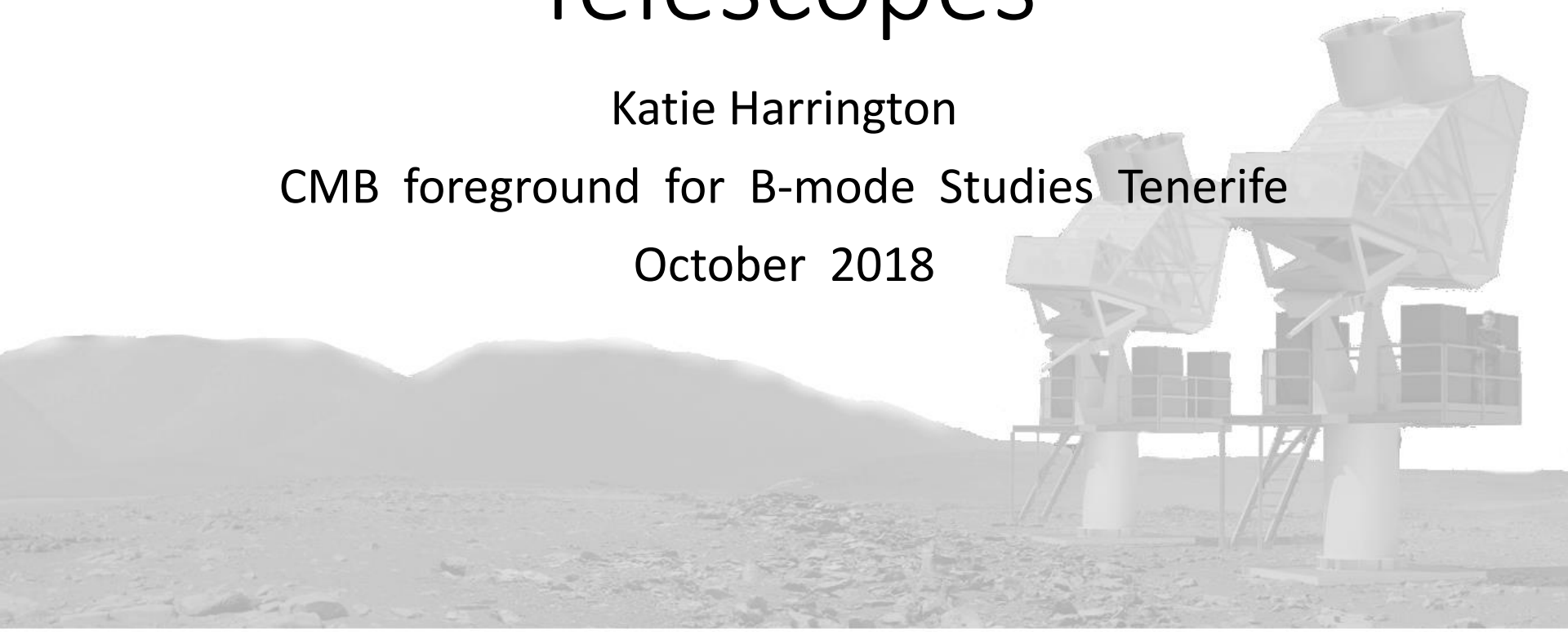
# Polarization Modulation with VPMs on the CLASS Telescopes

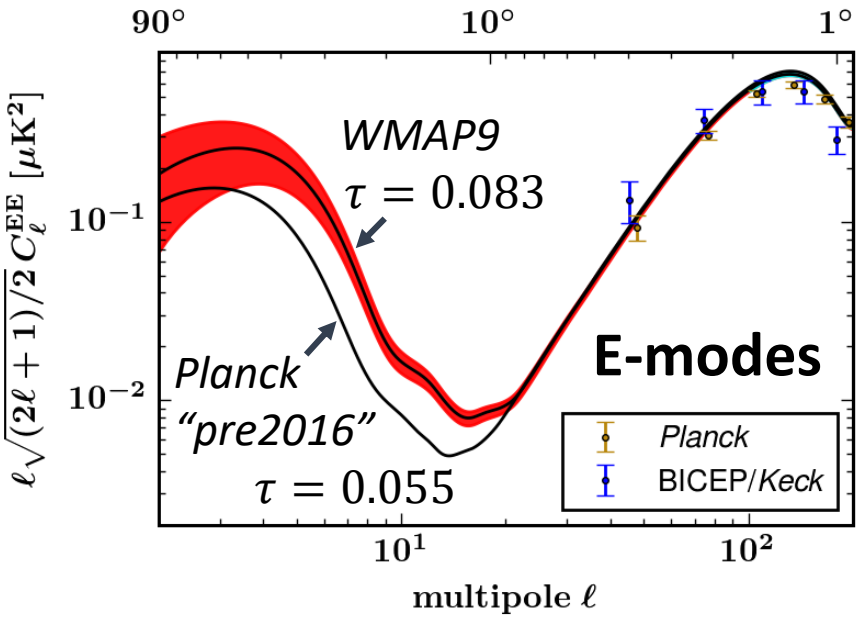
Katie Harrington

CMB foreground for B-mode Studies Tenerife

October 2018

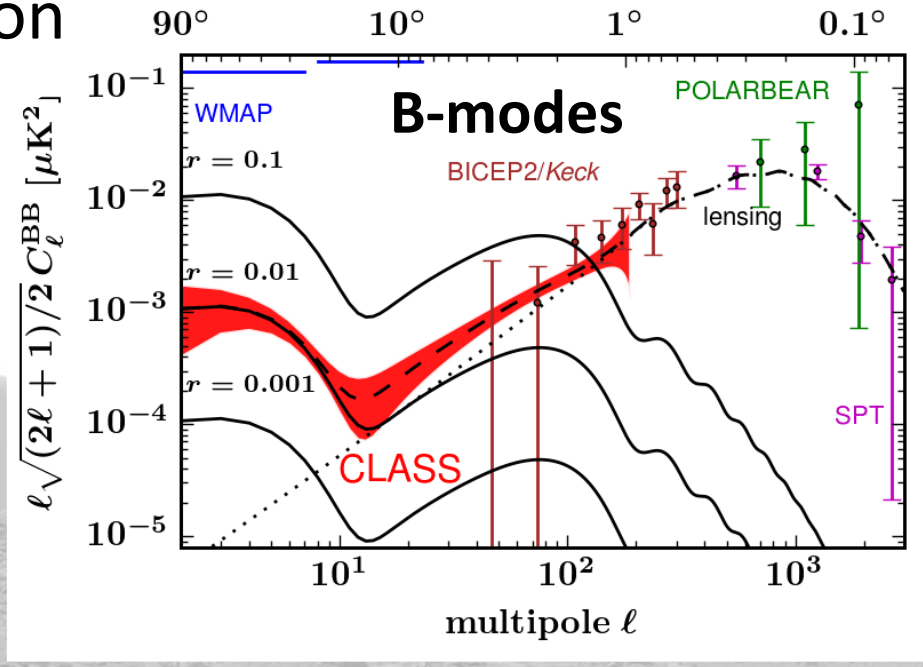


# CLASS is targeting the Largest Angular Scales on the Sky




E-mode Large Angular Scales
→ Optical Depth to Reionization

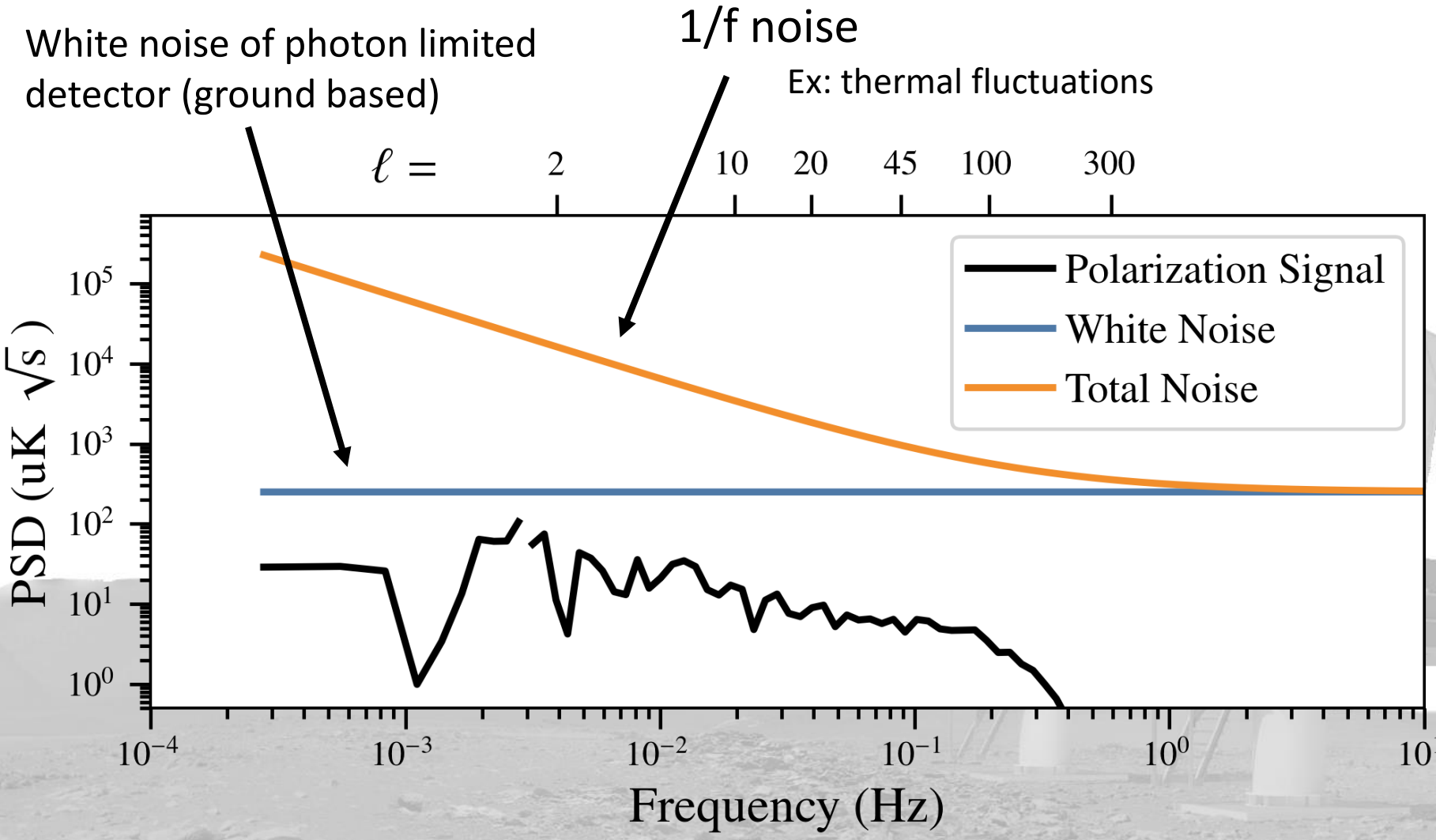
B-mode Large Angular Scales
→ Inflationary Gravitational Waves



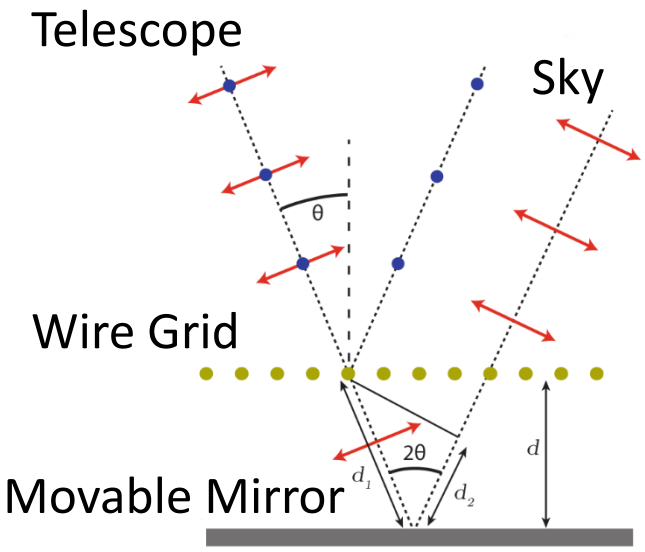


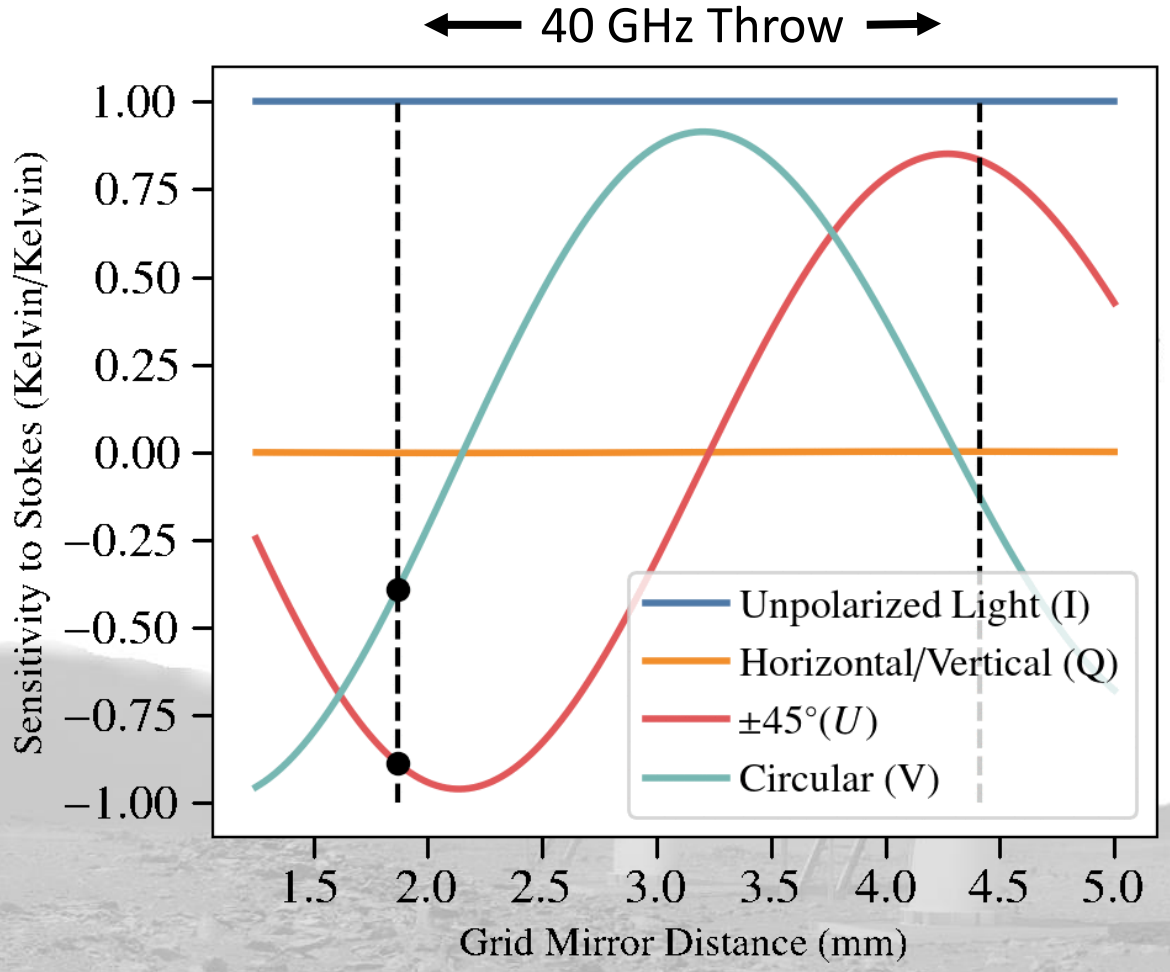
Watts, D. et. al. 1508.00017
Watts, D. et. al. 1801.01481

# Instrument Stability is a Key Challenge to measuring the Largest Angular Scales



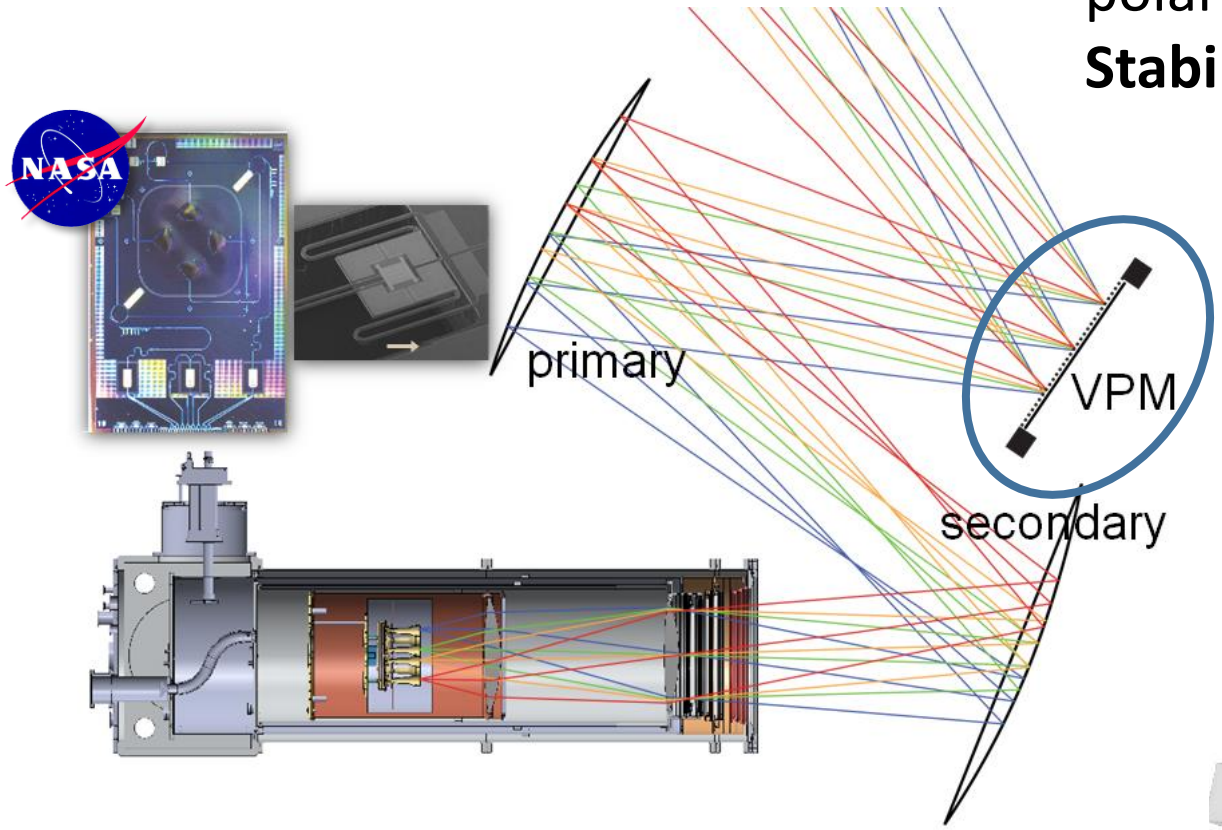
# Variable-delay Polarization Modulators



# CLASS Instrument

Variable-delay polarization modulator **Stability** and **Systematics**

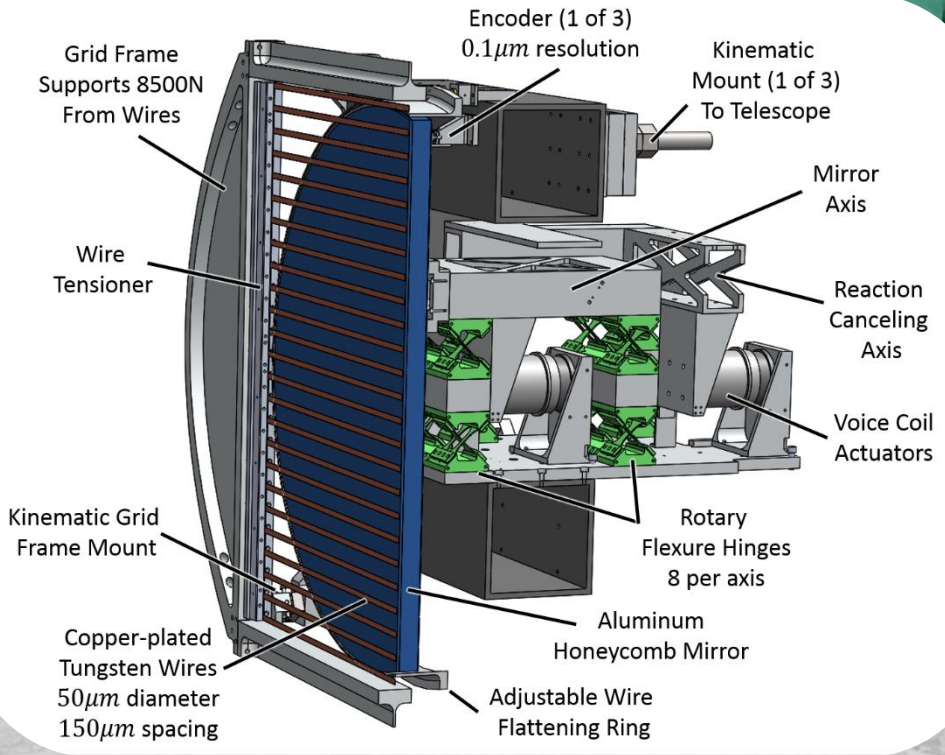



→ First element in telescope

→ Modulate polarization before effects of instrument polarization

J. Eimer et. al. (1211.0041) J. Appel et. al. (1408.4789) T. Essinger-Hileman et. al. (1408.4788)
K. Rostem et. al. (1608.08891) K. Harrington et. al. (1608.08234) J. Iuliano et. al. (1807.04167)
S. Dahal et. al. (1807.03927)

# VPMs Installed!




40 GHz VPM:
350 million cycles during our first observing era!

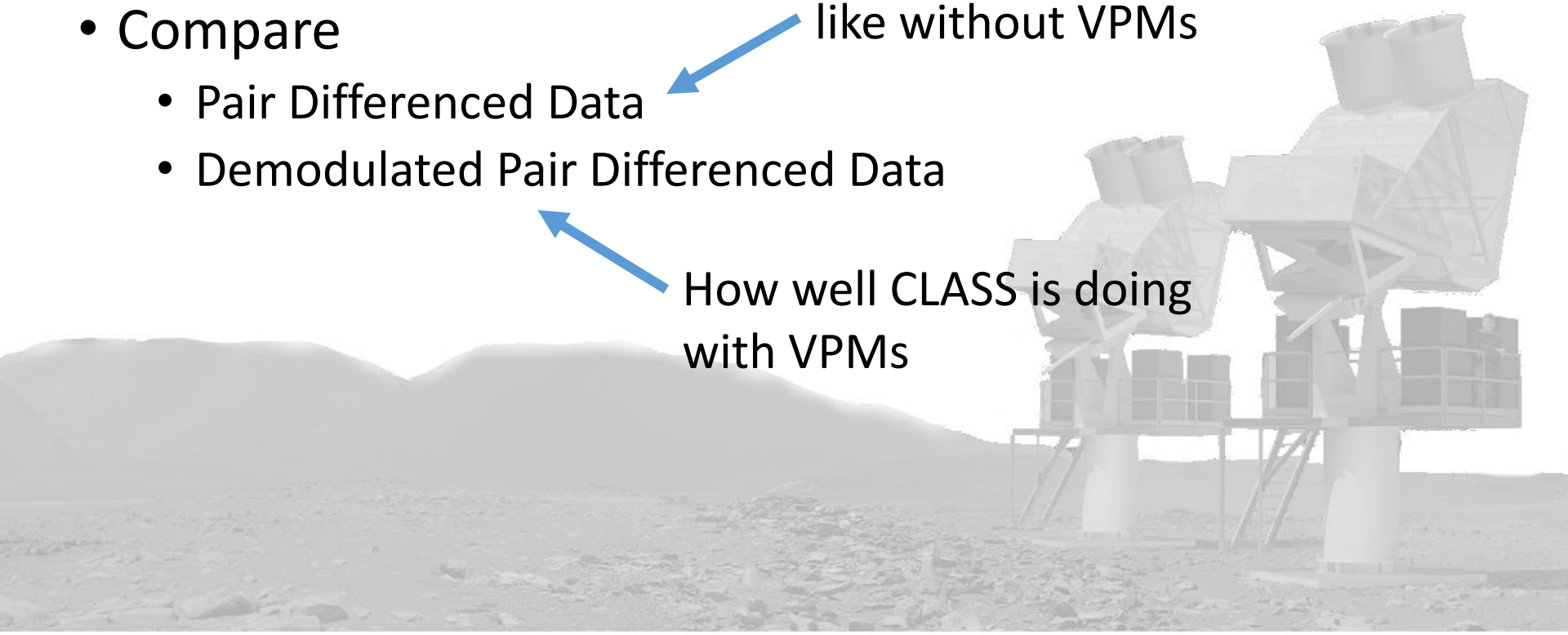
K. Harrington et. al. 1807.03807

# How much are the VPMs Helping?

- Use 14,129 segments of 2 hours of data
  - Between Sept. 2016 – Feb. 2018
  - All 40 GHz Data
- Compare
  - Pair Differenced Data
  - Demodulated Pair Differenced Data

What CLASS data looks like without VPMs

How well CLASS is doing with VPMs



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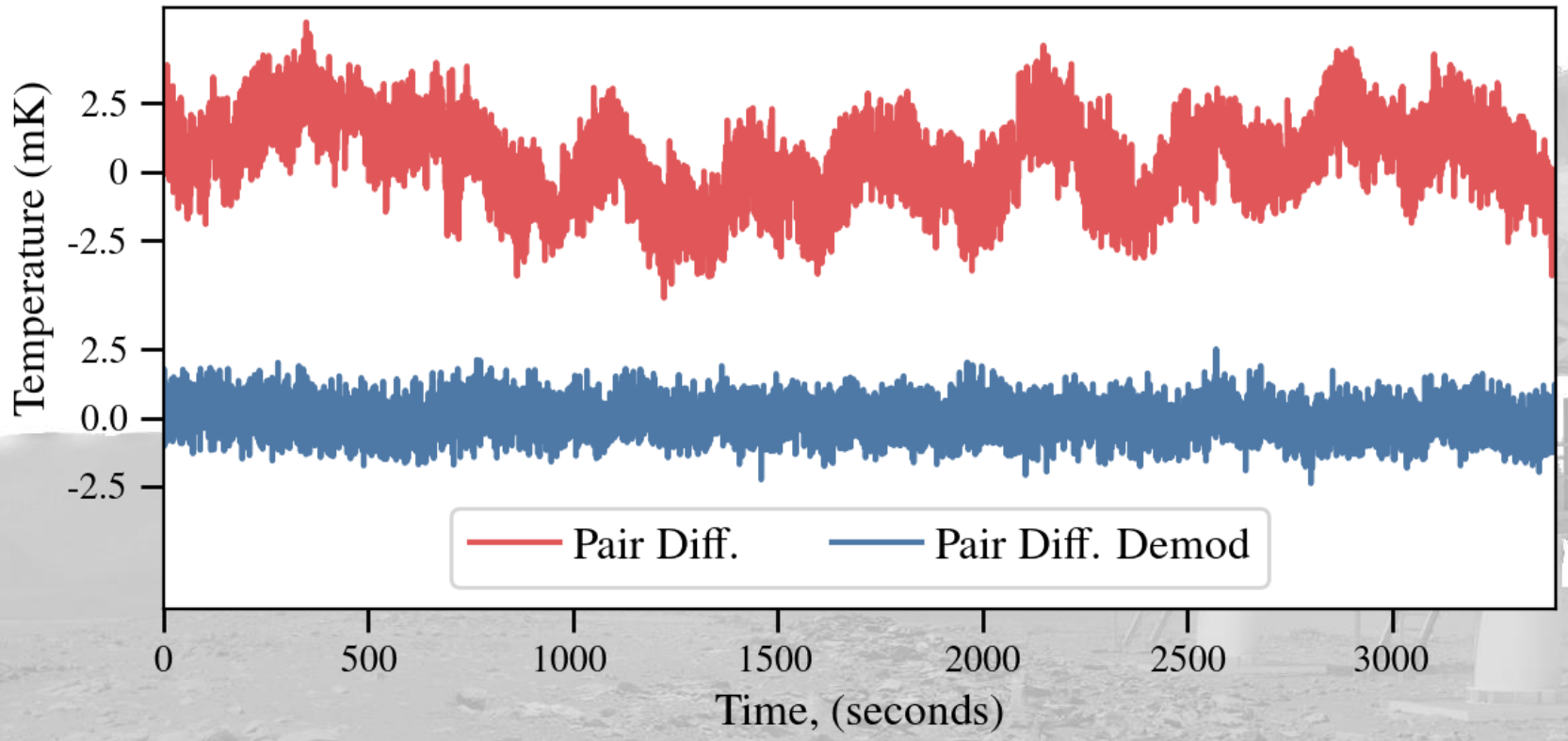
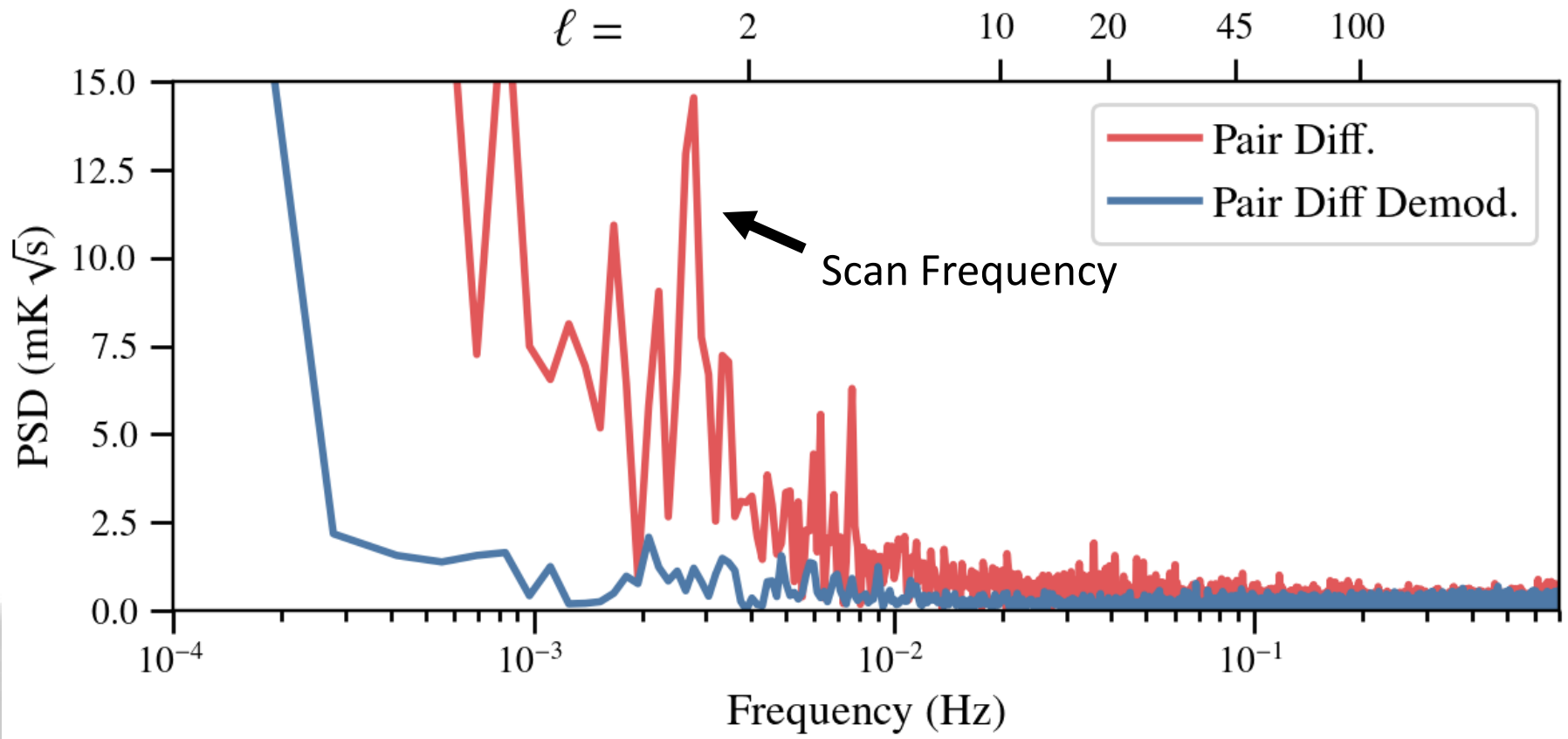
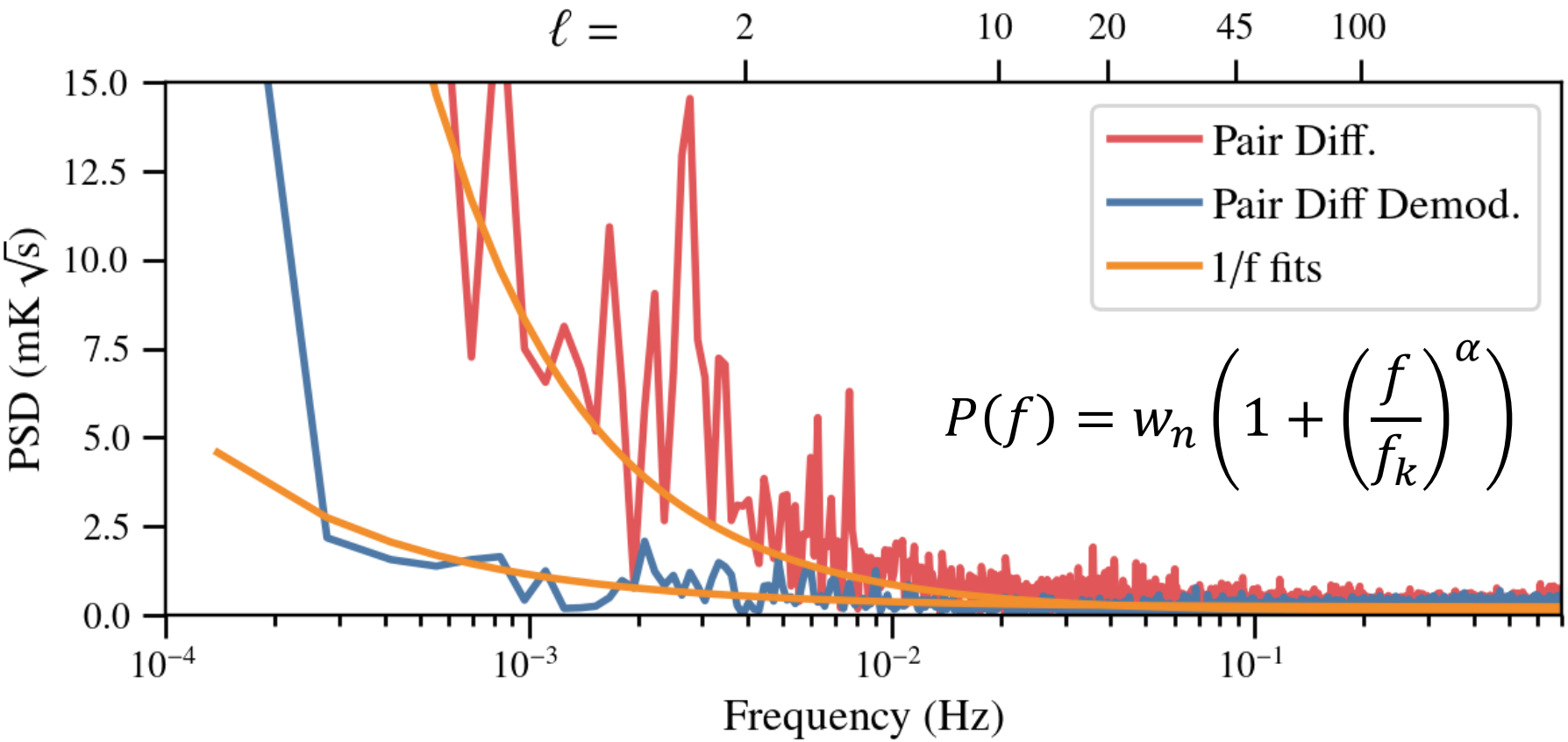
Typical Time stream



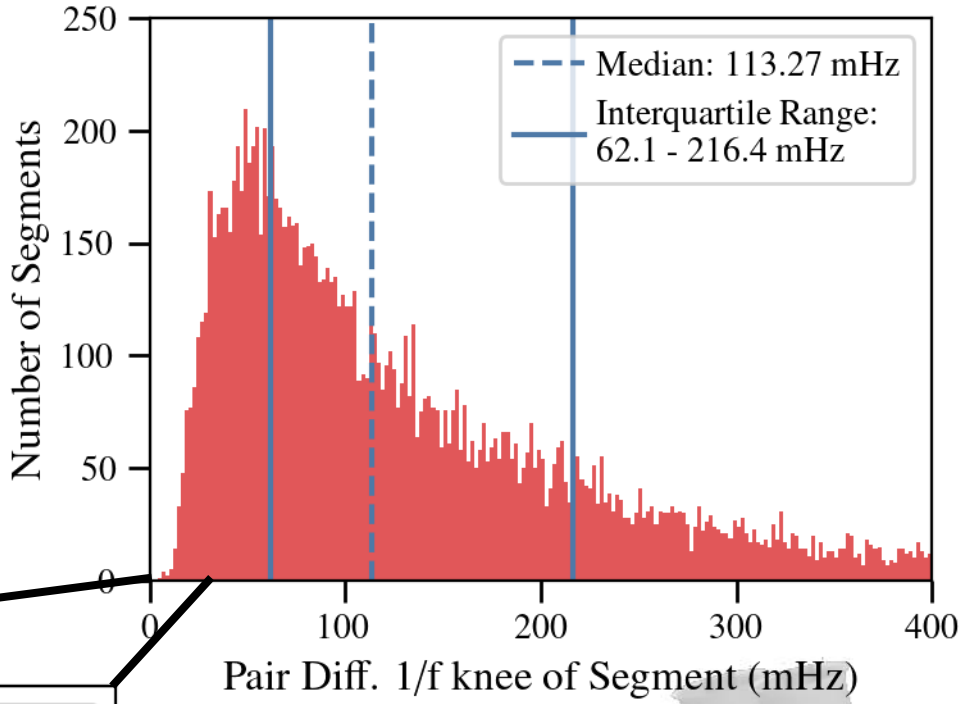
# Demodulation Significantly Suppresses 1/f noise

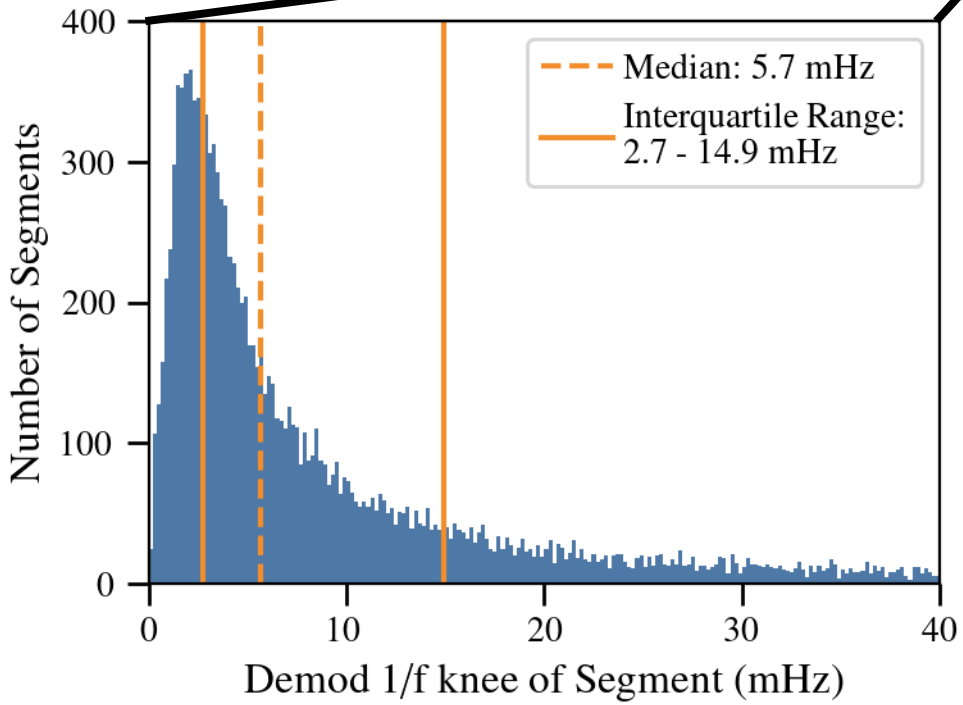


# Demodulation Significantly Suppresses 1/f noise below the Scan Frequency



# Median 1/f knee Reduced by 20x with Demodulation



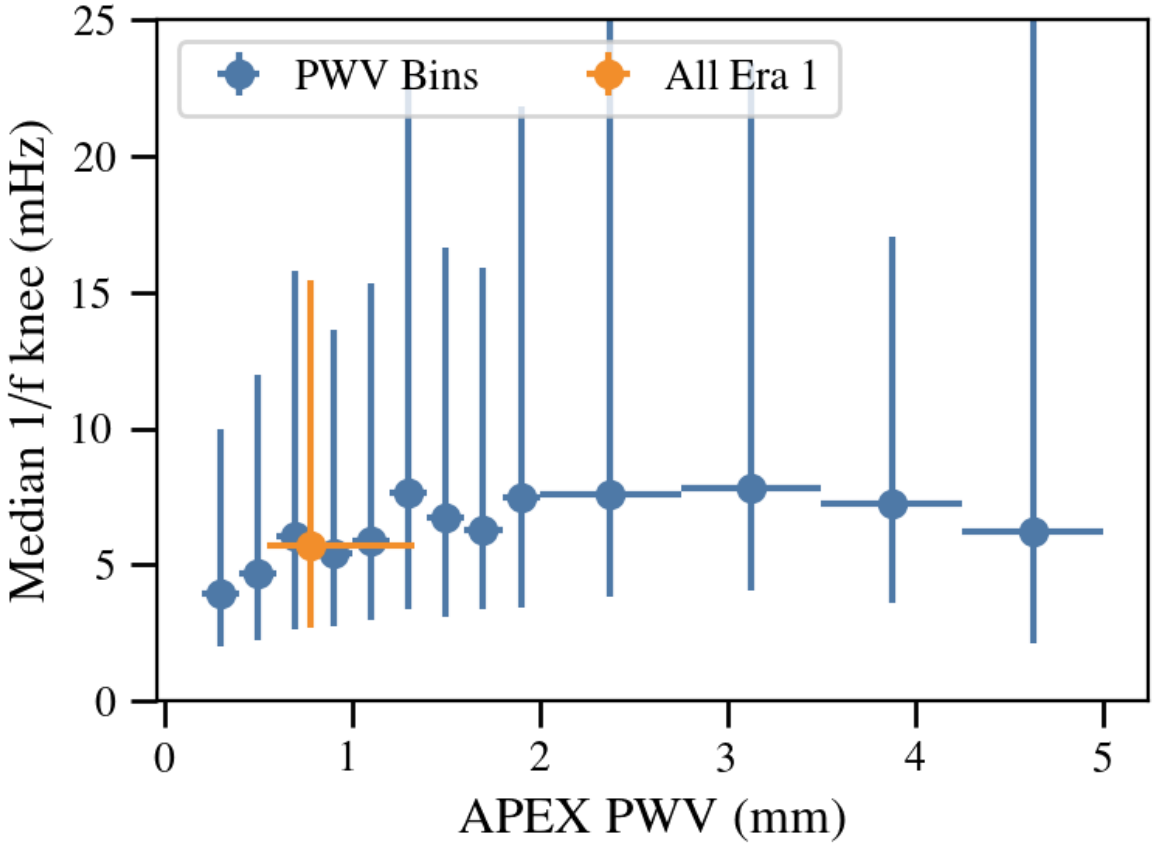

We are achieving space-like stability *from the ground.*

# Weather has slight effect on 1/f knee

9291 Segments overlap with PWV Data available from APEX

See slight increase in 1/f knee with increased PWV

Caveat – this is 40 GHz data.




Error bars – interquartile range

CLASS 90 GHz is on sky now, stay tuned!

# Summary

- Front-end VPMs are enabling space-like instrument stability from the ground.
- One of the key requirements for CLASS to map the largest angular scales of the CMB polarization has been achieved
- See Joseph Eimer's talk on Wednesday for more results!