astro-ph seminar 2023.07.12 (大澤)

Spatial variations in aromatic hydrocarbon emission in a dust-rich galaxy

J. S. Spilker et al., 2023, Nature, arXiv: 2306.03152

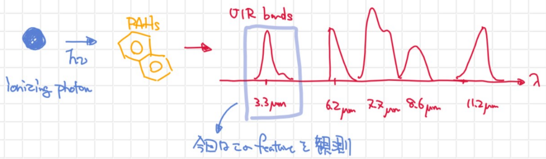
Dust grains absorb half of the radiation emitted by stars throughout the history of the universe, re-emitting this energy at infrared wavelengths[1–3]. Polycyclic aromatic hydrocarbons (PAHs) are large organic molecules that trace millimetre-size dust grains and regulate the cooling of interstellar gas within galaxies[4,5]. Observations of PAH features in very distant galaxies have been difficult owing to the limited sensitivity and wavelength coverage of previous infrared telescopes[6,7]. Here we present James Webb Space Telescope observations that detect the 3.3 μm PAH feature in a galaxy observed less than 1.5 billion years after the Big Bang. The high equivalent width of the PAH feature indicates that star formation, rather than black hole accretion, dominates infrared emission throughout the galaxy. The light from PAH molecules, hot dust and large dust grains and stars are spatially distinct from one another, leading to order-of-magnitude variations in PAH equivalent width and ratio of PAH to total infrared luminosity across the galaxy. The spatial variations we observe suggest either a physical offset between PAHs and large dust grains or wide variations in the local ultraviolet radiation field. Our observations demonstrate that differences in emission from PAH molecules and large dust grains are a complex result of localized processes within early galaxies.

Background

星間空間に存在する芳香族炭化水素 (⊃PAHs)

→ UV を吸収して赤外線バンド放射に効率よく変換する。

→ extinction free な star formation tracer として用いられてきた。



3μm feature は 赤外の SF tracer として比較的波長が短い。

→ JWST の感度があれば high-z の SF tracer としても有効利用できる??

Observation

ターゲット銀河: SPT-S J041839-4751.9 (sub-mm selected, SPT catalog)

z = 4.2248, lensed galaxy (magnified by 30-35)

no merger sign in [CII] 158μm → JWST detected merging companions

metal rich. (comparable to the solar abundance)

観測: MIRI/JWST による面分光観測. (~15-18 μm)

rest frame で 2.95 – 3.45 μm に対応, medium resolution mode.

z = 4.22 の銀河を空間分解して 3.3μm PAH feature を検出.

ALMA の観測と合わせて、以下の成分の空間分布に注目.

- 3.3μm band (PAH)
- 3.1 μm continuum (hot dust)
- 760 μm continuum (large, warm dust)

Fig 1. MRS spectrum

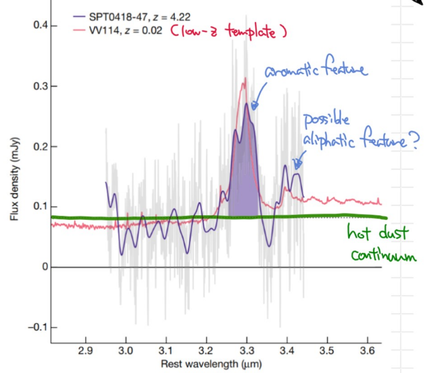
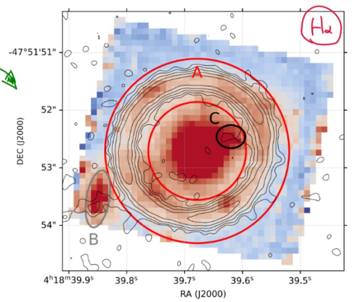


Fig 1. of Peng+(2023)

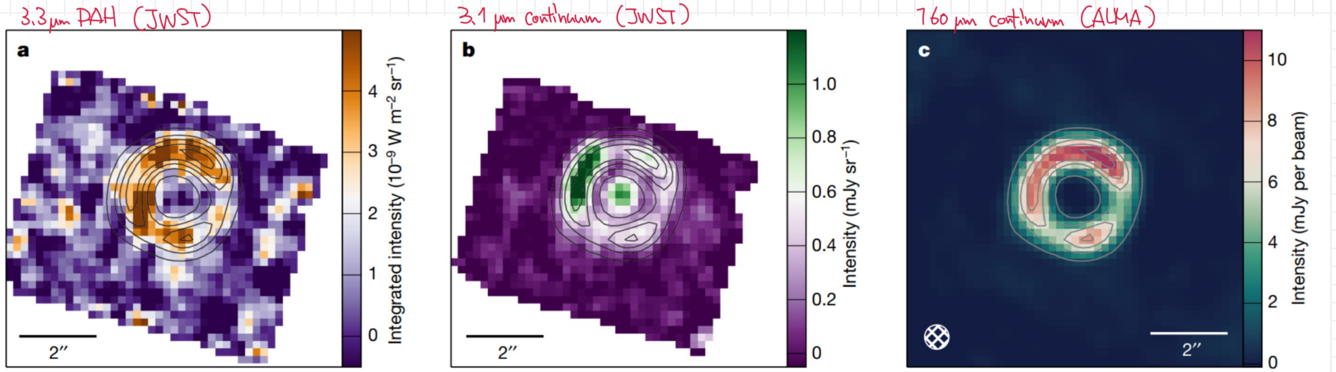


A が SPT 0418-47 本体.

B と C は z = 4.22 にある companion

中心にあるのは前景 (z ~ 0.263) の銀河.

3.3μm PAH (JWST) 3.1 μm continuum (JWST) 760 μm continuum (ALMA)



Contours はいずれも 760 μm flux density を表している.

どの components もそれなりに星形成と関係が深いはずであるが、空間分布が異なっている.

空間分解能を実スケールに直すと 800 pc 程度. (GMC の分解まであと一歩)

3.3μm PAH EW が極端に小さくないので AGN が隠れている可能性は低い (少なくとも dominant ではなさそう)

空間分布に違いが生まれる理由は不明 (UV field or dust abundance?) → high-z & resolved な ケースで 3.3μm が SF tracer として機能するか怪しい

(low-z の empirical law を外挿していることに注意. 空間分解能が低いので効果が見えていない可能性もある.)