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Polycyclic aromatic nitrogen heterocycles in starburst-dominated galaxies

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Abstract. Analyses of the polycyclic aromatic hydrocarbon (PAH) features profiles, especially the 6.2 and 7.7 μm features, could indicate the presence of nitrogen incorporated to their rings. For this work, 155 galaxies (starburst-dominated, in general), extracted from the Spitzer/IRS ATLAS project, have their 6.2 μm profiles fitted and distributed into the Peeters' classes. 67% of these galaxies were classified as class A objects which have only been explained by carbon replaced by nitrogen into the aromatic rings. Therefore, these spectra suggest a significant presence of PANHs (polyciclic aromatic nitrogen heterocycles) in the astrophysical environments of these galaxies that could be related to their starburst-dominated emission. To compare and complement these findings the same procedure is been applied to the 7.7 and 8.6 μm features.

Resumo. Análises dos perfis de bandas de hidrocarboneto policíclico aromático (PAH), especialmente as características de 6.2 e 7.7 μm, podem indicar a presença de nitrogênio incorporado aos seus anéis. Para este trabalho, 155 galáxias (*starburst-dominated*, em geral), extraídas do Spitzer/IRS ATLAS project, tiveram seus perfis de 6.2 μm ajustados e distribuídos nas classes de Peeters. 67% destas galáxias foram classificadas como objetos classe A, que só foram explicados pelo carbono substituído por nitrogênio nos anéis aromáticos. Portanto, esses espectros sugerem uma presença significativa de PANHs (heterociclos policíclicos aromáticos nitrogenados) nos ambientes astrofísicos dessas galáxias que poderia estar relacionada à emissão dominada por *starbursts*. Para comparar e complementar essas descobertas, o mesmo procedimento foi aplicado aos perfis de 7.7 e 8.6 μm.

Keywords. infrared: galaxies – ISM: molecules – astrobiology

1. Introduction

Analyses of the polycyclic aromatic hydrocarbon (PAH) feature profiles could indicate the presence of nitrogen incorporated to their rings. For this work, 155 starburst-dominated galaxies extracted from the Spitzer/IRS ATLAS project (Hernán-Caballero & Hatziminaoglou 2011) have their 6.2, 7.7 and 8.6 μm profiles fitted allowing the separation of the sources into the Peeters' A, B and C classes (Peeters et al. 2002). Currently class A sources, corresponding to a central wavelength near 6.22 μm, seems only to be explained by polycyclic aromatic nitrogen heterocycles (PANH, Hudgins, Bauschlicher & Allamandola 2005), whereas class B may represent a mix between PAHs and PANHs emissions. PANHs could provide the missing link between the abundant PAHs chemistry at the interstellar medium and the nucleobases that compose all living beings.

Since 6.2 and 7.7 μm bands are both caused by the CC stretching vibrational mode, they are connected to each other in some cases, mainly for class A (van Diedenhoven et al. 2004). This association could furnish another strategy for deriving the variations of the 6.2 μm band in an indirect way. It is also possible to use the 8.6 μm band (CH mode) to compare the results.

2. Methods

Our main goal is to verify the presence of PANH molecules in starburst-dominated galaxies using the 6.2, 7.7 and 8.6 μm PAH bands. Firstly, the spectral contributions of the silicate absorption and the line emissions were subtracted from the spectra using PAHFIT (Smith et al. 2007). The continuum was fitted with a spline following the same method of Peeters et al. (2017) and was also subtracted from the spectra.

Table 1. Profile peak positions for each Peeters' classes.

Class	6.2 μm	7.7 μm	8.6 μm
A	< 6.23	~ 7.6	< 8.6
B	6.23 < λ < 6.29	~ 7.8	> 8.6
C	> 6.29	~ 8.22	——

We constructed a python based script to estimate the profile features through the submodule scipy.optmize.curve_fit. The separation of the sources into the classes followed the Tab.1. The 7.7 μm band presents both 7.6 and 7.8 μm features and we used their flux ratio to distinguish between classes A and B (for class A, $F_{7.6}/F_{7.8}>1$).

3. Results

Considering the 6.2 μm band, 67% of 155 galaxies were classified as class A, 31% were as class B and 2% as class C (Fig. 1, Canelo et al. submitted). Therefore, these spectra suggest a significant presence of PANHs in the ISM of the galaxies which could be related to their starburst-dominated emission. These results could also indicate another reservoir of nitrogen in the Universe, with density and temperature conditions different from those of gas phase and ices.

The class A objects are the most common in the Universe, as Pino et al. (2008) have already noticed. And we can see a correlation along the bands in some galaxies: more than one profile was classified as class A. This is more evident for the 6.2 and 7.7 μm bands, as expected because of the same CC vibrational mode. On the other hand, the 8.6 μm band is less connected than

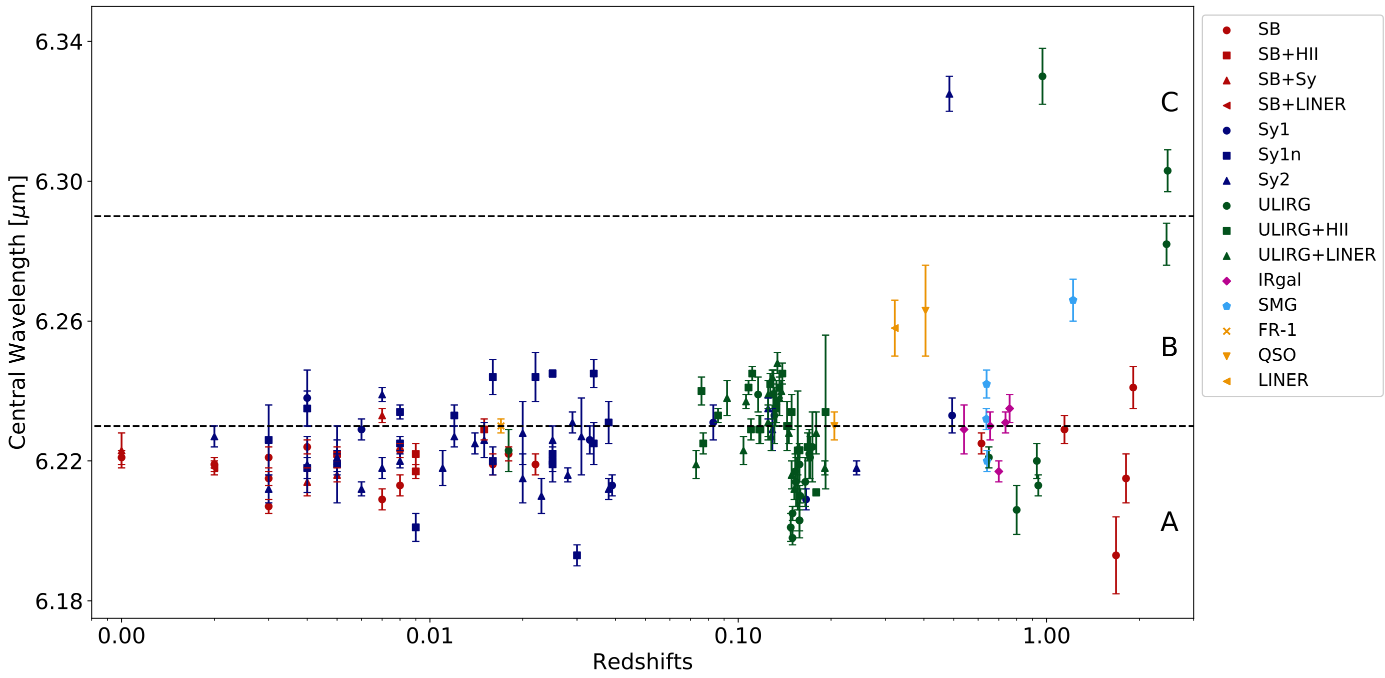

Figure 1. Distribution of the central wavelengths of the 6.2 μm band according to the redshift of the galaxies (Canelo et al. submitted). The dashed lines are the limits among the Peeters' classes, indicated also by A, B or C letter. Acronyms: AGN — Active Galactic Nucleus, FR — Fanaroff-Riley galaxy, HII — HII region, IRgal — Infrared galaxy, LINER — Low-Ionization Nuclear Emission-line Region, QSO — Quasi-Stellar Object, SB — Starburst galaxy, SMG — Submillimeter Galaxy, Sy — Seyfert galaxy, ULIRG — Ultra-Luminous Infrared Galaxy.

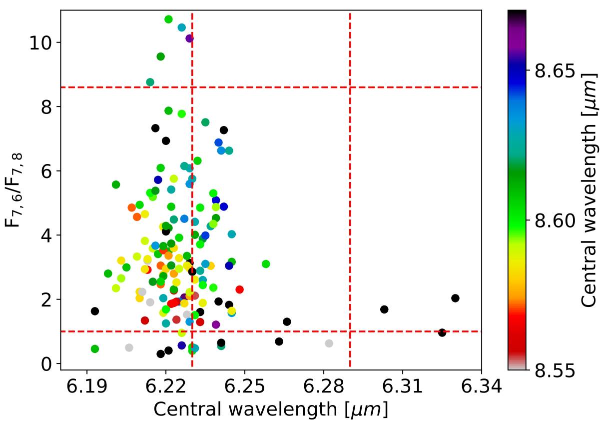

Figure 2. Colormap comparing the separation of the sources into the Peeters' class for the three analyzed PAH bands. The dashed lines are the limits among the Peeters' classes.

the others. Fig. 2 shows the comparison of the Peeters' classes separation for the 6.2 μm band and the preliminary results of the 7.7 and 8.6 μm bands.

4. Conclusions and perspectives

This study suggests that the ubiquity of PANHs could indicate that they are responsible for an important fraction of the mid-infrared emission, especially for the 6.2 μm band. These findings also give support to the idea of their contribution to the origins of life on Earth and elsewhere, since they could form nucleobase-type structures in the ISM (Elsila et al. 2006; Parker et al. 2015).

From an astrochemical perspective, metallicity and cosmic abundance variations may also be significant in ways not currently understood. Computational capabilities together with experimental measurements need to be further addressed to better determine PANHs vibration frequencies mainly in the galaxy environment.

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