from $\log L/L_\odot = 0$, where we set $t = 0$. We find that in reaching a given -low- luminosity value, iron WDs have to evolve for about a tenth of the time CO WD needs! Note that at high luminosities, there is a sudden change in the slope in the iron sequences. This is a result of the fact that, at this luminosity, the crystal front has reached the bottom of the helium rich envelope.

Our results indicate that iron WDs evolve in a very different way compared to standard CO WDs. These differences are due to the fact that the mean molecular weight per electron for iron is higher than for CO plasmas, and also to the stronger corrections to the ideal degenerate equation of state that cause the pressure of iron plasmas to be below the values corresponding to the case of CO. As consequence of the denser interior, iron WDs have smaller radii, greater surface gravities, higher internal densities, etc... compared to standard CO WDs of same mass. Very noticeable are the differences encountered in the crystallization process that occurs at very high luminosities.

The cooling process at very high luminosities proceeds in a much faster way (up to a factor of ten) compared to the standard case. In this context, it is worth mentioning that were iron WDs very numerous, they would have had time enough to evolve to luminosities much lower than the corresponding to the observed fall-off of the WD luminosity function. Thus, from a statistical point of view, the lack of tail in the observed luminosity function strongly indicates a very low spatial density of iron WDs and may be employed to constrain it quantitatively.

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