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On the pulsation modes and masses of RGB OSARGs

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Abstract. OSARG (OGLE Small Amplitude Red Giants) variables are RGB or AGB stars that show multi-periodic light variations with periods of about 10-100 days. Comparing linear nonadiabatic pulsation periods and period ratios with observed ones, we determined pulsation modes and masses of the RGB OSARG variables in the LMC. We found that pulsations of OSARGs involve radial 1st to 3rd overtones, p_4 of $l = 1$, and p_2 of $l = 2$ modes. The range of mass isfound to be 0.9-1.4$M_\odot$ for RGB OSARGs and their mass-luminosity relation is $\log L/L_\odot = 0.79\,M/M_\odot + 2.2$.

1. INTRODUCTION

OSARGs are multi-periodic variables found in the Galactic bulge by [1] and in the LMC/SMC by [2]. They are grouped into RGB and AGB OSARGs. The former group has three ridges (b1, b2, b3) and the latter has four ridges (a1, a2, a3, a4) in the period-luminosity (P-L) plane [2].

2. MODELS

We have obtained linear nonadiabatic pulsation periods for envelope models along the evolutionary tracks calculated with the MESA code [3] for several initial masses and adopting a mixing-length of 1.5 pressure scale height. We have adopted the chemical composition $(X, Z) = (0.71, 0.01)$ for the LMC and used OPAL opacity tables [4].

3. MODE IDENTIFICATION

Since the pulsation period itself depends on radius and mass, the period ratios are useful to identify pulsation modes, while pulsation periods are used to determine the appropriate luminosity (or mass) ranges. The left panel of Fig. 1 shows the period versus period-ratio diagram (also called Petersen diagram) for radial pulsations of 1.1$M_\odot$ models with luminosity ($\log L/L_\odot$) between 2.7 and 3.35, and the observed values for the RGB OSARGs. Period ratios of about 0.5 correspond to b3/b1, and ratios of about 0.7 correspond to b2/b1 and b3/b2. From the figure we conclude that radial 1st, 2nd, and 3rd overtones in the range of $3.0 < \log L/L_\odot < 3.15$ correspond to b1, b2, and b3, respectively.

To explain period ratios larger than about 0.9, it is necessary to consider non-radial pulsations. The presence of such high period ratios indicates that each ridge in the P-L plane might consist of more than one mode. The middle and right panels of Fig. 1 show period ratios obtained between $l = 1$ and radial modes and $l = 2$ and radial modes respectively, for 1.1$M_\odot$ RGB models within the luminosity range $3.0 < \log L/L_\odot < 3.15$. These figures indicate a period ratio of about 0.9 that can be explained by the

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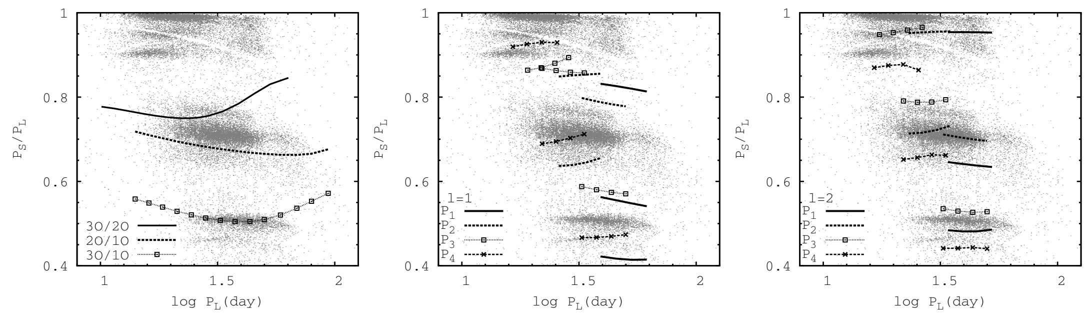

Figure 1. *Left*: Period-ratio *vs* radial period for 1.1M$_\odot$ red-giant models, compared with observed RGB OSARGs. *Middle*: Period ratios between $l = 1$ p$_1$ $-$ p_4 and radial modes compared with RGB OSARGs. *Right*: The same as the middle panel but for $l = 2$ modes.

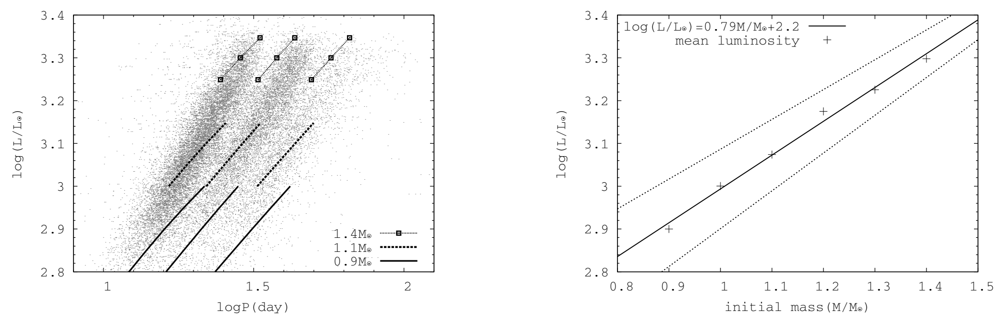

Figure 2. *Left*: Period luminosity relations of radial 1st (b1) , 2nd (b2), and 3rd (b3) overtones of 0.9, 1.1 and 1.4M$_\odot$ RGB models compared with observed RGB OSARGs. *Right*: The mass-luminosity relation of RGB OSARGs from our best fit models. Crosses are mean values of the luminosity range derived from each mass model. The two dotted lines are the upper and lower luminosity limits of this luminosity range.

presence of the $l = 1$p$_4$ modes in the ridge b3, while a ratio of about 0.95 is explained by the presence of the $l = 2$p$_2$ modes in the ridge b2.

4. THE MASS RANGE AND THE MASS-LUMINOSITY RELATION

Evolutionary models with a given initial mass can be consistent with only a small luminosity range of the OSARG P-L relations. Therefore, we need to superpose P-L relations for different masses to reproduce the whole range of the OSARG P-L relations. The left panel of Fig. 2 shows the necessary range of mass to fit the RGB OSARG P-L relations. We see that (initial) masses of RGB OSARGs should range from 0.9 to 1.4M$_\odot$. Then by assuming that a mean of the luminosity range is a typical luminosity of the model with a given initial mass, we have derived the following mass-luminosity relation: $\log \mathrm{L/L_\odot} = 0.79\,\mathrm{M/M_\odot} + 2.2$ (right panel of Fig. 2).

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