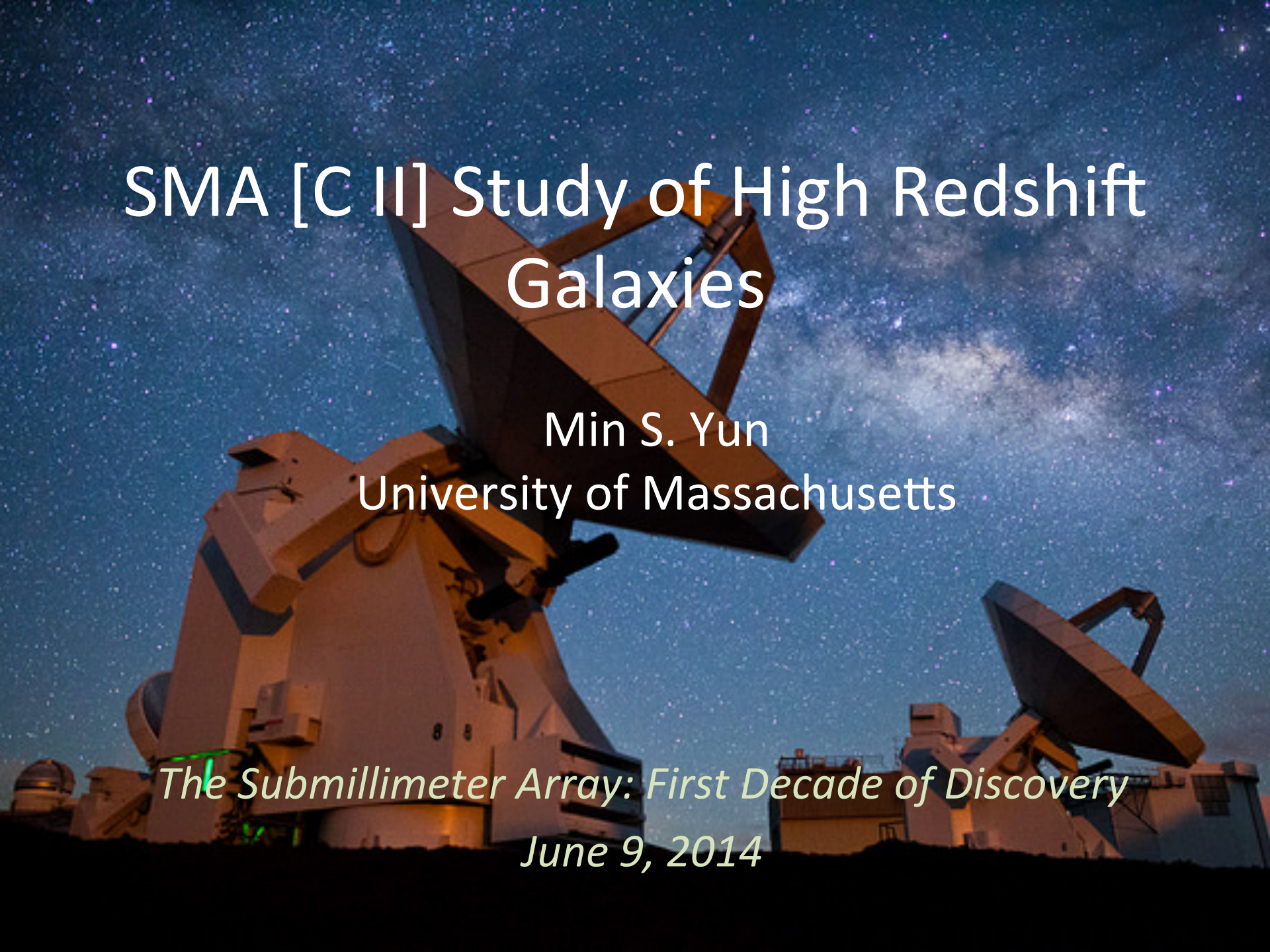

SMA [C II] Study of High Redshift Galaxies

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The Submillimeter Array: First Decade of Discovery

June 9, 2014

Contributors

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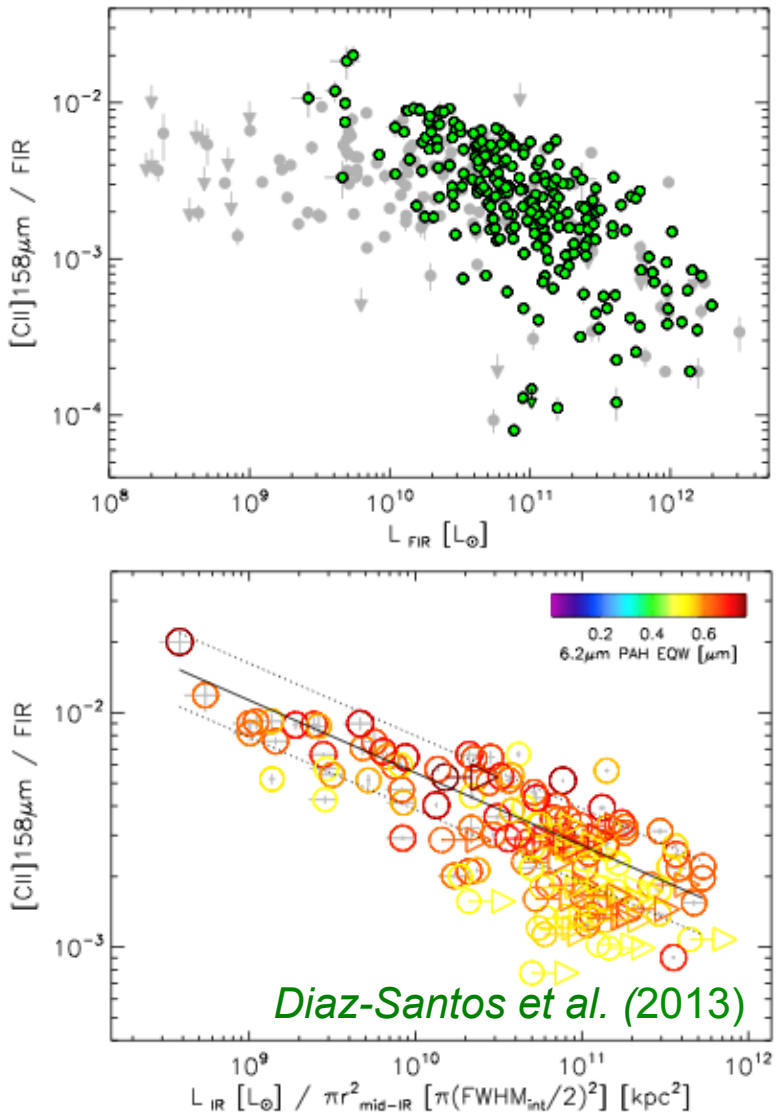
Others: D. Iono (ALMA-J), J. Younger

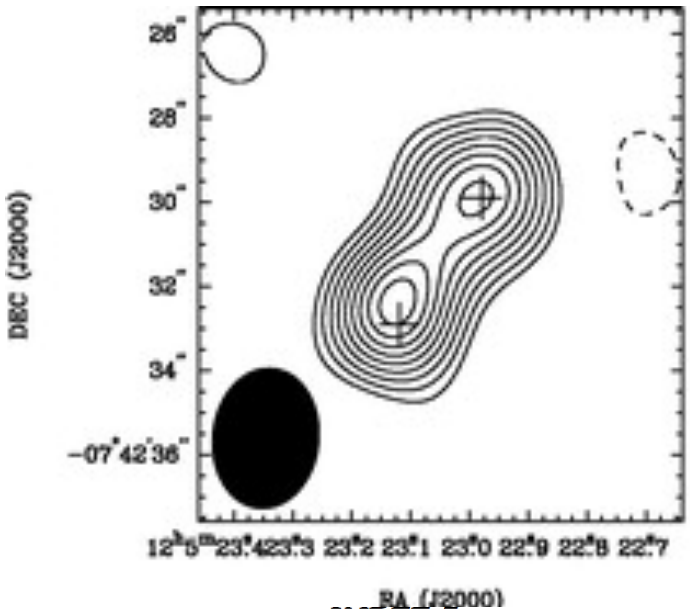
[C II] as a Tracer of Gas and SF in Galaxies

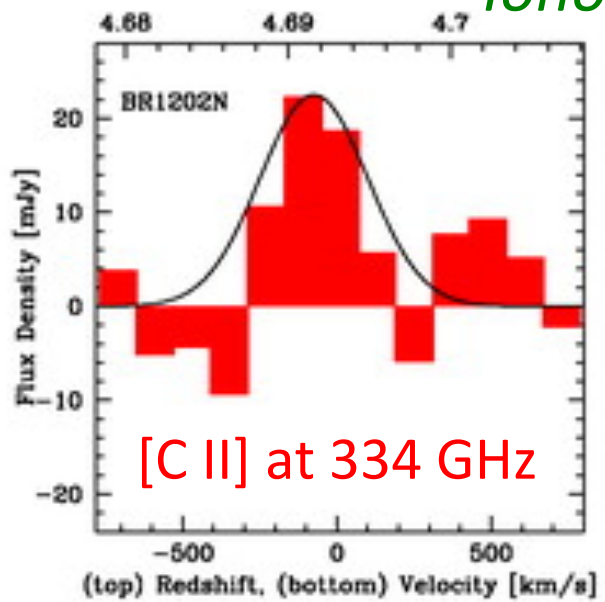


- [C II] 157μ line is the most intense far-IR emission line in normal, SF galaxies – as much as 1% of total IR luminosity.
- ISO, ZEUS/CSO, and now Herschel-PACS have surveyed a large number of nearby (and some distant) galaxies.
- Promising tool for studying SF galaxies in high-z galaxies (a motivation for SMA)

[C II] in z=4.7 QSO BR1202-0275

Iono et al. (2006)

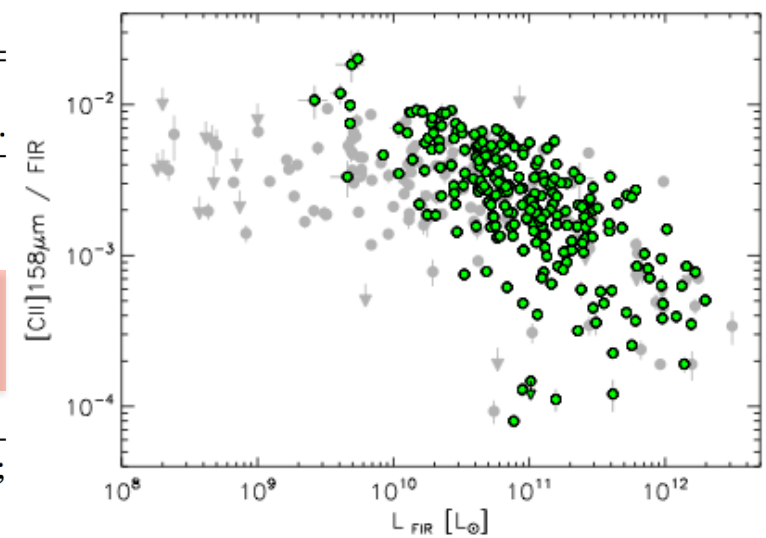




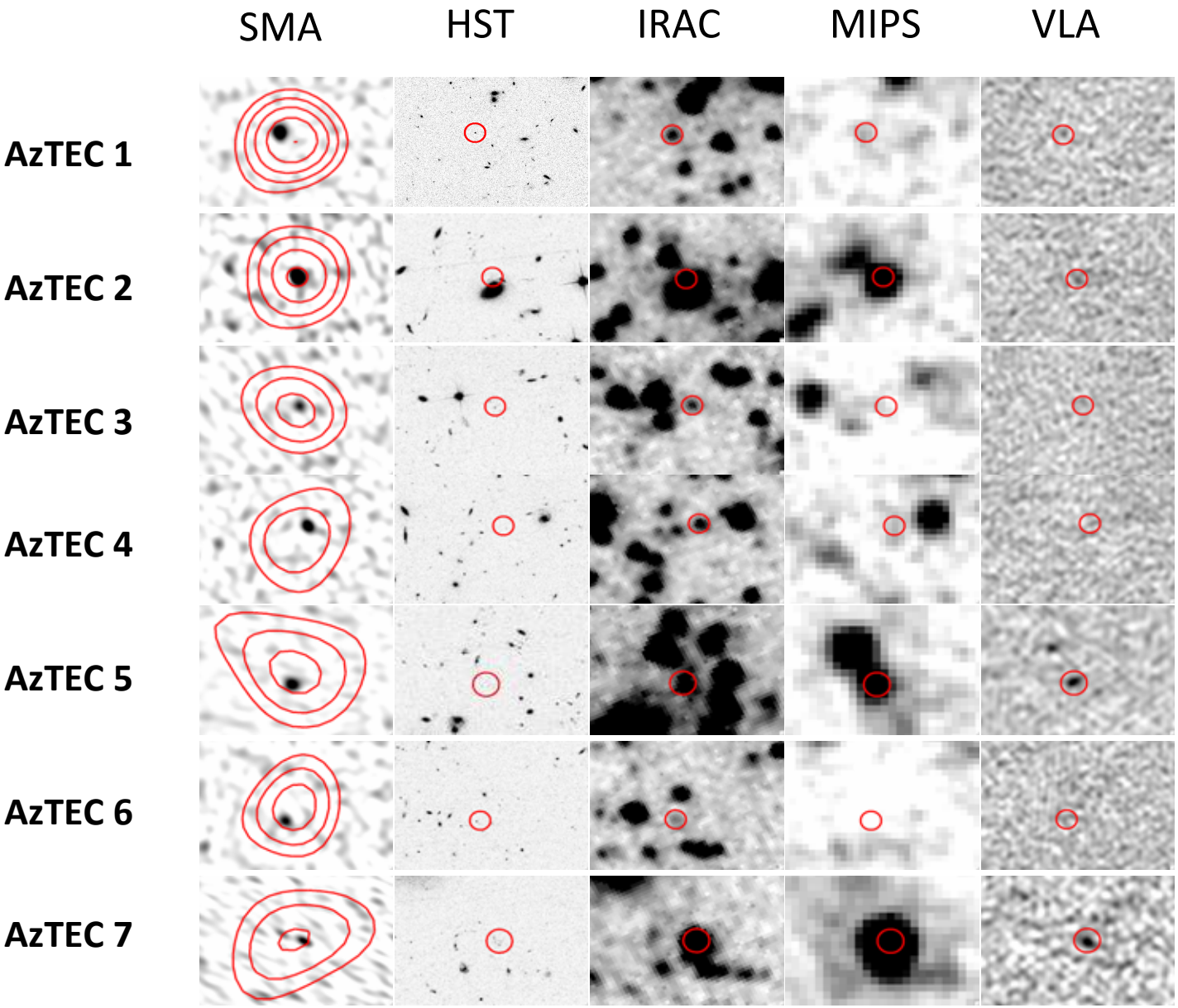
SUMMARY OF LUMINOSITY RATIOS

Source	L_{FIR} ($L_\odot$)	$L_{[C\,II]}/L_{FIR}$ (%)	Ref.
Normal galaxies	10^7–10^{11}	0.1–1	1
ULIRGs	$\sim 10^{12}$	0.01–0.1	2
High-z sources:			
BR 1202N (z = 4.7)	1.2×10^{13}	0.04	3
BR 1202S (z = 4.7)	2.6×10^{13}	<0.03	3
SDSS J1148+5251 (z = 6.4)	1.2×10^{13}	0.02	4
Cl 1358+62 (z = 4.9)	2.4×10^{12}	<0.4	5

REFERENCES.—(1) Malhotra et al. 2001; (2) Luhman et al. 2003; (3) this work; (4) Maiolino et al. 2005; (5) Marsden et al. 2005.

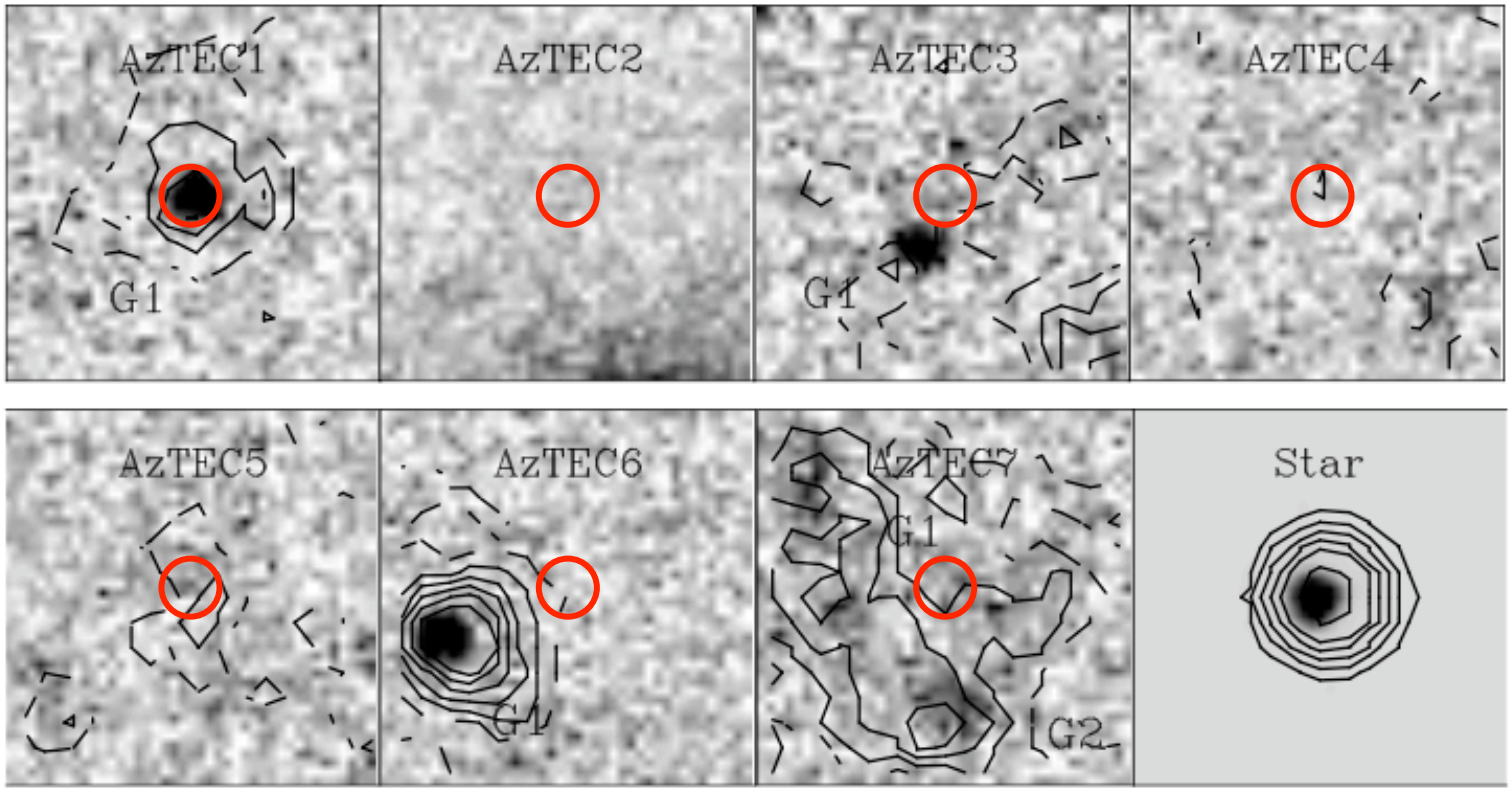


SMA Follow-up of AzTEC 1.1mm Sources



Younger et al. (2007,2009)

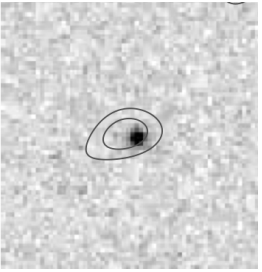
Young Massive SBs at high-z are Dark



SMA Greyscale: HST *i*-band, Contours: Subaru *r*-band

Many are exceedingly faint with *i* > *25 and r* > 27

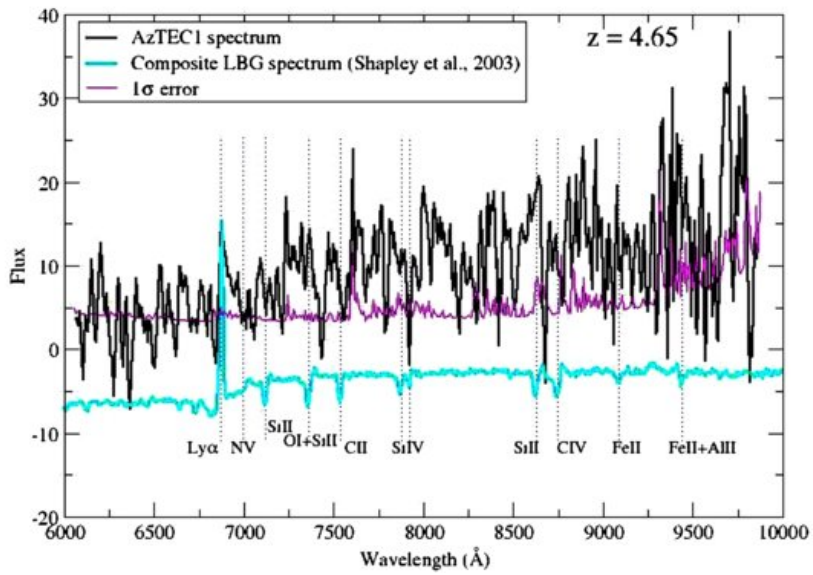
Younger et al. (2007)



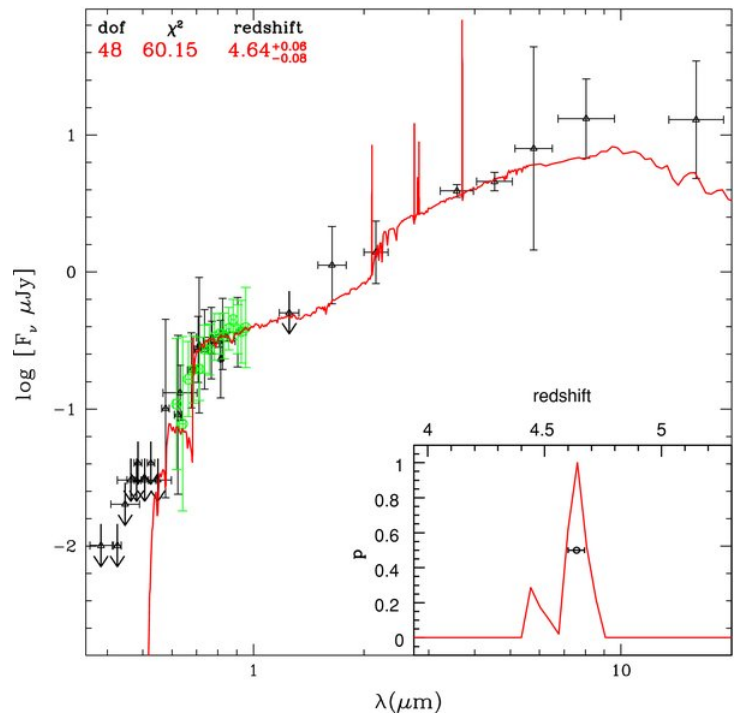
COSMOS AzTEC-1 at z=4.6?

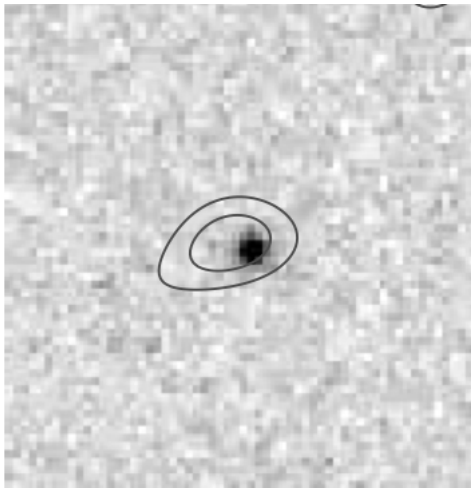
Smolcic et al. (2011)

- Keck DEIMOS Observations
  - No bright emission line
  - No clear Lyman break
- 20+ bands photometry
  - z_{PHOT} = 4.64+/-0.08



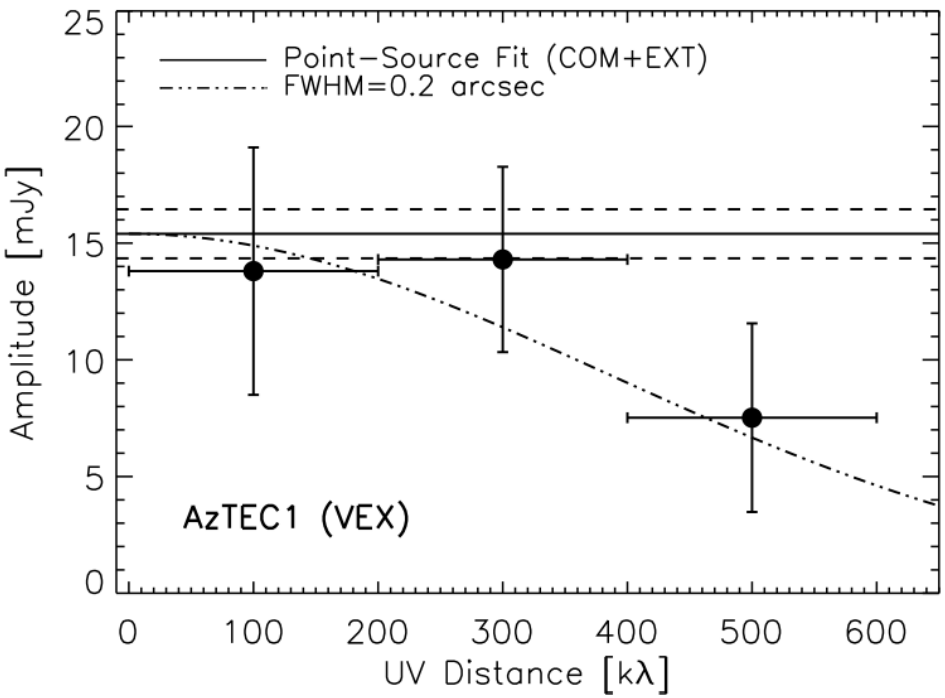
i = 25.3 mag





SMA 890μ Imaging of AzTEC-1

Younger et al. (2008)

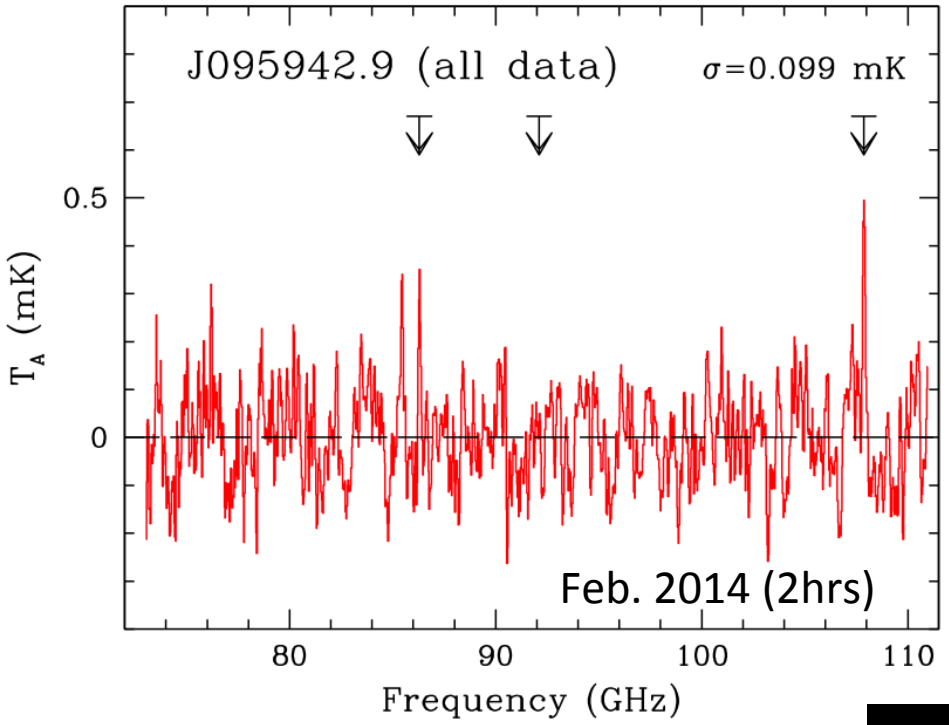


Resolved with the VEX configuration

-- Source size ~0.2" (1.4 kpc)

→ Σ_{SFR}= 880 $M_\odot/kpc^2$

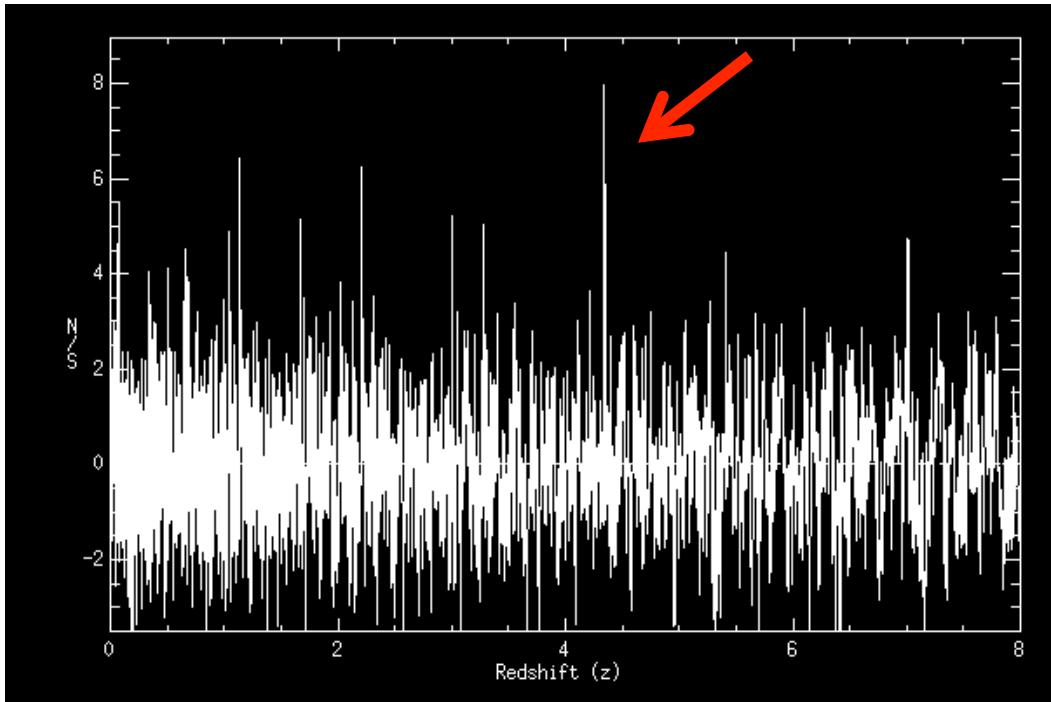
(Σ_{IR}= 1.1x10^{13} $L_\odot/kpc^2$)



LMT-RSR Observations of AzTEC-1

Yun et al. (in prep)

Z(CO) = 4.3421 +/- 0.0006



AzTEC-1: SMA [C II] Observations

Yun et al. (in prep)

Observed on March 1, 2014

[C II] at 355.8 GHz and 345 GHz continuum

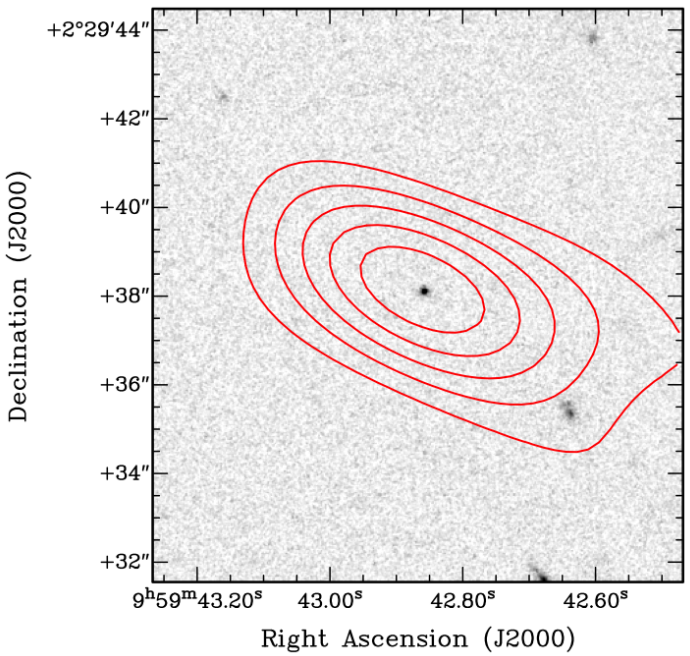
→ z(C II)=4.3415+/-0.0003

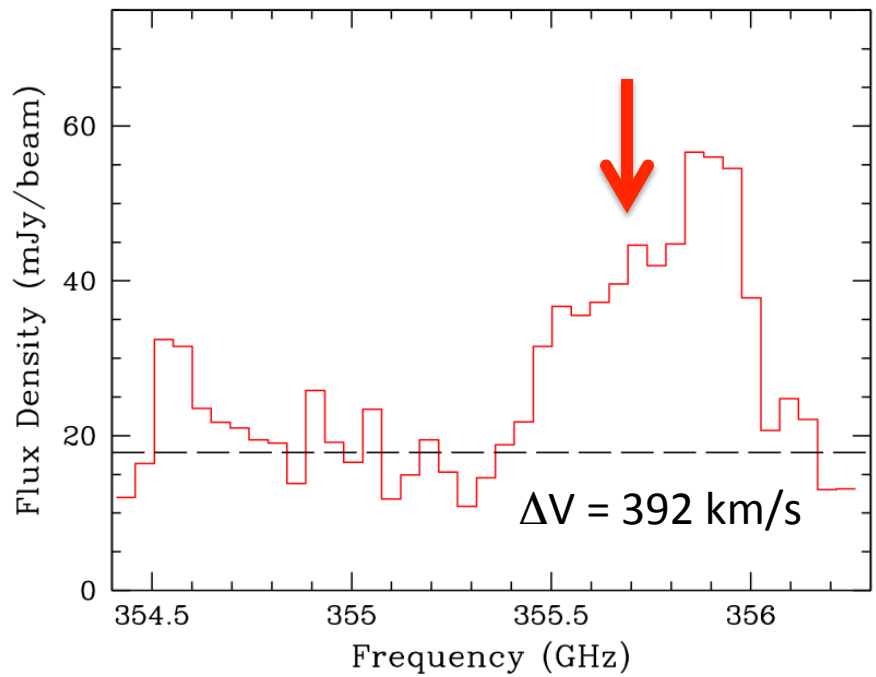
S(CII)ΔV = 13.1 +/- 0.9 Jy km/s

L(CII) = 7.8 x 10^9 $L_\odot$

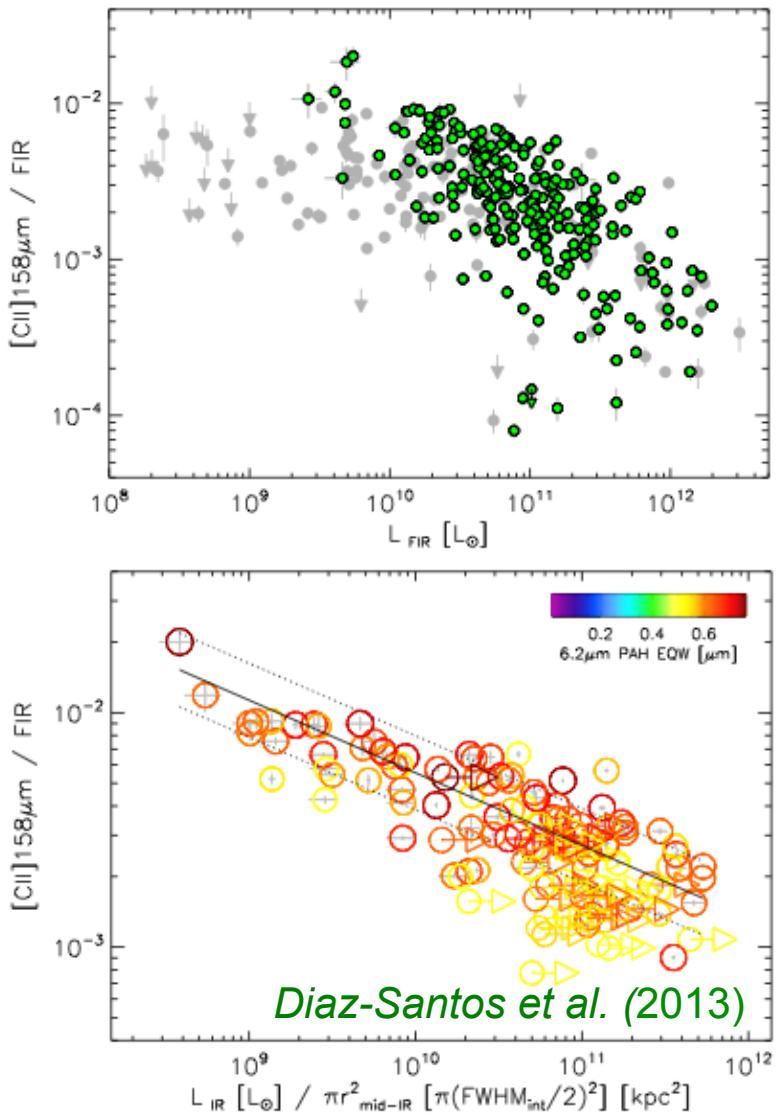
L(IR) = 1.7 x 10^{13} $L_\odot$

→ L(CII)/L(IR) = 0.00046





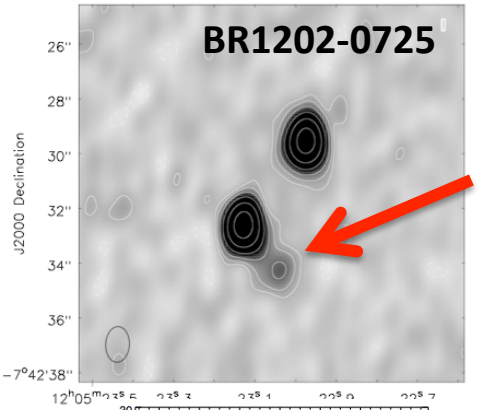
[C II] in AzTEC-1

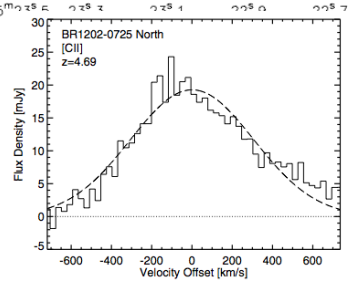


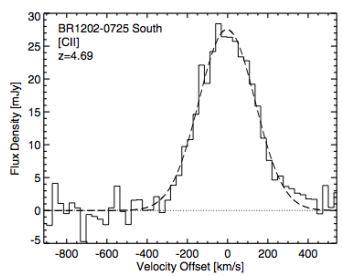
- SMA observations of [C II] line in AzTEC-1 (and BR1202) extend the observed local L(CII)/L(FIR) trend to z=4 galaxies
- These observations also extend the L(CII)/L(FIR) relation to higher IR surface brightness density by another order of mag

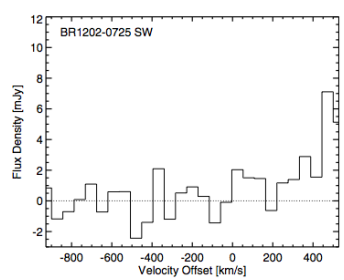
  → the deficit in [C II] due to an increase in ionization parameter <*U*>?

More Intriguing [C II] Observations

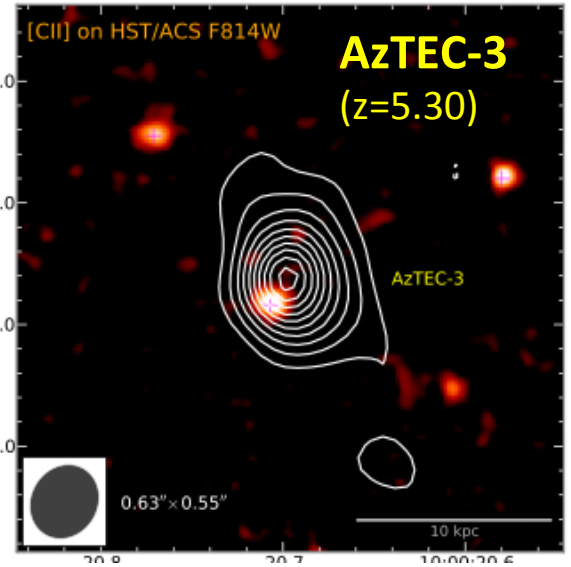


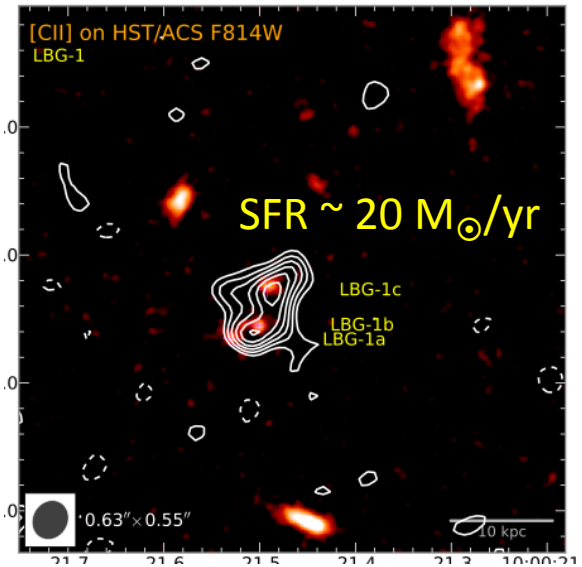




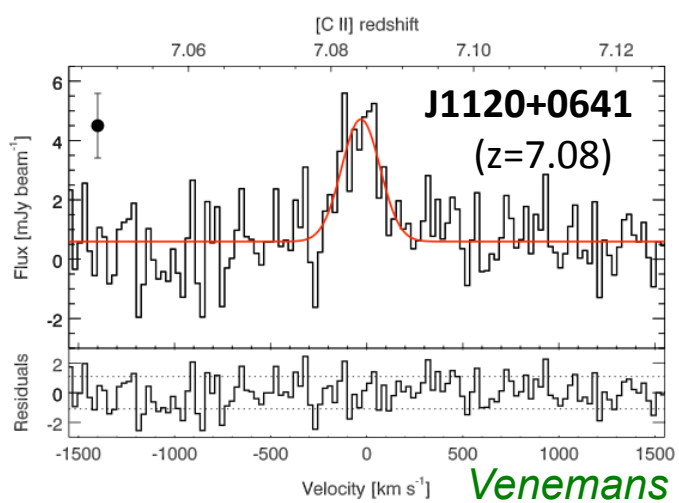


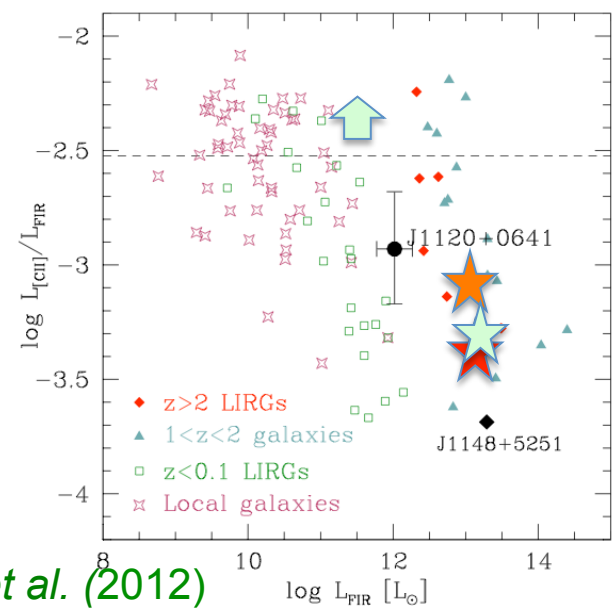
Wagg et al. (2012)





Riechers et al. (2014)



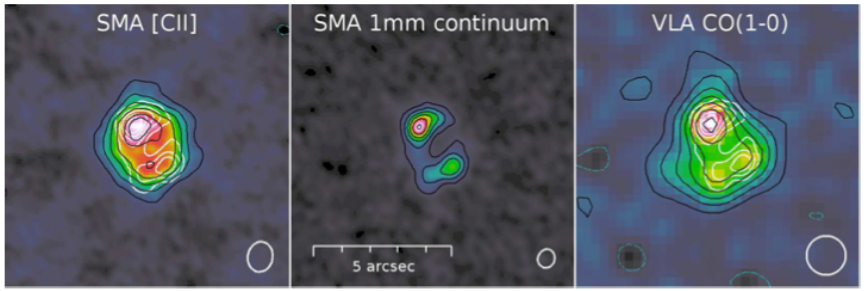


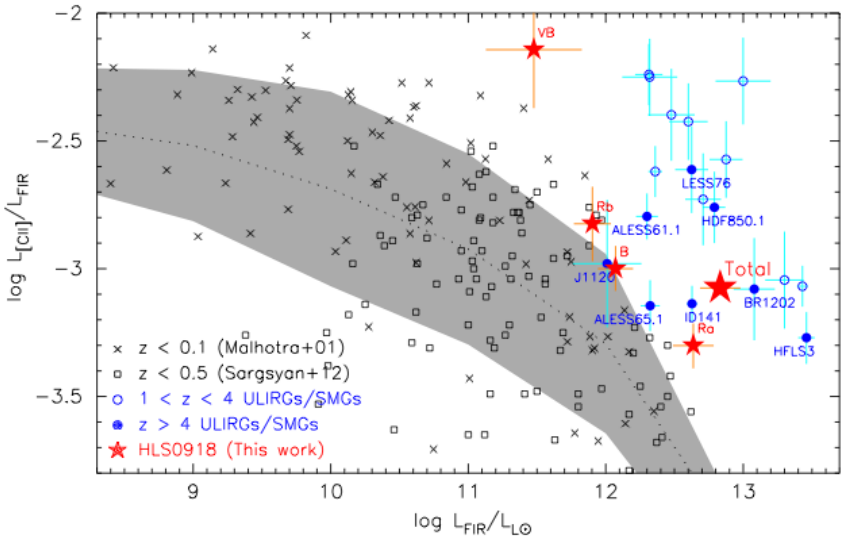
Venemans et al. (2012)

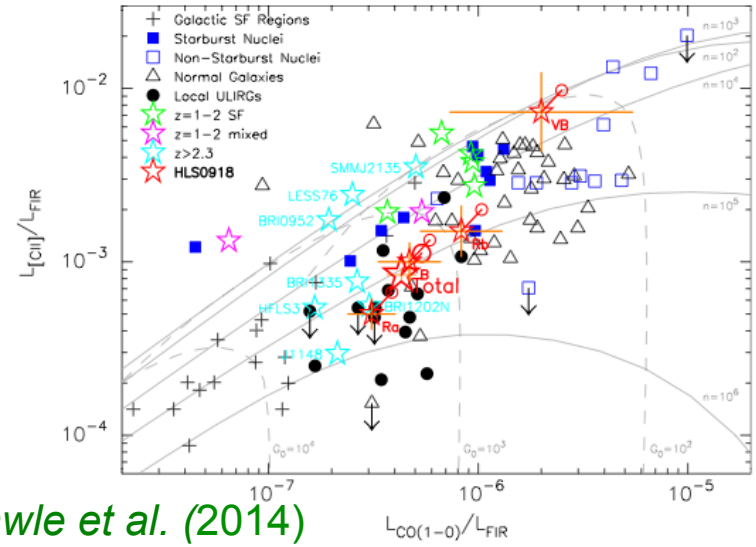
Strongly Lensed Sources

HLSJ091828
(z=5.24)

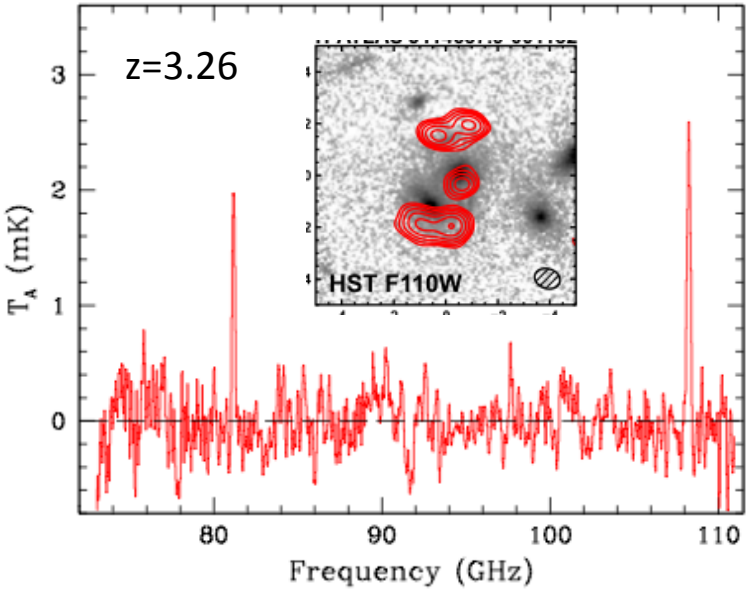
Bussmann+ (2013)

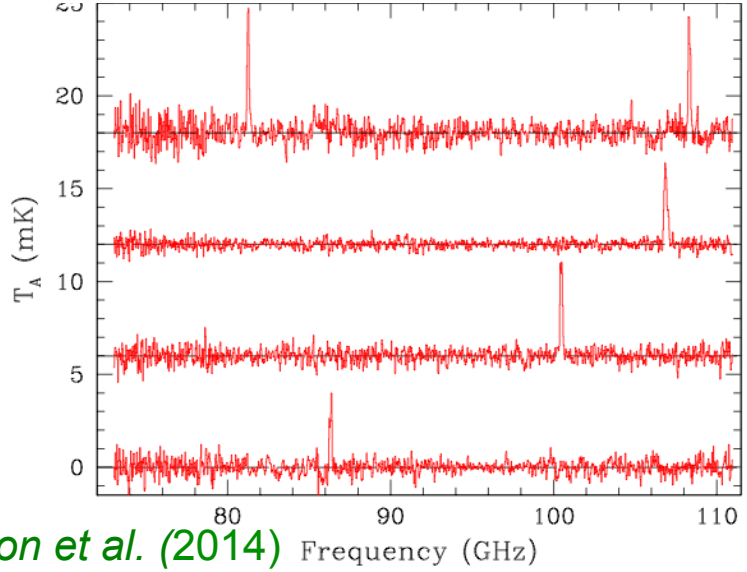






Rawle et al. (2014)





Harrington et al. (2014)

Summary

- [C II] 157μ line provides a highly sensitive tracer of gas and SF distribution in early Universe.
- SMA Observations of BR1202, AzTEC-1, and HLSJ091829 extended the local [C II]-FIR relations to z>4 and supports the "maximum SB" scenario (and only a minor contribution from a buried QSO) with high <U>.
- SMA [C II] studies of highly lensed sources can potentially yield a valuable new insight on the "Epoch of Galaxy Growth", including "normal" galaxies.

HCG 57: An Interesting Local Example

Alatalo et al. (2014)