

Implementation and testing of a 100 mK ADR cryocooler backed by a 4He/3He sorption fridge for CMB-S4 project

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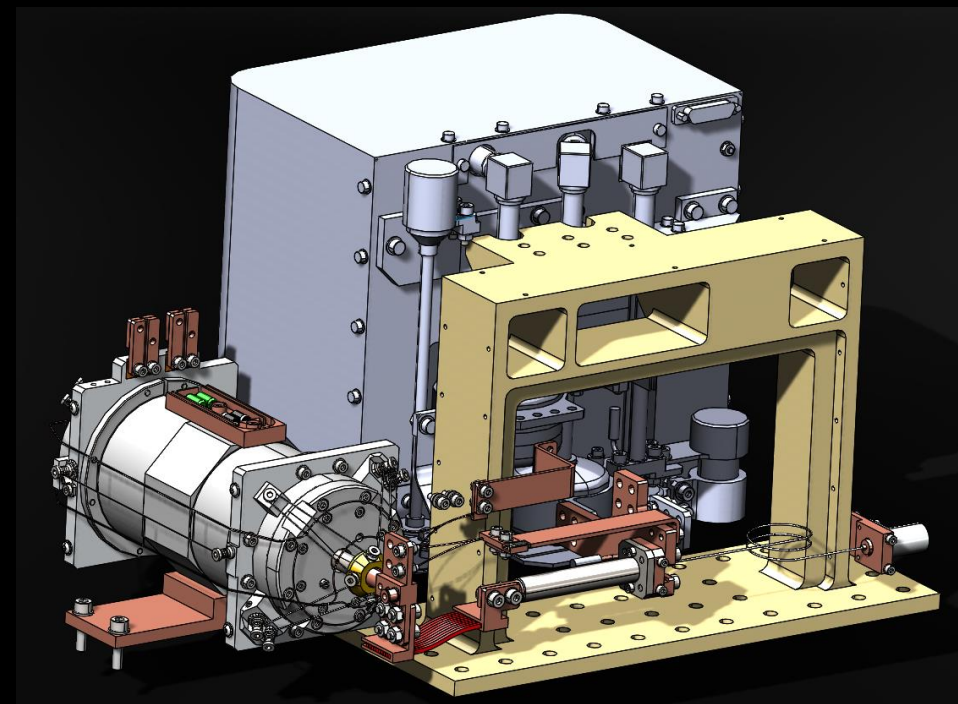


Forecast

- **Cryogenic temperatures to observe far Universe**
- We developed an **ADR** to cool detectors from 250 mK to **100 mK**
- Coupled to a 4He/3He sorption fridge through a **3He gas-gap Heat Switch**

- ADR will be used in a **pathfinder telescope for CMB-S4**

- Cooling power at 100 mK: **2 μ W for 48 hours**
- **4 times more observation** than cycling time



Outline

1. Background

- Observation of the Universe
- 100 mK refrigeration

2. Material & Methods

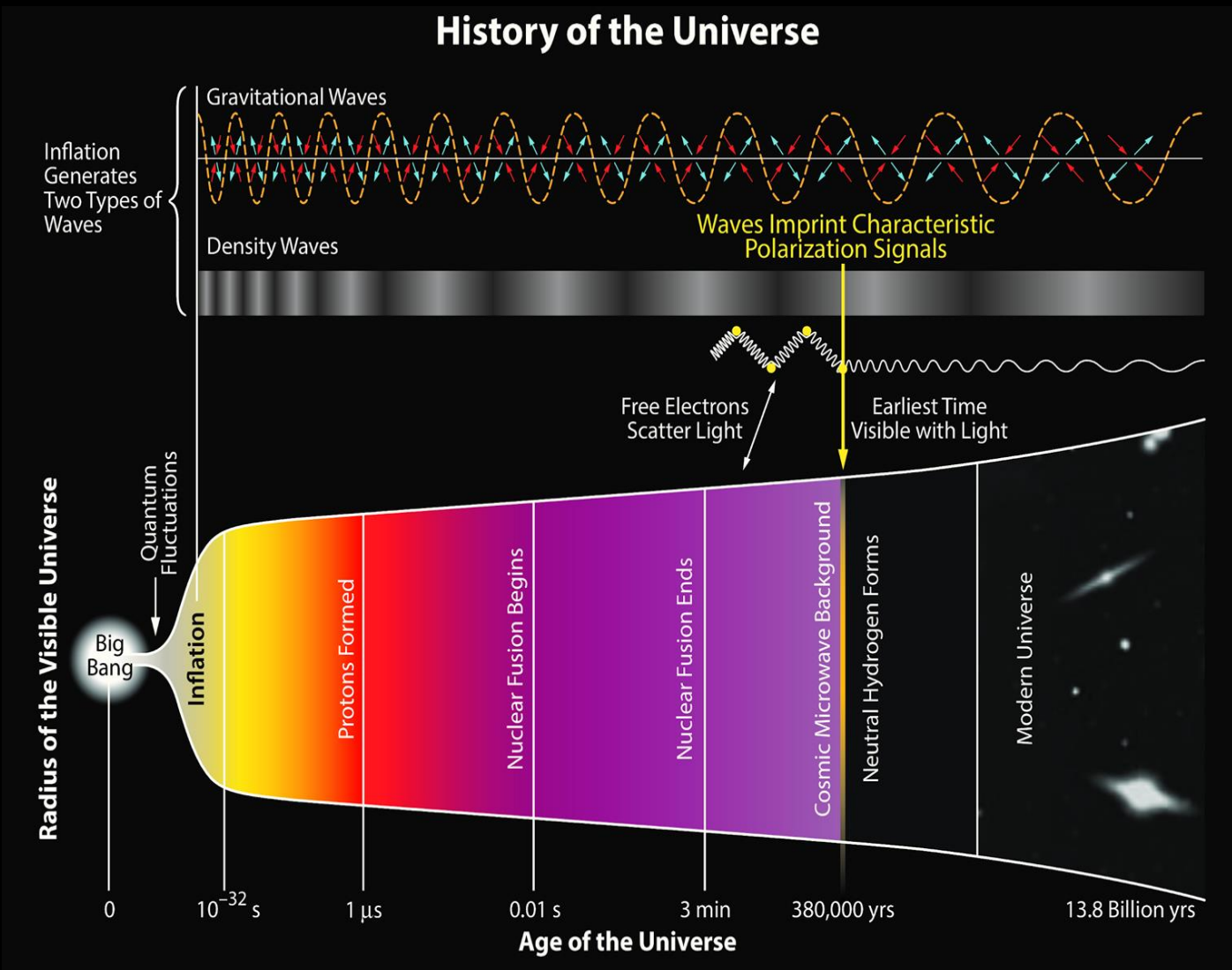
- Cryogenic chain presentation
- ADR specificities

3. Results

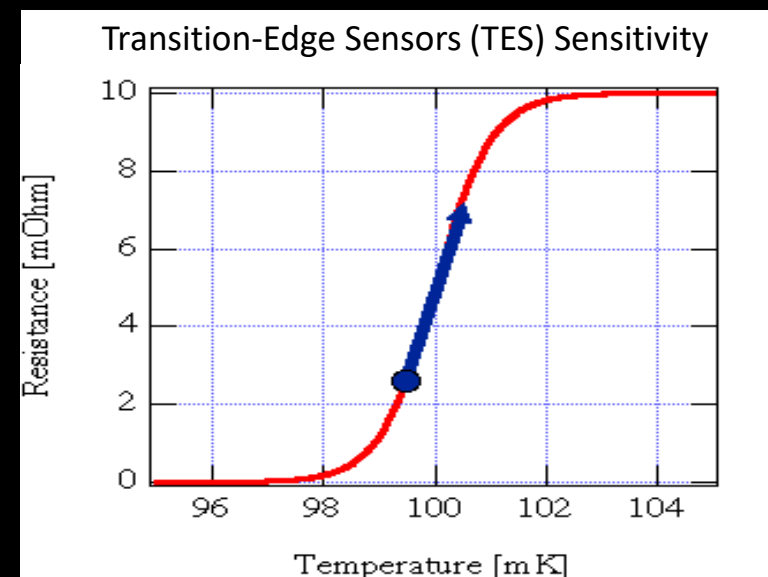
- Parasitic heat losses
- Pill's characteristics
- Parasitic magnetic field

4. Conclusion

Background: Observing our Universe



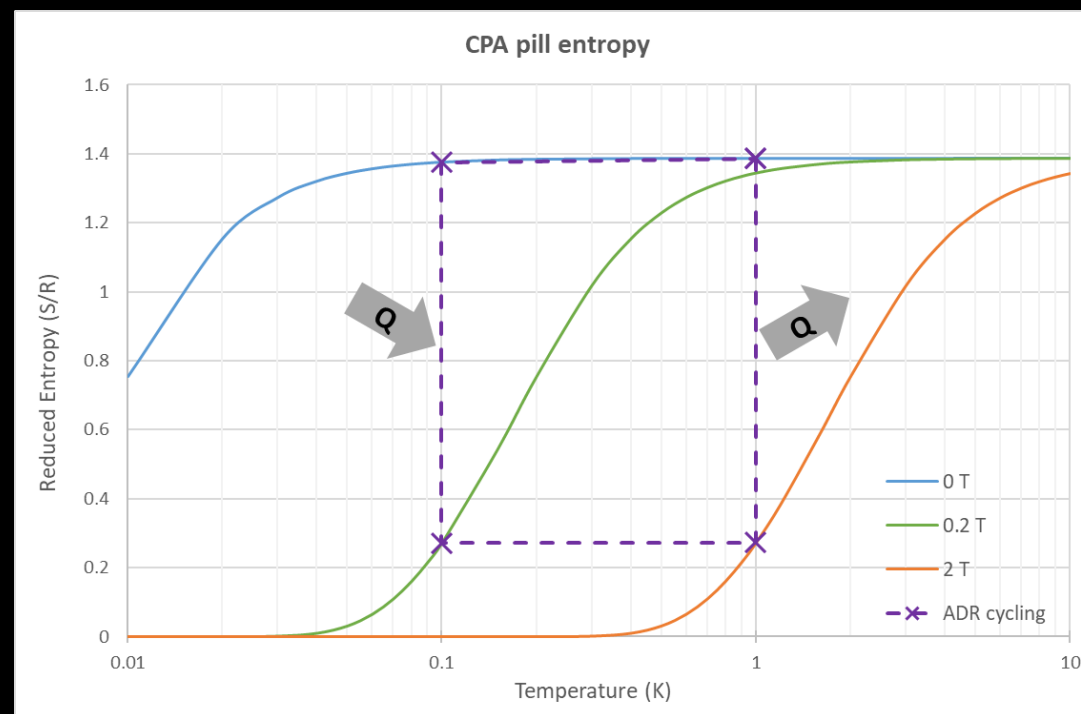
- Looking at **CMB frequencies**
- Searching for a specific **polarization pattern**
- Could validate **cosmic inflation**



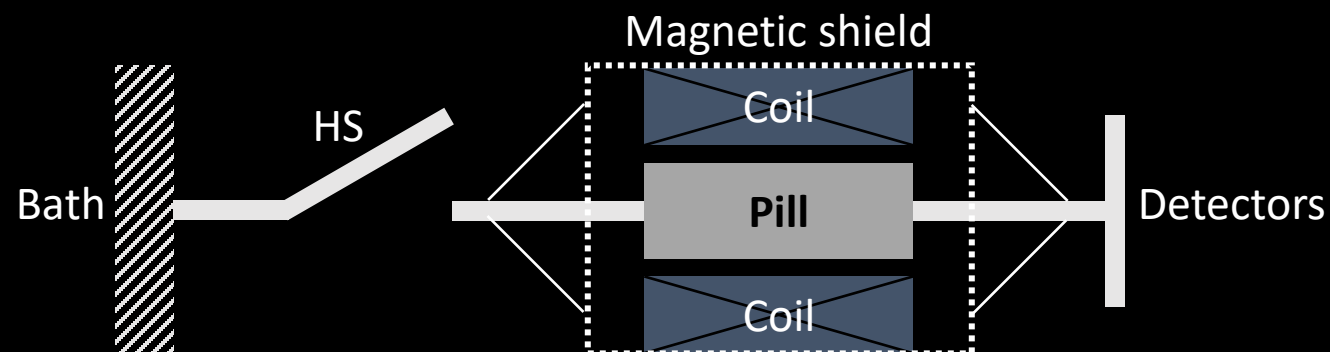
- Detectors must be cooled to **100 mK** for **48 hours** to increase their sensitivity
- Installed in dry places like the **South Pole**

Background : 100 mK Refrigeration

- Cosmic Microwave Background Stage 4 (**CMB-S4**) is the **largest ground-based CMB** experiment
- Existing cryostat: **250 mK sorption fridge**
- Pathfinder: **compact 100 mK ADR**
- Same telescope, new detectors
- **Adiabatic Demagnetization Refrigerator (ADR):**

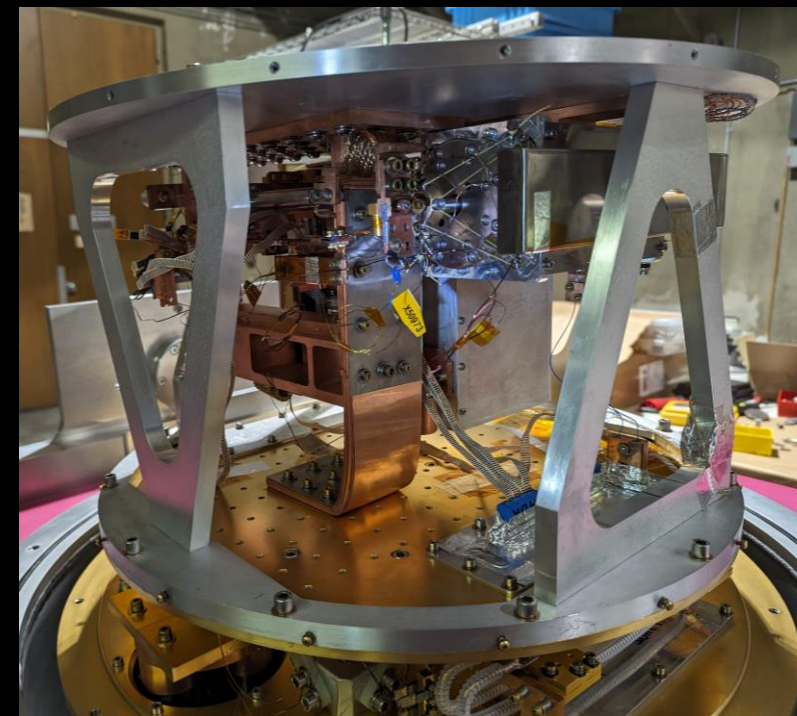
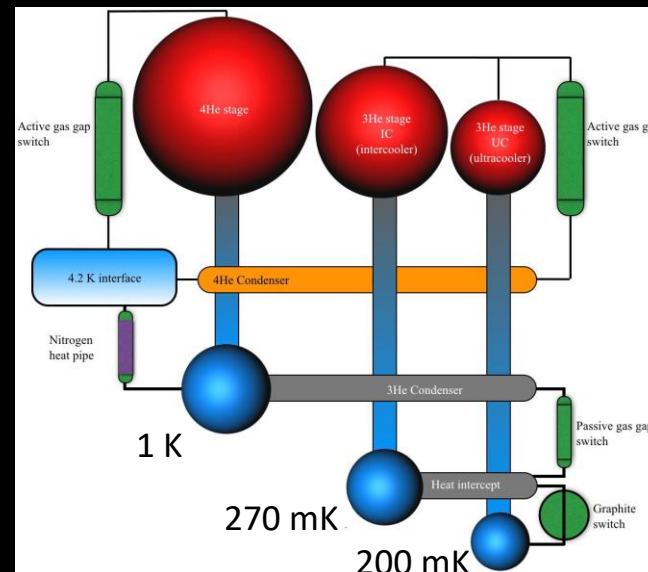


- ✓ Paramagnetic pill
- ✓ Strong magnetic field
- ✓ Heat **dissipated** to a thermal bath
- ✓ Cold finger **thermally isolatable**



Material and Methods

- Cryomech PT-415 cooling 2 radiative shields
- 3-stages (4He/3He/3He) **sorption fridge**
- **ADR** connected to its biggest 3He evaporator
- ADR specificities:
 - ✓ 226 g CPA pill
 - ✓ 16 **doubly-intercepted** Kevlar lines
 - ✓ 3He HS with **deported pump**
 - ✓ Superconducting coil reach **1.3 T** w/ 6 A
 - ✓ **Ferromagnetic** magnetic shield
 - ✓ Recycled **during** sorption fridge cycle
 - ✓ **12 hours** total cycling for 48 hours observations

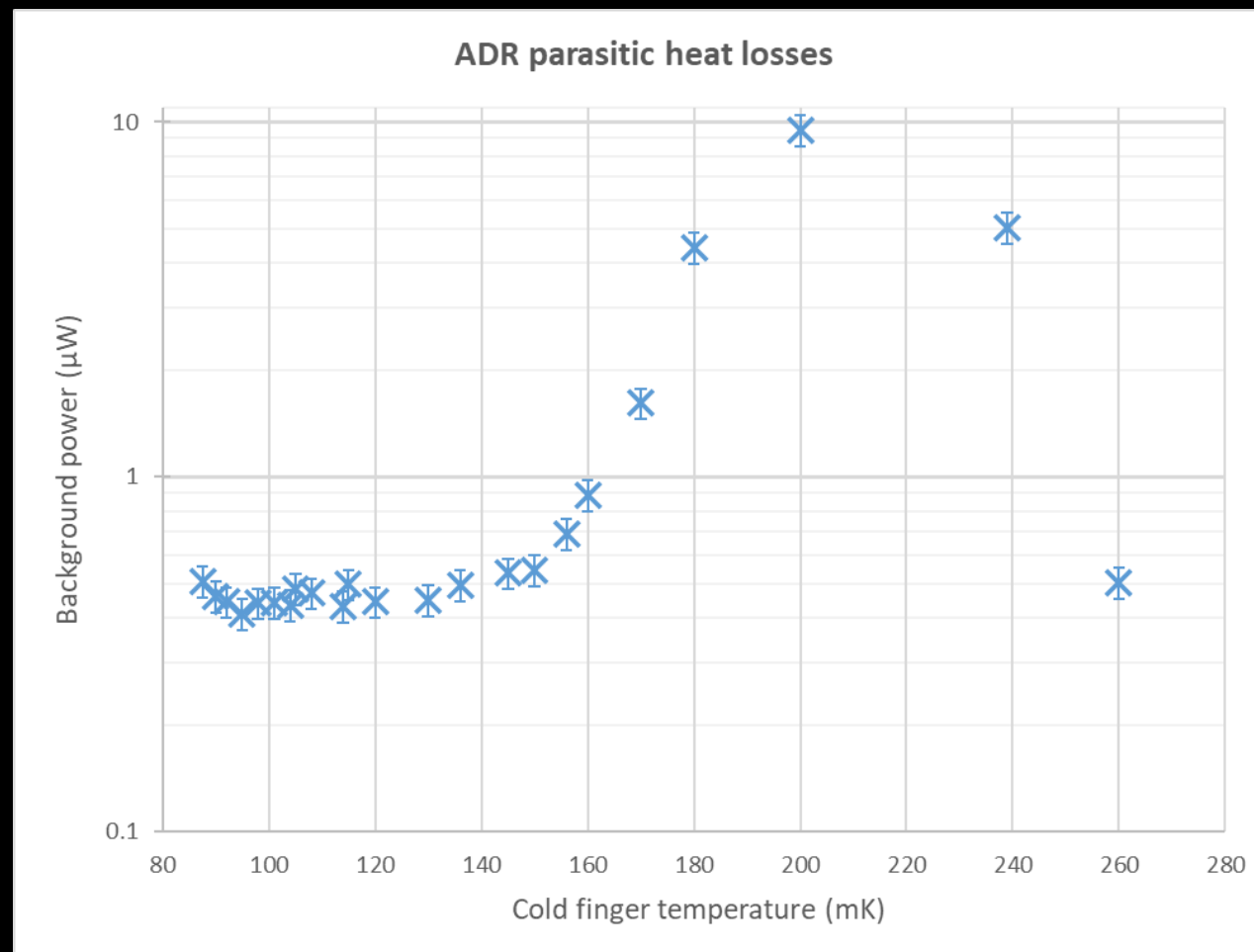


Results: Parasitic Heat Losses

- Background power = **Radiation + Conduction**
- Radiation: minimized thanks to **Carbon-loaded Stycast coating**
- Conduction: estimated to be **0.3 μW** (HS + Kevlar lines)

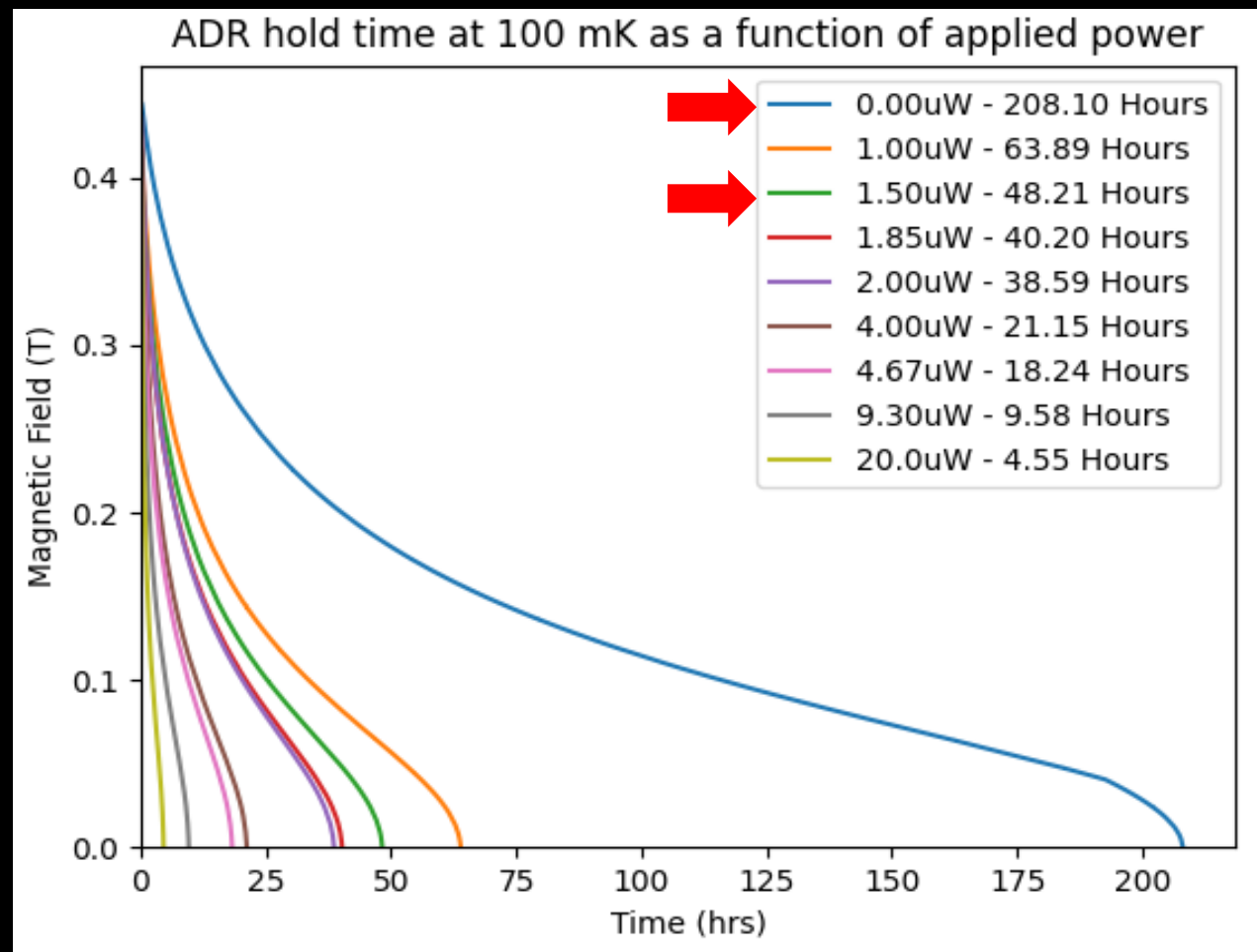
- Around **0.45 μW** at **100 mK**

- Increase above **150 mK** due to **liquid ^3He** in the HS



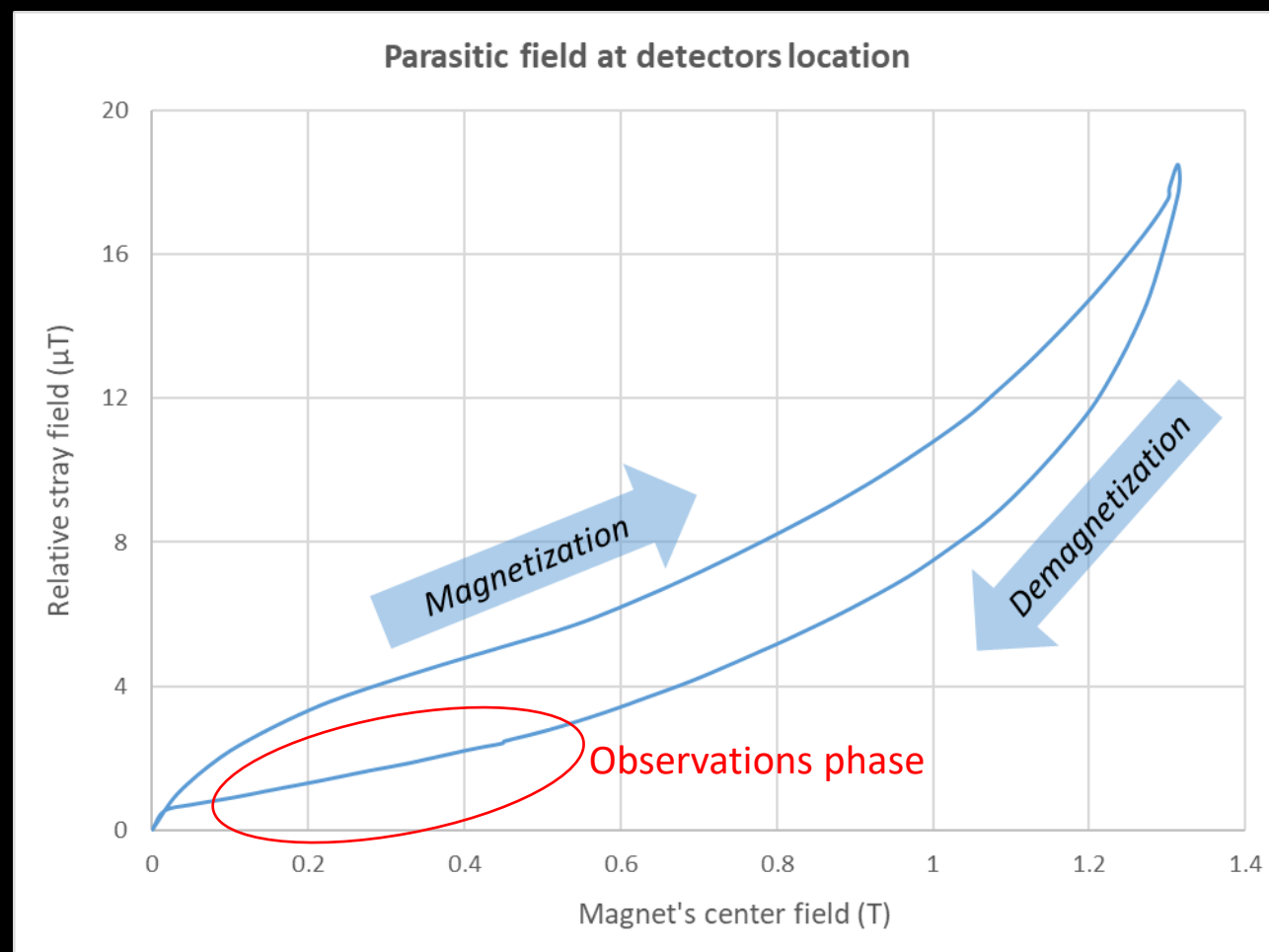
Results: Pill's Characterization

- Several **hold time** runs at **100 mK** with \neq applied power
- Reference hold time $t_0 = \mathbf{208 \text{ hours}}$ (4He stage ran out before ADR)
- Enthalpy $H = t_0 \cdot P_0 = t_1 \cdot (P_1 + P_0)$
 P_0 : background power
- Pill's enthalpy at 100 mK: $\mathbf{0.34 \text{ J}}$
- Cooling power for 48 hours:
 $\mathbf{1.5 + 0.45 \approx 2 \mu\text{W}}$



Results: Parasitic Magnetic Field

- ADR needs **1.3 T** to be recycled
- Detectors and amplification circuit **extremely sensitive** to magnetic field
- Thermally treated **ferromagnetic magnetic shield**
- **Relative parasitic field (detectors location)**
 - ✓ **18 μT** maximum during ADR cycling
 - ✓ **Below 2.5 μT** during observations



Conclusion

- ADR backed by a 4He/3He/3He sorption fridge cools **CMB detectors to 100 mK**
- Ratio cycling/observations: **4**
- Cooling power at 100 mK: **2 μ W for 48 hours (0.34 J)**
- Background power at 100mK: **0.45 μ W**
- Parasitic field during observations: **2.5 μ T**

- ADR will **transform an existing telescope** into a **CMB-S4 pathfinder** with new detectors
- Larger scale telescope may use a **Dilution Fridge**

- More results in the paper!