

2025 HELIOTECH/SUBORBITAL SYMPOSIUM

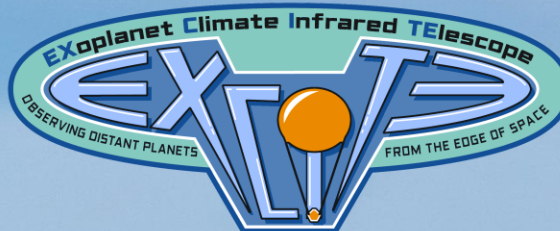
The EXoplanet Climate Infrared TElescope (EXCITE)

A cryogenic near-infrared balloon-borne observatory with
milli-arcsecond pointing stability

Peter C. Nagler

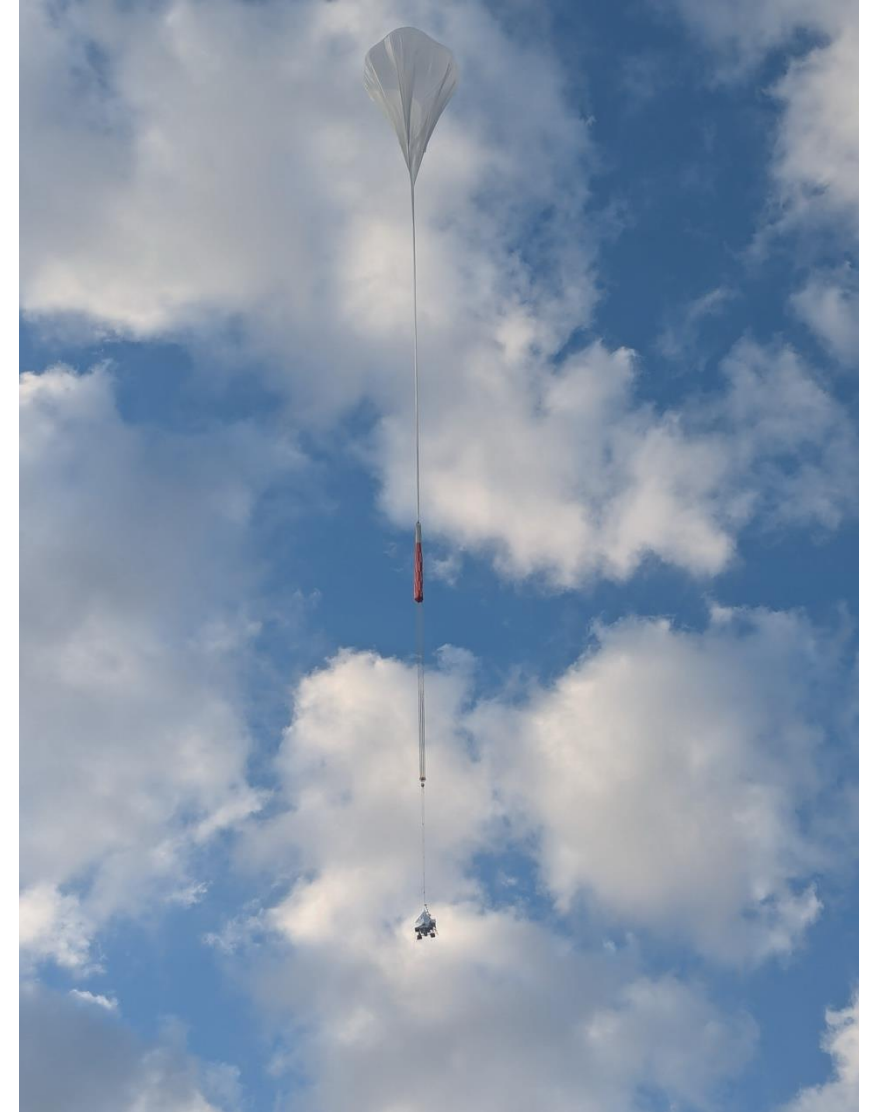
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EXCITE mission overview

- EXCITE is a balloon-borne 0.5 m diameter IR telescope.
- Science instrument: cryogenic IR spectrograph operating from $0.8\text{ }\mu\text{m}$ to $4\text{ }\mu\text{m}$, $R \simeq 50$.
- Gondola: based on successful SuperBIT platform.
- Science motivation: spectroscopic characterization of the atmospheres of hot Jupiter exoplanets
 - **Phase resolved spectroscopy**
 - Primary transit spectroscopy
 - Eclipse spectroscopy
- Designed to achieve excellent photometric stability & precision over the long, continuous stares required for phase curve measurements.
- Uses many new & advanced technologies that are enabling for low-cost, high precision exoplanet science missions.
- EXCITE flew an engineering flight in August 2024.
- Currently preparing for 2026/2027 Antarctic science flight.



Measure spectroscopic phase curves of hot Jupiter exoplanets from 0.8 – 4 μm .

NIR spectroscopic phase curves allow one to:

- Constrain planet's global energy budget.
- Measure atmospheric circulation.
- Probe spectral features from molecules like H_2O , CO_2 , CO , CH_4 , NH_3 , TiO , VO .
- Measure peak of planet's peak emission.
- Probe atmospheric properties as function of pressure/altitude.
- Plus, get transits/eclipses for free.

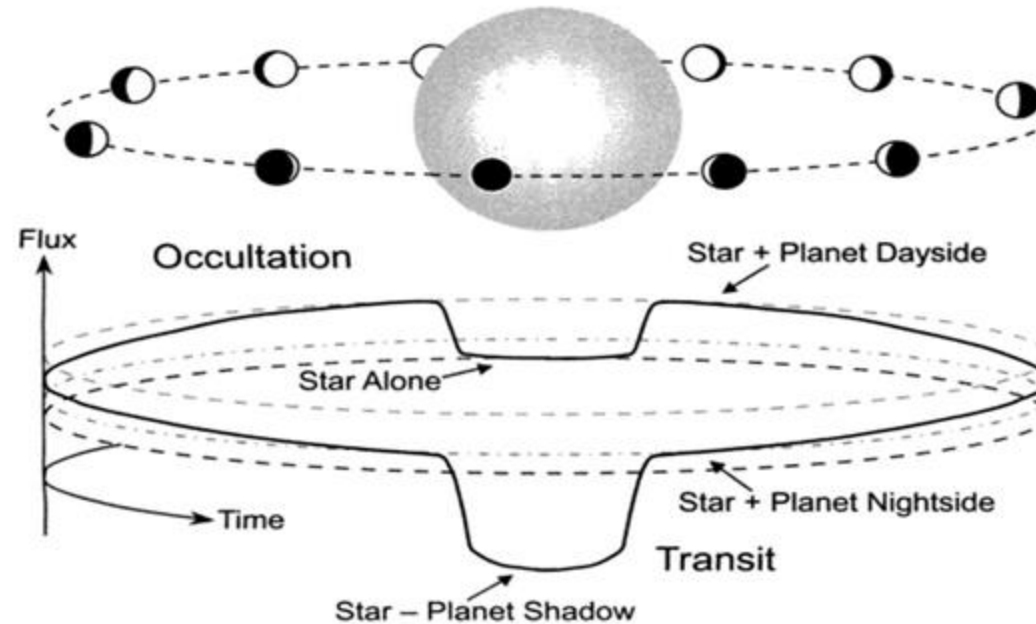
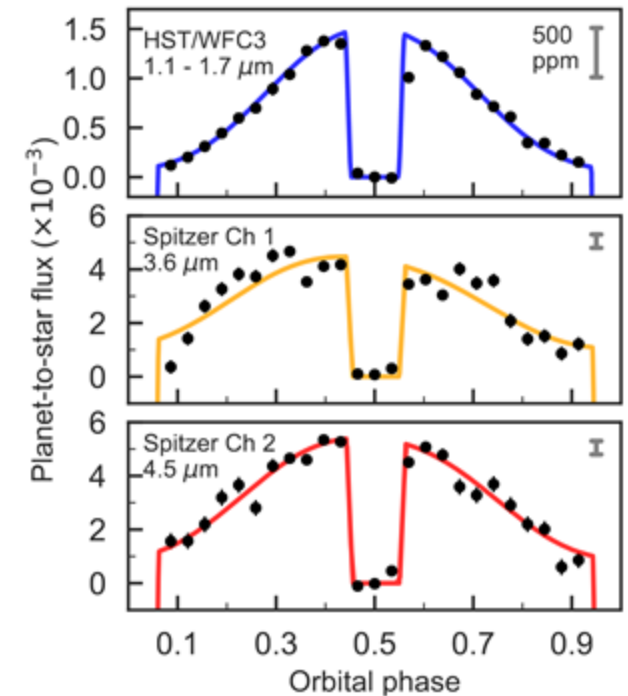


Figure from Kreidberg et al., 2018.

EXCITE science motivation

- Some information derived from phase curve measurements:

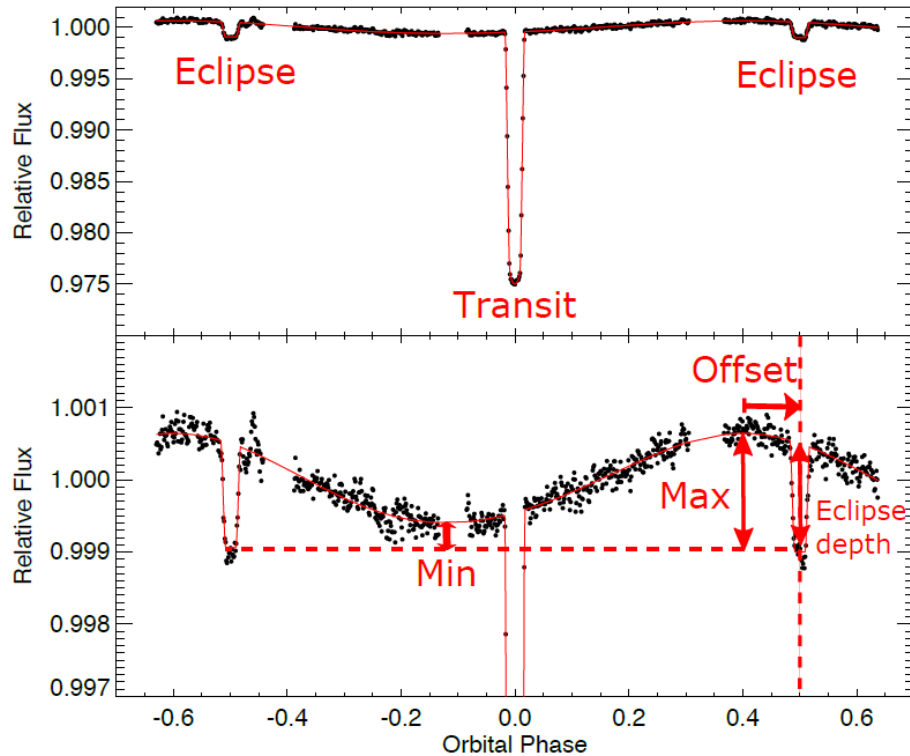
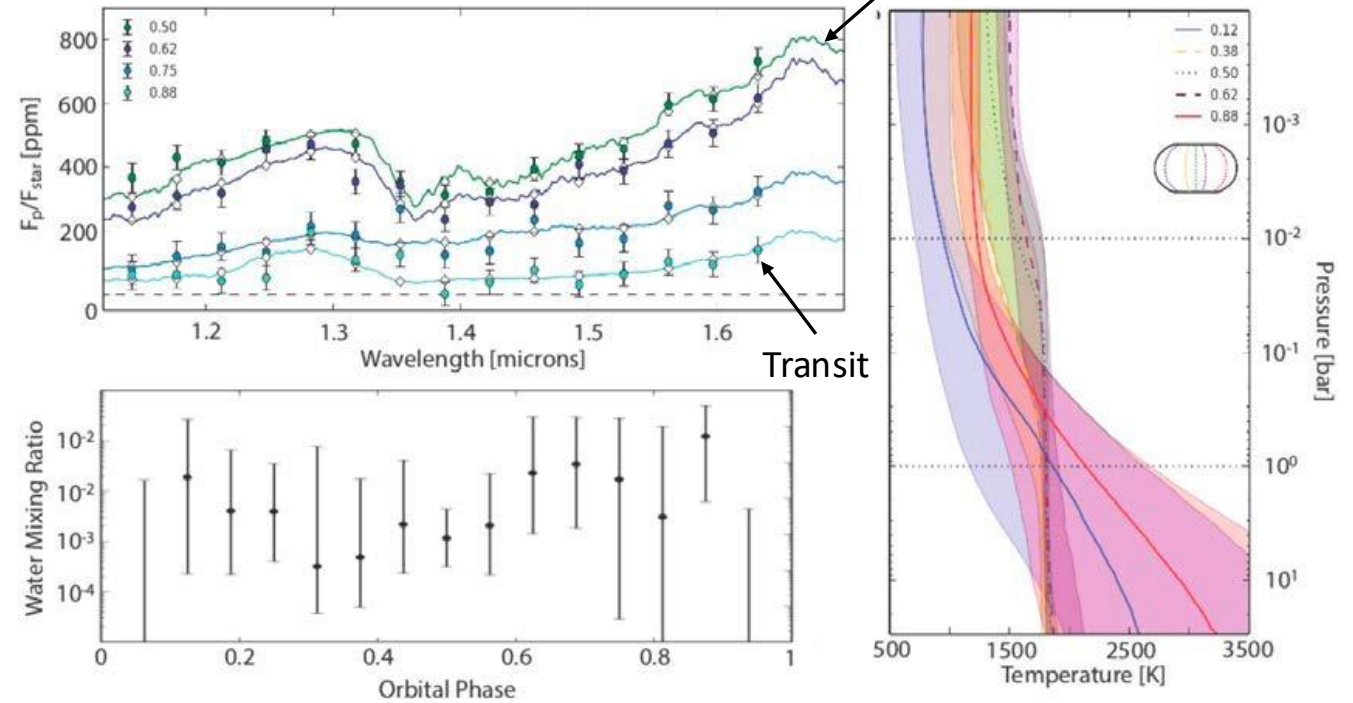


Figure adapted from Stevenson et al., 2014

Scientifically rich, but difficult and time consuming, especially from LEO.
Ideally suited for balloon measurement from near Earth's poles.

EXCITE science motivation

- LEO phase curve measurements are time consuming, inefficient, and subject to large settling effects (see below). First two measurements in literature required 100+ hours of space telescope time to observe planets with ~ 20 hr periods.
- From balloon altitudes, Earth's atmosphere is stable and transparent in 1-4 μm region (see right), and near the poles, many targets never set. **EXCITE will pioneer “point and stare” phase curve observations.**

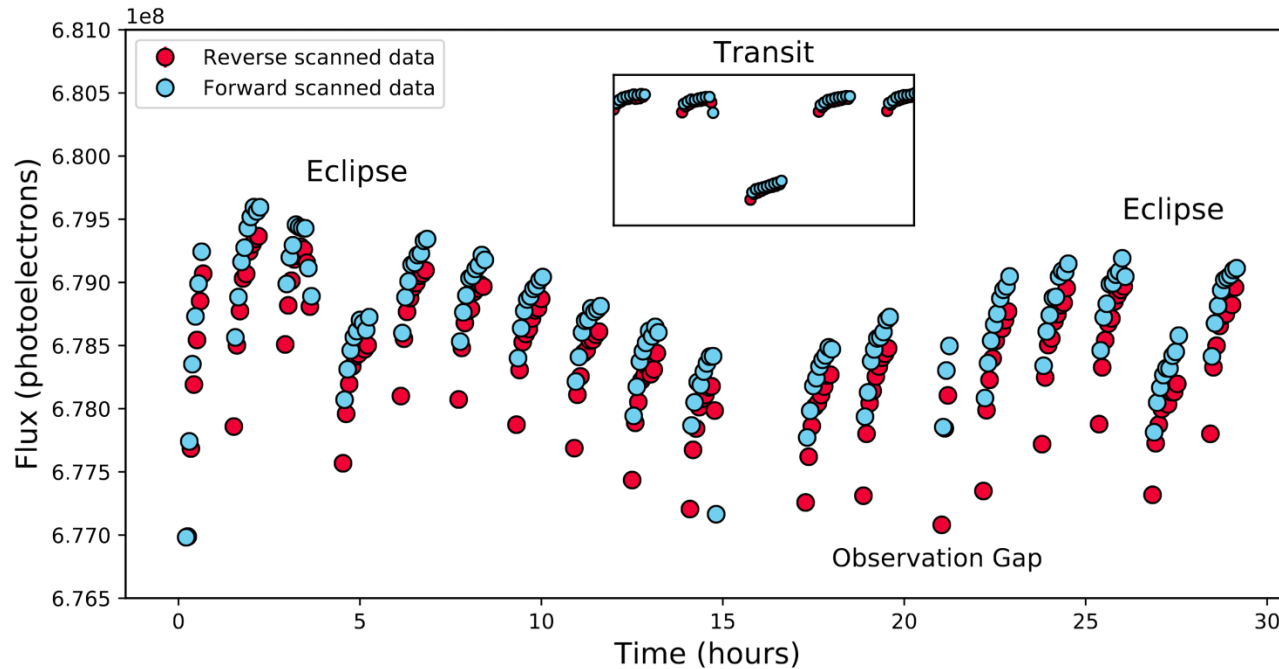
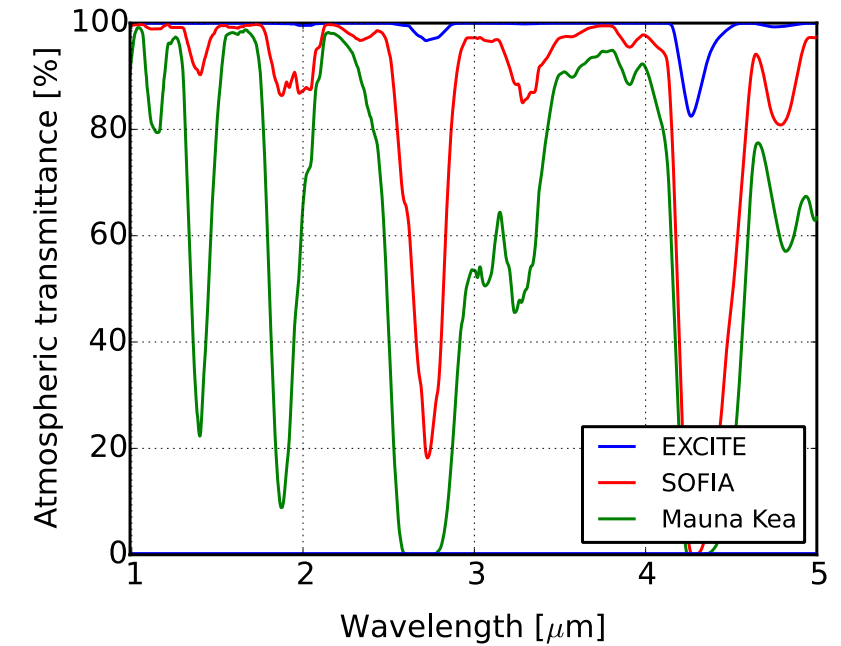
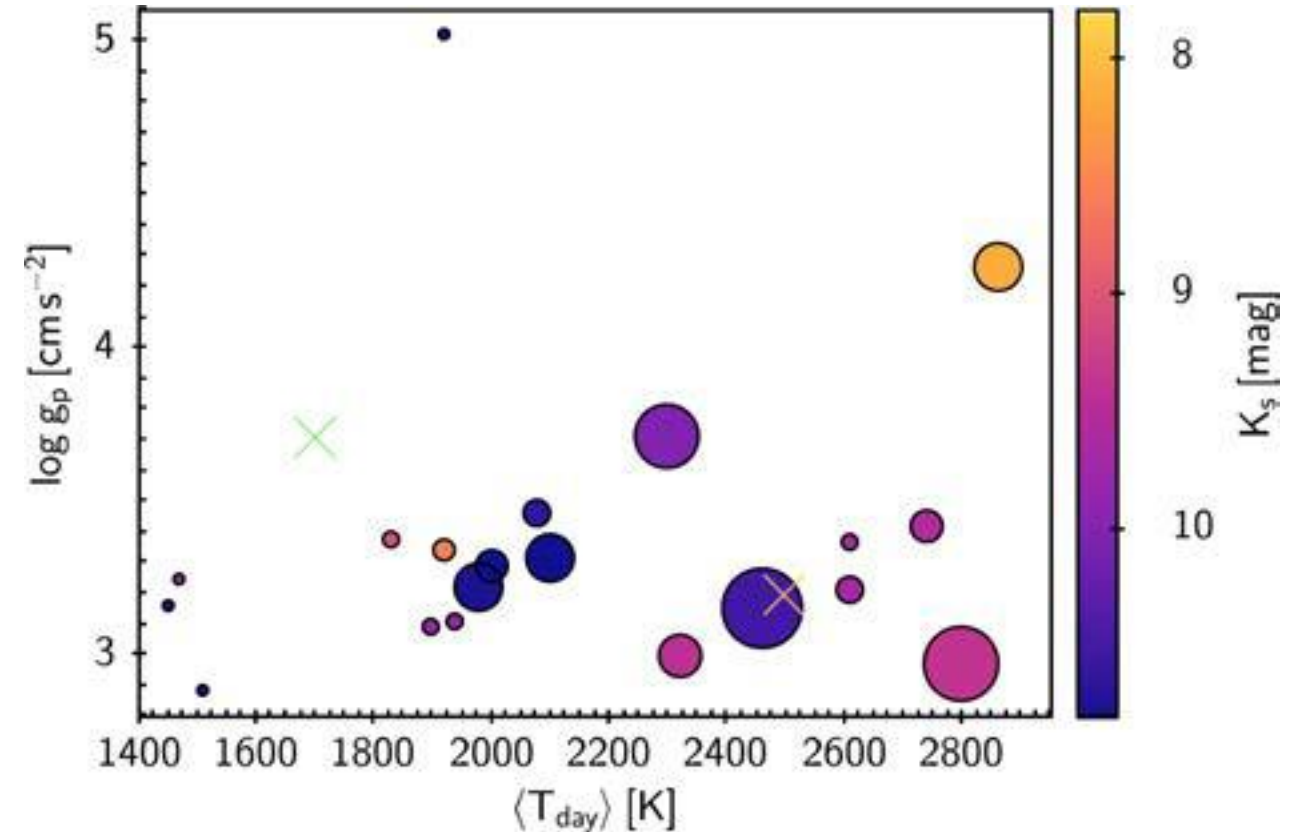


Figure from Arcangeli et al., 2019



EXCITE science impact

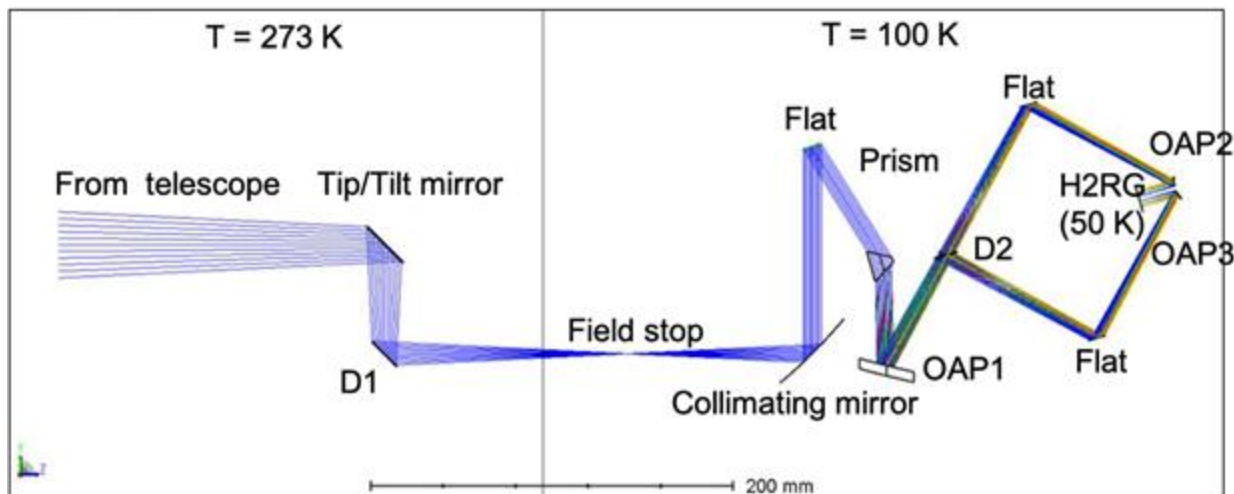
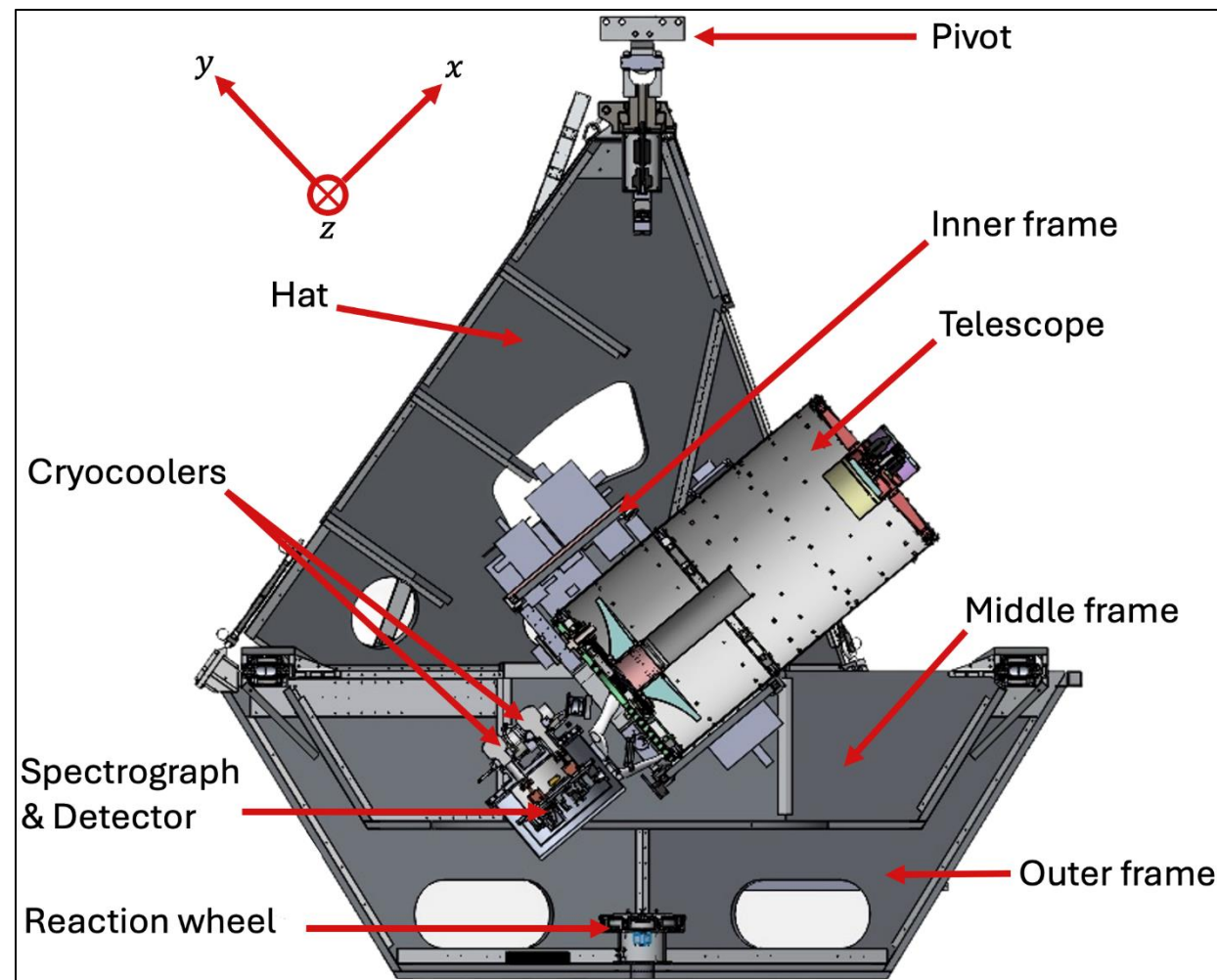
Name	RA	Dec	P _{orb} [d]	$\langle T_{\text{day}} \rangle$ [K]	log g_p [cm s ⁻²]	ΔK_s [ppm]	K_s [mag]
KELT-15	07:49	-52	3.33	1940	3.11	600	9.85
WASP-4	23:34	-42	1.34	1980	3.22	1700	10.75
WASP-5	23:57	-41	1.63	2080	3.46	1000	10.60
WASP-18	01:37	-45	0.94	2860	4.26	1600	8.13
WASP-19	09:53	-45	0.79	2460	3.15	2800	10.48
WASP-23	06:44	-42	2.94	1340	3.29	260	10.45
WASP-41	12:42	-30	3.05	1470	3.24	390	9.68
WASP-64	06:44	-32	1.57	2000	3.29	1100	10.96
WASP-72	02:44	-30	2.22	2610	3.36	600	9.62
WASP-87	12:21	-52	1.68	2740	3.42	1100	9.55
WASP-95	22:29	-48	2.18	1920	3.34	700	8.56
WASP-96	00:04	-47	3.43	1510	2.88	330	10.91
WASP-97	01:38	-55	2.07	1830	3.37	600	9.03
WASP-100	04:35	-64	2.85	2610	3.21	900	9.67
WASP-108	13:03	-49	2.68	1900	3.09	600	9.80
WASP-121	07:10	-39	1.27	2800	2.97	2700	9.37
WASP-122	07:13	-42	1.71	2320	2.99	1500	9.42



EXCITE can vastly expand measured phase curve physical parameter space, but needs to achieve excellent photometric stability (goal: < 40 ppm/hour at 2.5 μm).

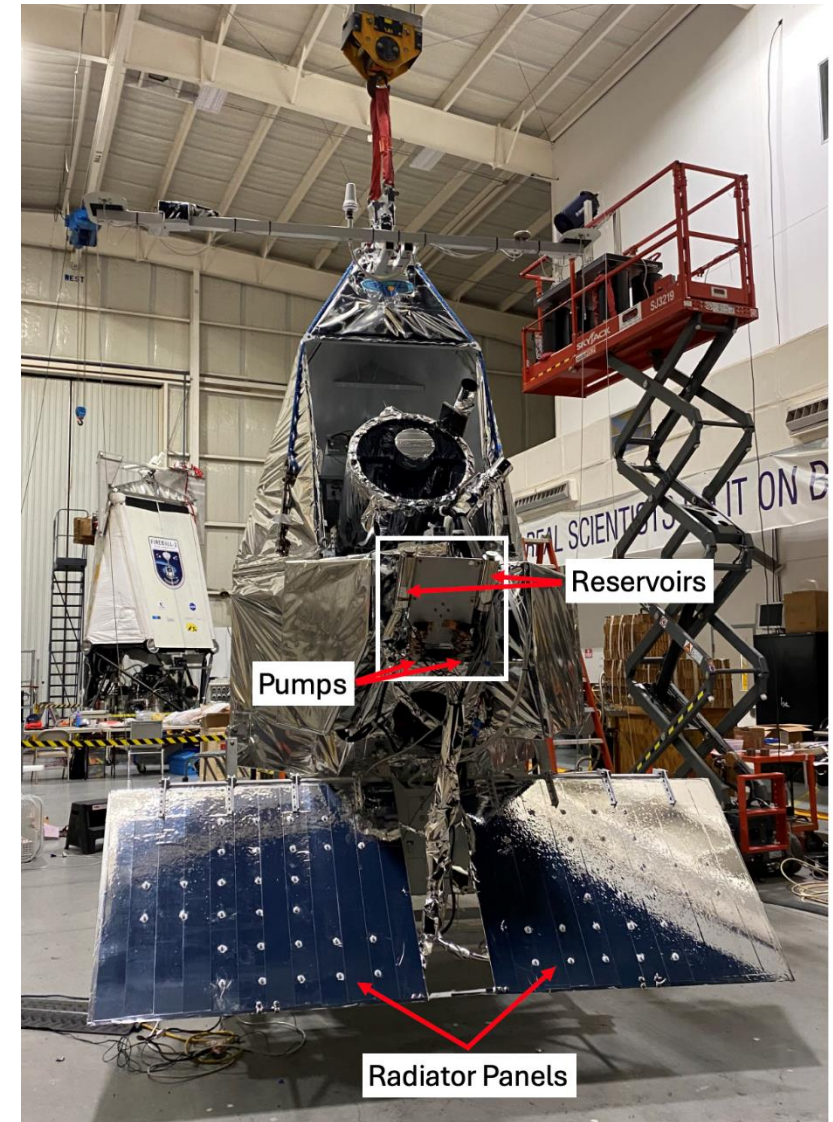
EXCITE payload overview

- Gondola is near-copy of SuperBIT. Three axis stabilization (yaw/roll/pitch) to better than 1" RMS, line-of-sight stability better than 0.050" RMS via tip/tilt mirror (requirement: < 450 mas RMS).
- Science instrument: Two channel cold (100 K) prism spectrometer with native resolving power $R \sim 50$, coupled to 0.5 m warm telescope. Science focal plane: H2RG detector (~50 K, JWST) read out by ACADIA (~130 K, RST) and MACIE (300K) electronics.
- Designed to achieve excellent photometric stability required for the science.

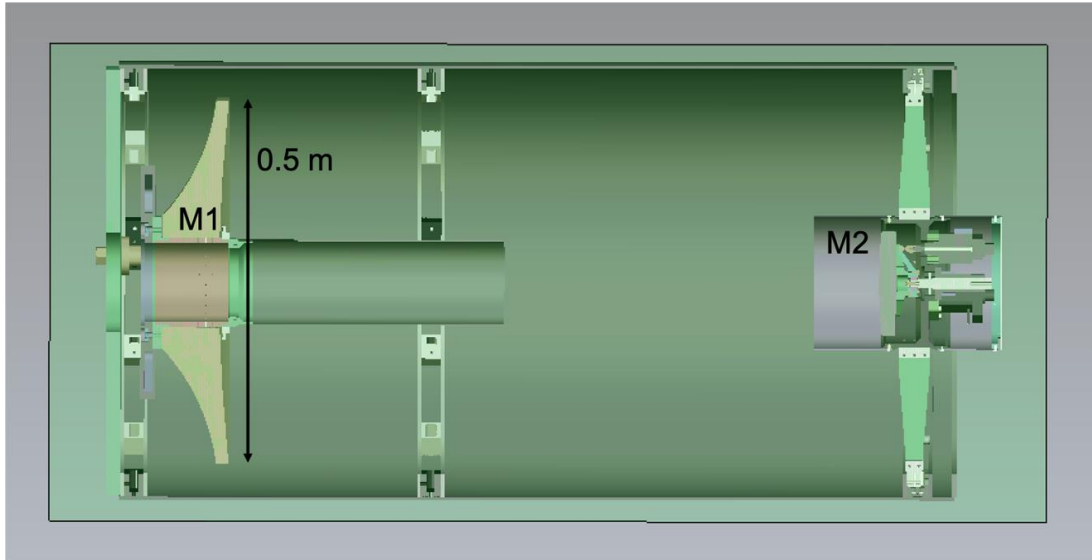


EXCITE gondola

- StarSpec Technologies, Inc. in Toronto, Canada is built the EXCITE gondola.
- Design is nearly identical to the highly-successful SuperBIT gondola, with some key changes to accommodate EXCITE's science instrument.
- Three gimballed frames are stabilized to better than 1" RMS using feedback from gyros and star cameras.
- Focal plane stabilized to $<100\text{mas}$ RMS using piezo-actuated tip/tilt mirror and feedback from optical camera at telescope focus.
- Solar powered for LDB; battery powered for conventional flights.
- 24h continuous daytime observations.
- Elevation: $22^\circ - 57^\circ$.
- Azimuth: $\pm 135^\circ$ from anti-Sun.
- See Romualdez *et al.*, 2024 for more information.



EXCITE telescope



- Officina Stellare (OS) in Italy built the telescope, which is minimally changed from the telescope that flew on SuperBIT.
- 0.5m primary, secondary has 3-axis actuation for focus correction.
- EXCITE-specific changes include: baffle interior wrapped in MLI (passively cool the optics), radiator plates mounted to exterior of baffle, Richey-Chrétien optical configuration, larger f/# (f/12 instead of f/10.8).

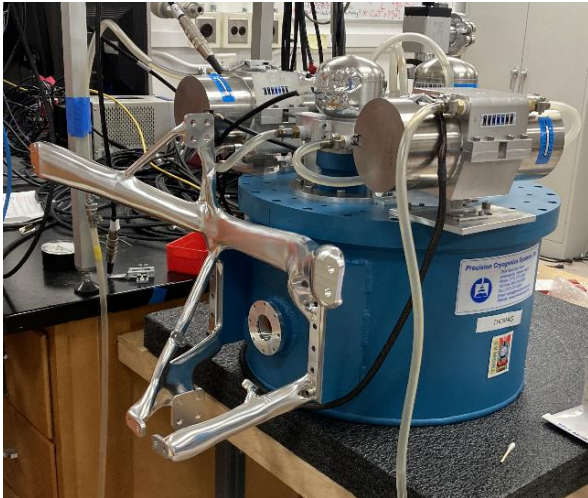
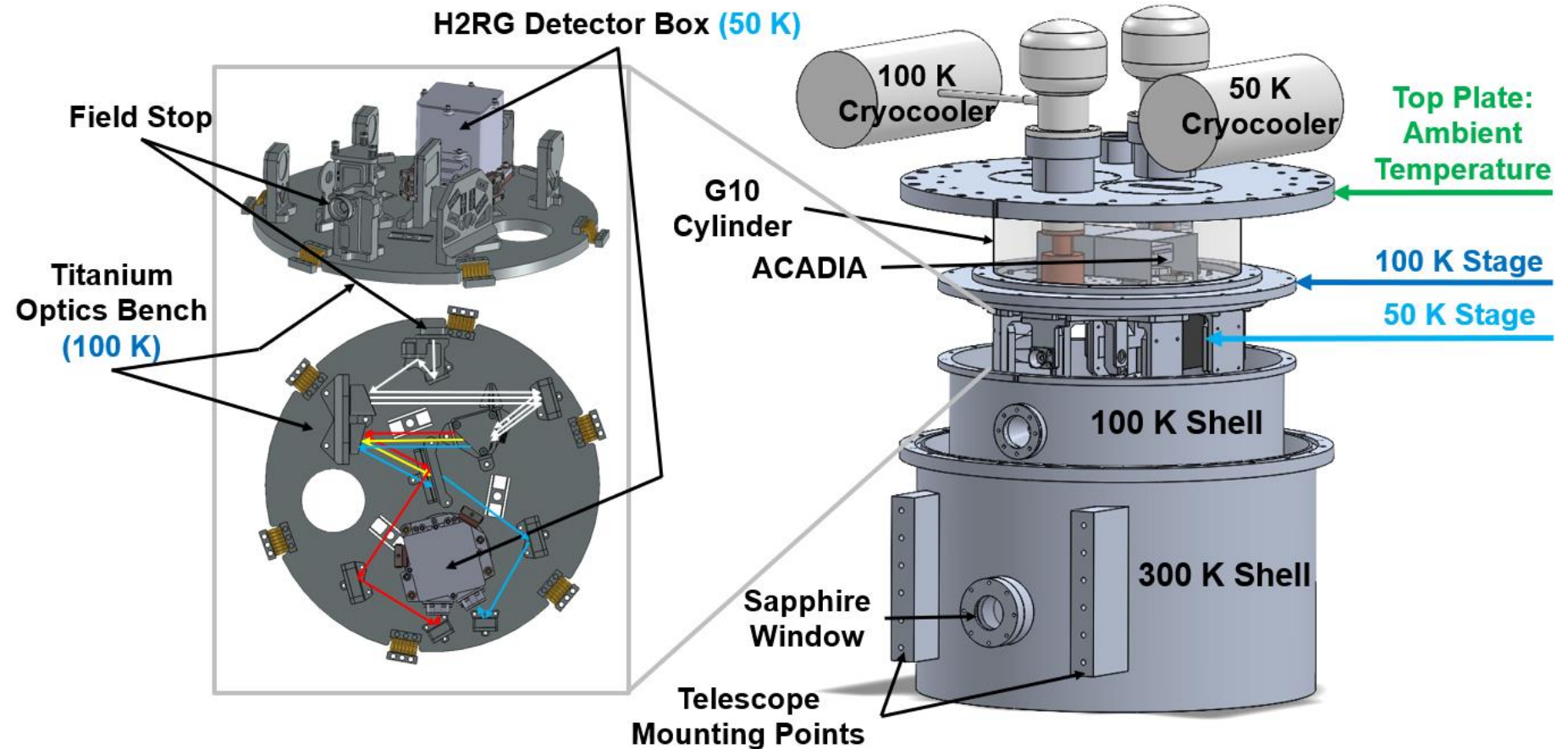


EXCITE receiver

Receiver consists of:

- Cryostat
- Spectrometer
- Detector system

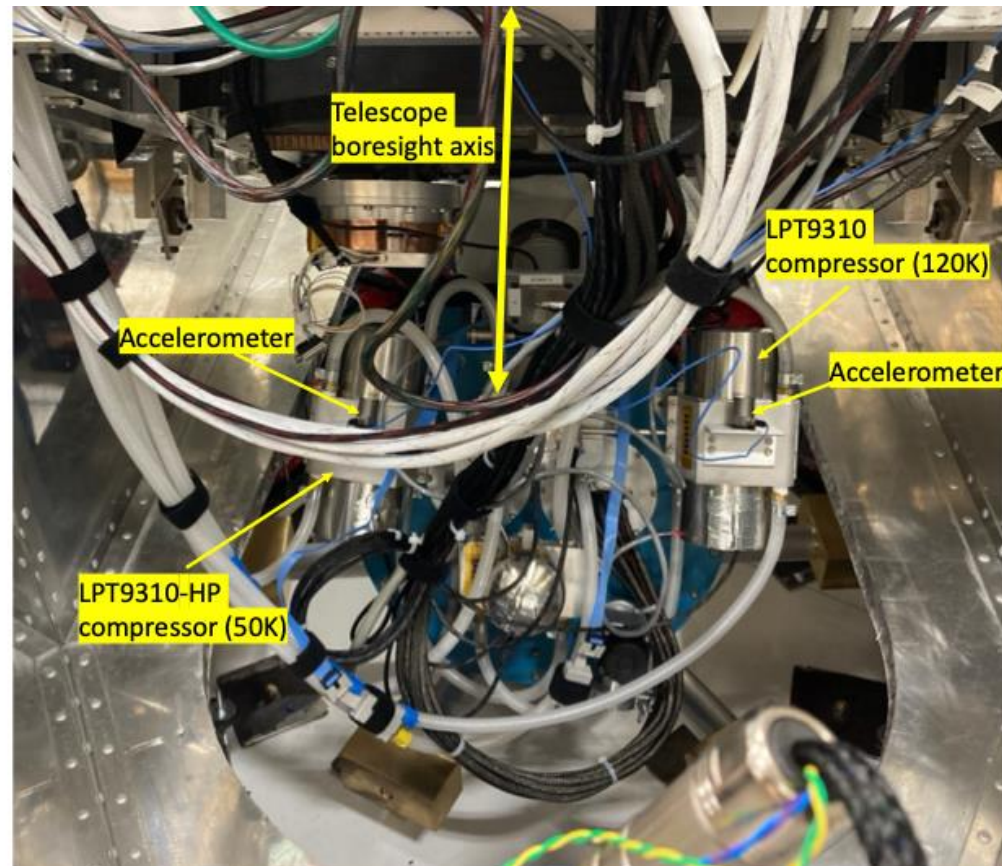
Coupled to telescope via generatively-designed “transfer box”, which also supports key components of the gondola’s fine guidance system.



EXCITE cryogenic system

Cryostat and cryocoolers

- Cryocoolers are Thales LPT-9310 (100 K) and LPT-9310-HP (50 K).
- Linear pulse tube cryocoolers have fewer moving parts and generate less vibration than other cryocooler technologies. This is their first implementation on a balloon payload.
- Pistons are oriented along boresight axis to minimize impact of vibrations.
- Semi-custom cryocooler drive electronics from West Coast Solutions/Creare allow passive and active vibration reduction.
- **EXCITE has measured zero negative impact from cryocooler exported vibrations on the instrument's pointing stability.**
- Heat dissipated by the coolers is removed via a pumped methanol liquid cooling loop.
- See Kleyheeg *et al.*, 2024 and Kirkconnell *et al.*, 2024 for more information about the cryostat and drive electronics.



EXCITE spectrometer

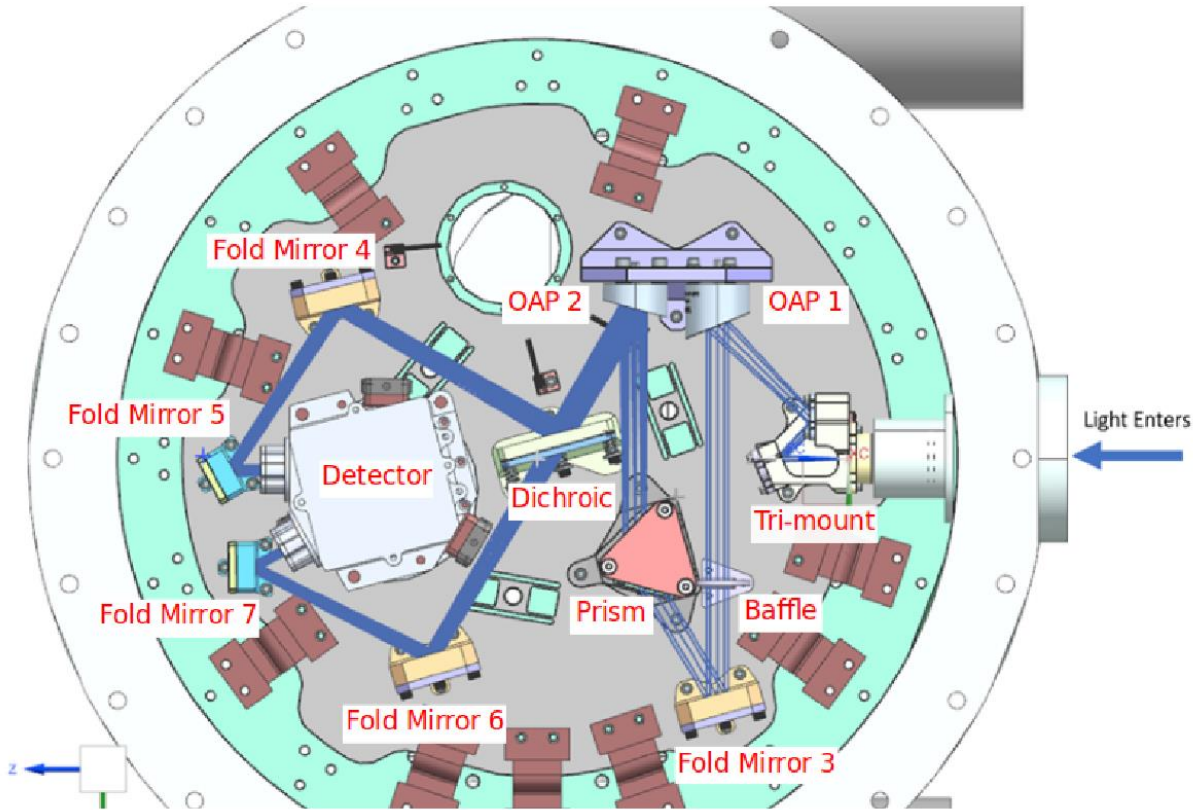
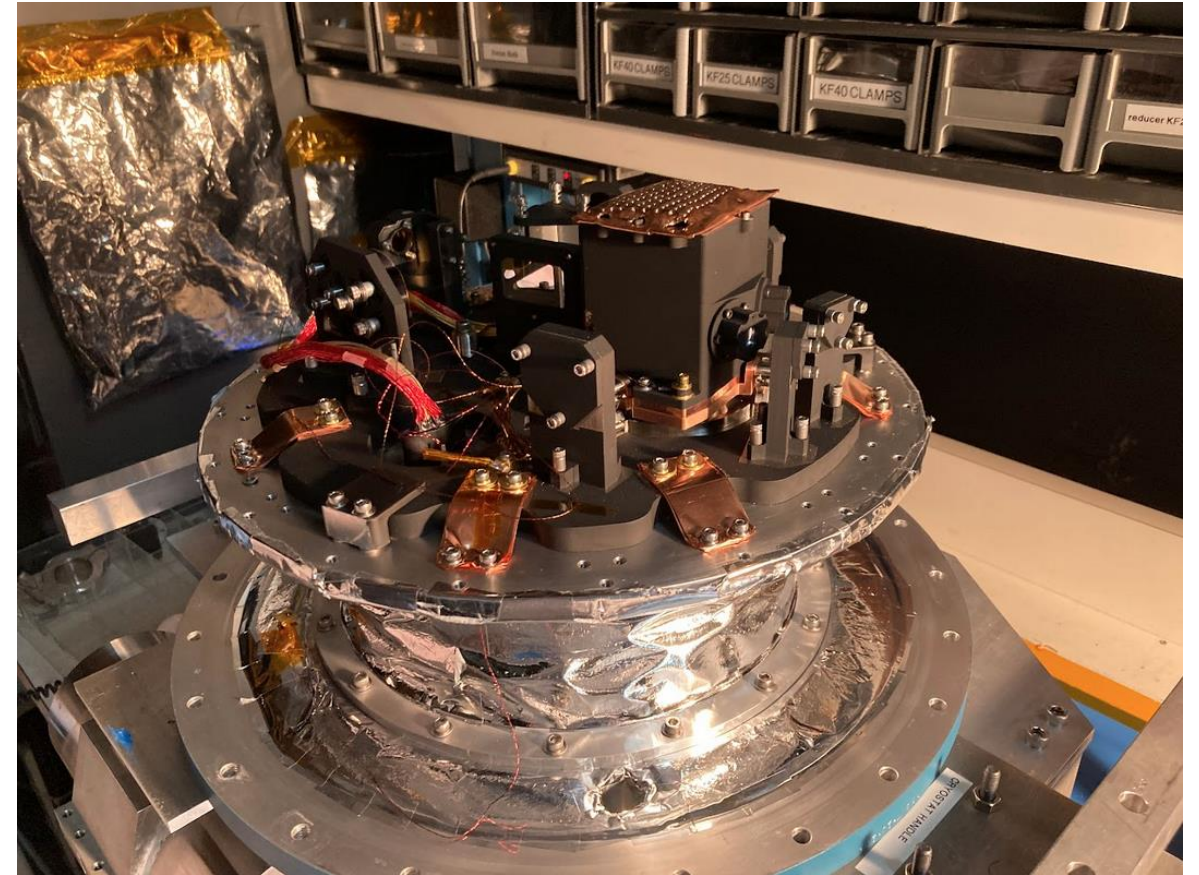
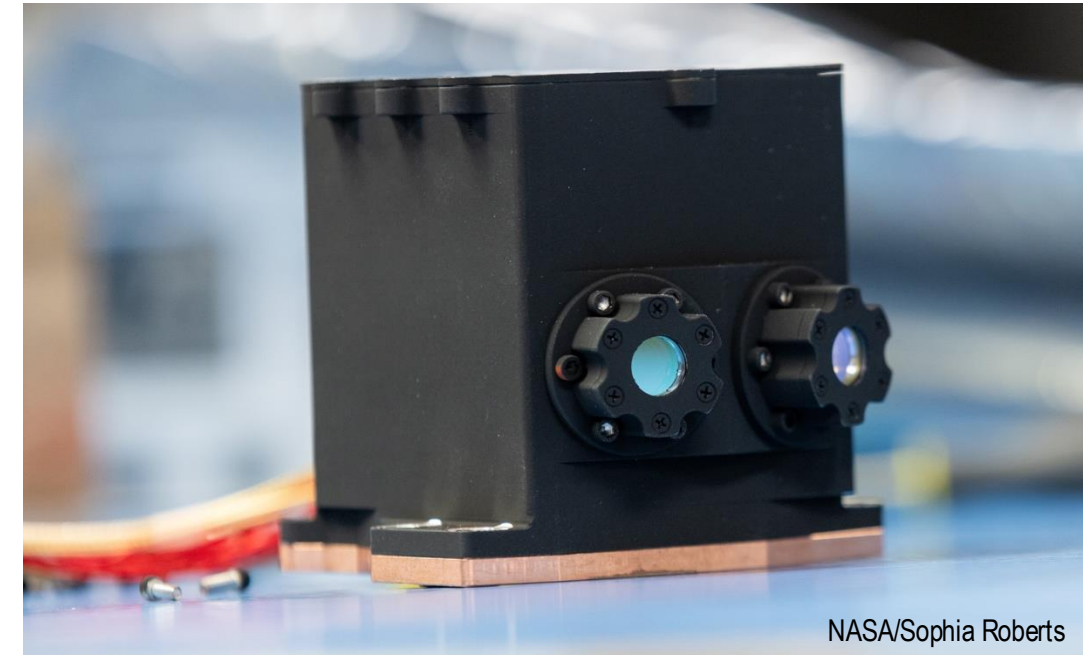


Figure from Bernard *et al.* 2024



- Optical bench machined from Ti-6Al-4V, chosen for high strength and low CTE.
- Kinematic flexures couple the optical bench to the Al cold plate.
- Spectrometer is aligned at room temperature and maintains alignment as it cools to its 100K operating temperature.
- Detector assembly is thermally isolated from the optical bench via Kevlar suspensions that maintain alignment during cooling.
- See Bernard *et al.*, 2024 for more information.

EXCITE detector system

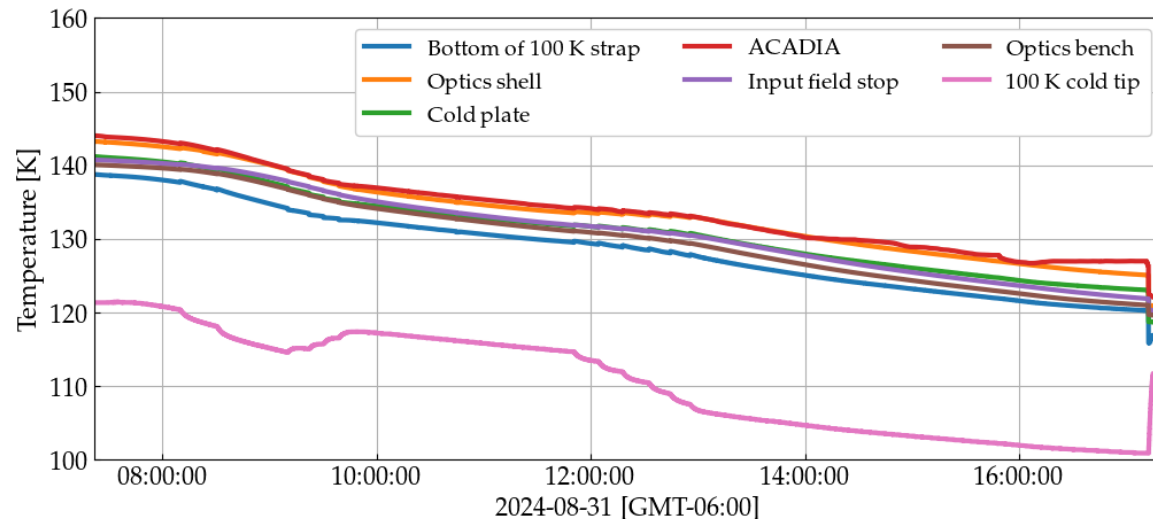
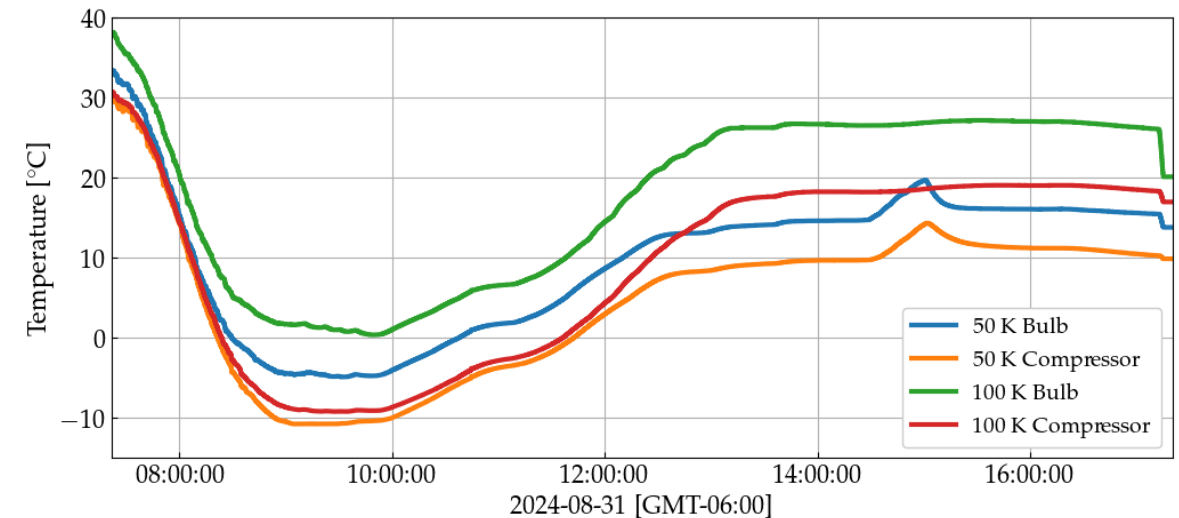


- EXCITE's detector is a JWST/NIRSpec flight candidate H2RG (4 megapixels) with 5.3 μ m cutoff. It has been extensively characterized.
- Detector read out using ACADIA (130K, RST) and MACIE (300K).
- Band-defining filters are used on detector enclosure to limit effective bandpass of detector.

EXCITE engineering flight

Overall performance:

- 10h13m flight, with ~7.5h at float altitude of >39 km.
- Achieved 3 axis gondola stabilization of <1" RMS, meeting requirements for science.
- Detector system performed nominally.
- Cryogenic system met all requirements with significant margin.



Challenges:

- GPS compass failed on pin release, limiting ability to solve for azimuthal position.
- Elevation axis had limited travel (~40-57 deg, instead of 22-57 deg) due to thermo-elastic deformation of bearing housing.
- Implemented both hardware and software changes to prevent recurrence and mitigate potential impact during science flight.

EXCITE current status

- EXCITE sustained minimal damage on termination/landing/recovery.
- Completed payload refurbishment and re-assembly in Summer 2025, including:
 - Cleaned telescope optics.
 - Rebuilt frameless motors designed to operate over wider temperature range; confirmed via TVAC at CSBF.
 - Rebuilt cryocooler power supply with features to limit RFI. Confirmed via EMI testing at GSFC.
 - Integrated solar panel arrays with gondola assembly.
- Built and currently testing pinhole sun sensors to provide redundant azimuth information in flight.
- Currently performing pointing tests using laboratory and sky sources.
- Installation of science detector planned for Fall 2025, followed by full system testing until next deployment.
- Instrument paper by Rehm *et al.* in prep. Submission expected this month.



EXCITE team

Thank you! Questions?

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