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PLANETARY NEBULAE: GETTING CLOSER TO AN UNBIASED BINARY FRACTION

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Abstract. Why 80% of planetary nebulae are not spherical is not yet understood. The *Binary Hypothesis* states that a companion to the progenitor of the central star of a planetary nebula is required to shape the nebula and even for a planetary nebula to be formed at all. A way to test this hypothesis is to estimate the binary fraction of central stars of planetary nebula and to compare it with the main sequence population. Preliminary results from photometric variability and infrared excess techniques indicate that the binary fraction of central stars of planetary nebulae is higher than that of the putative main sequence progenitor population, implying that PNe could be preferentially formed via a binary channel. This article briefly reviews these results and future studies aiming to refine the binary fraction.

Keywords: ISM: planetary nebulae: general, Stars: binaries: general, Stars: evolution, Infrared: stars

1 Introduction

Planetary nebulae (PNe) are presumed to be ejected by all $\simeq$ 1-8 $M_\odot$ stars, however when the observed PN population is compared with the theoretically expected population, a discrepancy in the number of objects appears: there are less PNe in the Galaxy than there should be (Moe & De Marco 2006). This could imply that only a subset of the parent population is actually forming PNe. This subset could be the binary progenitors (Moe & De Marco 2012). Indeed, more than 80% of PNe are non-spherical (Parker et al. 2006; Jacoby et al. 2010), showing structures such as lobes and jets that give an axisymmetric, point-symmetric or asymmetric shape to the nebula. The hypothesis traditionally used to account for these shapes has been the action of a magnetic field of the AGB star during the super wind phase upon the gas being ejected. However, this hypothesis has been disputed by Soker (2006) and Nordhaus et al. (2007), who showed that the magnetic field cannot be sustained for long enough on a whole-star scale due to the coupling between the magnetic field and the stellar rotation. Another hypothesis to account for the non-spherical shapes of PNe is the presence of a companion (e.g. Soker 1997). The hypothesis according to which a companion is required to shape an axisymmetric PN has been dubbed the *Binary Hypothesis* (De Marco 2009). To test it, it is necessary to estimate the binary fraction of central stars of planetary nebulae (CSPNe). If the observed binary fraction of CSPNe population is superior to that of the putative parent population (the main sequence (MS) stars with mass $\simeq$ 1-8 $M_\odot$, Moe & De Marco 2006), this indicates that PNe are preferentially a binary phenomenon (see De Marco (2009) for a detailed review). This paper describes briefly current efforts aimed at estimating an unbiased binary fraction of CSPN.

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2 The binary fraction obtained using photometric variability

Photometric variability of a binary CSPN can be due to an irradiation effect from the hot CSPN onto the companion, tidal deformations and eclipses (Bond 2000; Miszalski et al. 2009). The advantage of detecting bniaries using photometric variability is that it simply requires repeated observations of targets in average observing weather conditions and from the ground. For this reason, it is a reliable method and provides constantly new results (e.g. Hillwig et al. 2010). The main drawback of this method is that it is biased to small separations as irradiation effect, tidal deformations and eclipses all increase in intensity or frequency with decreasing separations, therefore it only gives access to the short period binary fraction.
Bond (2000) and Miszalski et al. (2009) already estimated close binary fractions (P $\lesssim$ 3 days) of CSPNe of 10-15% and 12-21% respectively. Although these fractions are lower limits, comparing them with the MS stars binary fraction at appropriately small separations i.e. 5-7% (Duquennoy & Mayor 1991; Raghavan et al. 2010; De Marco et al. 2012 reveals that more PNe are formed around binaries.

Hillwig et al. (these proceedings) are monitoring targets from the 2.5 kpc volume-limited sample of Frew (2008) to estimate a new close binary fraction. Although the method is similar, the sample is less biased than the previously used magnitude-limited samples and also deeper (V $<$ 21). In a similar experiment, Jacoby et al. (2012) are monitoring 5-6 CSPNe within the Kepler satellite field of view, to estimate an independent binary fraction. The sample is statistically small ; however, the CSPNe are observed with a precision never reached before ($\lesssim$ 1 mmag).

3 The binary fraction obtained using red and infrared excess

The red/IR excess technique aims to detect the signature of a cool, unresolved companion by measuring the absolute photometry of the CSPN. To do so, high precision absolute photometry needing photometric weather conditions in the B, V and I or J bands is required. This technique is fully described in De Marco et al. (2012). The measured $B-V$ color is compared to the expected $B-V$ for the single CSPN temperature according to atmospheric stellar models (e.g. Rauch & Deetjen 2003) and allows reddening to be determined whereas the $V-I$ or $V-J$ color allows the measurement of the red/IR excess, which is the difference between the $V-I$ or $V-J$ expected for a single star at the CSPN temperature and the measured one. If this difference is greater than the error on the photometric measurement, it is a binary detection. Since companions cooler than $\simeq$ M0-5 are faint, we need excellent photometric precision. Once a binary fraction has been estimated, it can be compared to the MS one (Raghavan et al. 2010) only after undetected systems are accounted for. Using the J-band allows to detect colder companions, while still not being contaminated by hot dust, although it requires a separate NIR observing run and is therefore time demanding.
Frew & Parker (2007) have used the photometry from the 2MASS and DENIS NIR surveys to determine a binary fraction ¿ 54% but the detection bias was poorly quantified. De Marco et al. (2012) have used the method described above on a sample of 27 CSPNe and have found a debiased fraction ¿ 30% from I-band data and of ¿ 54% from J-band data of a subset of 11 CSPNe in line with Frew & Parker (2007) J-band results. These preliminary results will be confronted by the study of an additional 23 objects for which optical absolute photometry has been acquired at the NOAO 2.1m telescope in March 2011 as well as $\simeq$ 30 objects for which J and H-band photometry has been obtained at the AAT 4m telescope in 2011 and the ANU 2.3m telescope in 2012. These new measurements should bring the sample to a statistically significant size and considerably reduce the error bars on the binary fraction. Recent surveys including J-band photometry will be analysed as well to extract the IR excess of other targets from the sample of Frew (2008).

4 Conclusion

Estimating an unbiased binary fraction of CSPNe is crucial to understanding whether companions play a key role in shaping PNe. Photometric variability has allowed us to determine a close binary fraction of 15-20% and is still being refined using a new, less biased sample to understand the biases inherent to the method. The red/IR excess technique has allowed us to obtain a CSPN binary fraction of 70-100%, much larger than for the MS population. However, this number carries a large uncertainty for the moment due to the small sample size. Current studies based on optical and NIR photometry as well as the use of recent NIR surveys will double the sample size to constrain the CSPN binary fraction precisely enough to support or refute the hypothesis that PNe could emerge preferentially from binary star evolution.

References

Bond, H. E. 2000, in Astronomical Society of the Pacific Conference Series, Vol. 199, Asymmetrical Planetary Nebulae II: From Origins to Microstructures, ed. J. H. Kastner, N. Soker, & S. Rappaport, 115

De Marco, O. 2009, PASP, 121, 316

De Marco, O., Passy, J.-C., Frew, D. J., Moe, M. M., & Jacoby, G. H. 2012, MNRAS

Duquennoy, A. & Mayor, M. 1991, A&A, 248, 485

Frew, D. J. 2008, PhD thesis, Department of Physics, Macquarie University, NSW 2109, Australia

Frew, D. J. & Parker, Q. A. 2007, in Asymmetric Planetary Nebulae 4 conference, APN IV Conference Proceedings, 475

Hillwig, T. C., Bond, H. E., Afşar, M., & De Marco. 2010, AJ, 140, 319

Jacoby, G., De Marco, O., Howell, S., & Kronberger, M. 2012, in American Astronomical Society Meeting Abstracts, Vol. 219, American Astronomical Society Meeting Abstracts #219

Jacoby, G. H., Kronberger, M., Patchick, D., et al. 2010, PASA, 27, 156

Miszalski, B., Acker, A., Moffat, A. F. J., Parker, Q. A., & Udalski, A. 2009, AA, 496, 813

Moe, M. & De Marco, O. 2006, ApJ, 650, 916

Moe, M. & De Marco, O. 2012, in IAU Symposium, Vol. 283, IAU Symposium, 111–114

Nordhaus, J., Blackman, E. G., & Frank, A. 2007, MNRAS, 376, 599

Parker, Q. A., Acker, A., Frew, D. J., et al. 2006, MNRAS, 373, 79

Raghavan, D., McAlister, H. A., Henry, T. J., et al. 2010, ApJS, 190, 1

Rauch, T. & Deetjen, J. L. 2003, in Astronomical Society of the Pacific Conference Series, Vol. 288, Stellar Atmosphere Modeling, ed. I. Hubeny, D. Mihalas, & K. Werner, 103

Soker, N. 1997, ApJS, 112, 487

Soker, N. 2006, ApJl, 645, L57