Hunt for eclipsing binaries in the centers of Planetary Nebulae

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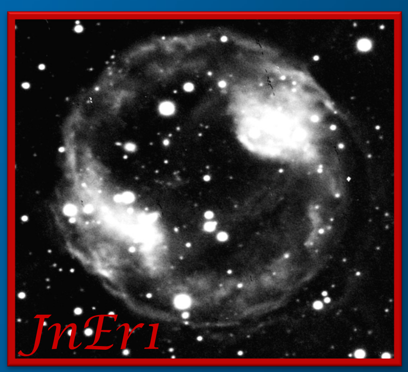
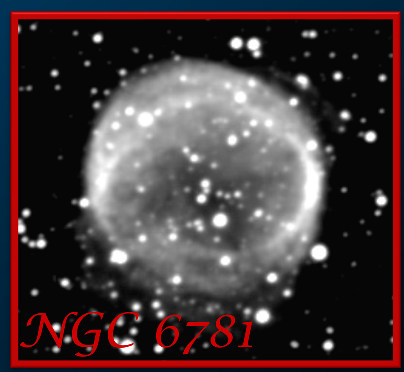
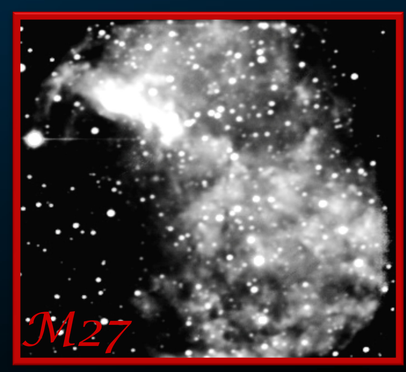
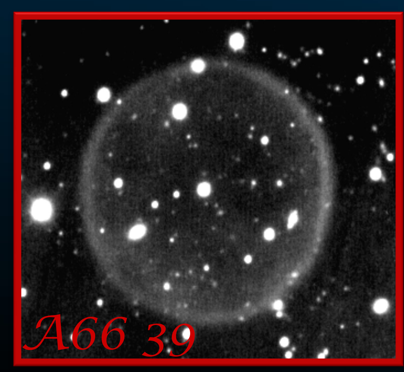
Abstract

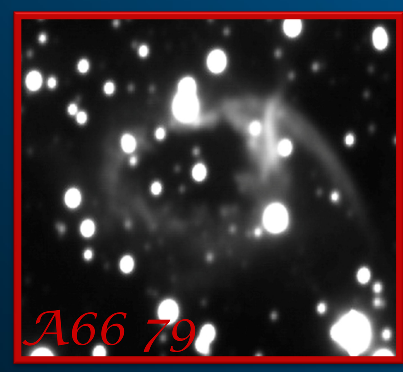
This work presents the long term and ongoing observational campaign for detection of eclipsing binary systems as central stars of Planetary Nebulae (PNe). From 2014 to date using the 2.3 m Aristarchos and the 1.2 m Kryoneri telescopes, systematic monitoring of more than 25 selected PNe has been conducted. Three of them have been revealed as very good candidates for hosting an eclipsing binary system as central star. The aim of this campaign concerns the discovery of as many as possible binary central stars in PNe, the identification of their stellar parameters, and, finally, the comparison of our results with the theoretical models of PNe regarding the connection of their central stars with the morphology of the surrounding PN. Through the complementation of this research, we anticipate to contribute substantially in clarifying the physical processes that determine the final stages of stellar evolution of low mass stars and the formation of PNe.

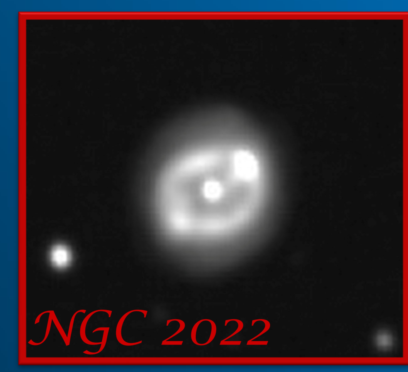


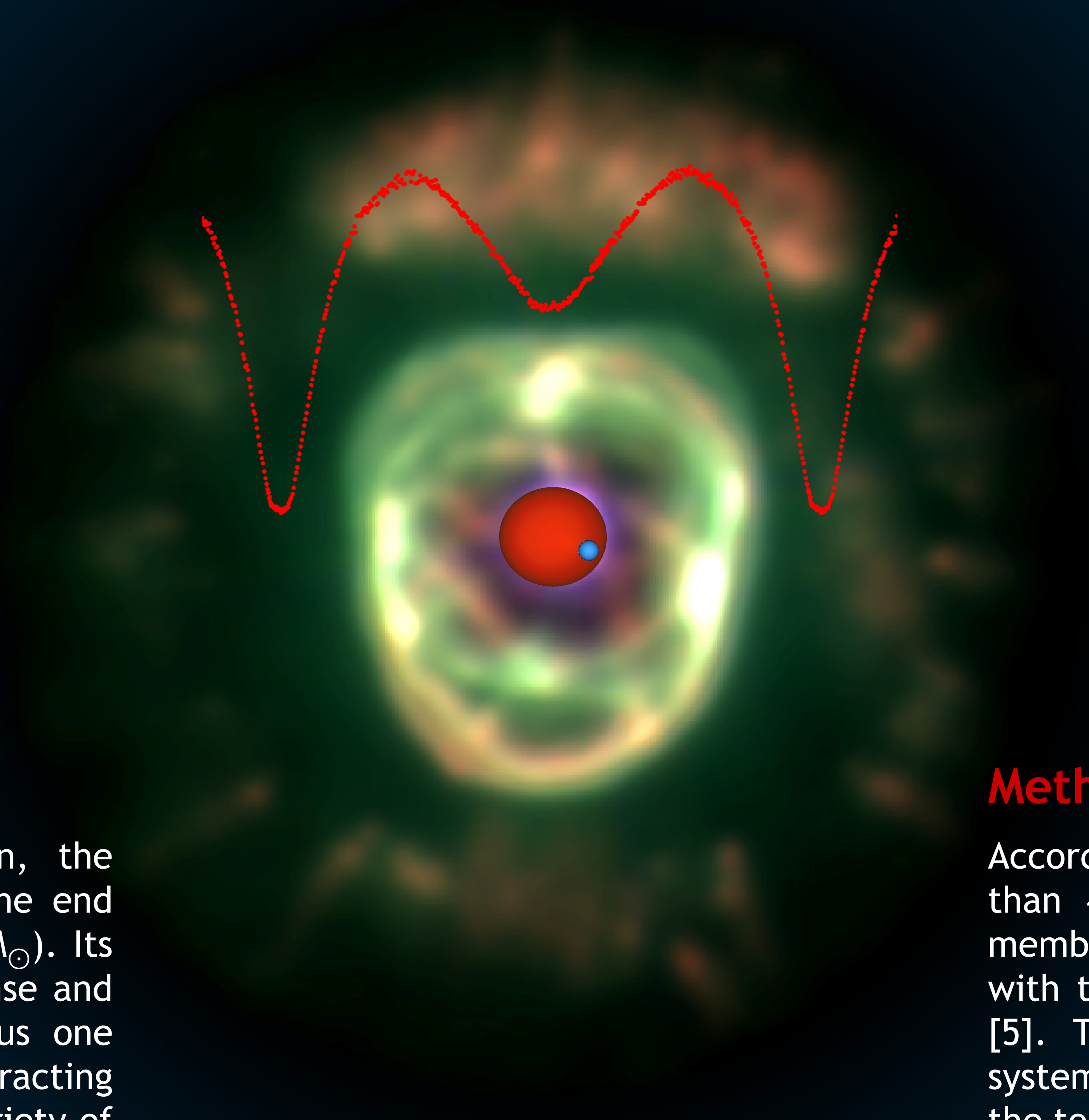












Scientific case

According to the theory of stellar evolution, the formation of a planetary nebula (PN) marks the end point of a low or intermediate mass star (1-8 $M_\odot$). Its formation is caused by the interaction of a dense and slow AGB stellar wind and a fast and tenuous one emerged during the early post-AGB phase (interacting stellar wind model; [1]). PNe display a great variety of shapes with the majority of them to be non-spherical but they reveal axis- and point- symmetries. Their morphology is attributed to the duplicity of the central star, where the mass outflows of the giant star carry the orbital angular momentum [2, 3]. Nevertheless, single star models have also been suggested claiming that the non-spherical shapes of the PNe are due to the stellar rotation and/or magnetic fields actions [4]. Whether the binary or the single star models can best explain the observed morphological zoo of PNe is still debatable. For this reason, the determination of the binary fraction of the central stars of PNe and the correlation of the binary properties with the morphology of the hosting PN is crucial.

Binarity as essential tool

Eclipsing binary systems (EBs) can be considered as the ultimate tools for the calculation of stellar absolute parameters. In particular, the light curves analysis derives the geometrical configuration, the inclination, the orbital period of the system, and so on. The spectroscopic analysis is used for the calculation of the radial velocities of both components, which produces the mass ratio of the system and ideally the temperatures of the components. The combination of these two observational methods provides the means for the calculation of the stellar parameters (masses, radii, luminosities) that are needed to check the current stellar evolutionary models.

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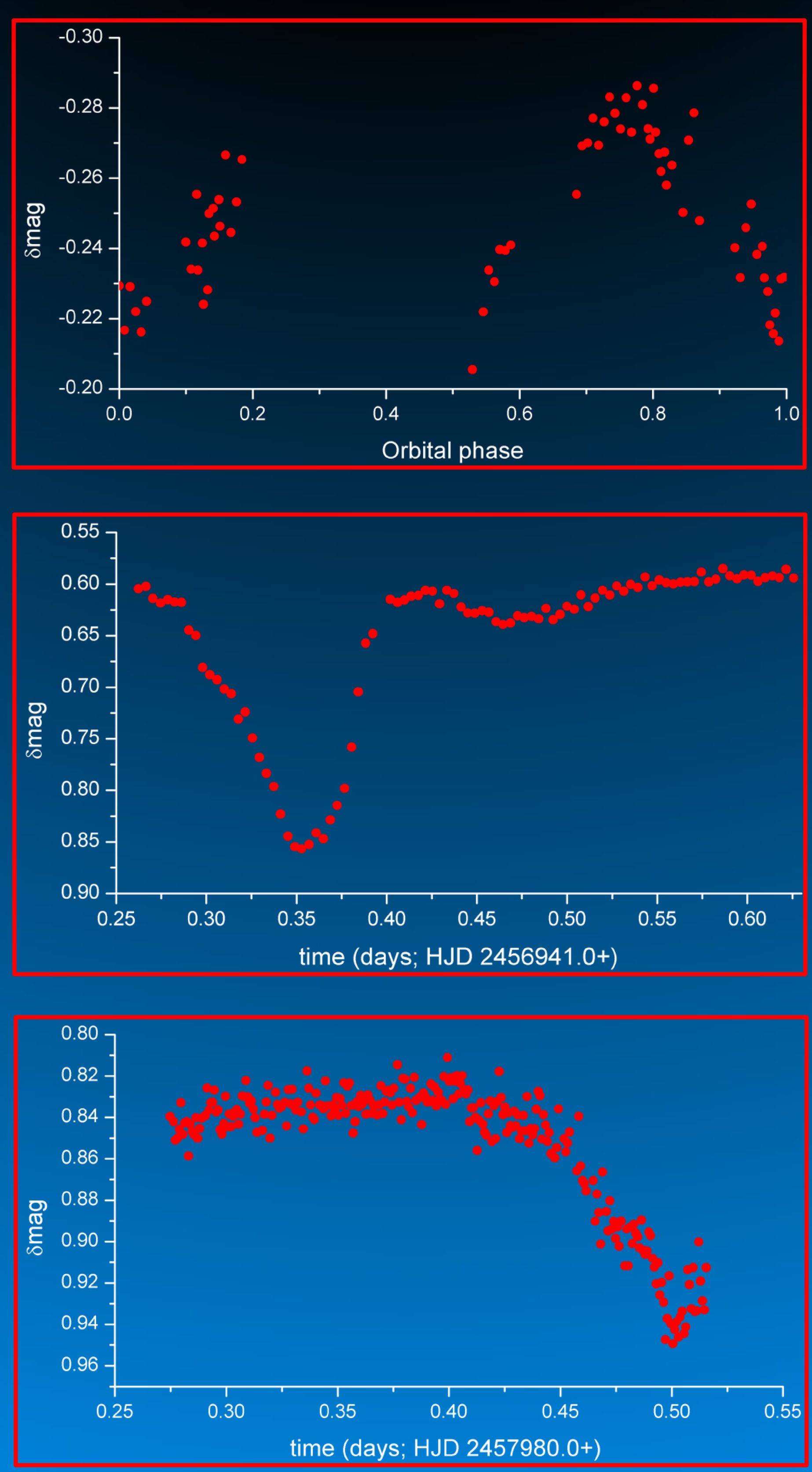

Figure 1. Examples of observations in central stars of PNe, which revealed as possible eclipsing binaries.

Methodology of the survey

According to past surveys [3, 5, 6], there are more than 40 known PNe whose their white dwarf is a member of a short-period binary system (P<3 days), with the average of the orbital periods to be ~12 hrs [5]. The number of PNe with close binary central system has been calculated to be around 10%-20% of the total population of PNe [3, 6].

Our survey aims to detect specifically EBs or ellipsoidal variables as central stars of PNe and through their photometric modeling to derive the absolute parameters of their components. The target selection for the survey is primarily based on the morphology of the hosting PN. PNe with non-spherical shapes are considered as very good candidates for hosting a binary system. The targets are chosen either from the lists of [5] (i.e. those showing infrared excess) or simply from the catalogues of PNe according to their morphology (e.g. bipolar, asymmetric). Then, the magnitude of the central star and its visibility inside the PN defines whether it can be observed either from Kryoneri (m_R<17 mag) or from Aristarchos (m_R<19 mag) telescopes. Each object is observed for many nights and hours in one or more photometric filters in order to check for possible light variations due to eclipses.

So far, 29 PNe have been observed during in more than 150 nights (~870 hrs). Three of these targets were found to present eclipse-like features (Fig. 1) revealing their possible binarity nature.

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