Outflows and Jets I: a personal take

Orsola De Marco
American Museum of Natural History

Abstract. As a session chair I have the privilege to write down a few comments on four talks that were delivered under the general title of “outflows and jets I”. This and the session that followed it, grouped work on circumstellar environments of, post-AGB stars, proto-PNe and PNe. After summarizing some of the highlights, I pose the question of which observations, if any, reveal the presence of a common envelope ejection in the past of a PN. Finally, I point out that the finding that most or all PNe have a binary origin, while solving some of our problems, might be in contrast with the number of known close main sequence binaries.

Highlights from the presentations of Sahai, Su, Corradi and Cox.
From the days of his first HST snapshot survey of young planetary nebulae (PNe) and proto-PNe (PPNe; Sahai & Trauger 1998), Raghvendra Sahai has made a very convincing argument that the seed of bipolar symmetry in PN shaping springs into action very early in the post Asymptotic Giant Branch (AGB) life of a star. Jet-like outflows suddenly appear during the late-AGB or early post-AGB and carve holes into the spherical AGB mass-loss. Any subsequent mass-loss results in PN morphologies that bare the imprint of this early hole-carving.

These young, extremely bipolar PPNe, seen in reflected stellar light or ionized radiation are investigated further by Pierre Cox and others in these proceedings, by looking at molecular light (H$_2$ and CO). Molecular observations can break the degeneracy of whether the observed morphologies describe ionized (optical line radiation) or neutral (optical stellar continuum reflected by dust in the neutral regions) regions and refine the location and dynamics of the jets-like structures and other components of the AGB envelope. Cox and collaborators also remark on the extreme similarity in the morphologies and kinematics observed across the PPN-PN division, which points to one jet-shaping phenomenon, acting from very early on, and carrying on into the PN phase.

Further out from the inner regions of PPNe and young PNe, we observe circular concentric rings in reflected light. In her comprehensive, quantitative study of the rings, Kate Su presents a summary of ring properties around 6 PPNe, 5 PNe and one AGB star. Three ring-forming scenarios from the literature are compared. Binary models, where periodic incursions of a companion during the AGB phase modulate the mass-loss. A fluid instability model, where the dusty outflow is unstable in a way that can lead to the observed structures and, finally, a magnetic activity model, where either magnetic surface spots or magnetic pressure oscillations are responsible for the mass-loss modulation.
The persistence of the ring structures all the way into the PN phase, appears to indicate that, after their creation during the AGB phase, the gas that bares the ring signature remains relatively undisturbed. This reinforces the theory that the shaping mechanism acts over small solid angles, in agreement with the Sahai and Trauger (1998) scenario of hole-piercing by jet-like structures in the early PPN phase.

I expect that in the near future, this excellent quantitative work will be able to rule out several of these models. As for the argument presented against the binary incursion model, namely that “orbital periods set the time interval between arcs/rings, which is very regulated, conflicting with the fact that some arcs are intersecting, and time intervals are not exactly the same.”, it appears to me that a binary incursion might not be as regular as the period of an undisturbed companion. Every time the companion enters the AGB envelope in its elliptical orbit, it will lose some energy via friction and the orbit and period will change as a result. Can this rescue the binary hypothesis with regards to ring production?

Venturing outside the volumes where the ring structures reside, large faint ionized halos have been observed by Romano Corradi (see also Corradi et al. 2003), by taking very deep images over large angular scales. With few exceptions these are spherical structures, and like the rings, point to a spherical AGB mass-loss. For the few cases where multiple structures are encountered, the entire ejecta are approximately coeval, excluding that recurrent phenomena might have taken place during the halo formation. Ionizing radiation, leaking from mass-bounded, inner PNe gives a glimpse of the the mass-loss geometry preceding the sculpting at the hand of the jet-like structures.

These observations, along with the results presented in the “outflows and jets, session II” by Valentín Bujarrabal, where the momenta of several PNe and PPNe are shown to exceed the radiation driving limit, appear to reinforce further the binary argument. Personally, I have recently jumped on the band-wagon of the binary proponents. However there are some tough questions we are facing, some of which I outline below.

Where are the post-CE stars. Having such detailed observations of the close circumstellar quarters of post-AGB stars, leaves me with a nagging question. If we are to admit to a sizable number of post-common envelope (CE) PNe to aid in the explanation of PPNe morphologies, and if we trust our (meager) understanding of CE ejections, we should be able to observe some peculiarities in the circumstellar environments of those PPNe and PNe which descended from CE events. CE events, are thought to be fast (time scales of one to a few decades) mass-losing events, leading to most or almost all of the AGB star envelope mass (several tens of a solar mass) and resulting in the winding in of the companion orbit (Sandquist et al. 1998; De Marco et al. 2003). The traumatized star should have a much reduced radius, with a resulting increase in effective temperature and/or reduced luminosity, but possibly be out of equilibrium. What are the expected excursions from the AGB position on the HR diagram?

Too Many Binaries? If we decided that binary companions were necessary to eject PNe on more than 10% of cases, the number of PNe in the galaxy might be too large to be produced by the known (close) binary main sequence
population. Until recently we could count on about 10% close binary central stars (e.g. Bond 2000), leaving us in a position to wonder how single stars make PNe, but also safe from the problem I am about to outline. The central star radial velocity surveys of Don Pollacco and collaborators and Howard Bond and collaborators (see De Marco et al., these proceedings), show a high (∼45%) percentage of radial velocity variables, possibly pointing to a similar fraction of post-CE binaries. According to Mathieu (1992) the main sequence binary fraction is of the order 60%. However, only ∼10% have periods which are short enough to result in a CE event. If we assume that of the 100 billions stars in the galaxy, only 10% have lifetimes shorter than the age of the Universe, and if we adopt a mean life for any such star of 10 billion years, and a mean life for a PN of about 20 000 years, then we expect to have only 2000 post-CE PN living in the Galaxy or ∼4000 PNe in total. This is too few by a factor of five, since recent counts, which include visibility effects point to ∼20 000 PNe. If the results of Pollacco and Bond don’t go away, we might rejoice in having explained how PNe form, but we will have a problem in explaining the number of binary central stars from a population perspective.

In conclusion, binaries might well be simpler to explain the large majority of PNe and, according to recent surveys, might well be present. However, we must reconcile their number with the main sequence binaries. Once it becomes clearer how many post CE PNe are out there, we should agree on a prototypical CE model and its observational predictions. Noam Soker might say that no model can be accurate enough, but I think we must start from a square cow if we are to end with one with legs and ears and a bell.

References

Bond, H. E. 2000, in Asymmetric Planetary Nebulae II, eds. J. H. Kastener, N. Soker & S. A. Rappaport (ASP 199), 115
De Marco, O., Sandquist E. L., Mac Low, M.-M., Herwig, F., Taam, R. E. 2003, RMxAC, 15, 34
Corradi, R. L. M. 2003, MNRAS, 340, 417
Mathieu, R. D. 1992, in Binaries as Tracers of Stellar Formation, eds. A. Duquennoy, & M. Mayor, (Cambridge University Press, Cambridge), 155
Sahai, R. & Trauger 1998
Sandquist, E. L., Taam, R. E., Chen, X., Bodenheimer, P., Burkert, A. 1998, ApJ, 500, 909