On the pulsation modes of OSARGs in the LMC

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Abstract

Wray et al. (2004) and SozSzyński et al. (2004) found a number of red giant variables in the Galactic bulge and the LMC/SMC showing relatively small photometric amplitude and irregular (multi-periodic) variability. Such variables were named “OSARGs (OGLE Small Amplitude Red Giant variables)” after the observation campaign, “OGLE”. Three and four ridges were appear on the Period-luminosity planes of RGB OSARGs and AGB OSARGs, respectively due to their multi-periodic variability.

In this poster, comparing the periods and period ratios of the RGB OSARGs with our theoretical models, we show that their three ridges (b1,b2,b3) on the PL plane correspond to the radial first, second and third overtone, and nonradial dipole P4 and quadrupole P2 mode. As a result of this, we also show to obtain the initial mass range of ~ 0.9 ~ 1.4Msun. Using the Mass - Luminosity relation, we have found that the scaled optimal frequency, \(\nu_{\text{max}}\), for the solar like oscillations goes through roughly the middle of the three ridges on the PL plane. It suggests that the stochastic excitations are likely the case of the pulsations in OSARGs.

1. OSARGs are usually within the period range of ~ 10 – 100 days and feature multi-periodic variability. Typical values of period ratios of RGB OSARGs are ~ 0.5, 0.7, 0.9 and 0.95. The period ratios of ~ 0.5 correspond to the b3/b1, while ~ 0.7 correspond to the b1/b2 and b2/b3. SozSzyński et al. (2004, 2007) showed that each of the sequence b2 and b3 has two narrow sub-ridges in addition to the main ridge, and they concluded that the period ratio of ~ 0.9 and 0.95 was consistent with the pair of the main ridge and the sub-ridge.

2. Models

We have obtained linear nonadiabatic radial and nonradial pulsation periods for envelope models along the evolutionary tracks calculated by the MESA code ( Paxton et al. 2011) with several initial masses 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 (Iglesias and Rogers 1996) opacity tables.

3. Data selection

We have obtained the pulsation periods and V- and I-band mean photometric magnitudes of RGB OSARGs (~45,500) of the LMC from OGLE-III. Some OSARGs have Long Secondary Periods (LSPs) that are mysterious long period (~ 500 – 1500 day) unsettled variable phenomenon. We have excepted stars having larger period than log10 P(day) = 2.1 and smaller period ratios then 0.4 then we have obtained non-LSP OSARGs (~5,000).

4-1. Mode identification(radial mode)

Since the pulsation period itself depends on stellar radius and mass, the period ratios are useful for determining pulsation modes, while pulsation periods are used to determine the appropriate luminosity (or mass) ranges.

Fig. 1 shows comparisons with the radial pulsations in the Period - Period Ratio diagram(Petersen diagram) for RGB OSARGs, respectively. From these figures we conclude that radial 1st, 2nd and 3rd overtone correspond to b1, b2 and b3, respectively.

4-2. Mode identification(nonradial mode)

Since period ratios larger than ~ 0.9 were not explained by radial pulsations, we have considered nonradial pulsations. The presence of such high period ratios indicates that each ridge in PL plane might consist of more than one mode. Figs. 2 and 3 show period ratios obtained between dipole and radial modes, and quadrupole and radial modes, respectively for 1.1Msun RGB models. According to Fig. 1, we have considered only luminosity range of 3.0 < log(L/Lsun) < 3.15 for 1.1Msun models corresponding to RGB OSARGs. Those figures show that the presence of dipole P4 mode in the b3 ridge correspond to a period ratio of ~ 0.9 while the presence of quadrupole P2 mode in the b2 ridge correspond to a period ratio of ~ 0.95. In addition the pair of dipole P4 and radial 2nd overtone and the pairs of quadrupole P2 and each radial 1st and 3rd overtone are consistent with a period ratio of ~ 0.7.

5. Discussion

Even if nonradial pulsations are considered, evolutionary models with an initial mass correspond to only a small part of each ridge on the period – period ratio planes. Therefore we need to consider deferent masses. Fig. 4 shows period luminosity relations of radial 1st – 3rd and nonradial dipole P4 and quadrupole P2 mode for 0.9, 1.1, 1.4Msun RGB models. Each mass models is consistent with three OSARG PL ridges in deferent luminosity range, respectively. We thus have concluded that initial masses of RGB OSARGs should range from 0.9 ~ 1.4Msun. As a result of this, we have obtained the (initial)mass – luminosity relation:

\[ \text{Log}(L/L_{\odot})=0.91(M/\text{M}_\odot)+2.05 \]

The black dashed line in this figure shows the scaled optimal frequency, \(\nu_{\text{max}}\), for solar like oscillations computed by using equation (1) and the effective temperature at each evolutionary phase and it goes through roughly the middle of the three ridges. It suggests that the stochastic excitations are likely the cause of the oscillations in OSARGs.

6. Conclusion

Comparing the RGB OSARGs in the LMC with linear nonadiabatic radial and nonradial pulsation periods and their period ratios, we have found that radial 1st, 2nd and quadrupole P2, and 3rd and dipole P4 mode for RGB models correspond to the sequence b1, b2 and b3 of RGB OSARGs, respectively. A luminosity range that is consistent with OSARGs PL relations differs by stellar mass. To explain the broad of the ridges or sequences of period – period ratio and period – luminosity relations, we have obtained the (initial)mass – luminosity range of 0.9 ~ 1.4Msun. Moreover, we have obtained the (initial)mass – luminosity relation of RGB OSARGs as equation (1) by considering the mean values of the luminosity range of each initial mass. Using equation (1), the scaled optimal frequency, \(\nu_{\text{max}}\), for solar like oscillations goes through roughly the middle of the sequence b2 and it suggests that the stochastic excitations are likely the cause of the oscillations of OSARGs. Recently, the evidence of solar like oscillations have been found in a lot of lower luminous red giant variables by CoRoT and Kepler. However, oscillations of Mira variables( the most luminous red giant variables) have been argued to be caused by \(\kappa\) – mechanism (self excitation) for hydrogen in outer layer of the star. OSARGs are much luminous than solar like oscillating red giant variable stars but a little dimmer than Miras. Those things suggest that OSARGs would be the most luminous solar like oscillators along red giant variables and be available to verify a convective theory.