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THE NATURE OF LOW-IONIZATION MICROSTRUCTURES IN PNe

Denise R. Gonçalves,[1] Antonio Mampaso,[1] and Romano L. M. Corradi[2]

We discuss here the nature of a rich zoo of knots, filaments, jets and jet-like systems, located—in terms of morphology and kinematics—either inside or outside the main nebular bodies of planetary nebulae (PNe). These features are low-ionization structures (LISs) especially prominent in [N II] and other low-ionization line emission, which are usually smaller than the main morphological components of the PNe (spherical and elliptical shells, bipolar lobes, and haloes). We have recently shown that LISs are equally spread amongst all morphological classes of PNe (Gonçalves, Corradi, & Mampaso 2001).

In order to understand the nature of LISs in PNe, one deals mainly with the following key questions: (i) Are magnetic fields—either in single or binary stars—necessary for producing jets in PNe? (ii) Which processes can produce multiple systems of highly collimated outflows that sometimes expand in directions almost perpendicular to each other? (iii) How do low-velocity collimated LISs form? (iv) Are symmetrical pairs of knots the result of recent ejecta from the central stars, or are they fossil condensations tracing a peculiar mass-loss geometry during the AGB phase? (v) Are non-symmetrical LISs formed by in situ instabilities? In what follows we briefly summarize our answers to these questions, obtained from a detailed comparison between the morphology and kinematics of LISs and the model predictions (Gonçalves et al. 2001).

Jets: Radially directed, two-sided collimated features moving with velocities substantially larger than those of the main shells. A few *low-ionization* jets (NGC 7009, NGC 6891 and NGC 3918) could be formed by HD and MHD interacting stellar winds. Others (K 4-47, M 1-16, and Fg 1) are better understood via collimation processes due to accretion disks. However, those jets that are younger than the main shells (Hb 4, NGC 6210, and NGC 6884) cannot be accounted for by the above processes.

[1]Instituto de Astrofísica de Canarias, Calle Vía Láctea s/n, E-38205 La Laguna, Tenerife, Spain.
[2]Isaac Newton Group of Telescopes, Apartado de Correos 321, E-38700, Sta. Cruz de la Palma, Spain.

Jet-like LISs: Features resembling jets, but which move with velocities similar to those of their environments. We studied all the jet-like systems for which adequate data are available (IC 4593, He 2-429, NGC 6881, K 1-2, and Wray 17-1) and concluded that the existing models can hardly account for them. HD and MHD collimation, either in binaries or in single stars, predict flows that are faster than the environments, just the opposite of jet-like LISs. One possibility for these low-velocity 'jets' (at least for those located inside the main shell) could be the quasi-stationary flows that expand inwards from the stagnation zones of some interacting winds (see Gonçalves, Corradi, & Mampaso 2002).

Symmetrical pairs of knots or filaments: Features that appear in pairs, symmetrically or point-symmetrically distributed. We found 26 PNe containing this kind of LIS, some with high velocities (FLIERs or BRETs) and others with low velocities with respect to the main nebular body. Those with high velocity could originate by HD and MHD interacting stellar winds and accretion disc systems, or the zones of stagnation of partially collimated winds. As the related outward-facing bow shocks are generally not observed, their surfaces might have been modified by HD instabilities.

Non-symmetrical LISs: Isolated knots or systems of non-symmetrical knots or filaments. Among 17 PNe that posses this kind of LIS there are some well studied cases, such as NGC 7293 and MyCn 18. These features may be formed by in situ (dynamical and/or radiative) instabilities, as well as by fossil AGB mass-loss inhomogeneities. Distinguishing between these processes is not an easy task, however. The position of most isolated LISs indicates that they are not related to dynamical instabilities due to the action of the fast post-AGB wind.

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