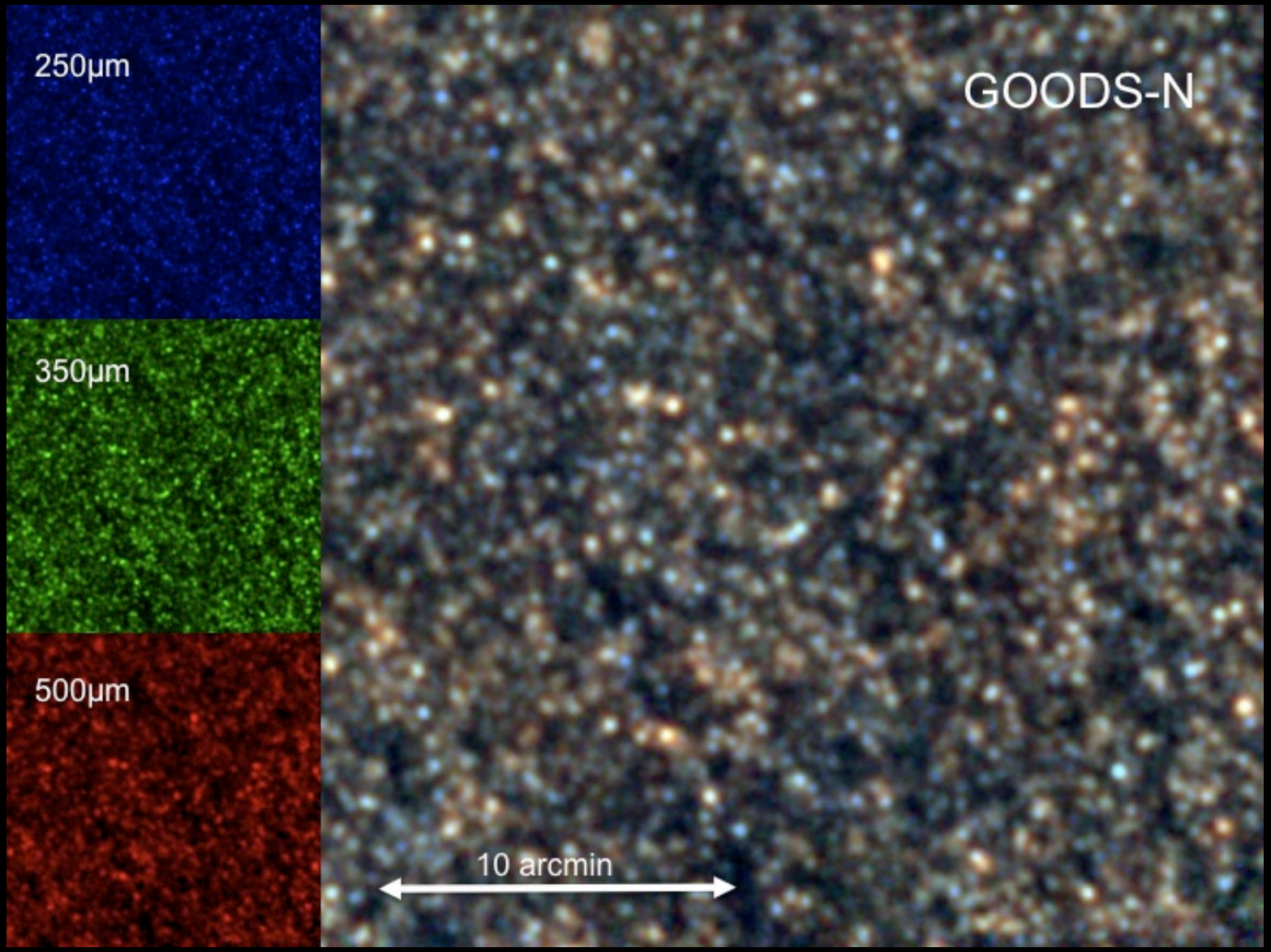
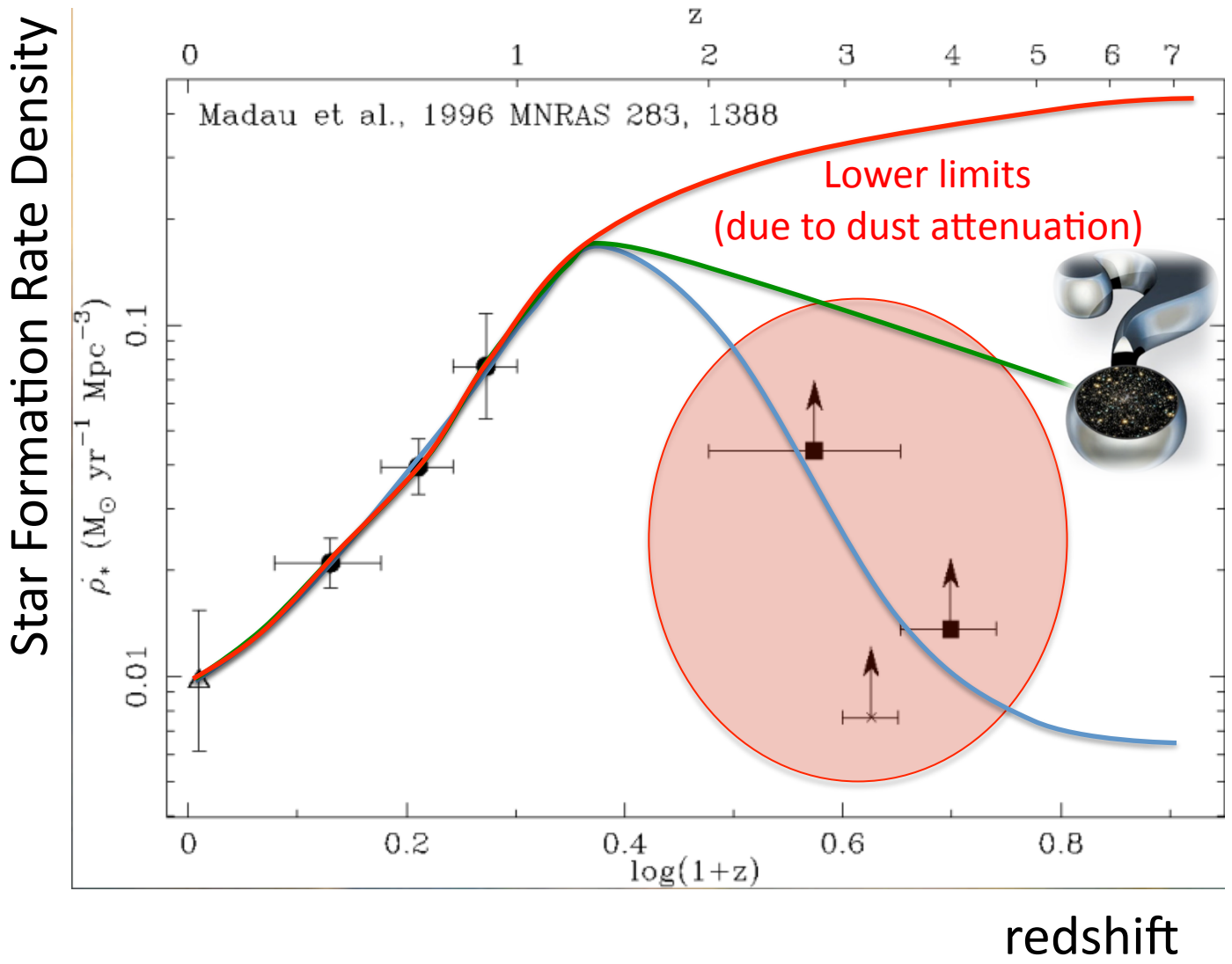
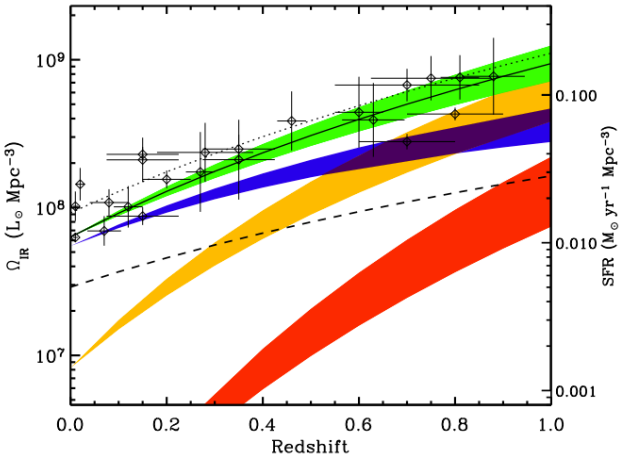
Herschel and the universe at z ~ 3 (and beyond)



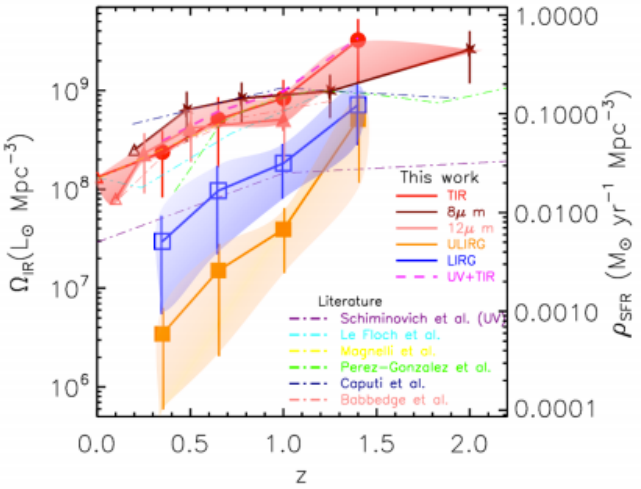
Madau et al. (1996)



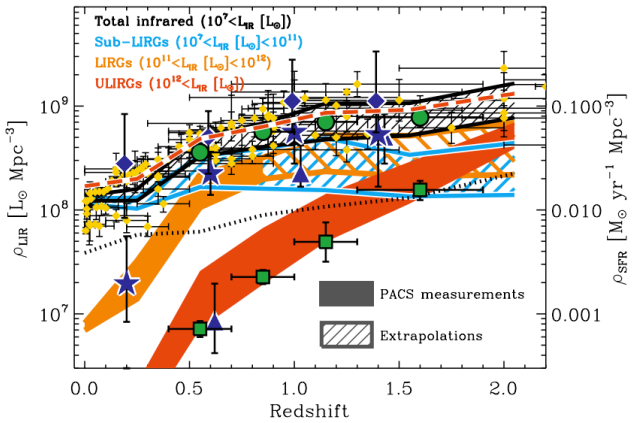
The Cosmic star formation history (UV + IR)



Le Floc'h et al. (2005)
from Spitzer to z ~ 1



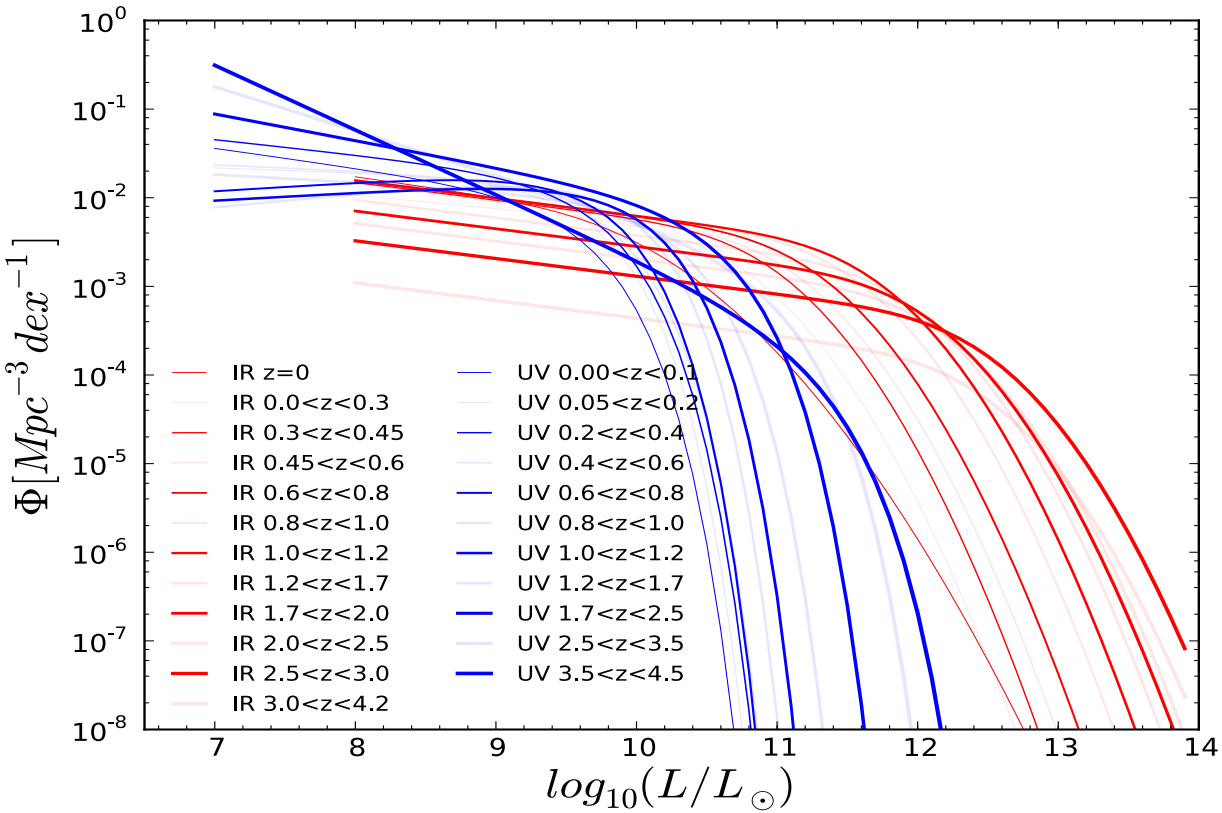
Goto et al. (2010) from
Akari to z ~ 1.5



Magnelli et al. (2012)
from Herschel/PACS to z ~2

VLT/VVDS + Herschel/PEP+HerMES

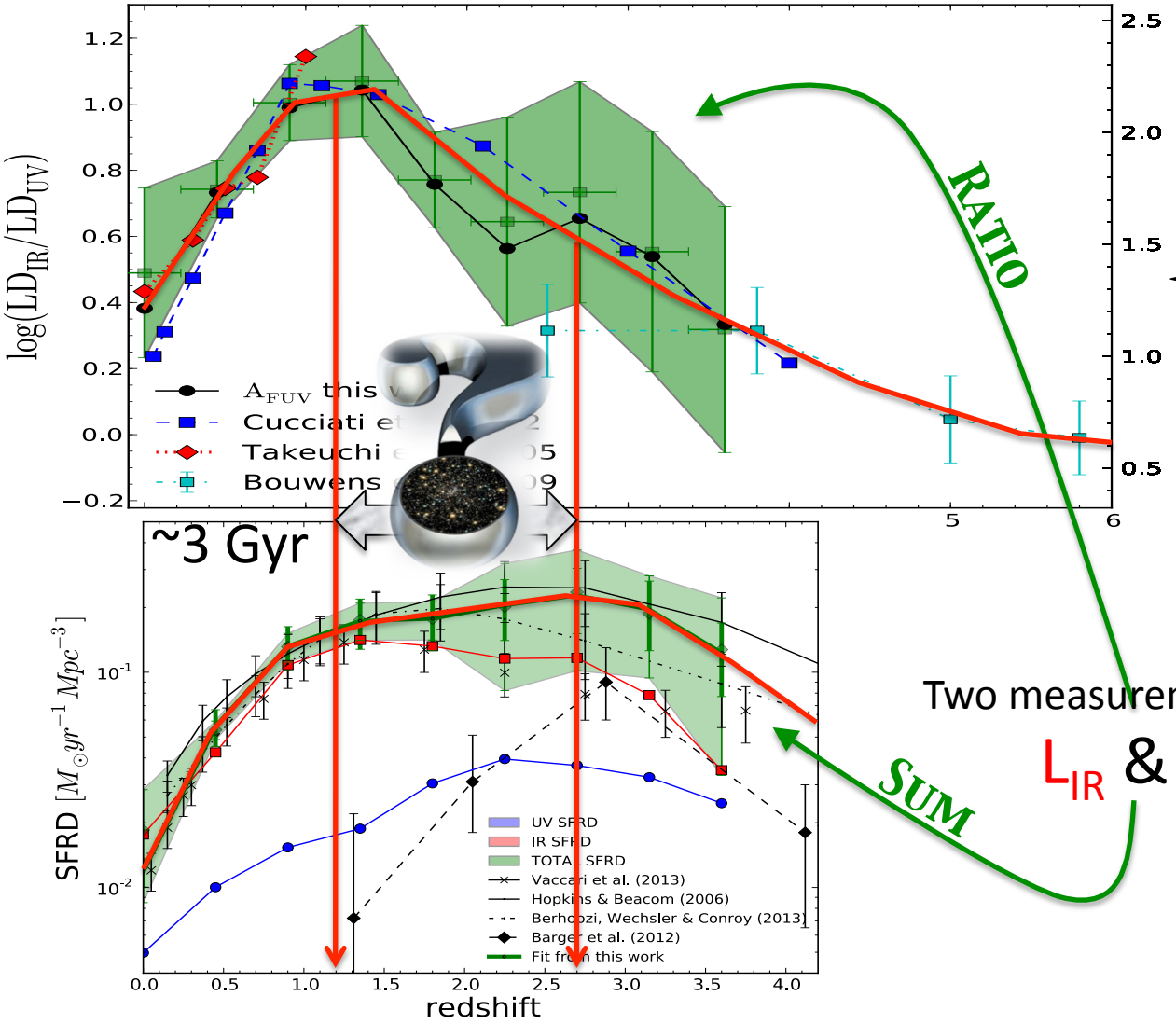
(Burgarella, Buat, Gruppioni, Cucciati, Heinis et al. A&A 2013)



Redshift evolution of the FIR (**red, Gruppioni et al. 2013 from PACS selection and PACS +HerMES data**) and FUV (**blue, Cucciati et al. 2012 from VVDS**) LFs. The FUV LFs are uncorrected for dust attenuation. The LFs at every other redshift are plotted boldly. The LFs are plotted within the limits of integration. **Uncertainties on faint-end slope defined and scaled in redshift**

VLT/VVDS + Herschel/PEP+HerMES

(Burgarella, Buat, Gruppioni, Cucciati, Heinis et al. A&A 2013)



RATIO

SUM

Two astrophysical quantities are deduced:

Dust Attenuation

Two measurements are used:

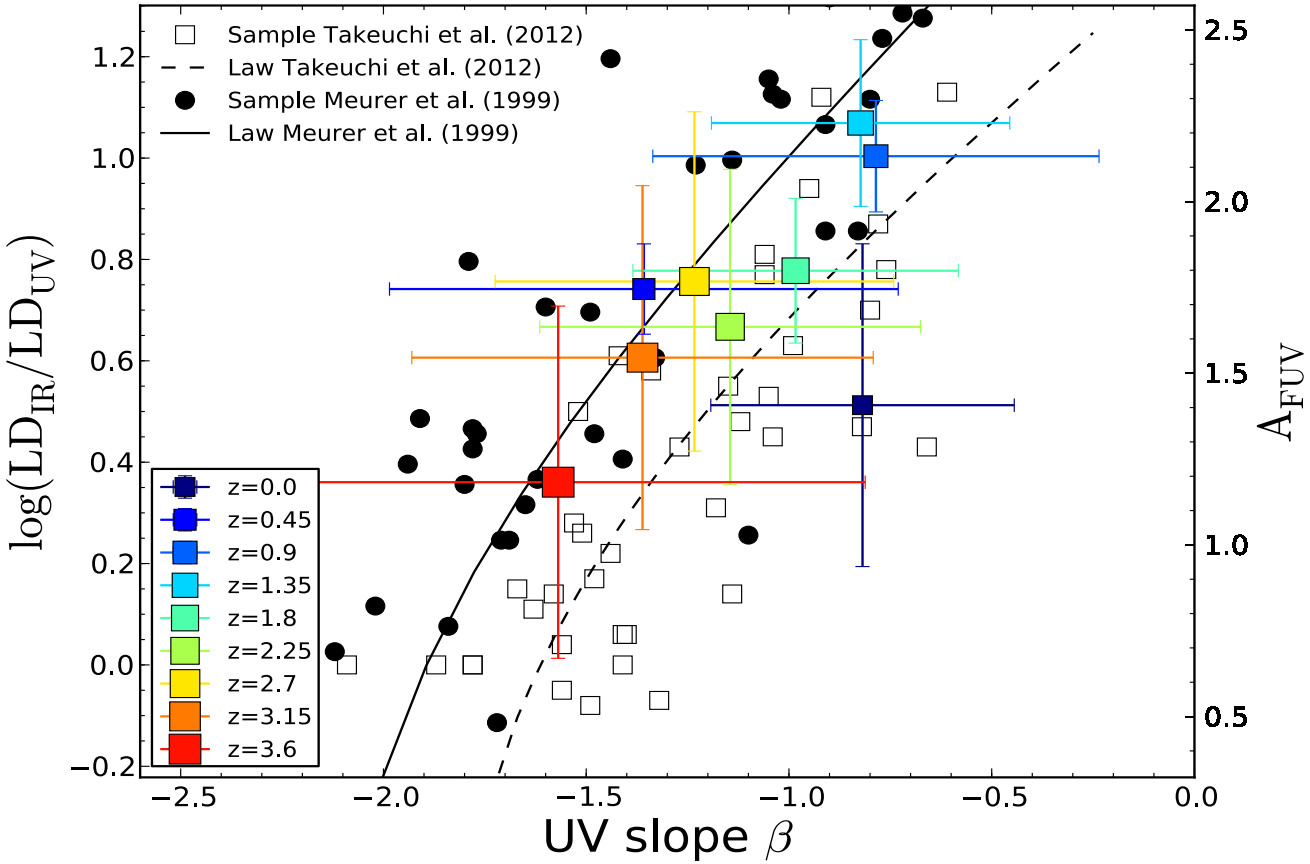
L_{IR} & L_{UV}

Star Formation

What is hidden behind this offset?

- Understanding the star formation phenomenon implies that we should able to understand the link between star formation itself and dust and metals formation.
- Several plausible (possibly not exclusive) explanations for this offset are related to:
  - the timescales of dust formation and destruction in AGB stars, SNae and onto dust grains in the ISM (Asano et al. 2013)
  - the time evolution of infalls and outflows
  - the build-up of metal in galaxies as a function of time
  - the properties of the dominant galaxies through the evolution of UV and IR luminosity functions

IRX – β diagramme



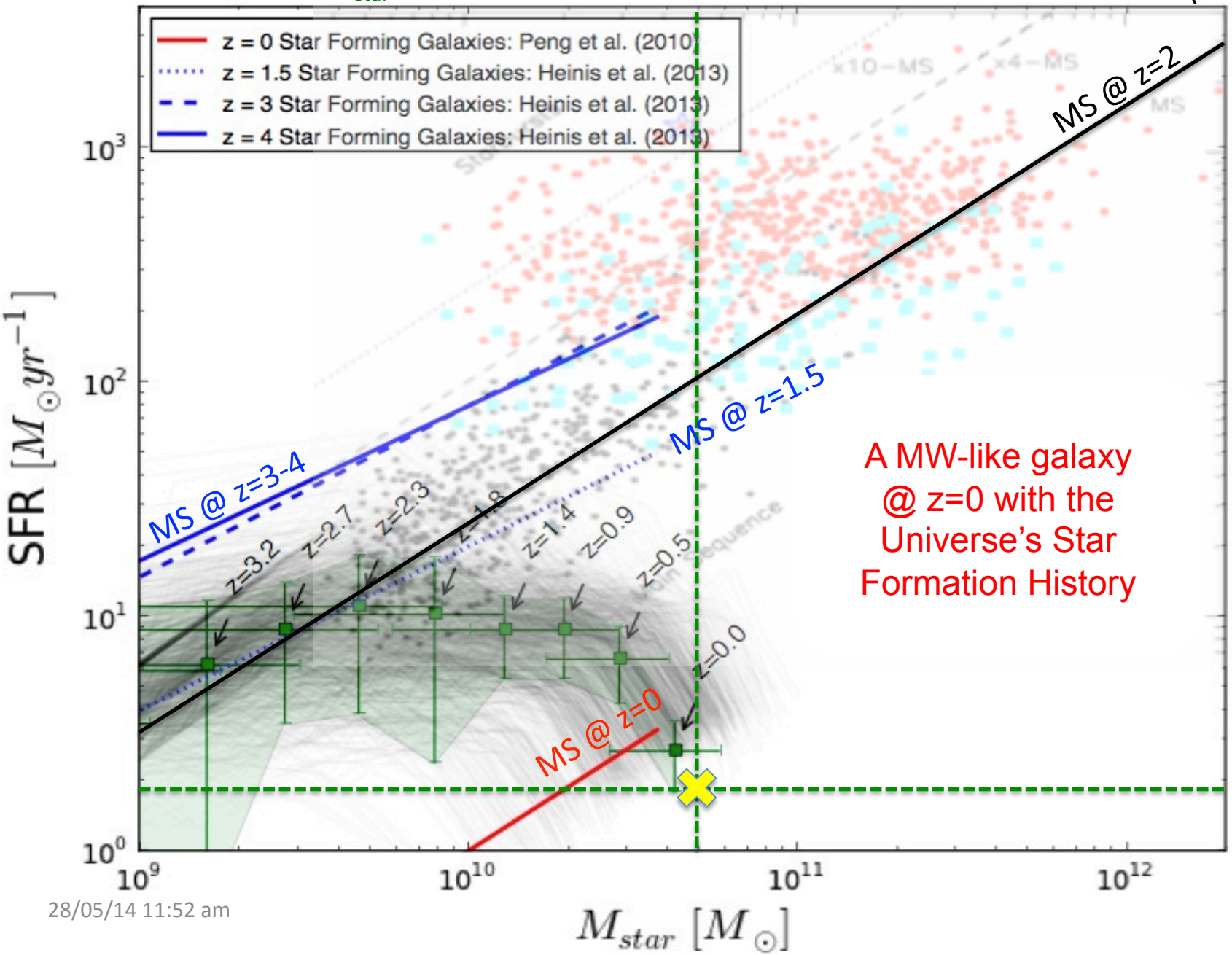
X-axis bars = dispersion in β. Y-axis = uncertainties in the LFs. Black dots/curve from Meurer et al. (1999). Grey boxes/dashed lines: update from Takeuchi et al. (2012). Our points and those from Meurer et al. (1999) are not comparable because we use volume-corrected LFs and not individual galaxies as in Meurer et al. (1999).

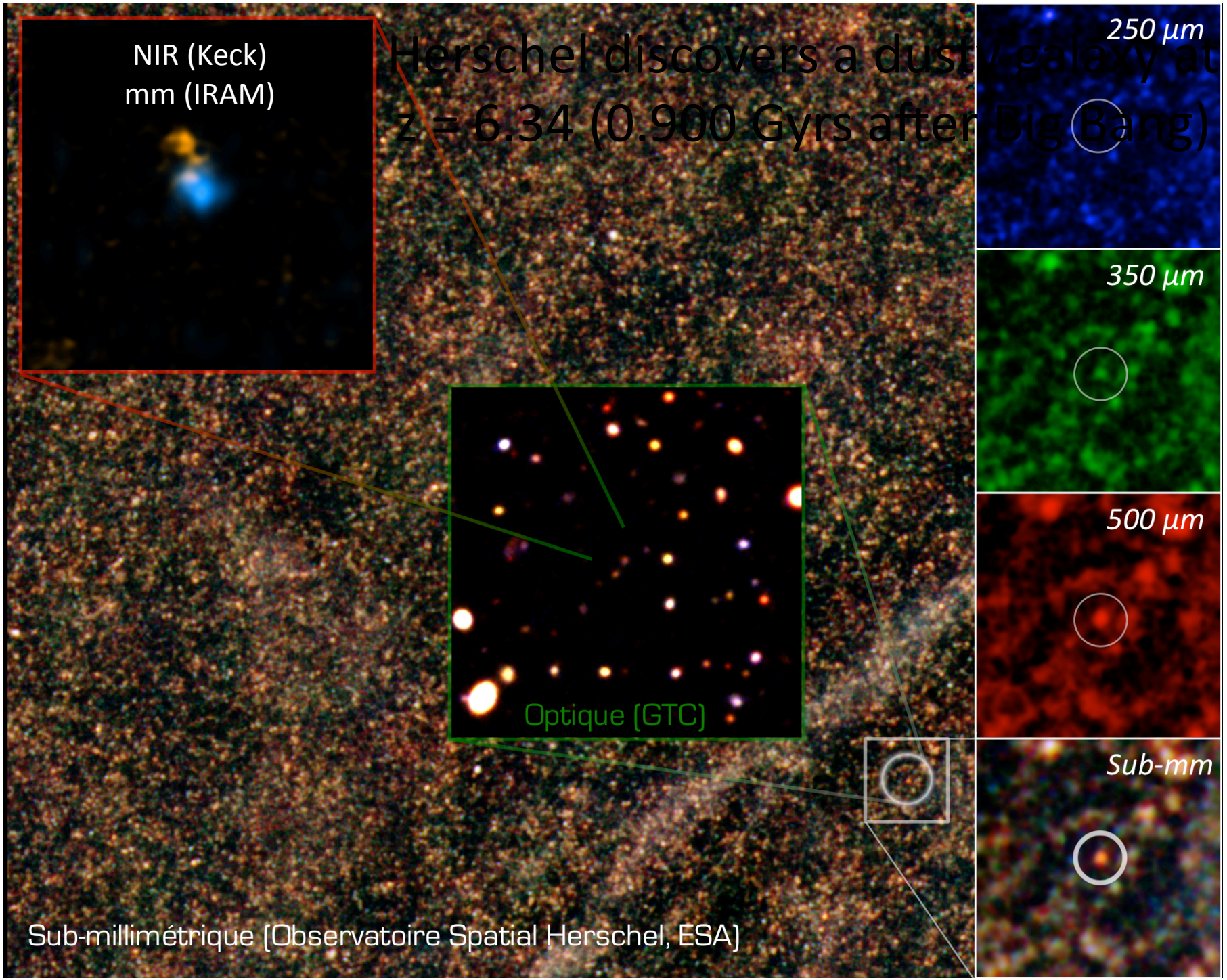
Chomiuk & Povich (2011) -> SFR_MW = 1.9 ± 0.4 M⊙ yr−1.

Hammer et al. (2007) -> M_{star}_MW = 5e10 Msun

Rodighiero et al. (2011)

Heinis et al. (2013)

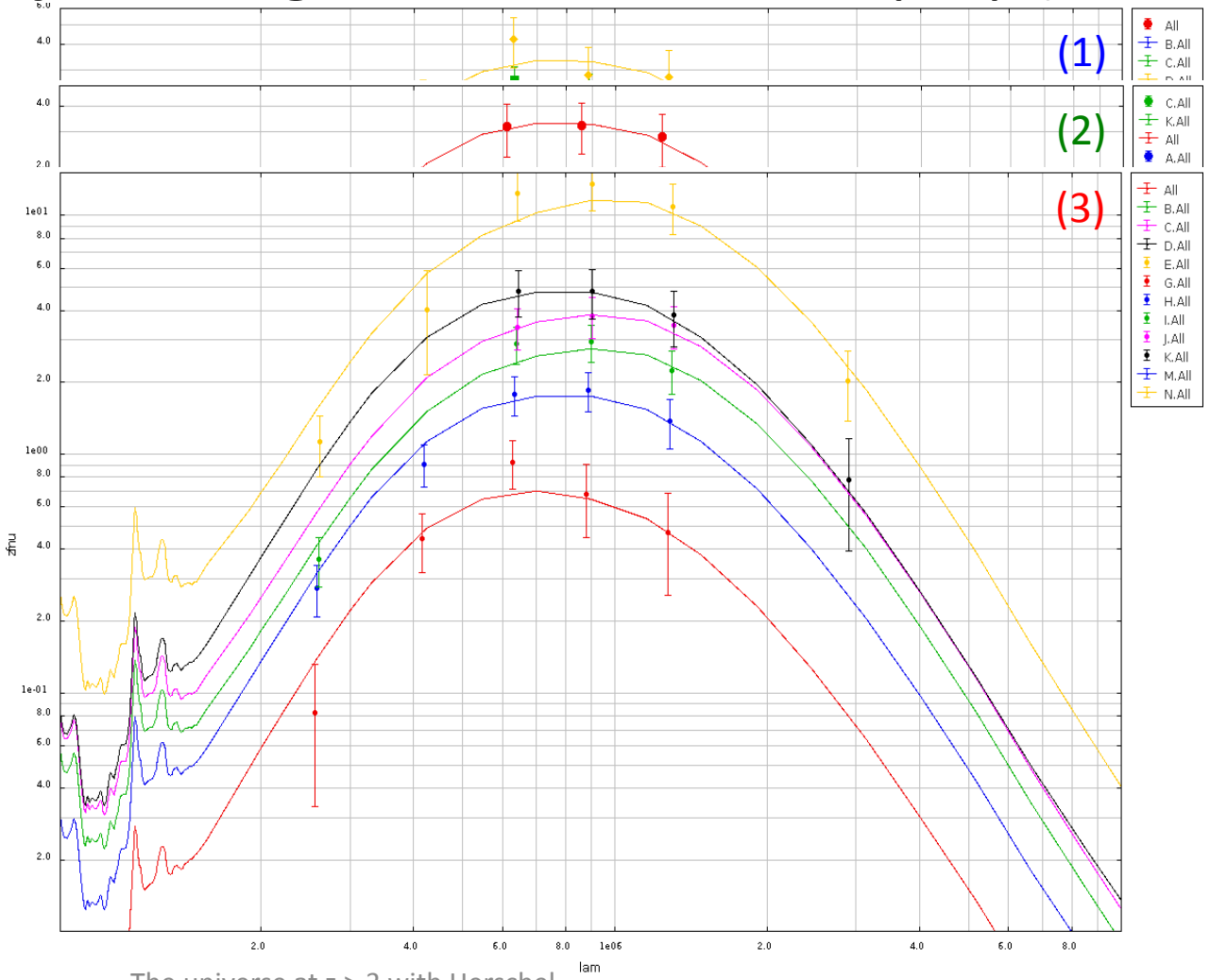



Herschel discovers a dusty galaxy at
z = 6.34 (0.900 Gyrs after Big Bang)
NIR (Keck)
mm (IRAM)
Optique (GTC)
250 µm
350 µm
500 µm
Sub-mm
Sub-millimétrique (Observatoire Spatial Herschel, ESA)

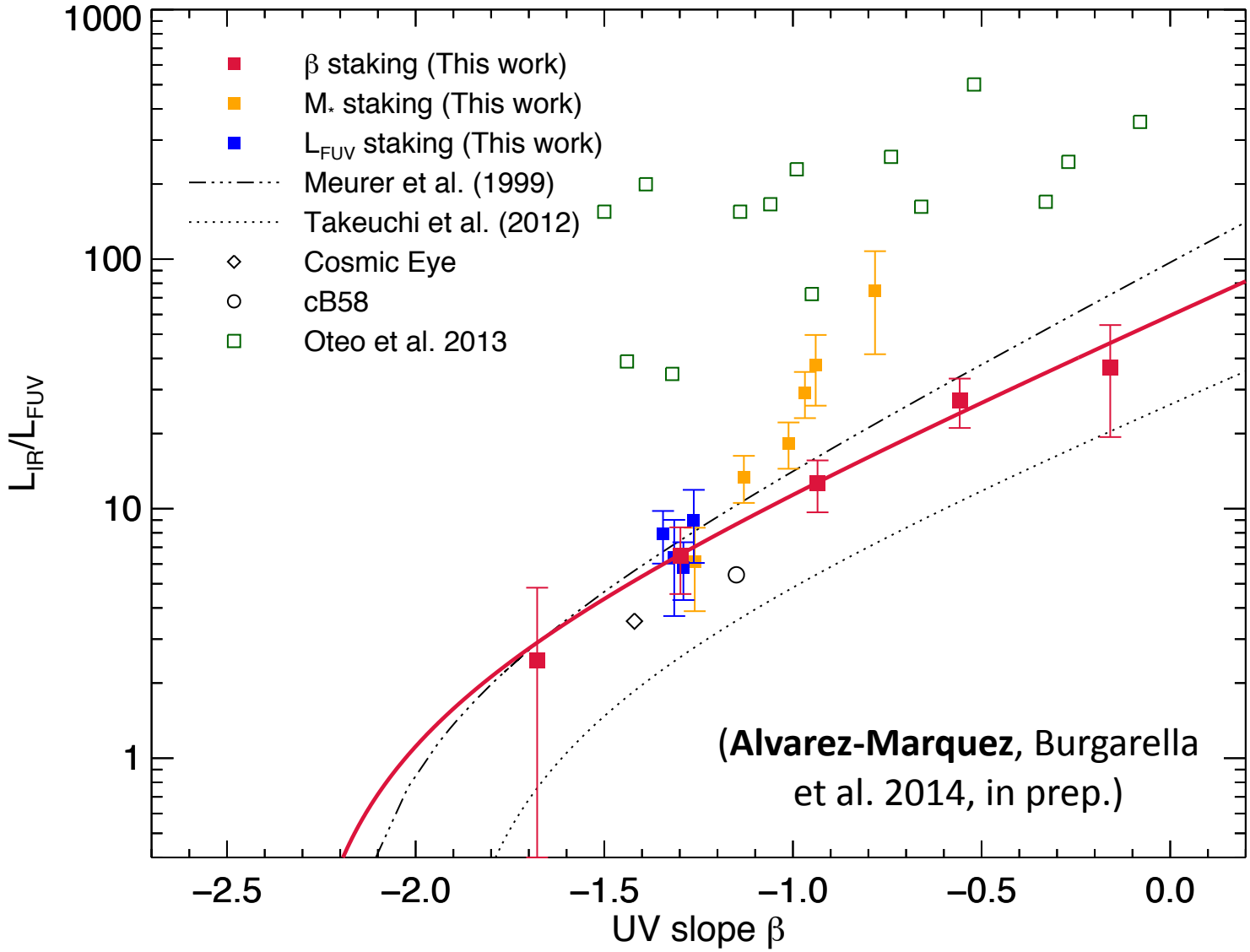
Stacking z~3 LBGs in the « PEP/HerMES/COSMOS » field

(**Alvarez-Marquez**, Burgarella et al. 2014, in prep.)

- **~ 15 000 LBGs**
- **Several bins in:**
  1. **UV slope (β)**
  2. **stellar mass**
  3. **UV luminosity**
- **Stacked in PACS, SPIRE and AzTEC bands**
- **All biases corrected (X-correlation & clustering)**



L_{IR} / L_{UV} => amount of dust attenuation => total Star Formation Rates at z > 3 where we do not measure the Far-IR emission... yet



Next steps

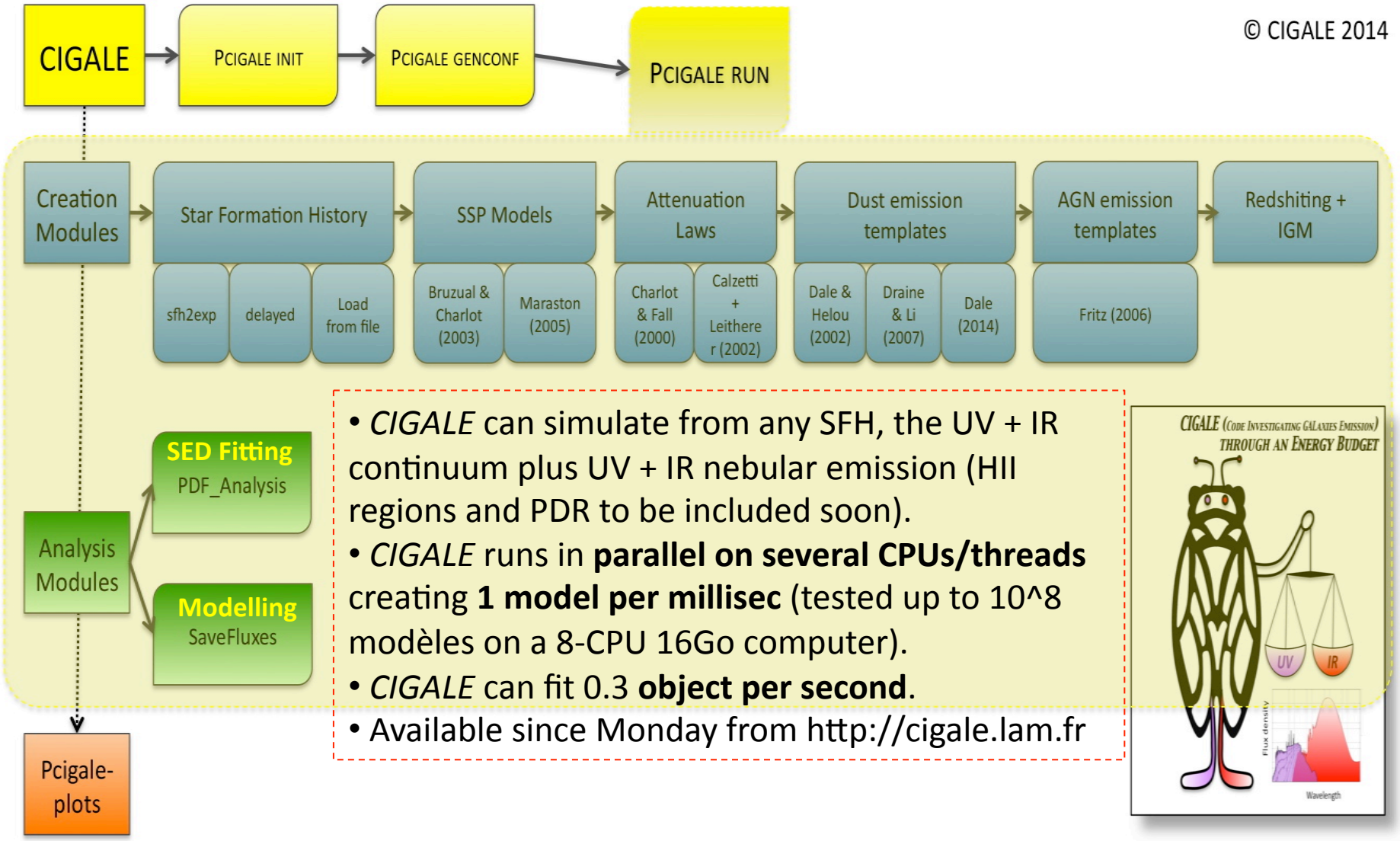
- Use this method to stack at higher redshifts

CIGALE (Code Investigating the Galaxies Emission)

by Denis **Burgarella** (Laboratoire d'Astrophysique de Marseille, Aix-Marseille Université, France), Médéric **Boquien** (Cambridge, UK), Véronique **Buat** (Marseille, F), Laure **Ciesla** (Heraklion, Gr), Yannick **Roehlly** (Marseille, F), Barbara **Lo Faro** (Marseille, F)
aka « The CIGALE Team »

CIGALE is a code / model to fit / model Spectral Energy Distributions

The new Python β version is ***now available***: http://cigale.lam.fr



One interesting option

- CIGALE can now be run in a « model mode ». This means that, assuming a star formation history (SFH), you can build the spectrum of a galaxy for whatever physical parameter you wish.
- E.g., numerical codes (GADGET, GALMER, RAMSES, ...) trace the SFH and the metal enrichment with time. Plugging CIGALE into such a code allows to compute the expected spectrum not only in the optical *but also in the infrared*.

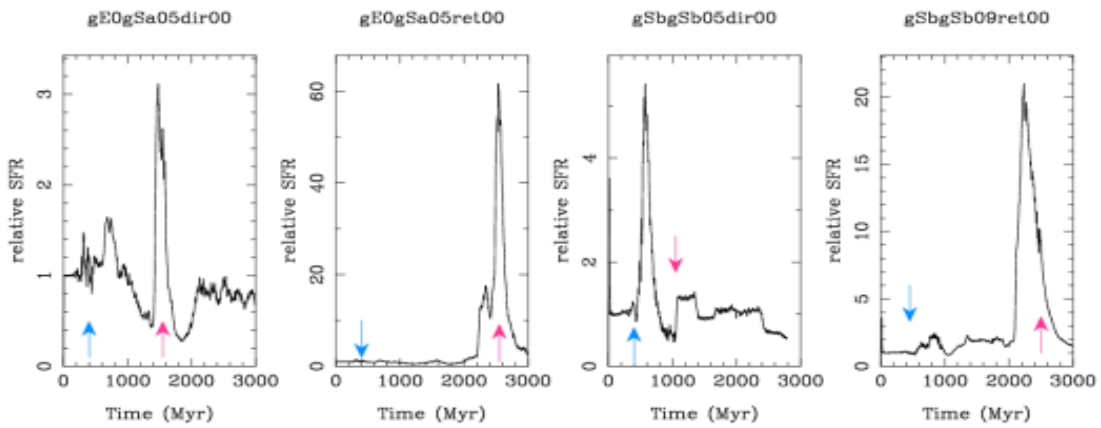
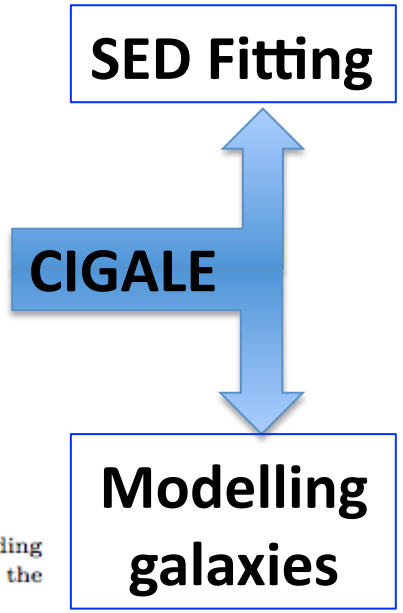
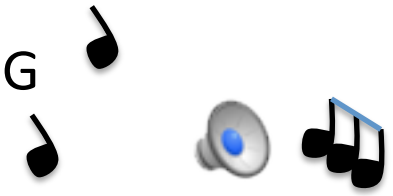


Fig. 2. Star formation rate, versus time, for some galaxy mergers. The SFR is normalized to that of the corresponding isolated galaxies. The blue arrows indicate the first pericentre passage between the two galaxies, and the red arrows the merger epoch. See Di Matteo et al. (2007a).



WITH SUMMERTIME, A NEW CIGALE WILL SING



	Old FORTRAN CIGALE	New PYTHON CIGALE
Energy Balance	✔	✔
Different dust attenuation for old and young stellar pops	✔	✔
Star Formation History	Constant & exponential	Constant, exponential, delayed, analytical, from file
AGN component	✔	✔
Parallelization of runs		✔ (Python 3)
Creation of modelled SEDs from SFH	✔ (but difficult)	✔
Lines	✔ (basic only in UV- optical)	✔ (from Far-UV to Far-IR)
Mock catalogue	✔	✔

Videos made by Médéric BOQUIEN (Cambridge)

Merci