Multi-chroic Detectors for Observing the Cosmic Microwave Background Polarization

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Journée des doctorants

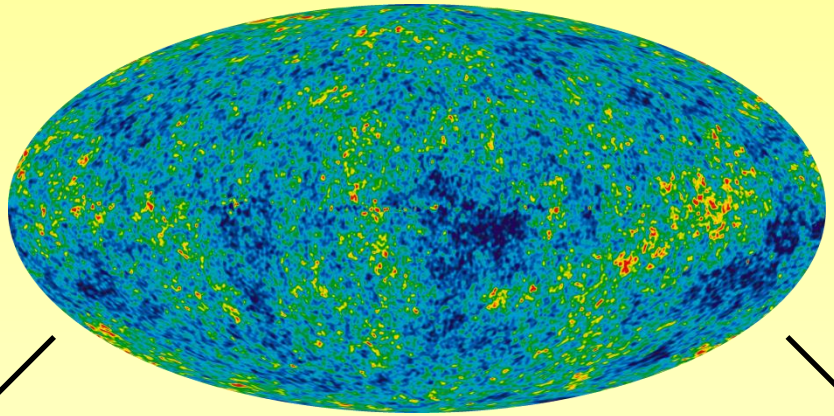
10-11-2016

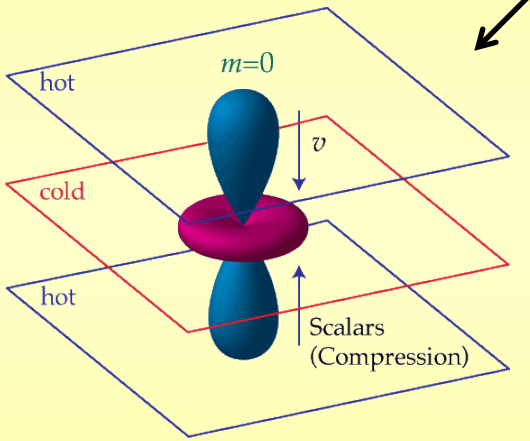
Outline

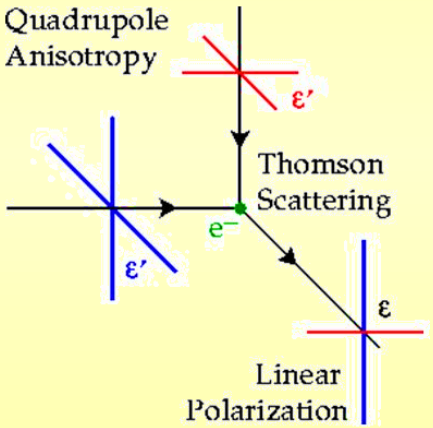
- Cosmic Microwave Background Polarization
- Past Space mission receivers
- Cosmic Origin Explorer (COrE)
- Kinetic Inductance Detectors

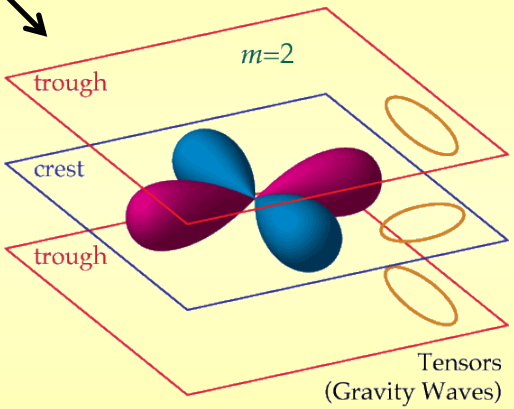
CMB polarization – E,B Modes

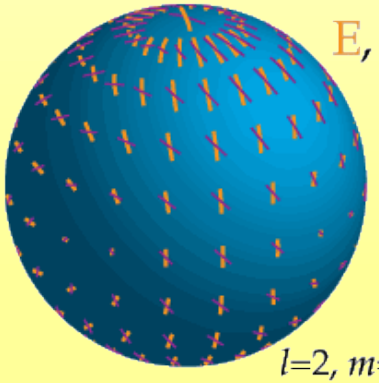
Ref: arXiv:astro-ph/9706147

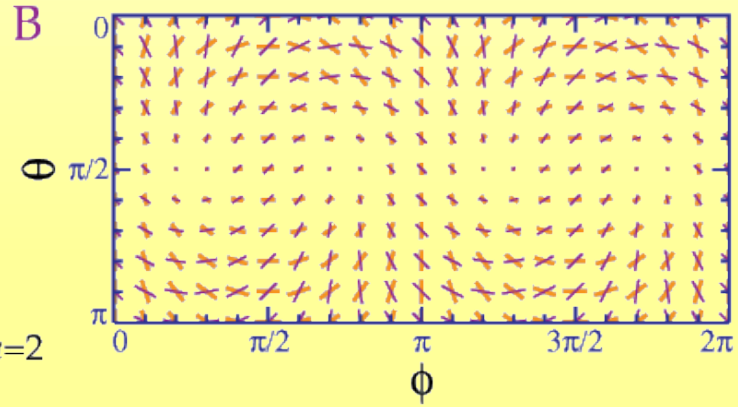






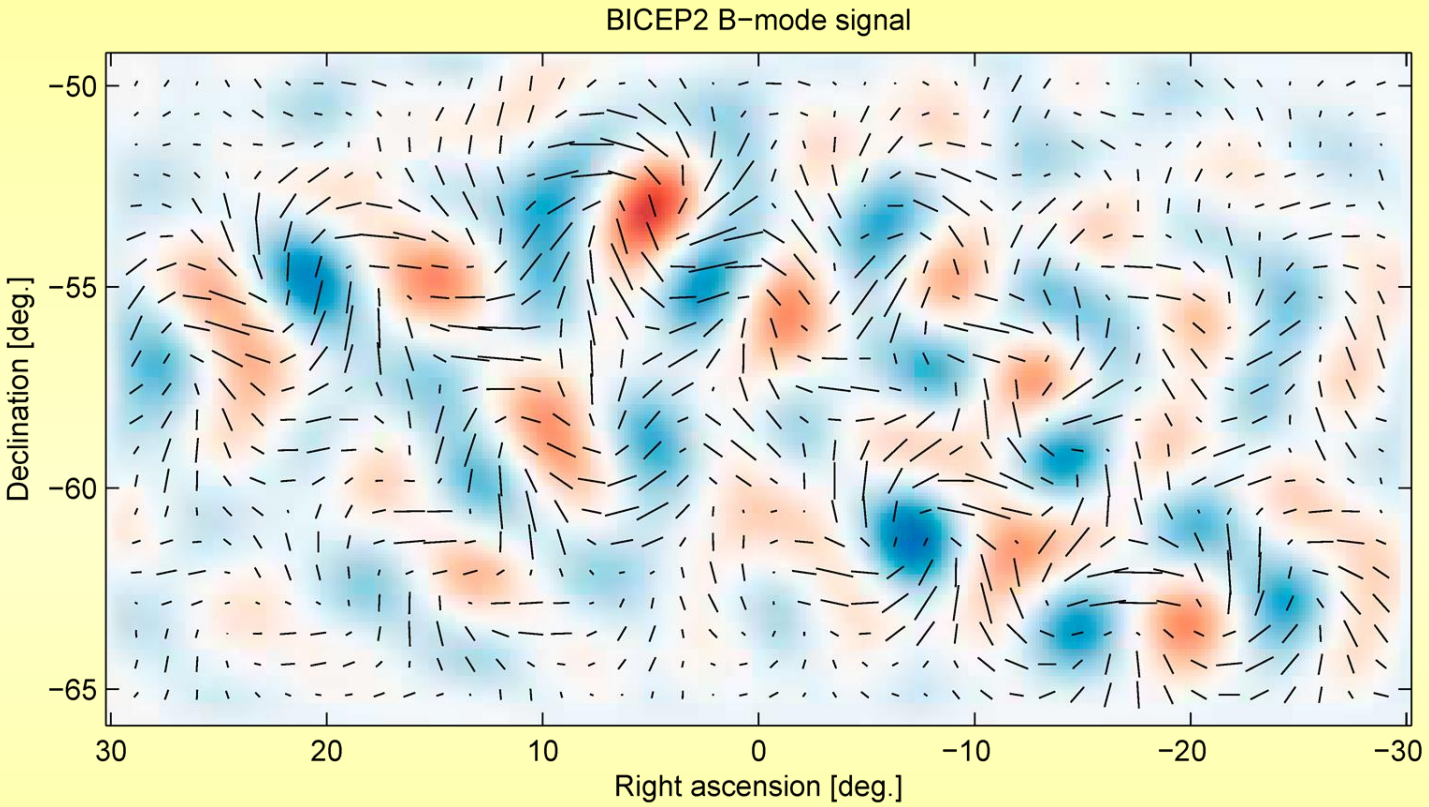






B-Modes

Ref: arXiv:1403.3985

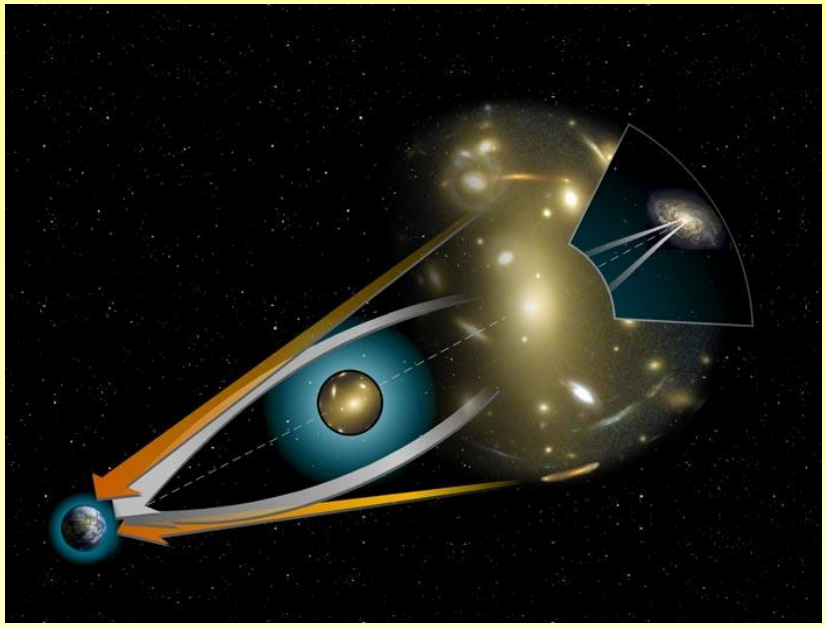


Approximately the 10% of CMB is polarized

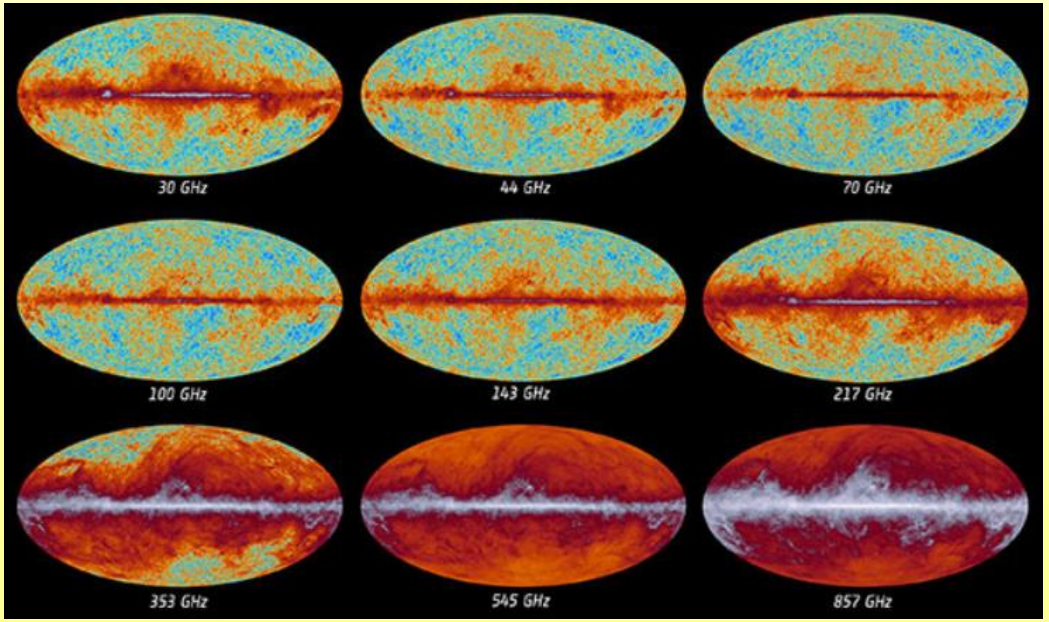
TENSOR to SCALAR ratio from Planck (and Bicep2)

$$r < 0.11$$

B-Modes Contaminations



Lensing B-modes

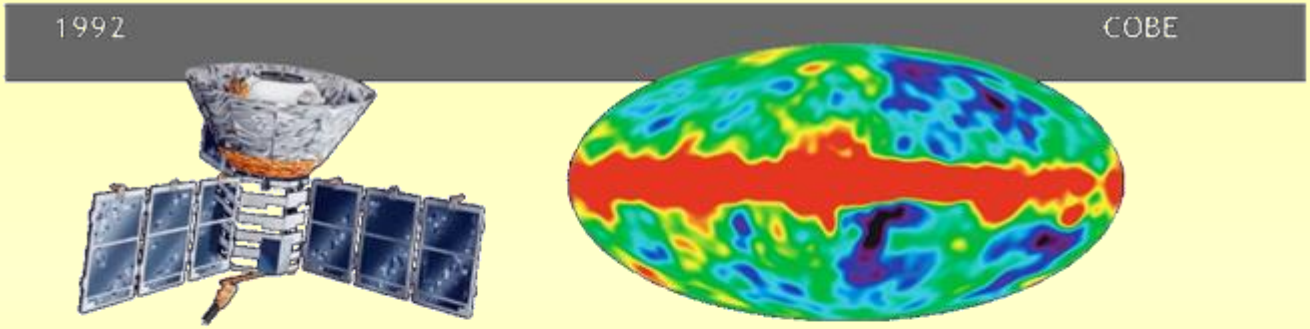


Galactic Dust

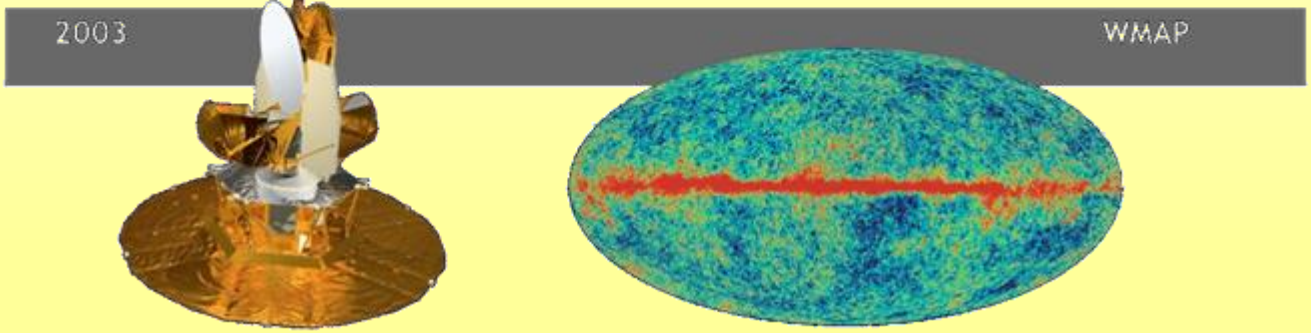
Past space mission receivers (before Planck)

- Mostly based on Radiometers
- No data over 100 GHz

31.5 GHz, 53 GHz and 90 GHz

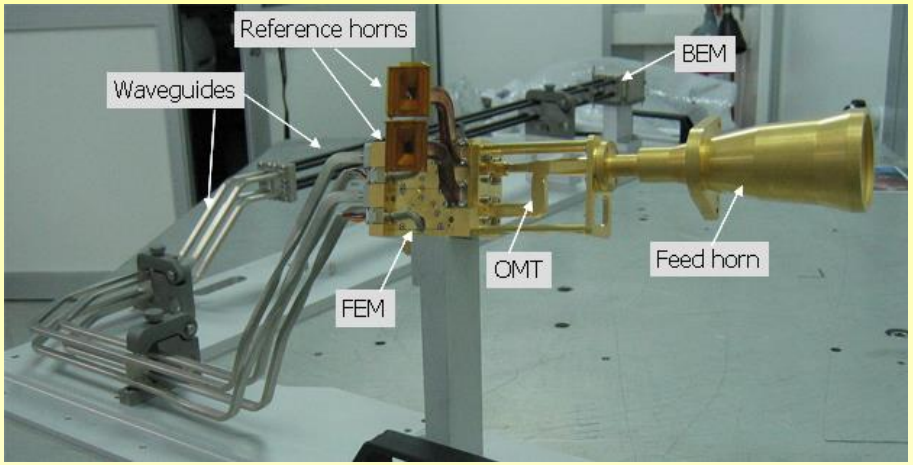


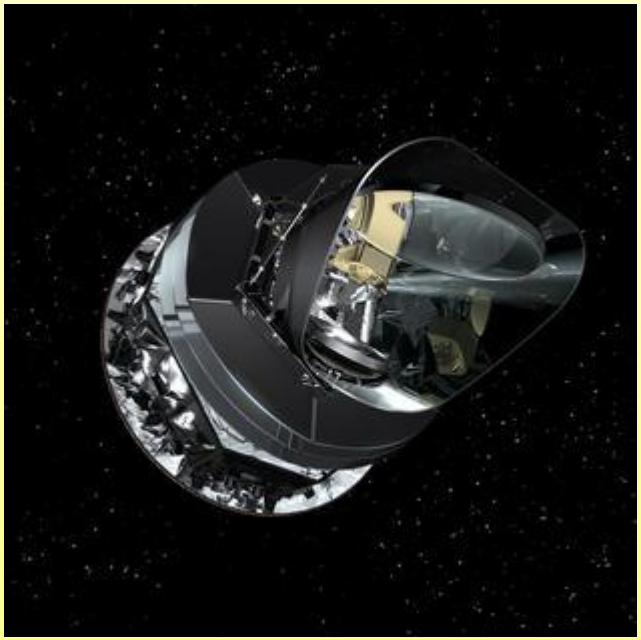
23 GHz to 94 GHz



Planck (2009-2013)

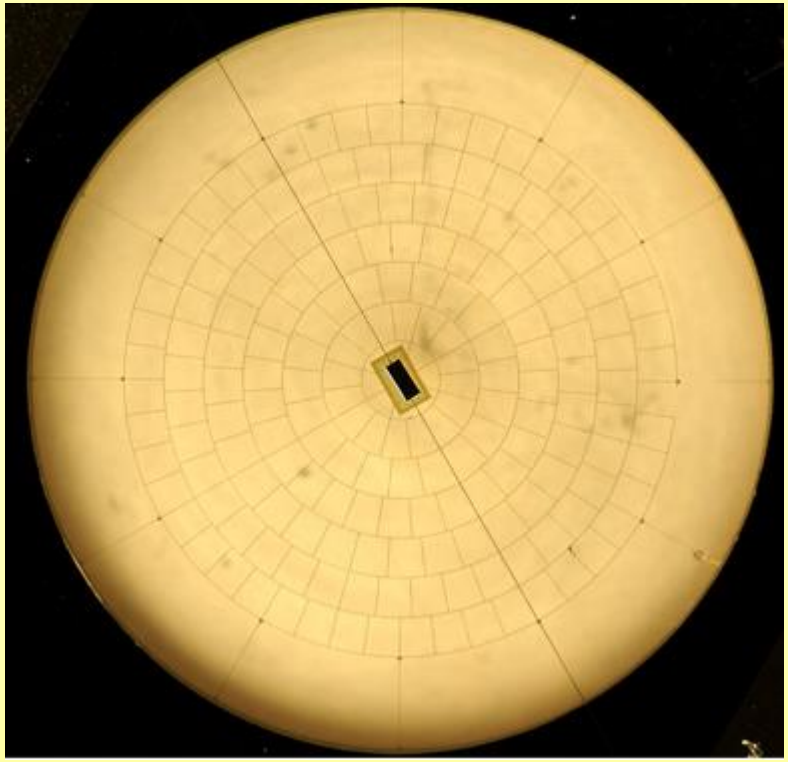
LFI: Radiometer (30 to 70 GHz)





HFI: 52 detectors (bolometer)
(100 to 857 GHz)

Photon noise limited



$$r < 0.11$$

Statistical noise limitation

Future space Mission – Technological Challenges

- From theory(ies): expected tensor to scalar ratio $r \sim 10^{-3}$

↓

100 times smaller than Planck constraint $r < 0.11$

↓

Almost x100 number of detectors required (5k-10k)

- Mapping the galactic polarized dust emission

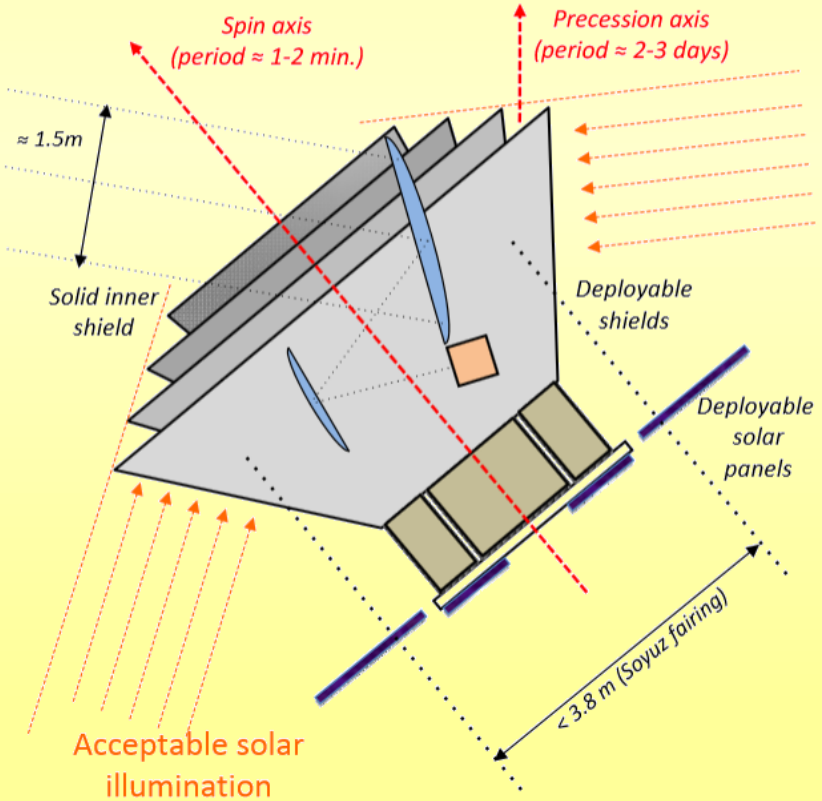
↓

Wide frequency ranges from 60 GHz to 600 GHz

COrE – Cosmic Origin Explorer

Ref: COrE white paper

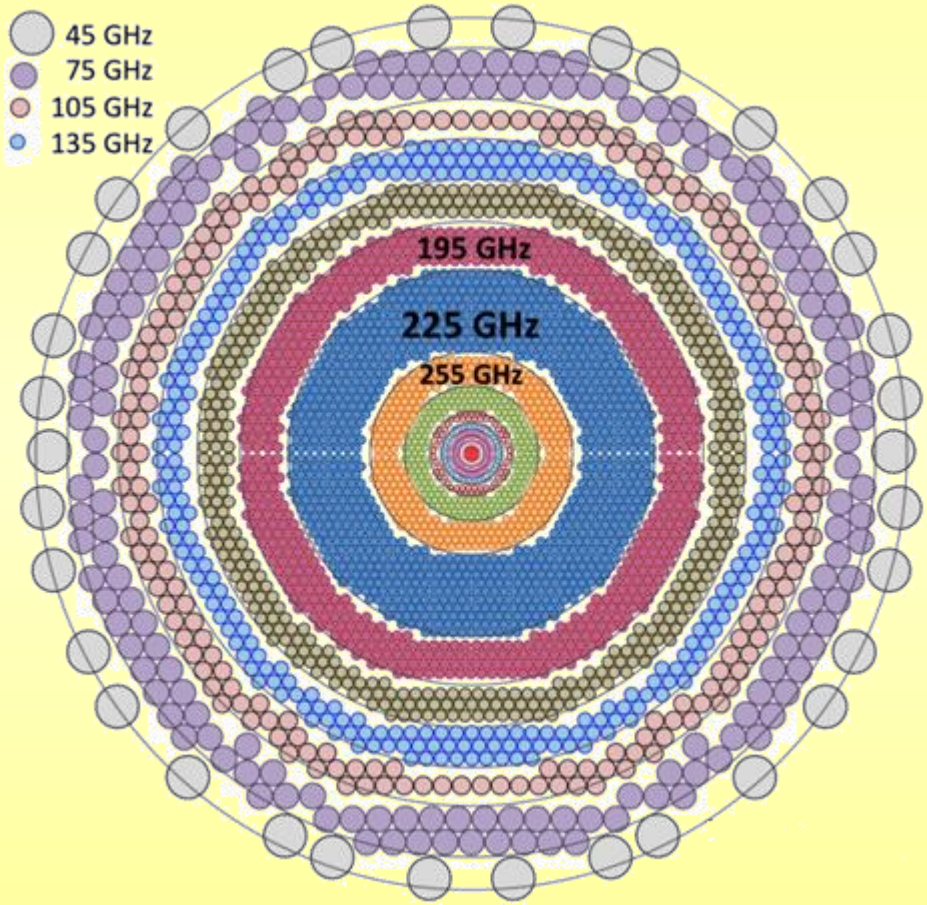
M5 proposal to ESA



Looking for a TENSOR to SCALAR ratio $\sim 10^{-3}$

COrE focal plane

Central Freq. (GHz)	$N_{detectors}$
45	64
75	300
105	400
135	550
165	750
195	1150
225	1800
255	575
285	375
315	100
375	64
435	64
555	64
675	64
795	64



More than 6000 detectors !!

CMB polarization – Bolometers

Bolometers are photon noise limited …but for large array:

- Expensive
- Complex to fabricate
- Complex readout

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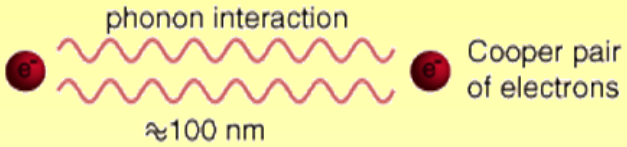
POSSIBLE ALTERNATIVE

KID - Kinetic Inductance Detector

About Kinetic Inductance in Superconductors

Charge carriers in superconductor



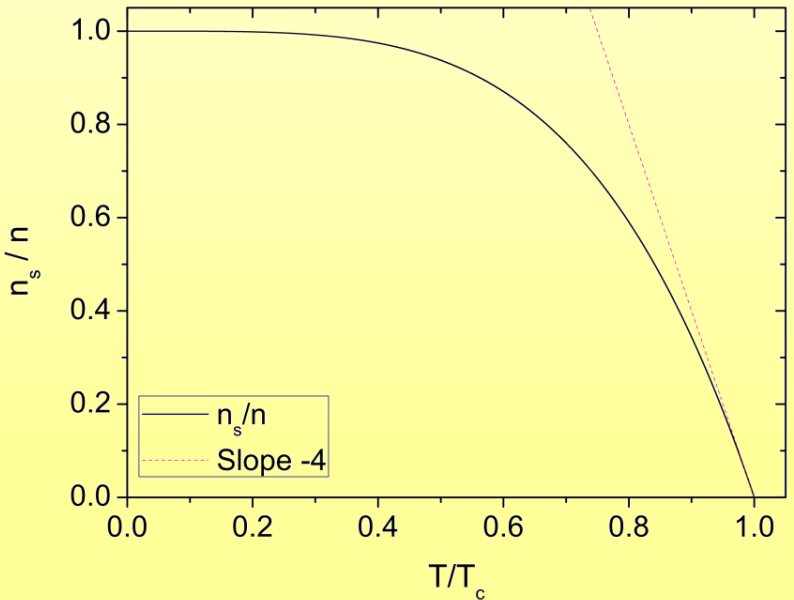
Integer spin ⟶ No scattering!

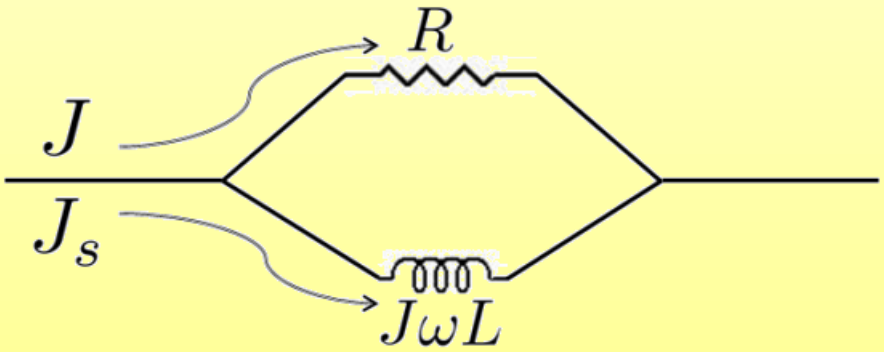
Resistance ⟶ Charge carriers Scattering

Impedance ⟶ $Z = R + iX$ ⟶ Reactance ⟶ Geometry

⟶ Charge carriers Inertia

Cooper Pair density

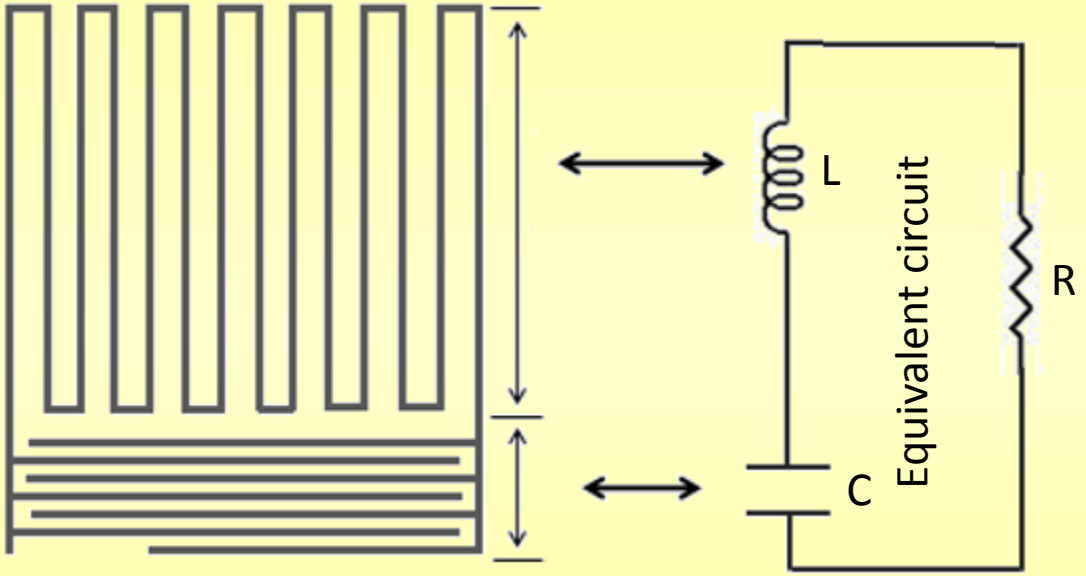




KID – Kinetic Inductance Detector

Series RLC resonant circuit
transmission line

$$\omega_r = \frac{1}{\sqrt{LC}}$$

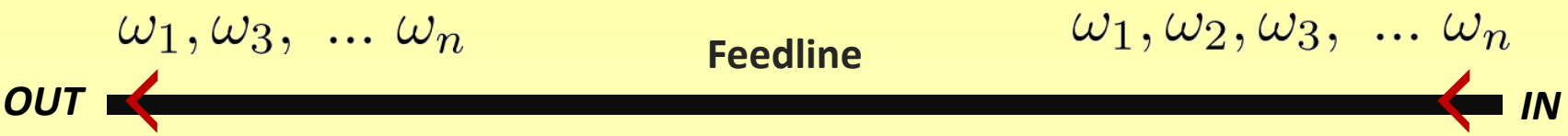


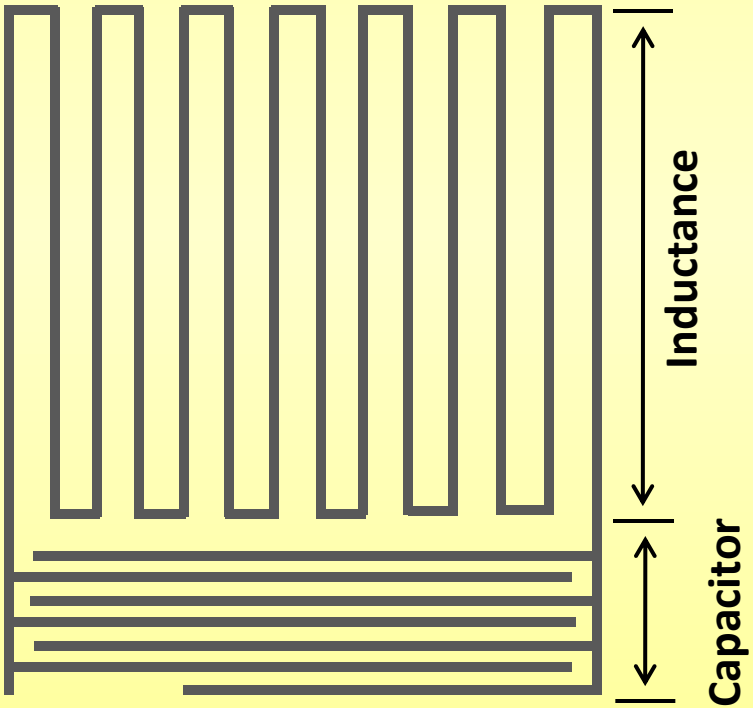
$$L_{tot} = L_g + L_k$$

Contributions to L:

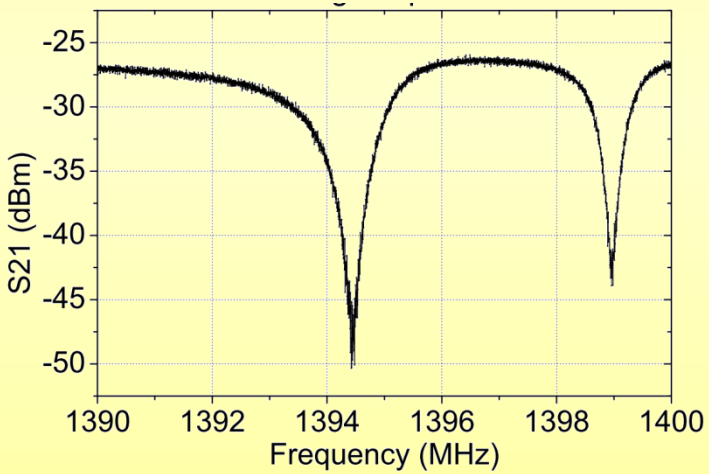
- Geometry
- Cooper Pair (Kinetic Inductance)

KID – Kinetic Inductance Detector

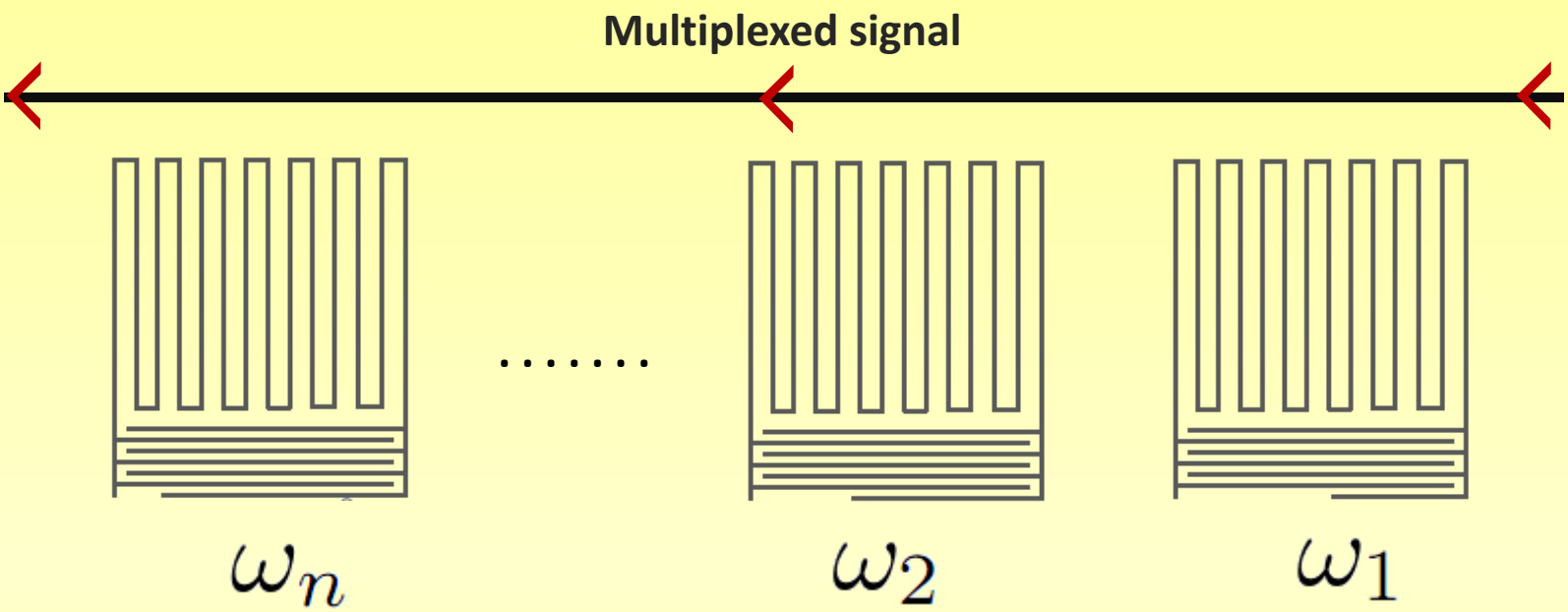


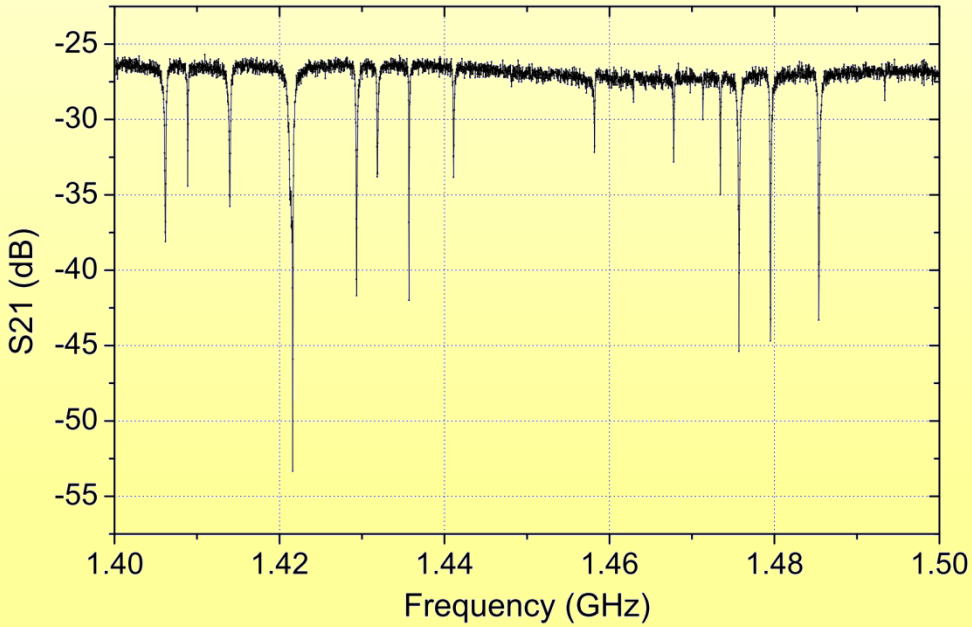


$$\omega_r = \omega_2$$

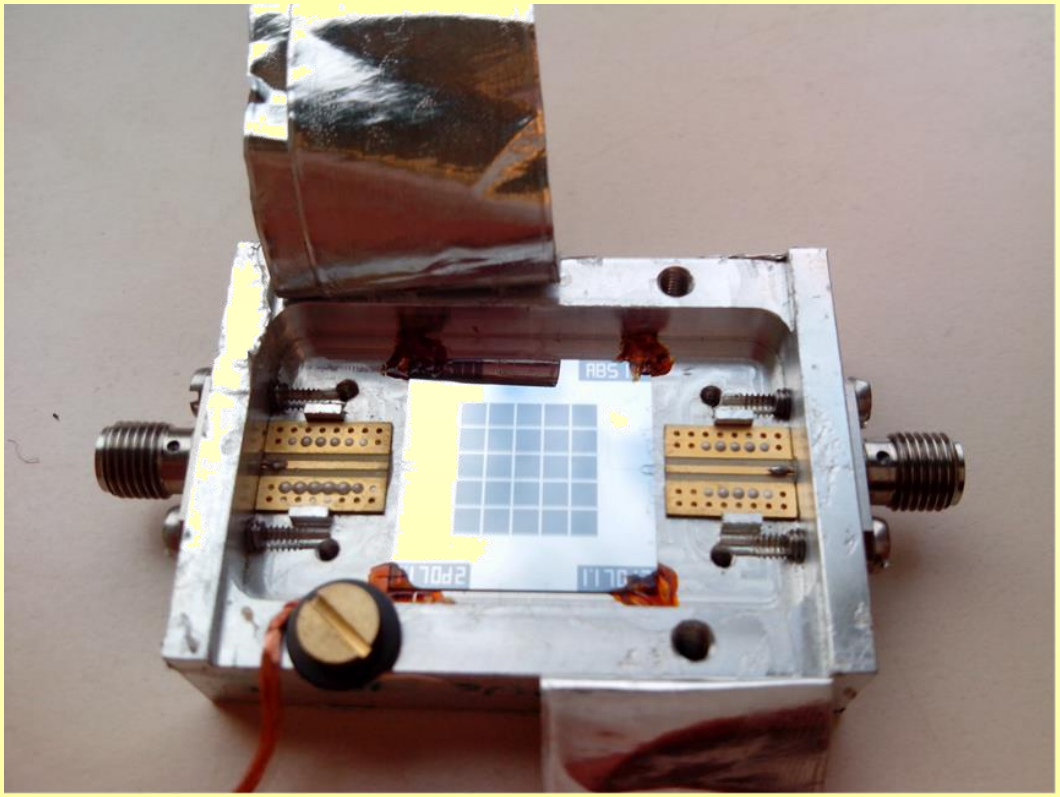


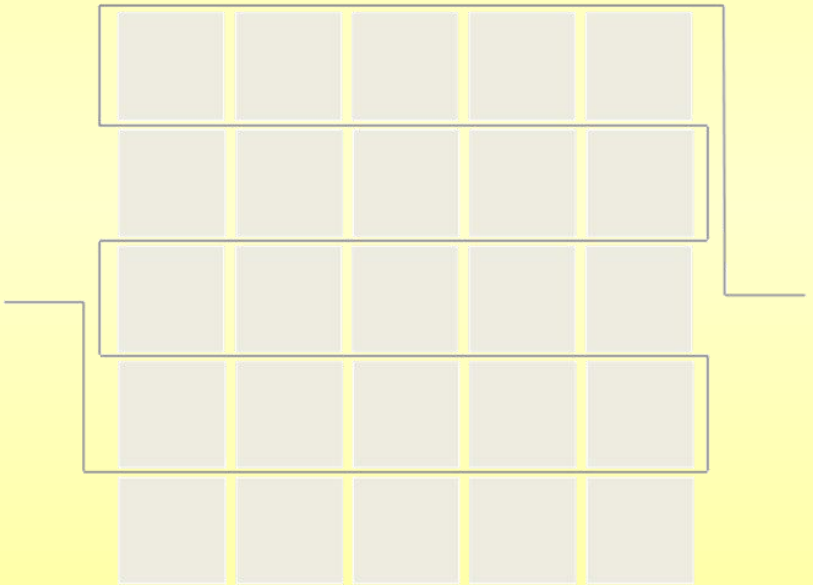
KID – Kinetic Inductance Detector





KID – Kinetic Inductance Detector





KID - Summary

- Less expensive than Bolometers
- Easy to fabricate
- Naturally multiplexed
- Short time constant
- Less sensitive to temperature fluctuation
- Vibration insensitive
- Antenna coupling - can have multi band/polarization or very wideband