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Hydrogenated amorphous carbon (HAC) grains as possible carriers of unidentified infrared emission (UIR) in fullerene-rich PNe

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Abstract

One of the most outstanding astrochemistry problems, since the advent of the IRAS satellite, is the identification of the chemical carriers (structure and composition) of the cosmically widespread unidentified infrared (UIR) emission features. The mid-infrared spectra of a particular group of evolved stars like fullerene-rich planetary nebulae (PNe) are dominated by aliphatic hydrocarbon-rich dust, showing several broad UIR emission features such as the 6-9 (7 μm hereafter) and the 9-13-micron (12 μm hereafter) plateau emission features, among others. In particular, the 7 and 12 μm plateau emission features have been suggested to emerge from hydrogenated amorphous carbon (HAC) dust grains or similar mixed aliphatic-aromatic hydrocarbon nanoparticles (HAC-like). The laboratory optical constants of specific HAC-like dust grains (i.e., in terms of structure/composition) have been recently used in conjunction with a photoionization code, showing for the first time that HAC-like dust grains convincingly reproduce the 12 μm plateau emission feature observed in the prototypical fullerene PN Tc 1 (and yet consistent with the dust continuum emission and the 7 μm plateau feature observed). Interestingly, the same HAC-like grains may reproduce the far-UV rise circumstellar extinction observed towards PN Tc 1. The possible detection of HAC-like dust grains in the circumstellar envelope of a fullerene PN is of special interest to the fullerene formation mechanism, suggesting that fullerenes around in PNe could be formed by the processing and/or destruction of HAC-like dust. Our very recent work thus strongly encourage more laboratory experiments to obtain the optical constants (n and k indices) of HAC-like dust grains with several structures/compositions in order to extend this kind of modelling studies to more fullerene PNe and/or even other astrophysical objects.

1 Introduction

The evolution of low- and intermediate-mass stars leads to the formation of planetary nebulae (PNe). During the Asymptotic Giant Branch (AGB) and post-AGB phases, these stars shed significant amounts of material into the interstellar medium (ISM), contributing to the dust production and molecular enrichment of the Interstellar medium (ISM). Since the advent of IRAS many unidentified infrared emission bands. Aromatic features at 3.3, 6.2, 7.7, 8.6, and 11.3 μm; aliphatic features at 3.4 and 6.9 μm; and broad emission plateaus at 8, 12, and 17 μm. In addition, some PNe show fullerenes C60 features (Fig. 1)

Post-AGB phases, are major providers of dust and molecules, and responsible of the chemical enrichment of the interstellar medium (ISM). Then, low intermediate masss evolved stars play a crucial role in the production of cosmic dust

2 IUE study of planetary nebula with fullerenes.

The interstellar medium (ISM) extinction curves provide key insights into the properties of interstellar dust, including its composition, size distribution, and structural characteristics. Two prominent features in these extinction curves are the UV bump at 217 nm and the far-UV rise at wavelengths shorter than 200 nm (see Fig. 2). The 217 nm bump is one of the most distinct features of the extinction curve. Its origin is widely attributed to graphite grains ([2]). However, other more complex and disordered carbonaceous materials, such as hydrogenated amorphous carbons (HACs), soot, and other mixed organic materials, have also been proposed as carriers ([3]). In Fig. 3) we show that the best fit is the HAC model of ([3]). The far-UV rise circumstellar extintion in two PN (Hen 2-5 and TC 1) can be explained by a HAC-like dust grain as small as 1nm.

We carried out CLOUDY models with different dust composition, and the best fit is with HACs, see Fig. 4

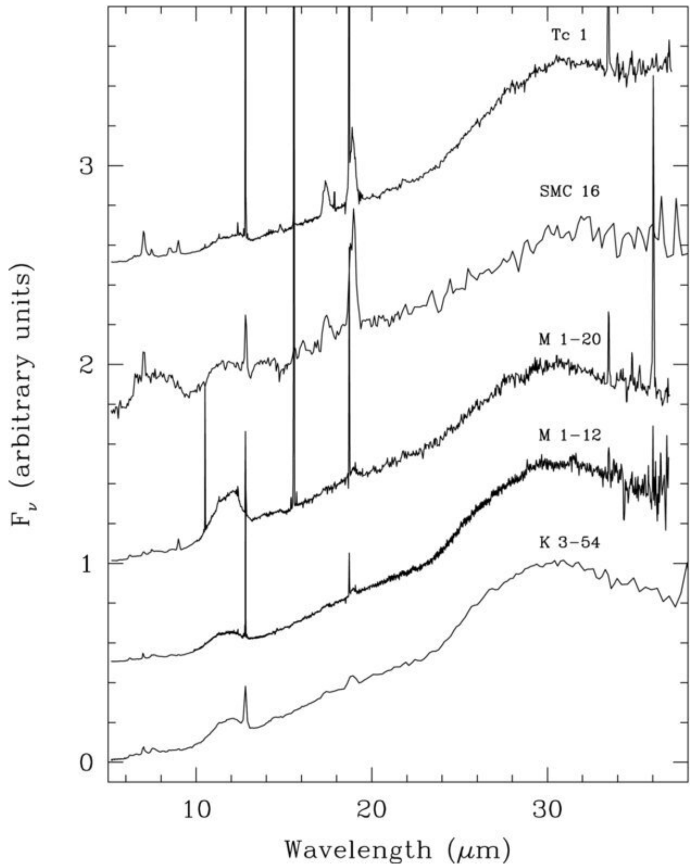

Figure 1: PNe with fullerene C60 features. Note the plateau at 11-13 μm ([4])

3 HACs as possible carrier of the 12 μm feature in Tc 1

We carried out CLOUDY models for TC 1 including, for the fist time, laboratory optical constants of a HAC, wth H/C = 0.35 and T=300 K. The 12 μm plateau feature were reproduced with spherical grains and typical ISM grain distribution; dust temperature similar to excitation temperature of C60 (300 K; [1]), see Fig. 5)

4 Conclusion

The C abundance in dust form represent $\approx$ 37 % per cent of the total C abundance (gas + dustphase) The UV bump is well explained by

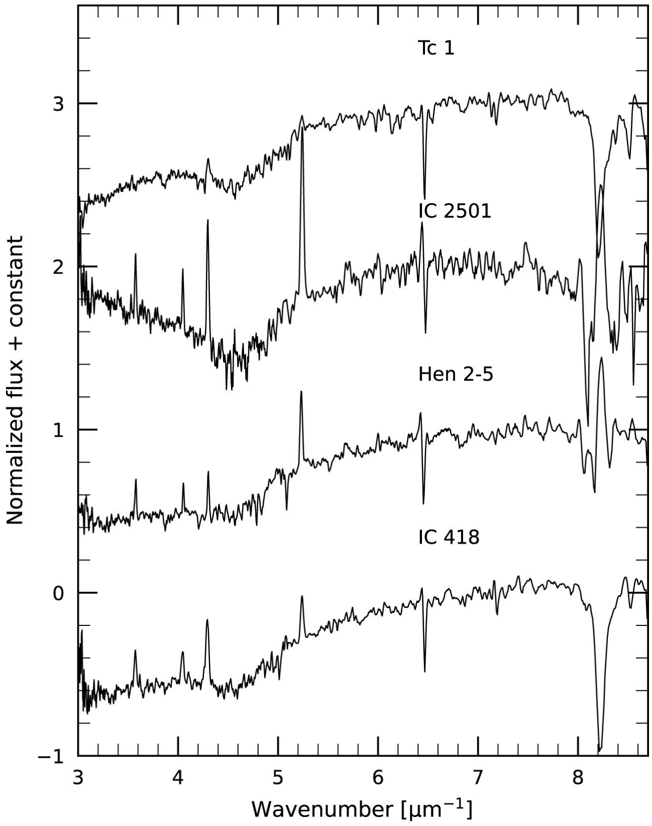

Figure 2: IUE spectra of PN with fullerenes. The spectra are composed of both the SW and LW matched at 5.13 μm^{-1} ([5])

interstellar extinction. Species different from those of the foreground interstellar medium, e.g. large fullerene-related species like carbon onions, are not the carrier. HAC-like grains are a convincing alternative explanation (i.e., different from the often assumed SiC) for the broad 12 μm plateau emission feature seen in the fullerene PN Tc 1. HAC-like grains are likely related to the fullerene formation process (possibly as fullerene precursors) in the circumstellar environment of planetary nebulae.

References

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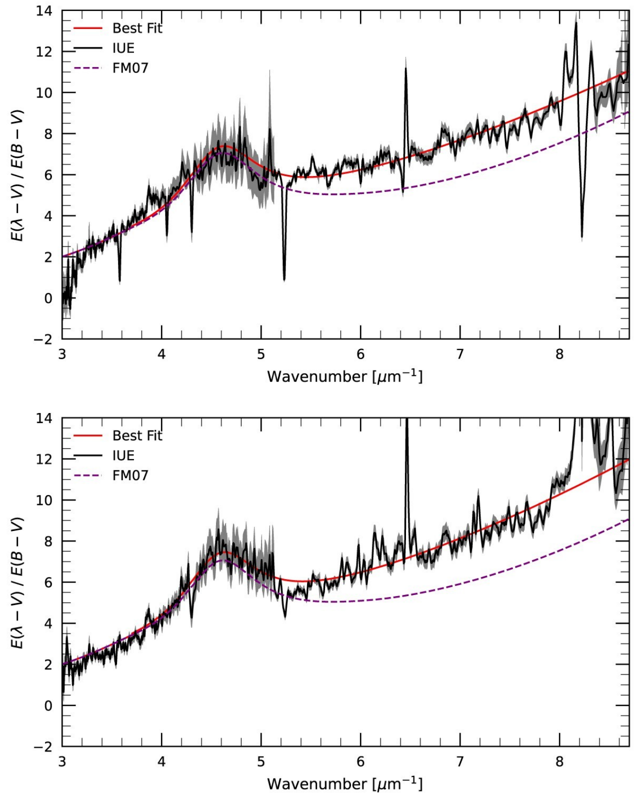

Figure 3: Best fit of the parametric extinction curve to Hen 2-5 (top) and Tc 1 (bottom)

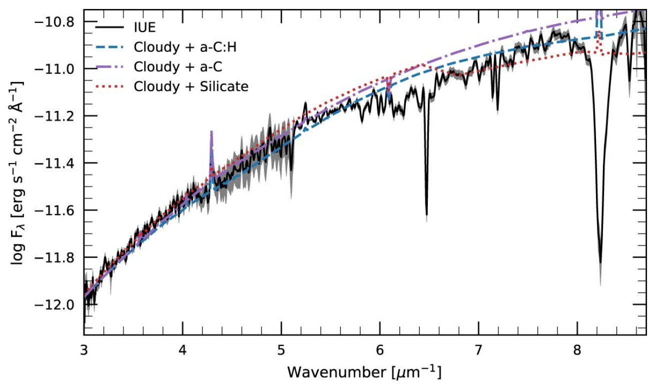

Figure 4: Cloudy models, with different compositions, for TC 1 ([5])

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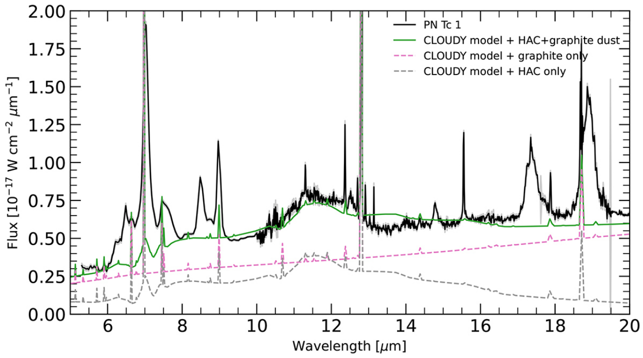

Figure 5: Spitzer mid-IR spectrum of the PN Tc 1(black line) compared with the best photo-ionization model spectrum including HAC-like dust grains (green line).

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