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HOW FAST ARE COLLIMATED OUTFLOWS IN PLANETARY NEBULAE?

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A significant fraction of planetary nebulae (PNe) show jet-like features. These features are usually interpreted as fast collimated outflows, although their true space velocities are uncertain, as their measured radial velocities cannot be properly corrected for projection effects. We have compiled the measured expansion velocities and radial distances of collimated outflows for a sample of 33 PNe and analyzed statistically their distributions. Our analysis indicates that the true space velocities of collimated outflows have a bi-modal distribution. Most of them are consistent with true expansion velocities $\leq$ 70 km s^{-1}; only a small fraction of them expand faster.

The discovery of jet-like features, pairs of point-symmetric bright knots, and *ansae* in PNe has proliferated in recent years (see the review by López 2000). These features are typically highlighted in the emission of low-ionization lines and have peculiar expansion velocities relative to the surrounding nebula. They are often cited as collimated high-velocity outflows, but their true space velocities are unknown because the inclination angles of the outflows are not known and therefore the observed radial velocities cannot be corrected for projection effects. It is paradoxical that some of the observed velocities are slower than the expansion velocities of the host PNe (e.g., IC 4593, Corradi et al. 1997).

There exists a large number of PNe in which collimated outflows have been verified by high-dispersion spectroscopic observations. It is thus possible to undertake a statistical analysis of the distribution of the apparent expansion velocities ($V_{\rm exp}$) and projected radial positions of these collimated outflows in PNe in order to investigate their true space velocities.

We have compiled the $V_{\rm exp}$ and radial distances of collimated outflows in 33 PNe. The observed distribution of $V_{\rm exp}$ (Fig. 1) peaks at $\sim$ 30 km s^{-1} and drops sharply at higher velocities. We have compared this distribution to those expected from simple distributions of the space velocity. We find that the observed distribution is consistent with a bi-modal distribution of space velocities, in which:

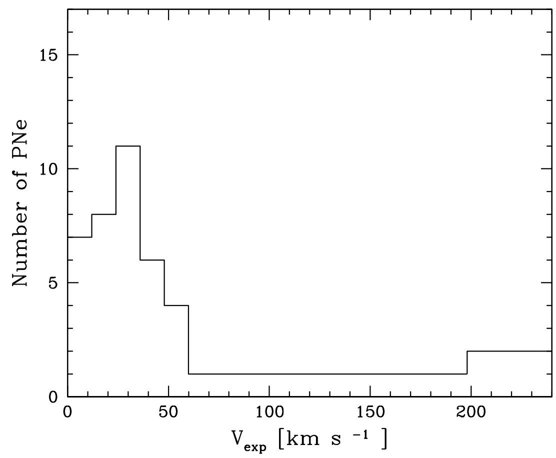

Fig. 1. Histogram of the distribution of observed expansion velocity of collimated outflows in PNe. The small number with velocities > 240 km s^{-1} are not shown.

- Most of the collimated outflows have true space velocities in the range of 35–75 km s^{-1}.
- A smaller fraction ($\sim$ 25%) of collimated outflows have true space velocities above 100 km s^{-1}.

The distribution of the projected radial positions of the collimated outflows shows that only a small fraction of them are found at distances greater than 2 nebular radii. Most outflows are projected within their host PNe, hence suggesting that they are embedded in the nebular material.

Two possible selection effects have been considered to assess the bias in the sample. First, collimated outflows close to the line of sight (and high projected velocity) would be projected on the bright nebular emission and may be missed. Second, fast collimated outflows moving close to the plane of the sky would be located at several nebular radii making it difficult to find them. Neither of these possibilities significantly affect the observed distributions.

A comprehensive analysis, including the list of the PNe in our sample, will be published elsewhere.

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