Exploring the Evolution of Dust Temperature using Spectral Energy Distribution Fitting in a Large Photometric Survey

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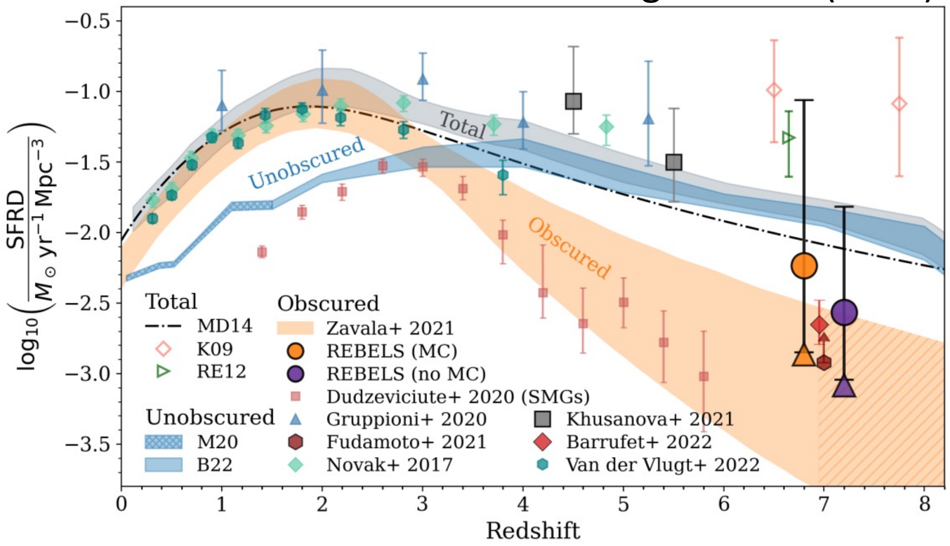
Why do we study dust?

- Acts as sites for formation of molecular hydrogen
- Regulates star formation
- Modifies the spectra of stars
- Influences galactic dynamics
- Absorbs and reprocesses stellar emission

Algera et al. (2022)



Dust Temperature Evolution

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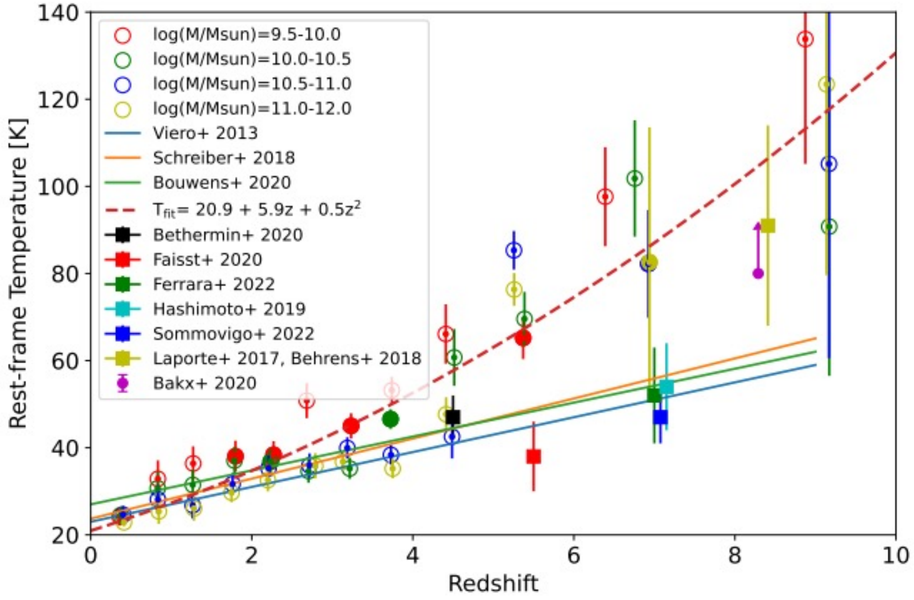
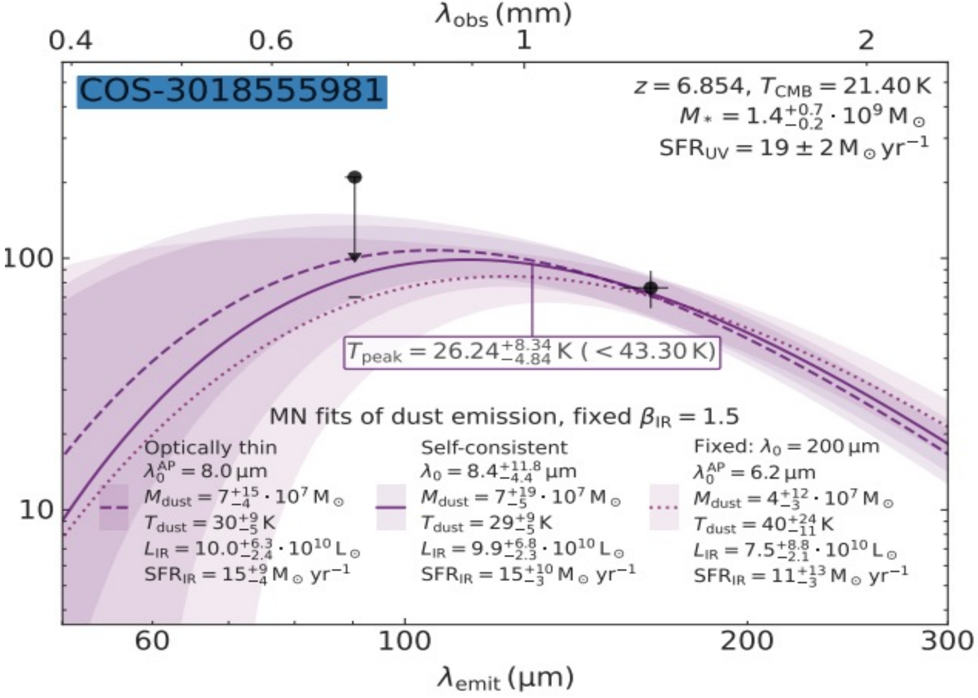
Dust temperature can affect attenuation curves and fragmentation, and thus is crucial to understand galaxy evolution.

Various temperature evolution relations have been proposed from no or plateauing to linear or exponentially increasing.

Viero et al. (2022)



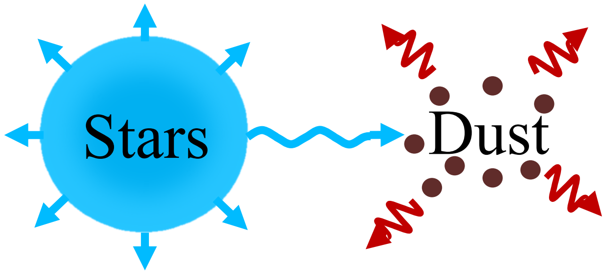
Previous Methodologies



Witstok et al. (2022)

Most previous analyses fit only a dust emission model and ignore the stellar component.

However, dust emission is strongly connected to the starlight irradiating it.



Sample and Observations

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Selected star-forming galaxies from COSMOS2020 survey (Weaver et al. 2022), splitting into 4 mass and 23 photometric-redshift bins.

UV-Optical-NIR

Take photometric flux measurements from the catalogue and combined to get a typical galaxy for each sample.

Mid- and Far-IR

Stack fluxes from objects in the image plane using SIMSTACK (Viero et al. 2013, 2022).

Fitting Algorithm

Simultaneously fit UV-to-IR using BAGPIPES spectral fitting code (Carnall et al. 2018)

- BPASS SPS models (Eldridge et al. 2017) with da Cunha et al. (2008) empirical dust emission formalism.
- Delayed-tau SFH for young and old stellar populations.
- Fixed metallicity at 70% solar.
- Fitted for warm and cold grain temperatures.

Dust Temperature Evolution

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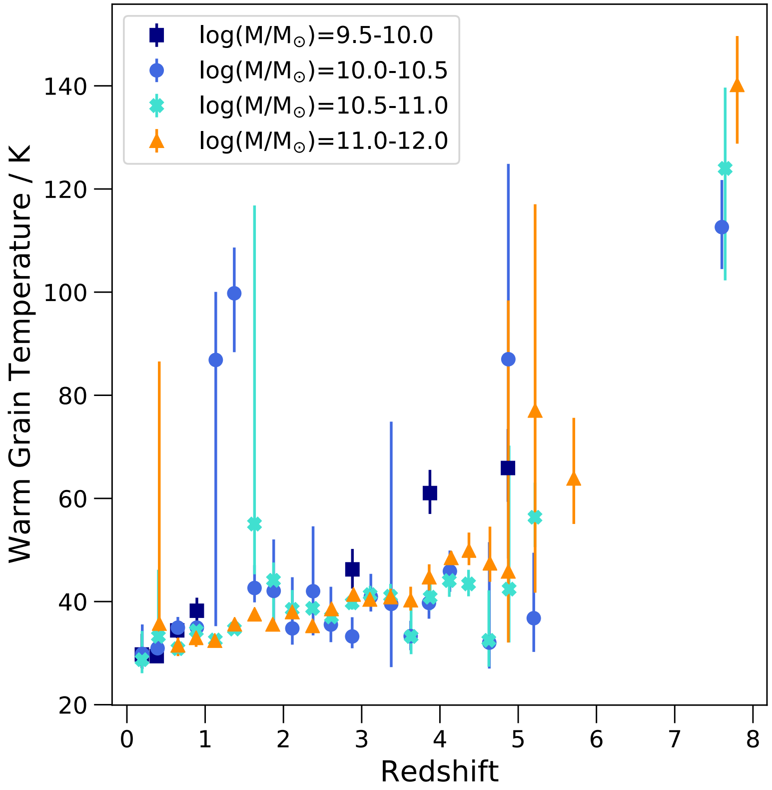

Bimodal distribution:

- Low grain temperatures (< 50K) and small errors (uncertainty < 15%)
- High grain temperatures (> 60K) and/or large uncertainties

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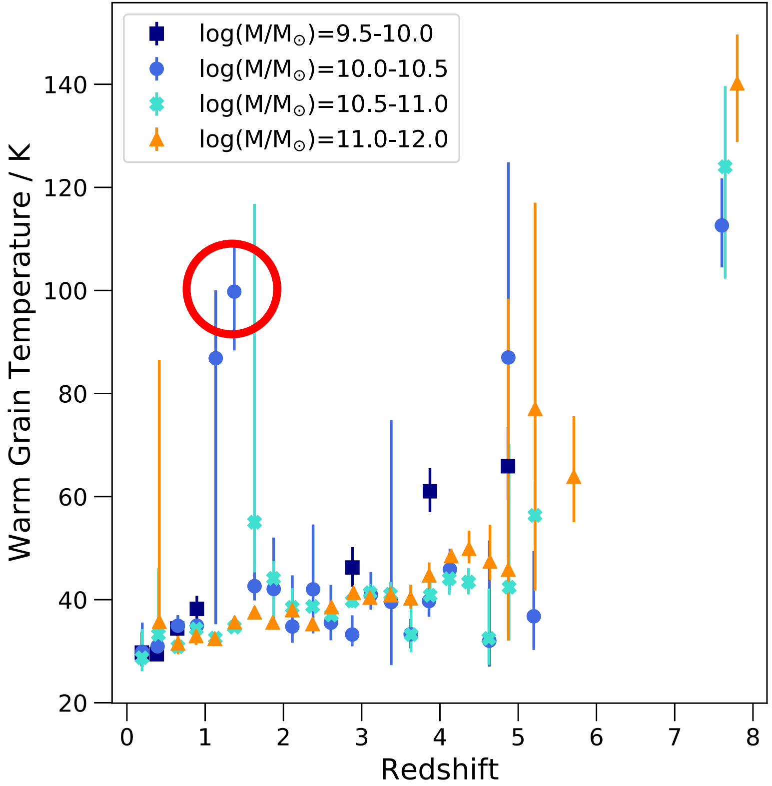
Dust Temperature Evolution



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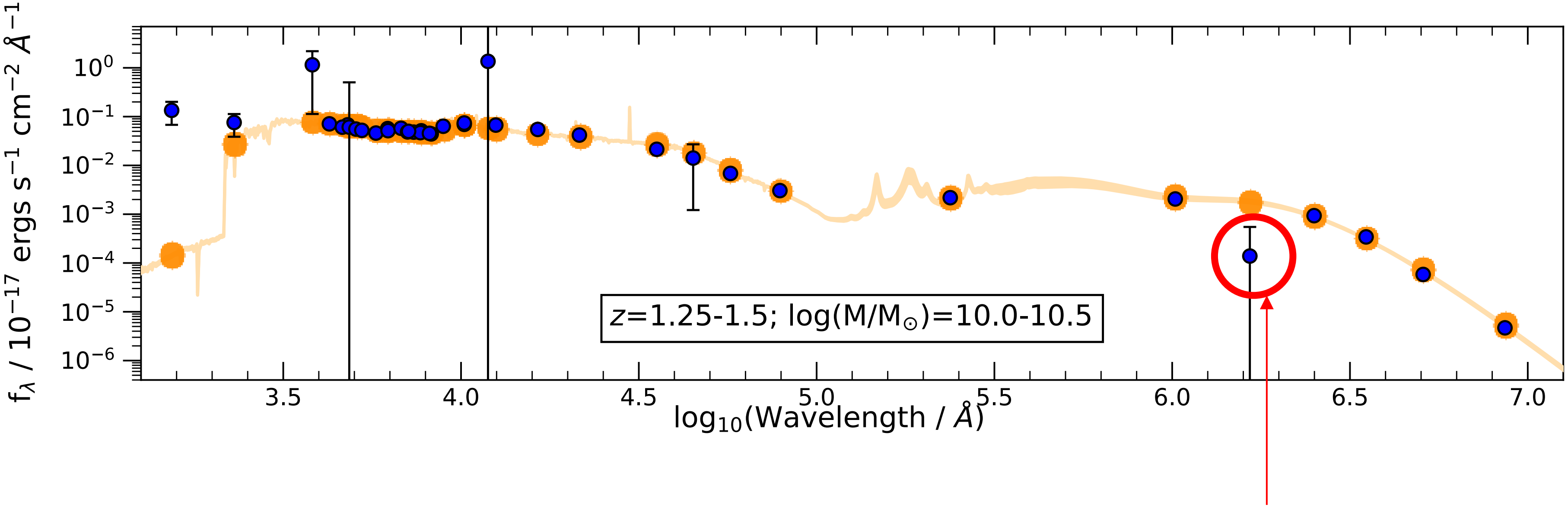
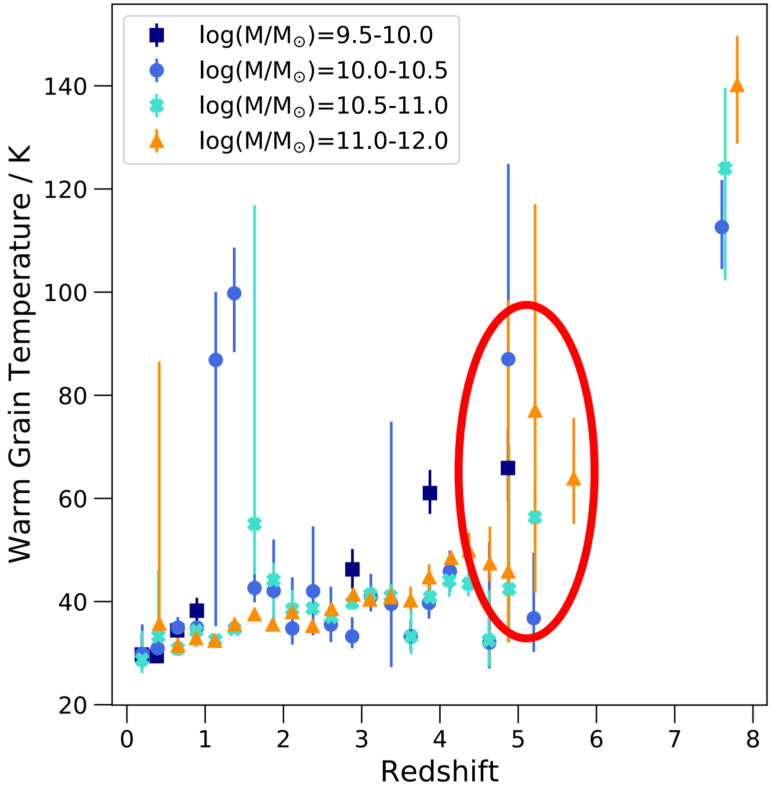
Anomalous Galaxy



Large uncertainty in 150 micron data point which lies around the peak of emission

Dust Temperature Evolution



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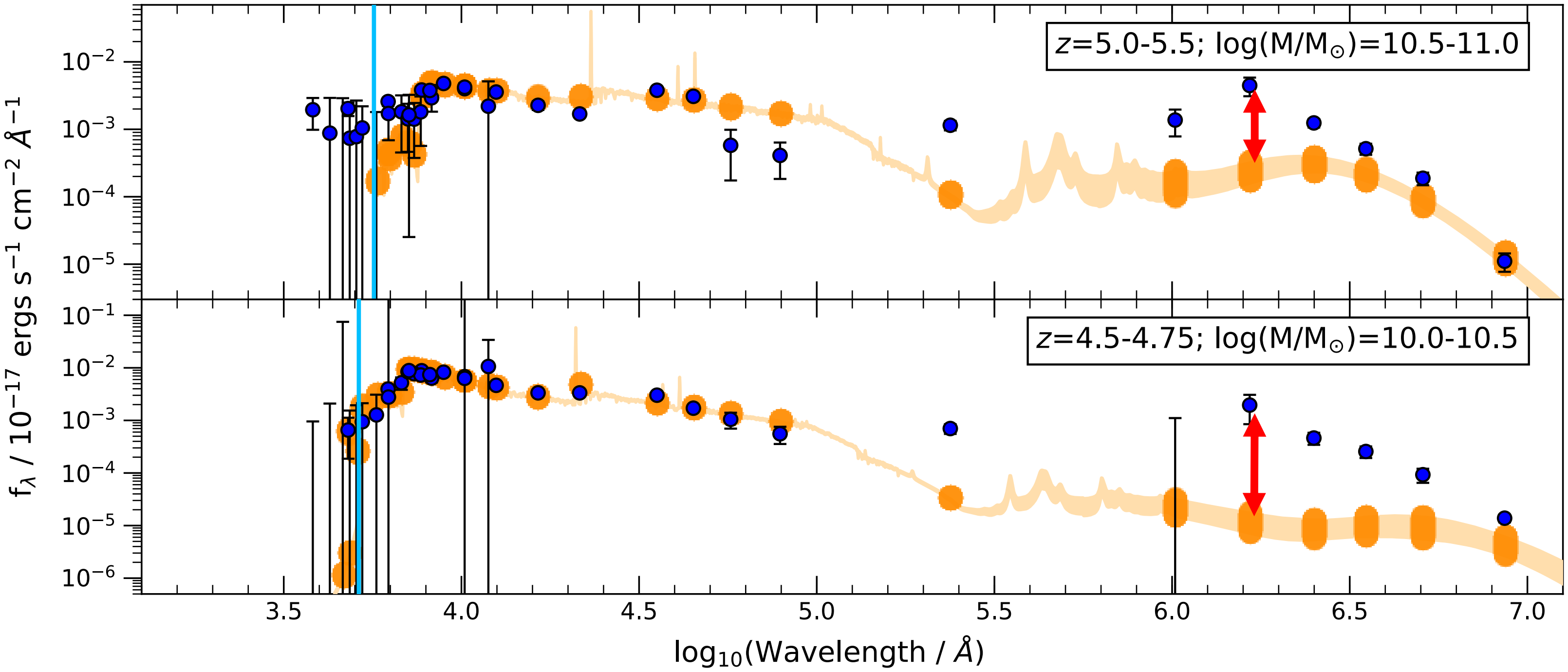
Model Fit Mismatch



Large (> 5 sigma) difference between the observations and best fitting model

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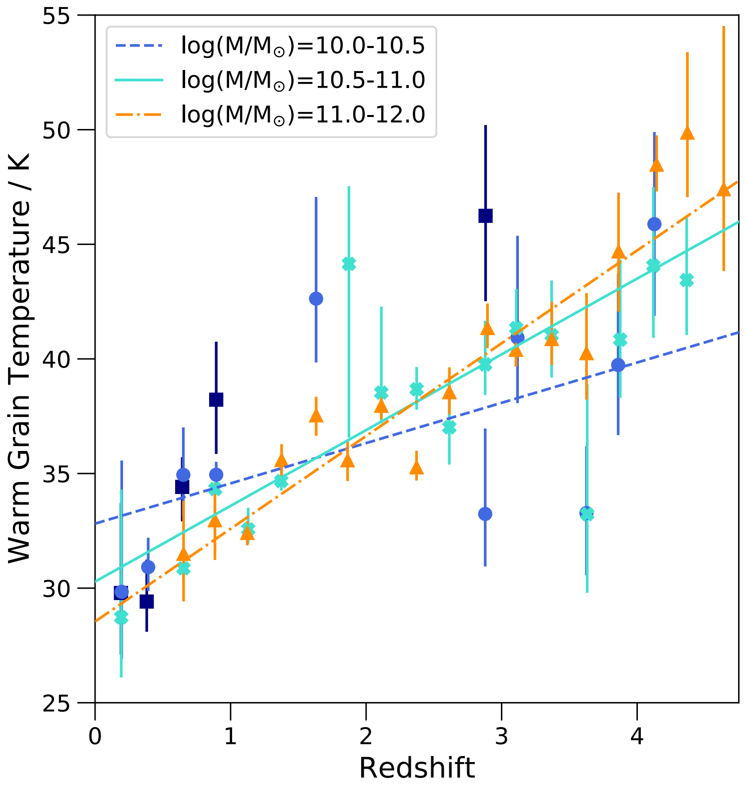
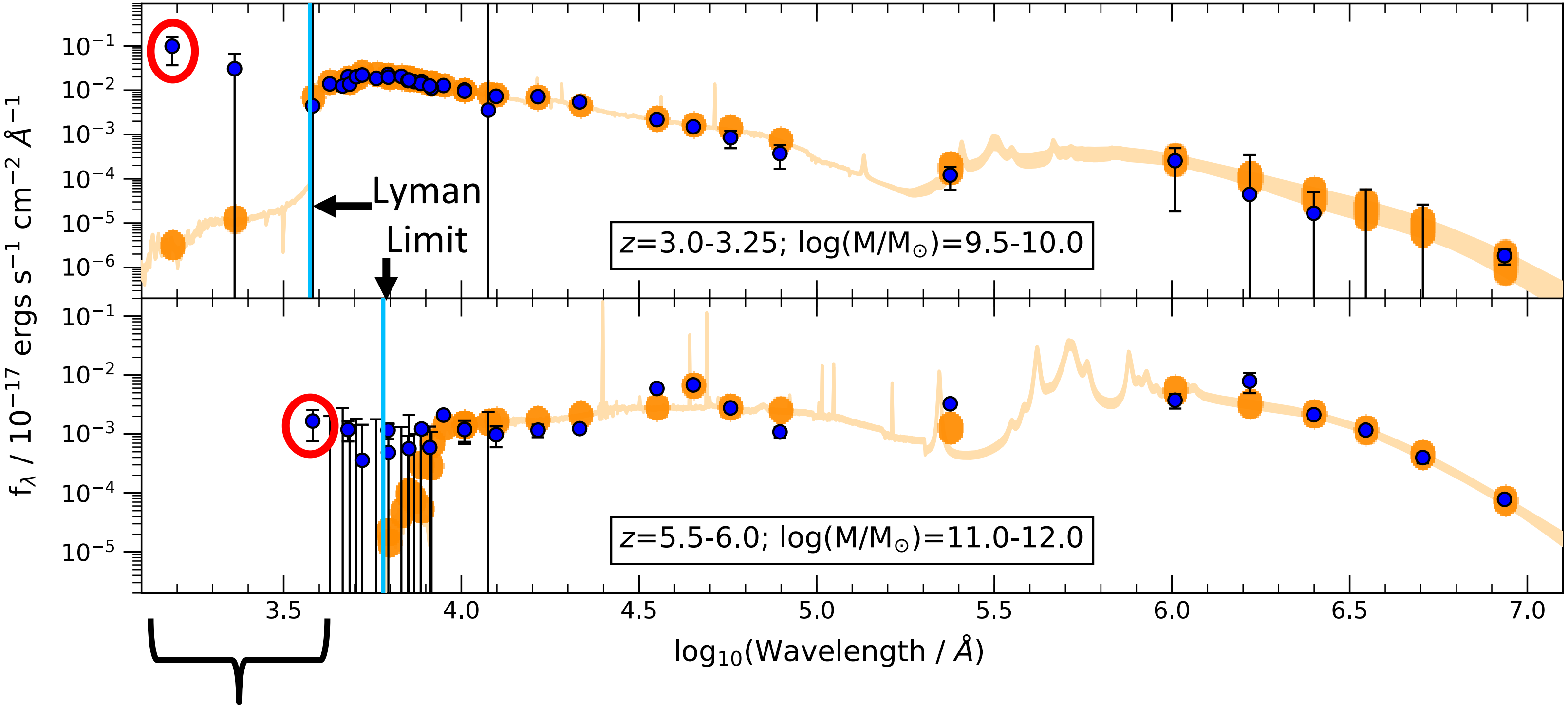
Dust Temperature Evolution



$$T(z) = Az + B,$$

Mass Bin	A / K per unit z	B / K
10.0 – 10.5	1.8 ± 0.9	32.8 ± 1.1
10.5 – 11.0	3.3 ± 0.5	30.3 ± 0.7
11.0 – 12.0	4.0 ± 0.5	28.5 ± 1.1

UV Excess

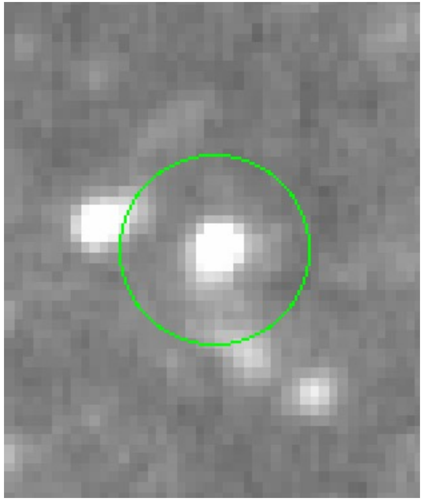


Detections longward of Lyman limit

Probability of Chance Alignment Cut

Select galaxies which exist within a low density region.

- Calculate density of objects within 6’’ from each target galaxy.
- Times by area covered by MIPS 24 µm filter PSF to get probability.
- Keep galaxies with $P_{Chance} < 0.1$



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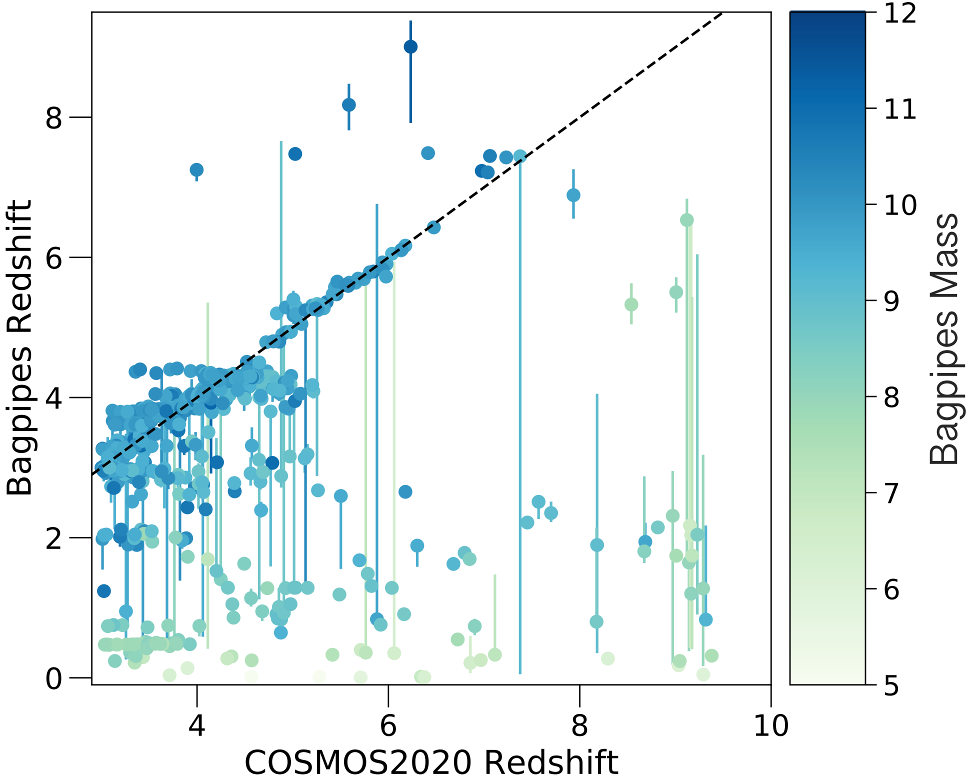
Photometric-z Robustness



Fit for z in remaining sample and removed any galaxy with large difference to COSMOS2020 value or with a large uncertainty (>30%).

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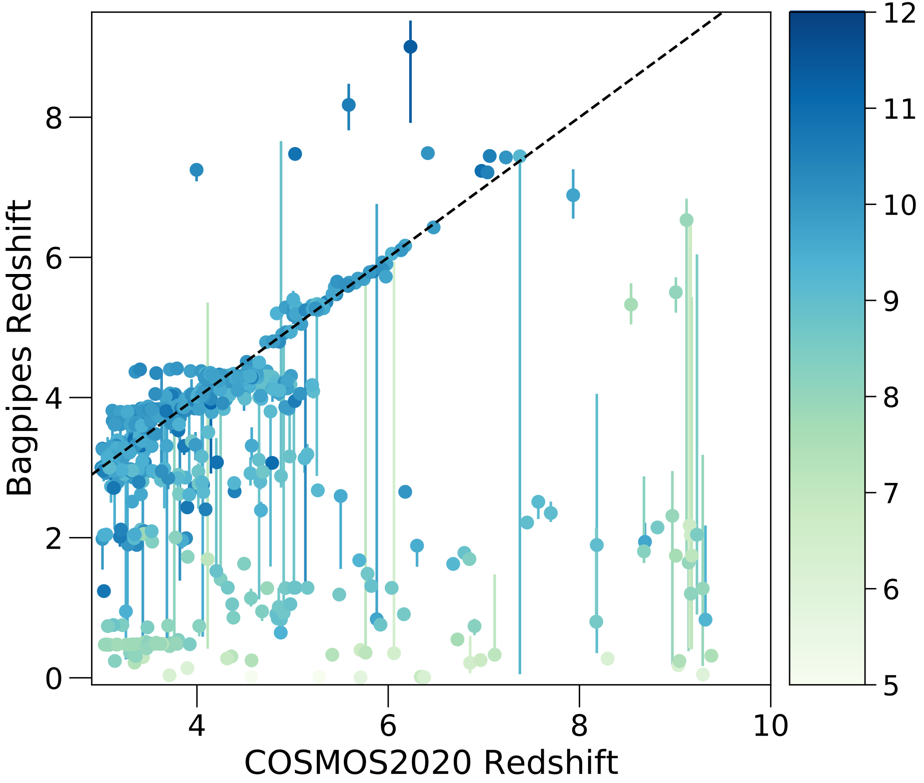
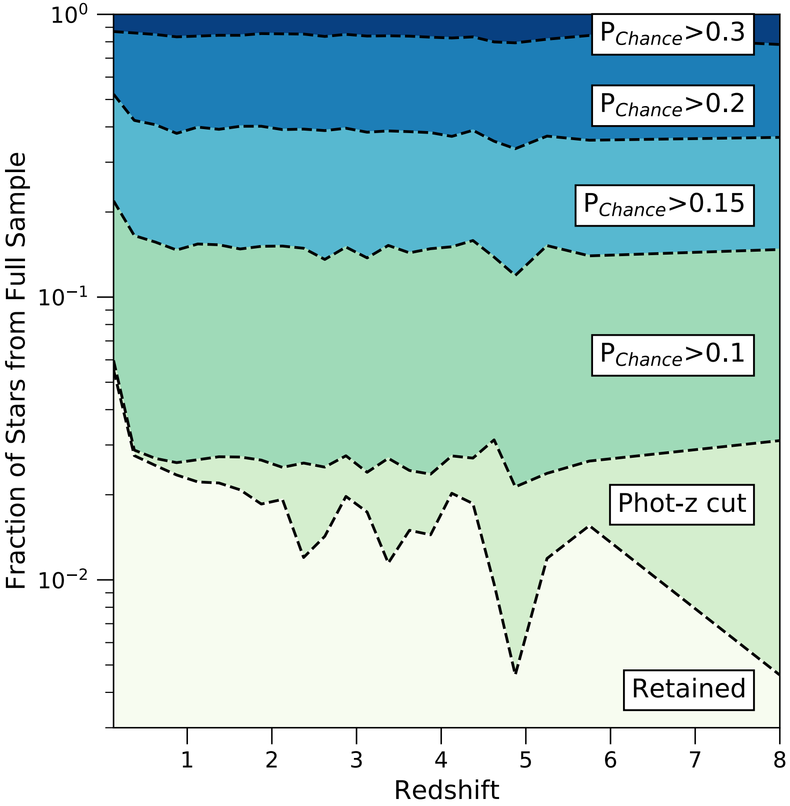
Photometric-z Robustness





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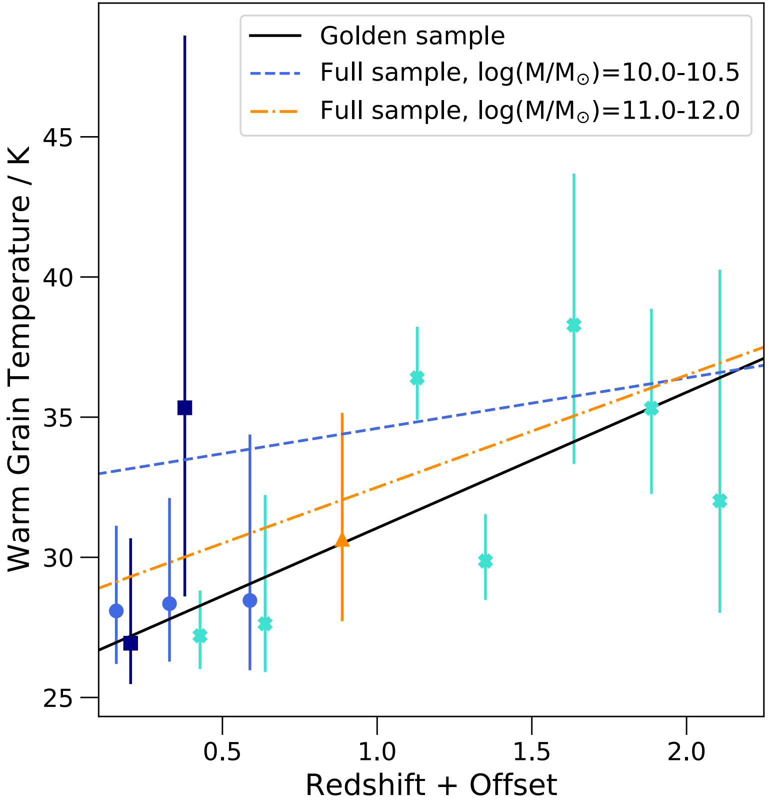
"Gold" Sample Results



Full sample:

Mass Bin	A / K per unit z	B / K
10.0 – 10.5	1.8 ± 0.9	32.8 ± 1.1
10.5 – 11.0	3.3 ± 0.5	30.3 ± 0.7
11.0 – 12.0	4.0 ± 0.5	28.5 ± 1.1

"Gold" sample:

$$T_d(z) = (4.8 \pm 1.5) \times z + (26.2 \pm 1.5)\ \mathrm{K}.$$

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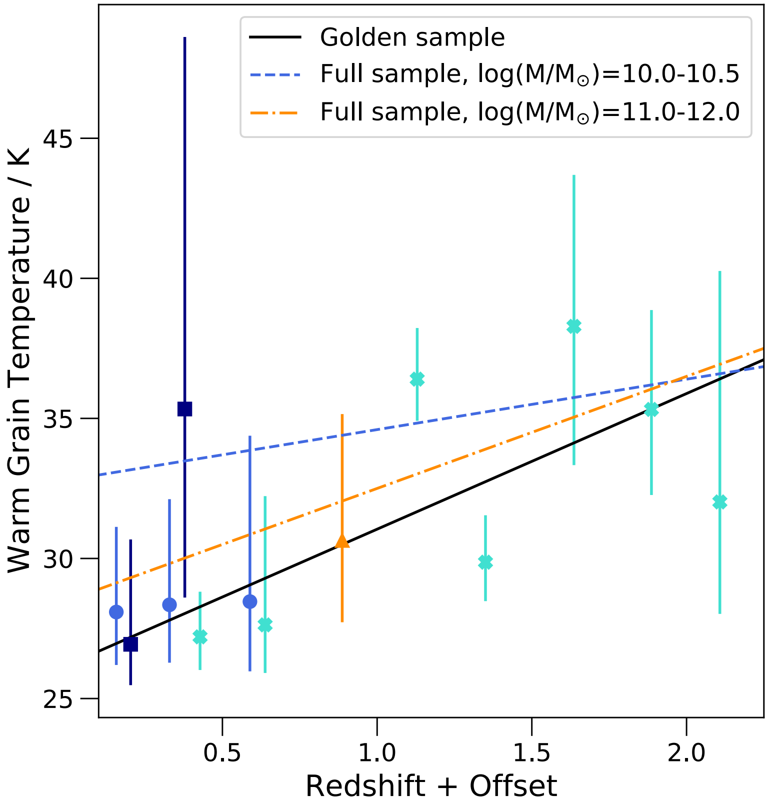
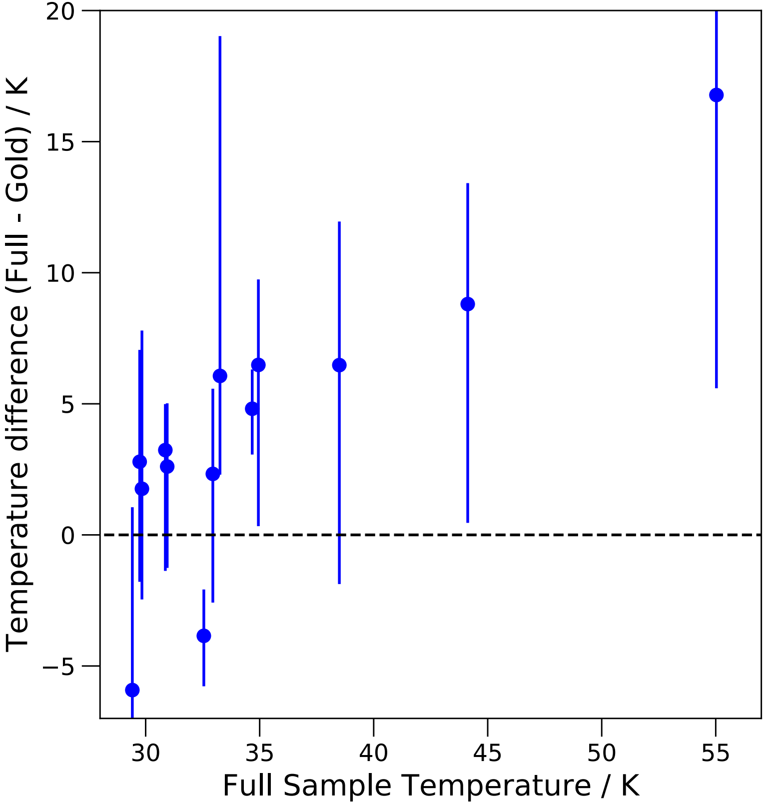
"Gold" Sample Results





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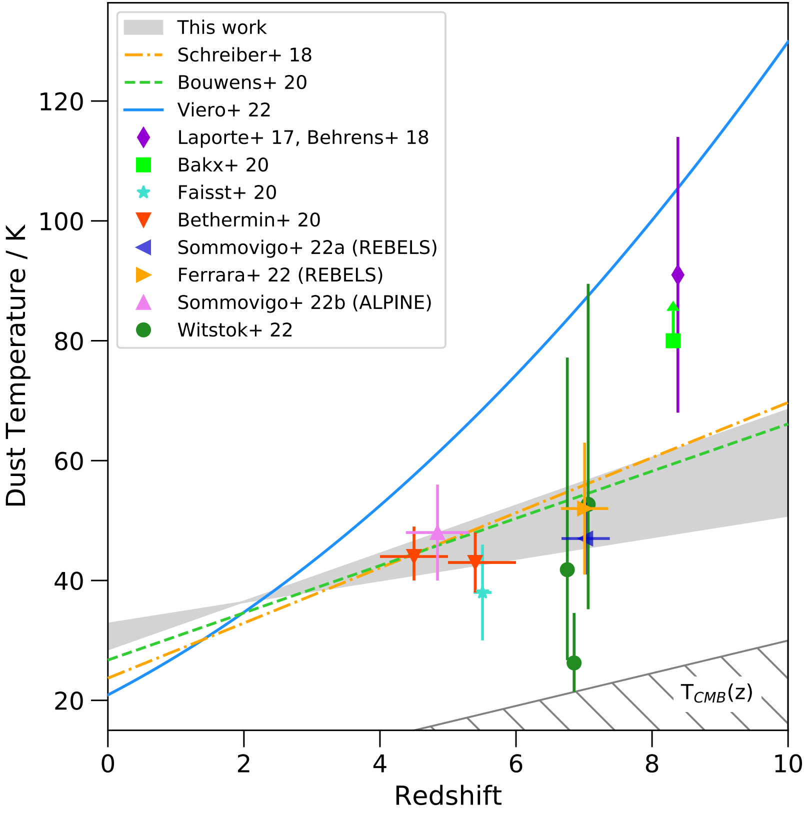
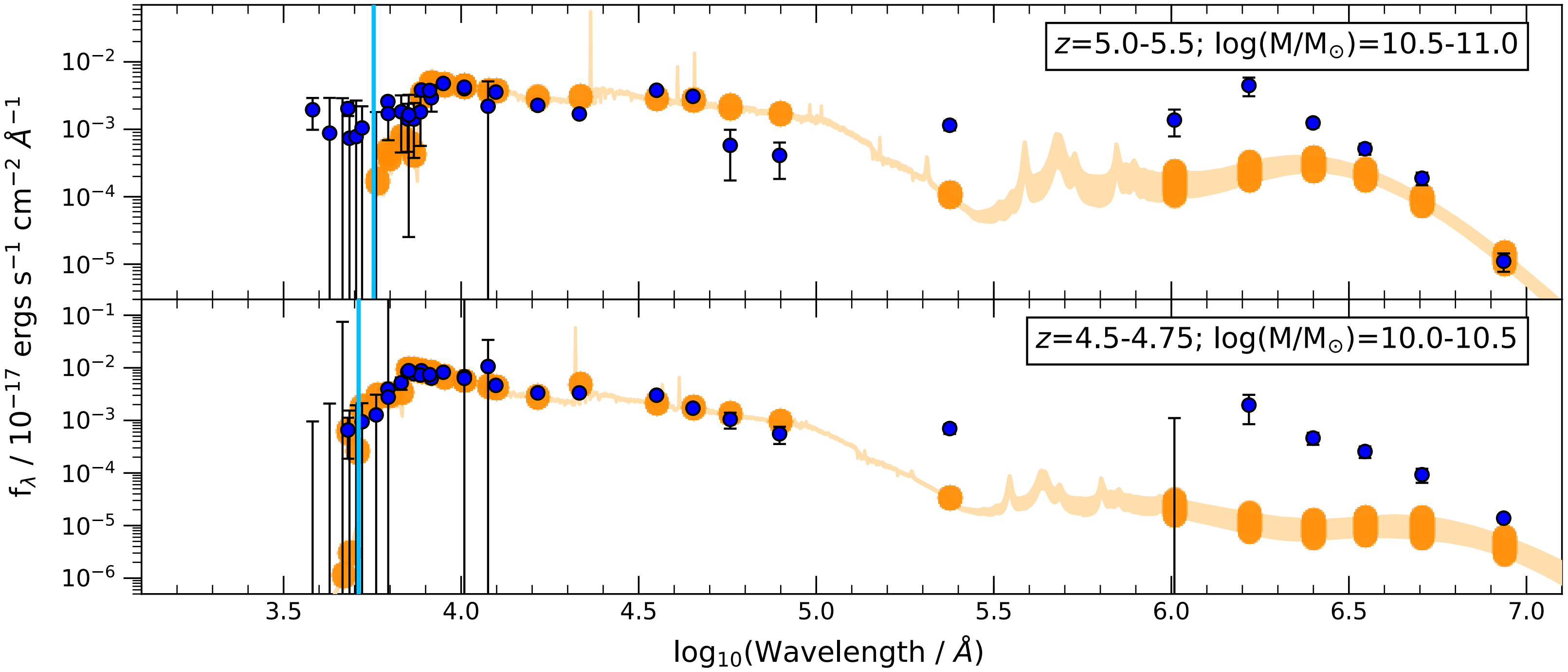
Comparison to Literature



UV/Optical-IR Disconnect



UV/Optical-IR Disconnect

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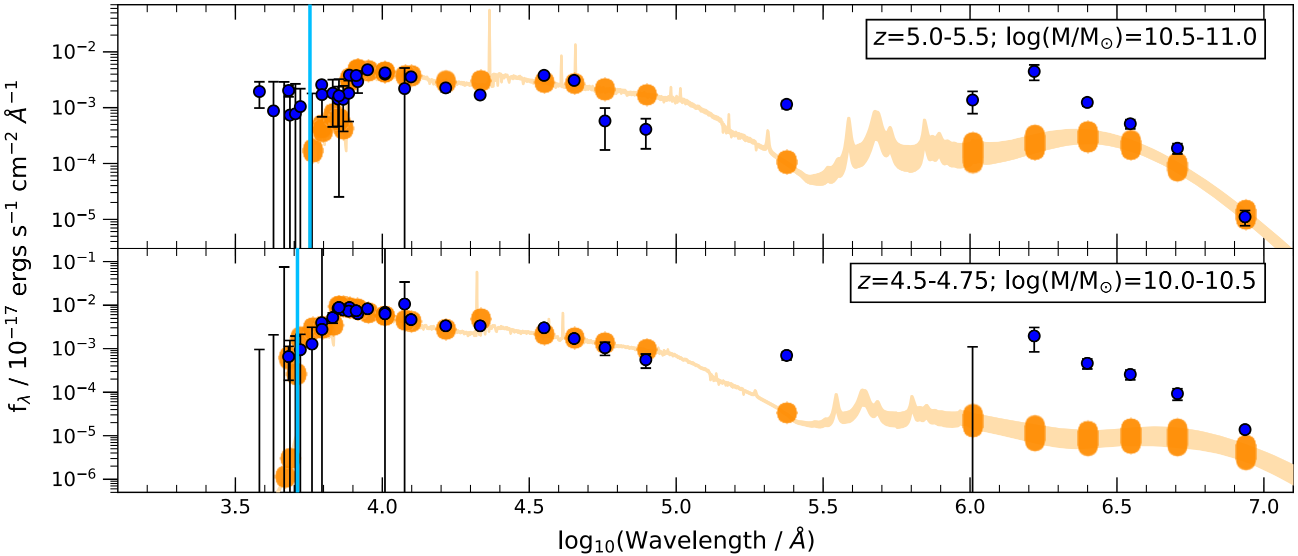
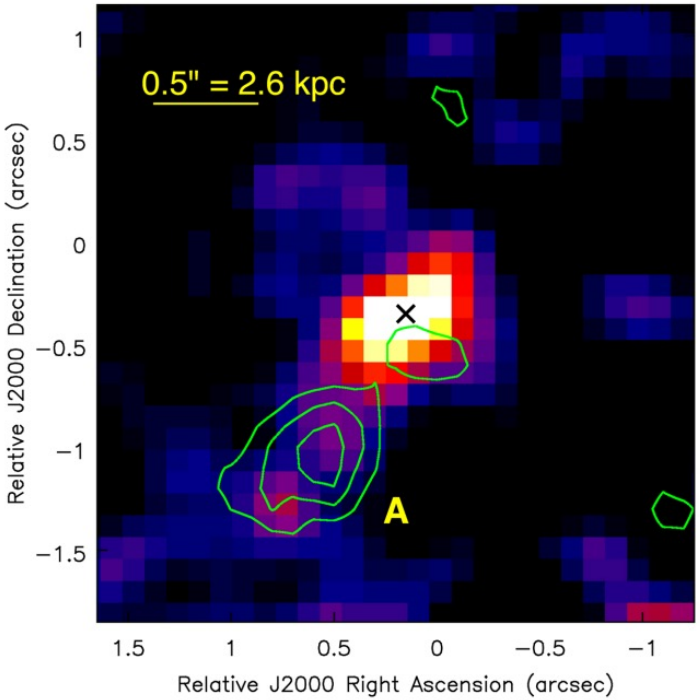
UV-optical/stellar component drives the energy-balance estimate over the IR/dust.



A spatial disconnect between the peak UV-optical and IR emission or changes in dust assumptions breaks the energy-balance formalism.

UV/Optical-IR Disconnect



Maiolino et al. (2015)

Maiolino et al. (2015) found a spatial disconnects between the optical (Y-band, colour background image) and the infrared ([CII] detection, green contour lines) in high-z galaxies (z=7.109).

Possible Extensions

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- Fitting different samples
- Future missions and observations
- Using other methodologies (i.e. molecular lines)
- Other observational constraints
- Compare with simulations
- Will JWST observations help?

Conclusions

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- Insufficient wavelength coverage and sensitivity and frequent presence of interloping galaxies prevents robust dust temperature determinations at $z>4$.
- Both samples support a linear increase in dust temperature out to $z=5$ in line with linear-relations derived by previous authors.
- A UV/optical-IR disconnect from spatial separation of peak emission or the over-simplification of dust properties breaks the energy-balance formalism.