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Maser-emitting Planetary Nebulae

L. Uscanga[1], *J. F. Gómez*[2], *L. F. Miranda*[2], *P. Boumis*[1], *O. Suárez*[3] *J. R. Rizzo*[4]
[1]IAASARS, National Observatory of Athens, Greece
[2]Instituto de Astrofísica de Andalucía, CSIC, Spain
[3]Observatoire de la Côte d'Azur, France
[4]Centro de Astrobiología, INTA-CSIC, Spain

Abstract: We present updated information about a special type of planetary nebulae (PNe), those showing maser emission (of OH and/or H_2O). These masers are expected to extinguish shortly after (<1000 yr) the end of the asymptotic giant branch (AGB) phase. Therefore maser-emitting PNe are probably extremely young and, in consequence, key objects to understand the formation and evolution of PNe. Up to now, only 9 PNe are known to harbour maser emission. Most of these sources show a bipolar morphology in the radio continuum, optical and/or infrared images. However these sources do not form a homogeneous group. Some objects are optically obscured, and compact in size (∼10 000 AU, e.g., IRAS 17347−3139), while others are optically bright and very extended (∼1 pc, e.g., NGC 6302), and thus, they might be PNe in a somewhat more evolved stage. Here we review the properties of these sources and their implications in our understanding of PN formation.

1 Characteristics of OHPNe and H_2O-PNe

Most of the OHPNe present a bipolar morphology in resolved images of their ionized emission at different wavelengths, suggesting that the OH maser emission in PNe is related to nonspherical mass-loss phenomena. The OH maser spectra in PNe present a clear asymmetry, tending to show blueshifted emission with respect to the systemic velocity. Their infrared colors suggest that most of these objects are very young PNe (Uscanga et al. 2012).

All H_2O-PNe exhibit a bipolar morphology in the optical, infrared and/or radio continuum images, indicating that these sources might pertain to a usual, but short phase in the evolution of bipolar PNe. H_2O masers are usually located toward the central region of the nebula (e.g., IRAS 17347− 3139 and IRAS 16333−4807, see Fig. 1), they could be related to dense equatorial structures. Also H_2O masers were observed once at the tips of the bipolar jets in K3-35 (Miranda et al. 2001), which suggests that this characteristic could be a transient phenomenon in these sources.

2 Evolutionary Implications

We suggest that OH masers pumped in the AGB phase may disappear during the post-AGB phase, but reappear once the source becomes a PN and its radio continuum emission is amplified by the OH molecules. Therefore, OH maser emission could last significantly longer than the previously assumed 1000 yr after the end of the AGB phase.

Among the 5 known H_2O-PNe, IRAS 15103−5754 would be clearly younger than the rest (Fig. 2), being the only PN that is still a "water fountain" (Gómez et al. 2015). H_2O maser emission traces high-velocity jets in this kind of sources. IRAS 17347−3139, IRAS 16333−4807, and K3-35, would be in a somewhat later evolutionary stage. Finally, IRAS 18061−2505 would be more evolved since it is completely visible in the optical.

It is possible that H_2O-PNe and OHPNe belong to the same underlying type of objects or that there is and evolutionary trend, with the H_2O-PNe being comparatively younger.

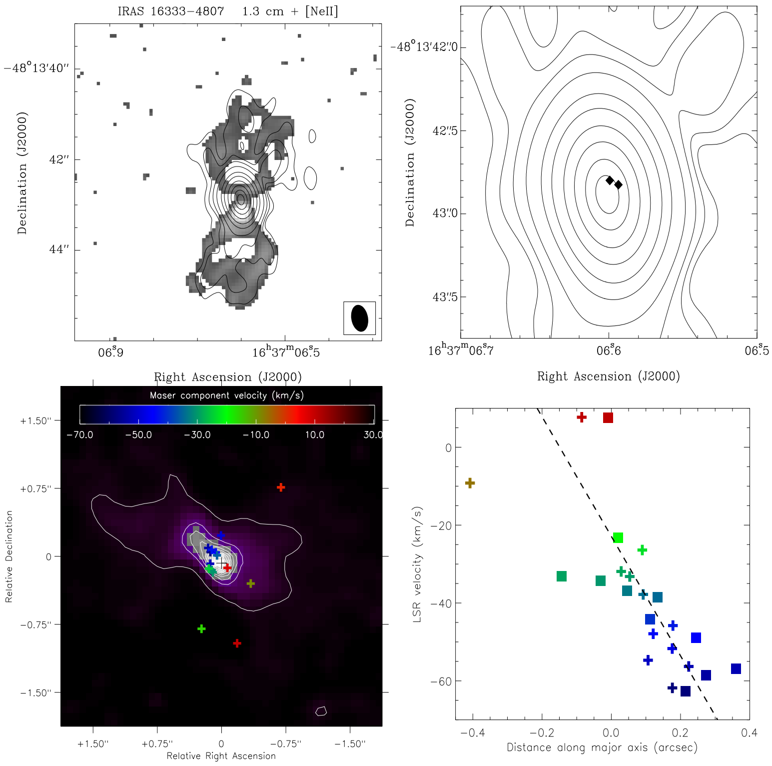

Figure 1: *Top left*: Contour map of the radio continuum emission of IRAS 16333−4807 at 1.3 cm from ATCA (Uscanga et al. 2014), superimposed to a mid-infrared image in the [NeII] filter (12.8μm) (Lagadec et al. 2011). *Top right:* Close-up of the central nebular region showing the radio continuum emission and the location of the H_2O maser components (filled diamonds). *Bottom left:* H_2O maser components (coloured crosses) detected towards IRAS 15103−5754 with ATCA in 2011 (Gómez et al. 2015), plotted on a mid-infrared image in the [NeII] filter (Lagadec et al. 2011). H_2O masers show a wide velocity spread ($\sim$75 km s^{-1}) and are tracing a collimated high-velocity outflow. *Bottom right:* LSR velocity of the maser components vs. projected distance to the radio continuum emission, along the major axis of the maser structure. Crosses and closed squares represent the data on 2011 and 2012, respectively. This velocity pattern is consistent with a "Hubble-like" flow (higher velocities at larger distances from the centre), maybe indicating a short-lived, explosive mass-loss event.

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