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# Evolution of Planetary Nebulae in the Mid-Infrared

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**Abstract.** The evolution of planetary nebulae is studied using MSX data on a sample of 214 objects situated near the galactic plane. The observed MSX magnitudes are compared with synthetic magnitudes obtained by convolving synthetic spectra generated by CLOUDY with MSX filter curves. Color-color diagrams show that the evolutionary tracks are similar as the star begins its post–AGB phase. Young PNe can be identified using the [14.7]−[21.3] color index, because of the significant contribution of dust to the continuum at this phase. On the other hand, dust-poor nebulae are also located in a characteristic region of the ([14.7]−[21.3]) × ([8.3]−[14.7]) diagram. There is also some segregation with respect to the mass of the central star in this diagram that might help the diagnosis of objects severely affected by extinction.

## 1. Introduction

Various infrared color-color diagrams have been used to study AGB and post–AGB evolution. Ortiz et al. (2005) used MSX magnitudes to show that extreme OH/IRs share their position in the ([14.7]−[21.3])×([8.3]−[14.7]) diagram with PNe and post–AGB stars. Synthetic evolutionary models provided by Volk (1993) reproduce the range of color indices of the PNe observed. However, because the evolutionary tracks in the diagrams appear somewhat erratic and the set of parameters was very restricted, a more detailed study became necessary. The main scope of the present work is to provide a physical description of PN evolution in MSX color-color diagrams using synthetic models. We assume the evolutionary tracks of the central star proposed by Schönberner (1981, 1983) and use the photoionization code CLOUDY (Ferland 1998) to model the nebula, which includes infrared emission from dust. Several central star masses are considered as well as a wide range of electron densities and chemical abundances.

## 2. Results

Figure 1 shows that the tracks of PNe during their early phases are similar, irrespective of the mass of the central star or the electron density of the nebula. A few objects situated near the lower-left corner have been identified as proto–PN or suspected symbiotic stars, which makes this diagram suitable for identifying new objects of this kind. As the PN evolves, it describes a clumsy track in the diagram; however, the "red loop" feature (caused mainly by dust emission in the [21.3] band) is characterictic of lower-mass objects. According to the theoretical tracks, more evolved nebulae are situated on the left side of the diagram, but because of their low luminosity their detection is restricted to nearby objects.

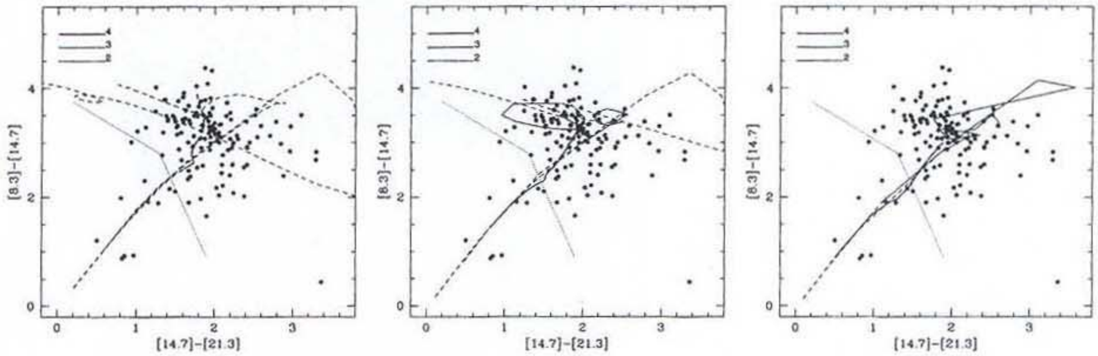


Figure 1. Evolutionary tracks of oxygen-rich PNe, for the following central star masses: 0.55 $M_\odot$ (*left*), 0.64 $M_\odot$ (*center*) and 1.40 $M_\odot$ (*right*). The data (*points*) refer to the sample of PNe studied in Ortiz et al. (2005). The different line types denote various electron densities: $n_e = 10^4$ cm$^{-3}$ (*bold*), $10^3$ cm$^{-3}$ (*medium*), and $10^2$ cm$^{-3}$ (*fine*). Dashed lines designate synthetic PNe which would be beyond the detection limit of the MSX survey if their distance were 1 kpc.

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## References

Ferland, G.J., Korista, K.T., Verner, D.A., Ferguson, J.W., Kingdon, J.B., & Verner, E.M. 1998, PASP, 110, 761

Ortiz, R., Lorenz-Martins, S., Maciel, W.J., & Rangel, E.M. 2005, A&A, 431, 565

Schönberner, D. 1981, A&A, 103, 119

Schönberner, D. 1983, ApJ, 272, 708

Volk, K. 1993, in IAU Symp. 155, Planetary Nebulae, ed. R. Weinberger & A. Acker (Kluwer), 469