New CO detections of lensed submillimetre galaxies in A2218: Probing molecular gas in the LIRG regime at high redshift

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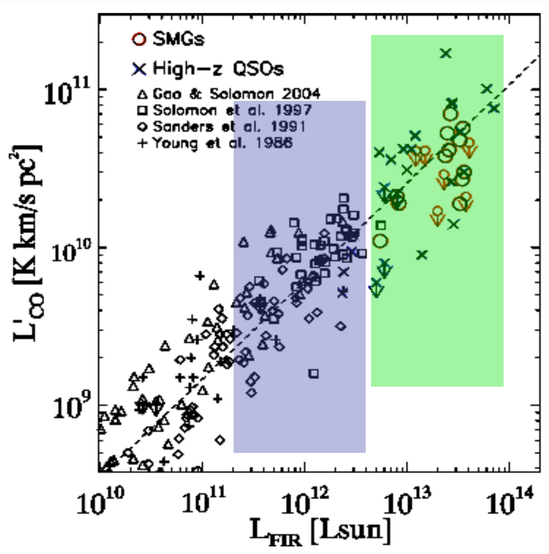
ABSTRACT:

We present new CO detections of high redshift submillimeter galaxies (SMGs) in the galaxy cluster field A2218, which provide strong gravitational lensing. The SMG SMMJ163555 has the lowest FIR luminosity yet probed by lensed SMGs. Combining with previous results for a lensed SMG in A2218, we find that the L'_{CO}-L_{FIR} relation differs from the local relation by only a 1σ. Only a larger sample of faint SMGs with future telescopes can clarify if this is a real difference, which could be caused by high-z ULIRGs having a higher star formation efficiency.

INTRODUCTION, MOTIVATION:



L_{FIR} ~ 10^{13} $L_\odot$ only probed at high redshift
- quasars, submm galaxies, 24μm galaxies etc.
- many CO detections

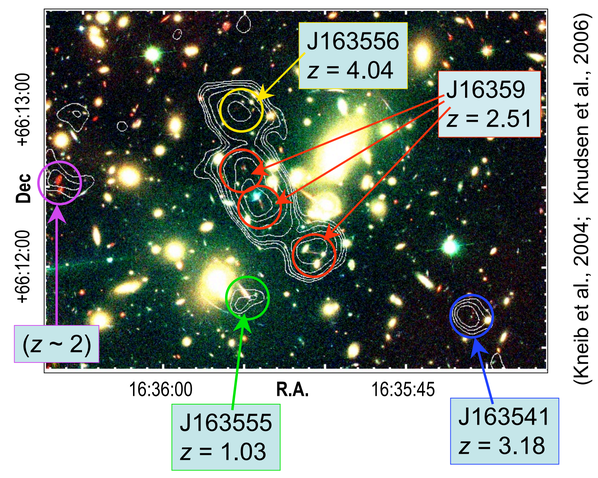
L_{FIR} ~ $10^{11\text{-}12}$ $L_\odot$ common in local Universe/low z
- starbursts, LIRGs, and ULIRGs
- systematic CO surveys

Challenge with current instrumentation:

L_{FIR} ~ $10^{11\text{-}12}$ $L_\odot$ at high-z !

Are LIRGs/ULIRGs at high-z same as the local?

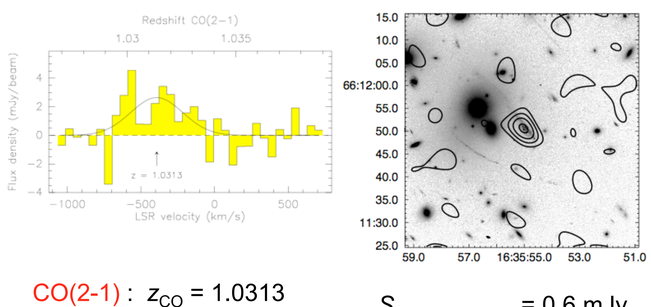
Cluster field Abell 2218 has
- one of the deepest SCUBA maps (50h, 1σ rms = 0.6-1 mJy/beam)
- strong gravitational lensing
- largest number of reliably identified faint SMGs



RESULTS: CO DETECTIONS IN A2218 SMGs

Using IRAM PdBI observations

SMMJ163555



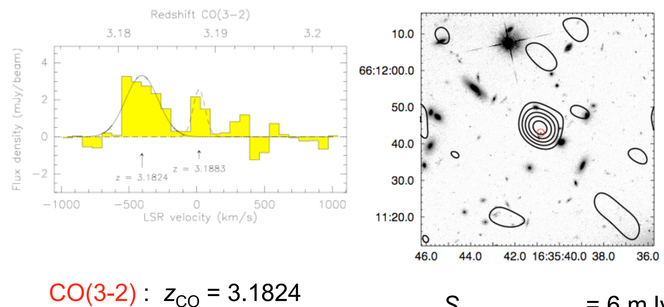
CO(2-1) : z_{CO} = 1.0313

I_{CO} = 1.2±0.2 Jy km/s
Line width ~ 410 km/s

L'_{CO} = 2.3×10^9 K km/s pc^2
M_{H2} = 1.8×10^9 $M_\odot$ ⇒ SFE ~500 $L_\odot/M_\odot$
(when using X_{CO} = 0.8 $M_\odot$/(K km/s pc^2))

$S_{850\mu m,unlensed}$ = 0.6 mJy
L_{FIR} = 4×10^{11} $L_\odot$

SMMJ163541



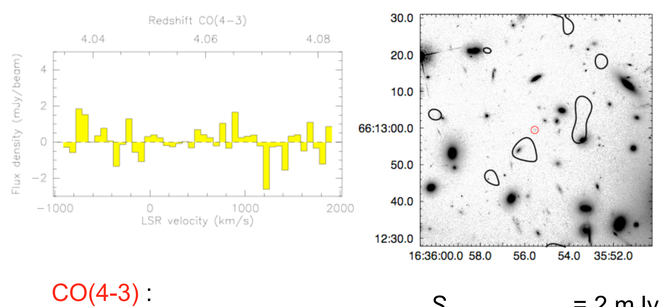
CO(3-2) : z_{CO} = 3.1824

I_{CO} = 1.0±0.1 Jy km/s
Line width ~ 280 km/s

L'_{CO} = 2.8×10^{10} K km/s pc^2
M_{H2} = 2.2×10^{10} $M_\odot$ ⇒ SFE ~500 $L_\odot/M_\odot$

$S_{850\mu m,unlensed}$ = 6 mJy
L_{FIR} = 9×10^{12} $L_\odot$

SMMJ163556



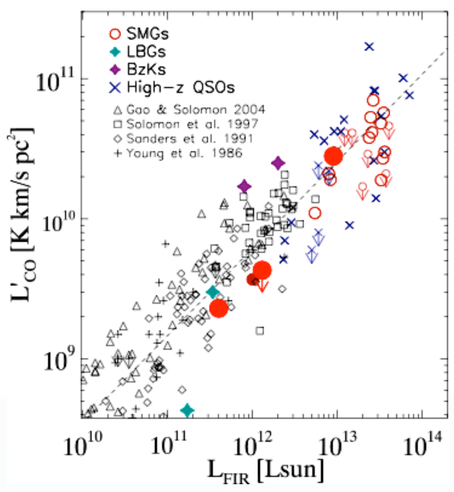
CO(4-3) :

I_{CO} < 0.45 Jy km/s
Line width ~ 400 km/s (assumed!)

L'_{CO} < 0.4×10^{10} K km/s pc^2

$S_{850\mu m,unlensed}$ = 2 mJy
L_{FIR} = 1.3×10^{12} $L_\odot$

DISCUSSION: CO IN HIGH-z LIRG/ULIRGS

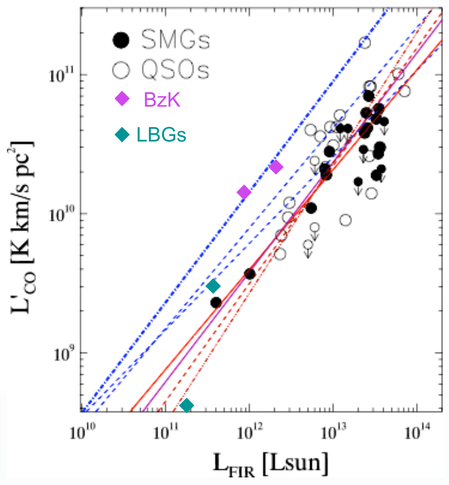


At L_{FIR} < 3×10^{12} $L_\odot$:

SMGs: two CO detections (Knudsen ea, 2009; Kneib ea, 2005; Sheth ea, 2004)

LBGs: two CO detections (one without submm continuum detection) (Coppin ea, 2007; Baker ea, 2003)

BzKs: two CO detections [appear to have low SF efficiency] (Daddi ea 2008)



Difference between fitted lines is ~1σ

Red: only high redshift sample

Blue: local or combined (local + high-z)

Difference between the high redshift and the local samples could be caused by:

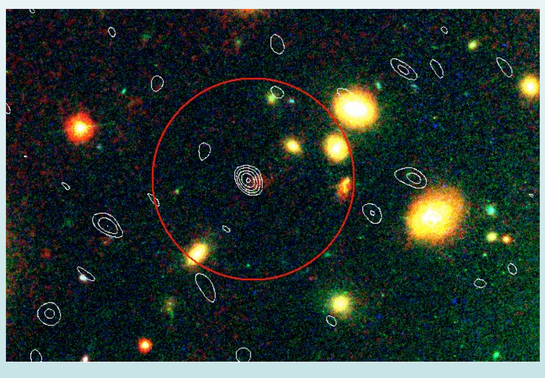
- Faint SMGs being more efficient at forming stars than local LIRGs/ULIRGs
  - Need larger sample to address this, future telescopes such as LMT, C-CAT, ALMA, etc)
- Systematic uncertainties in L_{FIR}
  - we have a SHARC-II program to derive accurate FIR SEDs
- Comparison between different CO J-transitions
  - Need systematic observations, preferably using CO(1-0)

REFERENCES: Baker et al., 2003, ApJ, 604, 125; Coppin et al., 2007, ApJ, 665, 936; Coppin et al., 2008, MNRAS, 389, 45; Daddi et al., 2008, ApJ, 673, 21; Greve et al., 2005, MNRAS, 359, 1165; Kneib et al., 2004, MNRAS, 349, 1211; Kneib et al., 2005, A&A, 434, 819; Knudsen et al., 2006, MNRAS, 368, 48; Knudsen et al., 2009, A&A, 496, 45; Riechers et al., 2006, ApJ, 650, 604; Sheth et al., 2004, ApJ, 614, L5; Sanders et al., 1991, ApJ, 370, 158; Solomon et al., 1997, ApJ, 478, 144; Tacconi et al., 2008, ApJ, 680, 246; Young et al., 1986, ApJ, 304, 443.

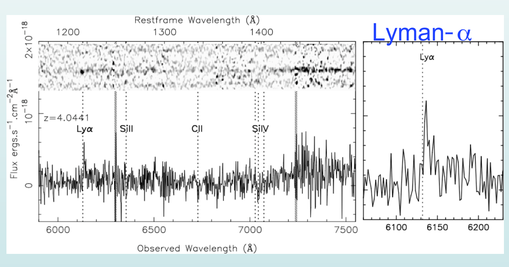
BONUS SECTION

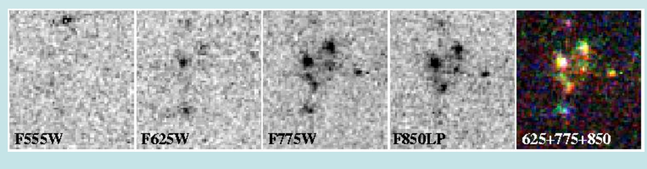
NEW z=4 IDENTIFICATION OF FAINT SMG

SMMJ163555.5+661300



White contours: SMA, 3.8, 4.7, 5.6, … mJy
Red circle: SCUBA beam, FWHM=15 arcsec





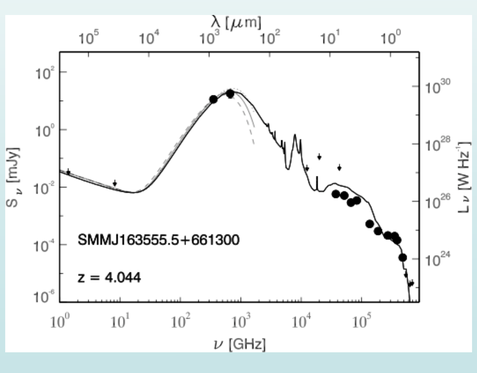
z = 4.044±0.001

L_{FIR} = 1.3×10^{12} $L_\odot$

SFR = 230 $M_\odot$/yr

Σ_{SFR} > 150 $M_\odot$/yr/kpc^2

Area < 2.1kpc × 0.7kpc



Knudsen et al., 2009, ApJ, submitted