



CCAT: Submillimeter Line Intensity Mapping of [CII] and CO with FYST



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University of Cologne
On behalf of the CCAT Collaboration



Canadian Consortium



FYST/CCAT

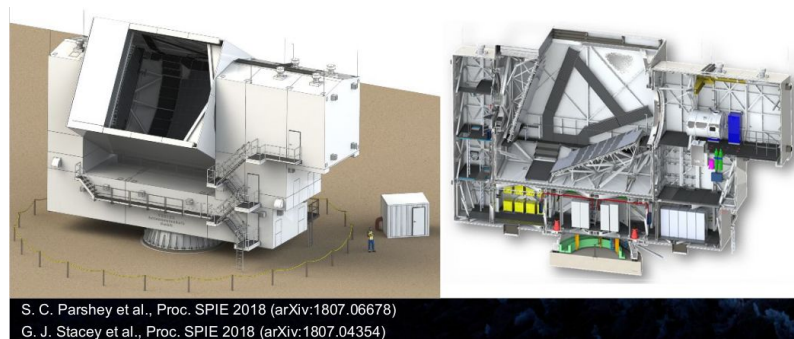
Fred Young Submm Telescope

CCAT Collaboration, multi-national -
Cornell, Bonn/Cologne, MPI Garching,
multiple Canadian institutions

6m telescope, focus on Submm astronomy

Cerro Chajnantor - extra 600 m above
ALMA/plateau

([CCAT Collab+23](#))



([Radford and Peterson+16](#))

Prime-Cam and EoR-Spec

Prime-Cam receiver does LIM via **EoR-Spec** module

Fabry-Perot Interferometer

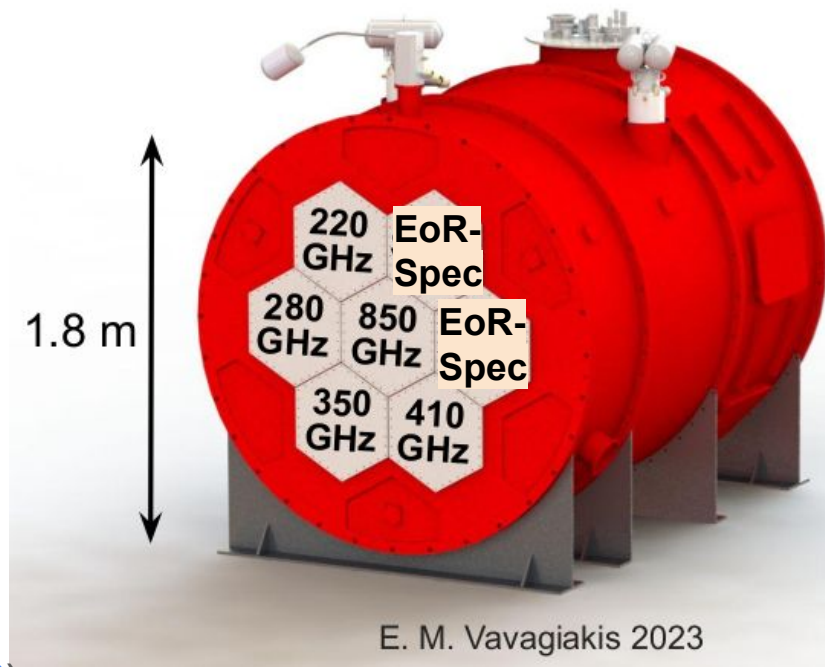
KIDS (Kinetic Inductance detectors)

- **6000** detectors for EoR-Spec (equally distr.)

EoR-Spec: On-chip spectrometer module, **210 – 420 GHz** with **R ~ 100**

Total Field of View (FoV): ($\sim 1.3^\circ$ /module)

Angular resolution 33" to 58" ([Choi+19](#))

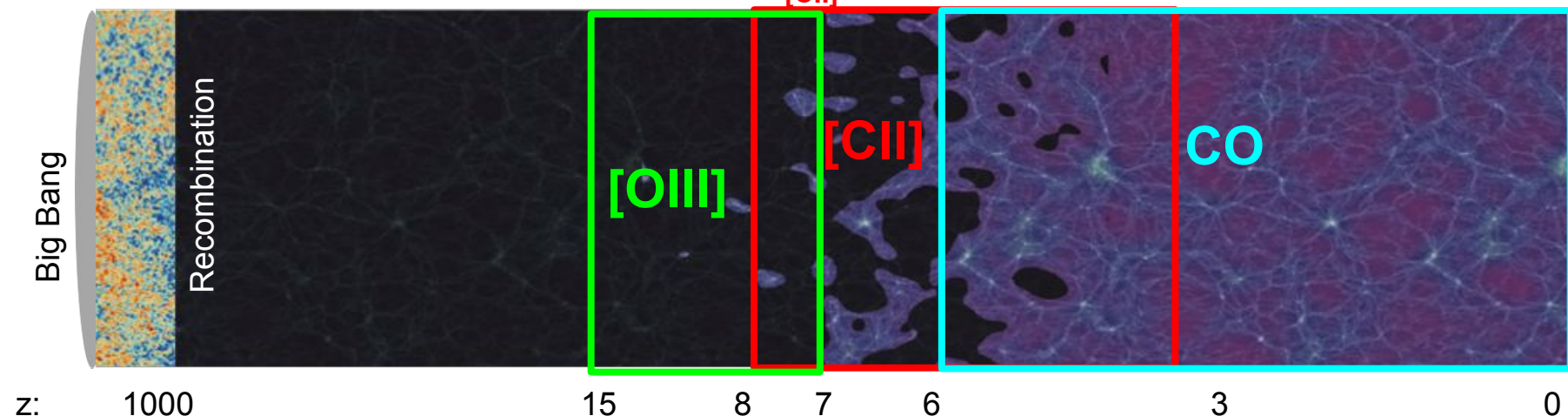


Planned LIM at the Epoch of Reionisation (EoR)

Aiming for **[CII]** and **CO** line intensity mapping with auto-correlations

Potential **[OIII]** detections with cross-correlations

210 – 420 GHz corresponds to $3.5 < z_{\text{[CII]}} < 8.1$ - epoch of reionisation



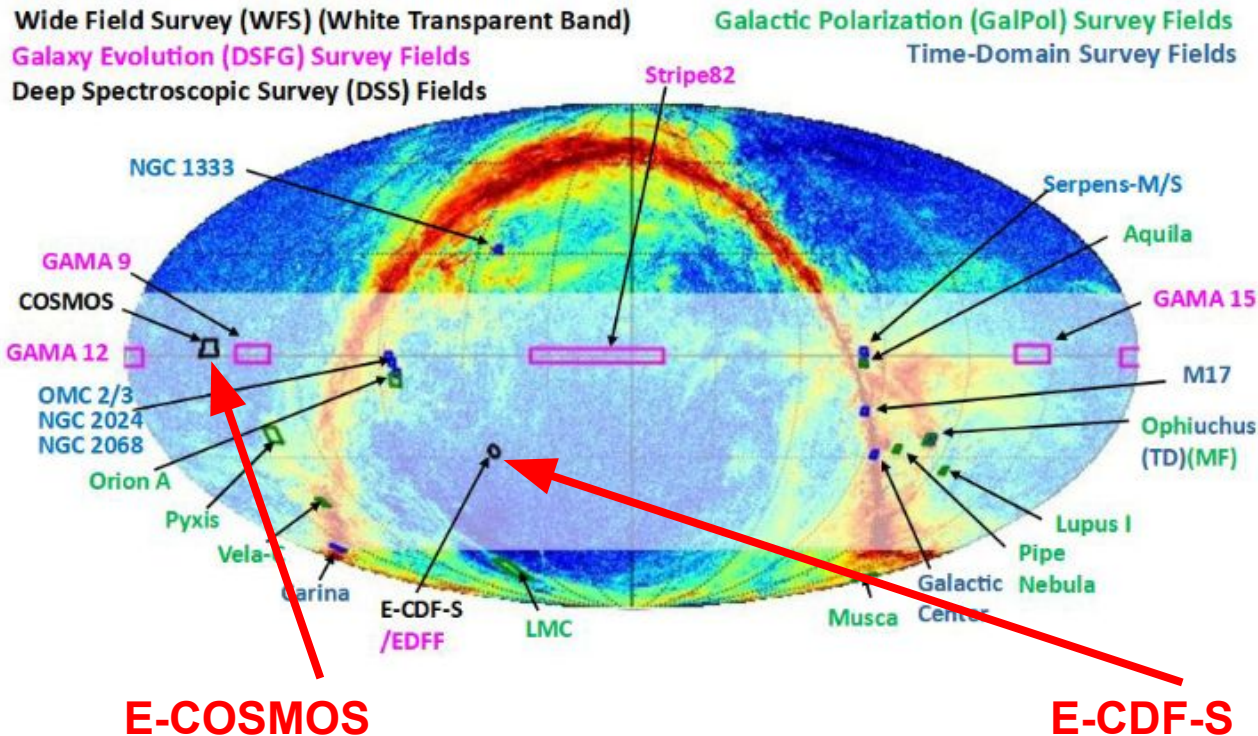
Survey fields

Deep Spectroscopic Survey (DSS) fields

- **4000** hours over **E-COSMOS**, **E-CDF-S** in 5 years
- Align with prior COSMOS surveys, Euclid

2x2 deg² fields

~36Mpc a side at $z \sim 8$



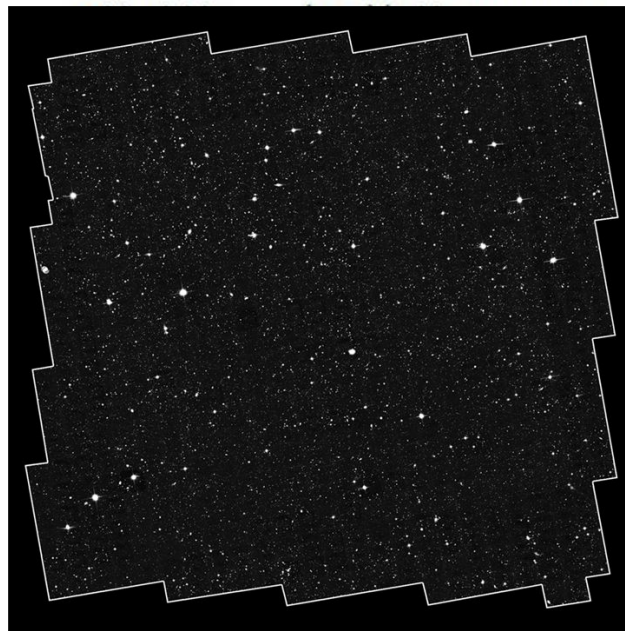
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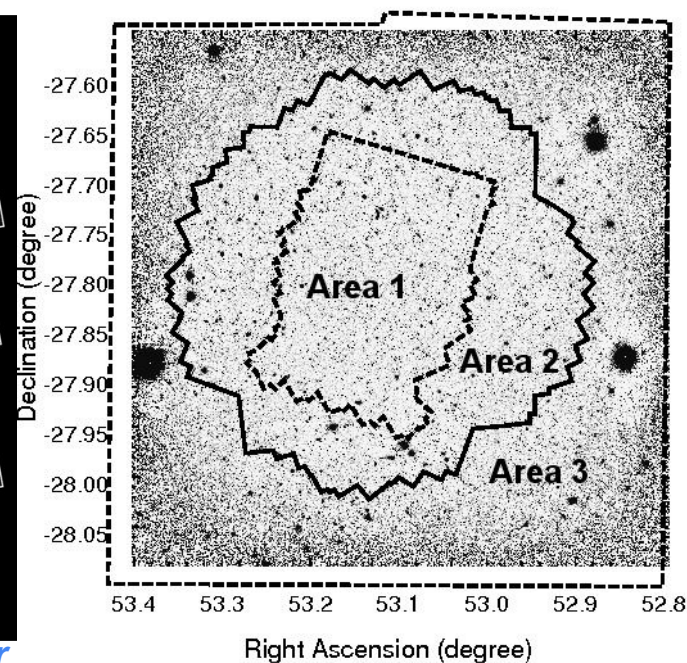
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[NASA, ESA, Anton M. Koekemoer \(STScI\), Nick Scoville \(Caltech\)](#)



[Hsu+14](#)

E-CDF-S

Timelapse:

https://youtu.be/GK4Ekjira_o?si=BnLd-CN-9Ww-f_wW



Current status of FYST...

Assembly as of May 2025 (first light early 2026, PrimeCam likely late 2026/early 2027)

First half of
2024 - final
testing of
chassis,
Duisburg



Timelapse:

https://youtu.be/GK4Ekjira_o?si=BnLd-CN-9Ww-f_wW



Current status of FYST...

Assembly as of May 2025 (first light early 2026, PrimeCam likely late 2026/early 2027)

Packing up

(End of 2024)



Timelapse:

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Current status of FYST...

Assembly as of May 2025 (first light early 2026, PrimeCam likely late 2026/early 2027)

Voyage of the Sloman Discoverer

Journey of the
telescope,
Feb. 2025



3/24/2025

CCAT/FYST History

23

Timelapse:

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Current status of FYST...

Assembly as of May 2025 (first light early 2026, PrimeCam likely late 2026/early 2027)

Arrival in
Santiago,
March. 2025



Timelapse:

https://youtu.be/GK4Ekjira_o?si=BnLd-CN-9Ww-f_wW



Current status of FYST...

Assembly as of May 2025 (first light early 2026, PrimeCam likely late 2026/early 2027)

Arrival on
Mountain

April 2025



Timelapse:

https://youtu.be/GK4Ekjira_o?si=BnLd-CN-9Ww-f_wW



Current status of FYST...

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Current status

May 2025

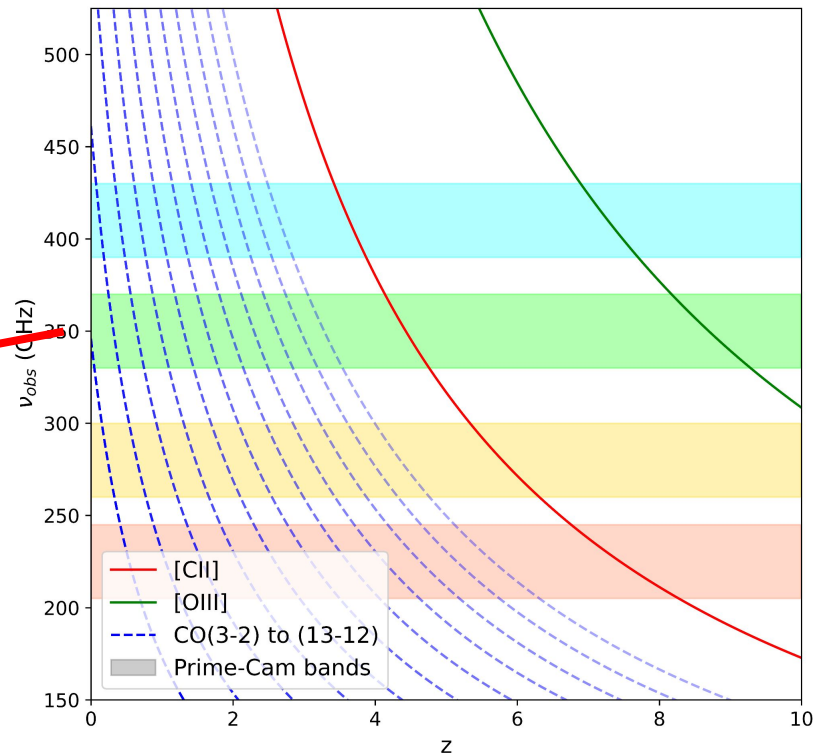
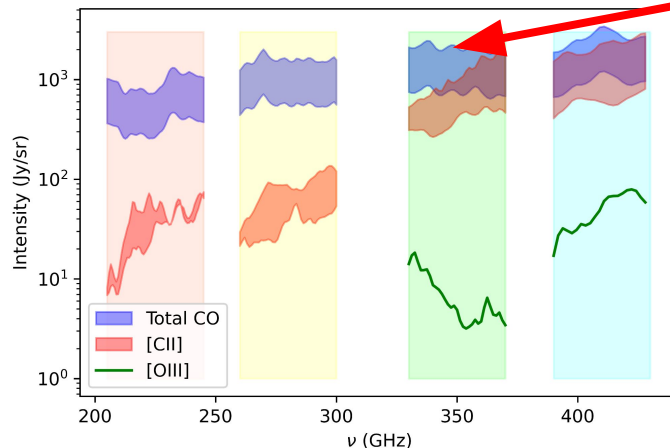


Predictions for LIM

For simulations use nominal bands **210-245, 260-300, 330-370, 390-420GHz** to avoid atmospheric features

Even after removing atmospheric+white noise, and accounting for scan patterns (see **Ankur Dev, Yoko Okada talks**), total CO and [CII] signal are comparable.

For [CII]
power
spectra,
need to
remove CO
foregrounds

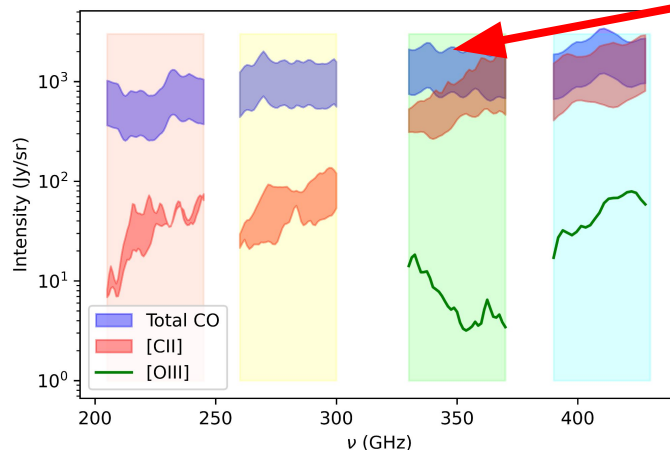


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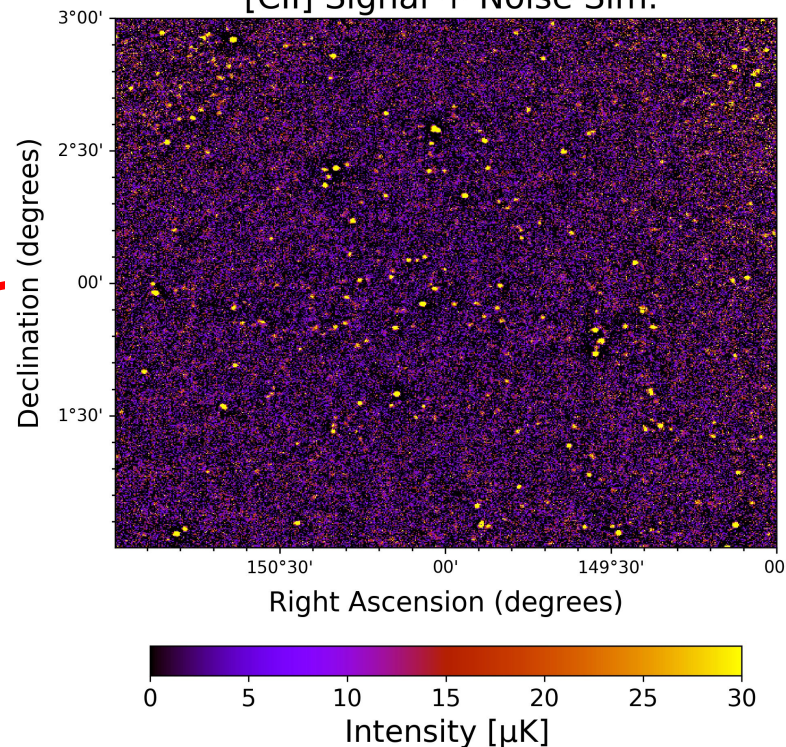
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Chnl 333GHz Filtered and Binned Output:
[CII] Signal + Noise Sim.



Recovering [CII] (Targeted Masking)

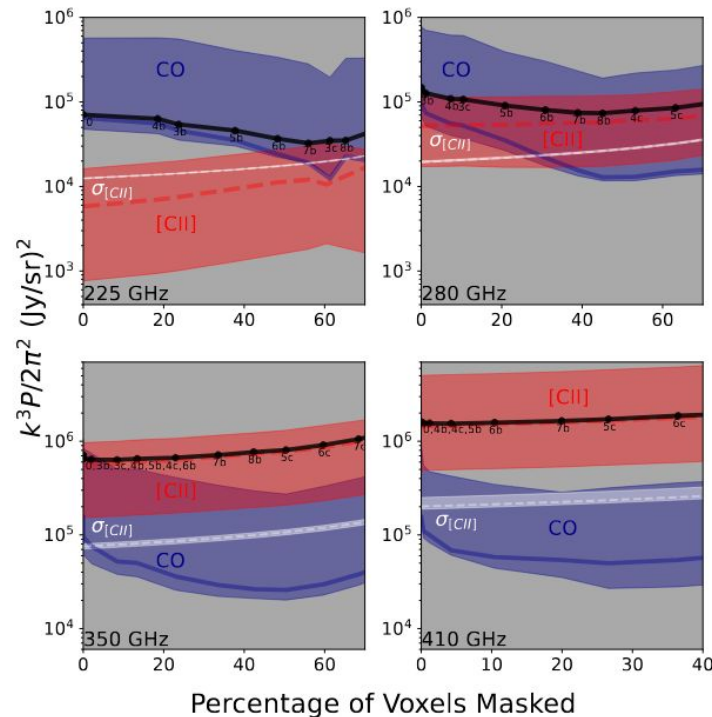
([Karoumpis+2024](#)) focused on **targeted masking**

Applied CO models to **IllustrisTNG300** simulation set

Assuming **knowledge of foreground sample** (have with COSMOS, Euclid).

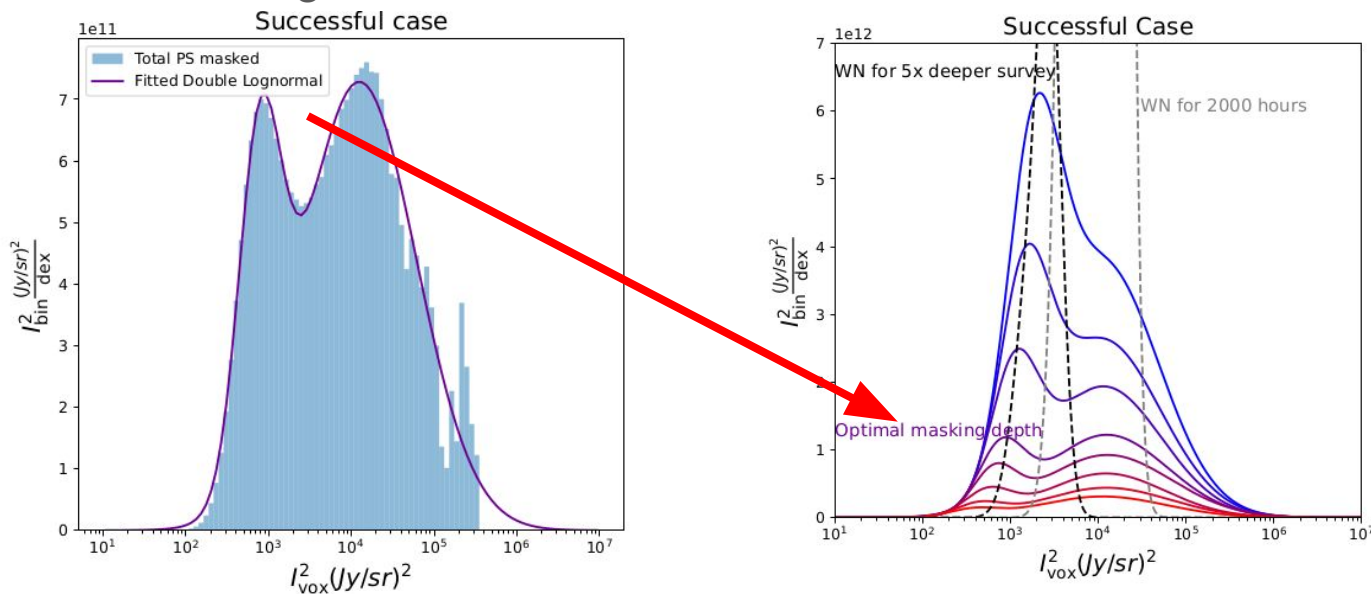
- Know certain galaxies should be major CO emitters
- Use to **systematically mask** out CO from each line transition

Masking the CO at $k = 0.02 - 0.32 \text{ Mpc}^{-1}$



Recovering [CII] (Targeted Masking)

Can statistically determine optimal masking point from the tomography to mitigate overmasking



Recovering [CII] (Existing Catalogue Data)

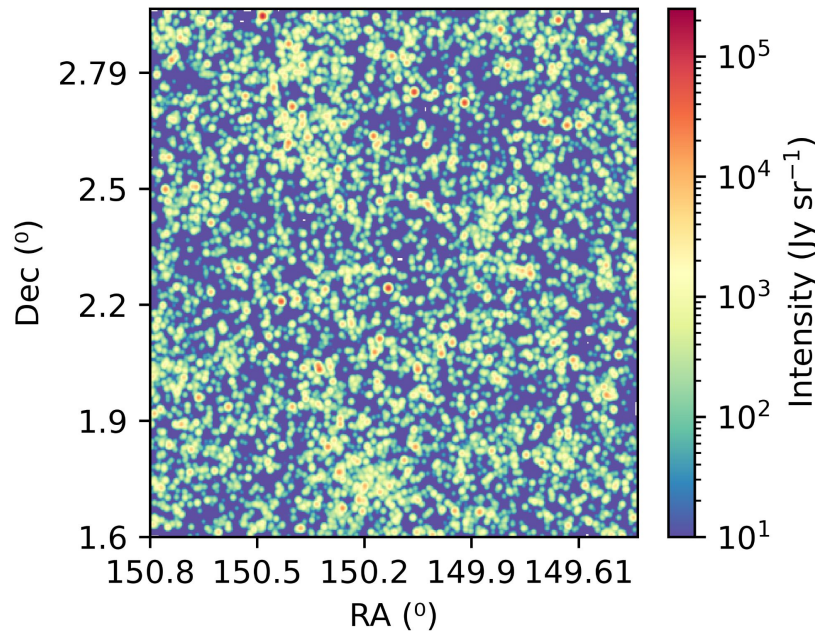
Alternatively, can use galaxy catalogue data to construct simulated maps

- COSMOS2020, Euclid Quick Data Release 1 bulk property data

Empirical data - lower limits ([Clarke+24](#))

Can **extrapolate** out using **known incompletenesses**

Most work done on smaller COSMOS2020 field ($1.2 \times 1.2 \text{ deg}^2$)



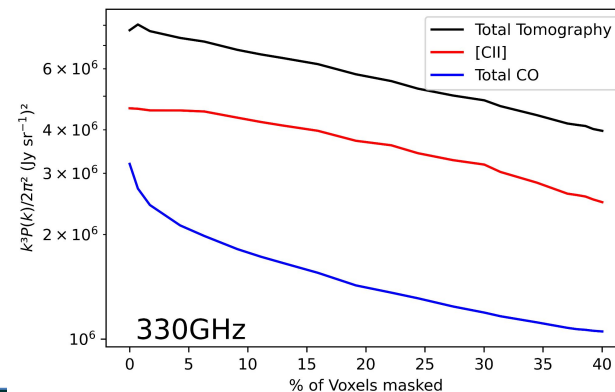
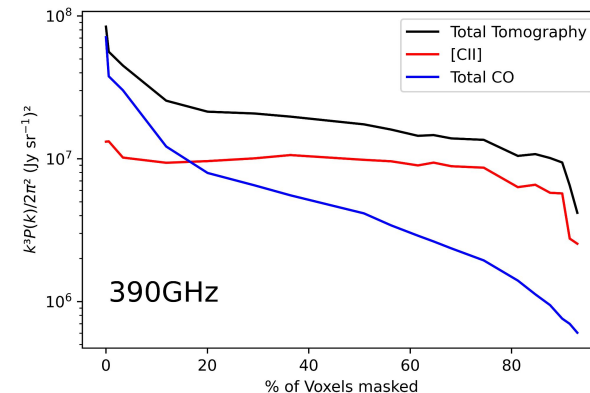
410GHz, COSMOS2020, [CII]+CO map

Recovering [CII] (Existing Catalogue Data)

Tested targeted masking techniques that have been developed

Run into issues - overmasking a concern

- CO heavily overlaps in location with [CII], reducing signal of both
- **Sample variance** issue - covering $\sim 1/3$ of area of actual E-COSMOS
- ([Gkogkou+23](#))
- Still comprises part of field - must be careful



Recovering [CII] (Spectral line deconfusion)

Work of [Tejas Oak](#) (poster has more details)

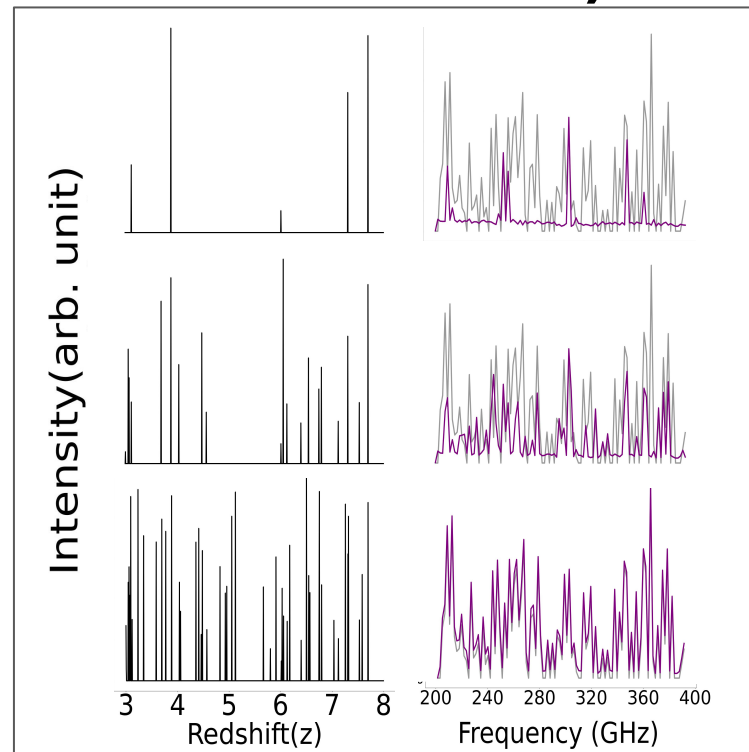
At low frequencies, masking is less effective (increased uncertainty from survey volume loss)

With cross correlation, product of line biases create limits on individual line luminosities

Spectral line deconfusion ([Cheng+20](#)):

ALTERNATIVE, fitting CO spectral line template to the intensity map and converging at a sparse distribution of line emitting sources.

Enhanced w/ priors from foreground e.g. COSMOS field

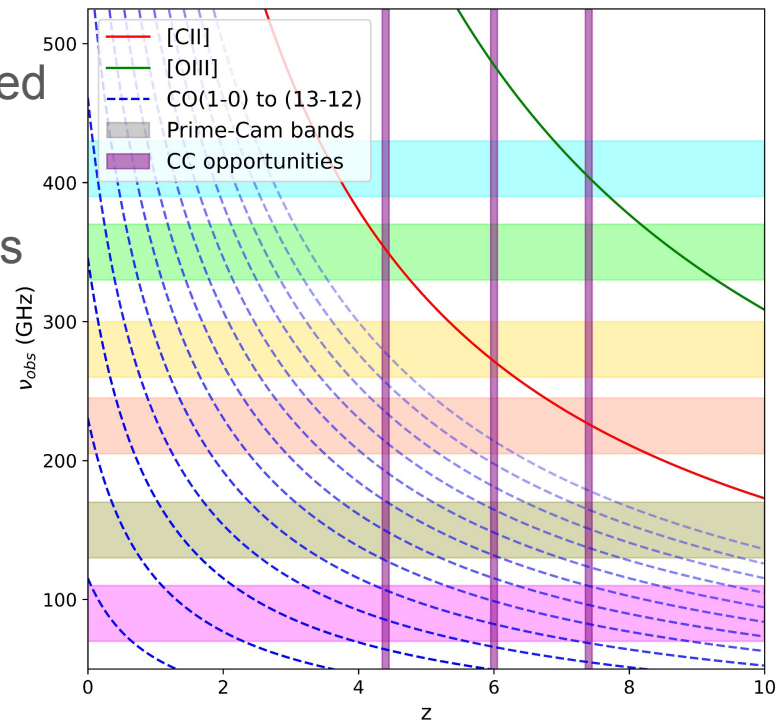


Recovering [CII] (Potential of lower frequency range)

Lower frequency bands for future on-chip spectrometers (90GHz, 150GHz) are being considered (far future!). Allows for:

- **CO autospectra**, synergies with other detections
- **Blind masking** (pair bright voxels, model emission, mask out if CO. Similar to TIFUUN)
- **Cross correlation** opportunities ([Roy+24](#)), including **triple CC**

Plus more opportunities for synergies with other experiments!





Summary

- FYST currently being assembled, first light 2026, LIM starting 2026/2027
- Focus on [CII] and CO LIM - first round of observations 210-420GHz
- Assuming noise properly treated, need to isolate [CII] signal
 - Targeted Masking
 - Spectral line deconfusion
 - Cross-correlations
- Additional low frequency bands being considered for future spectrometer

<https://ccatobservatory.org/>

We are hiring!

1) D. Riechers (U Cologne, EoR-Spec DSS Science Lead):

- Postdoc position: DSS Predictions and Analysis & Cross-Correlations

2) D. Riechers, J. Baselmans (TU Delft, Global Faculty U Cologne)

[AMKID, DESHIMA 1+2, TIFUUN, PRIMA]

- Postdoc & PhD position: CCAT/FYST 2nd generation instrumentation;
focus broad-band multiplexing (sub)mm spectroscopy

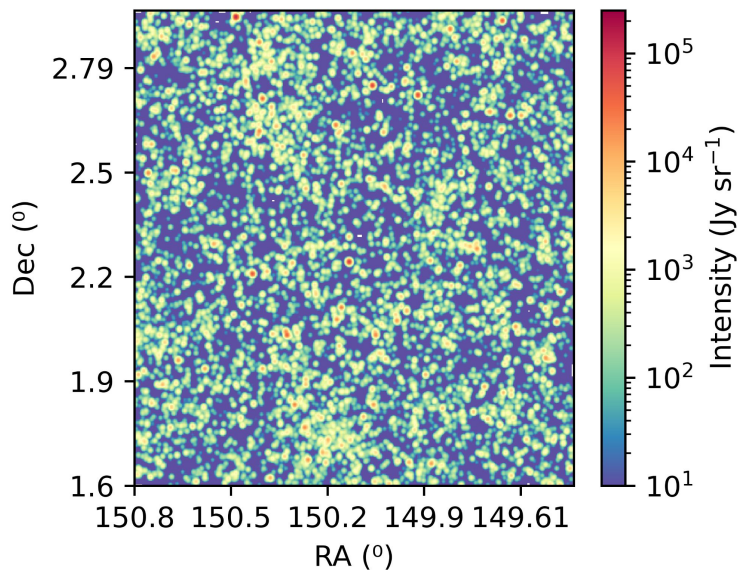
Ads to be put out; positions starting 2026, securely funded until end of 2032

Interested? Provide your information to Jonathan or Yoko to be looped-in

More info: <https://dynaverse.astro.uni-koeln.de/>

Euclid vs COSMOS

COSMOS2020



Euclid QR1

