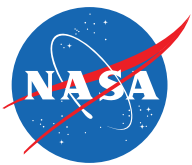


# 1/f Noise literature study for the CMB Probe

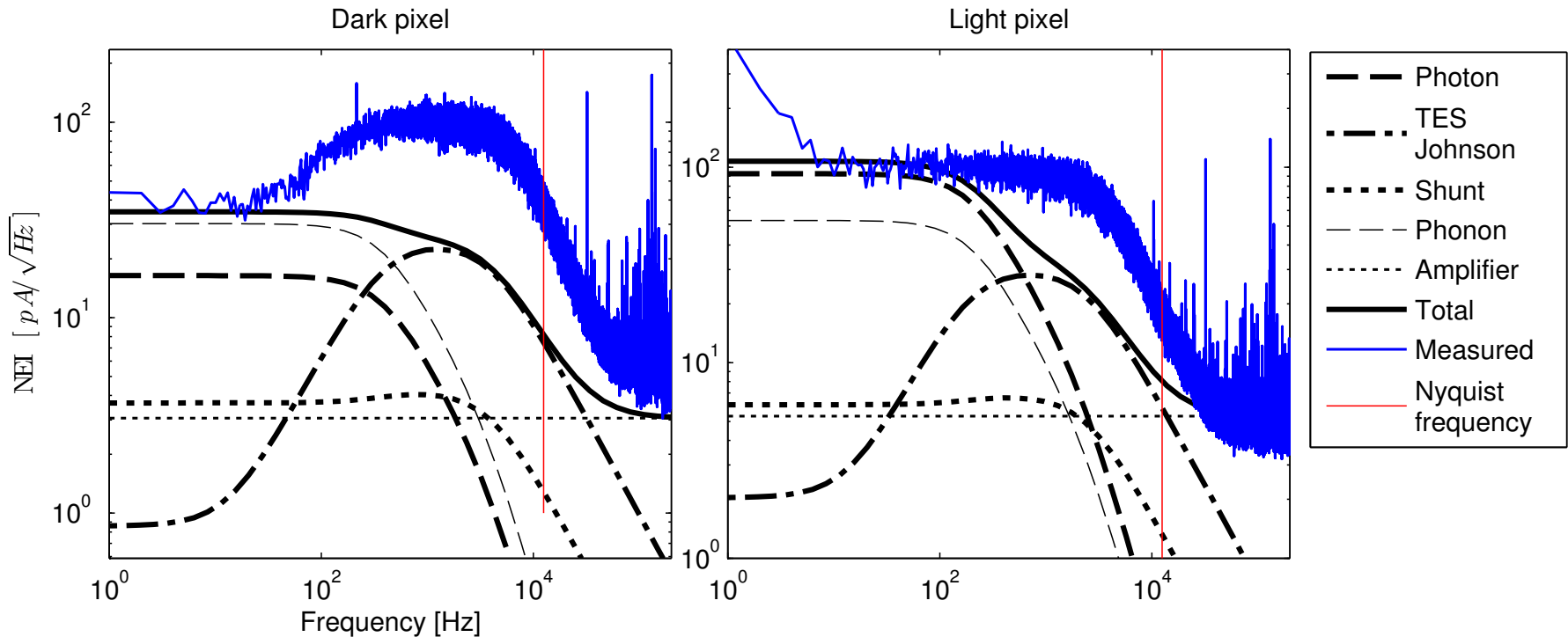
Roger O'Brient

Jet Propulsion Laboratory,  
California Institute of Technology

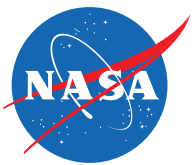


# Comparison with BICEP2/Keck Array<sup>1</sup>

- Measured White Noise in Keck Array 150GHz: Dark vs light
- This is *on-the-sky*, observing from the South Pole. Single detector samples.

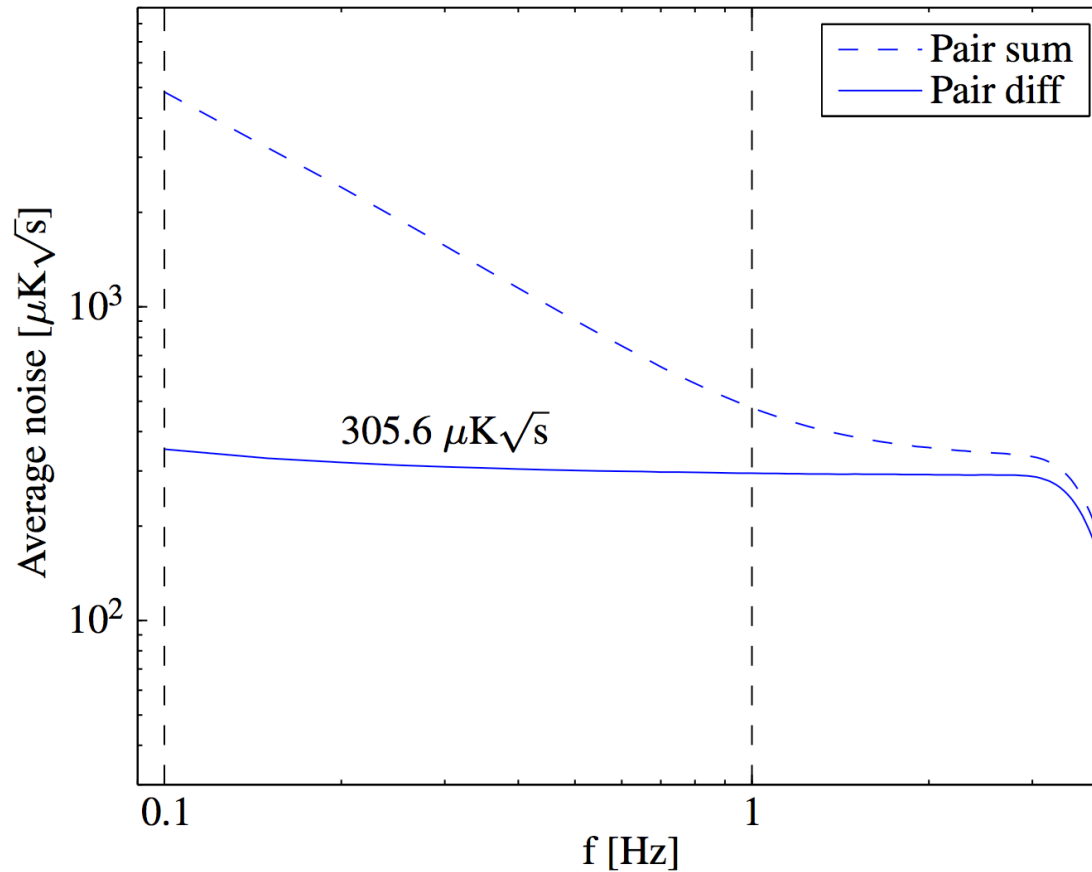


- $1/f \sim 2-3\text{Hz}$
- Knee is  $<1\text{Hz}$  in dark detectors.
- Atmospheric fluctuations



# BICEP2 1/f noise

- Average of all detector pairs, 2011-2012 observing



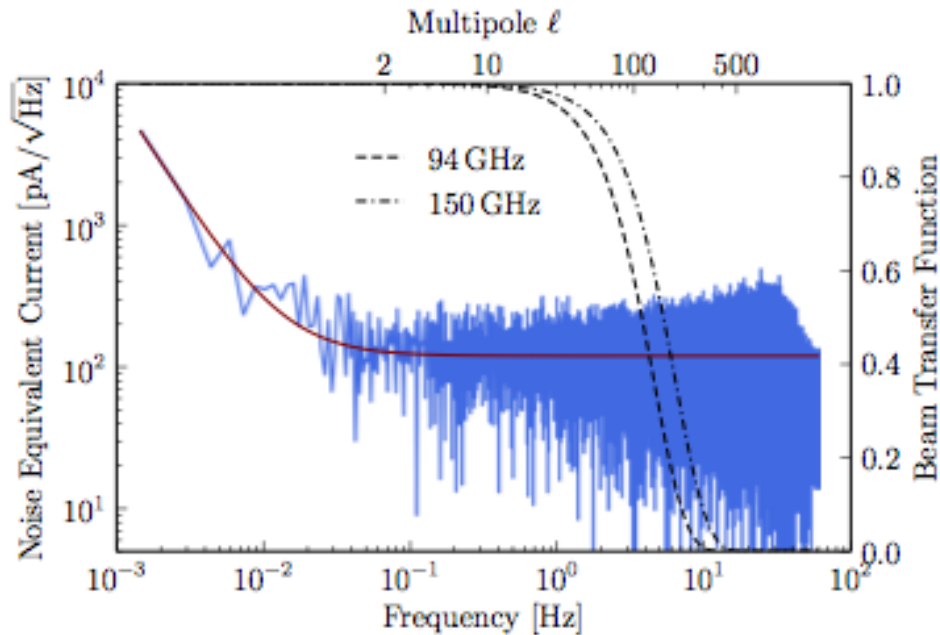
knee location:

- 1-2Hz in sum
- <100mHz in difference

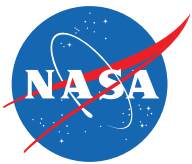
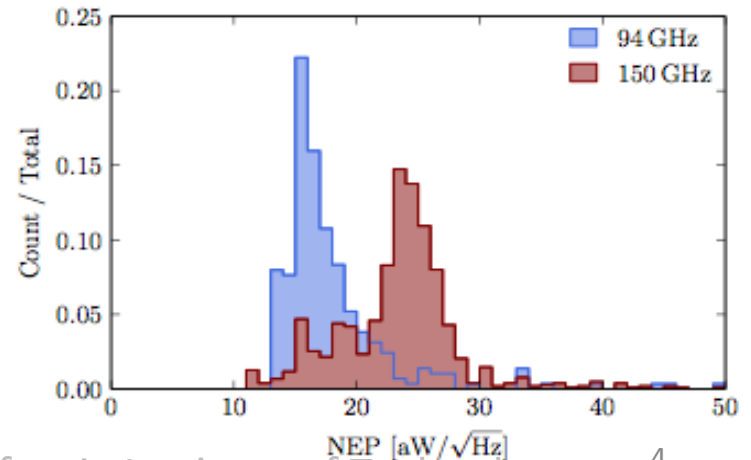
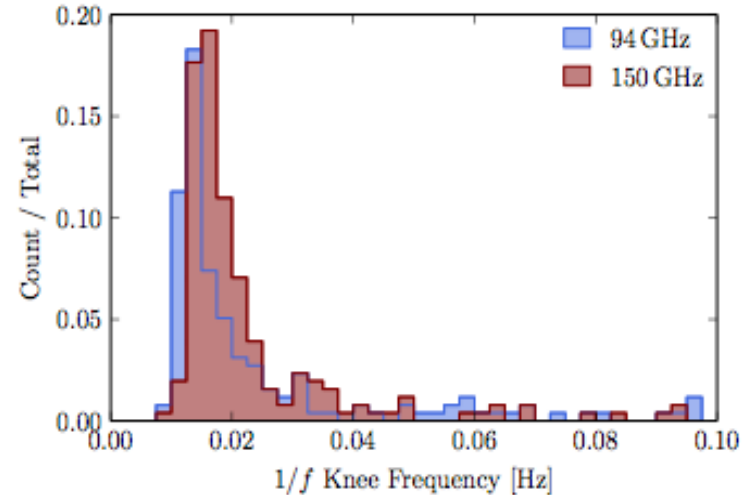


# TDM Noise Stability in SPIDER pre-flight<sup>2</sup>

- Pre-flight SPIDER Noise Characterization (in the lab) with an internal cold load:

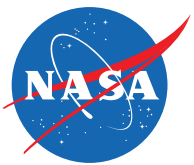
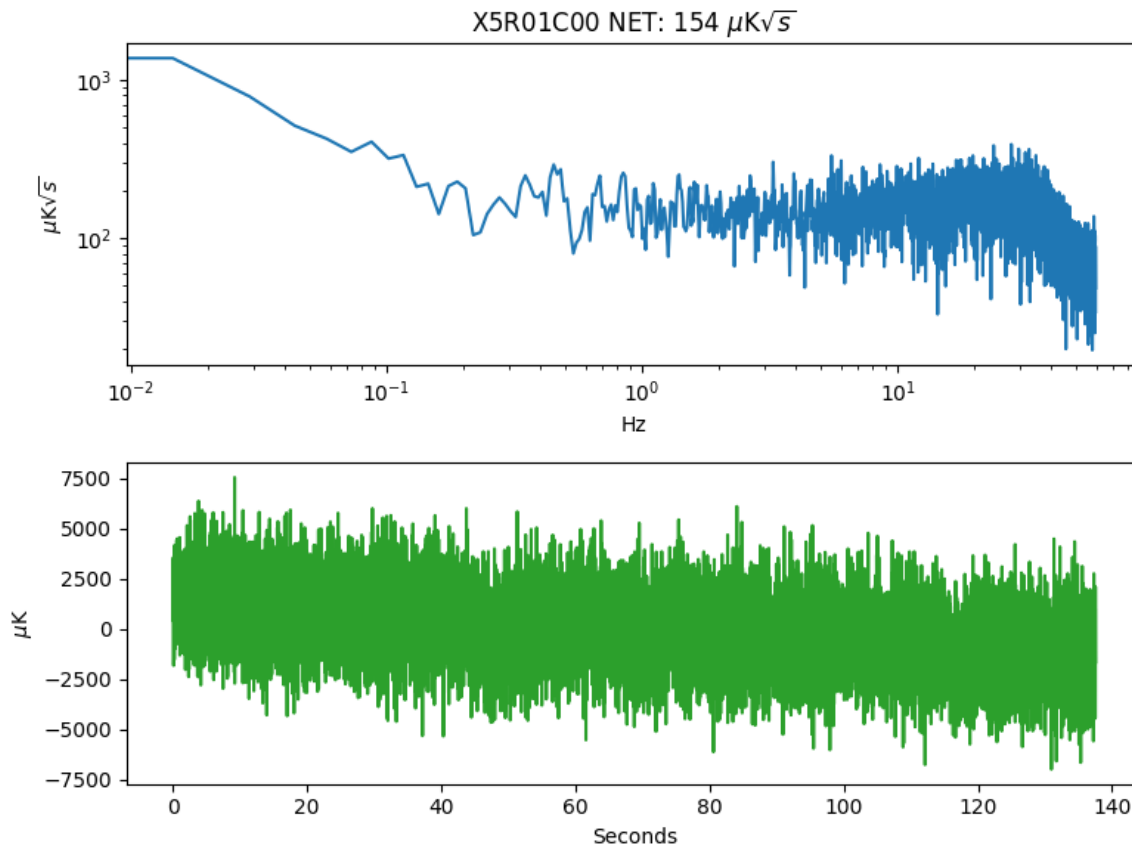


- 1/f knee 15-20 mHz, *without pair differencing*.



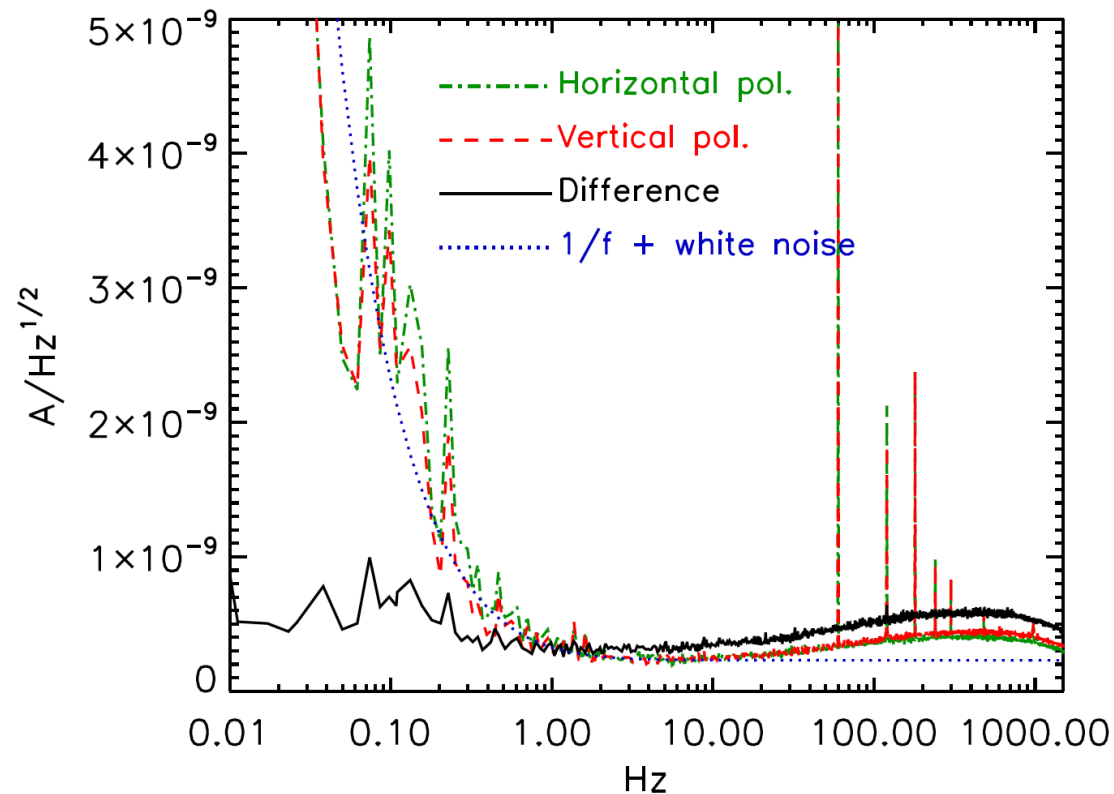
# TDM Noise Stability in SPIDER in flight<sup>3</sup>

- Emailed by Bill Jones last week
- Not filtering or processing, aside from 30Hz digital filtering
- Still no pair differencing
- Pay-load was static: no scan-synchronous pickup
- ~100mHz knee

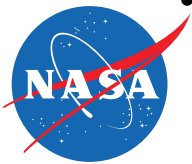


# TDM Noise Stability, lab tests<sup>4</sup>

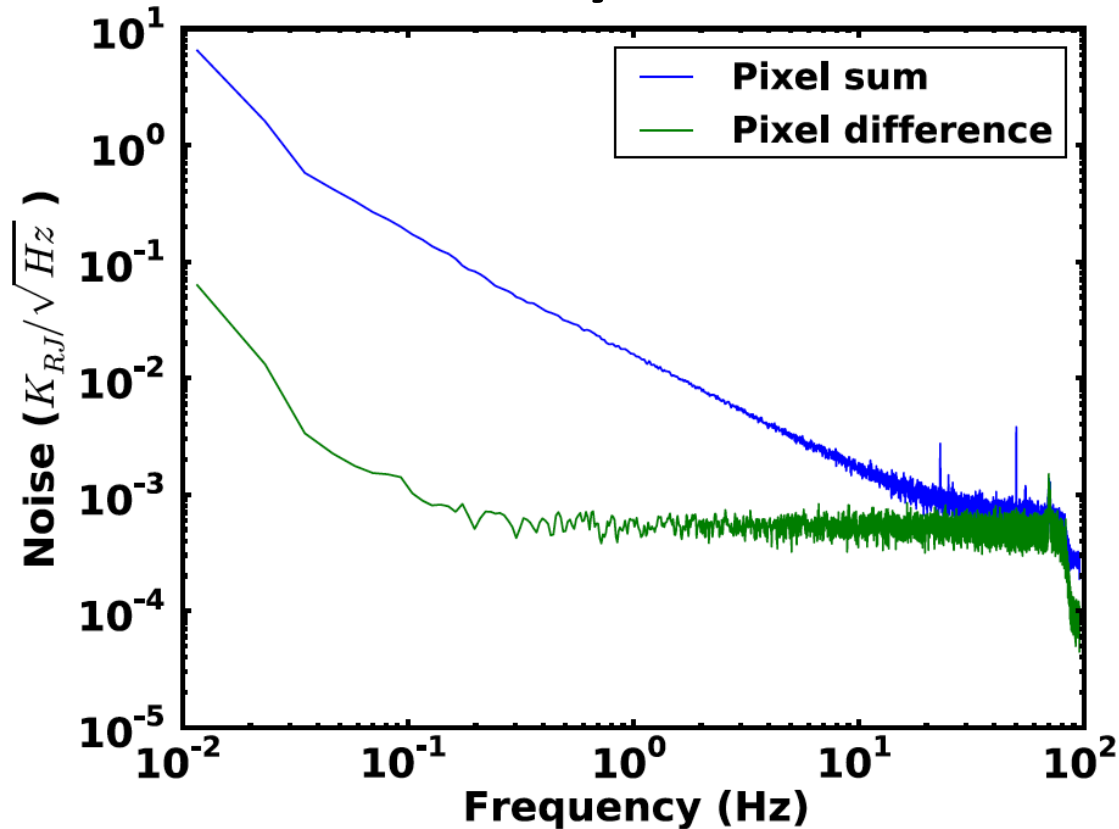
- Lab Characterization at NIST, dark tests with TES bolometers, so bound to be flattering



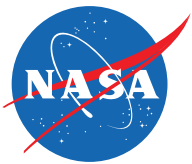
- $1/f$  knee at  $\sim 1\text{Hz}$
- Noise is Common mode between pairs- Difference  $< 10\text{mHz}$
- Consistent with SPIDER's experiences



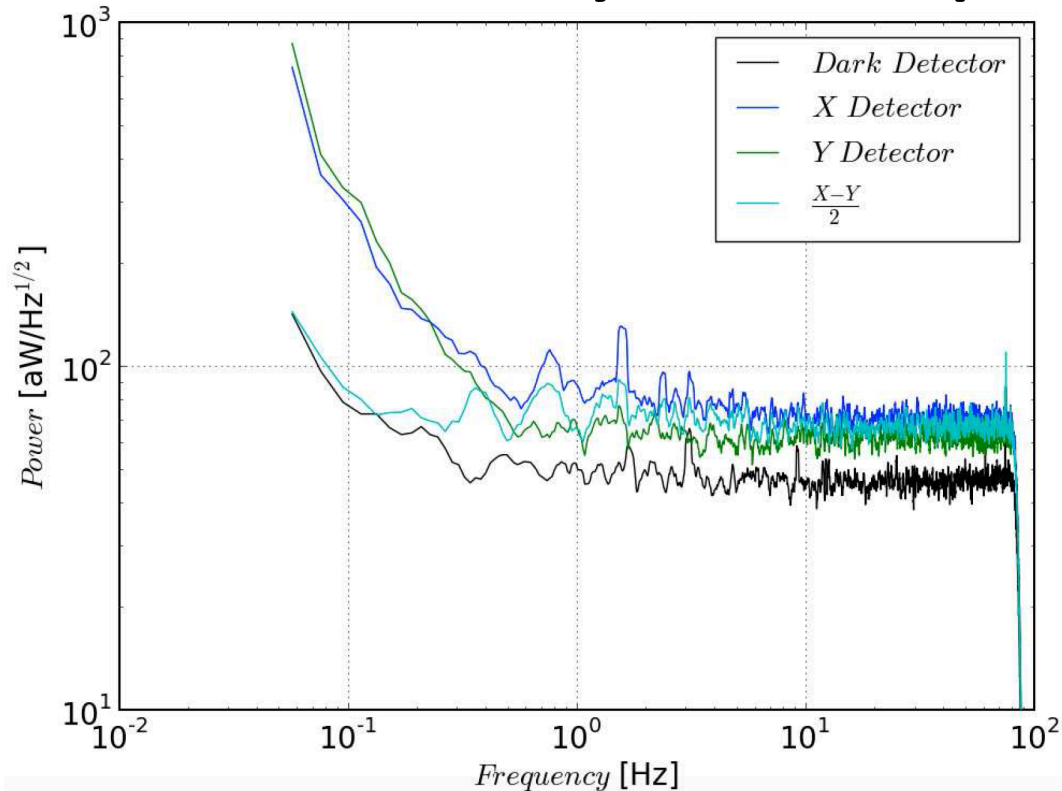
# FDM Stability in Polarbear



- Pair-differenced and summed detectors from Polarbear using FDM<sup>5</sup>:  $1/f \sim 10\text{Hz}$  before differencing (atmospheric fluctuations?) and  $\sim 100\text{mHz}$  after.
- Dates to (2012), includes atmosphere, and the Polarbear team was not optimizing for this. I presume FDM can do better.



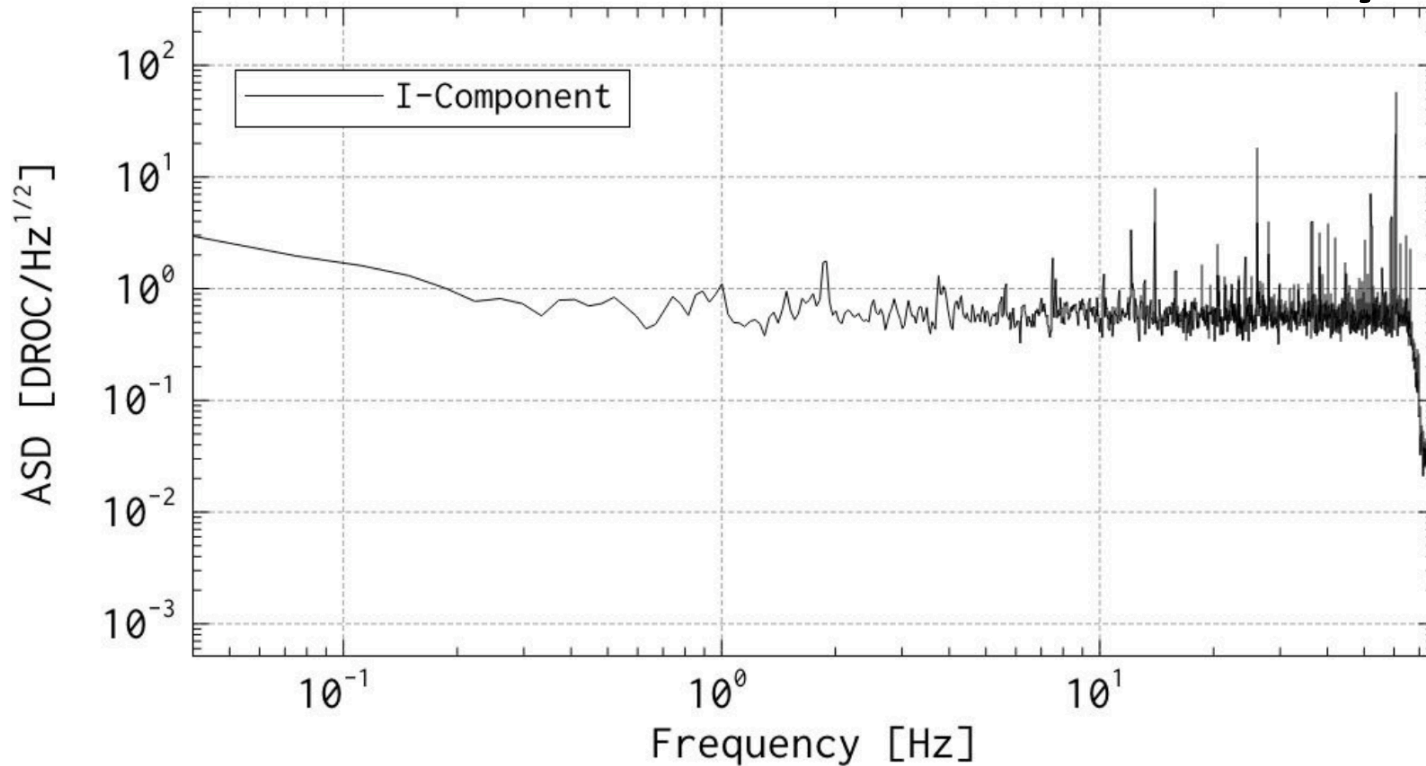
# FDM stability in SPTpol



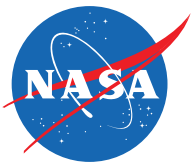
- Pair-differenced and individual detectors from STP-pol using FDM<sup>6</sup>:  
1/f~0.7Hz before differencing and ~100mHz after.
- Similar epoch as the Polarbear measurements, different team using it
- Note: Dark detector and differenced have similar 1/f knee: atmosphere was common mode.
- Another 1/f term persists, at similar frequency as Polarbear



# Lab tests of FDM stability



- Measurement at McGill of an over-biased detector in a dark cryostat<sup>7</sup>, so noise is mostly:
  - Shunt johnson noise (temp dependent)
  - Readout noise
- 1/f knee ~100mHz? Similar to Polarbear & SPT-pol
- Only *I* shown. With *Q* included, does knee drop a little?
- Disclaimer: I don't fully understand this measurement



# References

1. O'Brient, R. et al. "Antenna-coupled TES bolometers used in BICEP2, Keck Array, and SPIDER." The Astrophysical Journal Vol 812 No 2. arXiv:1502.00619
2. Rahlin, S. et al. , "Pre-flight integration and characterization of the SPIDER balloon-borne telescope." Proc. SPIE Vol 9153 (2014) arXiv:1407.2906
3. Gambel, Anne. Personal correspondance via Bill Jones. 2017
4. Niemack, M. et al. "Optimizing Feedhorn-Coupled TES Polarimeters for Balloon and Space-Based CMB Observations." J Low Temp Phys (2012) 167:917.  
<http://doi.org/10.1007/s10909-012-0554-2>
5. Kermish, Z. et al. "The Polarbear Experiment." SPIE Proc. Vol 8452. arXiv: 1210.7768
6. Henning, J.W., "Feedhorn Coupled TES polarimeter camera modules at 150GHz for the CMB Polarization measurements with SPTpol". SPIE Proc. Vol 8452. arXiv 1210.4969
7. Montgomery, J. "Development of Multiplexed Bolometer Readout Electronics for mm-wave Space Astronomy." McGill University (2015)

