

# Status of the Simons Array Experiment

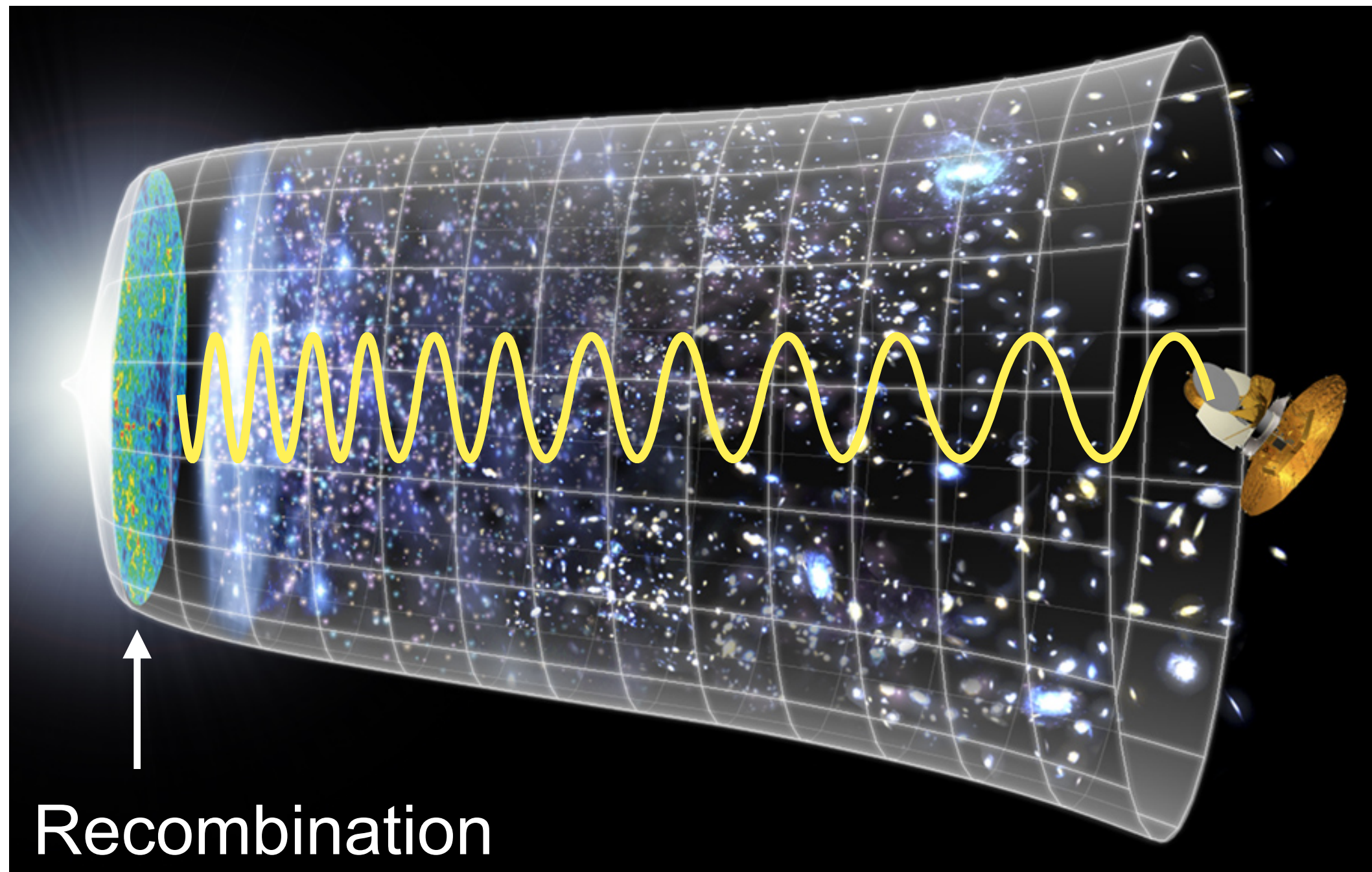
International Conference on the  
Physics of the Two Infinities

University of Tokyo  
Atsuto Takeuchi  
for POLARBEAR Collaboration

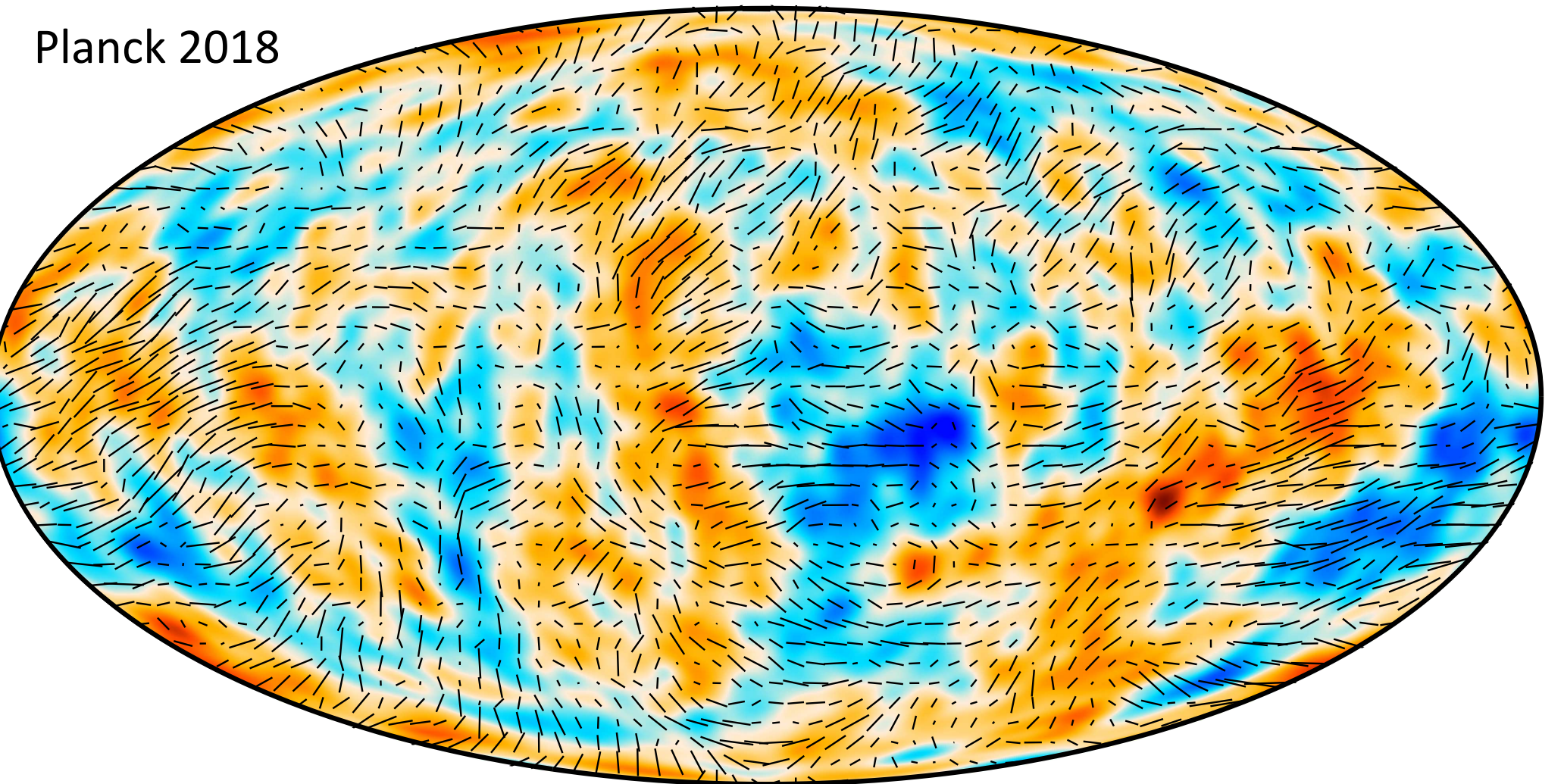


# Cosmic Microwave Background

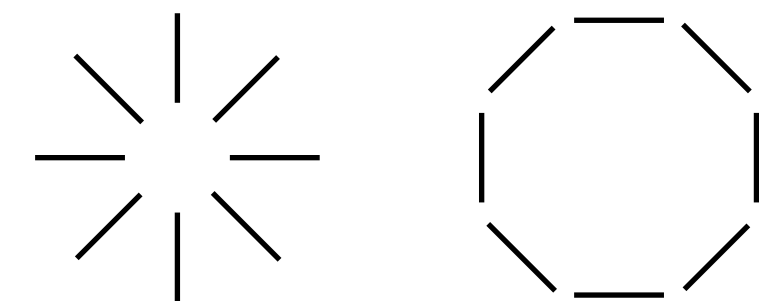
- Cosmic Microwave Background = remnant radiation from recombination of the Universe
  - ~2.7 K black body radiation
  - Small fluctuation
  - Polarization components : E-mode and B-mode



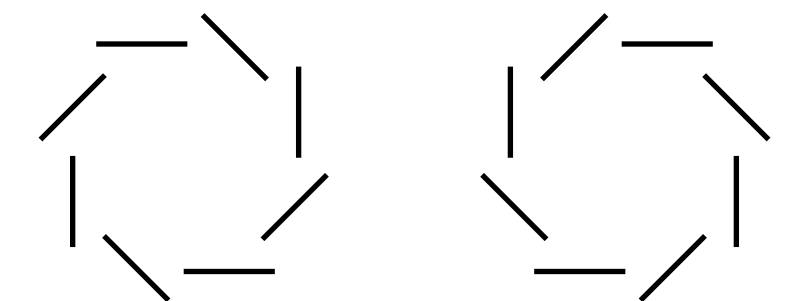
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**E-mode : even**

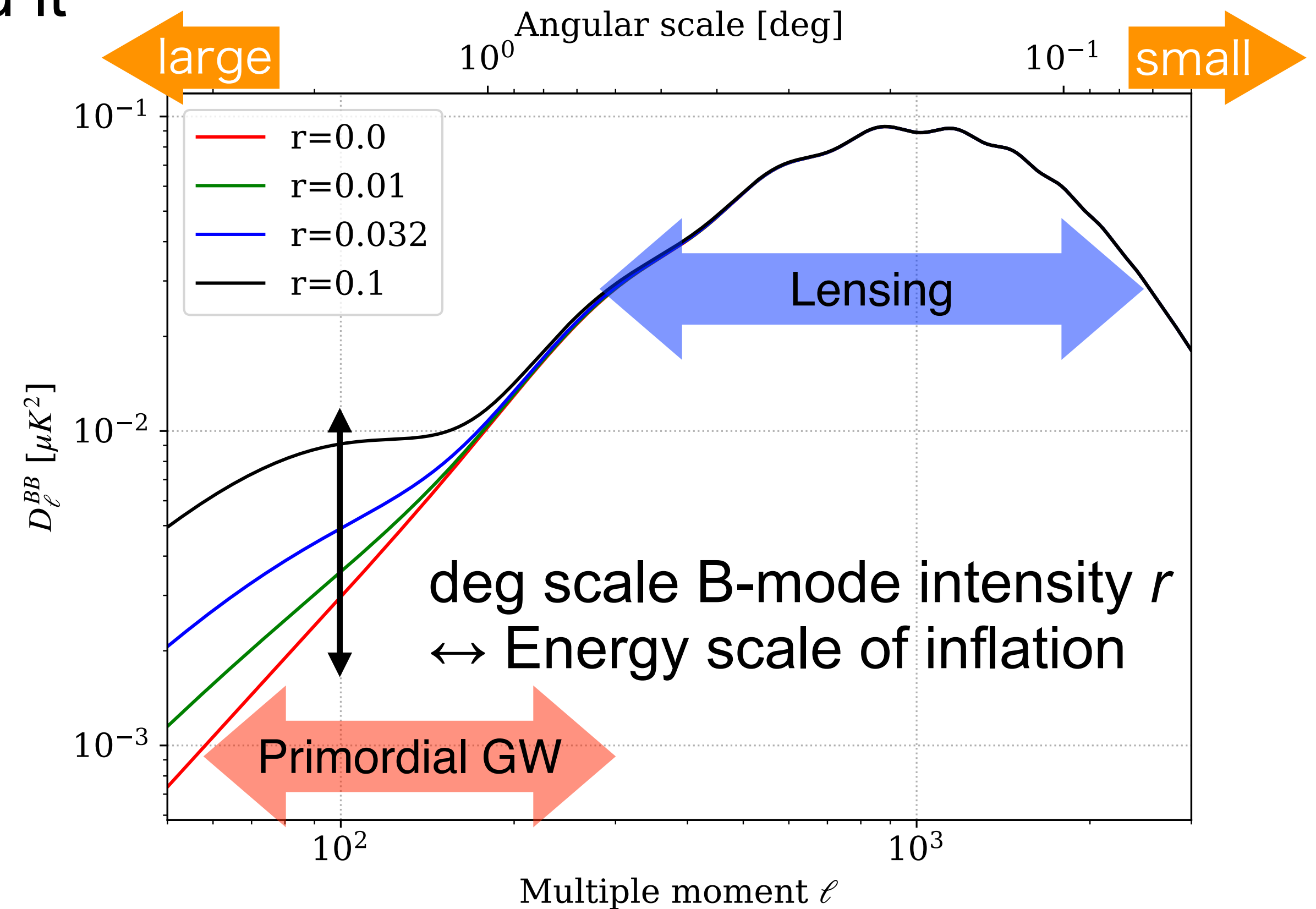
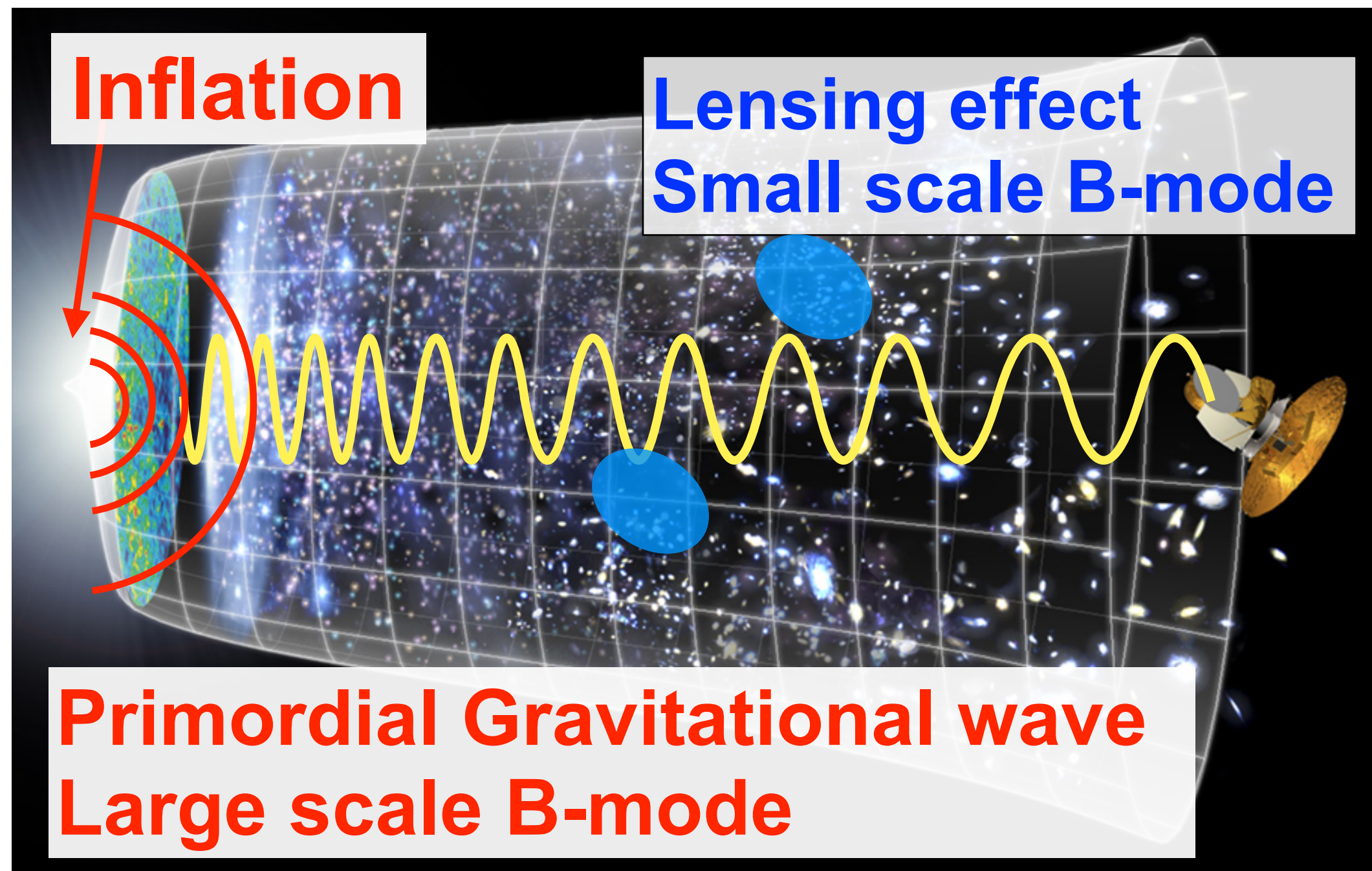


**B-mode : odd**



# CMB B-mode and Inflation

- Two main sources that induce B-mode pattern :
  - Gravitational lensing effect ... smaller angular scale (sub degree)
  - Primordial gravitational waves from inflation ... larger angular scale (degree scale)  
→ direct evidence of inflation if we find it



Simons Array aims to detecting the primordial B-mode to test the Inflation theory.

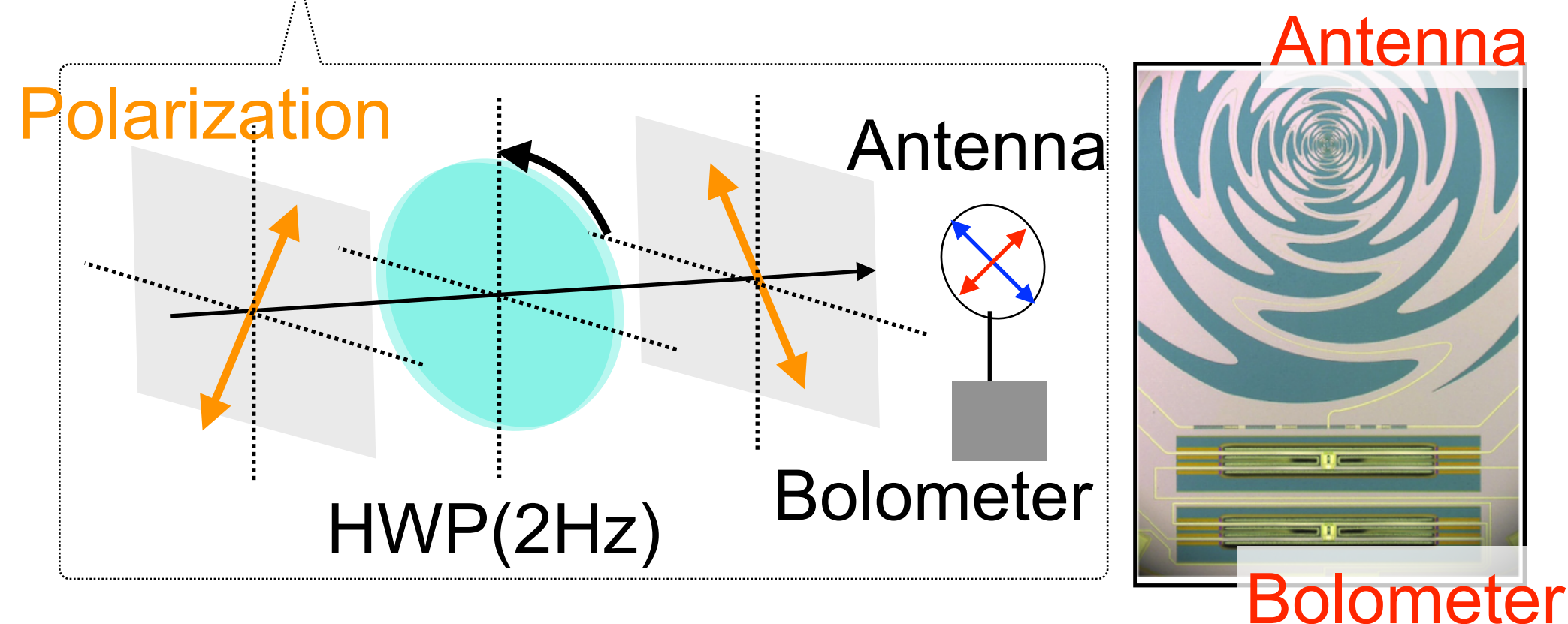
# Simons Array – Big Picture

- Off-axis Gregorian telescopes placed at Atacama Desert, Chile.  
Searching for primordial B-mode polarization to test the Inflation theory.



## Key technics of Simons Array (SA)

- 90/150 GHz dichroic pixels , 7588 bolometers per telescope  
→ High statistic + Foreground removal
- Continuously rotating half-wave plate (HWP)  
→ Distinguish the polarization signal from non-polarized noises allowing us to scan the sky.

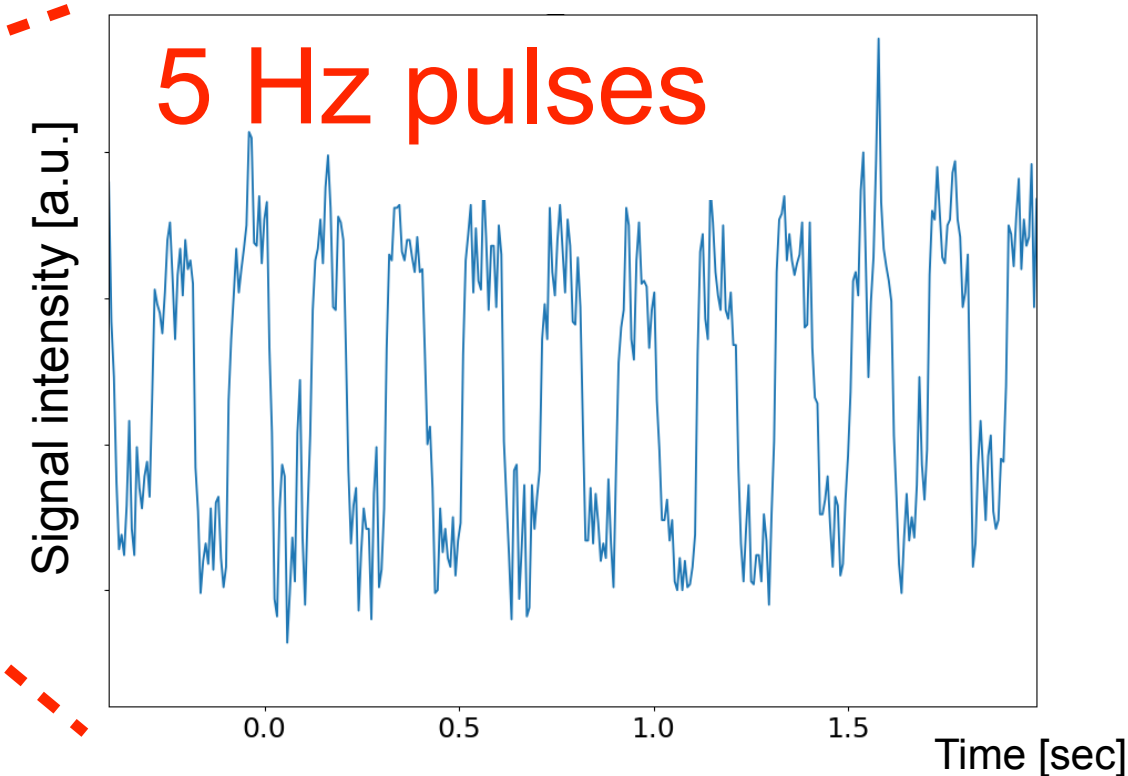
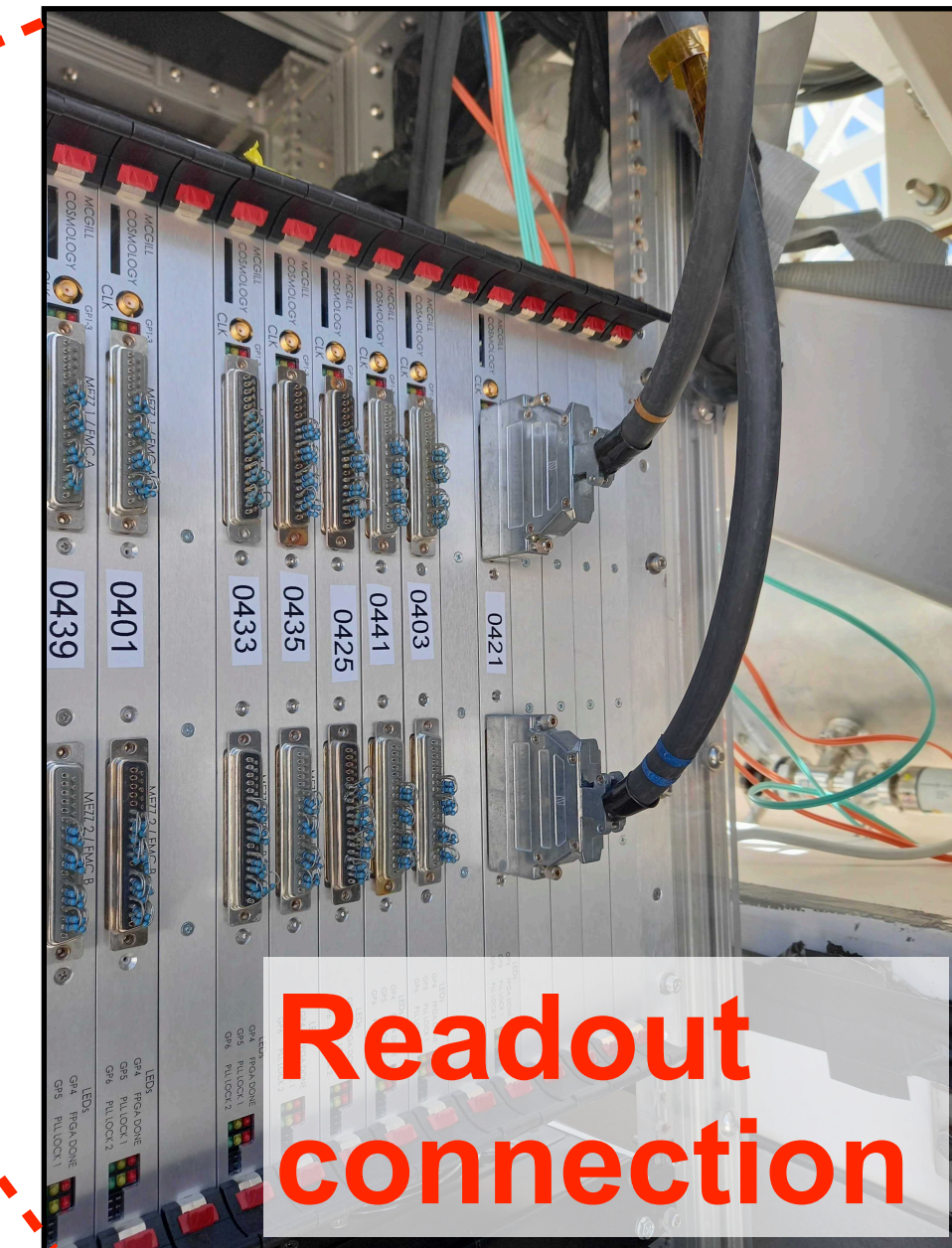
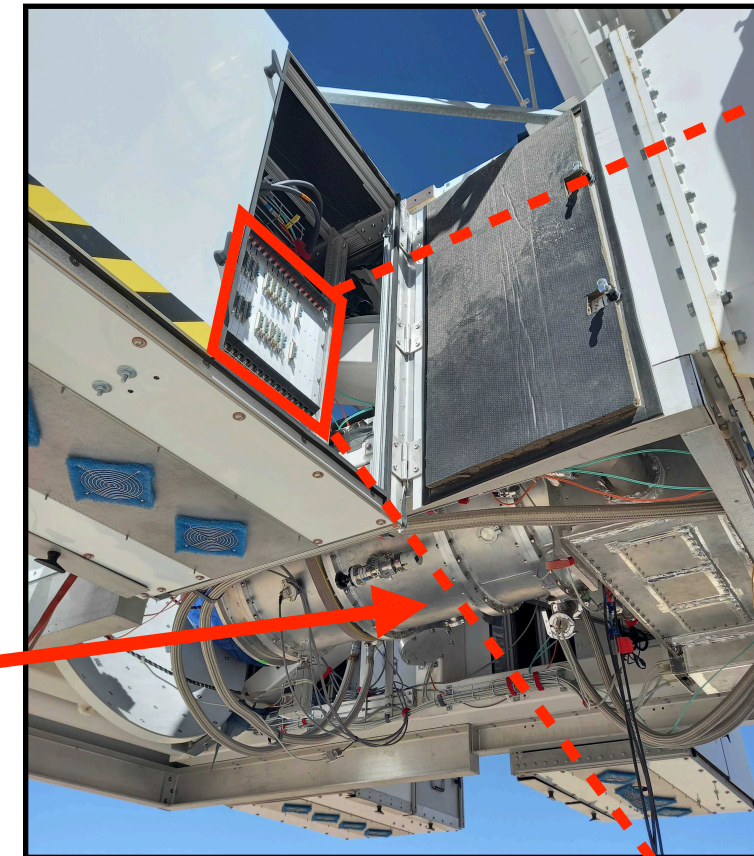


## Current status

- 1st receiver ... Physics observation in progress
- 2nd receiver ... First light achieved!


# Status of the Second telescope

# Status of Second Telescope Preparation



2022

Now



• Receiver installation (HWP, bolometers)  
Readout connection

• First light (end of 2022)

• HWP rotation test

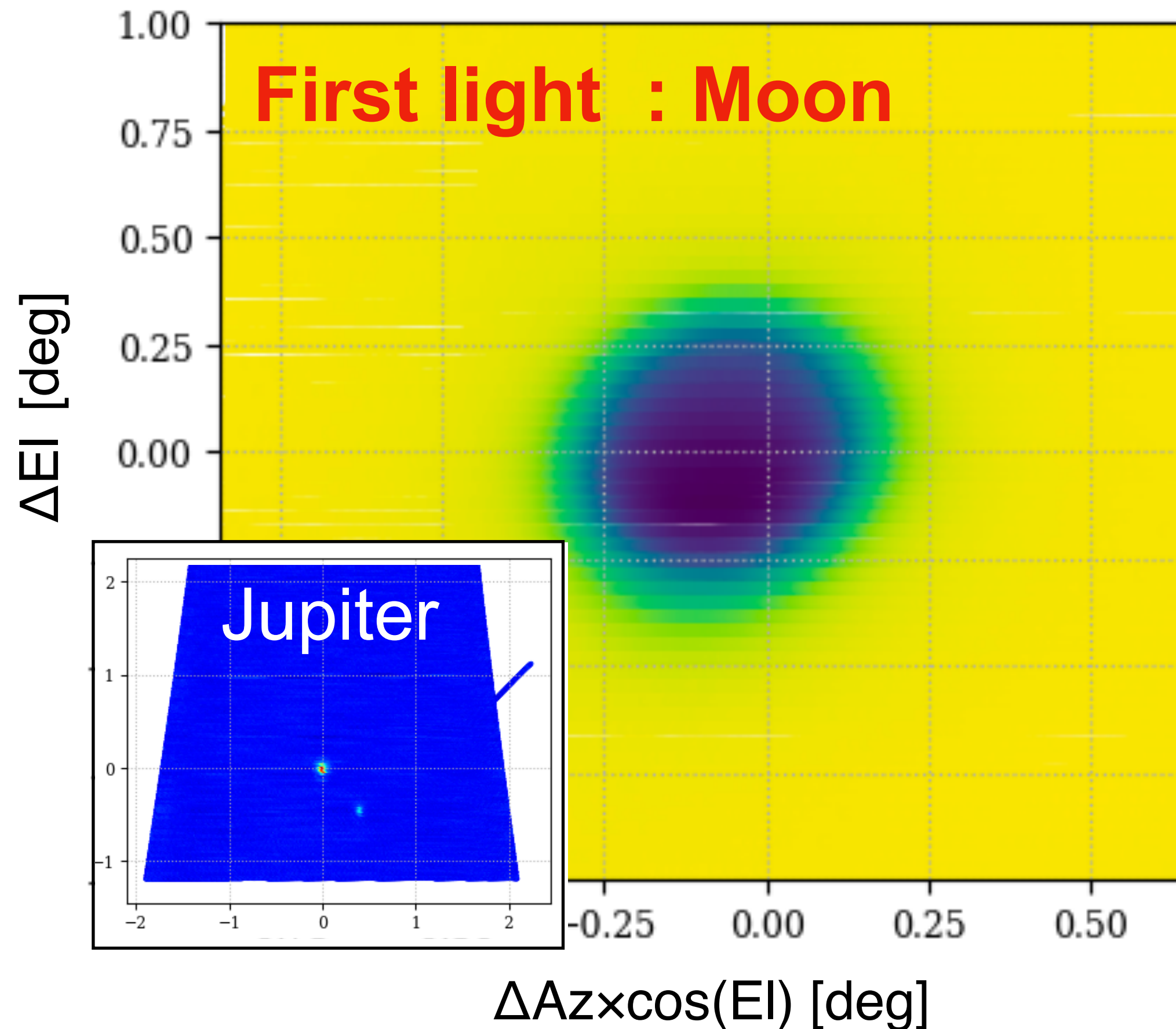
• Test observations

A vertical blue arrow pointing downwards, indicating the progression of time from 'Now' at the bottom to '2022' at the top. The arrow is positioned to the left of a list of tasks.

See also poster by Kana Sakaguri

# Test Observation Status

- Observation of various kinds of light sources have been implemented successfully.



## Observations

- Stimulator (artificial light source)
- Moon
- Planets : Jupiter, Venus, Saturn
- TauA

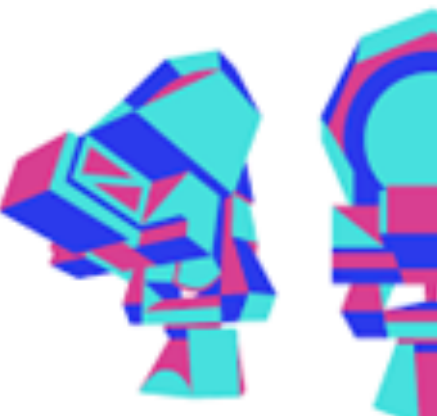
- Pointing adjustment
- Scan speed adjustment
- Observation w/ rotating HWP

Calibration and understanding of the second telescope is in progress.  
→ Move onto CMB observation soon!

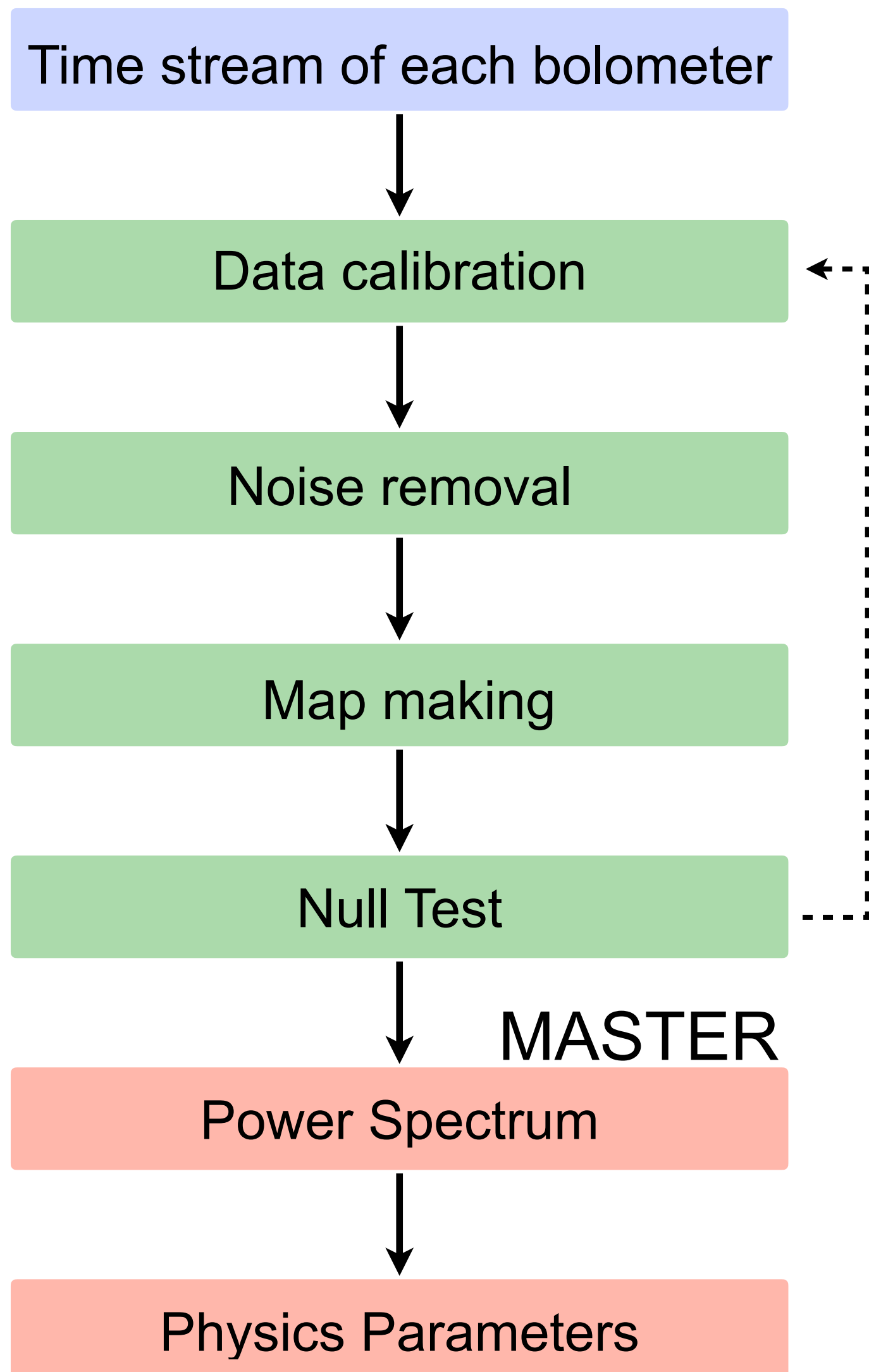
# Status of Analysis Framework



# Overview of SA Analysis



- SA analysis is processed as follows :



## Raw data

- Output of each bolometer
  - Pointing of telescope
  - Rotation angle of HWP
- } : Time stream format data

## Data calibration

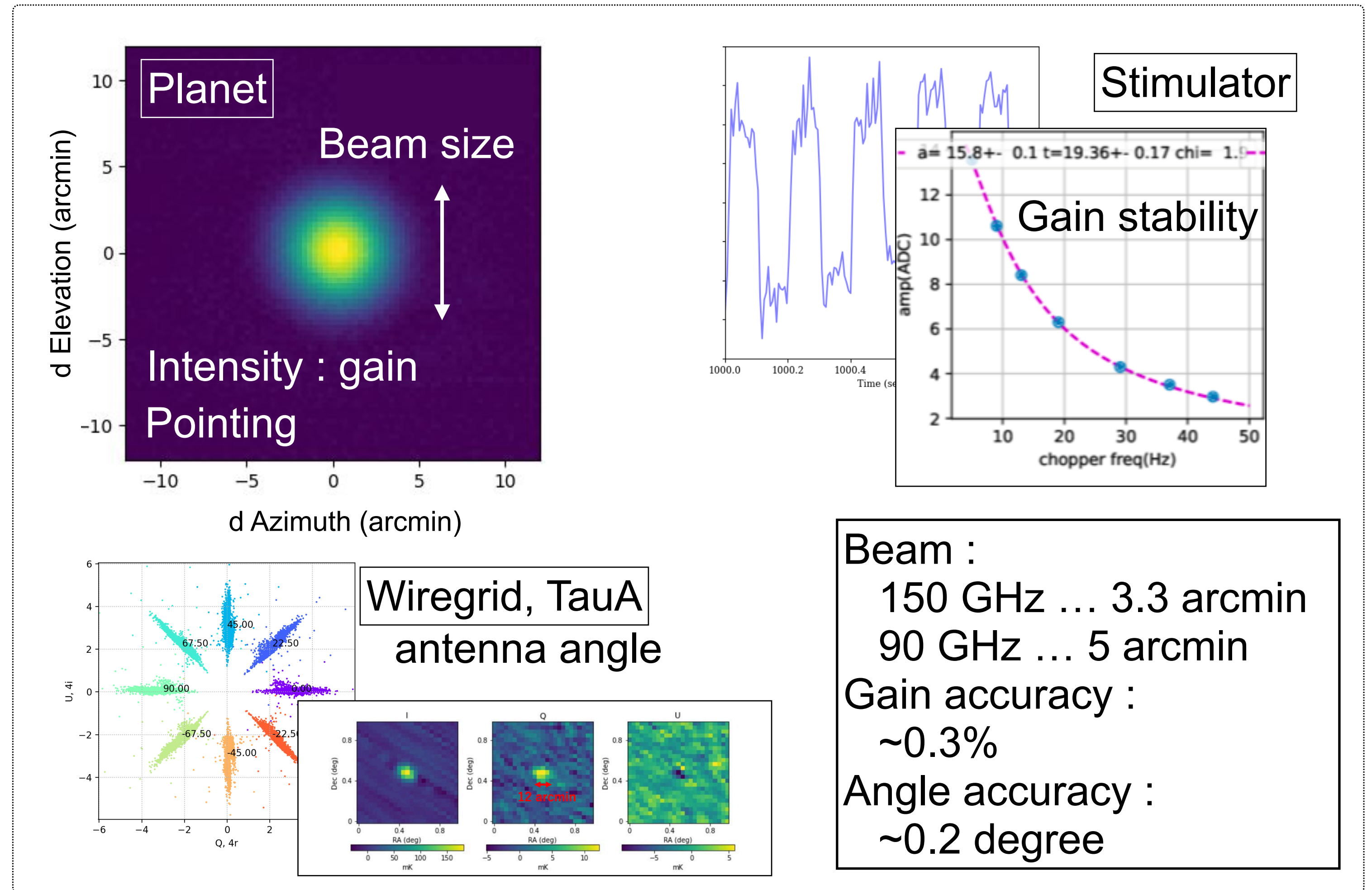
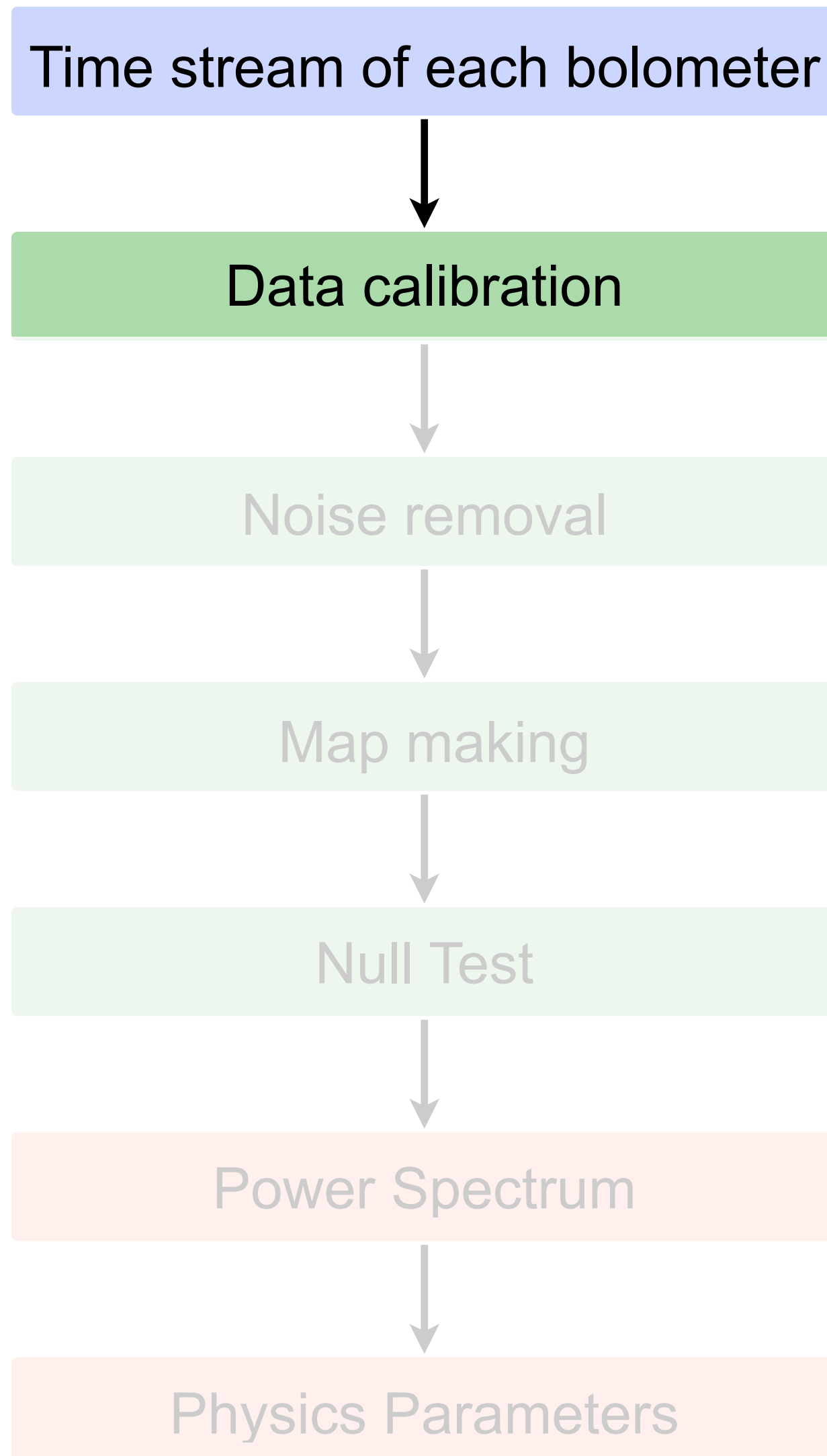
- Convert the unit of bolometers output to K
- Correct the pointing of the telescope
- Correct the angle of the antennas

## Physics analysis

- Noise removal
- Make CMB map on the sky from the time stream data
- Bias check by “null test”  
→ Constrain physics parameters by power spectra calculation

# Data Calibration

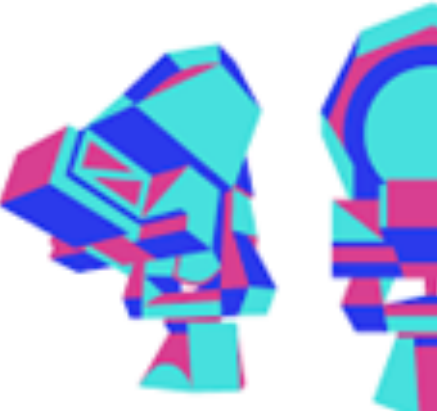
- Understand the characteristics of the telescopes by looking at observation results of planets and so on.



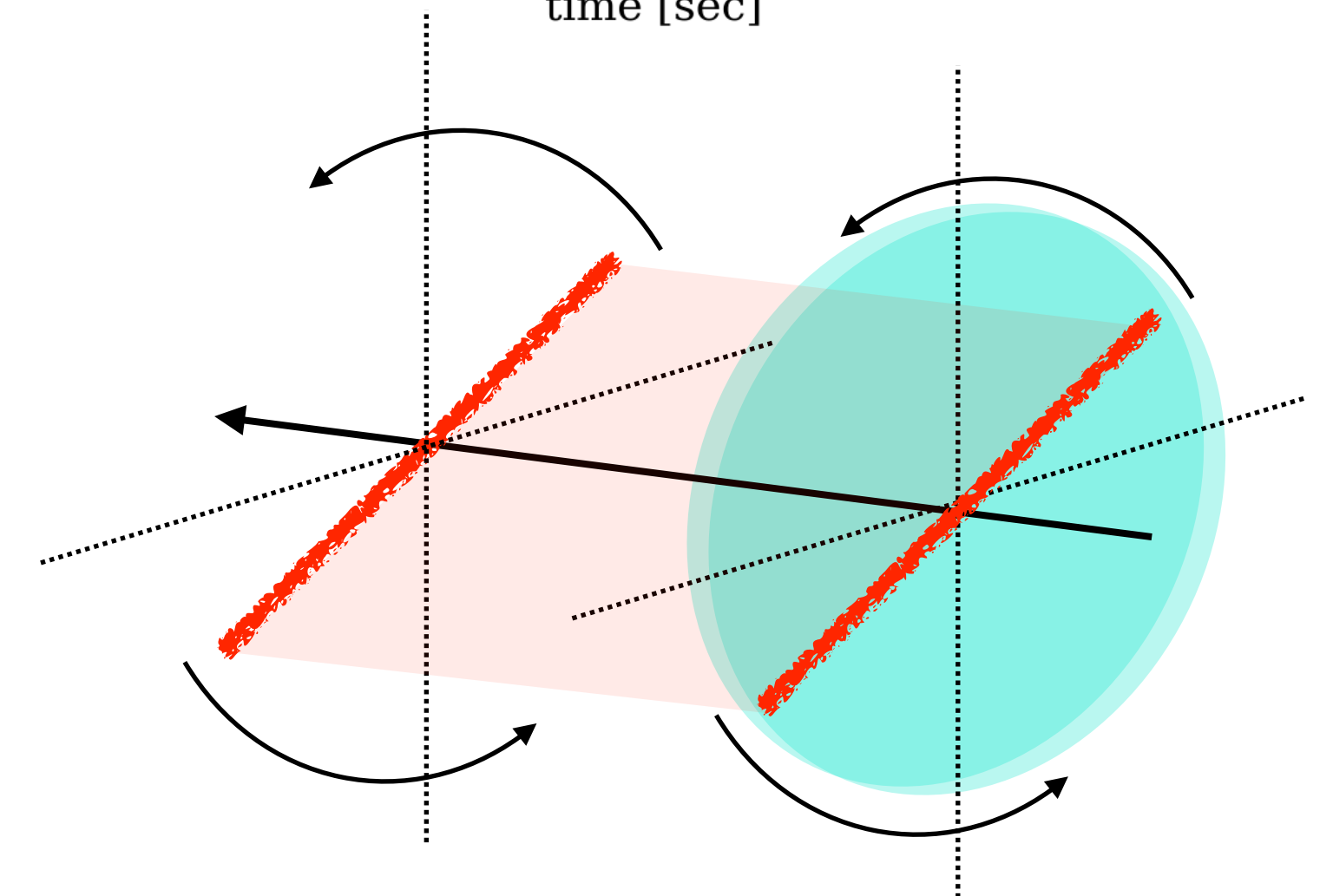
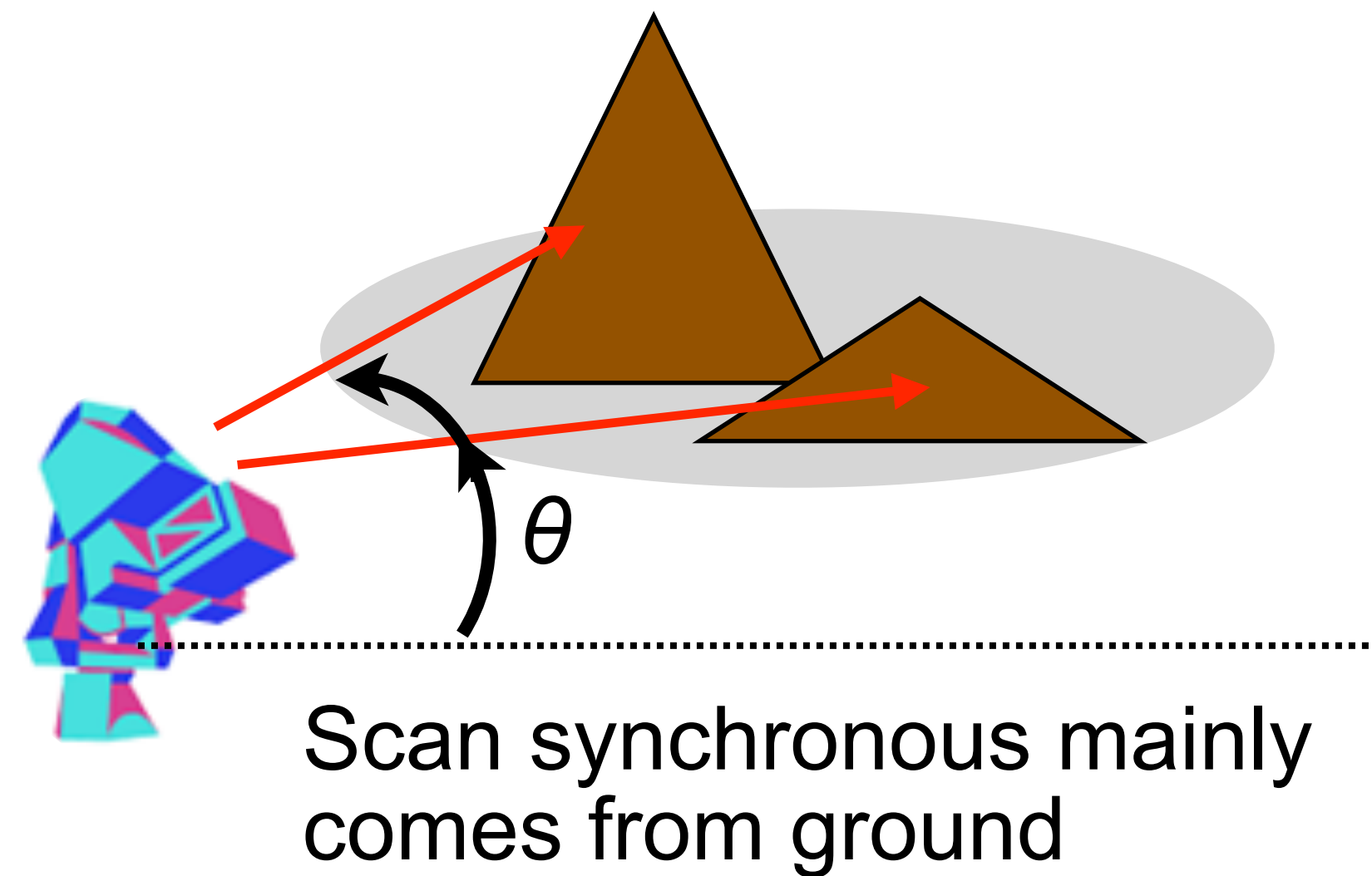
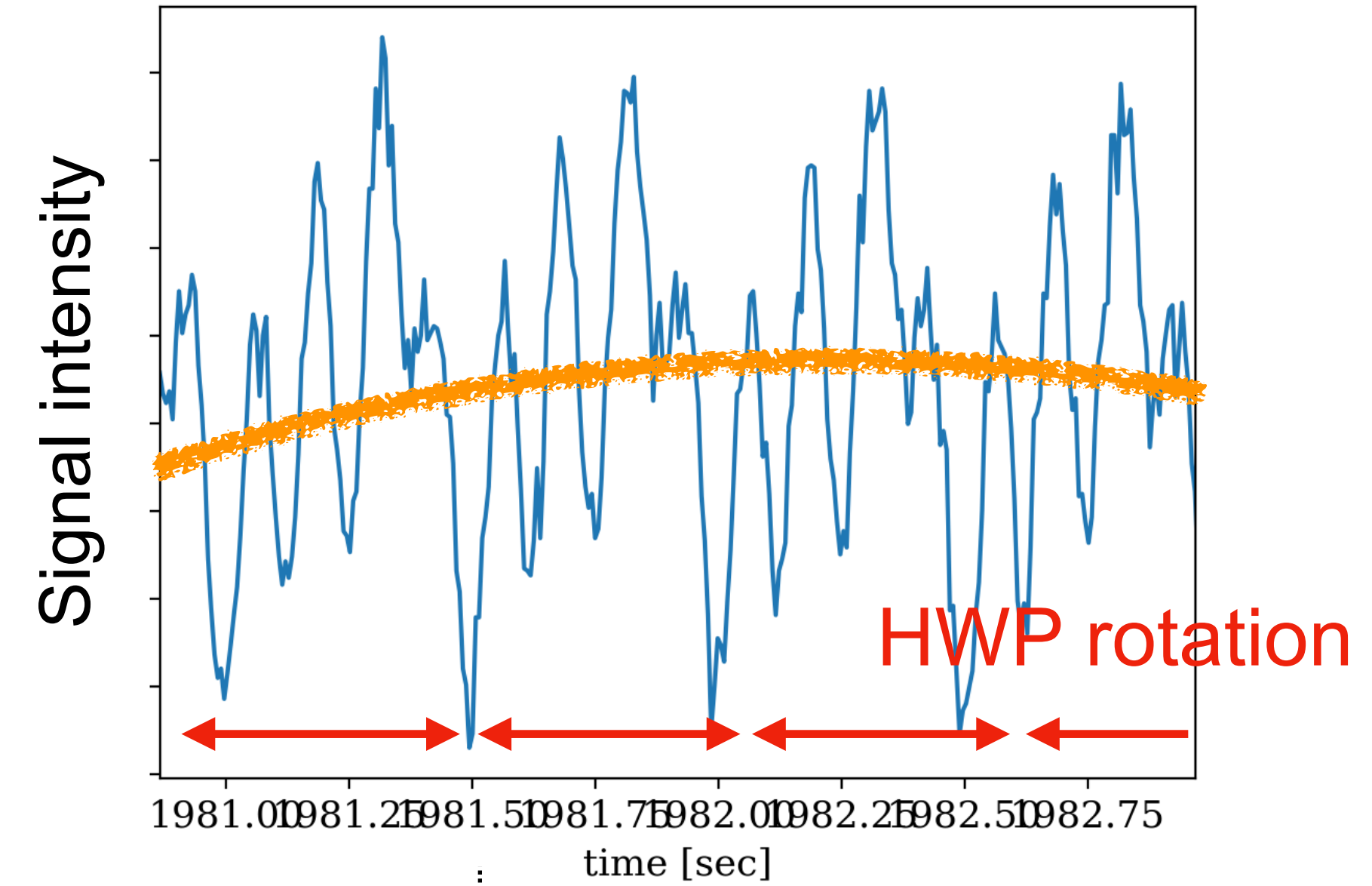
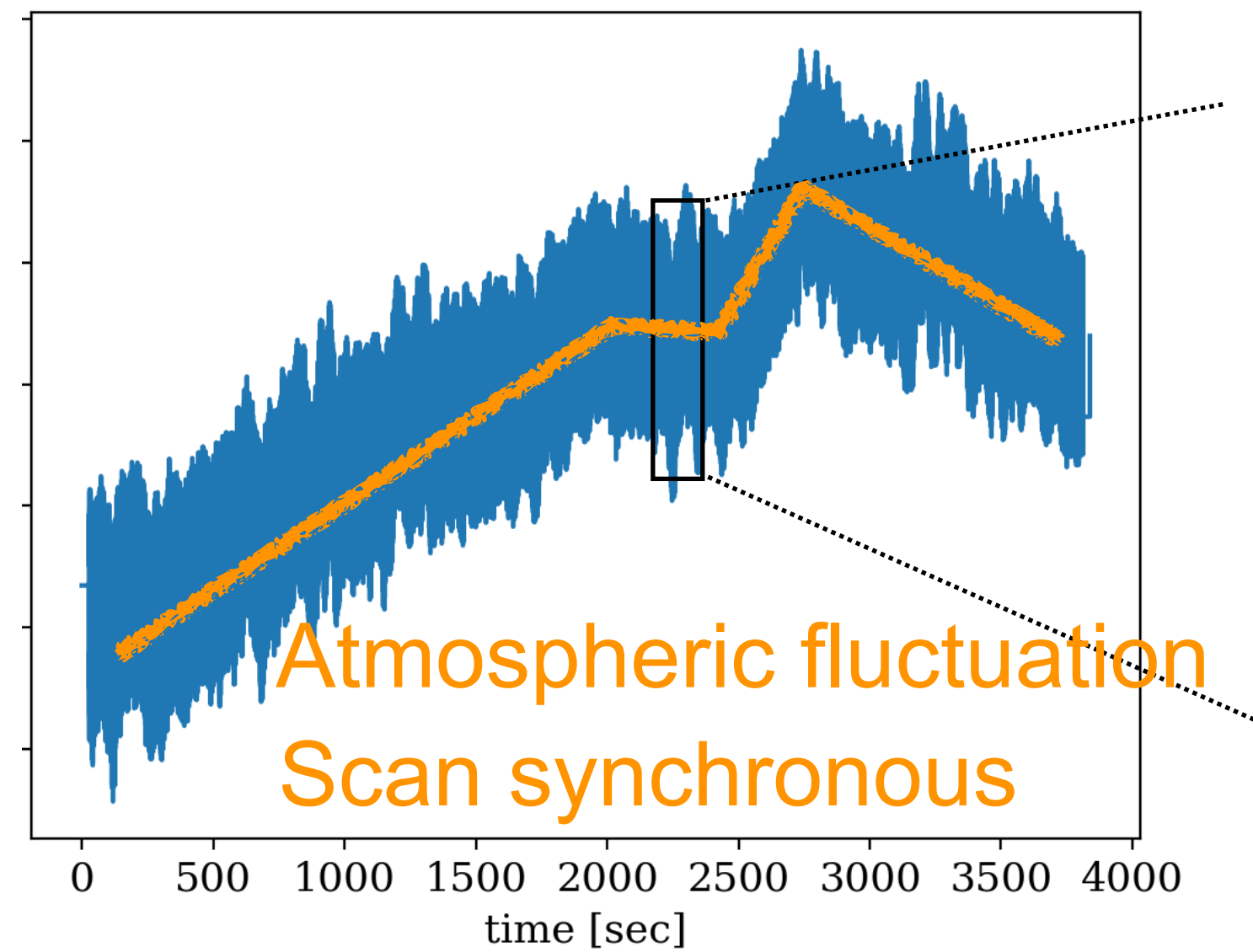
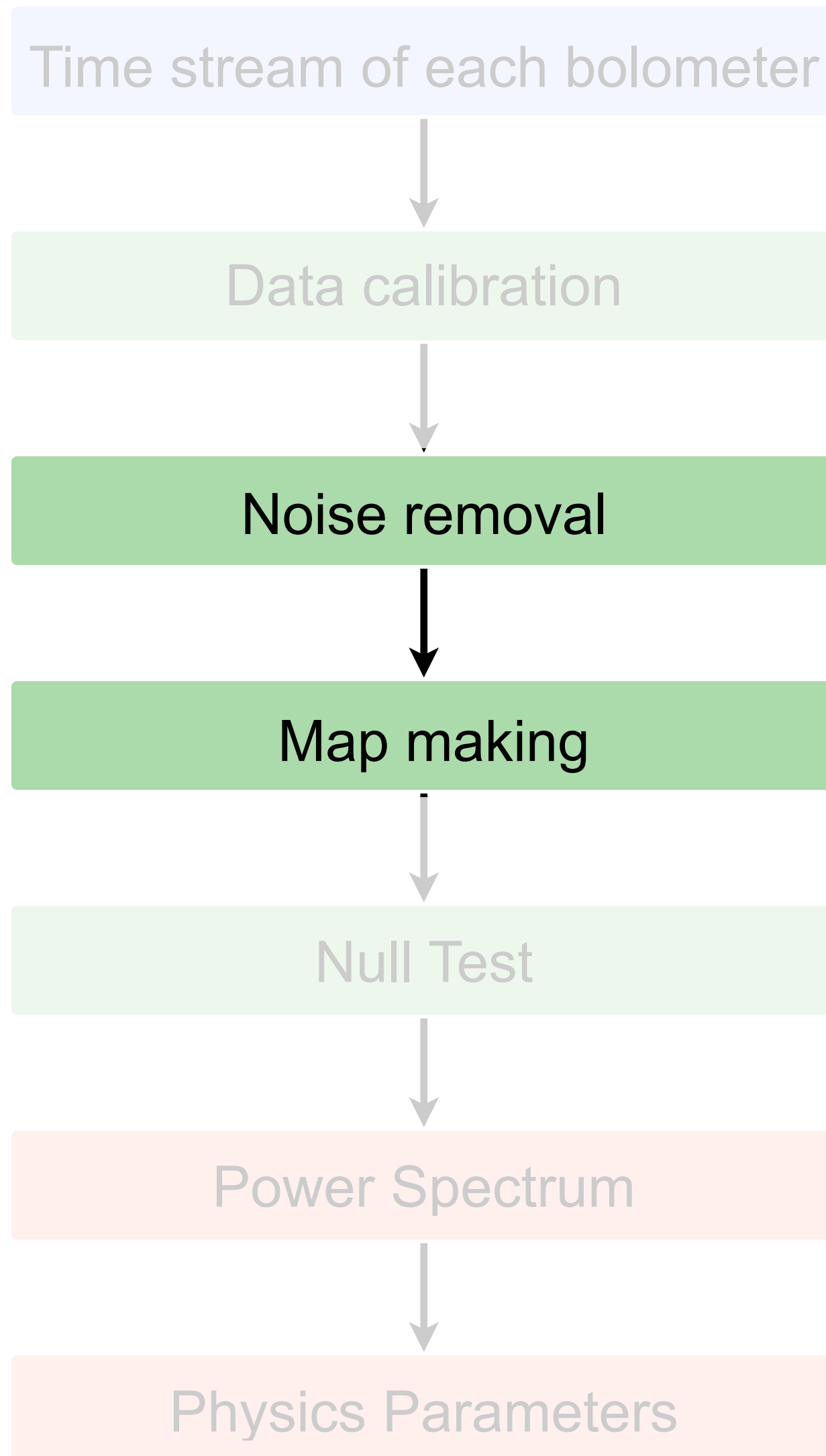
**Data calibration framework is ready.**

Applied to 1st telescope. Calibration of 2nd telescope is also on going.

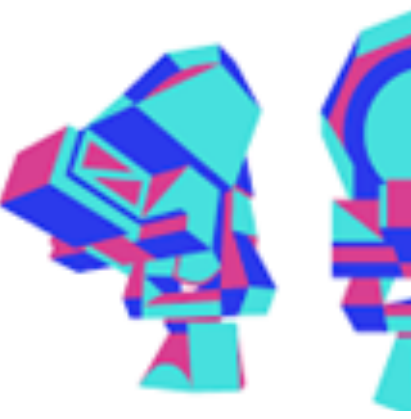
# Noises in Simons Array



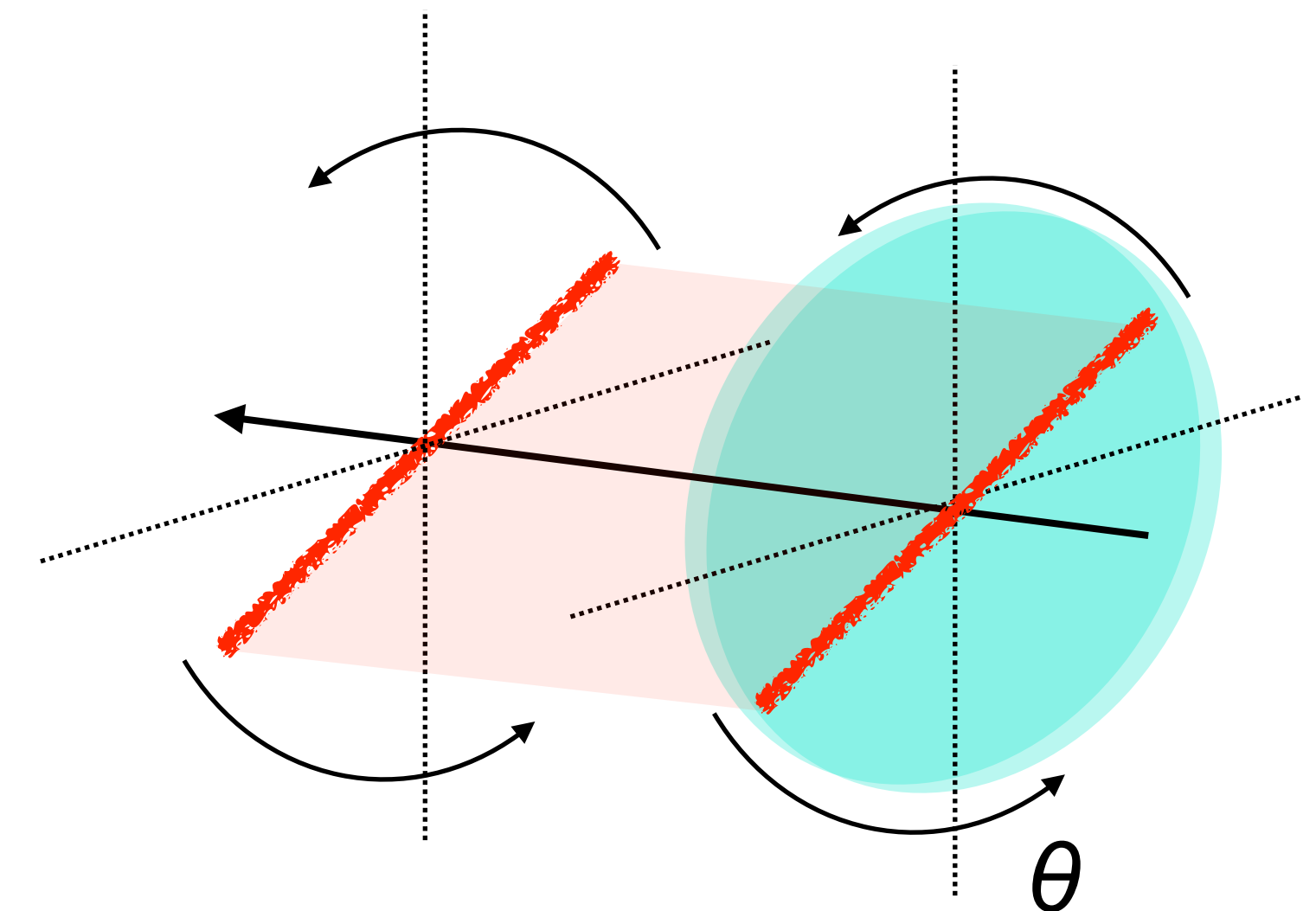
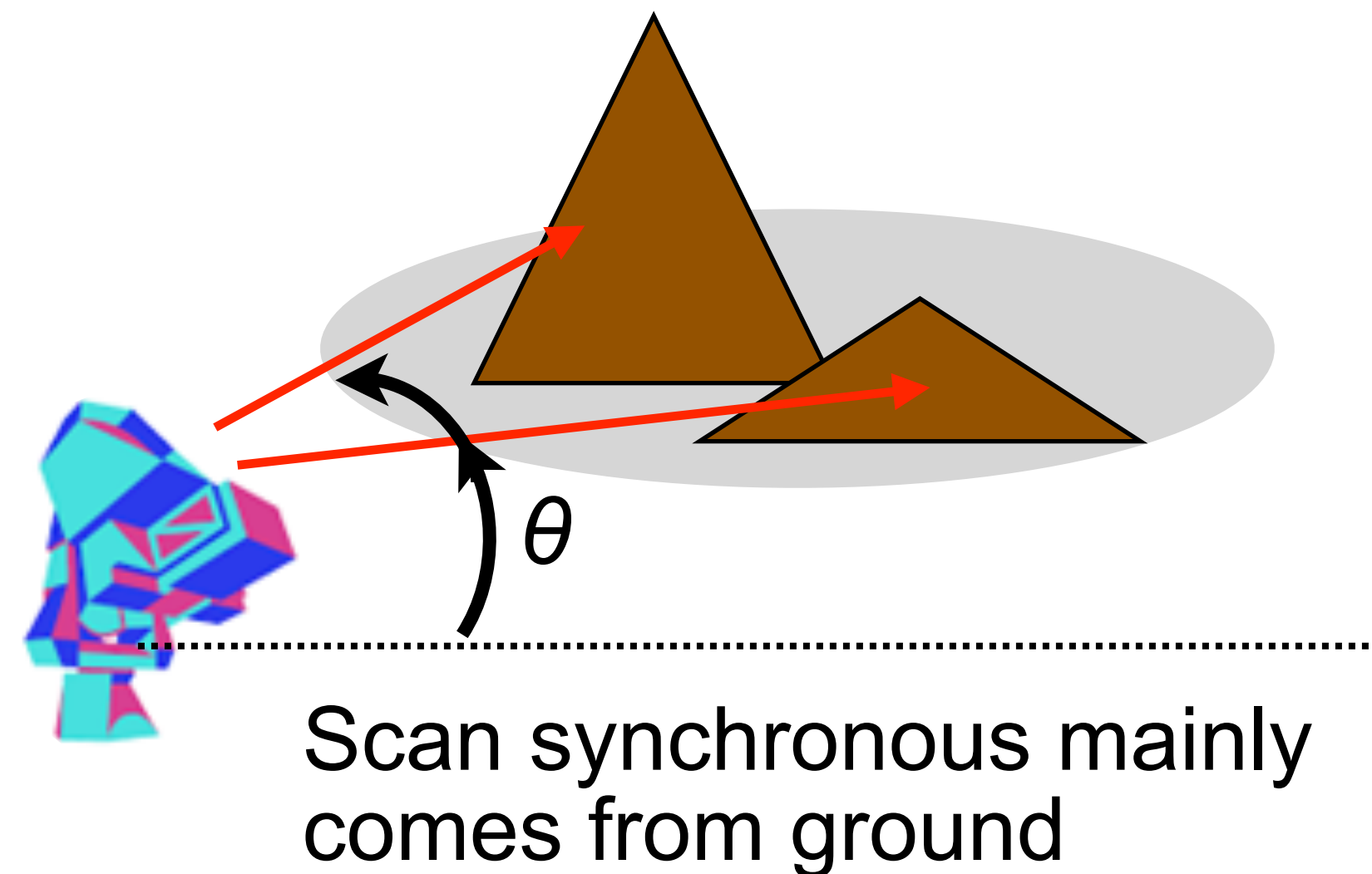
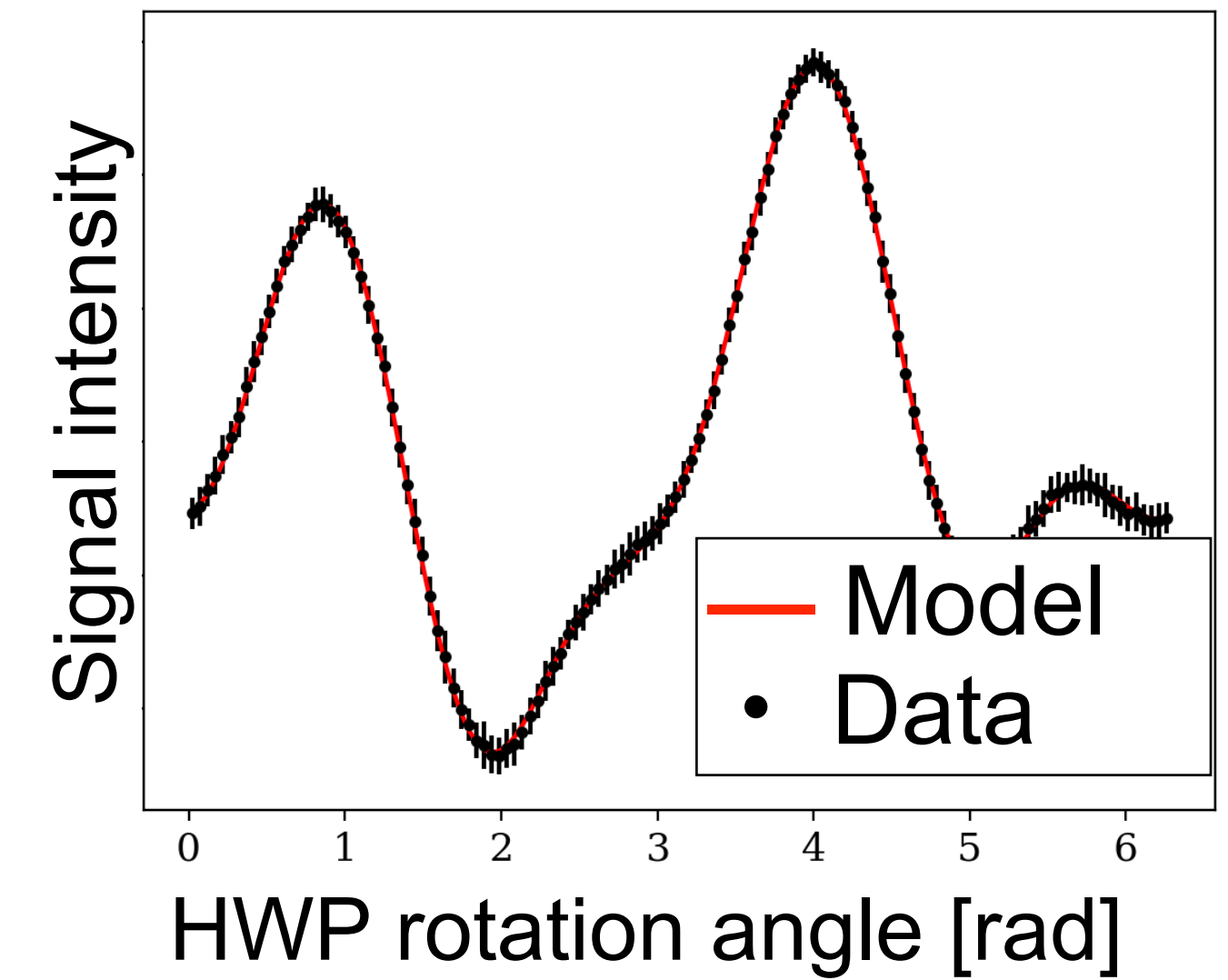
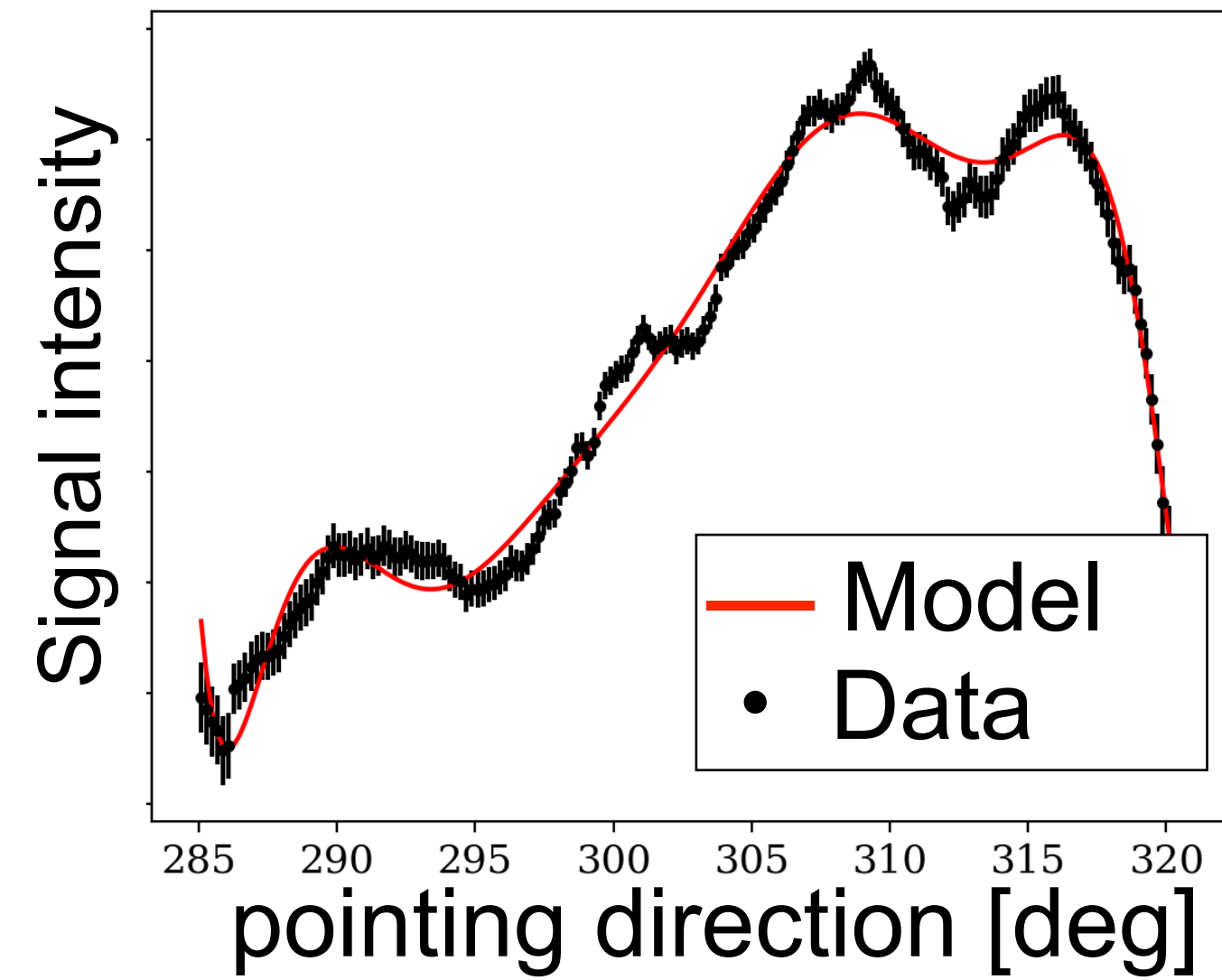
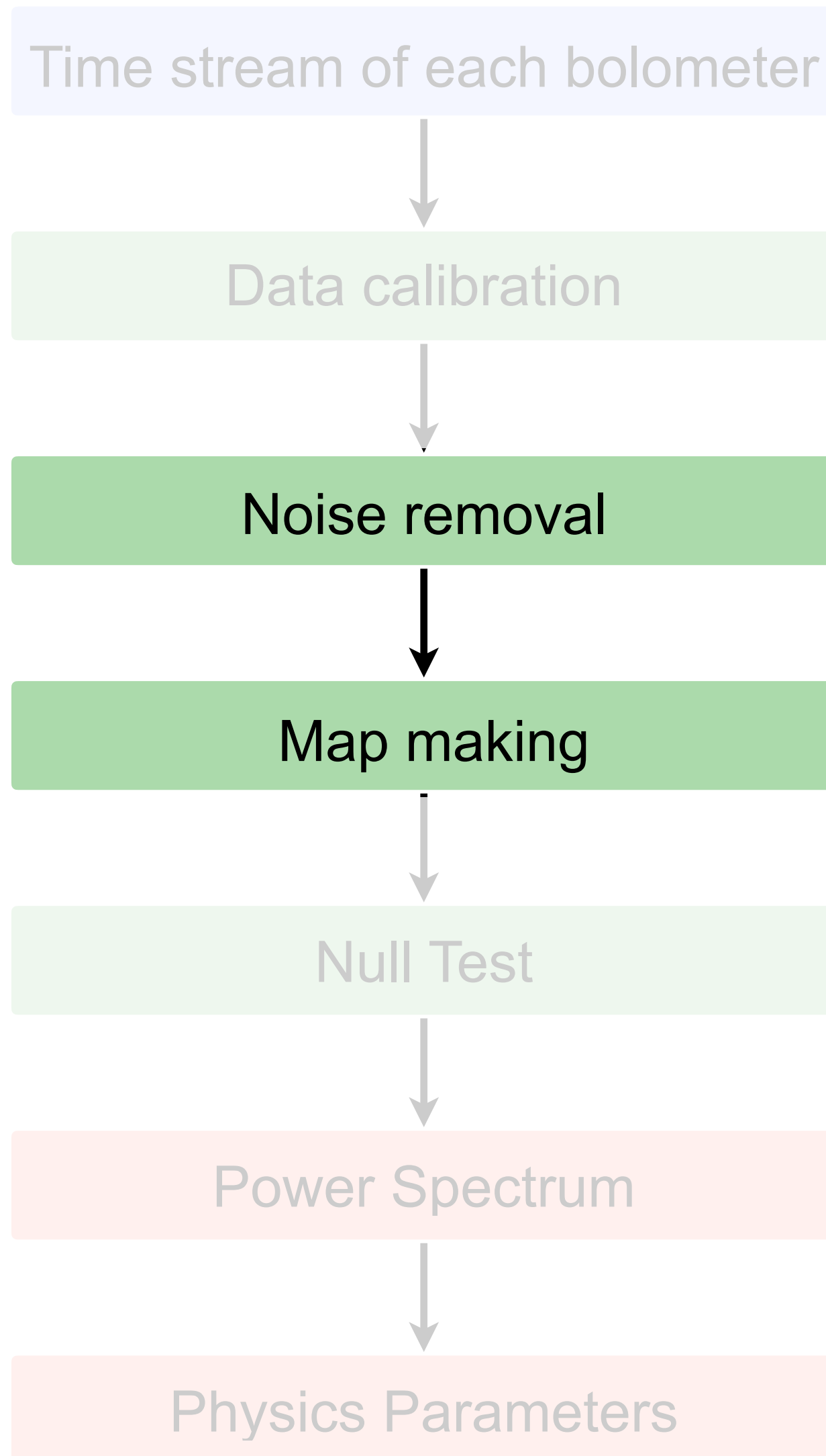
- Time stream includes noises that should be removed. They are filtered by modeling them.



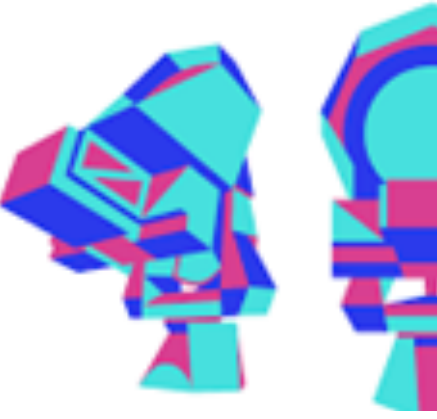
# Modeling Noise



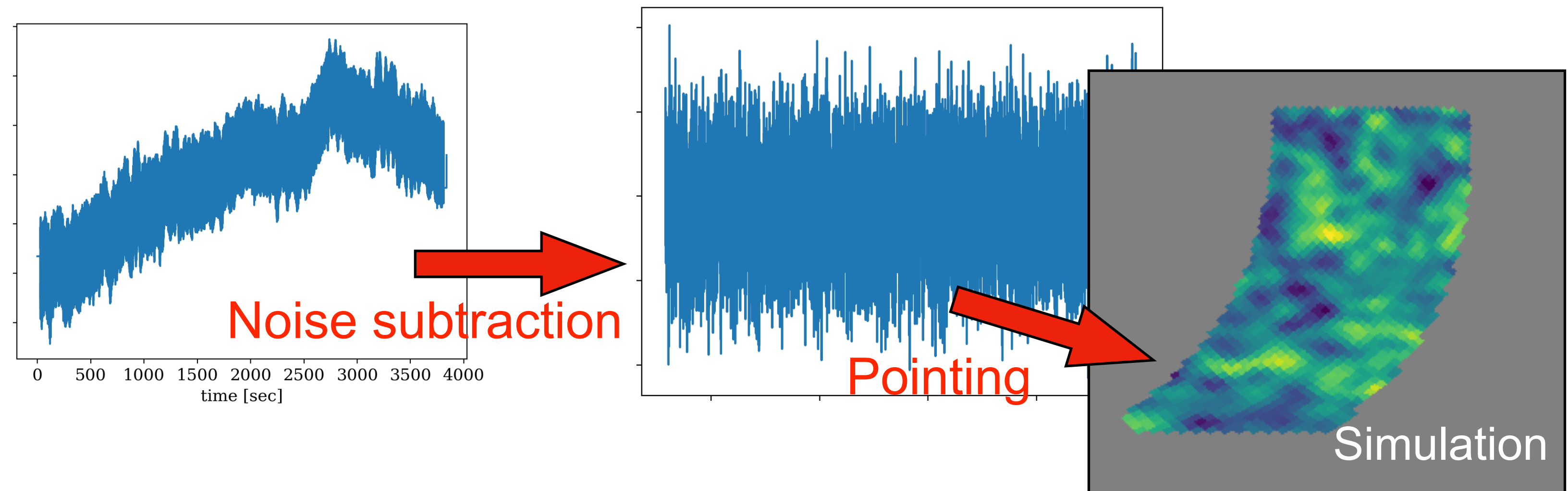
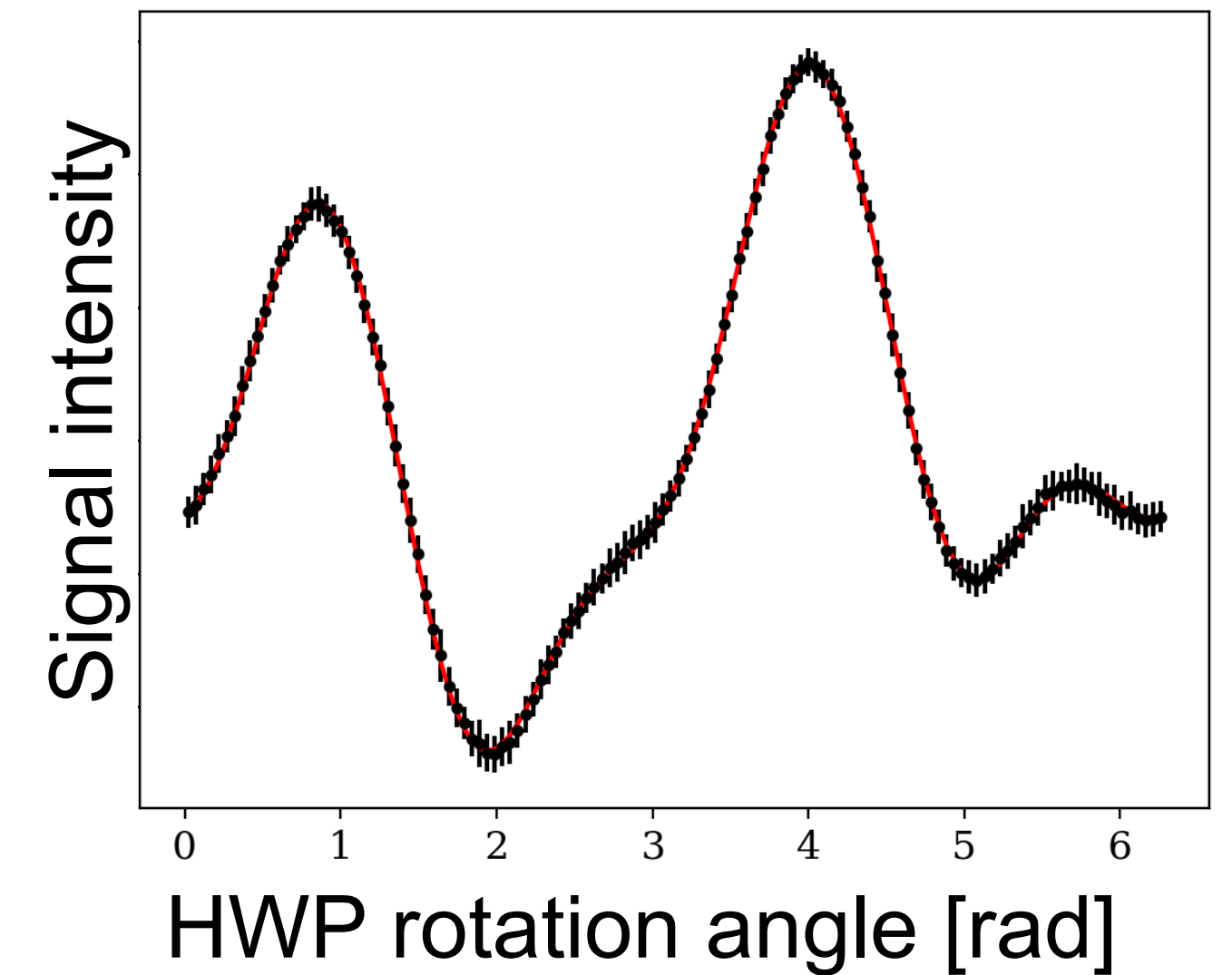
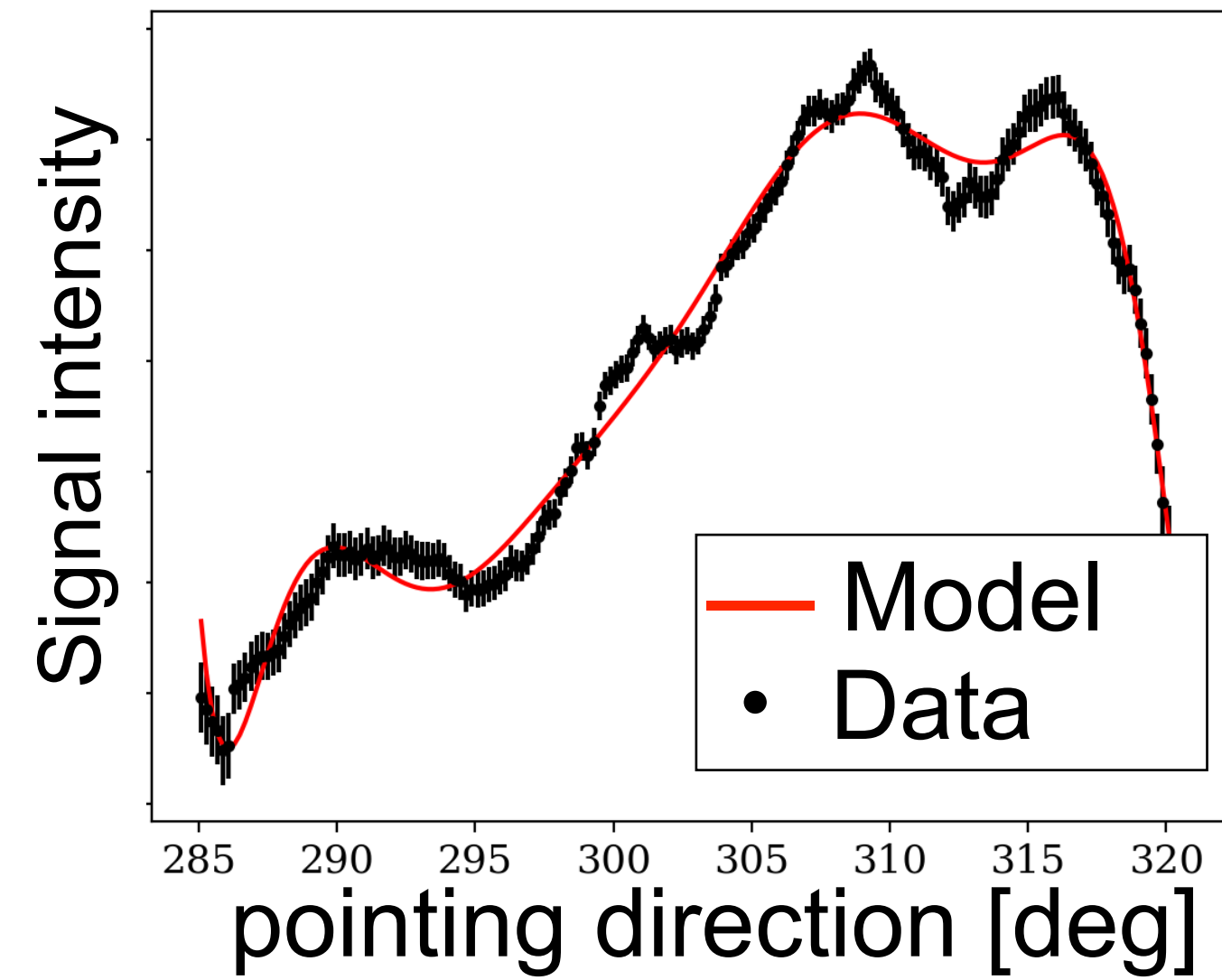
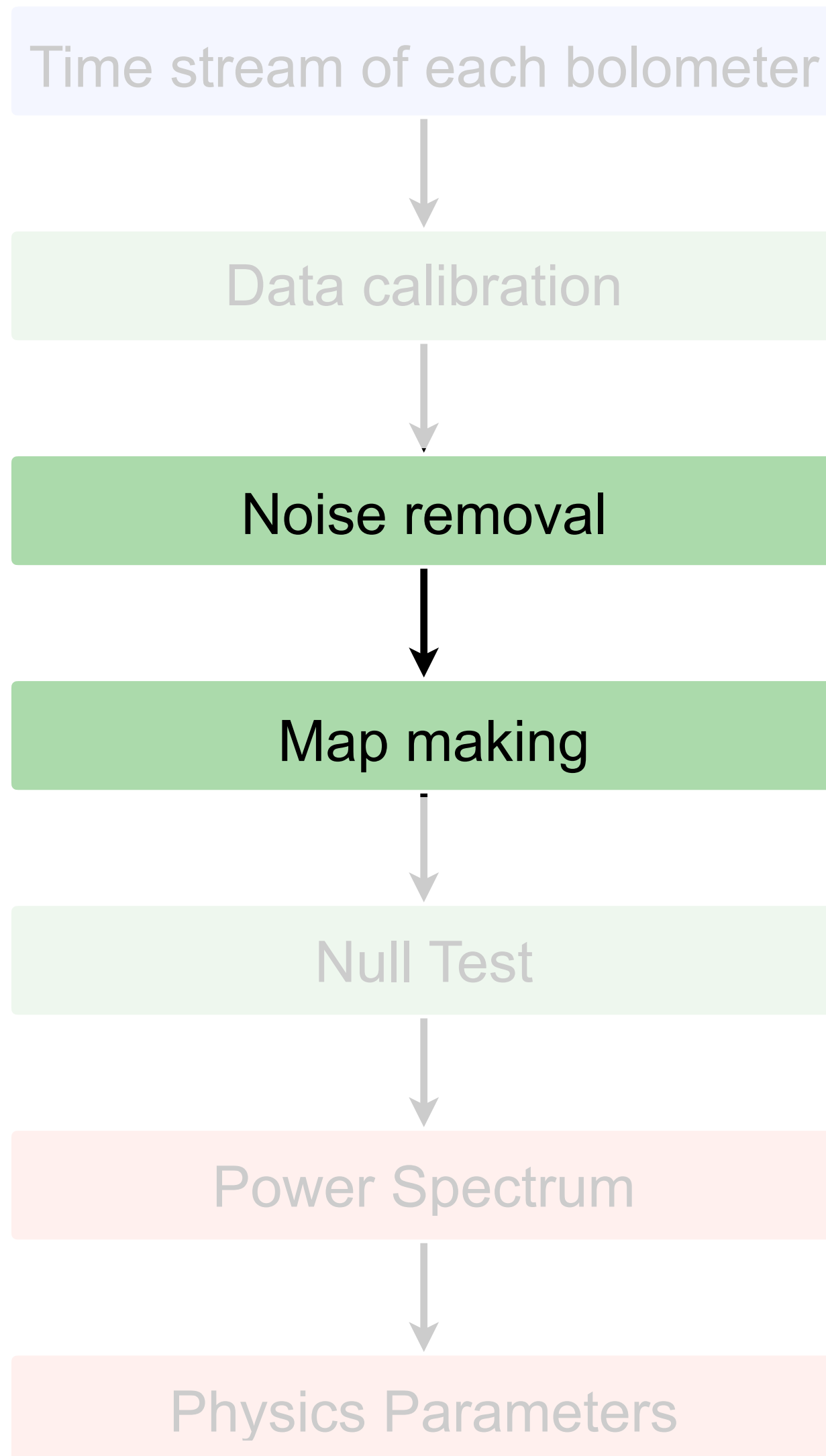
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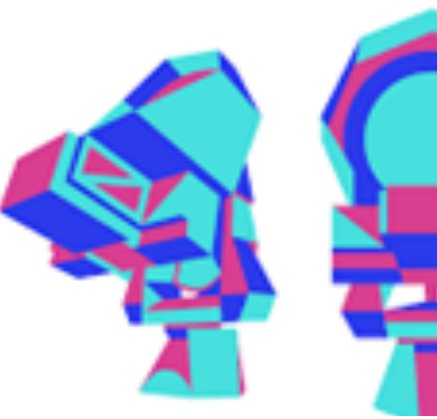
# Noises in Simons Array



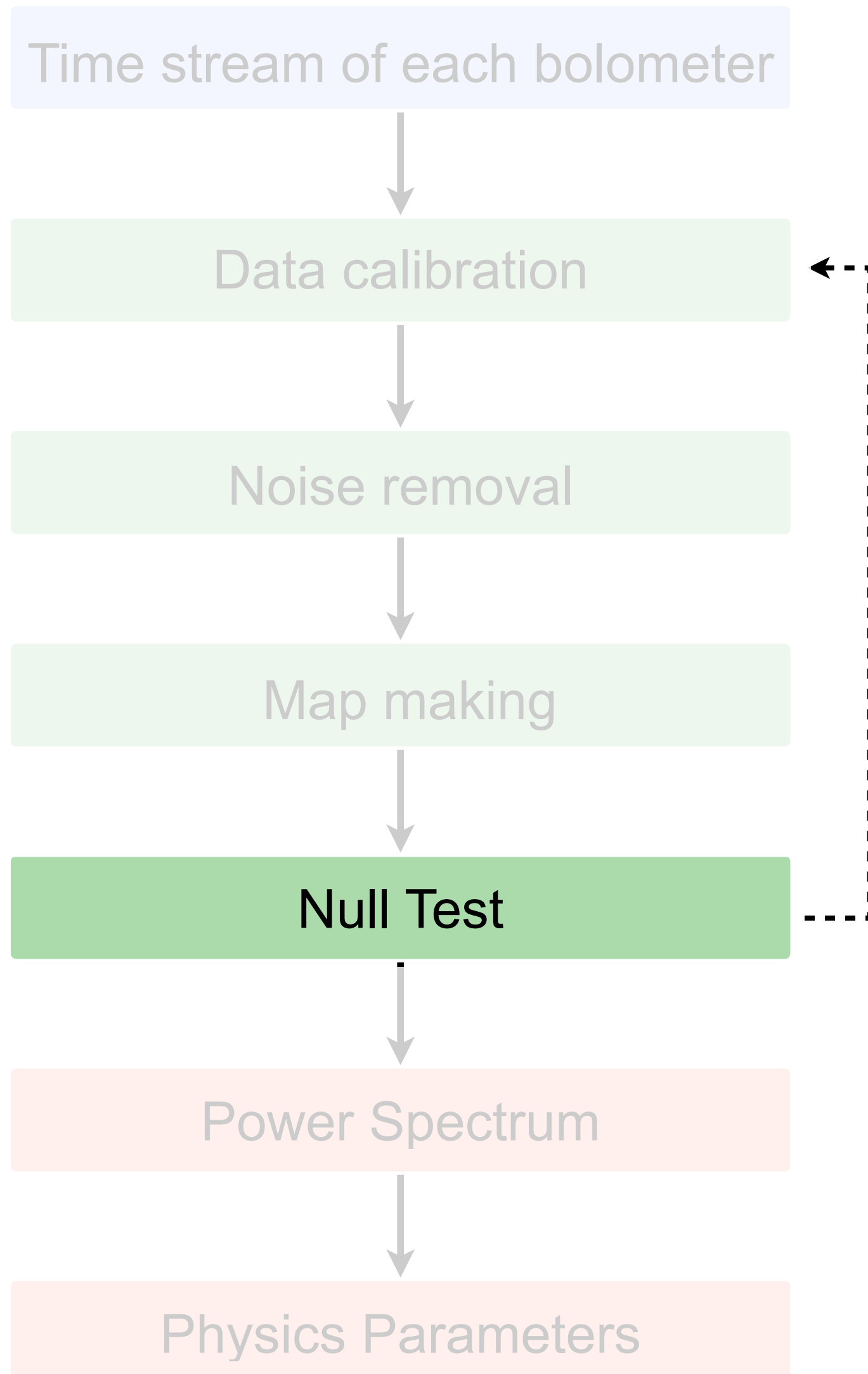
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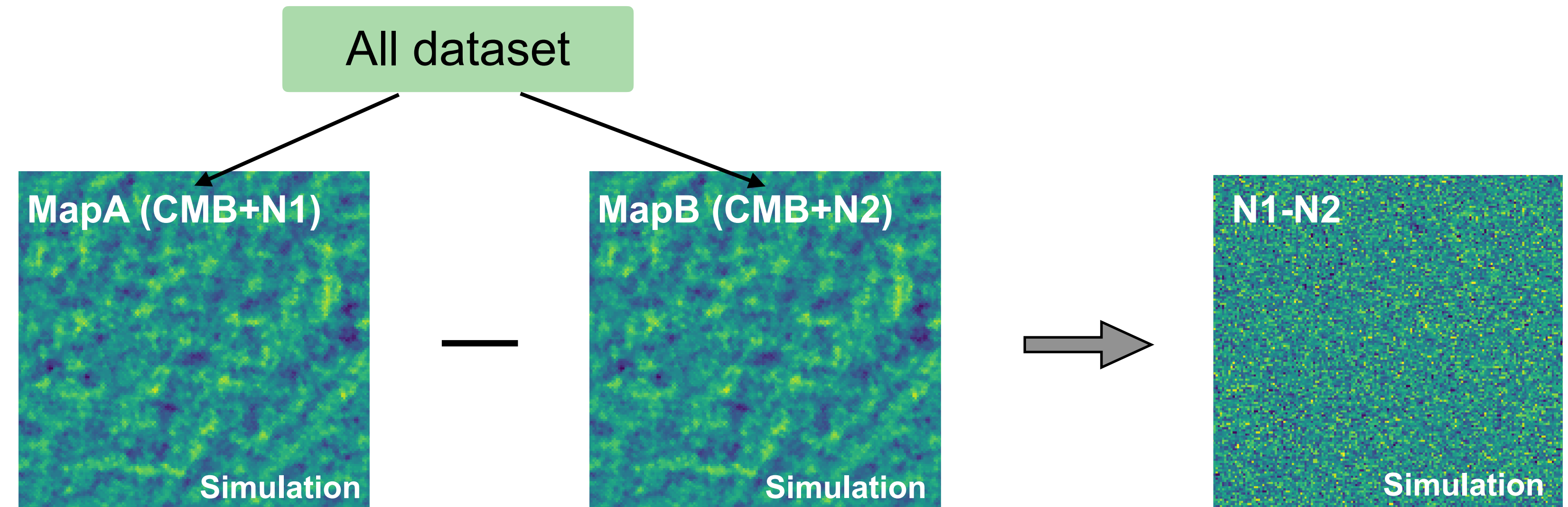
# Null Test



- Null test is performed to confirm that the data does not include systematic bias.



- Perform in advance before physics analysis.
- Detect biases without looking at the data itself to avoid human bias.

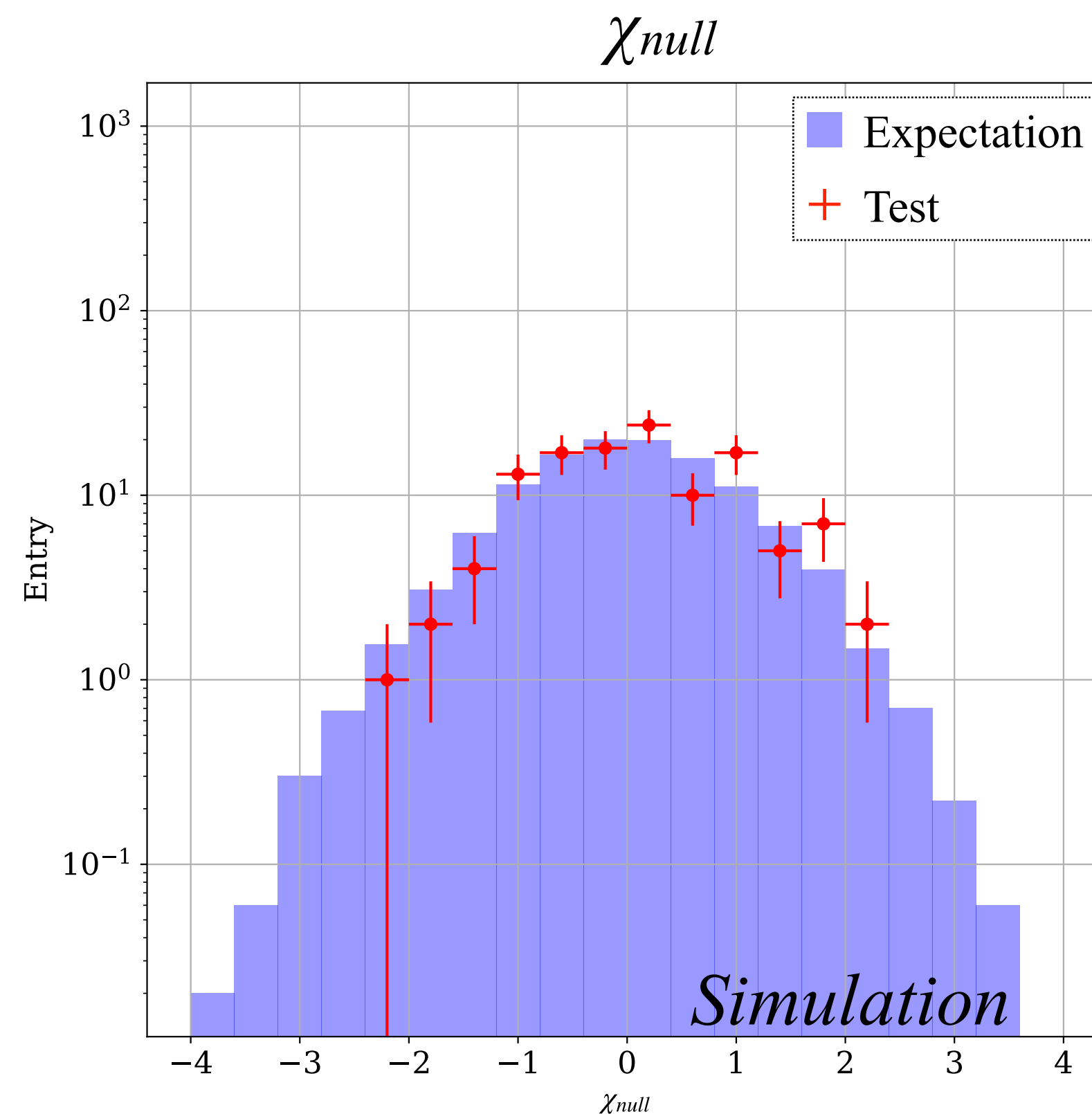
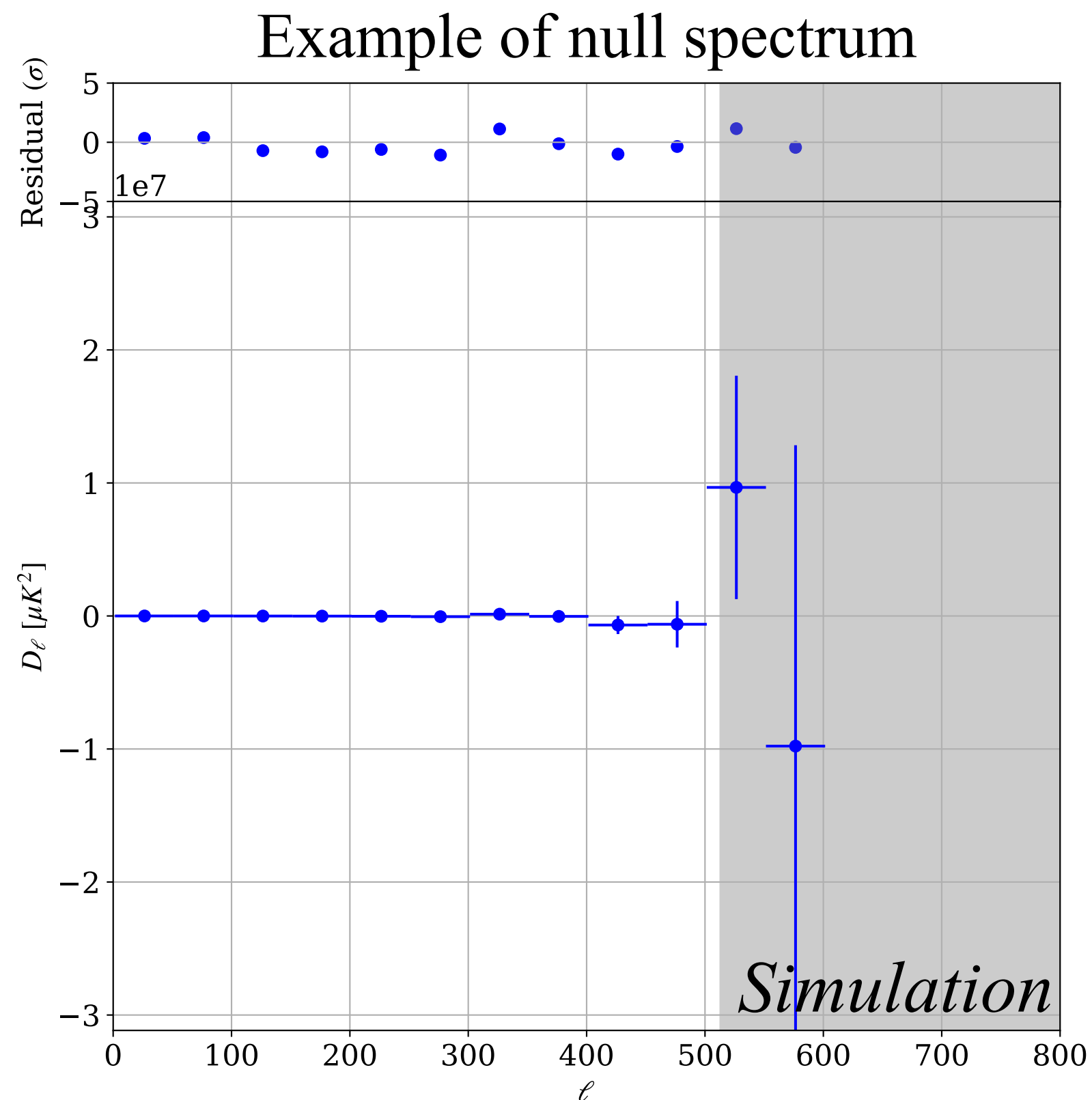


- Divide the dataset into two :
  - (e.g.) • Scan direction(right/left)
  - detector location on the focal plane (top/bottom, right/left)
  - first/later half in the observation period

Then, check if the difference between their power spectra is null.

# Validation of SA Null Test Framework

- The null test framework for SA analysis has been developed and evaluated.
  - Simulation is generated according to the actual scan of SA.
  - Input the simulation to the framework.
    - ☑ Spectrum of the difference is consistent null.
    - ☑ The distribution of the discrepancy from null is as expected.



**Framework from calibration to null test is ready**  
→ **Start physics analysis soon**

# Summary

- The Simons Array Experiment is searching for primordial B-mode to test inflation theory.
  - Physics observation of the first telescope is in progress.
  - Deployment and test observation of the second telescope is being proceeded in parallel. We will move onto physics observation soon.
- Data analysis framework of SA has been developed.
  - Completed from calibration to null test.
  - Start physics analysis once we obtain enough amount of data.

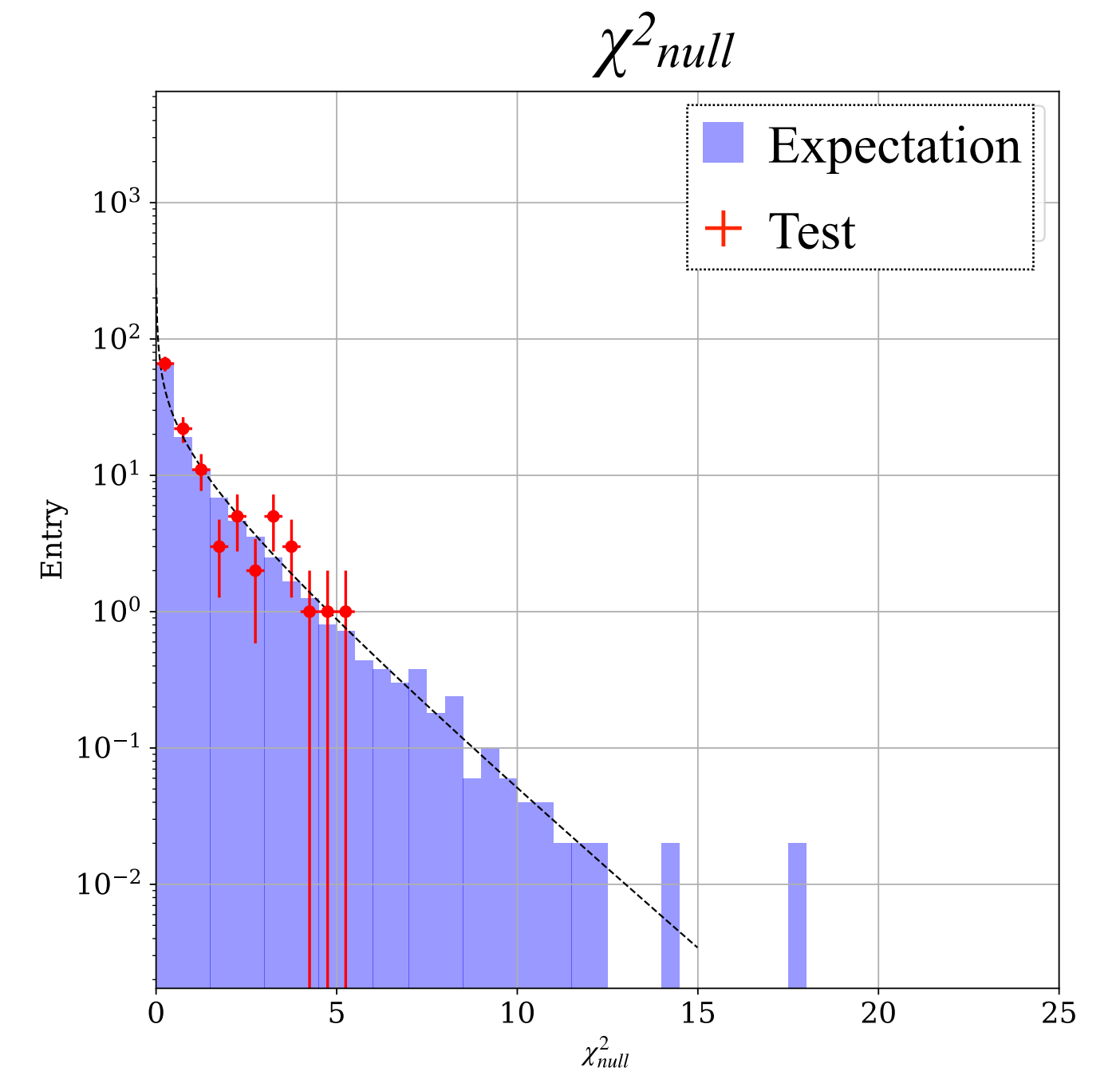
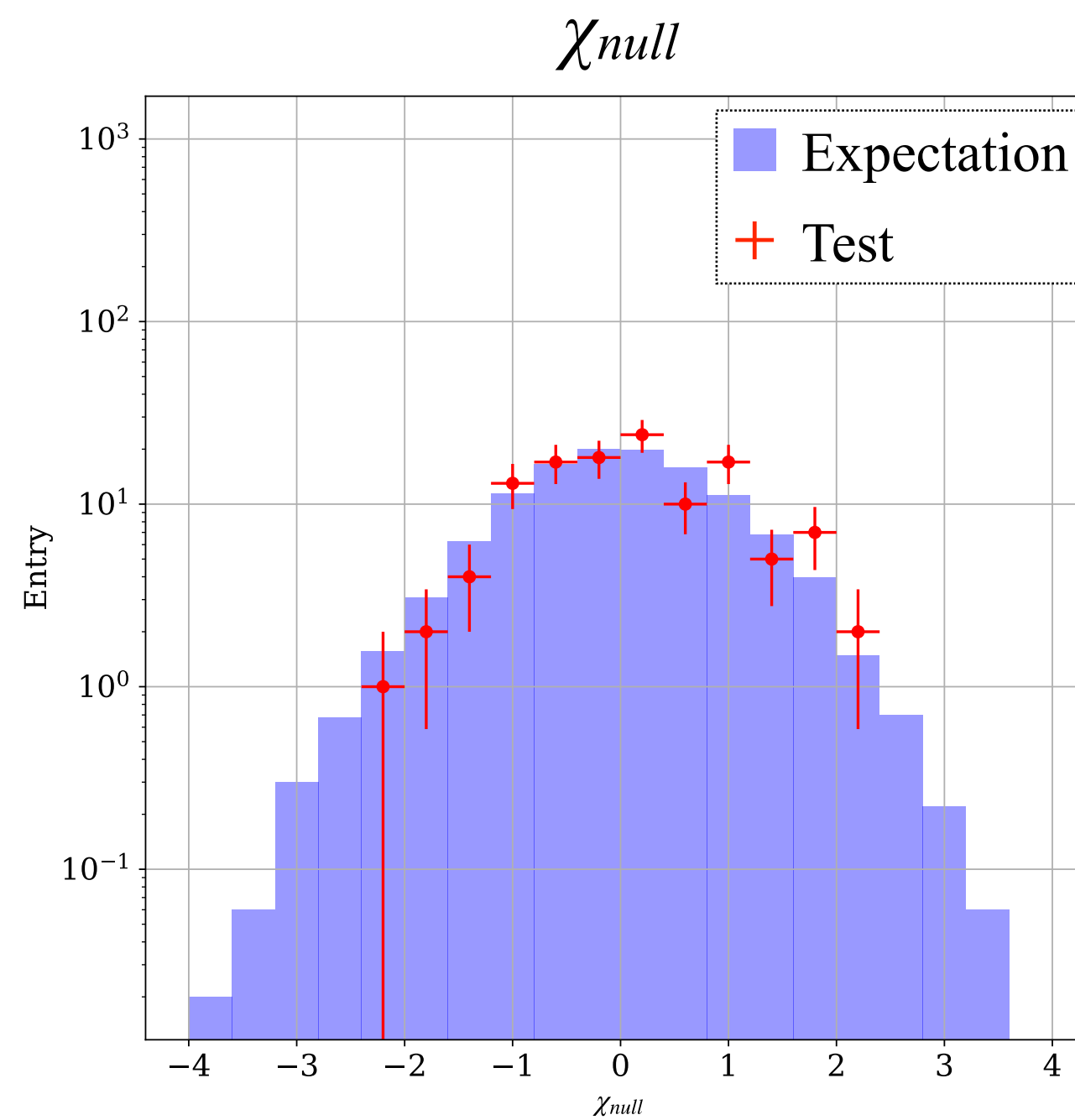
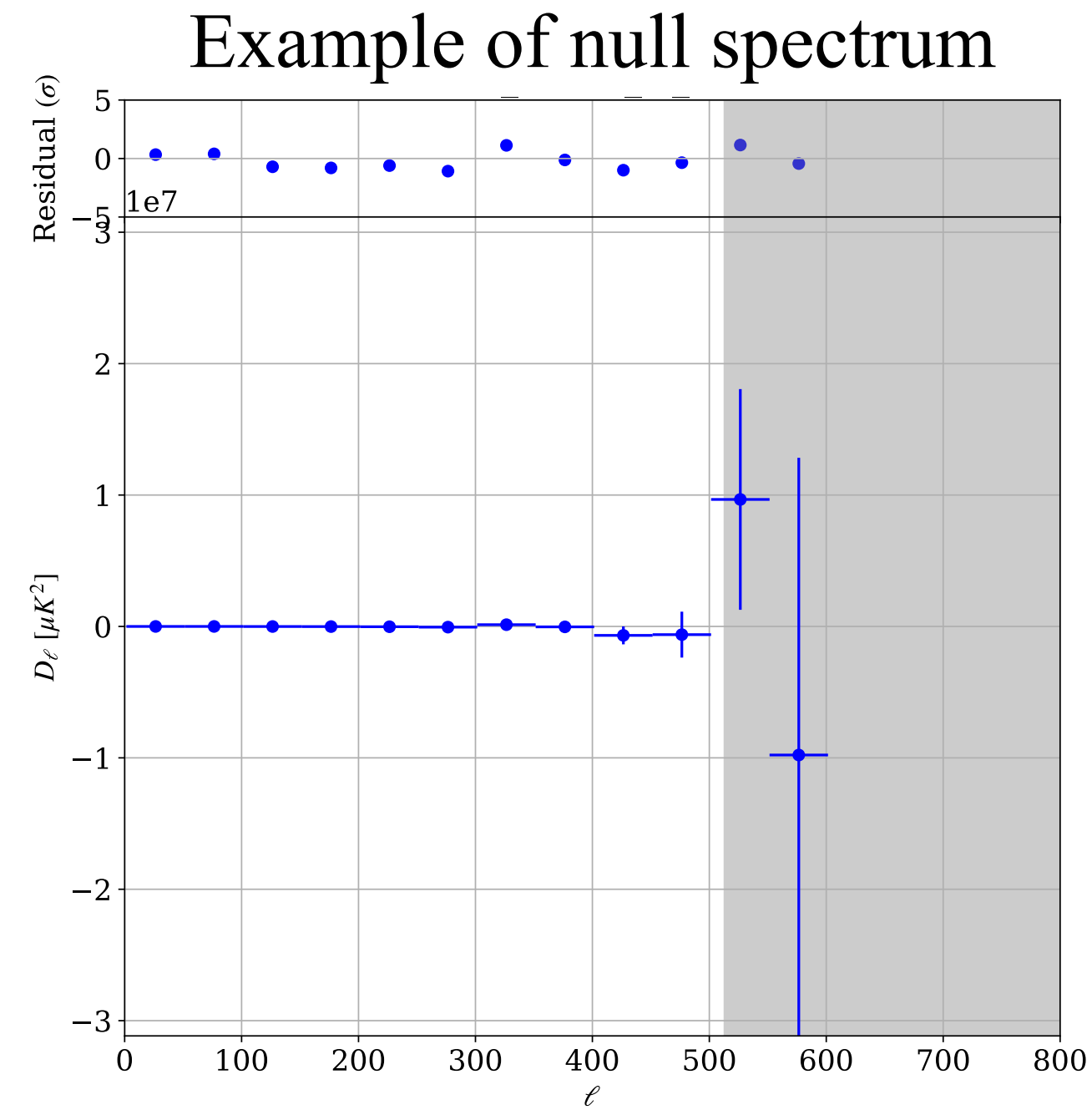


**POLARBEAR Collaboration**  
~20 Institutes, ~100 people



# Back-up Slides

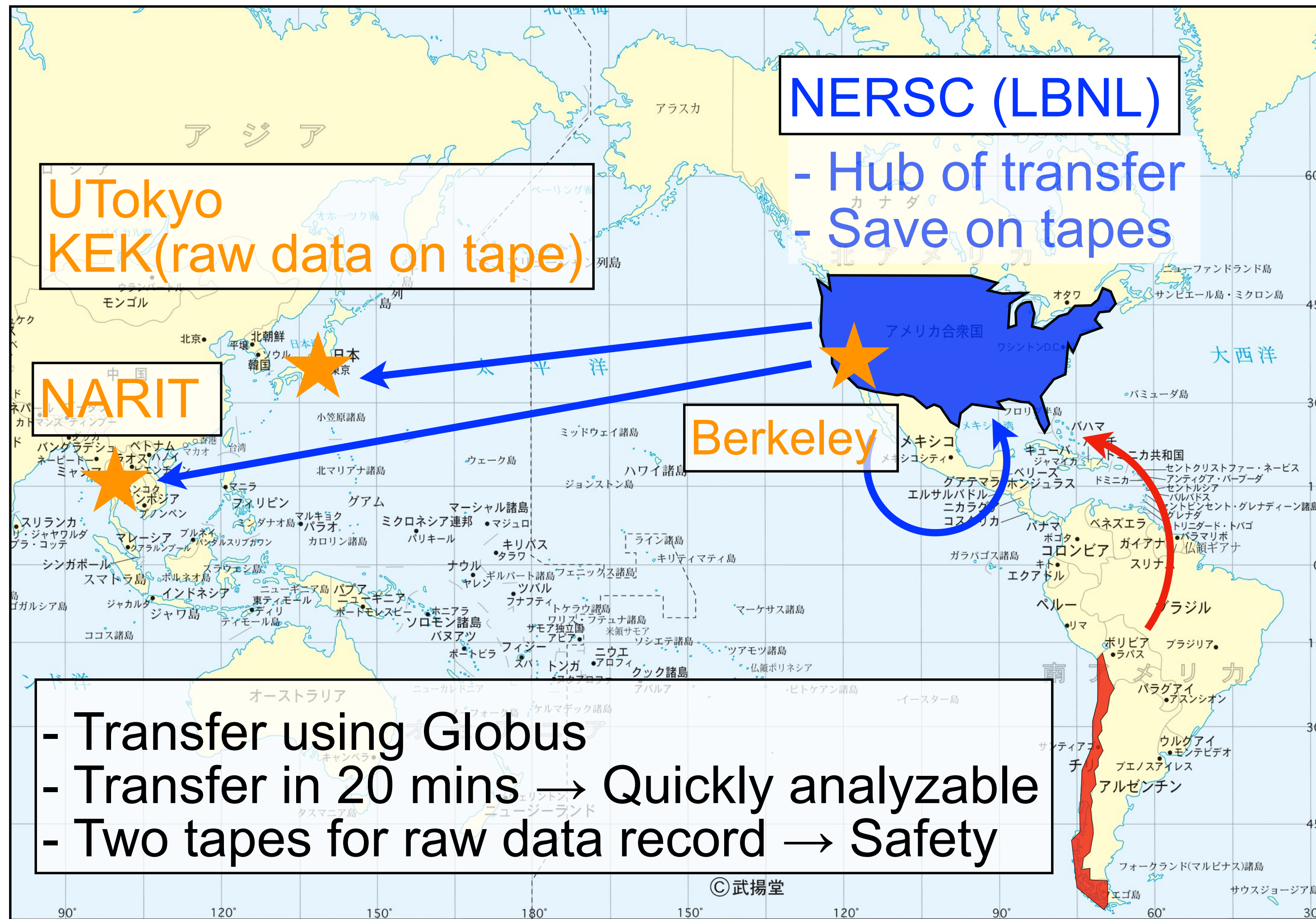
# Validation of the Null Test Framework



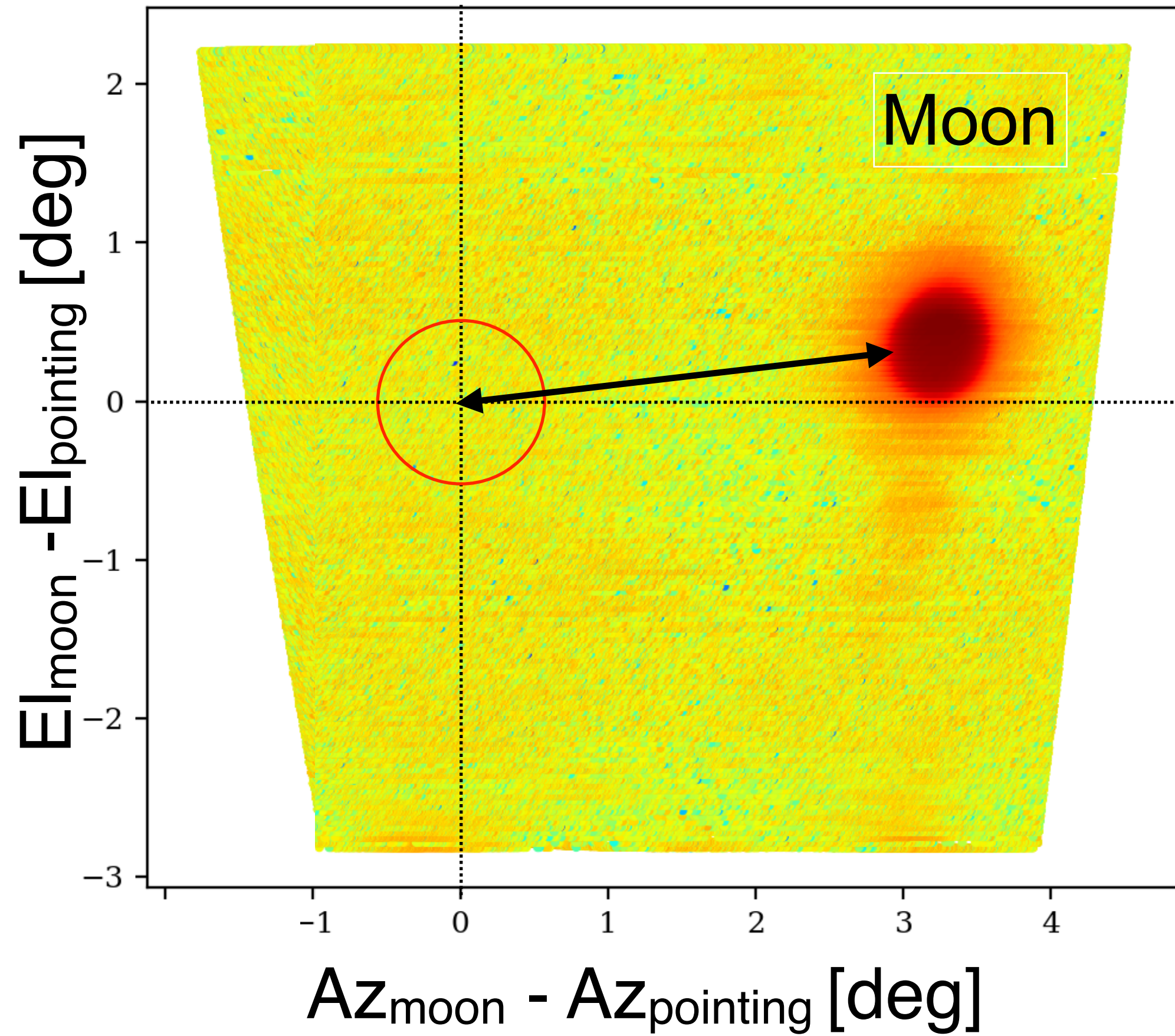
One of null spectra from many  
null-test trials.  
(left/right, top/bottom, Q/U, ...)

$\chi$  and  $\chi^2$ .  $\chi$  is defined by  $C_{null}/\sigma_{null}$  of each bin of each null spectrum.  
Blue histograms are obtained by null spectra of noise simulation.  
Red is entry from tested data.  
(Here, both are calculated using simulation)

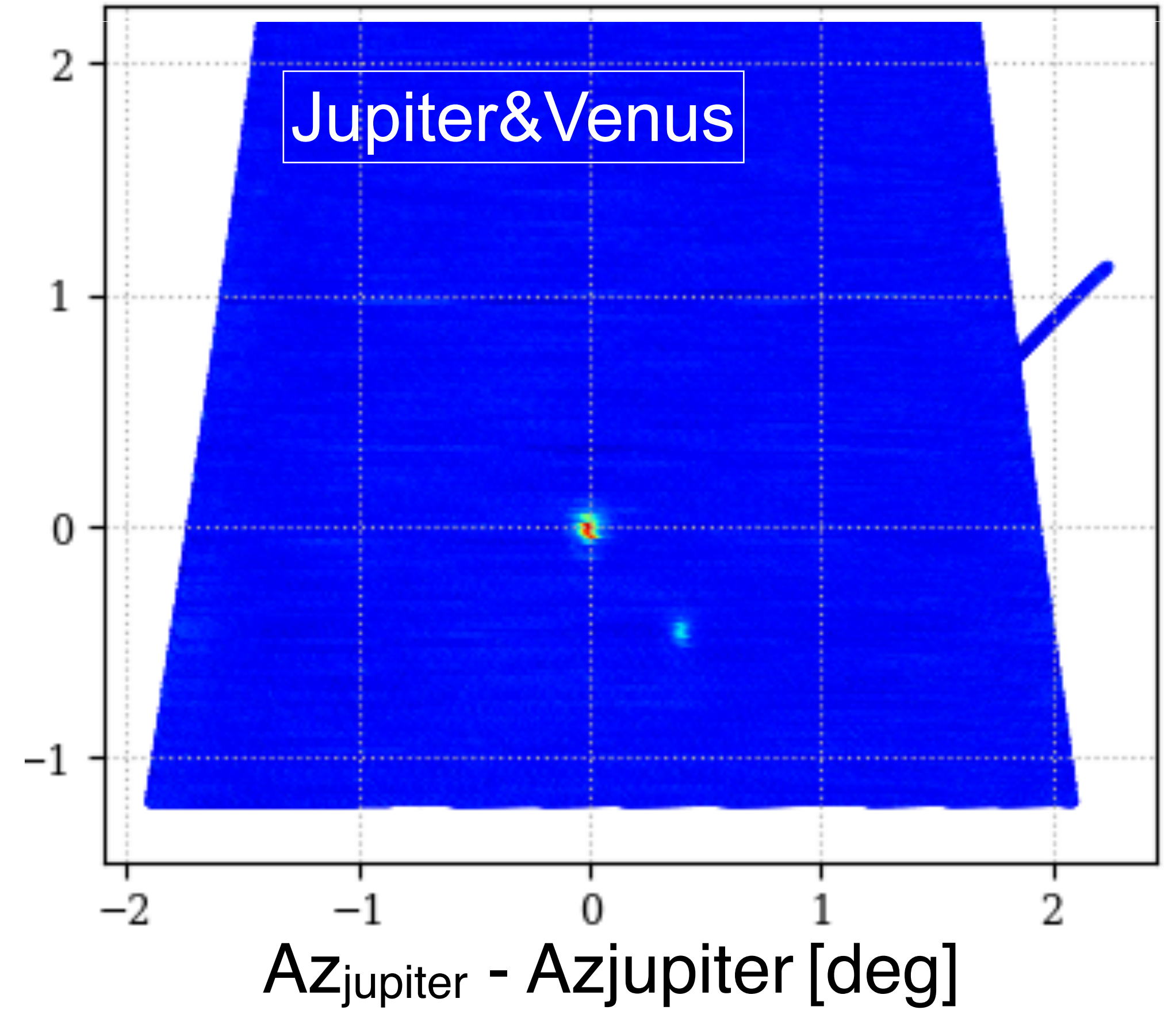
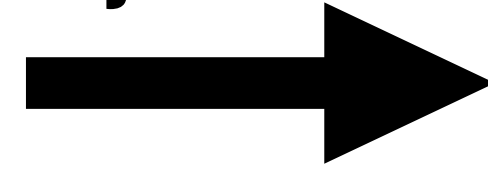
# Data Transfer



# Pointing Offset



Adjustment



# HWP Synchronous Signal

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- HWP : generates phase shift using birefringence.
  - 2f HWPSS : Differential transmission  
Differential emission
  - 4f HWPSS : reflection at the primary mirror