GroundBIRD

GB NOW

Osamu Tajima (Kyoto University)
on behalf of GB collaboration

The GB Collaboration

RIKEN Satoru Mima, Shugo Oguri, Chiko Otani (co-PI), Taketo Nagasaki

Kyoto Shunsuke Honda, Takuji Ikemitsu, Junta Komine, Junya Suzuki, Yoshinori Sueno, Osamu Tajima (co-PI)

KEK Masashi Hazumi, Hikaru Ishituka, Tomohisa Uchida, Mitsuhiro Yoshida, (O. Tajima as visiting staff)

NAOJ Makoto Nagai

ISAS/JAXA Yutaro Sekimoto

Japan, Spain, Korea, and Netherlands

Tohoku Makoto Hattori, Fumiyasu Kanno, Hiroki Kutsuma, Tomoka Okada

Tokyo Kenji Kiuchi, Makoto Minowa, Nozomu Tomita

Saitama Ryo Koyano, Masato Naruse, Toru Taino

Korea Yongil Jo, Kyungmin Lee, Junhyeok Moon, Eunil Won

IBS Jihoon Choi

TU Delft Kenichi Karatstu

IAC Ricardo Génova-Santos, Rafael Rebolo, José Alberto Rubiño-Martín, Mike Peel

Led by young guys!

Science of CMB obs.

Primordial
Gravitational
Waves

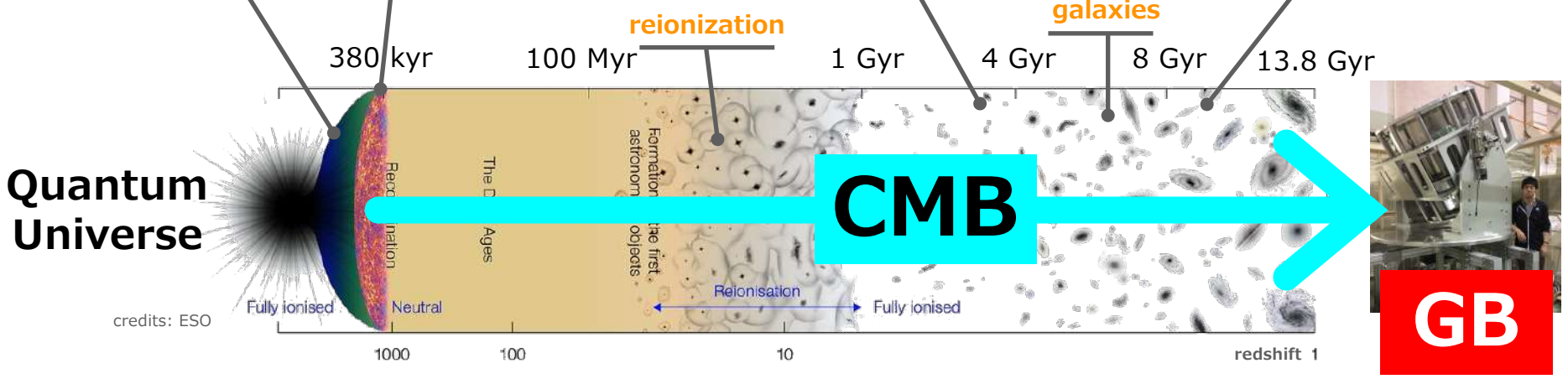
PGW

Contribution via "optical depth" (τ)

Σm_ν

Dark Energy

Dark Rad.



GB

GB aims CMB polarization patterns in large angular scale, O(1˚~10˚)

B-modes from PGW

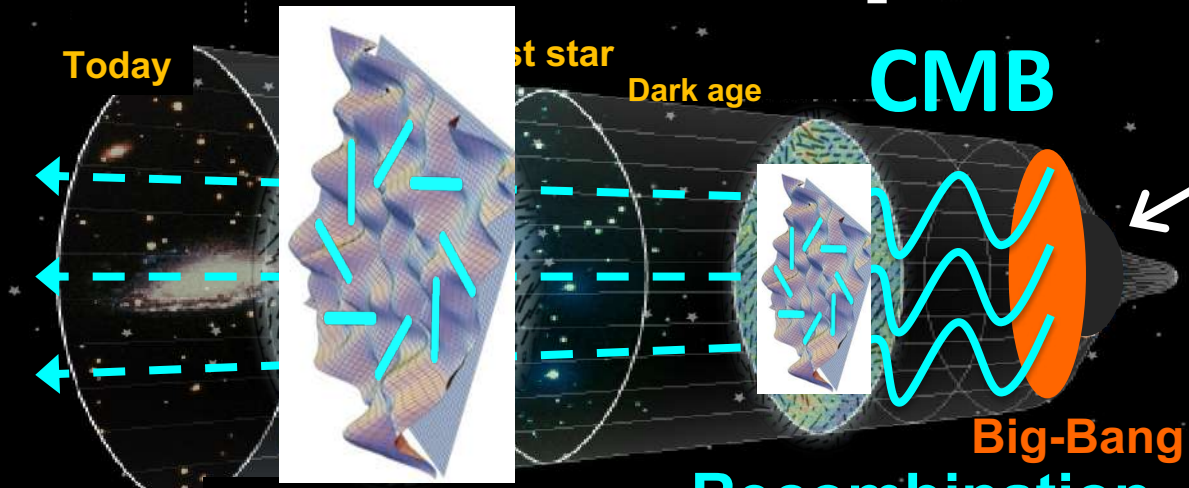
Looking at asymmetric patterns on wave surface

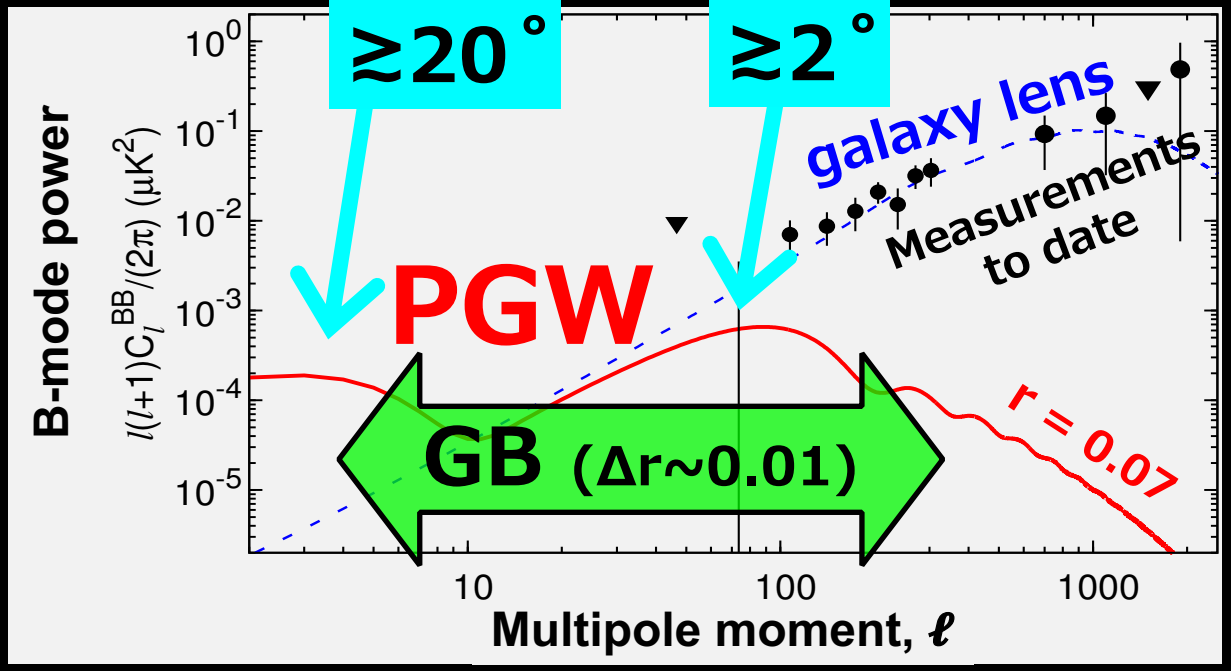
Large angular scale > 2°

Wave surface of PGW

Interferometers, e.g. LIGO
"look laser fluctuation"

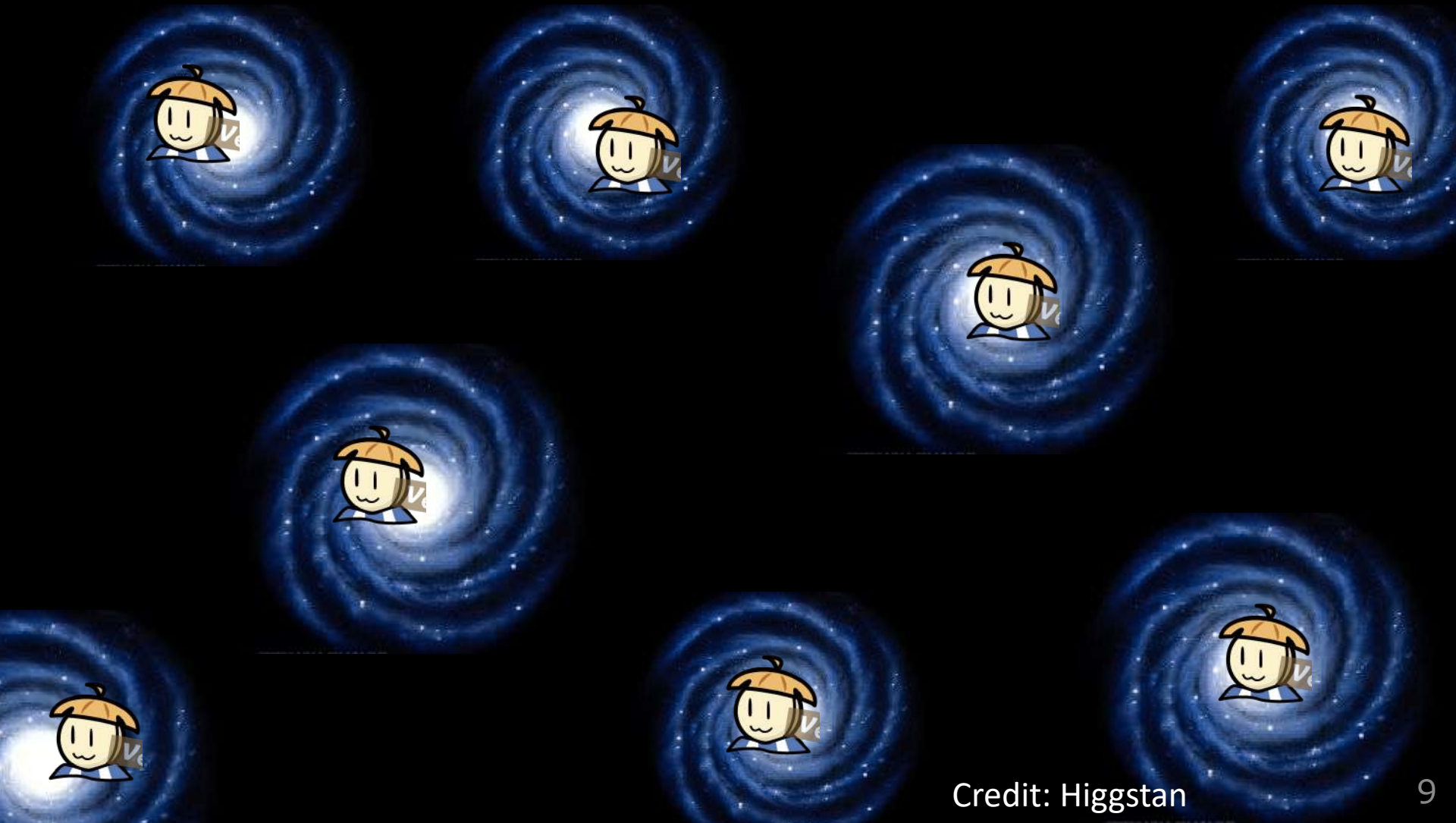
"Look" B-modes patterns





Courtesy of Y. Chinone

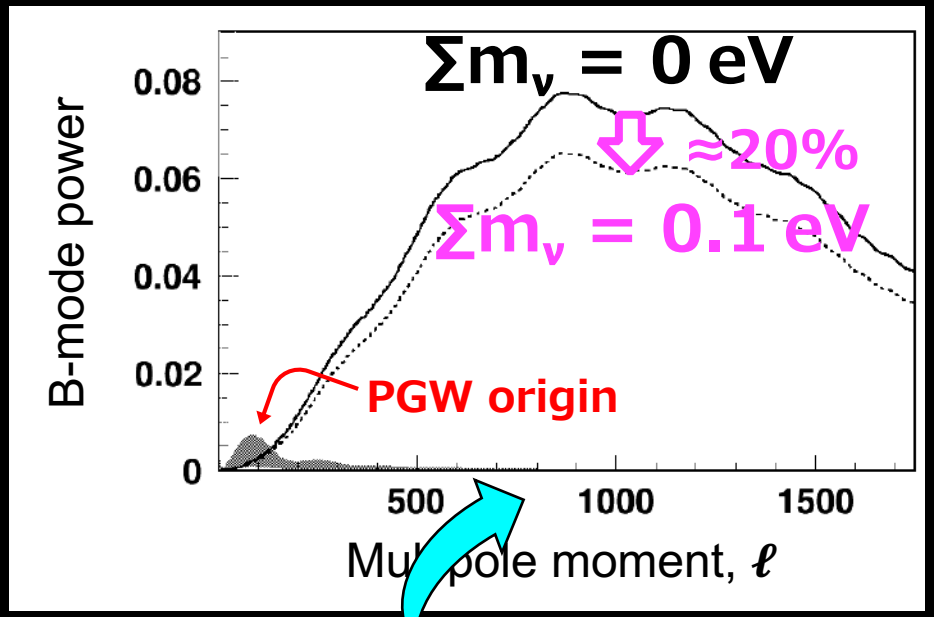
CvB is unique massive particle NOT localized in galaxy haloes

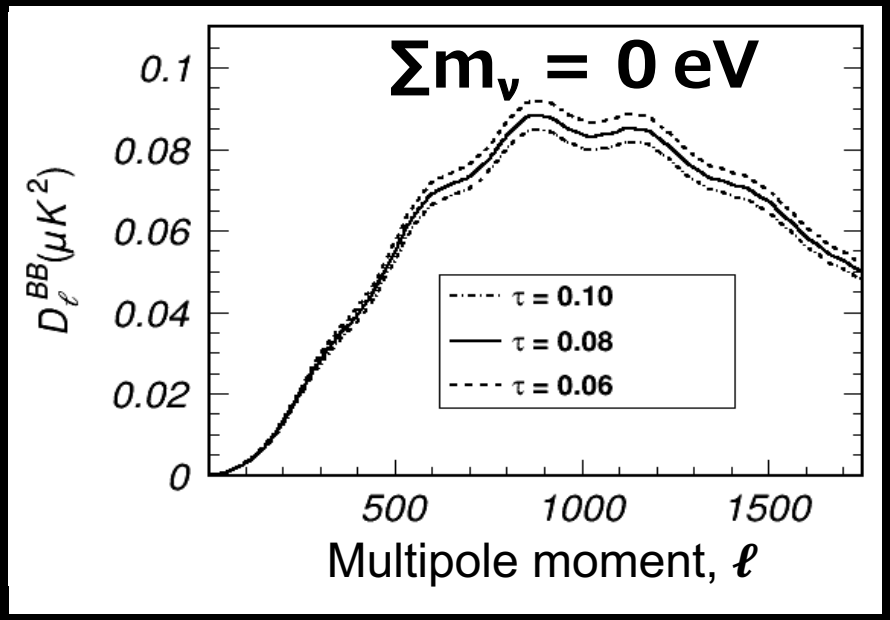


Credit: Higgstan

Σm_ν makes thinner lens

Correlation with τ should be unfolded



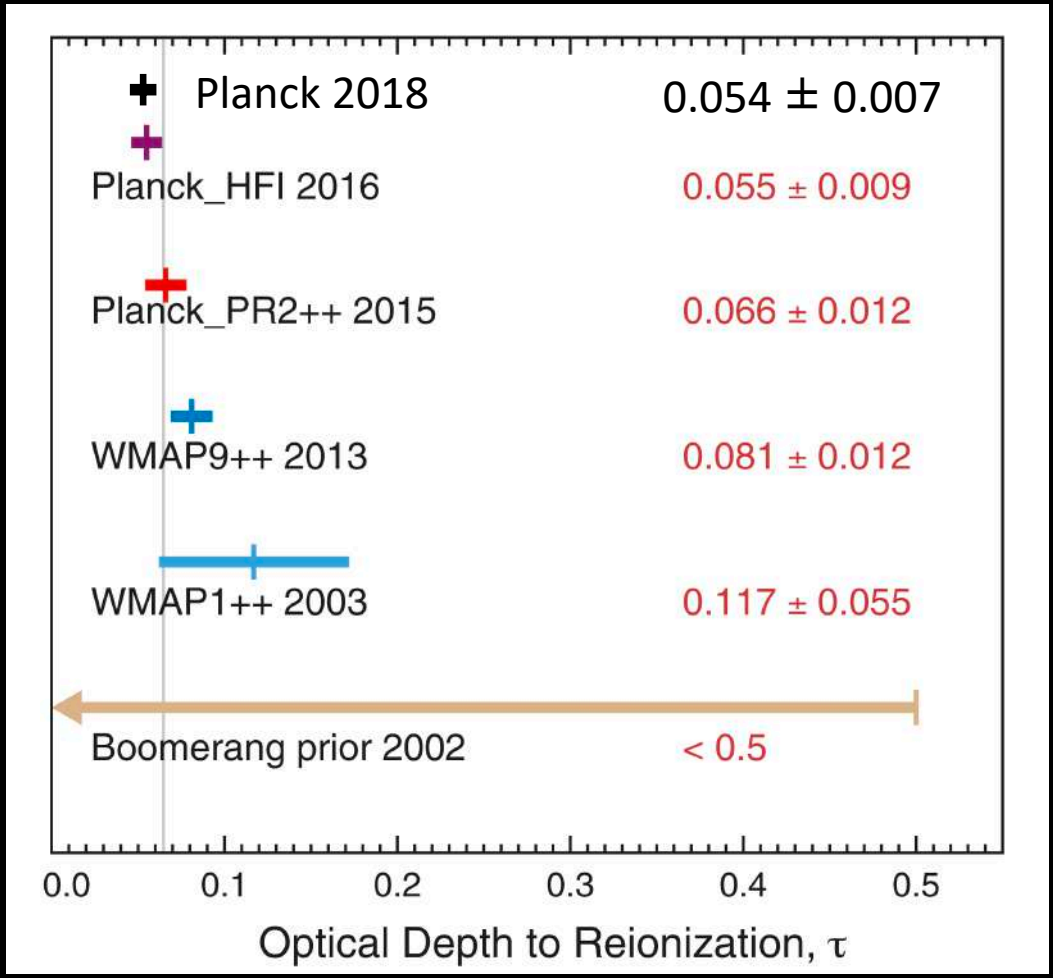


Moon scale
(0.5°)

Planck 2018: τ = 0.054 ± 0.007

$\Delta(\Sigma m_\nu)$ ~ 0.03 eV

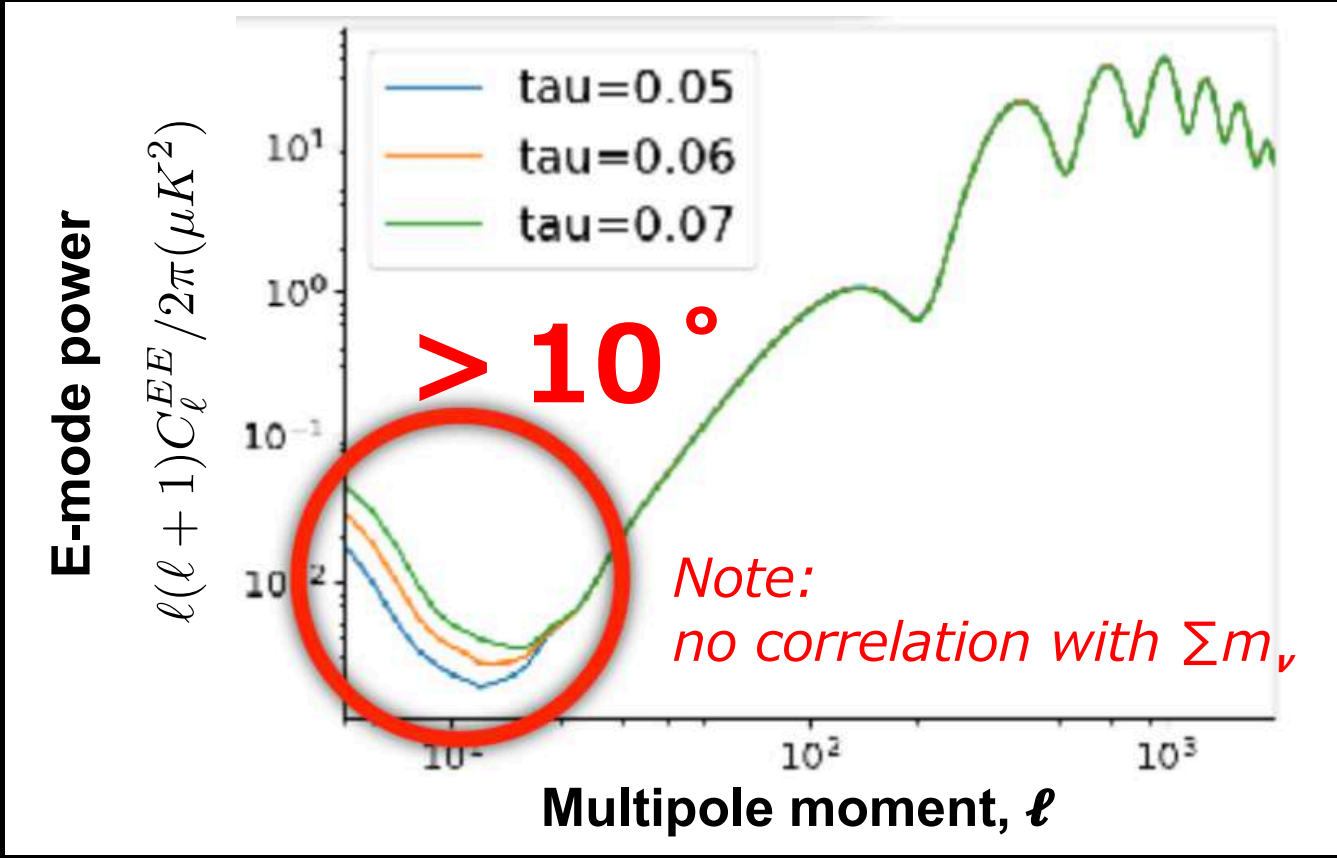
History of measured τ



collage plot of LAMBDA web

Why don't you measure it ?

$\tau \Leftrightarrow$ Reionization in E-modes (target $\Delta\tau \sim 0.01$ from single exp.)

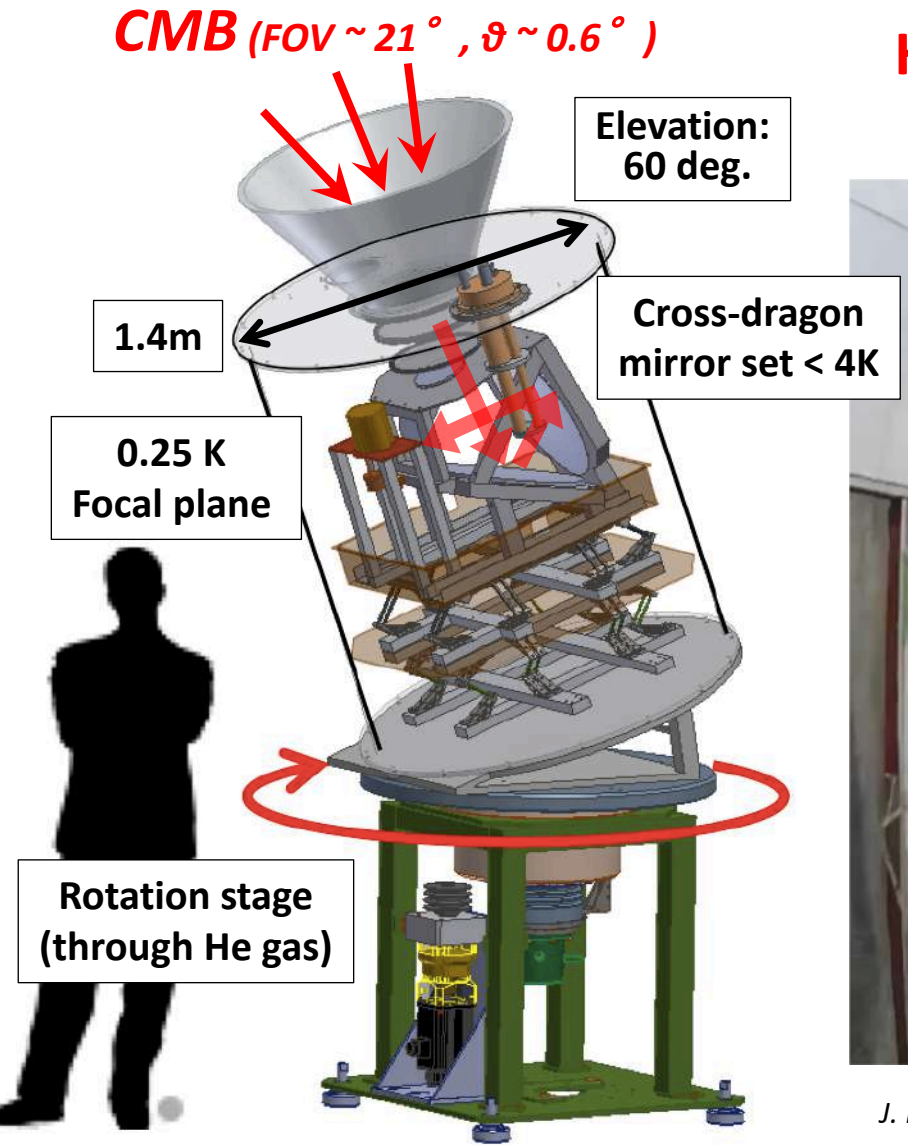


Experimental concepts to measure O(10˚) patterns

- **Wide scan with fast modulation**
  - → **High-speed Rotation-scan (HsRs)**
- **Fast time response for HsRs**
  - → **MKID ($\tau \lesssim 100$ μs)**
- **Be sensitive even though no-large focal plane**
  - → **Cryogenic optics (< 4K)**
- **Be robust for foregrounds**
  - → **DUST-band (220 GHz) + CMB (150 GHz)**
  - → **(future) alliance with QUIJOTE (10-40 GHz)**

Compact size is preferred

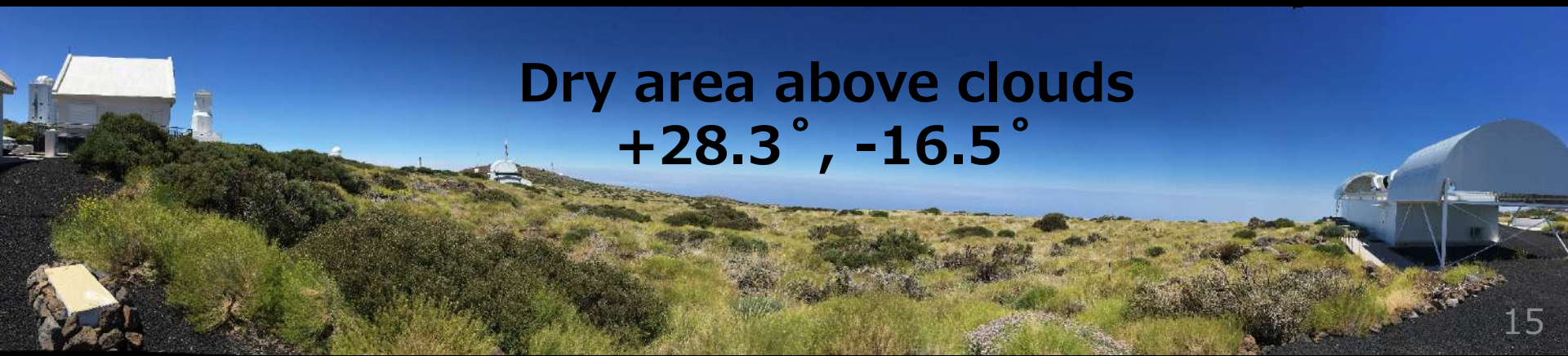
Overview of GB



HsRs (120°/s in Az) mitigates effects of atmospheric fluctuation

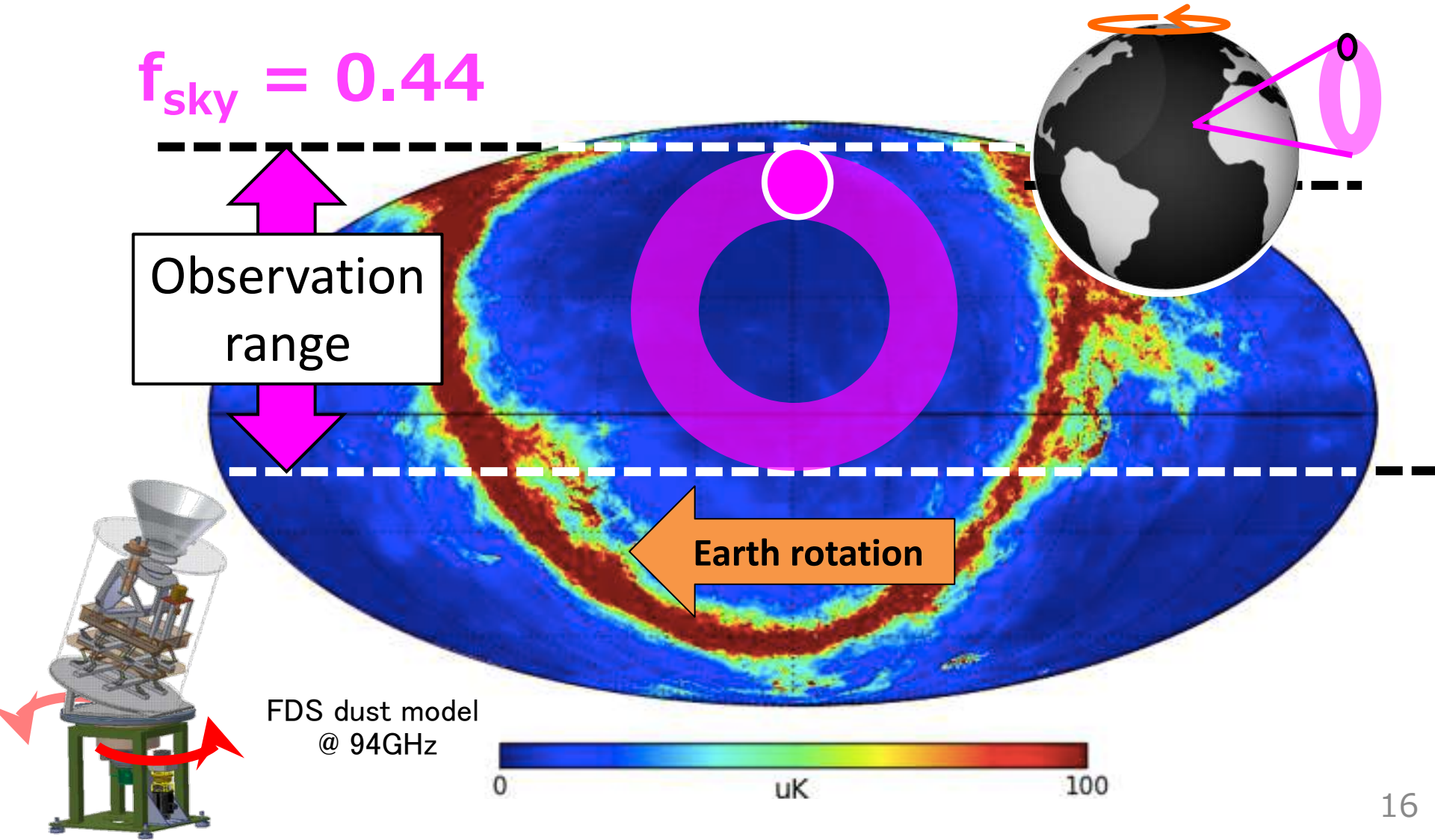
J. Low Temp. Phys. 176, 691 (2014), and Proc. SPIE 8452, 84521M (2012).

To be deployed in the Canaries, soon
Teide Observatory, 2,400 m alt.



Dry area above clouds
+28.3˚, -16.5˚

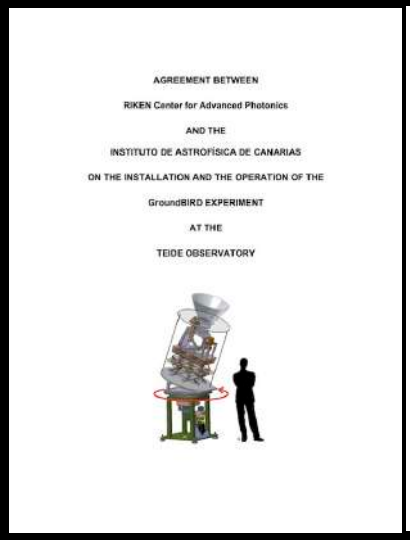
High-speed Rotation-scan provides large-sky coverage



Prep. observation site

MOU RIKEN btw IAC (May, 2015)

Agreements (Aug. 2016)



AGREEMENT BETWEEN

RIKEN Center for Advanced Photonics

AND THE

INSTITUTO DE ASTROFÍSICA DE CANARIAS

ON THE INSTALLATION AND THE OPERATION OF THE

GroundBIRD EXPERIMENT

AT THE

TEIDE OBSERVATORY

PREAMBLE

The RIKEN Center for Advanced Photonics (hereafter RIKEN) and the Instituto de Astrofísica de Canarias (hereafter IAC) plan to install one GroundBIRD experiment at the Teide Observatory (hereafter OT), dedicated to perform millimeter observations of the Cosmic Microwave Background (hereafter CMB) polarization.

The GroundBIRD experiment at the OT (hereafter, the GB-North experiment) is a non-profit scientific experiment dedicated to the search for the B-mode polarization of the CMB. The GB-North experiment consists of a high-speed rotating telescope, cooled optics, and high-sensitivity superconducting detectors. The rotating speed of the telescope is 20 rpm, enabling the 'multipoles' coverage of $\ell \approx 300$. The size of the aperture window is 30 cm in diameter, and two observing frequencies centered at 145 and 220 GHz are adopted.

The OT is an ideal location for the GB-North experiment, not only for its internationally recognized quality and its low precipitable water vapor (PWV), but also because of its geographical location covering the northern hemisphere sky. The GB-North experiment will be essential for searching the B-mode polarization as well as for the complimentary examination of the uniformity of the B-mode signals by comparing with observations obtained from the southern hemisphere. Moreover, the GB-North experiment is complimentary to the ongoing "Q-U-I JOint TEnerife" (QUIJOTE) experiment at the OT. The combination of the GB-North and QUIJOTE experiments can be advantageous for precisely removing the Galactic synchrotron and dust radiation components. The first-rate infrastructure and the opportunities for outstanding scientific interactions make the IAC and the OT a perfect host for the GB-North experiment. This in turn will open a new window to experimental cosmology, allowing us to clarify the history of the universe and to give the important keys for studying fundamental physics. It is expected that the operation will start in 2017 and continue for three years.

In view of the fact that the Kingdom of Spain has opened the IAC Observatories to the international scientific community since the International Treaty "Agreement on Co-operation in Astrophysics and its Protocol", was signed on 26 May 1979, the proposed GB-North experiment is welcome to be installed at the OT. In accordance with the International Treaty, an International Scientific Committee (hereafter "CCI") has been established to provide the Telescope Operators a forum where they can express their needs and preferences in regard to the Observatory Management and its Common Services.

The IAC shall represent RIKEN and the GB-North Experiment vis-a-vis all third parties related to the Observatorios de Canarias, such as the CCI and shall endeavor to obtain those customs duty and tax exemptions that are available to the other telescope operators.

Ground shielded area for GB

AC power & network lines are available

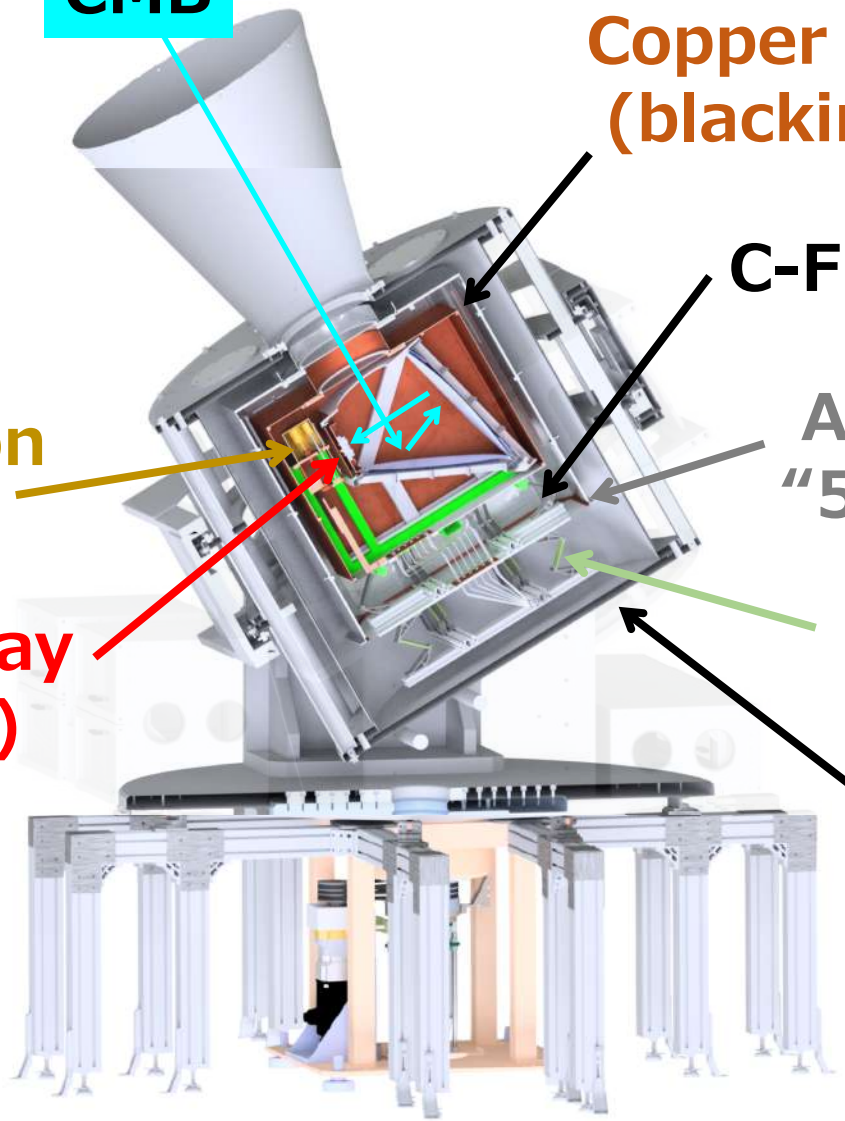
Dome for weather proofing
end of Oct. 2018

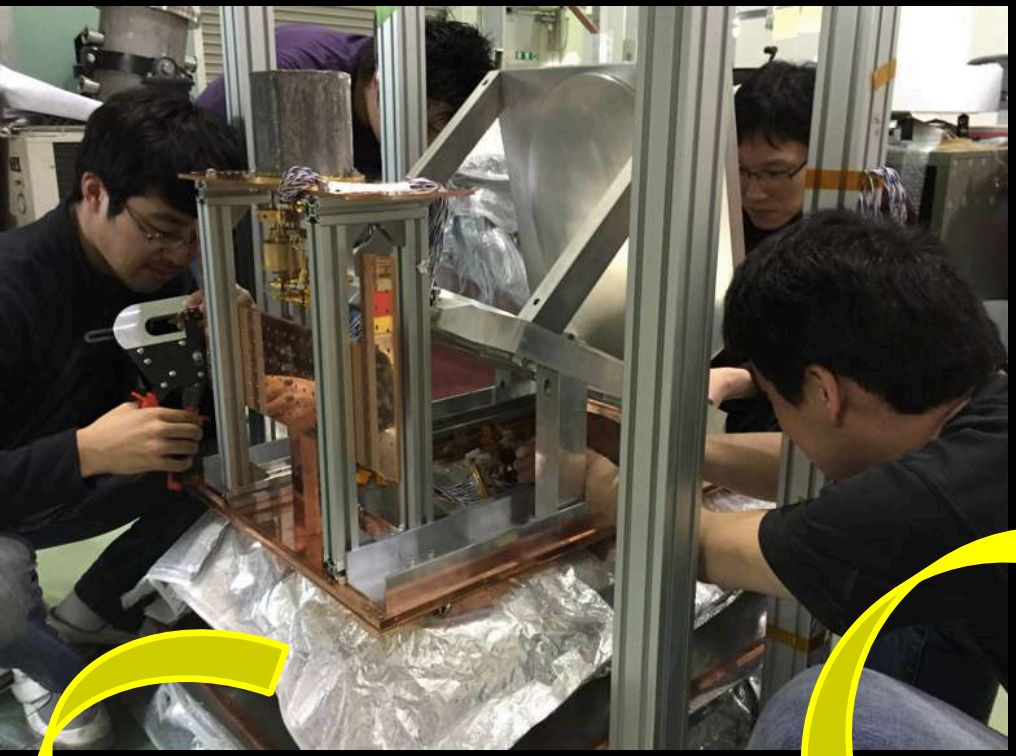
Miscellaneous constructions cable trays, etc. etc. …

Shugo Oguri (RIKEN)

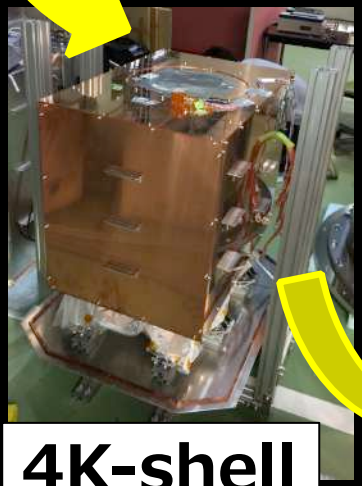
Kyungmin Lee (Korea U.)

Cryogenic optics





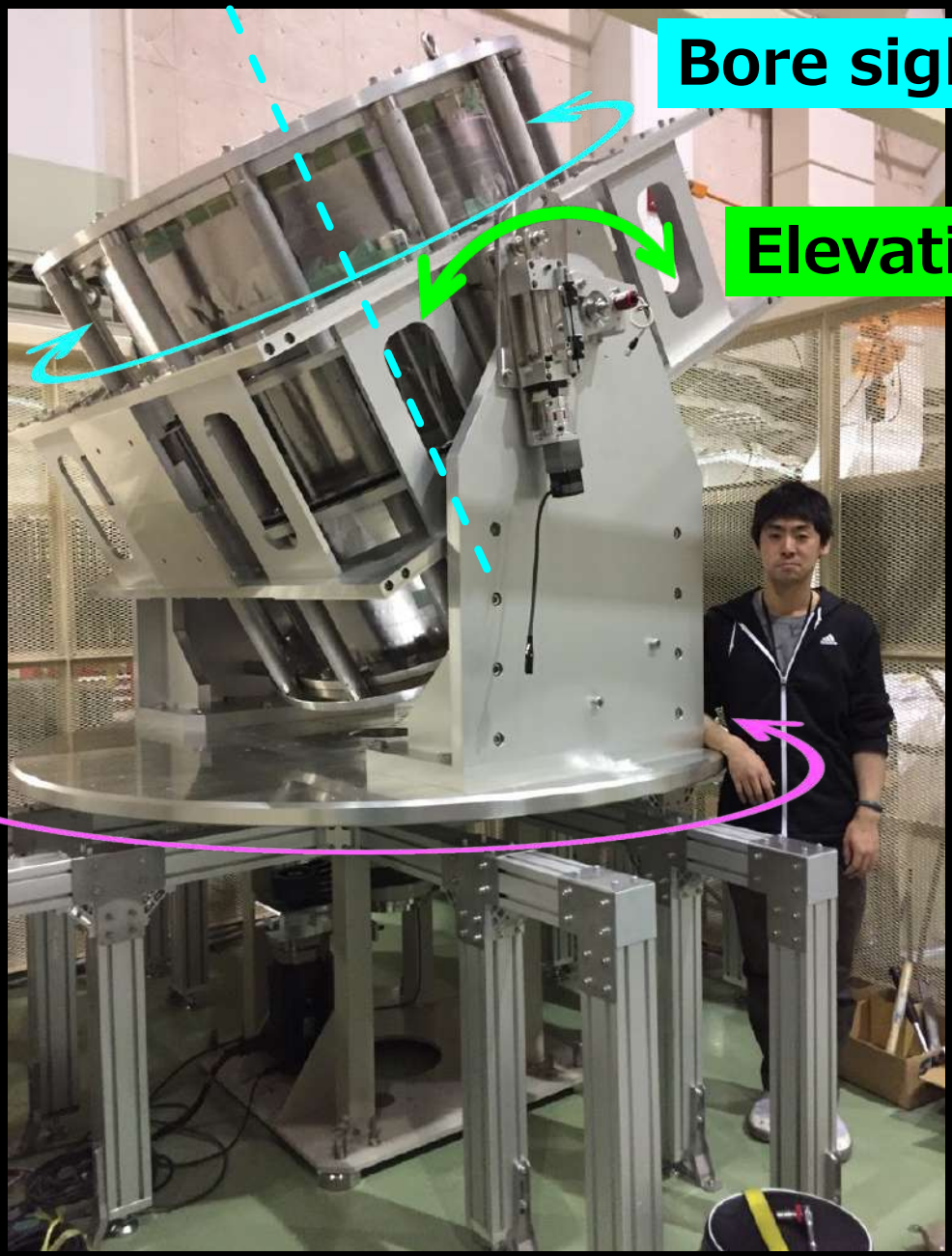
Receiver window is here



4K-shell

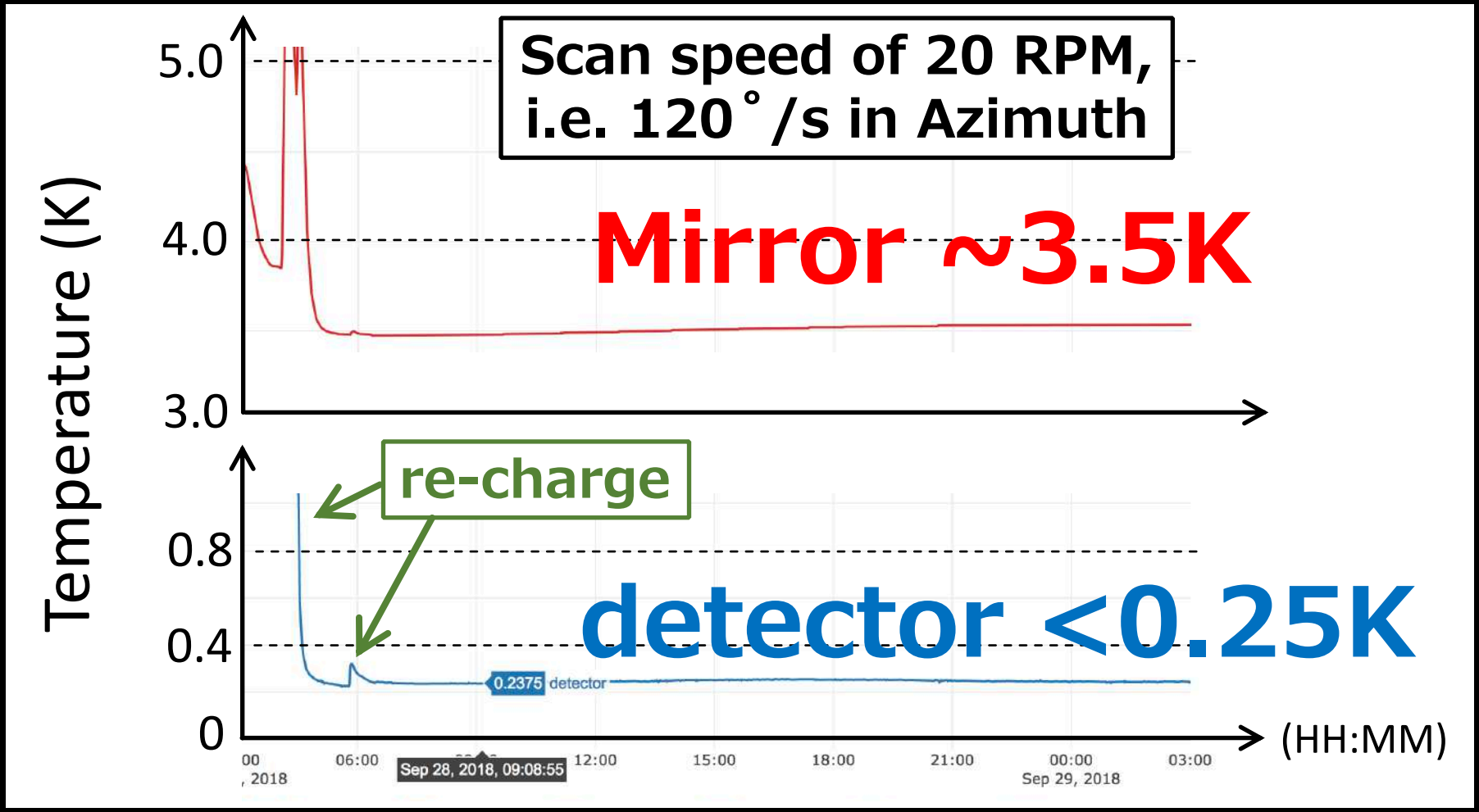
50K-shell

Vac. chamber


Bore sight
Elevation
Azimuth

High-speed Rotation-scan of 120˚/s

24H *T* trends with HsRs under Eccosorb in T_{room}

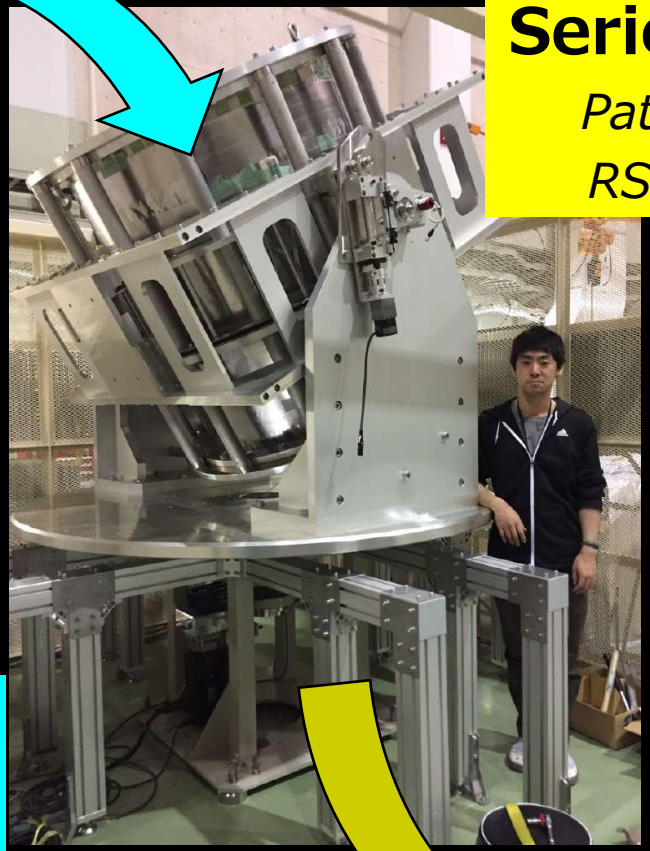


“Cool” technologies for GB

RT-MLI for IR-blocking

Patent: JP6029079

RSI, 84, 114502 (2013).



Series of rotary joints

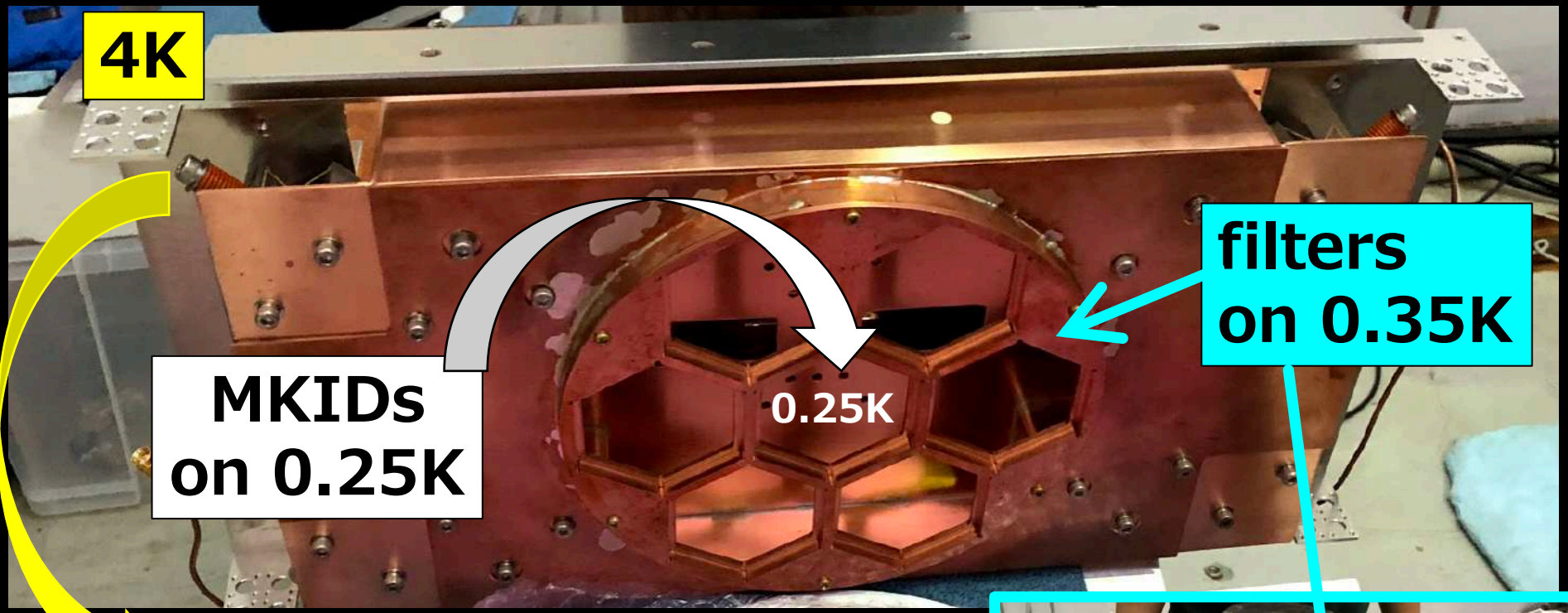
Patent: US 9,316,418-B2

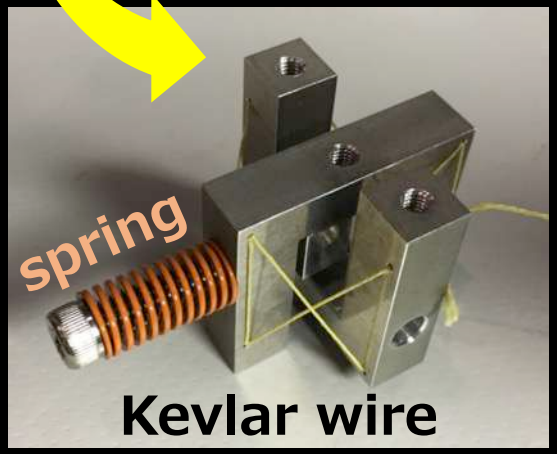
RSI, 84, 055116 (2013).

He-gas lines for PTC

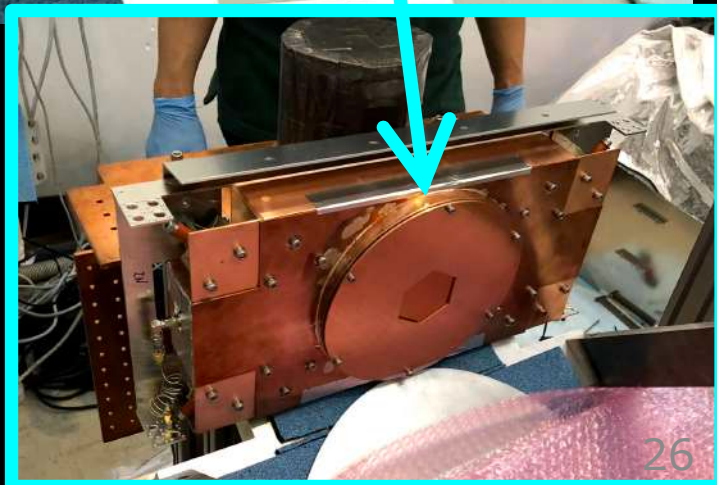
Electric lines

Focal plane set in 0.35K box



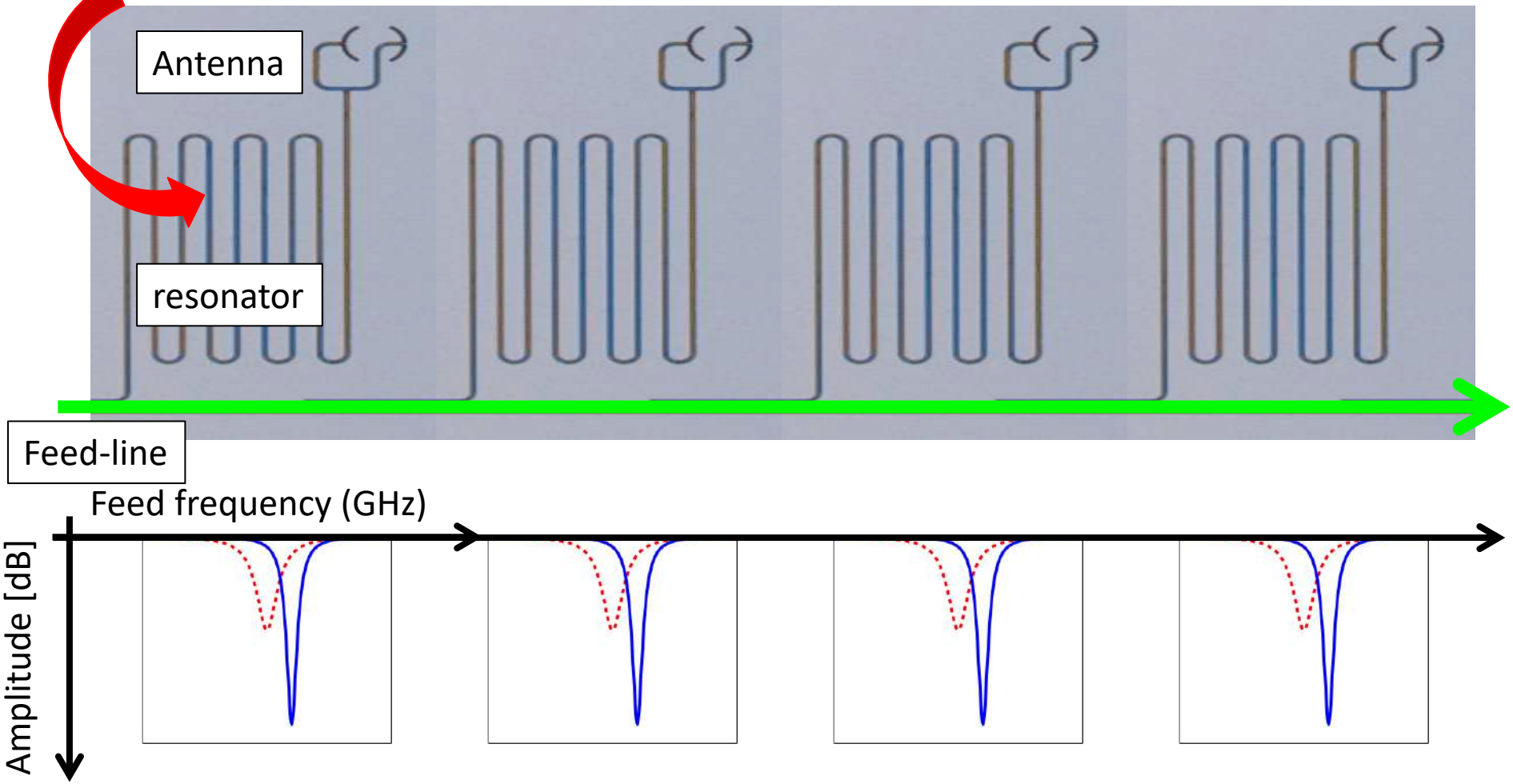


Blacking inside



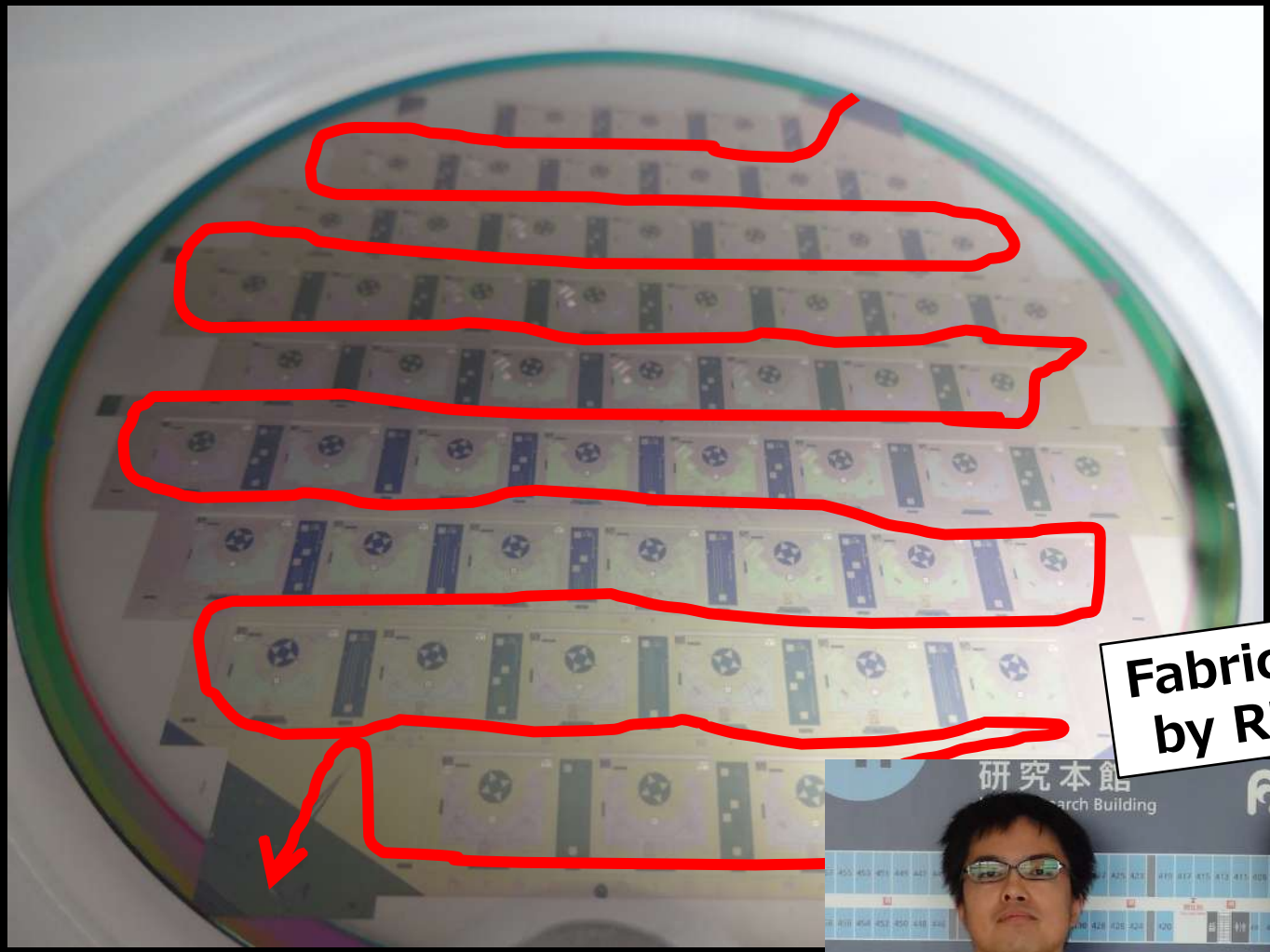
Benefit of MKID
“resonator = detector”

Input signal breaks cooper-pairs in resonator. It varies resonance condition.

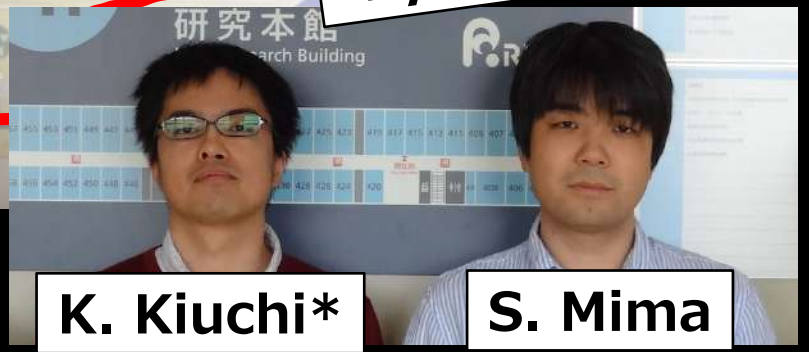


Natural frequency domain MUX

Single line for readout



Fabrication by RIKEN



K. Kiuchi*

S. Mima

*Now in UTokyo

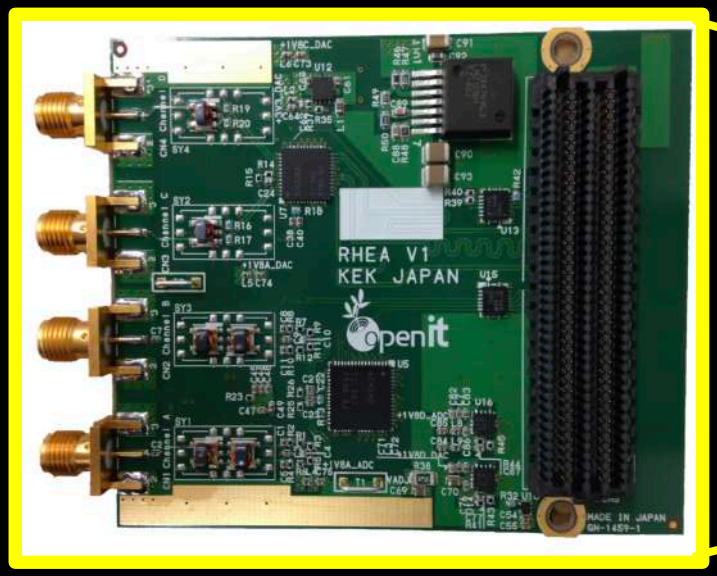
Details will be covered by next speaker

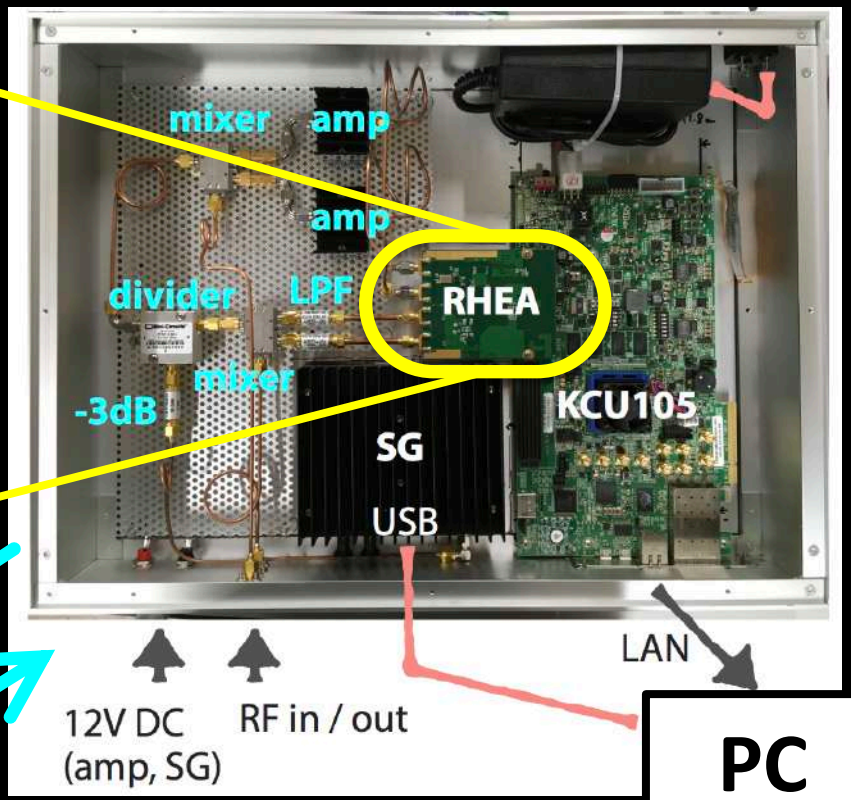
MKID readout electronics

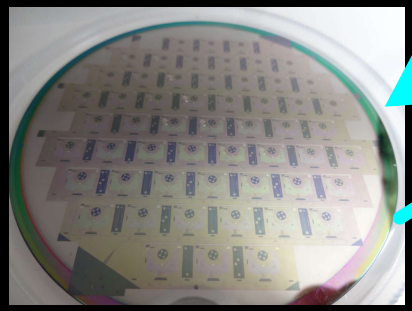
DA/AD board "RHEA" :

- 120-MUX in 250 MHz band width
- 1 kSpS high-speed sampling w/o deadtime

H. Ishitsuka et al, J. Low Temp. Phys., 184, Issue 1 (2016)







MKIDs in cryostat

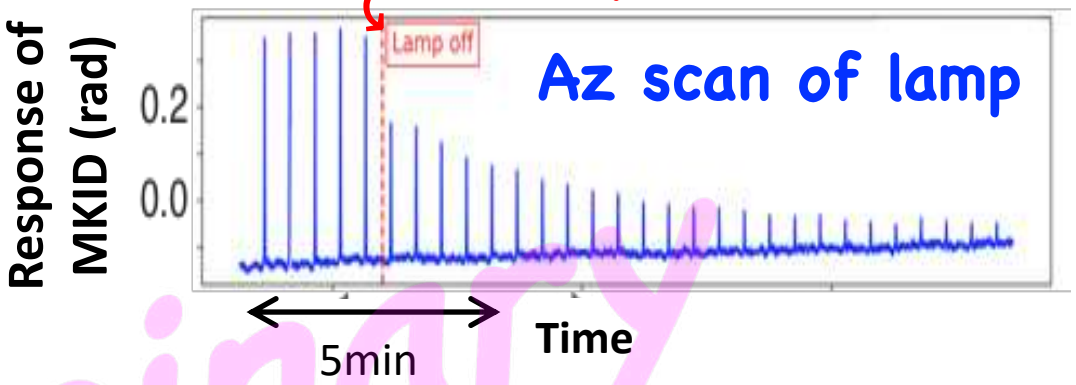
PC

なんちゃってファーストライト

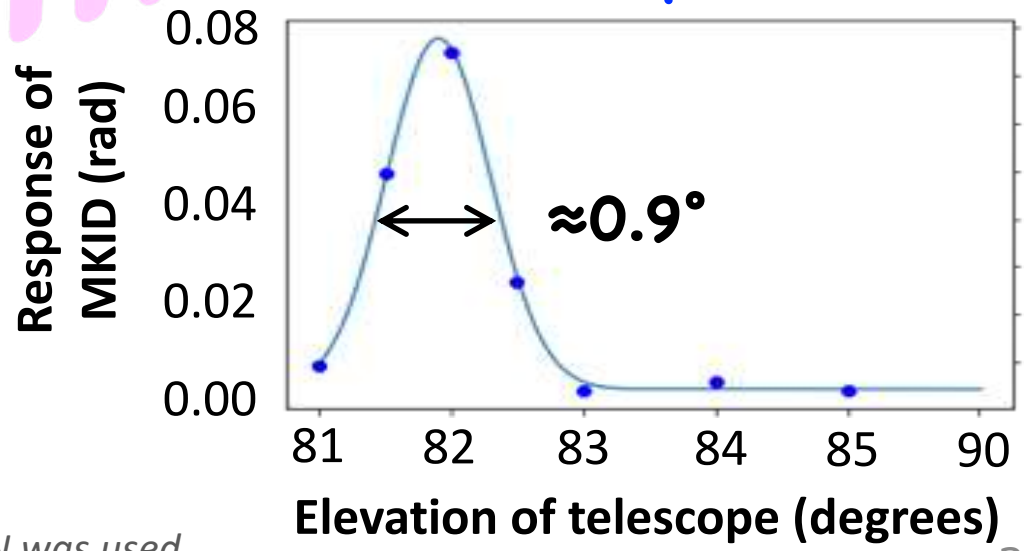
“First light” in high-bay

Benefit of MKID:
No saturation in T_{room} loads

Turn off the lamp

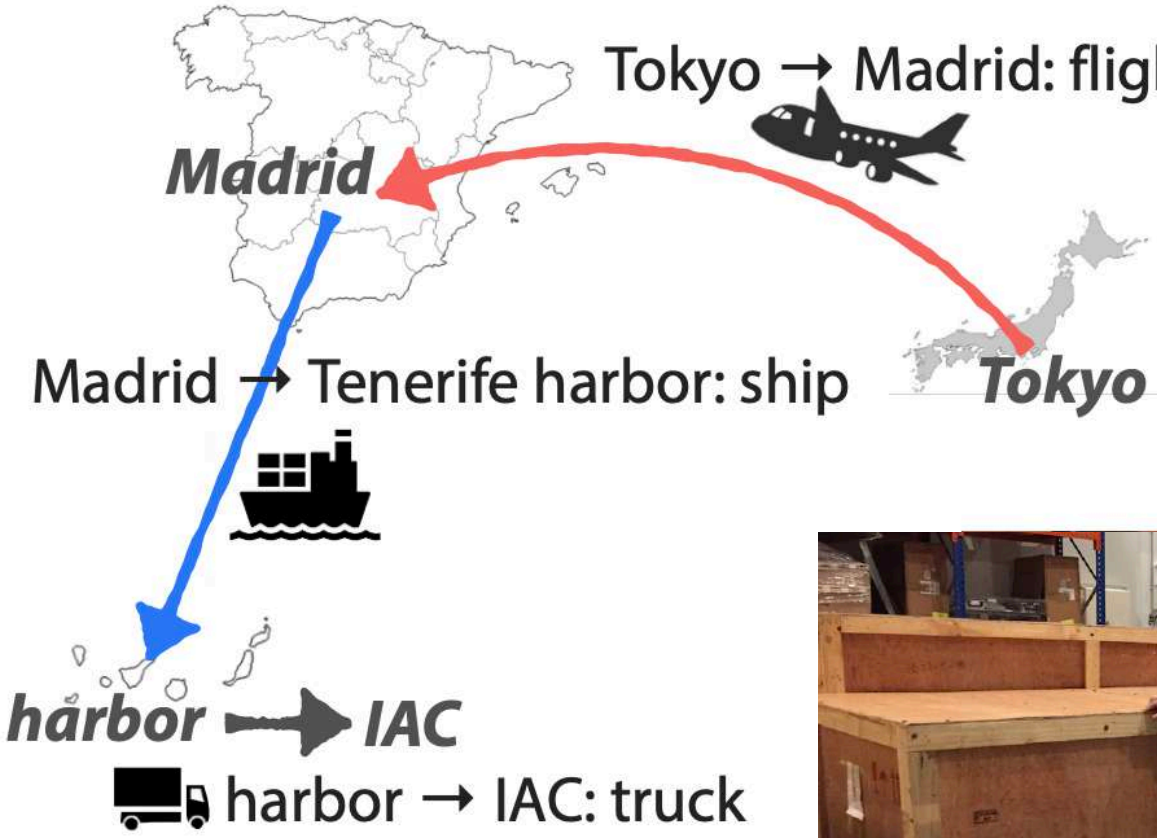


Size of lamp ⊗ beam



Acknowledgement: MKID borrowed from SRON was used.

Japan → the Canaries



Departure
Feb. 13, 2019

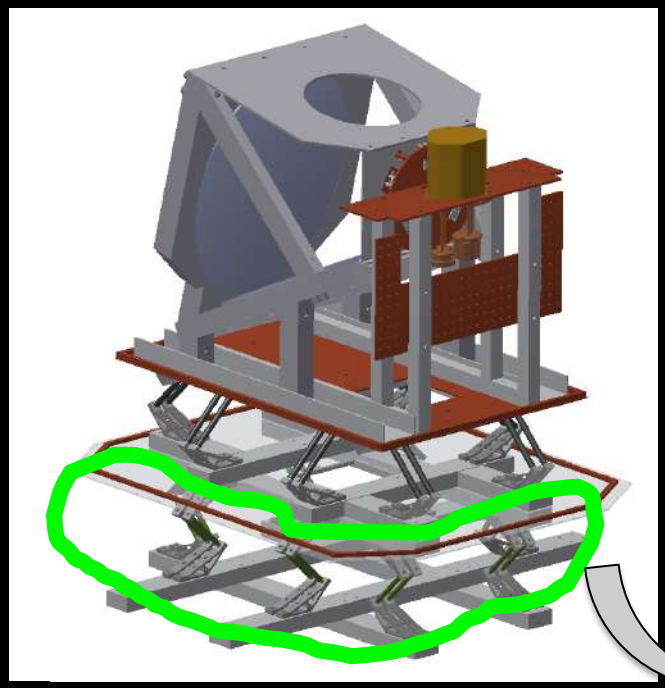
Arrival
Mar. 8, 2019

Taketo Nagasaki
(RIKEN)

Let's start "final" cool down test
in IAC (lab at 500m alt.)

Let's start "final" cool down test
in IAC (lab at 500m alt.)

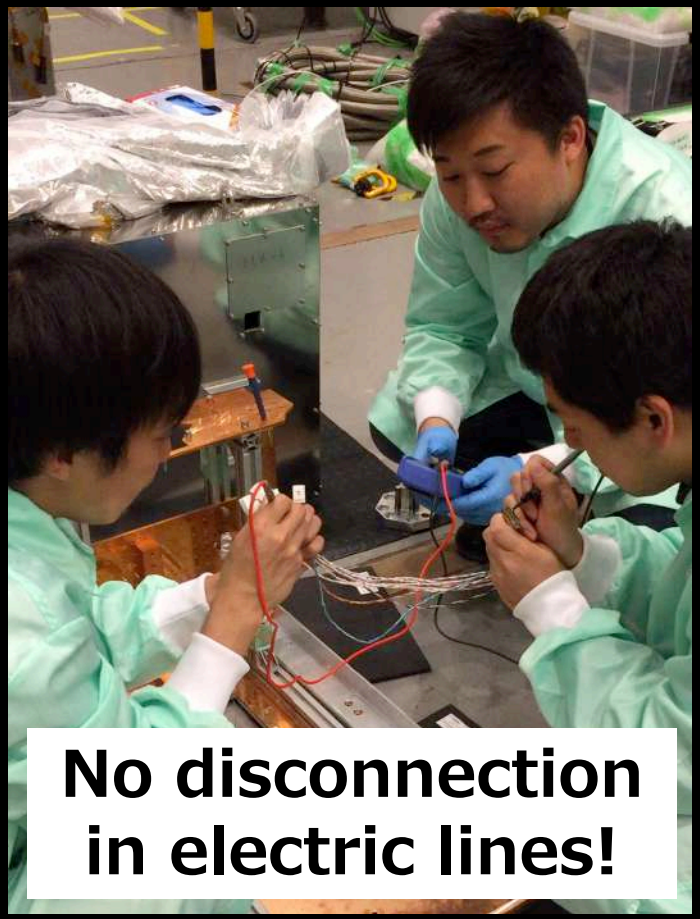
Serious damage ☹ in support structure for 40K – 300K (during the transportation)



All G10 rods were broken

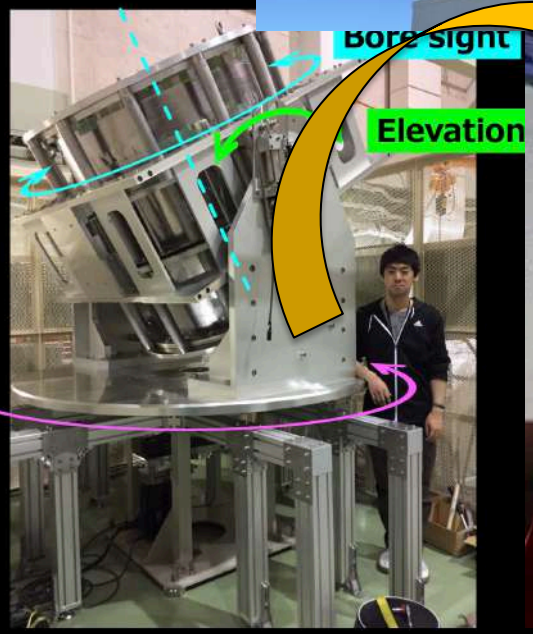
These parts will be replaced in next week

Others are survived ☺



Cooldown tests will be done in July
“First light” is planned in Aug.

Telescope mount was set on the observatory in June 11 !



S. Oguri
& C. Otani

K-M. Lee

M. Peel

S. Honda

Summary of GB

- **Low-ell CMB for PGW & τ**
- **Unique concepts & techs.**

  High-speed Rotation-scan, MKID, …
- **”Scan” demonstration in Japan**

  → Transportation to the Canaries

  → Deployment is underway
- **“First light” soon**

SNS like Summary

User name: GB

The Canries NOW