

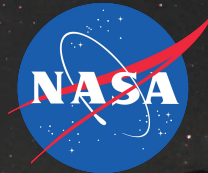


JOHNS HOPKINS
UNIVERSITY



Calibration strategies for the Cosmology Large Angular Scale Surveyor (CLASS)

John William Appel

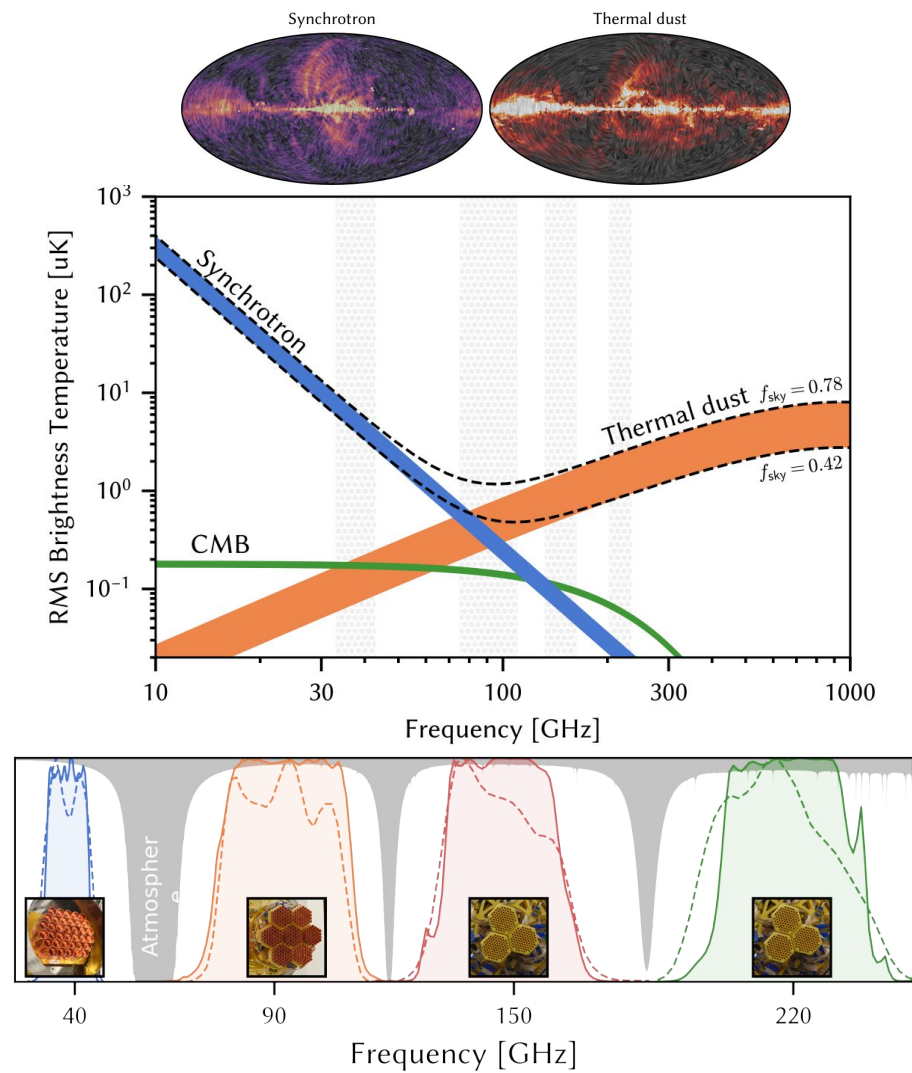
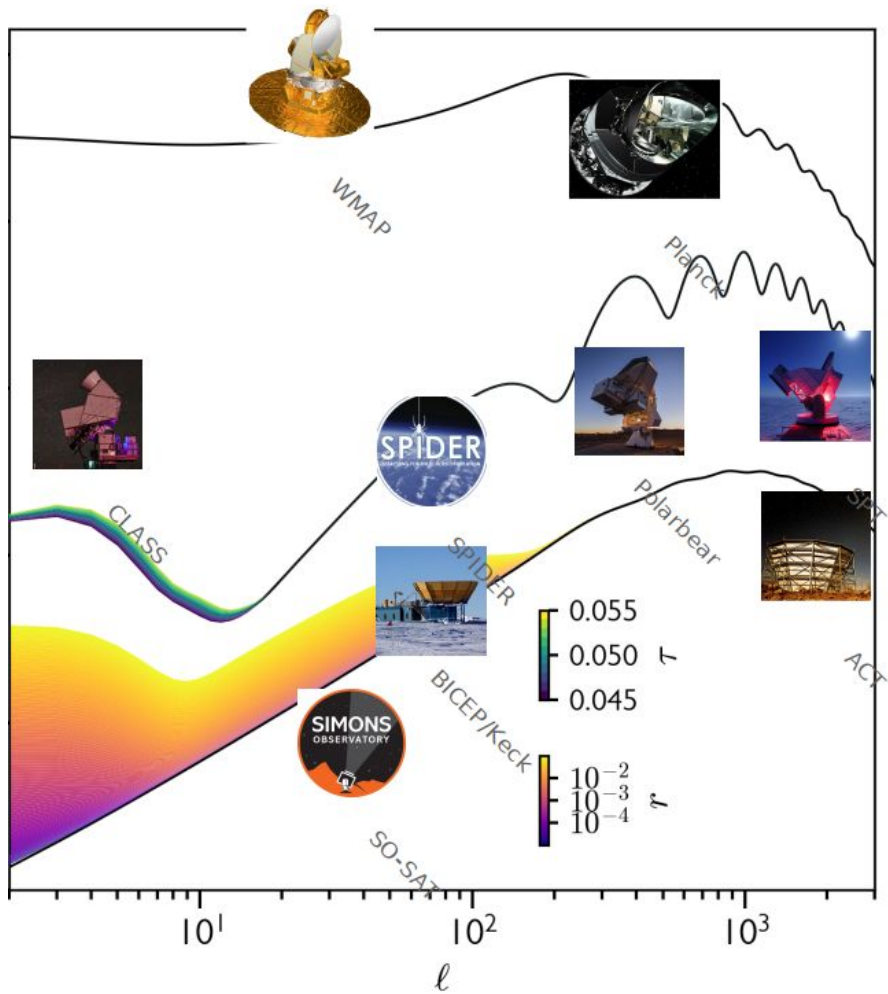


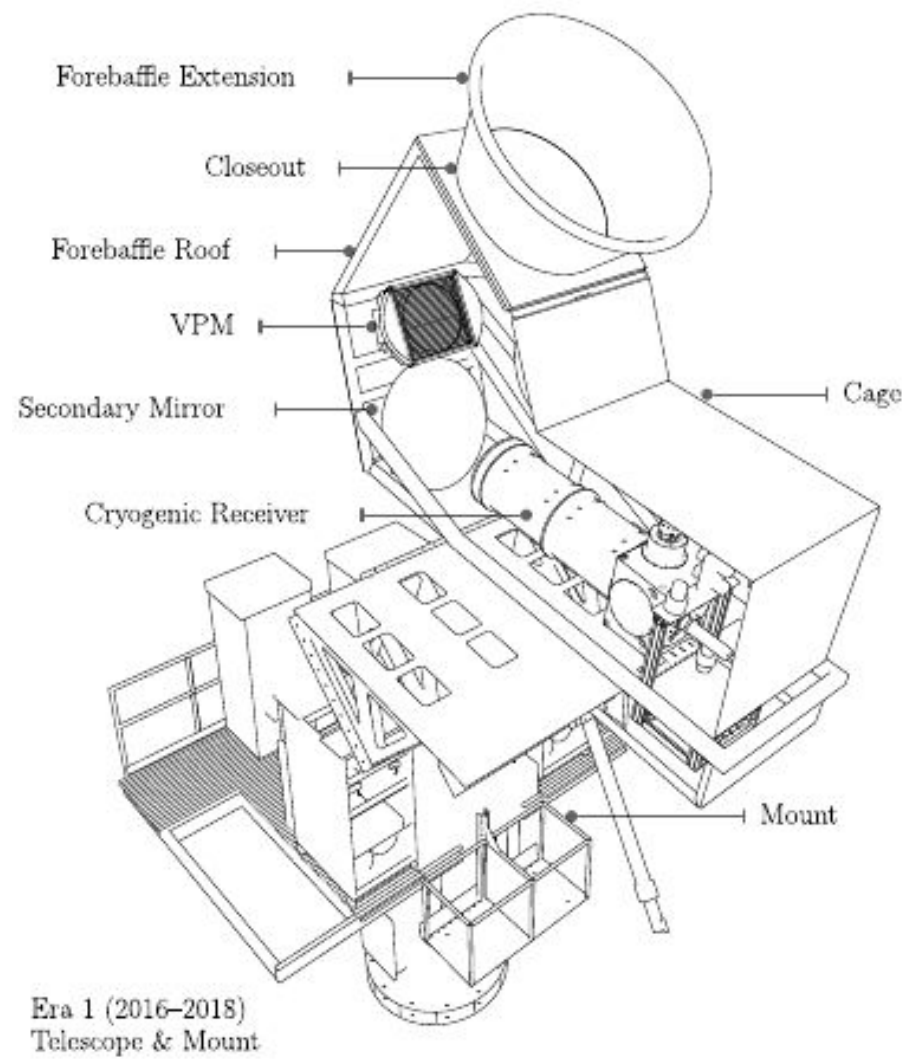
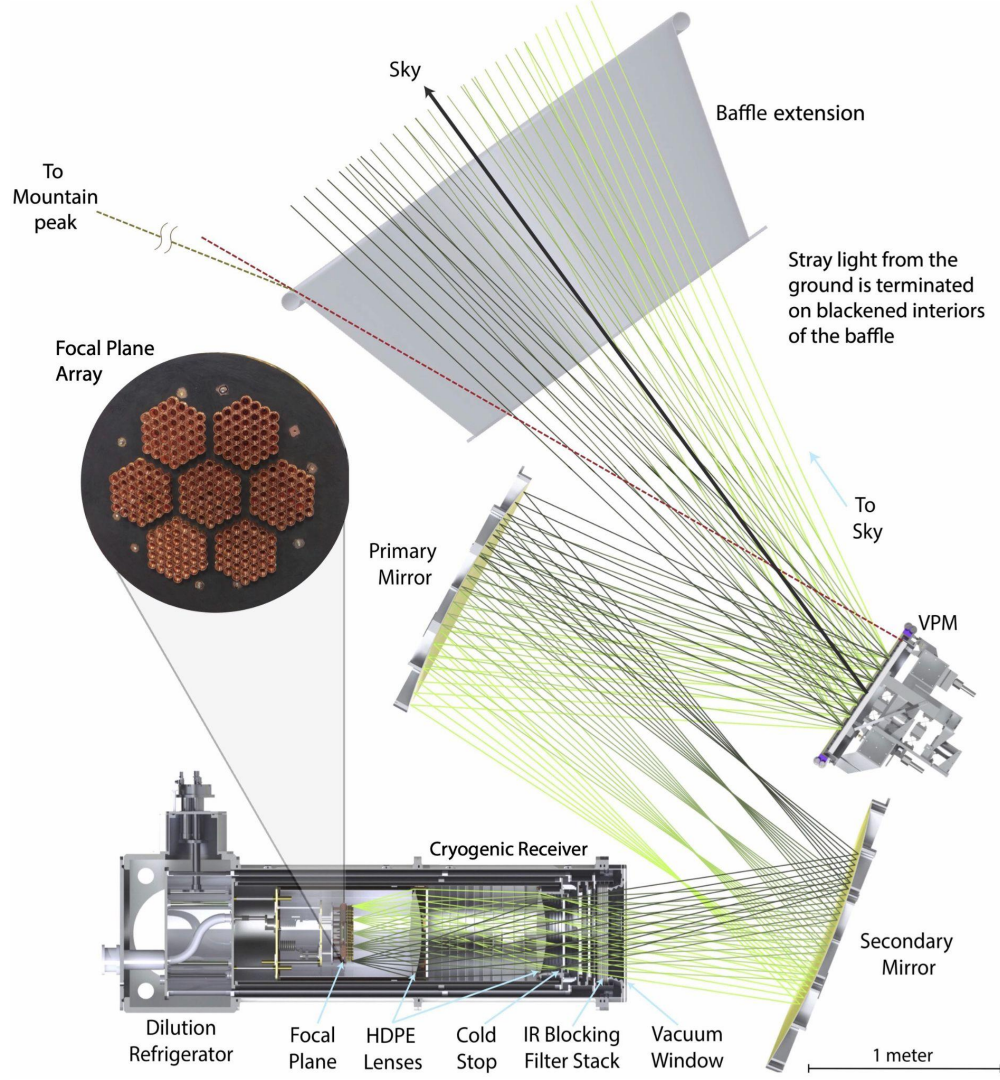
NIST



Outline

- Overview of the CLASS project
- Results and recent instrument upgrades
- Calibration strategies

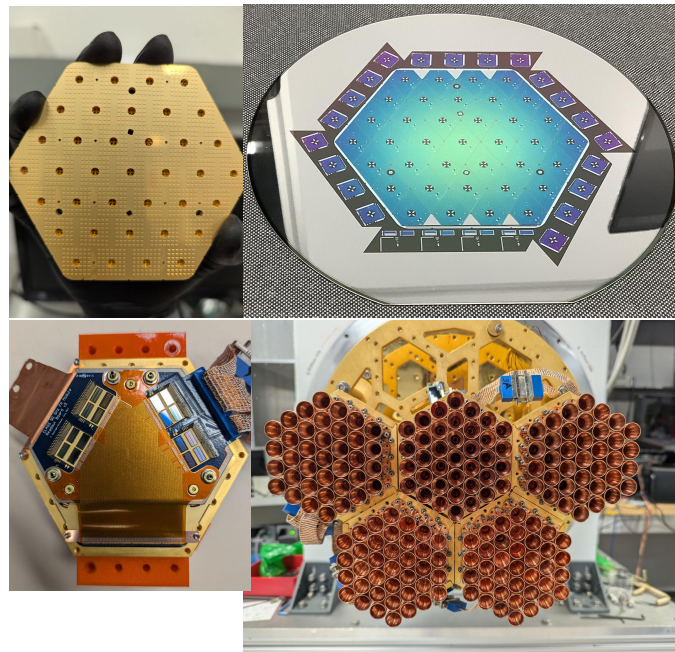
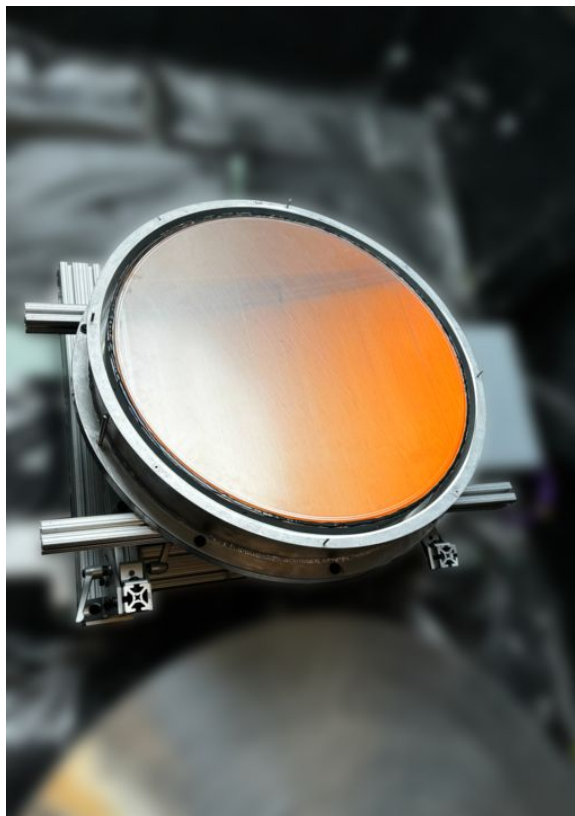
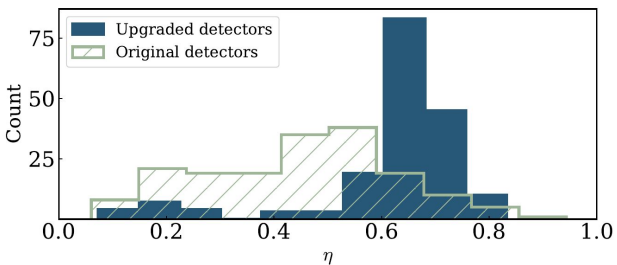
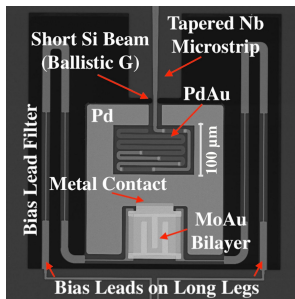
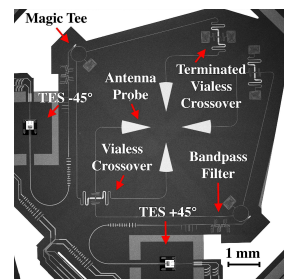




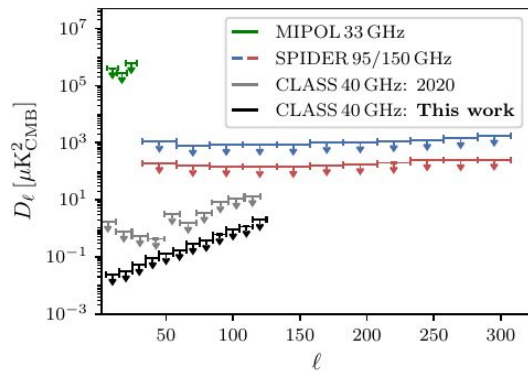
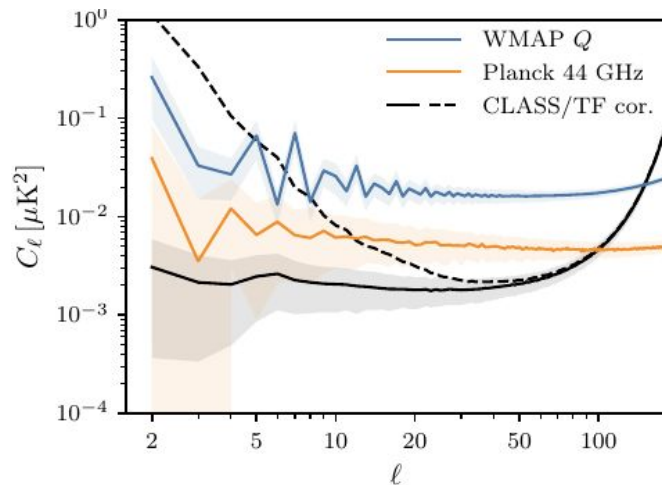
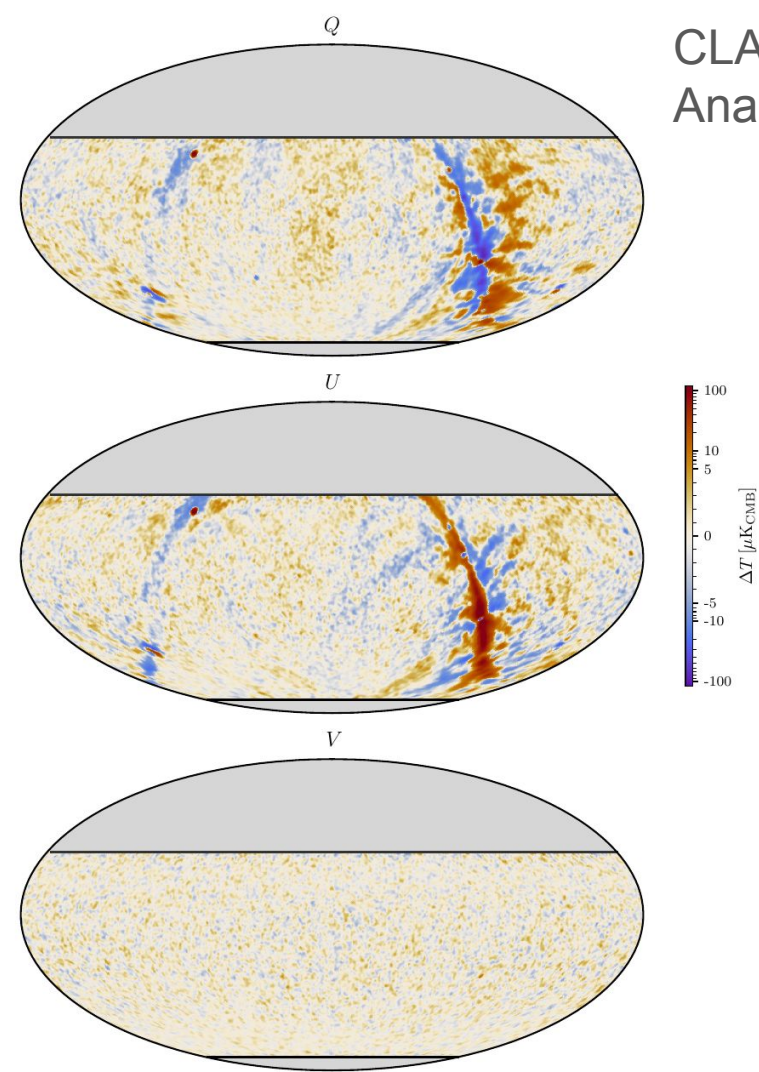
Upgraded NASA 90 GHz detectors deployed July 2022

RHWP 90 GHz deployed June 2024

Testing second CLASS 90 GHz telescope at JHU with new NIST detectors



CLASS Angular Power Spectra and Map-Component Analysis for 40 GHz Observations through 2022

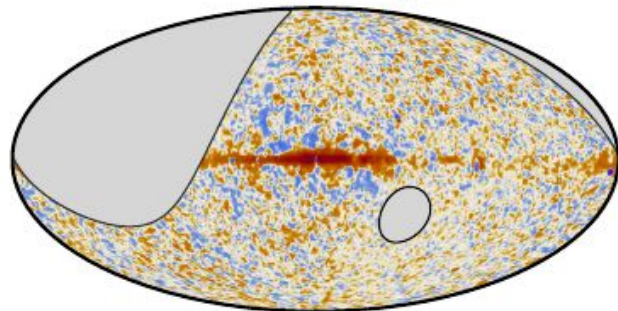
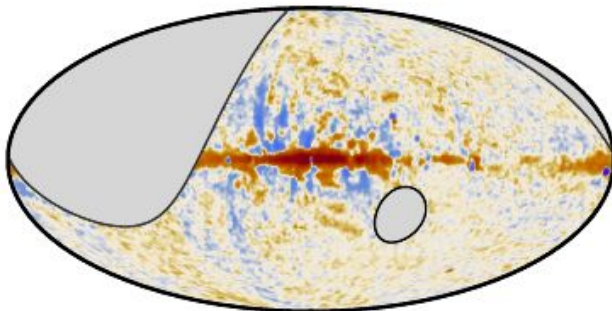
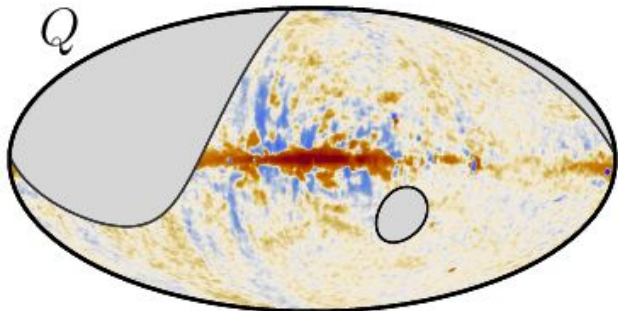


rWMAP K

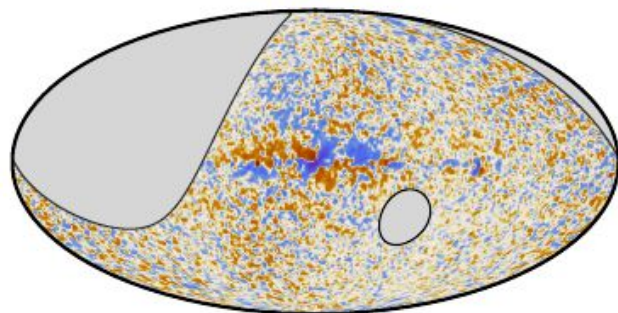
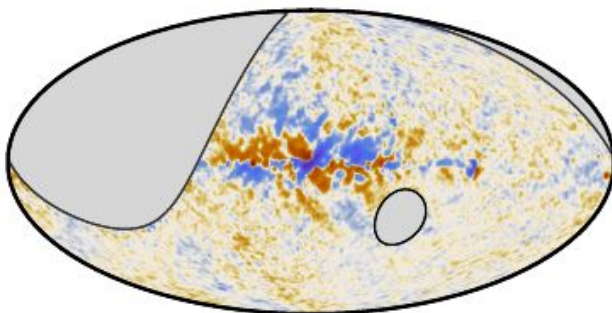
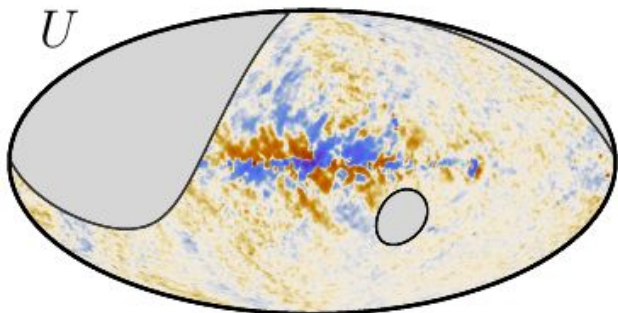
CLASS 40

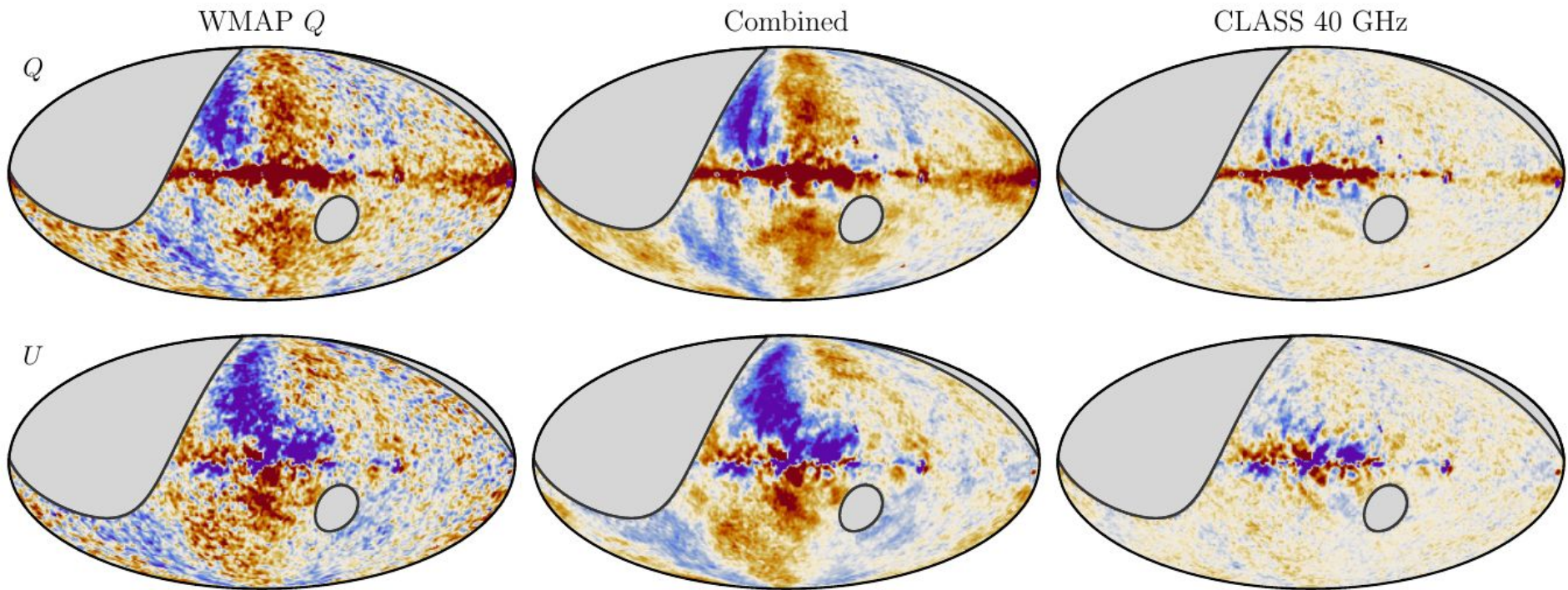
rWMAP Q

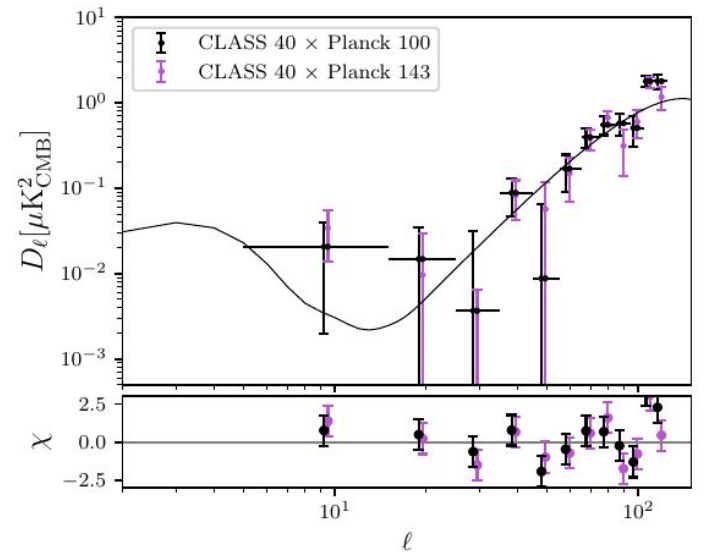
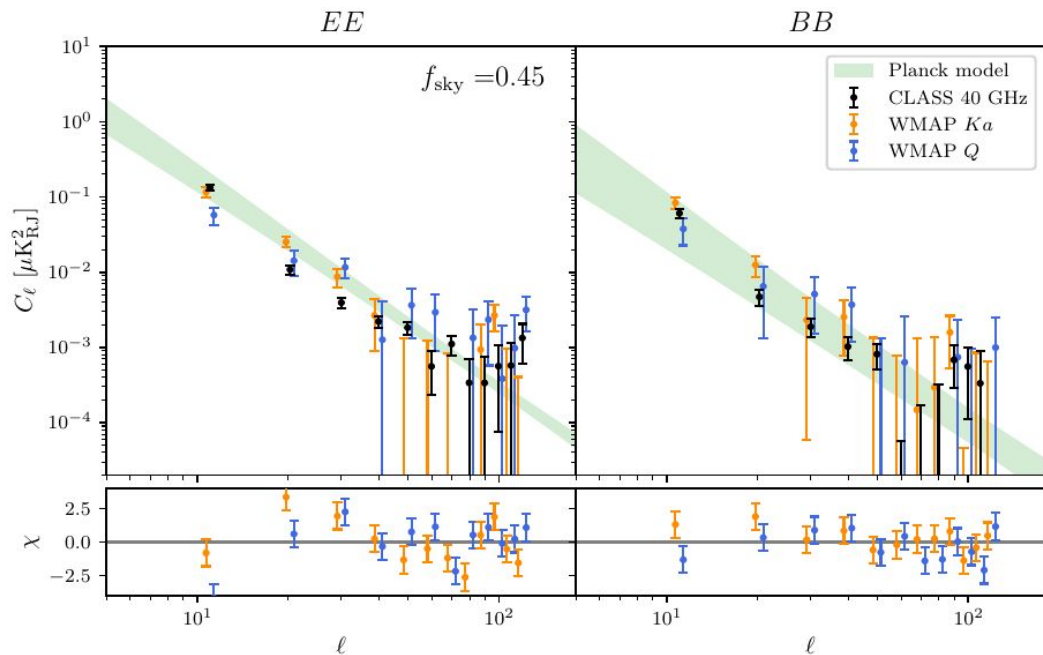
Q



U



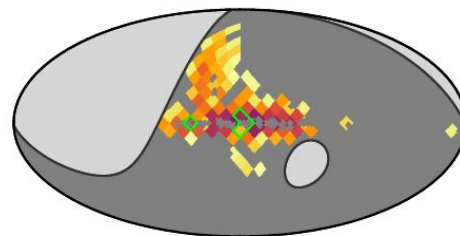
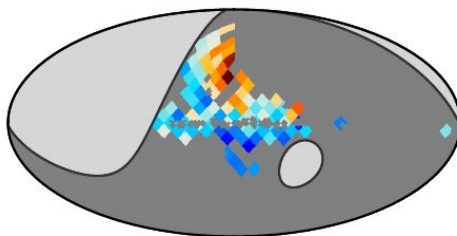
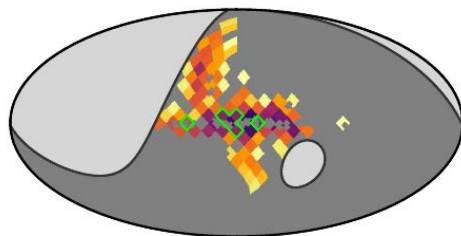
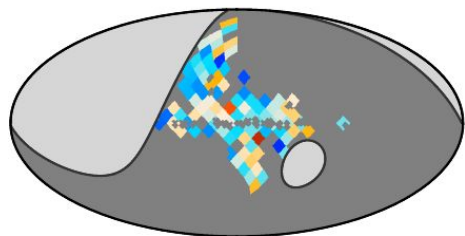




Eimer+ 2024

WMAP *K*–WMAP *Ka*

WMAP *K*–Combined



–3.5 $\hat{\beta}_s$ –2.5

0.0 $\Delta\beta_s$ 0.2

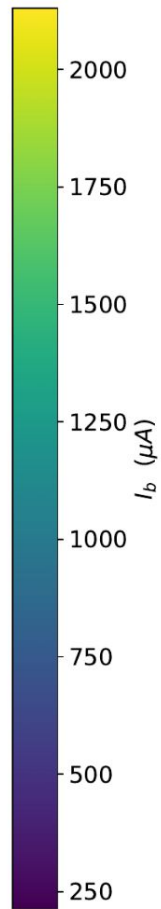
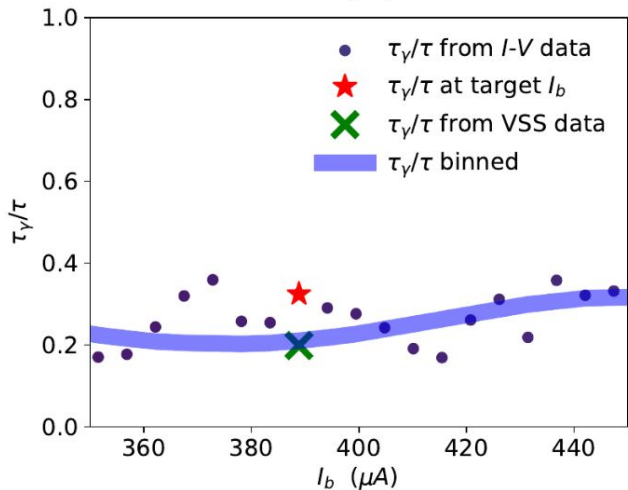
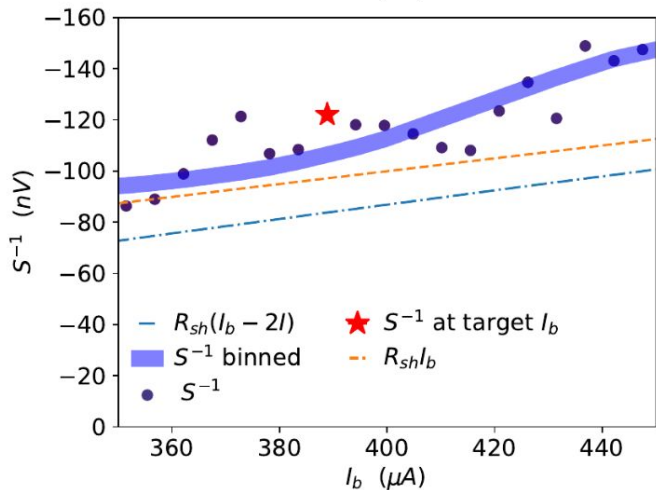
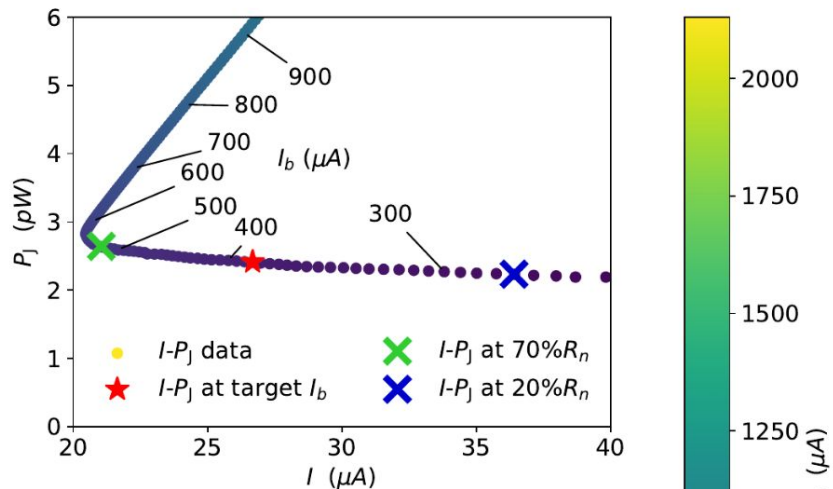
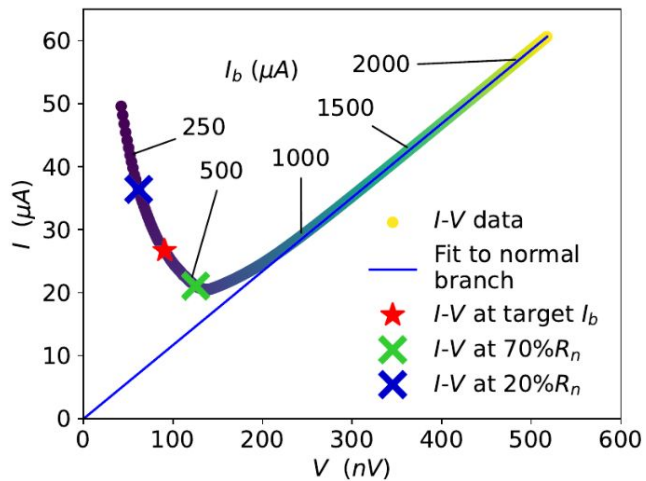
–3.5 $\hat{\beta}_s$ –2.5

0.0 $\Delta\beta_s$ 0.2

Shi+ 2024

Calibration

- Gain calibration
- Beams from source observations
- Absolute calibration from sky maps
- Drone measurements

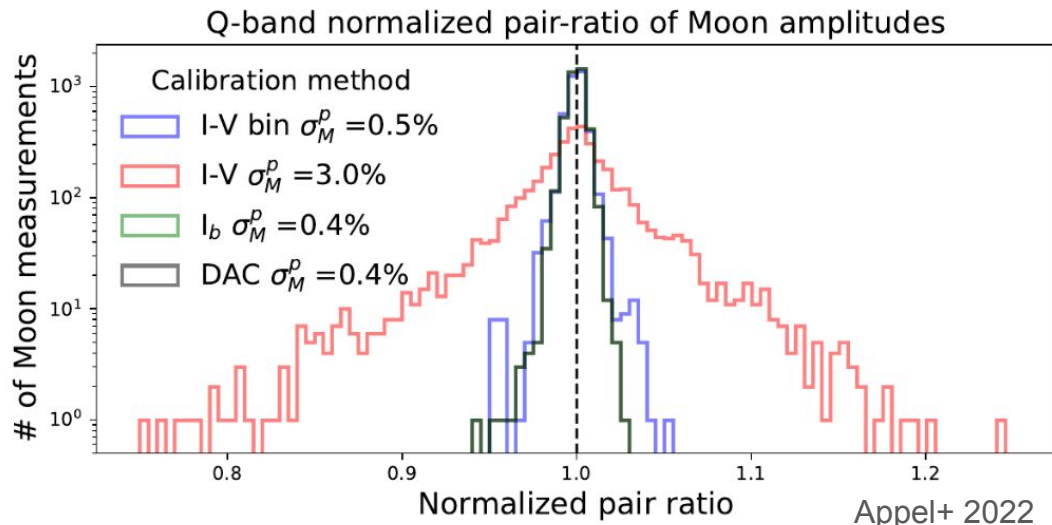
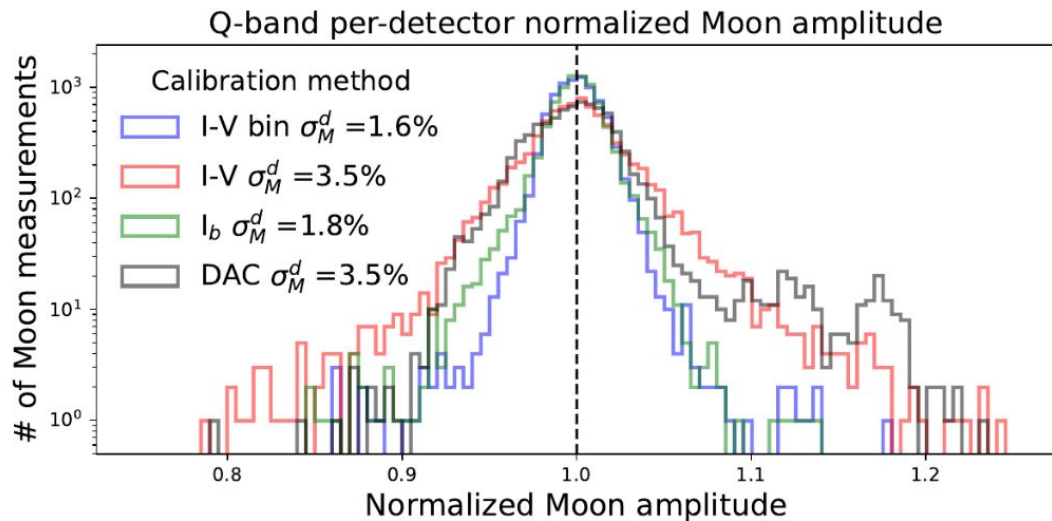


- 40 GHz detector gain calibration options:
 - DAC
 - I-bias
 - I-V
 - I-V bin

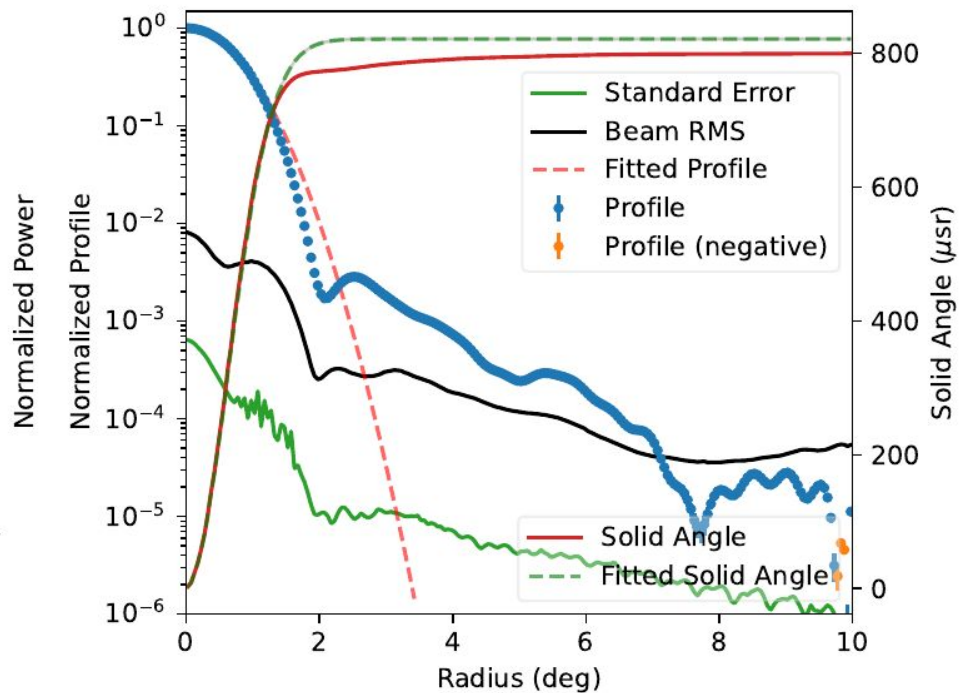
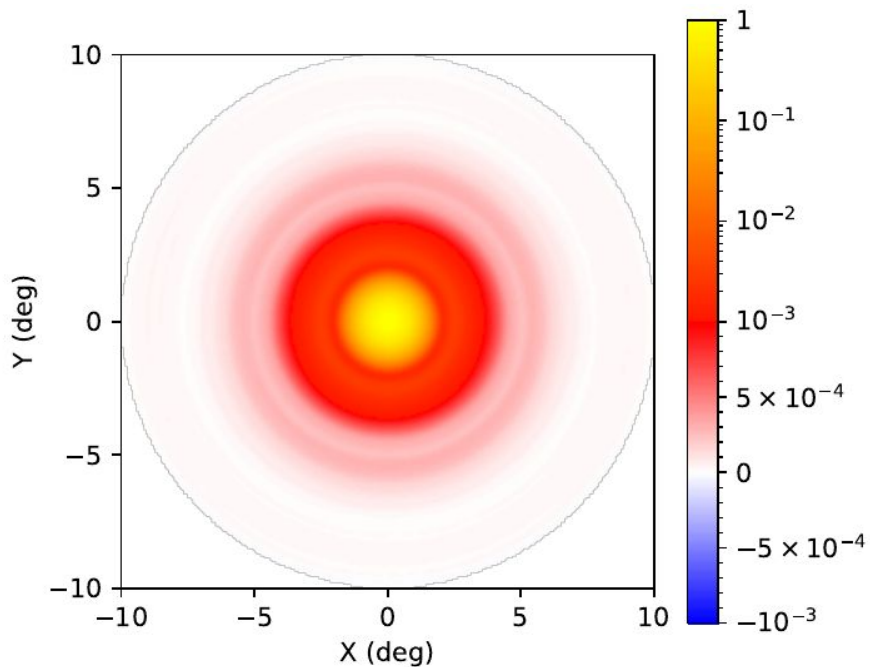
- Tested detector gain calibration with Moon observation

- Top histogram shows variance of individual detectors calibration factors

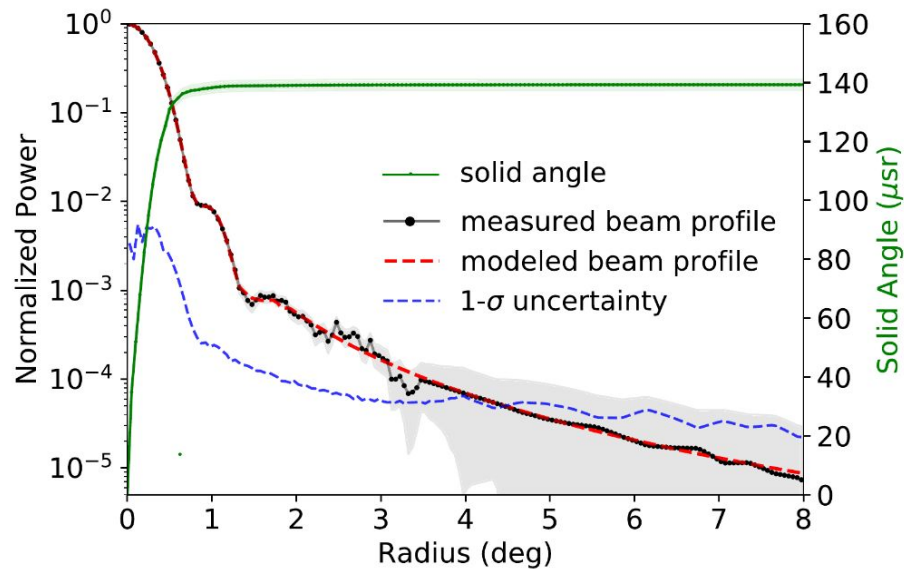
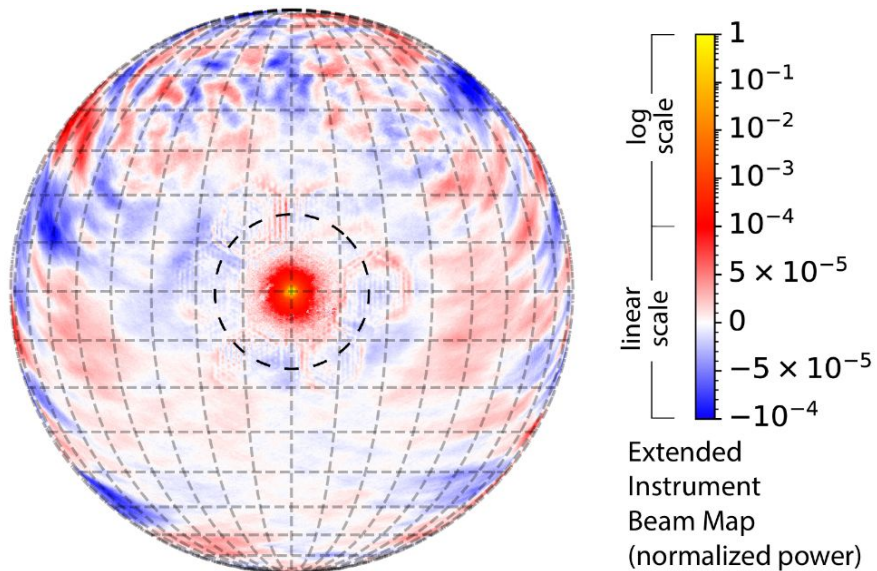
- Bottom histogram shows variance of the relative gain calibration between detector pairs. Divides out Moon amplitude fluctuations



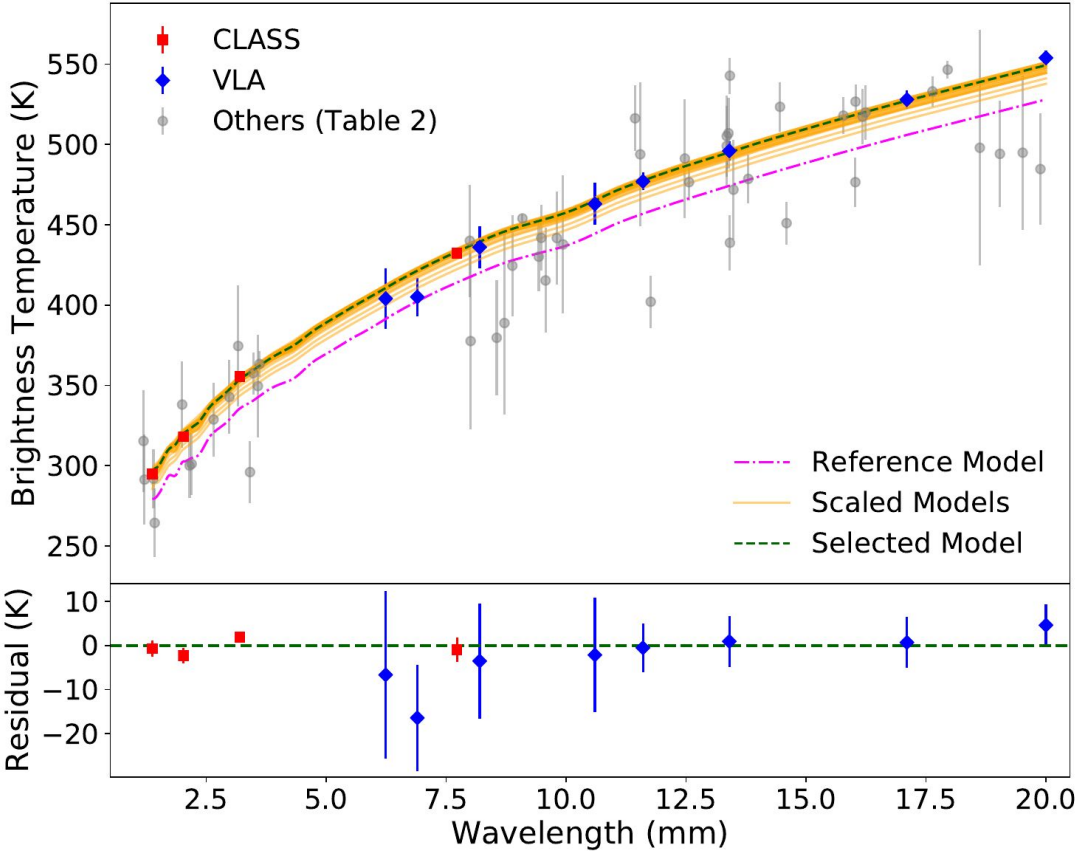
40 GHz beam map from Moon observations



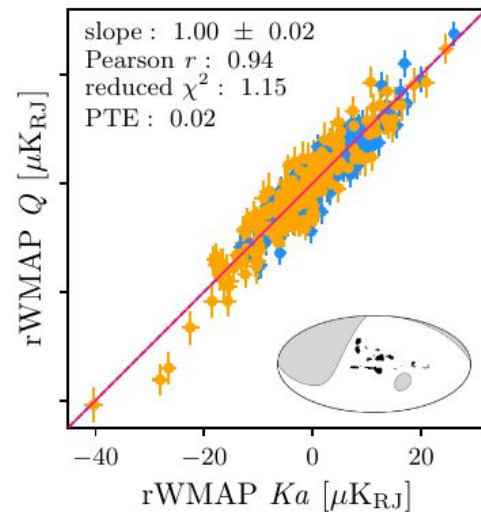
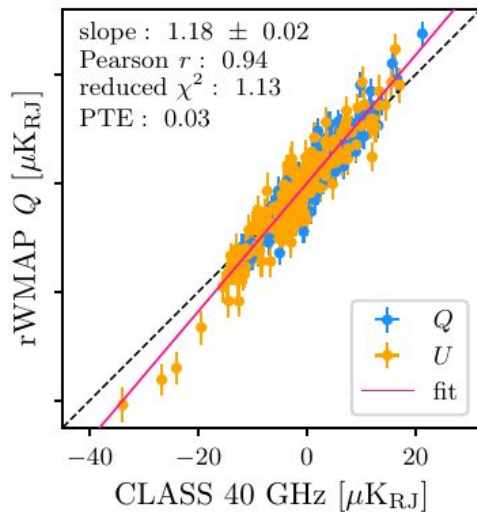
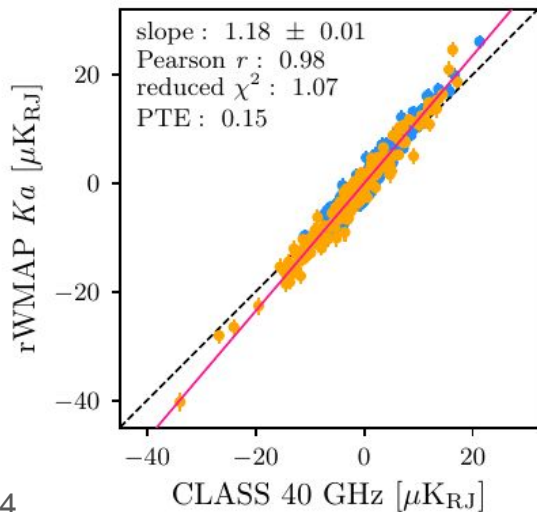
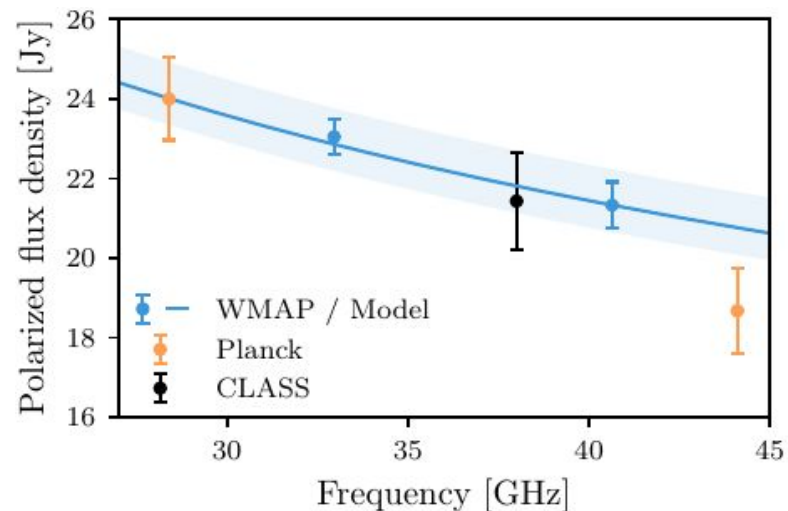
90 GHz beam map from planet and Moon observations



Absolute temperature of Venus



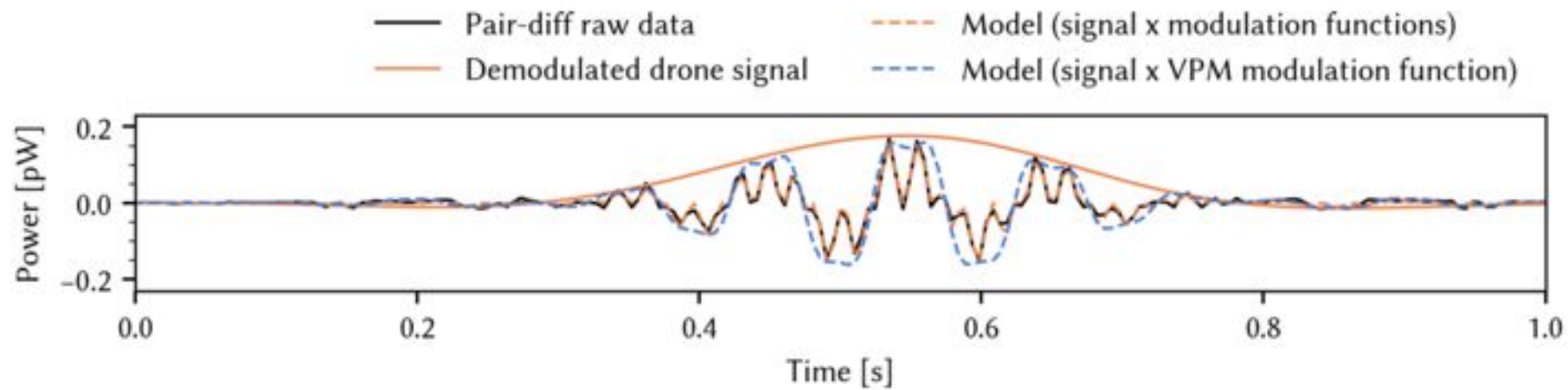
Absolute calibration of CLASS 40 GHz maps

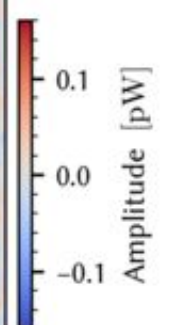
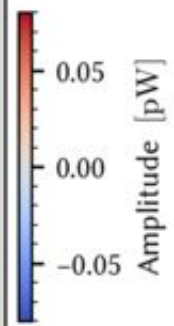
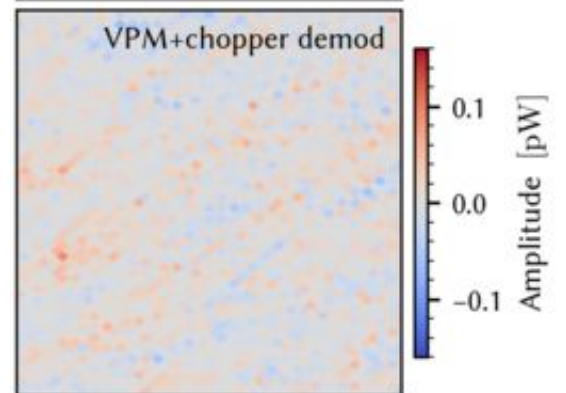
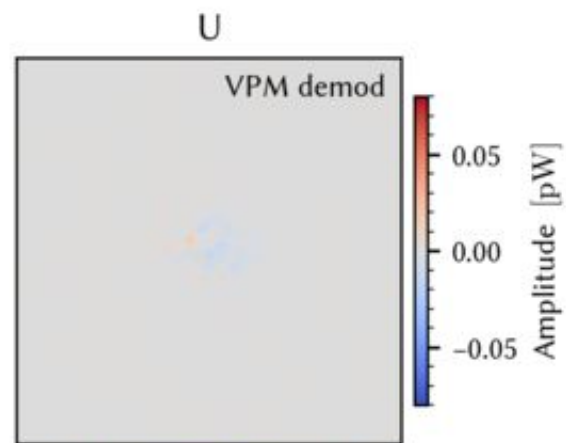
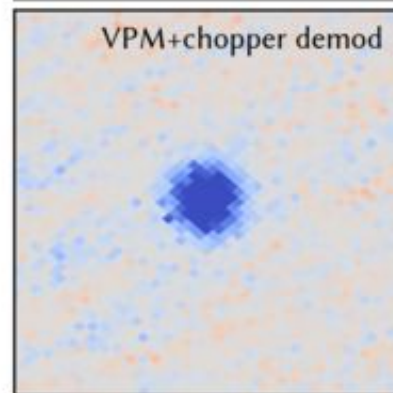
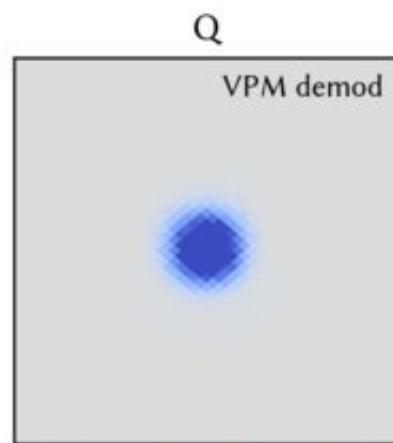
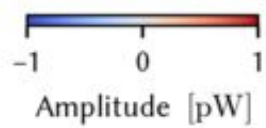
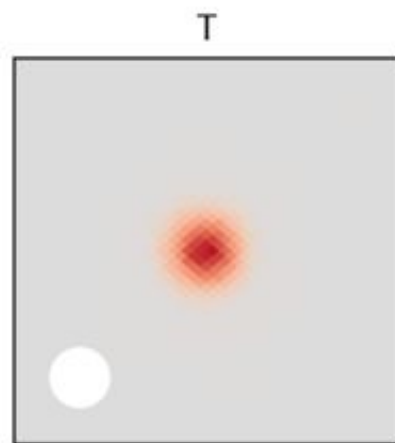


CLASS & HoverCal + PoloCalC

- CLASS telescopes scan ± 7.5 degrees in Az at 2 deg / sec
- Telescope elevation typically set to 45 degrees
- Boresight angle set to: -45, -30, -15, 0, 15, 30, 45
- Elevation scan flight: drone changes elevation by ± 4.5 degrees
- Telescope to drone distance ~500m. Far-field ~100m
- Tested polarized 90 and 150 GHz sources mounted on drone
- Sources chopped at 47 Hz

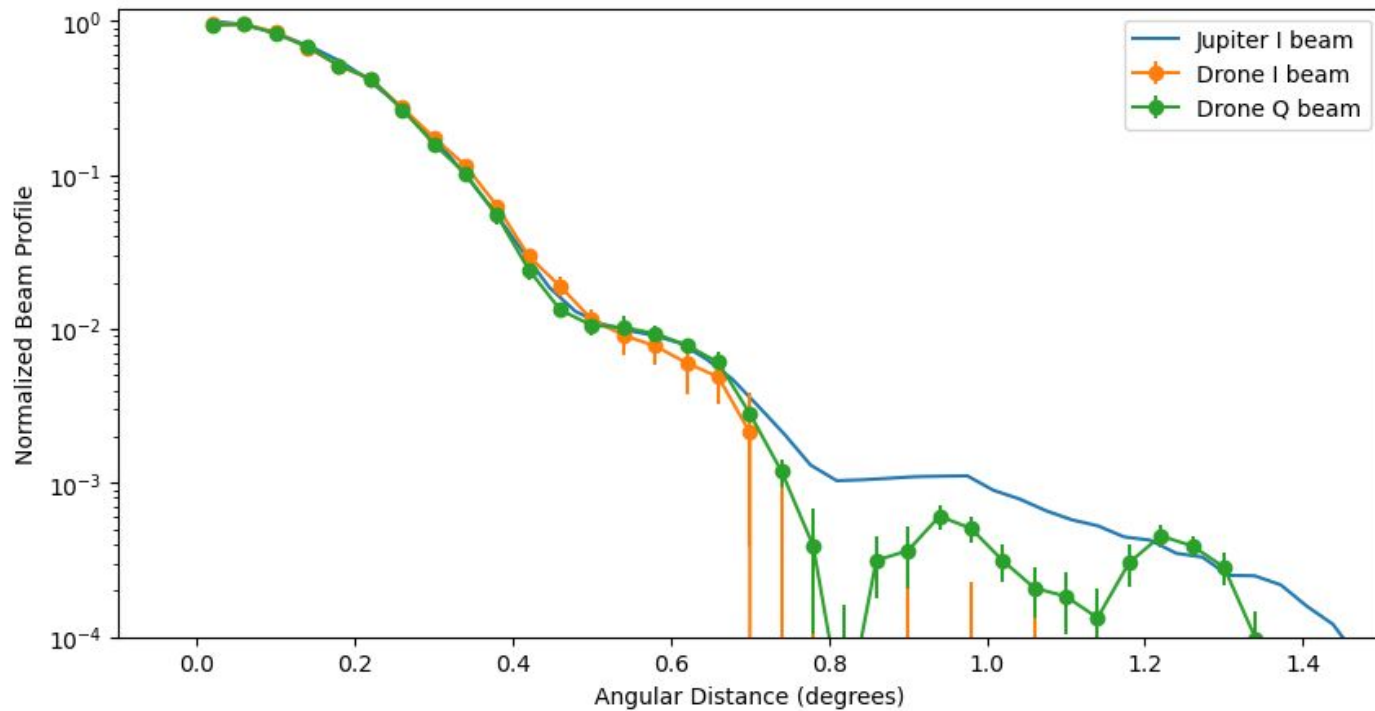


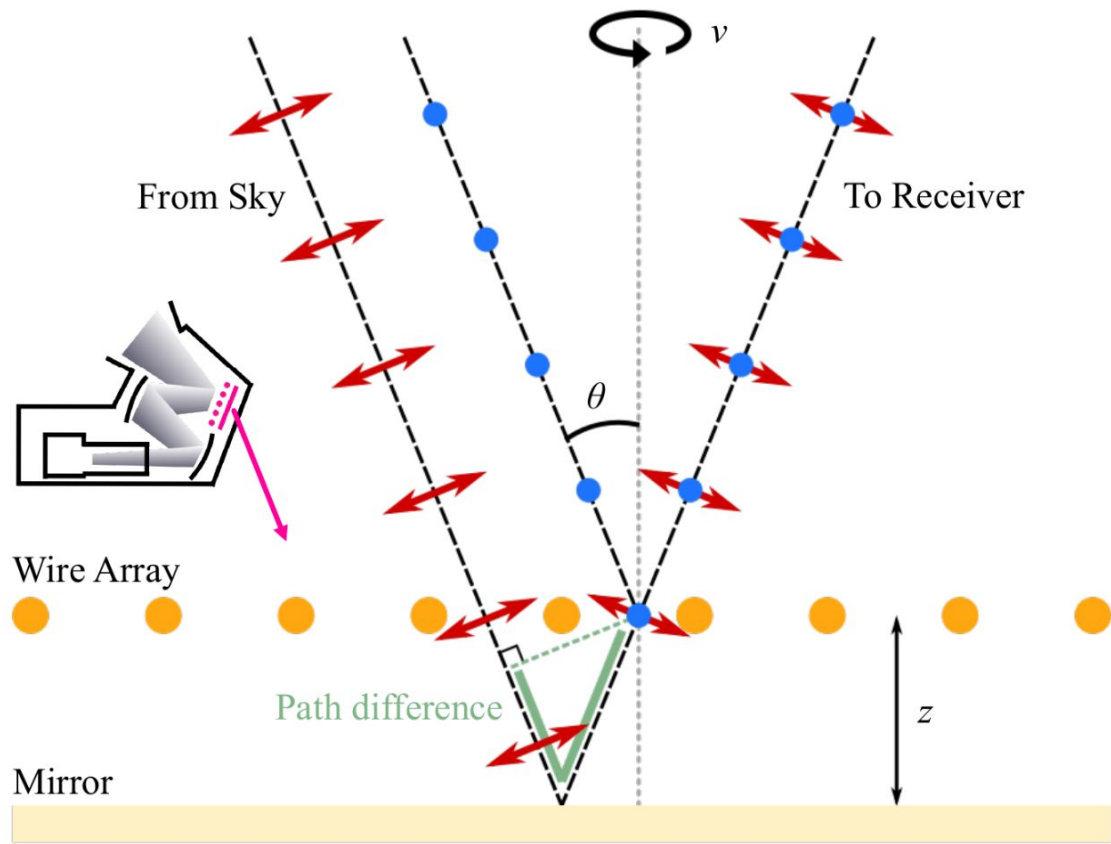




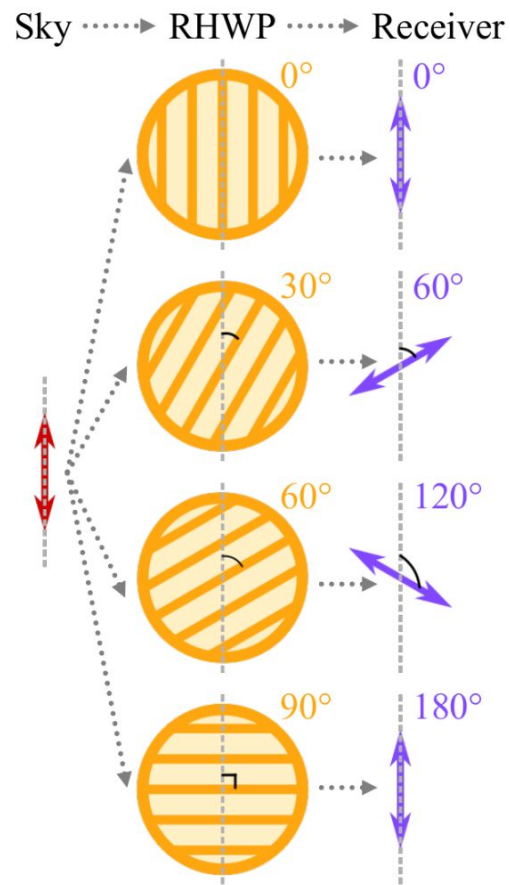
Questions?

CLASS 150 GHz Beam





(a)



(b)