

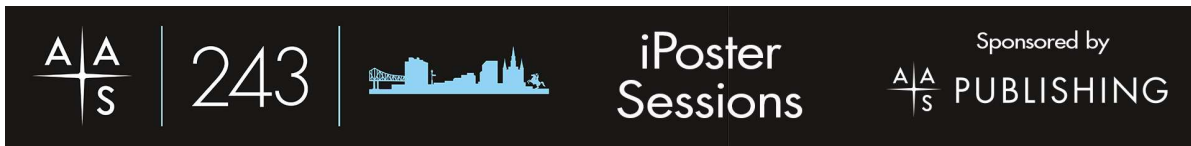
EXCLAIM, The EXperiment for Cryogenic Large Aperture Intensity Mapping

Maryam Rahmani, Emily M. Barrentine, Giuseppe Cataldo, Sumit Dahal, Thomas Essinger-Hileman,
Thomas R. Stevenson, Eric R. Switzer, Carolyn G. Volpert

NASA, Goddard Space Flight Center



PRESENTED AT:



ABSTRACT

EXCLAIM, the EXperiment for Cryogenic Large-Aperture Intensity Mapping, is a long-wave far-infrared (420-540 GHz) balloon-borne cryogenic telescope mission to study the star formation from the present day, out to redshifts of $z = 3.5$, including during the period of decline in the star formation rate since $z = 2$, while dark matter halo masses have continued to condense. EXCLAIM will observe singly- ionized carbon and carbonmonoxide emission lines using an intensity mapping approach. EXCLAIM features six compact and sensitive on-chip μ -Spec spectrometers with a resolving power $R = \Delta\lambda/\lambda = 512$ and a noise equivalent power, $NEP < 8 \times 10^{-19} \text{W}/\sqrt{\text{Hz}}$, utilizing 355 aluminum Microwave Kinetic Inductance Detectors (MKIDs) per μ -Spec . The MKIDs are read out through a single microwave feedline in a frequency multiplexing scheme and using RadioFrequency System on a Chip, RFSoc digital electronics. The telescope optics operate at a temperature $\leq 5 \text{ K}$ while the spectrometers operate at 0.1°K , well below the transition temperature of aluminum. The combination of cooled optics and minimal upper atmospheric background emissions at the balloon flight altitude ($\sim 36 \text{ km}$) provide an exceptionally sensitive environment for achieving the mission's science goals, and for evaluating the performance of the spectrometers and MKIDs, and their promise for application in future space-based telescopes. In this work, the current status of the EXCLAIM instrument in development is presented.

SCIENCE

Question: Why did the star formation has had a rapid increase till about redshift-2 followed by a fairly steep decline by a factor of 20?

What is the efficiency of star formation?

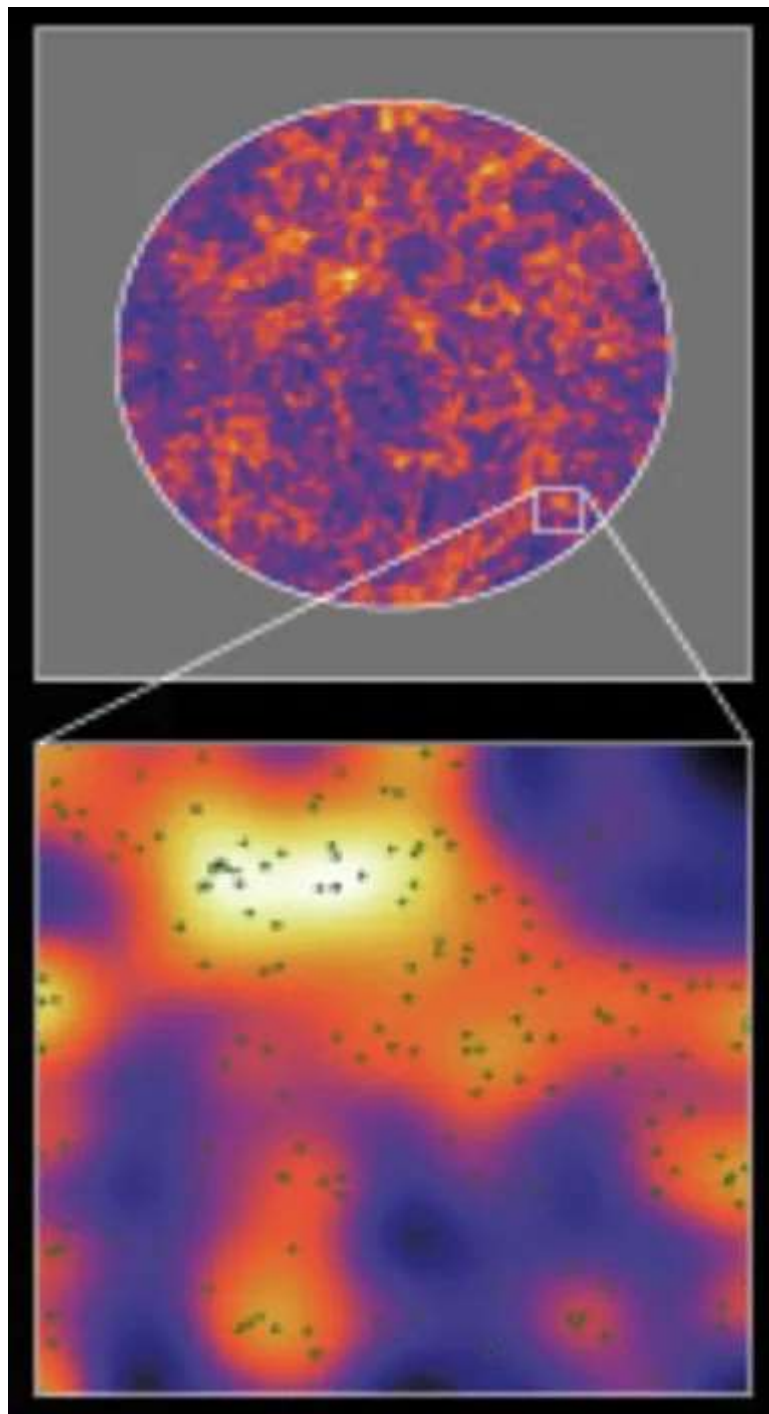
Approach: Measurement of the abundance, phases, and excitation of molecular gases by looking at atomic lines to get redshift information.

Intensity Mapping (IM)

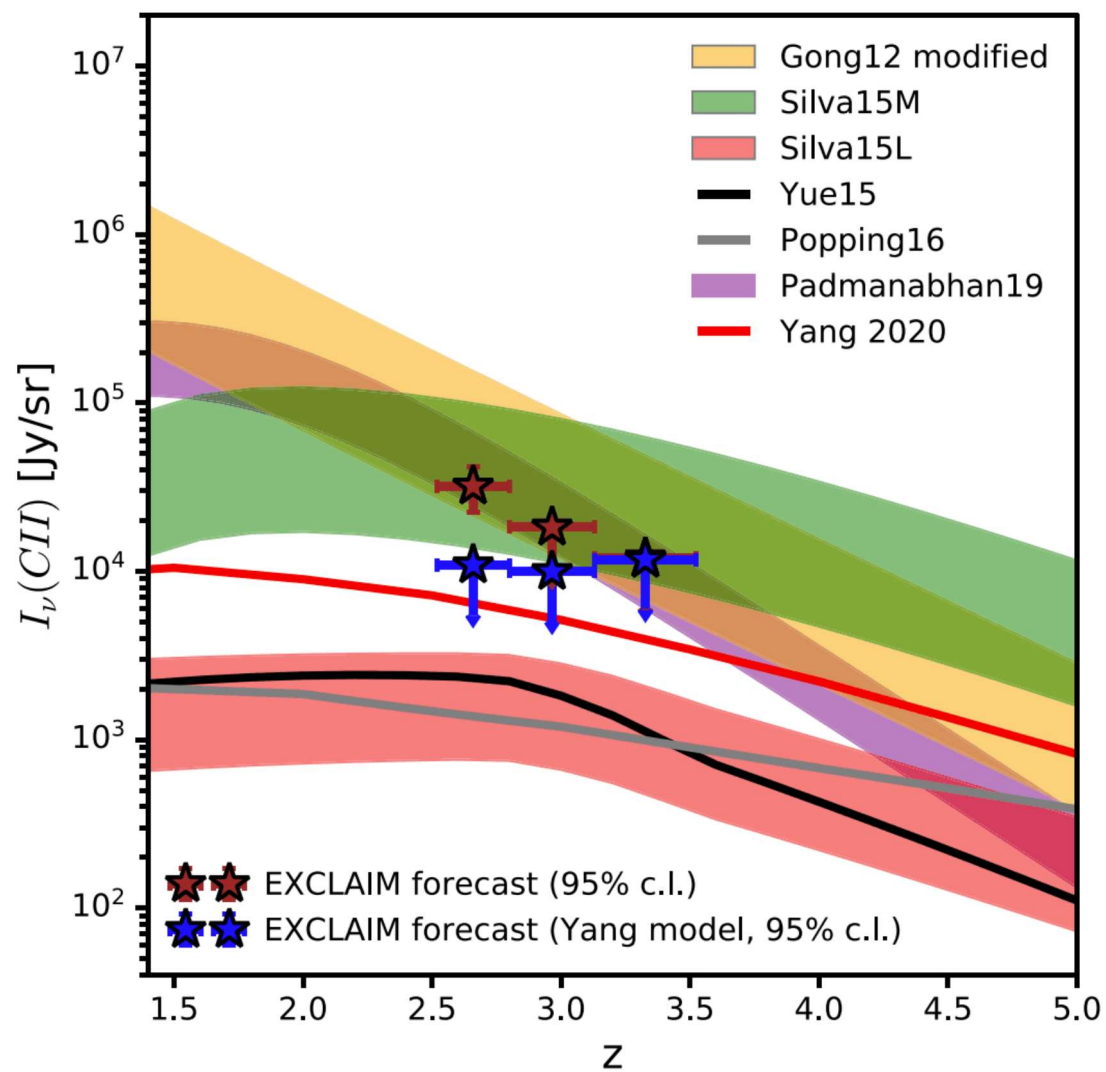
The line emission from objects at different redshift occur at different frequencies and indicate the structure and density of structure in the universe.

IM measures of all objects rather than just brightest objects.

IM studies surface brightness rather than the flux of individual sources. It's a complete blind census plus all other forms of radiation as contamination. The survey area covers a region three times the typical area of an over dense region so avoids the cosmic variants of smaller area sky surveys. A wide variety of lines trace different ionization states and aspects of galaxies over time are detected.



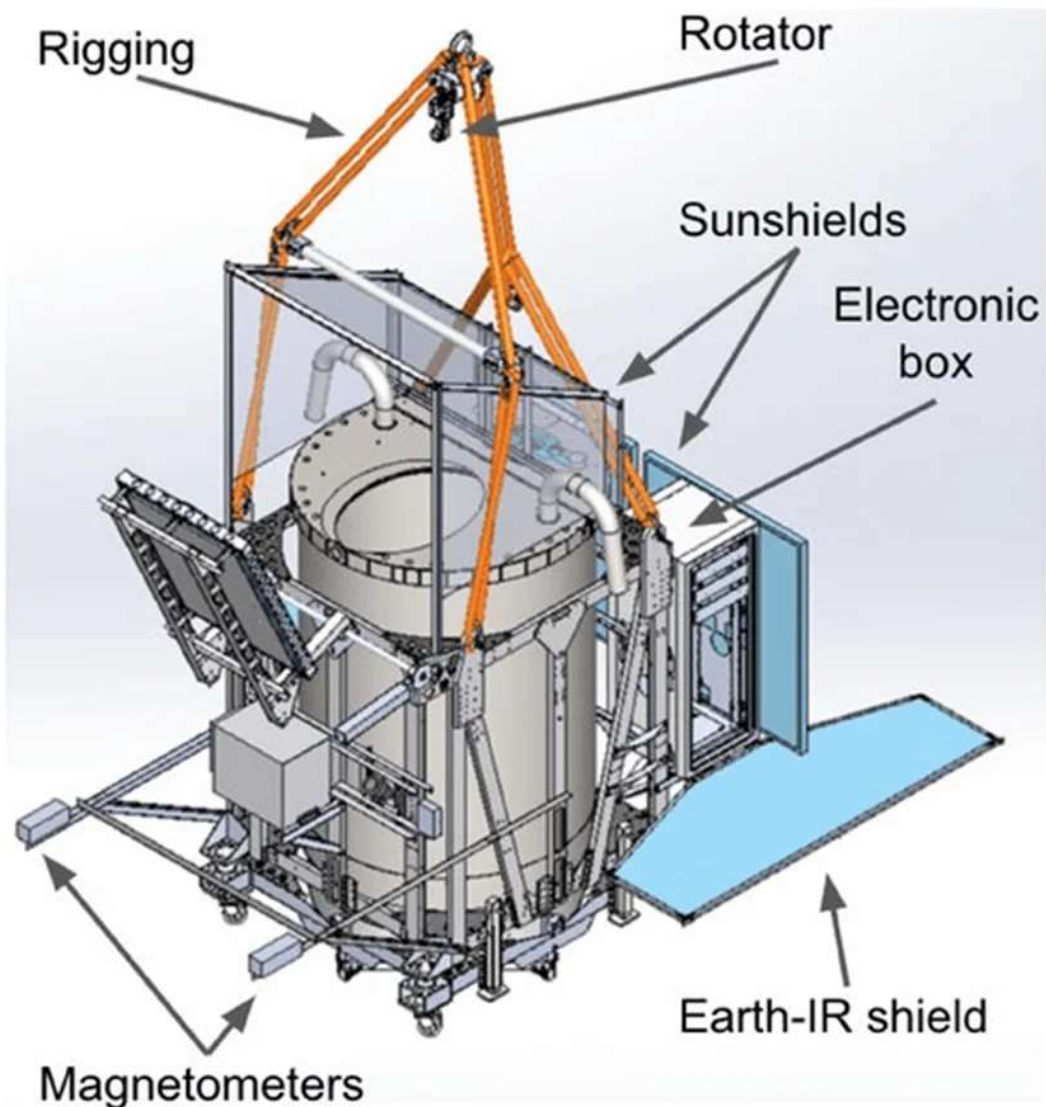
"Various [C II] models for the intensity I_ν as functions of redshift, along with EXCLAIM forecasts for both fiducial [C II] models including joint constraints from $P(k)$ and CVID measurements with a prior. The shaded regions for most of the models correspond to the range of predictions associated with those models. Crosses denote detection, while arrows denote upper limits" (Pullen et. al).



INSTRUMENT

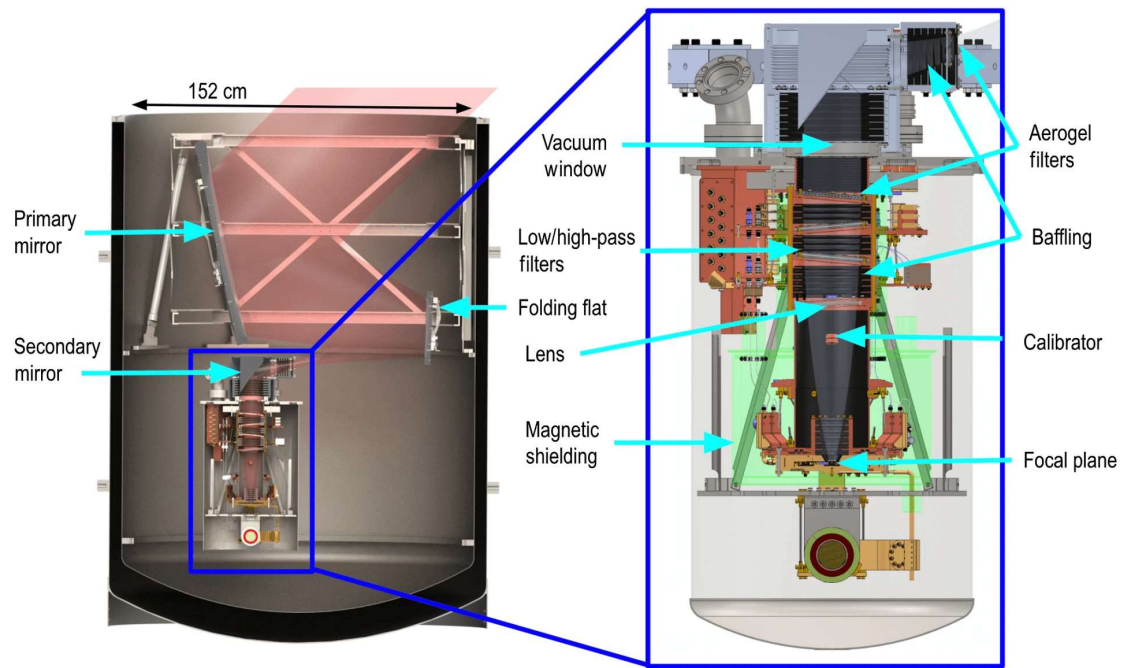
Cryogenic Balloon-Borne Instrument:

- Launch with 2400 liters of liquid helium supports 12 hours of science operation at 1.7 K.
- An adiabatic demagnetization refrigerator backed by 4He adsorption cooler supports a 100 mK focal plane.
- Launch with 11 or 34 million cubic foot (heavy) conventional balloon.
- Superfluid He pumps distribute the liquid He to cool the optics.
- The pointing elevation is fixed at 45 degree, controlling spill and atmospheric modulation.
- A sinusoidal scan with 14 sec period and 7 degree throw maps ± 1.4 degree about the celestial equator.
- Pointing: star camera, gyro, magnetometer, tilt. Online pointing to 1 degree
- Heritage: Primordial Inflation Polarization Explorer (PIPER) [17]. Uses gondola, housekeeping electronics, software, and ADR designs.



EXCLAIM Instrument & Telescope Parameters

Mass	2200 kg
Height(+sun shields)	4.6 m
Telemetry rate	57.6 kbps
Data rate	18 MB/s
Gondola Power	900 W
Readout Power	≤ 120 W
Projected aperture	74 cm
Angular resolution	4' – 5'
Edge Taper	15 dB
Optical Spill	-40 dB
Telescope f/#	1.5
Instantaneous FOV	16.1'



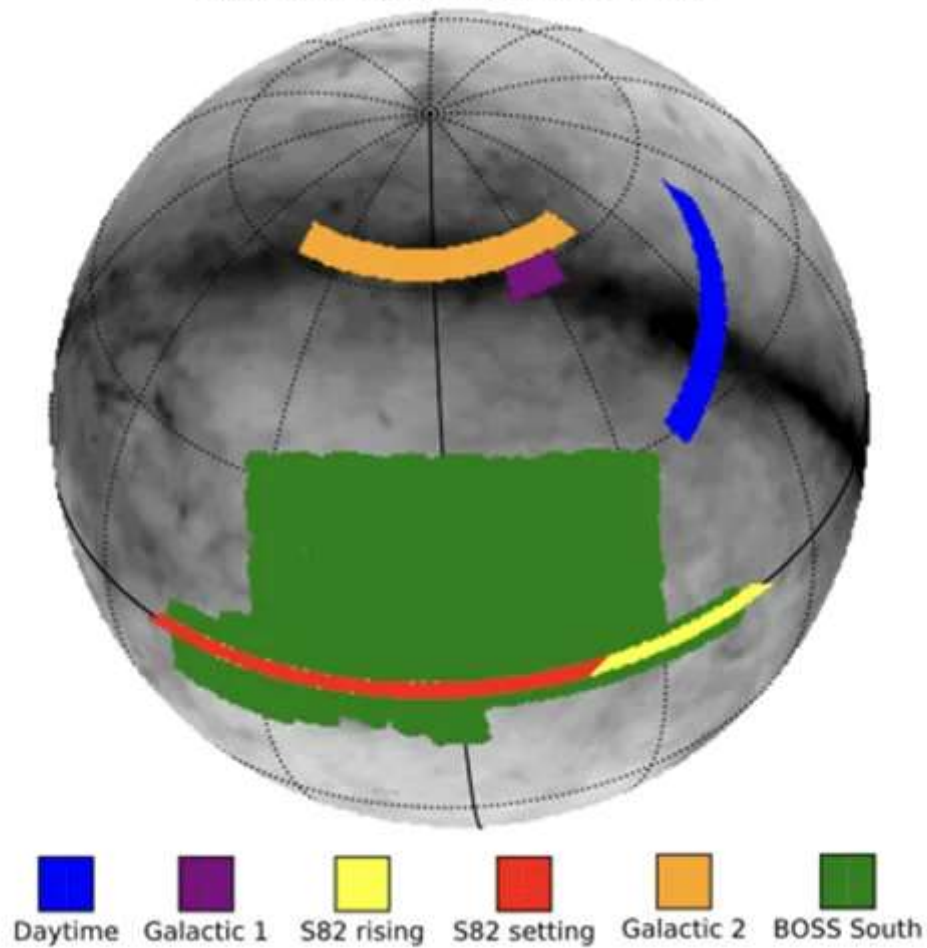
Please refer to: Switzer, Eric R., et al. "Experiment for cryogenic large-aperture intensity mapping: instrument design." *Journal of Astronomical Telescopes, Instruments, and Systems* 7.4 (2021): 044004-044004.

SURVEY

- Cross-correlation with BOSS for primary science, CII $z \sim 3$, CO $0 < z < 1$.
- Large area: Cross-correlation can/should go wide (more isotropic volume); in contrast, auto-power aims for SNR ~ 1 per mode.
- Access linear scales up to $k \sim 1 \text{ h Mpc}^{-1}$.
- Cryogenic telescope for fast integration in dark atmospheric windows.
- Conventional flight from TX or NM: well-matched to BOSS regions, simple logistics, high recovery rate, regular flight opportunities. Start: 4/2019, flight 2024
- Versatile platform for testing FIR spectrometer technology in space-like environment.

Parameter	Symbol [unit]	Value
Observed frequency range	ν_{obs} [GHz]	420–540
Observed wavelength range	λ_{obs} [μm]	555–714
Spectral resolution	$R = \nu/\Delta\nu$	512
Beam FWHM at 480 GHz	θ_{FWHM} [arcmin]	4.33
Sky Area (Extragalactic, GP)	Ω [deg^2]	305, 100
Number of spectrometers	N_{specs}	6
Survey duration	t_{surv} [hr]	10.5

EXCLAIM regions from Ft. Sumner



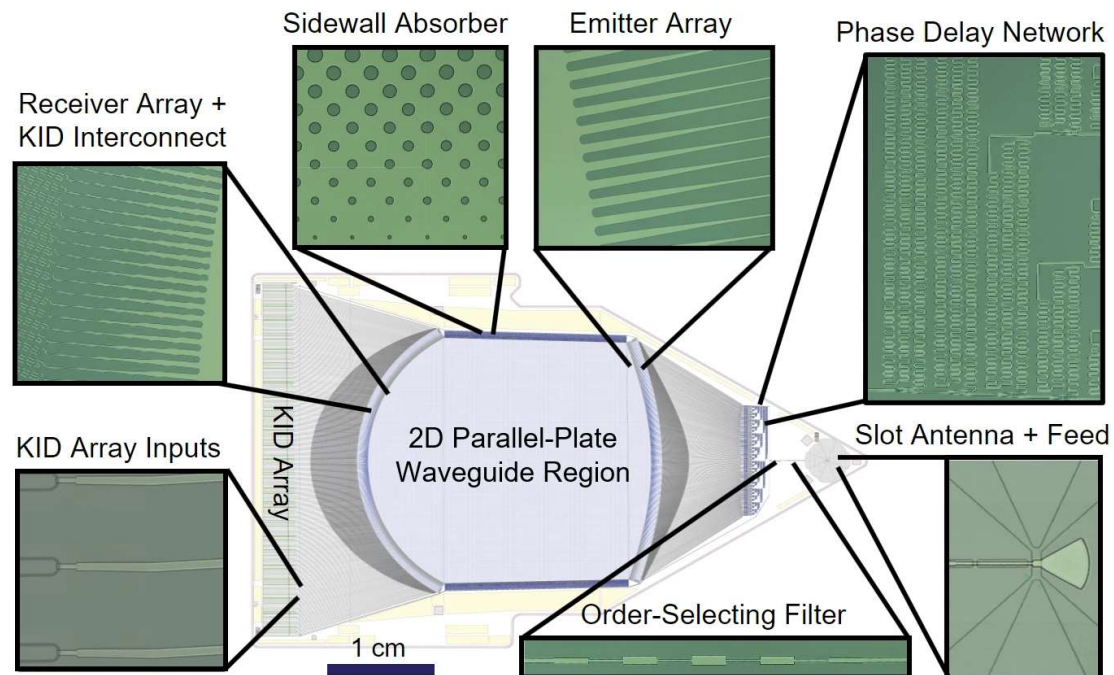
Preliminary survey plan (all local time)				
Daytime field anti-solar scan, 200 deg ² , crosses the galactic plan	Galactic field 1	BOSS S82 field rising 305 deg ²	BOSS S82 field setting	Galactic field 2
3PM -6PM	6PM – 7PM	7PM – 1AM	1AM – 5:30 AM	5:30AM - 7AM

U-SPEC

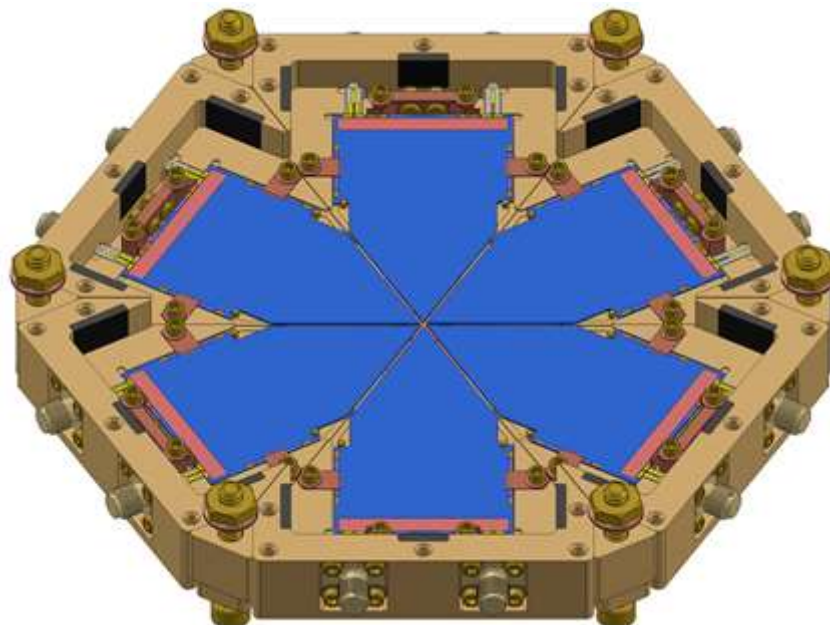
[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1701971318/aas/74-A4-90-17-C2-E6-92-31-3C-63-B3-F0-64-69-0C-DF/Video/181510MicroSpecAnimv6_szo3s3.mp4

A superconducting microwave kinetic inductance detector (MKID) provides ultra low sensitivity, high dynamic range, and intrinsic frequency multiplexing (355 KIDs read out on a single coaxial cable).

This is implemented by using a thin film Al in a microstrip half wave resonator design with a Nb ground plane.



EXCLAIM achieves high sensitivity using a cryogenic telescope coupled to six integrated spectrometers with spectral resolving power $R=512$ and employing microwave kinetic inductance detectors.









CURRENT STATUS

The mirrors delivered are being integrated onto the frame.

The spectrometer are under fabrication and we are expecting devices in spring 2024

The silicon lens and window AR coating will hopefully be complete by mid- January 2024.

The forecast paper (Pullen, et al.) has been put out.

The science flight is scheduled for Fall 2024.

TRANSCRIPT

ABSTRACT

EXCLAIM, the EXperiment for Cryogenic Large-Aperture Intensity Mapping, is a long-wave far-infrared (420–540 GHz) balloon-borne cryogenic telescope mission to study the star formation from the present day, out to redshifts of $z = 3.5$, including during the period of decline in the star formation rate since $z = 2$, while dark matter halo masses have continued to condense. EXCLAIM will observe singly-ionized carbon and carbon monoxide emission lines using an intensity mapping approach. EXCLAIM features six compact and sensitive on-chip μ -Spec spectrometers with a resolving power $R = \Delta\lambda/\lambda = 512$ and a noise equivalent power, $NEP < 8 \times 10^{-19} \text{ W}/\sqrt{\text{Hz}}$, utilizing 355 aluminum Microwave Kinetic Inductance Detectors (MKIDs) per μ -Spec. The MKIDs are read out through a single microwave feedline in a frequency multiplexing scheme and using Radio Frequency System on a Chip, RFSoc digital electronics. The telescope optics operate at a temperature $\leq 5 \text{ K}$ while the spectrometers operate at 0.1 K , well below the transition temperature of aluminum. The combination of cooled optics and minimal upper atmospheric background emissions at the balloon flight altitude ($\sim 36 \text{ km}$) provide an exceptionally sensitive environment for achieving the mission's science goals, and for evaluating the performance of the spectrometers and MKIDs, and their promise for application in future space-based telescopes. In this work, the current status of the EXCLAIM instrument in development is presented.

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