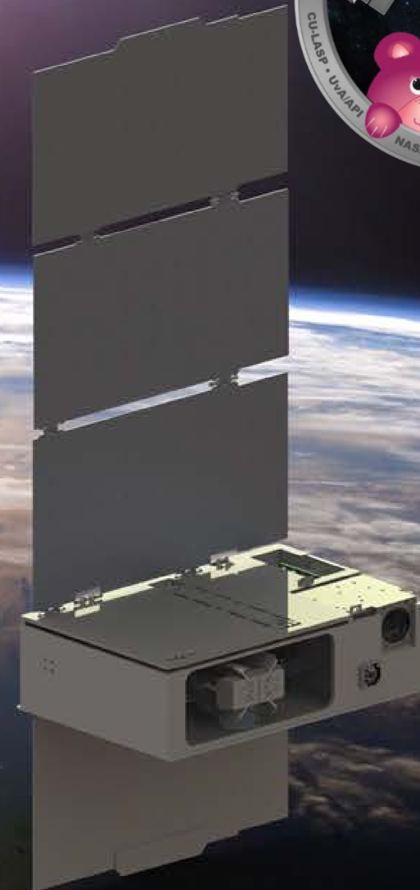
ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY

JcUVa

Atmospheric Escape from Extrasolar Planets: From stellar inputs to exoplanetary signatures with the ESCAPE and CUTE missions

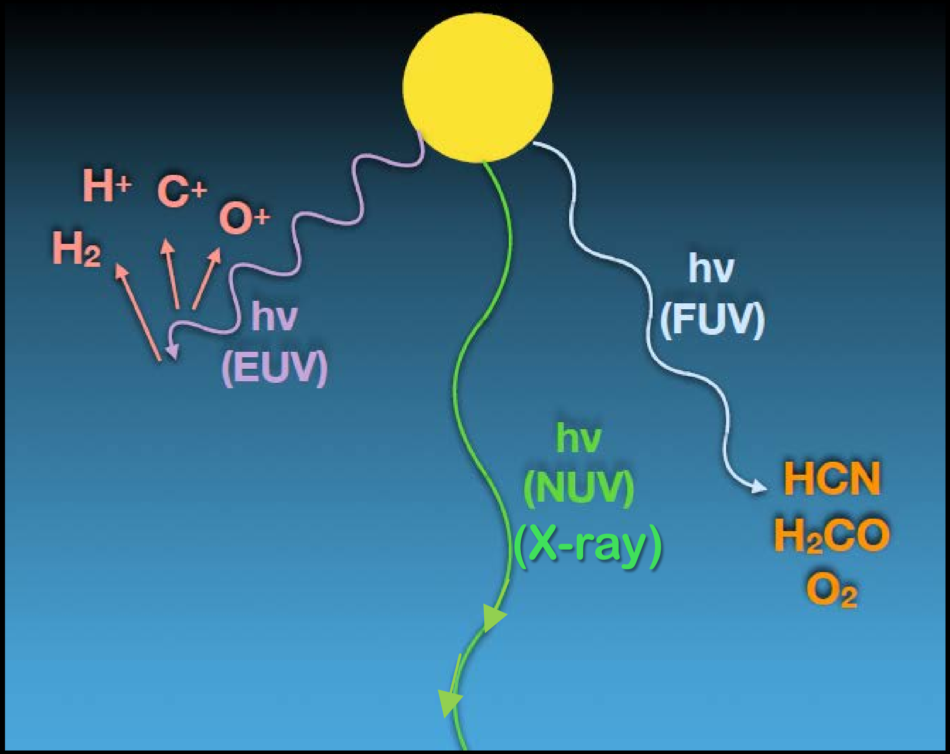


Kevin France
University of Colorado

NUVA 2020

Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

Introduction: Star-Planet Interactions and Atmospheric Impacts

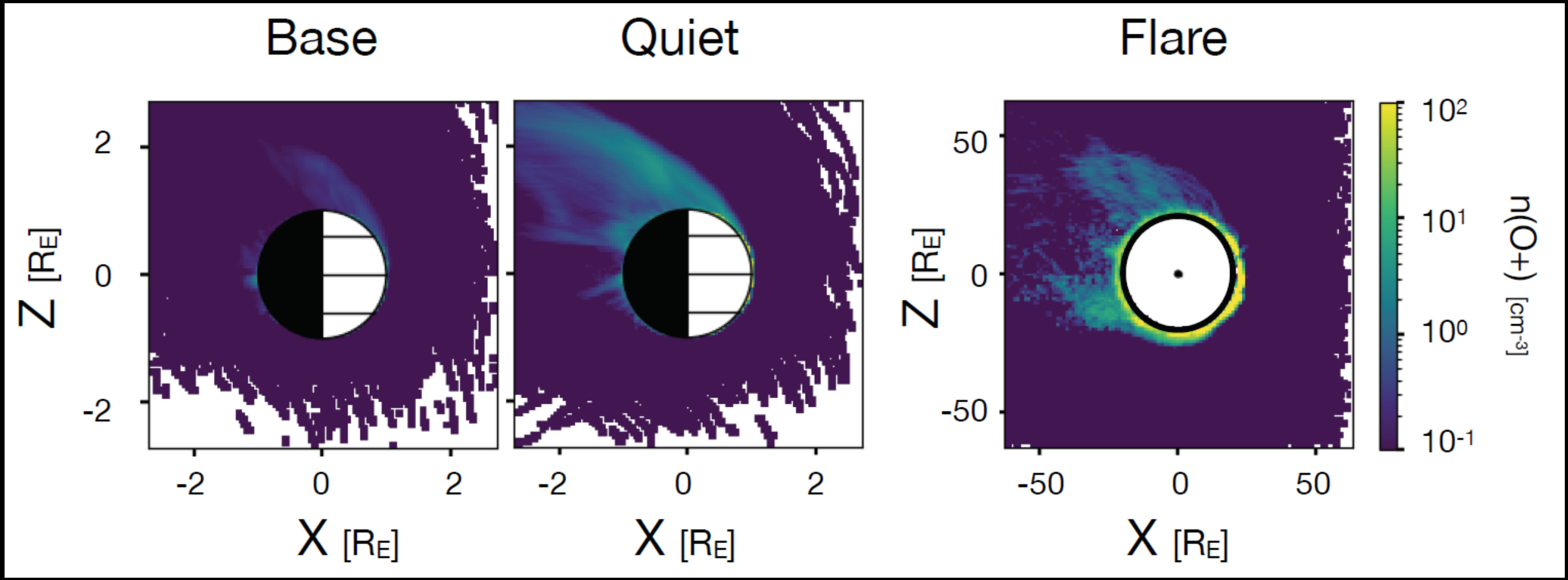


- Photons of different energy play distinct roles, and all contribute to the observable signatures of that atmosphere

- The high-energy stellar emission dominates atmospheric photochemistry, ionization, and heating

Figure courtesy of
Paul Rimmer - Cambridge

Introduction: Star-Planet Interactions and Atmospheric Impacts



France+ 2020

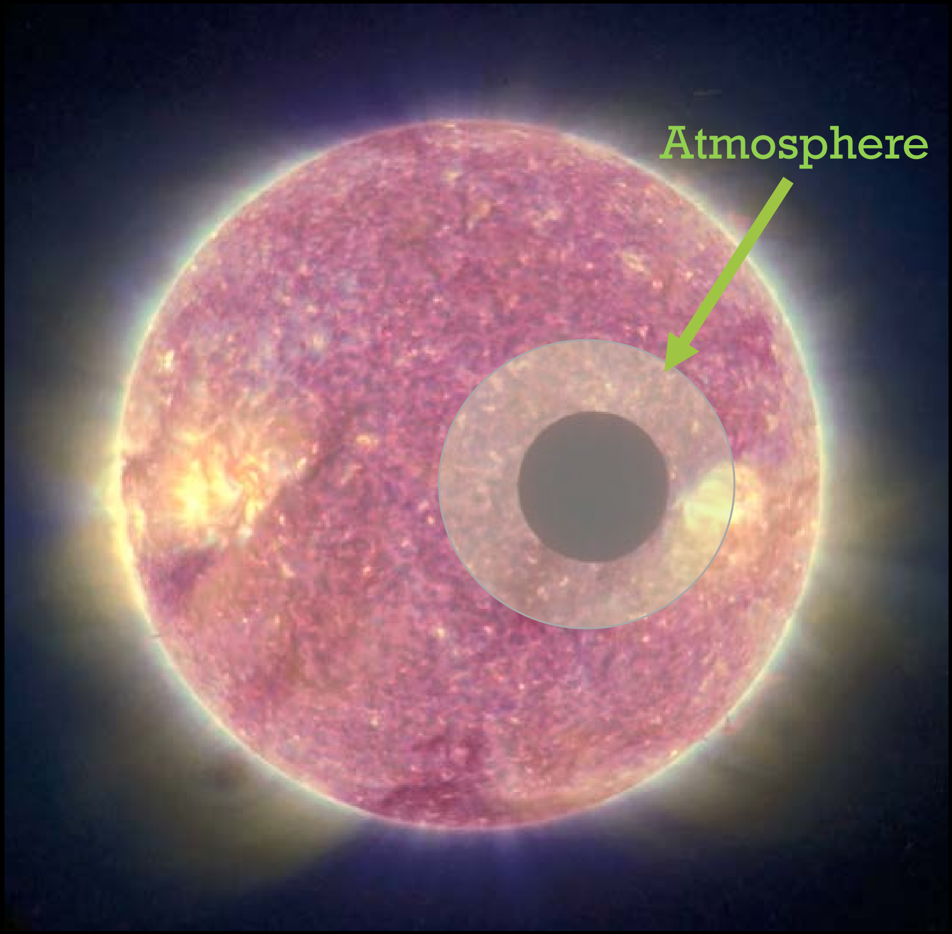
- Example: Rapid atmospheric escape driven by a combination of stellar EUV photons and particles (stellar winds, CMEs) may prevent exoplanets from maintaining habitable environments over geologic timescales

STUDYING ATMOSPHERIC ESCAPE TODAY

Occultation Depth = $(R_P / R_*)^2$

EXOPLANET ATMOSPHERES

- Narrow-band/spectroscopic transit analysis can probe absorption by specific atmospheric constituents



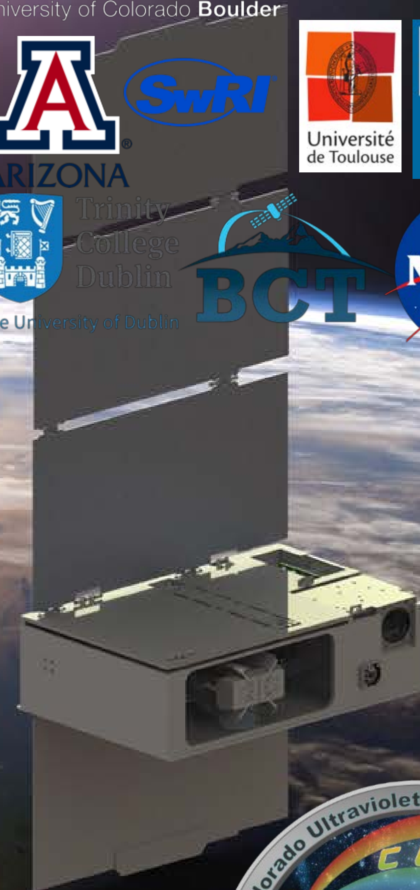
Occultation Depth = $(R_P(\lambda) / R_*)^2$

Transit Spectroscopy:
in-transit vs. out-of-transit

- Composition
- Temperature structure
- Velocity flows
- Mass-loss rates

The Colorado Ultraviolet Transit Experiment (CUTE)

Laboratory for Atmospheric and Space Physics
University of Colorado Boulder



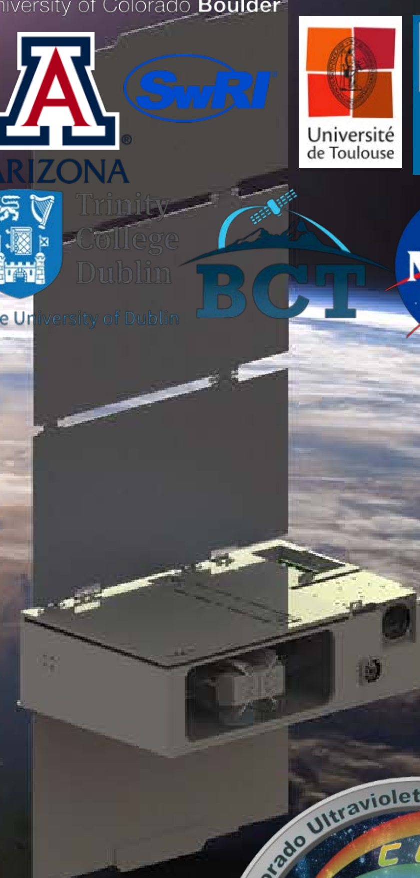
University of Colorado:
Kevin France (PI), Brian Fleming (PS), Arika Egan*, Rick Kohnert (PM), Nicholas Nell*, Stefan Ulrich, Nick DeCicco, Ambily Suresh

United States:
Tommi Koskinen (UofA), Matthew Beasley (SwRI), Keri Hoadley (Caltech/Iowa)

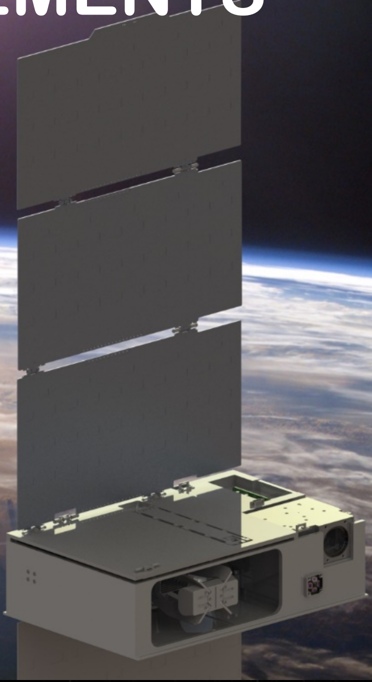
Europe:
Jean-Michel Desert (Amsterdam), Luca Fossati (ÖAW), Pascal Petit (UdeT), Aline Vidotto (TCD)

CUTE:
11.0 cm x 23.7cm x 36.2 cm

Family Size Cheerios available on Walmart.com:
7.8 cm x 23.9 cm x 34.4 cm

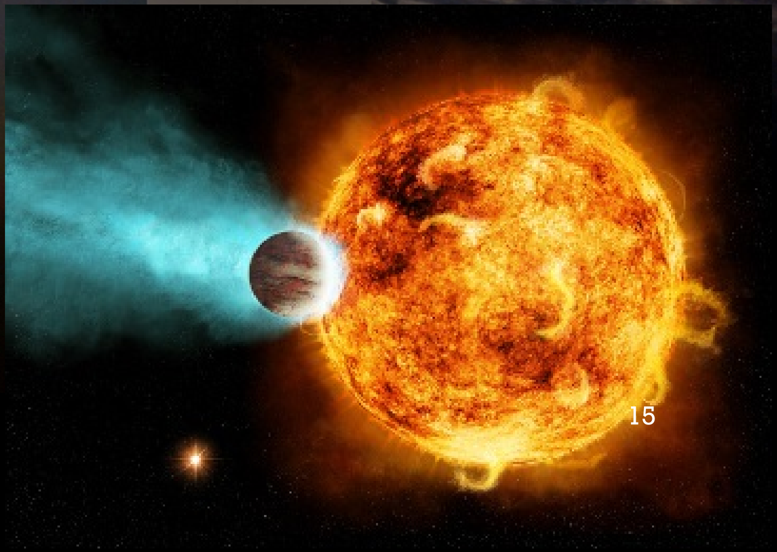


CUTE: A NEW APPROACH TO ATMOSPHERIC MASS-LOSS MEASUREMENTS



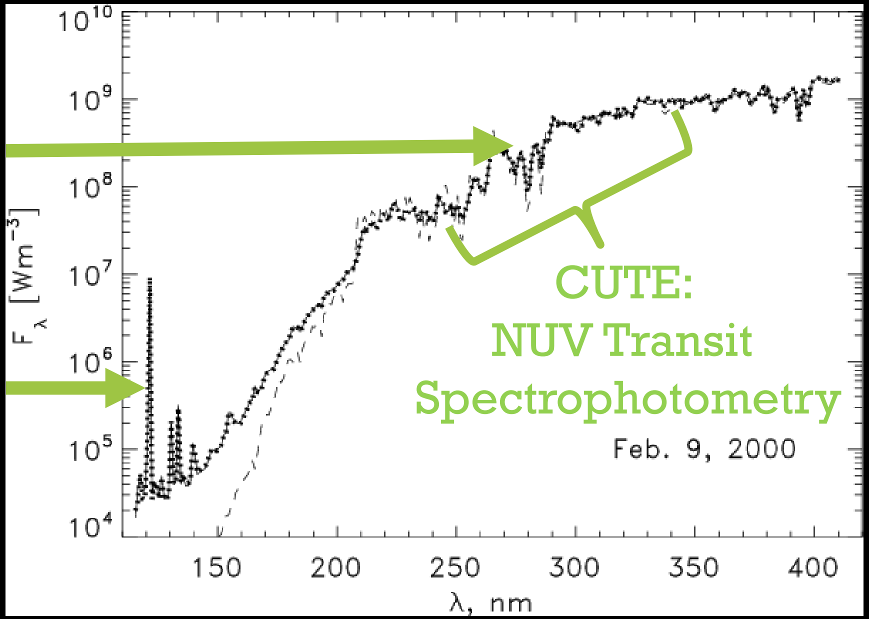
Survey of ~12-24 short-period transiting planets around nearby stars:

1) Atmospheric mass-loss rates
2) Escaping atmosphere composition



CUTE: A NEW APPROACH TO ATMOSPHERIC MASS-LOSS MEASUREMENTS

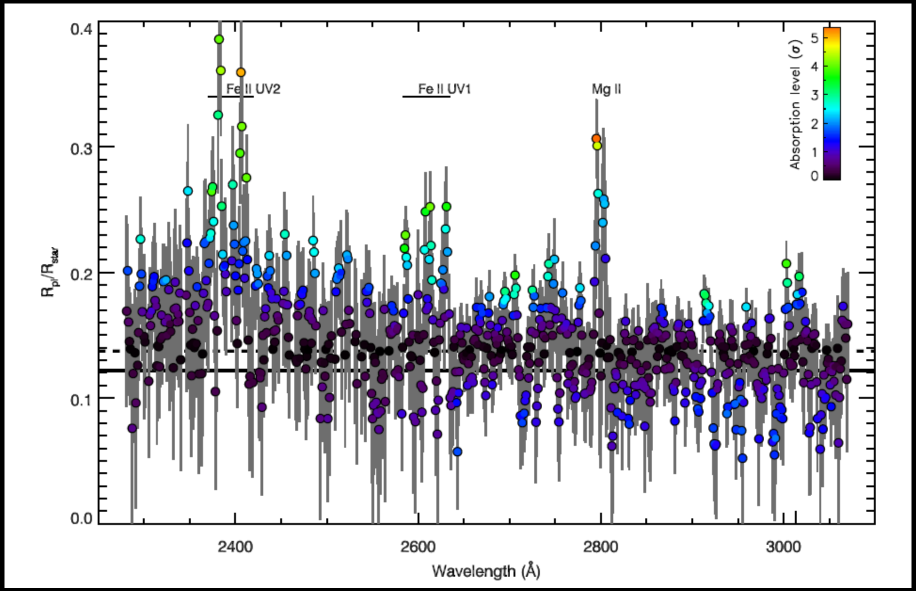
Source: SDO



Krivova et al. 2006

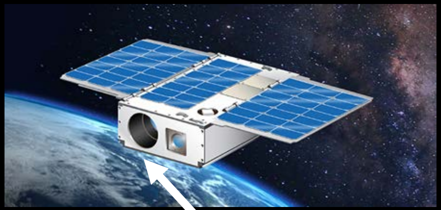
- Uncertain chromospheric intensity distribution (e.g., Llama & Shkolnik 2015).
- The NUV has both a more uniform, mainly photospheric, intensity distribution compared to FUV, and an **overall brighter background for transit observations, ~50-1000x brighter for K – F type stars.**

CUTE: A NEW APPROACH TO ATMOSPHERIC MASS-LOSS MEASUREMENTS



Sing et al. 2019

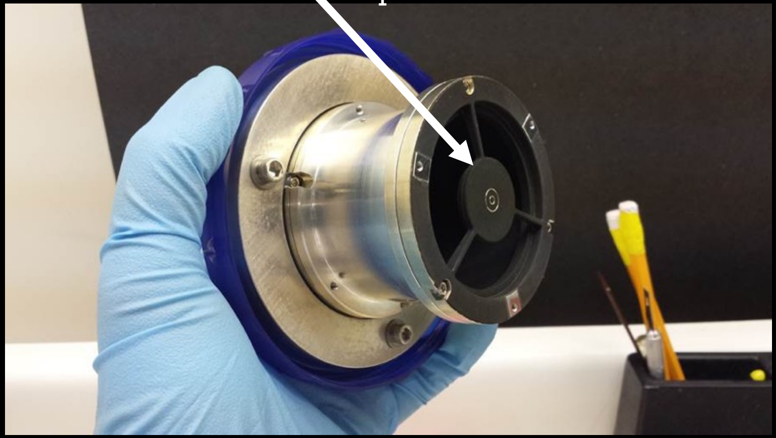
- Brighter stellar flux enables spectroscopy in a correspondingly smaller platform
- <u>Spectroscopy</u> required to isolate escaping gas species

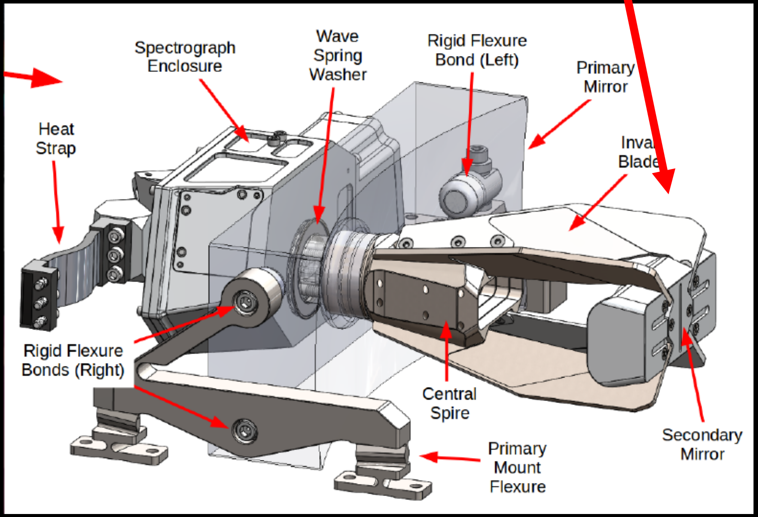


CUTE Telescope

See CUTE design overview in Fleming et al. (2018)

Source: Nu-Tek Precision Optics

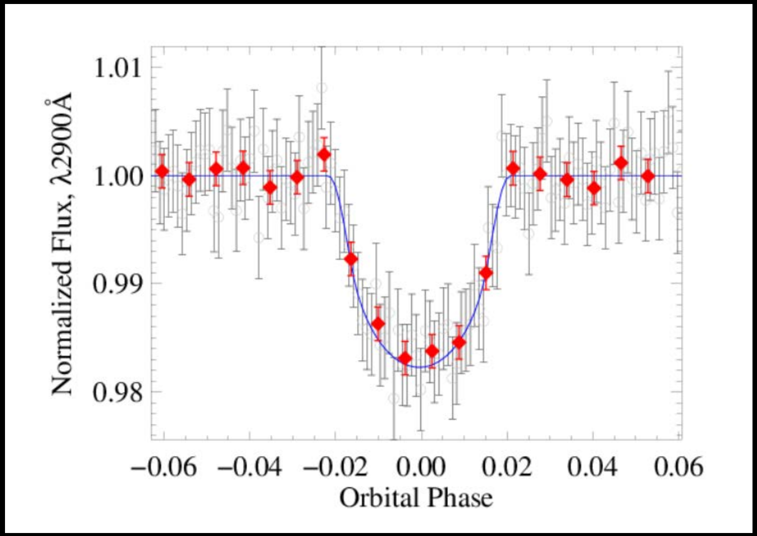


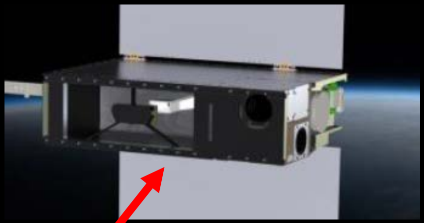


Geometric clear area for a 9cm Cassegrain: A_T ~ **47 cm^2**

Geometric clear area for a 20 x 8 cm Cassegrain: A_{CUTE} ~ **140 cm^2**

$A_{T,r}/A_{CUTE}$ = **3 x** more collecting area





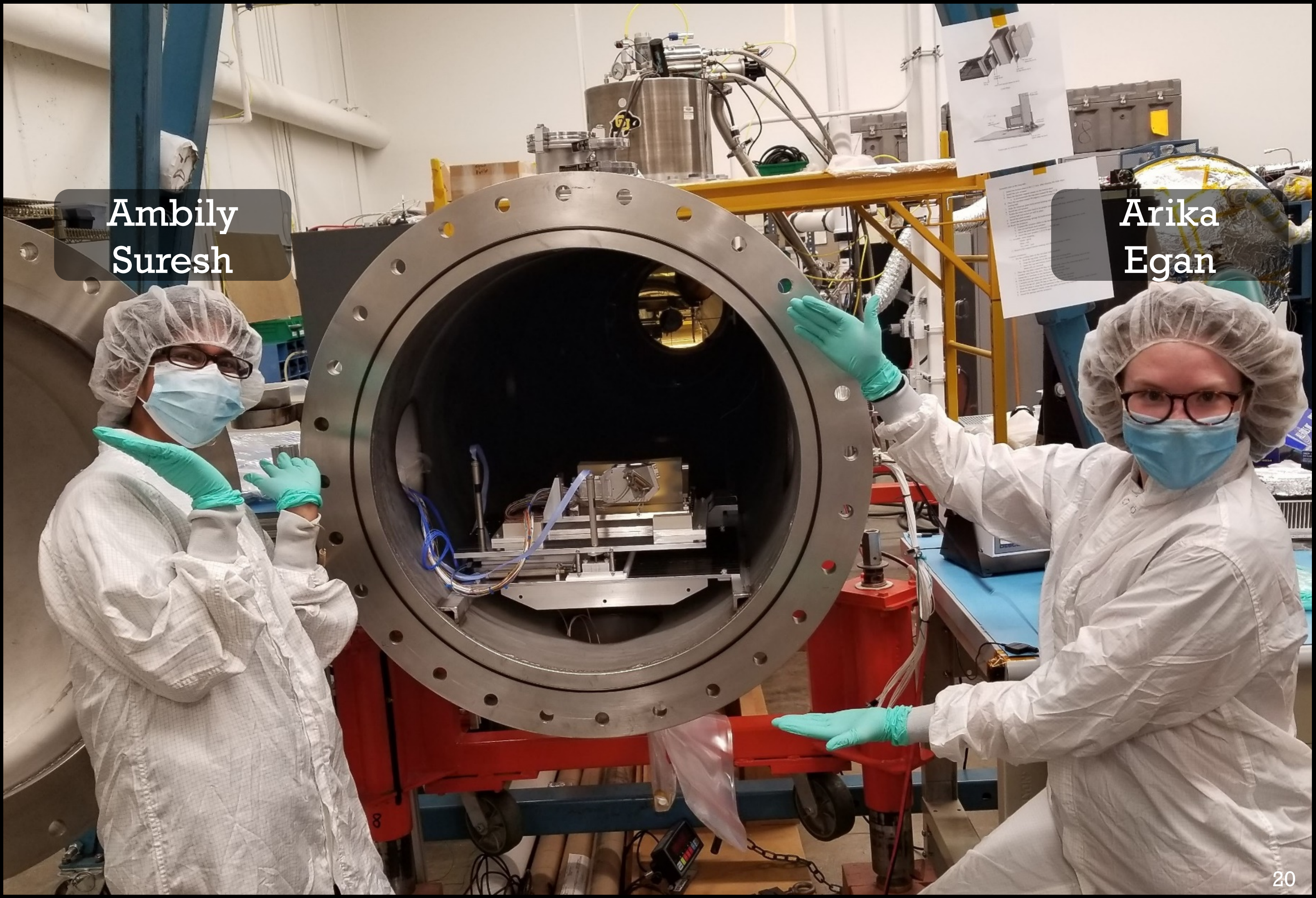
See CUTE design overview in Fleming et al. (2018)

CUTE will achieve >3σ detections of NUV continuum transits as low as 0.1% depth for the brightest targets, and < 1% for all baseline targets with 5+ lightcurves per target:

- Continuum transit sensitivity to 0.7% depth for median target over 1 transit (1.2% in Mg II)

= Capable of detecting geometric transit and atmospheric transit

CUTE Telescope Testing – Sept 2020



See CUTE design overview in Fleming et al. (2018); Egan et al. (2018);
mission overview in France et al. (2020) – Nature Astronomy – in press

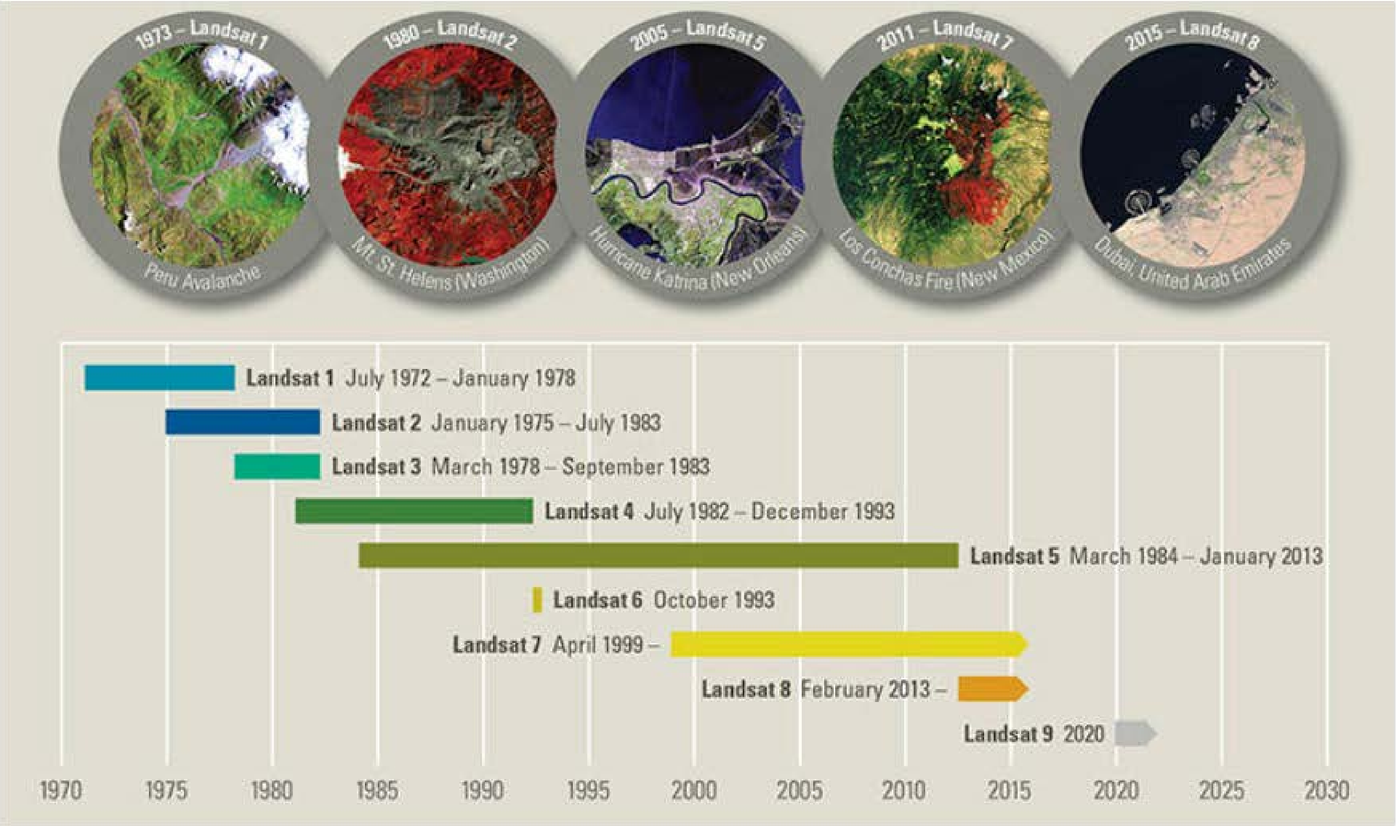
CUTE Status

When will the Landsat 9 satellite be launched?

Landsat 9—a partnership between the USGS and NASA—has a launch readiness date of December 2020.

Landsat 9 will be launched from Space Launch Complex 3E at Vandenberg Air Force Base in California and will be delivered into orbit by a United Launch Alliance Atlas V 401 launch vehicle.

Learn more: Landsat 9 Mission



CUTE

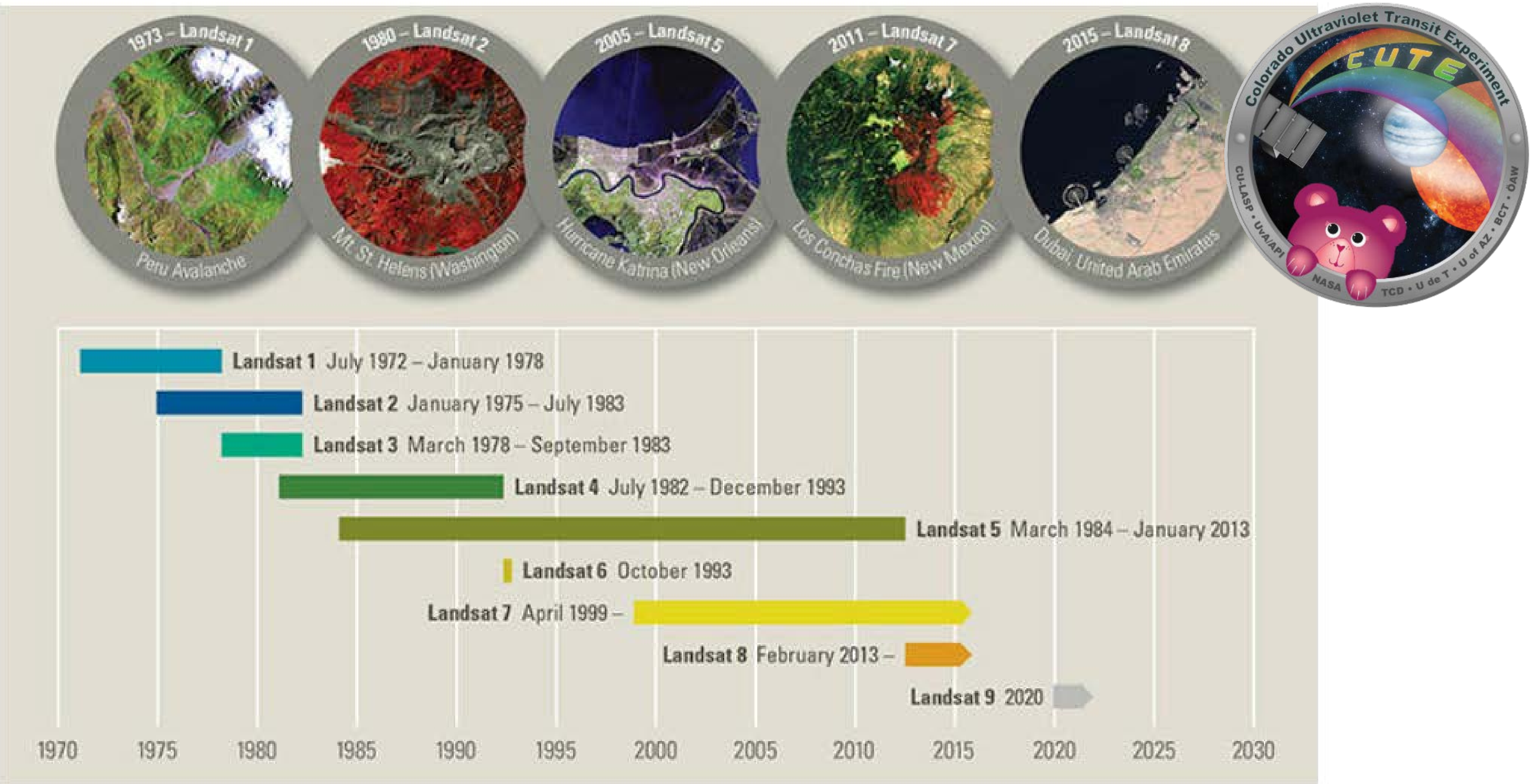
When will the ~~Landsat 9~~ satellite be launched?

Landsat 9—a partnership between the USGS and NASA—has a launch readiness date of ~~December 2020.~~

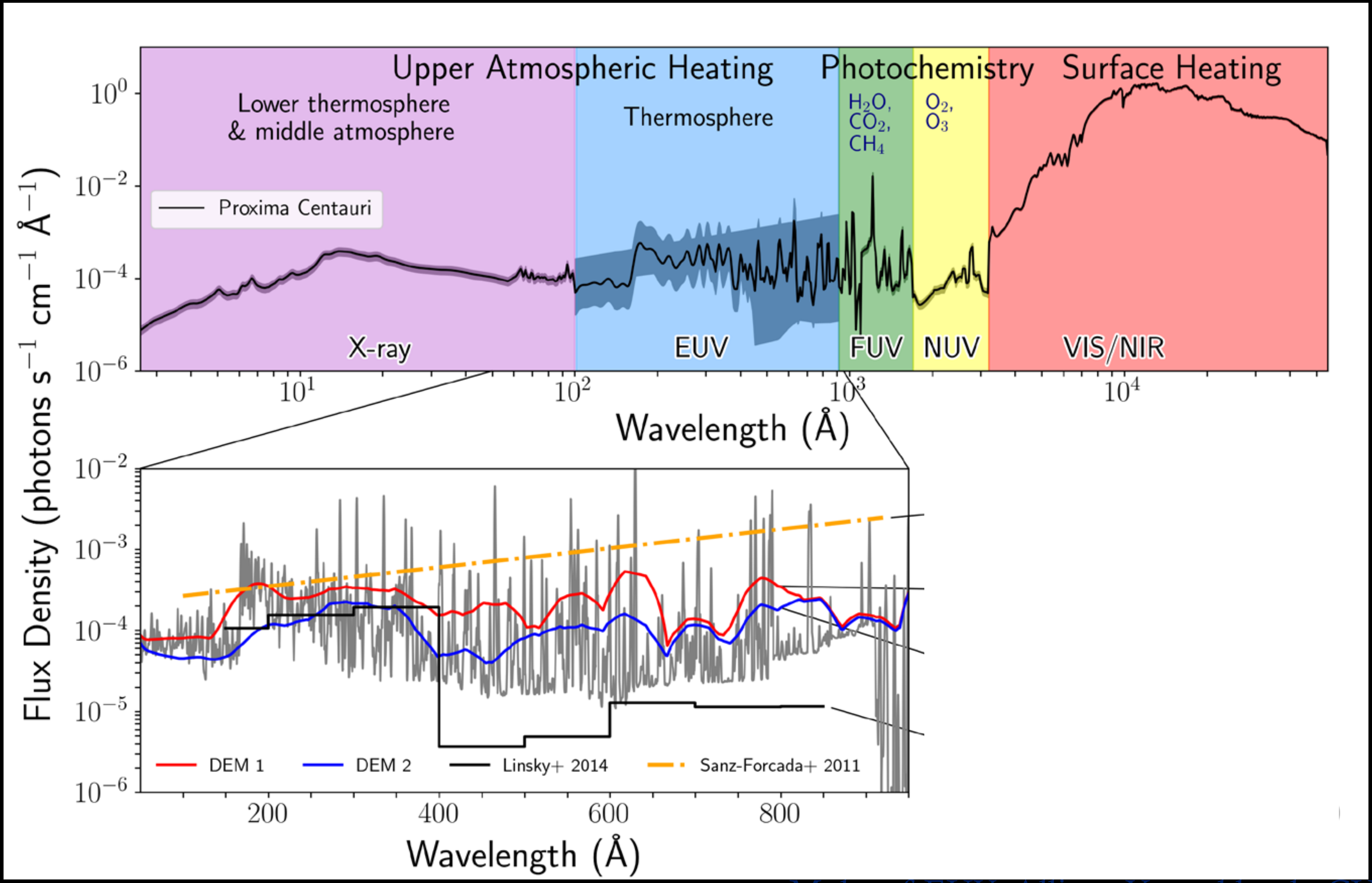
Landsat 9 will be launched from Space Launch Complex 3E at Vandenberg Air Force Base in California a
be delivered into orbit by a United Launch Alliance Atlas V 401 launch vehicle.

Sept 2021

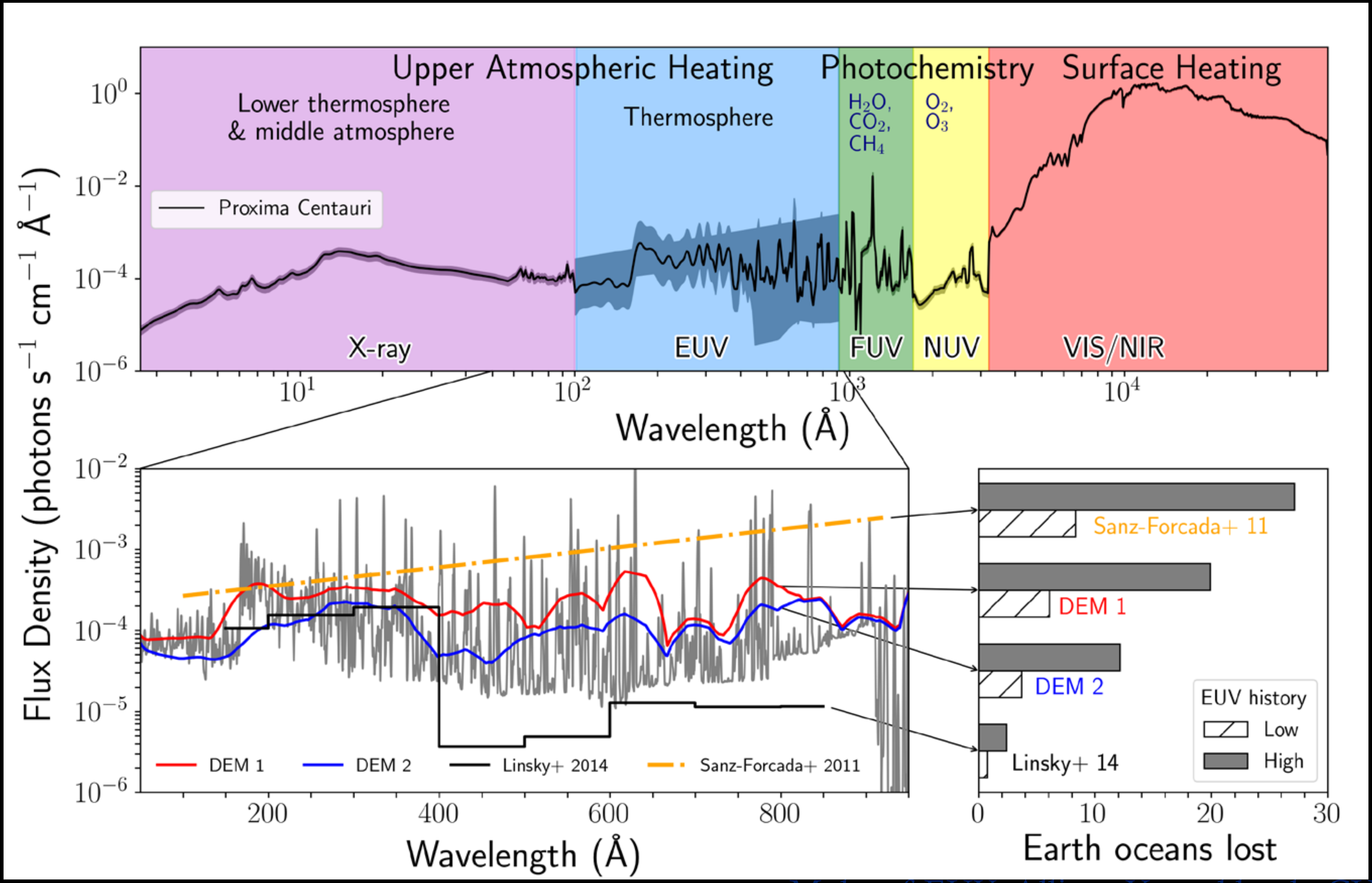
Learn more: [Landsat 9 Mission]



EUV environment remains a key uncertainty for all atmospheric escape calculations



EUV environment remains a key uncertainty for all atmospheric escape calculations

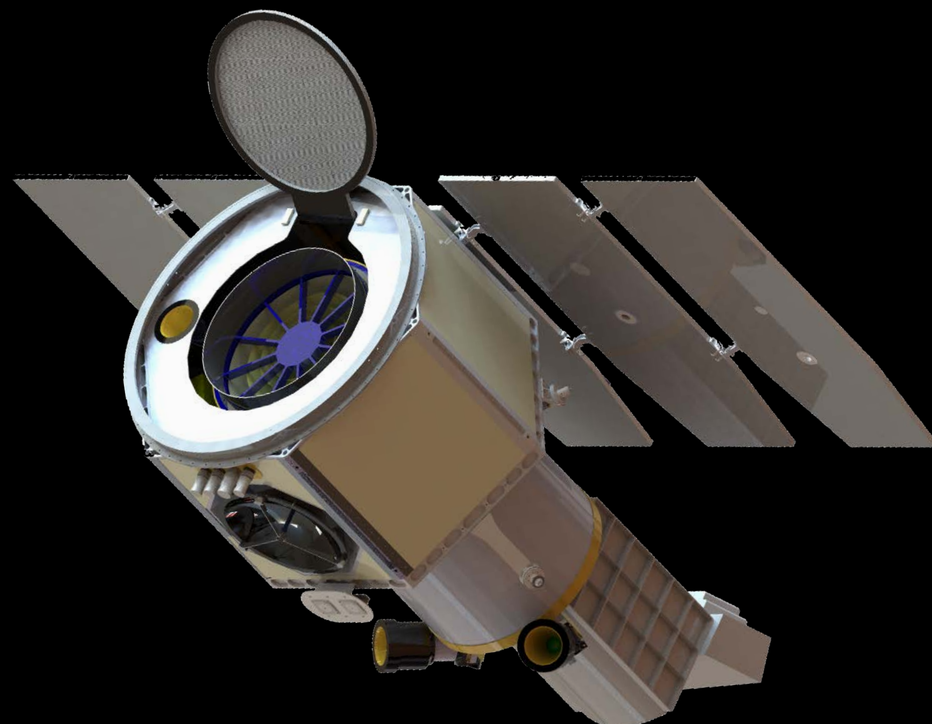


M dwarf EUV: Allison Youngblood - CU

Laboratory for Atmospheric and Space Physics
University of Colorado Boulder
Marshall Space Flight Center
PennState
CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN
SSL UC Berkeley

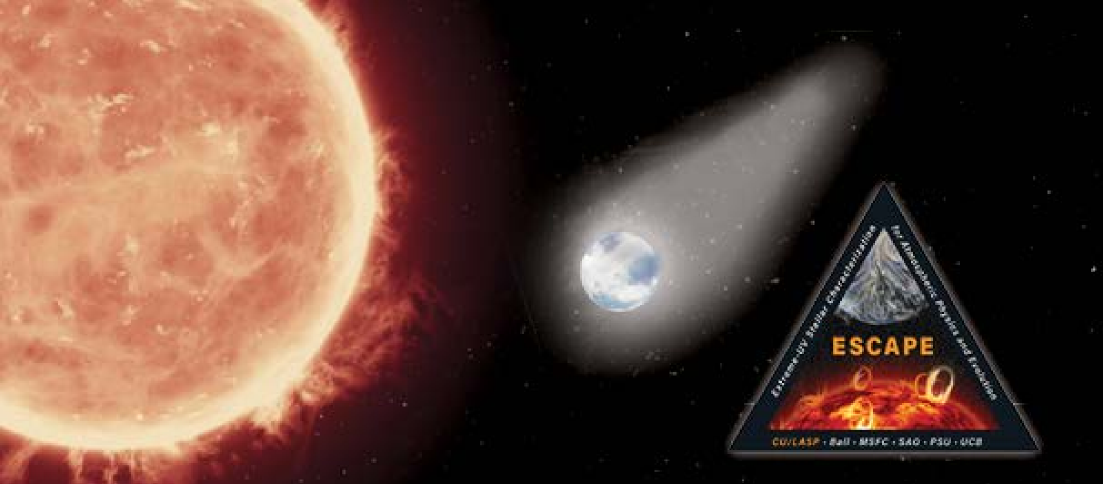
The ESCAPE Small Explorer Concept

(Euv Stellar Characterization for Atmospheric Physics and Evolution)



A NASA Small Explorer mission currently in Phase A

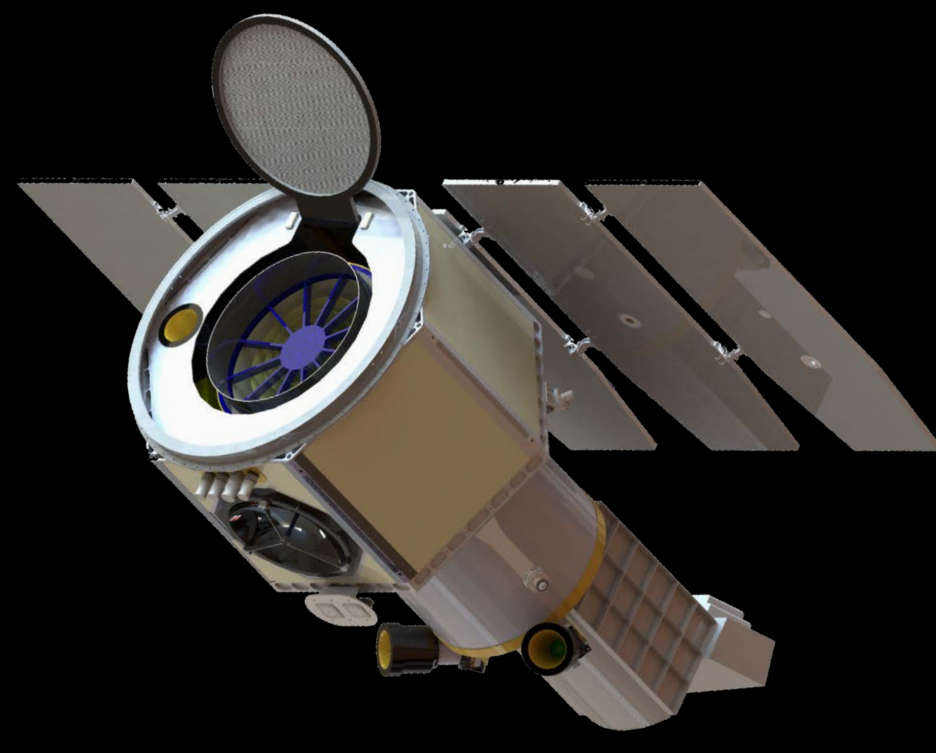
PI – K. France



ESCAPE

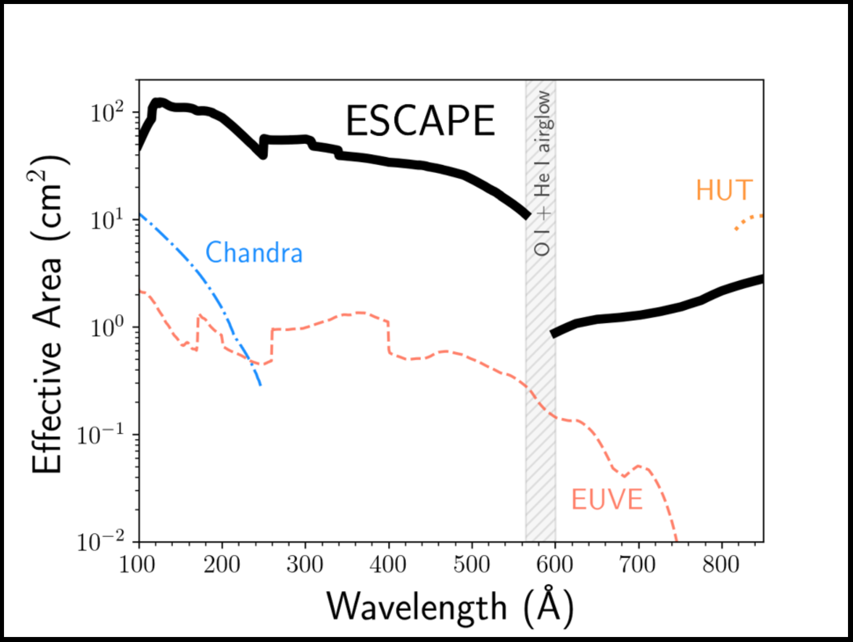
EUV & FUV (70 – 1650 Å) spectroscopy of 200 stars, spectral types F - M

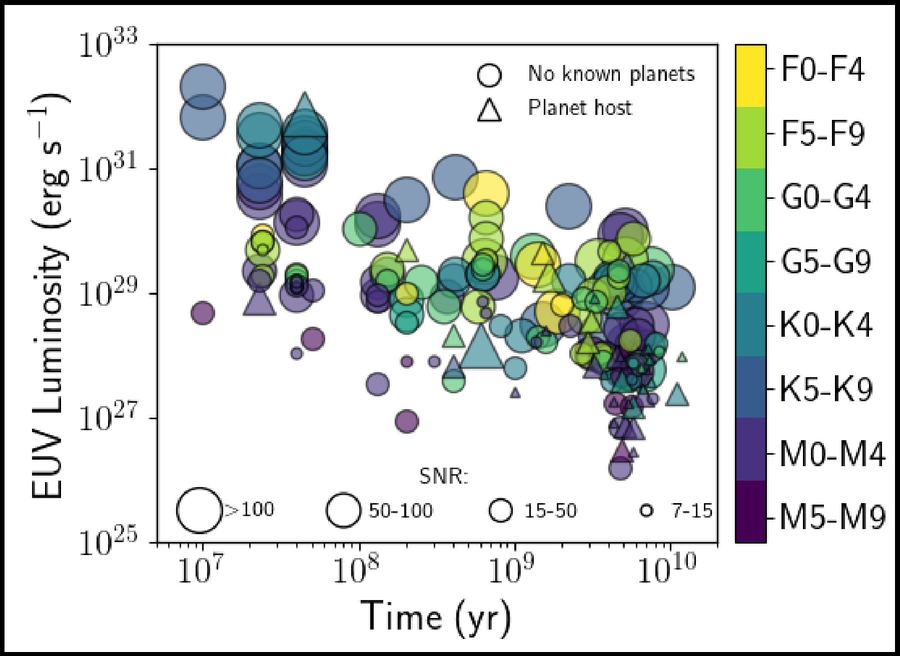
Deep monitoring observations of 24 targets of interest (flare and CME frequency)



The ESCAPE Small Explorer Concept

(Euv Stellar Characterization for Atmospheric Physics and Evolution)





> 100 x sensitivity of EUVE:

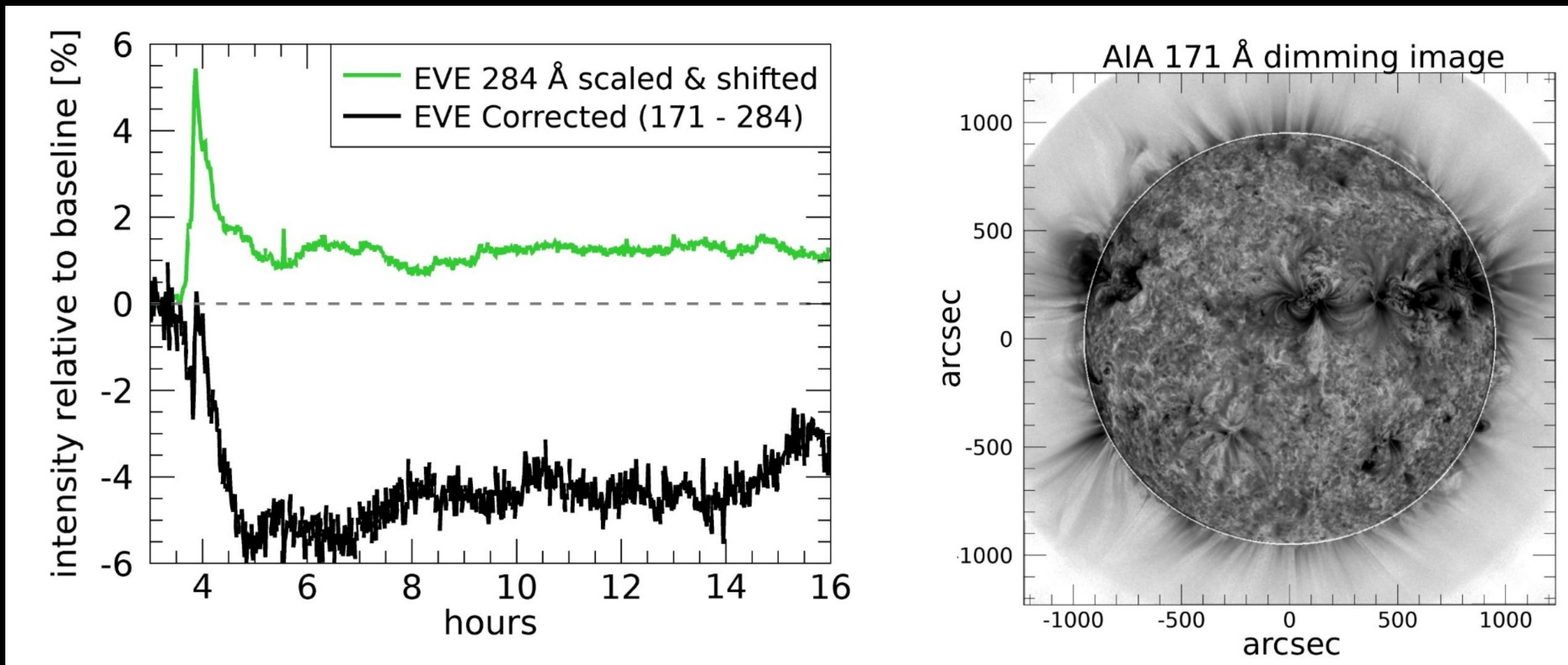
First statistical study of EUV irradiance on planetary environments, capturing important stellar/planetary timescales.

1) Evolutionary (Myr – Gyr)
2) Rotation/Stellar Cycle (days – years)
3) Impulsive (minutes – hours)

Extreme-UV Stellar Characterization for Atmospheric Physics and Evolution
ESCAPE
CU/LASP • BATC • MSFC • SAO • PSU • UCB

The ESCAPE Small Explorer Concept

(Euv Stellar Characterization for Atmospheric Physics and Evolution)



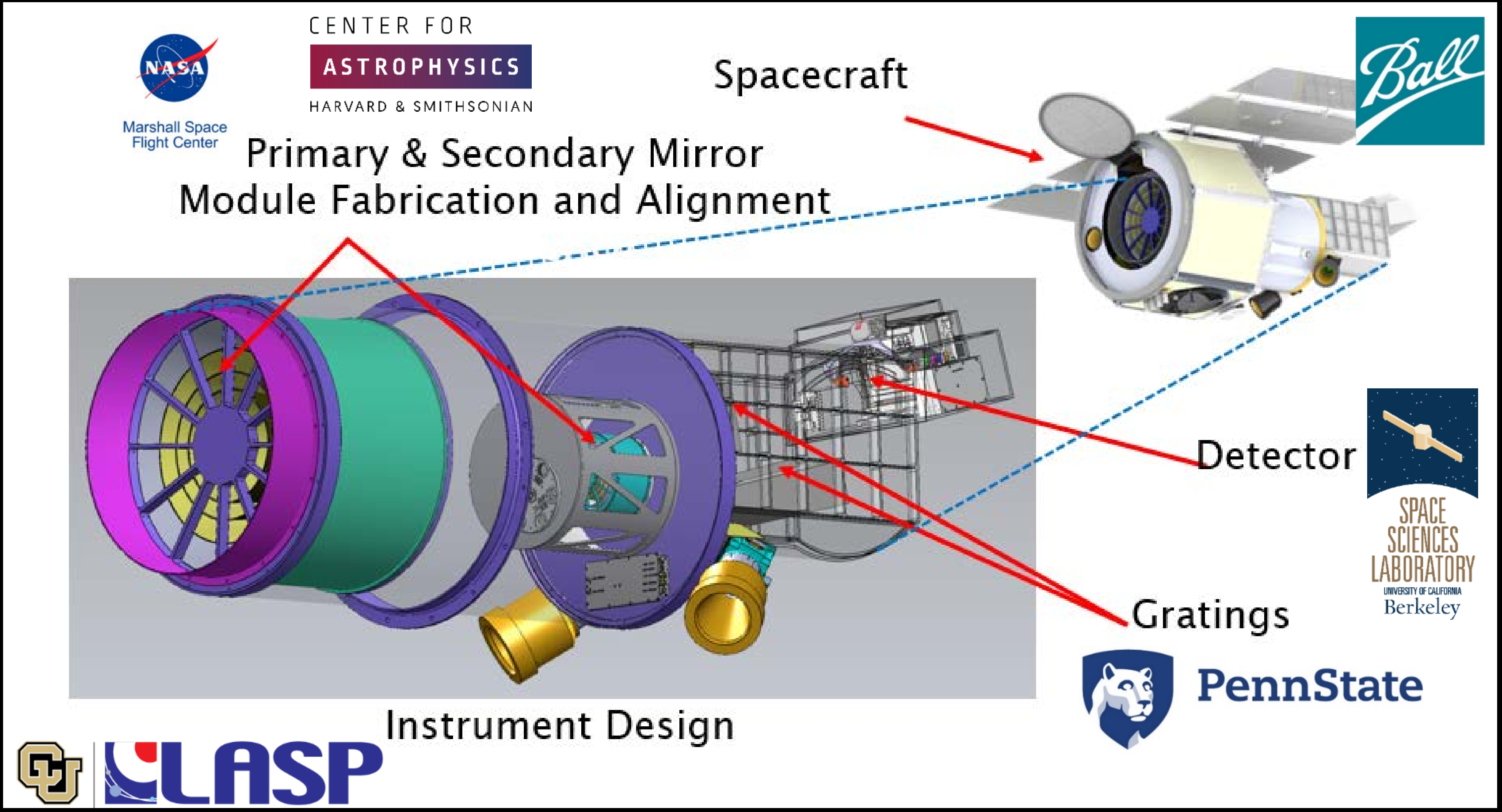
> 100 x sensitivity of EUVE:

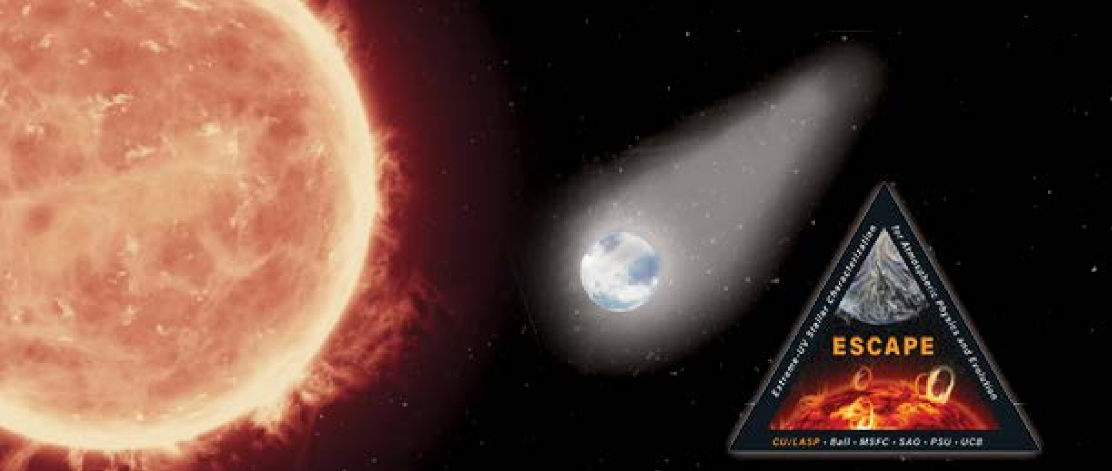
1) CME frequency distribution via **coronal dimming** (10 – 15 F, G, and K stars)
2) Relationship between flares and CMEs
3) CME kinetic energy for brightest stars

Adapted from Mason et al. (2016)

The ESCAPE Small Explorer Concept

(Euv Stellar Characterization for Atmospheric Physics and Evolution)





ESCAPE

Phase A Concept Study:
today – March 2021
Phase A Site Visit:
June 2021
Phase B down select:
October 2021 (?)
Launch:
~August 2025
Science Mission:
2025 – 2027