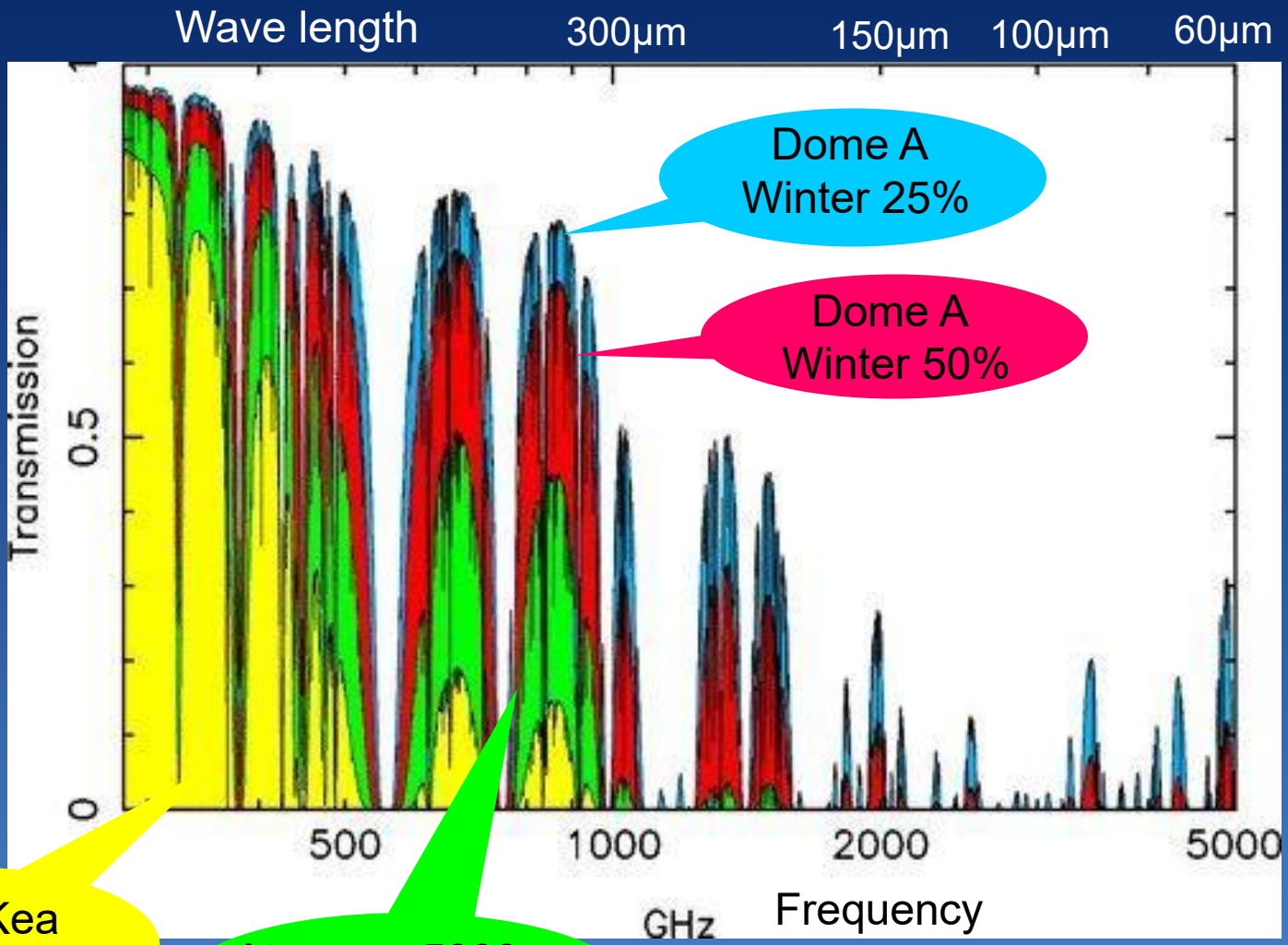
Activities on Antarctic Astronomy in Japan

Nario Kuno
（University of Tsukuba）

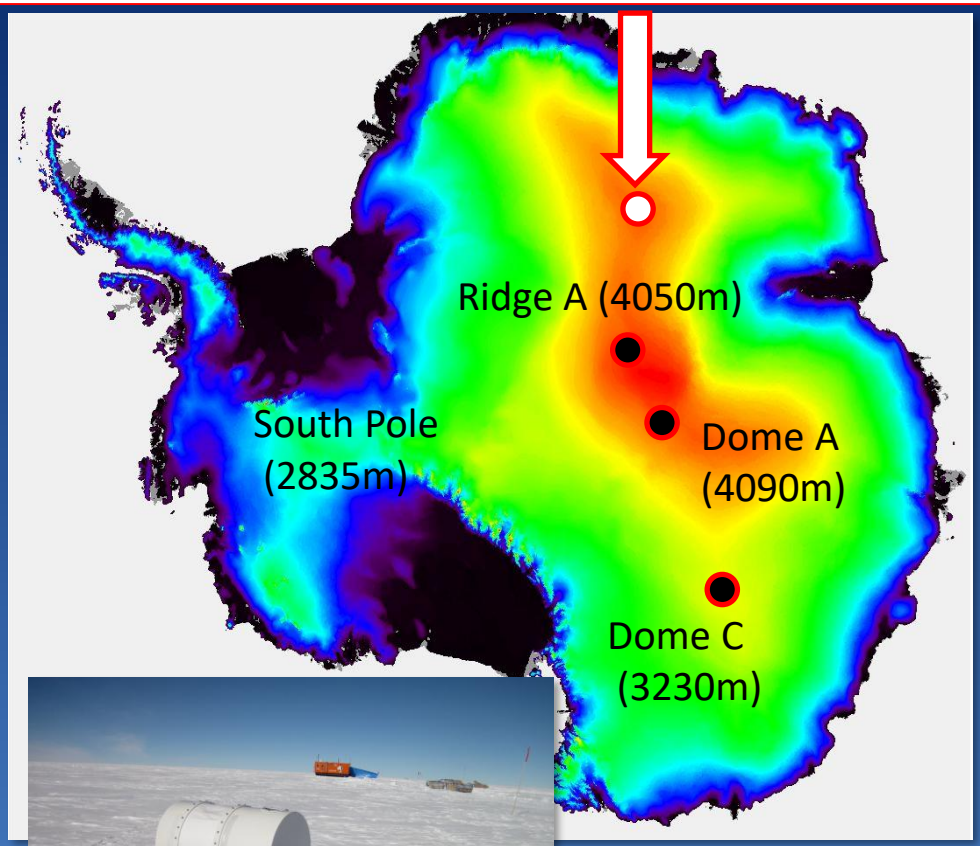
Sky transmission



(Yang et al. 2010)

⇒ **Best conditions for submm/THz observations!!**

Dome Fuji Station (3810 m) 1995-
(National Institute of Polar Research)



筑波大学
University of Tsukuba

TOHOKU UNIVERSITY

40-cm Infrared telescope (AIRT40
(Okita et al. 2010)

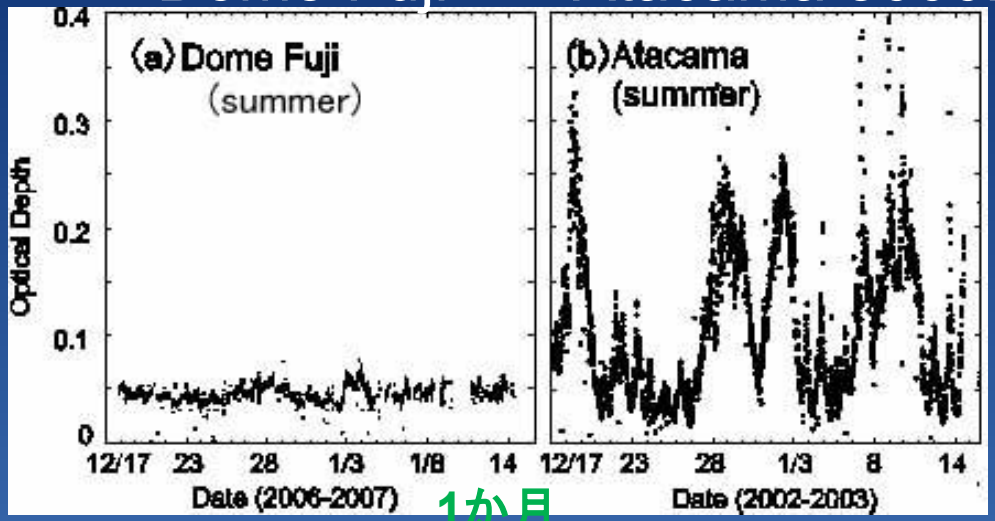
Measurements of atmospheric transmission at 220 GHz in 2006-2007
(Ishii et al. 2010)

Atmospheric transmission at Dome Fuji

220 GHz (2006-2007)

Dome Fuji　　Atacama 5000m

Optical depth

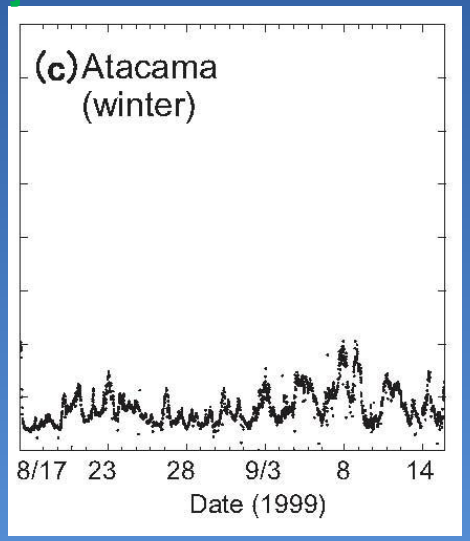


1か月

Summer

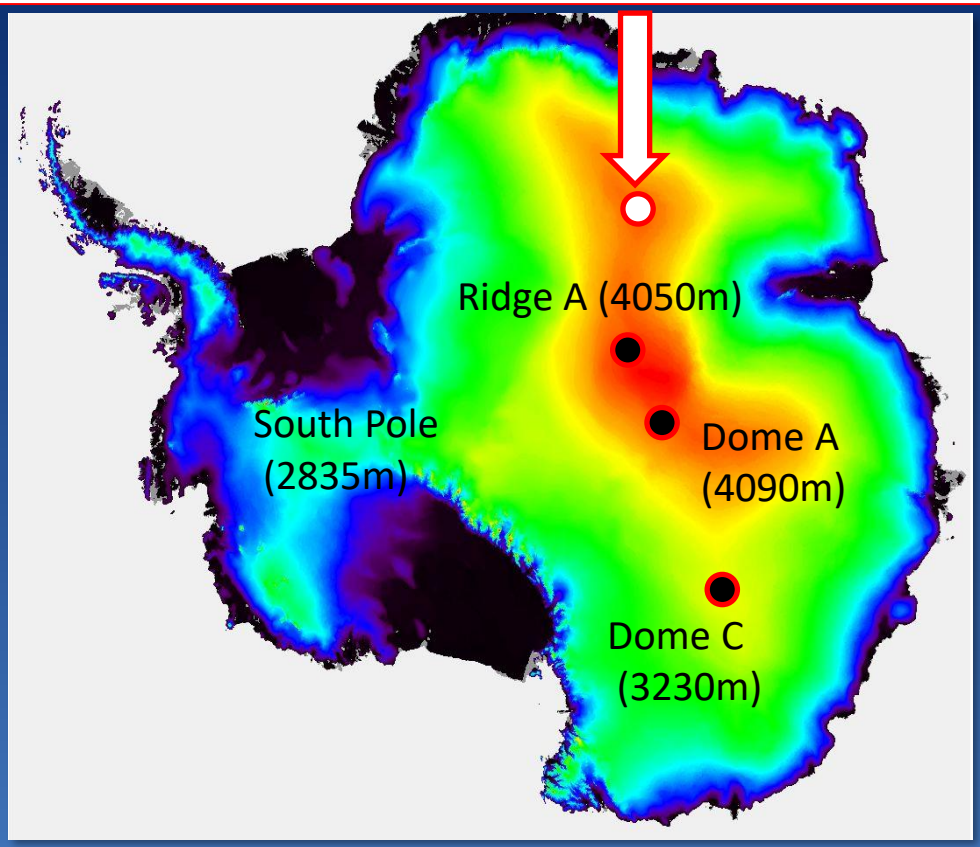
Ishii et al. (2010)

?



Winter

Dome Fuji Station (3810 m)
(National Institute of Polar Research of Japan)

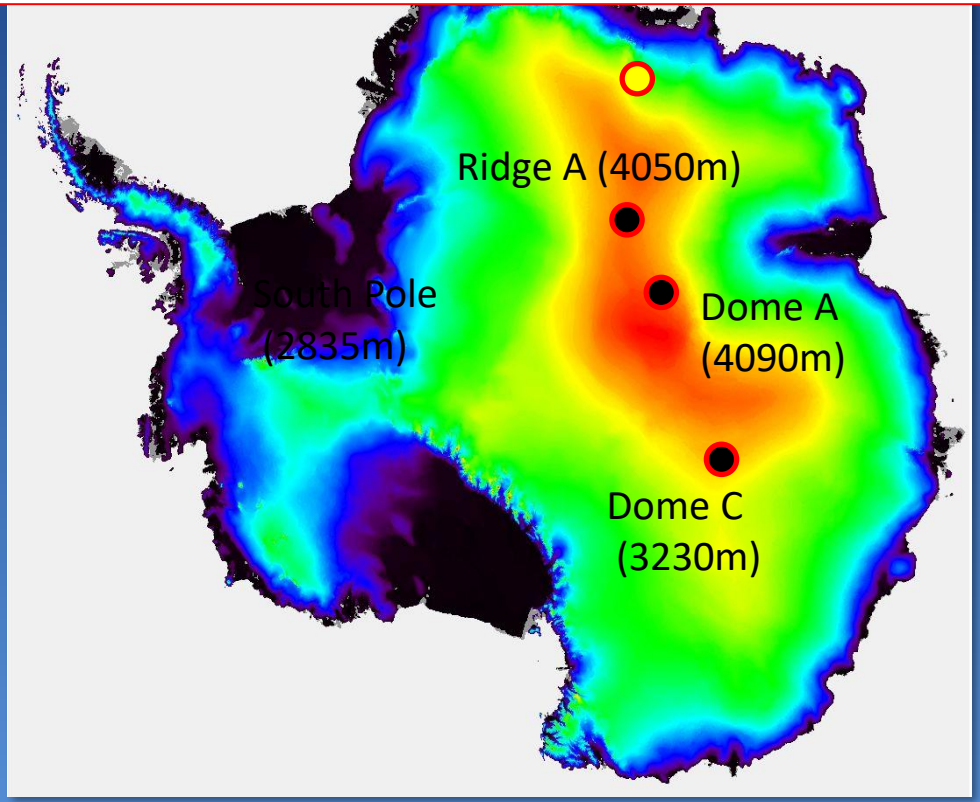


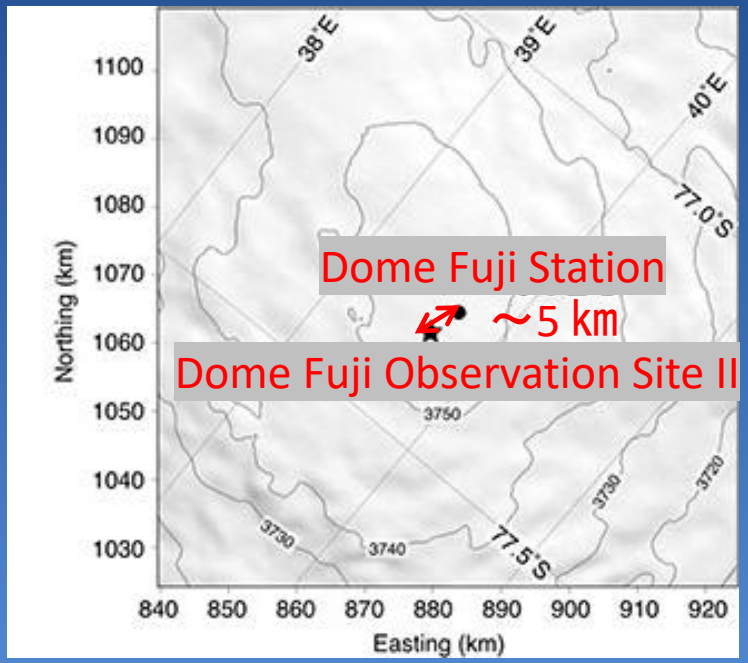
- Dome Fuji station is now under snow…

Dome Fuji Observation Site II

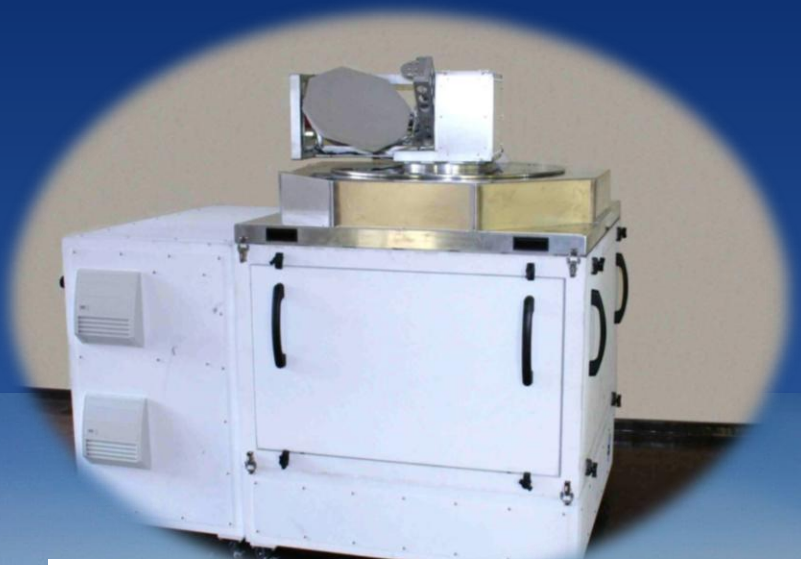
- ~ 5 km from Dome Fuji Station
- Ice core drilling ⇒ astronomical observation

Dome Fuji Observation Site II (3800 m)
(National Institute of Polar Research of Japan)





Antarctic submm/THz Telescopes



30-cm submm Telescope

12-m THz Telescope

30-m class THz Telescope

Dome Fuji Observation Site II

Antarctic Astronomy Consortium of Japan

Antarctic 30-cm Submm Telescope

Galactic Plane Survey

- [CI]($^3P_1$-$^3P_0$) : 492 GHz
- CO(J =4-3): 461 GHz

Simultaneous observations

NiPR General research observation（2023—2028）

- 2025: Transportation to Syowa station 2025
- 2026: Start of observations

Galactic Plane Survey with 30-cm submm telescope

Evolution of interstellar gas

Diffuse gas ⇒ Molecular clouds ⇒ Dense gas ⇒ Stars

- [CI]($^3P_1$-$^3P_0$) @ 492 GHz

  Diffuse CO-dark gas

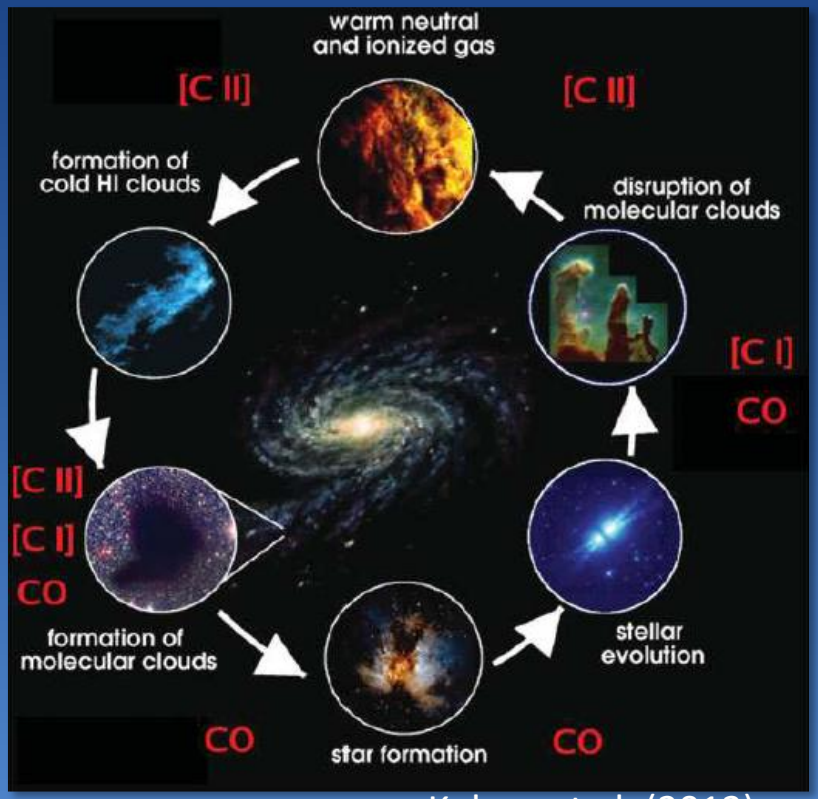
  ⇒ Formation/disruption of molecular cloud

  $E_U/k = 23.4$ K, n_c~500 cm^{-3}
- CO(J =4-3) @ 461 GHz

  Warm and dense gas

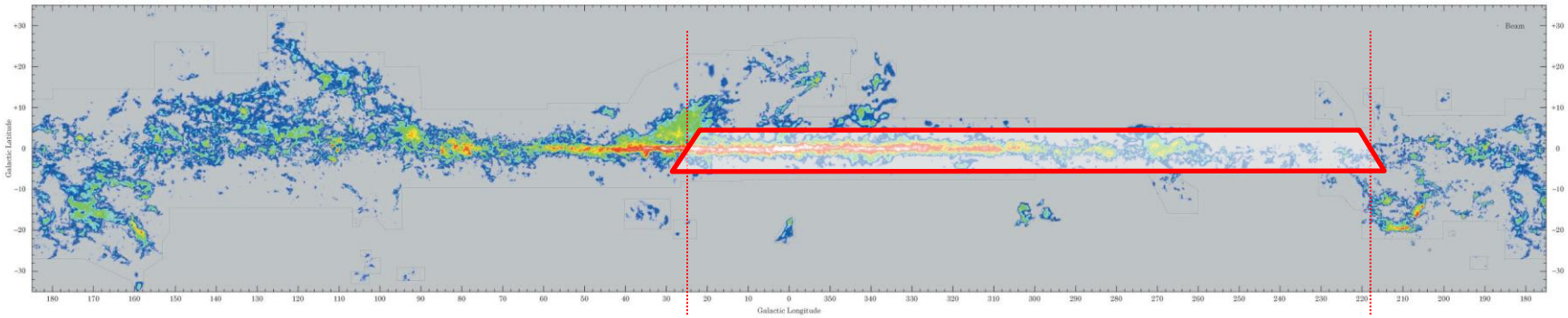
  ⇒ Star forming phase

  $E_U/k = 55.6$ K, n_c~10^5 cm^{-3}



Kulesa et al. (2012)

Galactic Plan survey in [CI]($^3P_1$-$^3P_0$) and CO(J=4-3)



High transmission and stability of atmosphere

⇒ Large scale survey（half of the Galactic plane）

（Total observing time ～1500 hr）

CfA CO(J =1-0) survey (Dame et al. 2001)

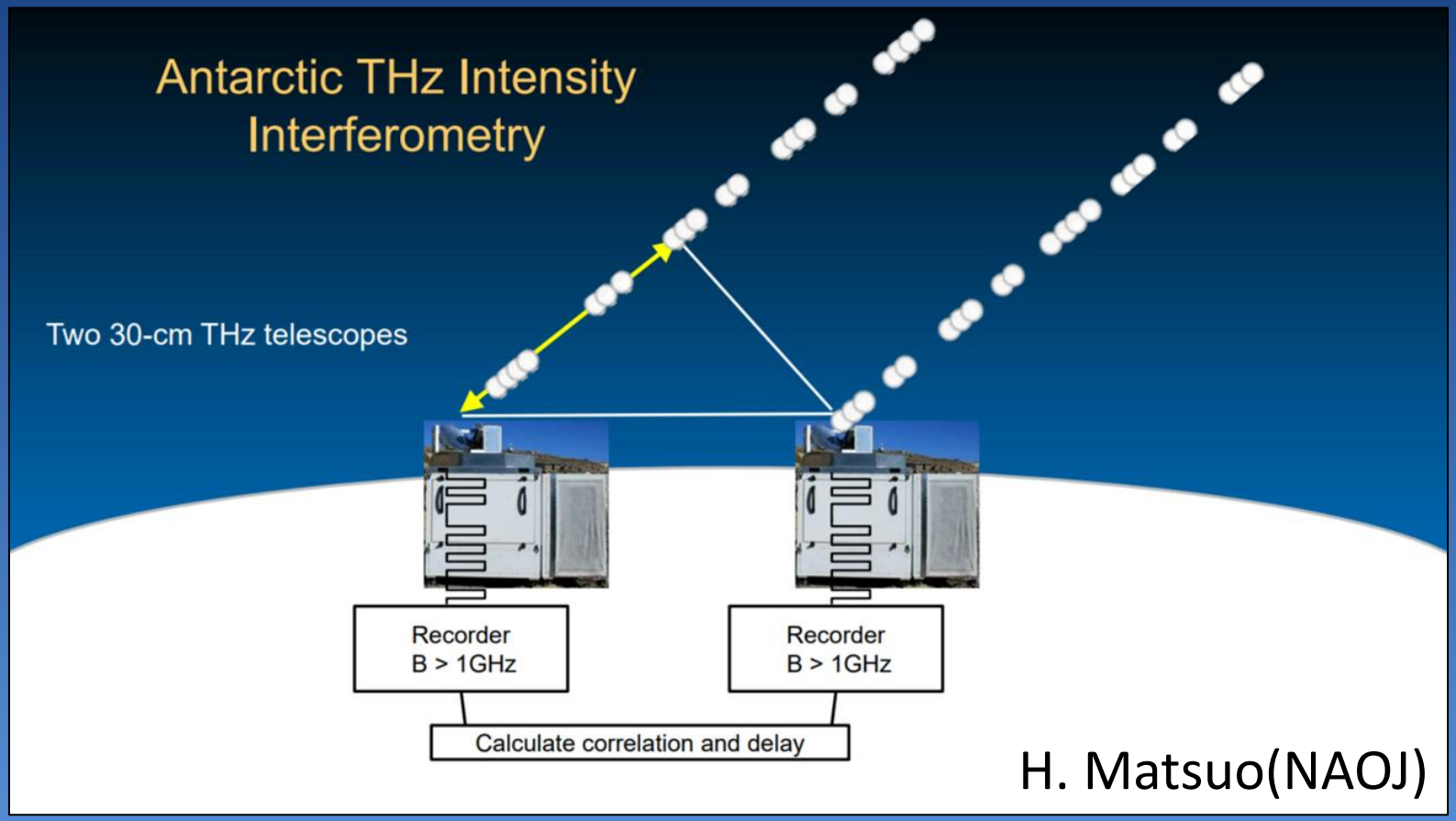
- Same beam size ~9’
- Comparable S/N ratio

Direct comparison ⇒ Physical properties of molecular gas

Talk by Shunsuke Honda

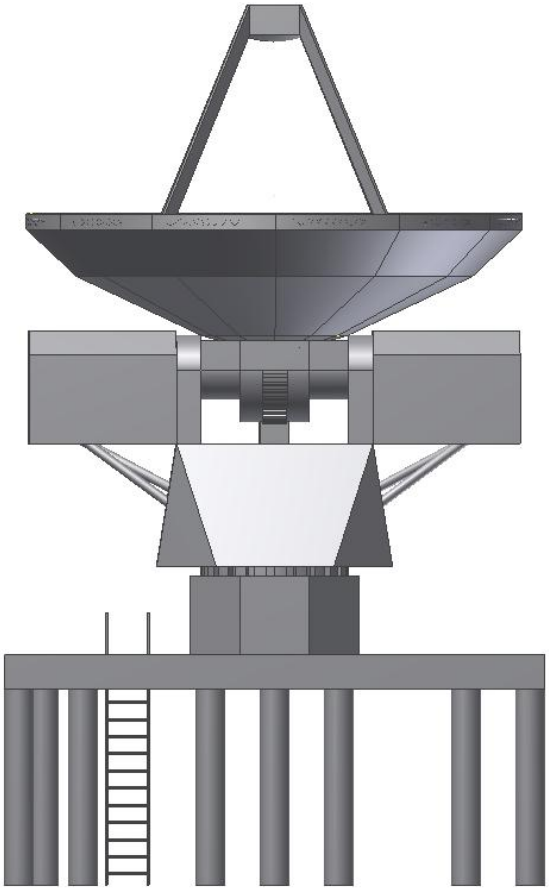
Antarctic THz Intensity Interferometry

- Deployment of a second 30-cm submillimeter telescope (replica of the first unit)
- Acquisition of intensity correlation data using two spatially separated antennas (~10 m baseline)
- Successful demonstration of the first intensity interferometry experiment at submillimeter wavelengths (500 GHz)
- Identification and assessment of key challenges toward the realization of a terahertz interferometer



12-m Terahertz Telescope (ATT12)

Not yet secured the budget



- Diameter : 12 m
- Frequency : 200 GHz-2 THz
- Surface accuracy : < 15 μm
- Field of view : ~ 1°
- Pointing accuracy : 0.5″
- Power consumption: < 35 kVA
- Low temperature steel
- Pedestal
- De-icing system

Angular resolution

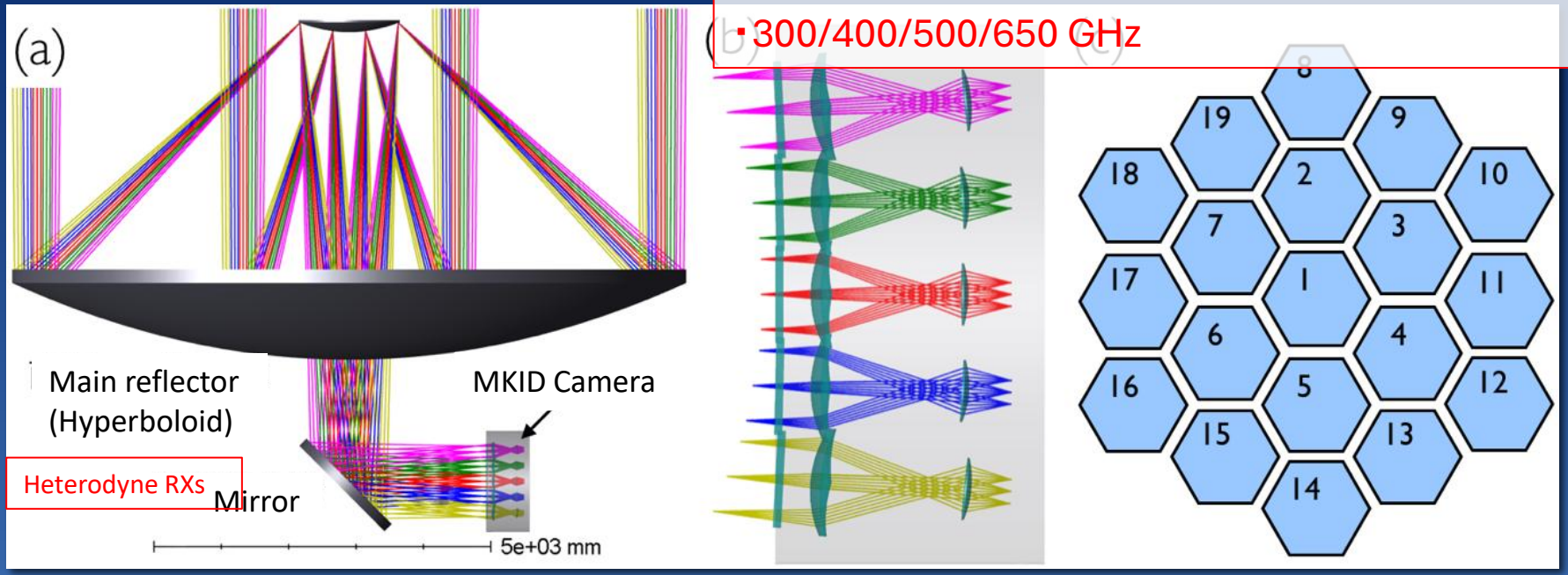
400 GHz	860 GHz	2 THz
15.6″	7.3″	3.1″

MKID Camera

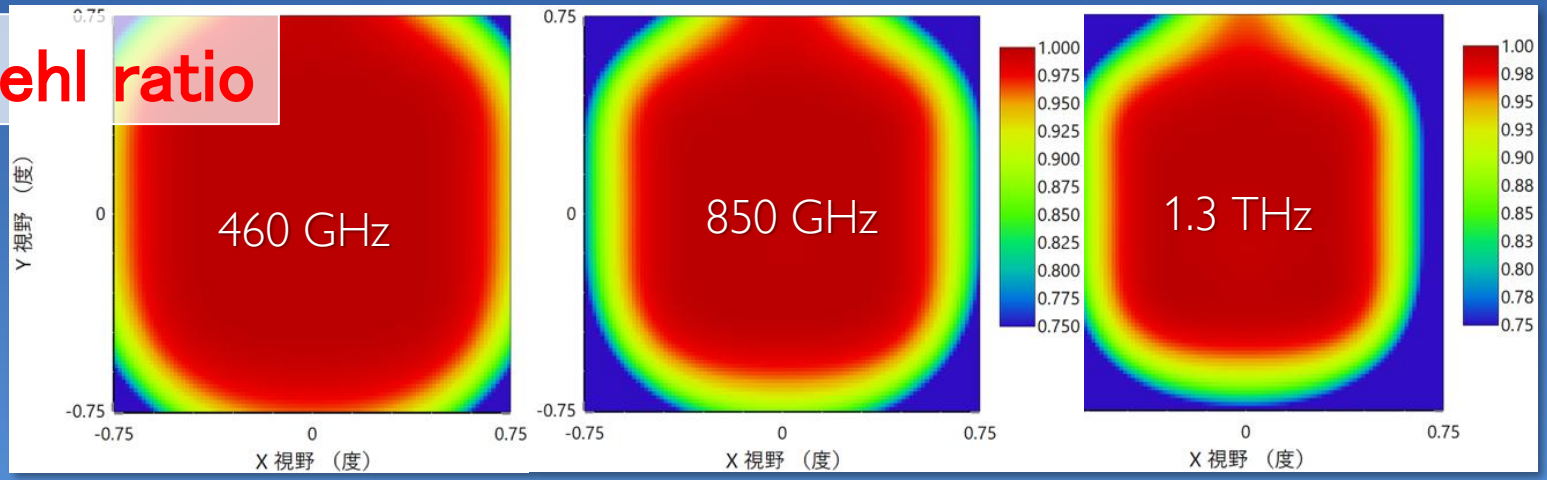
Optical system : Ritchey–Chrétien

Microwave Kinetic Inductance Detector Camera

- 850 GHz
- 300/400/500/650 GHz

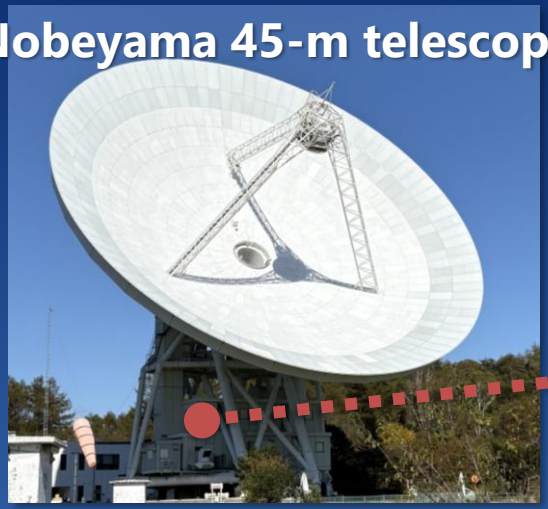


Strehl ratio



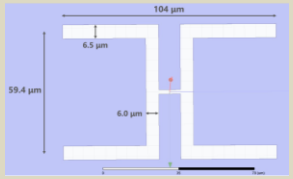
100-GHz band MKID camera

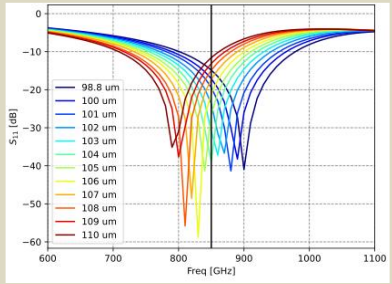
Nobeyama 45-m telescope



100-GHz band MKID camera

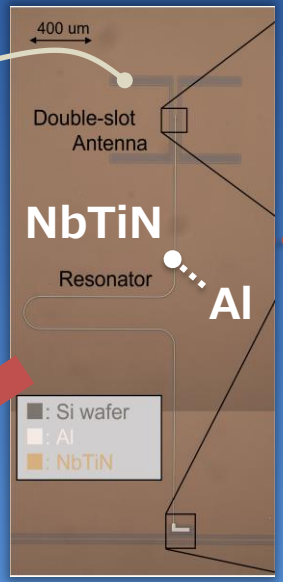
850 GHz antenna simulation





(A. Inoue)

Antenna-coupled MKID



developing a new design to suppress noise

109pix array

- operation temperature <100 mK

SI lenslet + MKID

S. Honda, URSI GASS, 2023

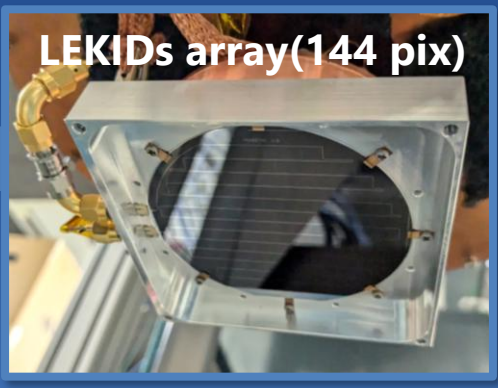
LEKID (with Univ. Grenoble Alpes)

Collaboration with the Univ. Grenoble Alpes in France.

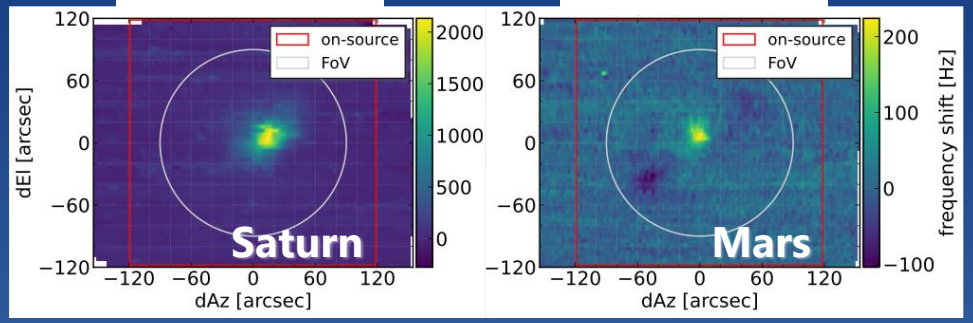
- 2024/10 Test of the 100-GHz LEKID installed on NRO 45-m telescope.
- Developments of an 850-GHz LEKID is currently underway.

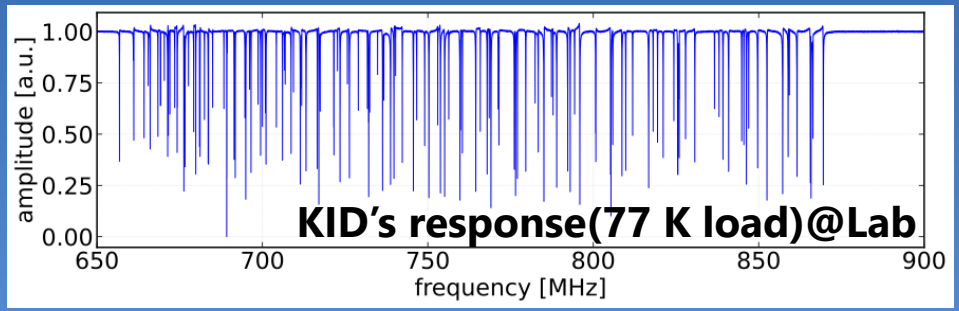
100-GHz band LEKID

- Al-Ti bi-layer
- Hilbert meander
- 144 pix



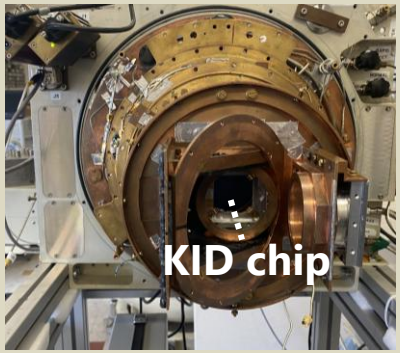
Commissioning 2024@NRO

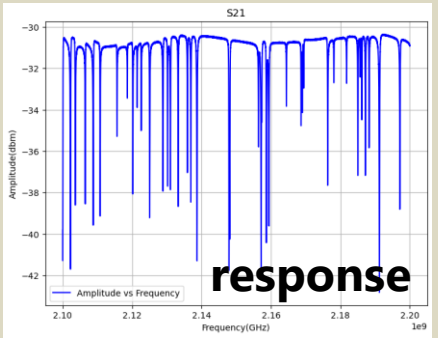




850-GHz band LEKID (Y. Sato)

Measurement at Univ. Grenoble Alpes

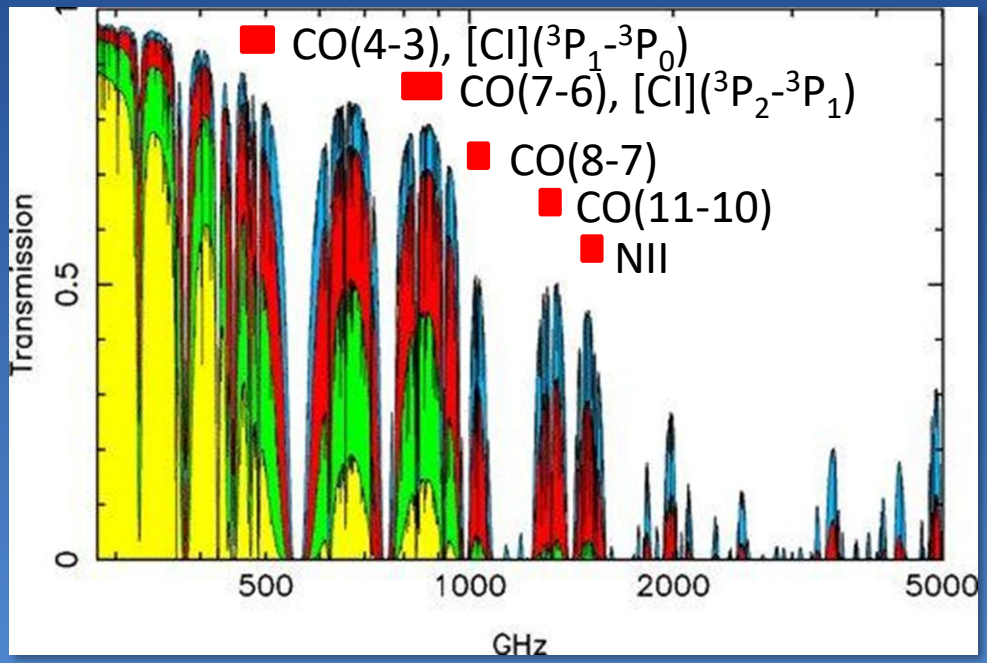


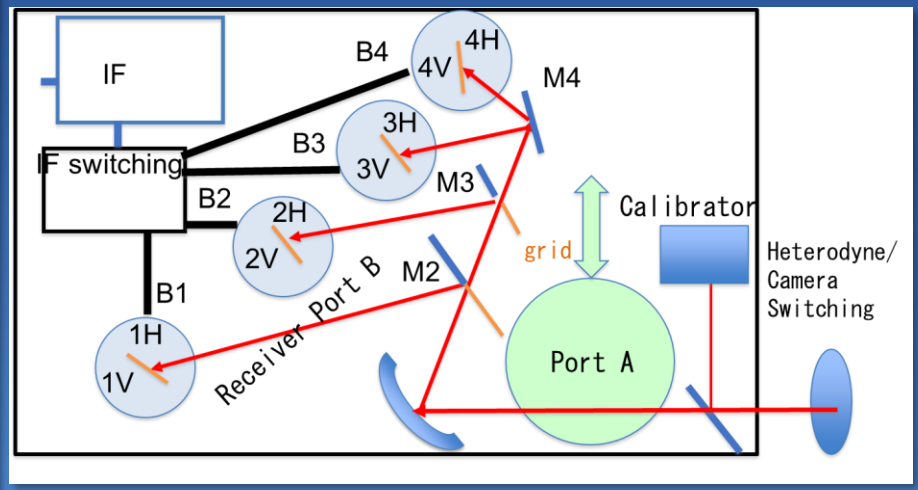


using 5 K blackbody

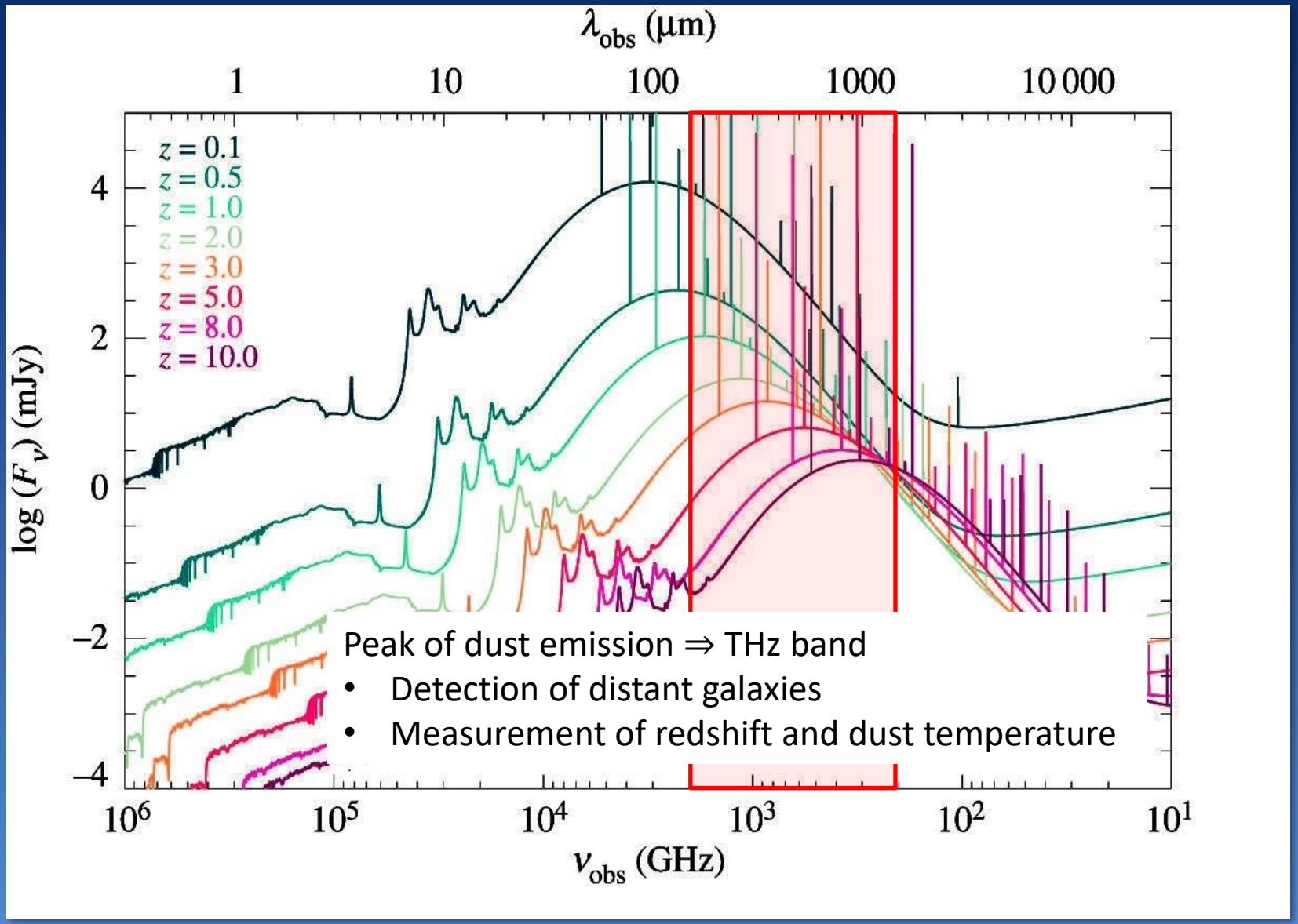
Heterodyne receivers

- Line observations through the atmospheric windows
  - 450 GHz, 650 GHz, 800 GHz, 1 THz, 1.3 THz, 1.5 THz, 1.9 THz
- Development of Receiver for THz band (SIS or HEB?), multi-beam Receiver





Scientific Objectives



(Hodge and da Cunha 2020)

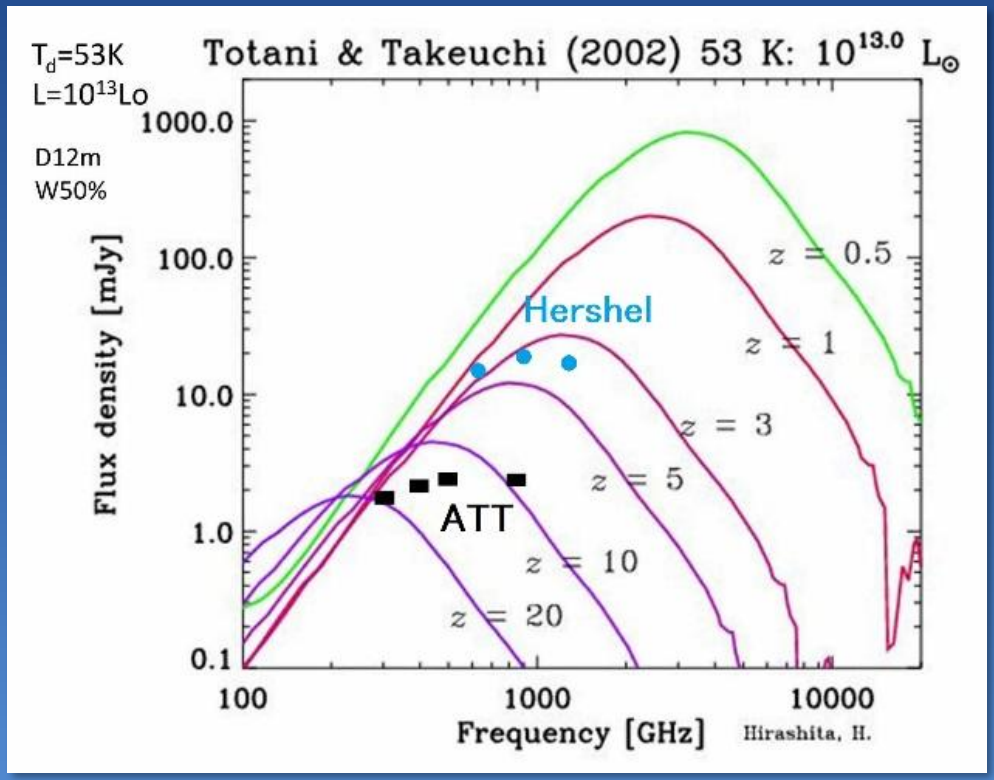
Study of galaxy evolution with ATT12

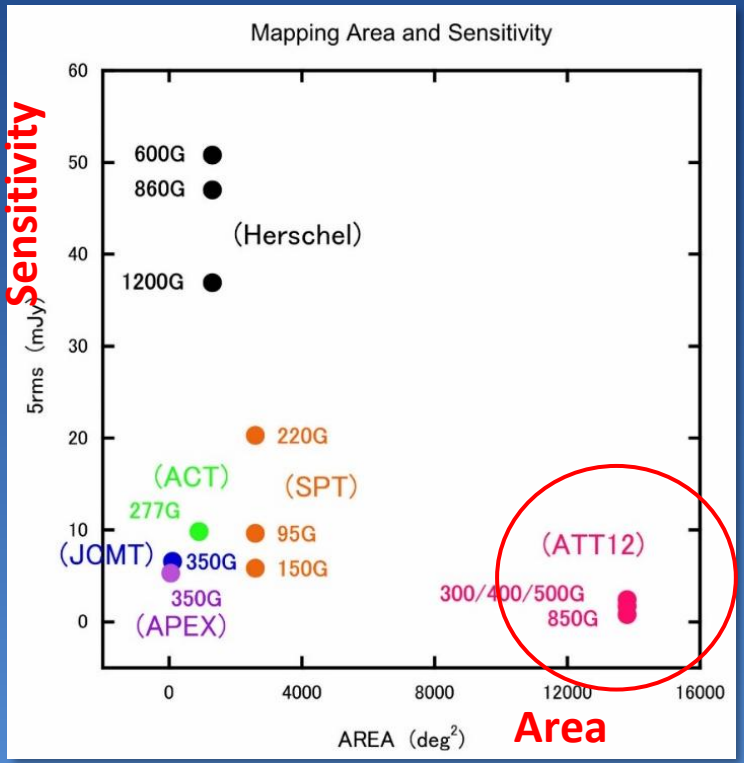
(Cont.) Southern sky survey with confusion limit at 300, 400, 500, 650, 850 GHz

⇒ Detections of more than 10^7 galaxies with dust emission
→ Determination of SED covering peak frequency

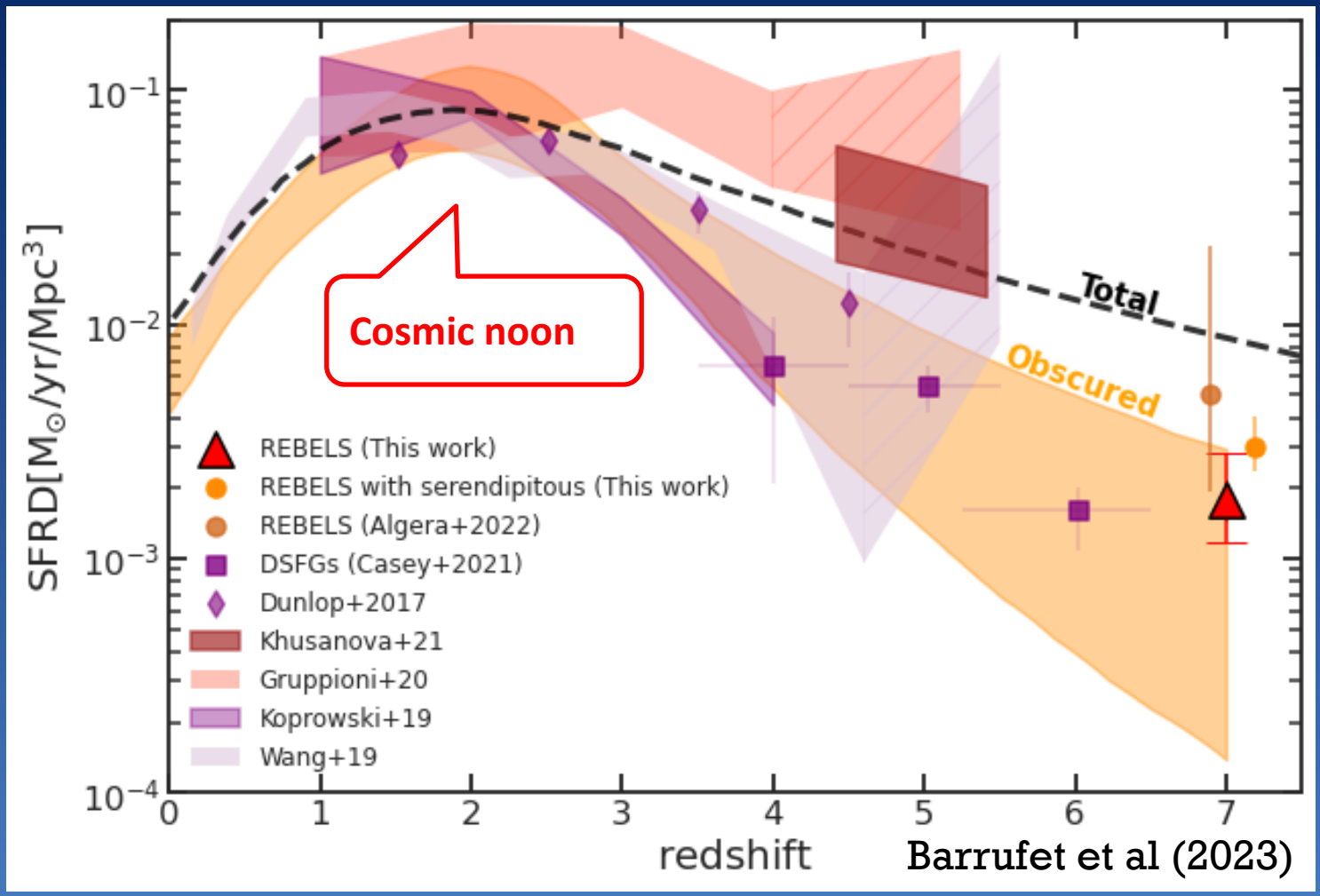
⇒ Cosmic star formation history & Evolution of Supper massive Black Holes

⇒ When hyper luminous galaxies formed?





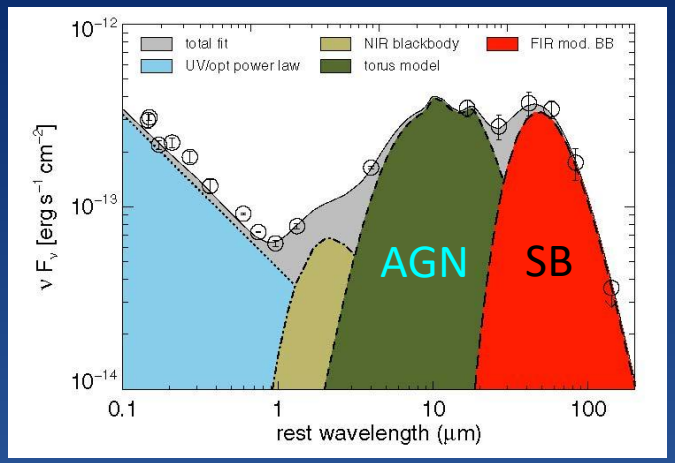
Cosmic star formation history

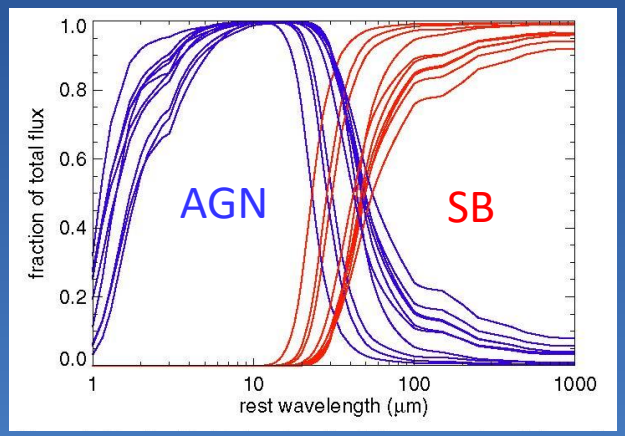


Before cosmic noon（z > 2）: Dust obscured SF galaxies

More sample ⇒ THz observations

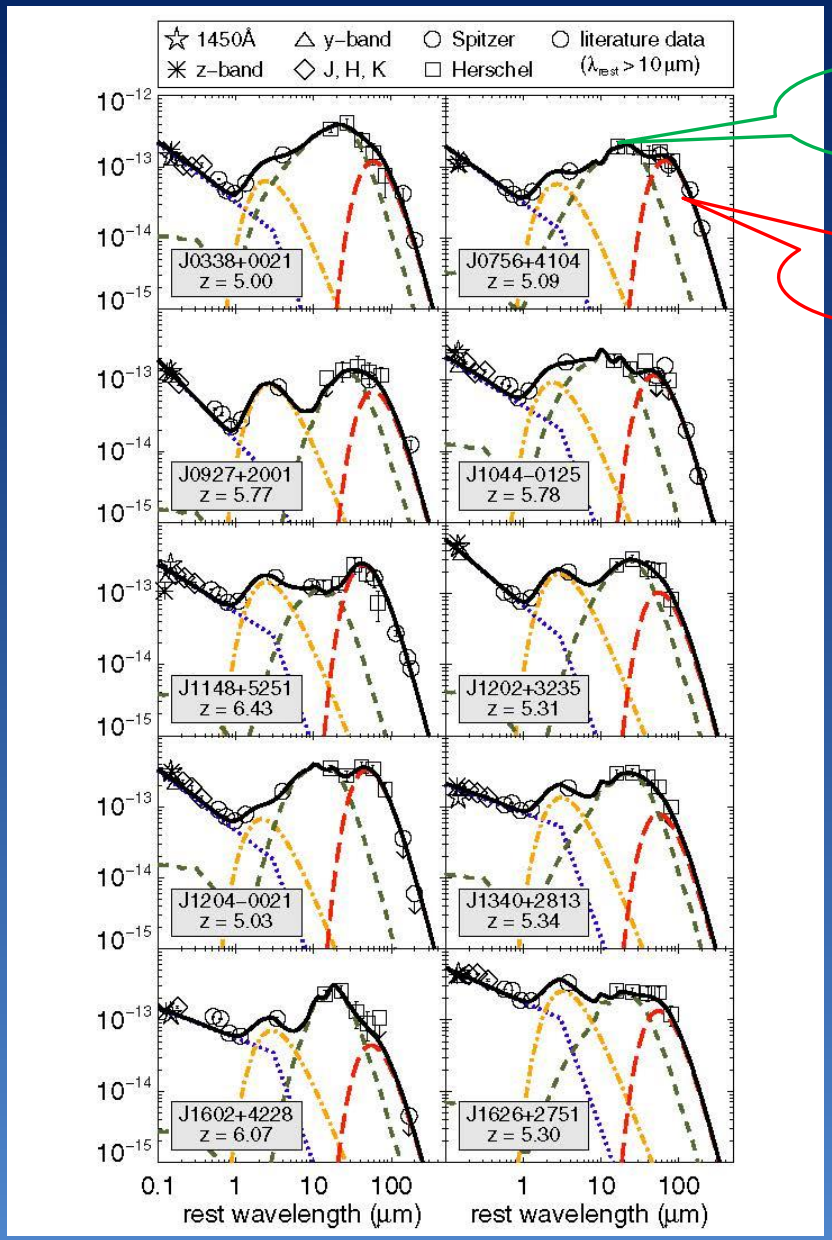
Dust continuum





rest λ～
20-60μm

z>7 λ～
160-480μm
THz,submm



AGN-torus

Cold dust

(Leipski+2014)

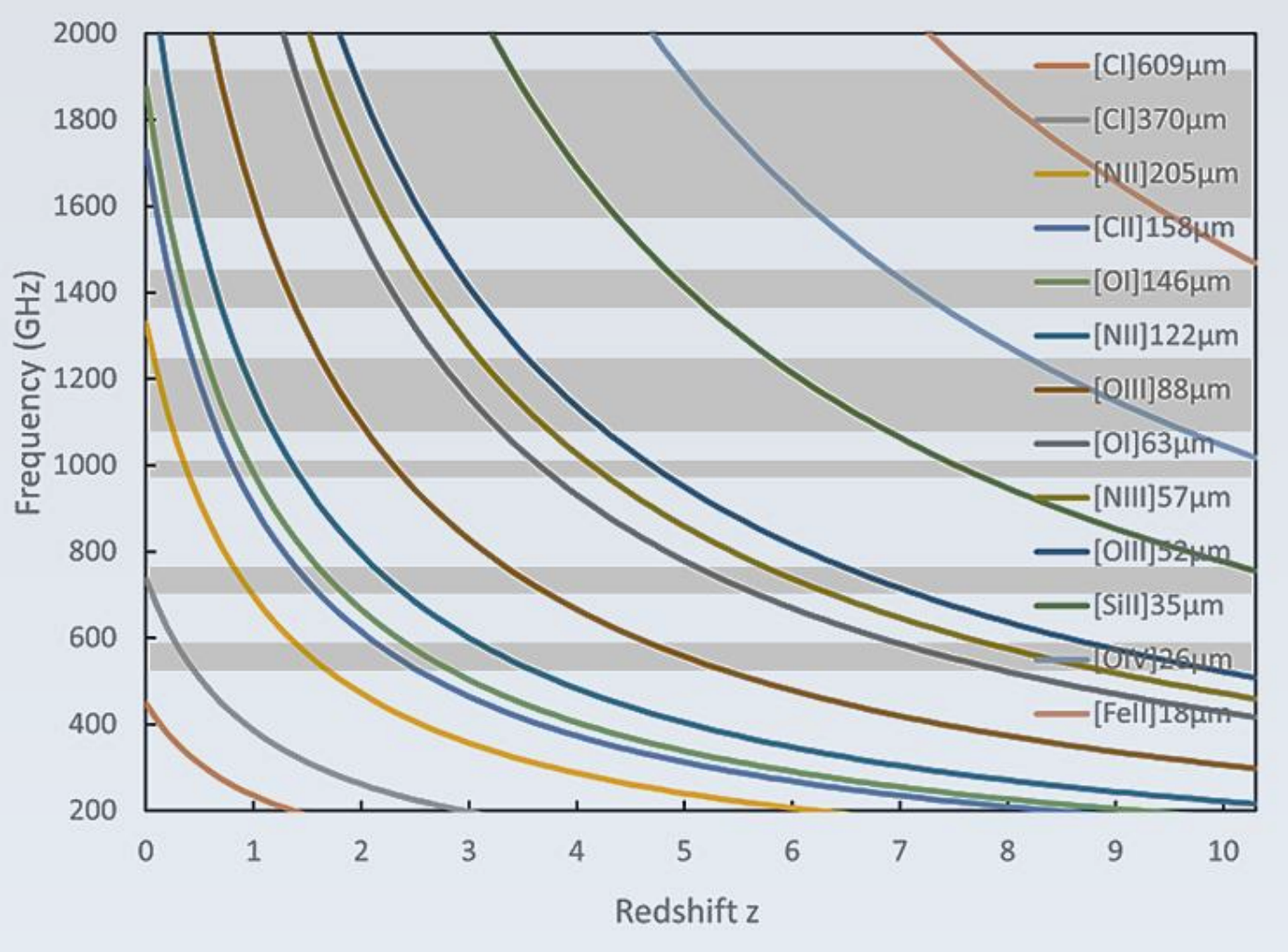
Study of galaxy evolution with ATT12

（Line）Fine structure lines from high z objects

（[CII]158, [OI]145, [OIII]52/88, [NII]122/205…）

⇒ Evolution of ISM in galaxies

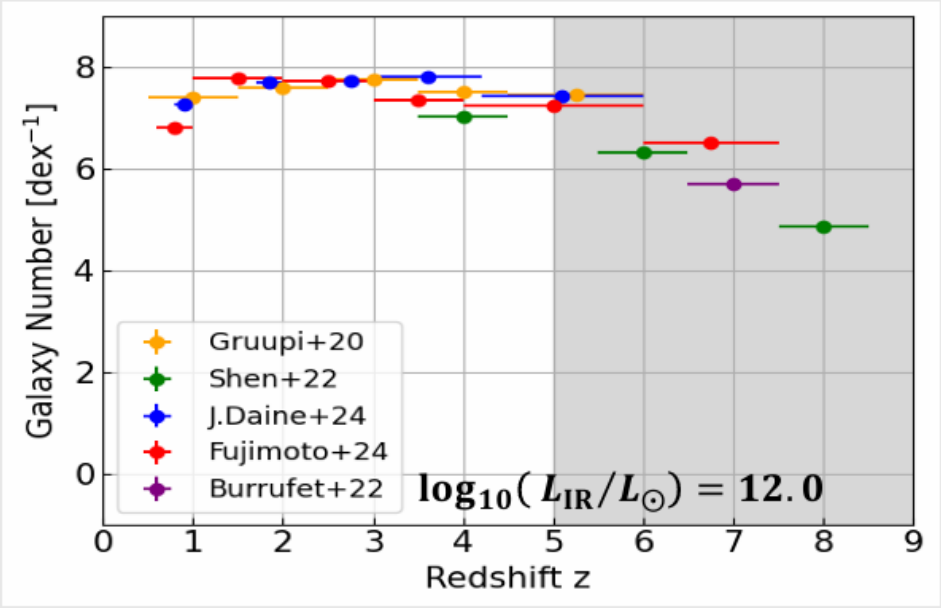
(Electron density, Metallicity, Ionized state)

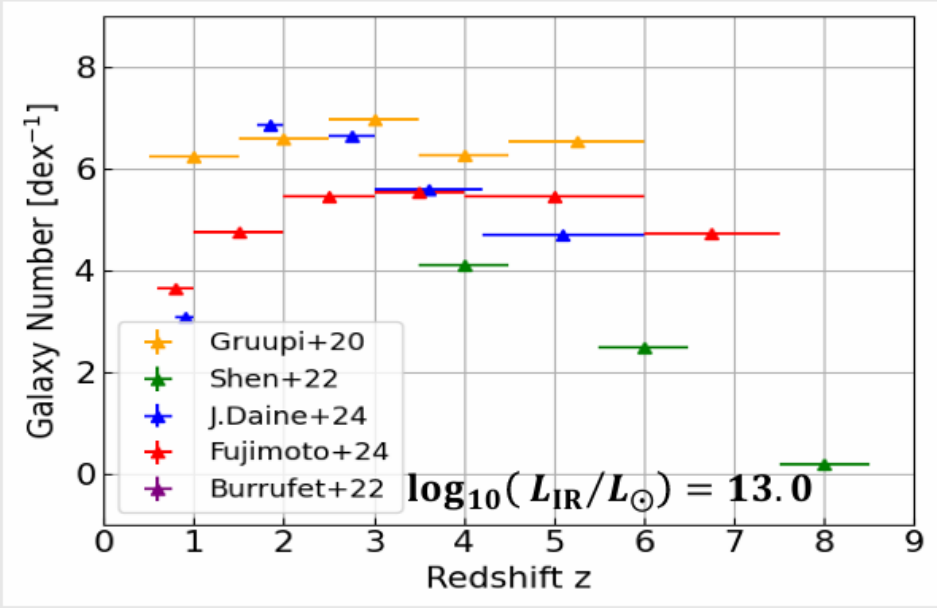


Properties of ISM

Physical properties	lines	Redshift range	Lower limit log ($L_{IR}/L_{\odot}$)
Electron density	[OIII]52/88 [μm] [NII]122/205	z ～ 0.7 – 6.0	13.4 13.0
Metallicity	[NIII]57,[OIII]52/88 [CII]158, [NII]205	z ～ 0.4 – 6.0	14.0 13.0
Ionized state	[OIII]88, [CII]158 [OIII]88, [OI]145	z ～1.2 – 6.0	12.8 13.0
AGN	High-J CO (e.g., J_{up}=12)	z = 0.4-0.8 and 2-5.6	～14

Number of detectable galaxies





(Wakasugi, 2025 Master thesis)

Antarctica 30-m class Terahertz Telescopes

- Diameter : 30m
- Surface accuracy : < 20μm
- Frequency : 200GHz-1.5THz
- Field of view : 1° (Ritchey–Chrétien)
- Pointing accuracy : 0.2″??
- Radio camera + Heterodyne
- International collaboration

Angular resolution（30m）

200GHz	850GHz	1.5THz
12″	2.9″	1.7″

Summary

- **Dome Fuji Observation Site II (NiPR)**
- **Antarctic 30-cm telescope**
  - [CI]($^3P_1$-$^3P_0$) & CO(J =4-3) Galactic plain survey
  - 30-cm THz intensity interferometer
  - Start astronomical observations at Dome Fuji II from 2026
- **Antarctic 12-m THz telescope**
  - ultra-wide field of view
  - Evolution of galaxies and AGN
  - International collaboration
- **Antarctic 30-m class THz telescope**