

Monitoring clouds for Simons Array

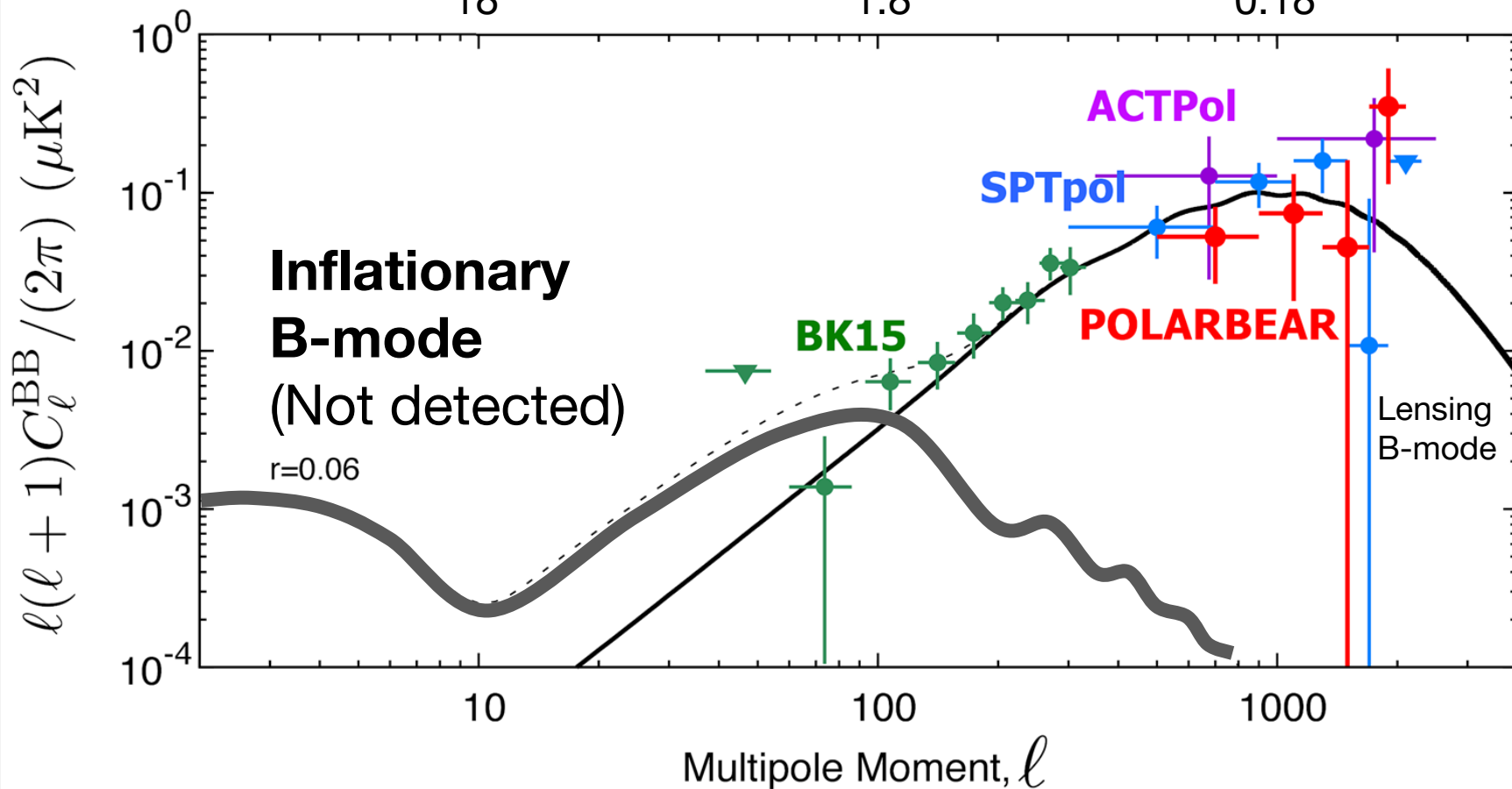
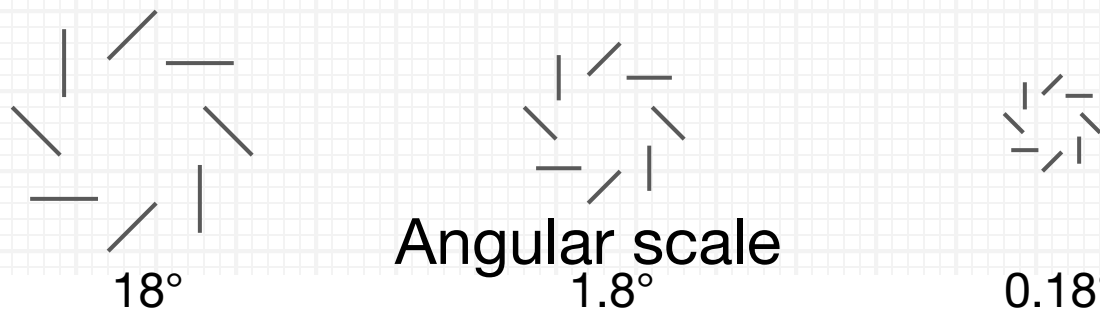
Satoru Takakura
Kavli IPMU

公募研究「CMB偏光観測望遠鏡のための偏光補正装置の開発」(18H04362)

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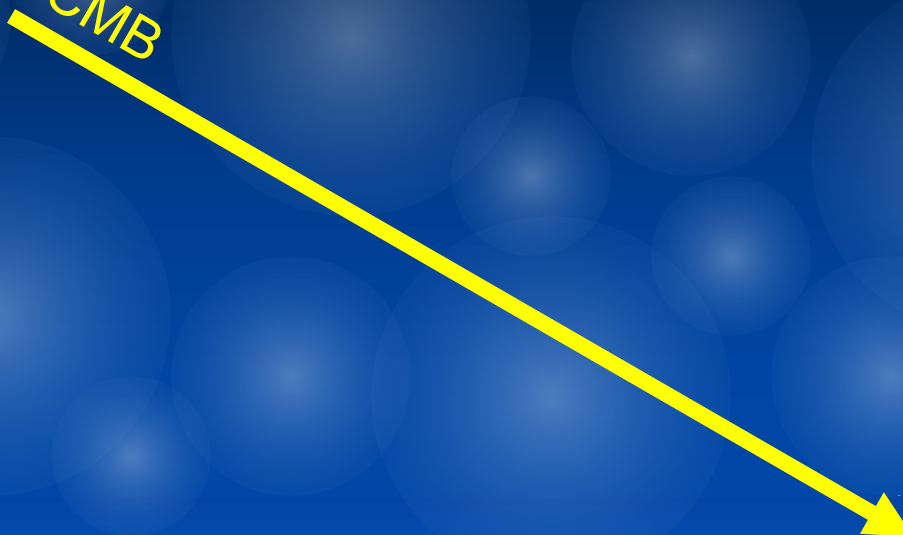
- Introduction
- Polarization from clouds
 - Measurement of cloud in POLARBEAR
- Monitoring clouds
 - IR camera
 - Whole sky camera
- Future prospects

CMB B-mode from inflation



CMB observation from ground

CMB

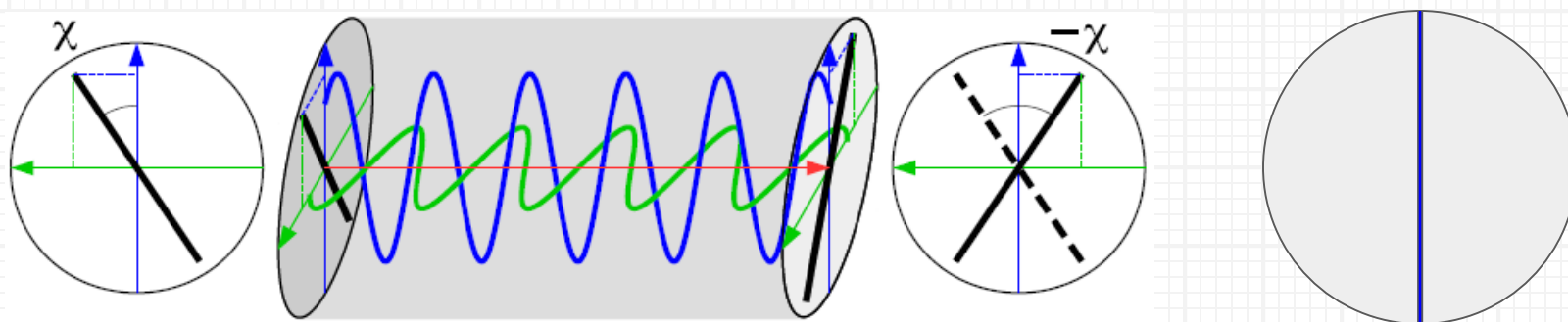


Atmospheric turbulence causes higher noise at larger angular scales.

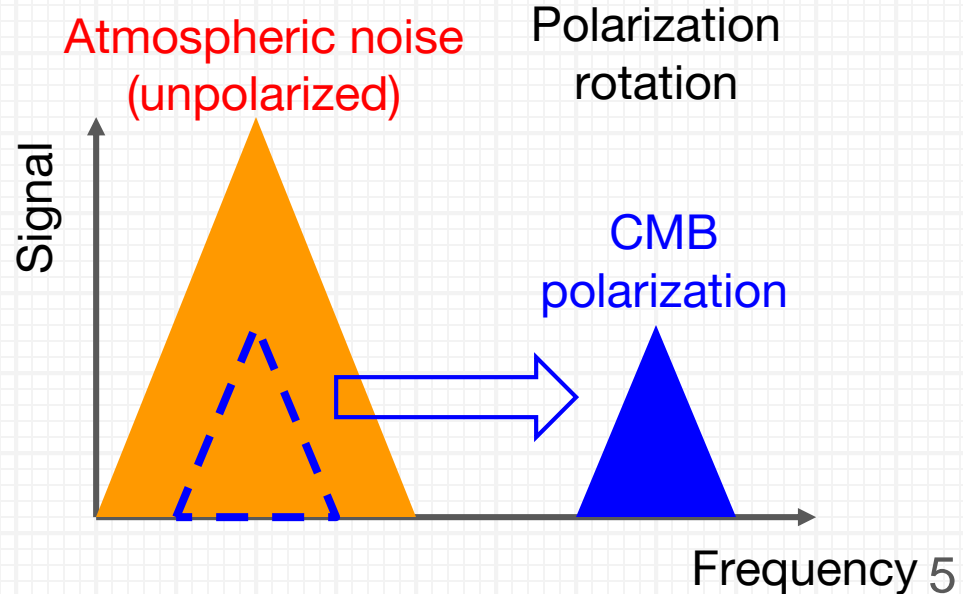


If atmosphere is unpolarized...

Continuously rotating half-wave plate (HWP)

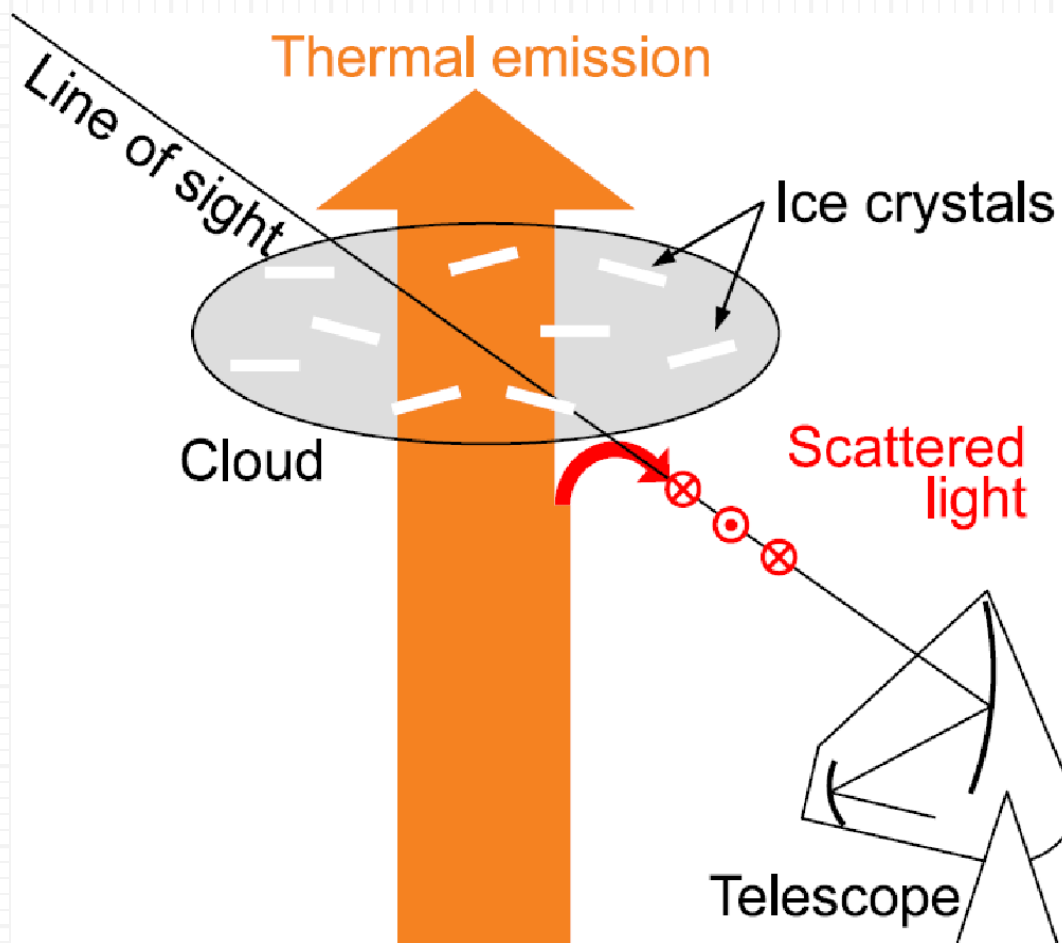
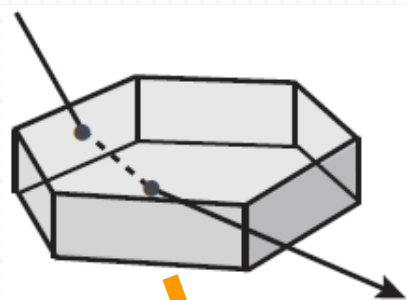


POLARBEAR HWP



Polarization from clouds

Rayleigh scattering by cloud particles



Ground

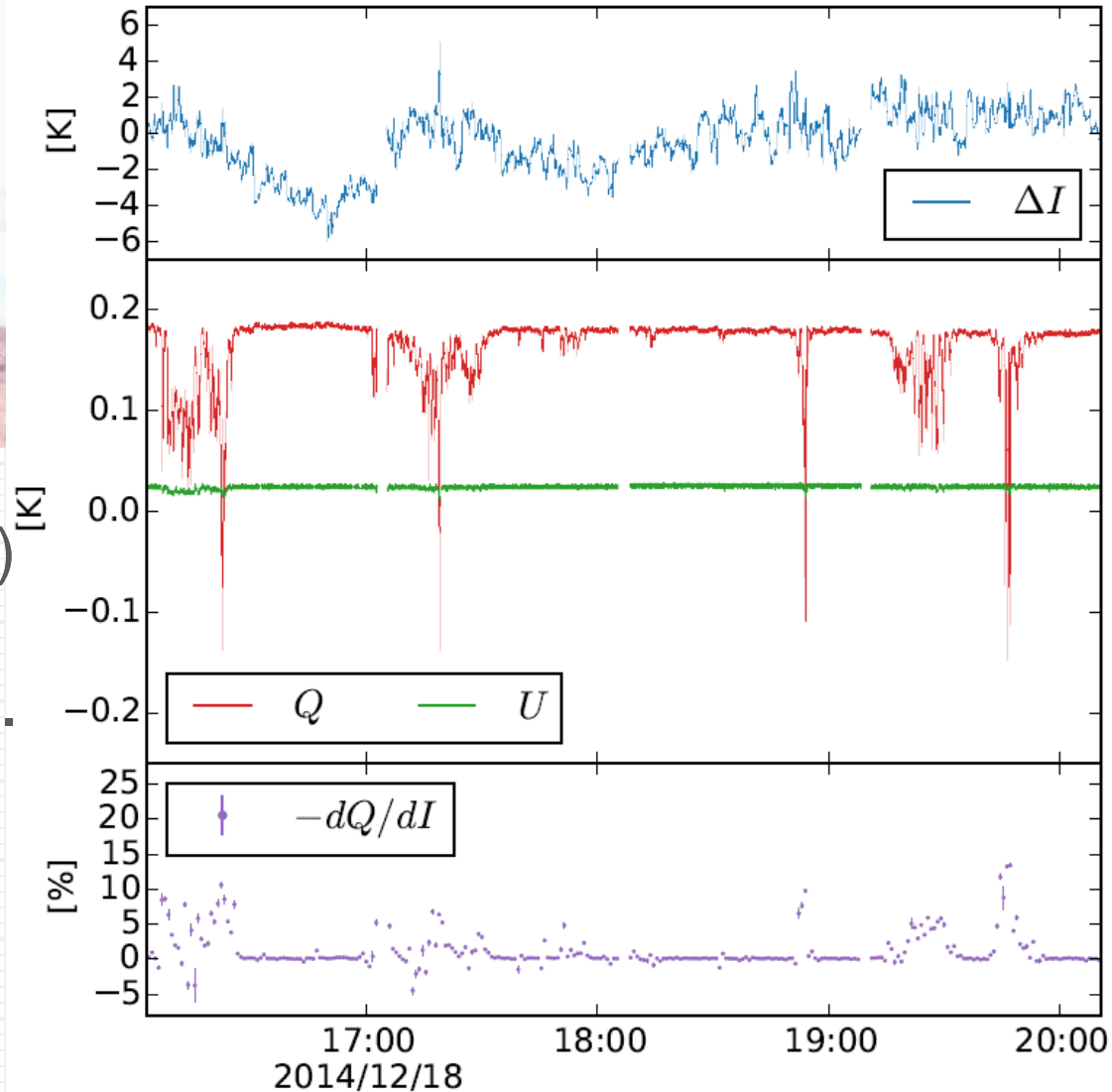
Example in POLARBEAR

HTT @ Chile on 2014-12-18T16:03:57Z



Horizontally polarized ($Q < 0$) extra noise is measured during cloudy observations.

Coincidence is confirmed using 3 yr of data.



ST *et al* 2019 *ApJ* **870** 102
(arXiv:1809.06556)

Impact of clouds

- Max. $\sim 0.1\text{K}$ @ 150 GHz $\propto \nu^4$
- Large angular scale (size of clouds $> 1^\circ$)
- Moves by wind
- Occasionally exists ($\sim 30\%$ in Chile)
- Cannot be mitigated by HWP or rapid scan.

Clouds are one of the most concerning sources of noise and systematic errors in large angular-scale measurements for all the ground-based CMB experiments.

Possible approach in future

1. Monitor clouds and drop data with clouds
 - Whole sky camera
 - IR camera for night

1. Mitigate cloud signal as foreground removal

IR camera

FLIR One Pro

- $\lambda = 8-14 \mu\text{m}$
- FoV: $50^\circ \times 43^\circ$
- 160×120 pixels
- ~50,000 yen



Whole sky camera

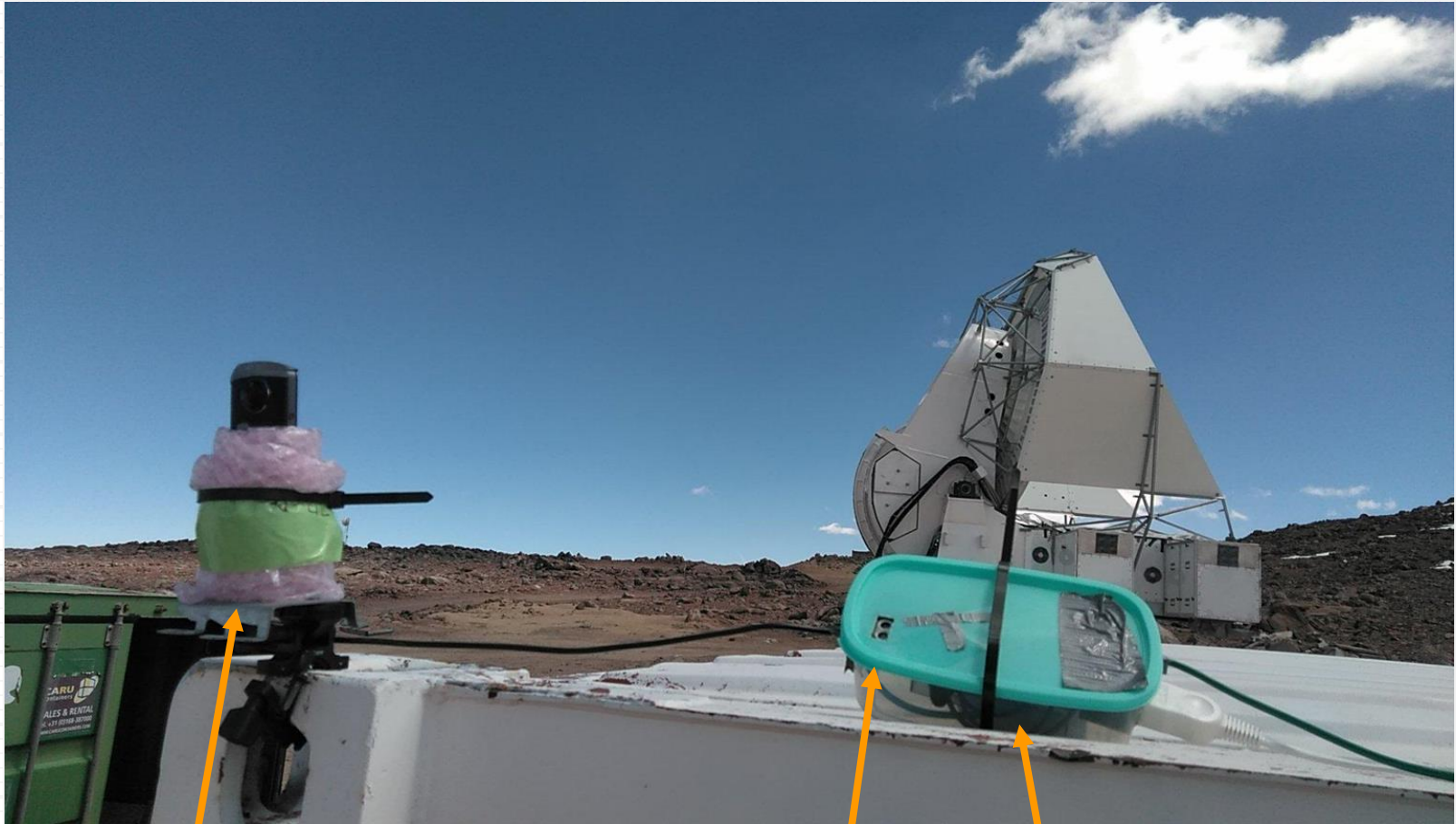
RICOH THETA S

- 2048×1024 pixels
- ($\phi = -\pi \dots \pi, \theta = 0 \dots \pi$)
- ~30,000 yen



Test operation in Chile

January 2019



Whole sky
camera

IR camera

Controller
(Raspberry Pi)

Example

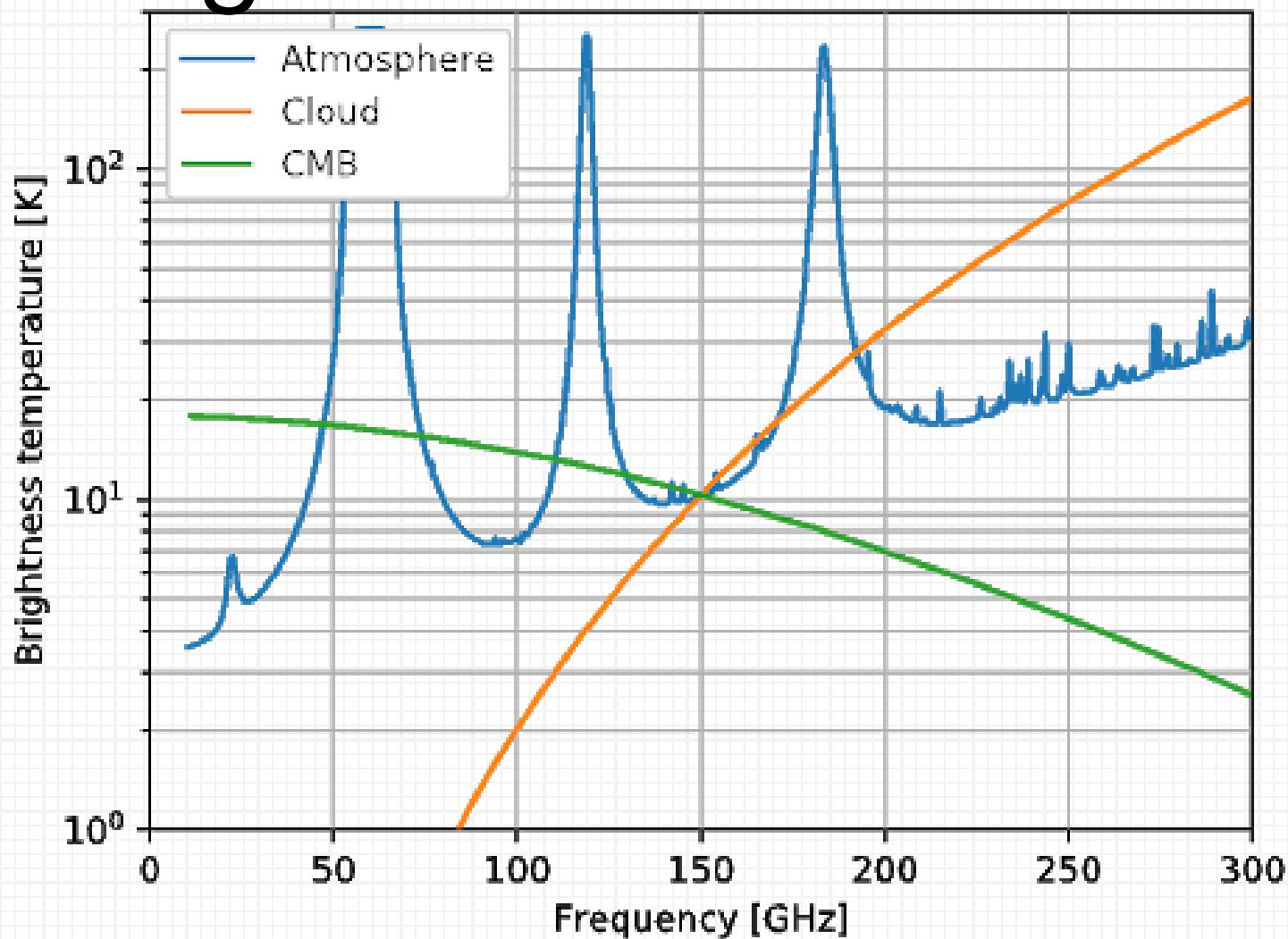
IR camera



Wholesky camera



“Foreground” removal?



Using Simons Array 90&150 GHz measurements?

Summary

- Polarization from tropospheric clouds is a big concern for ground-based CMB experiments.
- POLARBEAR observed signal from clouds.
- Monitoring clouds is the first step for better understanding of systematic error from clouds.
- IR camera and whole sky camera are installed.
- “Cloud removal” using multiple frequencies are interesting with Simons Array.