Final Report (November 2000)

NAG 5-1223

Principal Investigator: **Dr. Bruce J. Hrivnak**
Valparaiso University

Title: Proto-Planetary Nebulae and IRAS "25 Micron Peakers"

In this program, we used the IRAS database to identify and study proto-planetary nebulae (PPNs), objects in transition from the asymptotic giant branch (AGB) to the planetary nebula (PN) phase. Such objects radiate predominately in the mid-infrared 10-30 μm region, due to emission from warm (150-300 K) circumstellar dust. We used the IRAS database to identify 55 objects whose fluxes peak in the IRAS 25 μm band and which are associated with visible stars. We combined IRAS and supporting ground-based data to delineate their spectral energy distributions. For PPN, we find that they have a double-peaked spectral energy distribution, with one peak in the visible from the reddened photosphere and the second in the mid-infrared from the re-emission by the warm dust. This study has led to a number of new results in our understanding of these transitional objects.

One of the expected properties of PPNs is that their elemental abundances will show the effects of nucleosynthesis on the AGB and the subsequent mixing of these products to the surface of the stars. We have been investigating this for several PPNs by making detailed studies of their chemical composition. For IRAS 19114+0002, we find the abundances to be consistent with that of a PPN of intermediate mass; however some of the spectral features suggest a more massive star. Thus the evolutionary status of this star is still not resolved (Reddy & Hrivnak 1999, Astron. J., 117, 1834-1844). The results for IRAS Z02229+6208 and 07430+1115 are clearer. The two objects are carbon-rich, overabundant in CNO, and overabundant in s-process elements; all of this is consistent with their being PPNs. The results for these two stars also show the correlation with other signatures of a carbon-rich chemistry and a PPN nature (Reddy, Bakker, & Hrivnak, 1999, Astrophys. J., 524, 831-848). An additional study of a new carbon-rich PPN is near completion (Reddy & Hrivnak 1999, Bull. A.A.S., 31, 846).

We have completed visible and mid-infrared ground-based studies of a sample of PPNs, and these results have been published. We obtained ground-based visible-band imaging observations of a sample PPNs at high resolution, to try to resolve scattered light from their circumstellar envelopes. We were able to obtain subarcsecond (~0.75") image quality, and resolved nine of the thirteen objects observed. Of the nine, four appear to be elliptical in shape. Many PN are known to display axially symmetric nebulae. Our results indicate that this aspherical symmetry develops early in the transitional phase (Kwok, Hrivnak, Zhang, & Langill 1996, Astrophys. J., 472, 287-293; Hrivnak, Langill, Su, & Kwok 1999, Astrophys. J., 513, 421-427). Mid-infrared imaging observations of a large sample PPNs and related objects were made at IRTF and UKIRT, and several were found to be resolved. These observations directly trace the dust distribution, rather than the scattered light seen in the visible, and will be used to model directly the circumstellar envelopes (Meixner, ..., Hrivnak, et al. 1999, Astrophys. J. Suppl., 122, 221-242). These studies have led to new observations of these objects with the Hubble Space Telescope.

We have essentially completed the reduction and analysis of the ground-based follow-up observations of our newly identified sample of PPNs with visible counterparts. These ground-based data, in combination with the IRAS data, define the spectral energy distribution from 0.4 to 100 μm. This project has led to the discovery and study of several new and interesting PPNs, and the results have been published in the papers listed above.

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