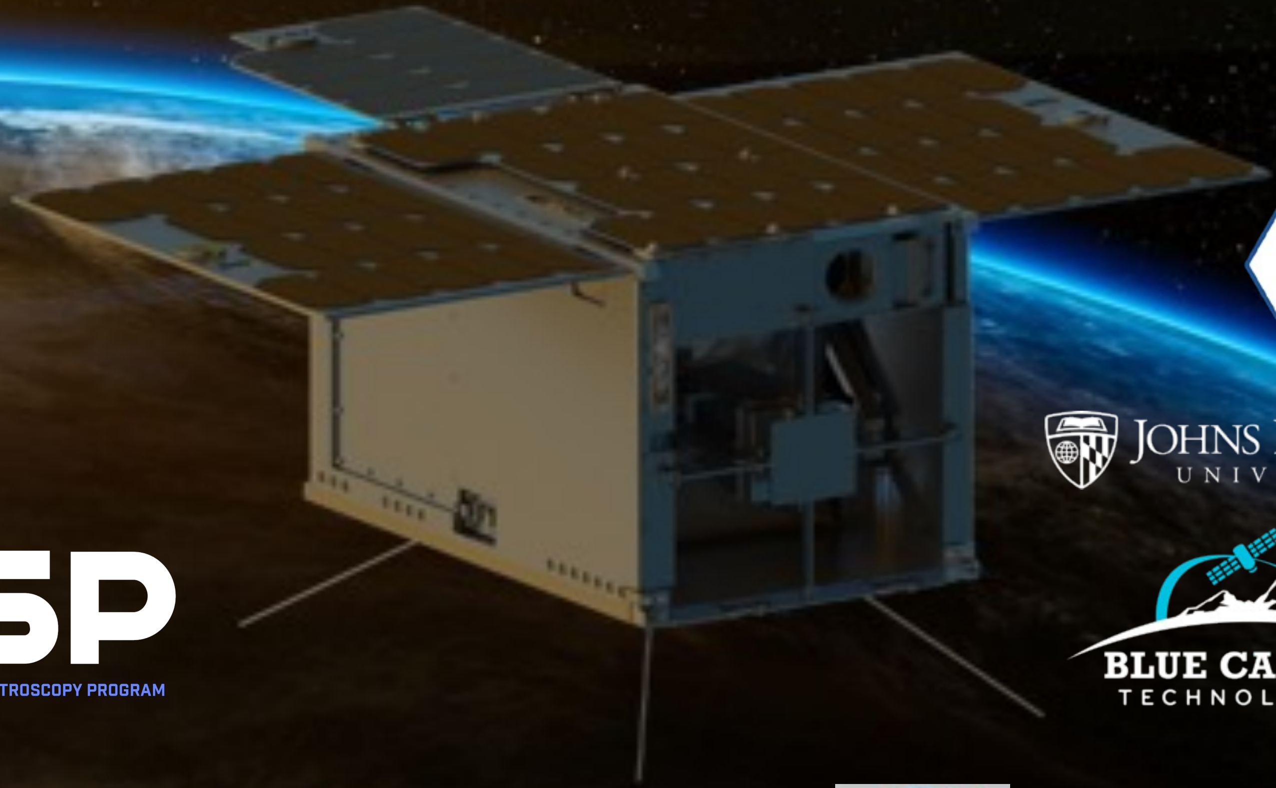
The SPRITE Ionizing Radiation Escape Survey (SPIRES)



Brian Fleming
CU – Boulder - LASP

Lyman Labyrinths
April 21, 2023
OAC, Crete, GR

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University of Colorado Boulder

Today's Colorado SPRITE Team

Scientists


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Briana Indahl


Kevin France

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Maitland Bowen

Post-Bac


Daniel Szewczyk


Destry Dewitt

Undergraduate Students


Abigail Durell


Sidney Koehler


Adriana Diaz


Tobias Jacobson

Engineers


Diane Brening


Dana Chafetz


Jack Williams


Stefan Ulrich

Beth Cervelli

Secondary School Interns


Graham Soukup


River Randolph

The Forever/Everywhere SPRITE Team

LASP Co-Investigators
Dmitry Vorobiev (IS, I&T)
Briana Indahl (I&T Science)
Kevin France (Science)

Principal Investigator
Brian Fleming

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John O'Meara (WM Keck)
Ravi Sankrit (STScI)
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Manuel Quijada (GSFC)
Javier Del Hoyo (GSFC)
John Hennessy (JPL)
Oswald Siegmund (SS)

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Giselle Koo**#
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Eric Dean**#

Media
Zayna Sheikh**#

* Graduate Student
** Undergraduate Student
# Retired/Graduated

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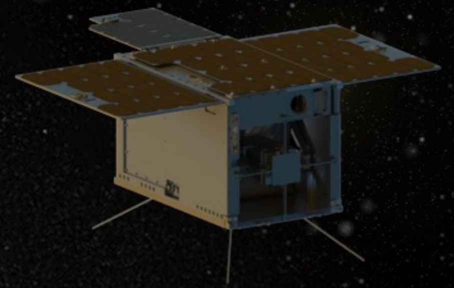
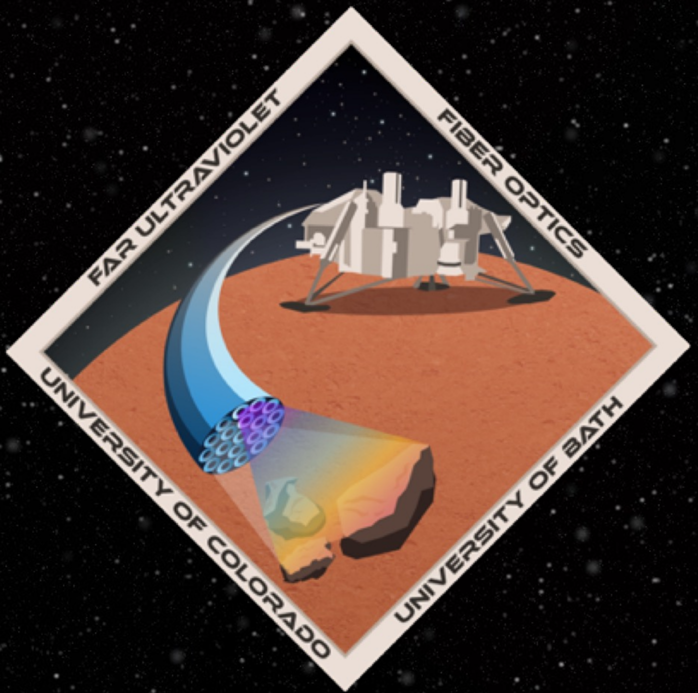
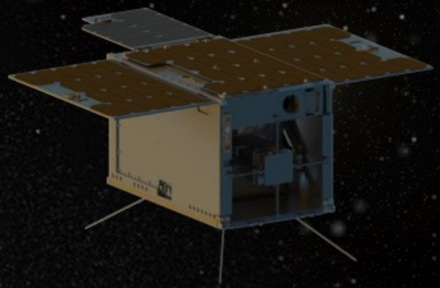
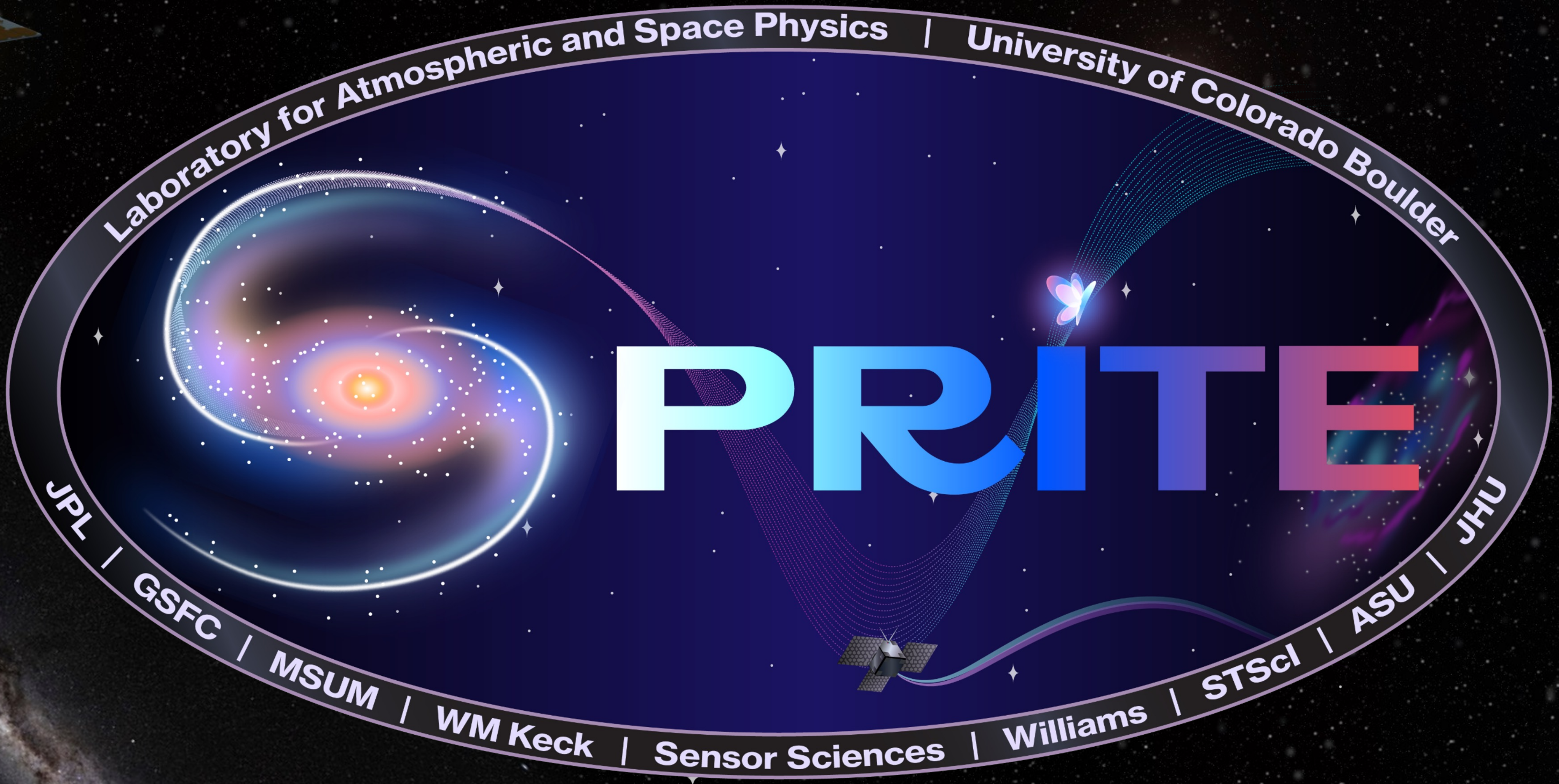




Project Introduction





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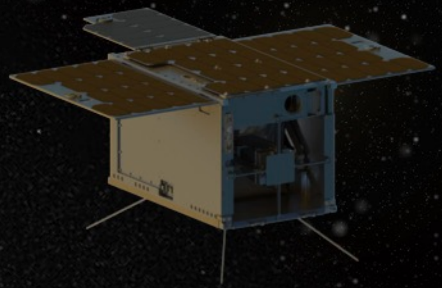
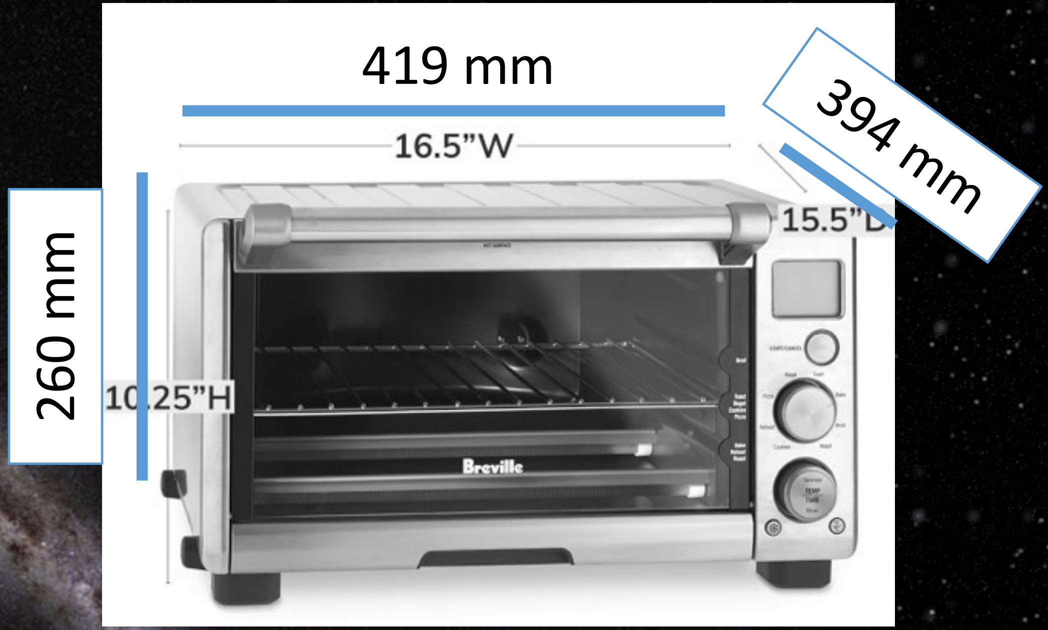


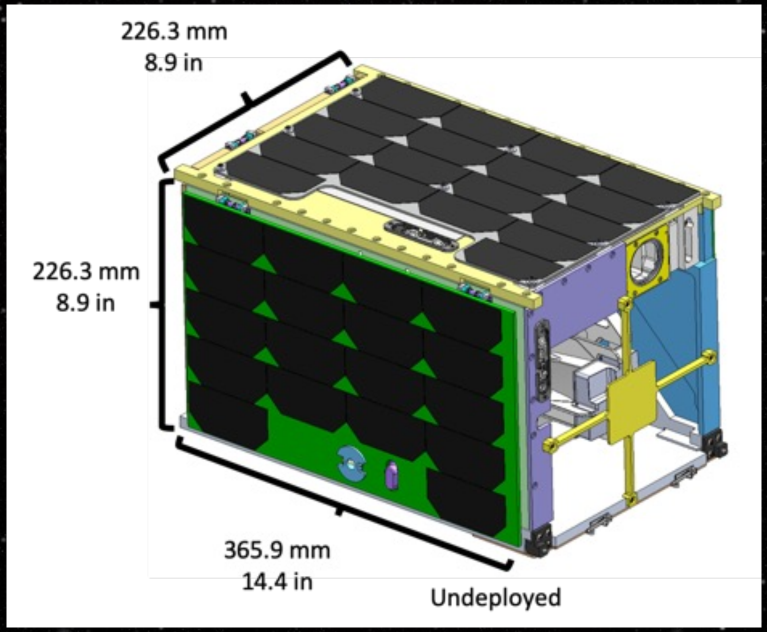
Technical Challenge:
“You can’t do science with a space toaster”

-something Brian Fleming probably would have said, circa 2013

Breville compact smart oven: **$189.95**
Creates toast and other tasty foods
Could possibly reflow solder on electronics

SPRITE compact “smart” CubeSat: **$4.1M**
Stares at seemingly empty patches of sky
for long periods of time
Does not make food





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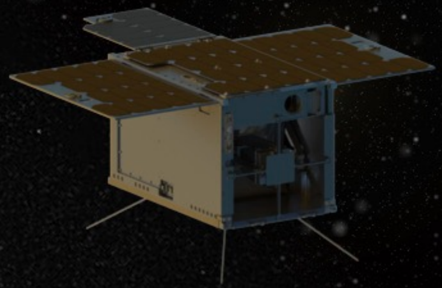
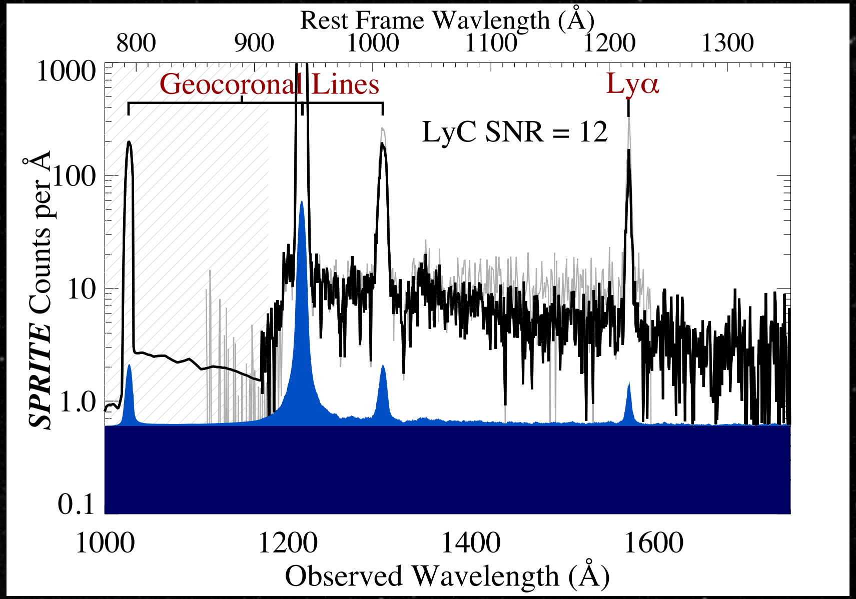
Science Program



The SPRITE Science Surveys

SPRITE Science Surveys

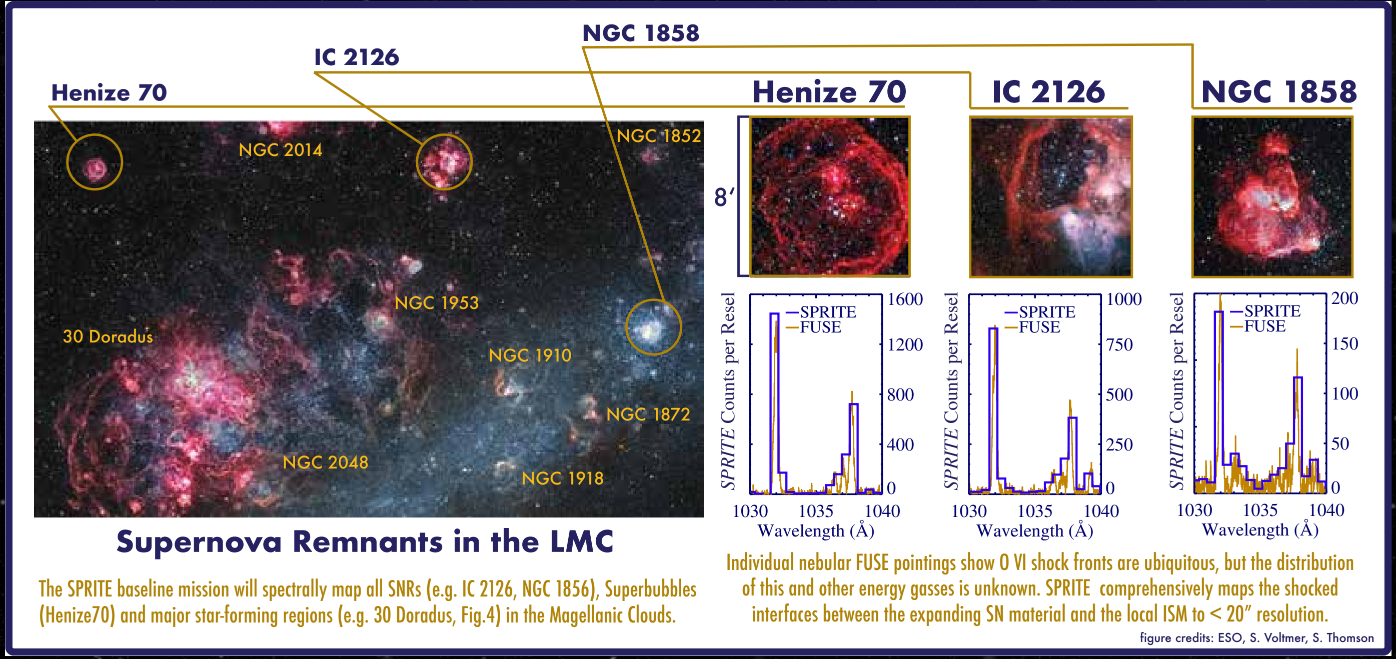
SPRITE Ionizing Radiation Escape Survey (SPIRES)



Requirements

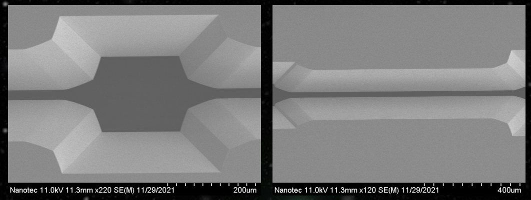
- Short-wave LUV bandpass for low-z LyC **(1000 Å)**
- Long-wave bandpass for z < 0.4 Lyman alpha **(1750 Å)**
- **High sensitivity** required
  - High throughput
  - **Low background**
- Long-slit imaging spectroscopy for scattered geocorona
- Low spectral resolution

SPRITE Remnant Interface and Galaxy mapping Survey (SPRIGS)

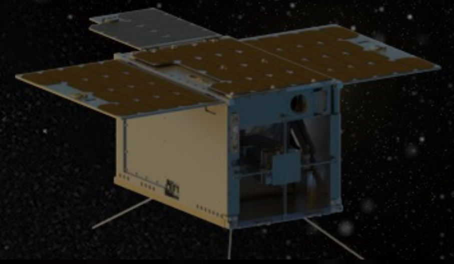


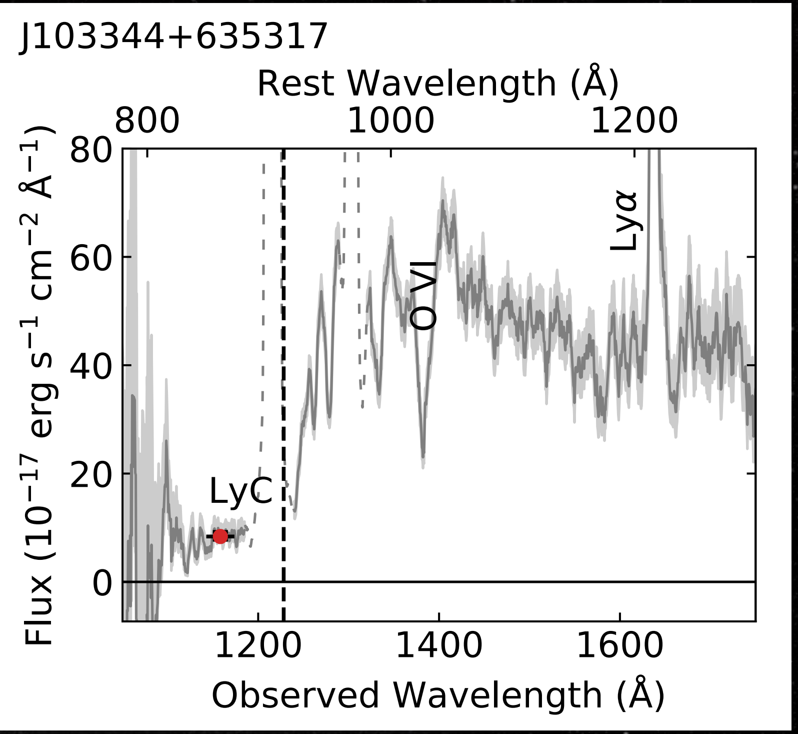
Requirements:

- Long Slit **with imaging resolution < 30"** along slit
  - 1800" x 10" slit
  - 60" x 60" center
- Pointing knowledge and stability
  - "Push-Broom" observing mode
- Low spectral resolution < 4 Å for O VI resolution
- Push-broom of local galaxies, CGM emission



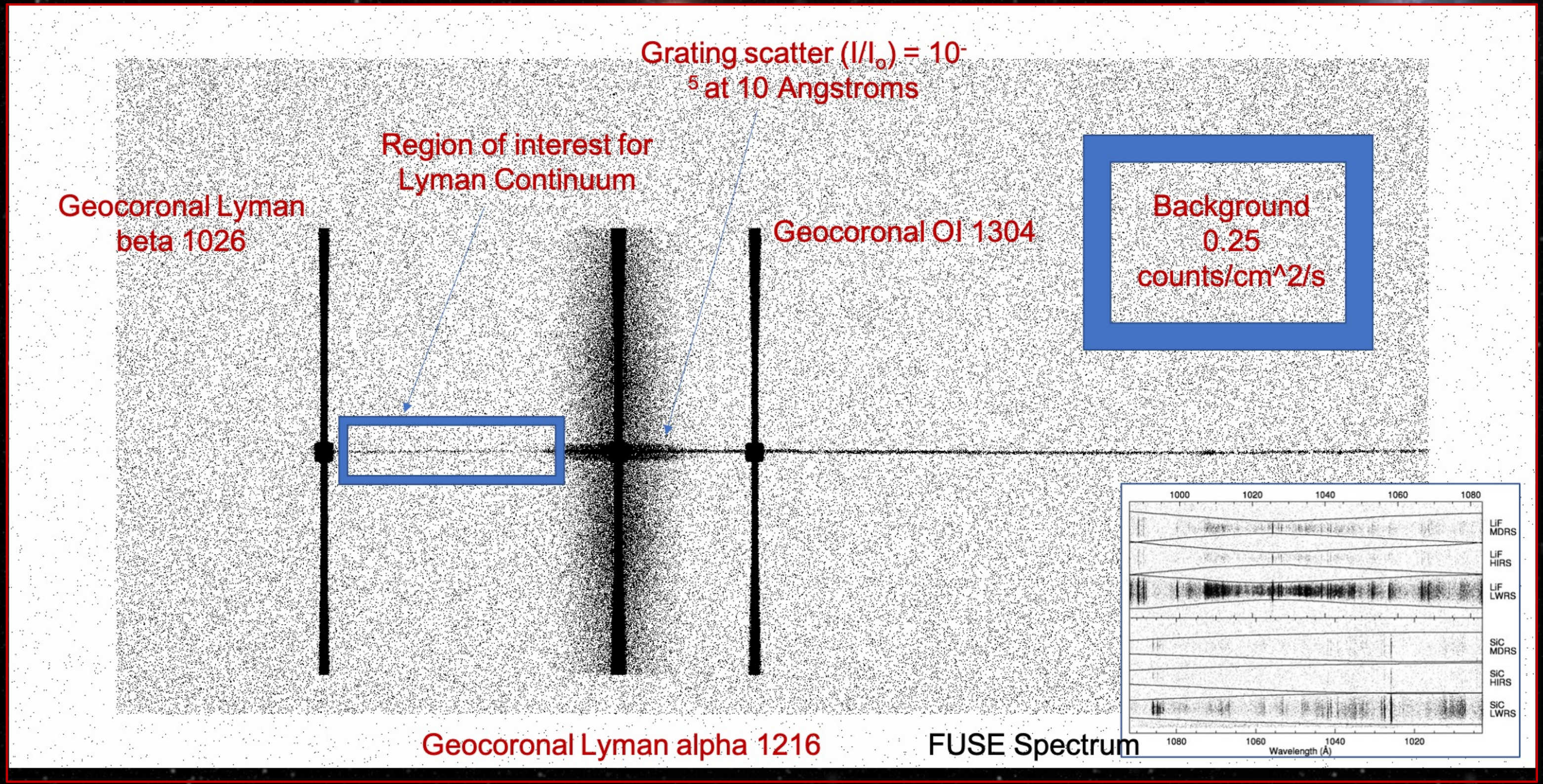
SPIRES: High-sensitivity in the Lyman UV





Fluery et al, 2022

Simulated Spectrum: SPRITE's imaging spectrograph drastically reduces backgrounds relative to HST_COS/FUSE



Signal-to-Noise is signal AND noise – reducing noise boosts SNR

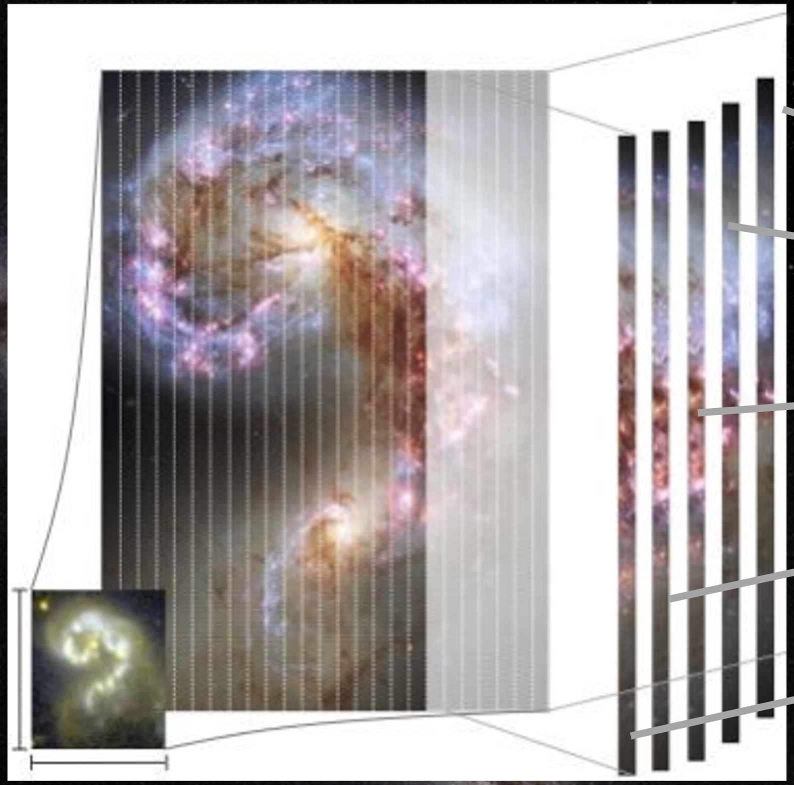
Flux targets ~ 10^{-17} erg cm^{-2} s^{-1} Å^{-1} for low redshift sources (z ~ 0.2-0.4)

50 galaxies at $0.2 < z < 0.4$ to $F_{LyC} > 10^{-17}$ erg cm^{-2} s^{-1} Å^{-1}

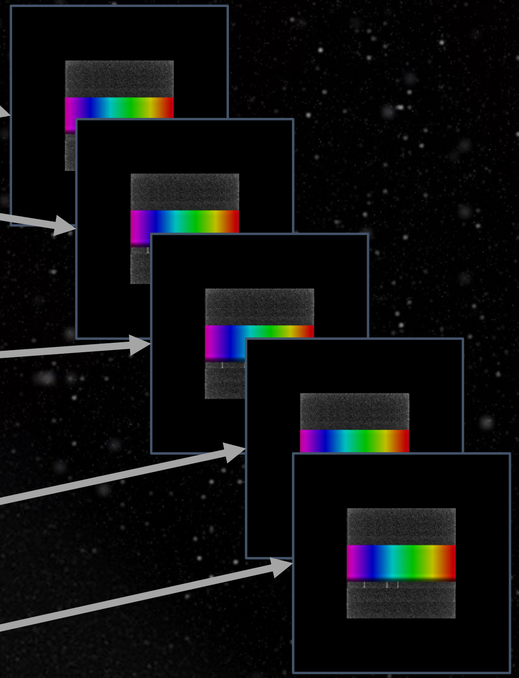
SPRIGS: Push Broom Observation Mode

Pushbroom Observation Data Products

- Get both spatial and spectral information in the form of a 3D data cube (X, Y, λ)



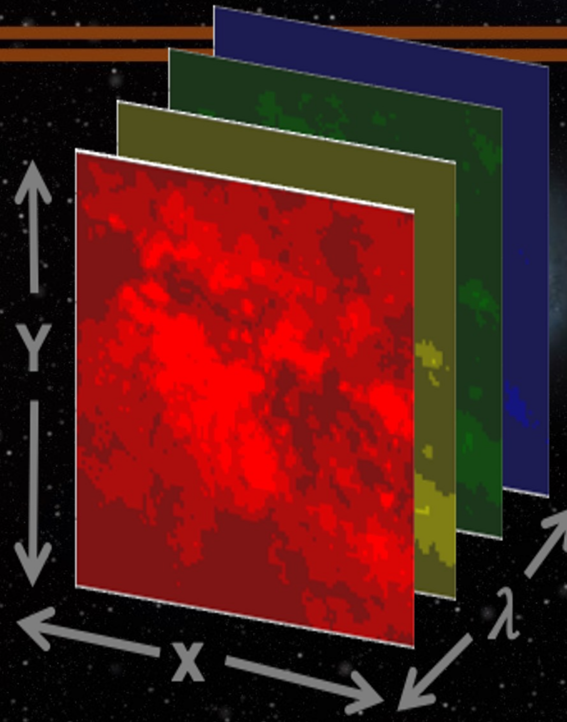
Pushbroom Observation



Individual Spectra from each long slit observation

Obs	RA	DEC
1	20h 45m 0.0s	30° 57' 59.99"
2	20h 45m 7.0s	30° 57' 59.99"
3	20h 45m 14.0s	30° 57' 59.99"
4	20h 45m 21.0s	30° 57' 59.99"
5	20h 45m 28.0s	30° 57' 59.99"

Spatial Mapping File



Data Cube

50 SNRs in MCs
2 sq. deg. Of Cygnus/Vela
15 Local Galaxies
2 Local CGMs

Ground Processing and Archiving

LEVEL 0

Raw Data (Downlink from Spacecraft):

<u>TTAG Data</u>
- lists of 32-bit words for all events
- Lyα region position arrays
- Lyα region P histograms

<u>ACCUM Data</u>
- position arrays
- P histograms

LEVEL 1

<u>For all observations:</u>
- Build data header from housekeeping data
- Provide wavelength calibration
- Remove background noise

<u>For TTAG observations:</u>
- Truncate P distribution
- write into user readable tables

LEVEL 2

<u>For all observations:</u>
- Provide a flux calibrated spectrum and error spectrum
- Apply field distortion corrections

LEVEL 3

<u>Data Products Provided to MAST archive</u>

<u>Point Sources:</u>

Multi-extension fits file containing 1D Spectra of:
[1] flux
[2] flux err
[3] wavelength solution
[4] background
[5] calibration-standard spectrum

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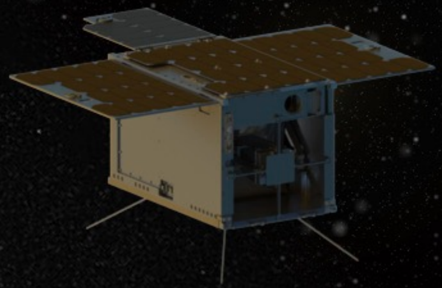
<u>Extended Sources:</u>

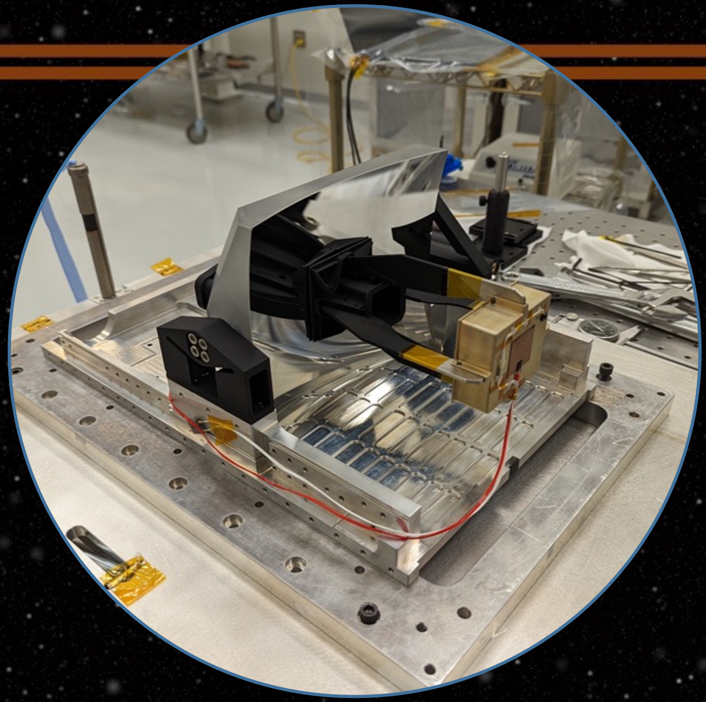
-Grouping of all spectra for a pushbroom observation in same format as point sources

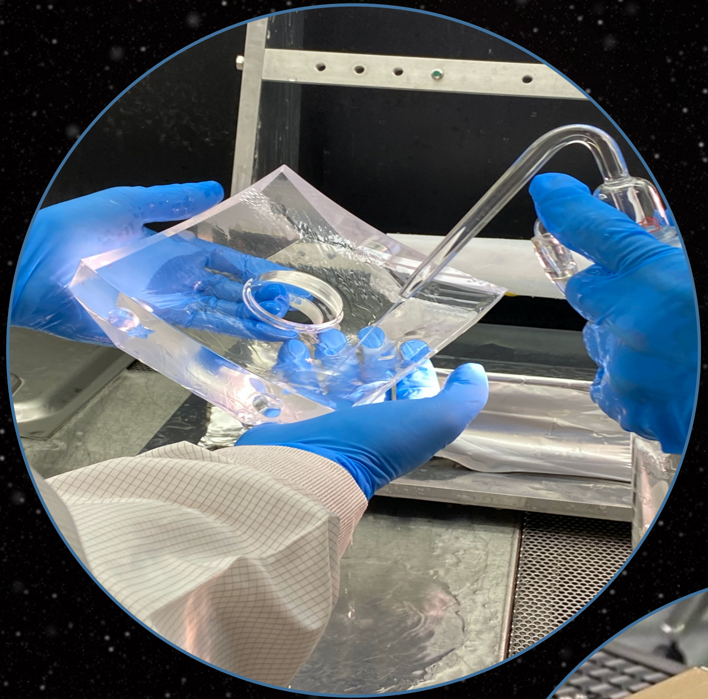
-Spatial mapping file for each grouping

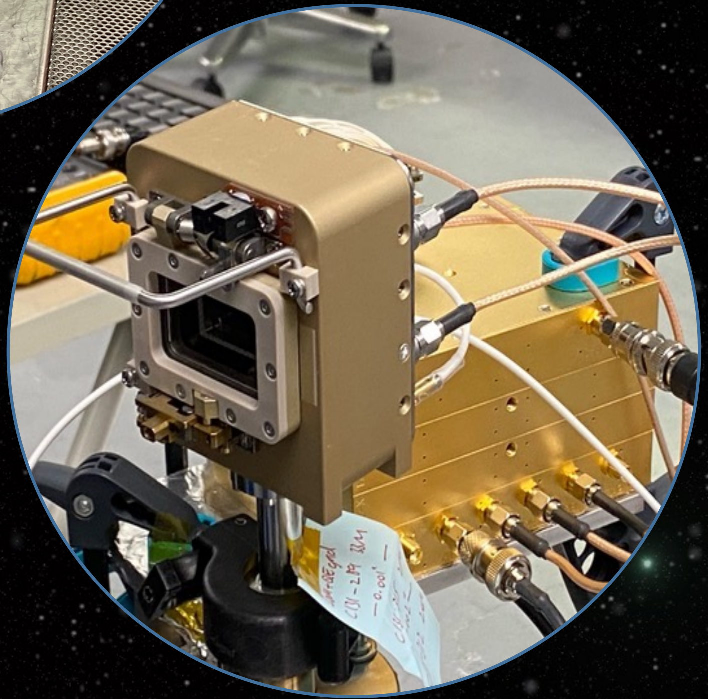
- Interpolated Flux Data Cube and error cube for each pushbroom grouping (3-D Image [x, y, λ]) for visualization

Technical Program



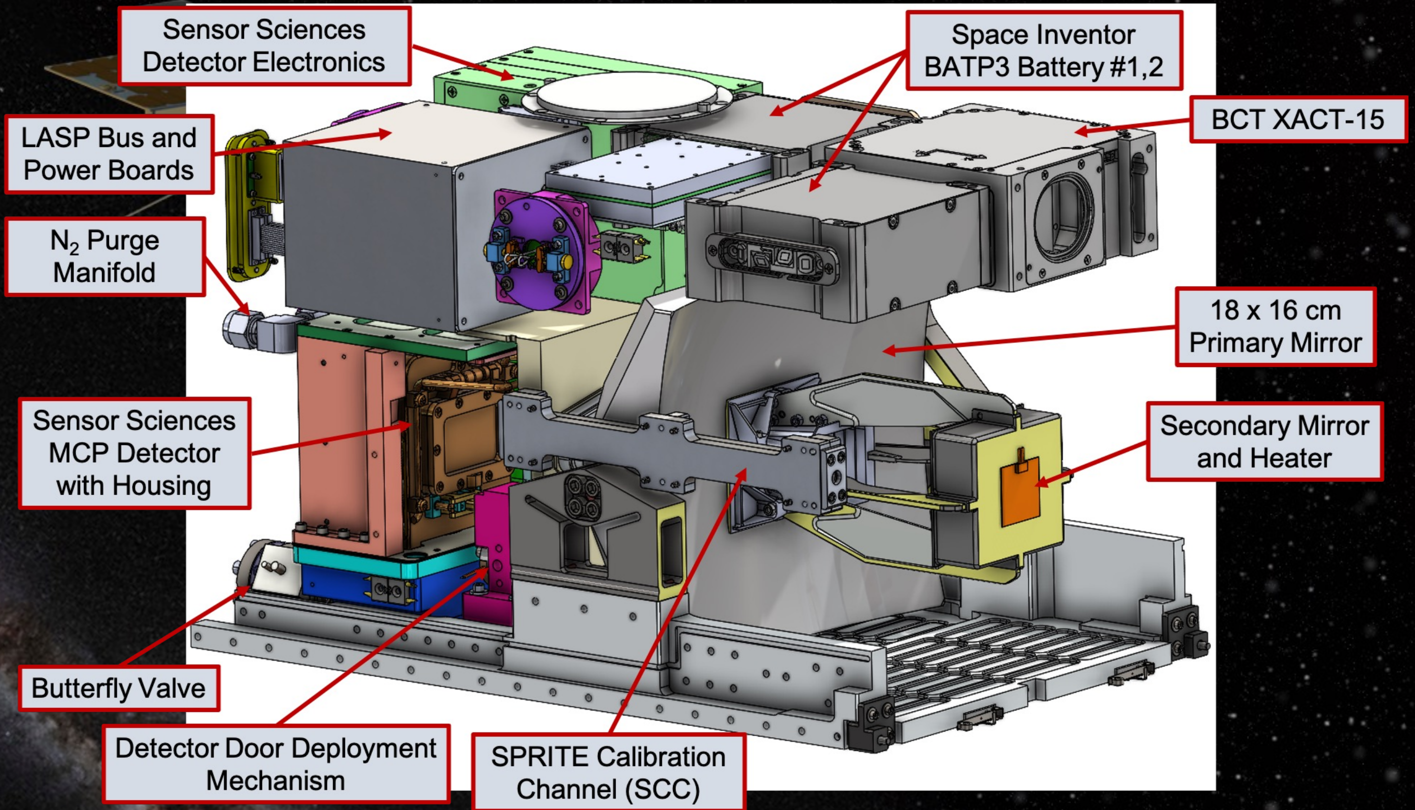


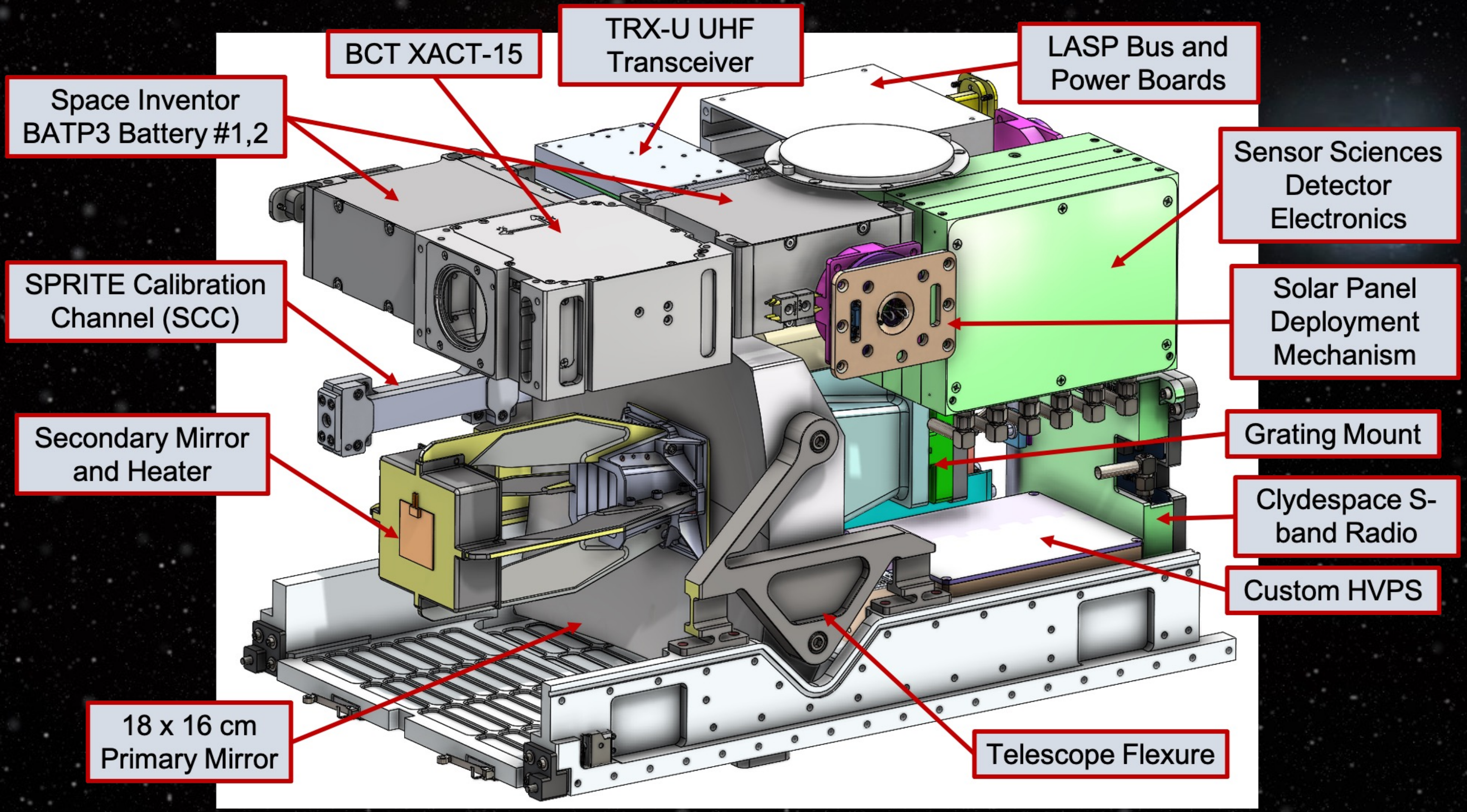




The SPRITE Design and Performance

SPRITE Overview





- 3D Design with 12U Volume (22.6 x 22.6 x 36.5 cm)
  - A bit smaller than most toaster ovens – Smaller footprint than MacBook PRO
- Well baffled optical system with tungsten detector shielding
- Calibration Channel with CaF_2/BaF_2 windows
- "Bird of Prey" solar panel design

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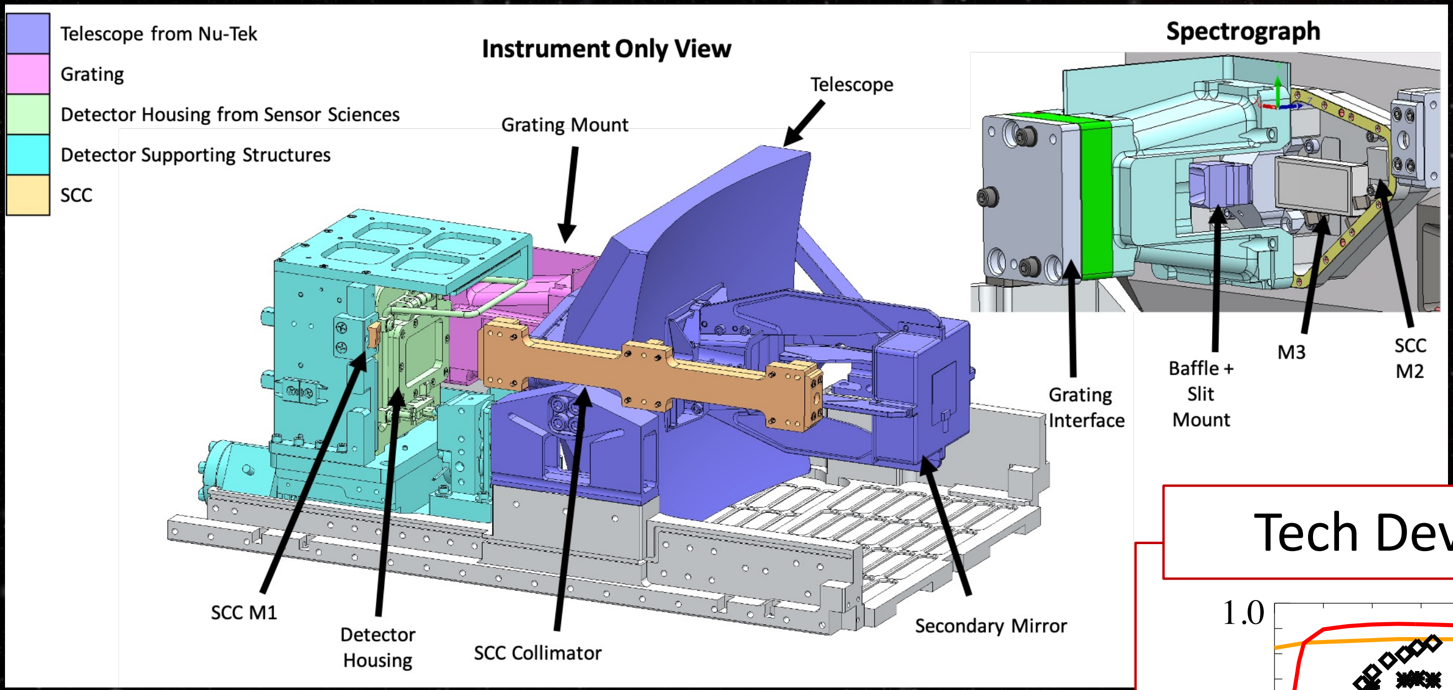
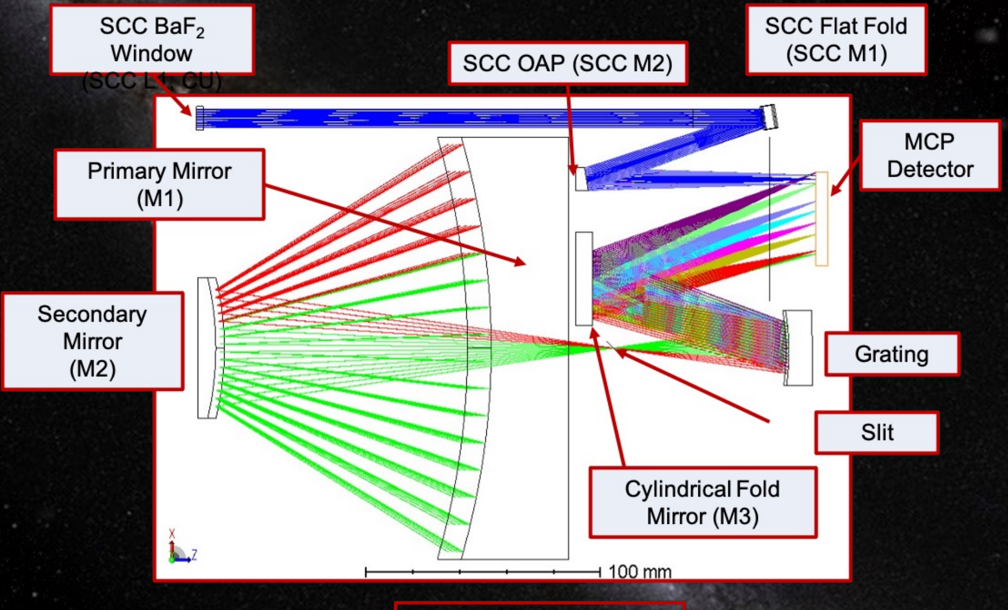
SPRITE Instrument Overview

	Primary Science Channel	SPRITE Calibration Channel
Purpose	Imaging Spectroscopy	Calibration Imaging
Aperture Size	18 x 16 cm (244.8 cm^2 C.A.)	0.8 x 0.8 cm (0.64 cm^2)
Angular Resolution	10” – 22”	2’ – 10’
Field of View	1800” x 10” 60” x 60” Center	2° x 2°
Bandpass	1000 – 1750 Å	1350 – 2000 Å
Spectral Resolution	1.3 Å	-- --

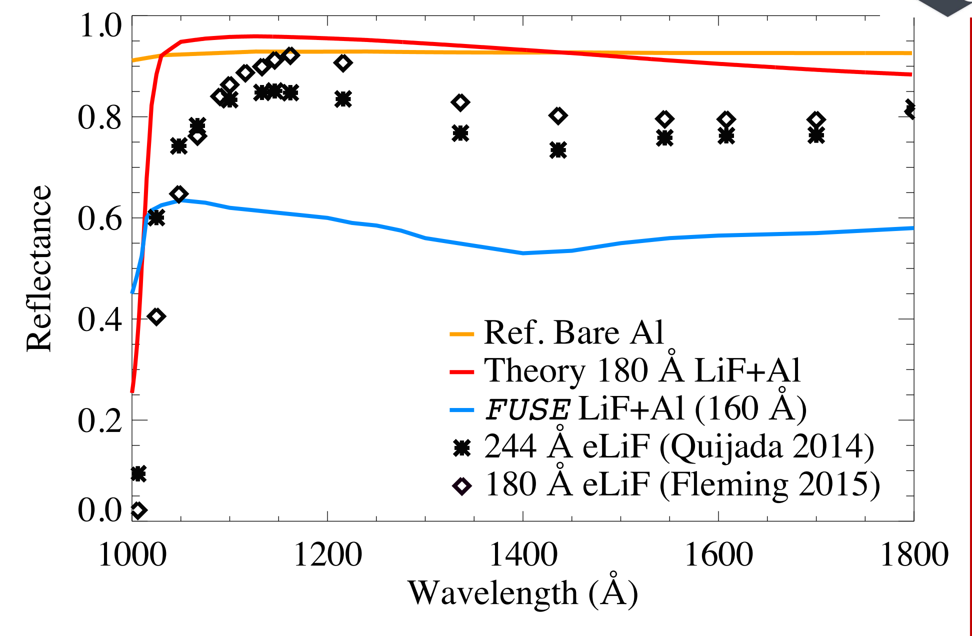




*Not shown – spectrograph baffles

18 x 16 cm telescope: 0.6% of a Hubble!

Tech Dev. – eLiF Mirror Coatings



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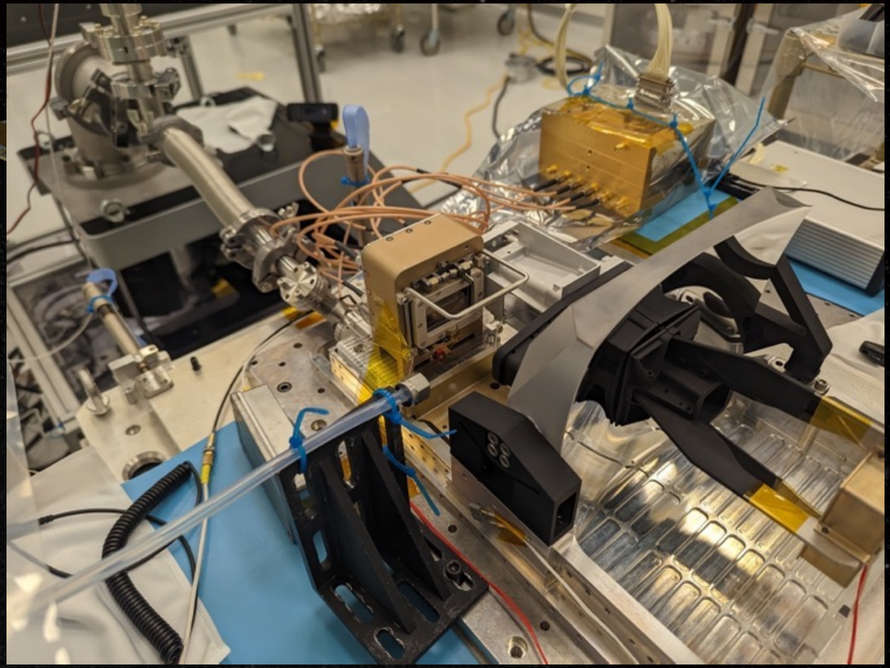
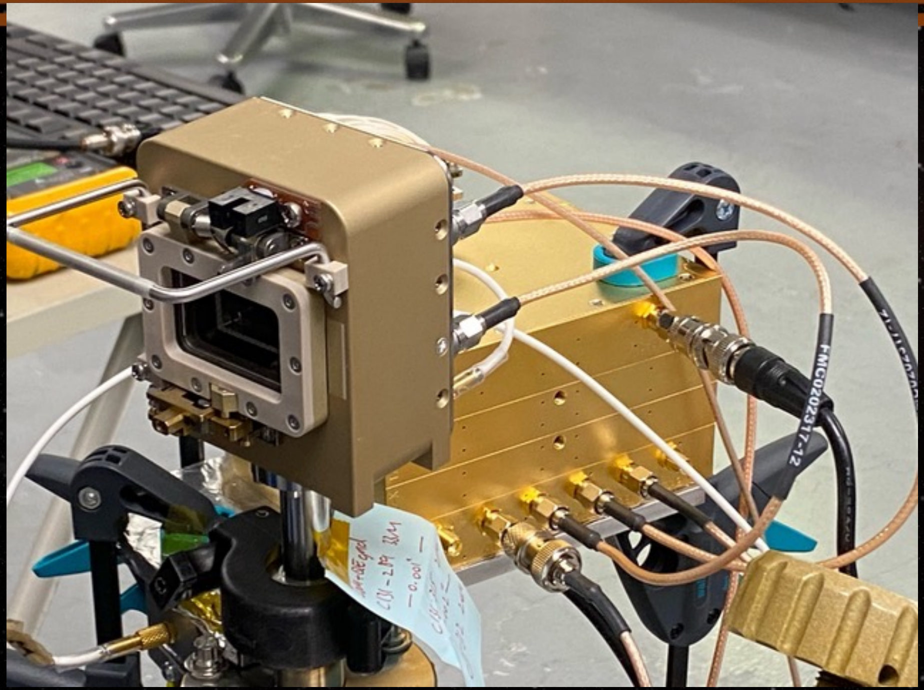
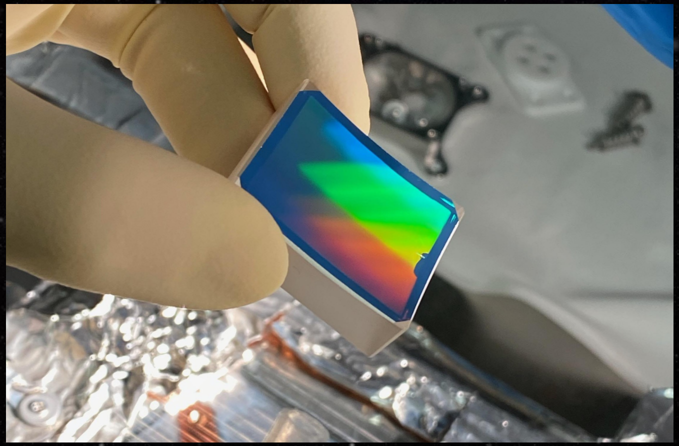
SPRITE Instrument Components



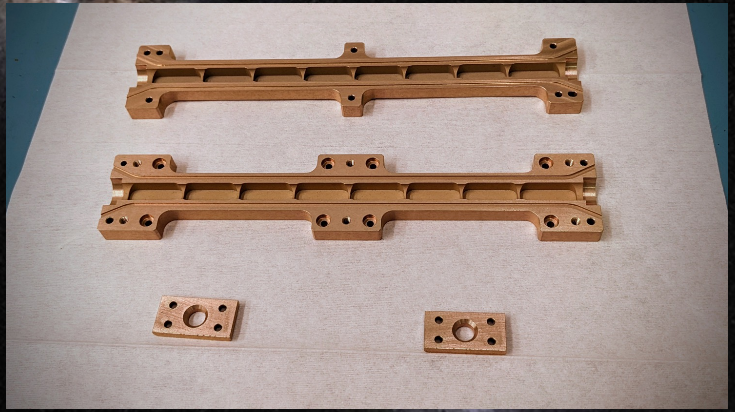
Telescope (delivered; Nu-Tek)
- Tested to GEVS Qualification (14.1 G_{RMS})
- Image quality meets specifications



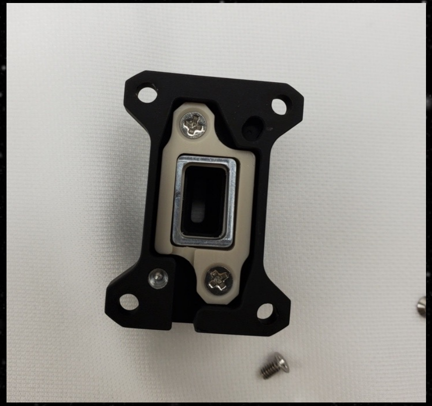
Flight Detector (delivered; Sensor Sciences)
- Currently evacuated to 1.1 x 10^{-7} torr
- Thermistors installed, tested



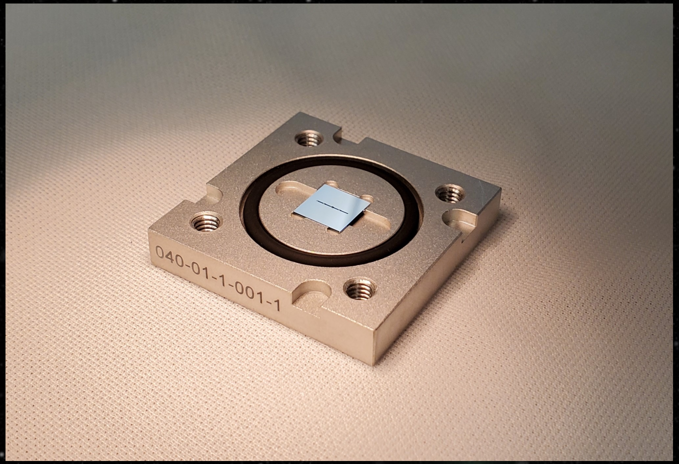
Grating (flight and spare)
- Delivered (Horiba)



Cal Channel
- Collimator
- Custom

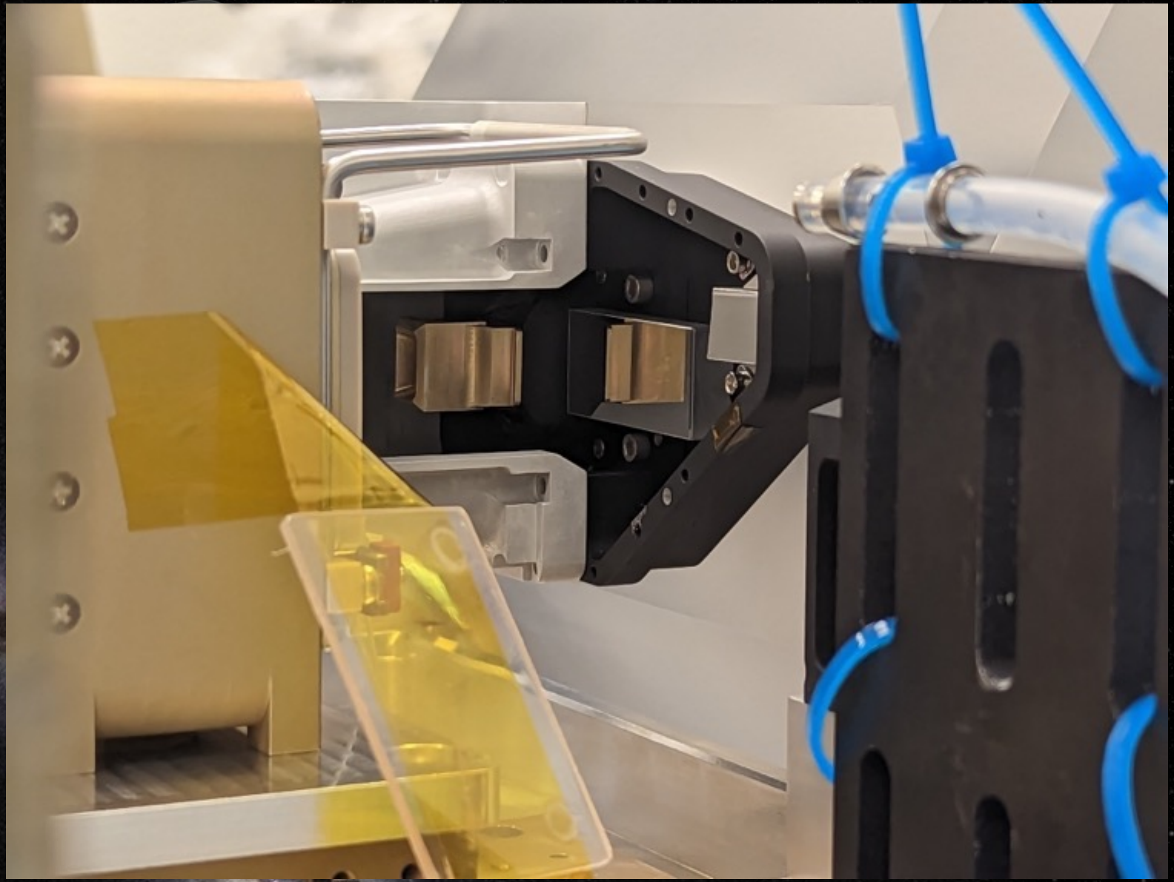


Ion Repeller
- Custom

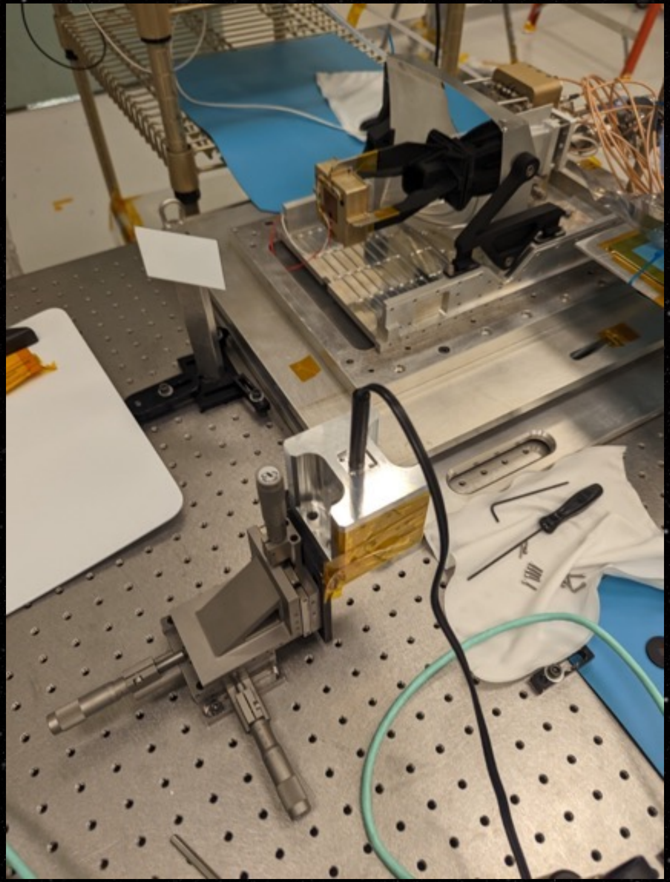


Slits (delivered; Nanotec)
- Etched silicon

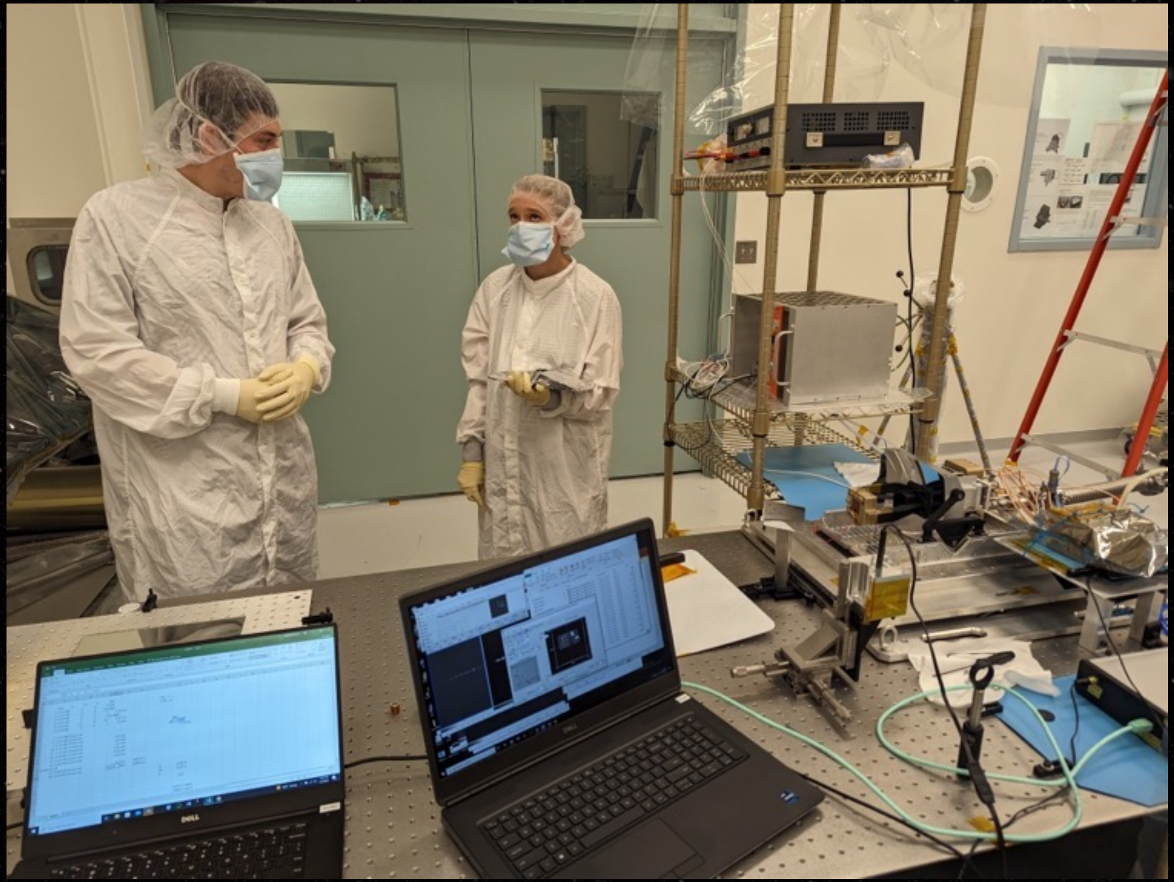
First Light – Feb. 07, 2023



A view into the SPRITE bathtub showing M3, the OAP for the calibration channel, and the slit baffle (small gold part nested in the structure). First light was accomplished through the MgF_2 window on the detector door.



The Hg penray in a mount with a 25 micron pinhole aperture. The beam is folded towards a collimator that fills the SPRITE aperture.



Team members Daniel Szewczyk (left) and Briana Indahl (right) discuss essential things while a 500s exposure is being integrated. EM SPRITE can be seen on the right happily collecting photons.

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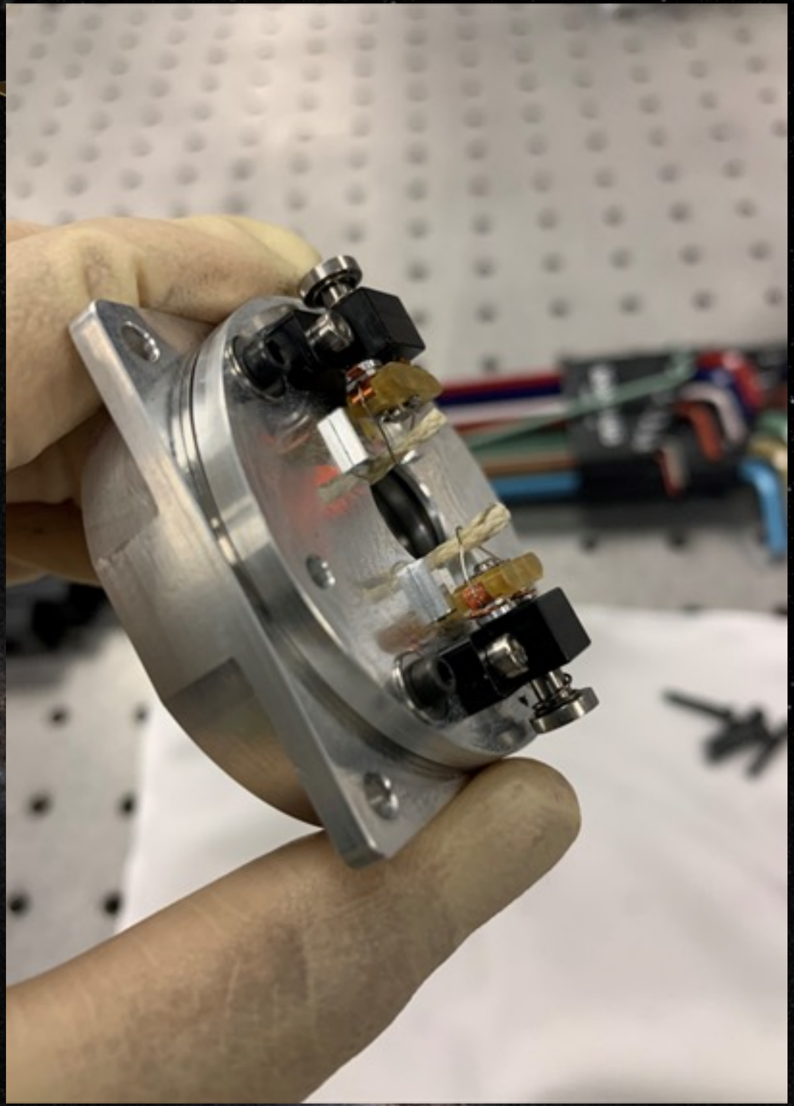
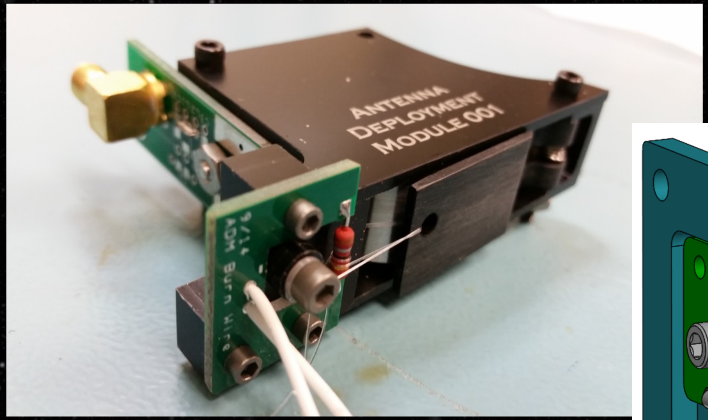
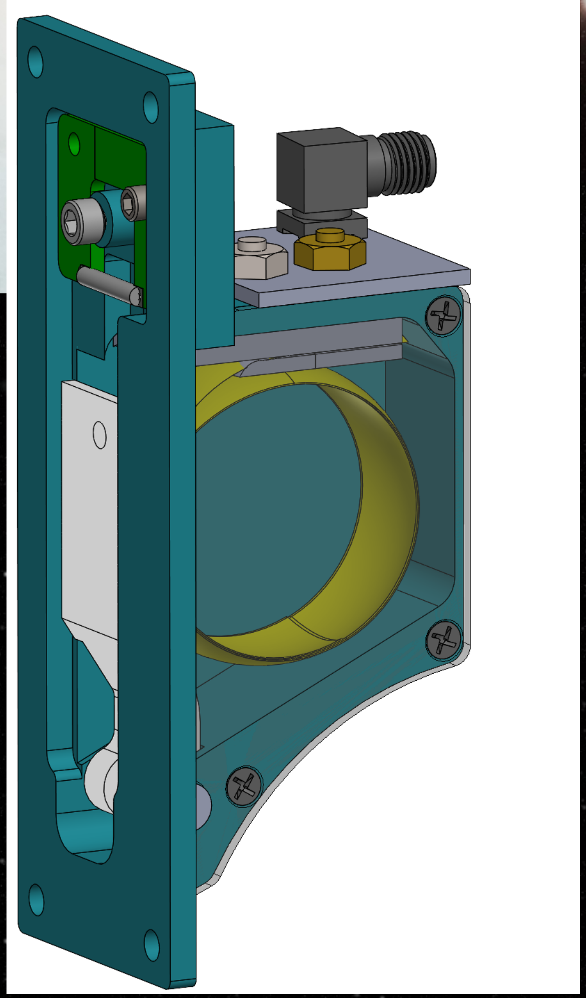
Mechanisms

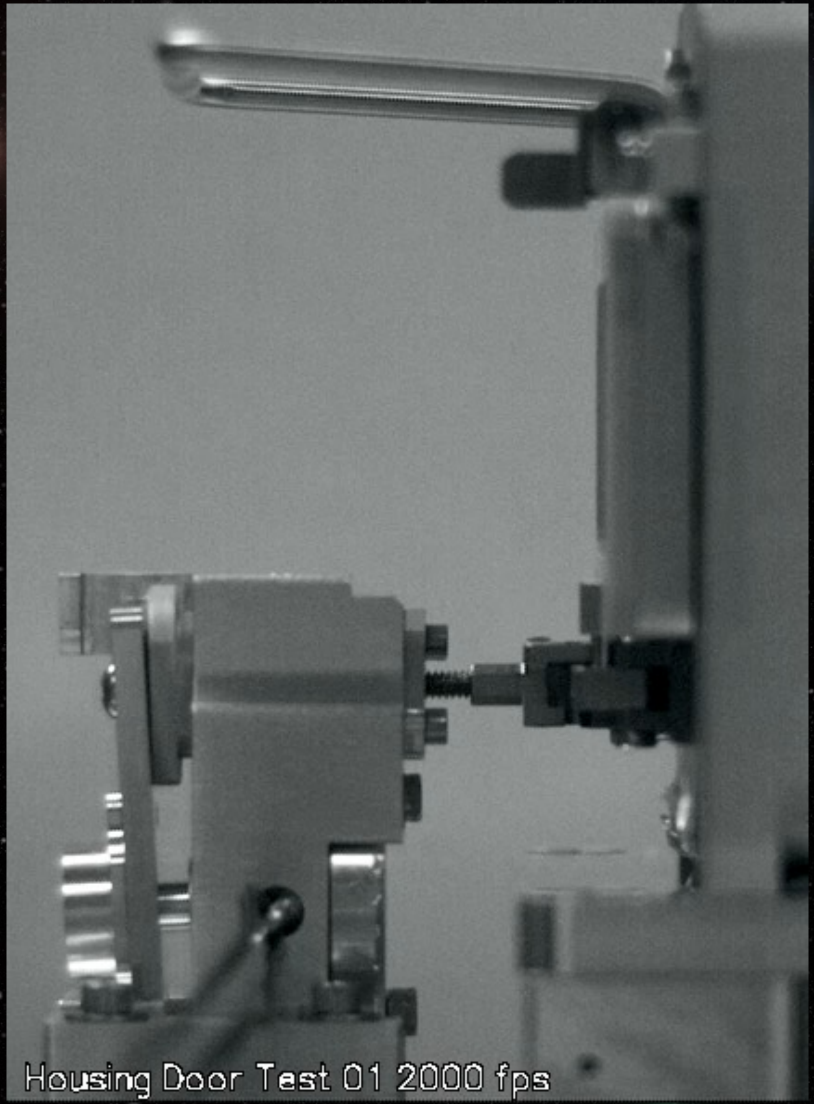


Solar panel deployment mechanism (burn wire)



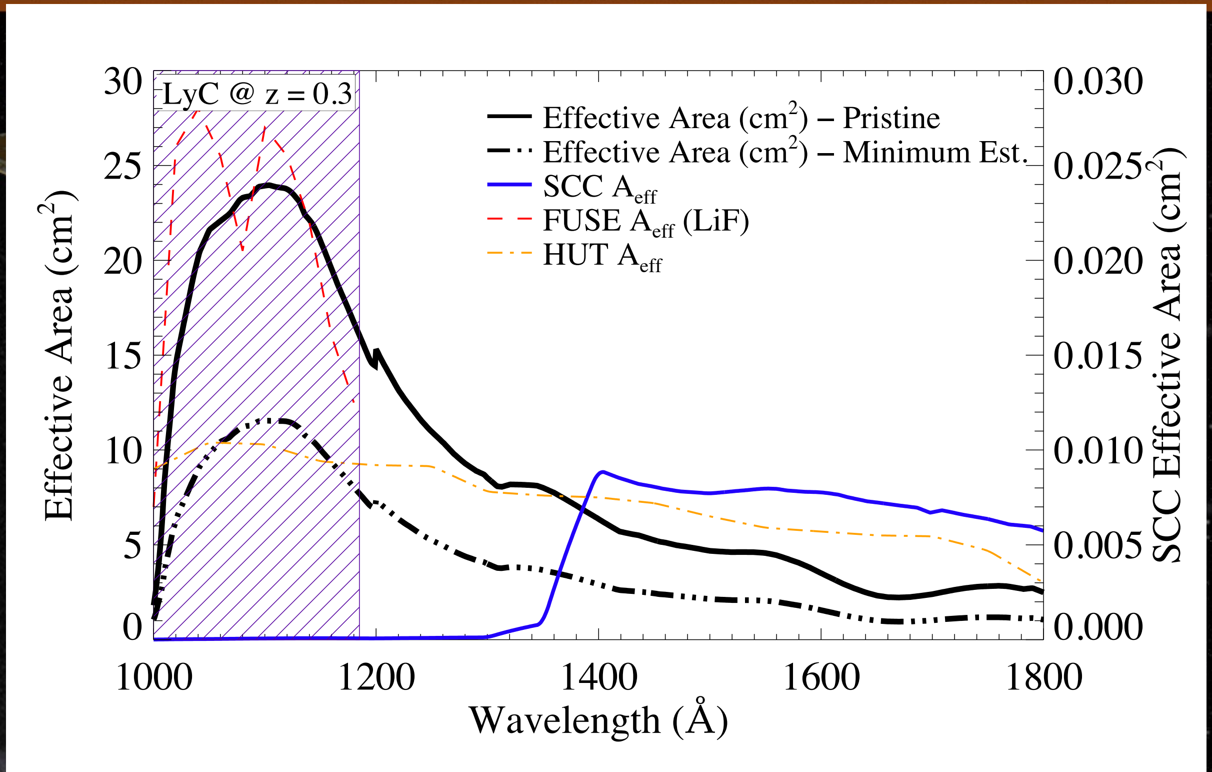
UHF Radio antennae – tape measure

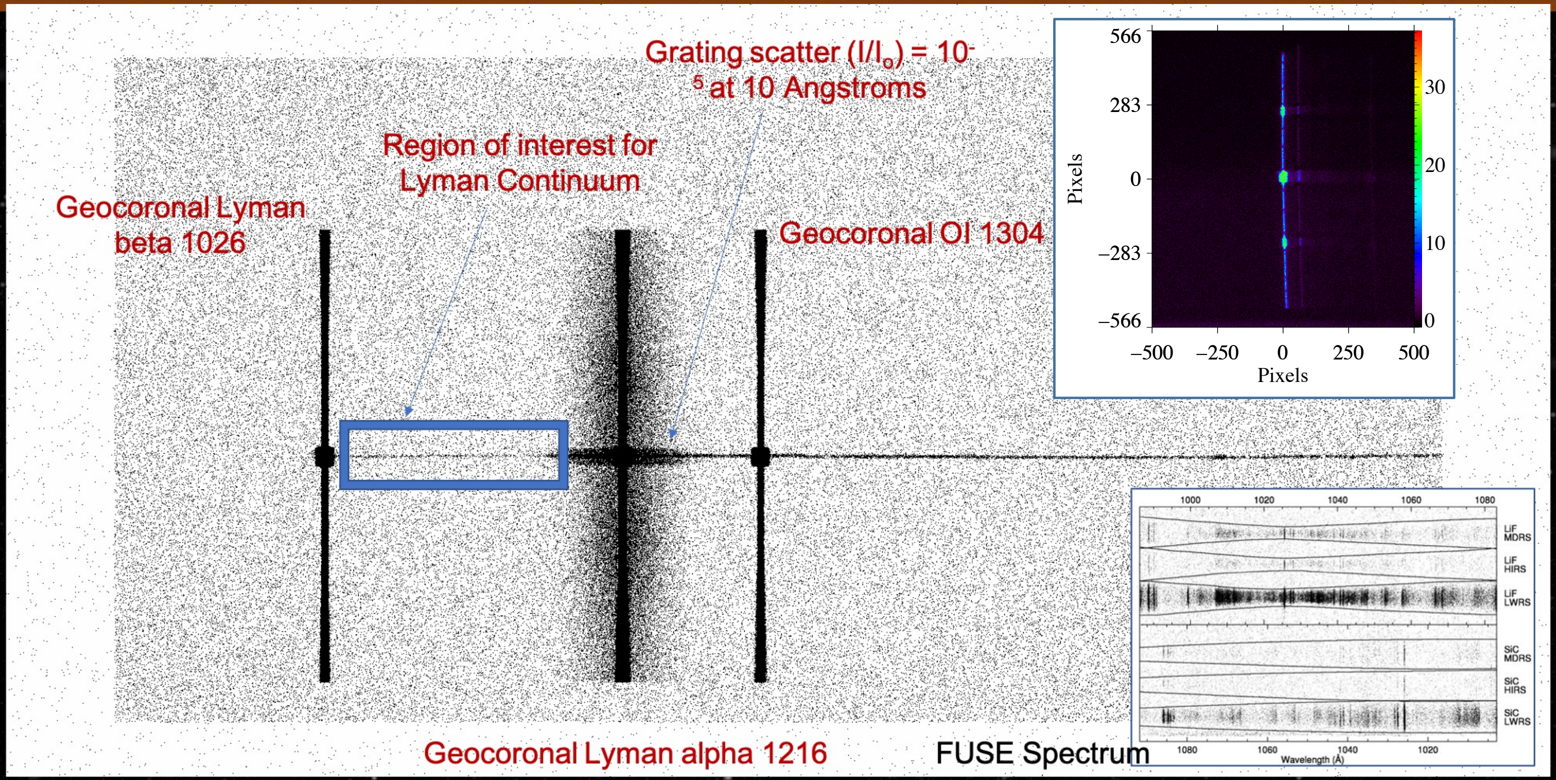




Detector housing manual test (done: hot/cold in vac w/TiNi)

Instrument Performance: Sensitivity





Parameter	Requirement	CBE	Margin
Effective Area @ 105 nm	7	17.3 (degraded)	60%
Background	2.5 (2x HST-COS)	0.225	1000% (in-space est.)
Resolution	100 micron	60 micron (average)	67%
Sensitivity (100ks)	**5.4×10^{-16} erg cm^{-2} s^{-1} Å^{-1}**	**1.1×10^{-16} erg cm^{-2} s^{-1} Å^{-1}**	**390%**
Sensitivity (100ks, 20 Å)	6.7×10^{-17} erg cm^{-2} s^{-1} Å^{-1}	9.3×10^{-18} erg cm^{-2} s^{-1} Å^{-1}	620%

Conclusions

- Launch August 30, 2024 – Vandenburg SFB (California)
- Estimate 2 months for commissioning before science observations
  - Early Release Science: Repeat 2-3 choicest known emitters to validate instrument
- Data available on MAST ~ 12 months after observation
  - This is not a "proprietary period". We just have too small of a team to get it out earlier!

Friends of SPRITE (or anyone) can propose targets!

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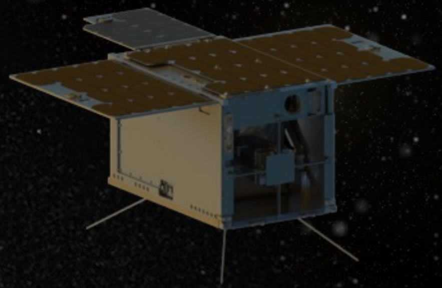
Friends of SPRITE (Please be our friend!)



CUSP

THE COLORADO ULTRAVIOLET SPECTROSCOPY PROGRAM

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SPRITE Only: @SPRITECubeSat

We will observe anything (almost)! Just ask!

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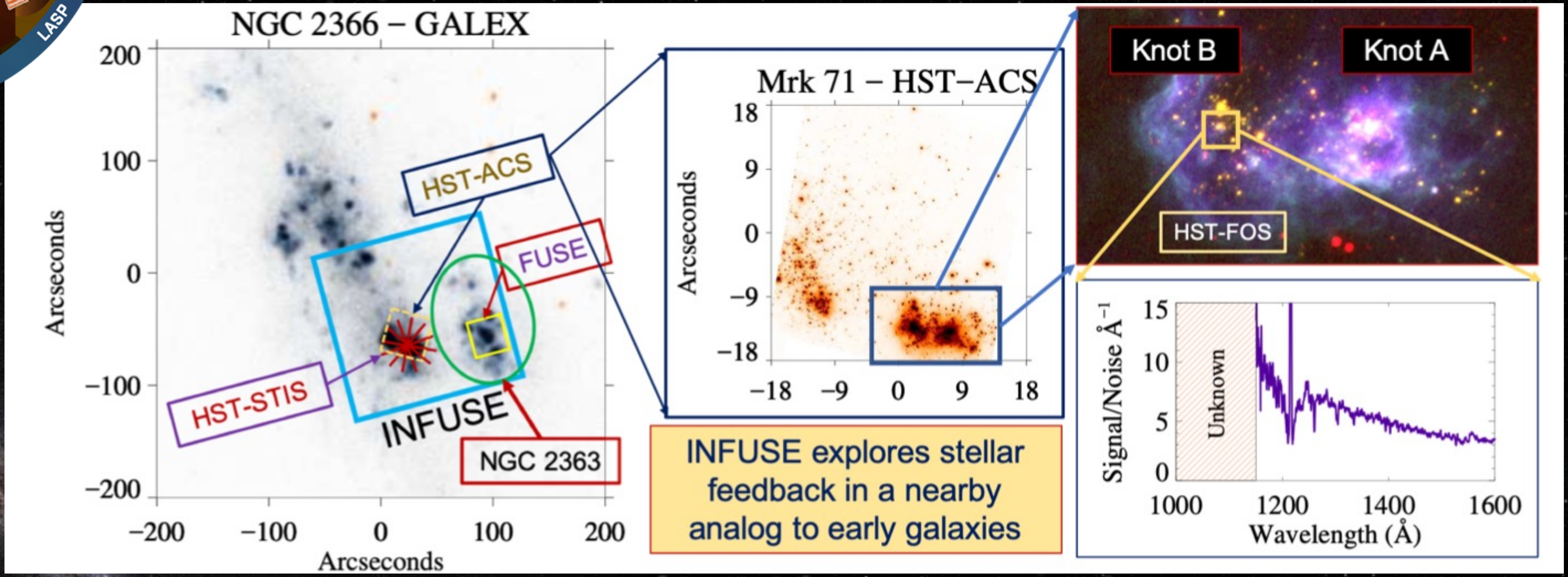
The Near Future…

The CUSP Team is working on a prototype far-UV (100 – 200 nm) IFU, **INFUSE**, which will do a cursory study of NGC 2366 (a potential GP analog).

If successful, look for an orbital mission in the late 2020's



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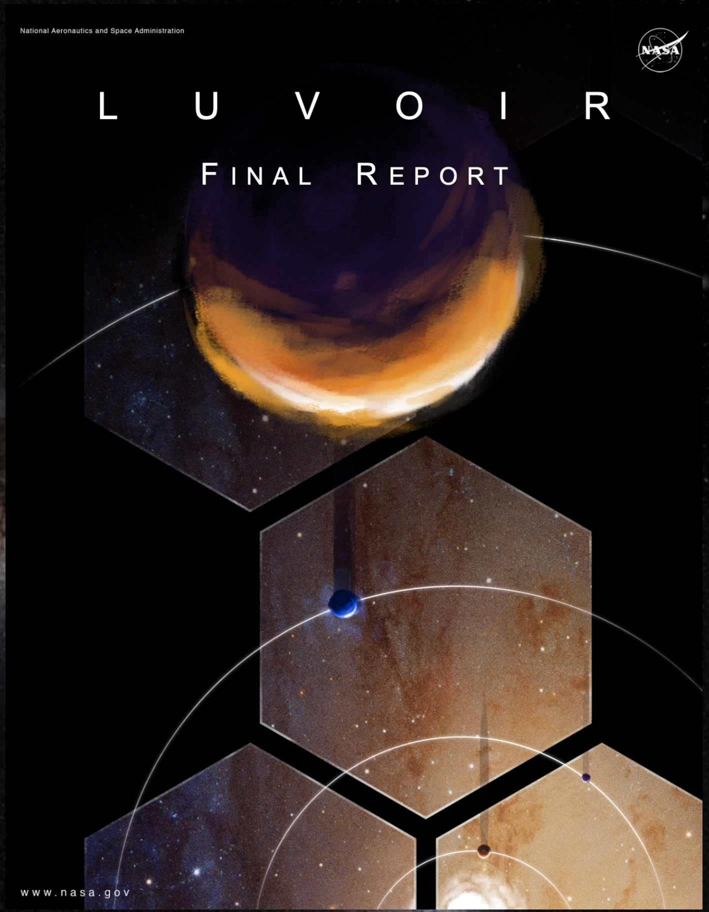
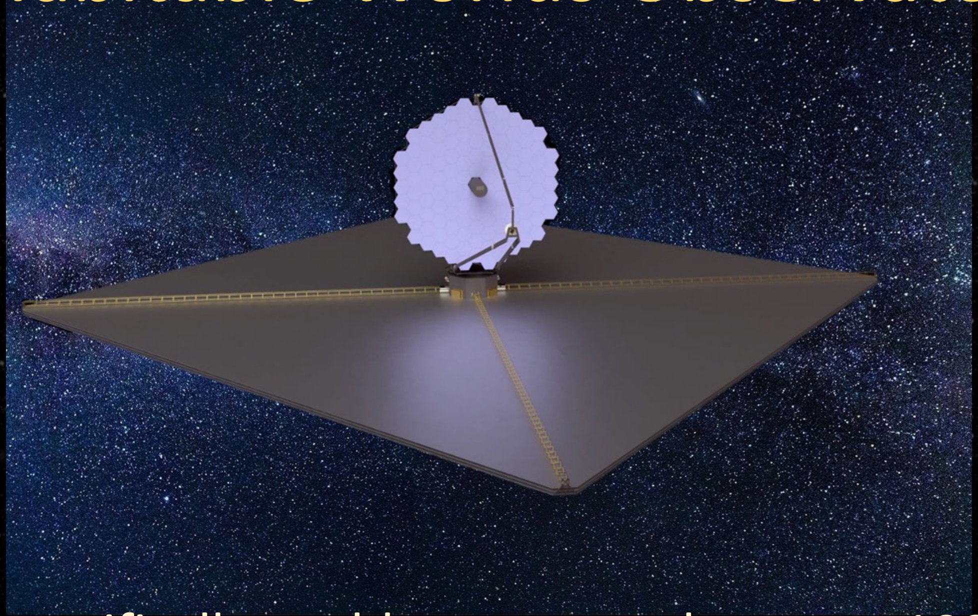
The Distant Future…

SPRITE is a testbed for enabling technologies for the UV spectrograph on the Habitable Worlds Observatory (HWO)





SPRITE specifically enables coverage between $100 \text{ nm} < \lambda < 115 \text{ nm}$ through advancement of eLiF mirror coatings. Our detector is neat too.

eLiF has already been baselined on one new mission and several proposed

As endorsed by the 2020 US Decadal Survey, HWO is very similar to LUVOIR-B in the LUVOIR final report

Really the last slide (I promise*)

"We just have too small of a team to get it out earlier!"

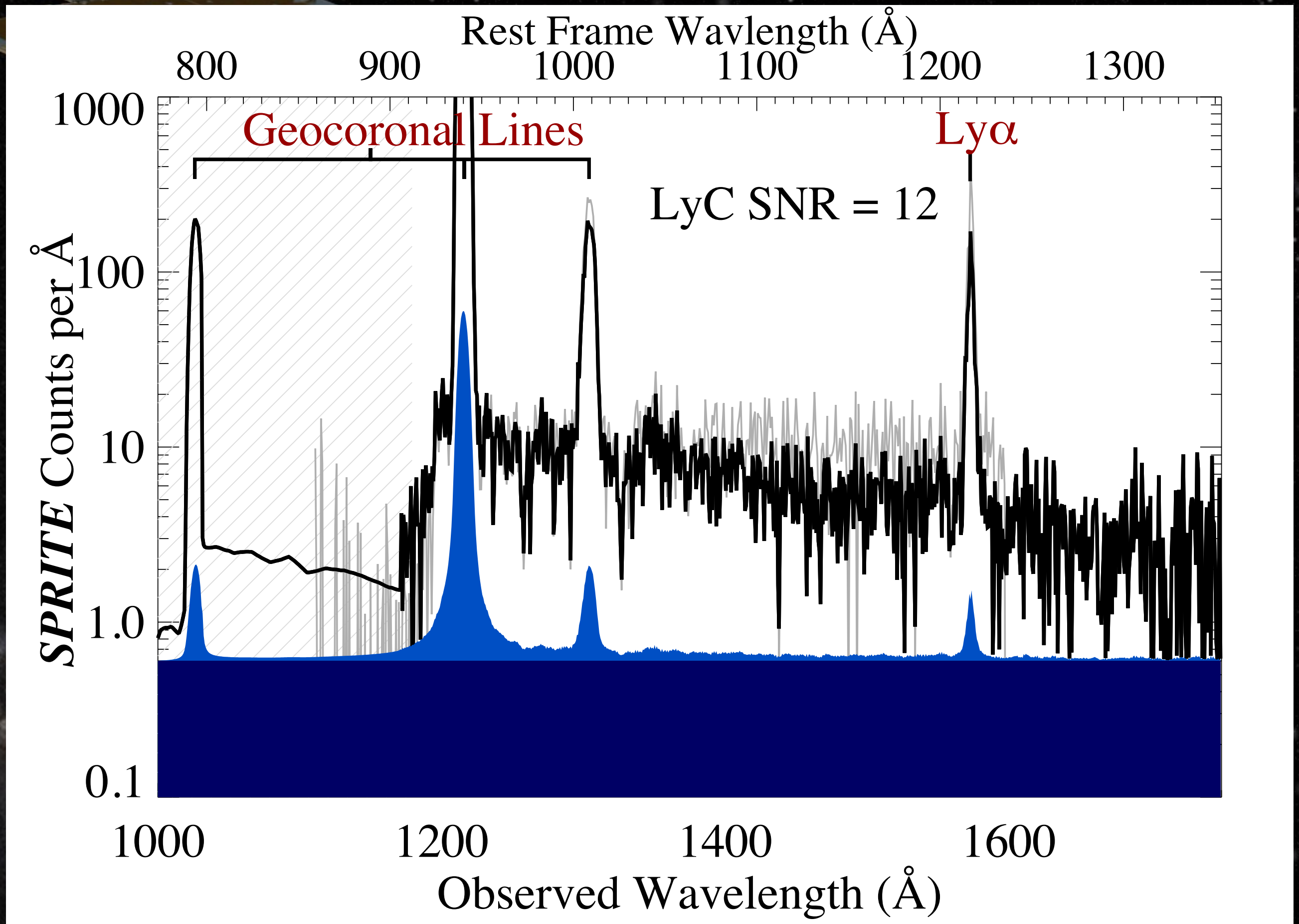
The CUSP team will be hiring a research scientist (think "postdoc" but with higher pay and the opportunity for a long-term (or short if you prefer) appointment) for anytime later this year, with the primary focus centered around LyC/Lyα, with the role of helping lead SPRITE analysis

Please apply or prod others to apply

The job ad will likely out in early May – or just e-mail me at brian.fleming@lasp.colorado.edu

*unless we get to the backups

Backup - SPIRES Survey



Simulation of detection from J1442-0209 (Izotov et al., 2016). f_{esc} = 7.4%
T_{exp} = 60 ks

- ~ 50 galaxies surveyed, 0.2 < z < 0.4
  - ~ 100 ks per target, on average
  - F_{LyC} sensitivity to ~ 10^{-17} erg cm^{-2} s^{-1} $Å^{-1}$ for 20 Å bins
- This is less than LzLCS – what do we add?
  - ~ 10-15 targets that align with LzLCS targets
  - ~ 35-40 targets that probe new discovery space
    - Redshift, depth, β, O_{32}, etc
    - Test prediction models!
    - Larger portion of the LyC (λ > 715 Å)
  - No time allocation constraints
    - "Tenuous" detections? Just add time!

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