Symbiotic or planetary nebulae?

Miguel Santander-García[1,2], Romano L.M. Corradi[1,2], and Antonio Mampaso[2]

[1] Isaac Newton Group of Telescopes, Ap. de Correos 321, 38700 Sta. Cruz de la Palma, Spain
msantander@ing.iac.es; corradi@ing.iac.es

[2] Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain
miguelsg@iac.es; rcorradi@iac.es, amr@iac.es

Summary. The link between planetary nebulae and symbiotic stars has been widely discussed in the past. In particular, there are some remarkable objects, often classified as PNe, which are suspected to host a symbiotic nucleus (e.g. M2-9 and Mz 3). In this work, the similarities and differences between planetary and symbiotic nebulae are reviewed. Special emphasis is put on recent results about several basic observational properties of several of these nebulae (like their ionized mass or their photometric variability), which show the difficulties of setting a clear observational distinction between the two classes of objects.

Key words: symbiotic stars: Hen 2–104, Hen 2-147 – planetary nebulae: Mz 3, M2–9 – interstellar medium: dynamics

1 Introduction

Although similar in many aspects, nebulae around symbiotic stars and planetary nebulae (PNe) are truly different objects. In principle, the Mira in a D-type symbiotic star would eventually expose its core and ionize its own envelope, leading to the formation of a genuine PN. However, the presence of an accreting companion somewhat "anticipate" the event by ionizing and shaping the Mira's wind: the study of these "premature" PNe allows us to investigate the mass loss history and geometry at different stages of the AGB for interacting binaries. Hence the importance of telling symbiotic from planetary nebulae apart and separately studying the physical processes at work.

Unfortunately, this is not an easy task. Some objects currently classified as planetary or protoplanetary nebulae show some indications that they might instead possess a symbiotic core. Supporting these evidences are their high density nebular cores and their Hα line profiles with broad wings, similar to those of symbiotic systems [29]. Also, their location in NIR colour-colour diagrams ([23] and [17]) lie far away from those of PNe and close to the region occupied by symbiotic stars. As neither of the aforementioned papers include measurements of proto-planetary nebulae (PPNe), we have analysed a sample of PPNe from Kelly et al. [12] and Bujarrabal et al. [3]. We computed the dereddened DENIS $(I-J)_0$ and $(J-K)_0$ colour indices for every PPN whose extinction is available in the literature. These values, together with those for symbiotic stars, suspected symbiotic Miras and a large sample of PNe, are shown in the NIR colour-colour diagram of Fig. 1. Note that the suspected symbiotic Miras are scattered along the broad boundaries between PNe/PPNe and genuine symbiotic stars, but seem closer to the latter.

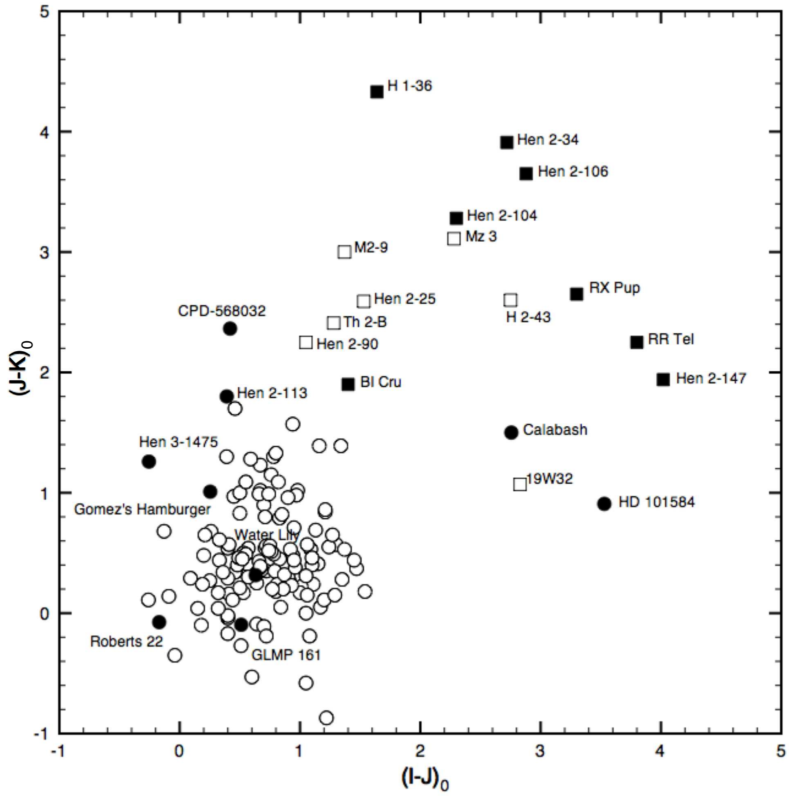

Fig. 1. Dereddened J-K *vs.* I-J colours of a sample of central stars of PNe (white circles), PPNe (black circles), symbiotic stars (black squares), and suspected symbiotic Miras (white squares).

Separating PNe from symbiotics based on morphological or kinematical characteristics is also not possible, since most of the dozen known, optically resolved, symbiotic nebulae [6] show bipolar morphologies and expansion patterns, similar to many PNe and PPNe (e.g. [5, 19]). Examples are R Aqr (e.g. [28, 16]) and BI Cru ([24, 4]).

In the following, we will discuss two observational properties commonly used to distinguish between symbiotic and planetary nebulae: the measurement of the ionized mass and the detection of a cool giant in the system.

2 Ionized Mass

Nebulae around symbiotic Miras are believed to be shaped as a result of winds interaction in the binary system [4], [15]. A small, ~1% fraction of the mass lost from the Mira is accreted by the white dwarf (WD), eventually producing a thermonuclear outburst on its surface. The fast winds generated in this event collide with the surrounding, much slower winds from the Mira and shape the nebula, which is in turn ionized by photons from the WD. The resulting nebula is believed to encompass ionized masses of 10^{-4}–10^{-2} $M_{\odot}$ [4].

These values are significantly lower than those of typical PNe, which range from 0.1 to 1 $M_{\odot}$ [18], indicating that, in principle, a reliable measure of the ionized mass can be used to distinguish symbiotic nebulae from planetary nebulae.

However, this is not the rule. Let's take the example of the symbiotic star He 2–104, the Southern Crab. [4] derived a rough ionized mass of 0.02 $M_{\odot}$ for its nebula, but their estimation was based on a distance of 800 pc. A more reliable distance of 3.3±0.7 kpc, obtained by measuring the expansion parallax of the nebula [22], increases the ionized mass to ~0.1 $M_{\odot}$, a value typical of a respectable PN. One can always claim that Hen 2–104 is an extreme case, unrepresentative of the majority of symbiotic nebulae, but it is enough to invalidate the use of the ionized mass as a clear discriminant between symbiotic nebulae and PNe.

3 Looking for the Mira

The only unequivocal way to demonstrate that a high excitation nebula hosts a symbiotic core is to find direct evidence of the red giant at its centre. This can be very difficult. At optical wavelengths, in fact, the Mira emission is often overwhelmed by emission from a dense circumstellar nebular core, the hot companion, or is severely absorbed by circumstellar dust. The NIR domain, where the Mira has its peak emission, seems a more appropriate region where to look for signatures of the red giant. There the Mira can be detected by either photometric monitoring or spectroscopy. Photometry aims at detecting the periodic pulsation of Mira stars, which have timescales of several hundreds of days (e.g. Hen 2–104, [1] and [30]; Hen 2–147, [21]).

In addition, absorption bands from the Mira should be visible in NIR spectra. This is the case, for example, of Hen 2–147, where the Mira dominates the NIR spectrum, showing multiple deep absorption bands (see Fig. 2). However, in other cases, like He 2-104, the NIR spectrum is almost featureless and seems dominated by warm dust emission. In Hen 2–104 only three weak CO bands from the Mira photosphere are visible (see Fig. 3 or, for a more detailed analysis, [22]).

3.1 Two special symbiotic candidates

This section focuses on the search for the Mira in two nebulae which have been suspected since long ago to host a symbiotic nucleus.

Mz 3. This remarkable nebula shows four distinct outflows with different degree of collimation [10], [20]. The shaping mechanism of such a complex, multiple structure, defies the standard interacting stellar wind (ISW) model [13] and its posterior

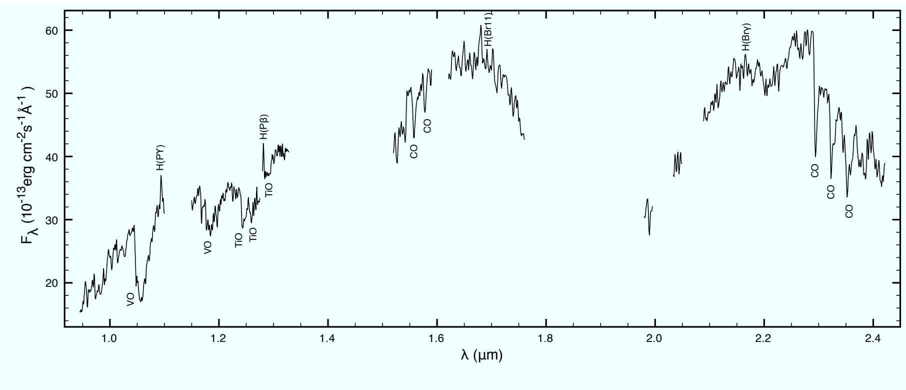

Fig. 2. NTT+SOFI NIR spectrum of the core of Hen 2–147. Regions were telluric absorption bands severely degraded the spectrum have been removed.

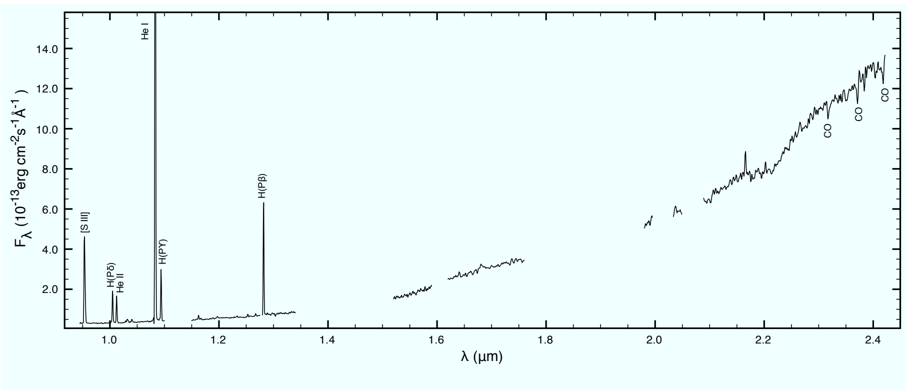

Fig. 3. NTT+SOFI NIR spectrum of the core of Hen 2–104. Regions were telluric absorption bands severely degraded the spectrum have been removed. Despite being a genuine symbiotic Mira, the spectrum is dust dominated, and the only visible signatures from the cool giant are three very weak CO bands.

generalizations (GISW). As a matter of fact, current HD or MHD models can only reproduce similar nebulae when invoking critical rotators, strong magnetic winds, or binary interaction (e.g. [8] and [9]). There are other hints that might support a symbiotic nature of Mz 3: its high density nebular core [26] and its spectrum, as well as its near-IR colours (although not far away from those of PPNe, see Fig. 1) are typical of symbiotic Miras.

However, there is currently no direct evidence of a Mira in Mz 3: its almost featureless NIR continuum spectrum shows no absorption bands characteristic of a cool giant [27], and there is only a small, 0.15 mag amplitude variation in the K band out of 6 records (Whitelock, private communication), certainly not enough to determine whether it is a symbiotic Mira or not.

M2–9. In addition to a multiple outflow structure [25], a high density core with double-peak, broad Hα profiles [2] and NIR colours (see Fig. 1) unusual for PNe, the butterfly nebula shows a unique characteristic: several bright features which move laterally, apparently inscribed in the walls of its inner lobes and rotating around the symmetry axis of the nebula. Current explanations for this light house effect involve a polar jet from a hot star being bent by density gradients in the circumstellar gas distribution as a consequence of strong mass loss from a cool companion [14], [7]. The light-house period of rotation was found to be of $\sim$100 years, compatible with the orbital periods of symbiotic Miras. The spectrum of the dense nebular core is also similar to those of some symbiotic stars.

Nevertheless, it must be stressed that this does not constitute enough proof that M2-9 is a symbiotic Mira. As a matter of fact, all attempts to detect a cool giant in M2-9 have failed so far: again, its NIR spectrum show no bands from a cool giant [11], and there is no NIR photometric variability in the K band, out of 4 records (Whitelock, private communication).

4 Summary and Conclusions

The importance of correctly classifying and studying planetary nebulae and symbiotic nebulae is obvious, given their different nature and physical processes which take places at their cores. However, in practice this is not an easy task. Despite the hints that might point towards a symbiotic origin, the direct detection of the Mira in a system is the only current way of proving its nature.

Such a detection is sometimes very difficult: NIR photometric monitoring needs several years to produce robust results, and the NIR spectra do not always reveal the signature of the cool giant, which might be hidden by strong emission from the dust envelope that surrounds some D-type symbiotics.

In the case of two of the most studied nebulae, Mz 3 and M 2–9, there is currently no direct evidence that any of them are in fact symbiotic Miras. Nevertheless, it would help to gather more NIR photometric data of these nebulae, in the hope that long-term monitoring could either rule out or confirm their symbiotic nature.

References

1. Allen, D. A., 1982, in "The Nature of Symbiotic Stars", IAU Coll. 70, eds. M. Friedjung, R. Viotti, Reidel, Dordrecht, p. 27
2. Balick, B., 1989, AJ, 97, 476
3. Bujarrabal, V., Castro-Carrizo, A., Alcolea, J., & S'anchez-Contreras, C., 2001, A&A, 377, 868
4. Corradi, R.L.M., & Schwarz, H., 1993, A&A, 268, 714
5. Corradi, R.L.M., & Schwarz, H., 1995, A&A, 293, 871
6. Corradi, R.L.M., 2003, in 'Symbiotic stars probing stellar evolution', Corradi R.L.M., Mikolajewska J. & Mahoney T.J. eds., ASP Conf. Ser., Vol. 303, p. 393
7. Doyle, S., Balick, B., Corradi, R. L. M., Schwarz, H. E., 2000, AJ, 119, 1339
8. García-Segura, G., Langer, N., Rózyczka, M., & Franco, J., 1999, ApJ, 517, 767
9. García-Segura, G., & López, J. A., 2000, ApJ, 544,336

10. Guerrero, M. A., Miranda, L. F., & Chu, Y.-H., 2004, AJ, 128, 1694
11. Hora, J. L., Latter, W. B., & Deutsch, L. K., 1999, ApJS 124, 195
12. Kelly, D. M. & Hrivnak, B. J., 2005, AJ, 629, 1040
13. Kwok, S., Purton, C. R., & Fitzgerald P. M., 1978, ApJ, 501, L11
14. Livio, M., Soker, N., 2001, AJ, 552, 685
    Mikolajewska J. & Mahoney T.J. eds., ASP Conf. Ser., Vol. 303, p. 9
15. Morris, M., 1987, P. A. S. P., 101, 966
16. Paresce, F., & Hack, W., 1994, A&A, 287, 154
17. Phillips, J. P., 2007, MNRAS, 376, 1120
18. Pottasch, S. R., 1984, 'A study of Late Stages of Stellar Evolution', Astrophysics and Space Science Library, Volume 107
19. Sahai, R., 2002, RMxAC, 13 ,133
20. Santander-García, M., Corradi, R. L. M., Balick, B., & Mampaso, A., 2004, A&A, 426, 185
21. Santander-García, M., Corradi, R. L. M., Whitelock, P. A., Munari, U., Mampaso, A., Marang, F., Boffi, F., & Livio, M., 2007, A&A, 465, 481
22. Santander–García, M., Corradi, R. L. M., Mampaso, A., Morisset, C., Munari, U., Schirmer, M., Livio, M., & Balick, B., 2008, A&A in press
23. Schmeja, S., & Kimeswenger, S., 2001, A& A, 377, L18
24. Schwarz, H. E., Aspin, C., Lutz, J.H., 1989, ApJ 344, L29
25. Schwarz, H. E., Aspin, C., Corradi, R. L. M., &Reipurth, B., 1997, A&A, 319, 267
26. Smith, N., 2003, MNRAS, 342, 383
27. Smith, N., 2005, MNRAS 342, 383
28. Solf, J., & Ulrich, H., 1985, A&A, 148, 274
29. Van Winckel, H., Duerbeck, H. W. & Schwarz, H. E., 1993, A&AS, 102, 401
30. Whitelock, P. A., 1987, PASP, 99, 573