

Study of dust extinction on PAH emission in starburst galaxies

V. N. Avelaneda¹, D. A. Sales¹, C. M. Canelo¹, J. C. Fischer¹, & E. R. Ruiz¹

¹ Institute of Mathematics, Statistics and Physics, Federal University of Rio Grande, 96203-900, RS, Brazil.
e-mail: avelaneda.vitor@gmail.com

Abstract. This study investigates the effects of dust extinction on the emissions of Polycyclic Aromatic Hydrocarbons (PAHs) in starburst galaxies. Using a sample of 21 galaxies from the IDEOS/Spitzer database, we synthetically modeled the impact of attenuation in the mid-infrared (MIR) by applying the extinction curve of HD20 with optical depths (τ_{sil}) ranging from 0 to 5. A severe suppression of PAH bands is revealed by spectral decomposition with the PAHFIT code, particularly at $8.6 \mu\text{m}$ and $11.3 \mu\text{m}$ (with reductions of up to 95% for $\tau_{sil} = 5$). Critically, the $11.3/7.7 \mu\text{m}$ ratio decreases with increasing extinction, falsely simulating high ionization states and apparent changes in molecular size. We conclude that robust extinction corrections are essential for accurate diagnostics of the physical and chemical properties of PAHs in dense environments, recommending the use of alternative ratios that are less sensitive to attenuation.

Resumo. Este estudo investiga os efeitos da extinção por poeira nas emissões de Hidrocarbonetos Aromáticos Policíclicos (PAHs) em galáxias starburst. Utilizando uma amostra de 21 galáxias da base de dados IDEOS/Spitzer, modelamos sinteticamente o impacto da atenuação no infravermelho médio (MIR) aplicando a curva de extinção de HD20 com profundidades ópticas (τ_{sil}) variando de 0 a 5. Uma severa supressão das bandas de PAH é revelada pela decomposição espectral com o código PAHFIT, particularmente em $8.6 \mu\text{m}$ e $11.3 \mu\text{m}$ (com reduções de até 95% para $\tau_{sil} = 5$). De forma crítica, a razão $11.3/7.7 \mu\text{m}$ diminui com o aumento da extinção, simulando falsamente altos estados de ionização e aparentes mudanças no tamanho molecular. Concluímos que correções de extinção robustas são essenciais para diagnósticos precisos das propriedades físicas e químicas dos PAHs em ambientes densos, recomendando o uso de razões alternativas menos sensíveis à atenuação.

Keywords. ISM: molecules – Galaxies: starburst – Galaxy: nucleus

1. Introduction

Astrophysical dust, composed of silicates, carbonaceous grains, and PAHs, plays a crucial role in the interstellar medium (ISM) by absorbing stellar radiation and re-emitting energy in the mid-infrared (MIR) (Salim & Narayanan 2020). In Starburst galaxies, PAH emissions can account for up to 50% of the total luminosity (Li 2004), providing important diagnostics of the physicochemical state of the ISM (Draine & Li 2001). Spectral ratios, such as $11.3/7.7 \mu\text{m}$, have been used to infer the degree of molecular ionization (Gordon et al. 2008; Smith et al. 2007; Sales et al. 2010, 2011, 2013, 2015), but extinction — particularly due to silicate absorption at $10 \mu\text{m}$ — may compromise these interpretations (Hernán-Caballero et al. 2020; Lai et al. 2024). In this work, synthetic spectral models were developed to analyze the impact of extinction on PAH emissions in Starburst galaxies, and the limitations of traditional diagnostics in highly obscured environments were highlighted.

2. Methodology

2.1. Sample selection

The spectral sample of 21 starburst-dominated galaxies was selected from the IDEOS/Spitzer database (Spoon et al. 2022), which comprises more than 3000 MIR observations. Three main criteria were applied to ensure data quality and to select galaxies with starburst-dominated emission:

- **MIDIRCLASS = 1C:** This classification, based on the “fork” diagram (Spoon et al. 2007), selects galaxies whose MIR emission is dominated by starburst activity.

- **SILSTRENGTH** between -0.15 and 0 : This criterion targets galaxies with silicate absorption at $9.7 \mu\text{m}$, indicative of low dust extinction.
- **SNR66** and **SNR24** ≥ 30 : This ensures a high signal-to-noise ratio in the spectral regions of the main PAH emissions, thus guaranteeing data quality.

2.2. Spectral decomposition

The pahfitMCMC tool (Gallimore et al. 2010; Gleisinger et al. 2020), a variation of the PAHFIT code (Smith et al. 2007), was applied to decompose the spectra into their components, separating PAH fluxes, dust continuum, and emission lines from atomic and rovibrational molecular hydrogen. The code employs the Markov Chain Monte Carlo (MCMC) method for robust parameter estimation, enabling the calculation of fluxes, equivalent widths, and silicate indices, together with their associated uncertainties, from samples of the probability distribution.

2.3. Synthetic spectrum of the sample

The sample was decomposed, and all spectral components were normalized by the continuum flux at $23 \mu\text{m}$. A synthetic spectrum was then constructed, using the average values of each attenuation-free component (continuum, PAH, and lines; see Figure 1) to represent the galaxy sample.

2.4. Extinction modeling

The extinct flux (F_v^{ext}) was modeled following Canelo et al. (2021) by applying the HD20 (Hensley & Draine 2020) extinction curve — which was observed toward the luminous blue hypergiant Cyg OB2-12 and shares characteristics with the dif-

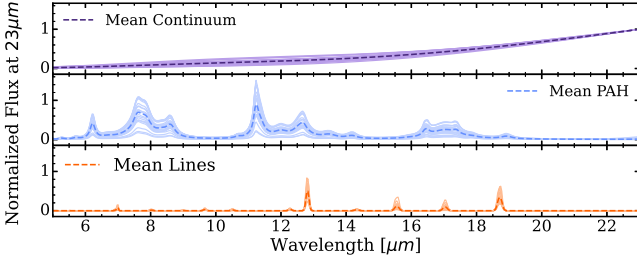


FIGURE 1. Attenuation-Free Average of Sample Components (Continuum, PAHs, and Lines).

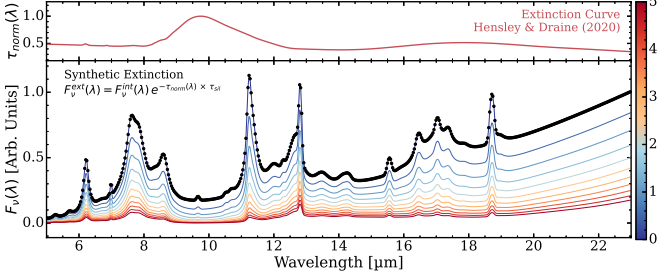


FIGURE 2. In the upper panel, the HD20 extinction curve is highlighted in red. In the lower panel, the attenuated spectra (solid lines color-coded by τ_{sil}) are shown together with the synthetic sample spectrum (black points).

fuse interstellar medium — to the synthetic spectra (F_{ν}^{int}) in a dust screen geometry. This approach simulated obscuration scenarios ranging from $\tau_{sil} = 0.0$ to 5.0, as illustrated in Figure 2.

3. Results

The results reveal a pronounced suppression of PAH bands with increasing silicate optical depth (τ_{sil}). As illustrated in Figure 3, the intensities of the 8.6 μm and 11.3 μm bands are reduced by up to 95%, while the bands near 17 μm exhibit reductions of approximately 10%. In contrast, the 6.2 μm band shows variations below 5%, and the 12.7 μm band displays almost negligible variation at $\tau_{sil} = 5$. Furthermore, the results show that from $\tau_{sil} \approx 3$ onward, the attenuation regime becomes more pronounced, particularly for the bands located farther from the 9.7 μm silicate profile.

Figure 4 shows that an increase in τ_{sil} leads to a systematic decrease in the 11.3/7.7 μm ratio, potentially resulting in a misinterpretation of a higher degree of PAH ionization, particularly due to the strong impact of extinction on the 11.22 μm feature. Complementarily, the decrease in the 6.2/7.7 μm ratio suggests a change in molecular size, indicating the predominance of larger molecules under higher extinction conditions. These results highlight the limitations of traditional diagnostic diagrams in optically thick environments, where extinction effects obscure the intrinsic properties of PAHs.

4. Conclusions and perspectives

In conclusion, high extinction levels can significantly interfere with spectral ratios, compromising physico-chemical analyses in dense regions. This emphasizes the need for robust extinction corrections and the adoption of alternative ratios (e.g.,

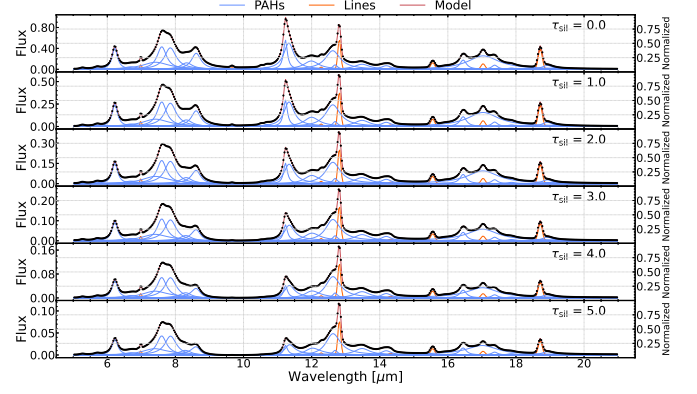


FIGURE 3. Spectral decomposition using pahfitMCMC for different τ_{sil} scenarios. The components shown in the figure have been continuum-subtracted.

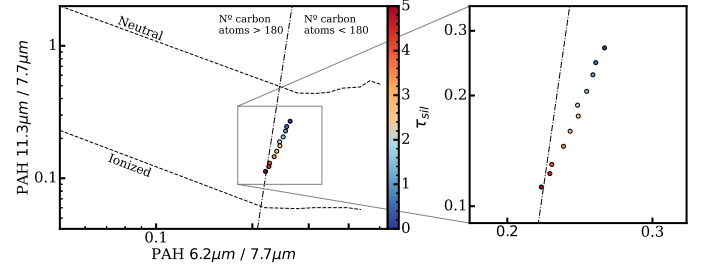


FIGURE 4. Diagnostic diagram of PAH ratios. Symbols represent the sample objects, color-coded according to τ_{sil} . Theoretical lines indicate neutral/ionized PAHs (Draine & Li 2001) and molecular size (180 carbon atoms).

12.7/11.2 μm), that are less sensitive to attenuation. These findings reinforce the importance of integrating extinction models into spectral analyses to enhance accuracy in studies of star formation and galactic evolution in obscured environments.

Acknowledgements. The authors would like to thank the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES) – Financial Code 001, the Research Support Foundation of the State of Rio Grande do Sul – Brazil (FAPERGS) and the National Council for Scientific and Technological Development - Brazil (CNPq).

References

- Canelo, C. M., et al. 2021, MNRAS, 507, 6177
Draine, B. T. & Li, A. 2001, ApJ, 551, 807
Gallimore, J. F., et al. 2010, ApJS, 187, 172
Gleisinger, R. C., et al. 2020, ApJ, 905, 42
Gordon, K. D., et al. 2008, ApJ, 682, 336
Hensley, B. S. & Draine, B. T. 2020, ApJ, 895, 38
Hernán-Caballero, A., et al. 2020, MNRAS, 497, 4614
Lai, T. S.-Y., et al. 2024, ApJ, 967, 83
Li, A. 2004, ASP Conf. Ser., 309, 417
Salim, S. & Narayanan, D. 2020, ARA&A, 58, 529
Sales, D. A., et al. 2010, ApJ, 725, 605
Sales, D. A., et al. 2011, ApJ, 738, 109
Sales, D. A., et al. 2013, MNRAS, 429, 2634
Sales, D. A., et al. 2015, ApJ, 799, 25
Smith, J. D. T., et al. 2007, ApJ, 656, 770
Spoon, H. W. W., et al. 2007, ApJL, 654, L49
Spoon, H. W. W., et al. 2022, ApJS, 259, 37