

The Binary Evolution of the subdwarf B star PG 1336-018



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Abstract

We present a study of possible progenitors of the pulsating subdwarf B (sdB) star in the very short-period, eclipsing binary PG 1336-018. Using results from detailed stellar evolution models, we reconstruct the common envelope (CE) phase in which the sdB star was formed. Our results constitute a fruitful starting point for our seismic work on this star, which is based on high-precision VLT photometry and spectroscopy of this target star.

Introduction

Subdwarf B stars are core-He burning stars ($\sim 0.5 M_{\odot}$) with an extremely thin H-envelope ($< 0.02 M_{\odot}$). It is not clear how they manage to lose almost their entire H-envelope when the core is close to He-ignition, i.e. near the tip of the RGB. The fact that many sdB stars are found in binaries suggests that Roche-lobe overflow may play an important role in their formation. To test this, and other formation channels, a detailed investigation of the sdB interior structure is needed. Since pulsations have been detected in a significant fraction of sdB stars, we can use asteroseismology to test the outcome of sdB formation channels.

PG 1336-018

A promising candidate for a detailed evolutionary and asteroseismic analysis is the pulsating and eclipsing sdB star PG 1336-018. The period of the orbit is extremely short at 0.101016 d [1]. Our goal is to restrict the initial orbital parameters of the system's progenitor.

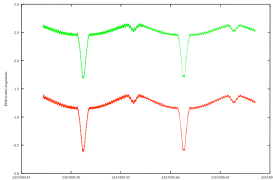


Figure 1. ULTRACAM-VLT g' and r' band lightcurves showing the eclipsing and pulsating nature of PG 1336-018.

The pre-CE binary

The range that a giant's core mass and radius can have for the core to still ignite He after loss of the envelope, has been calculated by Han et al. [2] as a function of ZAMS mass. We use their results to calculate the pre-CE orbital period as a function of the sdB progenitor ZAMS mass, see fig. 2. We also studied the effect of the companion's mass on the initial period. Since the influence is small we take $M_2 = 0.15 M_{\odot}$ here, as proposed by Kilkeny et al. [1].

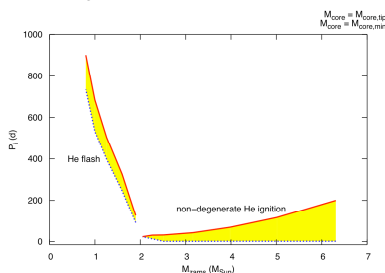


Figure 2. The pre-CE orbital period as a function of the sdB progenitor ZAMS mass. Model assumptions are solar metallicity, convective overshooting and Reimer's wind mass-loss. Furthermore, it is assumed that the companion has not accreted any mass.

The CE Phase

During the CE phase the two stars spiral inwards due to friction. It is commonly assumed that the orbital energy released in the spiral-in process is used to eject the CE with some efficiency α . The binding energy of the envelope can be expressed as $GMM_{\text{env}}/\lambda R$, with λ depending on the stellar density distribution. We calculated $\alpha\lambda$ as a function of the ZAMS mass (fig. 3).

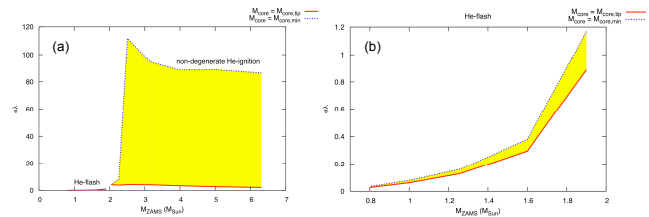


Figure 3. The parameter $\alpha\lambda$ as a function of the sdB progenitor ZAMS mass. We calculated λ using stellar evolution models, and found $\lambda \sim 0.4 - 1.0$ for this mass range. (a) Notice that α takes unphysically high values in the case of non-degenerate He-ignition. In (b) we zoom in on the He-flash region, which corresponds to core masses of $\sim 0.4 - 0.5 M_{\odot}$, and find more realistic values for α .

An alternative algorithm for the CE evolution is provided by Nelemans et al. [3], and assumes that the specific angular momentum carried away by the ejected envelope is γ times the specific angular momentum of the initial binary. Our results using the γ -algorithm are shown in fig. 4.

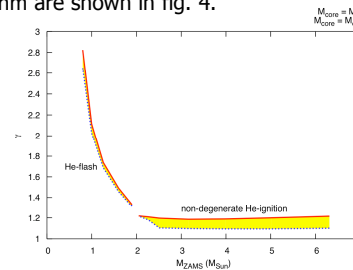


Figure 4. The parameter γ as a function of the ZAMS mass.

Conclusions

If the CE phase is described by the α -formalism, we can reject the non-degenerate He-ignition scenario for PG1336-018. We then expect the sdB mass to be between $0.4 - 0.5 M_{\odot}$, and the sdB progenitor ZAMS mass to be $< 2 M_{\odot}$. The results for the γ -algorithm are not exclusive, and a broader mass range is still possible in this case. We have now made a first selection of possible progenitors, which we will use for a detailed evolutionary and seismic study in future work.

References

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- [2] Han, Z., Podsiadlowski, Ph., Maxted, P.F.L., Marsh, T.R., Ivanova, N., Mon. Not. R. Astron. Soc. 336, 449-466 (2002).
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