AGN - Dust-Obscured Galaxies at z~2-3 in the COSMOS field revealed by near-to-far infrared SED-fitting

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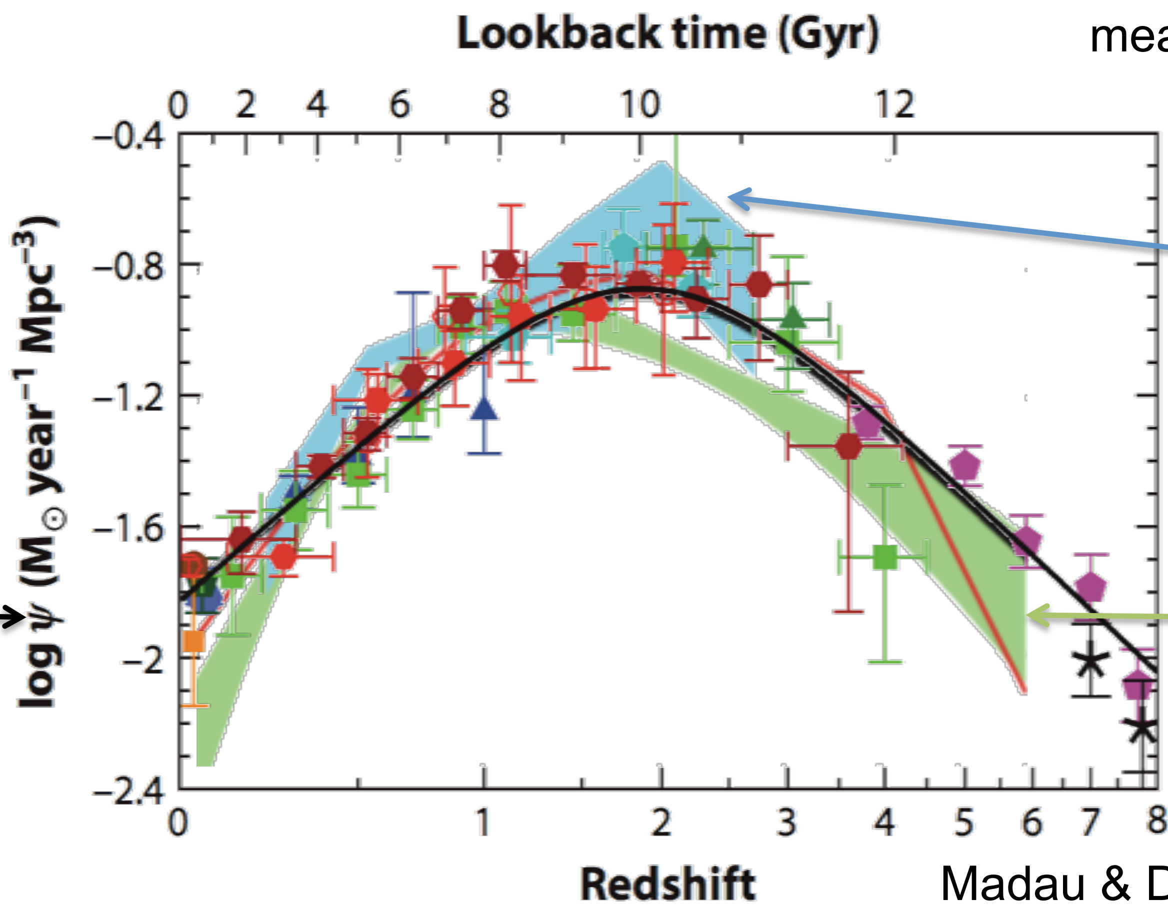
+ PEP team

Journées du PNCG 2015, Nice

16/12/2015

Studying the star formation in the universe

FUV + IR rest-frame measurements



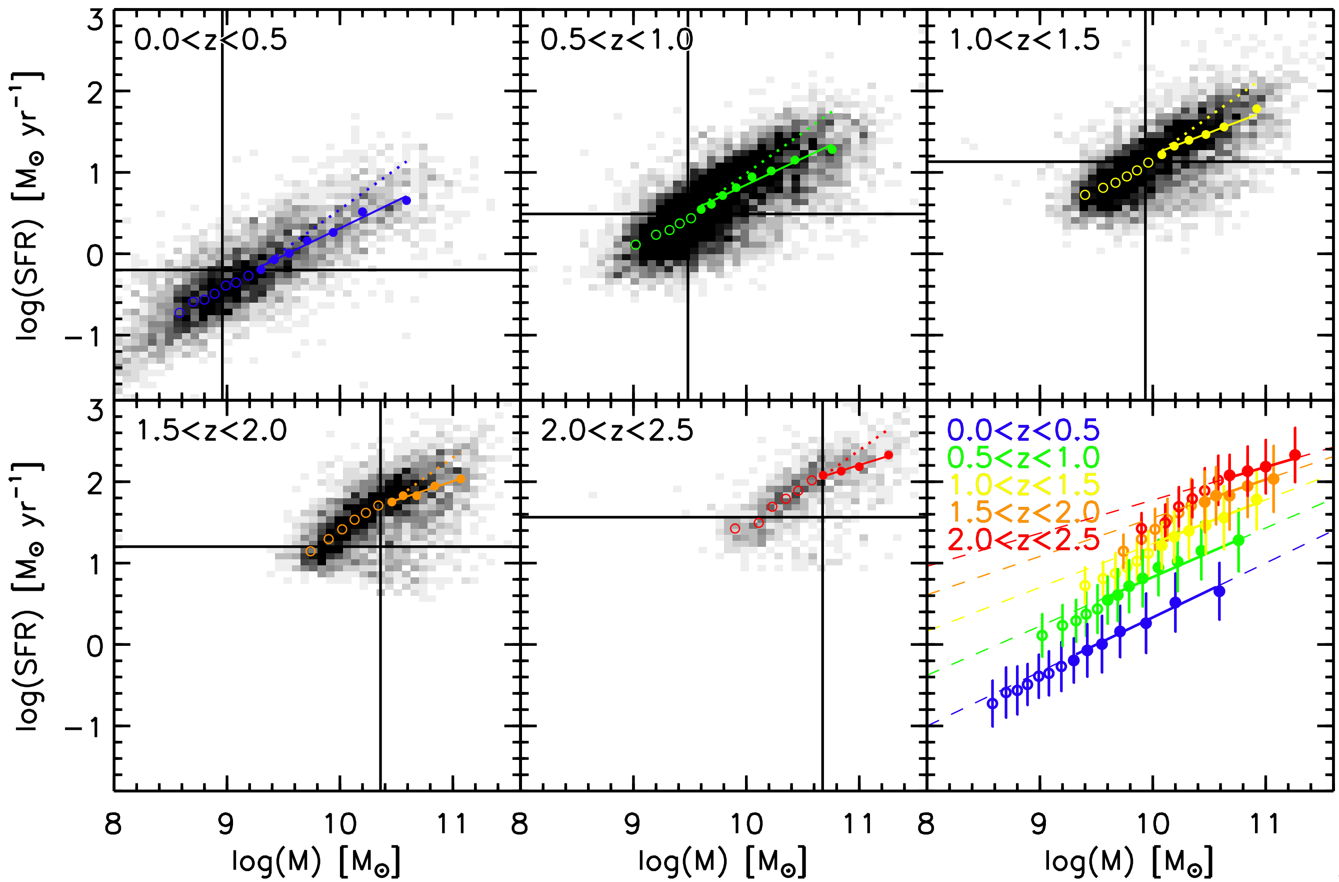
Star formation density

Black hole accretion history from IR

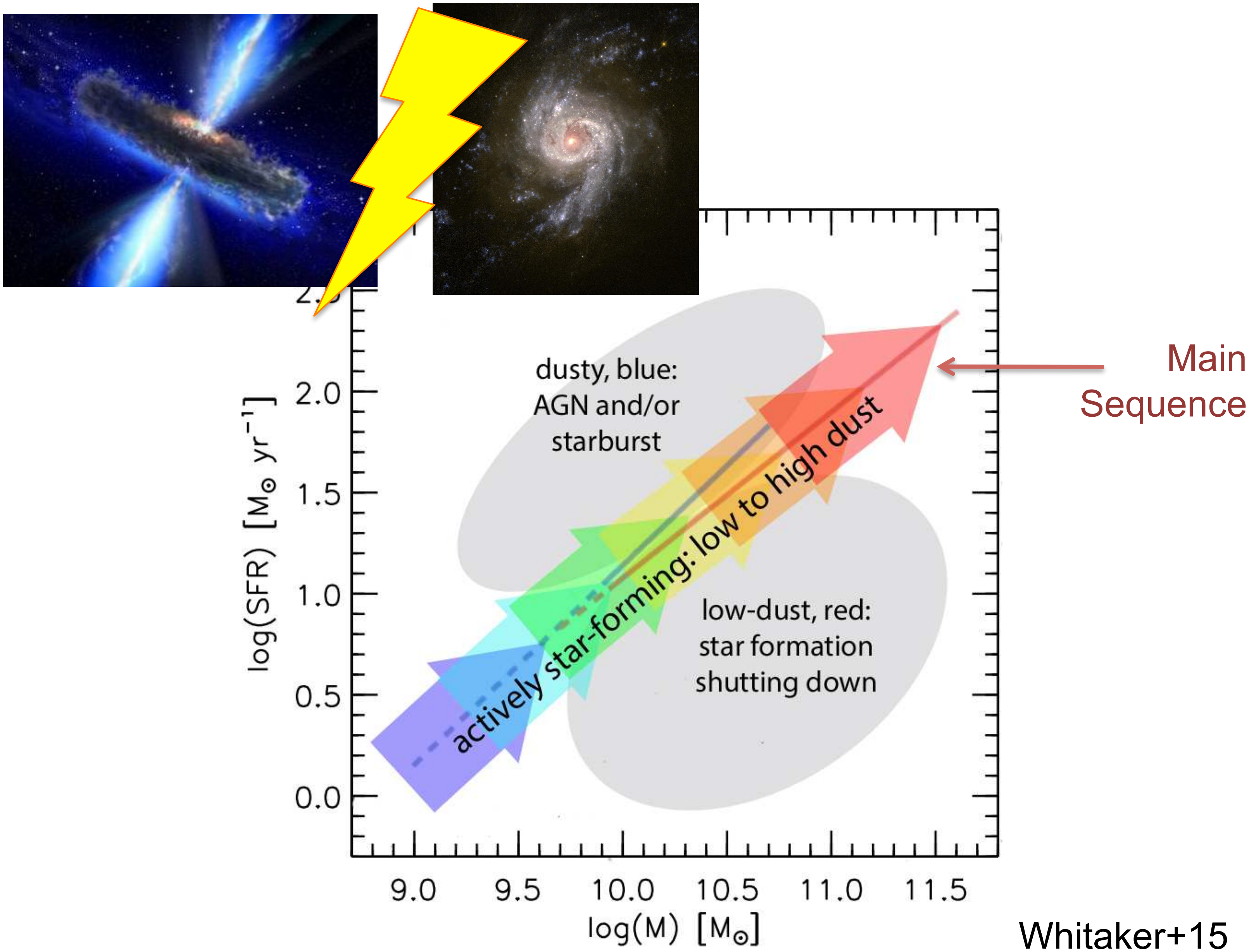
Black hole accretion history from X-ray

Madau & Dickinson (2014)

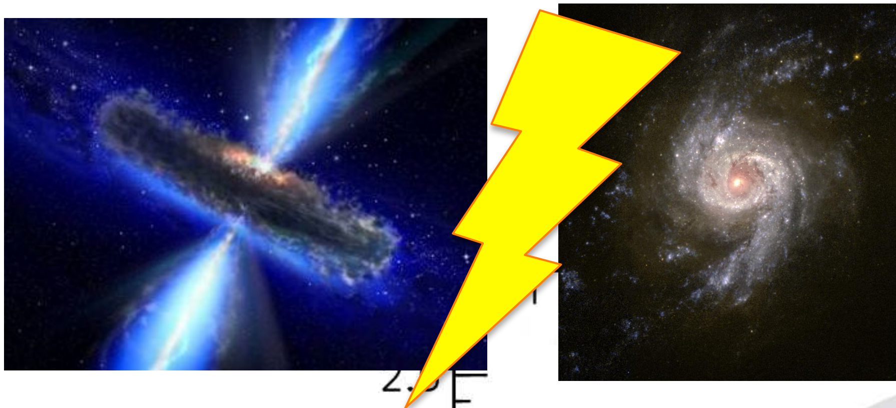
The Main Sequence of star-forming galaxies

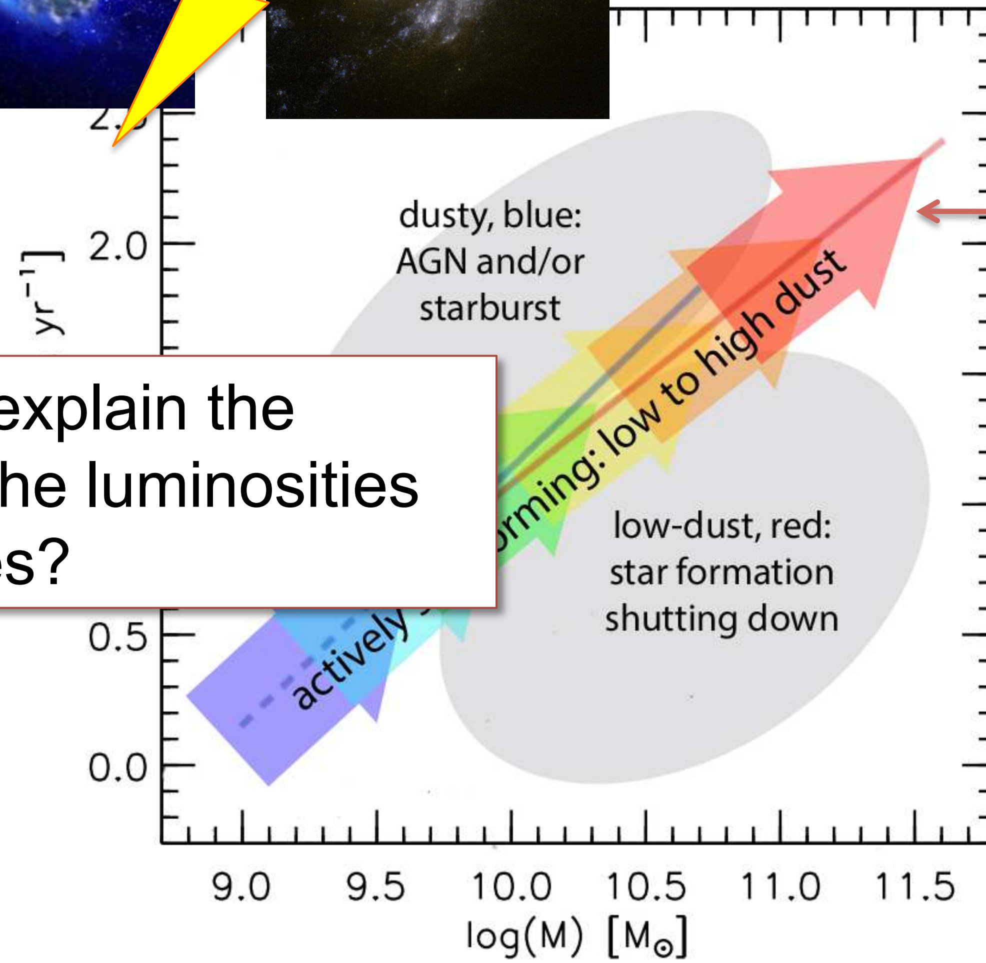


Whitaker+15


dusty, blue:
AGN and/or
starburst
low-dust, red:
star formation
shutting down
actively star-forming: low to high dust
log(SFR) [M⊙ yr⁻¹]
log(M) [M⊙]
0.0
0.5
1.0
1.5
2.0
9.0
9.5
10.0
10.5
11.0
11.5
Main
Sequence

Whitaker+15

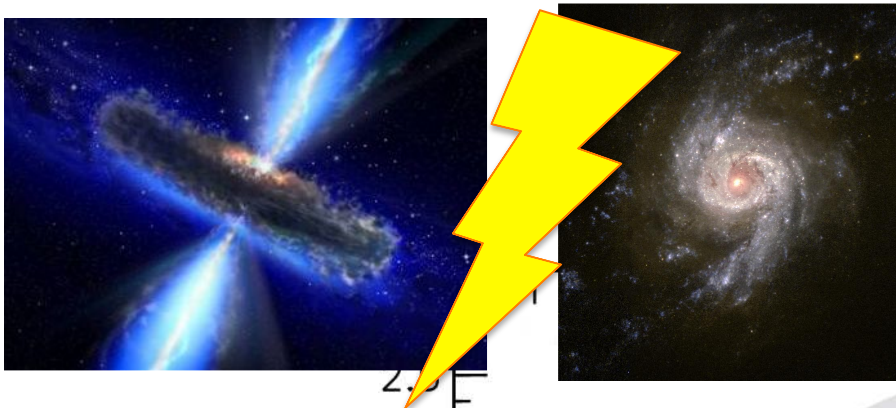


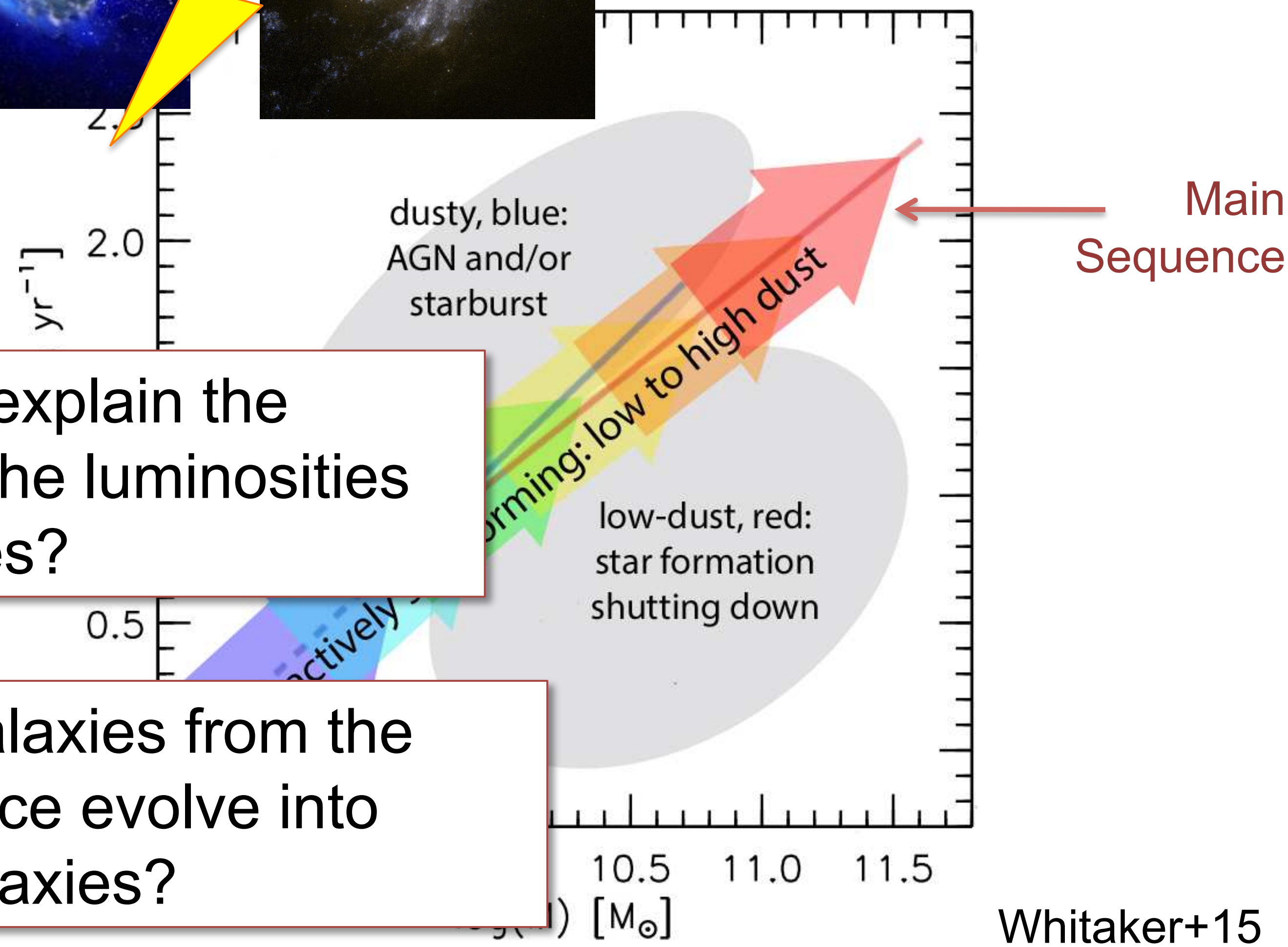


Main Sequence

1) how can we explain the starbursts and the luminosities of these galaxies?

Whitaker+15



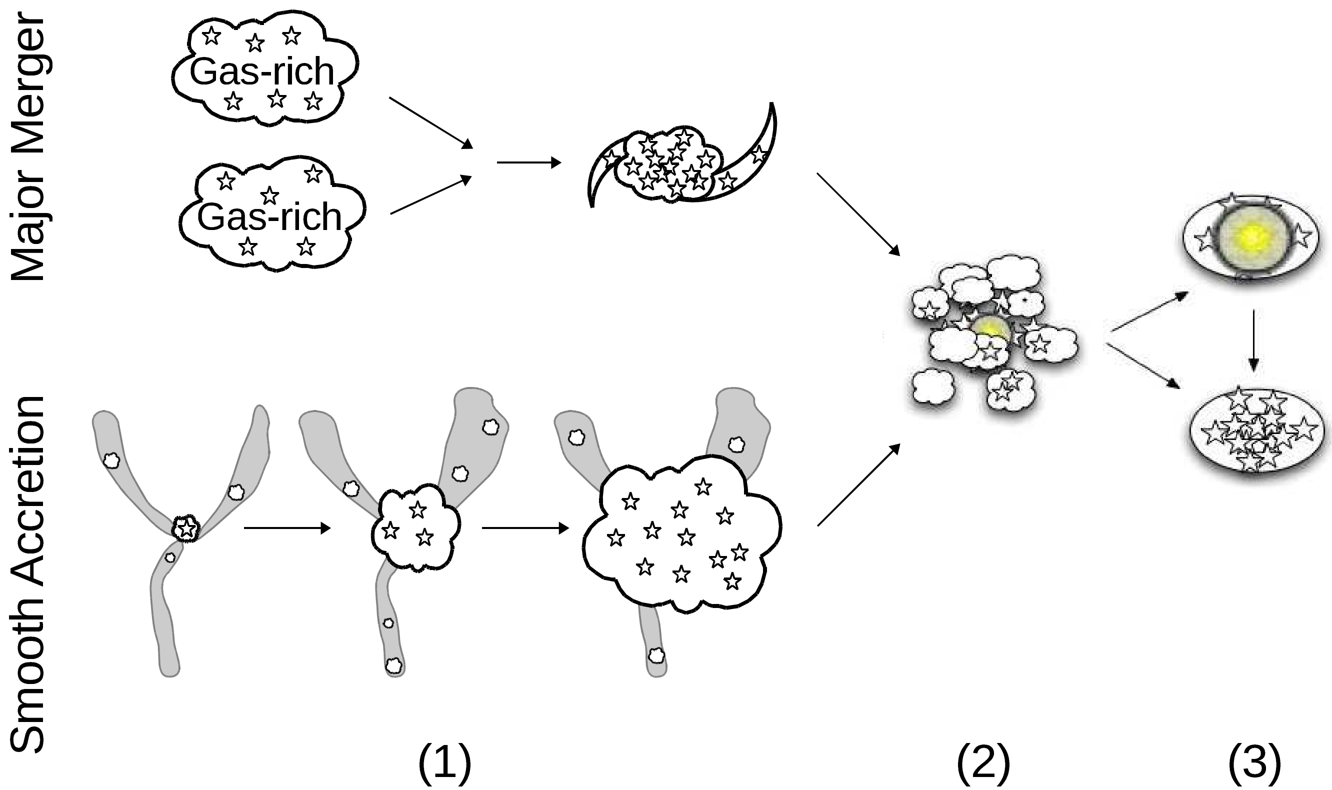


1) how can we explain the starbursts and the luminosities of these galaxies?

2) how the galaxies from the Main Sequence evolve into quiescent galaxies?

Whitaker+15

Possible evolutionary paths for massive galaxies at z~2

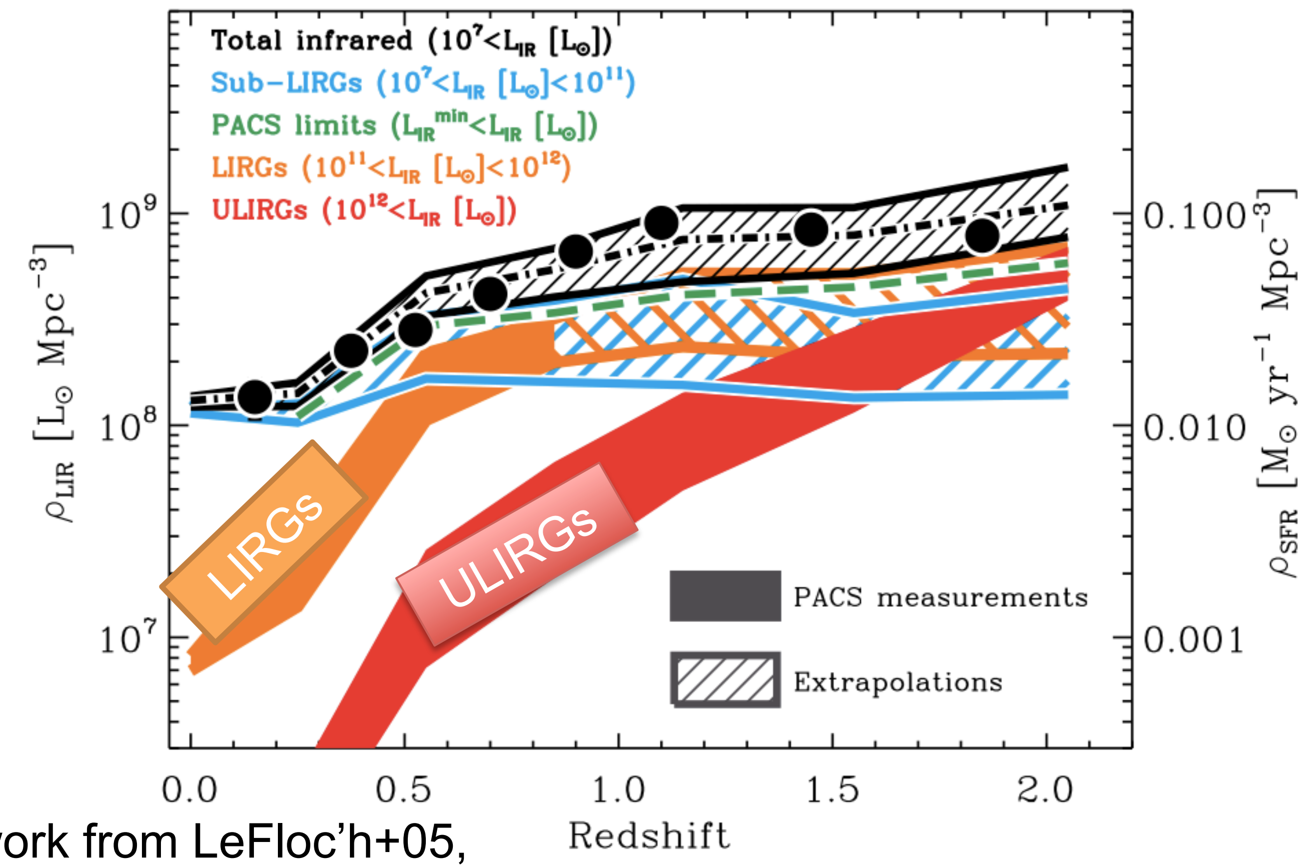


Bussmann+11 (see also Dey+09, Sanders+88)

Importance of the Infra-red (IR) - I

LIRGs = Luminous IR Galaxies : $10^{11}\,L_\odot < L_{\rm IR} < 10^{12}\,L_\odot$

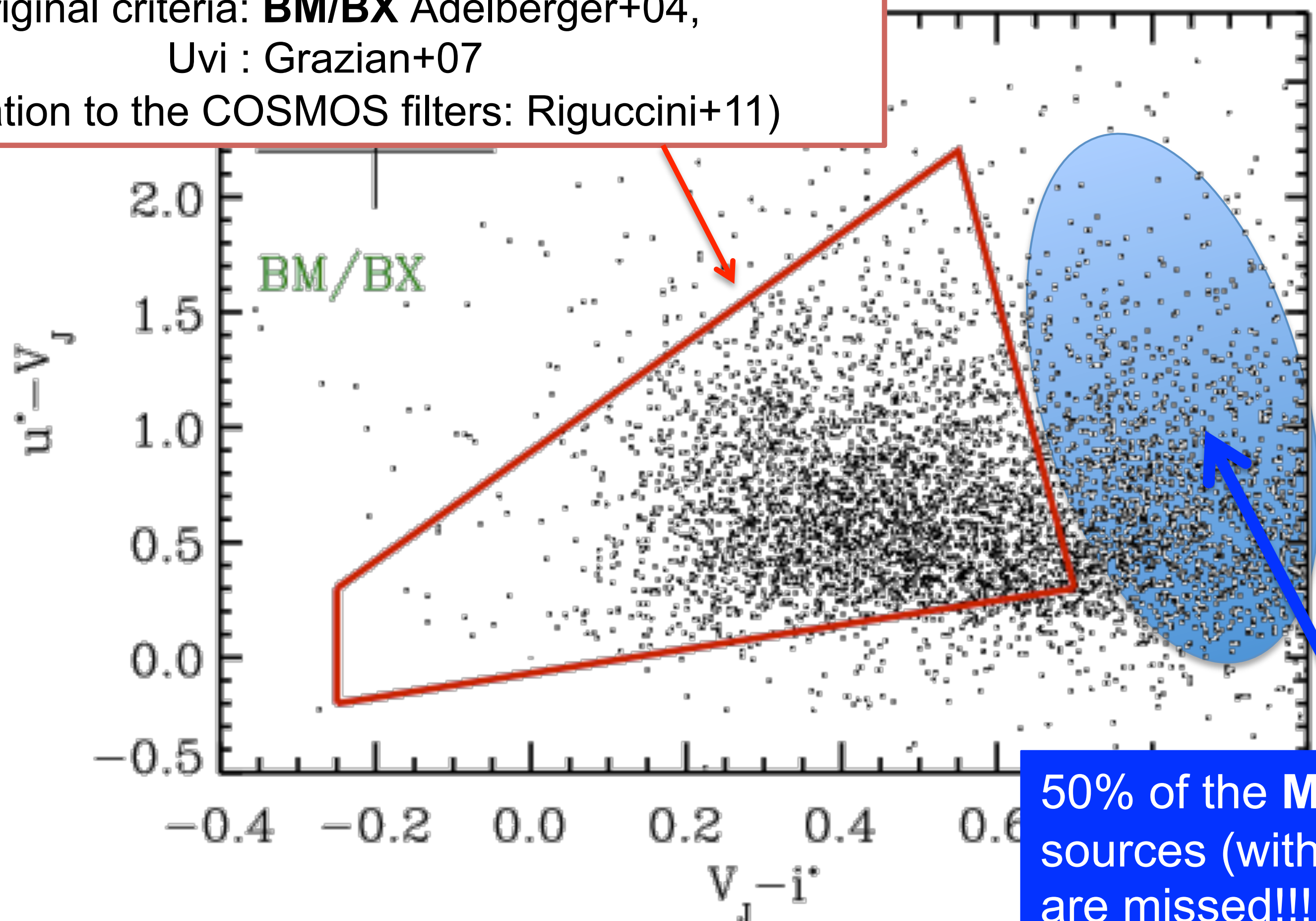
ULIRGS = Ultra- Luminous IR Galaxies : $L_{\rm IR} > 10^{12}\,L_\odot$



Magnelli+13, + work from LeFloc'h+05, Magnelli+11, Burgarella+13, etc.

Importance of the IR - II

Optical selection to select star-forming galaxies at ~ 1.5<z<3
(original criteria: **BM/BX** Adelberger+04,
Uvi : Grazian+07
Adaptation to the COSMOS filters: Riguccini+11)

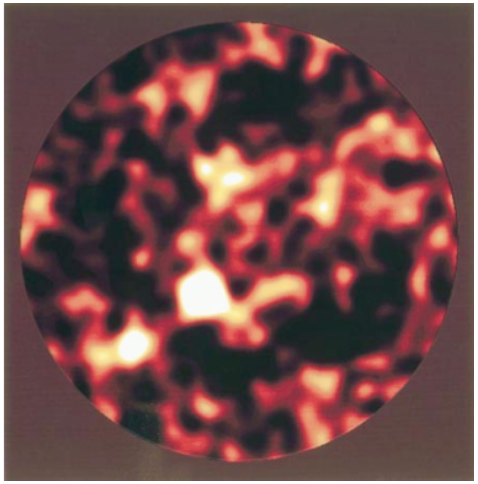


50% of the **MIR-selected** sources (with 1.5<z<3) are missed!!!!

Riguccini+11

Importance of the IR - III

IR and submillimeter detections



SCUBA 850μm HDF field

- Submillimeter (SCUBA): Galaxies detected at submillimeter wavelength (850μm) with really faint optical counterparts. (Hughes+ 98)

- Infrared (Spitzer): large population of **luminous galaxies at z~2 detected at 24μm but really faint at optical wavelength** ('Dust-Obscured Galaxies', DOGs, Dey+ 08)

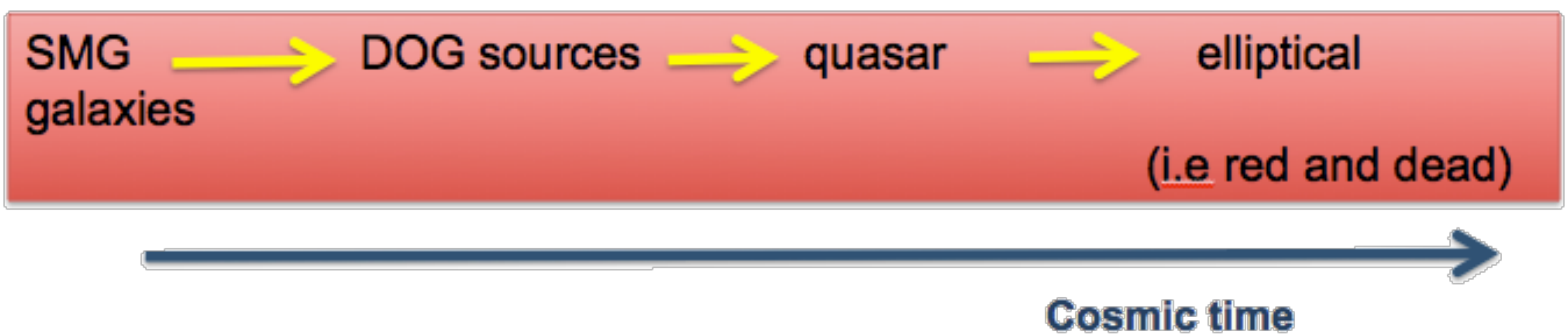
Our sample of DOGs

- 95 DOGs in the COSMOS field
  - Selected at 24 μm: $f_\nu(24\mu m)/f_\nu(R) > 982$
  - 1.5 < z < 3
  - Detected in the Herschel bands

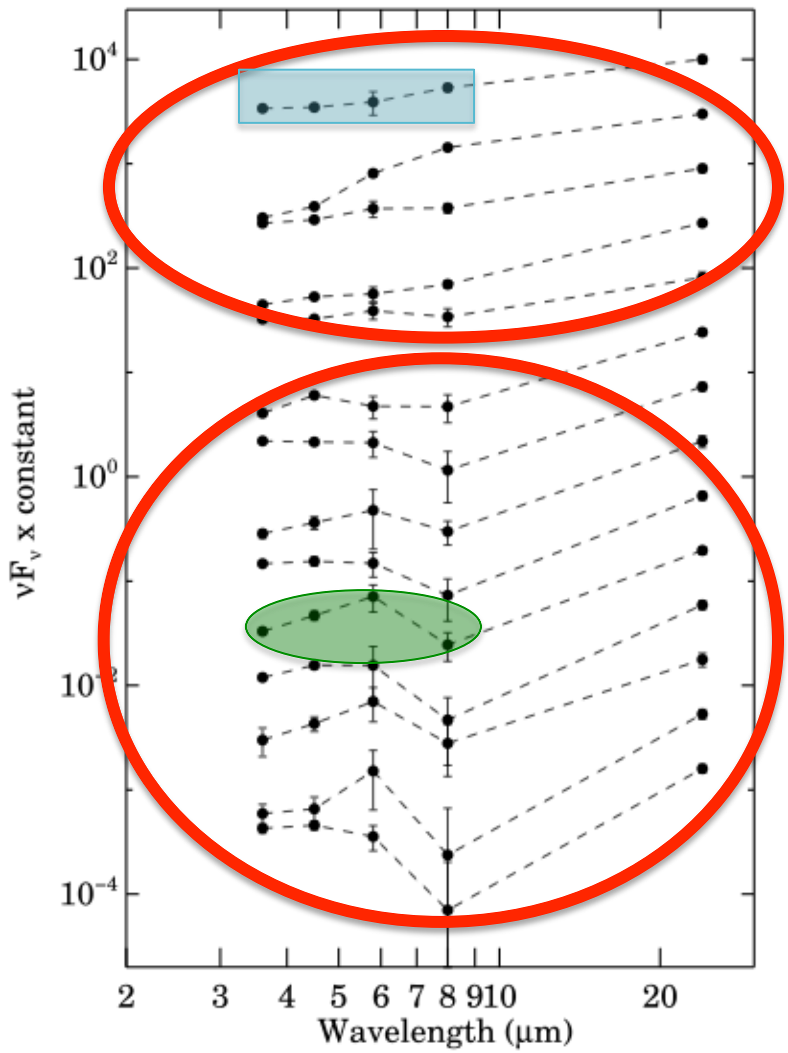
- Seeking for their AGN contribution to their IR luminosity

Particularities of the Dust-Obscured sources (DOGs)

- Contribute for 25% to the ρ_{IR} at z~2
- Present LIRG and ULIRG luminosities (ie luminous and Ultra-luminous IR Galaxies with $L_{IR}>10^{11}\ L_{\odot}$)
- Important step in the evolution of galaxies (e.g., Bussmann+ 11)



Some evidences of AGN activity among the DOGs



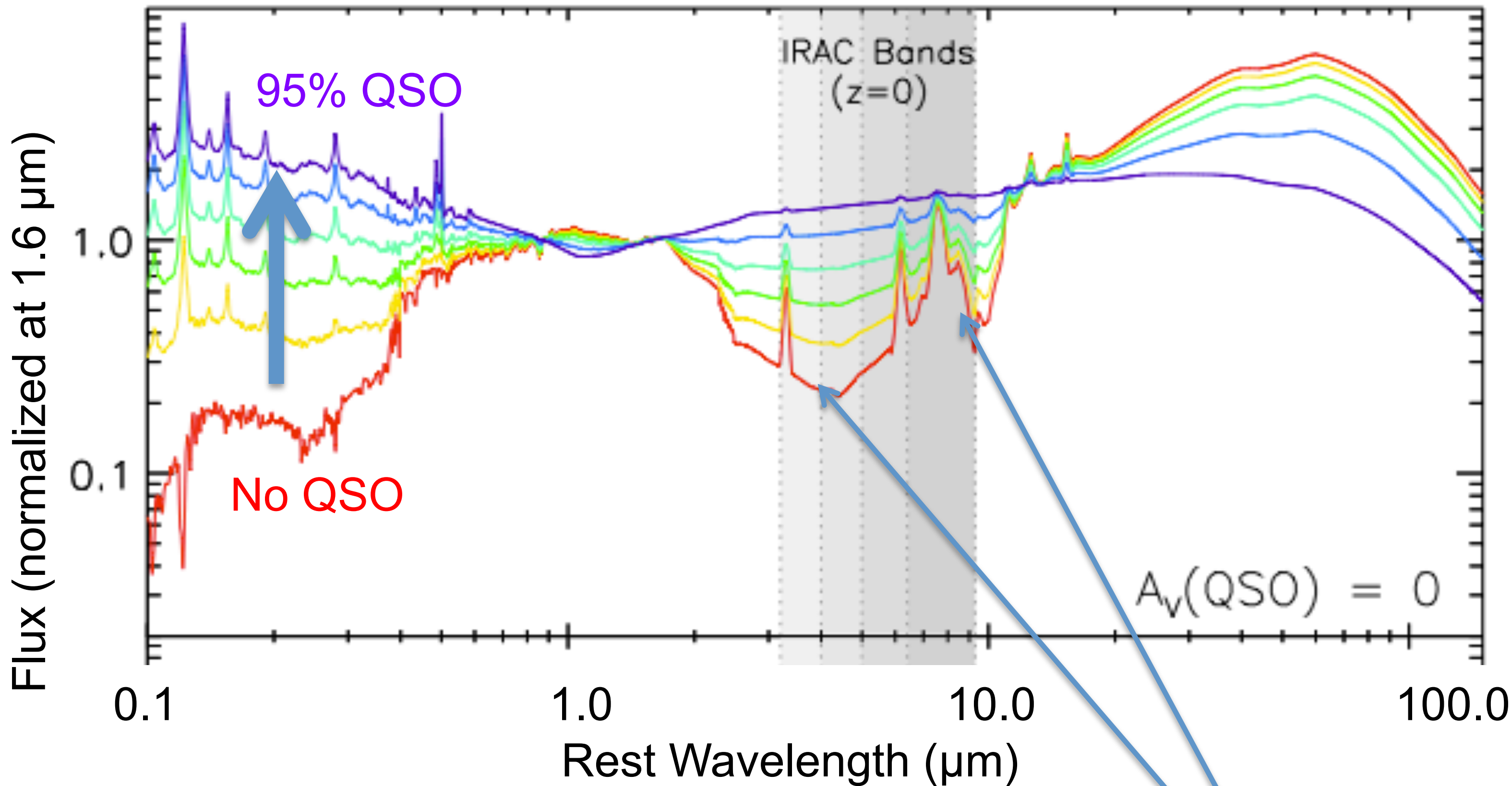
Power-Law DOGs
= power-law SED
in the near-IR

versus

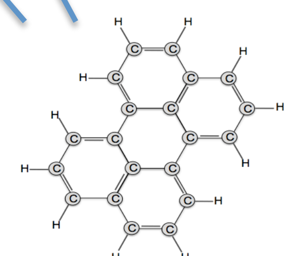
Bump- DOGs

Dey+08

Increase of the contribution of the QSO

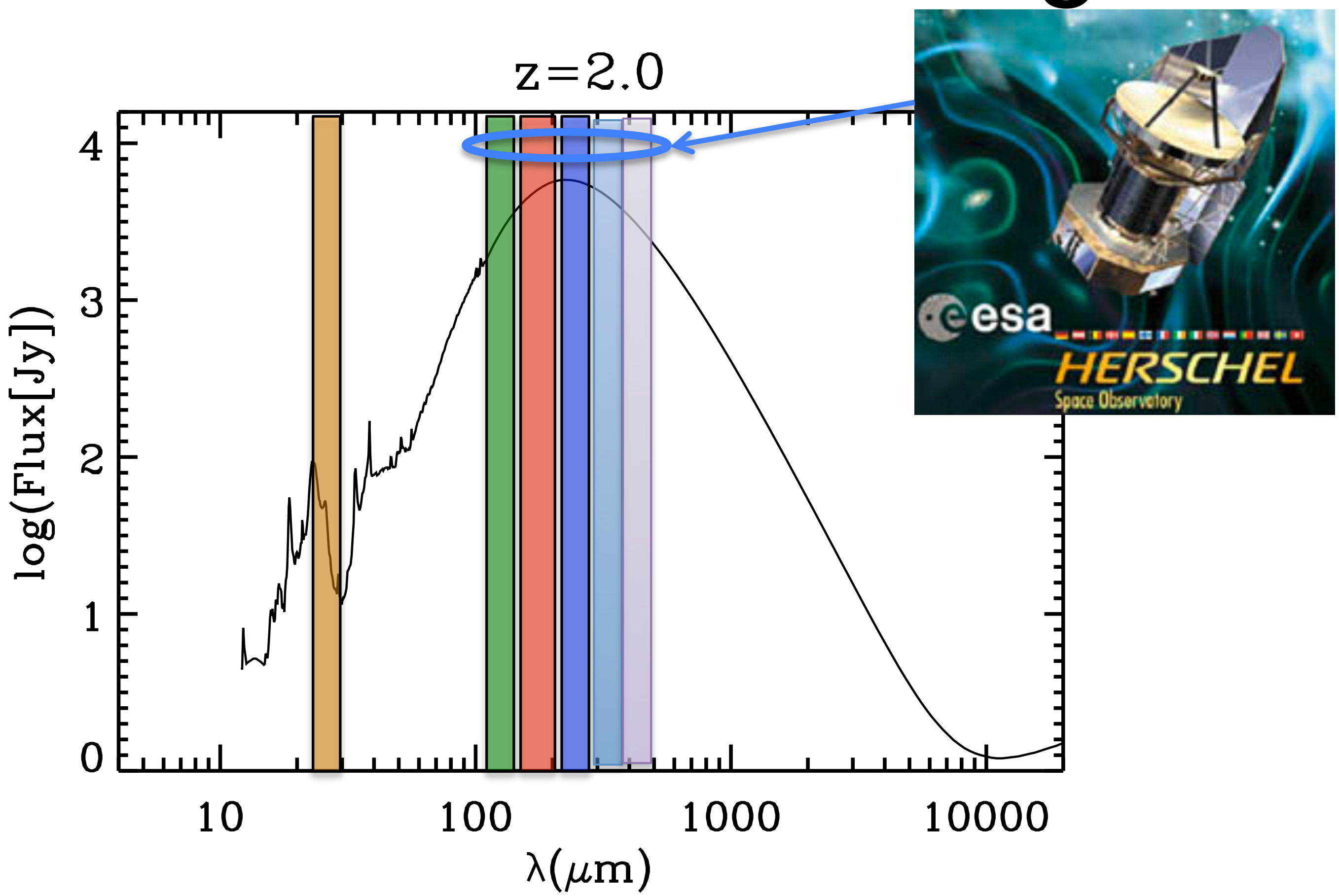


Donley+12



PAHs

Evolution of SED along z

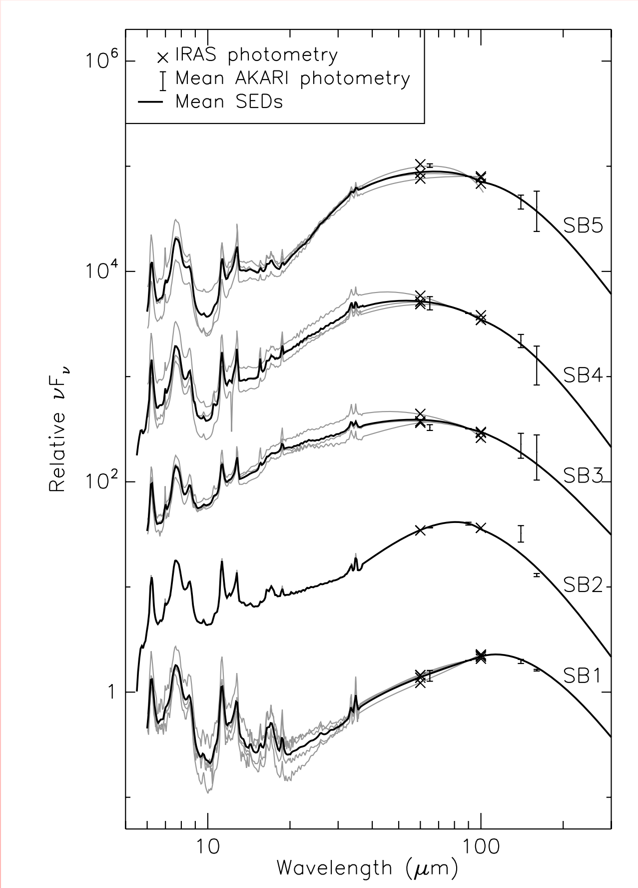


MIPS-24μm
PACS-100μm
PACS-160μm
SPIRE-250μm
SPIRE-350μm
SPIRE-500μm

Spectral Energy Distribution (SED) of an ultra-luminous galaxy ($L_{IR}=10^{12}L_{\odot}$) obtained from the Rieke et al. (2009) library.

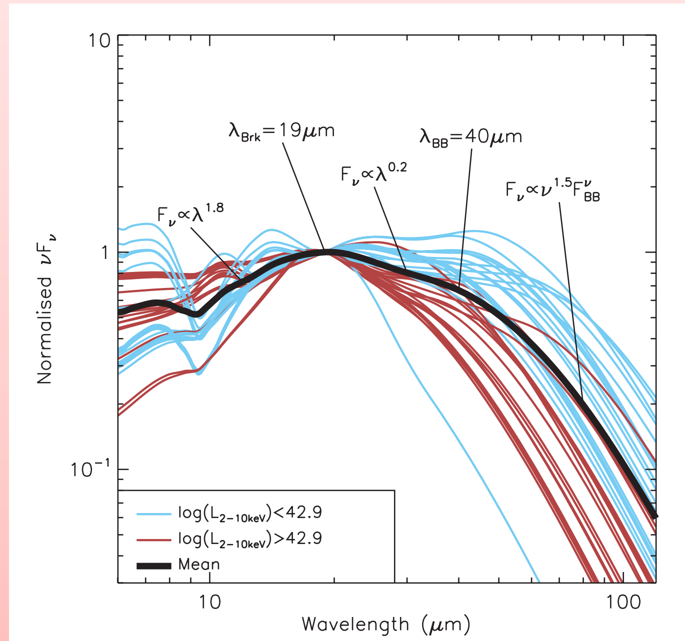
Composite Spectra with DecompIR

They provide 5 average host galaxy templates:



+

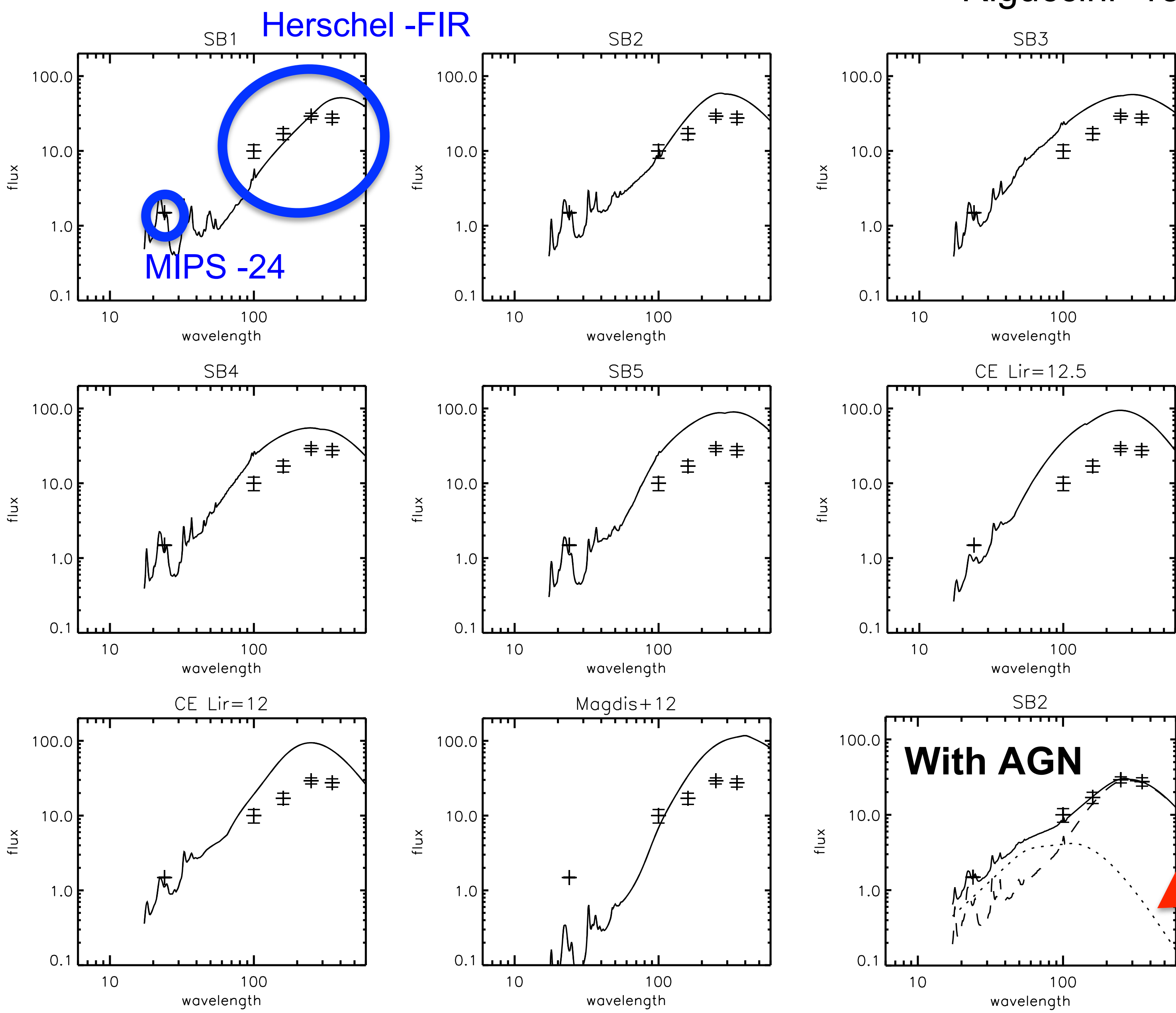
And an average AGN Template:



Mullaney+11

We add 2 ULIRGs templates (Chary & Elbaz, 2001) + 1 z~2 dusty galaxy template (Magdis+12)

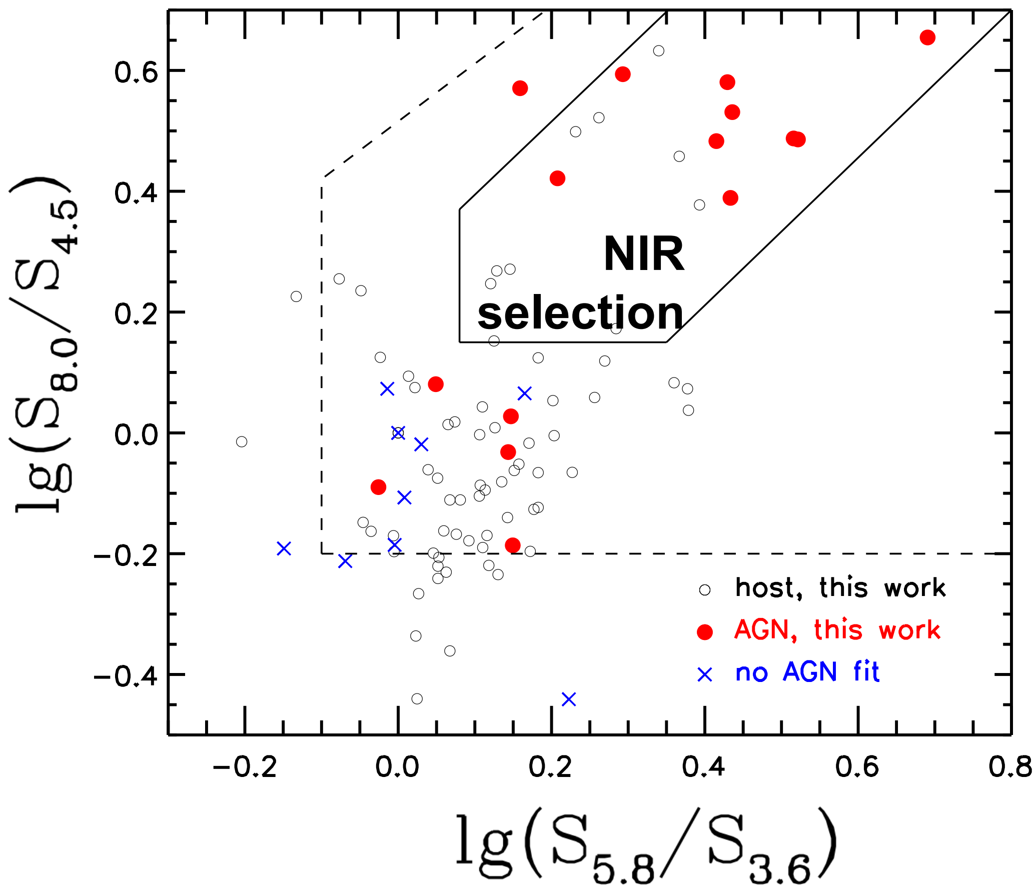
Riguccini+15 (MNRAS)



Contribution AGN Torus

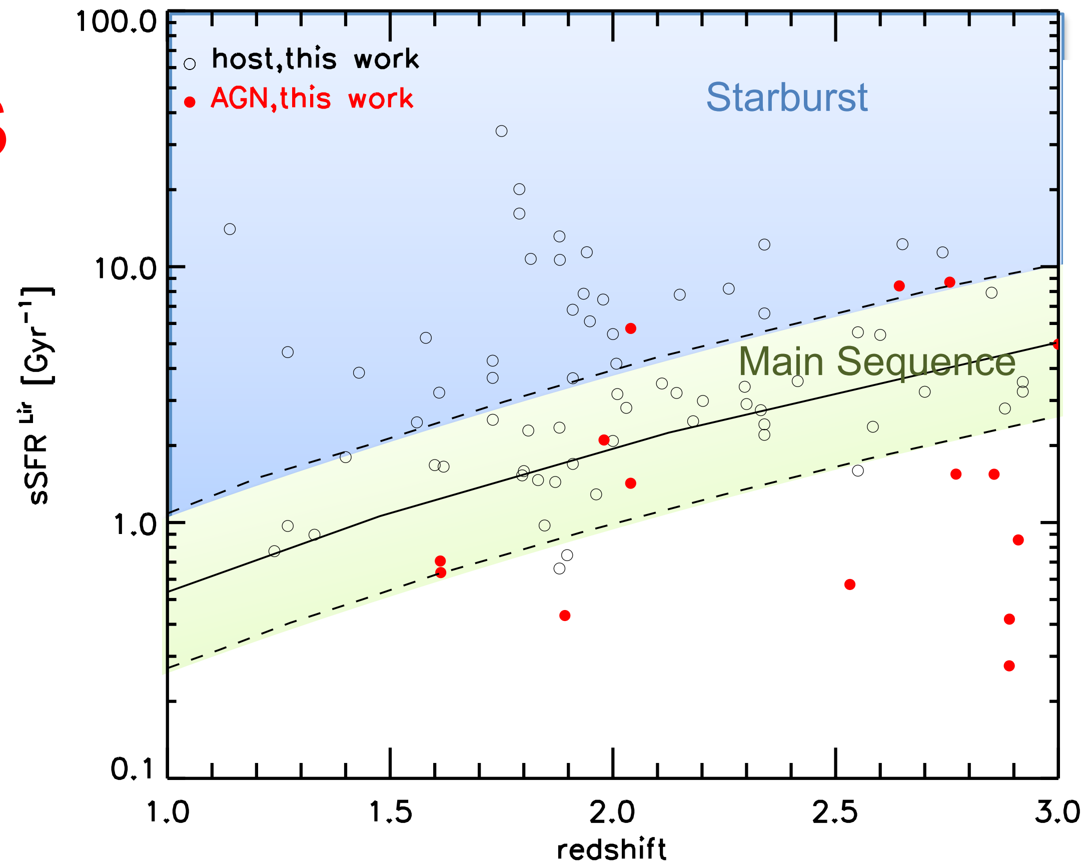
AGN-DOGs

- 95 Herschel DOGs
- 15 are fitted by « composite spectra » and then considered as AGN-DOGs
- More than 60% of the AGN-DOGs are inside the NIR-AGN selection box



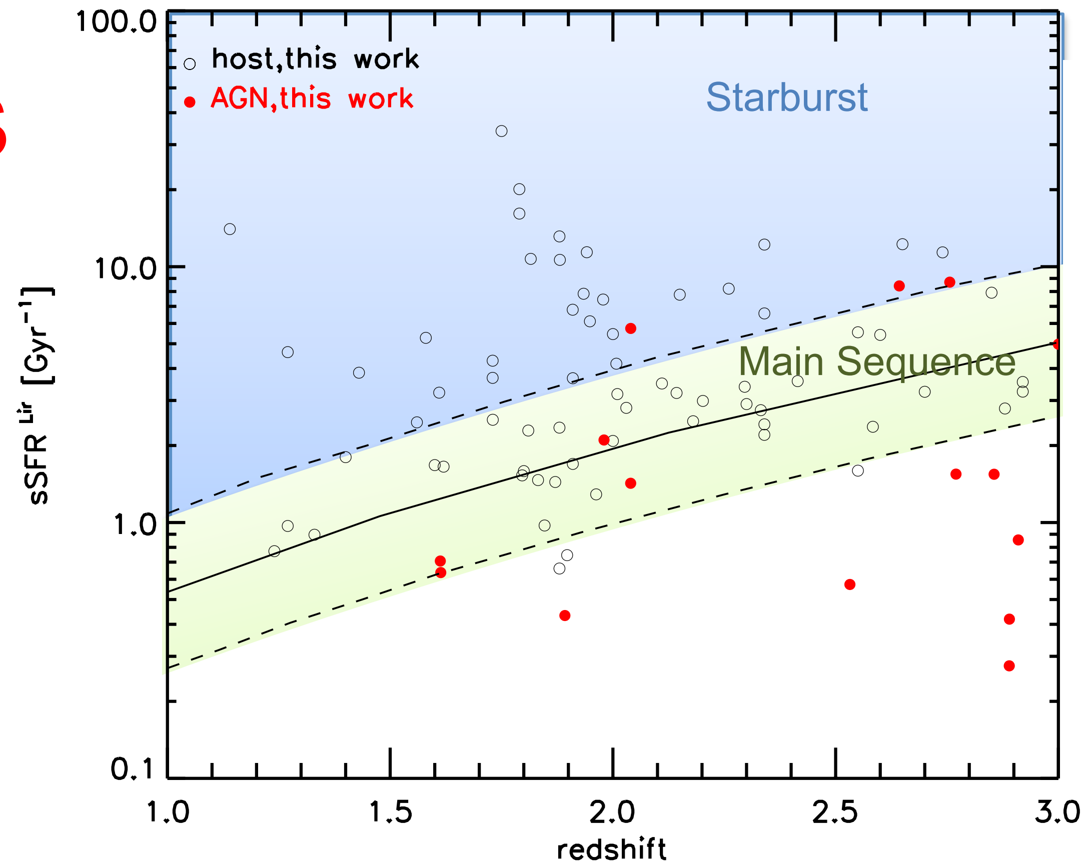
Riguccini+15

AGN-DOGs



Riguccini+15,
Check also Elbaz+11

AGN-DOGs



Riguccini+15,
(Check also Elbaz+11,
Rodighiero+11, etc.)

SMG galaxies → DOG sources → quasar → elliptical

(i.e red and dead)

Cosmic time

Dust temperatures and Masses: Far-IR Fit

- A two-temperatures fit

$$L(\nu) \propto \alpha B\left(\nu, T_d^1\right)\nu^\beta + (1-\alpha)B\left(\nu, T_d^2\right)\nu^\beta$$

With β the standard emissivity for big dust grains (β= 1.5 or 2, e.g. Draine & Li 1984, etc.)
And B(ν,T) a blackbody spectrum
α gives the luminosity ratio of the two dust species
T_d^1 is constrained between 10 and 45 K
T_d^2 is constrained between 45 and 95 K

- A single-temperature fit

$$L(\nu) \propto B(\nu, T_d)\nu^\beta$$

T_d is constrained between 10 and 95 K

$\lambda_{\text{rest-frame}} > 40$ μm to avoid emission from the AGN

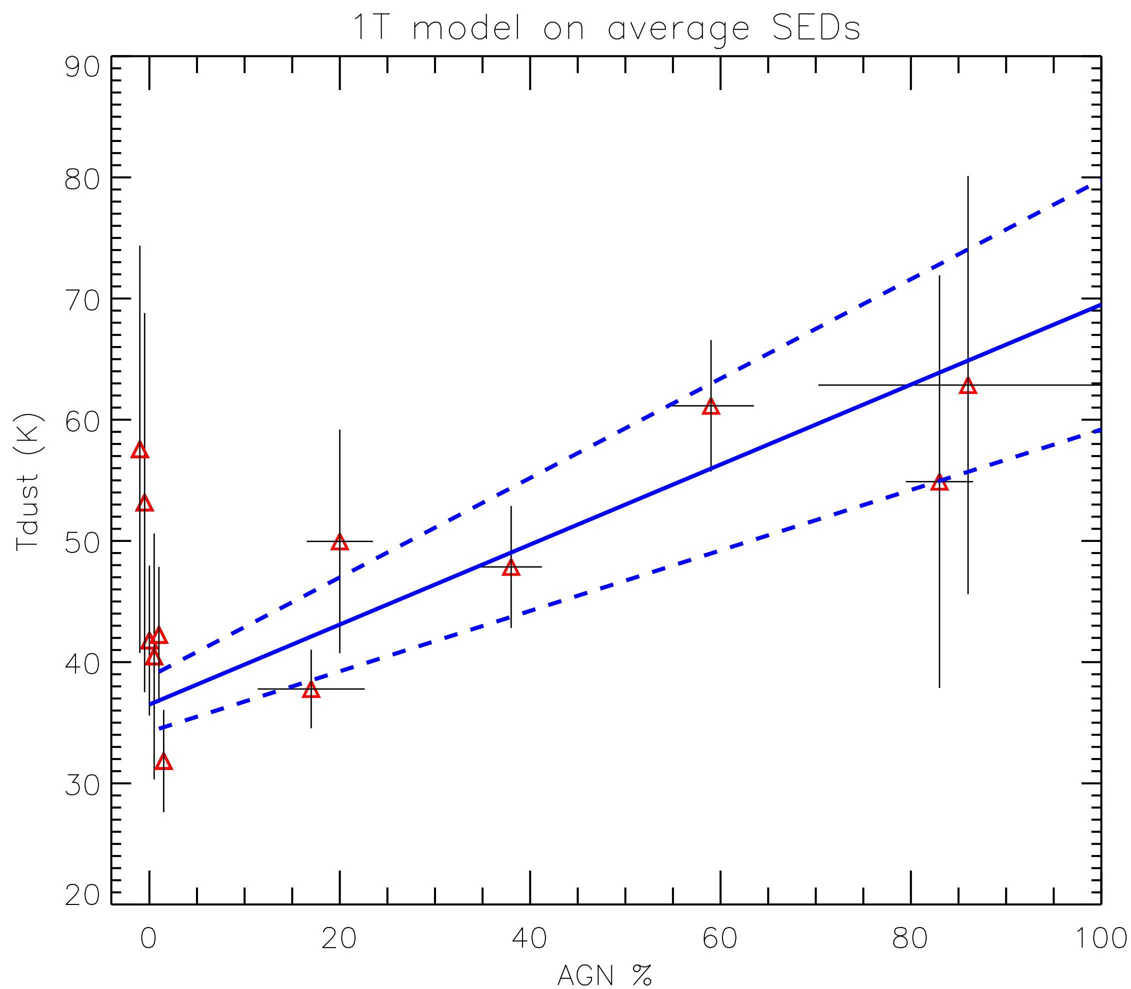
Median dust temperature:

*T*d ~(40.6 ± 9.2) K

(good agreement with the literature, i.e. Calanog+13)

Dust Mass:

$7 \times 10^7 < M\text{dust} < 10^9\ M_\odot$ and a median dust mass of $\sim (3 \pm 3) \times 10^8\ M_\odot$ (good agreement with the literature, i.e. Bussmann+09)



Conclusions

- DOGs ($f_\nu(24\mu m)/f_\nu(R) > 982$) are a key step in the evolution of galaxies

  SMG ➔ DOGs ➔ quasar ➔ elliptical

- 74% of our FIR-sample are fitted by a host galaxy template, 16% show a contribution from an AGN

- AGN-DOGs populate peculiar places on evolution diagram, not starburst anymore

  ➔ DOGs = transition phase

On-going work

X-ray properties of the X-ray detected and undetected DOGs using Chandra COSMOS-Legacy, uniformly covering the ~1.7 deg2 COSMOS/HST field with 2.8 Ms of Chandra ACIS-I (Garmire et al. 2003) imaging, at ~160 ksec depth, expanding on the current deep C-COSMOS area by a factor of ~3 at $\sim 3\times10^{-16}$ erg cm^{-2} s^{-1} (1.45 vs 0.44 deg^2).