Constraining Star Formation Histories of IR-bright high-z Galaxies with Herschel

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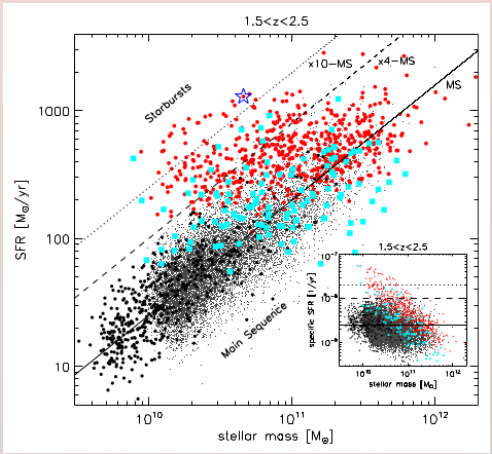
Outline

- Context
  - The question of the SFHs at high-z
- Aims
- Method
  - SED fitting, with the IR as a constrain
- Sample
- Results – implications
- Conclusion - future work

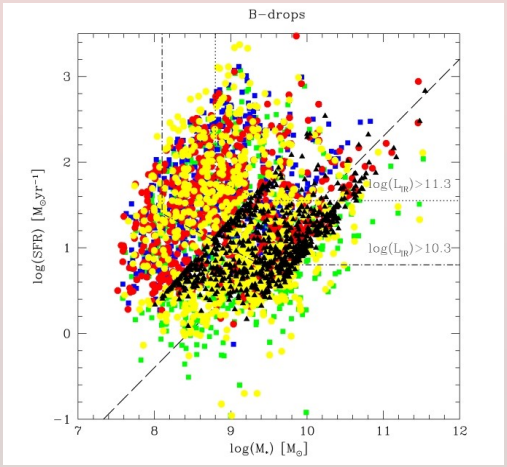
Context

- The question of SFHs in the SED-fitting of high-z galaxies
  - Local galaxies well represented by exp. declining SFHs
  - Numerous works point out that such SFHs are ill-adapted at higher z (e.g., Maraston et al. 2010 ; Reddy et al. 2012; Pacifici et al. 2013)
  - Using declining models on red/dusty galaxies can result in degeneracies (age/extinction, Reddy et al. 2010; Sklias et al. 2014)
  - Varying SFHs cause important scatter on the *M** – SFR relation (Schaerer et al. 2013; Buat et al. 2014)

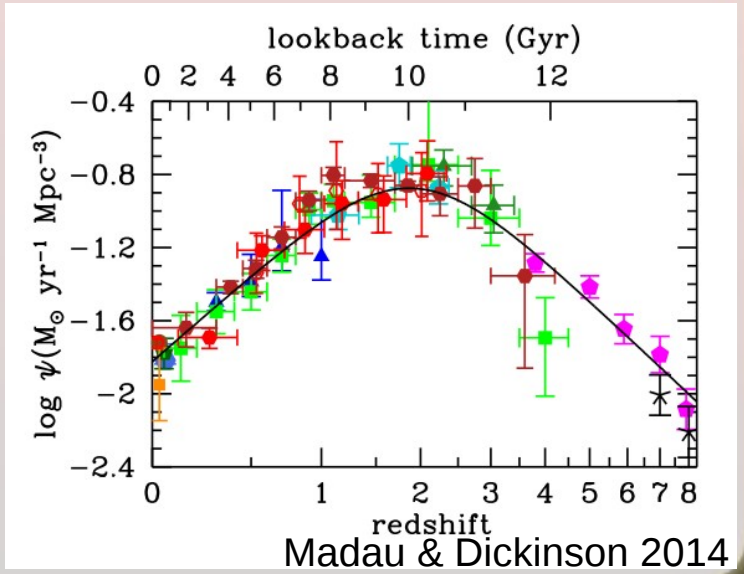


Rodighiero+2011, UV&IR SFRs

?



SFRs from variable SFH fits (Schaerer+2013, high-z LBGs)



Madau & Dickinson 2014

- Cosmic SF is rising until z ~ 2, what about individual galaxies ?

Aims

- Study the properties of a large sample of IR-detected high-z galaxies, by modelling their SEDs with different variable SFHs
- Utilize the accurate IR luminosities provided by *Herschel*, to produce models consistent with observations, and explore how the choices in SFH are affected/constrained.
  - Physical parameters
  - SFR indicators, IR+UV vs SED
  - Trends in SFH preference and properties (such as timescales)

$SFR(t) \alpha e^{-t/\tau}$	$SFR(t) \alpha e^{t/\tau}$	$SFR(t) \alpha t e^{-t/\tau}$	$SFR(t) \alpha$ cst.
declining	rising	delayed	constant

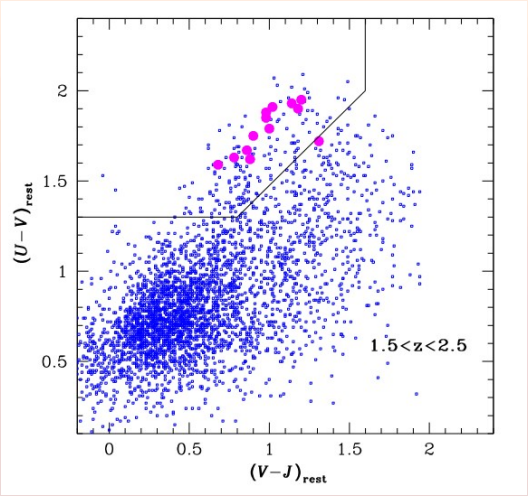
(Sklias et al., in prep.)

Method

- SED fitting tool *HyperZ* (Bolzonella et al. 2000), upgrated version with nebular emission (Schaerer & de Barros 2009,2010)
  - Fit stellar and dust emission separately :
    - Use of Bruzual & Charlot 2003 library, variable SFRs, extinction as a free parameter → Derive ***stellar properties*** with a standard approach (use Calzetti law, t_{min}=50 Myr, solar Z)
    - IR fits to measure ***observed IR luminosity,*** using various sets of templates (Chary & Elbaz 2001, Vega et al. 2008, Rieke et al. 2009, Berta et al. 2013)
  - Use the ***observed IR/UV ratio to fix the extinction***, assuming ***energy conservation*** (star light absorbed by dust re-emitted in the IR). The L_{IR}/L_{UV} ratio is an effective tracer of UV attenuation (Burgarella et al. 2005; Buat et al. 2010, Reddy et al. 2012). We use the relation between L_{IR}/L_{UV} and A_V from Schaerer et al. 2013.

Sample selection

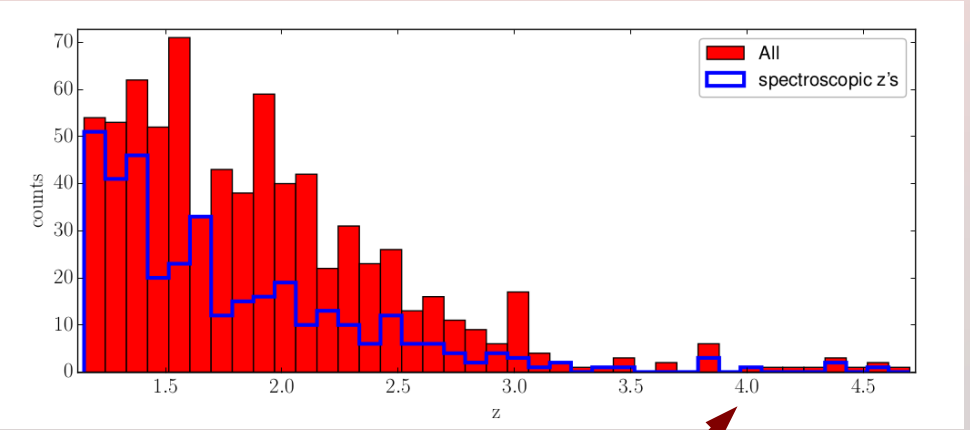
- We select all Herschel-detected galaxies from GOODS-N and S (Elbaz et al. 2011, 24μm priors) starting from z~1.2 (spec and phot), selected as star-forming (Panella et al. 2014) via the 2-color UVJ criterium (Williams et al. 2009)
- Starting sample of 753 (365 spec-z).



Pannella + 2014

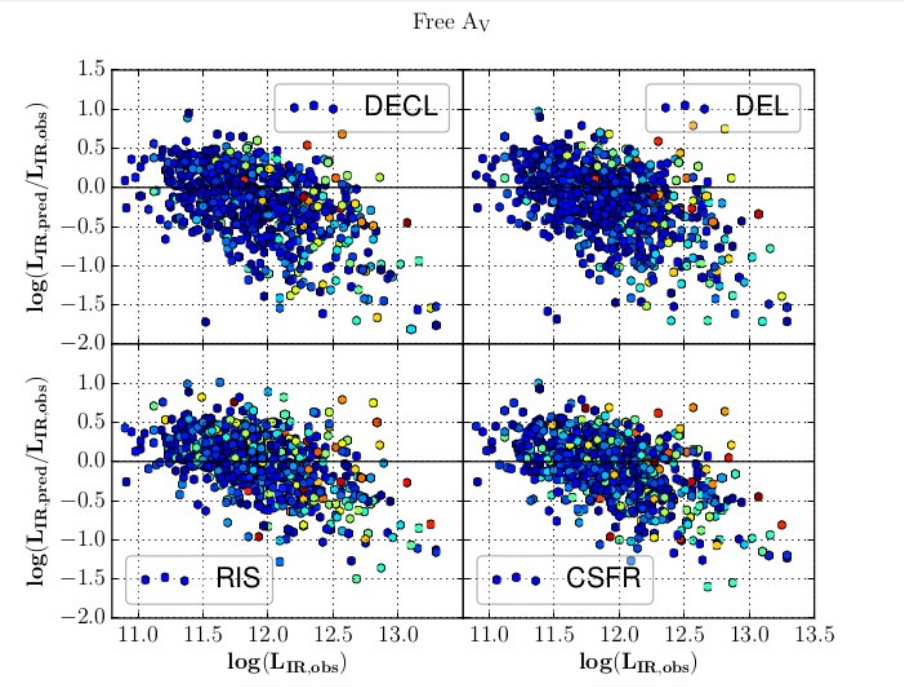
- Bad photometry and possible strong AGN-contaminated sources (IRAC colors) were excluded thanks to a χ^2 cut.

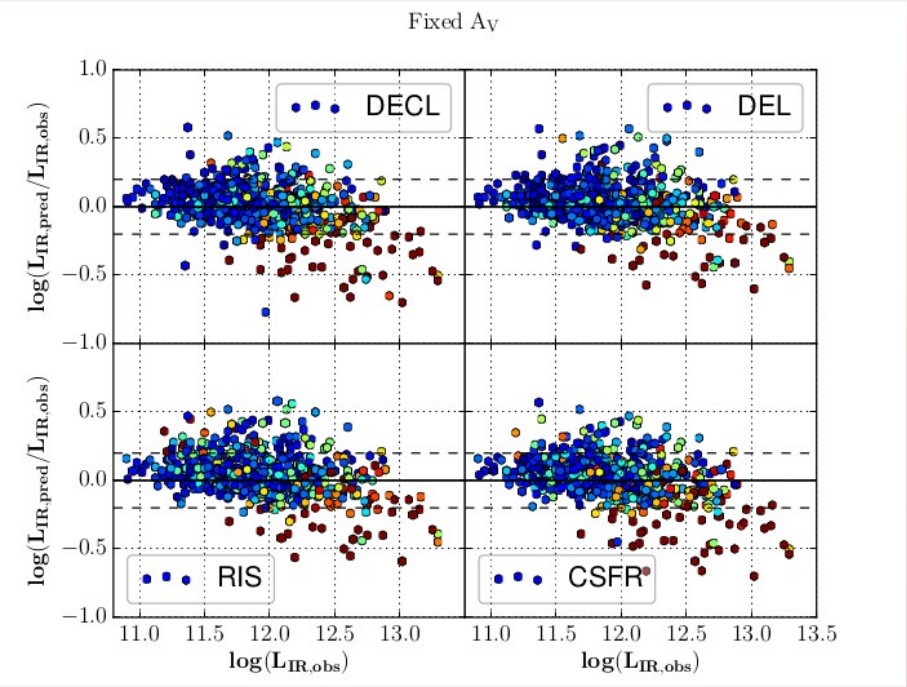
→ 704 sources



Limited by luminosity → small numbers / **biased** towards high *L*

Results : before / after constraining A_V

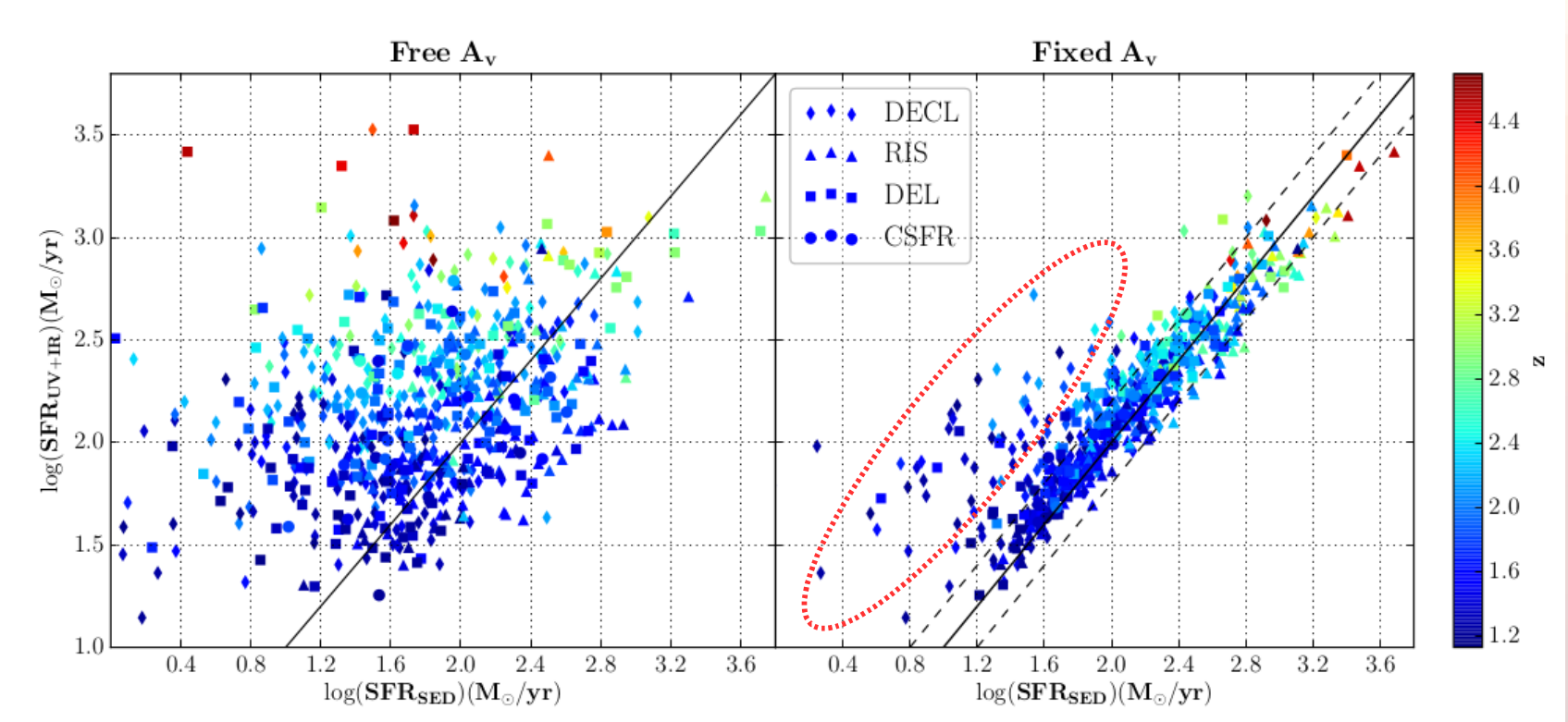




- Unconstrained fits underpredict L_{IR} on average above $\log[L_{IR}]$~12, the underestimation increases with L_{IR} (z ?)
- Constrained fits work well : 87 % of the sample reproduce L_{IR} within 0.2 dex
  - But, the high luminosity end still is underpredicted, and the χ^2 values are among the largest in the sample

→ not discussed here (N. Reddy's comment this morning, decoupling of UV and IR dominating stars...), we focus on the sources that fare well under the energy conservation assumption (**633 sources**)

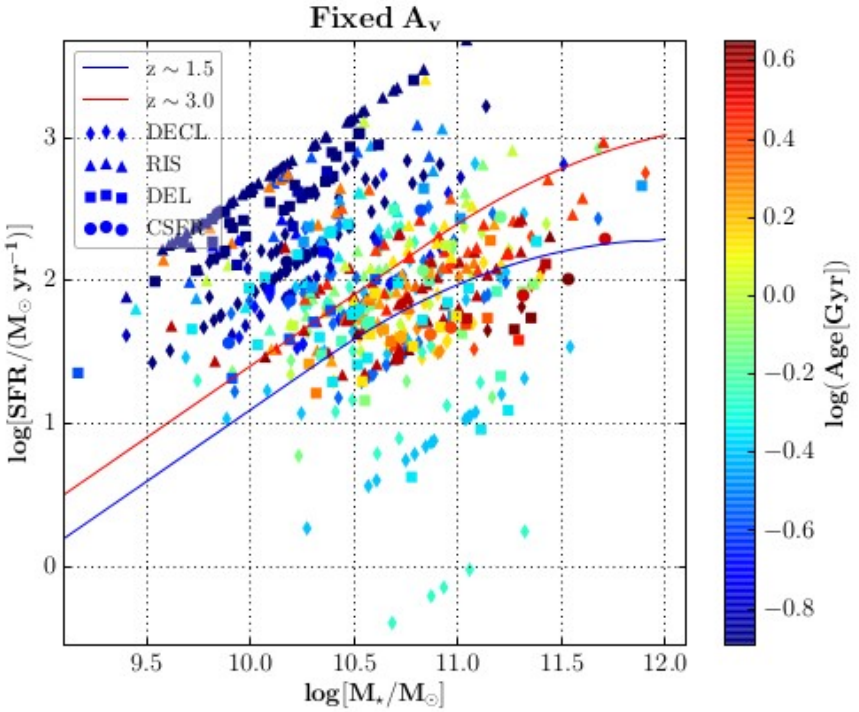
SFR indicators : UV+IR Vs SED

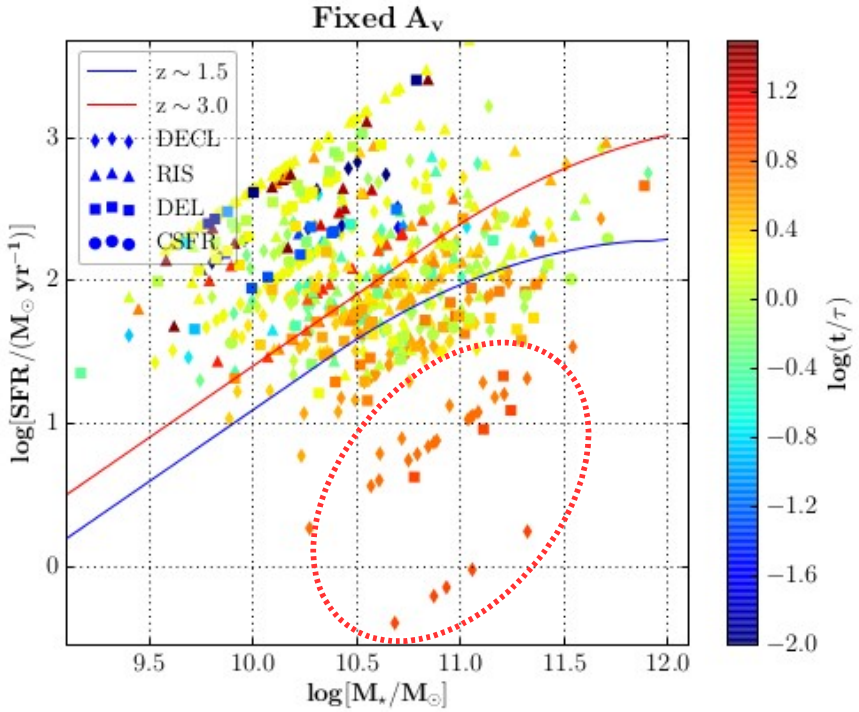


- With A_V left a free parameter, most declining/delayed SFH models produce $SFR_{SED} < SFR_{IR+UV}$ (also in Wuyts et al. 2011, Reddy et al. 2012), but also the rising and constant to a lesser proportion.

- With A_V fixed via the IR/UV ratio, the majority fall on the 1-to-1 relation → near/at a state of equilibrium assumed by the Kennicutt calibrations
- BUT, true (instantaneous) SFR **smaller** than classical value for a fraction of the sample (~7 % at 0.6 dex or more)

Mass – SFR

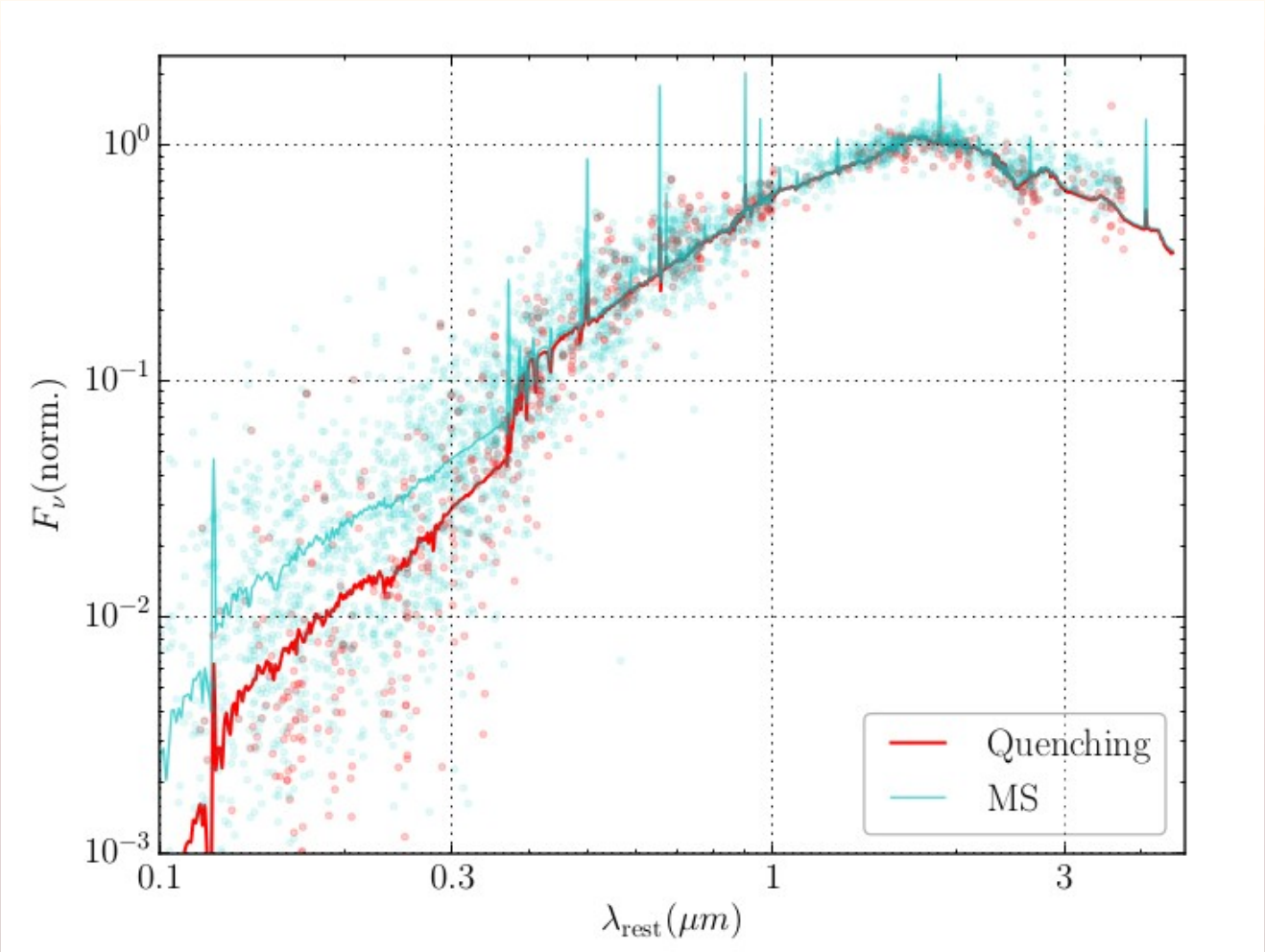




MS from Schreiber et al. 2014

- MS galaxies are majoritarily fit with large ages and timescales
- SB galaxies are young and with mostly short timescales
- Below the MS the SFRs of galaxies are rapidly declining : « quenching/post-starbursting » ?

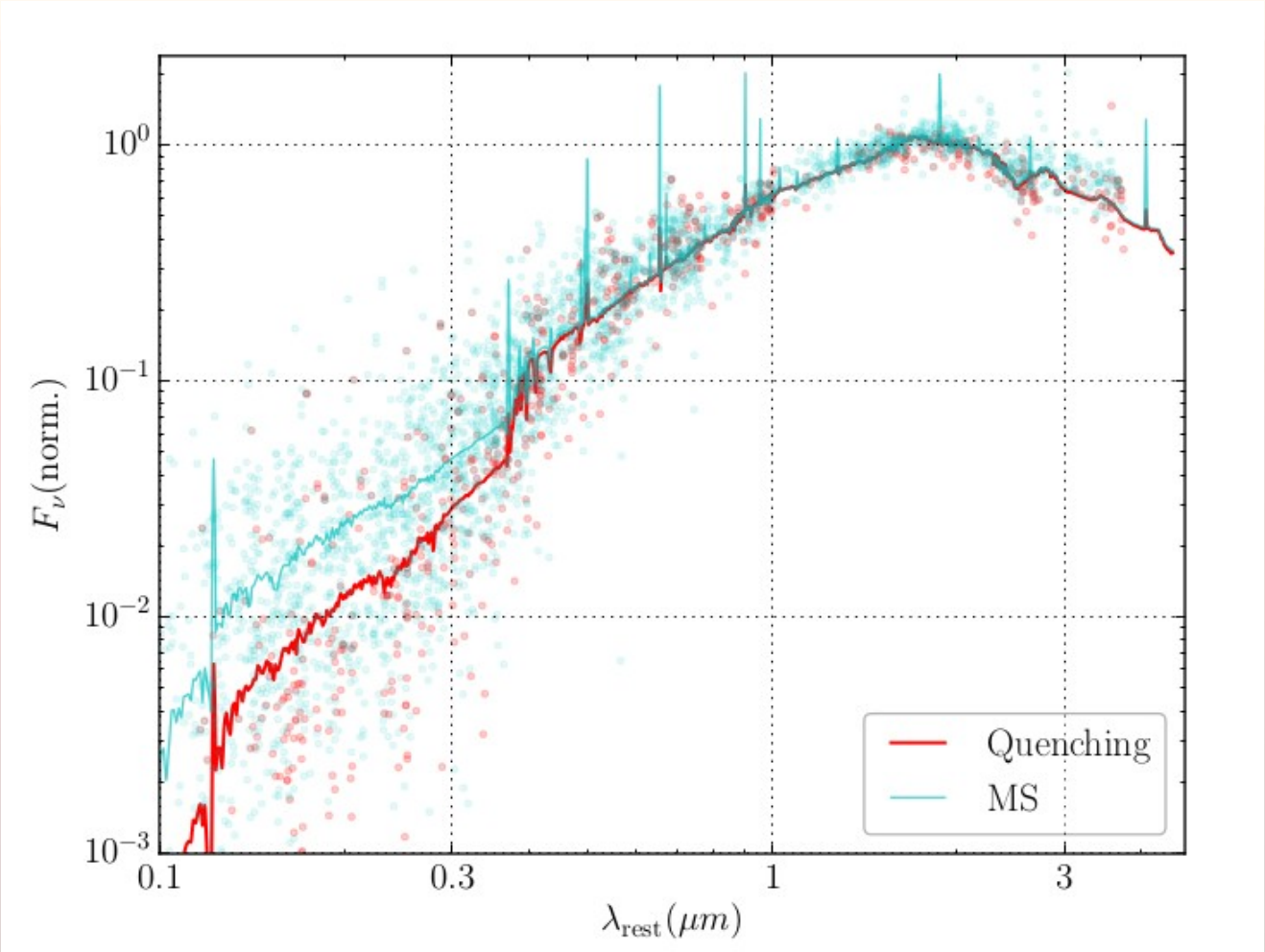
The « quenching » mean SED



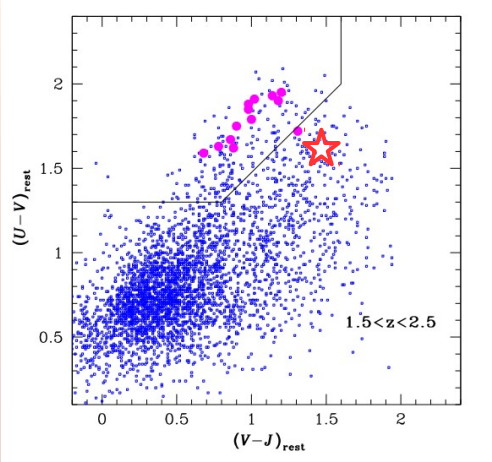
In comparison to a MS subsample in the same mass range :

- Extinction is similar
- Balmer break is ~ 2x larger
- Predicted line EW's are almost 10x weaker

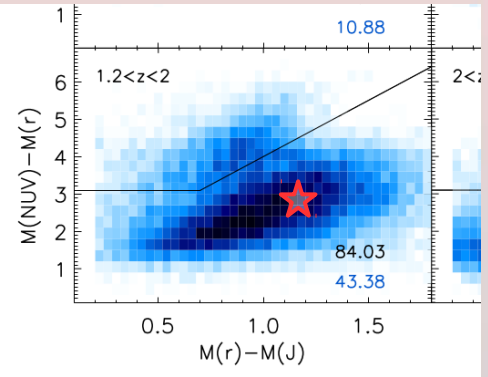
The « quenching » mean SED



Reminder : selected as star-forming



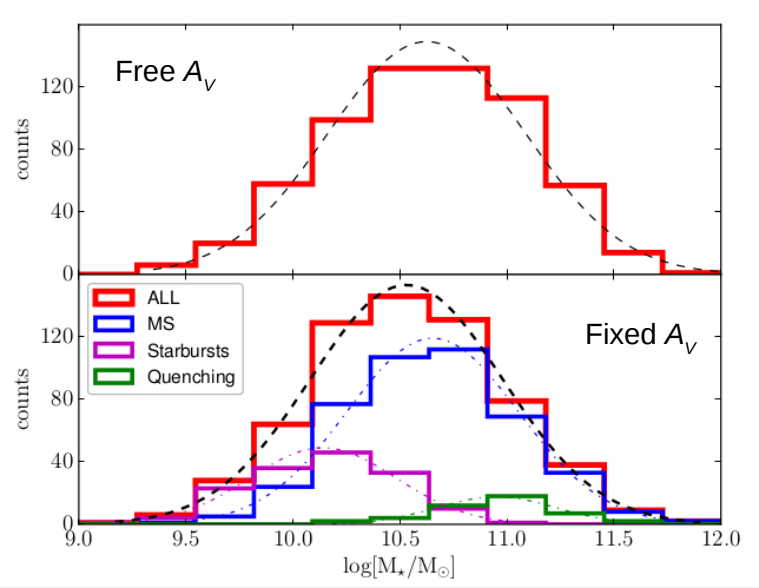
(Pannella+2014)

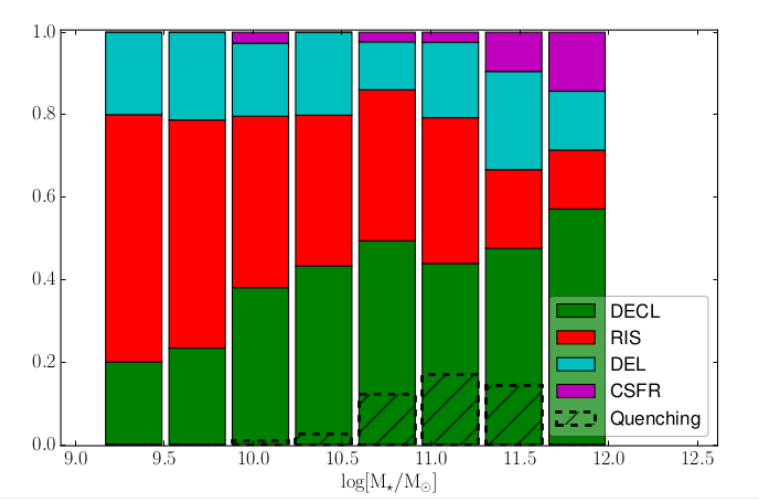


NUV-r-J color diagram (Ilbert+2013)

Lesson : if allowed by the SFH used, a fraction of sources can have an ongoing SFR well reduced compared to SFR(IR), while being consistent with the high IR emission. (Hayward et al. 2014)

Masses and SFH preferences





Energy conserving method impacts M_* very little :

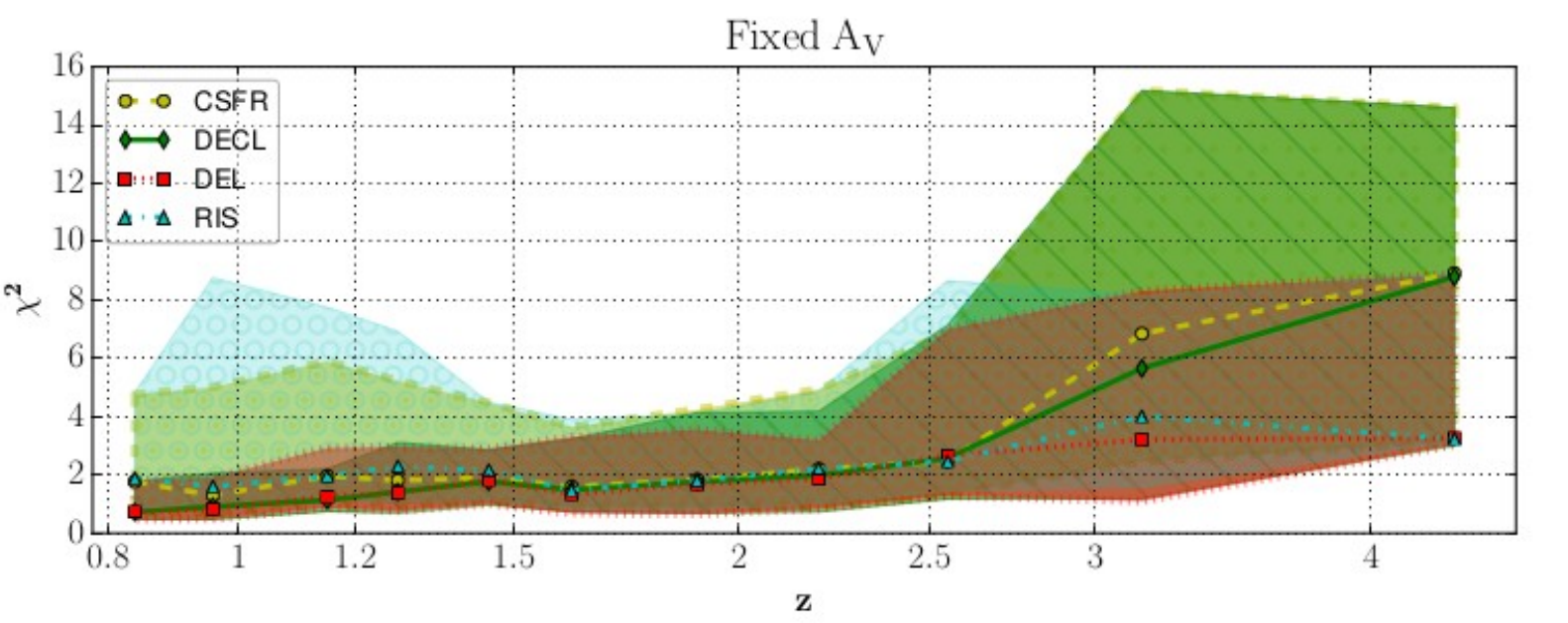
Sample's median mass differs by ~0.1 dex, within typical uncertainties of mass estimates.

SFHs	CSFR(%)	DECL(%)	DEL(%)	RIS(%)
Free A_V	3.6	50.8	23.3	22.3
Fixed A_V	1.9	43.0	17.0	38.1
Fixed A_V($z > 3$)	0	22.2	18.5	59.3

- In the free A_V fits, the majority of the sample is best fitted with the *declining* SFHs (with the known issues)
- When A_V is constrained via the IR/UV ratio, the preference shifts towards the *rising* SFHs
- The fraction of best fits with the *rising* SFHs **increase with *z*** (but numbers decrease : 27 sources at $z > 3$)

- SFH fraction changes with mass
- «quenching» fraction ~< 20 % at log[M_*] = 11, *BUT*: due to biased sample selection, eventual impact on global SF not straightforward.

SFH preferences in the MS as a function of *z*

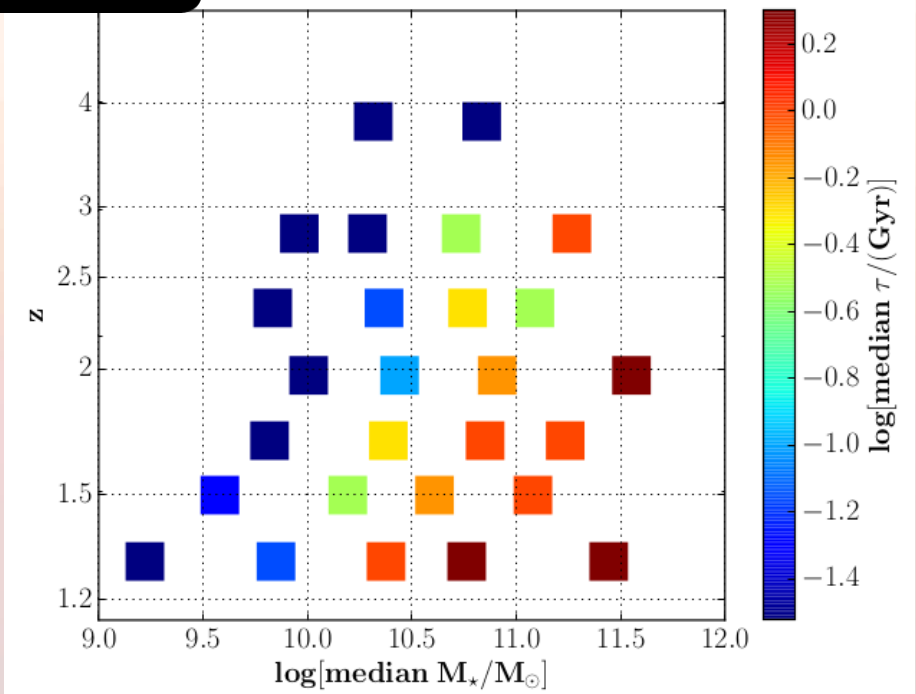


Median χ^2 values, 68 % intervals.
NB : for this plot our analysis was extended to lower z~0.8

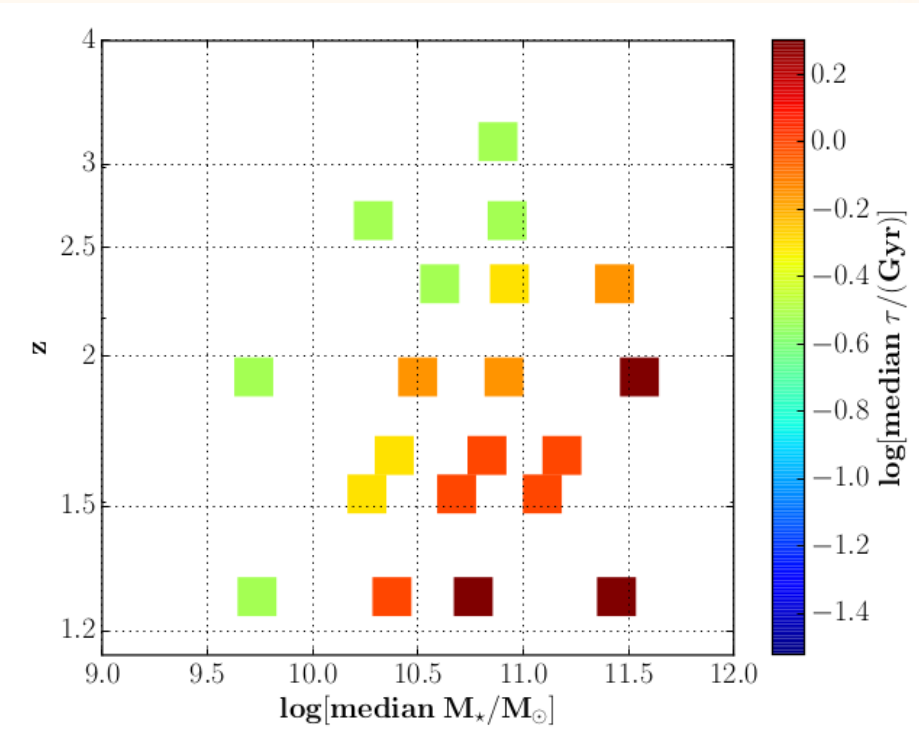
- Low-z galaxies still prefer declining or delayed SFHs
- The high-z end rejects declining SFHs and instead fits better with the rising models
- This change in trends appears **only** when using the IR constrain on A_V, the unconstrained fits show **no** notable tendencies
- Temptative similarity with CSFH, but keep in mind that high-z sources are **few and biased** towards very high L_{IR}

Timescales

All sources



Main sequence



- Rising SFHs (shown above):
  - e-folding parameters τ increase with mass and z
  - smallest τ's are found in starbursts
- No trend in the declining SFHs, but similar differences between MS and starbursts, as with the rising.

Conclusions

- Our energy-conserving models based on the observed IR/UV ratio work well for the bulk of the sample, with the notable exception of the high-luminosity end (limitations/caveats discussed in Sklias et al., *in prep*.)
- IR&UV infered SFRs are well retrieved for most of the sample but also are capable to produce decreased SFRs, while matching the LIR, thus catching eventual «quenching» galaxies for which SFR(IR) can be an overestimation (cf. Hayward et al. 2014)
- The IR effectively helps reducing the age/extinction degeneracy, but scatter around MS can only be larger than with the classical assumptions
- Smaller masses by ~0.1 dex, slightly younger age, (evolution in τ ?)
- SFH preference is shifted towards rising models thanks to the IR constrain, more so at higher z

Future work :

- Further explore the ability to constrain SFHs with the use of nebular emission, in particular confront the line predictions of the «quenching» galaxies to observations
- Explore possibilities for accurate modelisation of the highest L_{IR} sources (e.g., 2-pop..)
- Study fainter sources beyond z~2 with the *Herschel Lensing Survey* (PI: Egami).

Thank you.