*Planetary Nebulae in our Galaxy and Beyond*
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# Mid-Infrared Observations of Planetary Nebulae

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**Abstract.** We present the results of a small mid-infrared imaging survey of planetary nebulae. Of 21 objects observed 19 were resolved. Only in NGC 6210 was there a marked contrast between the dust morphology and the emission line morphology. For all the other objects the dust and the gas must be well mixed even in the faint lobes of bipolar objects such as Fg3, Pe1-7, and NGC 6881.

**Keywords.** (ISM:) planetary nebulae: general

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We have obtained mid-infrared images of 21 planetary nebulae chosen based on estimated N-band surface brightness. In most cases the PNs were imaged using three filters, one of which was a medium-band 11.7 $\mu$m filter that only includes dust continuum emission. Most of the images presented here are from this filter. Two objects, Vo1 and Hb12, were unresolved although they are brighter than many of the resolved objects, indicating distinctly different dust properties than normal for these nebulae. Of the other objects only NGC 6210 shows distinct morphologies between the 11.7$\mu$m filter and the optical emission line images, as well as images in the N$'$ filter which includes the 10.5 and 12.8 $\mu$m lines. Almost all objects have very similar optical and mid-infrared morphologies, indicating that the dust is generally uniformly mixed through the ionized region, possibly in the form of globules. This is particularly interesting for objects such as Pe1-7, NGC 6881, and Fg3 which show faint lobes as well as a bright central region in both optical emission line and mid-infrared dust emission images. The large differences in surface brightness for these objects may reflect changes in the grain size or in optical depth.

Three objects were of unknown dust composition due to a lack of previous mid-infrared spectroscopy. Fg3 and H1-35 are shown to have silicate grains and NGC 6881 is shown to have carbon-based grains from our observations.

We also have resolved the protoplanetary nebula IRAS 19500−1709, which is about two times smaller than expected based on dust radiative transfer models of its *Infrared Space Observatory* (ISO) spectrum. This probably indicates that the dust grains are much larger than expected, of order 2 $\mu$m in radius.

Figure 1 below shows our images. All are given in Jy/square arc-second based upon direct calibration of the imaging observations. Where ISO or IRAS spectra are available, the in-band fluxes we derive are usually very close to what is expected from the space observations, but for a few objects there are significant differences at about the 40% level.

We intend to derive dust colour temperature and optical depth maps from these images, to seek indications of whether optical depth or dust size plays a role in the wide range of surface brightnesses in these PNs.

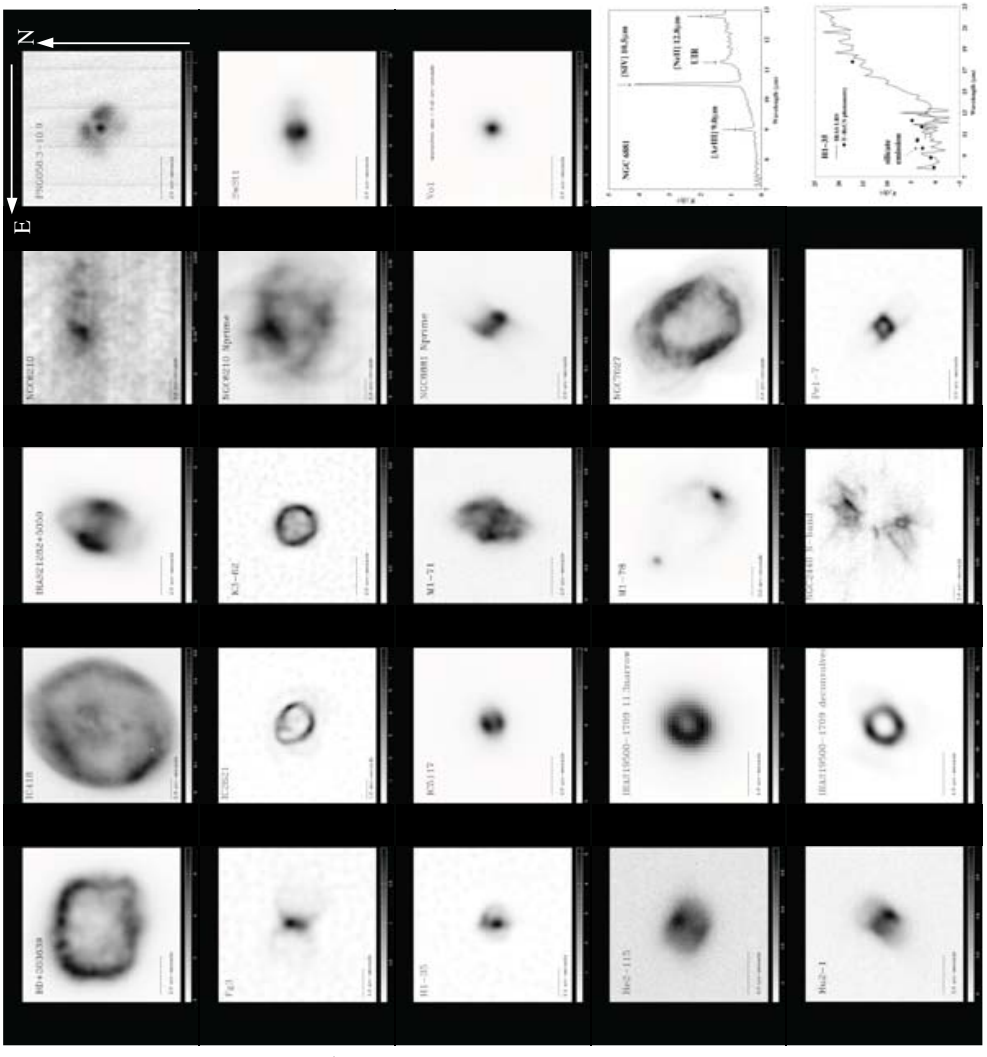


**Figure 1.** Absolutely calibrated mid-infrared images of planetary nebulae, plus the protoplanetary nebula IRAS19500−1709. All the images are in the standard orientation, as indicated above. Unless noted the images are in an 11.7 $\mu$m medium-band filter ($\Delta\lambda \sim 1.0$ $\mu$m). The images of the small nebulae K3-62, Pe1-7, Fg3, and H1-35 have been deconvolved; the images for SwSt-1 and Vo-1 have not been deconvolved. Vo1 is unresolved, although it is slightly larger than a point source. For IRAS 19500−1709 we show the raw and deconvolved images. We also show our N-band spectrum of NGC 6881 and our N-band photometry plot for H1-35, from which we found the nature of the dust grains.

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