ASTRONE:

ALMA Survey for Tracing Molecular gas Reservoirs

with Band ONE

11 Dec 2025, Niigata, EAMA 11th

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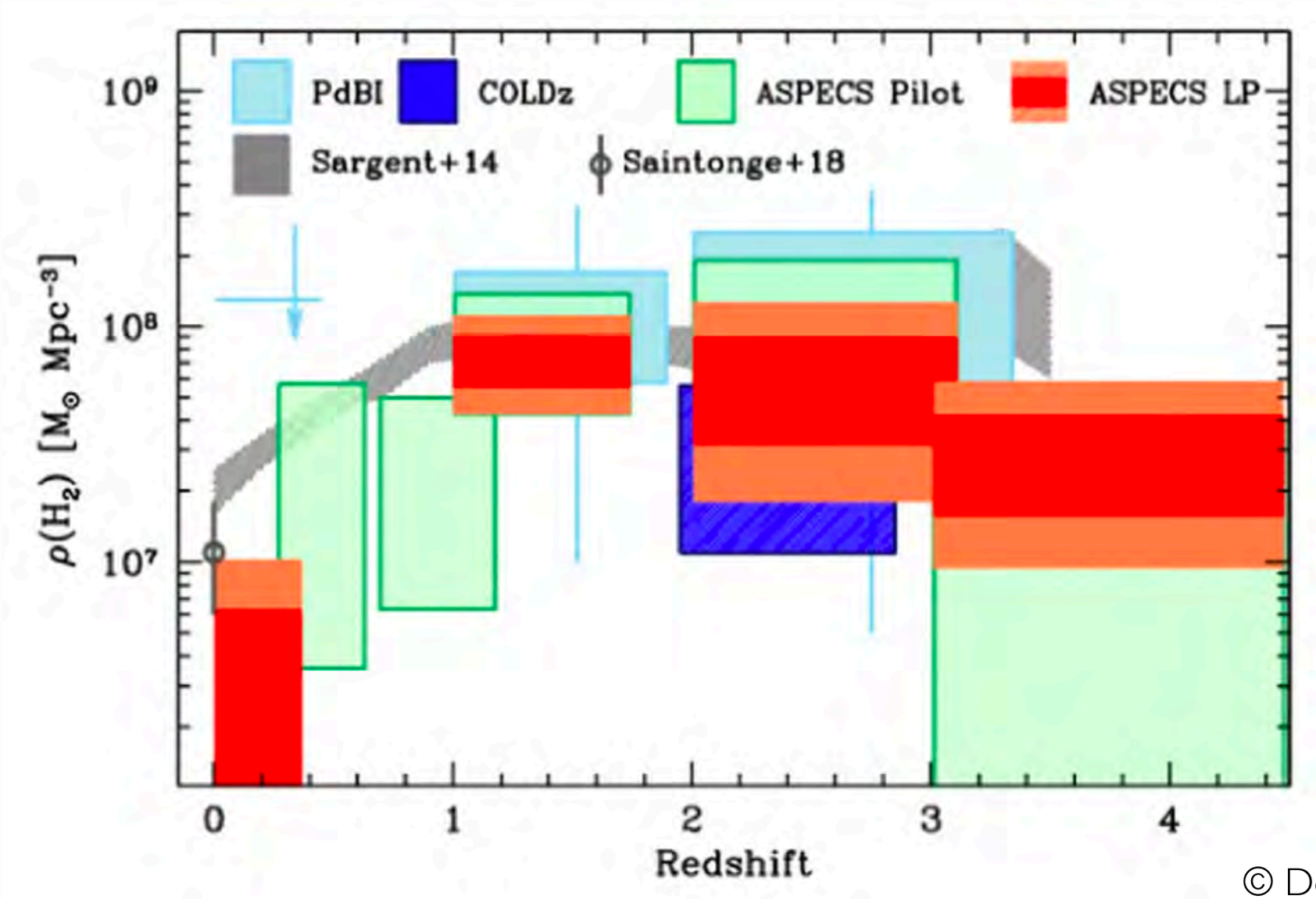
Masayuki Akiyama, Xiaoyang Chen, Naoki Matsumoto (Tohoku U.)

and ASTRONE team

Cosmic molecular gas evolution

- For understanding the cosmic SFR density evolution, it is important to measure the cosmic molecular gas density, tracing with CO observations

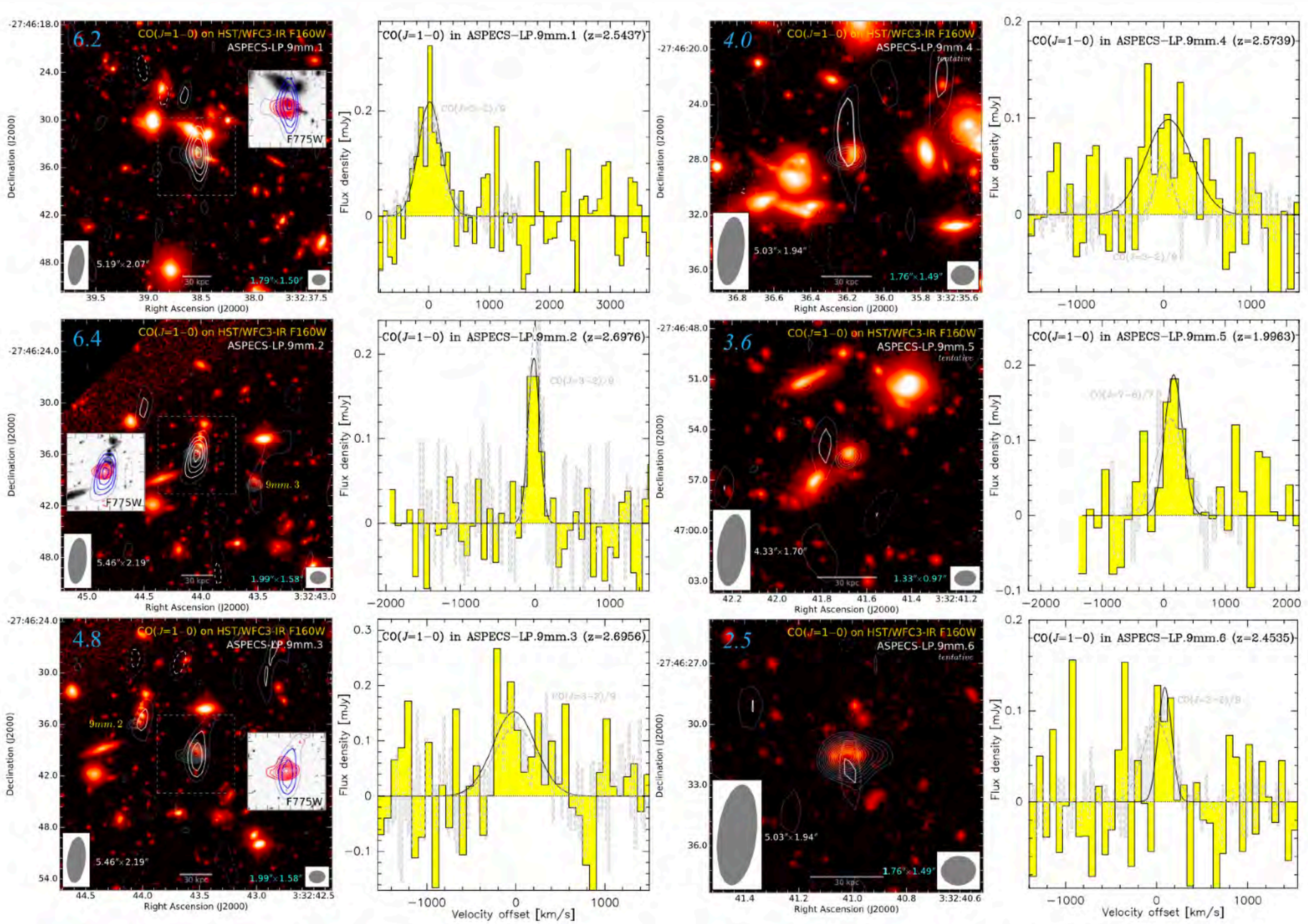
- Inconsistency between ASPECS (ALMA) and COLDz (VLA) at z~2-3



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Cosmic molecular gas evolution

- VLA CO(1-0) follow-ups of ASPECS CO(3-2) emitters derived r_{31} (VLASPECS)

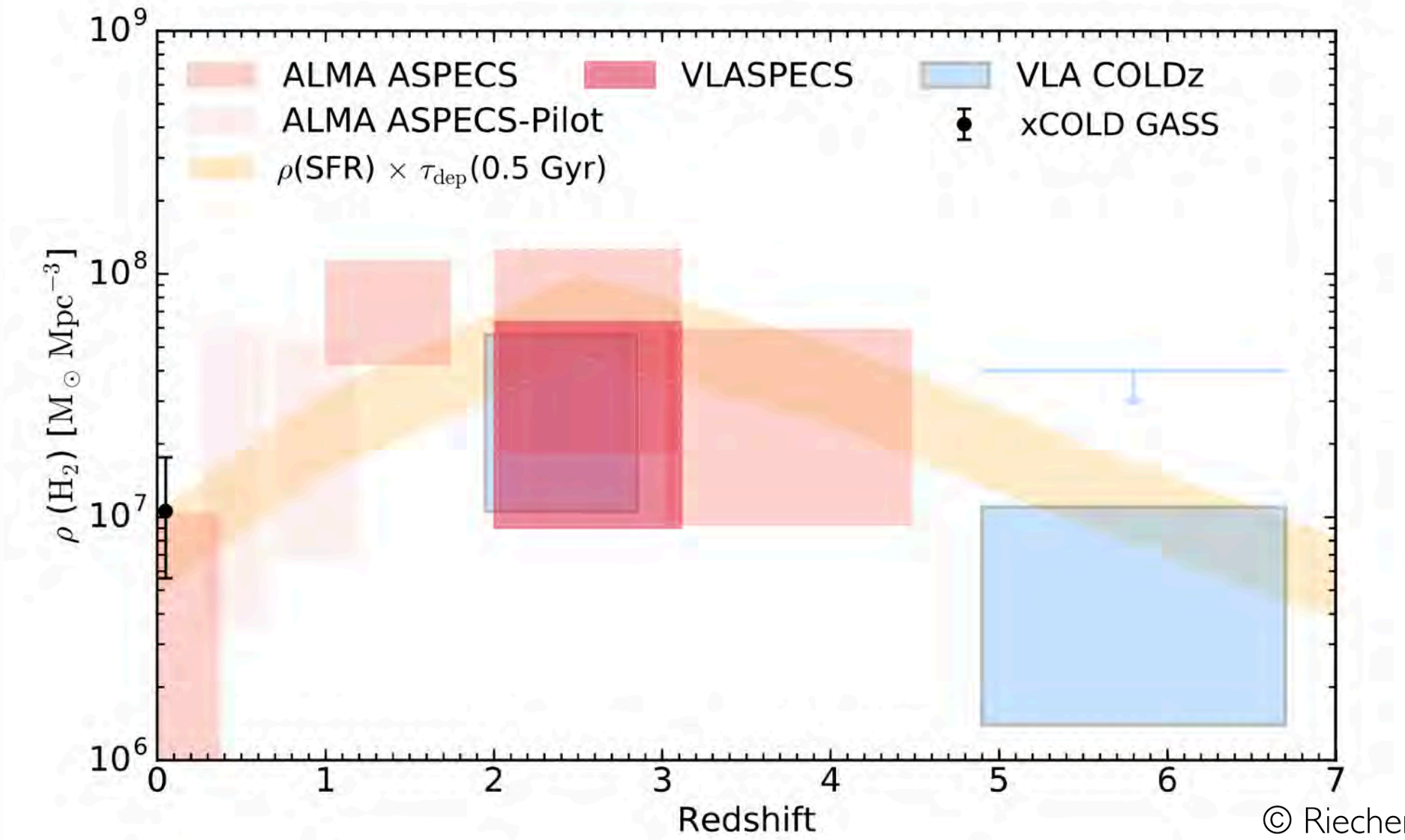


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Cosmic molecular gas evolution

- VLASPECS found $r_{31} \sim 0.84$
  which is about twice higher than the value adopted in ASPECS

- The r_{31}-corrected result is consistent with COLDz

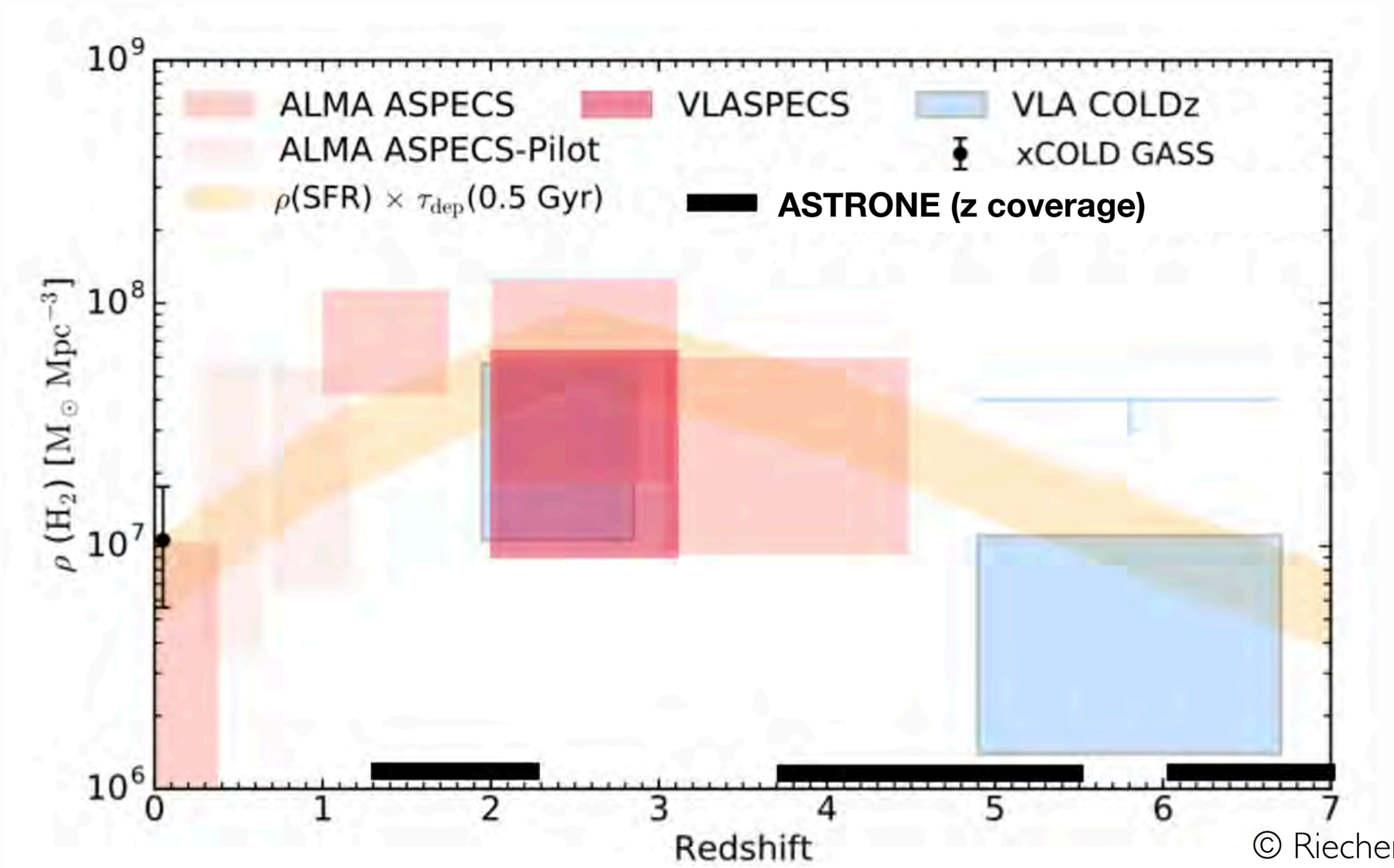


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ASTRONE: ALMA Survey for Tracing Molecular Gas Reservoirs with Band ONE

- Newly launched ALMA Band 1 receiver allows us to search CO emitters at different range of redshift

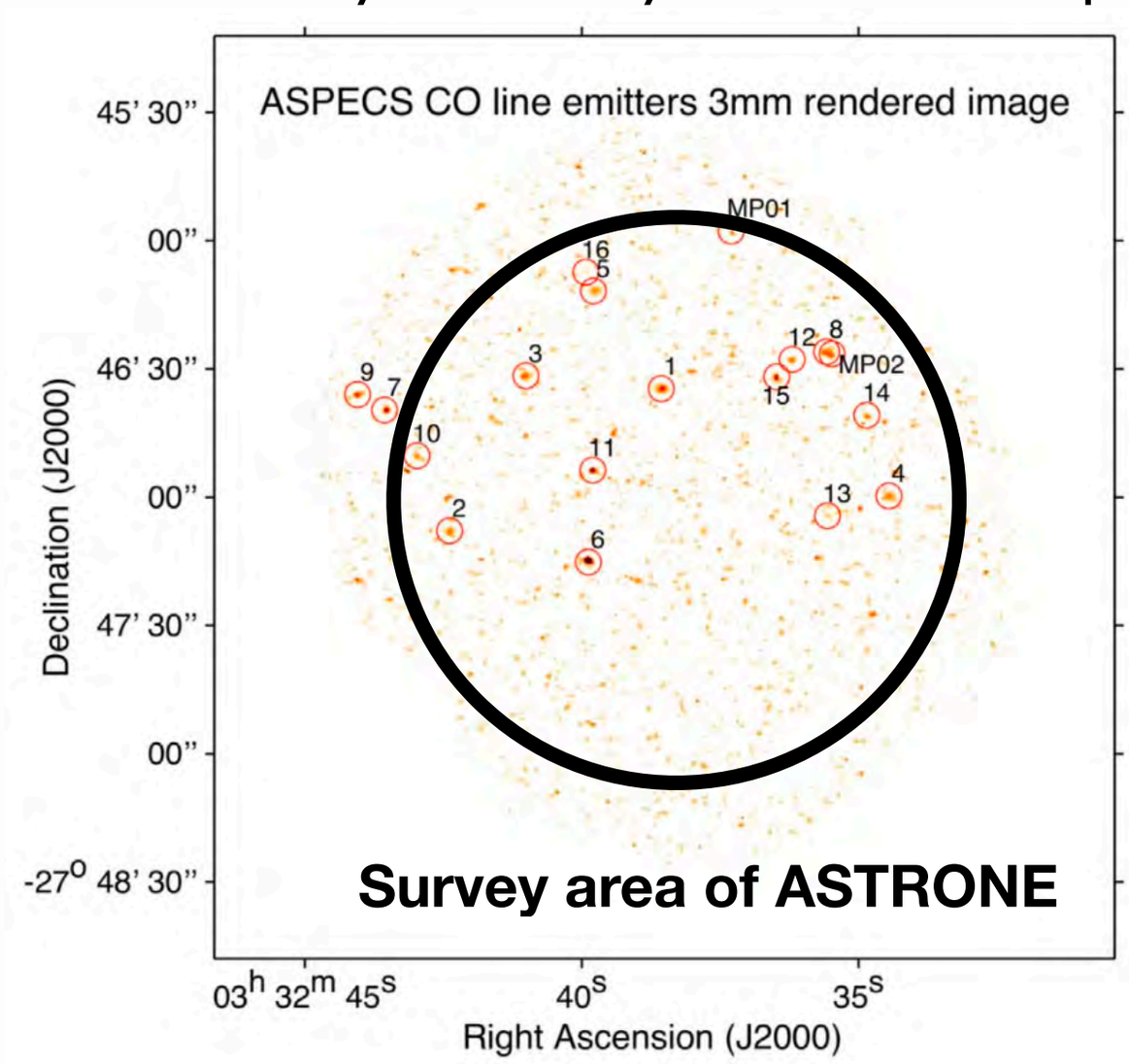
- The overlapping with CO(2-1) emitters (z~1.5) allow us to measure r_{21}

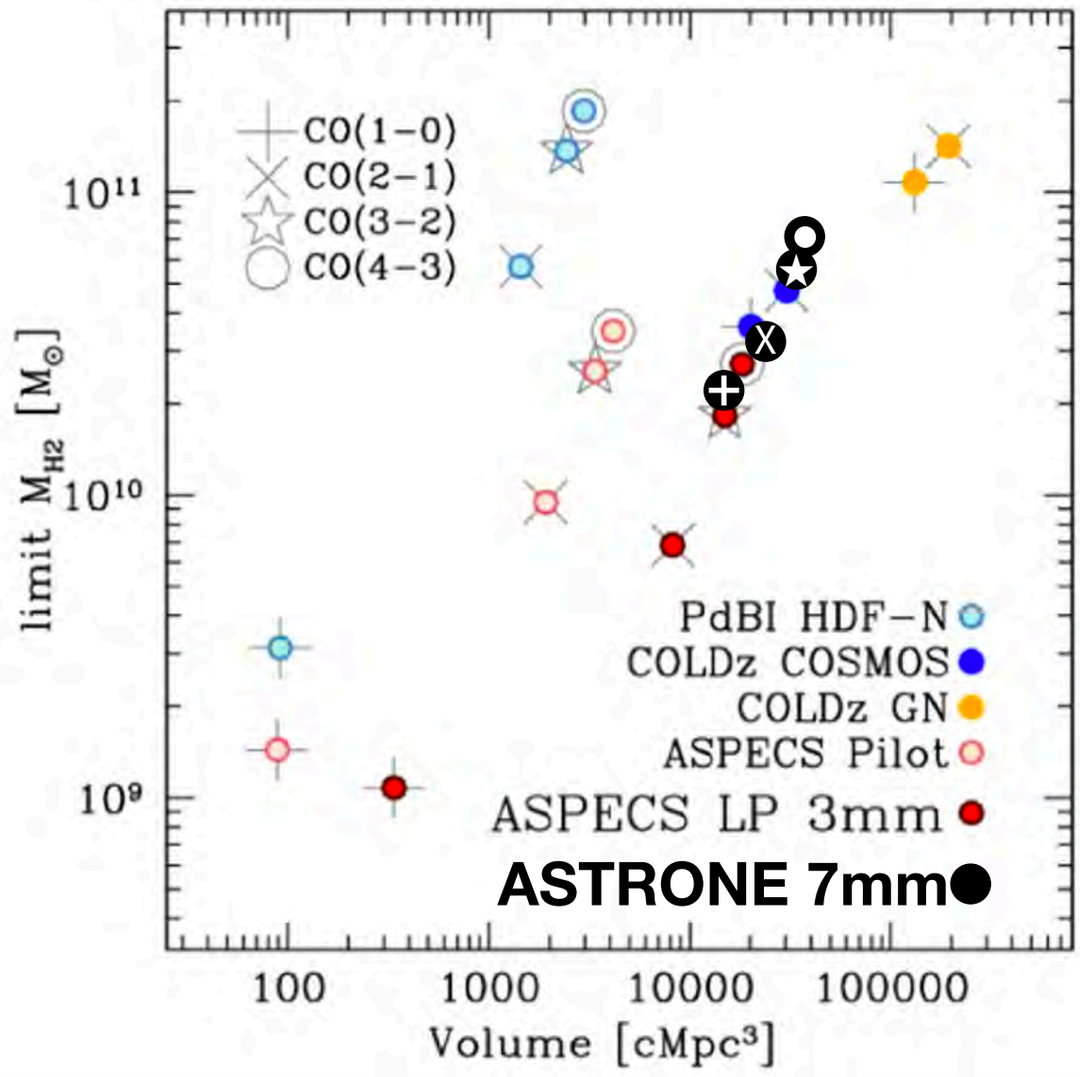


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ASTRONE: ALMA Survey for Tracing Molecular Gas Reservoirs with Band ONE

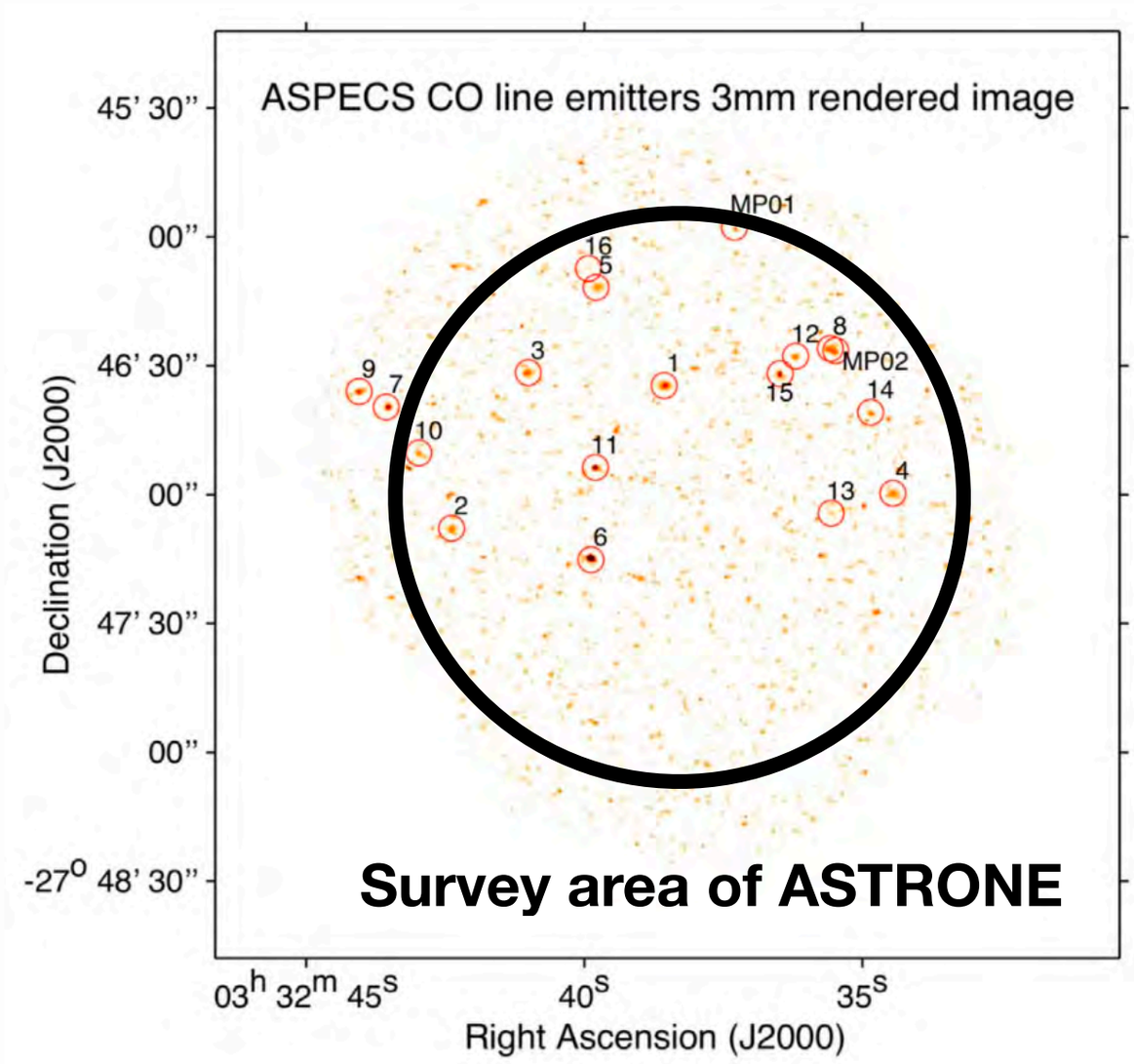
- ALMA 7mm spectroscopic survey in HUDF (Cycle 11; PI: KL)
- The survey area is comparable with ASPECS (with only one pointing)
- Sensitivity and Survey Volume are comparable with ALMA and VLA large programs

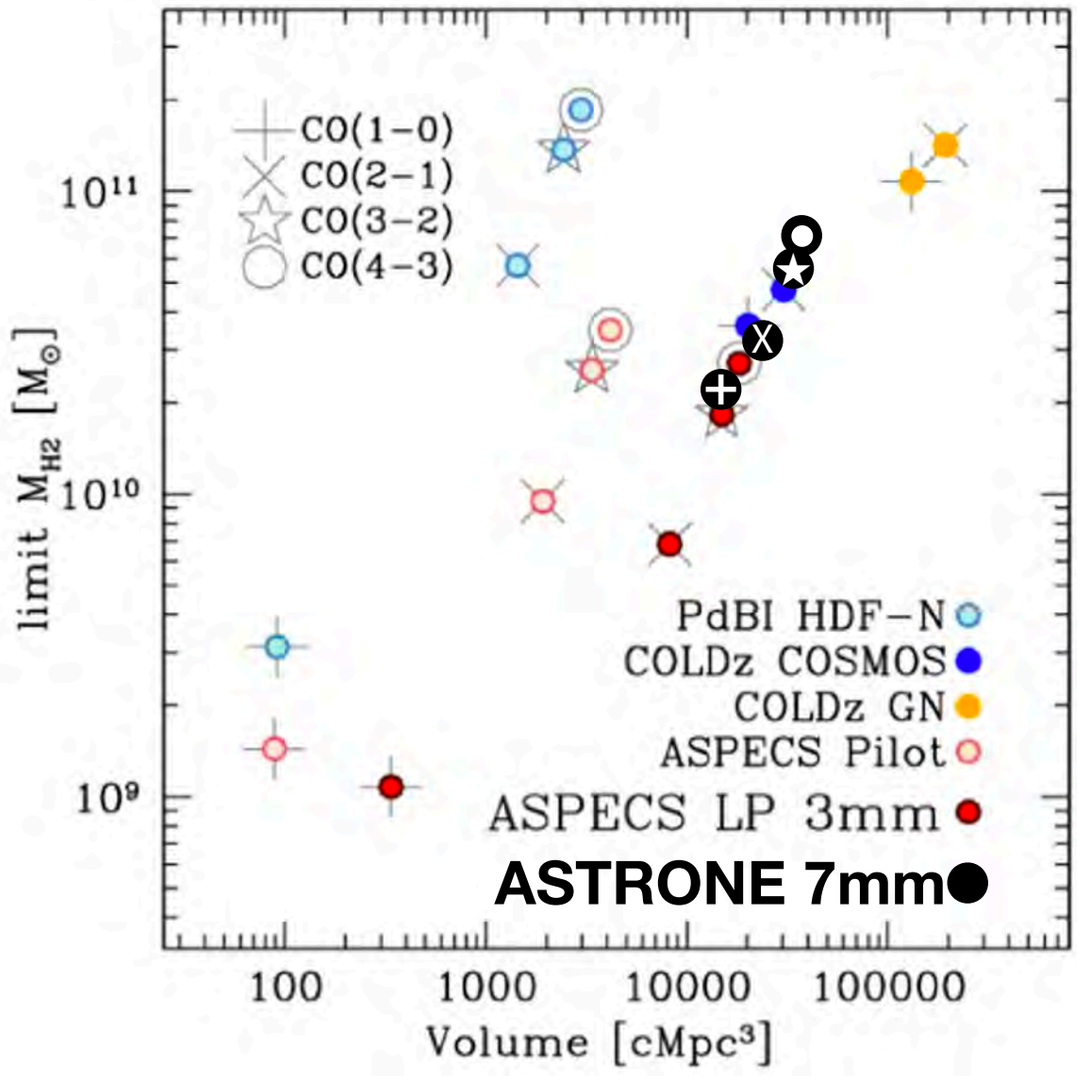




ASTRONE: ALMA Survey for Tracing Molecular Gas Reservoirs with Band ONE

- CO(1-0) follow-ups of ASPECS CO(2-1) emitters
- Blind search of CO line emitters





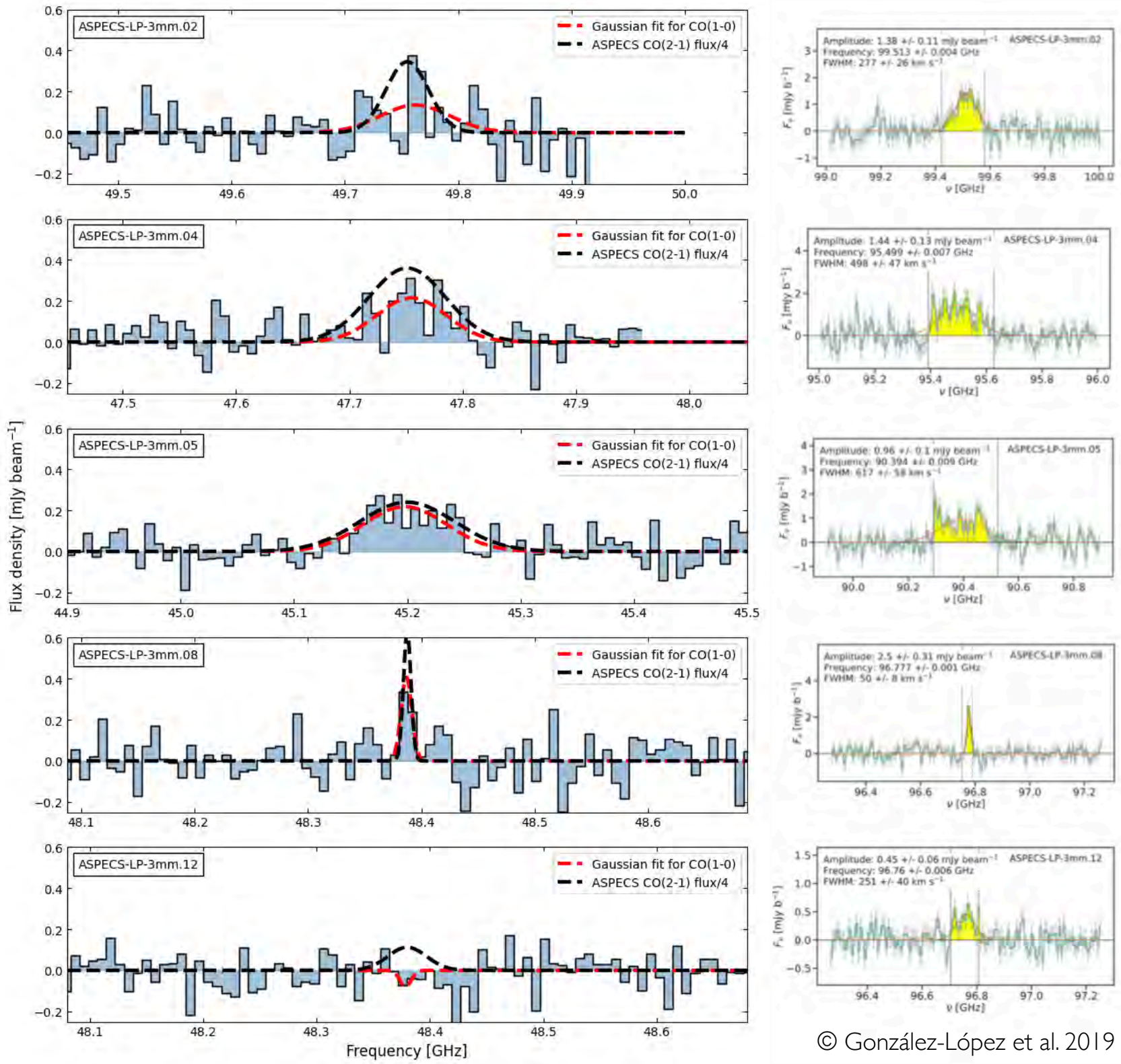
Comparison with ASPECS CO(2-1) emitters

- $r_{J1} = \dfrac{S_{\mathrm{CO}(J-(J-1))}}{J^2 S_{\mathrm{CO}(1-0)}}$
- $r_{21} = \dfrac{1}{4}\dfrac{S_{\mathrm{CO}(2-1)}}{S_{\mathrm{CO}(1-0)}}$
- $\dfrac{1}{4}S_{\mathrm{CO}(2-1)}$ **Black line**

  $S_{\mathrm{CO}(1-0)}$ **Red line**

- $r_{21} \sim [1.58, 1.84, 1.26, 1.10, -]$
- $r_{21} > 1$

  (ASPECS using 0.76)
- The real r_{21} is larger by at least a factor of 1.3



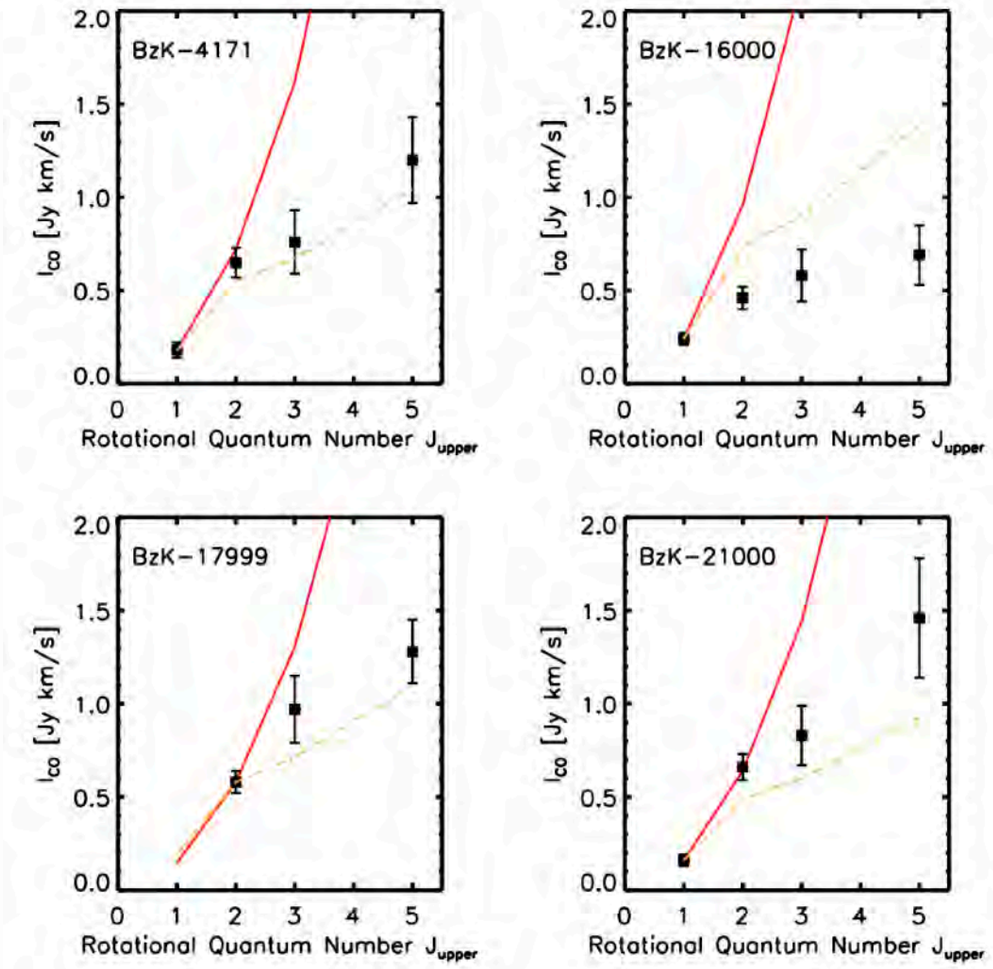
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Where is 0.76 from?

- Four (three) main-sequence galaxies at z~1.5 in Daddi et al. 2015

Source	Redshift[a]	Δv[b] km s^{-1}	$I_{CO[1-0]}$ Jy km s^{-1}	$I_{CO[2-1]}$ Jy km s^{-1}	$I_{CO[3-2]}$ Jy km s^{-1}	$I_{CO[5-4]}$ Jy km s^{-1}	$f_{1.3\ mm}$[d] mJy	R_{21}	R_{31}	R_{51}
4171	1.4652	600	0.178 ± 0.039	0.65 ± 0.08	0.76 ± 0.17	1.20 ± 0.23	0.14 ± 0.15	0.92 ± 0.23	0.47 ± 0.15	0.27 ± 0.08
16000	1.5250	250	0.240 ± 0.027	0.46 ± 0.06	0.58 ± 0.14	0.69 ± 0.16	0.44 ± 0.14	0.48 ± 0.08	0.27 ± 0.07	0.12 ± 0.03
17999	1.4138	575	–	0.58 ± 0.06	0.97 ± 0.18	1.28 ± 0.17	0.30 ± 0.11			
21000	1.5213	525	0.161 ± 0.026	0.66 ± 0.07	0.83 ± 0.16	1.49 ± 0.32	0.84 ± 0.36	1.02 ± 0.20	0.57 ± 0.14	0.36 ± 0.10
Average[c]	–	–	0.193 ± 0.018	0.59 ± 0.04	0.73 ± 0.09	1.12 ± 0.14	–	0.76 ± 0.09	0.42 ± 0.07	0.23 ± 0.04

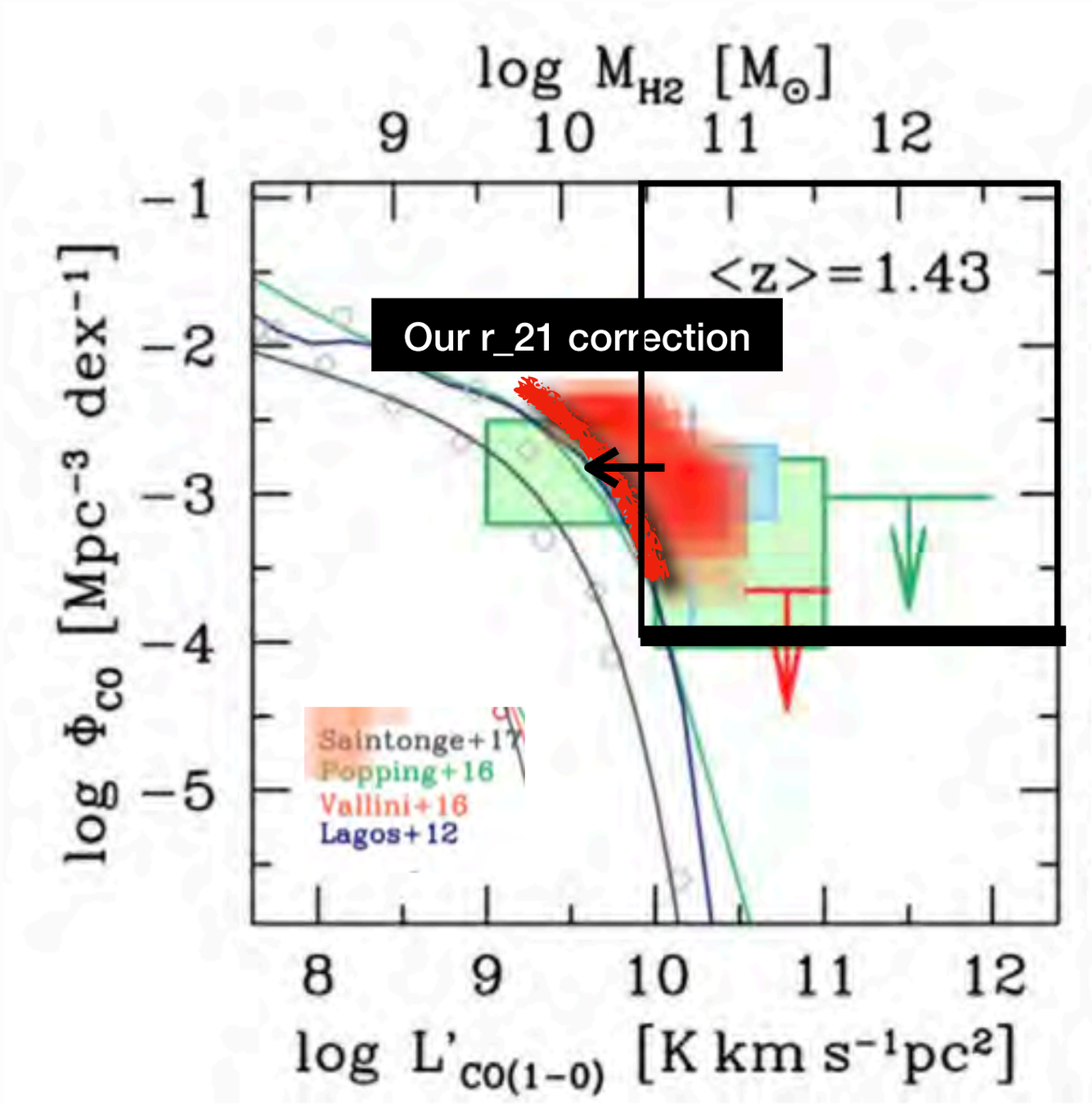
- Actually,
  two out of three
  show $r_{21} \sim 1$



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CO Luminosity Function

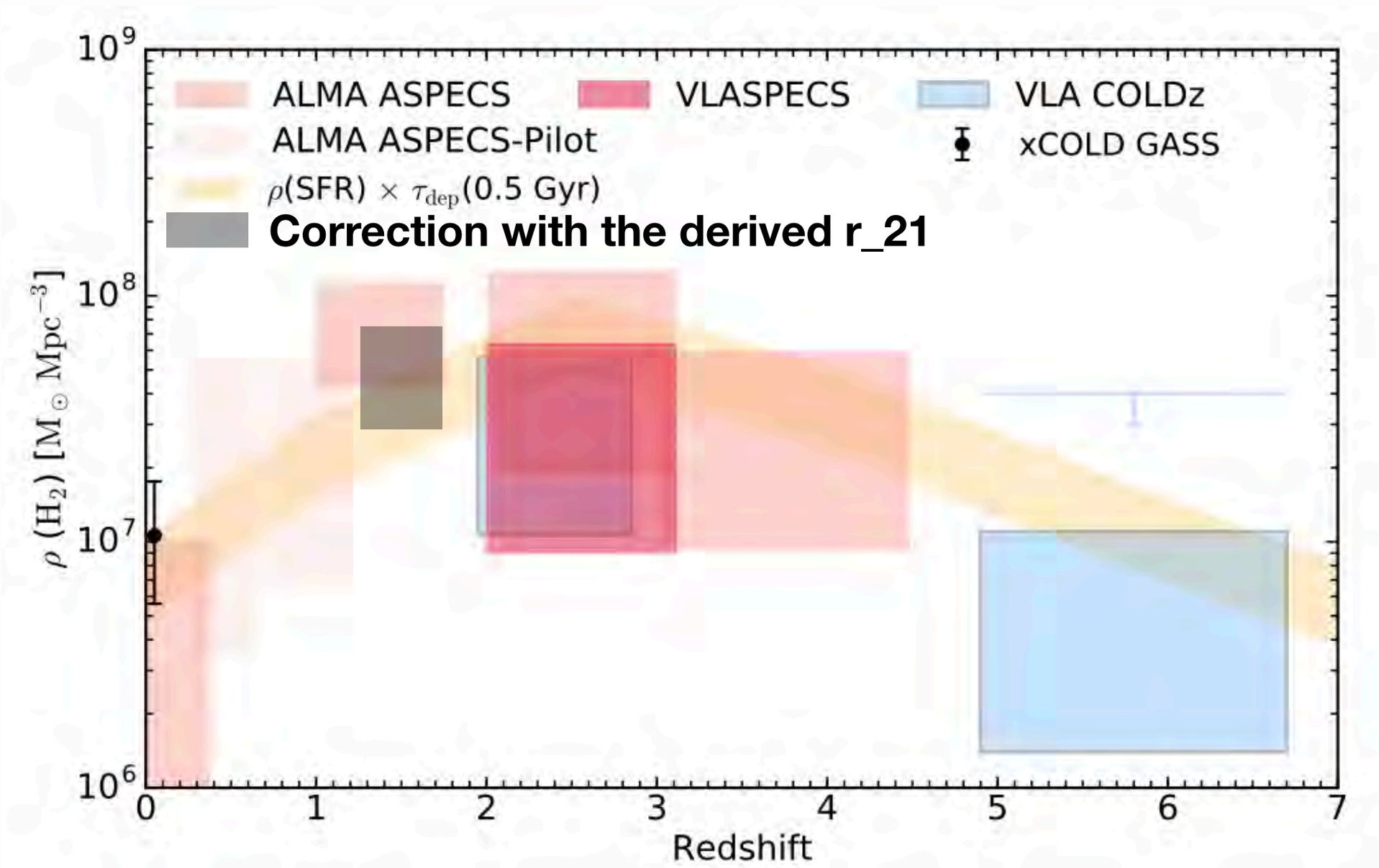
- With corrected r_{21} , the L'CO* derived by ASPECS reduced by at least a factor of 1.3
- Deeper observations are crucial



Cosmic molecular gas evolution with corrected r_21

- With corrected r_{21} , result of ASPECS reduced by at least a factor of 1.3

- Consistent with constant SFE evolution



ASTRONE: ALMA Survey for Tracing Molecular Gas Reservoirs with band ONE

- The first ALMA Band 1 survey in HUDF
- We obtained the CO(1-0) spectra of five ASPECS CO(2-1) emitters at z~1.5
- We found that the r_{21} is larger than what ASPECS adopted by at least a factor of 1.3, implying constant SFE evolution
- Even CO(2-1) can be strongly biased without the measurement of r_{21} !
- Deep CO(1-0) survey is important for constraining cosmic molecular gas density