PROPERTIES OF POST-AGB STARS WITH IRAS COLORS TYPICAL OF PLANETARY NEBULAE.

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Abstract

We have investigated the infrared properties of a sample of objects with *IRAS* colors typical of planetary nebulae. The selected objects have not yet evolved to the planetary nebula stage since they have no detectable radio continuum emission and they are therefore likely post-AGB stars.

1. INTRODUCTION

A most intriguing challenge is to understand how Asymptotic Giant Branch (AGB) stars transform their surrounding mass-loss shells in a couple of thousand years into the variety of shapes and sizes observed in Planetary Nebulae (PNe). There are a number of theories currently being investigated. No consensus about the dominant physical process responsible for the shaping of PNe has emerged so far, but there is agreement that the shaping occurs during the early AGB-to-PN transition stage.

The details of the rate of evolution and the strength of the stellar wind during the AGB-to-PN transition phase are essential ingredients in understanding the shaping of the PN. However, both are very poorly known, either theoretically or observationally. To remedy this we have started to study a sample of *IRAS*-selected post-AGB candidates.

2. SAMPLE SELECTION

Objects were selected from the *IRAS* catalogue with far infrared colors typical of PNe. Apart from PNe, only post-AGB stars are typically found in this part of the color-color diagram (van Hoof et al. 1997). Furthermore, we selected objects that were not detected in the radio continuum above a detection limit of 3 mJy (Van de Steene & Pottasch 1993). Hence we may assume that they have not yet evolved to the PN stage.

3. OBSERVATIONS

We obtained JHKL images of the candidates with CASPIR on the 2.3-m telescope at Siding Spring Observatory in Australia. To search for hydrogen emission, we obtained Brγ spectra with IRSPEC on the NTT at ESO. The objects showing Brγ in emission were re-observed in the radio continuum with the Australia Telescope Compact Array.

4. RESULTS

The *IRAS* counterparts were identified on the basis of their position and near infrared colors. Accurate positions were obtained by using the USNO catalog. The weather was photometric and accurate JHKL magnitudes were determined for the *IRAS* counterparts. By combining the JHKL and *IRAS* photometry, various color-color diagrams were constructed. In these diagrams our objects show evidence for a very large range of extinction. The observed trends in the infrared colors are consistent with the expected evolution of the circumstellar shell (van Hoof et al. 1997).

Of 16 positively identified objects, 6 show Brγ in emission, 7 in absorption, and in 3 no clear Brγ absorption or emission was visible. The absorption lines are very narrow in six objects, indicating a low surface gravity. The objects showing Brγ in emission have a strong underlying continuum, unlike normal PNe.

The fact that our objects were mostly selected from the region in the *IRAS* color-color diagram where PNe are typically found may explain our higher detection rate of emission line objects compared to previous studies.

None of the objects showing Brγ in emission were detected above a detection limit of 0.6 mJy/beam at 6 cm and 0.7 mJy/beam at 3 cm, while they should have been easily seen, if the radio emission was optically thin and Case B recombination was applicable. We argue that the Brγ emission is likely due to ionization in the post-AGB wind, present before the star is hot enough to ionize the AGB shell (Van de Steene et al. 2000).

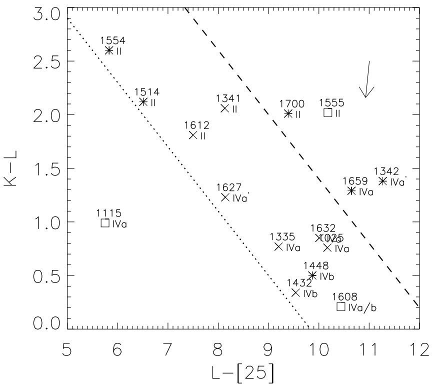

Figure 1 The K-L, L-[25] diagram. The crosses represent objects having Brγ in absorption, the asterisks objects having Brγ in emission, and the squares flat spectrum sources. The objects are labeled by the first four numbers of their *IRAS* name. The SED CLASS of each object is indicated next to its symbol. The arrow shows the effect of reducing A_V by 5 mag.

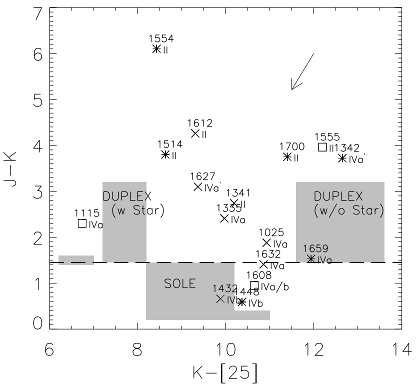

Figure 2 The J-K, K-[25] diagram, as proposed by Ueta et al. (2000). The grey regions show the location of the sample of Ueta et al (2000). These regions are labeled according to their definitions as STAR-OBVIOUS LOW LEVEL ELONGATED (SOLE) and DUST PROMINENT LONGITUDINALLY EXTENDED (DUPLEX) with and without star. The dashed line separates these two kinds of objects.

In the near- and far-infrared color-color diagrams, no distinction can be made between objects showing Brγ in emission, Brγ in absorption, or a flat spectrum. Whether the positions of the objects in the color-color diagrams can be directly related to the temperature and core mass of the central star needs further investigation, but doesn't seem likely based on our data.

5. COLOR-COLOR DIAGRAMS

In Figs. 1 and 2 we show two of the color diagrams we have constructed. The K−L and J−K colors follow the evolution of the circumstellar extinction. The L−[25] and K−[25] colors relate the stellar component with the peak of the dust emission, a larger color indicating a more prominent dust shell. We note that the L−[25] color is relatively insensitive to extinction.

In Fig. 1, stars obscured by their dust shells lie in the upper half of the diagram (larger K−L) while stars visible through their dust shells lie in the lower half. The objects located to the right of the dashed line are extended and some show bipolar morphology in the K-band. Probably they have thicker, cooler circumstellar dust shells than objects located below the dashed line (more

25 μm-band flux) and/or their central star temperatures are higher (less L-band flux).

For our limited sample, all but one of the objects are found to the right of the dotted line. This may reflect the evolution: K$-$L decreases when mass loss ceases and the inner edge of the circumstellar shell expands, and L becomes fainter as the central star becomes hotter at constant luminosity, causing L$-$[25] to increase.

In Fig. 2 there is virtually no overlap between the sample of Ueta et al. (2000) and our sample. This may be because of different selection procedures for the two samples. Ueta et al. (2000) selected known post-AGB candidates from the literature and imaged their nebulosities with WFPC2 in the optical. We selected objects from the PNe region in the *IRAS* color-color diagram: very few of them have bright optical counterparts.

All our objects are located within 5 degrees of the galactic plane, compared with only 11 of the 27 objects of Ueta et al. (2000) (3 *SOLE*, 6 *DUPLEX*, and 2 stellar). The arrow in the diagram indicates an extinction correction of $A_V = 5$ mag. Clearly, larger interstellar extinction alone cannot explain why our samples appear different. If they are at similar distances, it is plausible that we have more massive central stars in our sample, and that they are evolving faster across the HR diagram. Further investigations will be needed to understand the differences between both samples.

References

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