Asteroseismic constraints on the physical properties and formation of blue stragglers

(*popular-science description*)

Blue stragglers (BS) are stars that appear much younger than the population they belong to and in which they formed. These objects have been identified mainly in stellar clusters and they differ from most other stars in that they are much brighter and hotter. BS are much younger than the standard theory of single-star evolution predicts. Single stars follow a particular path of evolution determined by mass and chemical composition. Masses and age of BS contradict this standard path and these objects appear to linger (straggle) in their evolutionary process, hence their name. Apparently, the blue stragglers must be formed in a different, non-standard way. Two mechanisms have been proposed for their rejuvenation. The first one involves a mass transfer or coalescence in primordial binaries. The second mechanism is collisions of stars in dense cluster regions. How to distinguish which mechanism contributed to the formation of a given blue straggler? Despite many theoretical and observational efforts, the physical processes governing the formation and further evolution of BS are still not fully understood. Furthermore, we do not have a clear picture of how cluster dynamics influences the formation of these peculiar stellar objects.

So far, the only method of probing the internal structure of stars in detail is asteroseismology. This relatively young branch of astrophysics is based on the analysis of periodic changes of stellar brightness caused by the propagation of acoustic and buoyancy waves in stellar interior. By constructing seismic models, that is, the models that reproduce the observed frequencies of pulsational modes, one can obtain strong constraints on mass, age, chemical composition and rotation. In addition, one can get information on the rotational profile, the efficiency of energy transport by convection and the efficiency of various mixing processes in the stellar interior.

Oscillating blue stragglers have been found in globular and old open clusters as well as in Local Group dwarf galaxies. They exhibits pulsations with usually short periods of about 0.01−0.15 day. In globular clusters and the galactic halo they are called SX Phoenicis variables. Despite the great importance of BS in terms of evolutionary theory and cluster dynamics, the seismic study of pulsating BS is still in its infancy and waits to realize its enormous potential. This innovative project aims to fill this gap.

From seismic modelling of BS, we will derive their mass, age, metallicity, helium abundance and internal/surface rotation. The evolutionary models will be computed for single, binary and collisional stars. In particular, one can expect both differences in pulsational frequencies as well as in the pulsational excitation due to the change in chemical composition by mass transfer or collision. All the derived physical parameters can shed some light on the origin and formation history of BS. Moreover, because BS are among the most massive objects in clusters, the knowledge of their exact masses and ages is crucial for studying cluster dynamics. There are about 10 field SX Phe stars residing in the galactic halo and suitable for our studies. Some of them are in binaries. We will construct seismic models of them and compare the physical properties of the field and cluster oscillating BS.

We will mainly on BS pulsating radially in two modes. This is because the period ratio of these modes takes values in a very limited range. On the other hand, modern observations, especially from space (e.g., from the Kepler or TESS missions), give the accuracy in the period ratio down to the sixth decimal place.

In addition, we will try to find possible correlations between the pulsational and physical properties of blue stragglers and parameters of the host clusters. Also within a given cluster there may be some correlations between different physical parameters. For example, there is a relationship between age and metallicity in the globular cluster ω Centauri, which has a very complex stellar population.

Finally, using the asteroseismic values of luminosity we will construct the period-luminosity relation for pulsating BS. This relation is used to measure distances in the Universe.