Investigating the Early Universe:

A Study of Dusty Star-Forming Galaxies at high redshift to understand the Baryonic Evolution

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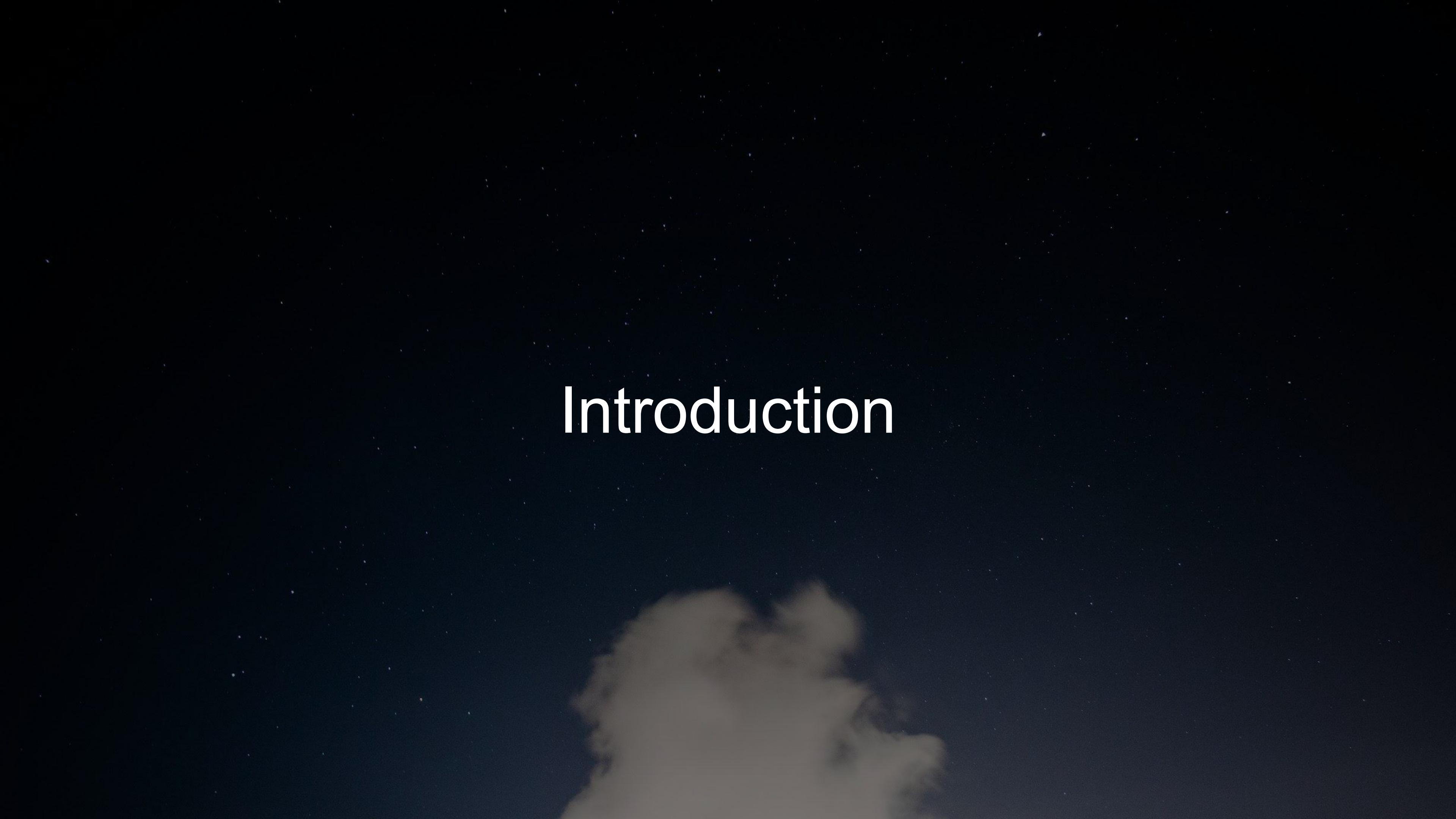
Introduction

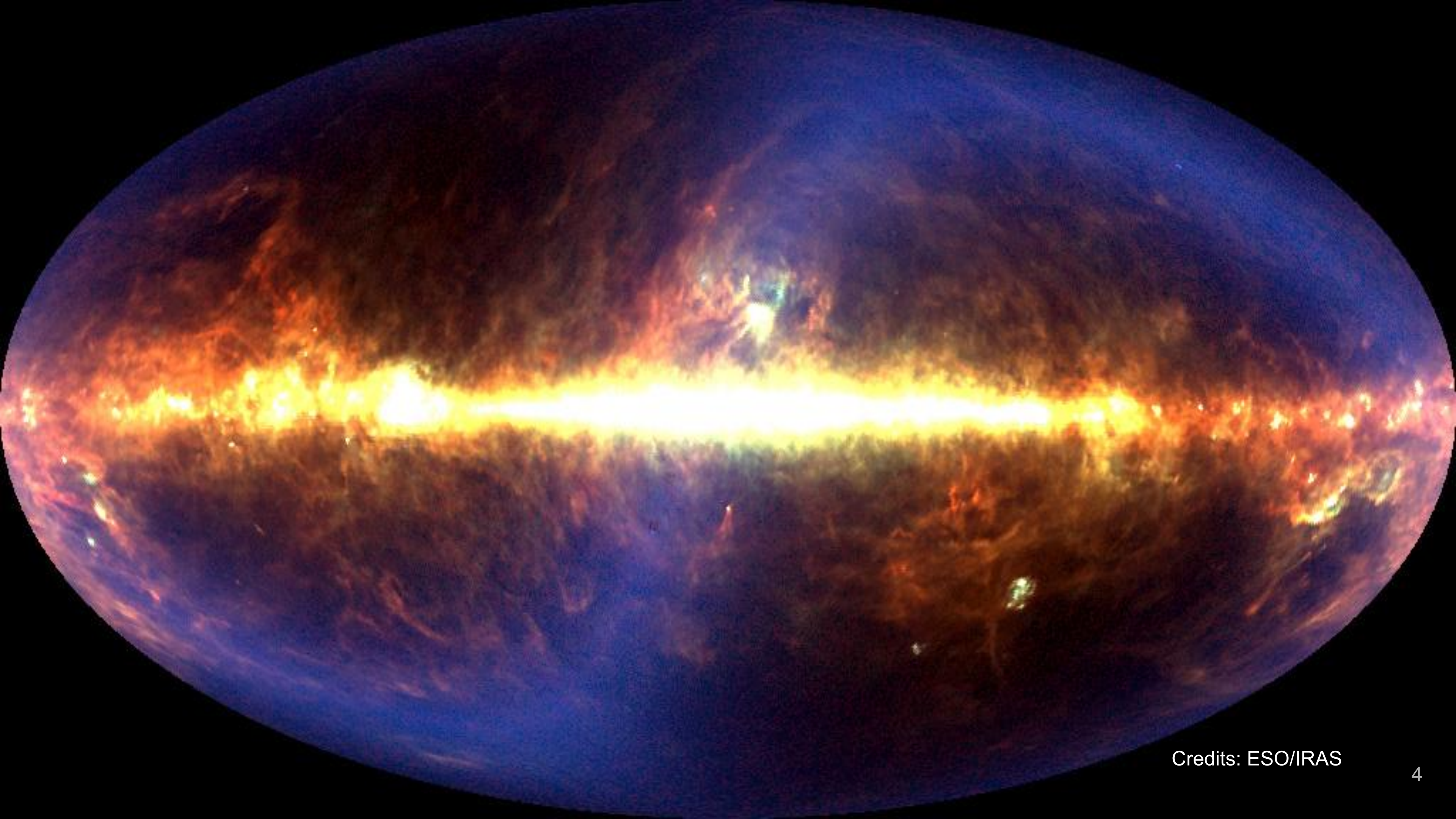


A hidden (*and dusty*) Universe

Observed by Far-InfraRed Absolute Spectrophotometer (FIRAS) aboard the Cosmic Background Explorer (COBE) satellite.

Implied that the Universe emits almost same energy density as UV/Optical domain as in Infrared domain.

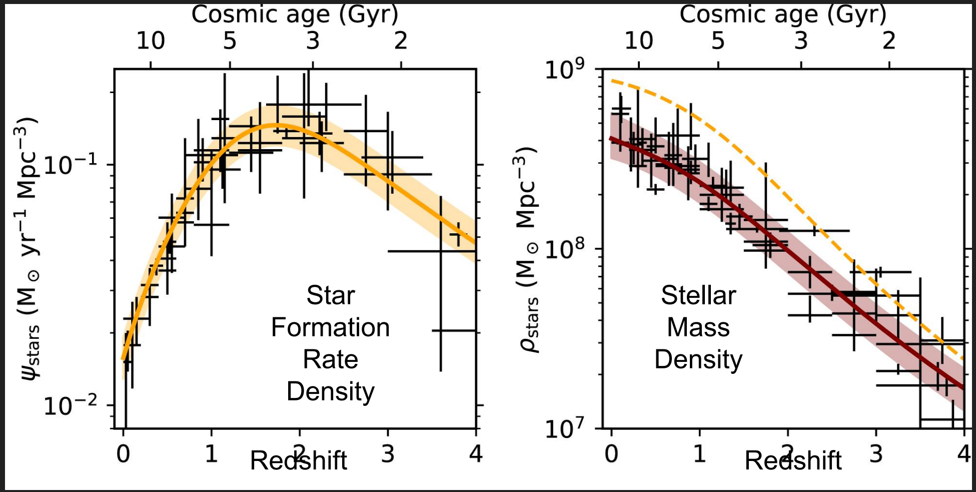
Herschel, ALMA and NOEMA detected galaxies in sub-mm domains with increased resolutions.



Credits: ESO/IRAS

Cosmic History

Time evolution of physical parameters of galaxies.



Credits: Walter+20

Cosmic History

Time evolution of physical parameters of galaxies.

Existence of “main - sequence” of galaxies.

Credits: CANDELS

Cosmic History

Time evolution of physical parameters of galaxies.

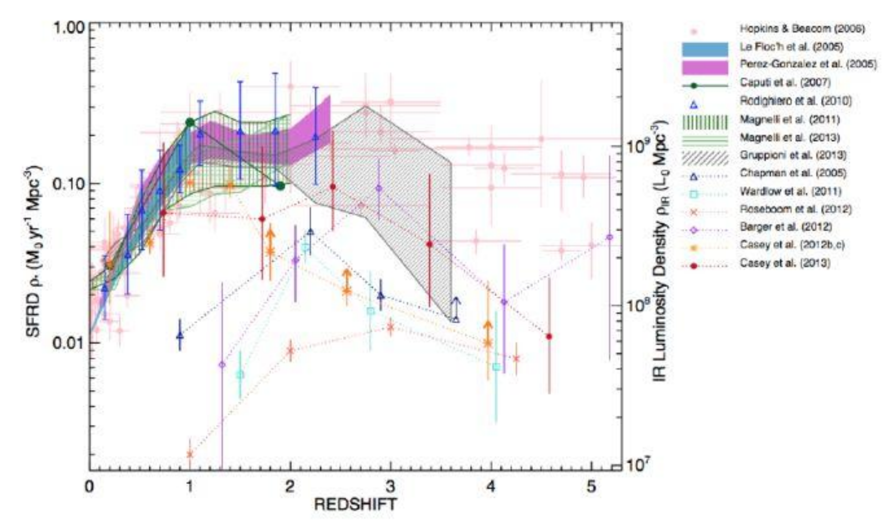
Existence of “main - sequence” of galaxies.

Indicates a order in nature and not an inherent stochasticity.

Credits: CANDELS

Dusty Star Formation in Early Universe

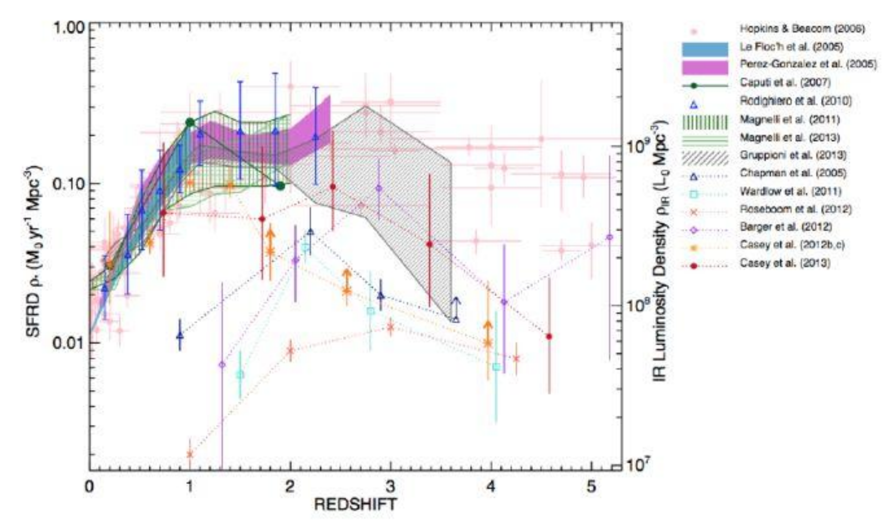
- A clumpy structured universe from a smoothly distributed matter.
- Ultra luminous IR sources in early universe.
- Dusty Star Forming Galaxies (DSFGs) contributing to the cosmic SFRD.



Credits: Casey+14

Trouble in the Early Universe?

- No models are able to match the observed number counts and inferred physical properties simultaneously.
- Scaled up versions of extreme galaxies in local universe?



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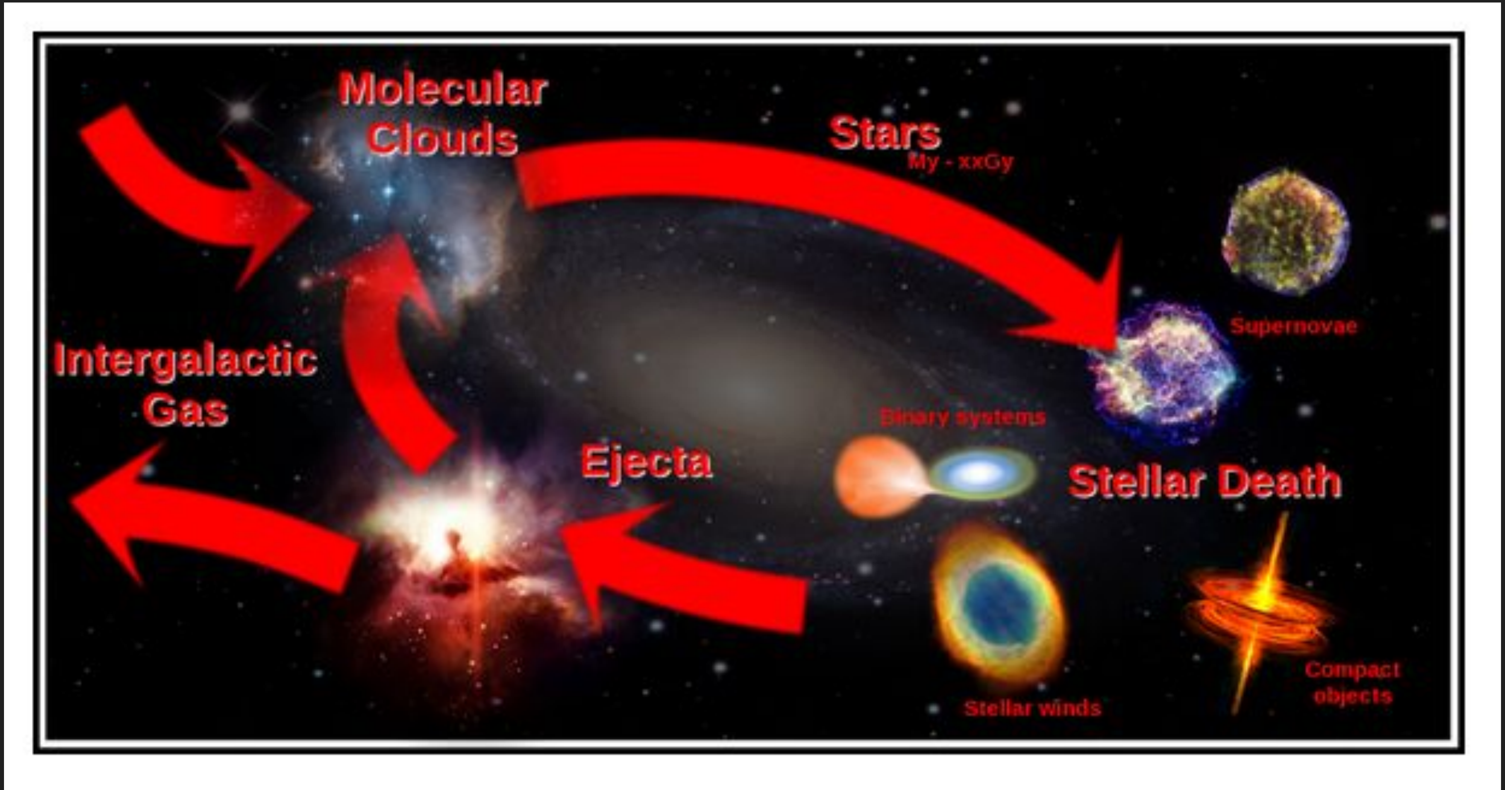
Baryonic evolution

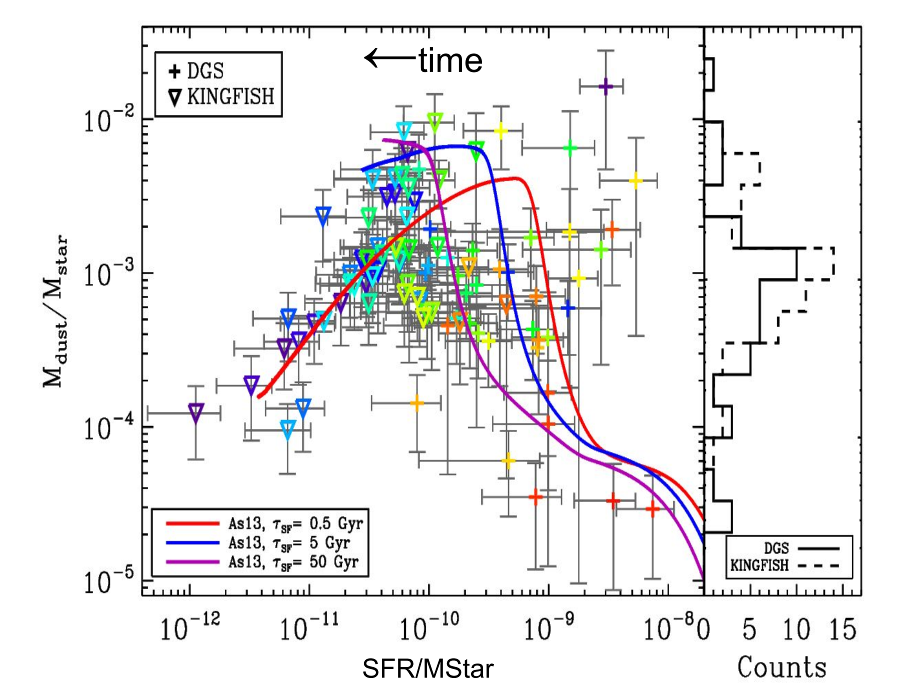


Credits: Richard Longland

Evolutionary Models

- Evolutionary models help us to probe the baryonic processes and test our models with observations.

- Enrichment of ISM
- Dust Growth and Destruction
- Inflows/Outflows



Credits: Remy-Ruyer+15

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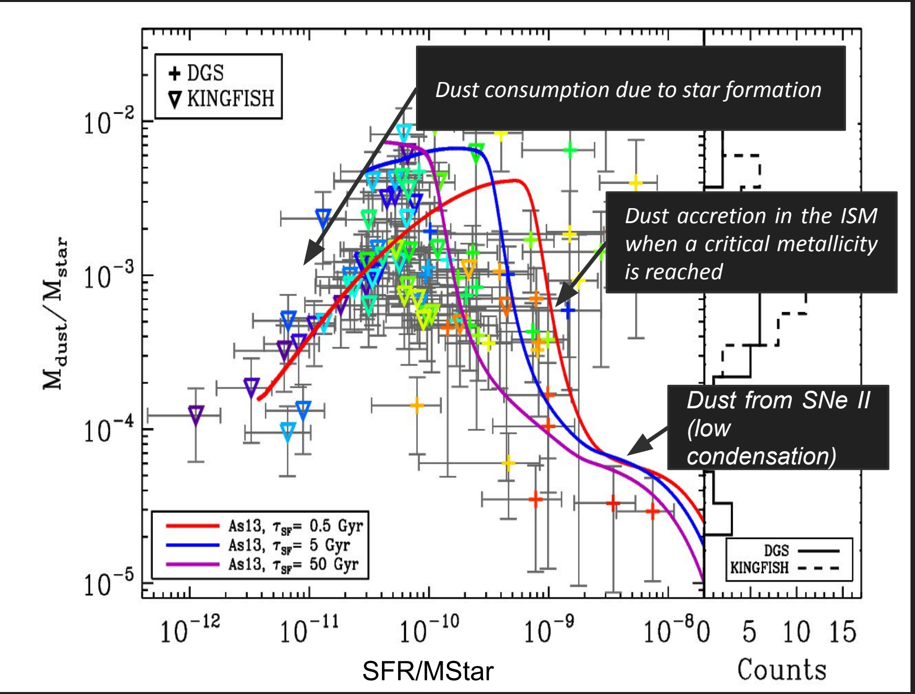

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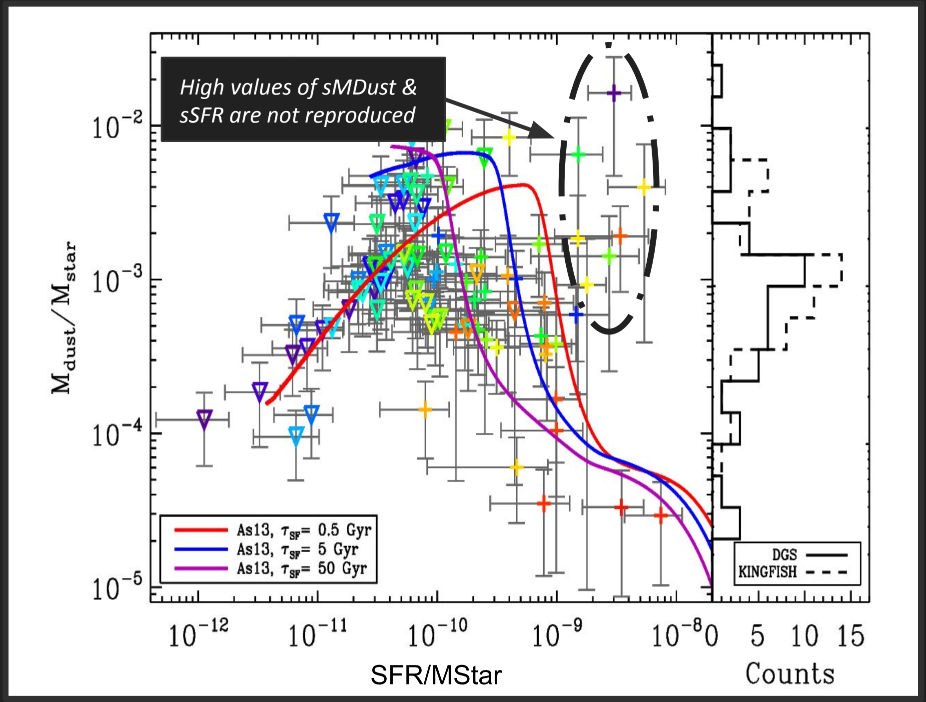


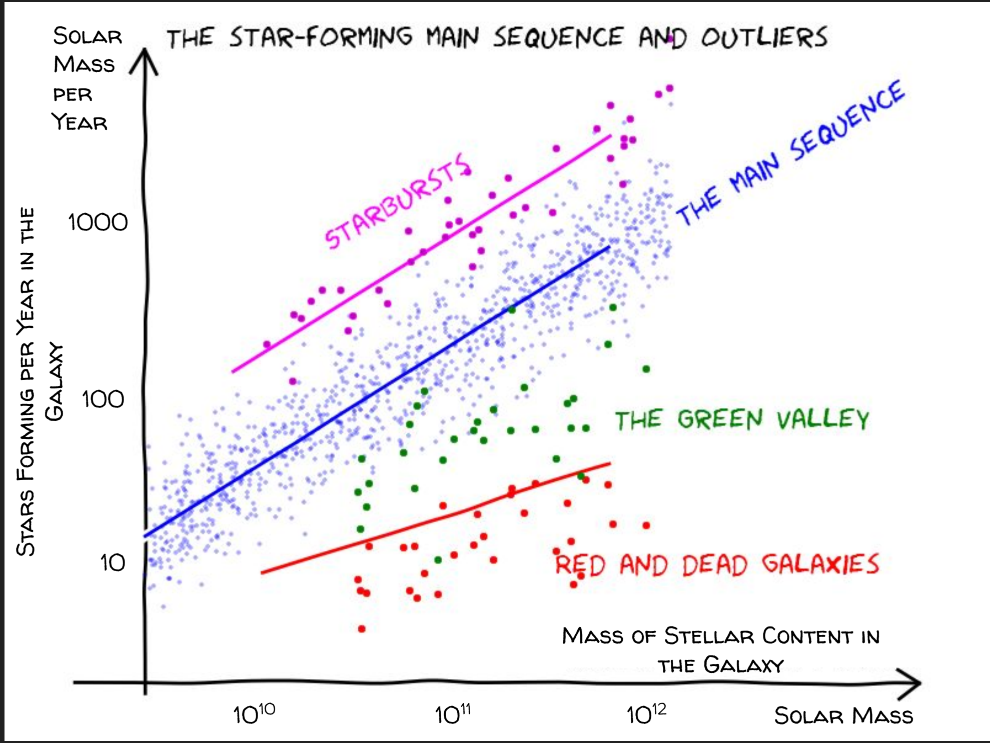
Credits: Remy-Ruyer+15

Motivation

- Galaxies in early universe have proven to be a significant challenge for theoretical models of galaxy formation.
- Are we able to explain the heavy dust content at the beginning of baryon cycle in these galaxies?

Methodology

A Comparative study



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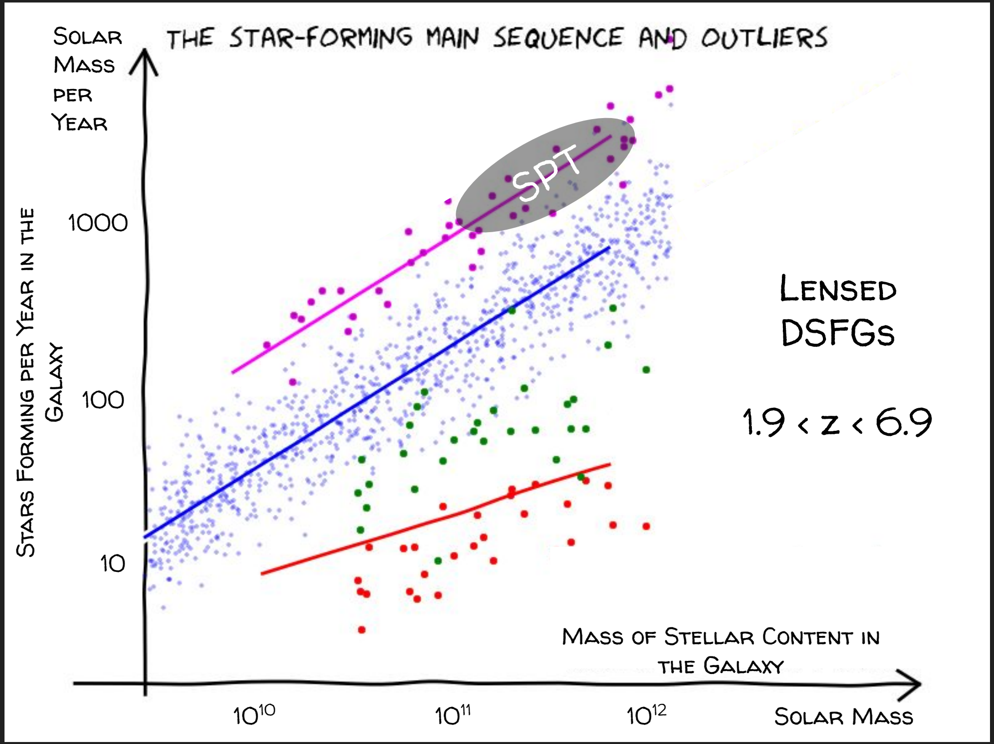

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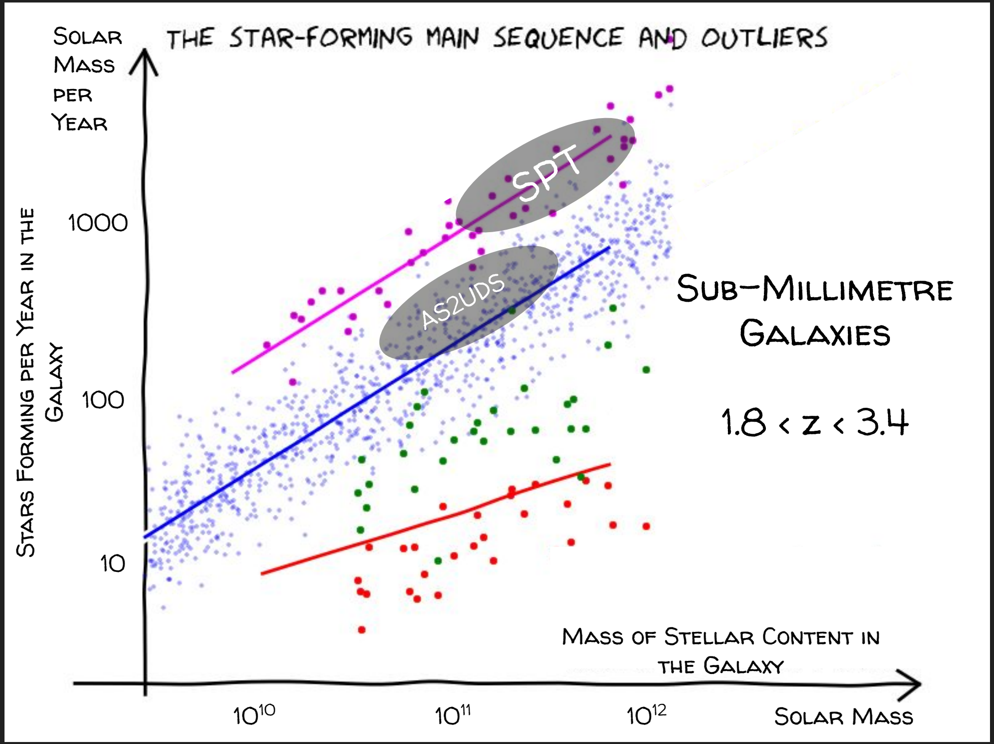

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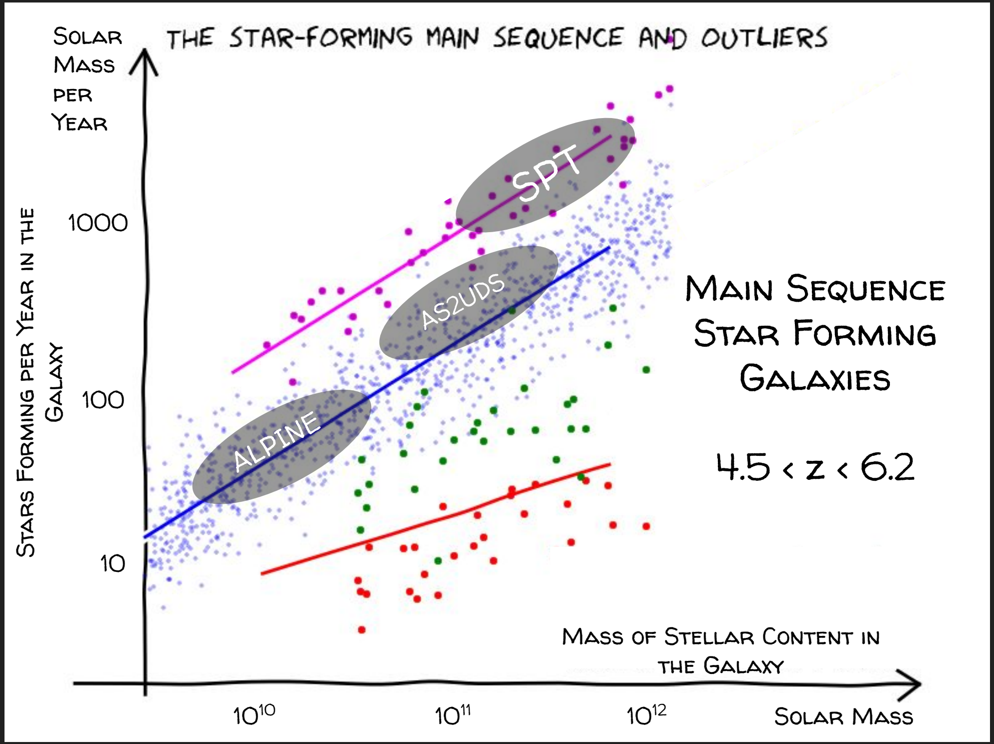
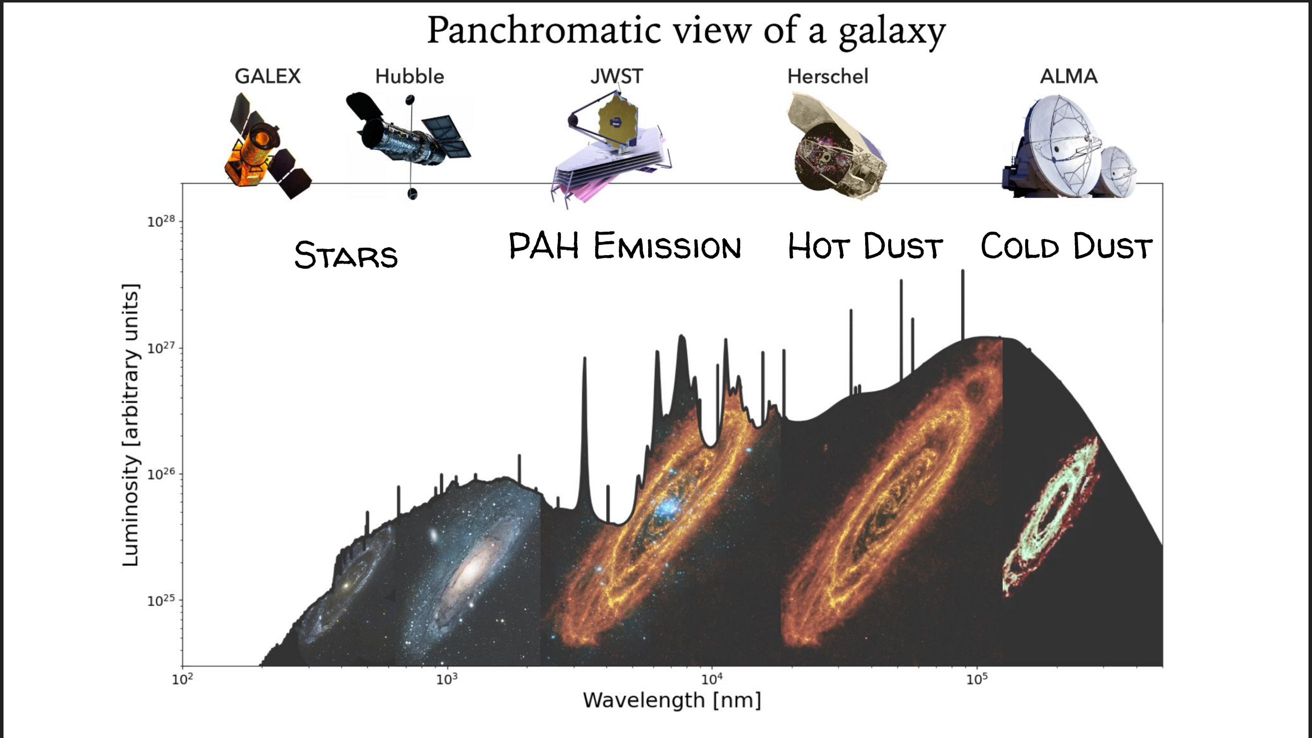
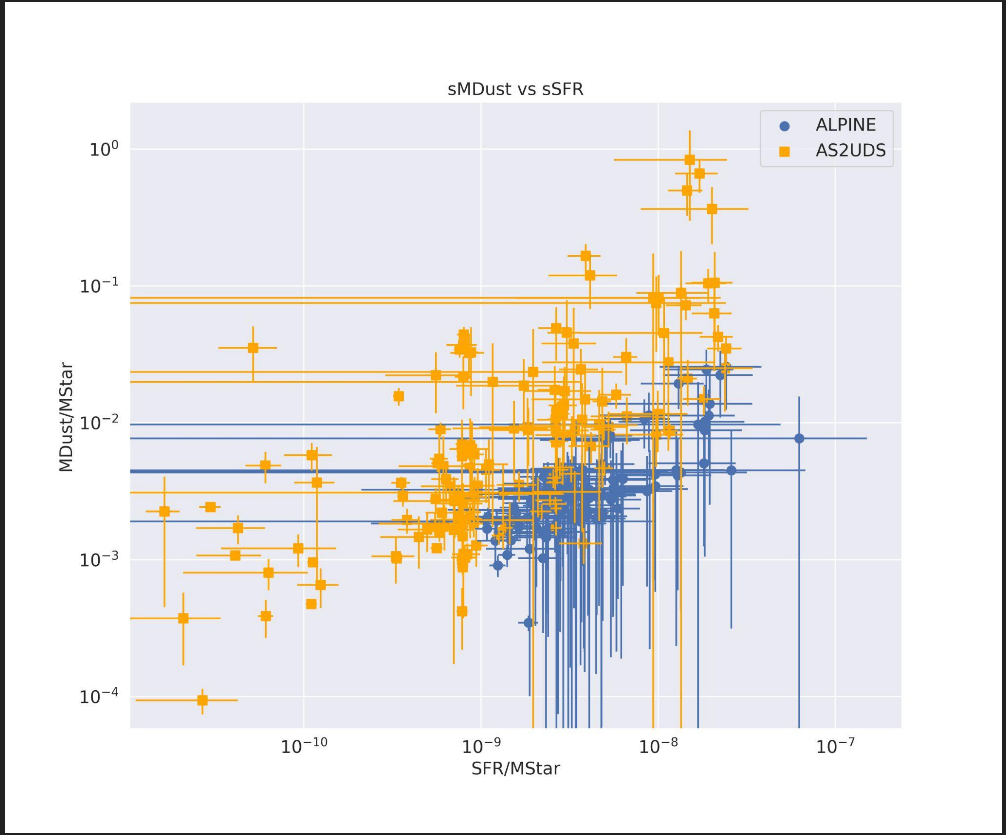


A Panchromatic view of Galaxy



Credits: M. Hamed

The Dust Formation Rate Diagram



Credits: Sawant et. al (in prep)

SPT (*a different case*)

- Strongly lensed and high - z galaxies.
- Peak in submillimetre domains.
- No resolved optical counterparts.
- No information on the stellar content of galaxies.

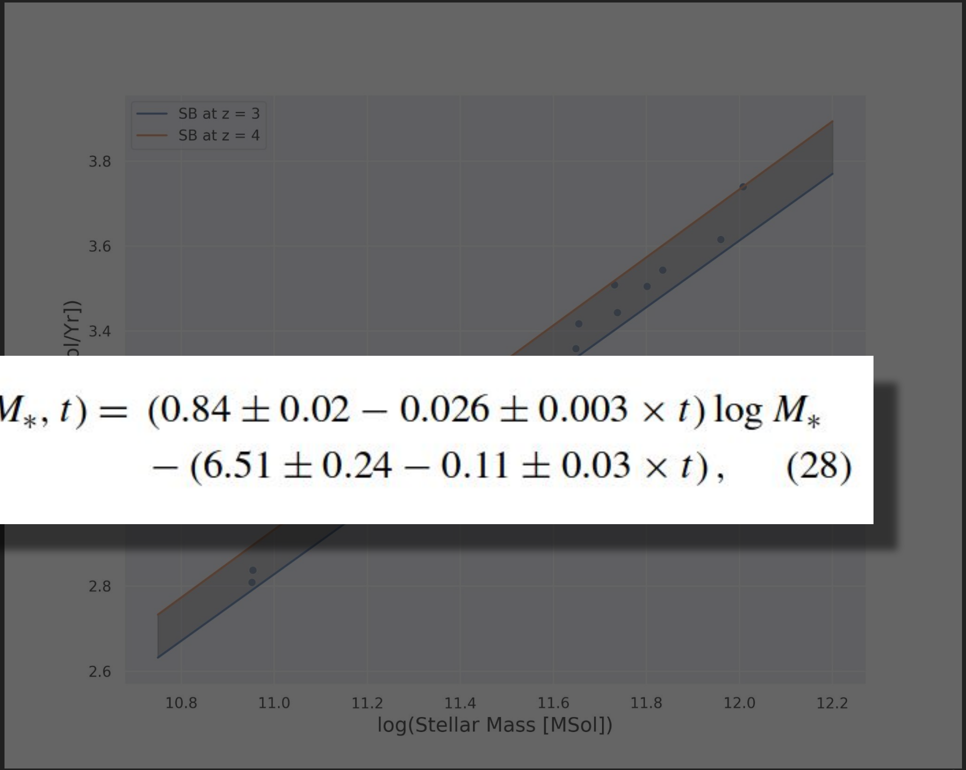
Stellar Mass (*the other ways**)

Using empirical relation between SFR, Redshift and Stellar Mass.

Derived from “main - sequence” of galaxies.

Based on the studies done in Speagle 2014.

*Will be an upper limit on the stellar mass estimate.



$$\log \psi(M_*, t) = (0.84 \pm 0.02 - 0.026 \pm 0.003 \times t) \log M_* - (6.51 \pm 0.24 - 0.11 \pm 0.03 \times t), \quad (28)$$

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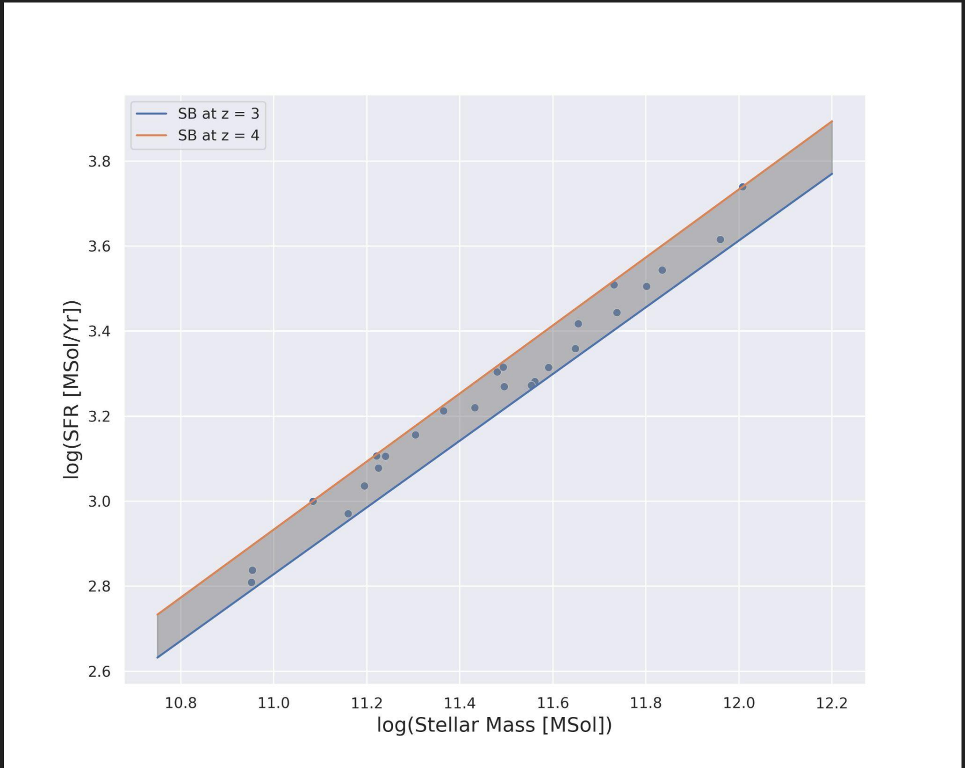
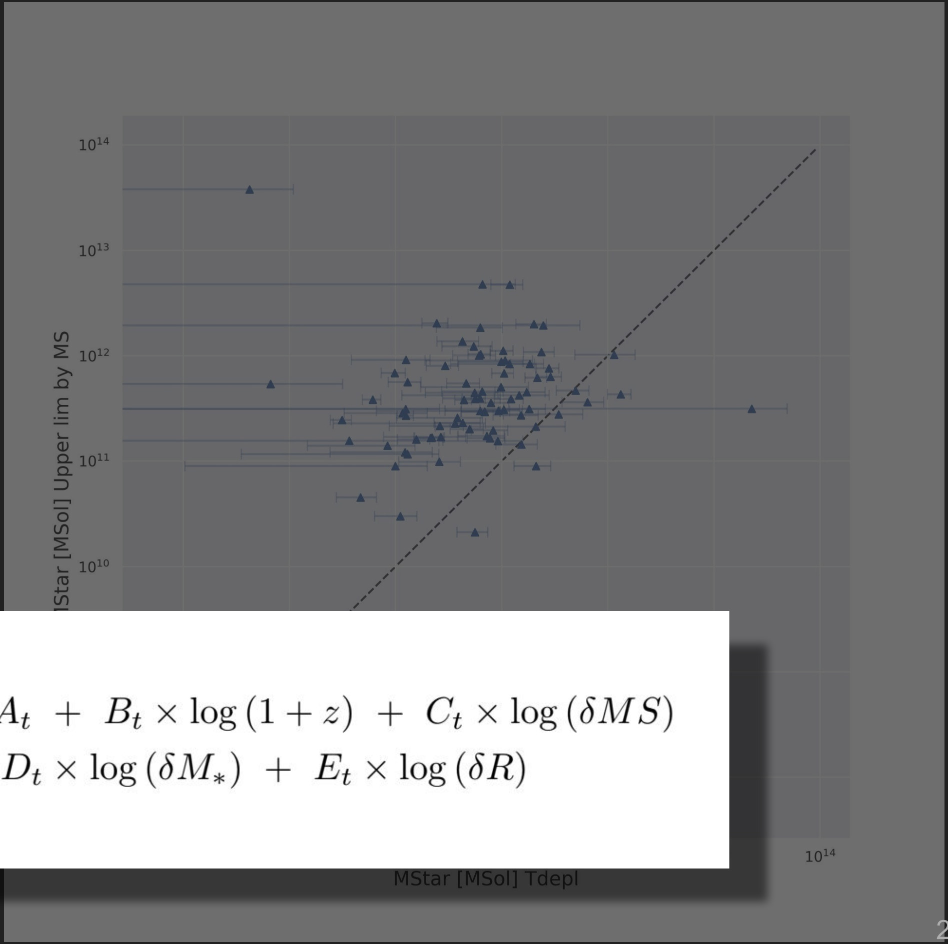


Stellar Mass (*the other ways*)

Using the empirical relation using the depletion timescales.

Derived from molecular gas estimates using different gas tracers.

Based on the studies done in Tacconi 2018.



$$\log\left(t_{depl}(z, sSFR, M_*, R_e)\right) = A_t \ + \ B_t \times \log\left(1+z\right) \ + \ C_t \times \log\left(\delta MS\right) \\ + \ D_t \times \log\left(\delta M_*\right) \ + \ E_t \times \log\left(\delta R\right)$$

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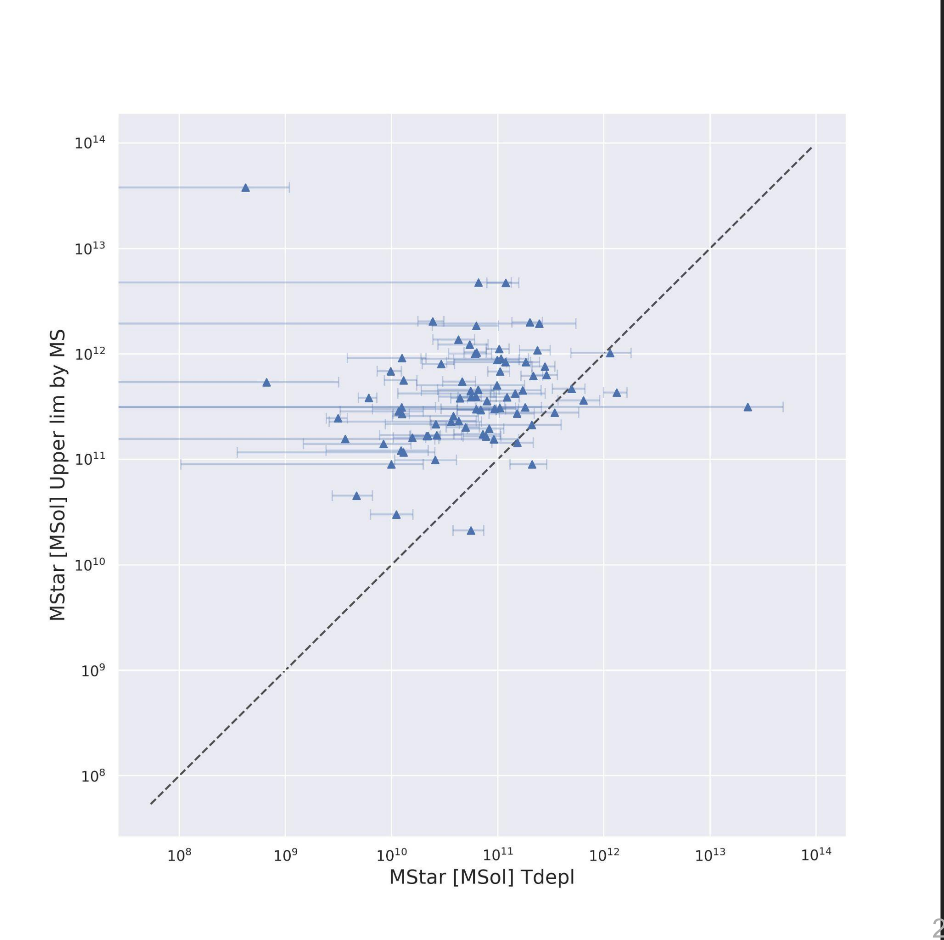
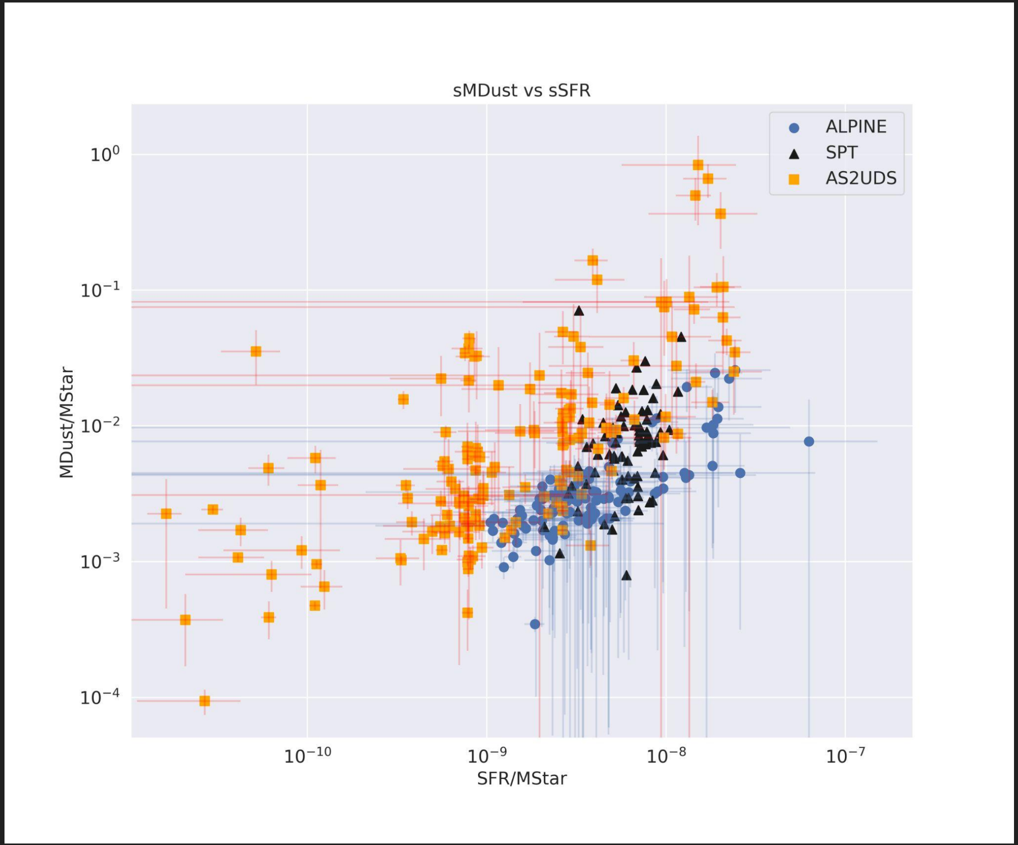


Results

The Dust Formation Rate Diagram



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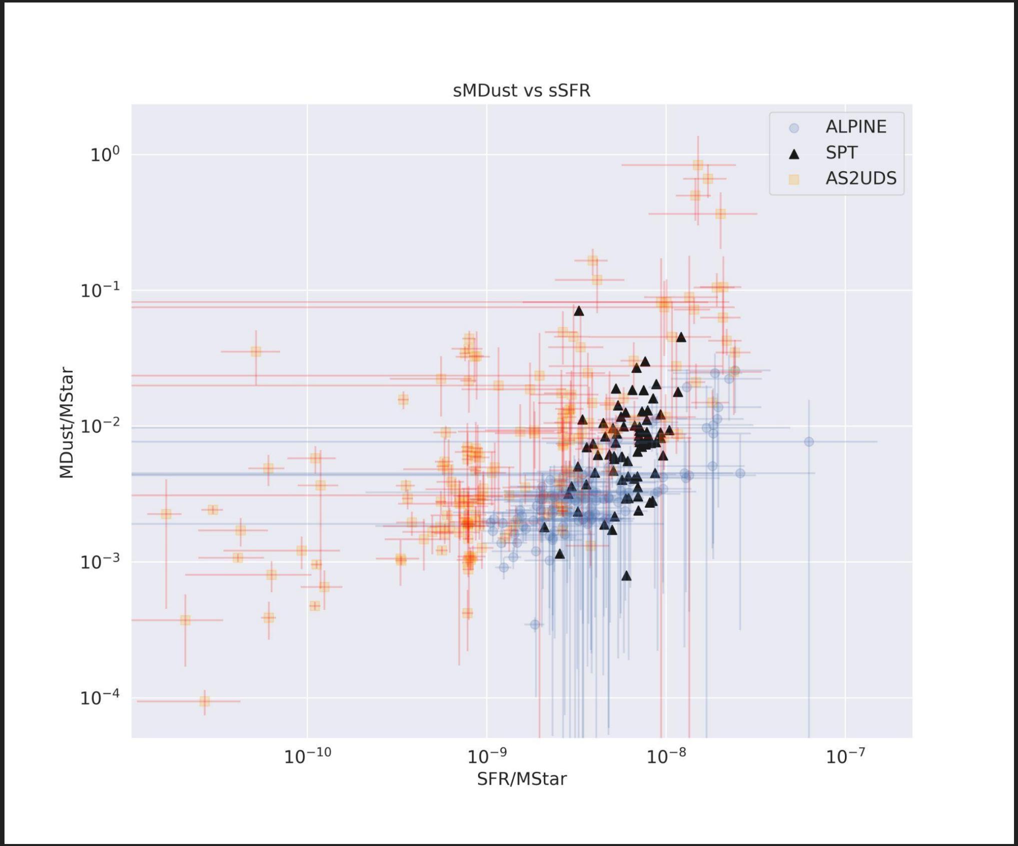
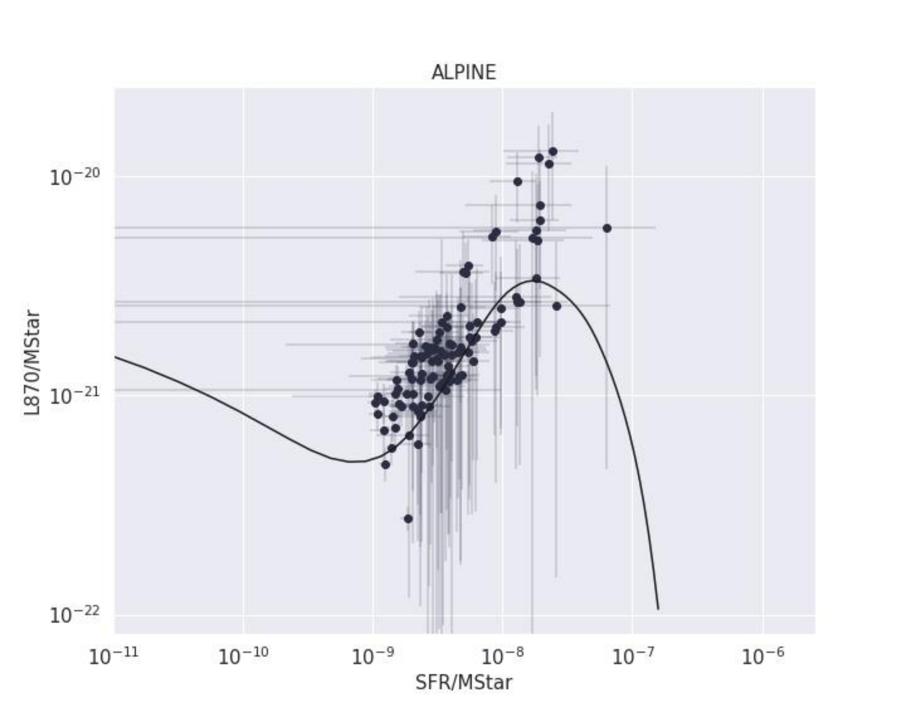
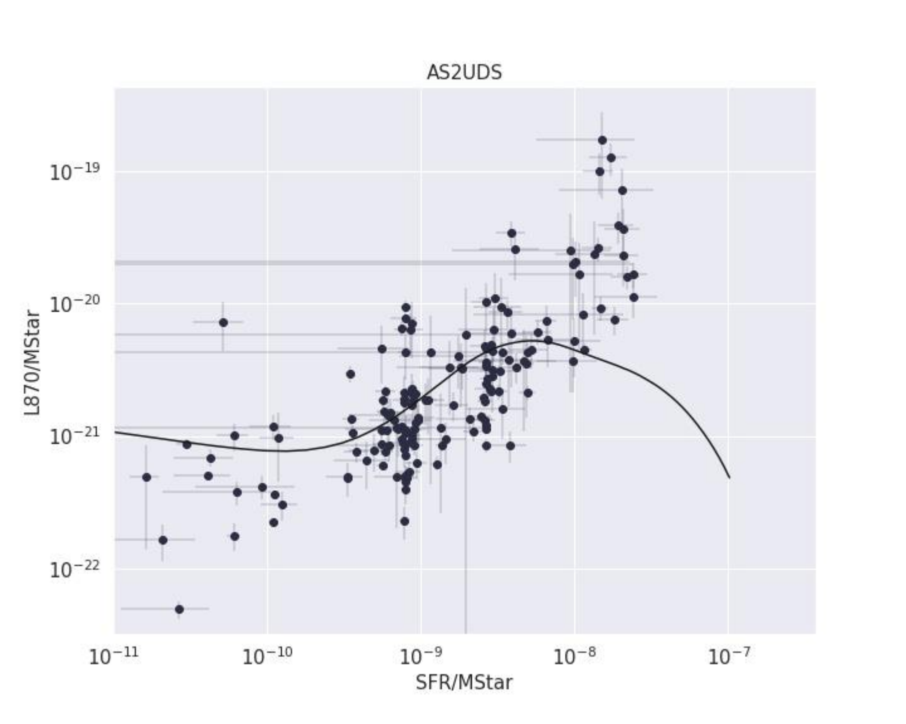


With Evolutionary Models (In Progress)





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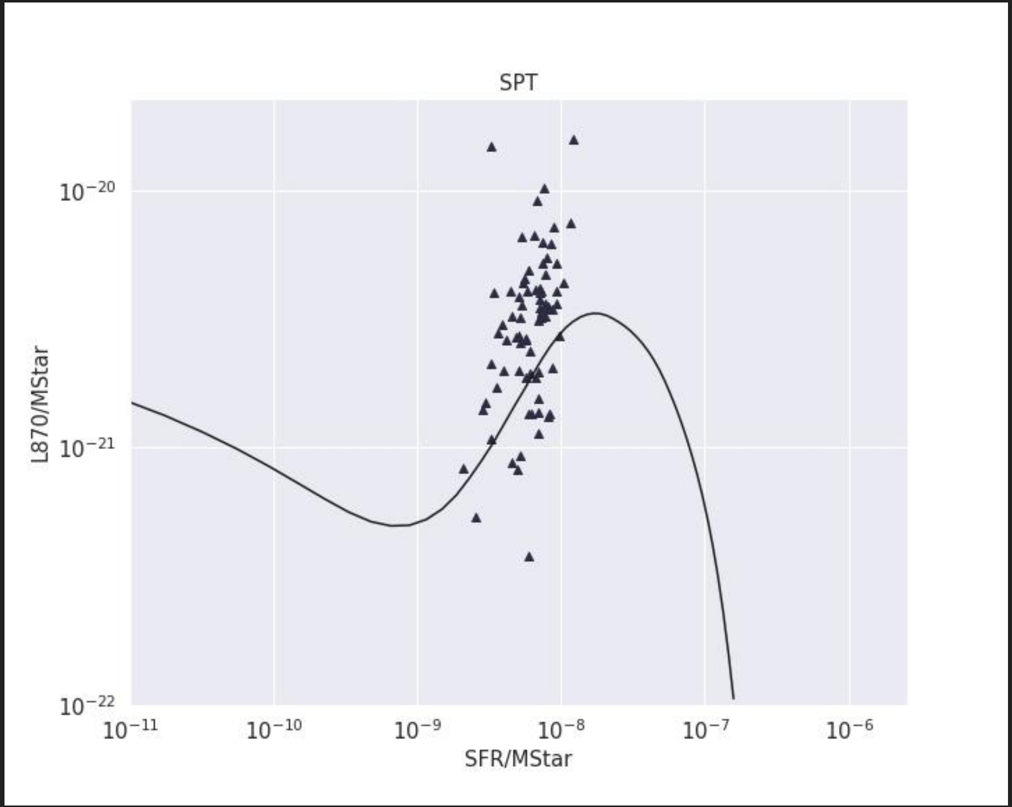

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Future Prospects

- Testing of Top - Heavy IMF hypothesis in SED fitting using CIGALE.
- Follow-up observations using JWST of a sample of SPT galaxies to have better constraints.
- Modeling of 3um feature observed in one of the SPT galaxy (Spilker+23).

Summary

- Understanding the dust build up at the peak of star formation density.
- Derived sSFR & sMDust values to probe the baryonic evolution in different types of galaxies.
- Use of empirical relations to derive the stellar mass for SPT galaxies.
- Study of the galaxies and relevant evolutionary models.

Thank You