
Terahertz Intensity Mapper
some call me...
TIM

CII Science and Cross-Correlation at Cosmic Noon

Ryan Keenan

Max Planck Institute for Astronomy, Heidelberg, Germany

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Terahertz Intensity Mapper – “European Project Lead”

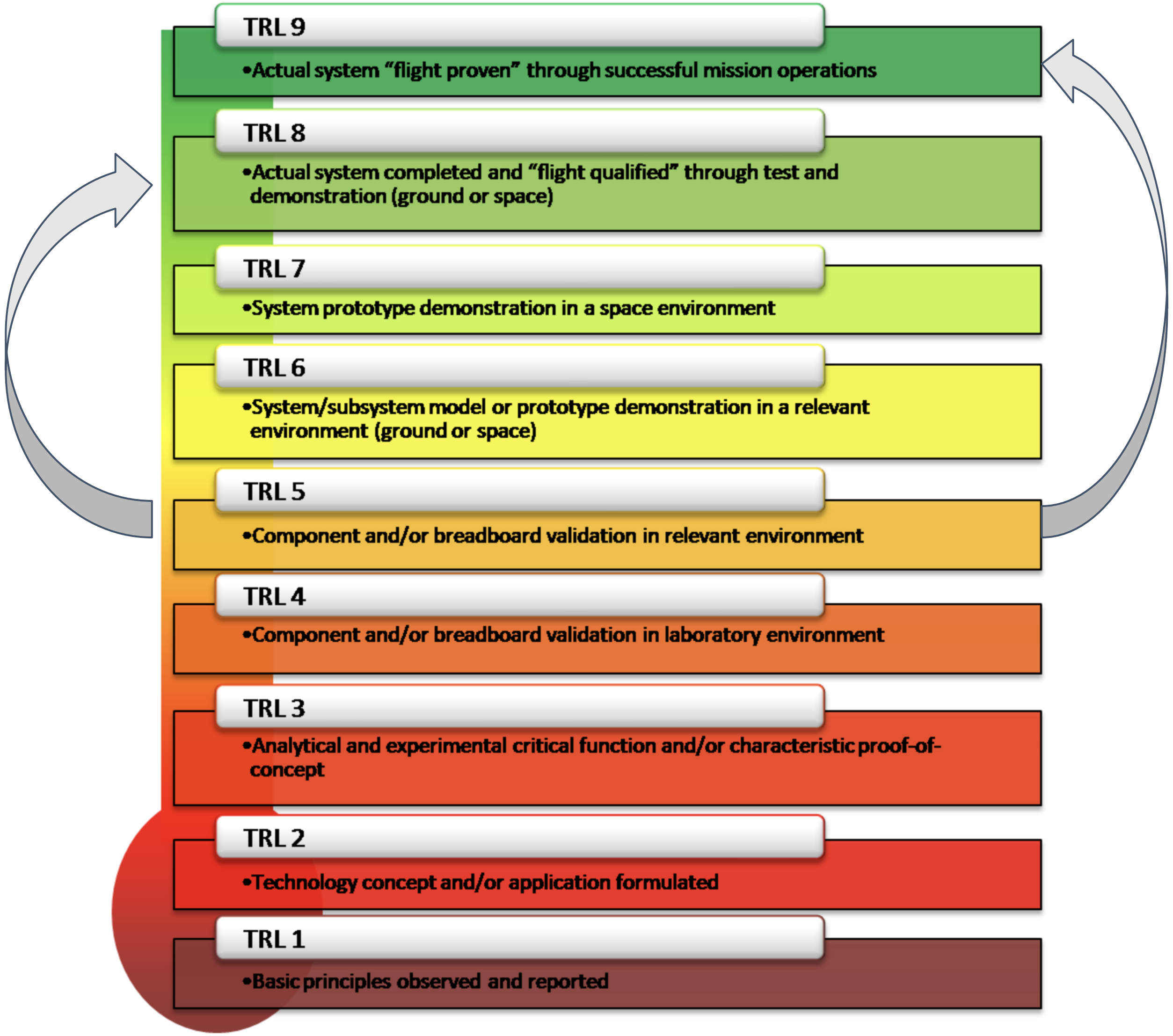
The TIM Team

University of Illinois J. Vieira (PI), J. Filippini, J. Alameda, H. Athreya, B. Brendal, J. Fu, K. Garcia, S. O'Donnell, M. Van Cuyck
Caltech/JPL R. Janssen, M. Bradford, S. Hailey-Dunsheath, L.-J. Liu
Arizona State University C. Groppi, D. Joralmon, P. Mauskopf, T. Saeid
University of Arizona D. Marrone, I. Lowe, E. Mayer
University of Pennsylvania J. Aguirre, S. Agrawal, J. Bracks, A. Manduca
Max Planck Institute for Astronomy R. Keenan
Harvard & Smithsonian G. Keating
University of Chicago J. Zebrowski
Princeton University S. Tartakovsky

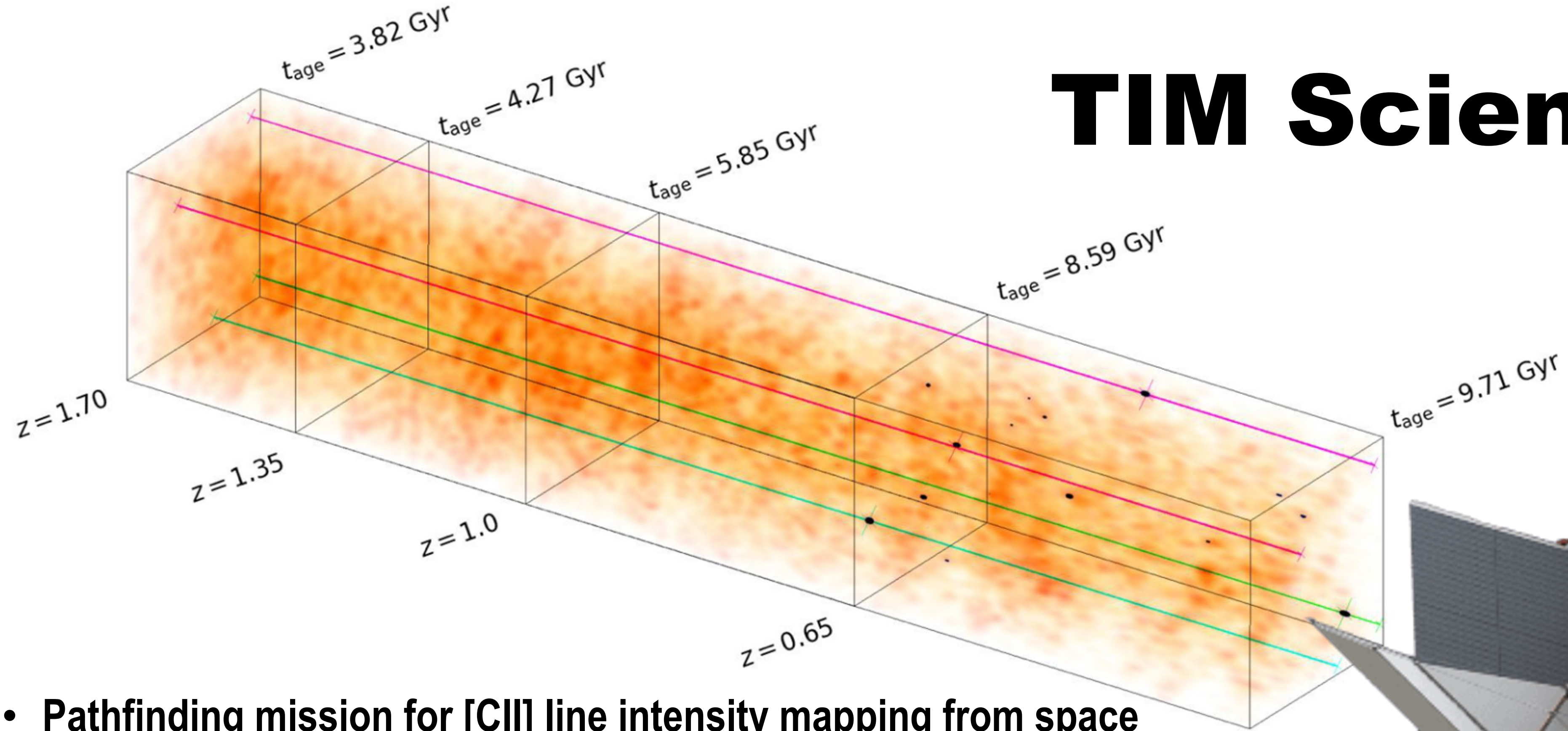
ILLINOIS JPL Jet Propulsion Laboratory California Institute of Technology ASU THE UNIVERSITY OF ARIZONA Penn

TIM Technological Goals

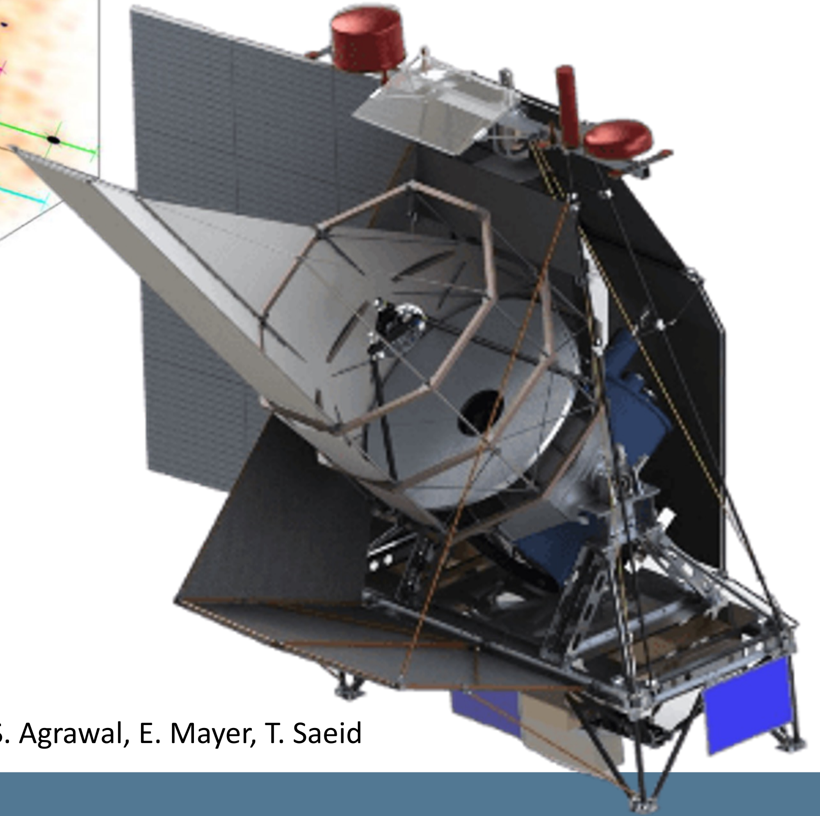
- **Raising the TRL of relevant technologies by deploying them in a near-space environment**
  - Kilopixel Low-noise MKID arrays
  - Low power RFSoC-based readout systems
- **Demonstrating these will strengthen the case for future missions**
- **Training the next generation of instrument builders and designers**



TIM Science Goals



- **Pathfinding mission for [CII] line intensity mapping from space**
  - Bridges regimes covered by ground-based facilities and future space missions
  - Target a redshift regime with ample ancillary information and opportunities for cross-correlation
- **Measure the total [CII] luminosity in stellar-mass-selected stacks of galaxies in the GOODS-S field and use these to investigate changes in star formation modes**
- **Directly detect the brightest [CII] emitters in the GOODS-S field**

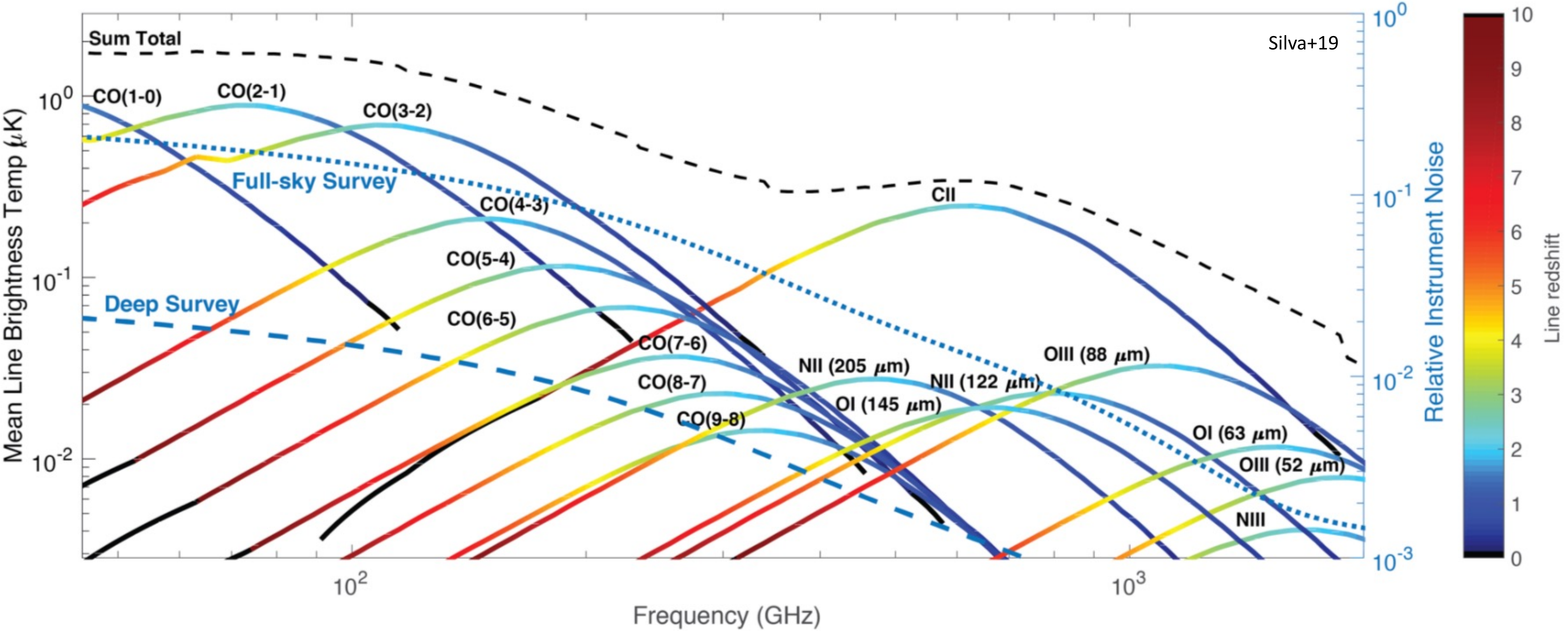


S. Agrawal, E. Mayer, T. Saeid

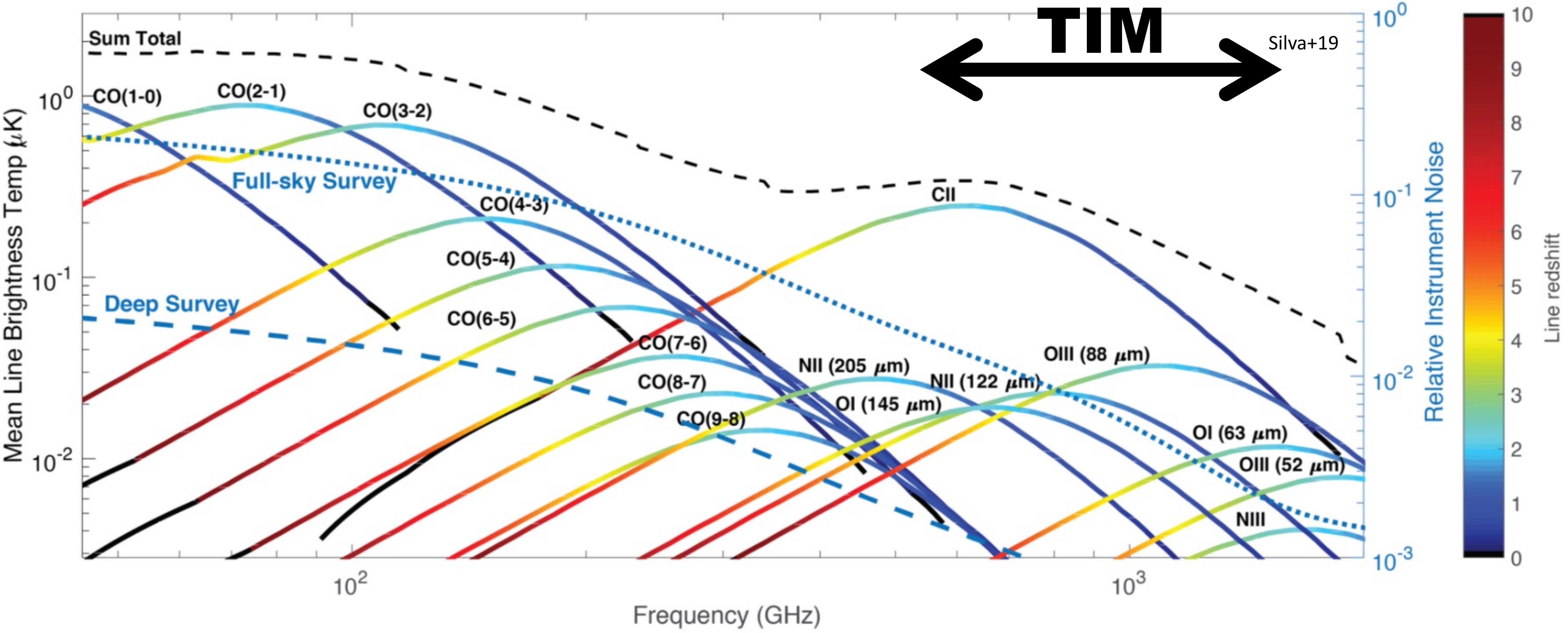
TIM Science Background

Why Terahertz? Why [CII]?

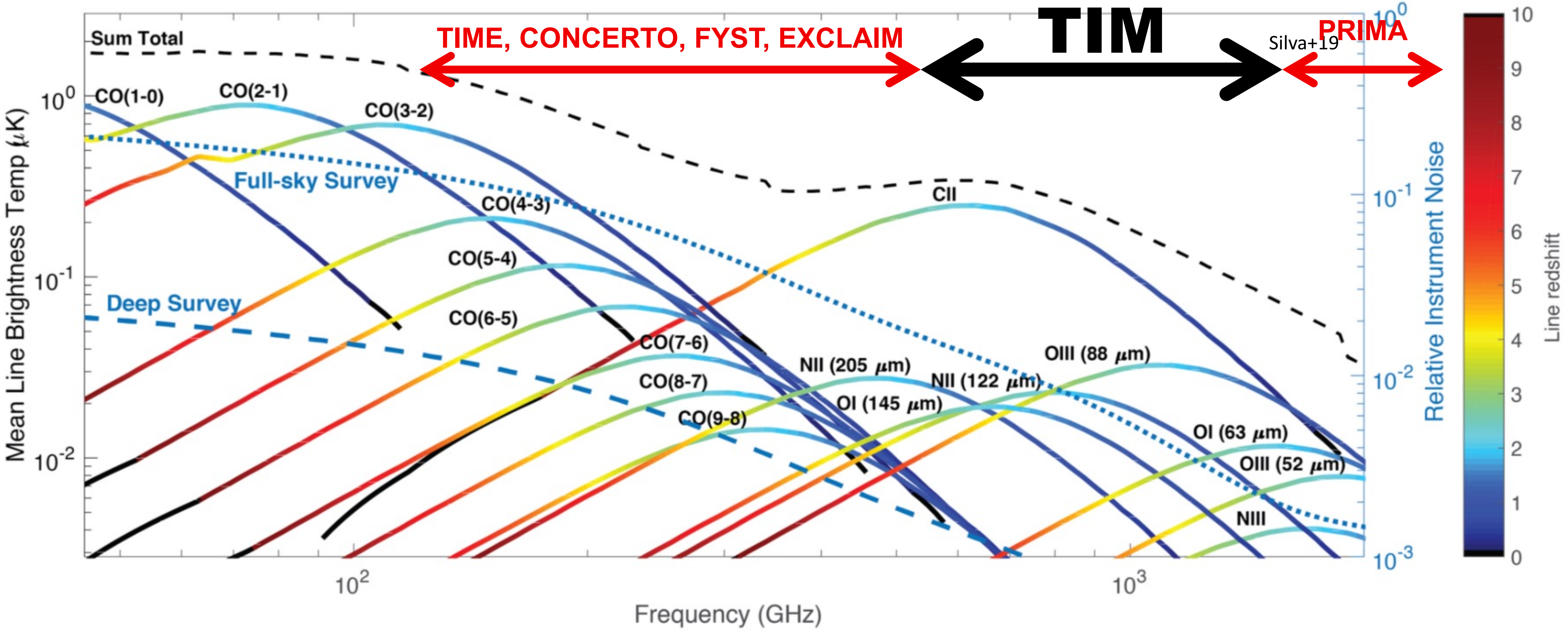
LIM in the Far-Infrared



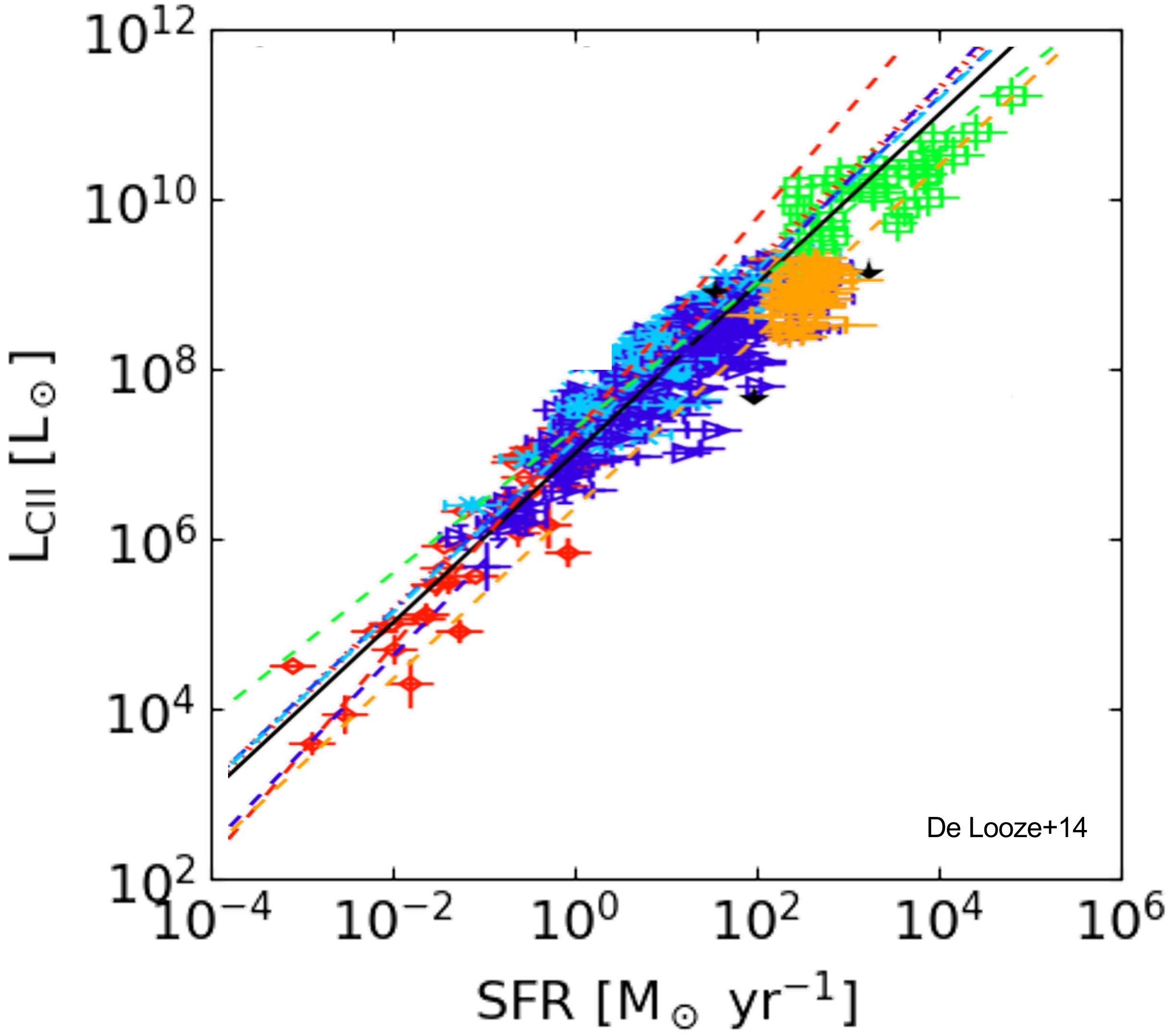
LIM in the Far-Infrared

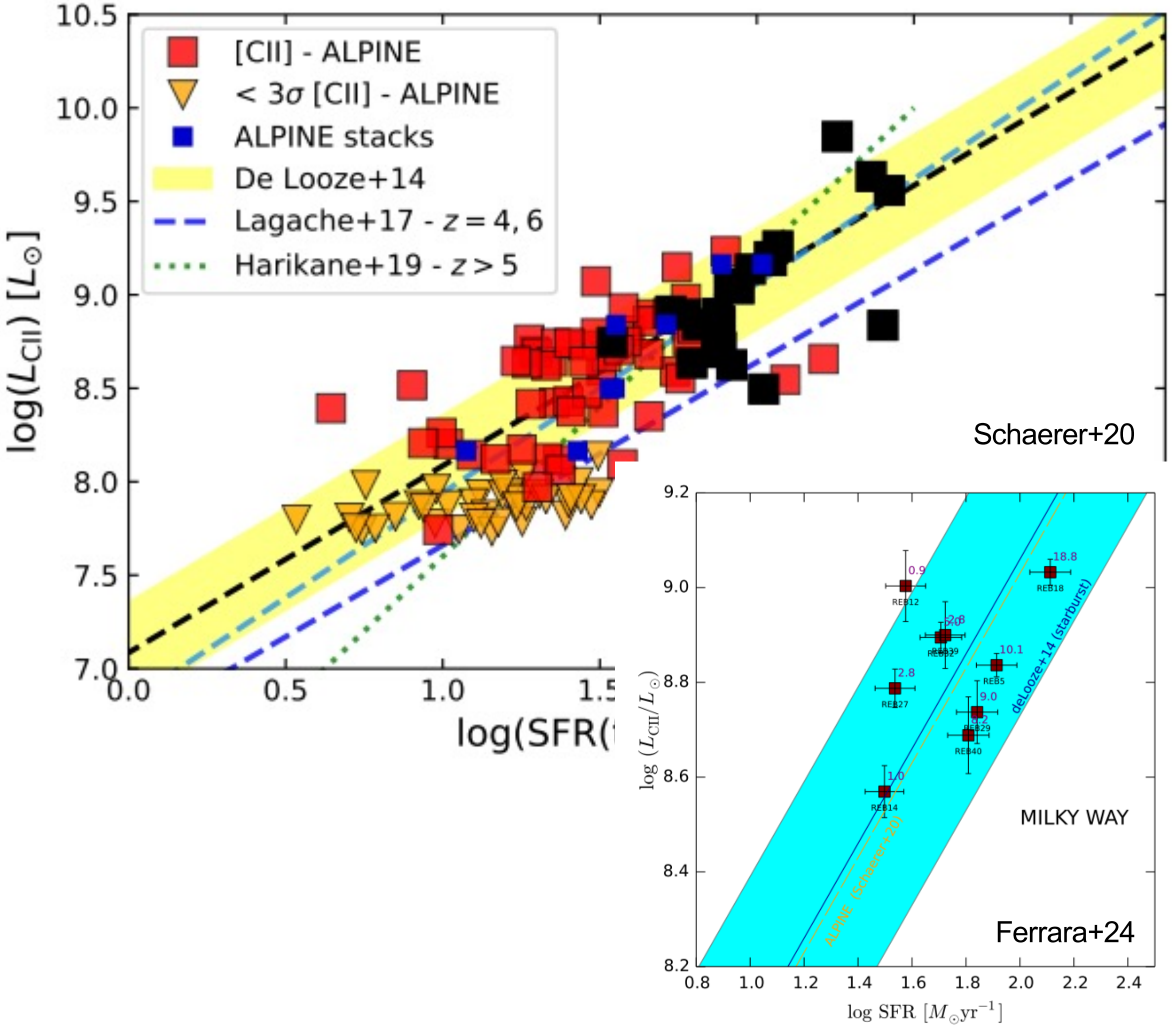


LIM in the Far-Infrared

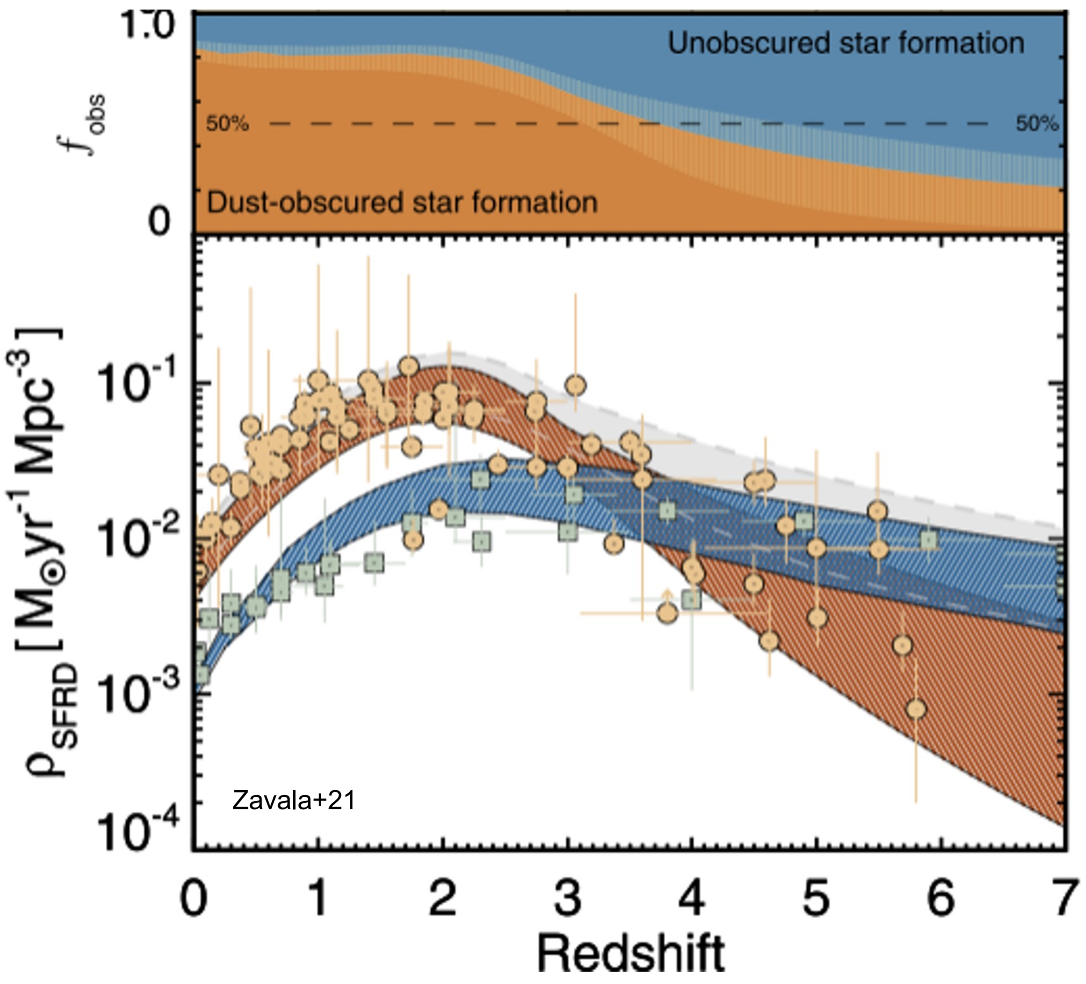


The [CII]-SFR Connection





The Cosmic Star Formation History



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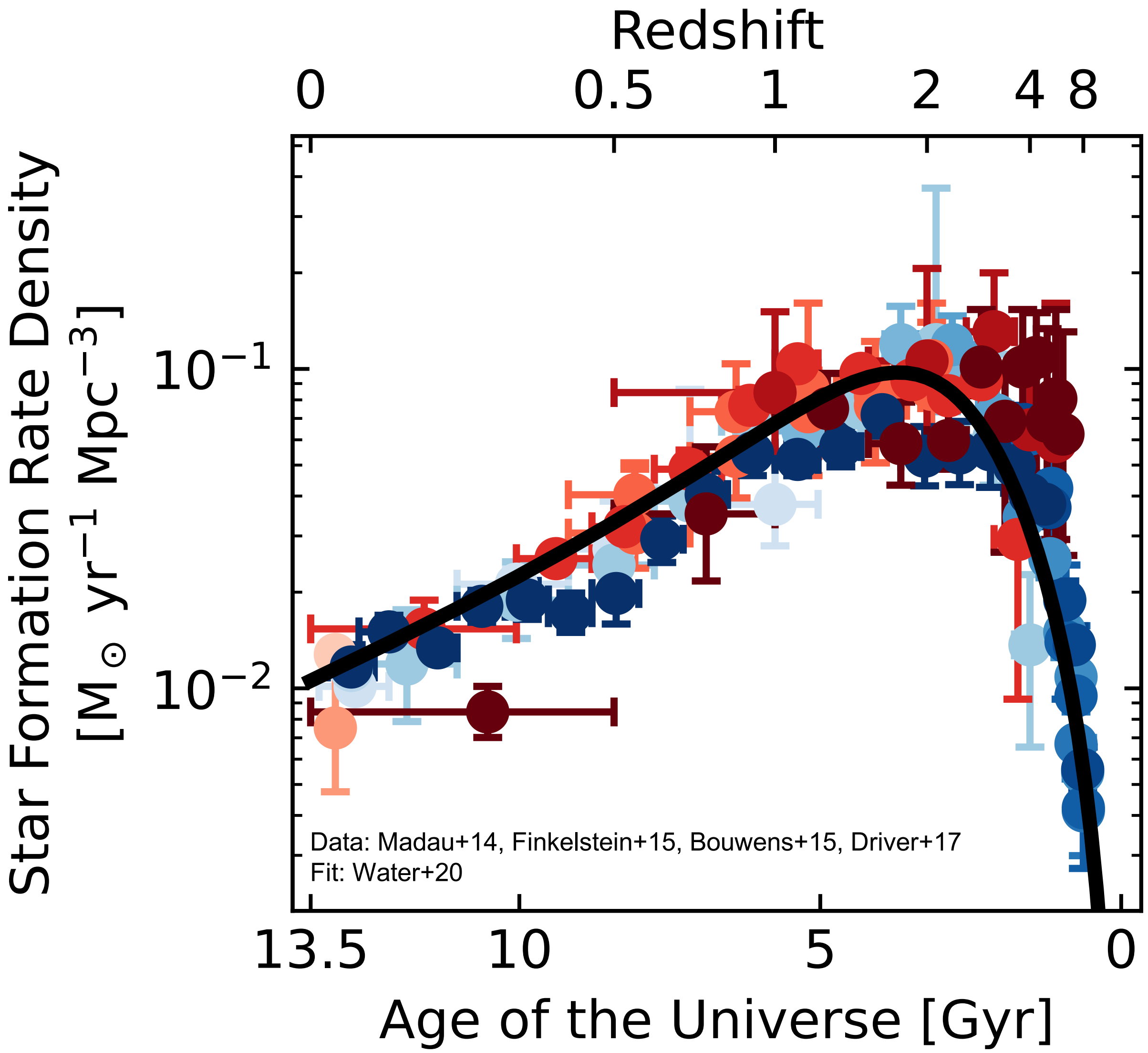

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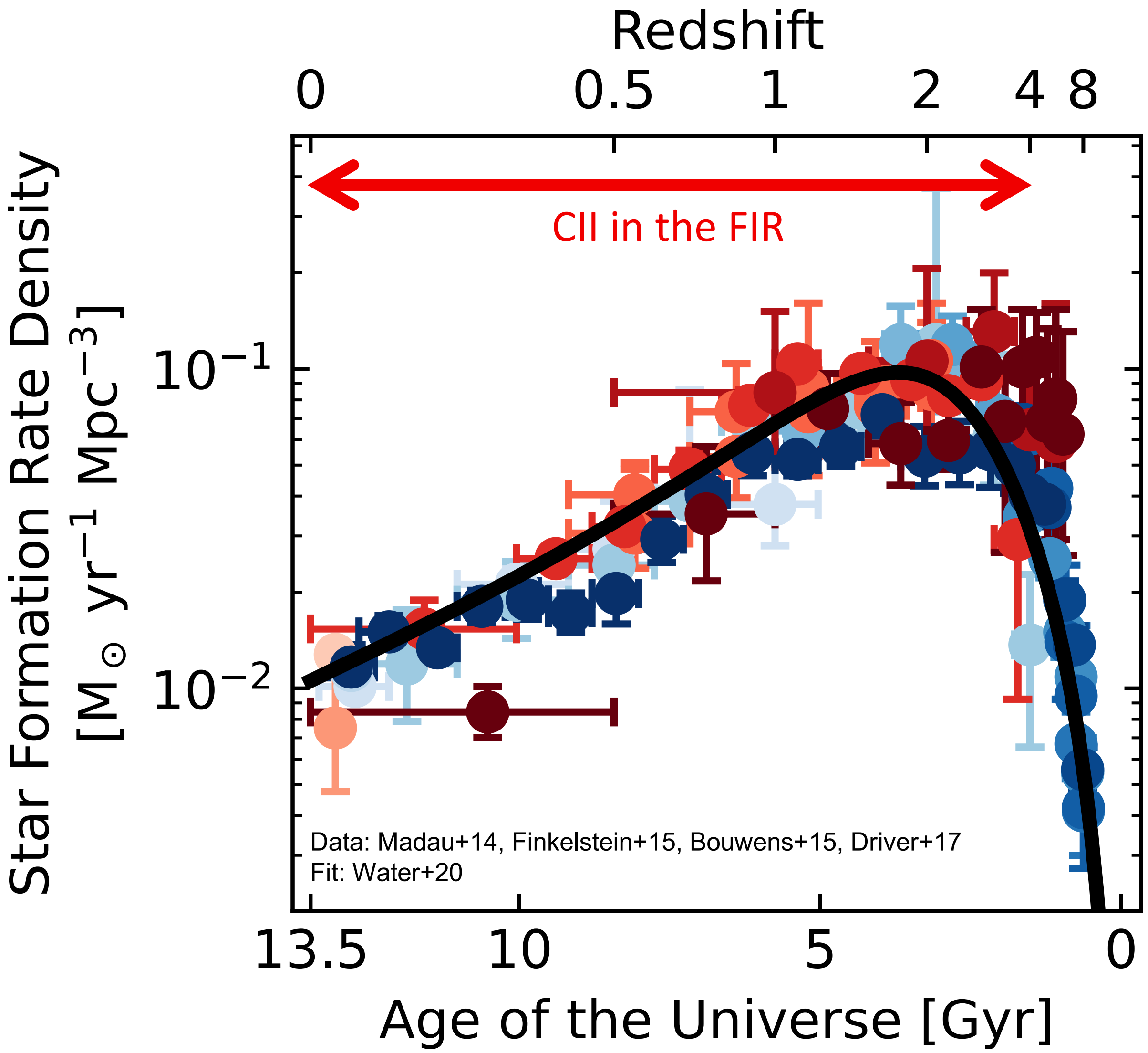

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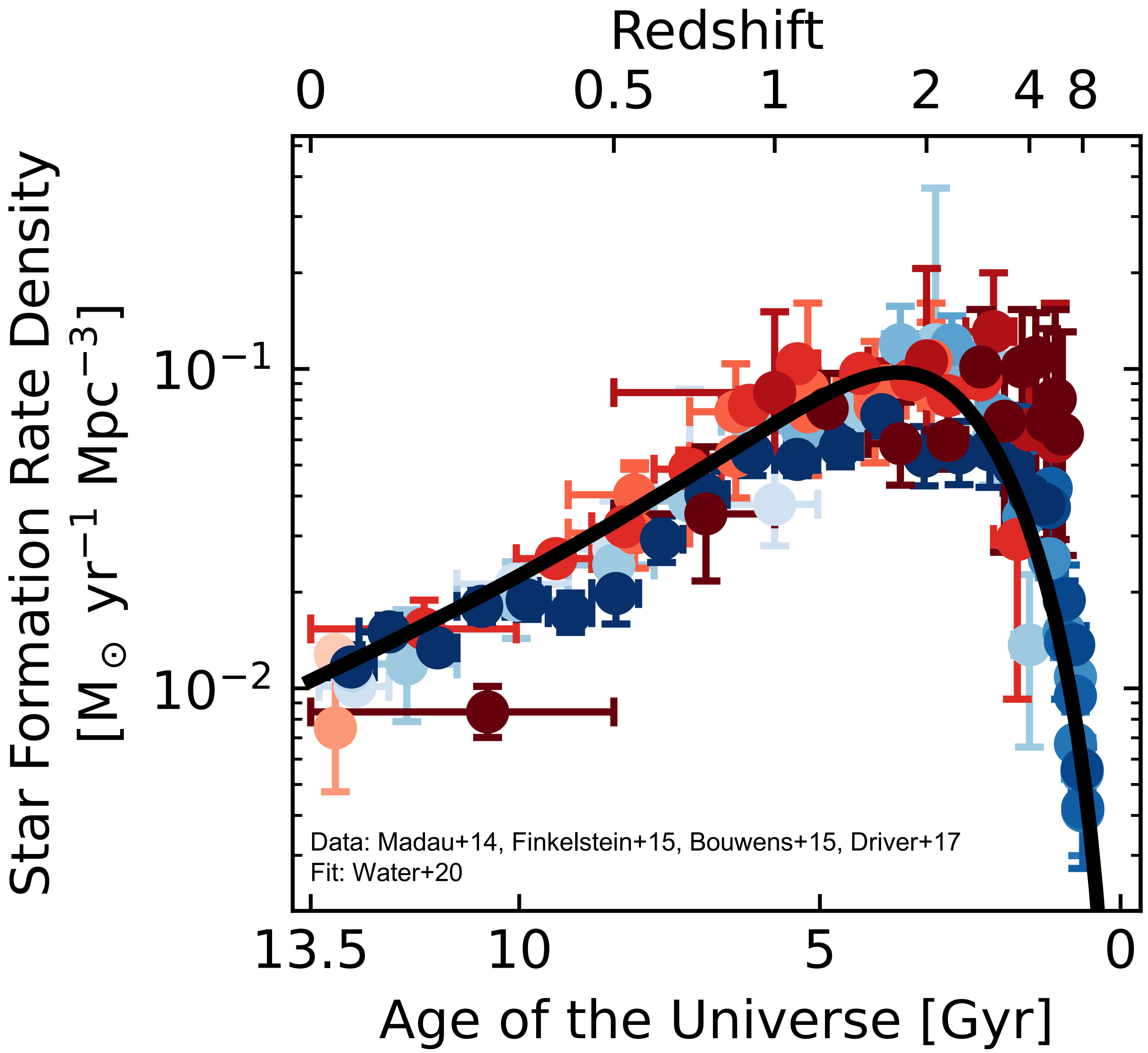
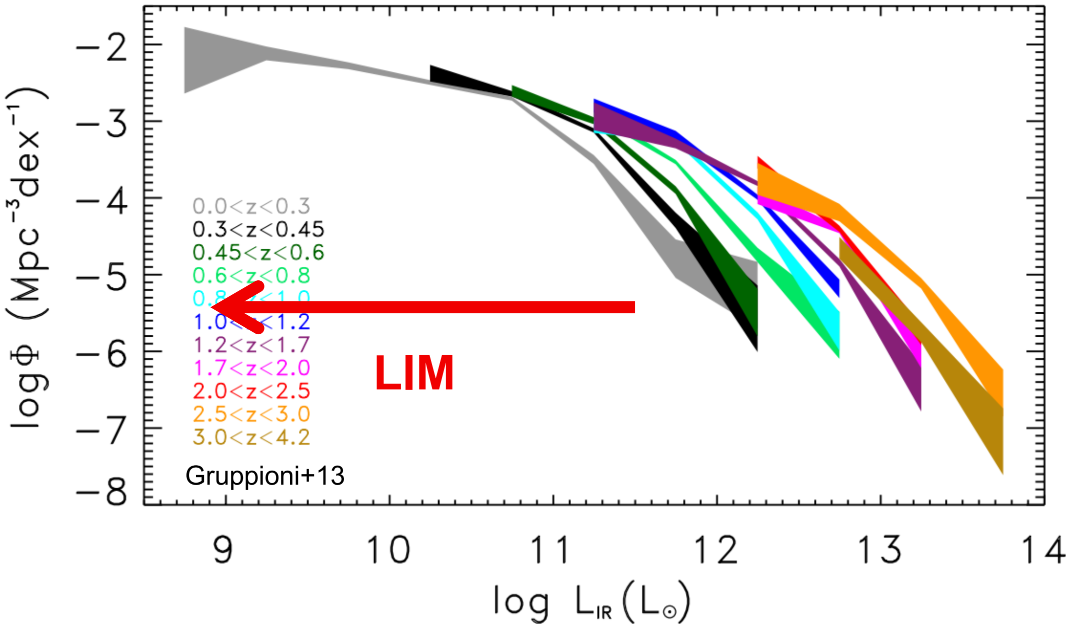


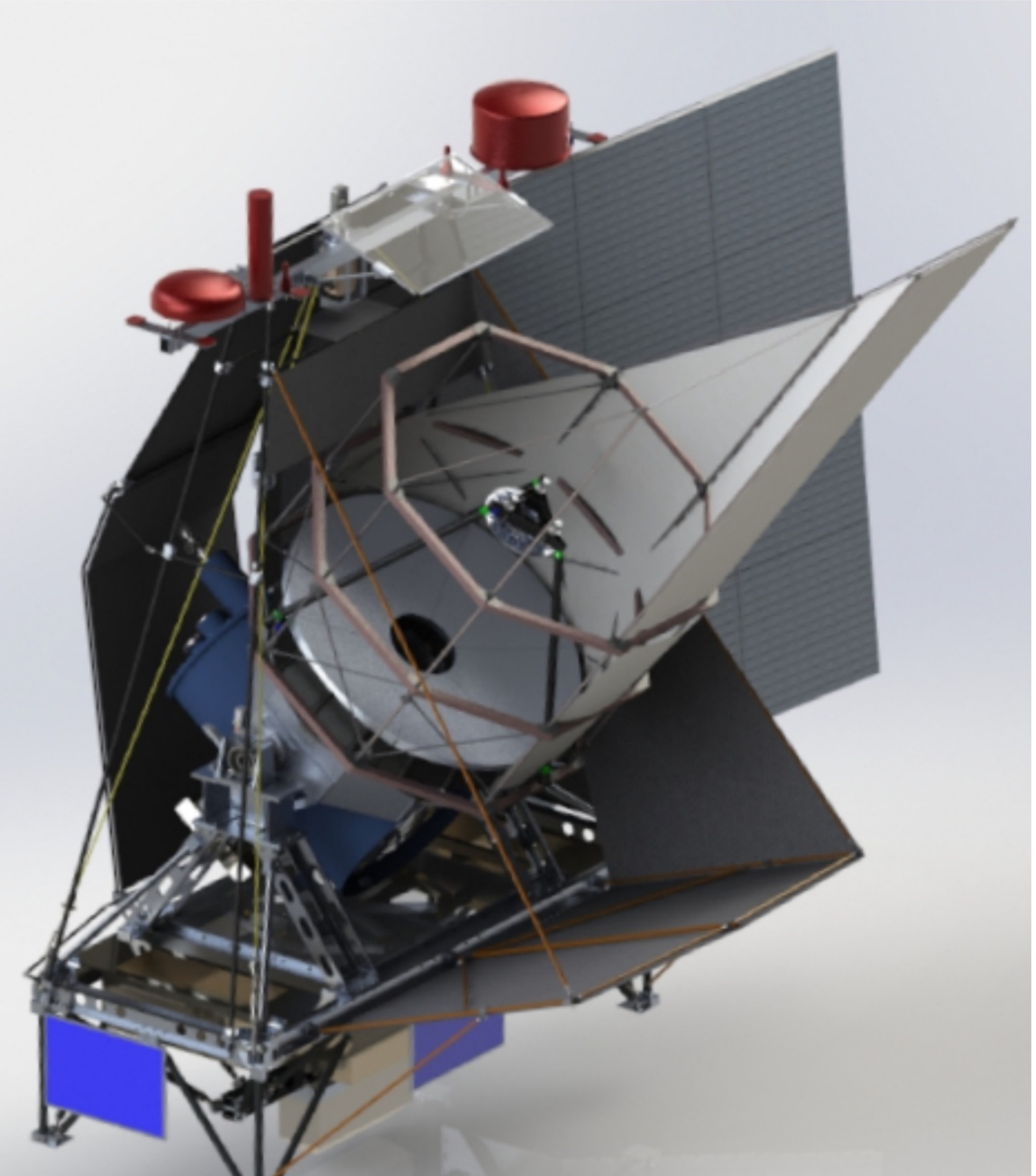


The TIM Instrument

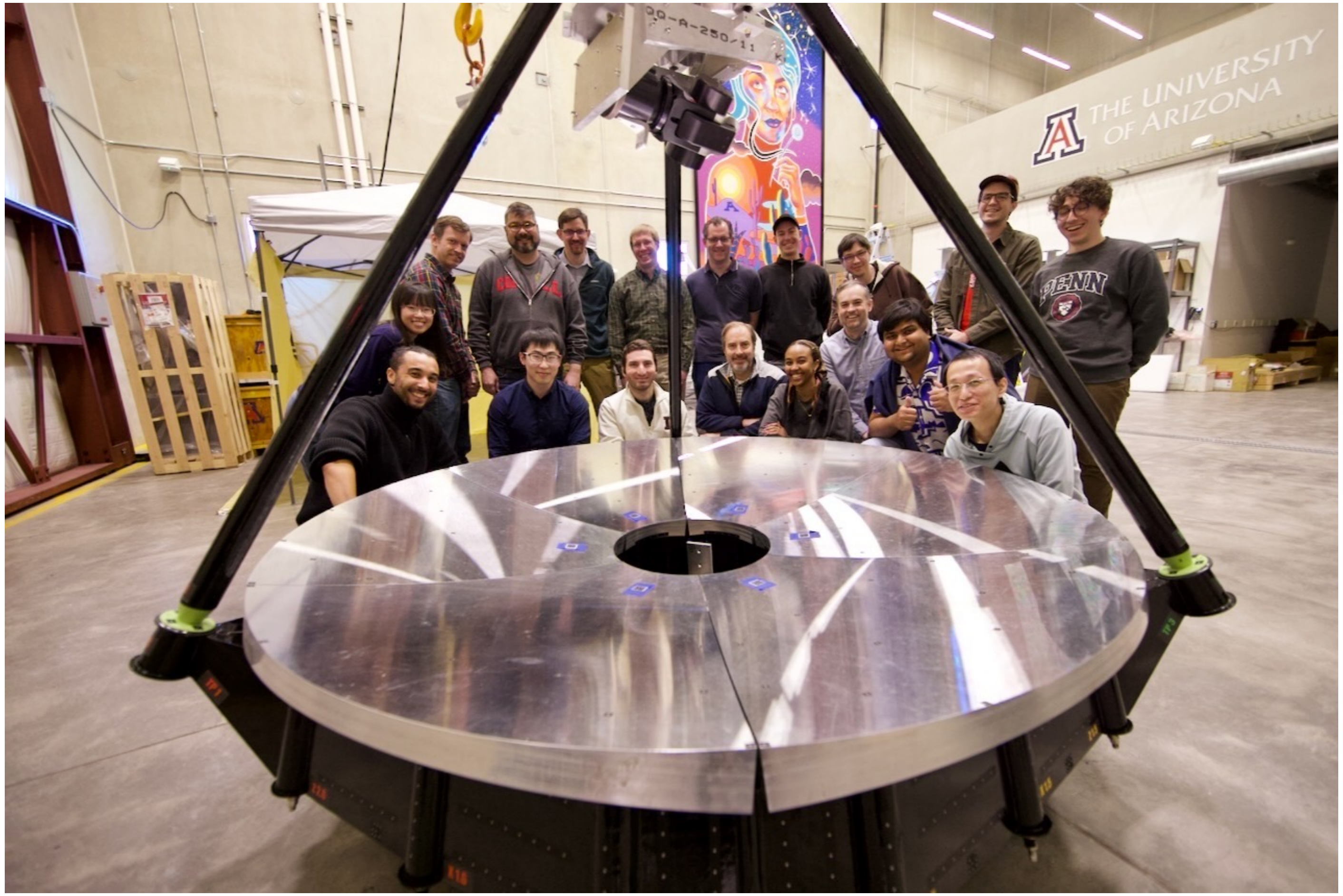
The TIM Instrument

- **Antarctic Stratospheric Balloon**
  (‘26/’27 Austral summer launch)
- **Evolution of BLAST: gondola, pointing system, cryostat, readout**

- **Telescope Specifications**
  - 2m primary mirror, Cassegrain design
  - ~25” resolution at 240μm
  - 5μm surface accuracy
  - 1 degree field of view
- **Instrument Specifications**
  - Two grating spectrometers
  - 240 – 317 & 317 - 420 μm at R~250
  - 1 degree slit length
  - Liquid-Helium cryostat with sorption cooler (~250mK)
  - 2x MKID arrays with ~3600 detectors each


T. Saeid

The TIM Instrument



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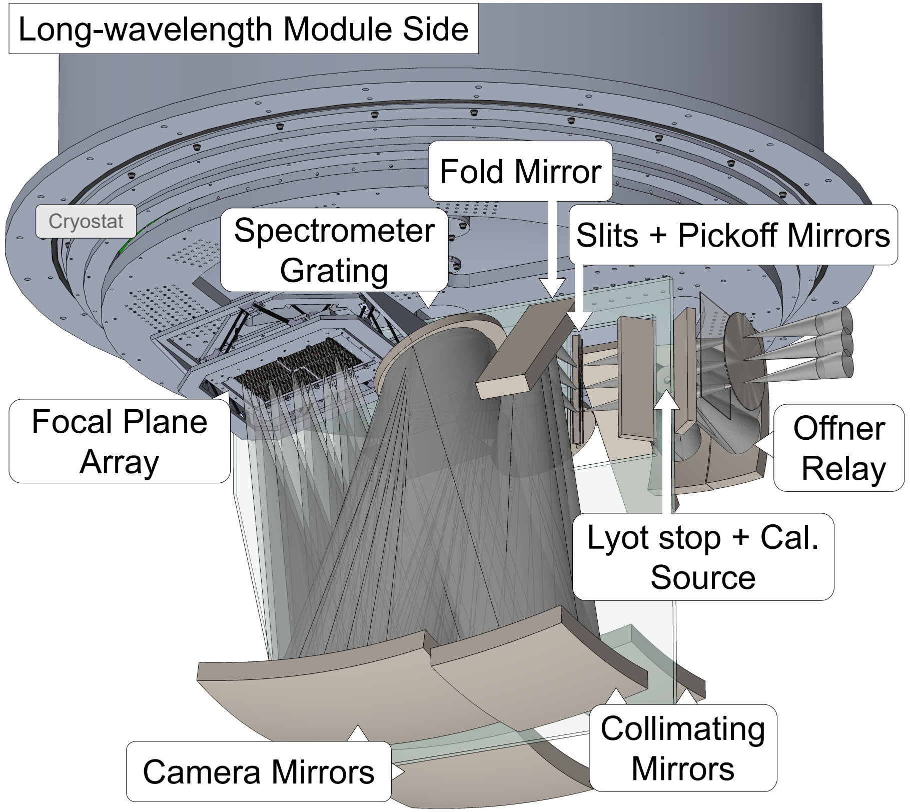

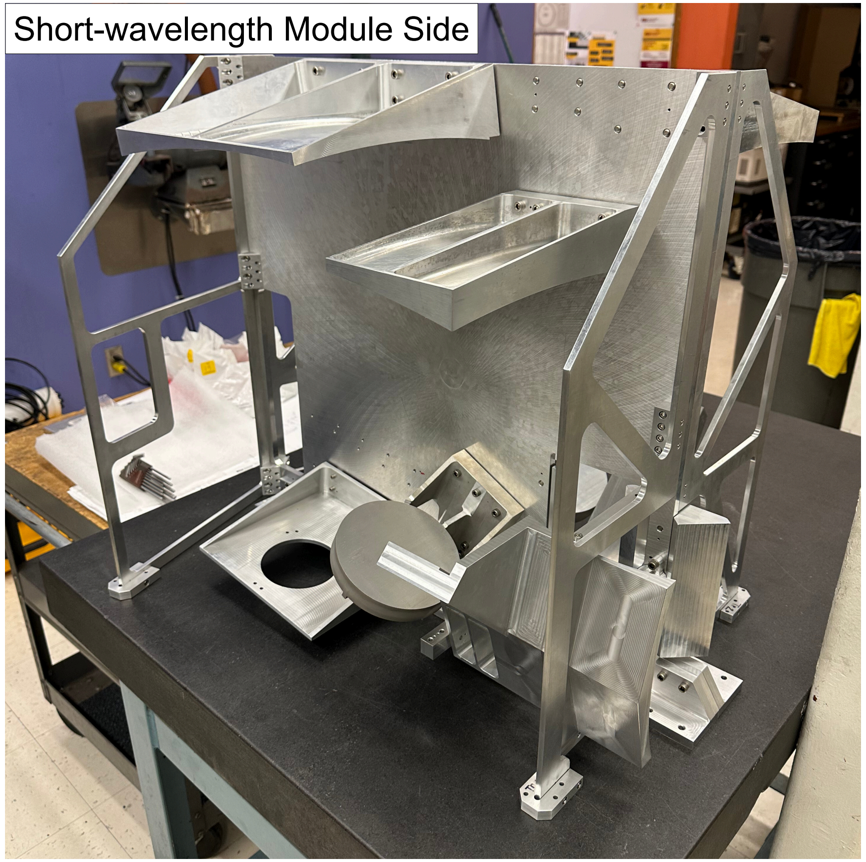

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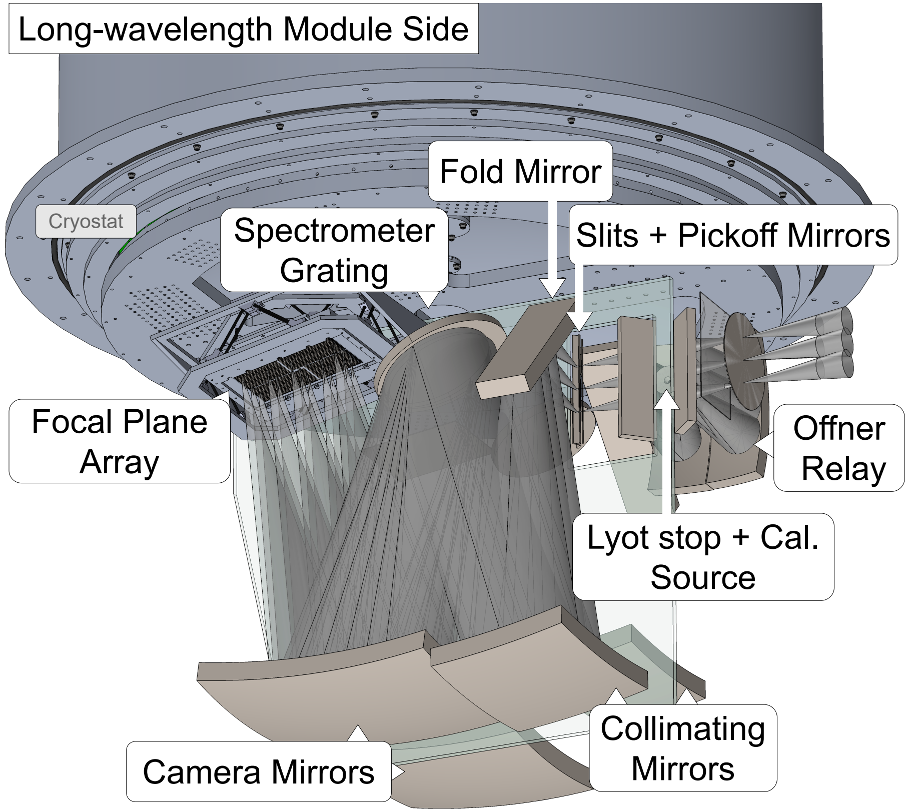
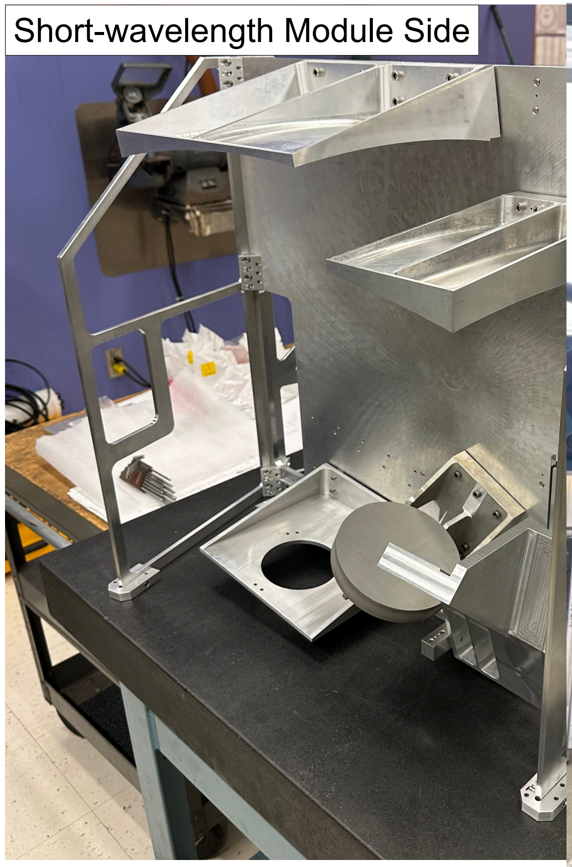


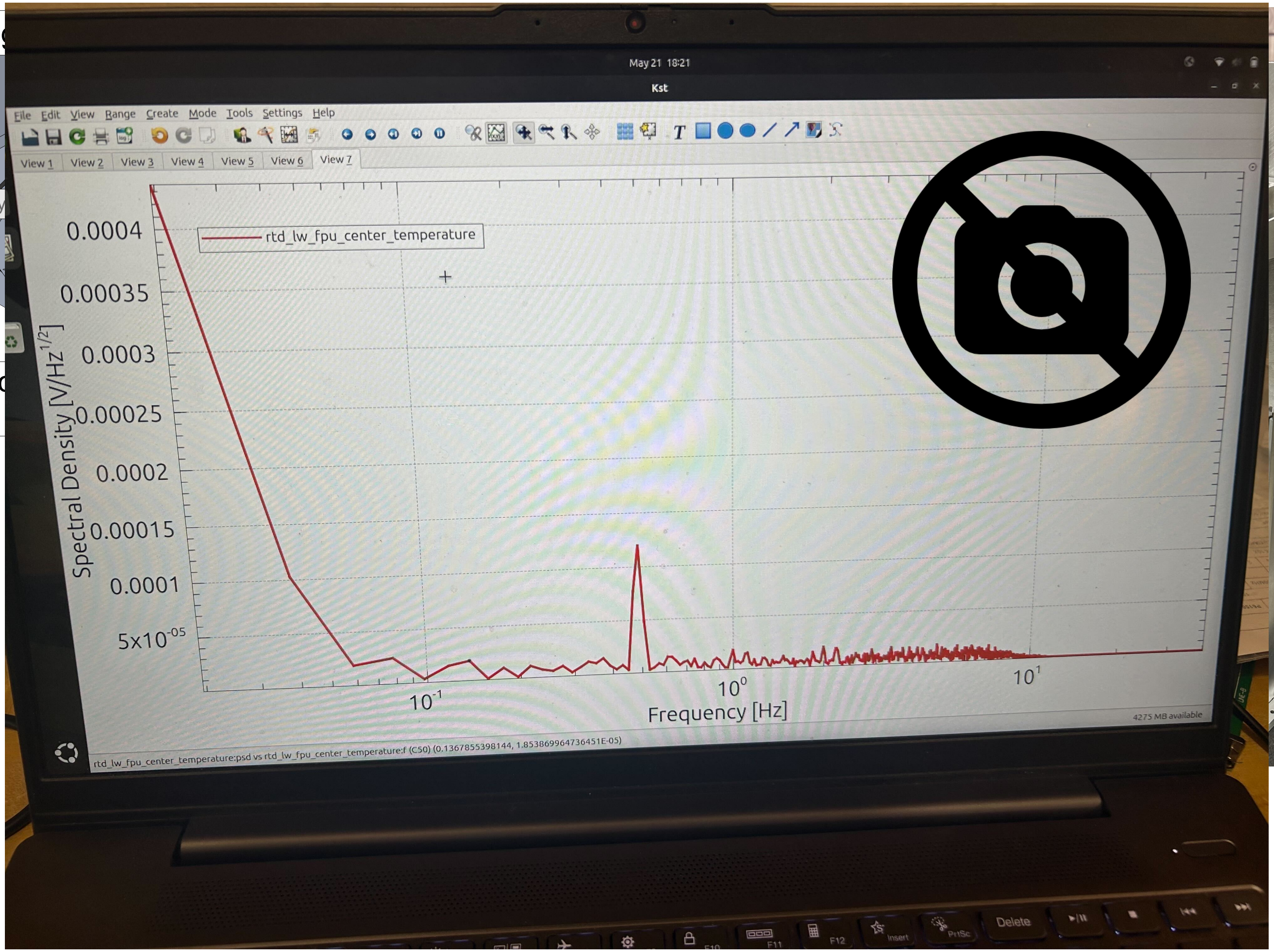


The TIM Instrument

Long

Cry

Foc



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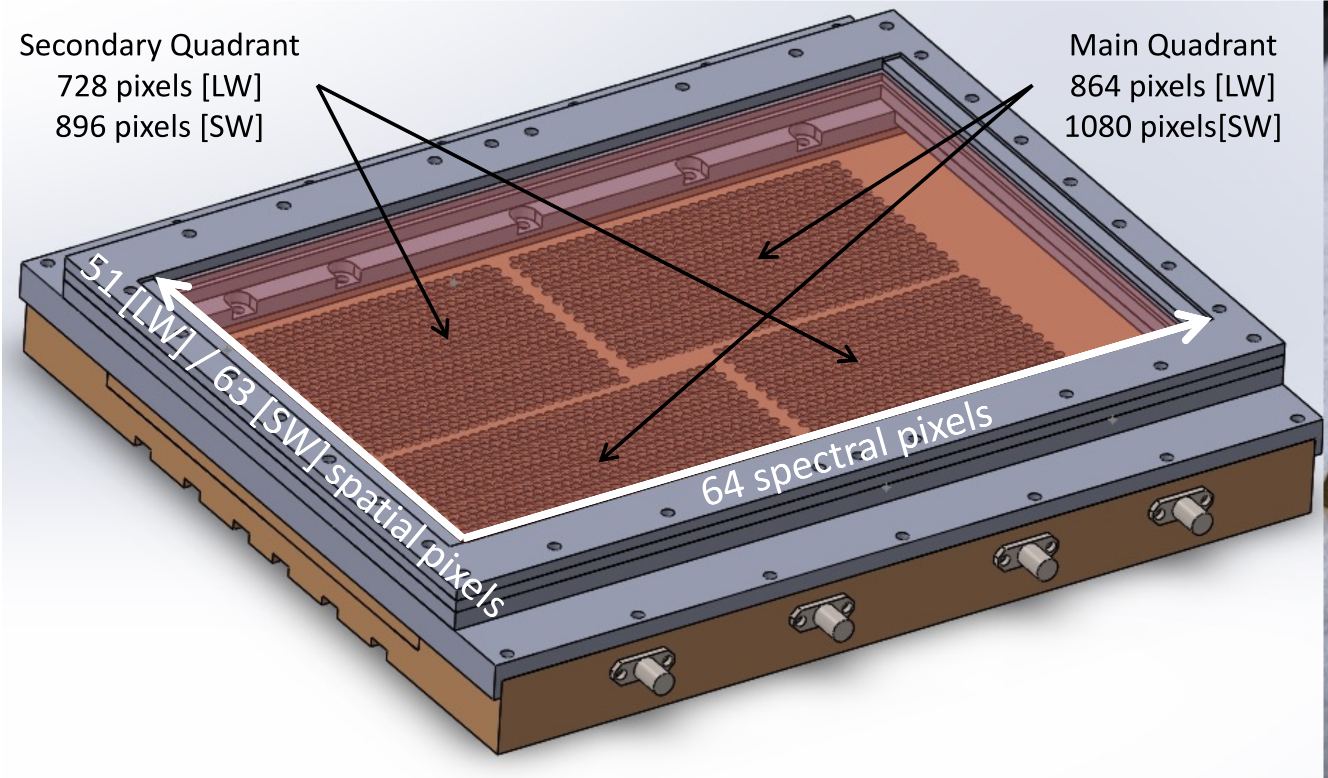
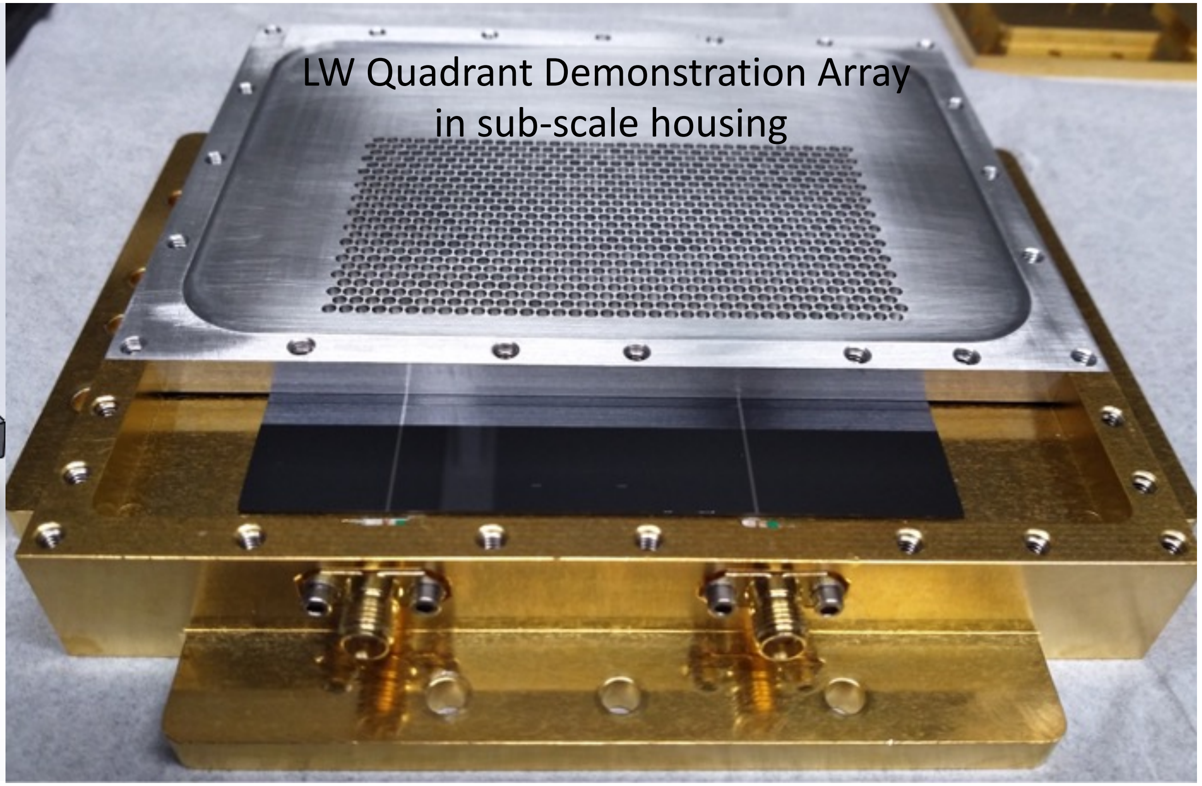




Test Flight

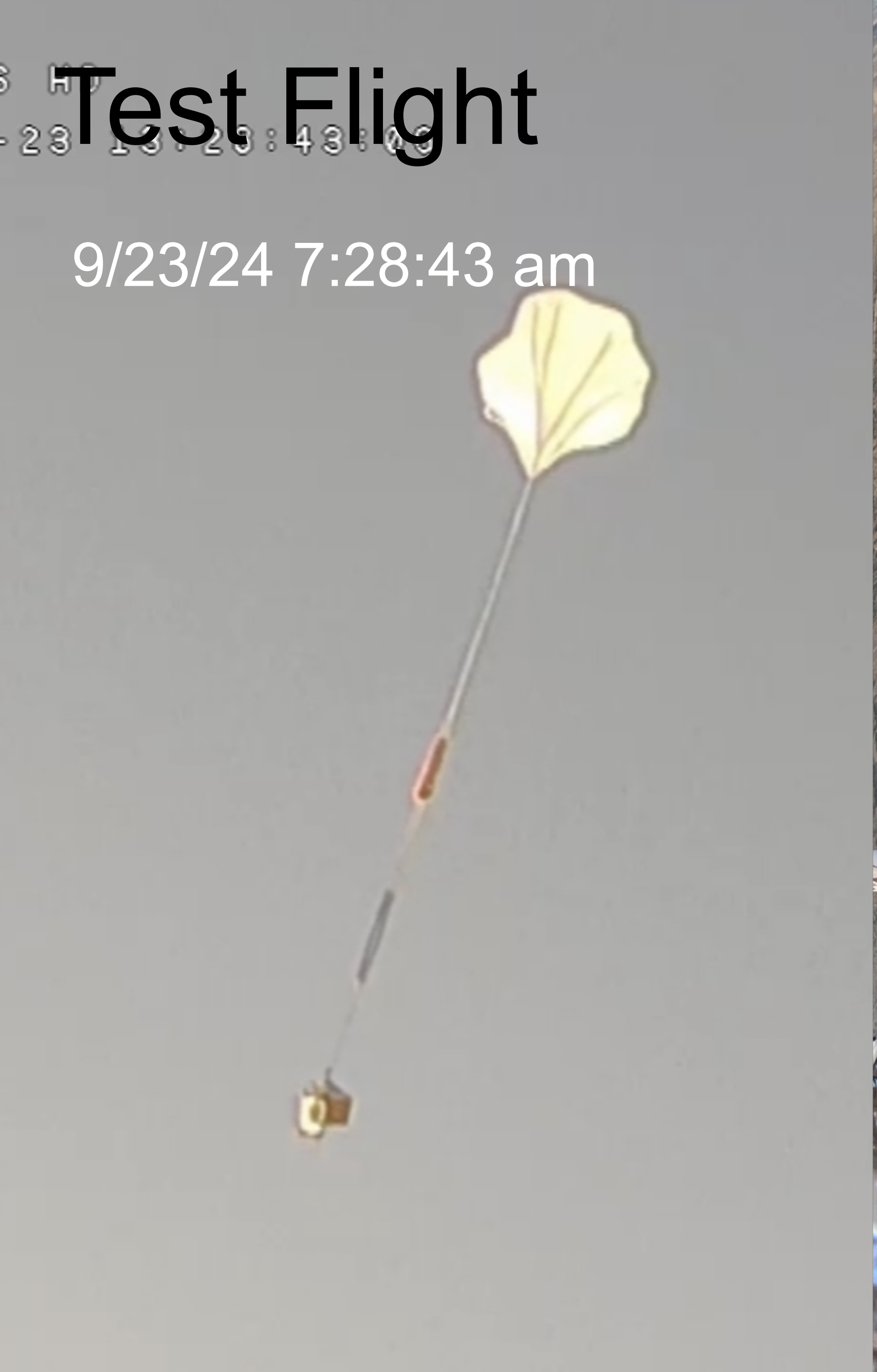
9/23/24 6:42 am

Test Flight

9/23/24 7:26:51 am

Test Flight

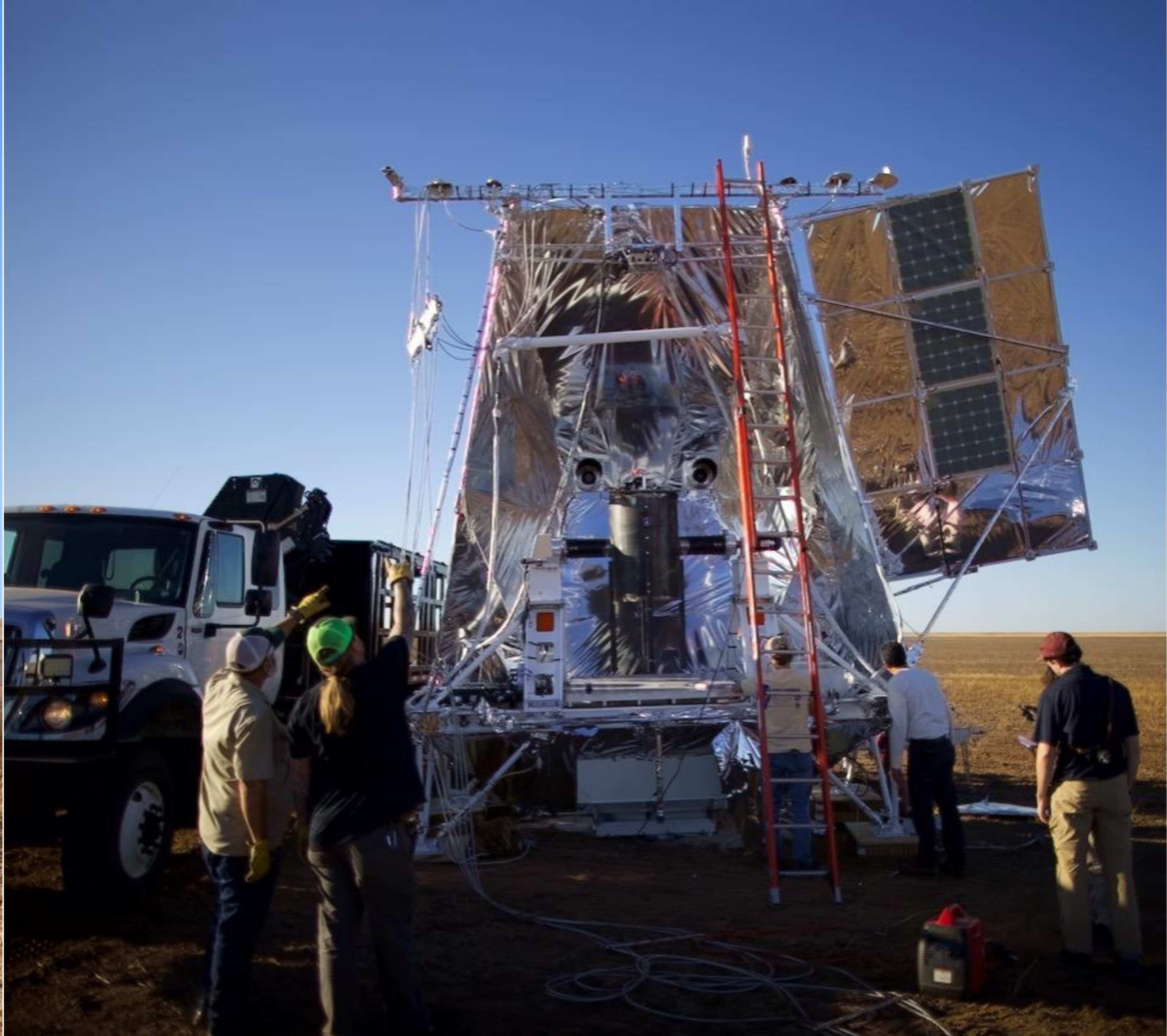
9/23/24 7:28:43 am



Test Flight

9/23/24 10:36 am
120kft altitude

Test Flight

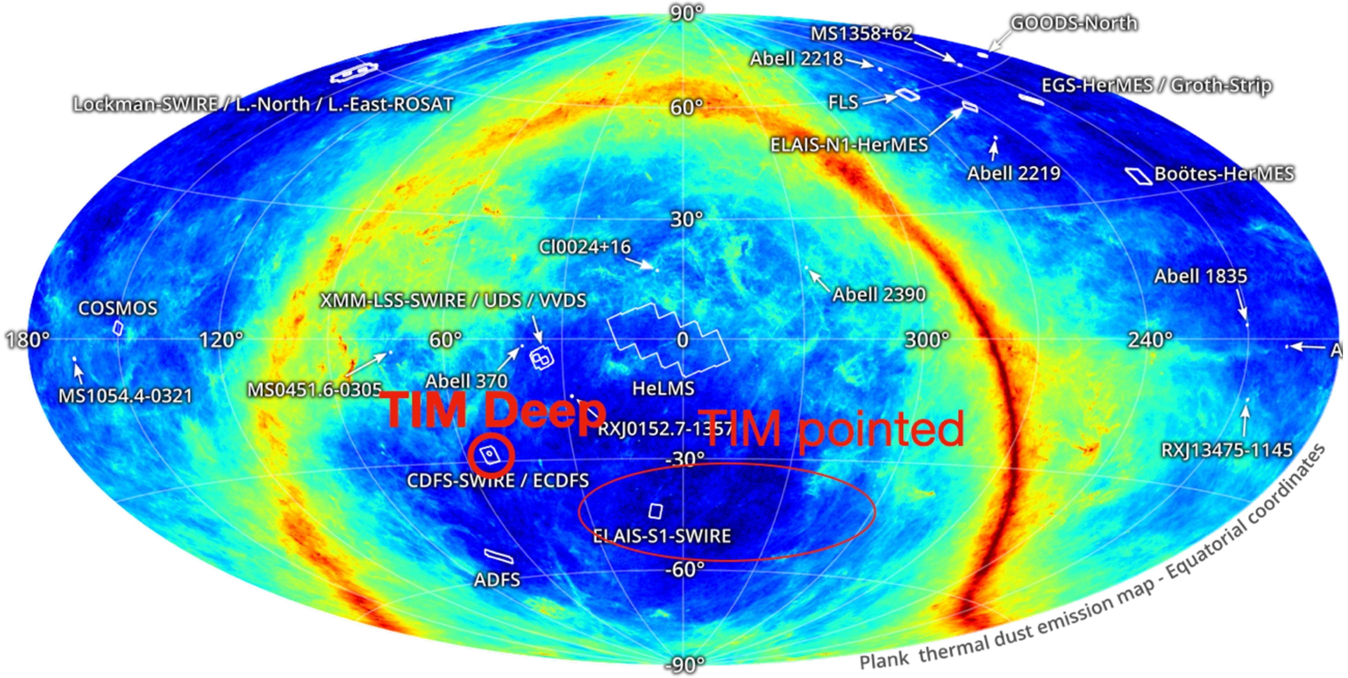


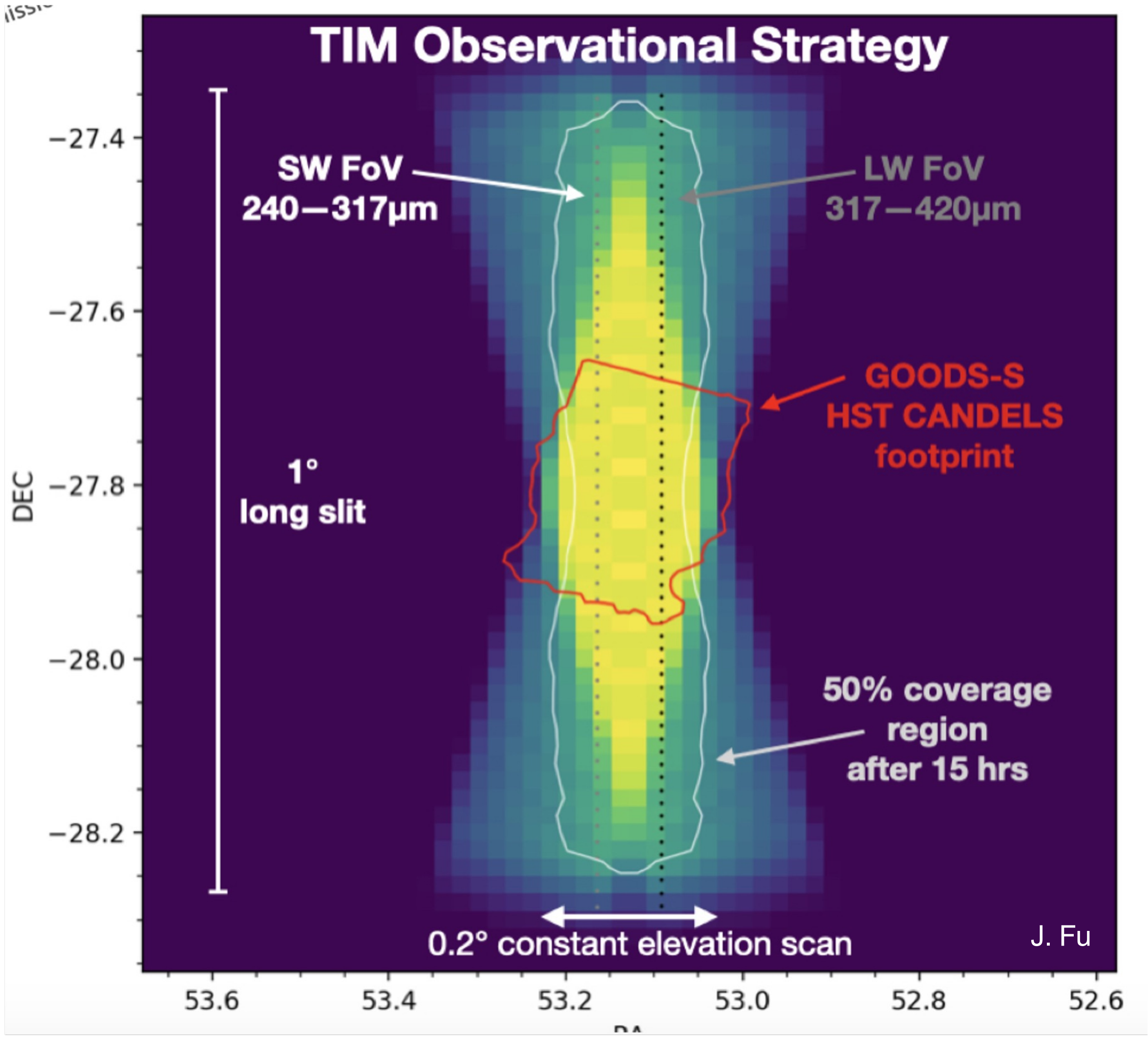
Mission Integration Lab
Tucson, Arizona

Up next: science flight from Antarctica in 2026/2027

NASA

TIM Observational Strategy

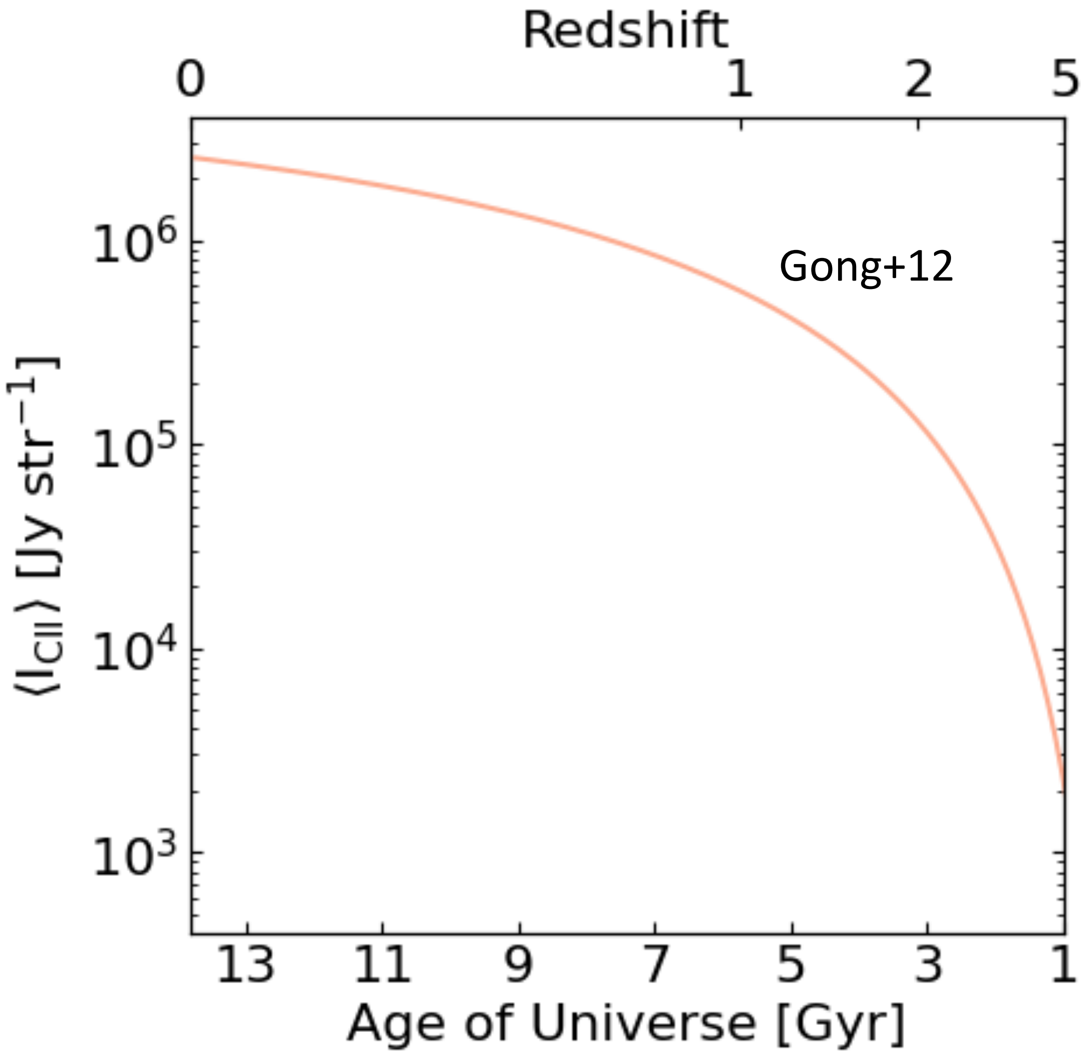




- **"Deep field" centered on GOODS-S**
  - Also coincides with Euclid's Fornax Deep Field
  - Few hundred square arcmin
- **Survey area also targeted by MeerKAT/LADUMA, and accessible to CO experiments like TIME-ext and SPT-SLIM**

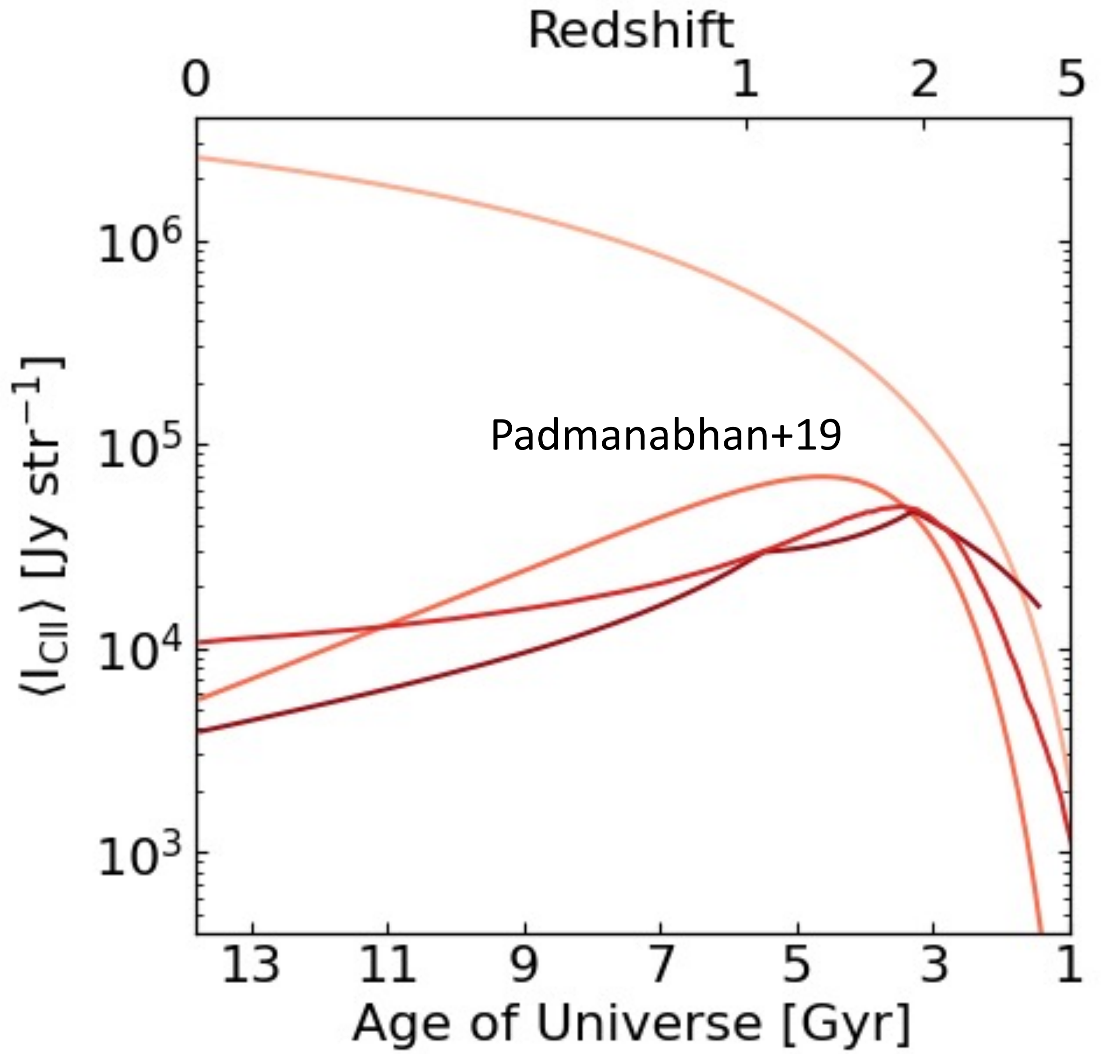
Science with TIM

A Broad Range of Models



Keenan et al. in prep

A Broad Range of Models



Keenan et al. in prep

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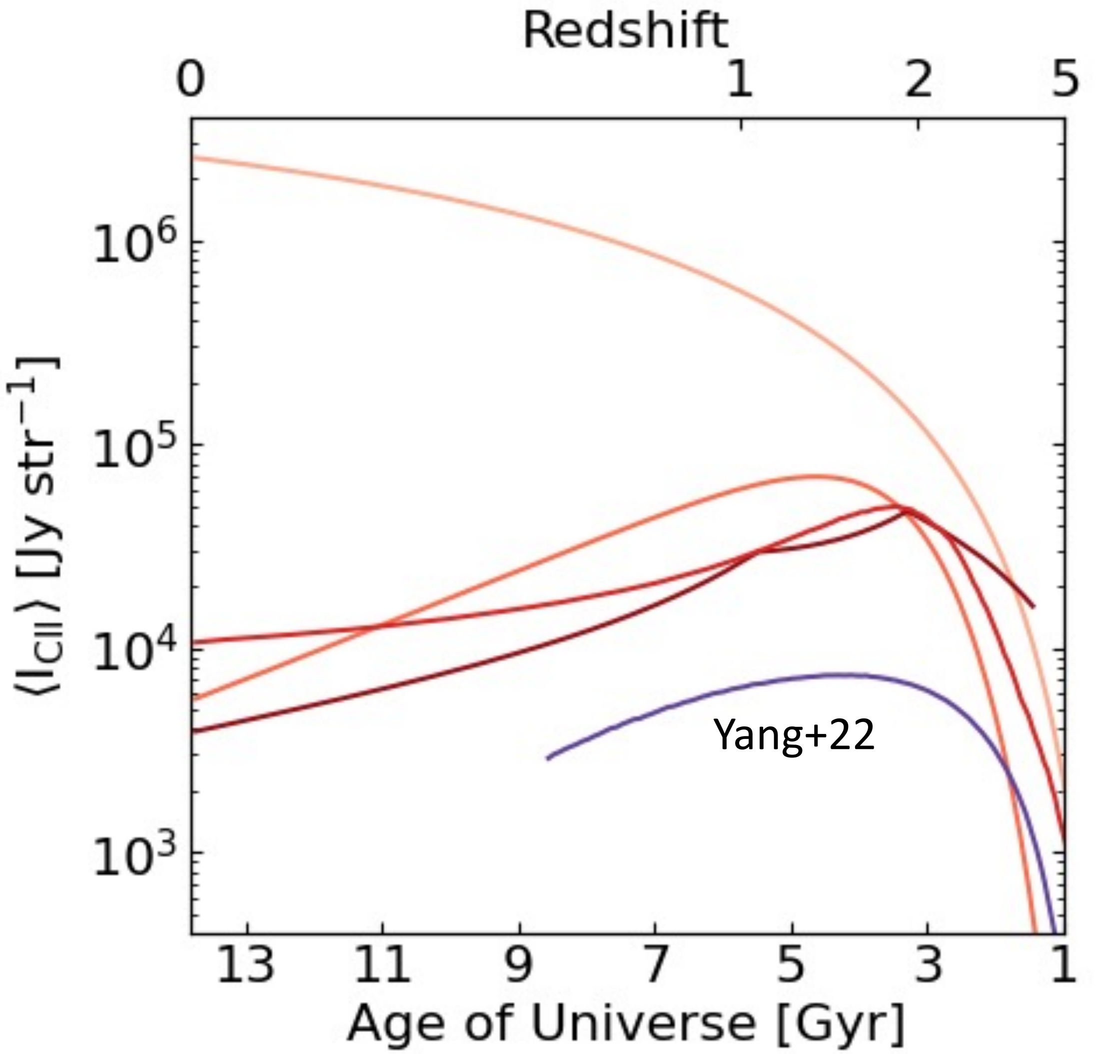

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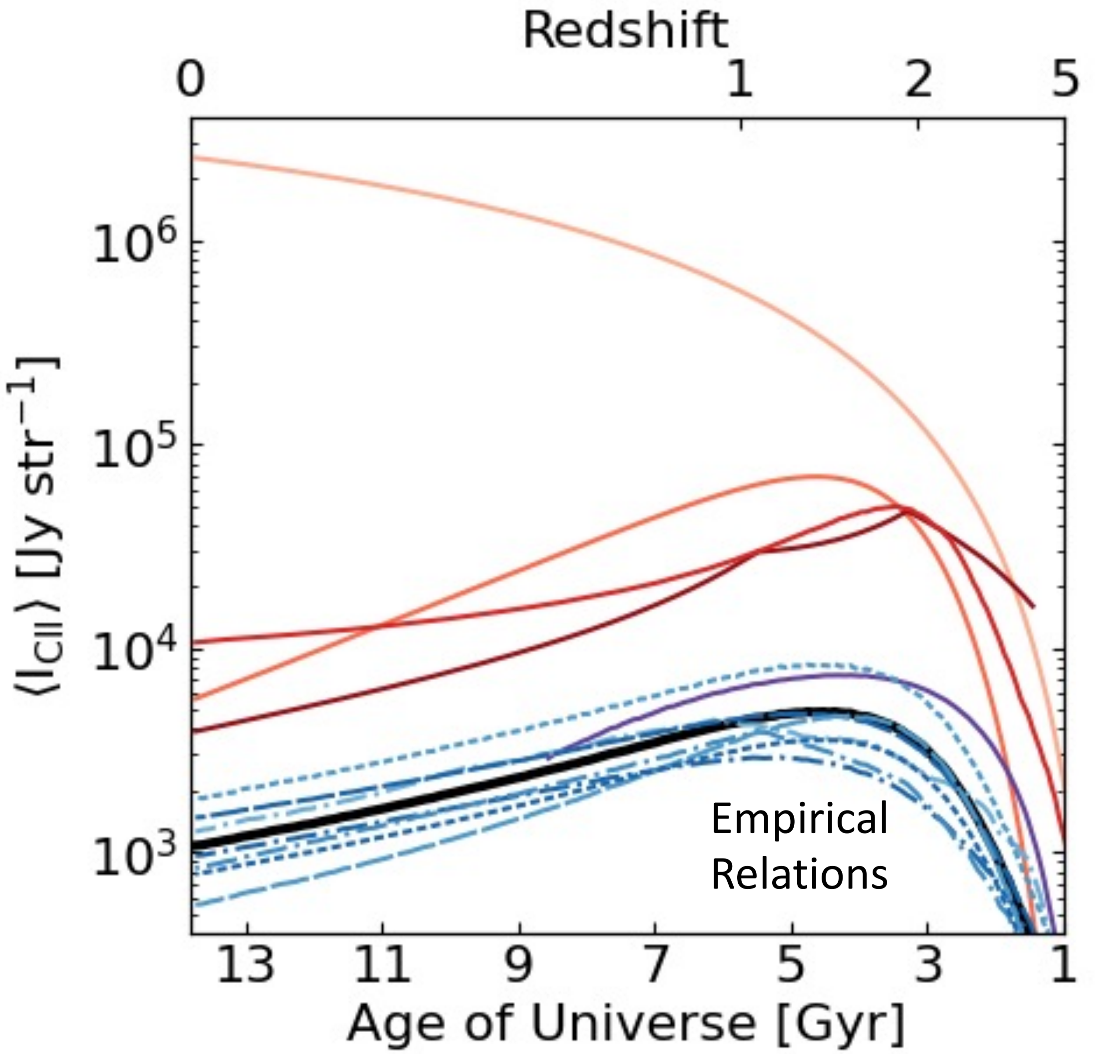

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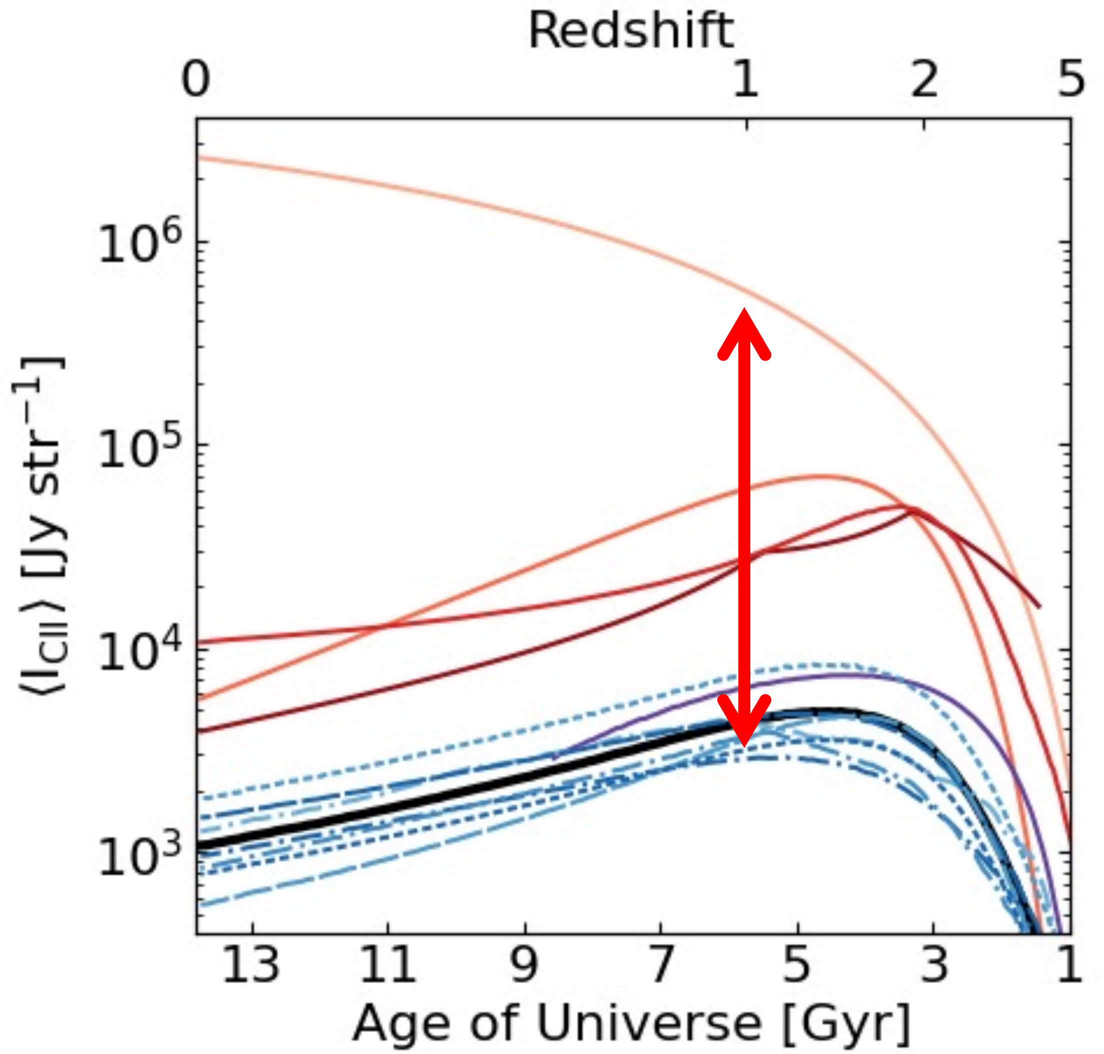

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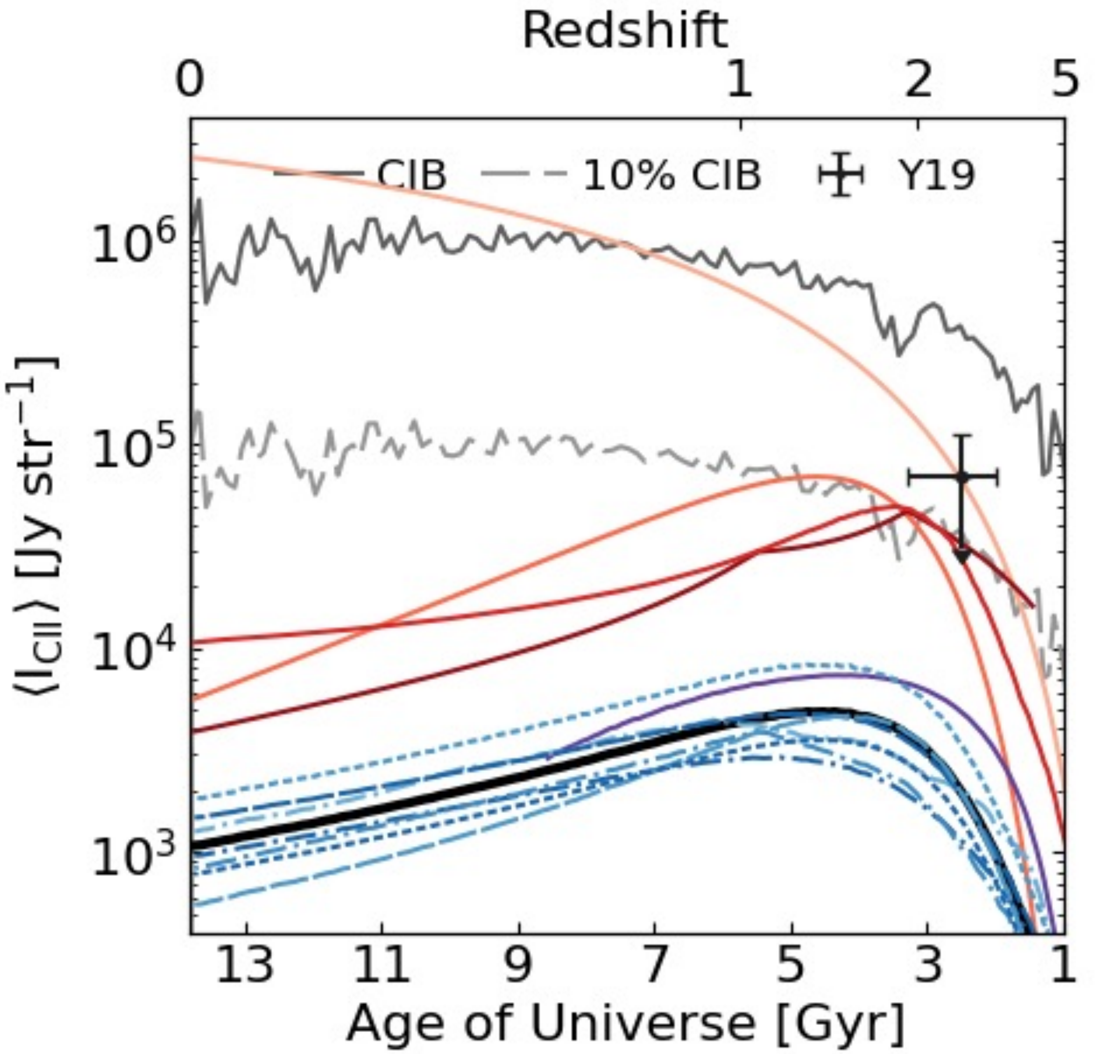

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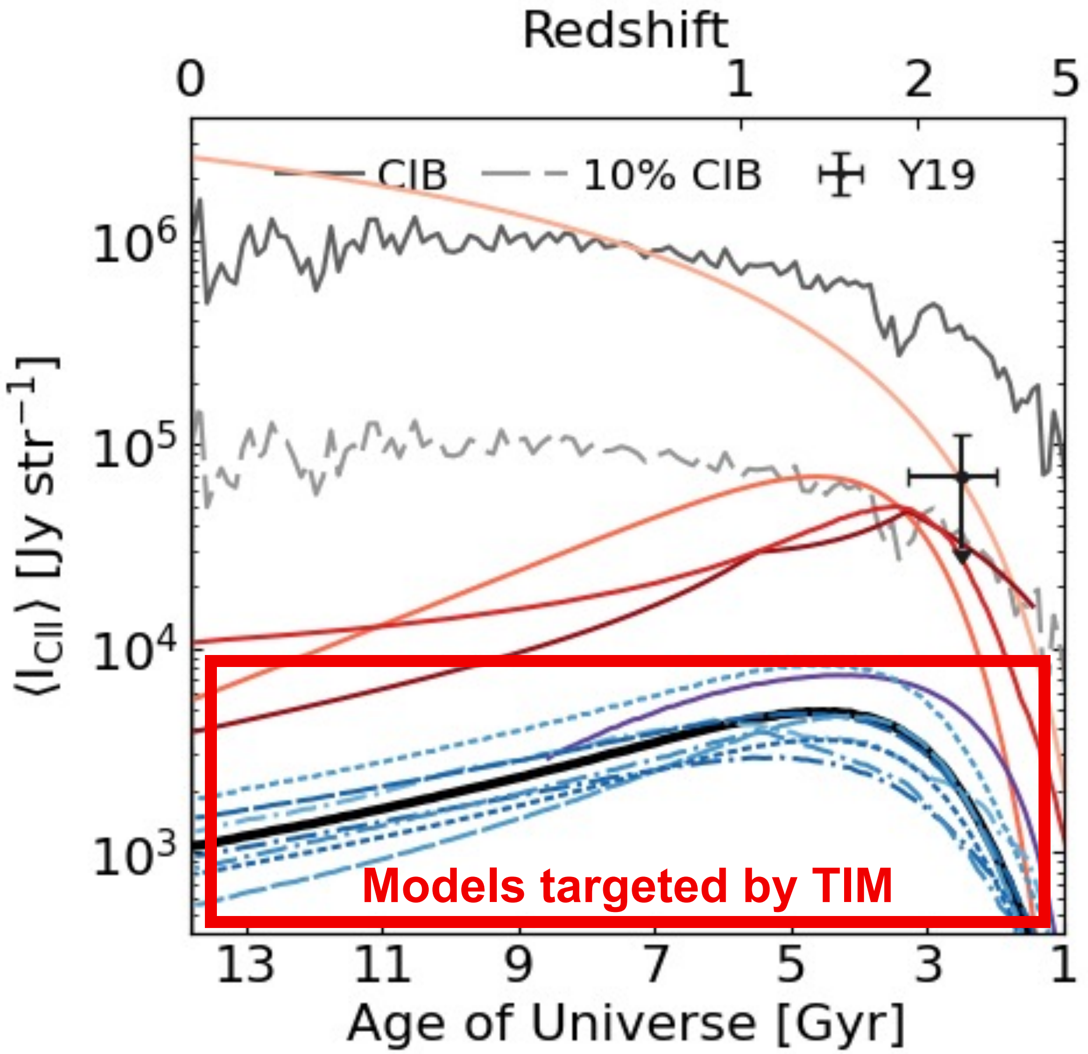
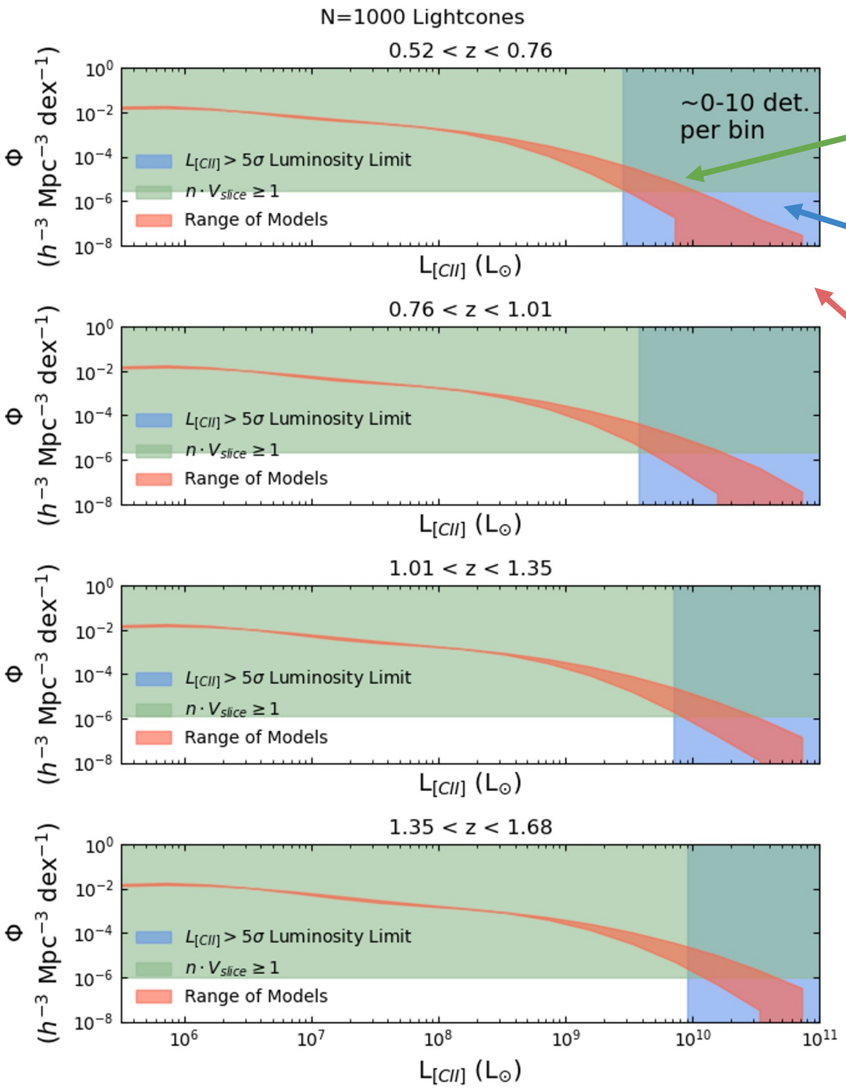


Keenan et al. in prep

Direct Detections



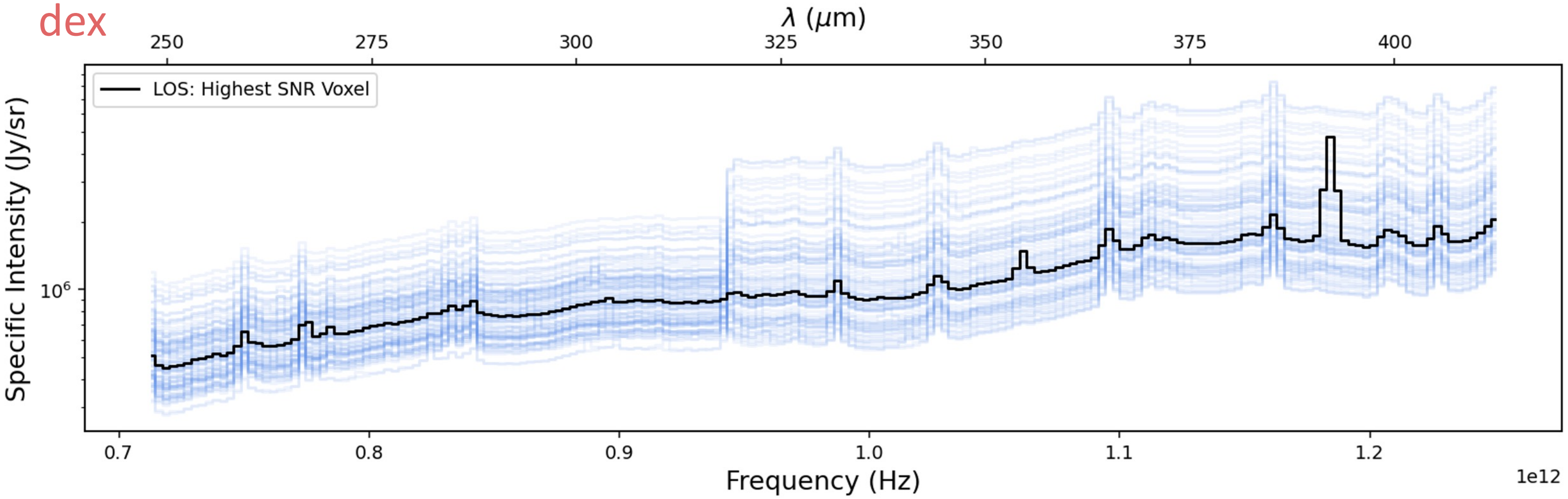
Green box:
Volume needed for >= 1 source

Blue box:
Sources bright enough for TIM

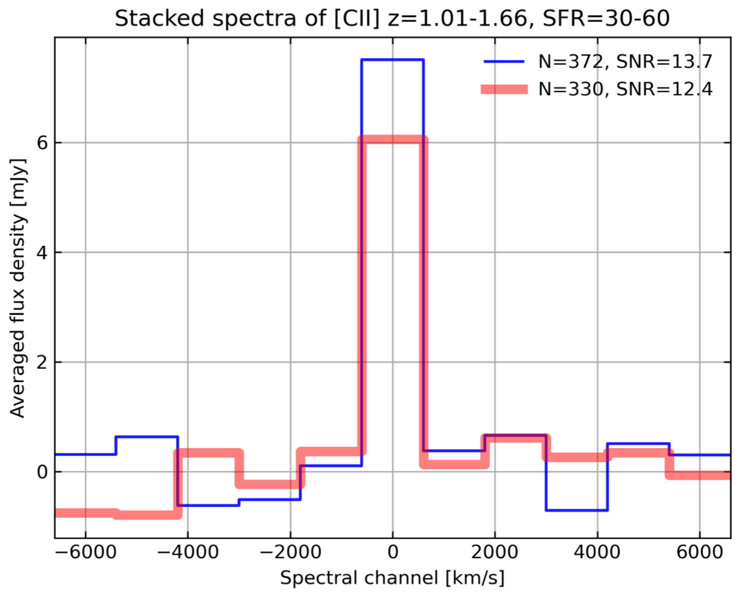
Red band:
Monte Carlo LFs ranging SFR-L[CII] scatter 0.4-0.6 dex

Evan Mayer

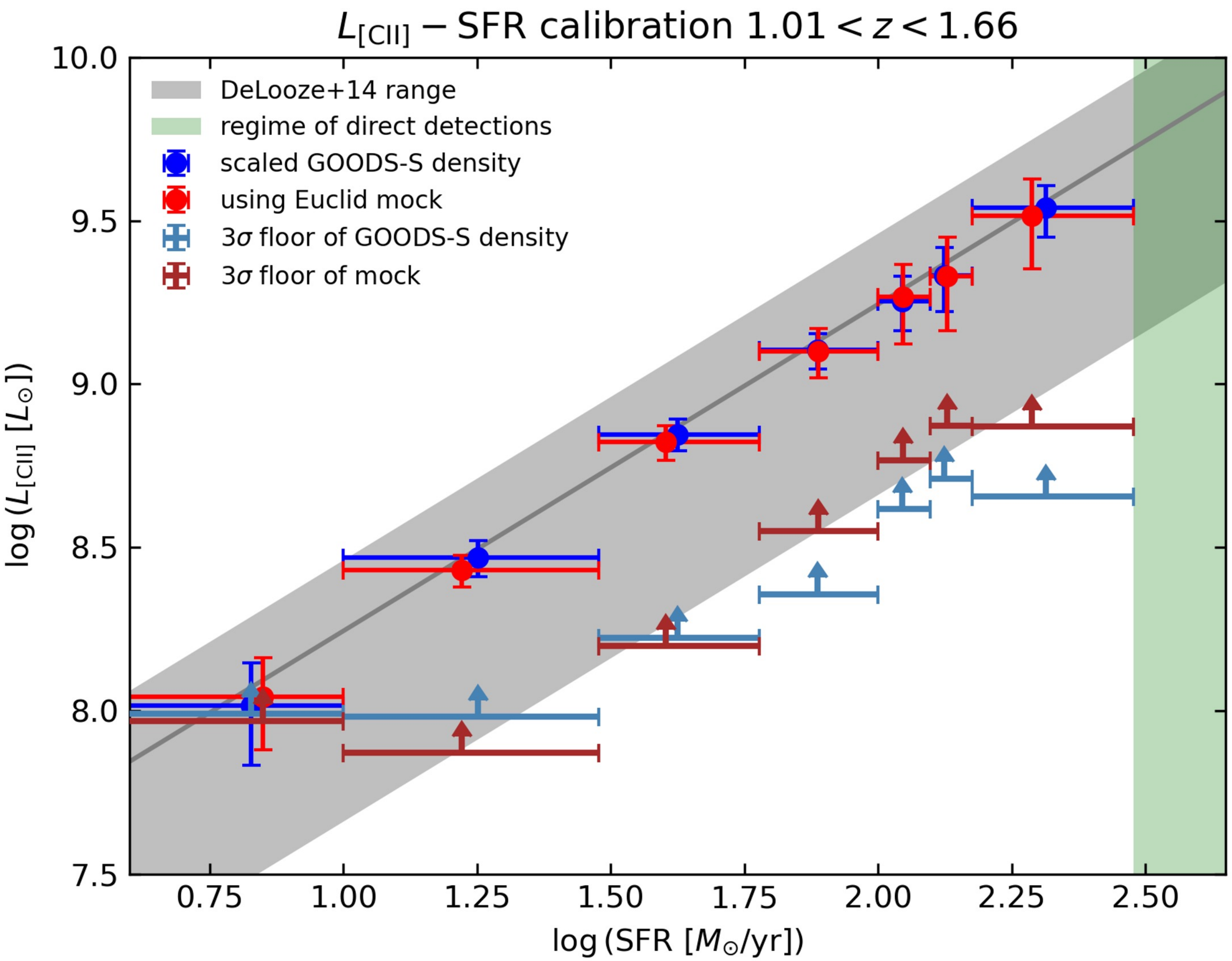
~0-10 detections expected across full TIM band

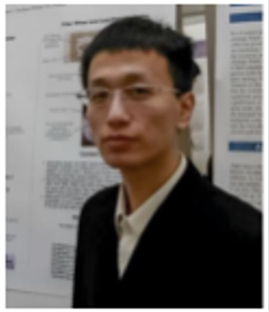


[CII]-SFR Calibration



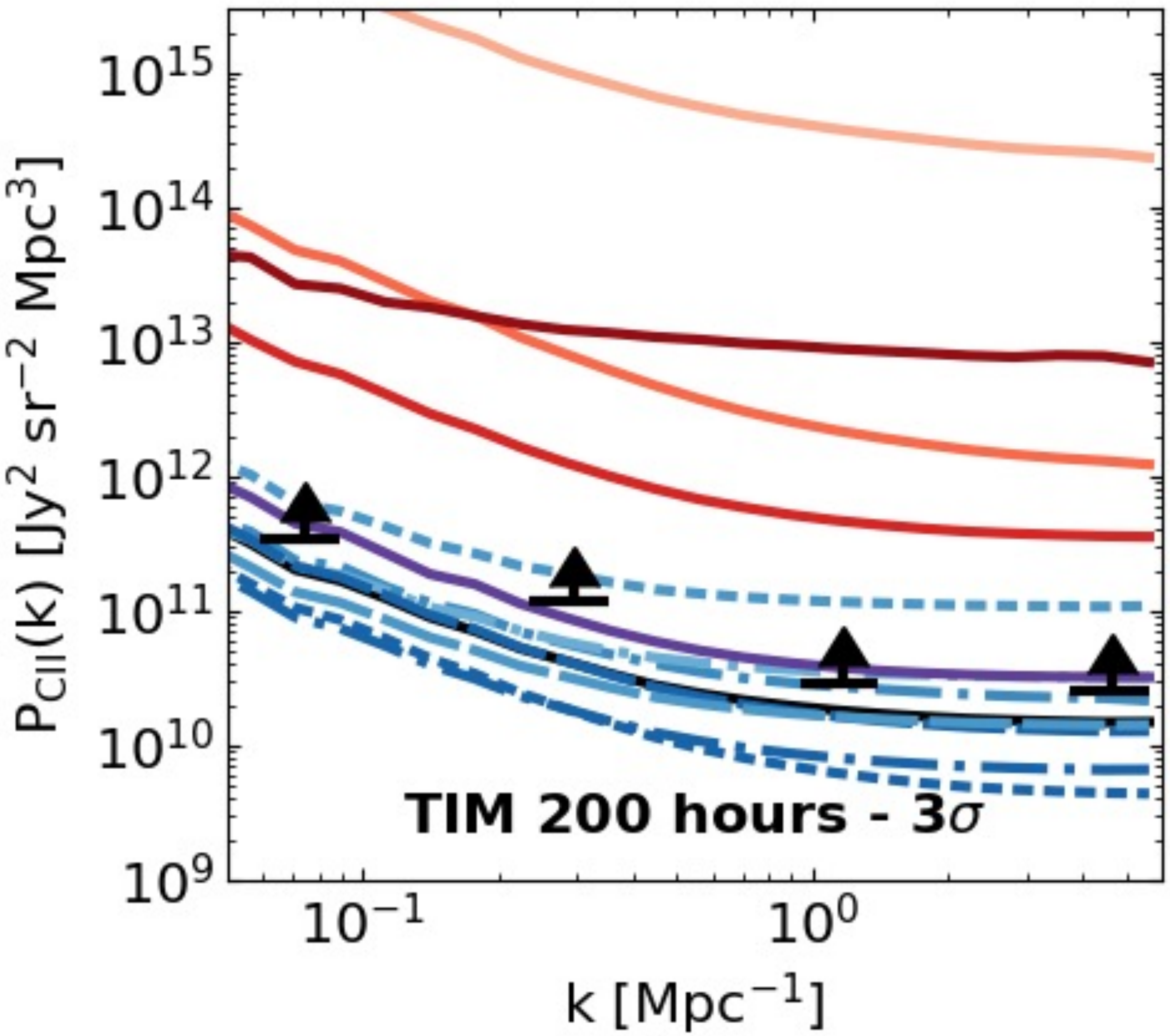
Preliminary





Lunjun (Simon) Liu

The [CII] Power Spectrum



Keenan et al. in prep

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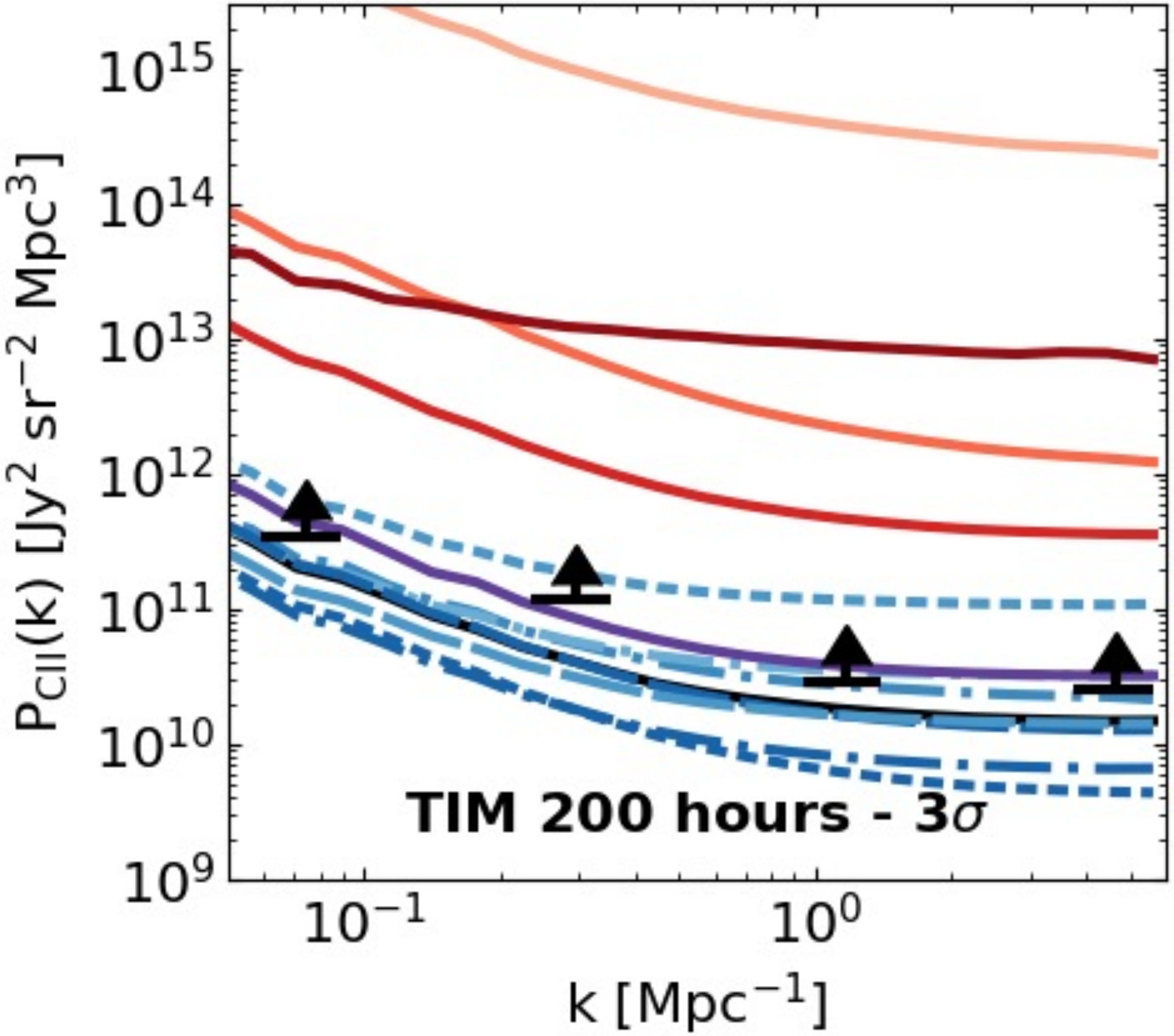
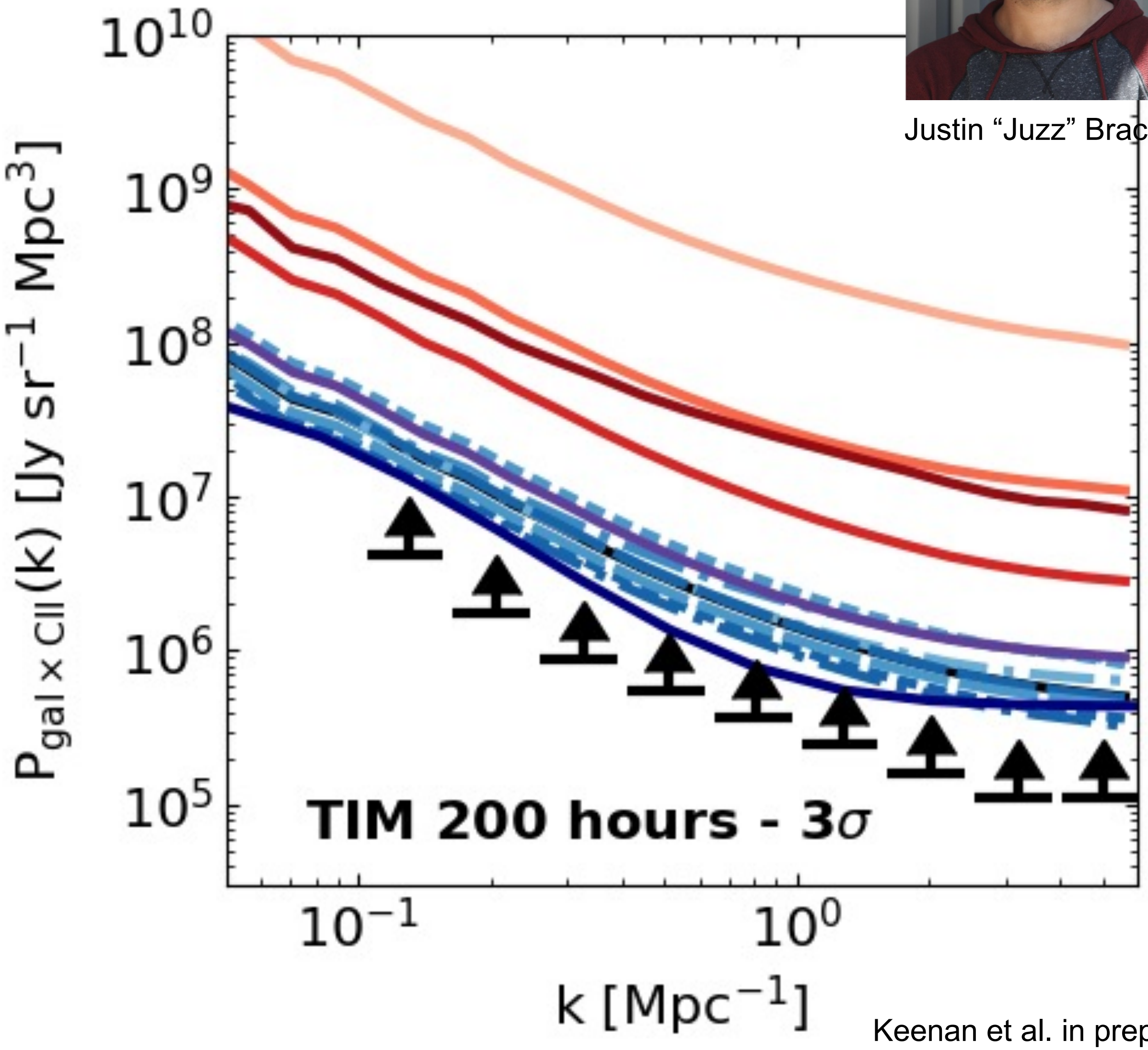
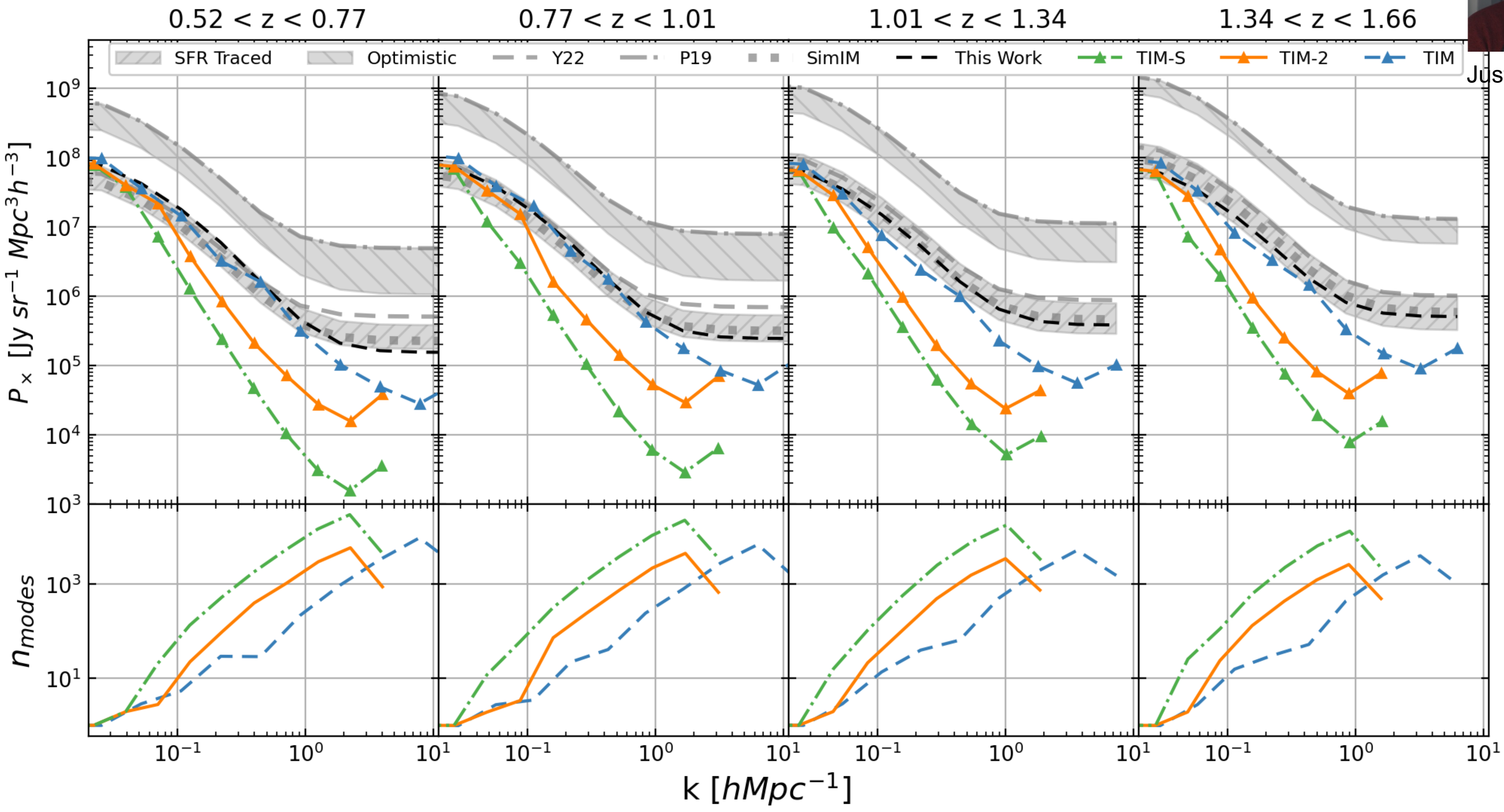




Justin “Juzz” Bracks

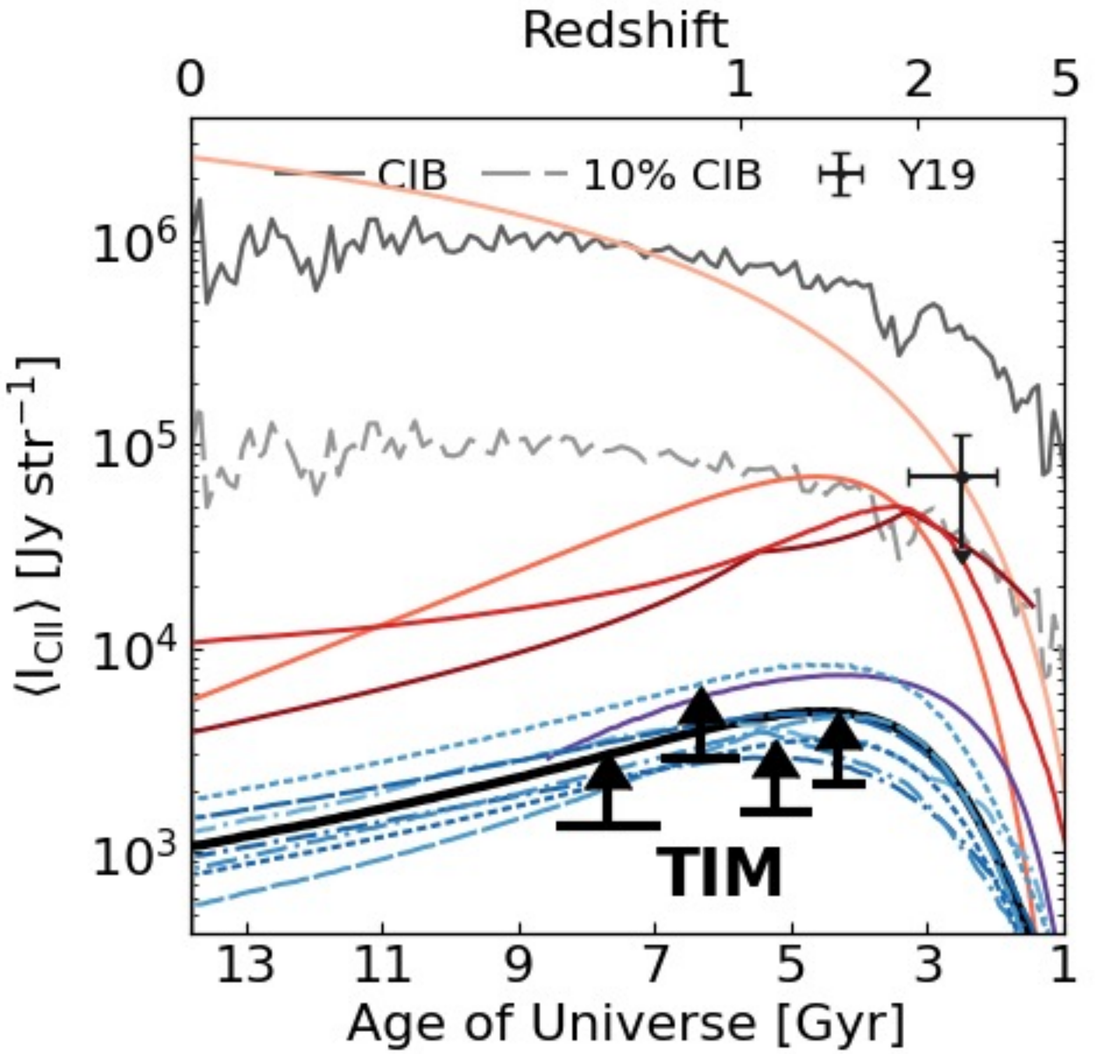
Keenan et al. in prep
Bracks et al. in prep

The [CII] Power Spectrum



Justin "Juzz" Bracks

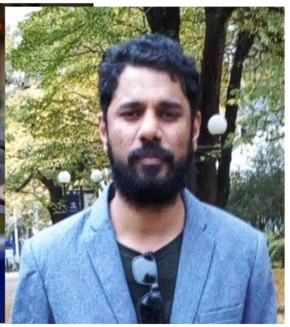
The [CII] Power Spectrum



Keenan et al. in prep
Bracks et al. in prep

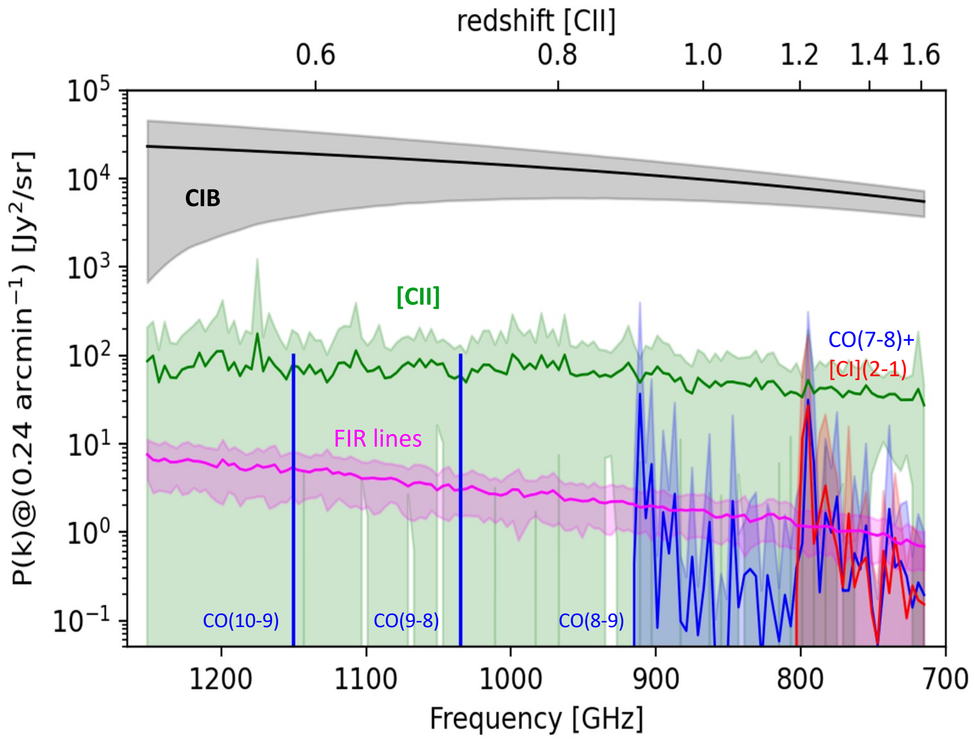
Foreground Separation

Mathilde Van Cuyck in TIM's cryostat



Srini Raghunathan

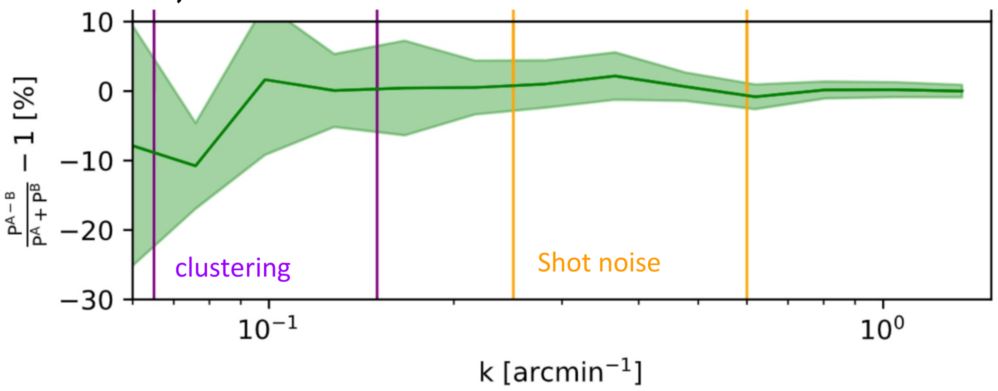
- In TIM regime ($0.5<z<1.7$, $240\mu m<\lambda<420\mu m$), [CII] dominates the interlopers outside of z~0 bright sources, easy to mask out.
- The main challenge will be CIB.



SIDES forecast from 100 TIM-like fields of (1 x 0.2)-deg^2

Methods investigated:

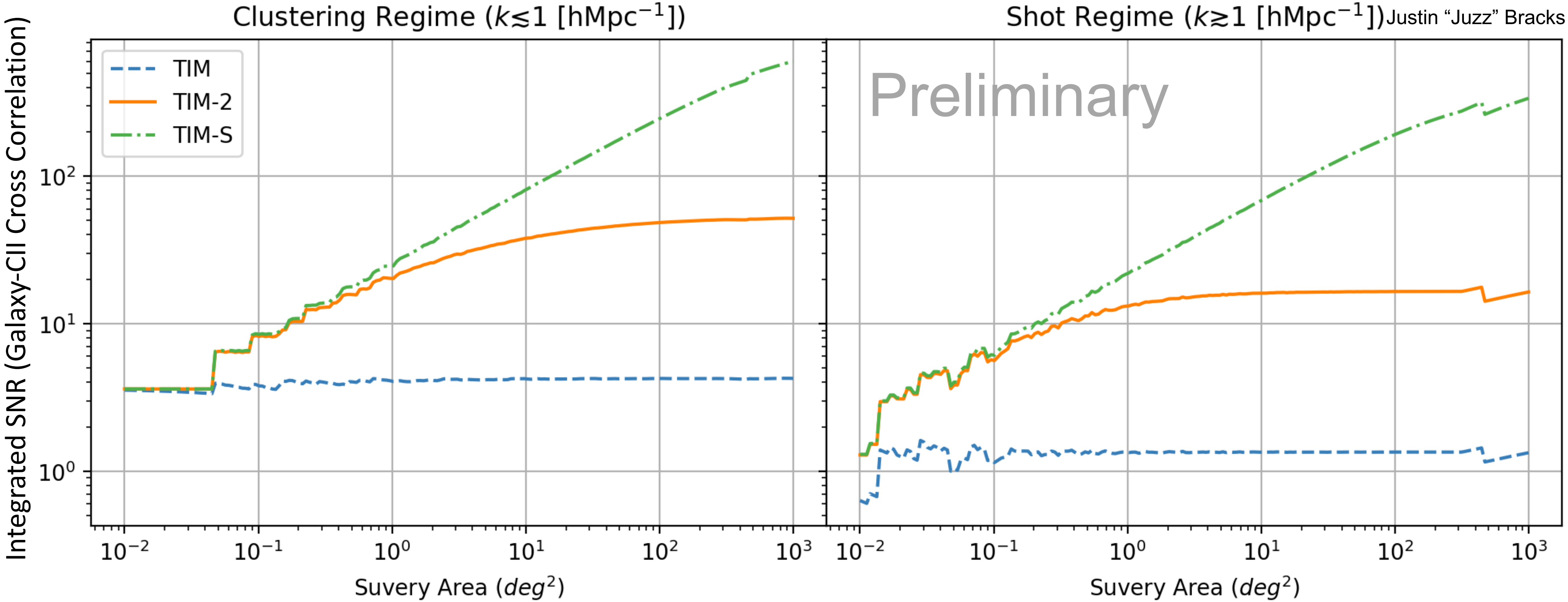
- Frequency difference technic (Van Cuyck, Srini Raghunathan in prep.)
  - Preliminary: efficient for shot noise, >10% lost in clustering with ±10% uncertainties
- Foreground wedge in Terahertz regime
- PCA, PCA in time domain.



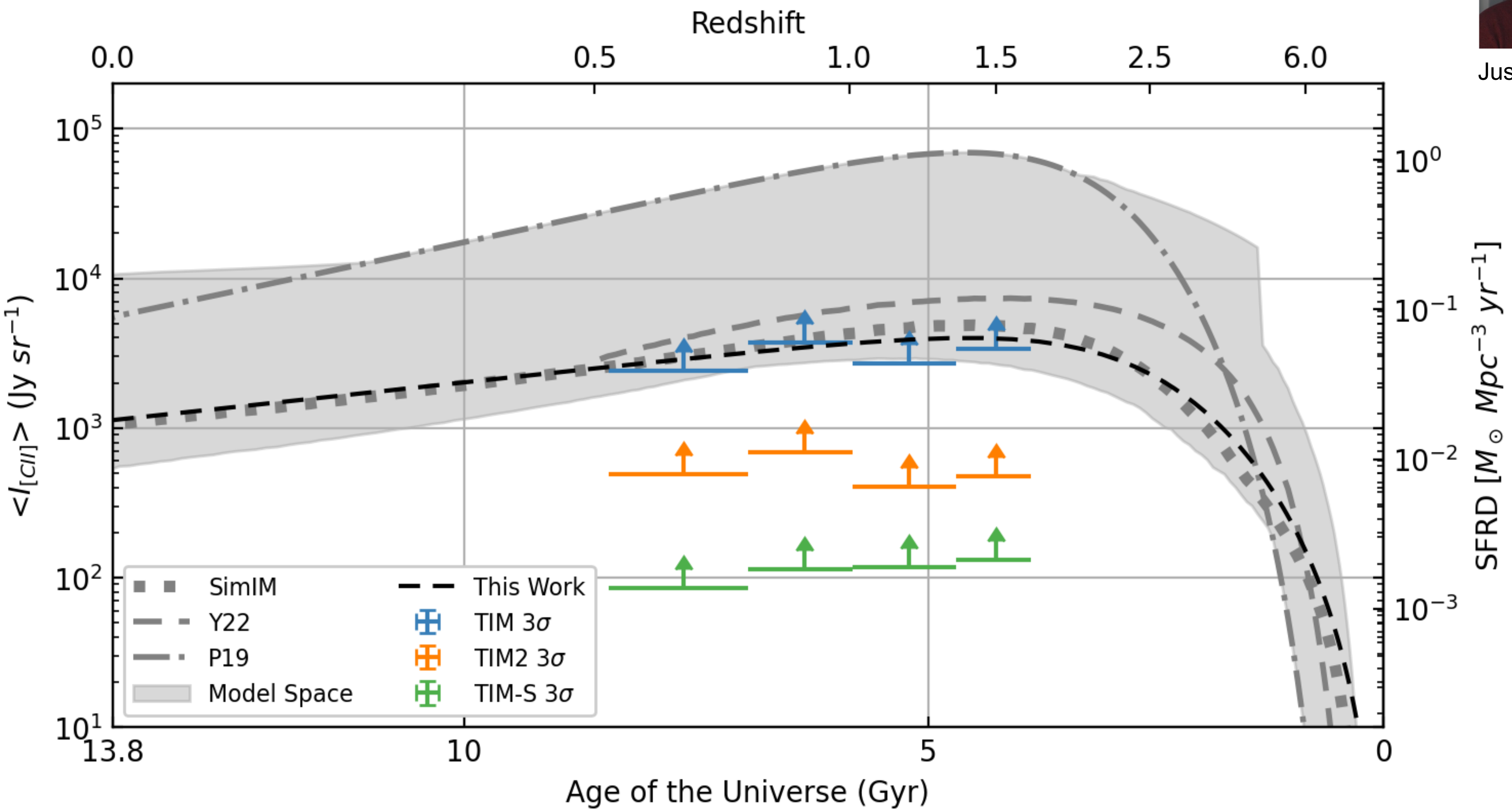
freq. diff tech. for [CII]@z=1.0, from 12 SIDES fields of 9-deg^2

The Glorious Future


Justin “Juzz” Bracks

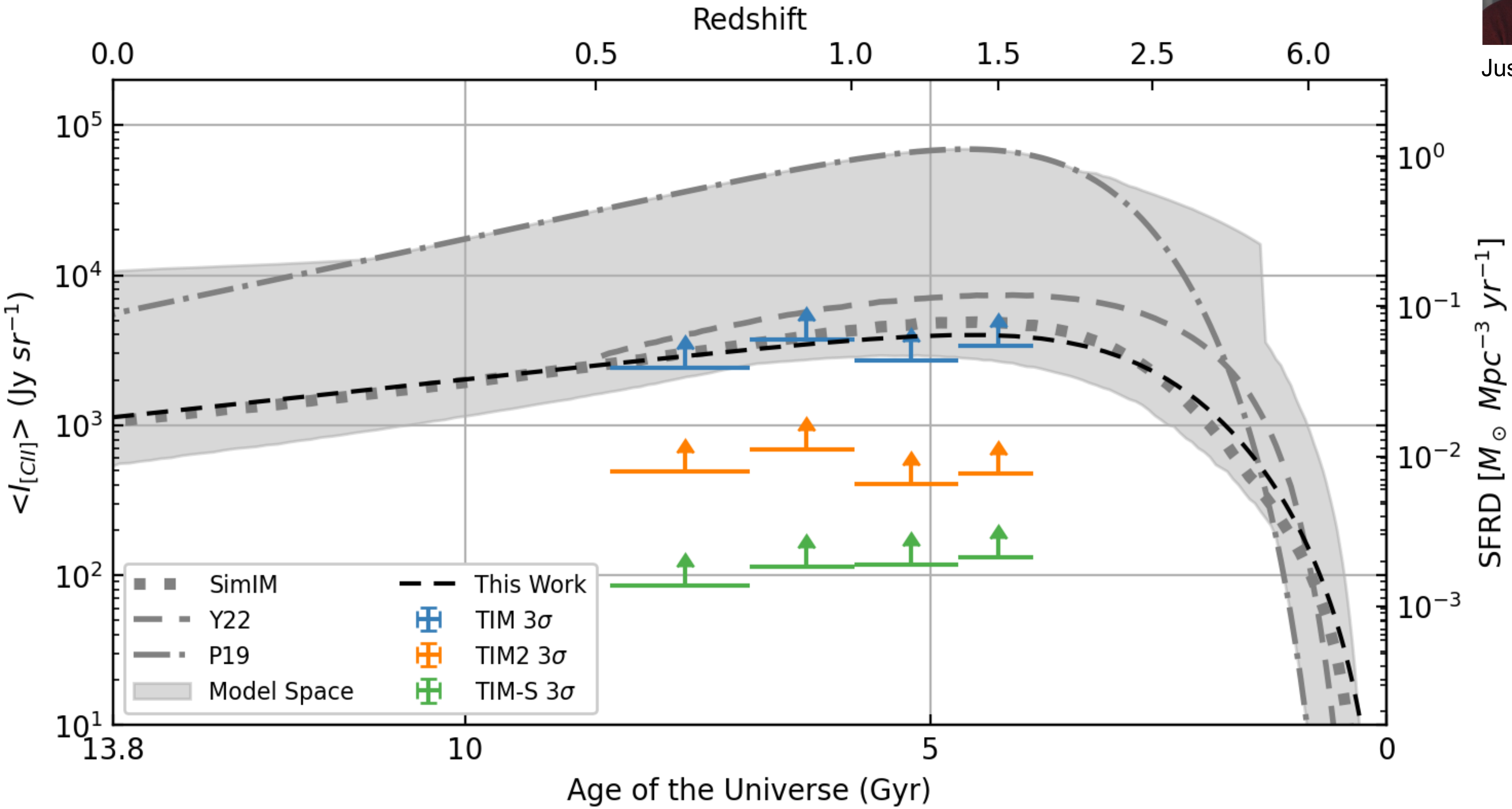


The Glorious Future



Justin “Juzz” Bracks

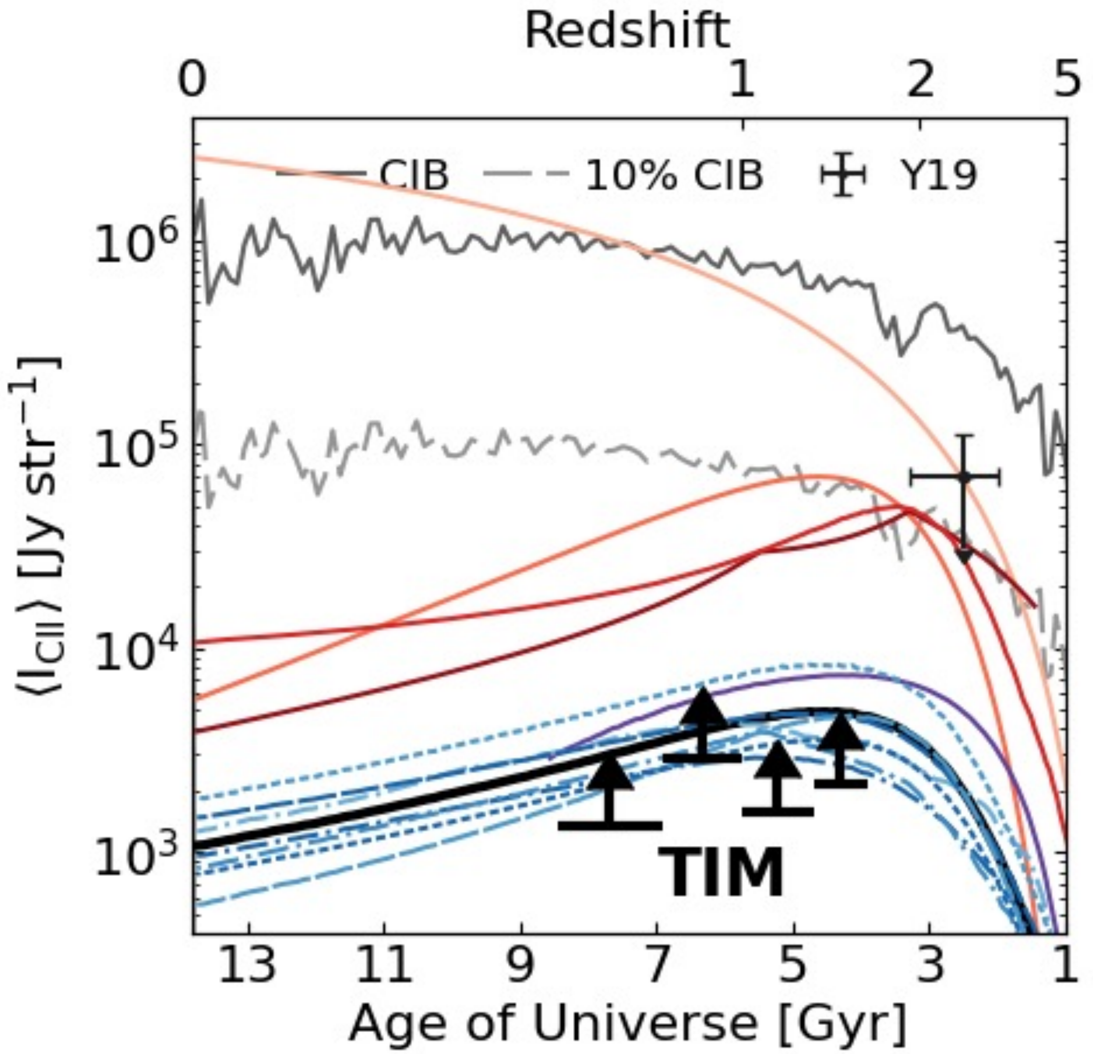
The Glorious Future



Take Home Message

TIM will

- detect the [CII]-Galaxy cross-spectrum at z~1, with further opportunities for cross-correlation tracers like CO and HI
- provide a bridge to EoR [CII] experiments in an easier redshift regime
- demonstrate key technologies for future LIM experiments.



Backup Slides