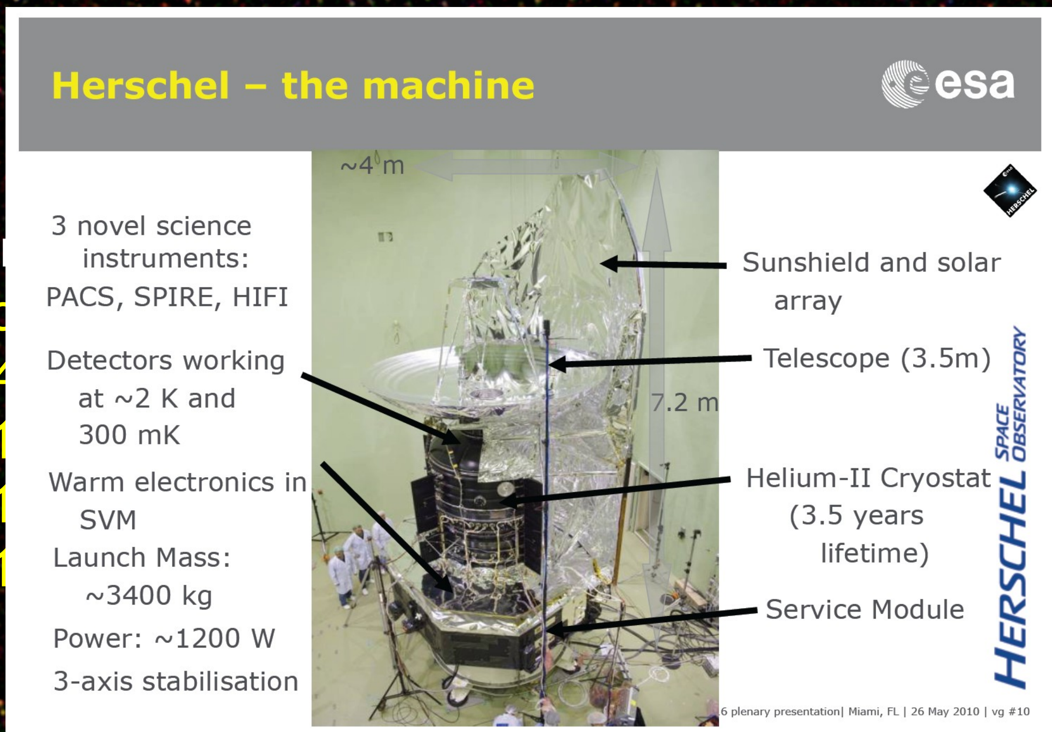
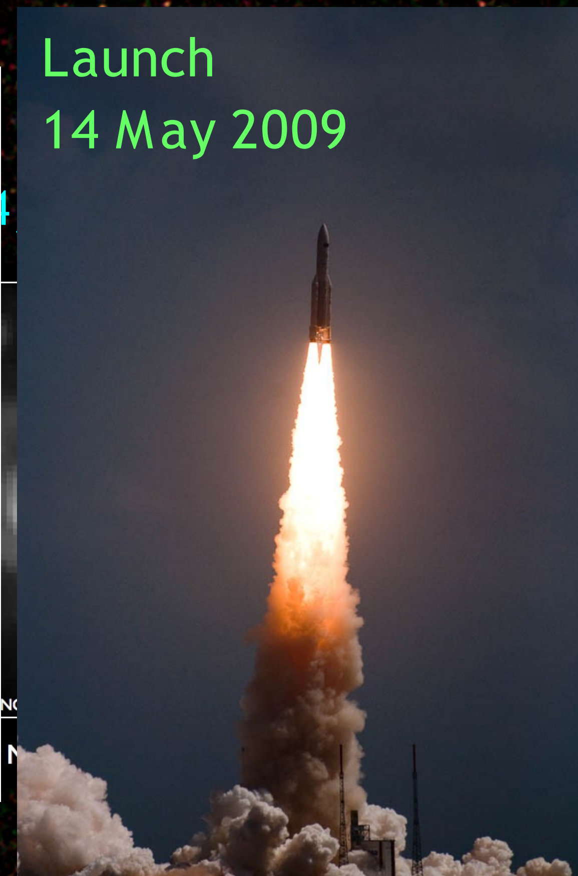
First Science on galaxy evolution with the Herschel far-infrared & submillimeter space telescope

Reinhard Genzel
MPE Garching (FRG)
& Department of Physics, UC Berkeley (USA)

see special Astr.& Astrophys. issue 518 on Herschel initial science

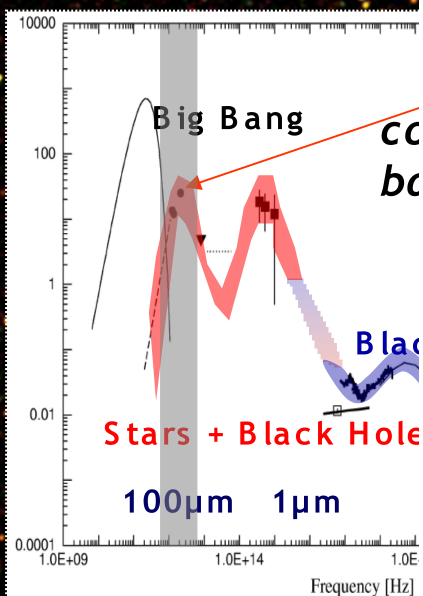
The Herschel FIR/submm Telescope

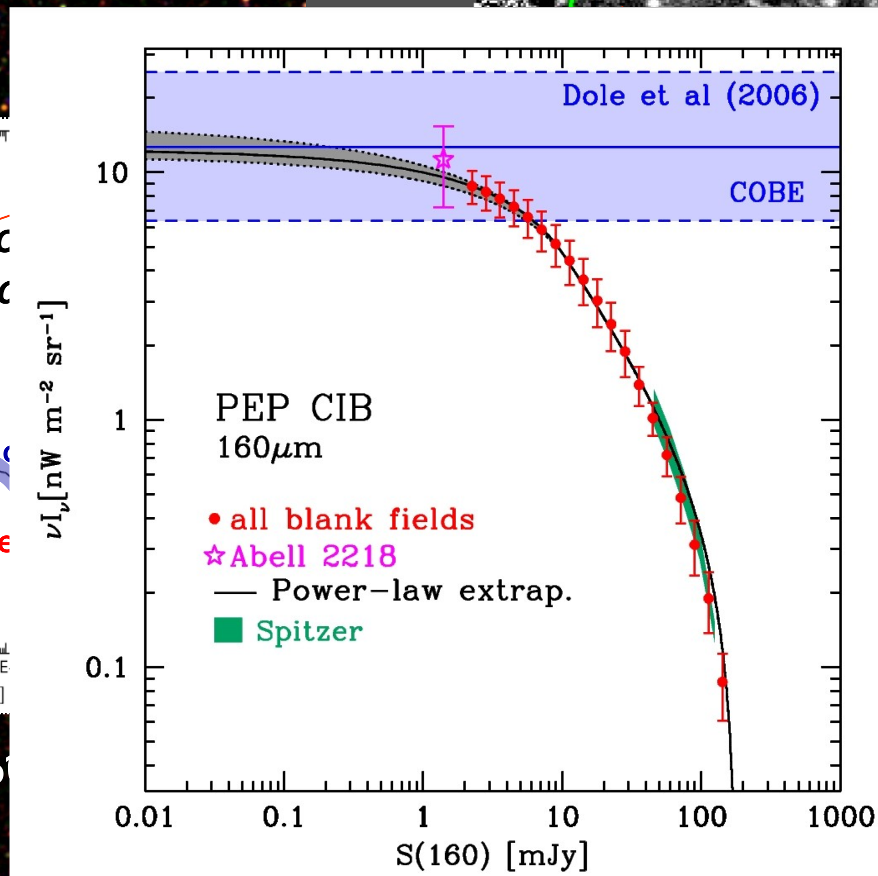




PACS: PI A.Poglitsch (MPE)
SPIRE: PI M.Griffin (Cardiff)

Herschel deep surveys resolve far-IR background





GOODS-S PACS 16

FIDEL team

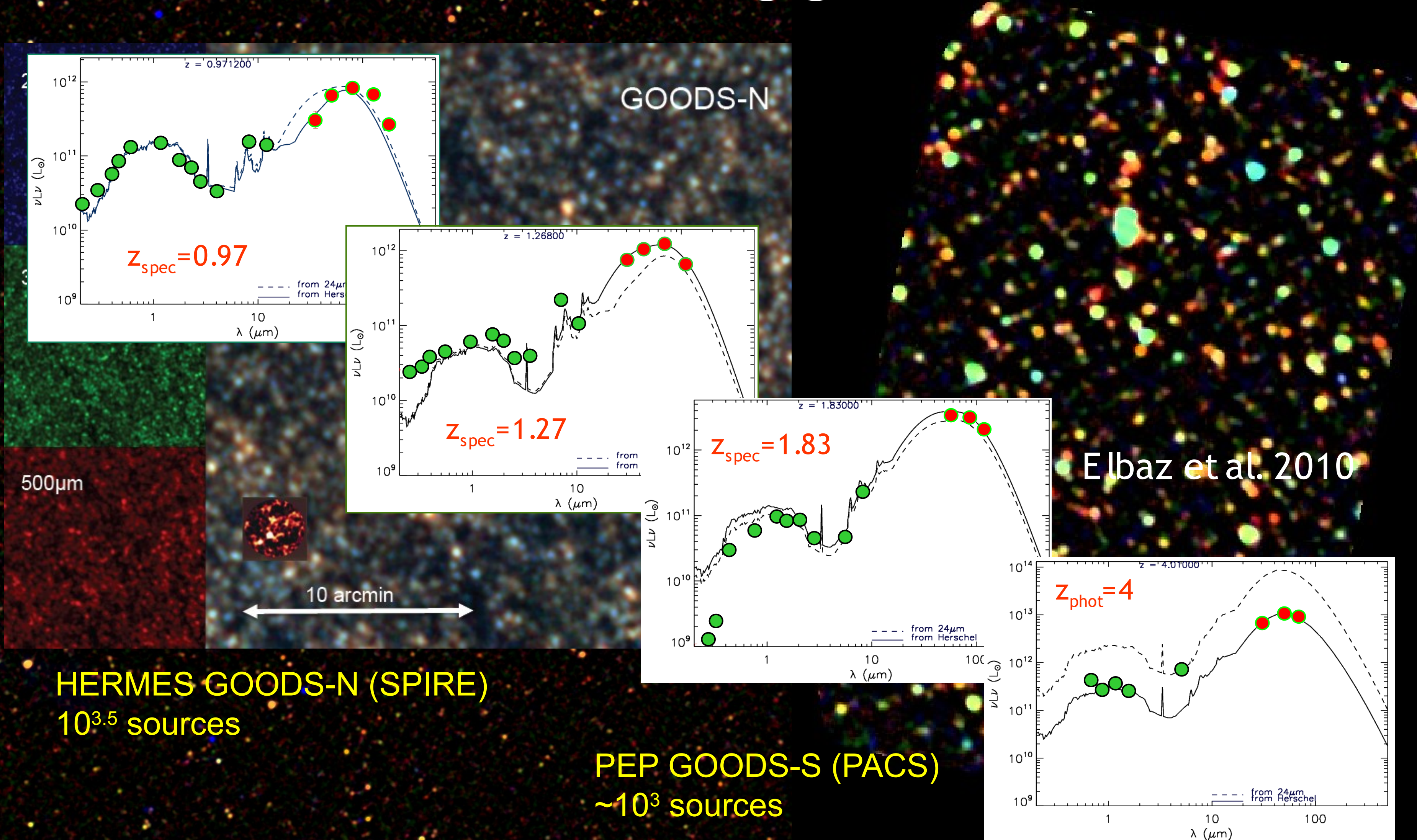
Berta et al. (2010)

Lutz, Berta & PEP team (PACS)

GOODS-South

COSMOS deep field with PACS & Spitzer

The deepest Herschel-PACS blank fields study massive star forming galaxies to z~4



HERMES GOODS-N (SPIRE)
$10^{3.5}$ sources

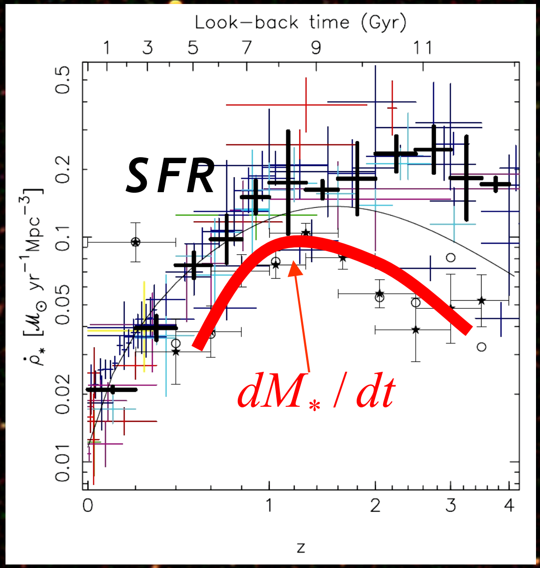
PEP GOODS-S (PACS)
~10^3 sources

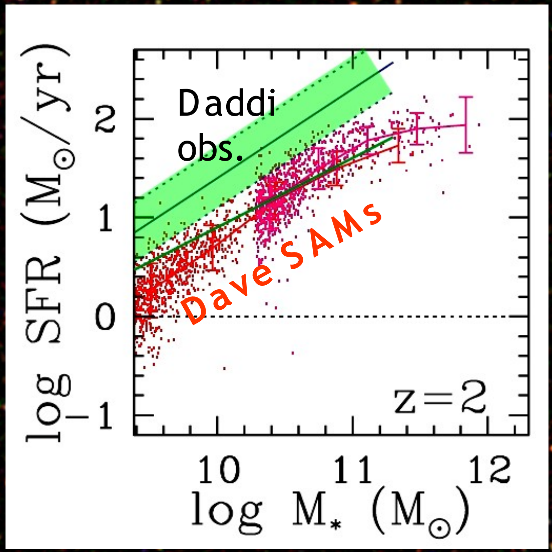
Oliver & HERMES team; Lutz, Elbaz, Nordon & PEP team

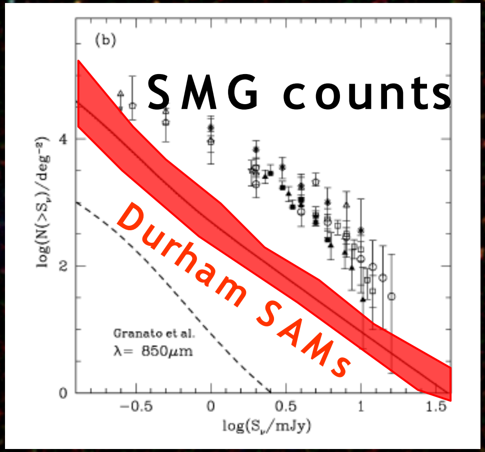
Reconciling observed and theoretical SFRs at high-z

- observed number counts and SFR of SMGs cannot be matched by SAMs
- inferred SFRs of z~2 SFGs about a factor of 1.5-2 higher than best models
- derivative of cosmic stellar mass is about a factor 1.5 to 2 lower than inferred SFR for z>1

→ wrong calibration of SFR ? low T_{dust} ?
top heavy IMF ?

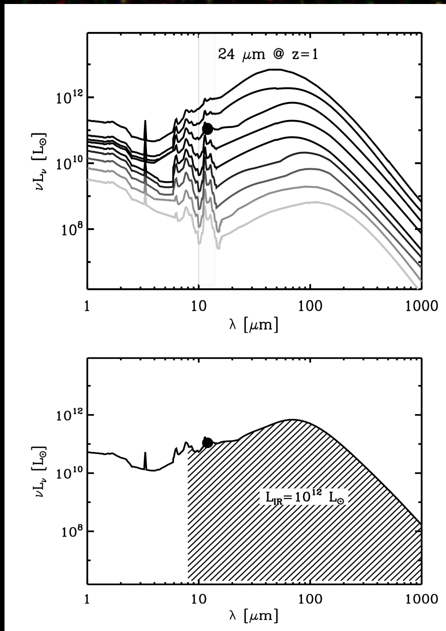




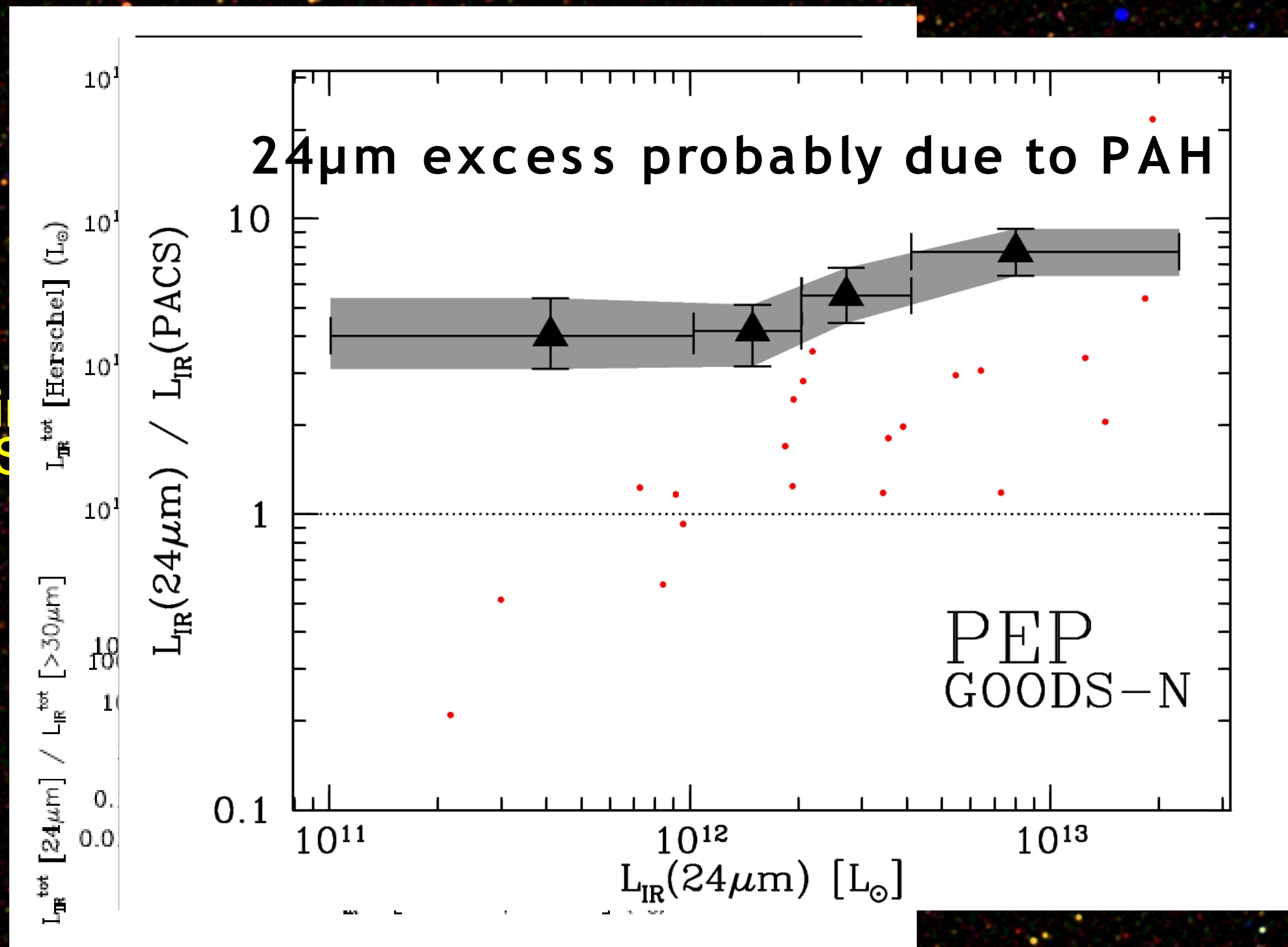


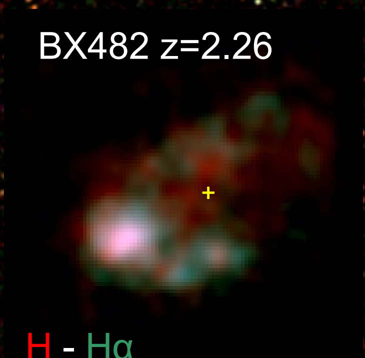
Baugh et al. 2005, Dave 2008, 2010, Perez-Gonzalez et al. 2008

Mid-IR vs PACS



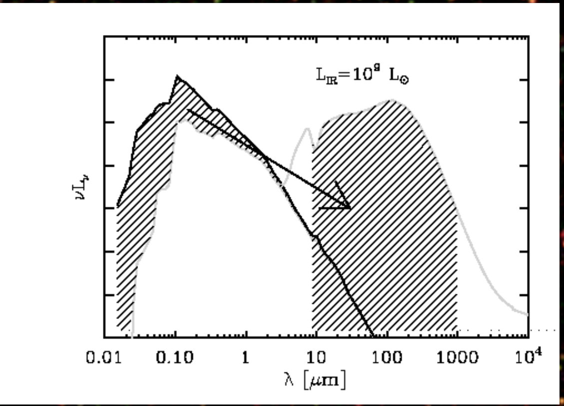
306 BzK star-formi
galaxies in GOODS
K_{AB}<22, z=1.5-2.5





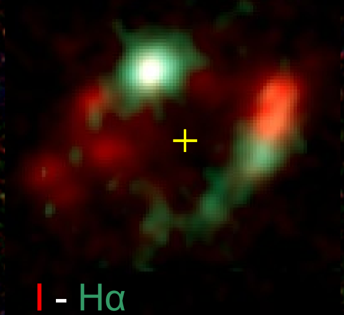
Nordon et al. (2010)
Elbaz et al. (2010)

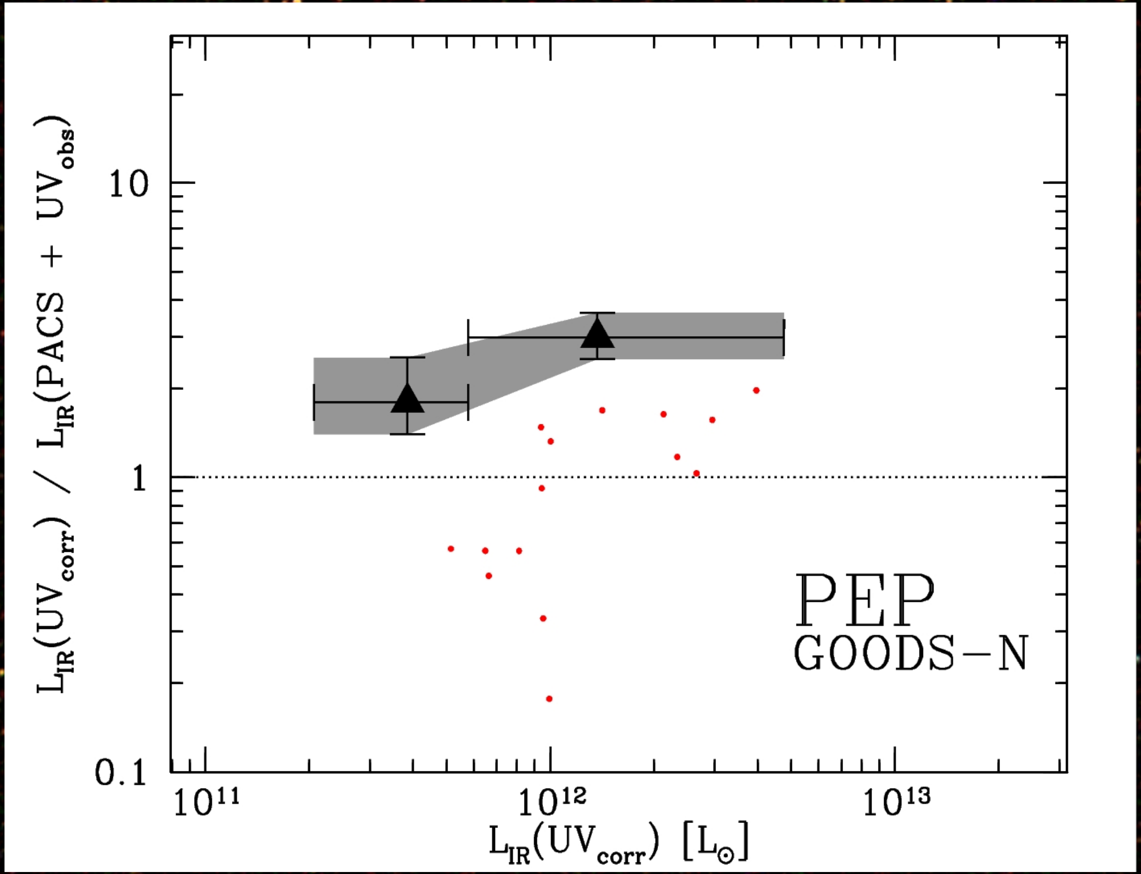
UV SFR at z~2



75 BzK star-forming galaxies in GOODS-N, K_{AB}<22, z=1.5-2.5

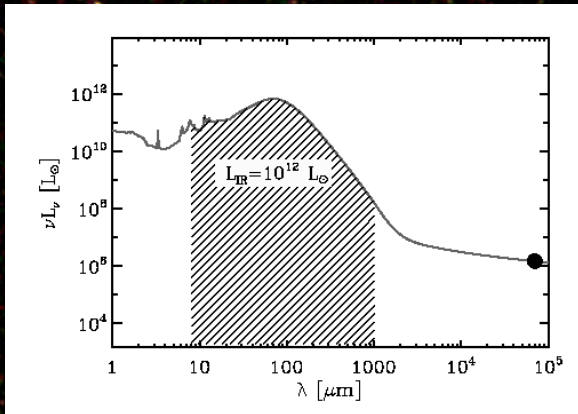
ZC406690 z=2.2

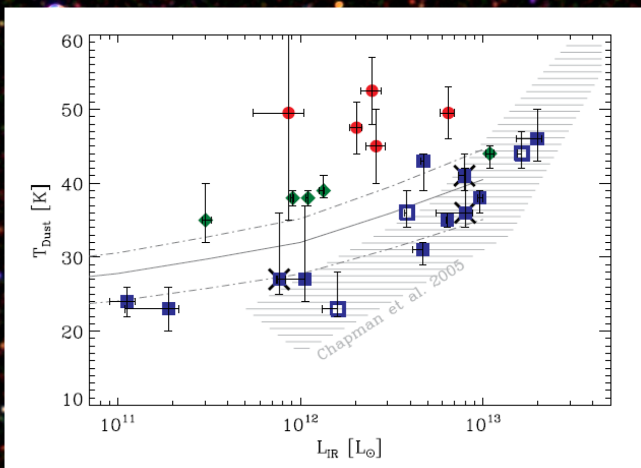


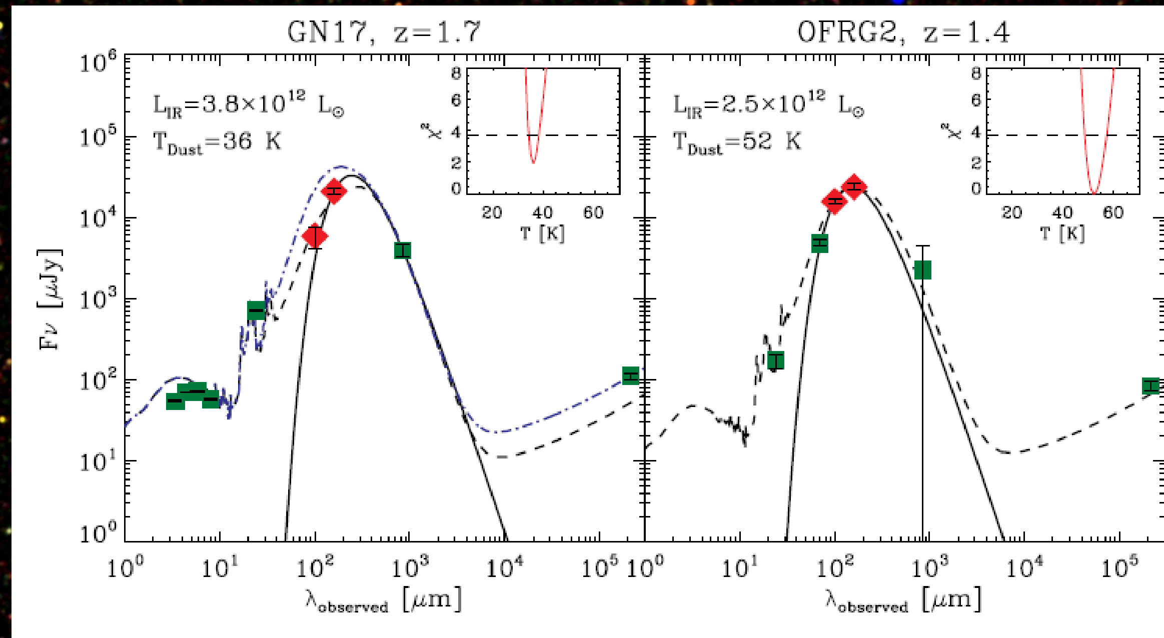


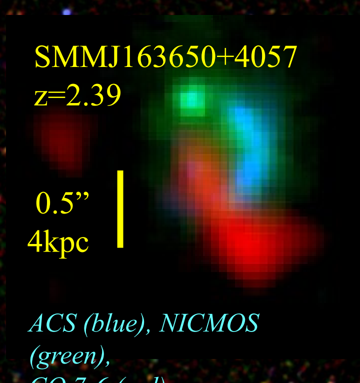
Nordon et al. (2010)

star formation rates of SMGs





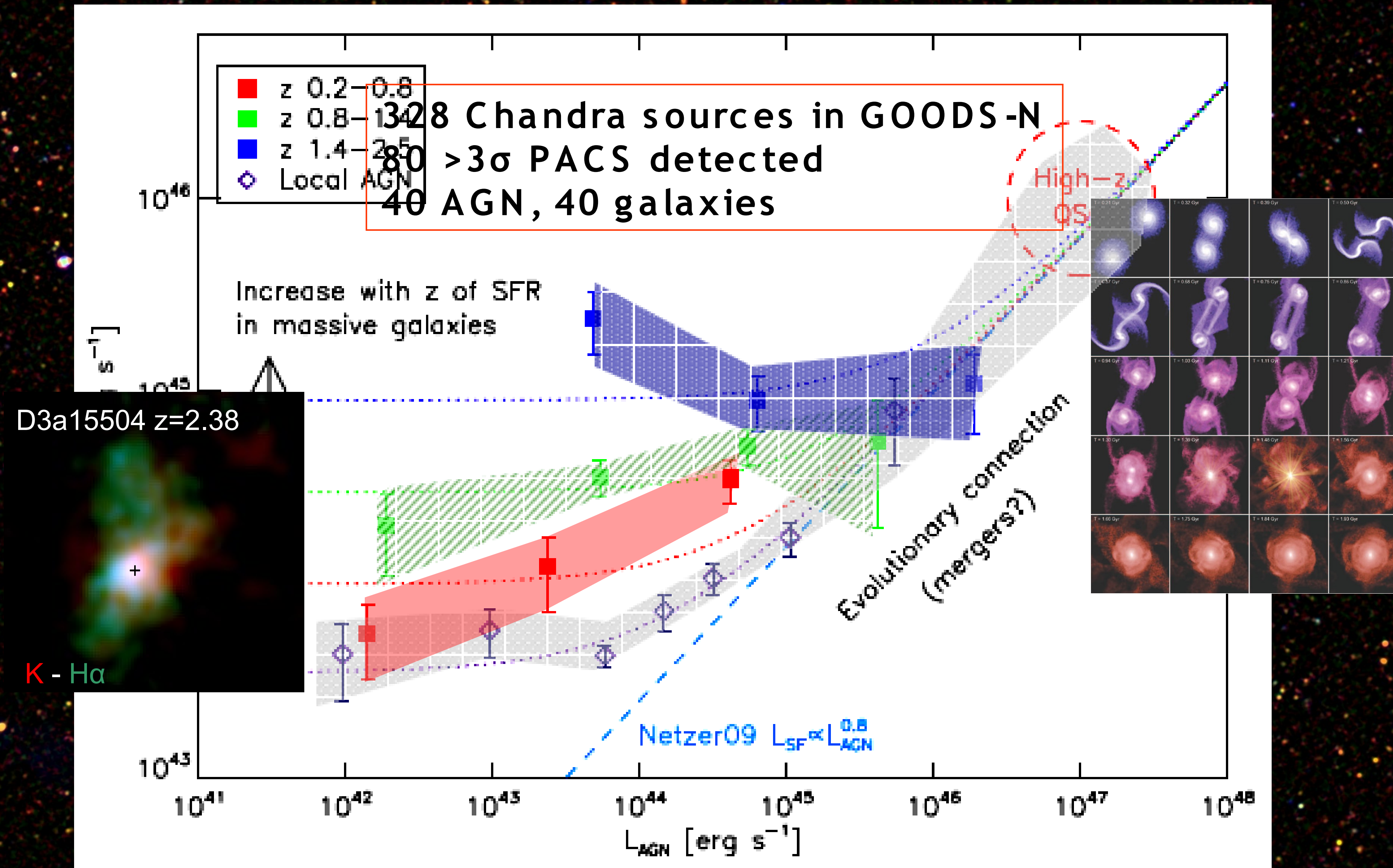




very large star formation rates (SFR ~ 1000 $M_\odot$/yr !), T_{dust}~35 K , and high masses of ‘submillimeter galaxies’ confirmed

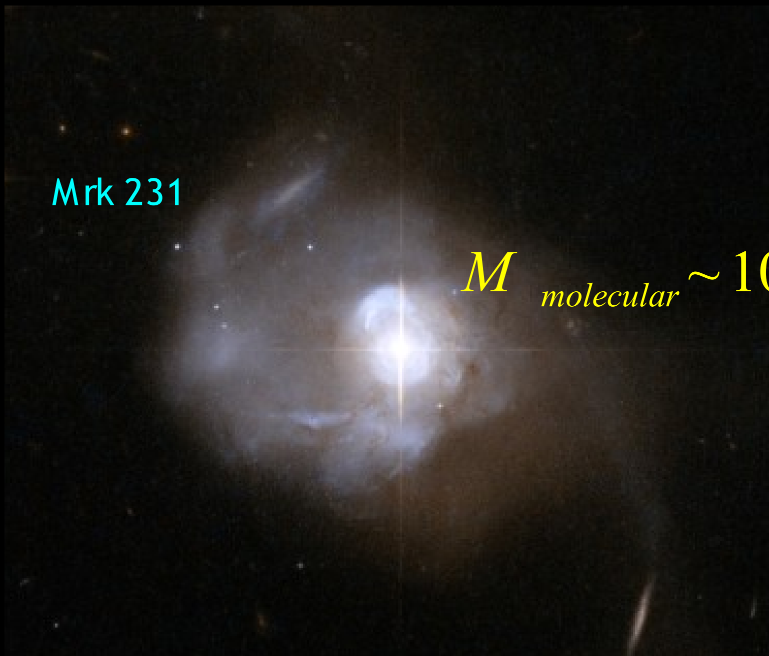
Magnelli & PEP team, Maddox & HERMES team 2010

Two modes of AGN/SF co-evolution

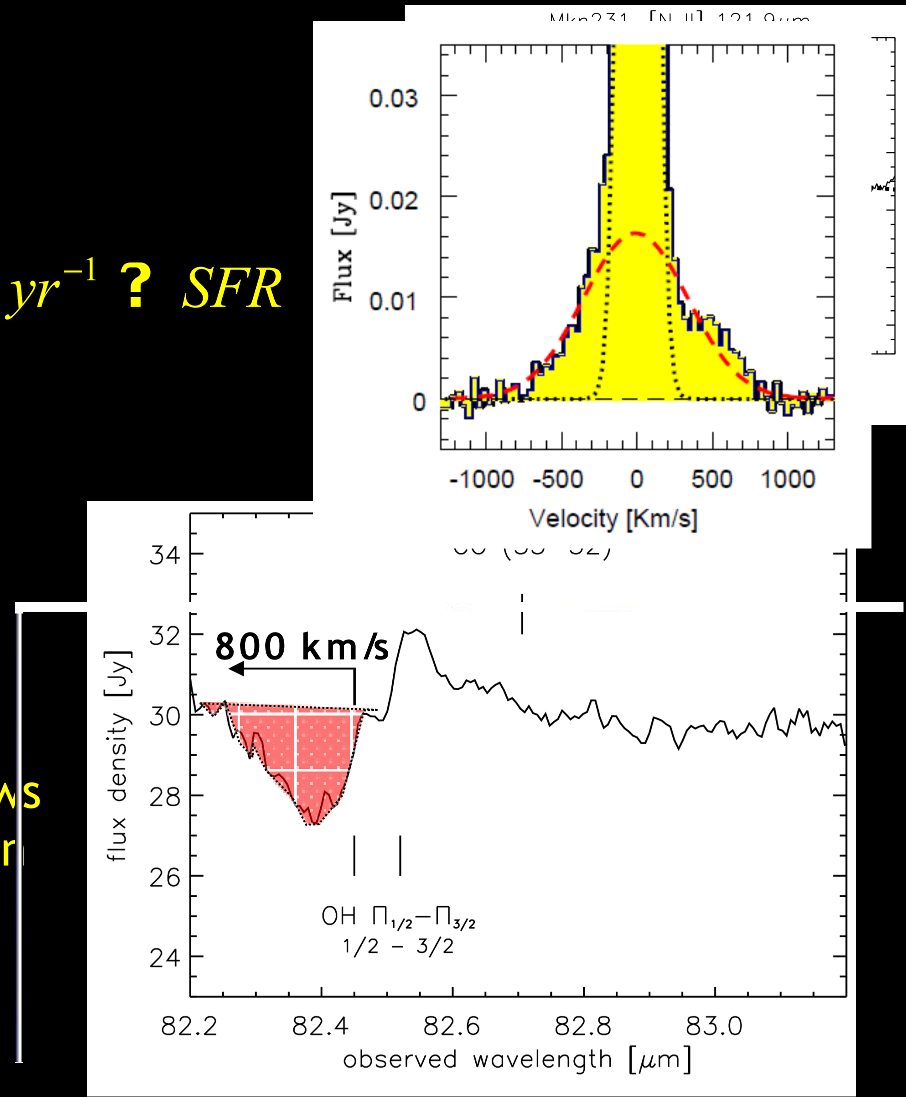


Shao, Lutz et al. (2010)

Evidence for 'quasar feedback'?



$M_{molecular} \sim 10^{3} M_{e}\, yr^{-1}$? SFR



spatially resolved PdBI IRAM observations of CO emission of Mrk231 outflow

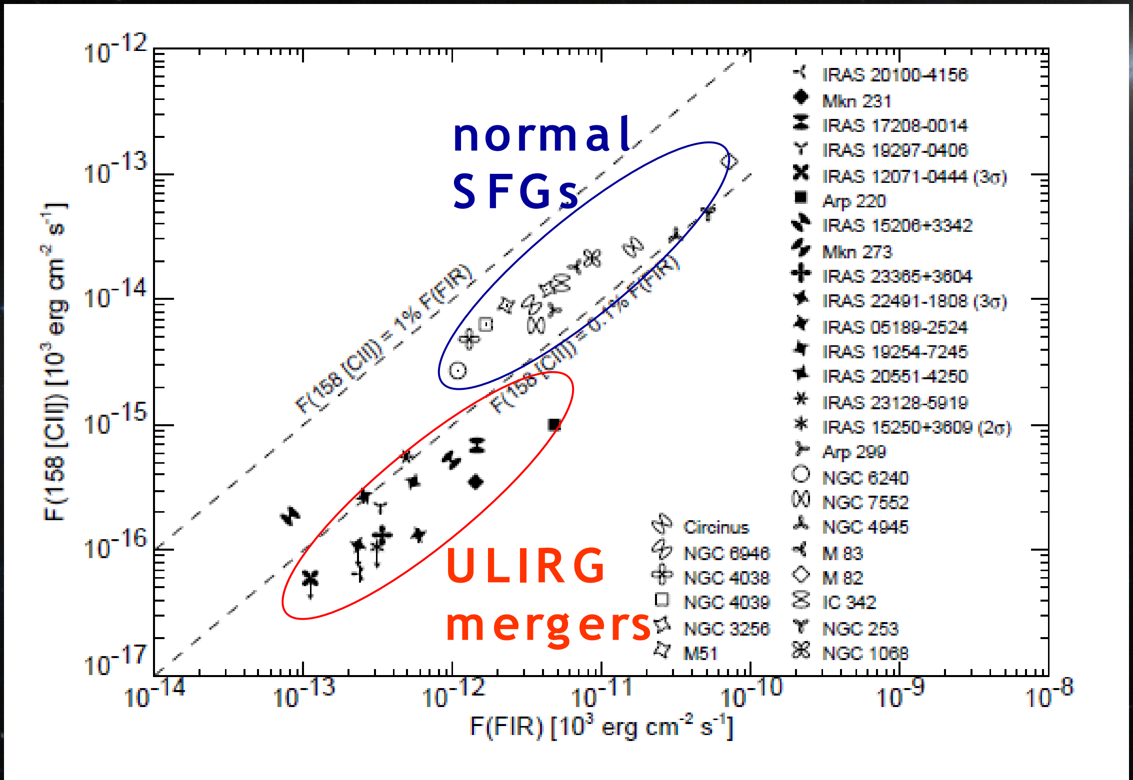
discovery of massive molecular outflows in late stage ULIRG mergers: expulsion of gas by active central QSO?

Feruglio et al. 2010

Fischer & SHINING team 2010

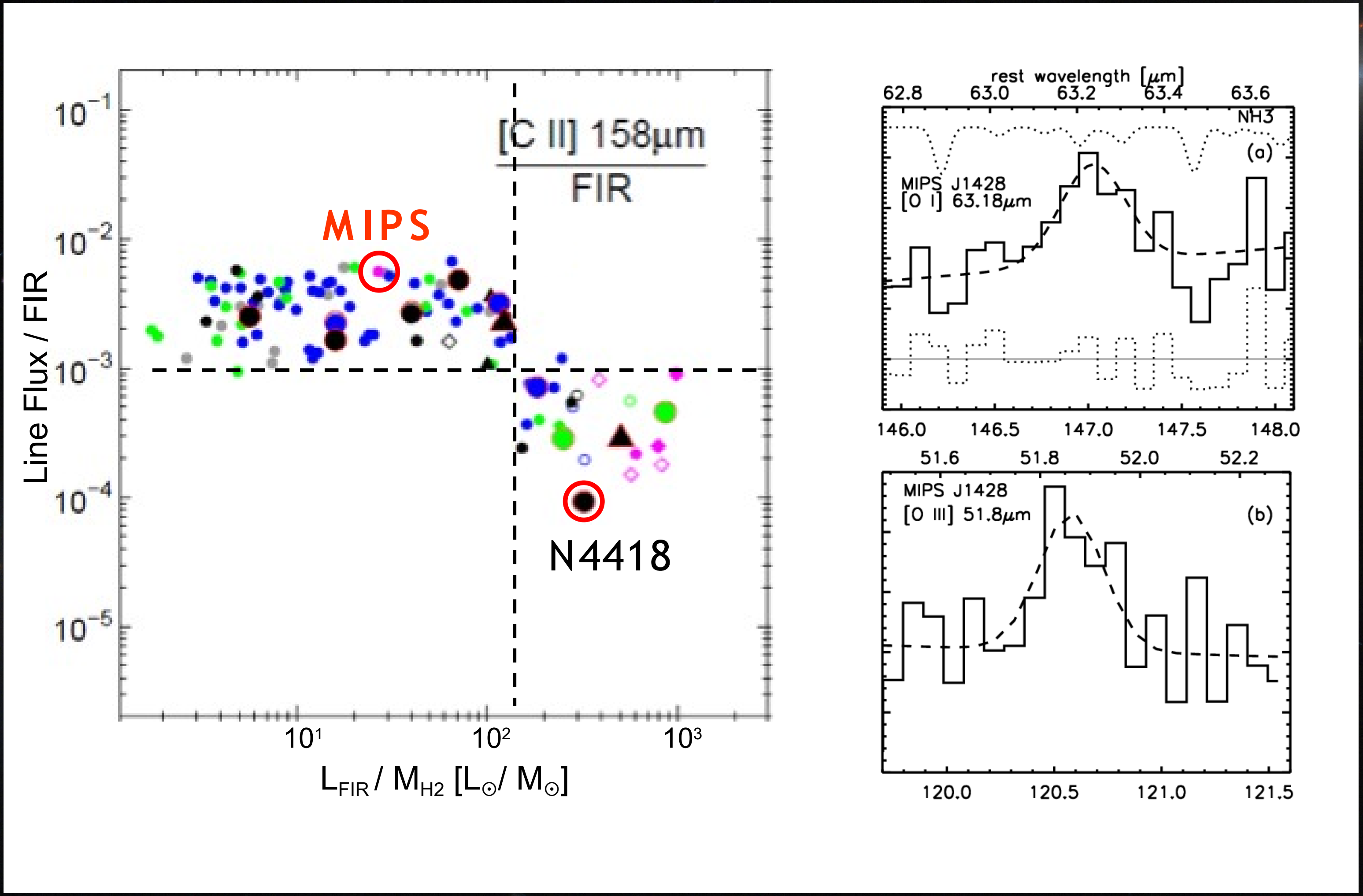
The [C II] Deficit

The 158µm fs-line of [C II] is one of the most important cooling lines of the atomic/warm ISM



Stacey et al. 1991 (KAO)
Luhmann et al. 2003 (ISO)

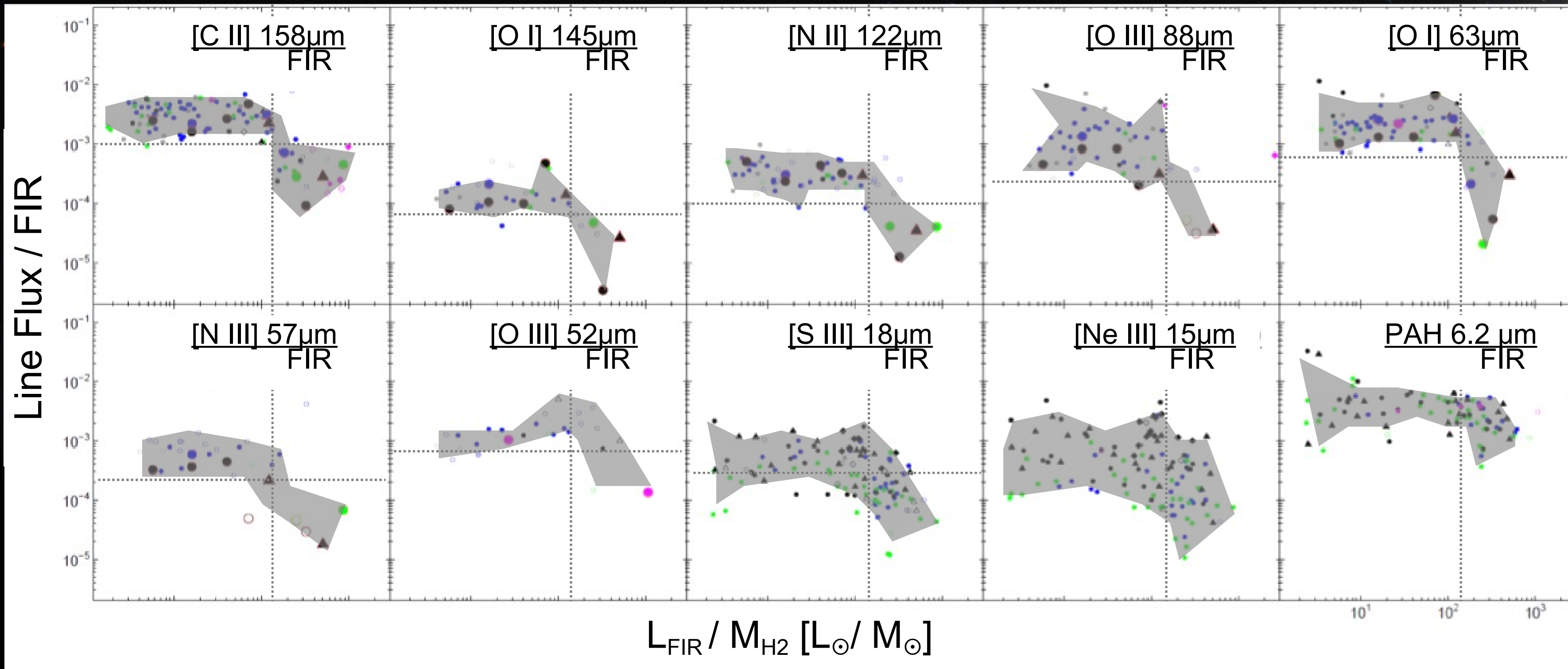
[C II] Deficit with Herschel



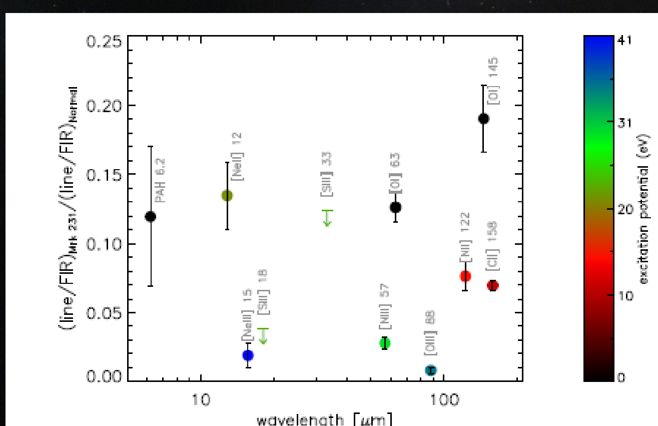
Hailey-Dunsheath et al. 2010

SHINING Survey: Sturm et al. 2010, Gracia-Carpio et al. 2010

[C II] Deficit → Line Deficit



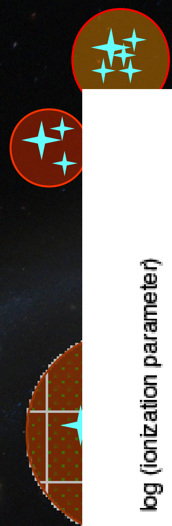
SHINING: Gracia-Carpio et al. 2

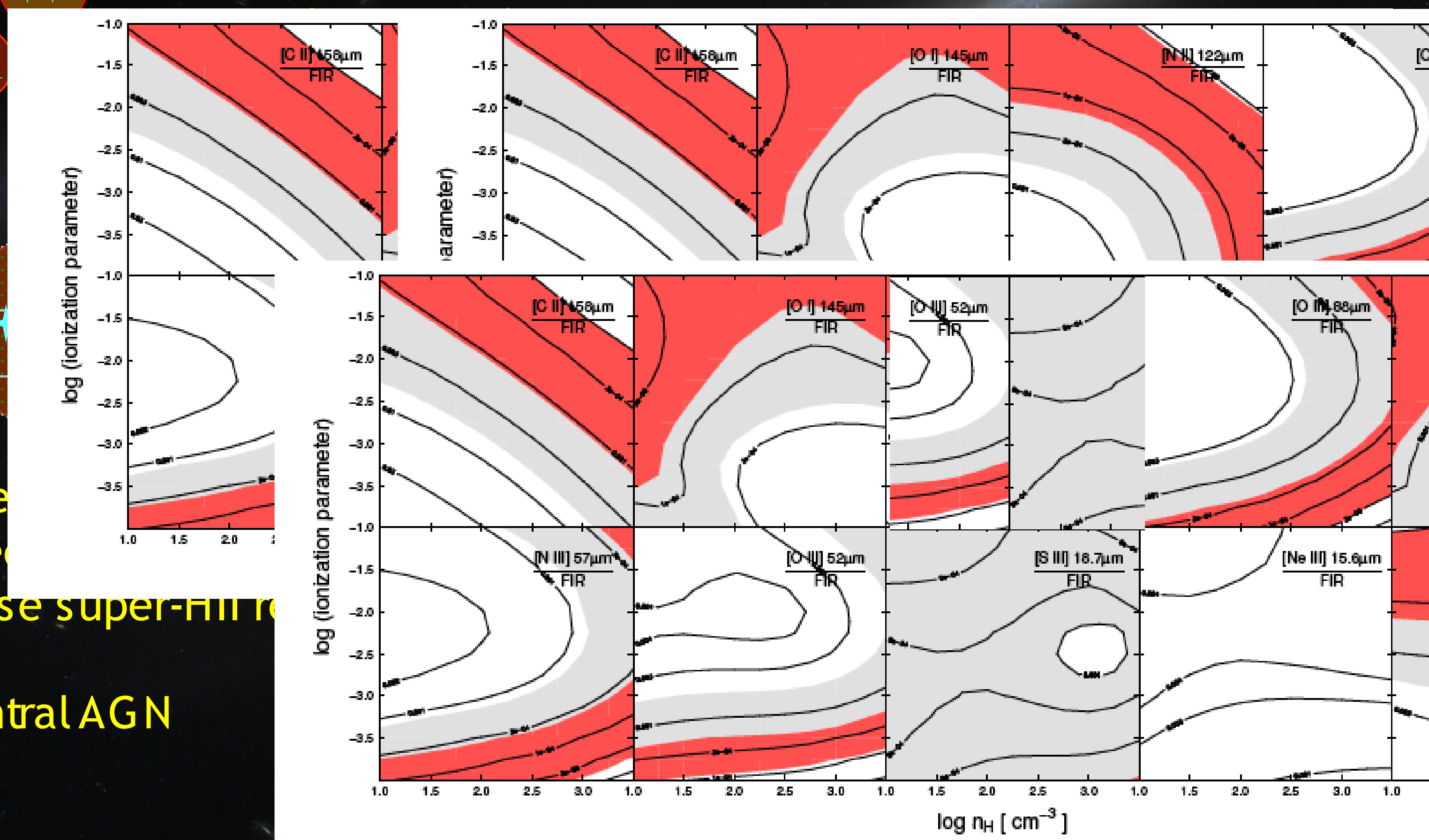


no dependence on wavelength

Fischer et al. (2010)

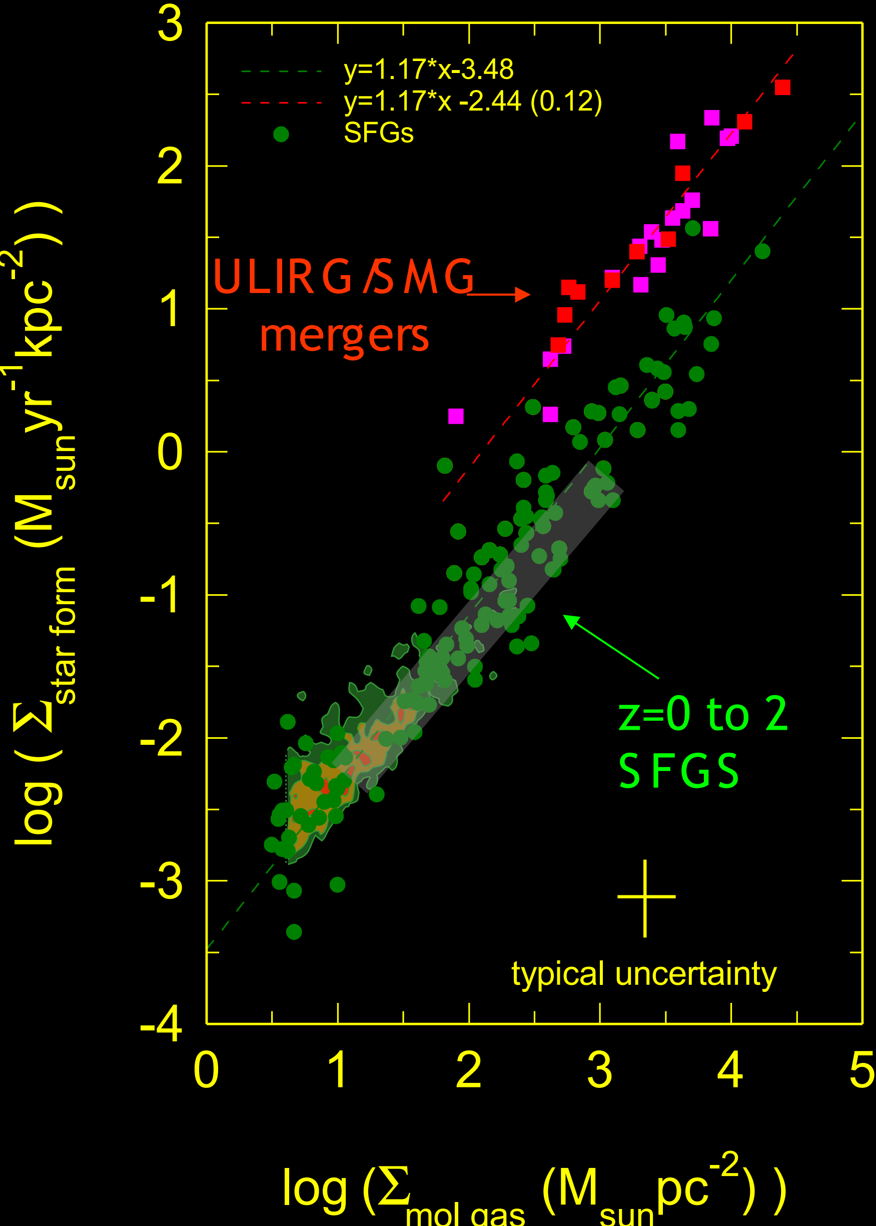
Evidence for a second mode of star formation?





merge
cause
a dense super-HII r
effect
of central AGN

gas-star formation relation

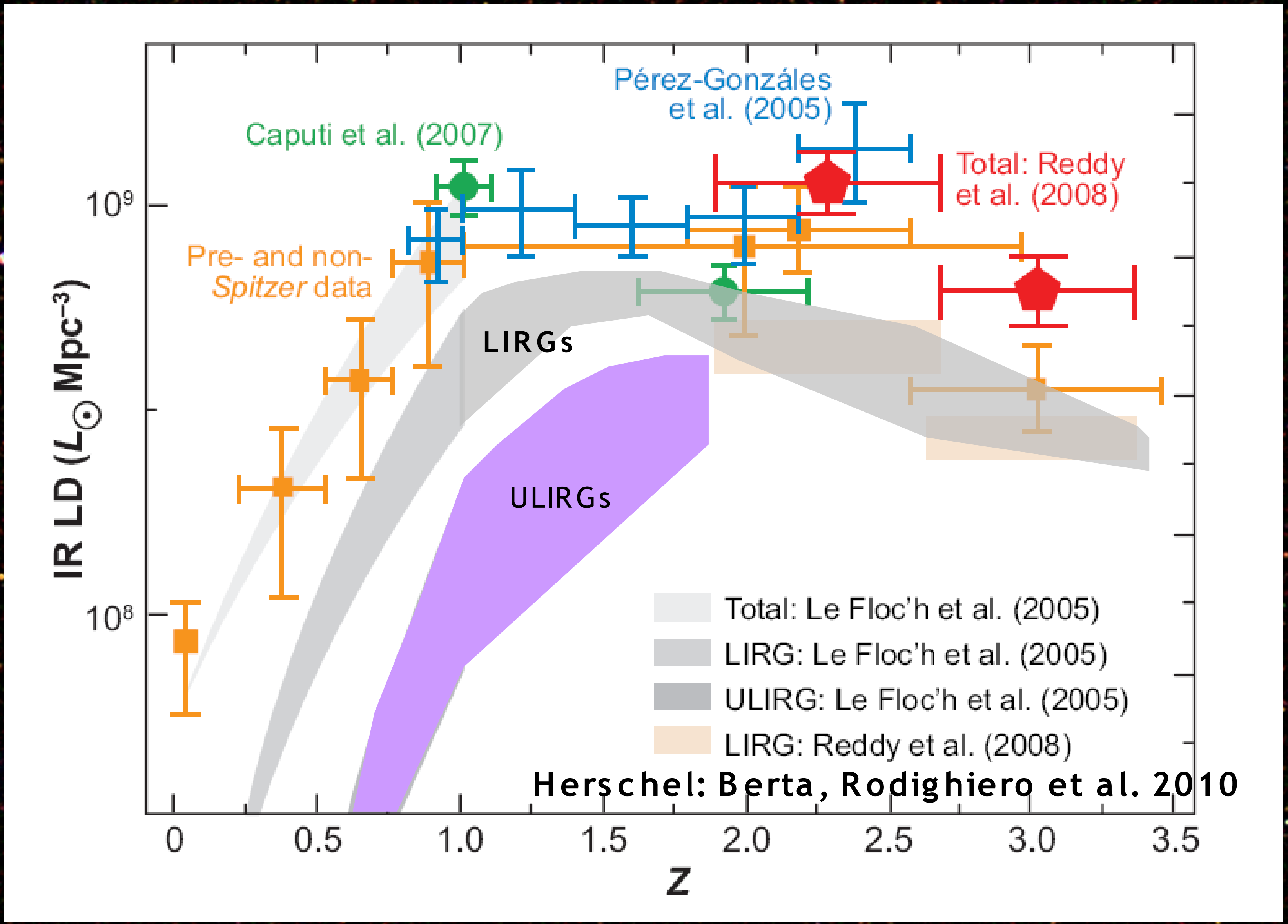


see Linda Tacconi's talk

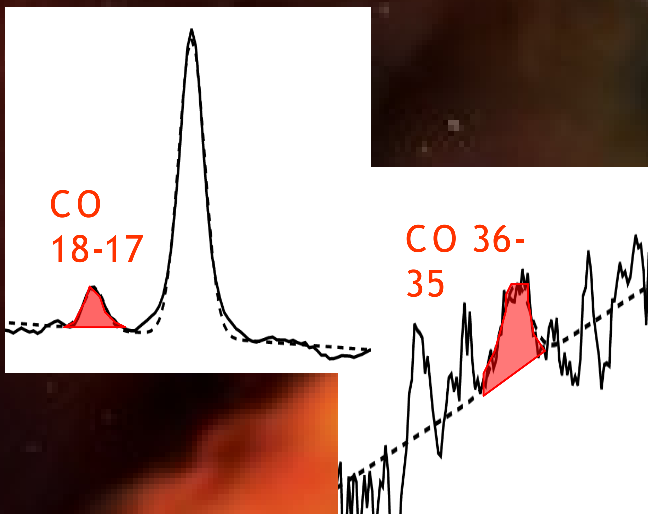
possible origin: compression and smaller dynamical time scale in mergers

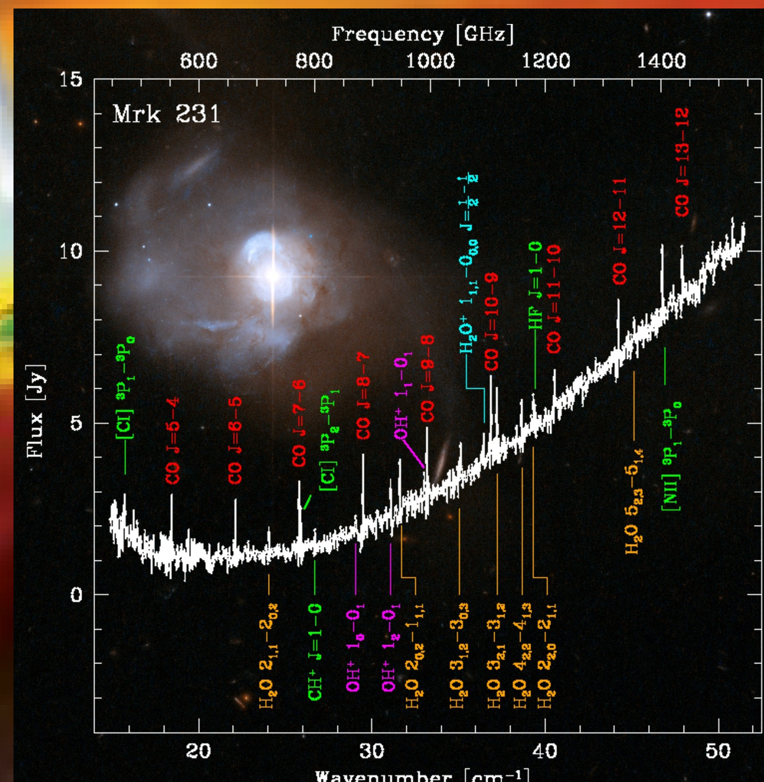
Genzel et al. 2010
Daddi et al. 2010

cosmic star formation history



Far-IR lines in AGNs: evidence for X-ray excited circum-nuclear gas

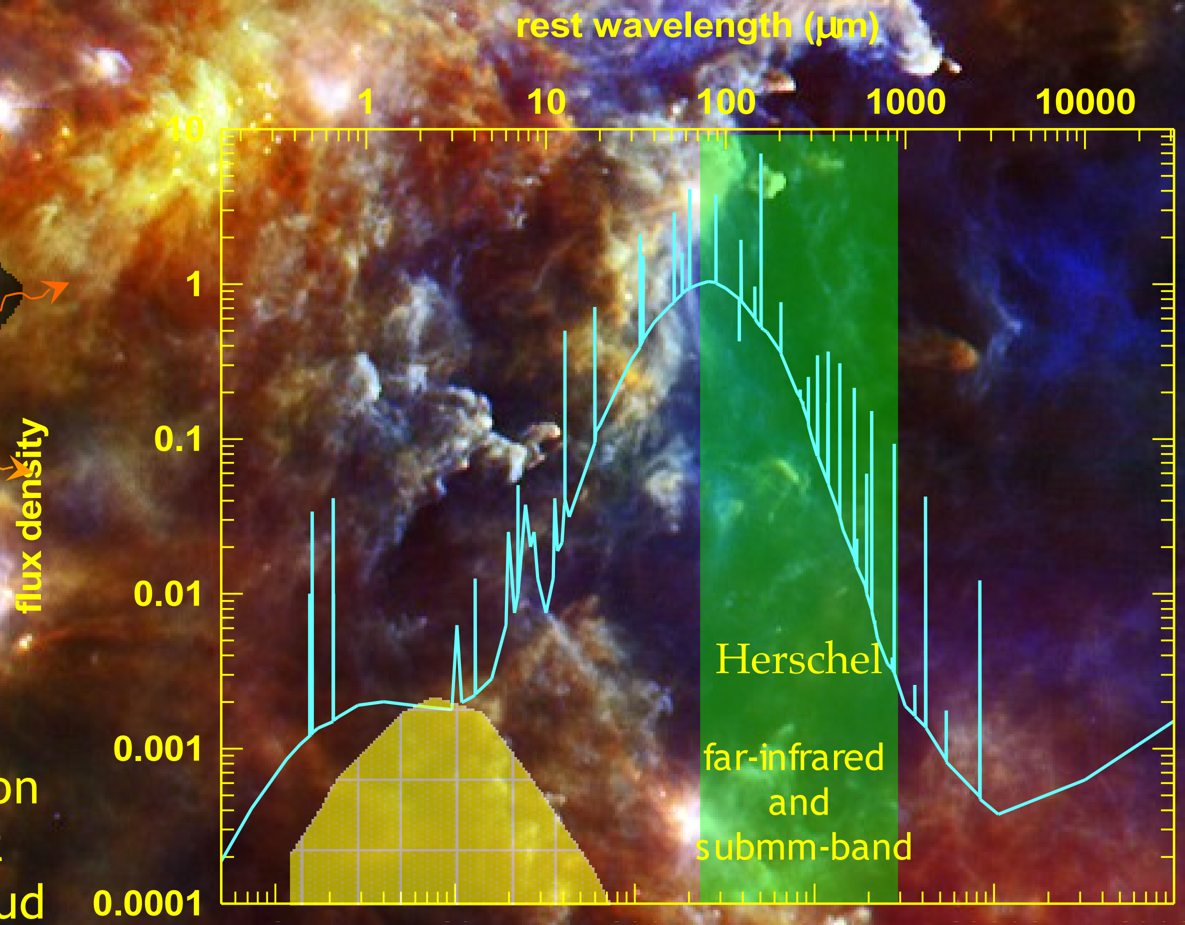




highly excited CO (and H_2O) lines discovered by SPIRE & PACS probably require 'XDR'-component powered by AGNs

van der Werf, Gonzalez-Alfonso & HERCULES team, Hailey-Dunsheath, Sturm & SHINING team

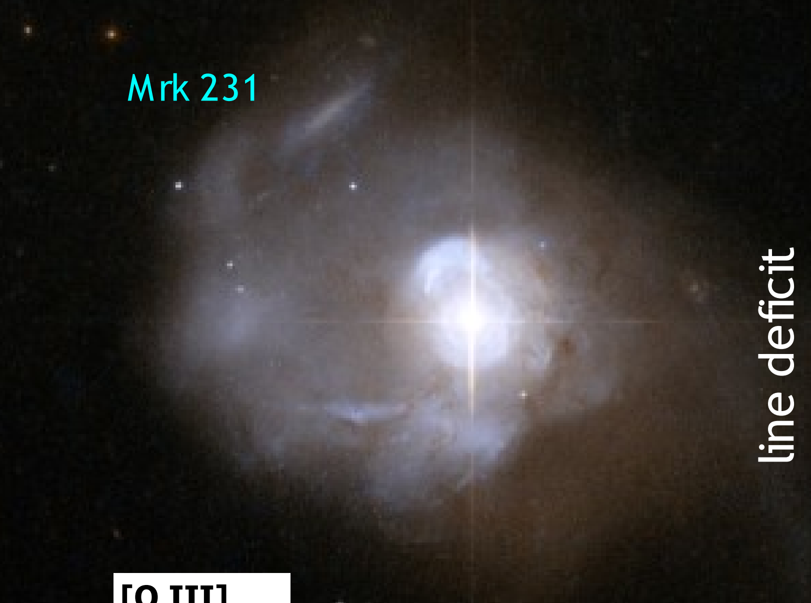
Herschel's main theme: the cool, dusty Universe & star formation

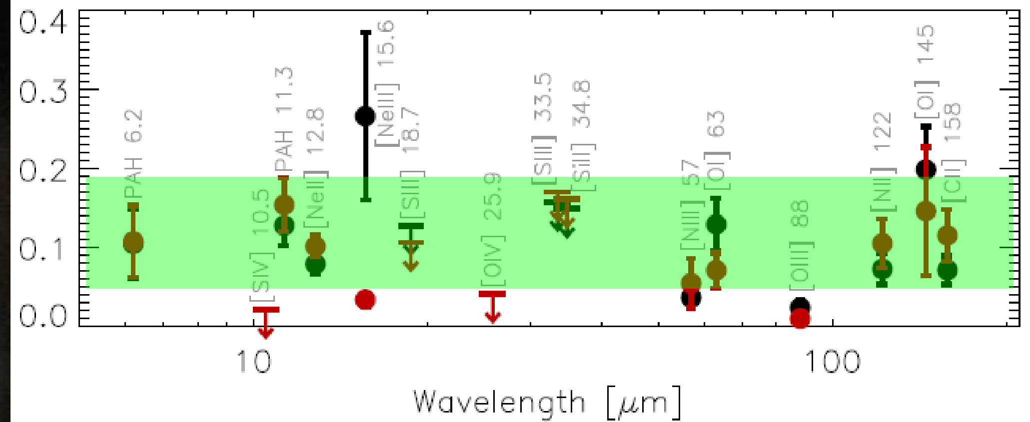


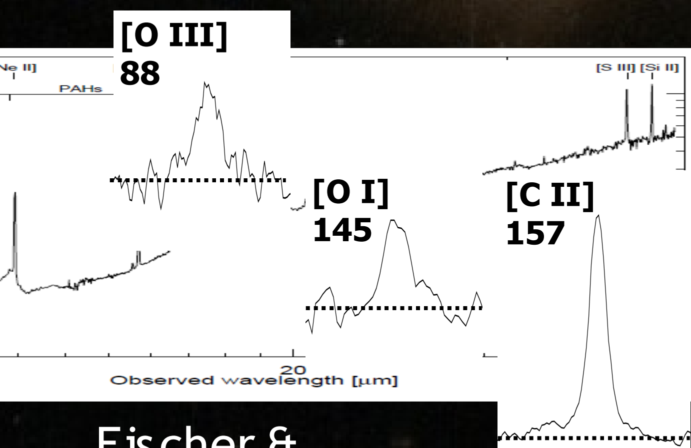
conversion of X-/UV-radiation into far-infrared emission at the interface of a dense cloud

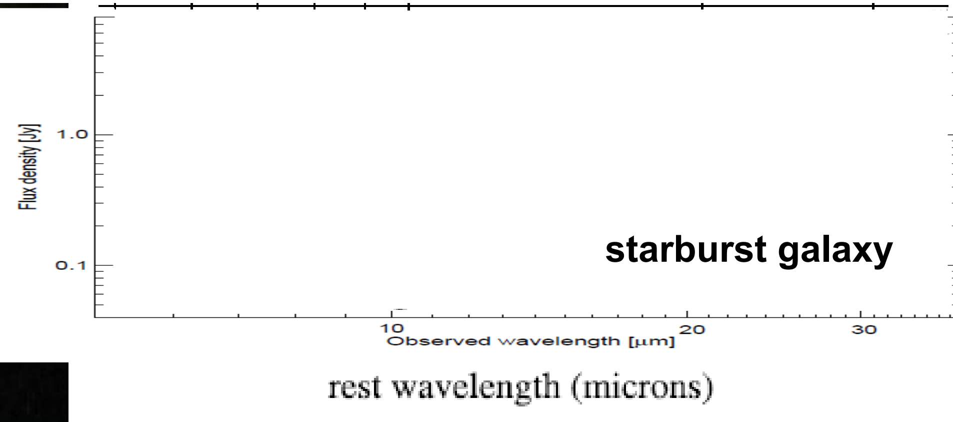
Evidence for a second mode of star formation in luminous infrared galaxies ?

Mrk 231





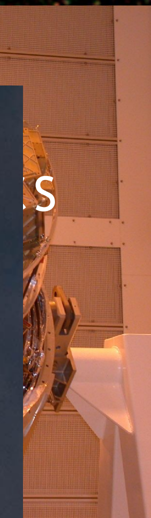


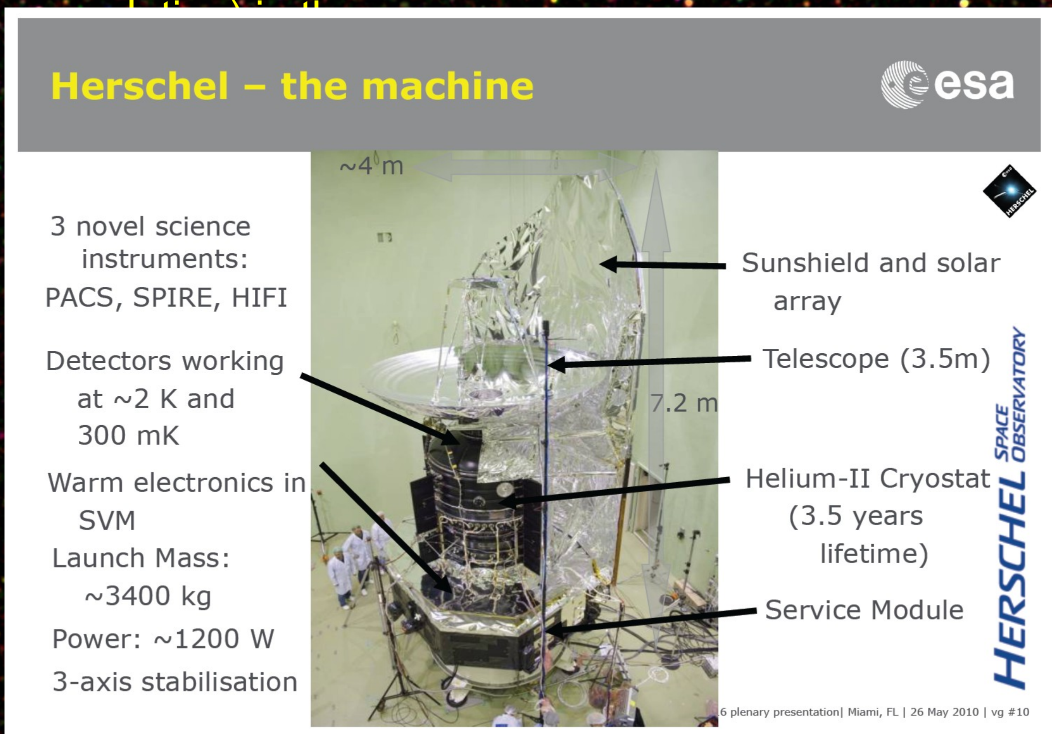


Fischer & SHINING team

Herschel and its three instruments

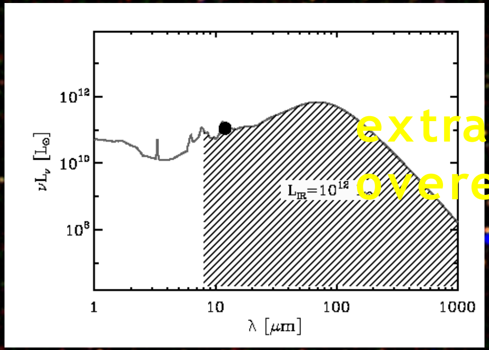
- SPIRE: camera and spectrometer (low to medium spec



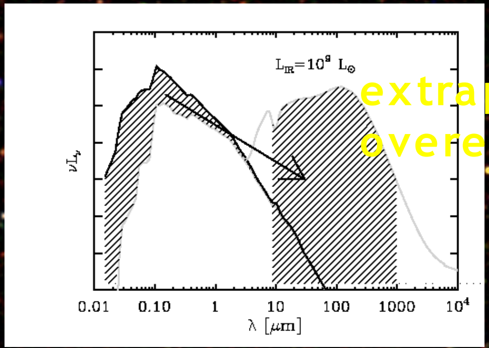


Summary high-z star formation estimators with Herschel

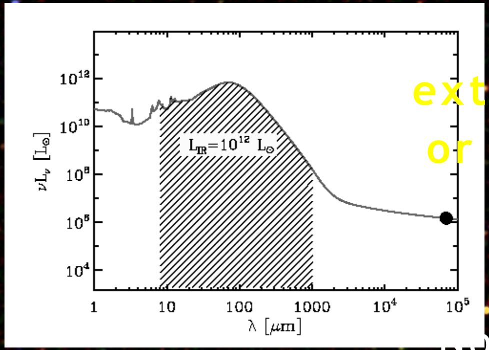
PEP (PACS) and HERMES (SPIRE)



extrapolation from 24μm luminosity with local Universe
overestimates SFR_{FIR} by 3-5 at z>1.5, ok at z<1.5



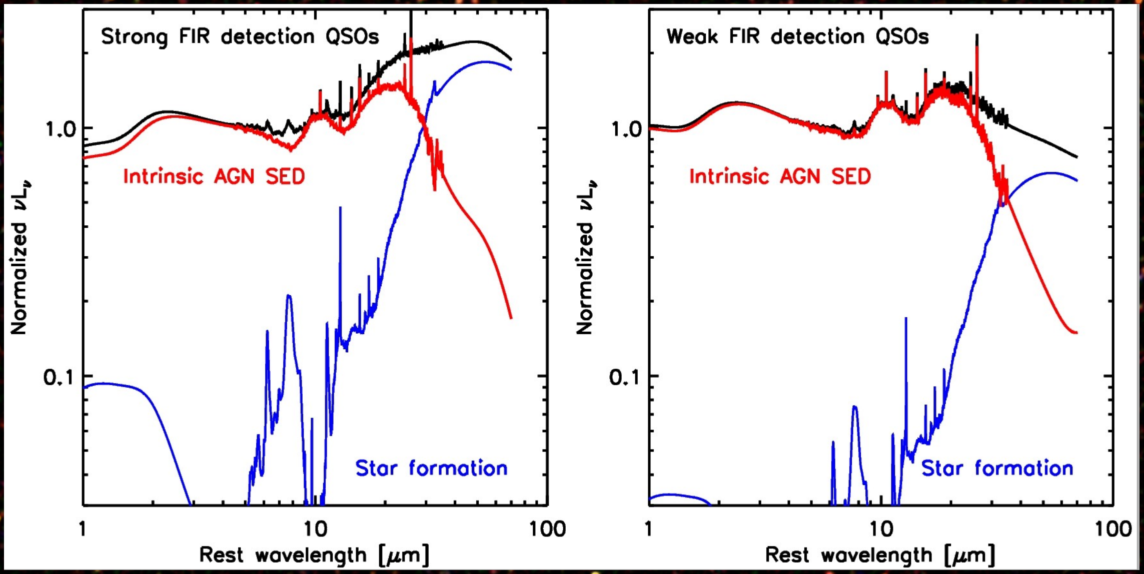
extrapolation from UV luminosity, plus Calzetti extinction corr
overestimates SFR_{FIR} by 1.5-2 at z>1.5



extrapolation from $S_{850\mu m}$ with T_{dust}~30-40 K,
or $S_{1.4\,GHz}$ with radio-FIR relation: ok within uncertainties

rdon et al. 2010, Magnelli et al. 2010, Elbaz et al. 2010, Ivison et al. 20

AGN and SF co-evolution



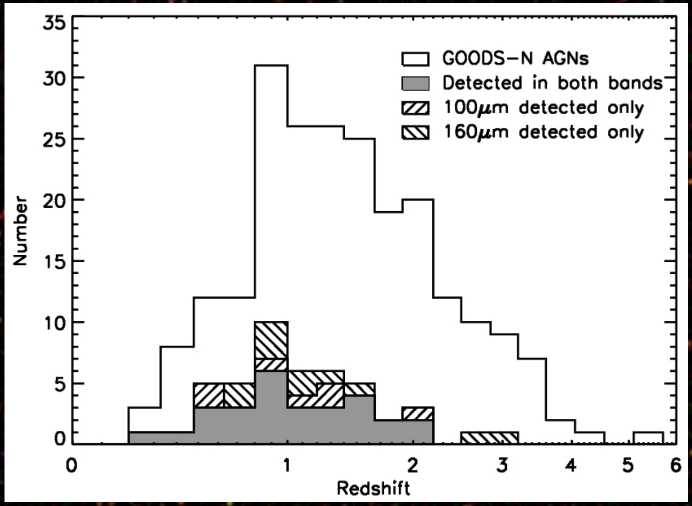
far-IR comes from star formation

Netzer et al. (2007)

Based on:

FIR detection of X-ray AGNs: 21%

+ stacking



Shao et al. (2010)