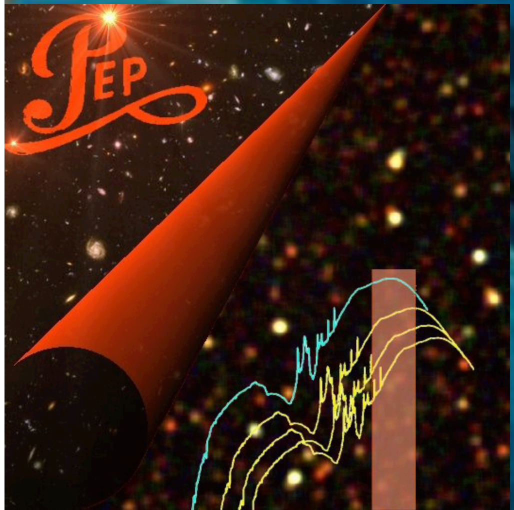
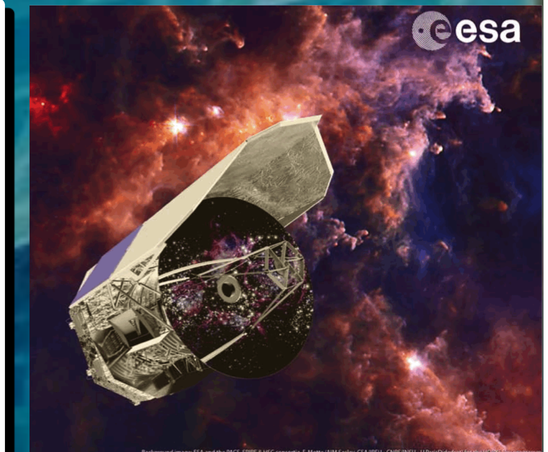
The PACS Evolutionary Probe (PEP): a Deep Extragalactic GTO Survey with Herschel



C. Gruppioni
(INAF - OABo)
on behalf of the
PEP Team



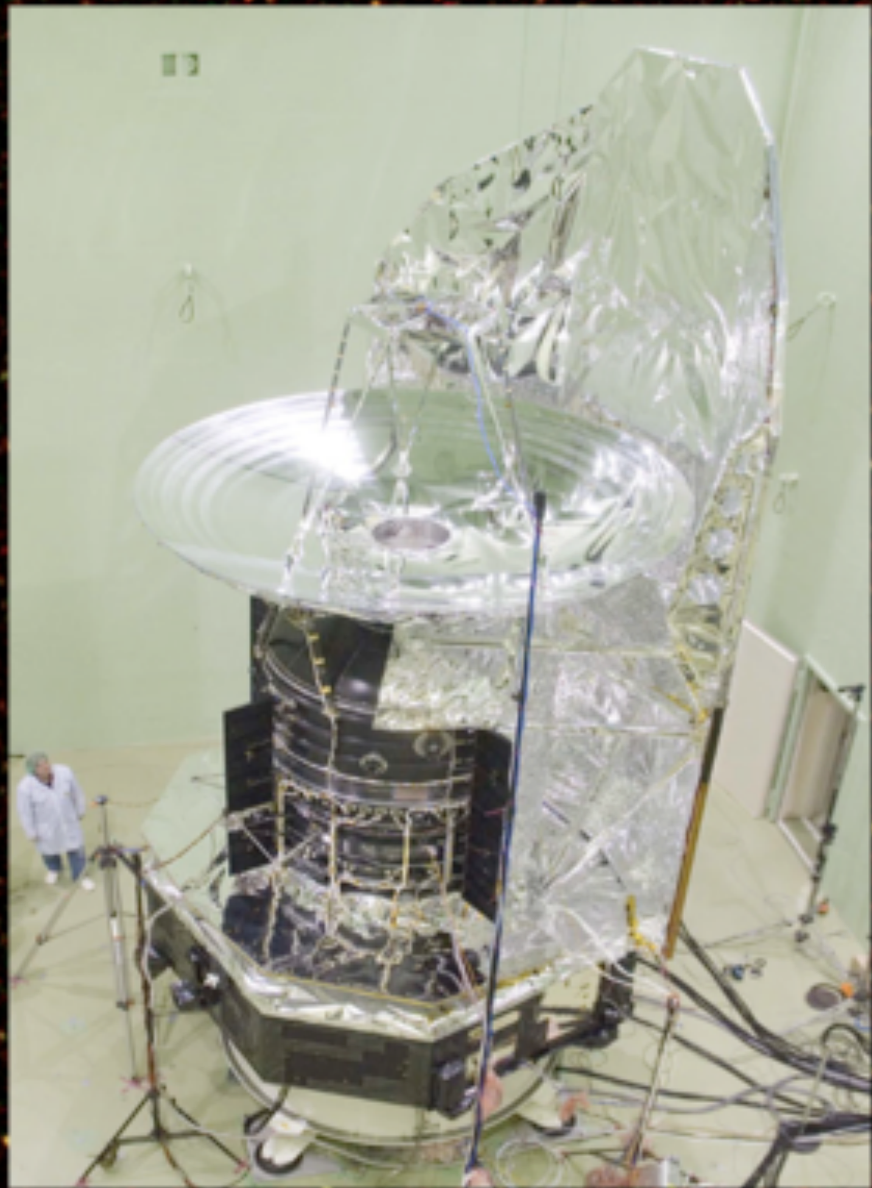
Ischia - 2011, September 2

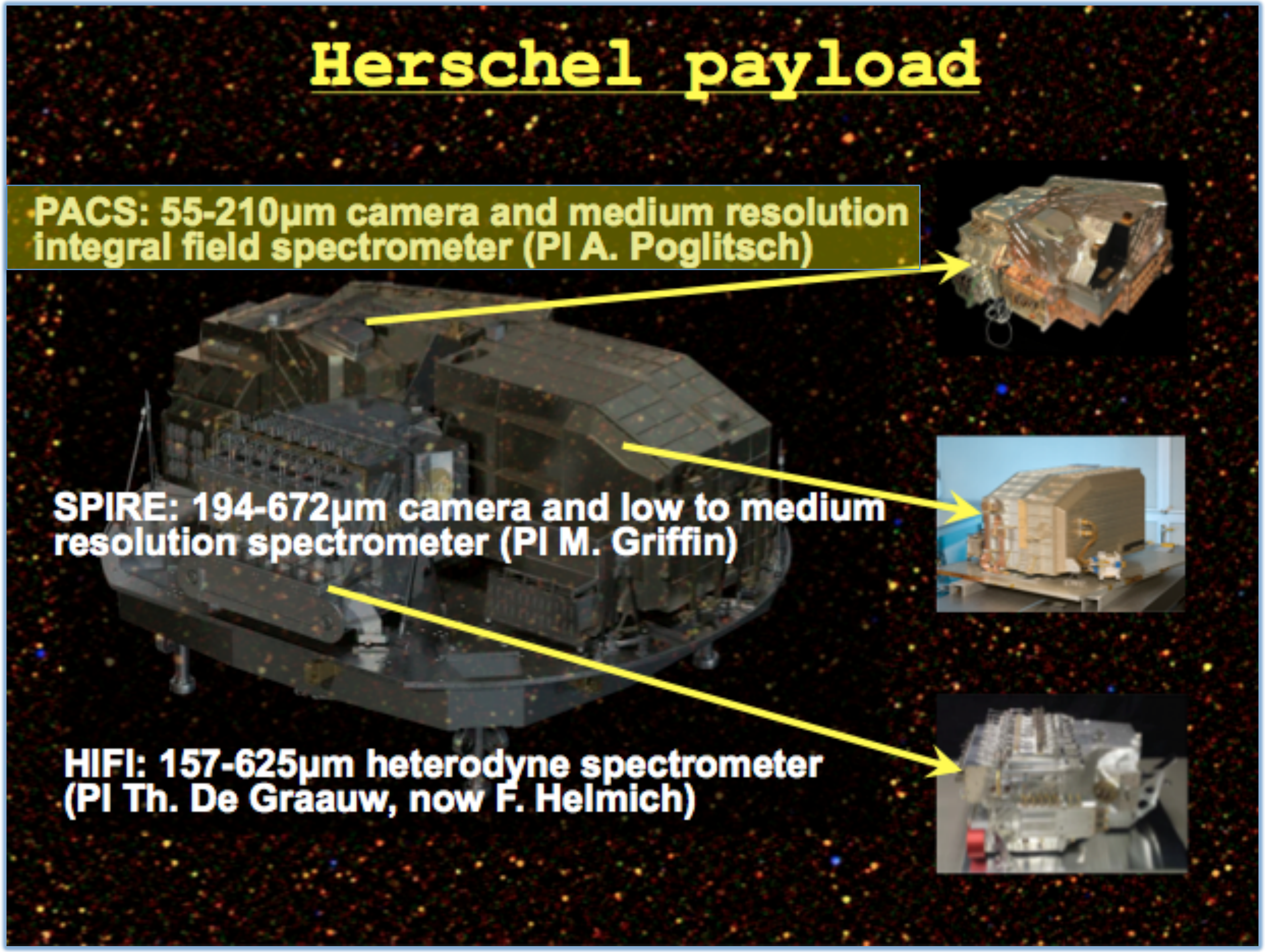
Outline

- ✓ Herschel and Galaxy Evolution in the IR
- ✓ What is PEP?
- ✓ The PEP Survey and its early results

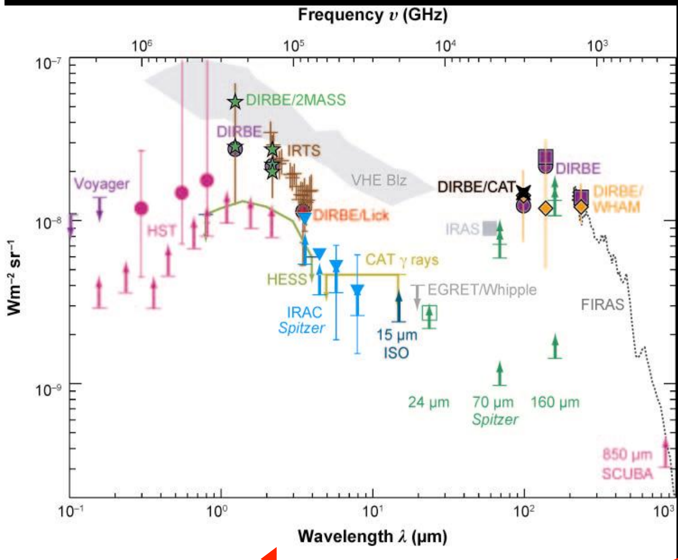
Herschel in a nutshell

- Large telescope
  - 3.5 m diameter
  - collecting area and resolution
  - Reduced source confusion wrt. IRAS, ISO, Spitzer, Akari
- New spectral window
  - 55 – 672 μm: bridging the far-infrared & submillimetre
- Novel instruments
  - wide area mapping in 6 bands between 70 and 500 μm
  - imaging spectroscopy
  - very high resolution spectroscopy

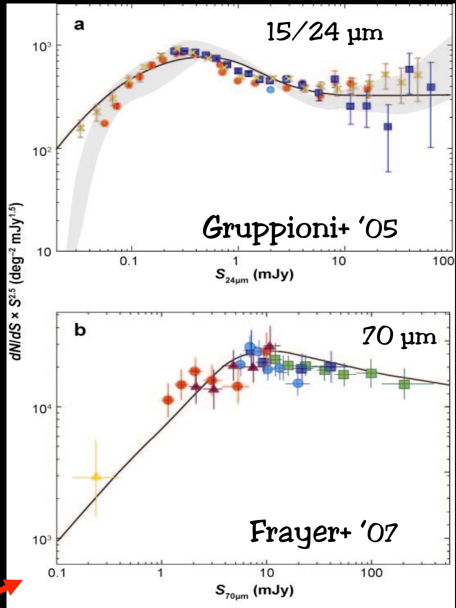



Herschel payload
PACS: 55-210µm camera and medium resolution integral field spectrometer (PI A. Poglitsch)
SPIRE: 194-672µm camera and low to medium resolution spectrometer (PI M. Griffin)
HIFI: 157-625µm heterodyne spectrometer (PI Th. De Graauw, now F. Helmich)

Deep IR Surveys: what did we know before Herschel?



Soifer BT, et al. 2008.
Annu. Rev. Astron. Astrophys. 46:201–40



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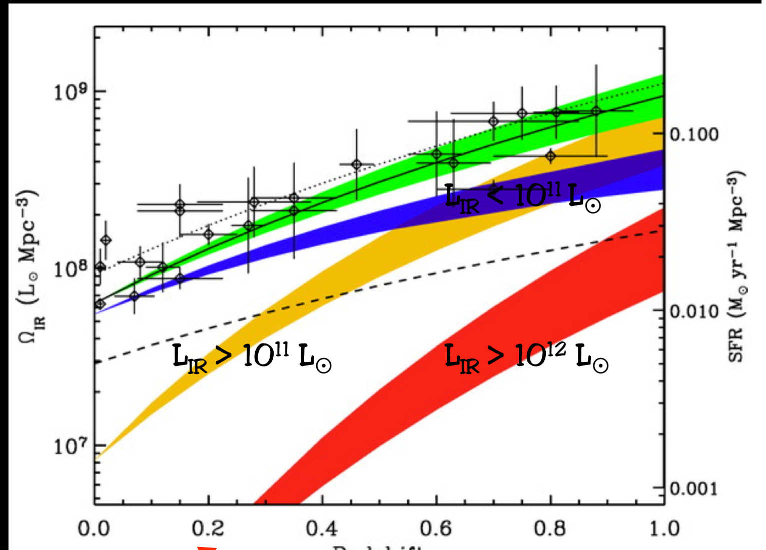
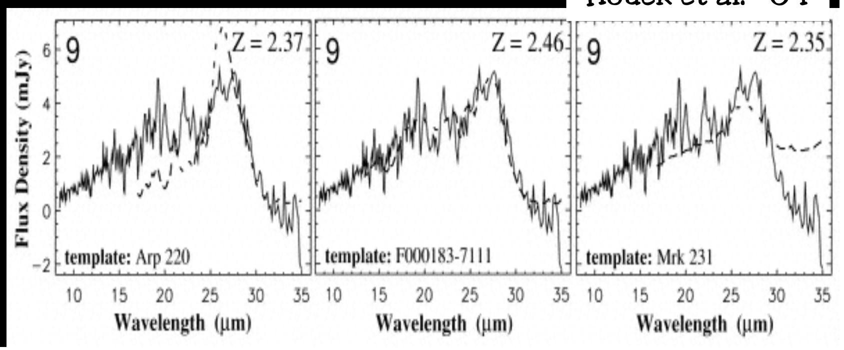


LeFloch et al. '05

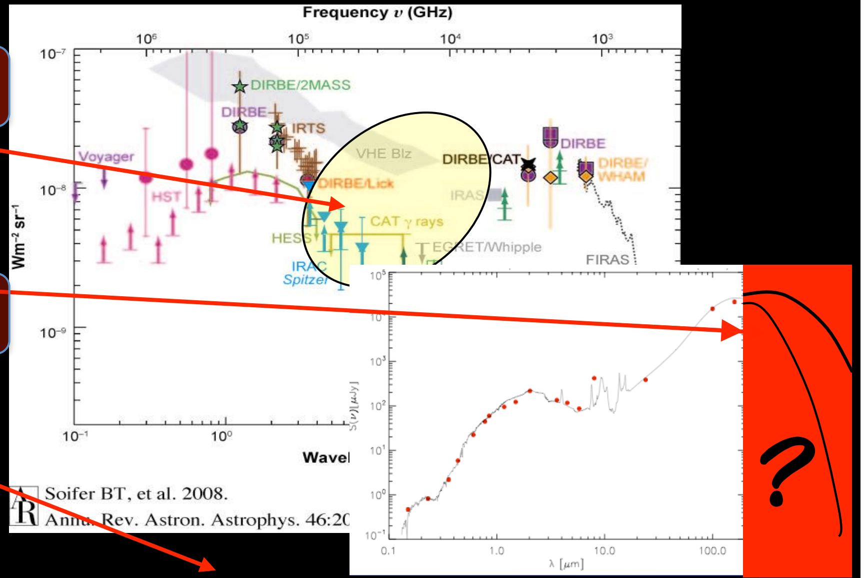
- CIRB + Source Counts: Strong Evolution for Galaxies & AGNs in the MIR/FIR
- LF up to z~1: LIRGs dominance at z>0.5, ULIRGs prominence at z>1-2
- At z~2 (but also at z~0-1?) MIR samples are rich in embedded AGNs and MIR-enhanced SEDs

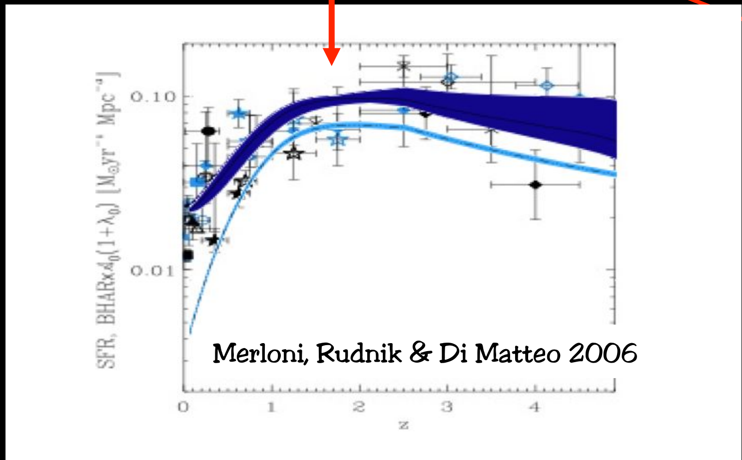
Houck et al. '04

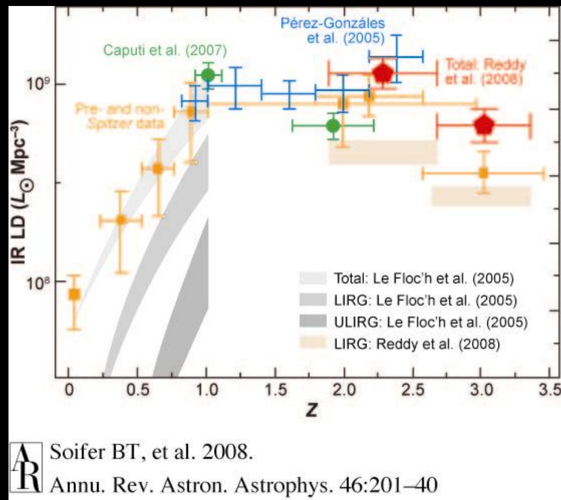


Deep IR Surveys:
what do we need to learn from Herschel?

- CIB poorly constrained in FIR
- Total energetics of known galaxy populations?
- z>1 Universe?
- Accretion/SF activity vs z ?

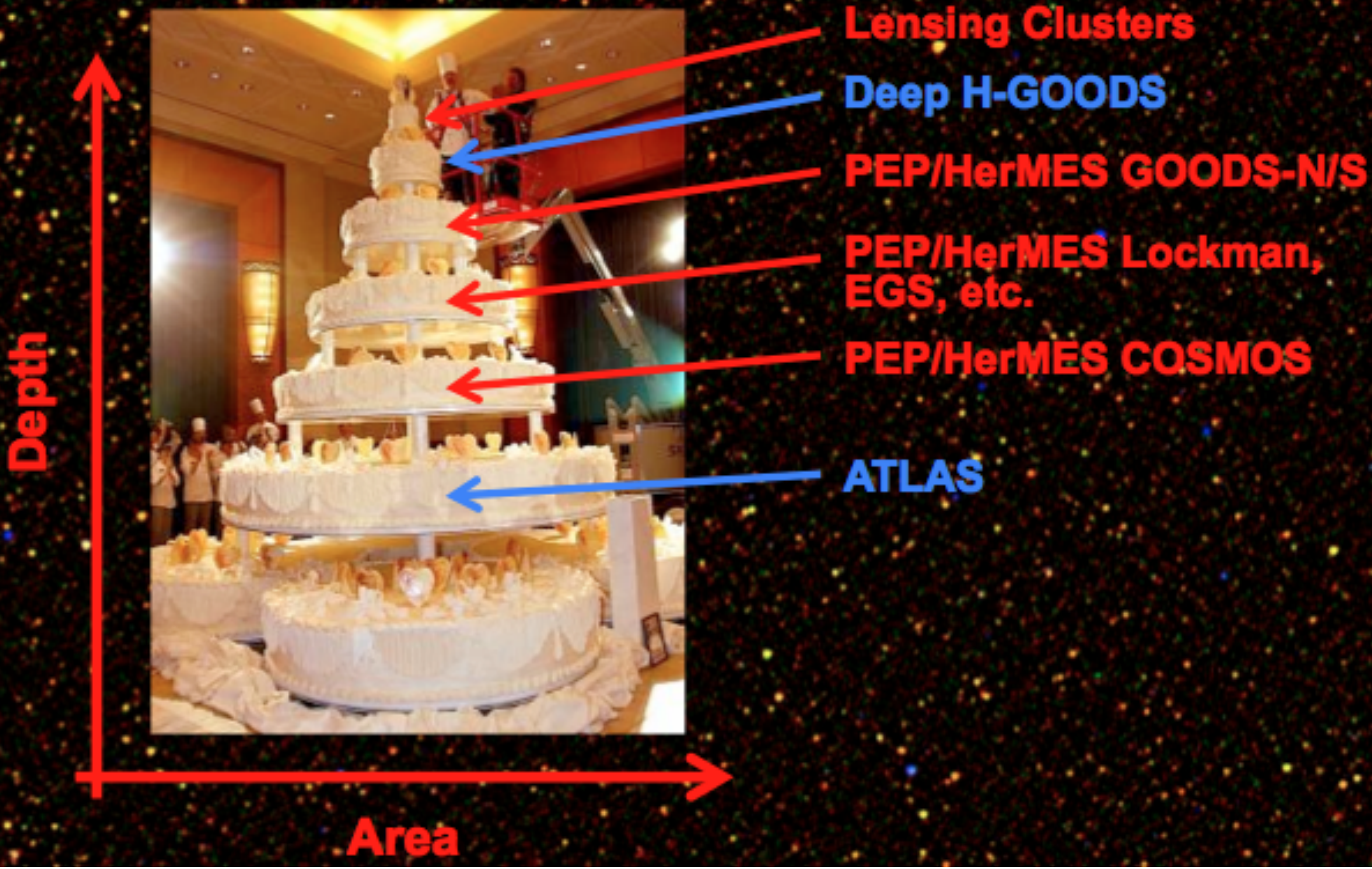




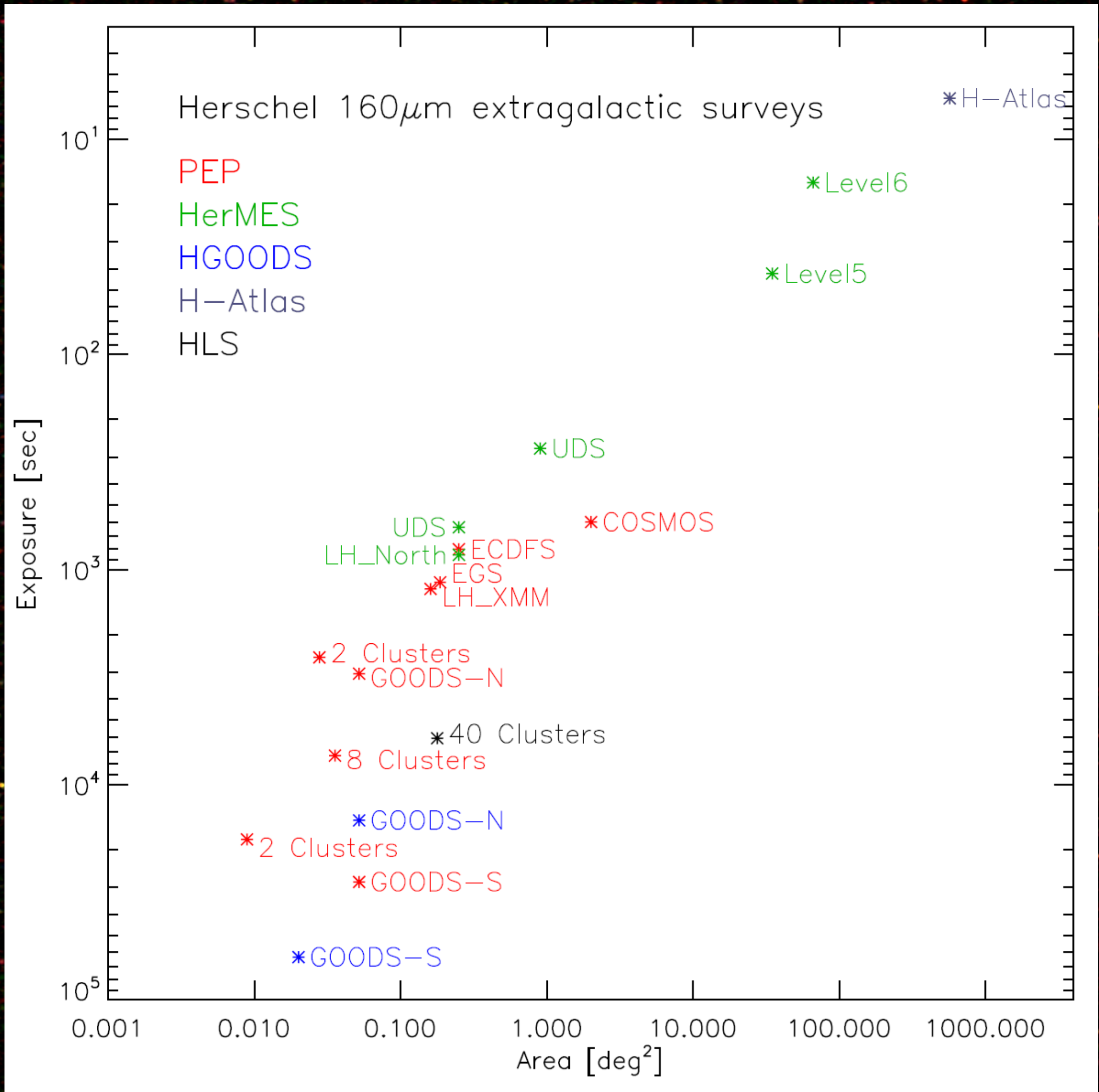


AGN/galaxy formation/co-evolution
Complete census of SMBH in the Universe

The cosmological wedding cake



PACS Evolutionary Probe (PEP)



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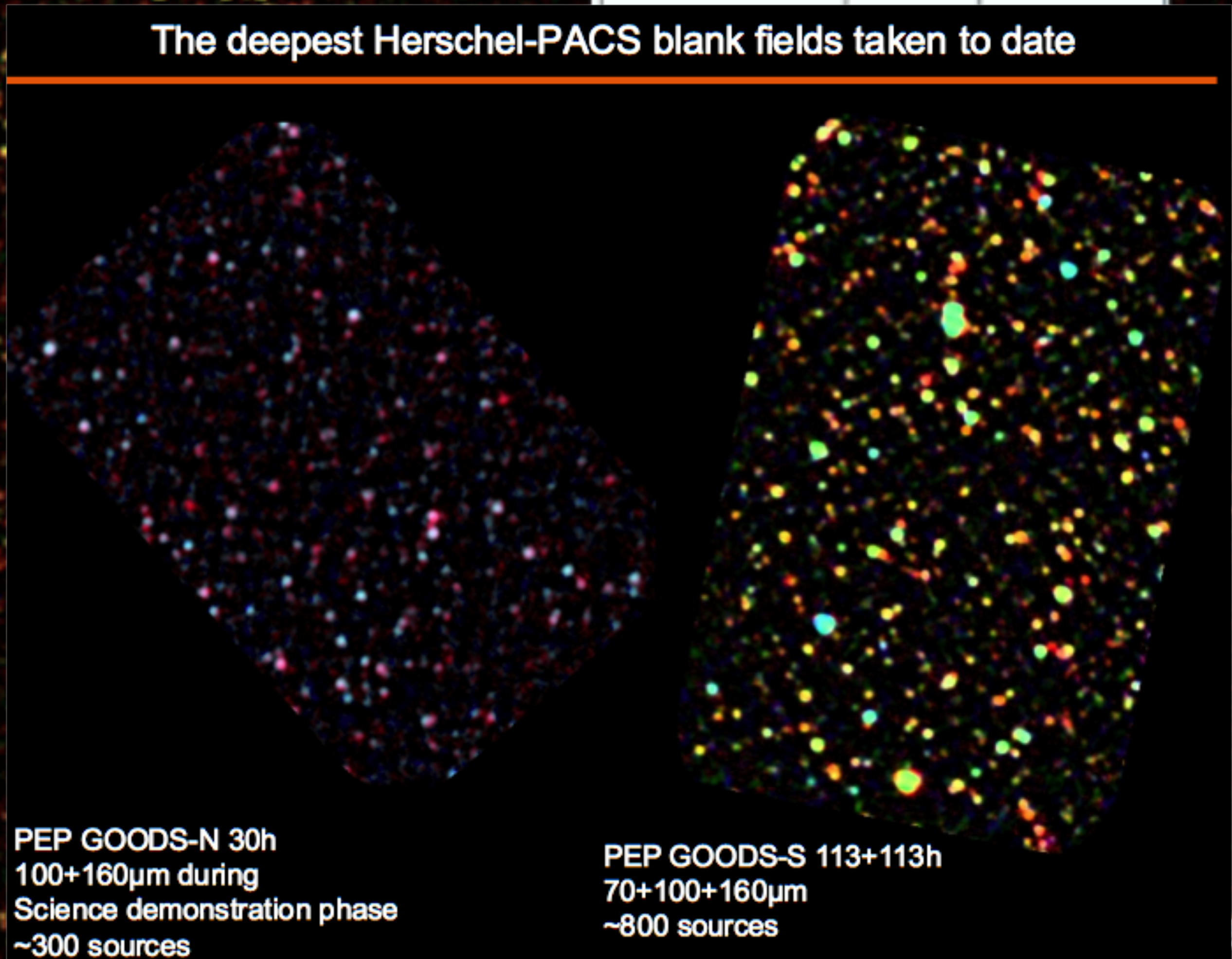
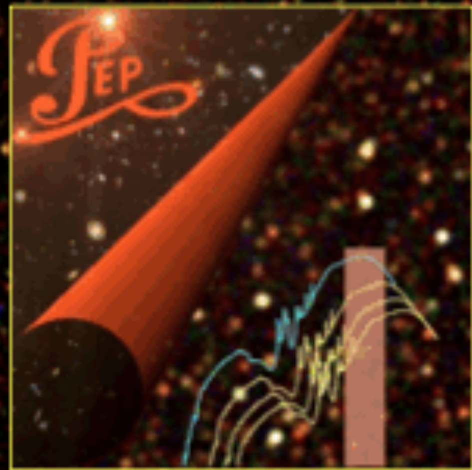
What is PEP?

- PEP is the major Herschel 100/160μm imaging extragalactic survey of key multiwavelength fields





z~1 clusters

g2); H-GOODS (ultra-deep); Herschel lensing survey.

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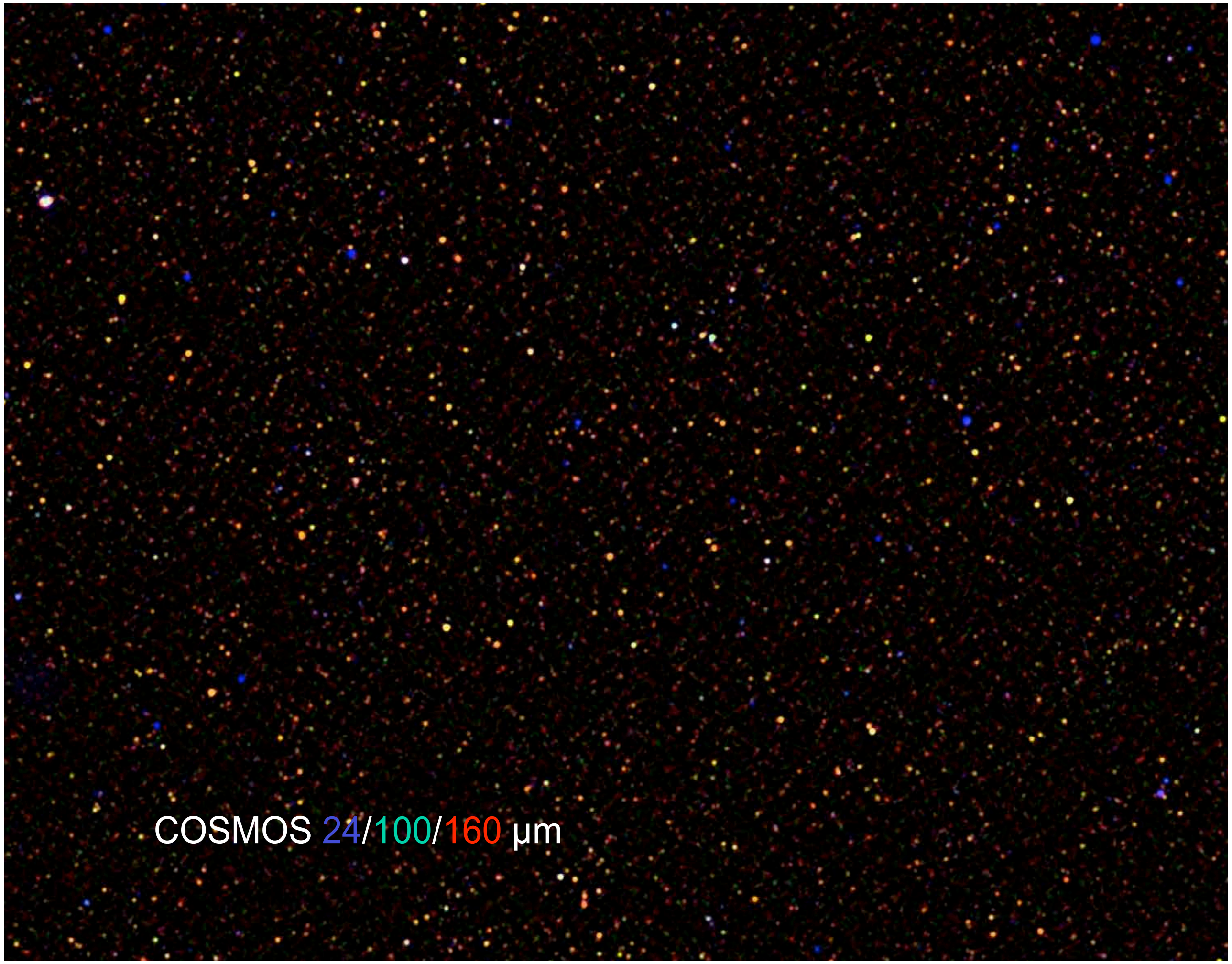
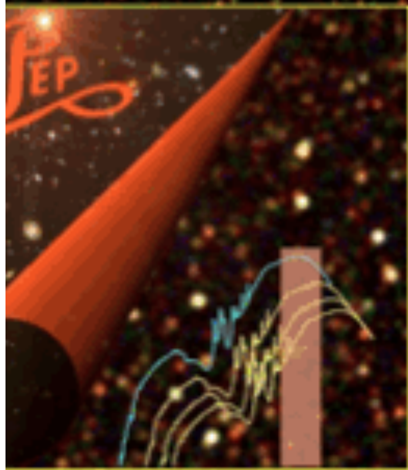
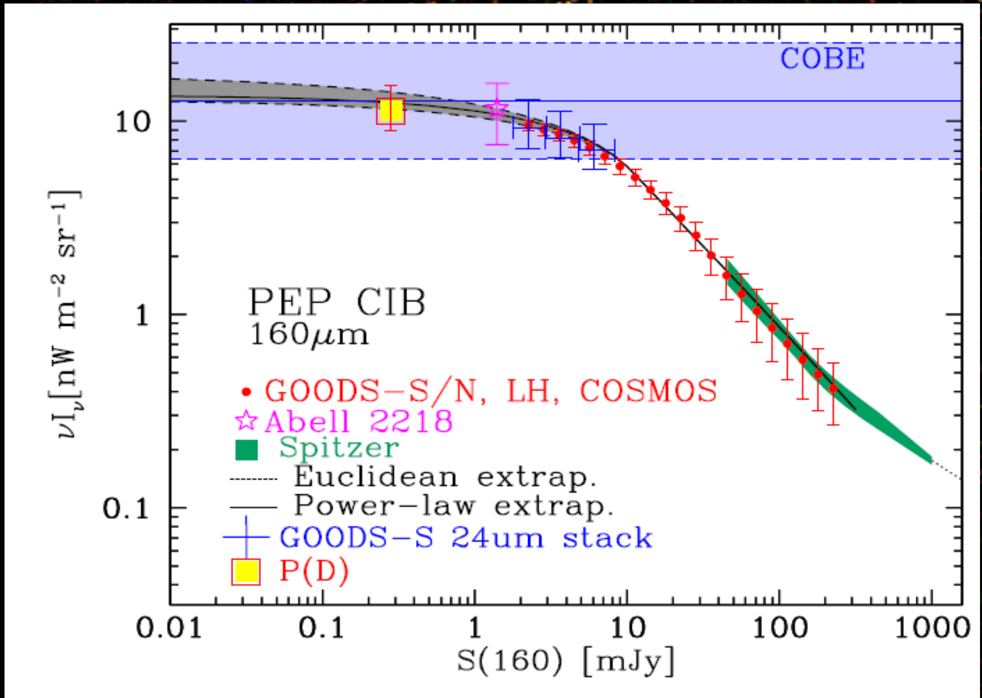


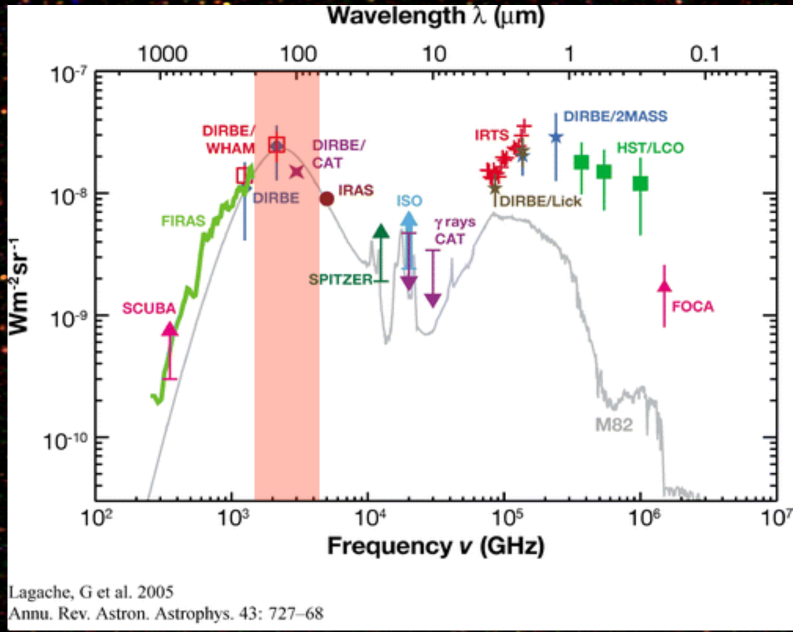


clusters

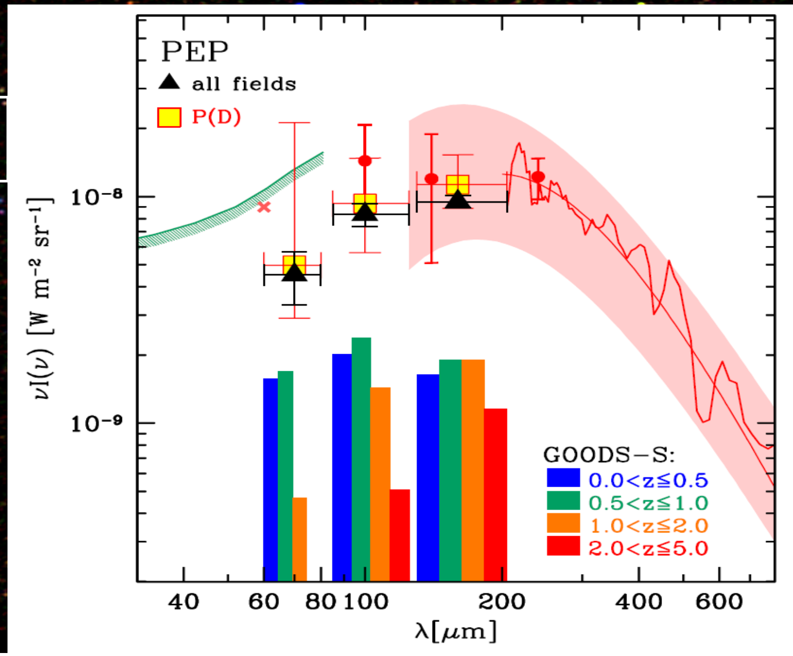
; H-GOODS

Resolving the Cosmic Infrared Background





Berta+ 2010, 2011



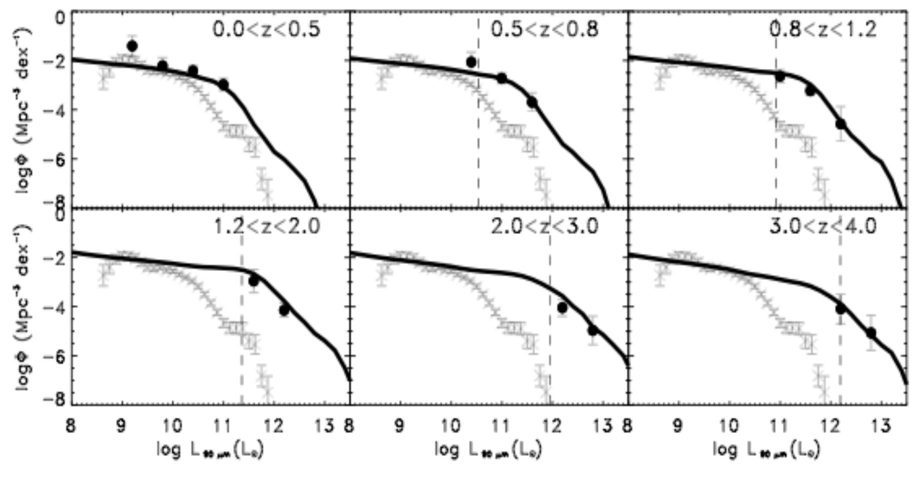
10x deeper than Spitzer

Resolved into individual sources:
(~35% @ 70μm)
~58% @ 100μm
~74% @ 160μm

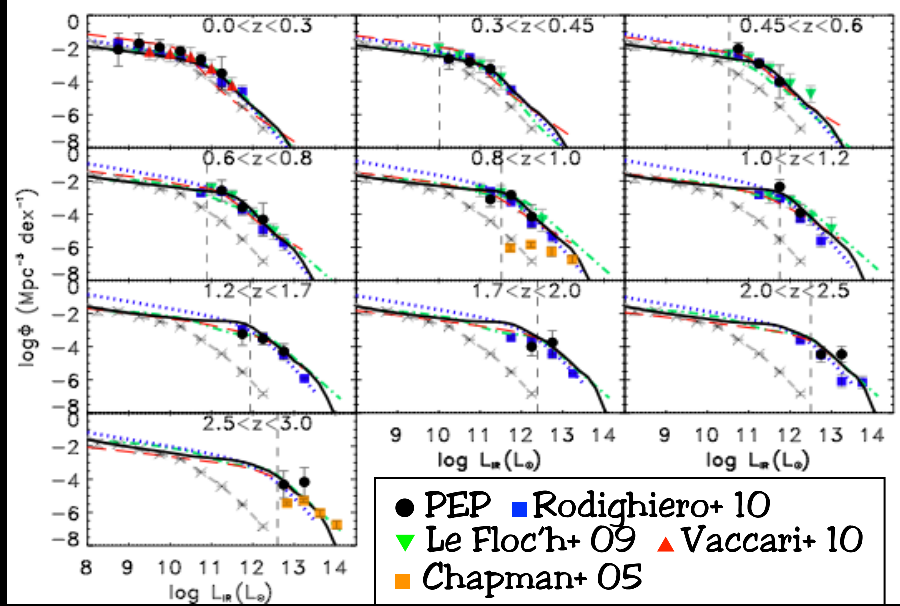
First Herschel Probe of Dusty Galaxy Evolution up to z~3

Gruppioni+ 2010

90 μm Rest-frame LF



Total IR LF

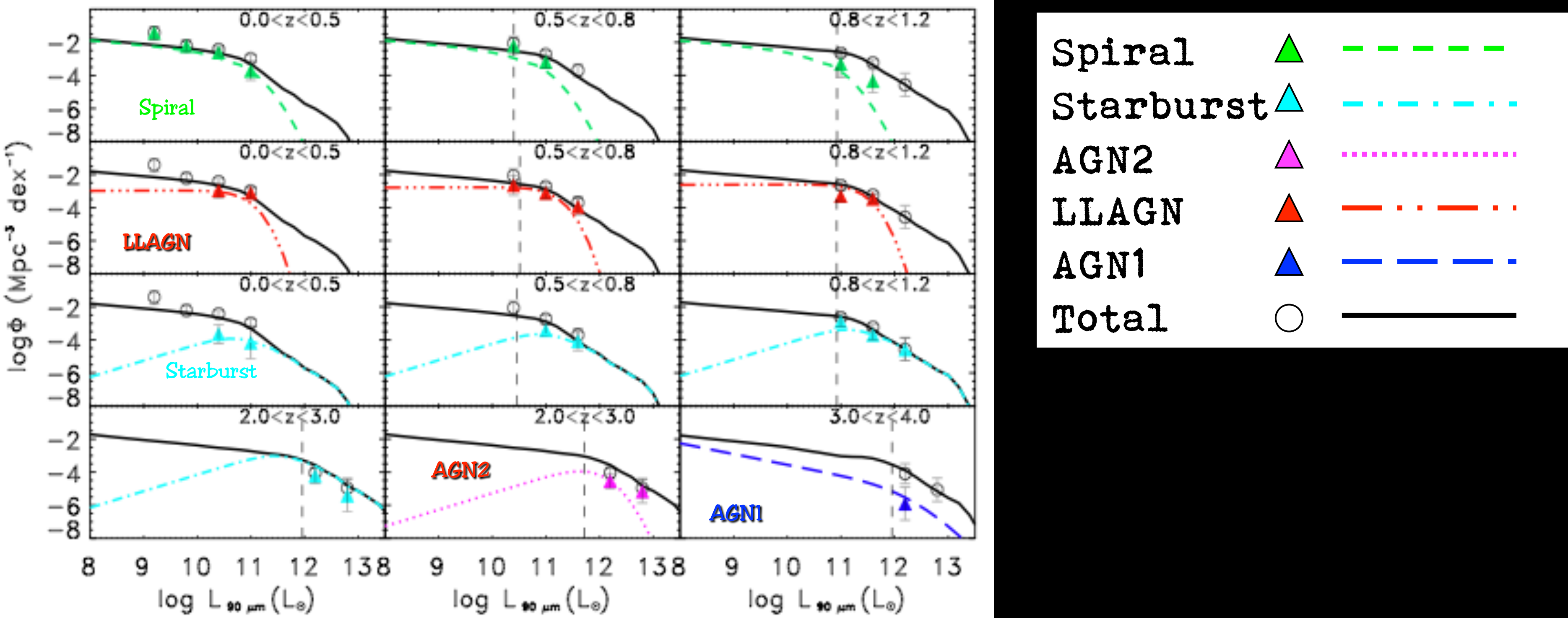


- First Rest-frame 60 and 90 μm LF up to z~4
- ➜ strong evolution
- Good agreement between data and models

- Total IR LF up to z=3
- PEP total IR LF in agreement with previous derivations from MIR
- STRONG EVOLUTION up to z~1.5-2 ($\propto(1+z)^4$)
- almost constant at z > 2 (NOT well constrained)

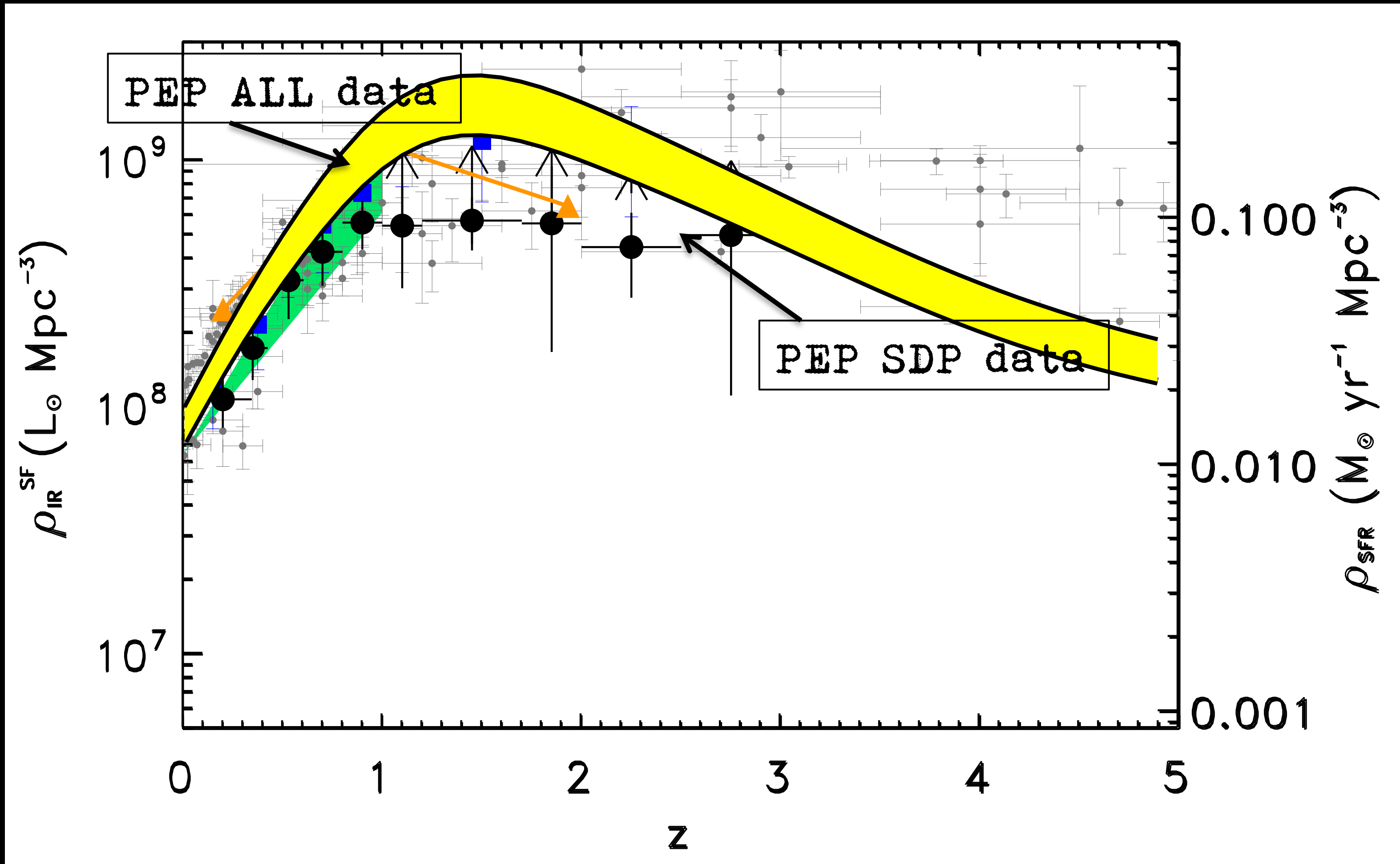
First Herschel Probe of Dusty Galaxy Evolution up to z~3

LF by population



- Galaxies containing a LLAGN dominate the LF around L* ($10^{10.5}L_\odot<L_{90}<10^{11.5}L_\odot$) at $0.5<z<1.2$ (then starburst galaxies prevail)
- The AGN1 and AGN2 populations are never dominant in the FIR, significantly contributing to the LF only at $z > 2$
- spiral galaxies dominate at $z<0.3$, while starbursts at high L and $z>1$

First Herschel Probe of Dusty Galaxy Evolution up to z~3

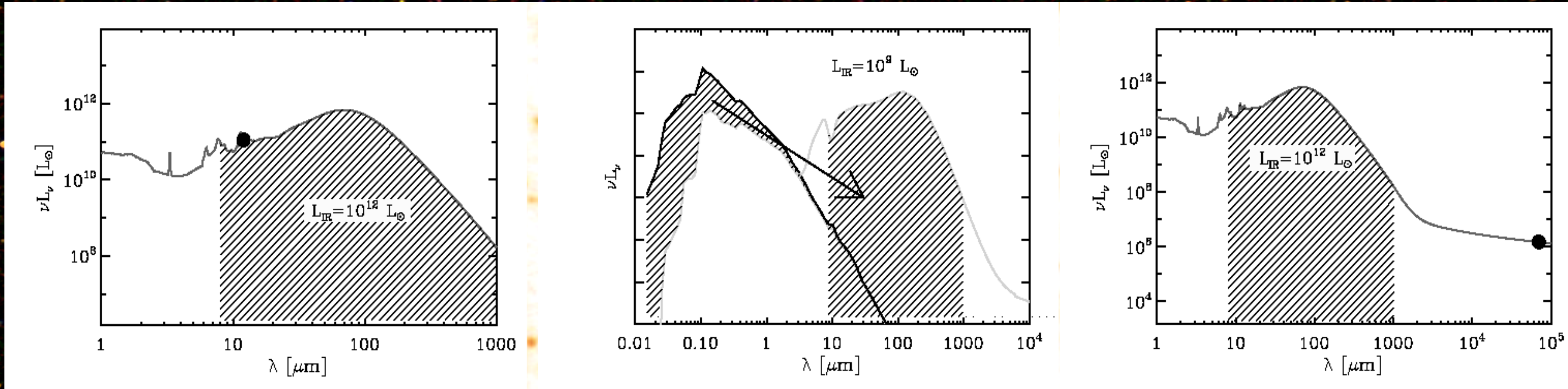


IR Luminosity density & SF density up to z~3-4

The need for far-IR calorimetric star formation rates

Our community has been relying almost exclusively on extrapolation from the optical and mid-infrared as the avenue towards studying galaxy evolution.and star formation rates

- We know this extrapolation is pretty good
- **But how good?**

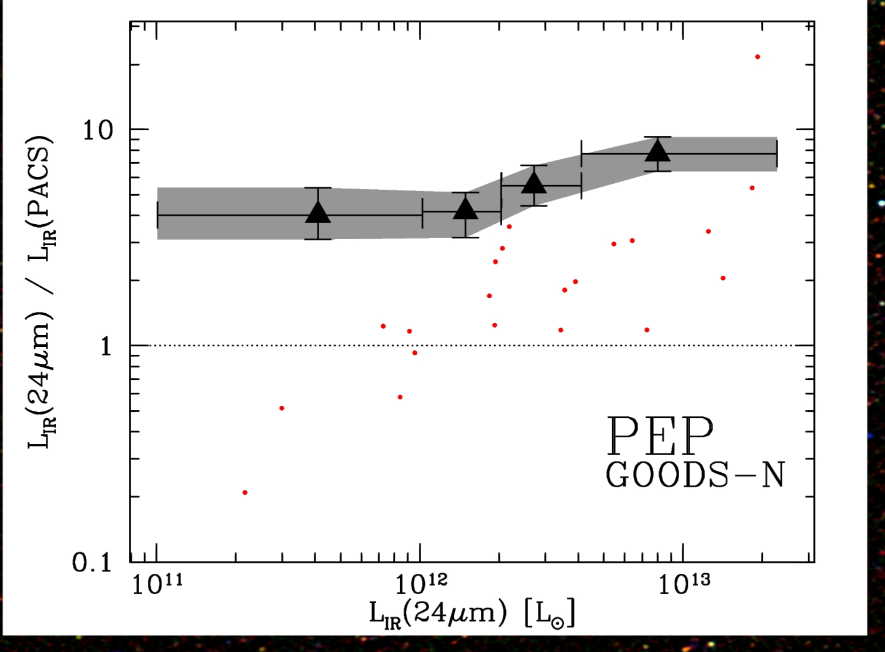


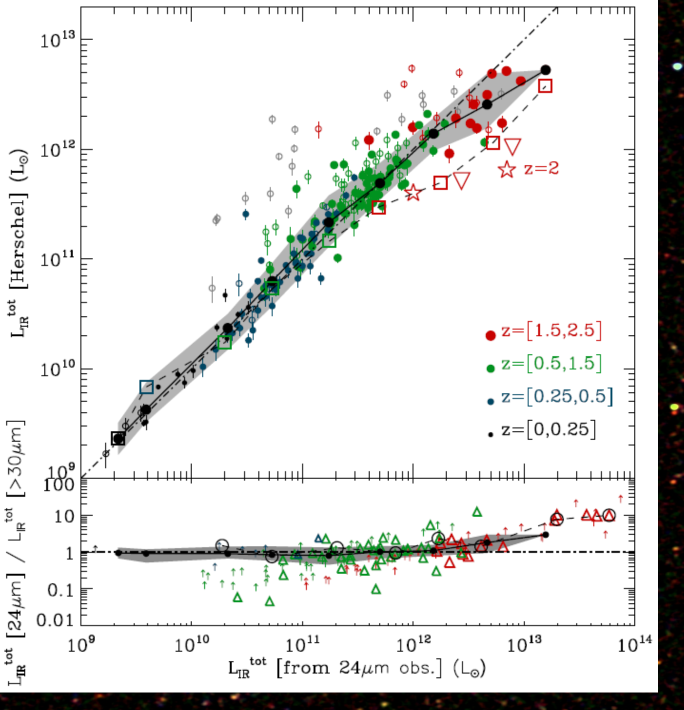
From 24μm — From rest frame UV — From submm/radio

The IR 'excess': overpredicted SFR from 24μm at z~2

SFRs based on 24-μm and Chary & Elbaz 01 templates overpredict the calorimetric FIR by factors of 4-7.5 at z~2

Change of SEDs' PAH/IR at given L, or mid-IR contribution by (obscured) AGN?

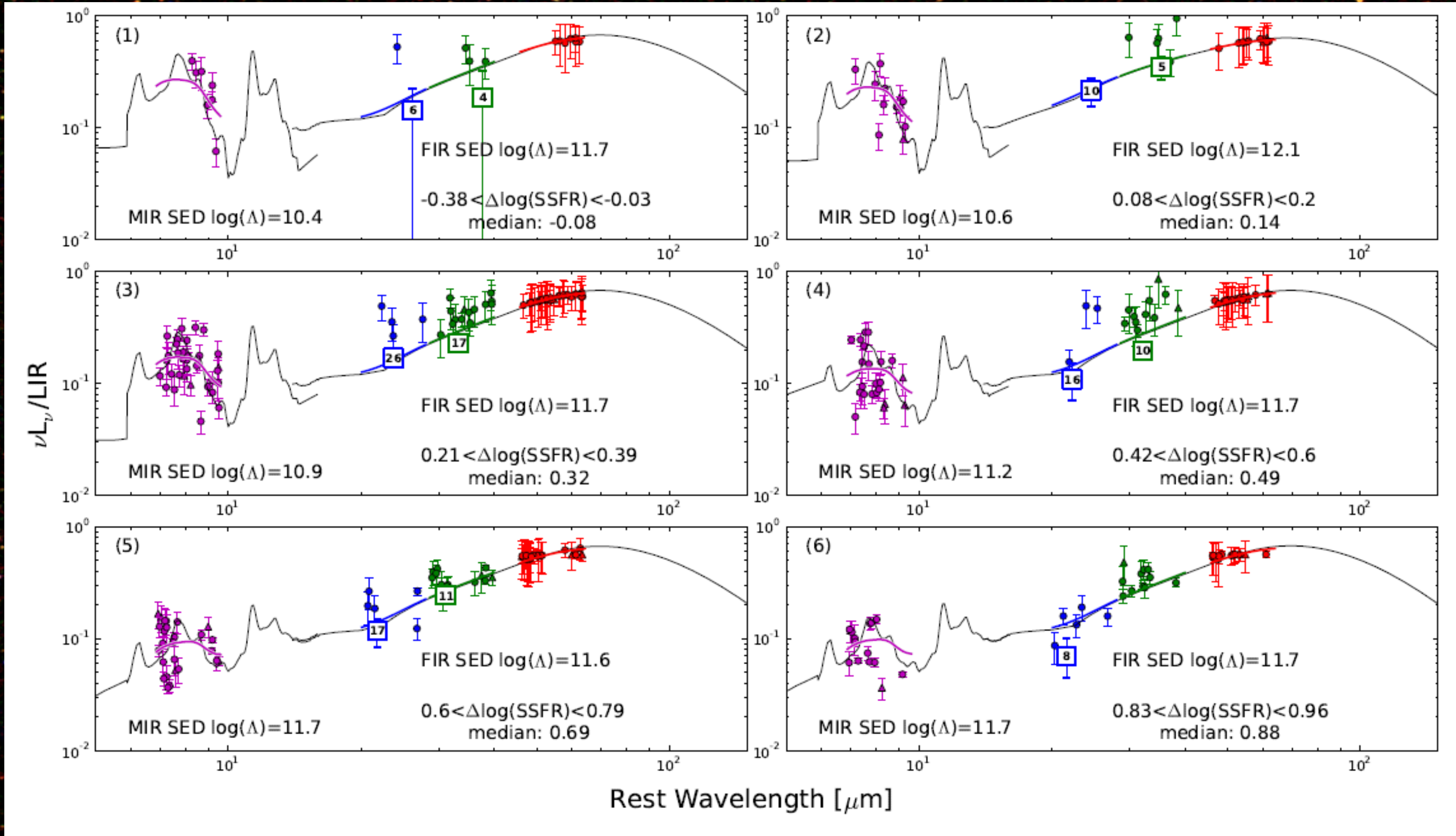




Nordon et al. 2010, 2011 + Elbaz et al. 2010

Extrapolations from rest-frame UV overpredicts by a factor of ~2 modification of extinction law needed?

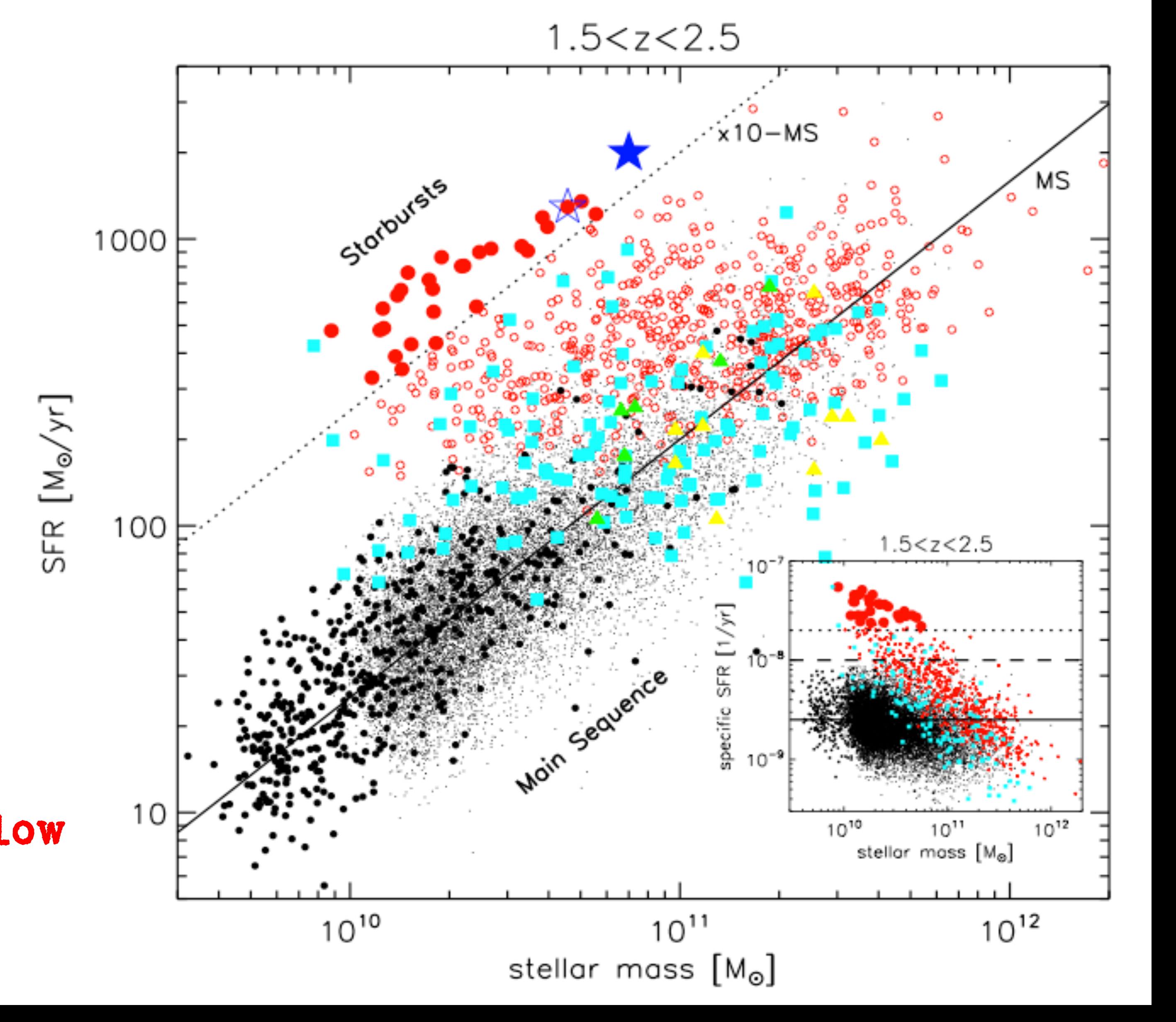
Reconstructing average mid-to FIR SEDs of z~1-2 FIR detected galaxies



SEDs and νLν(8)/IR from combination of Herschel/PEP with deep Spitzer MIPS/IRS peakup imaging

Nordon+ 1106.1186

What is the importance of above-MS star formation?

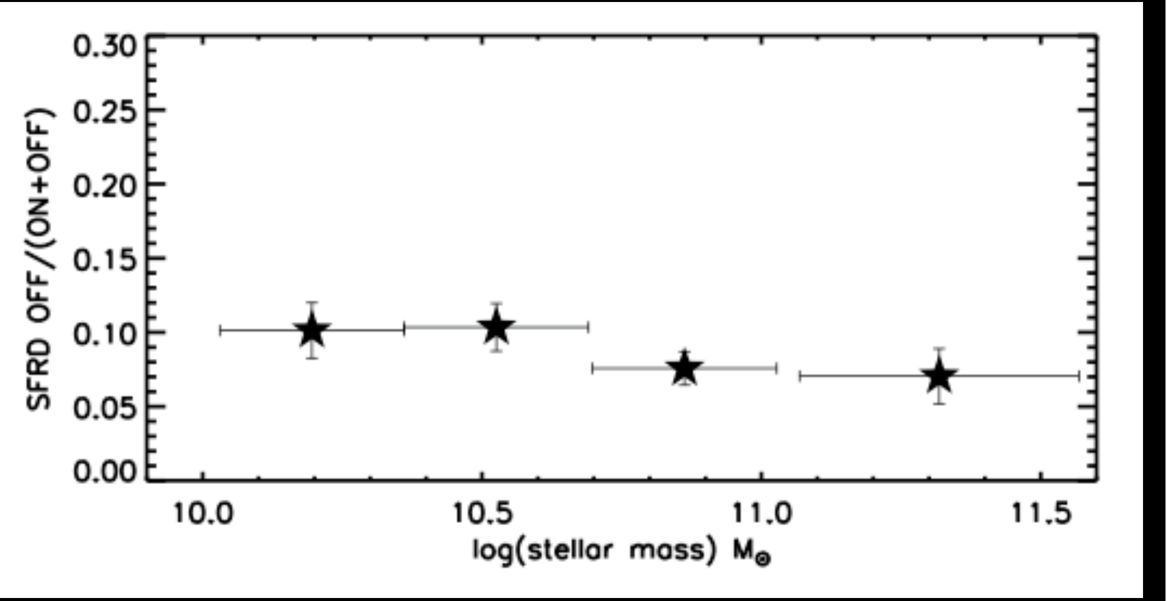


Rodighiero+11
A&A in press

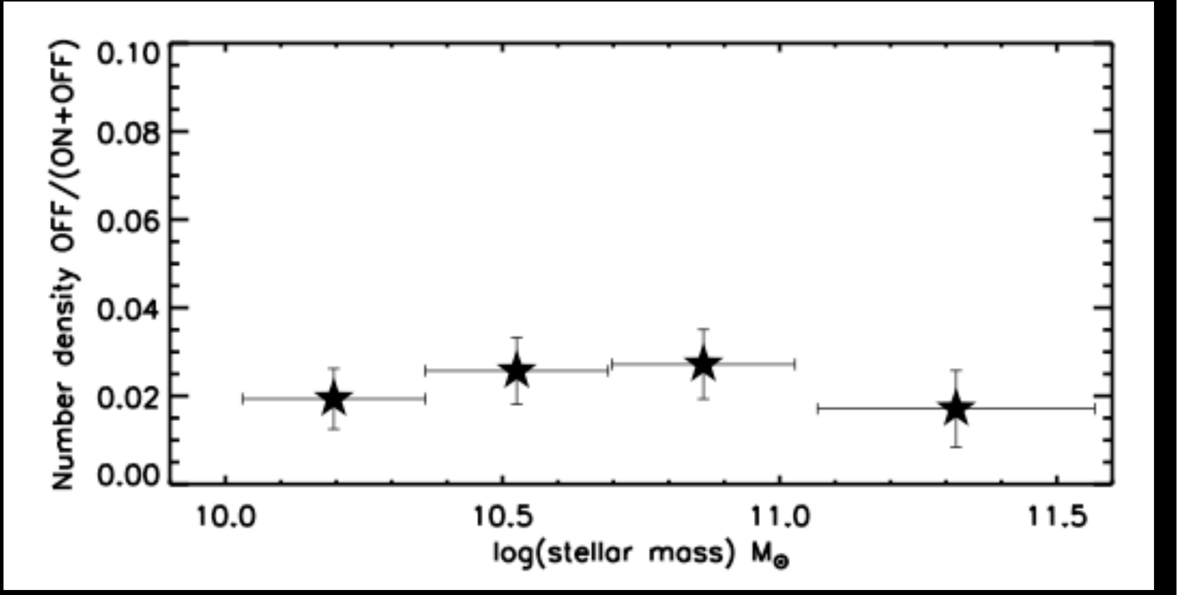
PACS-shallow
PACS-deep
BzK

Objects >4x above main sequence

~10% of SF density



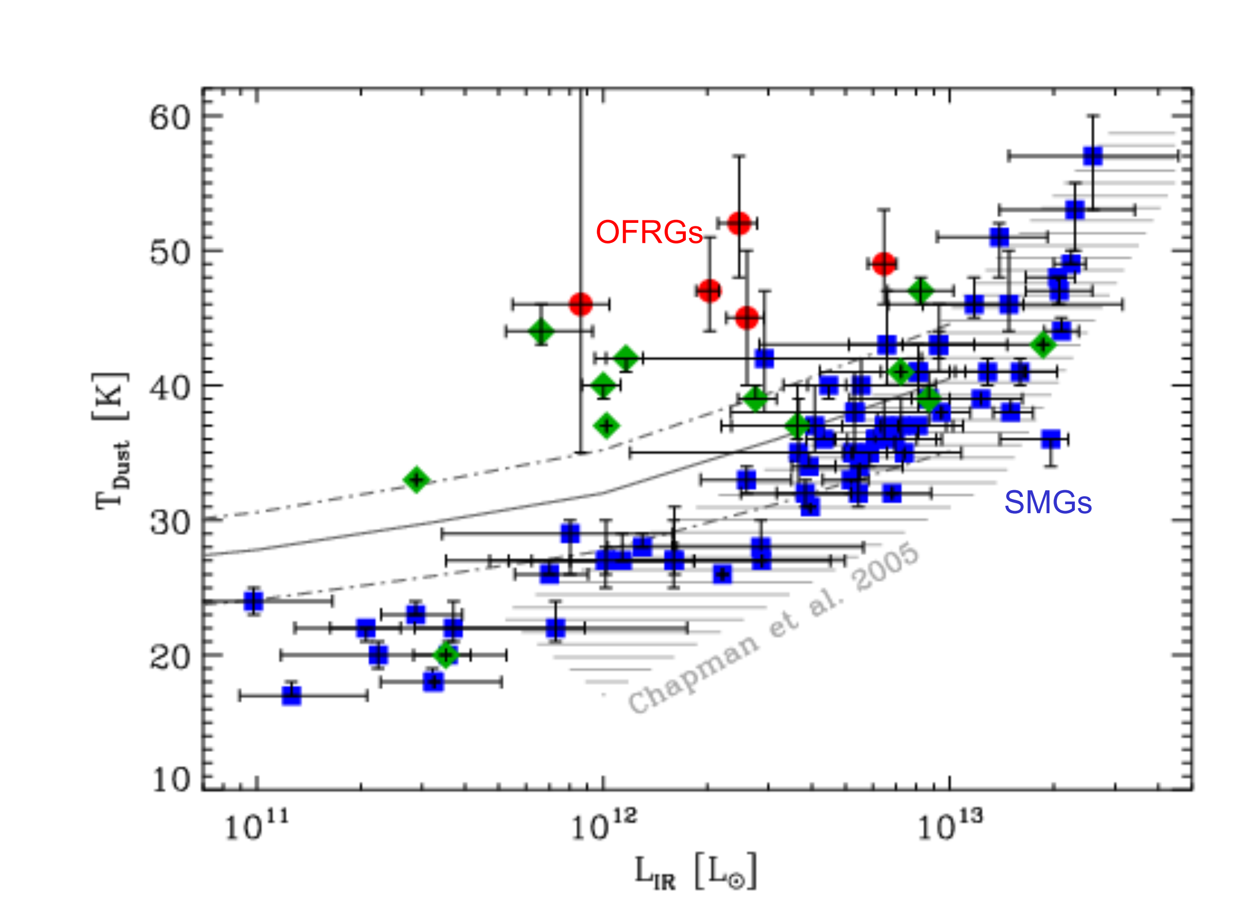
2% of number density



On average, each galaxy ~20Myr in this phase – short wrt period of elevated SFR in major mergers

Not all galaxies going through major merger in 1.5<z<2.5

Properties of the most luminous IR galaxies: the case for SMGs



Heterogeneity of the SMG population:

1. Extreme L_{IR} (~10^{13} $L_\odot$) and warm T_{dust} (50 K)

2. Fainter L_{IR} (few 10^{12} $L_\odot$) and colder T_{dust} (20-30 K)

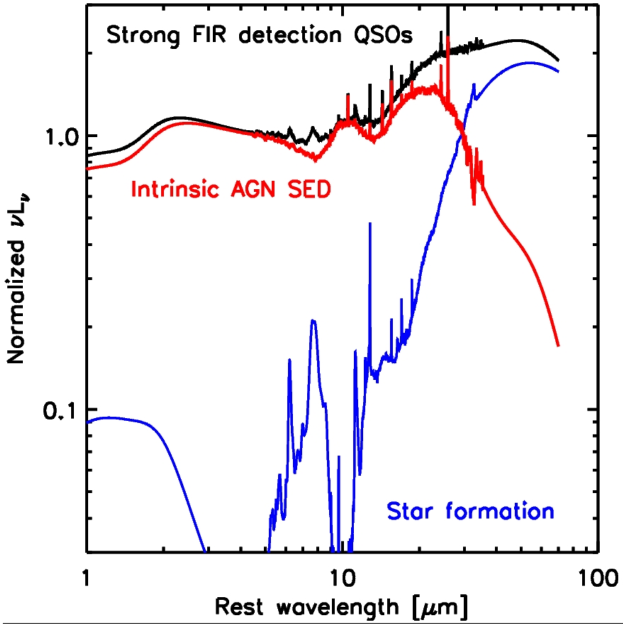
1. Major Merger vs. 2. Secular Evol. ?

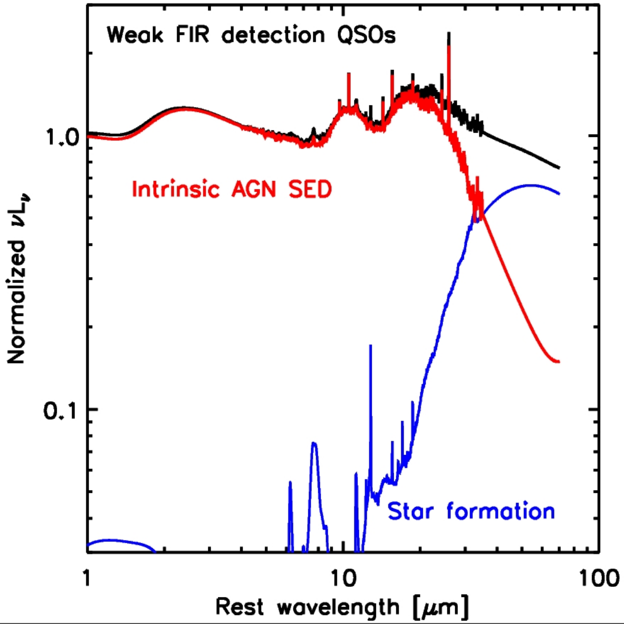
Star formation rates ~1000 $M_\odot$/yr

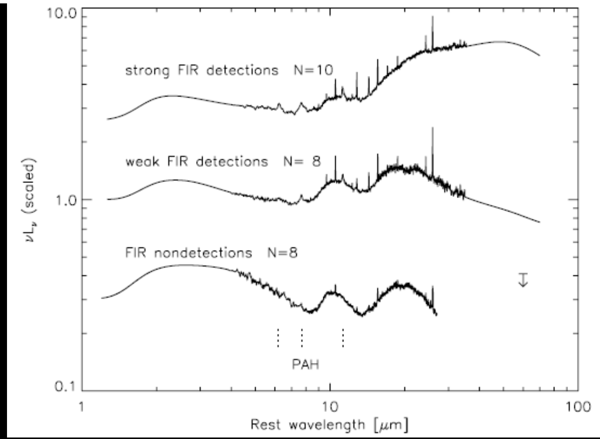
.. Note selection effects

Magnelli et al. 2010 and in prep., see also Chapman et al. 2010

Using Herschel to study AGN host star formation





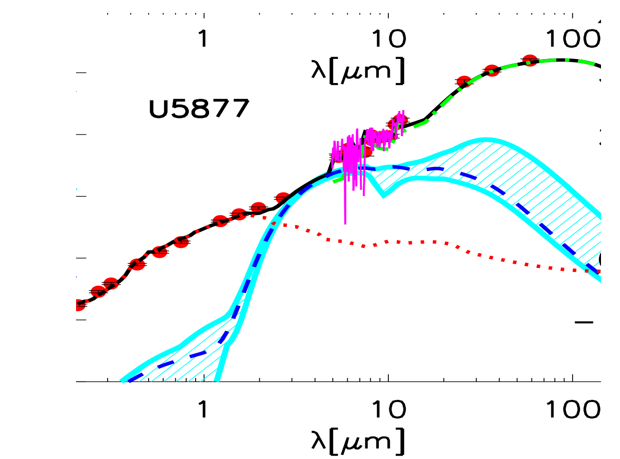


QSO SEDs from Netzer+07

FIR is SF indicator down to L(FIR)~0.1 L(BOL,AGN)

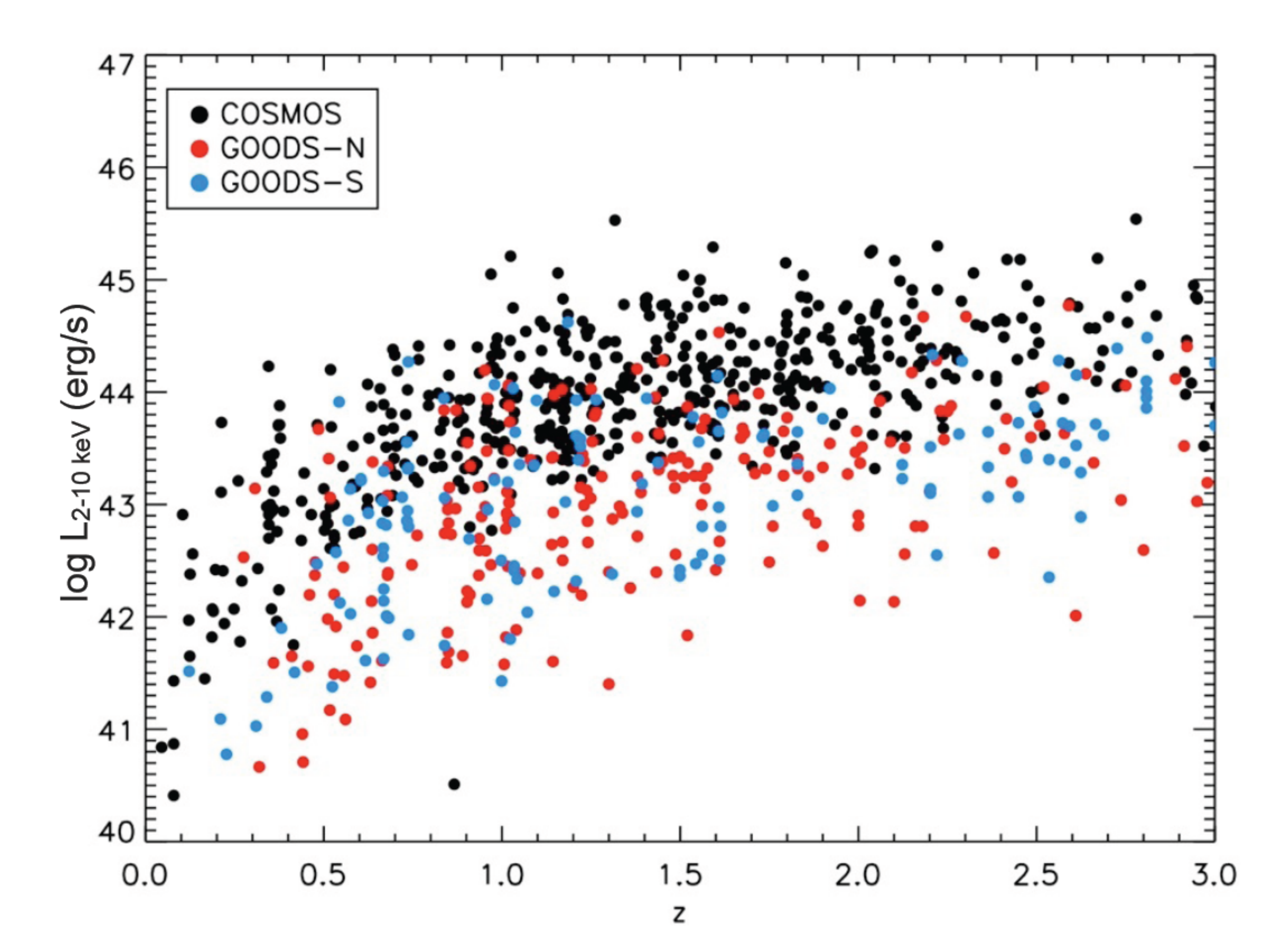
Pozzi+11, A&A submitted

The AGN content in ULIRGs at *z*~2 from Herschel



ULIRGs at z~2 are mainly powered by star-formation. AGN detected in ~35% of the sources but its energy contribution L(8−1000 μm) is only ~5% (~23% over the 3−35 μm range)

AGN over a wide L,z range

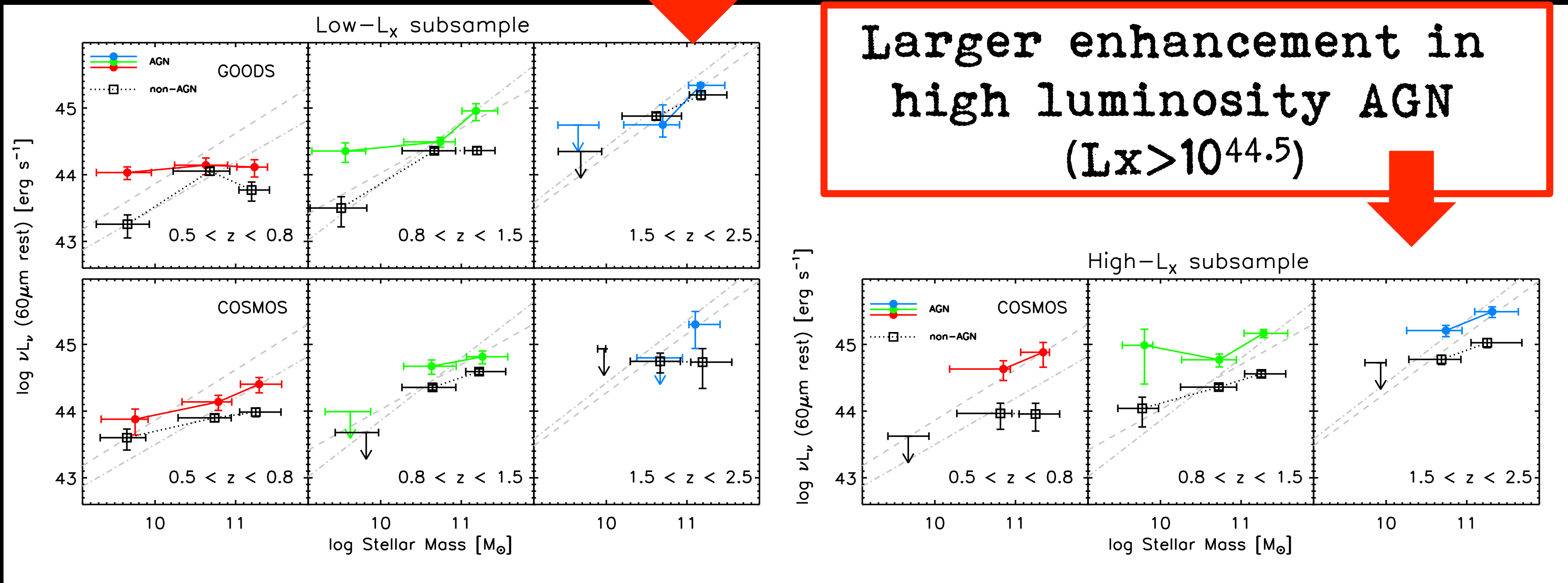


Enhanced SFR in AGN hosts

Smaller enhancement in moderate luminosity AGN ($L_X<10^{44.5}$)

Santini et al. 2011, in preparation

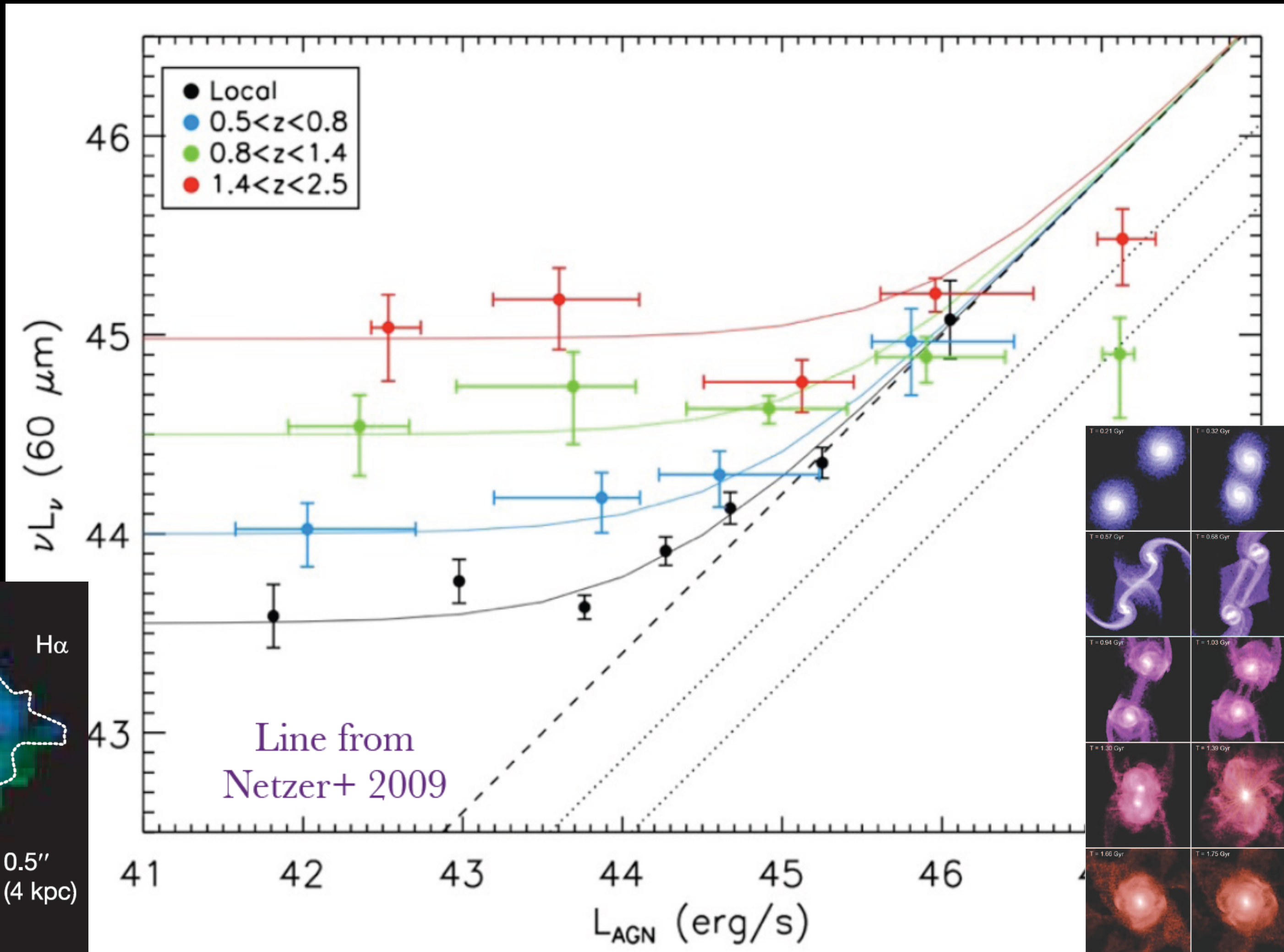
Larger enhancement in high luminosity AGN ($L_X>10^{44.5}$)

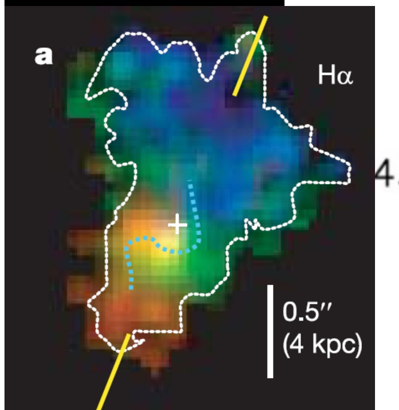


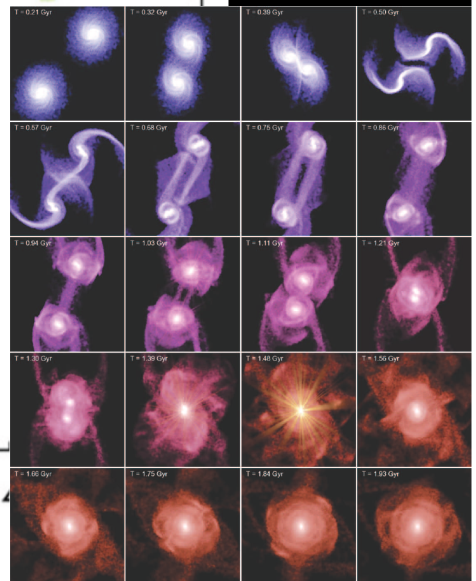
✓ Low LX AGN hosts undergo secular evolution

✓ Luminous AGNs co-evolve with their hosts through major merger iteractions

AGN / host coevolution: Merger vs. secular



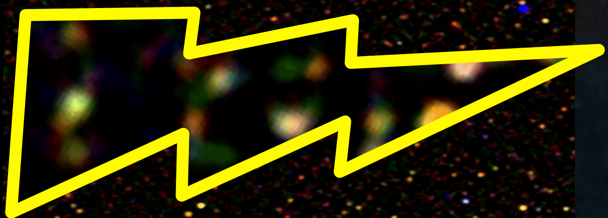


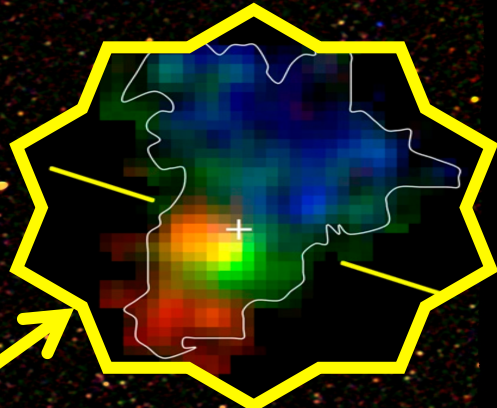


Shao et al. 2010, Rosario et al. in prep.
(see also Lutz et al. 2010 submm results, Mullaney et al. 2010 Spitzer, Mullaney+ 2011 GOODS-Herschel)

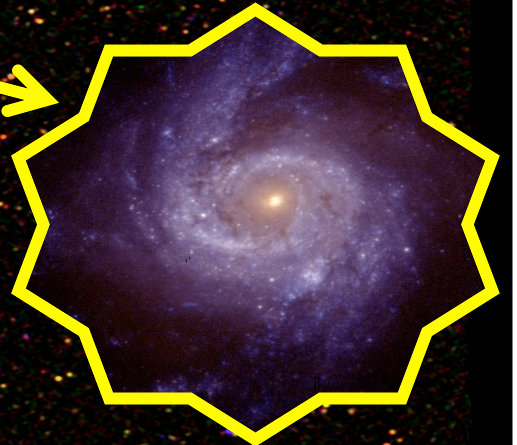
Feeding the Giants with PEP

Thousands of
IR galaxies
and AGNs





3-D spectra of
high-z ULIRGs



Morphology of
high-z dusty
galaxies