[C II] detectability forecasts

for CCAT-prime through empirical models

(updated from arXiv:1812.08135; 2020, ApJ, 892, 51)

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CCATp meeting—2020/04/08

a brief outline

guiding questions for this talk

- how best to model the [C II] intensity mapping signal?
- how do fundamental sensitivities (white noise + SV) of CCAT-p surveys compare with high-redshift signal expectations?
- what needs to happen ...
  - on the experimental front?
  - on the theoretical front?

line-intensity mapping

an emerging technique for statistical astrophysics

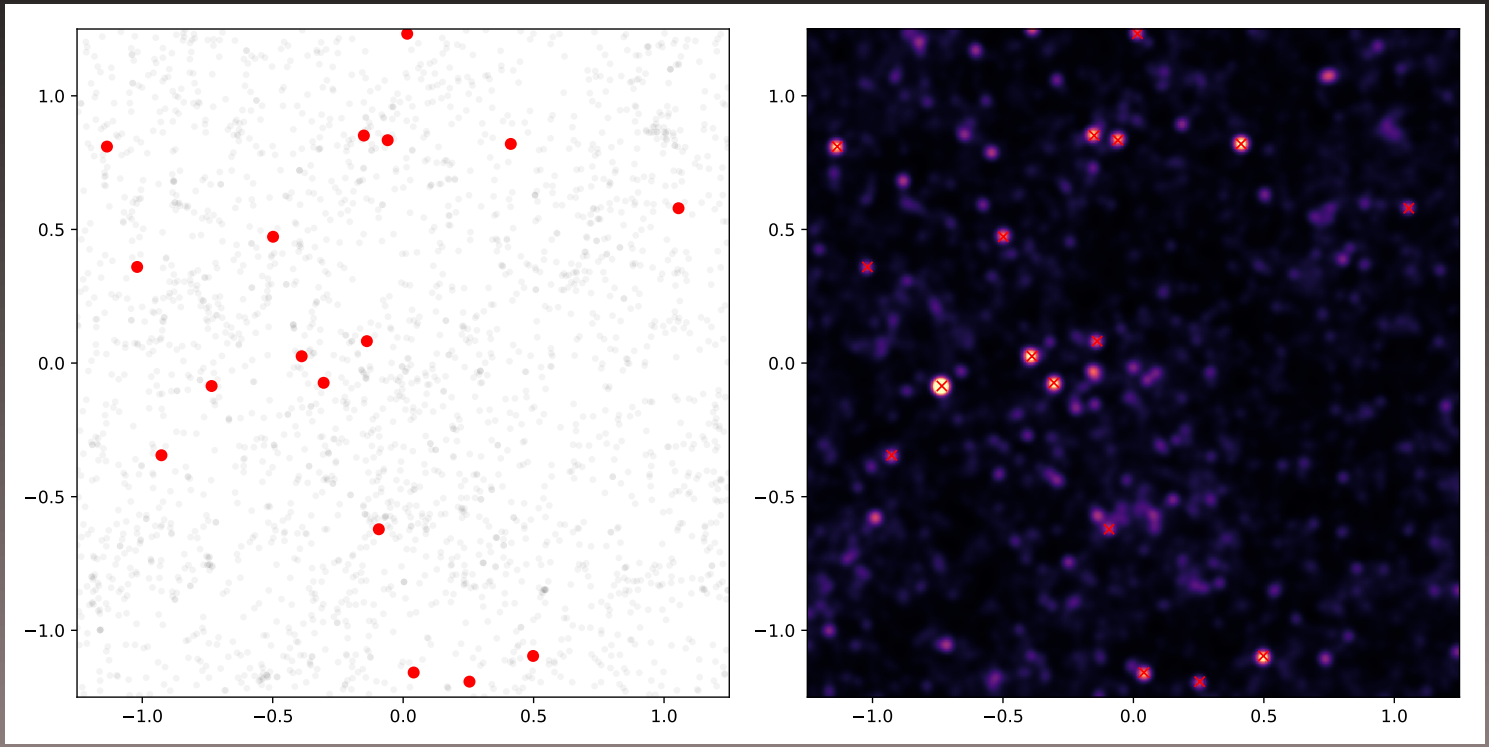


Figure: galaxies and [C II] across a 6.25 deg^2 $\times$ 40 GHz volume
(400 $\times$ 400 $\times$ 370 cMpc^3 at z = 6.0; [C II] map filtered at 3′ angular resolution)

intensity mapping w/ [C II]

why [C II] in particular?

- in principle, any atomic/molecular gas line will work
- [C II] is one of the better options to study star-forming galaxies at/post-reionisation
  - bright—as much as 1% of $L_{\rm IR}$
  - strong correlation with SFR

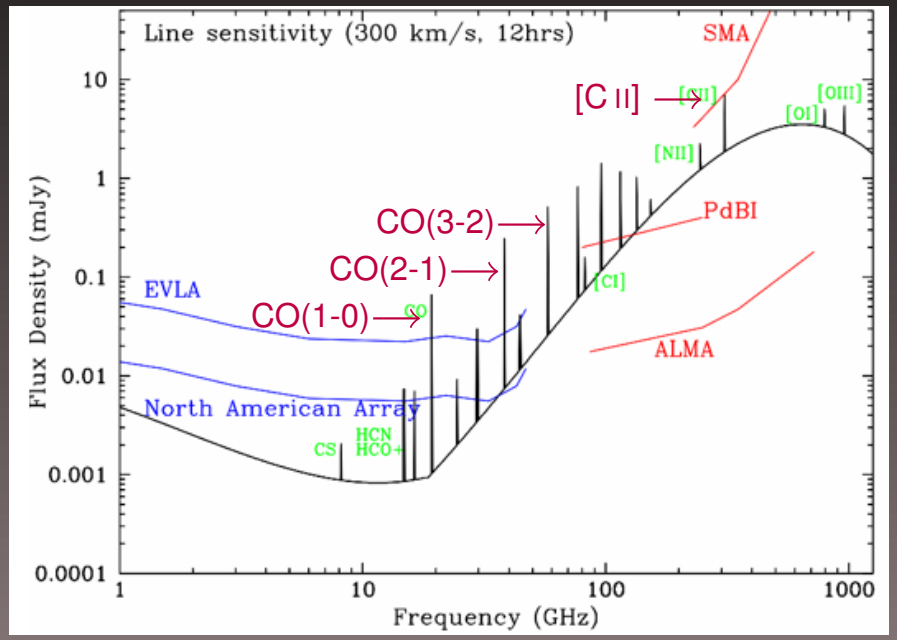


Figure: hypothetical: Arp 220 at $z = 5$ (Carilli+09—arXiv:0902.3671)

a major caveat: these strengths are not *necessarily* decisively demonstrated at high z!

a [C II] model at high redshift

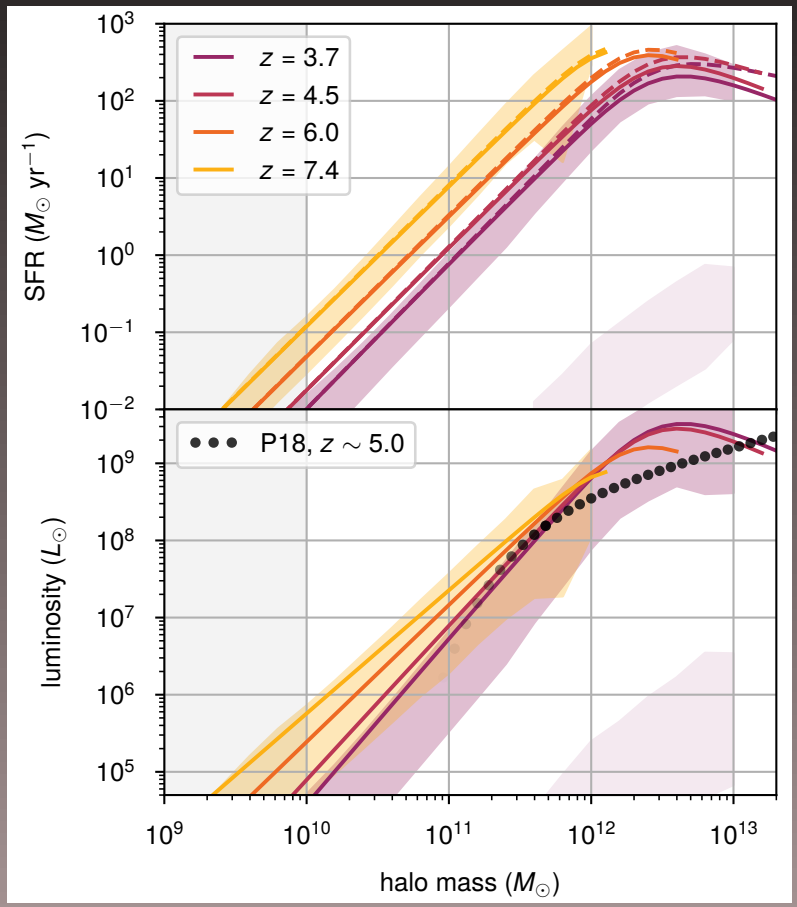
forecasts and sensitivities—DTC+20 (arXiv:1812.08135)

- existing literature is abundant with forecasts for the [C II] signal at high redshift, with these key ingredients:
  - an empirical halo mass–SFR relation (often a single unbroken power-law)
  - an empirical SFR–[C II] calibration (often local, often used beyond applicable redshift range)
- in our case, the recipe is ...
  - empirically modelled star-formation histories for each halo in a simulation (UNIVERSEMACHINE EDR, Behroozi+18)
  - the Lagache+18 $z \in (4, 8)$ simulated SFR–[C II] relation, which accounts for high-redshift effects including CMB heating/attenuation (leading to PDR-dominated emission)

a [C II] model at high redshift

forecasts and sensitivities—DTC+20 (arXiv:1812.08135)

- UniverseMachine EDR star-formation rates for BolshoiP halos account for quenching (at lower redshift), feedback at $M_h \gtrsim 10^{12}\,M_\odot$, ...
- Lagache+18 SFR–[C II] relation suggests local relations would over-estimate [C II] luminosities at given SFR by 2–10×



a [C II] model at high redshift

forecasts and sensitivities—DTC+20 (arXiv:1812.08135)

- assumed parameters:
  - early: 1 deg^2/400h (slightly unrealistic)
  - baseline: 2.25 deg^2/2500h (slightly pessimistic)
  - full: 9 deg^2/6000h w/ 2 tubes (somewhat optimistic)
- forecast suggests most notional goals will be met; questions remain at $z \sim 8$

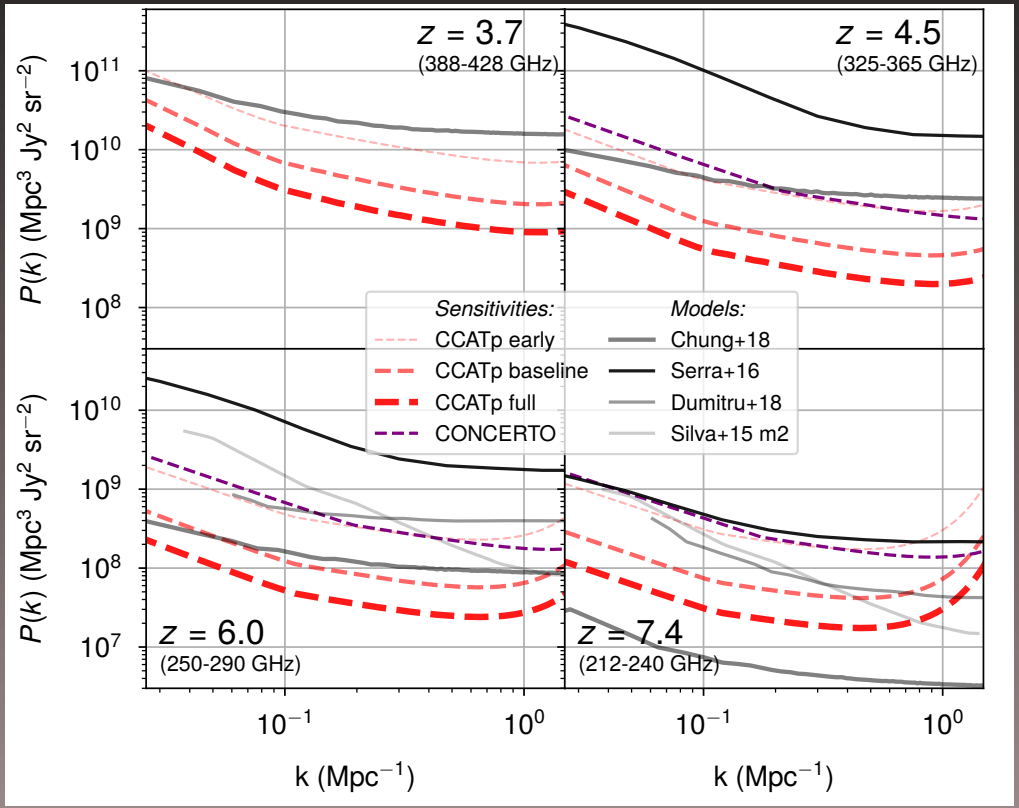


Figure: adapted from DTC+20

experimental obstacles

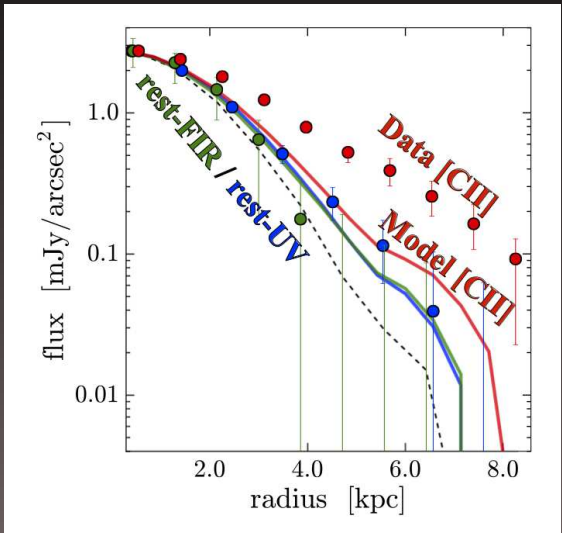
inherent instrumental and survey challenges

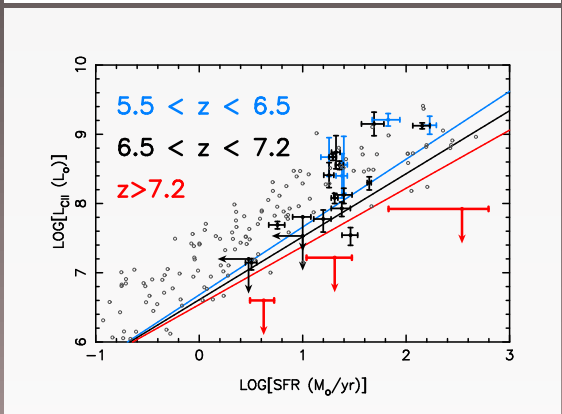
- power spectrum of non-white sky noise unclear, needs to be modelled and accounted for properly
- + assorted instrumental effects, including spectrometer channel passband, reflections and spillover, ...
- foreground removal is a significant concern
  - Galactic dust should be spectrally smooth and well-characterised in survey data over a broad frequency range (all experiments considered span $\Delta\nu_{\mathrm{obs}} > 100$ GHz)
  - interloper line emission in mid-to-high J CO lines from $z \lesssim 2$ will require more sophisticated strategies (eg masking informed by external galaxy surveys: Sun+18, arXiv:1610.10095)

cross-correlate with 21 cm or Lyman-α for validation (+ science!)

modelling directions

observations should drive better models, of full range of emitters





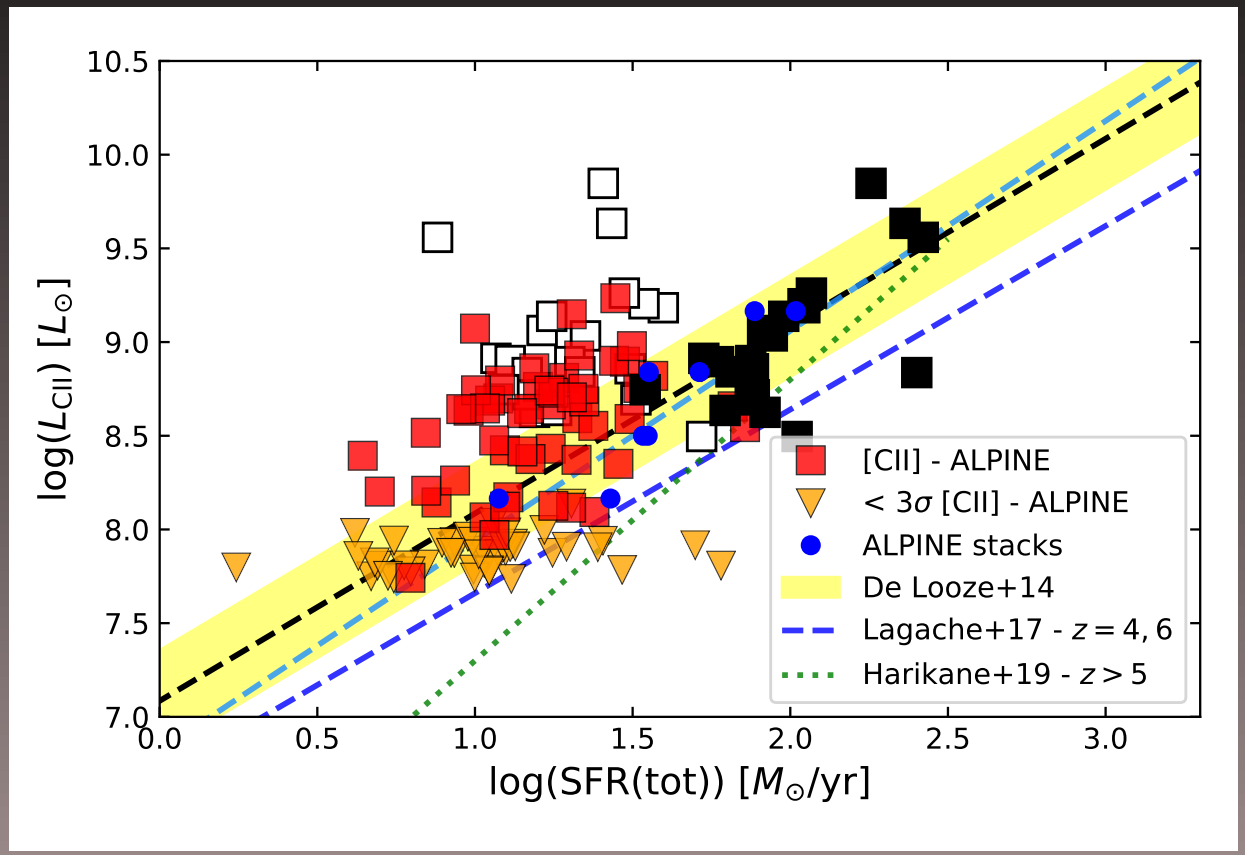


Figure: from Fujimoto+19 (arXiv:1902.06760, left ↑), Laporte+19 (arXiv:1906.01937, left ↓), Schaerer+20 (arXiv:2002.00979, right)

in summary

key takeaways from this talk

- [C II] intensity mapping forecasts suggest CCATp early/baseline programmes will enable interesting detections/limits at $z \lesssim 6$
  - baseline/full survey data likely needed for interesting detections/limits at $z \gtrsim 6$
- upcoming theoretical work must refine forecasts and simulate foreground removal to further inform instrumentation and survey details, but is tractable
- **important hints will arise as we move from inferences based on limited observations and simulations, to *direct LIM measurements***