A proposal to NAOJ Science Roadmap:

LST
Large Submillimeter Telescope

Study of the formation of astronomical objects and structures through the promotion of the LST/AtLAST project and multi-dimensional submillimeter survey observations

KOHNO Kotaro (Univ. of Tokyo) on behalf of LST team

NAOJ Future Planning Symposium 2024:
Science Roadmap of NAOJ
December 3-6, 2024 @NAOJ

DAY3 December 5th (Thursday), 10:30-10:45 (10 min talk + 5 min for Q&A)

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

Summary of the proposal: Exploring new discovery space at submm

- **Quantum technology innovations for quantum computers**

impact

Superconducting nanotechnology

Developing **superconducting resonators and ultra-low-power amplifiers** for detector applications.

Big terahertz antenna technology

Creating high-precision antenna, optics, and detection technologies through **architecture and statistical science integration.**

impact

- **Deep space ground-based antennas for planetary and lunar exploration.**
- **Enhancing "Beyond 5G/6G" networks for a safer, more convenient society.**

- **Complementing Frontier observatories**

impact

Multi-dimensional astronomical survey and exploration

Exploring **cosmic multi-scale structure formation** theories through **multidimensional sky surveys.**

Astro data science

Developing signal processing technologies for **large multidimensional data through engineering and mathematics.**

impact

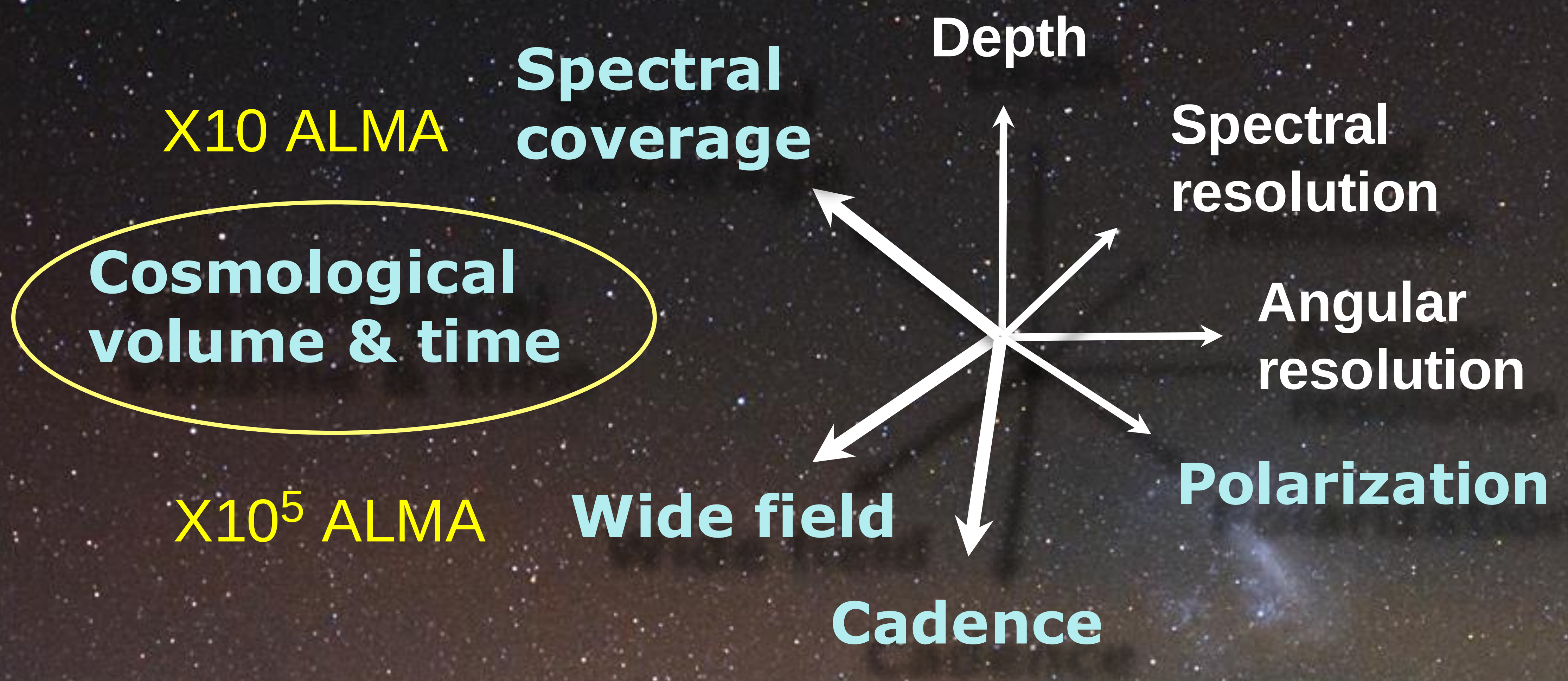
- **Advancing statistical science for noise reduction and precise medical imaging.**
- **Supporting non-destructive diagnostics of aging infrastructure with big data analysis.**

Further impact

- **Demonstrating resilient energy systems in extreme environments.**
- **Advancing renewable energy and SDG initiatives.**

Roles of single-dish telescopes in the ALMA era

New discovery space?



X10 ALMA

Spectral coverage

Depth

Spectral resolution

Cosmological volume & time

Angular resolution

X10^5 ALMA

Wide field

Polarization

Cadence

Image fidelity

ALMA still needs high quality total power data for spatially extended emission

e.g., Plunkett, Hacar, et al. 2023, PASP, 135, id.034501 (29pp.)

VLBI (including EHT) requires more antennas for better “uv” coverage
➔ better image fidelity

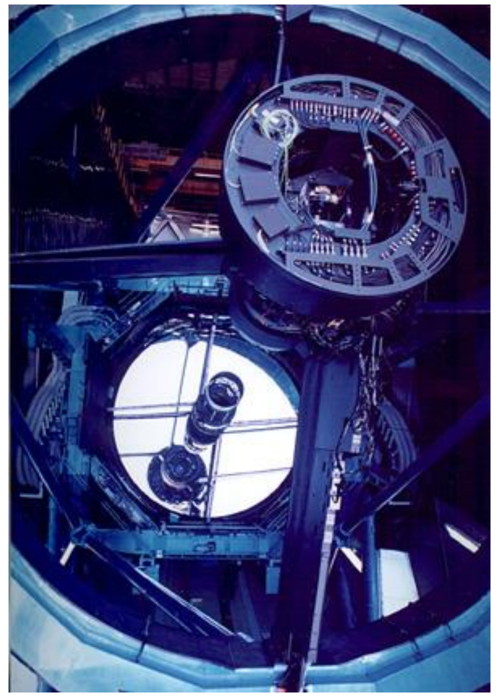
https://www.eso.org/public/images/potw1315a/

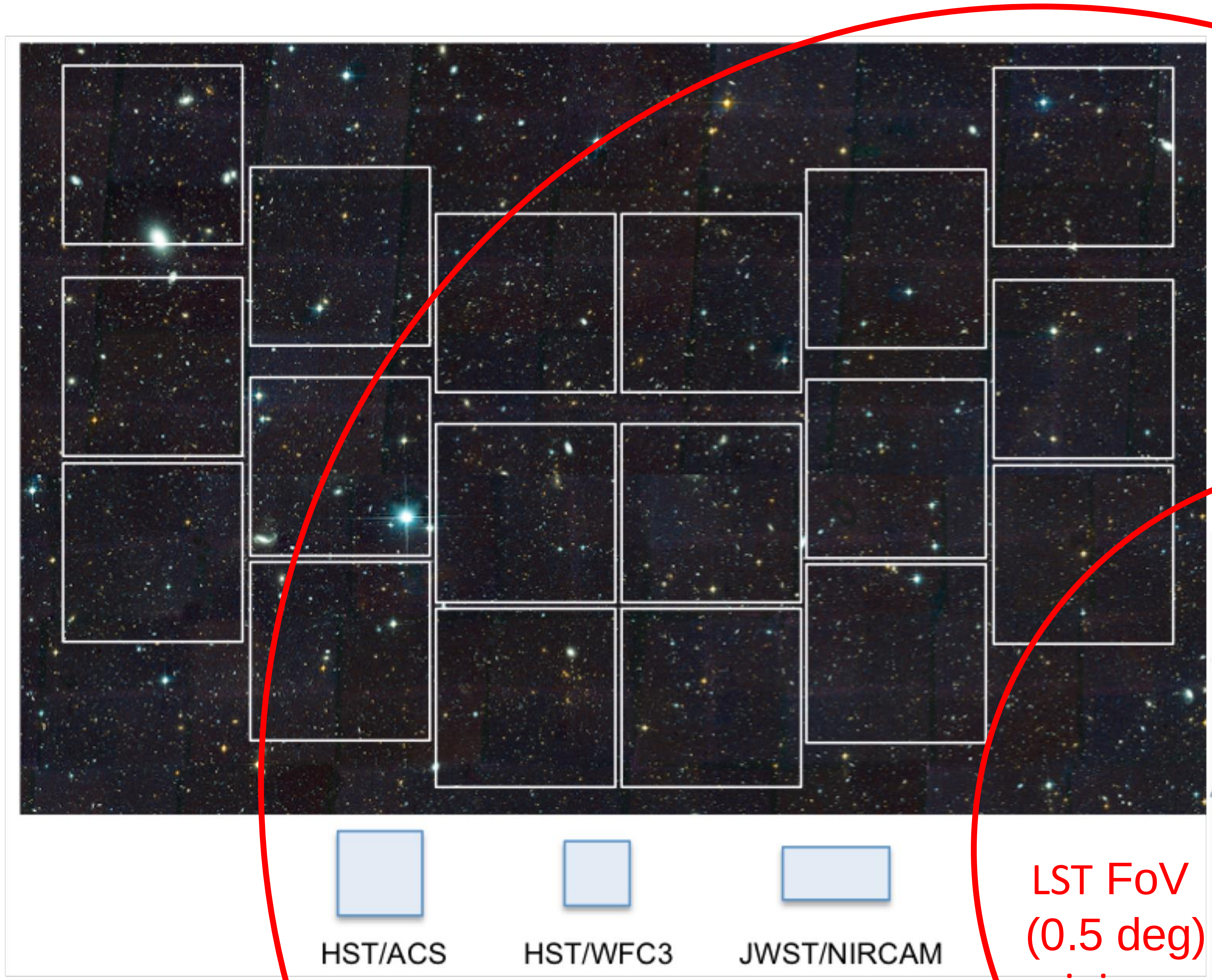
Subaru, Roman, GREX-PLUS, PRIMA → TMT, JWST @optical/infrared
LST/AtLAST → ALMA @mm/submm

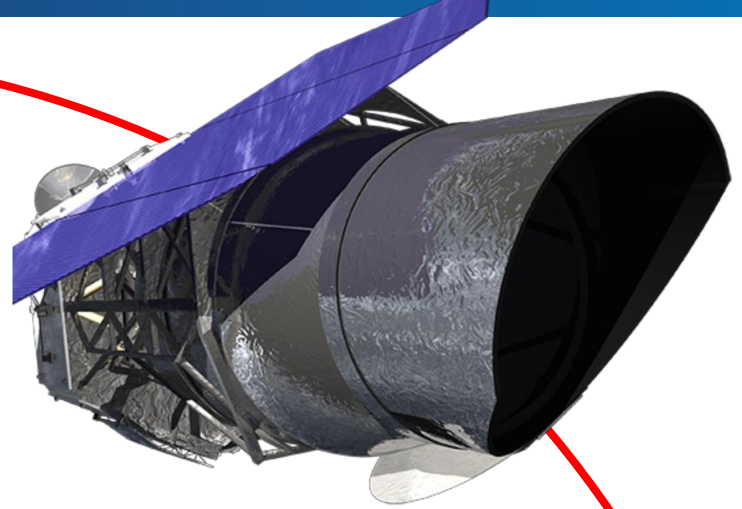
Hyper Suprime-Cam

Moon (average size seen from Earth)

SUBARU







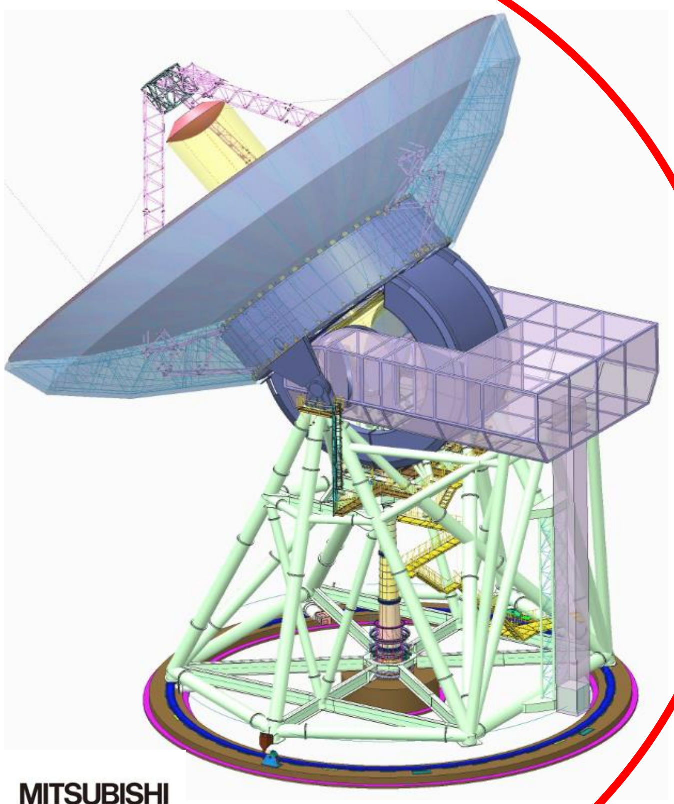
Roman Space Telescope

LST FoV (1 deg) goal

(0.3 arcmin = 0.005 deg)

ALMA/B7

LST FoV (0.5 deg) minimum



MITSUBISHI ELECTRIC

JWST

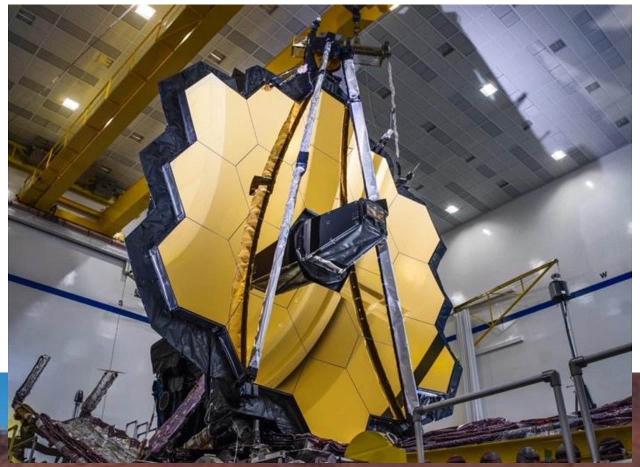


Photo: WeiHao Wang

Global discussion on the future of mm-FIR astrophysics

Slide
by Y. Tamura

International situation: Kavli-IAU WS on Global Coordination 2024

Probing the Universe from far-infrared to millimeter wavelengths: future facilities and their synergies

- WS aims to identify the scientific and technological significance of the far-IR to mm-wave astronomy beyond the 2030s (**findings**) and to present the pathways (**recommendations**) for future advancements from an international perspective. (Note: SKA1 is out of the WS scope)
- SOC: Bolatto, Cleeves, Dale, Helou, Motohara, Roche, Tacconi, van Dishoeck, Zmuidzinas
- ~70 people participated.
  From Japan, Motohara-san (SOC), Iguchi-san,
  ↪ALMA
  Inami-san, Kohno-san, Tamura
  ↪PRIMA ↪Galaxies ↪LST
  (, Endo-san@TU Delft, Fujimoto-san @UT Austin)
- Workshop report: arXiv:2409.07570


Kavli-IAU Workshop on Global Coordination
Probing the Universe From Far-infrared to Millimeter Wavelengths: Future Facilities and Their Synergies
March 26-28, 2024


Report of the Kavli-IAU Workshop on Global Coordination
Probing the Universe from far-infrared to millimeter wavelengths: future facilities and their synergies
Workshop held March 26-28, 2024 at Caltech, Pasadena, CA, USA

Helou, Zmuidzinas, van Dishoeck et al., arXiv:2409.07570

https://www.arxiv.org/abs/2409.07570

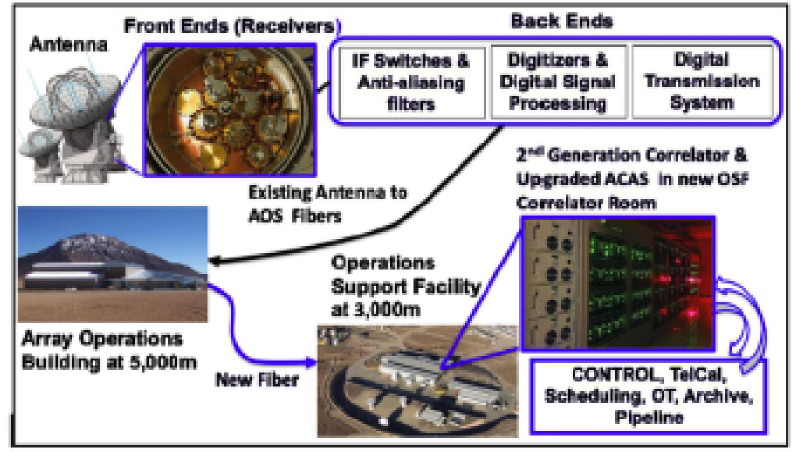
Kavli-IAU WS on Global Coordination 2024: Recommendations

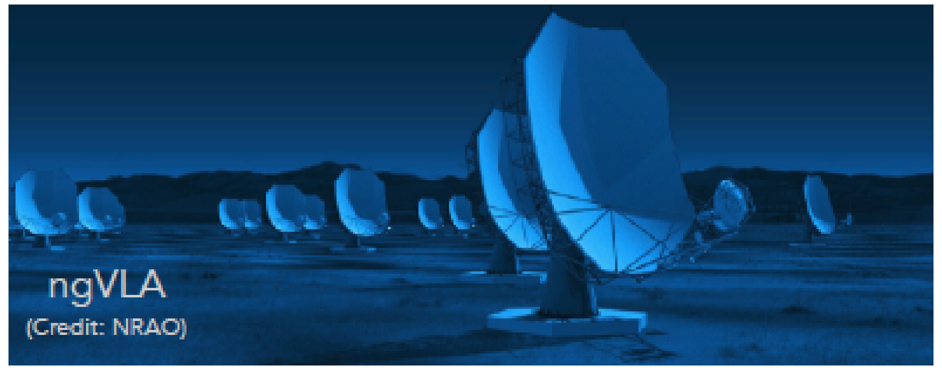
Slide
by Y. Tamura

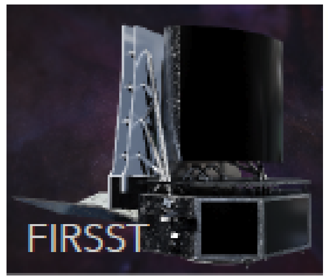
- Completing ALMA 2030 (WSU) and envisioning ALMA 2040
    - Necessary to make ALMA more sensitive. WSU is the 1st priority. Expanding baselines.
    - ALMA 2040, in which an order of gains in spectral line sensitivity should be considered ("10x ALMA", e.g. cheap, large antennas at core frequency bands at 0.8-1.4 mm)
- Promoting ngVLA (Note: SKA1 was out of the WS scope)
    - Maintain the momentum toward construction in 2020's.
    - Expand the engagement of int'l communities, which is heavily shared with ALMA.
- Far-infrared probe (FIRSST, PRIMA🏆, SALTUS) *alphabetical order
    - Necessary to fill the gap between *JWST* (< 30 μm) and ALMA (> 350 μm) that has been lacking since *Herschel* (-2013).
    - Loss of sciences, technologies and industries must be avoided.
- Large submm single dish (AtLAST/LST)
    - Further study on a ground-based large-aperture submm telescope is encouraged.
    - Vigorous technological development should be pursued at current/near-future facilities (LMT, FYST/CCAT-p, ..) and for high-frequency VLBI (e.g., ngEHT, BHEX).

Opportunities are unfolding in front of us.
How should we choose them under the (harsh) circumstances?

ALMA WSU (Carpenter+2023)



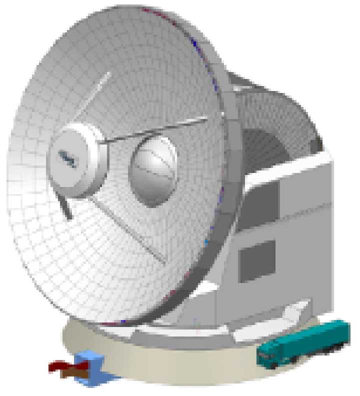

ngVLA
(Credit: NRAO)

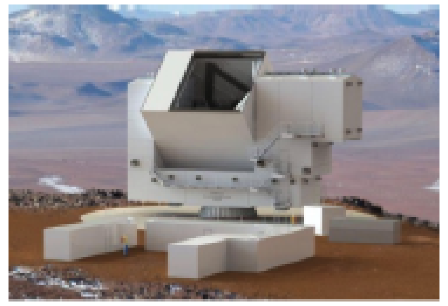

FIRSST

PRIMA



SALTUS


AtLAST design study
(Mroczkowski+2024)


FYST
(https://www.ccatobservatory.org)

2. Science goals and technical specifications

3. Science Objectives
4. Science Investigations

LST White paper

https://www.lstobservatory.org/

1. What processes drive the formation and evolution of stars, galaxies, and black holes in the earliest stages of cosmic history?
2. How do star clusters, stars, planetary systems including our solar system, and interstellar matter evolve in diverse environments?
3. What types of time-variable objects exist in the sub/millimeter regimes, and how ubiquitous are there?
4. What physical principles can describe the formation of structures across spatial scales ranging from molecular cloud cores to galaxy clusters?

	Where are all the baryons?	***How do structures interact with their environments?***	***What does the time-varying (sub-)mm sky look like?***
Detailed science goal	Measuring the total gas and dust content of the Milky Way and other galaxies, in the interstellar, circumgalactic, and intergalactic media, reaching down to the sensitivities required to probe the typical populations of sub-mm sources.	Understanding the lifecycle of gas and dust near and far; mapping the baryon cycle on multiple-scales; observing the interplay between gravity, radiation, turbulence, magnetic fields, and chemistry and their mutual feedback.	Identifying the mechanisms responsible for time variability across astrophysical sources: from the Solar corona and other objects in our solar system to luminosity bursts in everything from protostars to active galactic nuclei.
Detailed technical specification	***High sensitivity to the faint signals*** (at sub-mK levels) ***on large scales*** ($\geq$1 deg^2) from even the most diffuse and cold gas through sub-mm line tracers. Wide field ($>$500 deg^2) continuum surveys capturing the plane of our galaxy and resolving 80% of the cosmic infrared background, probing typical populations and looking back over 90% of the age of the Universe.	***High spectral resolution*** and ***polarisation*** measurements on the relevant size scales for cores (0.1 pc, our galaxy), clumps (10 pc, nearby galaxies) and cloud complexes ($\sim$ few kpc, distant universe) to quantify the chemistry, disentangle the dynamics, and measure the magnetic fields working together to shape the evolution of structures within their larger-scale environments.	An operations model that allows for ***highly cadenced and rapid response observations*** and data reduction pipelines with in-built ***transient detection algorithms***; high time-resolution (few seconds) observations of our Sun and other stars.

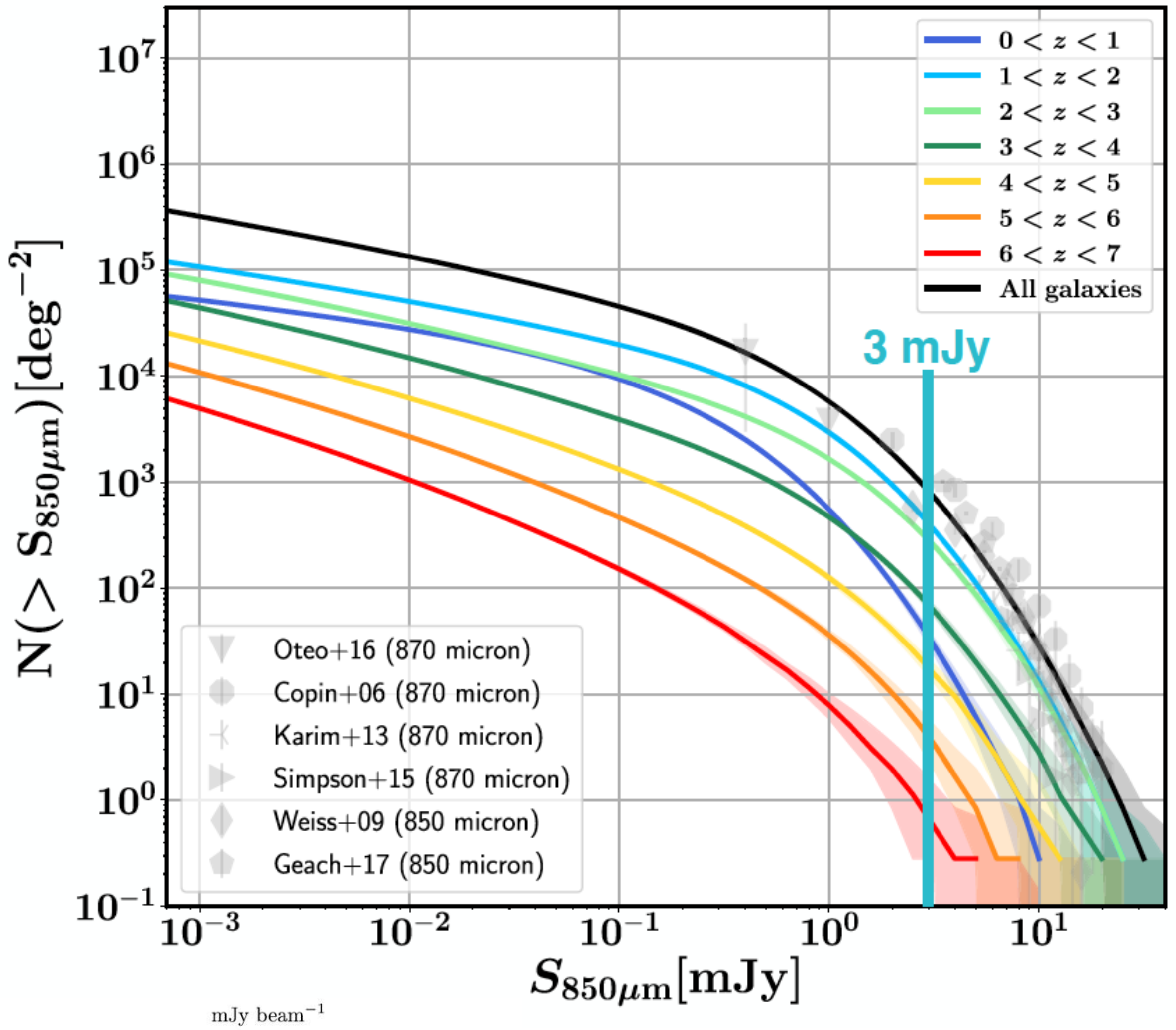
AtLAST Science Overview Report

https://arxiv.org/pdf/2407.01413

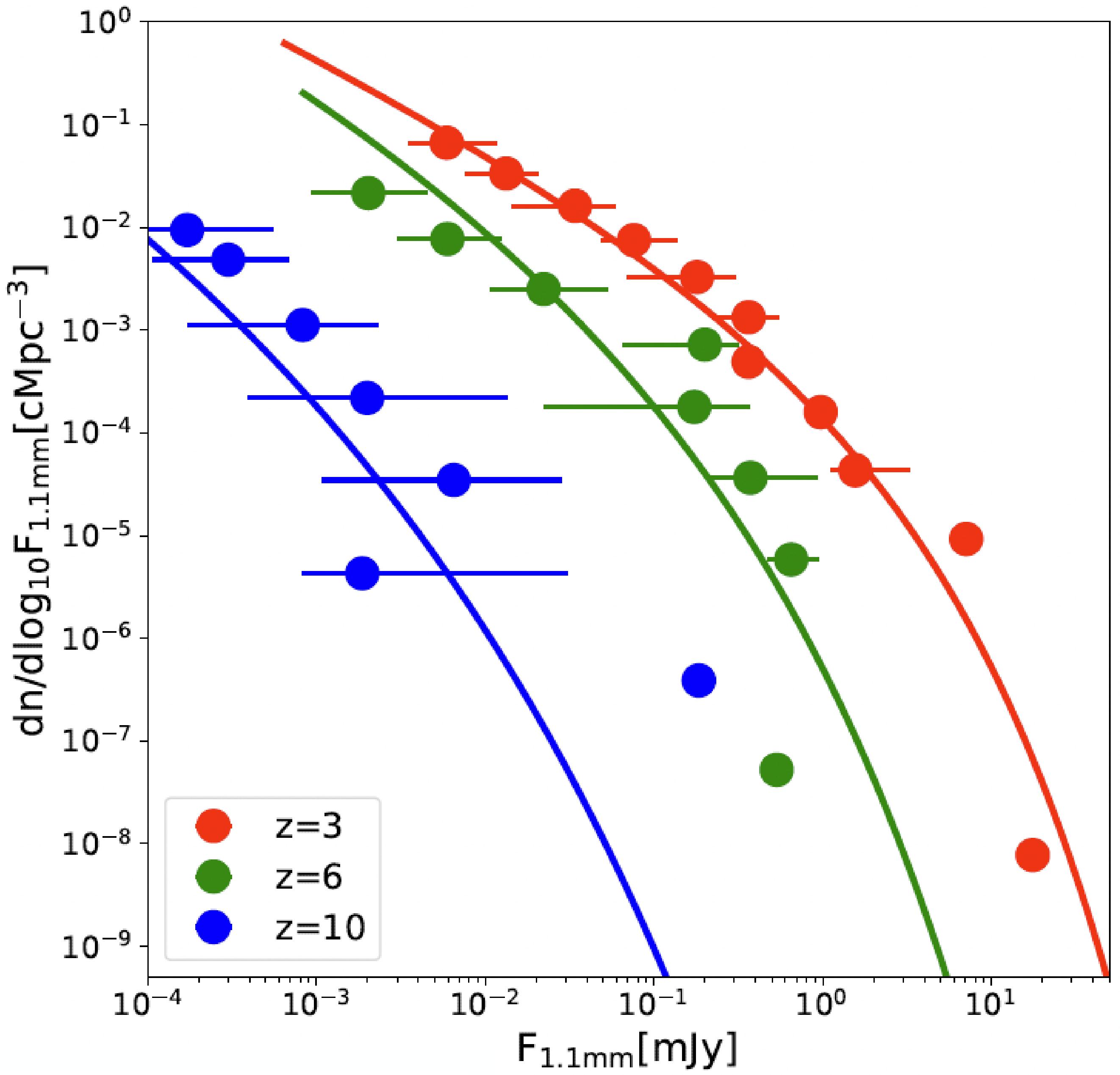
Need for a wide-field Imager with high angular resolution: Exploring metal enrichment in high-z galaxies

- 200 deg^2 multi-color survey with 1 mJy depth (5 σ) ➔ 10^3 galaxies at z>6 ➔ Ultra-wide-band spectroscopy survey

Statistically large (10^5) sample at z~6 can be derived if a survey of 1 Gpc3 with a sensitivity of 0.1 mJy ➔ tracing large scale structures to understand their relation to e.g., AGNs and reionization

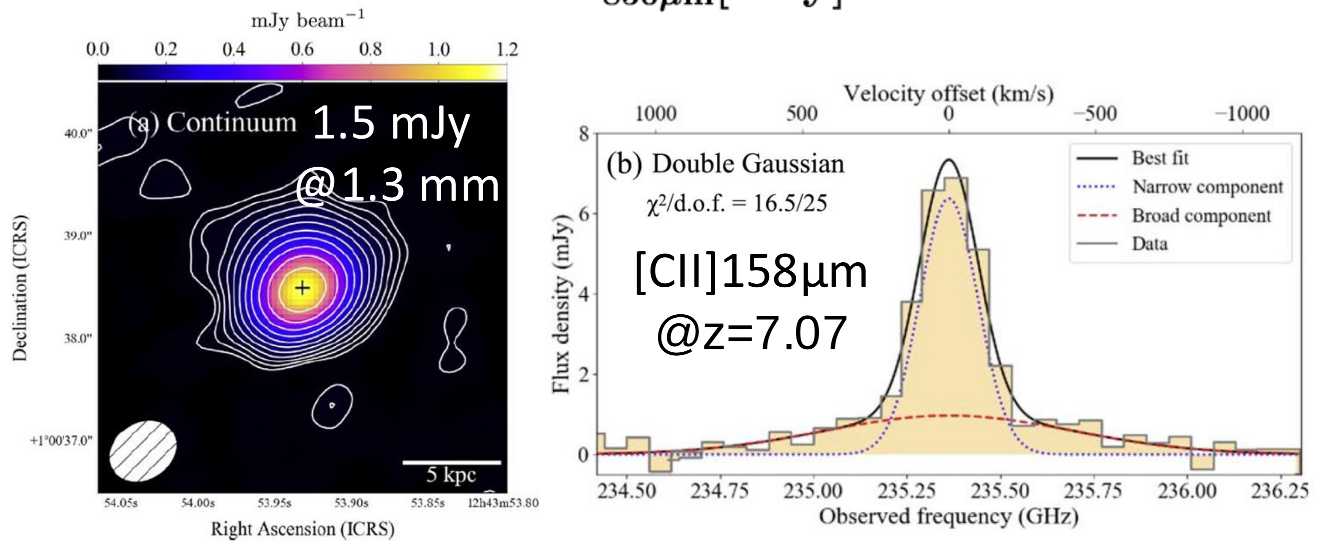


Talk by Tadaki,-san, https://sites.google.com/view/ng-singledish-ws2021/

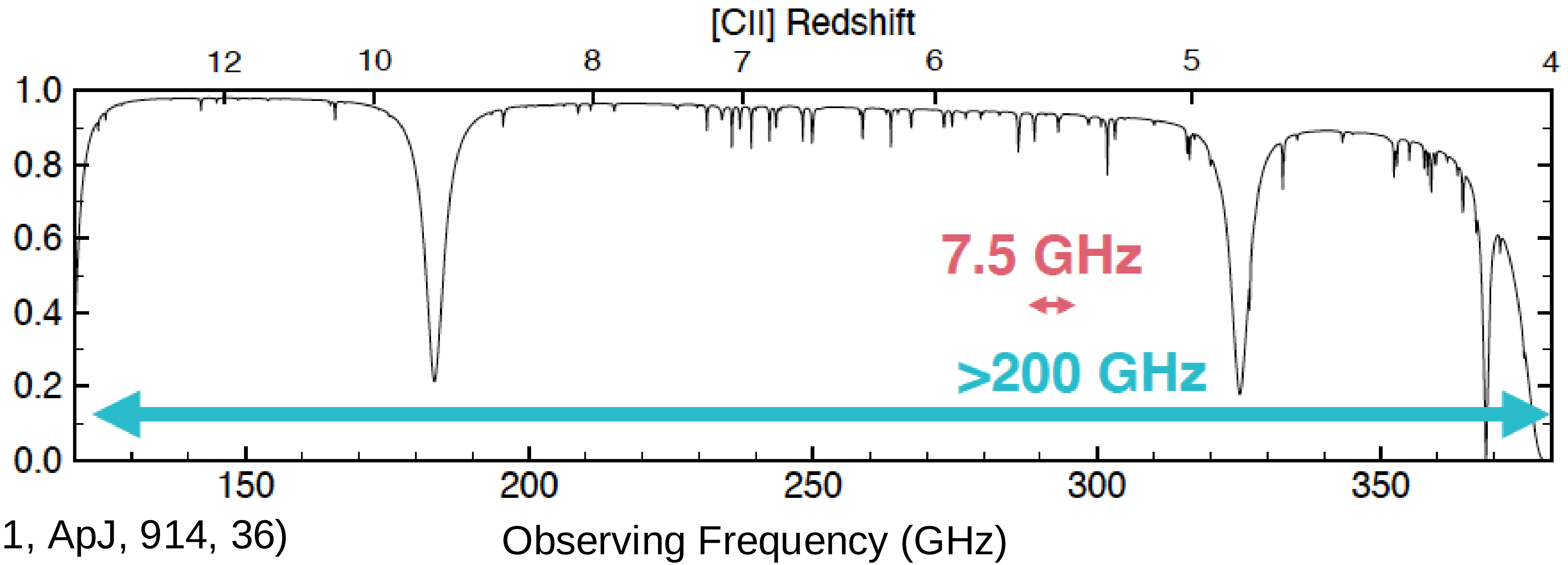


LST white paper, section 2.1.1, Fig. 2.8

Yajima. H., et al. 2022, MNRAS, 509, 4037

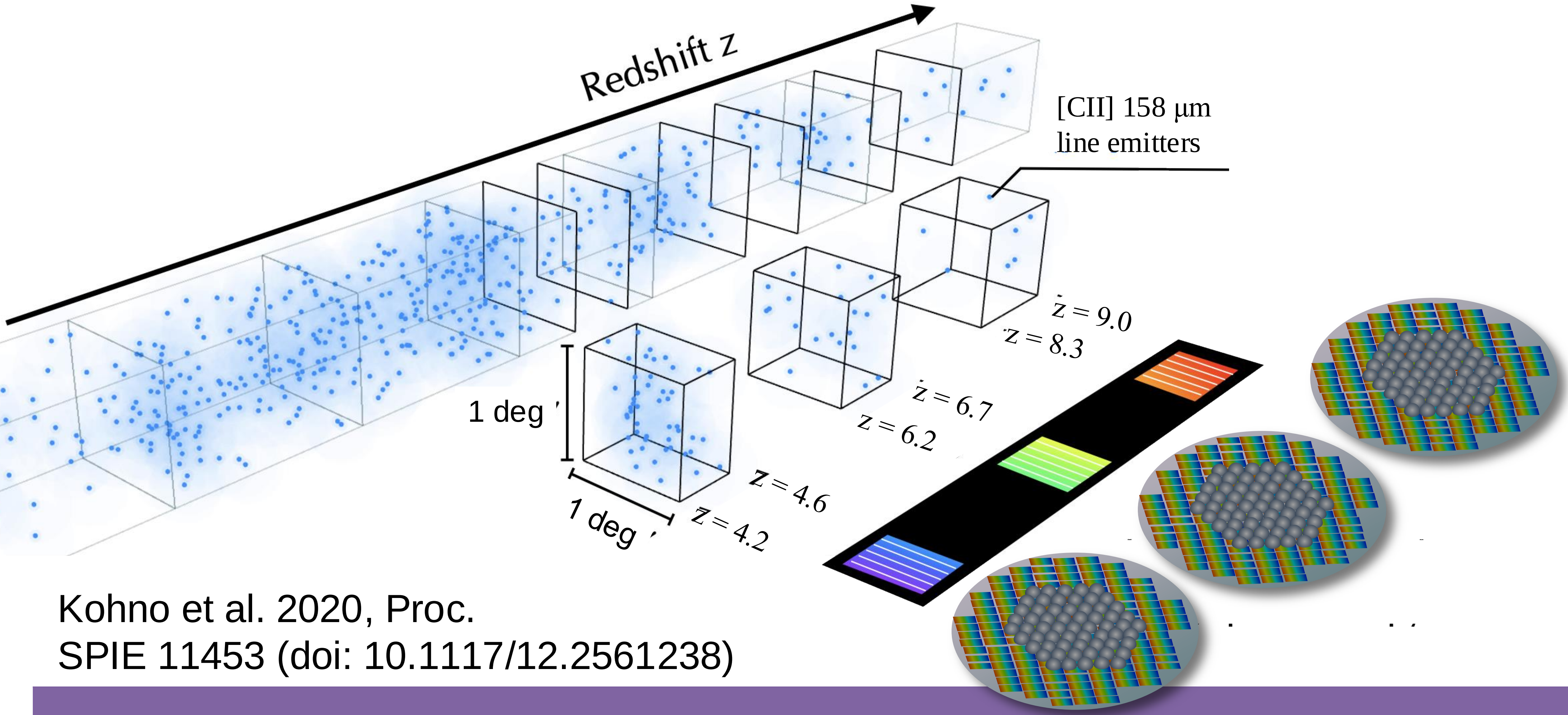


Subaru/HSC-selected low-luminosity quasar@z=7.07 (Izumi, T., et al. 2021, ApJ, 914, 36)

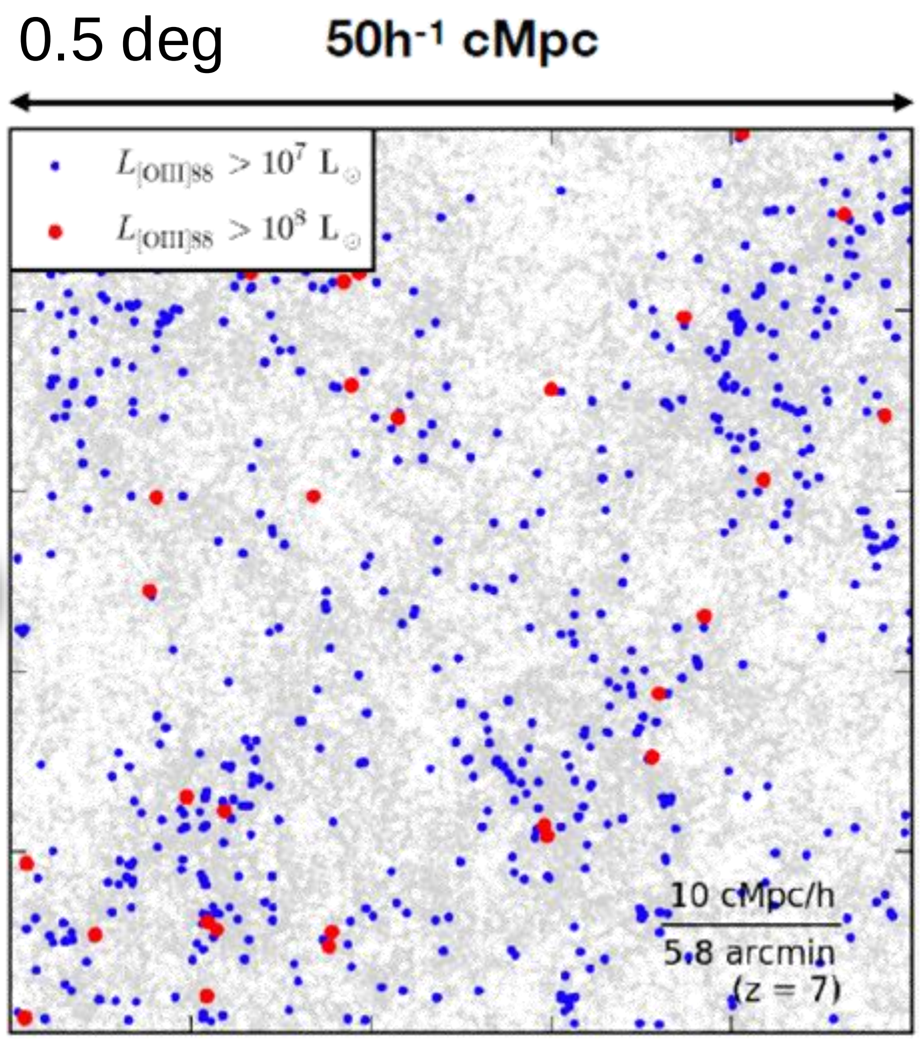


DESHIMA-like spectrograph
FINER-like receiver
can be powerful redshift machine using [CII], CO, etc.

Need for a wide-field Imager with high angular resolution: Exploring metal enrichment in high-z galaxies



Kohno et al. 2020, Proc.
SPIE 11453 (doi: 10.1117/12.2561238)



(0.3 arcmin = 0.005 deg)

ALMA/B7

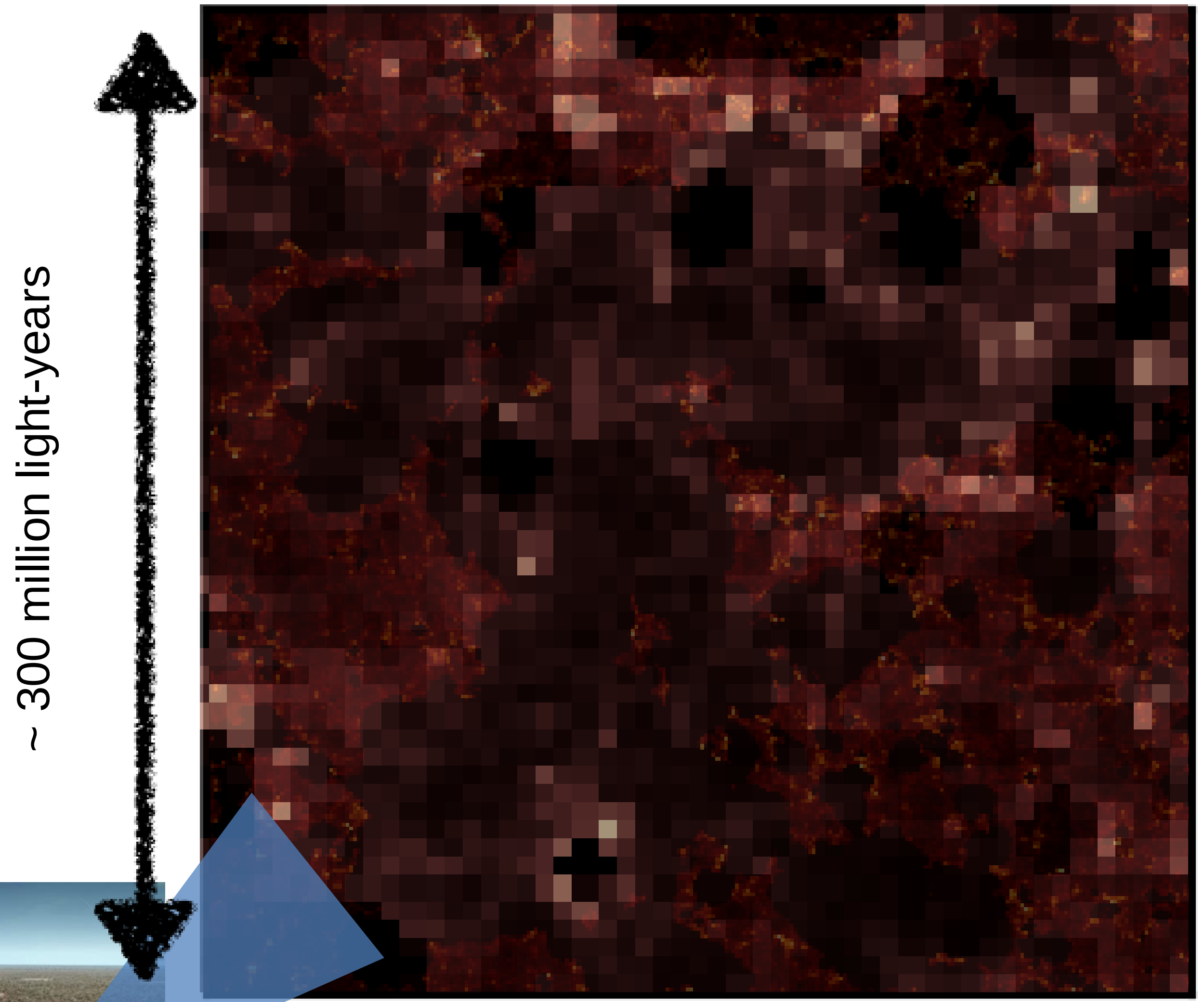
Simulated distribution of [OIII] 88 μm emitters @ z~7

Moriwaki et al. 2018, MNRAS, 481, L84

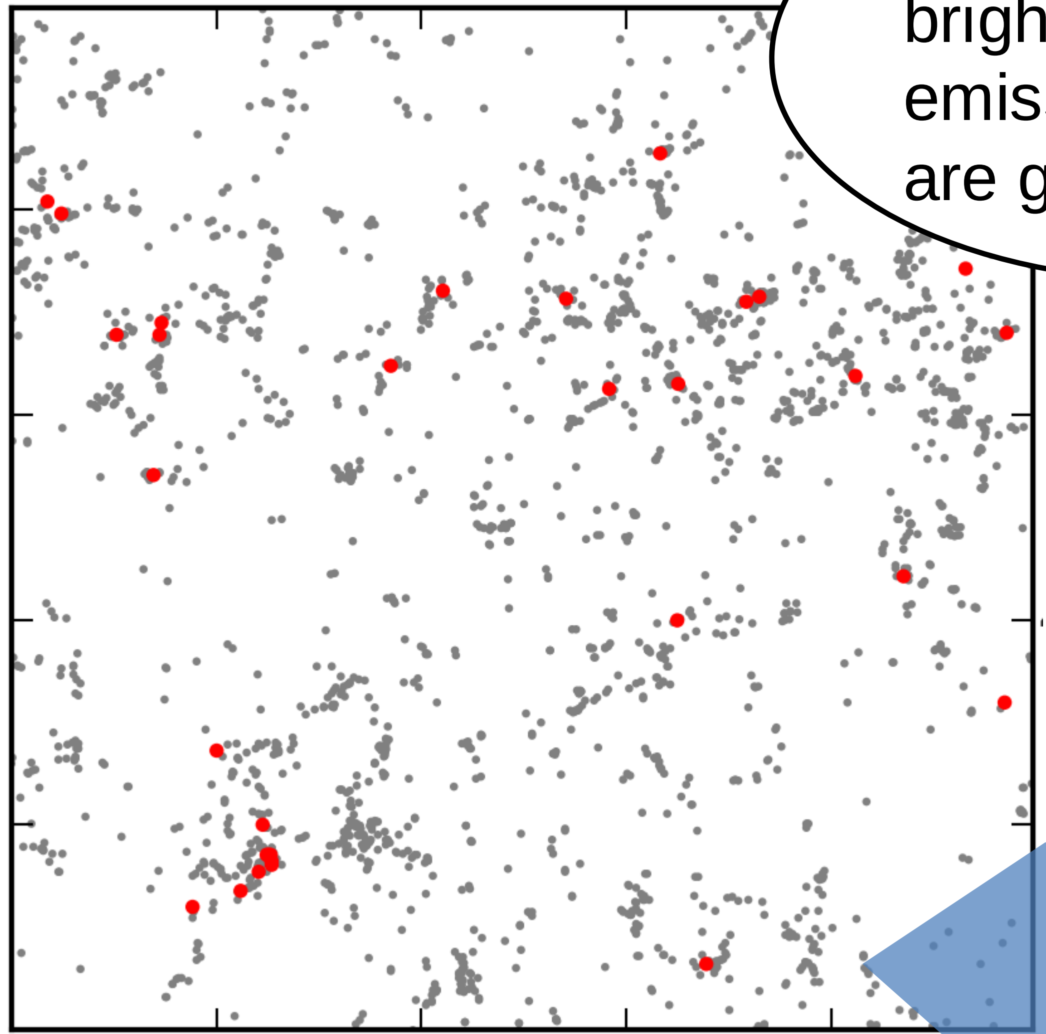
Band	Center frequency (wavelength)	Frequency range	Redshift range		Line sensitivity (5σ)	[OIII] 88μm line luminosity (5σ)
	3-band imaging spectrograph **R=2,000, ~1.5 M detectors**		[OIII] 88 μm	[CII] 158 μm	(mJy)	(L☉)
Band1	197 GHz (1.5 mm)	190 – 204 GHz	15.7 – 16.9	**8.32 – 9.00**	0.49	5.0 x 10^8
Band2	255 GHz (1.2 mm)	246 – 265 GHz	11.8 – 12.8	6.17 – 6.73	0.66	4.6 x 10^8
Band3	352 GHz (0.85 mm)	339 – 365 GHz	**8.31 – 9.00**	4.21 – 4.60	1.0	4.3 x 10^8

Need for a wide-field Imager with high angular resolution: Neutral Hydrogen at the Epoch of Reionization

Slides by K. Moriwaki

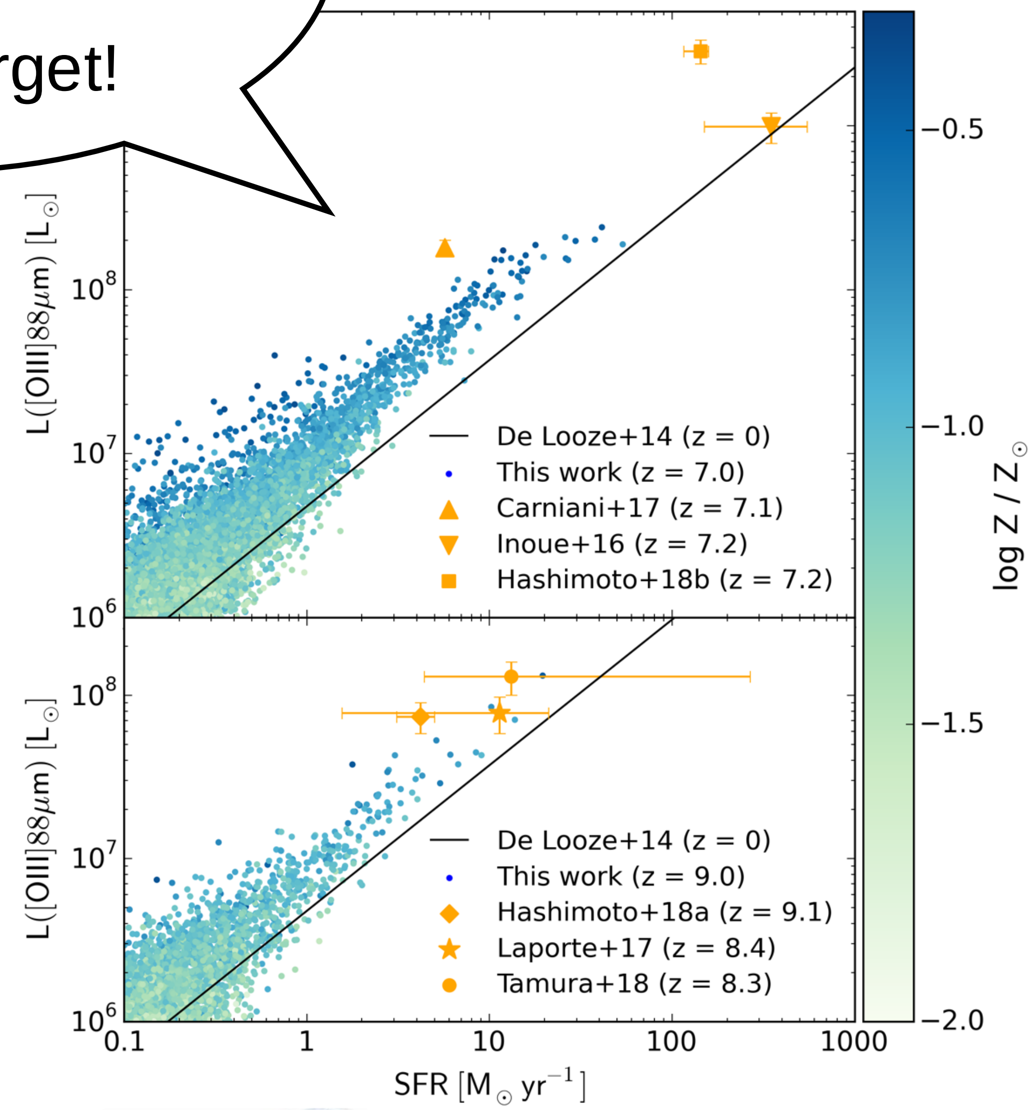


Neutral hydrogen distribution
(21cm line intensity map)



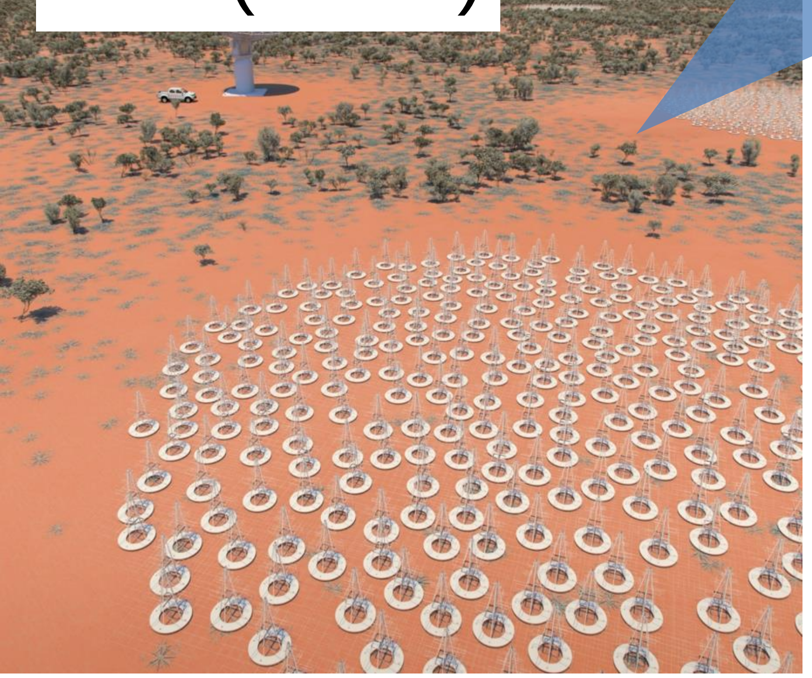
Galaxies

Galaxies with
bright oxygen line
emissions
are good target!



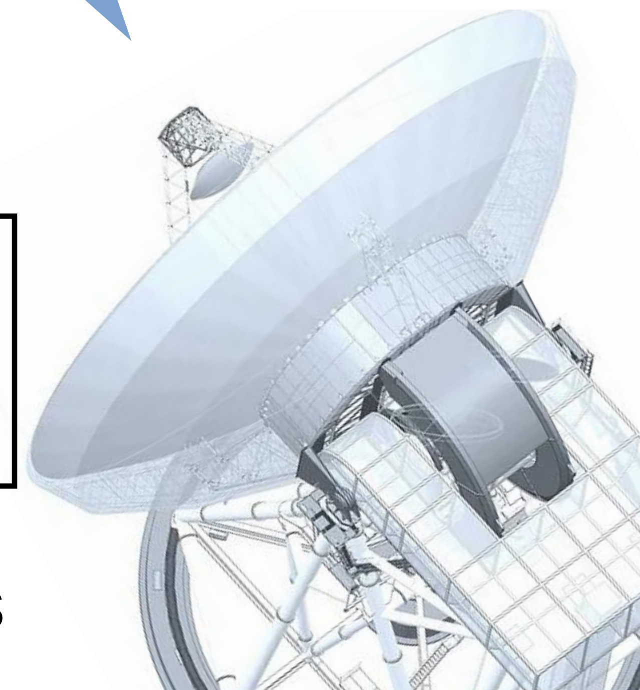
Moriwaki et al. 2018, MNRAS, 481, L84

SKA (2028-)



Combine galaxy survey data with 21-cm data to mitigate contaminations

In particular, emission-line galaxies

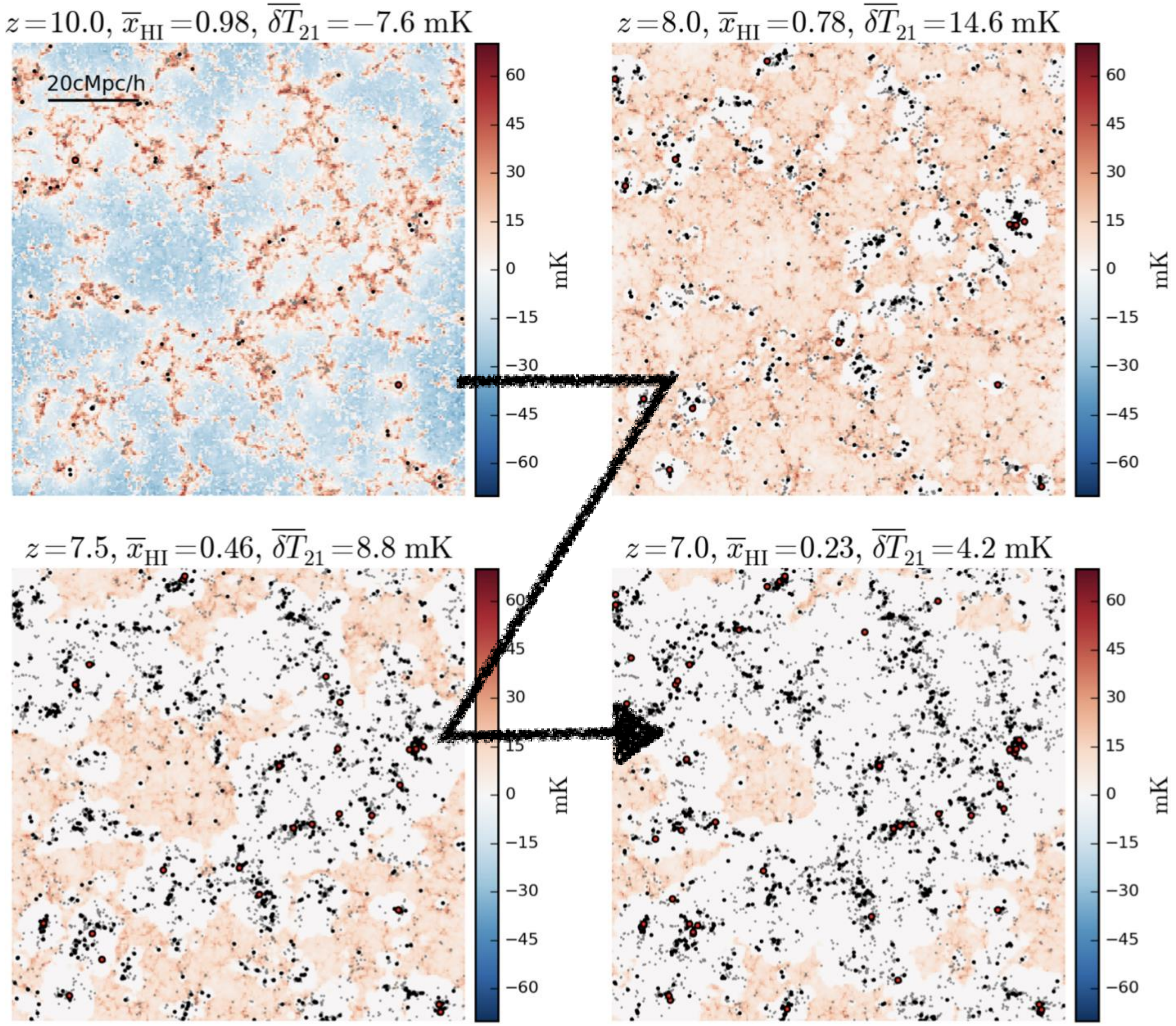


LST

Need for a wide-field Imager with high angular resolution: Neutral Hydrogen at the Epoch of Reionization

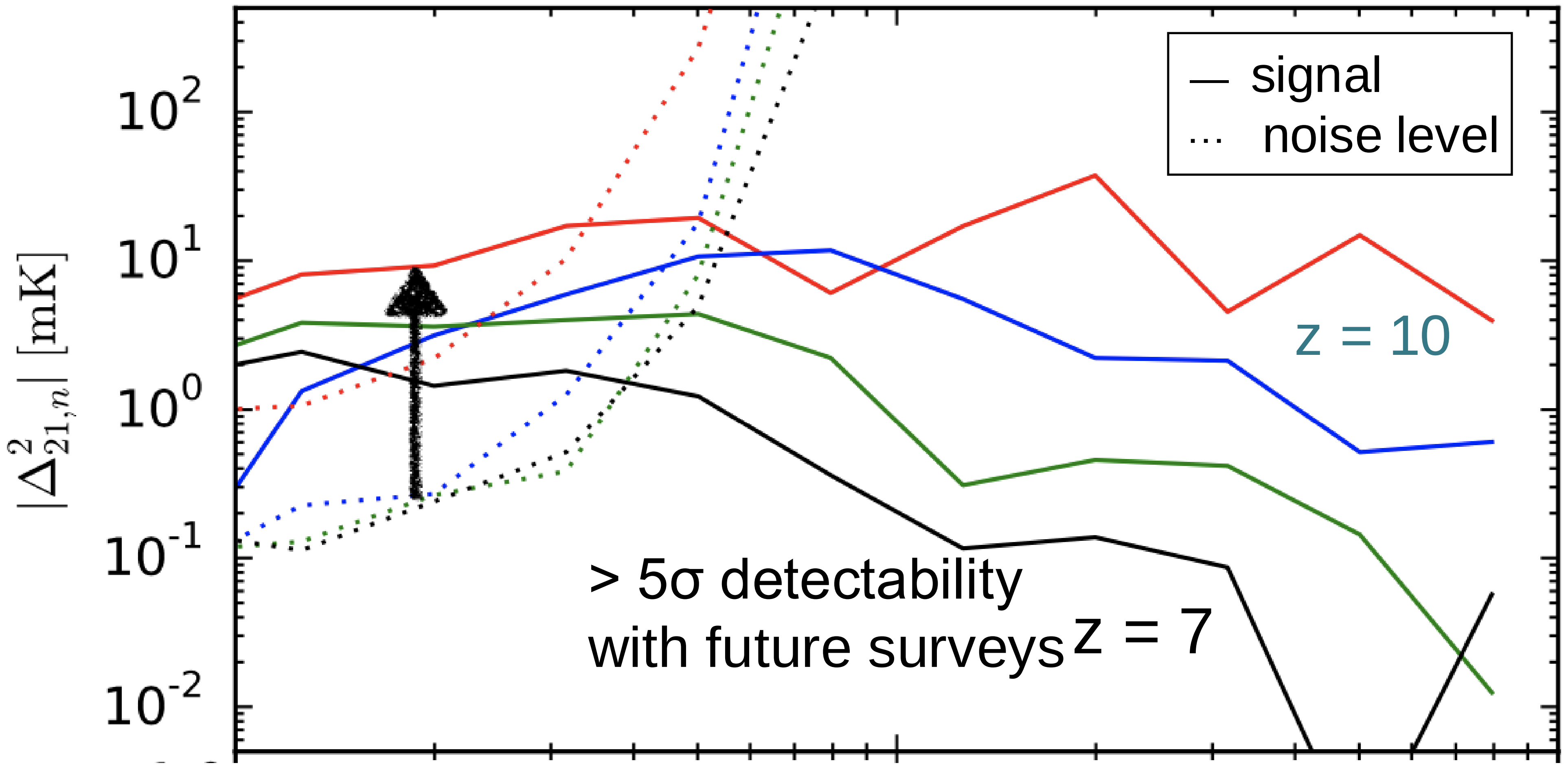
Slides by K. Moriwaki

Simulated distributions



Moriwaki et al. 2019, MNRAS, 489, 2471

Predicted
Cross-power spectrum between
21-cm (SKA) × [OIII] emitters



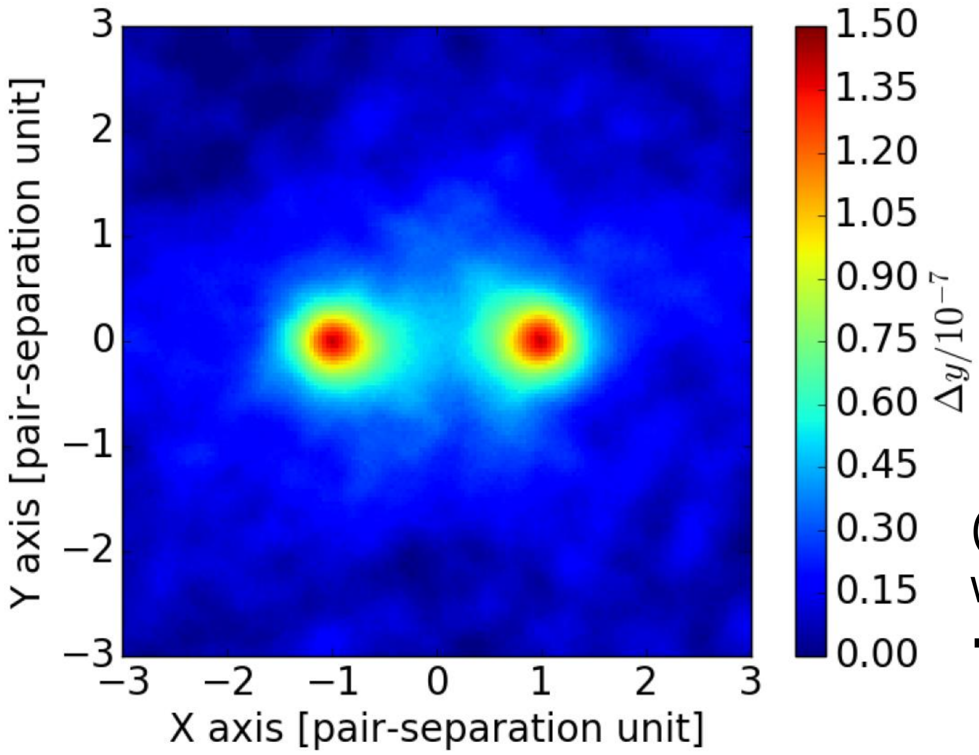
Scale k [h/Mpc]

Large scale ⟷ Small scale

Signals at very distant universe (z = 10) can be detected.
→ Probes for the progress of the reionization

Need for a wide-field Imager with high angular resolution: Missing baryon search via Sunyaev-Zeldovich effect

- SZE provides the ideal observational tool for the study of the hot baryonic component of cosmic matter,
- from the several tens of Mpc-scale intergalactic filaments, to the Mpc intracluster medium (ICM), all the way down to the circumgalactic medium (CGM) surrounding individual galaxies



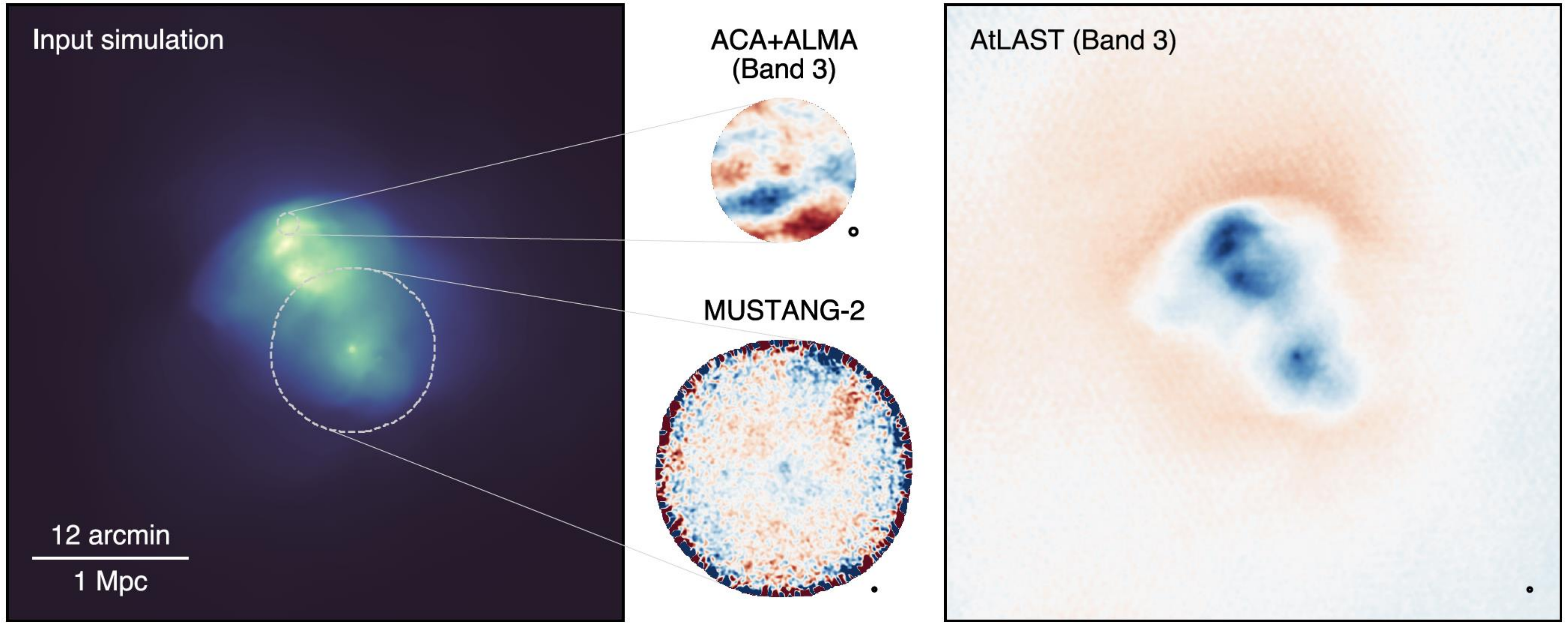
(Left) Detection of excess SZE signal (Comptn Y parameter) between galaxy cluster pairs by stacking of Planck data, suggesting the missing baron (WHIM)

Tanimura, H., et al. 2019, MNRAS, 483, 223

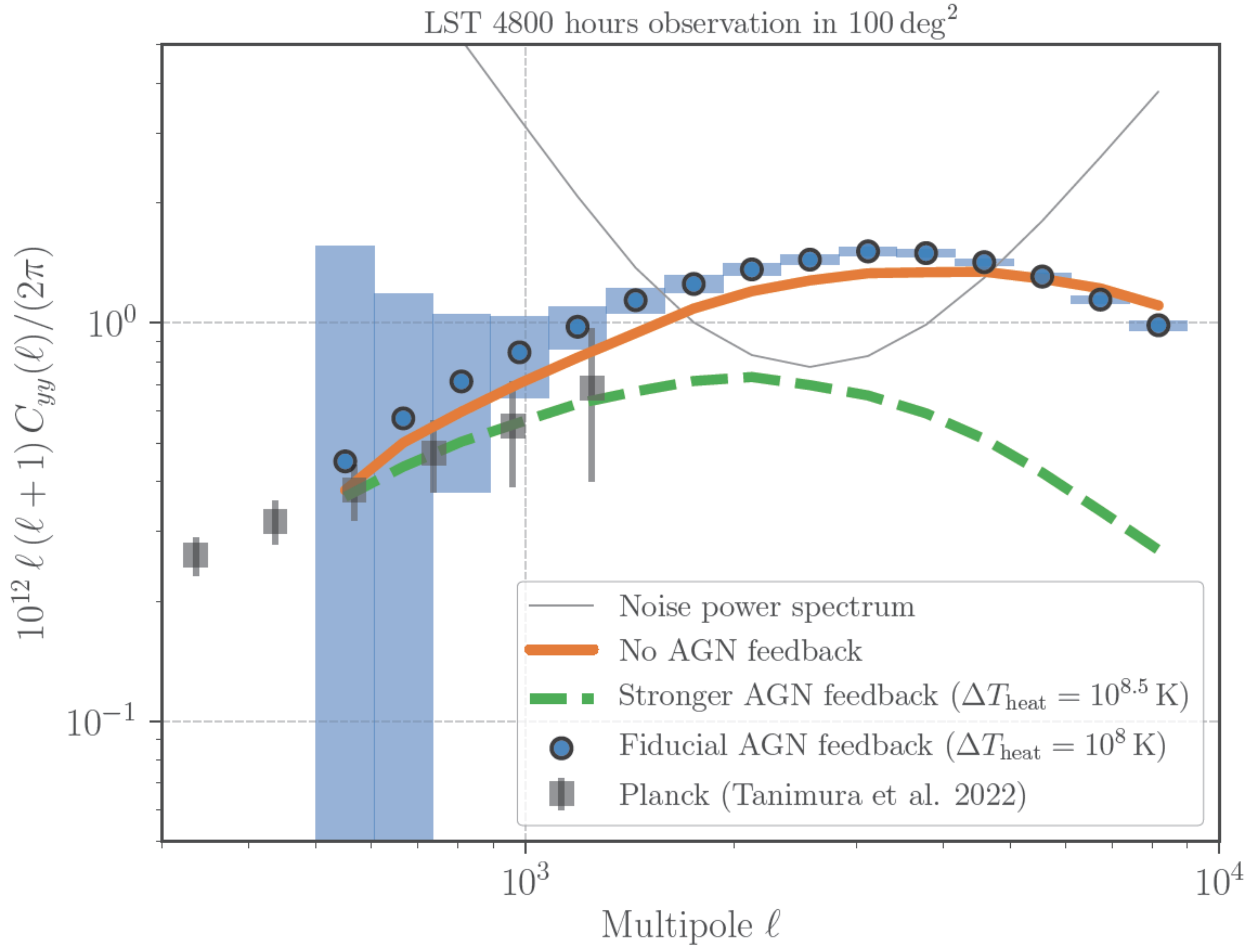
(Bottom) Compton Y parameter power spectrum with 100 deg^2, LST 4,800 hour observations

➔ will constrain Mpc scale AGN feedback

LST white paper, section 3.3.2, Fig. 3.18

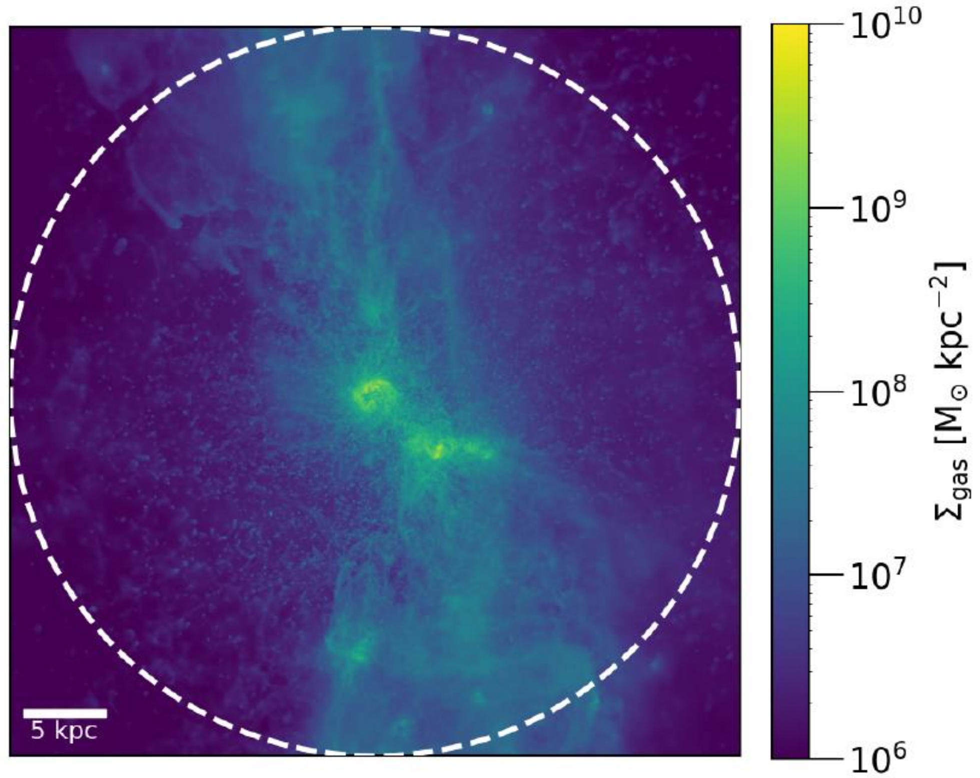


Di Mascolo et al. 2024, Open Res Europe, 4:113

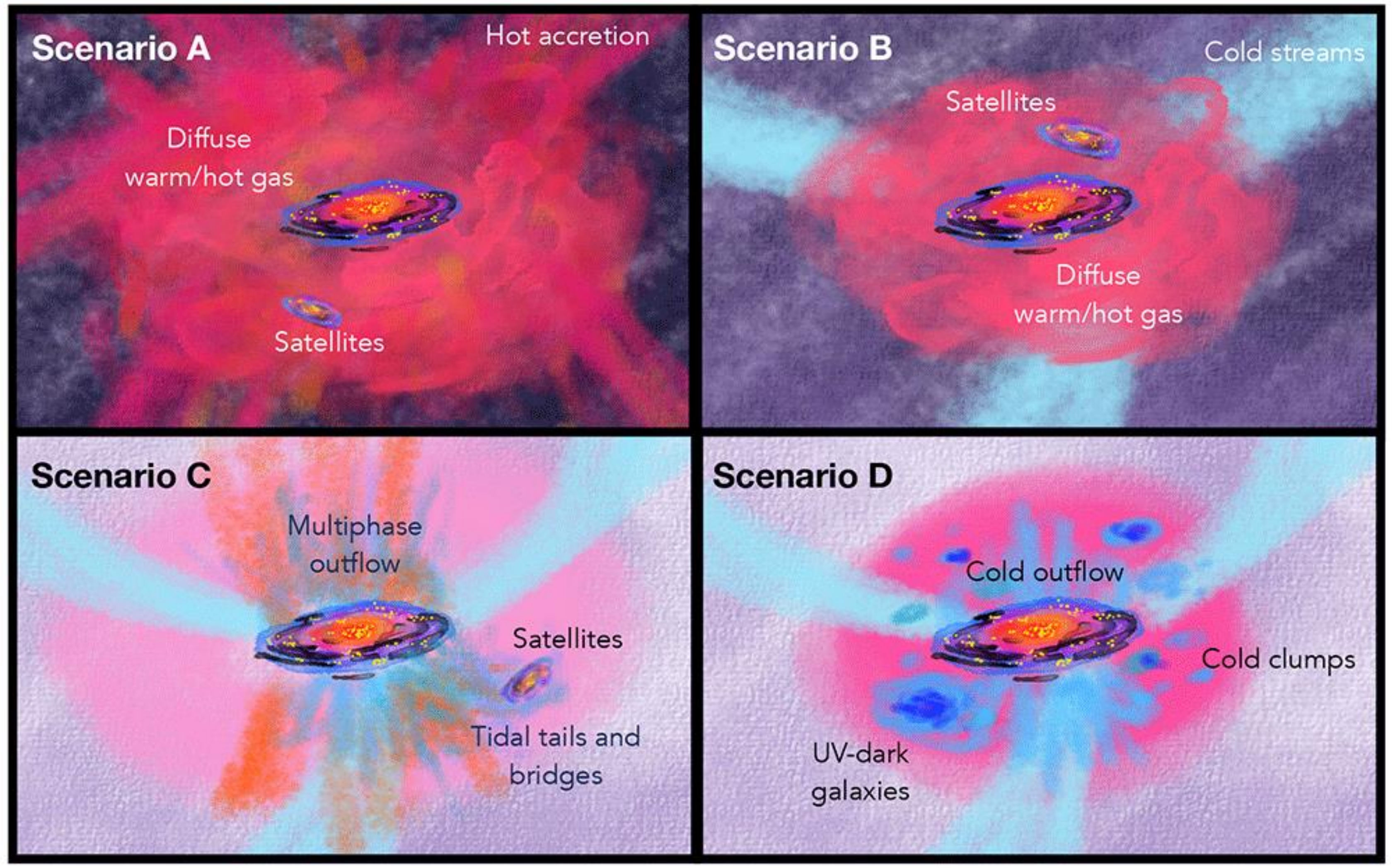


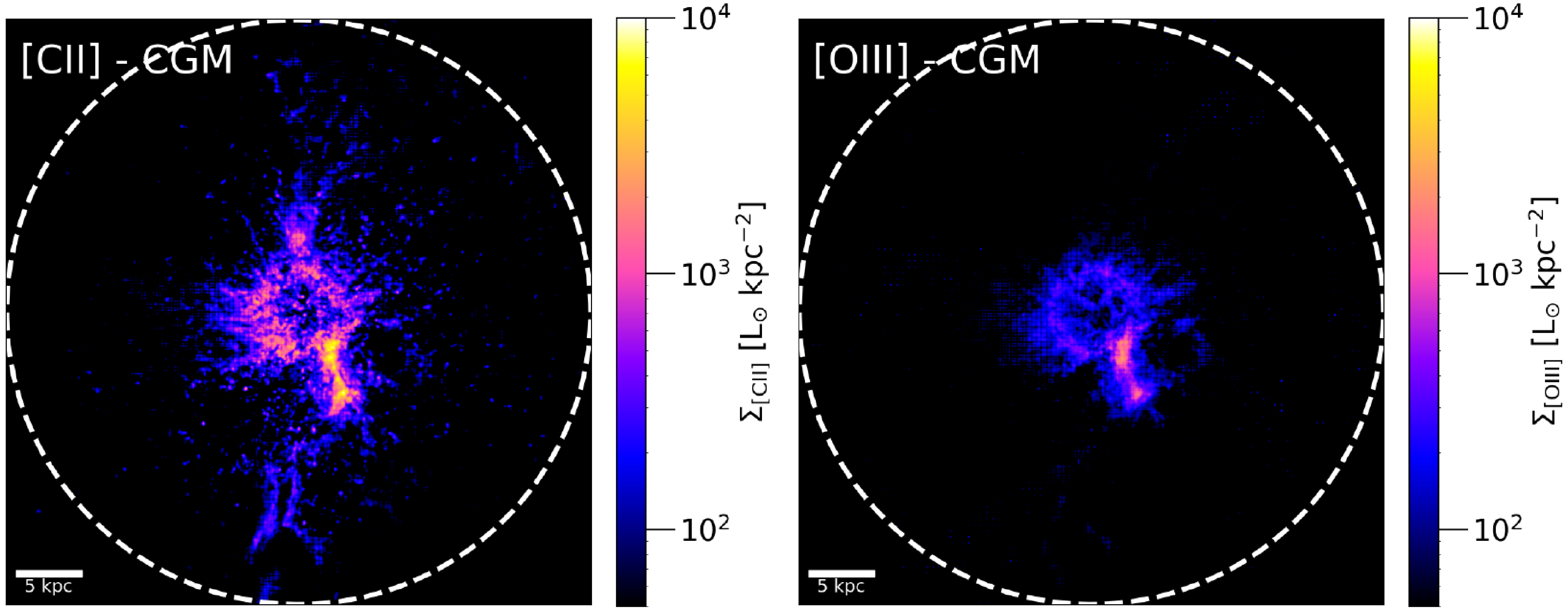
Need for a wide-field Imager with high angular resolution: Explore baryon cycle via circum-galactic medium

- Little is known about the physical properties of the more diffuse and lower surface brightness reservoir of gas and dust that extends beyond ISM scales and fills dark matter haloes of galaxies up to their virial radii, the circum-galactic medium (CGM).
- New theoretical studies increasingly stress the relevance of the latter for understanding the feedback and feeding mechanisms that shape galaxies across cosmic times, whose cumulative effects leave clear imprints into the CGM.



Simulated CGM distribution (left) and [CII] 158 μm and [OIII] 88 μm (bottom panels) at redshift z = 6.5



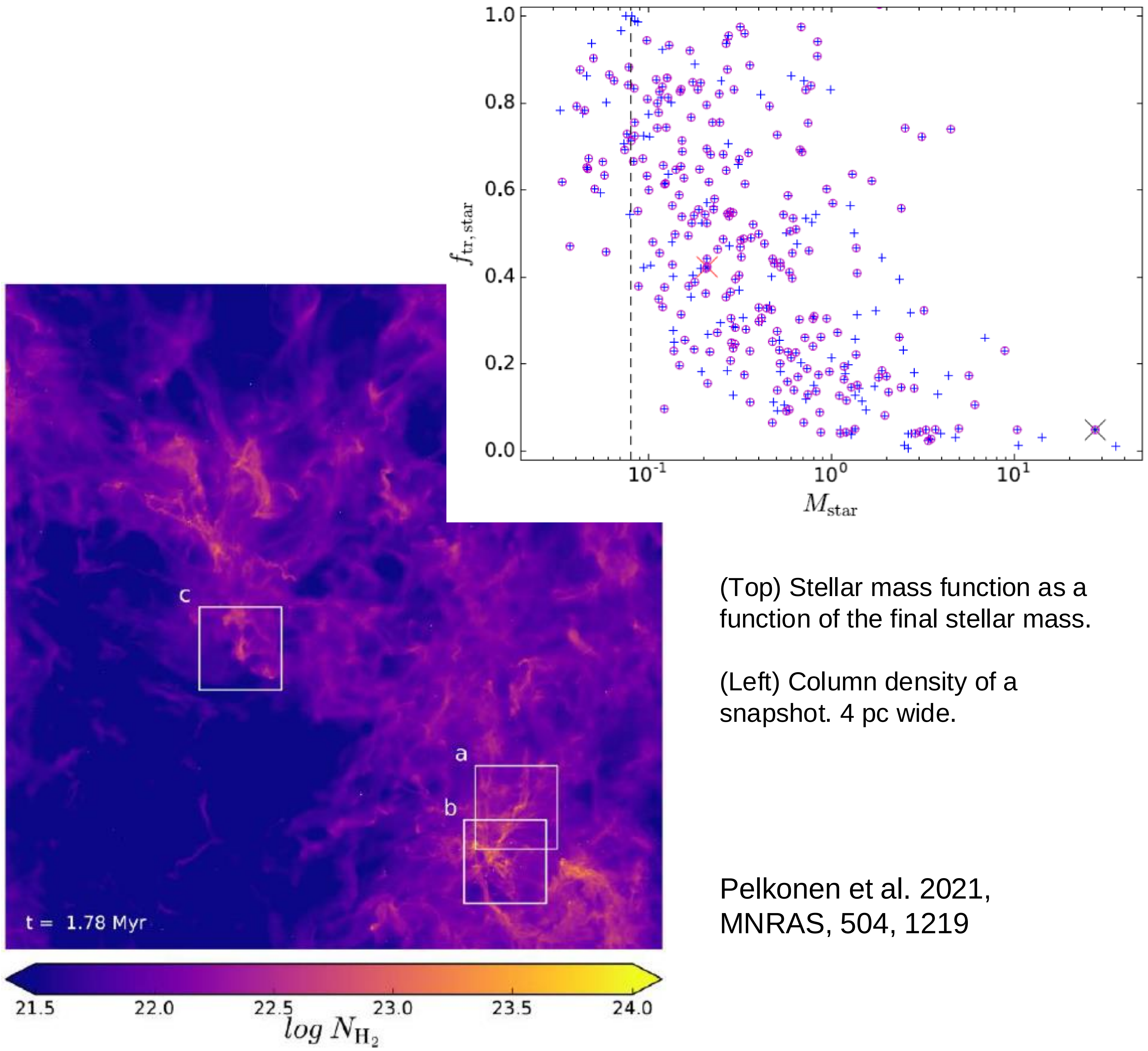


Schimek, A., et al. 2024, A&A, 682, A98

Lee, Minju et al. 2024, Open Res Europe, 4:113

Need for a wide-field Imager with high angular resolution: Origin of IMF beyond the core-collapse model

- The origin of stellar initial mass function (IMF) is one of the most fundamental questions in astrophysics.
- The simple and popular idea is: IMF shape is inherited from cores and even from filaments.
- But recent discoveries of "streamers" with ALMA indicate that cores and disks are not isolated system.
- Recent MHD simulations suggest that the core-star relation is not tight. In particular, for high-mass stars only a small fraction of the final stellar mass comes from the progenitor core. ➔ Multi-scale interplay, i.e., from clouds – filaments – cores, is the key!



(Top) Stellar mass function as a function of the final stellar mass.

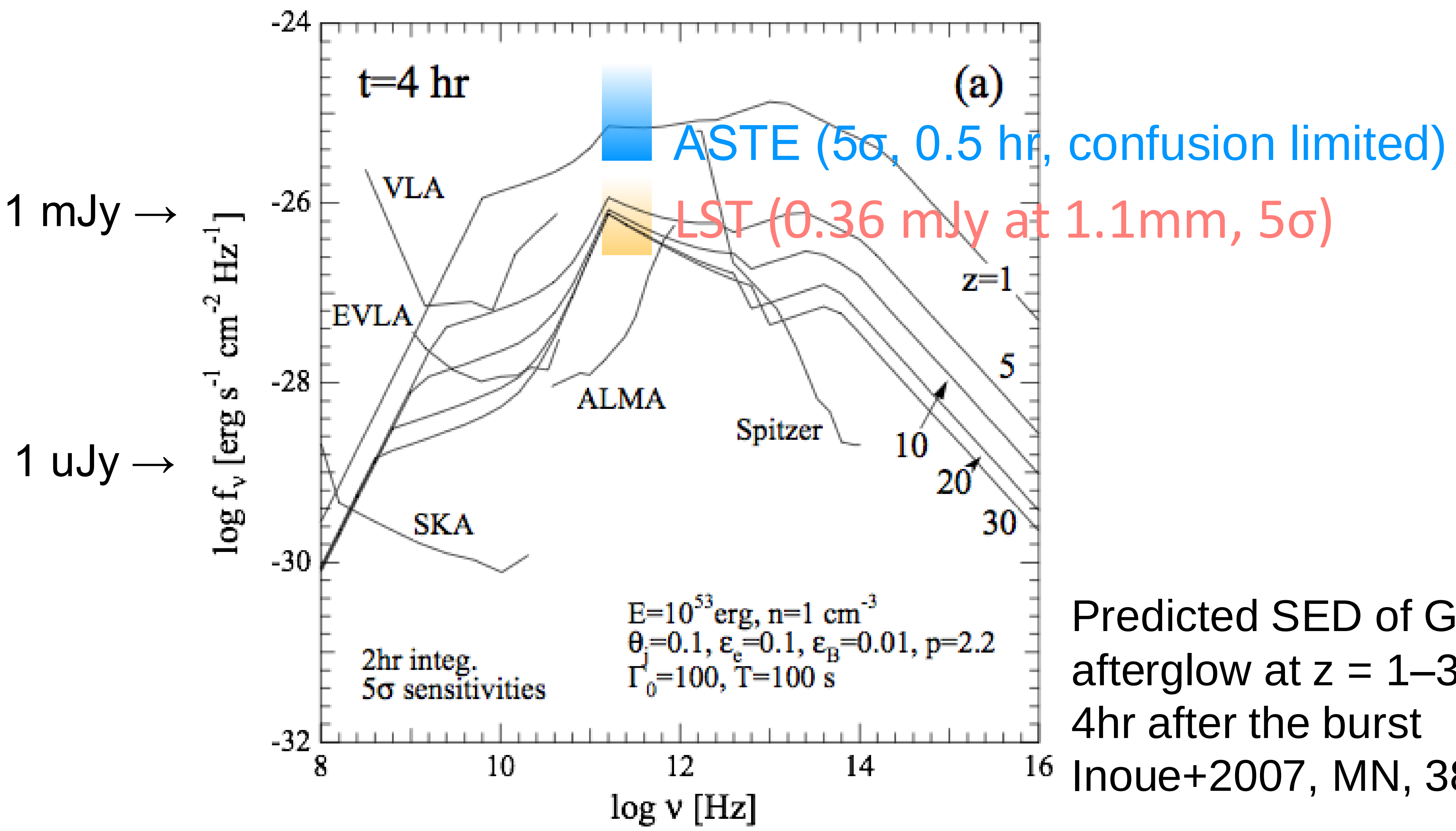
(Left) Column density of a snapshot. 4 pc wide.

Pelkonen et al. 2021, MNRAS, 504, 1219

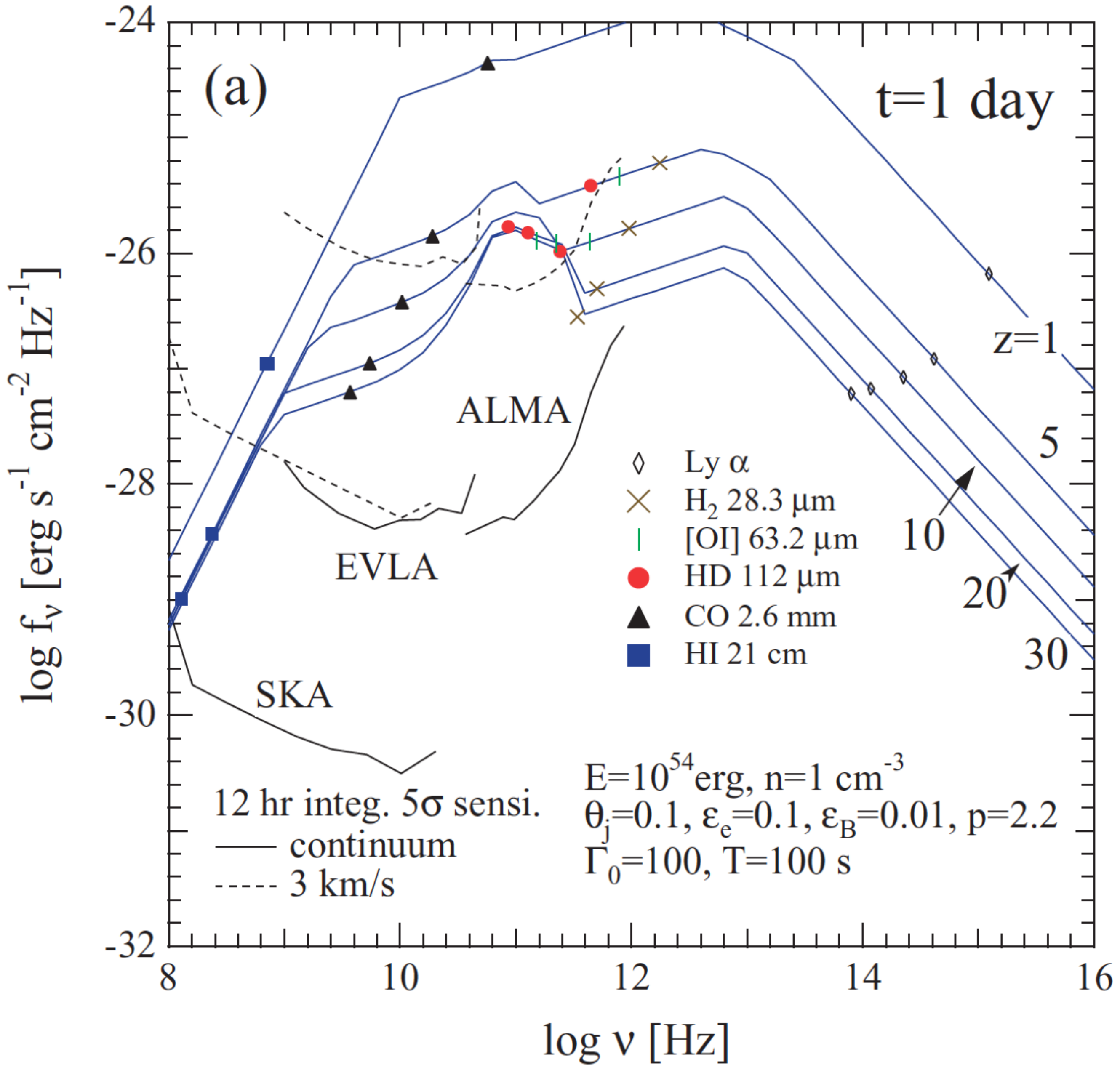
See Tomida-san's talk
https://nobeyama45.notion.site/45m-2024-13d8d4d4386380a3b313f6f11a0bb586

Need for a wide-field Imager with high angular resolution: Catching “Submm flare” from high-z Gamma-ray bursts

- Earliest afterglows from reverse shocks (< 4 hr) peak at ∼300 GHz, and bright (∼1 mJy) even at z > 10 (Inoue+2007).
- Bright compared to a typical galaxy at z > 5 (∼10 μJy)
- Wide-area, high cadence continuum survey ➔ flash detection pipeline ➔ immediate spectroscopy follow-up using wide-band heterodyne (FINER-like) receiver
- Search for HD, H2, [OI], etc., toward bright afterglow



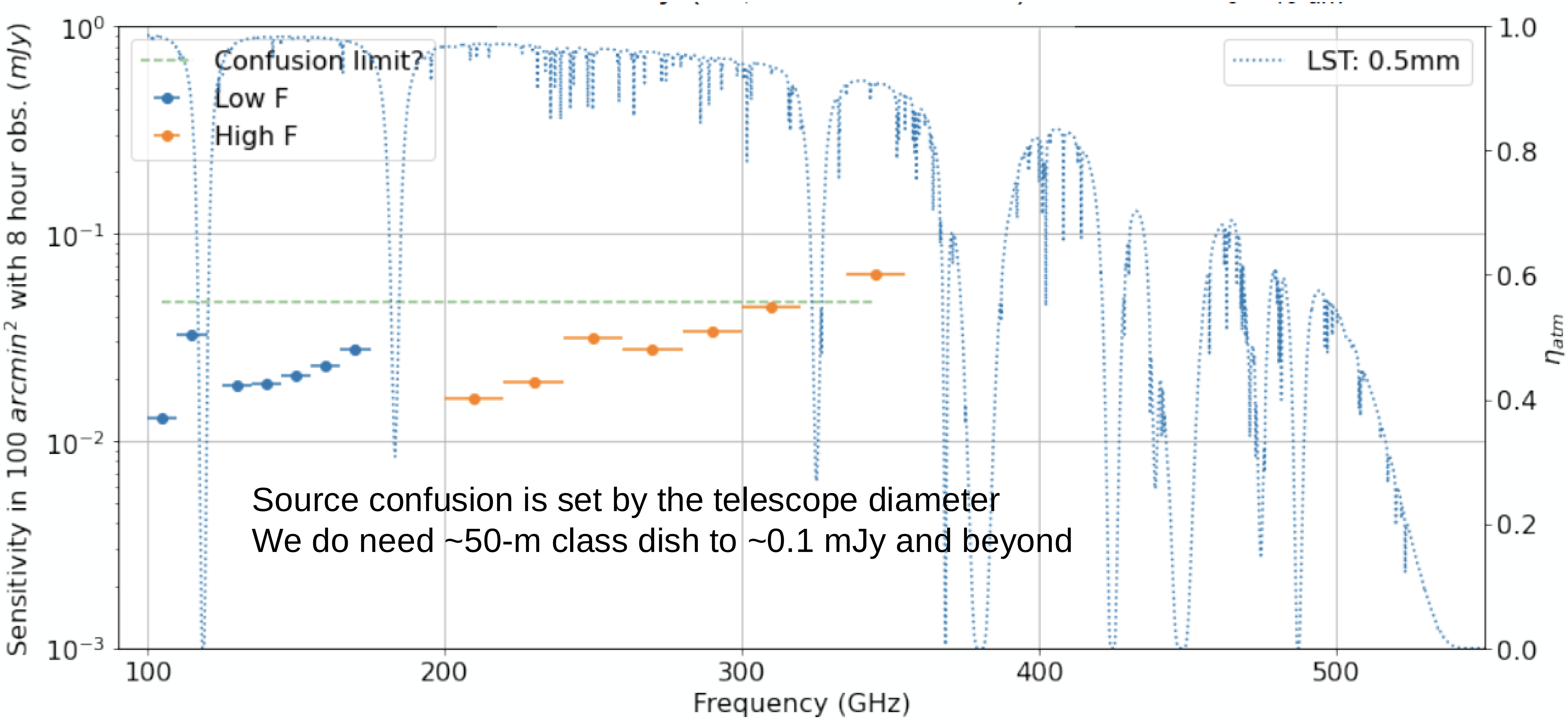
Predicted SED of GRB afterglow at z = 1–30
4hr after the burst
Inoue+2007, MN, 380, 1715



Need for a wide-field Imager with high angular resolution: What does the time-varying (sub-)mm sky look like?

- 100 deg^2, 1 mJy survey (day scale cadence)
- 1 deg^2 scale deep spectroscopy survey will also produce hour scale cadence database
- 14 color SED monitor survey for time-variable sources (e.g., AGNs)

will become available
for community
(e.g., Tominaga-san's talk)



Source confusion is set by the telescope diameter
We do need ~50-m class dish to ~0.1 mJy and beyond

LST white paper,
section 3.5, Fig. 3.22

5. Instruments and data to be returned

Required capabilities

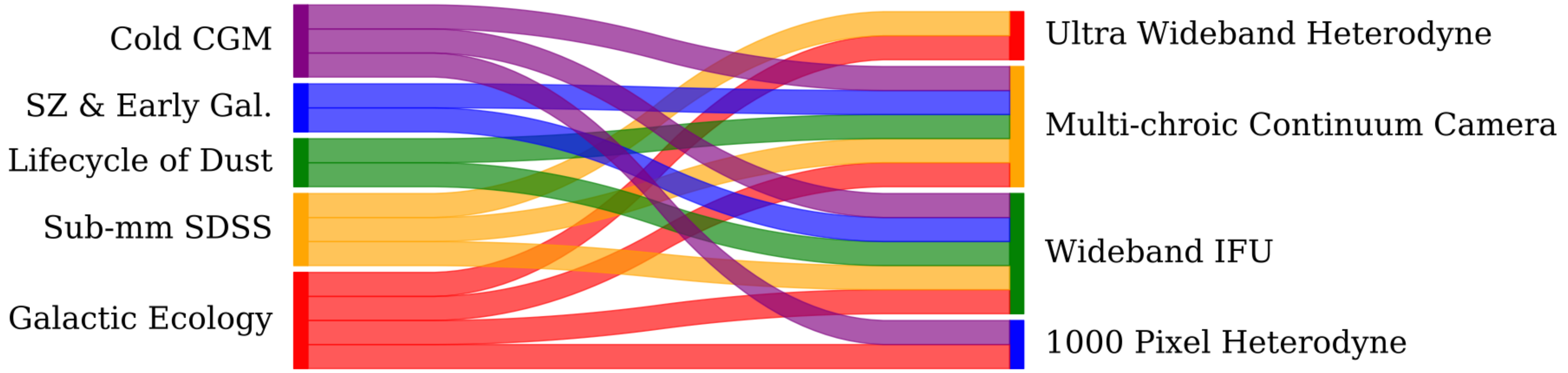
Under revision based on science white paper

	Frequency (GHz)	Beam size (″)	FoV (′)	Telescope drive	Vel. Resol. (km/s)	Receiver (# of pix)	Note
high-z gal	70–420 (seamless)	< 15″	> 30′	fastscan	300	FB/HD (10^2) C (10^6)	
SZE cluster	100, 150, 220, 270, 350	~5″	> 17′	fastscan tracking	Continuum	C (10^6)	
z ~ 1 gal. evo.	60-115, 115-230 (IF: 12)	(<15″?)	> 30′	tracking	50	HD	
Galactic plane	115, 230, 345, 492 (IF: 4-12)	< 15″	> 30′	fastscan	0.3	HD (100) C (10^5?)	
Astro-chemistry	70–230 (seamless)	n/a	n/a	tracking	(0.3?)	HD (1) *high eff	
VLBI	100-350 (< 950)	n/a	n/a	VLBI station tracking	Continuum *(1?)	HD (1)	WVR *: Maser clock
Time-domain	~200-300 *70–420	~5″ < 1′	> 30′ *n/a	fastscan *tracking	Continuum *1	C (10^6) *HD (1)	Fast switching of receivers

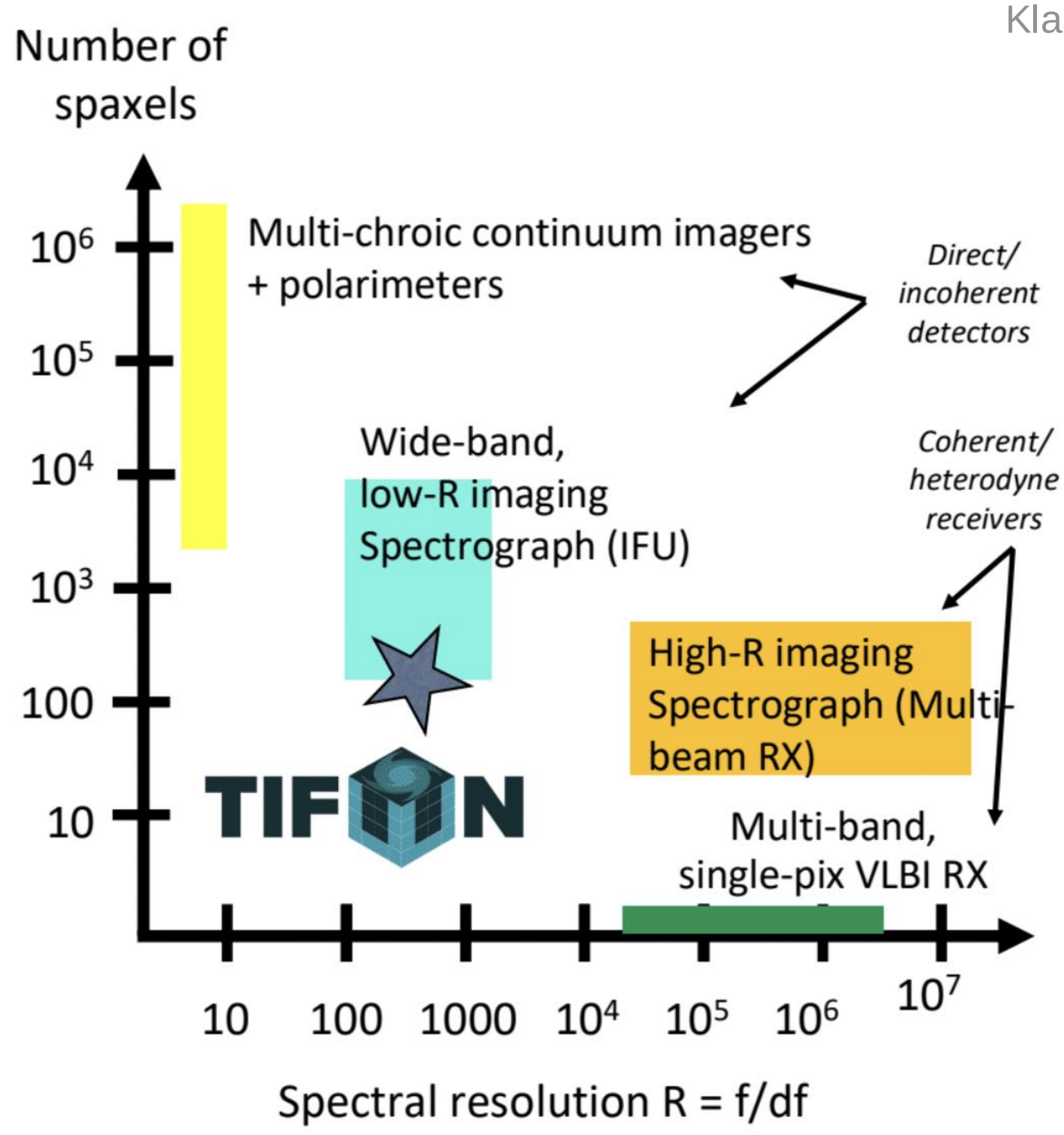
FB: filterbank-type, HD: heterodyne, C: continuum camera
fastscan: On-the-fly mapping with fast scan

3

1st gen. FPI



Klaassen et al. 2020, Astro2020 White Paper

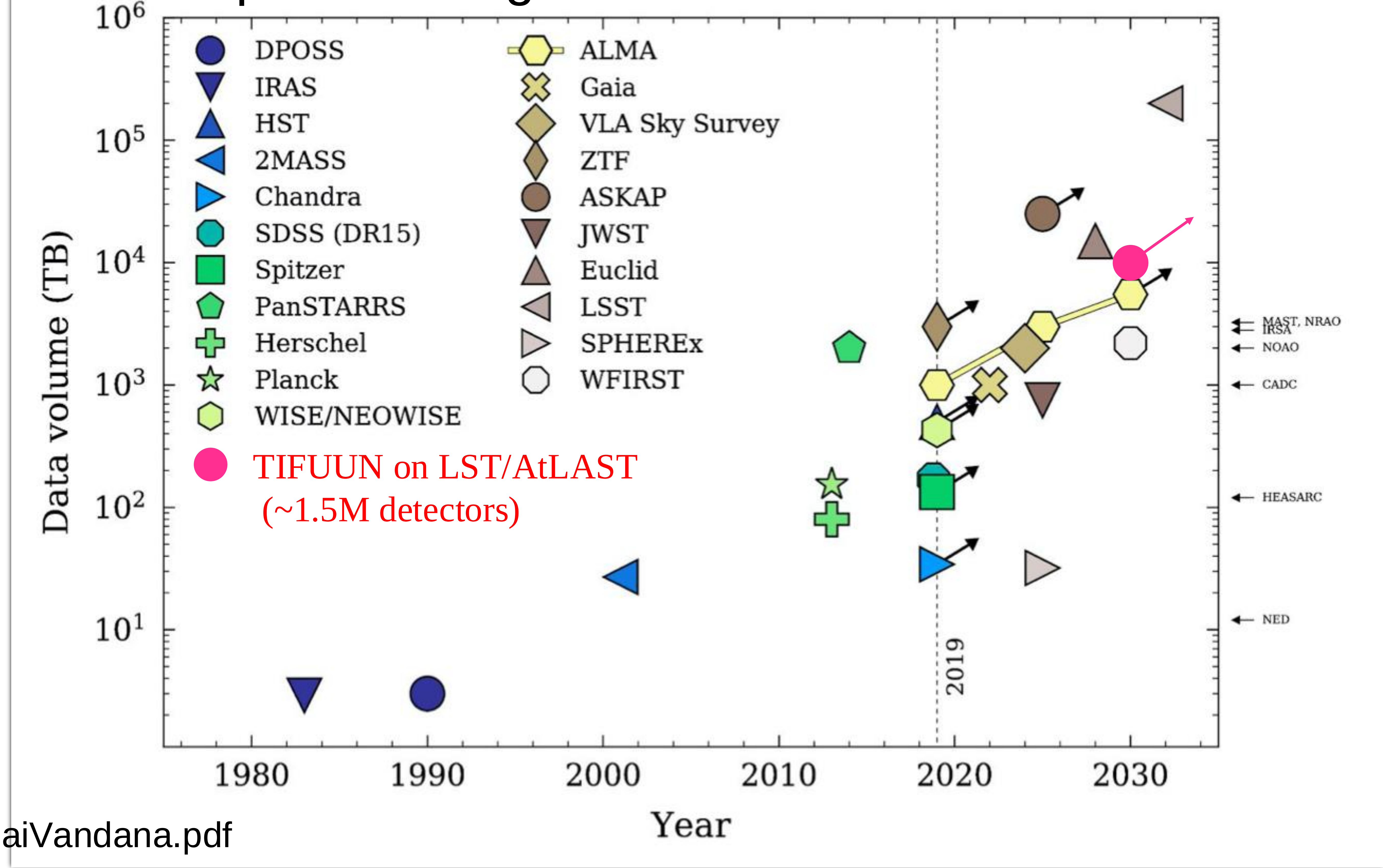


Necessity for Data-scientific methods

ALMA (66 MB/sec, 200 TB/year)
→ ALMA WSU
SKA1 (SKA1-low, 130k antennas + SKA1-mid 197 antennas、5TB/sec, 600 PB/year)
ngVLA (18m x 244 + 6m x 19）
CMB-HD? (190 TB/day)

LST/AtLAST (50m + Mega pix IFUs; 1GB/sec, 30PB/year)

Existing and planned observing facilities will produce huge amount of data



Desai et al. 2019
https://www.noao.edu/2020Decadal/files/DesaiVandana.pdf

“A large (D~50m class) telescope optimized for ~850µm” is originally driven by LST team → finally AtLAST also

2008

Proposed concept for a next-generation large-aperture single-dish for submm-wave, as a successor to the Nobeyama 45m and ASTE 10m telescopes

2009 ~2013

Scientific and technical studies for a next-generation large-aperture single-dish telescope

1st International LST workshop
2nd International LST workshop

2014

Planning of Large Submillimeter Telescope Concept

3rd International LST workshop

2015

Science requirements and feasibility studies by LST working group

LST

AtLAST working group

AtLAST

AtLAST workshops (Garching & Edinburgh)

2018

Start discussion with AtLAST project

EU Horizon 2020 AtLAST awarded (€3.5M)

2020

Listed in Master Plan 2020 by Science Council of Japan
日本学術会議マスタープラン2020大型計画掲載

AtLAST workshop (Mainz) with LST team; agreement with project unification

EU Horizon 2025 AtLAST2 awarded (€4.0M)

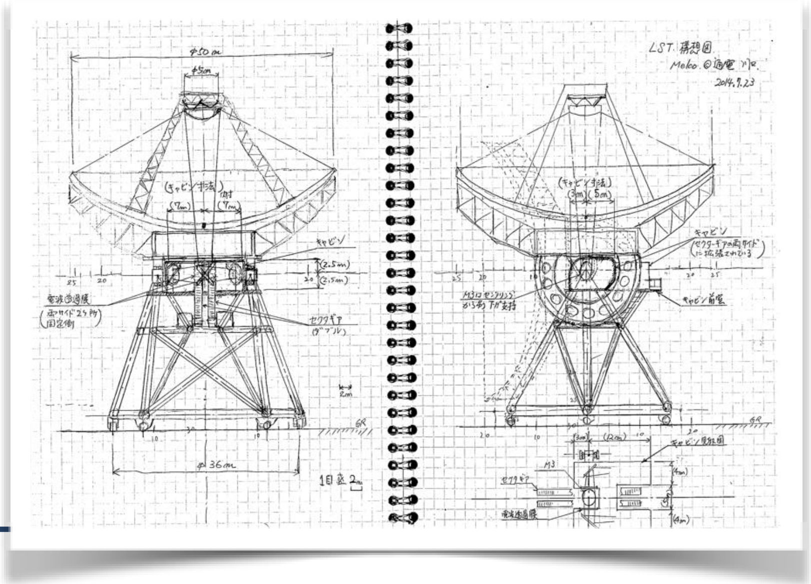
2025

mid-2030s

Start Construction?

late-2030s

Early Science?



A conceptual drawing by Kawaguchi-san (MELCO)

Two concepts of large submm-wave single-dish telescopes

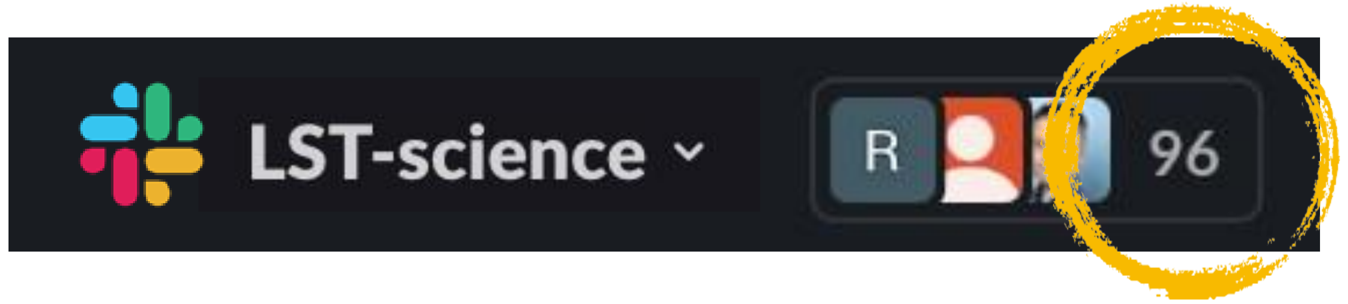
- Optimized for short wavelengths (e.g., 450 μm, 350 μm) with a modest dish; e.g., CCAT (D=25m)
- Optimized for ”work-horse” submm bands (e.g., 850 μm to ~2 mm) with a large dish; i.e., LST (D=50m)

Progress in Japan: Science White Paper

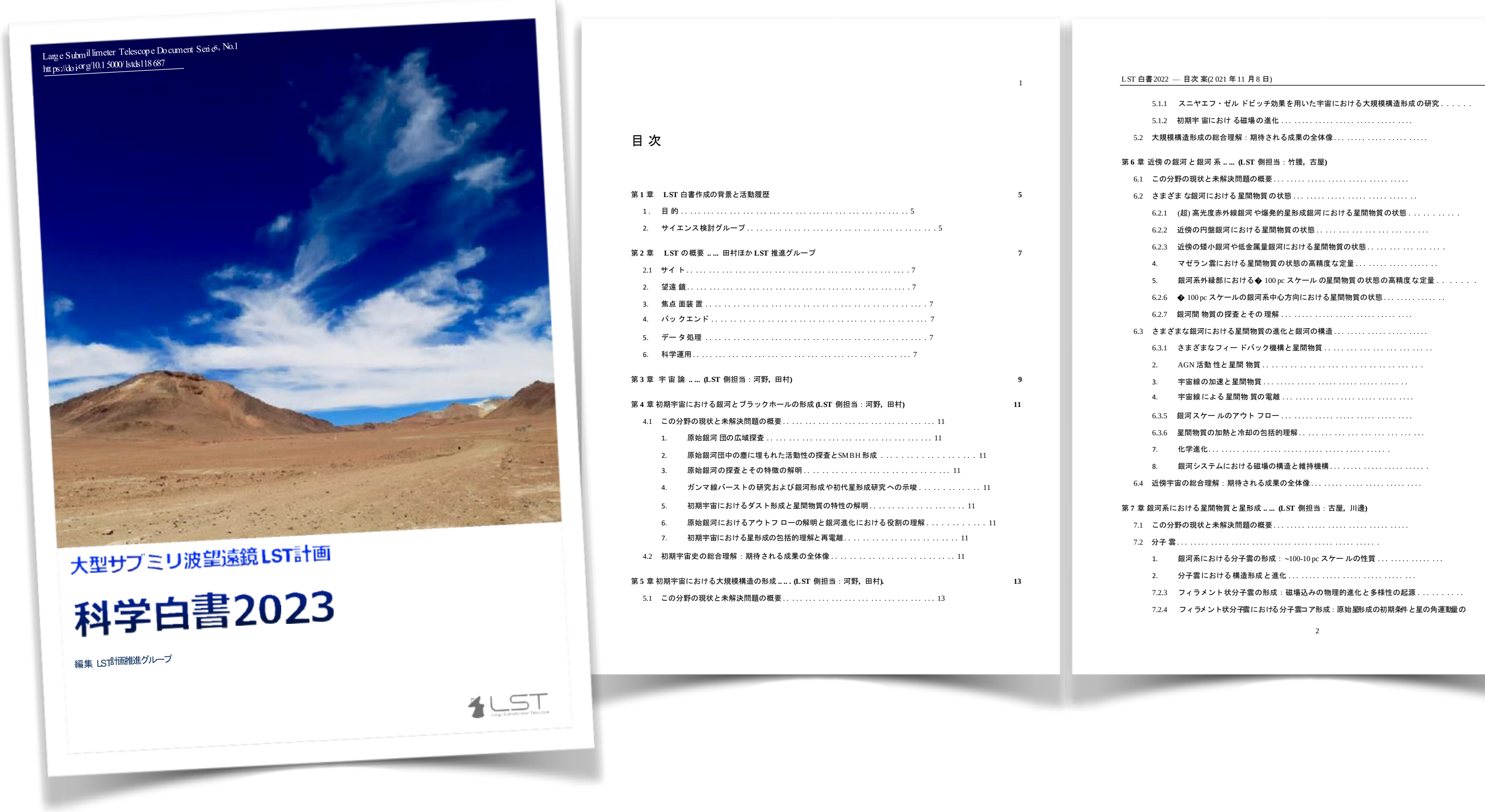
- Our community in Japan published a ~400-page science white paper (2023 October)
- Editor-in-chief: R. Furuya & T. Takekoshi

LST project	K. Kohno (UTokyo)
Galaxy formation	H. Inami (Hiroshima)
Galaxy clusters & cosmology	H. Akamatsu (SRON, NL→KEK)
Supermassive black holes and AGNs	H. Umehata (Nagoya)
Nearby galaxies	T. T. Takeuchi (Nagoya), T. Saito (NAOJ)
Star-formation	K. Tomida (Tohoku)
Solar system	T. Iino (UTokyo)
Astrochemistry	T. Shimonishi (Niigata)
Time-domain sciences	-

~100 astronomers!



https://doi.org/10.15000/lstds118687


Large Submillimeter Telescope Document Series, No.1
https://doi.org/10.15000/lstds118687

大型サブミリ波望遠鏡LST計画

科学白書2023

編集 LST計画推進グループ

👉 **New requirements:** High-frequency (~350 μm) imaging, ~1000-pix heterodyne array, polarization (in addition to wide-field imaging, IFU, wideband coverage, time-domain in < sec to year scales)

Progress in Japan: Technology

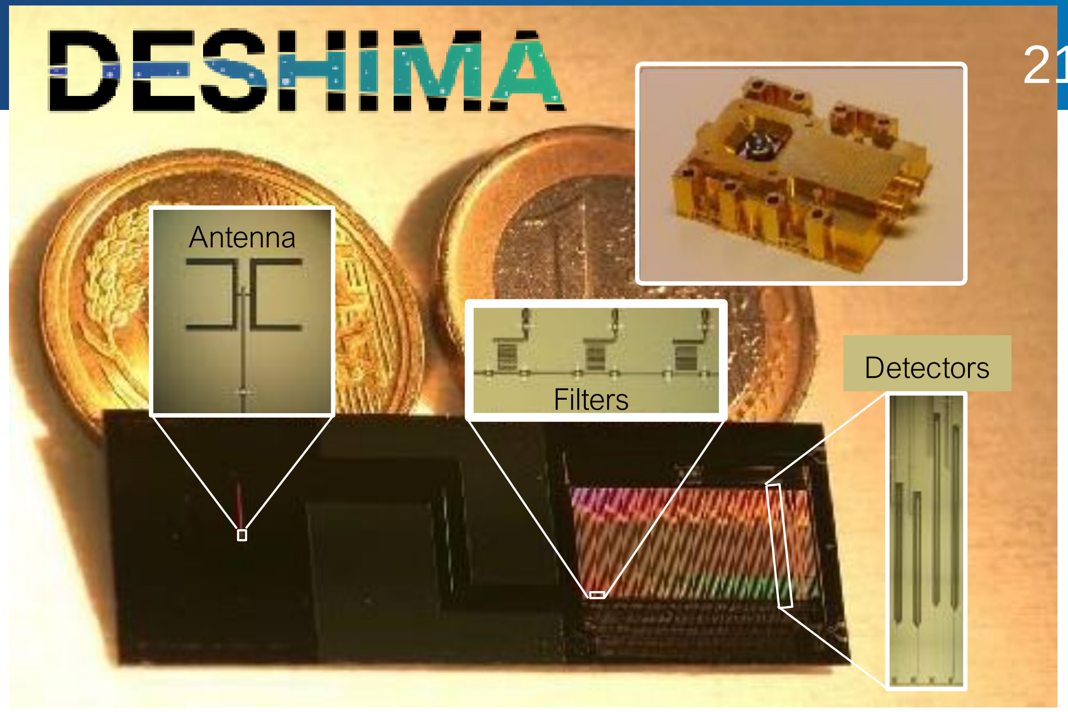
- GLT camera project (PI: T. Oshima)
  - 6-color continuum MKID camera for GLT 12m
  - Awarded **JSPS grant** (基盤 A & B, 2023-)

- TIFUUN/DESHIMA project (PI: A. Endo)
  - **ASTE/DESHIMA 2.0 campaign** is in progress (2023 Sep-Nov. & 2024 Jun-Nov.)
  - Started **ERC & JSPS programs for TIFUUN** (2022-)

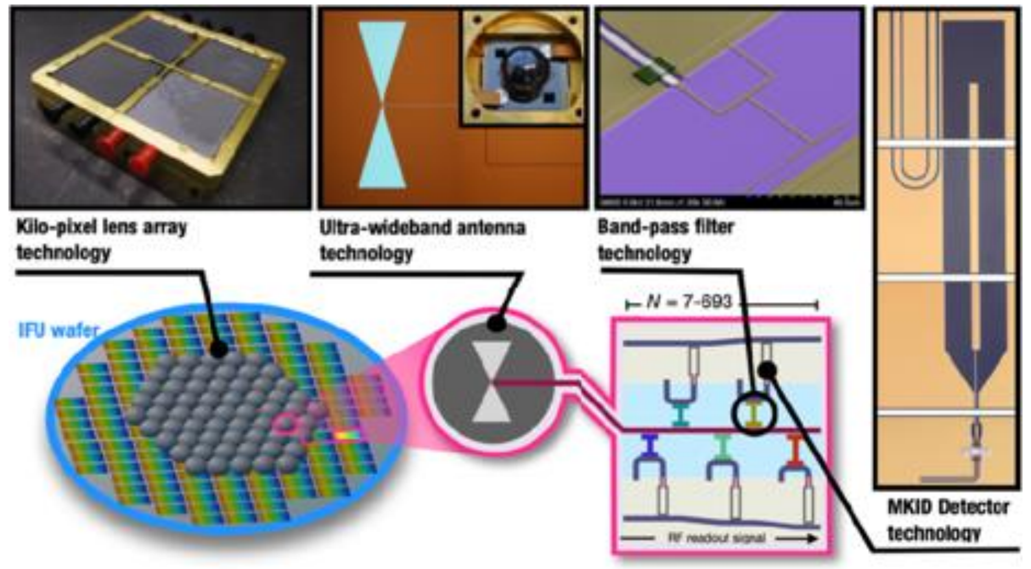
Data-scientific analysis

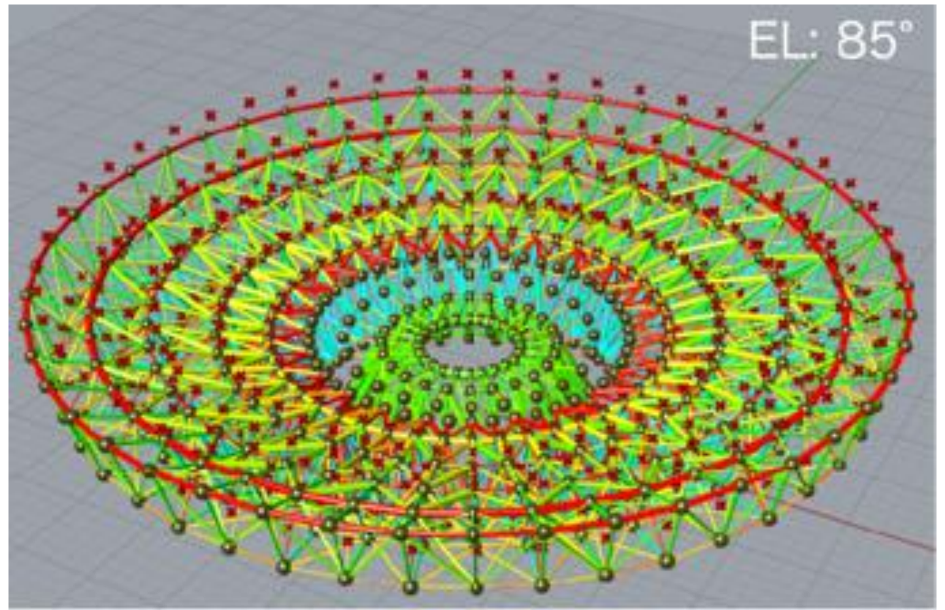
- FINER project (PI: Y. Tamura)
  - Heterodyne receiver covering Band 4 to 7 for 50m LMT
  - **ALMA WSU + integrated circuit technology** (T. Kojima & W. Shan) Support
  - from JSPS grant (基盤 S, 2022-)

- Telescope / optics (Y. Tamura+) 創発的研究支援事業 *(declined)*
  - Demonstration of **wavefront sensor for adaptive optics** at NRO 45m (2022-)
  - Structural optimization of telescope backup structure



TIFUUN concept





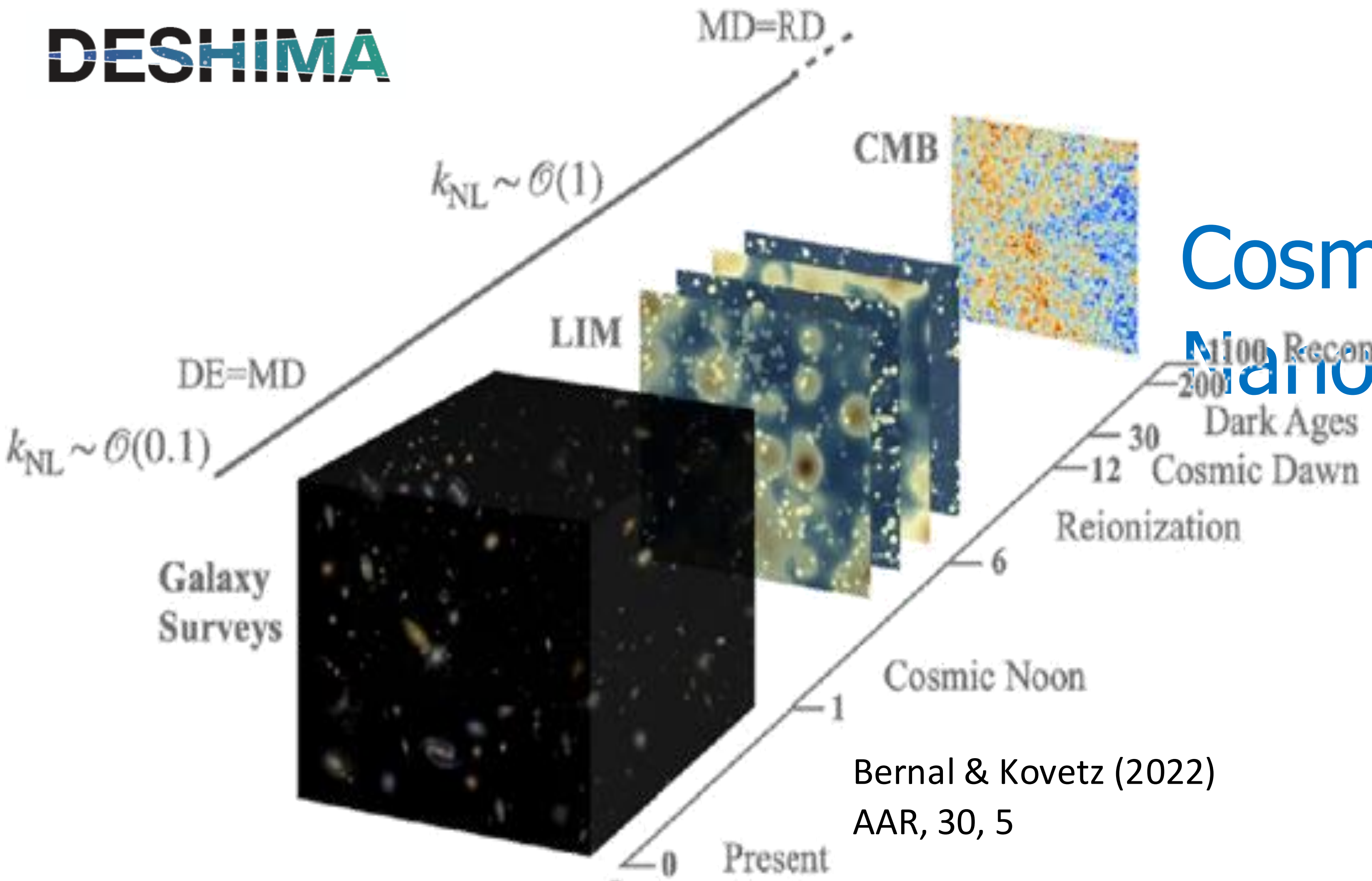
TIFUUN for Submillimeter-wave Line Intensity Mapping

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

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

S. Fujita Y. Nishimura E. Ogata A. Taniguchi E. Garaldi

DESHIMA



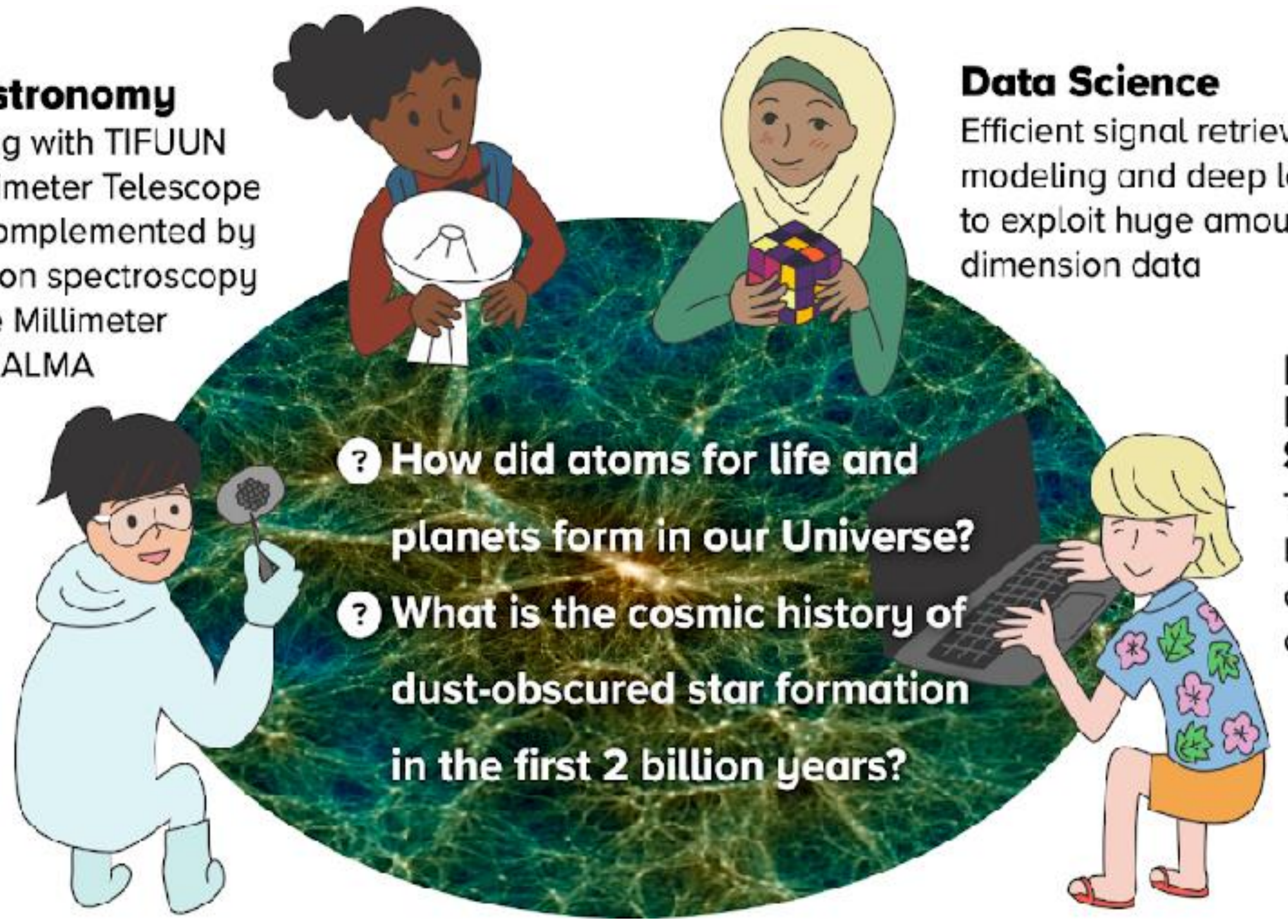
Bernal & Kovetz (2022)
AAR, 30, 5

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



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

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

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

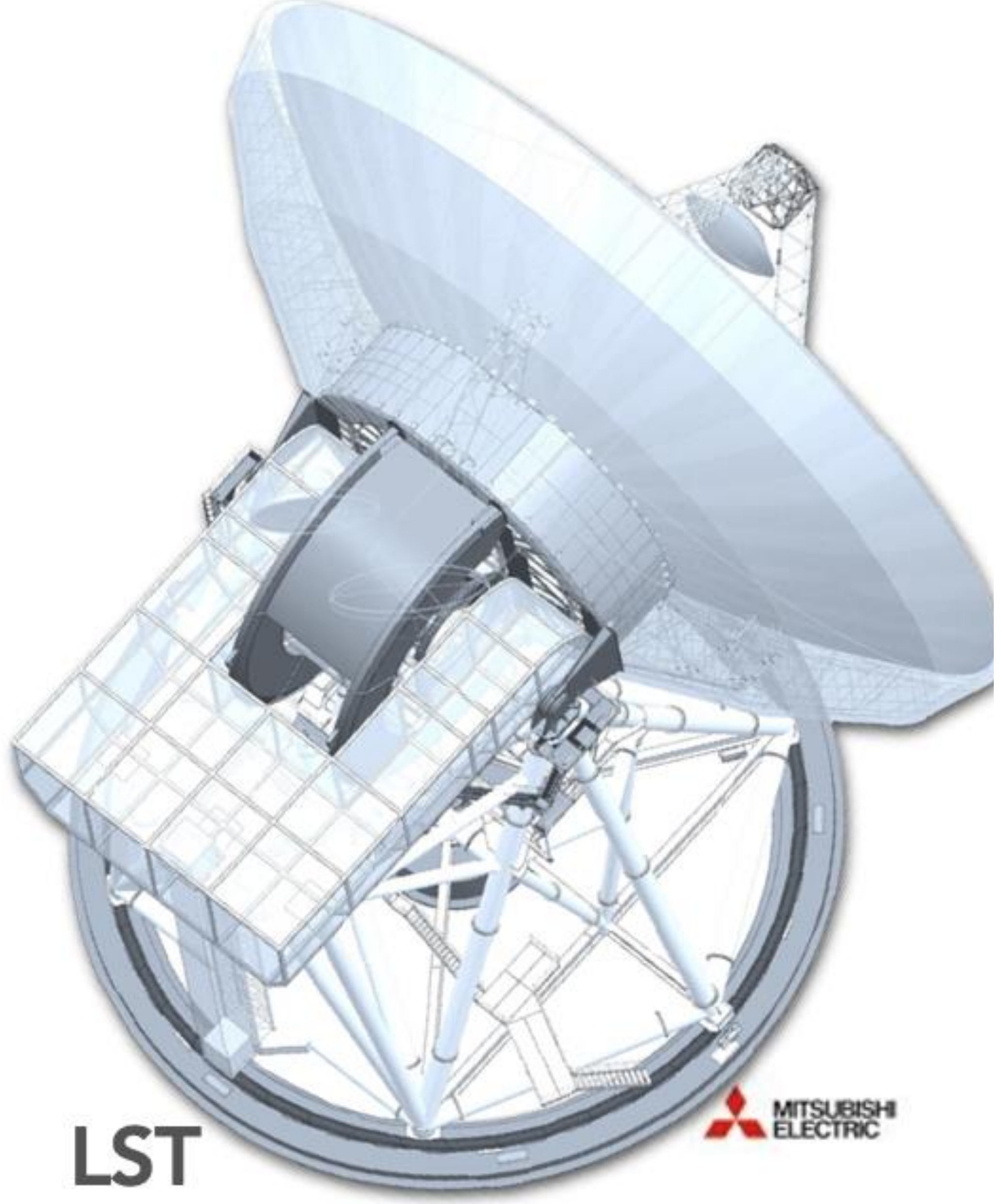
Superconducting Nanoelectronics
Development of novel Integrated Imaging Spectrograph TIFUUN

- **JSPS grants** (International Leading Research 国際先導研究 FY2023-2029 + Specially Promoted Research 特別推進研究 FY2024-2028 ~ €6M, PI: K. Kohno)
- **ERC Consolidate grant** (2022-2027 €3.4M, PI: A. Endo)

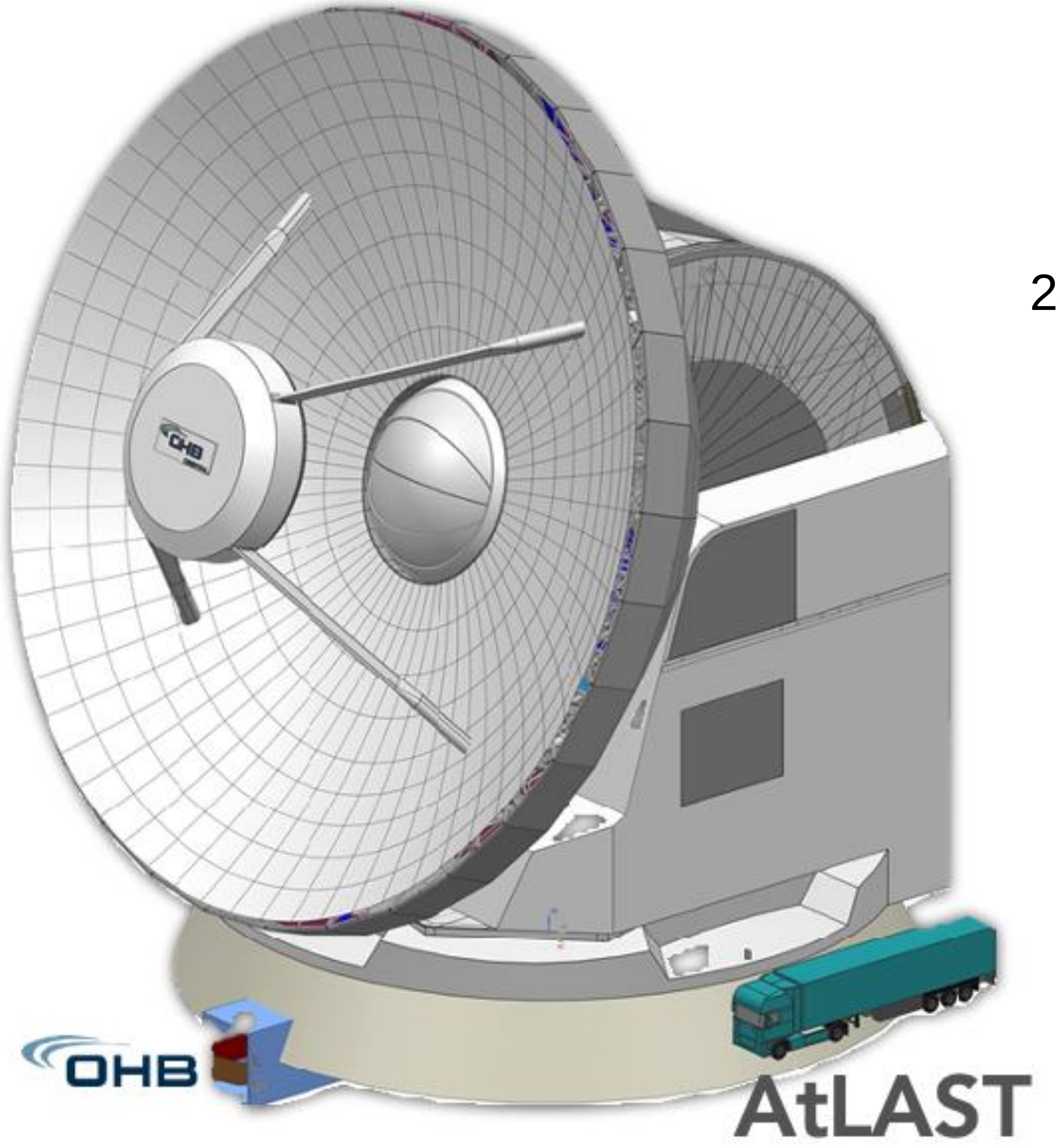
are awarded to TIFUUN/ASTE (and FINER/LMT)

Next generation sub/mm-wave survey telescope:

LST/AtLAST



https://en.lstobservatory.org/



https://www.atlast.uio.no/

AtLAST workshop, Meinz (May 2024)

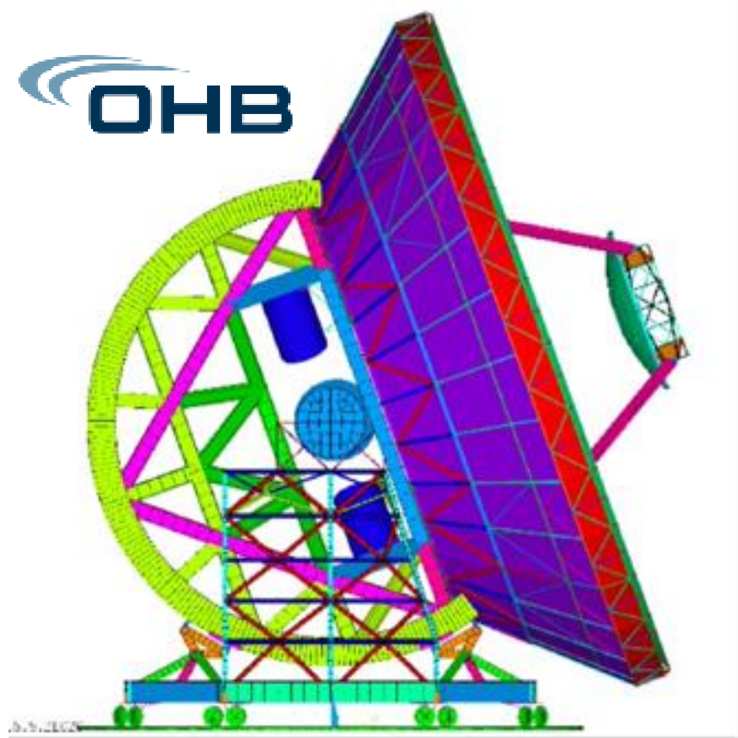
International collaboration with EU (AtLAST) & East Asia

- Collaboration with European AtLAST project
  - AtLAST was approved as EU Horizon 2020 (2021 March)
  - Antenna design study with OHB/MTMech is done (2023)
  - Science use cases are being discussed (since 2021 July) Site
  - selection report (2023)
  - Organized bi-monthly collaboration meeting (2023 February)
  - Discussions at international conferences (2022, 2024)
  - New EU Horizon 2025 proposal accepted !! (2024) → in-kind contribution from the LST team


C. Cicone


T. Mroczkowski


P. Klaassen



Mroczkowski et al. (2023)
arXiv:2308.10952

C. De Breuck

T. Saito

https://www.atlast.uio.no

- Collaboration with ASIAA
  - Letter of Intent between ASIAA and LST has been issued (2023).
  - Collaboration on individual instrument projects: Multi-chroic camera for GLT (PI: T. Oshima), eQ receiver for 45m (PI: C.-C. Chiong), FINER+ for LMT (PI: Y. Tamura), SCUBA-3


K. Kohno


R. S. Furuya

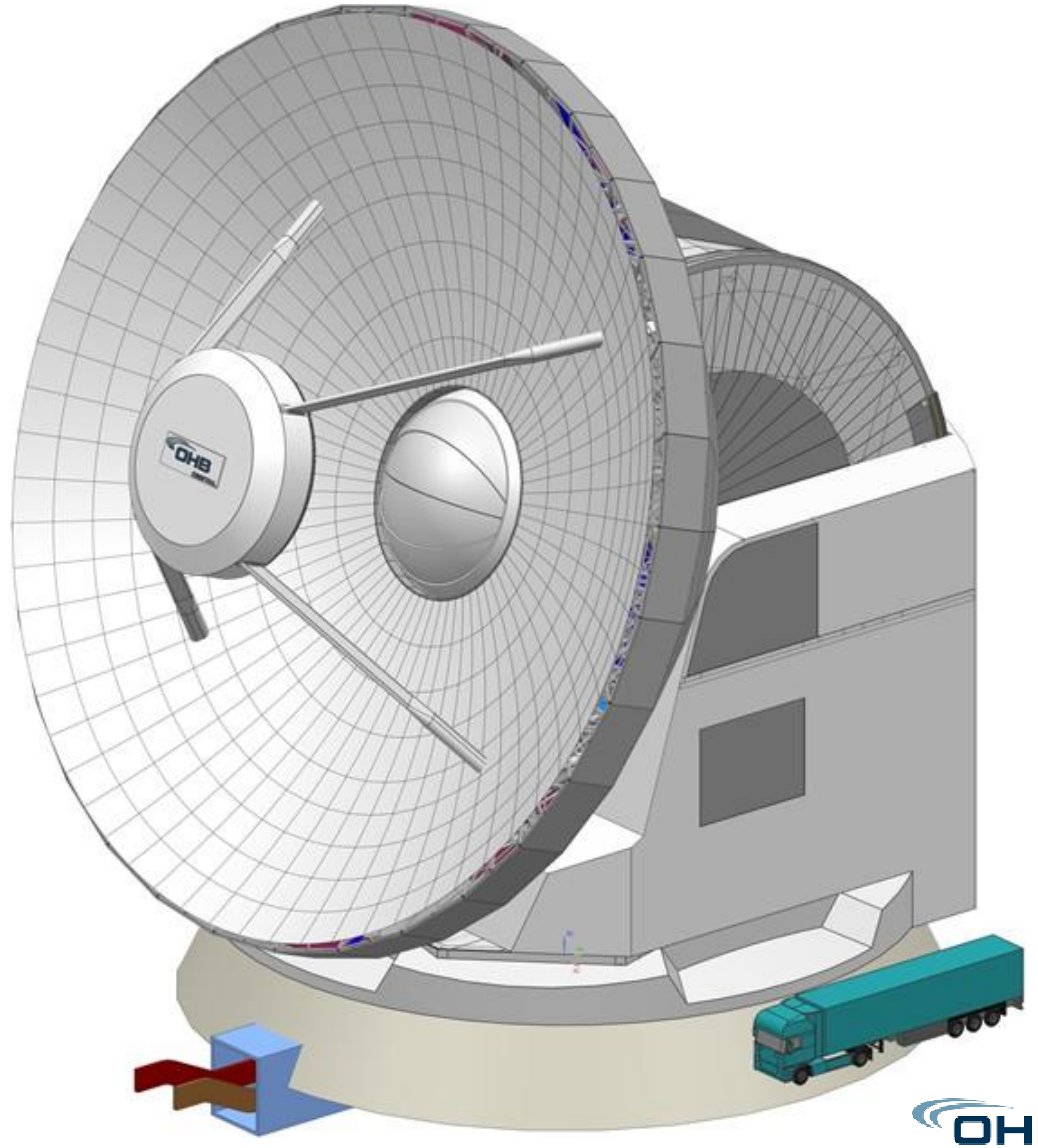

R. Kawabe


Y. Tamura

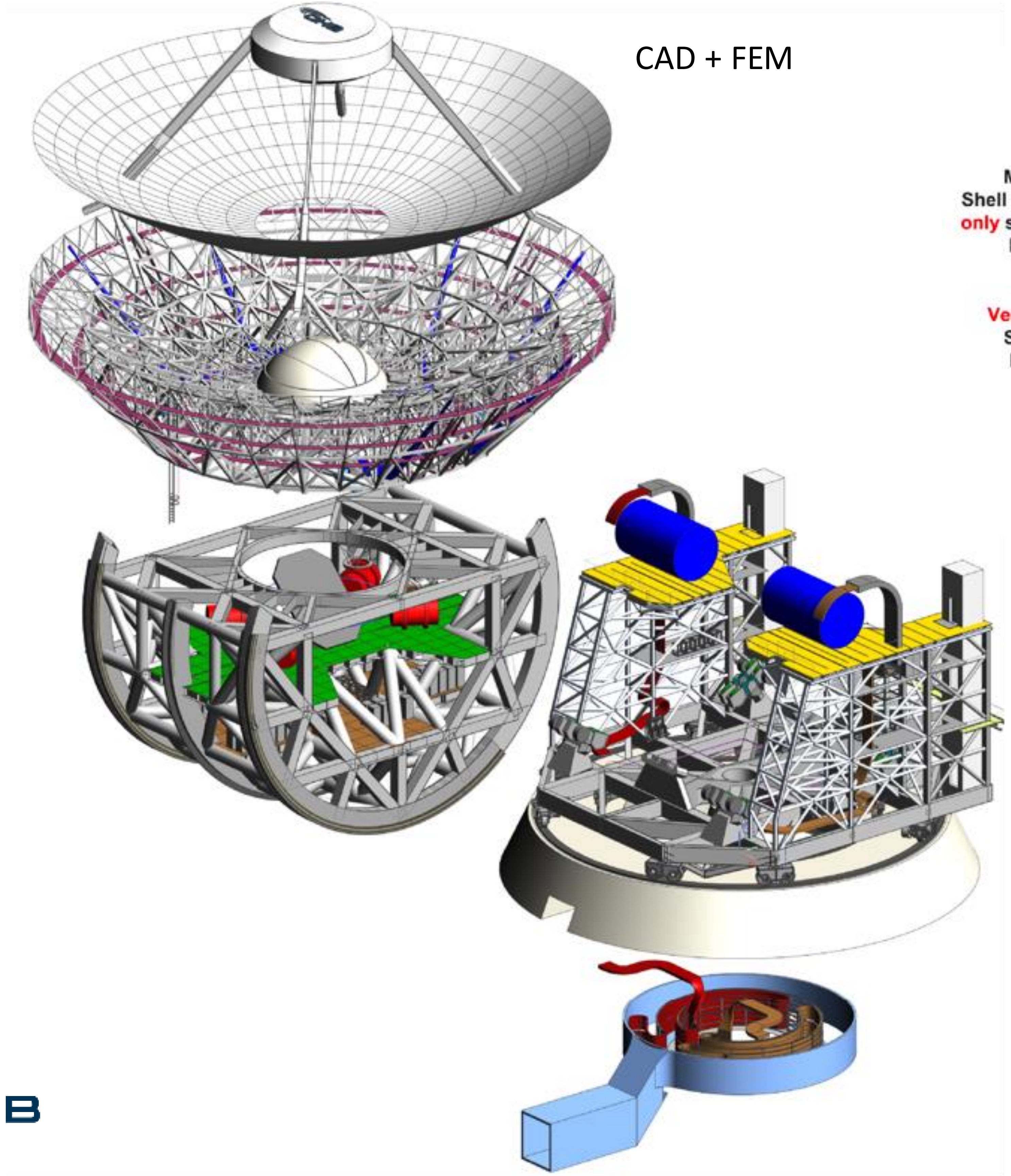
Mroczkowski et al. (2024) arXiv:2402.18645

AtLAST Design Study (EU Horizon 2020 research innovation prog.)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 951815

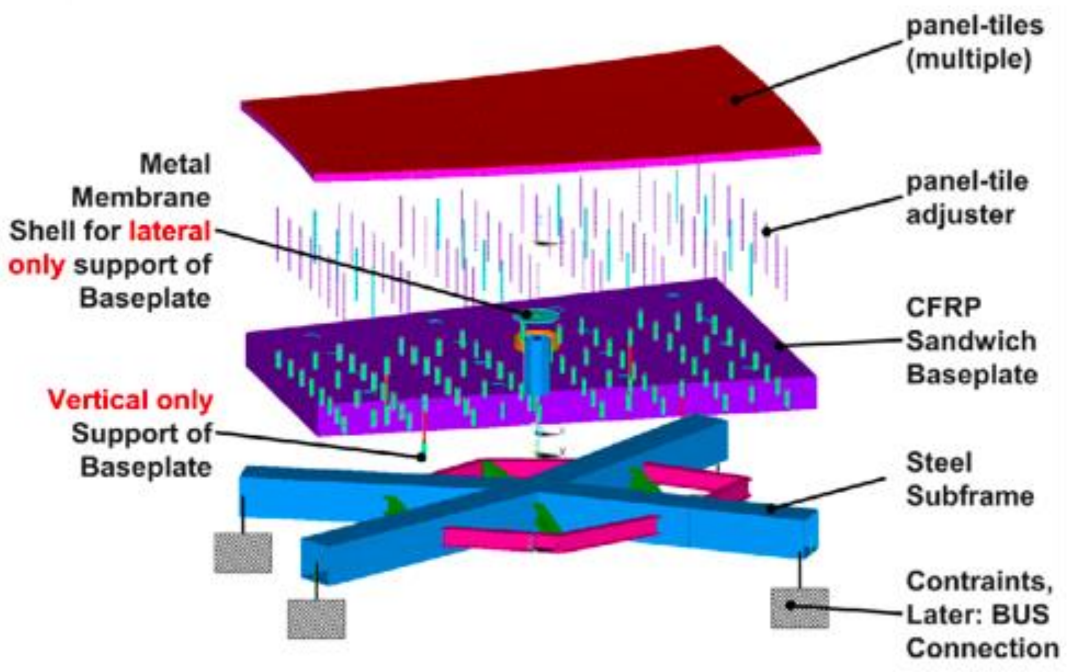


OHB



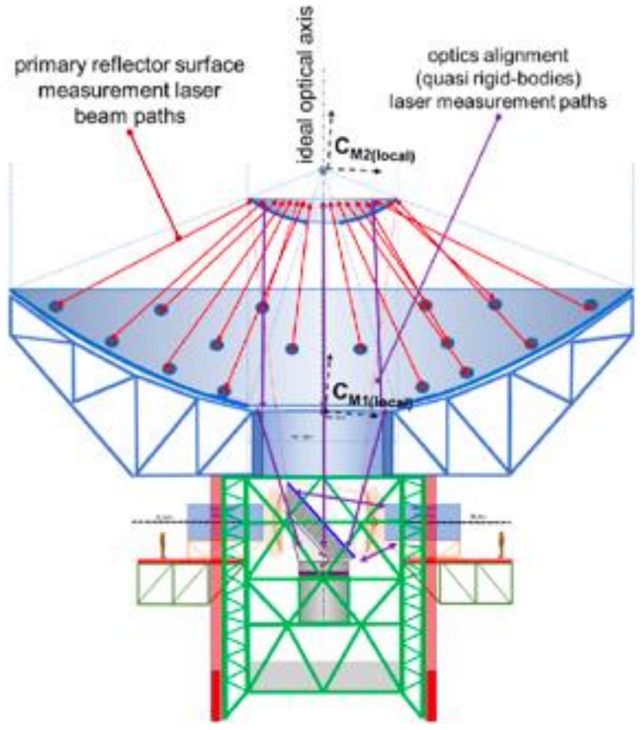
CAD + FEM

Segment mirror support structure



Laser metrology

(Etalon Absolute Multiline Technology™)



Mroczkowski et al. (2024) arXiv:2402.18645

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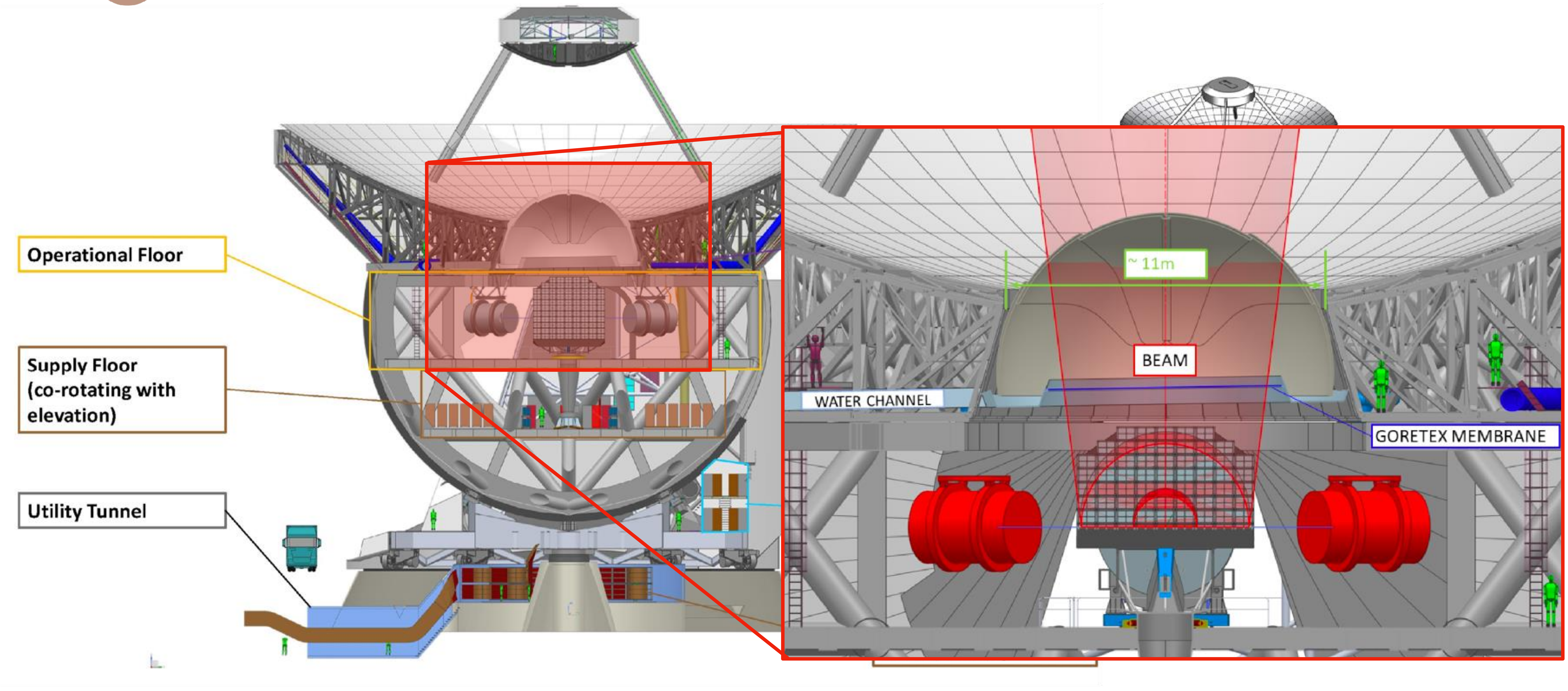
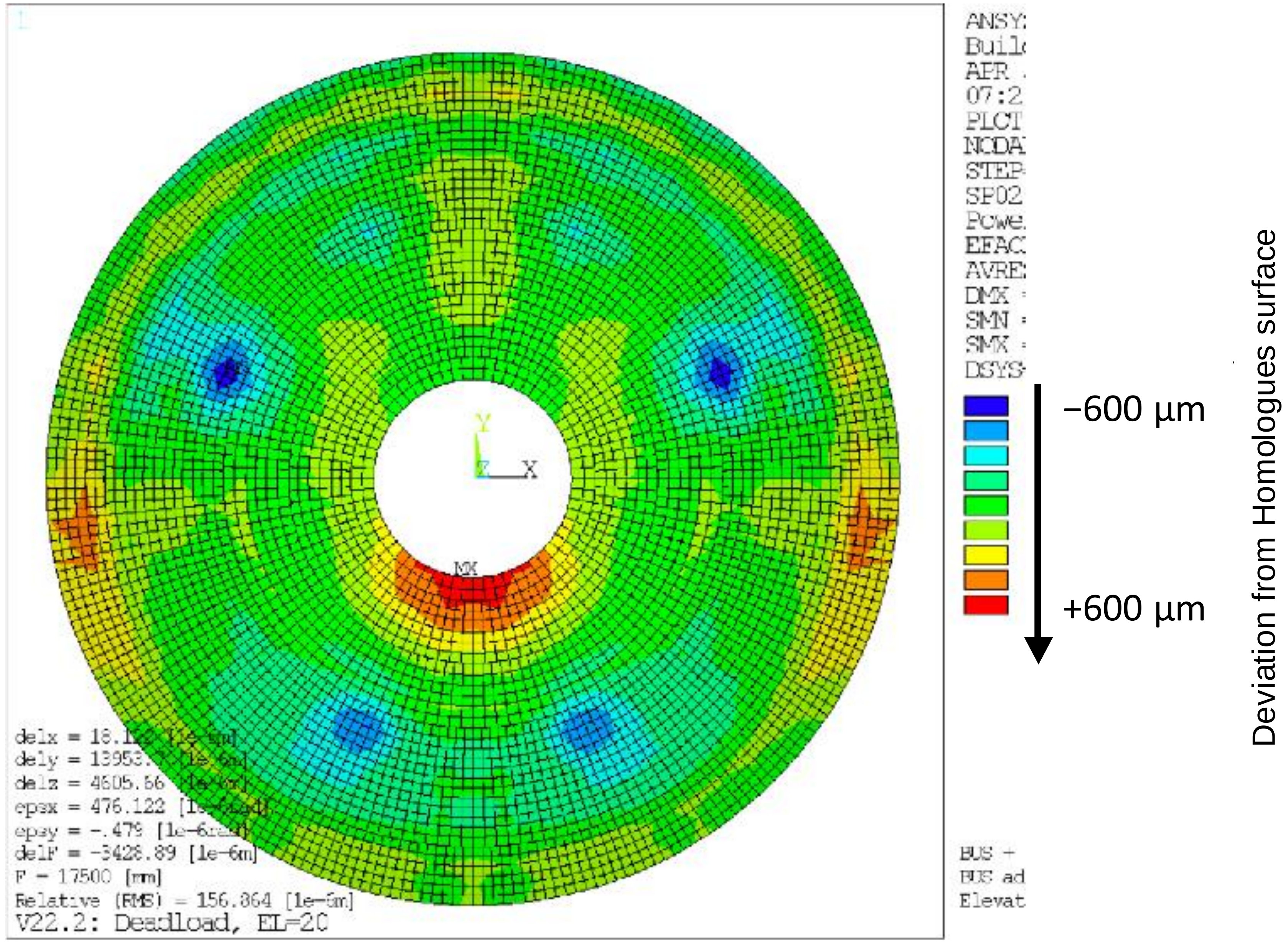


AtLAST Design Study (EU Horizon 2020 research innovation prog.)

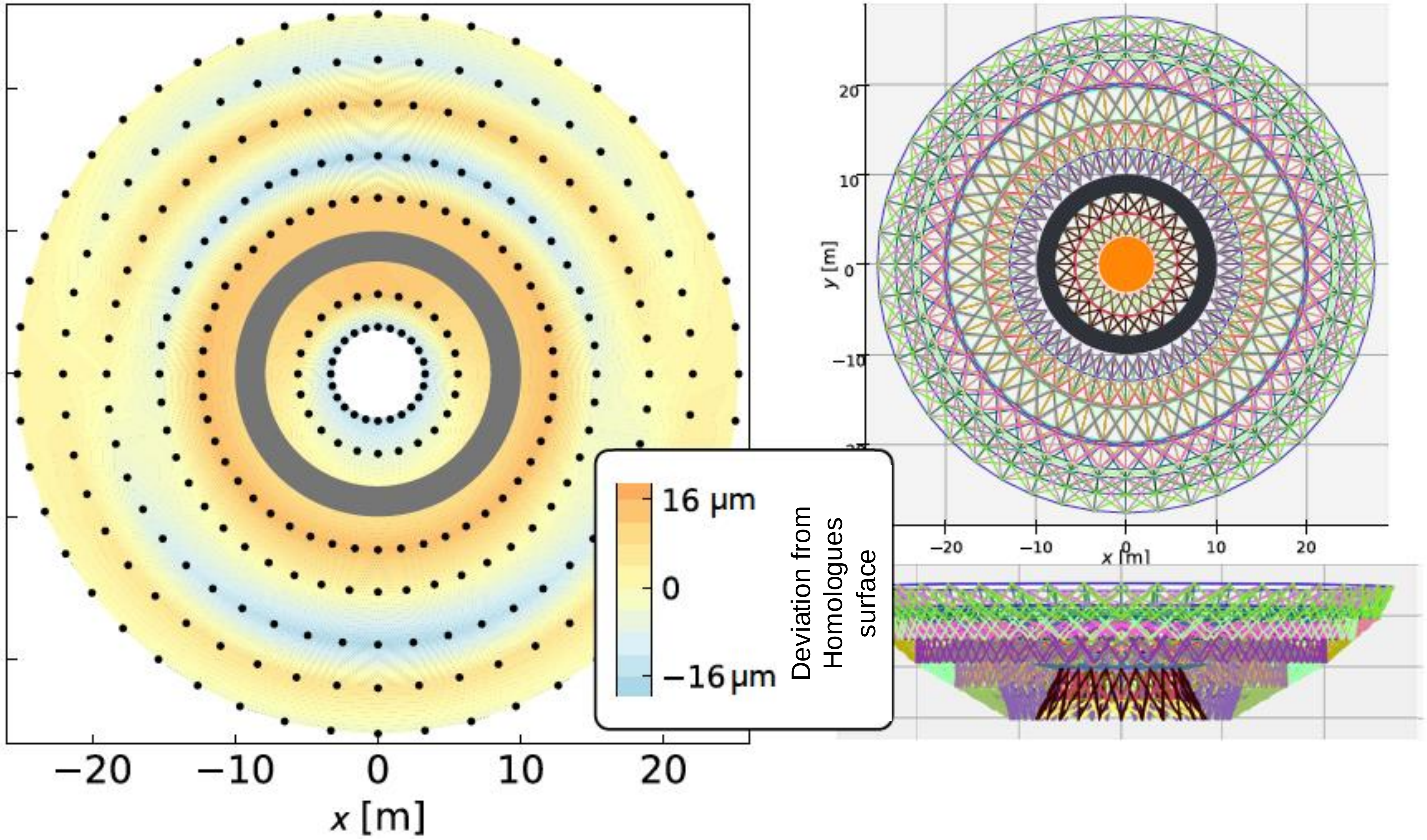
- Items to be tested: "a field demonstration of the closed-loop metrology to keep the overall optical surface accurate to better than 20 µm half wavefront error, ..." ← LST-led Structural optimization & MAO

AtLAST (gravitational deformation)



LST: Structural optimization of telescope backup structure

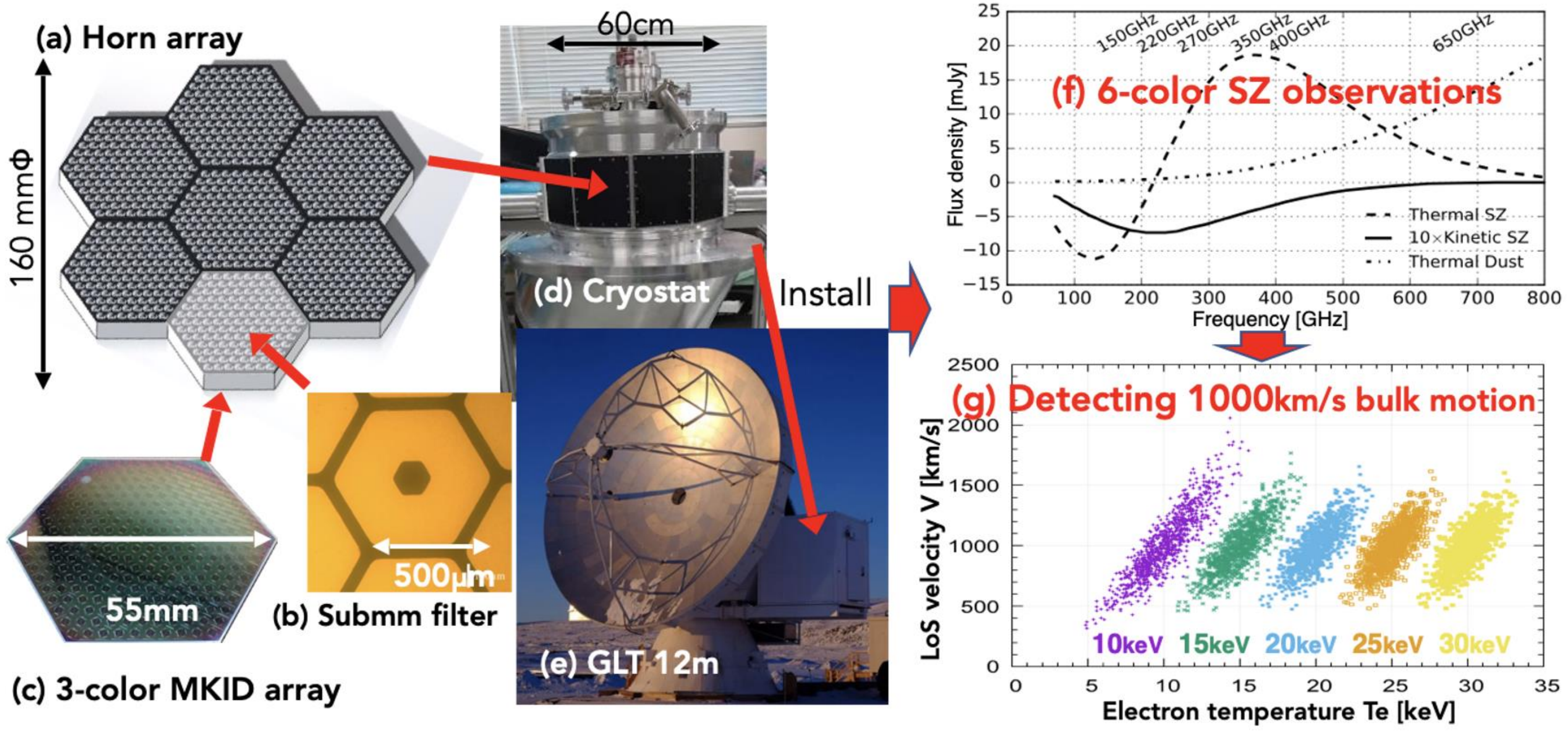
(Imamura, C., et al., in prep.)



10. Why NAOJ? – Harnessing the legacy of Nobeyama, ASTE, ALMA, ALMA-WSU and beyond

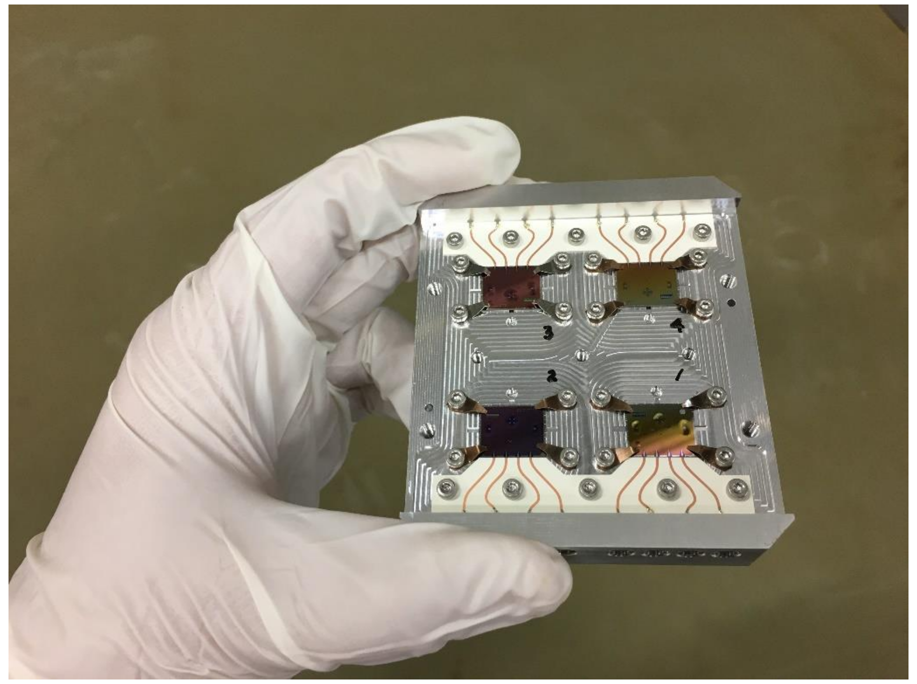
- Using the technologies and expertise that NAOJ has developed and operated over the years -- such as large, high-precision radio telescopes, superconducting detectors, digital signal processing, signal transmission, and remote control -- through projects including Nobeyama 45m, ASTE, and ALMA telescopes,
- we aim to maximize these resources to expand the scientific achievements of ALMA, one of NAOJ's flagship missions.
- And aim to open new discovery spaces and deliver groundbreaking scientific results.

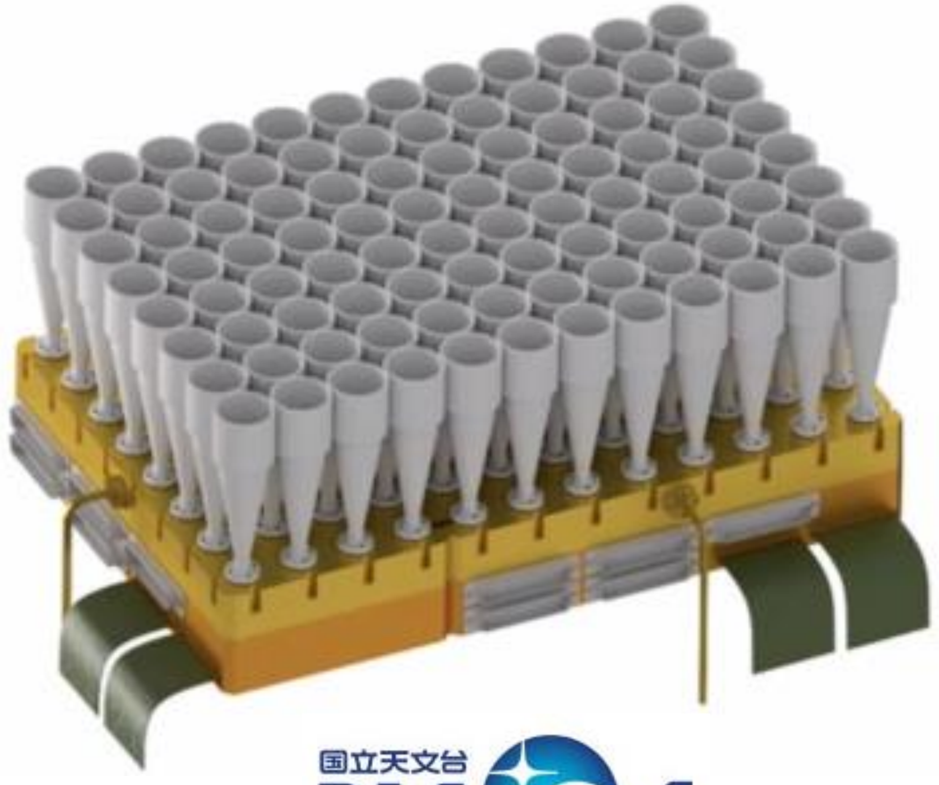
Expertise on direct detectors and SZE science



T. Oshima, et al.

Large-format Array with Hybrid-Planar-Integration





Wenlei Shan,
Shohei Ezaki, et al.