

Uno sguardo all'origine dell'Universo con rivelatori di nuova generazione



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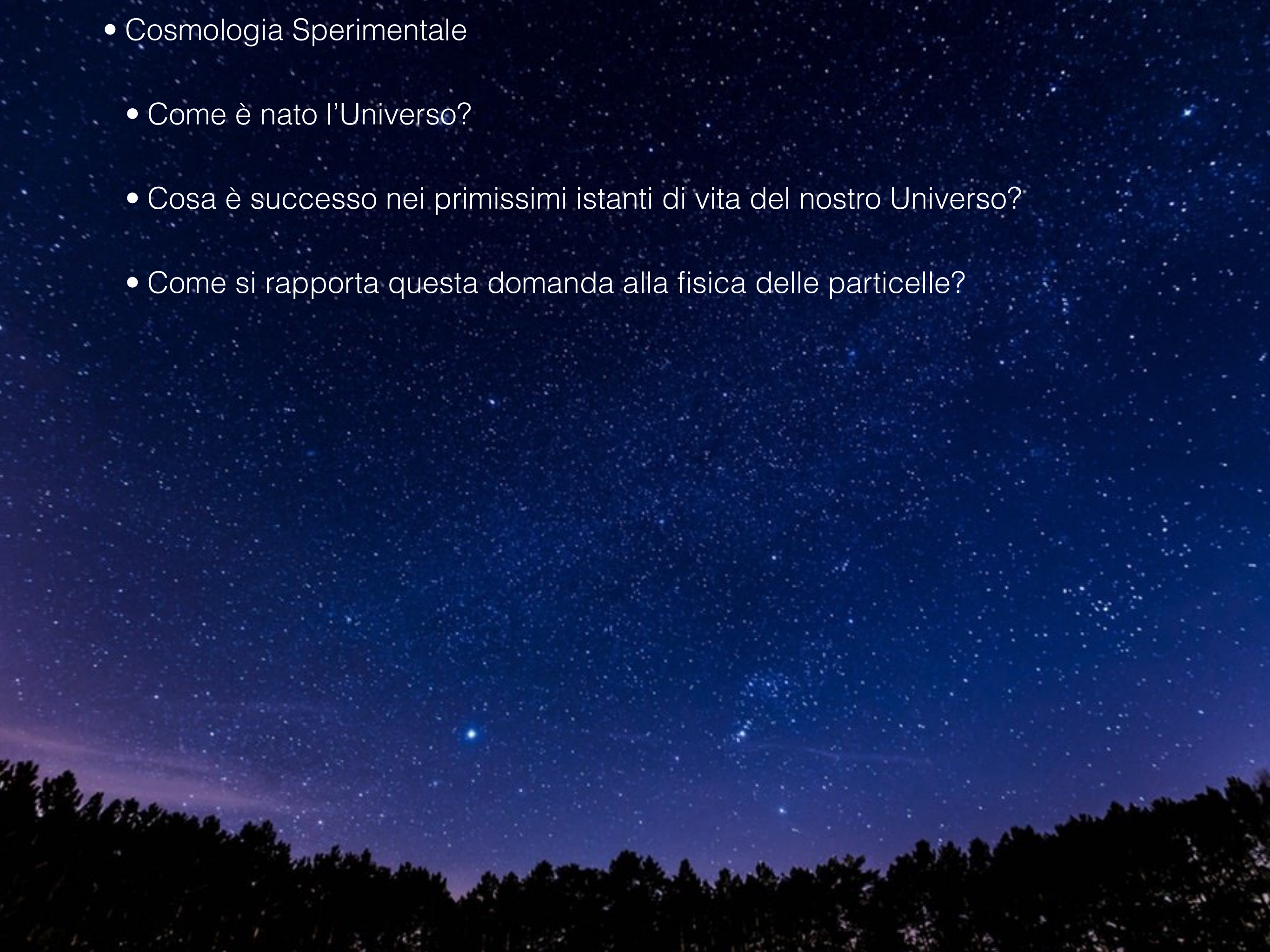


- Cosmologia Sperimentale

- Come è nato l'Universo?

- Cosa è successo nei primissimi istanti di vita del nostro Universo?

- Come si rapporta questa domanda alla fisica delle particelle?

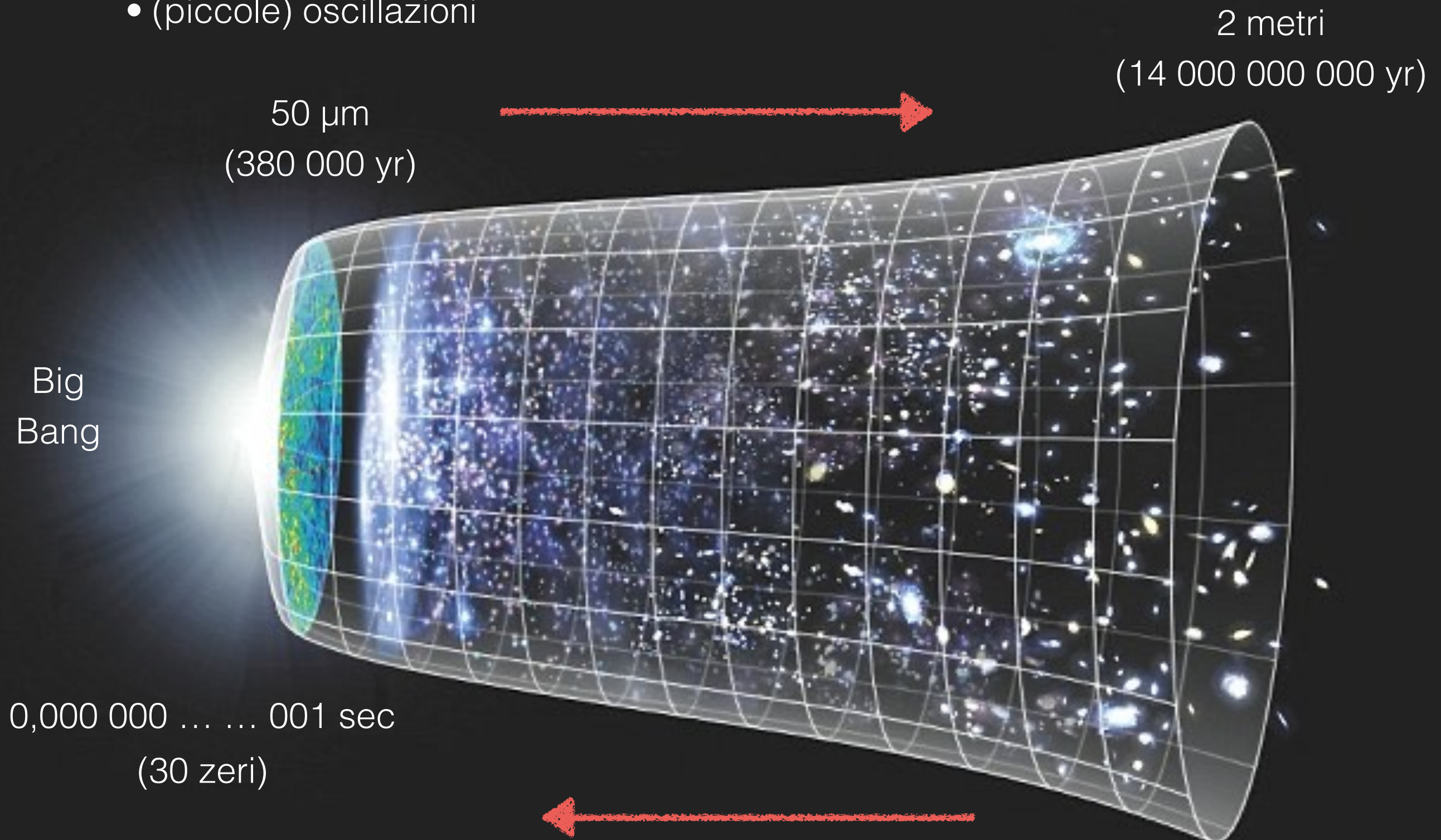


- Guardare lontano = guardare indietro nel tempo

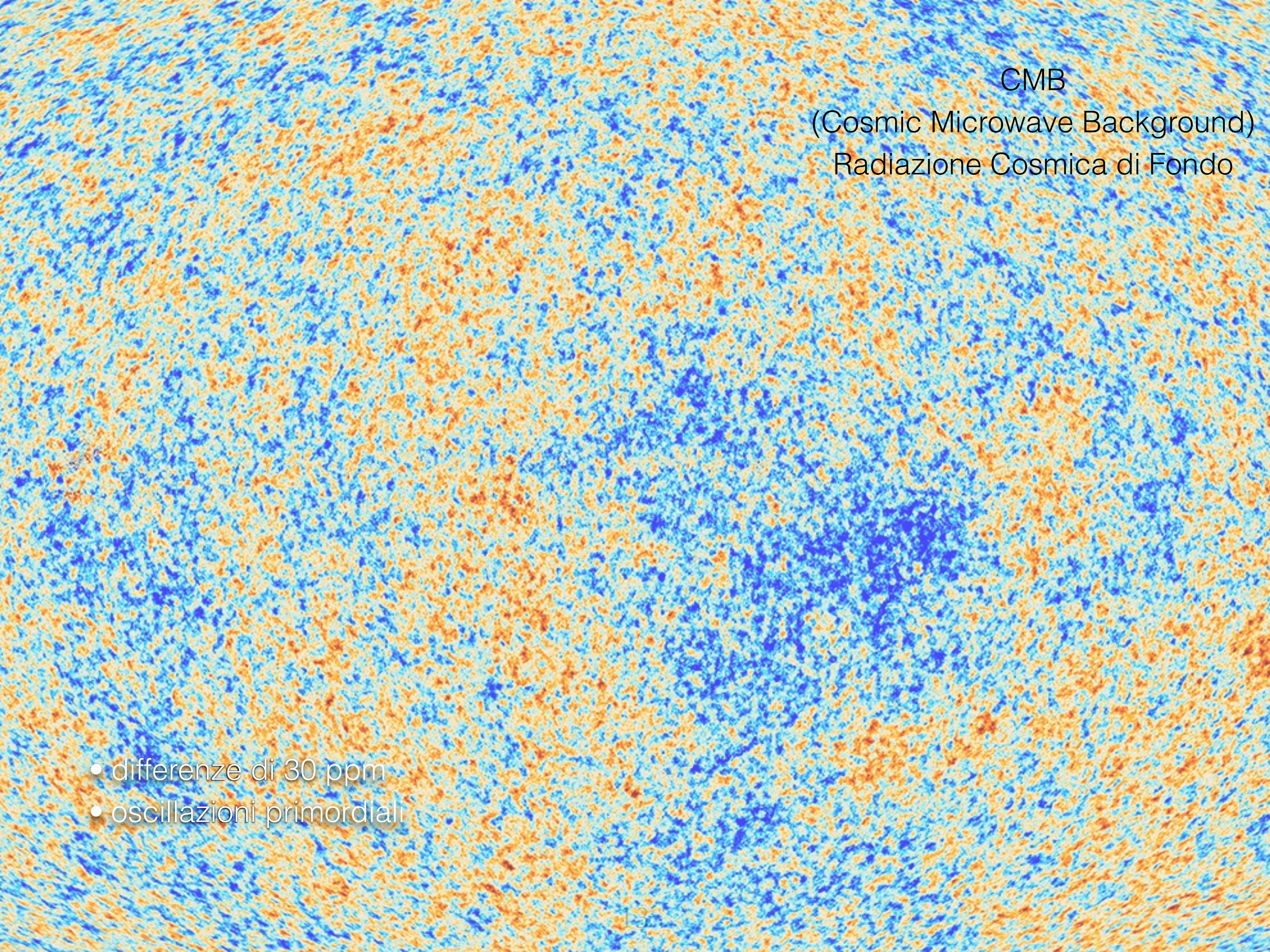


- Quindi se guardiamo lontano possiamo vedere l'universo primordiale?
- L'universo non è sempre stato così come lo conosciamo

- L'universo è in espansione
- Osserviamo un universo più “piccolo”
 - Conservazione dell'Energia $\rightarrow$ T maggiore
 - (piccole) oscillazioni



- 3 000 K $\rightarrow$ 2.7 K (−270 C)
- ora lo osserviamo nelle microonde

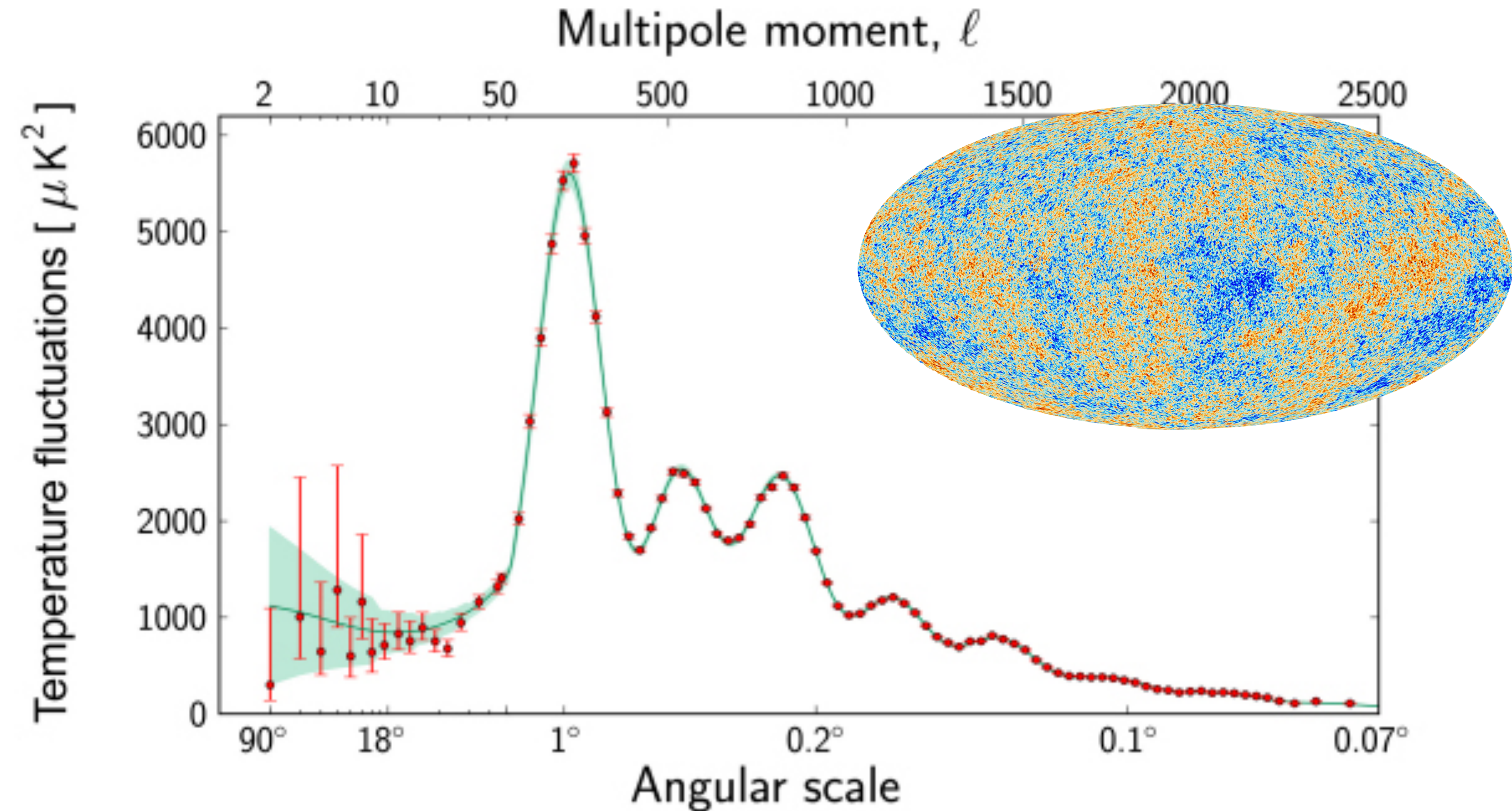


CMB

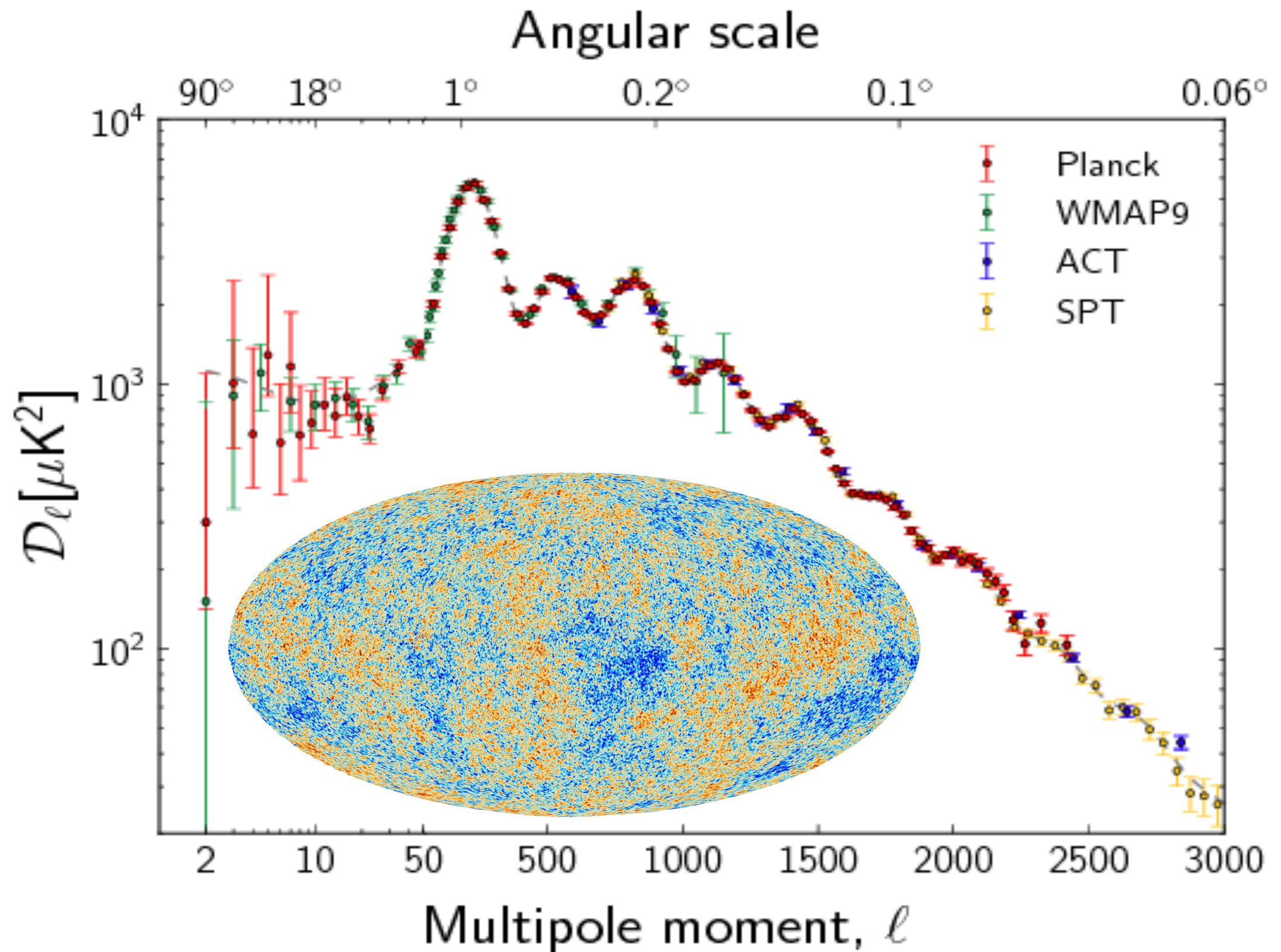
(Cosmic Microwave Background)
Radiazione Cosmica di Fondo

- differenze di 30 ppm
- oscillazioni primordiali

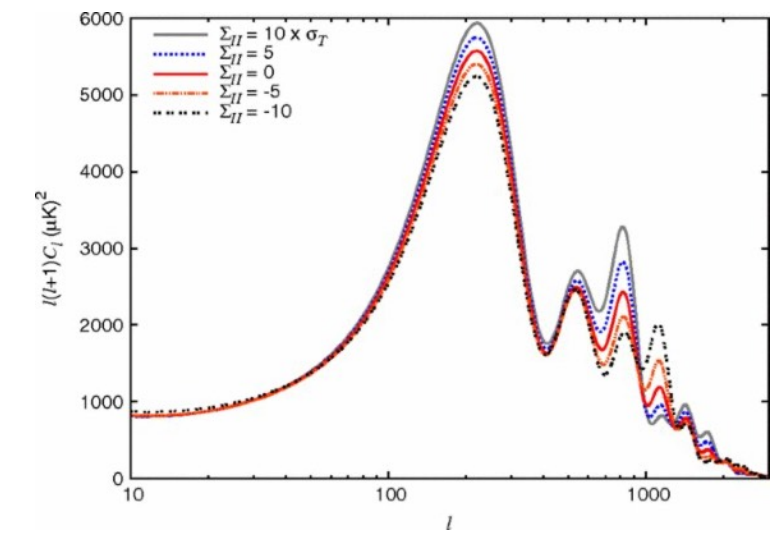
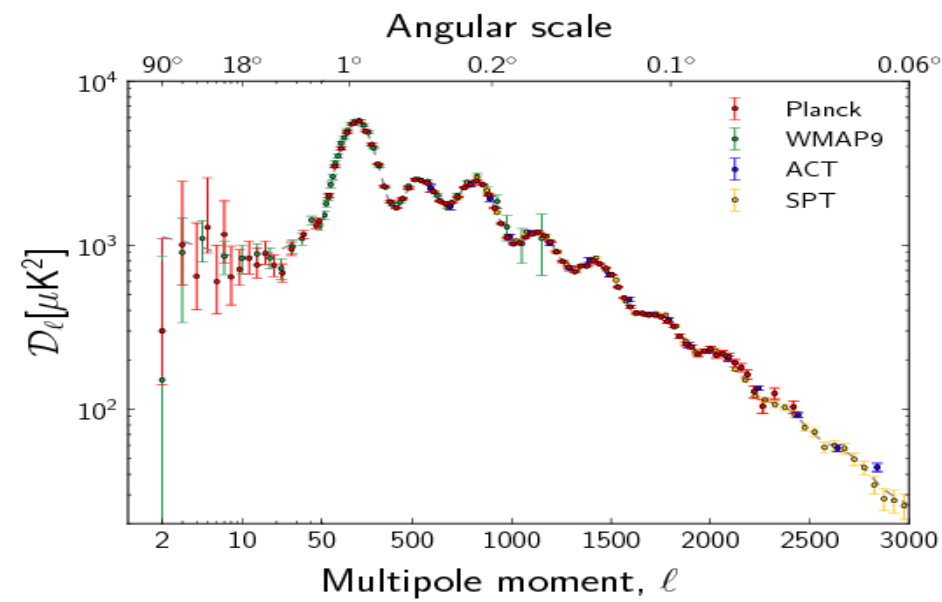
- **posizione** dei **picchi** → **dimensioni** (geometria) dell'universo
- **ampiezza** relativa dei **picchi** → “**materiale** di cui è composto”



- **posizione** dei **picchi** → **dimensioni** (geometria) dell'universo
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instrument wave shape

violin



flute



clarinet



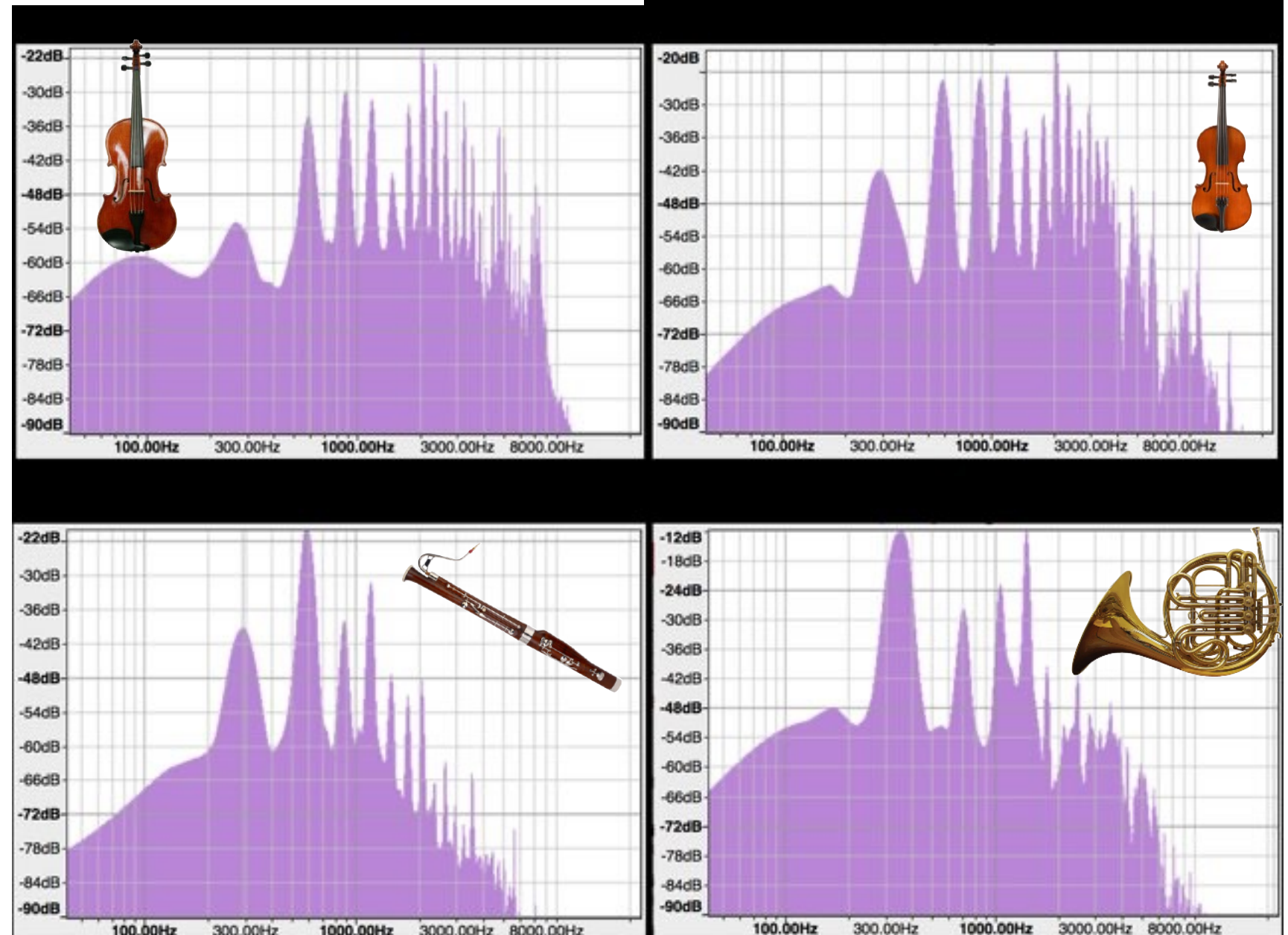
trumpet

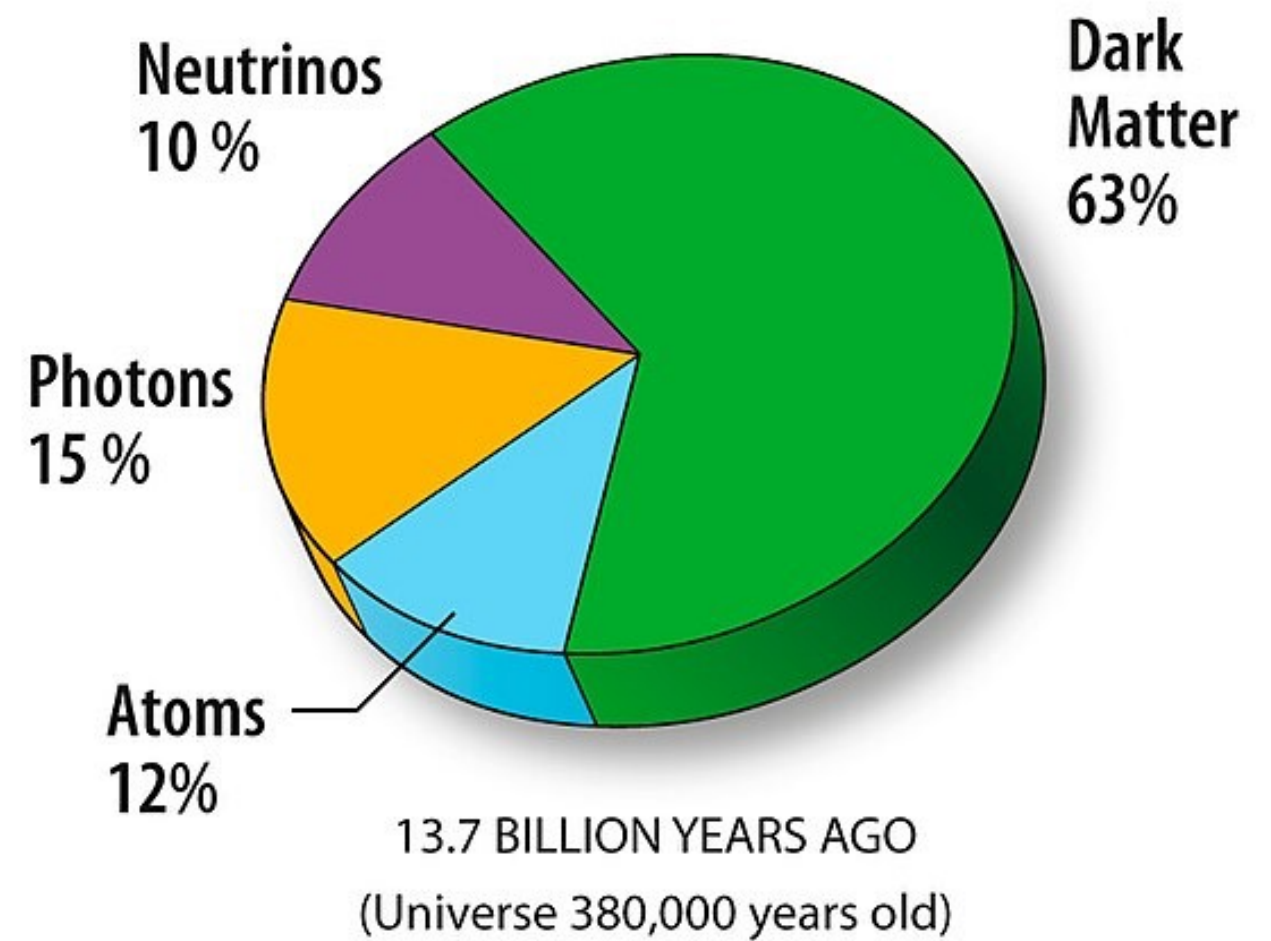
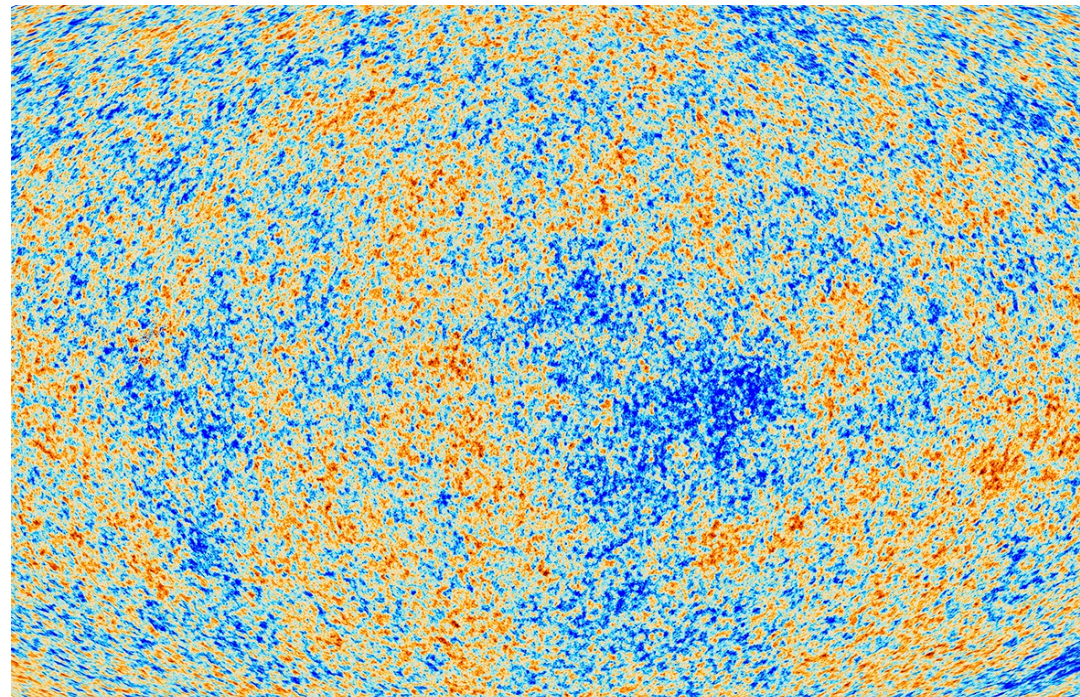
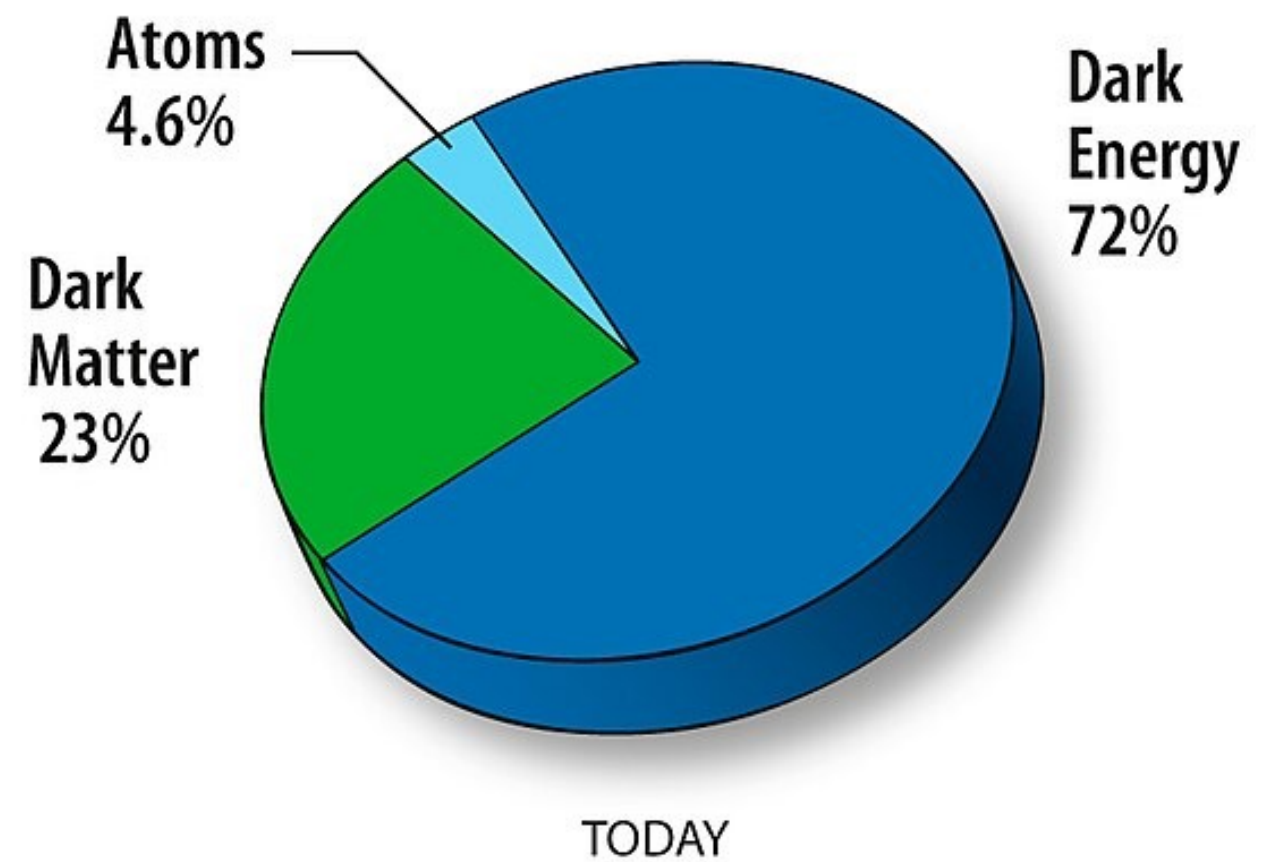


bell



cymbal



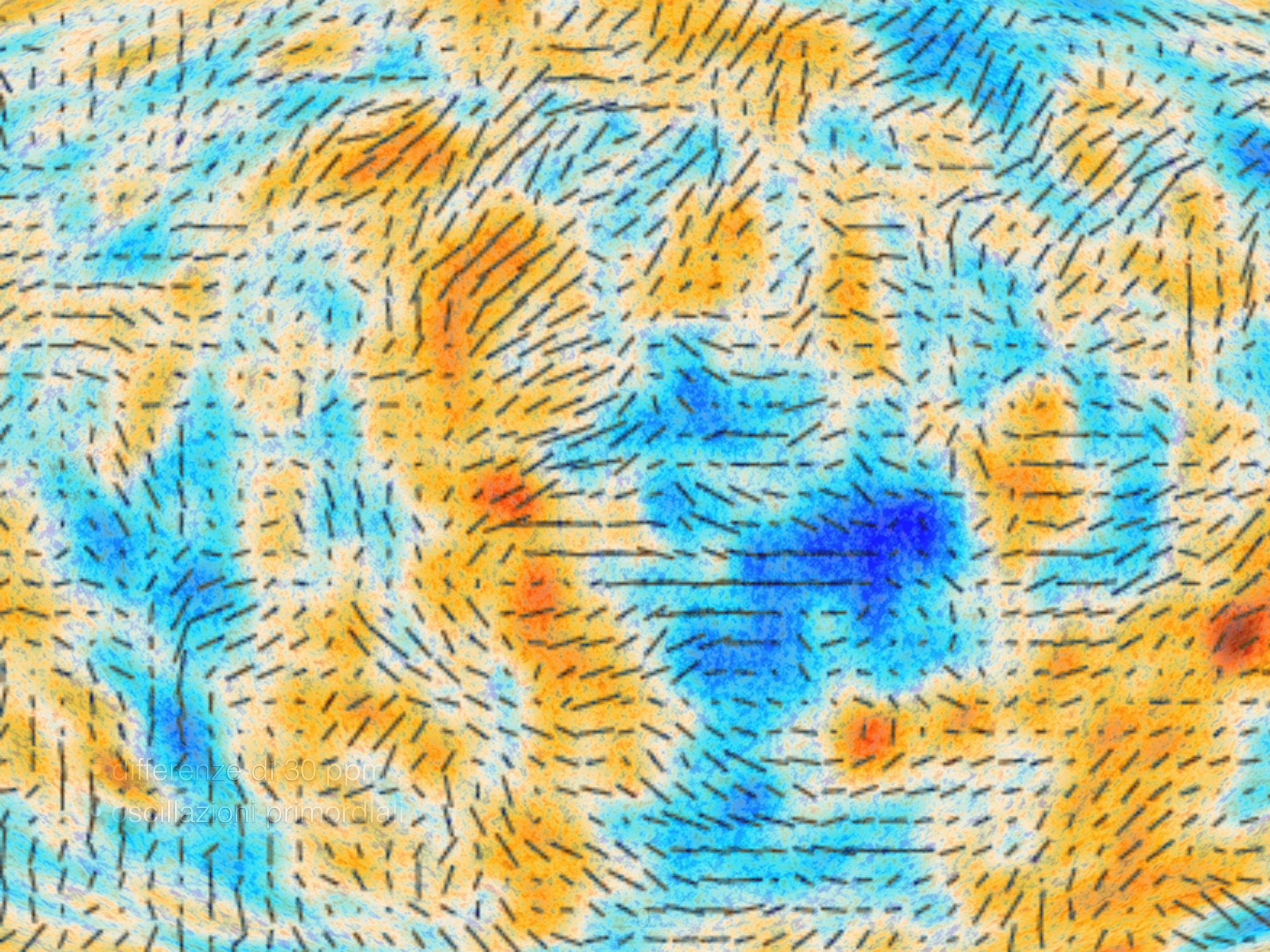


CMB

(Cosmic Microwave Background)

Radiazione Cosmica di Fondo

- 19



- differenze di 30 ppm
- oscillazioni primordiali

La polarizzazione, in fondo, non è così esotica...
(Tenete a mente la connessione tra riflessione della luce e polarizzazione)



32.46 € su Amazon

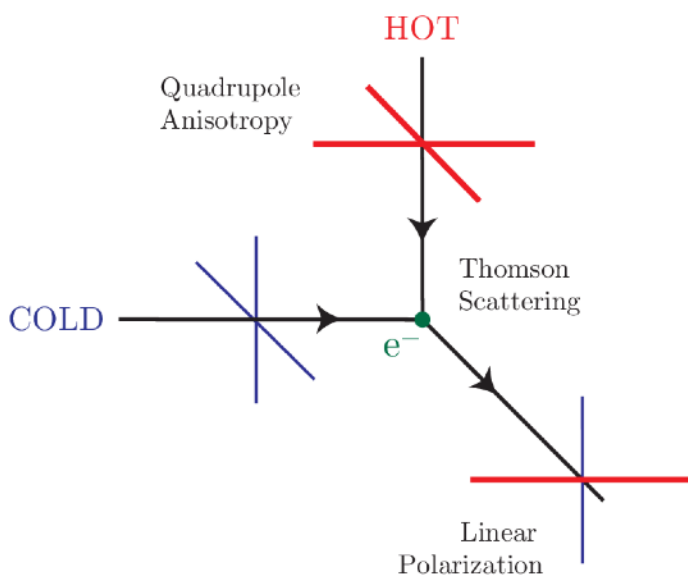


Without Filter

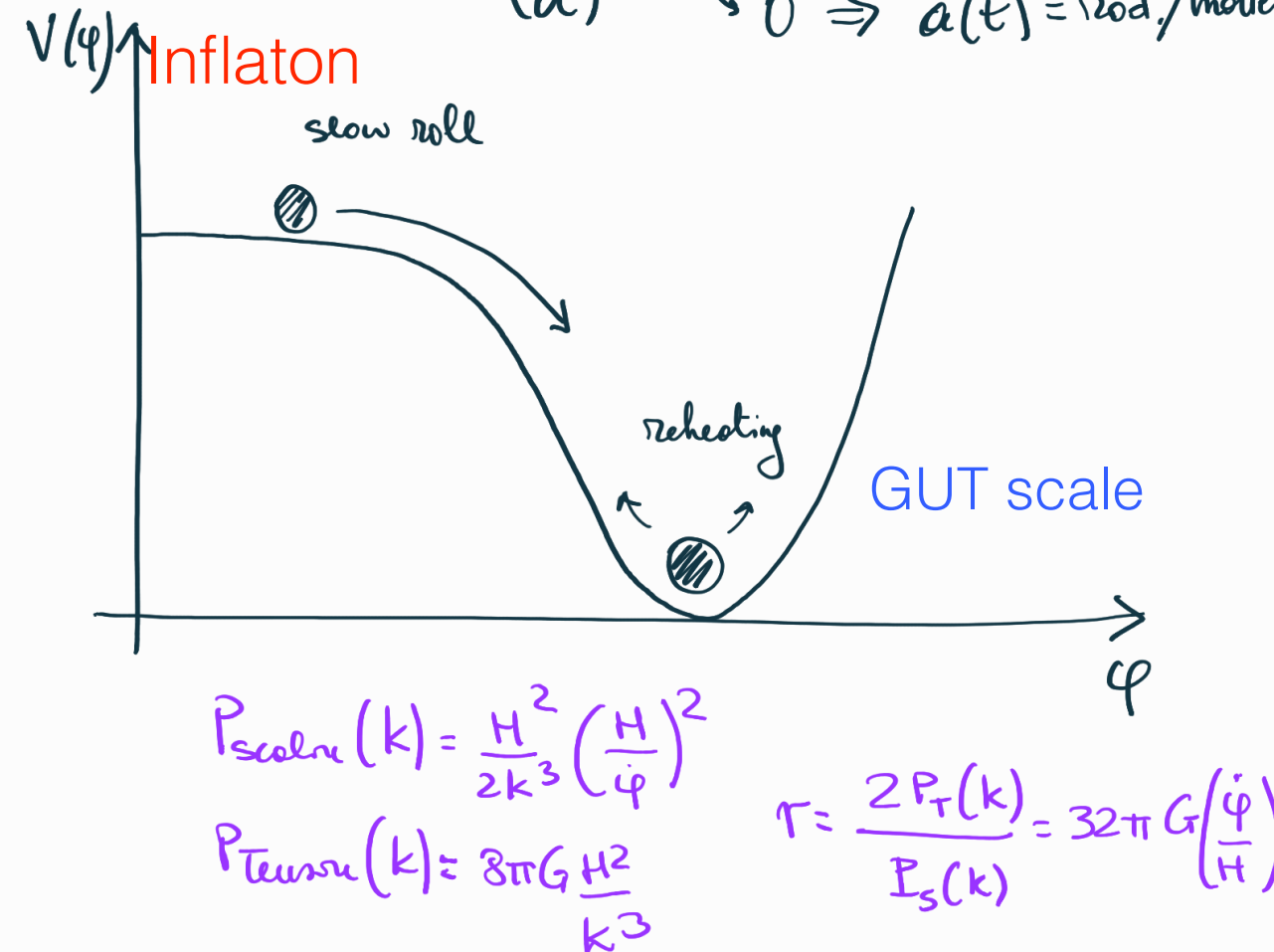
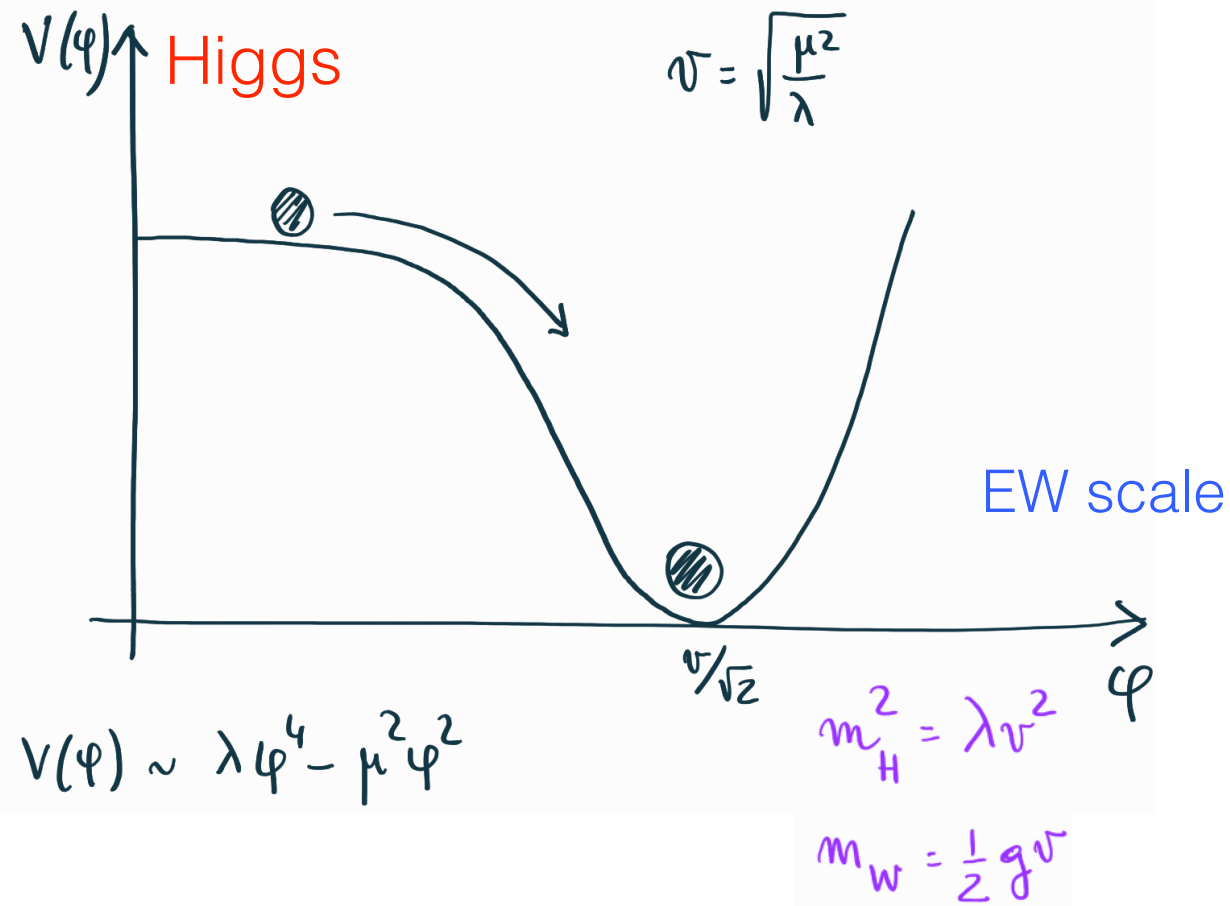


With Filter

- in realtà vogliamo misurare proprio la **luce riflessa** (e dunque **polarizzata**), perchè si porta dietro l'informazione sulla scala di energia dell'emissione delle onde gravitazionali primordiali.



- Straordinariamente simile al [meccanismo di Higgs](#)



- **Potenziale** → transizione da [falso vuoto](#) a [vero vuoto](#)

Higgs

- $SU(3) \times SU(2) \times U(1) \rightarrow SU(3) \times U(1)_{\text{e.m.}}$
- parametri del potenziale dal rapporto M_W/M_{Higgs}

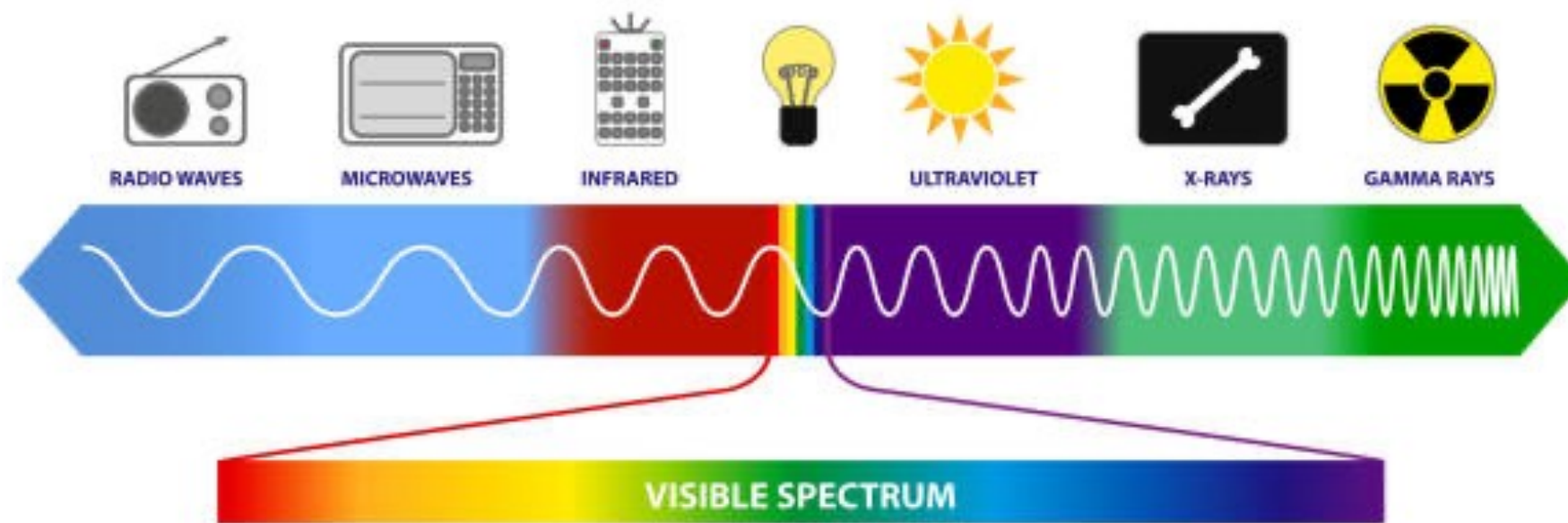
Inflatone

- $GUT \rightarrow SU(3) \times SU(2) \times U(1)$
- parametri del potenziale dal rapporto $r = \text{fluttuazioni tensoriali/fluttuazioni scalari}$
- Limite attuale $r \sim 0.07$ (Planck/Bicep)

$$r \approx 0.008 \left(\frac{V_{\text{infl}}}{10^{16} \text{ GeV}} \right)^4$$

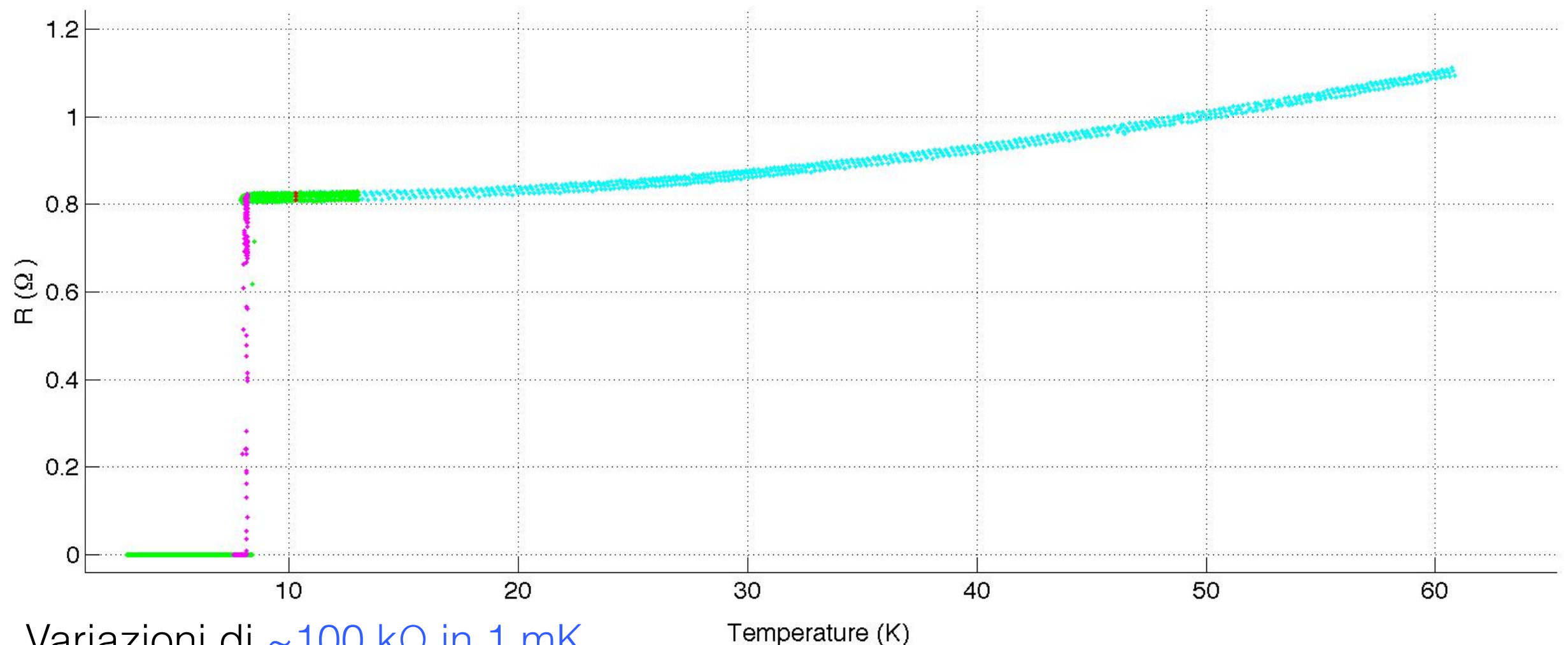
Misurare le microonde

- Le microonde, così come i raggi infrarossi, misurano la “temperatura”



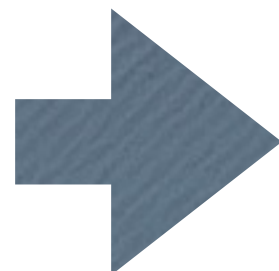
Superconduttività

- Misurare le **fluttuazioni di temperatura** con **risoluzione del nK**
- Alcuni materiali a temperature sufficientemente basse presentano **resistenza nulla** alla corrente **continua**



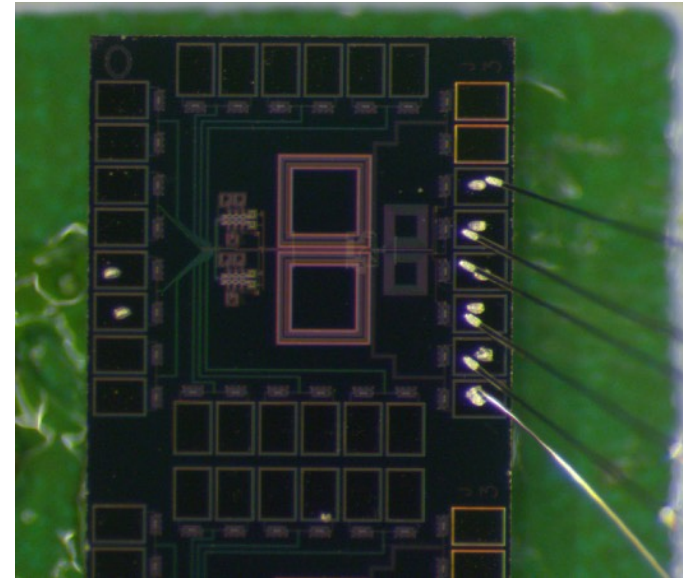
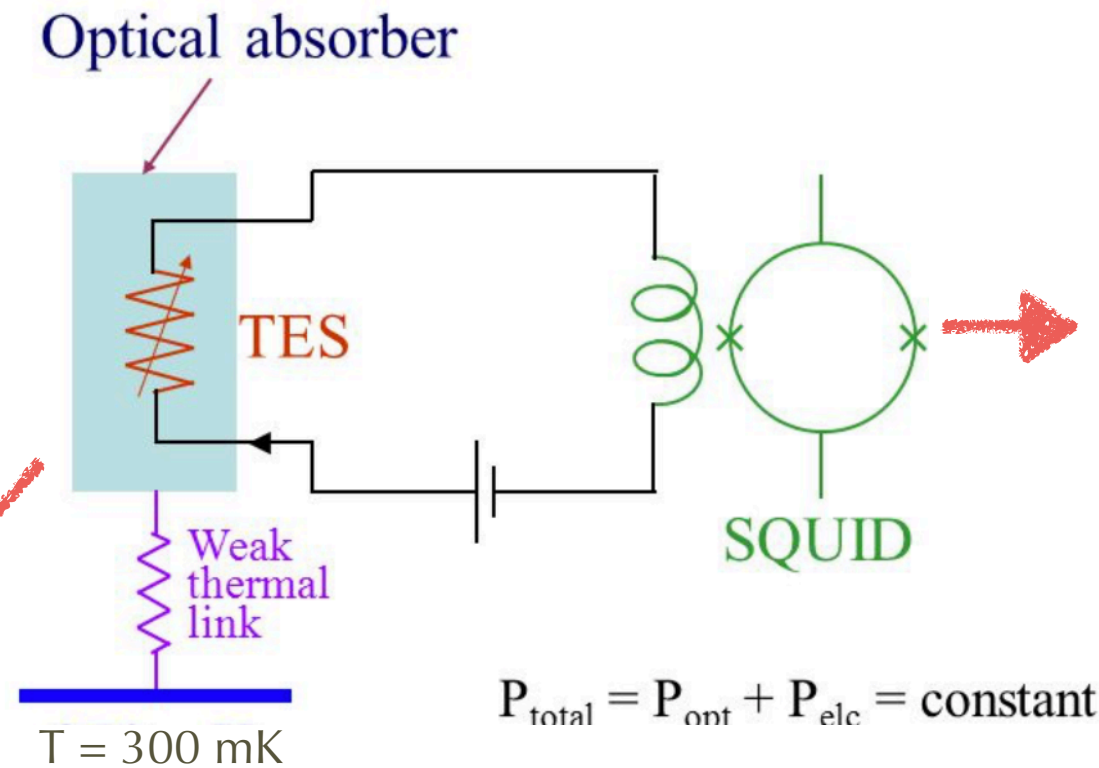
$$\Delta\Omega = 100 \text{ k}\Omega$$

$$\Delta T = 1 \text{ mK}$$

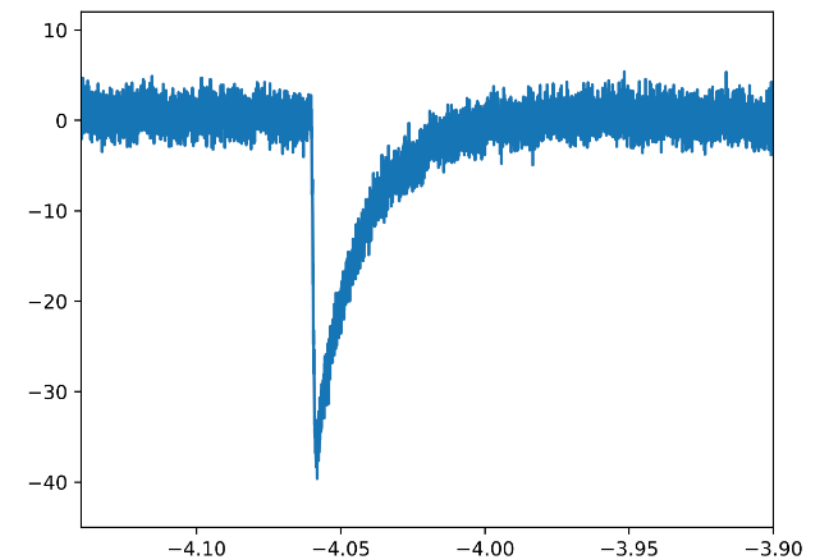
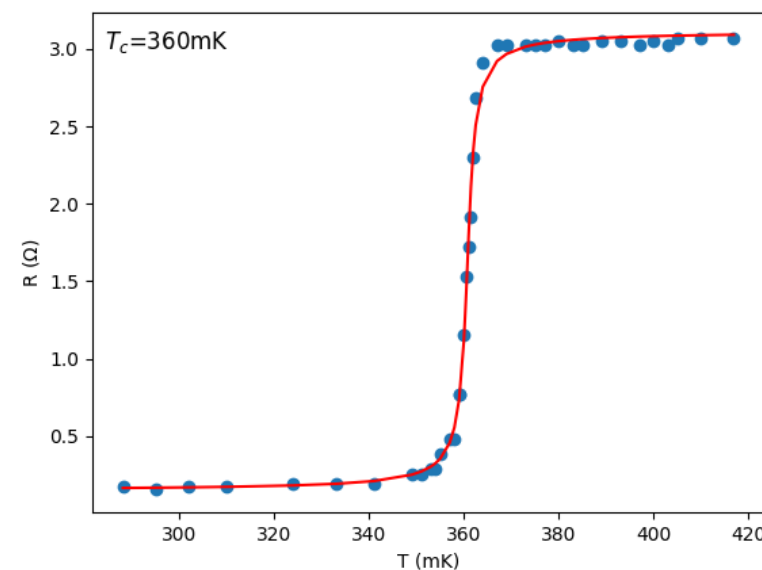
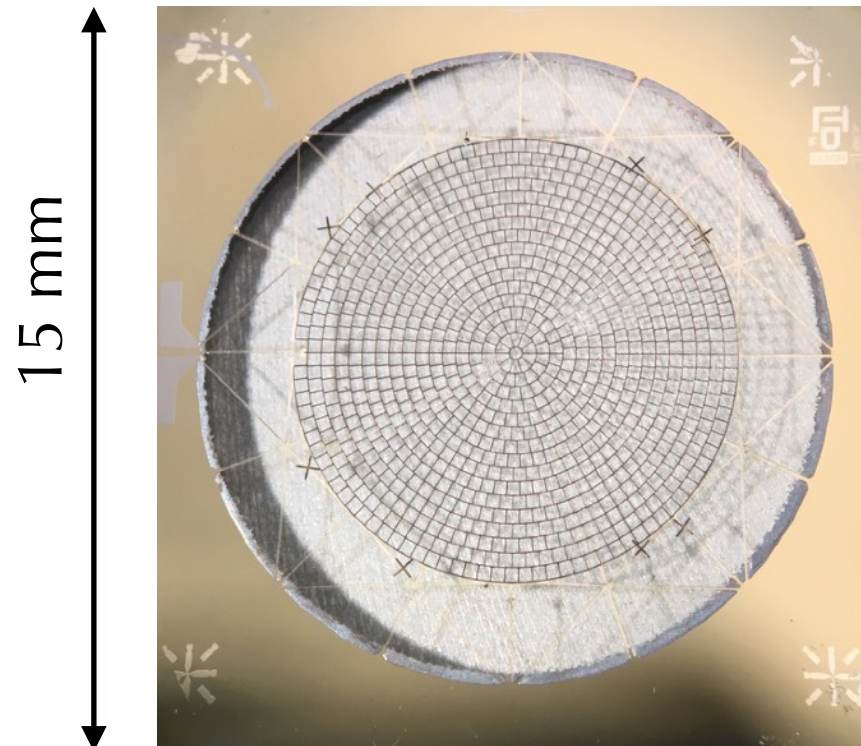


$$10^{-8} \text{ K}/\Omega$$

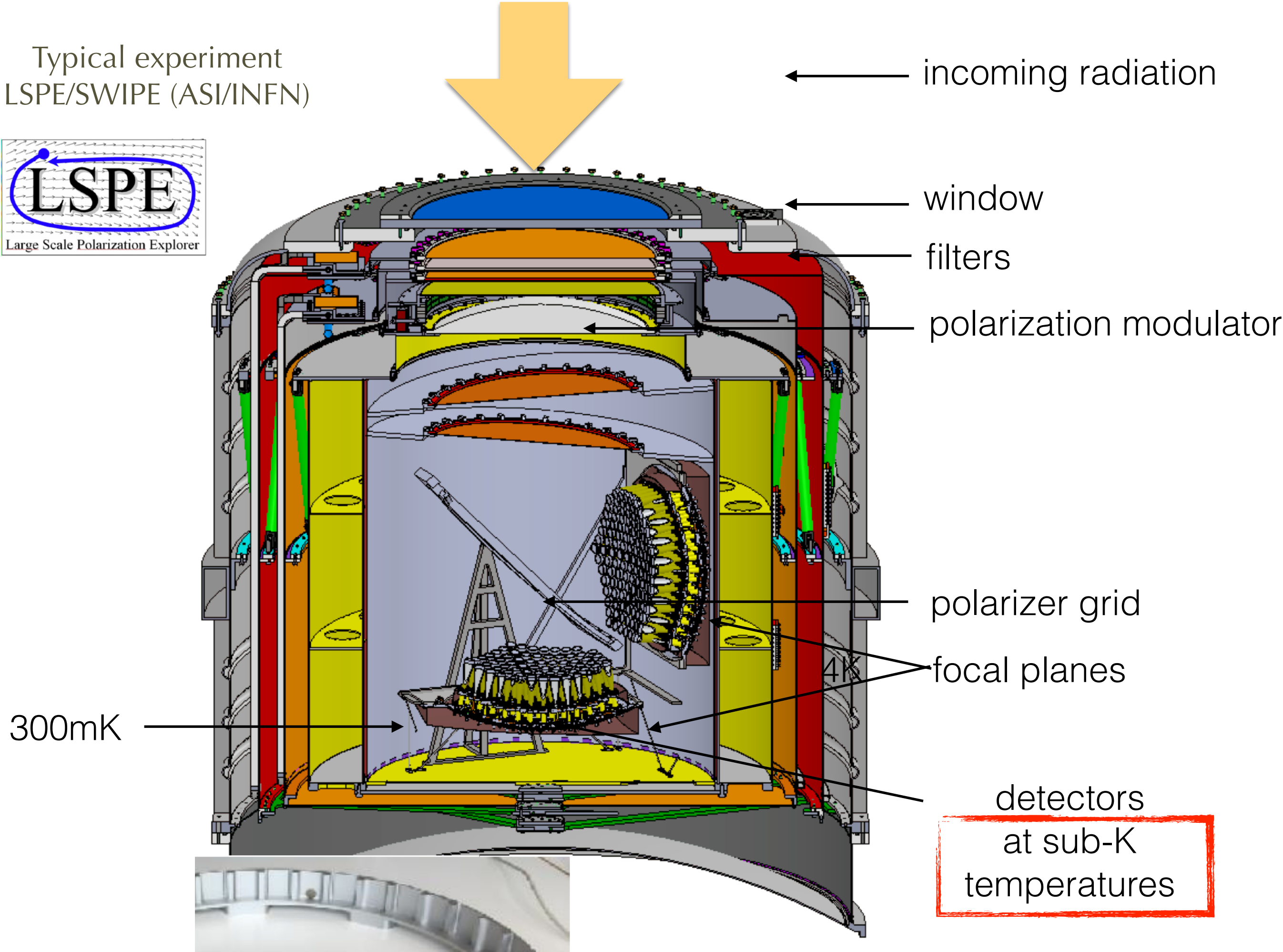
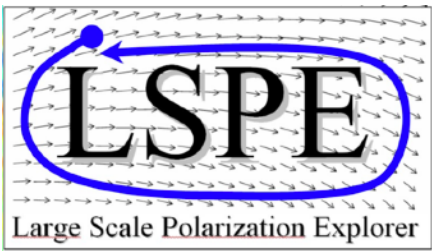
- Resistenza variabile inserita in un circuito
- Tensione di alimentazione
- Corrente letta da uno SQUID (Superconducting Quantum Interference Device)



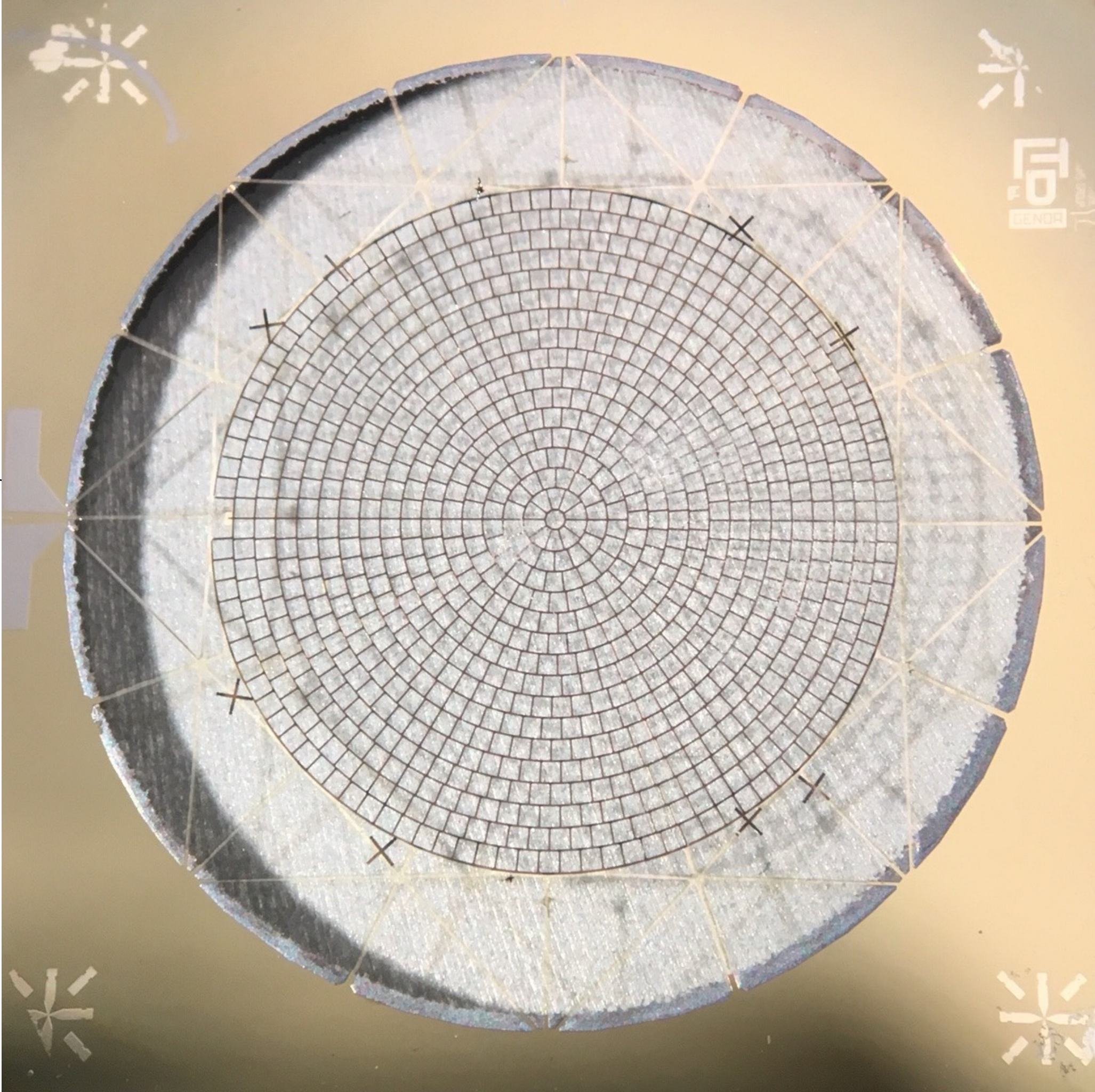
$$P_{\text{ott}} + \frac{V^2}{R} = C \frac{dT}{dt} + G(T - T_0)$$



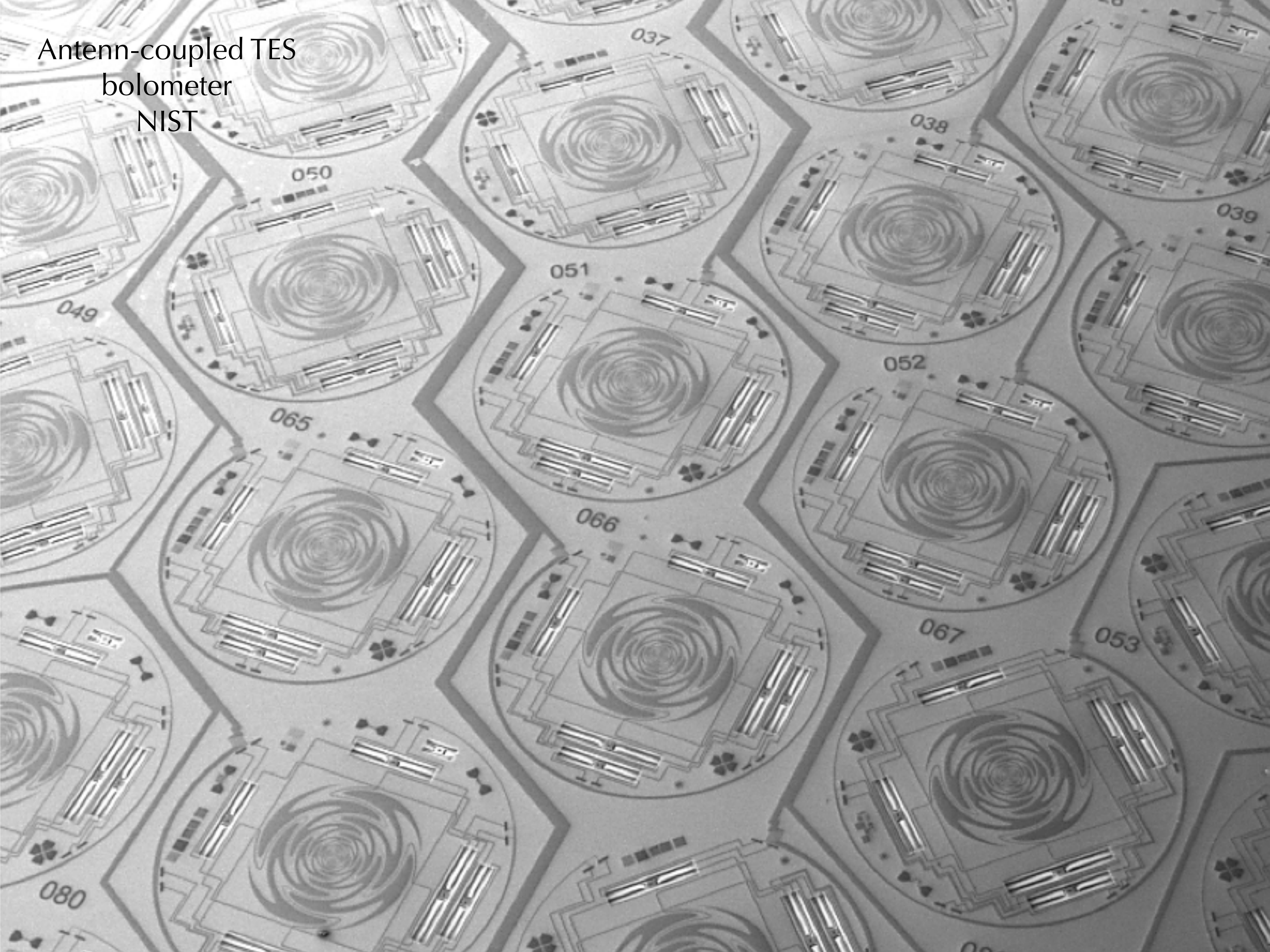
Typical experiment
LSPE/SWIPE (ASI/INFN)

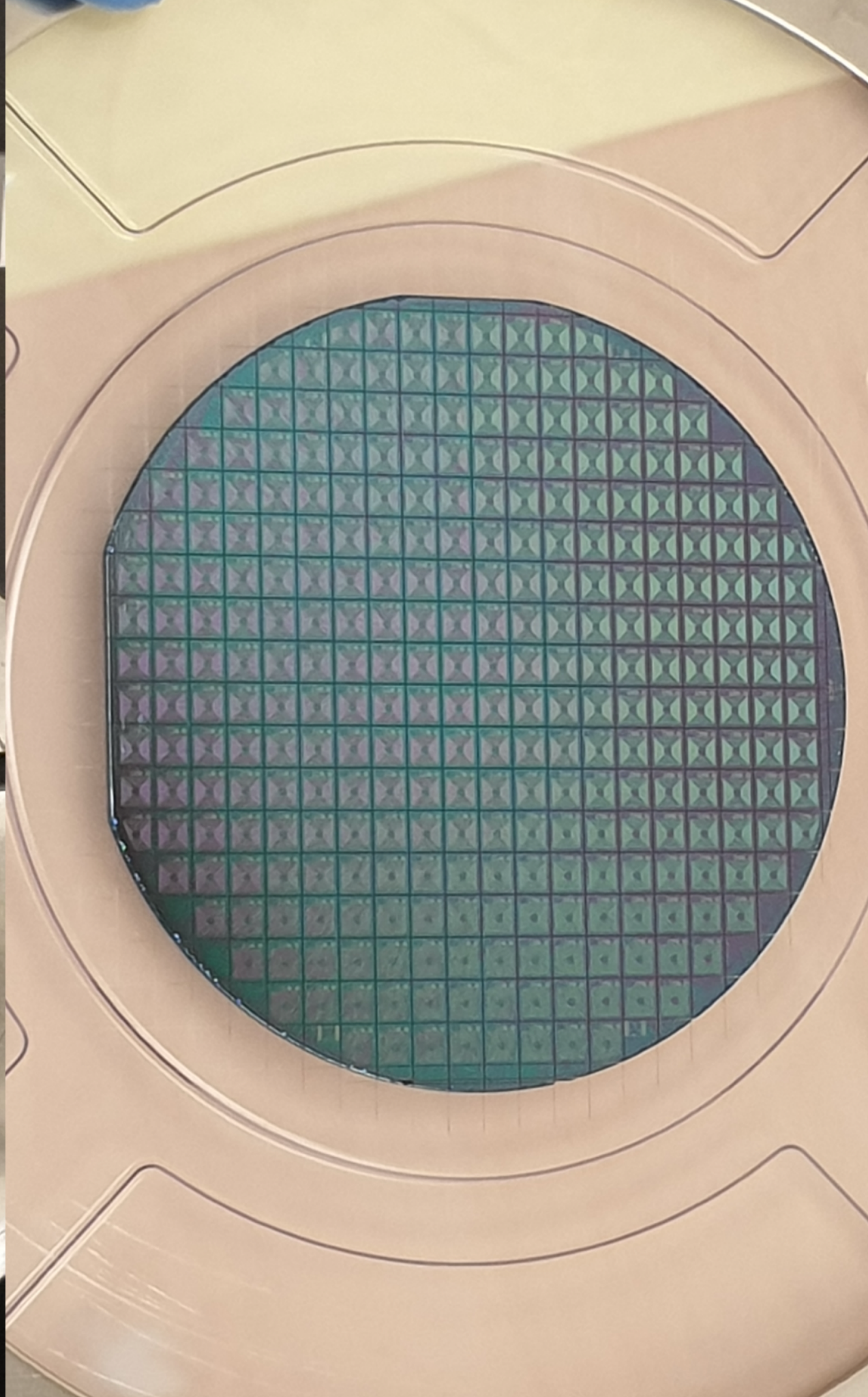
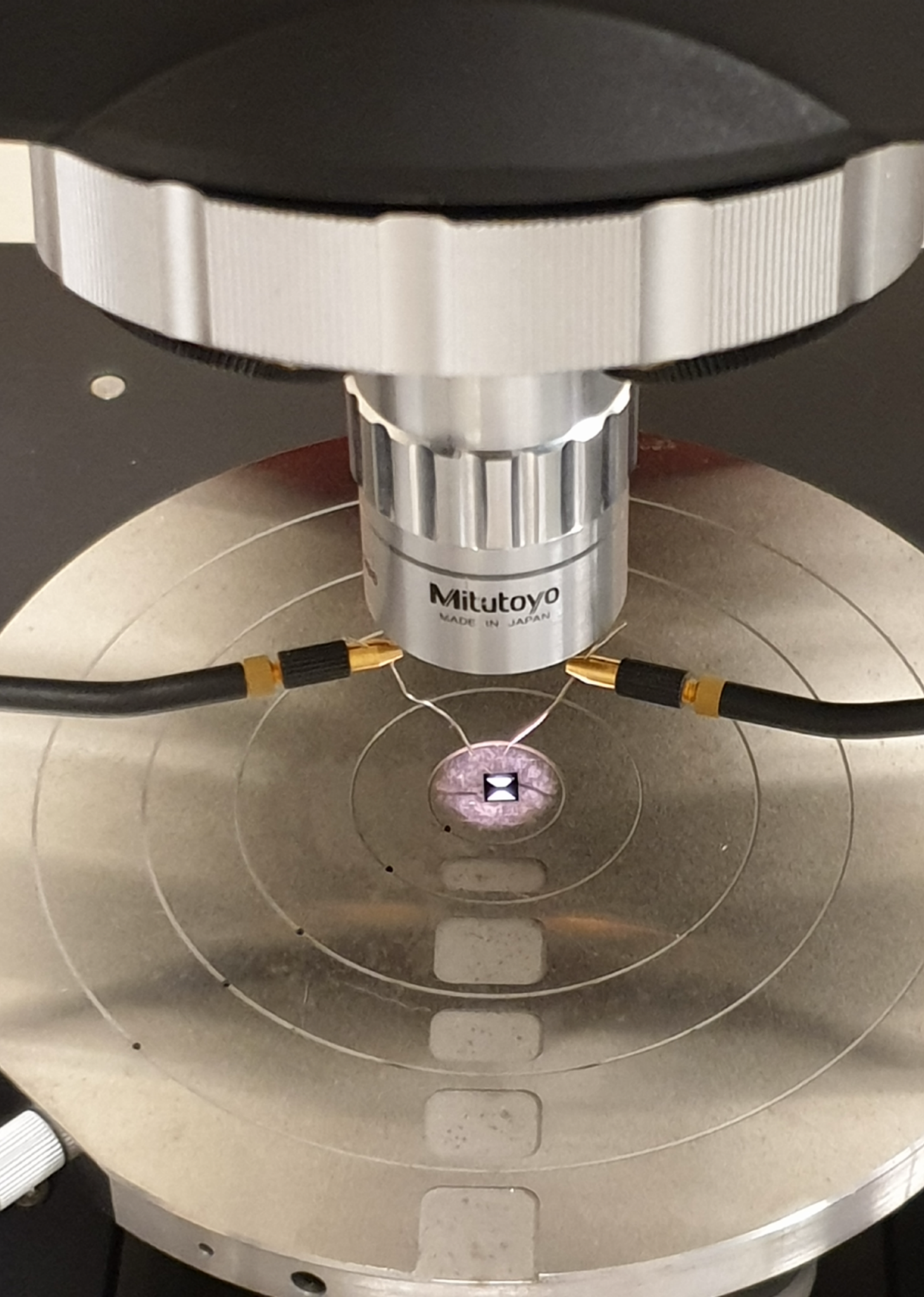


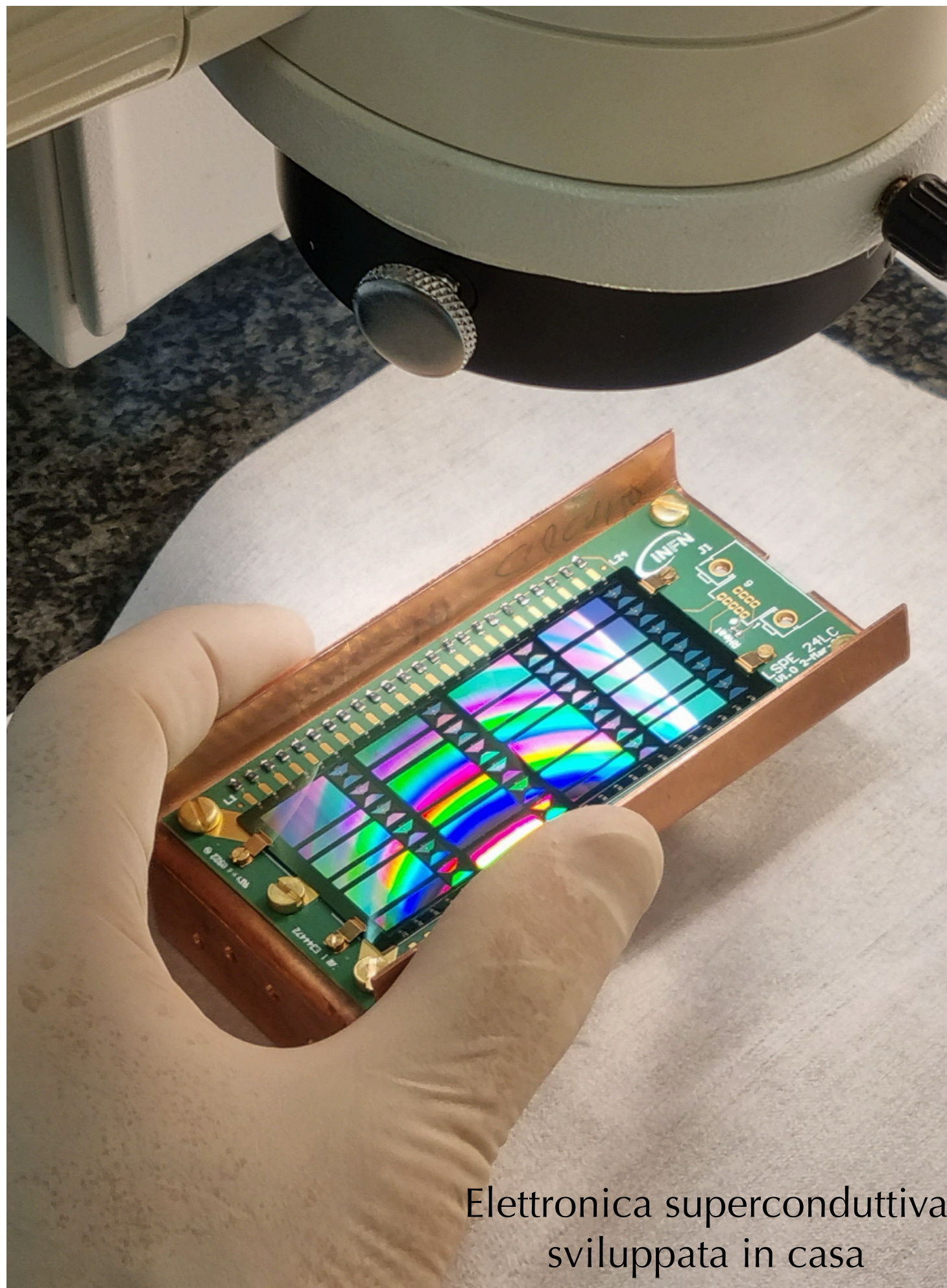
TES



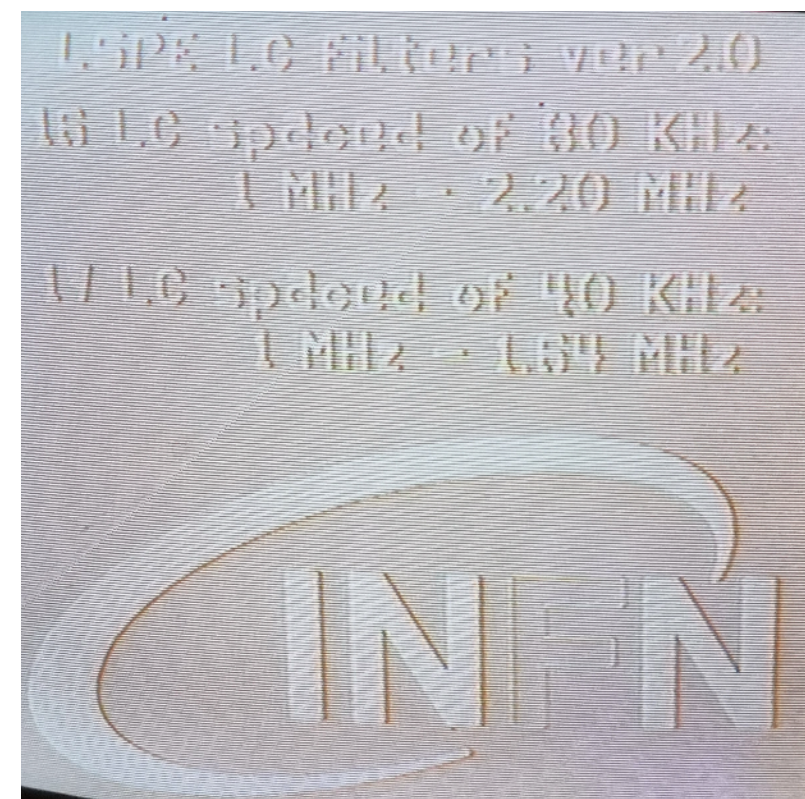
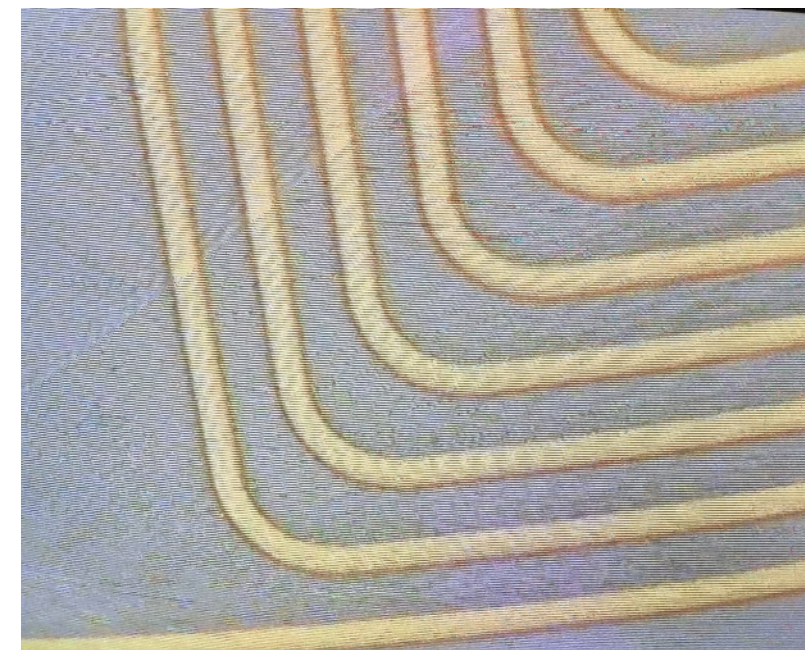
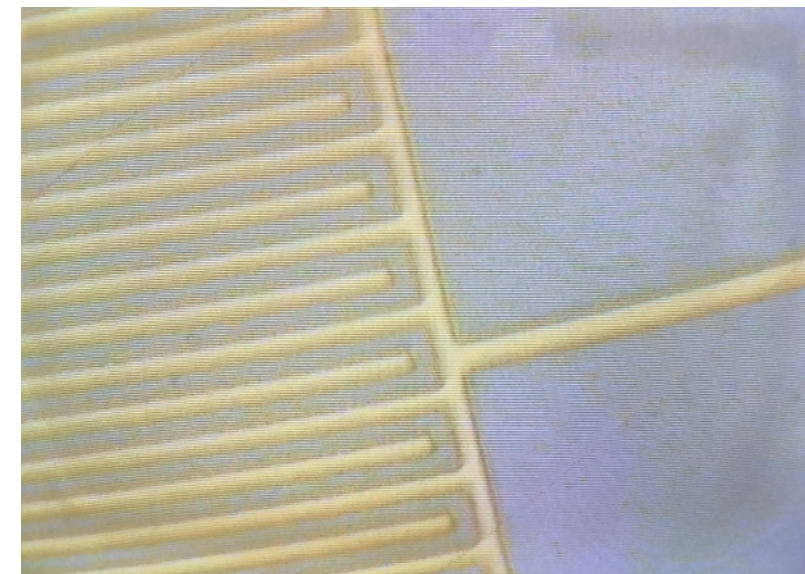
Antenn-coupled TES
bolometer
NIST

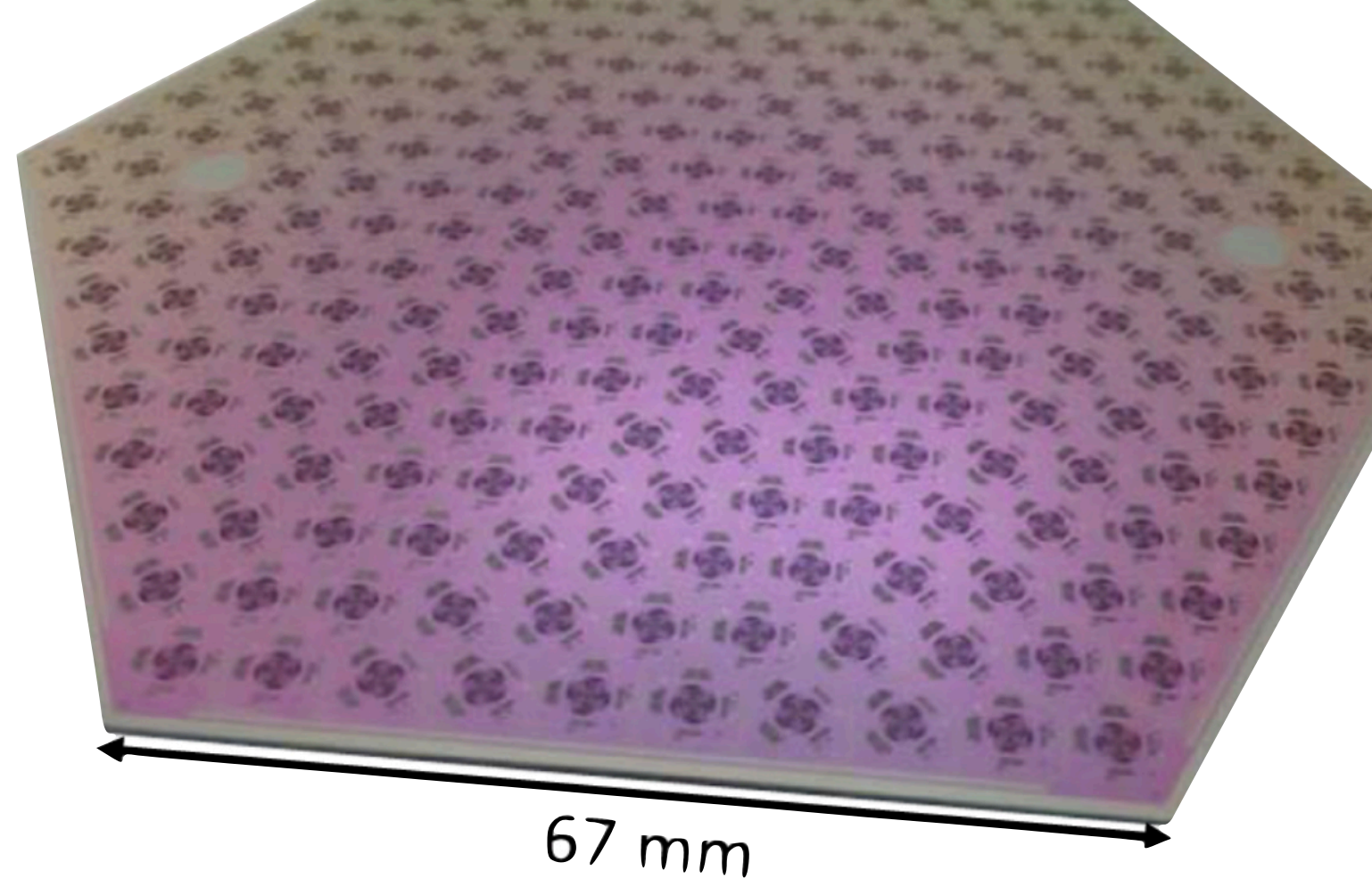
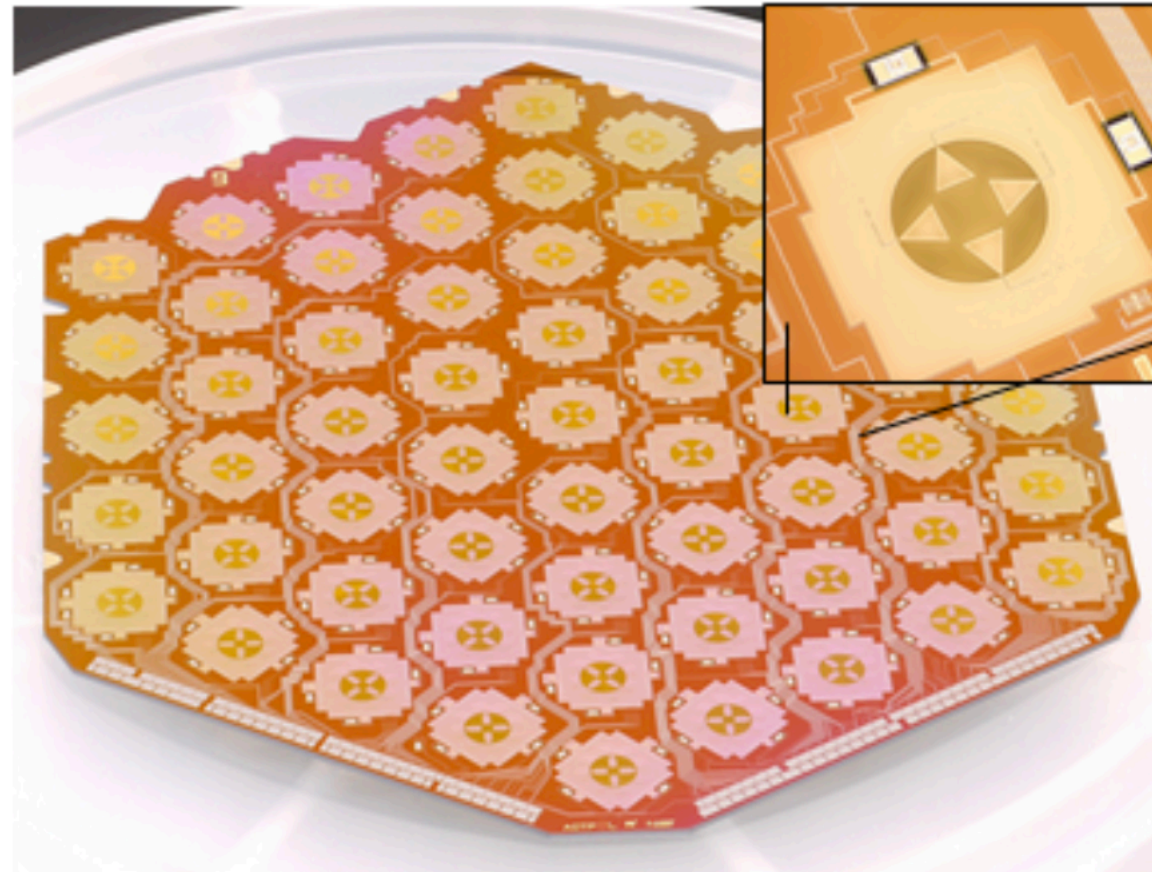




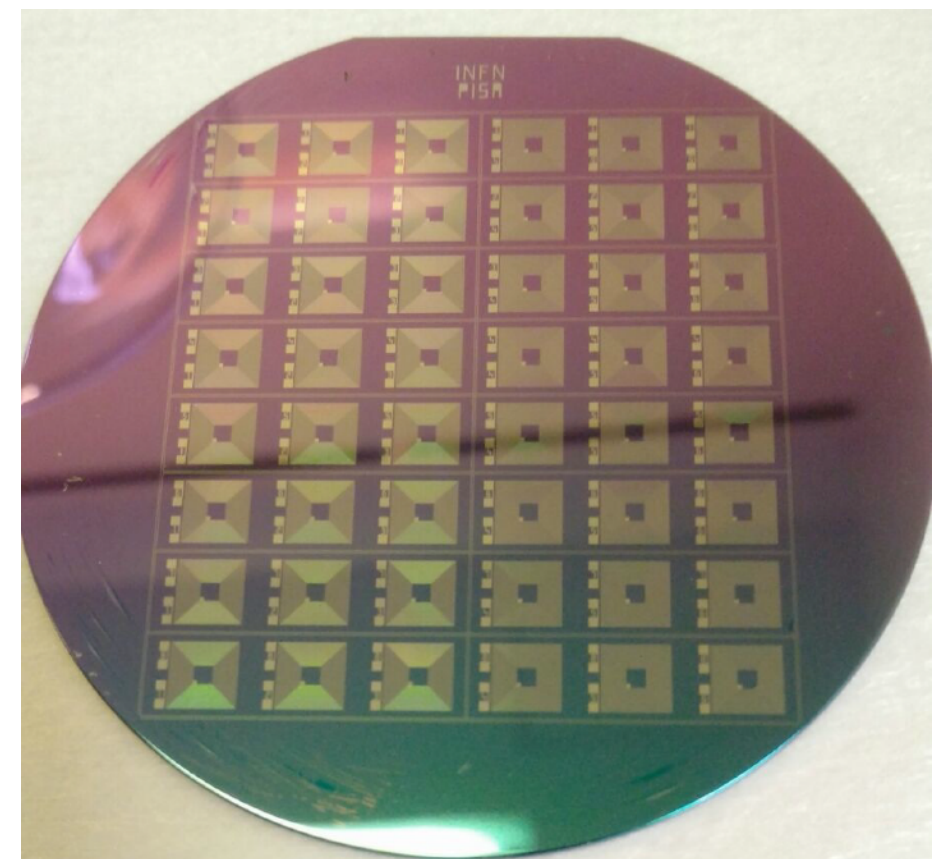
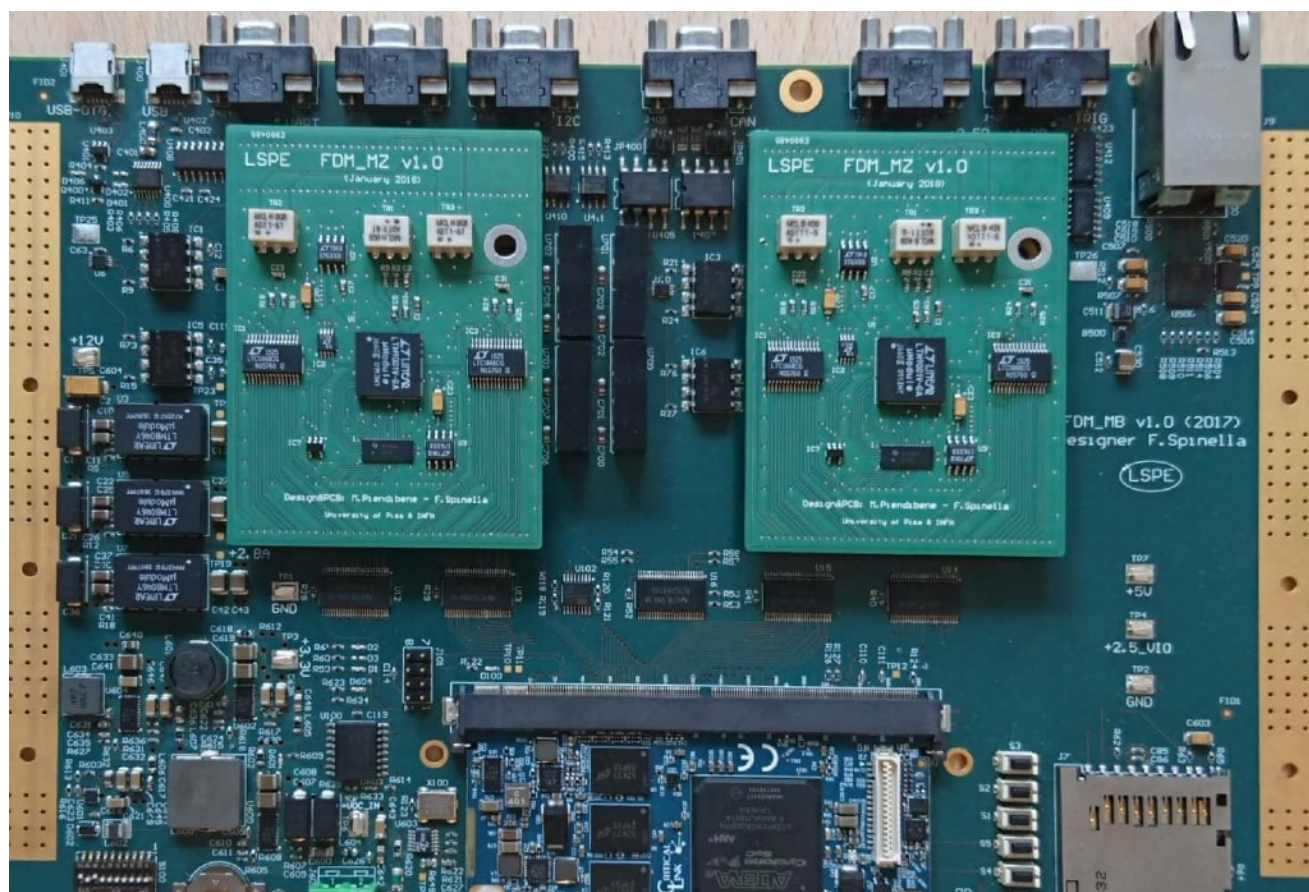


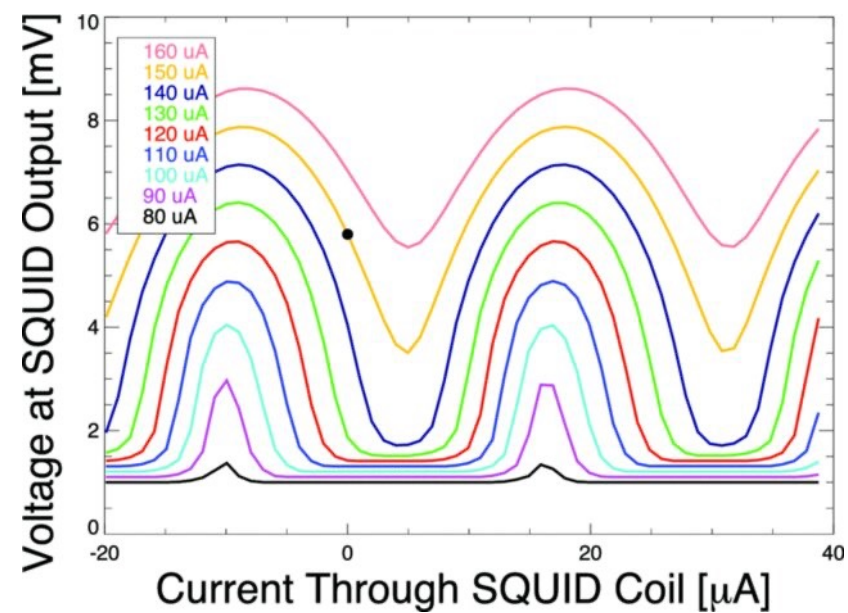
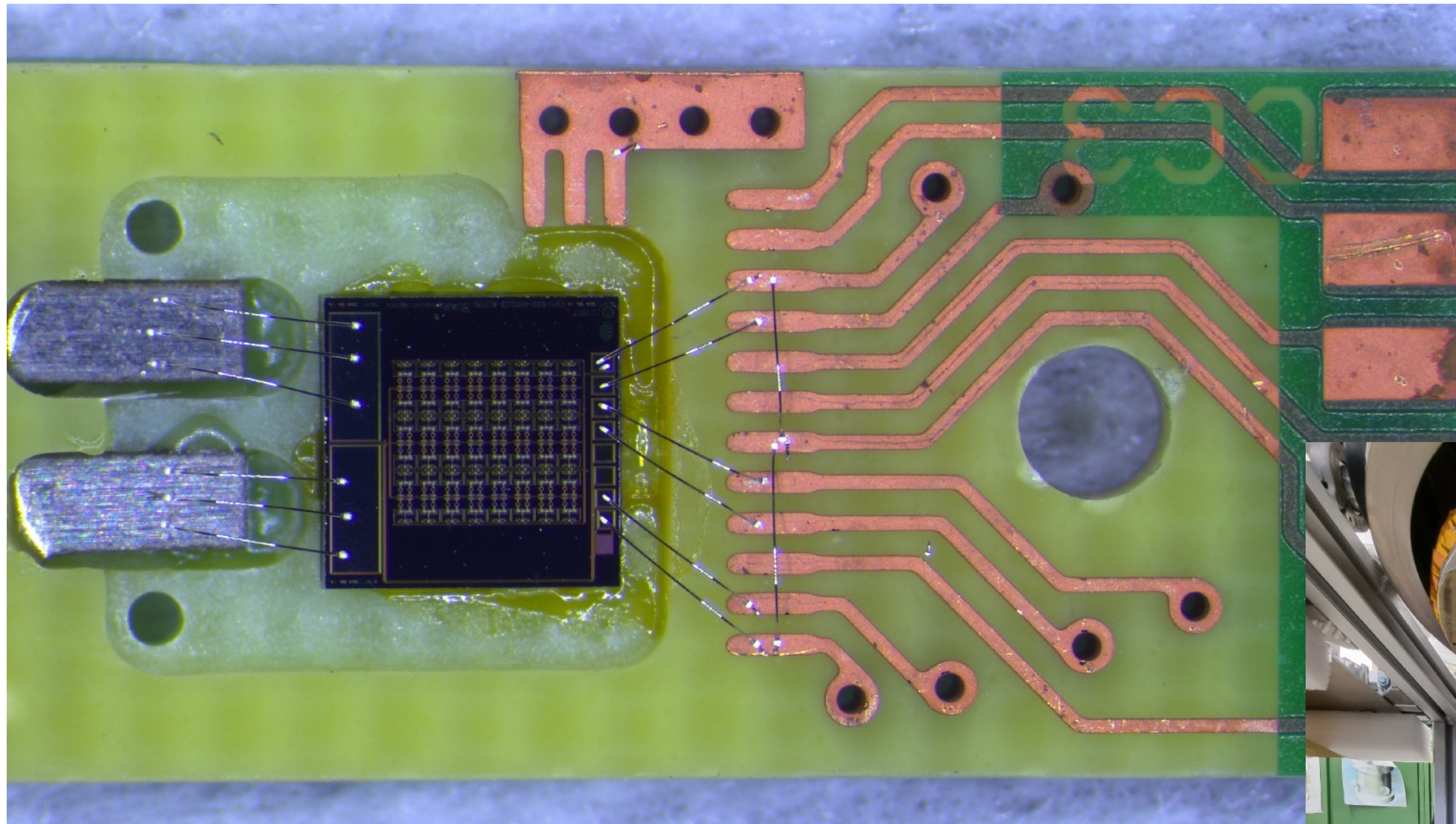
Elettronica superconduttiva
sviluppata in casa

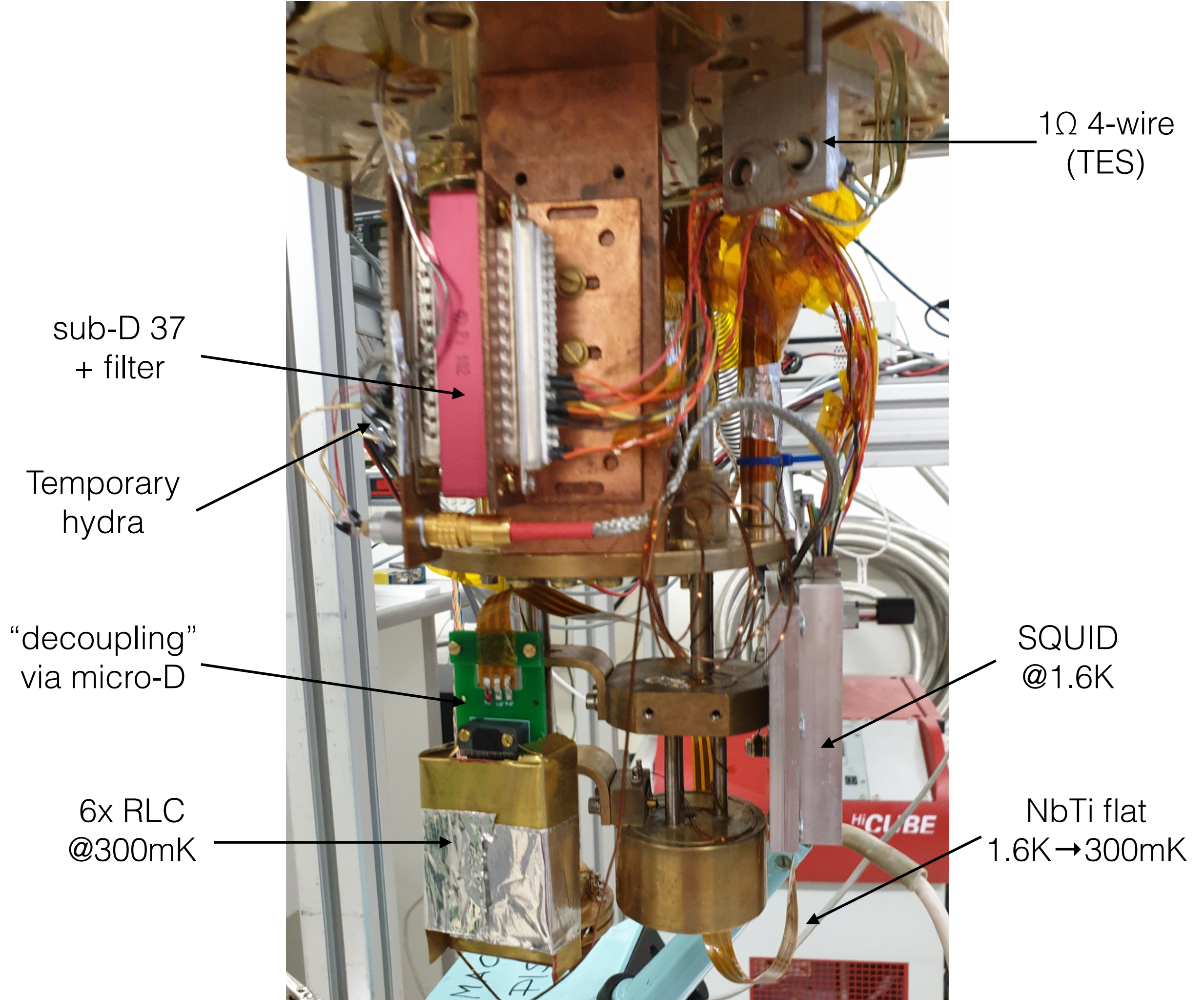




Array di centinaia o migliaia di detectors letti da un'elettronica "che non esiste"







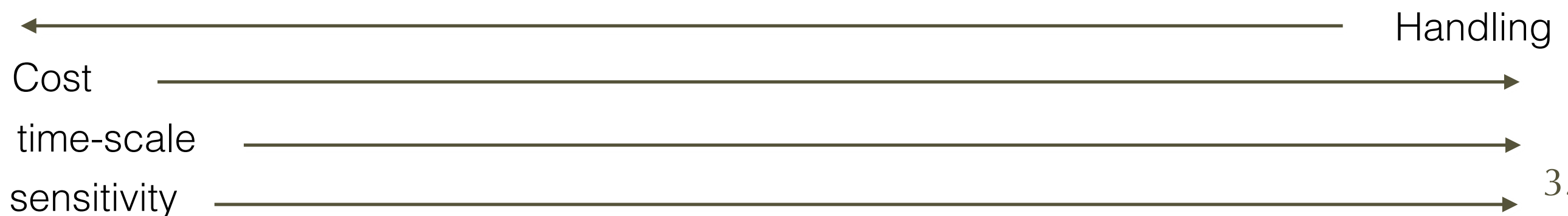
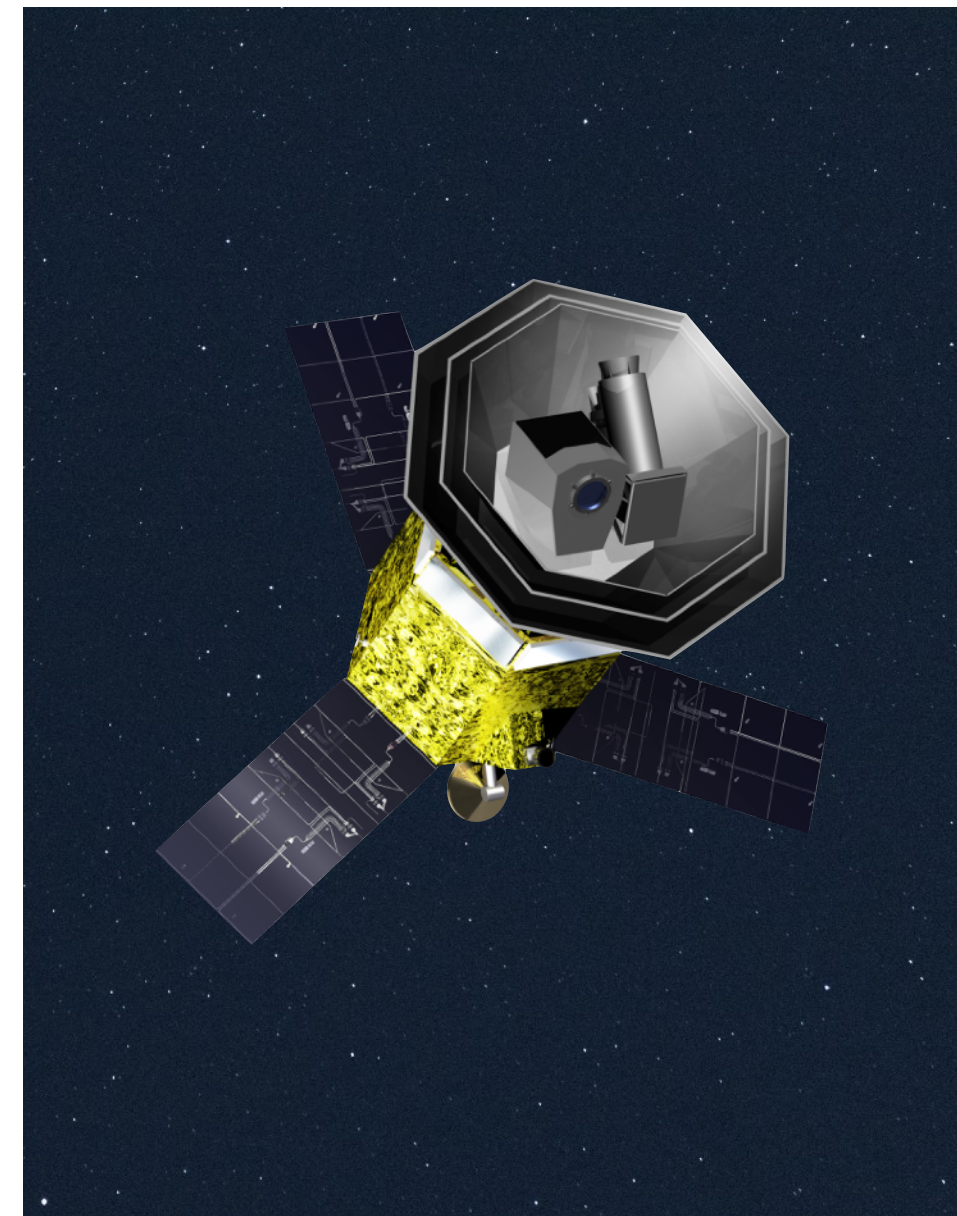
Terra
(es. SO, CMB-S4)



Pallone
(LSPE)



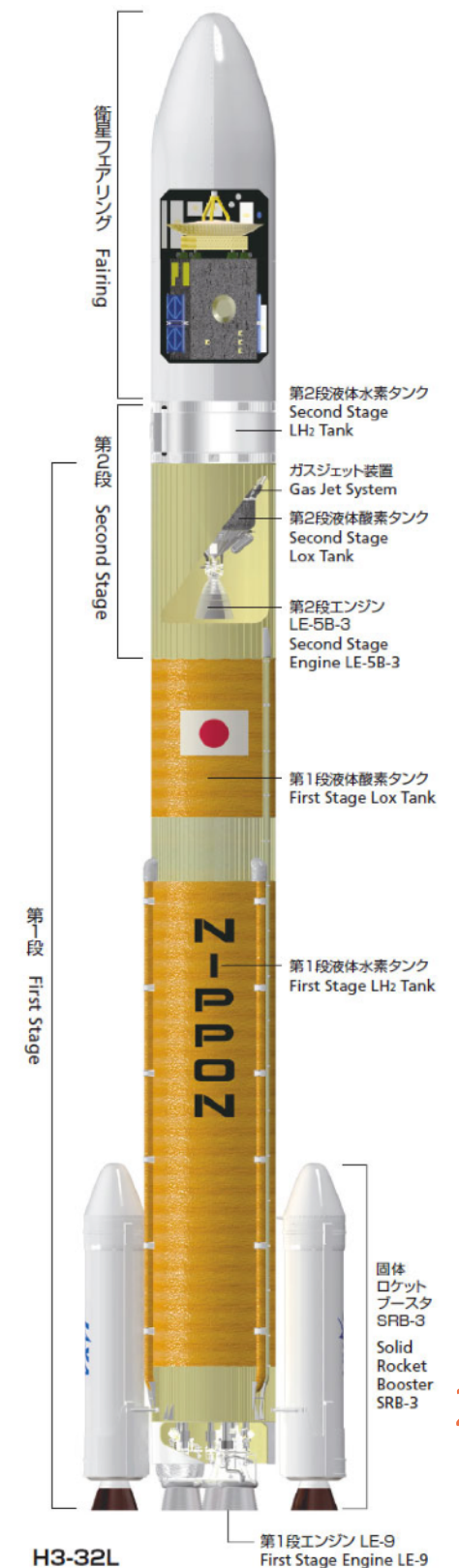
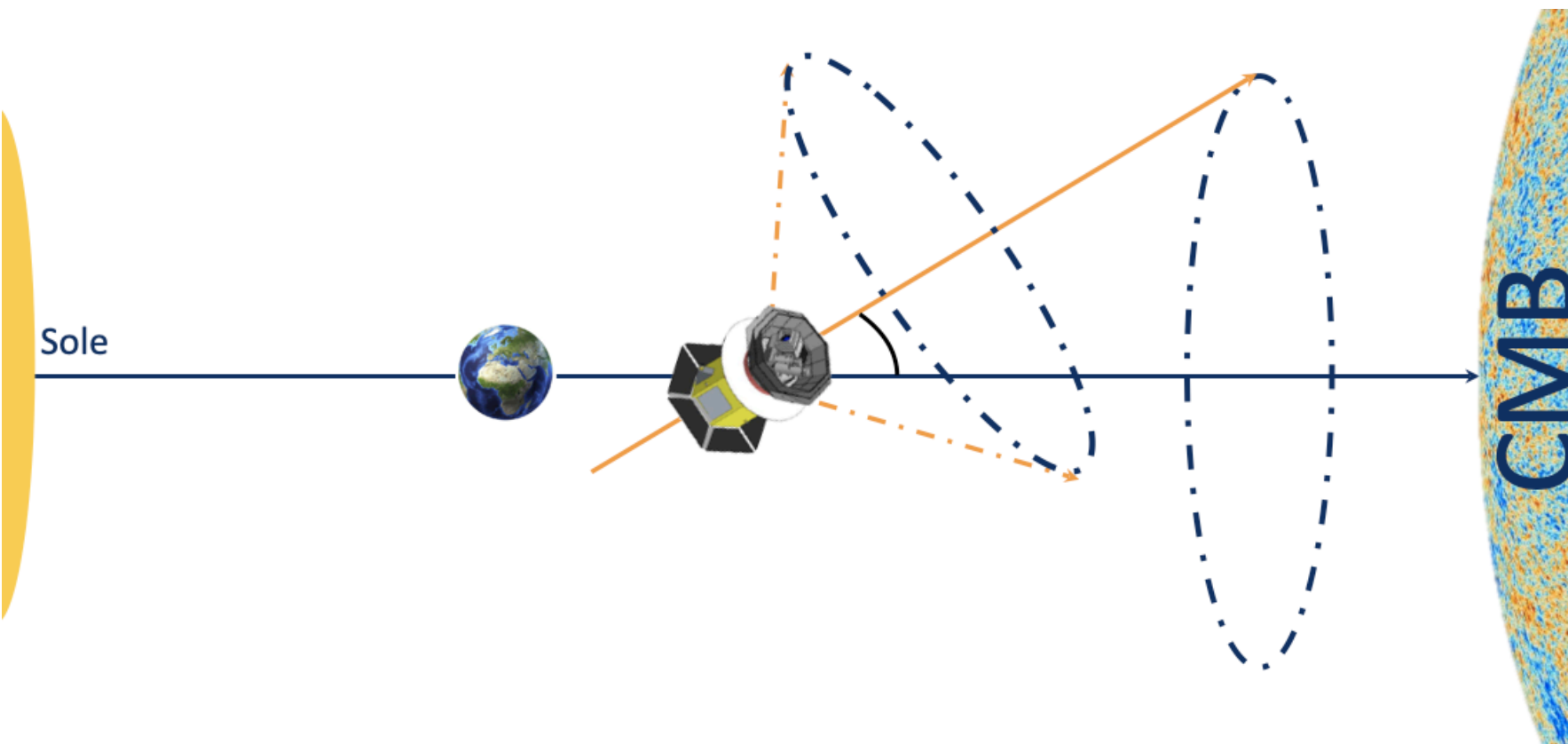
Spazio
(LiteBIRD)



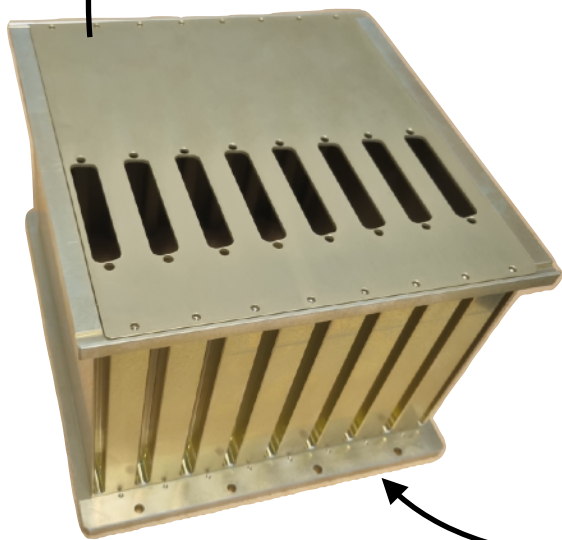
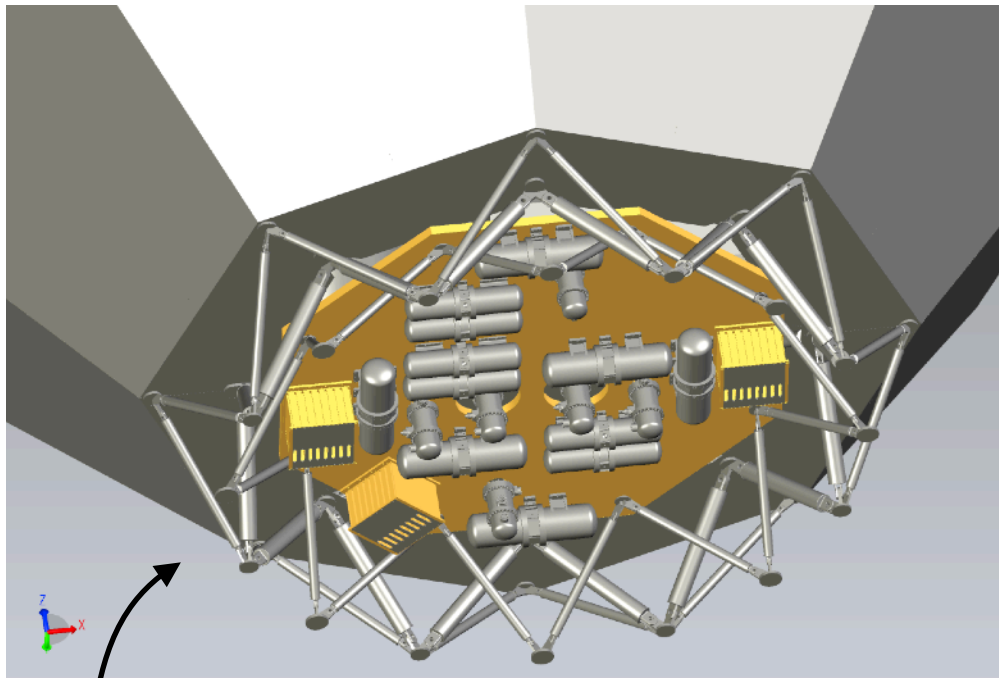
LiteBIRD Overview



- Lite (Light) satellite for the study of B-mode polarization and Inflation from cosmic background Radiation Detection
- JAXA (“ASI” Giapponese) Strategic Large-class mission selezionata a Maggio 2019
- Lancio previsto per il 2032 con il razzo H3 di JAXA
- Satellite Criogenico (120 mK) → circa 5000 bolometri TES letti da SQUID
- Survey di 3-anni, dal punto Lagrangiano L2
- Final combined sensitivity: $2.2 \mu\text{K.arcmin}$



- Pisa è leader in Italia (e non solo)
- SQUID controller unit
 - Elettronica di front-end dei rivelatori



Simulations

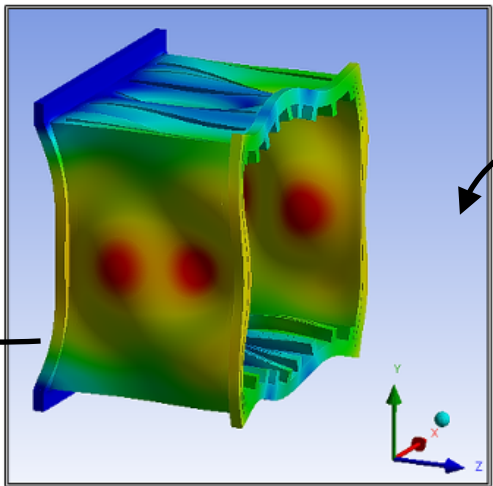
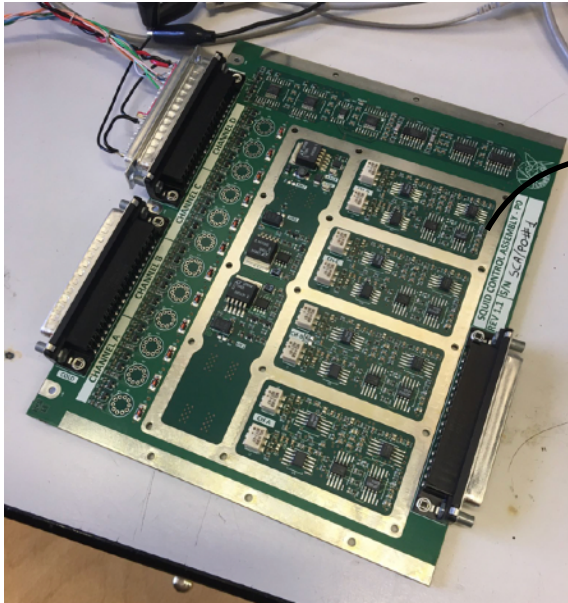
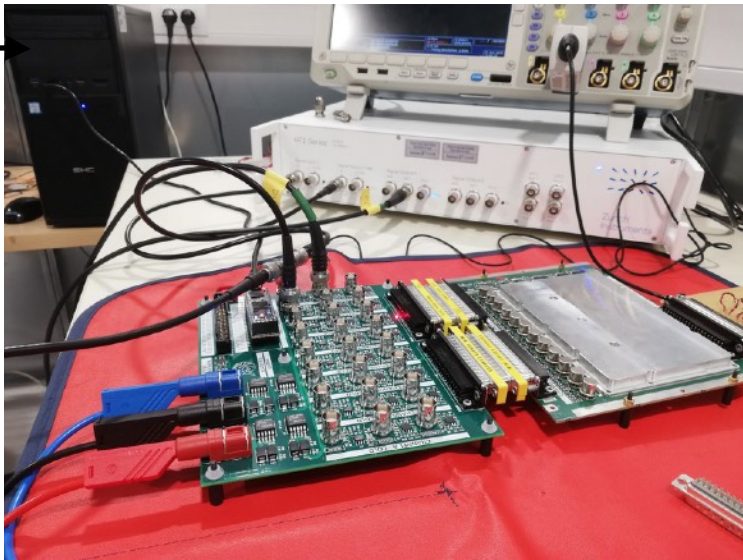


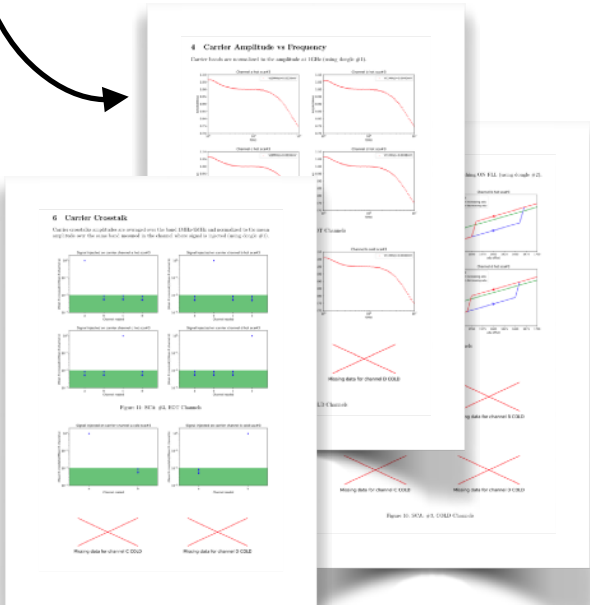
Figure 11 - Major Z mode (Mode 37), 4582,88 Hz



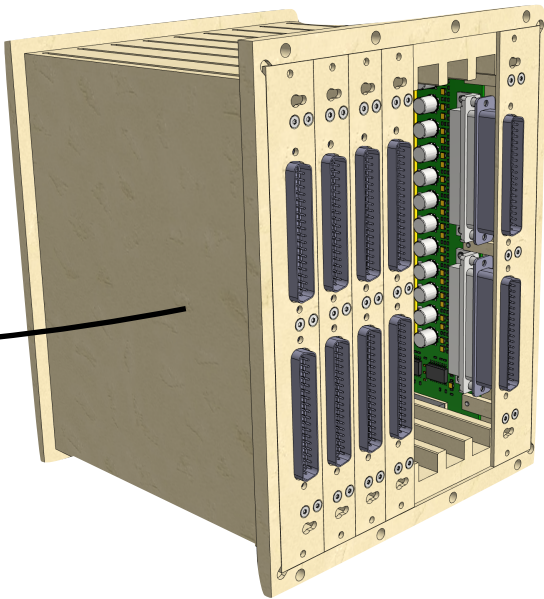
Electronics design



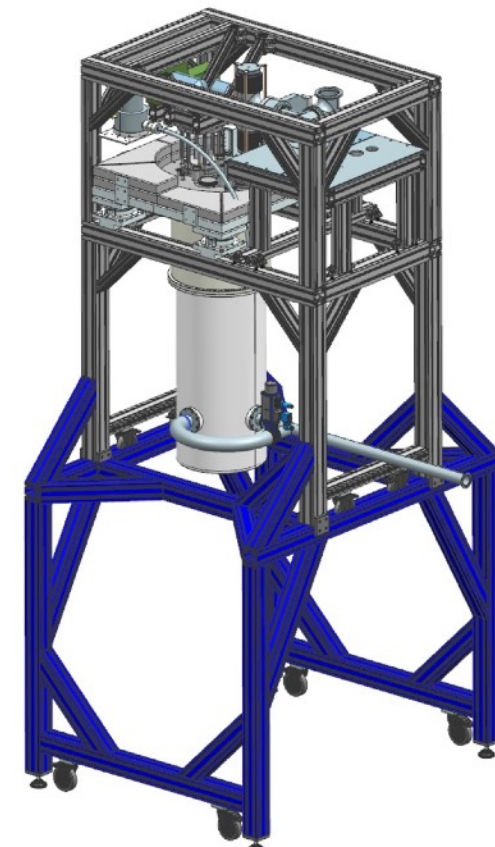
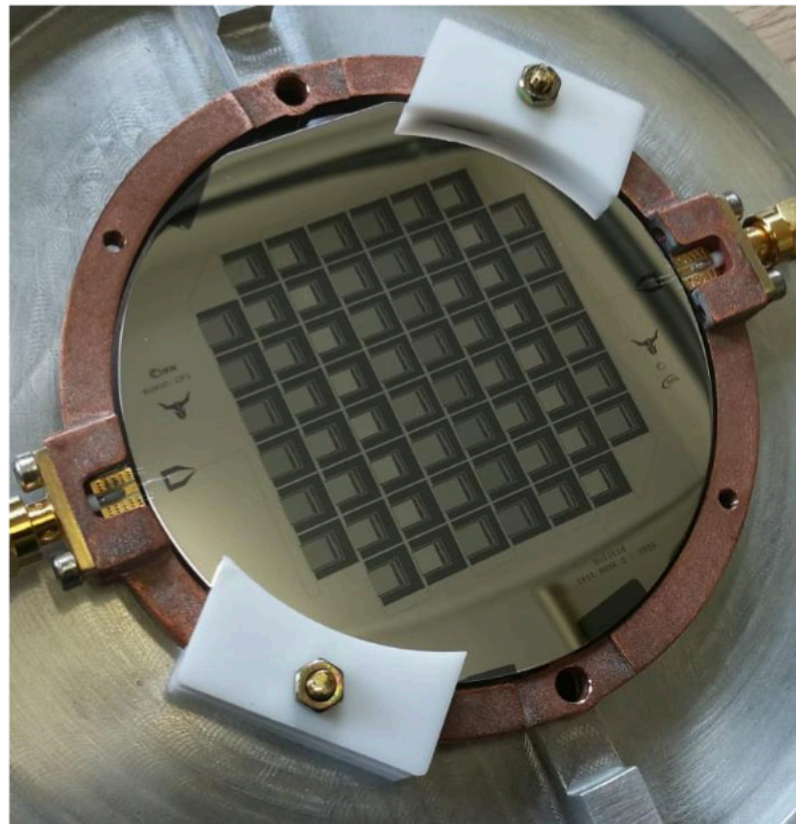
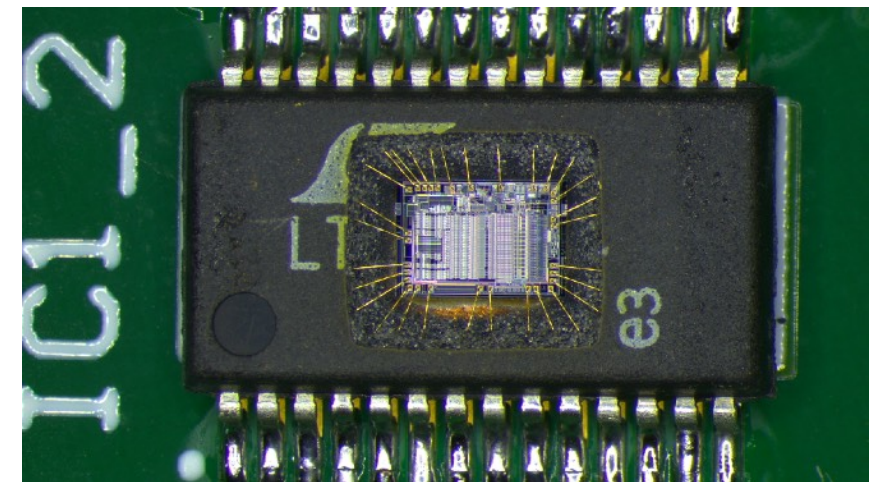
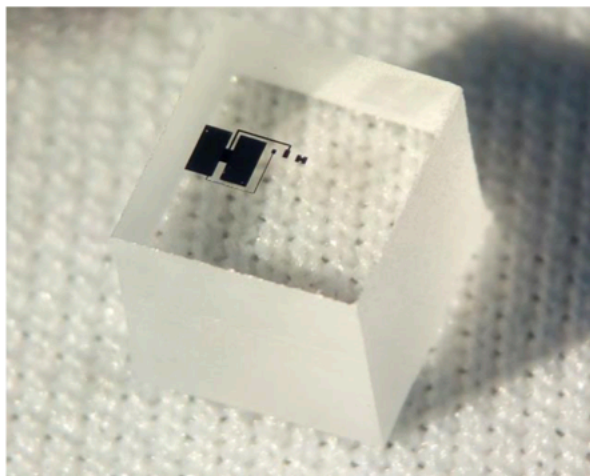
Tests



Mechanical design

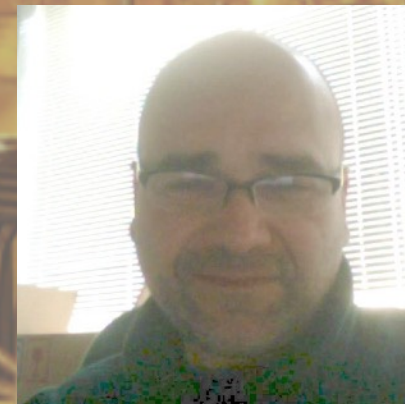
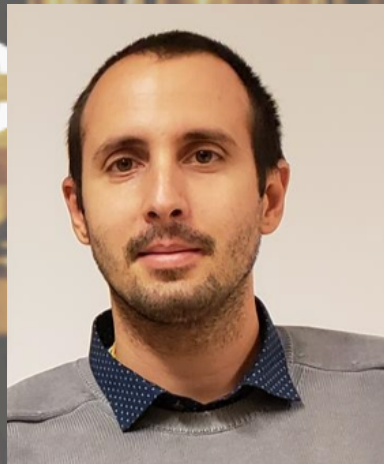


- Indagine **sperimentale** dell'**Universo primordiale**
- Una delle attività di **cosmologia sperimentale** in cui siamo coinvolti qui a **Pisa**
 - interazione dei **raggi cosmici** sui bolometri TES
 - uso di altri rivelatori (**KIDs**)
 - Sviluppo di **tecnologie quantistiche**
 - **Casi di fisica** differenti
 - Ricerca di **DM** mediante rivelazione diretta (BullKIDS_DM)
 - ricerca di **assioni**



- Nuove **infrastrutture**
 - **Camera pulita** wet → microfabbricazione
 - **Laboratorio** di tecnologie **criogeniche**
 - thanks to INFN, ASI, PNRR, CISUP, Dipartimento di Eccellenza
- **Personale** specializzato



[Expand/Collapse](#)[LiteBIRD](#)[LSPE](#)[BulKID](#)[Qua](#)



GRAZIE