ASTR 4800 - Space Science: Practice & Policy
Today: *The CUTE CubeSat Mission & the hunt for extrasolar planets – guest lecture by Arika Egan*

- Final paper is due on Dec. 7.

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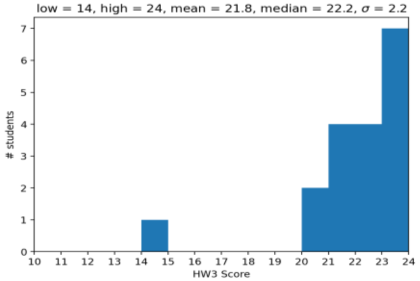
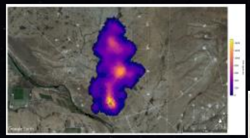
Homework #3 Results



2

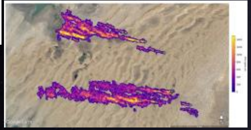
Presence of Methane 'Super Emitters'

By: Ana Kizhnerman

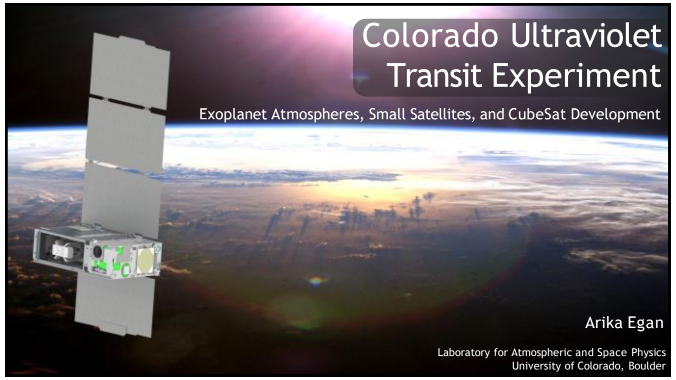

A 2 mile methane plume in Carlsbad, New Mexico.

- NASA's Earth Surface Mineral Dus Source Investigation(EMIT) instrument maps chemical composition of dust throughout desert regions
- More than 50 methane heat plumes have been discovered
- Reducing these emissions can help slow down global warming

Question: Is using EMIT to find more plumes a sustainable way to address global climate change?

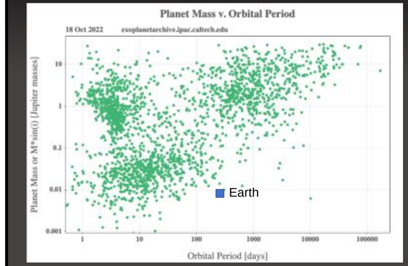

20 mile plumes in Hazar, Turkmenistan, a port city on the Caspian Sea.

3



4

Exoplanets: Discovery



October 18th, 2022:
5190 confirmed exoplanets

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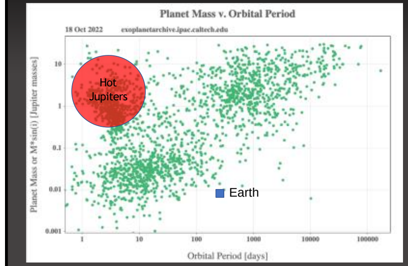
Exoplanets: Discovery



October 18th, 2022:
5190 confirmed exoplanets

- Majority are unlike planets in our own Solar System
- Fundamental change in Earth's place in the Universe
- Move from discovery to characterization:

  Comparative Exoplanetology

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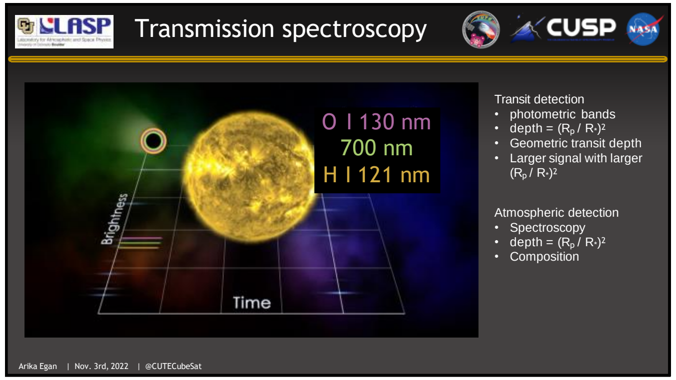
Transmission spectroscopy
CUSP
O I 130 nm
700 nm
H I 121 nm
Brightness
Time
Transit detection
• photometric bands
• depth = $(R_p / R_*)^2$
• Geometric transit depth
• Larger signal with larger $(R_p / R_*)^2$
Atmospheric detection
• Spectroscopy
• depth = $(R_p / R_*)^2$
• Composition
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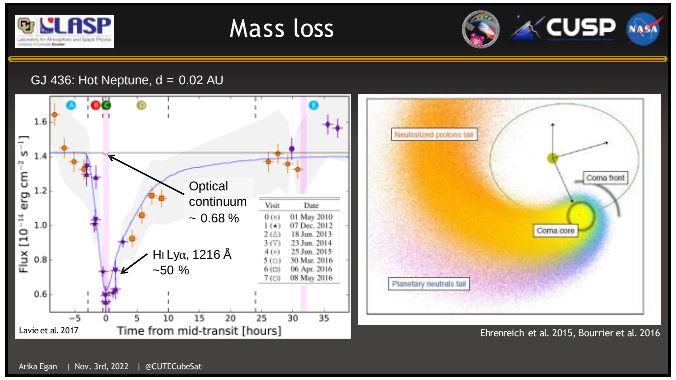
Mass loss
CUSP
GJ 436: Hot Neptune, d = 0.02 AU
Optical continuum ~ 0.68 %
HI Lyα, 1216 Å ~50 %
Time from mid-transit [hours]
Lavie et al. 2017
Neutralized protons tail
Coma front
Coma core
Planetary neutrals tail
Ehrenreich et al. 2015, Bourrier et al. 2016
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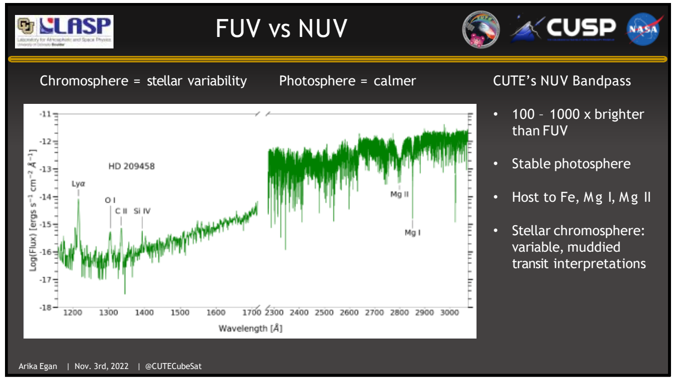
FUV vs NUV
CUSP
Chromosphere = stellar variability
Photosphere = calmer
HD 209458
Wavelength [Å]
CUTE's NUV Bandpass
• 100 - 1000 x brighter than FUV
• Stable photosphere
• Host to Fe, Mg I, Mg II
• Stellar chromosphere: variable, muddied transit interpretations
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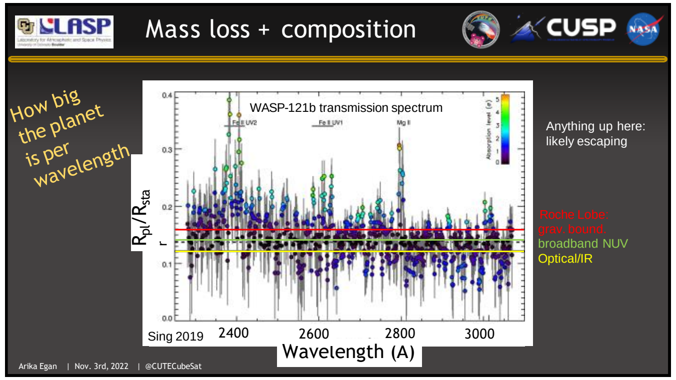
Mass loss + composition
CUSP
How big the planet is per wavelength
WASP-121b transmission spectrum
R_{pl}/R_{star}
Sing 2019
2400
2600
2800
3000
Wavelength (A)
Anything up here: likely escaping
Roche Lobe
grav. bound
broadband NUV
Optical/IR
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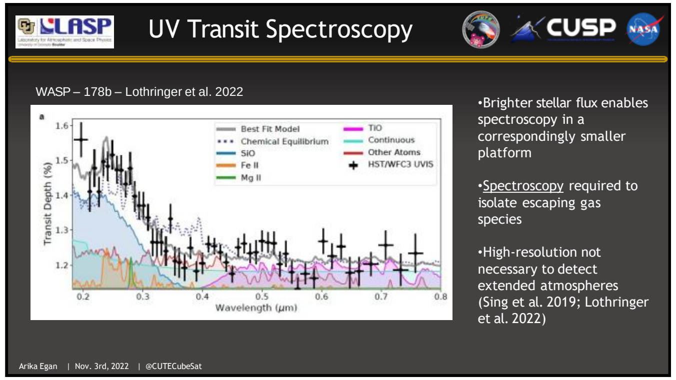
UV Transit Spectroscopy
CUSP
WASP – 178b – Lothringer et al. 2022
Best Fit Model
Chemical Equilibrium
SiO
Fe II
Mg II
TiO
Continuous
Other Atoms
HST/WFC3 UVIS
Transit Depth (%)
Wavelength (μm)
•Brighter stellar flux enables spectroscopy in a correspondingly smaller platform
•Spectroscopy required to isolate escaping gas species
•High-resolution not necessary to detect extended atmospheres (Sing et al. 2019; Lothringer et al. 2022)
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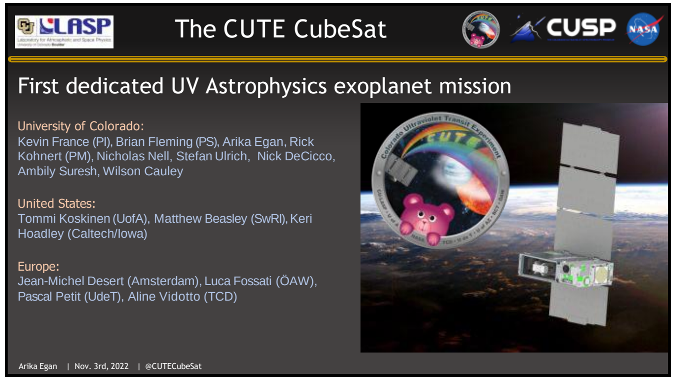
The CUTE CubeSat
CUSP
First dedicated UV Astrophysics exoplanet mission
University of Colorado:
Kevin France (PI), Brian Fleming (PS), Arika Egan, Rick Kohnert (PM), Nicholas Nell, Stefan Ulrich, Nick DeCicco, Ambily Suresh, Wilson Cauley
United States:
Tommi Koskinen (UofA), Matthew Beasley (SwRI), Keri Hoadley (Caltech/Iowa)
Europe:
Jean-Michel Desert (Amsterdam), Luca Fossati (ÖAW), Pascal Petit (UdeT), Aline Vidotto (TCD)
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The CUTE CubeSat

First dedicated UV Astrophysics exoplanet mission

- 8-month nominal mission lifetime
  - 2479 – 3306 Å
    - Fe, 2600 Å
    - Mg I, 2850 Å
    - Mg II, 2800 Å
  - > 10 targets, up to 10 visits each, 5 minute in-transit exposure cadence
  - 5-times transit duration for each target visit

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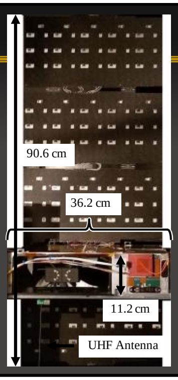
CubeSats



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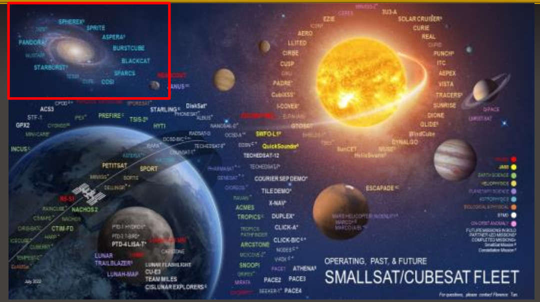
CUTE: Many firsts



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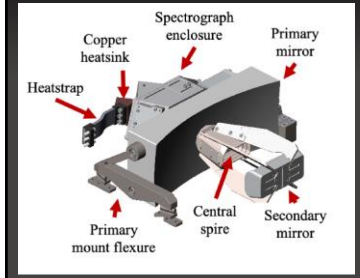
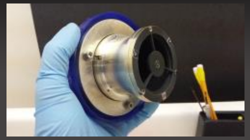
Instrument overview





Collecting area: ~ 122 cm²
> 3x more than 9 cm diameter

e2v CCD42-10 back-illuminated UV-enhanced CCD detector.
2048 x 515 pixels, 13.5 um square pixels

(Mars Science Laboratory ChemCham LIBS spectrometer)

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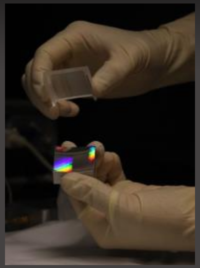
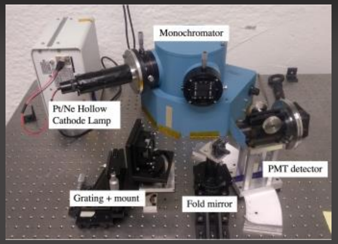
Optical Performance





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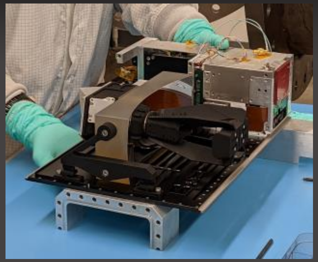
Optical Performance



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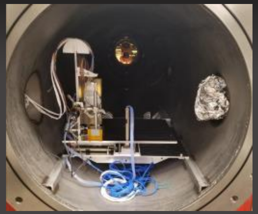
Optical performance



Focus spectrograph and test secondary placement
- 2 ft diameter hollow cylindrical vacuum calibration chamber for sounding rockets.
- Horizontal and vertical orientations

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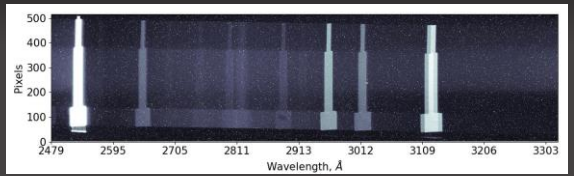
Optical Performance



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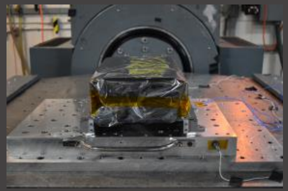
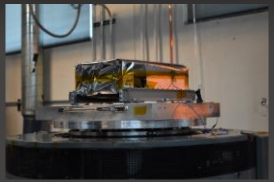
Environmental Performance

Clamp CUTE to an industrial vibration table and simulate the launch vehicle vibration environment.

Perform pre- and post-checks of everything





First vibe: some things broke ➔ we fixed them

Second vibe: good to go!

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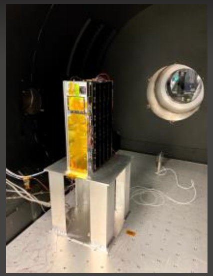
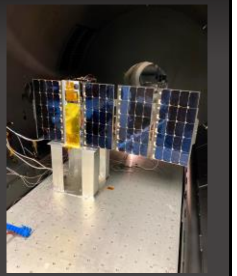
Environmental Performance

Make sure that the solar arrays will deploy in a variety of temperatures, and at the right time

After CUTE is dispensed, an electrical inhibit plunger is removed, and a 35 minute timer begins to countdown to deploying the solar arrays and UHF antenna

Success at:
- -10 deg C
- 20 deg C
- 45 deg C





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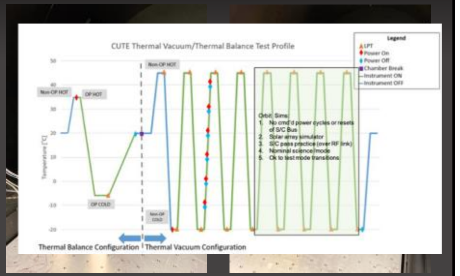
Environmental Performance

Make sure that the solar arrays will deploy in a variety of temperatures, and at the right time.

Subject the spacecraft to hot/cold cycles similar to that of its expected orbit.
- test the optical performance
- test the radios
- test all electronics and subsystems
- spoof the spacecraft ephemeris so it thinks it's actually in orbit



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Environmental Performance

Test the radios (UHF and S-band) a few miles away from the ground station

Success:
- UHF could receive commands and transmit telemetry
- S-band could transmit science images
- A single solar array kept us powered!

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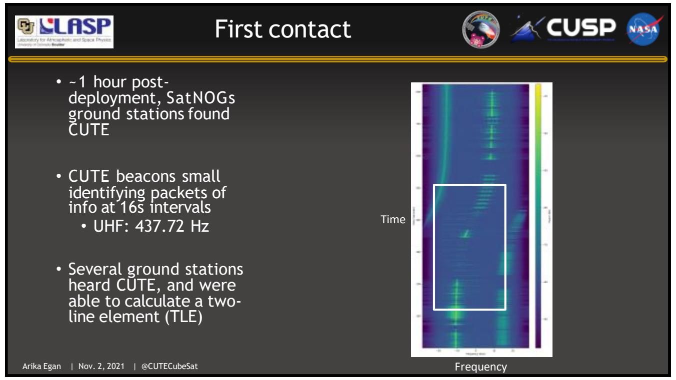

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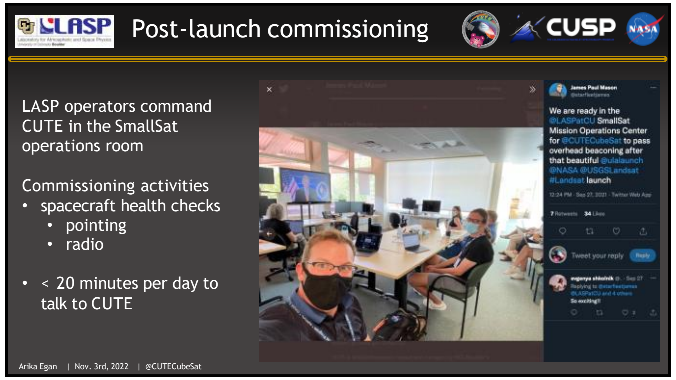

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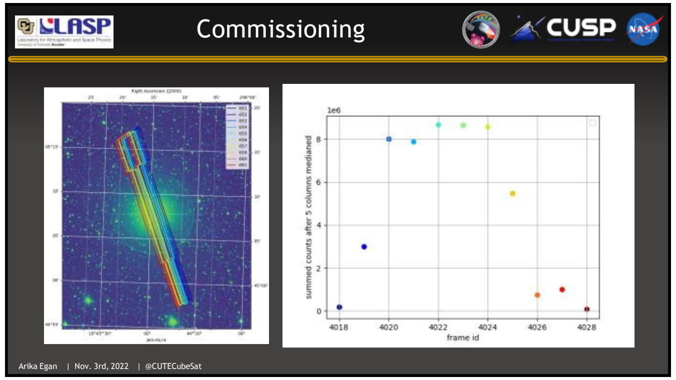

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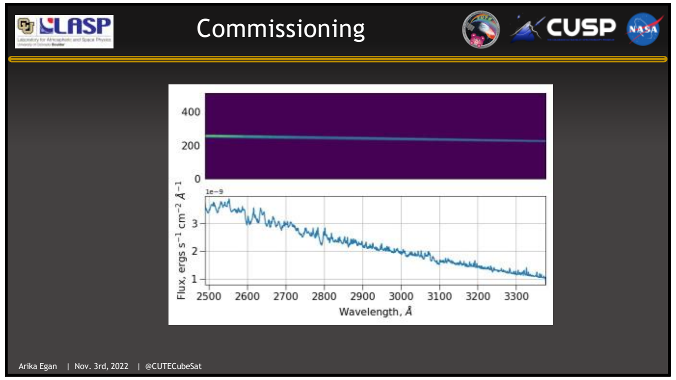
LASP
Commissioning
CUSP
NASA
400
200
0
1e-9
3
2
1
Flux, ergs s^{-1} cm^{-2} Å^{-1}
2500 2600 2700 2800 2900 3000 3100 3200 3300
Wavelength, Å
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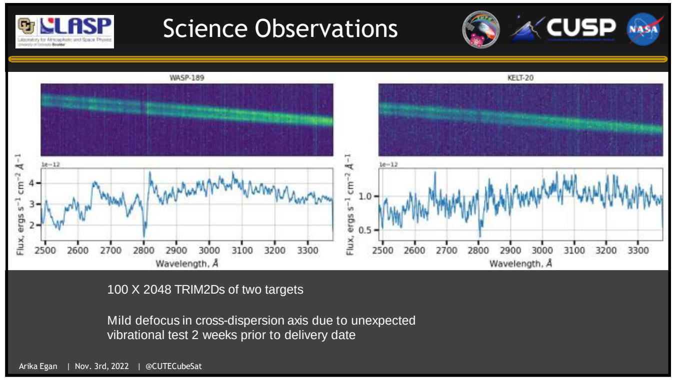
LASP
Science Observations
CUSP
NASA
WASP-189
KELT-20
1e-12
Flux, ergs s^{-1} cm^{-2} Å^{-1}
Wavelength, Å
100 X 2048 TRIM2Ds of two targets
Mild defocus in cross-dispersion axis due to unexpected vibrational test 2 weeks prior to delivery date
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LASP
Small platform large team
CUSP
NASA
University of Colorado:
Kevin France (PI), Brian Fleming (PS), Arika Egan, Rick Kohnert (PM), Nicholas Nell, Nick DeCicco, Stefan Ulrich, Ambily Suresh, Dmitry Vorobiev
United States:
Tommi Koskinen (UofA), Matthew Beasley (SwRI), Keri Hoadley (Caltech/Iowa)
Europe:
Jean-Michel Desert (Amsterdam), Luca Fossati (ÖAW), Pascal Petit (UdeT), Aline Vidotto (TCD)
+ more than 9 CU undergraduates
Trinity College Dublin
WAO
BCT
ARIZONA
Université de Toulouse
SwRI
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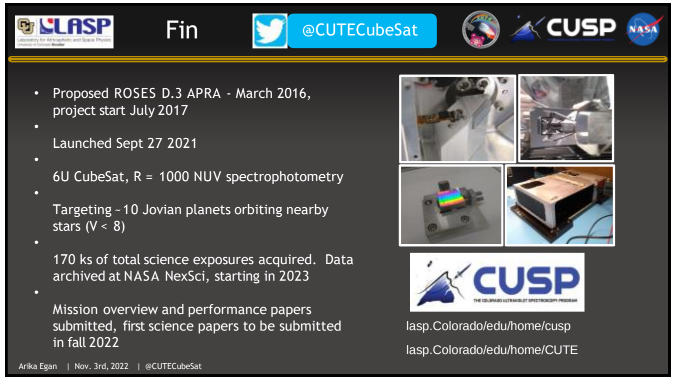
LASP
Fin
@CUTECubeSat
CUSP
NASA
Proposed ROSES D.3 APRA - March 2016, project start July 2017
Launched Sept 27 2021
6U CubeSat, R = 1000 NUV spectrophotometry
Targeting ~10 Jovian planets orbiting nearby stars (V < 8)
170 ks of total science exposures acquired. Data archived at NASA NexSci, starting in 2023
Mission overview and performance papers submitted, first science papers to be submitted in fall 2022
CUSP
lasp.Colorado/edu/home/cusp
lasp.Colorado/edu/home/CUTE
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