Probing the Interstellar Dust of Galaxies at Redshift ~ 0.4 - 0.8 in the AstroSat UV Deep Field

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In collaboration with

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BASIC SCIENCES 1986
1894-1974
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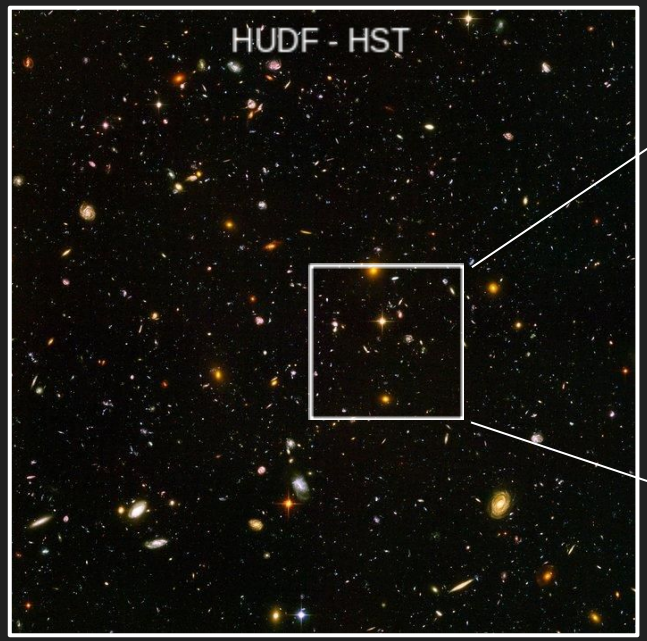
What is a ‘Deep Field’?

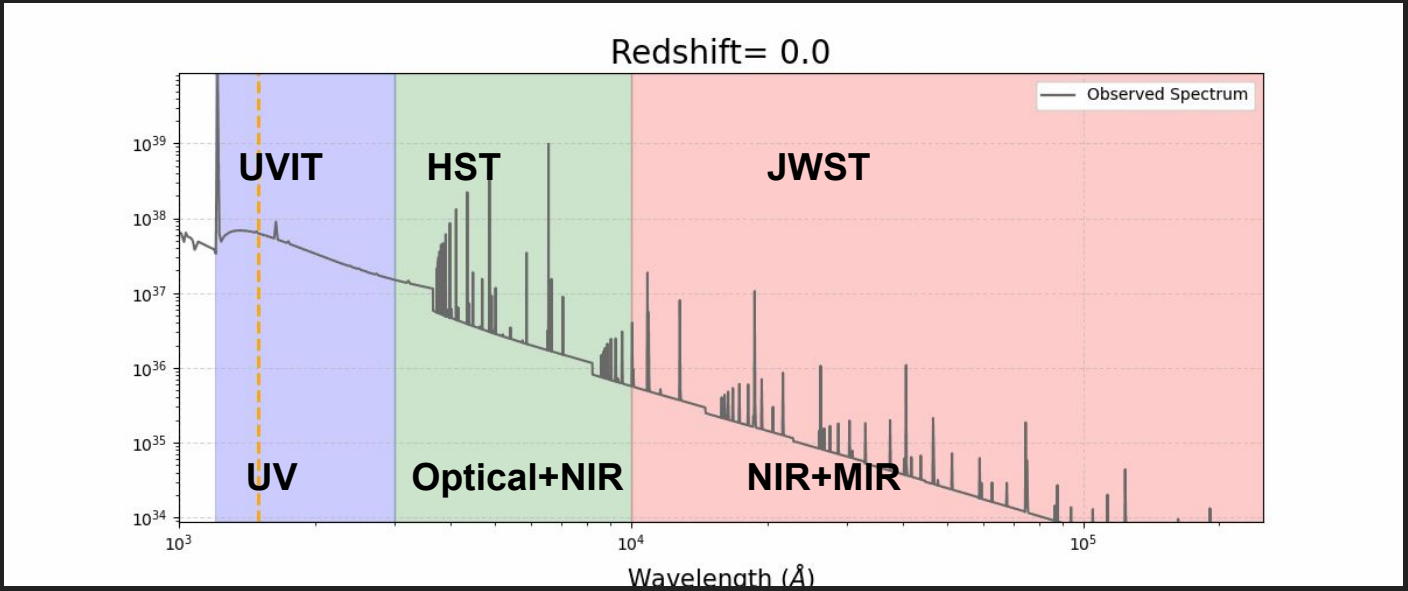
A region of the dark sky that contains very few bright stars and have ample observing time which enables studying faint deep sky objects at different redshifts.

Taking pictures of ‘Nothing’

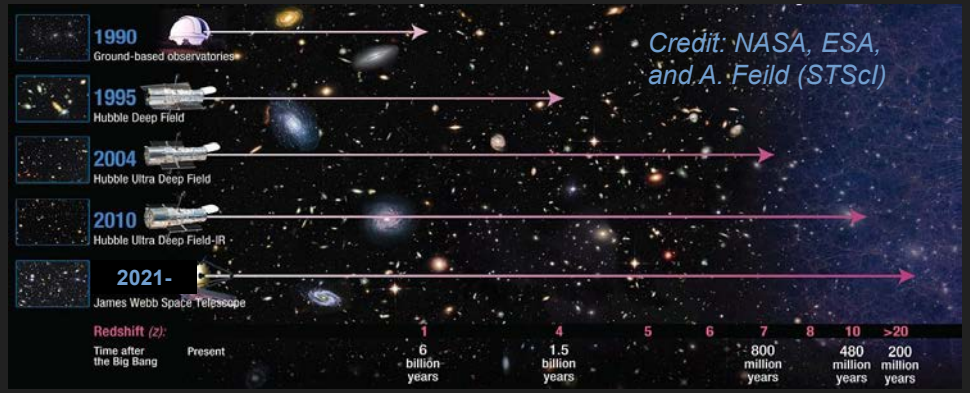


The total amount of exposure time was ~272 hours (400 Hubble orbits)

Credit: NASA, ESA, and S. Beckwith (STScI) and the HUDF Team

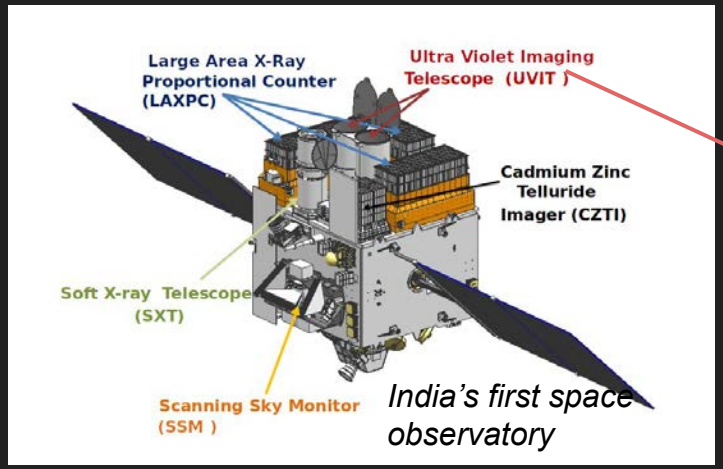


Why multi-band observation?

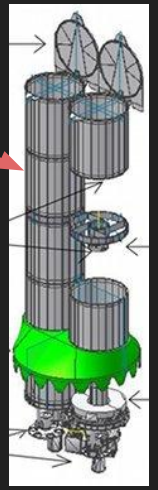


Redshift	wave_emitted	wave_observed
0.5	1500	2250 (UV)
4	1500	7500 (Optical)
10	1500	16500 (Near-IR)
15	1500	24000 (Far-IR)

AstroSat/UVIT – unique instrument to probe UV sky

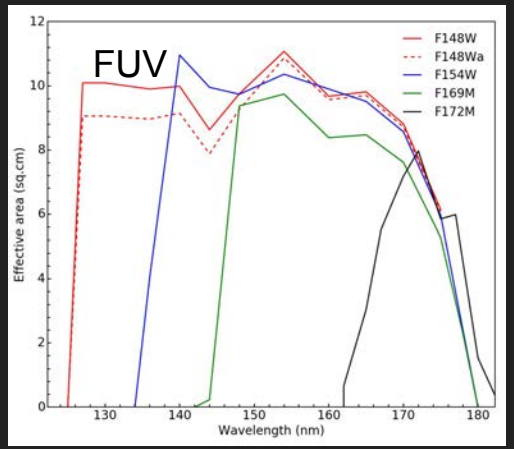


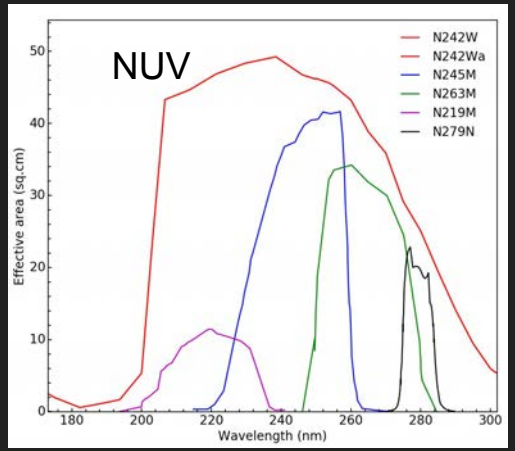
India's first space observatory

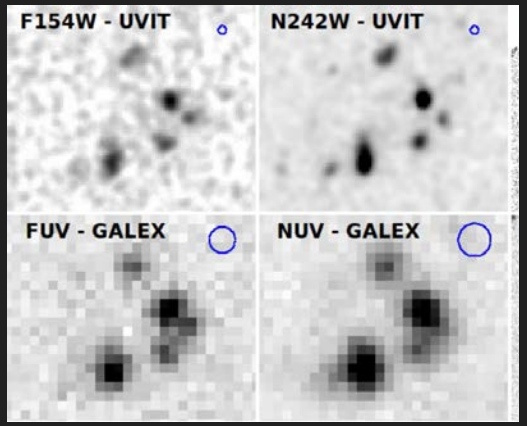


Ultra-Violet Imaging Telescope (UVIT)

- Simultaneous imaging in FUV and NUV
- Multiple filters in FUV and NUV channels
- Angular resolution ~ 1.2 arcsec







Credit: *Tandon et al. 2017, ISRO*

AstroSat UV Deep Fields

2016

GOODS-South (AUDFs)

GOODS-North (AUDFn)

2022

NEP (JWST NEP collaboration)

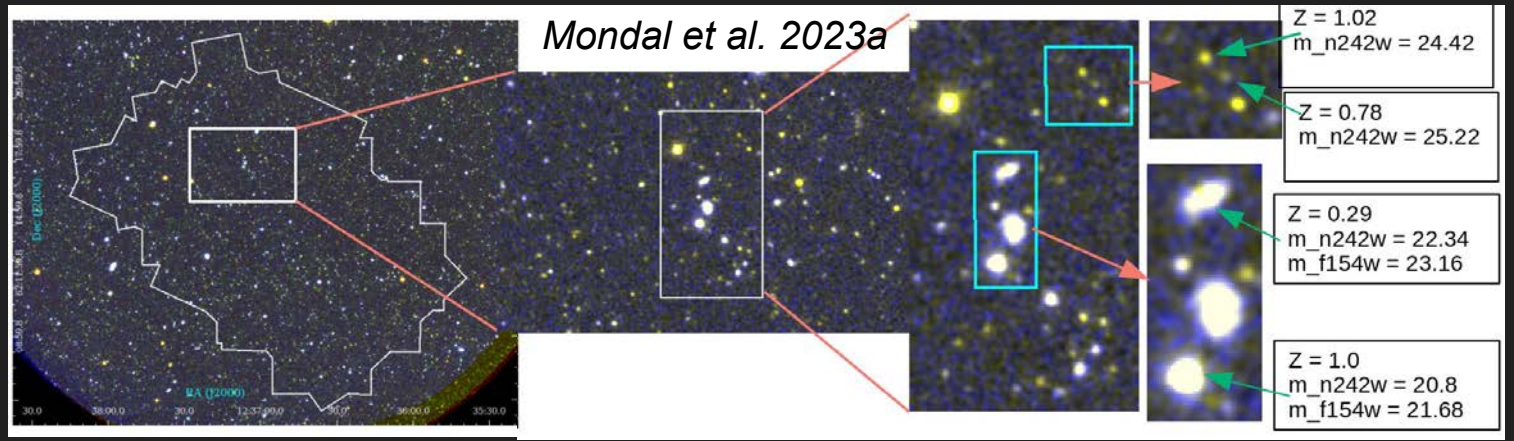
AEGIS

Abell 2744

Abell S1063

2023

MACS J0416.1-2403

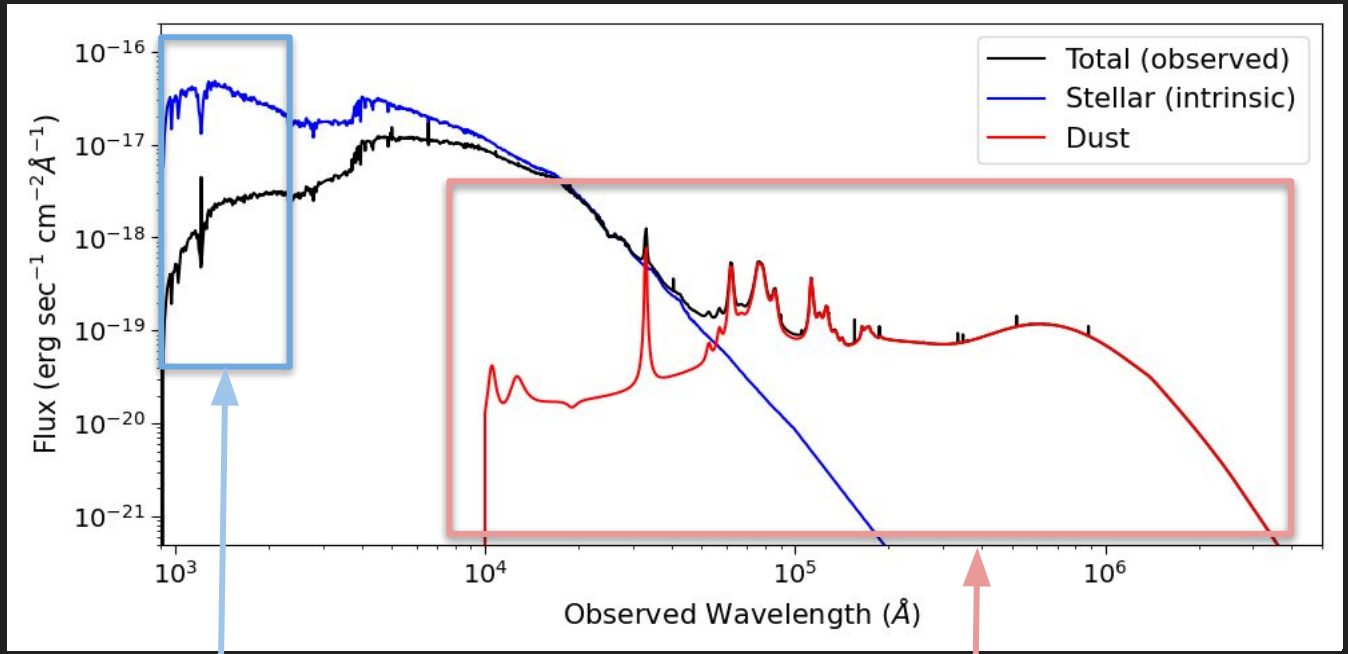


PI: K. Saha

Probing interstellar dust

Interstellar dust contributes only about 1% to the total ISM mass in galaxies

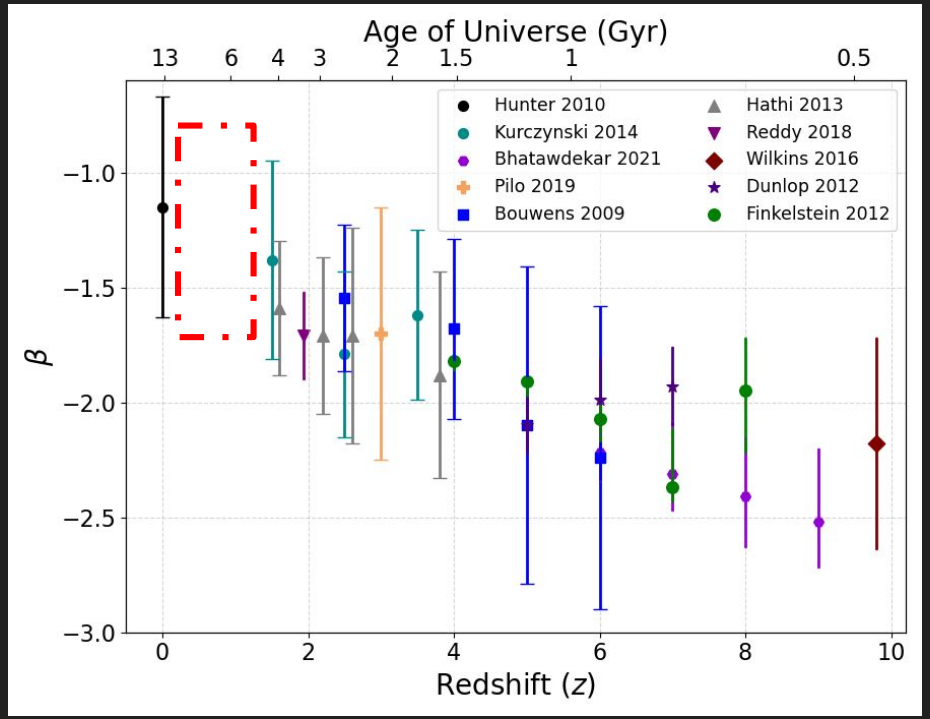
Though, negligible in mass, dust plays outsize role in shaping the galaxy SED that we observe

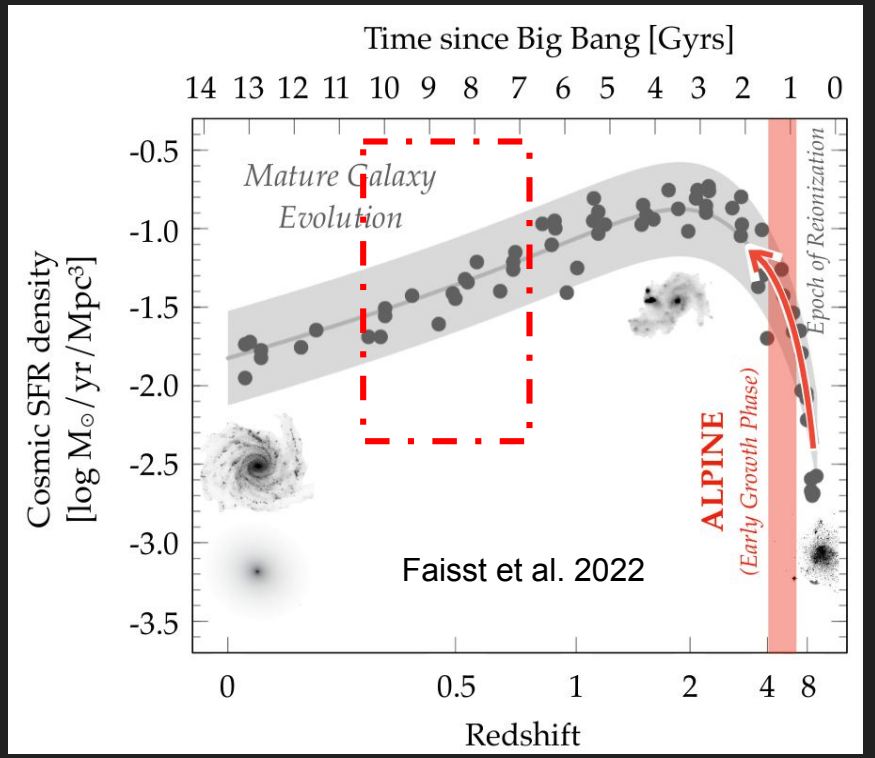


Indirect way of probing dust content in galaxies at higher redshifts

Direct way of probing dust content in galaxies

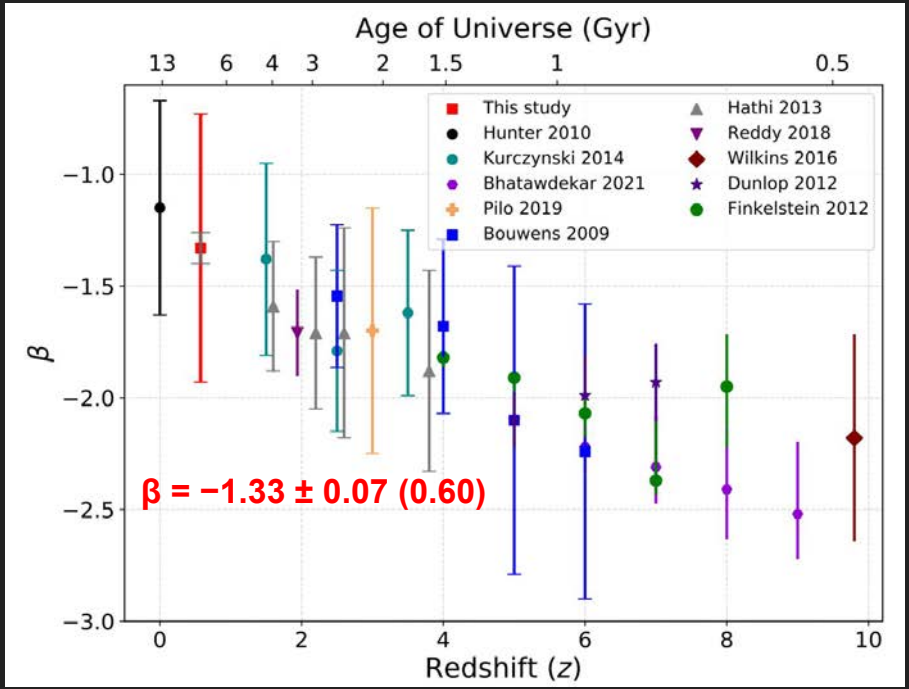
Cosmic evolution of dust extinction





To probe UV continuum at z~0.6, we need deep NUV imaging

Our measurement from 465 UV-selected galaxies at z~0.6



Our measurements fill this gap that connects the cosmic noon to the present day. It further reinforces the gradual reddening of galaxy's UV continuum with cosmic time

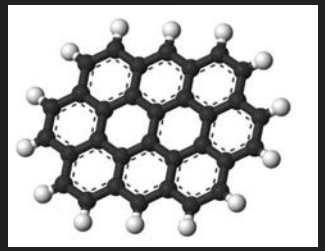
Mondal et al. 2023b

Properties of small dust grains

Polycyclic Aromatic Hydrocarbon (PAH)

What are PAHs?

- Carbon-based smaller dust particles consisting of ~ 10 to a few hundred carbon atoms
- Contribute up to ~ 15% of the total carbon content in galaxies and up to ~5% of the total dust mass



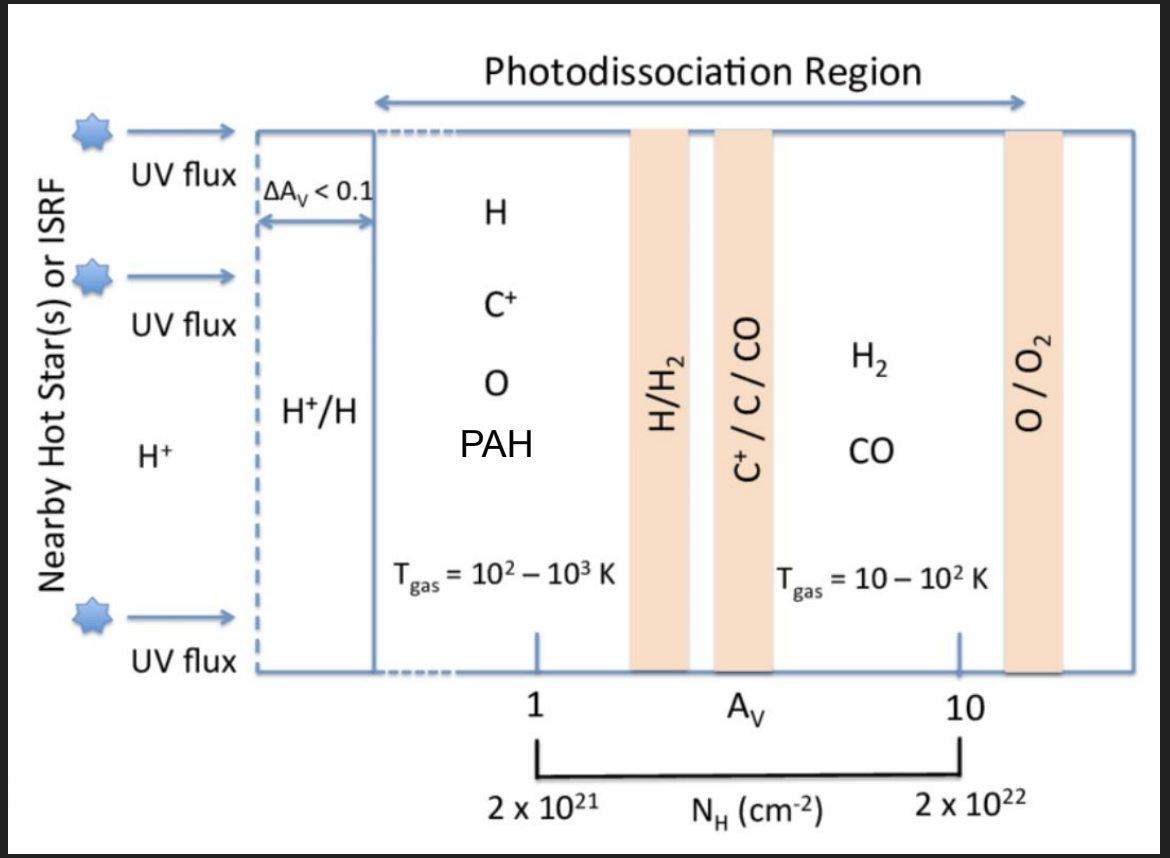
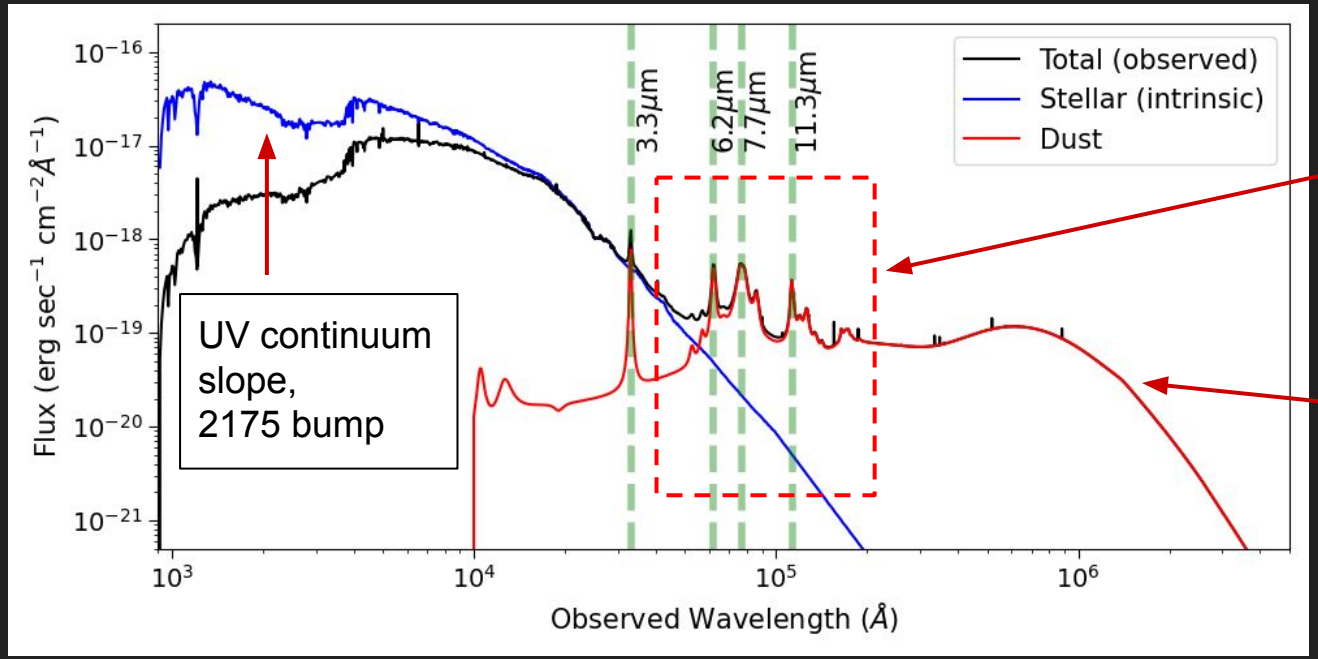


Image credit: Hollenbach & Tielens 1997

PAH emission

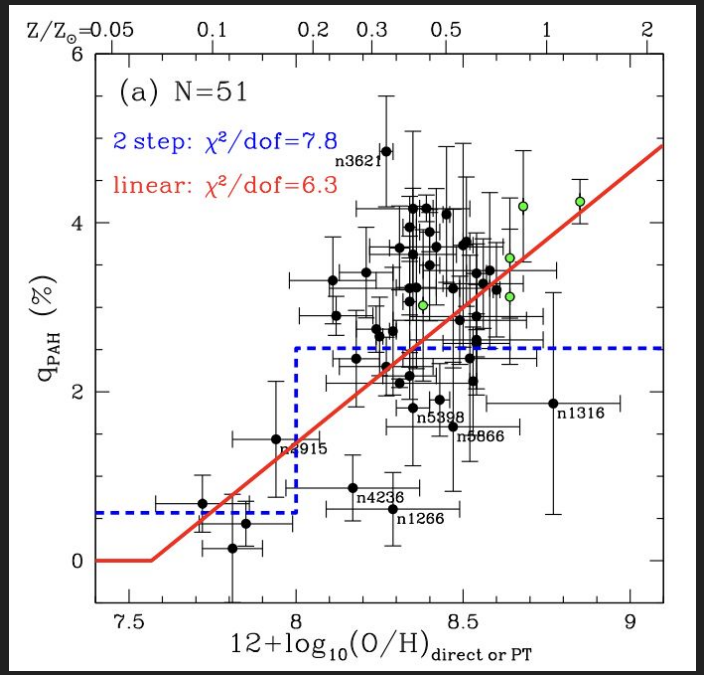


MIR emission features: Single photon stochastic heating of smaller dust particles (eg., PAH)

FIR continuum: Larger grains in thermal equilibrium with the radiation field

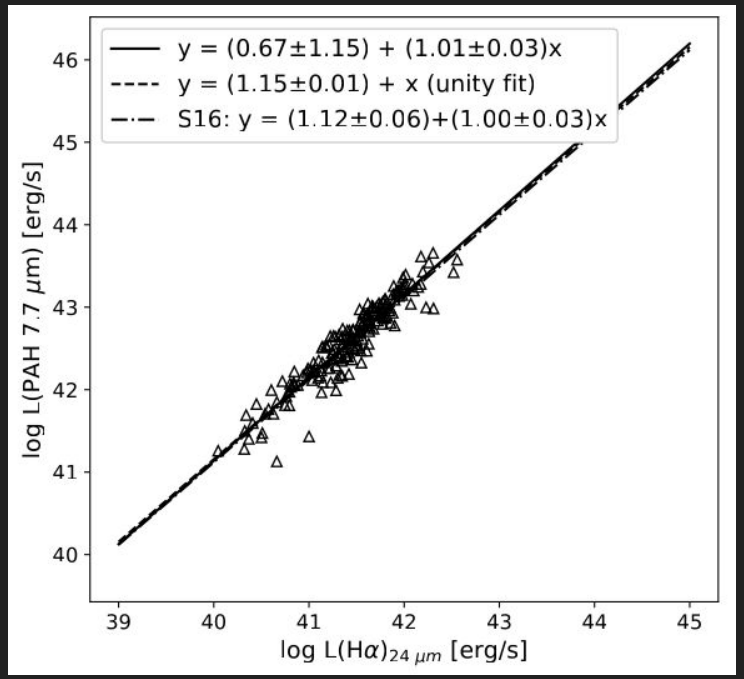
PAH: Galaxy evolution

→ PAH fraction increases with gas-phase metallicity



Aniano+2020

→ PAH luminosity can trace SFR of galaxies

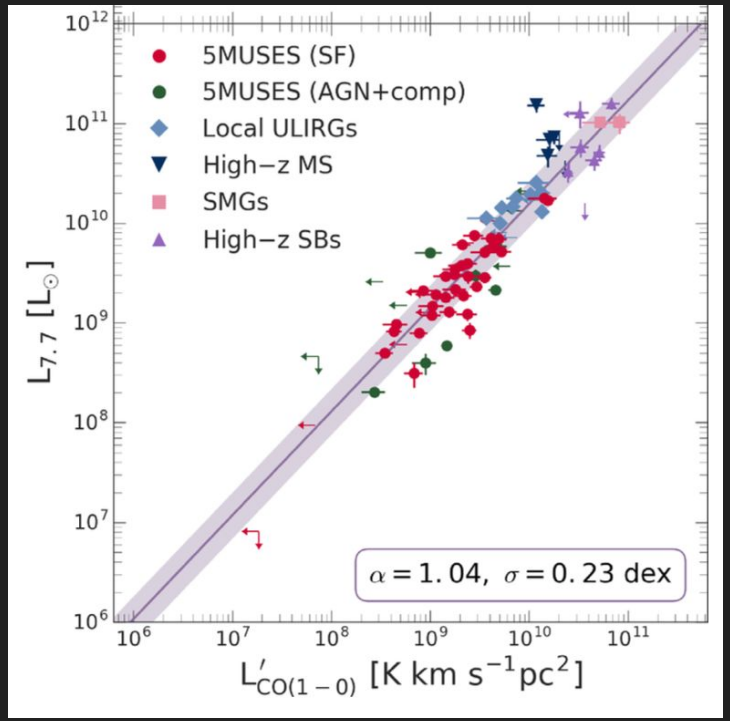


Kim+2024

PAH - Indirect probe of molecular gas

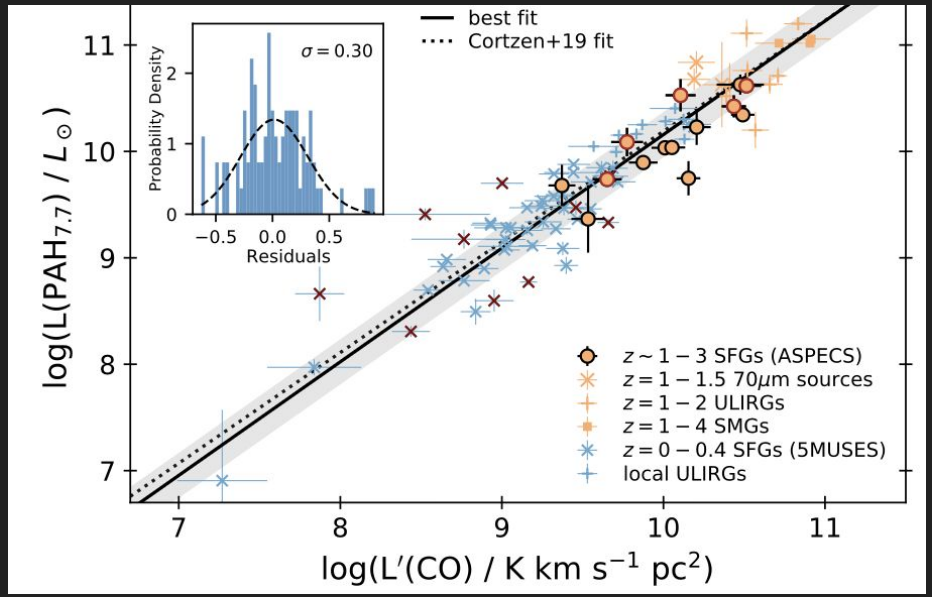
→ PAH intensity correlates well with molecular gas content

Nearby galaxies



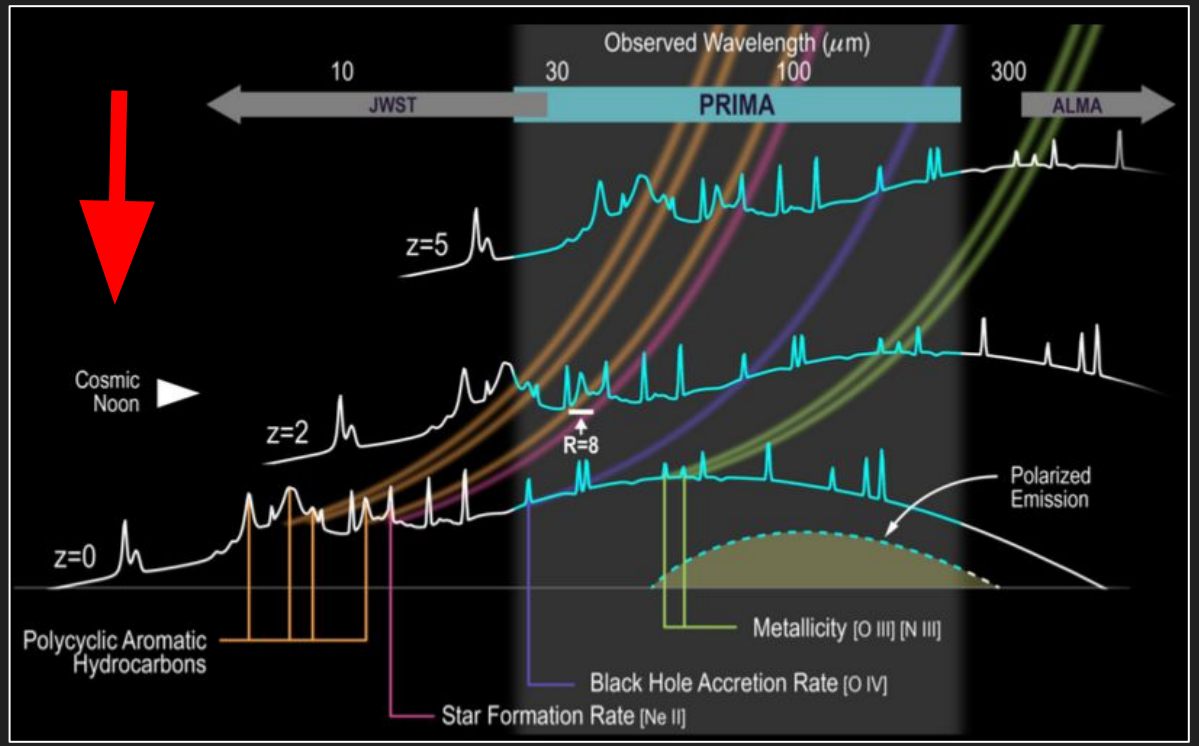
Cortzen+2019

Distant galaxies



Shivaei+2024b

Current PAH studies & the upcoming PRIMA telescope



Credit: PRIMA website

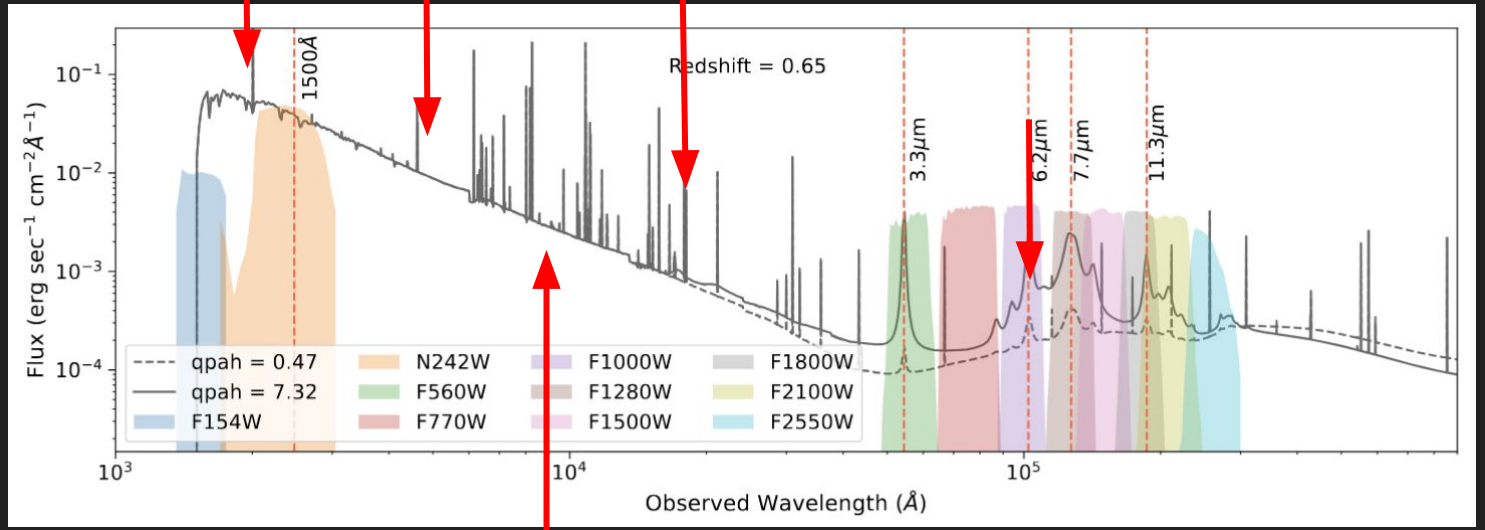
Our Objective

Q1. What drives PAH enrichment in galaxies at redshift ***z~0.5 - 0.8?***

Rest-frame FUV

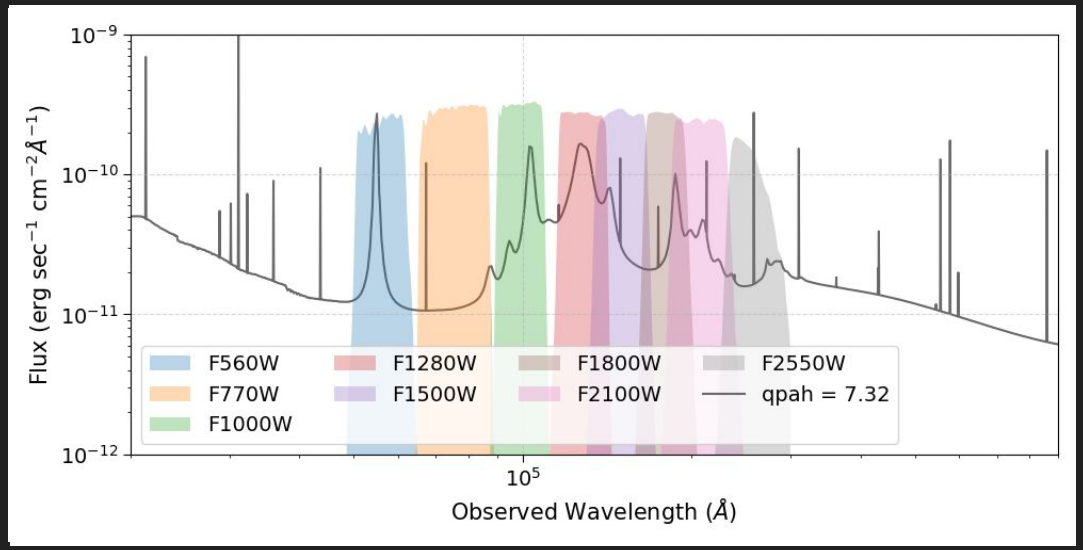
Rest-frame MIR (PAH)

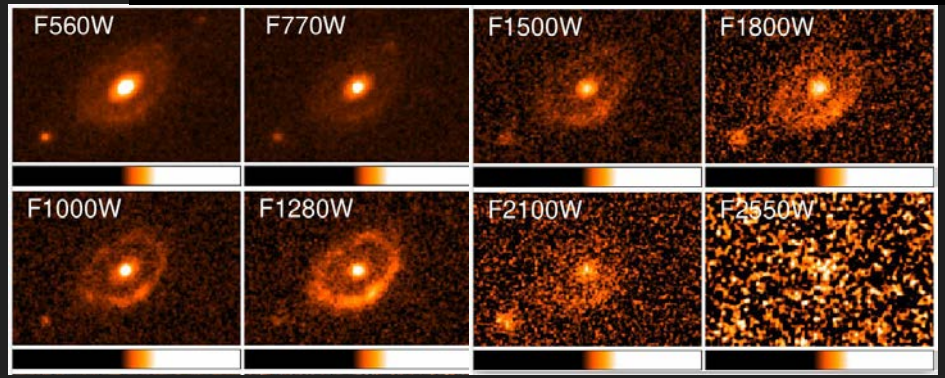
UVIT **HST** **JWST/NIRCam** **JWST/MIRI**



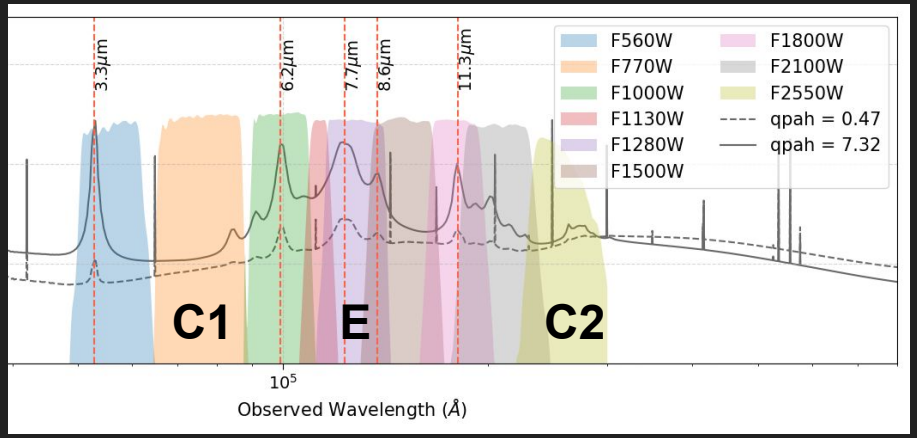
MUSE → Optical Emission lines → ISM ionization, metallicity

Probing PAH using JWST MIRI at z~0.65



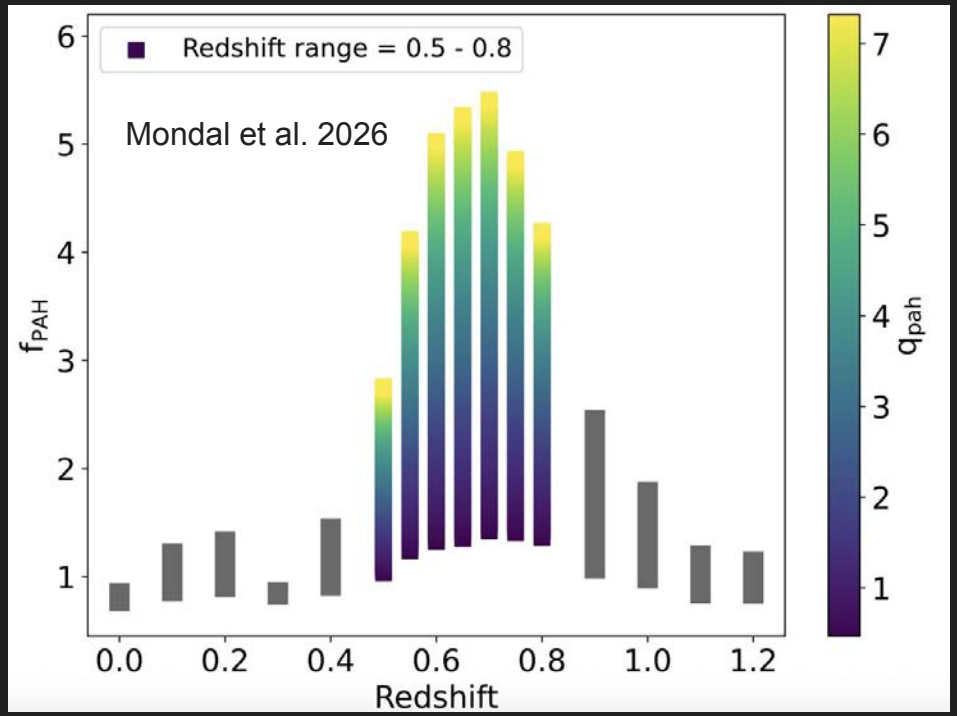


Diagnostic parameter to probe PAH emission at z~0.65



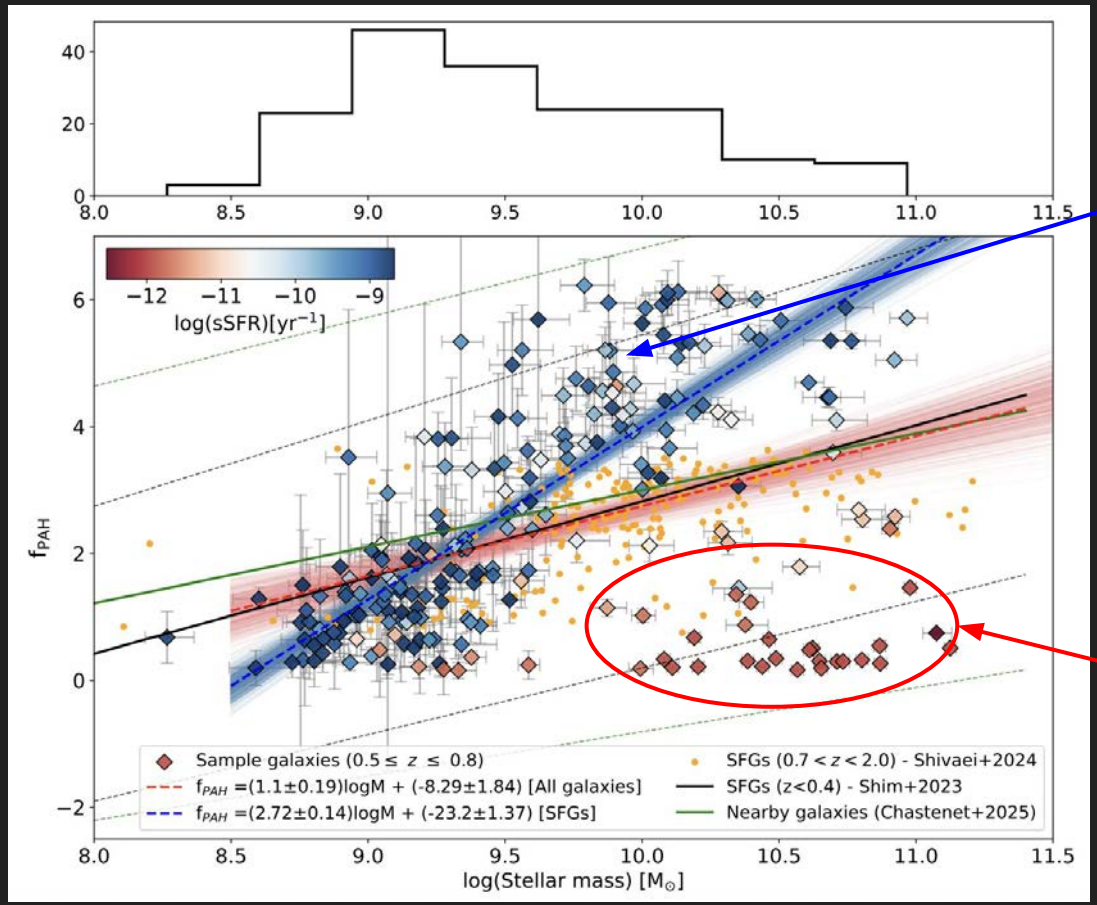
$$\mathrm{fPAH} = \frac{\mathrm{E}}{0.5 \times (\mathrm{C1} + \mathrm{C2})}$$

$$\mathrm{fPAH} = \frac{\mathrm{Flux_{F1280W}}}{0.5 \times (\mathrm{Flux_{770W}} + \mathrm{Flux_{F2550W}})}$$



fPAH (measured from MIRI fluxes) can probe the PAH mass fraction at z~0.65

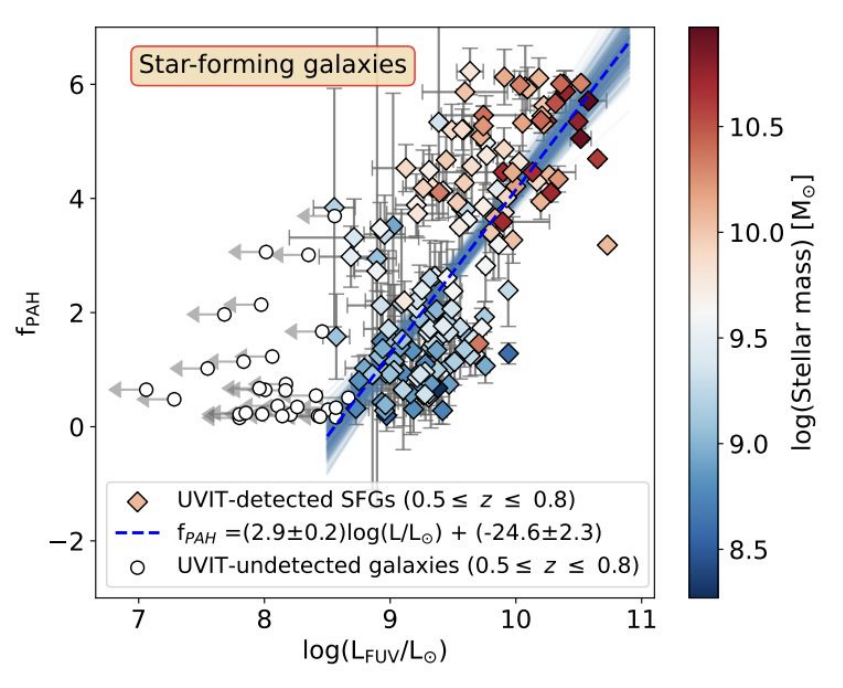
Relation with galaxy stellar mass



The PAH mass fraction of star-forming galaxies show a strong dependence on galaxy stellar mass

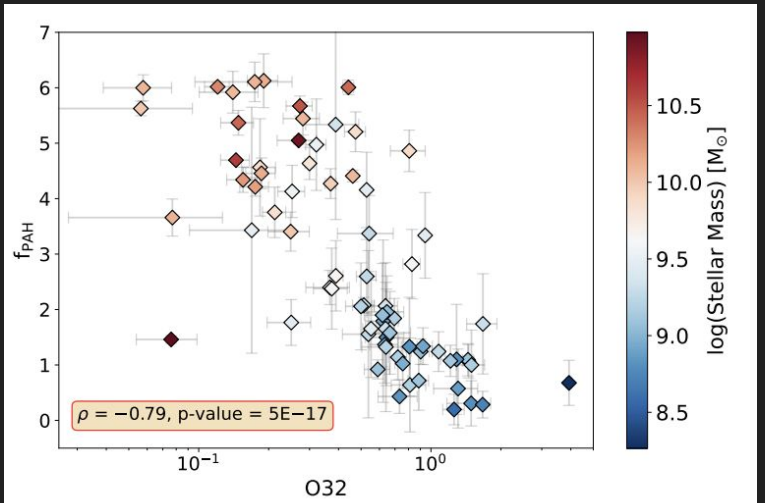
However, the massive quiescent galaxies show low PAH mass fraction

Relation with FUV luminosity

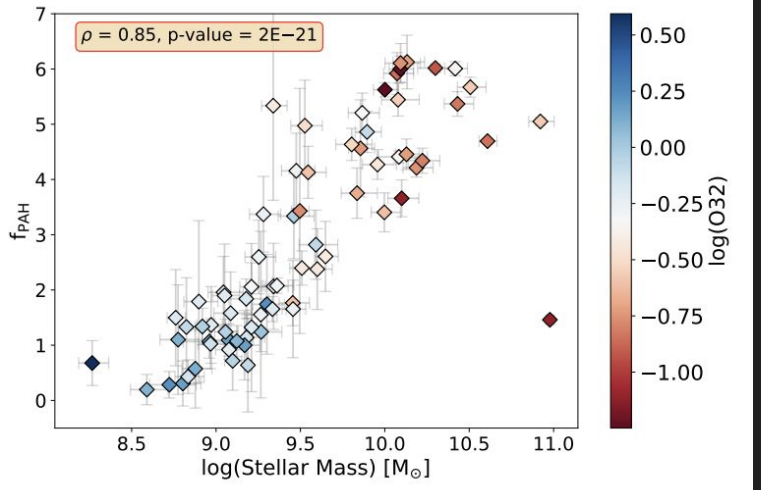


fPAH increases with stellar mass and rest-frame FUV luminosity, identifying massive, UV-bright galaxies to have higher PAH mass fraction

Relation with ISM ionization

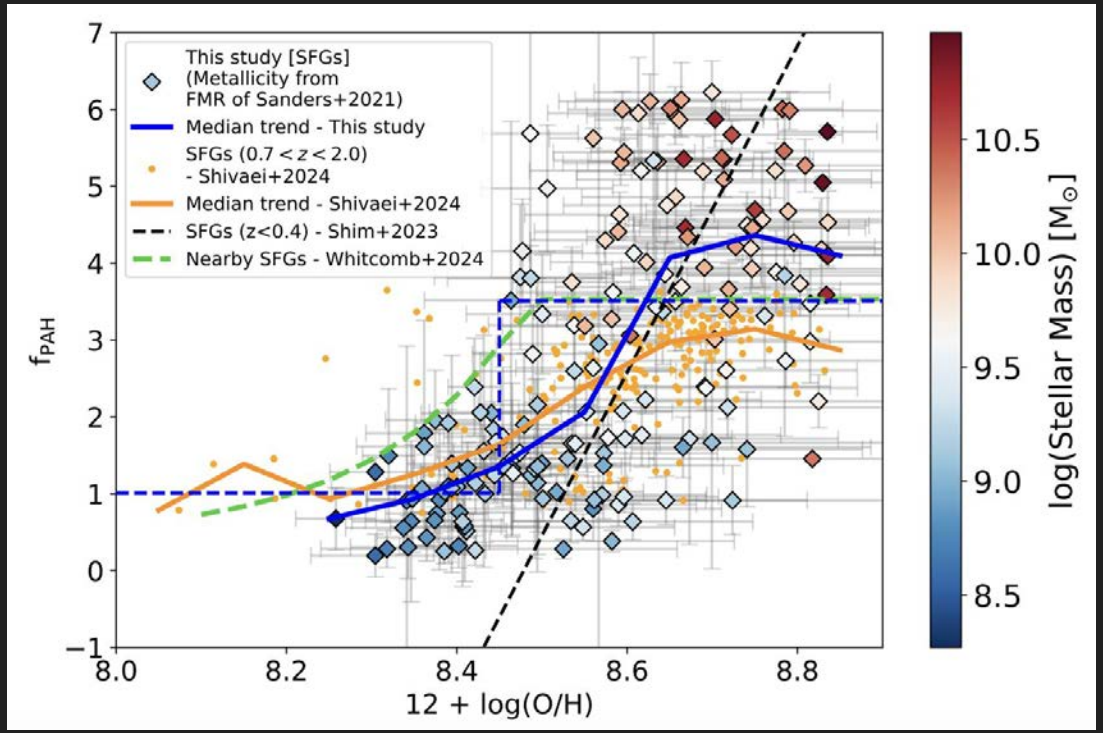


we observe an anti-correlation between fPAH and the O32 emission line ratio, suggesting PAH photo-dissociation in strongly ionized ISM



Star-forming dwarf galaxies are more prone to host highly ionized ISM which is less favourable for PAH survival

Relation with gas-phase metallicity

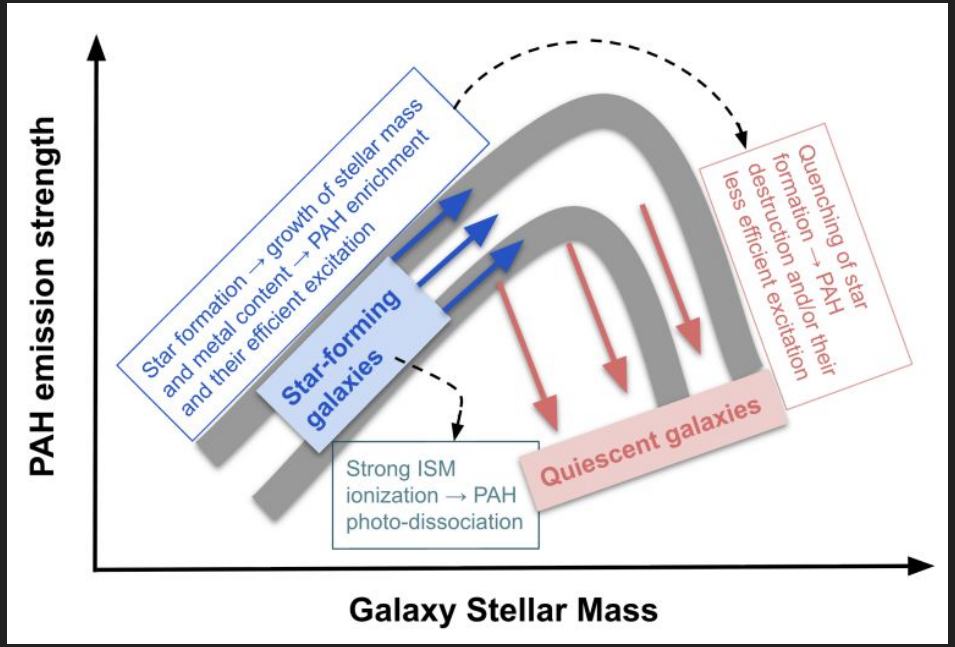
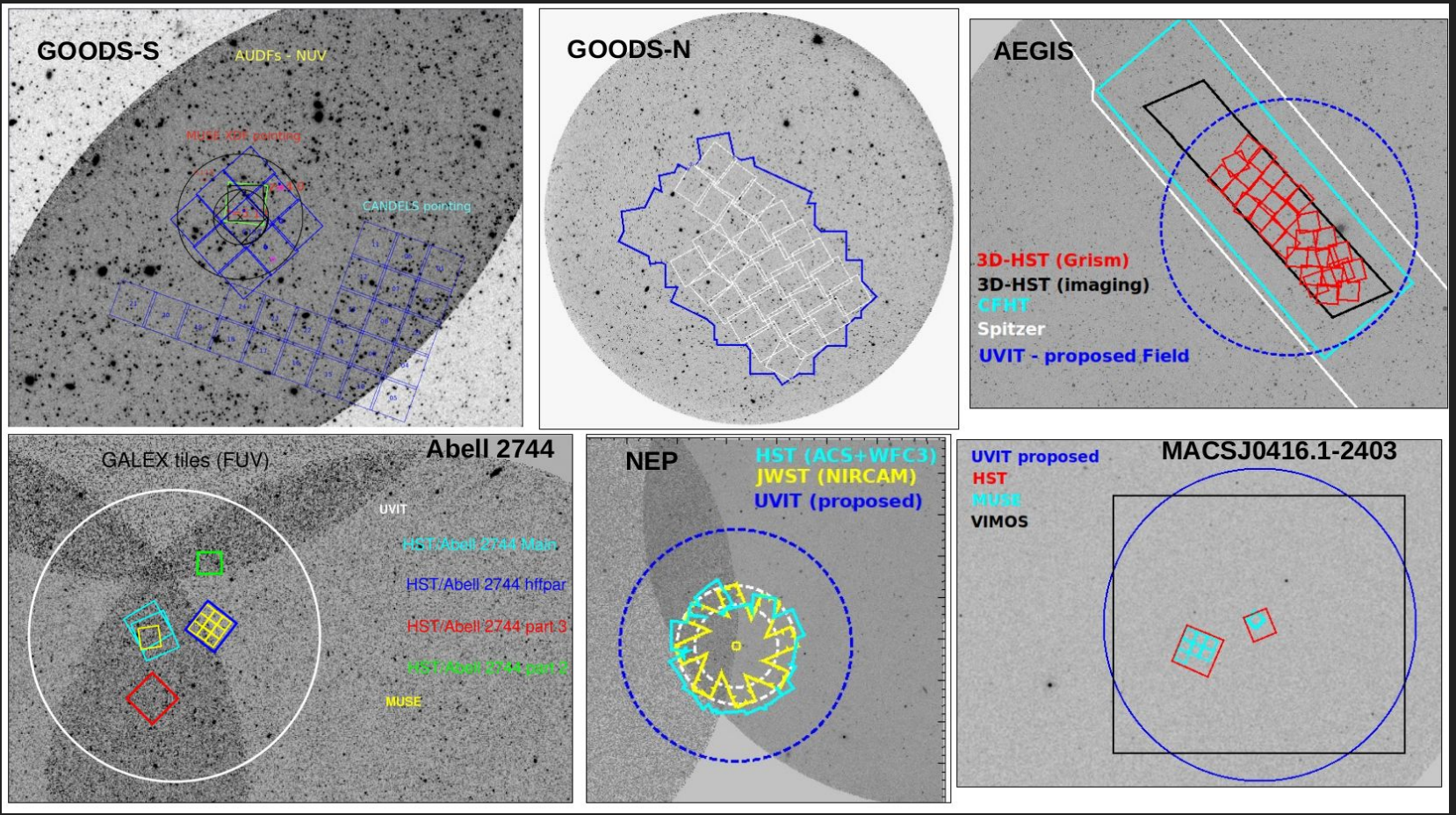


PAH enrichment in galaxies goes through a rapid transition phase from a PAH-poor to a PAH-rich system, at about 70\% solar metallicity

Low-mass metal-poor SFGs, which are increasingly common at even higher redshifts, host more extreme conditions less favorable for PAH production and survival

To Summarize

- For SFGs, galaxy stellar mass and UV luminosity together play the most important role in regulating PAH enrichment and emission
- However, SFGs with harder ISM radiation field can undergo efficient photo-dissociation of PAH molecules
- QGs show relatively lower PAH mass fraction, indicating that the quenching process that affected star formation in these systems could also destroy PAH molecules



More exploration ongoing in multiple AstroSat UV Deep Fields….