Scienza extragalattica con ALMA

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II

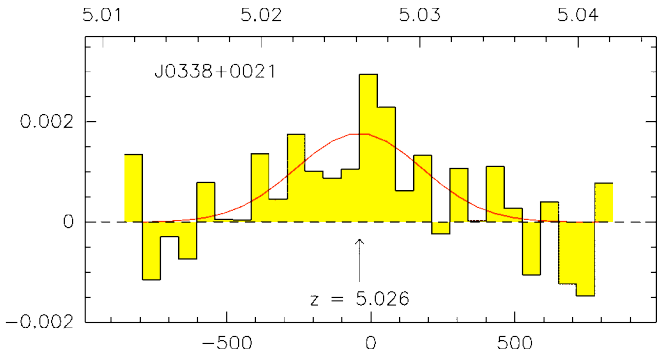
High redshift galaxies

Premessa

Gran parte degli studi mm-submm ad alto-z utilizzano
- dati a basso segnale-rumore (e.g. rispetto all'ottico)
- generalmente su campioni di oggetti estremamente luminosi, non rappresentativi (ULIRGs, QSO... la punta dell' iceberg)

QSO z=5

Maiolino+07



5.6σ
12 hrs on source
IRAM - PdBI

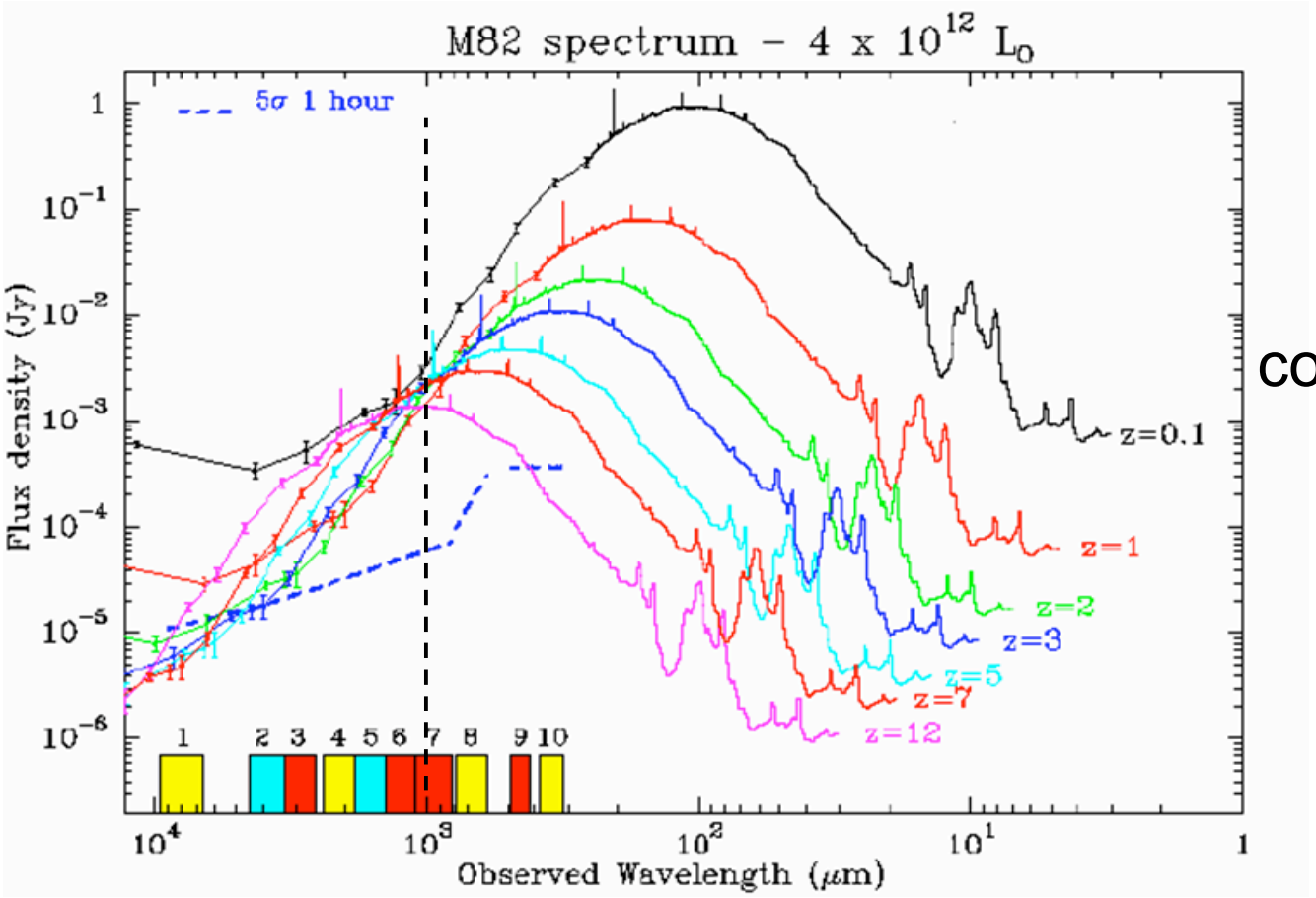
-> settore estremamente giovane

~ astronomia ottica alto-z anni '80

-> enorme potenziale di nuove scoperte e campi da esplorare

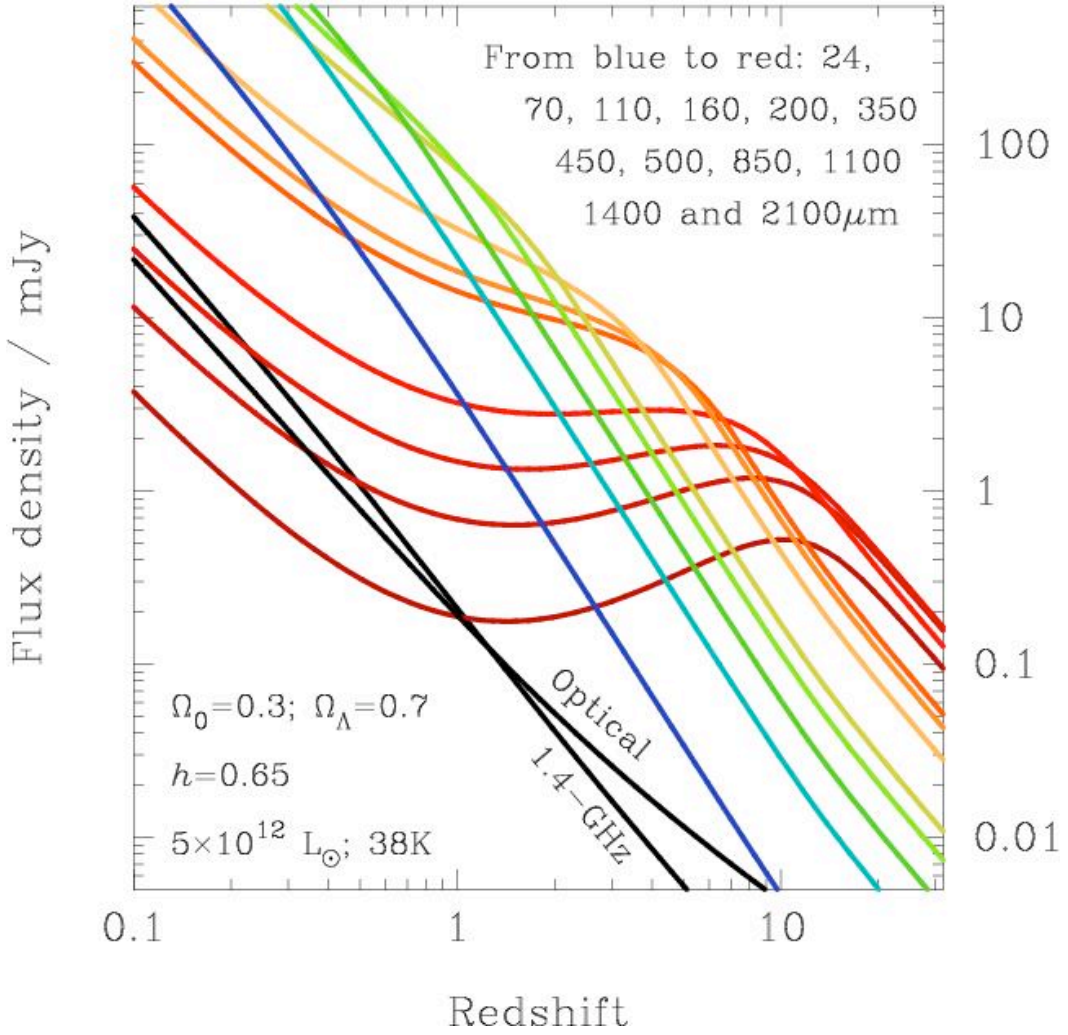
-> ALMA consentira' un repentino ed enorme sviluppo della scienza submm-mm ad alto-z

Strong negative K-correction at mm-submm wavelengths



The steep submm SED counteracts the $1/D^2$ cosmological dimming

Strong negative K-correction at mm-submm wavelengths



At $\lambda \sim 1$ mm detecting a source at z=10 is as easy as at z=1

Deep optical field (HDF): rich in low-z galaxies, poor in high-z galaxies.

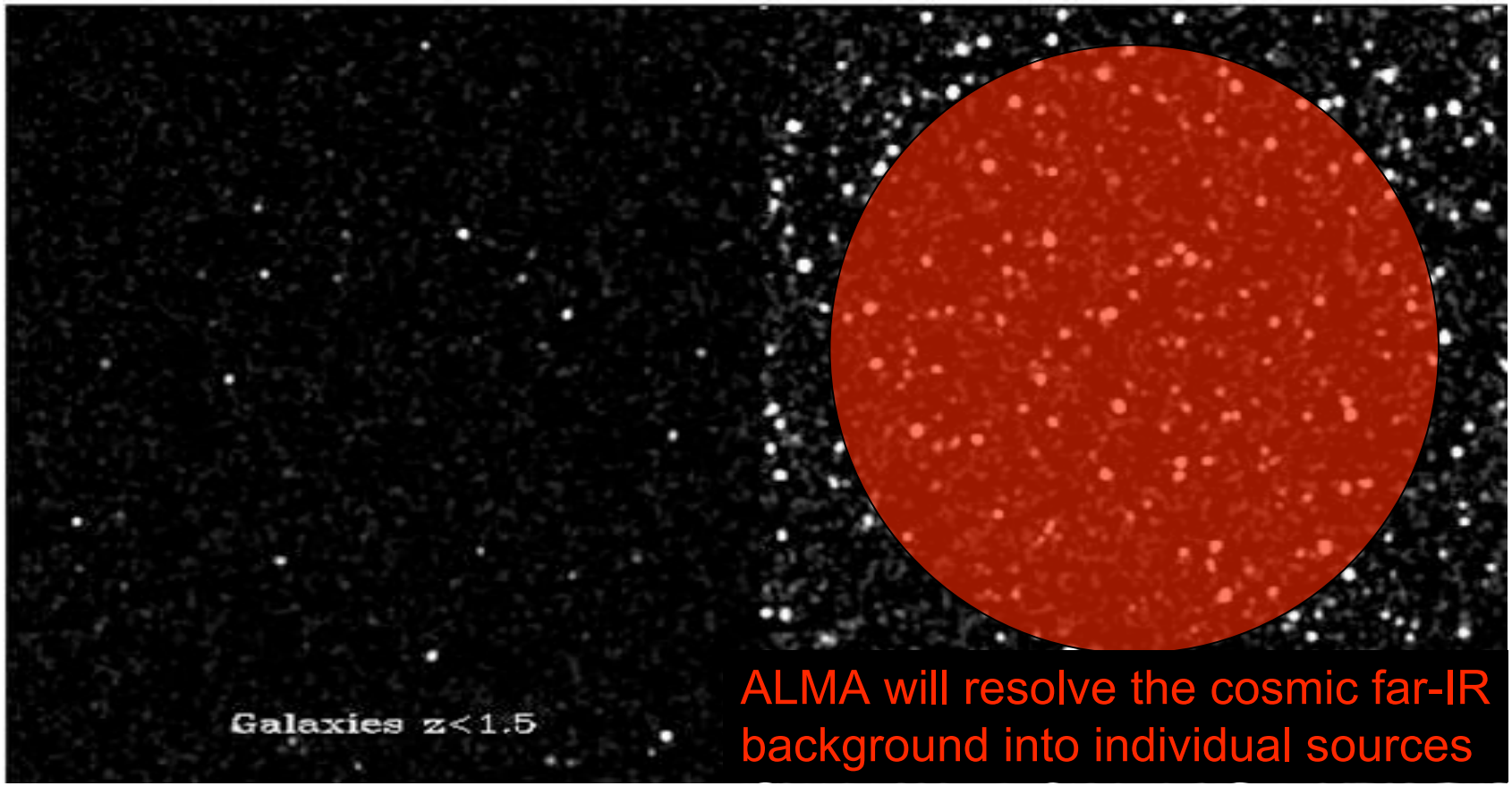
(12 days of integration)

z<1.5

z>1.5

ALMA deep field: poor in low-z galaxies, rich in high-z galaxies.

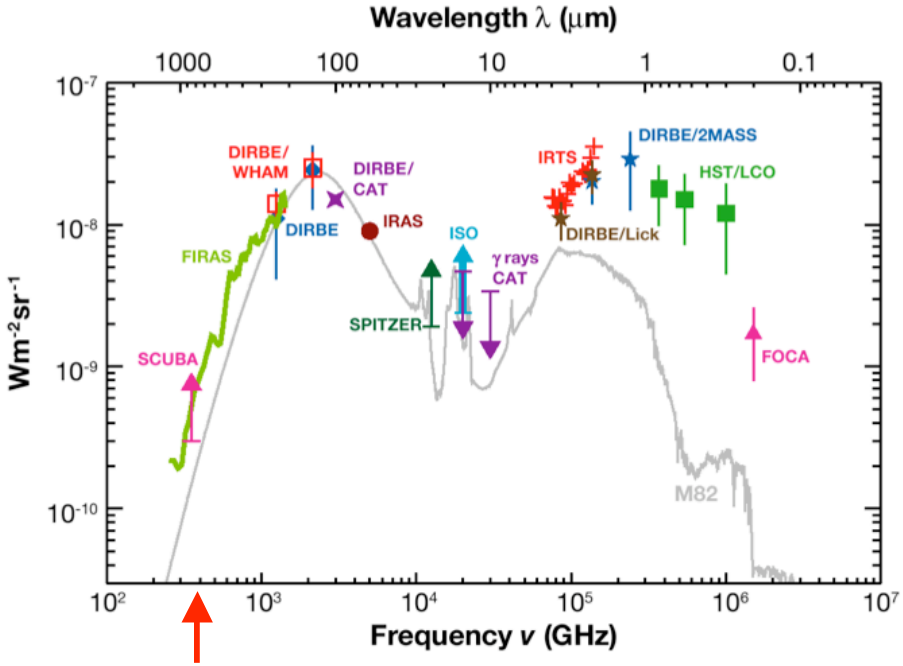
simulation 3 days of integration 4'x4' arcmin



z<1.5 z>1.5

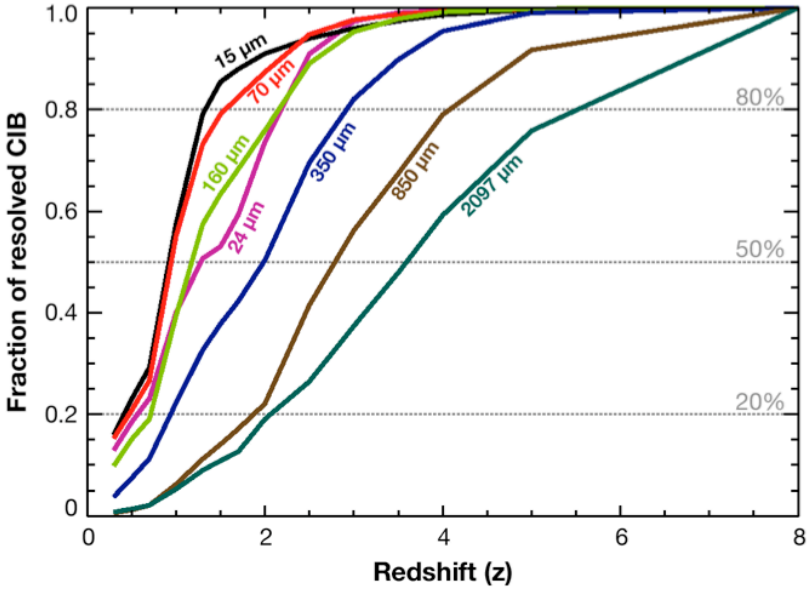
Wootten and Gallimore

Cosmic Infrared Background (CIB)



~50% resolved by SCUBA at 850μm

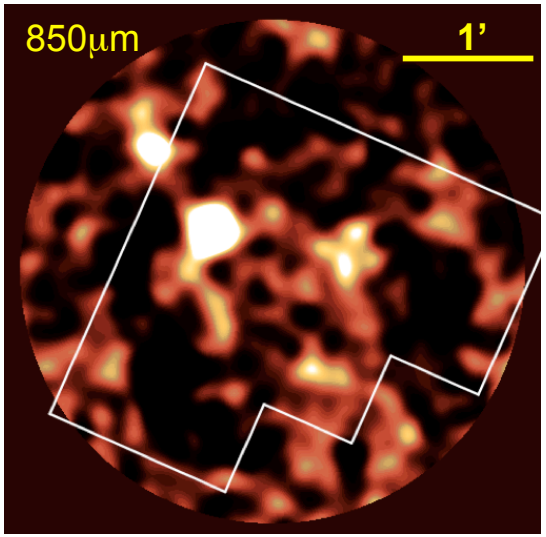
Expected (and partially observed) redshift distribution of sources resolving the CIB



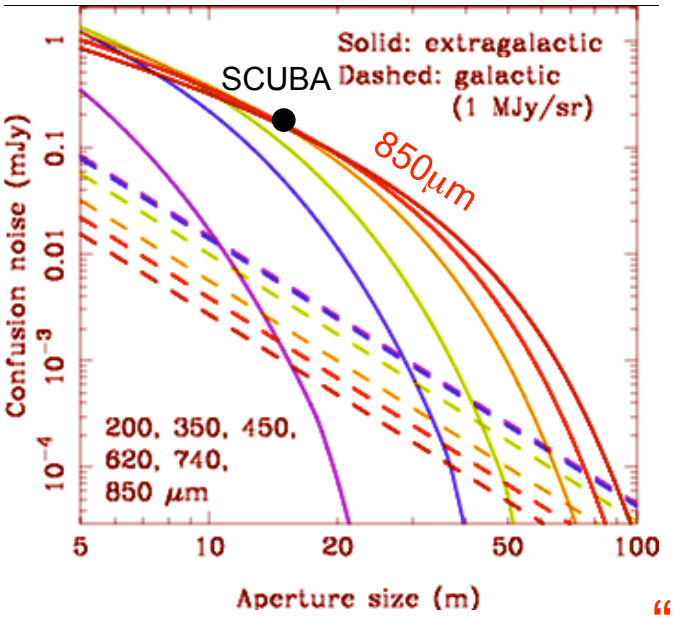
Lagache+05

The main limit of past and current facilities (SCUBA) is “confusion”: below a flux limit (which depends on the beam size) most sources blend together

deep SCUBA map (HDF)

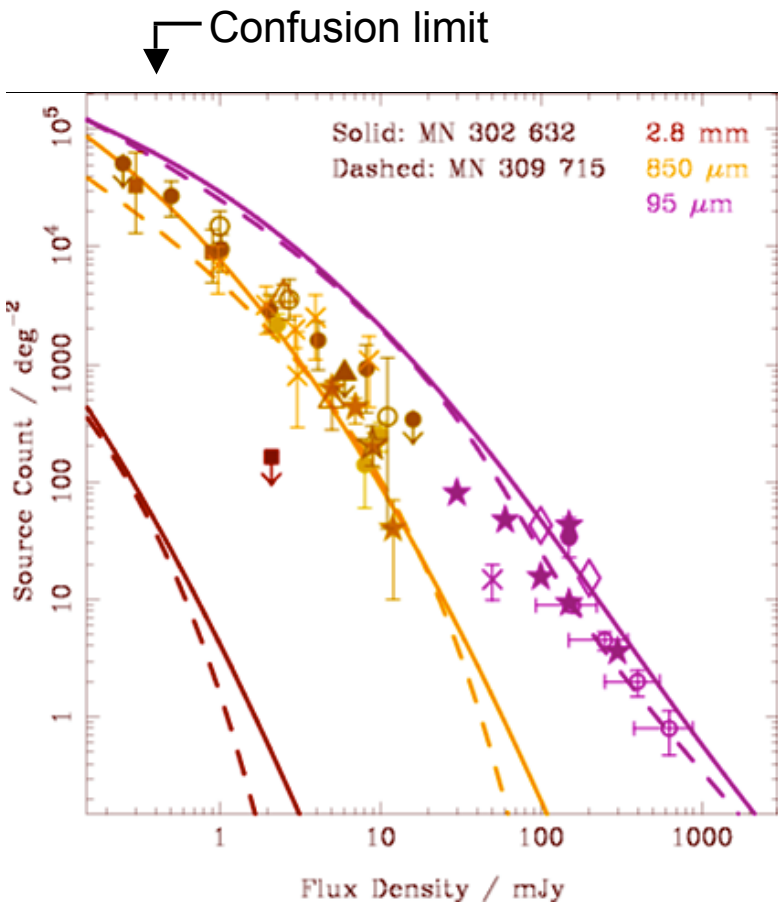


Hughes+98



“confusion” will not be a problem for ALMA

Initially submm (SCUBA 850μm) surveys high-z surveys provided source number counts

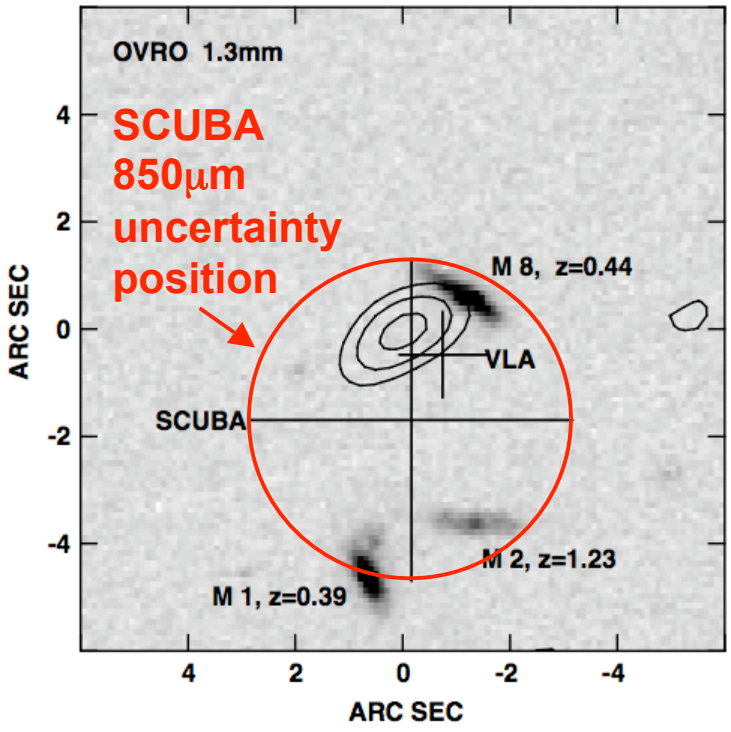


Blain+02

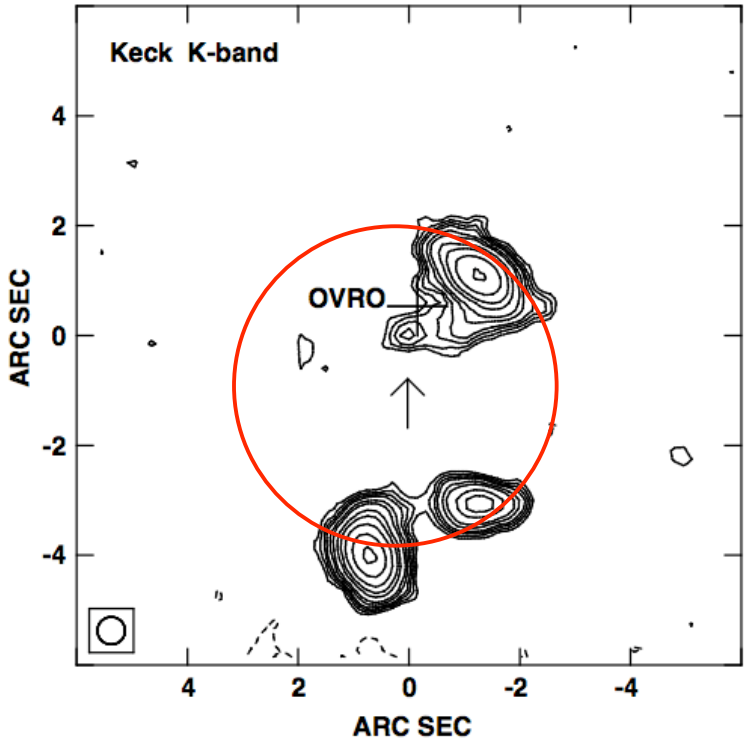
Obtaining the redshift (and activity) information requires spectroscopic identification

The low angular resolution of past/current submm facilities has been a major problem for the optical identification

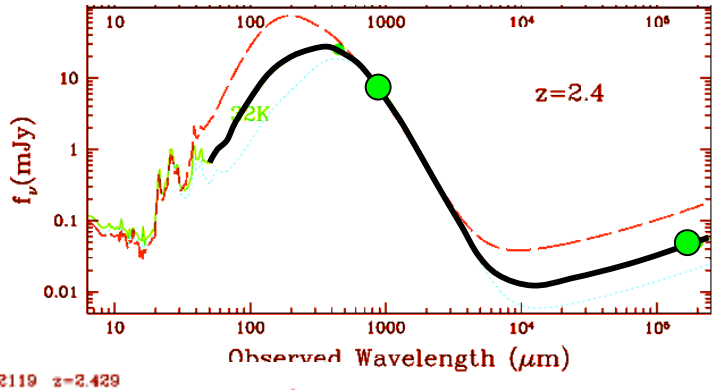
grayscale HST optical



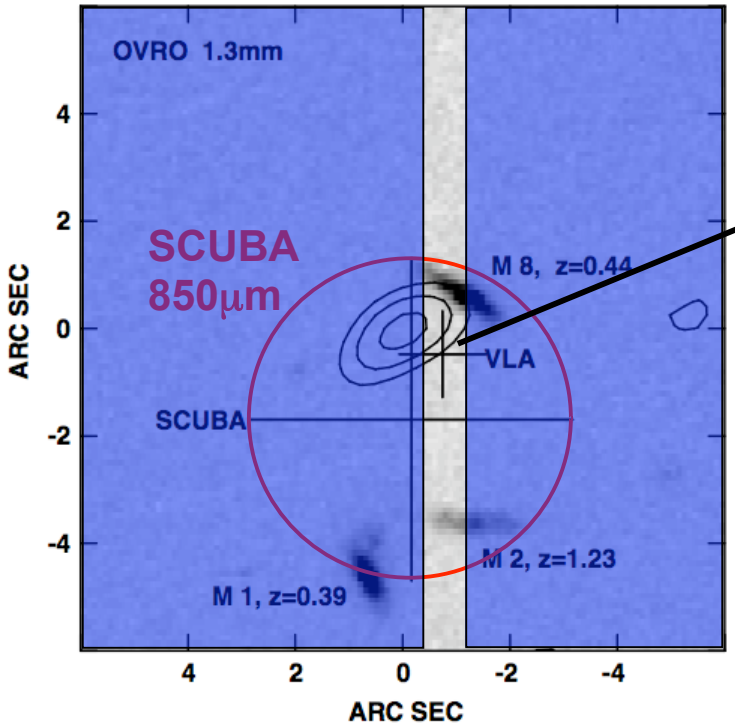
near-IR (2μm) image

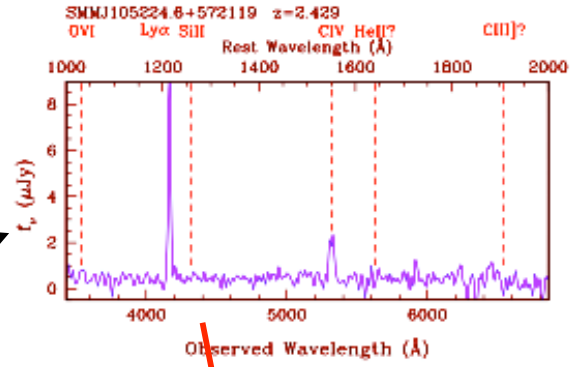


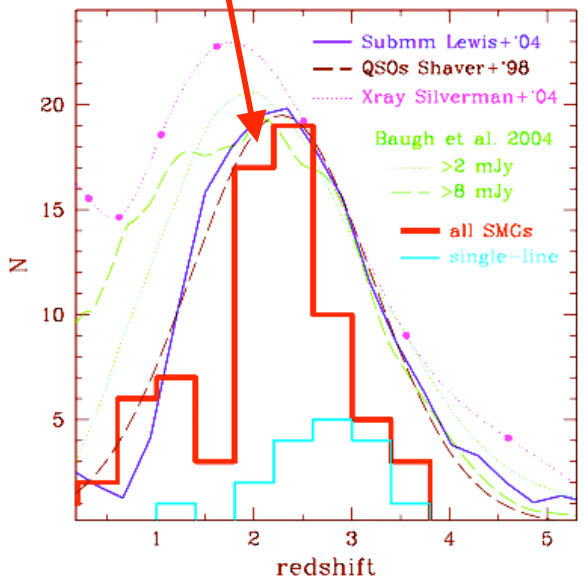
Chapman et al. (2004) exploit the FIR-radio correlation of galaxies to locate the source through the radio-VLA position and “blindly” place the slit for optical spectroscopy



grayscale HST optical

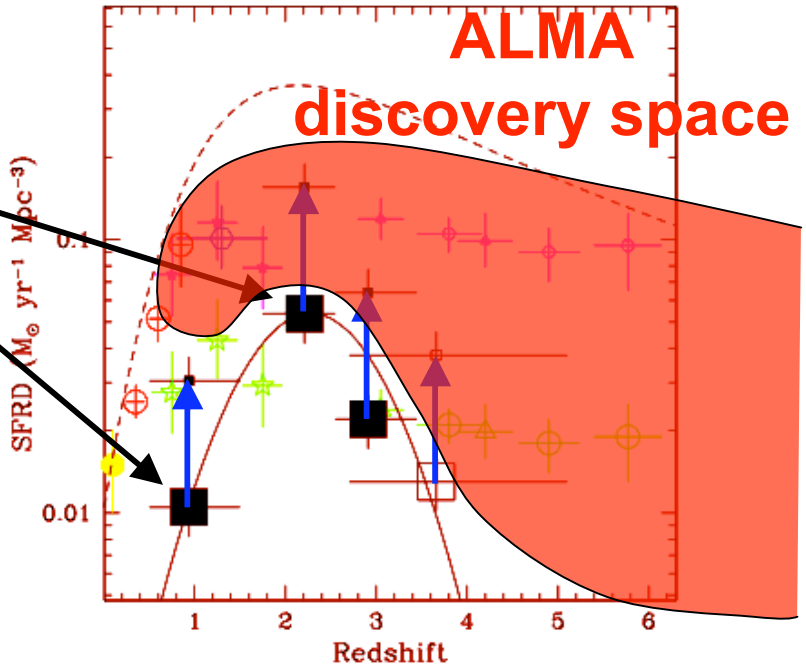






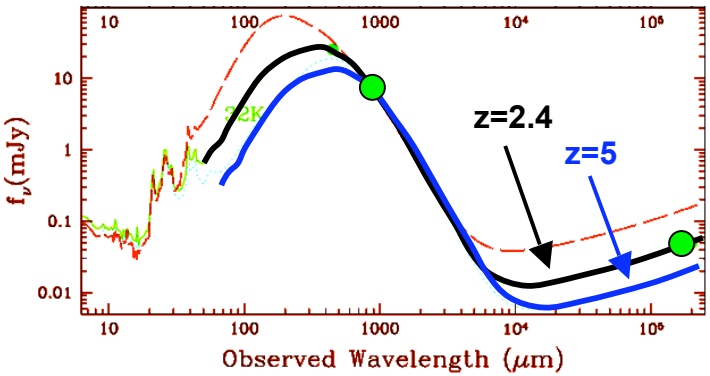
redshift distribution
<z> ~ 2.5

Inferred evolution of the cosmic star formation rate



Problems:

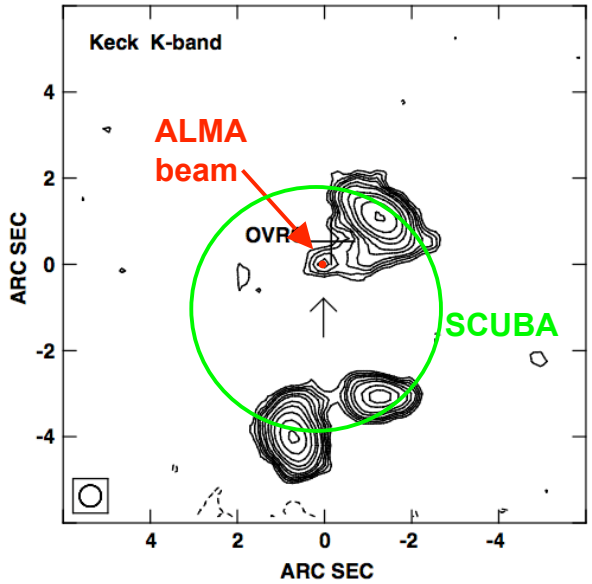
- Current submm surveys only sample extremely luminous objects ($L_{IR}>10^{12}\,L_\odot$, the tip of the iceberg) correct to "real" SFR with models



-Radio identification prevents the identification of high-z sources (radio K-correction goes other way)
- Also bias against cool SED

-The optical (=UV rest frame) spectroscopic identification has missed the most obscured objects

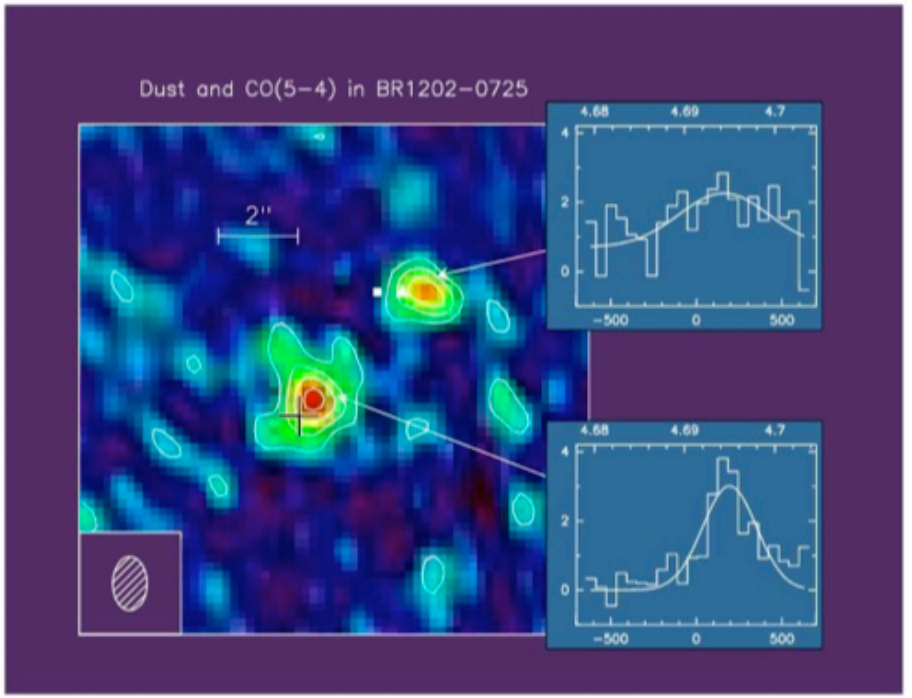
- ALMA will provide accurate positions of mm-submm sources ⇒ unambiguos cross-identification at other wavelengths



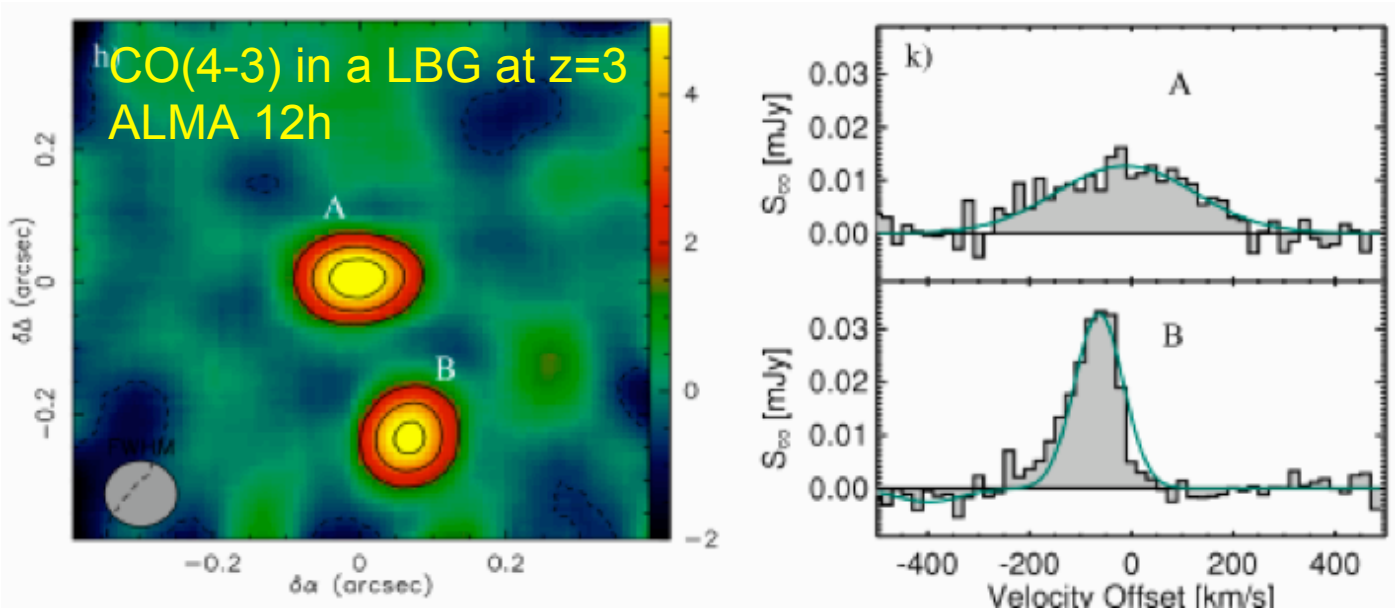
- ALMA will directly provide the redshift of the sources by detecting their CO transitions

So far CO detections at high-z have been obtained only in extremely luminous sources (ULIRGs-QSOs)

QSO BR1202-0725 at z=4.12

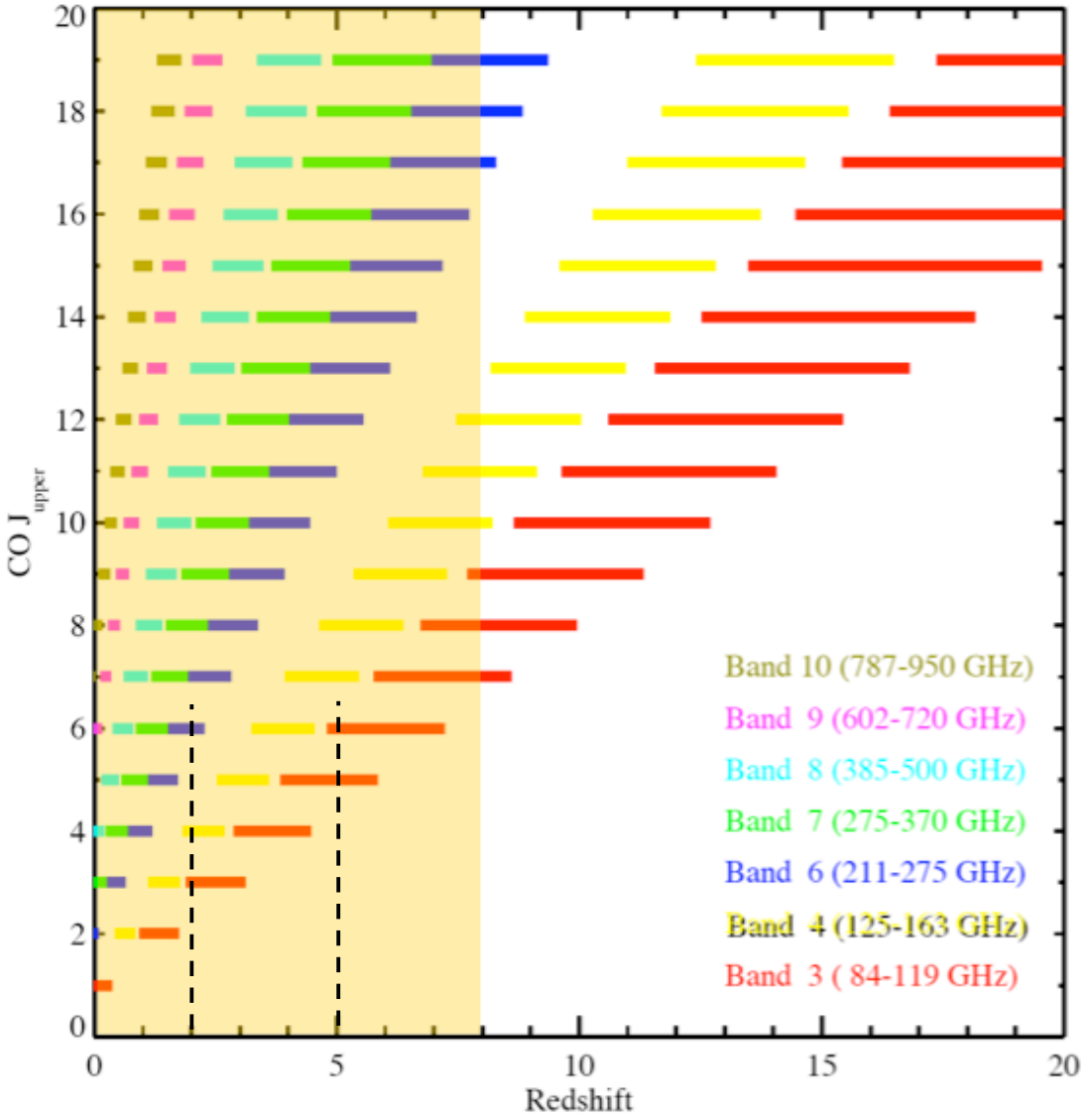


ALMA will be able to detect CO in a Milky Way at z=3



Greve & Sommer-Larsen 06

Use of CO lines to identify the redshift of high-z galaxies

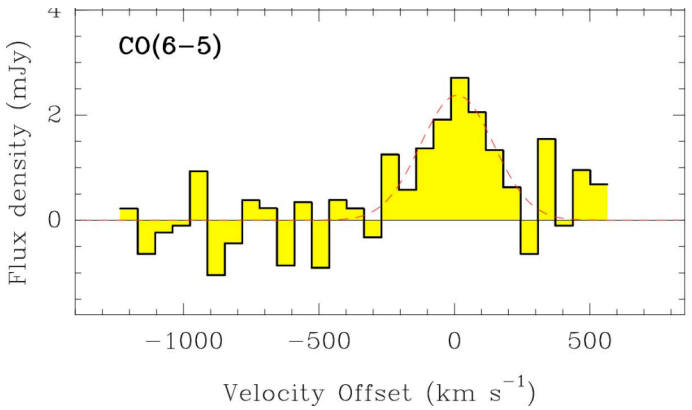


With 3 tunings it will be possible to fully cover band 3 (84-116 GHz) ⇒ at least one CO line

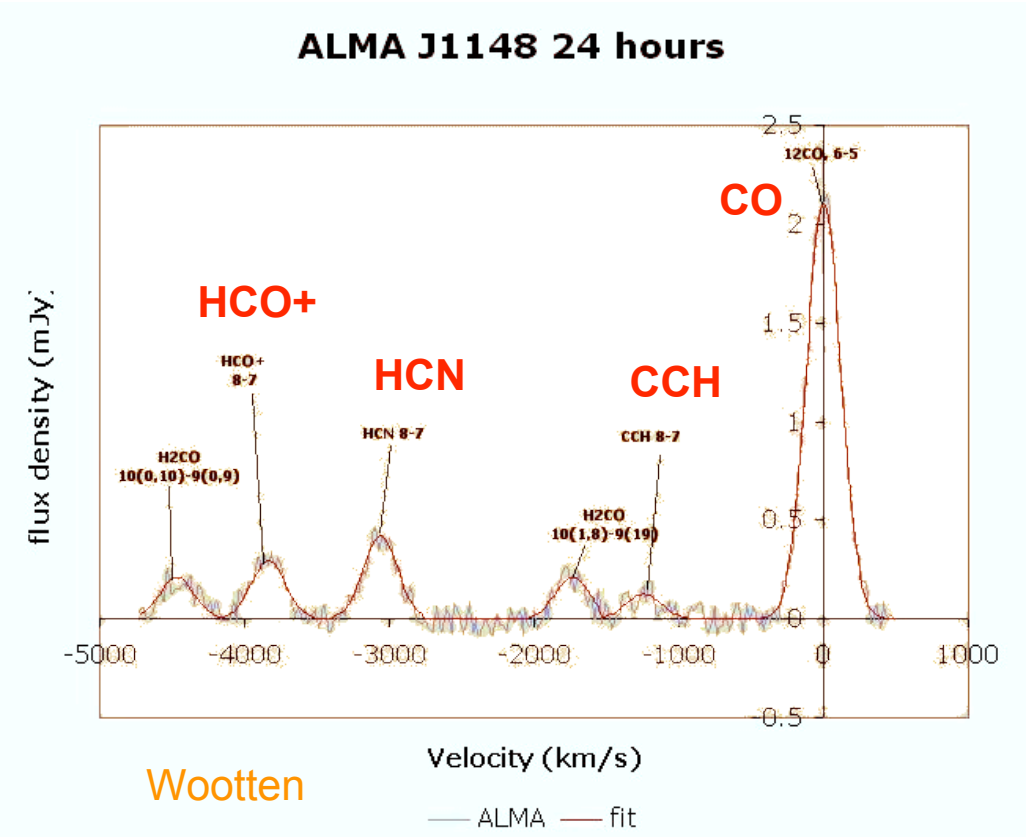
At z>3 at least 2 CO lines within band 3, else (z<3) observe another band to confirm redshift

Example of QSO at z=6.4

IRAM ~15 hours



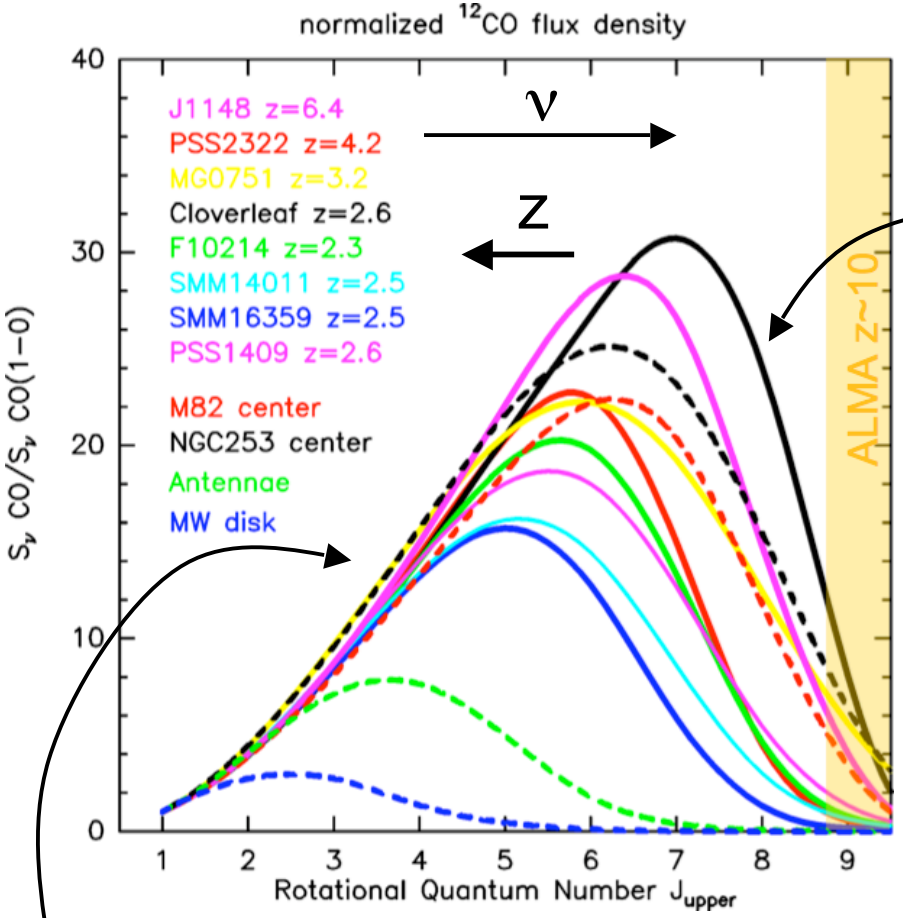
Bertoldi+03



Wootten

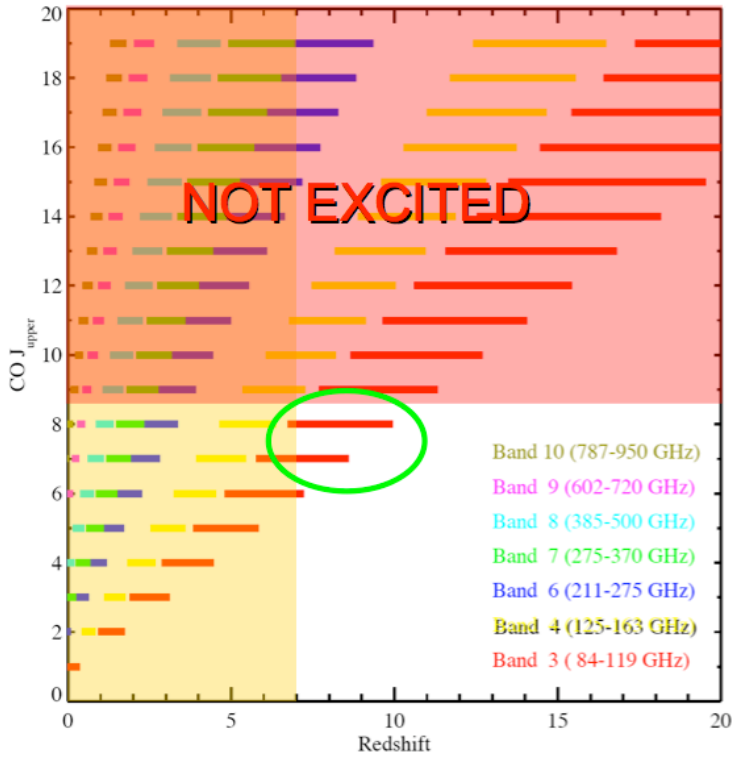
Not only ~∞ S/N on CO line (⇒ detailed dynamical studies, see discussion later on), but also several other molecular lines -> astrochemestry.

At **z>7** galaxies can be identified through the detection of high order CO lines, J_{upper}>7... are these transitions excited?



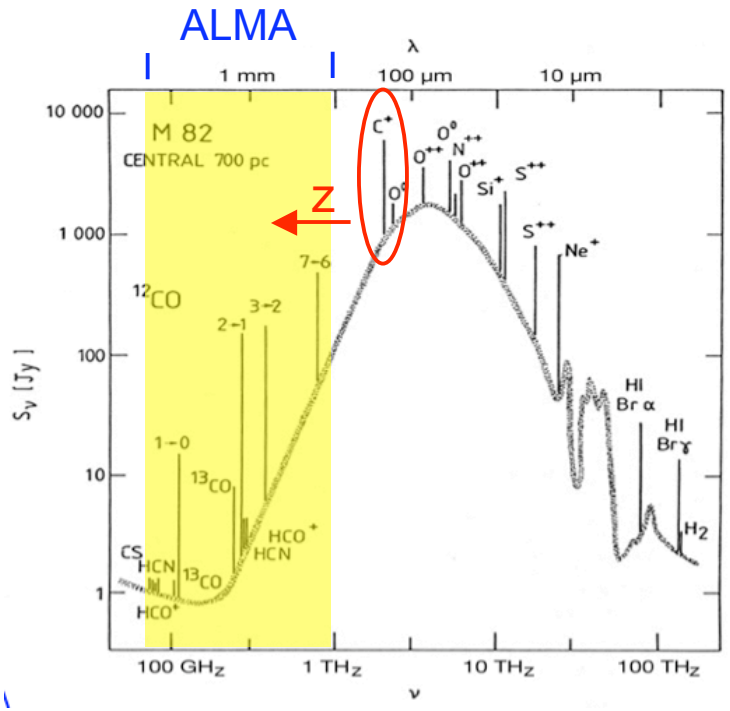
at z<7 J many galaxies follow the $S_{CO} \propto \nu^2$ relation (i.e. optically thick case) ~ negative k-correction

at high J rapid drop of intensity... bad news for ALMA: difficult to use CO at z>7, unusable at z>10



Walter 06

[CII]158μm line: the main coolant of the ISM

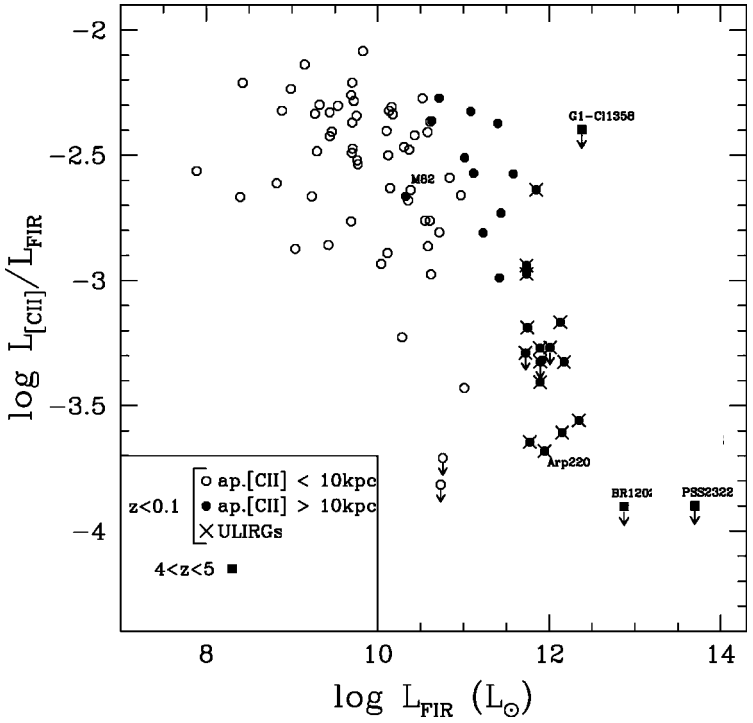


Emitted in PDR's ⇒ tracer of star formation

Generally the strongest line in the spectrum of galaxies
(~5-100 times stronger than CO lines)

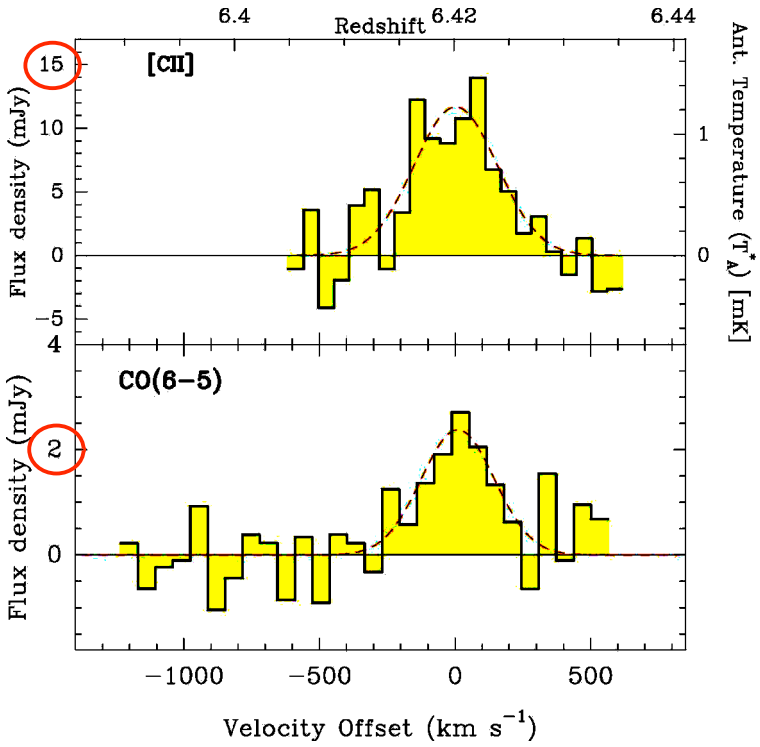
~1% of the whole bolometric luminosity is emitted in this single line

Issue: its luminosity drops at high bolometric luminosities ($L_{FIR} > 10^{11.5}\ L_\odot$)



First detection of [CII]158μm at high-z

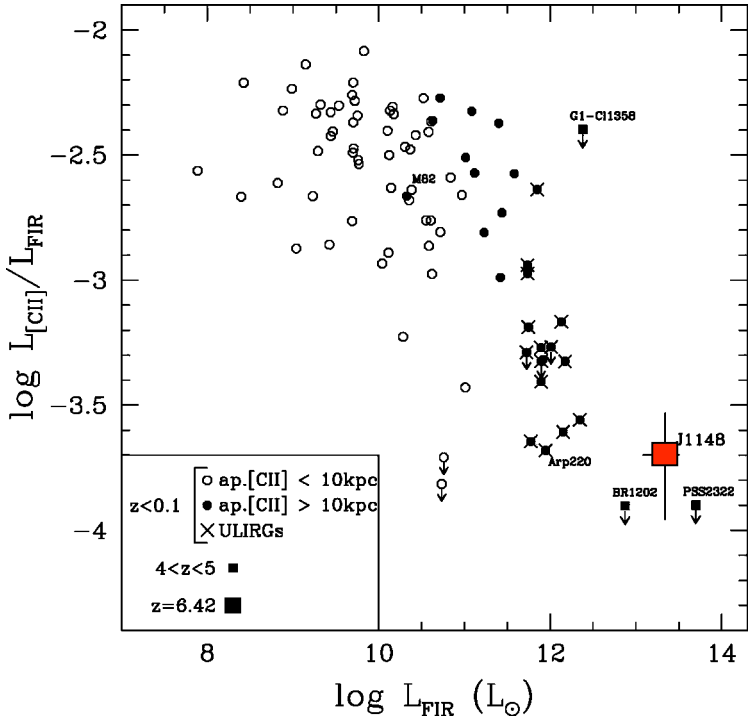
QSO at z=6.4



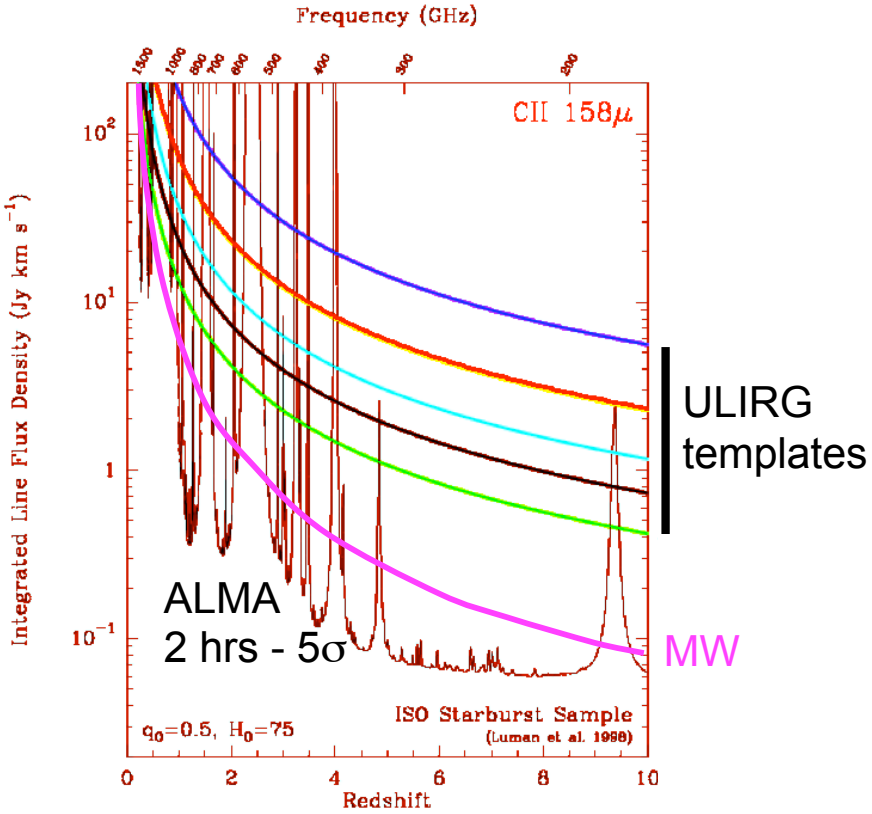
Maiolino+05

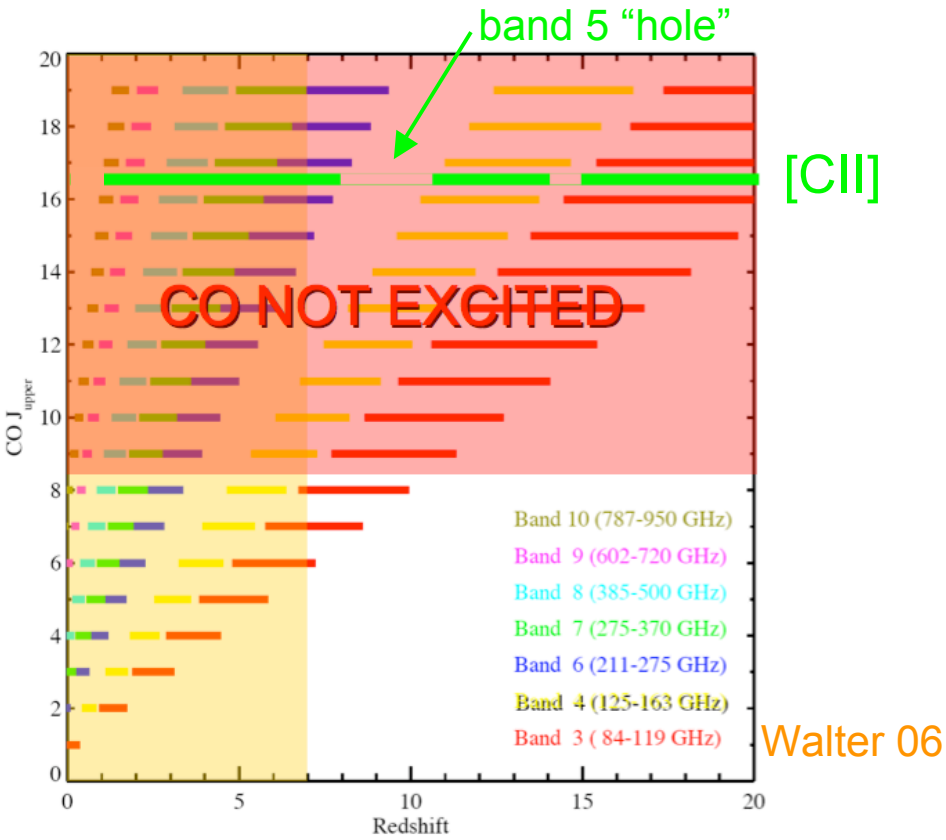
Six time brighter than CO

Even if in worse case still detectable



[CII]158μm: main ALMA tool to investigate high-z galaxies

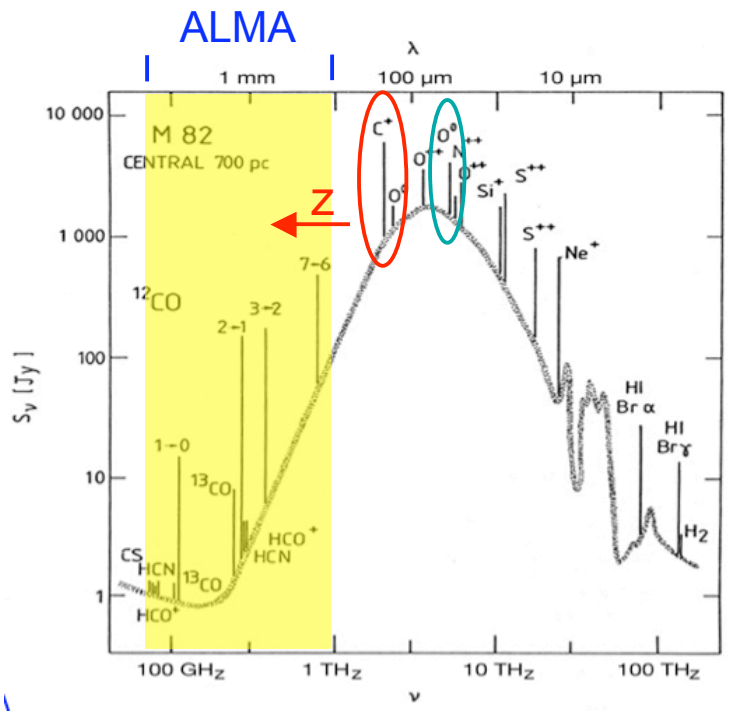


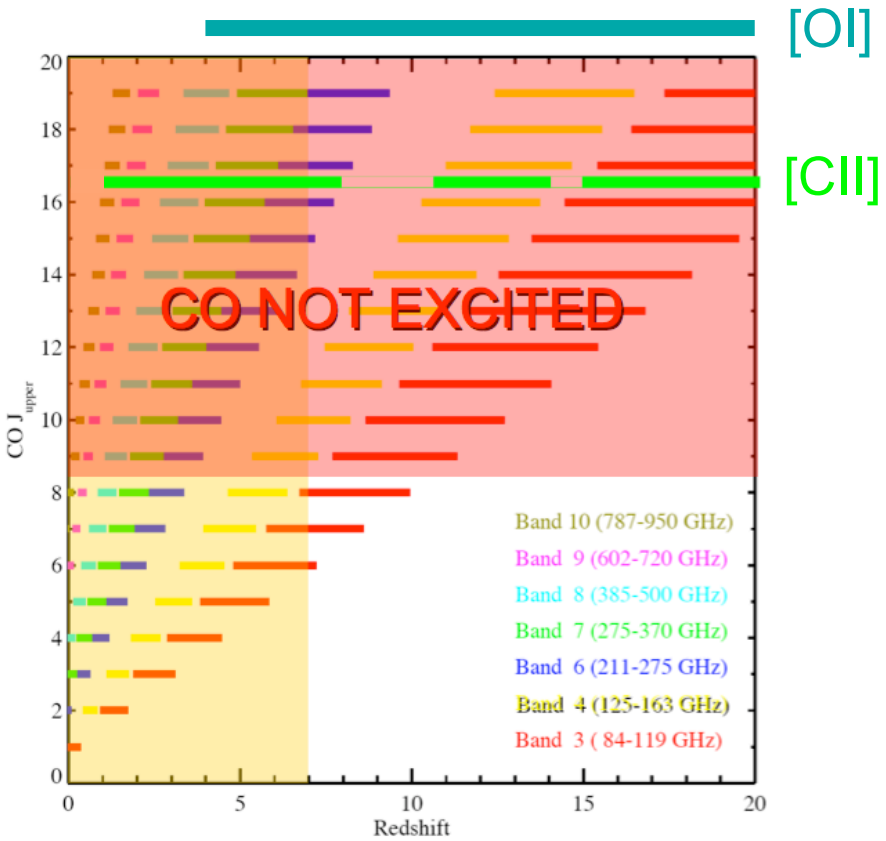


Relative to CO lines (besides begin brighter)
[CII]158μm has also the advantage of being observed at
higher frequencies ⇒ higher angular resolution (~ factor of 2-3)

[CII]158μm will provide the redshift, but also SFR and kinematics (-> M_{dyn})

[OI]63μm: second brightest line in galaxies, but is expected to be even stronger than [CII]158μm in young, high-z galaxies





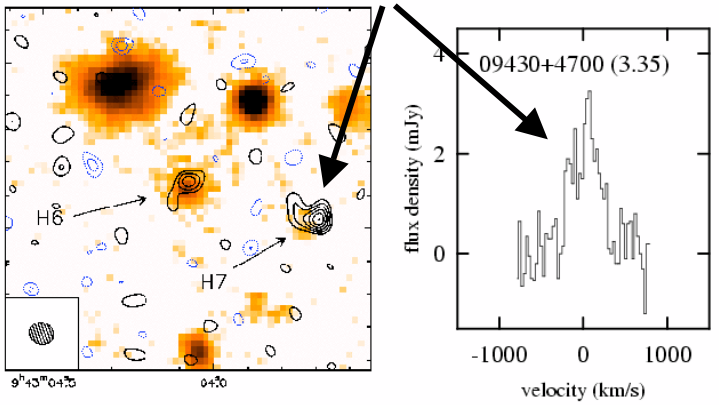
[OI]63μm additional ALMA tool to investigate high-z galaxies:

- redshift
- [OI]+[CII] -> Star Formation Rate
- [OI]/[CII] -> chemical enrichment

Dynamics of high redshift galaxies traced by mm-submm spectroscopy

Genzel+04

CO(4-3) at z=3.35

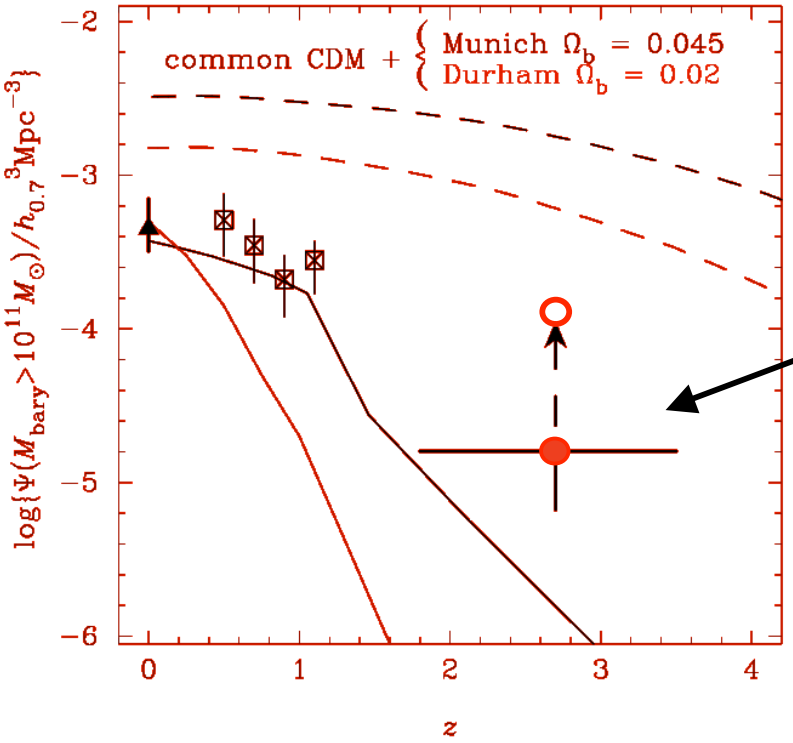


Currently obtained in few extremely luminous sources

Resolved line profile, but generally unresolved morphology

infer dynamical mass ~ 2×10^{11} $M_\odot$

infer density of massive galaxies ($>10^{11}$ $M_\odot$) at $2<z<3$

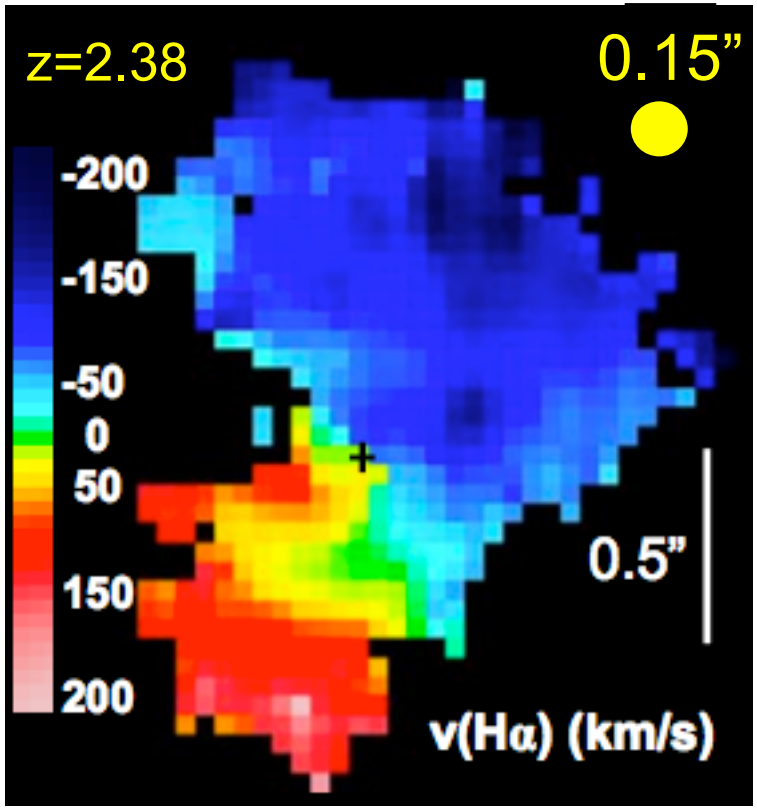


much higher than expected by classical hierarchical models

ALMA will allow us to fully resolve galaxy rotation curves at high-z

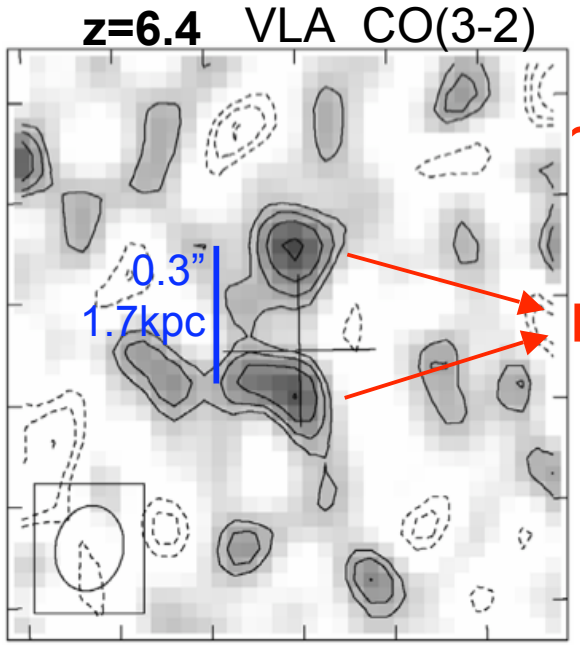
⇒ detailed dynamical mass estimates even in Milky Way-like galaxies

⇒ evolution of the (dynamic) mass function



Genzel+07

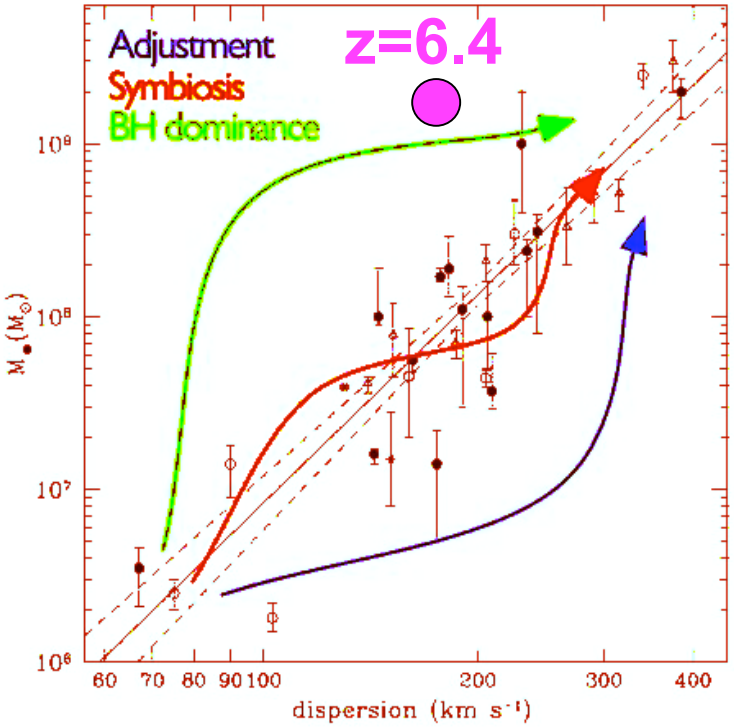
Masses of QSO host galaxies



~resolved rotation

M_{dyn}

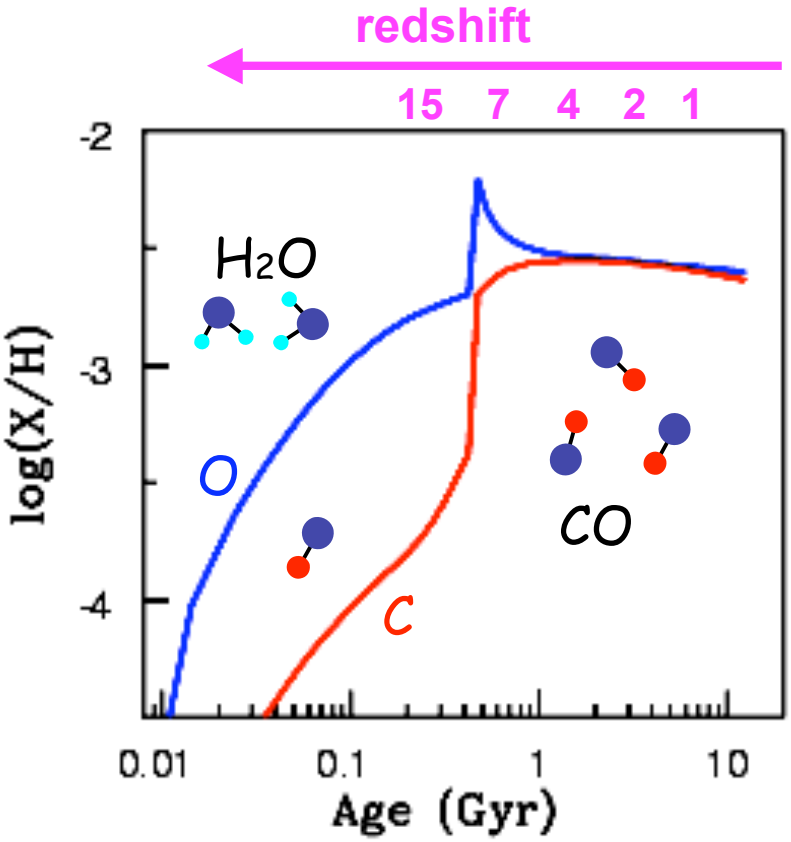
Walter+06



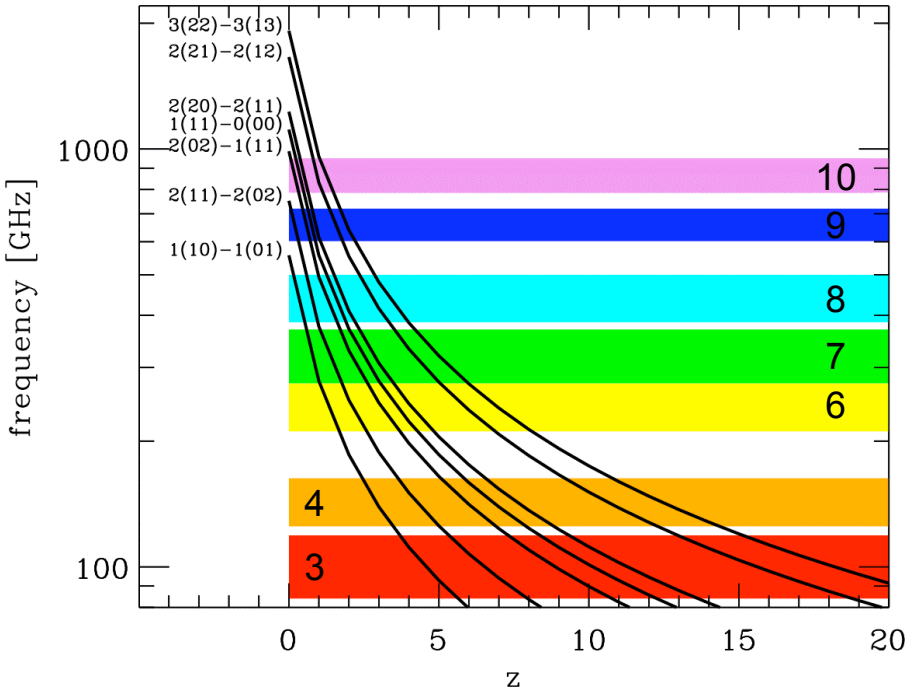
lezione di M. Colpi

ALMA: evolution of the M_{BH}-M_{galaxy} relation with redshift (evolution of offset and slope)

Astrochemestry in the early universe



Young galaxies should be “wet”



H_2O “easy” to observe at high-z

Water will be the mean of ALMA to detect primeval galaxies
~ “first light” sources