Planetary Nebulae in the Solar Neighbourhood: Statistics and Luminosity Function

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Abstract:

Recent Hα+[NII] surveys such as the AAO/ UKST Survey and SHASSA have been used to discover a number of new, large, nearby planetary nebulae (PNe). As a result, we have been able to compile a relatively complete census of PNe in the solar neighbourhood, based in part on a new Hα surface brightness – radius relation. We observe an inflection point (or dip) in the cumulative PNLF, seen in both [OIII] and Hβ. Our estimate of the PN formation rate is in quantitative agreement with the white dwarf birthrate. The number of Galactic PNe is estimated to be at least 30,000 and possibly as high as 50,000.

Planetary nebulae (PNe) are some of the most beautiful and photogenic non-stellar objects in the heavens, and are a "key tool" to understanding the evolution of low- and intermediate-mass stars. The main goals of this study are to provide the most accurate census of nearby PNe in the solar neighbourhood yet compiled, and to refine the statistical distance scale for old PNe. A key adjunct to this project is the AAO/UKST Hα Survey (Parker et al. 2005a). This is a high-resolution, narrow-band Hα+[NII] survey of the Southern Galactic Plane and the Magellanic Clouds using a large, high-quality interference filter on the 1.2-m UKST.

The survey comprises narrowband Hα and broadband short-red (SR) photographic images which have been digitized by the SuperCOSMOS measuring machine at ROE. The survey has led directly to the discovery of nearly 1000 new Galactic PNe, mostly of very low surface brightness (see figures 2 & 3). The Macquarie/ AAO/ Strasbourg/ Hα Catalogue (MASH) is a major product of this survey (Parker et al. 2003, 2005b), and includes a good many examples of very large angular diameter, up to nearly 30 arcminutes.

Slit spectra have been obtained on a variety of telescopes for all MASH PNe candidates, and we have obtained additional narrow-band imaging to get additional morphological data.

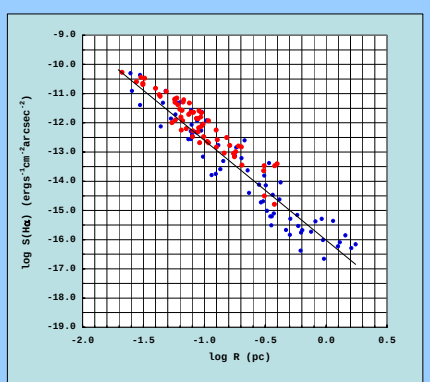


Figure 1 (above). A newly-derived Hα surface brightness – radius relation for PNe. Local PN data (blue) from Frew & Parker (2005, in preparation). LMC and SMC PN data (red) from Shaw et al. (2001) and Stanghellini et al. (2002, 2003). The trend line is based on the Galactic sample.

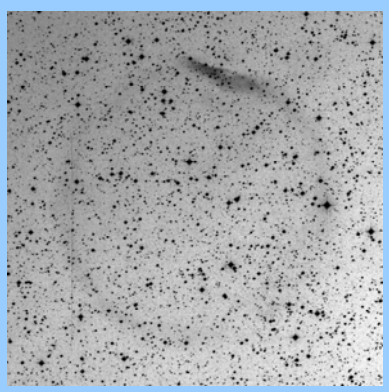


Figure 2. Hα+[NII] image of a highly-evolved PN (PFP 1) showing an interaction with the ISM (see Pierce et al. 2004). Field size is 25′ by 25′, illustrating the size of this giant PN.

We have produced an accurate database of fluxes in the main emission lines for these nearby, highly-evolved PNe. Data has come from our spectroscopy and imaging plus Hα fluxes from the SHASSA and VTSS sky surveys (Frew & Parker in prep.) from which other line fluxes can be bootstrapped via our spectroscopic information. We have also obtained Hα, Hβ, [OIII], and [NII] integrated fluxes for a number of northern PNe using the WHAM Fabry-Perot interferometer (Madsen & Frew, in prep.)

D.J.F. has also examined SHASSA images (Gaustad et al. 2001) and has found several new large candidate PNe. Additional WHAM data is being used to determine the nature of several unusual objects (Sh 2-174, DeHt 5, RE 1738+665, Ton 320, PHL 932, Hewett 1, etc), showing that some of these objects are examples of ionized ISM, and are not true PNe. As a result, we have compiled a 'clean', statistically-significant sample of bona fide PNe within 1.0 kpc.

Distances for all local PNe have been gleaned from the literature, or estimated anew using several techniques. When a primary method is not applicable, we determined a distance from a new Hα surface brightness – radius relation (Figure 1; see also Pierce et al. 2004). Shaw et al. (2002) find a similar relation for both LMC and SMC PNe that is well characterized by an R^{-3} law. The Galactic sample is broadly consistent with this finding (figure 1), with a power-law index of –3.4.

We also plan to derive chemical abundances and relate these to parameters such as the morphology, PN absolute magnitudes, and the properties of the PN central stars.

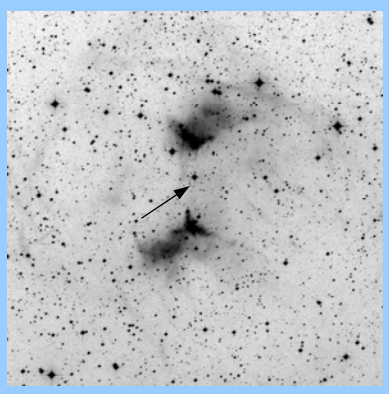
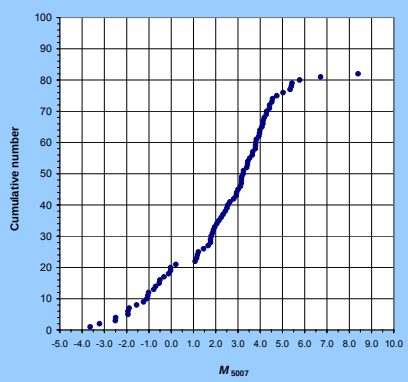


Figure 3 (right). Hα+[NII] image of RCW 24, a giant Type I bipolar PN previously catalogued as a H II region (Frew, Parker & Russeil 2005). An arrow shows the 18th mag central star. Field size is 20′.

Our new PN sample has increased the number of old objects and has allowed the faint end of the PN luminosity function (PNLF) to be seen clearly (see Figure 4). Especially noticeable are the inflection points (or 'dips') in the PNLF at $M_{5007} \approx +0.3$ and $M_{H\beta} \approx +2.6$. We attribute this to the rapid decline in luminosity of the central star as it starts descending the WD cooling track. While not unexpected, our PNLF's show this feature clearly for the first time.

We also aim to improve the statistics of the total space density and birthrate of PNe, as these parameters are critically dependent on the adopted statistical distance scale for old PNe (Ishida & Weinberger 1987; Pottasch 1996). Allowing for some incompleteness, a preliminary estimate of the PN birthrate is $1.2 \pm 0.5 \times 10^{-12}$ $pc^{-3}yr^{-1}$, which agrees with the white dwarf birthrate of $1.0 \pm 0.25 \times 10^{-12}$ $pc^{-3}yr^{-1}$ determined by Liebert et al. (2005). The total population of PNe in the Galaxy is estimated to be >30,000.



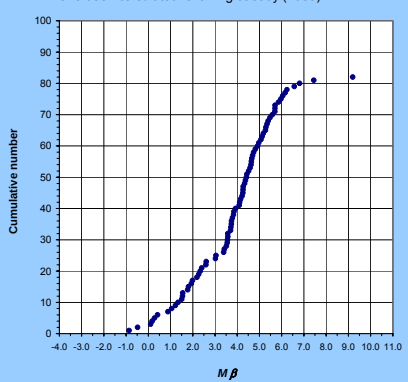


Figure 4. Preliminary cumulative PNLFs in [OIII] λ5007 (above) and Hβ (below) for PNe within 1.0 kpc, totalling 82 objects. Note the inflection points in both plots. Magnitudes have been calculated following Jacoby (1989).

Acknowledgements:

D.J.F. thanks Macquarie University and the conference organisers for financial assistance.

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