Effect of Simultaneous Modelling Dust and Stellar Populations on Inferred Galaxy Properties

Jones G. T., Stanway E. R., Carnall A. C., 2022, MNRAS, 514, 5706

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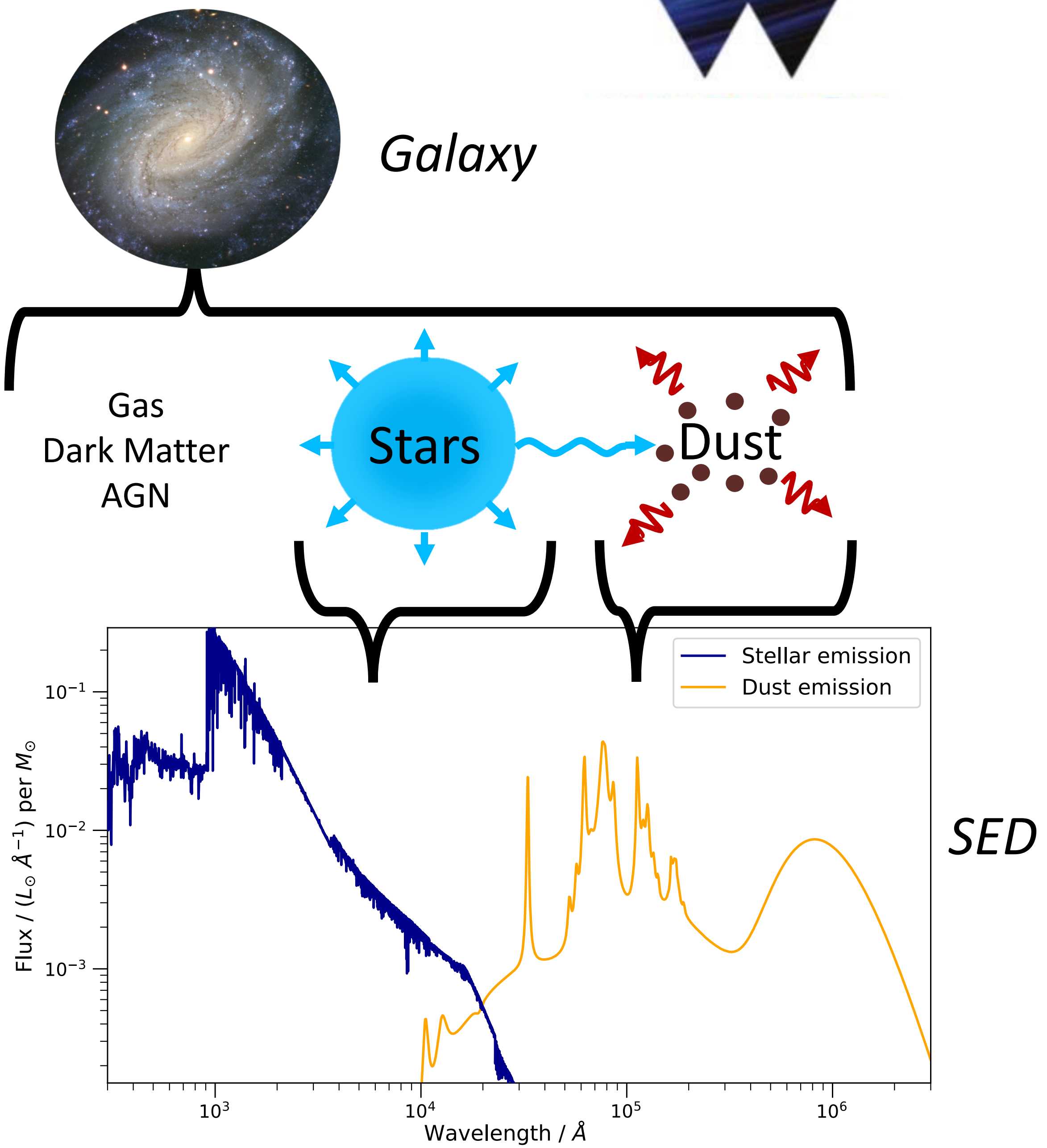
Galaxy Components

Dust is a key component in galaxies, affecting their evolution.

One role is the absorption and re-emission of incident starlight at longer wavelengths.

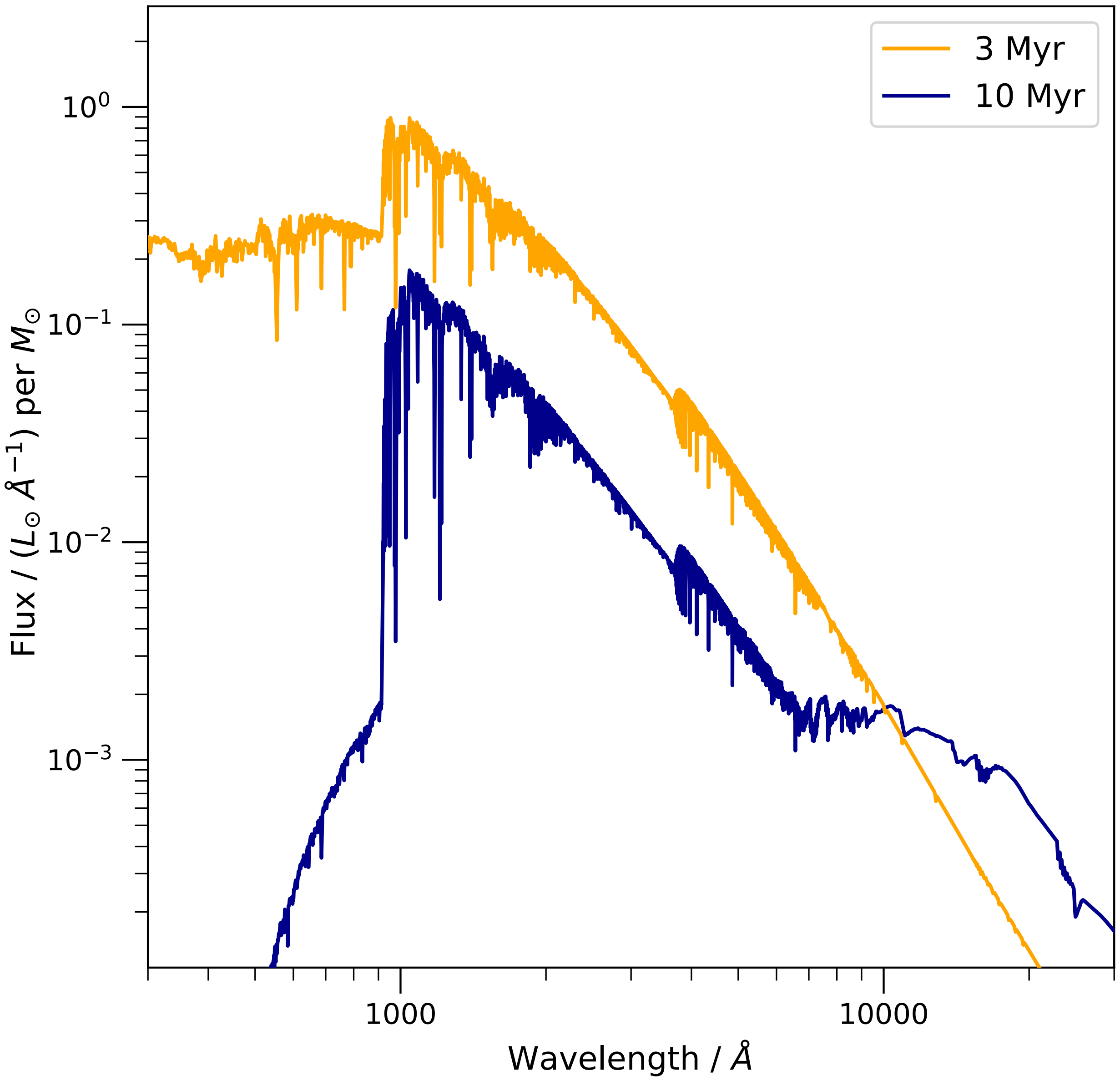


Stellar Emission

Stellar emission spectra vary between different aged populations.

Ultraviolet (UV) emission is dominated by young, O-type stars of age <10 Myr.

These young stars have the hardest ionizing spectra.

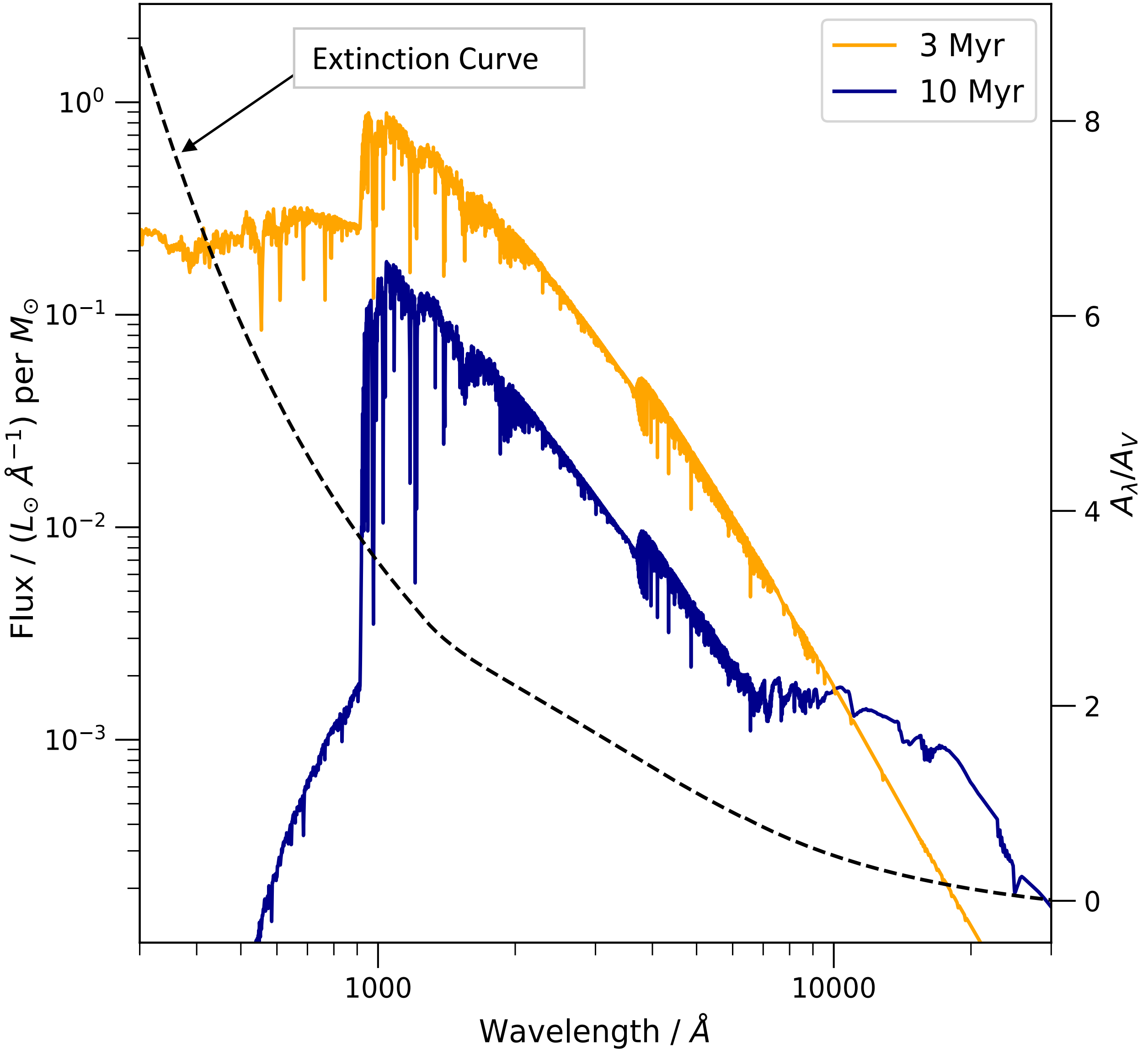


Energy Transfer to Dust

Dust causes more attenuation of shorter wavelength, harder ionizing radiation.

UV-luminous/star forming galaxies will therefore have more dust emission.

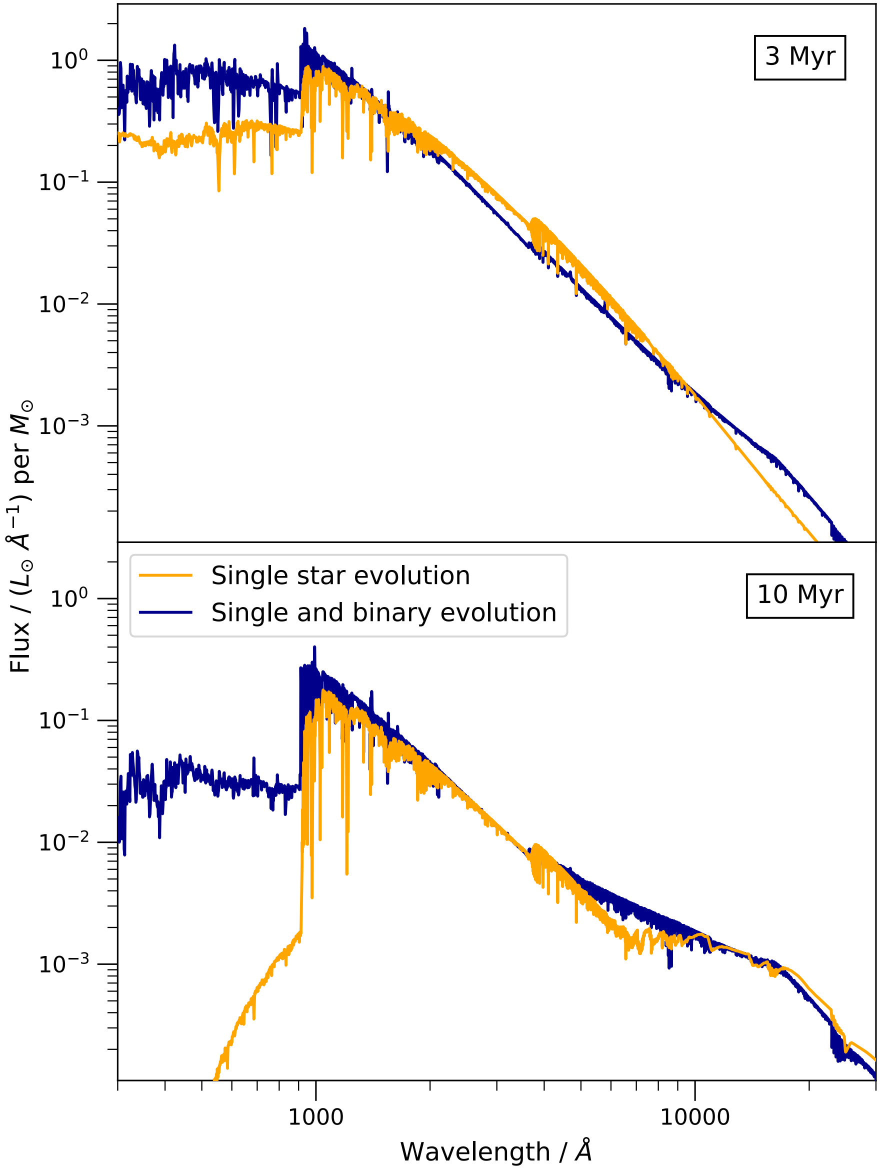
The hardness of the ionizing spectra can alter the dust properties (i.e. grain size).



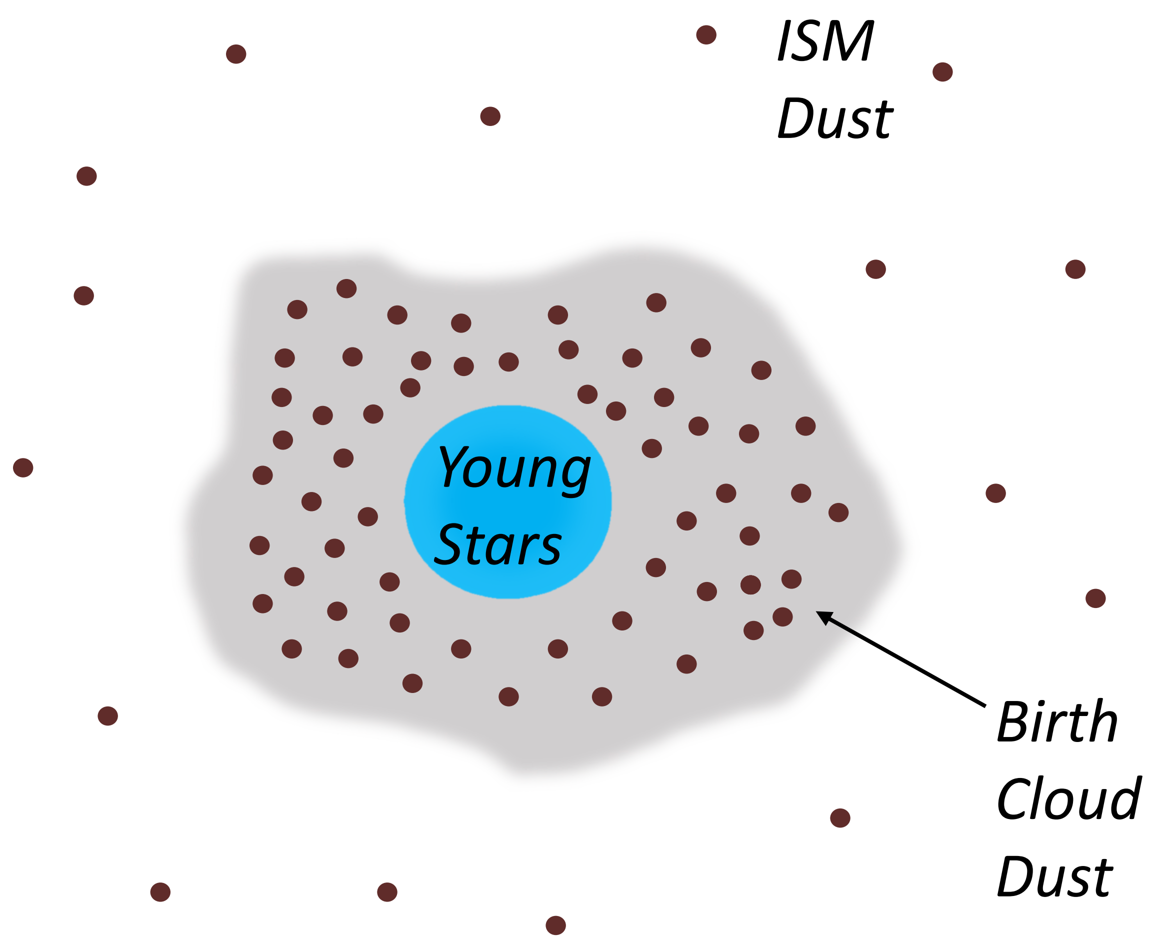
Young Stellar Emission in Models

Emission spectra vary between stellar population synthesis models due to differences in input physics.

Inclusion of binary evolution leads to younger stars existing for longer, creating harder ionizing spectra and more UV emission in older populations.



Birth Clouds



Stars are born within clouds; denser regions of gas and dust.

These birth clouds dissipate on the timescale of a few Myr.

This causes increased attenuation of harder ionizing starlight from young stars.

Stellar Models

Bruzual & Charlot 2003 (BC03)	*Updated 2016 version of Bruzual & Charlot 2003 (BC16)*	*Binary Population And Spectral Synthesis (BPASS, Eldridge et al. 2017)*
Single star evolution tracks	**Single** star evolution tracks	**Single** and **binary** evolution tracks
Most UV emission emitted by **5 Myr**	Most UV emission emitted by **5 Myr**	Most UV emission emitted by **10 Myr**
Padova 1994 stellar evolution library (Bressan et al. 1993)	Updated Padova evolution tracks (Bressan et al. 2013)	BPASS generated evolution tracks

Dust Emission Models

Draine & Li (2007, DL07)	*da Cunha et al. (2008, dC08)*	*Draine et al. (2021, D20)*
Template model based upon **single** star evolution	**Empirical** model	**Template** model based upon **single** and **binary** evolution
One model for all components, with a parameter to simulate a birth cloud-like component	**Two models** to incorporate a birth cloud and ISM component	**Separate template models** used for birth cloud and ISM components
Three free parameters	Seven free parameters including two grain temperatures	Four free parameters

Comparing Models

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Model combinations are fit to a sample of local, dusty, star-forming galaxies (z<0.5) from the COSMOS field (Laigle et al. 2015).

Galaxies stacked into groups to get a typical infrared galaxy for different redshifts and masses, each fit using BAGPIPES (Carnall et al. 2018).

Models compared using Bayesian Information Criterion (BIC), calculated as:

$$BIC = k\ln(n) - 2\ln(\mathcal{L})$$

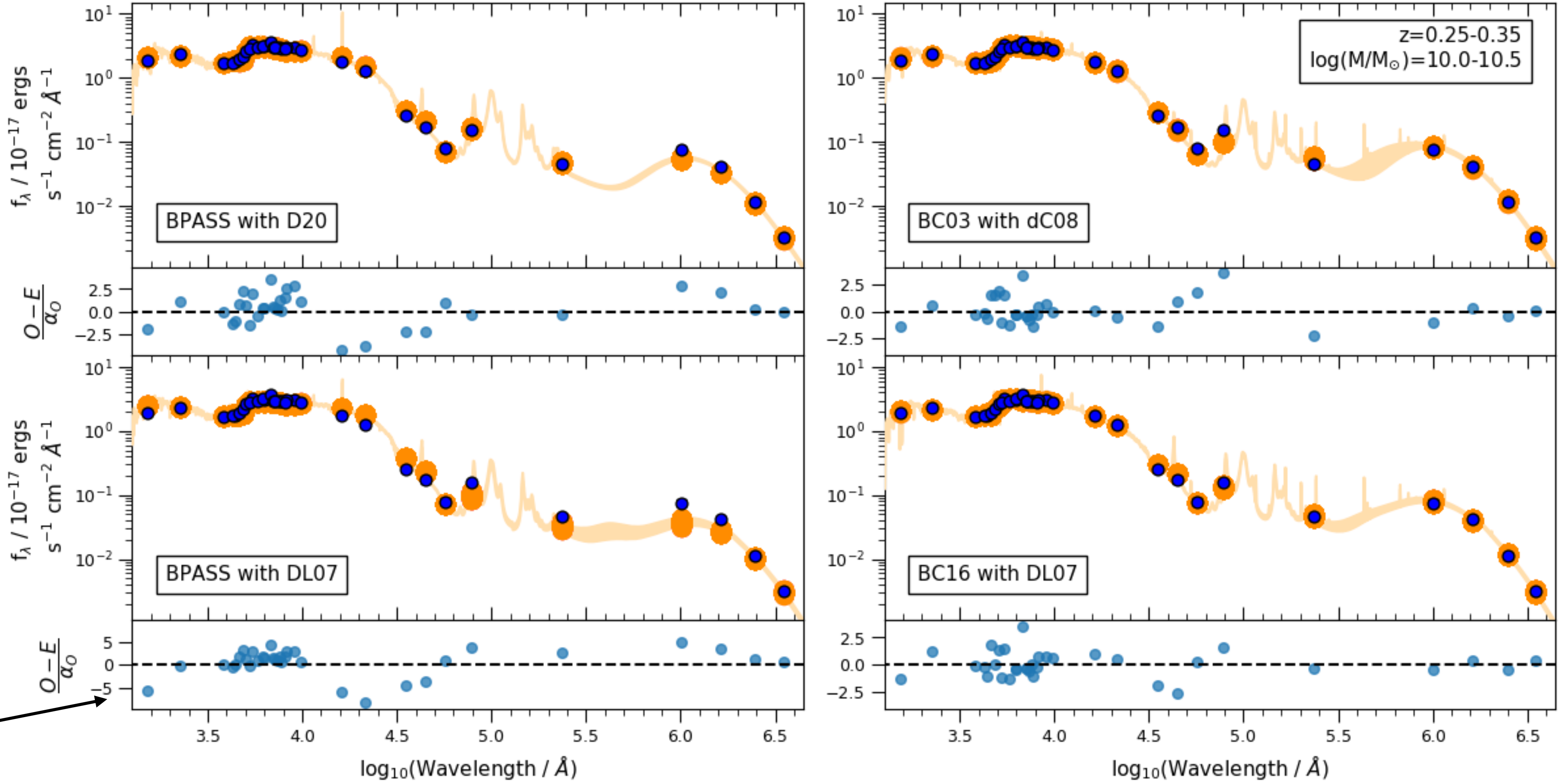
Number of parameters (k)

Number of observations (n)

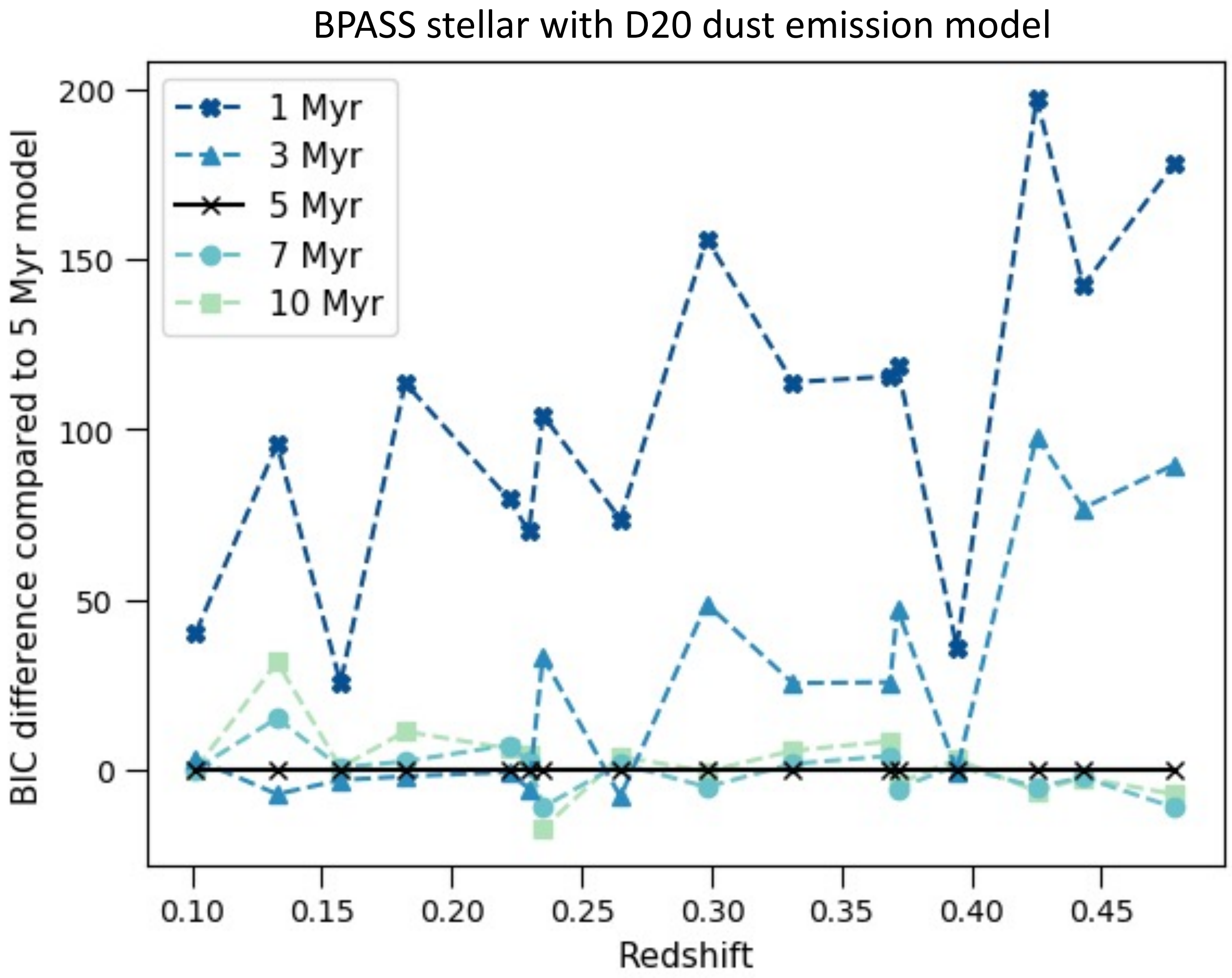
Maximum likelihood ($\mathcal{L}$)

Model Fits to Observations

Model fits are good except the BPASS and DL07 combination which have much larger residuals.



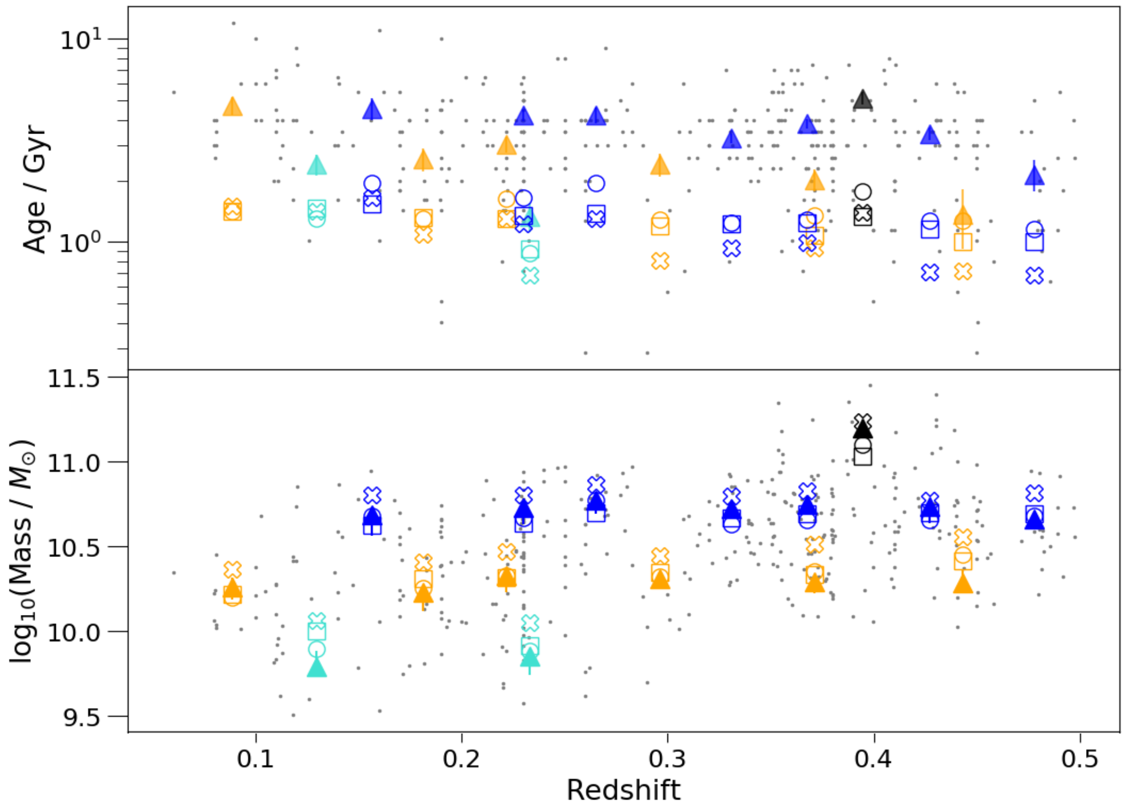
Birth Cloud Dissipation

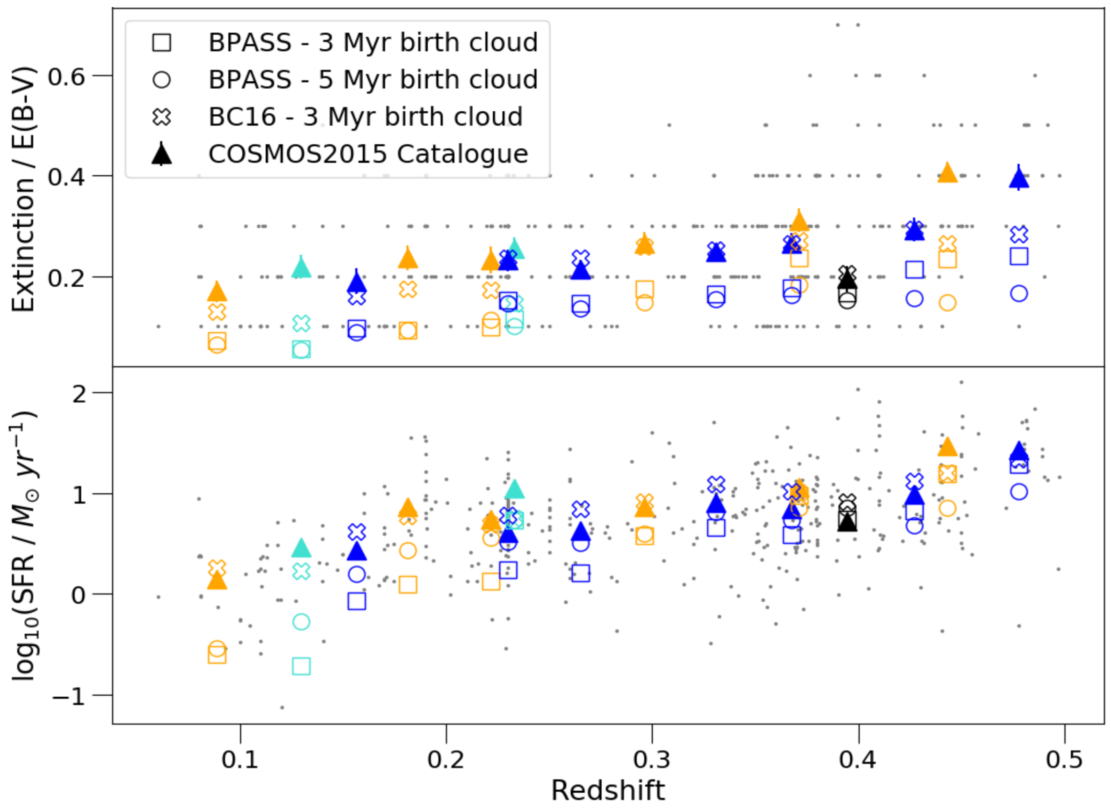


Birth clouds are required to exist for a minimum period, after which they disperse.

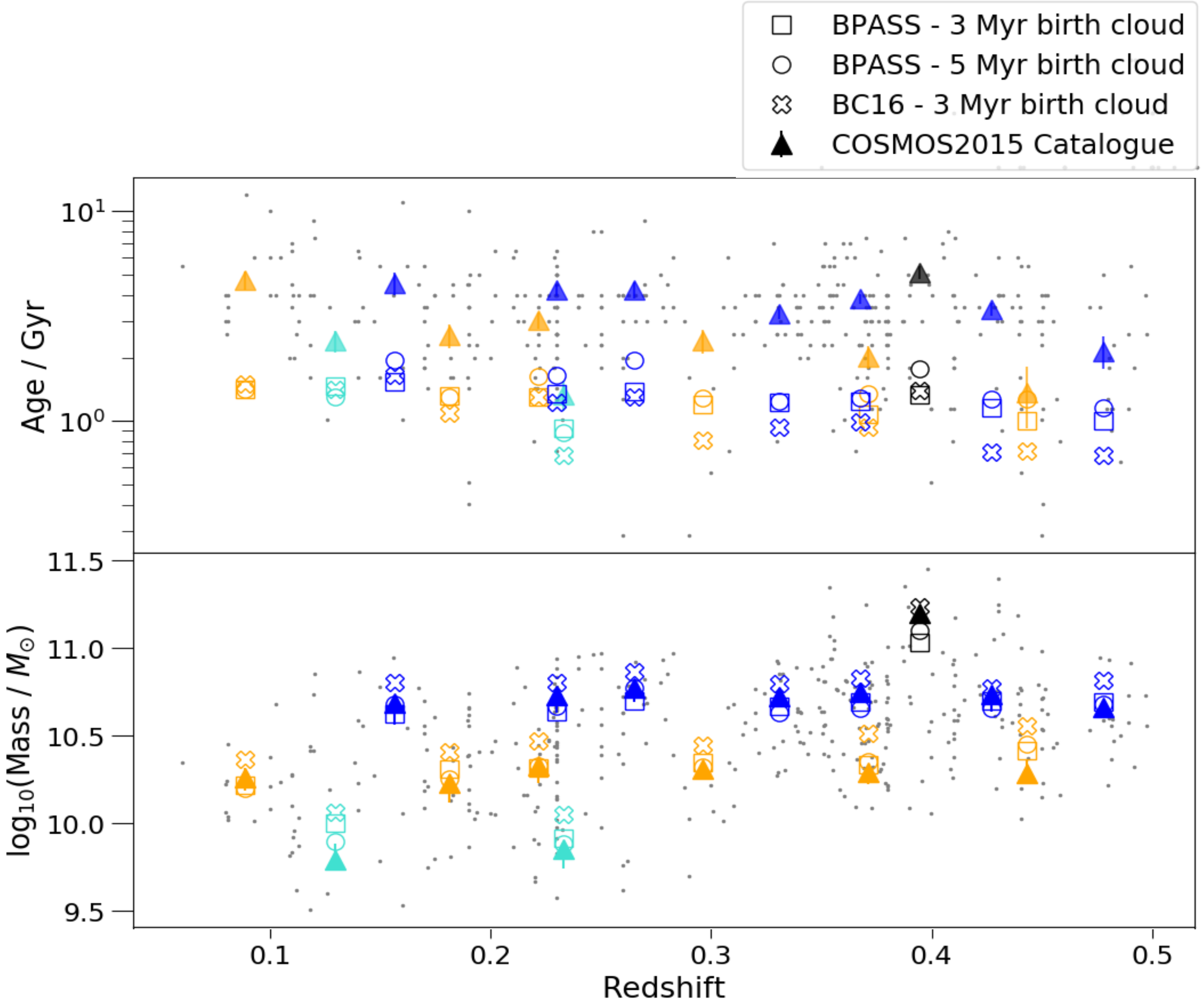
This length of time is required to generate enough dust emission.

Parameter Space





Parameter Space



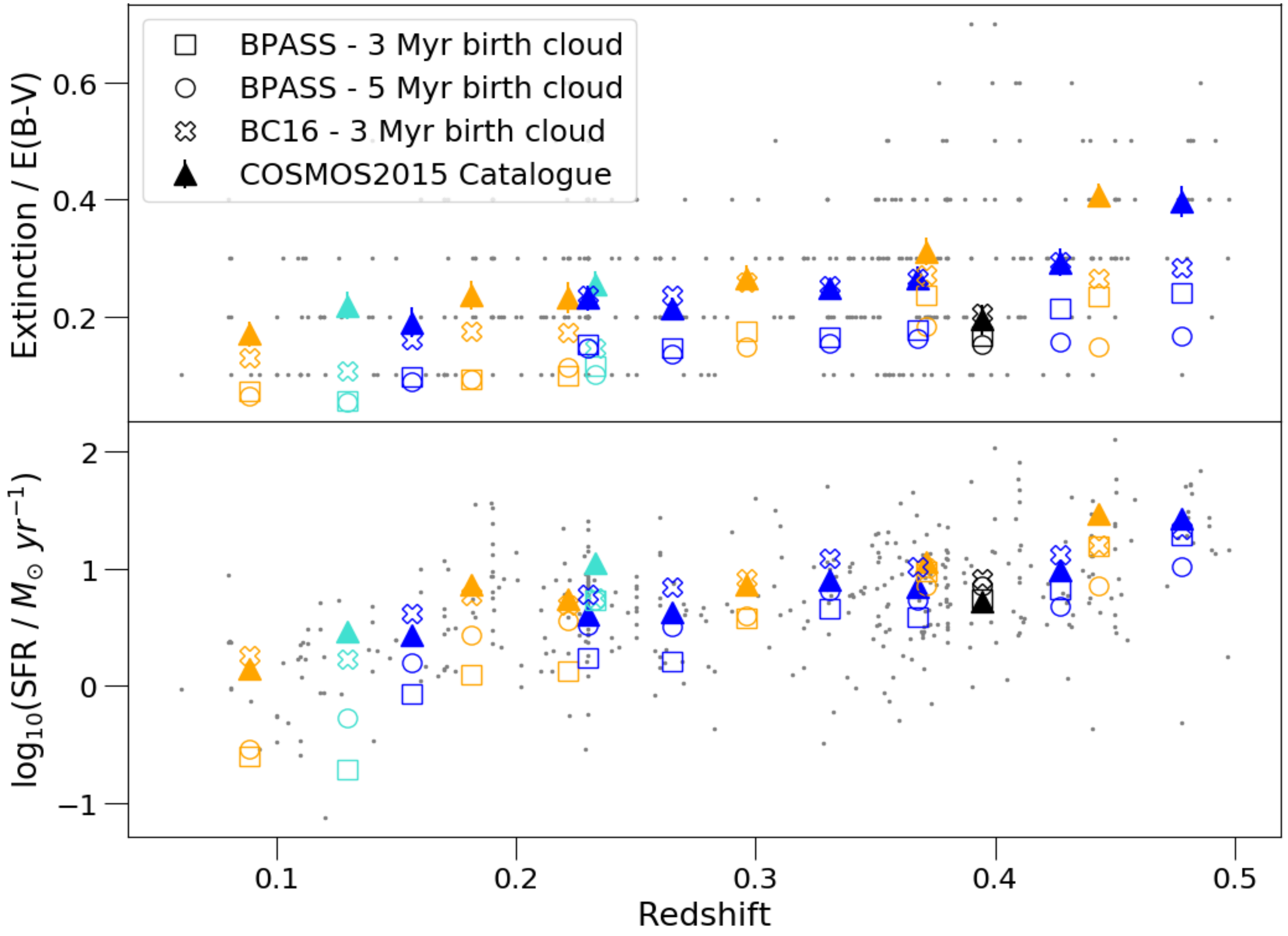
A simple parametric star-formation history was assumed, the simplicity of which causes our derived ages to show no systematic trends.

Since BPASS has a lower (optical) mass-to-light ratio than the BC16 models, the derived masses are lower by 0.15 dex using BPASS.

Parameter Space

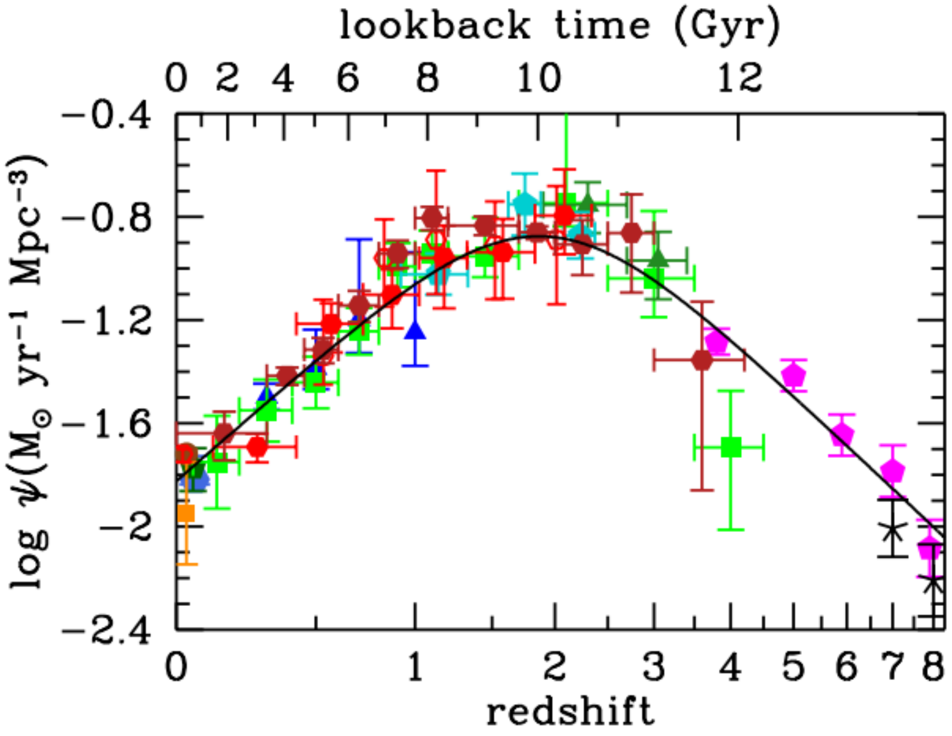
Since BPASS produces more UV flux, it needs lower extinction (attenuation) by E(B-V) = 0.07 to generate the same amount of dust emission.

Finally, BPASS has lower derived SFR than BC16 models, with an offset of 0.31 ± 0.18 dex.

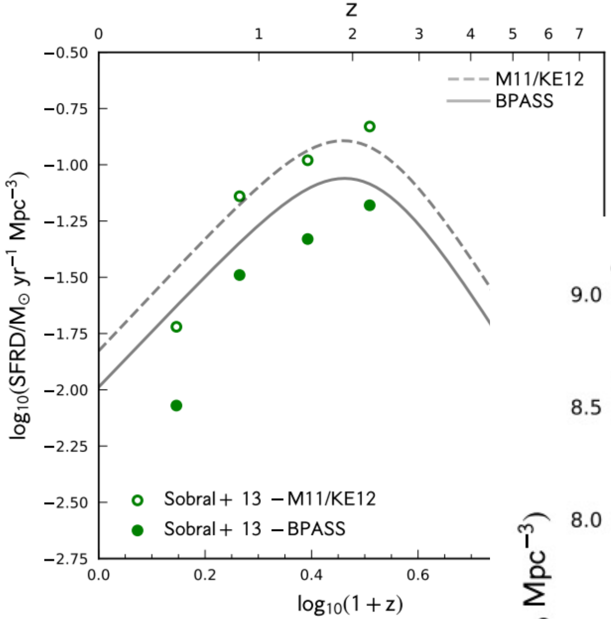


Star Formation Implications

Star formation rate at different epochs

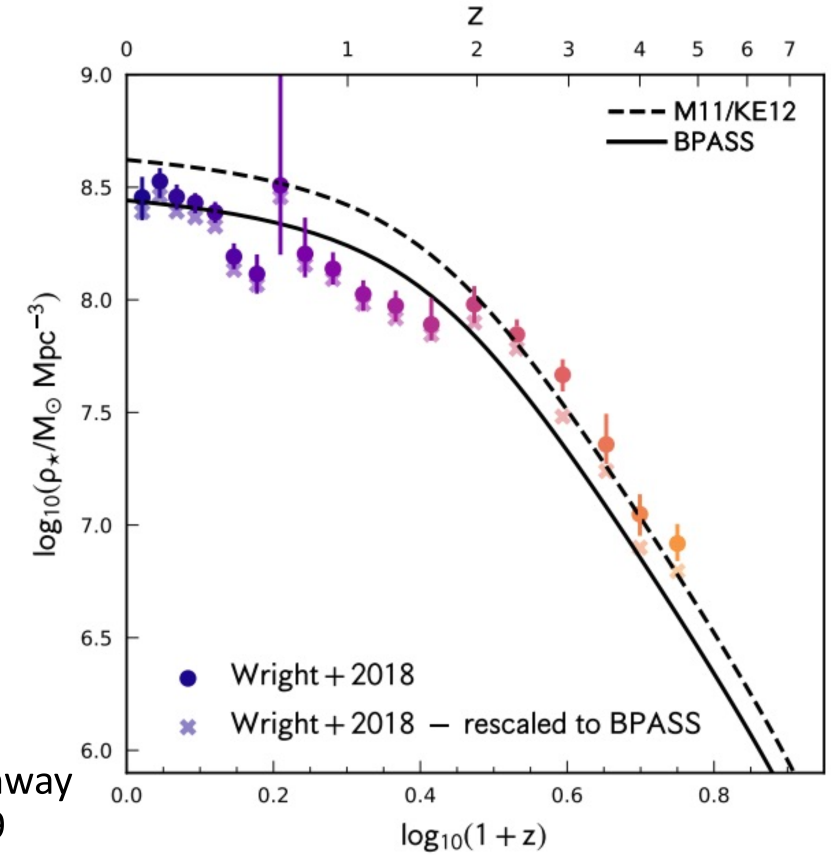


Madau P., Dickinson M., 2014, ARA&A, 52, 415

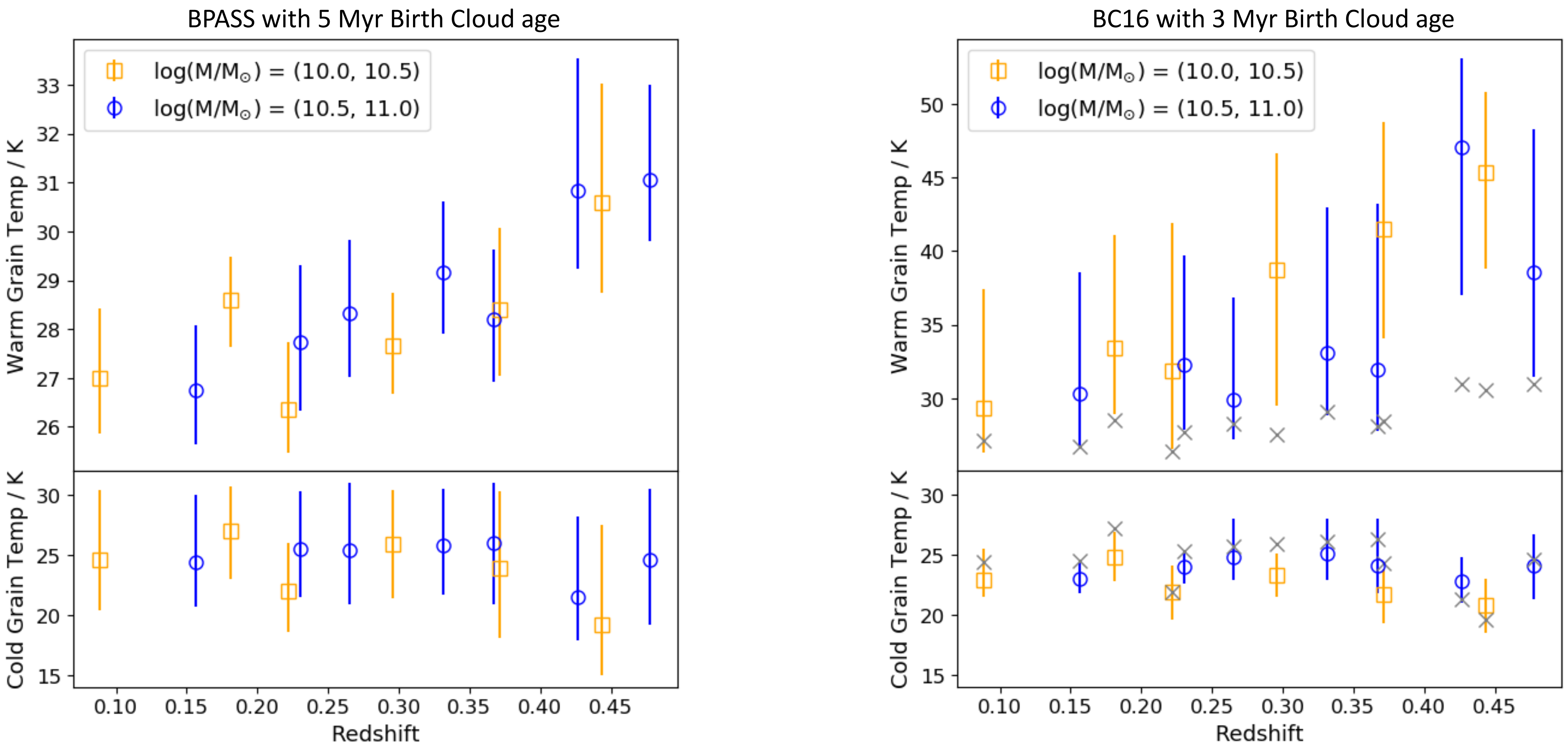


Wilkins S. M., Lovell C. C., Stanway E. R., 2019, MNRAS, 490, 5359

Mass density of Universe at different epochs



Dust Grain Temperature Variations



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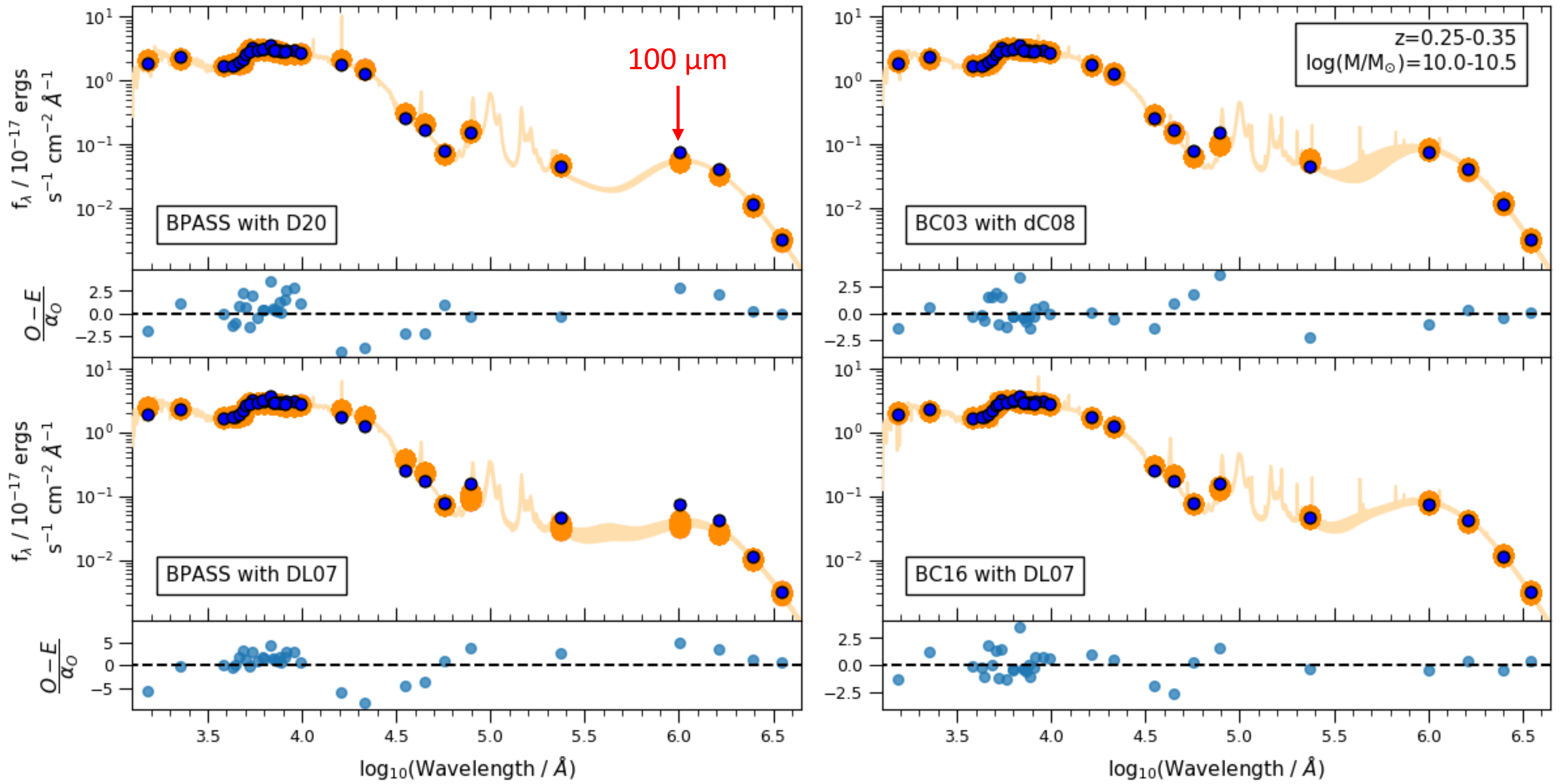

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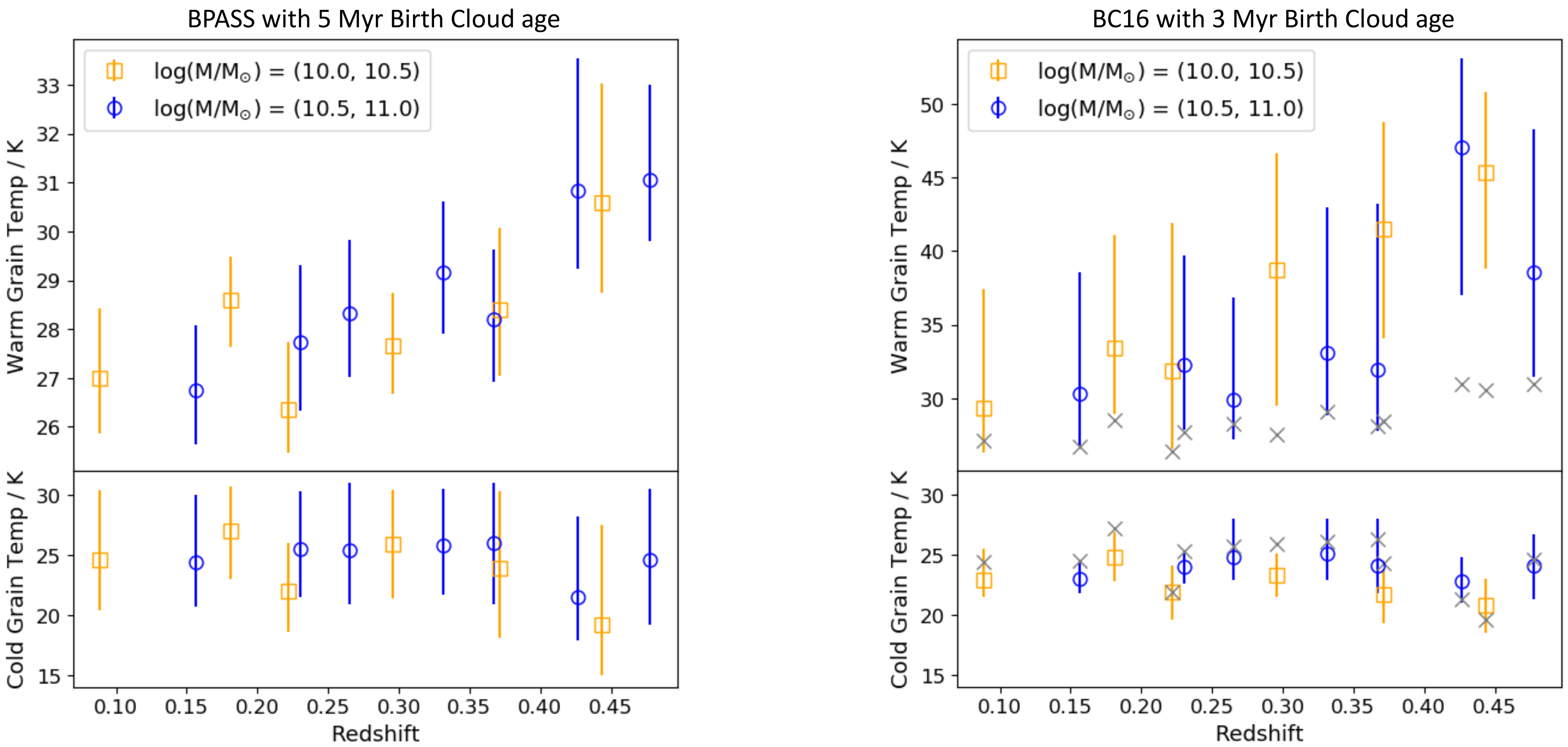

Future Work

- Investigate dust temperature evolution with redshift
- Investigate radio emission to explore correlations between infrared emission, radio emission and supernovae rates

Conclusions

- Derived galaxy properties has a dependence on both stellar population synthesis and dust emission model
- BPASS derives lower masses, extinction values and star formation rates than the BC16 models due to its harder ionizing spectrum
- Binary population synthesis corrections can help reconcile discrepancies between the cosmic star formation rate integral and the stellar mass densities
- BC16 models derive higher dust temperatures than the BPASS models due to weaker UV emission

Further details in: Jones G. T., Stanway E. R., Carnall A. C., 2022, MNRAS, 514, 5706