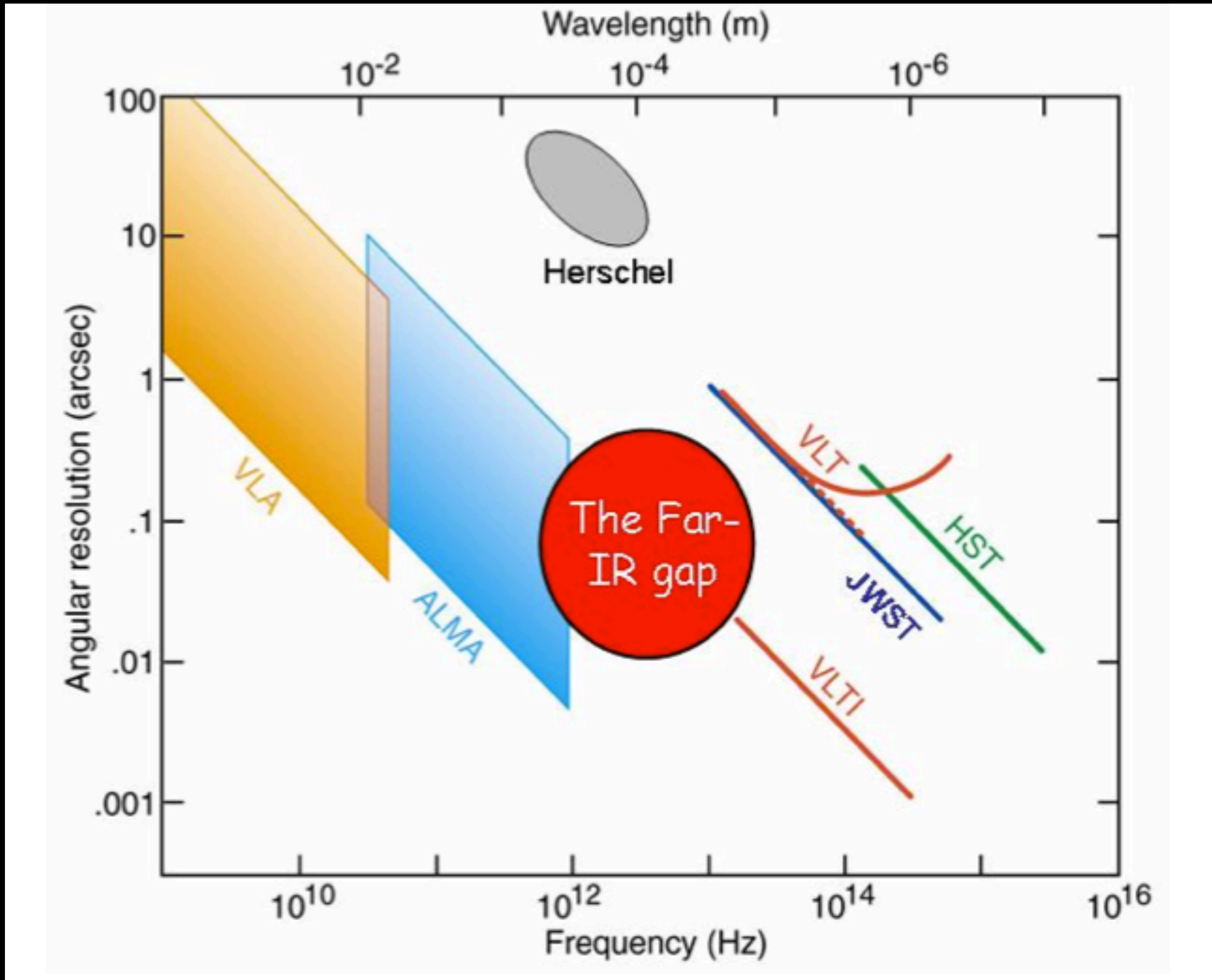
Studying Galaxy Evolution with FIRI

A Far-InfraRed Interferometer for ESA

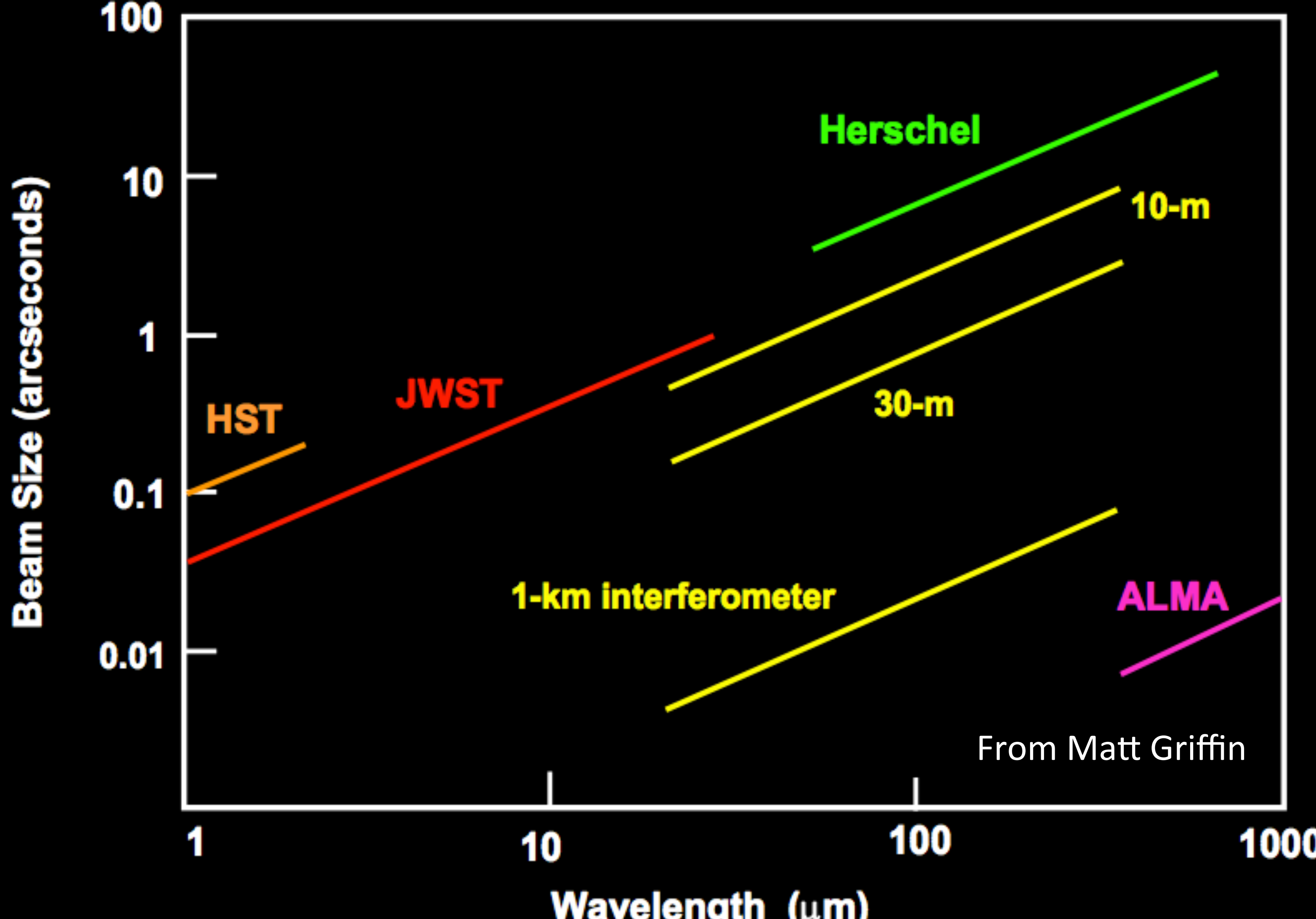
Dimitra Rigopoulou
Oxford/RAL-STFC

The FIR gap



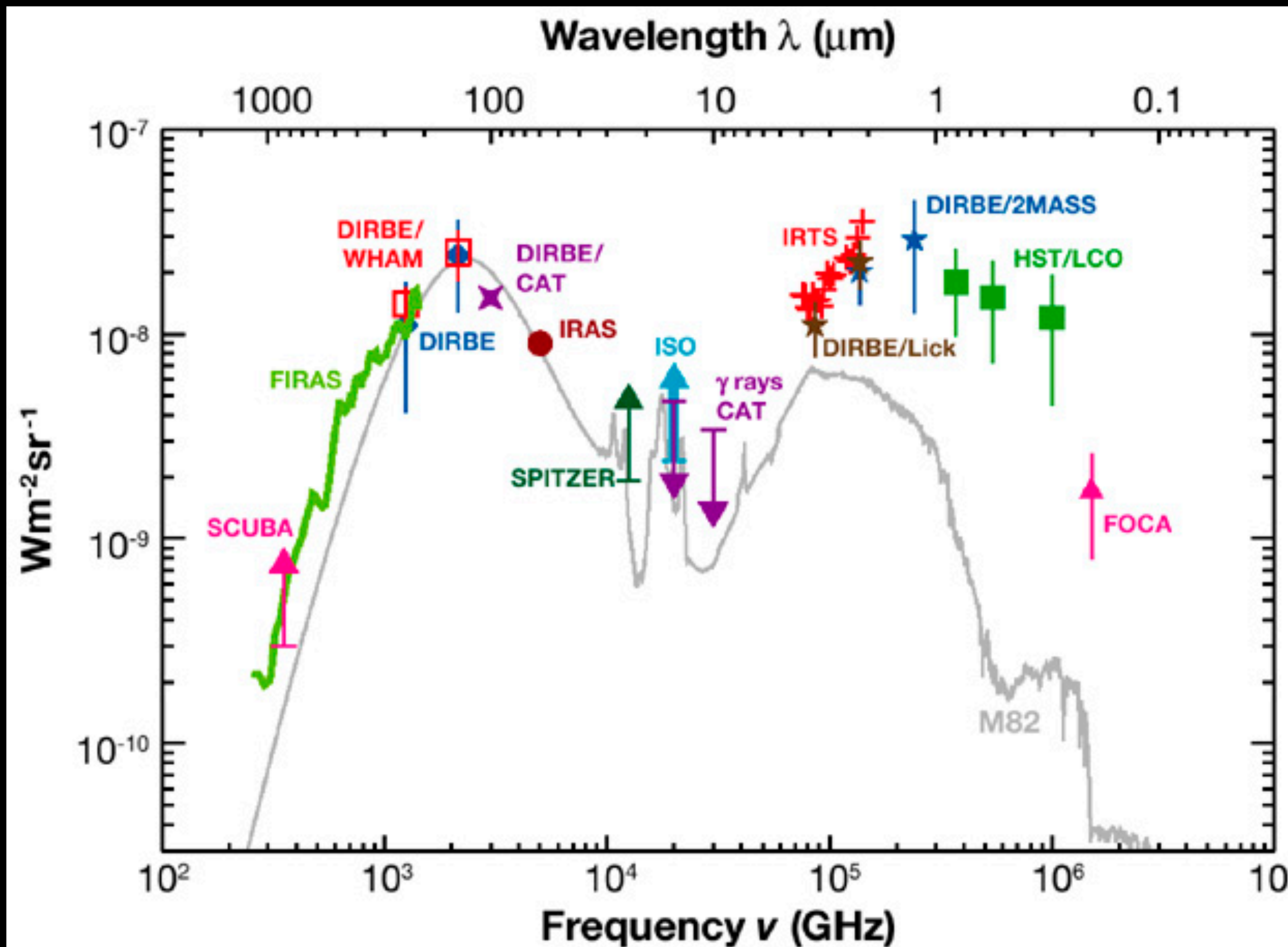
from Wild & Helmich SPIE 2008

Angular Resolution



)8

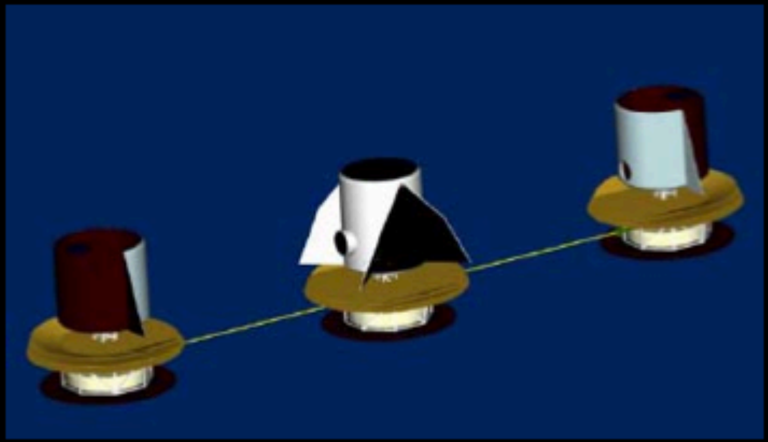
The cosmic background radiation: why the infrared is important

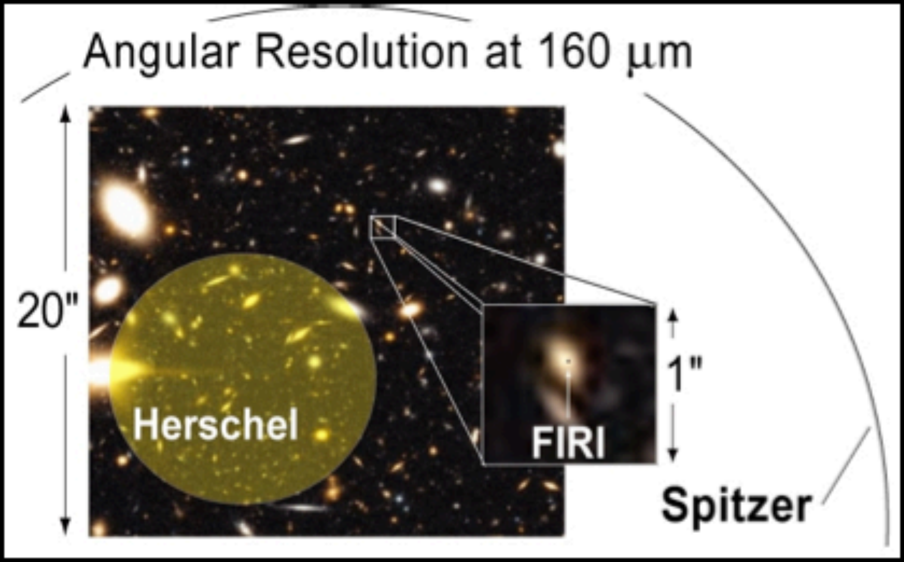


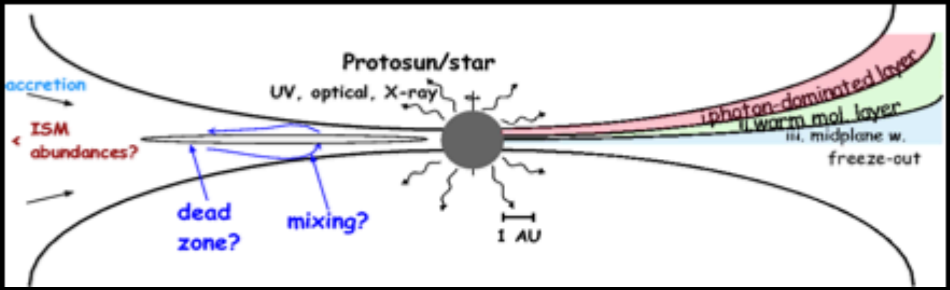
God lives at 100 μ m, Alan Sandage

SPECS/FIRI Concept

- Two or three cold 3 – 4 m apertures with central beam combiner
- Double-Fourier interferometer system to provide spectral imaging
- Separation up to 1 km
- λ = 25 – 400 μm
- 0.02" resolution at 100 μm for 1 km spacing (= 1 AU at 50 pc)
- $\lambda/\Delta\lambda$ = a few 1000
- Possible high resolution heterodyne capability





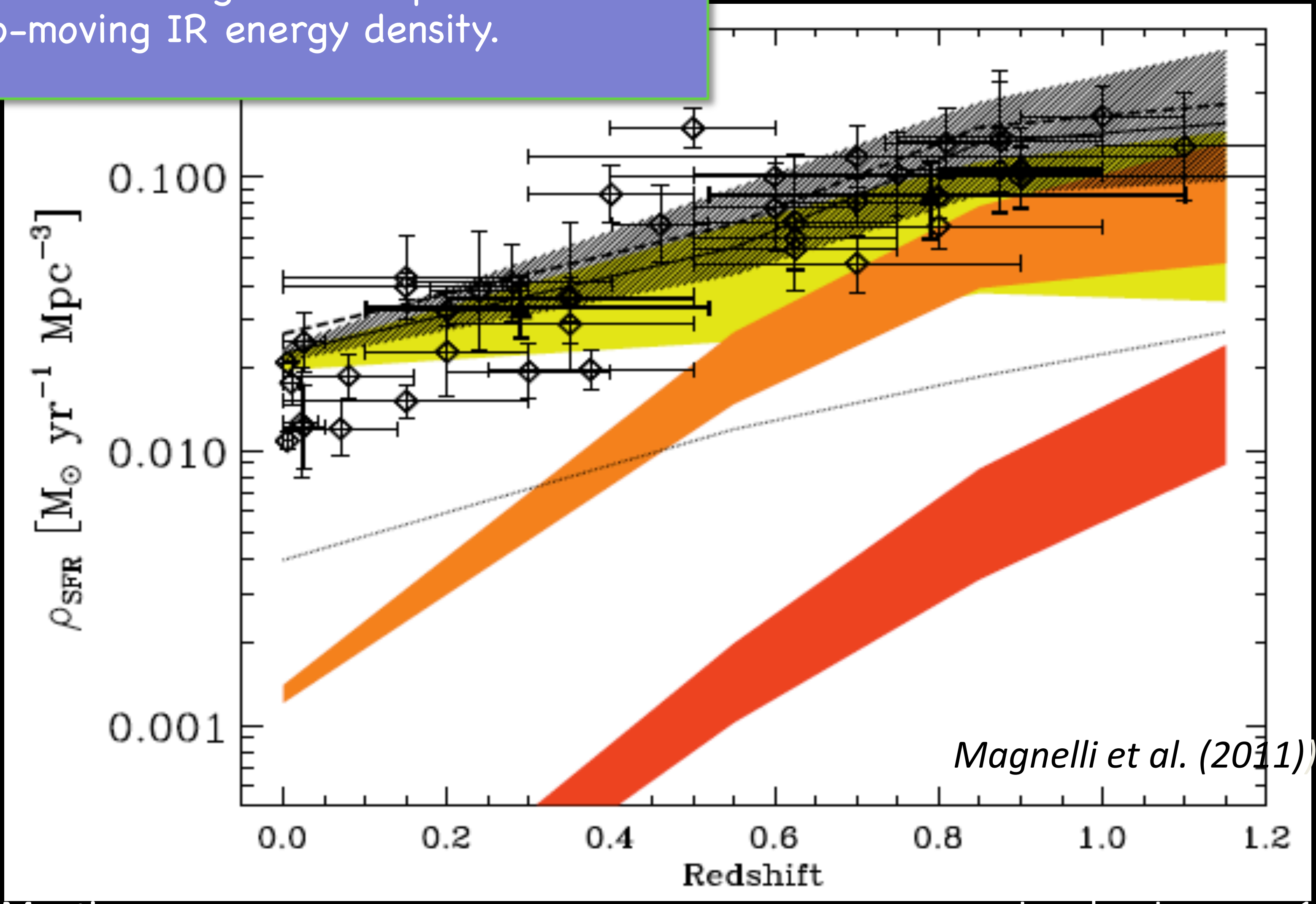


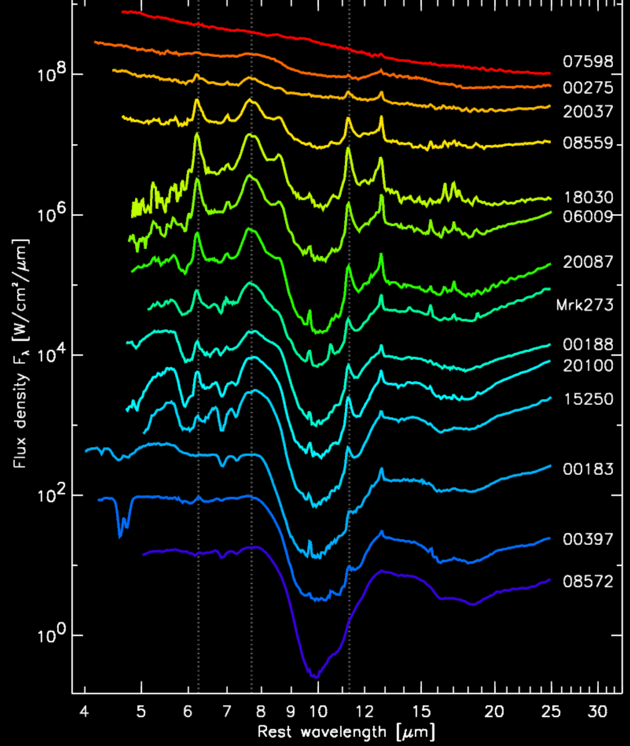
Luminous Infrared Galaxies

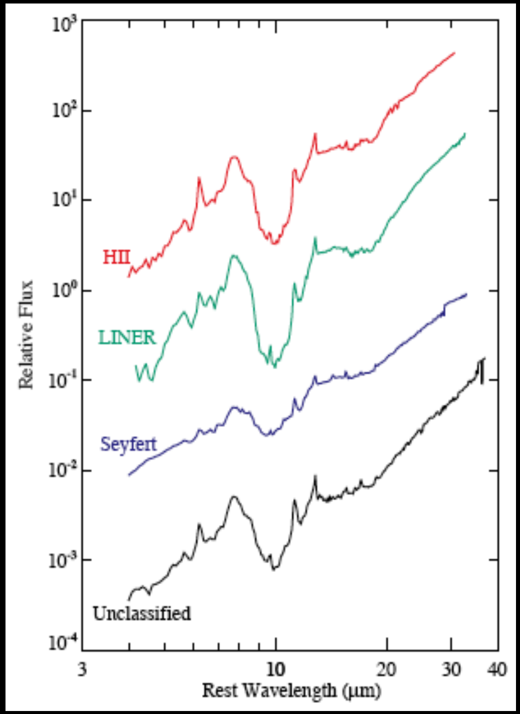
LIRGs ($10^{11} < L_{IR} < 10^{12} L_\odot$) and ULIRGs ($L_{IR} > 10^{12} L_\odot$)

Why do we care?

At z=1, IR-luminous galaxies represent ≥ 50% of the co-moving IR energy density.







- Large variation in MIR spectra driven by PAH, H_2O ice, hydrocarbon & silicate absorption
- 30-40% of the power of a typical ULIRG comes from an AGN. This rises with luminosity, dust temp, merger stage, etc.
- detection of SB signatures (PAH + cold dust) in QSOs strengthened evidence for rapid BH and bulge growth in dusty, merging galaxies.

Spoon +(2007), Armus +(2006,2007), Desai +(2007), Hao +(2007), Imanishi +(2007), Schweitzer +(2008), Lutz +(2008), Veilleux +(2009)

What FIRI can do for LIRGs/ULIRGs:

- Probe SFR through:

Spatially resolved (Redshifted) PAHs: 6.2, 7.7, 11.2, 17 μm

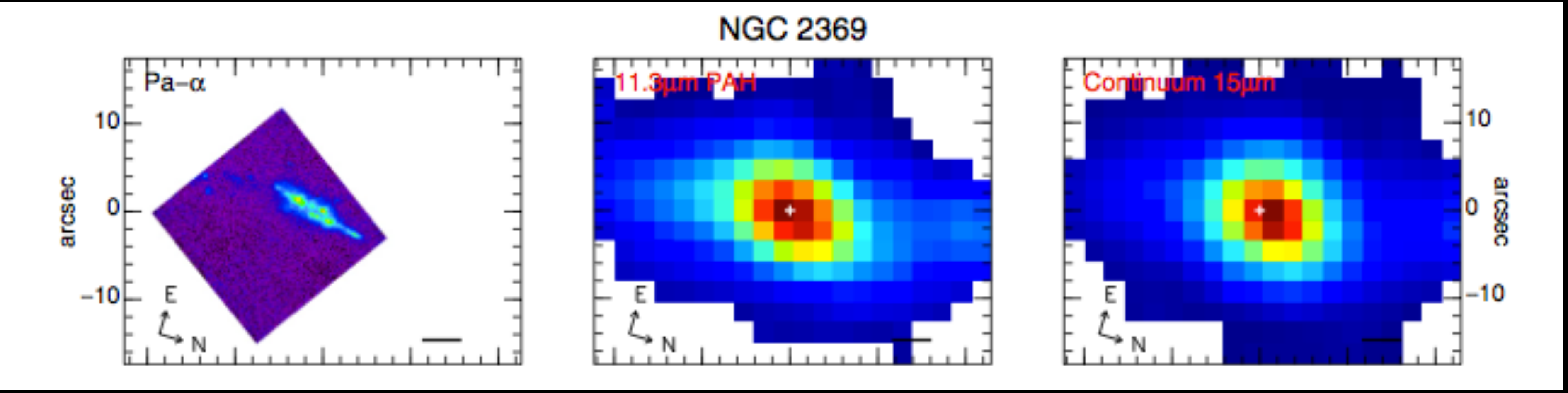
- Probe energy source and SB-AGN interplay through:

Spatially resolved (redshifted) MIR fine structure lines: [NeII], [NeIII], [NeV], [OIV] [SIII], [SiII], etc

- Probe cooling of the ISM through:

Spatially resolved FIR fine structure lines [CII], [NII],[OI],[OIII]

Spitzer-IRS PAH emission mapping in nearby LIRGs



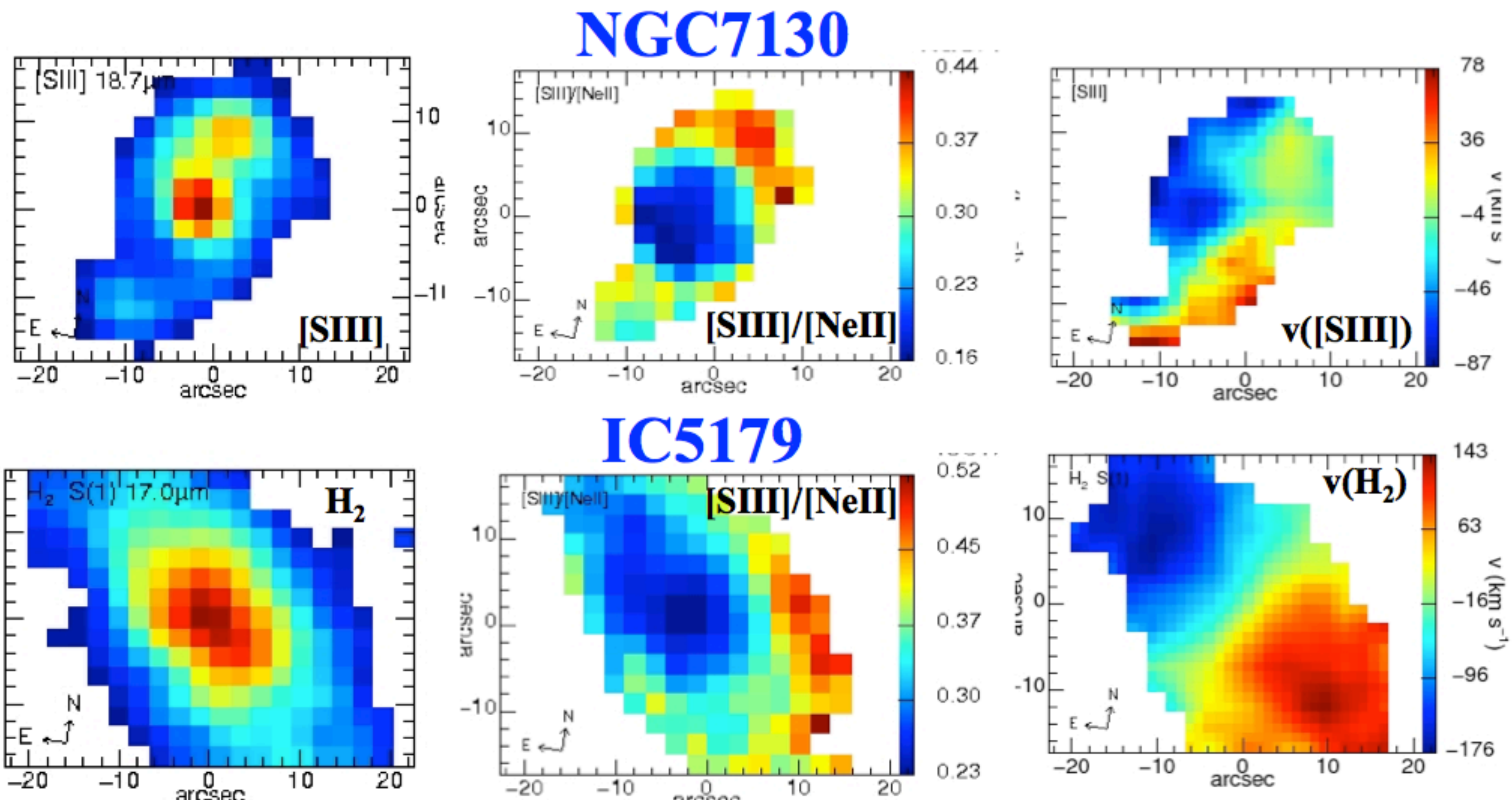
Pereira-Santaella '09

- Extended star formation regions (several kpc) as probed by the PAH emission, as well as the [NeII]12.81 μm and [NeIII] 15.56 μm emissions.

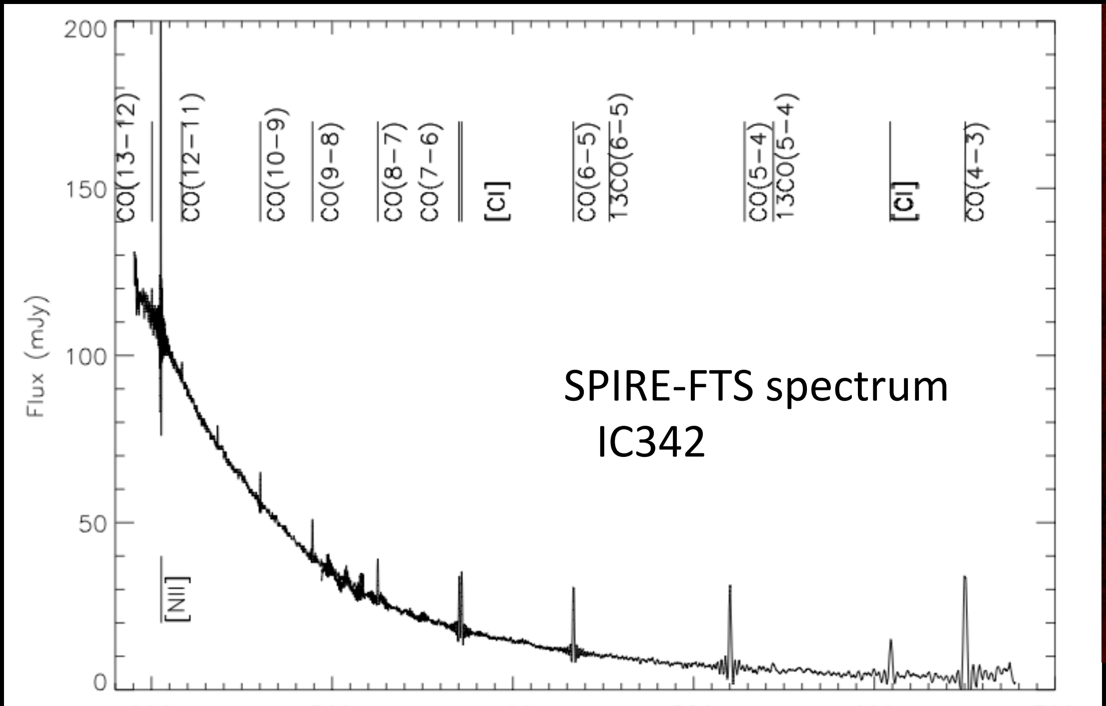
- The behavior of the integrated PAH emission and 9.7 μm silicate feature is similar to that of local starburst galaxies.

Spitzer-IRS MIR Fine Structure Lines Mapping

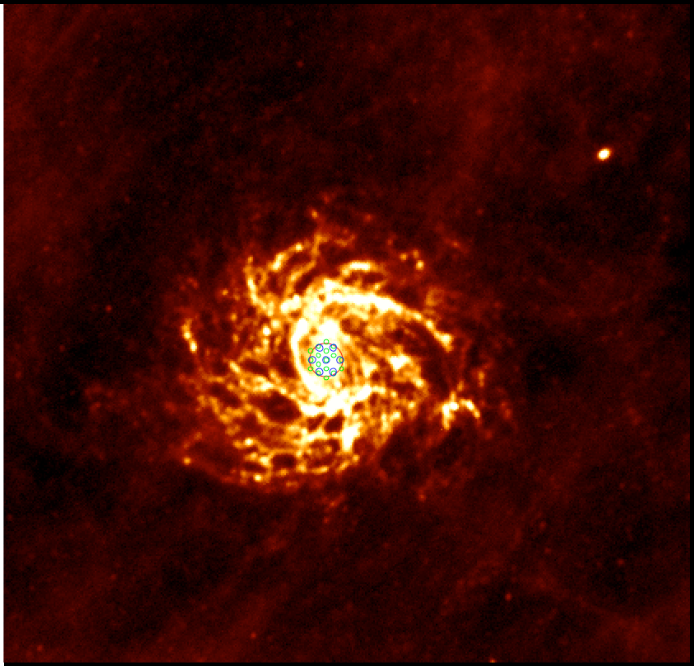
c.f. Spatial Resolution (FWHM) in SL ~ 4.5’,’, R~60-120, LL: R~300-500



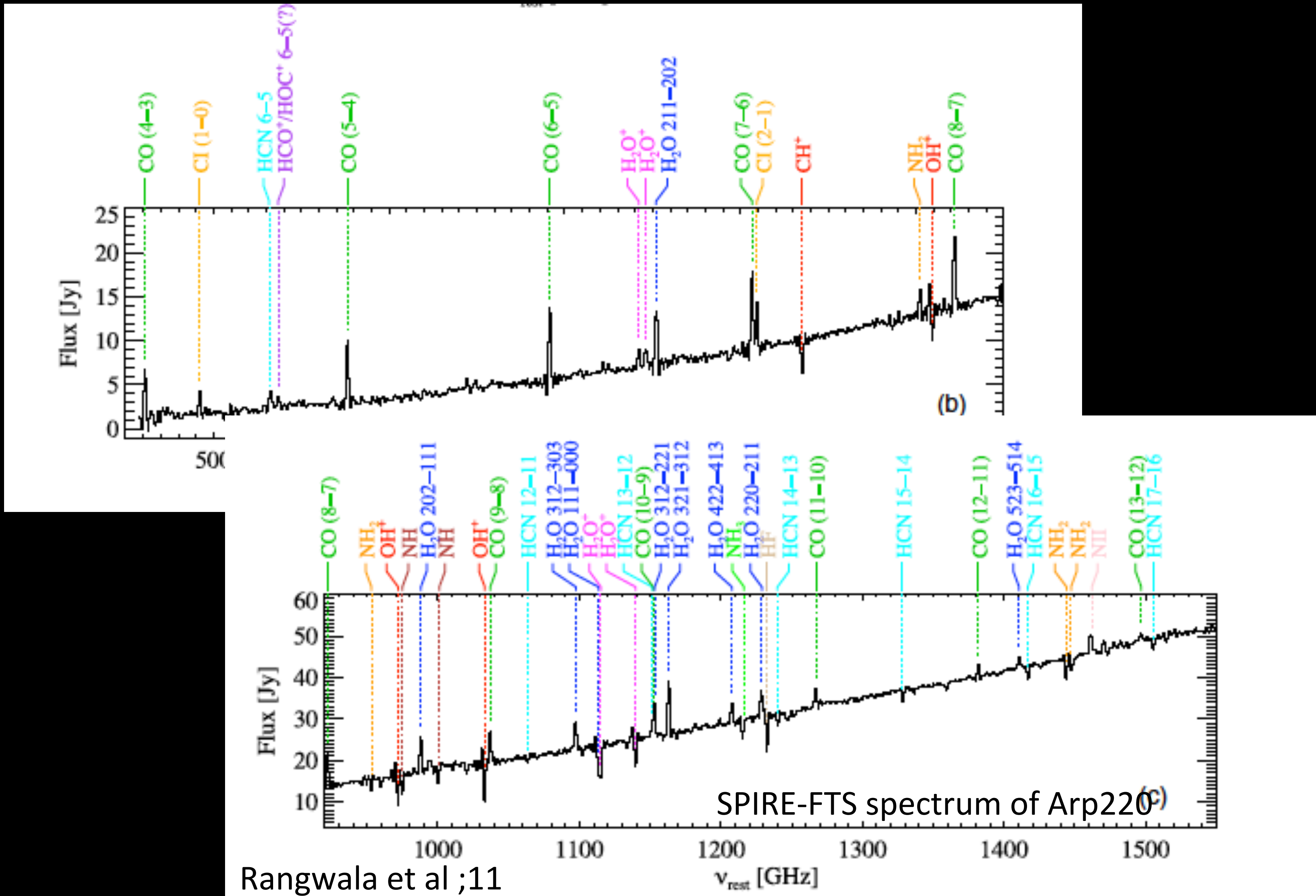
HERSCHEL has unveiled the power of FIR spectroscopy



Rigopoulou ea '13



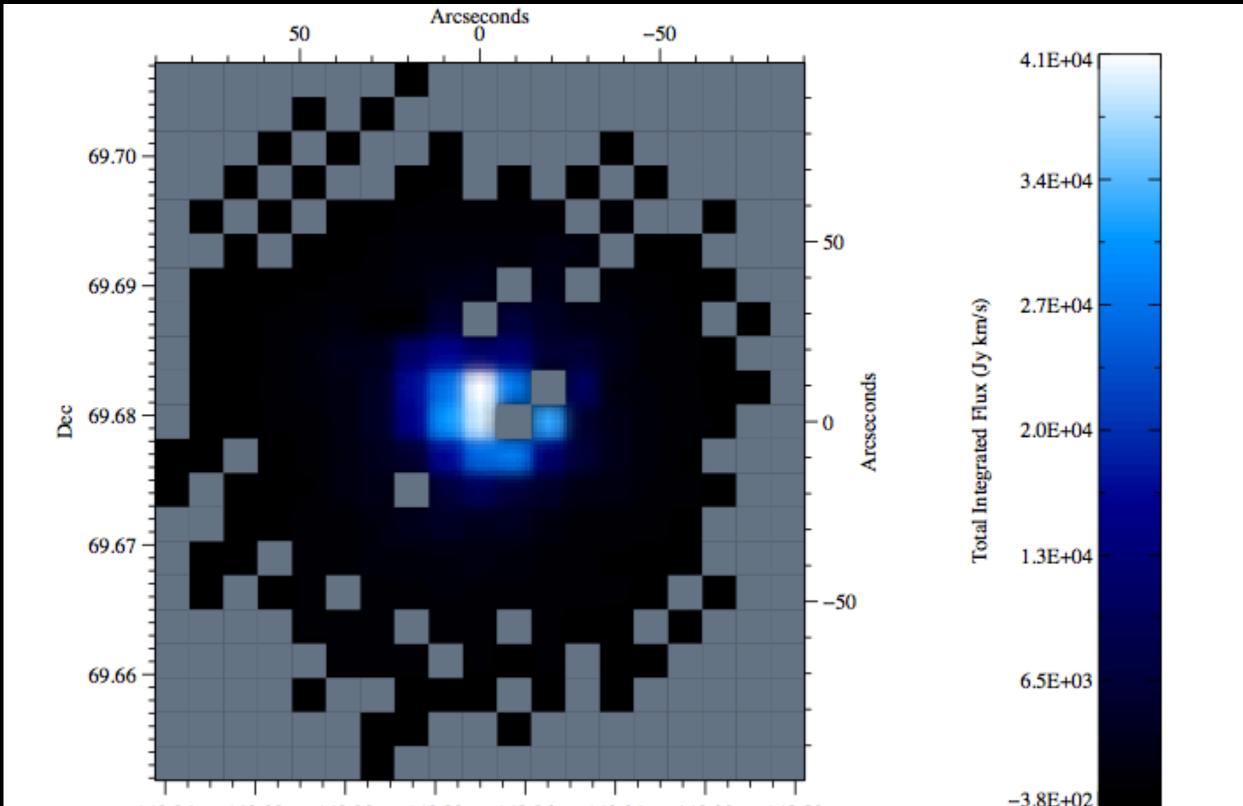
HERSCHEL has unveiled the power of FIR spectroscopy



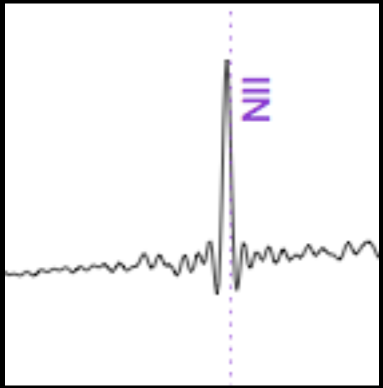
SPIRE-FTS spectrum of Arp220

Rangwala et al ;11

SPIRE-FTS Spectral Map of [NII] from M82

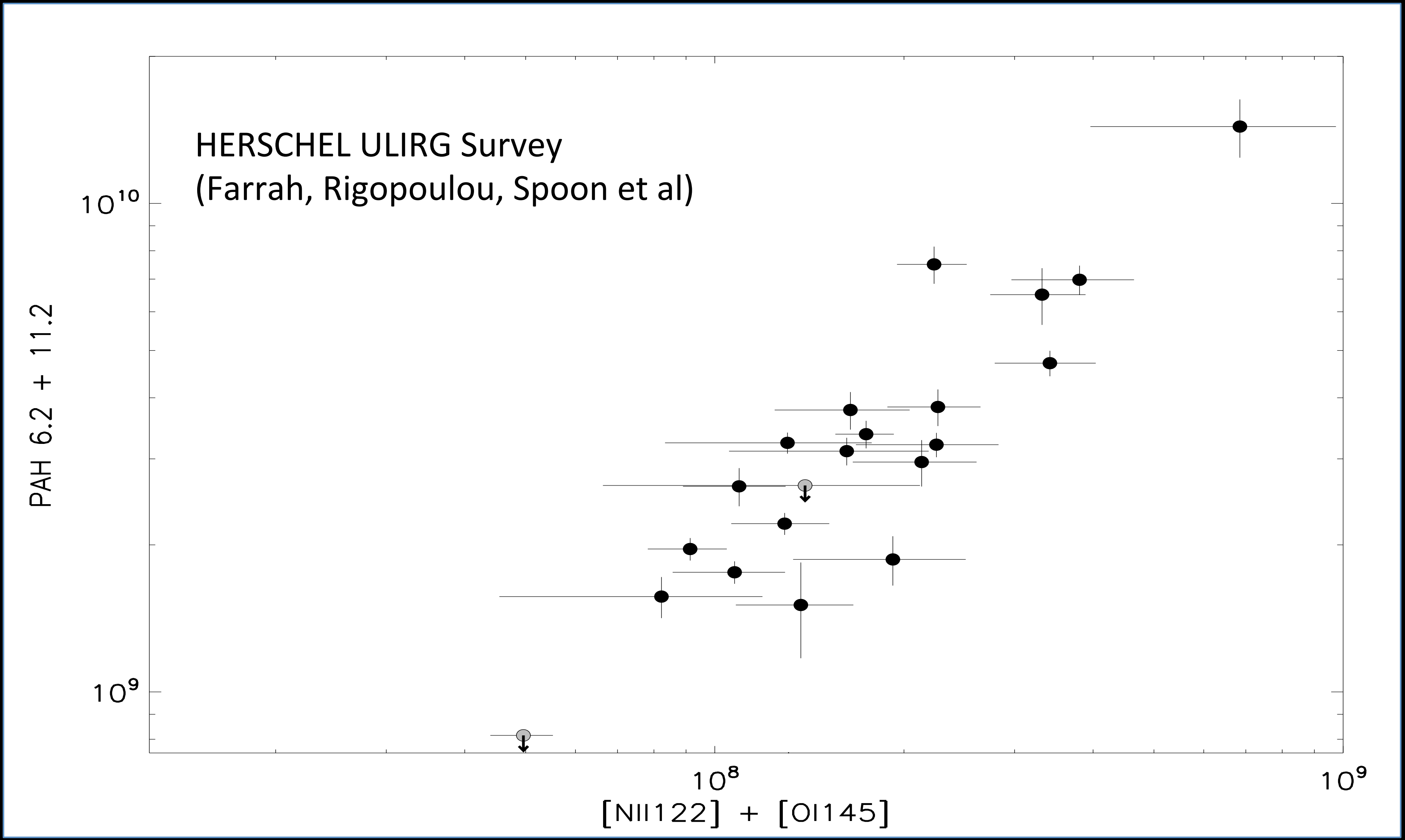


Kamenetsky ea 12



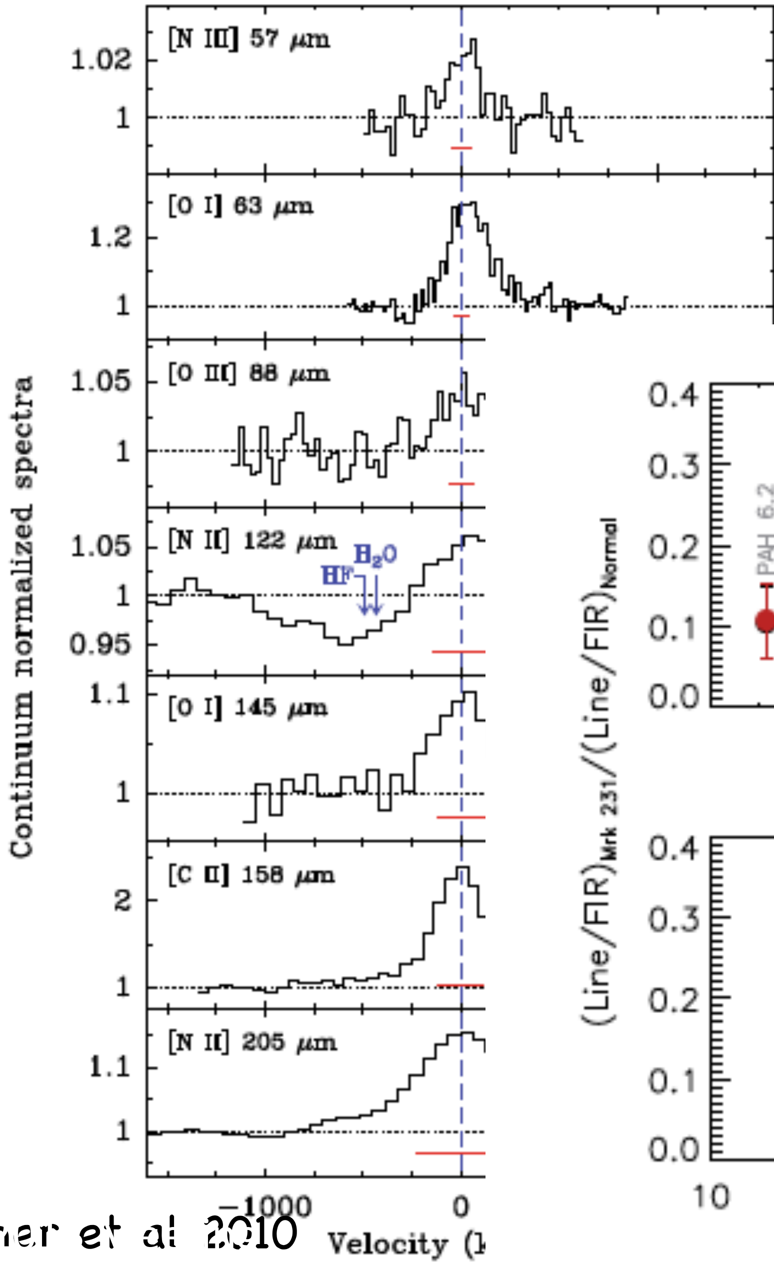
Combining FIR FS lines and CO ladder we can probe the atomic ionic and molecular ISM but urgently need resolution!

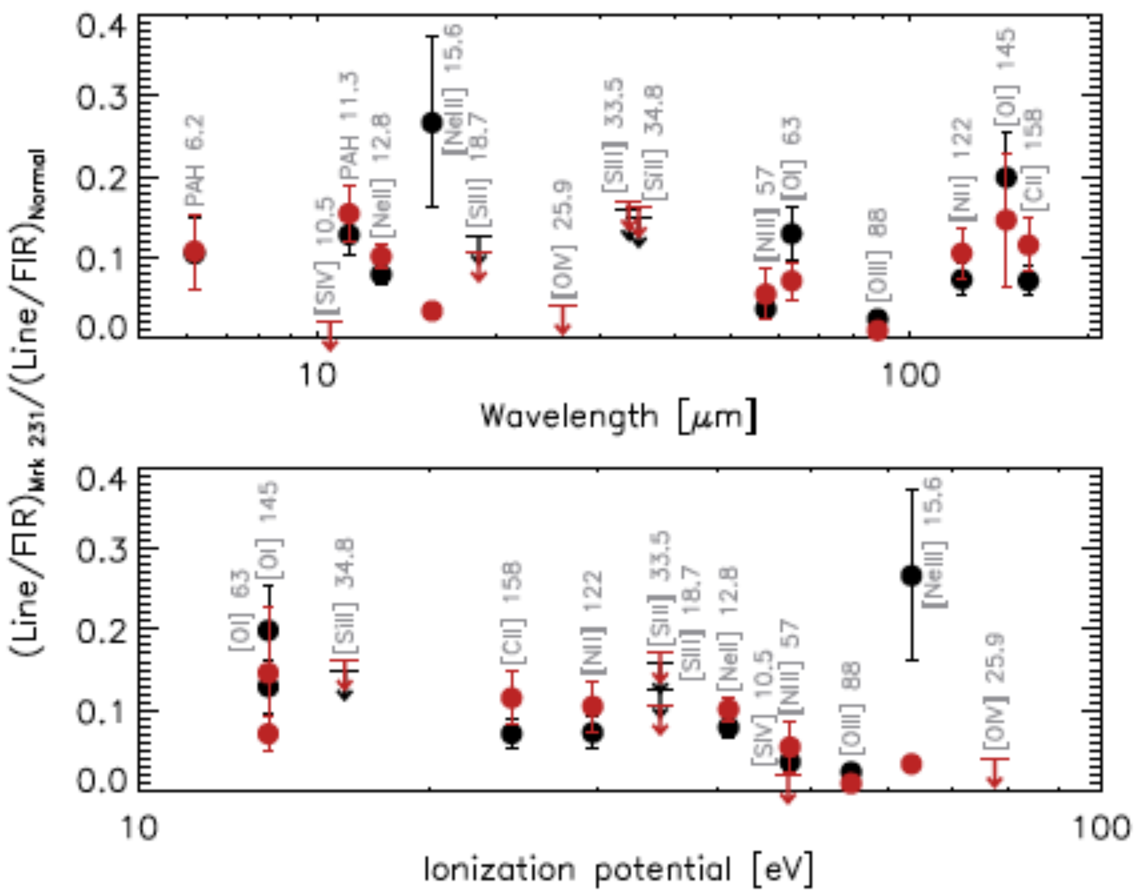
Combination of MIR-FIR lines o probe ionisation and energy sourc



PACS Spectroscopy of Mrk231

FIR-lines/L_{FIR} deficient wrt to lower luminosity galaxies esp the high ionization potential.
Aged starburst or partial covering of the highest excitation AGN-powered regions.





Fischer et al 2010

FIRI and the very high-z Universe:

H2 molecule: why do we care?

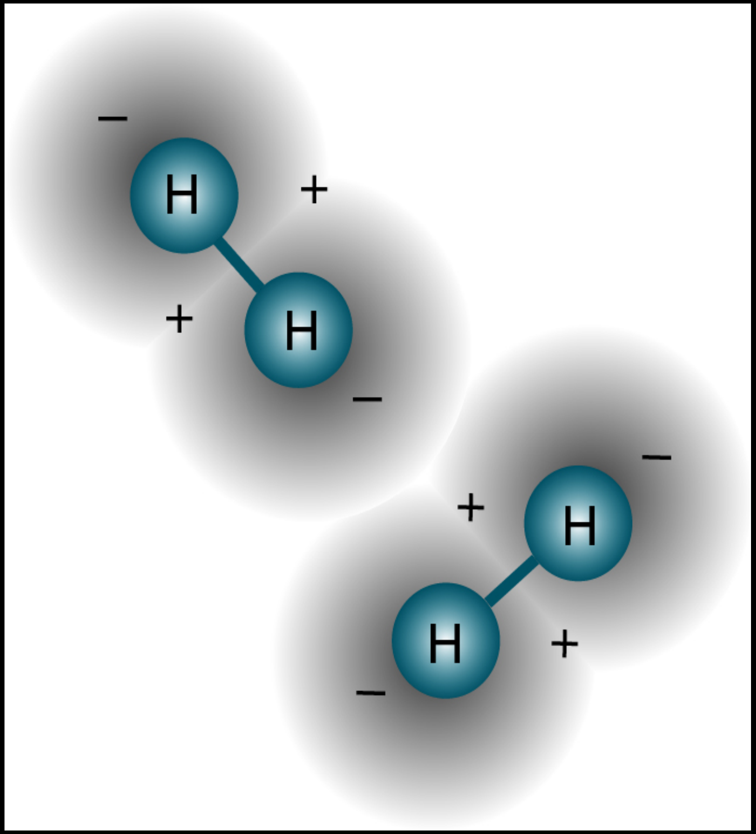
Probe pristine gas in protogalaxies through detection of the pure rotational H_2 lines 28 and 17 μm lines

- H_2 is the most abundant molecule in the Universe
- Its whereabouts:

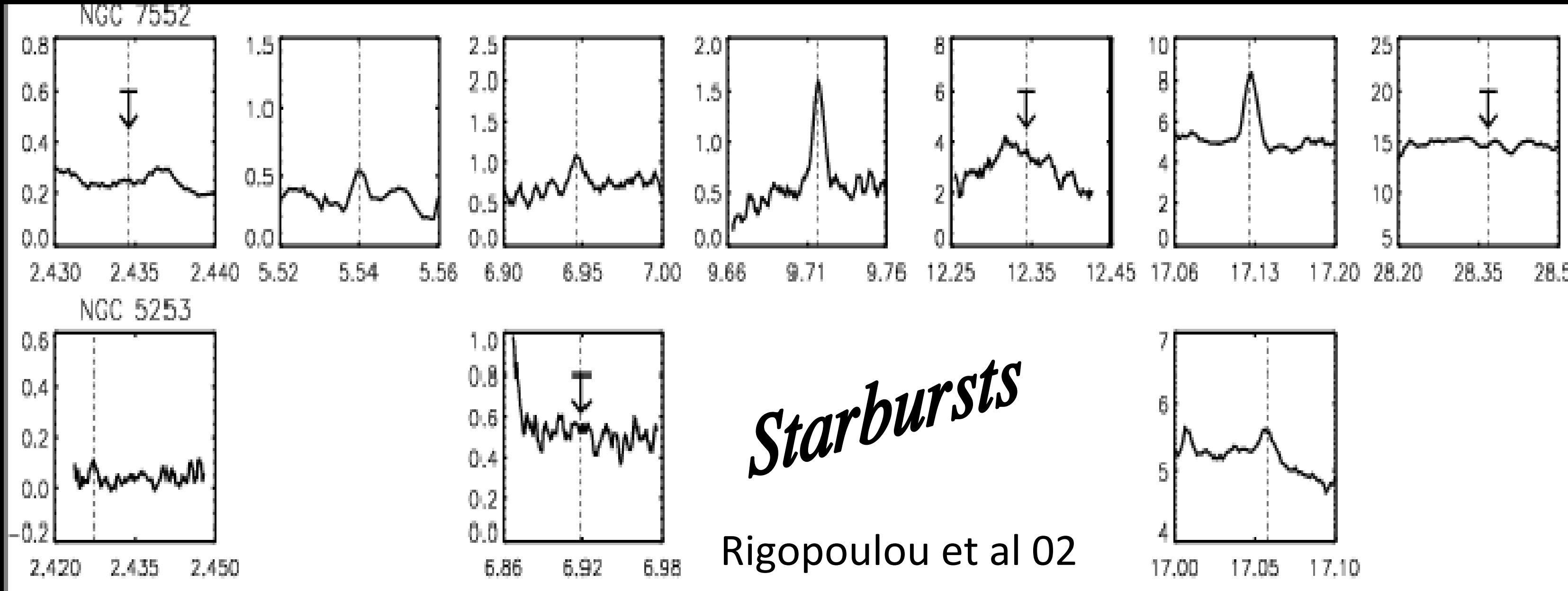
found in regions where shielding from UV photons (responsible for its dissociation) is sufficiently large Av >=0.5-1mag

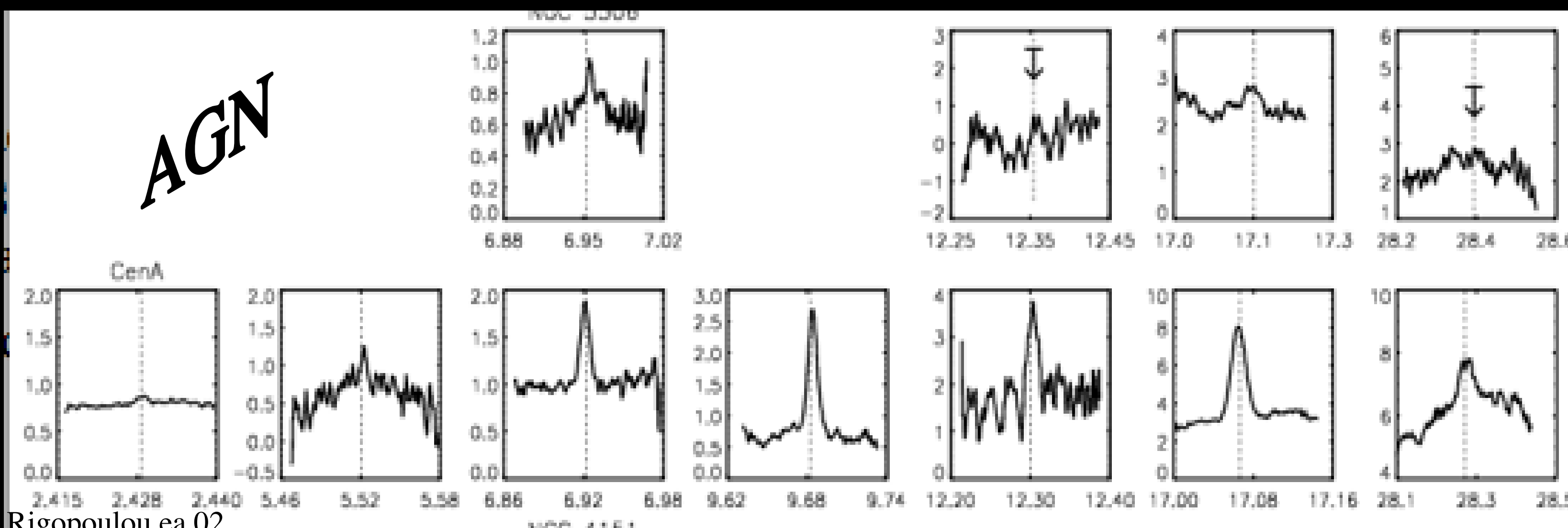
Key role:

- H_2 formation on grains initiates chemistry of ISM
- Major contributor to the cooling of astrophysical media

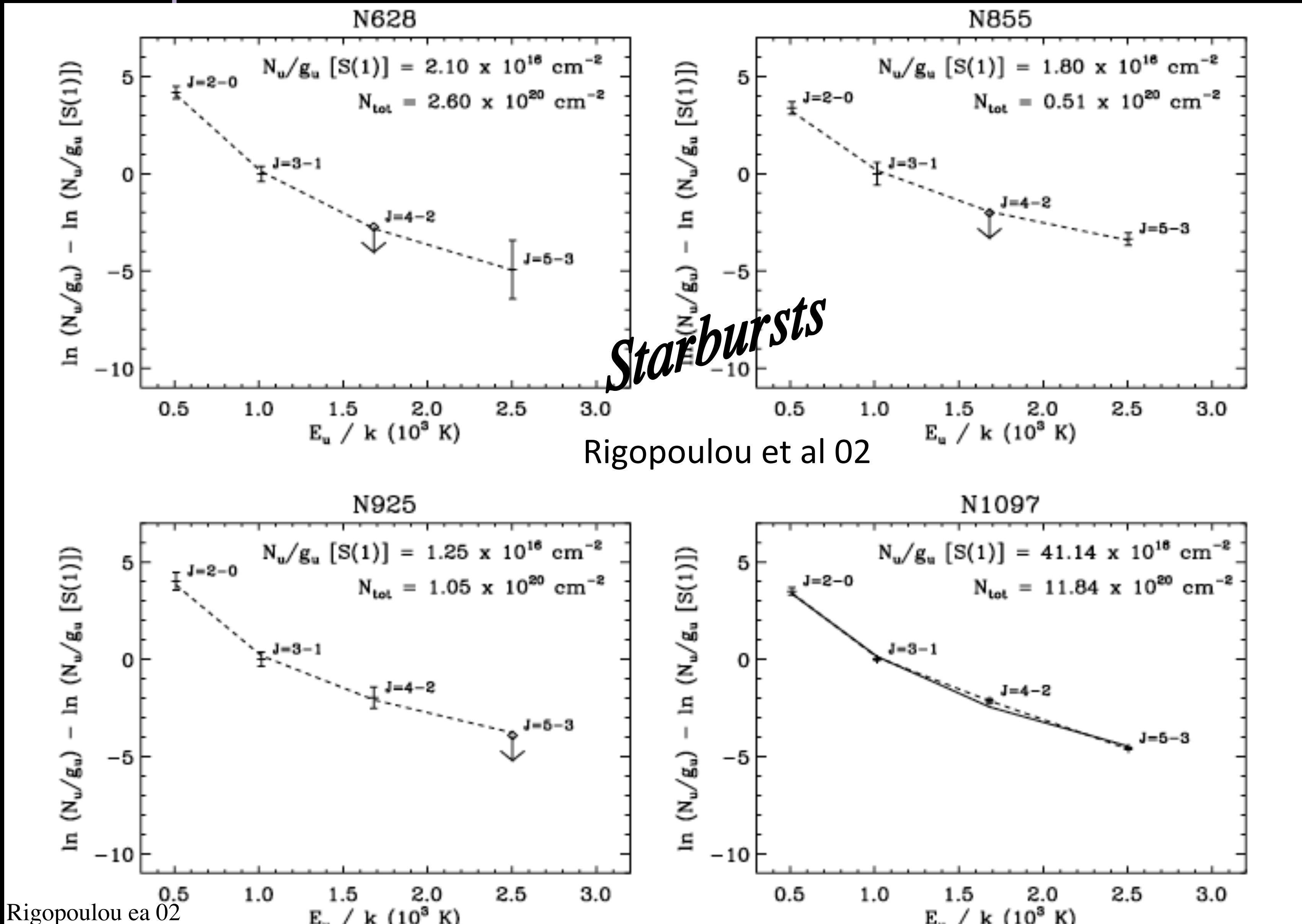


ISO & Spitzer observations of rotational H2 transitions





ISO & Spitzer observations of rotational H2 transitions



Rigopoulou et al 02

ISO & Spitzer observations of rotational H2 transitions

What does this mean for mass of molecular H2 ?

Star-forming galaxies : M H_2 5%-35% median 15% Tex~180 K

AGN/Liners : M H_2 1-40% median 10% Tex ~ 240 K

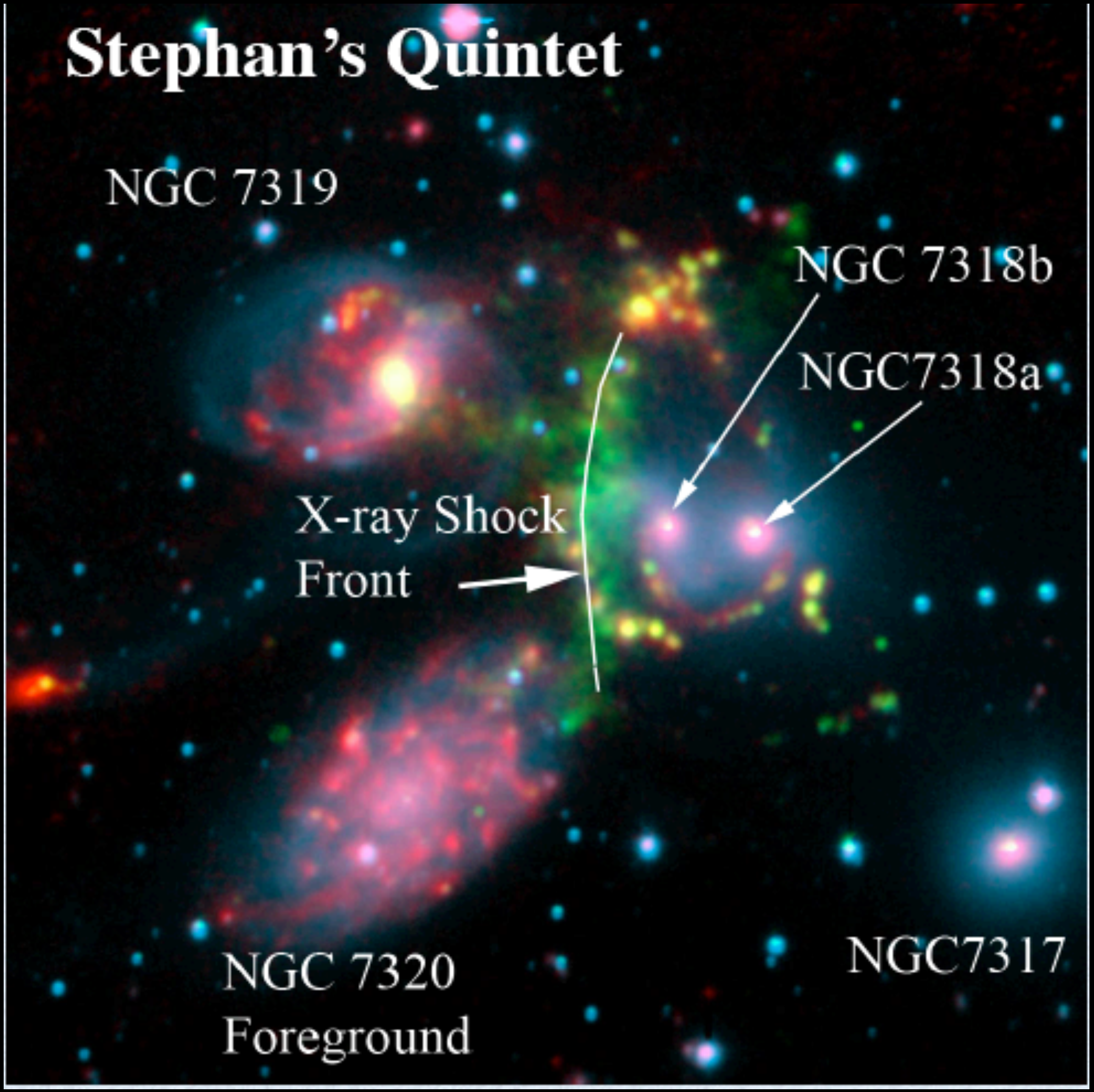
ULIRGs : M H_2 1-20% Tex~140 K (similar star-forming)

Also if scaled to [SiII] on average

$L(H_2)$ ~ 30% of L[SiII] or $L(H_2)$ ~ 10^{-4} of L_{IR}

R

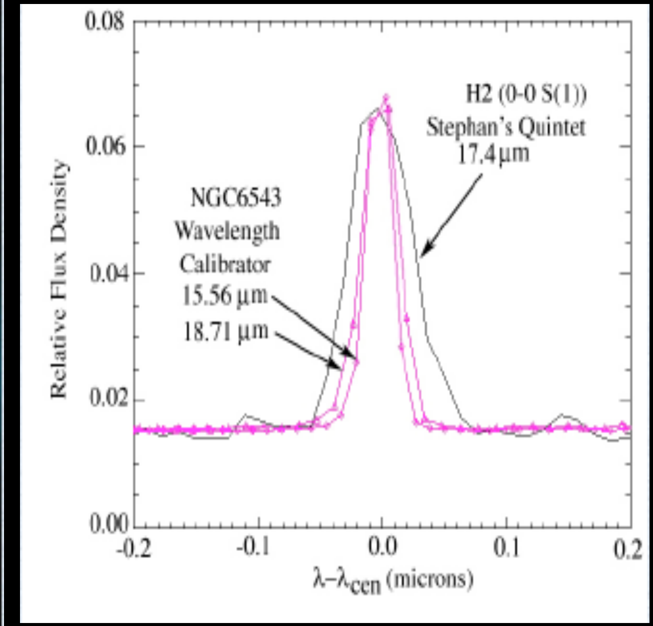
ISO & Spitzer observations of rotational H2 transitions



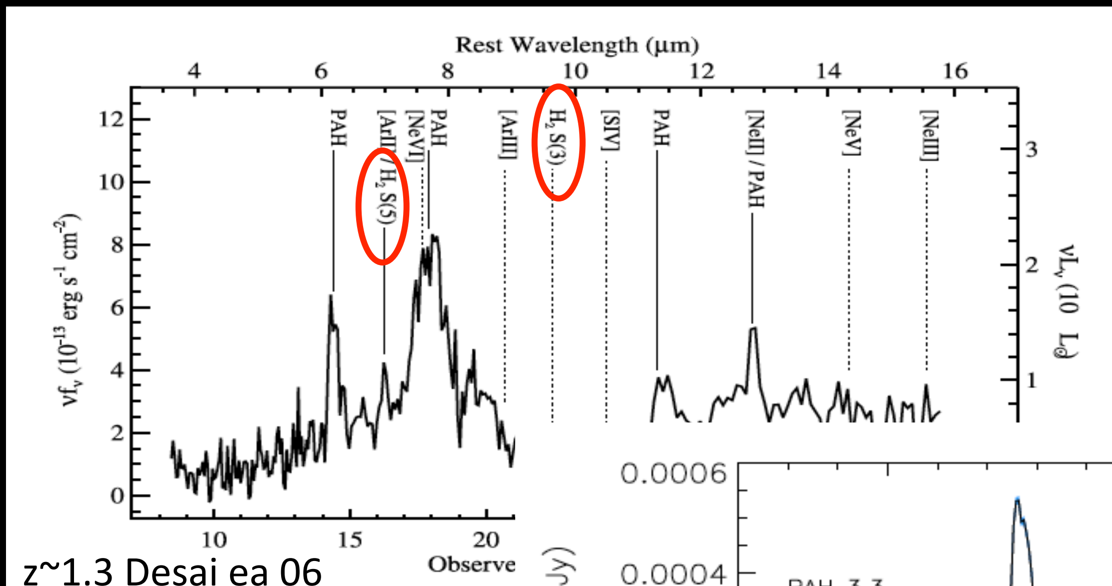
Galaxy-wide shock created by a 1000 km/s collision between a galaxy and a tidal tail

$L_{H2} > L_{x\text{-}ray}$

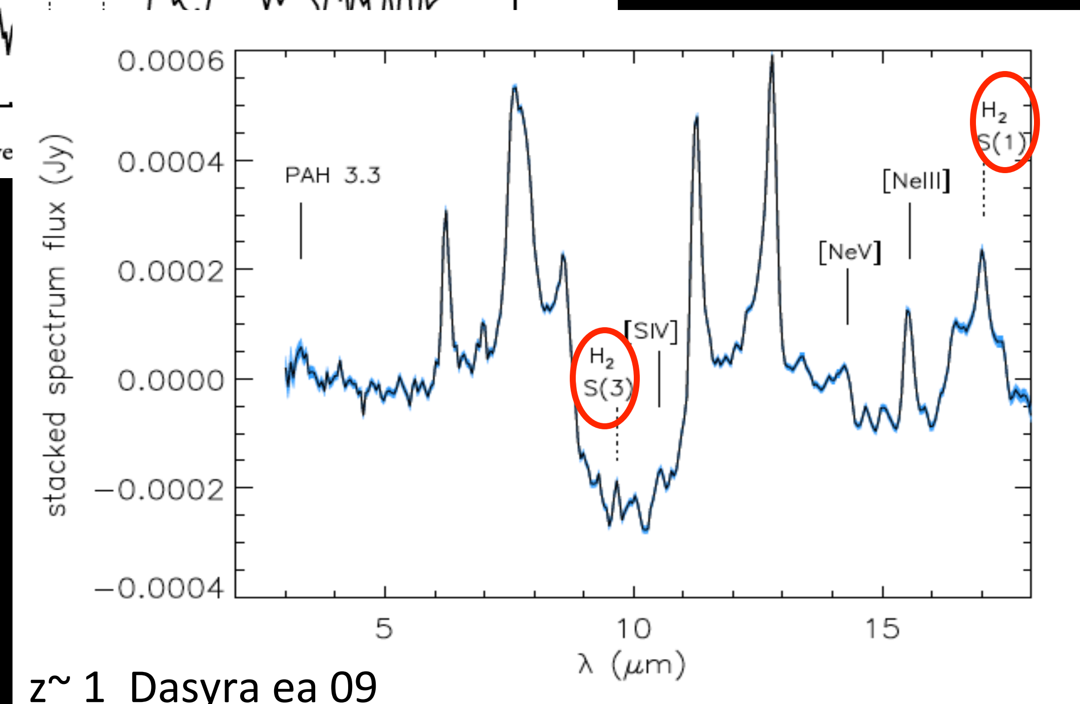
H2 line width ~1000 km/s
Appleton ea 06



What about H_2 in high-z galaxies?

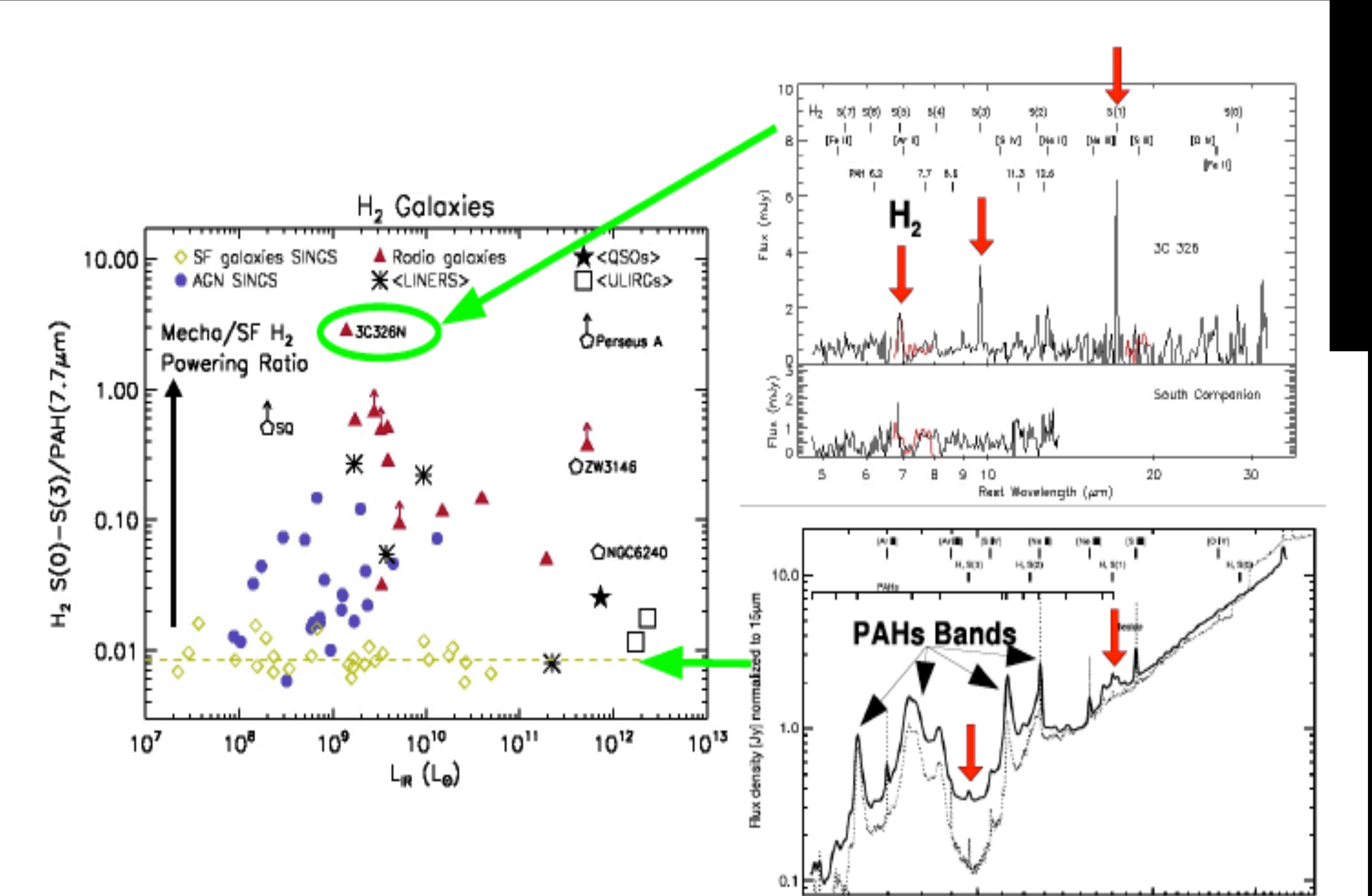


z~1.3 Desai ea 06



z~ 1 Dasyra ea 09

What about H_2 in high-z galaxies?



Guillard & Boulanger 08

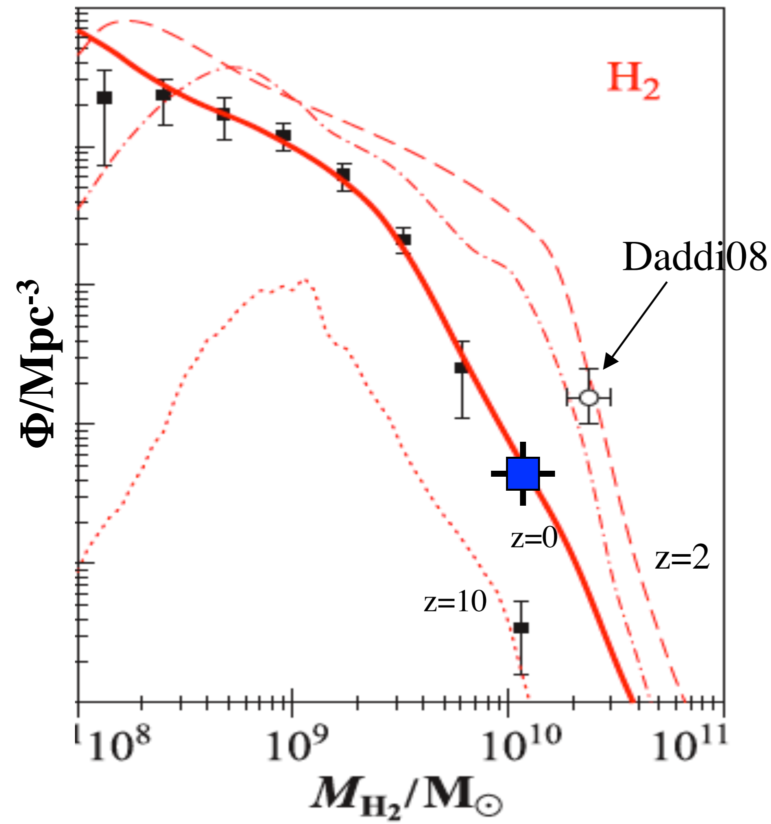
Is there more H_2 at high-z?

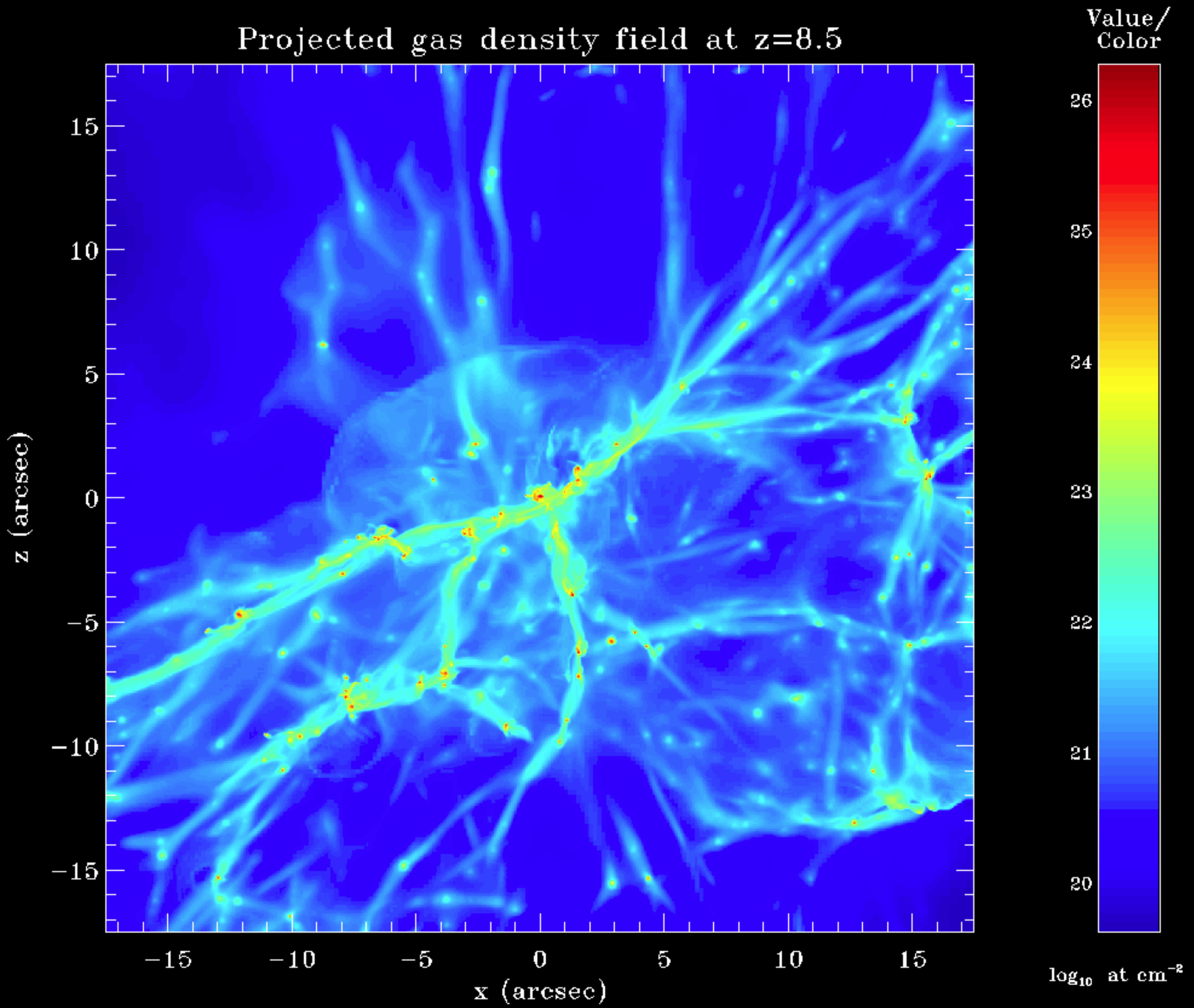
Prediction for the evolution of H_2 based on the Millenium Simulations

comoving space density of sources per log mass interval

H_2 evolves strongly…

Obreschkow & Rawlings 09





Projected gas density field at z=8.5
z (arcsec)
x (arcsec)
15
10
5
0
−5
−10
−15
Value/
Color
26
25
24
23
22
21
20
log10 at cm-2

FIRI in space is an ambitious project but the scientific advances it will provide are ground-breaking:

- Trace SFR through spatially resolved observations of PAHs and MIR lines

- Trace SB- AGN connection

- Combine MIR—FIR fine structure lines

- High Redshift Universe: detect H2 building blocks

- High Redshift Universe : study cooling mechanisms of the ISM