Developing Microwave Kinetic Inductance Detectors for Early Universe Signal

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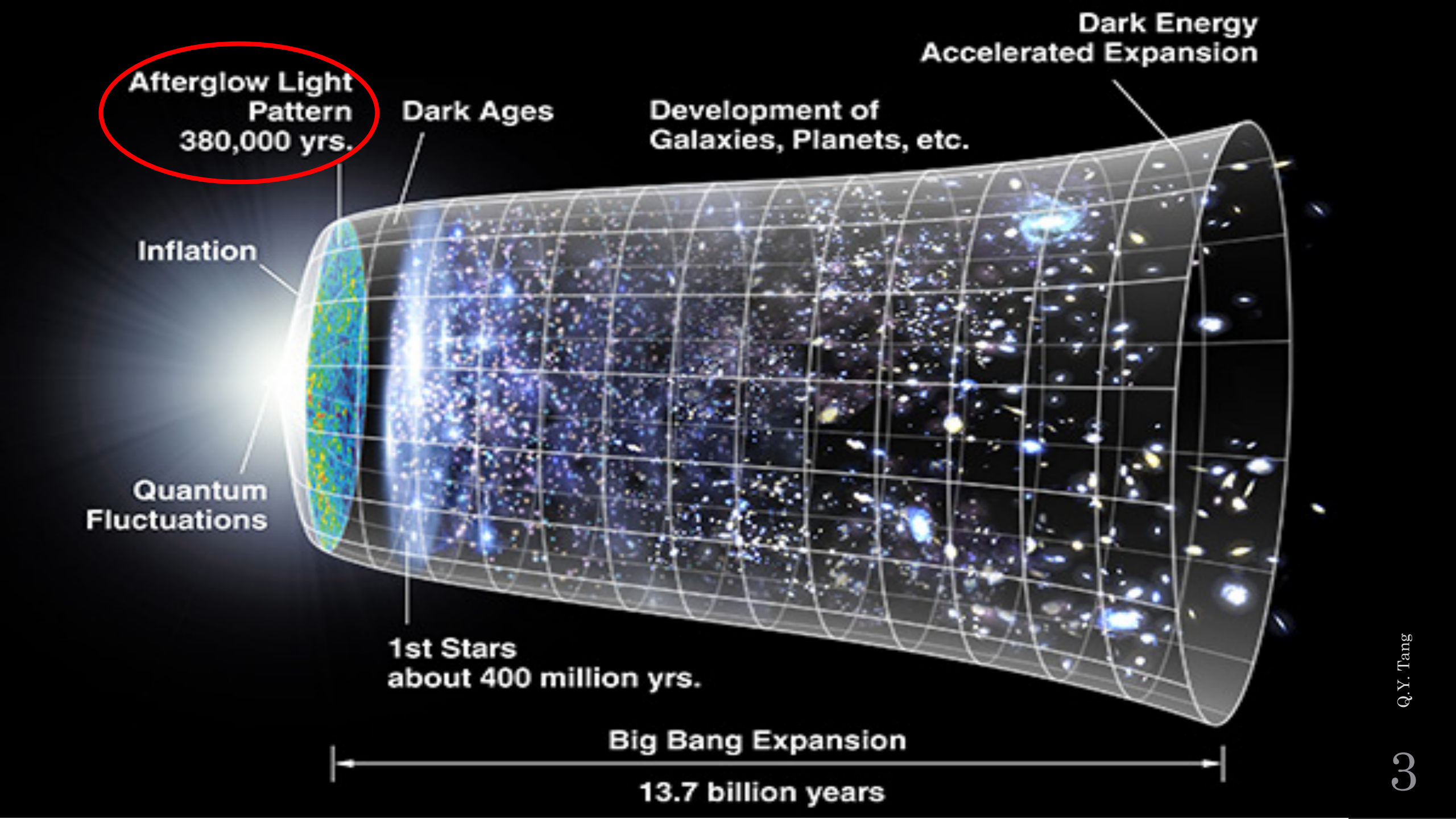
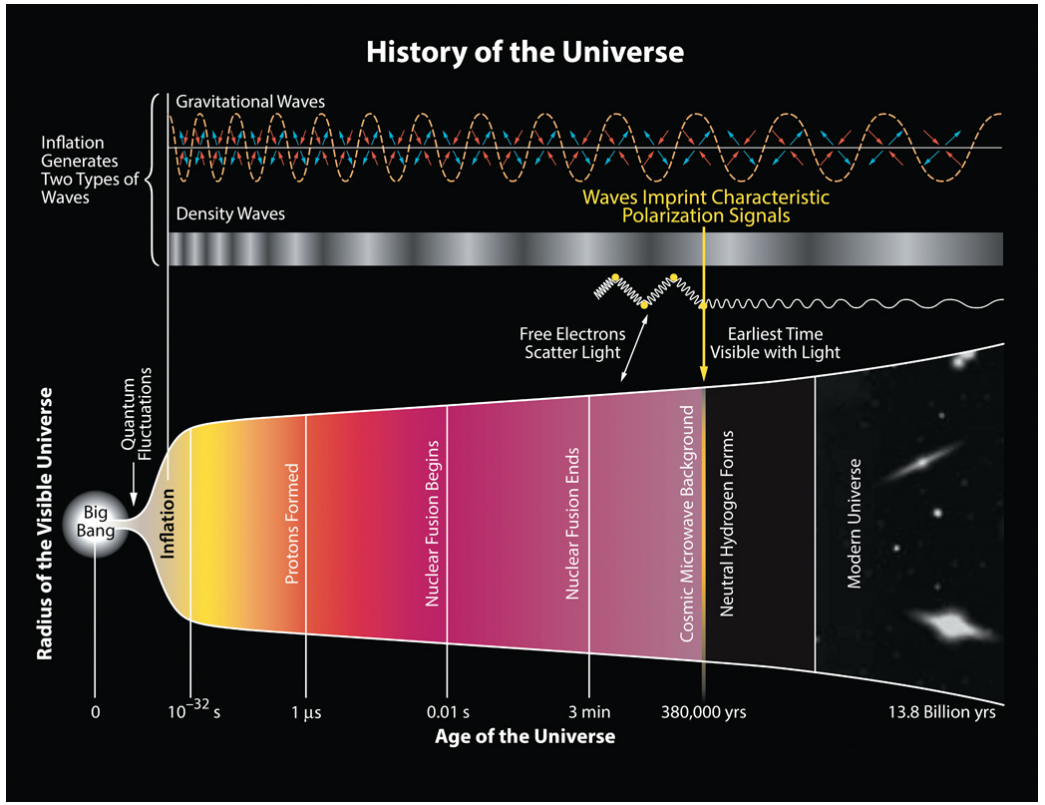
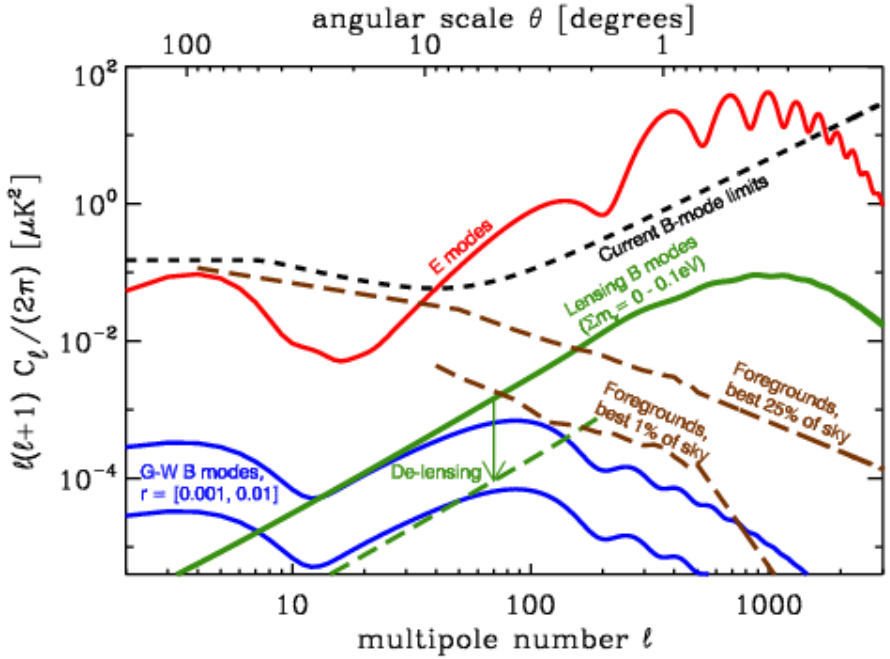
Outline

- Cosmic microwave background (CMB)
- Microwave Kinetic Inductance Detectors (MKIDs)
  - Design & Fabrication
- Preliminary Results
- Future Work


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

Inflation

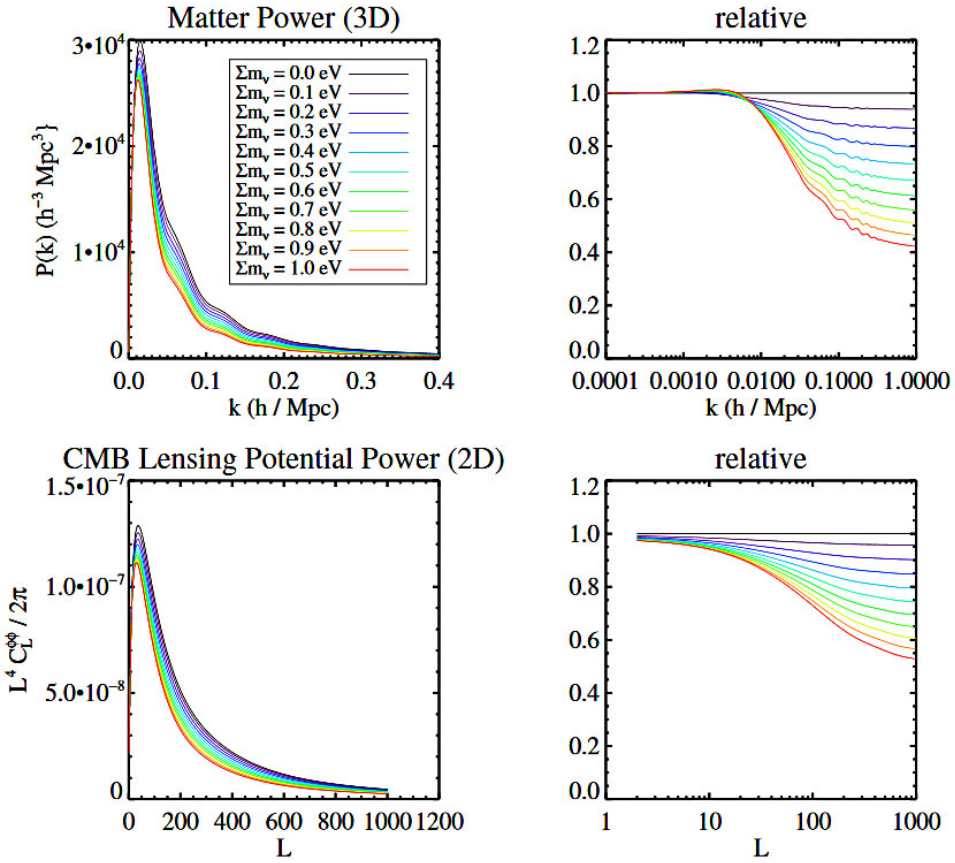


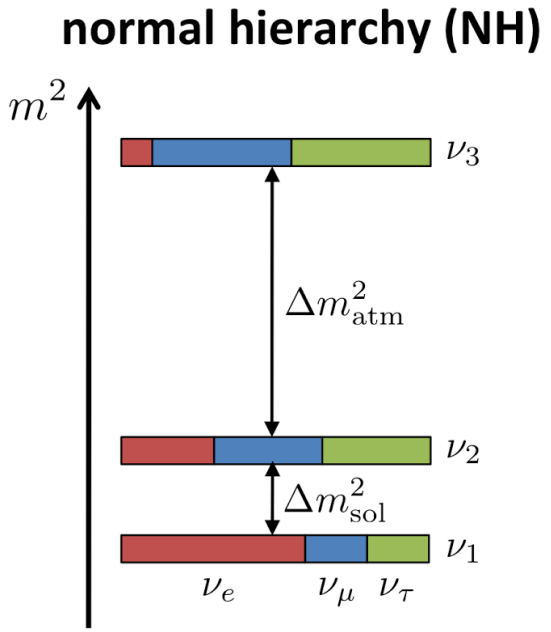


If detected, probe for energies at GUT scale ~10^{16} GeV

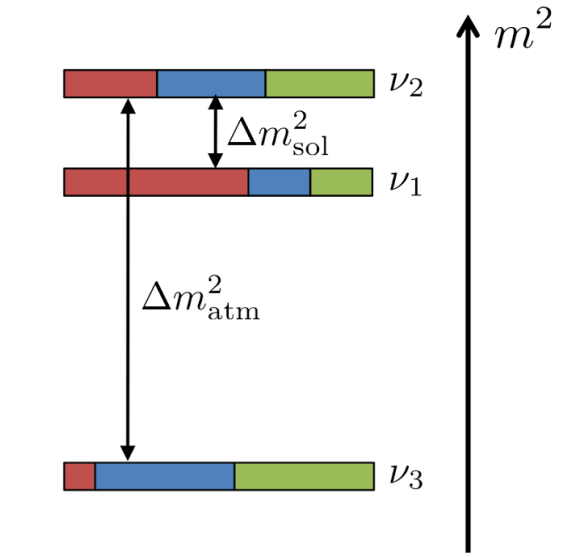
CMB-S4 Science Book

Neutrino Physics





$$\sum m_\nu \gtrsim 58 \text{ meV}$$



$$\sum m_\nu \gtrsim 105 \text{ meV}$$

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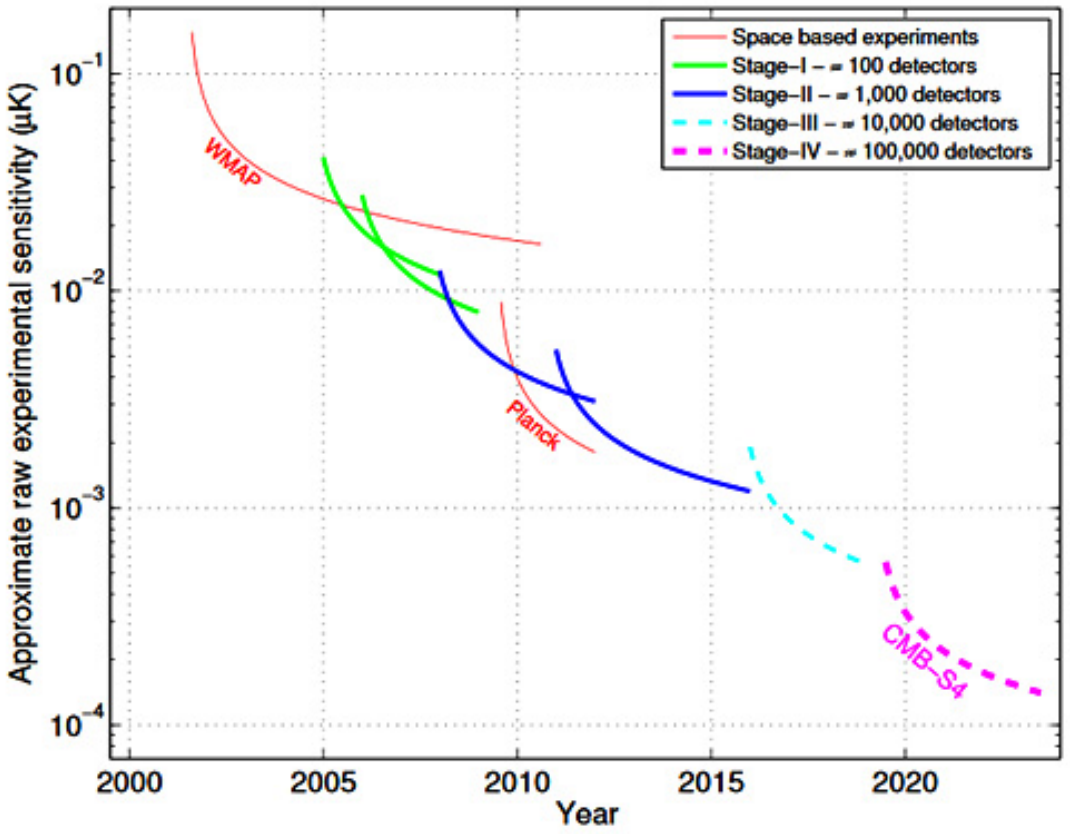


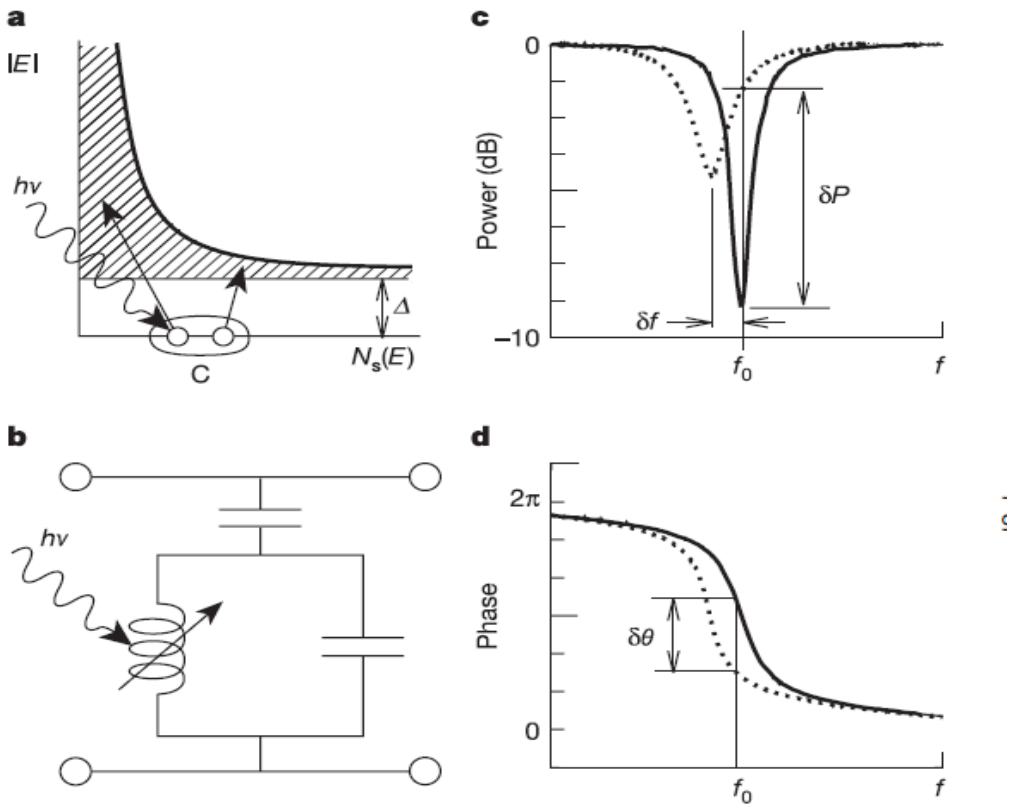
		Sensitivity (μK^2)	σ(r)	$\sigma(N_{eff})$	$\sigma(\Sigma m_\nu)$	Dark Energy F.O.M
2015	Stage 2 1000 detectors				Boss BAO prior	DES+BOSS SPT clusters
2016		≈10^{-5}	0.035	0.14	0.15eV	~180
2017						
2018	Stage 3 10,000 detectors					
2019					Boss BAO prior	DES + DESI SZ Clusters
2020		10^{-6}	0.006	0.06	0.06eV	~300-600
2021						
2022	Stage 4 CMB-S4 ~500,000 detectors					
2023					DESI BAO +τ_e prior	DESI +LSST S4 Clusters
Target		**10^{-6}**	**0.0005**	**0.027**	**0.015eV**	**1250**

- Going to ~ 500,000 detectors is extremely challenging for current CMB detector technology, especially with regards to *readout electronics* and *fabrication control*
- MKID is a promising technology for these problems

CMB-S4 Science Book

MKIDs

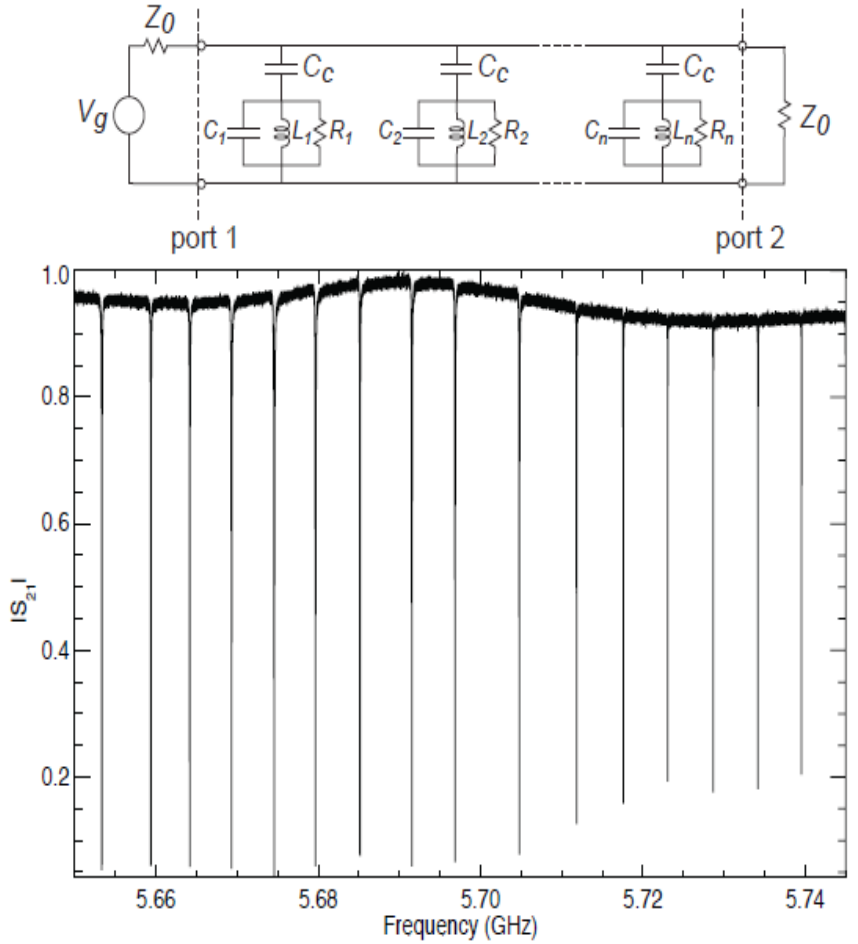
- Below transition temperature (T_c), electrons condense into Cooper pairs
- Photons with $E = hv > 2E_{gap}$ break Cooper pairs into quasiparticles
- Cooper pairs' inertial mass give rise to a kinetic inductance in an AC field
- Kinetic inductance changes with number of quasiparticles
  - Use a resonance circuit to see resonance frequency change when photons strike



Mazin+ 2011

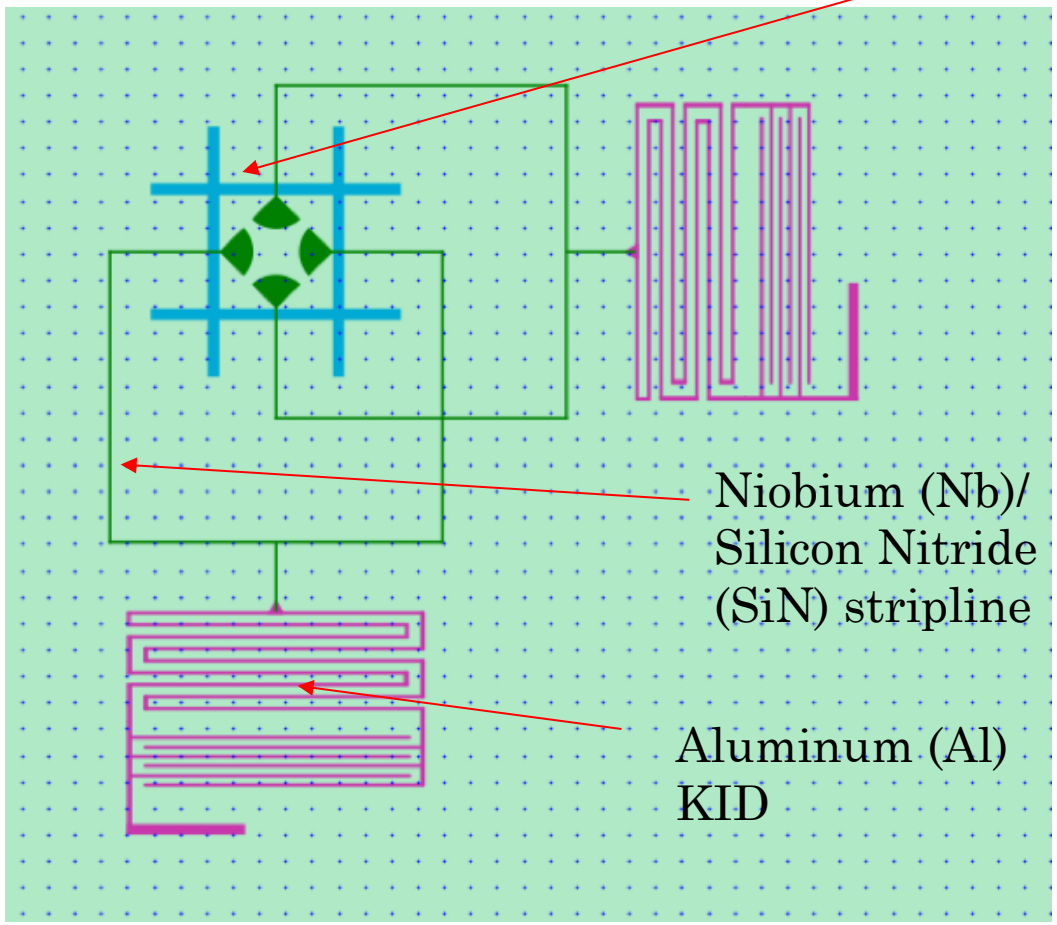
Multiplexing

- Can tune each resonances to have a slightly different frequency and couple them to a single transmission line
  - Able to read hundreds of MKIDs with one feedline
- High Q allows for more resonances to be read out



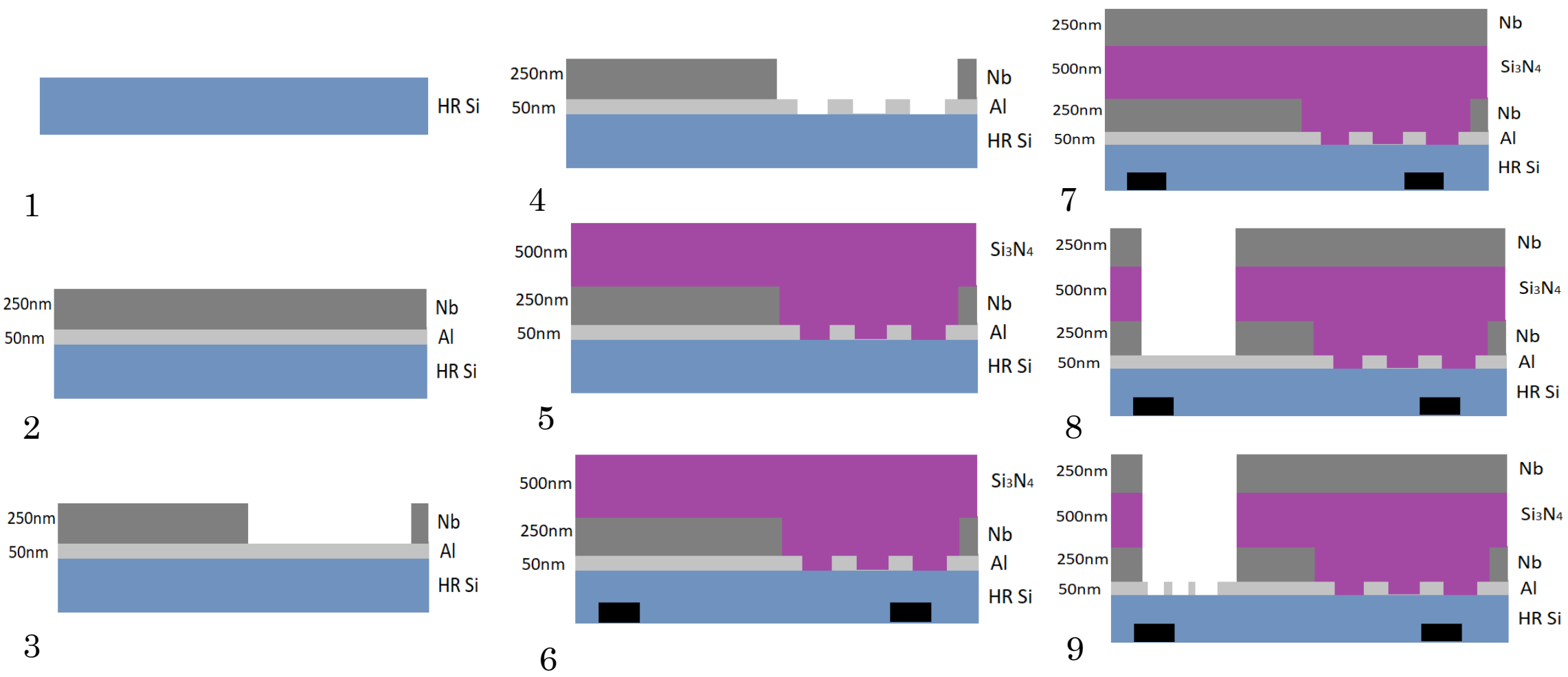
Mazin+ 2011

Design

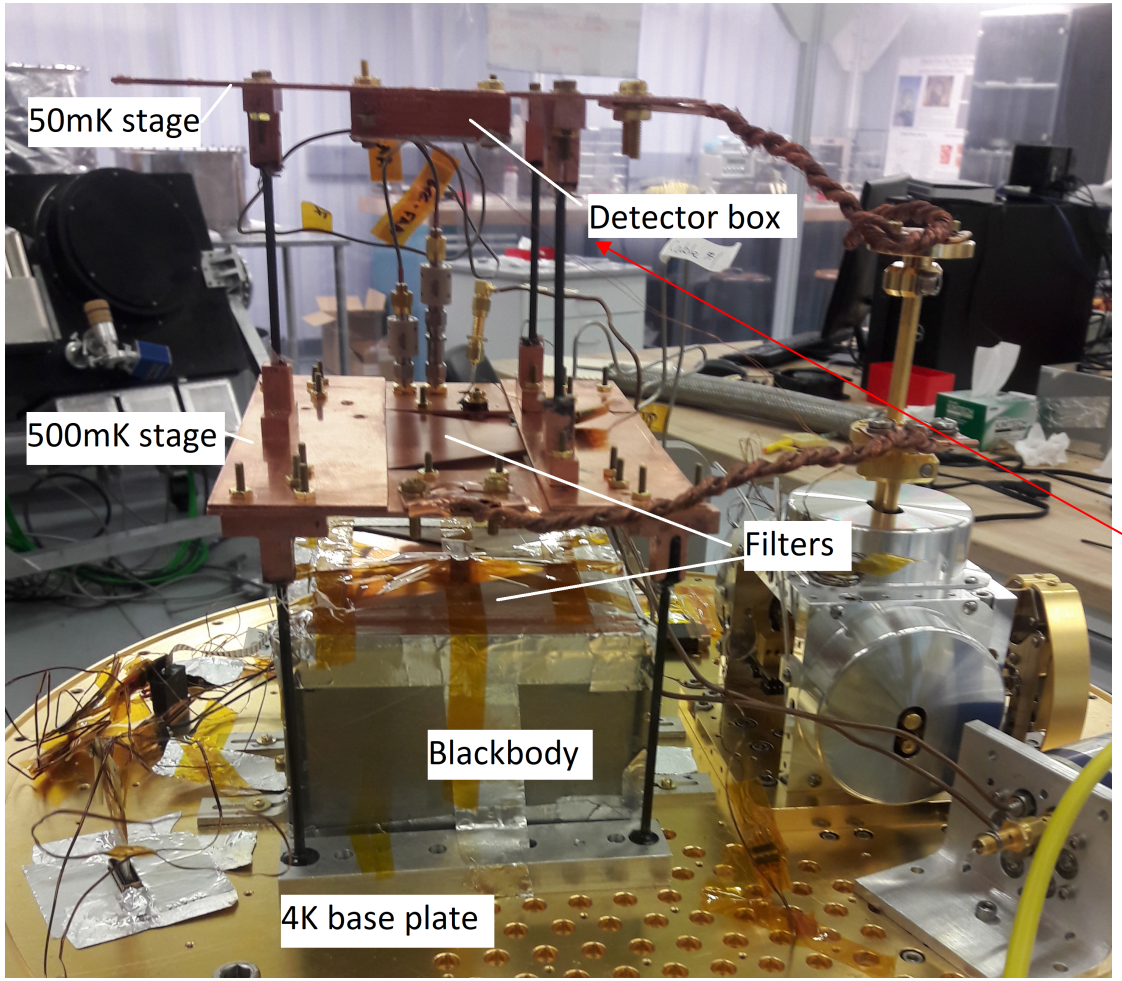


- Currently planned for 150 GHz and 220 GHz bands
- Al E_{gap} is appropriate for our bands of interest
- Nb/SiN microstrip gives very low loss in transmission and easy to fabricate

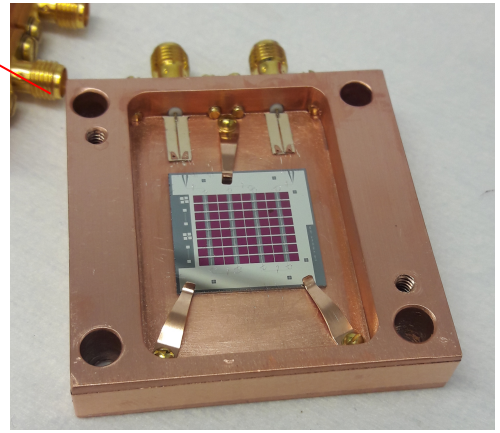
Fabrication



Experimental Setup

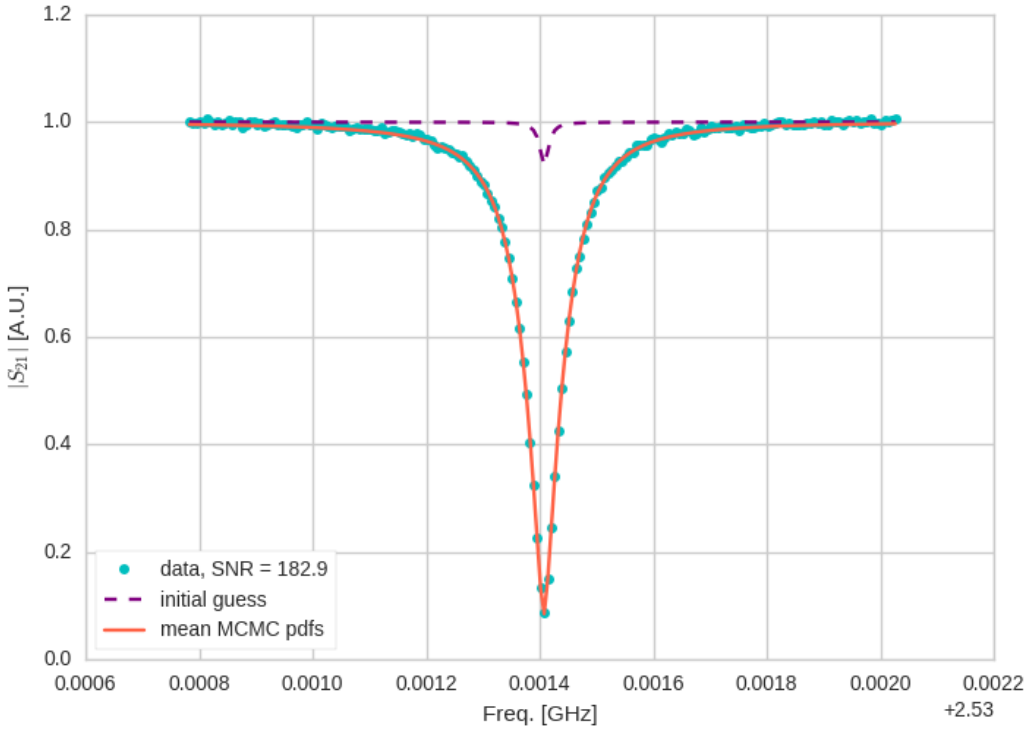


- ADR cryostat can reach ~50mK
  - Can regulate temperature of stage up to ~2K to test temperature response
- Blackbody with PID control to ~20K to test optical response
- Filters to define our bandpass

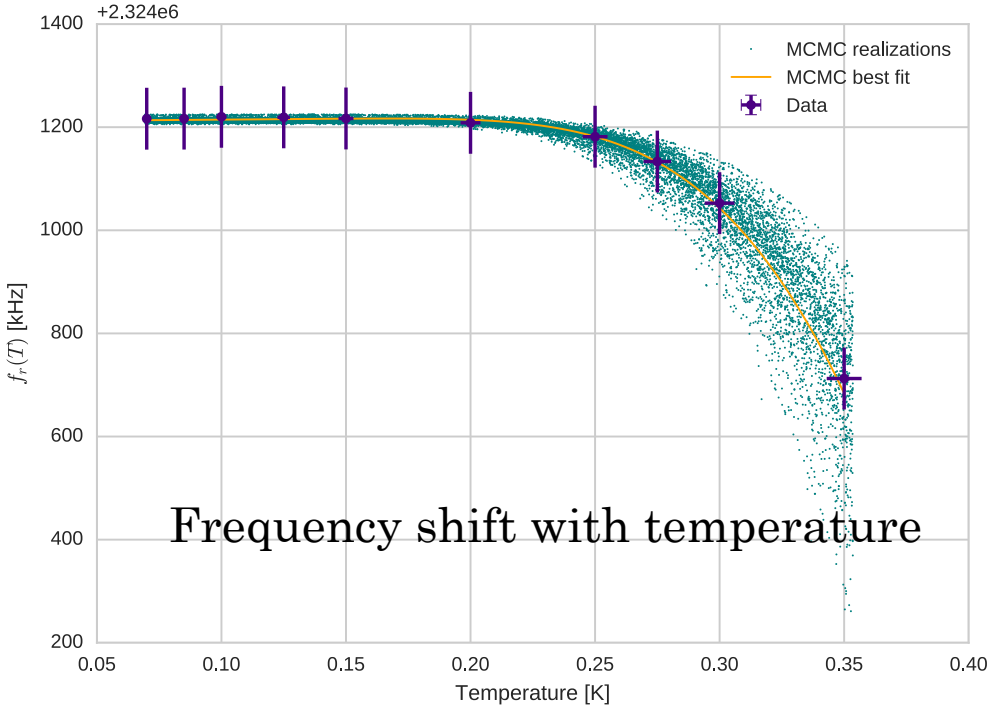


Preliminary Results

- Achieved Q_i ~ 270,000
- Characterized response with bath temperature and driving power



Transmission response of a KID



Frequency shift with temperature

Future Work

- Very close to characterizing optical response of MKIDs
  - Characterize frequency shifts with radiation power and understand kinetic inductance response of detectors
- Noise measurements and analysis
  - Sensitivity of our detectors, detector noise should be below CMB photon noise
- Upgrade to full-scale fabrication and testing for on sky performance

Thank you for listening!