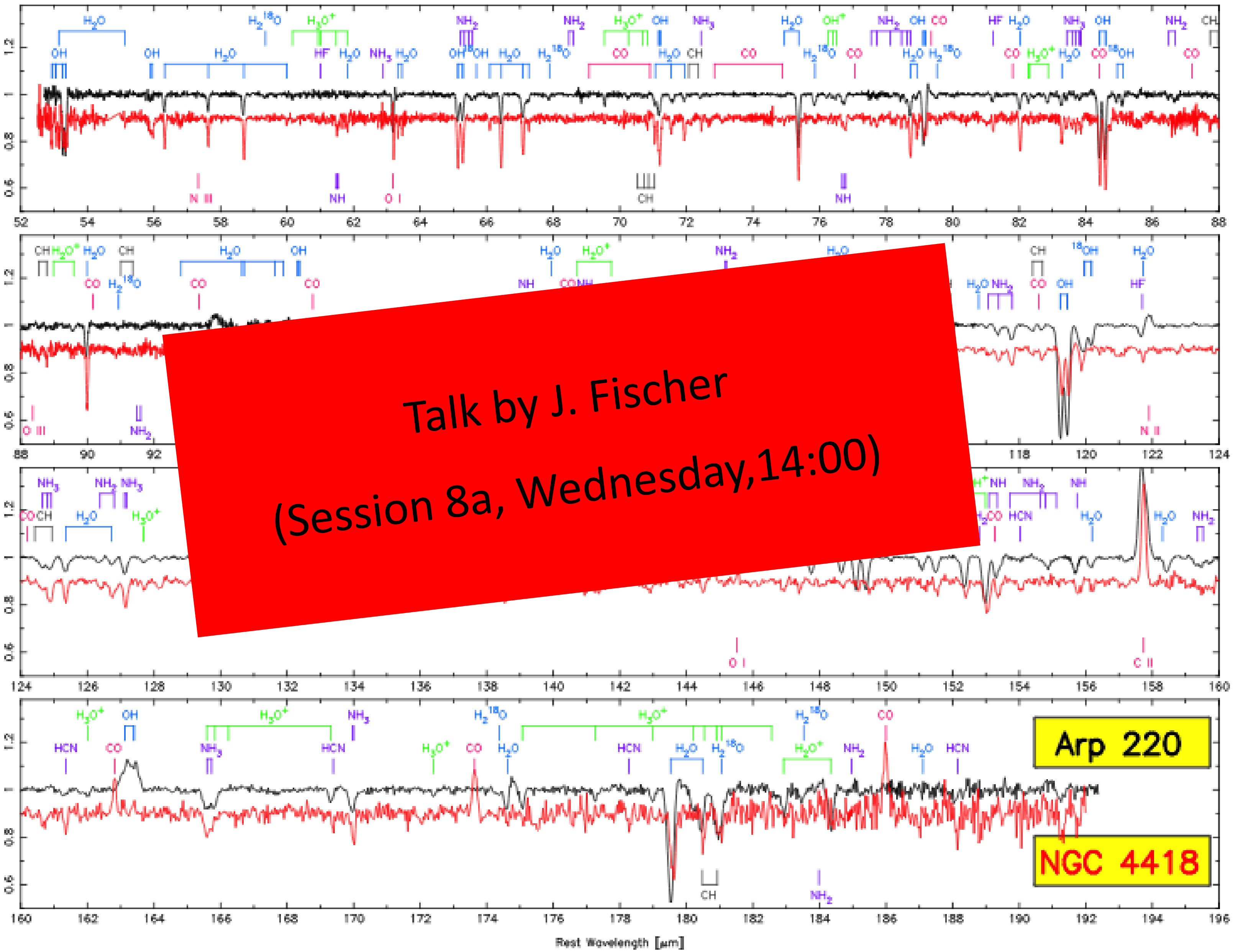
Galaxy Evolution as seen by PACS

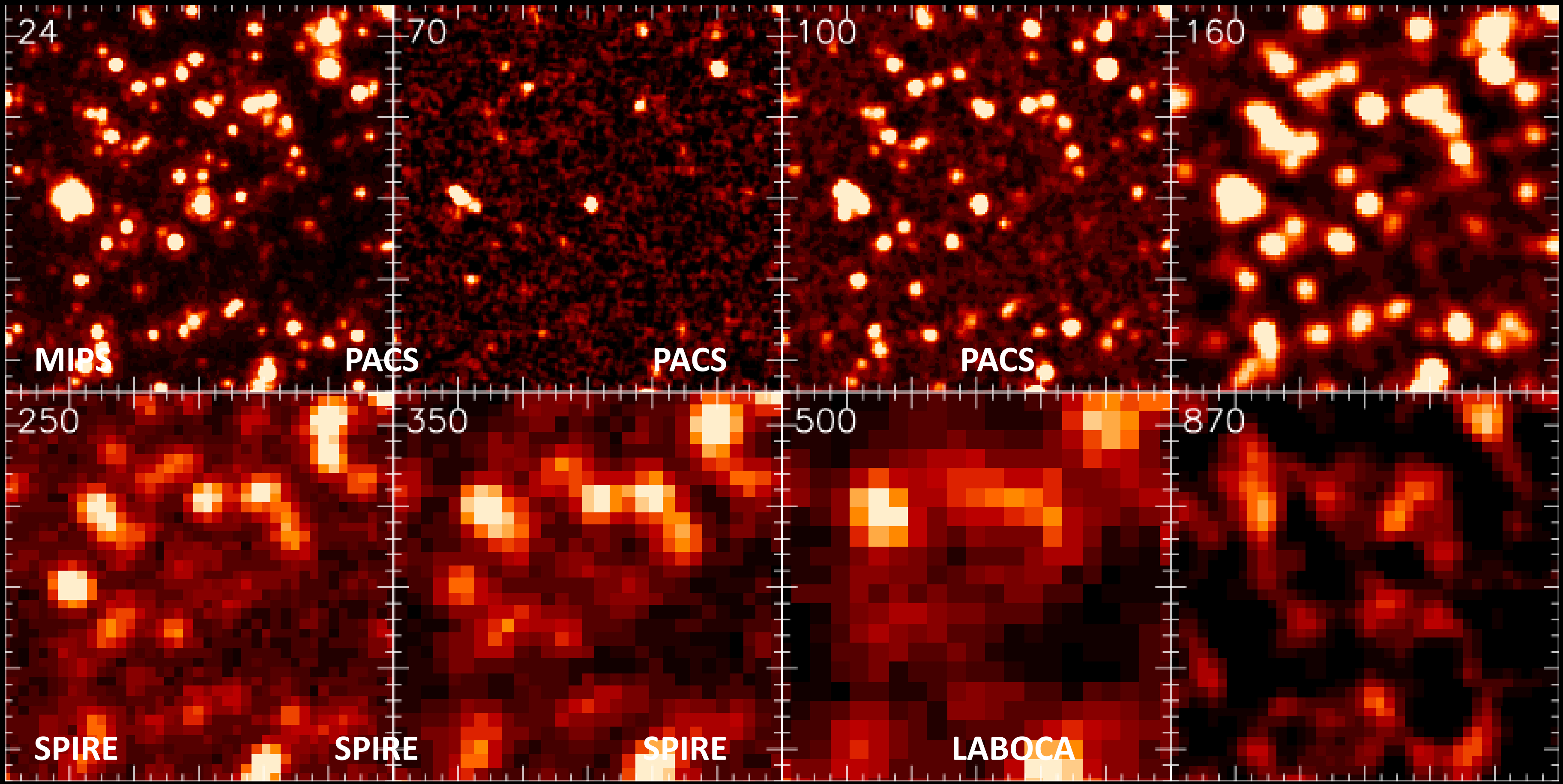
E. Sturm

(MPE)

for the SHINING and PEP Teams


Talk by J. Fischer
(Session 8a, Wednesday,14:00)
Arp 220
NGC 4418
Rest Wavelength [μm]

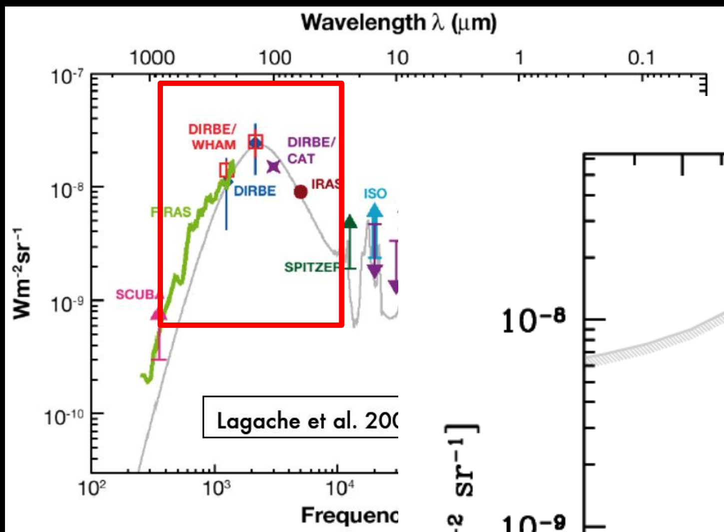
Current deep far-infrared data (4’x4’ cutout in UDF region)

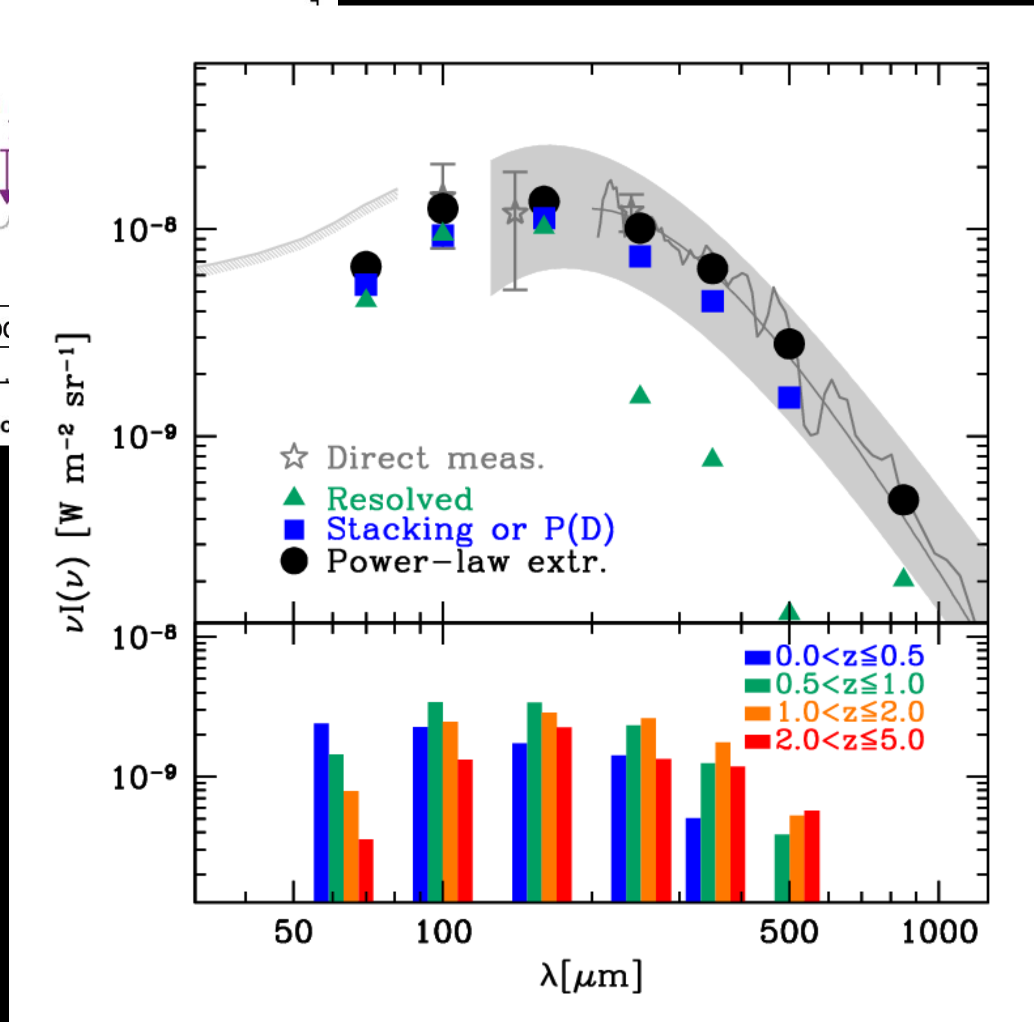


GOODS, PEP, HerMES, LESS

Resolved into individually detected sources:
~75% @ 100µm
~75% @ 160µm

The cosmic infrared background resolved



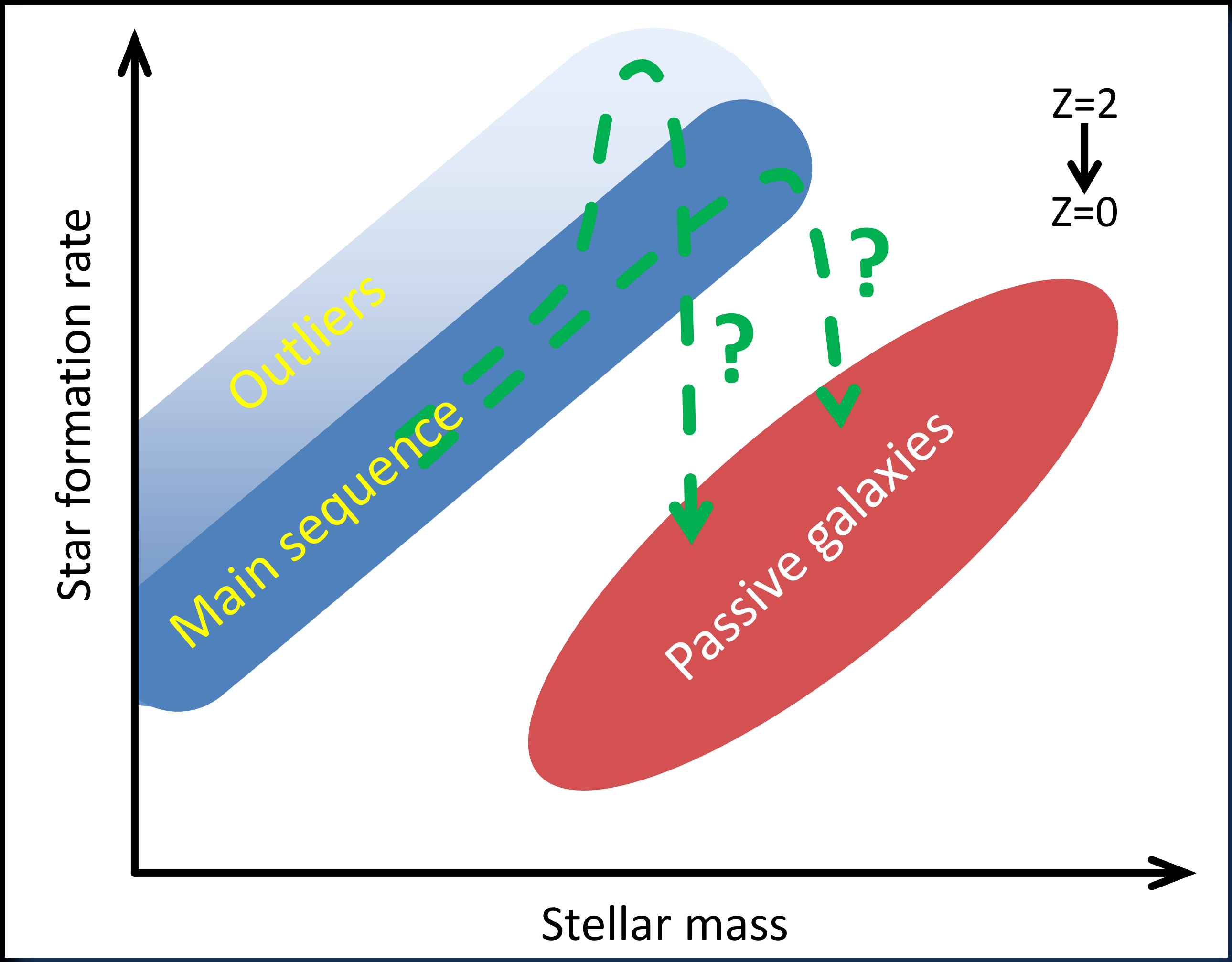


Berta+10,11
Magnelli+13

the contribution of different redshift bins to the CIB, i.e. the fraction of CIB emitted at different cosmic epochs:

At 160 μm half of the resolved CIB originates at z>1

The main sequence of star formation



Brinchmann+04, Noeske+07, Daddi+07, Elbaz+07, Peng+10, Rodighiero+10, …

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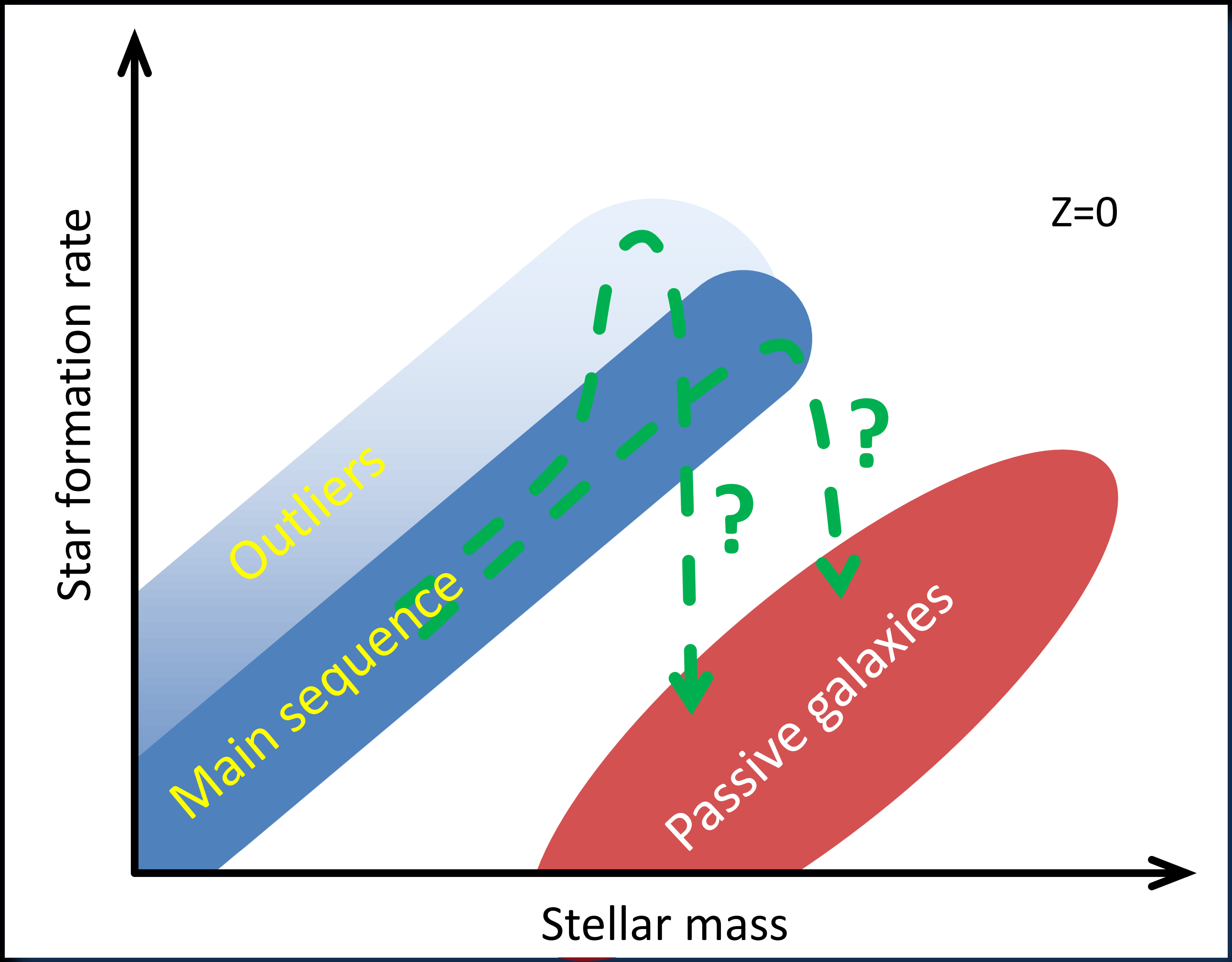

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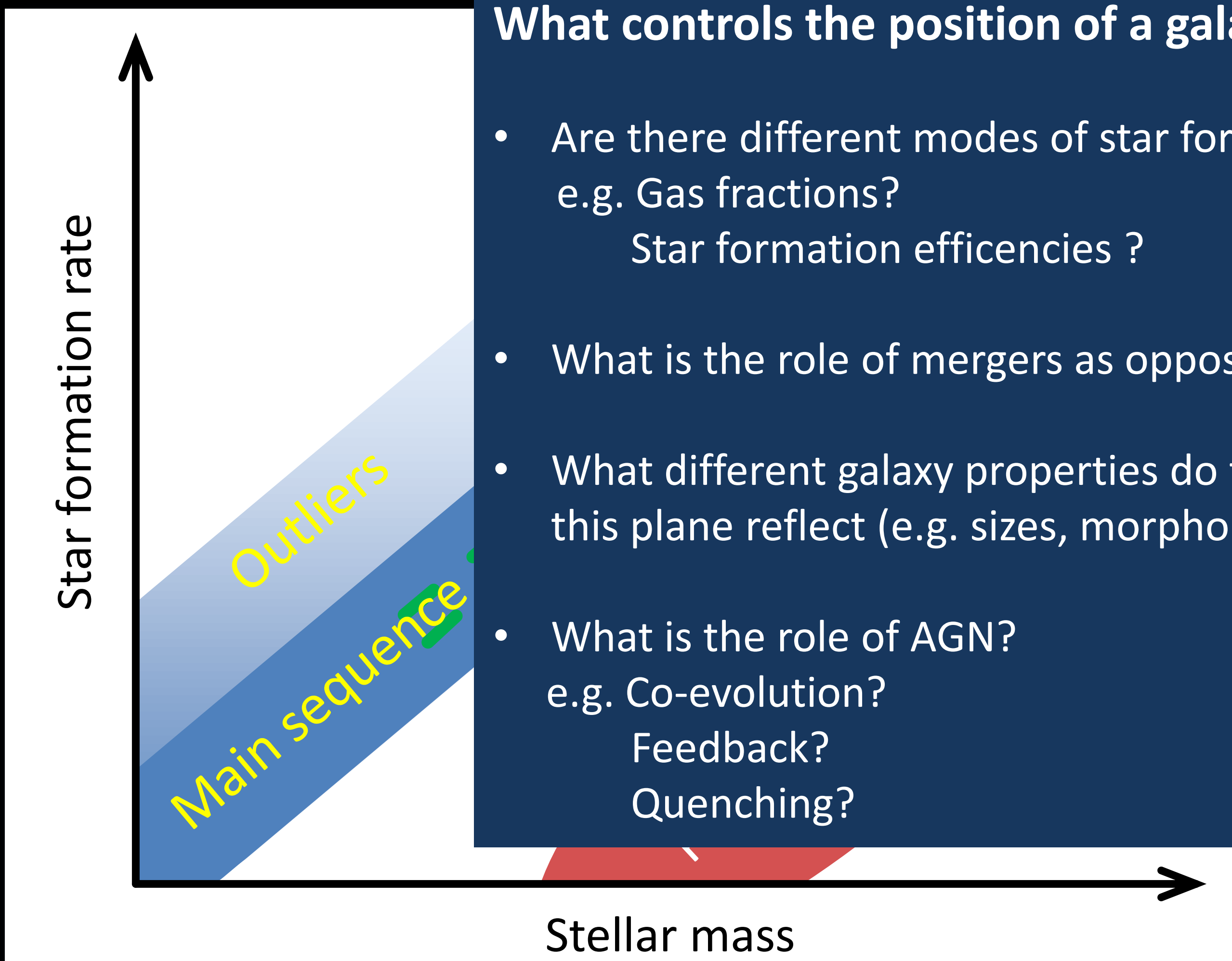
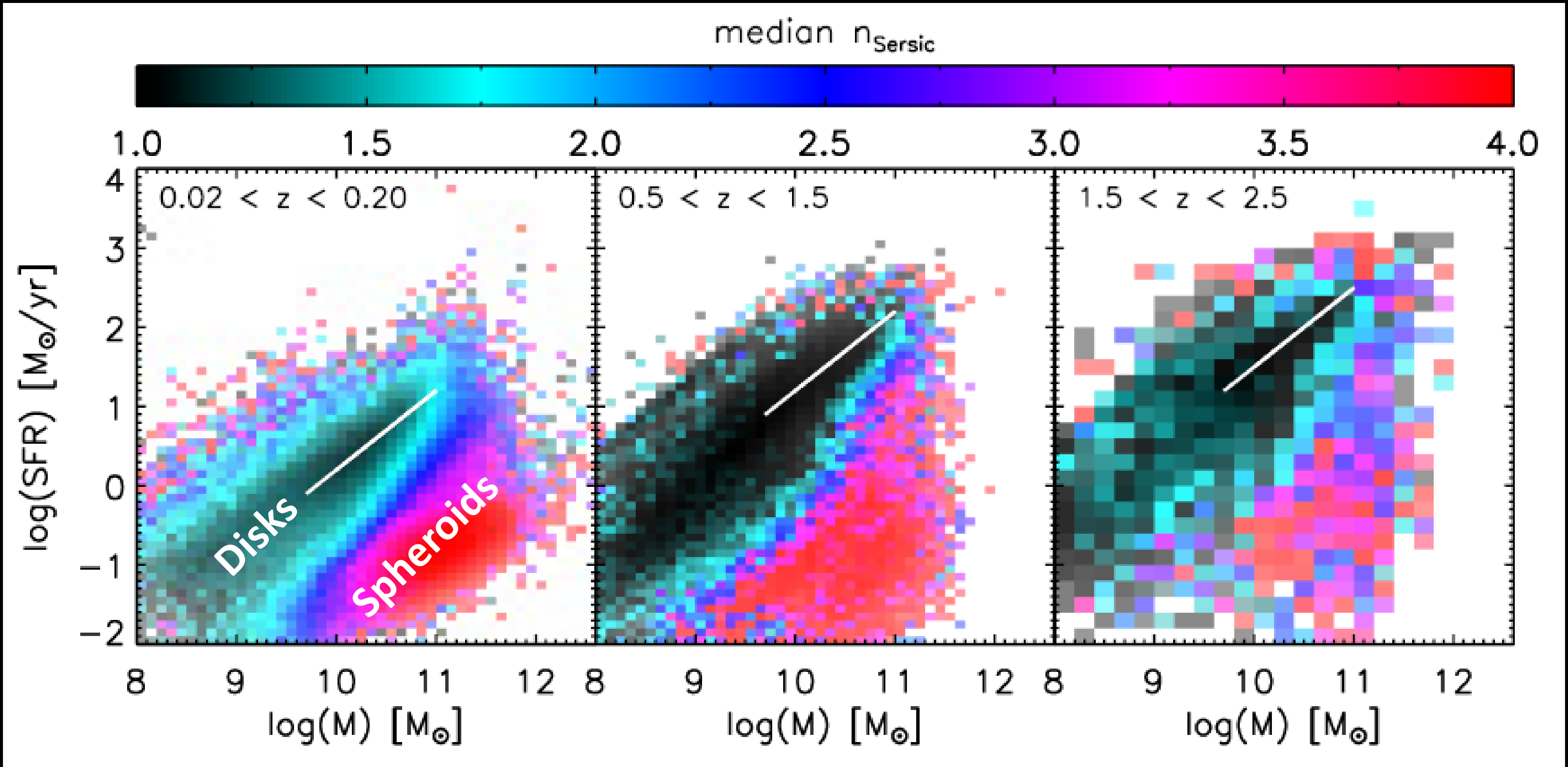


What controls the position of a galaxy in the SFR-M$_*$ plane?

- Are there different modes of star formation?
  e.g. Gas fractions?
  Star formation efficencies ?
- What is the role of mergers as opposed to secular evolution ?
- What different galaxy properties do the different populations in this plane reflect (e.g. sizes, morphology, dust temperature, etc.)?
- What is the role of AGN?
  e.g. Co-evolution?
  Feedback?
  Quenching?

Brinchmann+04, Noeske+07, Daddi+07, Elbaz+07, Peng+10, Rodighiero+10, …

A morphological `main sequence’



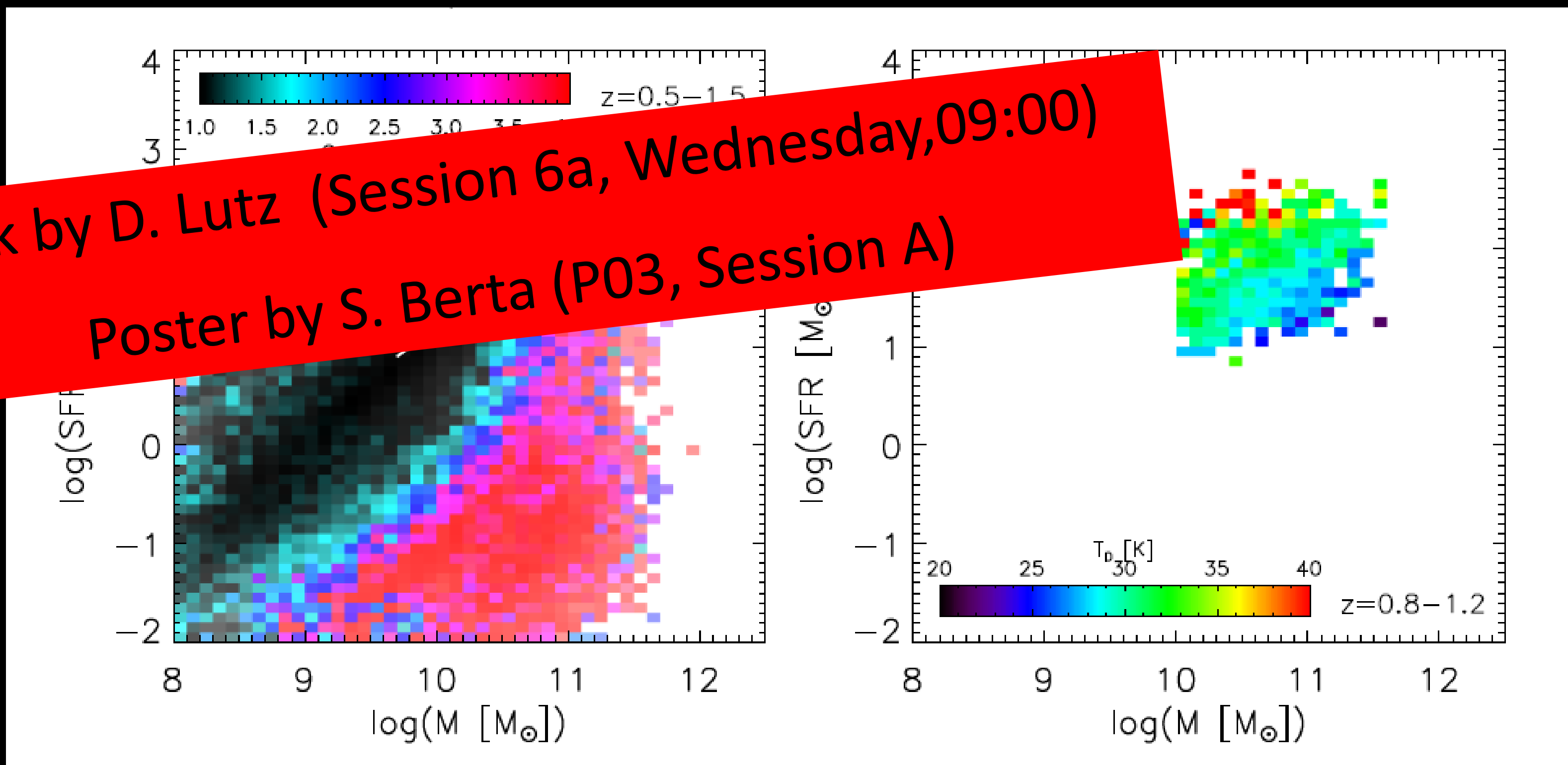
Nordon+ 2010, Wuyts+ 2011a,b, Rodighiero+ 2011, Nordon+ 2012, Magnelli+ in prep.

Dust temperatures

Elbaz+ 2011, Magdis+ 2012b, Magnelli+ 2013a

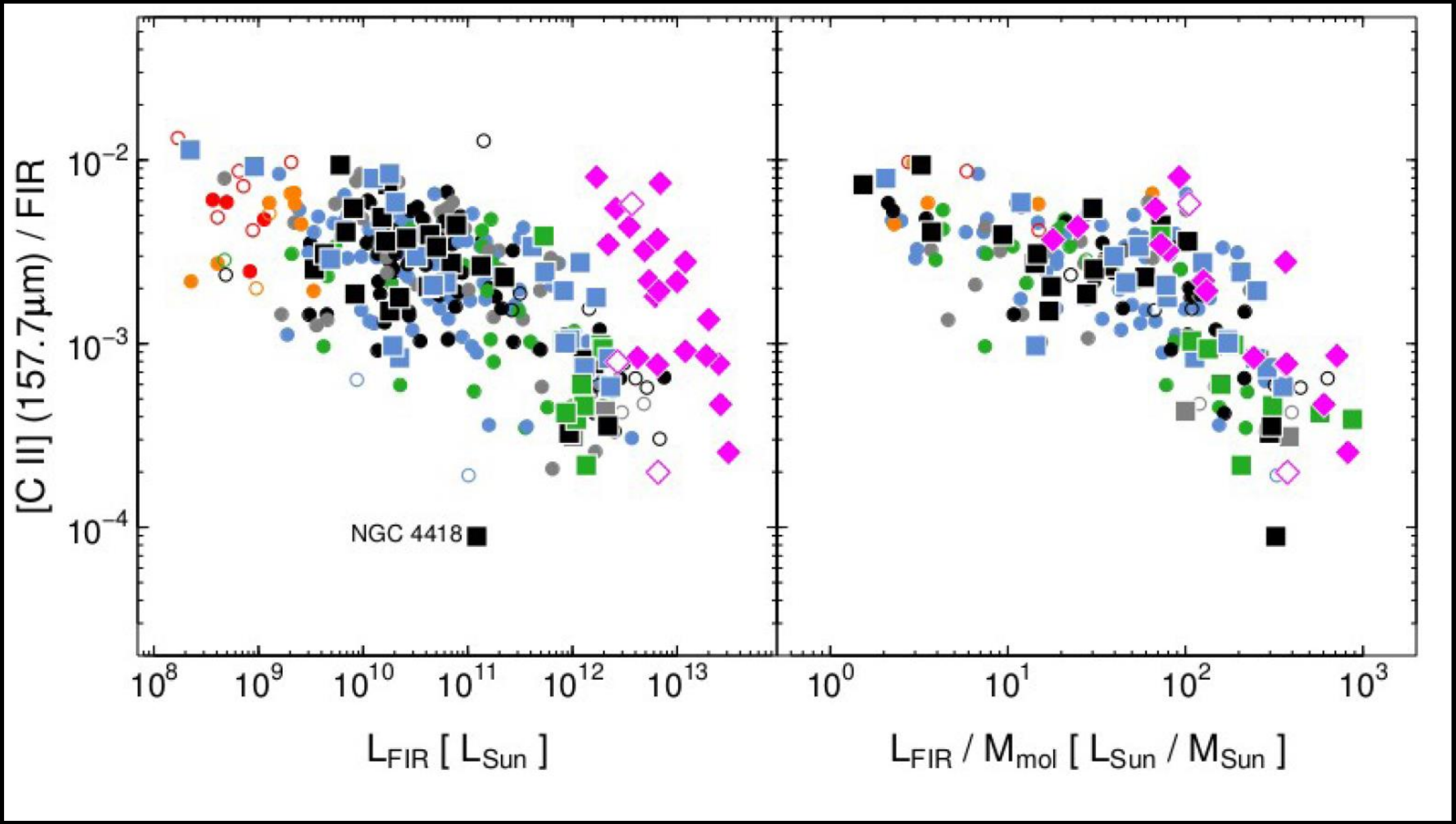
Talk by D. Lutz (Session 6a, Wednesday,09:00)

Poster by S. Berta (P03, Session A)



- high redshift starbursts above the main sequence show increased dust temperatures
- dust temperature can be expressed as a function of main sequence offset with less scatter and less redshift dependence compared to expressing temperature as a function of IR luminosity.

Galaxies on and above the MS: the “[C II] deficit”



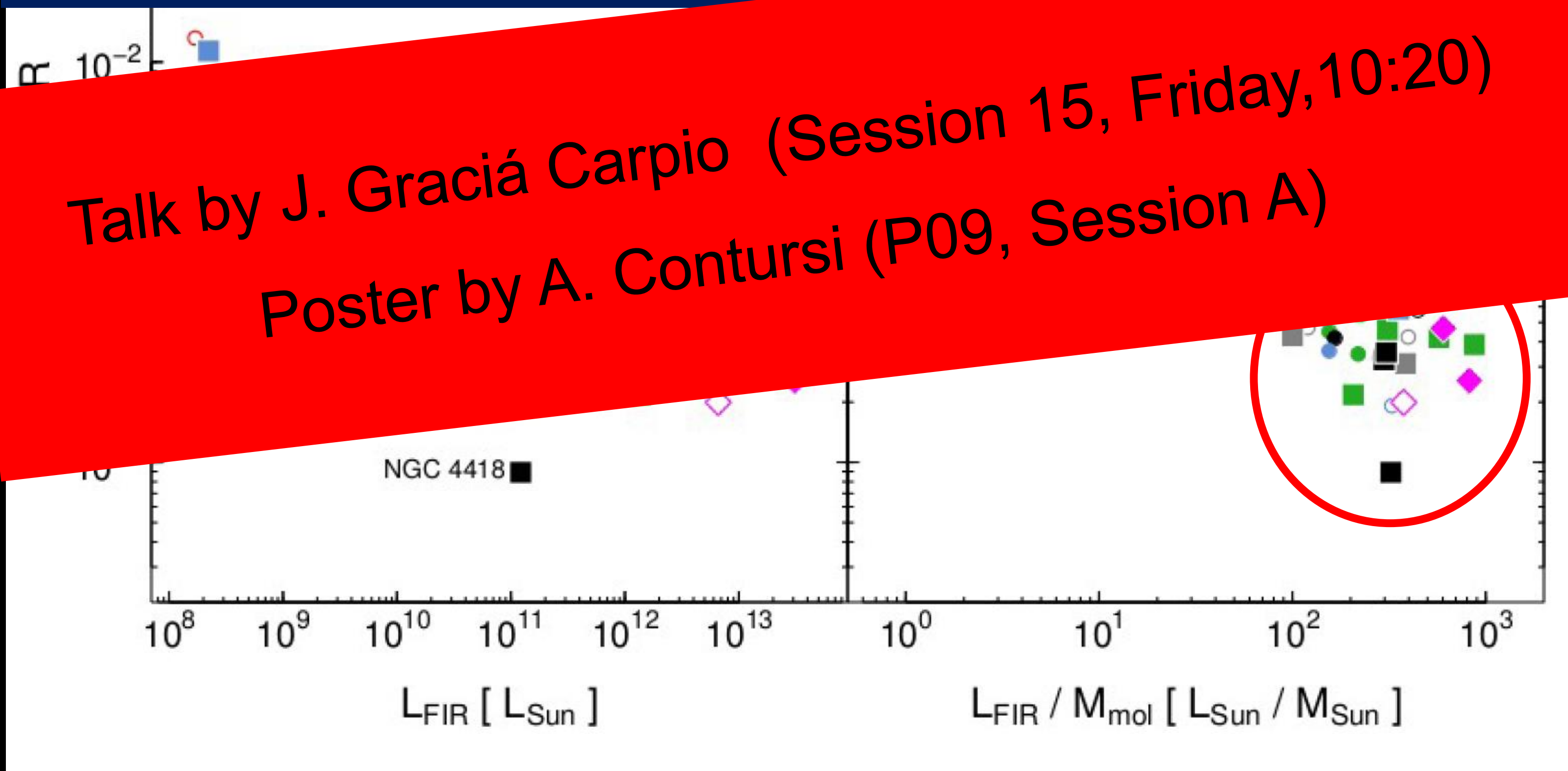
Graciá Carpio+ 2011

Galaxies on and above the MS: the “[C II] deficit”

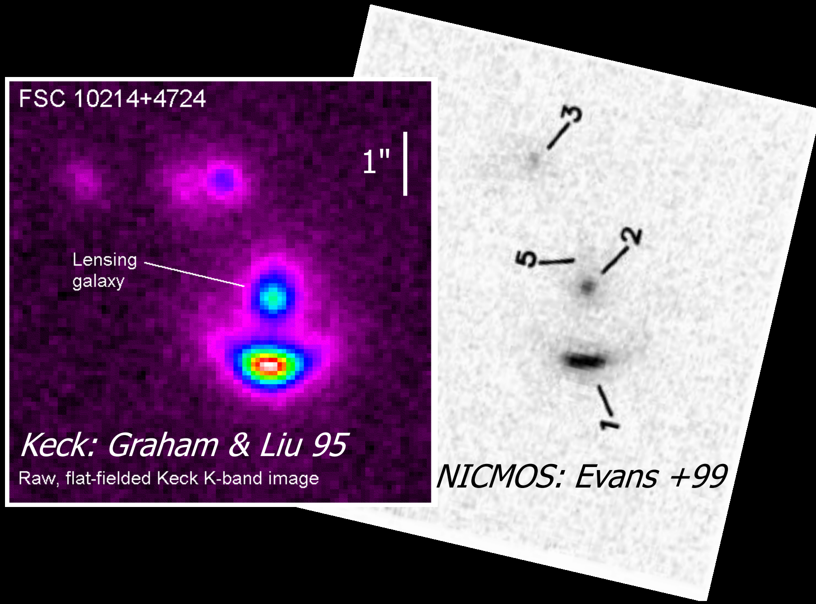
Objects above MS: enhanced SFE in warm and compact ISM

Talk by J. Graciá Carpio (Session 15, Friday,10:20)

Poster by A. Contursi (P09, Session A)

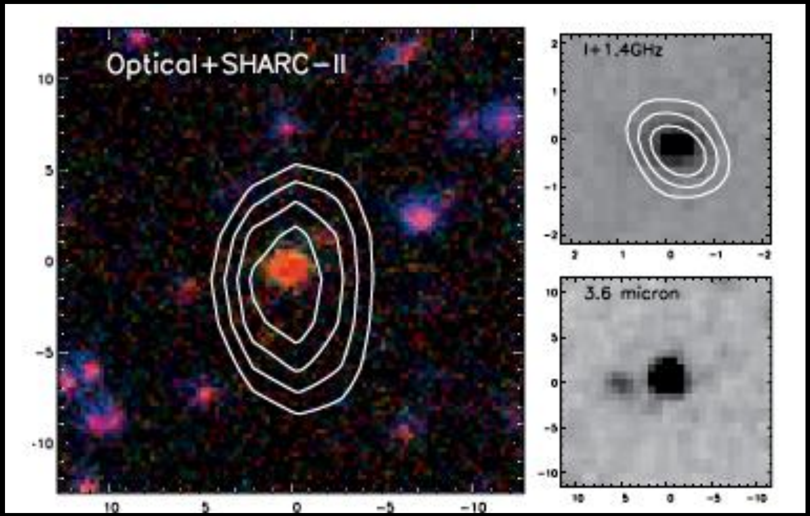


Graciá Carpio+ 2011



IRAS F10214+4724

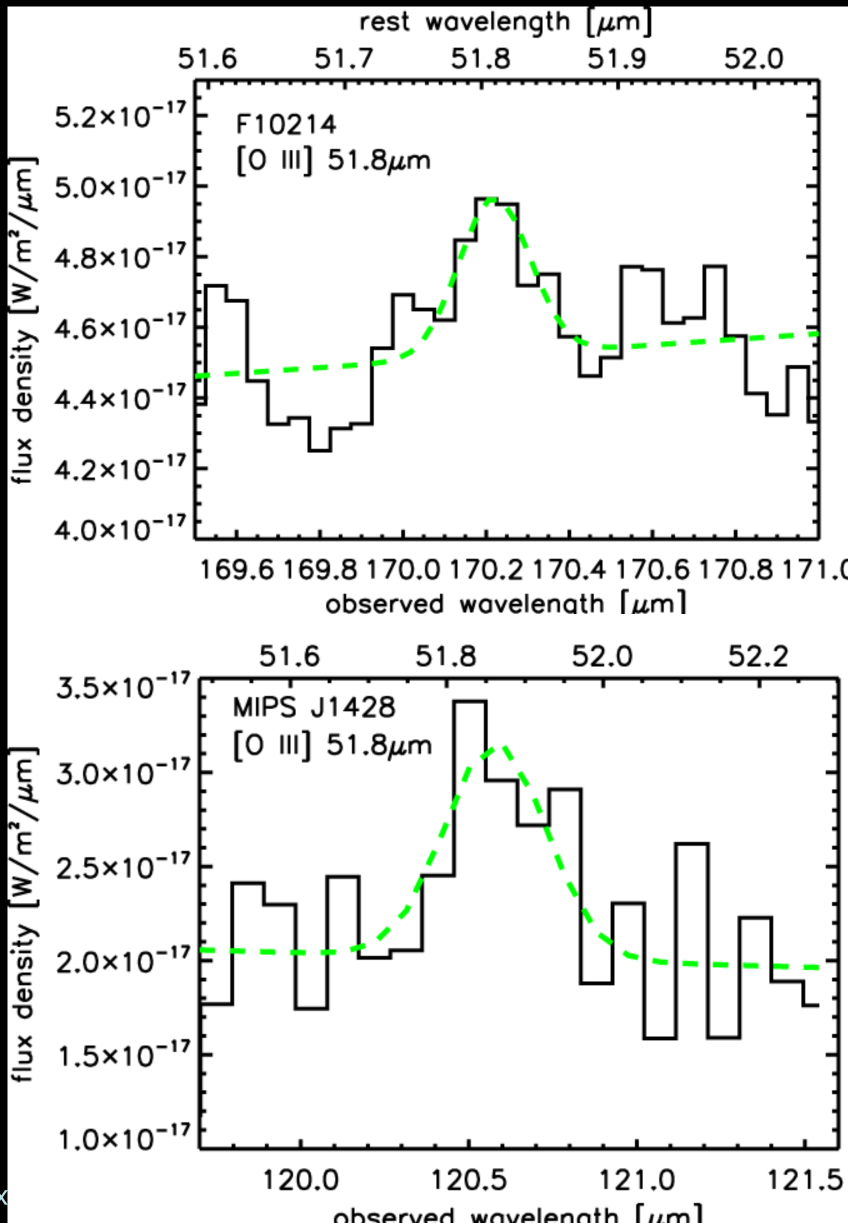
Well studied lensed z=2.29 HLIRG (Sy2)
Coeval star formation & AGN
Differential magnification AGN/Host ≈ 3



MIPS J142824.0+352619

- A hyperluminous "Monster": Extreme Starburst at z=1.325
- no AGN signatures
- Lensed by foreground z≈1 elliptical

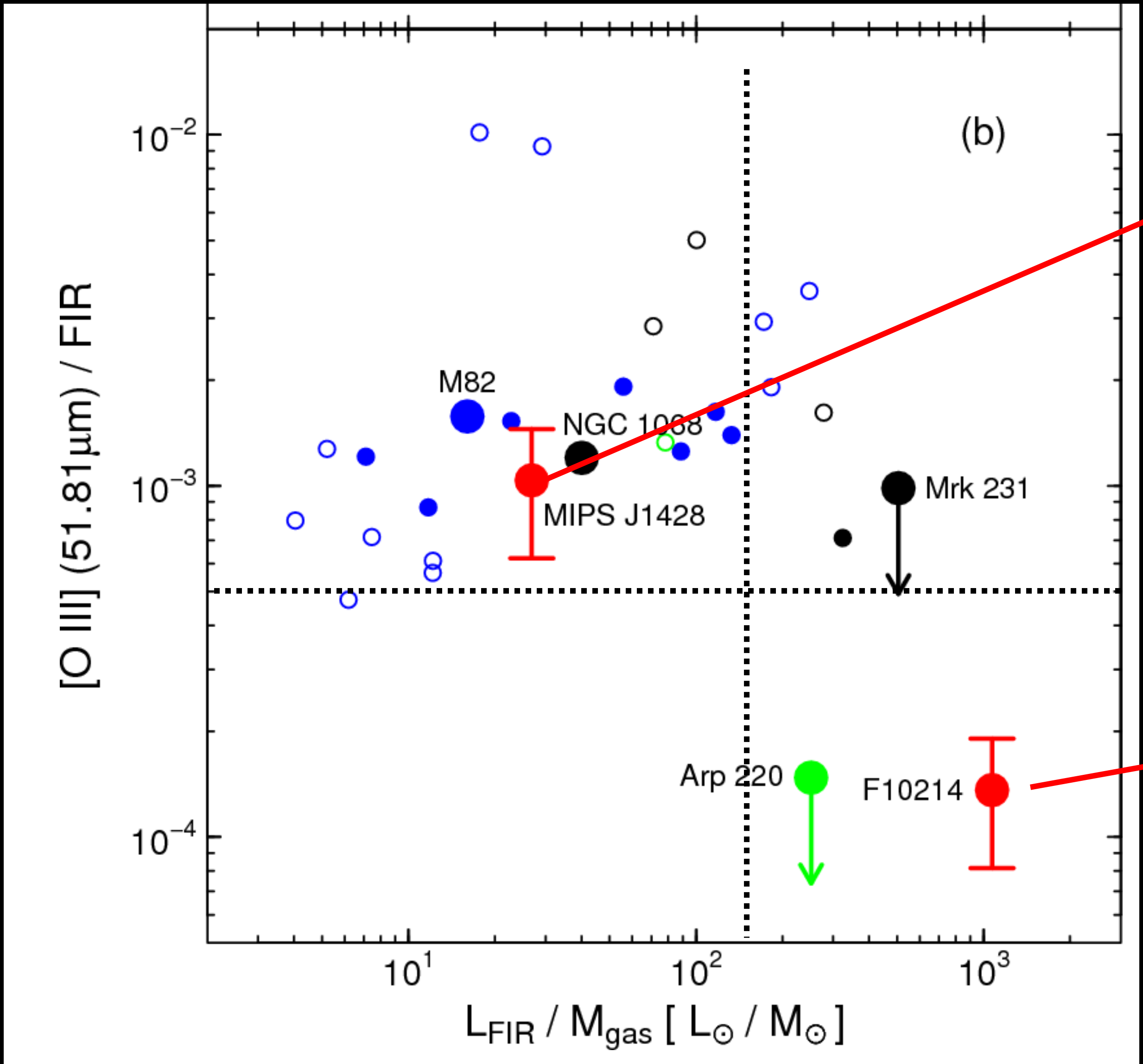
[O III] 52μm



12 hours

1.5 hours

Sturm+ 2010



The Luminosity of a ULIRG

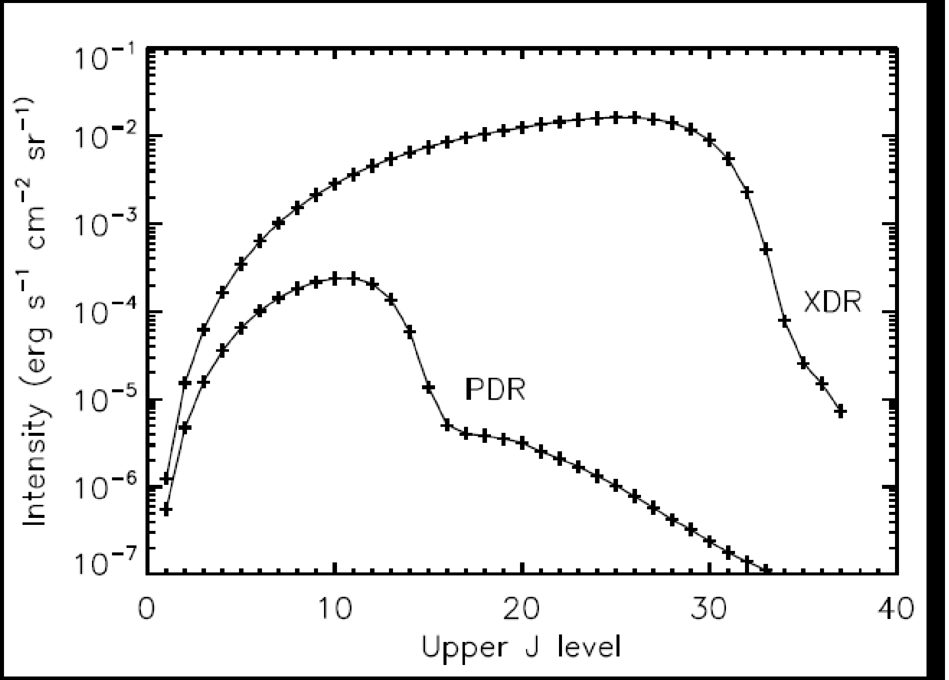
but

The SFE of a normal starforming galaxy

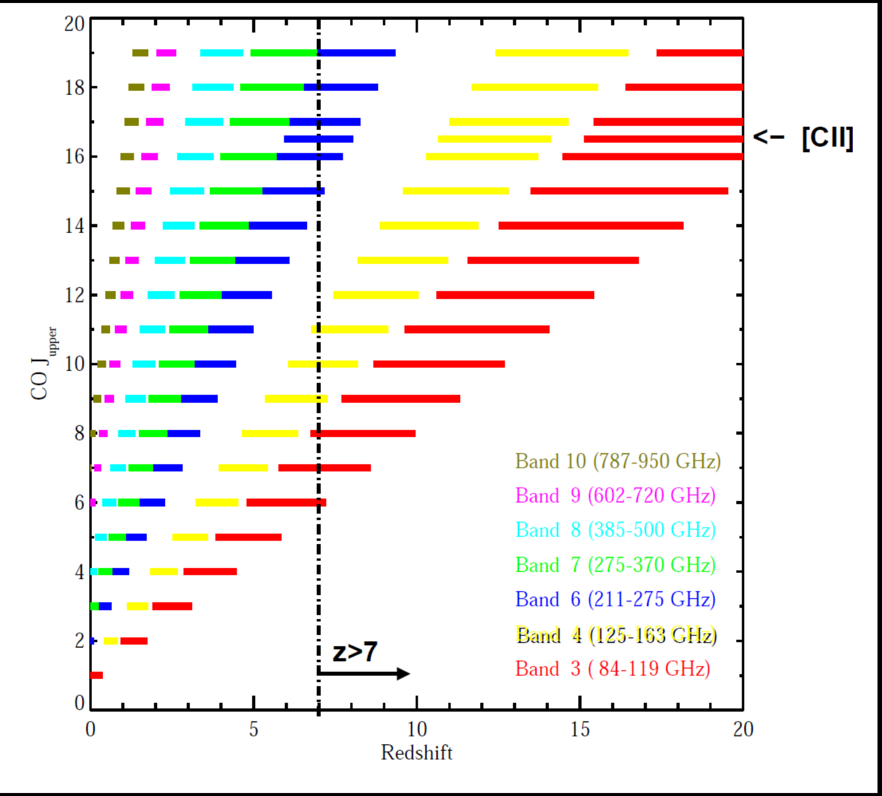
ULIRG / Merger - like

Sturm+ 2010

High-J CO - A new probe of warm and dense molecular gas

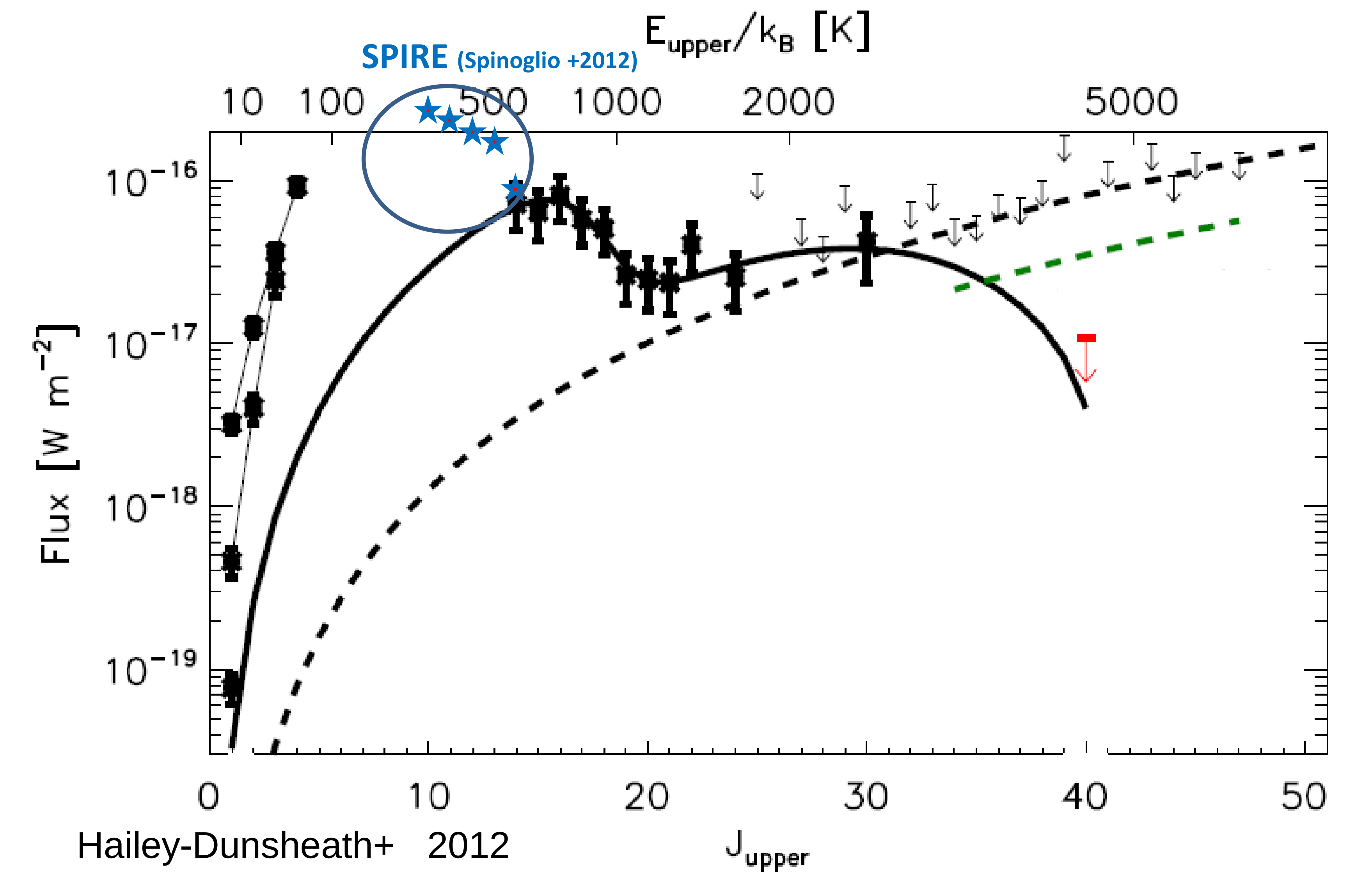


Spaans & Meijerink 2008



Walter & Carilli 2008

The CO Line-SED of NGC1068 from J=0 …40



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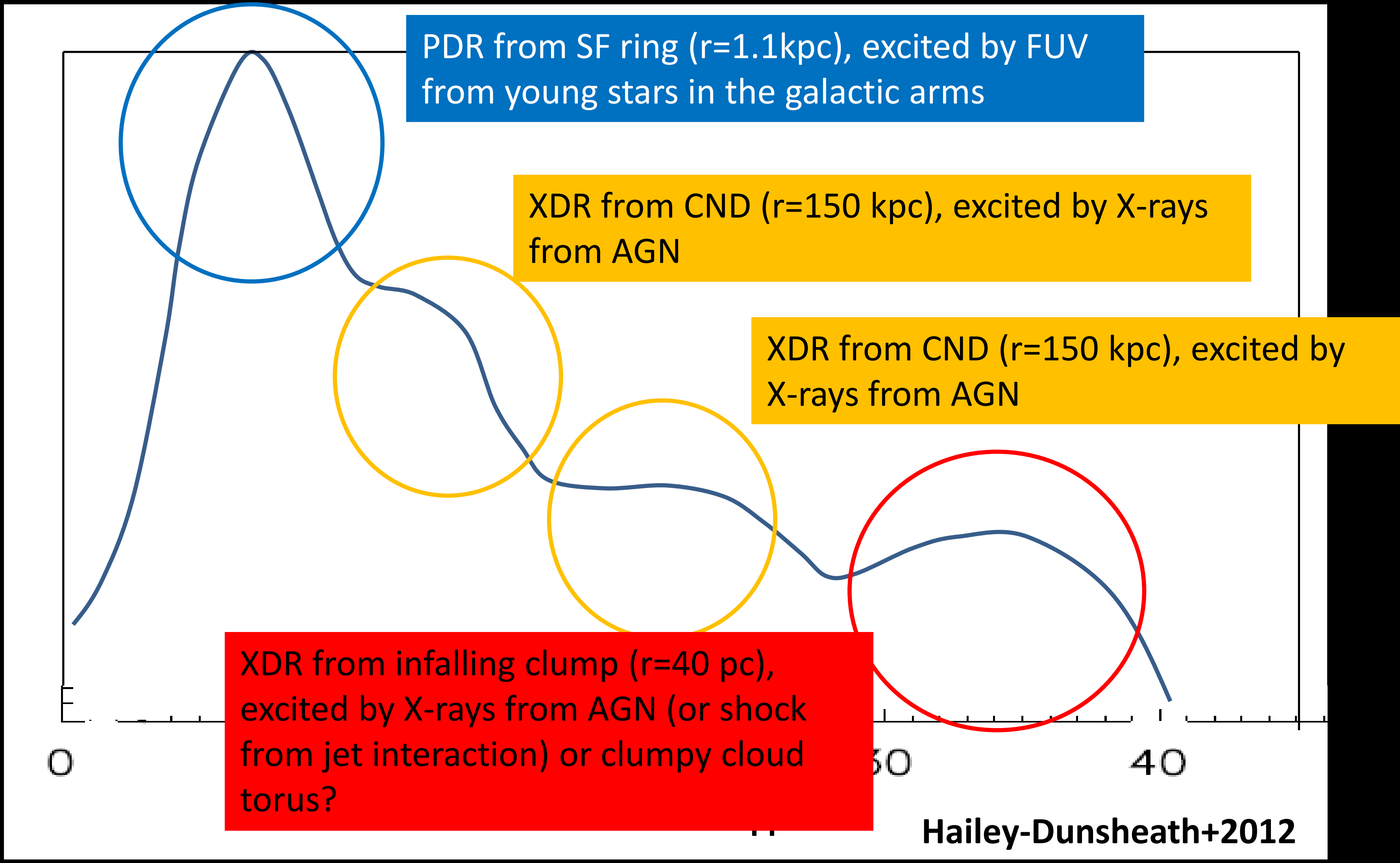
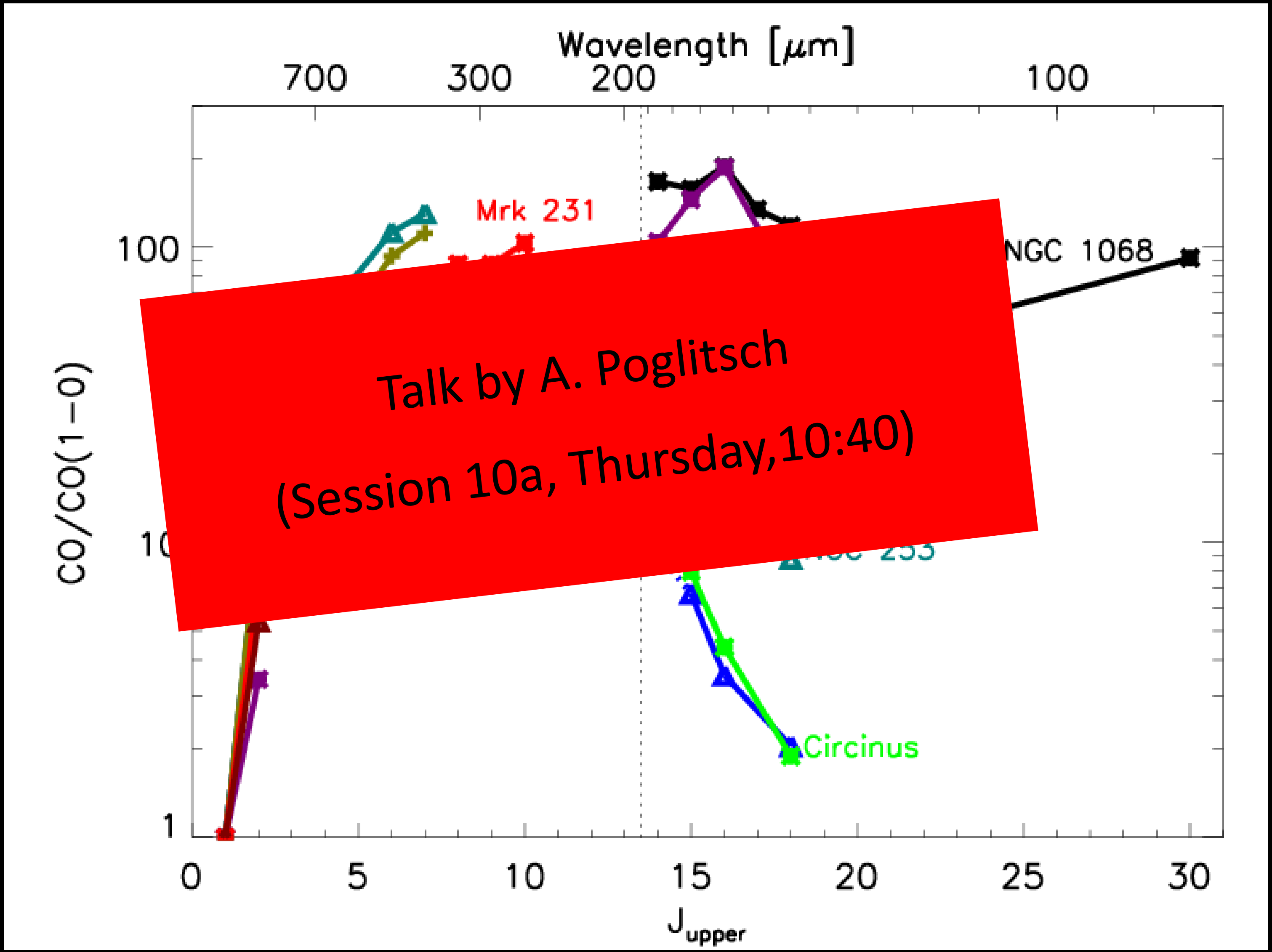
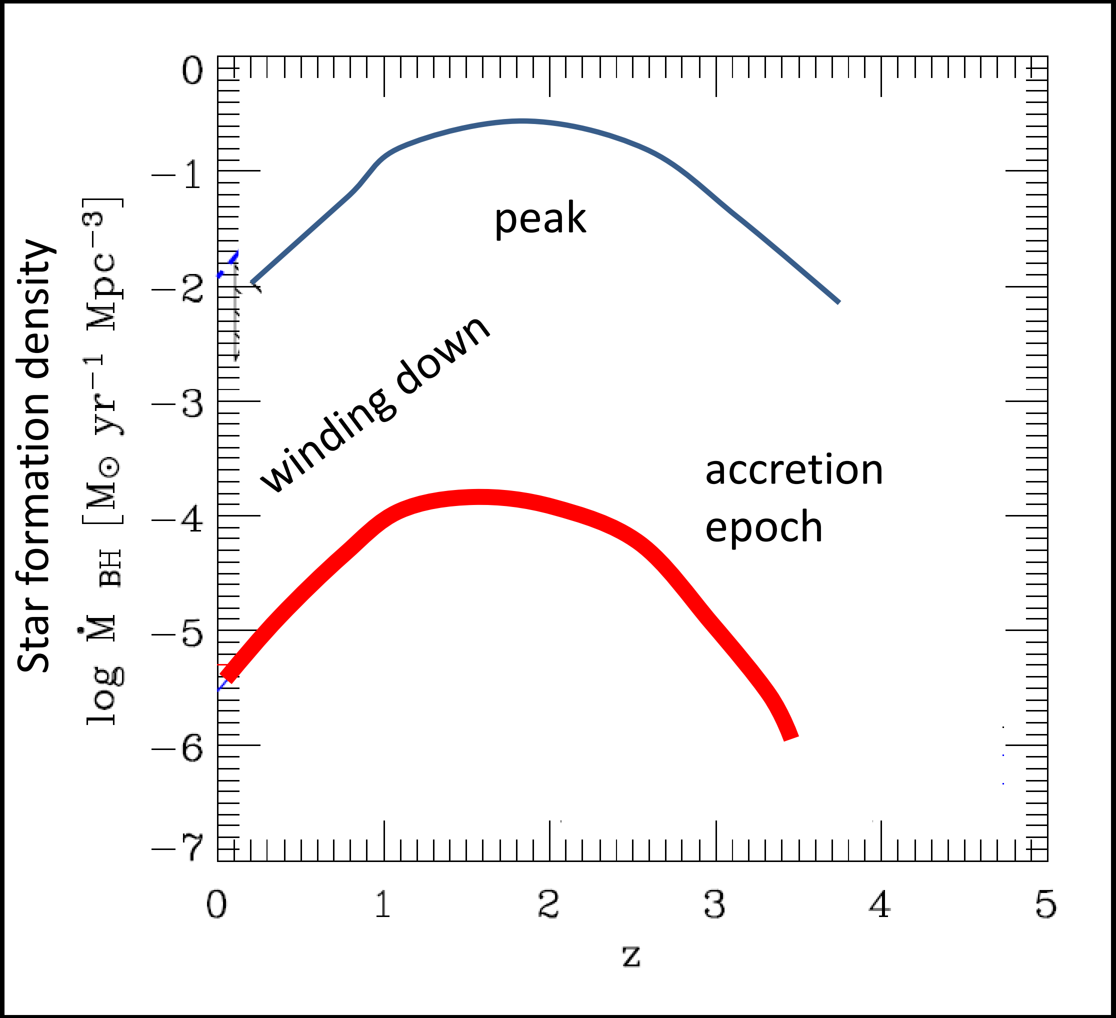


High-J CO - A new probe of warm and dense molecular gas



The role of AGN: co-evolution?



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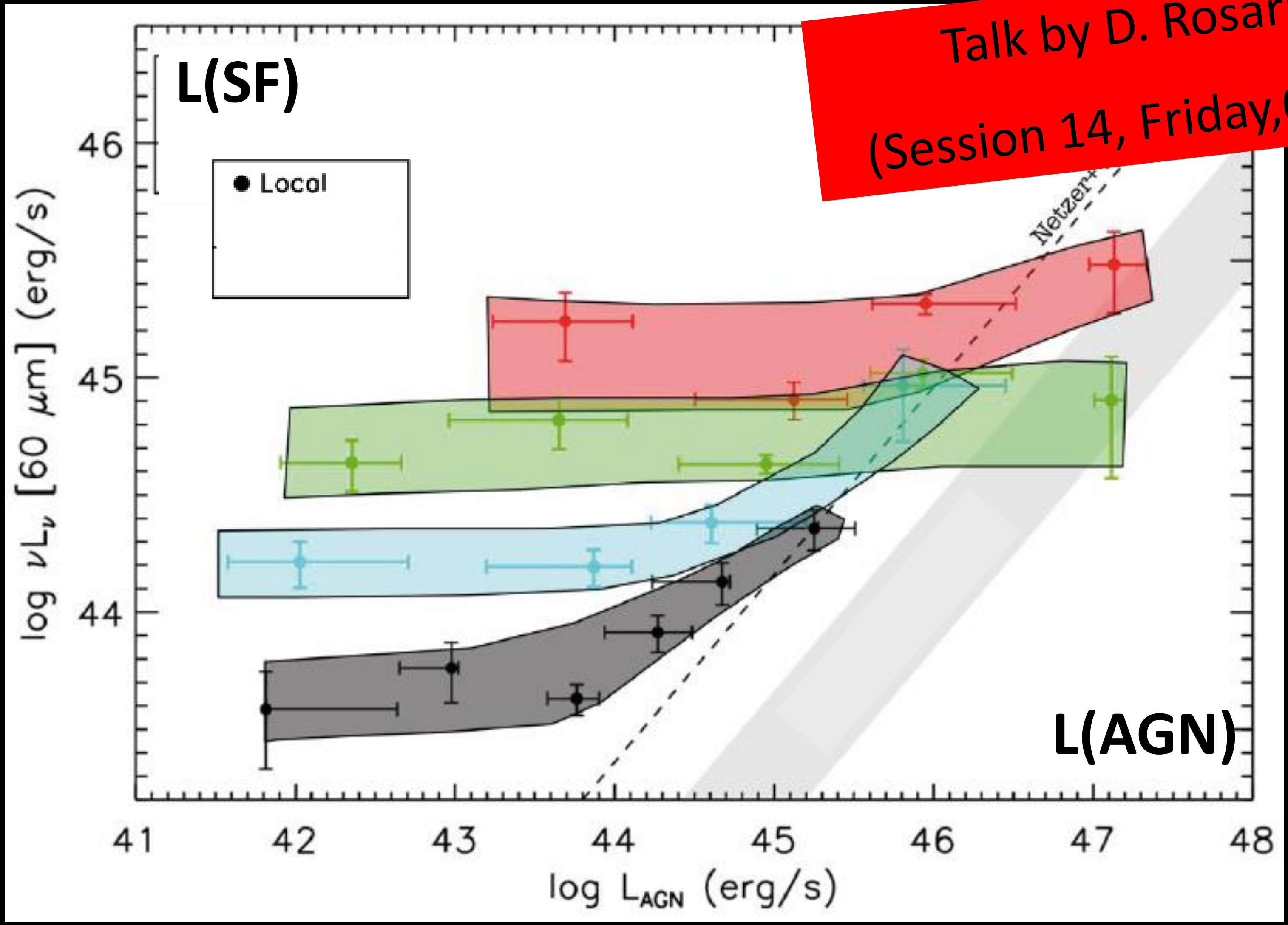
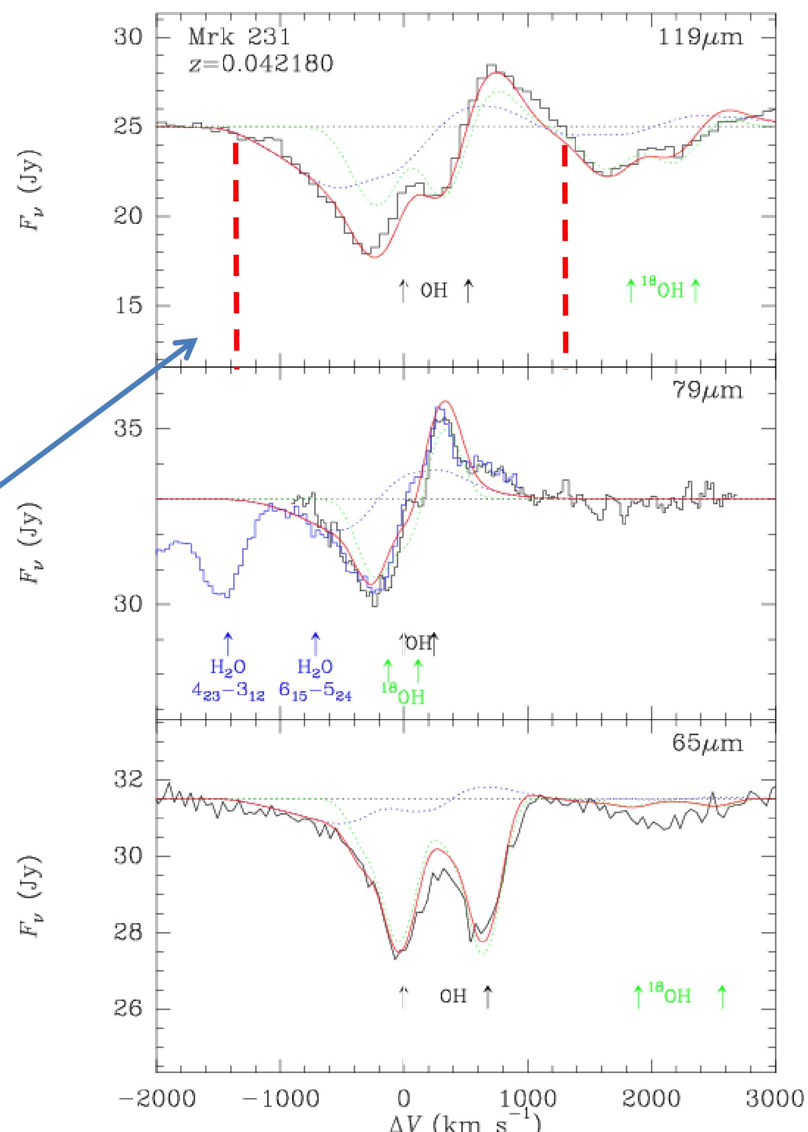


Talk by D. Rosario
(Session 14, Friday,09:20)

Rosario+ 2012, 2013

The role of AGN: feedback / quenching?

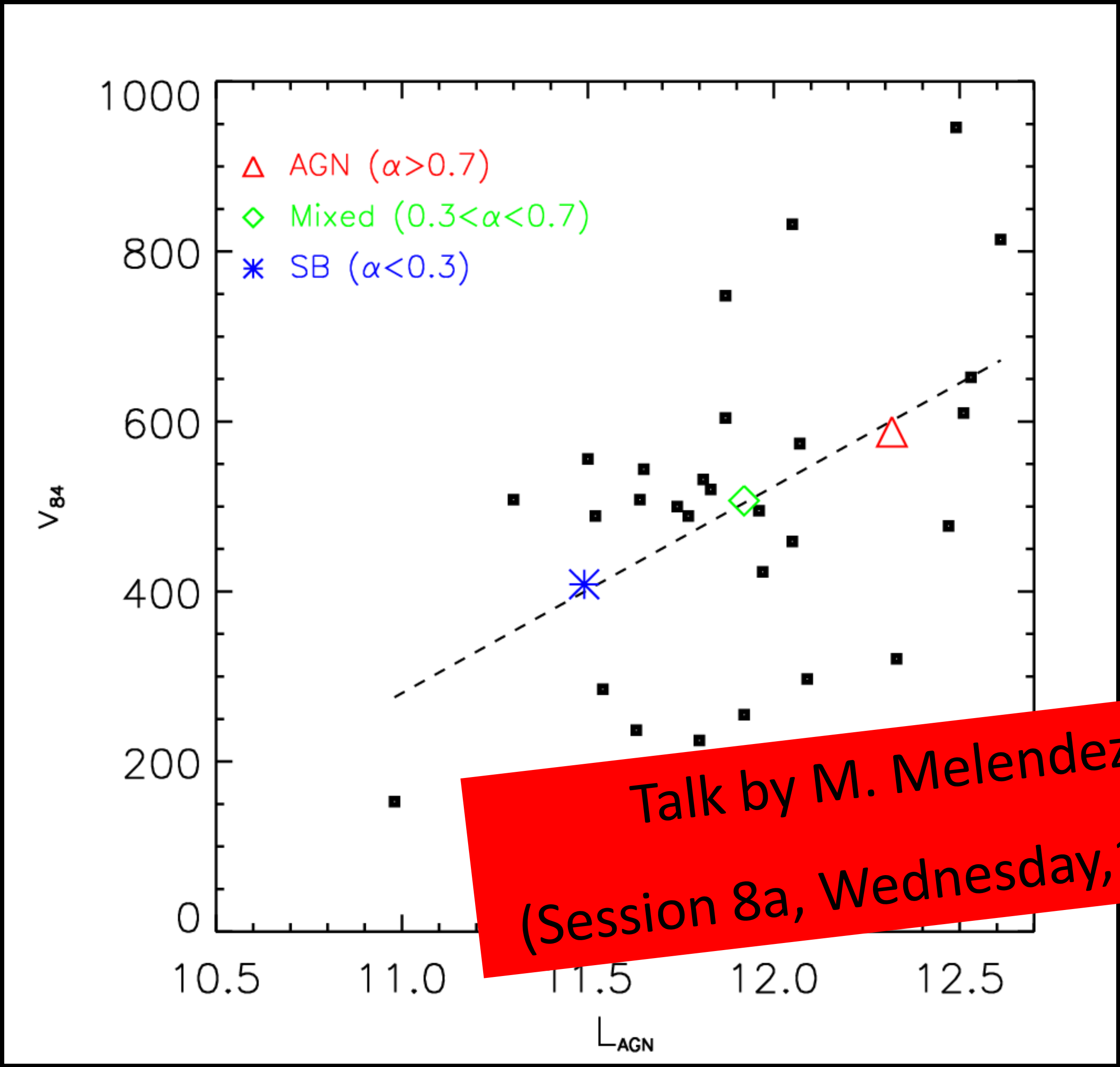


E. Sturm

Δv ~ 1,170 km/s

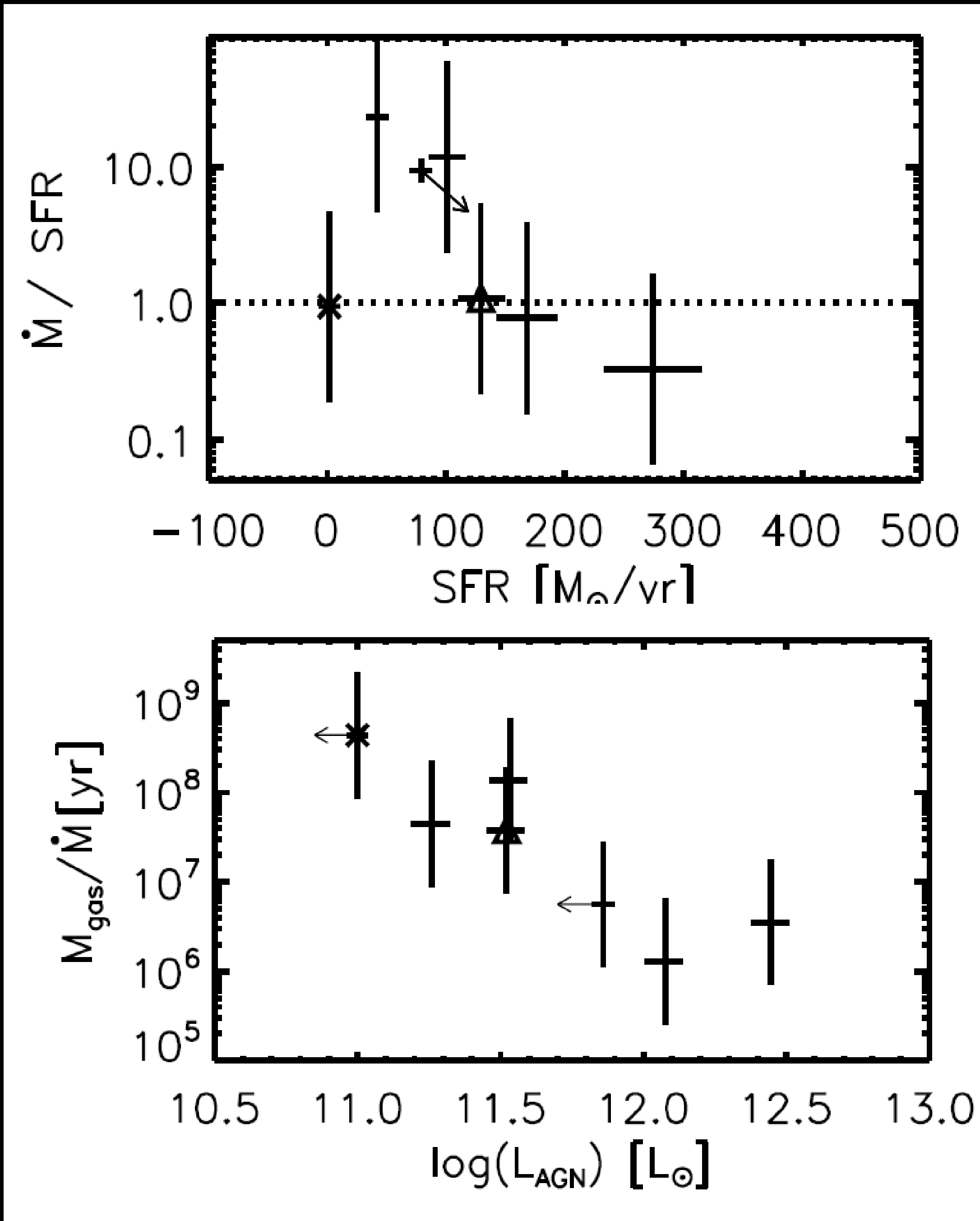
P-Cygni profile with blue-shifted absorption and red-shifted emission

Fischer + 2010



Talk by M. Melendez
(Session 8a, Wednesday,14:20)

Veilleux+ 2013
Gonzalez Alfonso+ 2012, 2013 in press
Spoon+ 2013



- Mass loss rates up to ~ 1000 M⊙/yr ~ 5 – 10 x SFR
- These ULIRG winds will totally expel the cold gas reservoir in the nuclei in about 10^6 - 10^8 yrs, therefore halting the star-formation activity on the same timescale.

Sturm+ 2011

What drives these outflows?

Mrk 231 (Sturm+ 2011, González-Alfonso+ 2013 in press):

Mass outflow rate: $\dot{M} \sim 1000\ M_\odot\ yr^{-1}$

Mass loading factor: $\dot{M}/SFR \sim 10$

Momentum flux: $\dot{M}v \sim 13\ L_{AGN}/c$ (with $L_{AGN} = 2.8 \times 10^{12}\ L_\odot$)

Mechanical luminosity: $0.5\ \dot{M}v^2 = 6 \times 10^{10}\ L_\odot$ (2% of L_{AGN})

Depletion time: $M_{gas}/\dot{M}$: ~10Myr

E.g. DeBuhr, Quataert & Ma 2012:

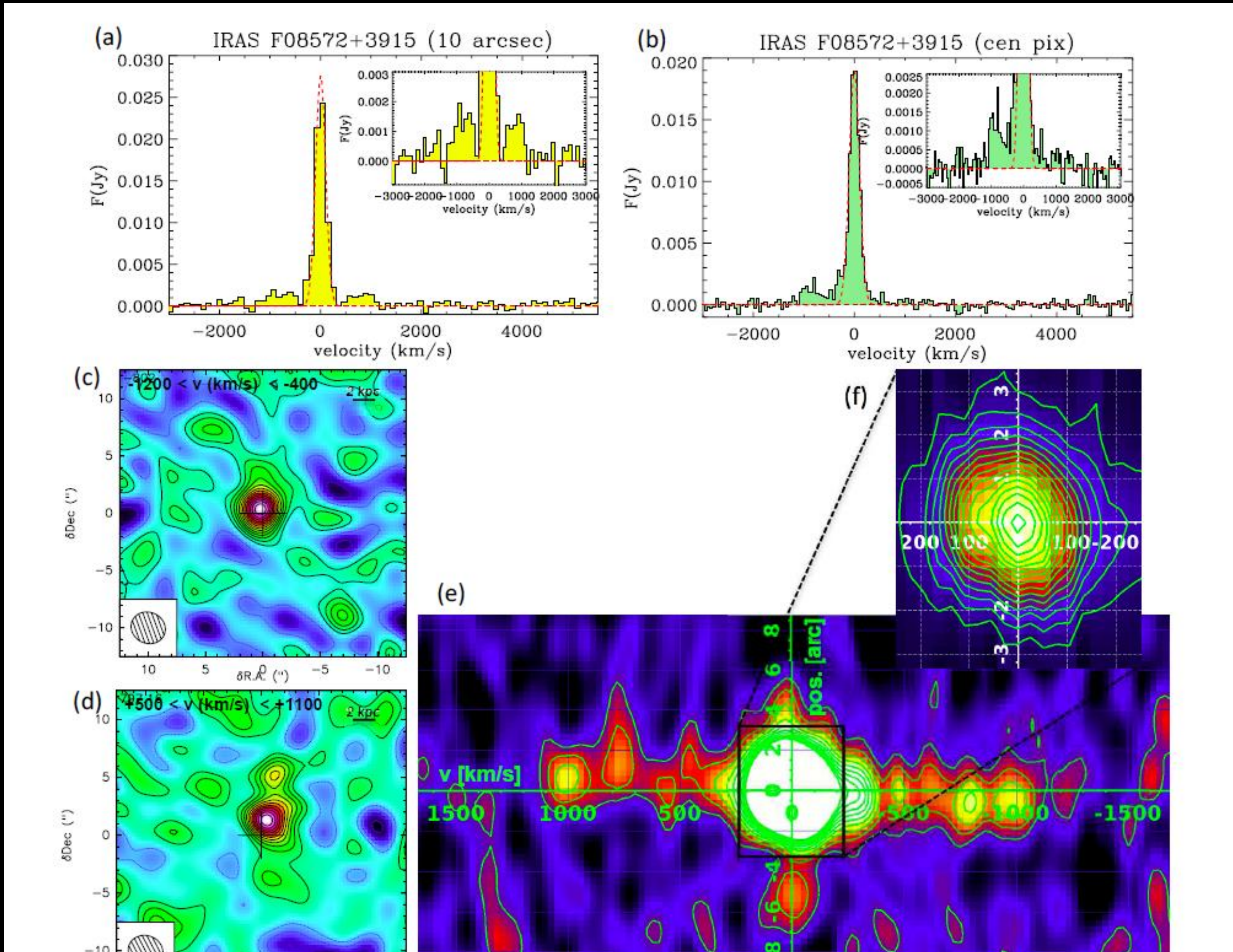
3D SPH simulations of the AGN Wind feedback plus radiation pressure feedback

Momentum flux: $\dot{p} \sim \tau\ L/c$,

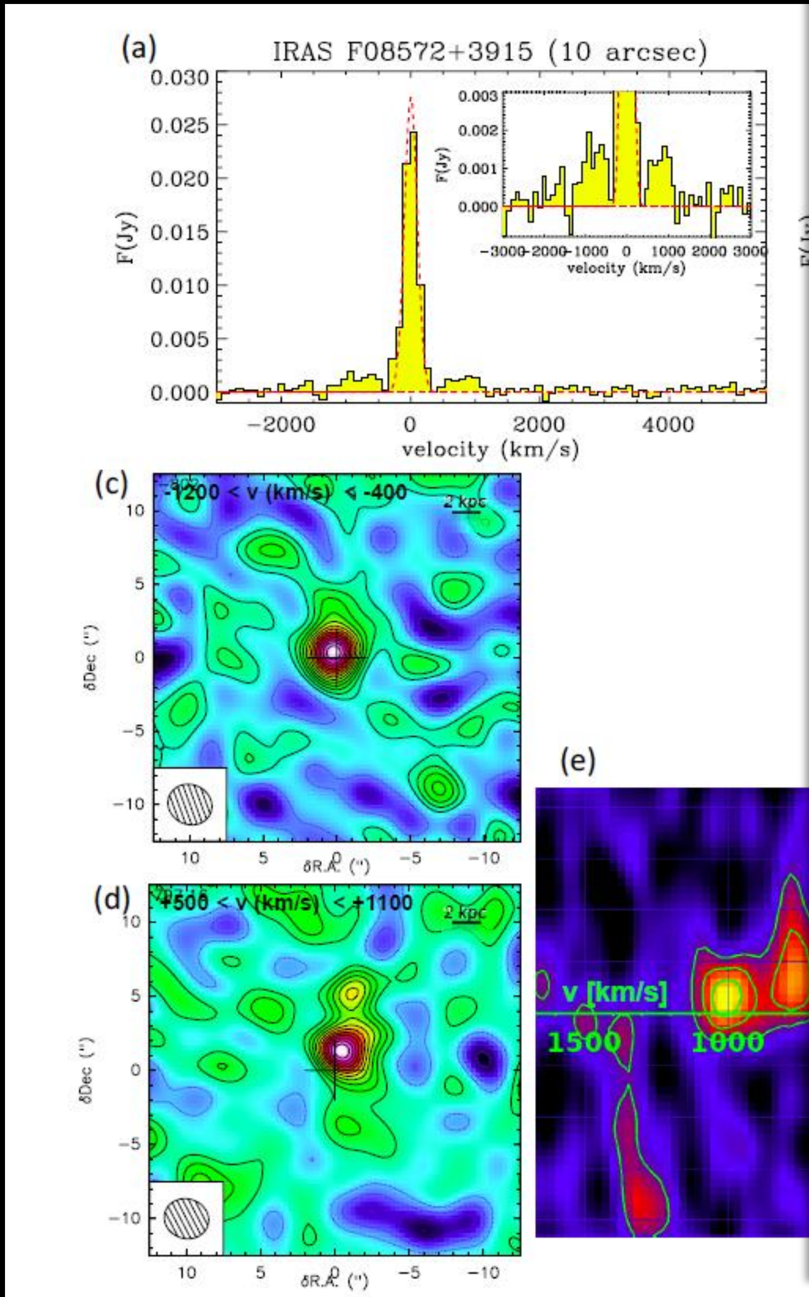
with τ~5-10 needed to explain the M_{BH}- σ relation

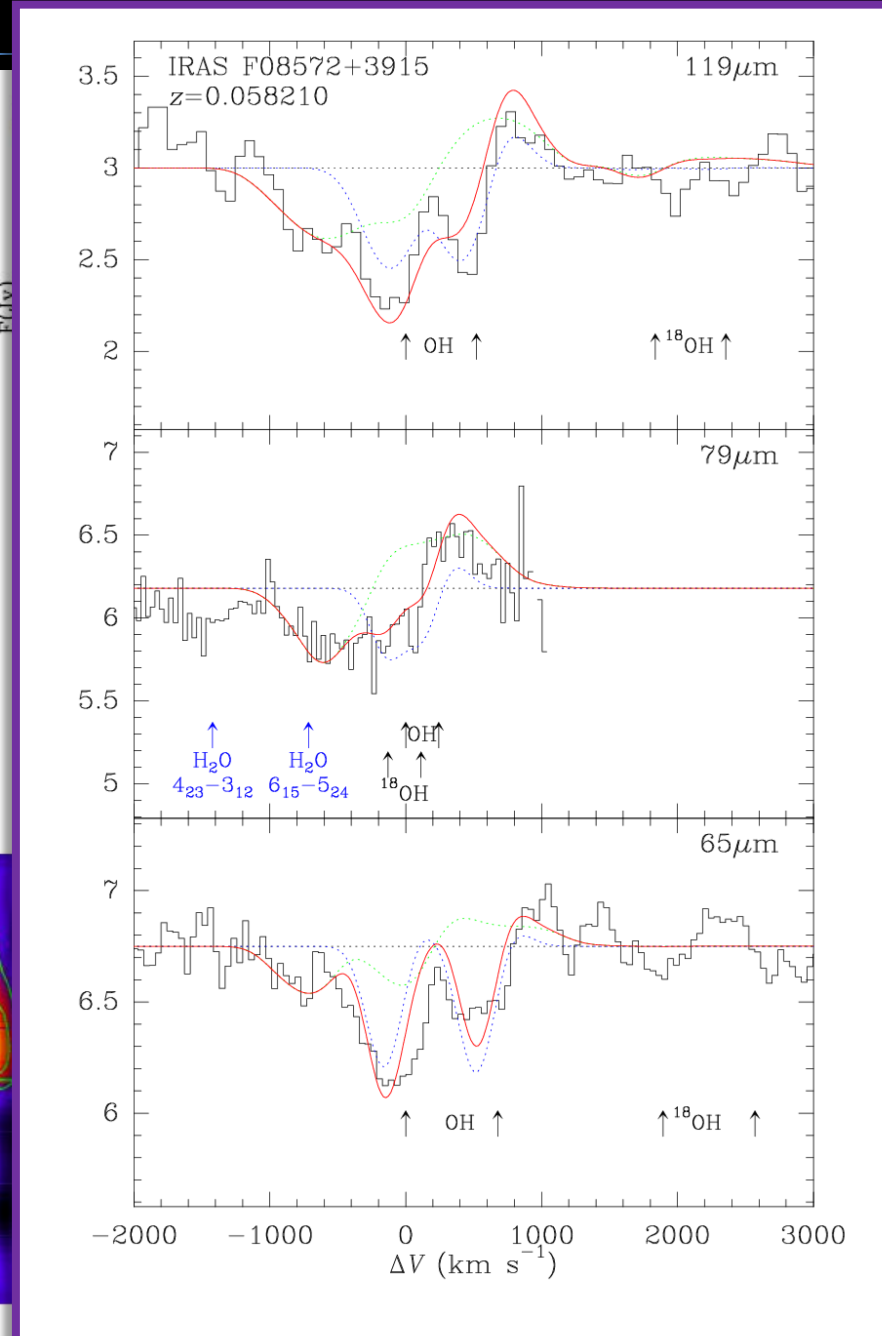
ram pressure: $\tau < 1$ → energy trapping

Depletion time ($M_{gas}/\dot{M}$) : ~10Myr



Cicone+ in prep


(a)
IRAS F08572+3915 (10 arcsec)
F(Jy)
velocity (km/s)
(c)
-1200 < v (km/s) < -400
2 kpc
δDec (")
δR.A. (")
(d)
+500 < v (km/s) < +1100
2 kpc
(e)
v [km/s]
1500
1000

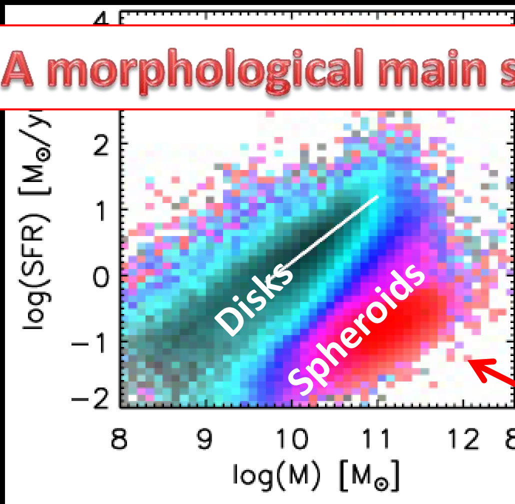

IRAS F08572+3915
z=0.058210
119μm
OH
18OH
79μm
H2O 4 23 −3 12
H2O 6 15 −5 24
OH
18OH
65μm
ΔV (km s−1)

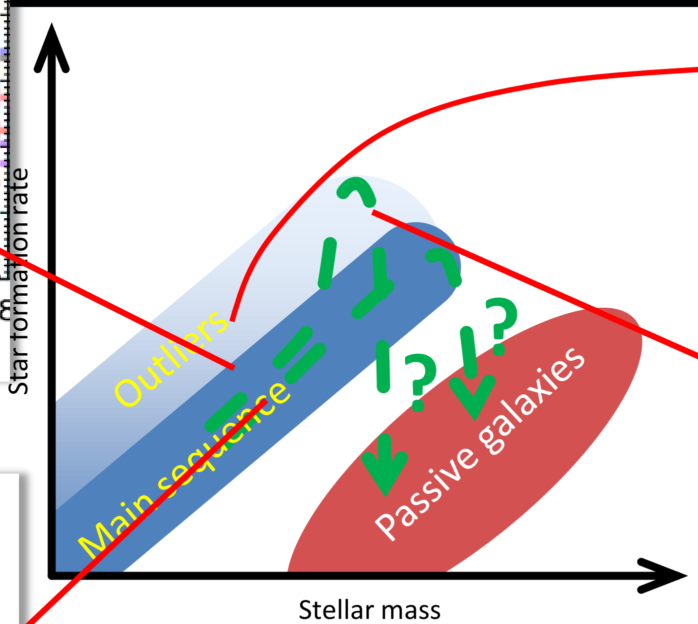
SUMMARY

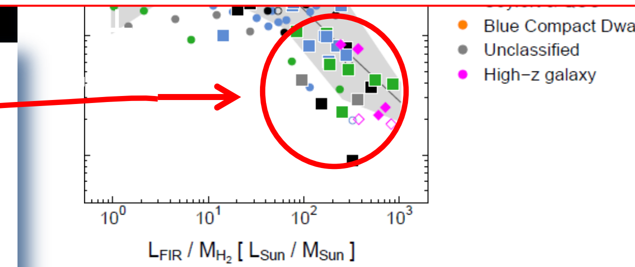
Different modes of star formation:

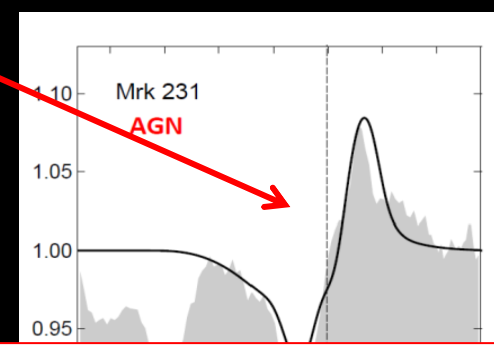
- merger-like, higher SFE vs.
- smooth accretion, normal SFE

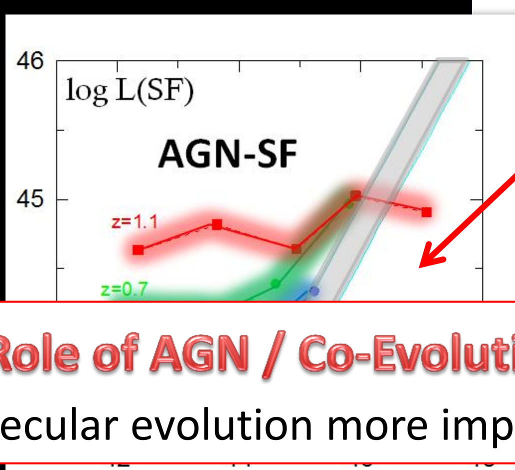
A morphological main sequence











Role of AGN / Co-Evolution:

Secular evolution more important at high z

Role of AGN / Feedback & Quenching:

"Caught-in-the-act" negative feedback from radiation driven, molecular outflows in AGN-dominated ULIRGs

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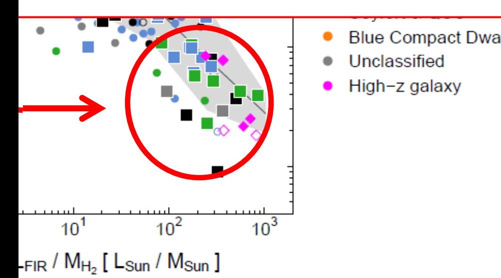
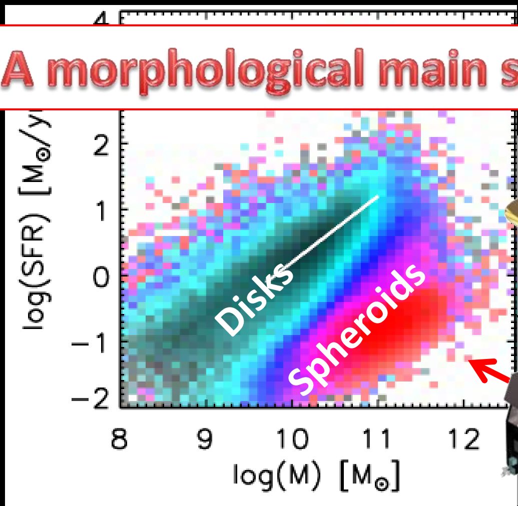
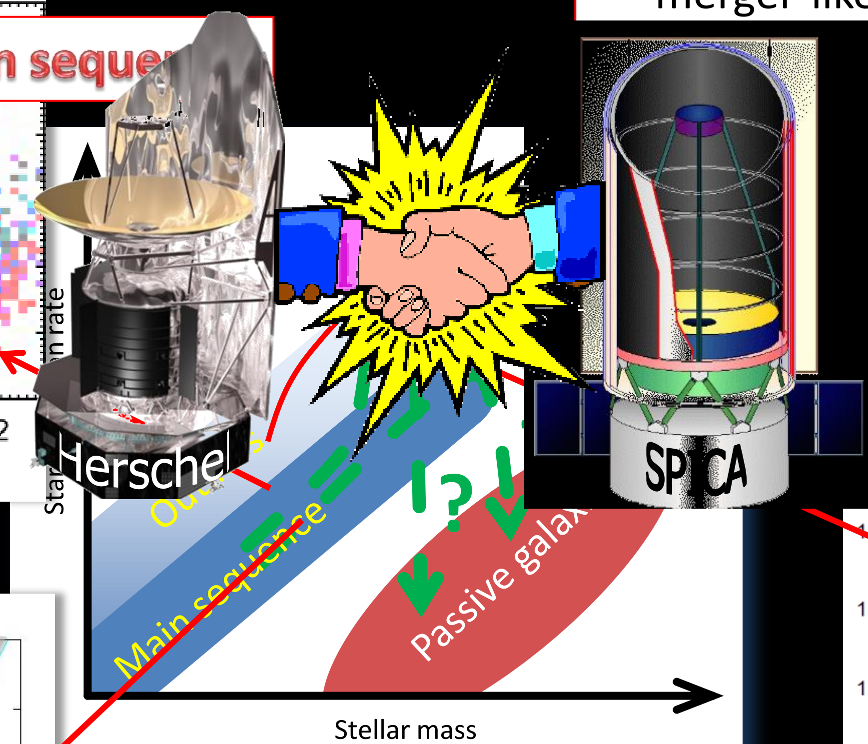
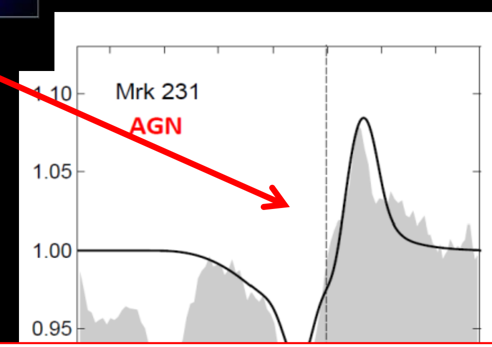
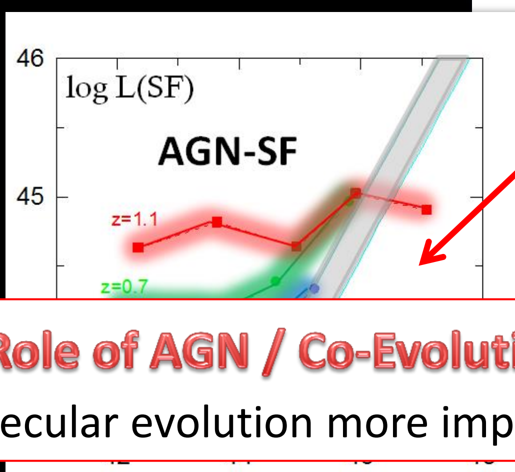


A morphological main seque[...]









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