The Evolving Universe: FIR deep field observations

UNIVERSITÀ DEGLI STUDI DI PADOVA

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HerMES Consortium

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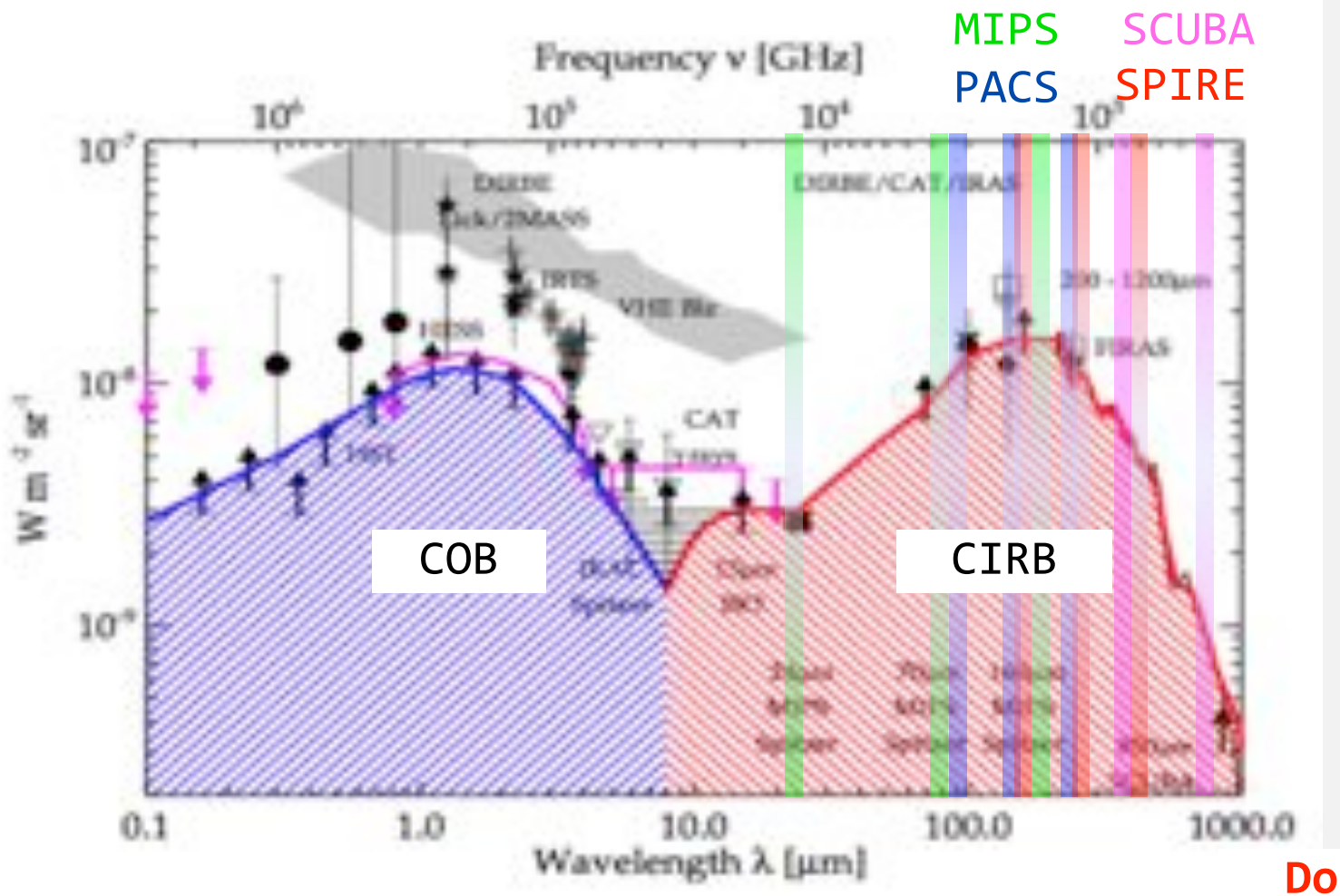
The Evolving Universe: FIR deep field observations

Why we need a sub-arcsecond resolution in Far-IR to study the formation and evolution of galaxies ?

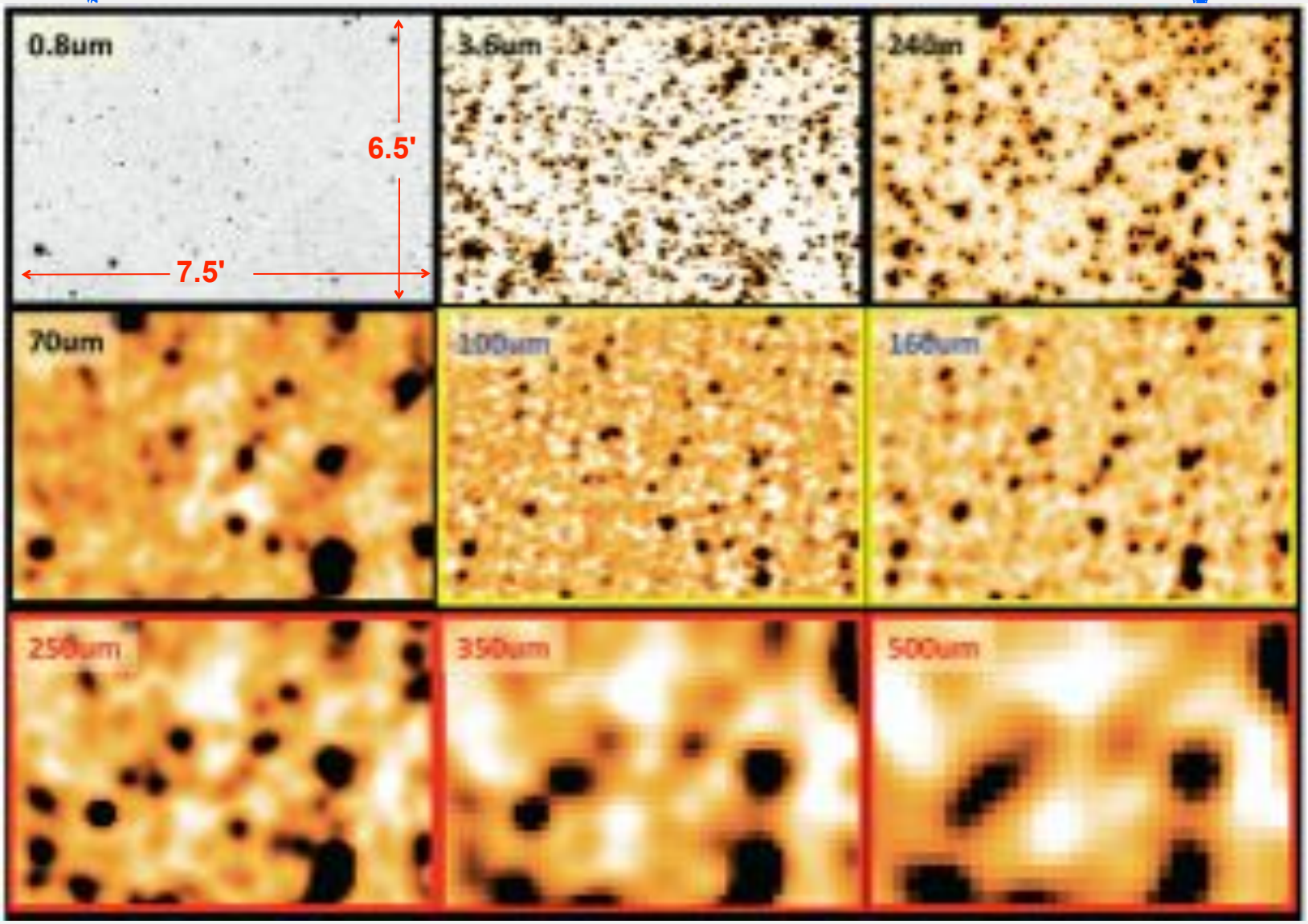
Resolving the background

A full understanding of galaxy formation and evolution requires resolving the CIRB into its constituent sources and studying their properties at 'all' wavelengths



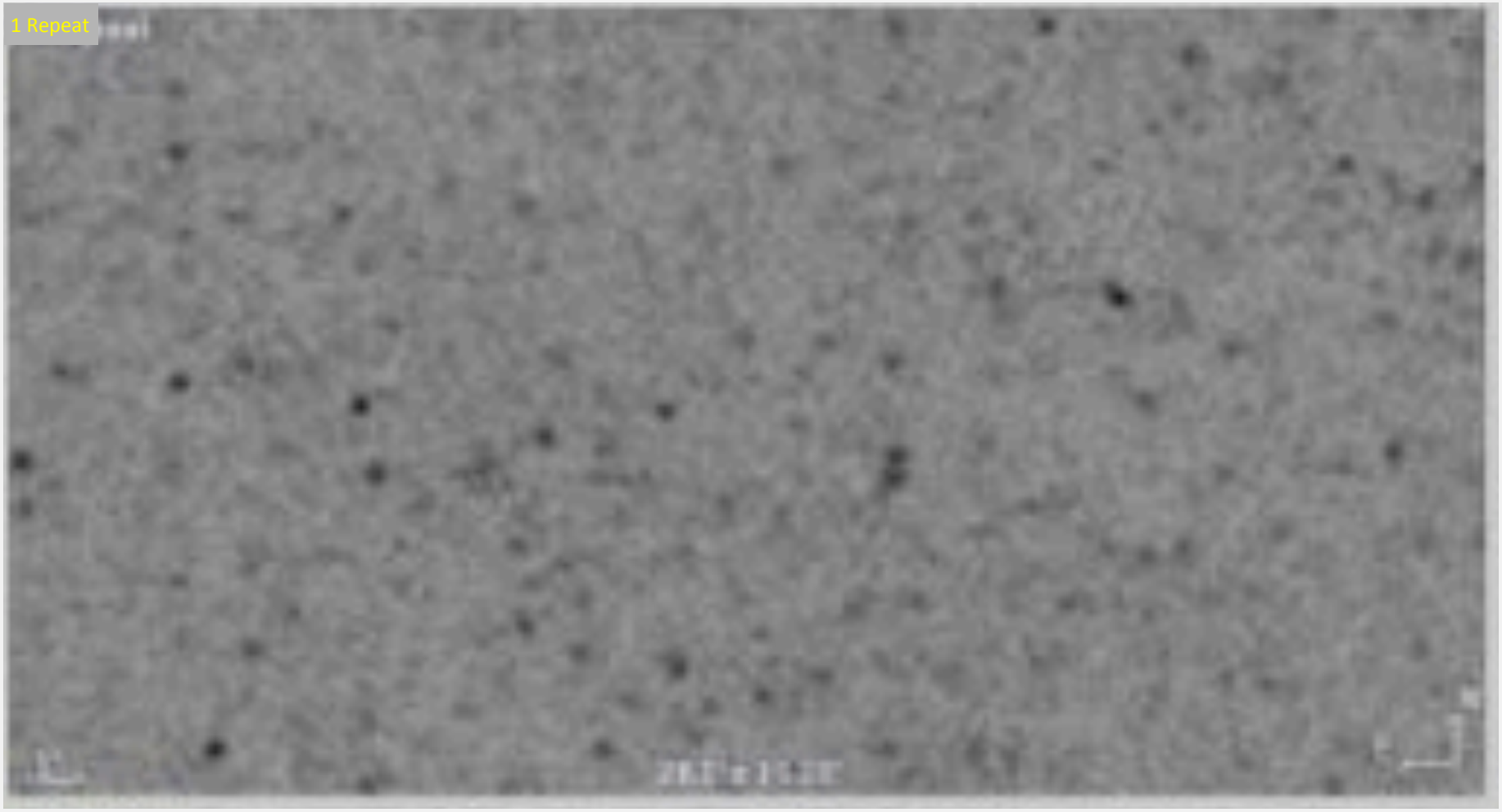
Dole+ 06

The Herschel/HerMES Confusion Challenge



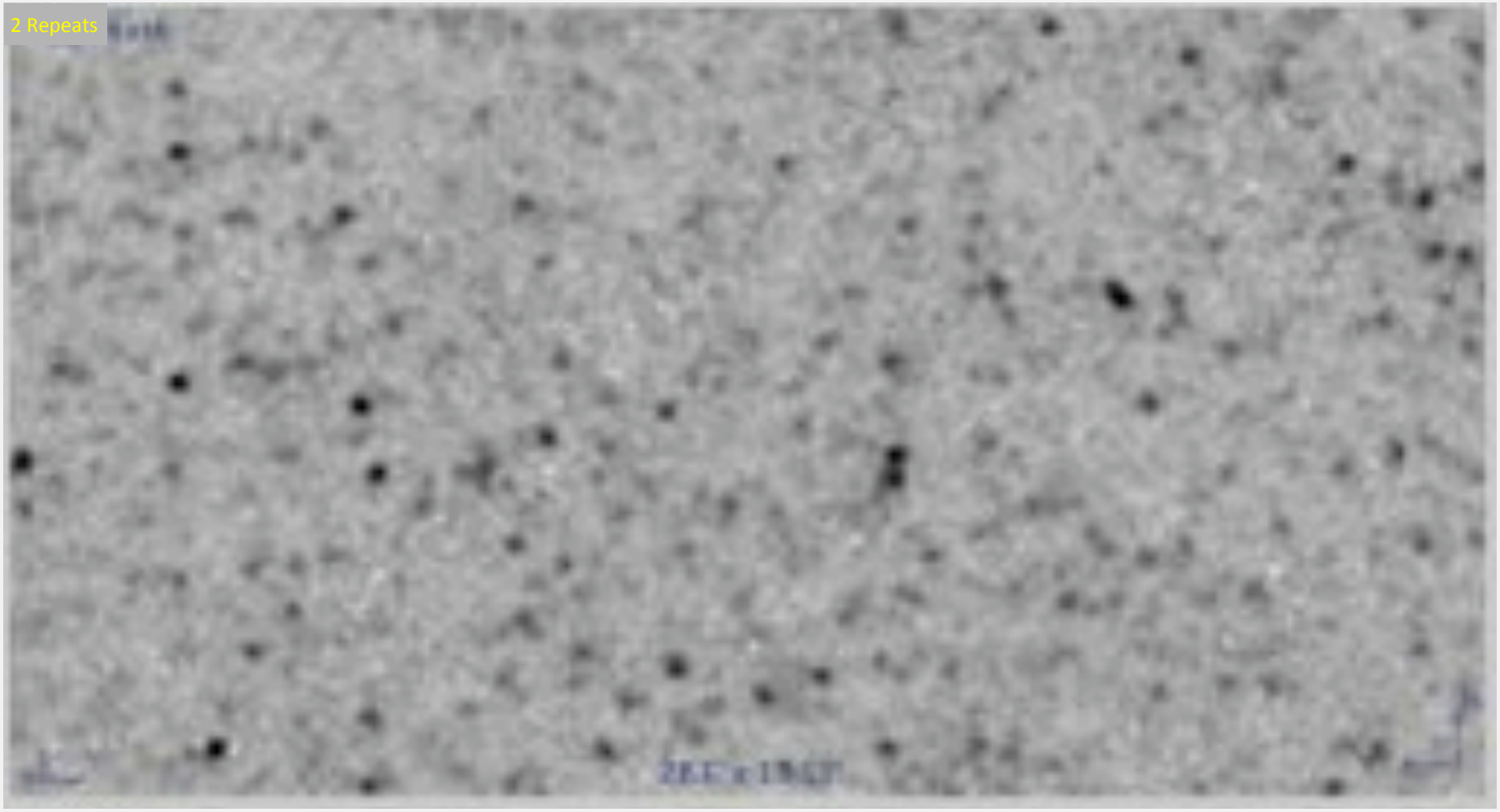
GOODS-N - D. Elbaz

Mapping to the Confusion Limit



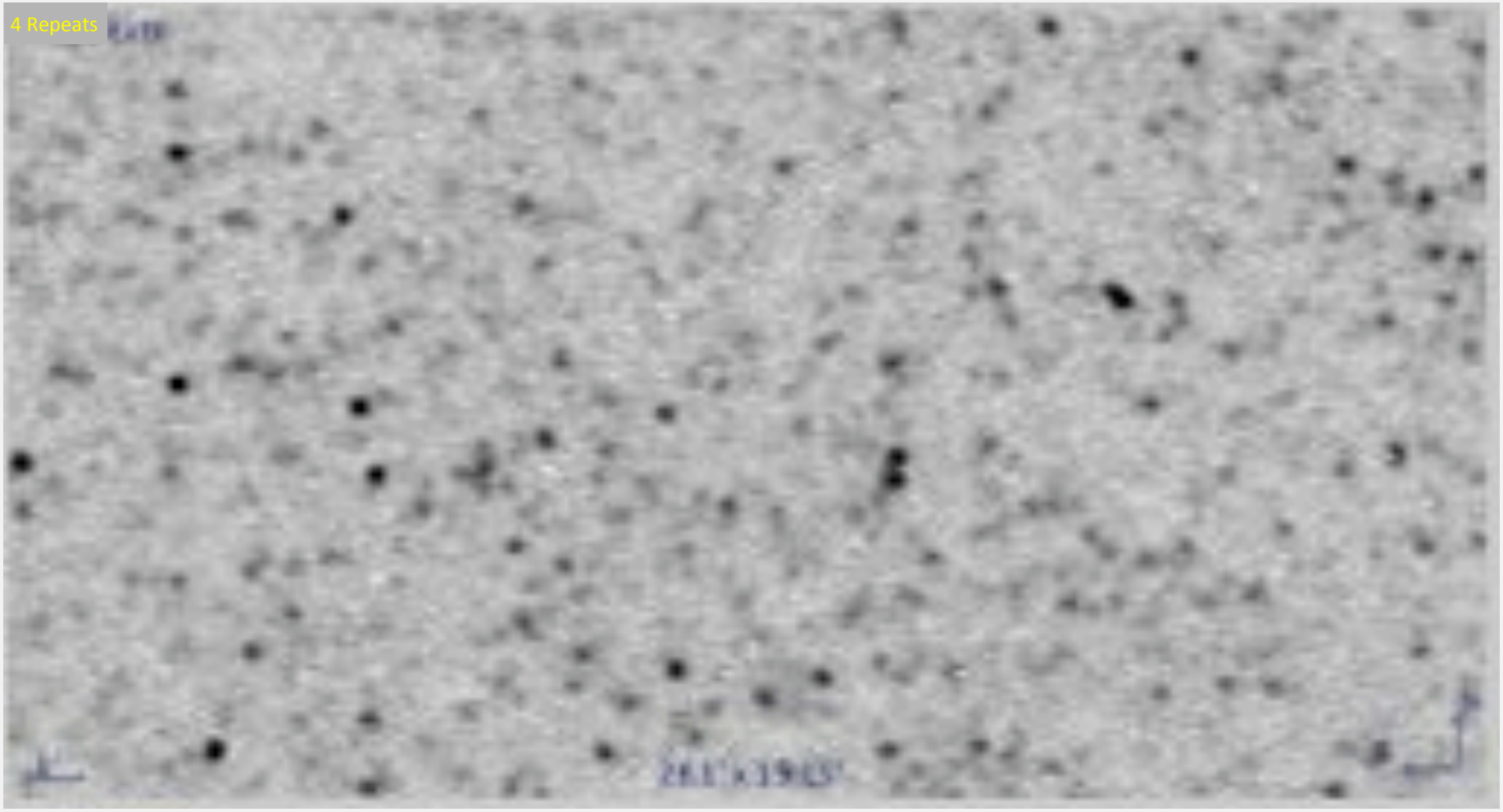
0.7 h for 1 sq. deg

Mapping to the Confusion Limit



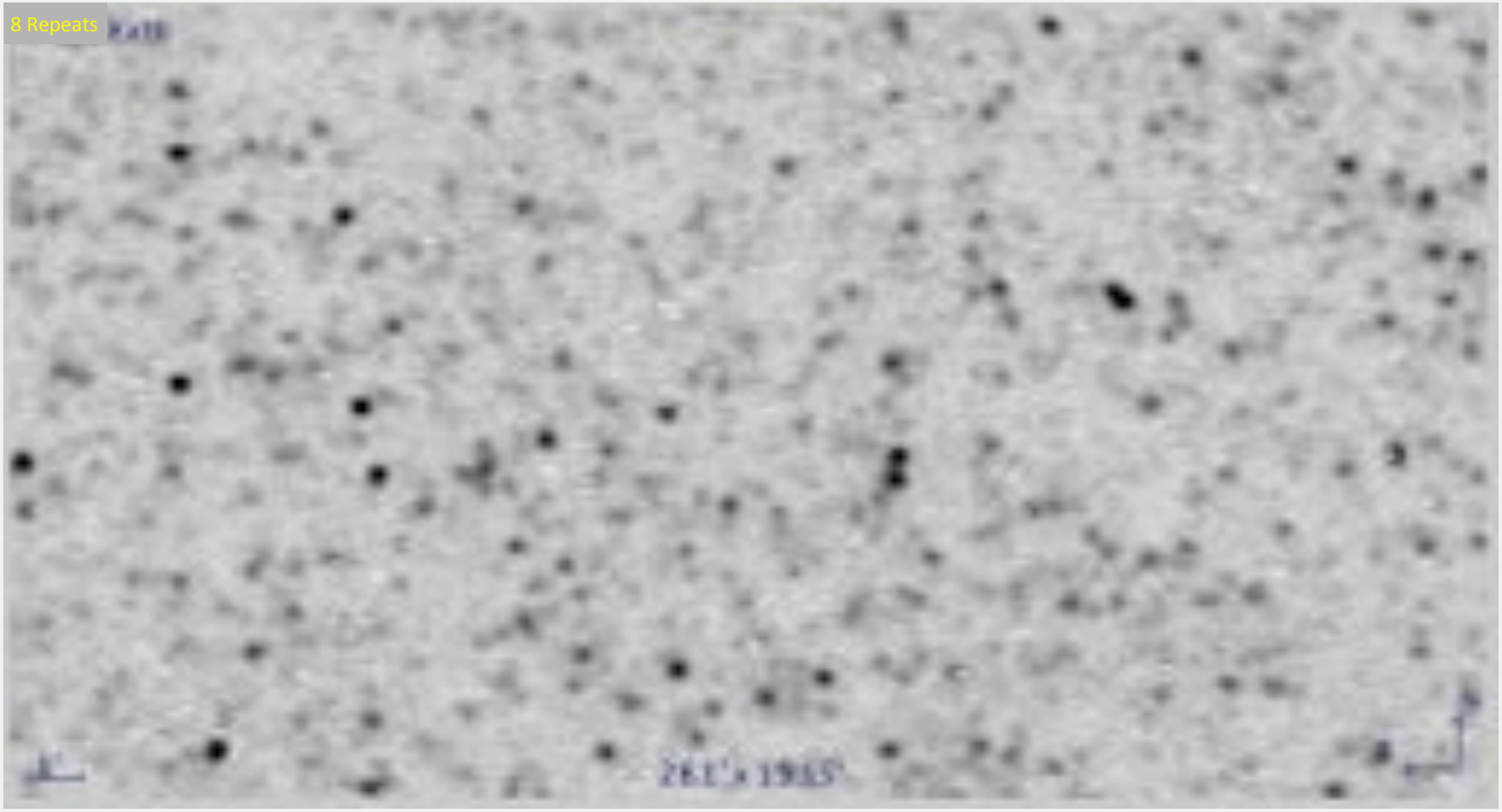
1.5 h for 1 sq. deg

Mapping to the Confusion Limit



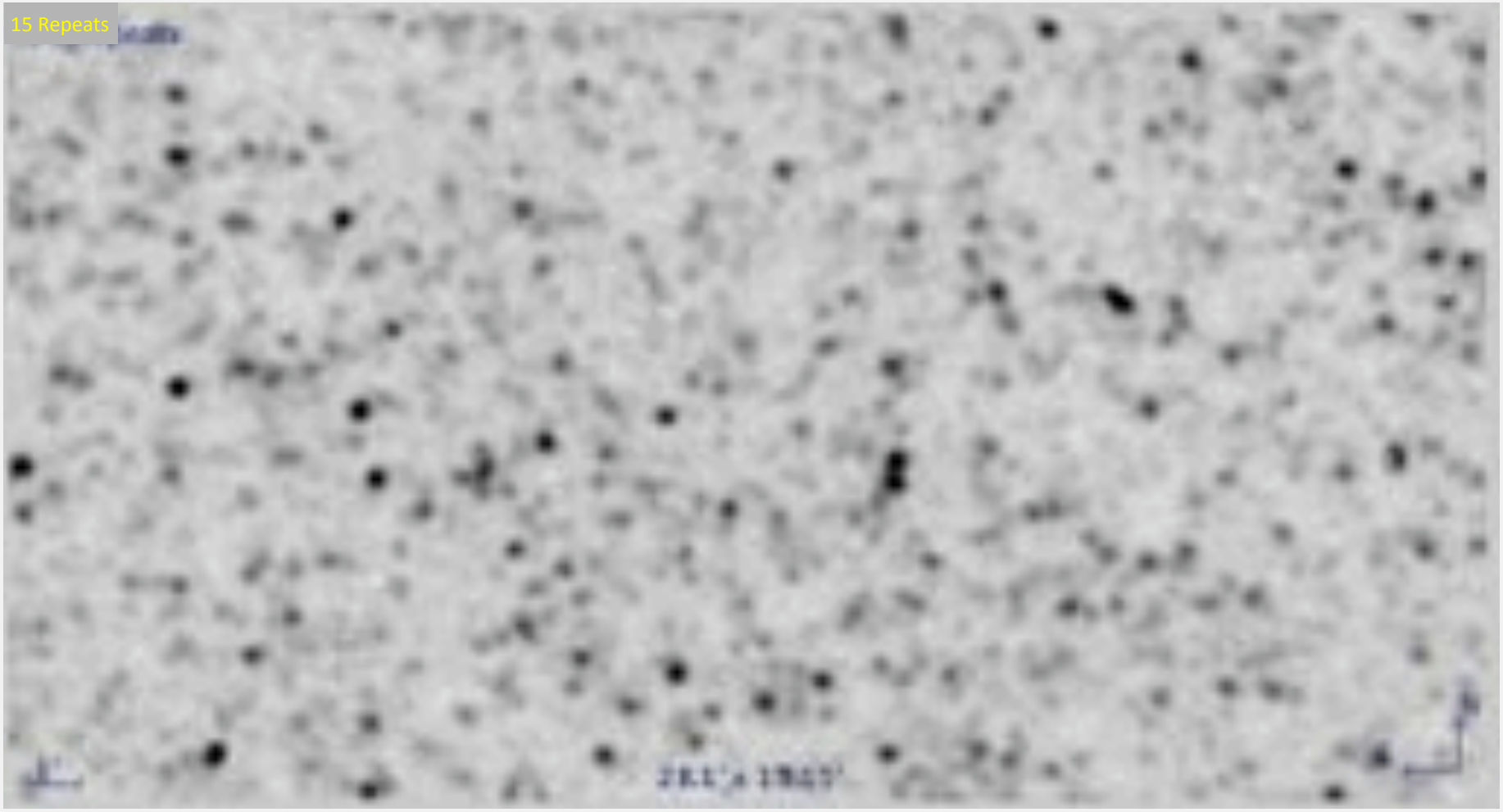
3 h for 1 sq. deg

Mapping to the Confusion Limit



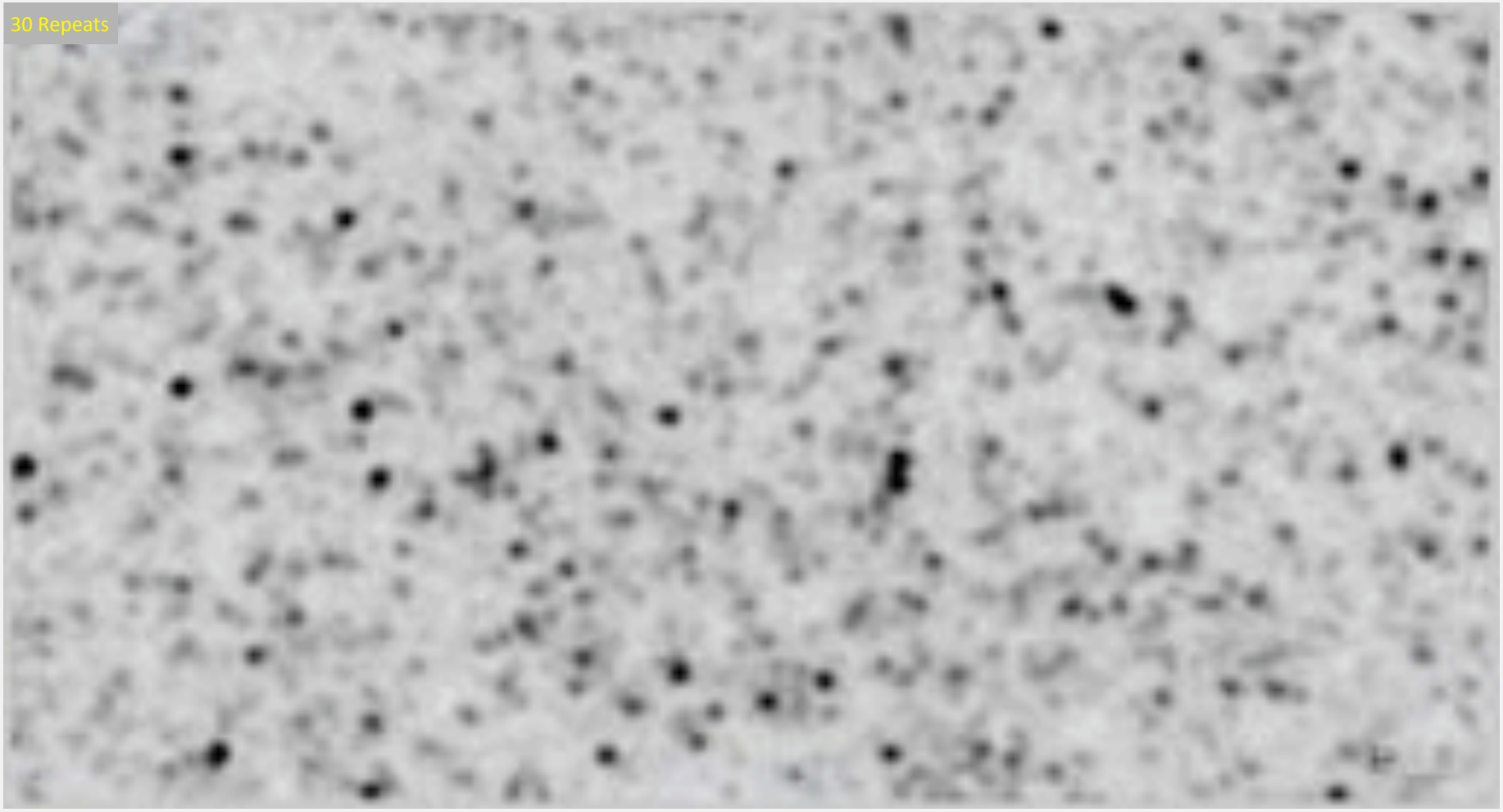
6 h for 1 sq. deg

Mapping to the Confusion Limit



11 h for 1 sq. deg

Mapping to the Confusion Limit



22 h for 1 sq. deg

Three Ways to Deal with Confusion

"Blind" Source Extraction

- Need to be careful about bias and source blending
- Blind follow-up in large beam is laborious (~SCUBA)
- However these are the most interesting source populations

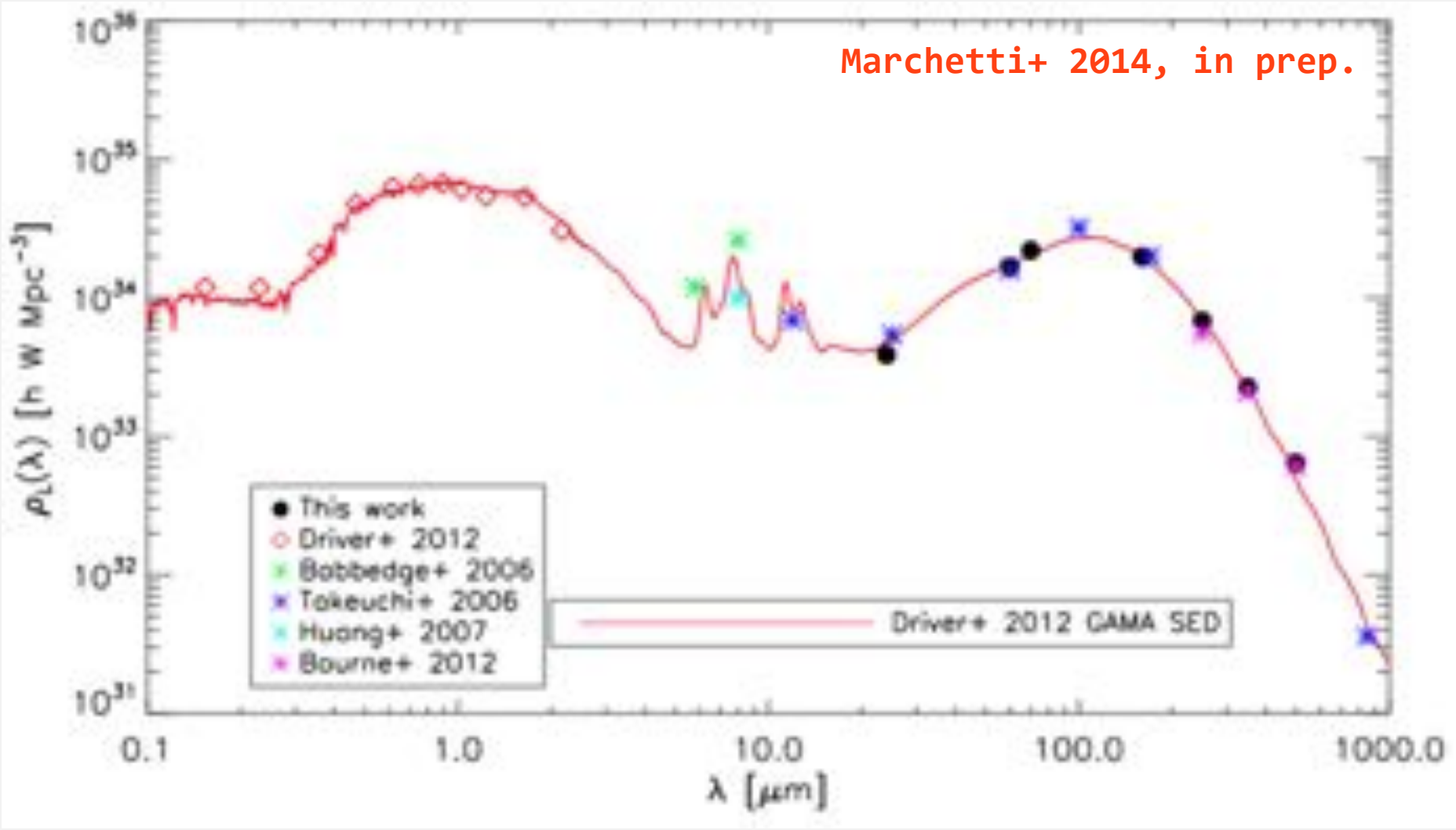
"Prior" Source Extraction

- Estimate Herschel flux of 'known' sources
- Reliable to within confusion noise
- Follows bias inherent in 'input' catalog

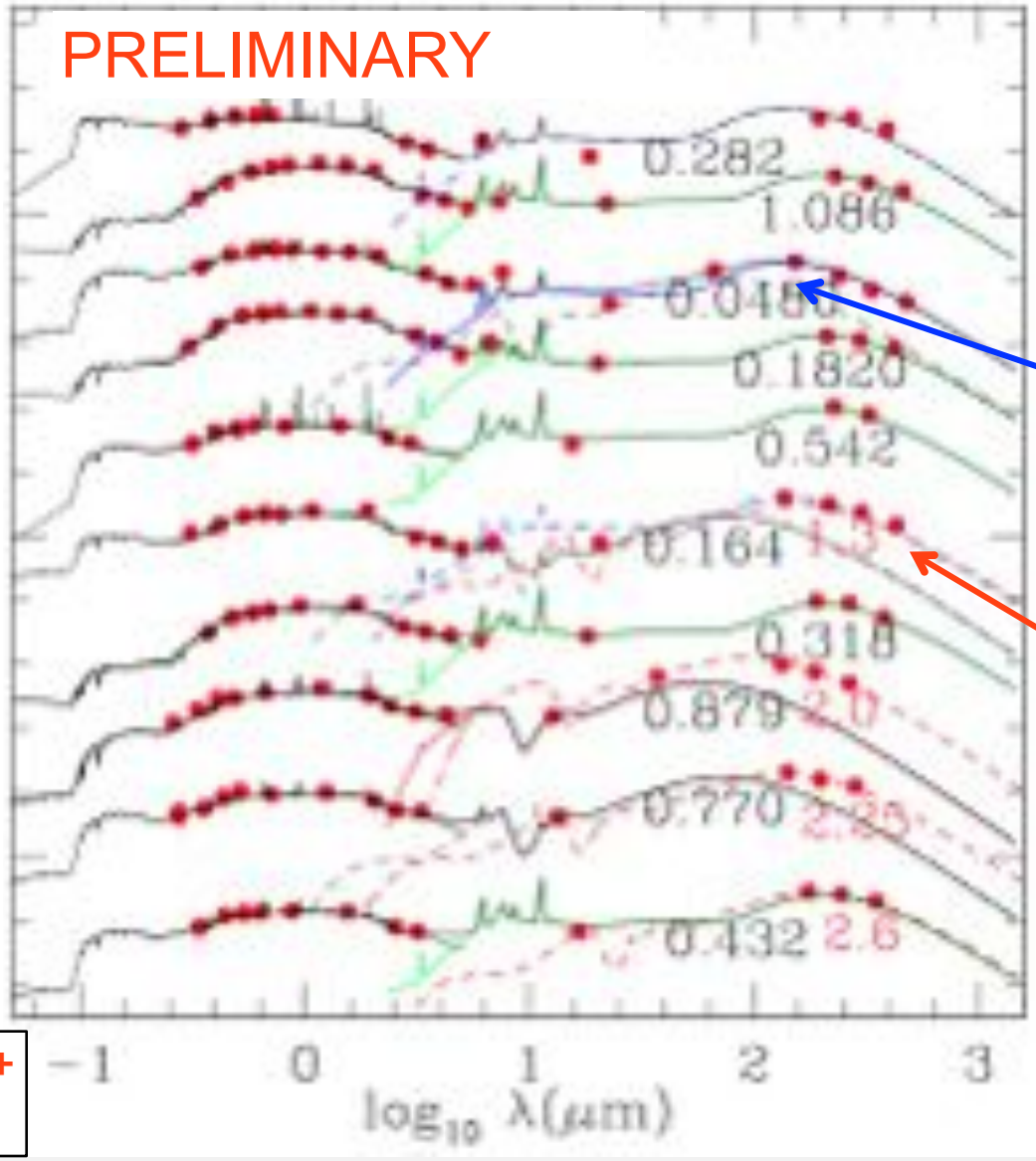
Map-Based Analysis

- Much more information in maps than in reliable sources
- Tends to be ensemble information : P(D), fluctuations, etc
- Maps have high statistical fidelity!

The Local SED as seen by HerMES



SED fitting : How well do galaxy templates work ?

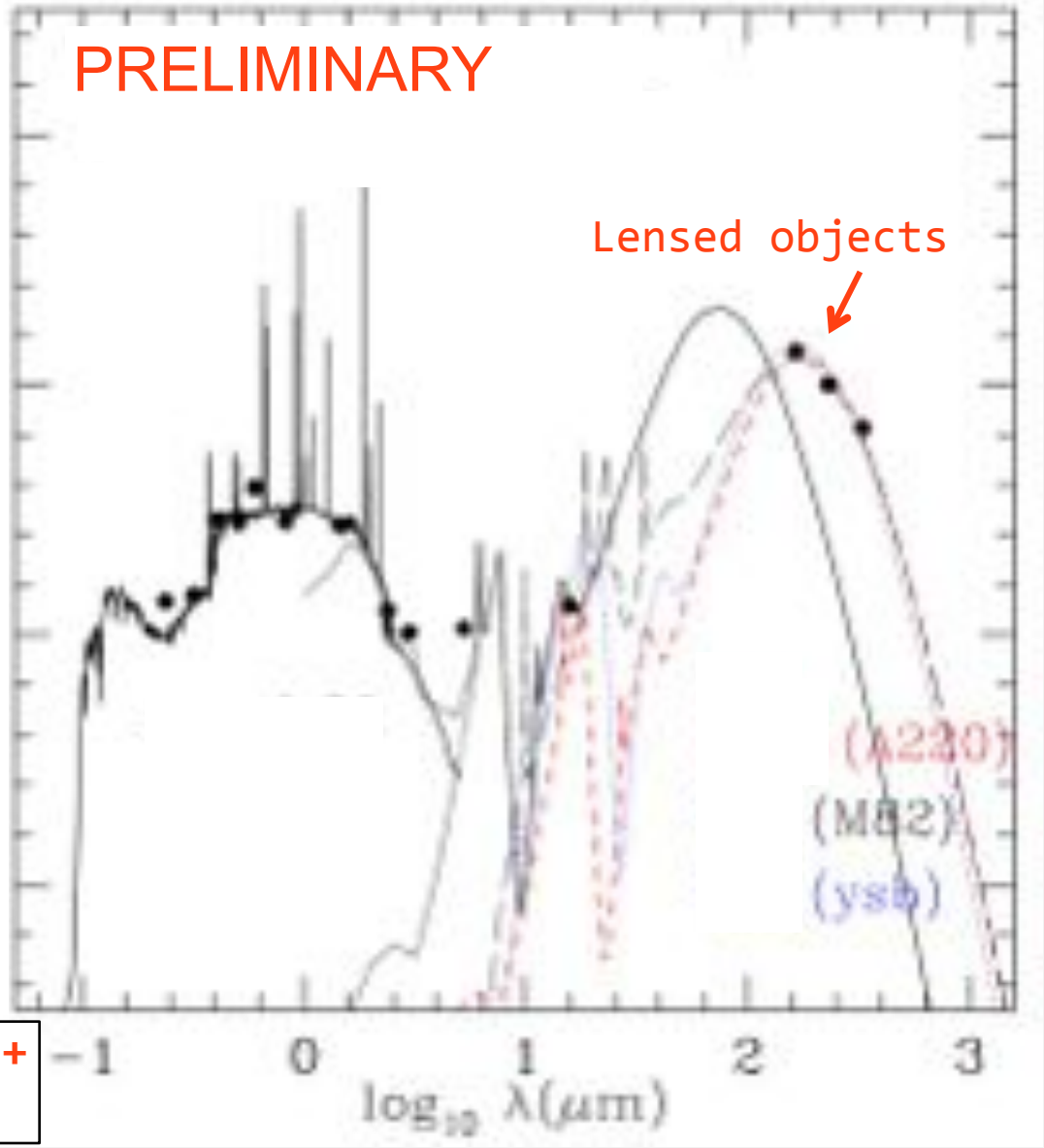


Cold cirrus component

Lensed objects

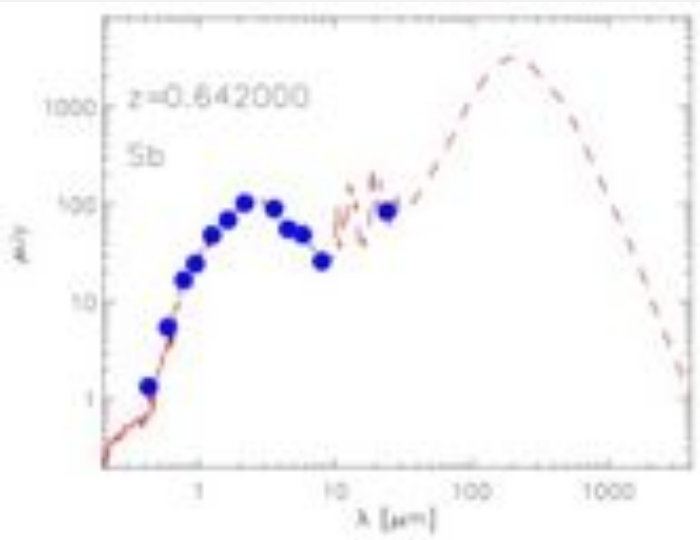
Rowan-Robinson+ in prep.

SED fitting : How well do galaxy templates work ?



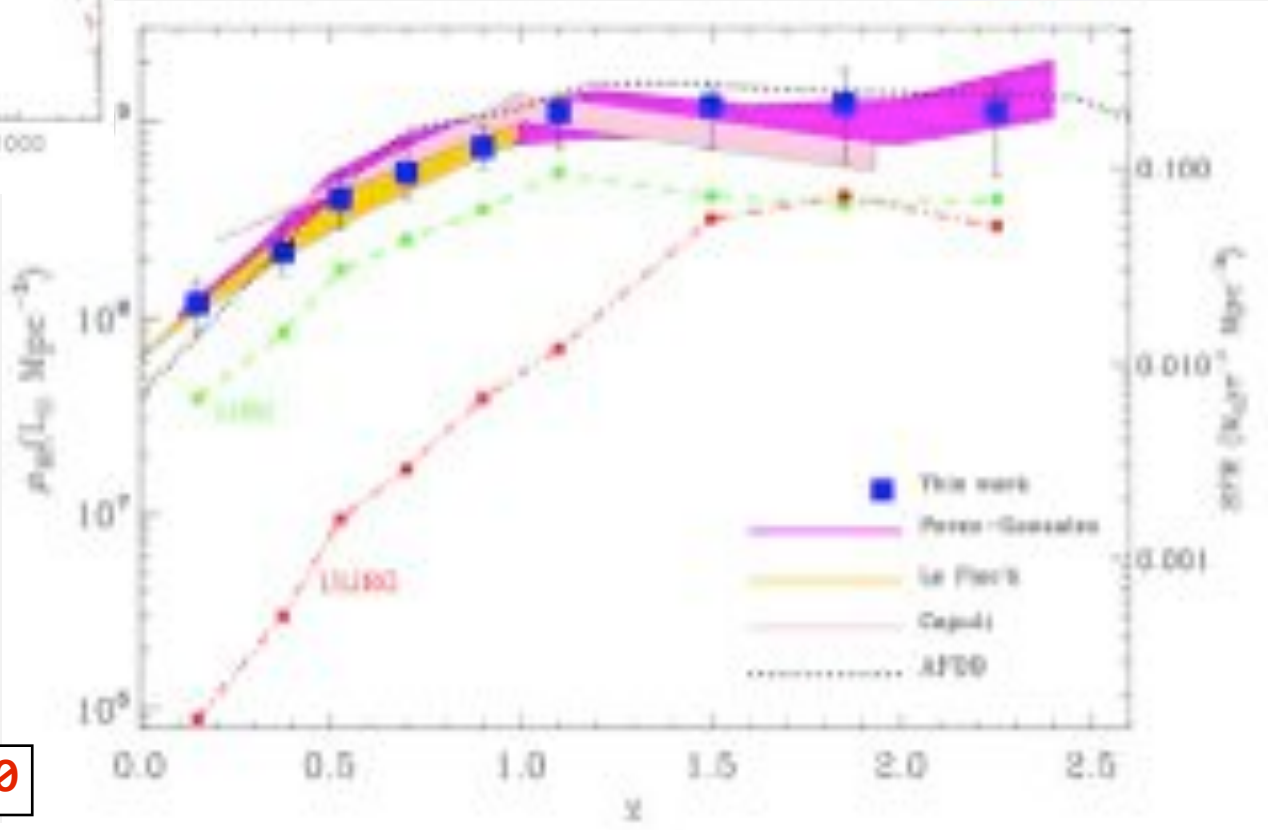
Rowan-Robinson+ in prep.

From the LF to the Cosmic SF Rate Density @ the end of Spitzer cold mission



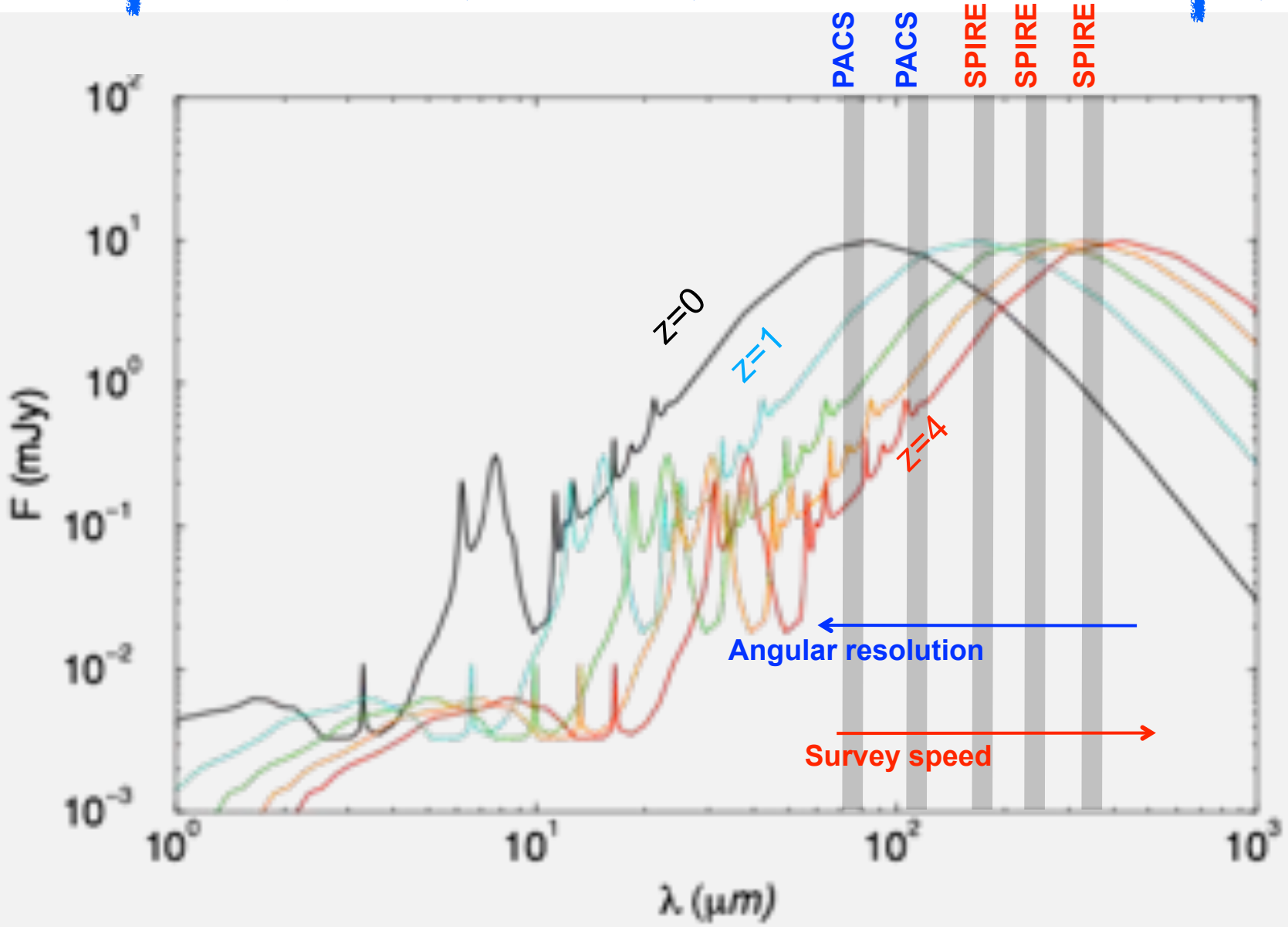
MIPS 24 micron observations cannot accurately constrain the 8-1000 micron emission of high-z starbursts but we have got to rely on low-z SED models

⇨ **they overestimate the SFR**



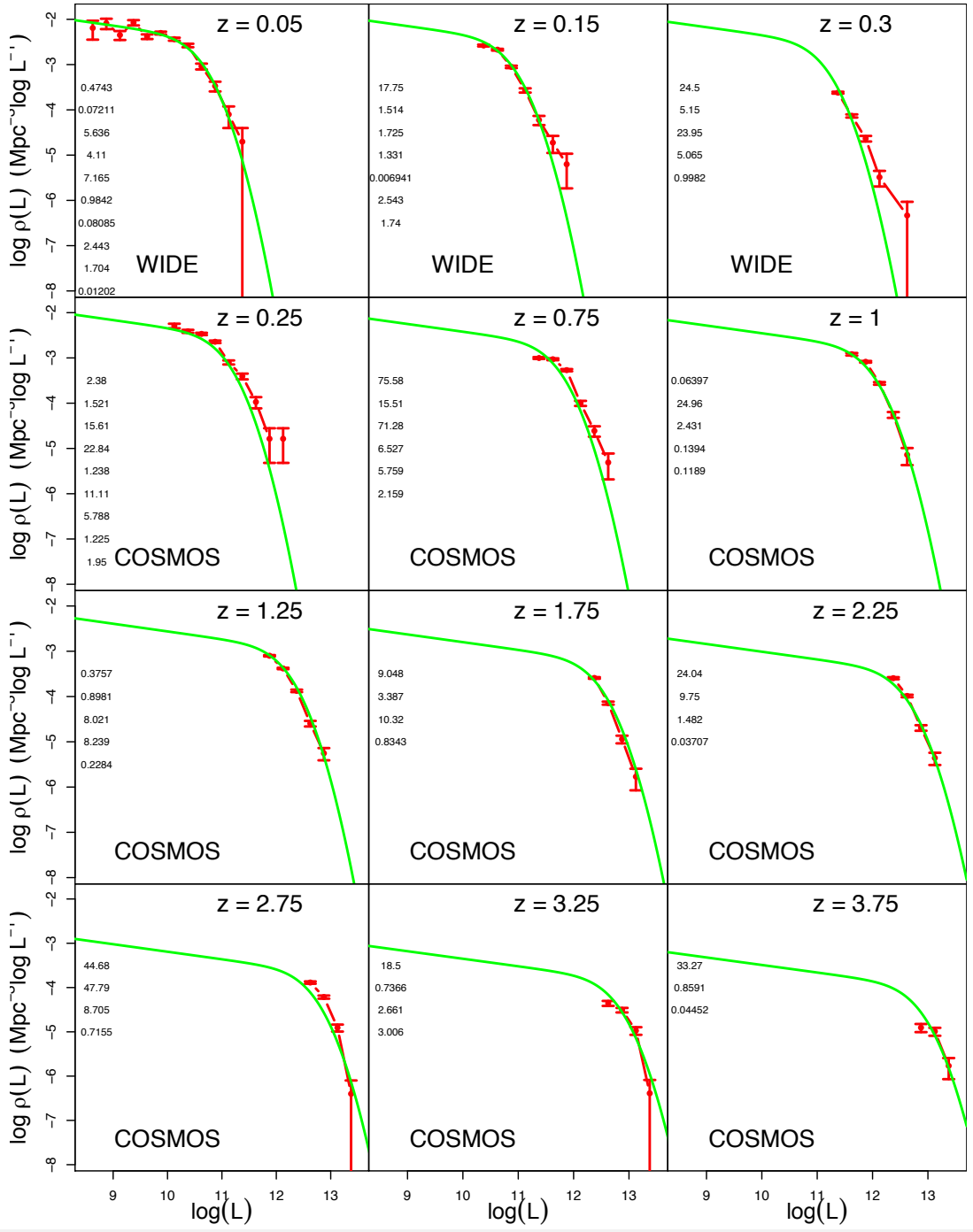
Rodighiero+ 2010

Herschel/HerMES SED evolution



The Evolution of the IR Bolometric Luminosity Function

Vaccari+ 2014,in prep.



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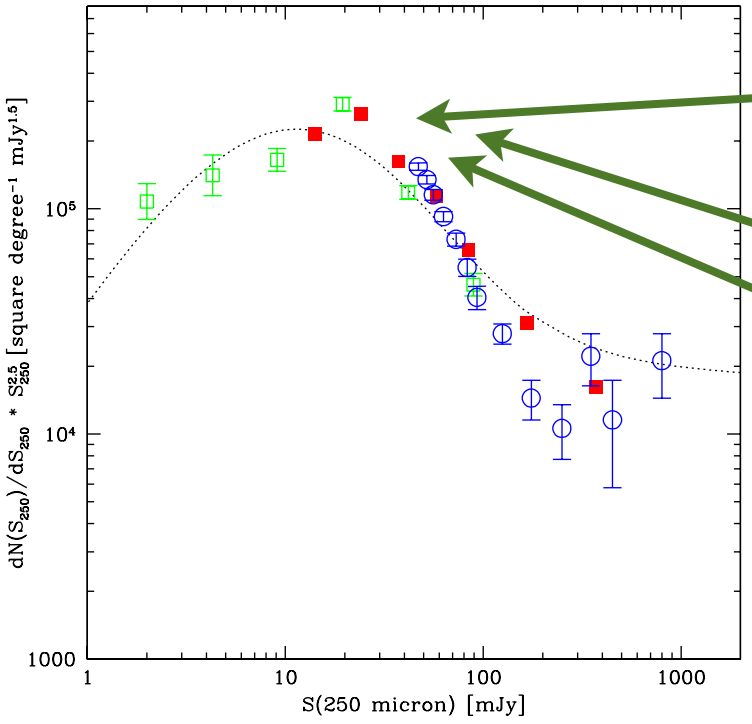

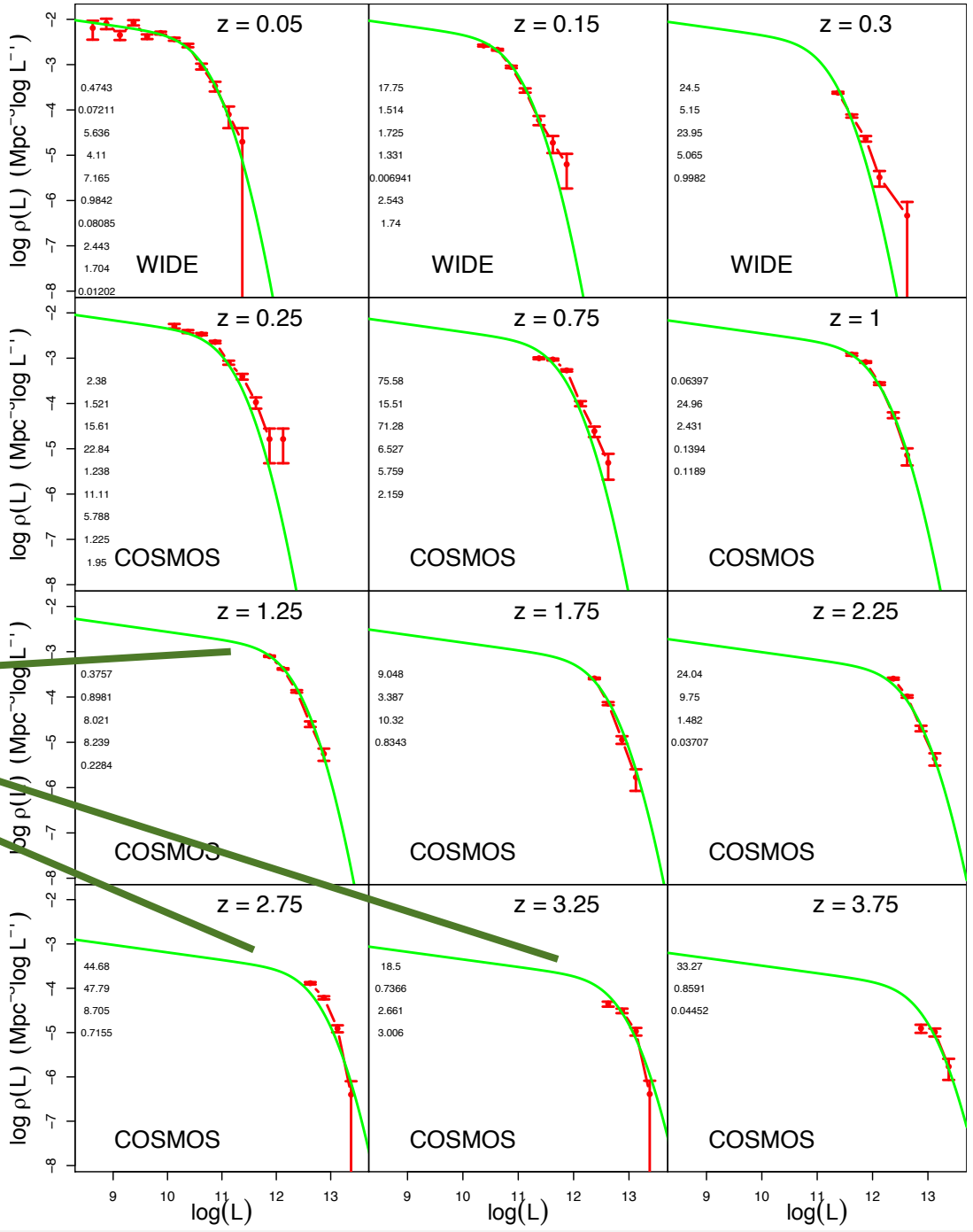

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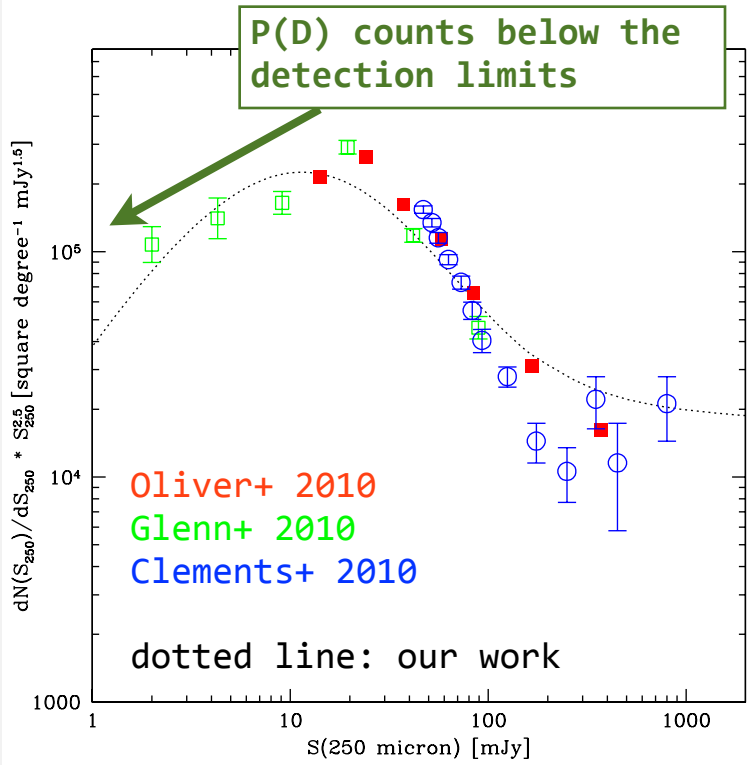
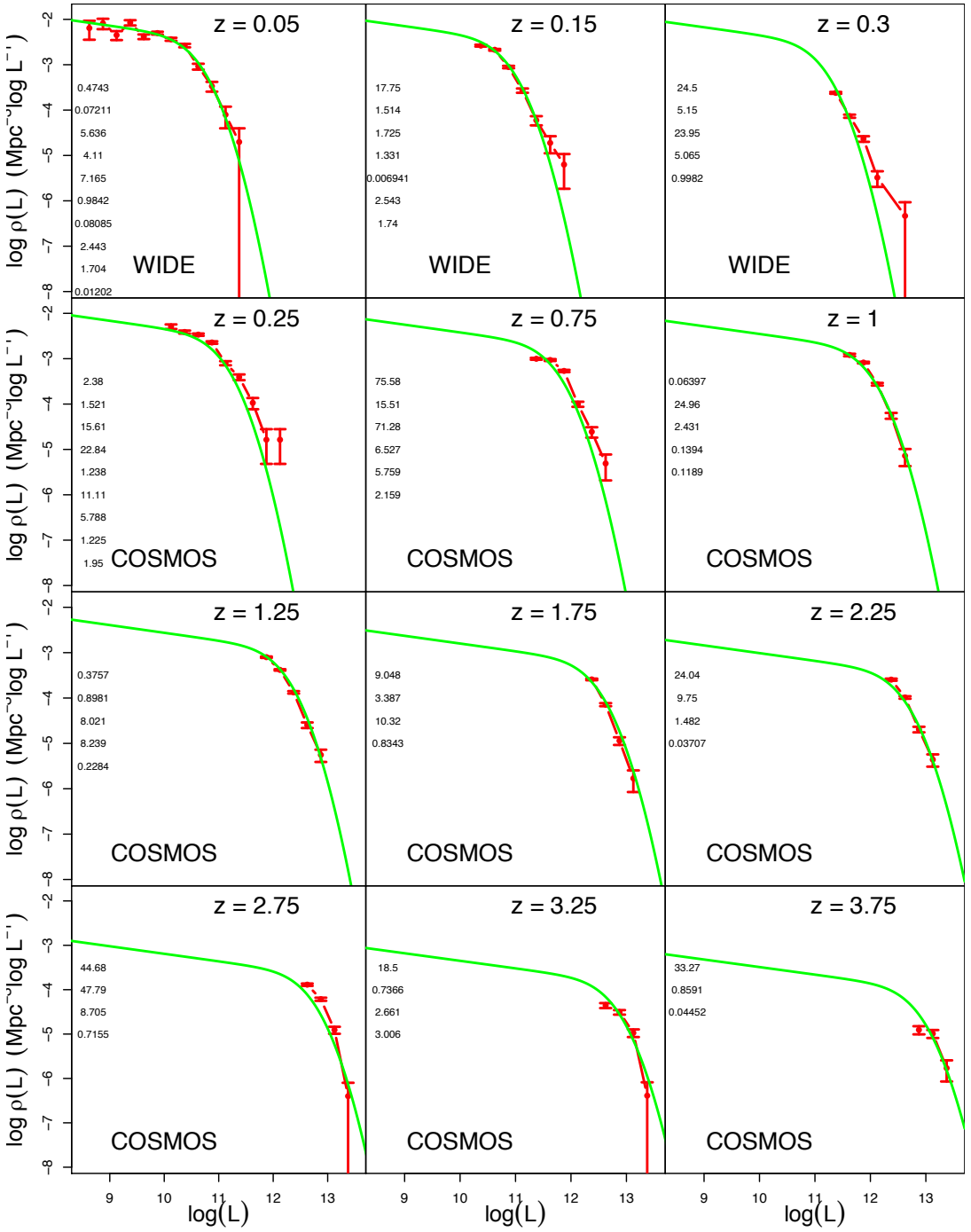
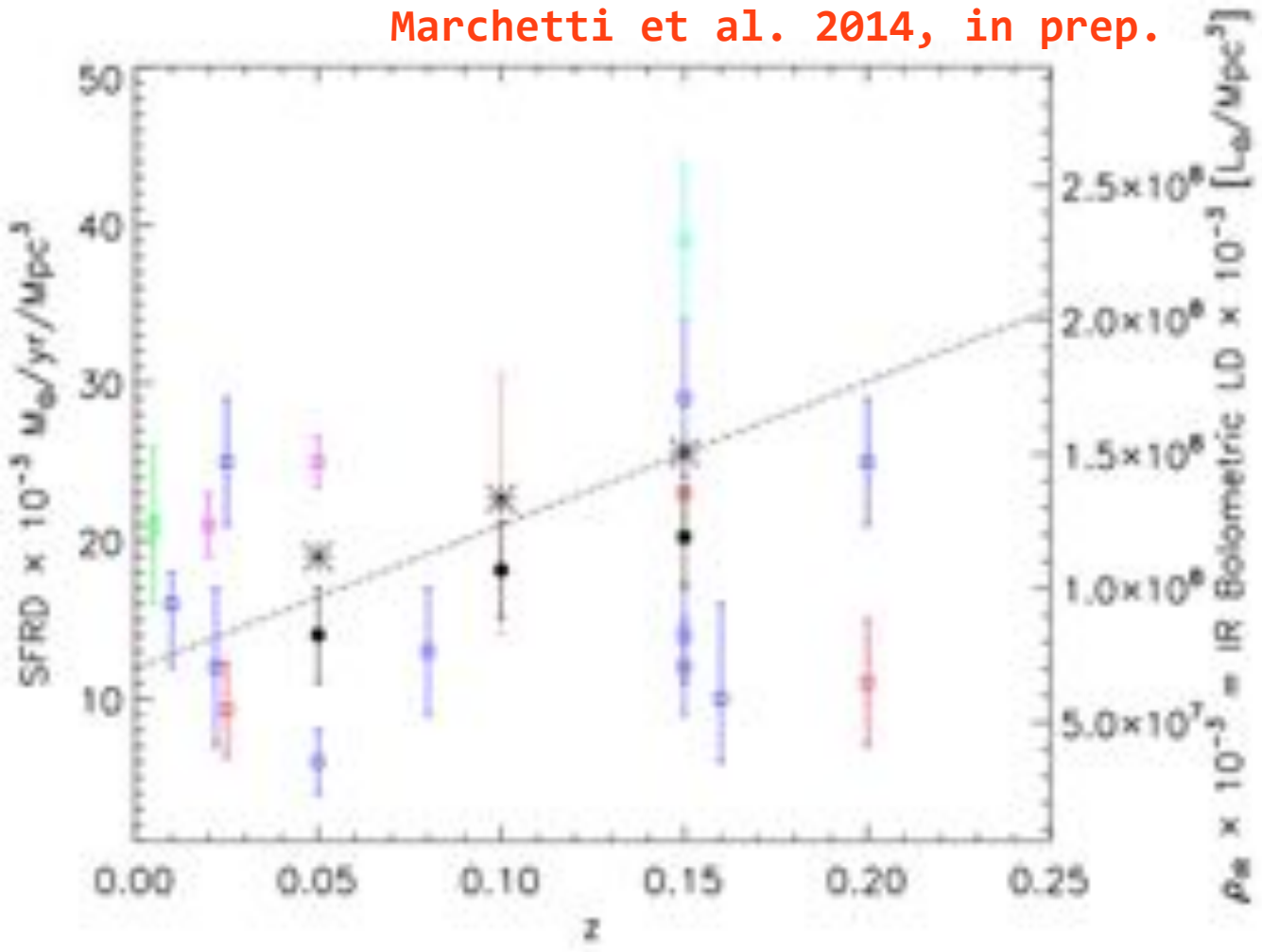




SFRD in the local Universe

Marchetti et al. 2014, in prep.



Black circles and stars:
our estimate in WIDE sample

Green:
Radio 1.4Hz derived estimate

Magenta:
FUV+IR derived estimate

Blue:
Hα derived estimate

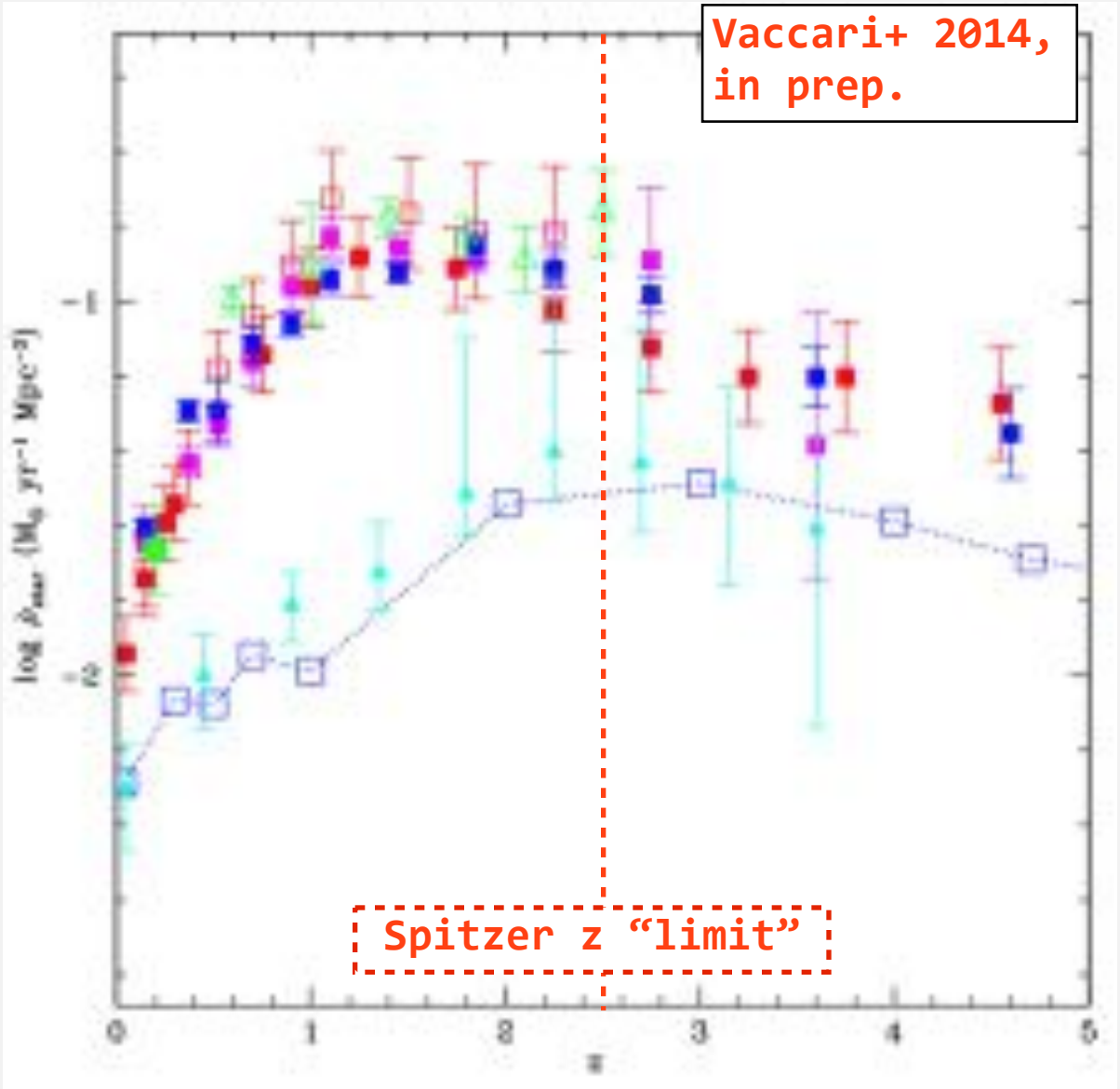
Cyan:
FUV derived estimate

Pink:
IR derived estimate

Red:
OII derived estimate

Black dot dashed line:
Hopkins & Beacon+ 2006

Bolometric luminosity density & comoving SFRD estimate



Herschel data show a relatively strong decrease of galaxy activity at z > 1.5.

Open squares:
Rodighiero+ 2010

Open triangles:
Perez-Gonzalez+ 2005

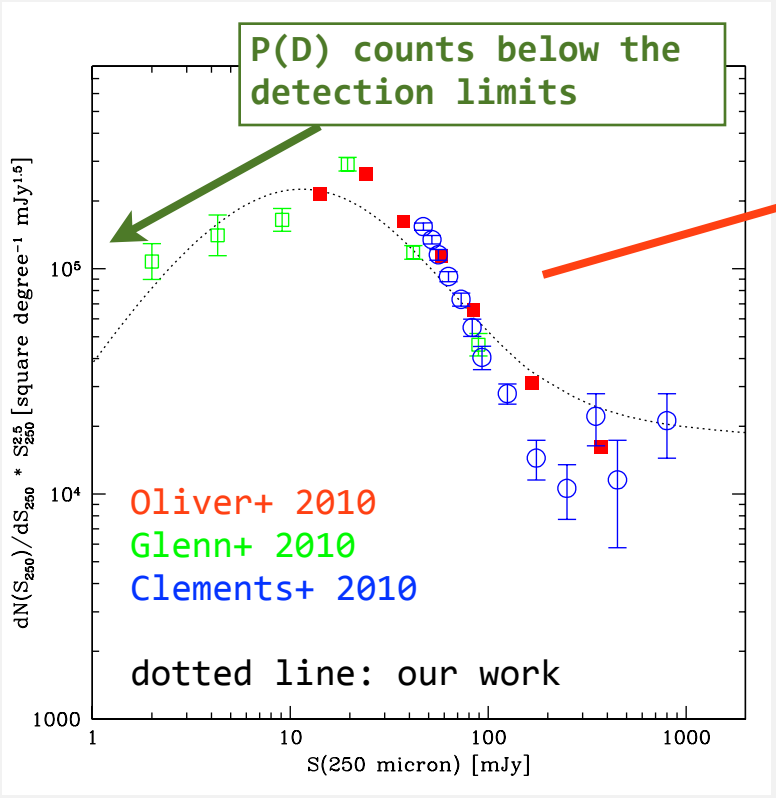
Filled circle:
Vaccari+ 2010

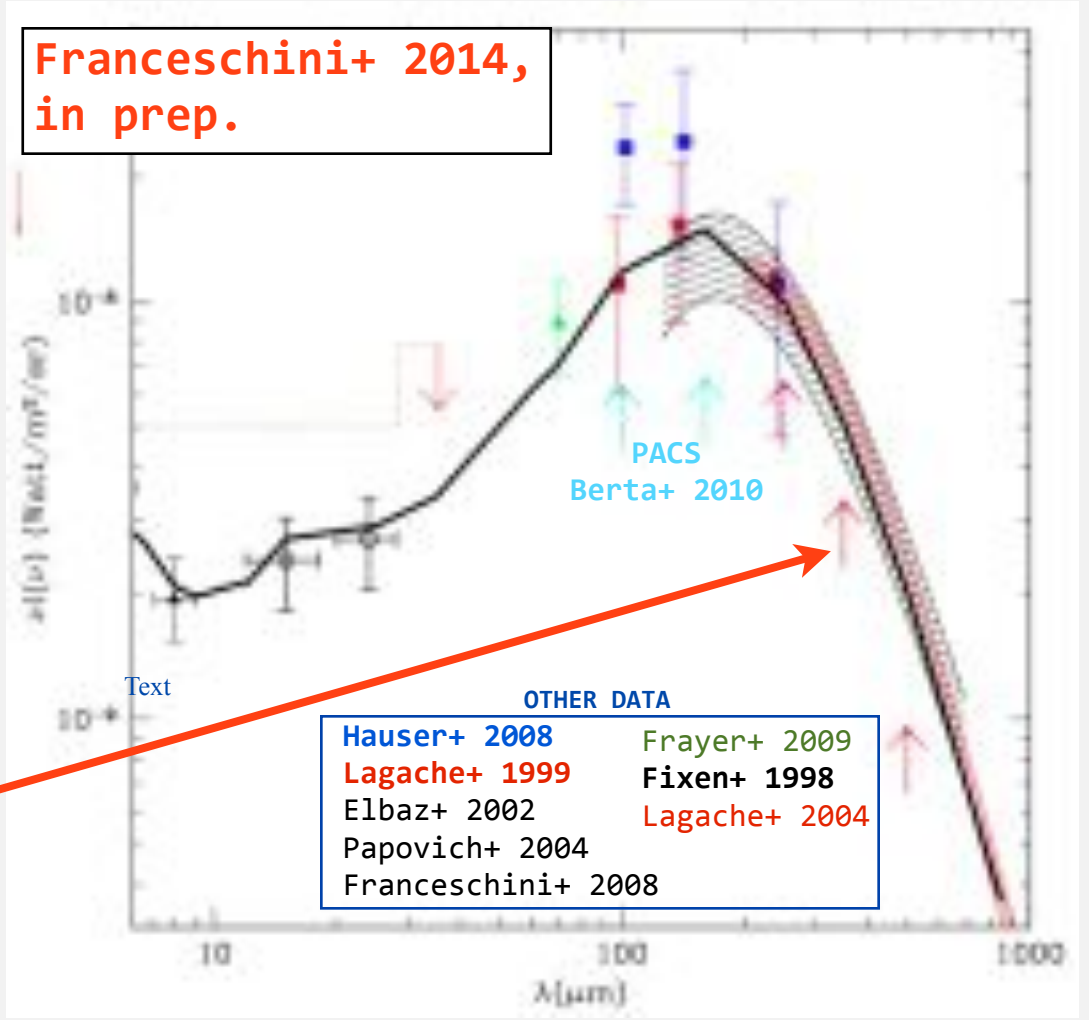
Open squares:
UV selected SFRD
Shimasaku+2005

Filled triangles:
UV selected SFRD
Burgarella+ 2013

Filled squares:
Gruppioni+ 2013

Derived fraction of detected CIRB



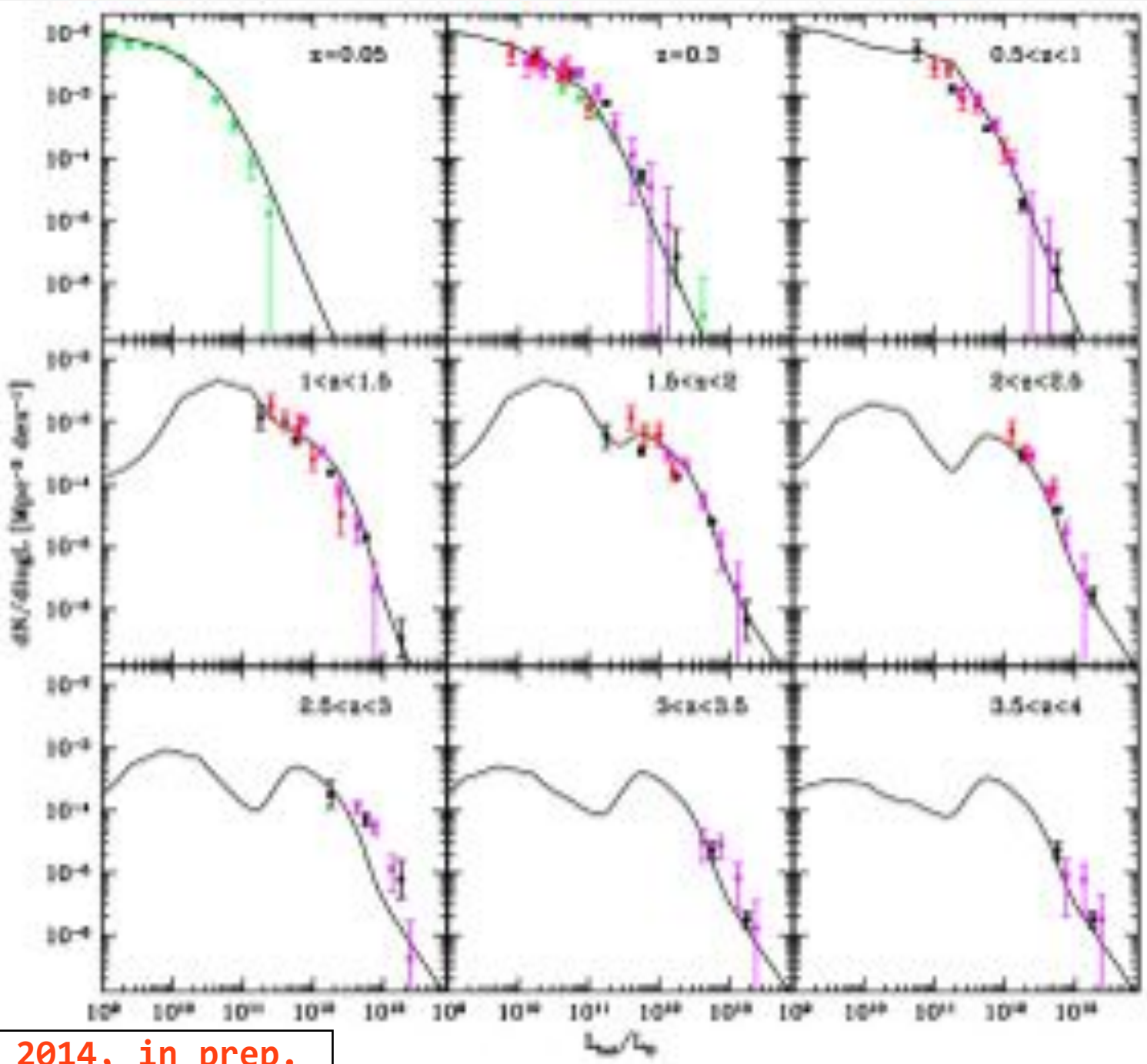


But we need higher resolution in FIR to RESOLVE sources and really constrain the LF @ mid/low luminosity and thus provide a stronger constraints on the CIRB contribution & IMF

Filled square:
Vaccari+ 2014

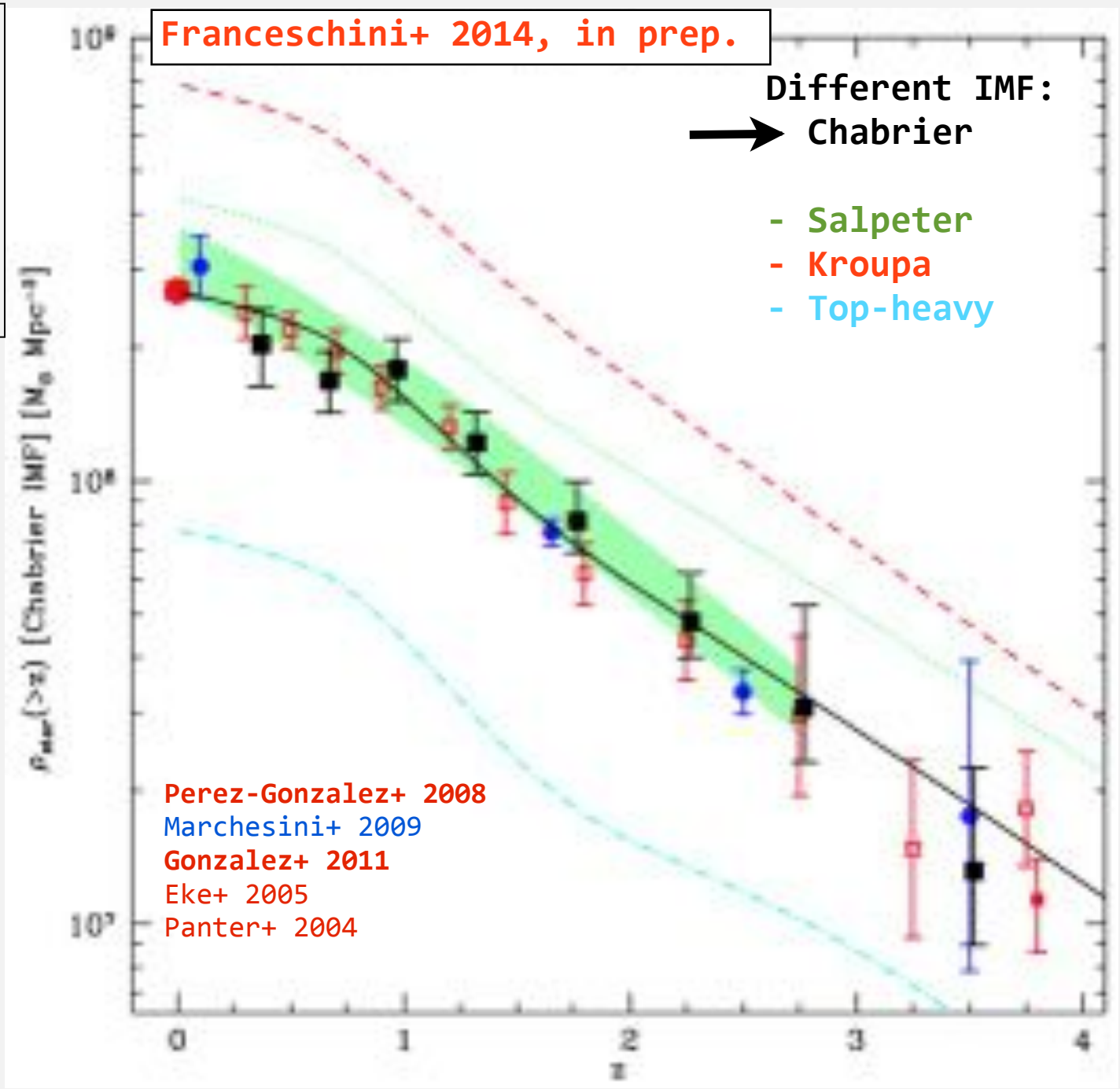
Filled squares
Marchetti+ 2014

Filled squares:
Gruppioni+ 2013



Franceschini+ 2014, in prep.

IMF & Physical models



Herschel @ extreme redshift

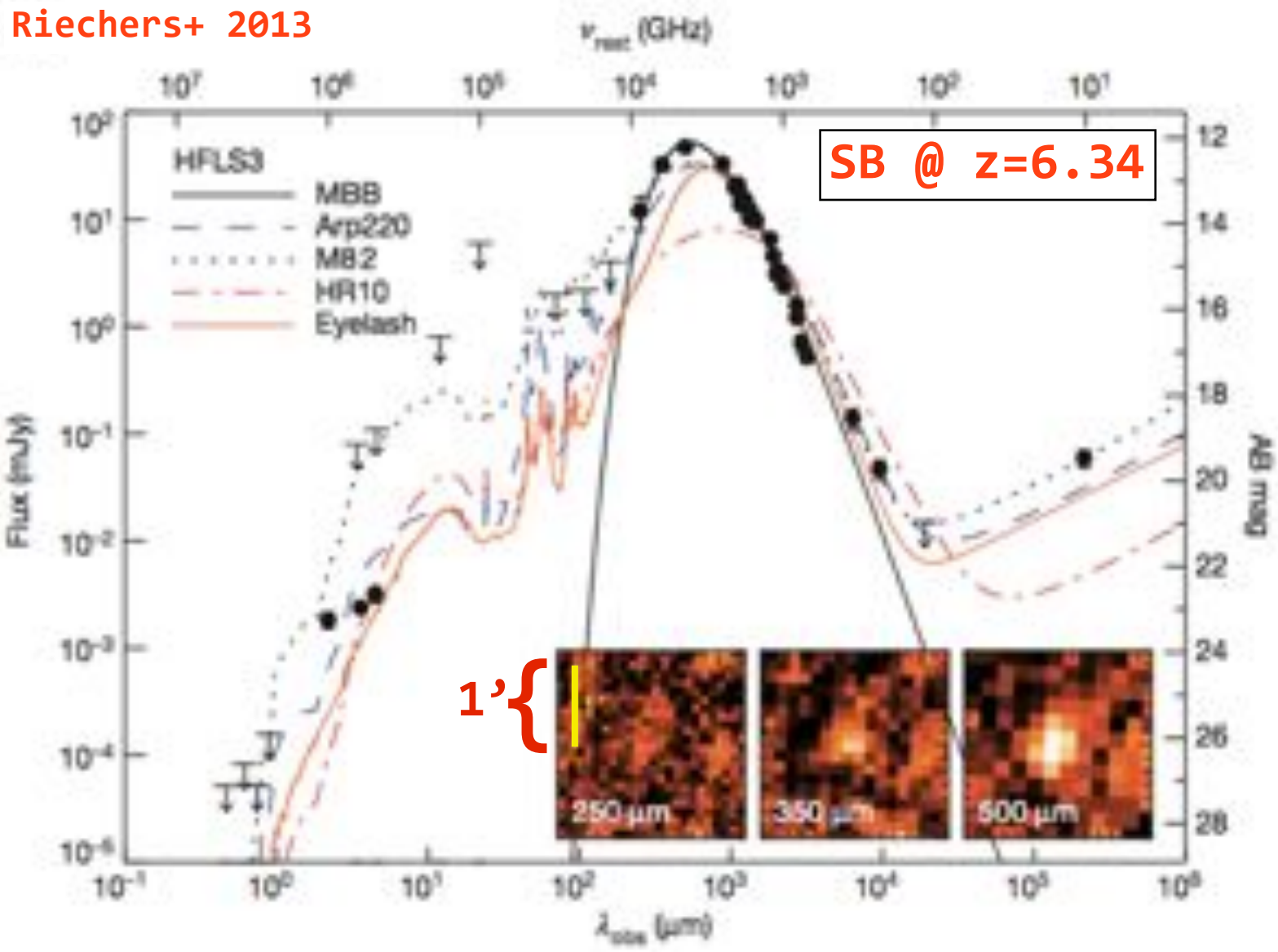
“ Massive present-day early-type galaxies gained the bulk of their stellar mass and heavy elements through intense, dust-enshrouded starburst in the most massive dark matter haloes at early epochs.”

Open Question:

How soon after the Big Bang massive starburst progenitors exist?

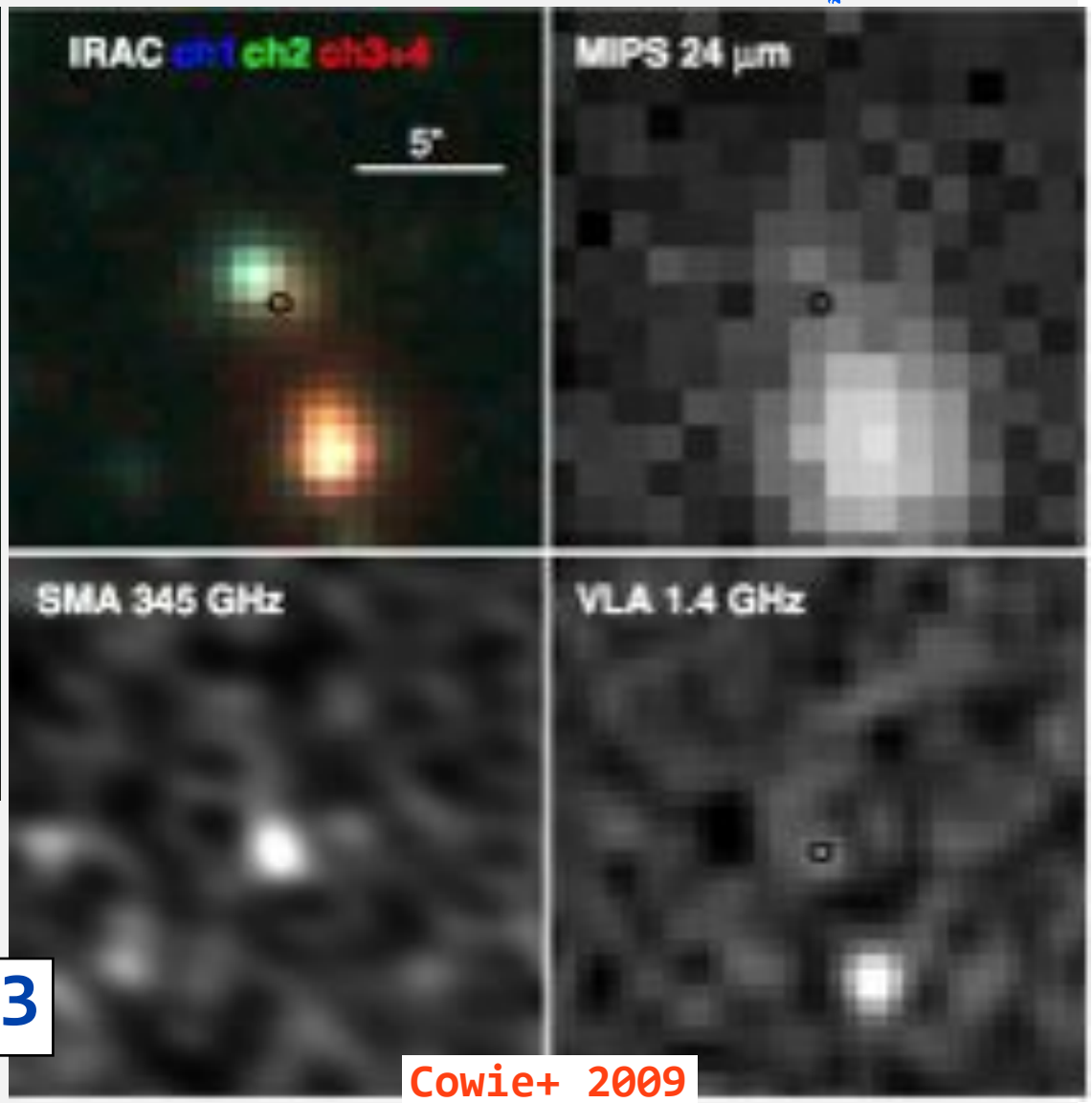
Herschel @ extreme redshift

Riechers+ 2013



Herschel @ extreme redshift

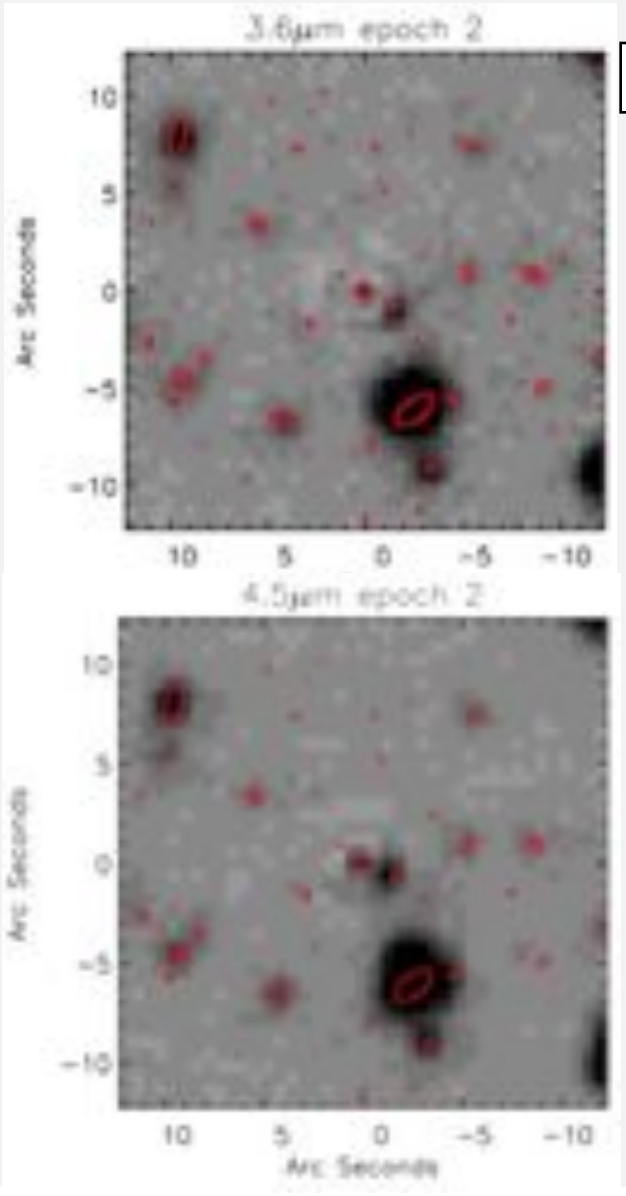
Serjeant, Marchetti 2014, in prep.



Cowie+ 2009

HDF850.1 @ z=5.83

Herschel @ extreme redshift



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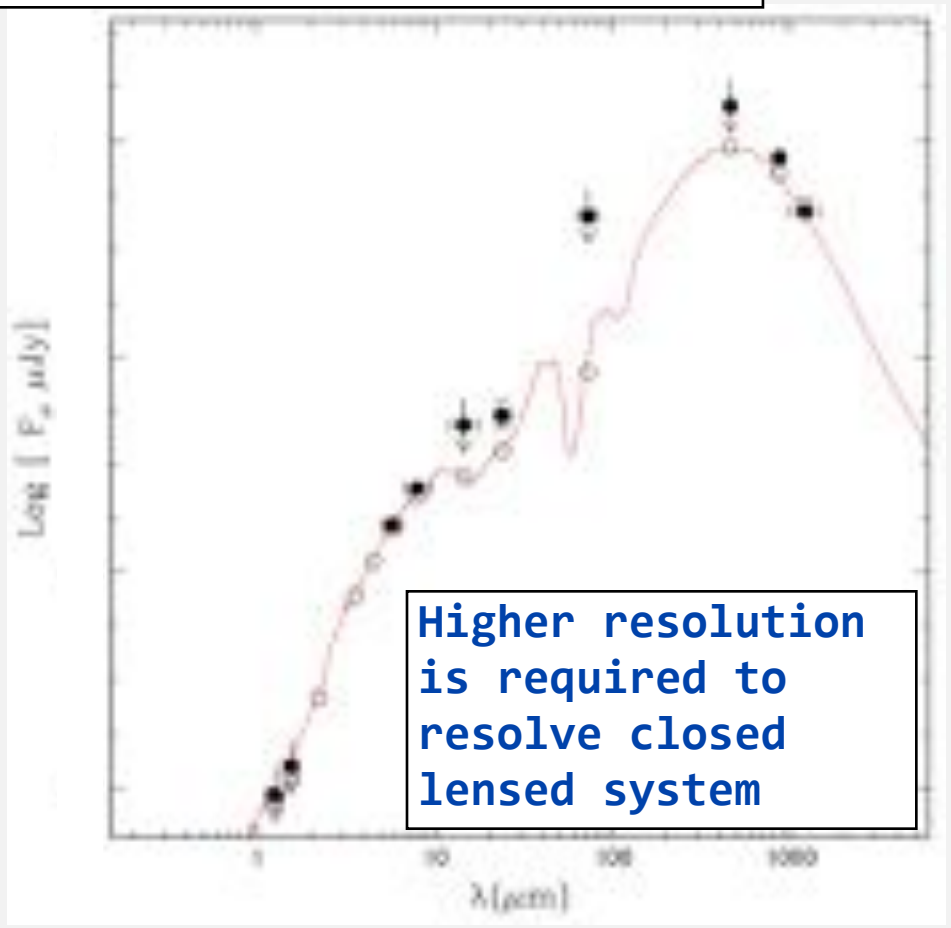
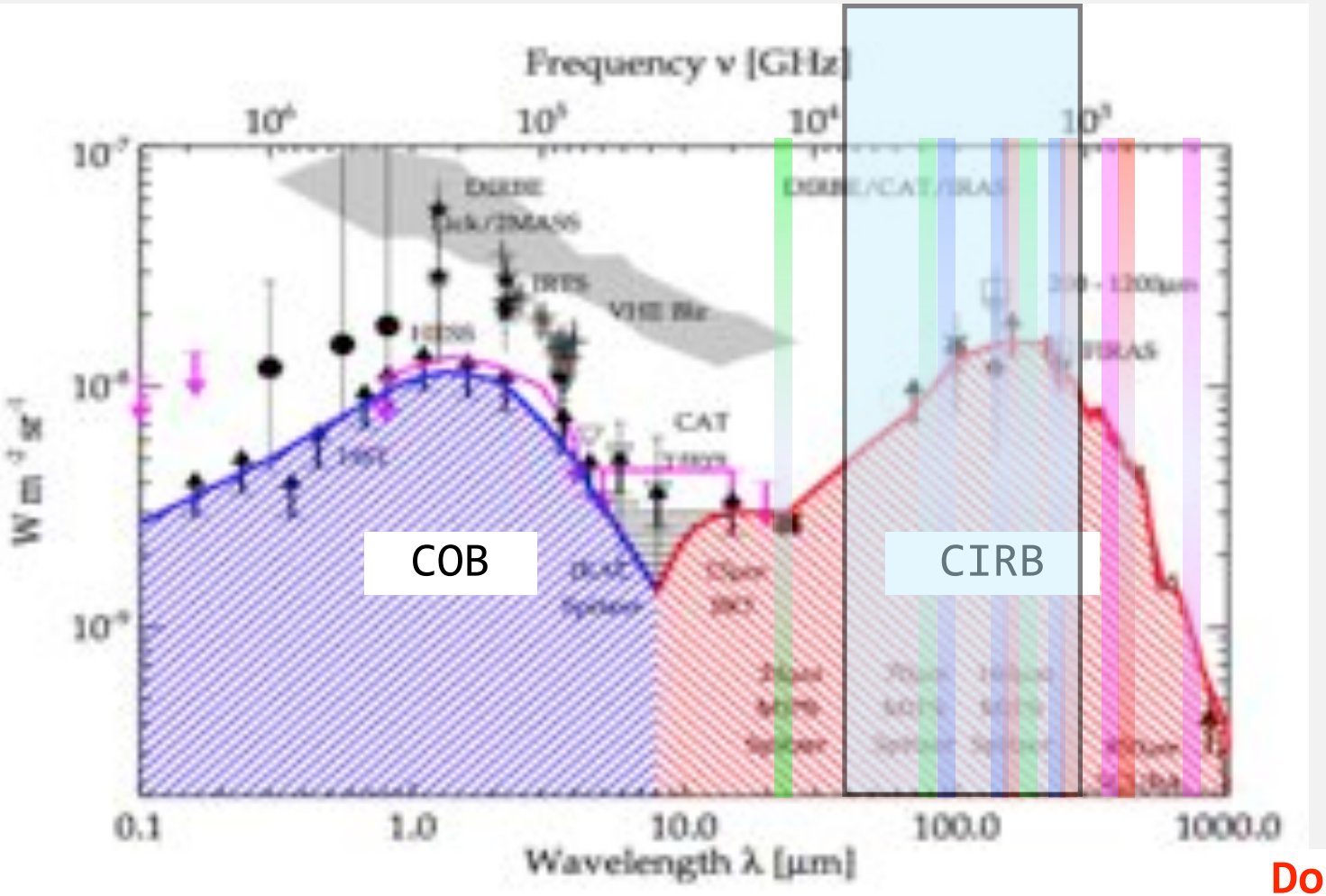


HDF850.1 @ z=5.83

Conclusions & Perspectives

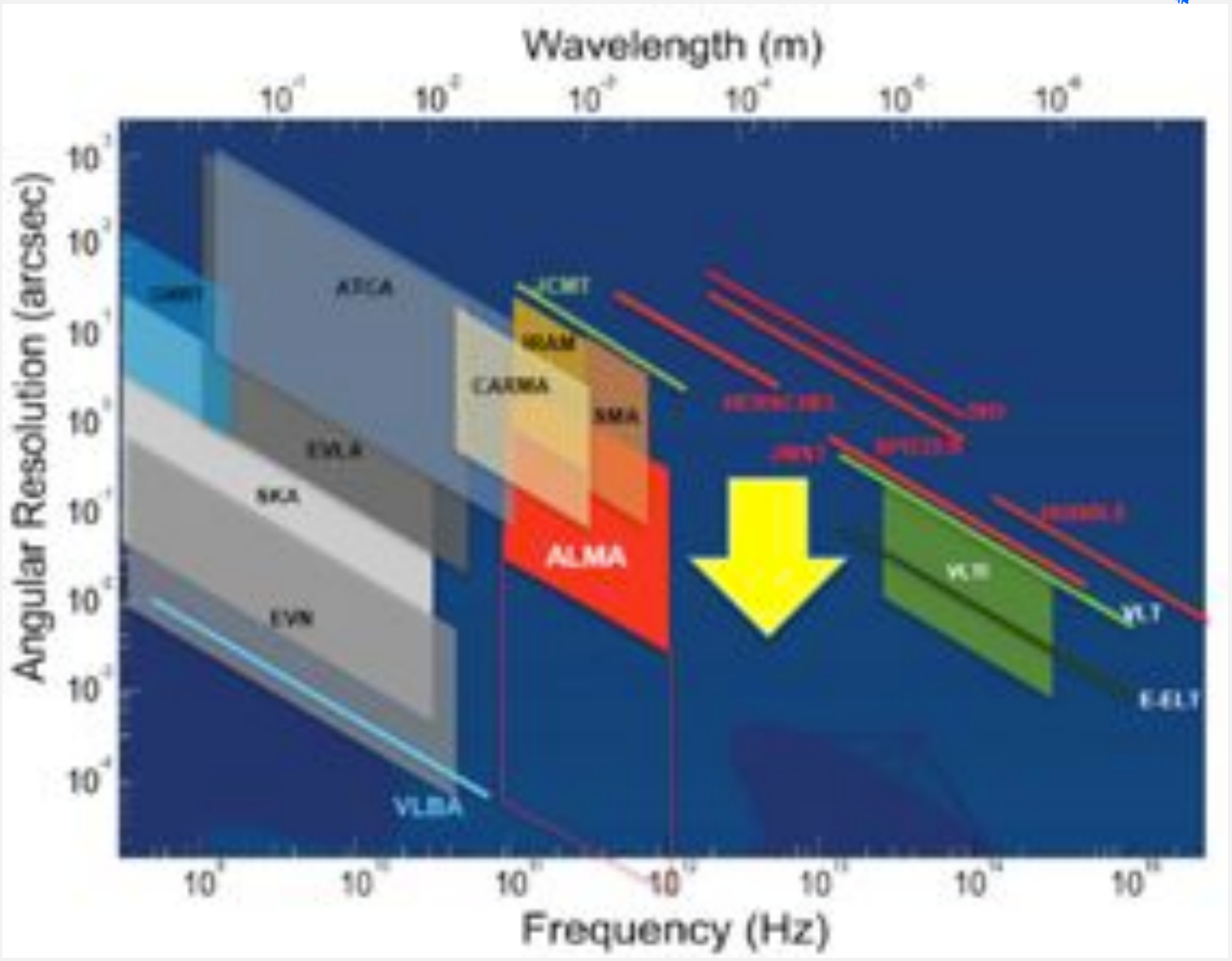
Resolving the background

The wavelength region explored by the FIR interferometer is the more important to study the SF and BH accretion processes but are the ones that mostly will suffer the lack of high resolution instruments.



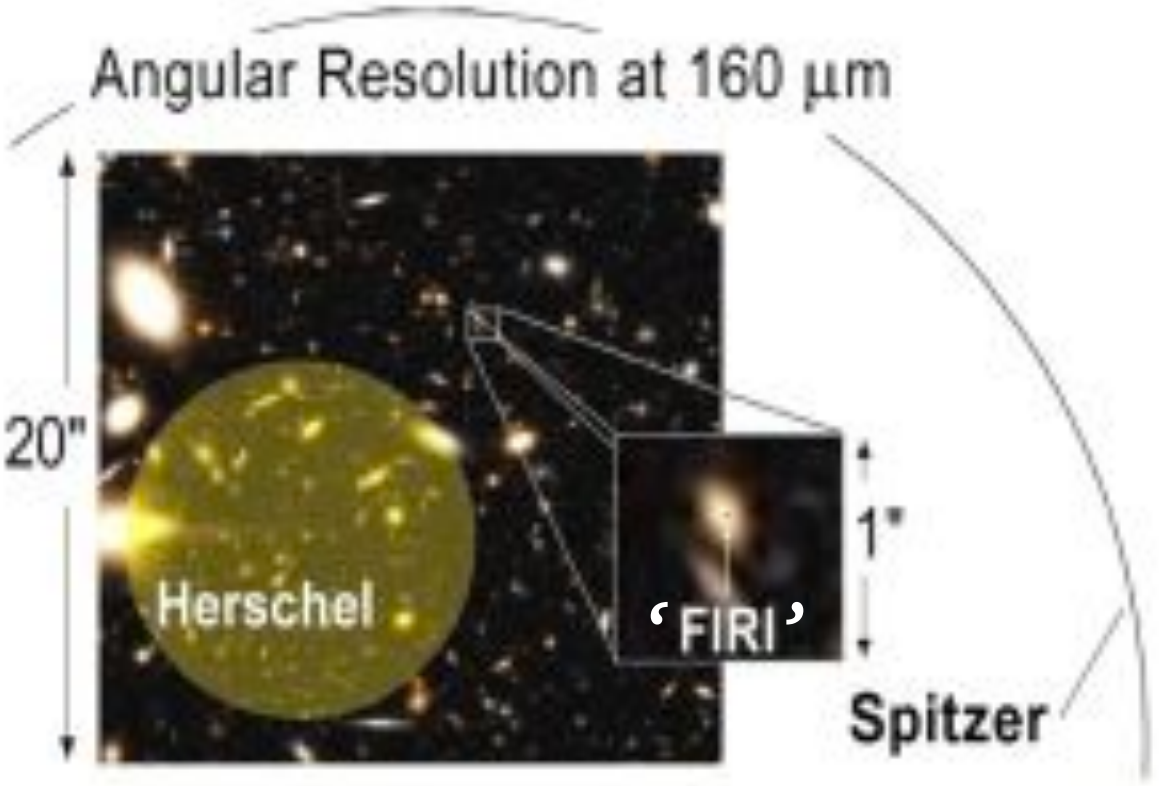
Dole+ 06

Angular Resolutions: state of the art



Angular Resolutions: The sub-arcsecond dream

THE CHALLENGE: sub-arcsecond resolution in the FIR

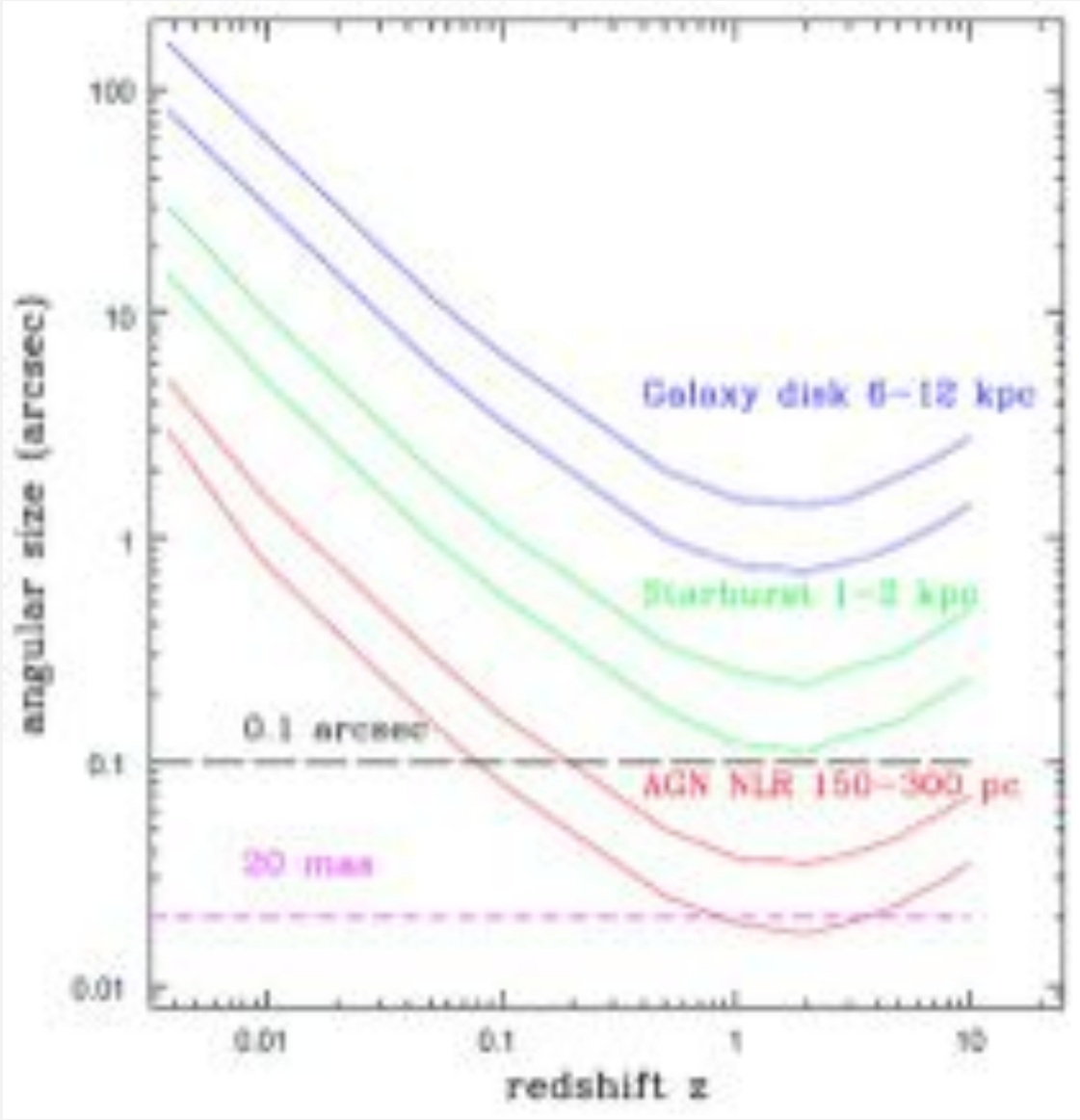


WE need high resolution in FIR to RESOLVE sources and thus:

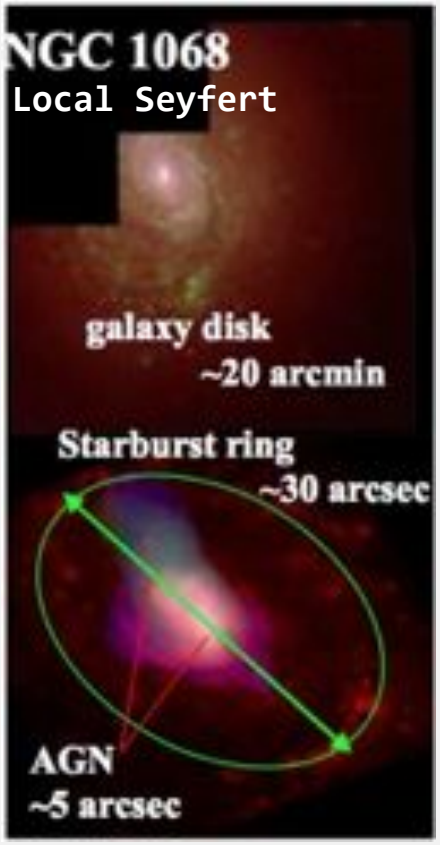
-statistics: constrain LF at mid/low luminosity and thus provide a stronger constraints on the CIRB contribution & IMF

-single objects : resolve closed (lensed) system at high redshift

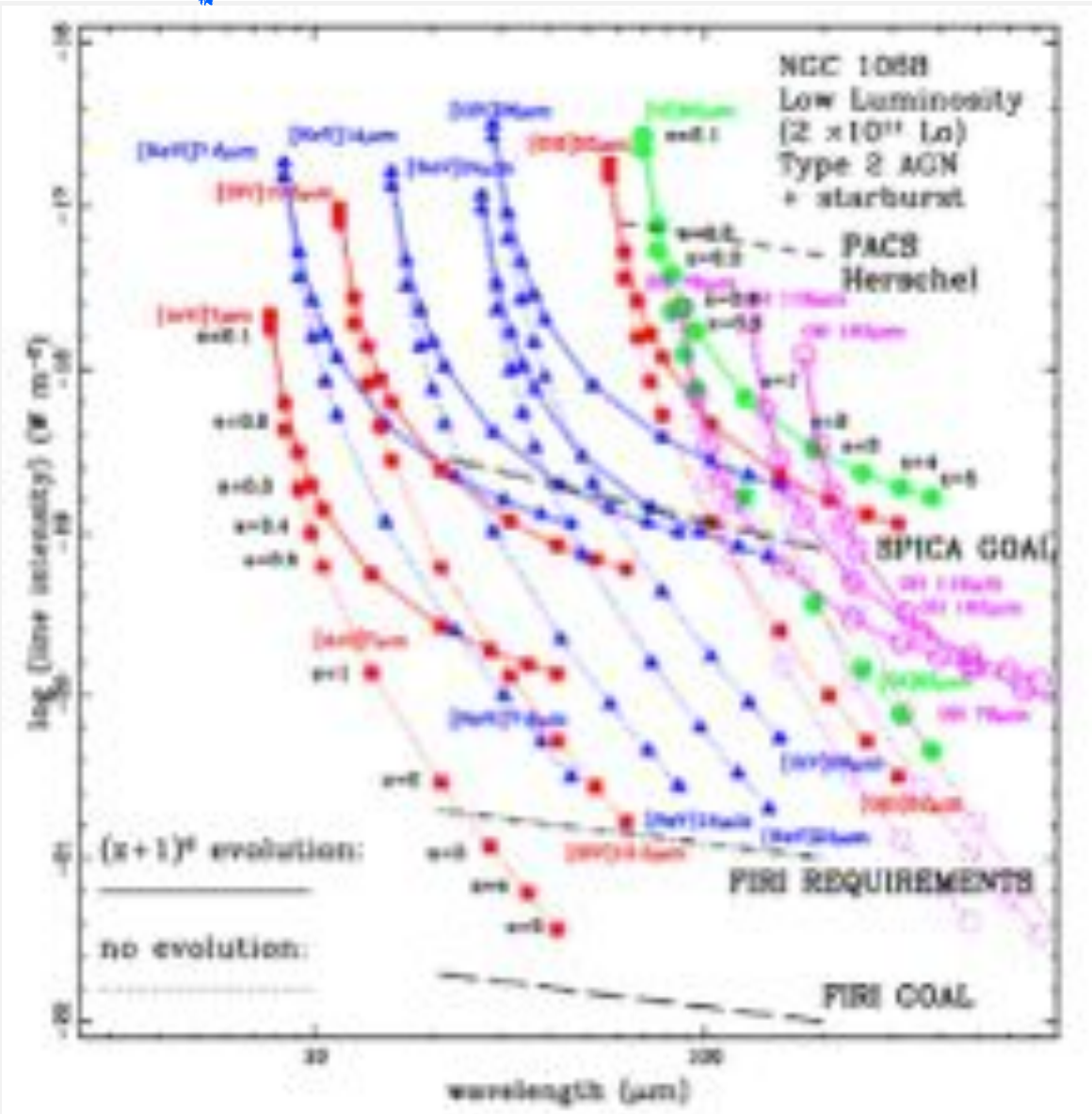
Starburst vs AGN evolution with cosmic time



We will be able to study both photometrically and spectroscopically how the starburst components evolve in cosmic times.



Sensitivity for line emission



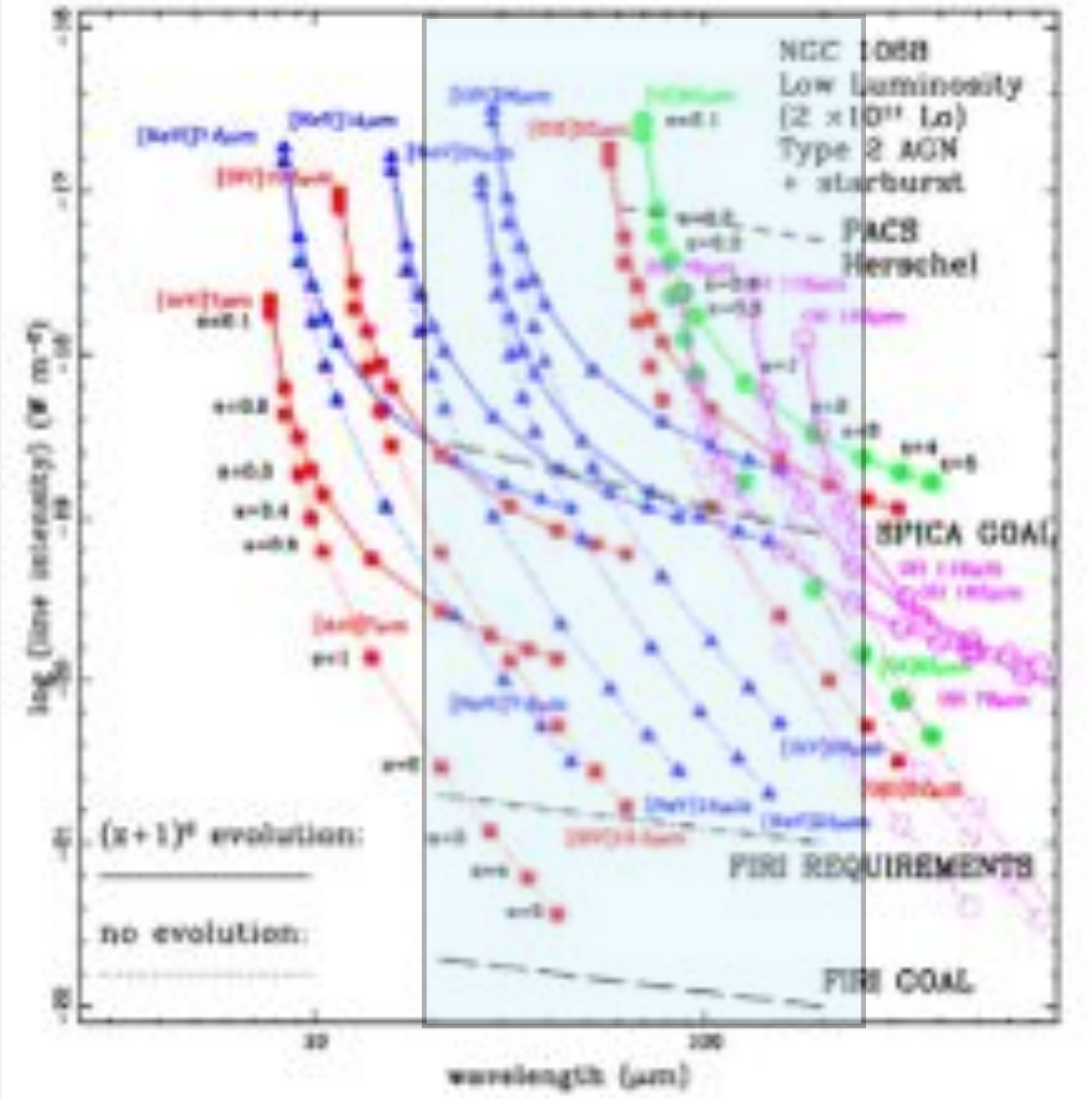
red squares
stellar ionization exited lines

blue triangles
AGN- excited lines

green circles
lines from photodissociation regions

magenta open circles
molecular lines from OH,
possibly originating in molecular tori.

Sensitivity for line emission



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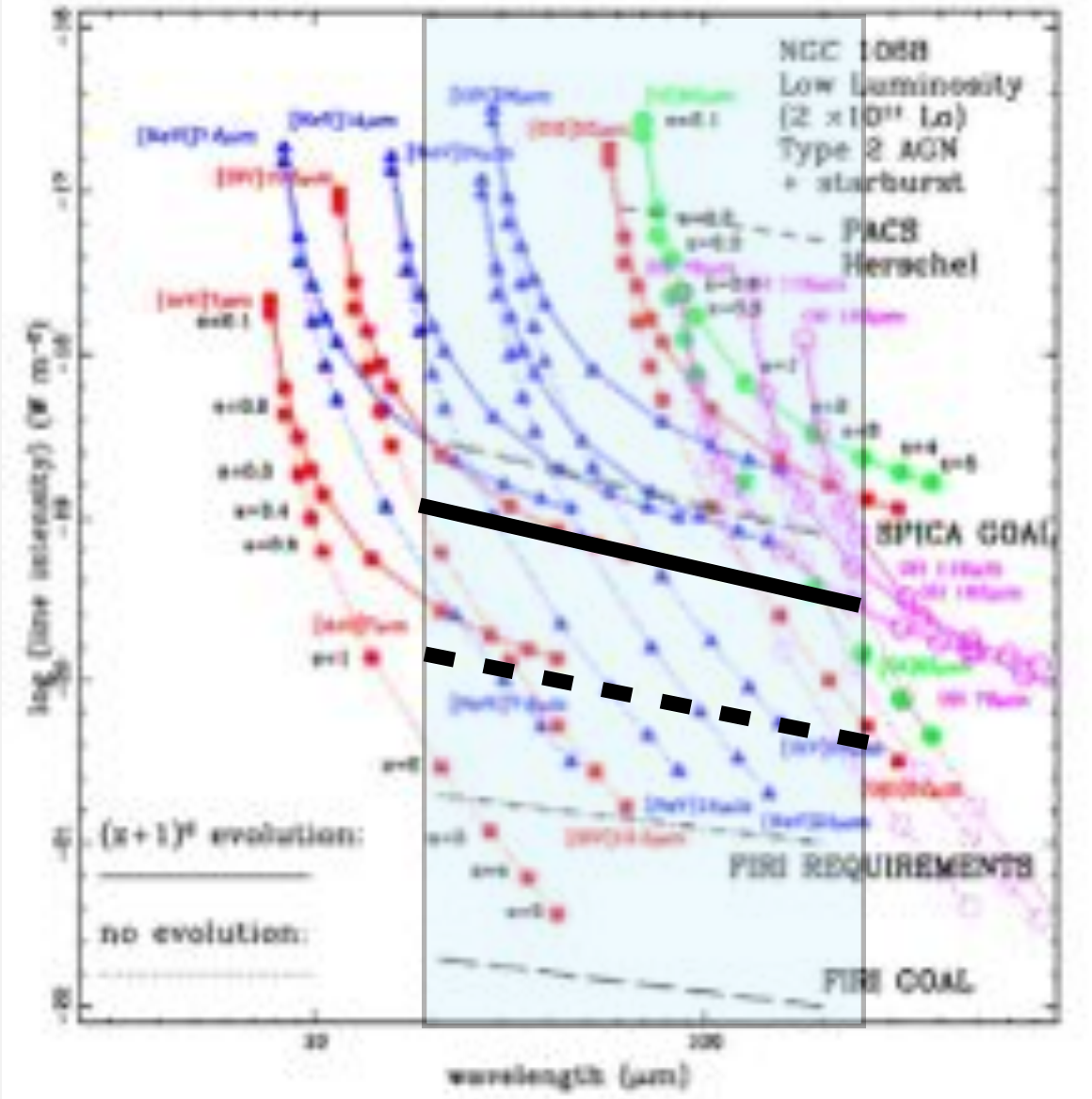

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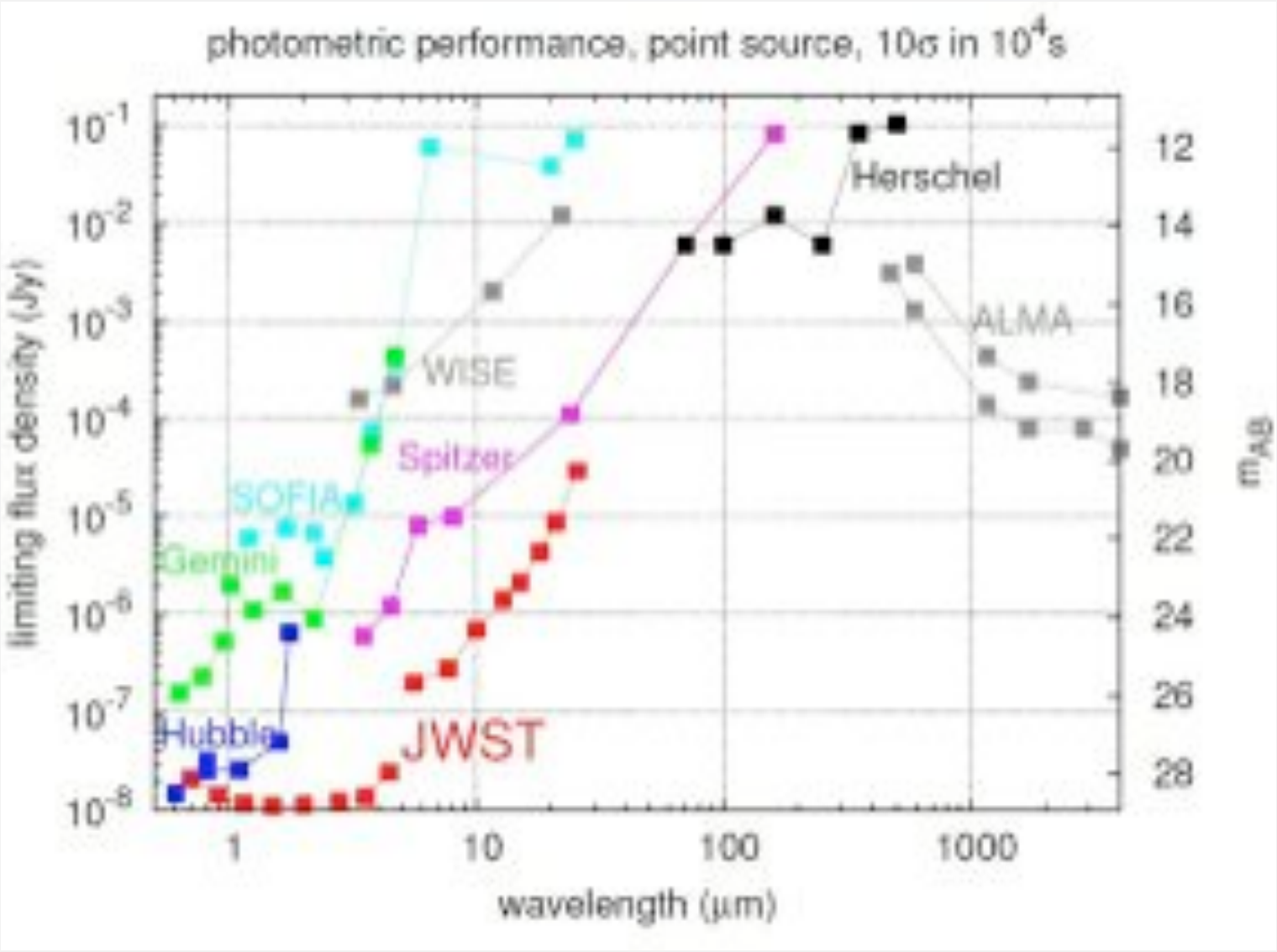
Sensitivity in the continuum: state of the art



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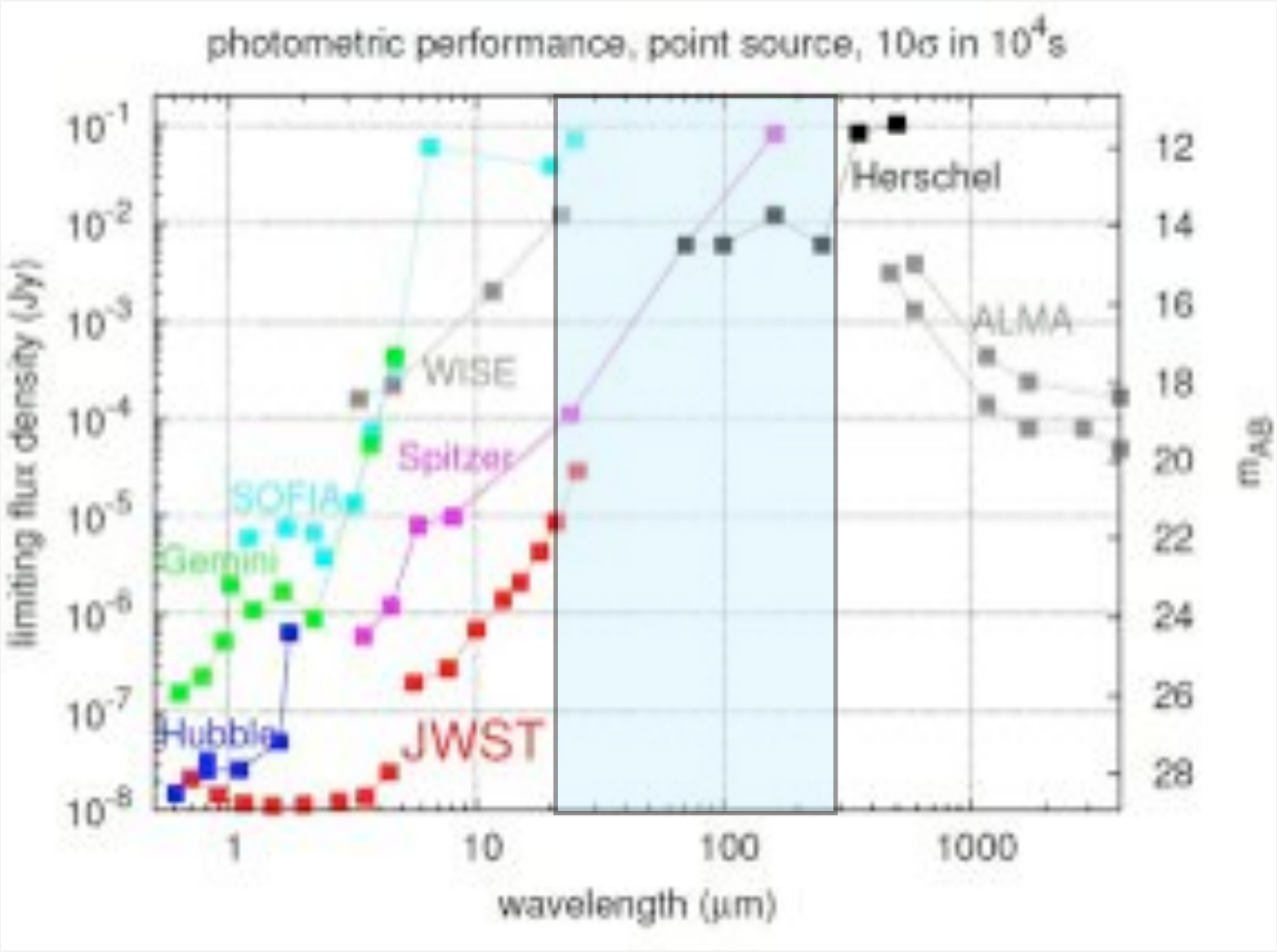
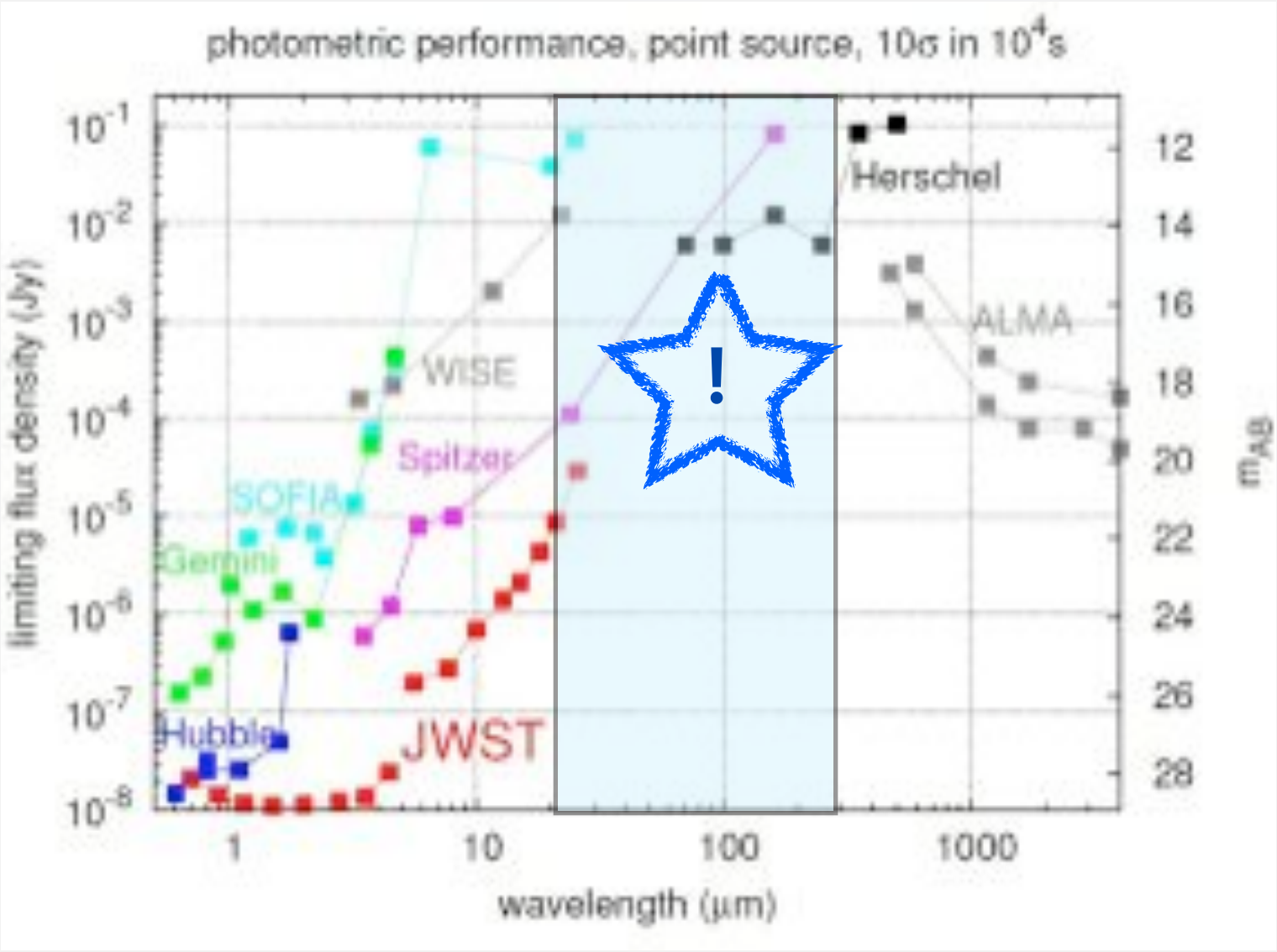
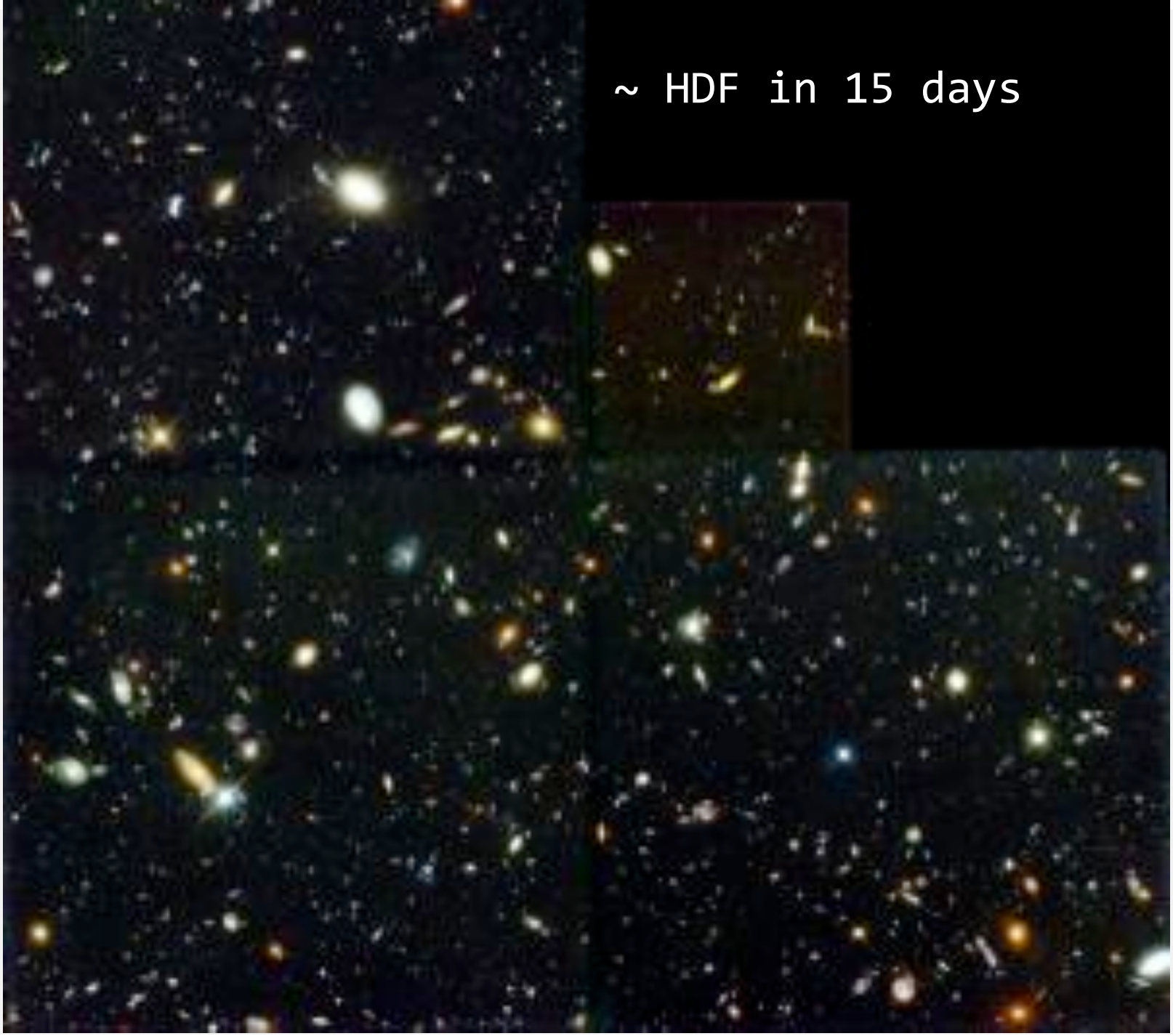


Sensitivity in the continuum: state of the art

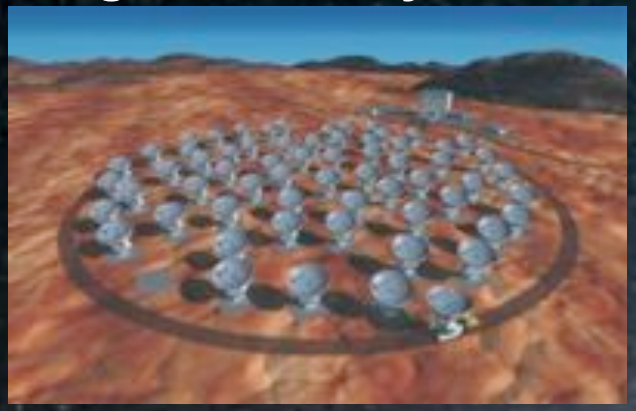



~ HDF in 15 days


ONE WAY
ANOTHER WAY
WE HAVE TO
REMEMBER....

James Webb Space Telescope (JWST) (launched in 2019)

ALMA :
Targeted Surveys Below Herschel Confusion Limits (Karim+ arxiv:1210.0249)



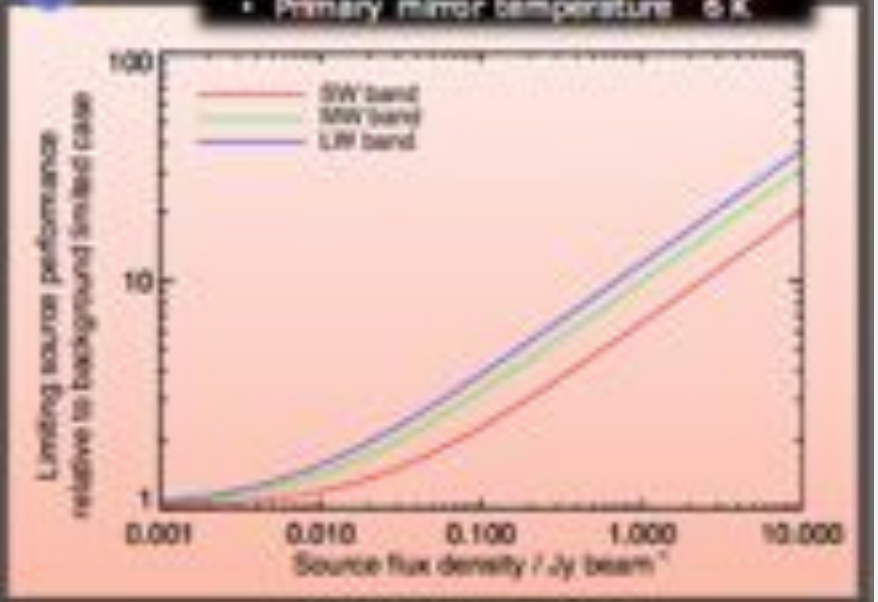
(completed in 2014)

SPICA/SAFARI Fact Sheet

SAFARI Overview

- Three band Fourier transform spectrometer
- Continuous spectroscopic capability from 34-210 μm
- Simultaneous broadband photometry in three bands
- Background limited performance
- Synchronous field of view of 2'x2' in all three bands

Parameter		Waveband SW	MW	LW	
Band centre		47 μm	85 μm	160 μm	General
Wavelength range		34-60 μm	60-110 μm	110-210 μm	
Band centre beam FWHM		4"	7"	13"	
Number of detectors		43 x 43	34 x 34	18 x 18	
Confusion limit		0.015 mJy	0.5 mJy	5 mJy	Photometry
Minimum Zodiacal background		8.0 MJy sr^{-1}	3.8 MJy sr^{-1}	2.1 MJy sr^{-1}	
Limiting source flux density (5σ-1hour)*		14 μJy	21 μJy	32 μJy	
Time to reach confusion limit at 5σ*		123 s	0.3 s	0.008 s	
Limiting line flux (5σ-1hour)*		3.7x10^{-19} W m^{-2}	3.4x10^{-19} W m^{-2}	2.9x10^{-19} W m^{-2}	Spectroscopy
Limiting line flux density 5σ-1hour*	High Res (R=2000)	11 mJy	19 mJy	31 mJy	
	Medium Res (R=320)	2.9 mJy	4.9 mJy	7.8 mJy	
	Low Res (R=50)	0.3 mJy	0.5 mJy	0.8 mJy	



- Change in system performance, as a function of target flux density, relative to the background limited case.
- The decrease in sensitivity is a result of the increased photon noise from the target source

SAFARI

*Values are based on single pixel raw sensitivity estimates