Scientific objectives

The main goal of our project is to improve our understanding of properties, structure and life of Cepheid variable stars, which are important and probably the most widely used objects in astrophysics. The connection between the length of their pulsation cycle and brightness allow us for a precise distance determination in the Universe. In the past this method led to a breakthrough in our understanding of the structure and size of the Universe, showing that many nebulae are in fact distant galaxies.

Today Cepheids are still important, being a base in the best method to determine the Hubble constant through a so-called distance ladder. As we currently aim at 1%-precision in determining this constant, we have to not only use these stars as tools – we have to understand them. The aim of this project is to study the physical properties of the stars, such as their masses and sizes, as well as their origin and life. It is also evident now that most of Cepheids are born in multiple systems, but the multiplicity rate, the characteristics of their companions or the interactions between the stars in such systems are still poorly known. All of these may directly affect the observed brightness and other properties of Cepheids and have to be studied.

There are two distance determination techniques that are commonly used for Cepheids, the period-luminosity relation, and the Baade-Wesselink method. However, both have problems that limit their precision. For Cepheids in eclipsing binary systems another, more direct and geometrical method is available, which may be used to test and improve the first two methods.

Project description

The project is separated in three parts: the extended analysis of already confirmed eclipsing binary systems with Cepheids, the observations and analysis of candidates for such systems, and the study of a newly identified population of binary Cepheids composed of giant stars.

There are six already known Cepheids in eclipsing binary systems for which we know their masses and radii. Their configuration and brightness make them the best target for more complex analysis. Using new data (e.g. photometry taken from space) we will be able to recover detailed important properties of the structure and behavior of Cepheids. We will also determine distances to these systems using three different methods. A comparison of the results will serve to improve them, leading to better distance determinations to other objects in the Universe.

There are also eight more, unconfirmed eclipsing systems with Cepheids. We will use the already collected data and carry out new observations to first, confirm these cases, and second, to determine the physical properties of these stars, including the most important masses and radii. We will look into the history and future of all Cepheids found in binary systems, which will lead to better understanding of the origing and life of all Cepheid variables. For that reason we will also study a mysterious group of apparently over-luminous Cepheids that are most probably accompanied by giant stars. Observations of this group will also be used to characterize both Cepheids and their companions.

Apart from using archived data, we will have to collect many new astronomical observations, including images and spectra of our target objects. The observations will be performed using the best world-class telescopes in several observatories located in Chile.

Project impact

The results of our research will have a significant impact on many different areas of modern astrophysics, starting from testing and possible improvement of two mayor distance determination techniques, which will help in the precise calibration of the distance scale of the Universe. We will thoroughly describe the structure and life of Cepheids. We plan to quadruple the number of Cepheids with known masses and double the number of known radii. We will also determine their chemical composition and properties of their atmospheres. Such information is crucial for theoretical understanding of pulsations and evolution of these objects. We will also characterize the multiplicity and companions of Cepheids, which apart from affecting their life and structure, directly influences the observed brightness of these stars, adding additional uncertainty to the determined distances. Based on the results obtained in this project, multiple follow-up studies of different kinds will be possible.