First Results from Herschel deep extragalactic surveys

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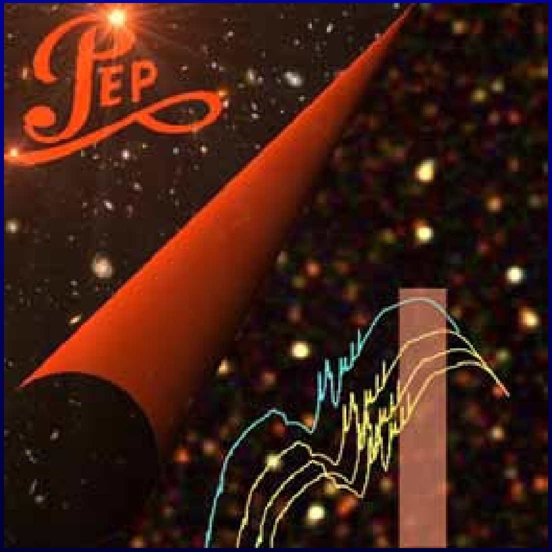
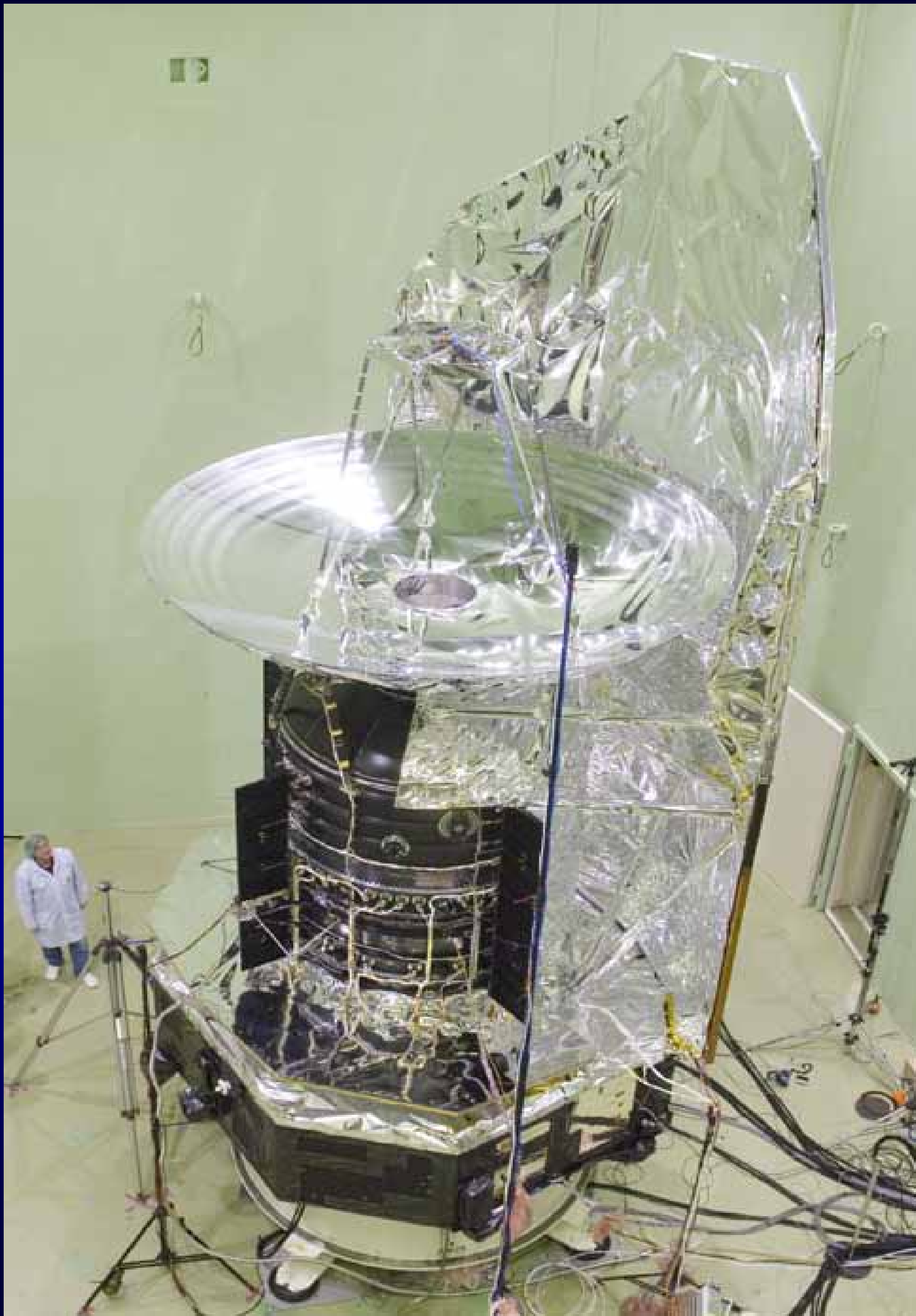
Colloquium Heidelberg

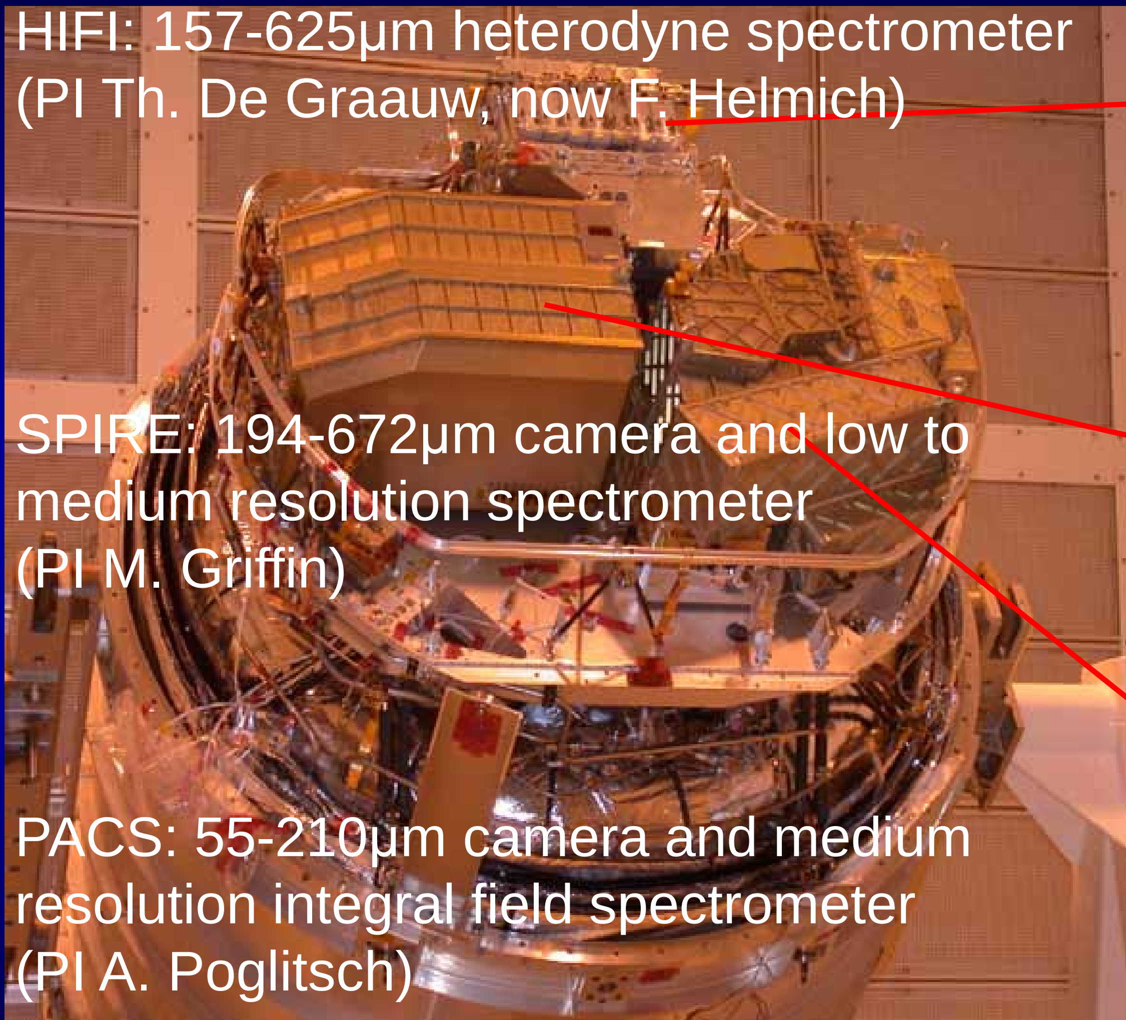
June 15, 2010

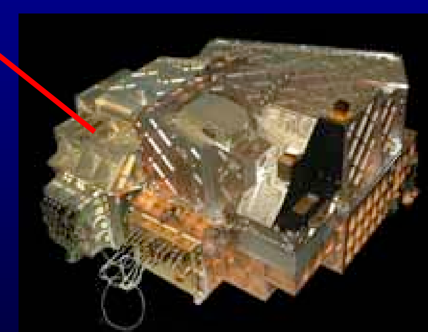


Herschel in a Nutshell

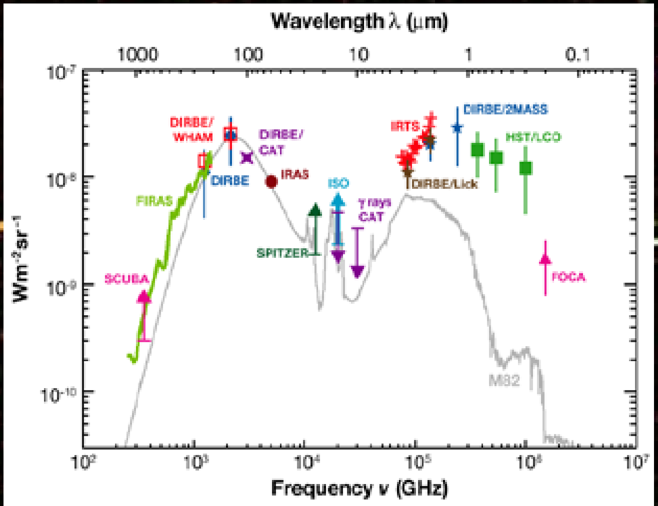
- Large telescope
  - 3.5 m diameter
  - collecting area and resolution
  - Reduced source confusion wrt. IRAS, ISO, Spitzer, Akari
- New spectral window
  - 55 − 672 μm: bridging the far-infrared & submillimetre
- Novel instruments
  - **wide area mapping in 6 ‘colours’ between 70 and 500μm**
  - imaging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




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



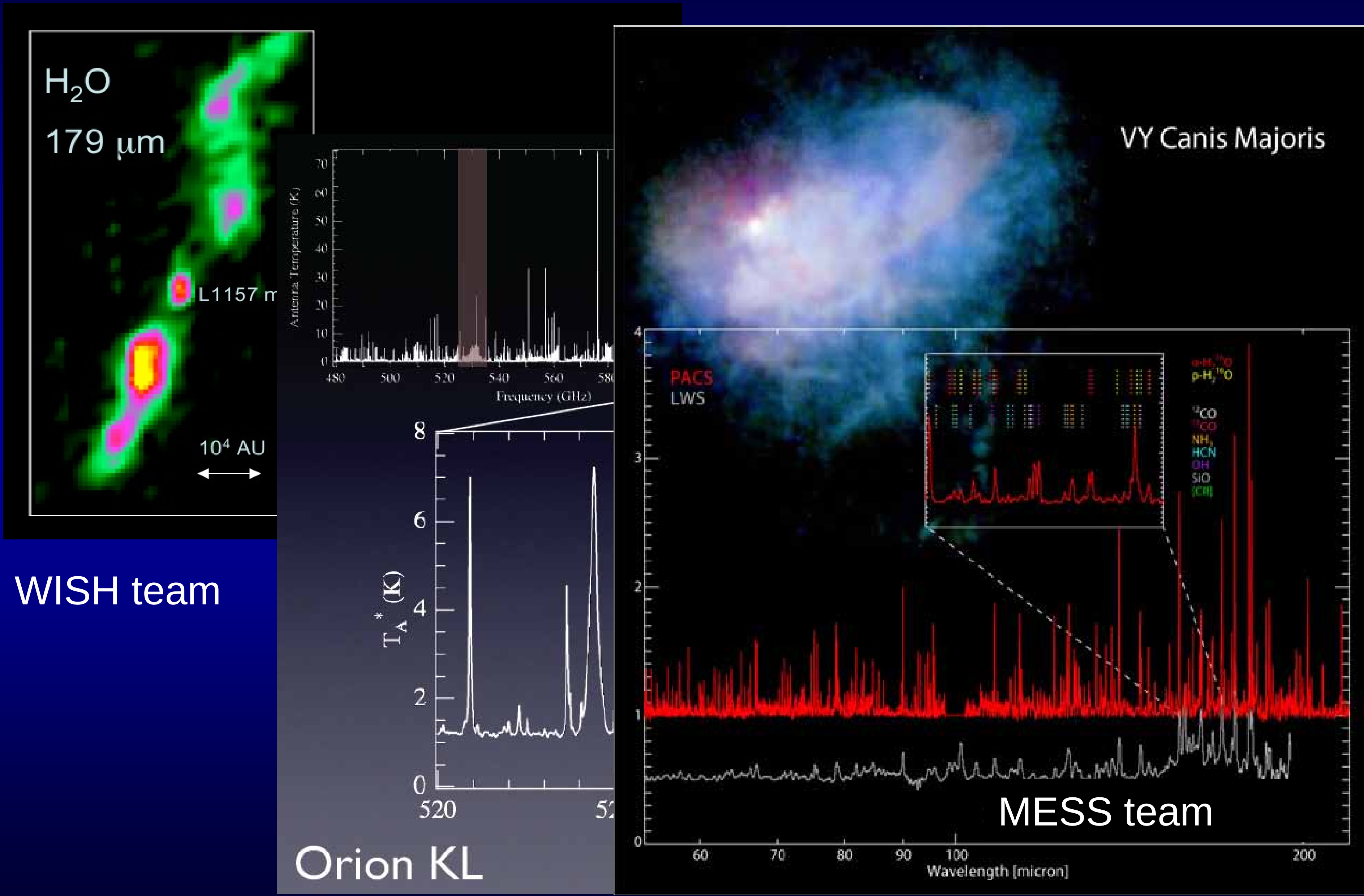
Study the formation of galaxies in the early universe and their subsequent evolution

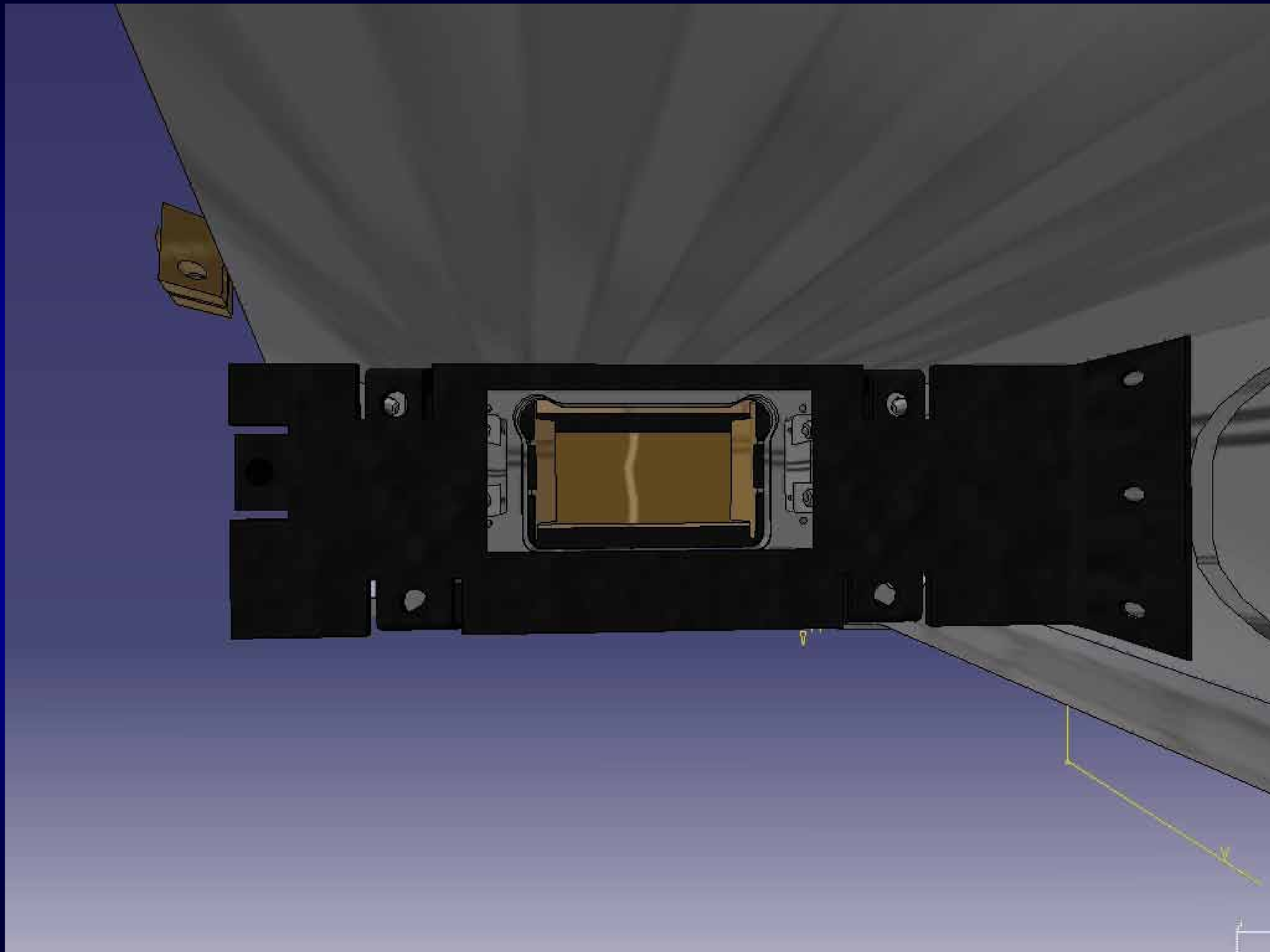


Part of COSMOS 2sq.deg. 24+100+160μm

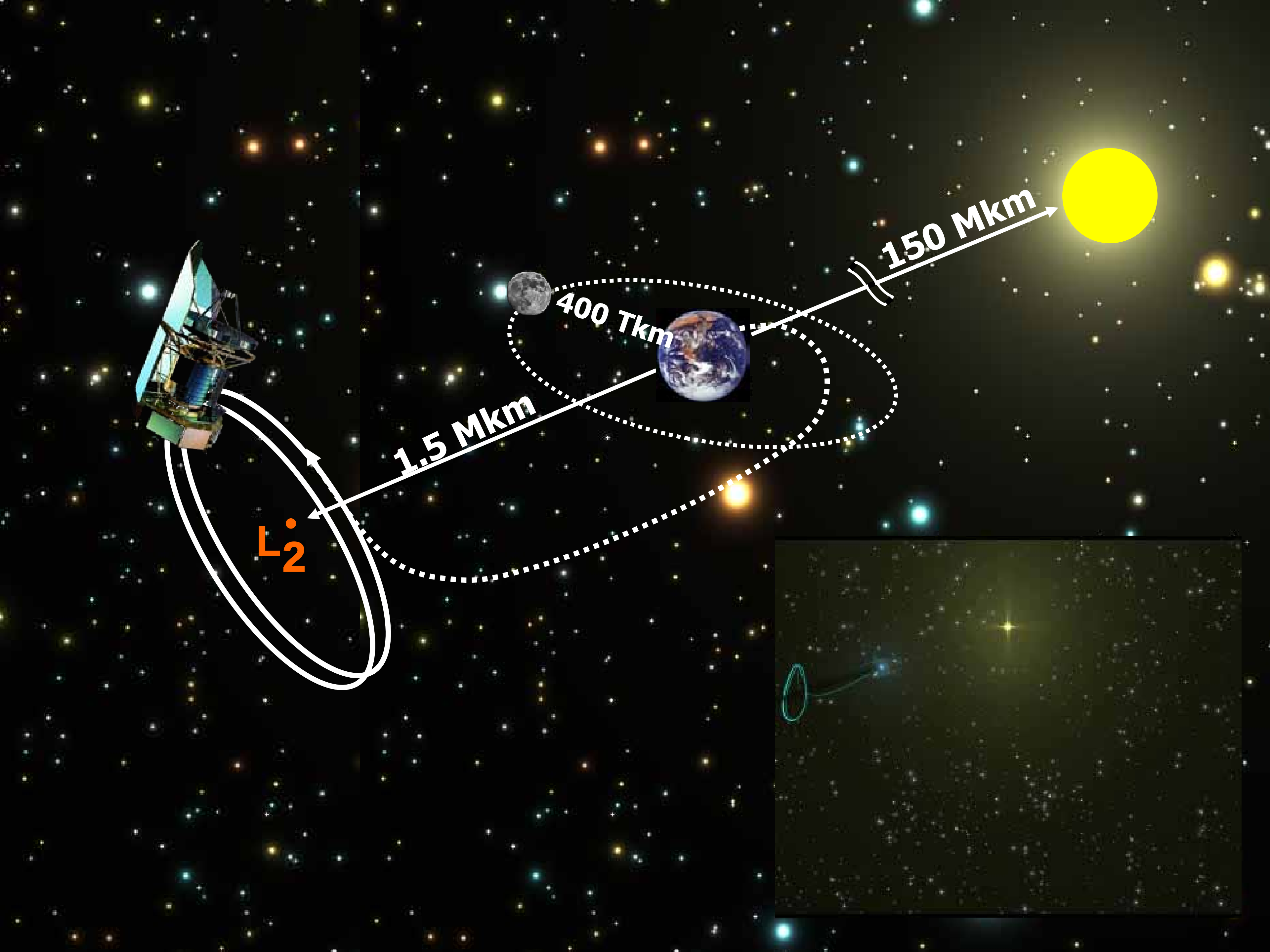
Investigate the creation of stars and their interaction with the ISM

Examine the molecular chemistry of the Universe

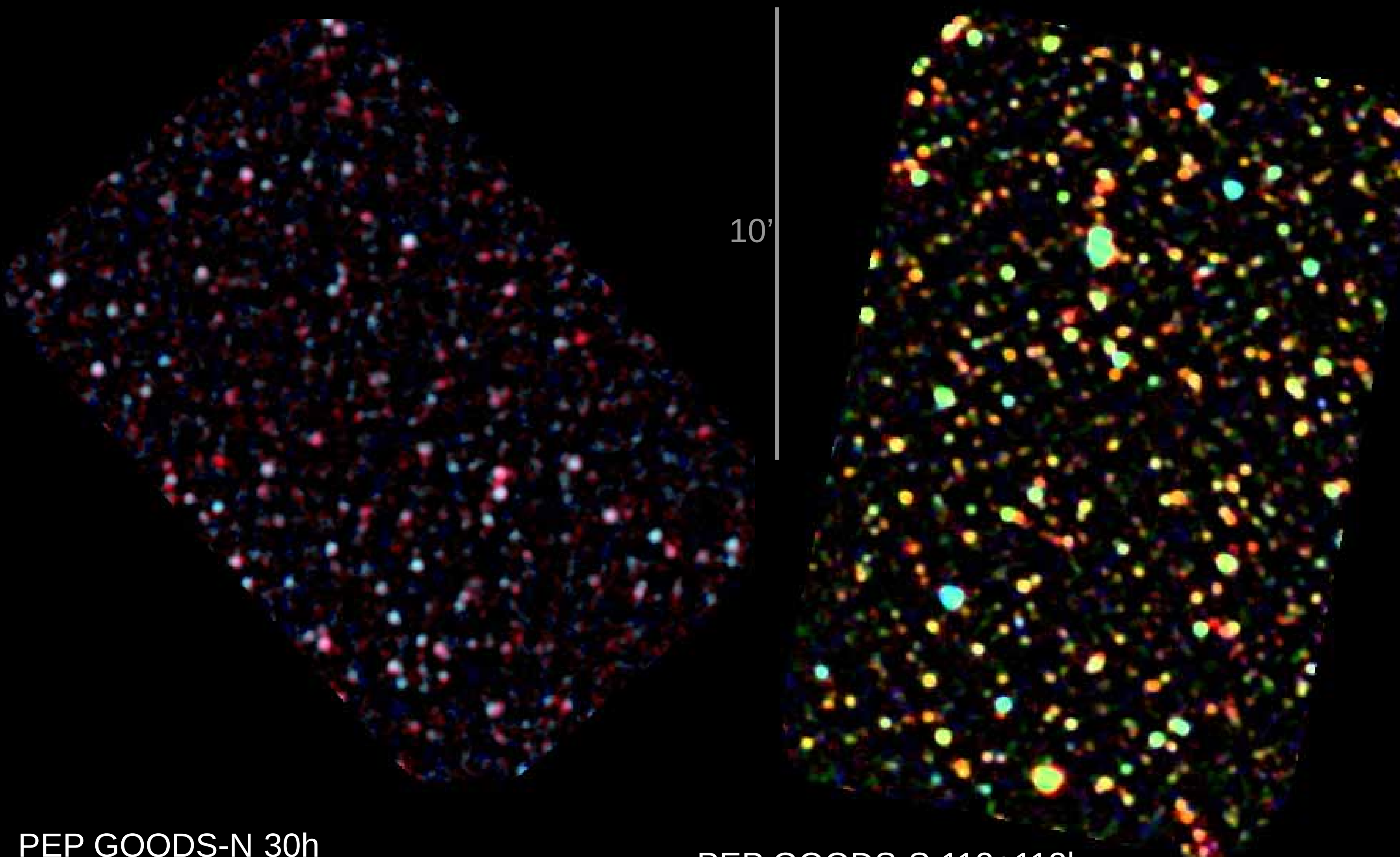





Launch
14 May 2009


150 Mkm
400 Tkm
1.5 Mkm
L2

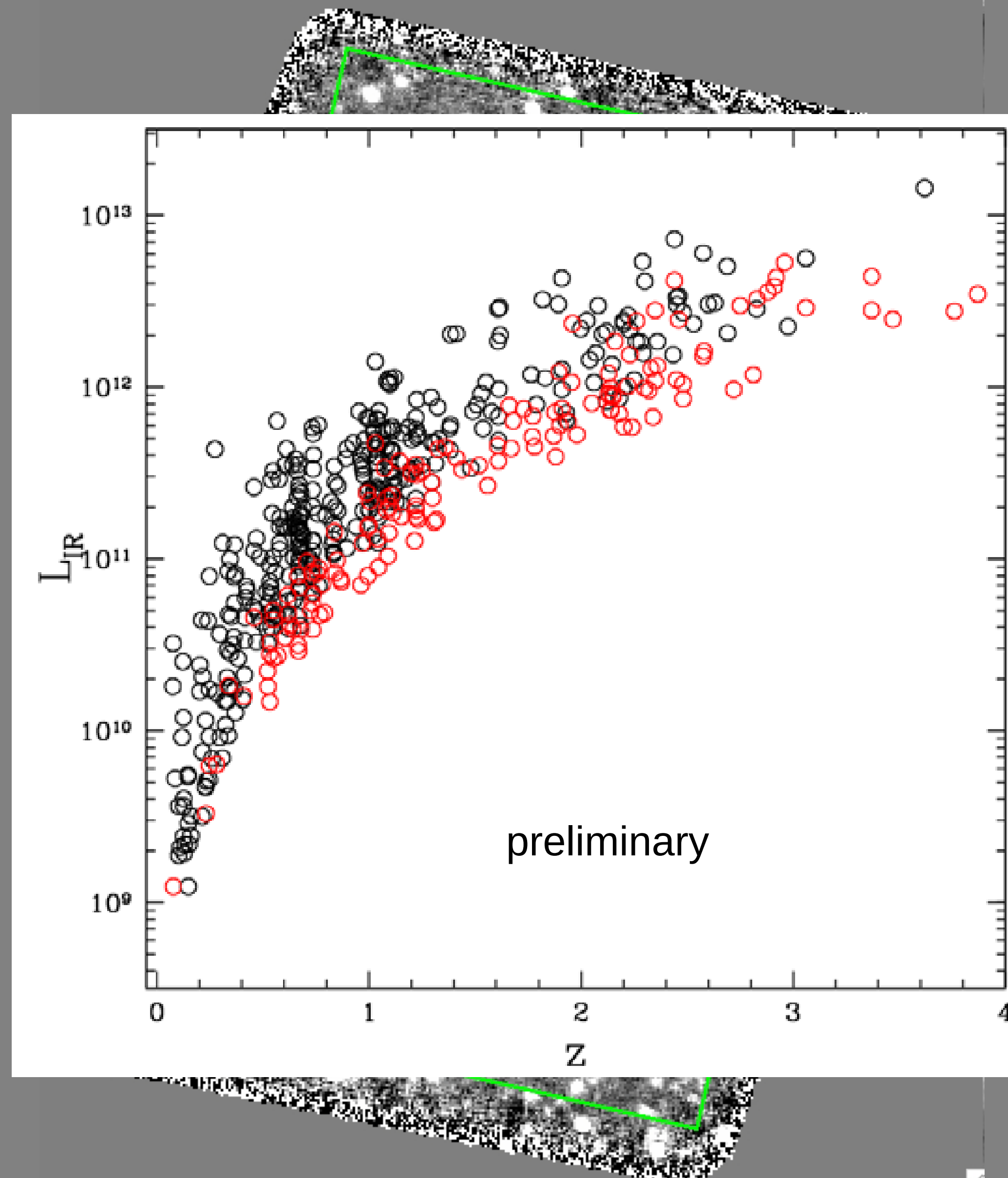
The deepest Herschel-PACS blank fields taken to date



PEP GOODS-N 30h
100+160μm during
Science demonstration phase
~300 sources

PEP GOODS-S 113+113h
70+100+160μm
~1000 sources

From MIPS to PACS



GOODS-S MIPS 160µm
FIDEL team

GOODS-S PACS 160µm
PEP team

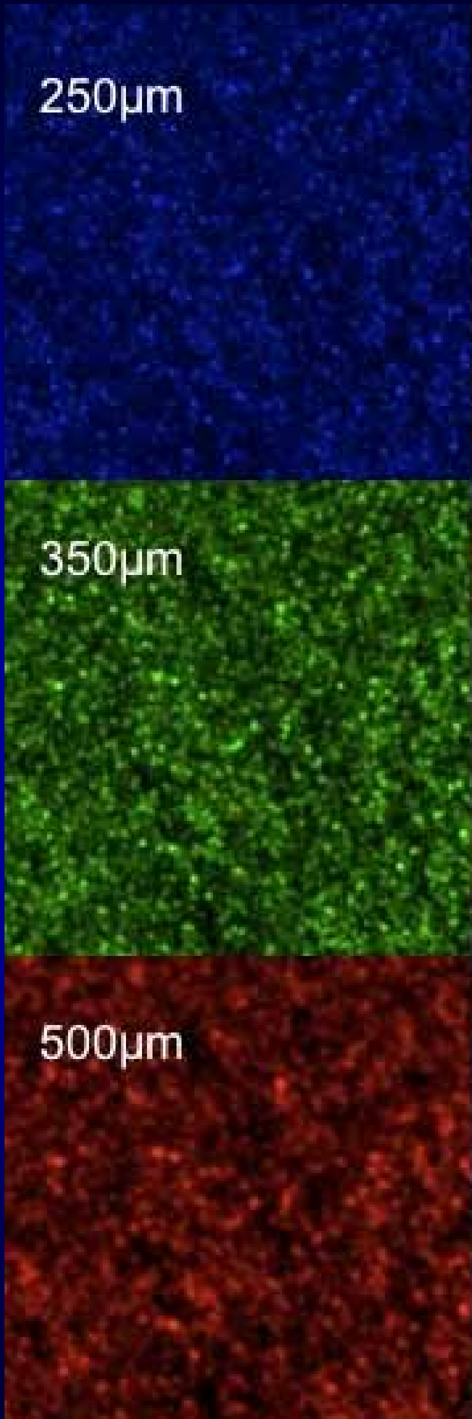
PACS Evolutionary Probe (PEP) - Fields

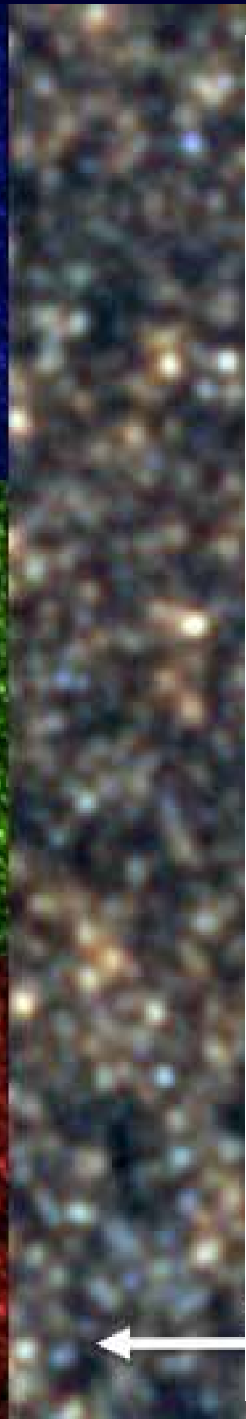
- PEP is the major Herschel 100/160μm extragalactic survey of key multiwavelength fields

Field	Area	Total Exp. [hours]
COSMOS	85'x85'	213
Lockman Hole	24'x24'	35
E-CDFS	30'x30'	35
Groth Strip	67'x10'	35
GOODS-S	10'x15'	113 113
GOODS-N	10'x15'	30

- +10 lensing galaxy clusters

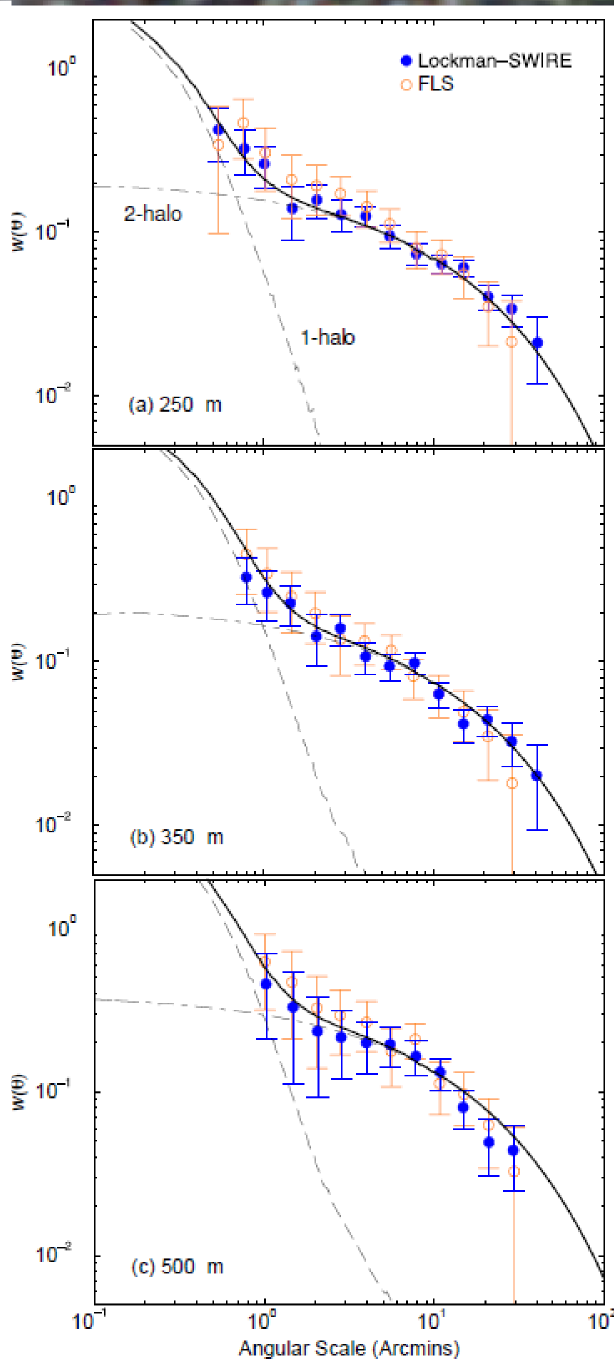
- Coordinated with Hermes for SPIRE coverage
- Hermes and Atlas extend to wider+shallower PACS coverage
- GOODS-Herschel will go deeper on (parts of) GOODS fields
- Herschel lensing survey substantially extends the number of lensing clusters



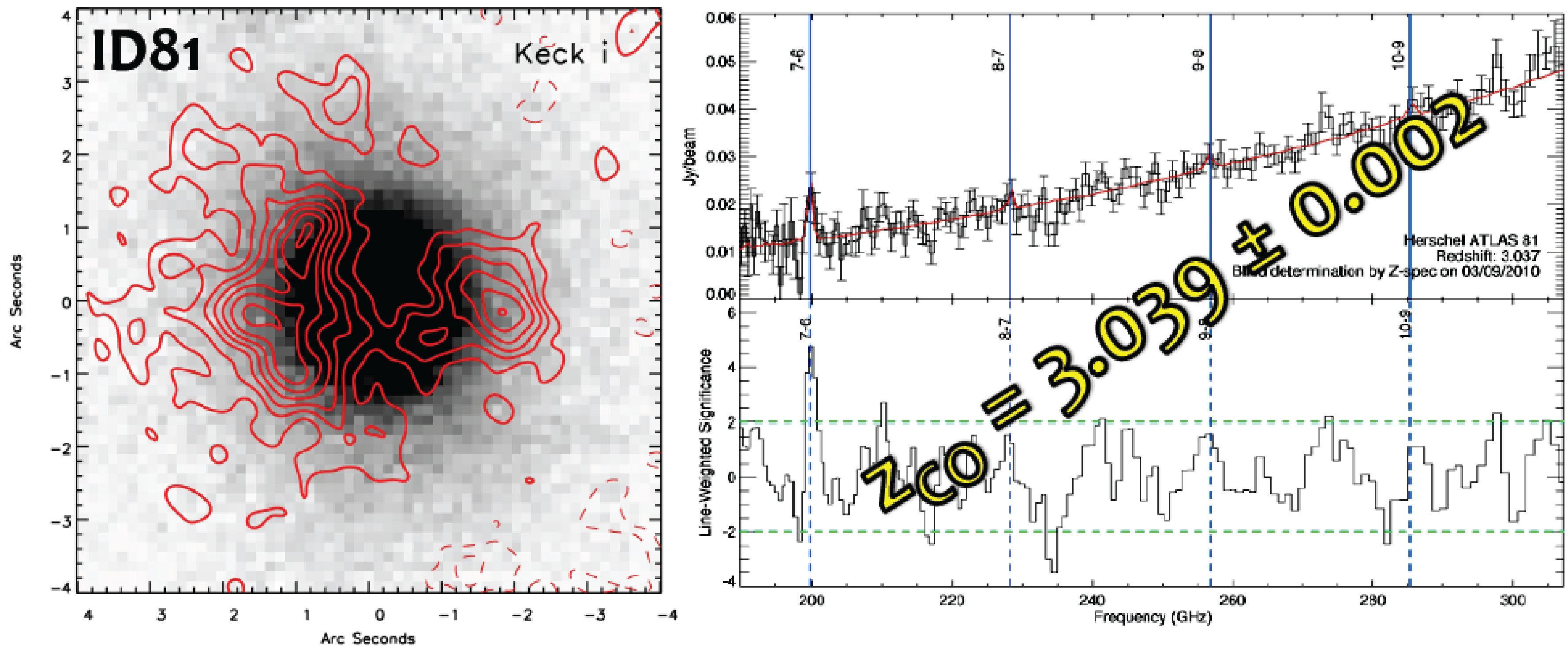


HERMES team
Cooray+ 10

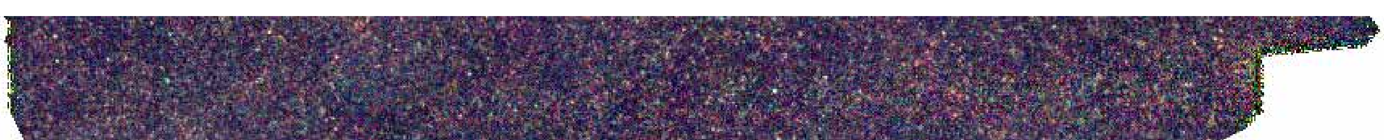
Clustering analysis
~5 $10^{12} M_{Sun}$ halos



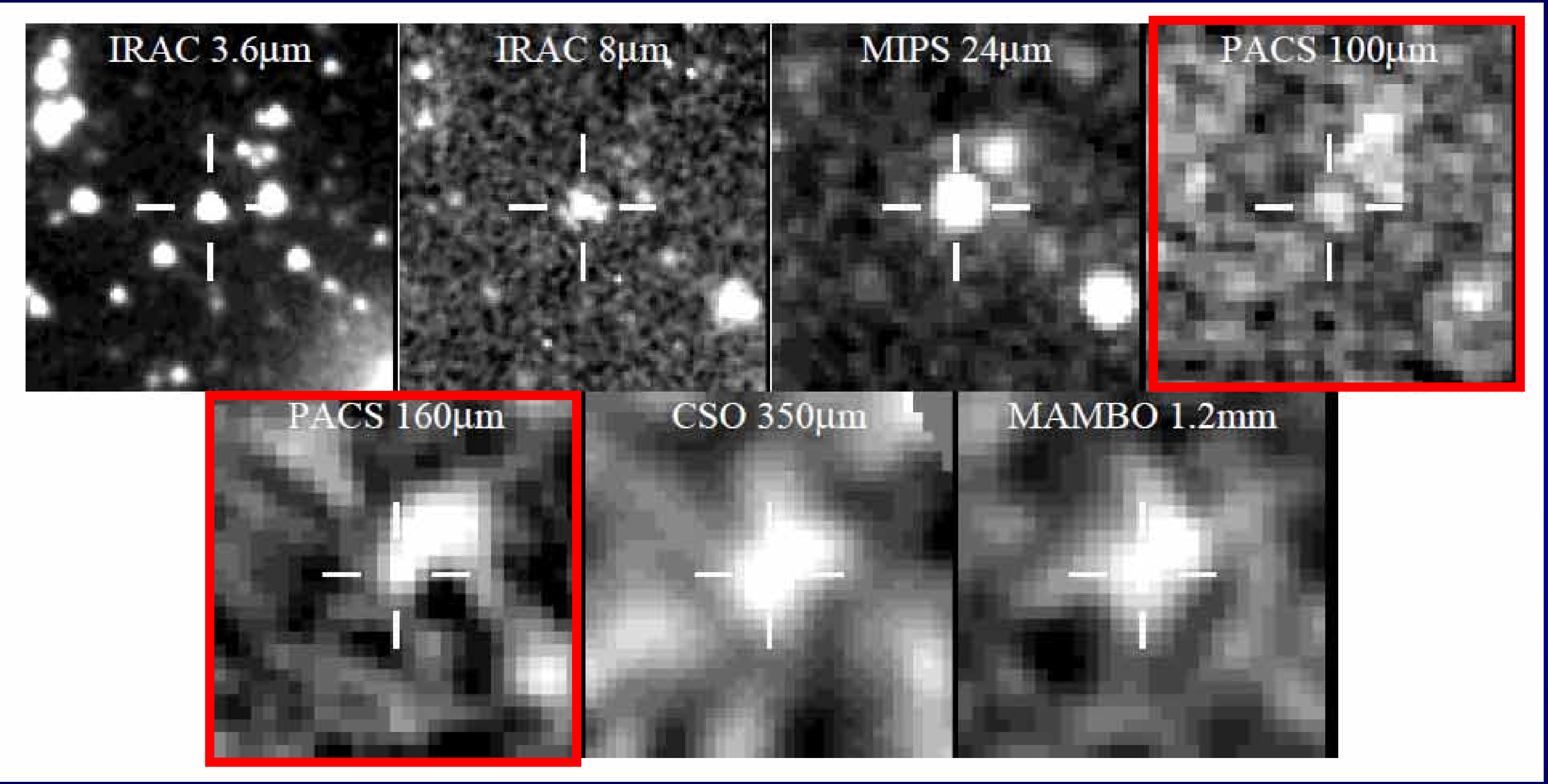
H-ATLAS 4*4deg
250/350/500μm



H-ATLAS Negrello+ and follow up teams with SMA, ZSPEC, IRAM PdB, Keck…

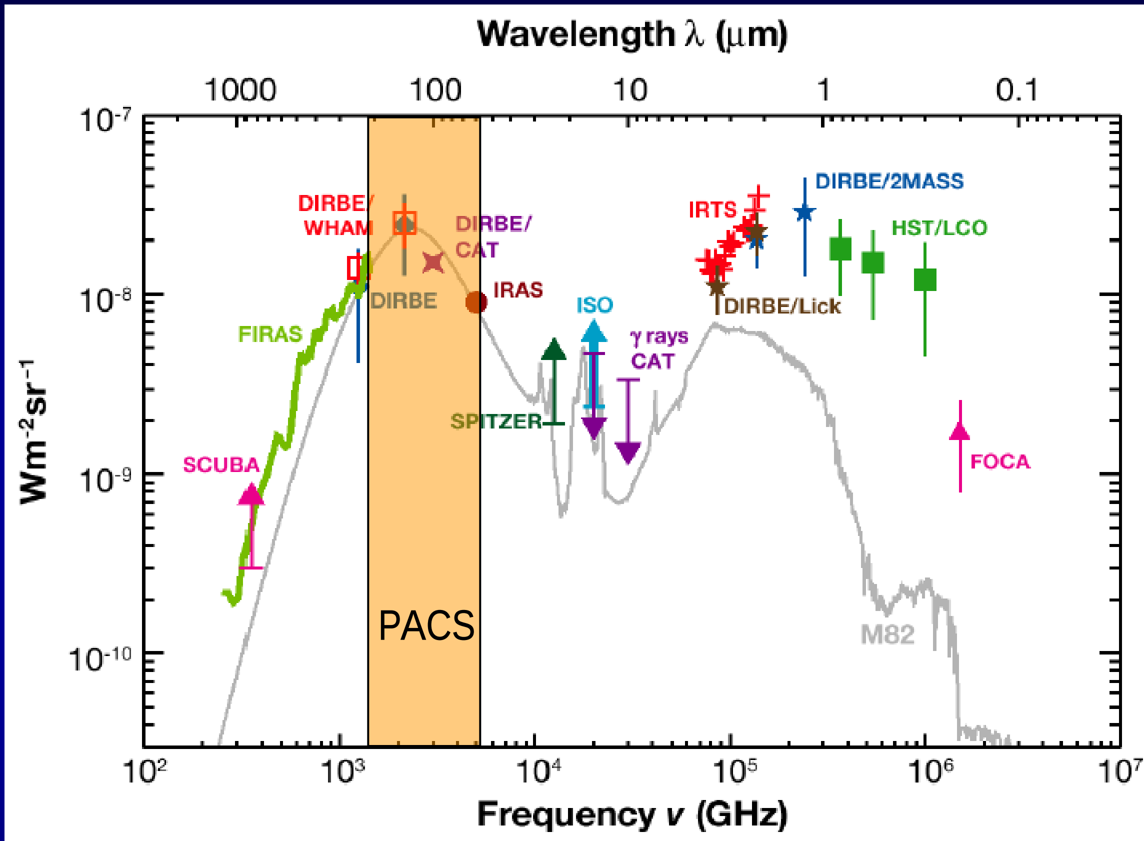


J1148+5251 z=6.42 QSO

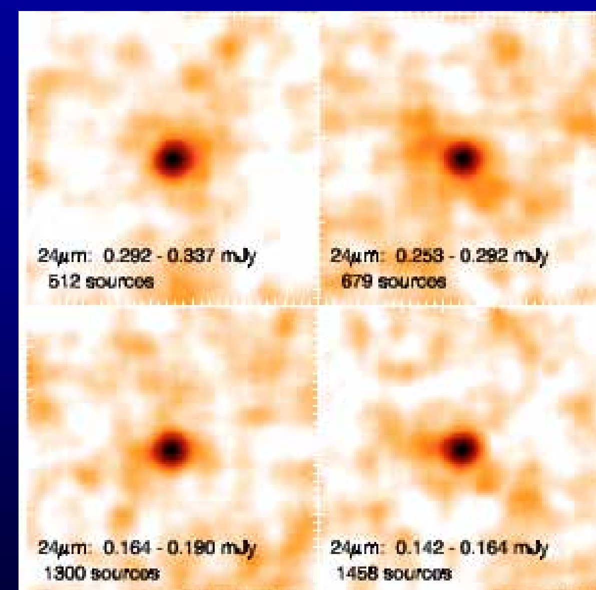


Leipski+ 10

Resolving the Cosmic Infrared Background with PACS

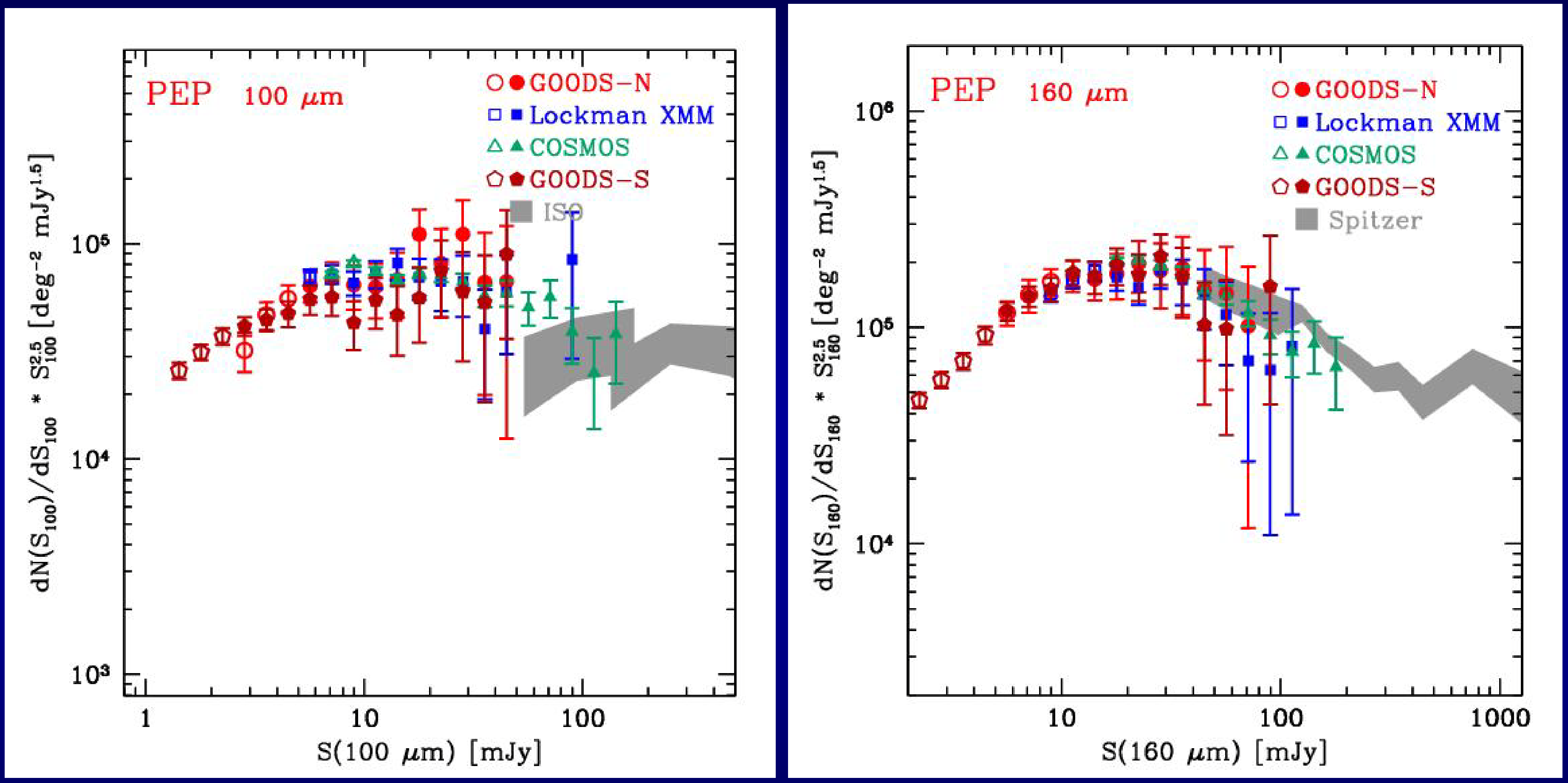


Lagache et al. 2005 ARAA



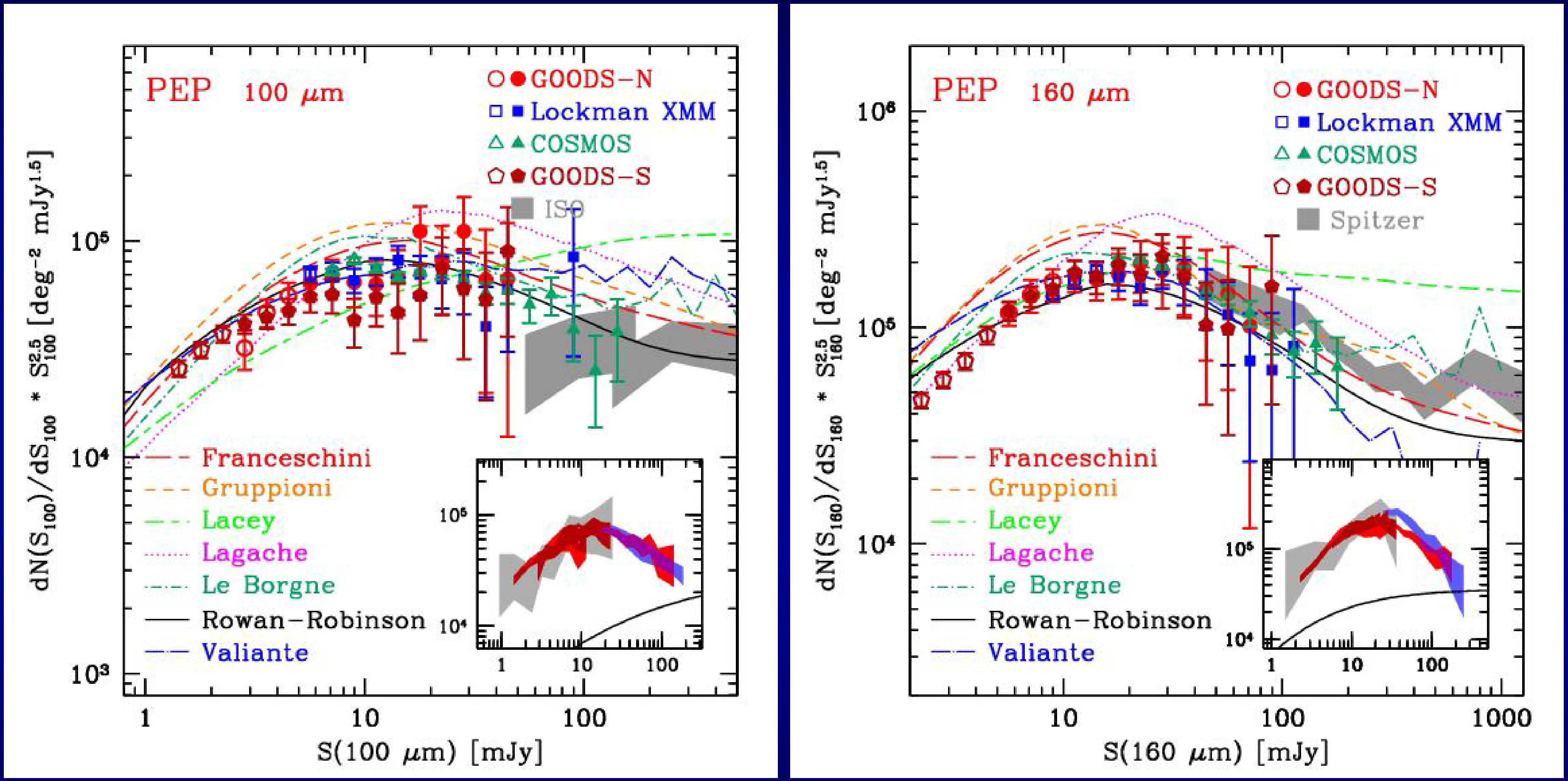
Dole et al. 2006

Far-infrared counts



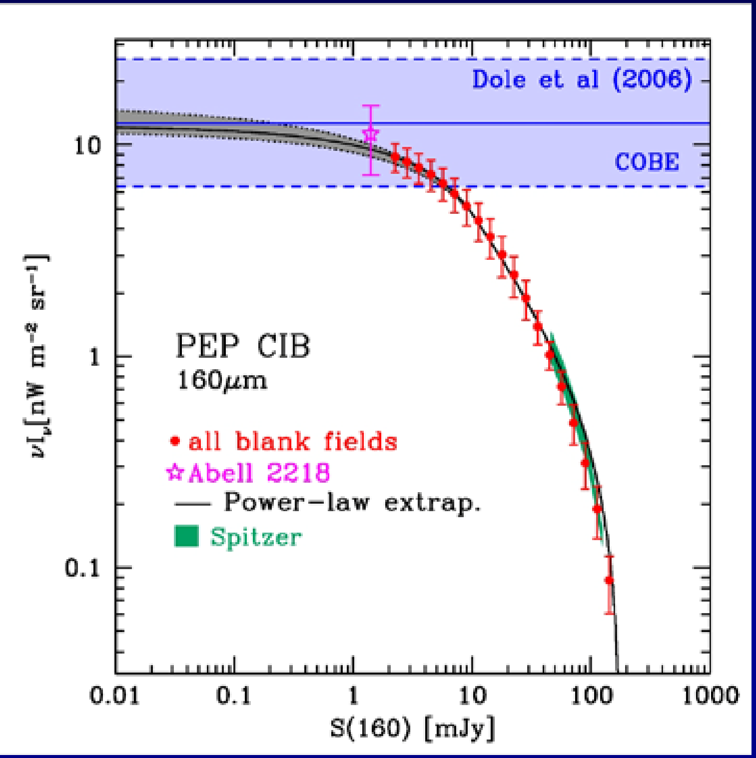
Berta+ 2010, Altieri+ 2010, and in prep.

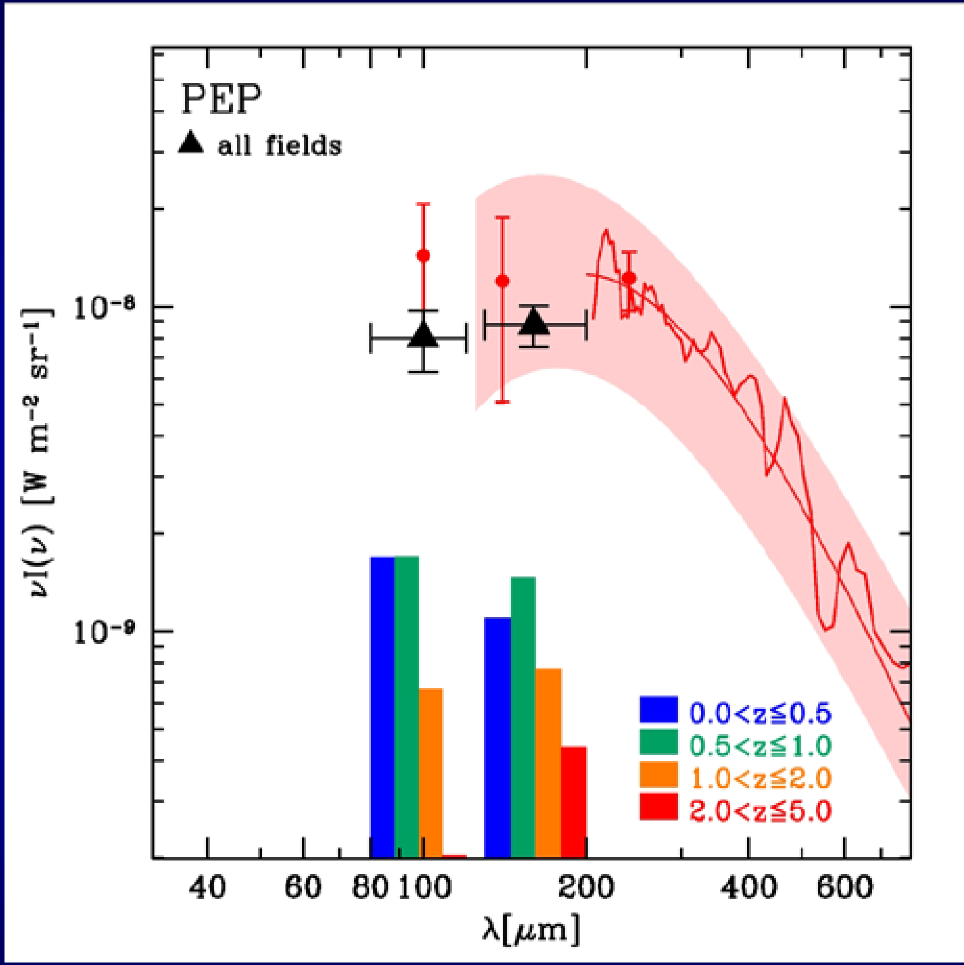
Far-infrared counts



Berta+ 2010, Altieri+ 2010, and in prep.

Resolving and slicing the CIB





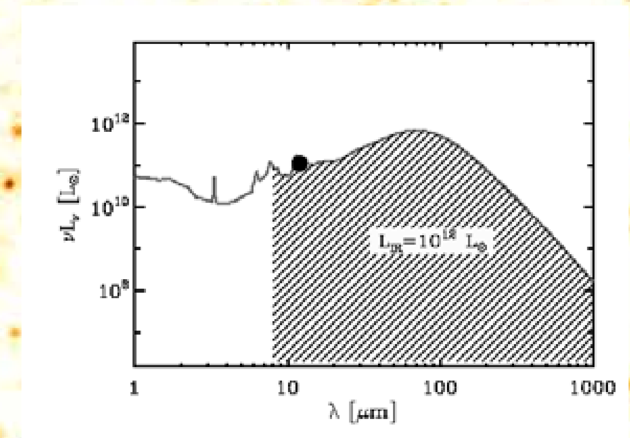
10x deeper!

Resolved into individual sources:
~55% @ 100μm
~70% @ 160μm

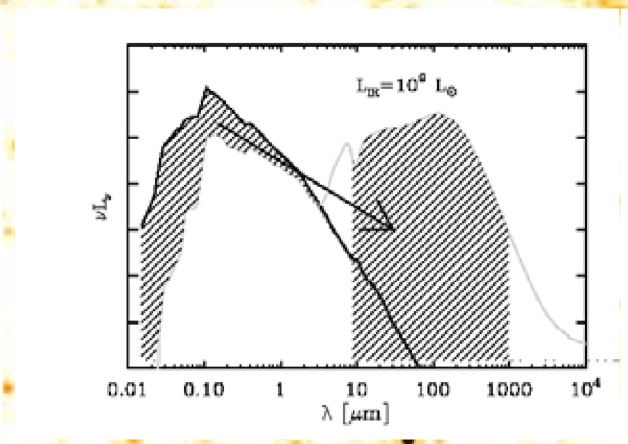
Berta+ 2010 and in prep.

The need for far-IR calorimetric star formation rates

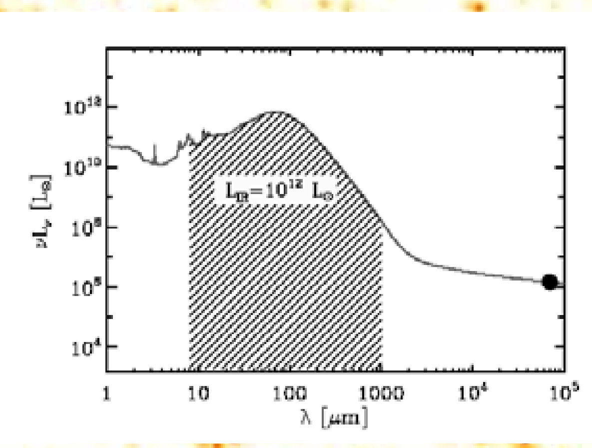
- Our community has been relying almost exclusively on extrapolation from the optical and mid-infrared as the avenue towards studying galaxy evolution.and star formation rates
- We know this extrapolation is pretty good
- **But how good?**



From 24µm

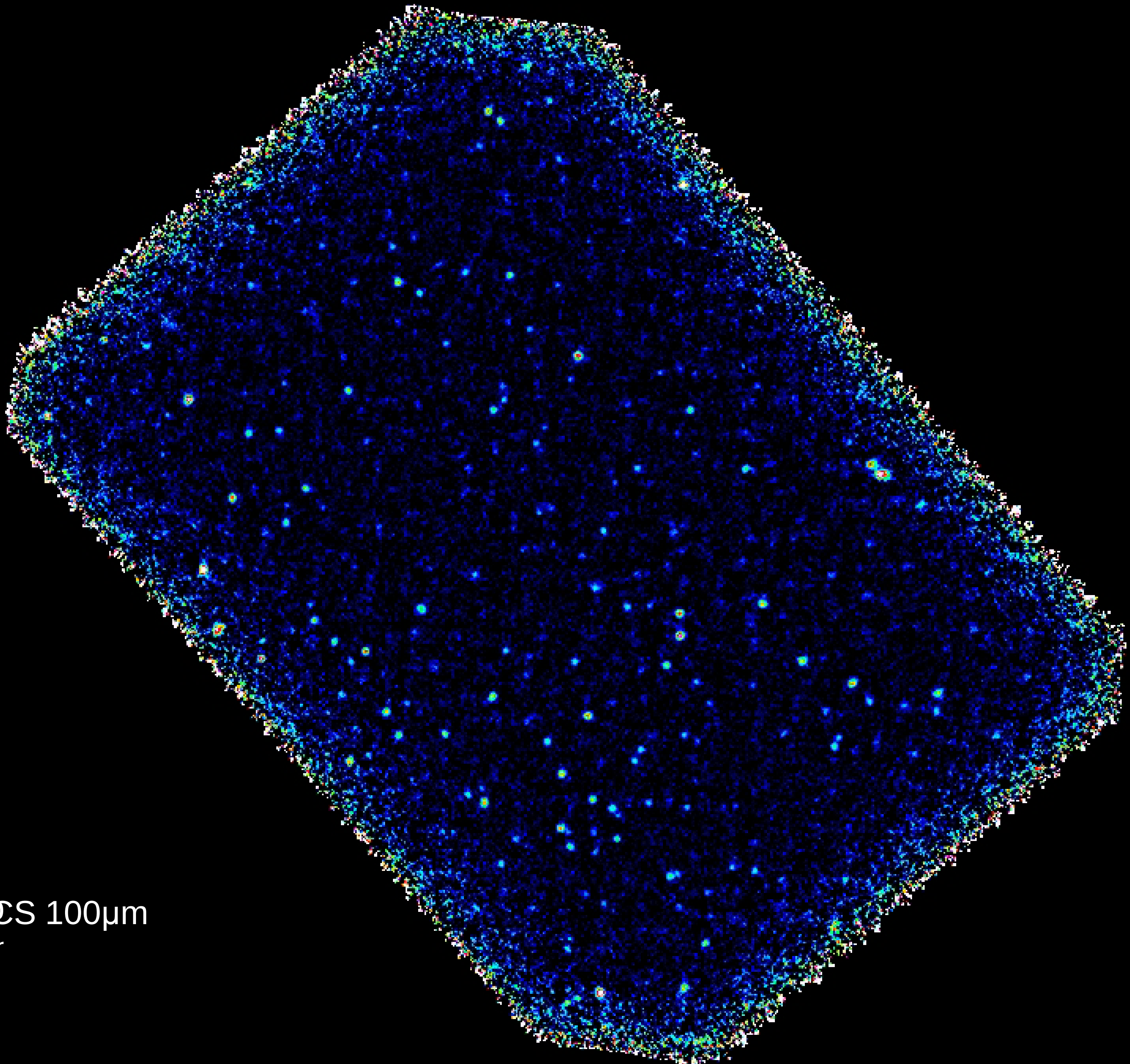


From rest frame UV



From submm/radio

COSMOS 24µm image

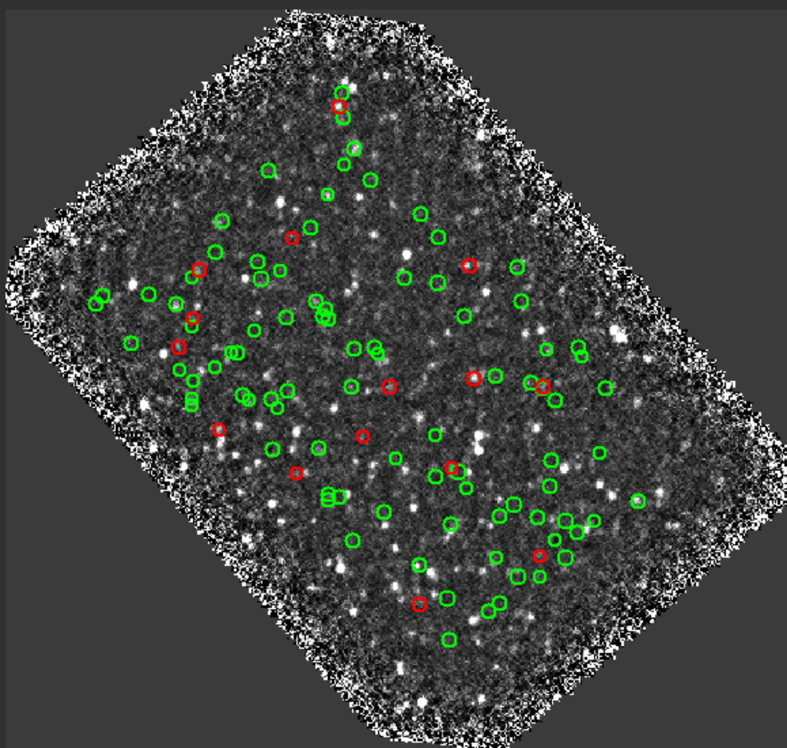


Extrap
100µm

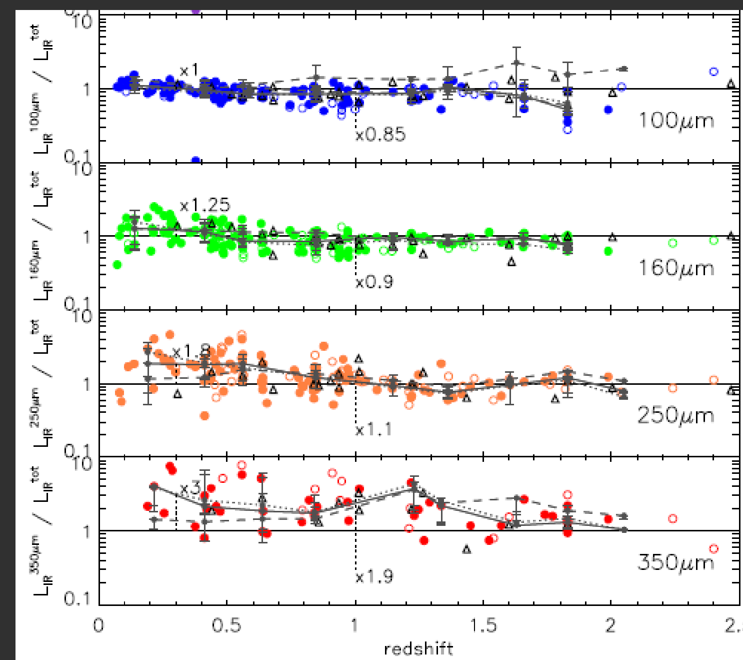
PACS 100µm

The star formation rates of typical z~2 star forming galaxies

- BzK star-forming galaxies in GOODS-N, $K_{AB}<22$, z=1.5-2.5
- Far-infrared luminosity from 160μm flux, redshift, Chary & Elbaz 2001 SED

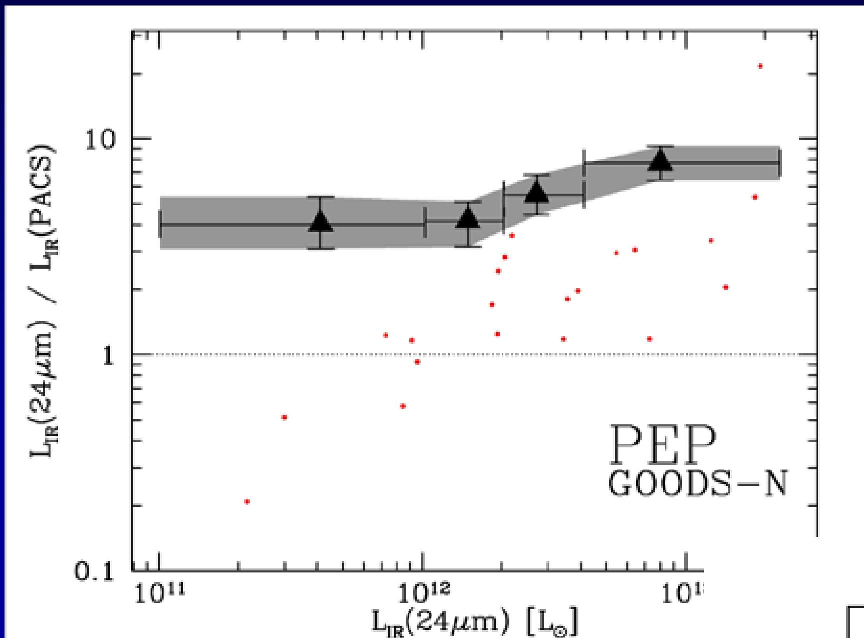


Nordon et al. 2010 (arXiv)



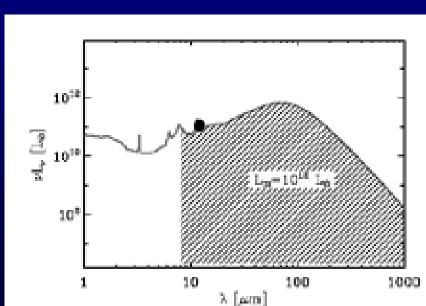
Elbaz et al. 2010

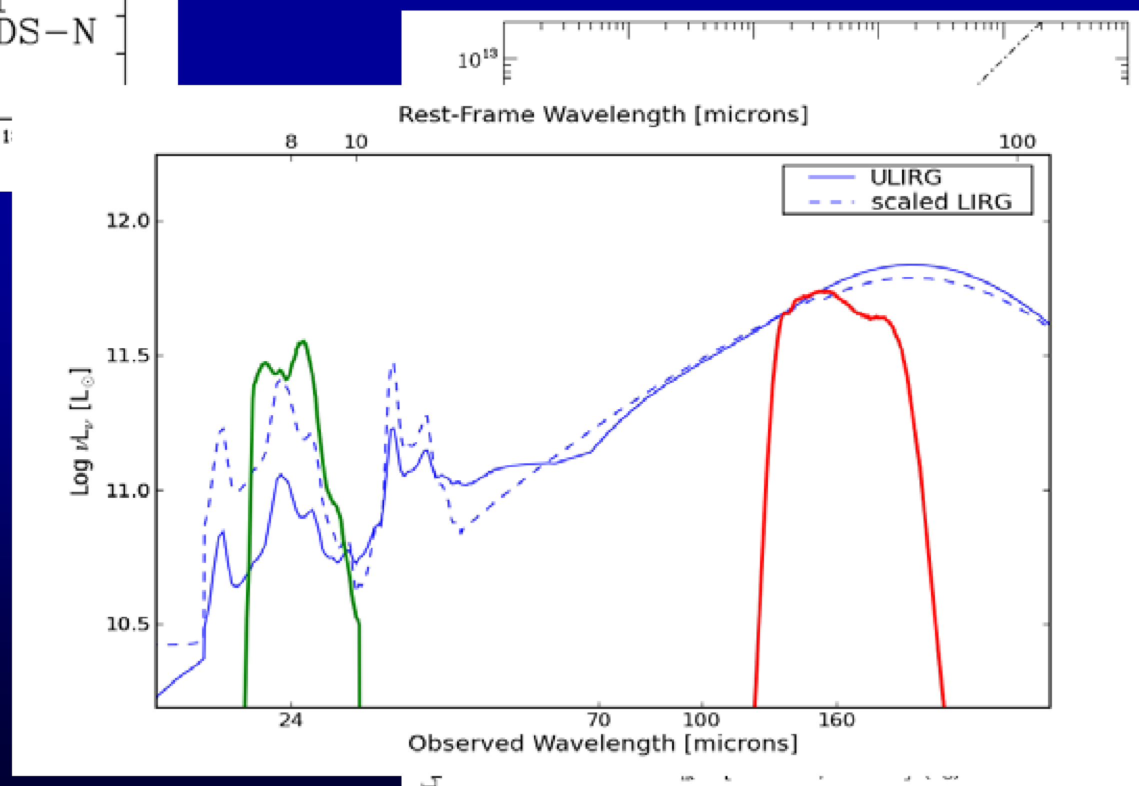
Z~2: Extrapolation from 24μm overpredicts FIR



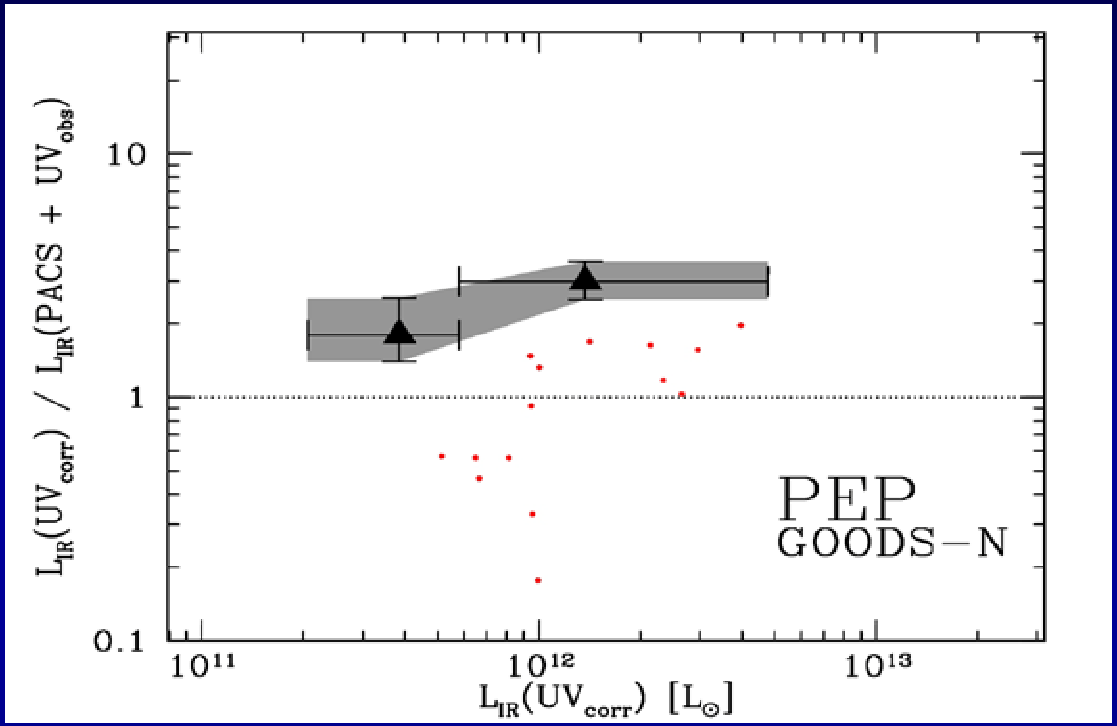
Obscured AGN and/or changing SED shape/PAH strength? Setting in of the effect at z=1.5 favours the latter, to be continued…

Nordon et al. 2010 (arXiv)

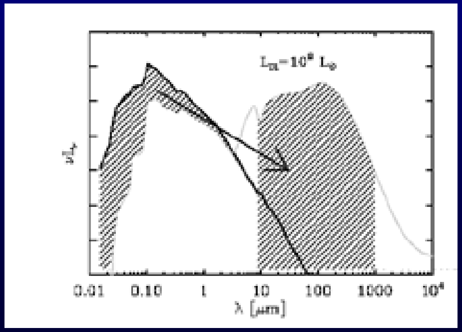




Z~2: Extrapolation from rest frame UV slightly overpredicts FIR

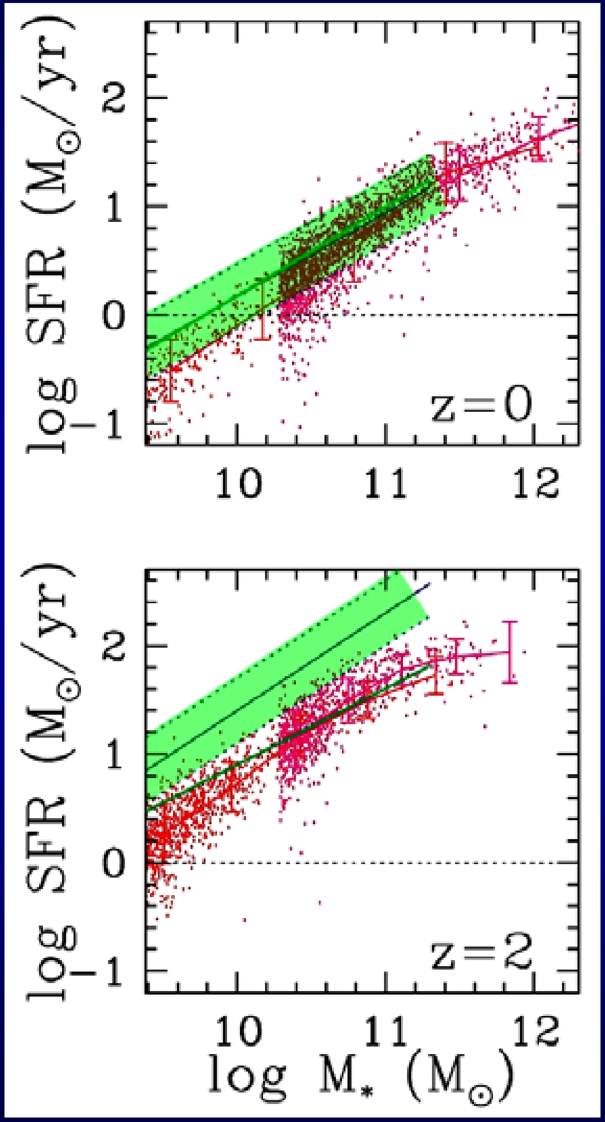


Modest modification to extinction law needed?

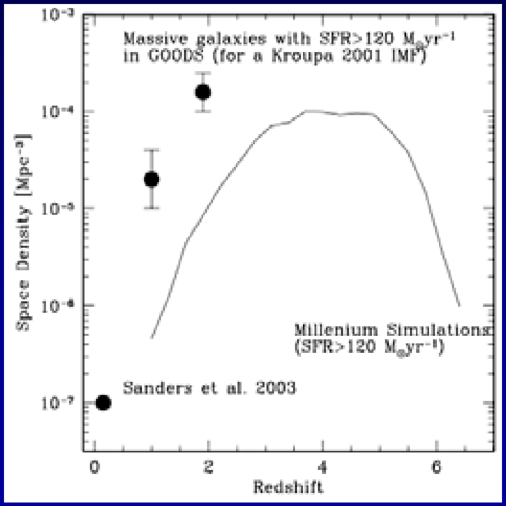


Nordon et al. 2010 (arXiv)

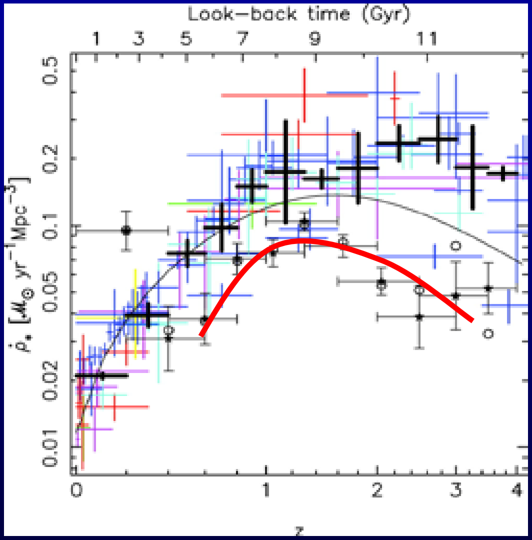
Towards reconciling observed and theoretical star formation rates



Dave 08

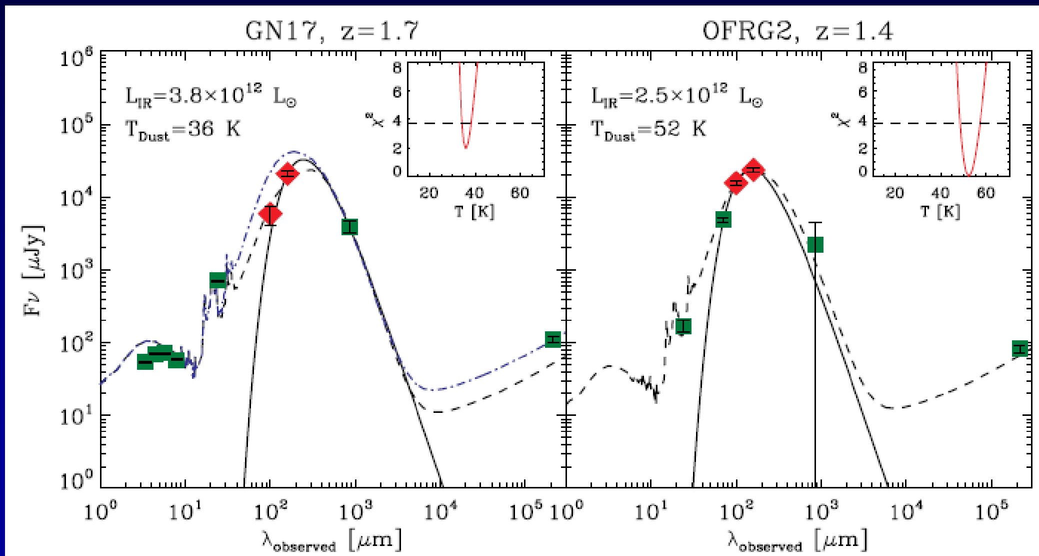


Daddi+ 07



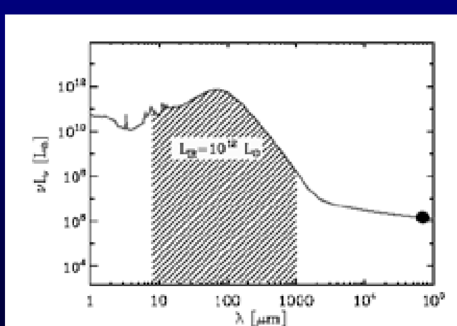
Perez-Gonzalez+08

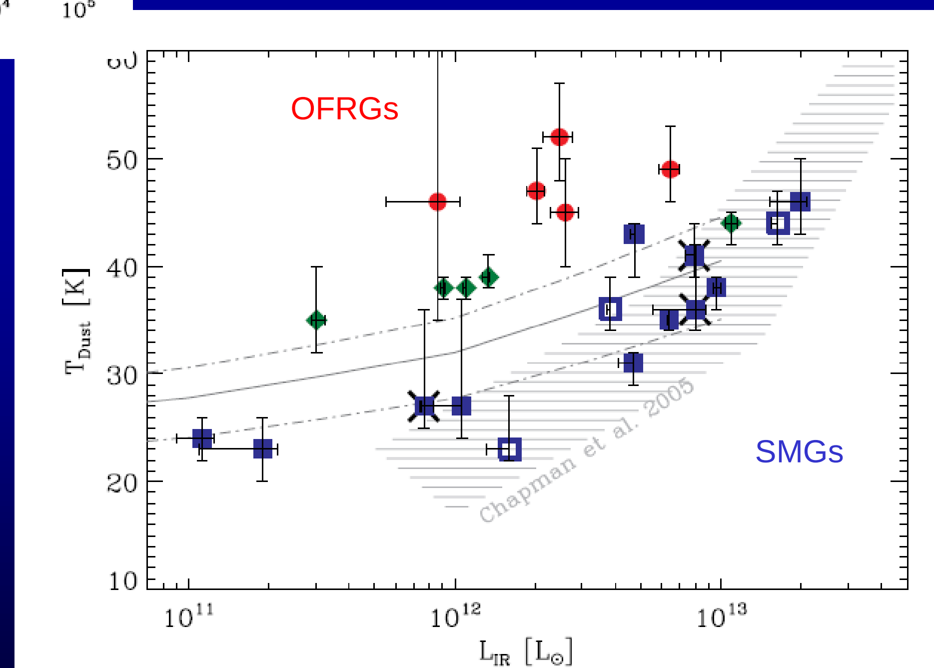
The most luminous star forming galaxies



Star formation rates ~$1000 M_{Sun}$/yr!

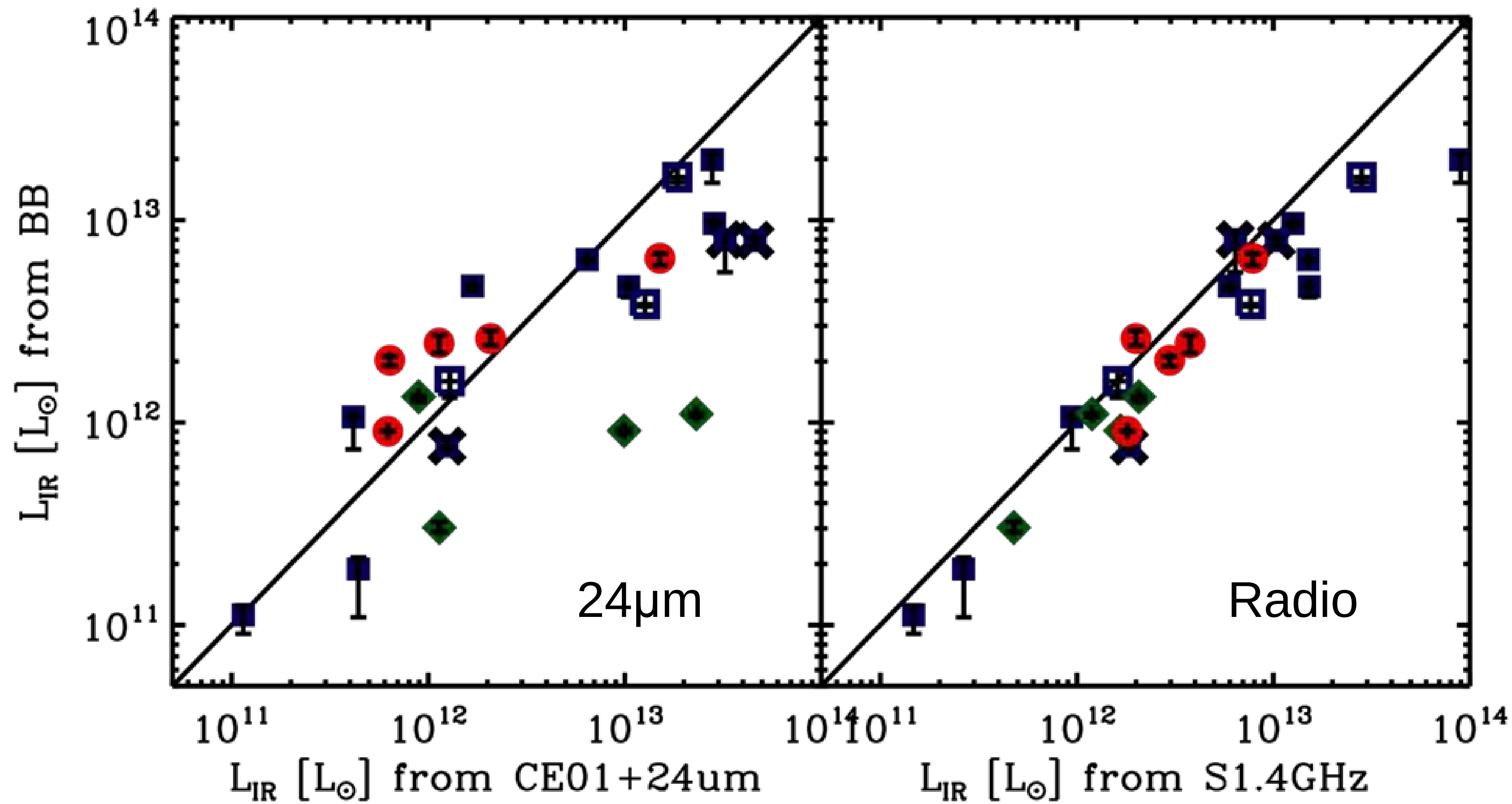
.. Note previous selection effects





Magnelli et al. 2010 (arXiv)

24μm and radio-based star formation rates vs. Herschel

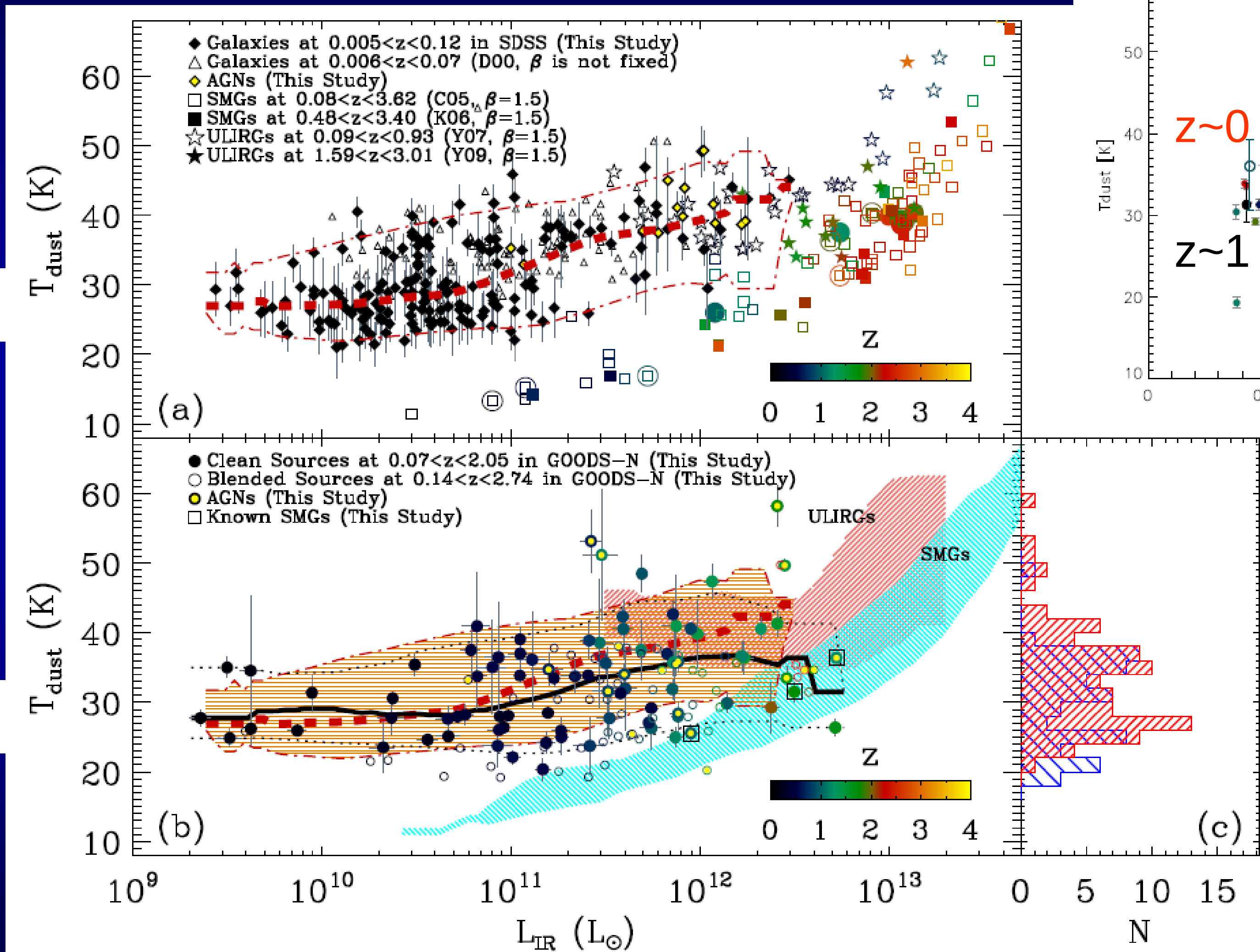


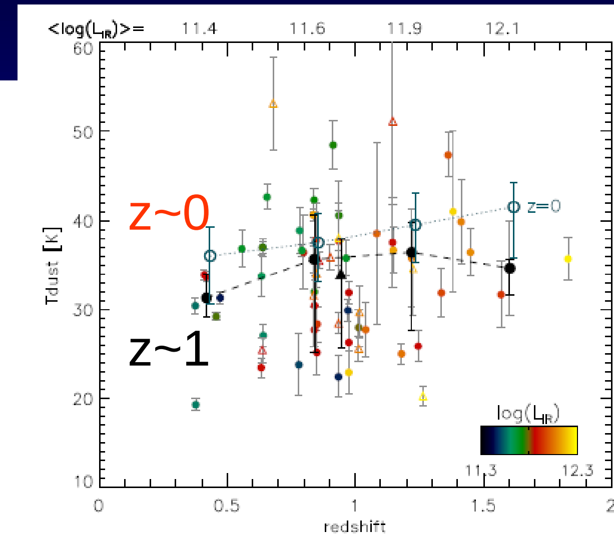
Magnelli et al. 2010 (arXiv)

Colder SEDs at a given IR luminosity

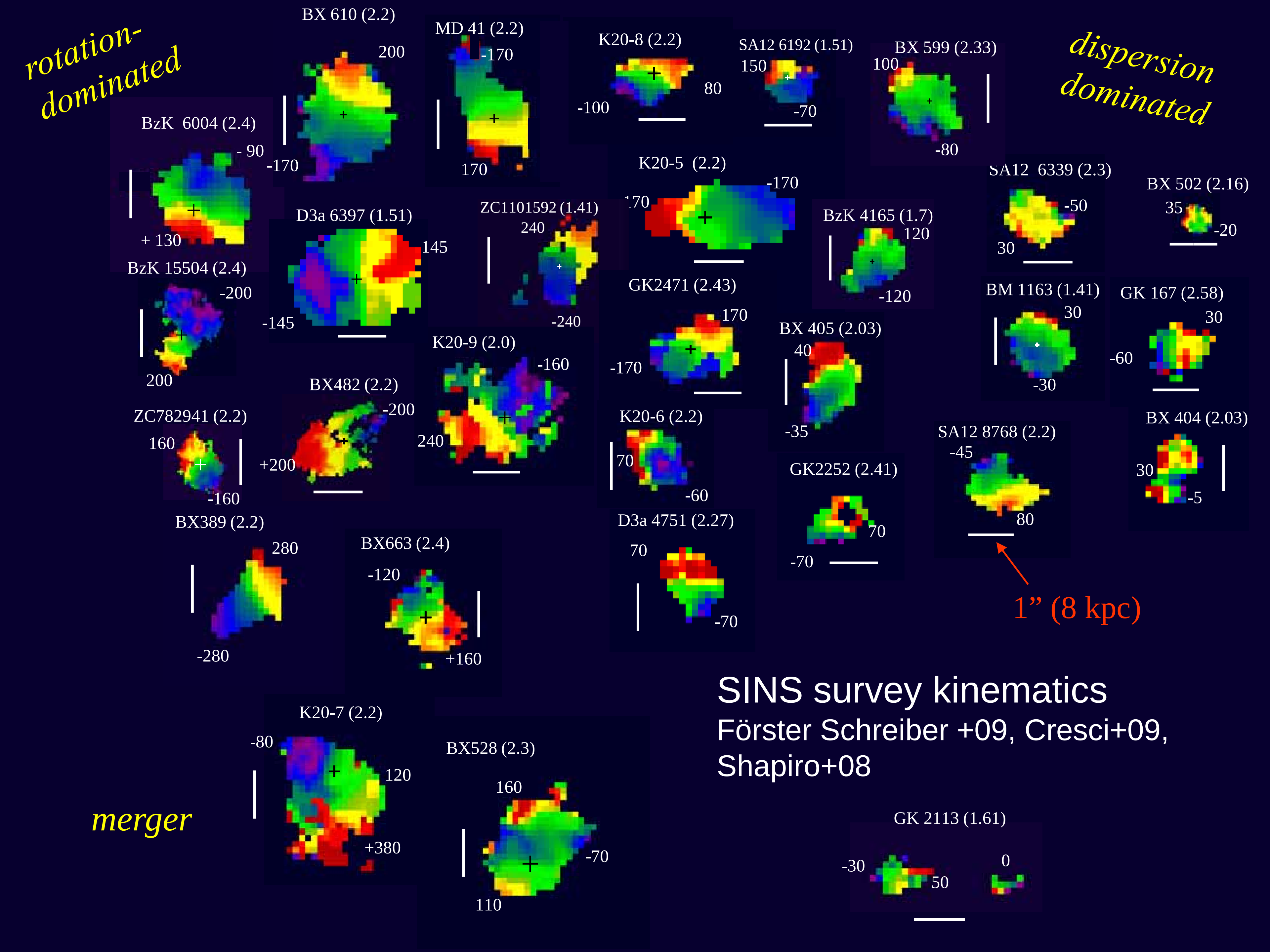
z~0

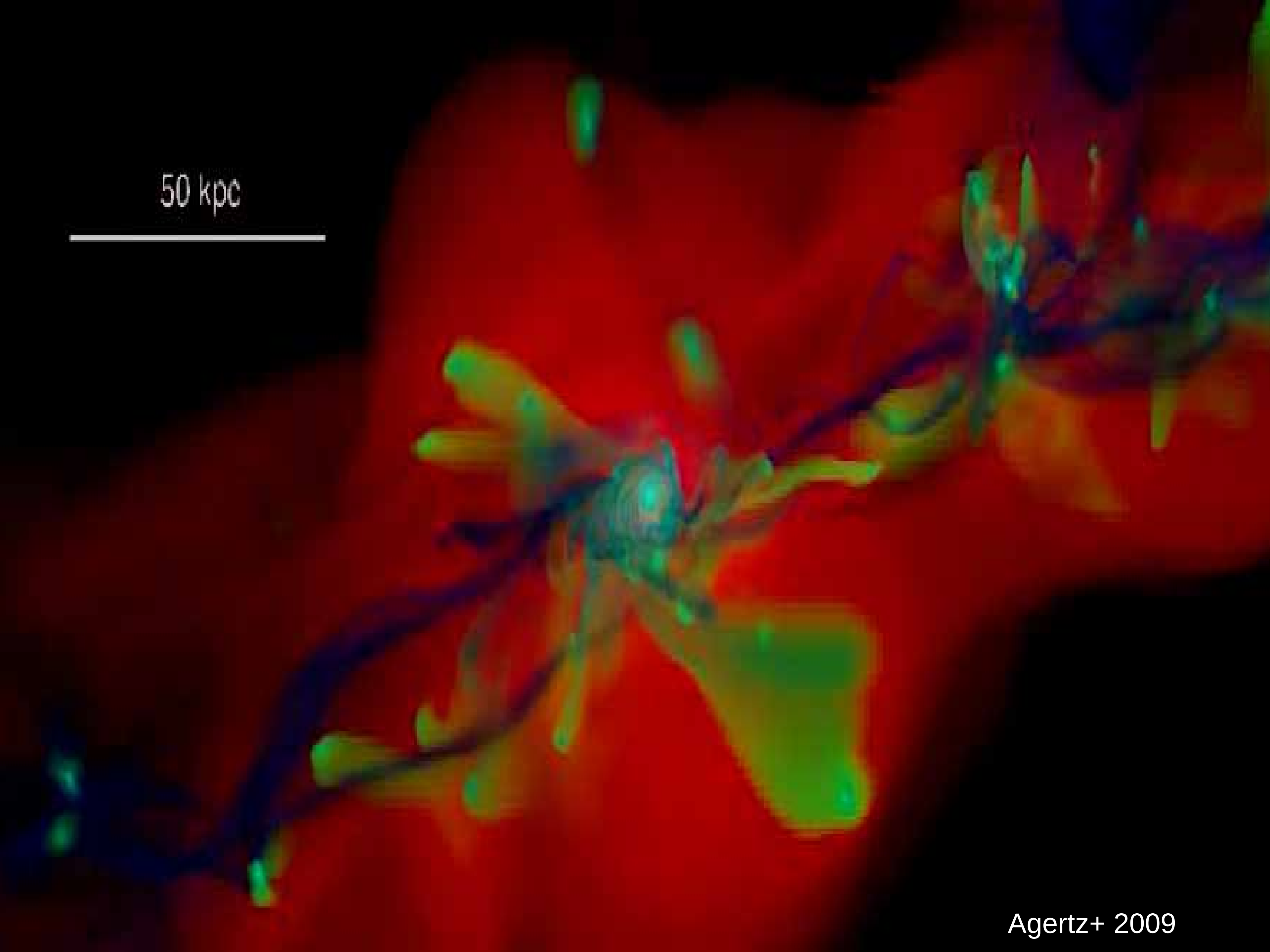
z~1





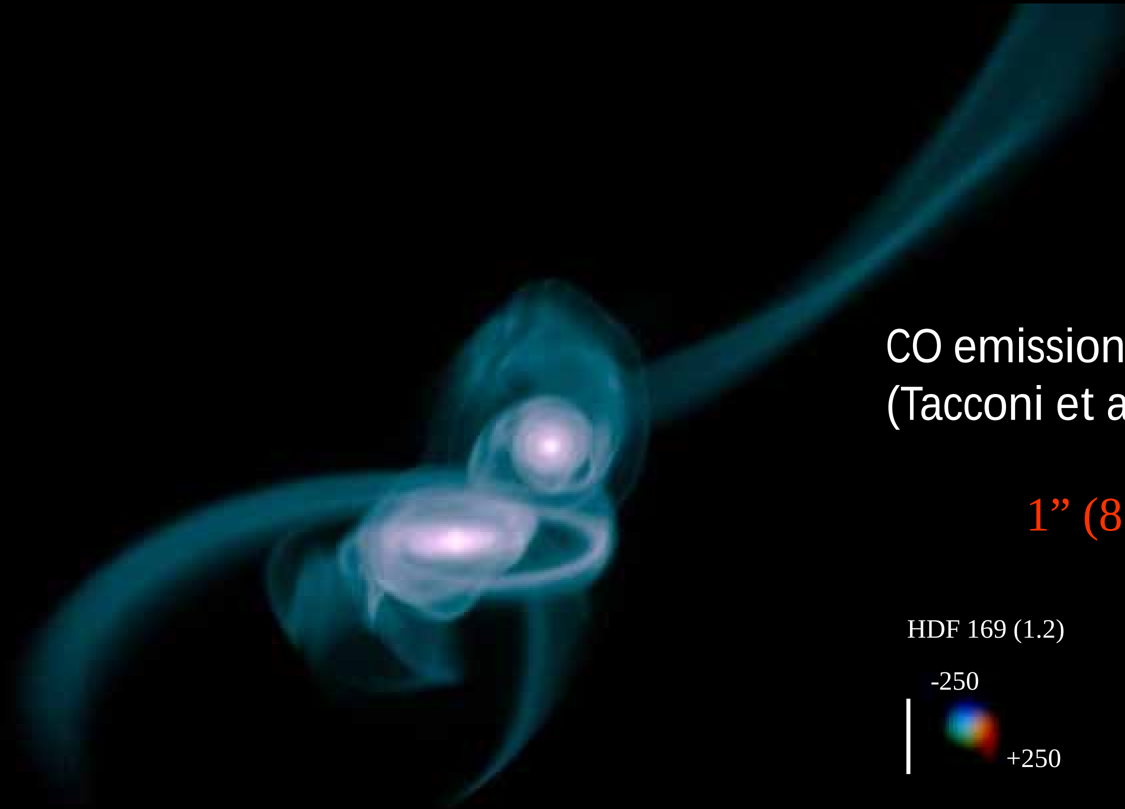
Hwang+ in prep., Elbaz+10


rotation-dominated
dispersion dominated
merger
BX 610 (2.2)
200
-170
MD 41 (2.2)
-170
170
K20-8 (2.2)
80
-100
SA12 6192 (1.51)
150
-70
BX 599 (2.33)
100
-80
BzK 6004 (2.4)
- 90
+ 130
K20-5 (2.2)
-170
170
SA12 6339 (2.3)
-50
30
BX 502 (2.16)
35
-20
D3a 6397 (1.51)
145
-145
ZC1101592 (1.41)
240
-240
BzK 4165 (1.7)
120
-120
BzK 15504 (2.4)
-200
200
GK2471 (2.43)
170
-170
BM 1163 (1.41)
30
-30
GK 167 (2.58)
30
-60
K20-9 (2.0)
-160
240
BX 405 (2.03)
40
-35
BX482 (2.2)
-200
+200
ZC782941 (2.2)
160
-160
K20-6 (2.2)
70
-60
SA12 8768 (2.2)
-45
80
BX 404 (2.03)
30
-5
GK2252 (2.41)
70
-70
BX389 (2.2)
280
-280
BX663 (2.4)
-120
+160
D3a 4751 (2.27)
70
-70
1" (8 kpc)
SINS survey kinematics
Förster Schreiber +09, Cresci+09,
Shapiro+08
K20-7 (2.2)
-80
120
+380
BX528 (2.3)
160
-70
110
GK 2113 (1.61)
-30
50
0

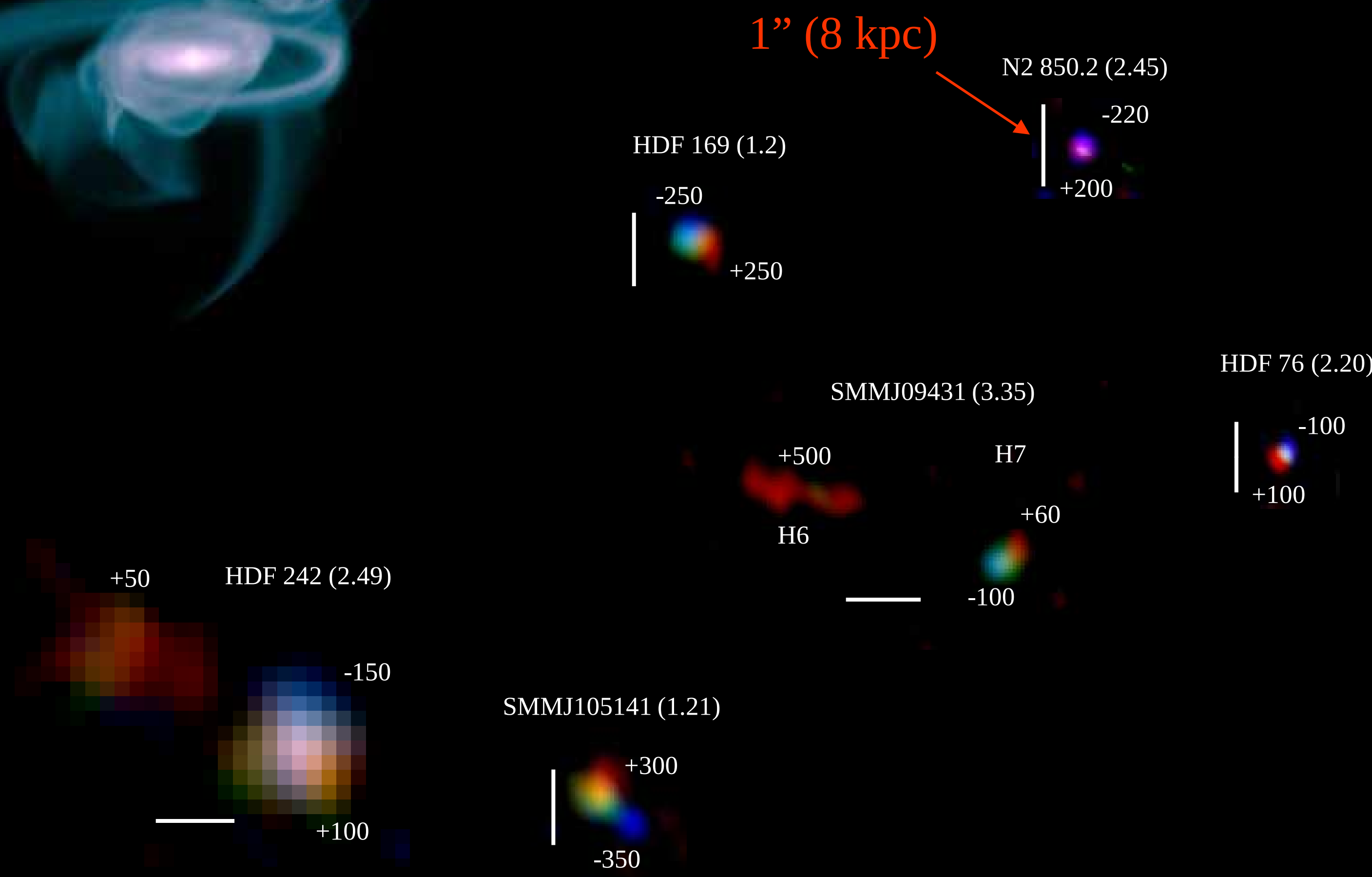


Agertz+ 2009

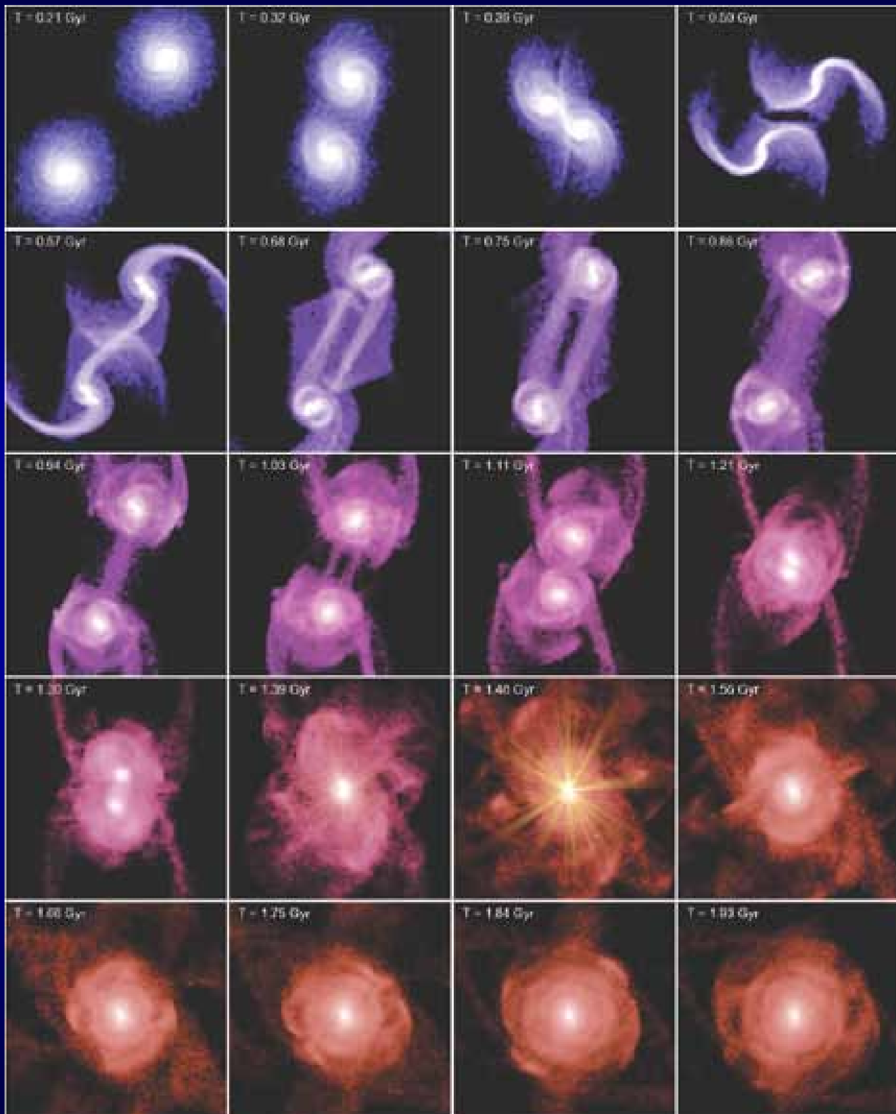
CO emission from submillimeter galaxies
(Tacconi et al. 2006, 2008, Engel et al. 2010)



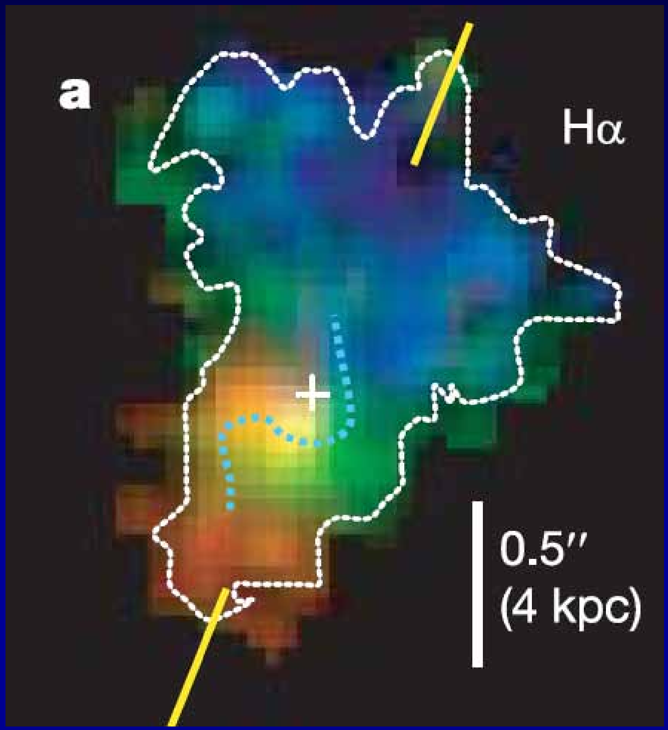
Dubinski+



The co-evolution of AGN and star formation

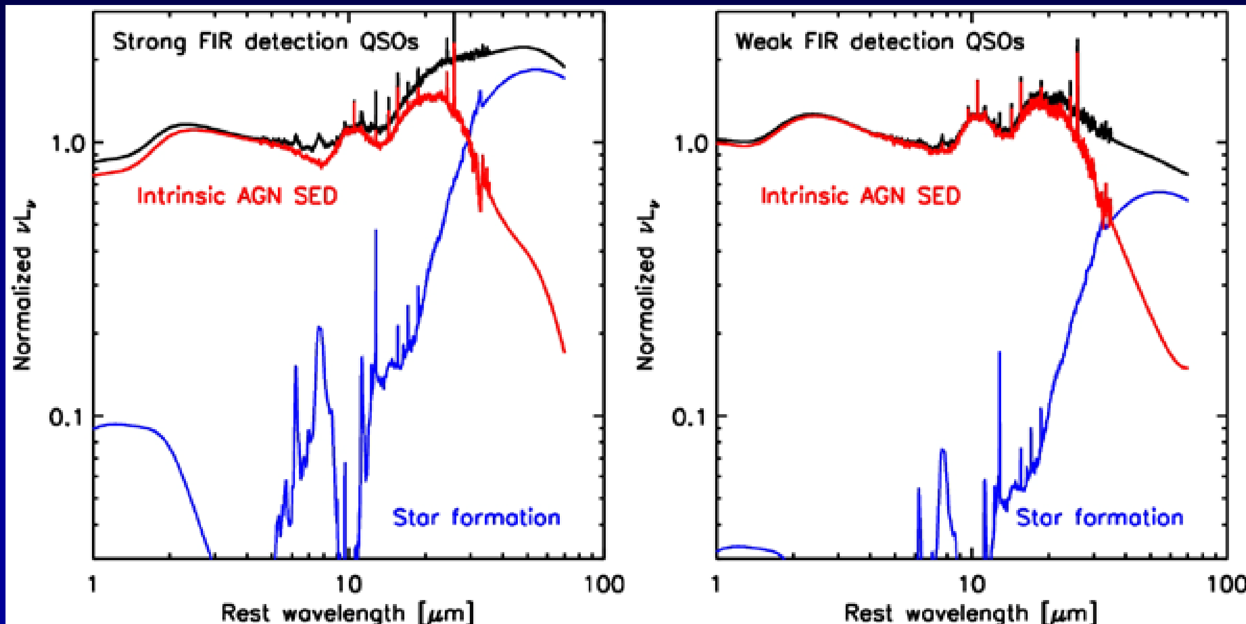


Models of merging galaxies (Hopkins+06)



BzK-15504 z~2.38 rotating disk with central AGN (Genzel+06,08)

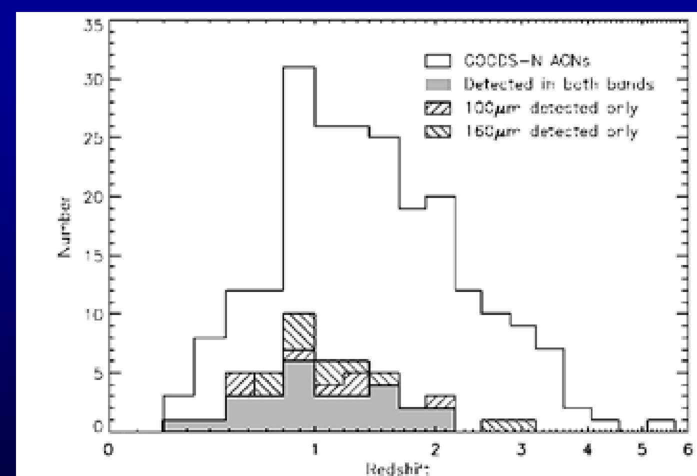
Using FIR to measure star formation



(QSO SEDs from Netzer+07)

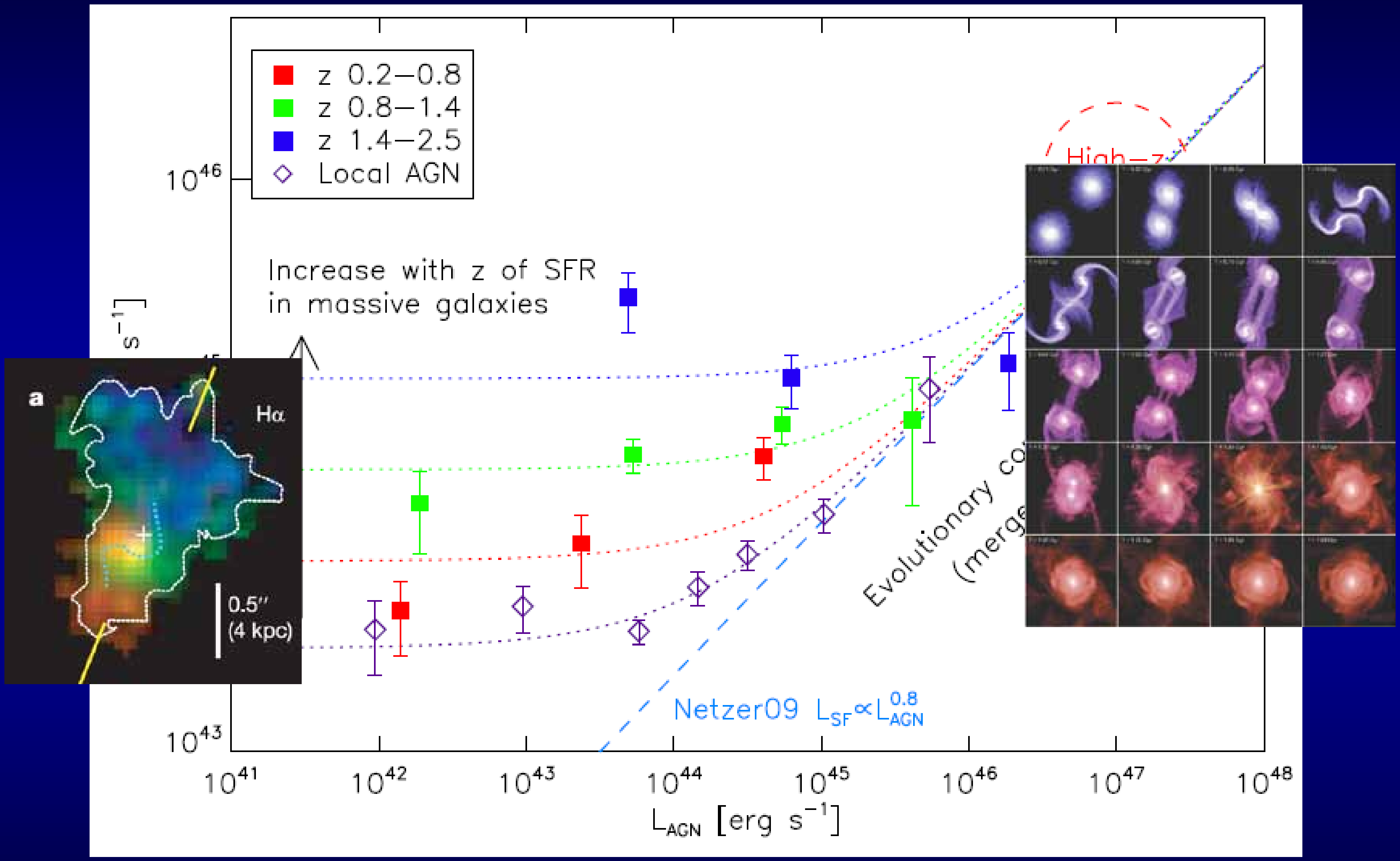
FIR detection rate 21% for X-ray AGN from 2Msec Chandra

+Stacking



Shao et al. 2010 (arXiv)

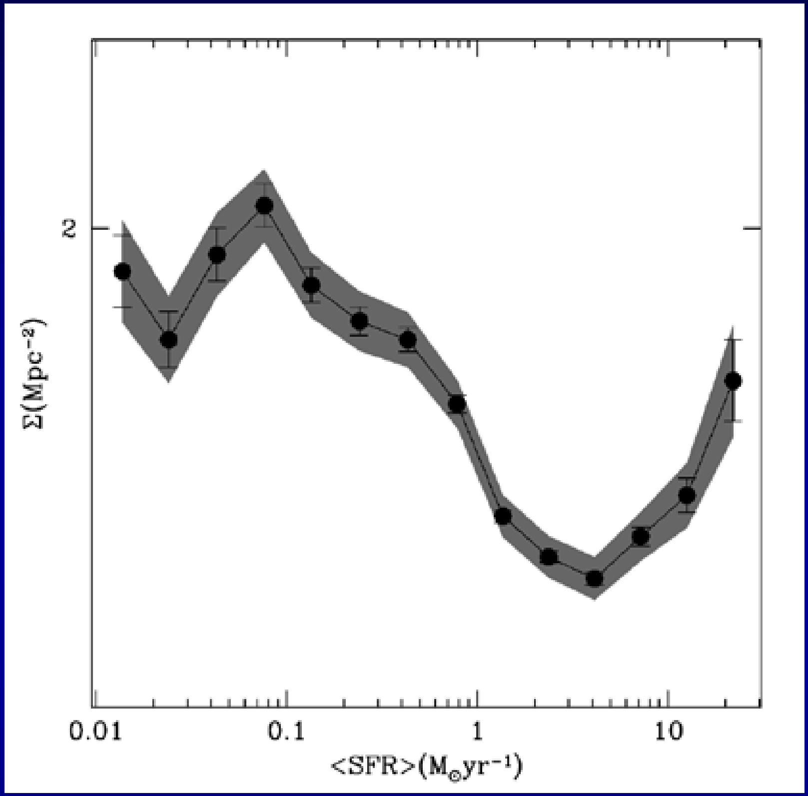
Two modes of AGN / host coevolution: Merger vs. secular



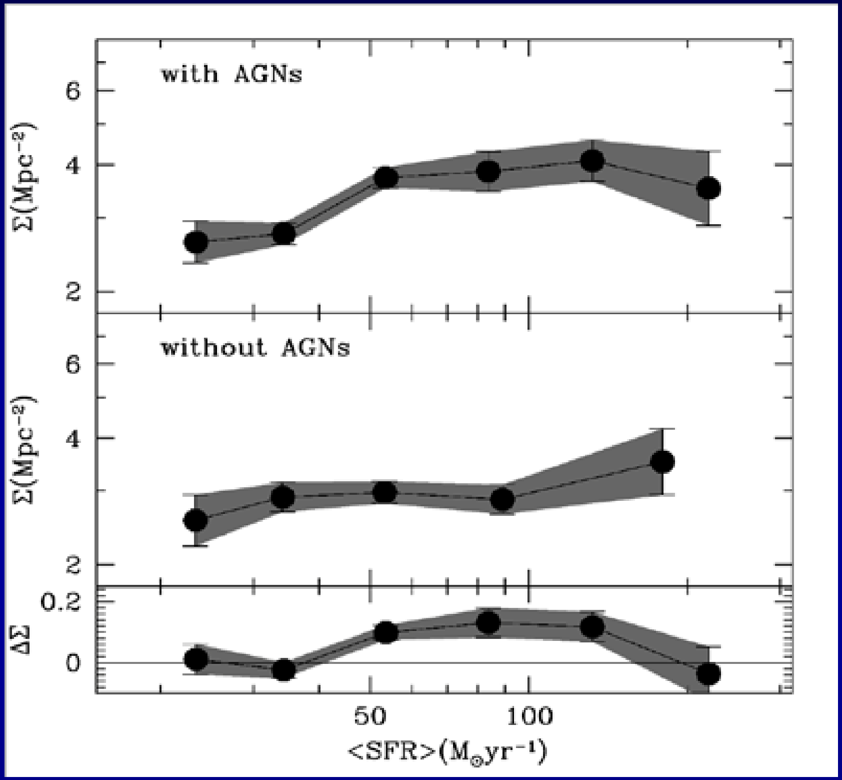
Shao et al. 2010 (arXiv)

(also Lutz et al. 2010 submm results)

The role of environment



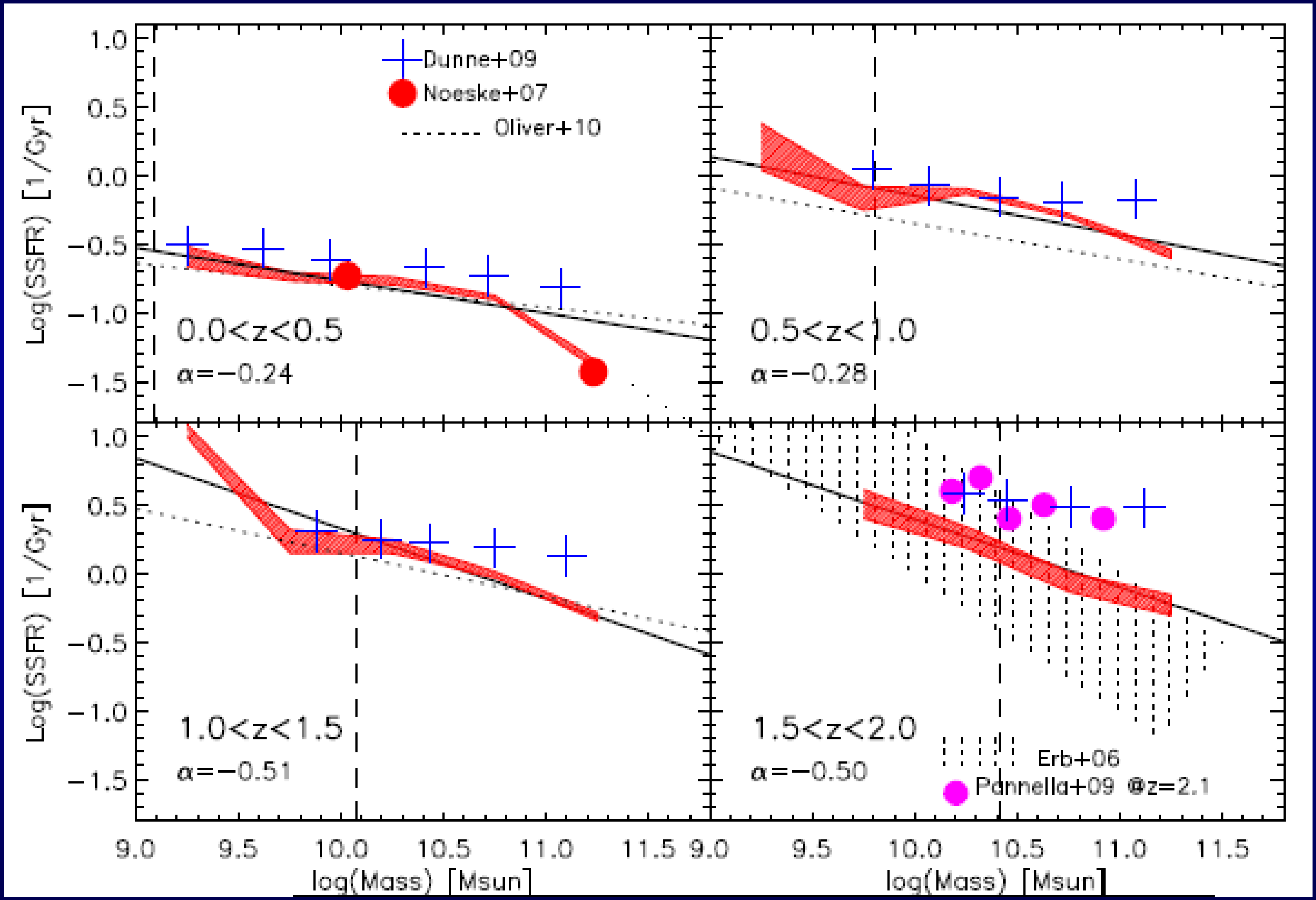
Local Universe (SDSS)



Z~1 Herschel
Popesso et al. in prep.

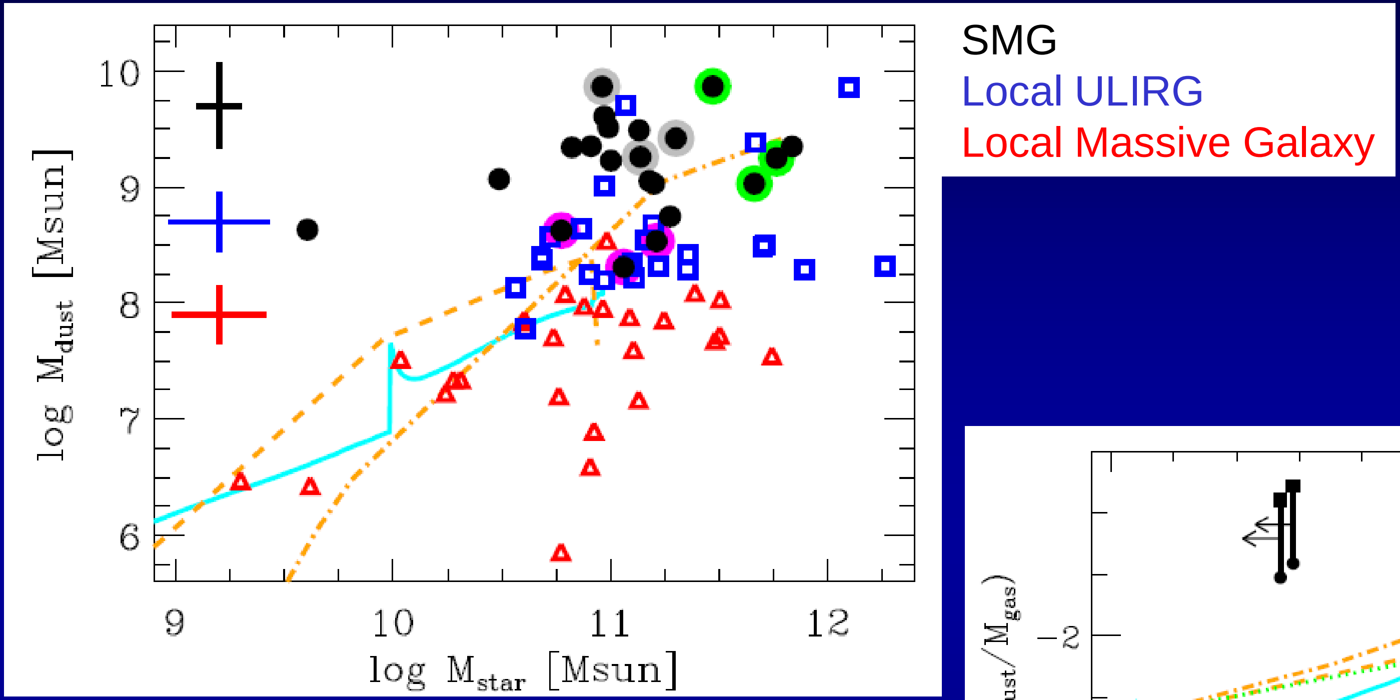
‘Reversal’ of star formation rate-density relation
(see also Elbaz+07, Cooper +08)

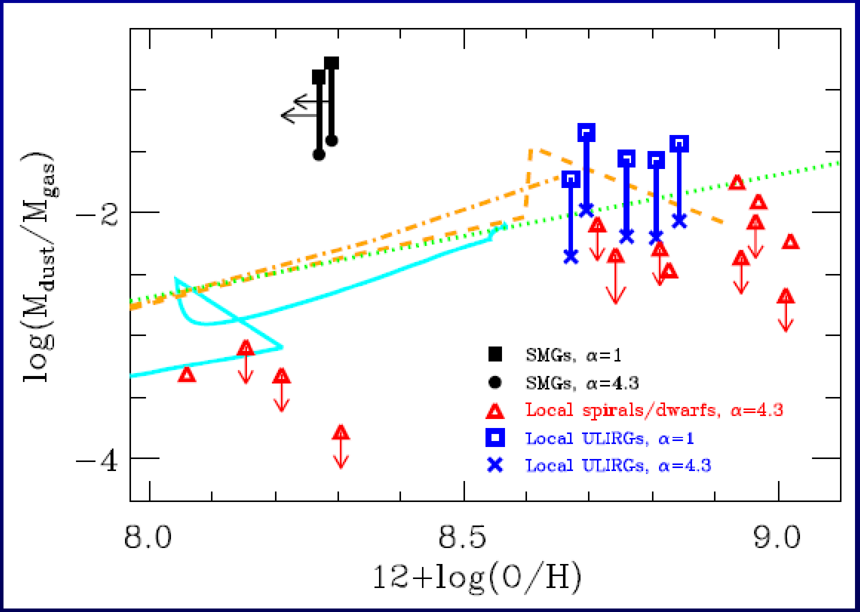
FIR-based determination of the specific star formation rate



Rodighiero et al. 2010 (arXiv)

Surprisingly large dust masses of submillimeter galaxies



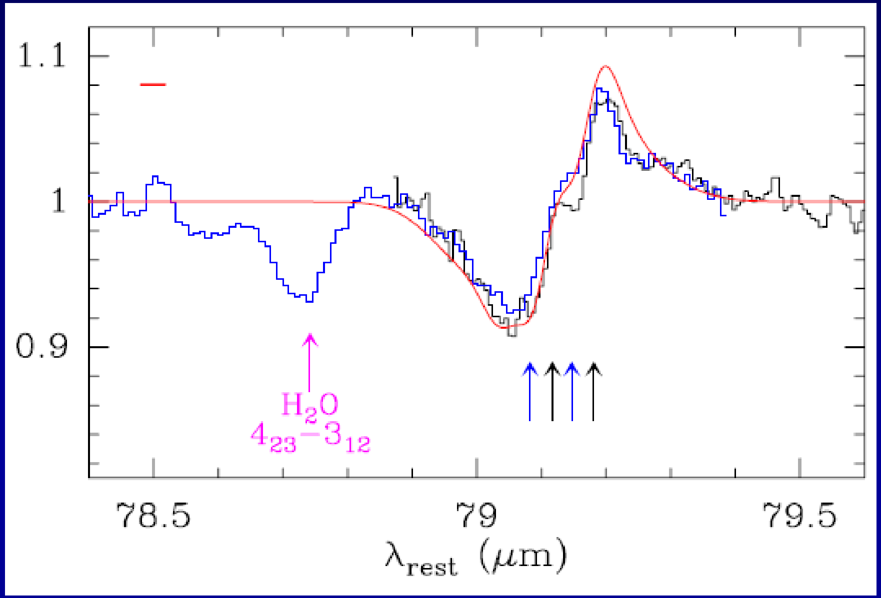


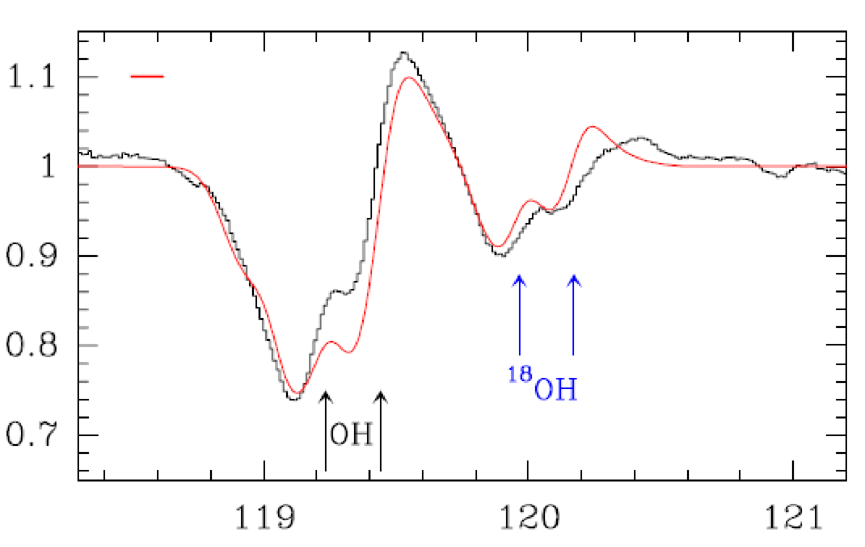
Santini et al. 2010

… more dust than expected for gas phase metallicity
Dust properties? Layering?

AGN(?) feedback at work…

OH absorptions in the AGN ULIRG Mrk 231

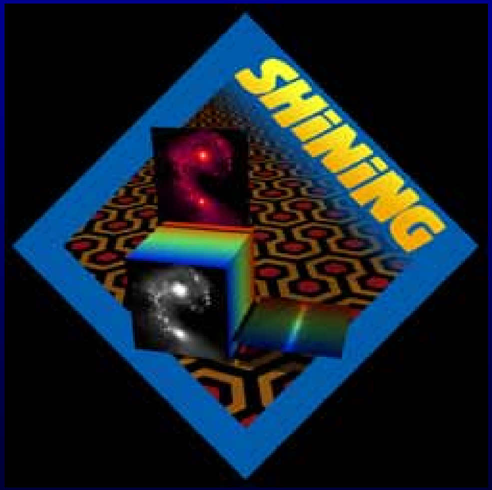




Fischer et al. 2010 (arXiv). First estimates:

- outflow mass of $7x10^7$ Msun
- outflow velocities of -1400 km/s
- Mechanical energy ≥ 10^{56} erg/s

See also Feruglio et al. 2010 arXiv (Mrk 231 CO IRAM PdB)



SHINING Herschel key programme (Sturm et al.)
– Spectroscopy of nearby IR bright galaxies

Summary

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- More than half of the cosmic infrared background resolved into individual sources
- Star formation rates: mid-IR and to some extent also UV over-estimate SFR at z~2.
- Huge star formation rates in Submillimeter Galaxies confirmed
- AGN host star formation rates suggest 2 evolutionary modes: merger vs. secular
- Reversal of z~1 star formation rate-density relation