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Point-Symmetry types in Planetary Nebulae

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Abstract. Point-Symmetric Planetary Nebulae (PSPNe) are an important part in morphological classification as they exhibit features (e.g. collimated jets, knots) that can directly be associated to physical processes such as precession, binarity or magnetic action. This connection seems more obvious than when it comes to bipolar Planetary Nebulae (PNe) for example, and PsPNe have often been referred to as a proper class. Also, we present a cross-analysis of a group of PsPNe as well as a more detailed physical and kinematical analysis of three point-symmetric Planetary Nebulae displaying what we consider to be different type of point-symmetry. The combination of the high resolution spectroscopy with the morpho-kinematical tool *Shape* is giving new insights in the understanding of those complex structures.

1. Introduction

Point-symmetric PNe are characterized by an S-shaped structure with the central star being the point of reflection and collimated outflows apparently tracing successive mass-loss events (e.g. PC 19, IC 4634). The variation in position angles and radial velocities of the symmetric pairs of outflows/jets is likely to be the sign of the occurrence of precession (Guerrero 2000). Another important aspect is the absence of waist which makes the difference with bipolar PNe. The origin of PsPNe is generally linked to the presence of a wobbling accretion disk inducing episodic precessing jets (Livio & Pringle 1997) or the action of magnetic fields through magnetic collimation around a precessing star (Garcia-Segura 1997). In both cases binarity would play a role as the precessing accretion disk would arise from the orbital movement in the (close) binary system (Soker & Rappaport 2000) and the mass-loss variation would then be due to tidal forces. In the case of magnetic action, by spinning up the primary's envelope, the secondary causes a dynamo effect inducing the jets (Nordhaus & Blackman 2006).The systematic analysis of such complex structures is therefore the key to the understanding of the processes responsible for their morphology.

2. PSPNe as a morphological class?

The well defined shapes and patterns exhibited by PSPNe have granted them the denomination of morphological class alongside round, elliptical and bipolar PNe (Schwarz 1993). However, we studied a sample of 23 PsPNe specifically answering the description mentioned above and we did not find any particular trend in their location above the plane that would be related to a common progenitor mass (as it has been proven for the other morphological classes (Corradi & Schwarz 1995)). Indeed PSPNe are spread at various galactic heights from $|z| \simeq 25$ pc to $|z| \simeq 600$ pc. The analysis of the radial velocity range (from 2 to 161 km s^{-1}) and as well as the expansion velocity range (with a mean value of 29 km s^{-1}) do not reveal any particular tendency. Moreover, point symmetry (via the presence of point-symmetric micro-structures) is found in diverse asymmetrical PNe (e.g. KjPn8, He 3-1475). Therefore, and in agreement with Guerrero et al. (1999), PSPNe cannot be established as a proper class based on these grounds alone.

3. Morpho-kinematical analysis

In order to understand the dynamics of point-symmetric PNe we performed high resolution spectroscopic analysis with the echelle spectrometer MEZCAL mounted on the 2.1m telescope of the Observatorio Astronómico Nacional at San Pedro Mártir (Baja California, Mexico). We present 3 PNe showing different aspects of point-symmetry: NGC 7354, NGC 6309 and Pe 1-17. The data obtained were subsequently modeled with the morpho-kinematical software *Shape* (Steffen & López (2006), Steffen et al. (2010)) which aims at the *reconstruction* of the PNe' 3D morphology.

3.1. NGC 7354

This PN is composed of a set of axisymmetric structures at different position angles and only the jets can be qualified as point symmetric. Contreras et al. (2010) gave a detailed description of this planetary nebula and discussed the kinematical characteristics of the four main structures defining the PN (Fig 1): an outer shell expanding at 45 km s^{-1} (deprojected radial velocity), an elliptical inner shell expanding at 35 km s^{-1}, a set of equatorial bright knots with velocities between 25 and 44 km s^{-1} and a pair of jets with an expanding velocity of 60 km s^{-1}, each one.

There is so far no evidence for the presence of a stellar companion in NGC 7354 but a possible scenario, according to the authors, would involve a binary system in common-envelope phase and the presence of a precessing accretion disk.

3.2. NGC 6309

NGC 6309 shows two point-symmetric arms composed of four pairs of symmetric knots around a bright elliptical structure which is in fact a torus expanding at $V_{exp} \simeq 25$ km s^{-1} (Vázquez et al. 2008). From the modeling it appears that a simple bipolar system cannot reproduce the observed structure and the best fit is found using a quadrupolar model as we have two lobes at two different position angles (Fig.2). The PN could be the result of the interaction of precessing jets (issued from high velocity bipolar collimated outflows ejected during the proto-PN phase) with the interstellar medium.

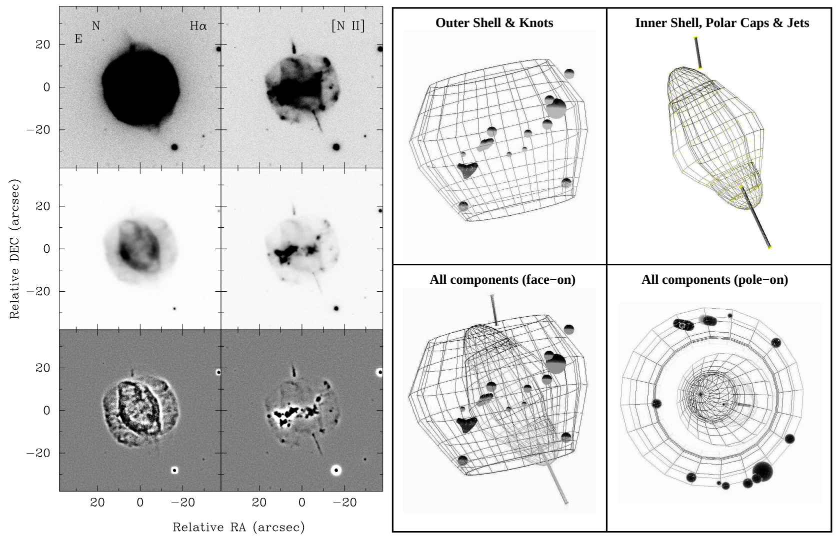

Figure 1. Left panel: Hα and [NII]6584 narrow-band images of NGC 7354 (from the Nordic Optical Telescope, NOT) displayed with different contrast levels and unsharped masking (lower row) to highlight the different structures. Right panel: Results of the Shape reconstruction.

In the long run the bow shocks/knots merged into a single shock front structure forming the non-homogeneous bipolar lobes which are symmetric respective to the central star.

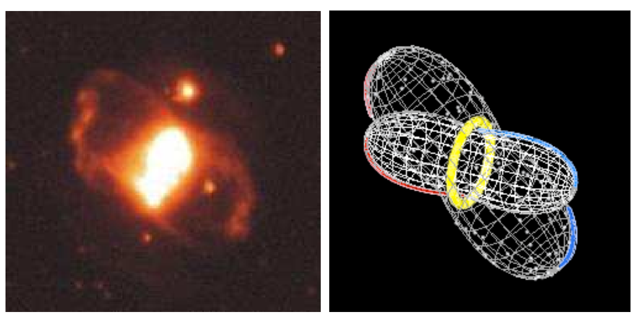

Figure 2. The bipolar lobes in NGC 6309 (left panel) are in fact the result several precessing collimated outflows from a quadrupolar system (right panel).

3.3. Pe1-17

This PN is considered as a very unusual and complex case of point-symmetry (Guerrero et al. 1999), indeed there is no visible central star and each opposite pairs of knots indicates a different geometric center. Our recent high resolution spectroscopic observations suggest that Pe1-17 may possess a ring related to its two brightest central structures and the analysis of [OIII] images shows an outer bipolar structure (Fig.3). A full scenario explaining such a structure is still missing nevertheless one should also consider that Pe1-17 may not be a PsPN but a bipolar PN experiencing anisotropic outflows.

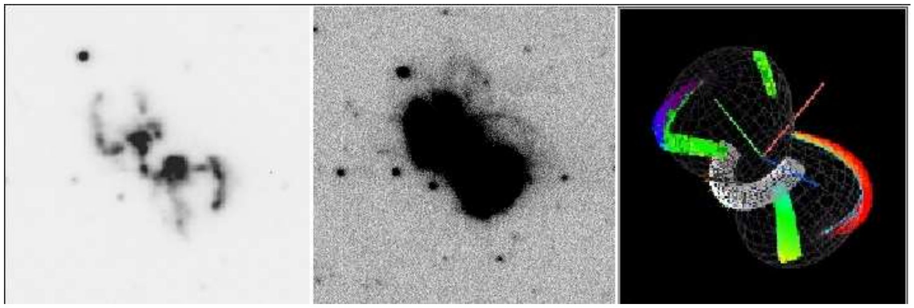

Figure 3. Left and middle panels: Pe1-17 in [NII] and [OIII] emission respectively (NOT images). The high contrast in the [NII] image underlines the knotty morphology of the nebula and the bipolar outer structure is shown in [OIII]. Right panel: Preliminary Shape model with the new ring structure.

4. Conclusion

We presented different types of point-symmetry in three planetary nebulae which are likely to be linked to physical parameters such as binarity and precession. The degree of implication of the latters is however still not clear. Although PSPNe do not seem to form a main morphological class, the analysis of their kinematics and the use of 3D modeling to determine the exact morphology of those objects is one of the keys to constrain the exact role of each physical parameter and (maybe) derive a common ground for PSPNe formation.

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