Tracing AGN accretion and star-formation with IR lines

C. Gruppioni (INAF-OABo)

+

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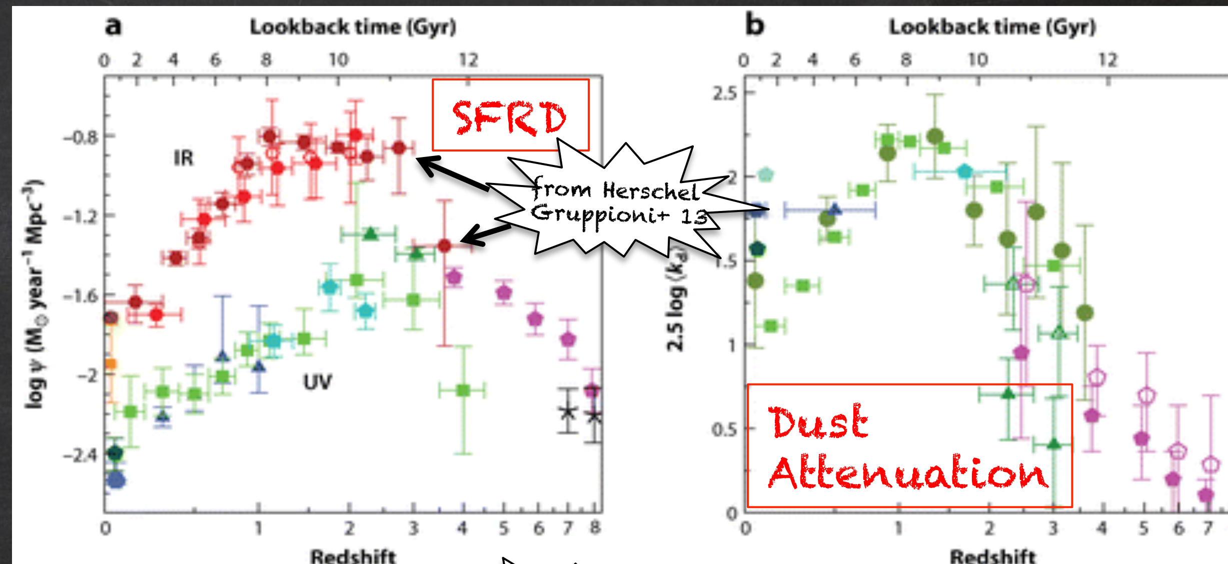
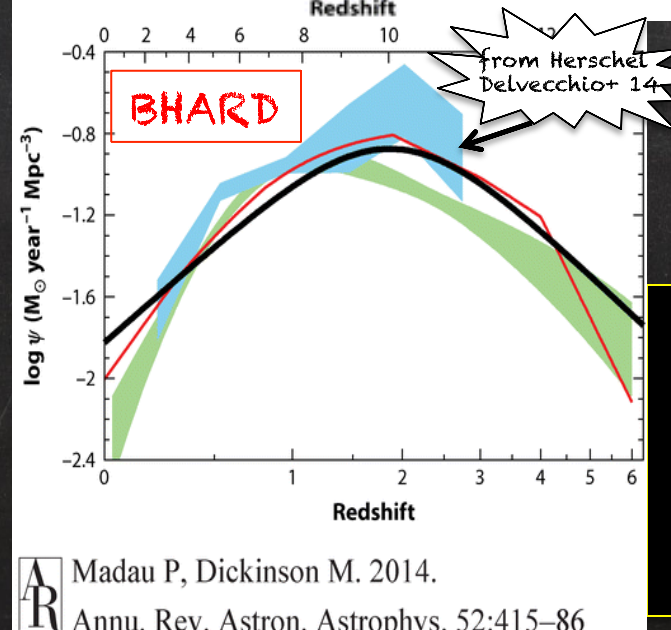
GDFS2015 - Crete, 2015 May 25-29

Co-eval growth of SMBHs and Host Galaxies





Dust enshrouded SF and AGN accretion

Both peak at z~2-3

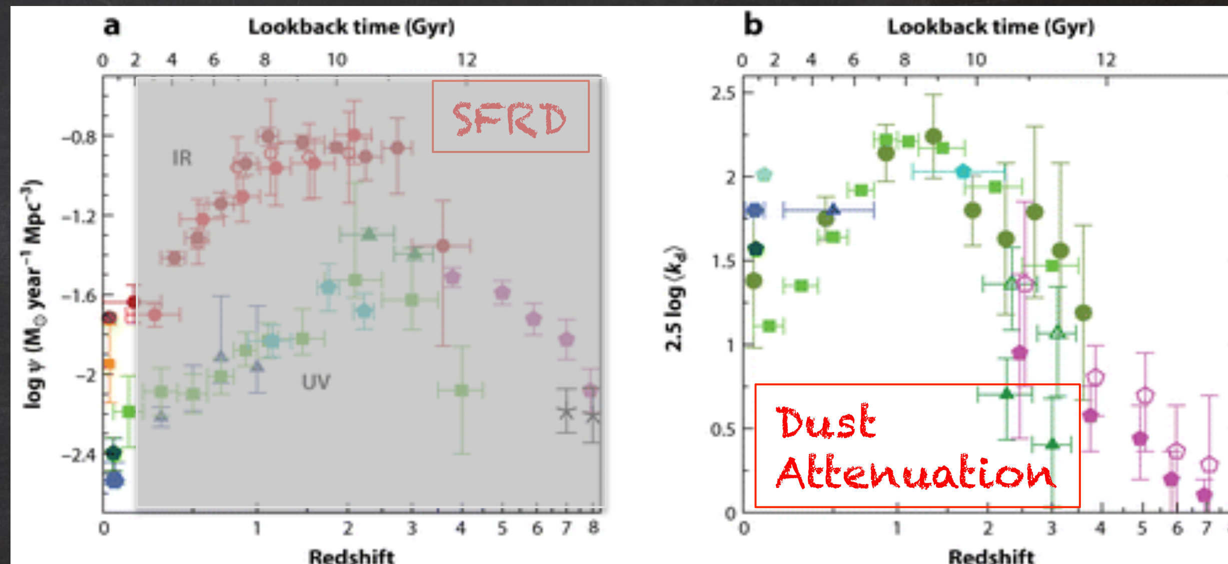
Key AGN signatures: high-excitation fine structure lines

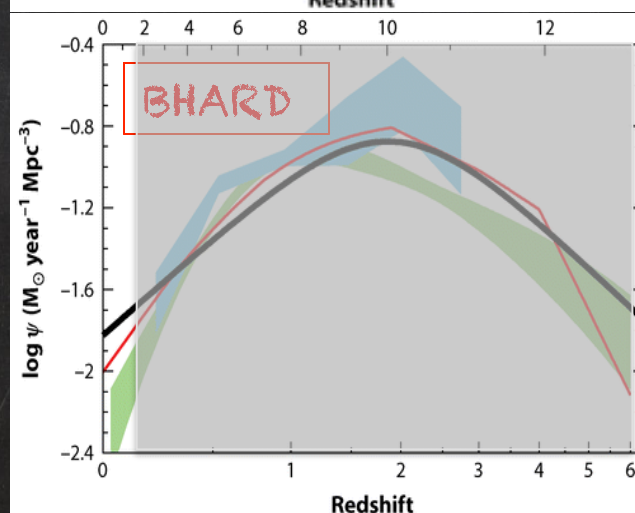
e.g. [NeV] 14.3 μm
[OIV] 26 μm

Co-eval growth of SMBHs and Host Galaxies

RECENT PAST & PRESENT

FUTURE…





Madau P, Dickinson M. 2014.
Annu. Rev. Astron. Astrophys. 52:415–86

Dust enshrouded SF and AGN accretion

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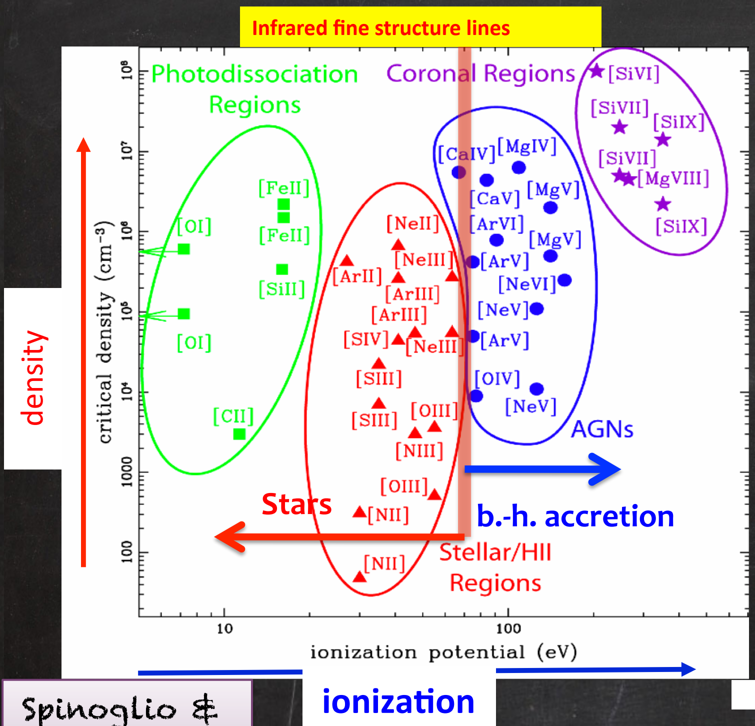
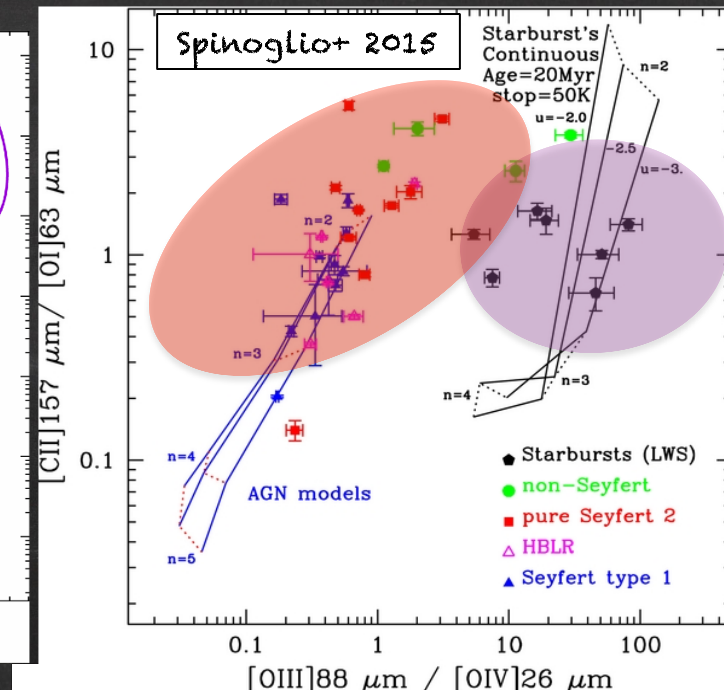
Key AGN signatures: high-excitation fine structure lines

e.g. [NeV] 14.3 μm
[OIV] 26 μm

MIR and FIR lines as AGN/SB diagnostics



Spinoglio & Malkan 1992



In the MIR:

[NeV]14.32 μm and [OIV]25.89 μm are the best AGN tracers

PAH EW are mostly tracing SF activity

IR fine structure lines:

- separate different physical mechanisms,
- cover the Ionization/density parameter space
- do not suffer from extinction

In the FIR:

1. AGN: strong [OIII] (NLR), but also strong [OI] (enhanced in XDR and with n_{crit}~10^6 cm^{-3})

2. Starbursts: strong [CII] (PDRs) and [OIII] (HII regions)

3. Pure PDR: from the quiescent disk in the spiral galaxy: strong [CII] and [OI], but no [OIII]

WORK OUTLINE

- START FROM A LOCAL SAMPLE OF AGN WITH DIFFERENT f_{AGN} IR LINES, MULTIWAVELENGTH PHOTMETRIC COVERAGE
- PERFORM SED-FITTING TO DERIVE L^{SF} (L_{IR}) and L_{ACC}
- FIND RATIOS BETWEEN (AGN/SF) L_{line} AND L^{SF} (L_{IR}) OR L_{ACC}
- DERIVE LINE LFs BY CONVERTING THE HERSCHEL TOTAL IR LFs
- ESTIMATE NUMBER OF SOURCES DETECTABLE IN DIFFERENT IR LINES AT DIFFERENT LUMINOSITIES AND REDSHIFTS

The Extended 12-μm Sample

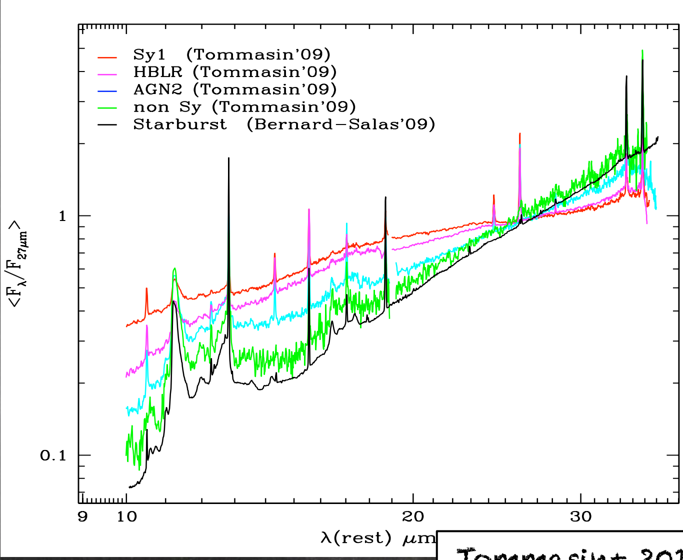
data available VIRTUALLY at ALL wavelengths !!!

★ 893 galaxies from the IRAS FSC-2: 12 μm flux limit > 0.22~Jy (Rush, Malkan & Spinoglio 1993)

★ 118 Seyfert galaxies (53 Seyfert 1 and qso, 63 Seyfert 2 and 2 blazar (13% of the total sample)

★ ISO spectra (Spinoglio, Andreani & Malkan 2002)

★ Spitzer IRS low (Wu+ 2009) and high resolution spectra (Tommasin+ 2010)



Tommasin+ 2010

★ PACS (Spinoglio+ 2014) of 26 and SPIRE spectra of 11 Seyfert (Pereira-Santaella+ 2013)

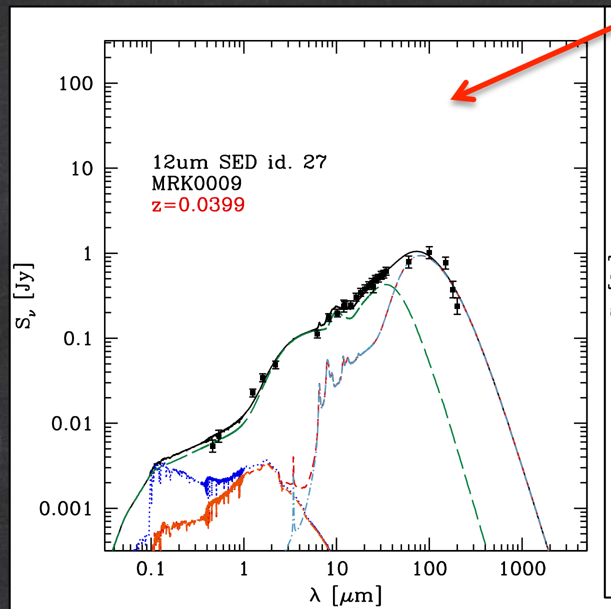
➔ Selected a sub-sample of 76 sources with good quality IRS spectra for SED analysis

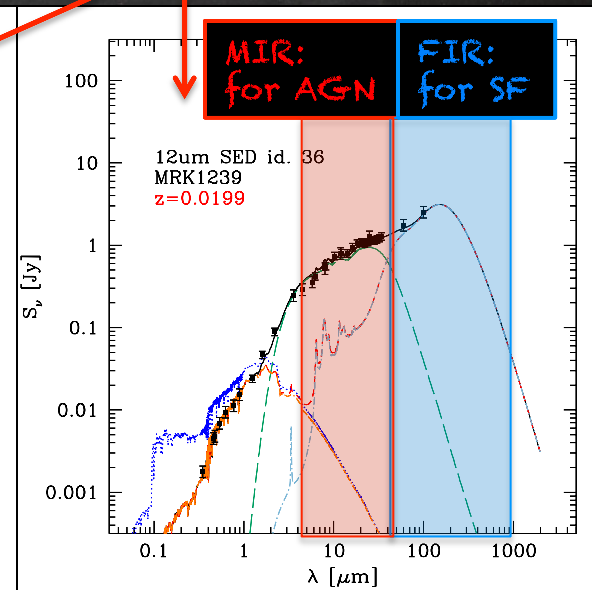
Broad-band SED-fitting Decomposition

Modified MAGPHYS + AGN
(daCunha+08 + Feltre+12 => **Berta+13**)

Some Examples of SED-decomposition

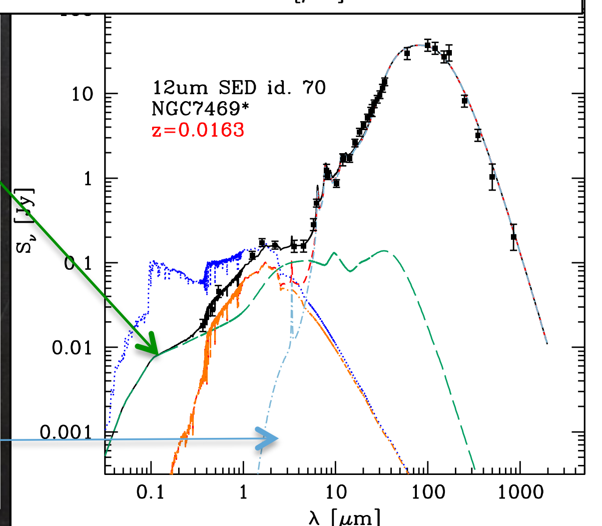
Self-consistent link of the energy absorbed by dust in the UV-**optical** and dust emission in the MIR/FIR + torus emission

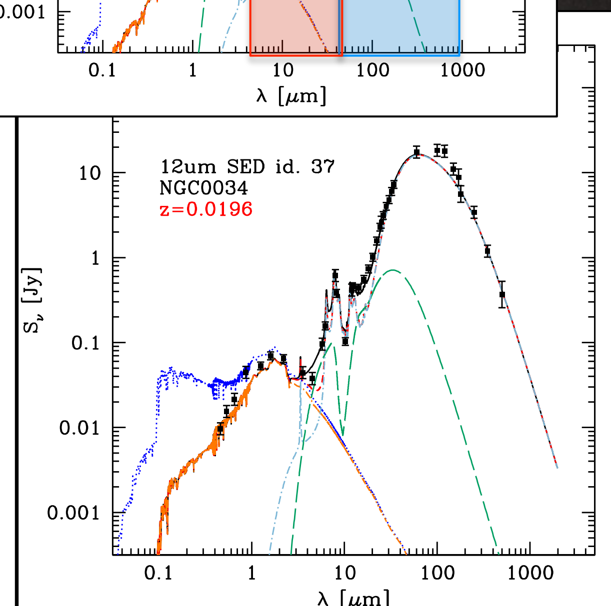




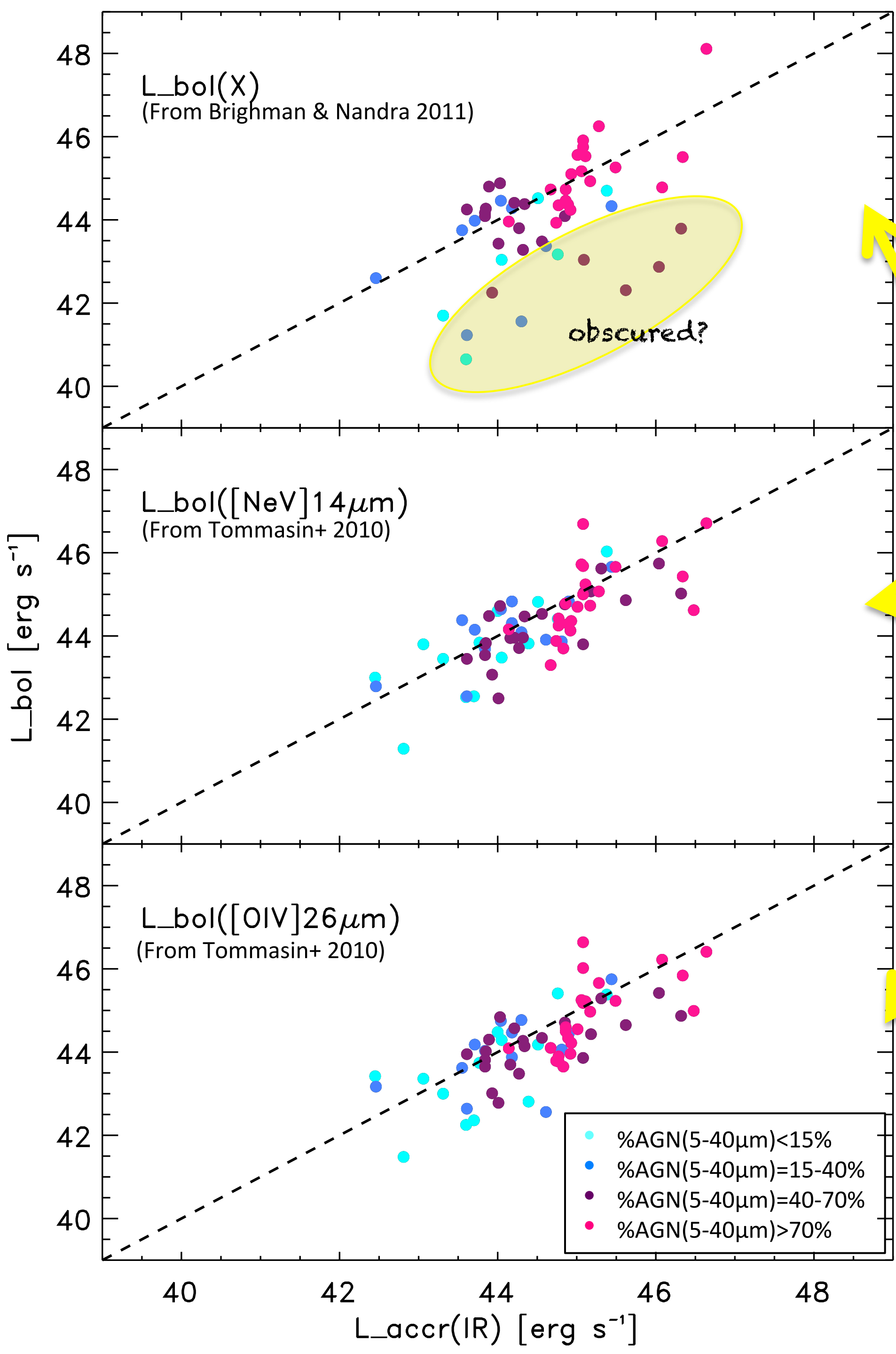
L_{ACC} from AGN torus model — —

L^{SF} from re-emitted stellar light (L_{IR}[8-1000μm] is a proxy) - - - -





CG, Berta, Spinoglio+ in prep.



L_{acc}(IR) derived from SED-fitting (= L_{bol}^{AGN}(IR)) compared with L_{bol}^{AGN} from other estimators (i.e. X-ray, [NeV], [OIV])

Very good Agreement!

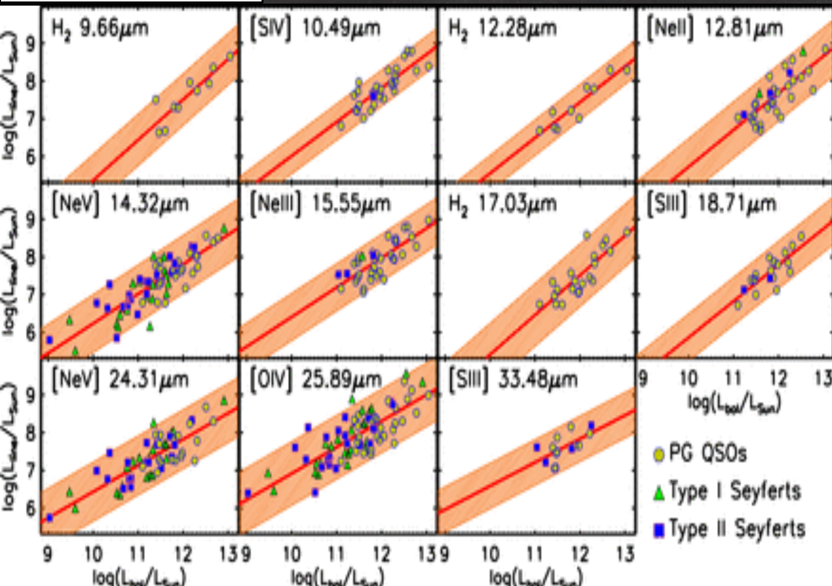
CG, Berta, Spinoglio+ in preparation

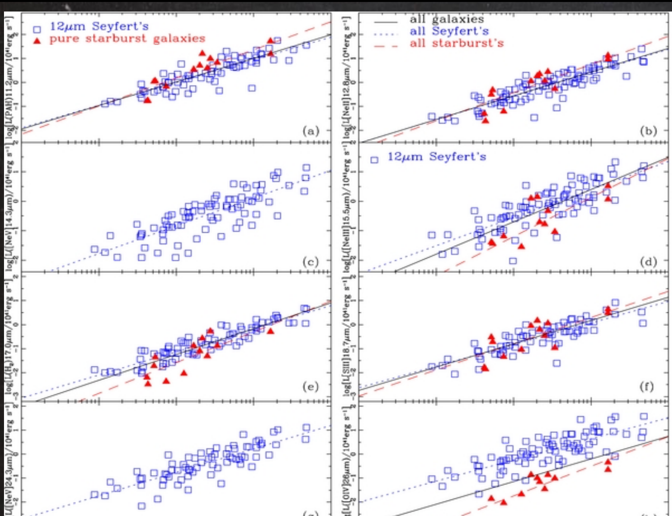
New relations between L_{line} & L_{IR}/L_{acc} (func of %AGN)

Example: $L_{[OIV]}$ vs. L_{acc}
slope steepens with increasing AGN% (@ 5-40μm)

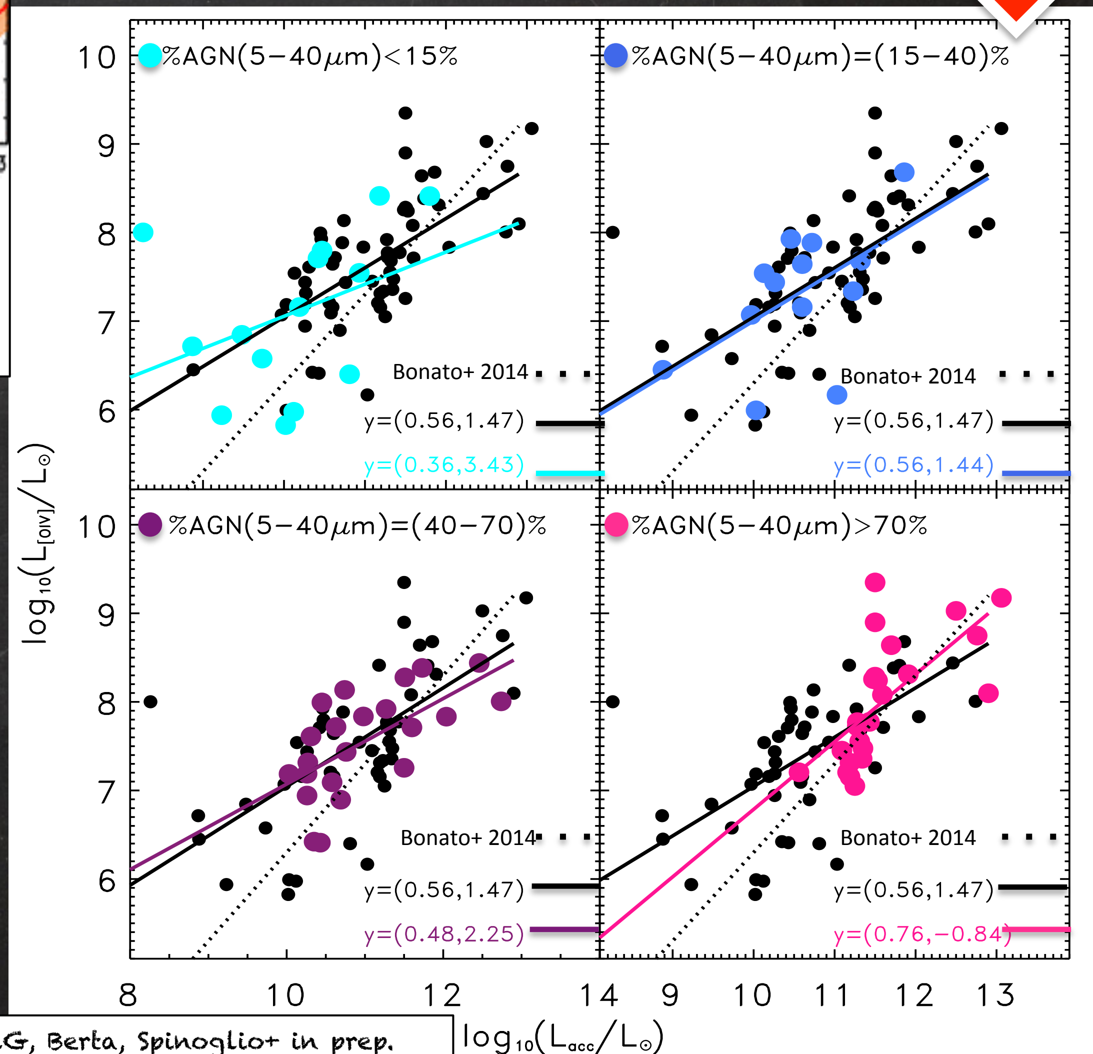
Previous Works

Bonato+ 2014

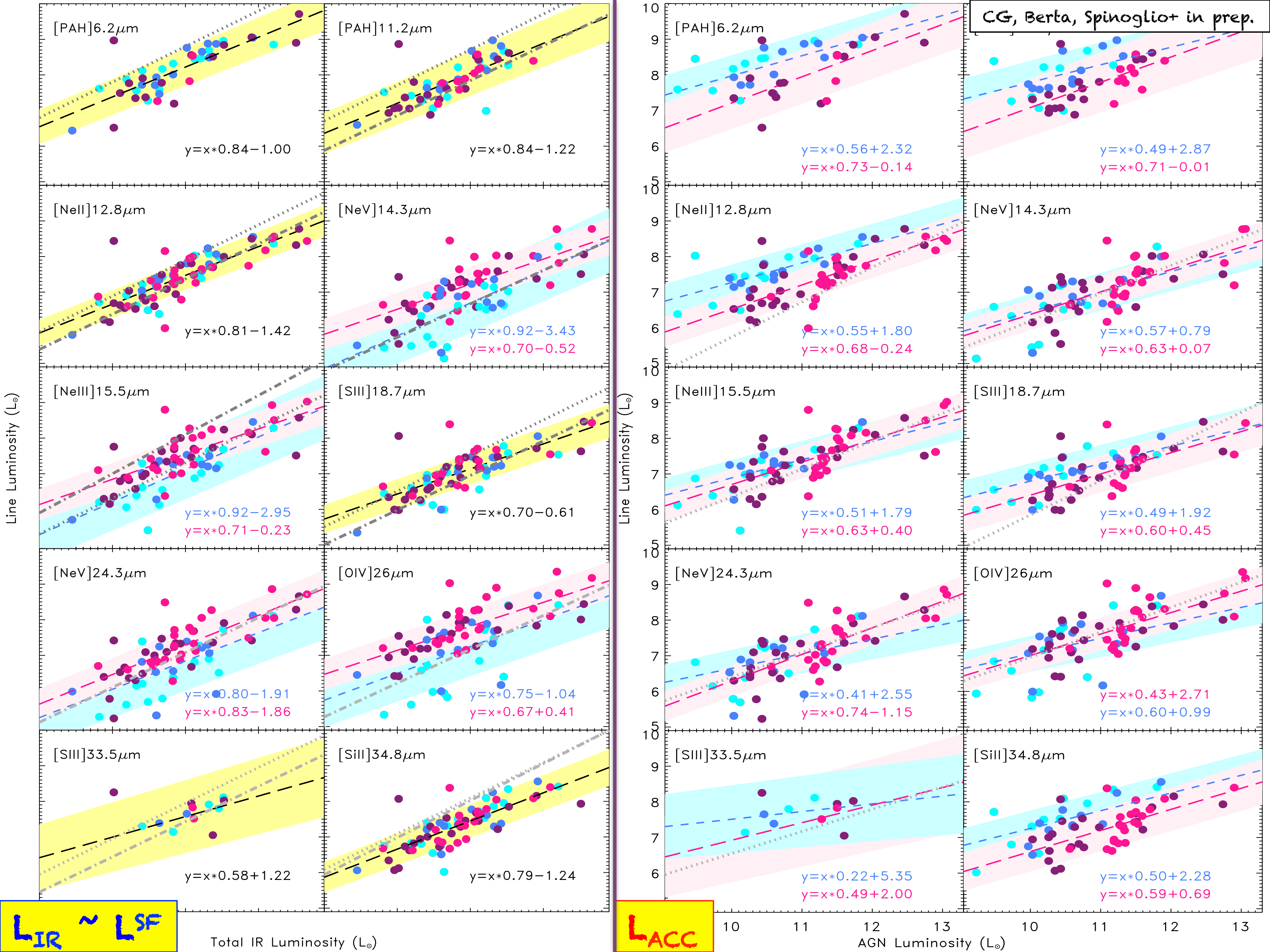




Spinoglio+ 2012



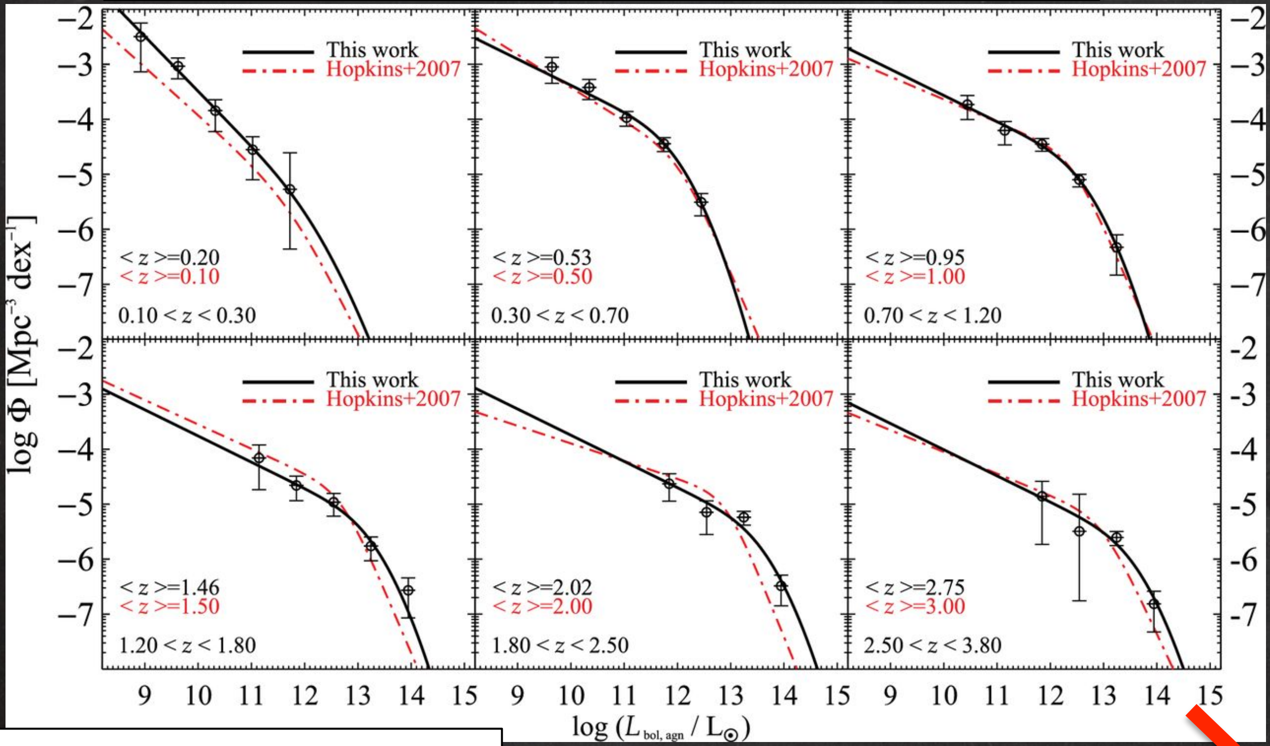
CG, Berta, Spinoglio+ in prep.



CG, Berta, Spinoglio+ in prep.
[PAH]6.2μm
y=x*0.84−1.00
[PAH]11.2μm
y=x*0.84−1.22
[NeII]12.8μm
y=x*0.81−1.42
[NeV]14.3μm
y=x*0.92−3.43
y=x*0.70−0.52
[NeIII]15.5μm
y=x*0.92−2.95
y=x*0.71−0.23
[SIII]18.7μm
y=x*0.70−0.61
[NeV]24.3μm
y=x*0.80−1.91
y=x*0.83−1.86
[OIV]26μm
y=x*0.75−1.04
y=x*0.67+0.41
[SIII]33.5μm
y=x*0.58+1.22
[SiII]34.8μm
y=x*0.79−1.24
Line Luminosity (L⊙)
Total IR Luminosity (L⊙)
L_IR ~ L^SF
[PAH]6.2μm
y=x*0.56+2.32
y=x*0.73−0.14
y=x*0.49+2.87
y=x*0.71−0.01
[NeII]12.8μm
y=x*0.55+1.80
y=x*0.68−0.24
[NeV]14.3μm
y=x*0.57+0.79
y=x*0.63+0.07
[NeIII]15.5μm
y=x*0.51+1.79
y=x*0.63+0.40
[SIII]18.7μm
y=x*0.49+1.92
y=x*0.60+0.45
[NeV]24.3μm
y=x*0.41+2.55
y=x*0.74−1.15
[OIV]26μm
y=x*0.43+2.71
y=x*0.60+0.99
[SIII]33.5μm
y=x*0.22+5.35
y=x*0.49+2.00
[SiII]34.8μm
y=x*0.50+2.28
y=x*0.59+0.69
Line Luminosity (L⊙)
AGN Luminosity (L⊙)
L_ACC

mid-/far-IR line Luminosity Function

Herschel BH accretion Function @different z



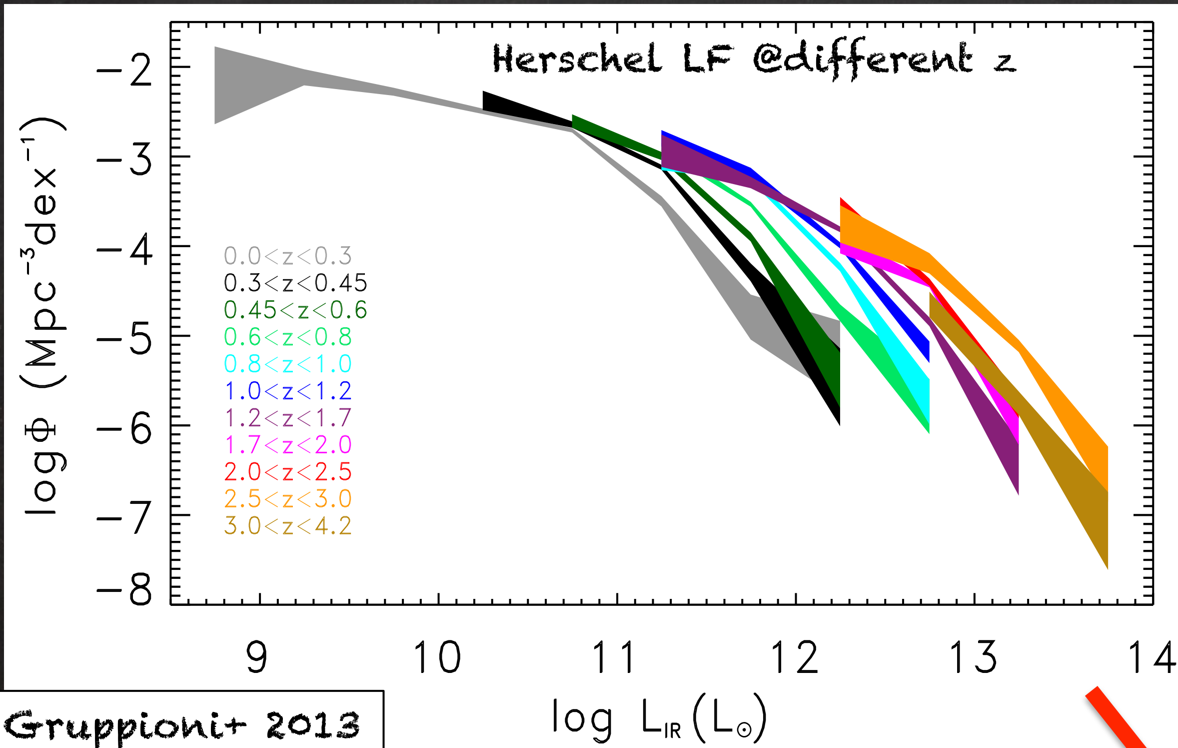
Delvecchio, CG+ 2014

L_{line}-L_{ACC} local relations

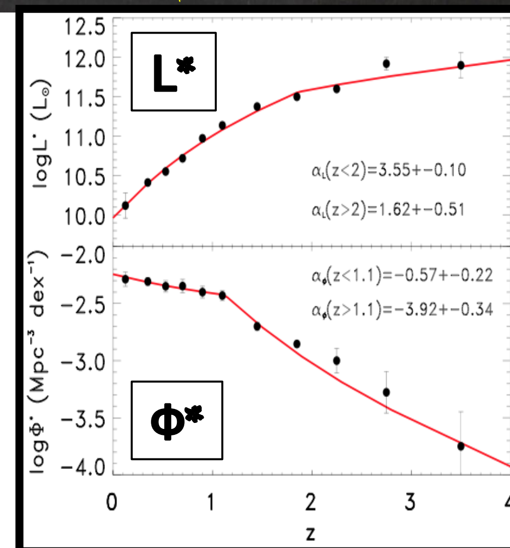
Apply BH accretion function evolution

AGN-Line Luminosity Function

mid-/far-IR line Luminosity Function

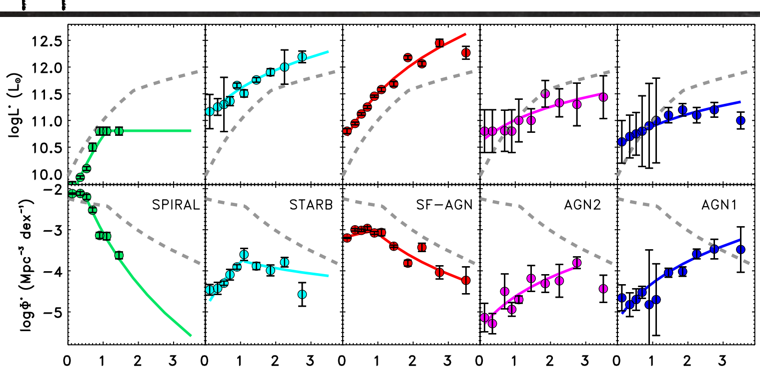


Gruppioni+ 2013



L_{line}-L_{IR} local relations for different AGN% applied to different Herschel populations

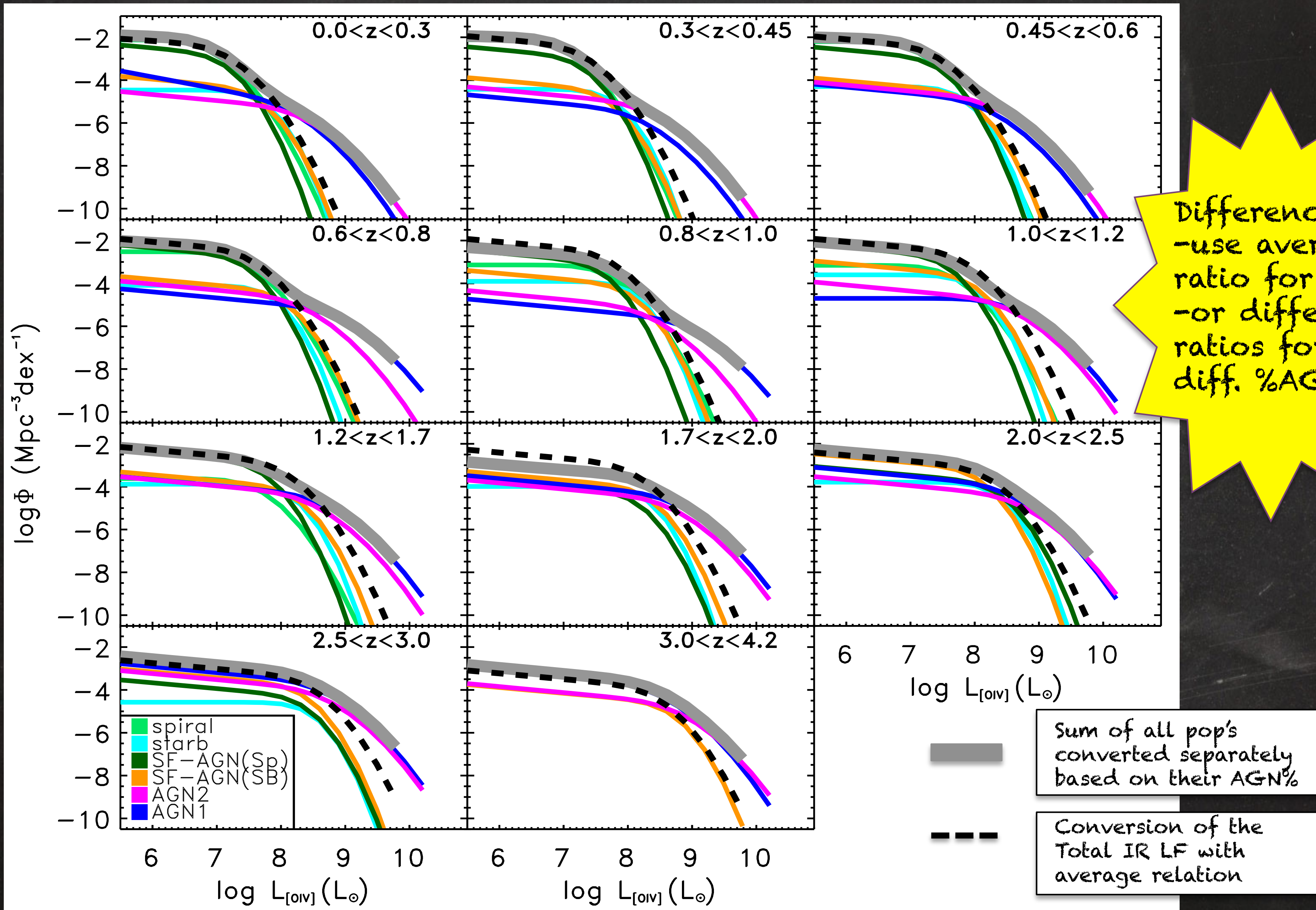
Different evolutions found for different populations



Apply different evolutions to different IR populations

Line Luminosity Function

mid-/far-IR line Luminosity Function



Difference:
-use average ratio for all
-or different ratios for diff. %AGN

CG, Berta, Spinoglio+ in preparation

CO Luminosity Function

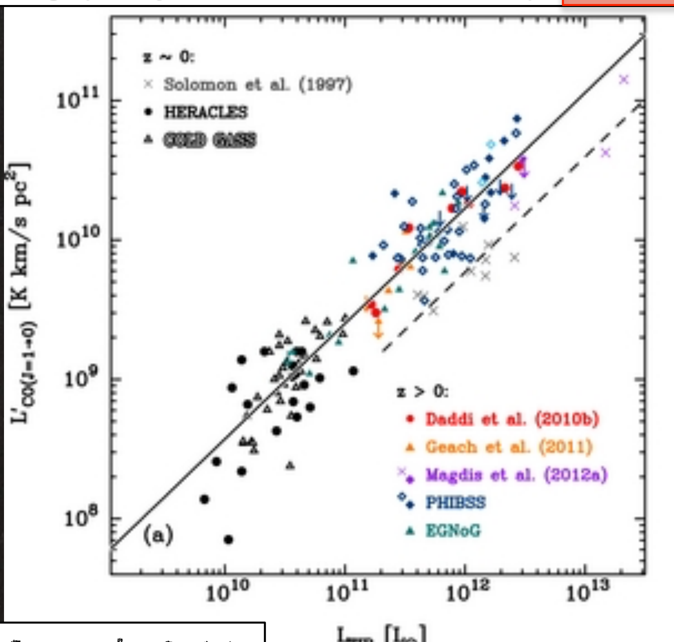
(Vallini, CG et al., in preparation)

- Start from Herschel LFs and different pop.'s evolutions (Gruppioni+ 2013)
- use Sargent+ 2014 $L'_{CO(1-0)}$ - L_{IR} relation for normal galaxies
- and Greve+ 2014 $L'_{CO(j+1-j)}$ - L_{IR} relations for Starbursts/(U)LIRGs/AGN

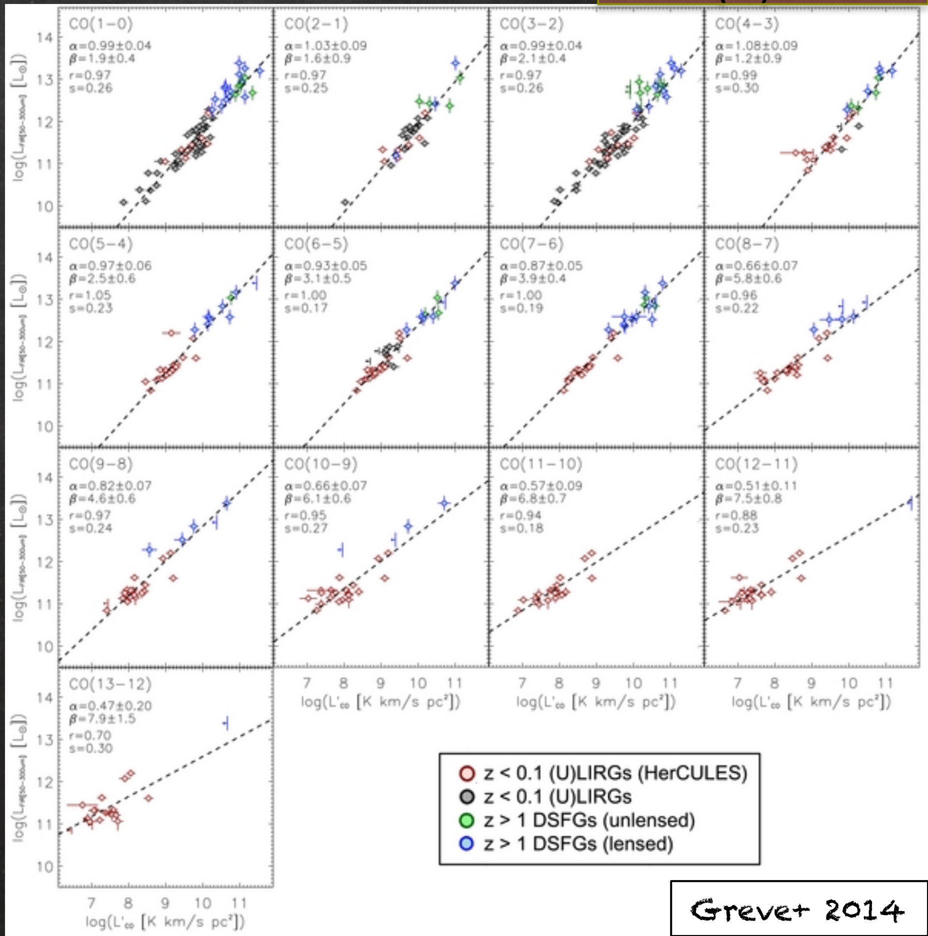
for (U)LIRGs

$$\log\left(\frac{L'_{CO(J=1\to0)}}{\mathrm{K\ km\ s^{-1}\ pc^2}}\right) = \alpha_1 + \beta_1 \log\left(\frac{L_{IR}}{L_\odot}\right), \quad \text{with} \qquad (1)$$

$(\alpha_1; \beta_1) = (0.54 \pm 0.02; 0.81 \pm 0.03)$ for normal galaxies.

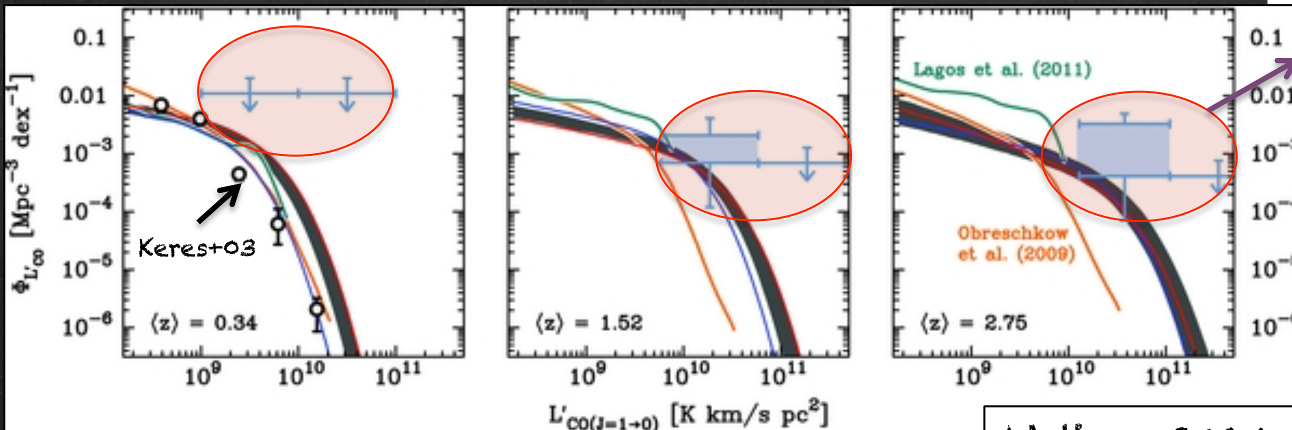


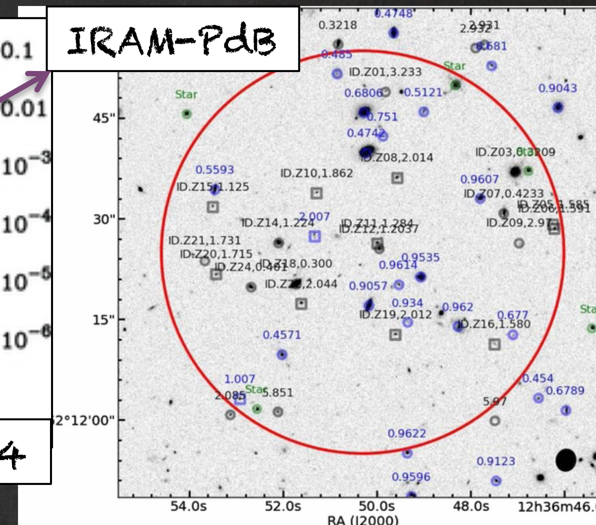
Sargent+ 2014



Greve+ 2014

CO Luminosity Function

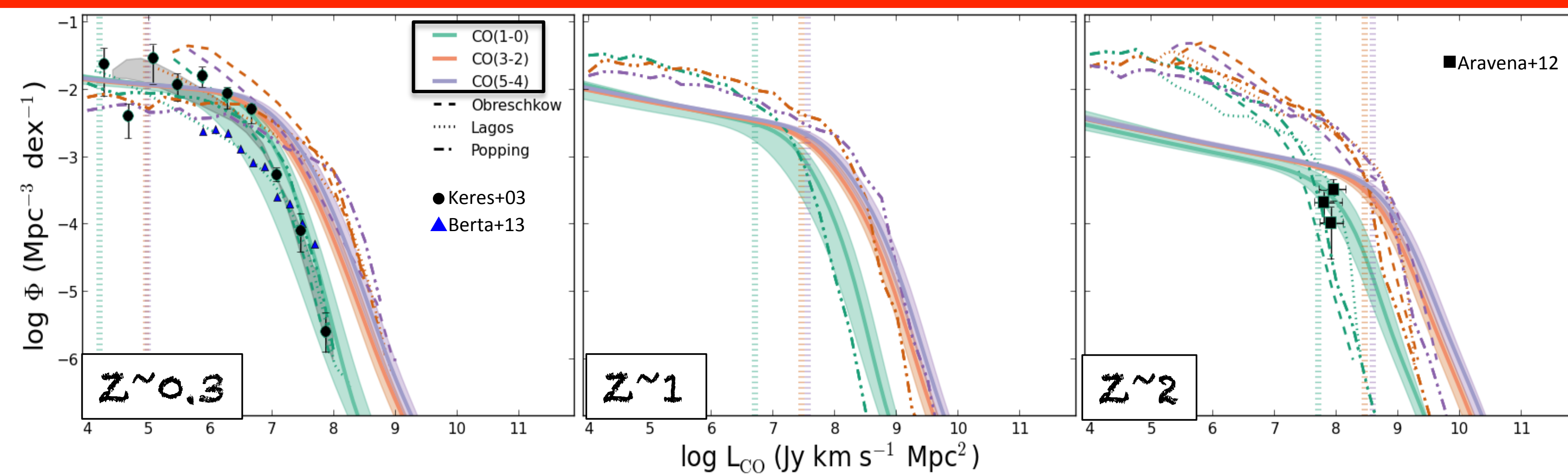




IRAM-PdB

Walter+ 2014

CO LF derived from the Herschel IR LF



Vallini, CG et al., in prep. (A)

Looking forward to Future CO Survey Data...

1) PI: Fabian Walter

A Molecular ALMA Deep Field in the UDF
(CO spectral scan of band 3 -> >20 srcs below the knee of the LF)

2) PI: Manuel Aravena

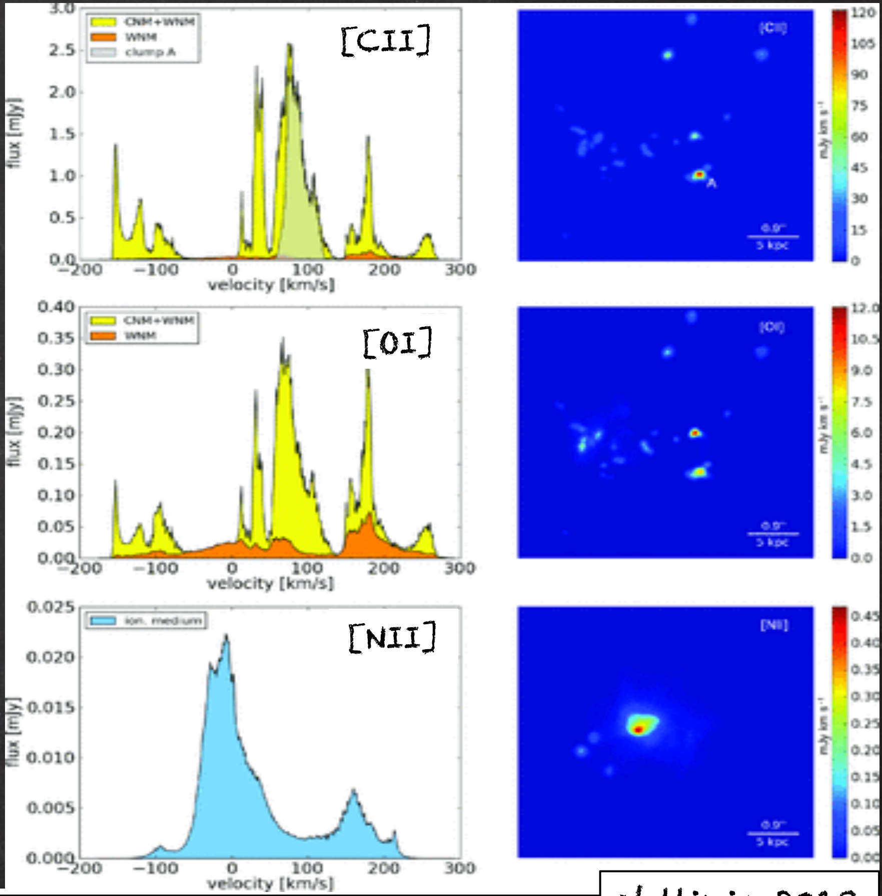
An ALMA 1.3 mm spectroscopic survey in the Hubble Ultra Deep Field
(deep CO/[CII] spectral scan and ultra-deep continuum imaging of 1 arcmin^2 in the UDF using ALMA in band-6 -> >25 CO emitters and 30 continuum sources)

Simulation of far-IR and sub-mm lines

- High resolution, radiative transfer cosmological simulations of galaxies with a multi-phase ISM model

- expected intensity of several far-IR emission lines for different values of the gas metallicity,

  (Vallini+ 2013)

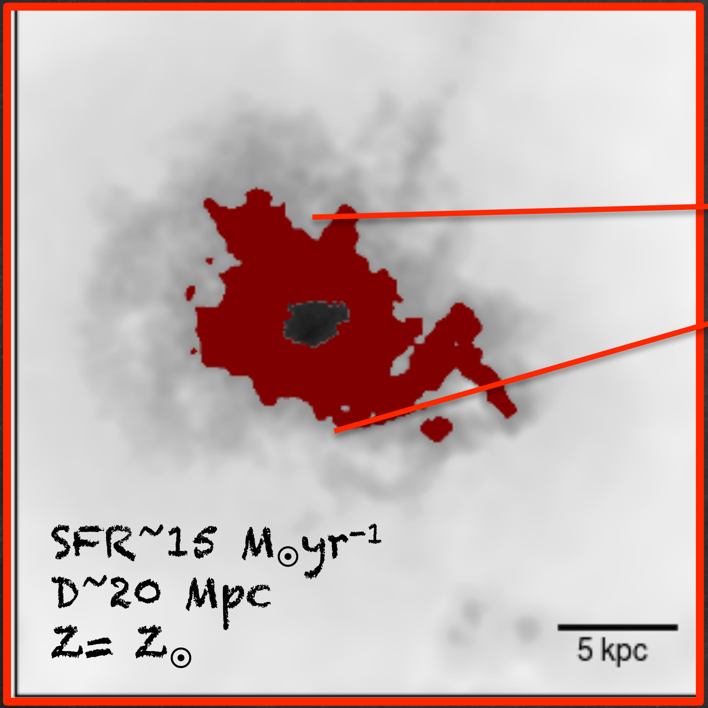


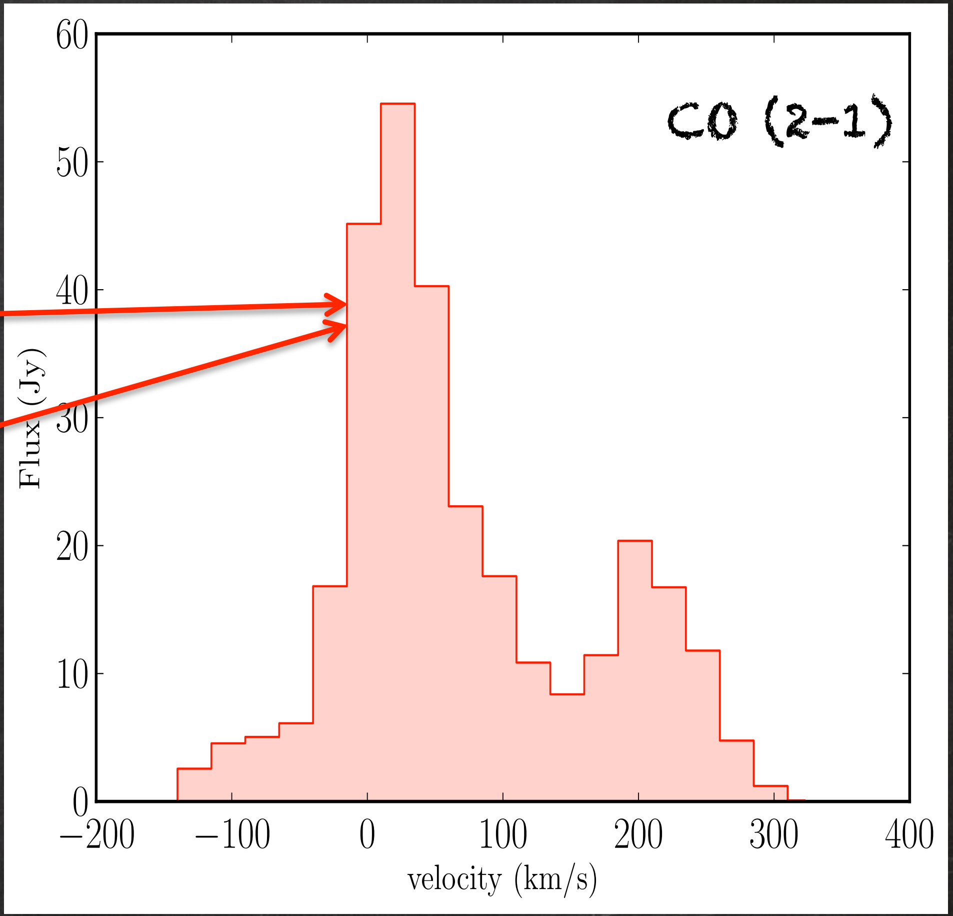
Vallini+ 2013

→ Work in progress:
Calibrate the model at different z's (typical SFR, M*, populations + different Z) based on Herschel/ALMA data and study how the ISM in galaxies evolves (diffuse, PDR, XDR)

→ Vallini, CG et al. (A), in preparation

CO (2-1) emission from NGC 1365





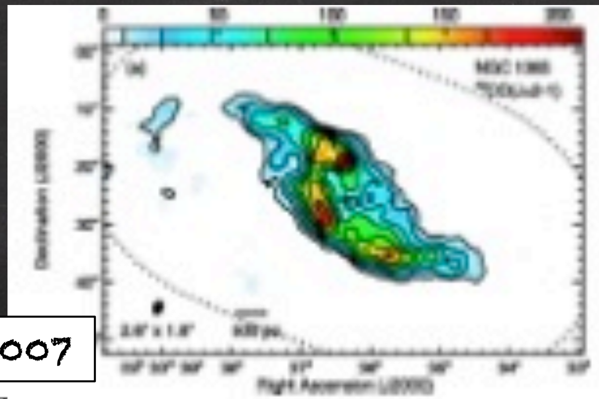
Input:
SFR, Z, age of stellar population

UCL_PDR

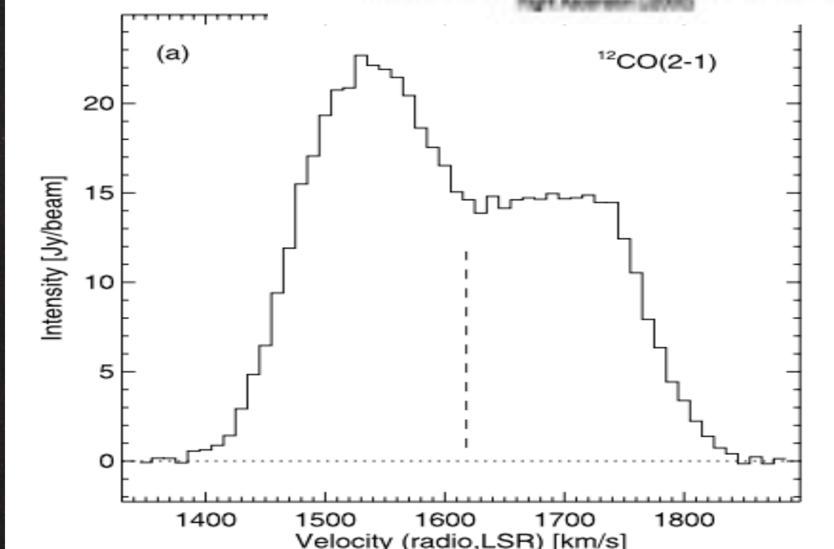
Output:
CO, [OI], [CII], ..., lines

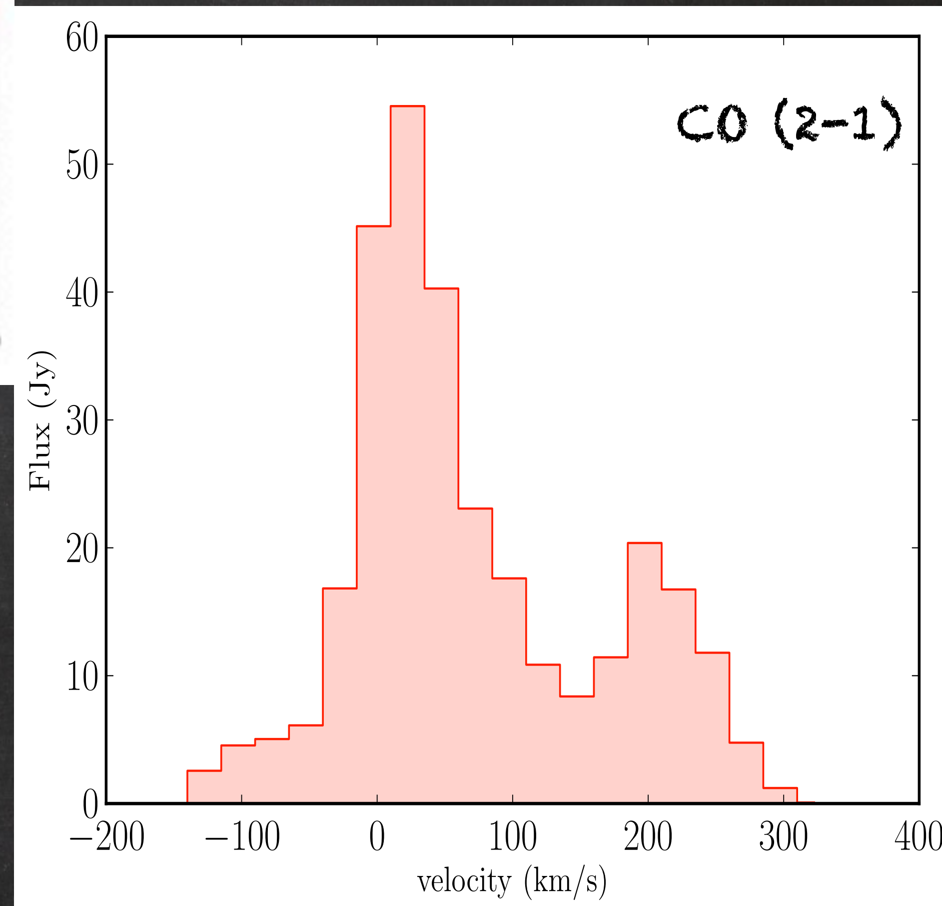
→ *Vallini, CG et al. (B), in preparation*

CO (2-1) emission from NGC 1365



Sakamoto+ 2007





Input:
SFR, Z, age of stellar population

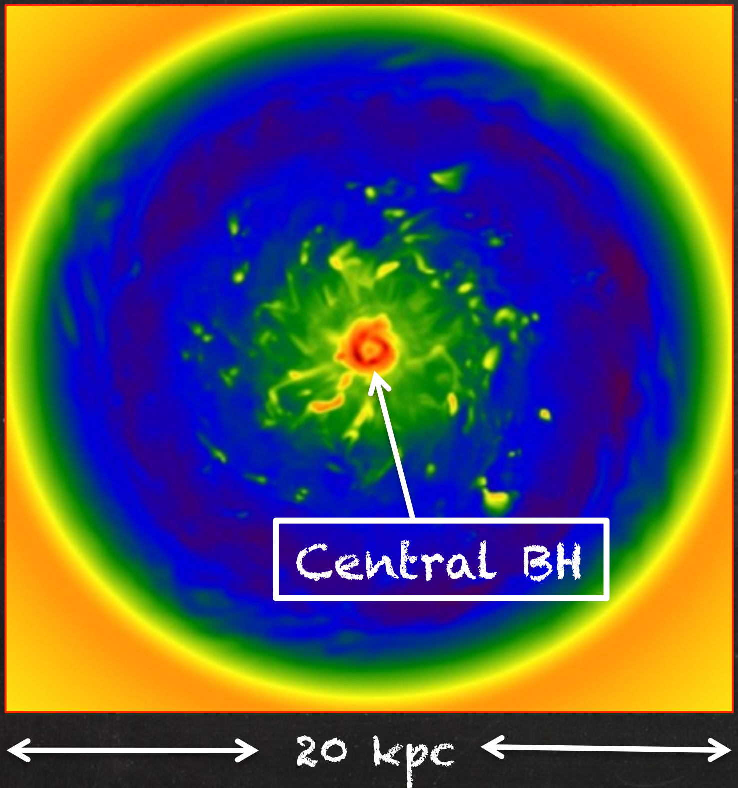
UCL_PDR

Output:
CO, [OI], [CII], ..., lines

→ *Vallini, CG et al.(B) in preparation*

Work in Progress: Single galaxy with AGN

Courtesy: A. Aykutalp



Hydrodynamical simulation with ENZO
(http://enzo-project.org)
up to physical scales of 15 pc

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Radiative transfer with CRASH
(Maselli, A., Ferrara, A. & Ciardi, B. 2003)

+

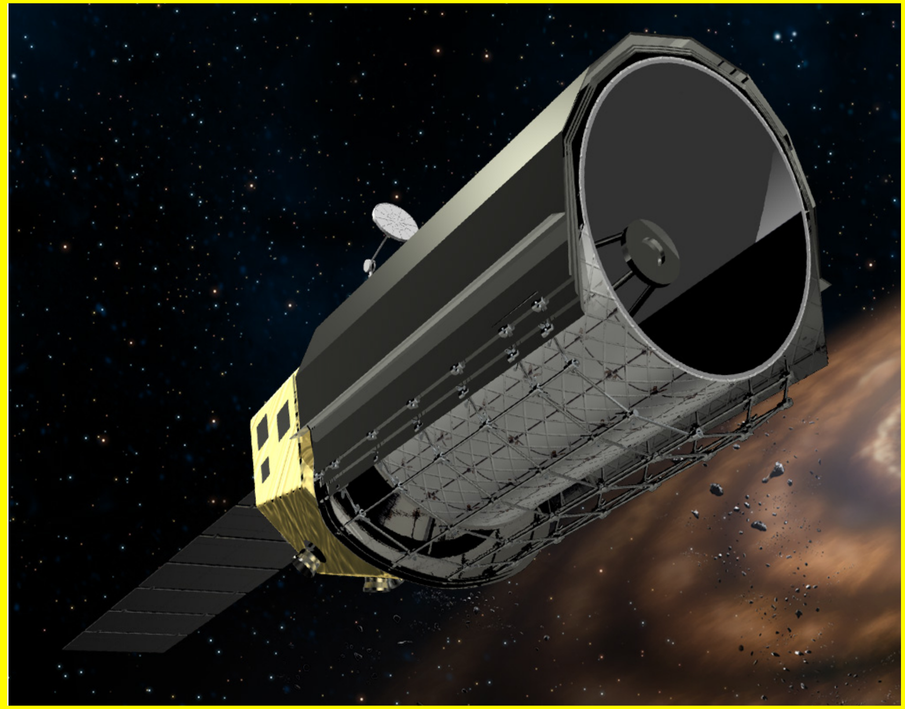
Coupling with PDR + XDR codes
(e.g., UCL_PDR + Meijerik & Spaans XDR)

Effect of the AGN and gas density on the luminosity of FIR lines

Vallini, CG et al. (B), in prep.

The Space Infrared Telescope for Cosmology and Astrophysics: SPICA

SMI	SAFARI
3 spec channels:	3-band grating spectrometer
LRS, MRS, HRS	continuous spectroscopy capability
12-37 µm	34-210 µm

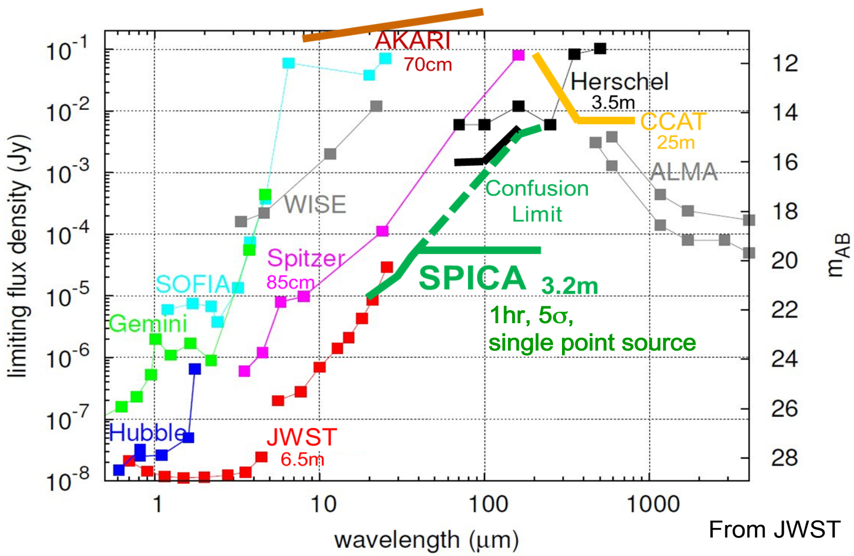


Telescope diameter: 2 - 3 m
Telescope temperature: < 6 K
Wavelength: 20-210 µm (or wider)
Total mass: < 3.7 t
Orbit: Halo orbit around liberation point S-E L2
Launch: in FT2025 or later by JAXA's H-X
Operation: 3 years (nominal), 5 years (goal)

SPICA
Space Infrared Telescope for Cosmology and Astrophysics

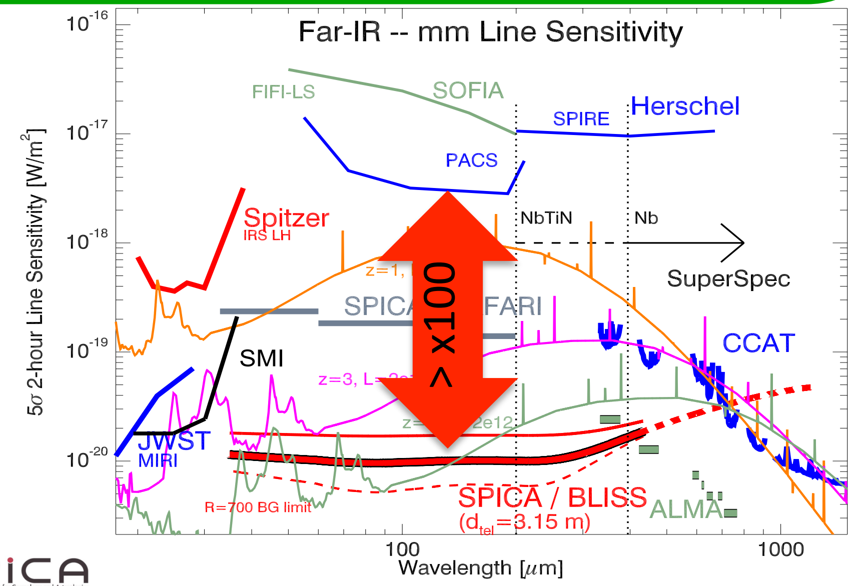
0

Continuum Sensitivities

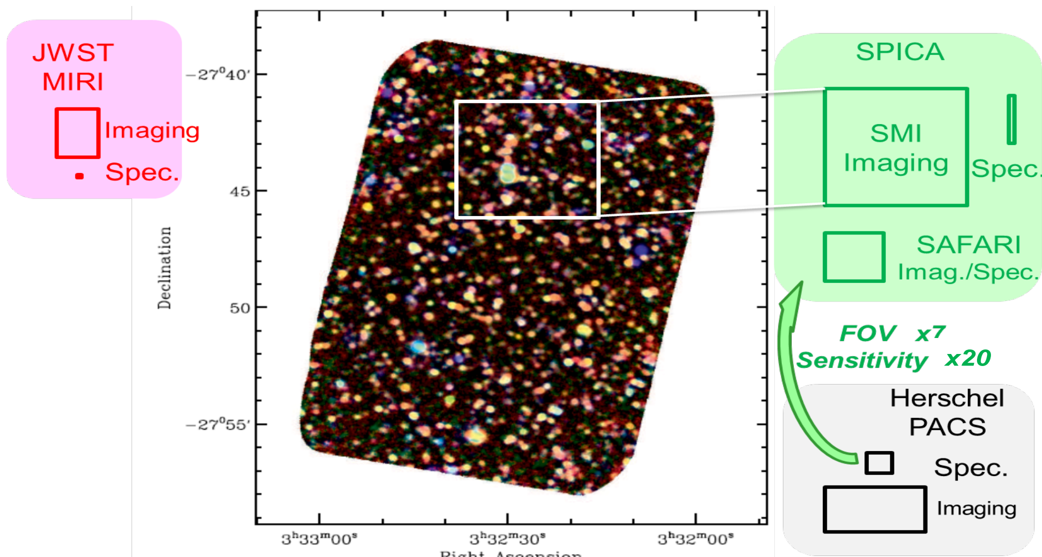


From JWST

Spectral Line Sensitivities



Field of Views (Survey Speed)



Far-Infrared Deep Survey of GOODS-S Field by Herschel PACS, 200hrs Integration,
False-color Image made with MIPS 24μm, PACS 100μm, 160μm, Magnelli et al. (2013)


Thank You !