

CCAT - New windows in the submillimeter sky



Nick Battaglia (Cornell, APC/Paris for the year)
Dec 19 2024
CMB France 2024

CCAT Collaboration 2023

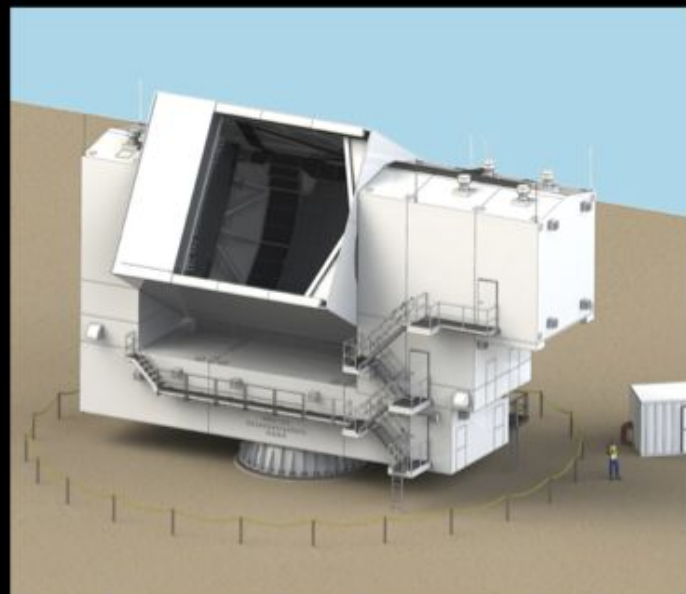
CCAT Observatory is building the Fred Young Submillimeter Telescope (FYST)



6 m off-axis submillimeter telescope

- Wide field of view: up to 8°
- High surface accuracy: $<10.7 \mu\text{m rms}$
- No blockage
- Exceptional site on Cerro Chajnantor at 5600 m
- State of the art wide-field instrumentation
- First light in 2026!

*Unsurpassed performance for wide-field
low surface brightness science*



Manufactured by Vertex Antennentechnik gmbh



Why so high?

Cerro Chajnantor ← FYST site at 5600 m

Great telescope: lets put it at a great site!

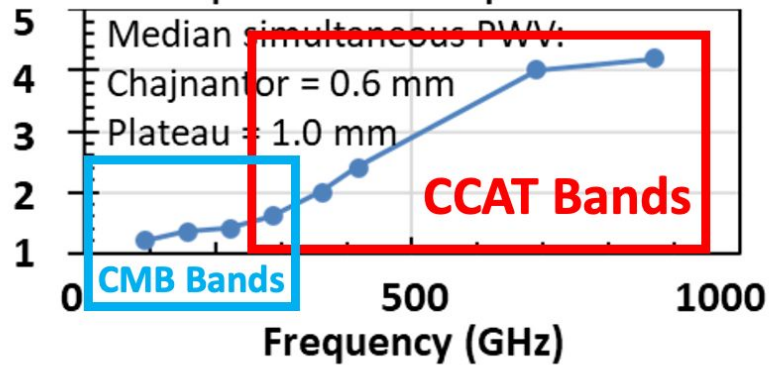
Chajnantor plateau
ALMA site at 5000 m

Summit of Chajnantor is even better!

← CMB Telescopes at Cerro Toco, 5200 m

Cerro Chajnantor/Plateau Mapping Speed

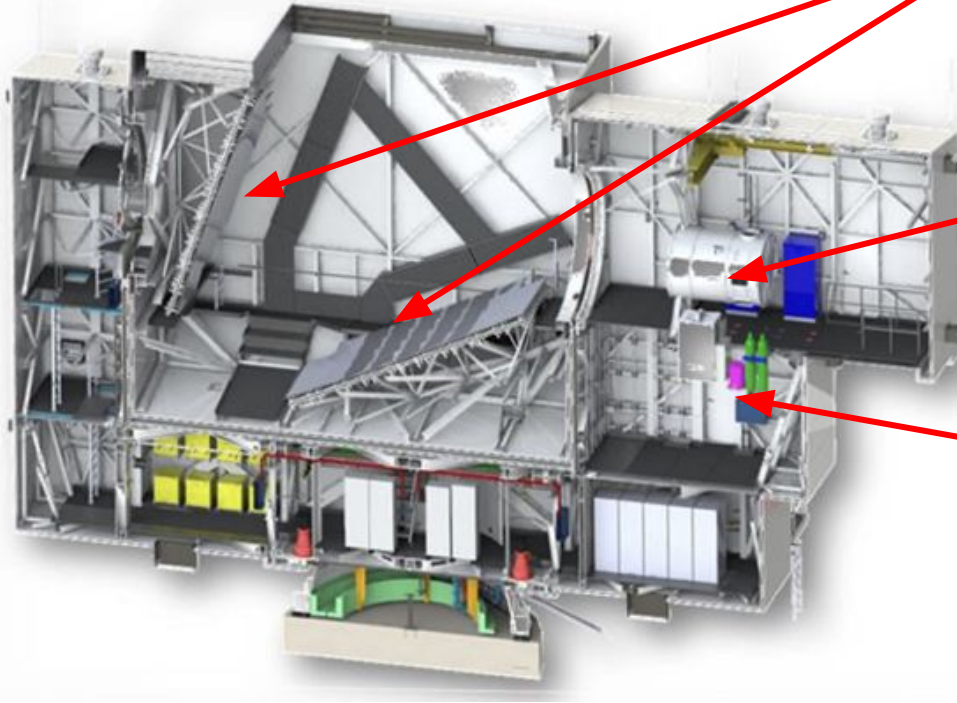
Top three weather quartiles



Giovanelli et al. 2001 PASP 113, 803G
Radford and Peterson 2016. *Pub. Astron. Soc. Pacific*, 128: 965.



FYST



Cross-Dragone design

- 2 Large Mirrors ~6m
- No Blockage
- Wide field of view: up to 8 deg
- Surface accuracy: $<10.7 \mu\text{m rms}$

Instrument Space 1

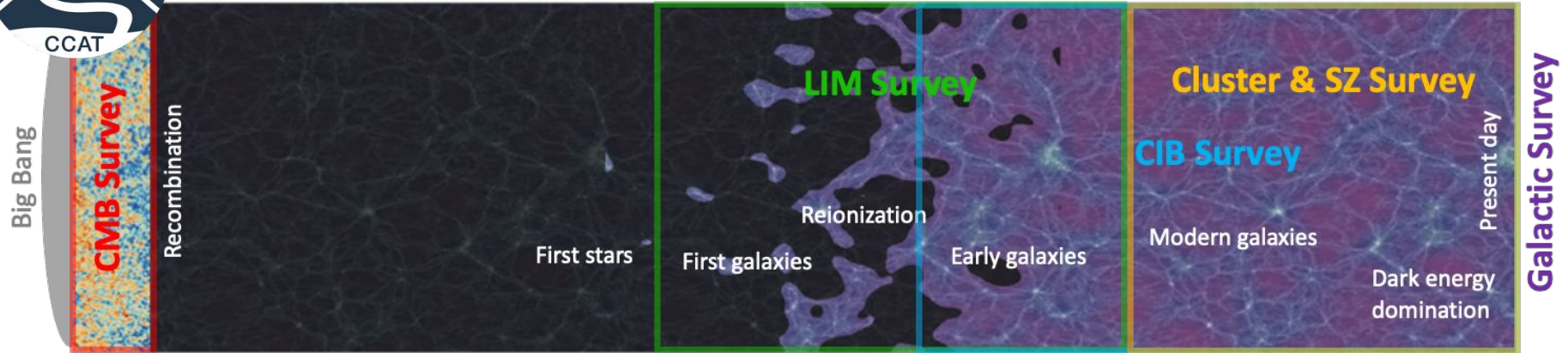
- Full 8 deg FOV access
- Prime-Cam Instrument

Instrument Space 2

- Deployable tertiary for smaller FOV
- CHAI instrument heterodyne spectrometer



CCAT Science



CMB Observations – Characterize foregrounds & Rayleigh scattering

SZ Observations – SZ spectrum from millimeter through to submillimeter

Line Intensity Mapping – LSS back to Reionization with CII and CO Lines

CIB Observations – Galaxy formation from the first billion years to Cosmic Noon

Galactic Polarization – Characterizing magnetic fields and galactic polarization science

Galactic Ecology – Characterizing cloud and star formation in the MW and nearby galaxies

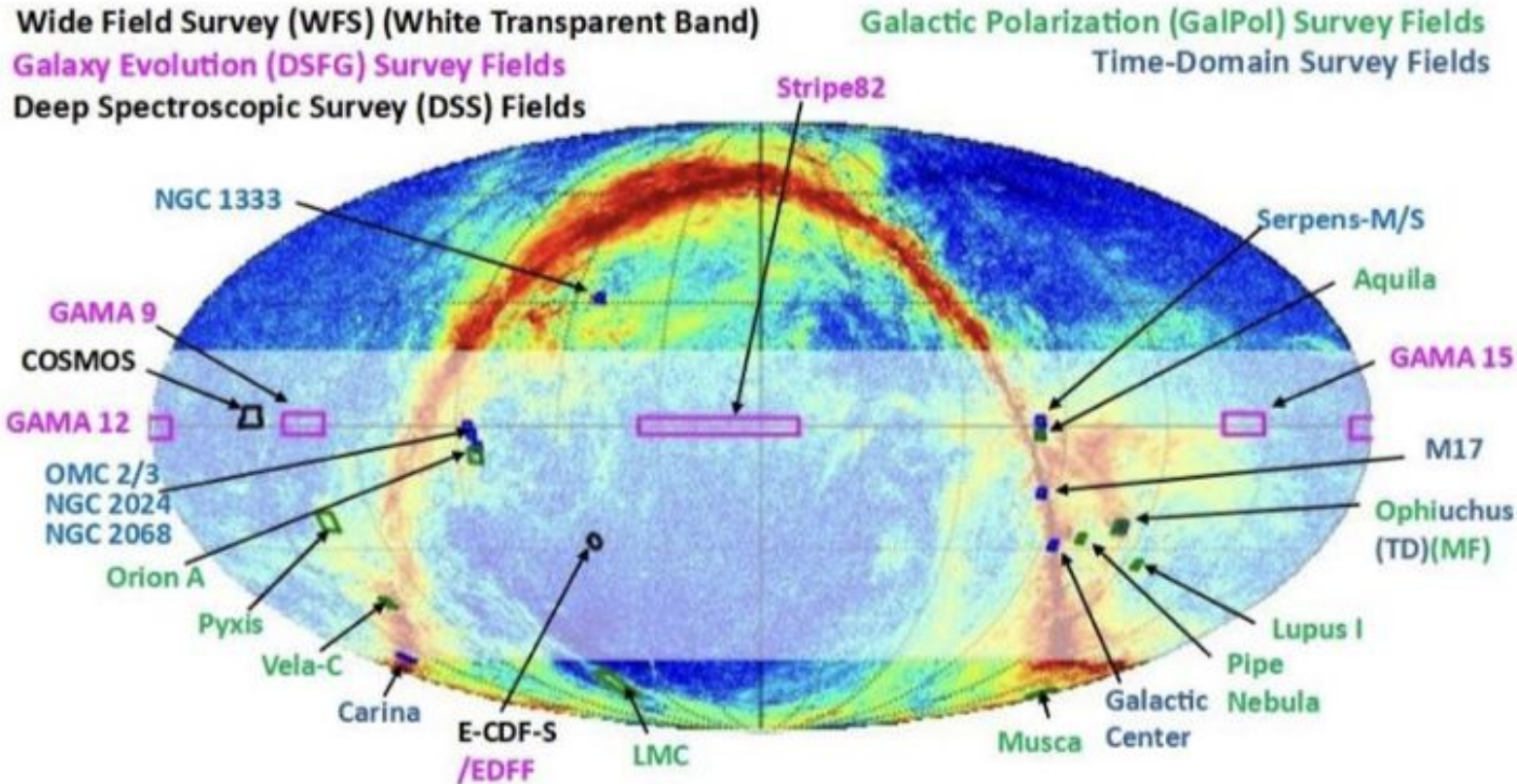
Transient Phenomena – Submillimeter transients Search and Protostar monitoring

Science Goals

arXiv:2107.10364



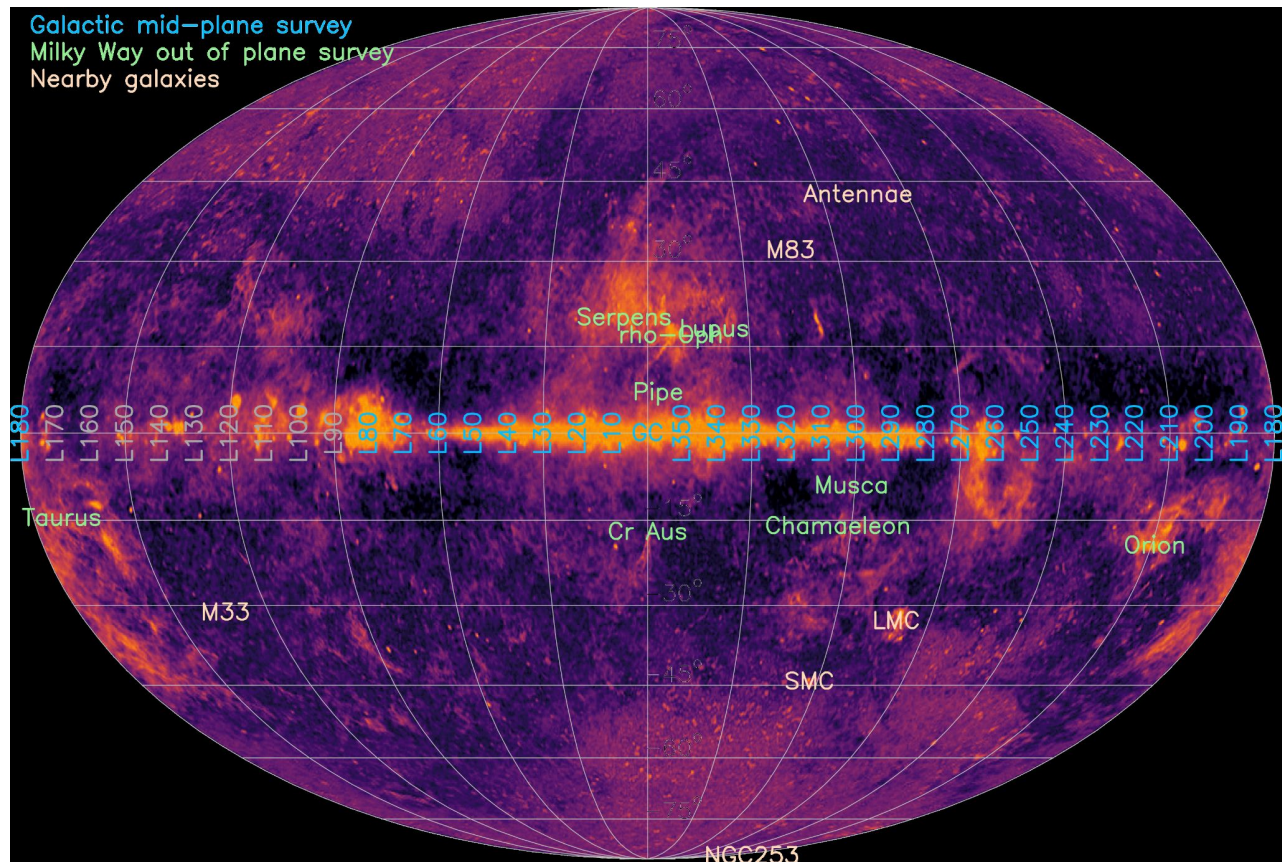
CCAT Surveys - Prime-Cam





CCAT Surveys - CHAI / Galactic Ecology (GEco)

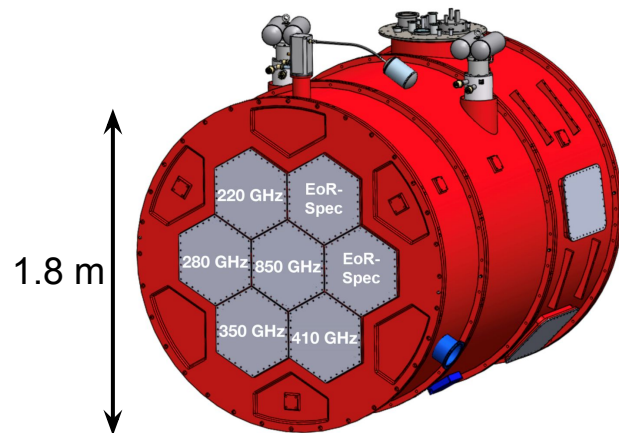
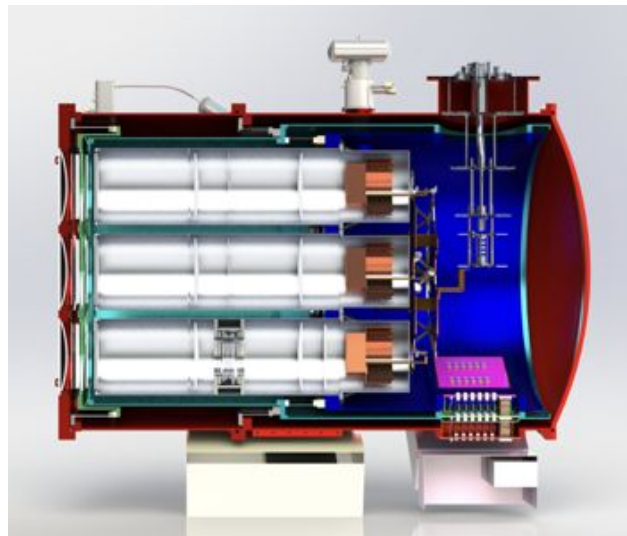
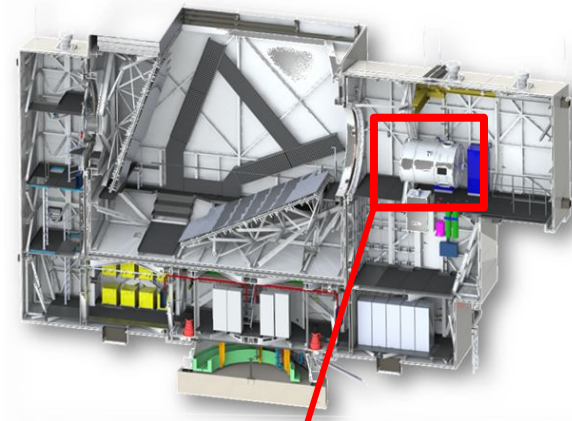
GEco survey fields on Galactic emission as seen by Planck.
Longitude ranges not visible from Chile are printed in grey.





Prime-Cam

- 1.8 meter diameter cryogenic receiver for FYST
- Up to 7 instrument modules each with up to ~ 1.3 degree FoV
 - Designed to target specific science goals
 - Populated with kinetic inductance detectors at 100 mK

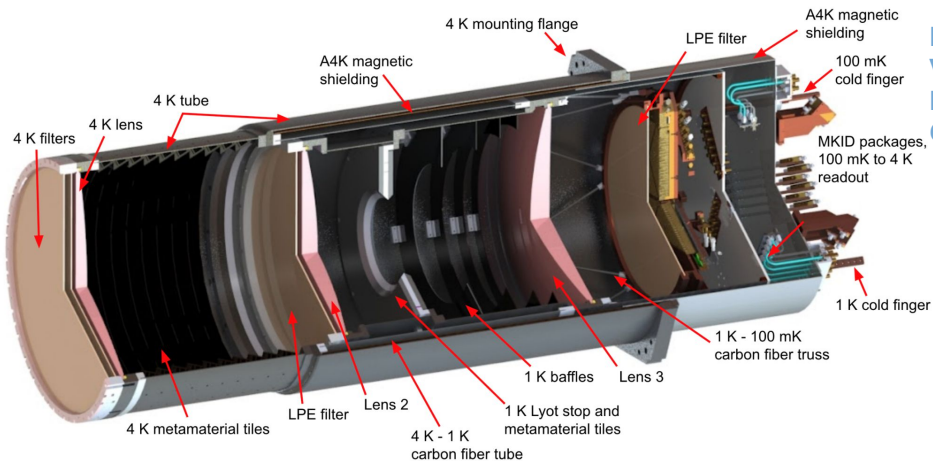


Huber+ (arXiv:2407.20873)
Choi+ (arXiv:1908.10451)
Vavagiakis+ (arXiv:1807.00058)

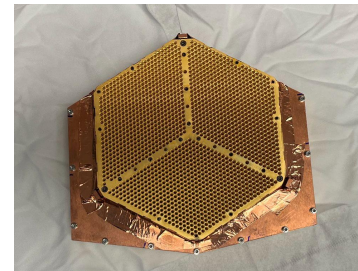
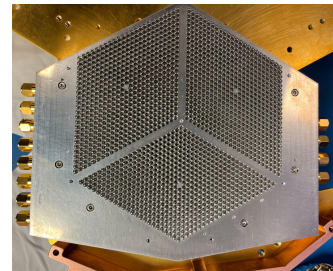
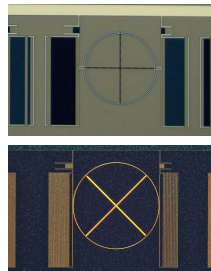


Prime-Cam: Modular design, targeted science goals

- Instrument modules contain optical elements, kinetic inductance detectors (KIDs), and readout components
- Expected to be the largest scale deployment of KIDs yet, with $\sim 10^5$ KIDs in a single instrument!
- Cryogenic stages at 4 K, 1 K, 100 mK



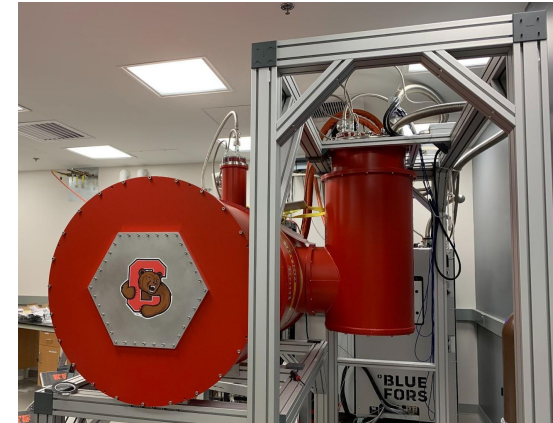
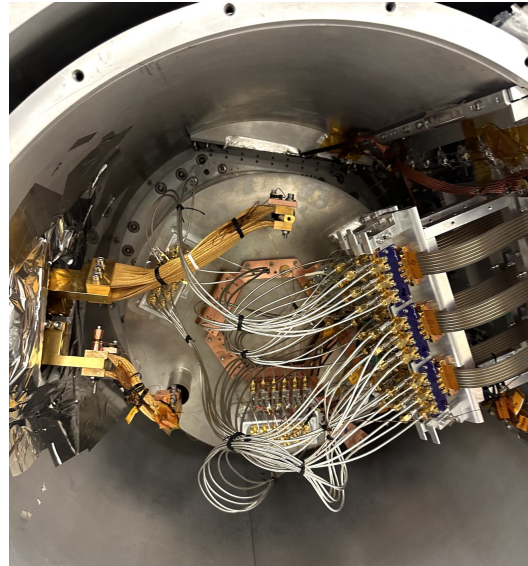
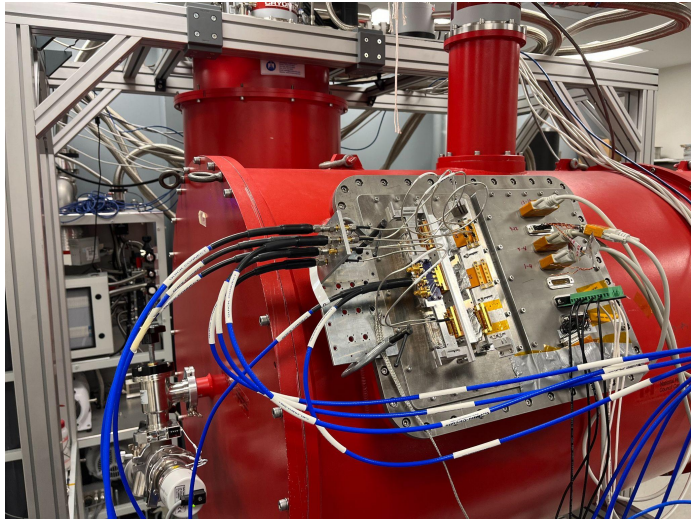
[Freundt+ \(arXiv:2409.05979\)](#)
[Vavagiakis, Duell+ \(2208.05468\)](#)
[Duell, Vavagiakis+ \(2012.10411\)](#)
[Chapman+ \(arXiv:2208.10634\)](#)





Mod-Cam: Single module testbed for Prime-Cam

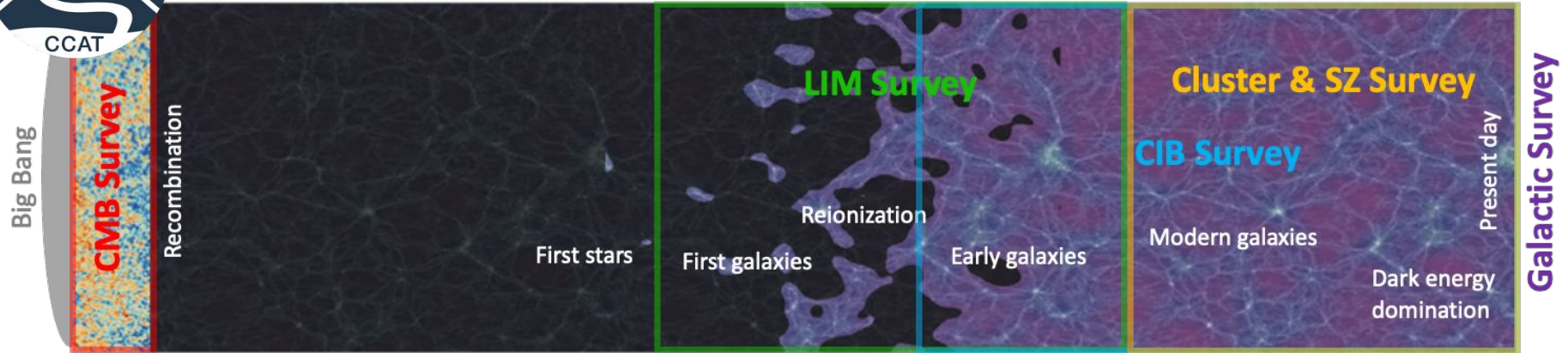
- Single optics module for first light and testbed for Prime-Cam
- Side-car DR design enables easy rear swapping of modules
- Deploying first module: 280 GHz



Vavagiakis, Duell+ ([arXiv:2208.05468](https://arxiv.org/abs/2208.05468))
Duell, Vavagiakis+ ([arXiv:2012.10411](https://arxiv.org/abs/2012.10411))
Vavagiakis+ ([arXiv:1807.00058](https://arxiv.org/abs/1807.00058))



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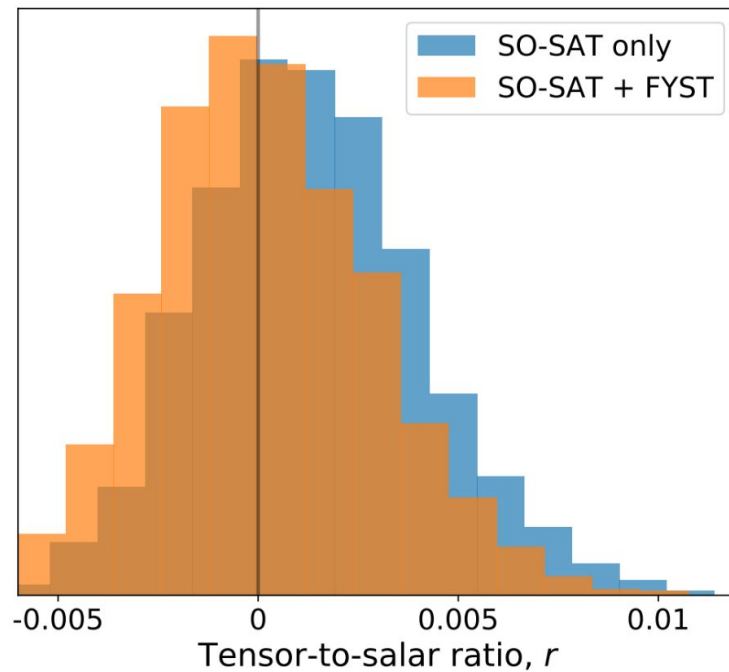
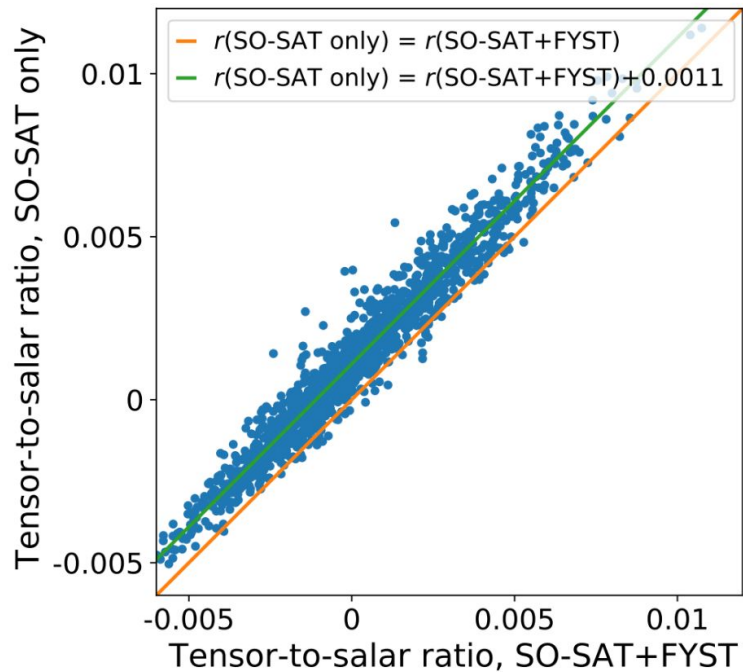
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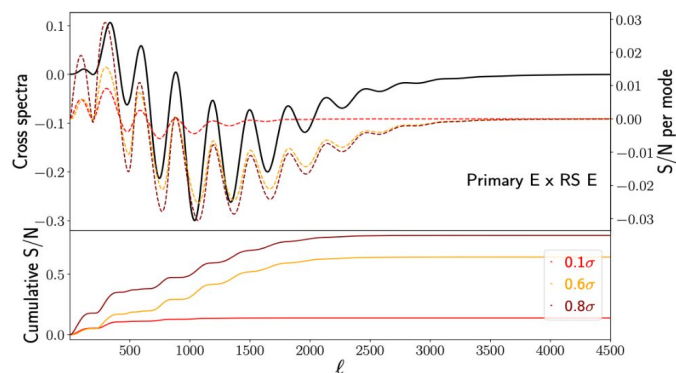
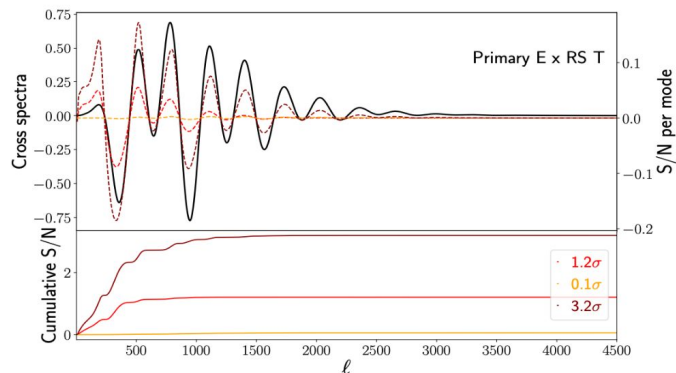
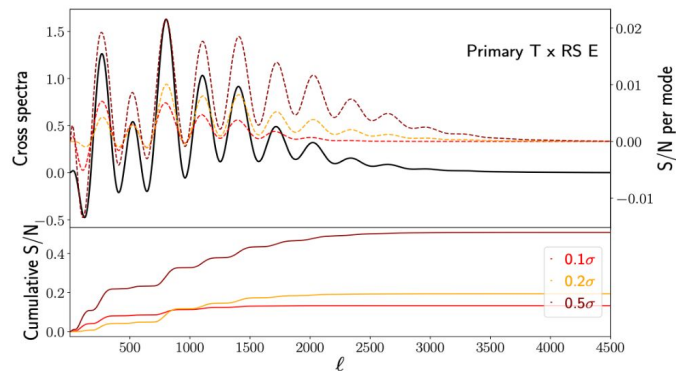
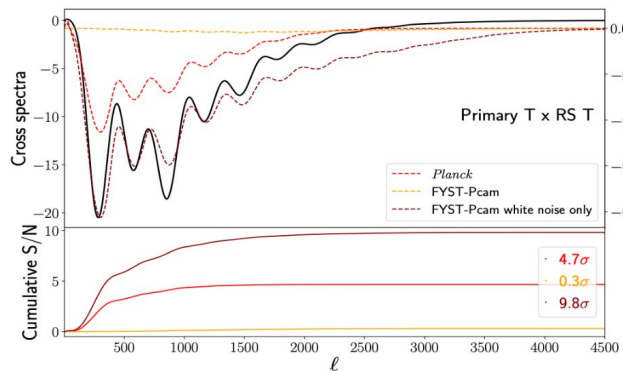


CMB - Foregrounds



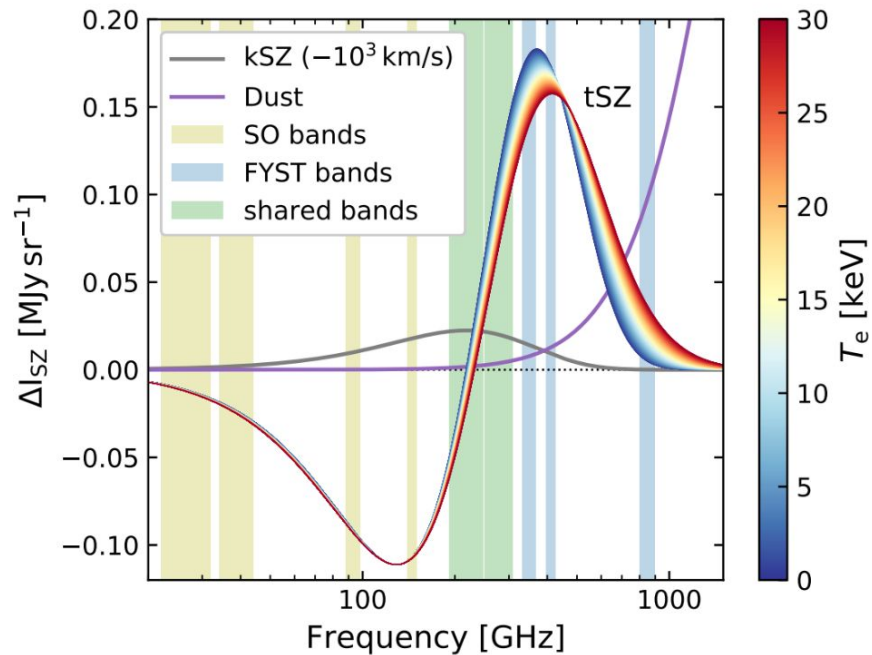
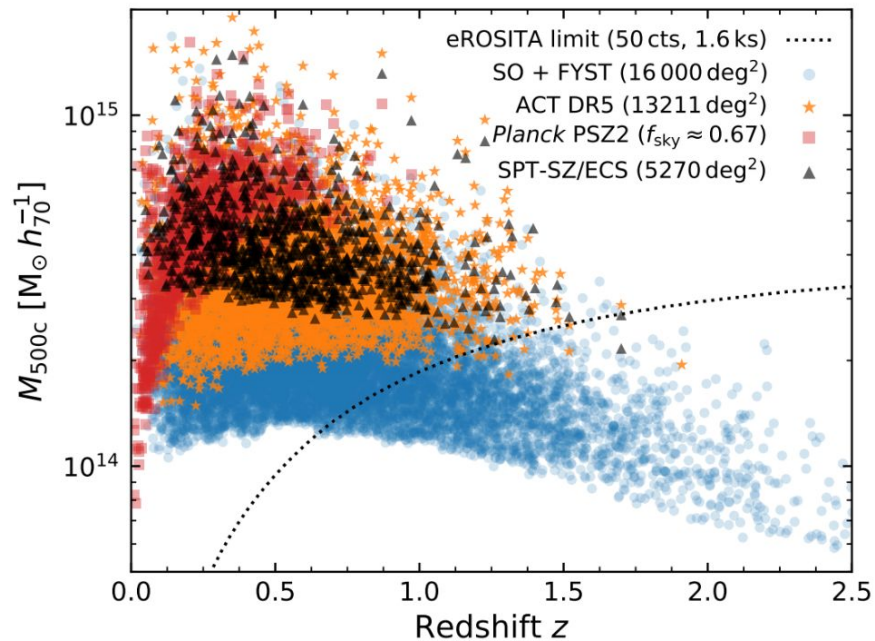


CMB - Rayleigh Scattering



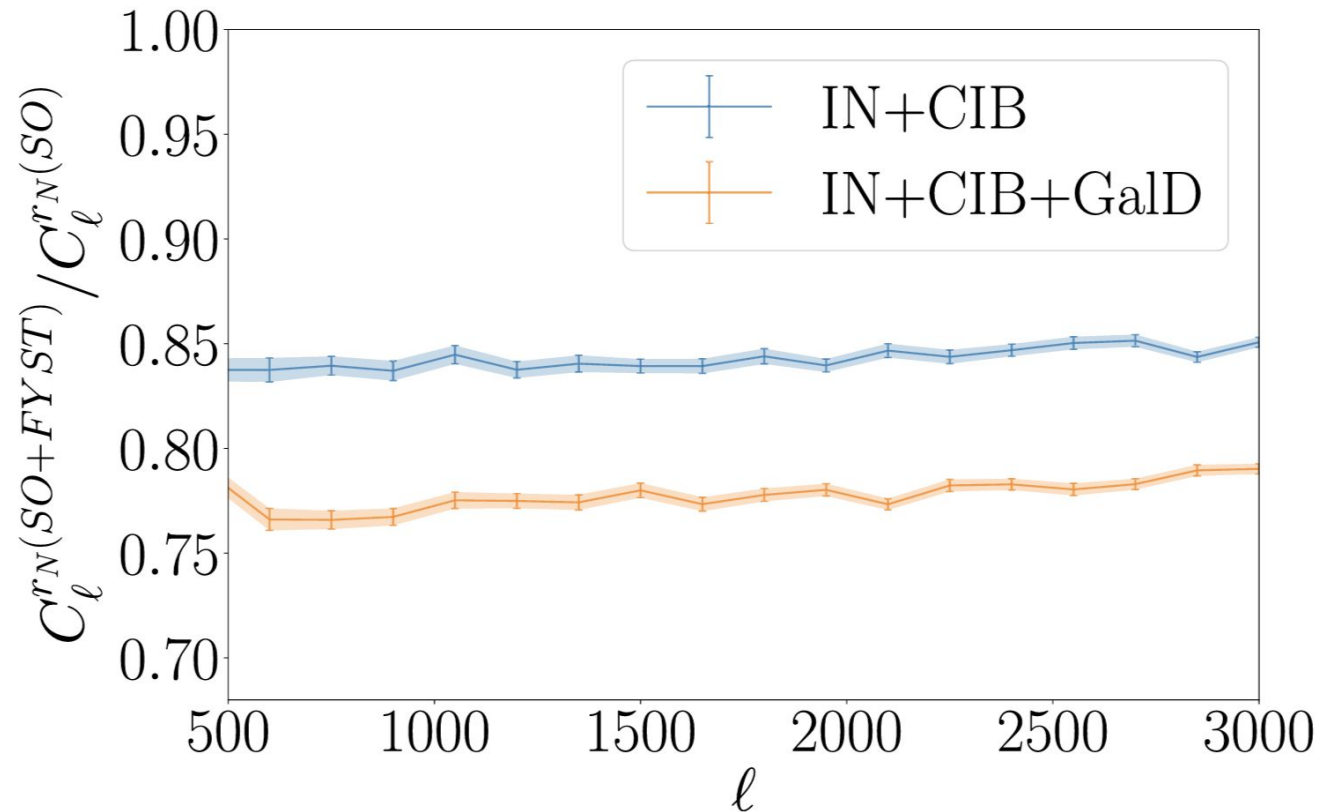


SZ - Clusters and Spectrum



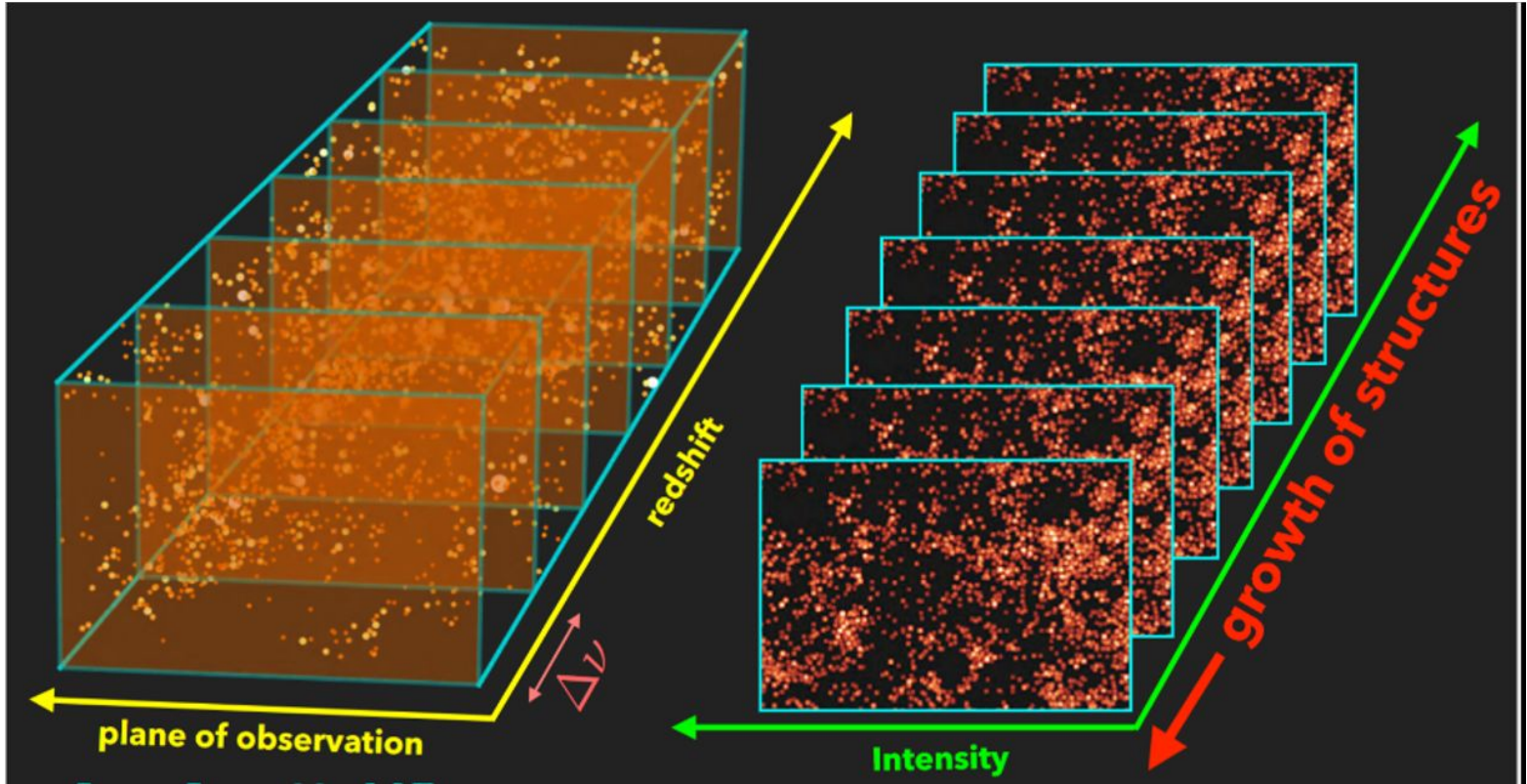


SZ - Clusters and SZ Spectrum



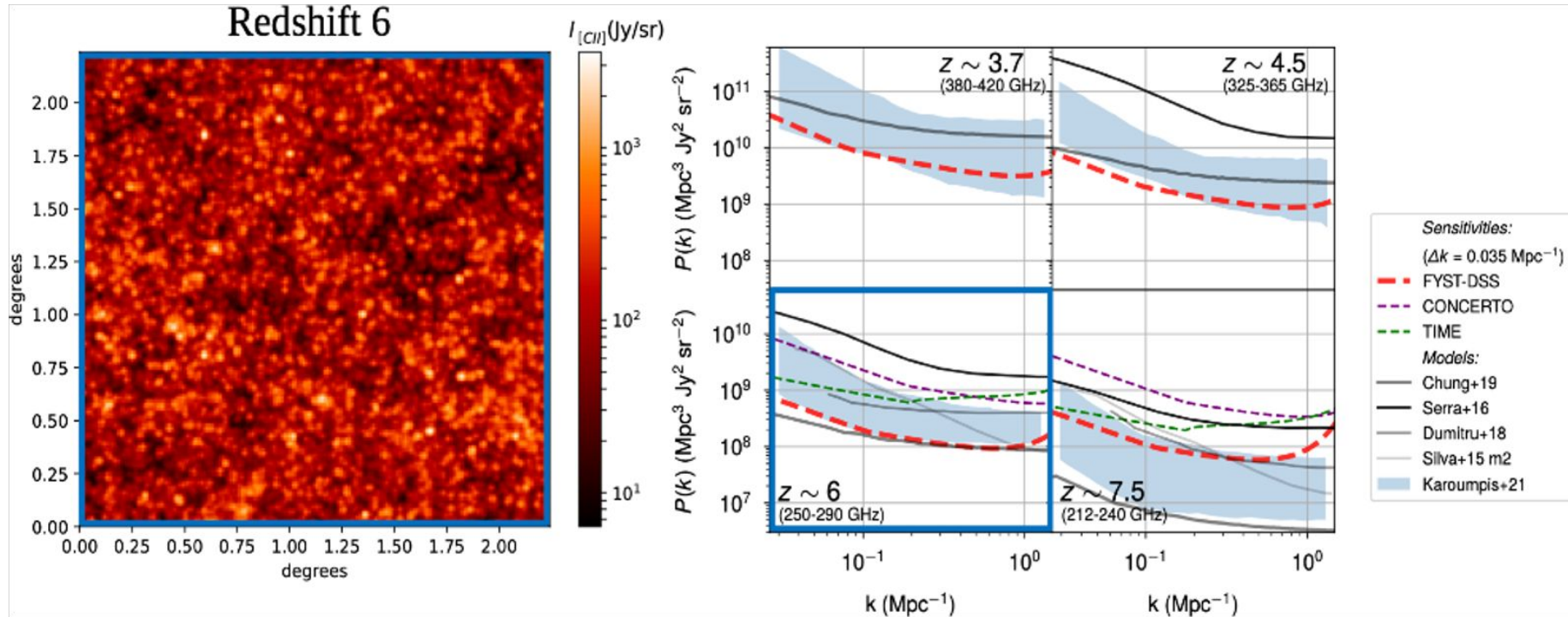


LIM - 3D Cosmic Structure from Extragalactic Lines



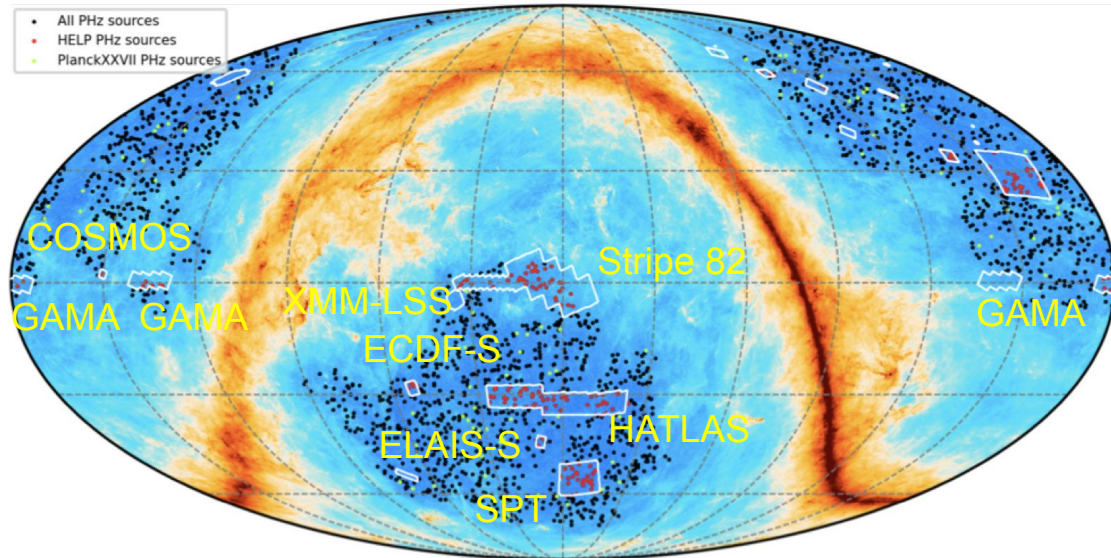


LIM - EoR-Spec Forecasts

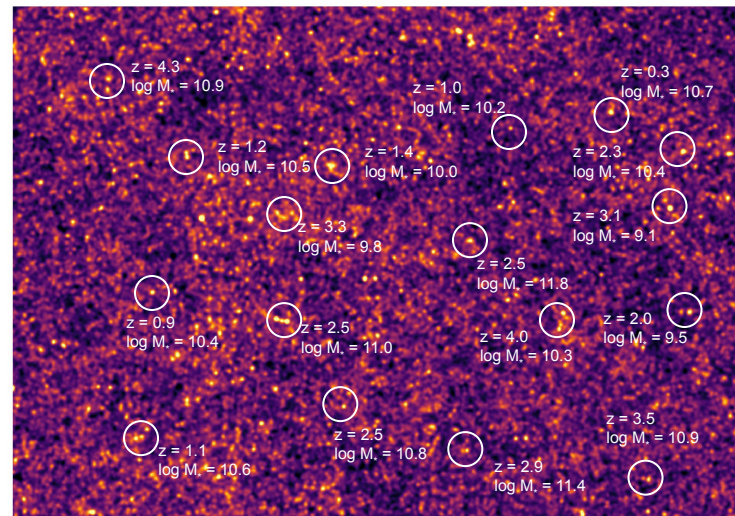




CIB - 1000deg² survey of star-forming galaxies



CCAT will cover 1000deg² of well-studied extragalactic fields.



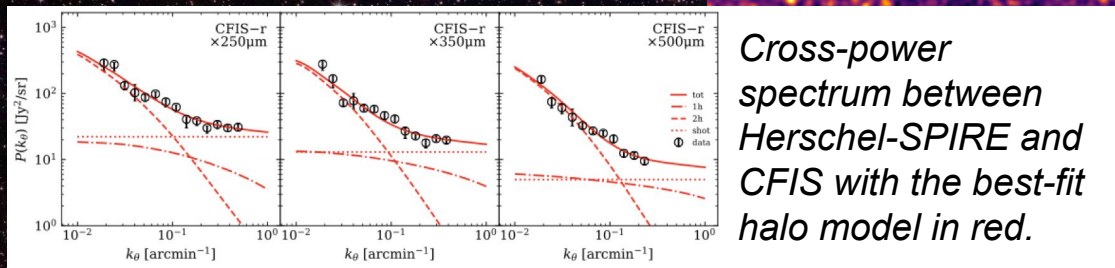
Multiwavelength data will constrain how galaxy properties correlate with large-scale structure.



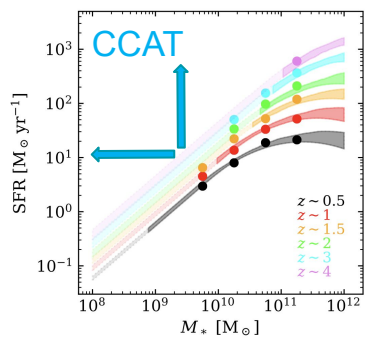
CIB - 1000deg² survey of star-forming galaxies

Cosmic (near-)infrared background
0.5 - 2 μm

Cosmic (far-)infrared background
350 - 1000 μm



Galaxy main sequence as a function of redshift predicted by the best-fit halo model. Both figures from Lim et al. 2022.



The longer wavelengths of CCAT + upcoming surveys like *Euclid* and Rubin will probe the galaxy main sequence to higher redshifts and smaller stellar masses.

Traces stars in galaxies

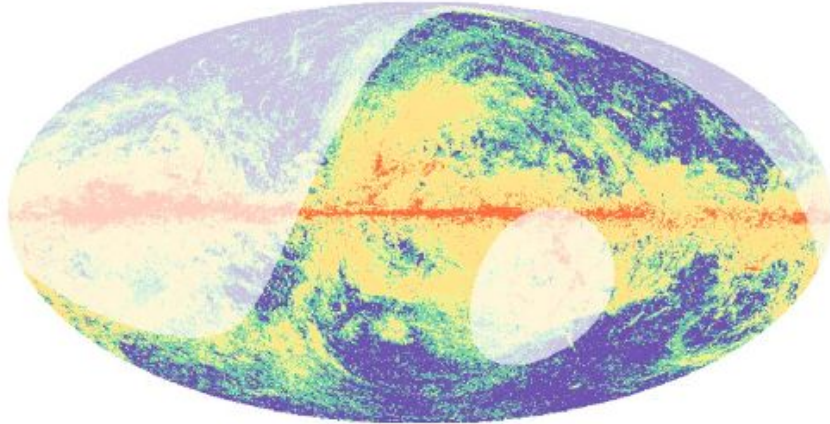
Traces star formation in galaxies



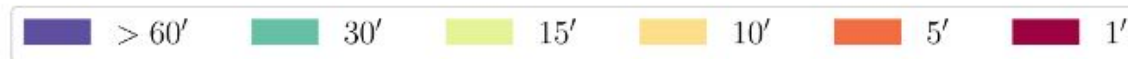
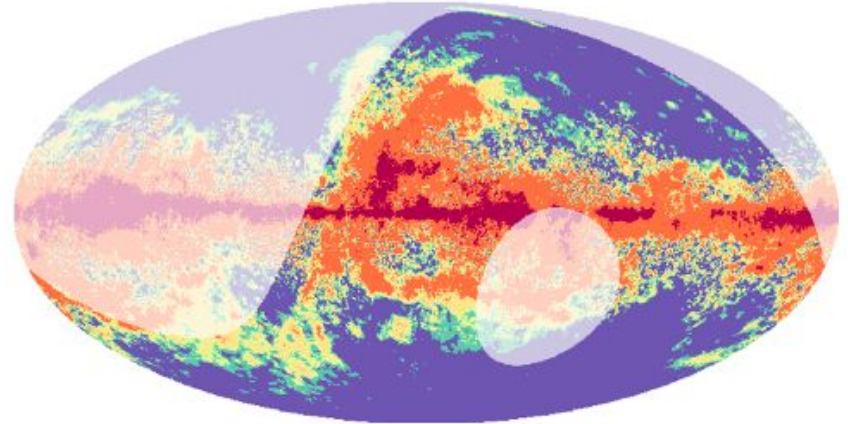
Galactic Polarization - High-resolution B-field maps over 60% of the sky

Effective resolution for >3 -sigma measurements of polarization

Planck 353 GHz



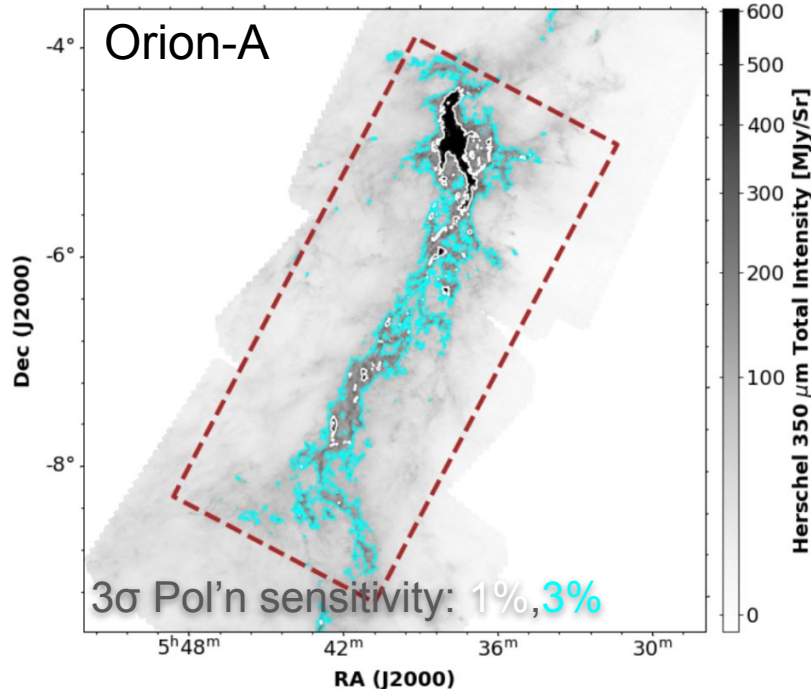
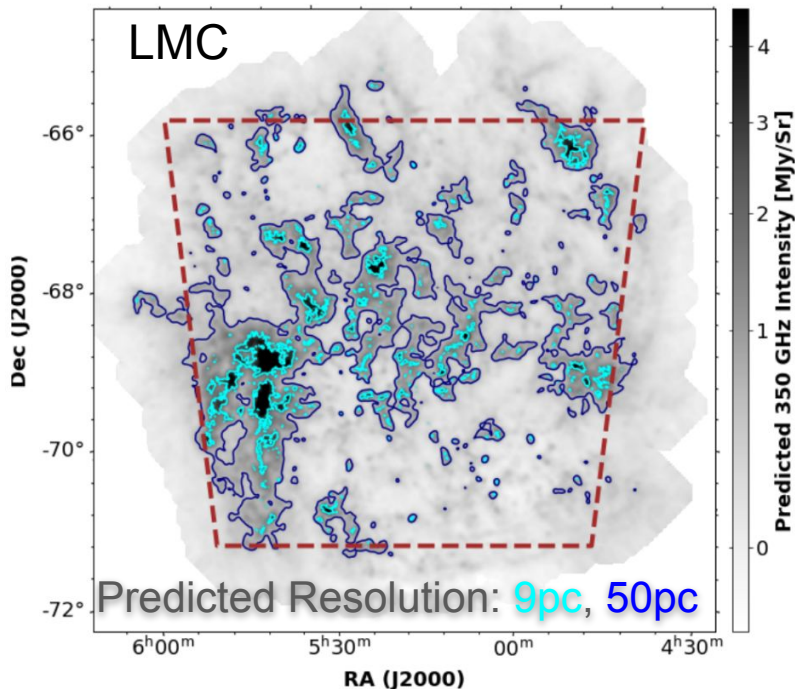
Prime – Cam 350 GHz





Galactic Polarization - Do B-fields affect star formation?

>500 hours for deep maps of 7 nearby clouds, the LMC + 1 translucent cloud

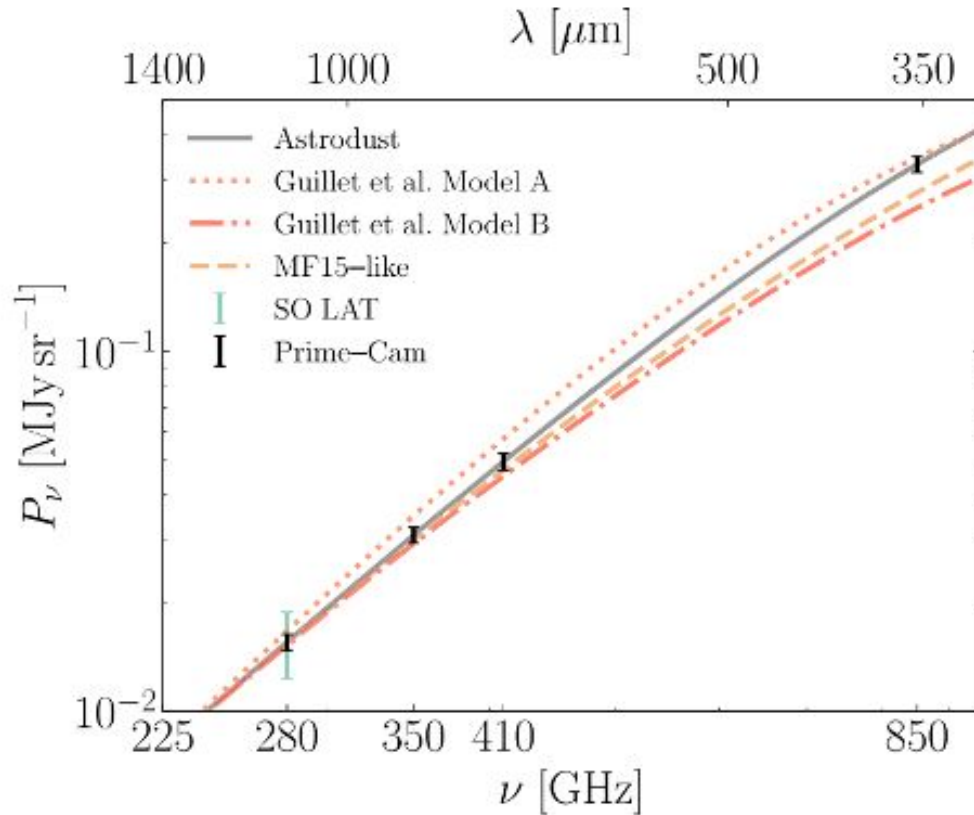


PrimeCam will: Trace B-fields from galaxy-scales to individual molecular clouds...

...and from cloud-scales down to individual star forming cores.

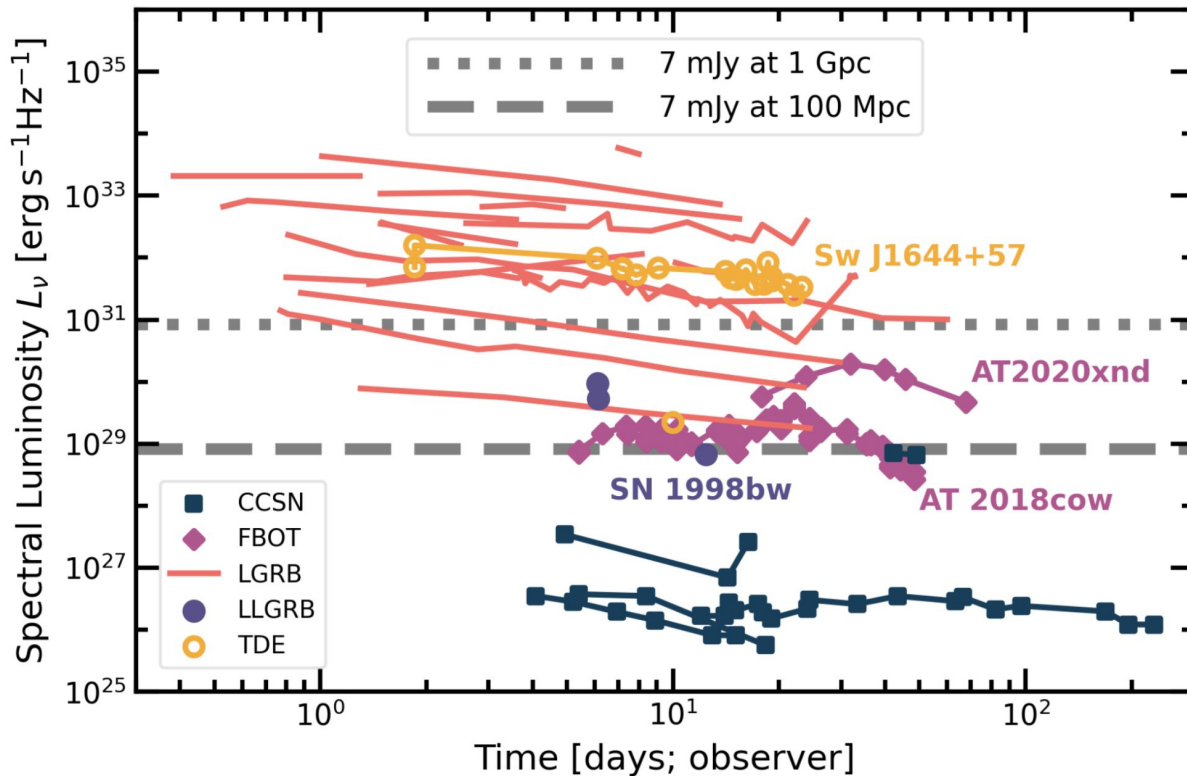


Galactic Polarization - Testing Dust Grain models





Transient Phenomena - Extragalactic





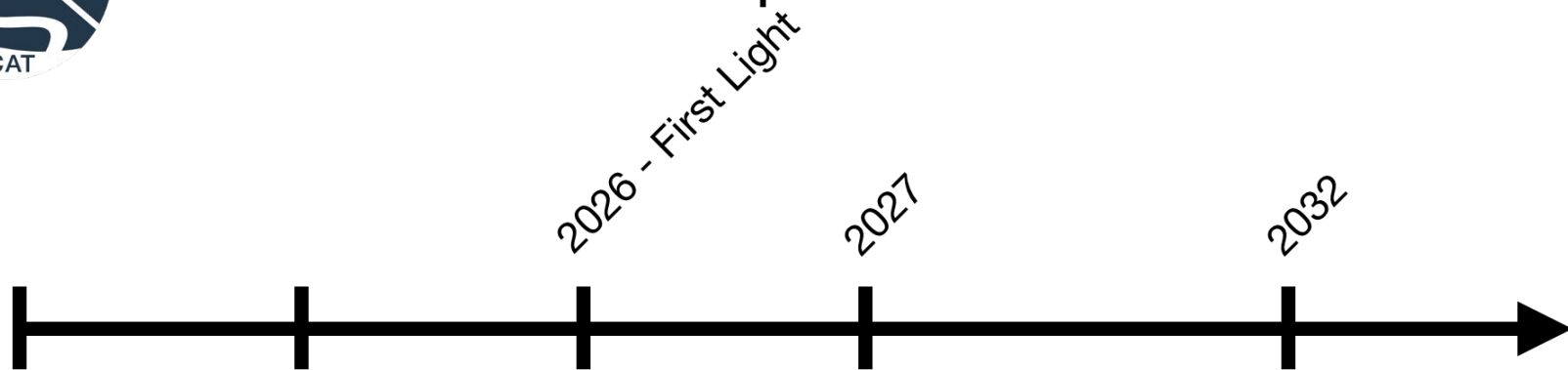
FYST Construction Update

FYST no longer looks like this it is all packed up in boxes and is being shipped to Antwerp. From there it head to Chile for construction.





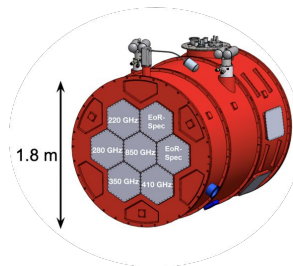
FYST Construction Update Site



FYST Constructed on Cerro Chajnantor telescope & instrument commissioning



CHAI and Prime-Cam deployed (including EoR-spec)



Nominal surveys on CCAT will finish!

- New surveys?
- New instruments?



CCAT - Collaboration & Membership

Relatively small collaboration

Which has its benefits!



CCAT - Collaboration & Membership

Relatively small collaboration

Which has its benefits!

We are looking for partners

Happy to talk about this offline

