Planetary Nebulae: A Universal Toolbox in the Era of Precision Astrophysics
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An evolved planetary nebula physically associated with the open cluster M37

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Abstract. We have found strong evidence that an extended bipolar planetary nebula (PN), lying in the line-of-sight of the Galactic open cluster M37, is actually its physical member. We estimated both the PN physical properties and the properties of its progenitor from cluster studies. The progenitor mass has been found to be around 2.8 $M_{\odot}$. There are only a handful of such confirmed associations and each of them provides valuable additional data to the initial-to-final-mass relation. The nebula has a major axis of 445 arcsec and a kinematical age of around 80 kyrs -the largest ever determined for a PN- suggesting that PNe in clusters do not dissipate as fast as field PNe.

Keywords. stars: planetary nebulae, open star clusters

1. Introduction

PNe that are physical members of star clusters, have many of their properties (e.g. distance, environment, progenitor star's initial mass and age) determined independently from cluster Color-Magnitude Diagrams (CMDs) and theoretical isochrones. These rare instances allow the study of the link between initial stellar mass and PN's chemical enrichment. Moreover, they provide additional, independent data for the, currently poorly constrained, Initial-to-Final-Mass Relation (IFMR, e.g. Cummings et al. 2018), which relates the central star's (CS) mass to its progenitor mass and is crucial for stellar evolution studies.

Only three PNe have been confirmed to be physically associated with Galactic open star clusters (Parker et al. 2011; Fragkou et al. 2019a,b, 2022). Such confirmations require good agreement in terms of the angular proximity, distance, reddening and most importantly radial velocities of the PN and the cluster.

2. A bipolar PN physically associated with the open cluster M37

The PN IPHASX J055226.2+32372 lies in a very close angular proximity to the well-studied open cluster M37. Multiple of their, reported in the literature, Gaia DR3 and estimated parameters (see Table 1, Fragkou et al. 2022) suggest that the two objects are physically associated. Crucially, the precise PN radial velocity, estimated using high resolution spectral data from MEGARA/GTC, is in an excellent agreement to that of the cluster, confirming that the PN is a physical member of M37.

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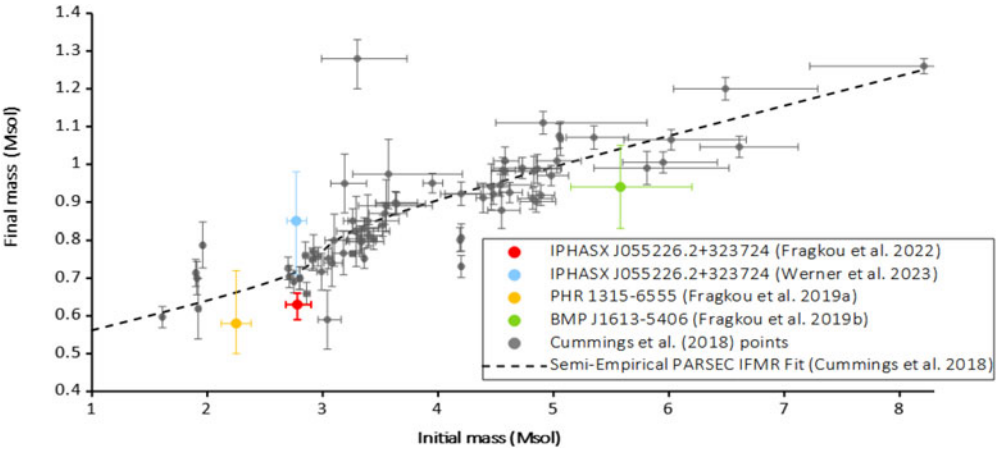


Figure 1. Our cluster PNe points plus the one estimated by Werner et al. (2023) over-plotted on the Cummings et al. (2018) white dwarf trend and points.

The nebular core is a hot hydrogen deficient PG1159 white dwarf (Griggio et al. 2022; Werner et al. 2023). The CS progenitor mass ($M = 2.78 \pm 0.12\,M_{\odot}$) has been estimated from theoretical predictions of the Padova theoretical isochrone that presents the best fit to the cluster Gaia DR3 CMD. Besides, the CS final mass ($M = 0.63 \pm 0.04\,M_{\odot}$) has been estimated from its V magnitude and nebular kinematical age using the latest evolutionary tracks (Miller Bertolami 2016). Recently, Werner et al. (2023) have estimated a higher final mass ($M = 0.85^{+0.13}_{-0.14}\,M_{\odot}$) from a detailed stellar spectral analysis.

A detailed study of this PN is currently underway. Deep long-slit GMOS/Gemini spectra, already partially acquired, will provide us with the necessary data to calculate the nebular abundances and precise nebular properties.

3. PNe in open clusters

All open cluster PNe confirmed so far are bipolar with enhanced nitrogen and relatively high-mass progenitors. Their estimated initial and final masses have been over-plotted along the latest IFMR estimates (see Figure 1). The cluster PNe represent generally well the previous trends Cummings et al. (2018) estimated from cluster white dwarfs and fill important gaps. The PN in NGC 6067 has the largest PN progenitor mass ($\simeq 5.6\,M_{\odot}$) ever determined. In the case of the PN in M37 its kinematical age was found to be 78 kyrs (or even larger according to Werner et al. 2023) - the largest ever determined for a PN. This suggests that PNe in clusters have a larger observable life time than field PNe, since they do not dissipate as fast due to the low velocity dispersion between cluster stars and the surrounding interstellar medium. In general the extreme characteristics of PNe in open clusters provide unique PN properties that deserve further studies.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1743921323005069

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