MID-IR (8-13μm) IMAGES OF THE 21 μm, CARBON RICH PROTO-PLANETARY NEBULAE
Snapshots of an Evolutionary Sequence

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Abstract. We present 9.7 and 11.8 μm narrow band (Δλ/λ = 10%) images of three carbon (C-) rich proto-planetary nebulae with an unusual 21 μm feature: IRAS 07134+1005, IRAS 22272+5435, and IRAS 04296+3429. The images were taken at UKIRT using the Berkeley/IGPP/LEA mid-IR camera. All three objects have a bipolar shape adding to the existing evidence that C-rich PPNe are by nature bipolar. Furthermore, we find the same bipolar morphology in a previous study of the C-rich, young planetary nebula, IRAS 21282+5050. We believe these four objects form an evolutionary sequence which links the C-rich asymptotic giant branch (AGB) stars with the C-rich planetary nebulae (PNe). From this evolutionary sequence, we conclude that bipolarity in C-rich PNe begins on the AGB and that the dynamical ages of these PPNe are in fair agreement with theoretical ages for a 0.6 M☉ hydrogen burning core star.

Key words: 21μm Proto-Planetary Nebulæ – Carbon Dust: PAHs – Stellar Evolution

1. Introduction

Proto-planetary nebulae (PPNe) are stars in transition from the asymptotic giant branch (AGB) and planetary nebula (PN) stages of evolution. PPNe have central stars with spectral types of K–A which are not hot enough to photoionize their detached circumstellar shells but are capable of heating the dust in the shells which emit in the mid-IR. Hence, mid-IR imaging offers a unique opportunity to learn about the morphologies of PPNe dust shells. In this article, we present mid-IR images of three carbon (C-) rich PPNe, IRAS 04296+3429, IRAS 22272+5435, and IRAS 07134+1005, which form 3/4 of the original group of 21μm PPNe.

The 21μm PPNe are a class of PPNe unto themselves of which there are almost a dozen known to date. They are considered PPNe because they have double peaked spectral energy distributions (SEDs), one peak in the optical from the star and the second in the infrared due to the circumstellar dust shell (Pottasch & Parthasarathy 1988; Kwok, Volk and Hrivnak 1989). In fact, both IRAS 22272 and IRAS 07134 have well known optical counter-
parts SAO34504 (HD235858) and SAO96709 (HD56126), respectively. The circumstellar dust shells around these stars have been identified as the remnant AGB envelope from the mm-wave observations of the CO J=1-0 which have the characteristic signature of an expanding shell (e.g., Woodsworth, Kwok, & Chan 1990). They are considered a class of PPNs because they all have a peculiar feature at 21 m in their IRAS Low Resolution Spectrum (Kwok et al. 1989). Further investigation of their circumstellar dust shells reveals that they are extremely carbon rich exhibiting features in the mid-IR (8-25 m) and near-IR (~ 3 m) attributed to Polycyclic Aromatic Hydrocarbons (PAHs; Kwok, Hrivnak & Geballe 1990; Geballe et al. 1992; Buss et al. 1990). In addition, their molecular envelopes emit carbon rich lines such as HCN and lack the common oxygen rich maser line OH (e.g. Omont et al. 1993). The central stars of IRAS 04196, IRAS 22272 and IRAS 07134 have peculiar, supergiant spectral types, G0Ia, G5pIa and F5I, respectively (Hrivnak et al. 1989).

We imaged all three PPNs at 11.8 and 9.7 m at UKIRT using the Berkeley/IGPP/LEA mid-IR camera (Arens et al. 1987; Keto et al. 1992).

2. Discussion of Results

In all three PPNs there is at least a suggestion of ellipticity or bipolarity. In Figs. 1 and 2), we display the 11.8 m images of IRAS 0429, IRAS 22272, and IRAS07134. The bipolar structure of IRAS 07134 is particularly well defined with two central peaks which we interpret as limb brightened edges of a torus. The 9.7 m images of these objects have a similar size and shape except for IRAS 22272 where the 9.7 m image is significantly smaller. This size difference is probably due to excitation differences of PAH features and is discussed in another paper (Meixner et al. 1993b).

2.1. EVOLUTIONARY SEQUENCE

The extreme carbon rich nature and morphology of these three PPNs is very similar to IRAS 21282+5050, a young planetary nebula (PN) that we have recently imaged in the mid-IR (Fig. 2; cf., Meixner et al. 1993a). While it does not have the 21 m feature, the IR spectrum of IRAS 21282 is rich with features attributed to PAHs (e.g. Roche, Aitken & Smith 1991).

Using effective temperatures and distance dependent luminosities (L*/D^2) from SED models (Hrivnak et al. 1989, Kwok et al. 1989, Kwok, Hrivnak & Langhills 1993), we place all four objects on an H–R diagram and compare their dynamical ages to those calculated from theory for a hydrogen–burning central–star model with 0.6 M⊙ (see Fig. 3). Despite the lack of accurate distances to these PPNs, we can still learn something if we assume that all four objects have the same luminosity. We choose 6300 L⊙ which is the appropriate value for a 0.6 M⊙ core mass theoretical track (Fig. 3 ; cf. Marten