Abstract of the doctoral dissertation

The impact of the evolution of binary systems on the properties of pulsating stars on the example of Cepheids and RR Lyrae stars

Paulina Karczmarek

This doctoral dissertation describes how the properties of pulsating stars, exemplified by RR Lyrae stars and classical Cepheids, can be changed as a result of the presence of a companion in a binary system. The study consists of three diverse projects which can be further developed and extended in the future.

The first project aims to show that RR Lyrae (RRL) pulsating stars are reliable and precise standard candles that follow the period-brightness-metallicity relation in the near-infrared. This relation is then used to determine the distance to two galaxies in the Local Group: Carina and Fornax. The results are consistent with the distances existing in the literature, but are of greater precision, at a level of 5%. The reason behind such precision is smaller contribution of systematic and statistical errors. For example, near-infrared observations are less affected by the interstellar extinction than observations in the visible domain. Also, the effect of metallicity on the brightness of RRL stars in the near-infrared is smaller than in the visible regime. These assets make the near-infrared period-brightness-metallicity relation for RRL stars a valuable tool for determining distances, in particular to nearby galaxies (distance module not larger than about 22 mag) which do not host classical Cepheid. The results agree with the distances determined using other standard candles, such as red clump stars or stars on the tip of the red giant branch, in the course of the Araucaria Project. A significant discrepancy between obtained results and other distance determinations would mean that additional and not yet addressed effects could alter the distance measurements. One of these effects – the presence of a companion in a binary system – will have been discussed in the next chapters of this doctoral dissertation.

The next two projects are of theoretical nature and use a binary population synthesis code StarTrack, created by Belczynski et al. (2002, ApJ 572, 40; 2008, ApJS 174, 223) and constantly developed since. The population synthesis method allows for statistical description of properties of binary systems as well as for the analysis of the interaction between the components on different evolutionary stages. Both projects examine binary systems with at least one star inside the instability strip, but one project focuses on systems that undergo the mass transfer, whereas the other project investigates the systems that are only gravita- tionally bound, without mass transfer episodes.

A study of a synthetic population of binary stars which experience mass transfer episodes leads to the confirmation of the existence of a new class of pulsating stars, so-called BEP (*Binary Evolution Pulsator*). The first and so far the only BEP star is OGLE-BLG-RRLYR-02792, the object discovered by Soszyński et al. (2010, Acta Astron. 60, 165) and further studied by Pietrzyński et al. (2012, Nature 484, 75) and Smolec et al. (2013, MNRAS 428, 3034). BEP mimics the pulsational pattern of RRL stars but – due to the mass transfer episode that it has experienced – its mass and evolutionary path are utterly different from RRL's. This project shows that BEPs are expected to populate the instability strip, in the areas of both RRL stars and Cepheids. Moreover, BEPs can be misclassified as RRLs or Cepheids due to the shape of their light curves. The most effective way to detect BEPs is to observe eclipses in their light curves or fluctuations in their radial velocity curves associated with the orbital motion. Unrecognized BEPs should not be abundant and therefore their presence should not

alter the distance measurements based on the period-brightness relation for Cepheids and RRL stars. Nevertheless, the interesting properties and evolutionary paths of BEPs encourage to search for more stars belonging to this new class and to continue to study already known candidates. The project reaffirms that the interactions in binary systems are crucial for explaining the observed properties of some binary pulsating stars.

A study of binary stars with no mass transfer episodes was performed in order to check whether the components residing in the instability strip – particularly Cepheids – follow the period-luminosity relation undisturbed by the presence of companions, or rather an additional light from the companions systematically shifts the period-luminosity relation. This issue has appeared frequently in the literature and discussed in a qualitative way. Isolated cases of Cepheid in binary systems that lay significantly above the period-luminosity relation are described by Pietrzyński et al. (2010, Nature 468, 542) and Pilecki et al. (2018, ApJ 862, 43). The project, which is presented in this doctoral dissertation, for the first time addresses the issue of the excess light of Cepheids' companions in both qualitative and quantitative way. Three synthetic populations of binary stars with metallicities of Milky Way, Small and Large Magellanic Clouds were used to determine the change in the accuracy of distance determinations calculated from period-luminosity relations for a mixed sample of Cepheids (single and binary stars) at different wavelengths and for different percentage of binary systems in the sample. The results reassure that distance determinations from the period-luminosity relation for a mixed sample are only slightly shifted due to the excess light from the companion, which can be further minimised if the observations are carried out at larger wavelengths.

Keywords:
binary stars
pulsating stars: Cepheids, RR Lyrae
period-luminosity relation
distances
Local Group
stellar evolution
population synthesis