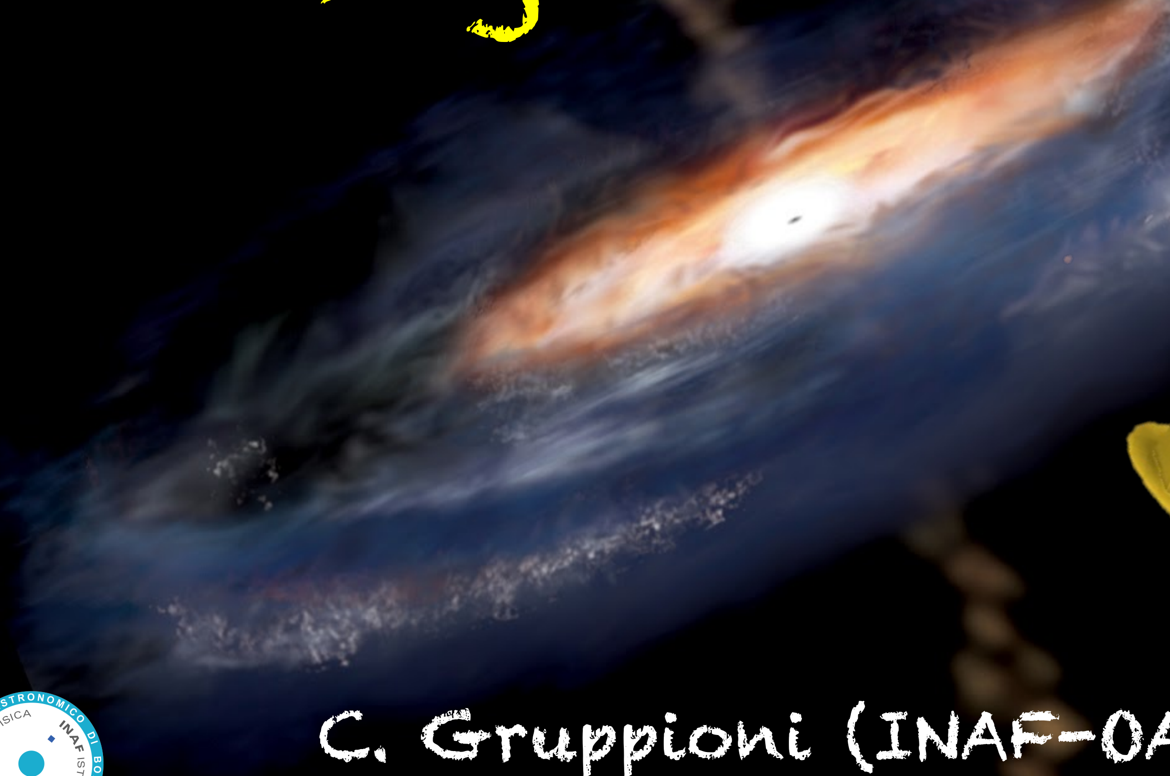
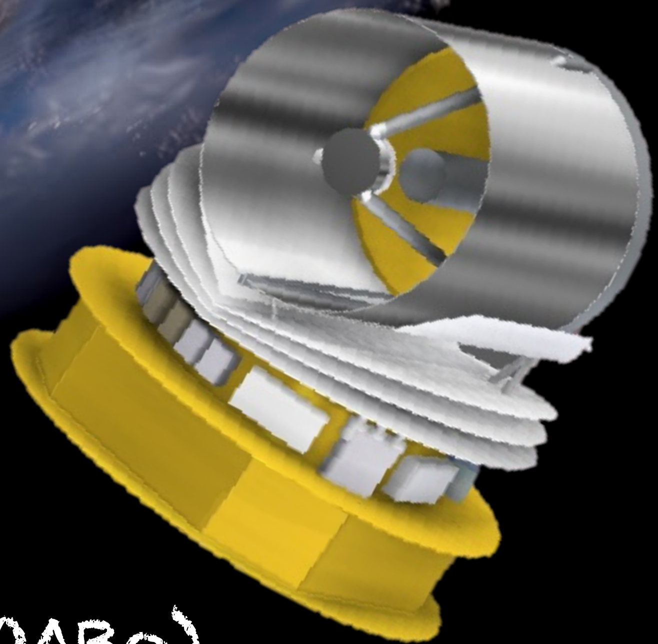
Status of the SPICA MS proposal for Extragalactic studies

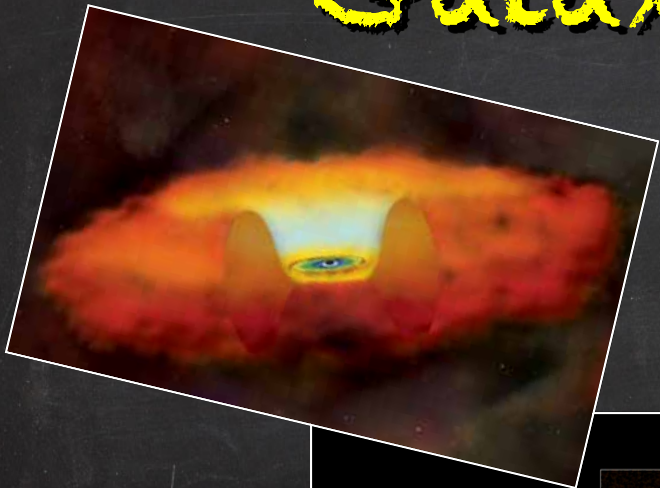


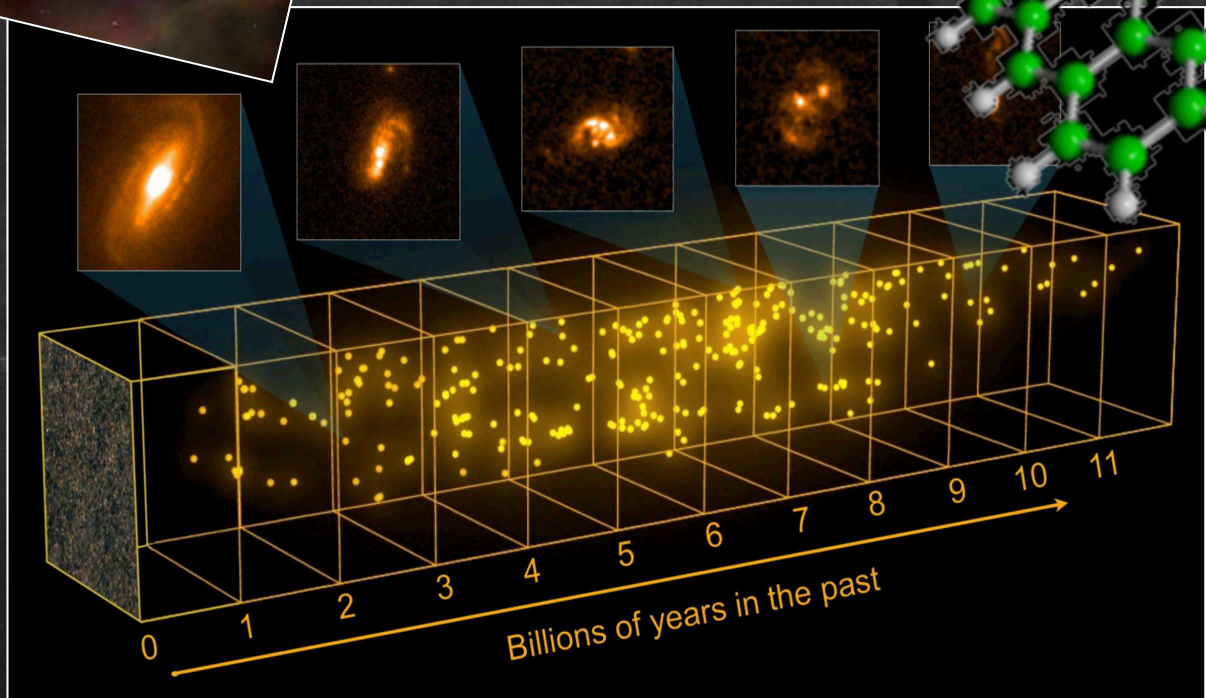


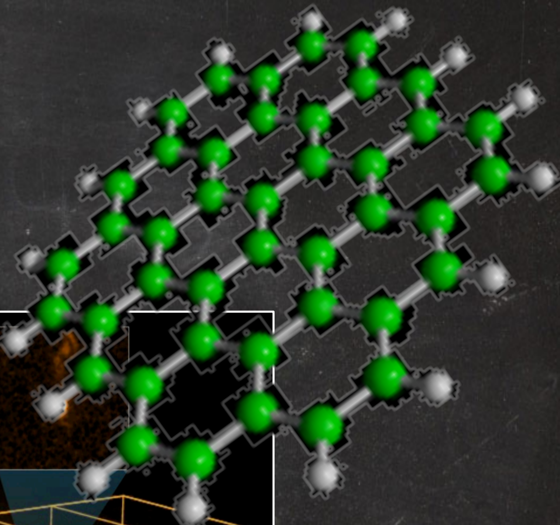
C. Gruppioni (INAF-OABo)
& SPICA extragalactic WG

INAF, Roma - 2016 April 4-5

Understanding the Physical Processes that Regulate Galaxy Evolution







Main Science Goals

① Star Formation and Black Hole Accretion across Cosmic Time

② Build-up of Heavy Elements in the Peak Epoch of Star Formation

③ Towards the Epoch of Re-ionization and beyond

Main Science Goals

① Star Formation and Black Hole Accretion across Cosmic Time

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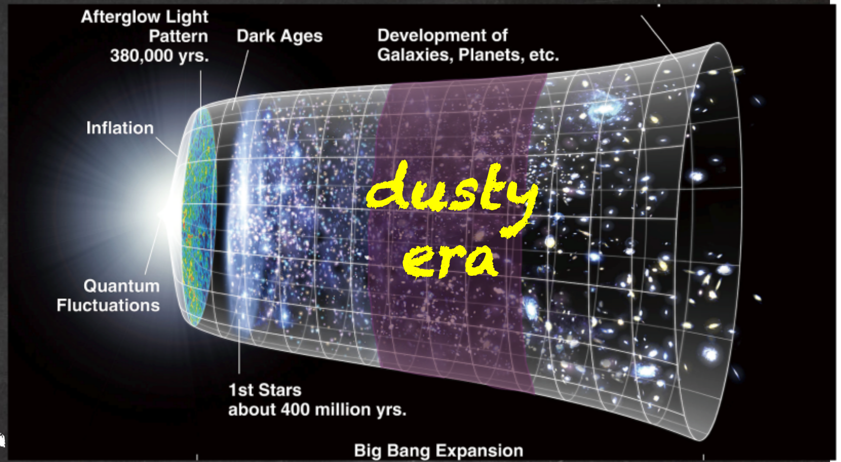
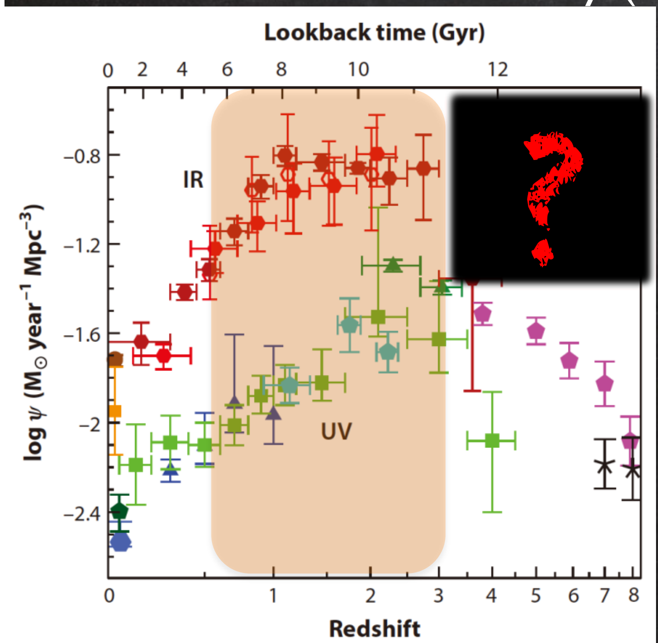
① Unveiling the "dusty era" of the Universe

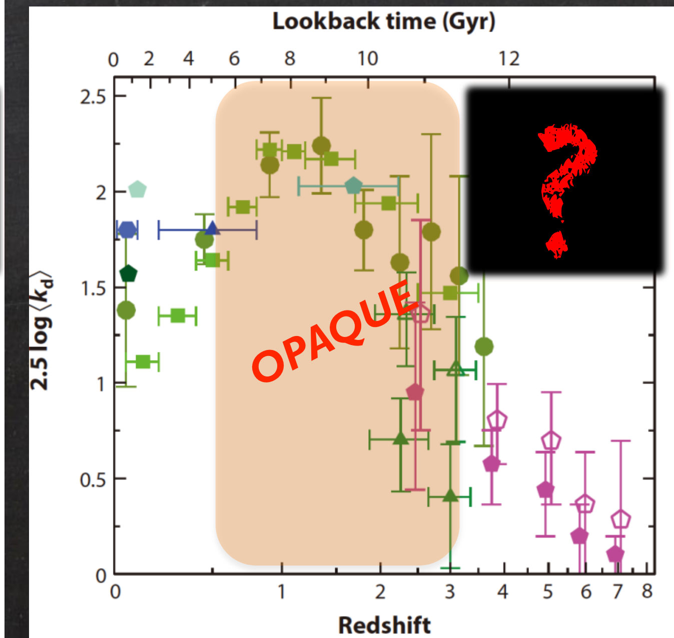
- ★ "Dusty era" (z~1-3) invisible at optical wavelengths,
- ★ Peak of the star formation and AGN activity in the Universe
- ★ most stars, massive black holes, and metal and dust are formed.



Star Formation Rate Density (SFRD)

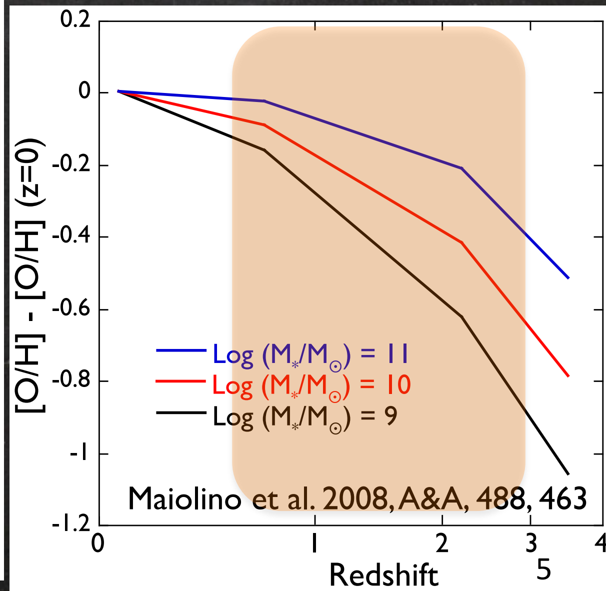


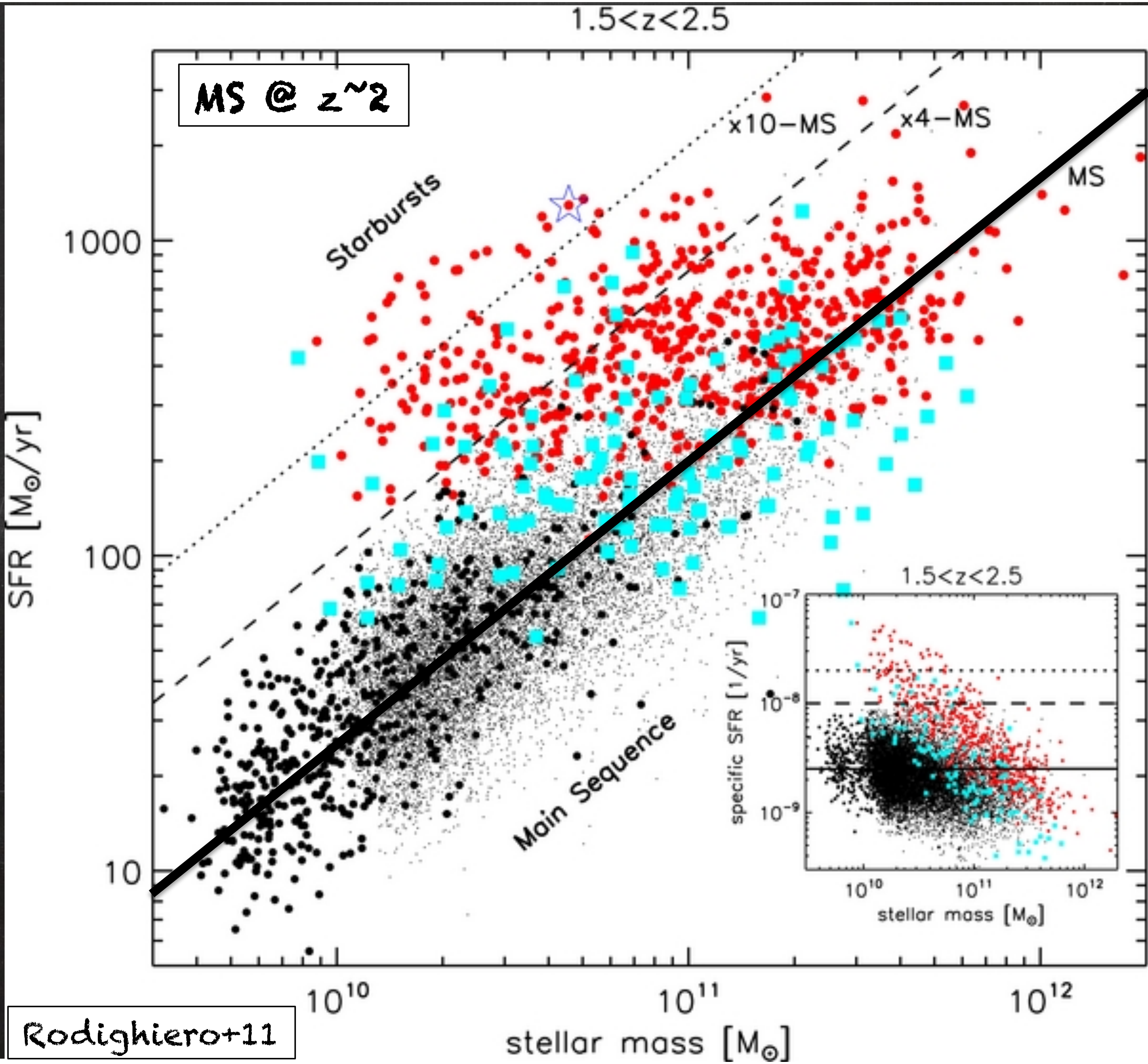
Dust attenuation



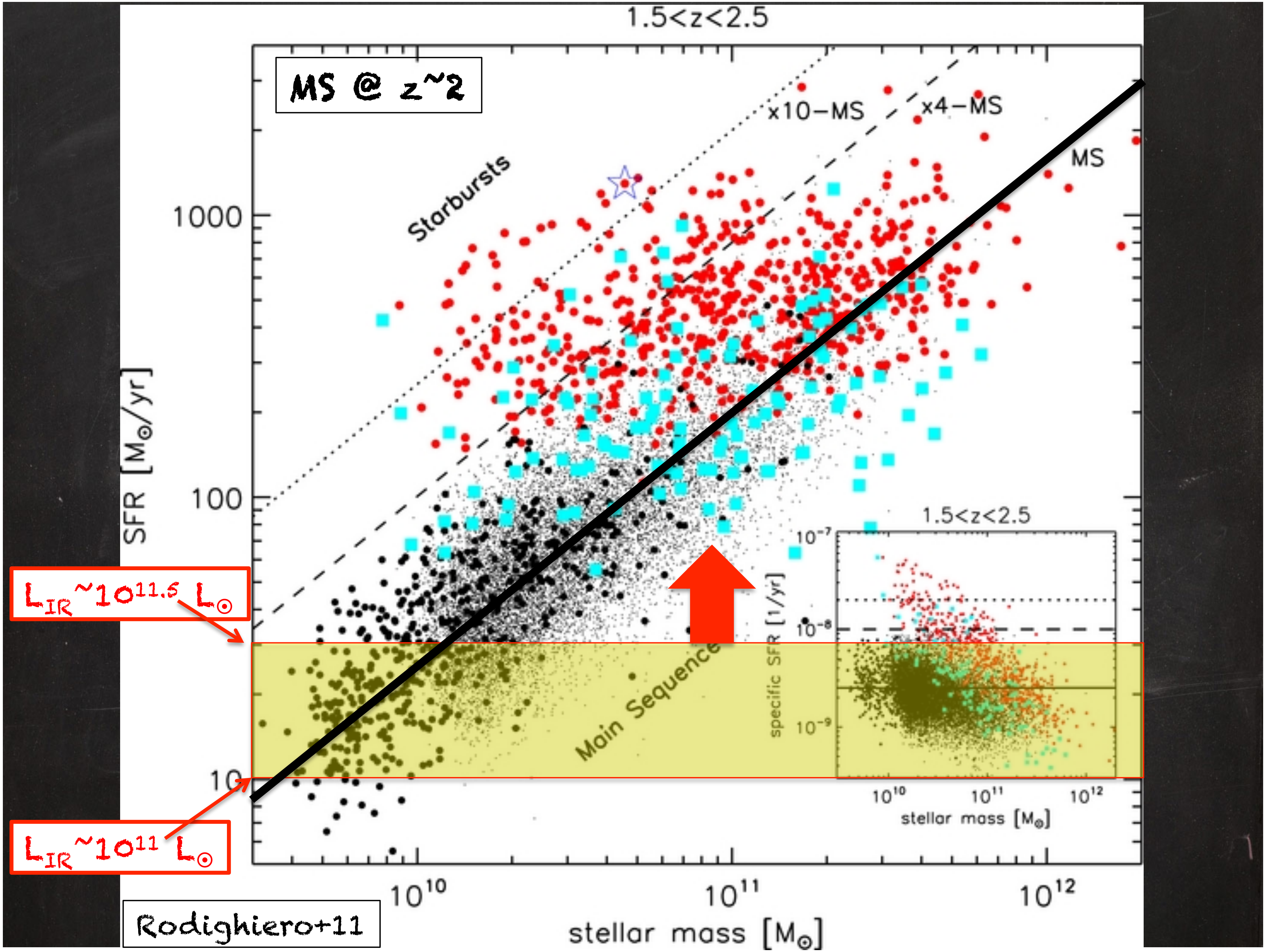
Madau & Dickinson 2014, ARAA, 52, 415

Metallicity (optical)

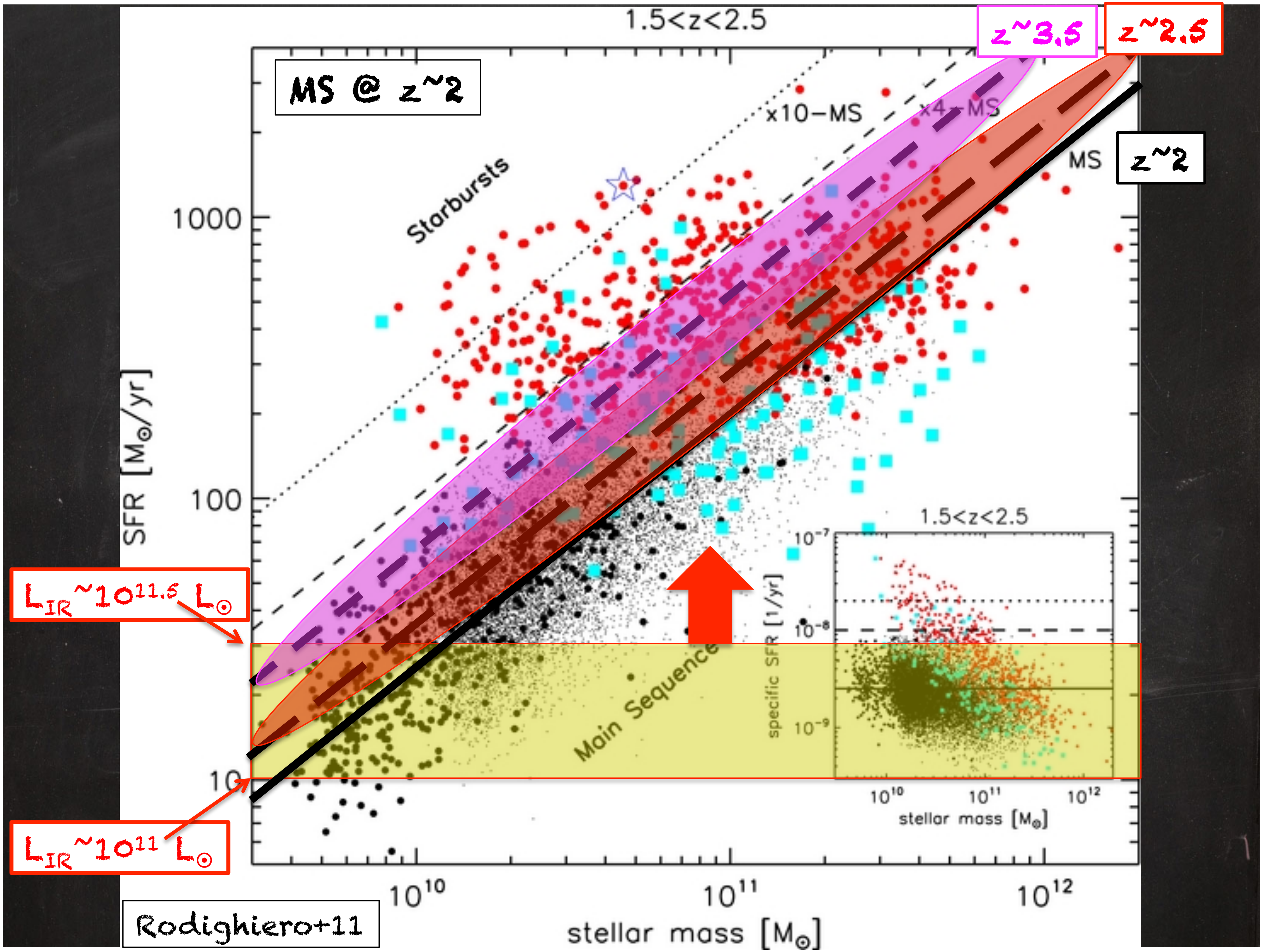




1.5<z<2.5
MS @ z~2
x10−MS
x4−MS
MS
Starbursts
Main Sequence
1000
100
10
SFR [M⊙/yr]
10^10
10^11
10^12
stellar mass [M⊙]
1.5<z<2.5
specific SFR [1/yr]
Rodighiero+11



1.5<z<2.5
MS @ z~2
x10−MS
x4−MS
MS
Starbursts
Main Sequence
SFR [M⊙/yr]
1000
100
10
L_{IR}~$10^{11.5}$ $L_\odot$
L_{IR}~10^{11} $L_\odot$
10^{10}
10^{11}
10^{12}
stellar mass [M⊙]
Rodighiero+11
1.5<z<2.5
specific SFR [1/yr]
10^{-7}
10^{-8}
10^{-9}
10^{10}
10^{11}
10^{12}
stellar mass [M⊙]



1.5<z<2.5
MS @ z~2
z~3.5
z~2.5
z~2
x10–MS
x4–MS
MS
Starbursts
Main Sequence
SFR [M⊙/yr]
1000
100
10
L_{IR}~$10^{11.5}$ $L_⊙$
L_{IR}~10^{11} $L_⊙$
10^{10}
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1.5<z<2.5
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10^{-7}
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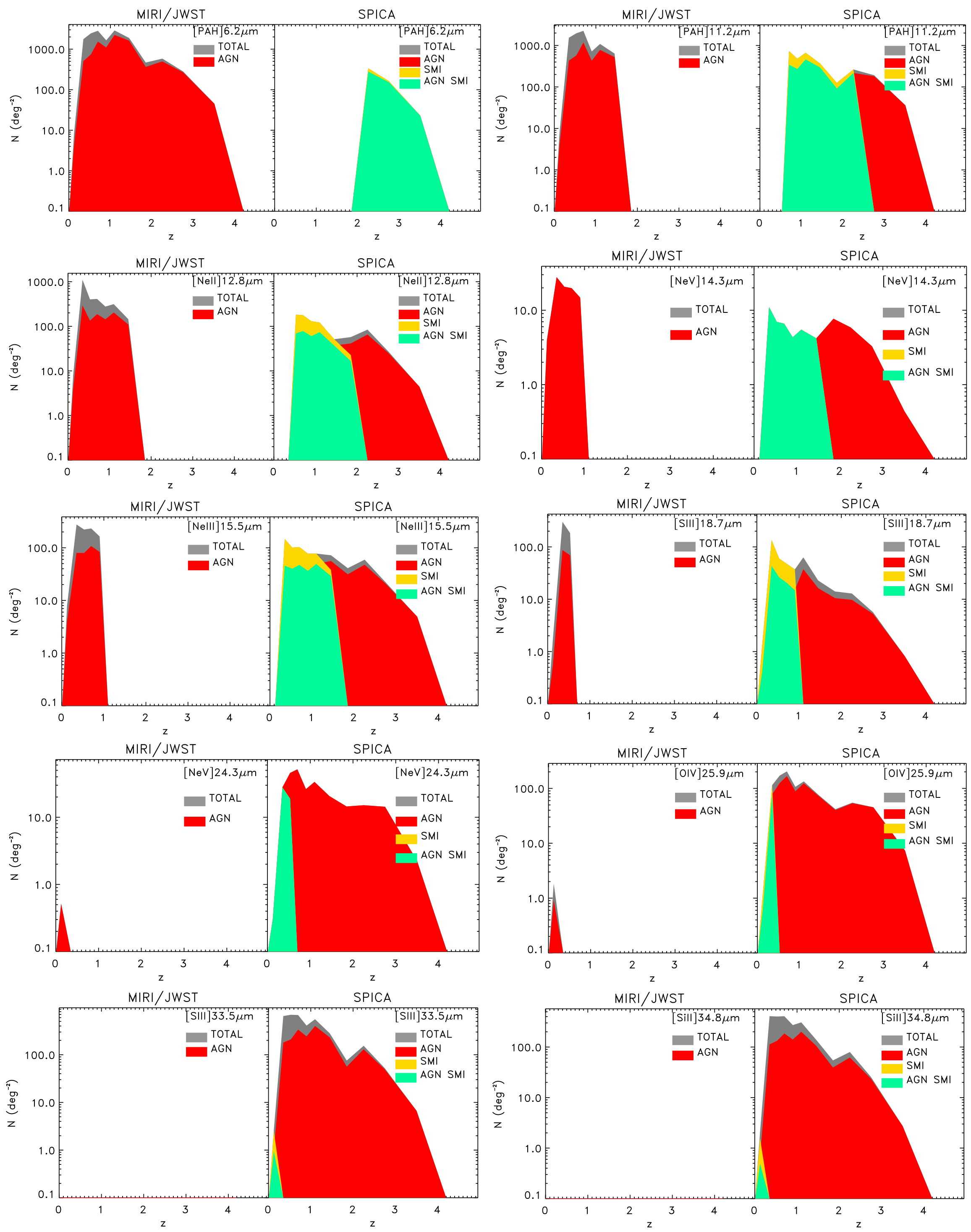
10^{-9}
Rodighiero+11



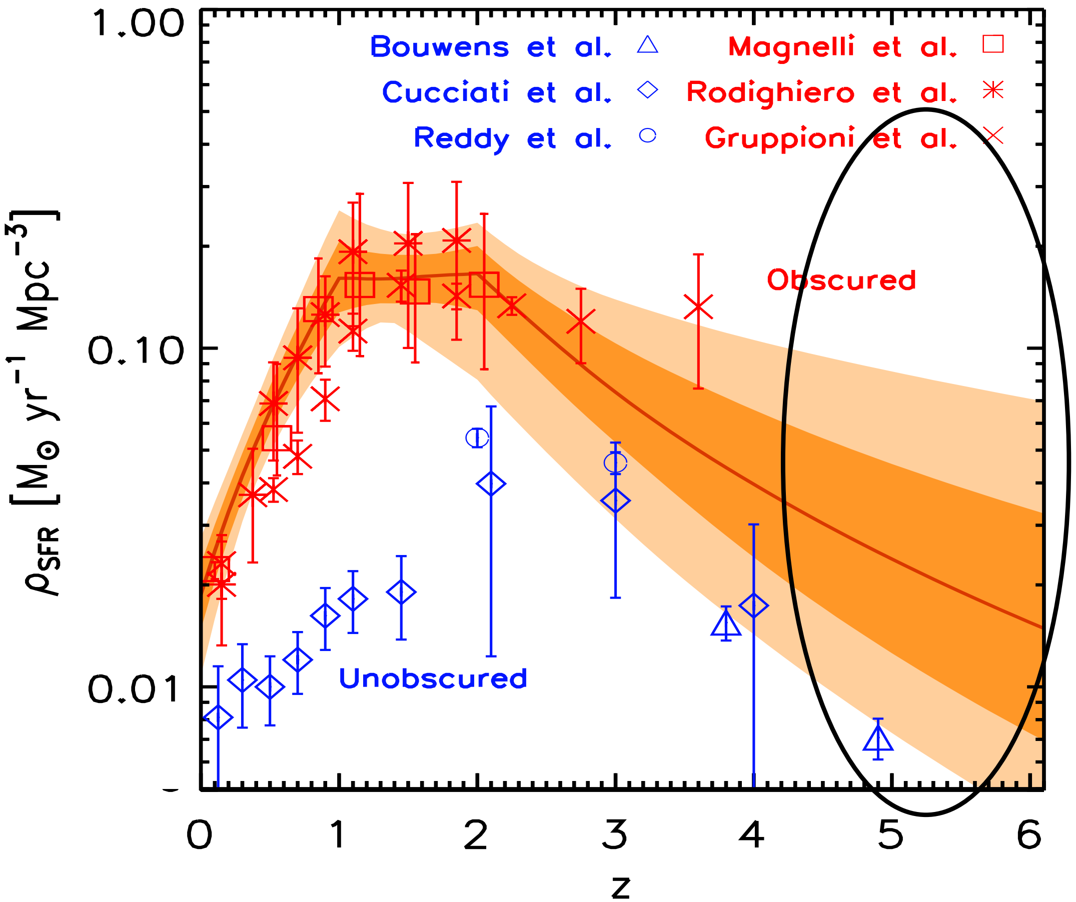
Redshift distributions of objects detectable in the different IR lines with MIRI/JWST and SMI+SAFARI/SPICA

Able to observe 100s of sources in the strongest lines (e.g. [OIV]) to z~3-4

What if we want to reach higher redshifts?

SPICA SMI Photometric Survey at 30-37 μm

Growth of Cosmic Star-Formation



SF history: Planck Paper 30

We would like to chart the onset and early growth of star formation in the epoch prior to z=4 (the first 1.5 Billion years) ?

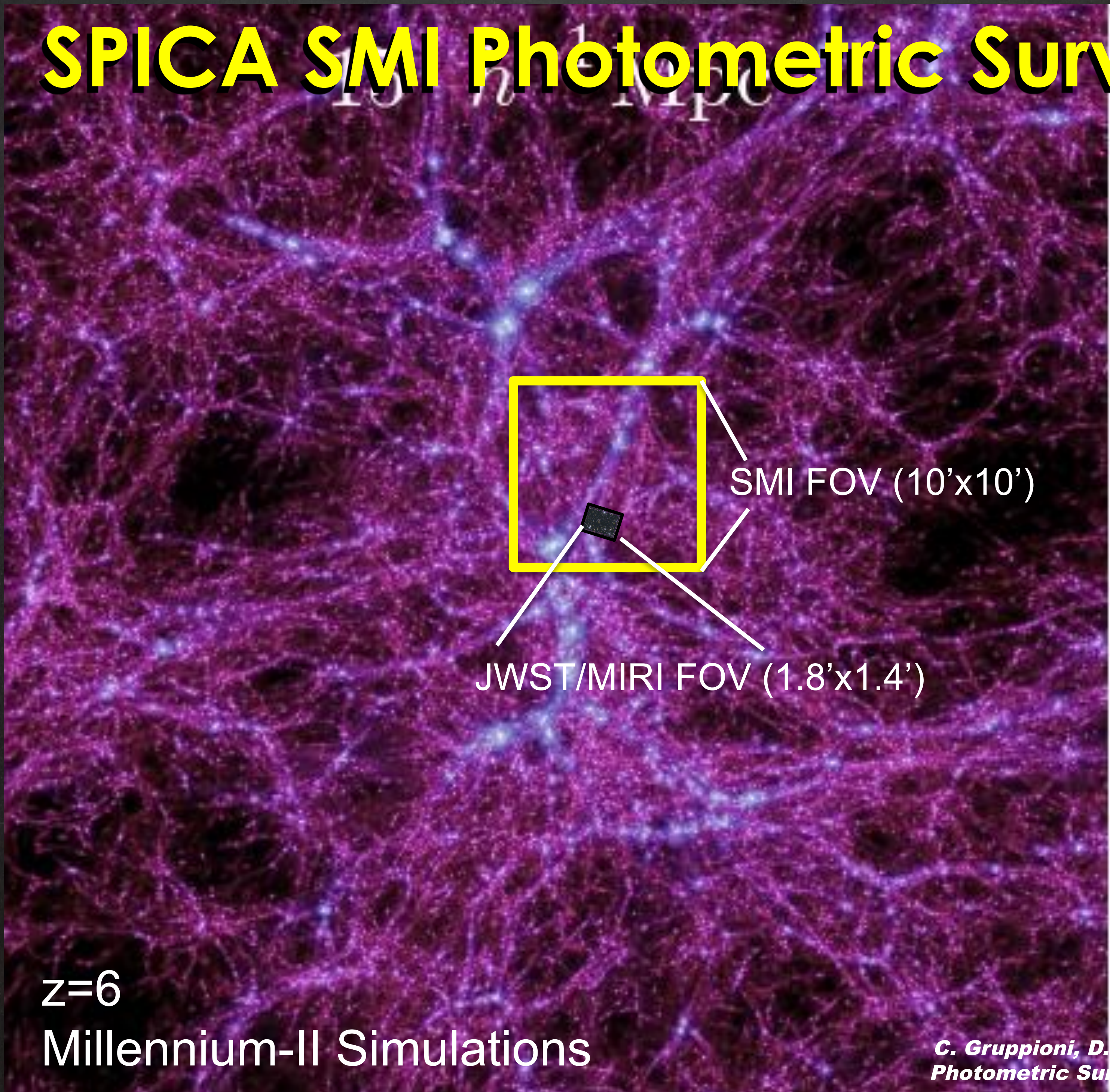
e.g. was this dominated by massive galaxies or small ones? How much does dusty SF contribute?

z>4 has large uncertainties and all data on this epoch comes from rest-frame UV / optical surveys (Lyman break sources) (GRB measurements and reionizaton constraints suggest flatter SFR at e.g. z~7.)

Require redshift-resolved far-IR / submm luminosity functions to complement UV-based studies.

(M. Bradford)

SPICA SMI Photometric Survey



1 deg^2 observable with SMI in ~64 h to confusion limit (9μJy)

C. Gruppioni, D. Clements, L. Ciesla: Photometric Survey: SPICA use case

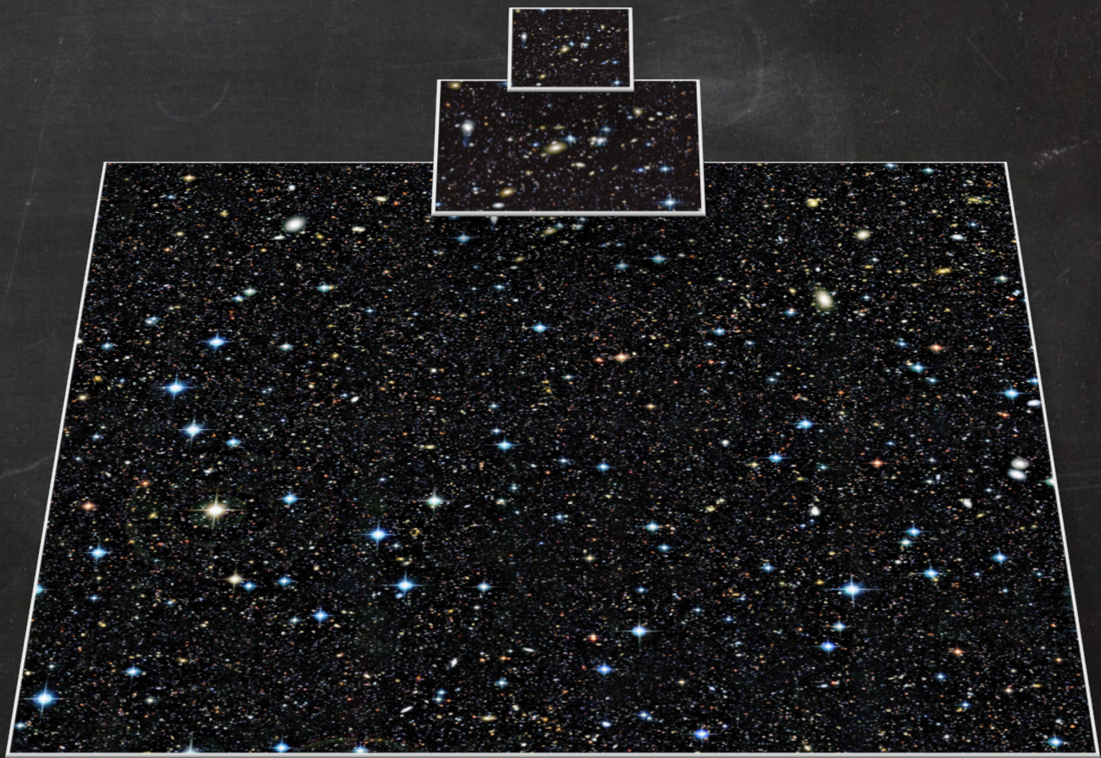
SPICA SMI Photometric Survey

- Survey Strategy (total amount of time ~210 hours):

- Ultradeep (sub-confusion):
  to ~3 μJy in two 10'x10' fields (32 hours)
  + six lensing fields for greater effective depth, >10x fainter fluxes (100 hours)

- Deep (confusion):
  to ~9 μJy in 1 deg^2
  (64 hours)

- Shallow:
  to ~0.2 mJy in 100 deg^2 (13 hours)



C. Gruppioni, D. Clements, L. Ciesla: Photometric Survey: SPICA use case

SPICA SMI Photometric Survey

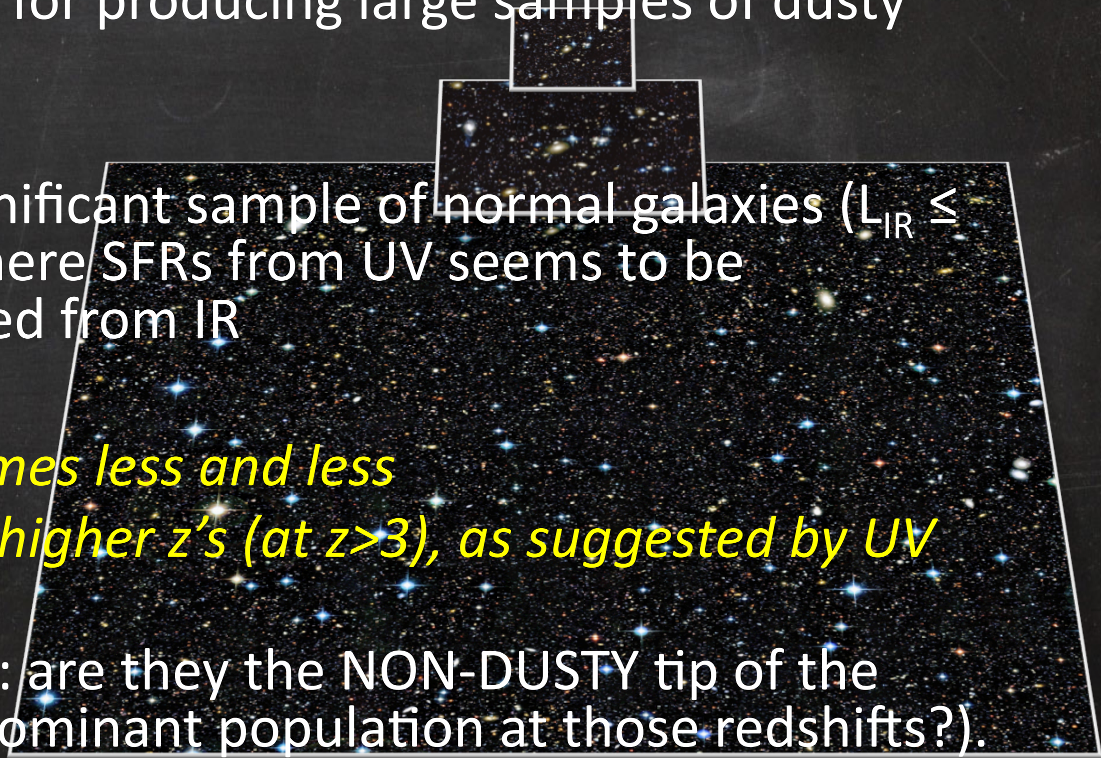
- We expect hundreds of high-z, IR-selected sources available for follow-up by the time SPICA flies (from surveys with Herschel, ALMA, SPT, JWST, Euclid and WFIRST), SPICA with SMI will be uniquely suited to *discover new samples of galaxies for detailed follow-up with SAFARI*.

- Such surveys will be ideal for producing large samples of dusty galaxies and buried AGN.

- Observe a statistically significant sample of normal galaxies ($L_{IR} \leq 10^{10}$-10^{11} $L_{\odot}$) at z~5-6, where SFRs from UV seems to be comparable to that derived from IR

=> *check whether dust becomes less and less important as we move to higher z's (at z>3), as suggested by UV observational results*

(e.g. Lyman break galaxies: are they the NON-DUSTY tip of the iceberg, or are they the dominant population at those redshifts?).



C. Gruppioni, D. Clements, L. Ciesla: Photometric Survey: SPICA use case

Clustering and environment

- Dust-obscured star-forming galaxies are ideal beacons for tracing the highest matter density peaks in the Universe:

  How do dense cluster environments shape the evolution of starbursts and AGN?

- Only SPICA will be able to:

(i) map entire z~1-3 proto-cluster environments by detecting most of (if not all) the SF cluster members;

(ii) identify PAH features in the cluster members for dust-composition analysis and redshift estimates;

(iii) unveil the presence of CT AGNs and reveal the build-up of the SMBH in rich galaxy clusters.

Towards the Epoch of Re-ionization and beyond

① Search for the First Supermassive Black Holes

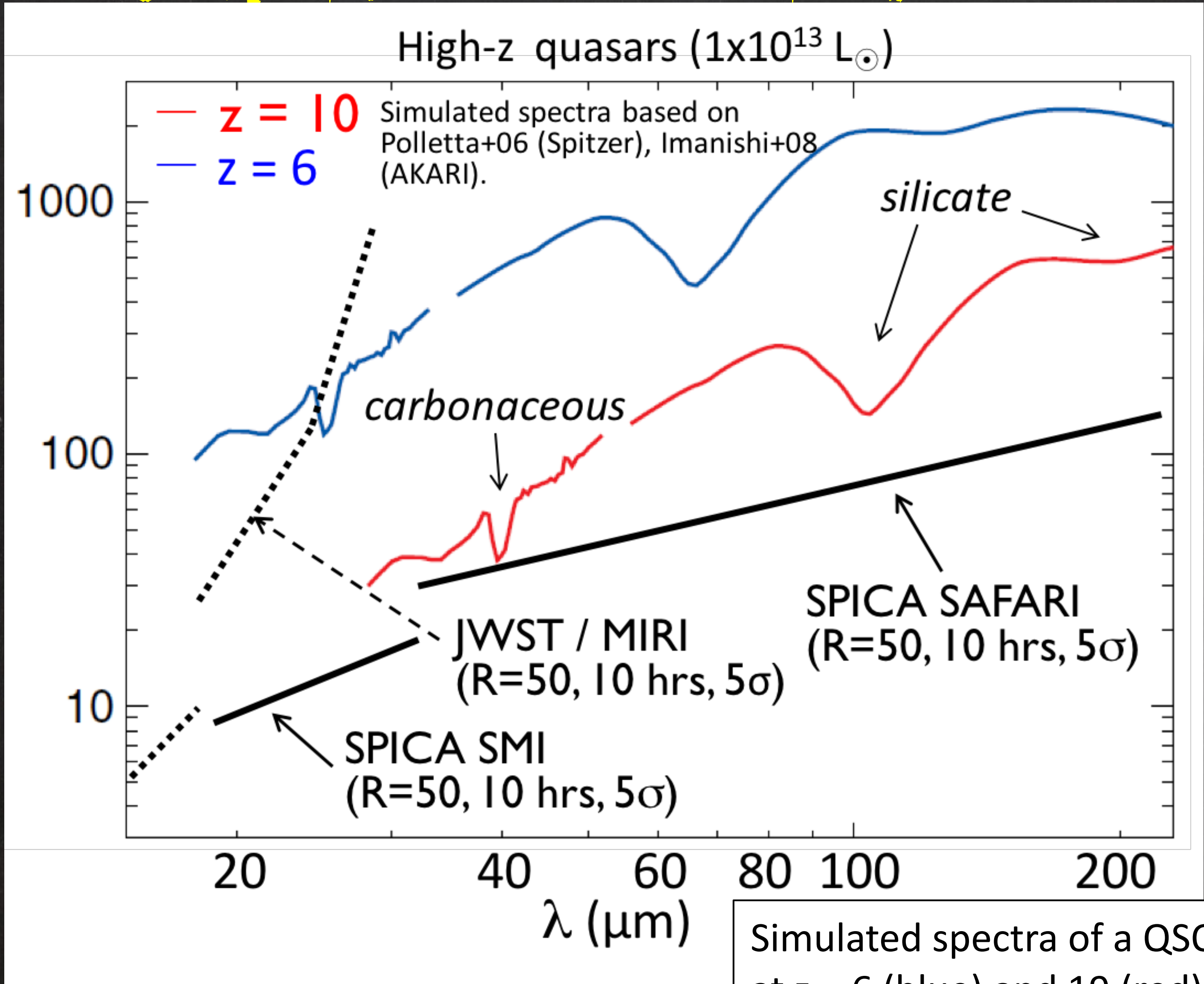
② The First Stars and the Rise of Dust

① Search for the First Supermassive Black Holes

- ★ What were the formation sites and hosts of the first supermassive BHs in the re-ionization epoch?

- ★ What fraction of these early QSOs are buried in dust and invisible in the UV and optical?

① Search for the First Supermassive Black Holes



Simulated spectra of a QSO with $L_{IR} = 1 \times 10^{13}\ L_\odot$ at z = 6 (blue) and 19 (red)

② The First Stars and the Rise of Dust

- ★ What is the dust composition of the Universe at z>5 and what does this imply about the properties of the first (Pop III) stars and early cosmic star formation history?

- ★ What are the properties of primordial gas clouds and nascent galaxies at z~5-10?

② The First Stars and the Rise of Dust

The rest-frame mid-IR spectral range is particularly important because:

(i) it reveals the dust composition, dependent on the properties of the first-generation (i.e., Pop III) stars that enriched the ISM;

(ii) it contains H_2 lines and fine- structure lines of key heavy elements (e.g., Fe, Si), which dominate the cooling of gas clouds that collapse to form stars.

② The First Stars and the Rise of Dust

When Pop III stars evolve and die, they seed the ISM with metals and trigger the formation of dust. *The composition of this dust is therefore a direct tracer of the properties of the first stars.*

wide range of progenitor masses (10 - 100 $M_{\odot}$) -> large C/Fe ratios (with [C/Fe]> 0.7).

The first carbon-dust factories: carbonaceous grains can be easily graphitized and hydrogenated in the ISM, serving as sources of organic molecules such as PAHs and readily available sites for the formation of H_2

② The First Stars and the Rise of Dust

When Pop III stars evolve and d… ISM with metals and trigg… dust. *The compositio… …ore a direct tracer of … first stars.*

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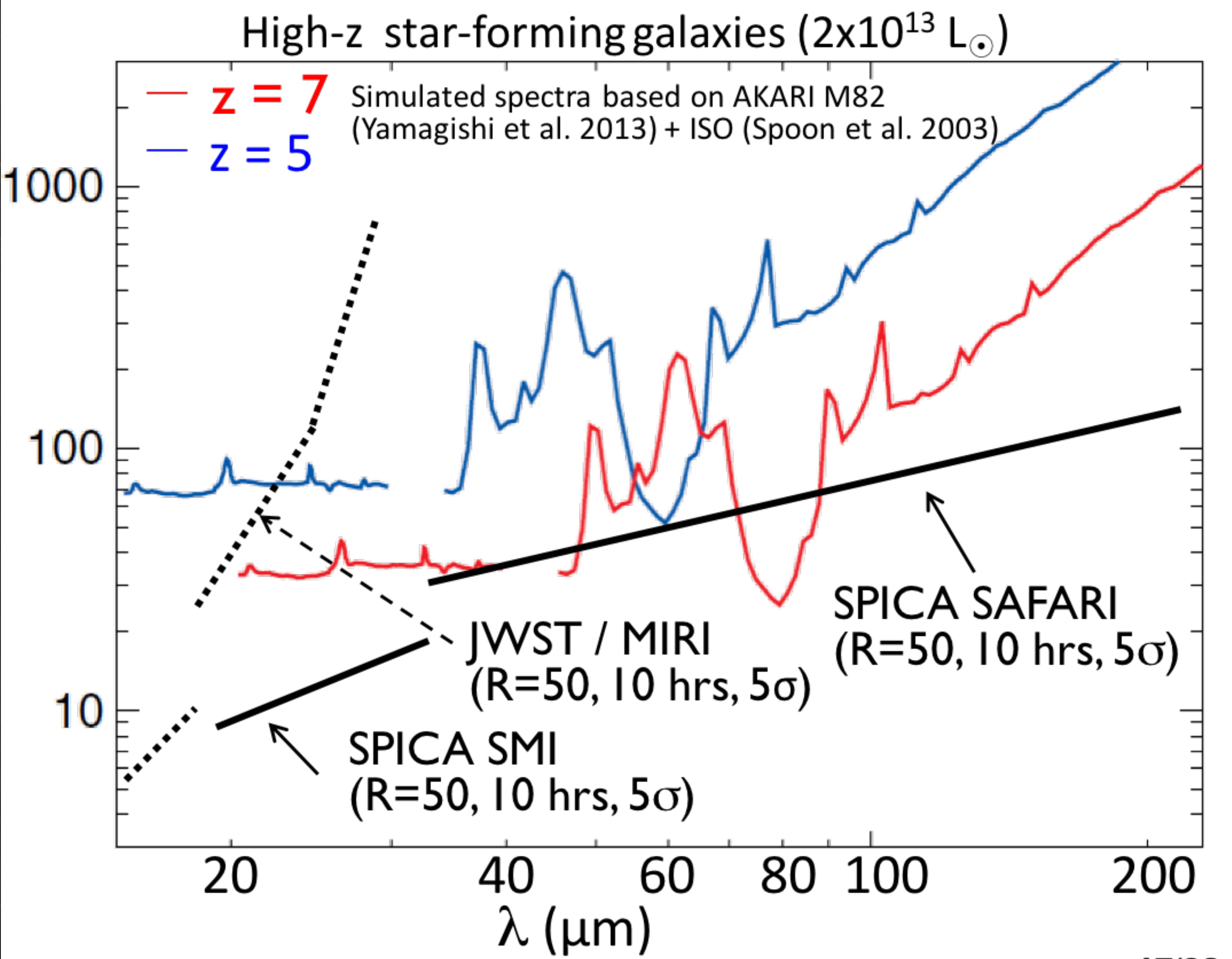
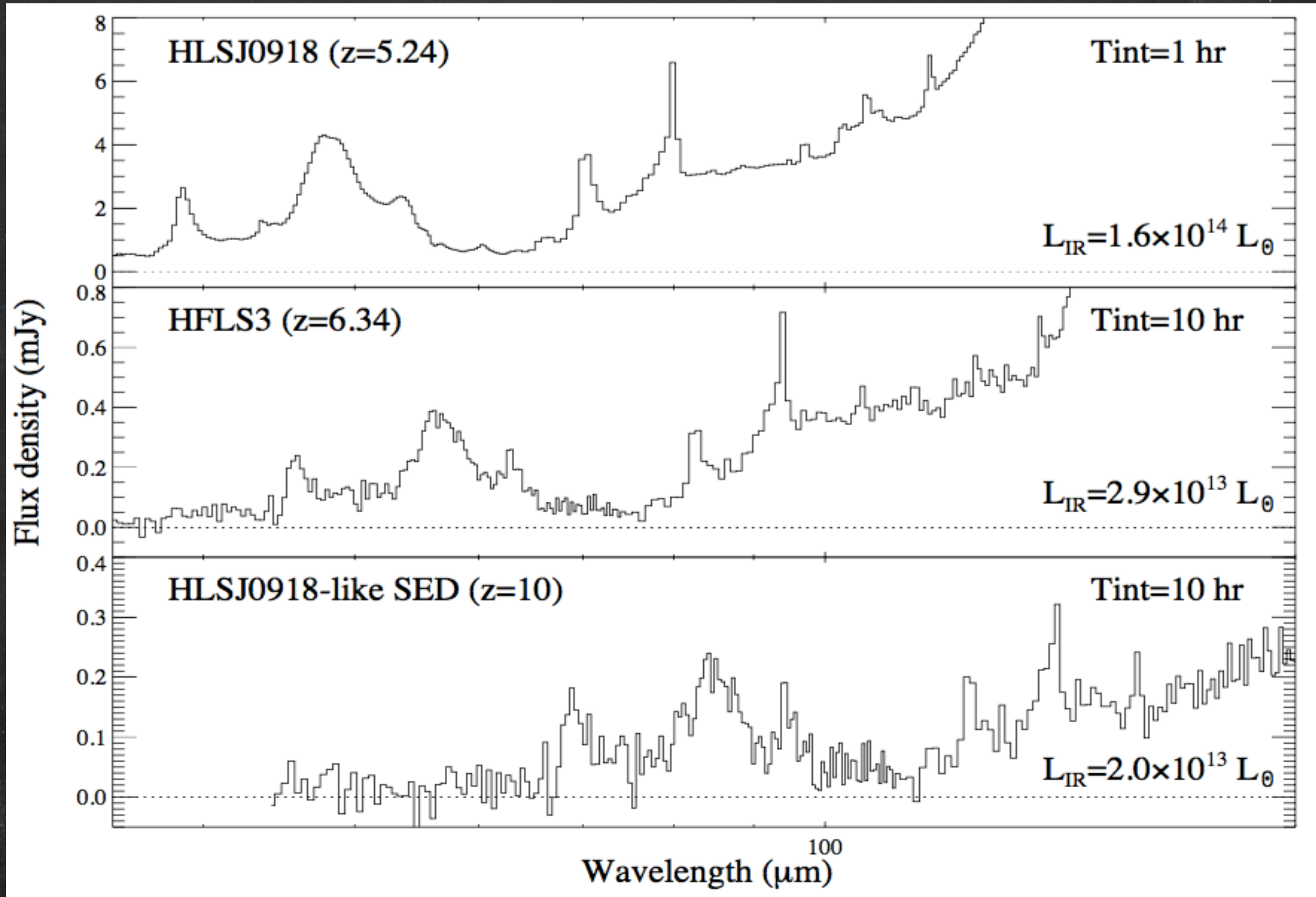
SEE SIMONA GALLERANI & RAFFAELLA SCHNEIDER'S TALKS!

② The First Stars and the Rise of Dust



SPICA will detect and characterize the PAH and silicate grains in galaxies responsible for re-ionization.

Individual luminous sources can easily be detected up to z~5-7 in long exposures (10hrs) with SAFARI



Simulated SAFARI spectra of HLS J091828.6+514223 (*z*=5.24: *Combes et al. 2012; Rawle et al. 2014 - top*) and HFLS3 (*z*=6.34: *Riechers et al. 2013; Cooray et al. 2014 - middle*)

Template SEDs (*Rieke et al. 2009*) scaled to the observed IR luminosities in each case + noise based on the SAFARI sensitivity and integration time.
HLSJ0918 and HFL3 are gravitationally lensed by a factor of ~10 and ~2, respectively.

CONCLUSIONS:
What (only)SPICA can do in the high-z (3-10) Universe

- ★ SPICA will detect organic matter and minerals in the early Universe (z~3-10) using PAHs and silicate

- ★ SPICA will trace the evolution of dusty SF and accretion up to the epoch of re-ionization and beyond (thanks to SMI low-res/ photometric capabilities)

Thank You !