Unveiling the Aromatic and Aliphatic Universe with JWST NIRCam/WFSS

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Introduction: A New View of PAHs with JWST

- Polycyclic Aromatic Hydrocarbon (PAH) molecules are ubiquitous and serve as key tracers of star formation (SFR) and galaxy evolution.
- The 3.3 μm (aromatic C-H stretch) and 3.4 μm (aliphatic C-H stretch) emission bands provide critical insights into PAH chemistry, structure, and processing.
- Before JWST, studies of these features were limited to bright ($L_{IR} \geq 10^{11} L_\odot$), local ($z \leq 0.1$) galaxies.
- The sensitivity of JWST's NIRCam/WFSS allows us, for the first time, to survey these features in statistically significant, less-biased samples of fainter galaxies ($L_{IR} \sim 10^{8.5} - 10^{10} L_\odot$) at $z \sim 0.2 - 0.5$.

Data, Sample, and Analysis

- **Data:** JWST/NIRCam Wide-Field Slitless Spectroscopy (WFSS) from the Cycle 1 FRESCO legacy program (Oesch+2023). This provides $R \sim 1600$ spectra covering $3.8 - 5.0$ μm.
- **Sample:** 200 galaxies at $z \sim 0.2 - 0.5$ within the GOODS-S and GOODS-N fields.
- **Analysis:** We fit the 3.3 μm aromatic and 3.4 μm aliphatic features using Drude profiles. We use extensive ancillary data (HST, Spitzer, etc.) and SED fitting (Prospector) to derive galaxy properties (L_{IR}, SFR, M_*, metallicity).

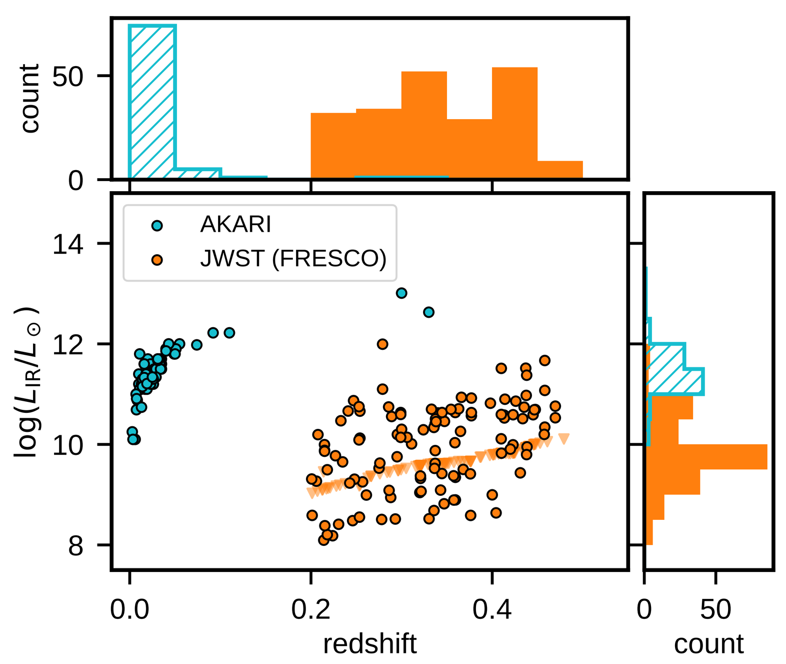

Figure 1 Our JWST/FRESCO sample (orange) probes galaxies ~100-1000x fainter than previous AKARI samples (blue) at $z > 0.1$.

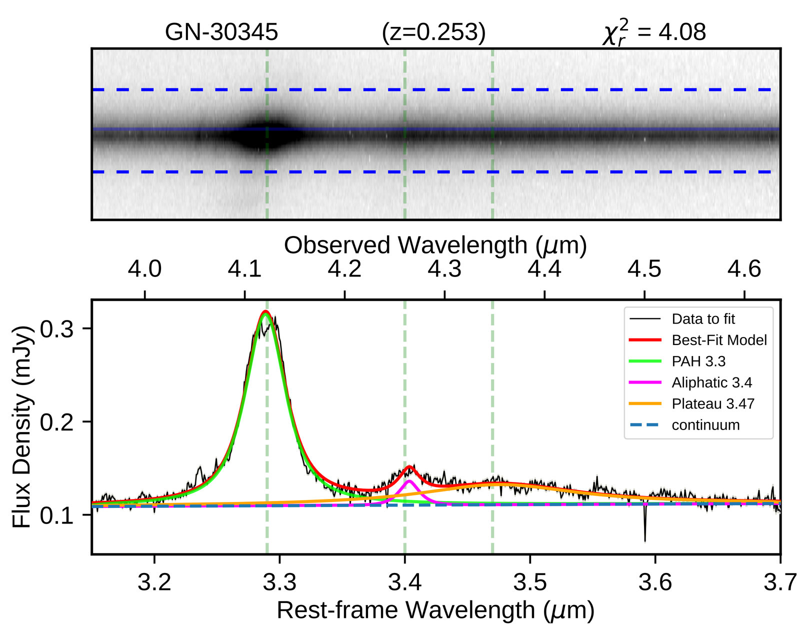

Figure 2 Example NIRCam/WFSS spectrum of a galaxy (GN-30345 at $z = 0.253$) showing clear detections of the 3.3 μm (green) and 3.4 μm (magenta) features.

The 3.3 μm Aromatic Band: A Robust SFR Tracer

The 3.3 μm aromatic feature ($L_{3.3}$) was detected in 88/187 galaxies.

- $L_{3.3}$ shows a tight correlation with total IR luminosity (L_{IR}) (Pearson $r \approx 0.71$) and SED-derived SFR.
- This confirms $L_{3.3}$ as a valid SFR tracer across 3 orders of magnitude in L_{IR}.
- We derive a new, robust calibration that coverage SFRs over a range of ~0.1–300 $M_\odot \mathrm{yr}^{-1}$:

$$\log\left(\frac{SFR}{M_\odot yr^{-1}}\right) = \log\left(\frac{L_{3.3}}{L_\odot}\right) - (7.17 \pm 0.32)$$

- This tight correlation establishes the usage of the 3.3 μm PAH feature to infer SFRs in large statistical samples of galaxies across cosmic time.

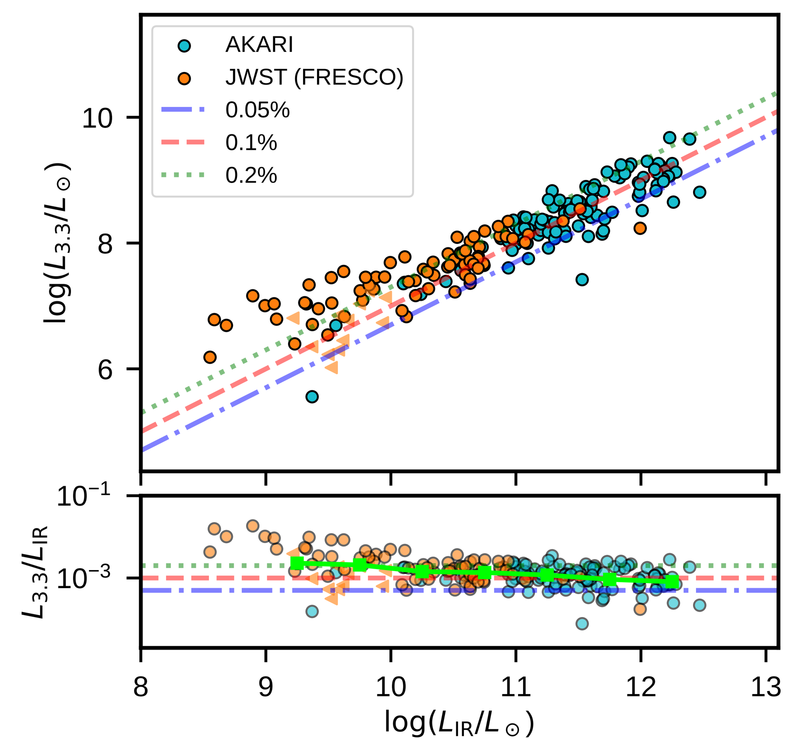

Figure 3 The strong correlation between 3.3 μm PAH luminosity ($L_{3.3}$) and total IR luminosity (L_{IR}).

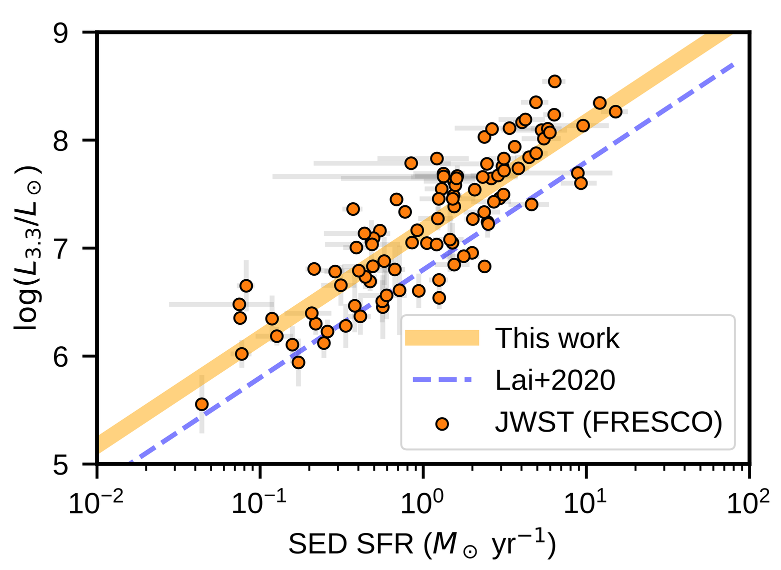

Figure 4 $L_{3.3}$ vs. the SED-derived SFR, showing a tight relationship (orange line is our best fit).

Results: PAH Properties vs. Galaxy Environment

1. Aromatic PAH Deficiency in Low-Metallicity Galaxies

- The relative strength of the 3.3 μm feature ($L_{3.3}/L_{IR}$) shows a **strong metallicity dependence**.
- The ratio drops by a factor of ≥ 10 at $12 + \log(O/H) \sim 8.4 - 8.5$ (toward lower metallicities).
- This is consistent with models where PAHs are either more rapidly destroyed by harder radiation fields or have their formation (from AGB stars) delayed in metal-poor environments.

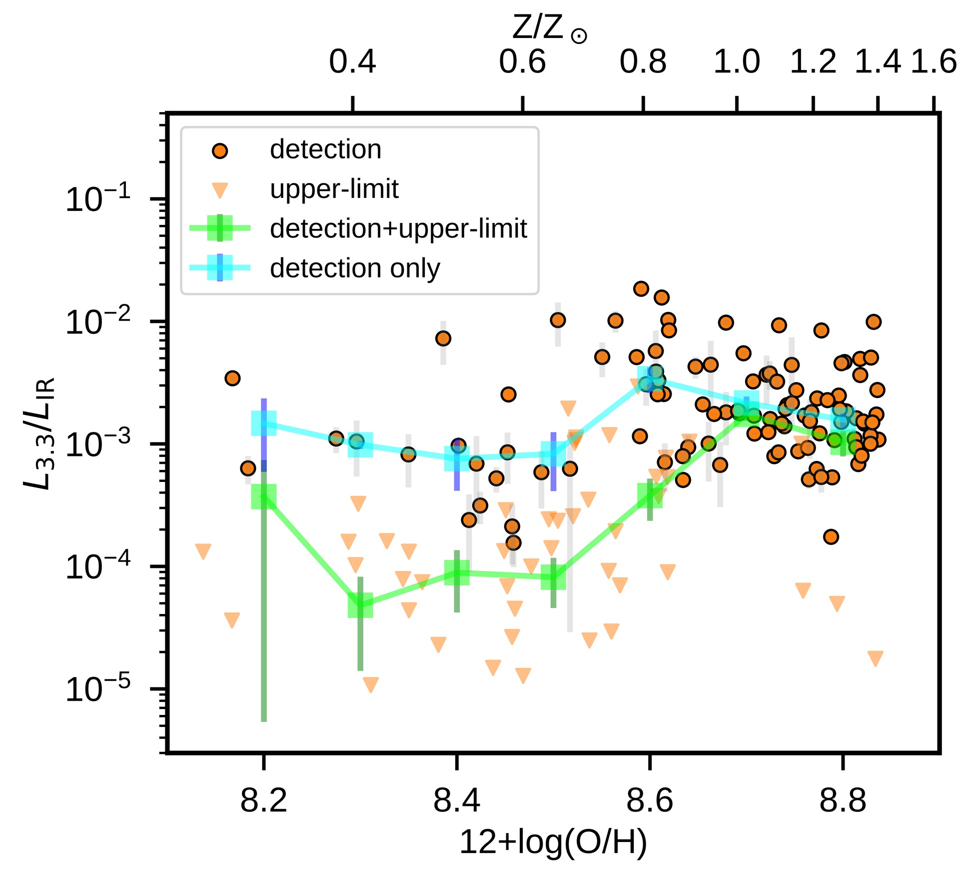

Figure 5 The aliphatic-to-aromatic ratio ($L_{3.4}/L_{3.3}$) *decreases* at higher SFRs, indicating destruction of aliphatic components.

2. Aliphatic (3.4 μm) Content Destroyed by Star Formation

- The weaker 3.4 μm aliphatic feature was detected in 37/159 galaxies.
- The aliphatic-to-aromatic ratio ($L_{3.4}/L_{3.3}$) shows a clear **negative correlation** with SFR, L_{IR}, and $L_{3.3}$.
- **Interpretation:** UV photons from active star-forming regions preferentially strip off or "destroy" the less-stable aliphatic side groups from the core PAH molecules.

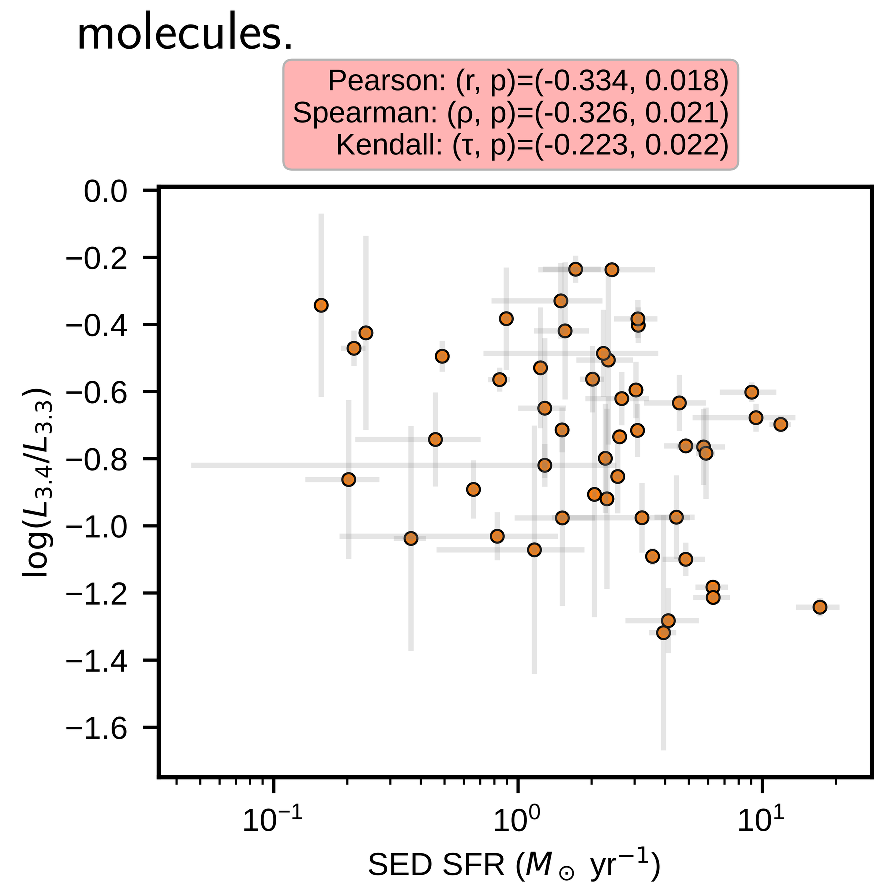

Figure 6 The aliphatic-to-aromatic ratio ($L_{3.4}/L_{3.3}$) *decreases* at higher SFRs, indicating destruction of aliphatic components.

3. PAH Aliphacity: A Local Process

- The $L_{3.4}/L_{3.3}$ ratio shows **no significant correlation** with global properties like redshift, stellar mass, metallicity, or galaxy morphology.
- This strongly suggests that the processing of PAH aliphatic content is governed by **local conditions** (i.e., the local UV radiation field) rather than the global properties of the host galaxy.

Summary & Conclusions

- We present the first systematic survey of 3.3 μm (aromatic) and 3.4 μm (aliphatic) PAH features in a large, unbiased sample of galaxies at $z \sim 0.2 - 0.5$, probing IR luminosities 100x fainter than previous studies.
- We confirm the 3.3 μm PAH feature as a **robust SFR tracer** and provide a new calibration.
- We find that this 3.3 μm emission is **suppressed in low-metallicity galaxies**.
- The aliphatic-to-aromatic ratio ($L_{3.4}/L_{3.3}$) is **anti-correlated with SFR**, suggesting that aliphatic components are destroyed by UV photons in active star-forming regions.
- This processing of aliphatic PAHs appears to be a **local phenomenon**, independent of global galaxy properties like mass or morphology.

References

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