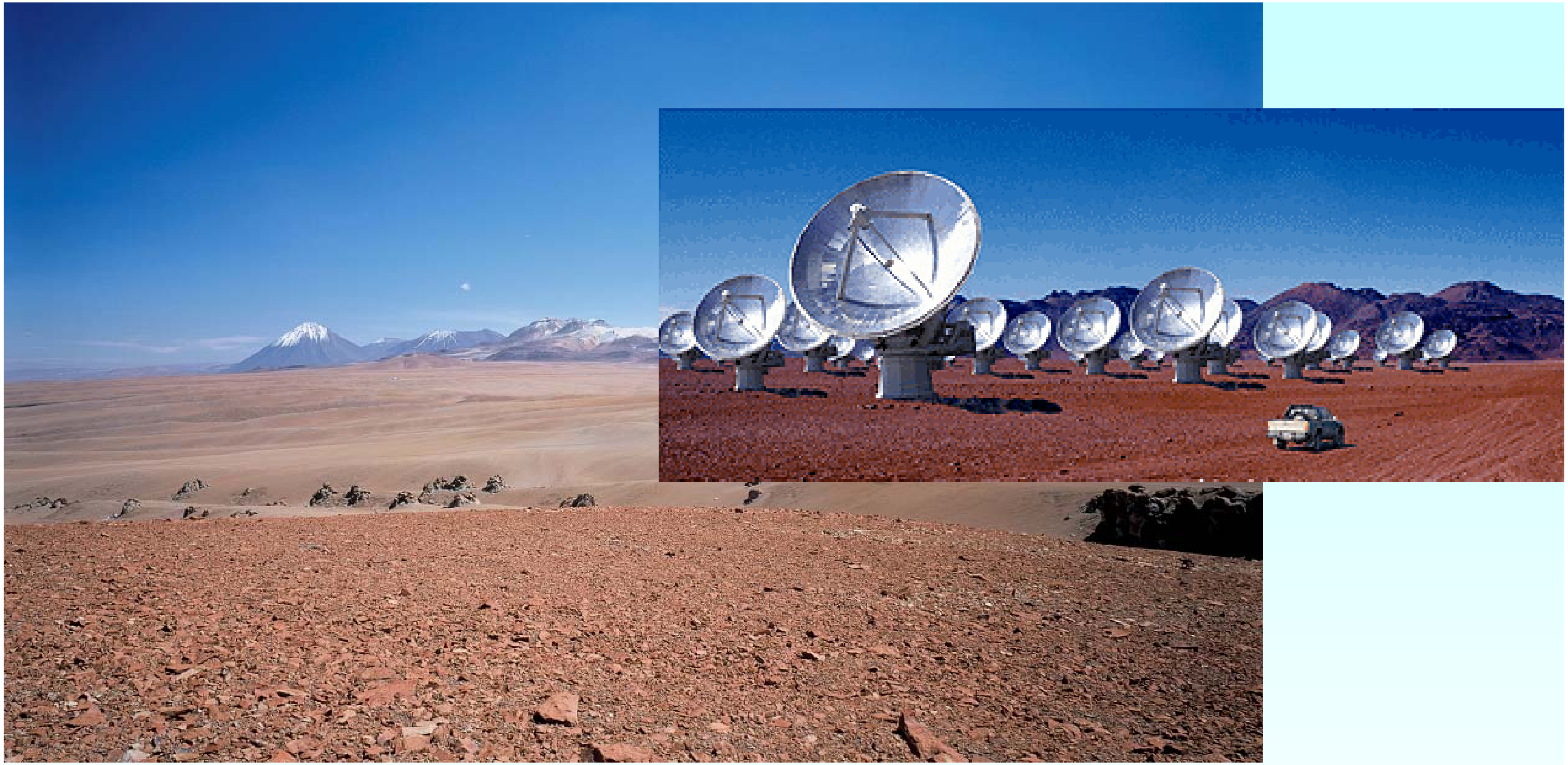


Fenêtres ouvertes par ALMA

Françoise Combes

Observatoire de Paris

PNG, 1er Avril 2008

ALMA et les galaxies

➔ Premières galaxies z> 5
sortie de l’âge sombre

➔ Histoire de la formation d'étoiles

➔ Matière noire des galaxies (évolution)

➔ SZ pour détecter les amas à tous z

➔ Exploration des systèmes d’absorption

+ galaxies proches, milieu interstellaire, etc..

Capacités d’ALMA

➔50 x 12m, bases de 200m à 14km, 3mm à 0.3mm
(facteur ~6 en surface par rapport à IRAM)
➔4 Bandes de fréquence au début
84-116 GHz, 211-275 GHz, 275-370 GHz, 602-720 GHz
Bande passante de 8GHz/polar

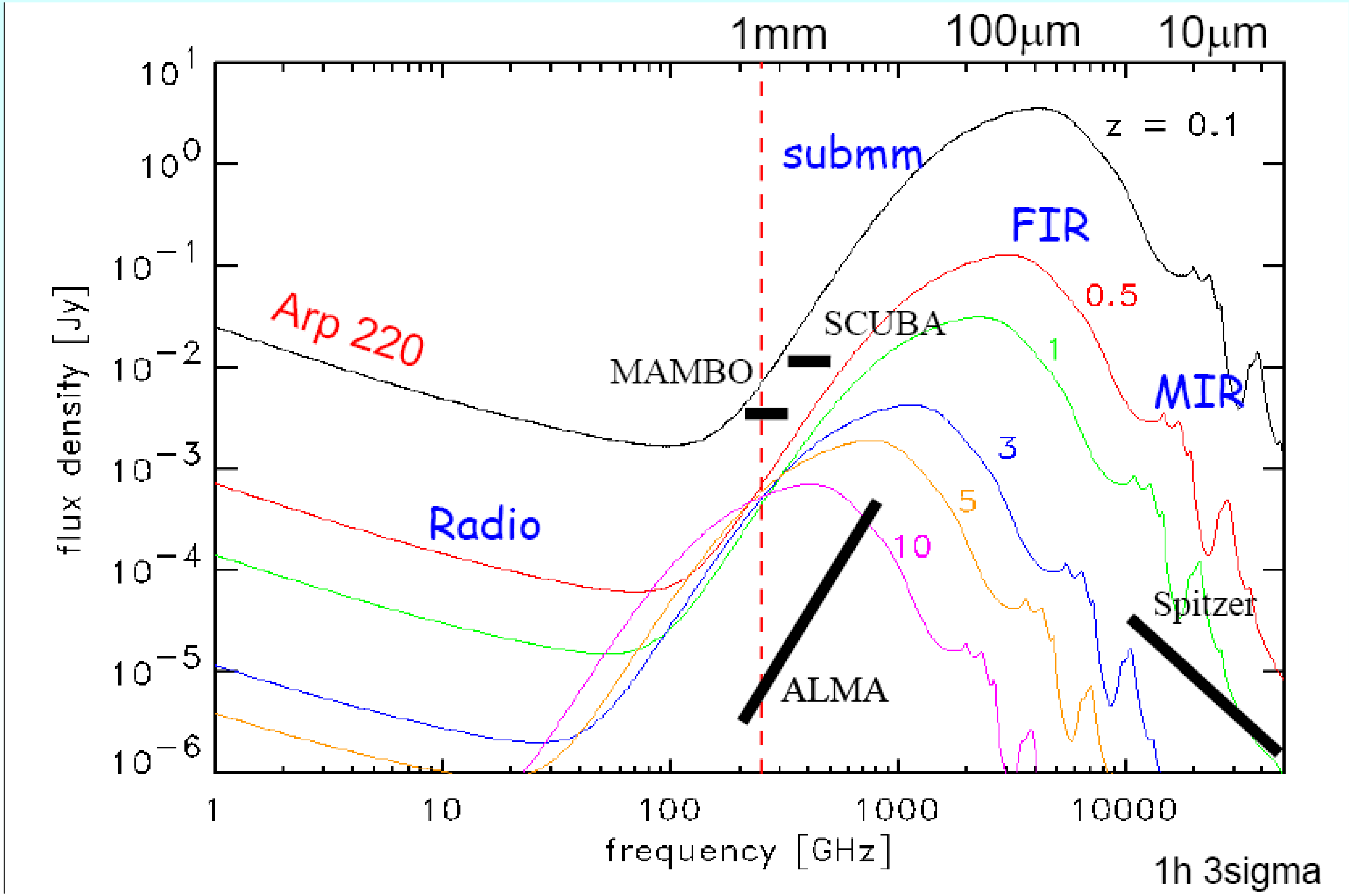
Résolution spatiale, jusqu’à 10mas,
Résolution spectrale jusqu’à R=10^8
Dynamique de 128x128 à 8192x8192 pixels

Petit Champ: de 1arcmin (3mm) à 6 arsec (0.3mm)
Possibilité de mosaïques

Early Science? En question **En 2012-3:** Full Operation

Intérêt du domaine mm/submm

Correction K négative: exemple de Arp 220



Galaxies à grand redshift

➔Pour les galaxies à grand z, les basses fréquences seront privilégiées

➔A 3mm (115GHz), champ de 1 arcmin x 1 arcmin
Le plus courant 300x 300 = 90 000 pixels/spectres
(idem pour PdB IRAM)

Bande passante 2x 8GHz ~ 16%, ou ~50 000km/s
Possibilité d'avoir plusieurs raies
de l'échelle de rotation de CO, ou autre molécule..

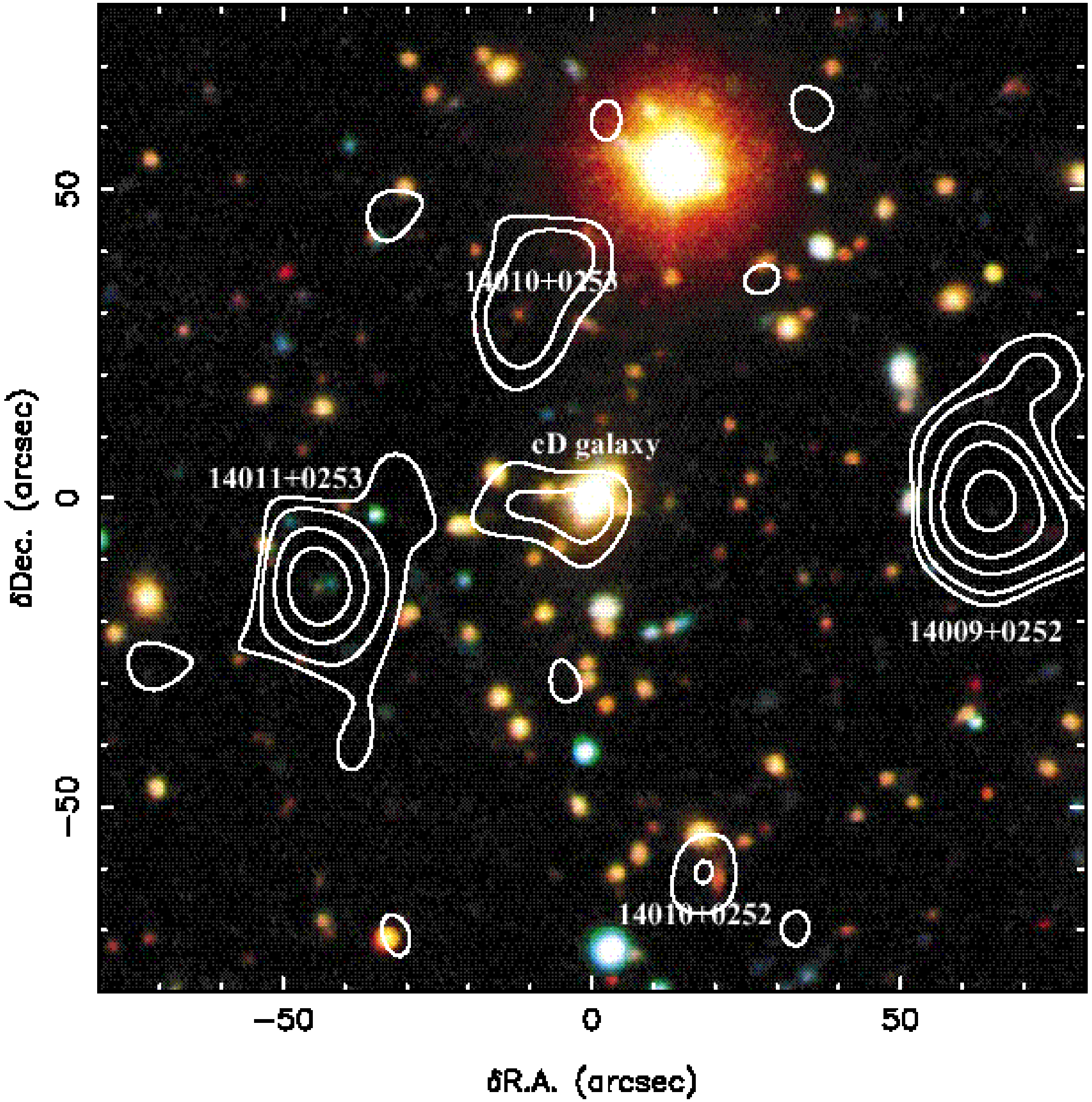
@z =6, l'espacement entre raies de CO est de 16 GHz.
Avec 2 tunings, on obtient une « redshift-machine »

Abell 1835, sources Scuba (Ivison et al 2000)

Beaucoup de sources submm (0.85mm) n'ont pas de contreparties optiques

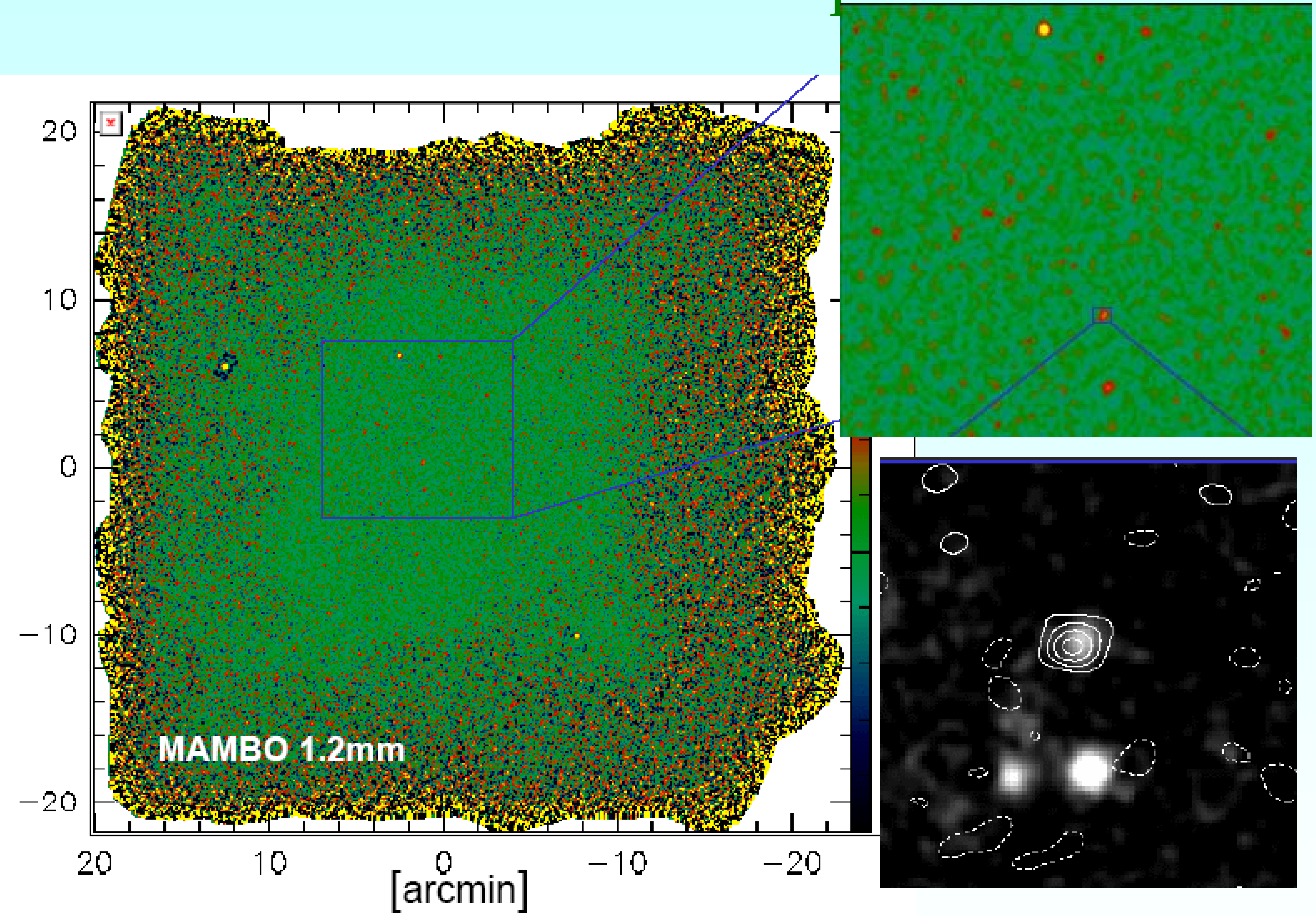
L'apport de plusieurs longueurs d'ondes est fondamental

MUSE + JWST+ELT-30m +ALMA



SCUBA ou MAMBO deep fields

Etat de l'art
aujourd'hui



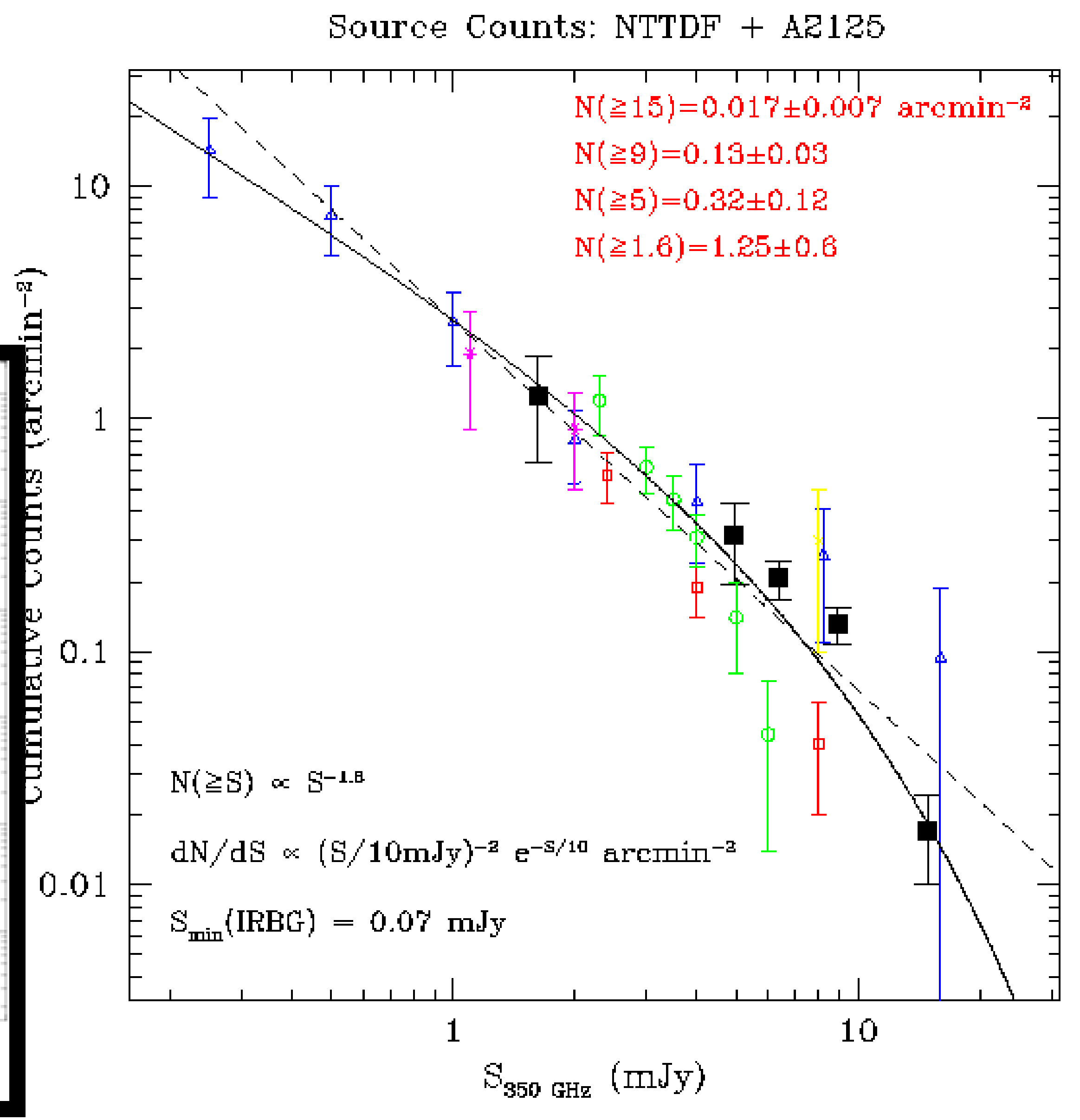
NIR (K)

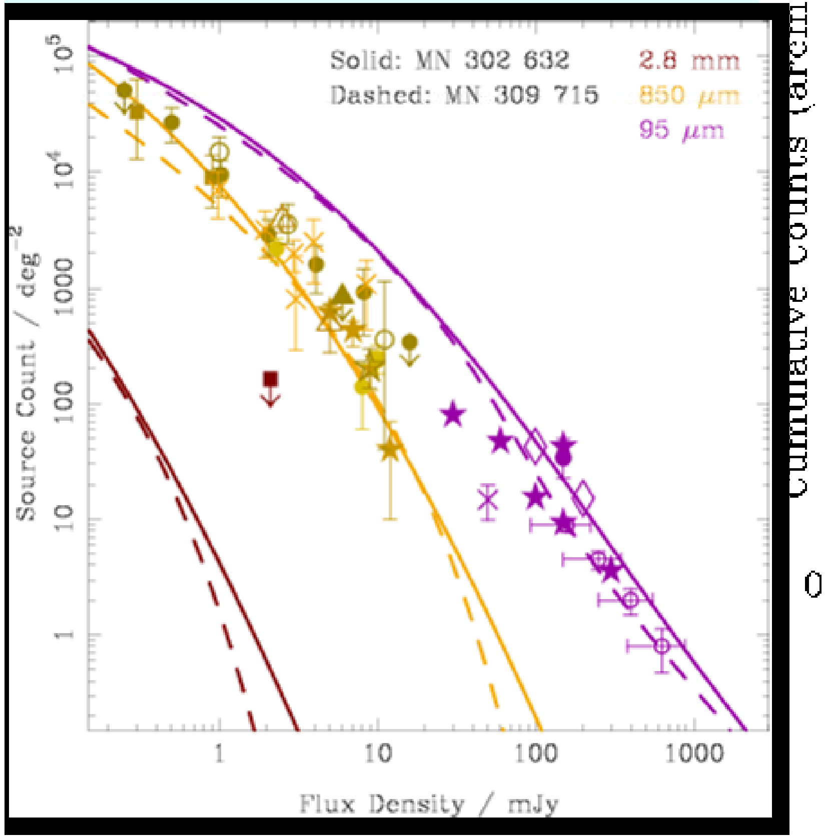
Bertoldi et a
Mambo on
IRAM-30m1.2mm

Surveys continuum mm

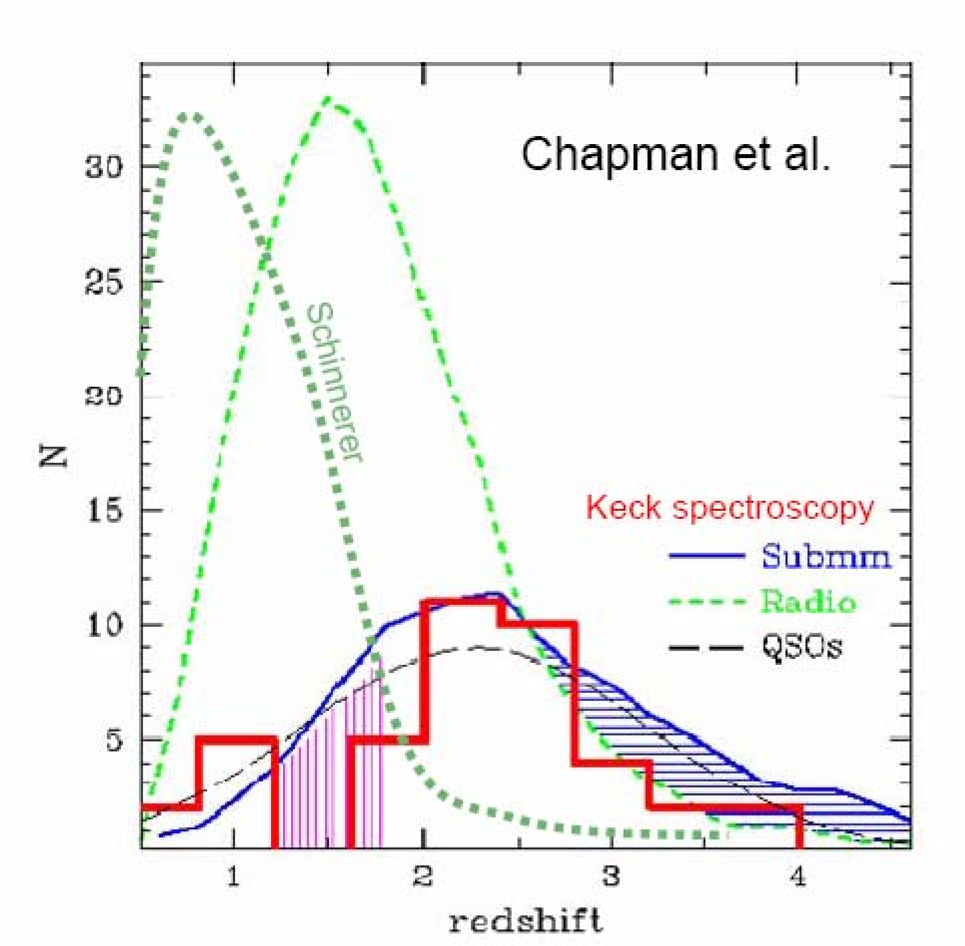
1-2 sources/ arcmin2 above 1 mJy

(e.g. Carilli et al. 2001, Blain 2004)





Distribution of Identified sources



Chapman et al 2003, 2004

z=1.5 redshift desert

High-z: lack of
high mass sources

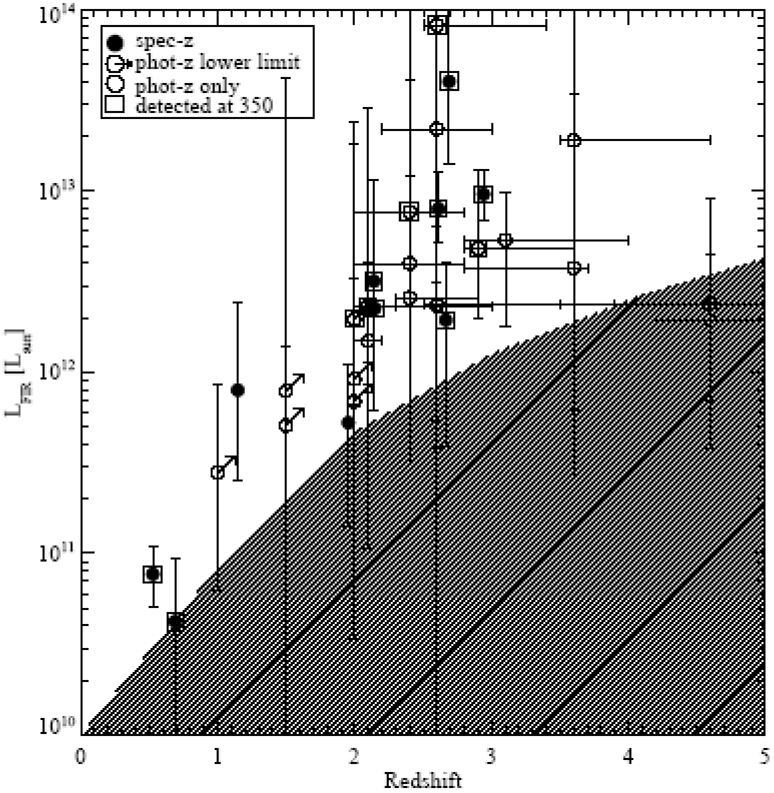
Identification due
to VLA radio sources,
and optical redshifts

Radio selection introduces bias against z >3

SHADES survey: 850µm and 350µm

Coppin et al 2008, follow up @ 350µm of 30 sources (rms 2mJy)
SCUBA Half Degree Survey (0.25 deg^2) ➔ 120 SMGs detected

Typical z ~2-3, degeneracy column density – temperature



Average temperature 35K
L_{FIR} 2 10^{12} Lo
SFR 400 Mo/yr

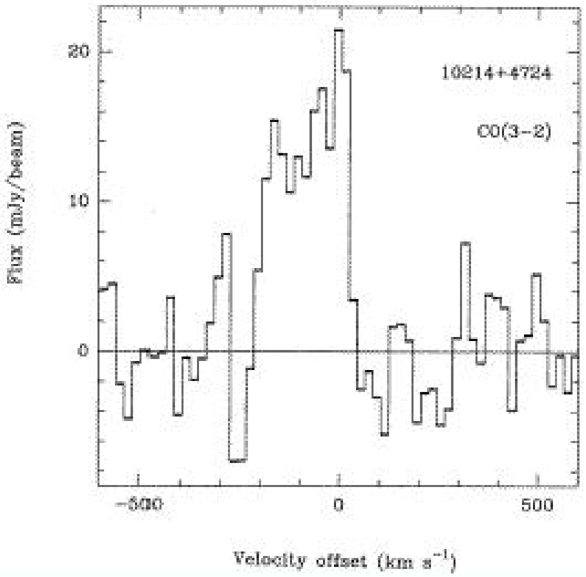
Luminosity evolution obvious

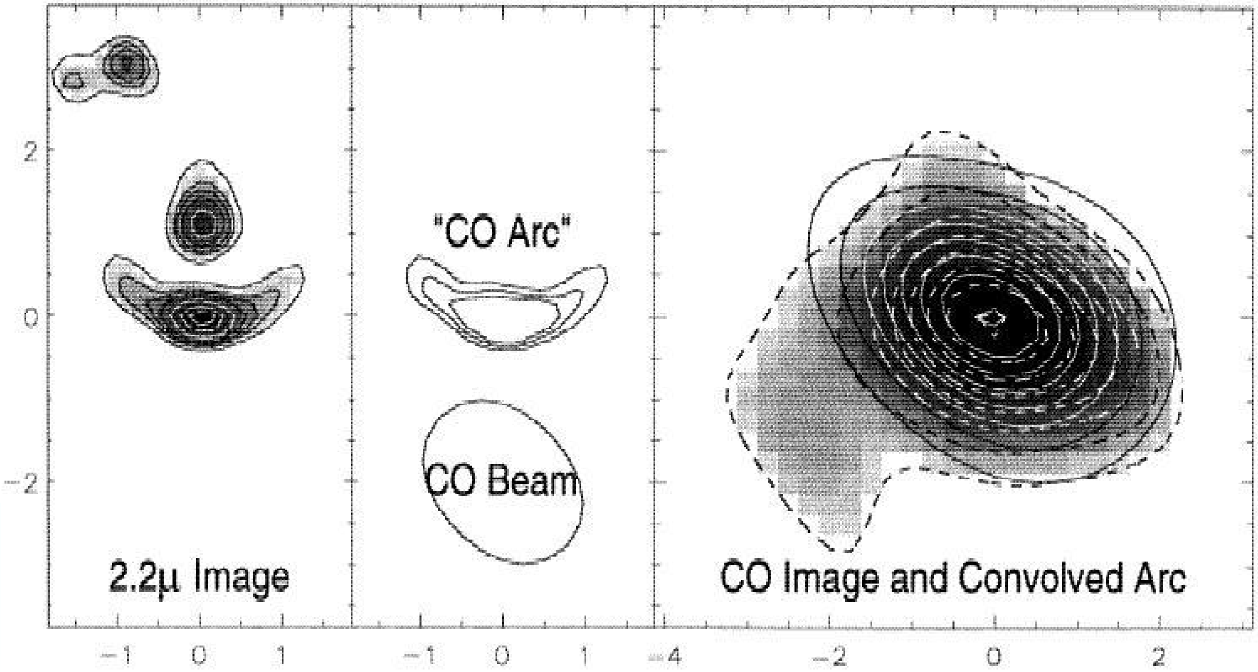
Not yet known whether SED evolution or selection effects

Observations des raies CO

Emission CO: ~40 sources à gd z (2008)

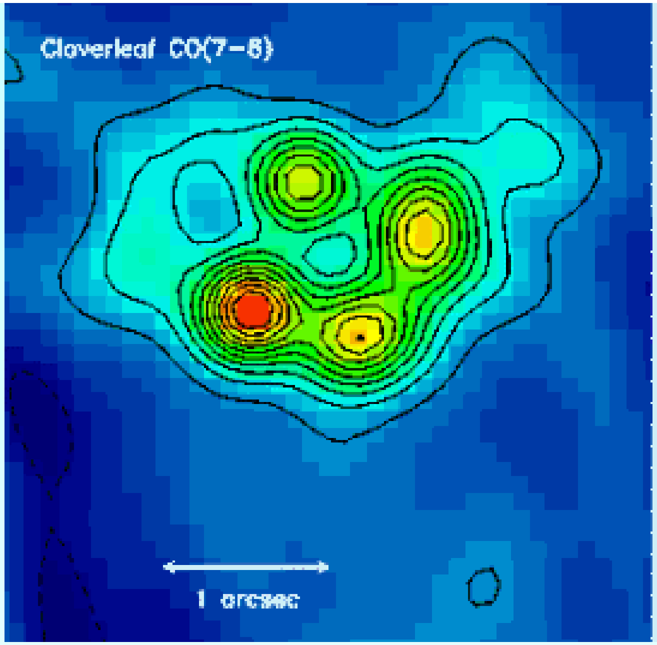
1ère détection: Faint IRAS source
F10214+4724 à z=2.3 (Brown & van den Bout 92, Solomon et al 92)



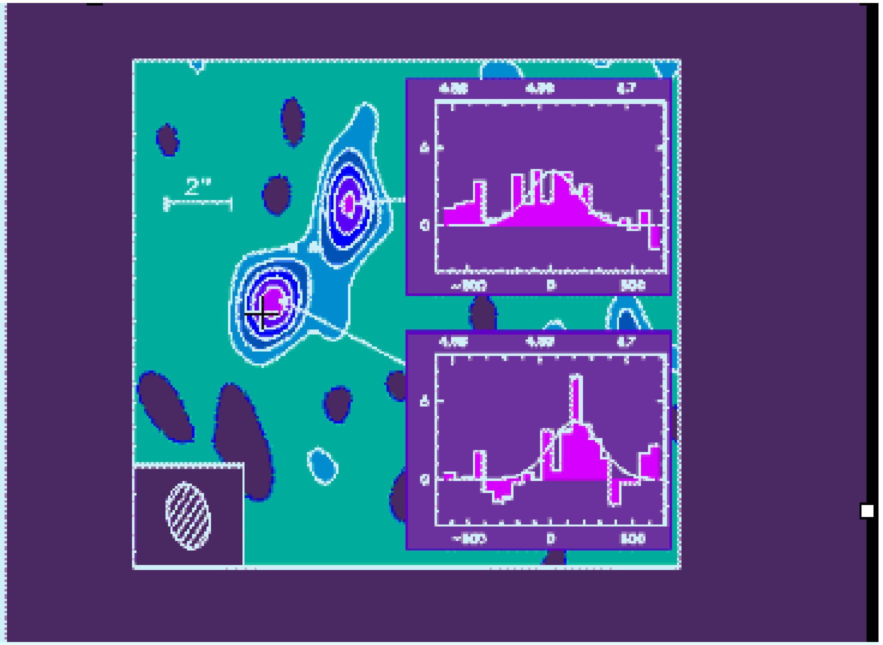


Downes et al 95

Raies CO à
haut J



Kneib et al 98

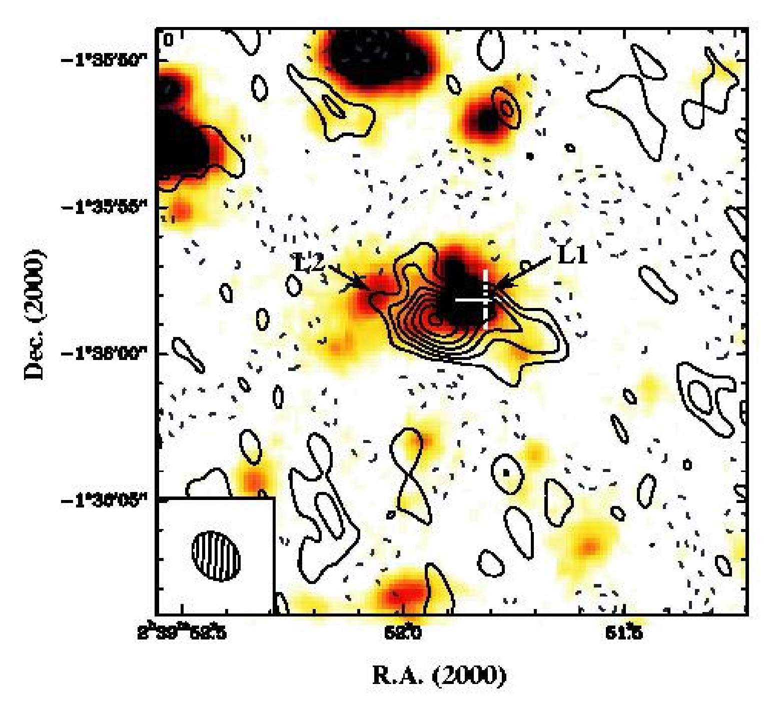


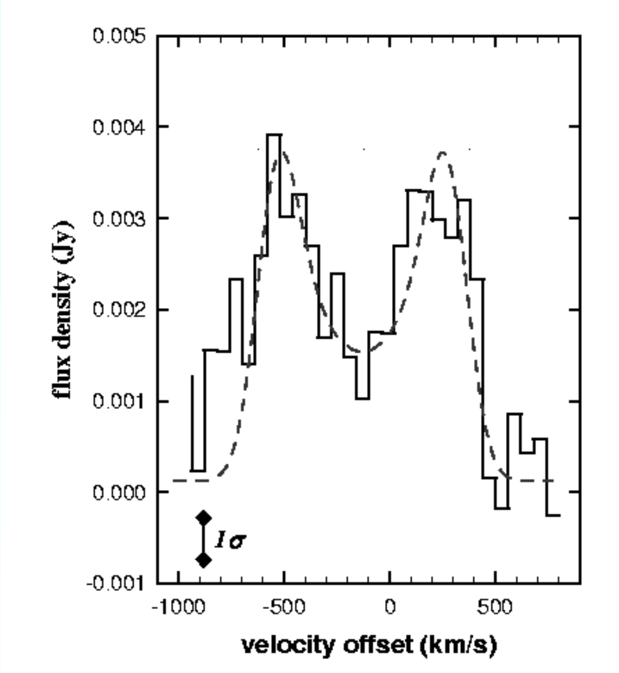
Omont et al 96

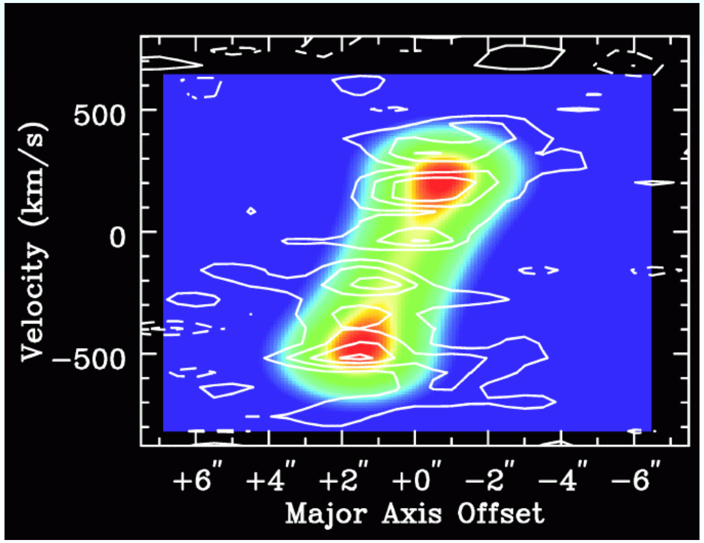
Avantage par
Rapport au HI
(hydrogène
atomique)

Plusieurs quasars ou objets ultra-lumineux IR ou submm,
avec amplification gravitationnelle, le plus souvent
On remonte 93% de l’ âge de l’ Univers
➔ enrichissement très tôt en éléments lourds

Suivi des SMM: spectro Keck

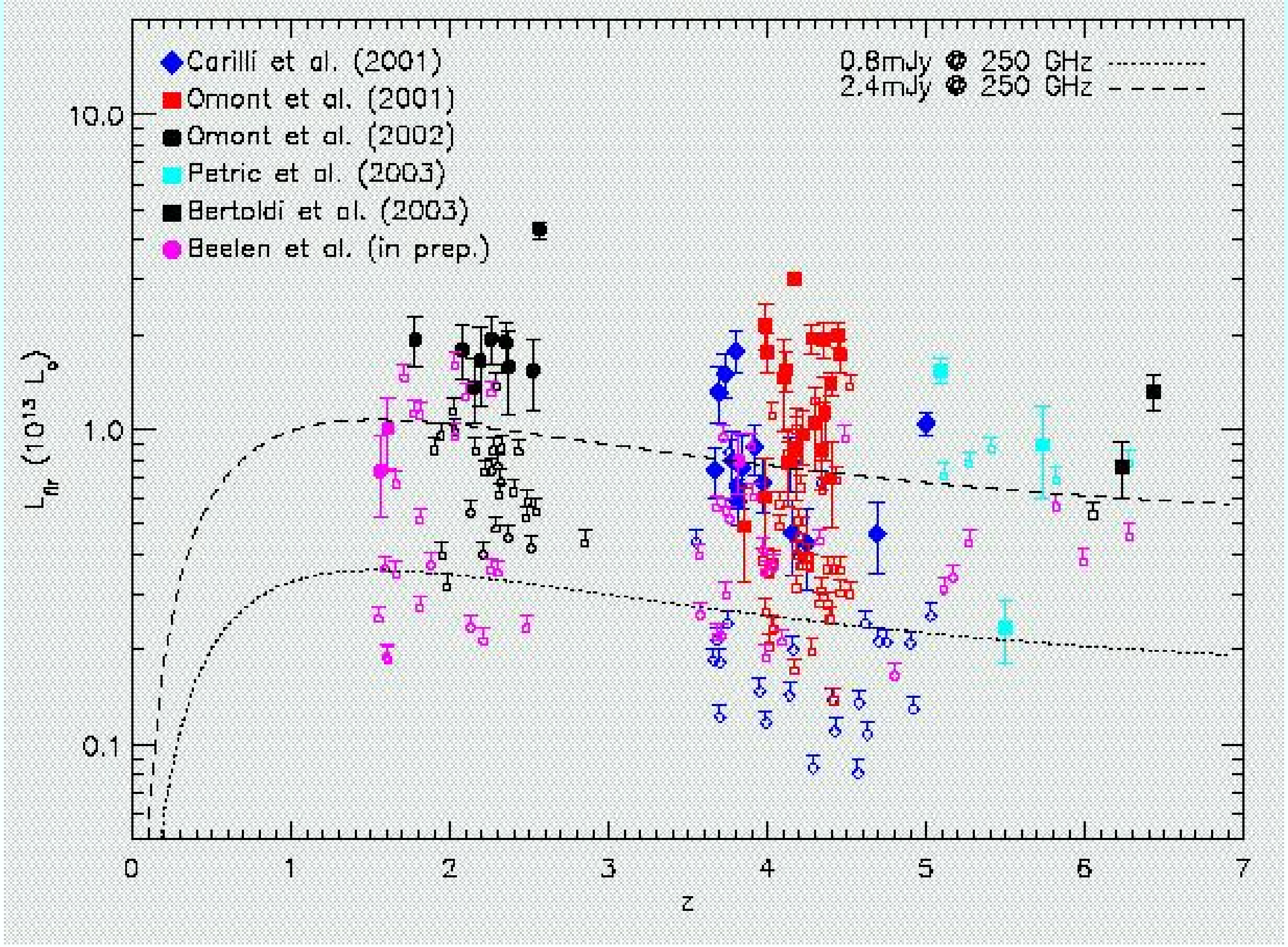






SMM J2399-0136
Frayer et al (1998) CO(3-2)
z=2.808
Genzel et al (2002) IRAM-PdB
Amplification de 2.5

High-z Quasars (30% détectés à z> 1.8)

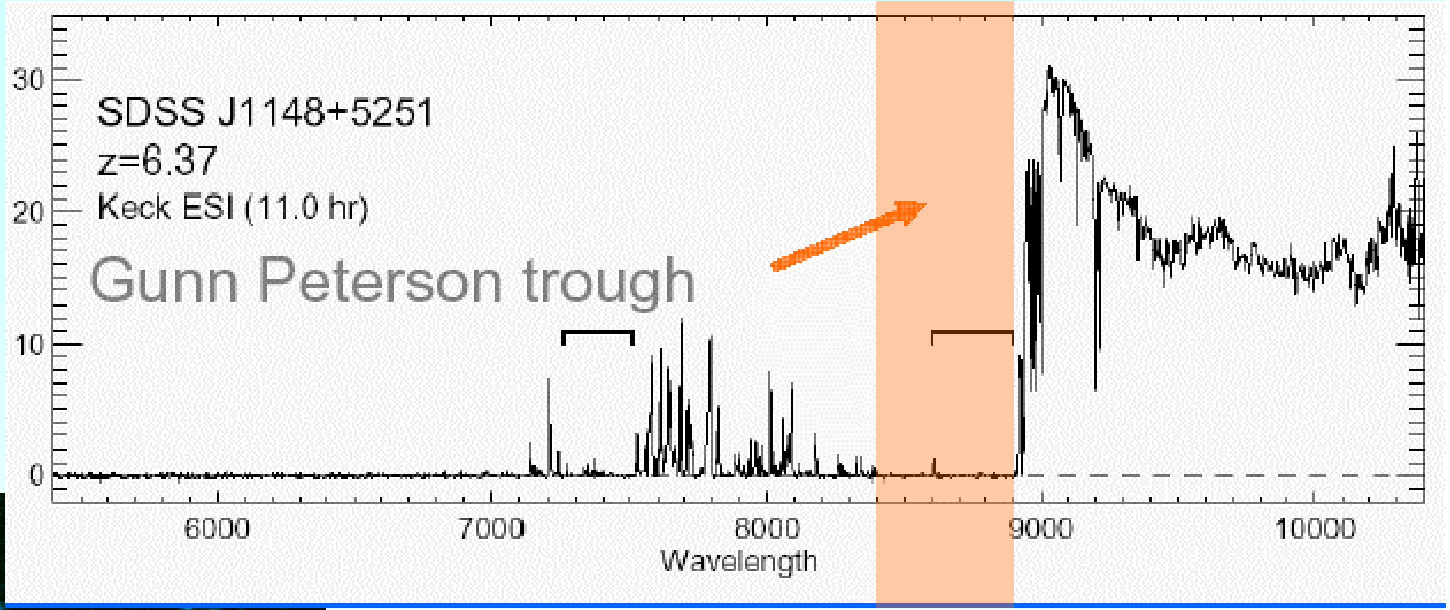


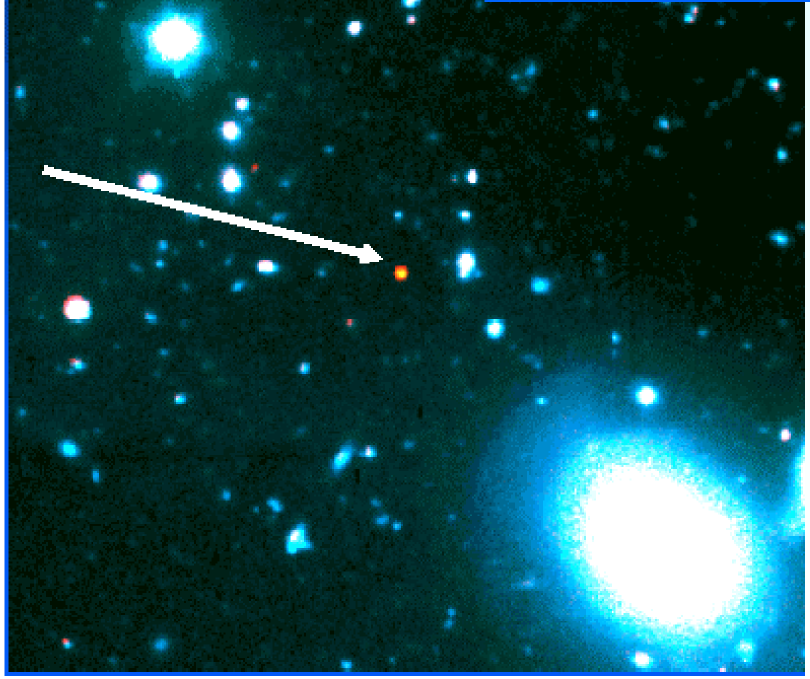
Beelen et al (2004)

The most distant QSO at z=6.4

Age ~ 1 Gyr

Keck z-band
Djorgovski et al



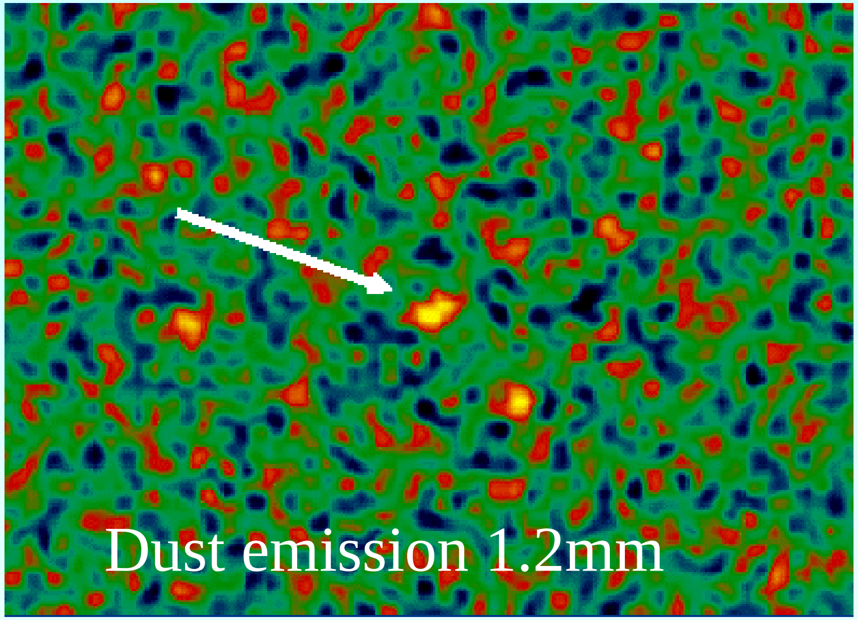


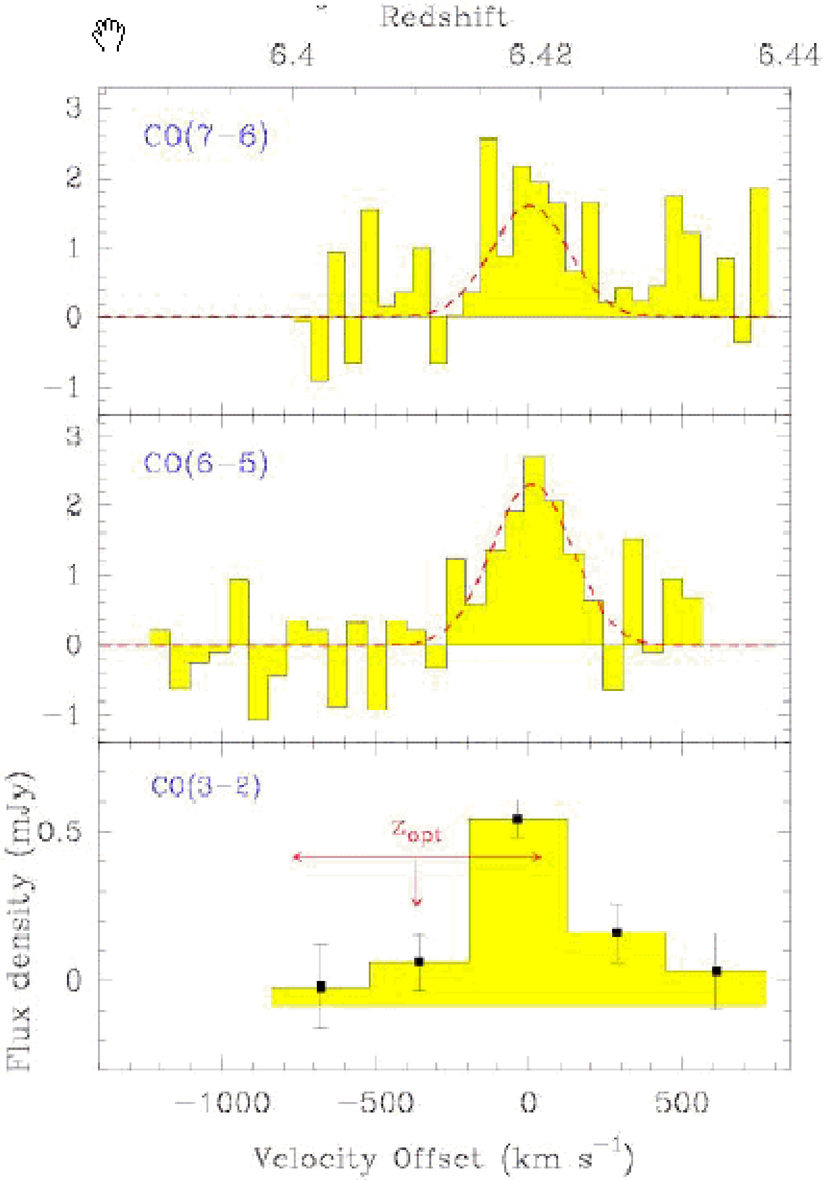
Fan et al 2003, White et al 2003

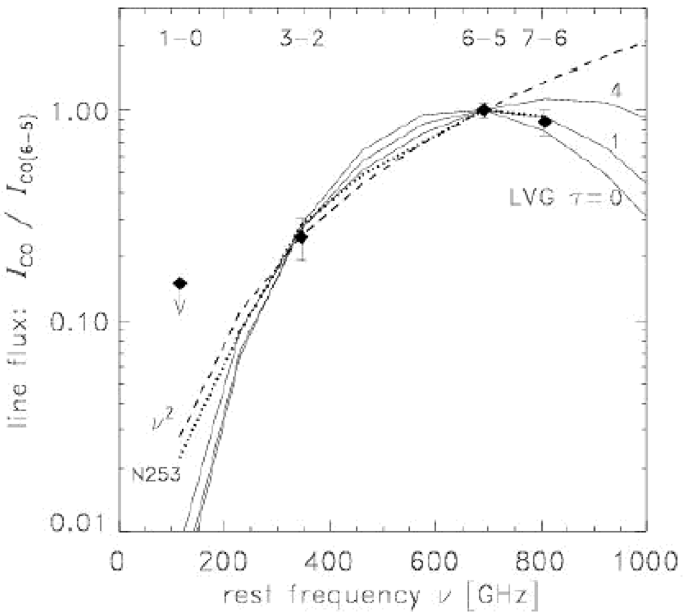
M_{dust} ~10^8Mo (Bertoldi et al 2003)
M_{BH} = 1.5 10^9Mo (Willot et al 2003)

SDSS 1148+5251 QSO z=6.4

M= 2 10^{10} Mo H_2







LVG

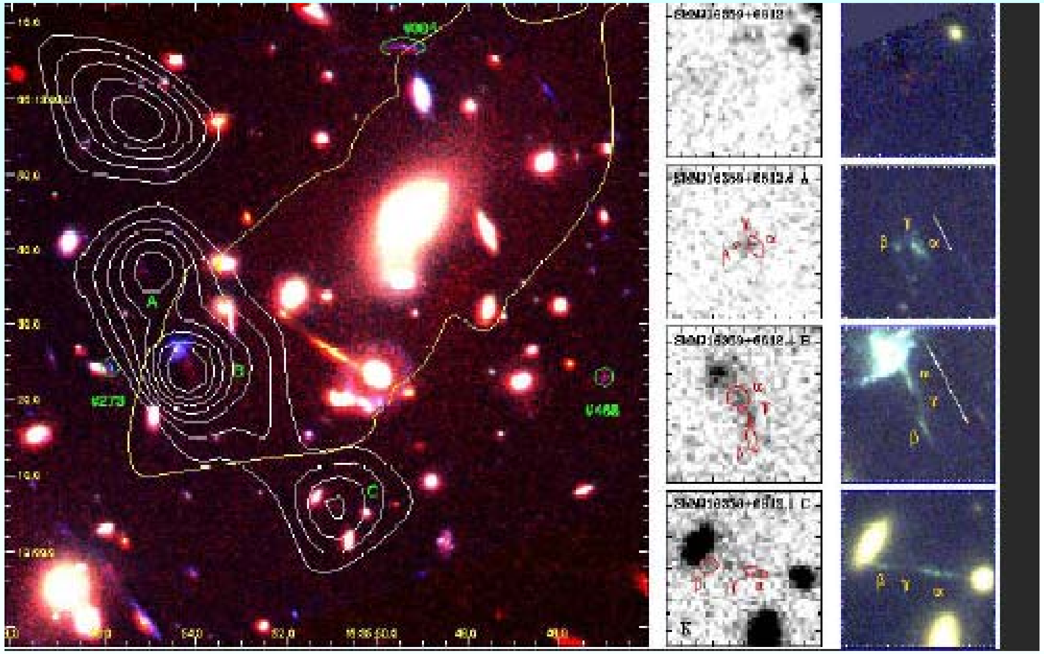
7 10^4 cm^{-3}

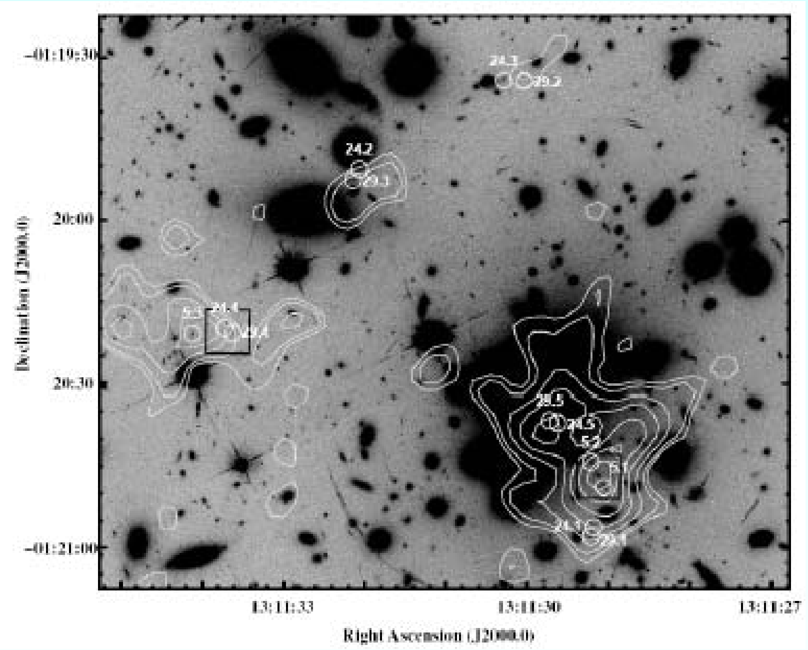
T= 100K

-- N253

Use of the gravitational telescope

5 strong SMG, lensed with S(350GHz) < 1 mJy



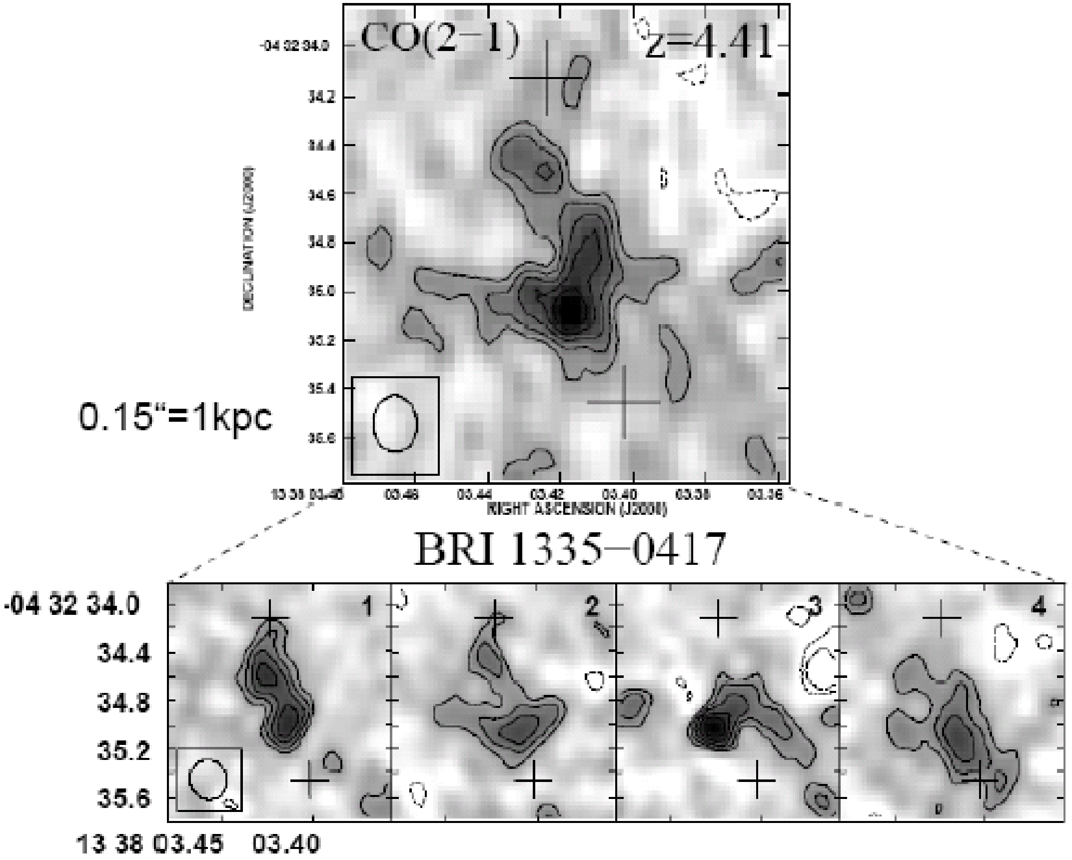


Abell 2218, Kneib et al 04

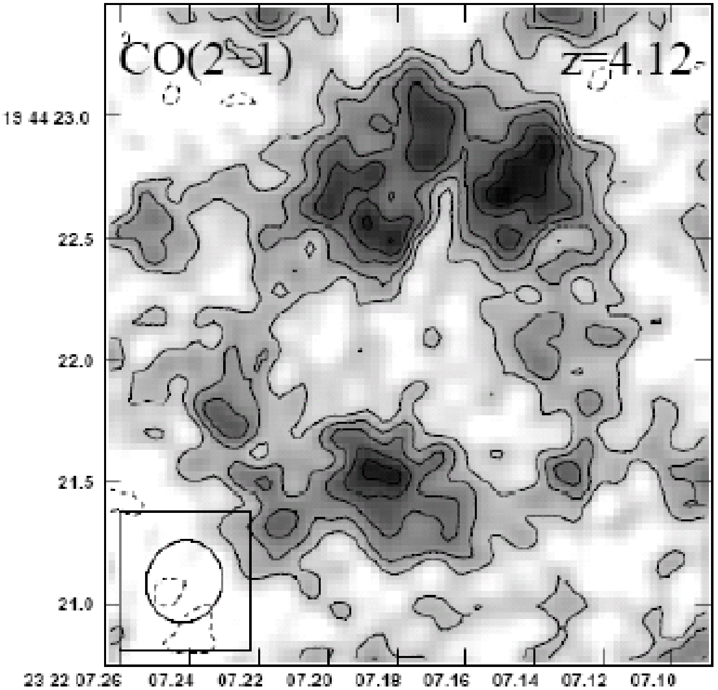
Knudsen et al 07

Molecular and atomic gas at sub-kpc scale

Mergers of galaxies



BRI 1335−0417



PSS J2322+1944 (Einstein Ring)

Riechers, Walter, Carilli et al 2007

Cosmic eye

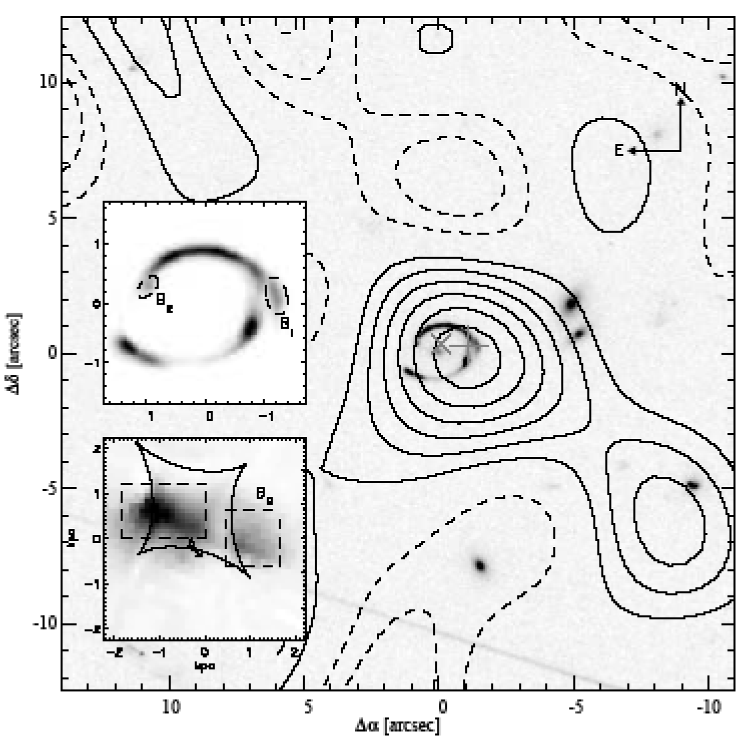
LGB @**z=3.07** Plateau de Bure CO(3-2) detection
(only the 2nd LBG, after cB58)
MH2 = 2.4 10^9 Mo M* = 6 10^9 Mo (Spitzer mid-IR)

SFR = 60Mo/yr life-time =40Myr
High-z analog of LIRGs

Magnification of 28
2 UV components, 3kpc apart
Coppin et al 2007

Dynamical mass ~10^{10} Mo
But inclination uncertain

HST ACS

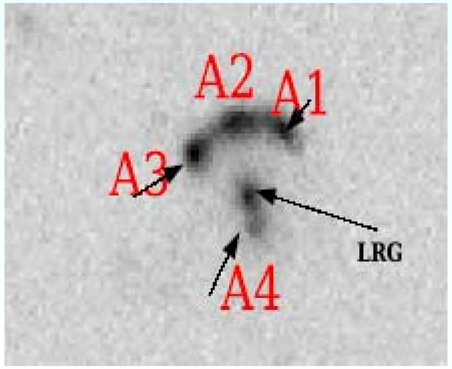


Star formation rate in LBGs

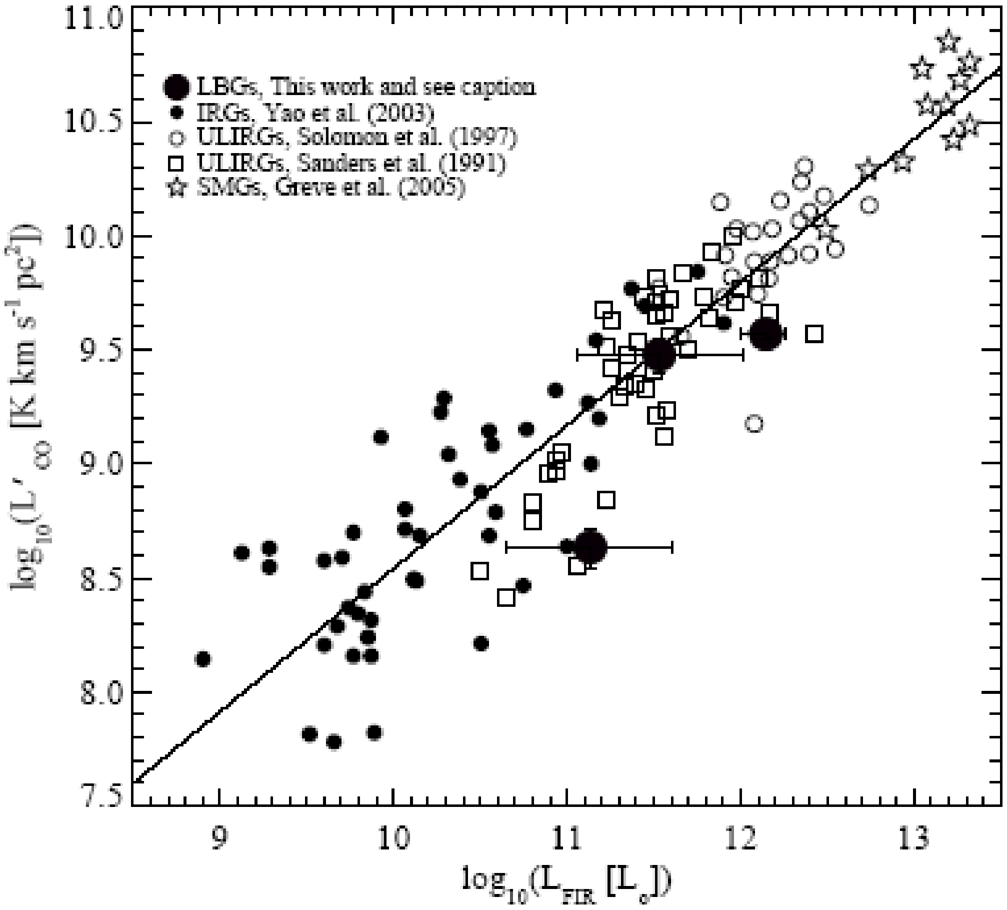
SFE ~140 Mo/Lo

LCO & gas mass
7 times higher than cB58

z=2.73

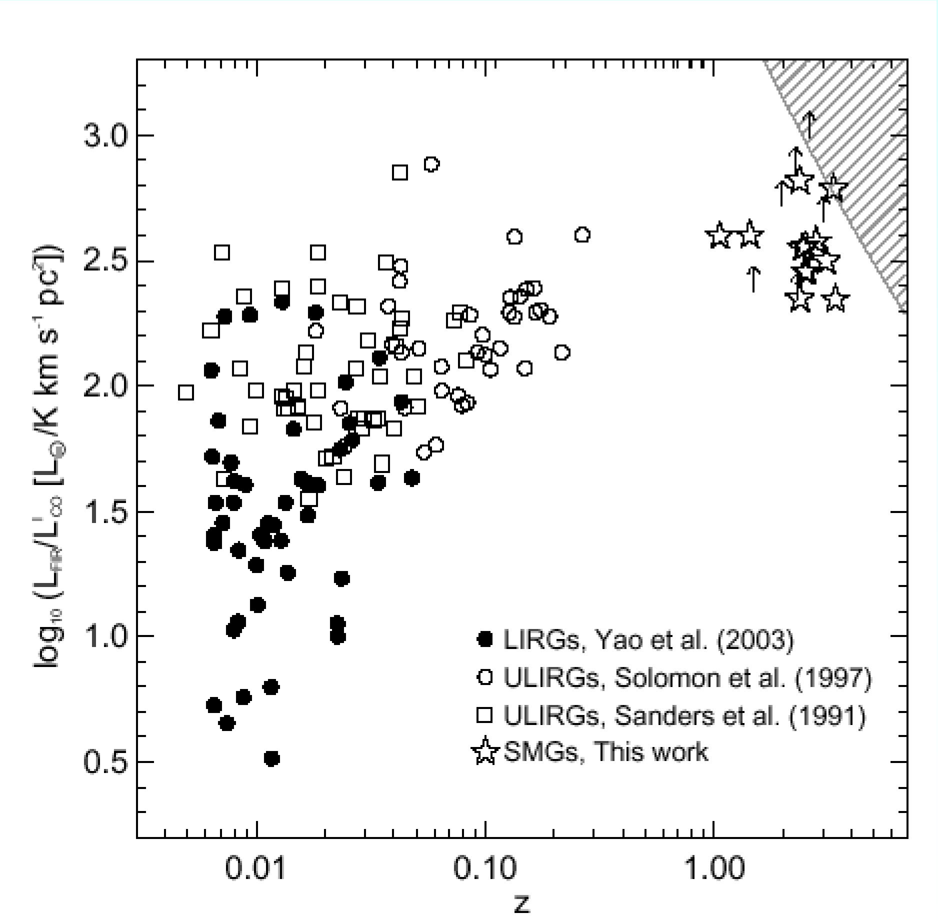


8 o'clock arc
Allam et al 2007



SMGs: Submillimeter Galaxies
Star formation efficiency L_{IR}/L'_{CO} vs z

Greve et al 2005



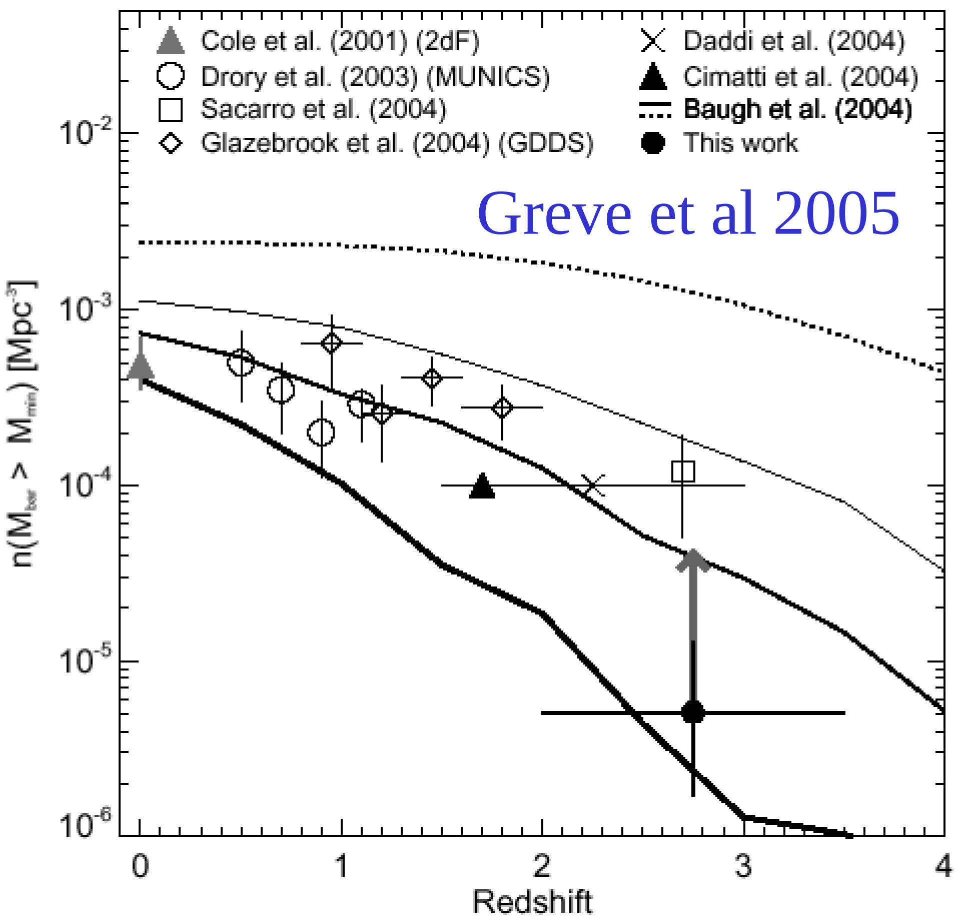
6 SMGs not
detected in CO

40- 200 Myr SB phase
SFR ~700 Mo/yr
More efficient than ULIRGs

Mergers without bulges?

Total masses ~0.6 M_*

Comoving number density of galaxies M_{bar} > 6 E10 Mo



Greve et al 2005

Models (Cole et al 01,
Baugh et al 04)
Recent top-heavy IMF
+SB at high z

Total baryonic mass
In dark halos > E11 Mo

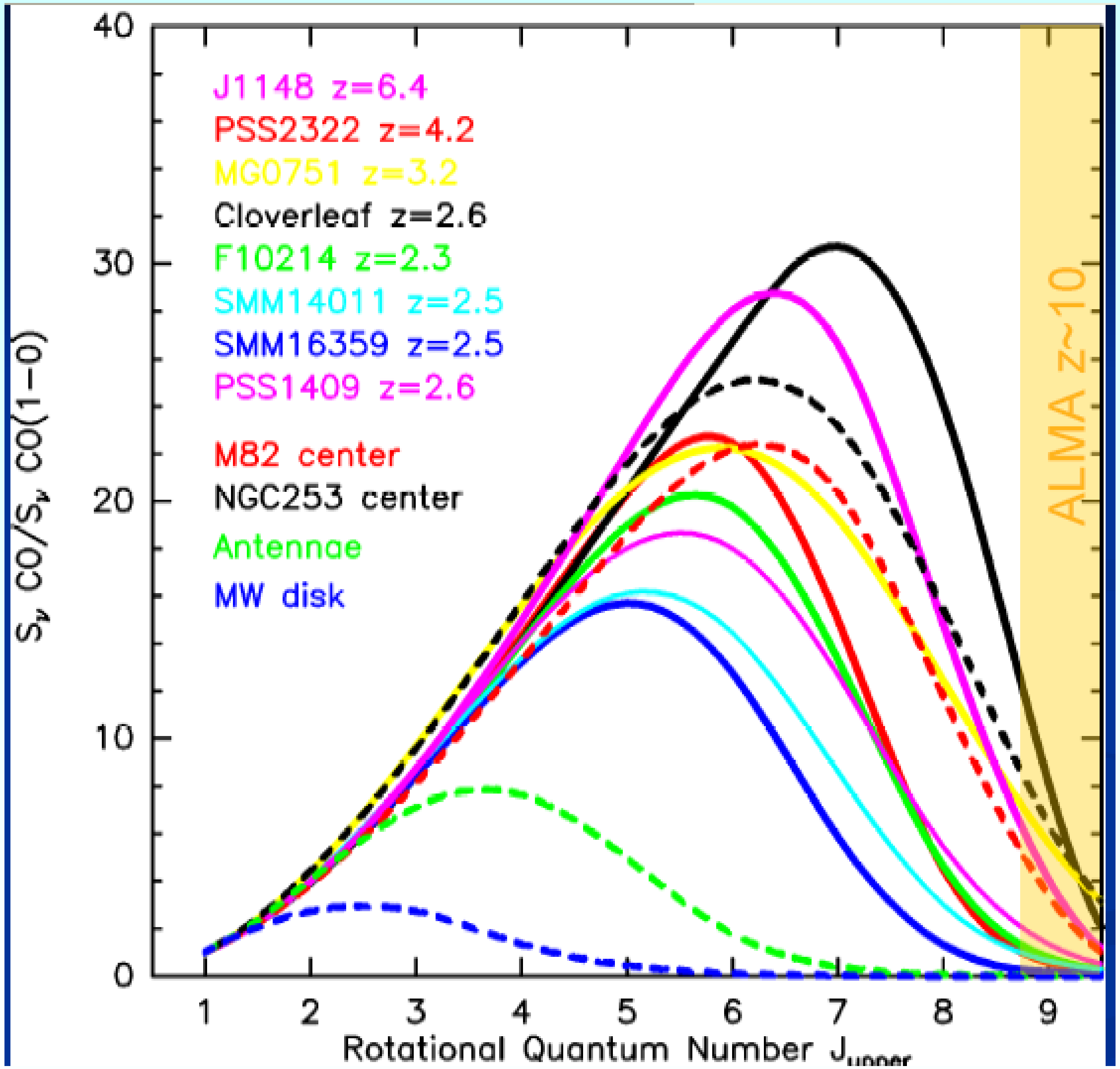
> 5 E10 Mo

> 7 E10 Mo

> 10 E10 Mo

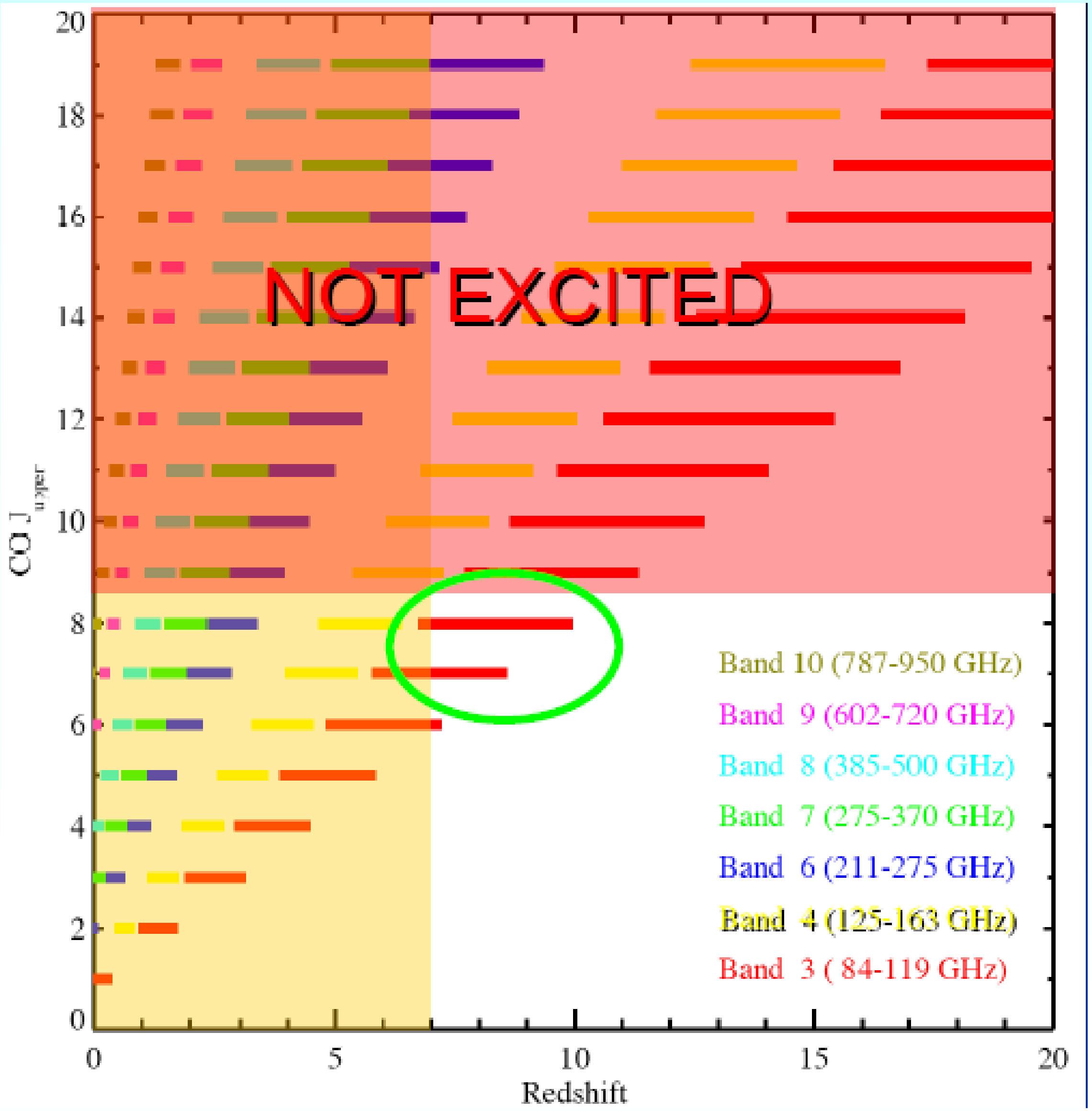
Compatible, if 10% baryons are rapidly converted into galaxies

Excitation in high-z starbursts



Weiss et al 2007

z> 7 sources: ALMA CO discovery space



Other lines CII 158 micron, CI, NII…

Difficult to predict: how much ionised/neutral gas? Optical depth?

Nagamine et al 2006: (HIM), WNM, CNM-
Anyway, can be used at larger frequency. Less numerous than CO
Not optimum for a z-machine

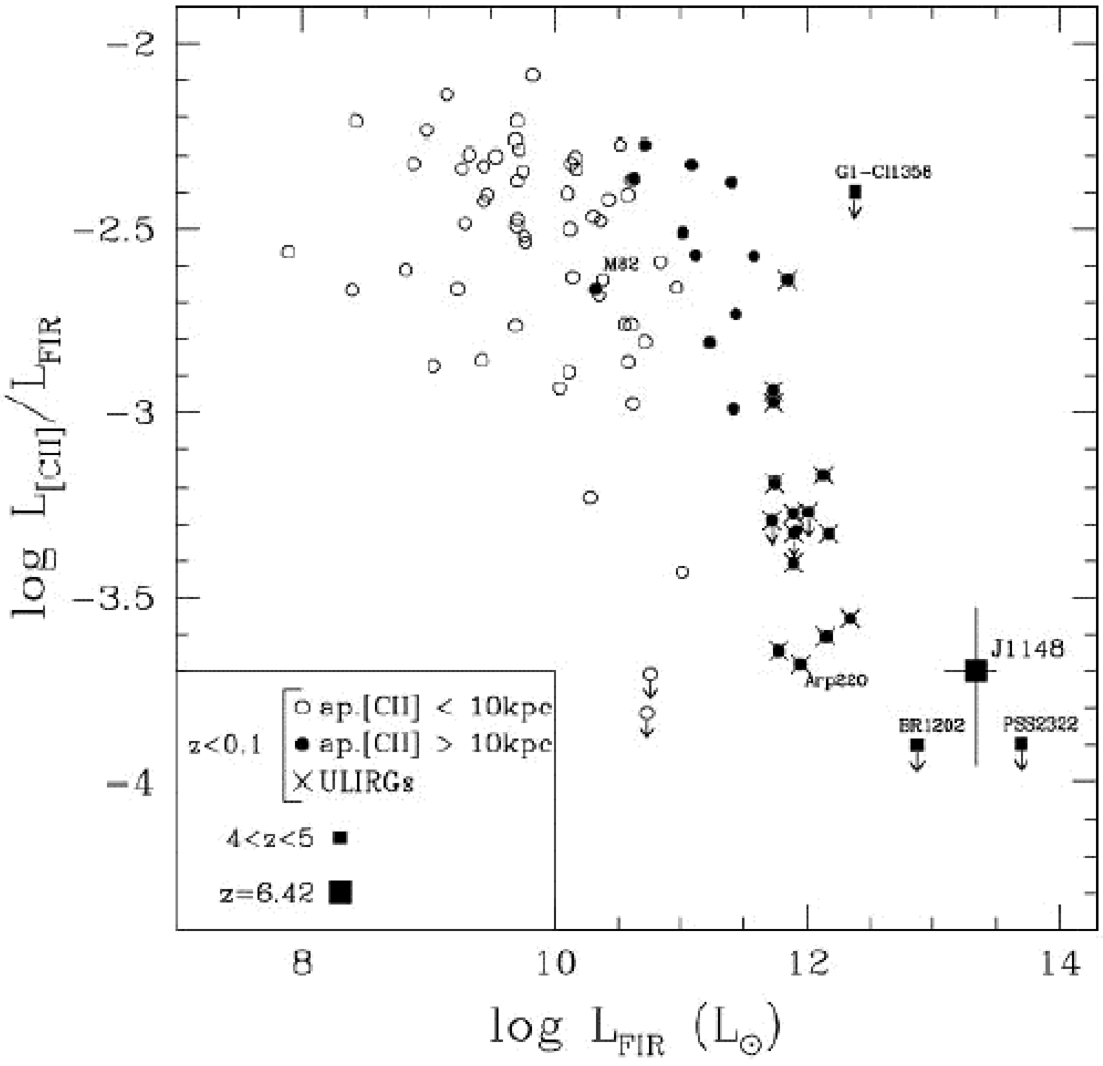
Sensitivity: detection of CO lines of 300km/s at 300 GHz, of 0.3 mJy, i.e. 10^{-21} Wm^{-2} at 5σ in 1hr with ALMA,
Lines spaced by 33GHz (if z=2.5), so about one source per $arcmin^2$, with a bandwidth of 16 GHz

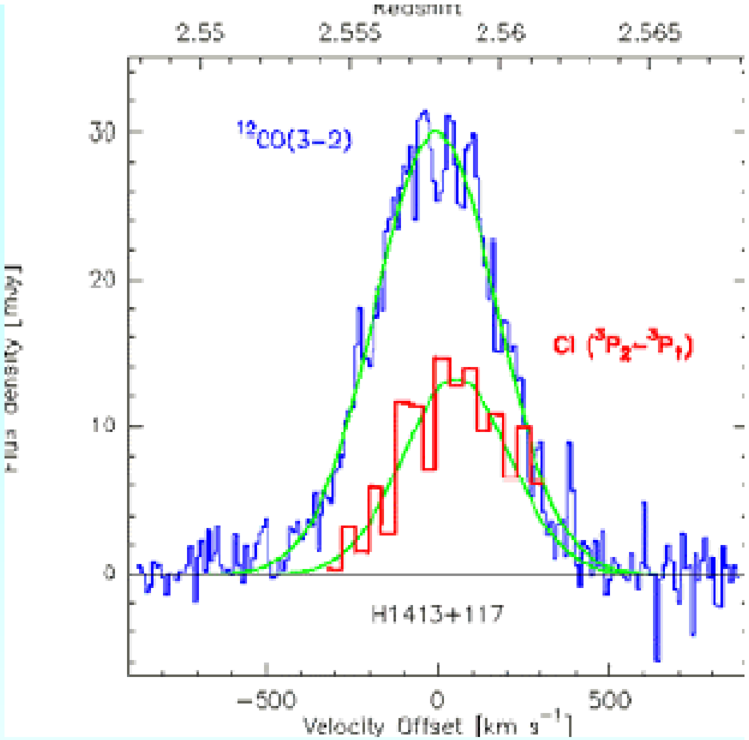
With a primary beam of 0.15 $arcmin^2$
➔Large mosaics should be done

Most will be detected at z=1-3, so at 1mm for CO54-CO98
Might be better to go to even lower frequency

CI/H$_2$ ~10^{-5}

CII/LFIR ~0.06%,
10 times less than locally





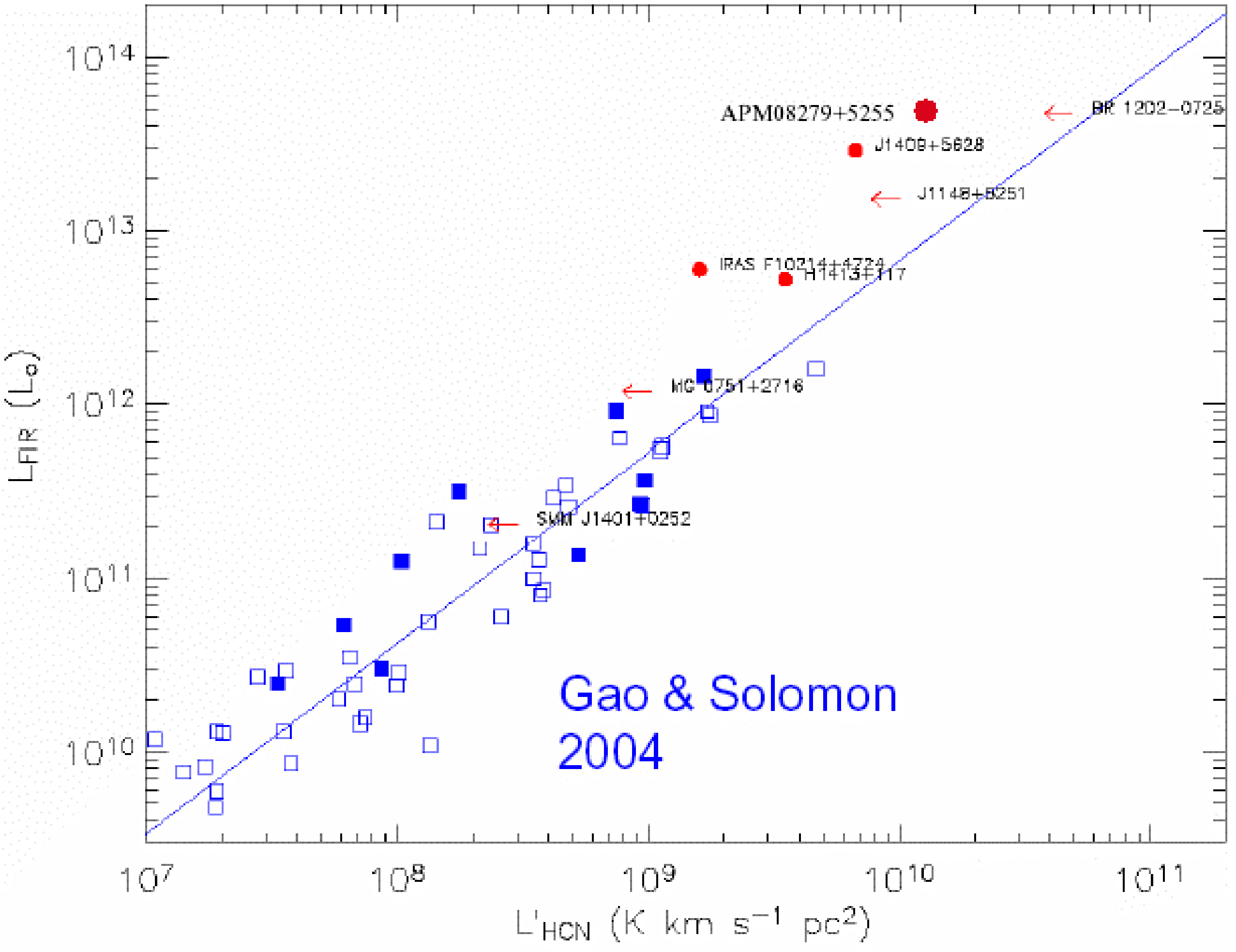
Cloverleaf

CII detected in
J1148 QSO at IRAM

High density tracers

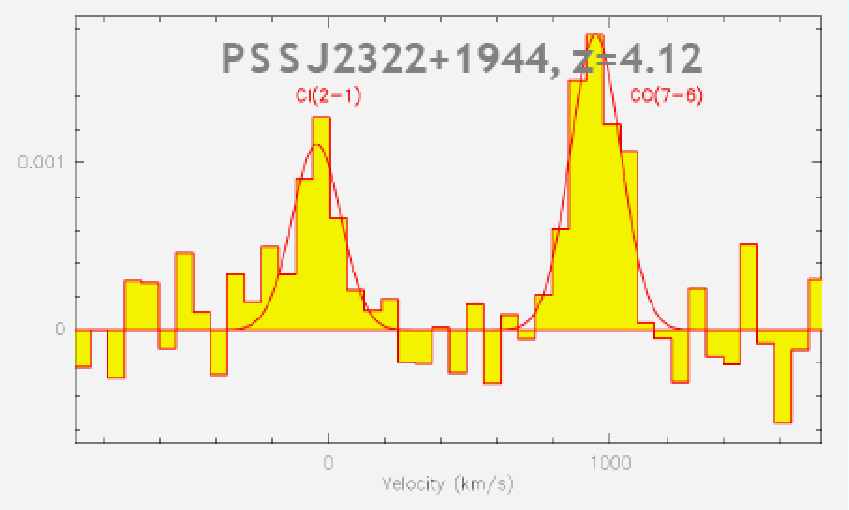
HCN appears better correlated to star formation that CO

CI is detected, CII is proportionally weaker in ULIRGs

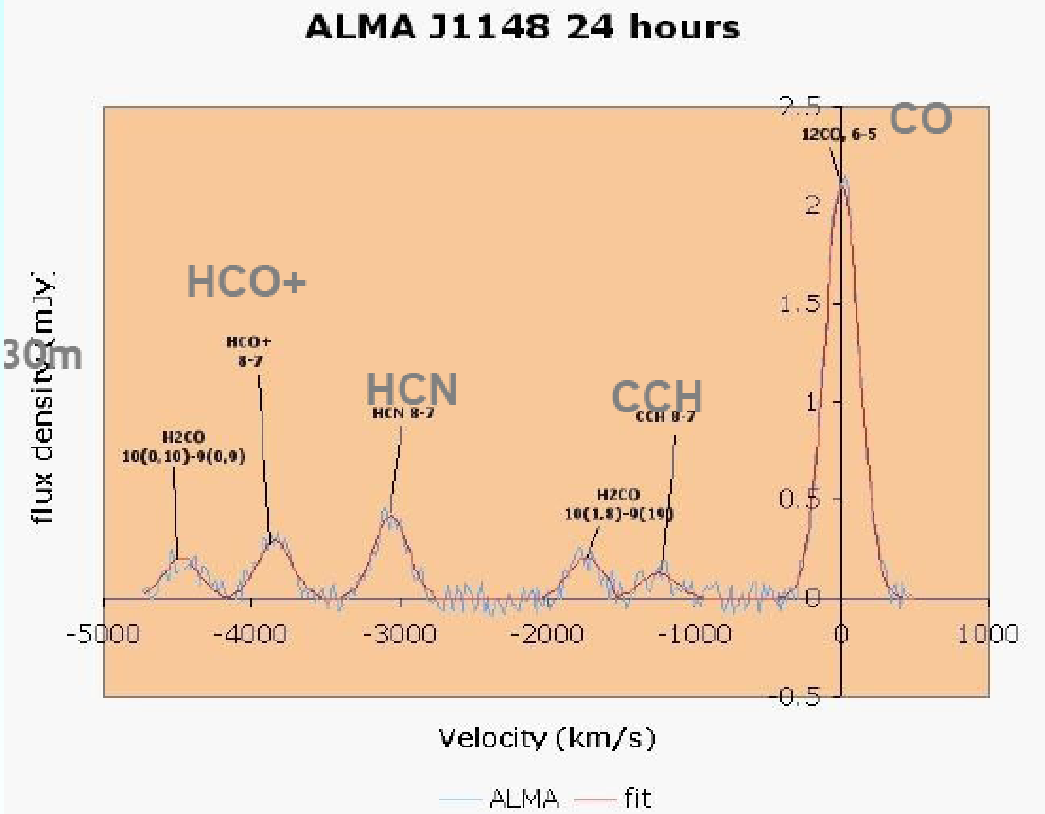


Molecular surveys

TODAY



TOMOROW



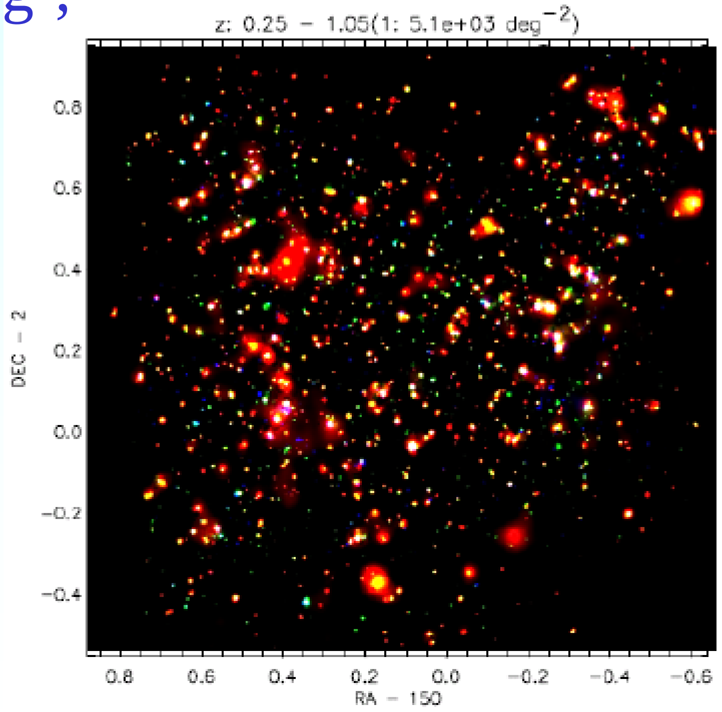
ALMA prediction

Cartographier les grandes structures et l'environnement des SMGs

Avec APEX, survey @870mu
➔COSMOS 2deg^2 à rms=2mJy: 300-600 sources avec S/N>4
➔20x20 armin2 au niveau de confusion, 0.5-07mJy: 200-400 sources

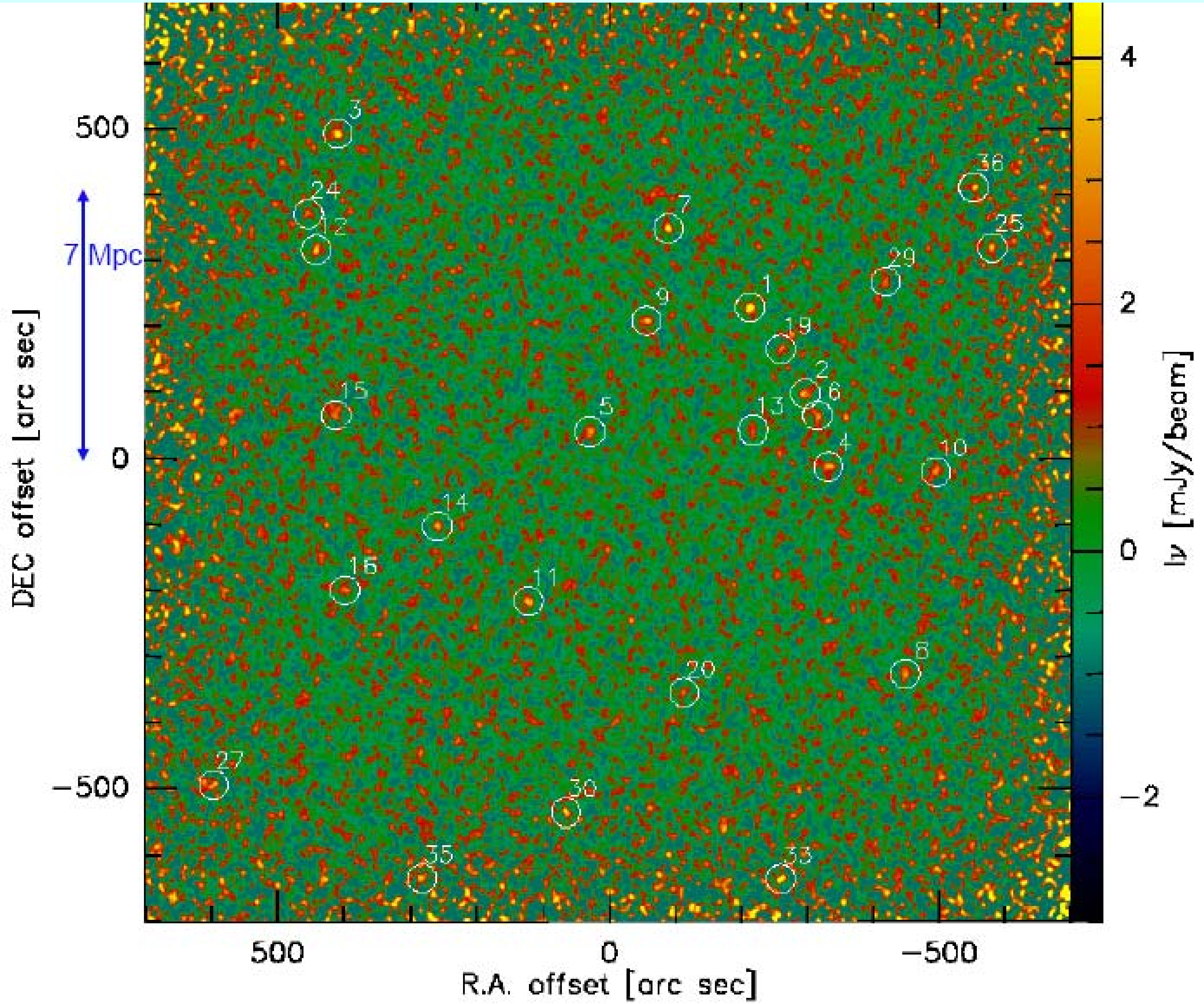
Plus profond avec SCUBA-2 @450mu, CCAT 200/350mu (25m)

ALMA rms=50µJy N (>0.2mJy) = 60 000/deg^2,
870mu FoV 19''
1h 1 armin2: 20sources
1an = 1sqdeg
Certainement plusieurs plus petites régions



COSMOS: overdensités
z=0.25-1.05

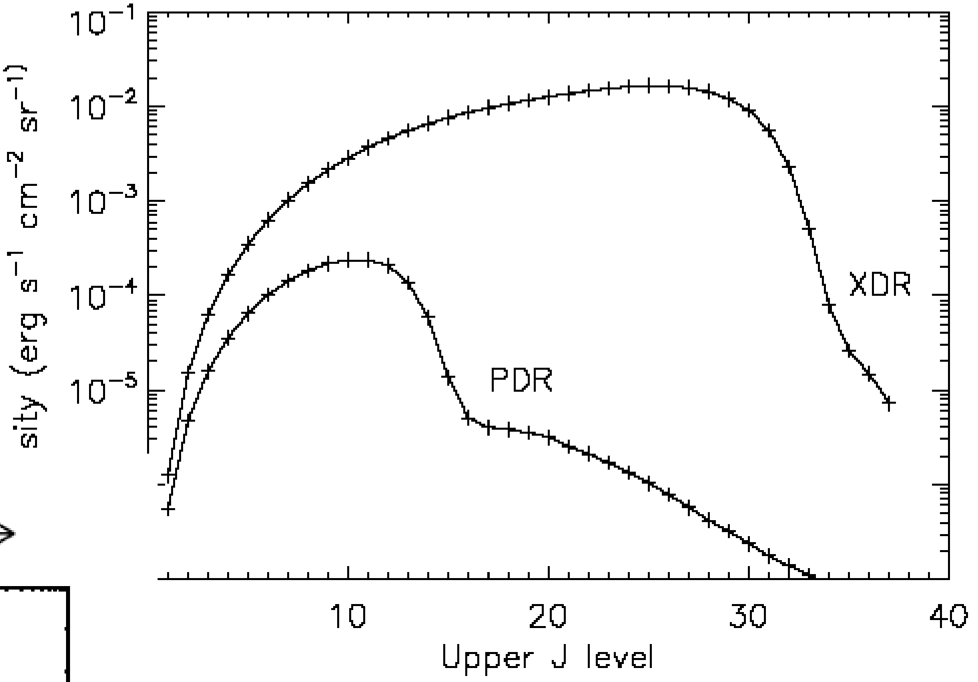
MAMBO 1.2mm survey of COSMOS

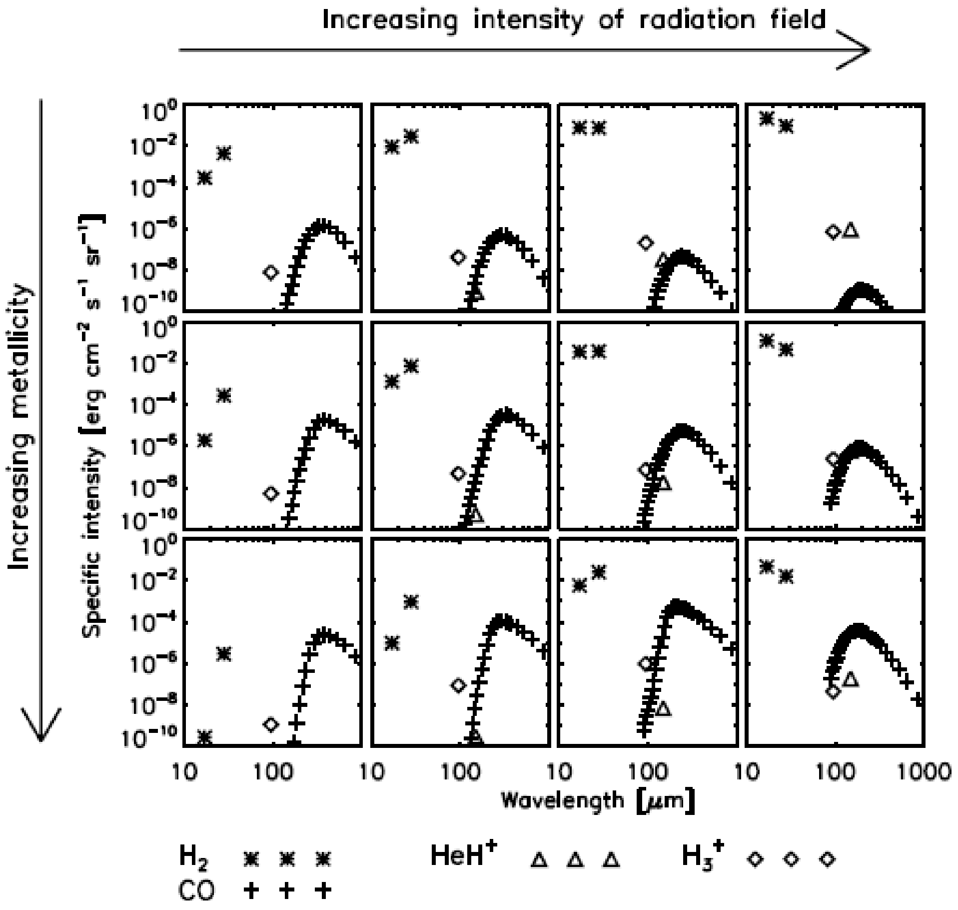


CO & H_2 lines for AGN at z ~10

Spaans & Meijerink 2008

H_3^+ 95μm, HeH^+ 149μm





100K < Tgas < 1000K

Eddington limit for AGN > $10^6 M_o$

CO from J=15 (170μm)

H_2 S(0) 28μm, S(1) 17μm

5 < z < 20

10^{22}-10^{24} cm^{-2}

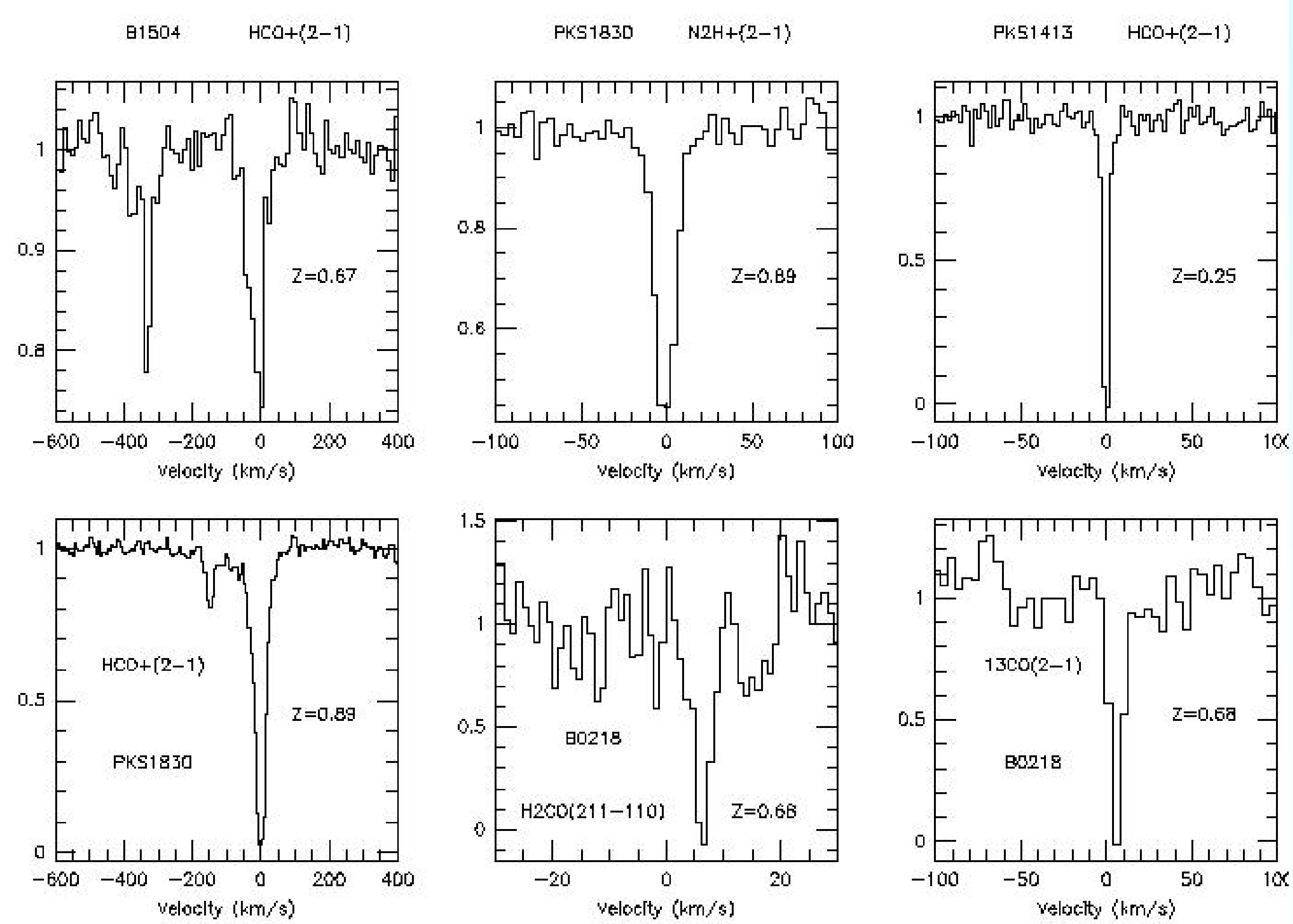
n ~10^3-10^5 cm^{-3}

Molecular Absorptions

Up to now, only 5 systems: PKS1413, B3 1504 (self-abs)
B0218, PKS1830, PMN J0134 (OH): gravit lenses
+ local: CenA, 3C293 (0.045), 4C 31.04 (0.06)

Chemistry @highz
Variations of cst

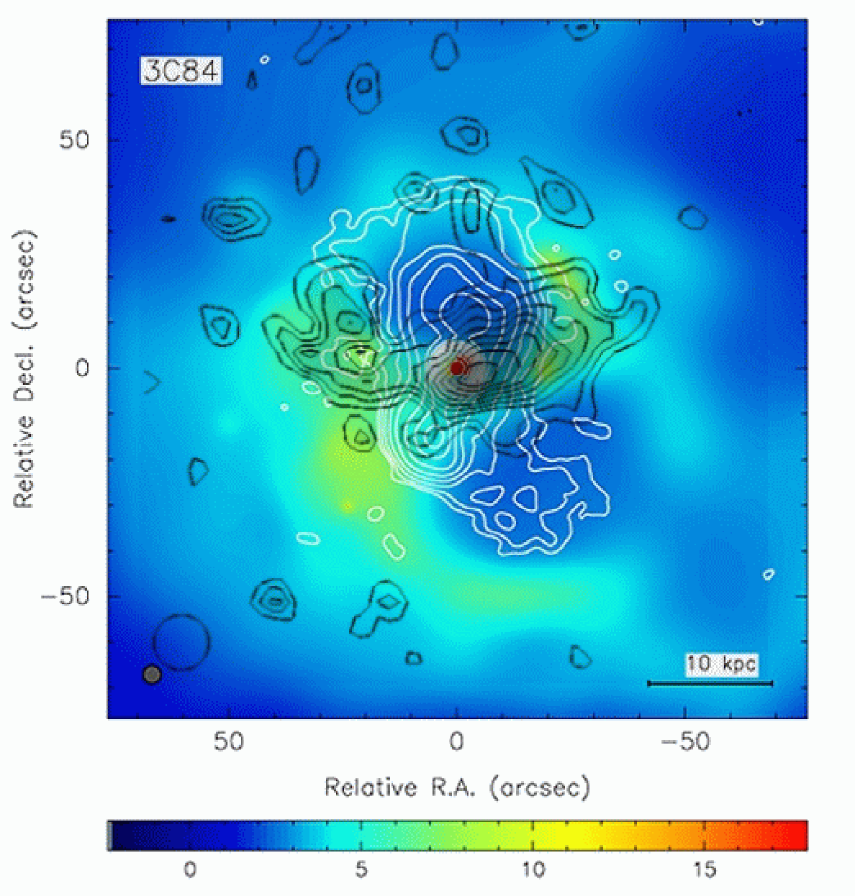
~ 30-100 times
more sources
with ALMA?

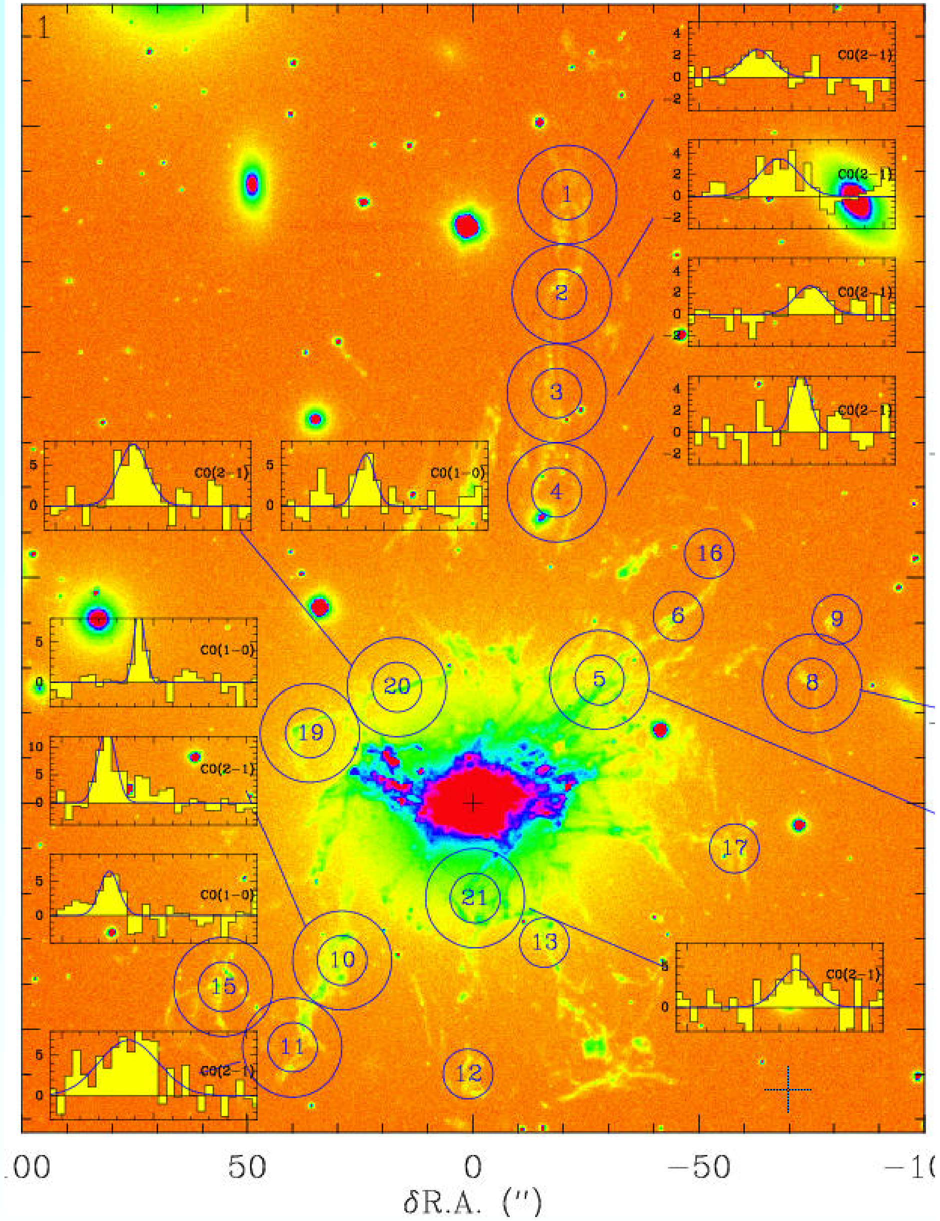


Combes & Wiklind 1998

Cooling flows

Salome et al 2006, 2008





Perseus A, nearby

Conclusions

- ALMA deep field en continuum: N(S) taux de formation d'étoiles (z)

- Les raies CO pourront être observées à grand z avec ALMA

- Beaucoup plus d'information que le continuum: masse de H_2 dans la galaxie, l'efficacité de formation d'étoiles en fonction du redshift, la cinématique

- Information complémentaire à l’optique, où la largeur de raies ne reflète pas la masse totale (outflows, extinction..)

- Matière noire en fonction du redshift: études de galaxies individuelles avec MUSE+JWST + ELT-30m + ALMA
  et études statistiques, avec loi de Tully-Fisher