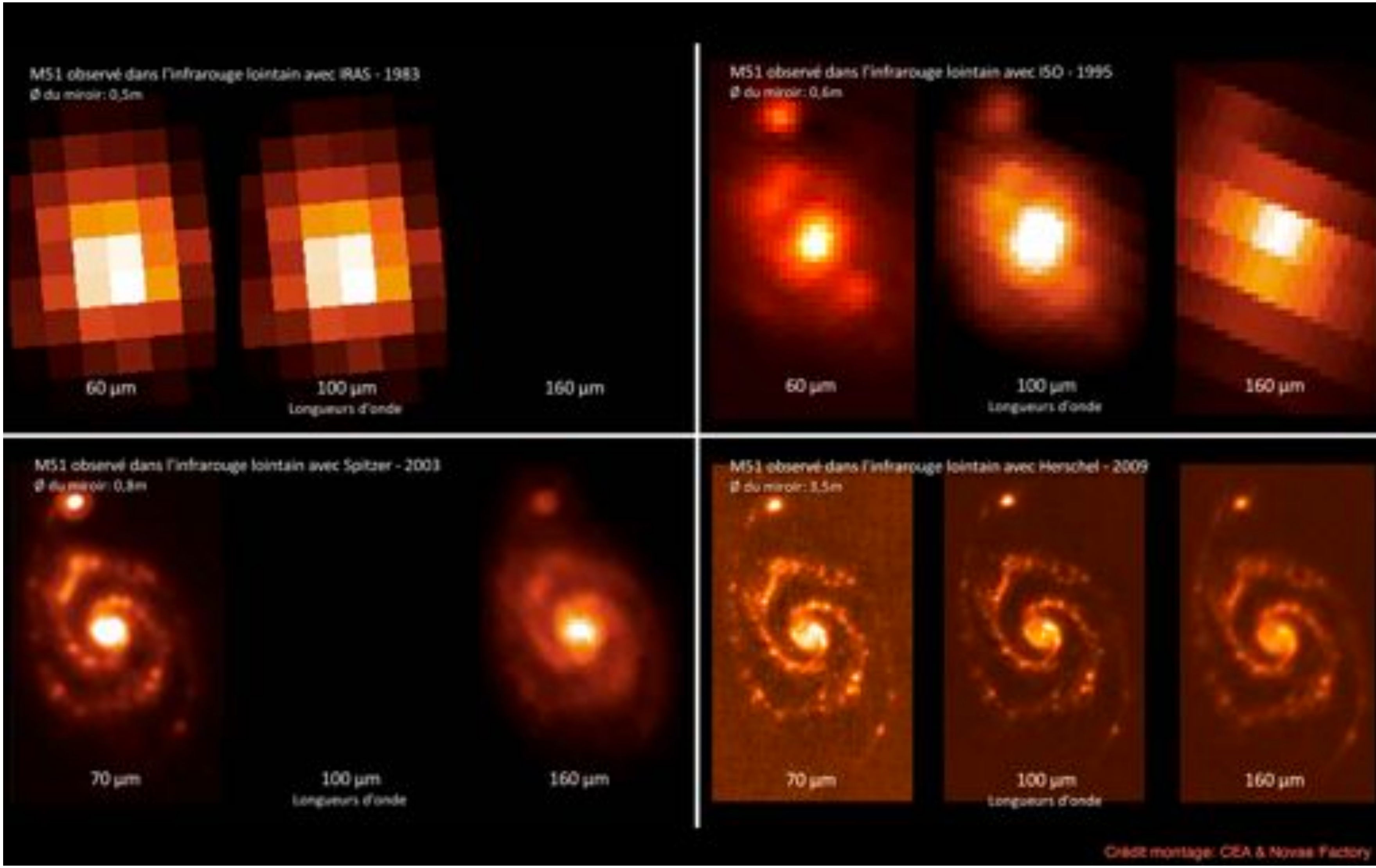
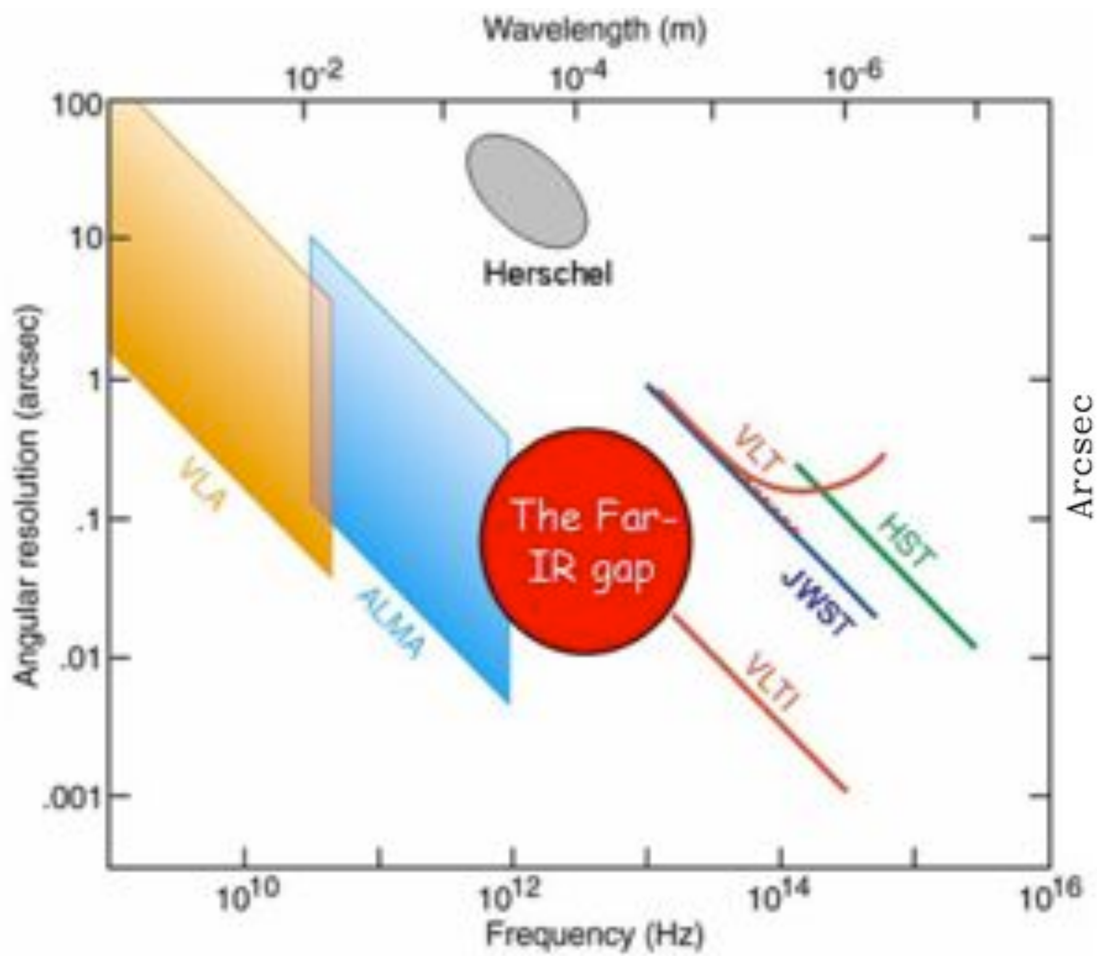
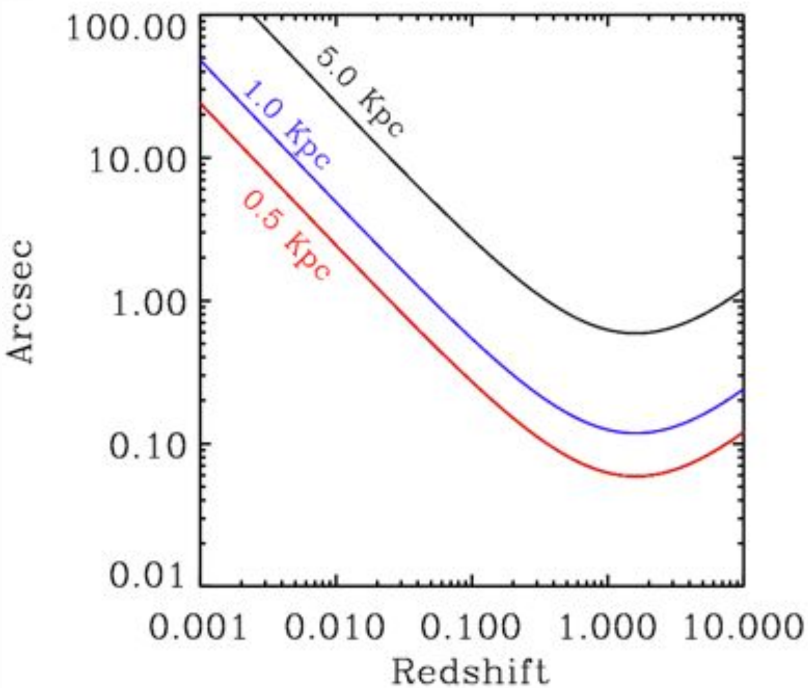
Resolving the FAR-IR emission from AGN and Star Forming Galaxies

Georgios Magdis


M51 observé dans l'infrarouge lointain avec IRAS - 1983
Ø du miroir: 0,5m
60 µm
100 µm
Longueurs d'onde
160 µm
M51 observé dans l'infrarouge lointain avec ISO - 1995
Ø du miroir: 0,6m
60 µm
100 µm
Longueurs d'onde
160 µm
M51 observé dans l'infrarouge lointain avec Spitzer - 2003
Ø du miroir: 0,8m
70 µm
100 µm
Longueurs d'onde
160 µm
M51 observé dans l'infrarouge lointain avec Herschel - 2009
Ø du miroir: 3,5m
70 µm
100 µm
Longueurs d'onde
160 µm
Crédit montage: CEA & Novae Factory

The Far-IR Gap

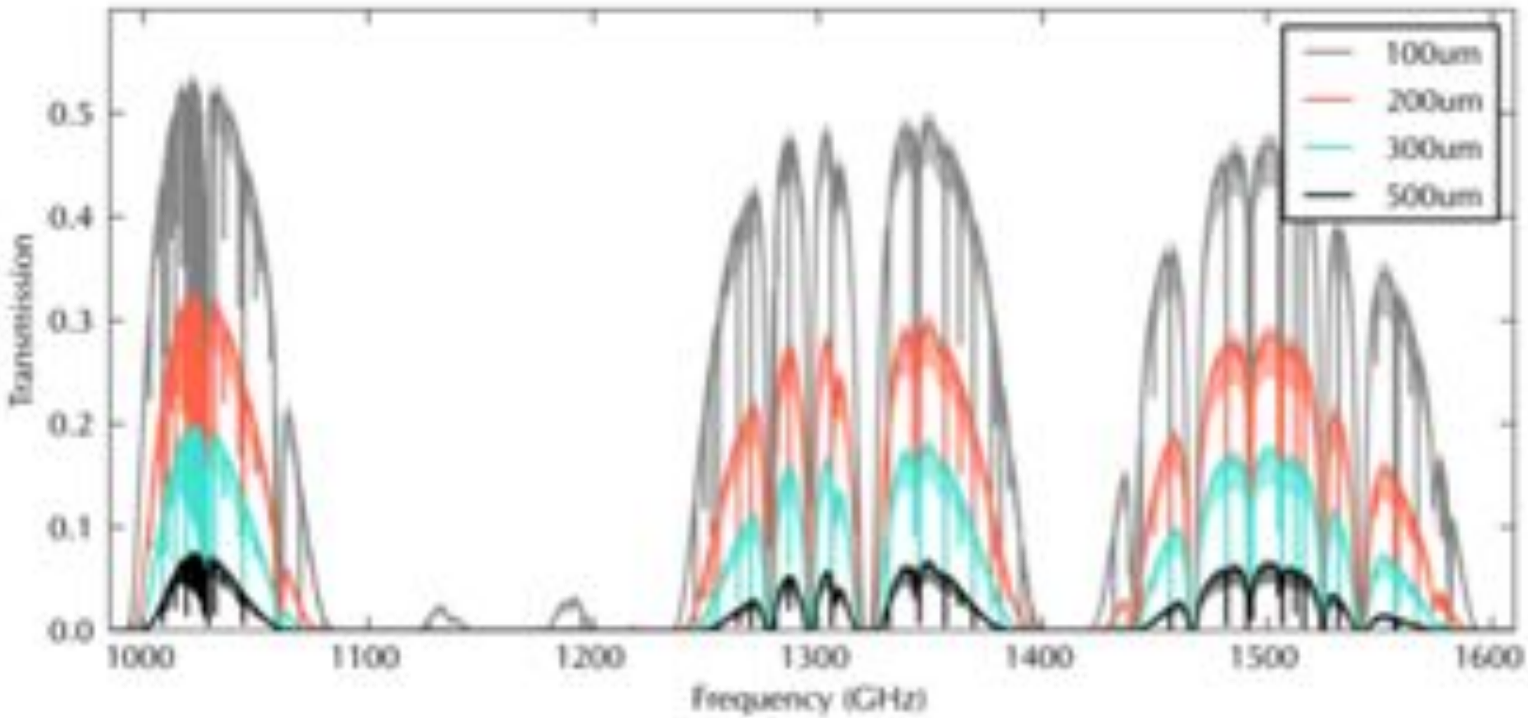




HERSCHEL has shown the way BUT
we need both better sensitivity and high spatial resolution to catch up with other wavelengths!

Need to go to space

300μm 250μm 180μm



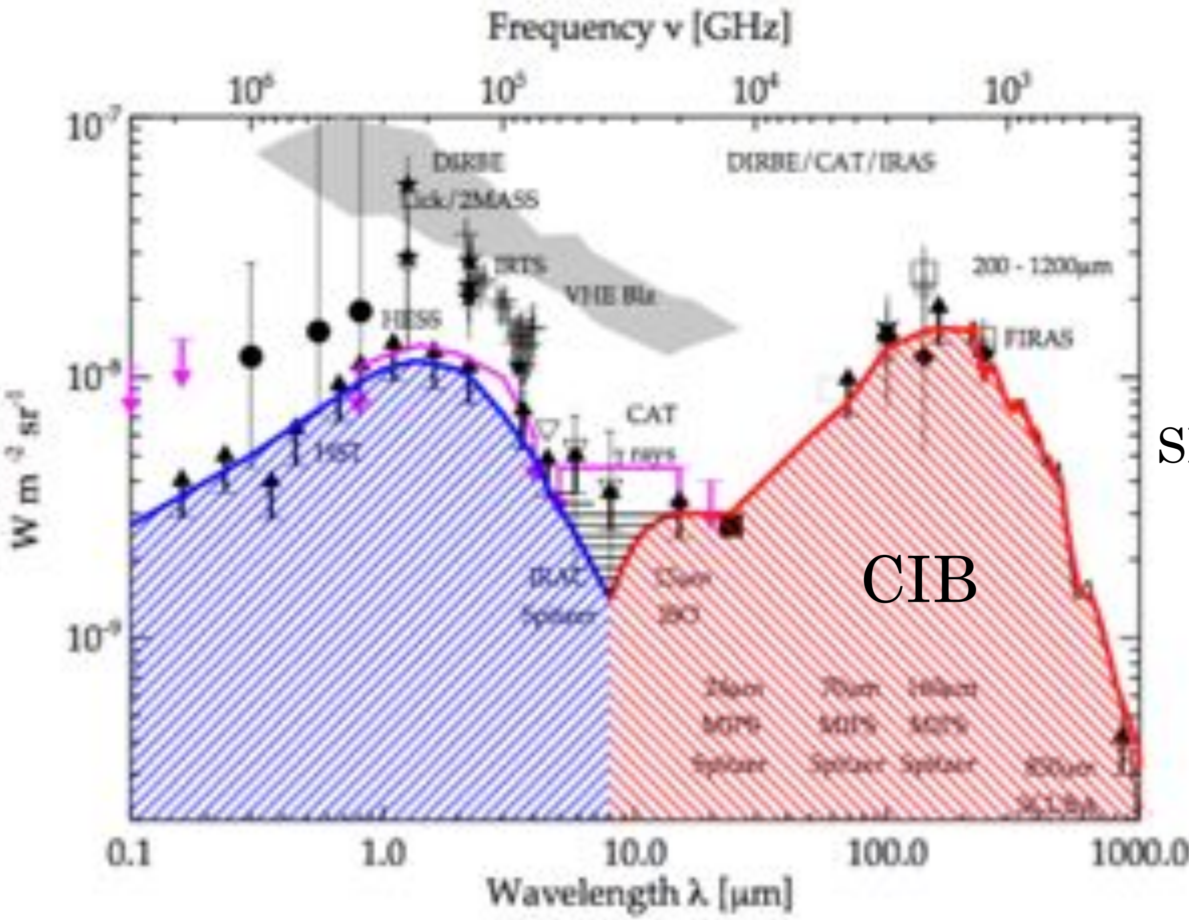
Atmospheric transmission at ~ 200μm at the ALMA site

Questions to be addressed

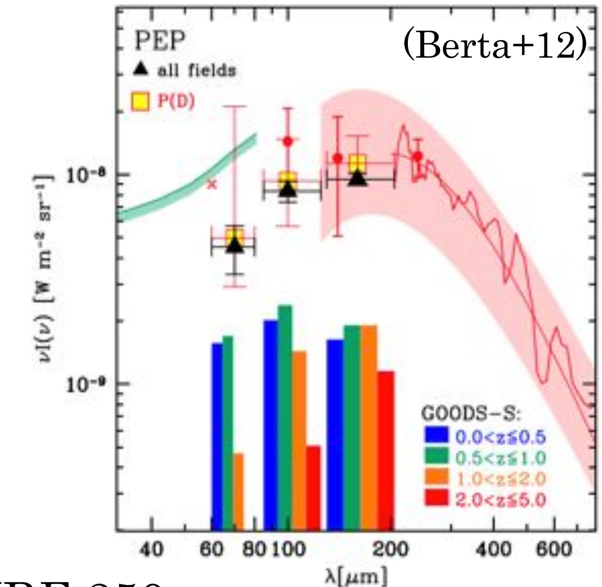
- The nature of the FAR-IR background
- The interplay between AGN and host galaxies
- The processes that shape the FAR-IR SED of galaxies
- The geometry of the accreting and star forming regions
- Cosmic star formation and black hole growth history
- Trace the first galaxies in our Universe

Resolving the CIB

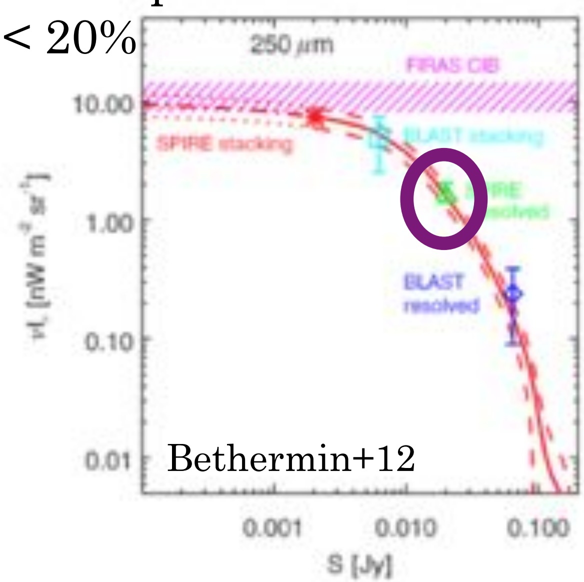
CIB peaks @ 100-200μm



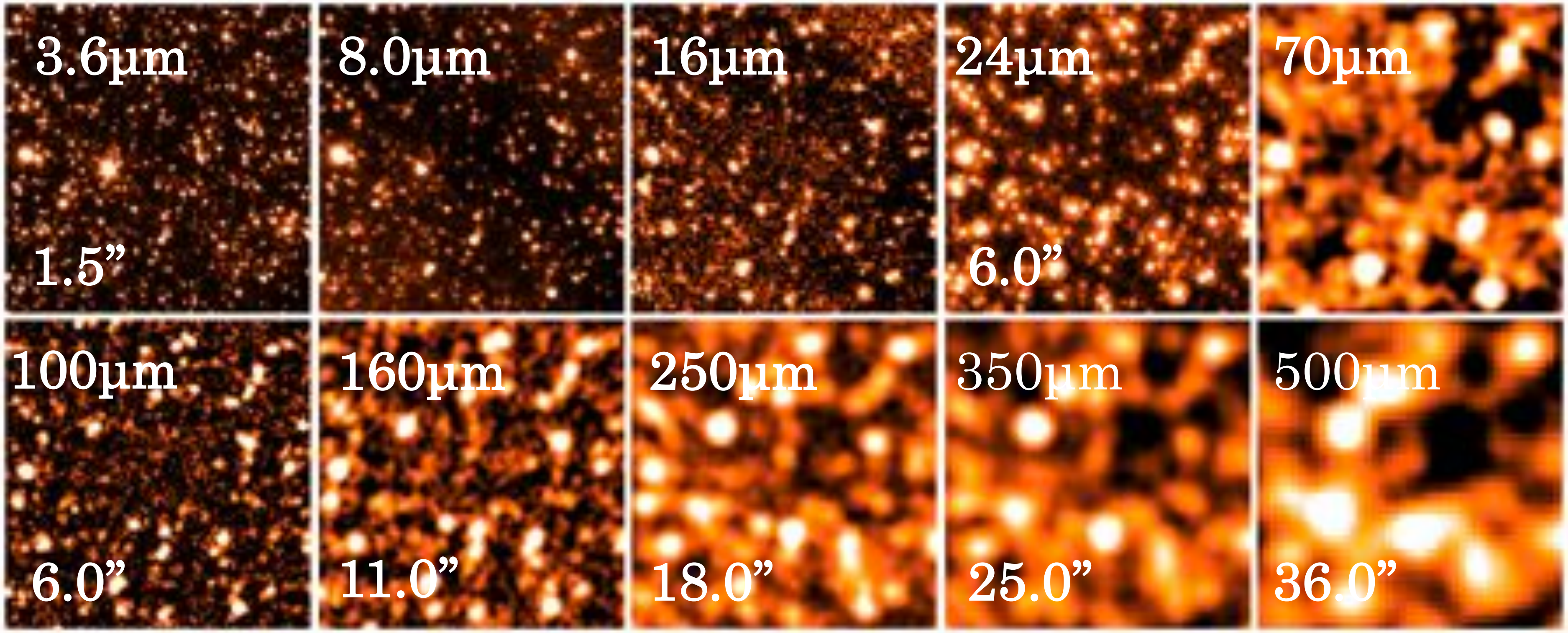
PACS (70-100-160μm)



SPIRE 250μm
< 20%



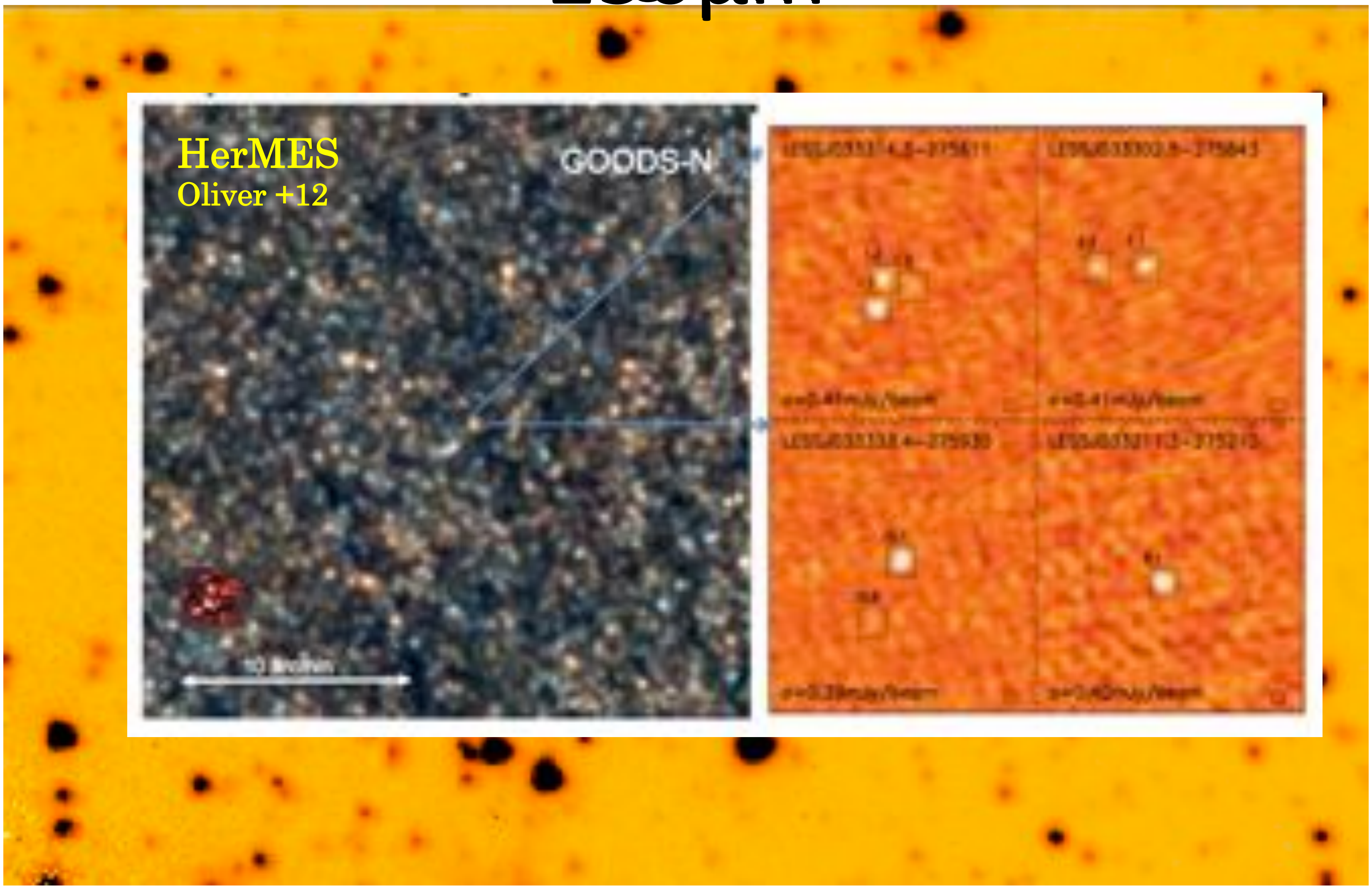
Beating Confusion



5’ x 5’ GOODS-N (Elbaz+11)

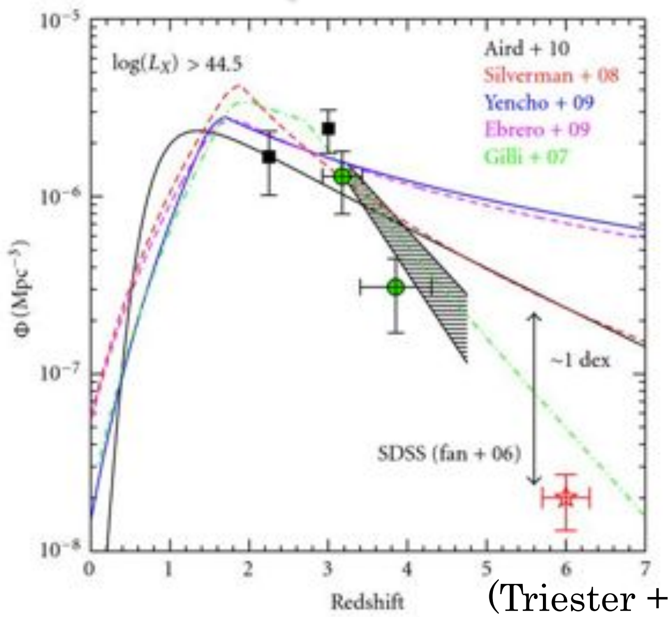
Beating Confusion

250µm
3.6µm

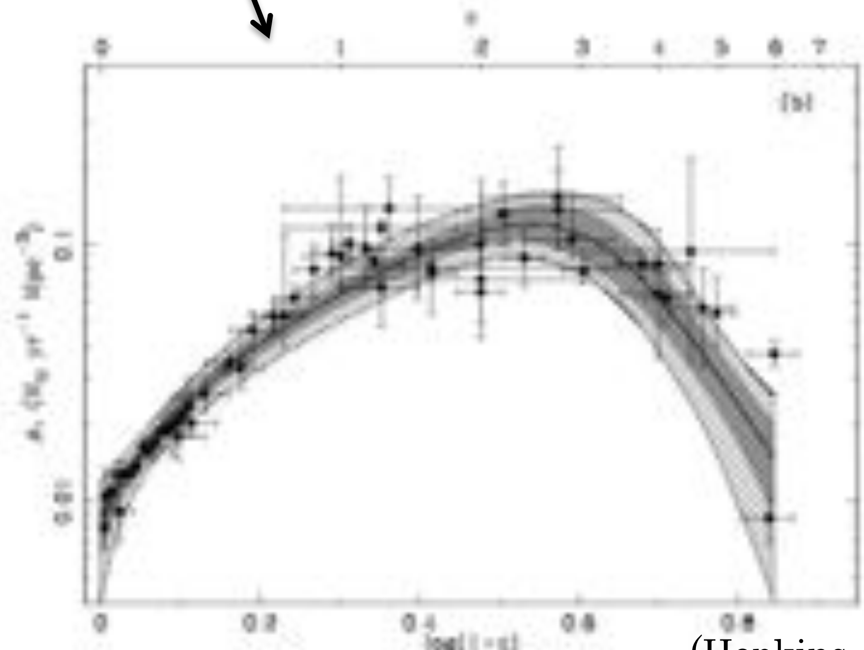


AGN and SF Cosmic History

Black hole accretion rate follows the star formation history of the Universe



(Triester +12)



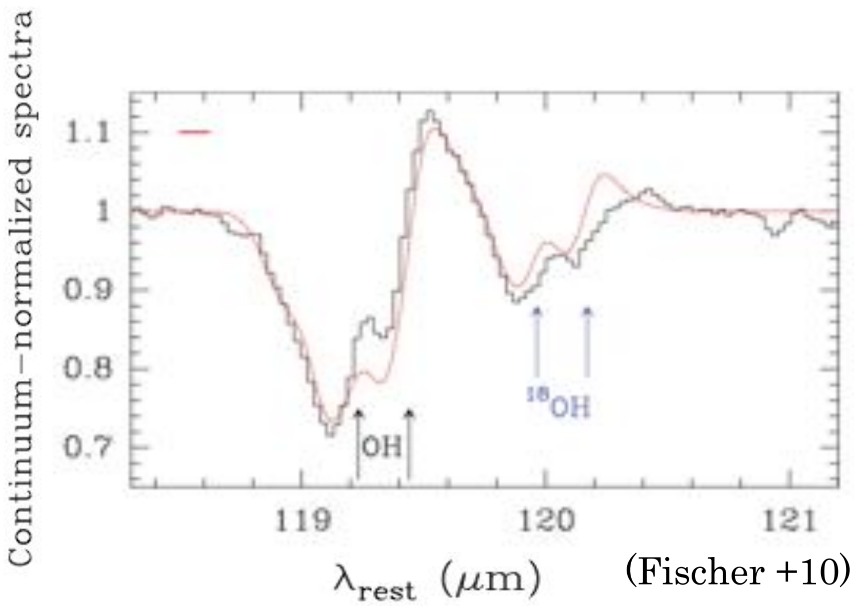
(Hopkins +06)

Understand the impact of an AGN on star formation

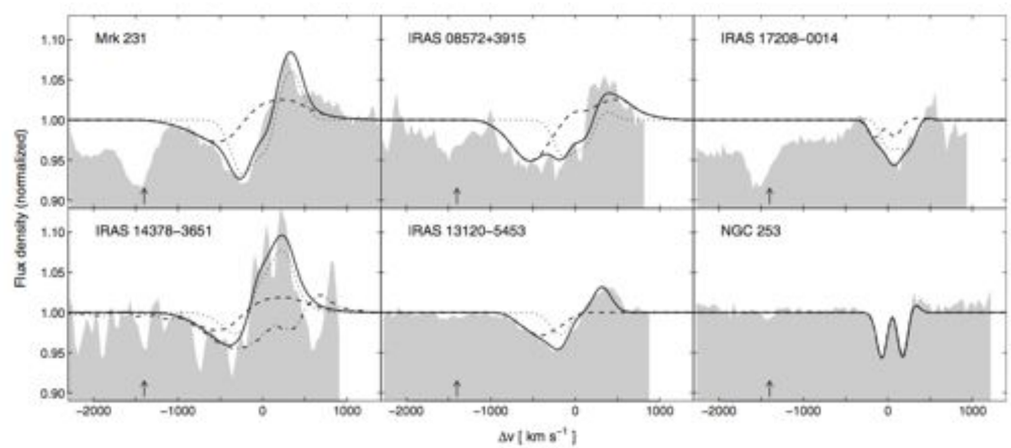
AGN Outflows

CO, HCN and OH have been used to trace outflows

OH : Strongest @ 119μm but in total 14 FAR-IR lines (34-163μm)



(Fischer +10)

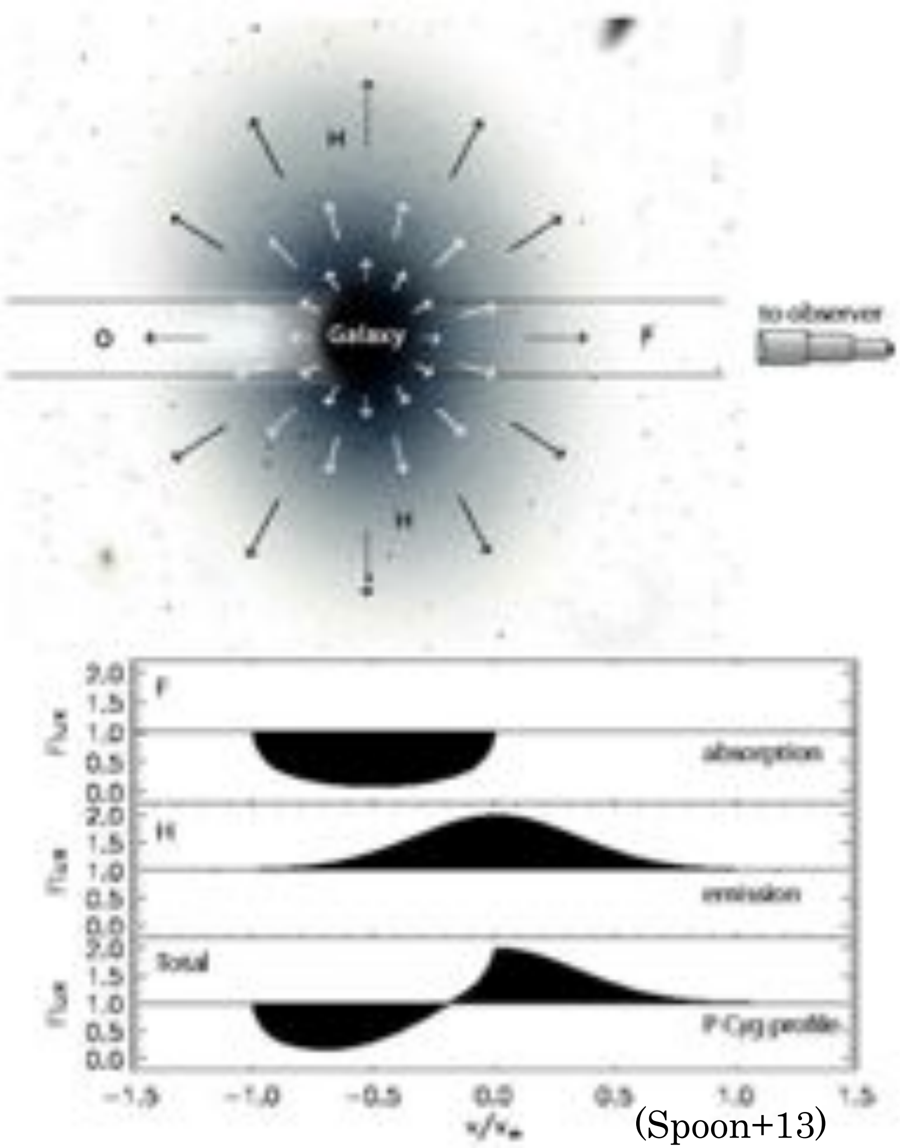


(Sturm+11)

Clear P-Cygni profile with blueshifted absorption and redshifted emission features of more than 1000 km s^{-1}

Strong outflows!

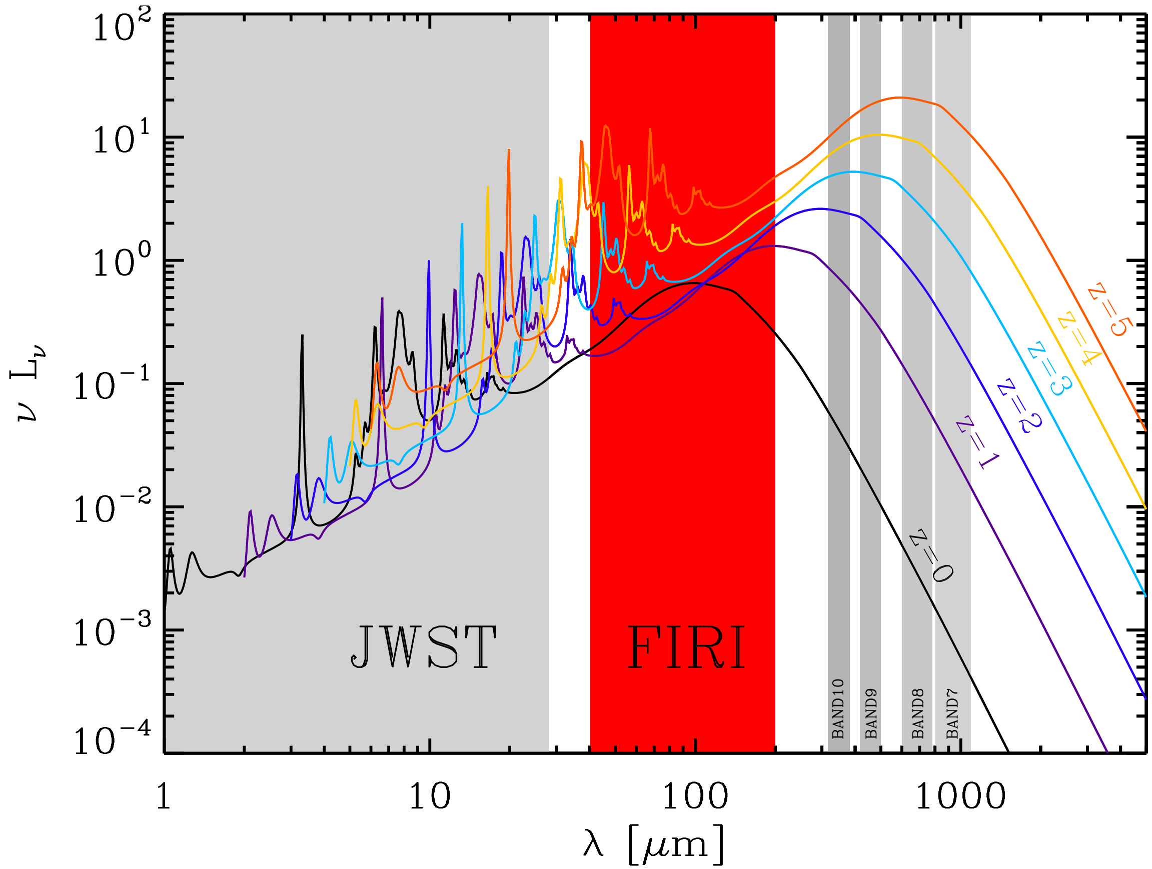
AGN Outflows



(Spoon+13)

We lack the spatial resolution to directly study the spatial distribution of the outflowing material

Warm Dust Emission

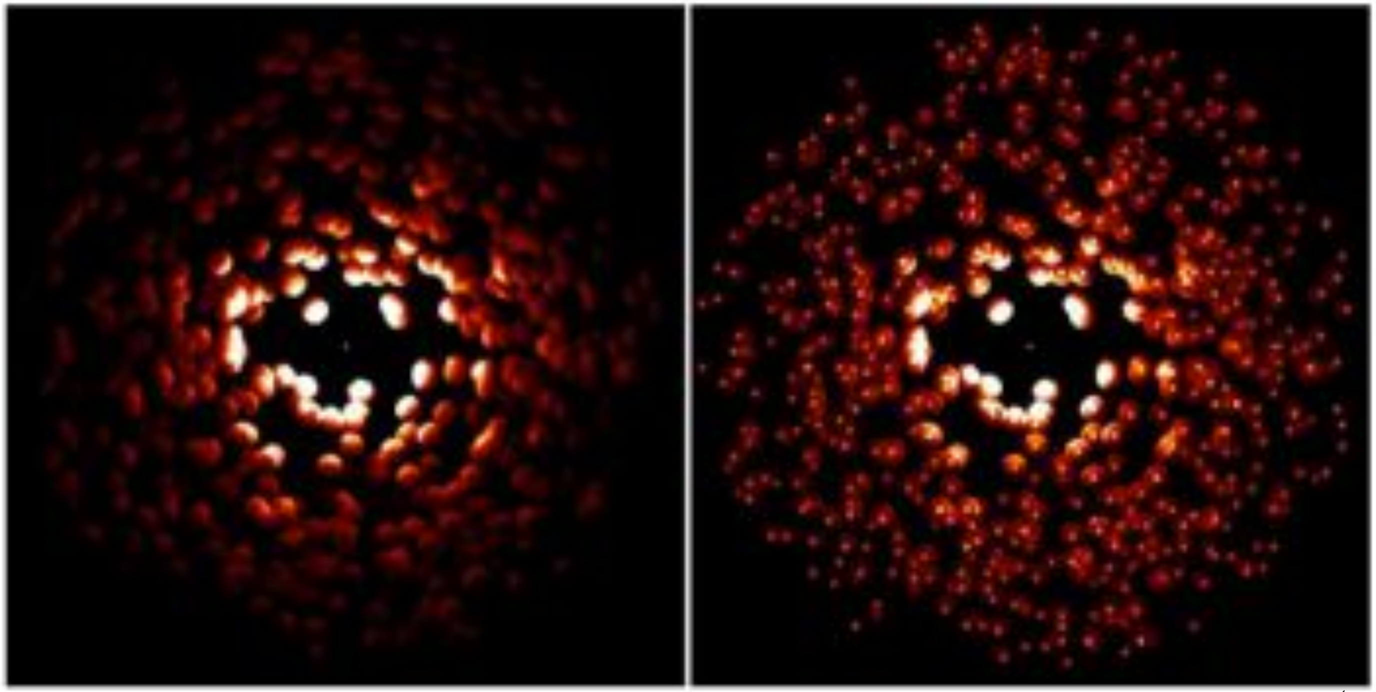


JWST → Hot dust emission (100K)
ALMA → Cold dust emission (~40K)

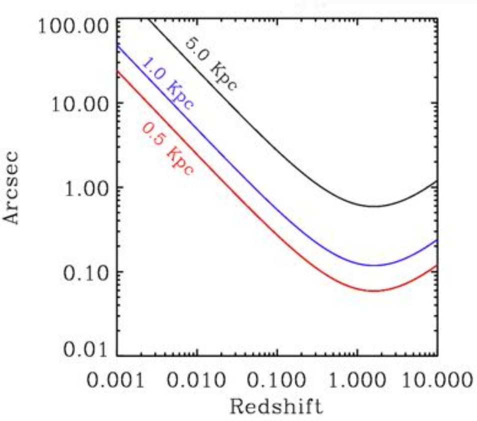
FIRI → Warm Dust emission (40-80K)

Warm Dust Emission

40μm emission model maps of 5 kpc x 5 kpc regions



pure AGN AGN+Star-Forming clouds (Schneider +14)

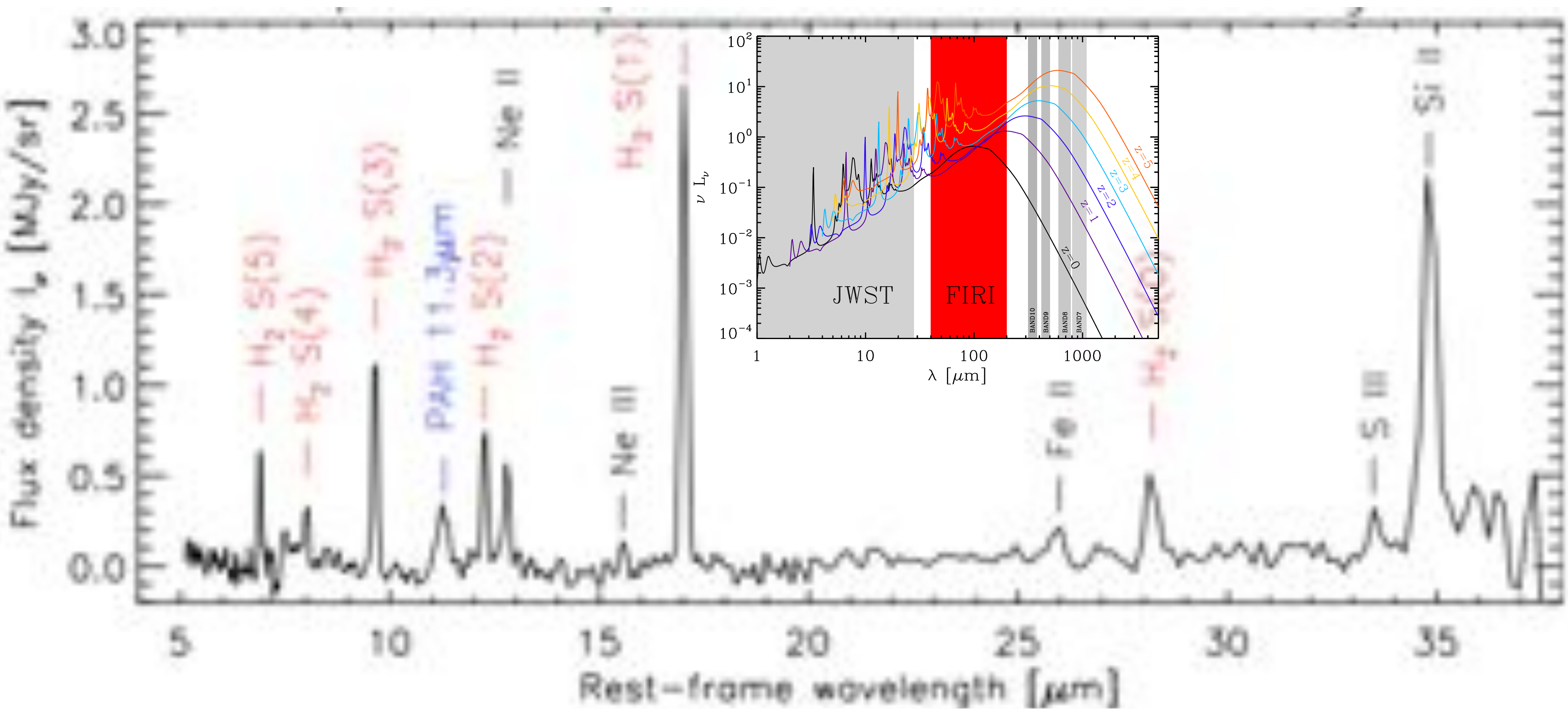


Reveal the geometry of warm dust emission.
Disentangle the heating mechanism.

Dust Features Emission

Redshifted PAHs 11.3, 12.7, 17.4μm

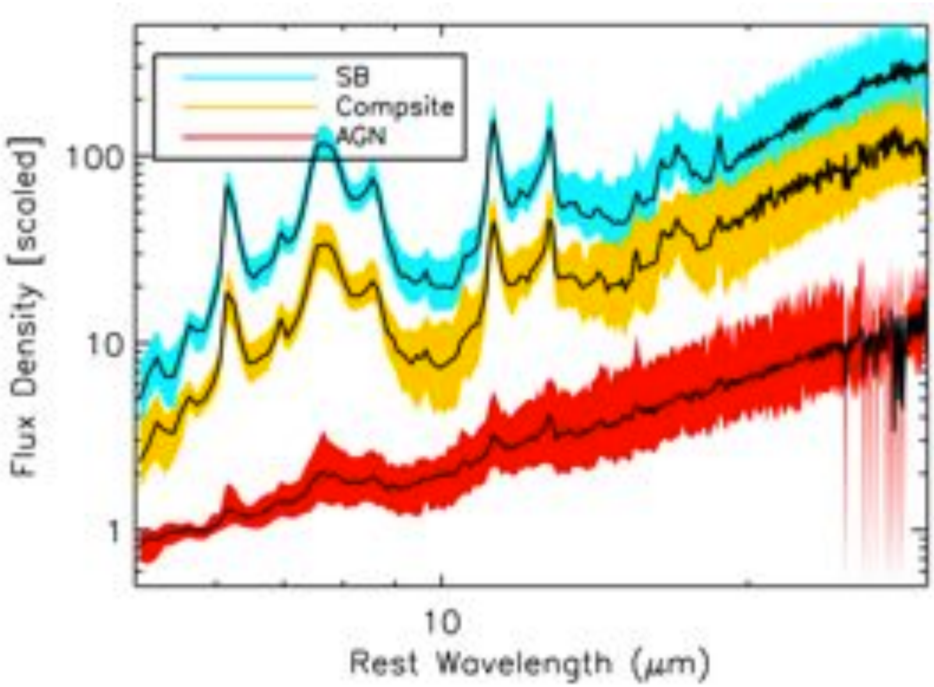
[Ne II] [Ne III], [S III], [Ne V], [O IV] [Fe II], [S II]



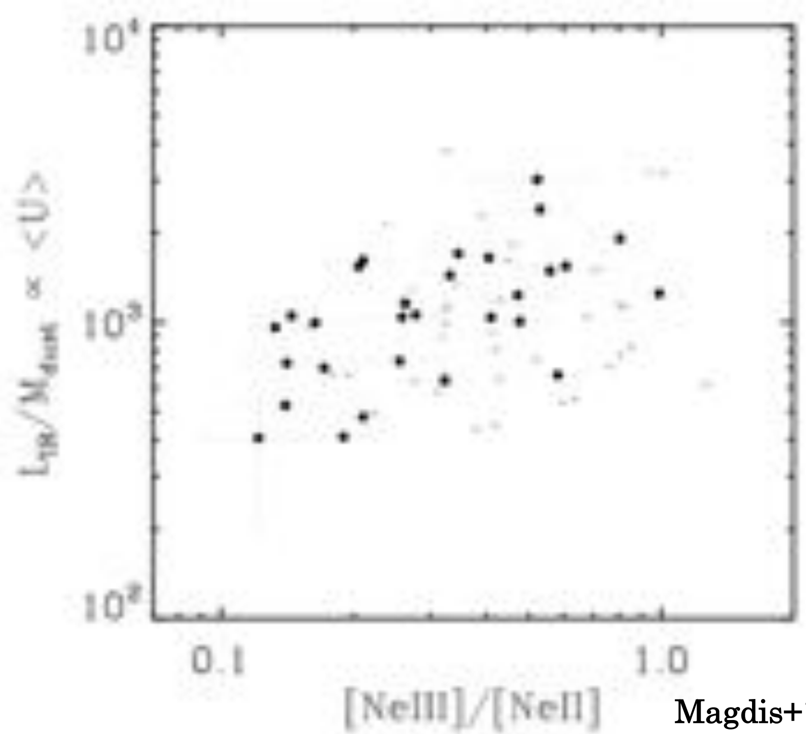
(Guillard +10)

Dust Features Emission

Classify and measure the AGN contribution to the energy budget



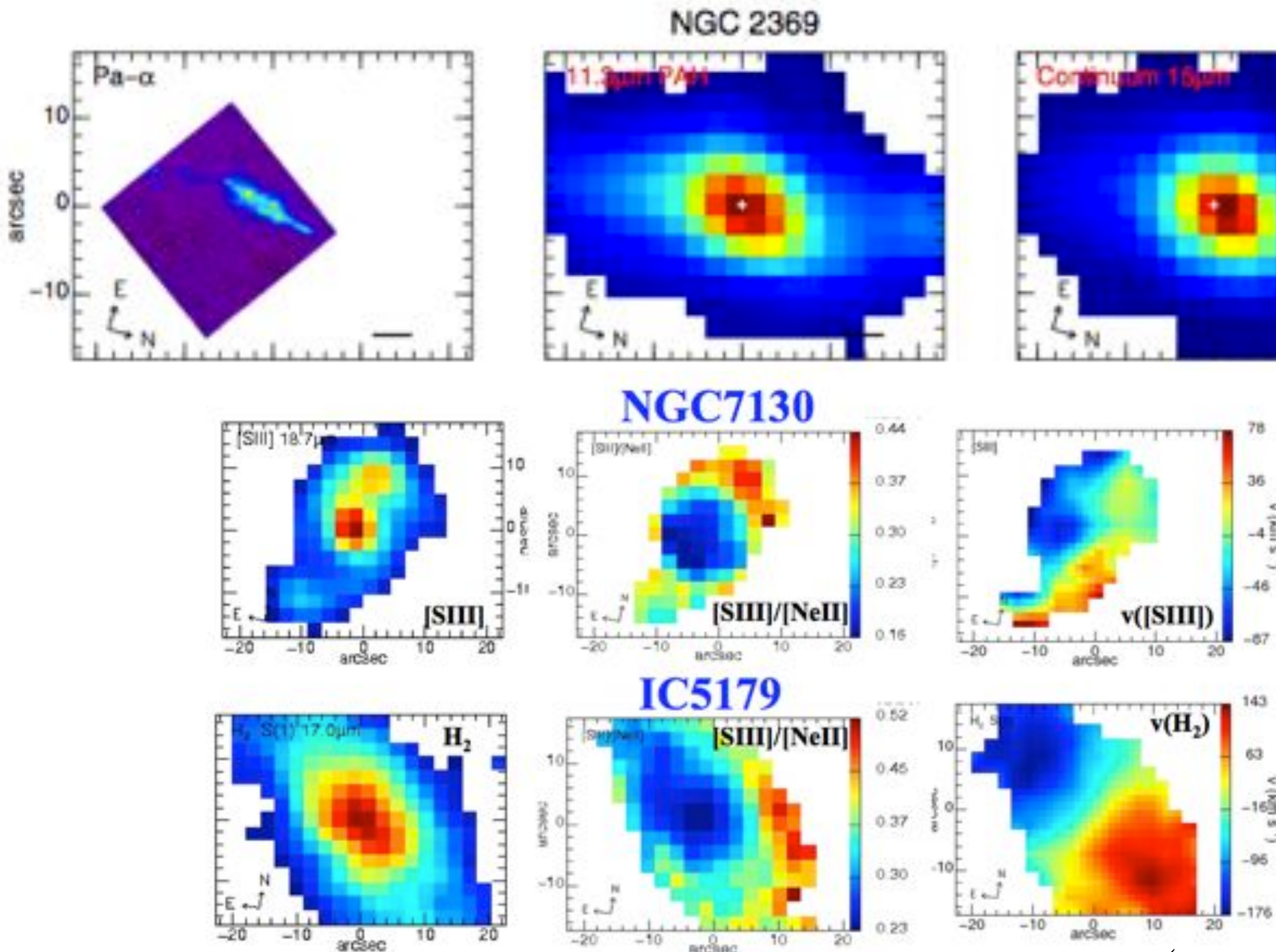
Measure the strength of the radiation field



Magdis+13

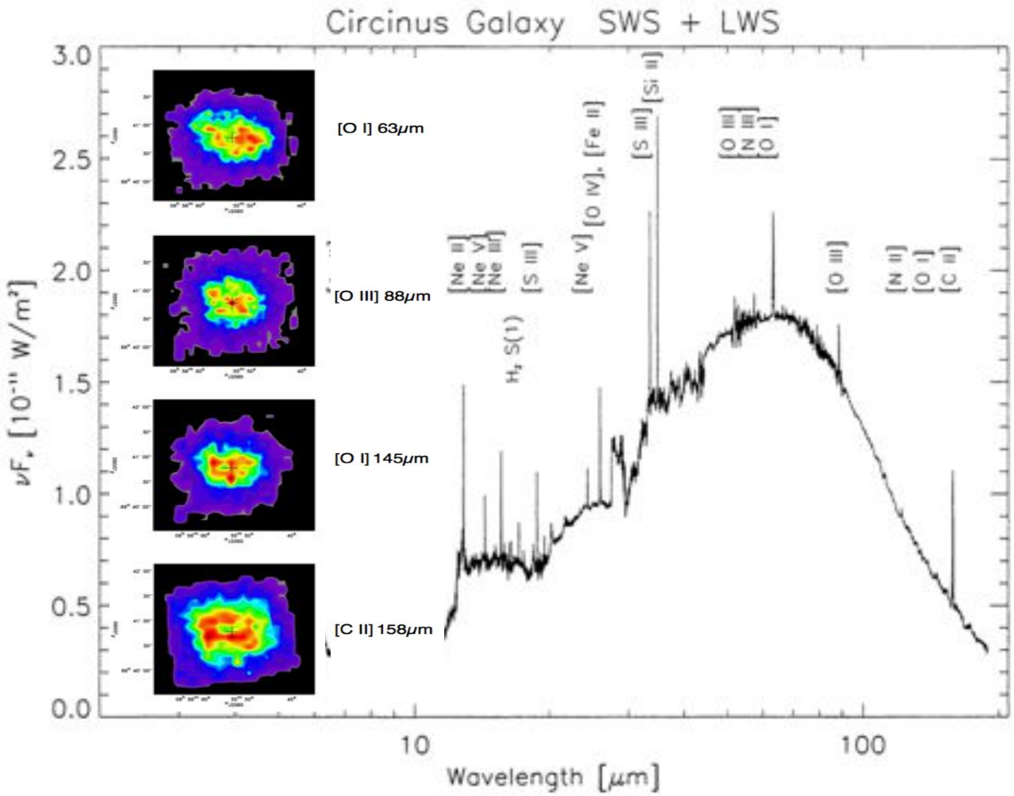
Dust Features Emission

Trace the spatial extend of star formation in high-z galaxies and how it compares to their local counterparts.

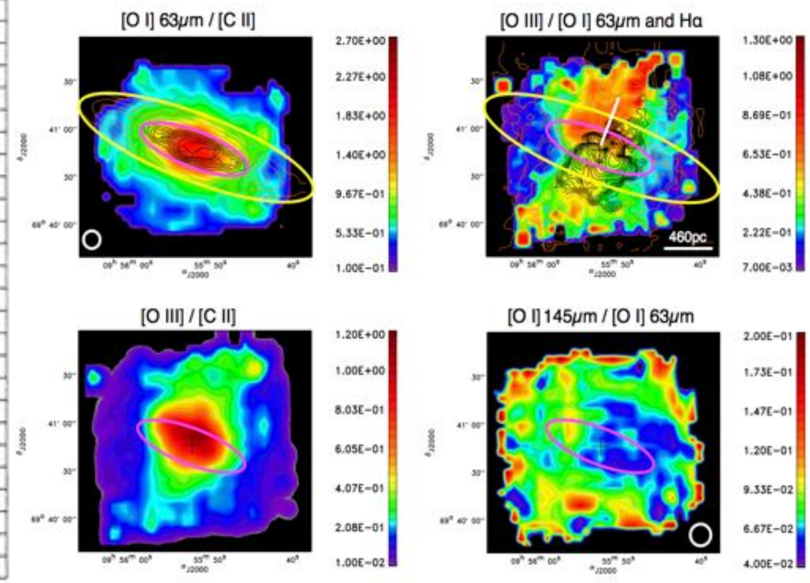


(Periera-Santaella +11)

Far-IR Atomic Lines



M82

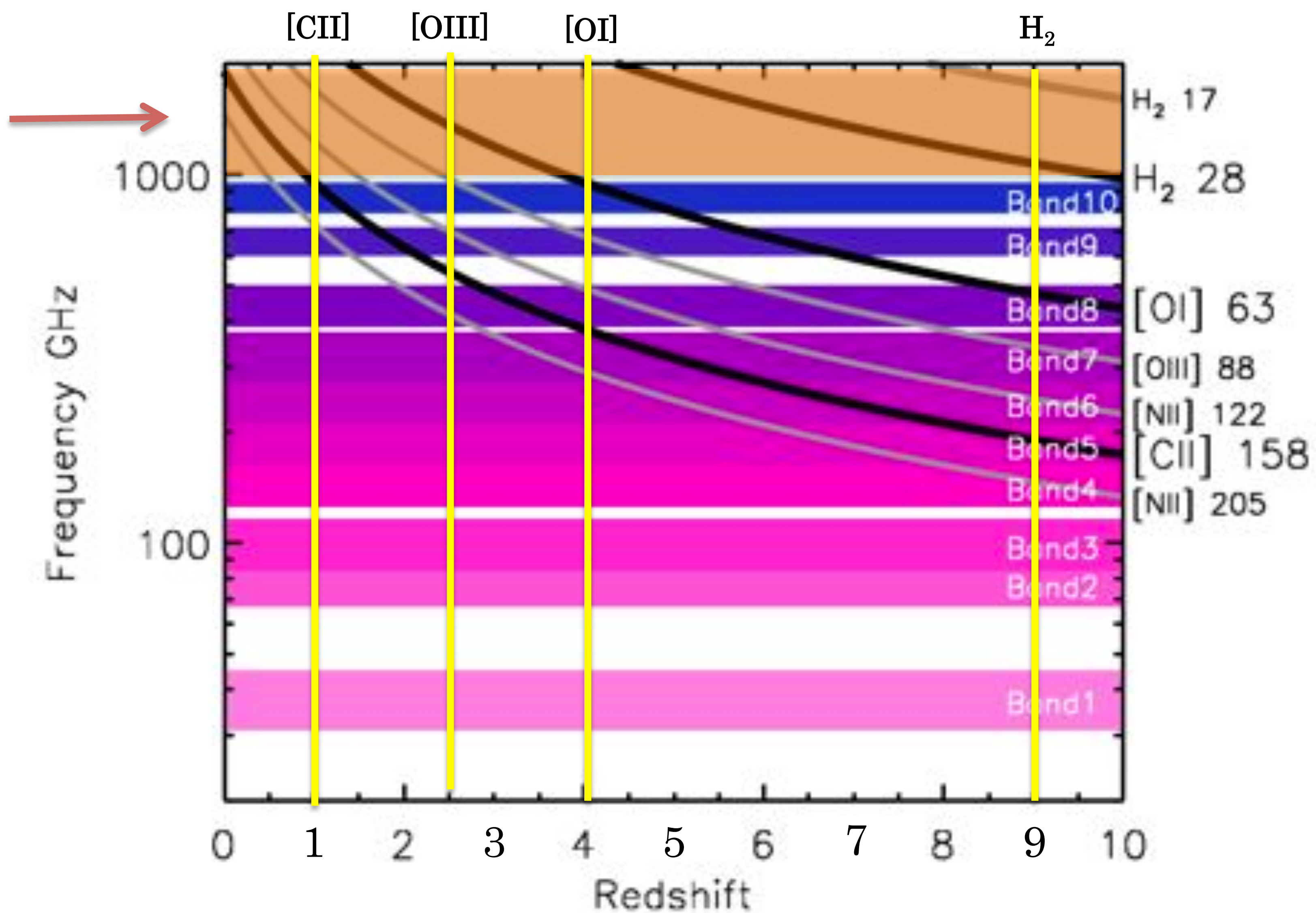


Contursi+12

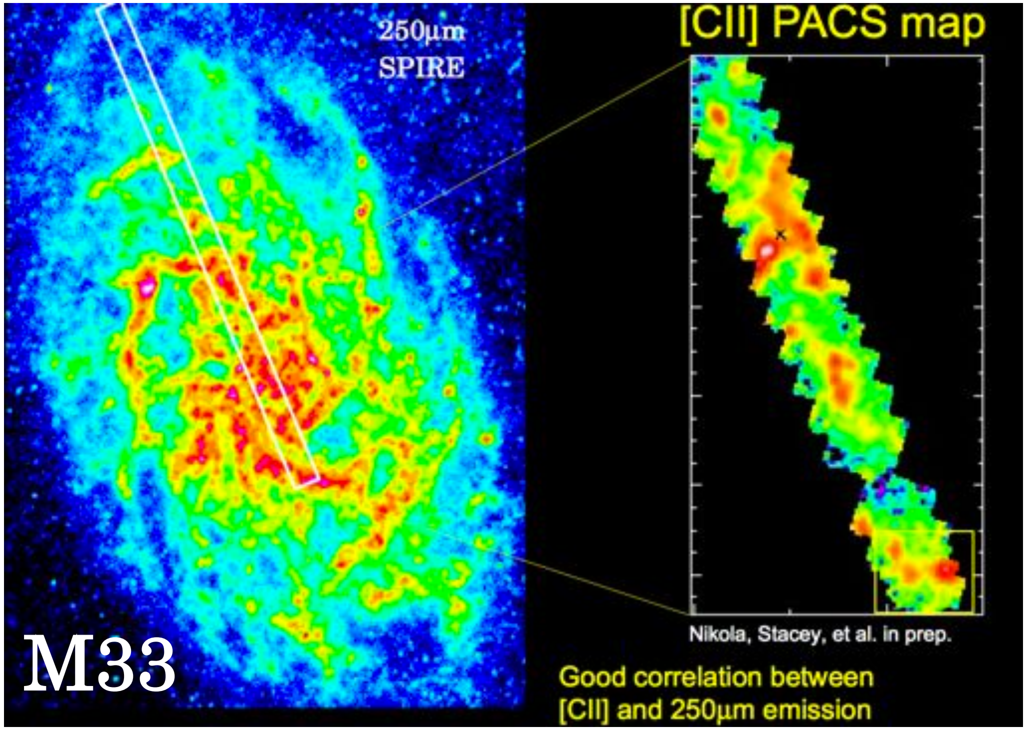
Far-IR and sub-mm (50-250μm) is rich in spectral lines
Fine structure lines: [CII] 158, [NIII] 57, [NII] 205, [OI] 63,145, [OIII] 52,88

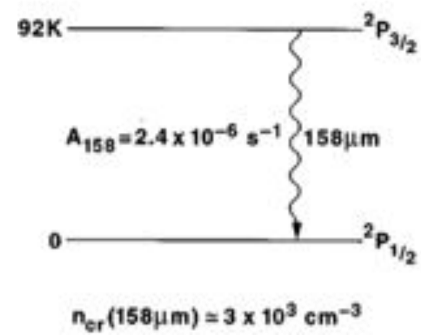
- Kinematic structure of ISM
- Physical properties (gas temperature & densities, radiation fields etc)
- Star formation rate indicators

Far-IR Interferometer



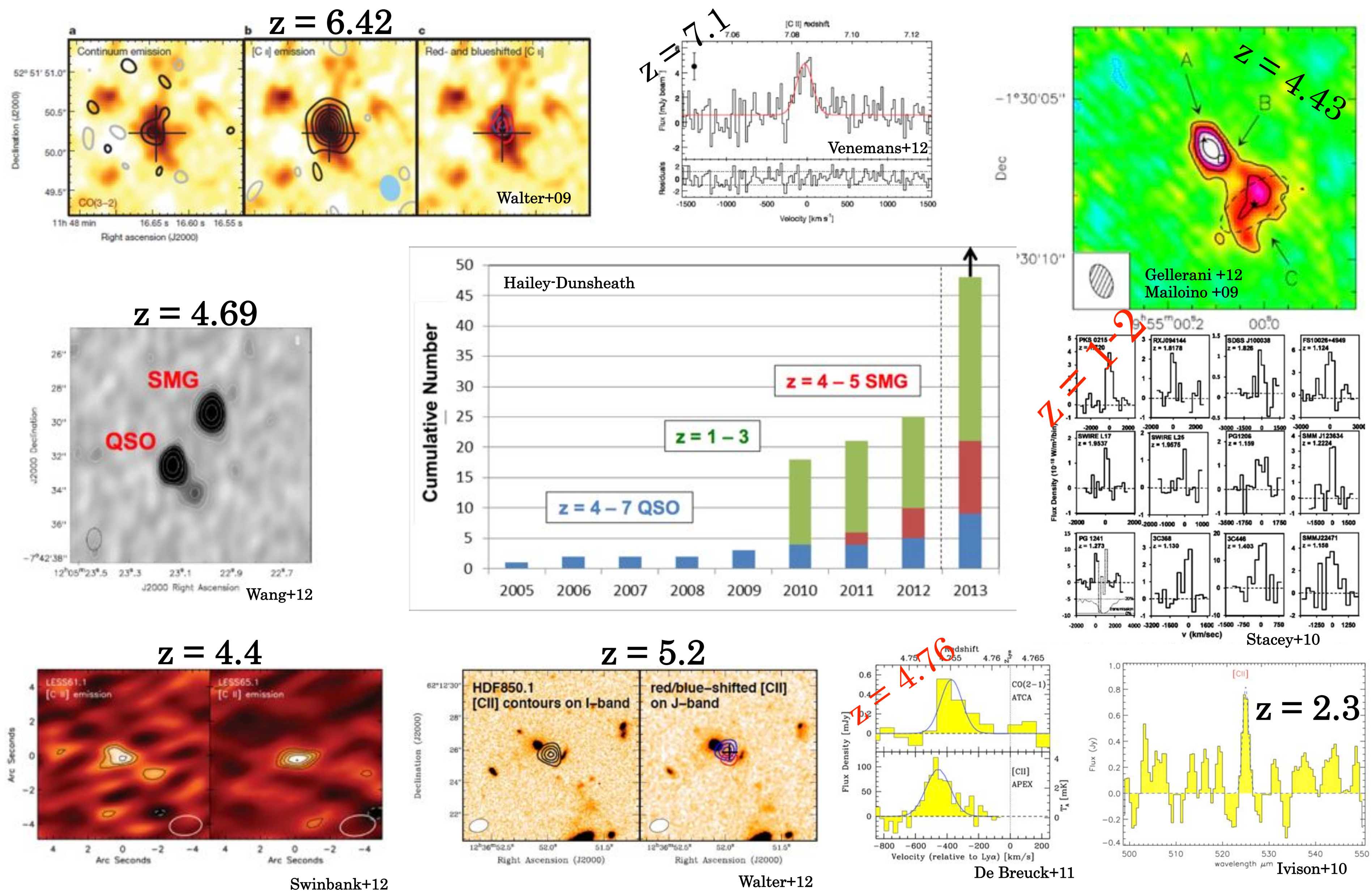
CII Emission



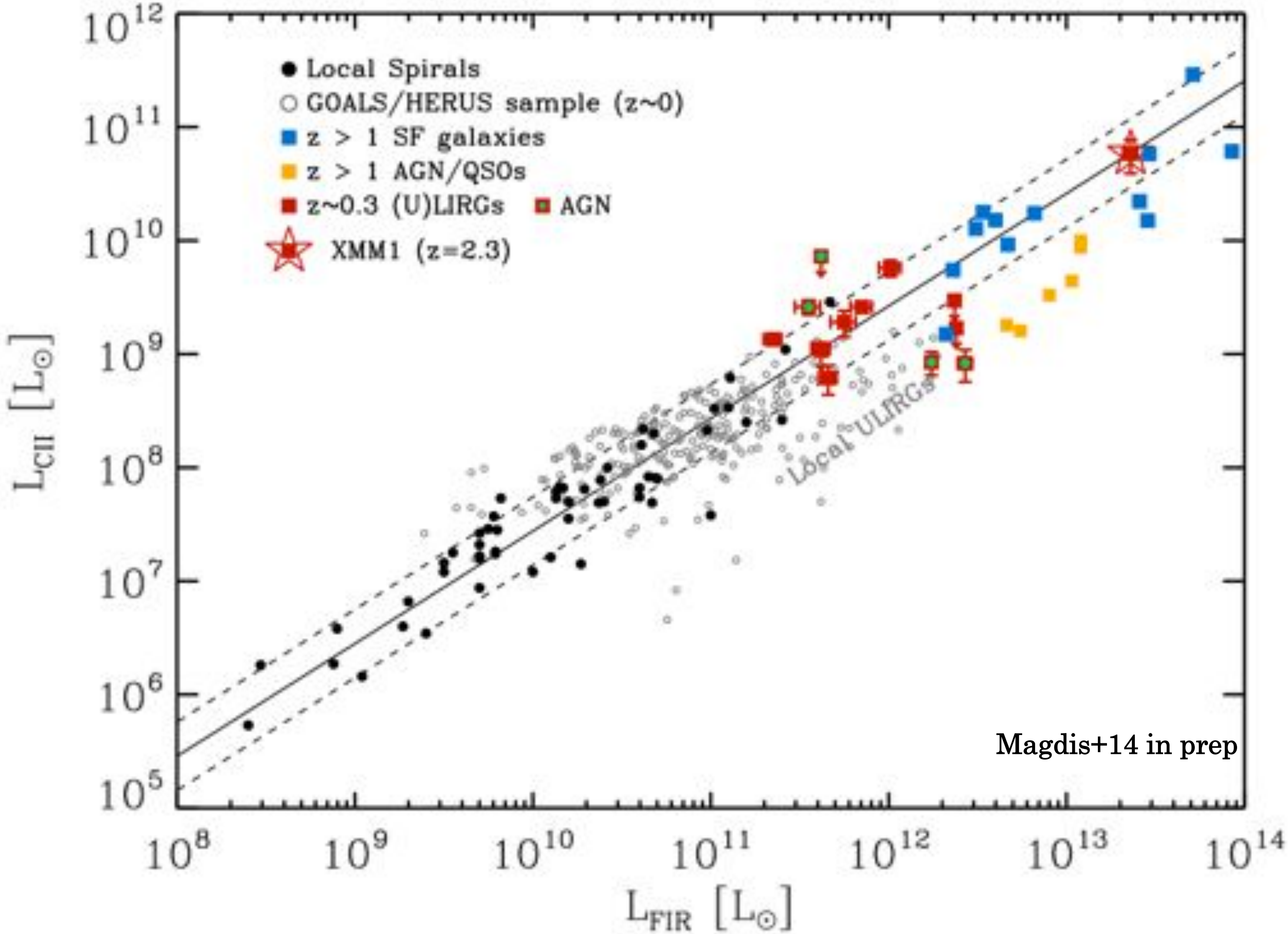


- [CII] 158μm is one of the strongest ISM cooling lines (T~90K)
- Accounts for 0.1-1% of the L_{IR}
- One of the most powerful spectroscopic tracers of the ionized & neutral components of the ISM
- Tracer of Star Formation Rate (?)

[CII] at high-z

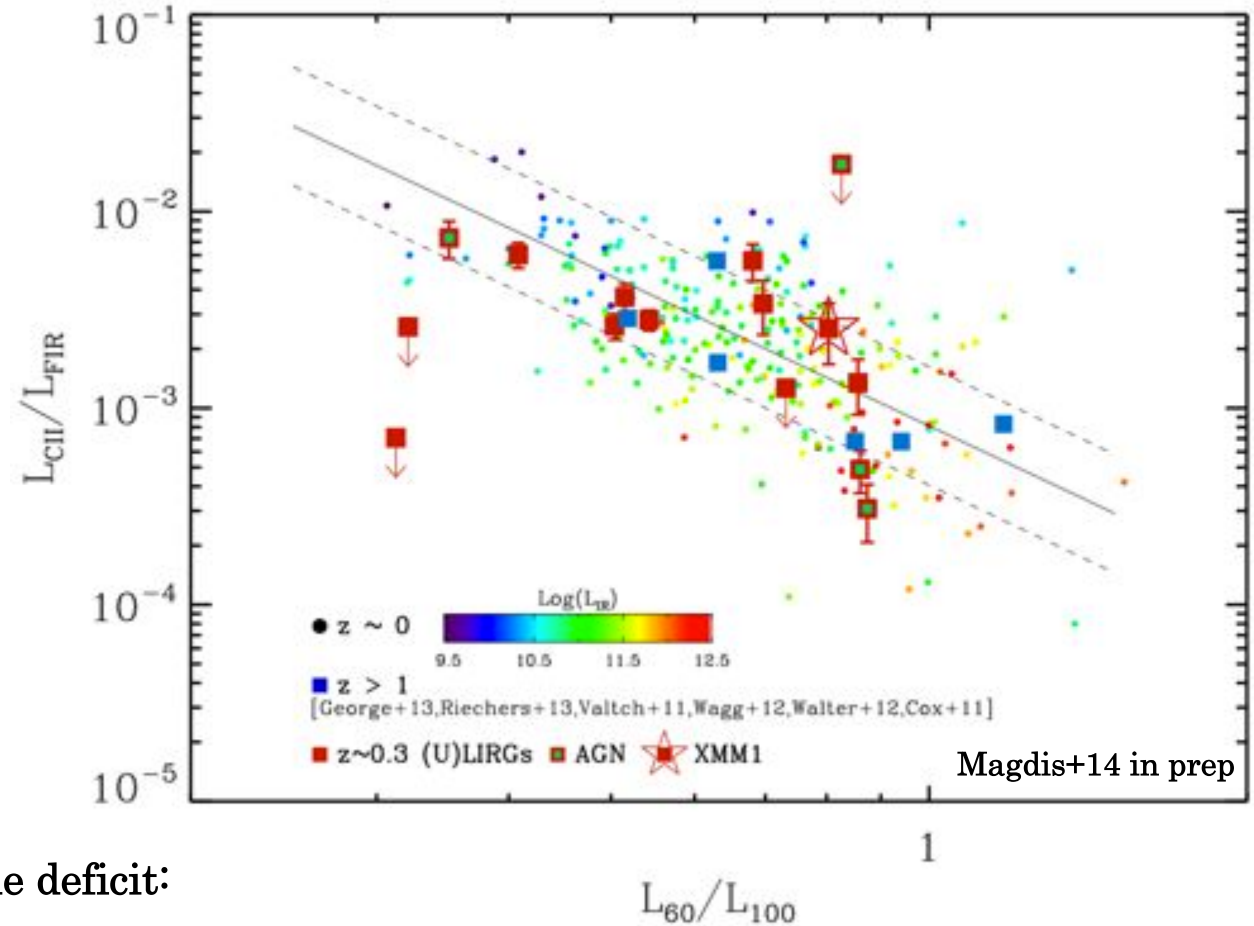

z = 6.42
Continuum emission
[C II] emission
Red- and blueshifted [C II]
CO(3–2)
Walter+09
z = 7.1
Venemans+12
z = 4.43
Gellerani +12
Mailoino +09
z = 4.69
SMG
QSO
Wang+12
Hailey-Dunsheath
Cumulative Number
z = 4 – 5 SMG
z = 1 – 3
z = 4 – 7 QSO
2005
2006
2007
2008
2009
2010
2011
2012
2013
z = 1-2
Stacey+10
z = 4.4
LESS61.1
LESS65.1
Swinbank+12
z = 5.2
HDF850.1
[CII] contours on I-band
red/blue-shifted [CII] on J-band
Walter+12
z = 4.76
De Breuck+11
z = 2.3
Ivison+10

[CII] Emission



The majority of galaxies at all redshifts follow a LCII-LIR relation but Local ULIRGs and high-z QSO's appear CII deficient. Why?

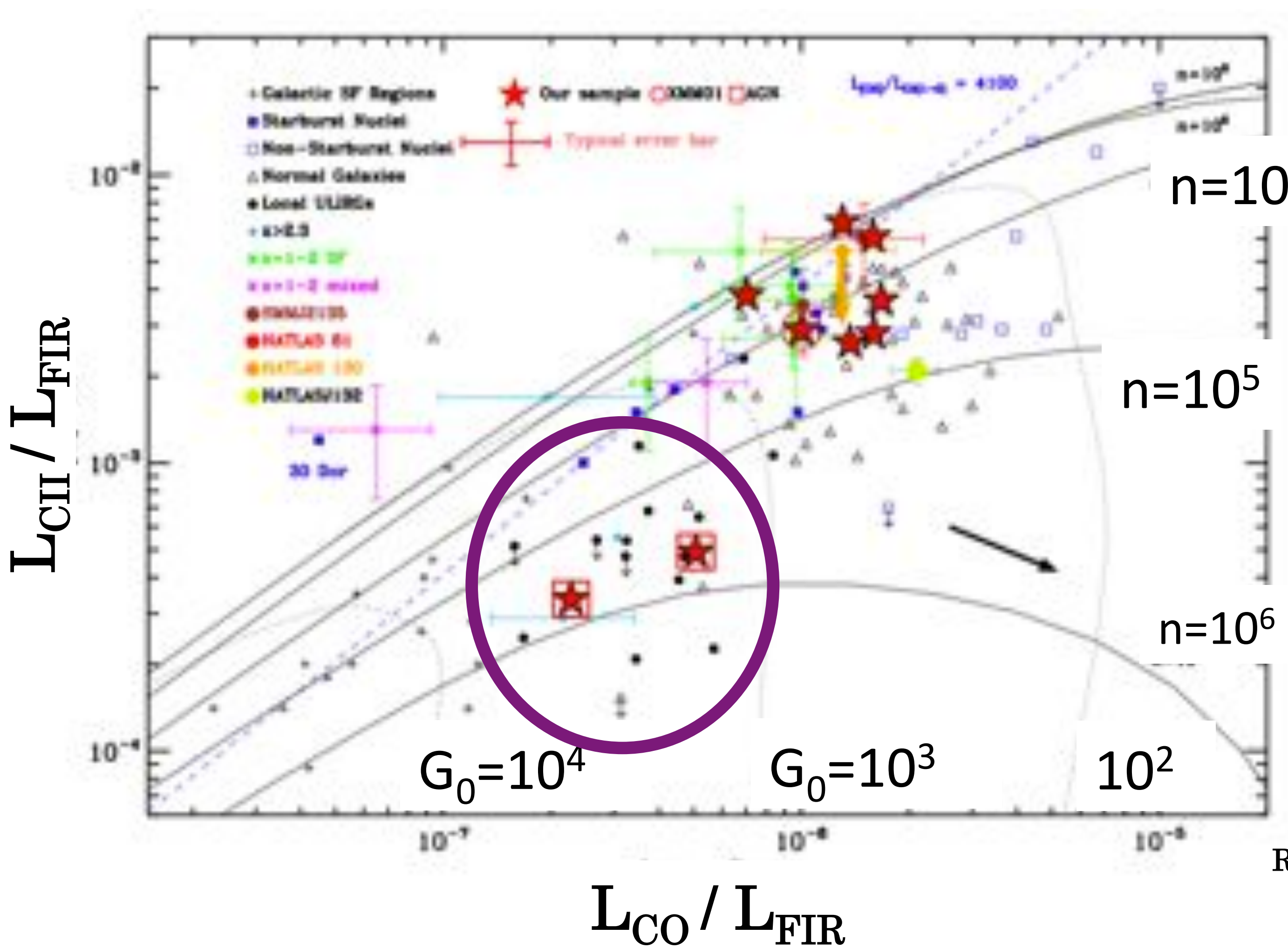
[CII] Emission



Origin of the deficit:

- AGN contamination → excess L_{IR} with respect to L_{CII}
- Stronger interstellar radiation fields (U) → increased dust to gas opacity
- n_H densities > n_{crit}, → recombination of C+ to C
- Self absorption

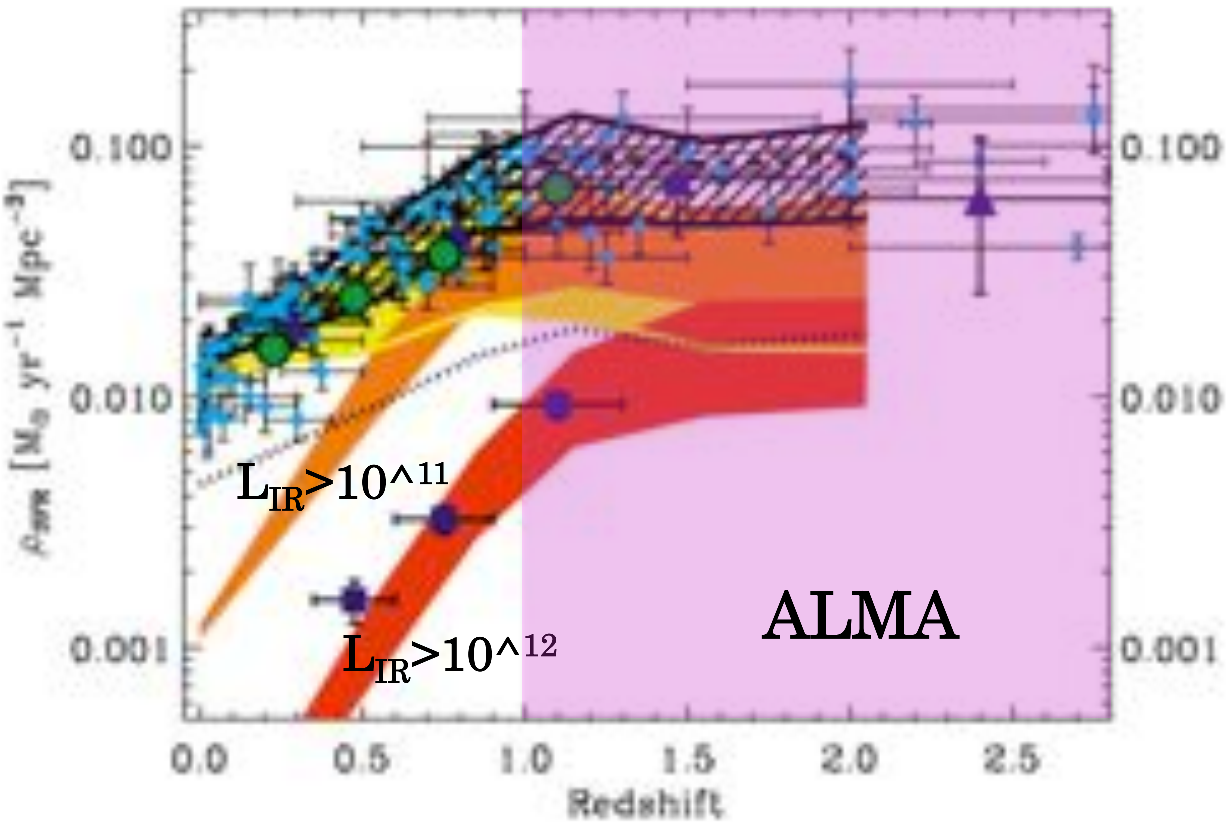
PDR fitting of [CII],CO, L_{IR}



Rigopoulou+13

Softer radiation fields compared to local counterparts
Caution! AGN?

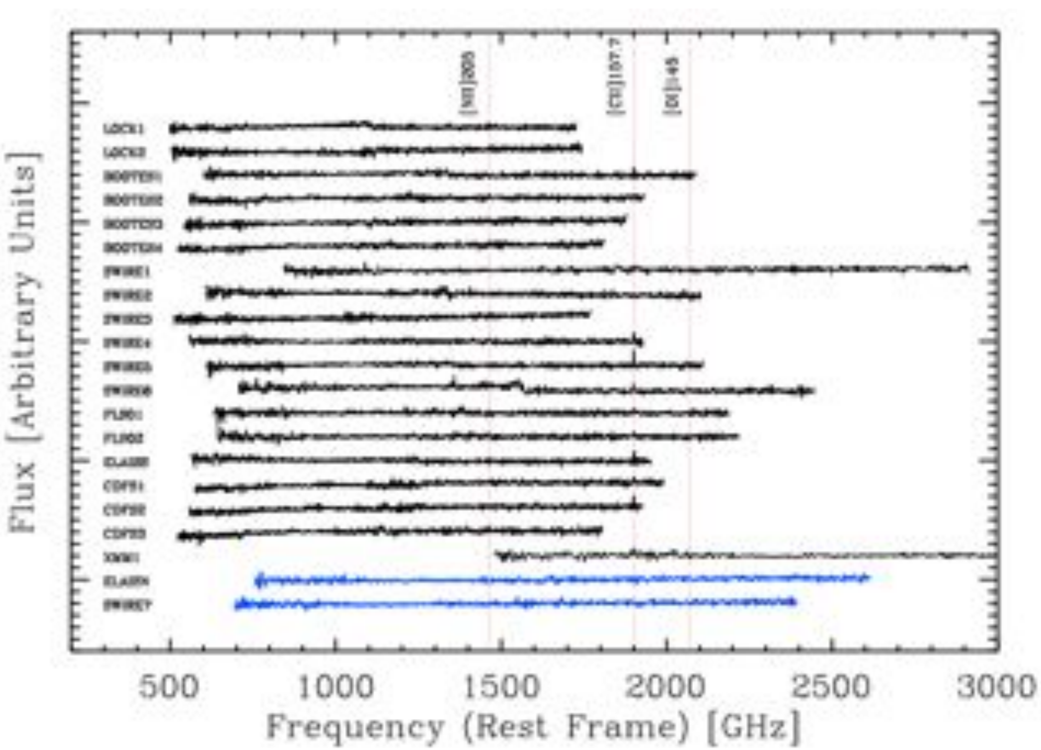
[CII] emission

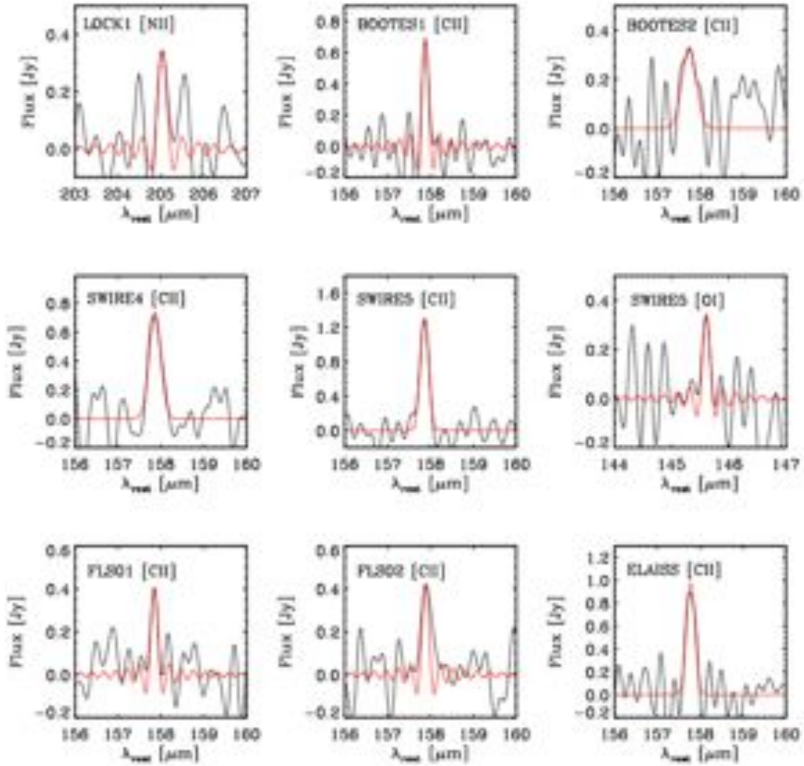


- We are building the picture at the one end of the evolution
- Need high resolution observations in the local and intermediate redshift ($0.0 < z < 1.0$) universe

Far-IR spectra of 0.2<z<0.6 (U)LIRGs

- Selected 0.2<z<0.8 (U)LIRGS
- Follow up with FTS onboard Herschel ([CII] and other lines)





(Magdis +14)

H_2 in the first galaxies

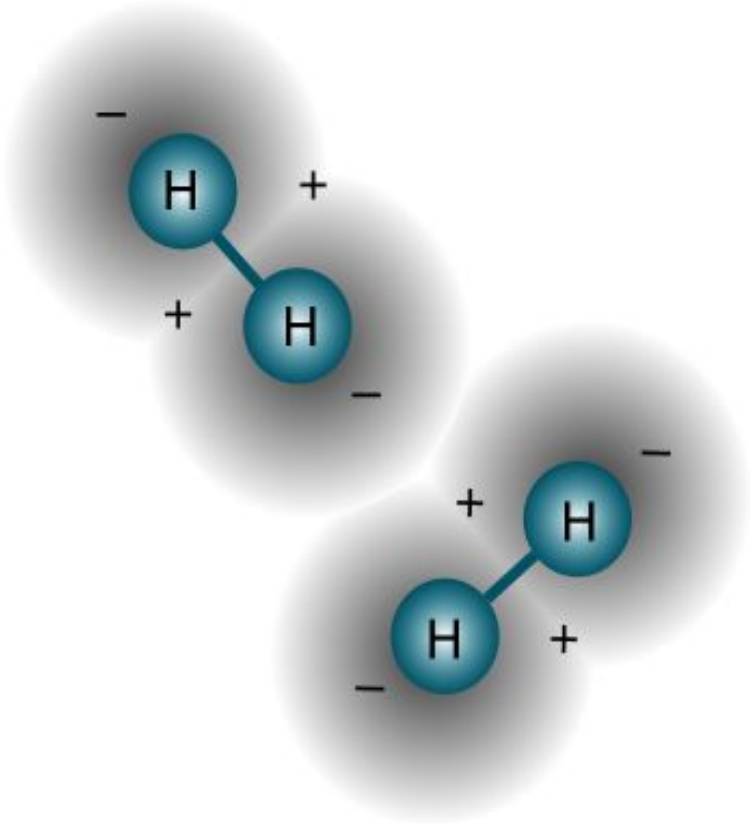
Probe pristine gas in proto-galaxies through detection of the pure rotational H_2 28 and 17μm lines

- 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:

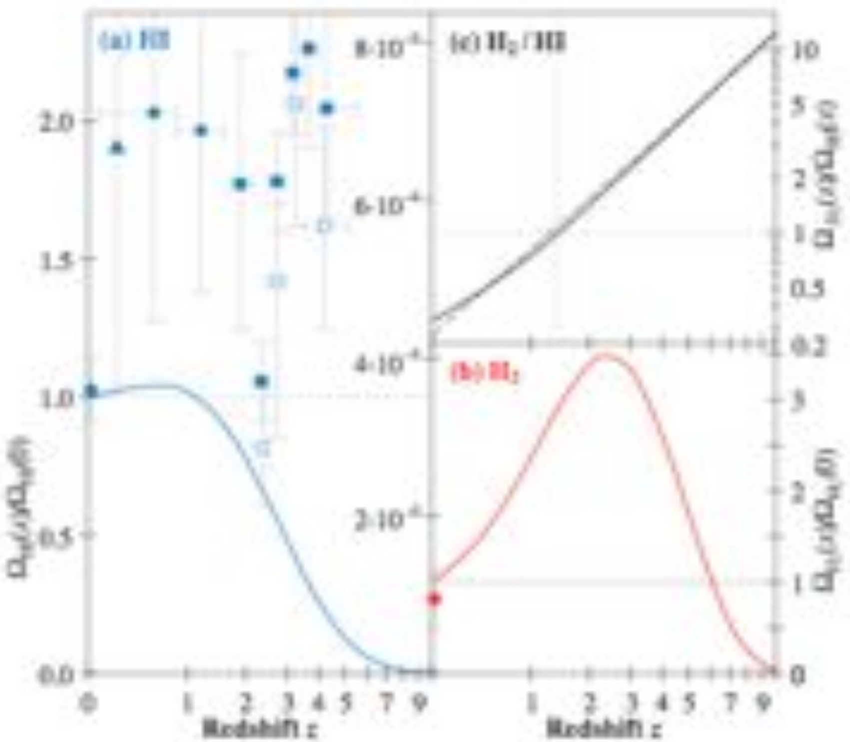
- H_2 formation on grains initiates chemistry of ISM
- Major contributor to the cooling of astrophysical media



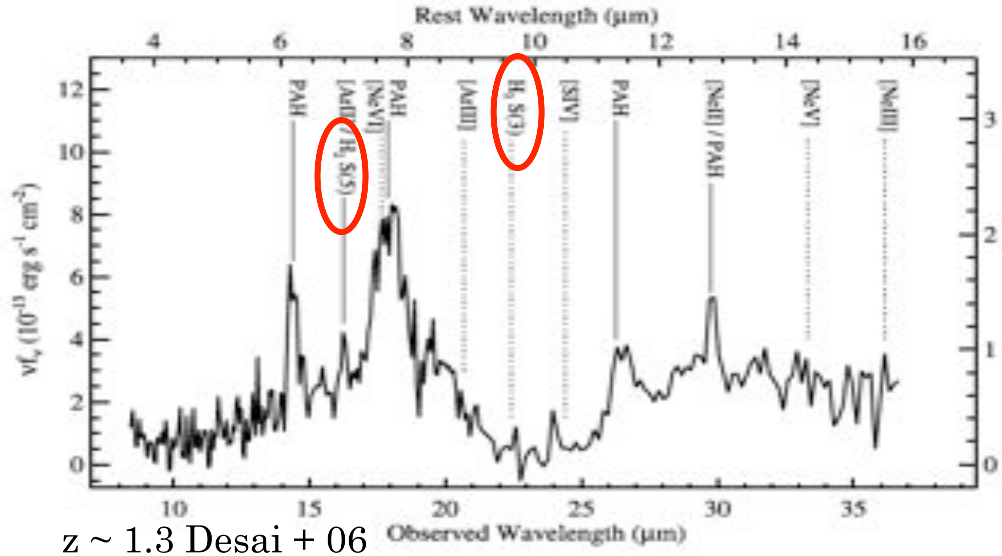
H_2 in the first galaxies

Is there H_2 at high-z ?

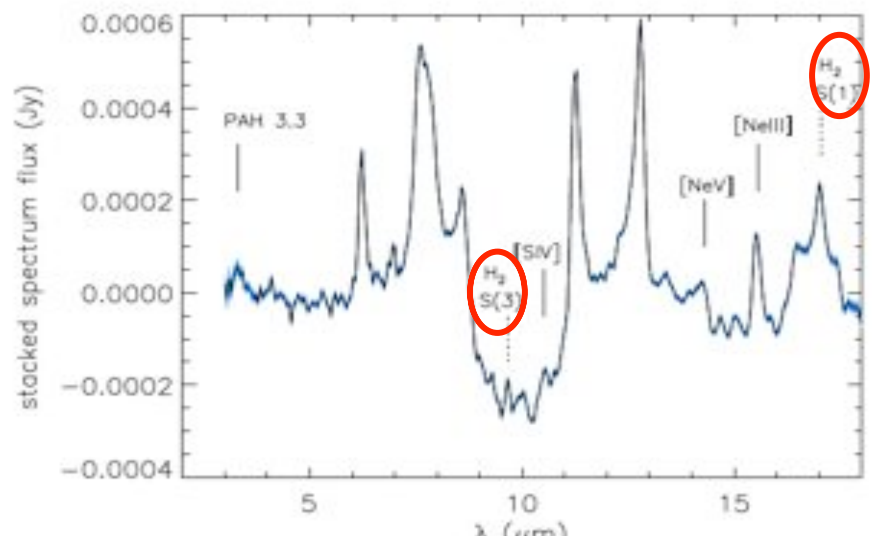
H_2 evolves strongly



Obreschkow & Rawlings 09

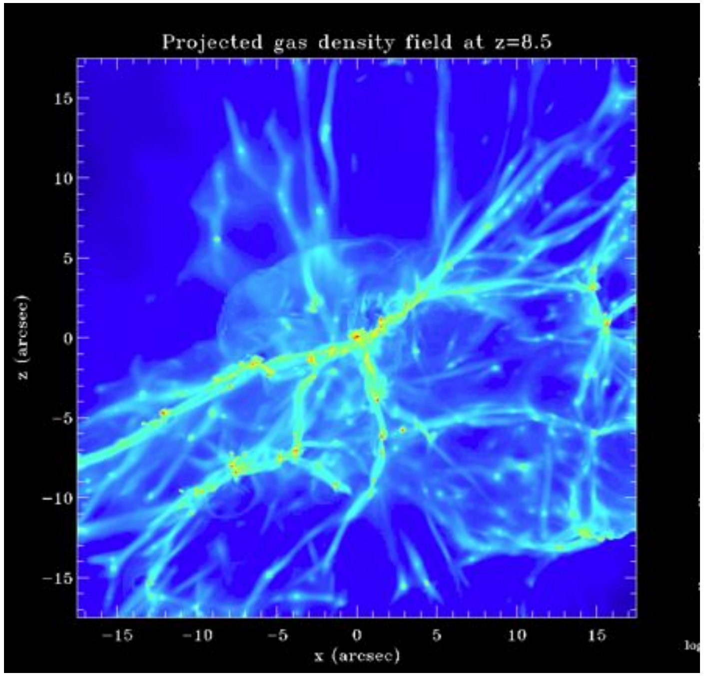


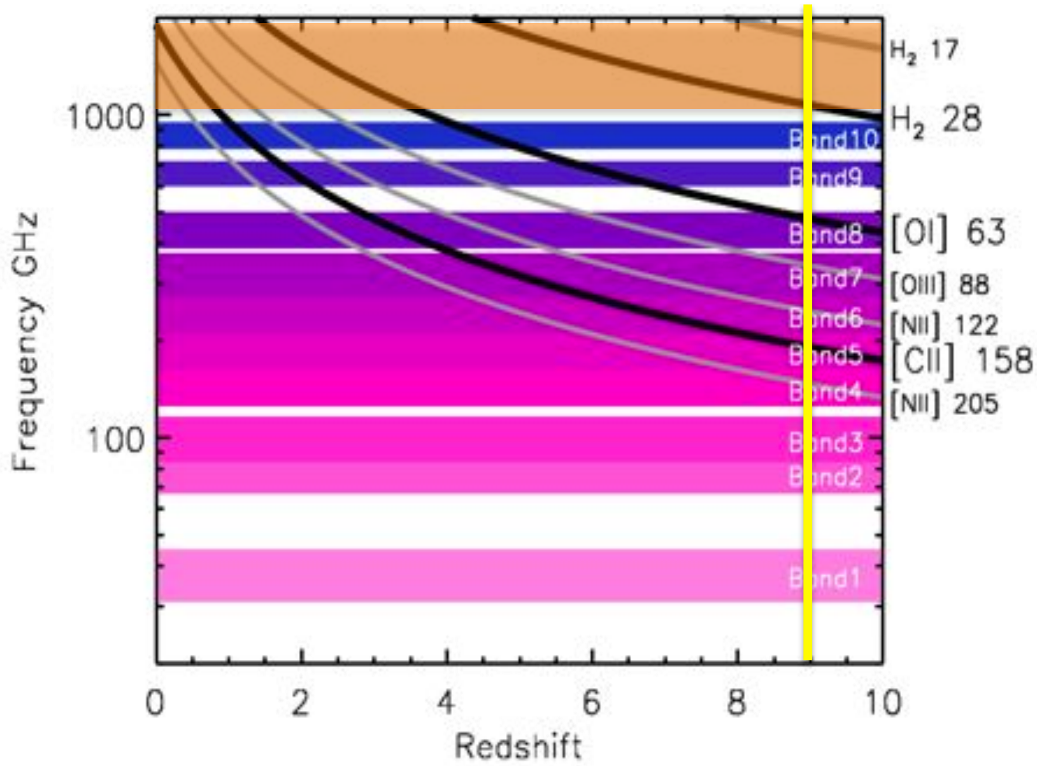
z ~ 1.3 Desai + 06



z ~ 1 Dasyra + 09

H_2 in the first galaxies





Summary

- Trace SF through spatially resolved observations of PAHs and MIR lines
- Trace SB– AGN connection
- Trace the distribution/geometry of the warm dust
- Study cooling mechanisms of the ISM through FAR-IR lines
- Detect H_2 building blocks

Thank you