



Possible Paths Toward Ultralow Vibration Cooling for milliKelvin Detectors

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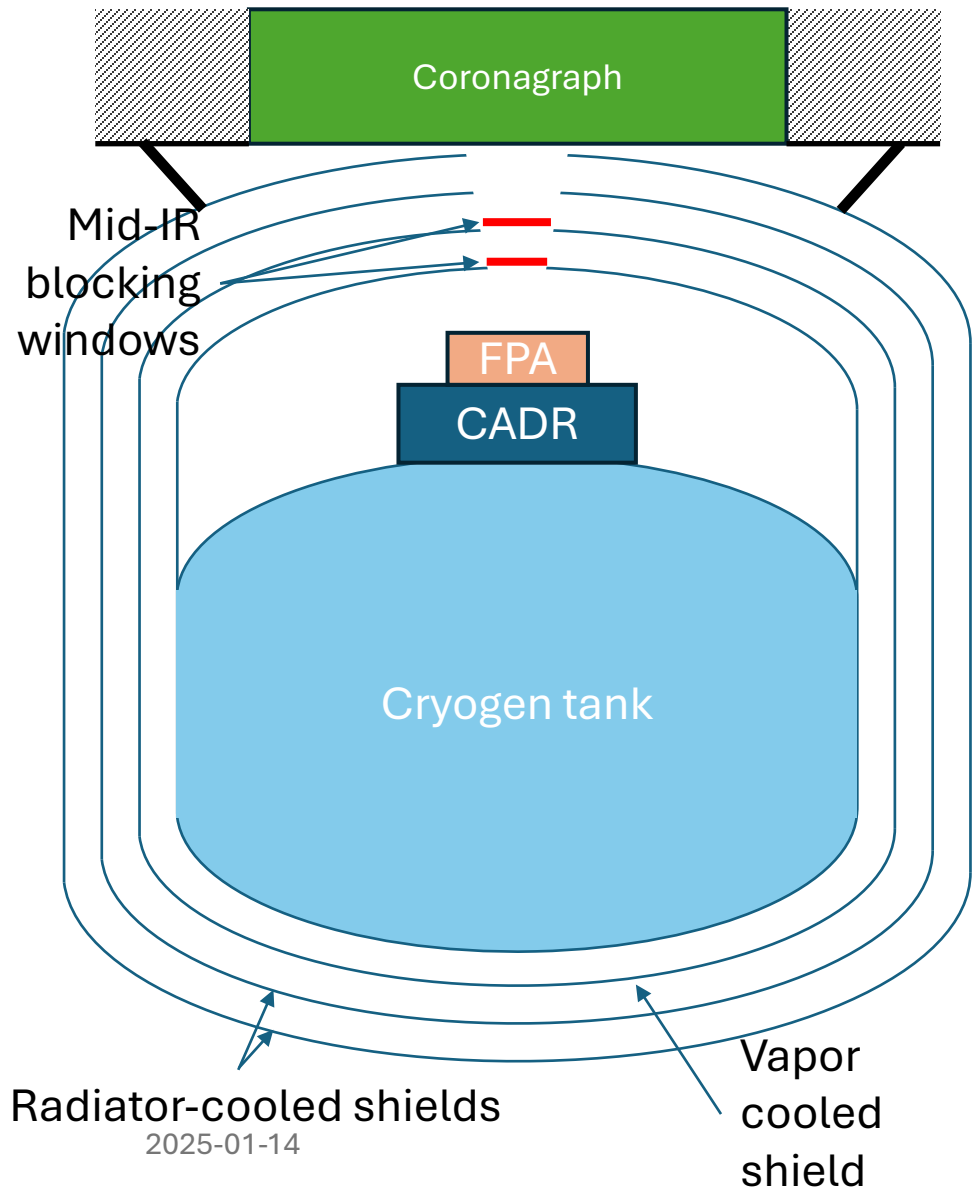


Sub-Kelvin Cooling



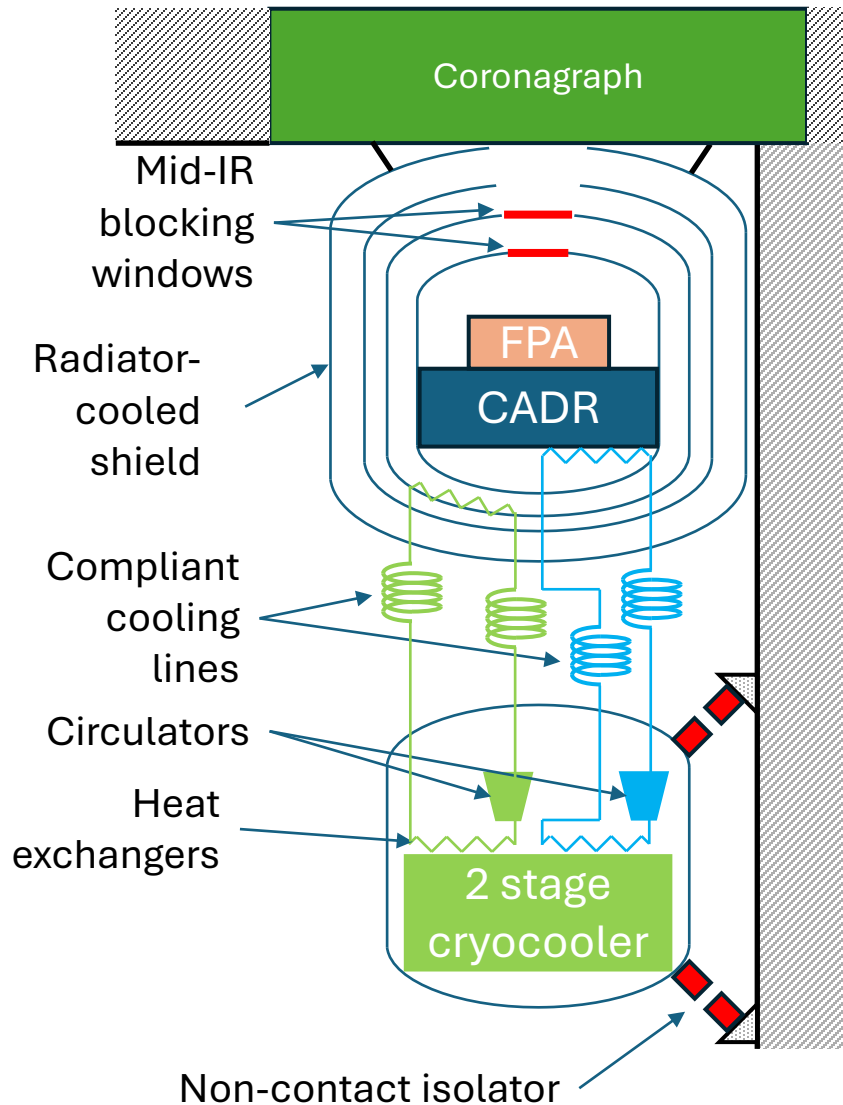
- Magnetic coolers are clear choice for low temperatures
 - Continuous Adiabatic Demagnetization Refrigerators (CADRs)
 - Solid state device, no detectable noise
 - TRL-9 ADRs lift heat from < 0.05 K reject to 4.5 K heat sink (Hitomi, XRISM)
 - Higher capacity CADRs under development for cooling large detector arrays on upcoming missions (PRIMA, ATHENA)
 - Higher heat rejection temperature advantageous
 - Upper temperature limited by T_c of superconducting magnets
 - GSFC has demonstrated ADR rejecting to 10 K sink (TRL 3)
 - Currently funding efforts to develop 20 K magnets
- Options for ultra-low vibration heat sink?

Option I: Cryogen Dewar



- Example: “back of envelope” design
- Assumptions:
 - 5 year operational lifetime
 - 4.5 K heat load from recent study
 - Additional ADR lifts heat 4.5 $\rightarrow$ 12 K with $\eta=50\%$
 - Solid H₂ tank at 12 K
 - Single vapor cooled shield
 - 2-stage radiator cools outer shields with low T_{sink}
 - Structural parasitic can be made negligible
- Estimated size: $\sim 1.2 \text{ m}^3$ of sH₂
- Cryocooler for ground hold, transit, (& non-coronagraph observation?)
 - Also may enable refilling
- Relatively large and heavy, but high TRL

Option II: Isolated Cryocooler with Thermal Link



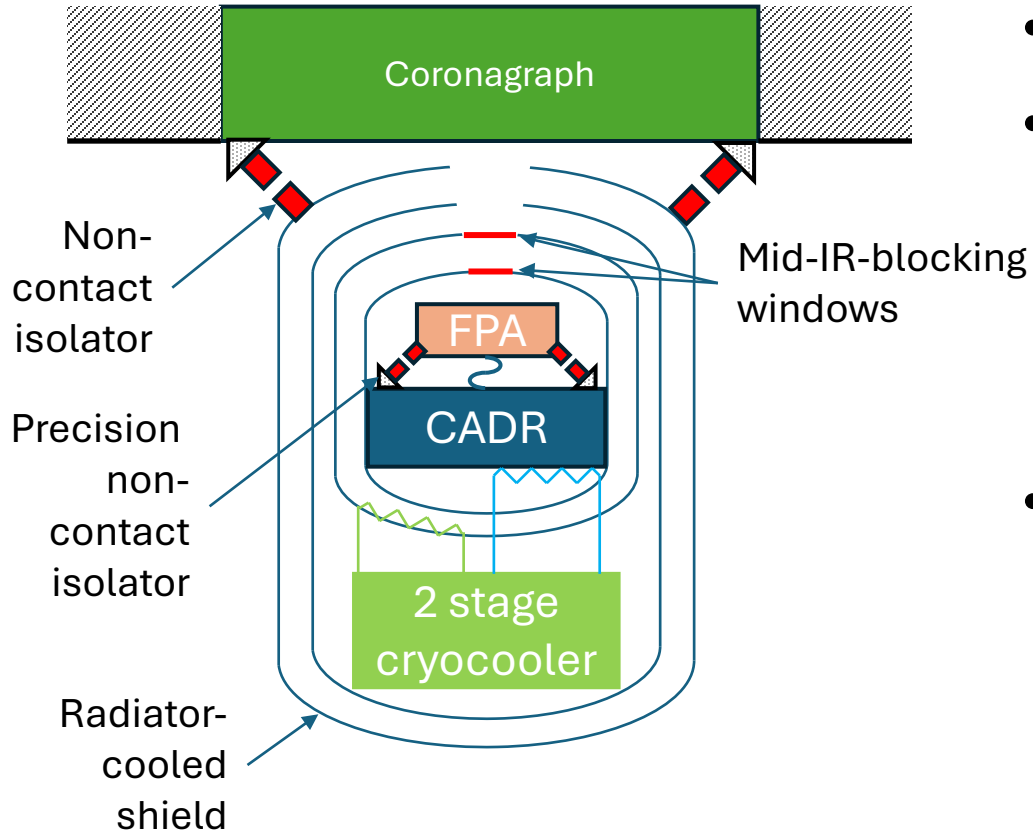
- Configuration

- Focal Plane Assembly (FPA) & CADR in a small cryostat directly mounted to coronagraph
- Cryocooler in separate cryostat in spacecraft bus (a la JWST/MIRI) or its own platform
- Cryocooler isolated from telescope through non-contact actuators (Disturbance Free Platform, DFP)
- Two stages of cooling linked through compliant cooling lines

- Minimizing exported disturbance

- Generation
 - Low vibration cryocooler
 - Design for laminar flow, no eddy-generating features
- Transmission
 - Suppress cooling line transmissivity with active control?

Option III: Isolated detector + cryocooler



- Entire cryostat isolated with DFP system
- Precision small isolator maintains detectors close to image plane
 - Key assumption: detectors are simply light buckets
 - Lateral position tolerance $\ll$ pixel dimension
 - Axial position tolerance $\ll$ depth of focus
- Path to strong decoupling from cooler
 - Radiators and electronics on cryostat
 - Non-contact transmission of power and digital data



Conclusions



- SubKelvin cooling systems meeting HWO's stringent noise requirements are challenging, but feasible with sufficient technology development
- Needs:
 - Requirements on allowable force inputs!
 - Currently in work with architecture studies
 - Ultra quiet facilities and sensitive instrumentation
 - Studies of basic phenomena (e.g. noise generation in laminar flow)
 - Essential for requirements verification
 - Technology development: Active noise suppression
 - Cryocooler noise reduction
 - Minimization of cooling line mechanical transmissivity
 - Technology development: cryocoolers
 - Raise TRL of inherently quiet cryocoolers
 - Technology development: magnetic coolers
 - Raise TRL of higher temperature CADR's