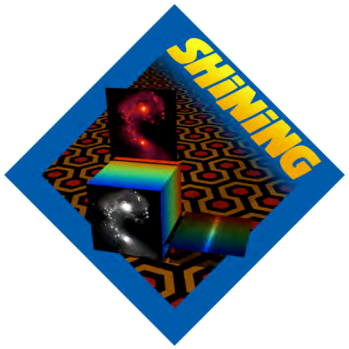

THE DUSTY YOUNG UNIVERSE:
PHOTOMETRY AND SPECTROSCOPY OF
QUASARS AT z > 2

an institute of the
Max-Planck-Gesellschaft

FIR Fine Structure lines at high-redshift

The Promise of PACS Spectroscopy

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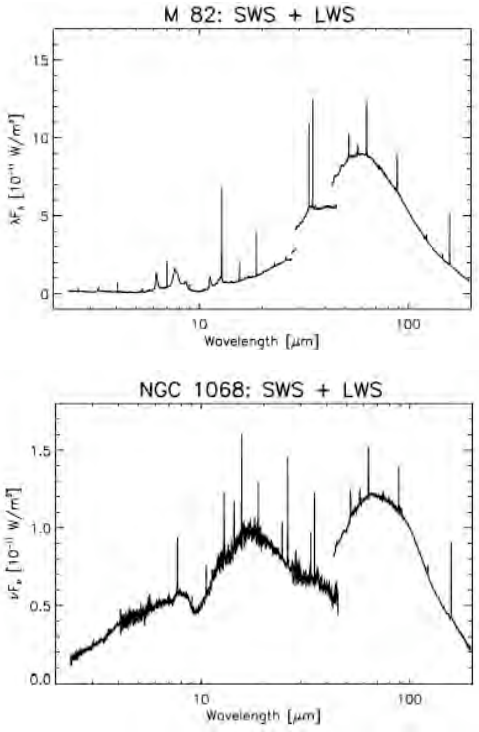
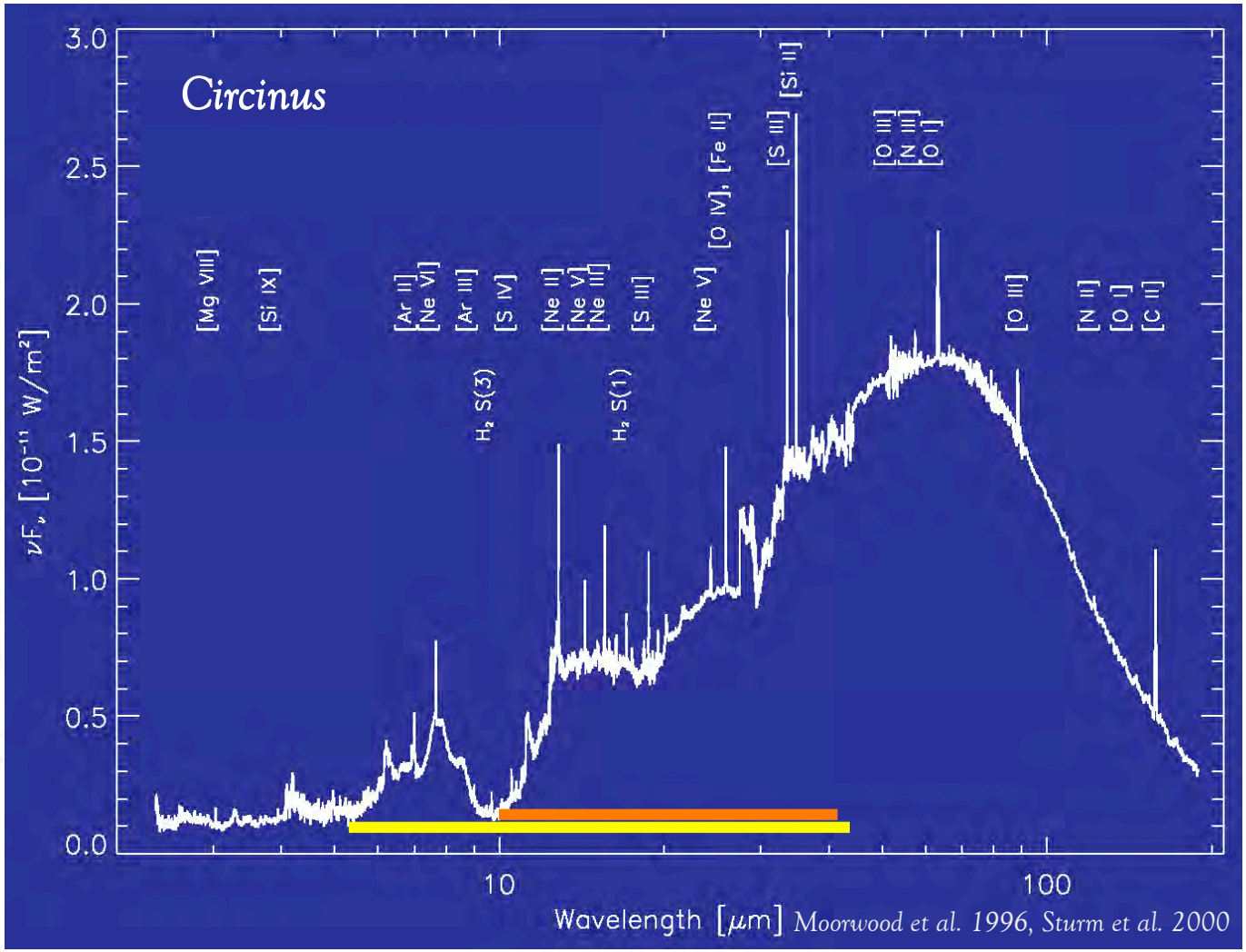
A. Contursi[2], J. Fischer[3,2], E. González-Alfonso[4], A. Poglitsch[2],
A. Sternberg[5], R. Genzel[2], D. Lutz[2], **L. Tacconi**[2], N. Christopher[1], J. de Jong[2]

[1]Univ. of Oxford [2]M.P.E. [3]US Naval Research Lab [4]Universidad de Alcalá de Henares [5]Tel Aviv University

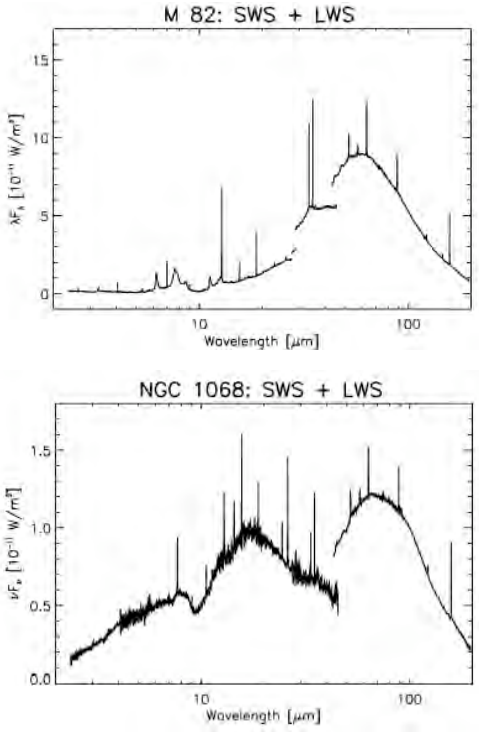
Building on ISO & Spitzer's Legacy

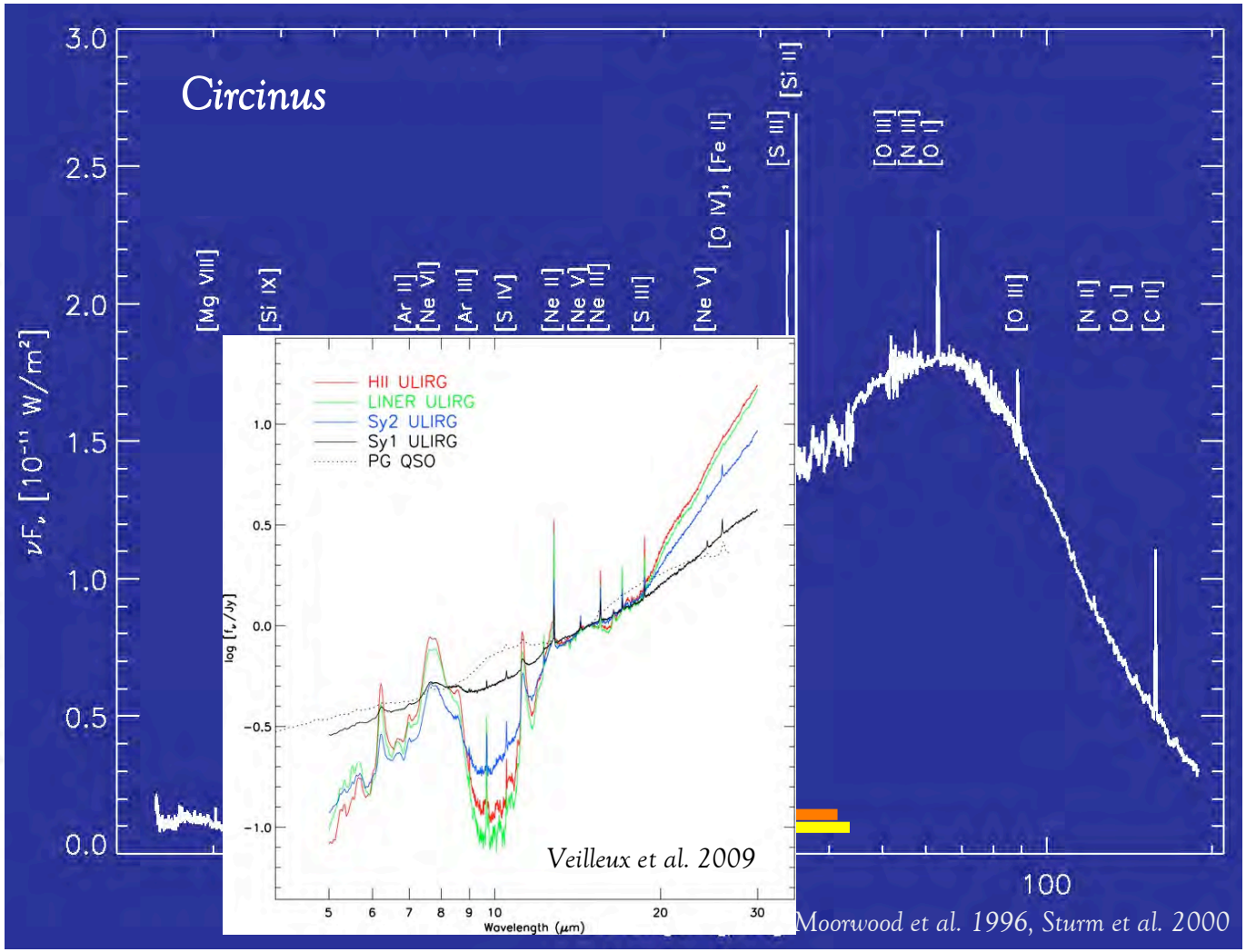




Starlight <5um PAHs H_2 rotational lines FIR cooling lines
H-recombination lines VSG continuum AGN torus SF regions Disk/cirrus

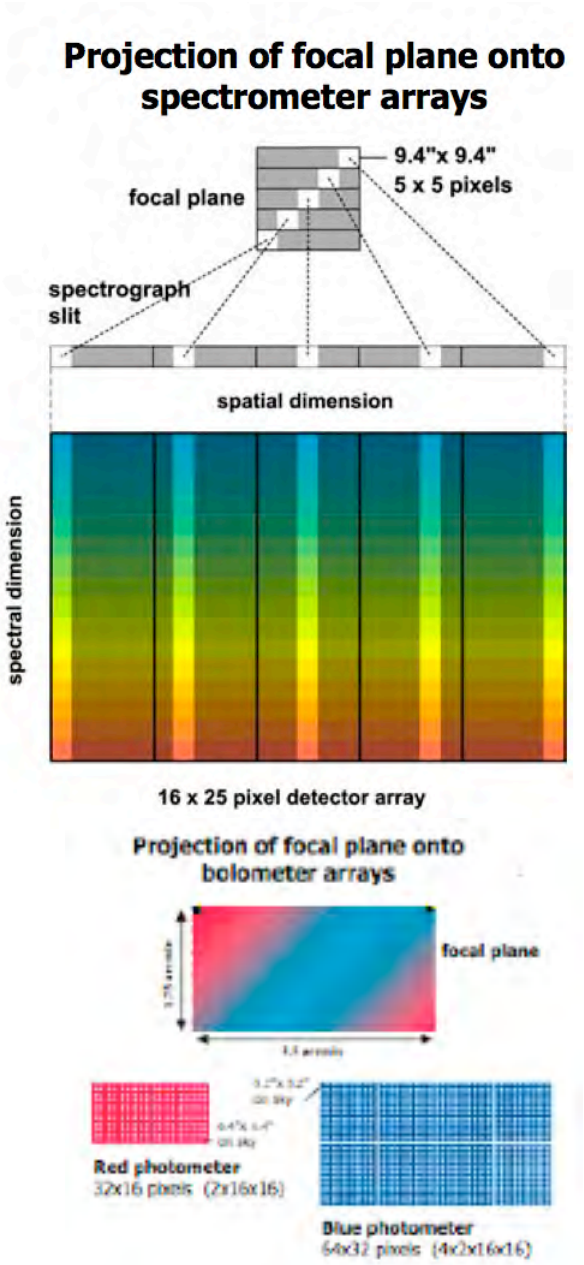
Building on ISO & Spitzer's Legacy

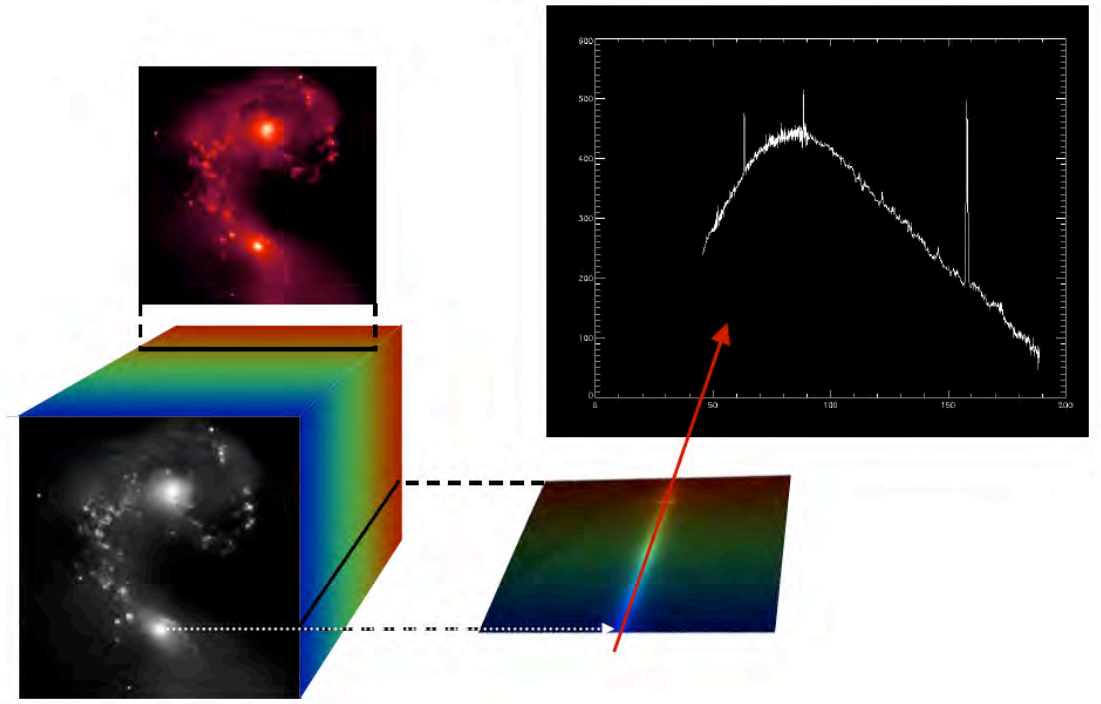




Starlight <5um PAHs H_2 rotational lines FIR cooling lines
H-recombination lines VSG continuum AGN torus SF regions Disk/cirrus

Spectroscopy with PACS





47”x47” (5x5 pixels) FOV rearranged via an image slicer on two 16x25 detector arrays

Simultaneous 55-98 & 102-210 μm spectroscopy

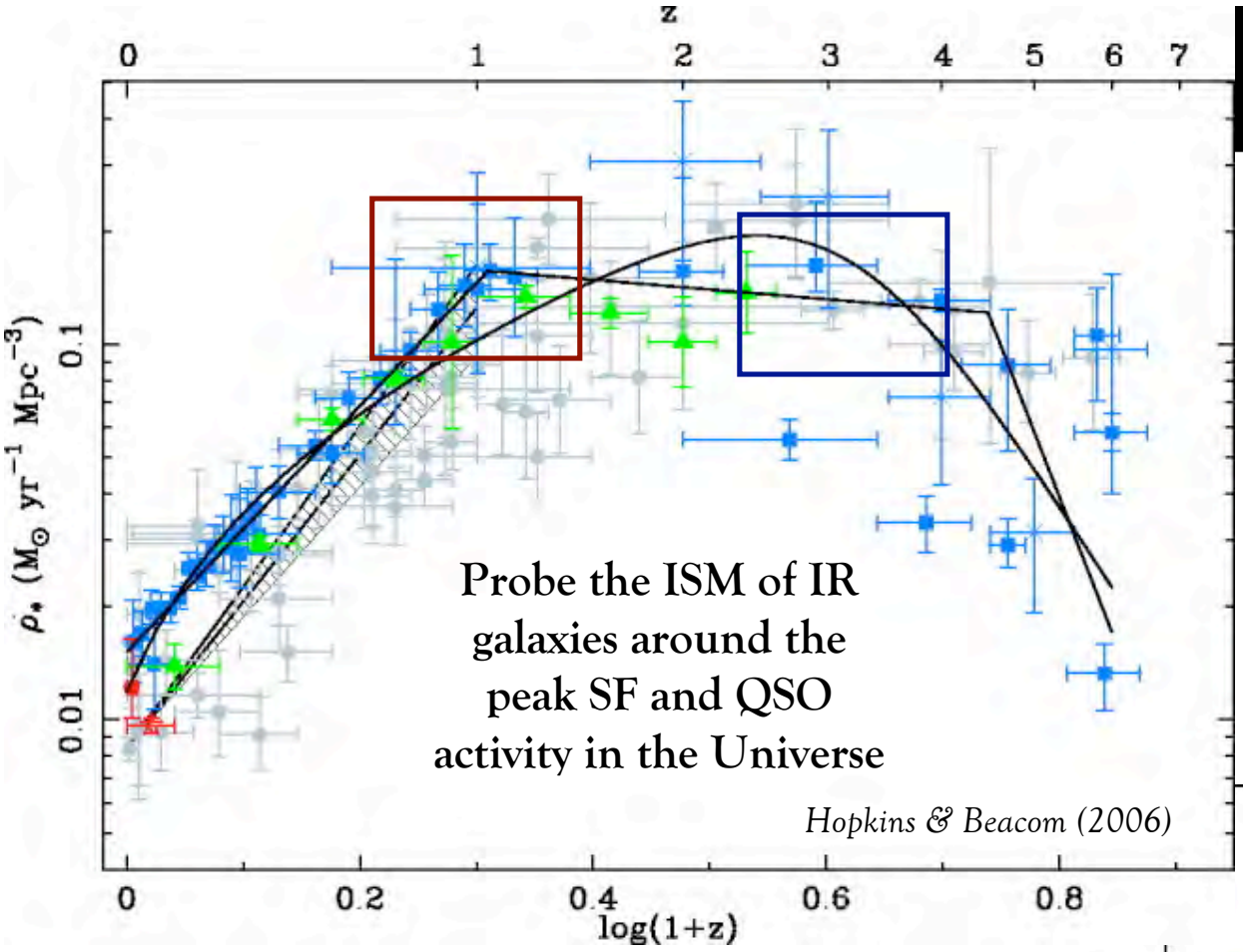
Performance:

- $\lambda/d\lambda \approx 1500$
- Sensitivity: 3 - 20 x 10^{-18} W/m2 (5σ, 1h)

This program: Deep integrations 5 - 10 h (A. Poglitsch's talk)

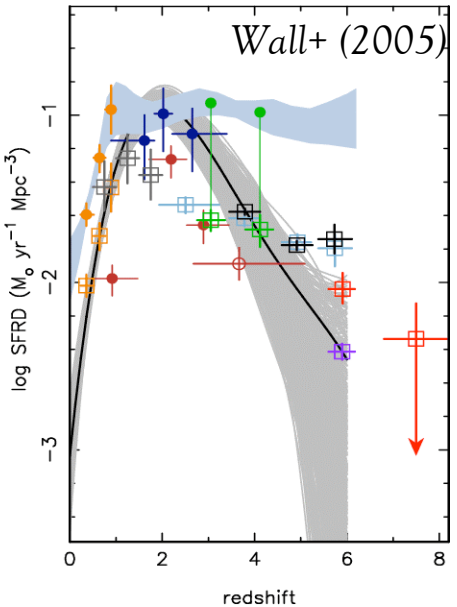
- **Explore the limits of the PACS spectrometer**
- **Sensitivity and at high-z**

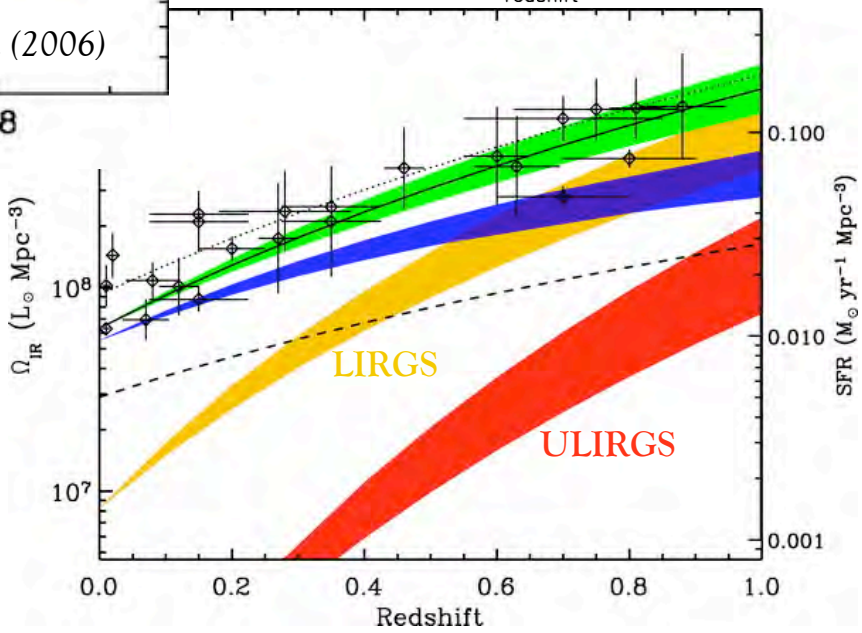
Motivation



Probe the ISM of IR galaxies around the peak SF and QSO activity in the Universe

Hopkins & Beacom (2006)

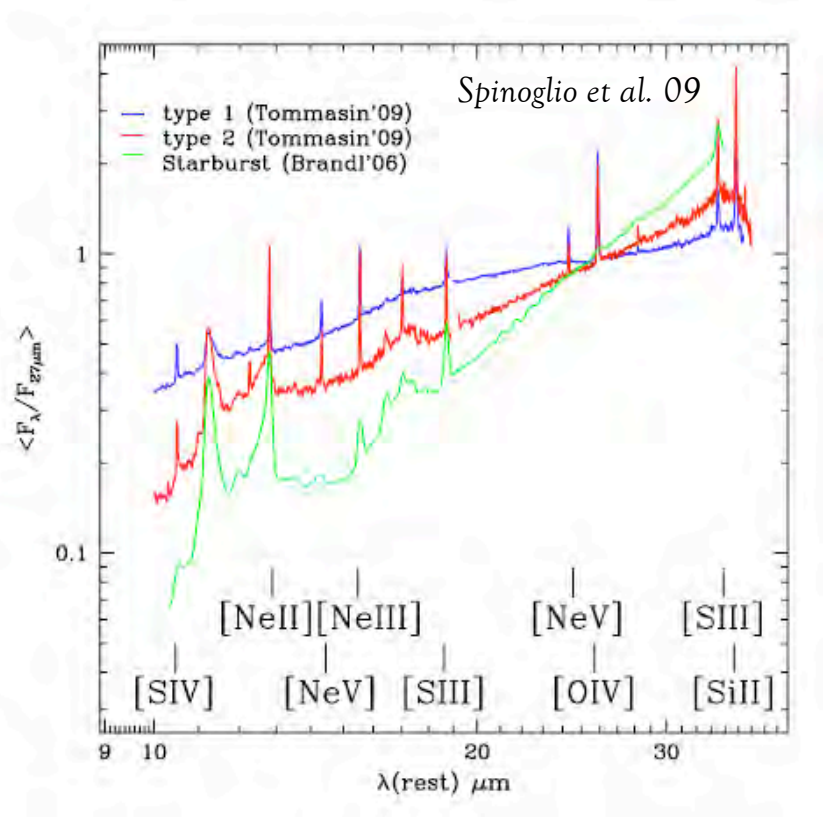


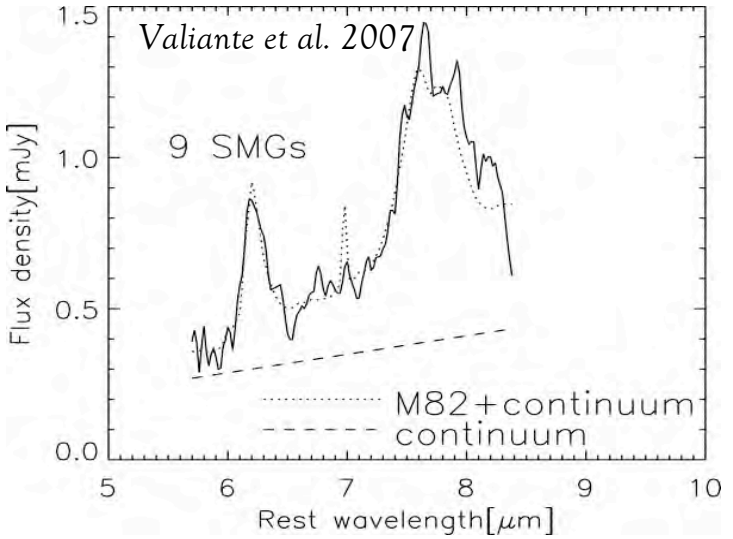


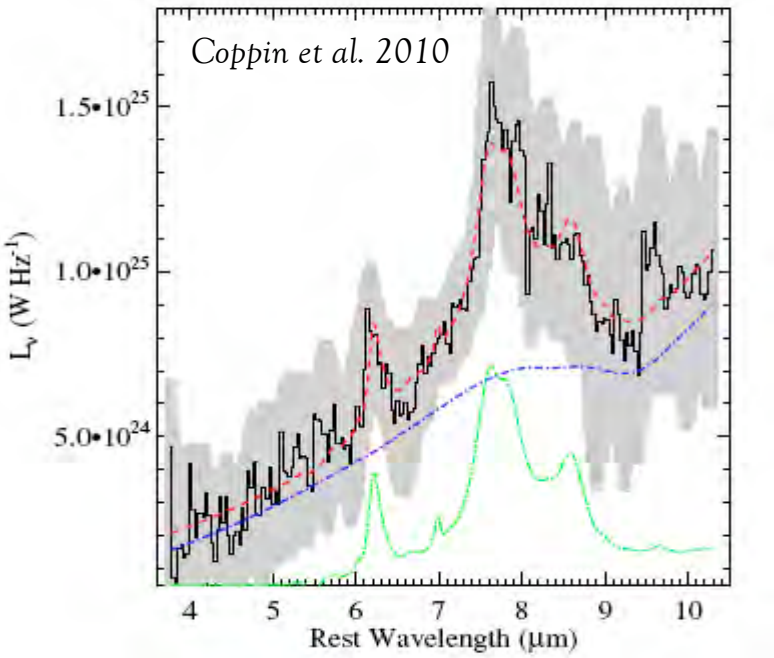
Le Floc'h+ (2006), also Magnelli+ 09

While Luminous Infrared Galaxies become more important population at high-z, they are not necessarily the same beasts - the high luminosity of IR galaxies at high-z is not necessarily due to major-mergers as at z≈0 (Genzel et al. 2010, Tacconi et al. 2010)

PACS Spectroscopy: z = 2 - 4



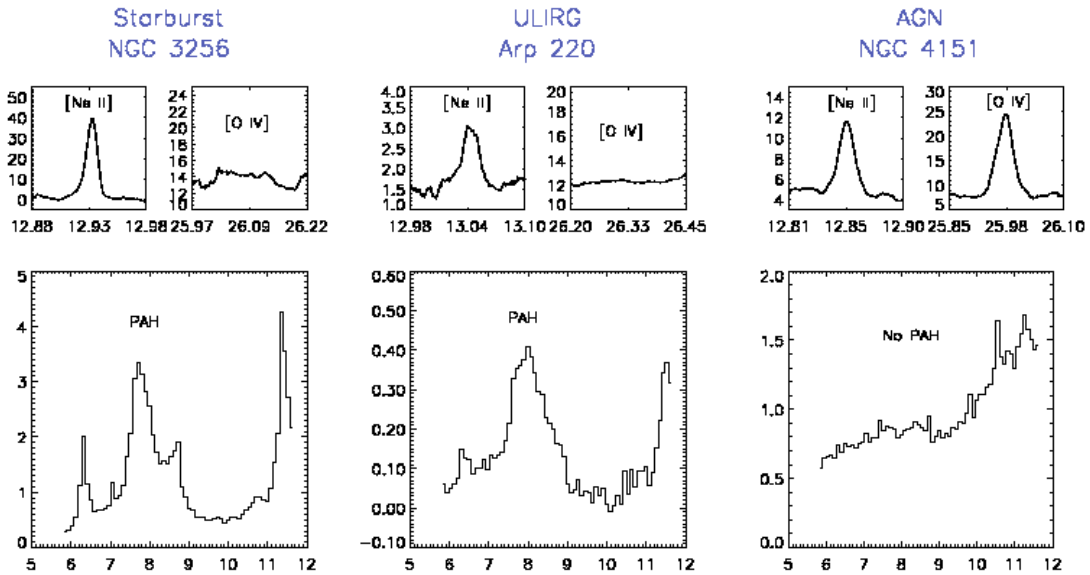




Diagnostic lines that were well studied by ISO-SWS and Spitzer IRS in z≈0 galaxies fall in the PACS range at high-z

PACS observations at z≈2-to-4 are complementary to Spitzer's results in galaxies at these redshifts

PACS Spectroscopy: z = 2 - 4

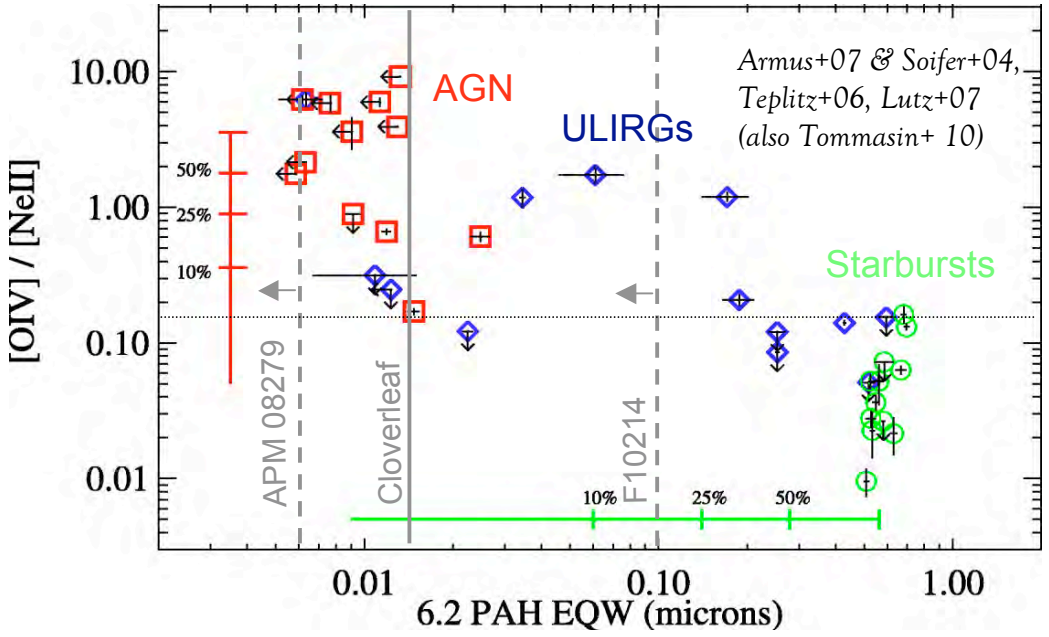


GTKP: The Dusty Young Universe
PI K. Meisenheimer
Co-PI L. Tacconi (PACS Spectroscopy)

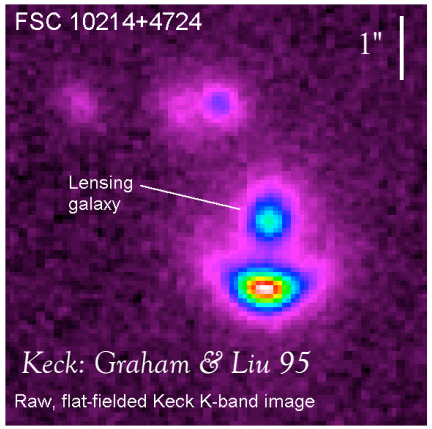
4 bright, **lensed** QSOs and SMGs

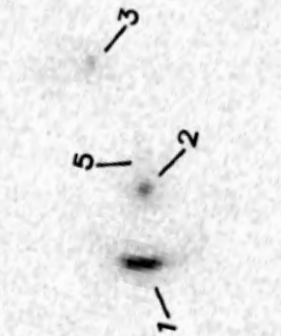
Redshifted [SIII]33.5 and [OIV]25.9
(SIII used as a proxy for NeII)
SIII (IP=23eV) traces low excitation gas
OIV(IP=55eV) traces high excitation gas
Starburst/AGN diagnostic

Name	*Type*	*z*	L_{IR} $10^{14} L_{\odot}$	*Mag*
IRAS F10214+4724	**Sy2**	**2.29**	**5.1**	**12**
SMM J14011+0252	SMG	2.57	1.1	3-30
Cloverleaf	QSO	2.57	8.1	11
APM 08279+5255	QSO	3.91	3.4	85



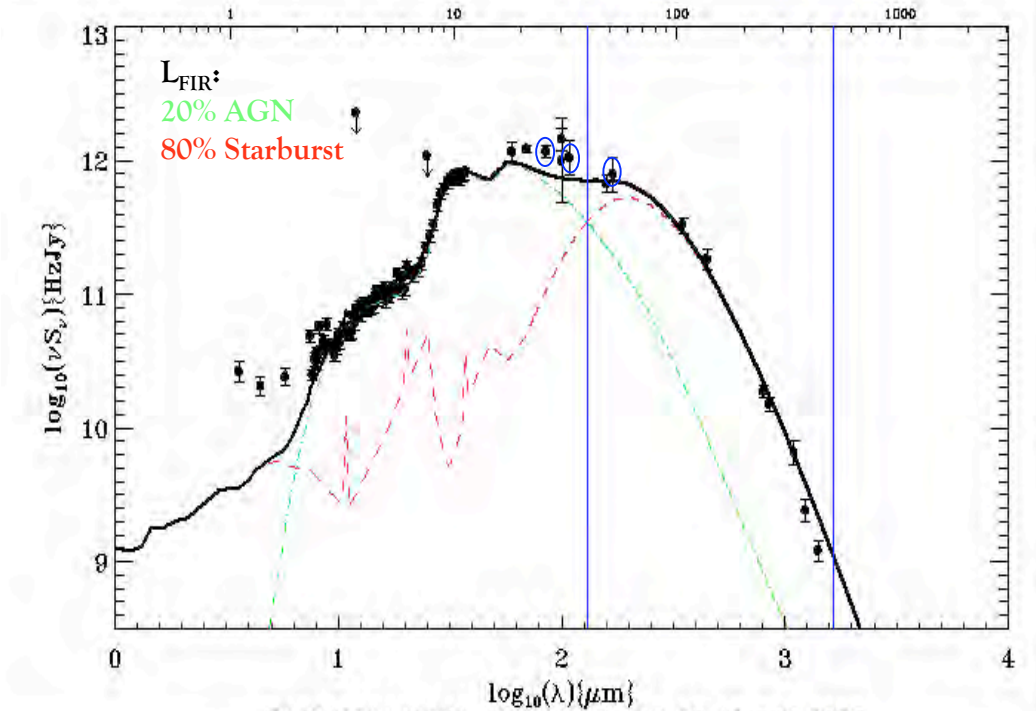
IRAS F10214+4724

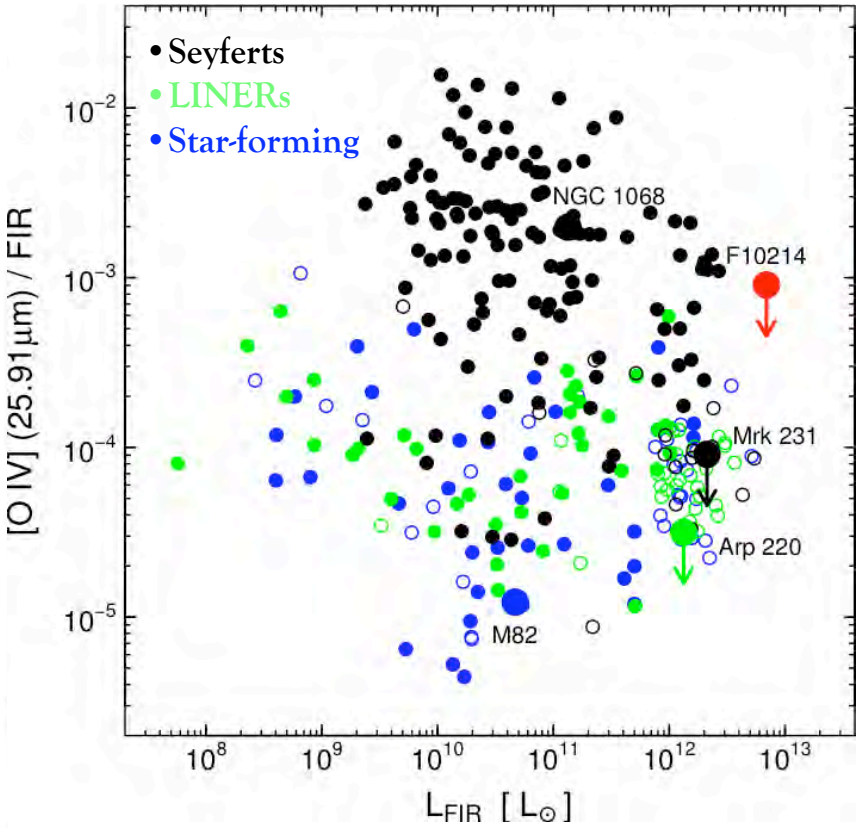




NICMOS: Evans +99

Well studied lensed z=2.29 HLIRG
Coeval star formation & AGN
Differential magnification AGN/Host ≈ 3





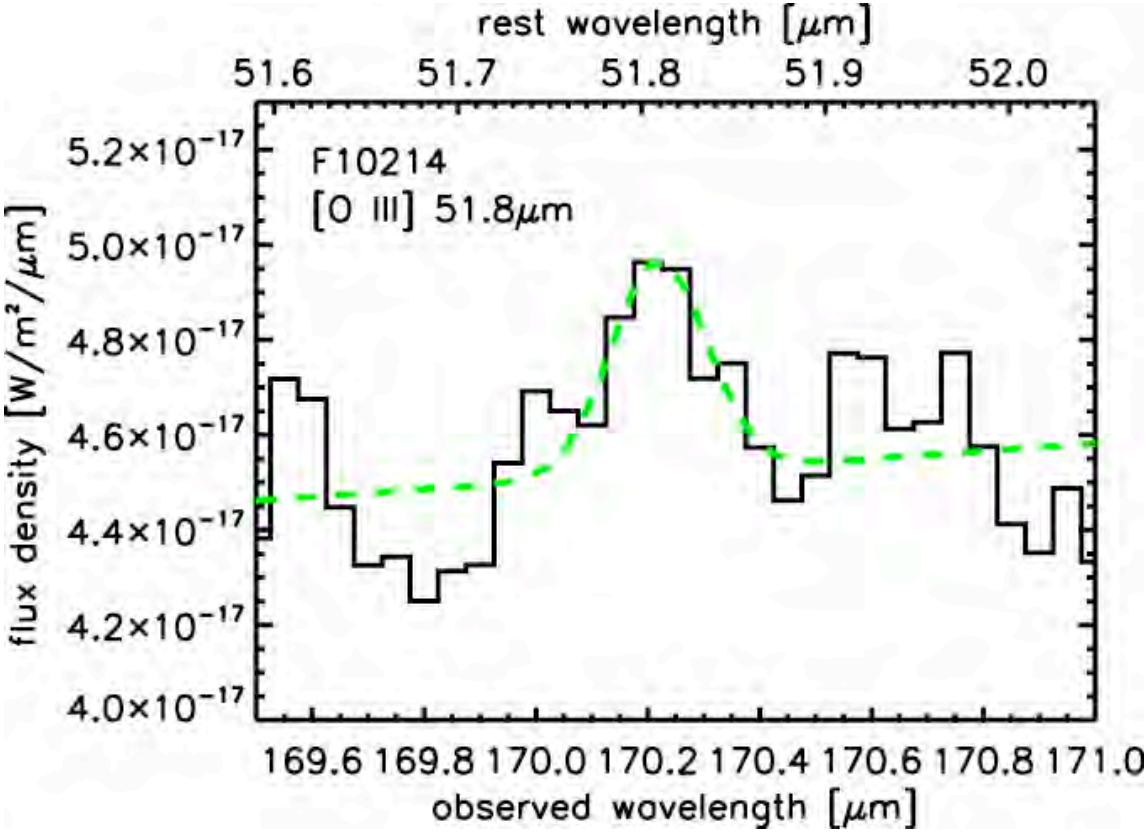
IR Line Database
Graciá-Carpio in prep.

IRAS F10214+4724

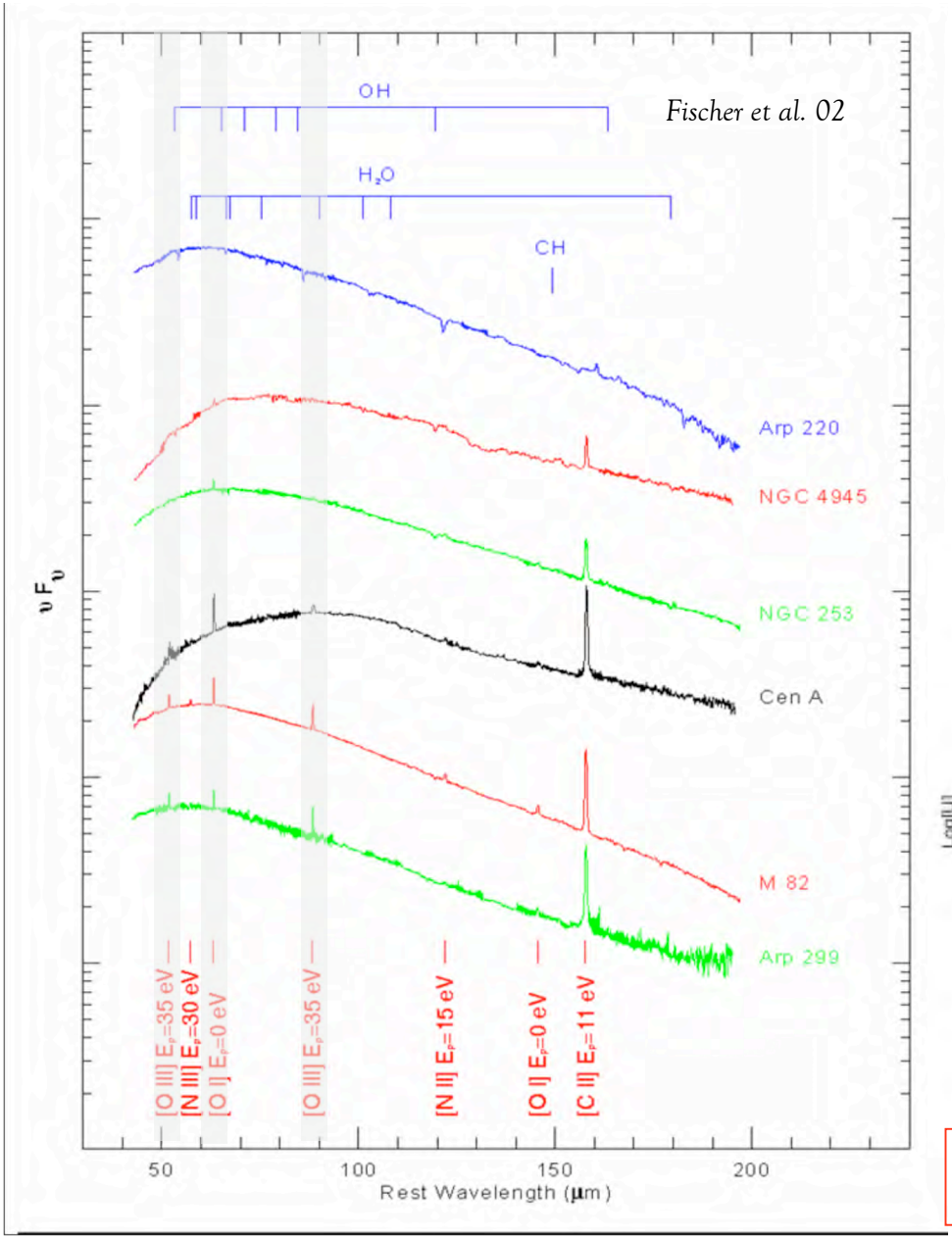
- [OIII]51.8μm tentatively detected at z=2.29!!

- simultaneously observed in 1st order with 2nd order [OIV]26μm obs

- more later...

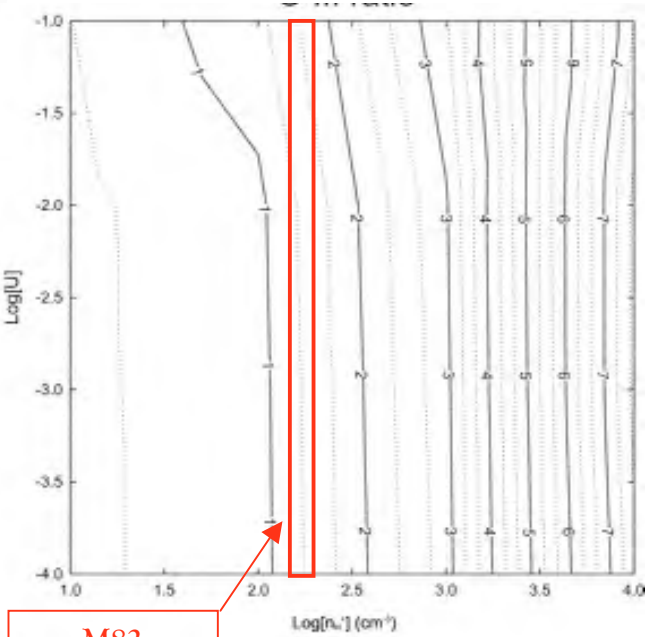


PACS Spectroscopy: z ≈ 1



- [OI]63μm, [OIII]52, 88 μm
- Comparative to low z sample, spanning AGN, starbursts, low-Z, ULIRGs…

Name	z	Type	LFIR
MIPS J1428	1.33	SB	2.8
Abell 0370_01	0.72	Arc/SB	0.9
SMM J02399	1.06	Sey/LoBAL	1.8
SDSSJ1772	0.74	Sey2	1.3
ELAISCJ1640	1.10	QSO	2.6



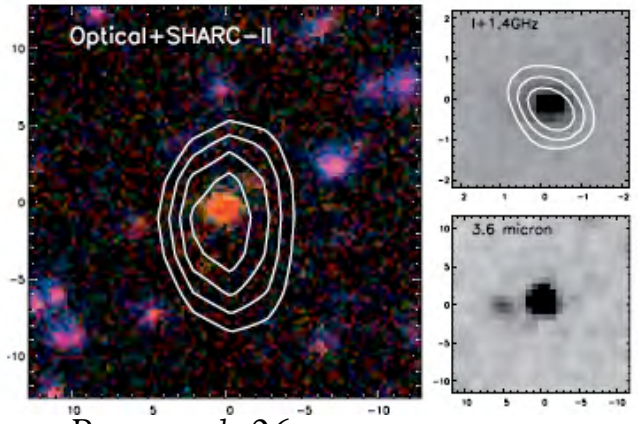
M82
Colbert+ 99

[OIII]52/[OIII]88

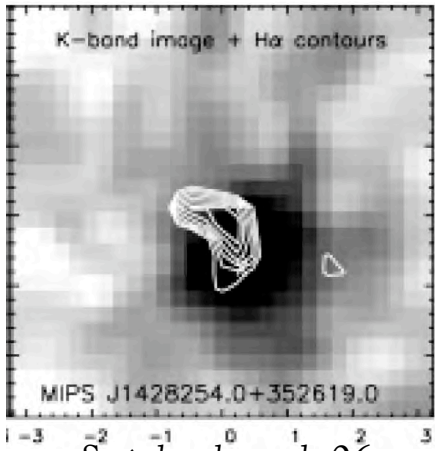
Good density diagnostic for HII regions with $n_H^+ > 10^2$ cm^{-3}

Abel et al. 05

MIPS J142824.0+352619

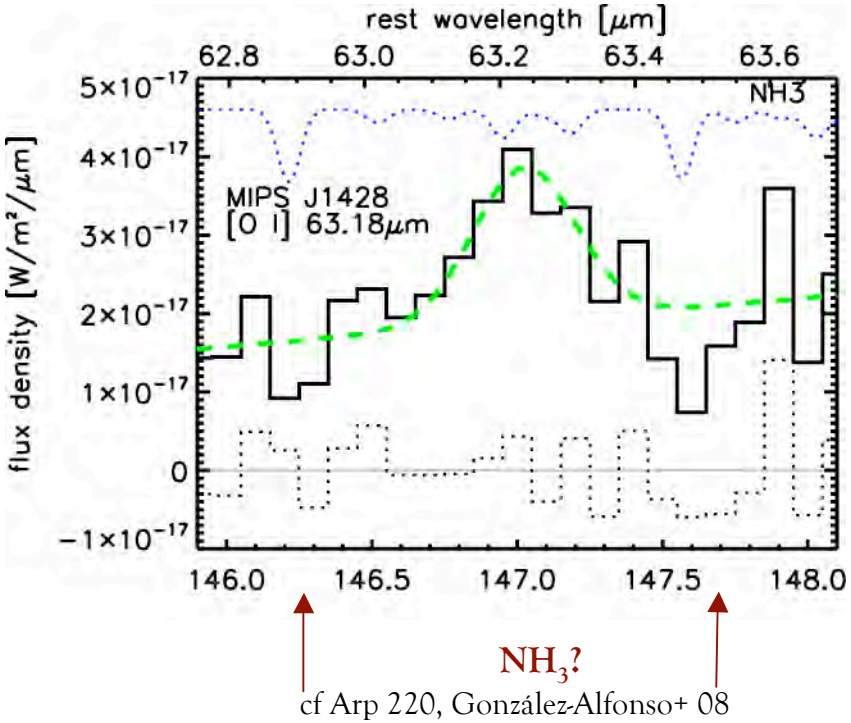


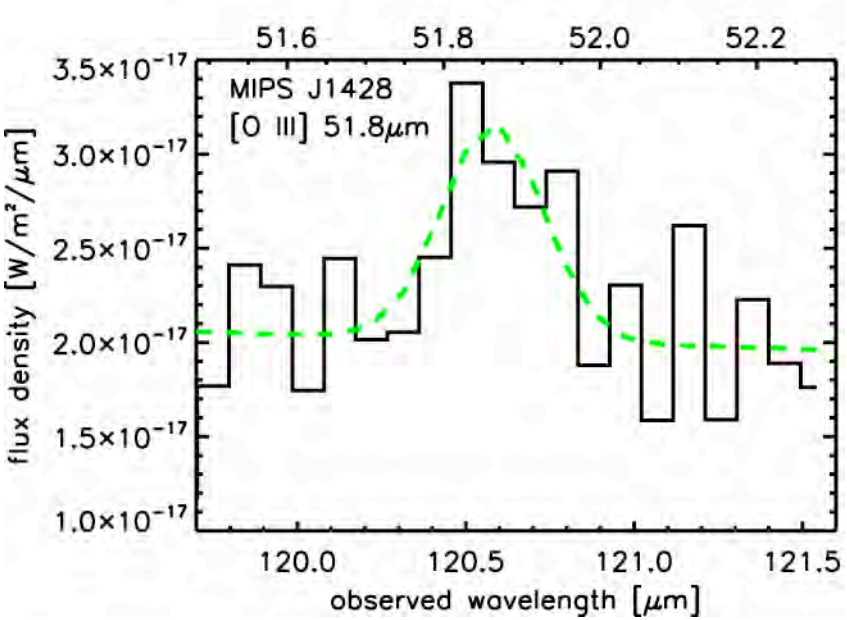
Borys et al. 06



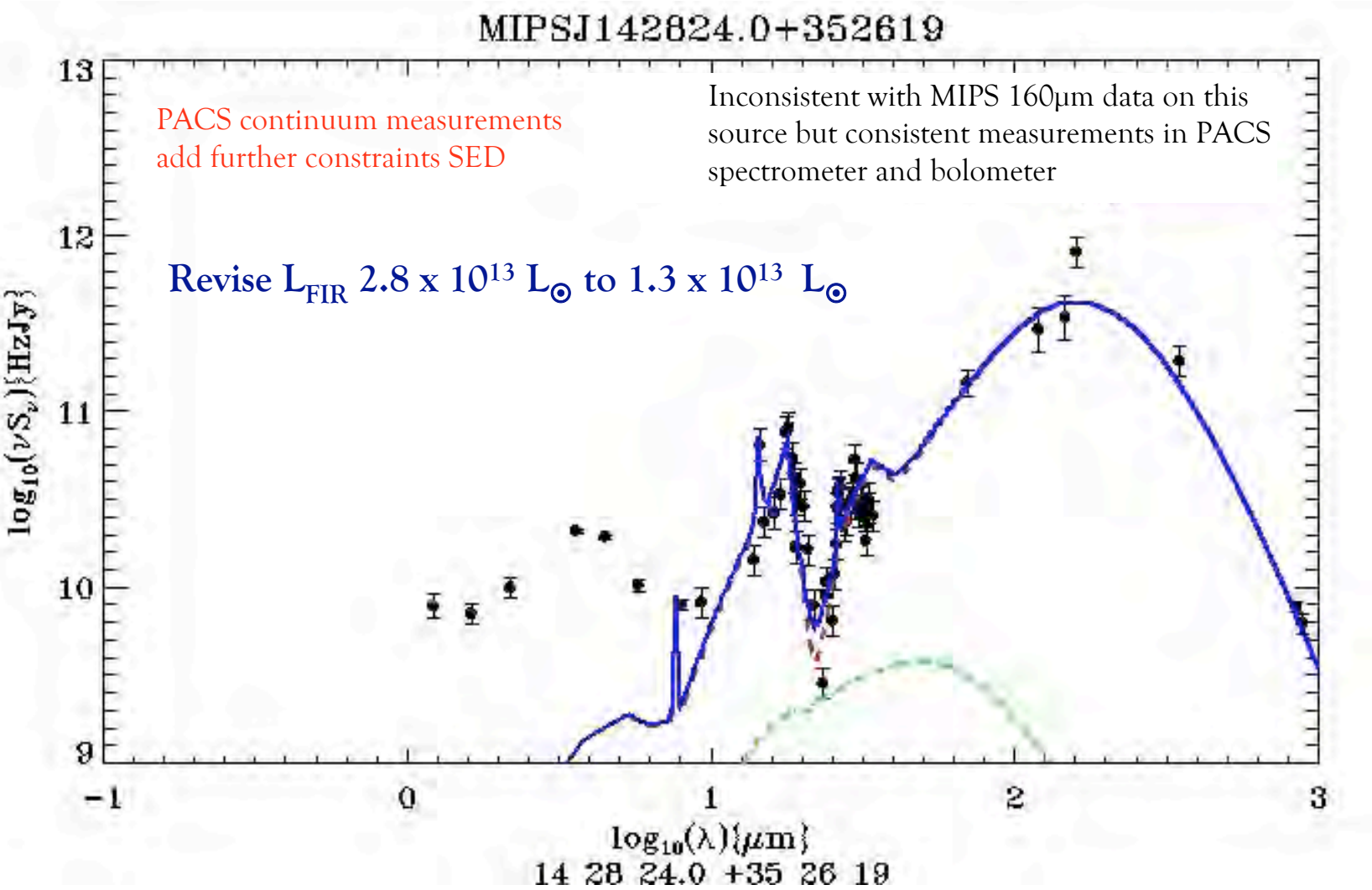
Swinbank et al. 06

- A hyperluminous "Monster": Extreme Starburst at z=1.325 selected from Bootes (Borys et al. 06, Desai et al. 06)
- no AGN signatures
- Lensed by foreground z≈1 elliptical - μ<8 (Borys+ '06) & confirmed by CO
- L(FIR)=2.8 ± 0.7×10^{13}Lsol (lensed)
- Bright CO (3-2) & CO (2-1) detections (NRO, Iono+ '06b) M(H2) ~ 10^{11} $M_{\odot}$,

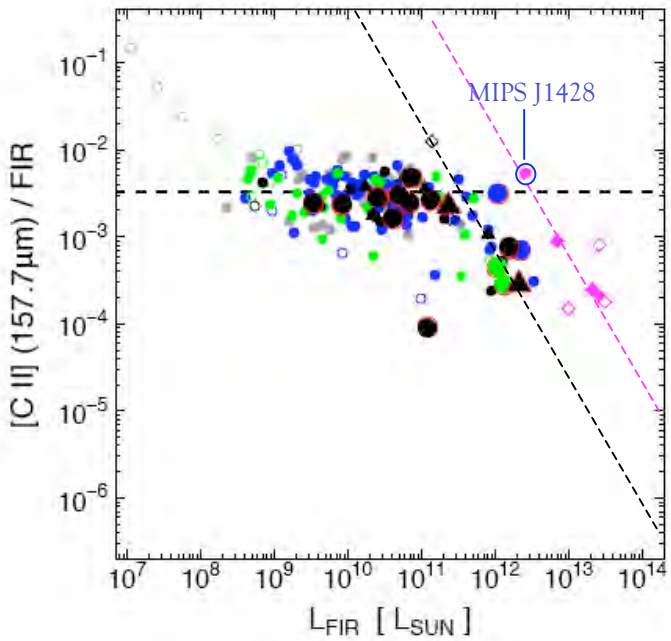




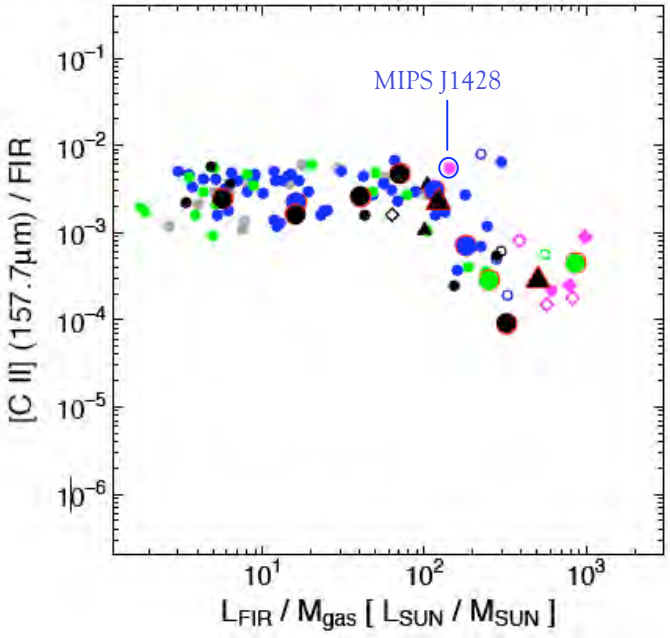
MIPSJ1428 SED



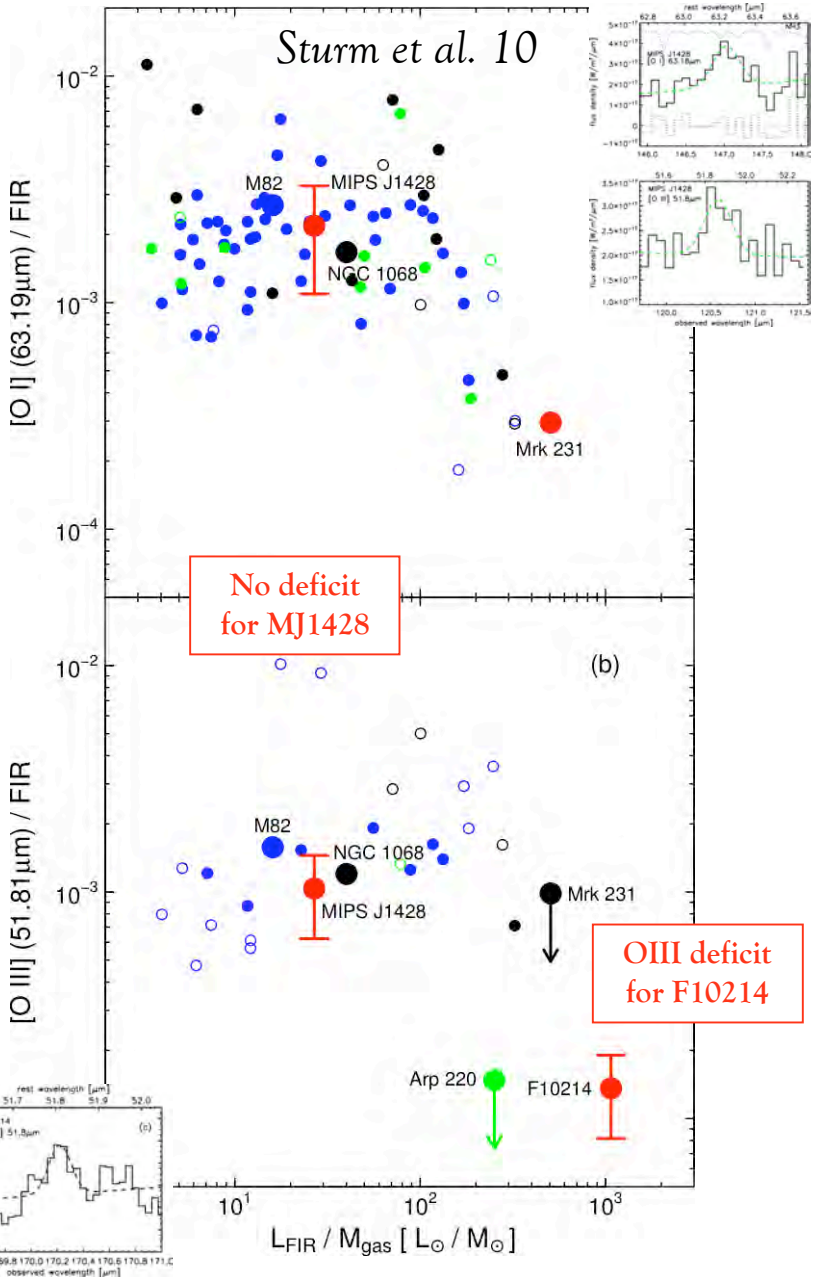
Deficient FIR FSLs at high-z/high-L?



- Seyferts
- LINERs
- Star-forming
- unclassified
- Maiolino et al. 09



Graciá Carpio et al. in prep

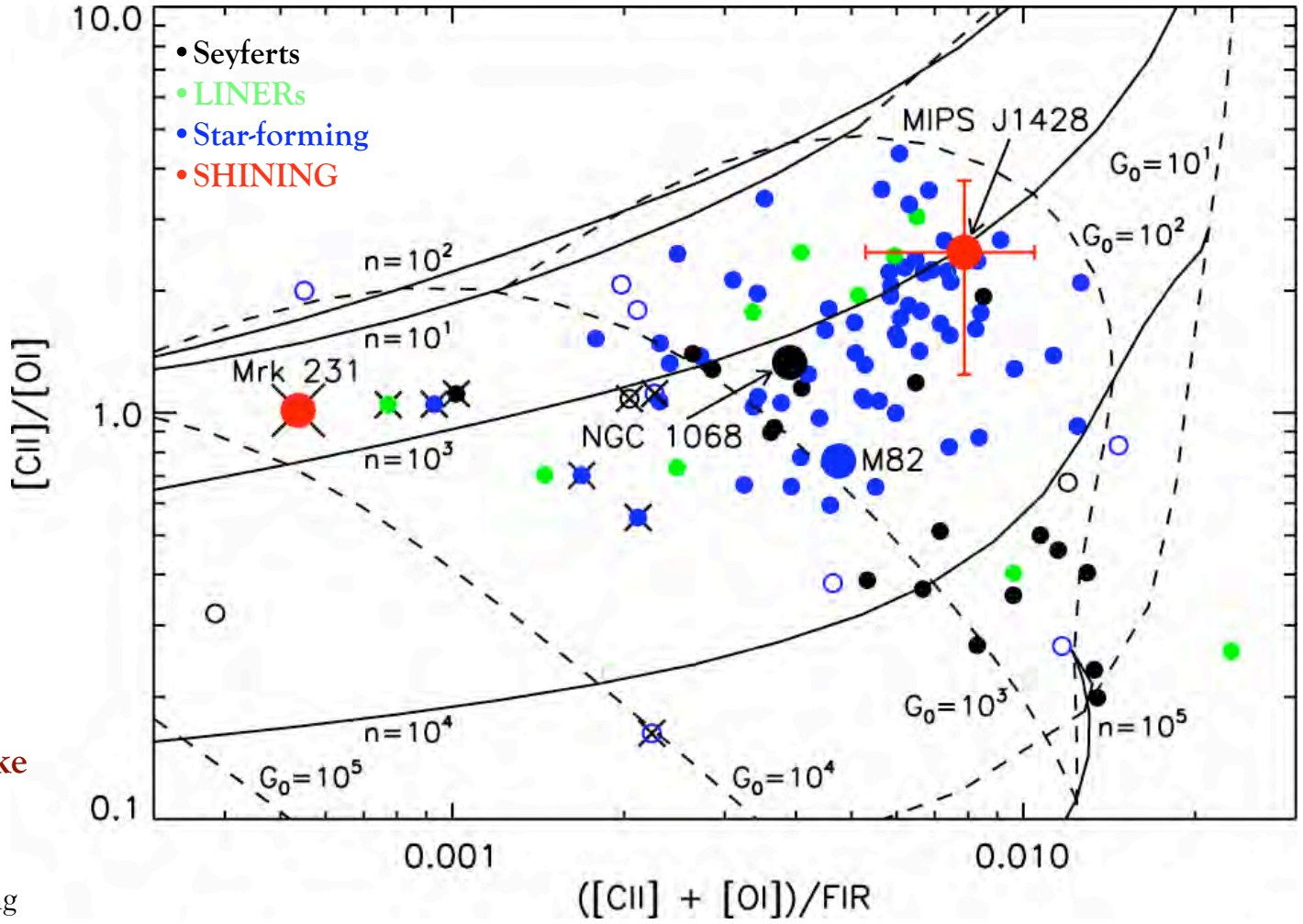


PDR diagnostic diagram

From ISO data
Red new points from SHINING data
Crosses - ULIRGs

First time we can combine [CII] and [OI] in a single diagnostic diagram and use PDR modelling to understand the ISM of a galaxy residing in the peak of the SFRD

MIPS J1428 is not like local ULIRGS or Seyferts.
More akin to star-forming galaxies.

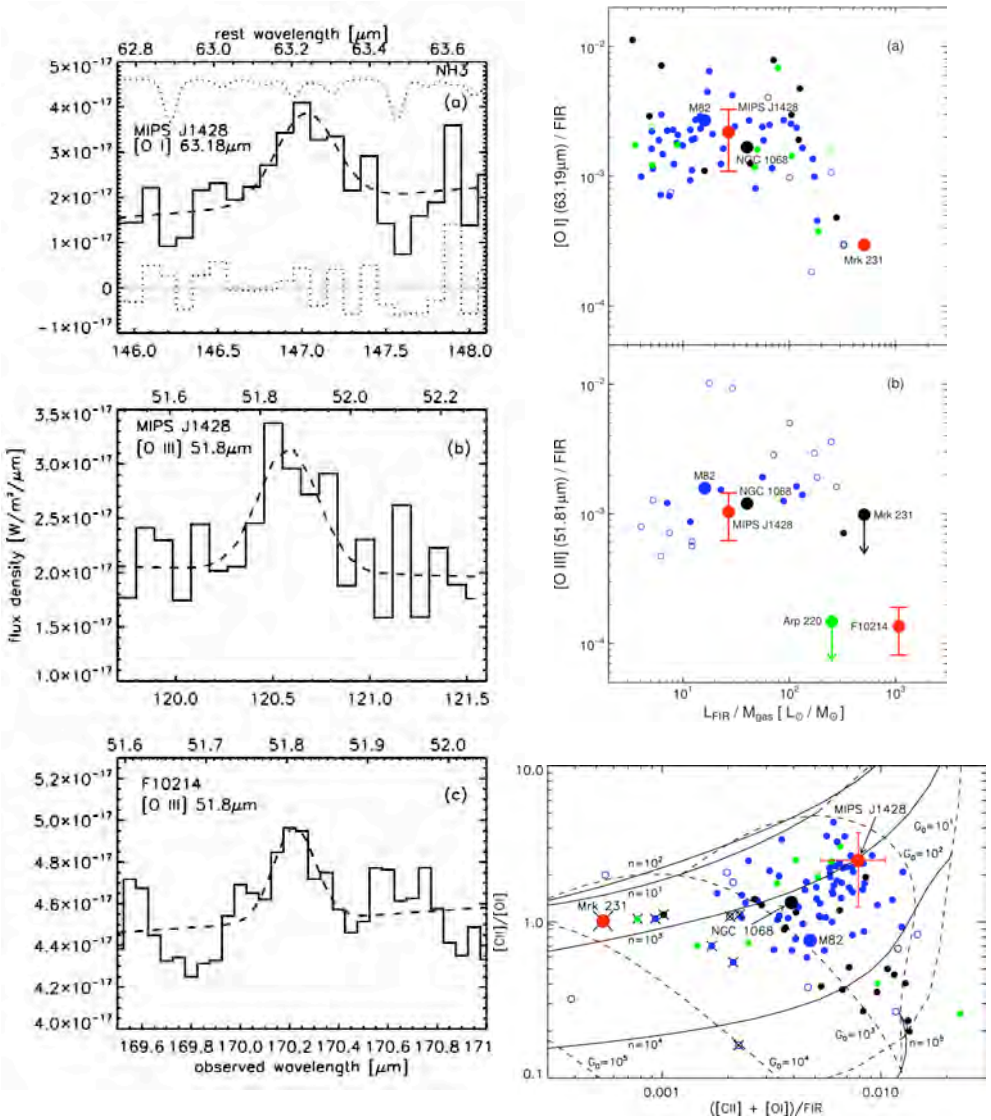


Gas Cooling / Total Heating

Mrk 231 J. Fischer's talk

Summary

- Herschel is heralding a new era in FIR spectroscopy - PACS high-z spec. feasible
- First detections of [OI]63.2μm and [OIII]51.8 μm high-z
- First time we can combine OI and CII and use PDR modelling to understand the physics of the ISM of galaxies at the epoch of peak star-formation activity
- Not all (U/H)LIRGs are deficient in FIR fine structure lines - MIPSJ1428
- F10214 undetected in [OIV] & [SIII] low OIII/FIR
- Complementarity & implications for observations of high-z galaxies with ALMA
- Much more to come!



Sturm et al. 10, E. Sturm's talk tomorrow