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A SURVEY FOR "PAH" EMISSION IN H II REGIONS, PLANETARY AND PROTO-PLANETARY NEBULAE

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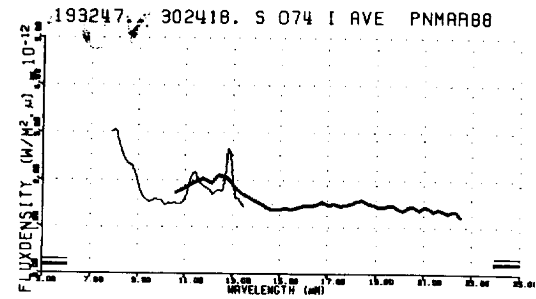
SUMMARY

We report on preliminary results of a systematic investigation of PAH emission in H II regions, planetary nebulae (PN) and proto-planetary nebulae (PPN). This emission occurs in a vast majority of H II regions showing the ubiquity of the carriers. With the remarkable exception of NGC 6302, PAH emission is only seen in carbon-rich PNs and PPNs and is quite common in this case. This shows that PAHs are formed at least in part in carbon-rich evolved objects.

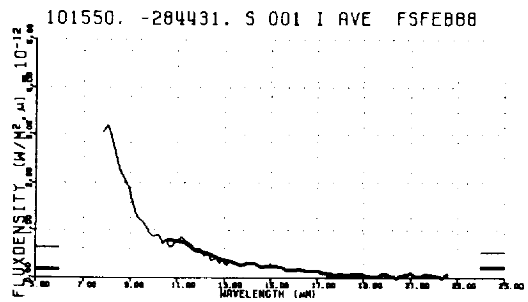
INTRODUCTION

We are engaged in a systematic search for infrared emission features in the IRAS/LRS (Low Resolution Spectra) data base. This data base contains a total of about 170 000 individual spectra of various qualities concerning about 50 000 IRAS sources. These spectra cover the spectral ranges 7.8 to 13.5 μm and 10.5 to 22.5 μm. A selection has been published in the LRS Atlas (IRAS Science Team, 1986) but many good quality spectra are still in the data base. We have systematically examined the individual spectra of known H II regions, planetary nebulae (PN) and proto-planetary nebulae (PPN) as well as all spectra with emission lines or with a flat or rising continuum in the LRS Atlas. The resulting selection constitutes a new data base which, although being neither complete nor homogeneous, contains a very large amount of information. An extensive literature search has added to this base a number of objects with published emission lines in the near IR (up to about 30 μm)

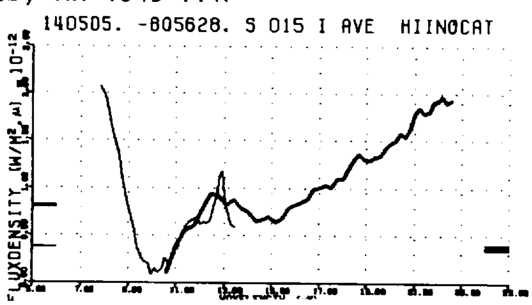
In the course of this work we experienced a number of difficulties with the Low Resolution Spectra:
1) Many individual spectra are affected by spurious "spikes" which sometimes superimpose over a real emission line. This problem is discussed by de Muizon et al. (1988) and necessitates examination of individual spectra. A revised version of the LRS Atlas where correction has



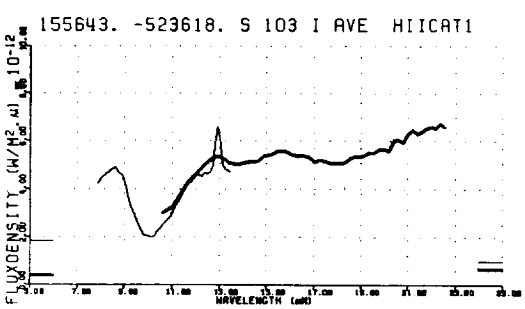
1a) BD+30°3639 PN



1b) HR 4049 PPN



1c) G 312.112 H II



1d) G 329.353 H II

Figure 1: IRAS Low-Resolution Spectra of representative objects

been made for spikes is in preparation.

2) The automatic classification given in the LRS Atlas can be misleading: a confusion is possible for example between silicate absorption centered at 9.7 µm and PAH emission at 7.7, 8.6 (generally unresolved) and 11.3 µm.

3) The LRS instrument being a slitless prism spectrograph, wavelength resolution varies with wavelength and with the angular extent of the source and the wavelength scale may be somewhat displaced depending on the brightness distribution over the source.

RESULTS

IR emission bands form a spectrum of features at 3.3 + 3.4, 6.2, 7.7, 8.6 and 11.3 µm which appear together in a variety of objects (see e.g. Cohen et al. 1986 and references herein). These features are generally attributed to a mixture of Polycyclic Aromatic Hydrocarbons (PAH): Léger and Puget (1984). Usually the observations with a single instrument do not cover the whole spectrum and one must combine observations made in various ways, resulting in a variable signal-to-noise ratio for a single source. The LRS include the 7.7 µm feature (on the edge of the spectra), the 8.6 µm one (often unresolved from the previous one) and the 11.3 µm band. Examples are shown on Fig. 1 for one PN (BD+30°3639, Fig. 1a), one PPN (HR 4049, Fig.1b, see Waelkens et al. 1987) and two H II regions: G312.112 (Fig. 1c), not in the LRS Atlas, is a typical spectrum with PAH emission while G329.353 (Fig. 1d) shows strong silicate absorption and apparently no PAH emission. The interpretation of this sort of objects at the shortest wavelengths may be ambiguous but there is no feature at 11.3 μm. Either there are no PAHs or their emission is very absorbed. There are only 2 certain H II regions without PAH emission and without silicate absorption. Both are of high excitation and deserve further attention.

We have added to our sample objects with PAH emission detected by other observers (the list of references is too lengthy to be given here). It should be remarked that higher-resolution spectra such as those of Roche ad Aitken (1986 and references herein) are more sensitive than LRS, but much less objects have been observed.

Provisional results are given in the following Table 1. Information on C/O ratios and exciting stars of PNs is mainly from Zuckerman and Aller (1986).

TABLE 1

STATISTICS FOR H II REGIONS

Certain H II regions	with certain PAH emission..................	83
	with possible PAH emission.................	31
	without PAH but strong silicate absorption.	14
	without PAH, without silicate absorption...	2
	Total...	130
Objects of unknown nature (many being probably H II regions)		
	with certain PAH emission..................	34
	with possible PAH emission.................	13
	without PAH but strong silicate absorption.	15
	without PAH, without silicate absorption...	3
	Total...	65

Note: strong silicate absorption may mimic or hide PAHs on LRS

STATISTICS FOR PNs AND PPNs

Carbon-rich, or ionized by a WC star		
	with certain PAH emission..................	15
	with possible PAH emission.................	5
	C/O>1, no detected PAHs (NGC 6543 and 6884)	2
	Total...	22
Oxygen-rich	certain PAH emission (NGC 6302)............	1
	possible PAH emission......................	3
	Total...	4

Notes to Table 1

CRL 618 = AFGL 618, in a transition stage from PPN to PN, is a carbon-rich object (from chemistry) showing rather surprisingly silicate emission. We class it as an object with possible PAH emission as a marginal emission at 3.3 and 6.2 μm can be seen on Fig. 1 of Russell et al. (1978). The good LRS shows no PAH feature. Radio continuum and recombination-line emission have been detected and there are fast increases in the continuum flux (Martin-Pntado et al. 1988). It may be that PAHs, if really absent, have not had time to form or to be excited by UV photons. Further observations of this fascinating object are clearly needed.

NGC 6302 is a type-I PN which has been consistently classed as carbon-rich (C/O > 1): see Zuckerman and Aller (1986). However as discussed by Roche and Aitken (1986) the value of C/O may be suspect in view of the very high range of ionizations which goes from Ne II to Ne VI. On the other hand it shows OH maser emission (Payne et al. 1988) which tends to confirm a low C/O ratio. This object clearly deserves further studies.

The 3 oxygen-rich objects with possible PAH emission are NGC 2440, 3242 and Hb 12. The only evidence for PAHs is the 3.3 μm emission reported by Martin (1987). There is no visible accompanying 3.4 μm emission and we suspect that one may be dealing with Pfδ rather than PAH emission.

CONCLUSIONS

From Table 1 and the previous discussion we can reach conclusions which although not really new (see e.g. Barlow, 1983, Cohen et al. 1986, Roche and Aitken, 1986, Zuckerman and Aller, 1986) are based upon a substantially increased data base, especially for the 7.7 μm feature which cannot be observed from the ground.

1) "PAH" emission is ubiquitous. It obviously requires the presence of UV photons and is seen near essentially all H II regions (presumably at the interface with neutral gas). This confirms the ubiquity of PAHs in the general interstellar medium.

2) In PNs and PPNs, "PAH" emission is seen only where an ionizing flux is present (for PPNs) and in carbon-rich objects, with the remarkable possible exception of NGC 6302. Most objects with C/O>1 show PAH emission: there are only 2 clear exceptions. Clearly carbon-rich evolved stars are sites for the formation of PAHs.

3) We confirm the existence of important variations in the 7.7/11.3 μm band intensity ratio first discussed by Cohen et al. (1986).

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