Title: Instrument Design and Implementation for Cryogenic Balloon Borne Telescope

Abstract: I have been working at NASA Goddard Space Flight Center on the EXCLAIM team. EXCLAIM's mission is to use a cryogenic balloon borne telescope to record a three-dimensional intensity map in the microwave electromagnetic range corresponding to carbon monoxide and carbon ion emission to study galaxy evolution and star formation. My work focused on the spectrometer package and readout, taking a preliminary design meeting mission requirements to a complete mechanical design that has been sent to machine shops for fabrication. These tasks have involved challenging spatial, thermal, magnetic, and electrical constraints. After everything was verified, drawings of highly complex parts were produced and sent to machine shops for quotes and future purchase.

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Instrument Design and Implementation for a Cryogenic Balloon Borne Telescope

Experiment for **C**ryogenic **L**arge-**A**perture **I**ntensity **M**apping (EXCLAIM)

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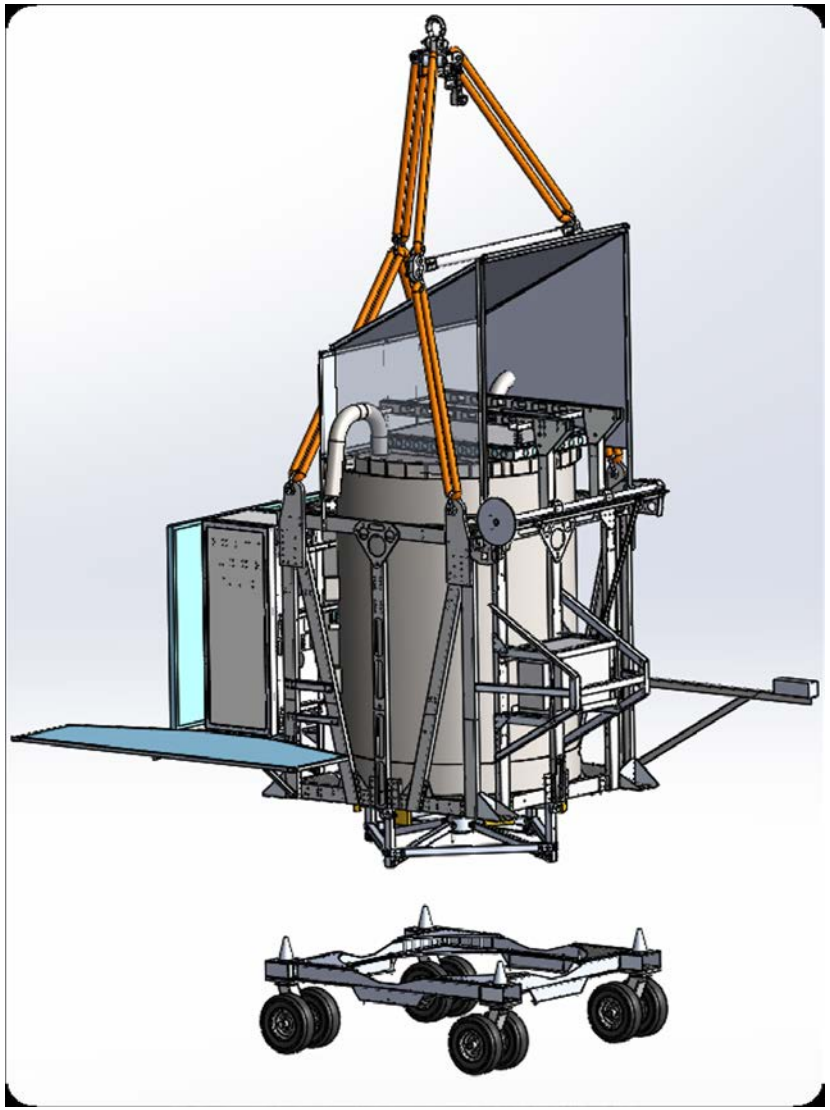
Co-Mentor: Tom Essinger-Hileman



Telescope

Why a balloon borne telescope?

- Ground Telescope – Atmospheric interference
- Satellite – Too expensive for 5-year mission
- Balloon – Test new technology
  - Payload – 3,000 Kg
  - Altitude – 100,000 ft.

Preliminary -> Critical Design

- Preliminary – Meets mission criteria
  – Parts fit and go together

- Critical – Designed
  – Manufactured
  – Assembled
  – Tested

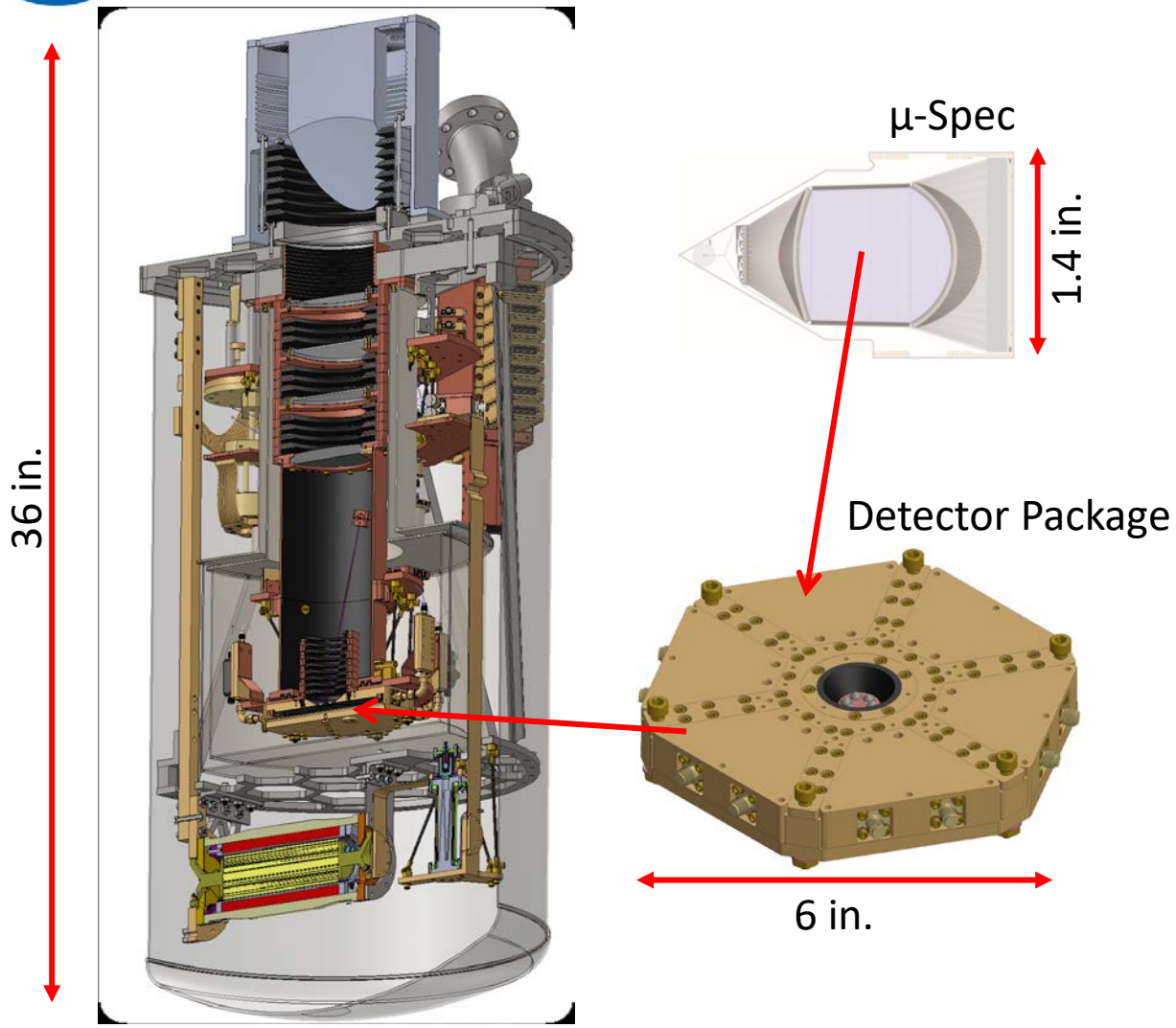
Dewar

Liquid Helium – used to cool the telescope

- Space is at 2.7 K
- L-He will cool telescope to 1.7 K (at 100,000 ft.)
- L-He will boil off limiting operation time

Large double walled dewar

- Very heavy
- Limits size of telescope



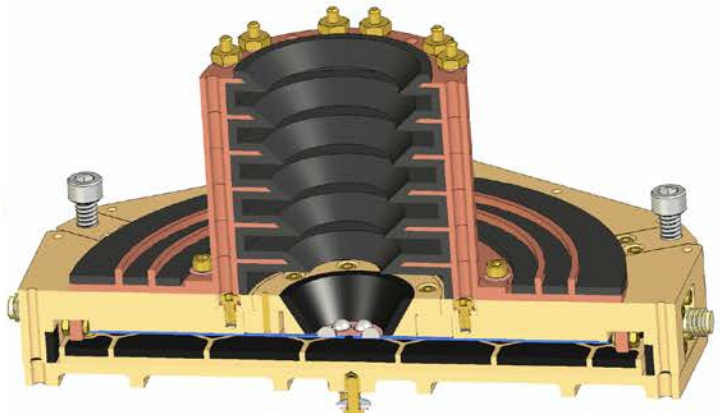
Receiver

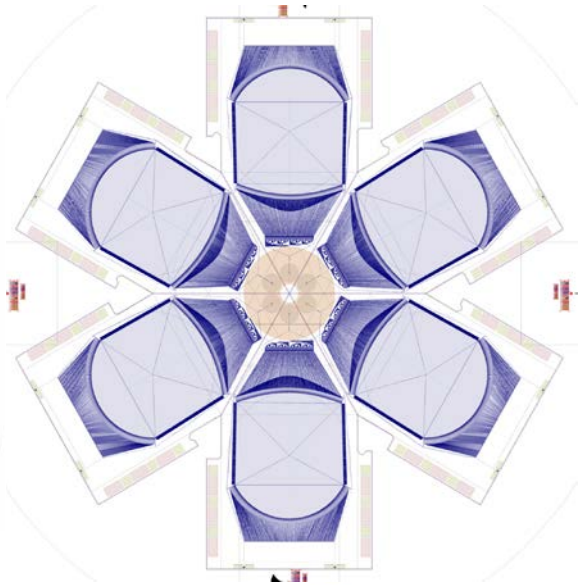
Cryogenic instruments – very low temperatures

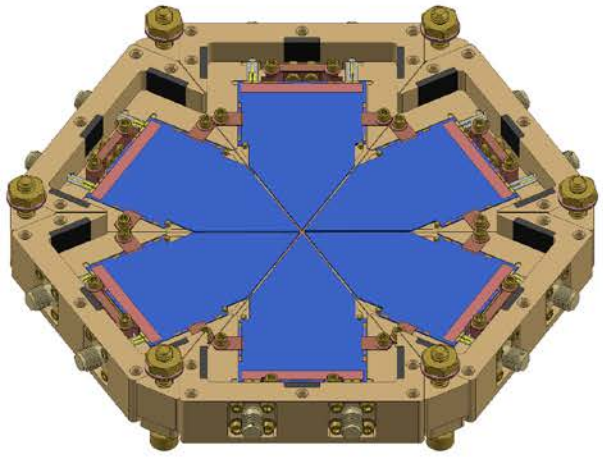
- Optics – 5 K
- Receiver – 1.7 K
- Readout – 0.9 K
- Detector – 0.1 K

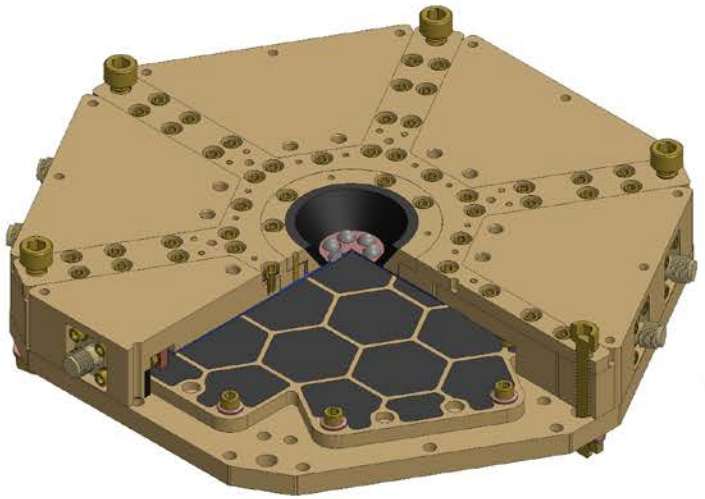
Design Considerations

- Light-weighting
- Thermal sinking
- Thermal expansion
- Thermal contraction









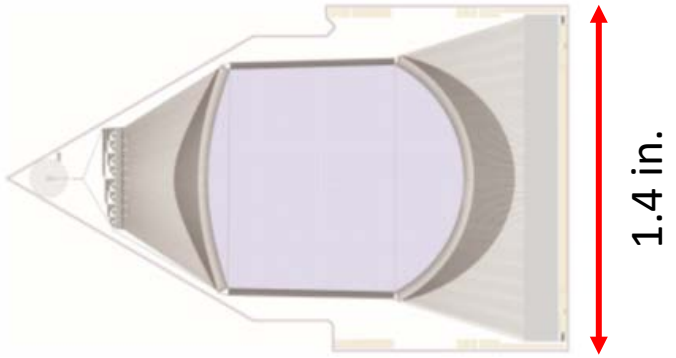
Detector Design

My work

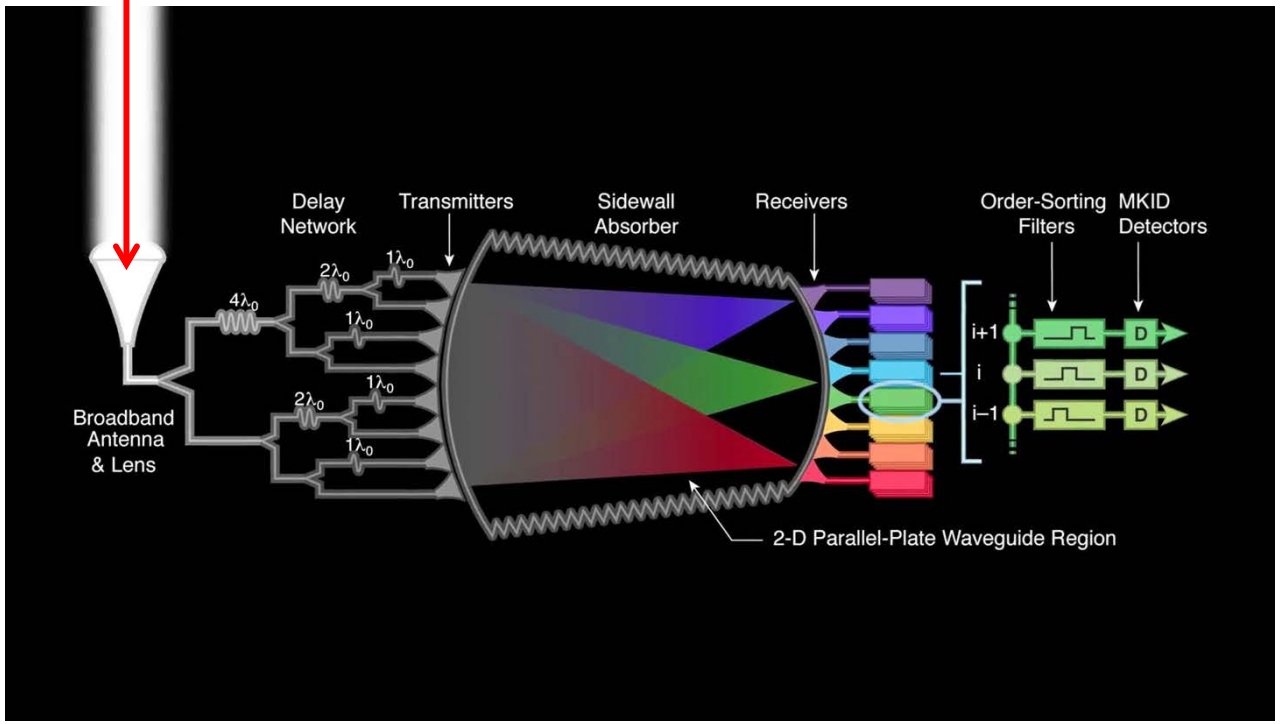
- Confirmed and corrected
  - Part sizes
  - Hole alignments
  - µ-Spec position
  - Fit test
- Completed complex drawings
- Sent for machining quotes

Manufacturing

- Inner radii
- Dimension tolerances
- Surface finish
- Surface plating



C⁻ emission
CO emission

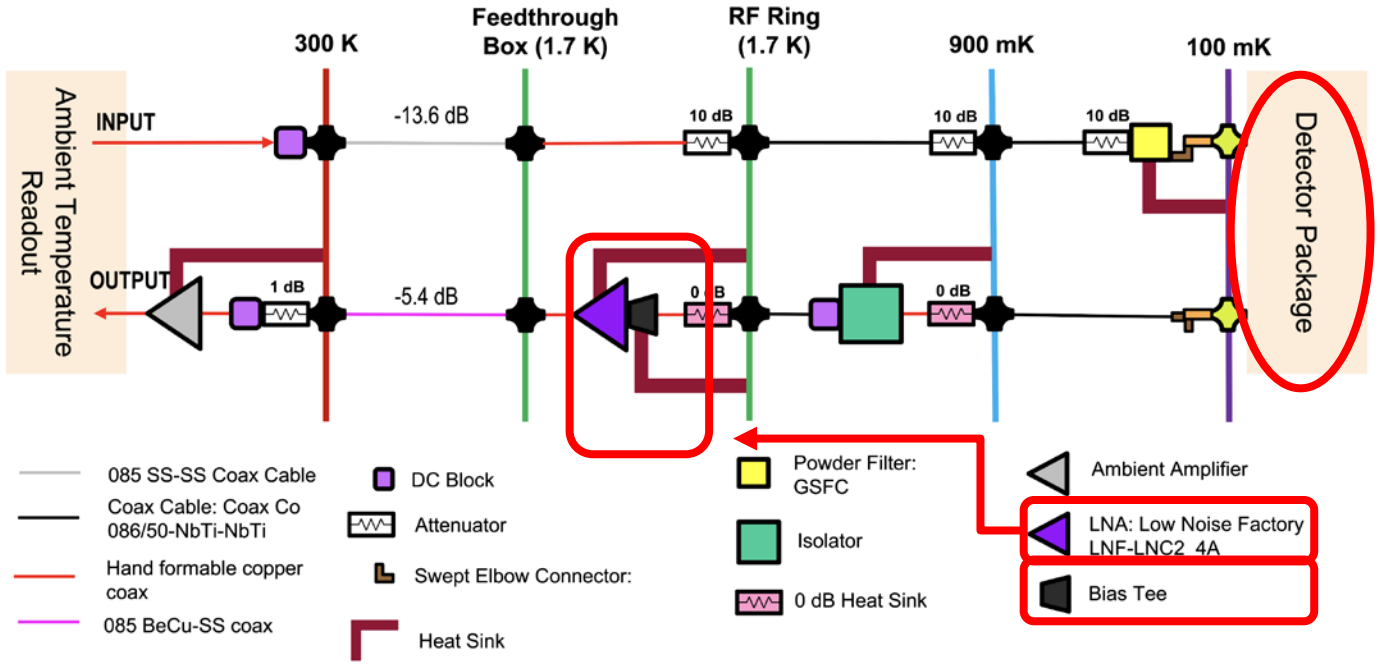


New Technology

μ-Spec

- Integrates traditional grating spectrometer
  - Synthetic grating on a single-crystal silicon substrate
  - Phase delay introduces using silicon's refraction properties
  - Superconducting lines provide high efficiency and resolution
  - Microwave Kinetic Inductance Detectors used for multiplexing
  - Capable of ultra-low sensitivity
- Silicon chip
- Fraction of the size!!!

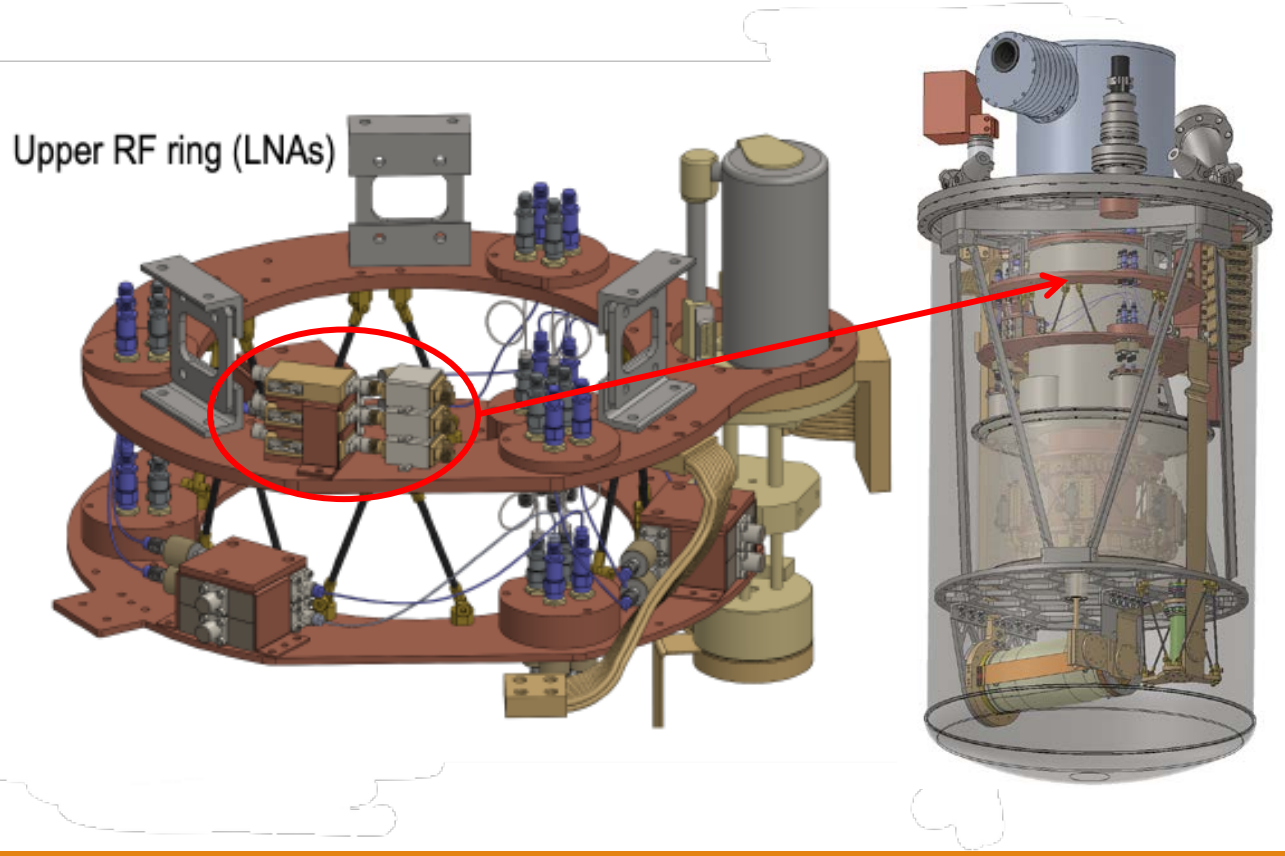
Detector -> Readout



LNA's

Bias Tee

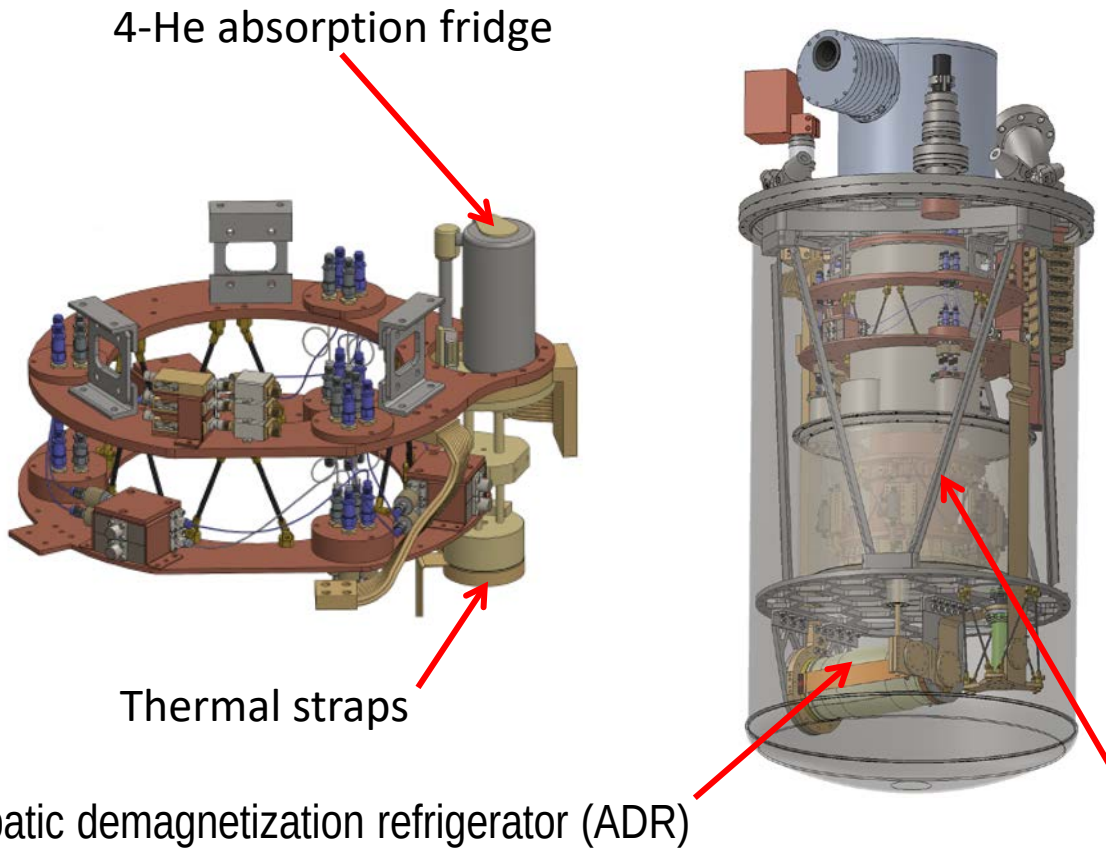
Readout Design



LNAs & Bias Tee's

- Designed custom L- style brackets
- Designed coax cable segments
- Sourced Nano-D connector parts
- Combined all parts into an assembly
- Placed 6 units on the upper ring
- Checked clearance to other nearby components

Receiver Cooling



Cooling power

- 4-He absorption fridge – cools readout to 0.9 K
- ADR – cools detector package to 0.1 K

New 4-He absorption fridge design

- Received from manufacturer
- Larger bottom dia.
- Adjusted thermal straps to match
- Size conflicted with ADR braces
- Brace angles and bottom plate were improved

Questions

Special Thanks!

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- Brad Conrad
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- Dr. Eric Switzer
- Dr. Tom Essinger-Hileman
- The EXCLAIM team and fellow NASA interns
- Sarah Alspaw

References (all images used from EXCLAIM literature)

1. Switzer, E. R., Adeb, P. A. R., Anderson, C. J., Barlisa, A., Barrentine, E. M., Beemanc, J., Bellisa, N., Bolattod, A. D., Breyssee, P. C., Bulchaa, B. T., Cataldoa, G., et al. (2020). Experiment for Cryogenic Large-Aperture Intensity Mapping: Instrument Design.
2. Essinger-Hileman, Tom. (2021). EXCLAIM: a new balloon mission to map the cosmological history of galaxies