CNRS-JSPS-JST Celebration Event for the
50th Anniversary of France-Japan Scientific Cooperation
From Particle Physics to Cosmology
Wednesday October 9, 2024, Miraikan, Tokyo

DESHIMA TIFUUN

http://aste.nao.ac.jp/index_e.html

Submm-telescope
ASTE (10m)

Astrophysics Programs

KOHNO, Kotaro 河野孝太郎
Institute of Astronomy, School of Science, University of Tokyo

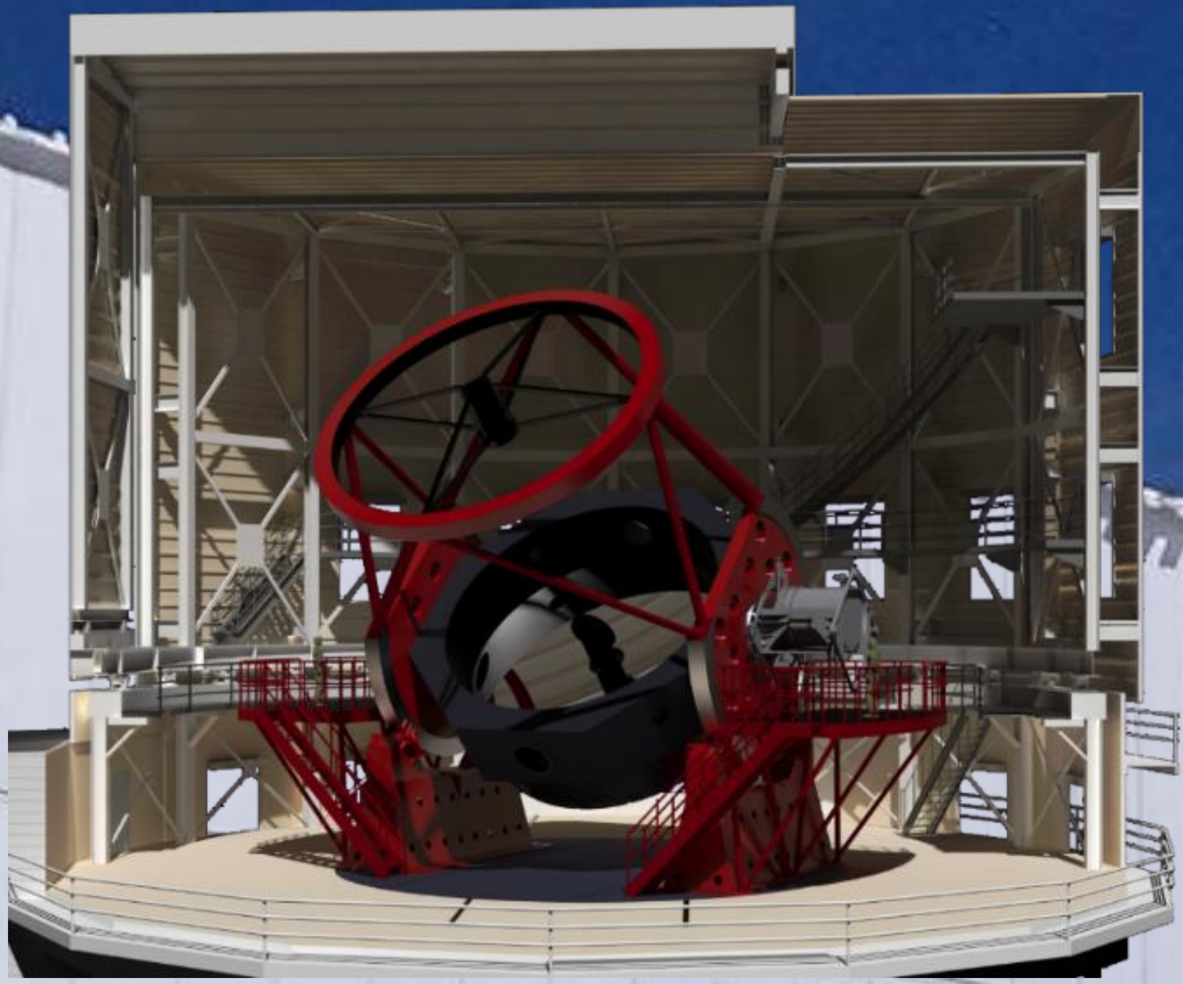
UTokyo ILANCE International Laboratory for Astrophysics, Neutrino and Cosmology Experiments

Photo by KK from the TAO site at Co. Chajnantor, November 20th, 2017

The University of Tokyo Atacama Observatory (TAO) project

The TAO Telescope Site Completion Ceremony:
April 30, 2024

6.5-m optical-IR
telescope
at 5,640m



TAO representative: Dr. YOSHII Yuzuru
Institute of Astronomy, School of Science, the University of Tokyo

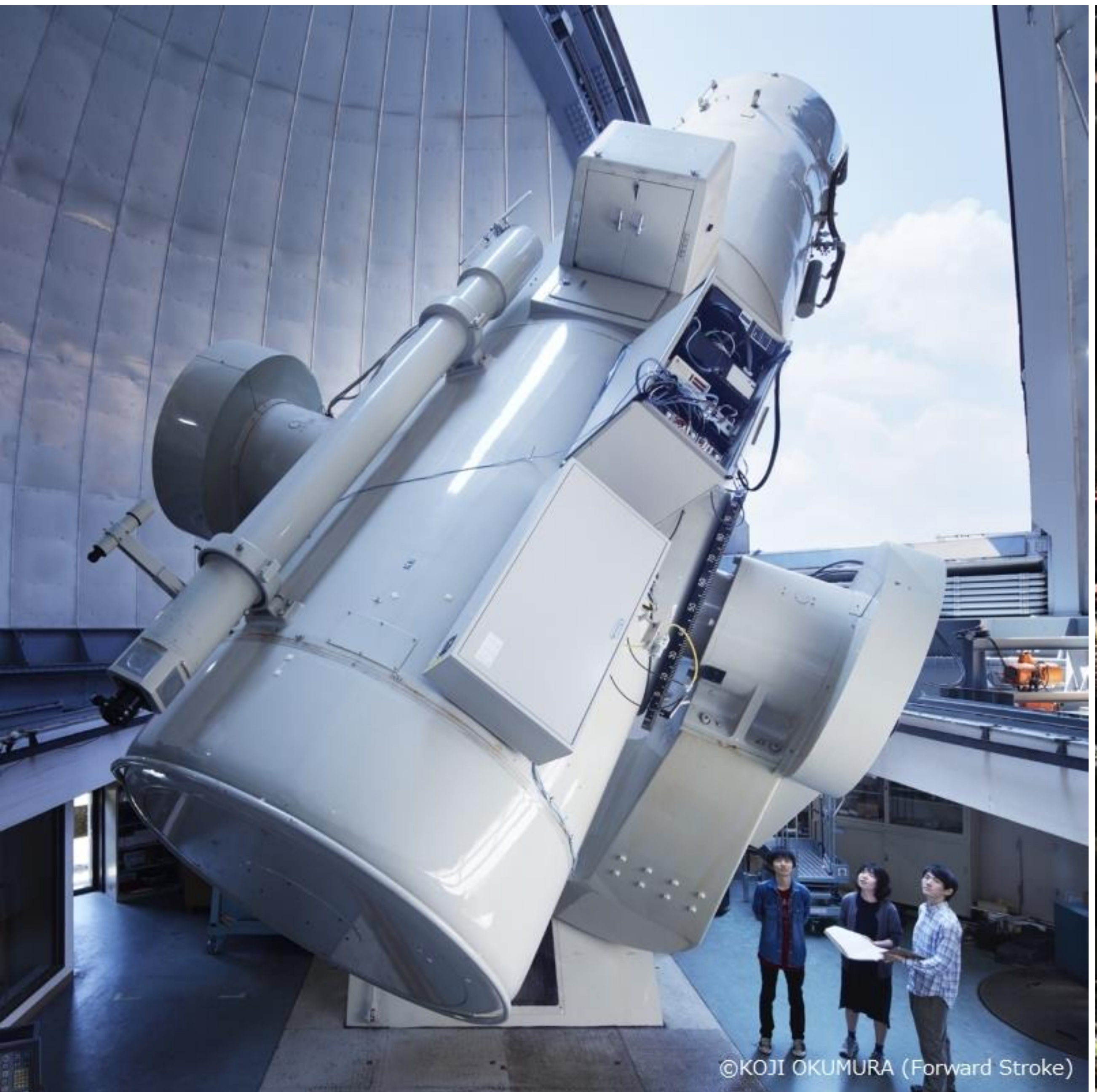
Collaboration with Department of Astronomy U. Tokyo, NAOJ, JAXA,
other Japanese universities

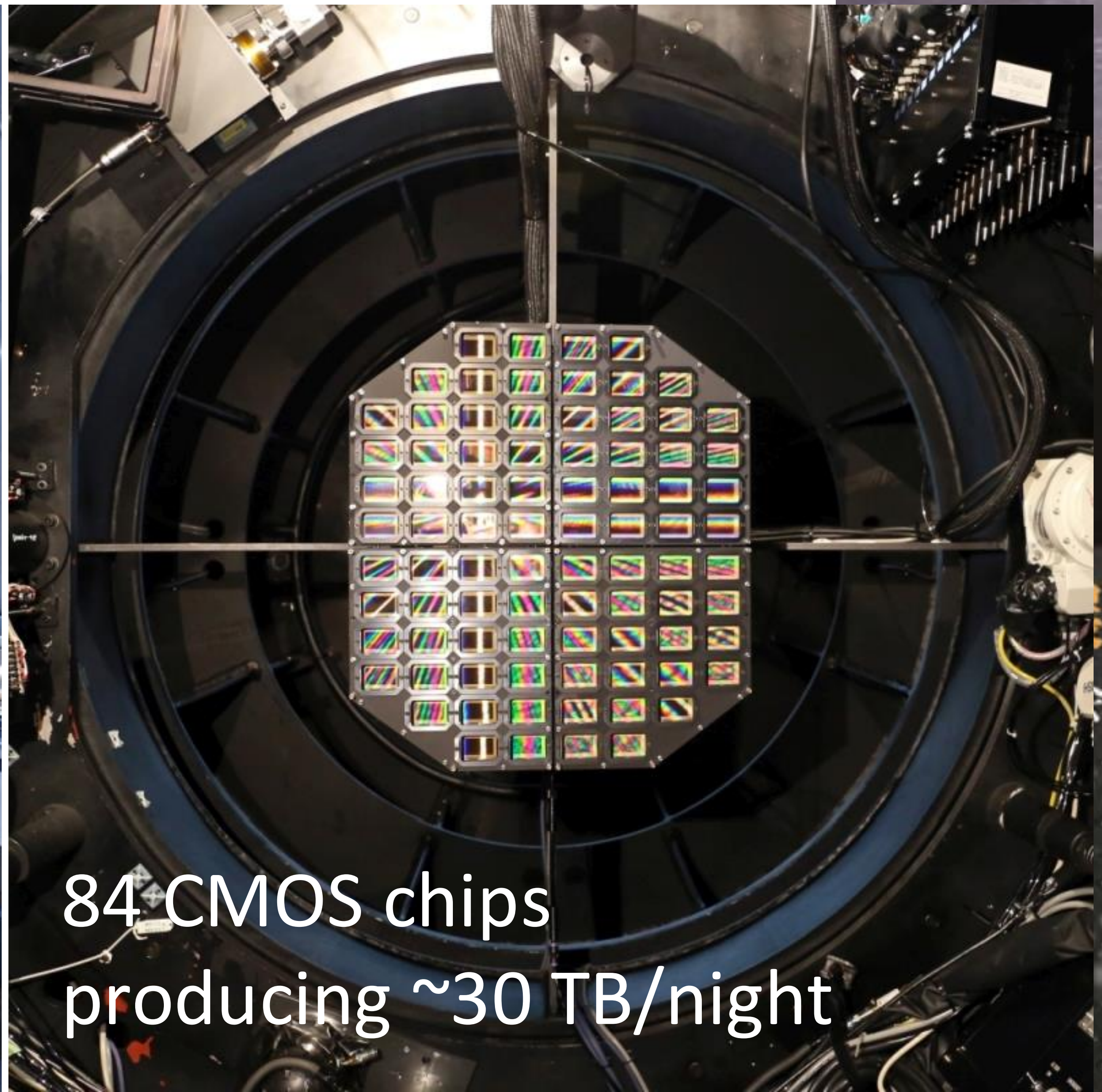
Chilean Government (Ministry of Science, Technology &Innovation, Foreign Affairs),
ANID, RegionII, San Pedro de Atacama city, .. and universities in Chile, including
Univ. of Chile, Pontifical Catholic Univ. of Chile, Catholic Univ. of the North, Univ. of Antofagasta, ..

CCAT-p, ALMA

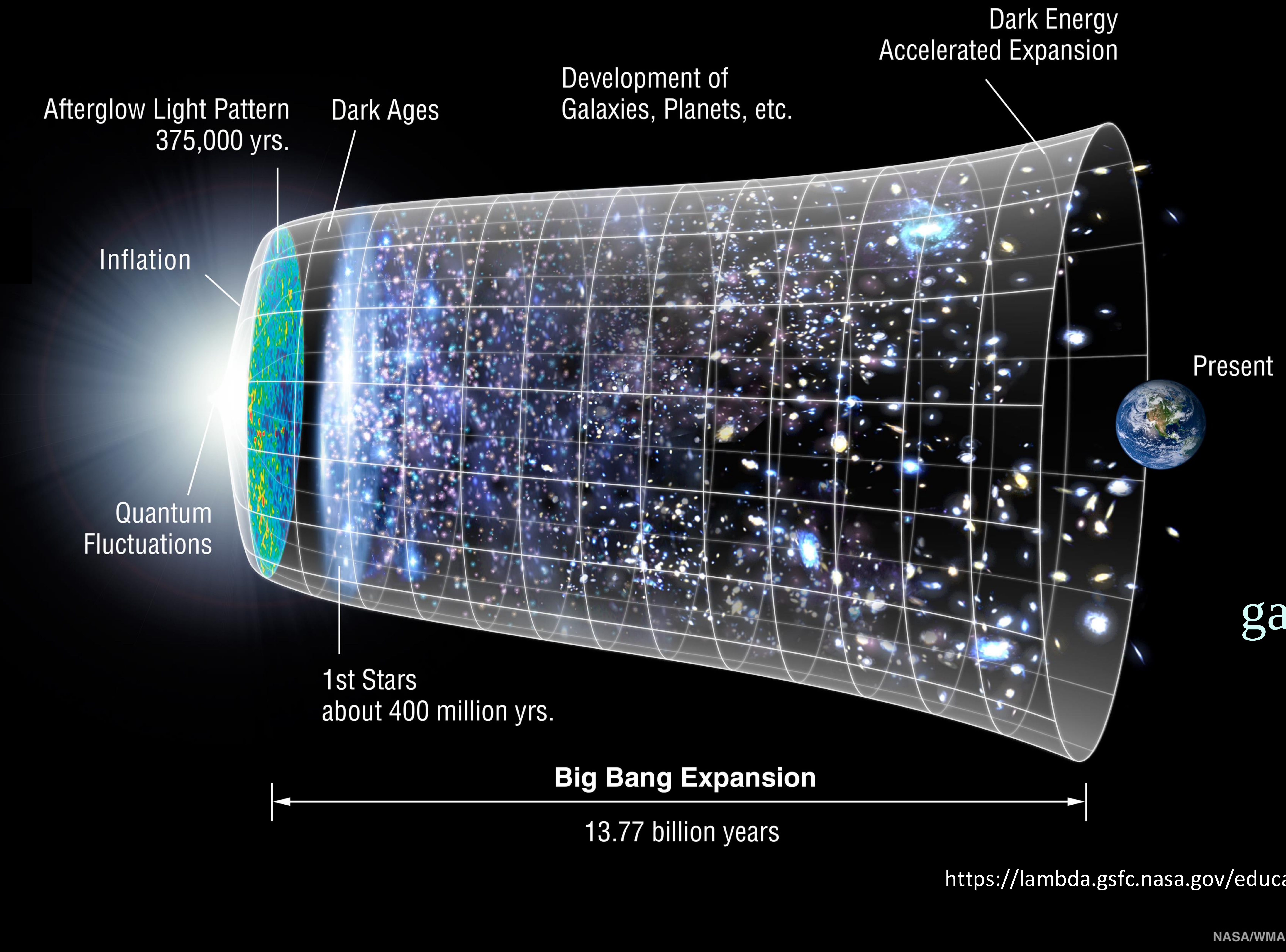
KISO Observatory 50th anniversary

- Focusing on time-domain astronomy using Tomo-e Gozen, CMOS array system, on the 1.05 m Kiso Schmidt Telescope.
- 20 deg^2, at the max. rate of 2 frames per sec
- Solar body objects, early-phase supernovae, optical counterparts of fast radio bursts, gravitational wave sources, neutrino sources, and unknowns.





Key questions in the Universe

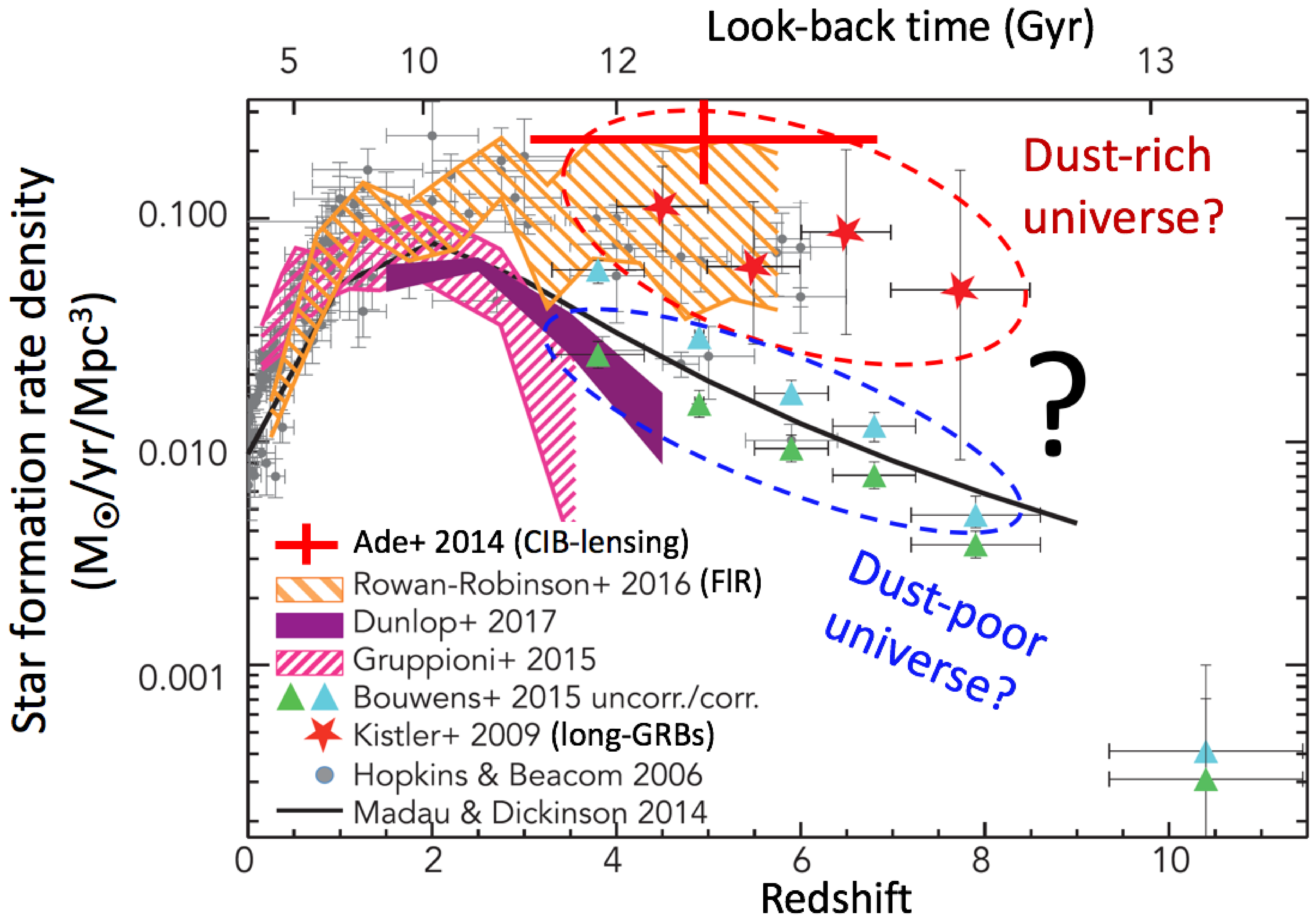


How did atoms for planets and life form in our Universe?

How did the first galaxies and stars form and evolve across cosmic time?

https://lambda.gsfc.nasa.gov/education/graphic_history/univ_evol.html

What is the cosmic history of dust-obscured star formation in the first 2 billion years?

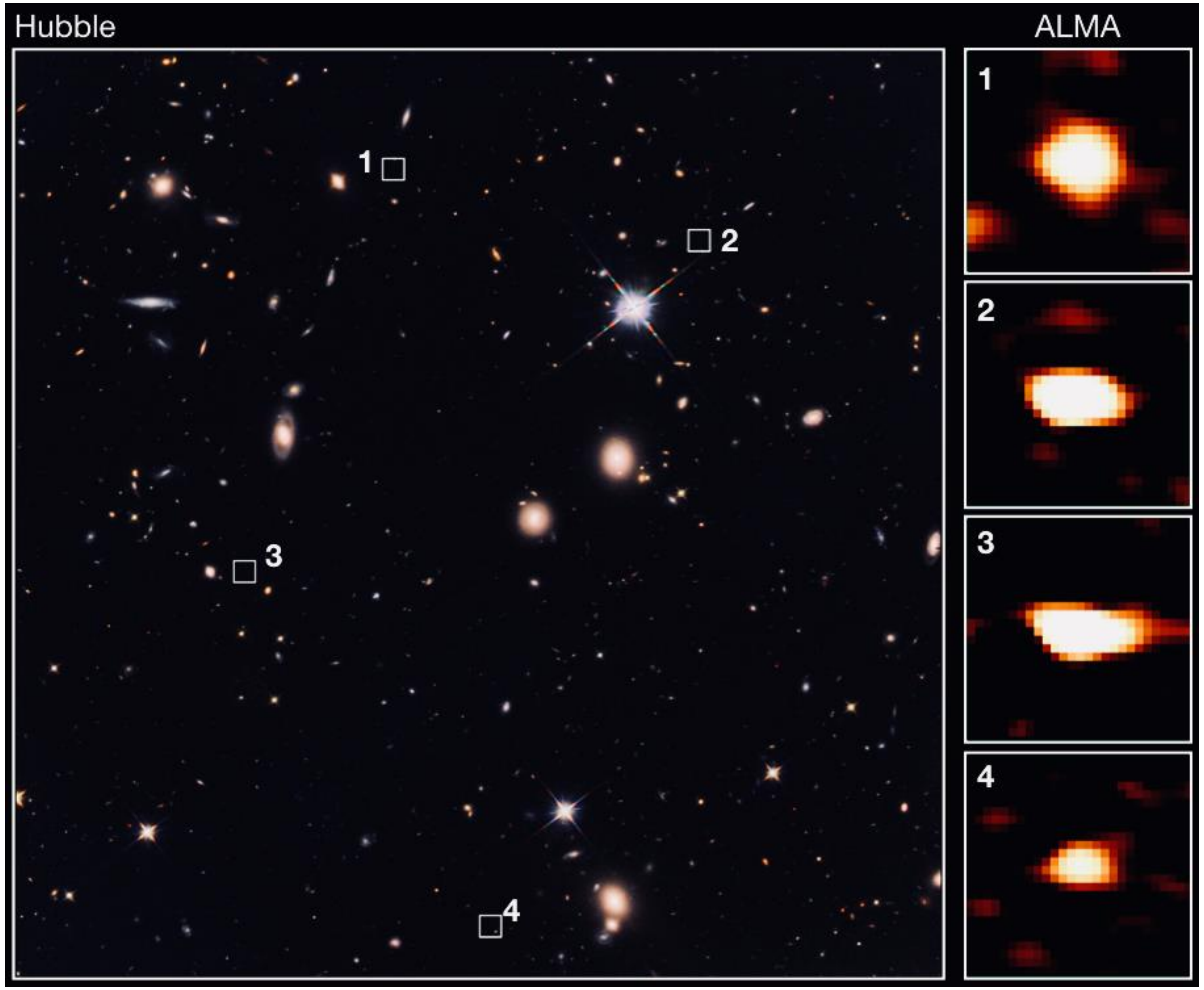


The redshift evolution of the cosmic star-formation rate density (SFRD), illustrating two inconsistent trends of measurements at z = 4−8, i.e., "dust-rich, actively star-forming universe" suggested by Herschel/SPIRE measurements and cosmic infrared background-light (CIB) lensing with Planck, and "dust-poor, calm early universe" suggested by observations of Lyman-break galaxies with dust-extinction corrections.

Recent ALMA and JWST observations suggest galaxies evolve much earlier than we expected.

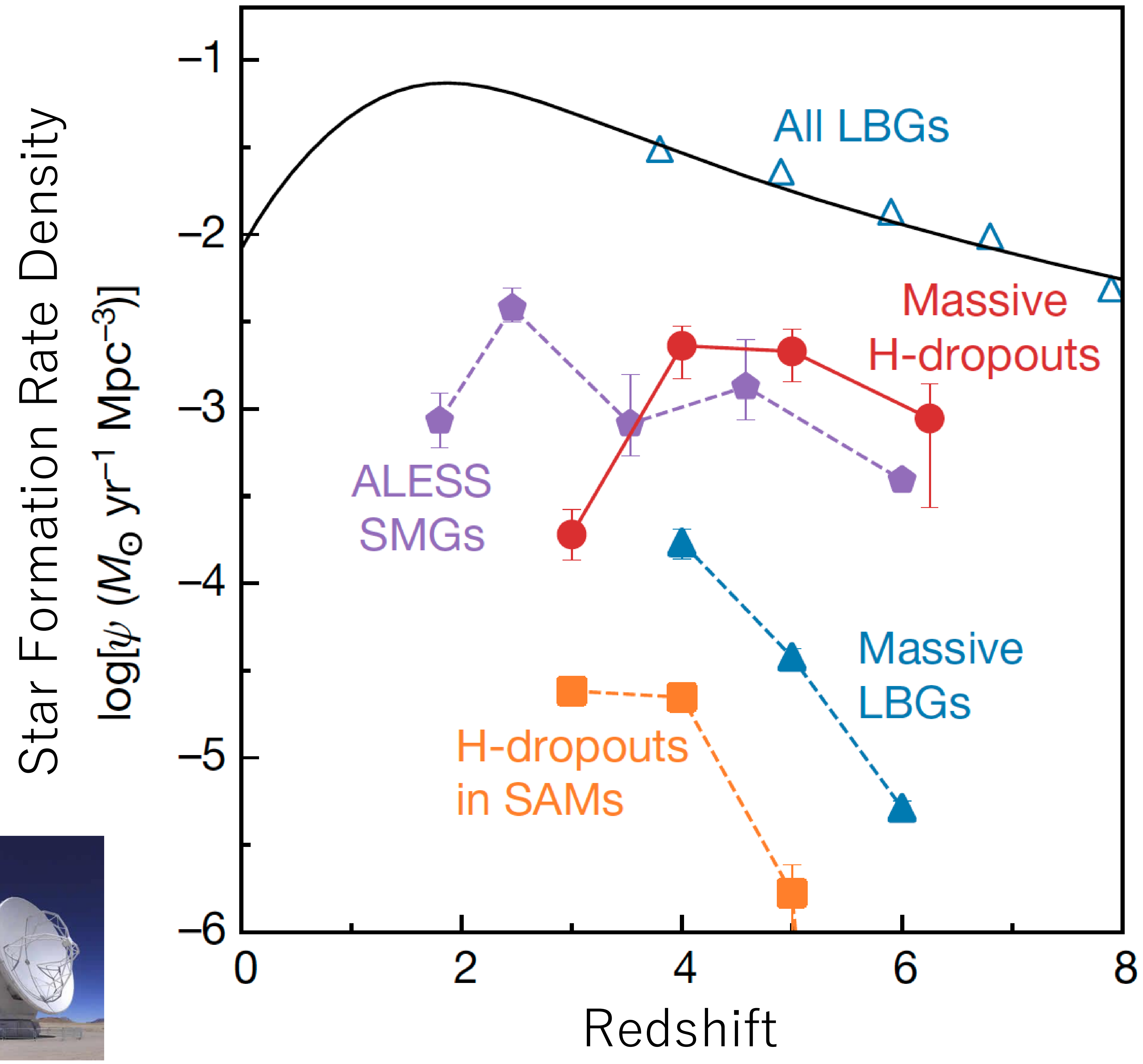
Gruppioni, C., et al. 2020, A&A, 643, A8

Observational evidence for dust-obscured galaxies in the early Universe: ALMA unveiled “Invisible galaxies” in Hubble Space Telescope



Wang, T., Elbaz, D., KK, et al., Nature, 572, 211 (2019)

CEA-Caclay

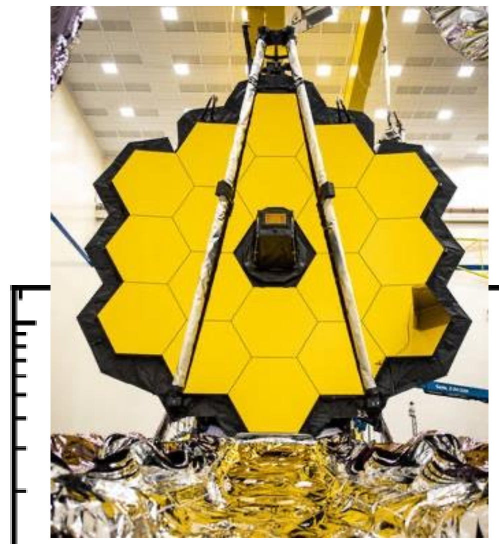


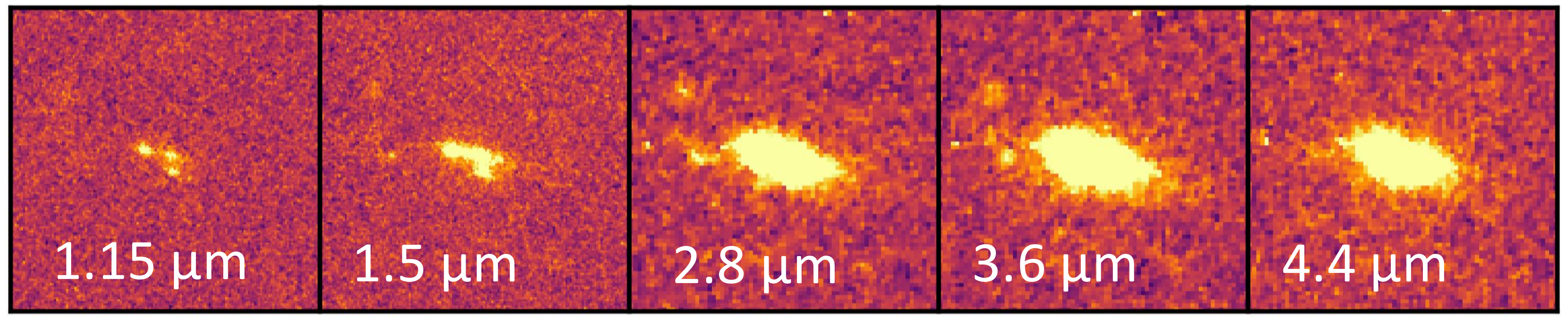
Near-infrared (H-band) invisible galaxies or “H-dropout galaxies” are found to be orders of magnitude more abundant than the state-of-the-art theoretical predictions
➔ challenge to the standard galaxy formation model

A lensed, massive “quiescent” galaxy in the Early Universe (at a redshift z = 5.4?) ➔ suggesting formation of galaxies occurred much earlier

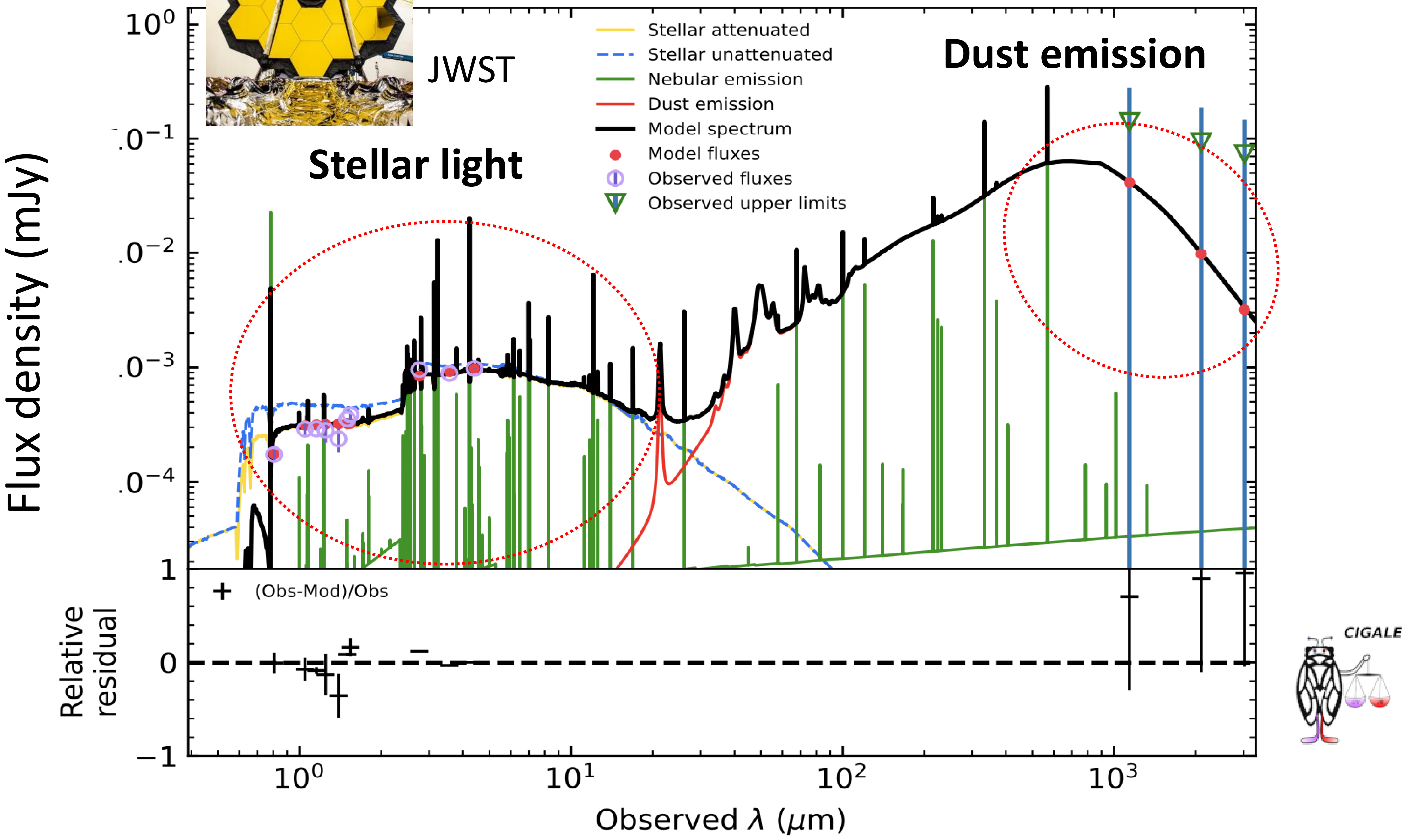
μ = 5 ➔ 25 times faster in follow-up observations

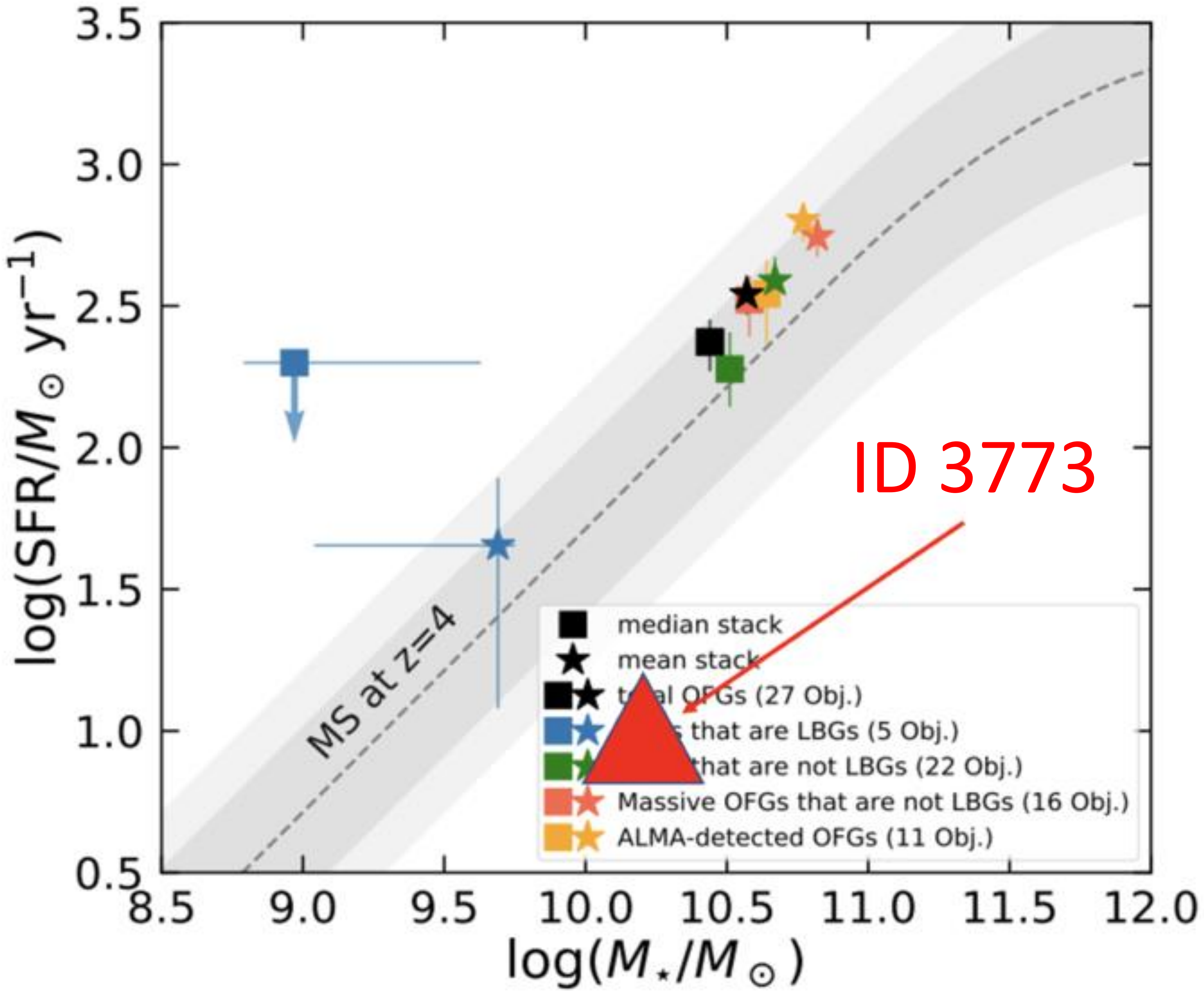
magnification





Best model for 3773
(z=5.44, reduced χ²=0.69)

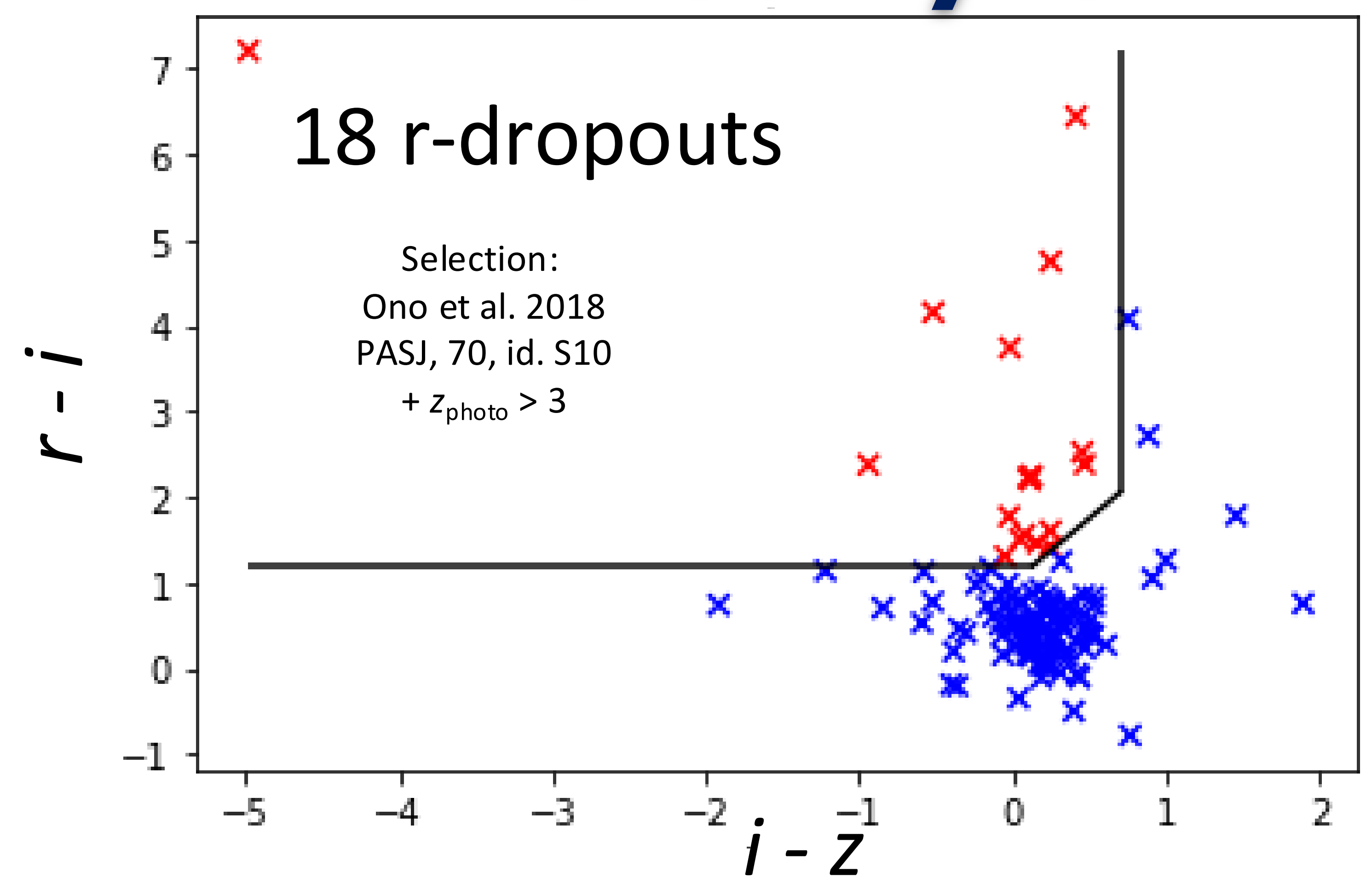


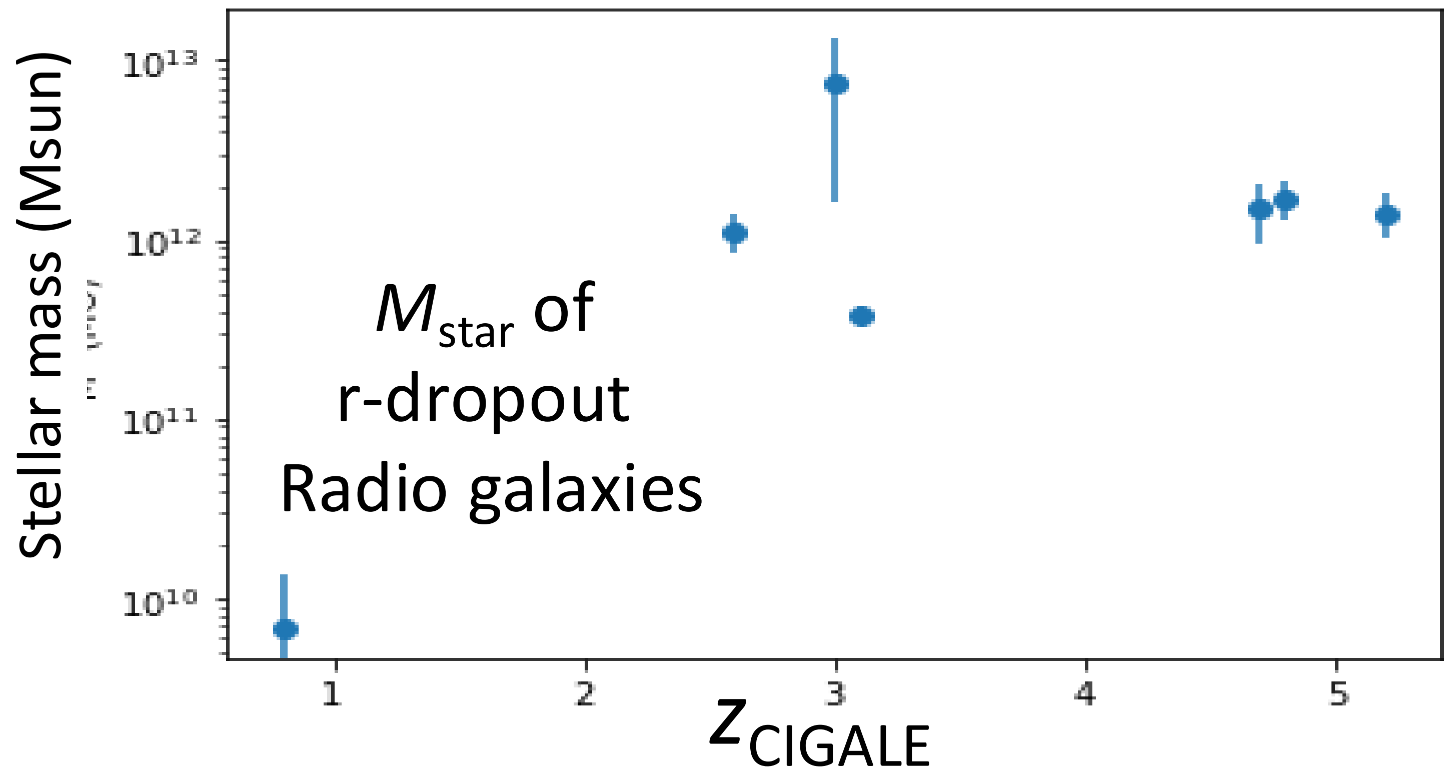


Large stellar mass (2 x 10^{10} M_sun) but no elevated dust-obscured star formation (SFR = 10 M_sun/yr, no ALMA dust-continuum detections)

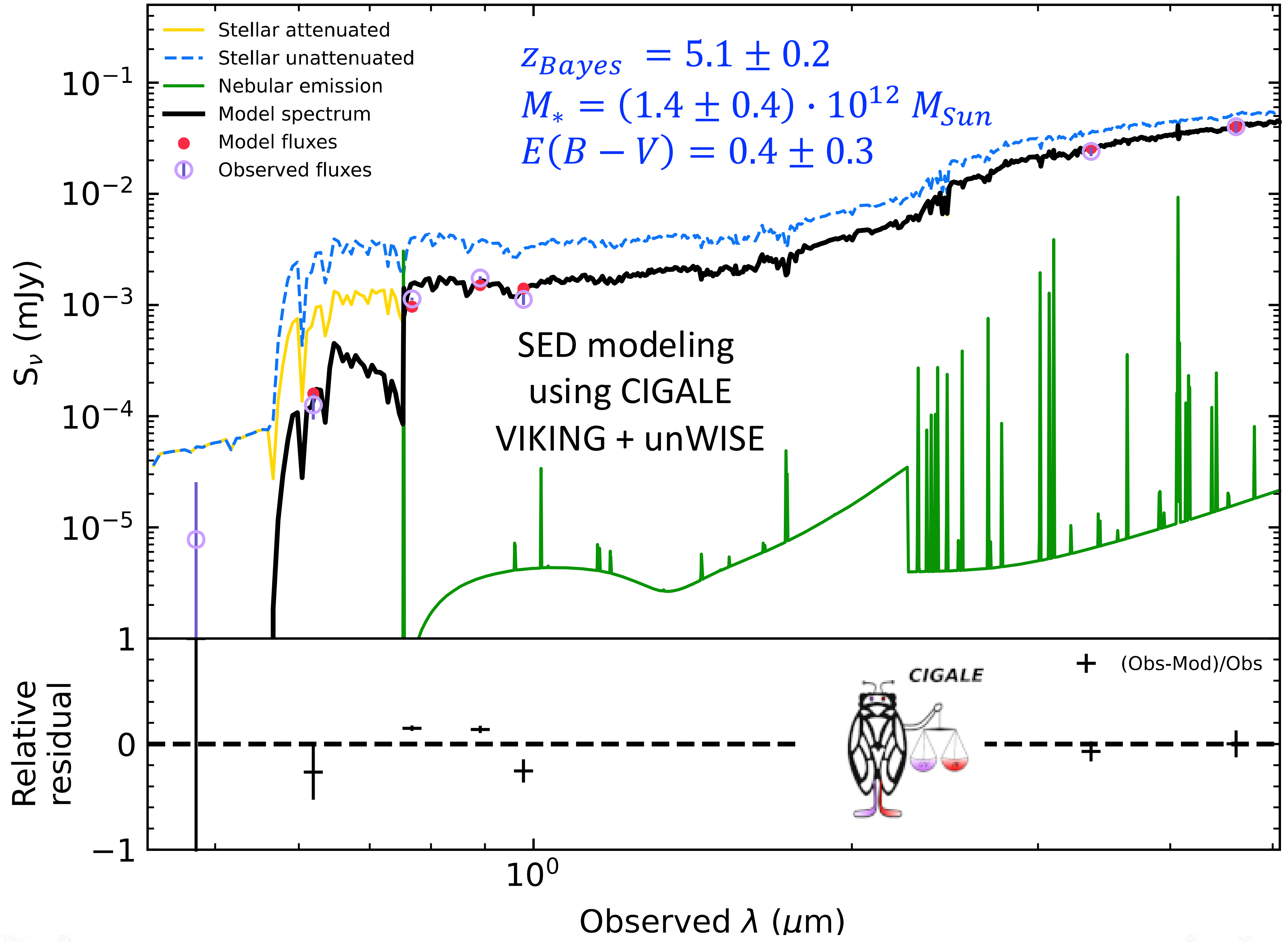
Search for Super-massive Blackhole candidates in the early Universe using Subaru/HSC x VLA-FIRST

Victor Kadri
INSTITUT POLYTECHNIQUE DE PARIS

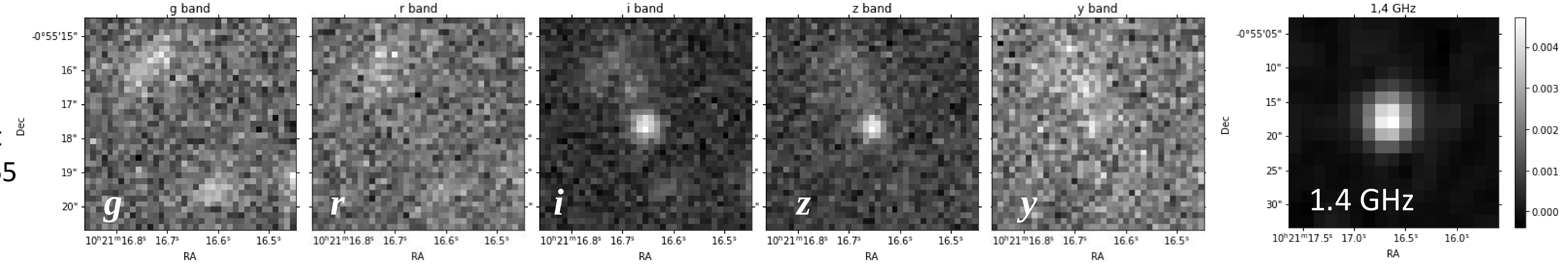


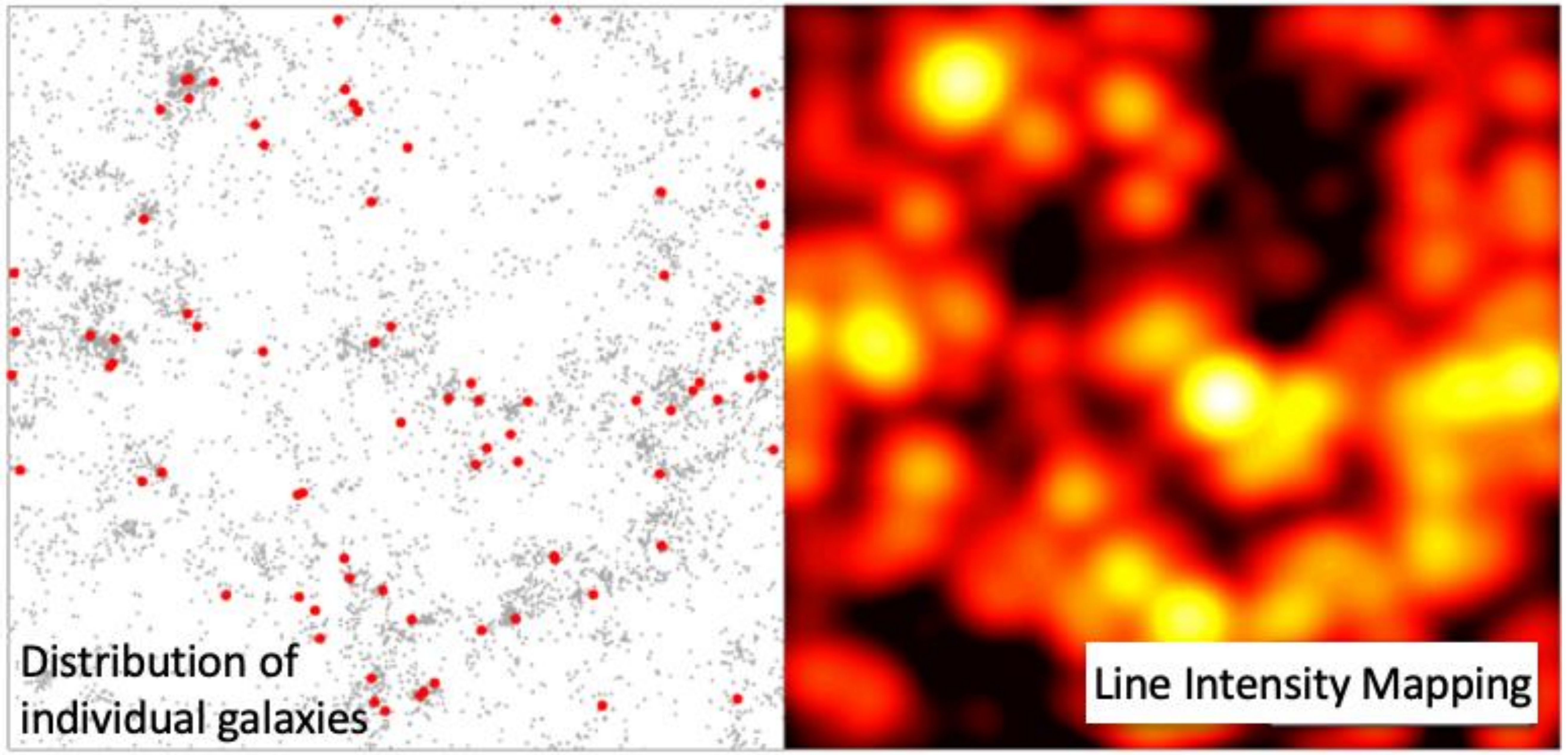


Best model for 41038872074801782 (HSC id)
(z=5.2, reduced χ²=1.3)



An example:
The r-dropout
HSC J102116.65
-005517.6



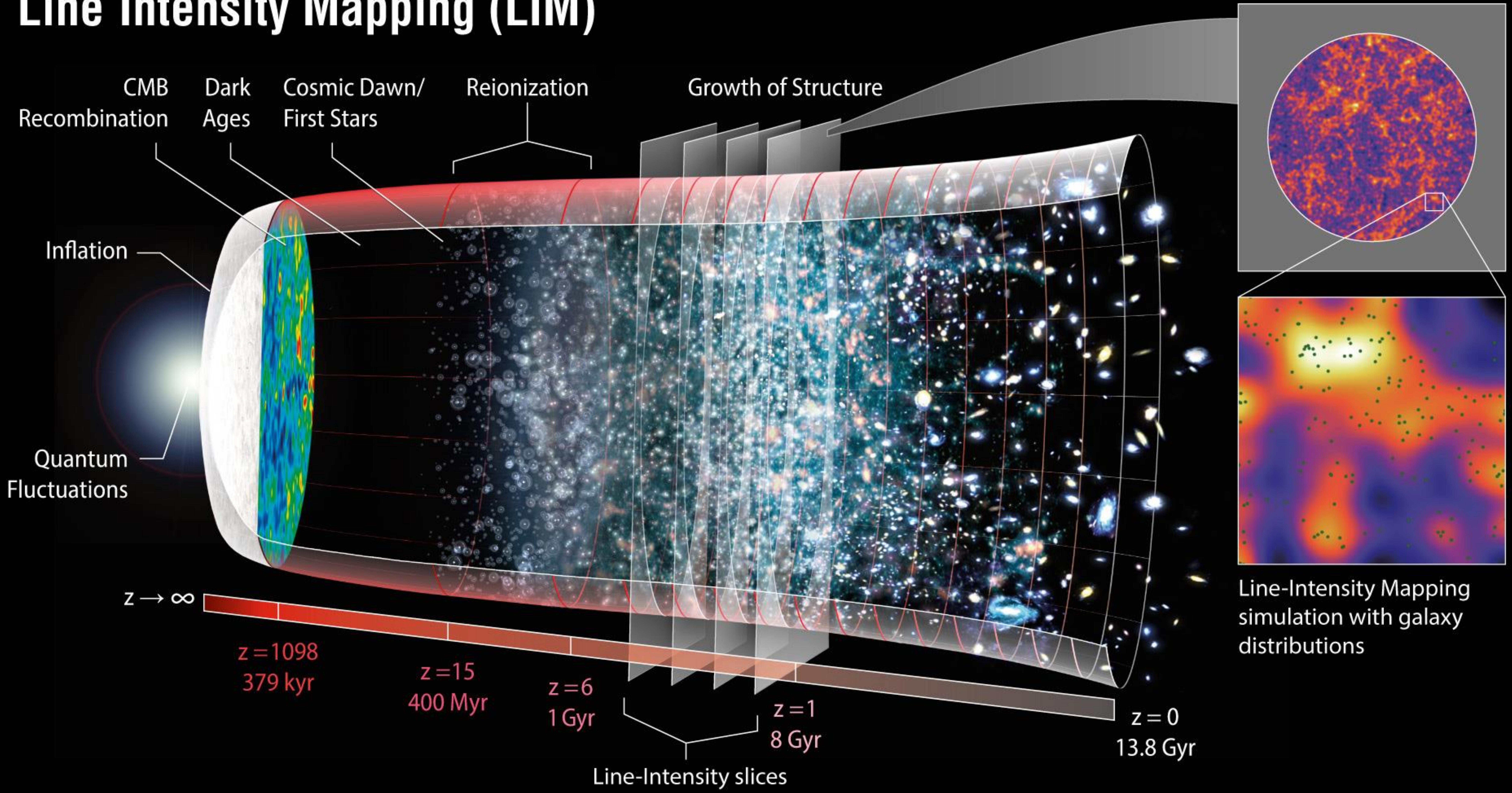


TIFUUN

THz **I**ntegral **F**ield **U**nits with **U**niversal **N**anotechnology

for Submillimeter-wave Line Intensity Mapping

Line Intensity Mapping (LIM)



https://lambda.gsfc.nasa.gov/education/graphic_history/intensitymapping.html

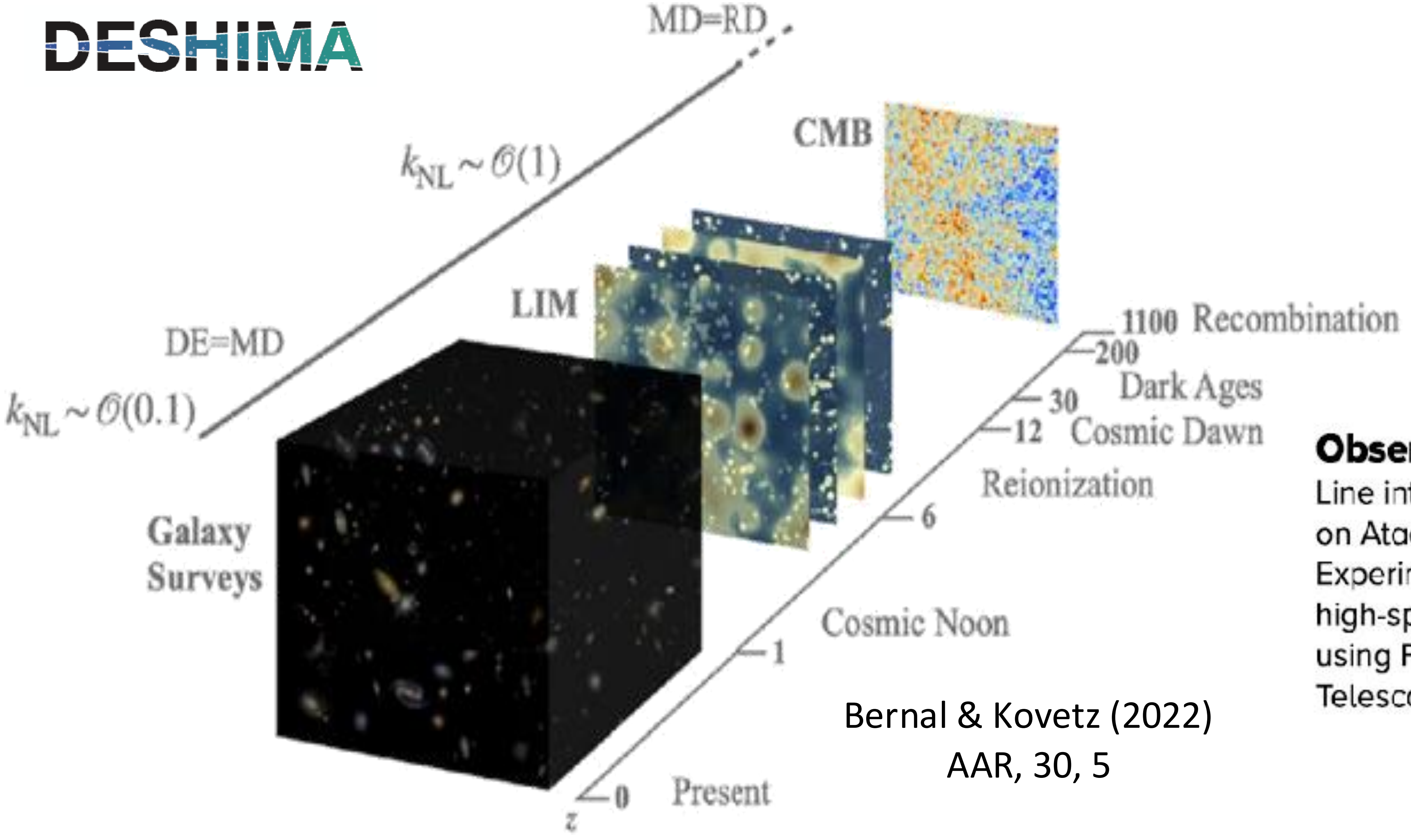
TIFUUN for Submillimeter-wave Line Intensity Mapping

https://sites.google.com/view/sublime-tifuun/home

A. Endo J. Baselmans K. Karatsu A. Monfardini

K. Kohno N. Yoshida K. Moriwaki S. Ikeda T. Takekoshi Y. Tamura

DESHIMA



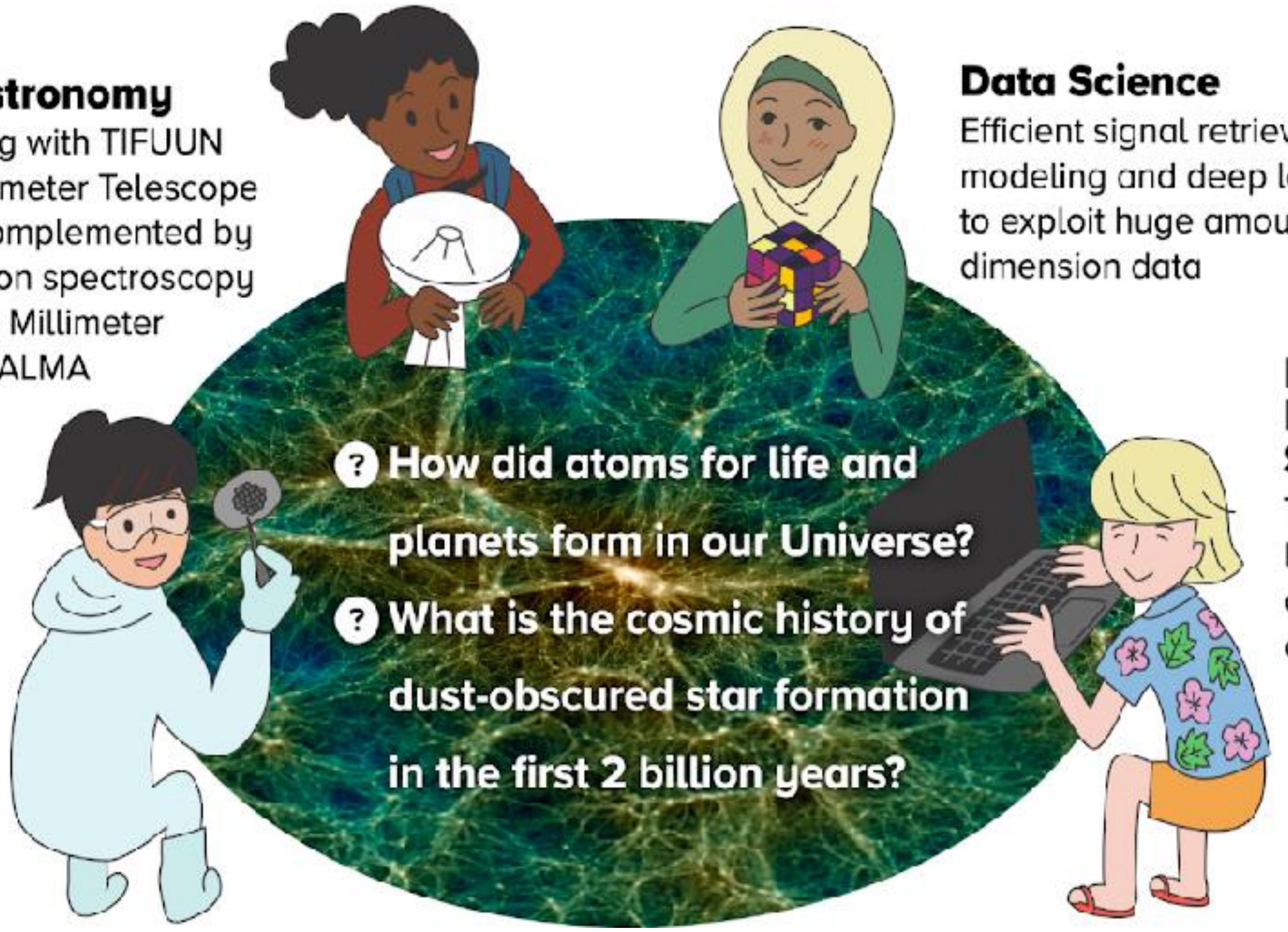
Bernal & Kovetz (2022)
AAR, 30, 5

Cosmology with Superconducting Nanotechnology

TIFUUN

Observational Astronomy
Line intensity mapping with TIFUUN on Atacama Sub-millimeter Telescope Experiment (ASTE), complemented by high-spectral resolution spectroscopy using FINER on Large Millimeter Telescope (LMT) and ALMA

Data Science
Efficient signal retrieval with sparse modeling and deep learning to exploit huge amount of multi-dimension data



Large Scale Numerical Simulations
Theoretical prediction of line intensity signals and comparing to cosmological models

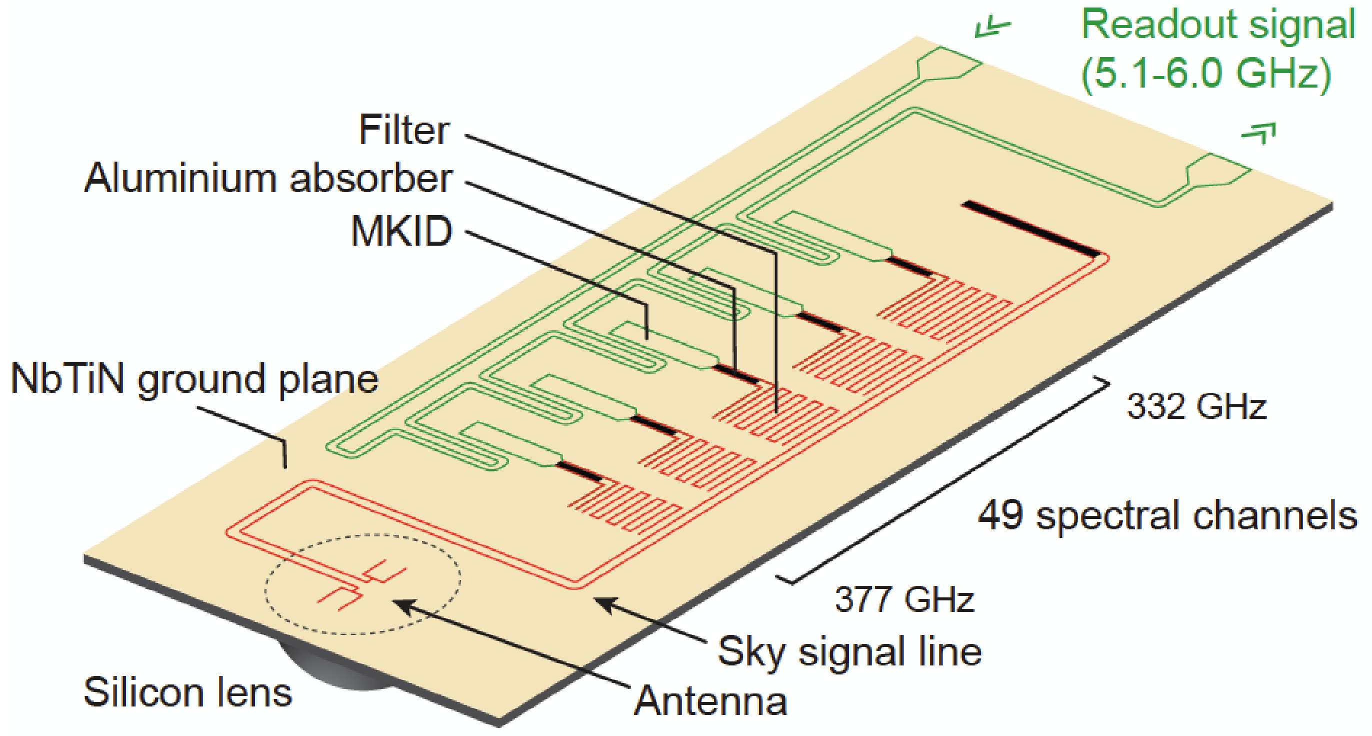
Superconducting Nanoelectronics
Development of novel Integrated Imaging Spectrograph TIFUUN

- **JSPS grants** (International Leading Research + Specially Promoted Research, ~ €6M, PI: K. Kohno)
- **ERC Consolidate grant** (€3.4M, PI: A. Endo)

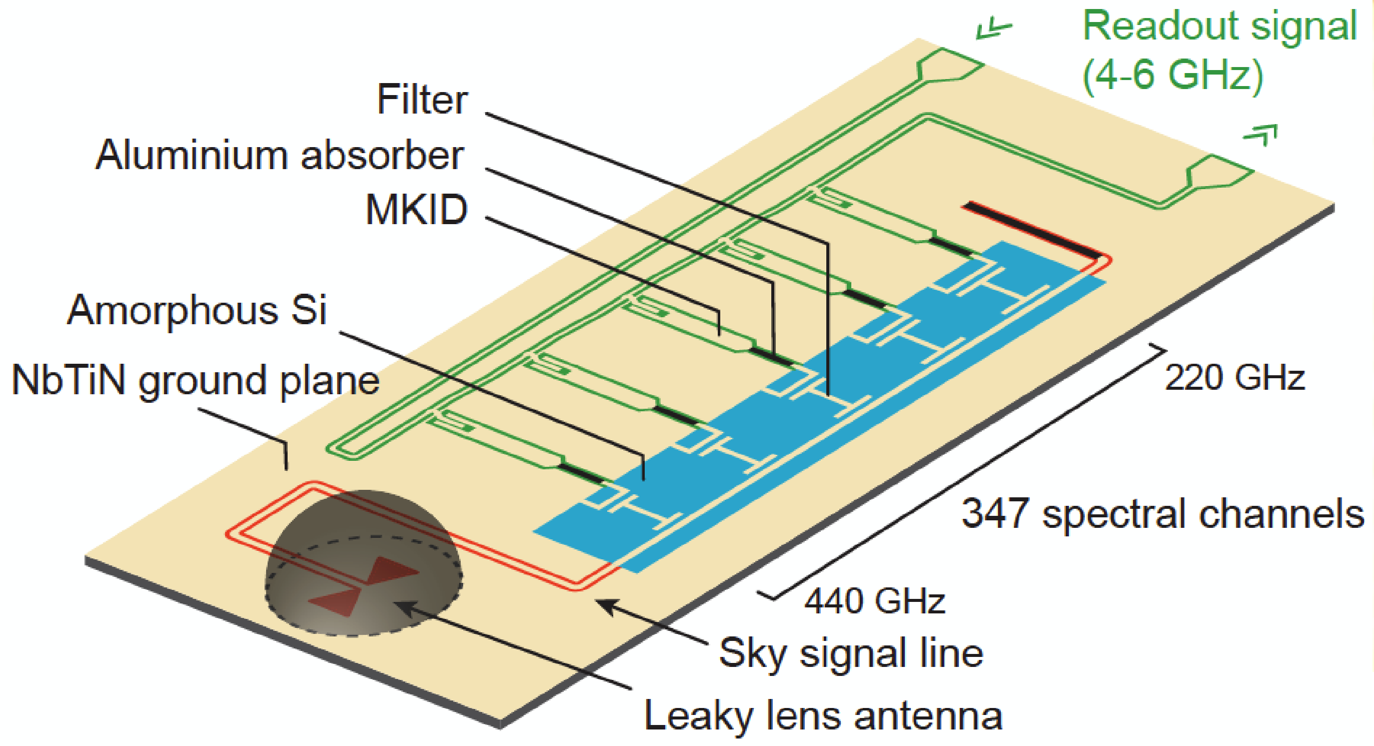
are awarded to TIFUUN/ASTE (and FINER/LMT)

Successful demonstration of the integrated superconducting spectrograph (ISS) technology: DESHIMA1.0 to DESHIMA2.0

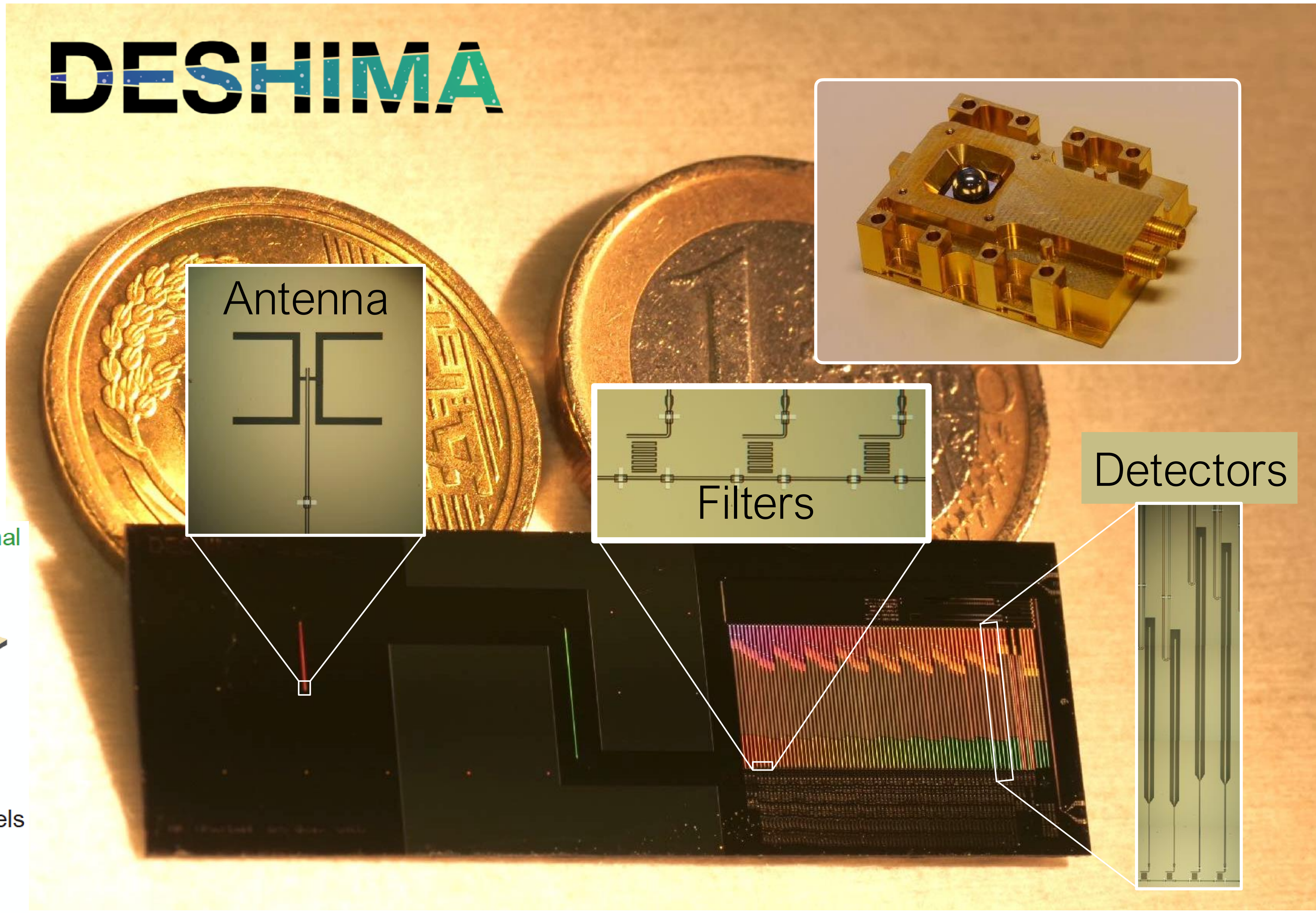
- DESHIMA
  - First proof of ISS concept via astronomical signal detections: Endo et al. 2019, **Nature Astron.**, **3**, 989
  - Laboratory demonstration of ISS: Endo et al. 2019, **JATIS**, **5**, 03500
  - ISS calibration methodology: Takekoshi et al. 2020, **J. Low Temp. Phys. 199**, 231
  - ISS calibration and noise removal "De:code", Taniguchi et al.
- DESHIMA 2.0: science grade tip with wider bandwidth
  - deployed on ASTE (finally! 2023 - 2024, on-going)
  - Simulator (TiEMPO, Huijten et al. 2020, **SPIE Proc.**)



DESHIMA 1.0

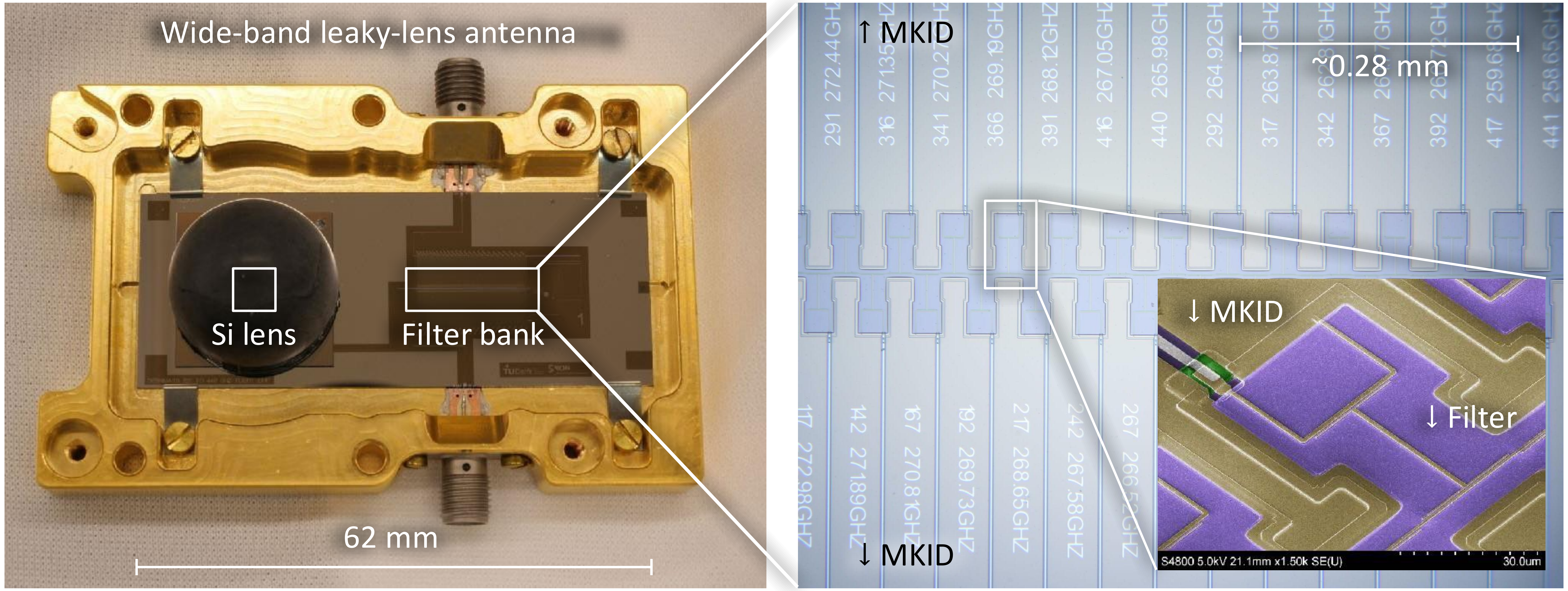


DESHIMA 2.0



TU Delft, SRON, Universiteit Leiden, 東京大学 The University of Tokyo, 名古屋大学 Nagoya University, 北見工業大学 Kitami Institute of Technology, NAOJ 国立天文台

Integrated Superconducting Spectrometer (ISS) Wide-band chip and quasi-optical designs

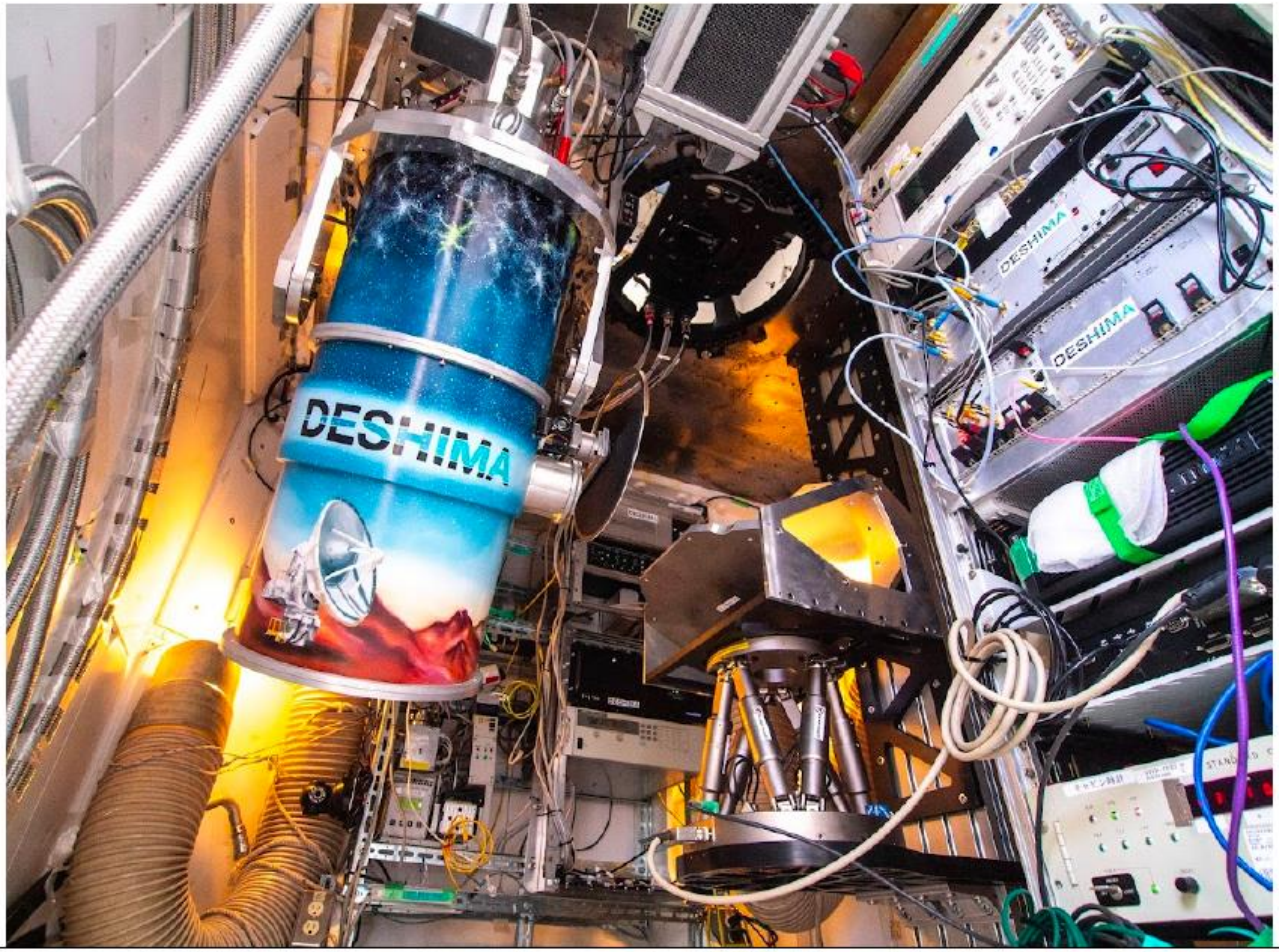


|| Fabrication of a telescope chip with full band-width

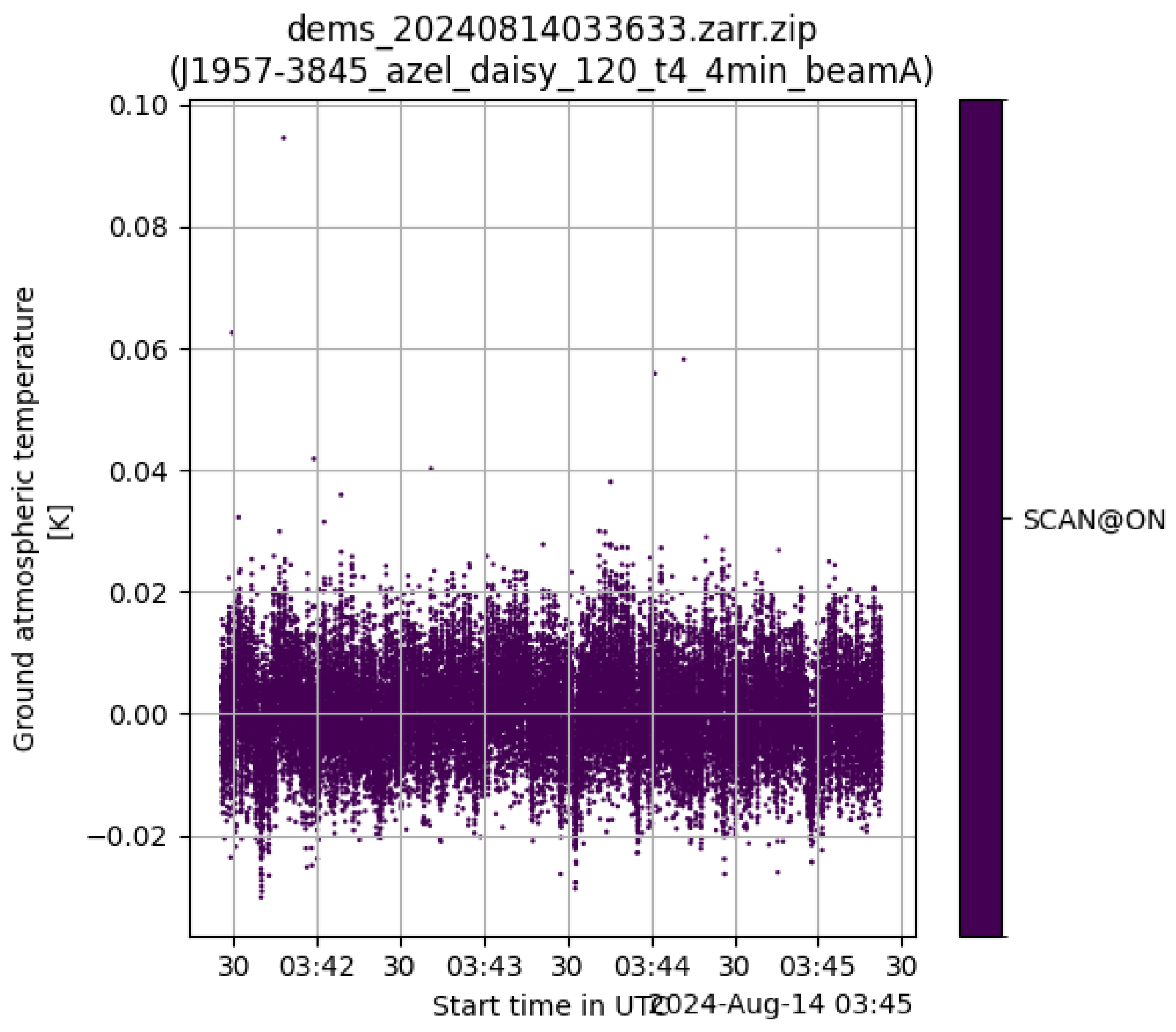
- The first telescope chip covers 222 - 425 GHz (92% of the spec. band-width)
    - Scatter of center frequency and Q-factor requires optimization
- Sufficient telescope-to-chip optical coupling by a novel wide-band antenna
    - aperture efficiency of η > 55% over the entire frequency range (Dabironezare, Ph.D thesis)

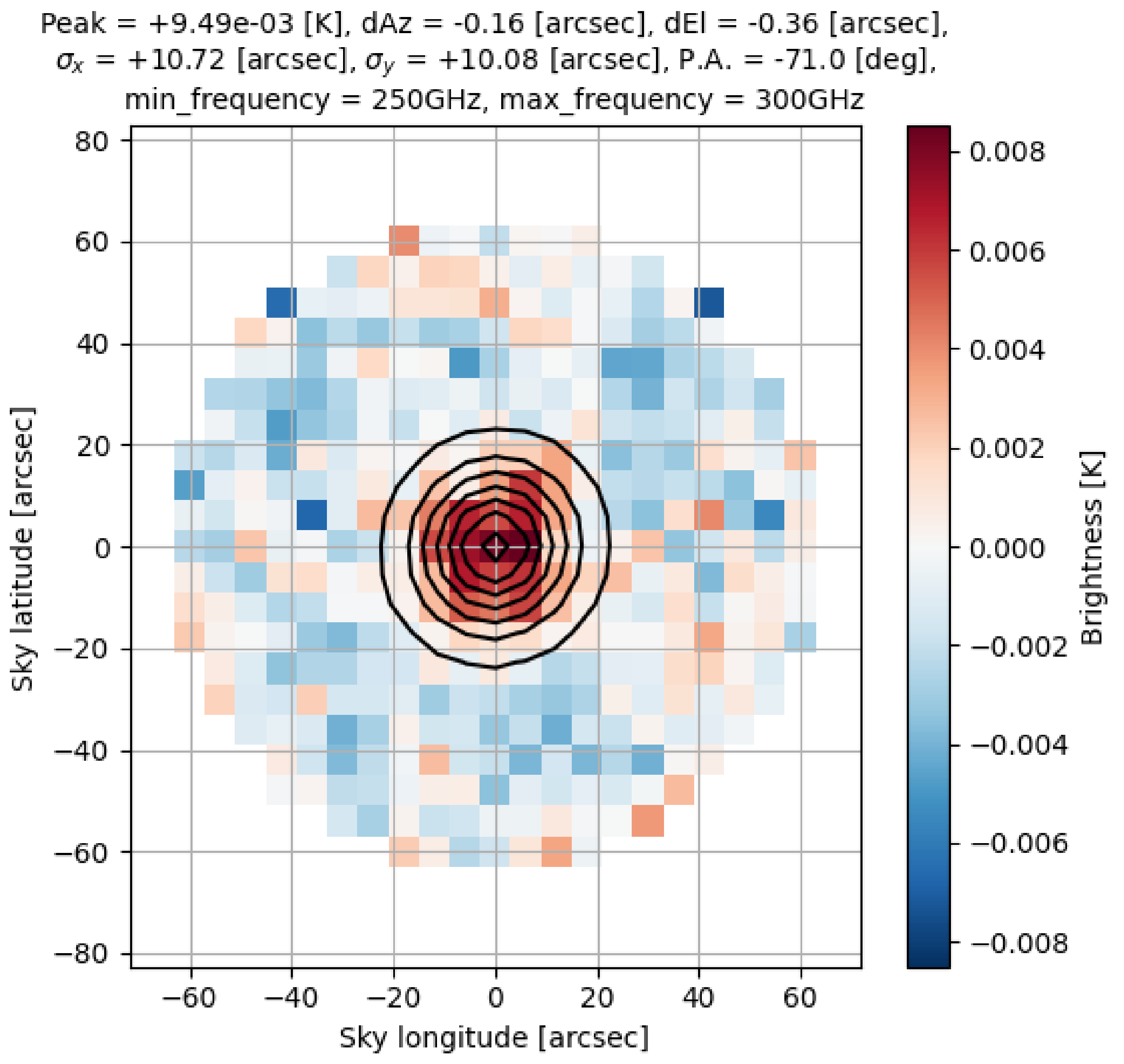
DESHIMA2.0 on ASTE 2023-2024

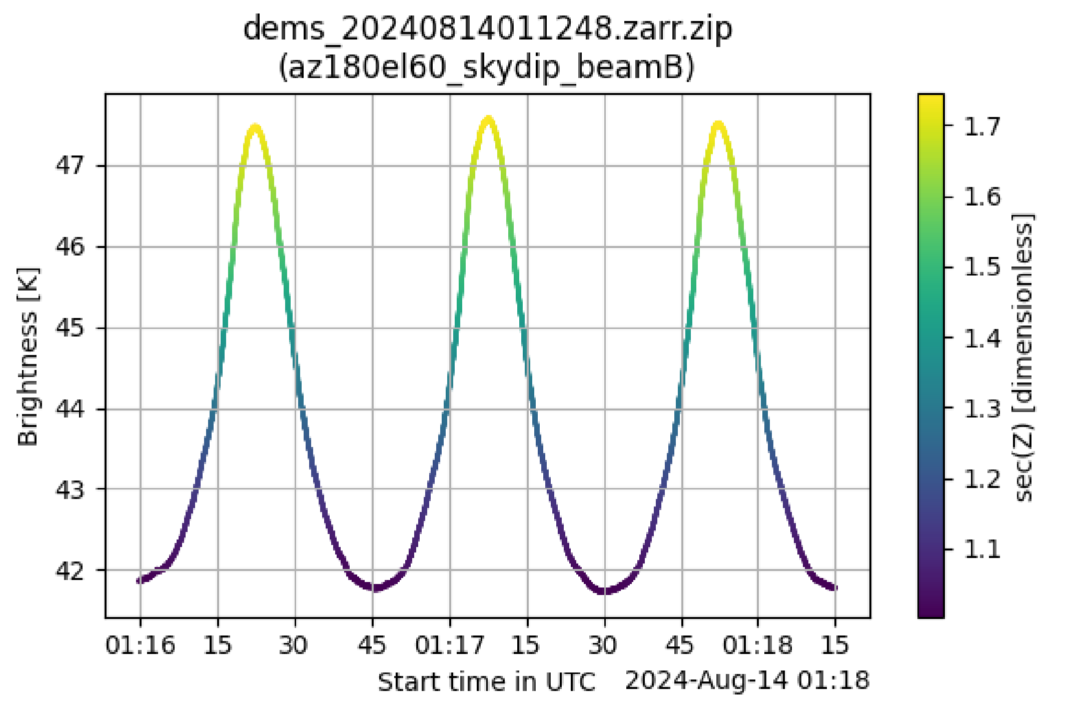
Hardware installation on ASTE

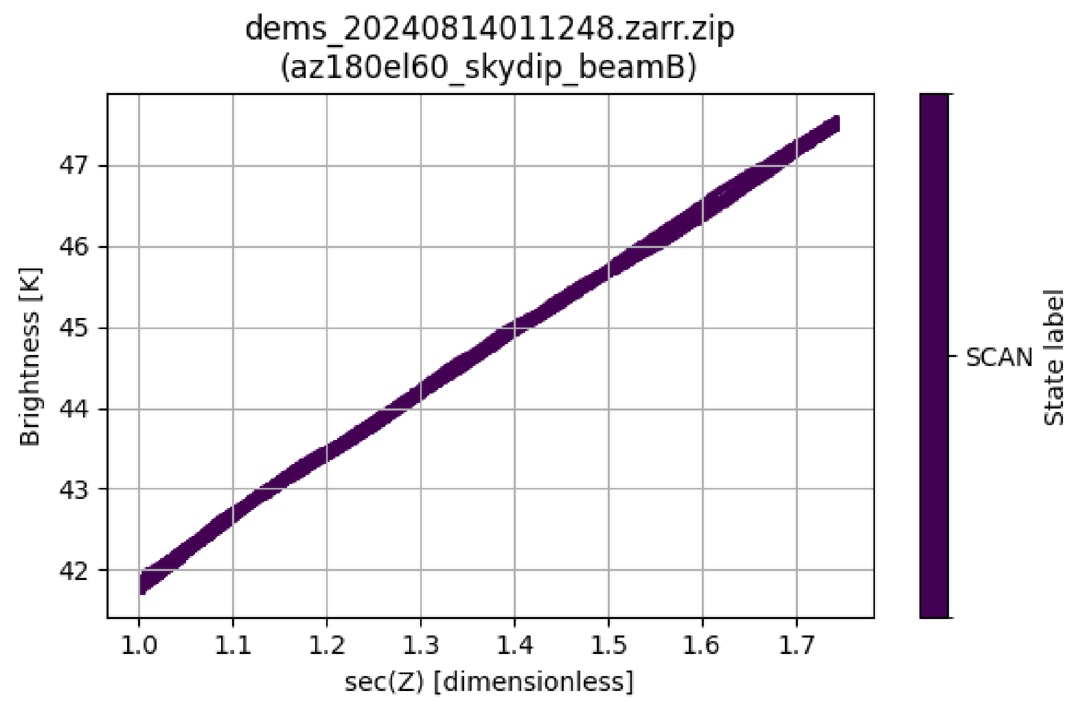


DESHIMA2.0 on ASTE 2024 commissioning in progress (till December)



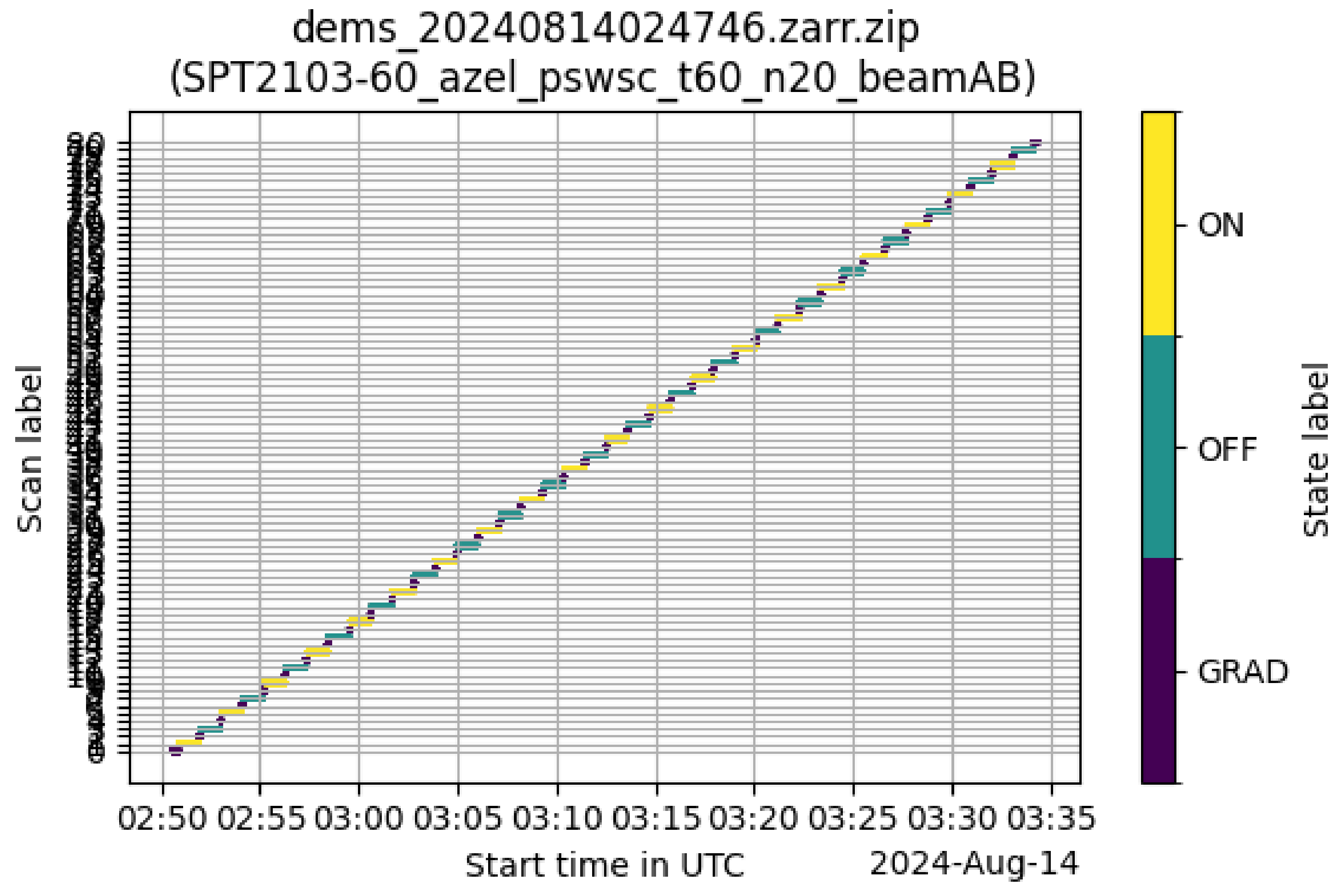


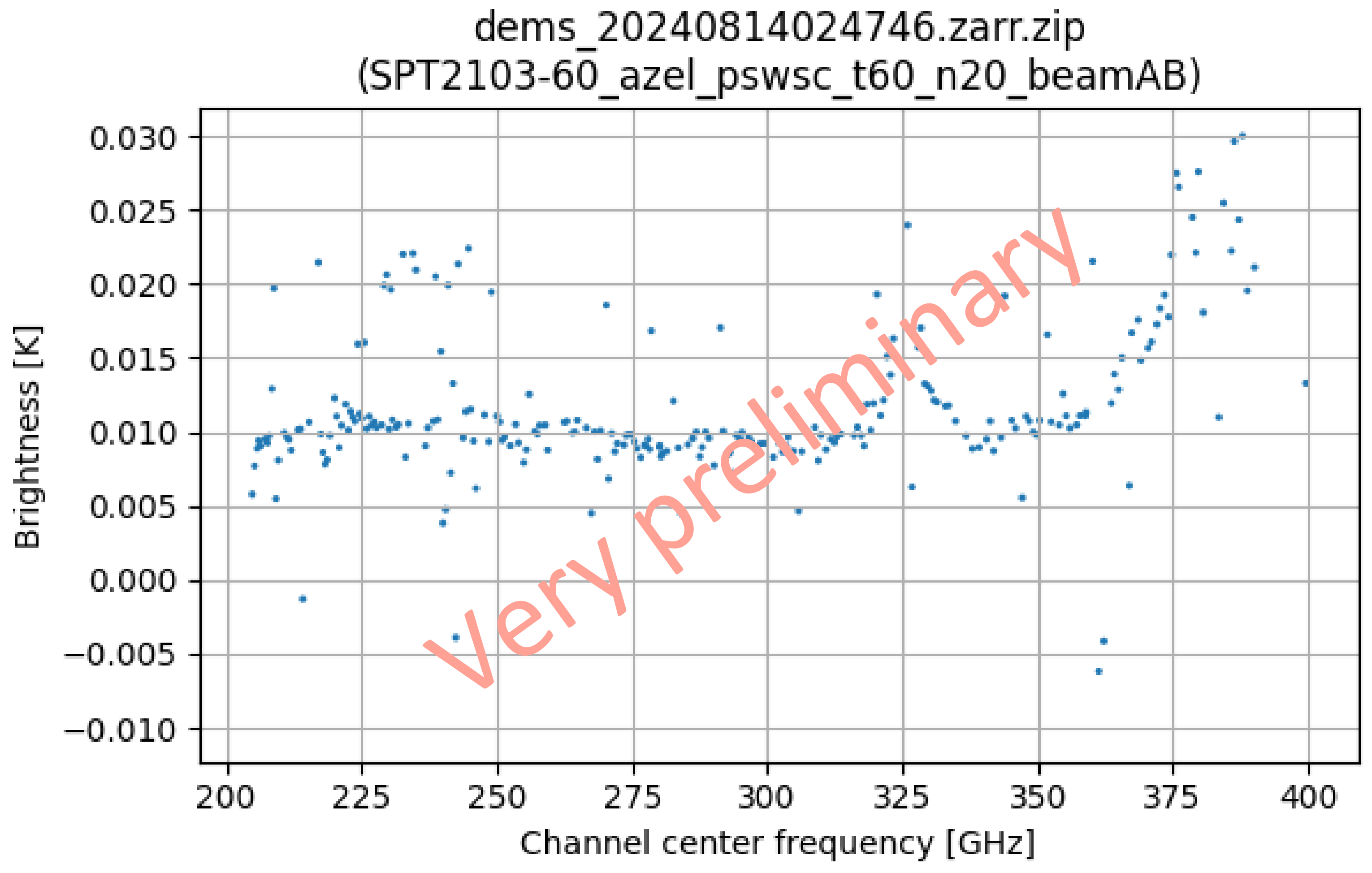




Skydip observations behave quite well under good weathers

A few Jy point source can be easily detected as pointing and flux calibrators





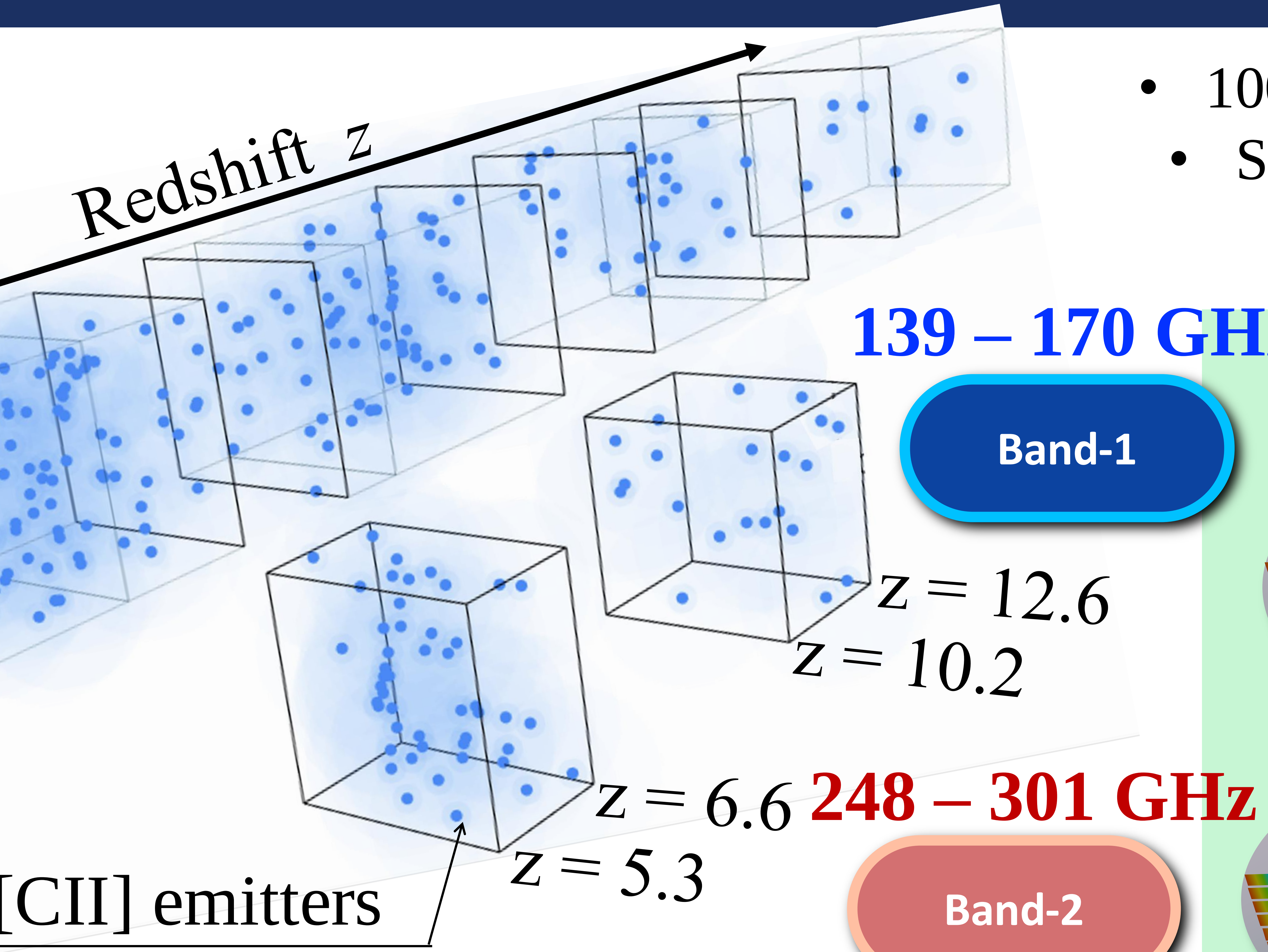
SPT2103-60
a dust enshrouded galaxy
in the early Universe

200 – 400 GHz spectrum in one shot
(just for your eyes)

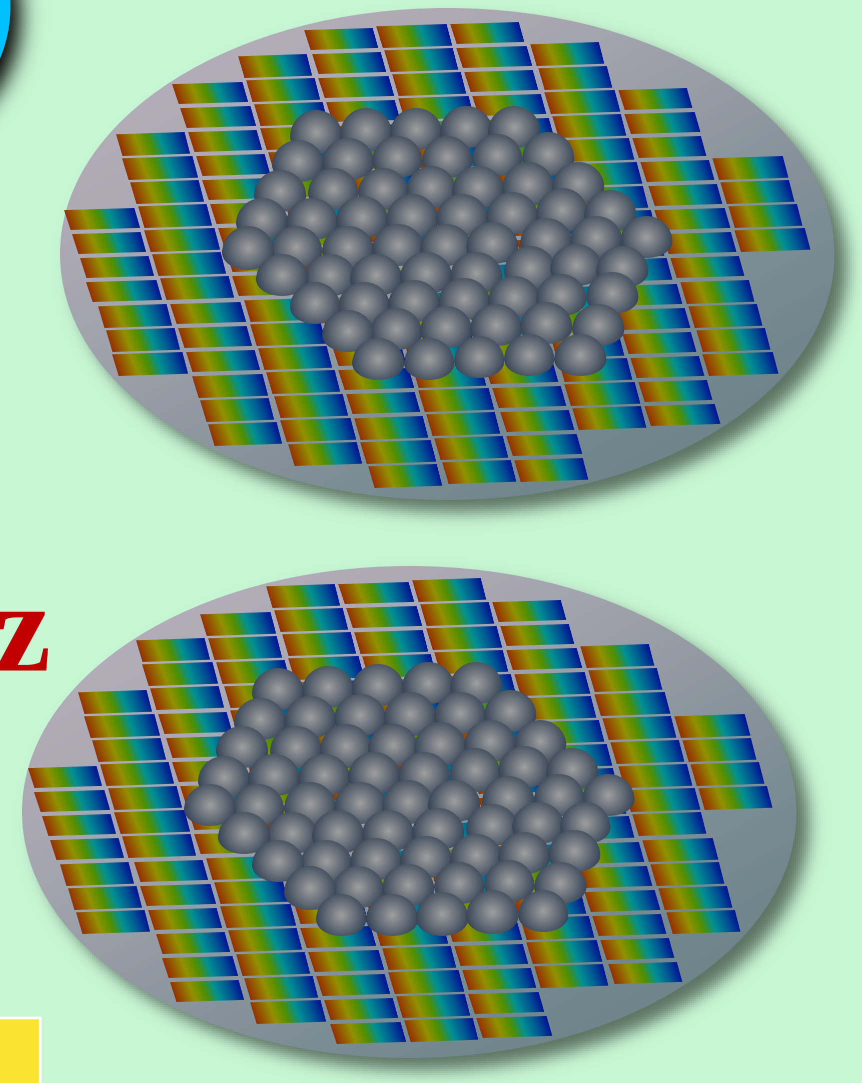
Dual-band line intensity mapping using TIFUUN

- 100 spaxels x 100 colors (R~500) x 2 bands = 20,000 voxels in total
  - Simultaneous observations of line pairs at the same redshift range

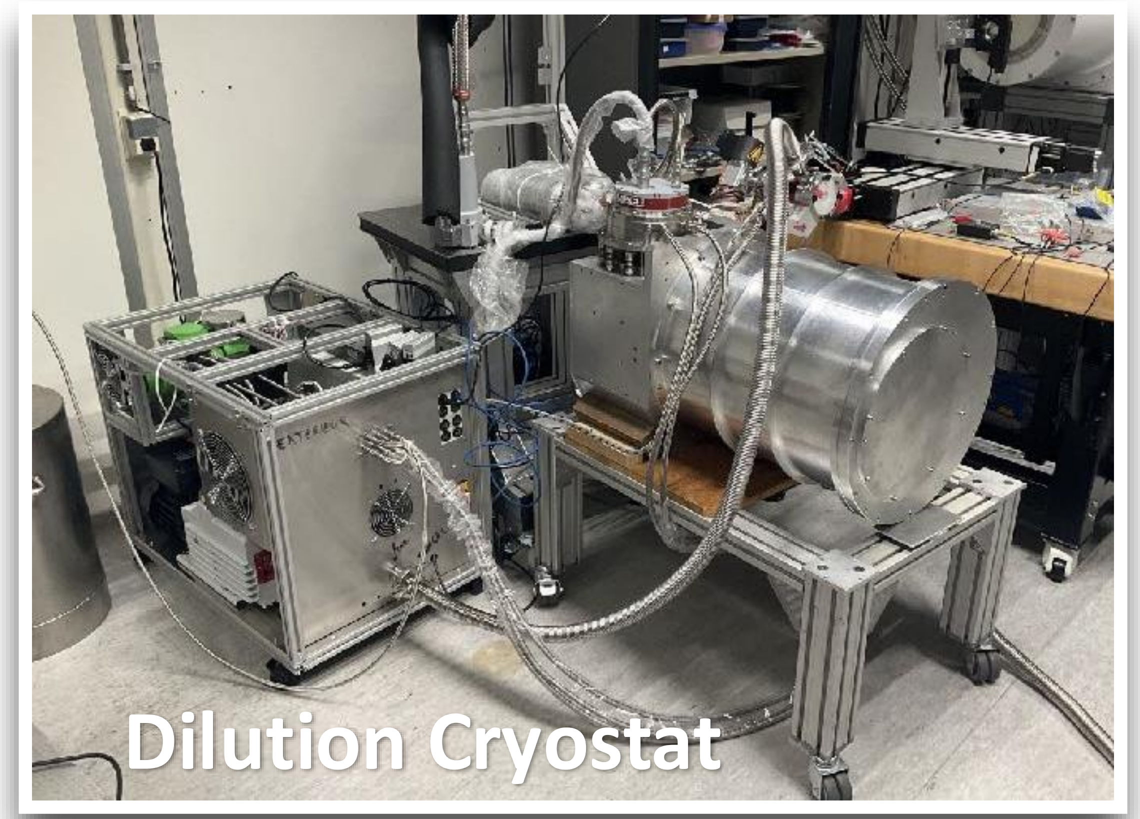
    ➔ cross-correlation to mitigate contaminations & systematics

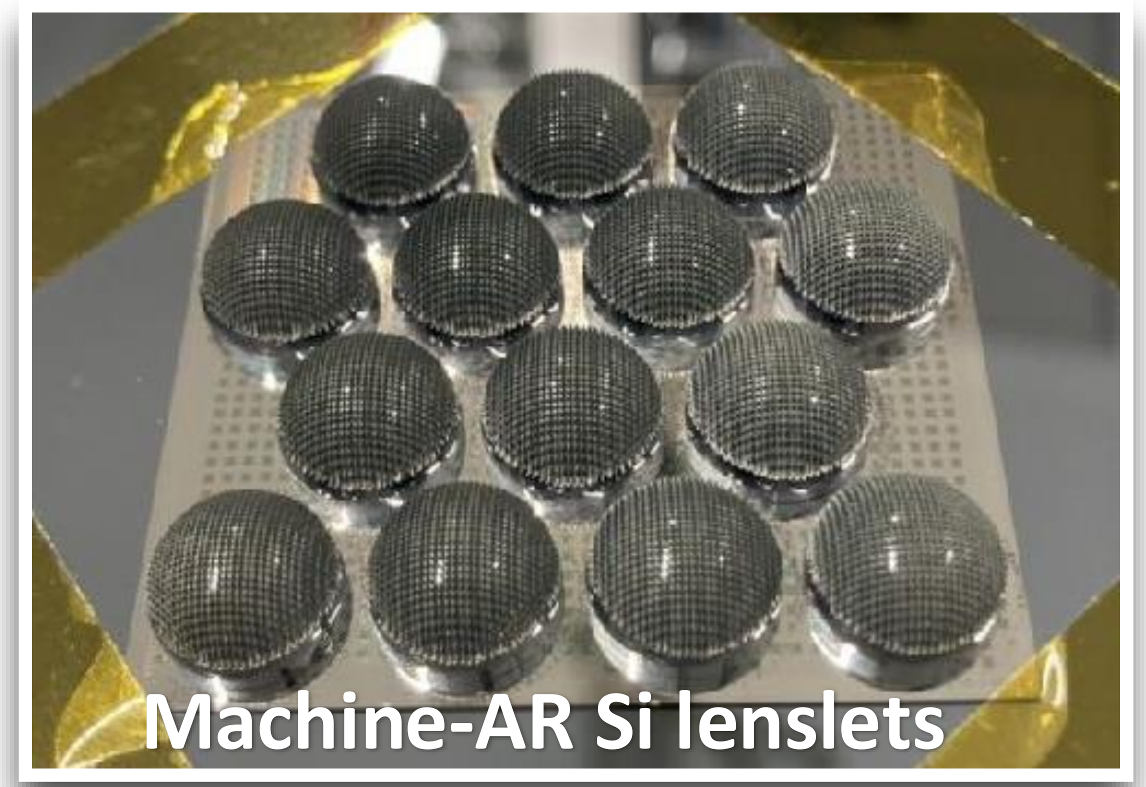


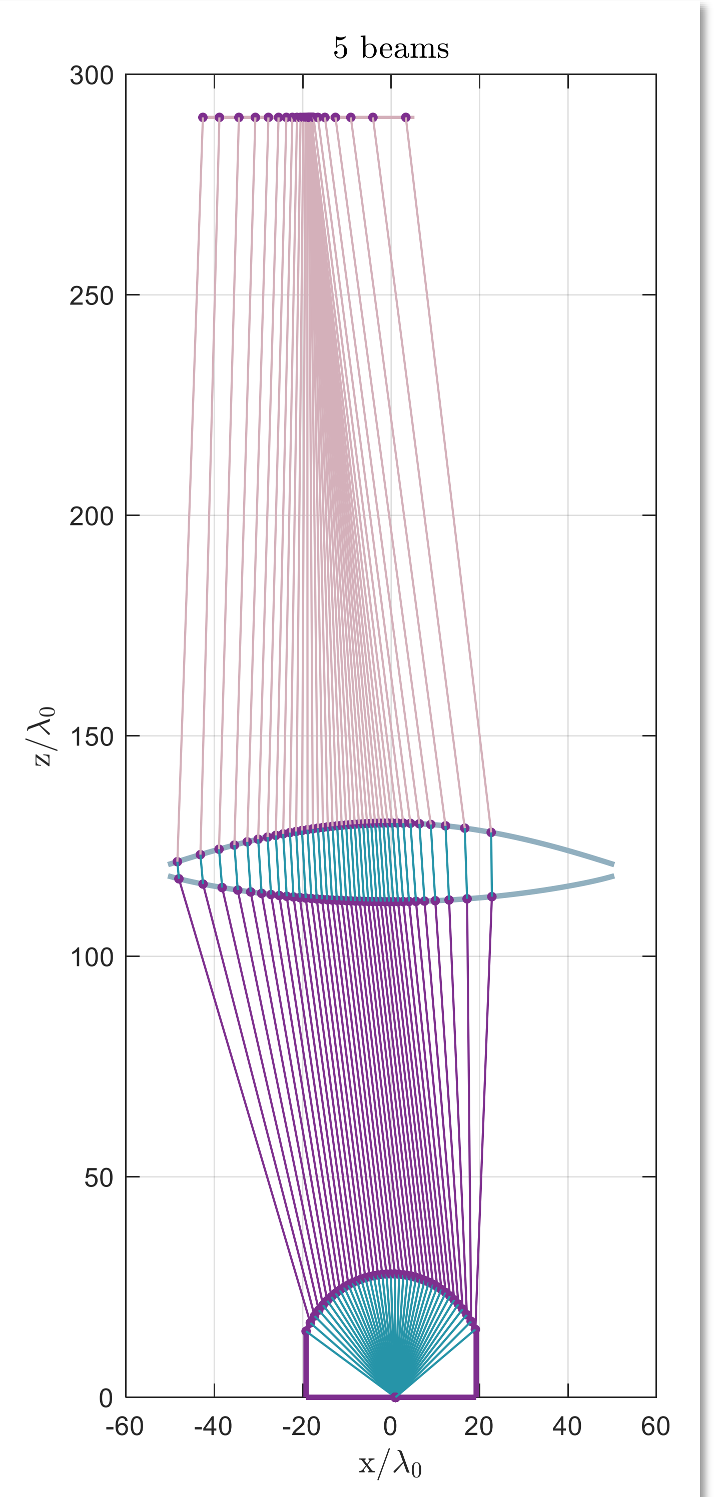
Integral Field Units



Field of view (@ASTE)
~8 arcmin (Band-1)
~5 arcmin (Band-2)





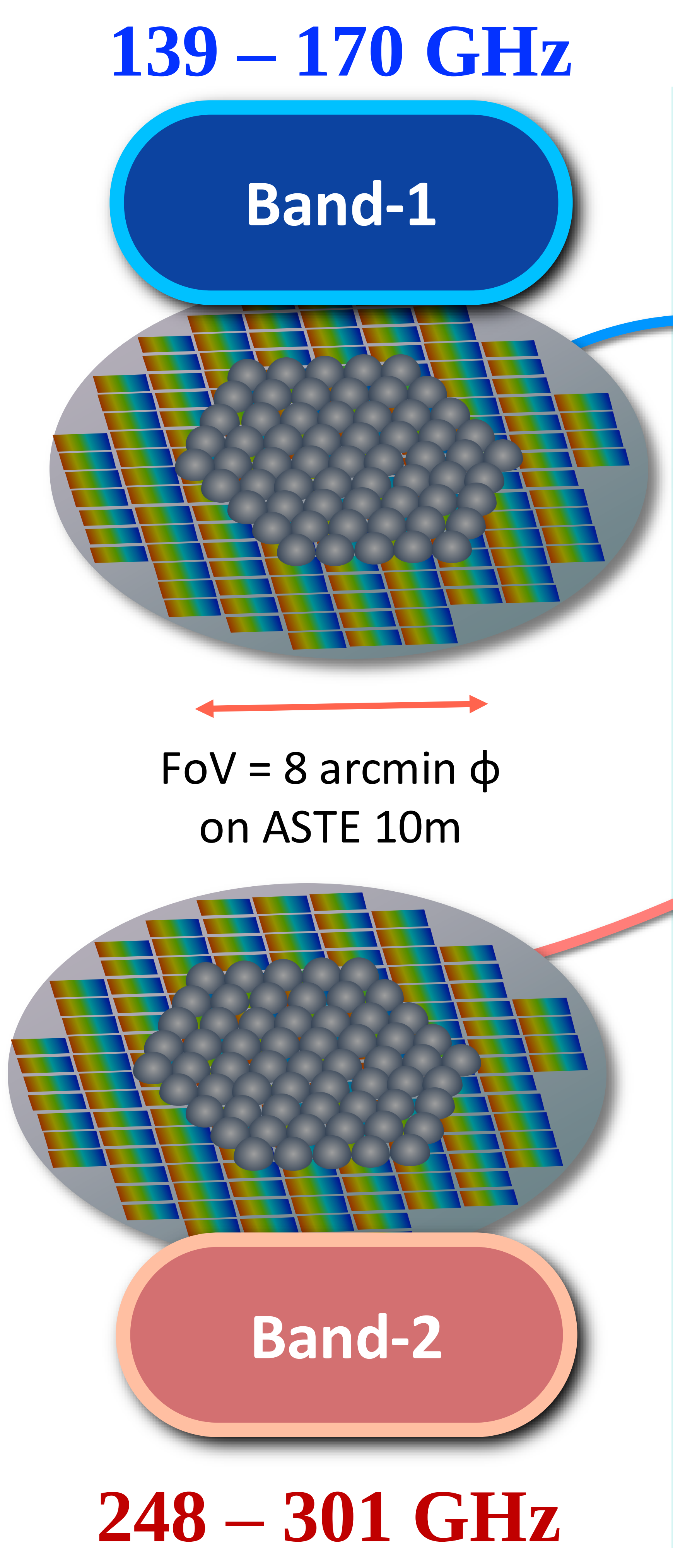


Wideband & Wide FoV optics

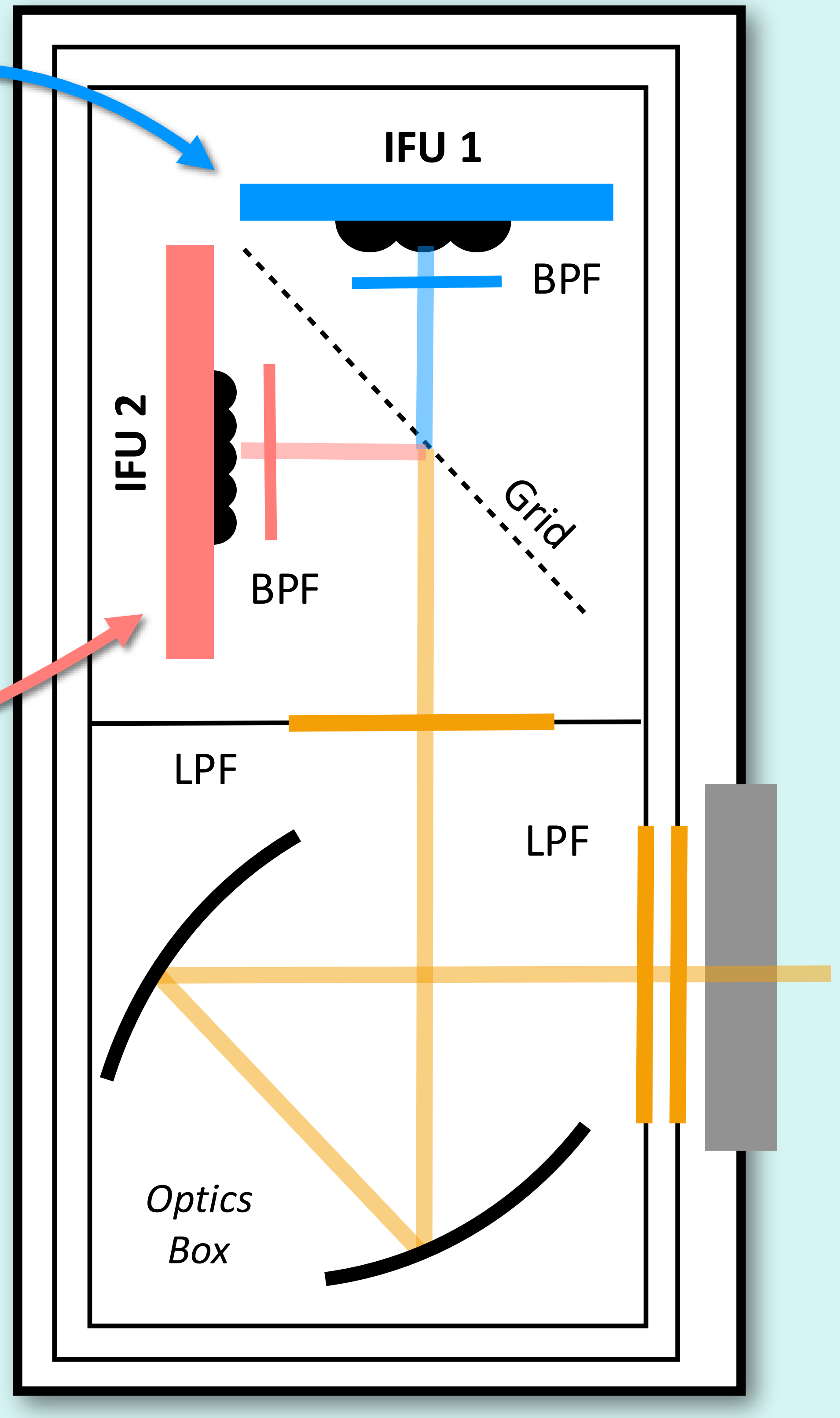
Redshift range	Band-1	Band-2
z = 10.2 – 12.6	[CII] 158 μm	[OIII] 88 μm
z = 1.9 – 2.2	CO(4-3), [CI](1-0)	CO(7-6), [CI](2-1)

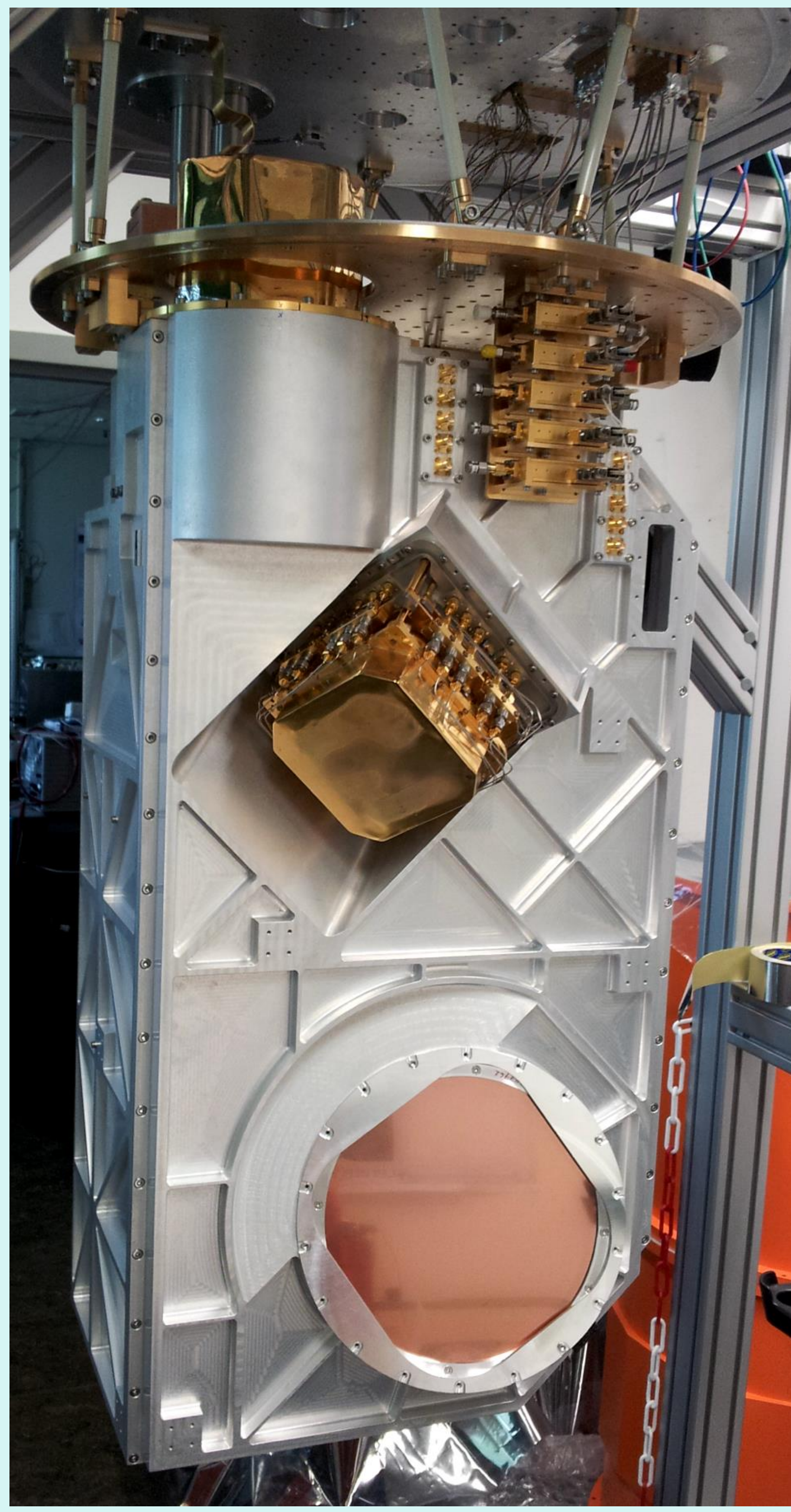
Dual-band line intensity mapping using TIFUUN

	DESHIMA 1.0	DESHIMA 2.0	TIFUUN for line intensity mapping	
			Band-1	**Band-2**
Frequency range	332 – 377 GHz	220 – 440 GHz	139-170 GHz	248-301 GHz
Band-width	45 GHz	220 GHz	31 GHz	53 GHz
Number of spaxels	1	1	100	100
Number of spectral channels	49	347	100	100
Spectral resolution	~380	~500	~500	~500
Number of KIDs (voxels)	49	347	10,000	10,000
Deployment	2017	2023-2024	2026-2029	



Optics and Cryogenics





The total number of detectors (voxels) including both Band-1 and 2 will reach ~20,000.
The maximum data rate shall be ~100 MB/sec (128 bit, 160 Hz sampling).

Summary

- Successful France-Japan collaboration studies using e.g., ALMA, Subaru Telescope, Hubble Space Telescope, James Webb Space Telescope on astrophysics
- Cosmology with Superconducting nanotechnology: TIFUUN for submillimeter-wave line intensity mapping based on integrated super-conducting spectroscopy (ISS) technology under Japan-Dutch-French collaboration

  → Narita-san's talk on TIFUUN
- Looking forward more fruitful collaborations