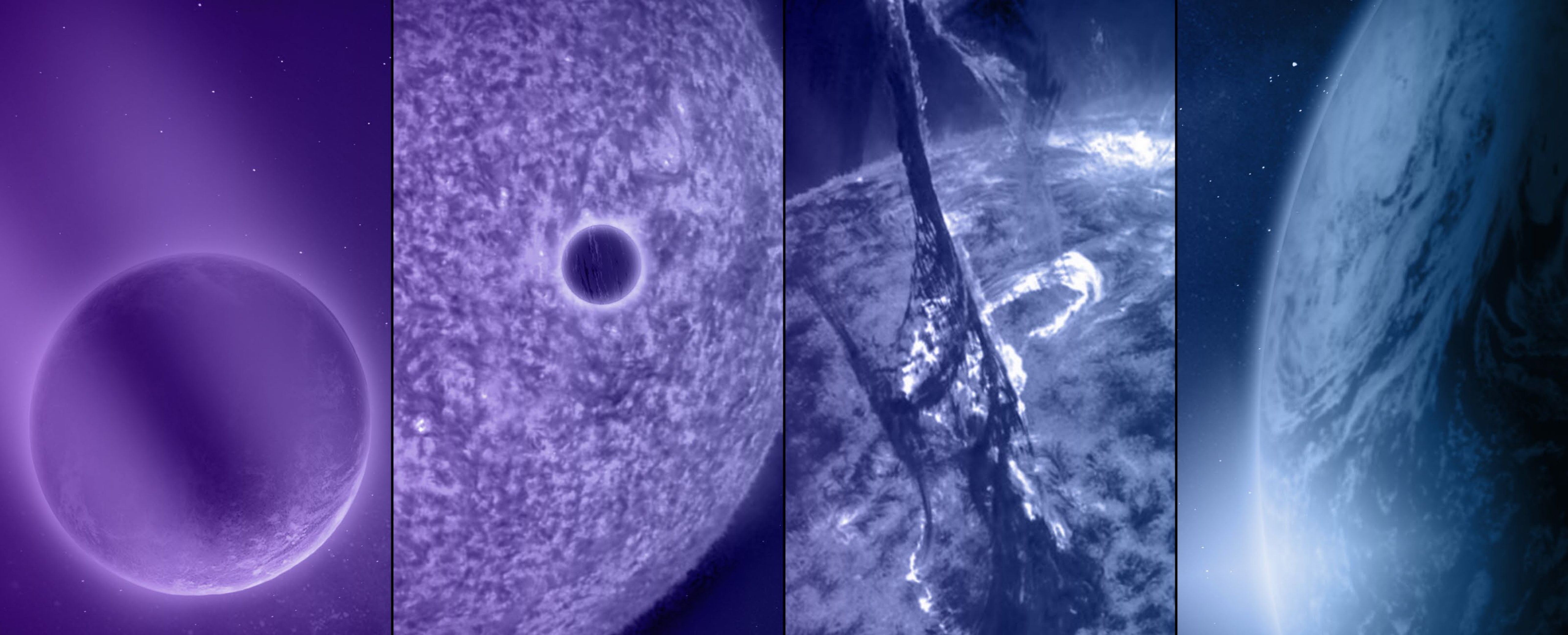


Exoplanet Science Drivers for UV-SCOPE

UltraViolet Spectroscopic Characterization Of Planets and their Environments

Evgenya Shkolnik, Arizona State University / David Ardila, Jet Propulsion Laboratory

Team

David Ardila
Jet Propulsion Laboratory

Travis Barman
University of Arizona

Courtney Dressing
UC-Berkeley

Michael Line
Arizona State University

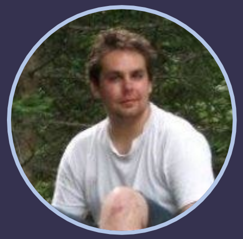
Josh Lothringer
Utah Valley University

R. Parke Loyd
Eureka Scientific, Inc.

Victoria Meadows
University of Washington

Ruth Murray-Clay
UC-Santa Cruz

Shouleh Nikzad
Jet Propulsion Laboratory



James Owen
Imperial College London

Sarah Peacock
NASA-Goddard

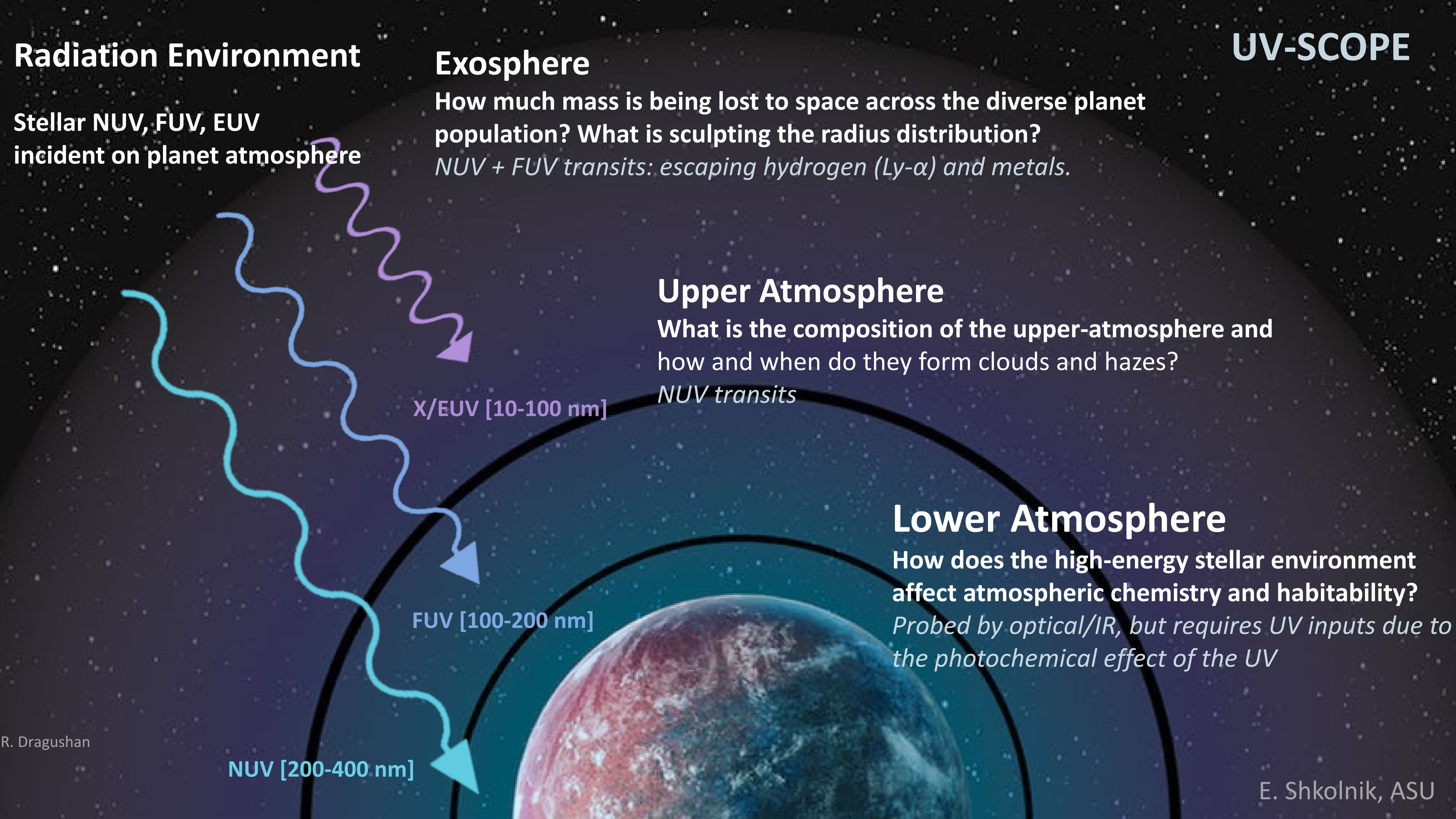
Hilke Schlichting
UCLA

Evgenya Shkolnik
Arizona State University

David Sing
Johns Hopkins University

Kevin Stevenson
Applied Physics Lab

Mark Swain
Jet Propulsion Laboratory

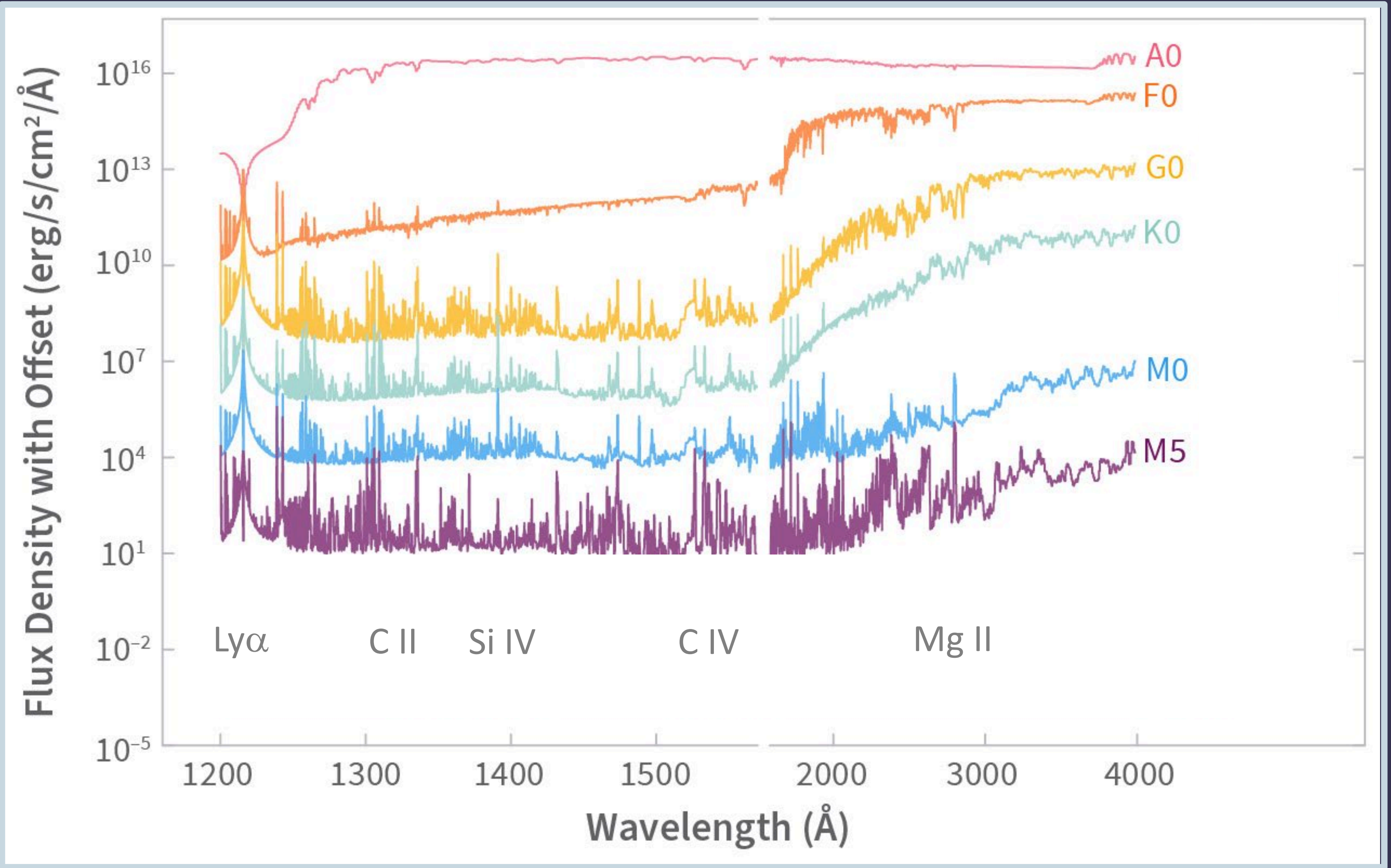

Radiation Environment
Stellar NUV, FUV, EUV
incident on planet atmosphere
Exosphere
How much mass is being lost to space across the diverse planet population? What is sculpting the radius distribution?
NUV + FUV transits: escaping hydrogen (Ly-α) and metals.
UV-SCOPE
Upper Atmosphere
What is the composition of the upper-atmosphere and how and when do they form clouds and hazes?
NUV transits
X/EUV [10-100 nm]
Lower Atmosphere
How does the high-energy stellar environment affect atmospheric chemistry and habitability?
Probed by optical/IR, but requires UV inputs due to the photochemical effect of the UV
FUV [100-200 nm]
R. Dragushan
NUV [200-400 nm]
E. Shkolnik, ASU

Spectra from 1205 to 4000 Å

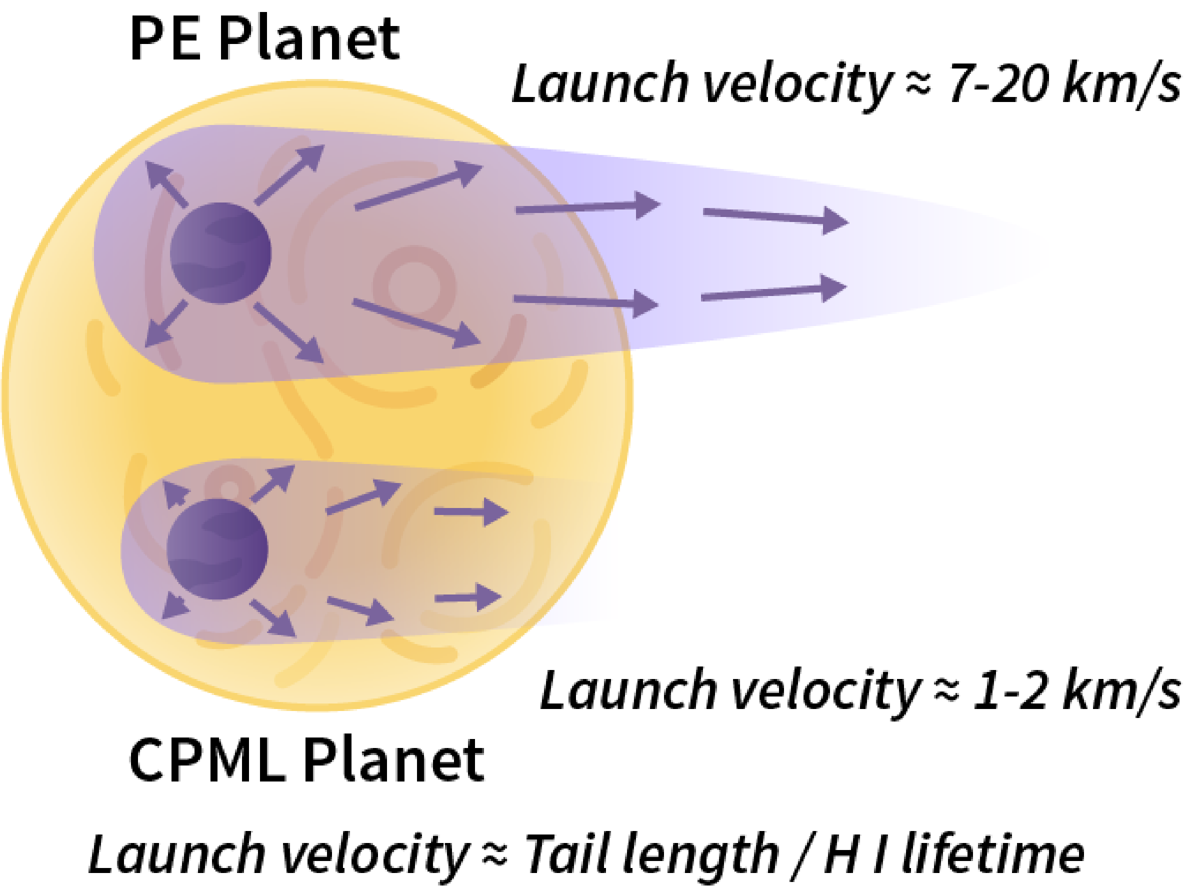
A 60-cm telescope

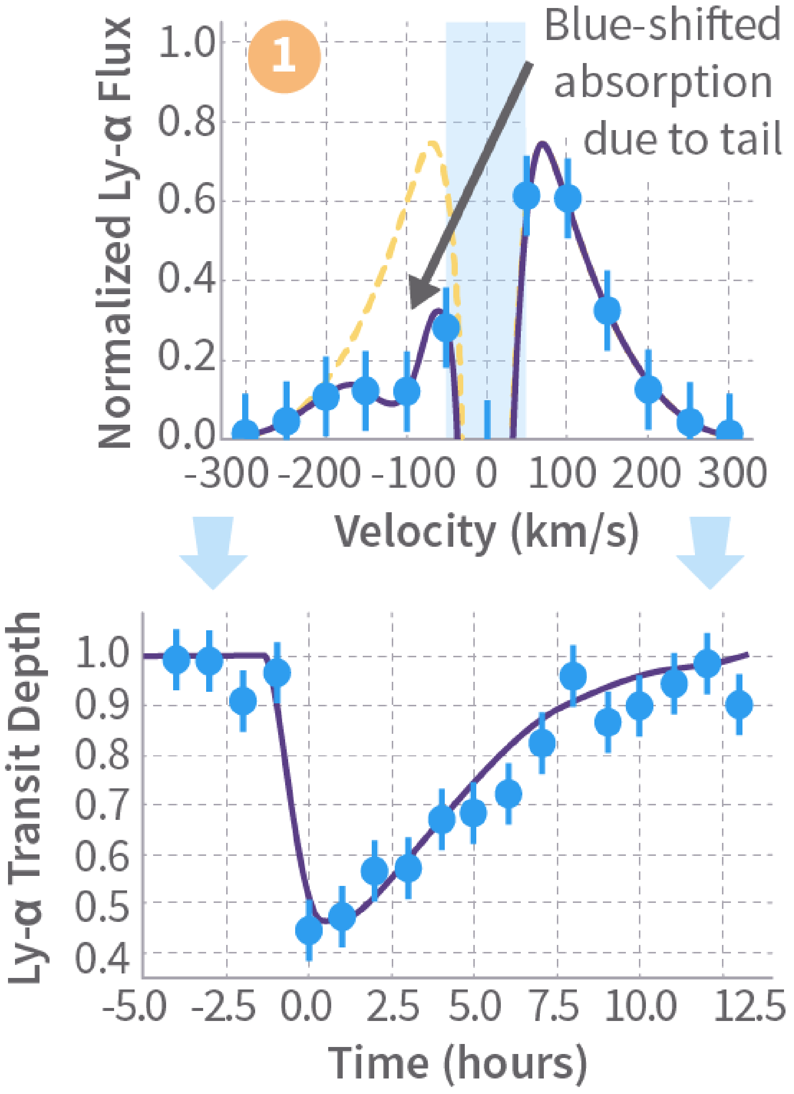
NUV + FUV spectrograph (R=100 – 6000)

High-quantum efficiency detectors (Nikzad et al. 2012, Jewell et al. 2019)



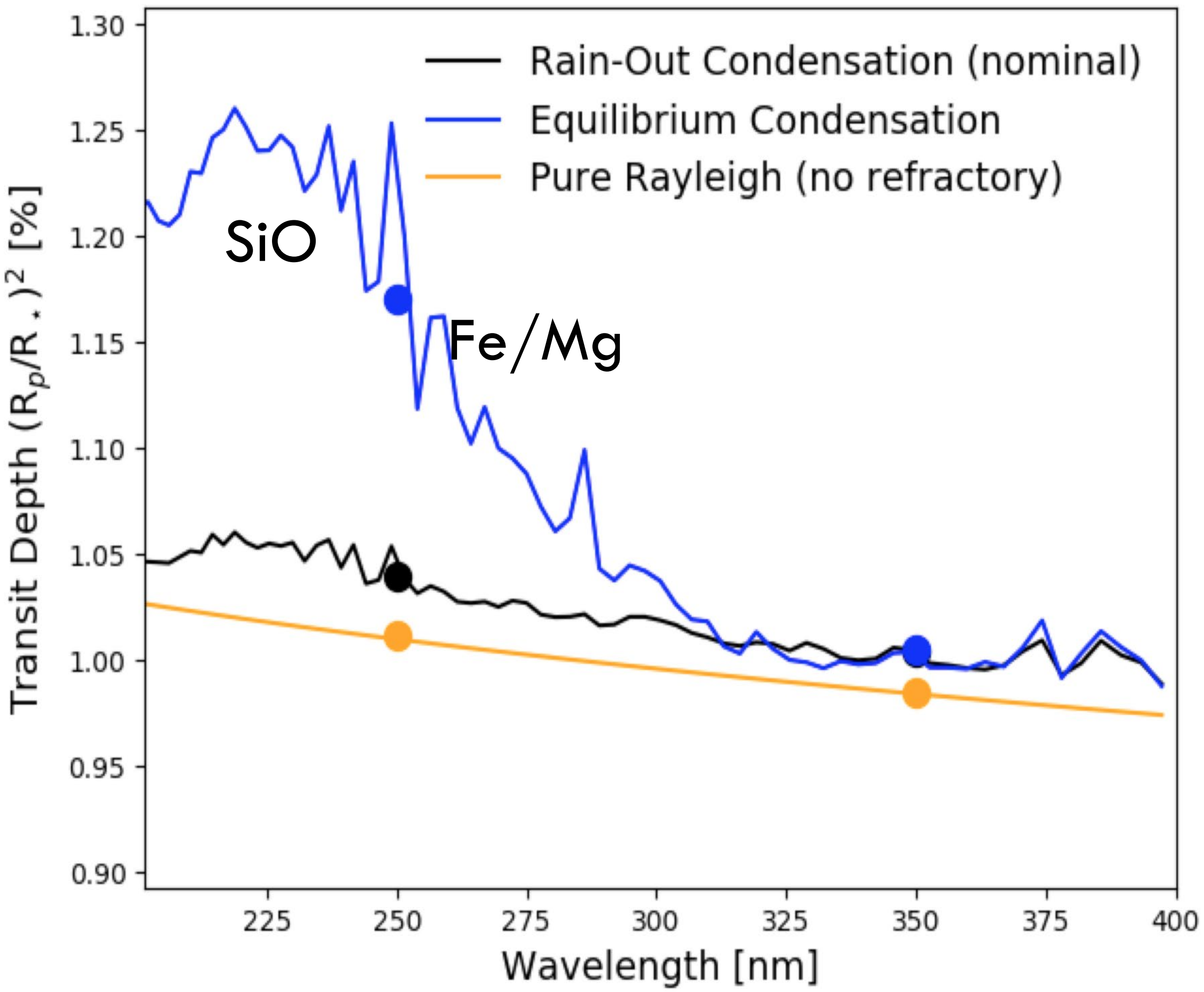
Science Case A: Measure Ly-α tail lengths of evaporating atmospheres of sub-Neptunes to distinguish between Photoevaporation (PE) and Core-Powered Mass Loss (CPML).



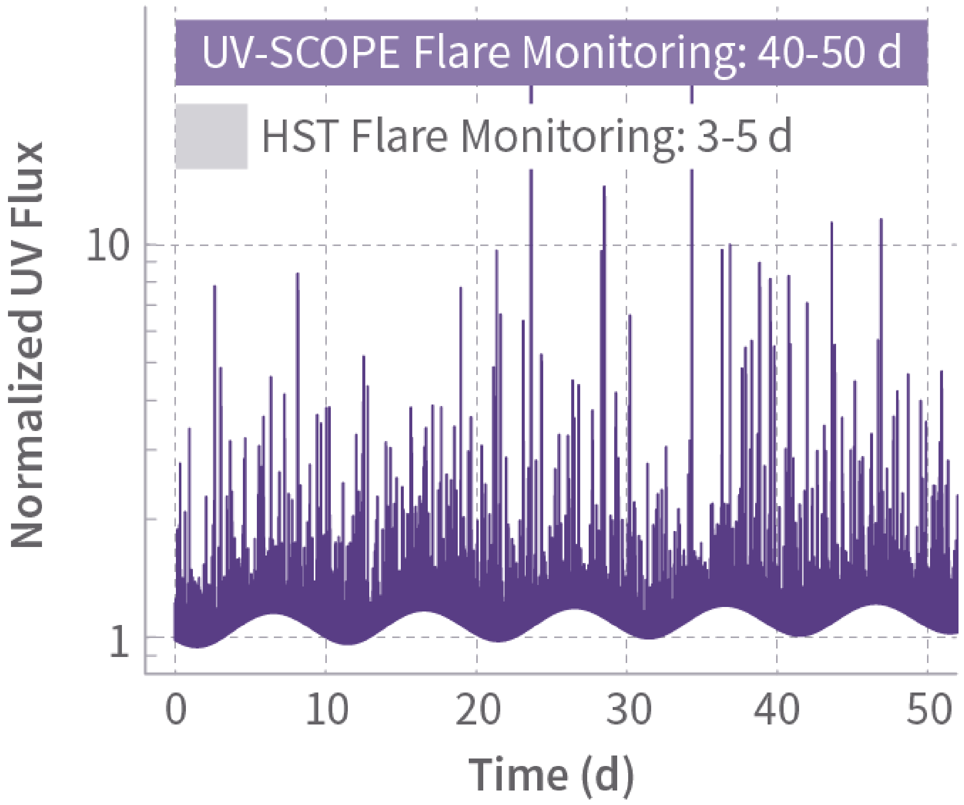


Owen et al. 2021

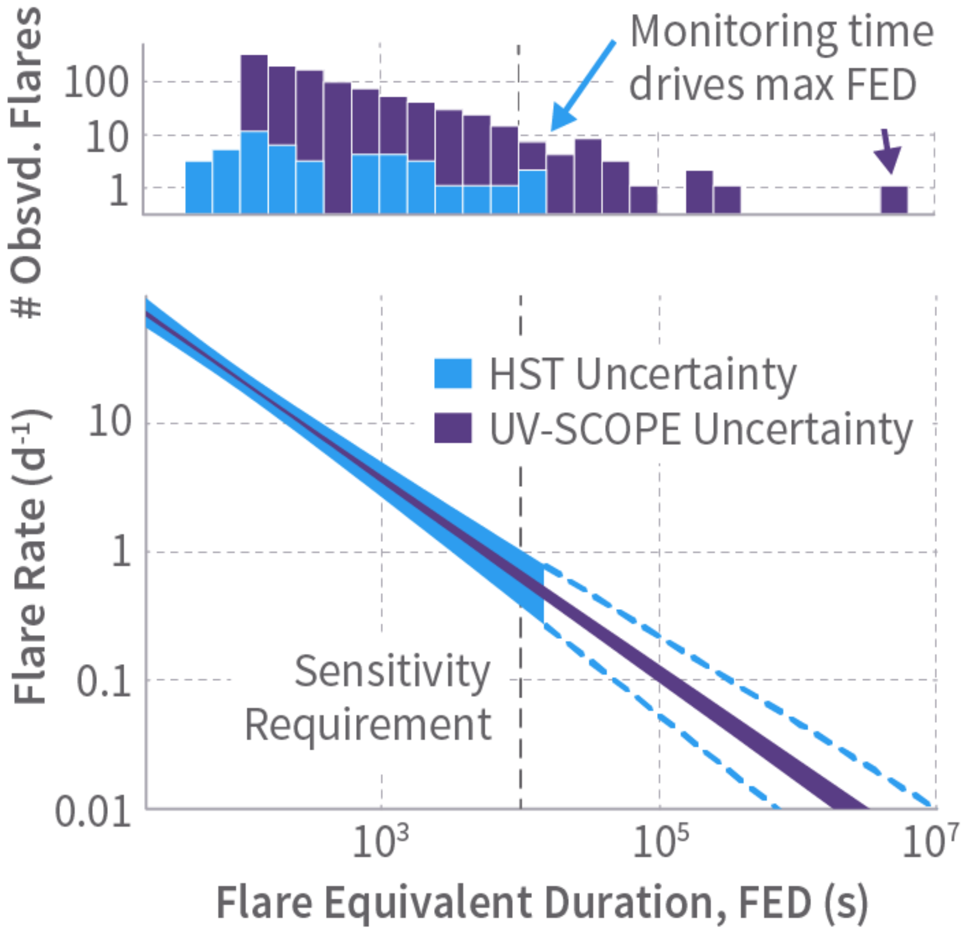
Science Case B: Determine the driving cloud chemistries in the atmospheres of the hot Jupiter population by observing the NUV SiO band complex.



Science Case C: Quantify the time-variable UV irradiation of exoplanets by measuring the flare and quiescent UV input from host stars.

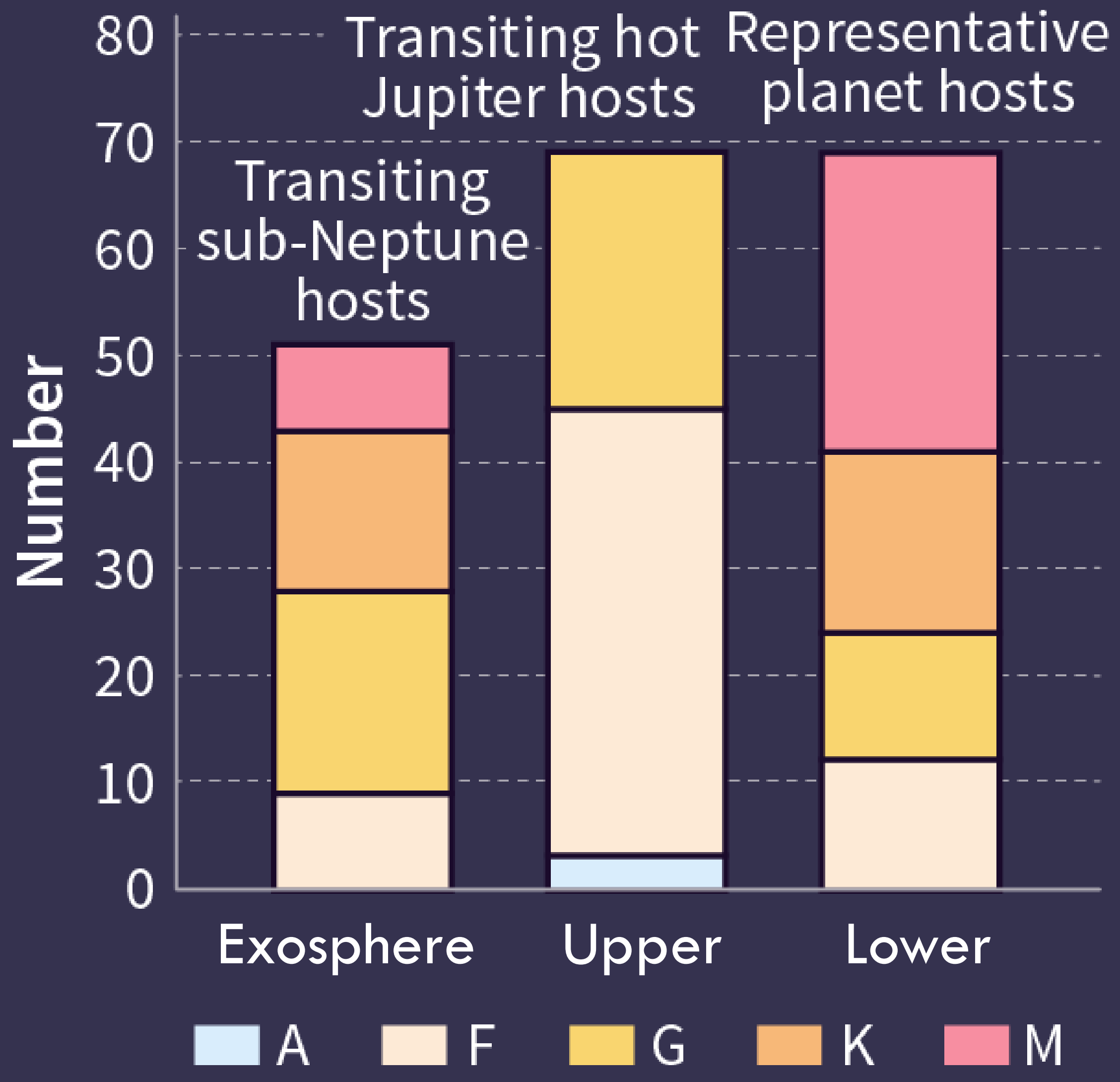


Template lightcurves superposing cyclic, rotational, and flare variability



Power-law fits to the relationship between flare rates and FEDs

Exoplanet & Stellar Targets

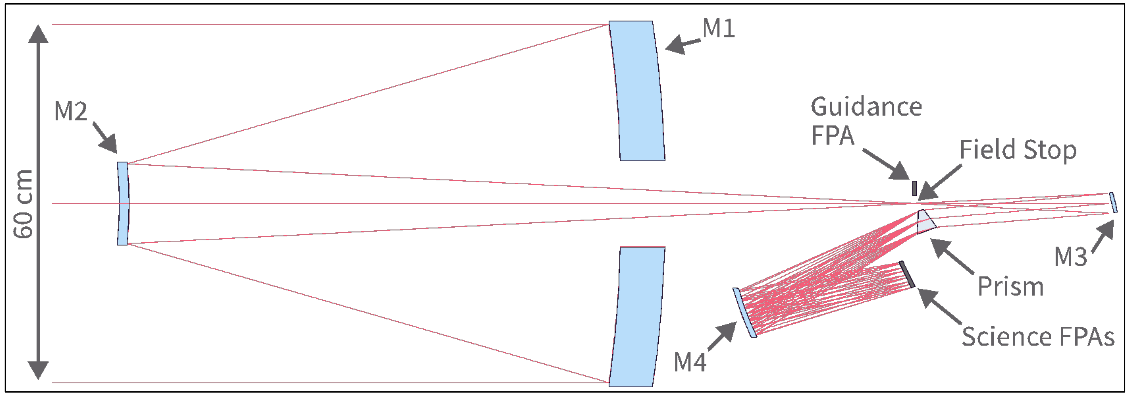


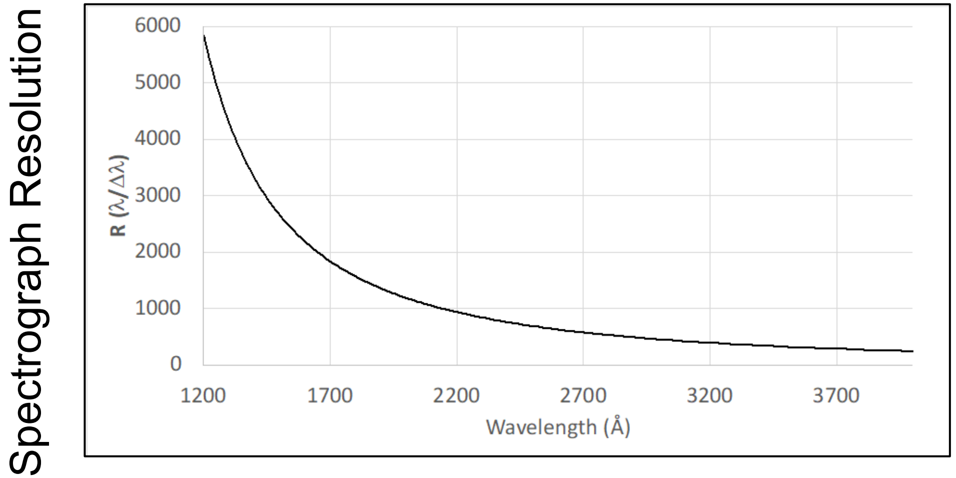
E. Shkolnik, ASU

The LiF prism as dispersion element

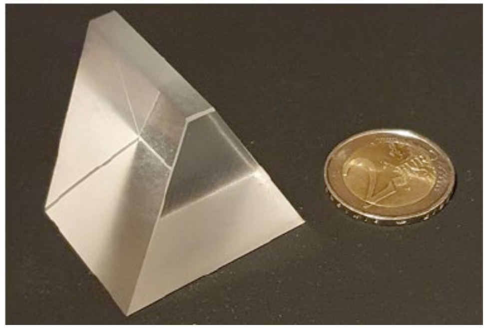
Effects of **radiation damage** and **luminescence (phosphoresce, fluorescence, Cherenkov):**

- The Radiation Effects Group at JPL exposed multiple LiF samples to increasing radiation doses. Radiation damage is manageable
- We also measured the fluorescence conversion factor in the lab. We incorporated a **negligible loss due to luminescence** of 1 week/year of observing in due to high background in the observation plan



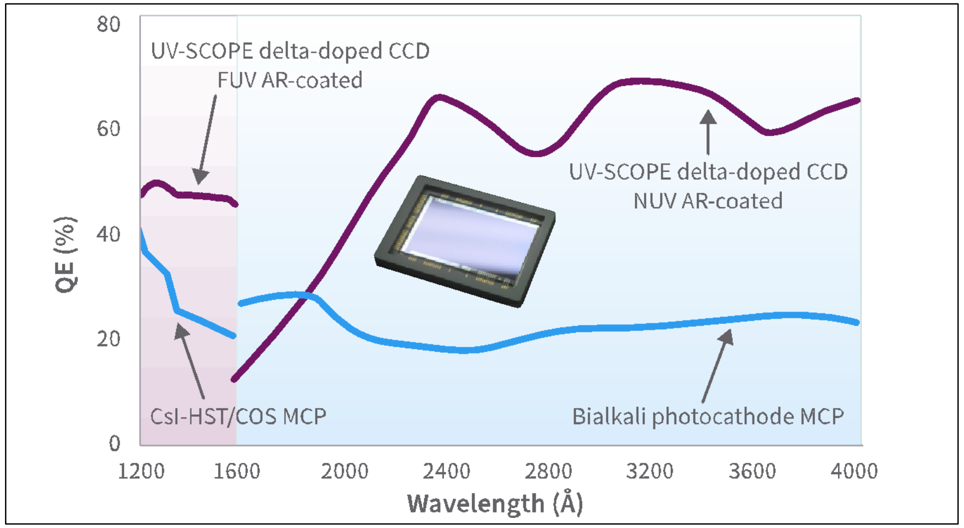


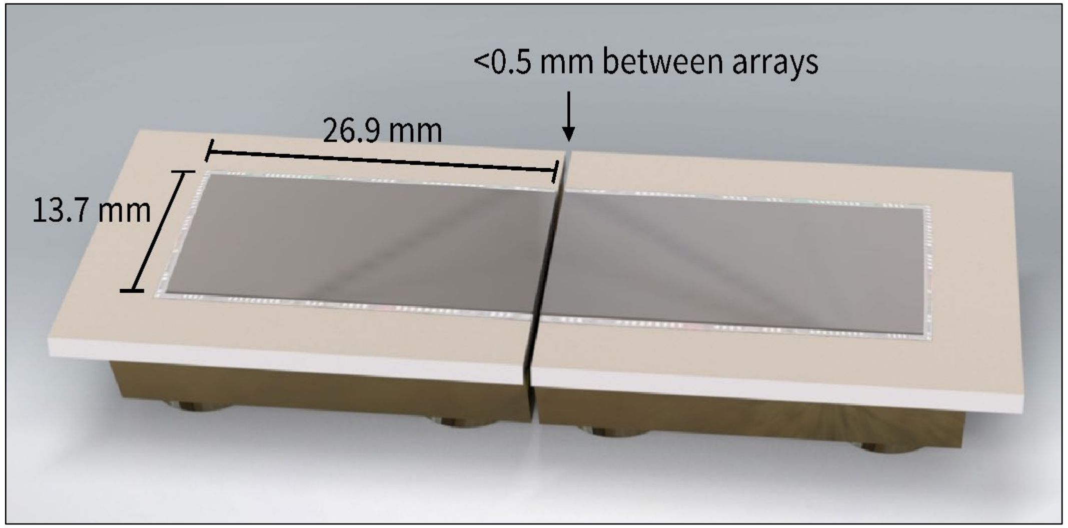
Δλ = System resolution element = Resel.



From Korth Kristalle

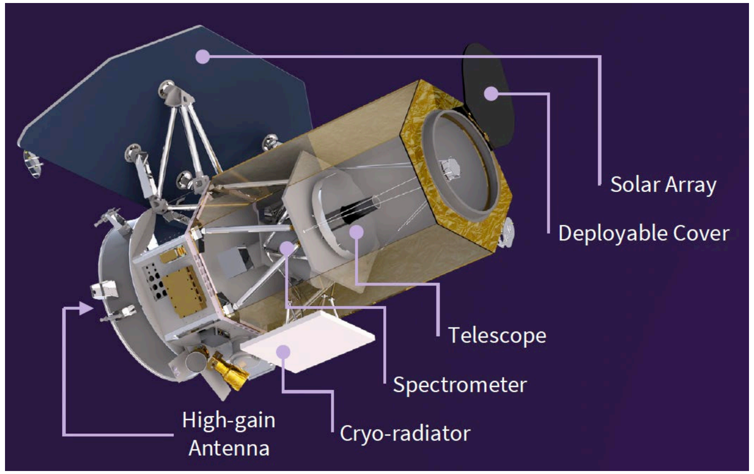
Science Detectors



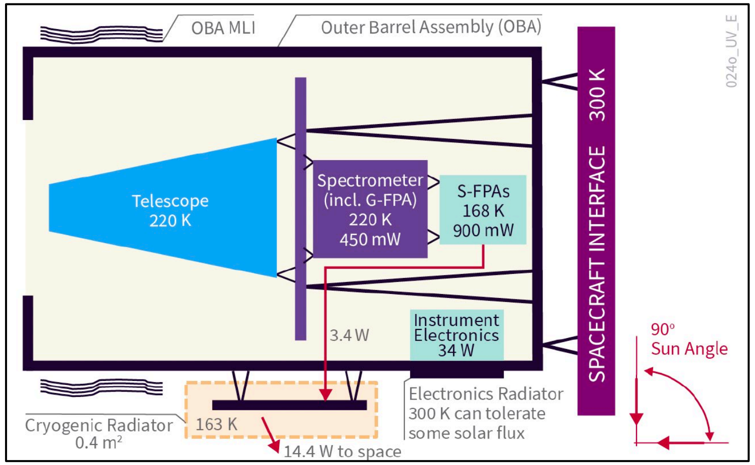


- Two 1K x 2K delta-doped EM-CCD detectors – Teledyne-e2V CCD201-20
  - Electron Multiplying (EM)-CCDs detectors have an operation mode that allows to detect very low fluxes
  - Kept at <168 K by passive cooling system
  - Coated with single-layer AR coatings AlF_3 and Al_2O_3
- Stray light due to target radiation emitted at wavelengths longer than 4000 Å is controlled by a strip of black silicon (not shown).

The Mission



- L2 halo orbit (low UV background, continuous observations)
- 3 years in space for primary mission
  - Fuel for 6 years
- Bus provided by Ball Aerospace (Ball Configurable Platform-type; BCP)
- Passively cooled
- Mission design and navigation by the Laboratory for Astrophysics and Space Science (LASP)

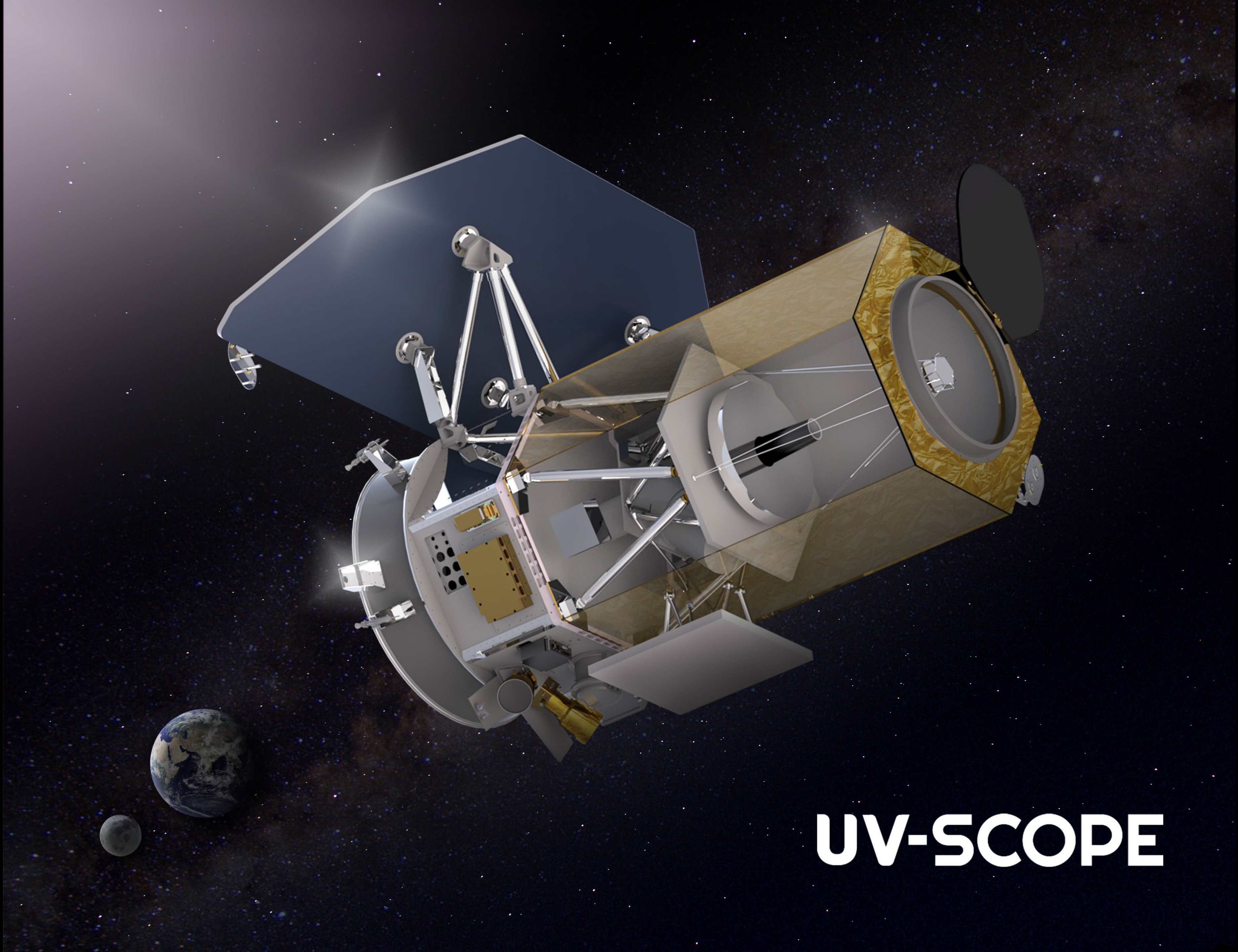


UV-SCOPE is a very efficient observatory

- No Earth eclipses: UV-SCOPE is 2x as efficient as HST
- No South Atlantic Anomaly: UV-SCOPE is 3x as efficient as HST
- Complete UV spectral range: UV-SCOPE is 2x as efficient as HST

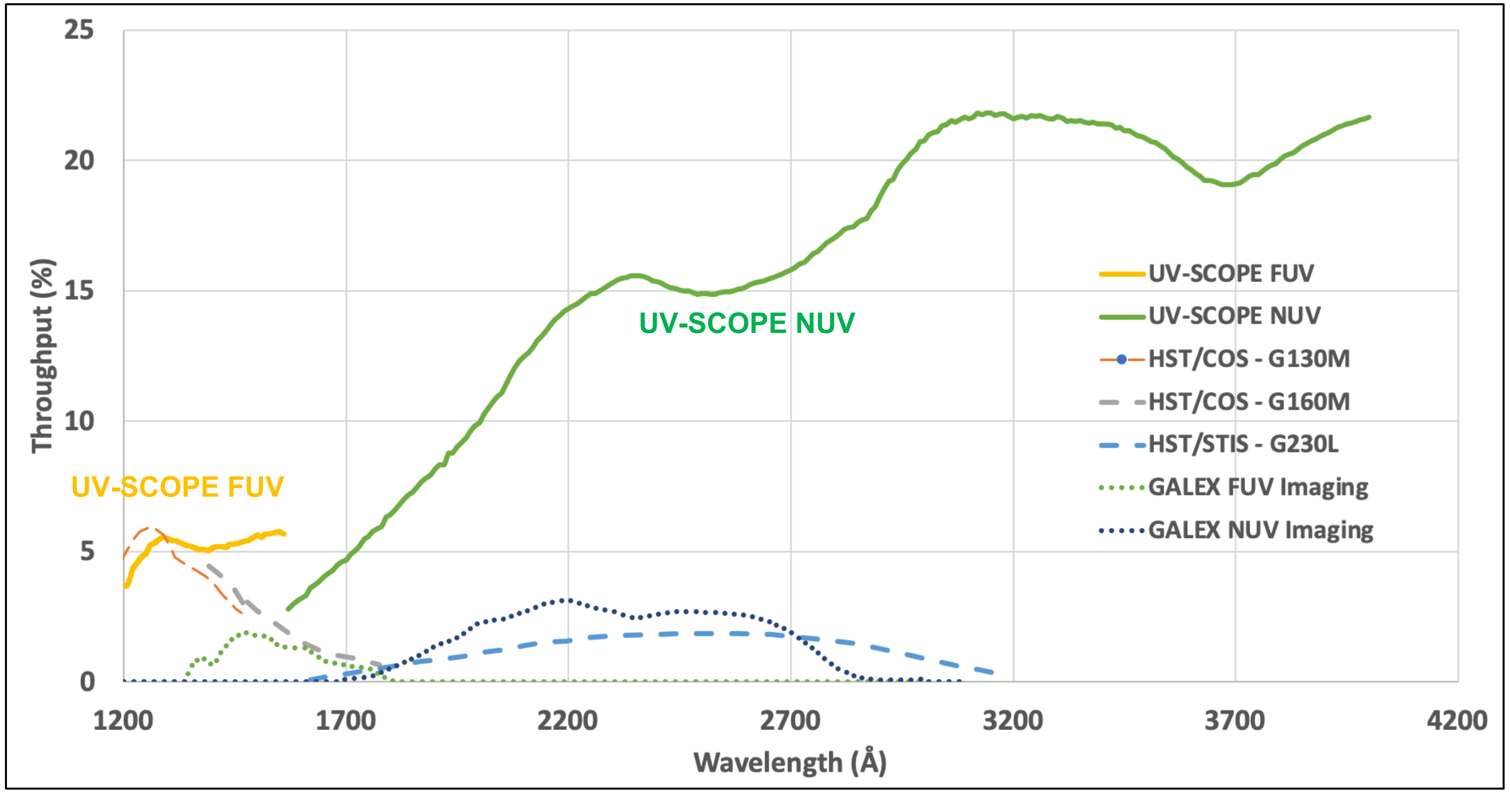
For example:

- **SCB would take 9 years with HST**
- **SCC would take 7 years with HST**, assuming nothing else is scheduled.


UV-SCOPE

Backup

Comparison with HST and GALEX

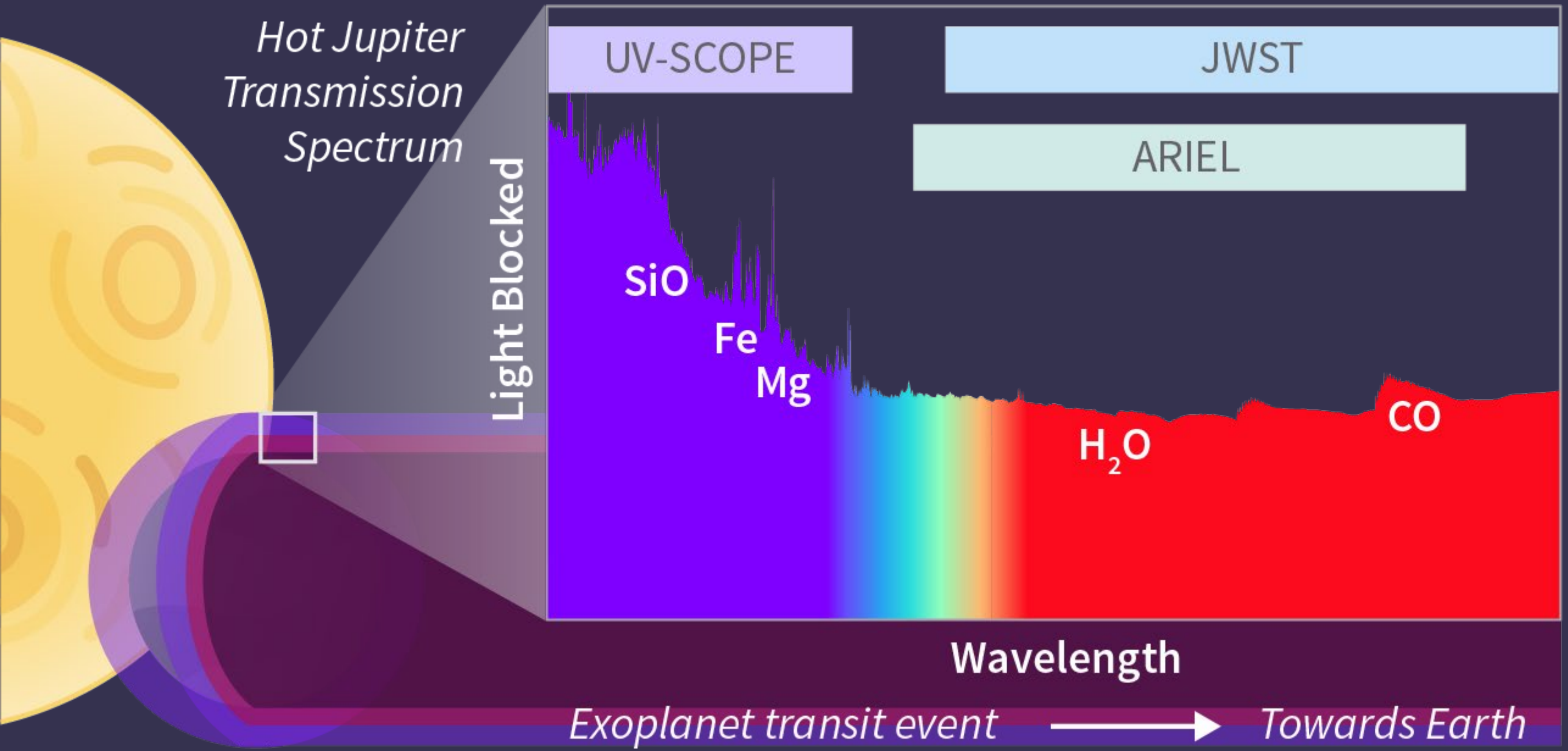


UV-SCOPE's throughput is

- FUV
  - Comparable to HST/COS in the FUV
  - 2.5x better than GALEX
- NUV
  - 7x to 10x better than HST/STIS and GALEX

HST/COS: Hubble Space Telescope Cosmic Origins Spectrograph
HST/STIS: Hubble Space Telescope Imaging Spectrograph
GALEX: Galaxy Evolution Explorer

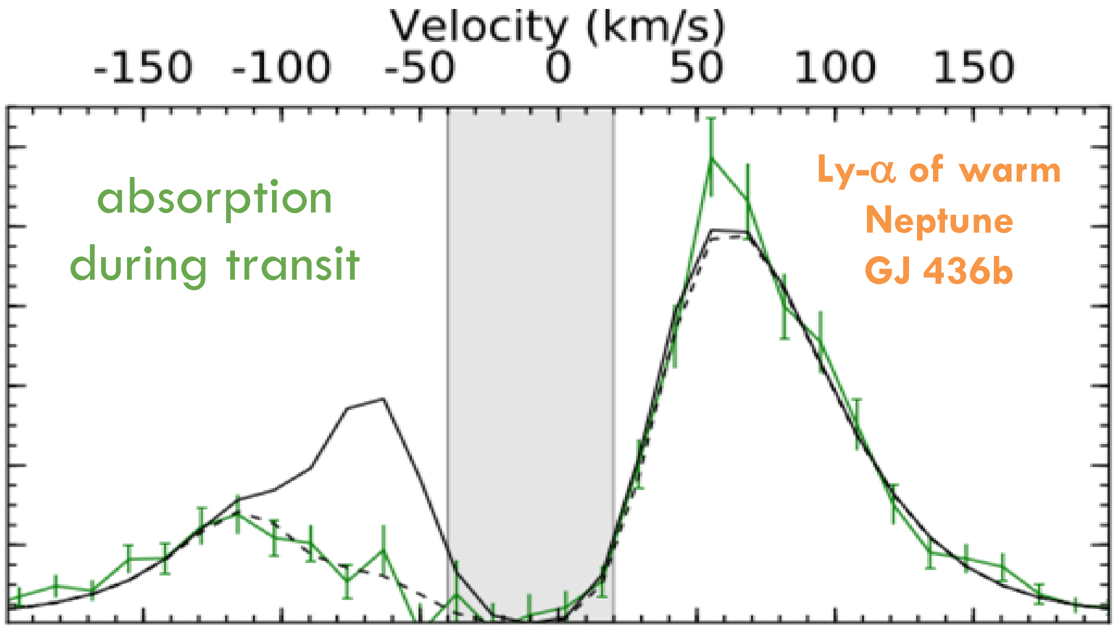
Observations



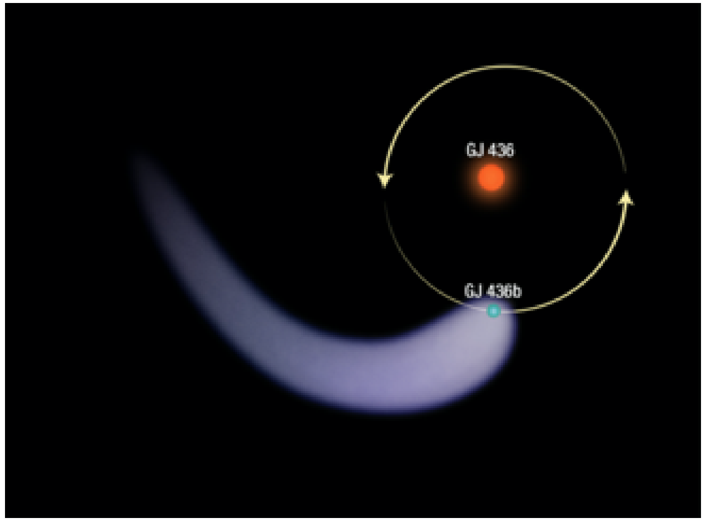
Transmission spectroscopy of ≈200 large and small exoplanets & stellar UV characterization

HST observations of escaping atmospheres

Exospheres: Directly measuring escape with Ly-α transits (at 1216 Å)



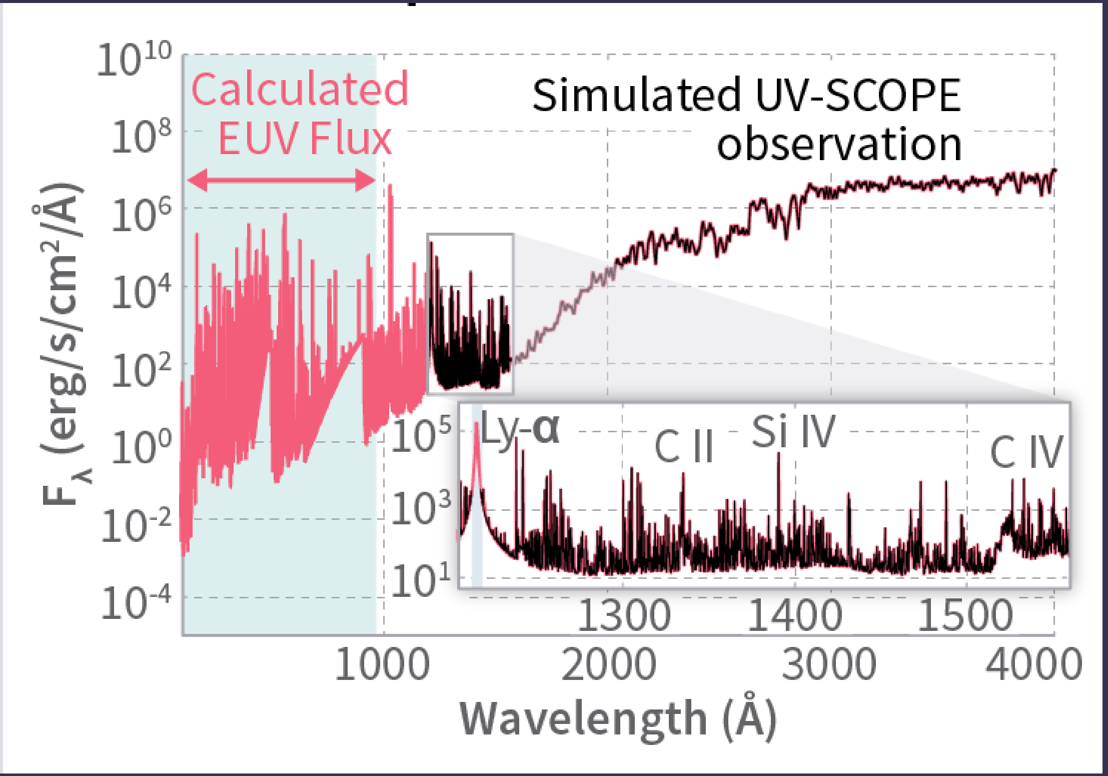
Bourrier et al. 2016

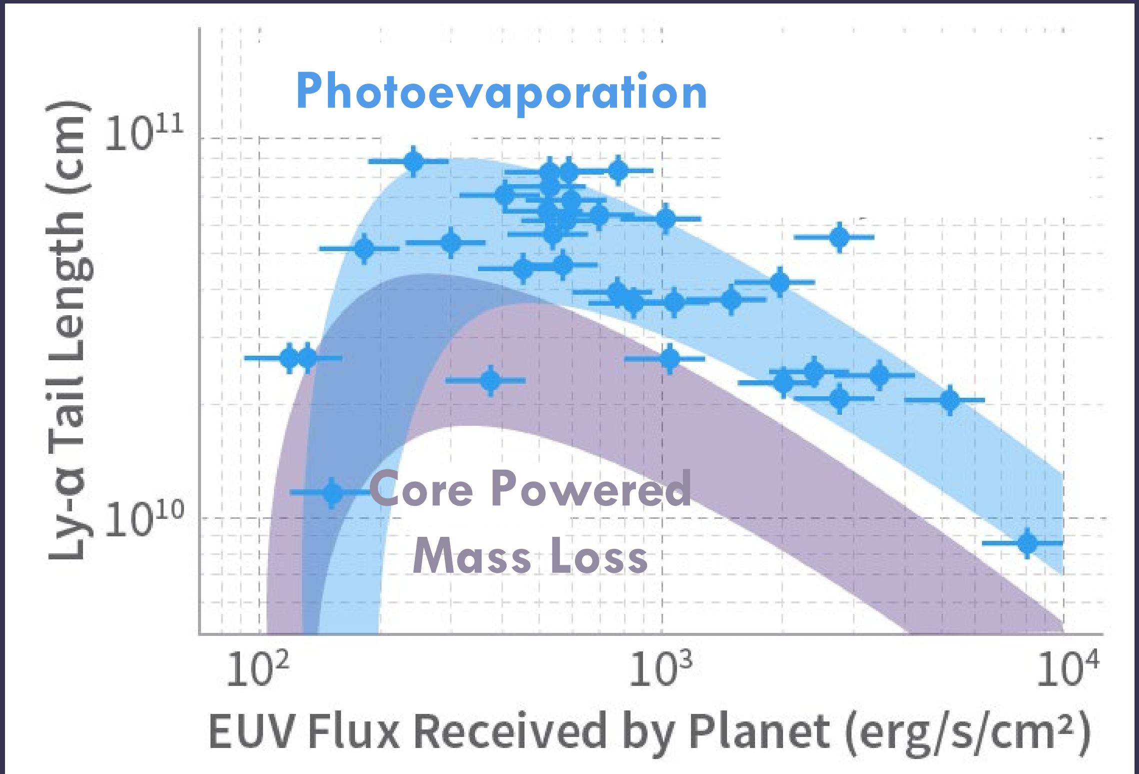


Challenge:

- Ly-α is heavily contaminated by geocoronal emission.
- HST cannot do broad population-wide studies. Need large time-investment.

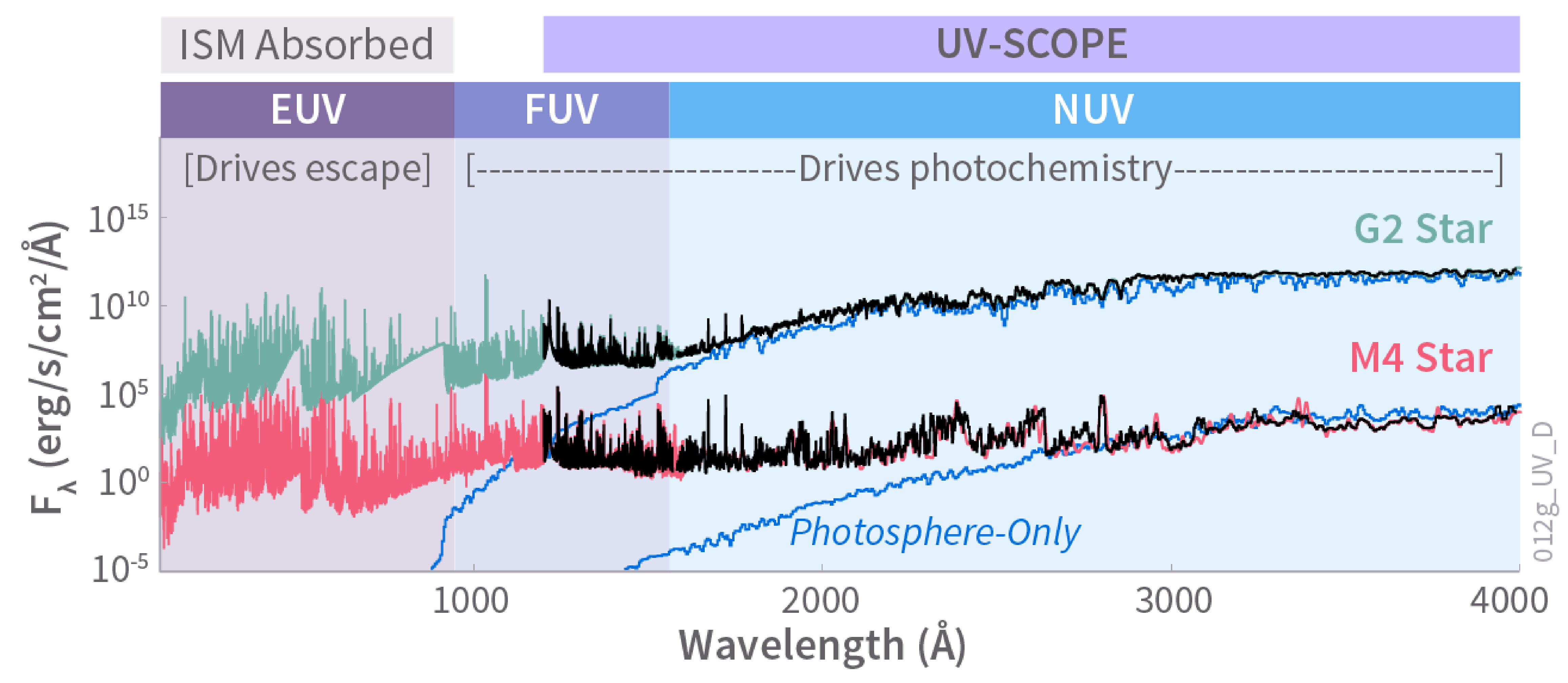
PE vs CPML Experiment





FUV-calibrated model reconstructions of the UV

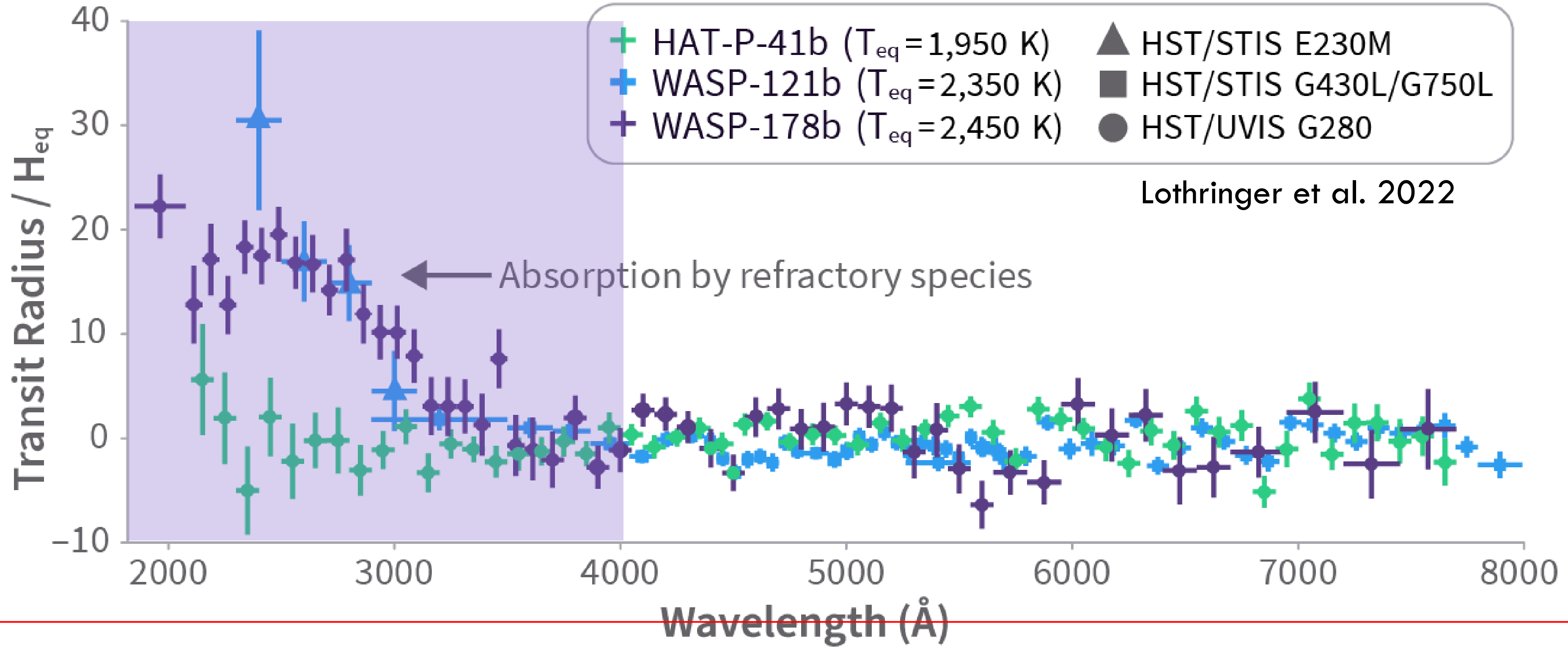
Predicting Stellar EUV Emission



Peacock et al., 2020, 2021

HST observations of upper-atmospheres

Upper-atmospheric composition & cloud/haze formation



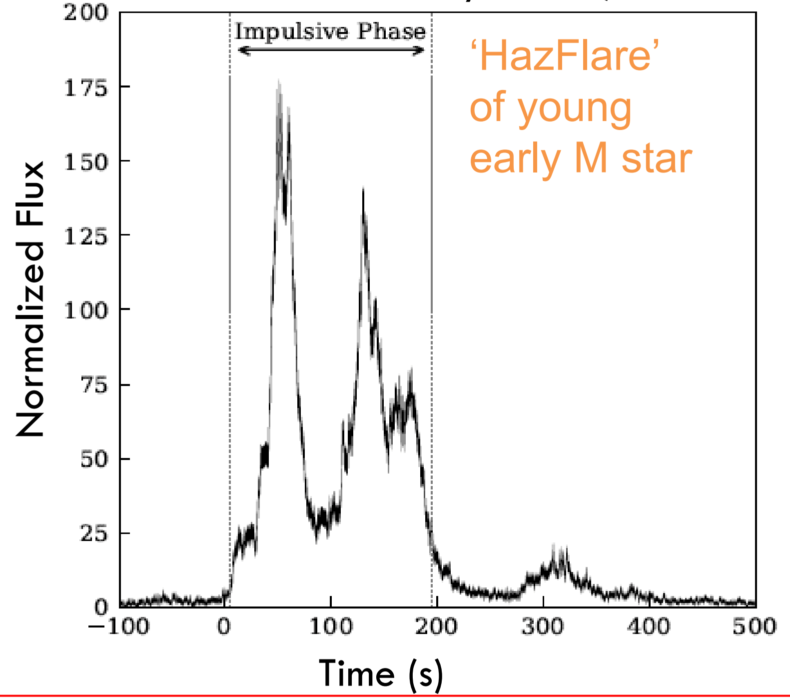
Challenge:

- No mode covers the full UV range simultaneously, requiring many visits with non-uniform analyses.
- HST cannot do broad population-wide studies. Need large time-investment.

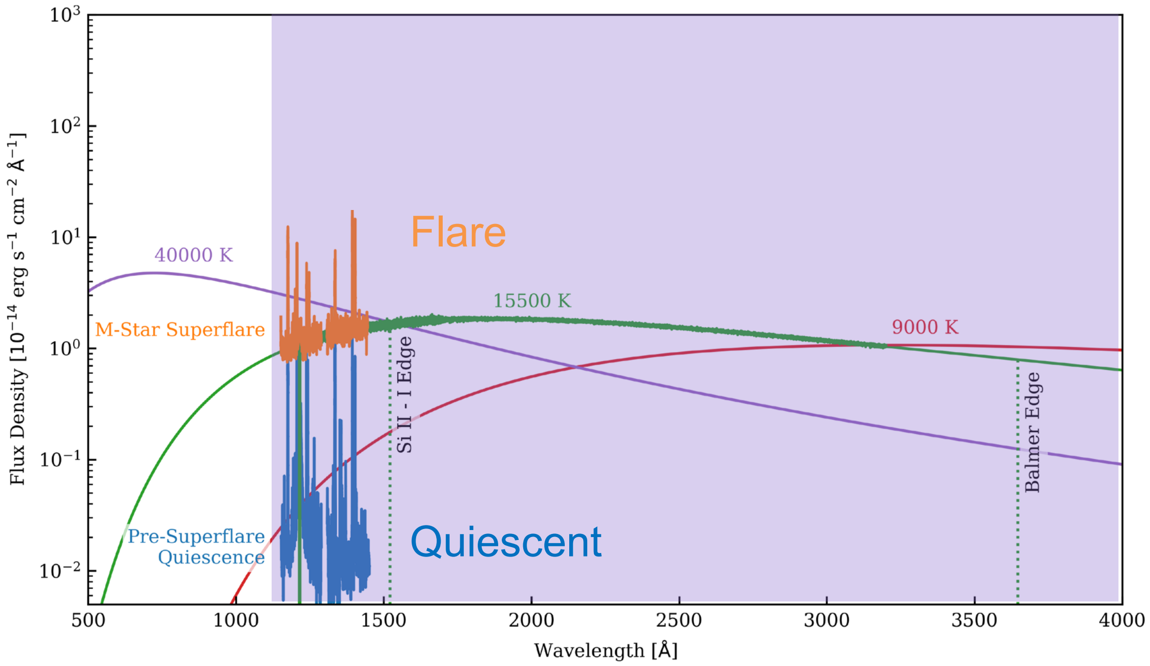
HST observations of stellar UV emission

UV environment of exoplanets & impacts on lower-atmosphere

Loyd et al., 2018



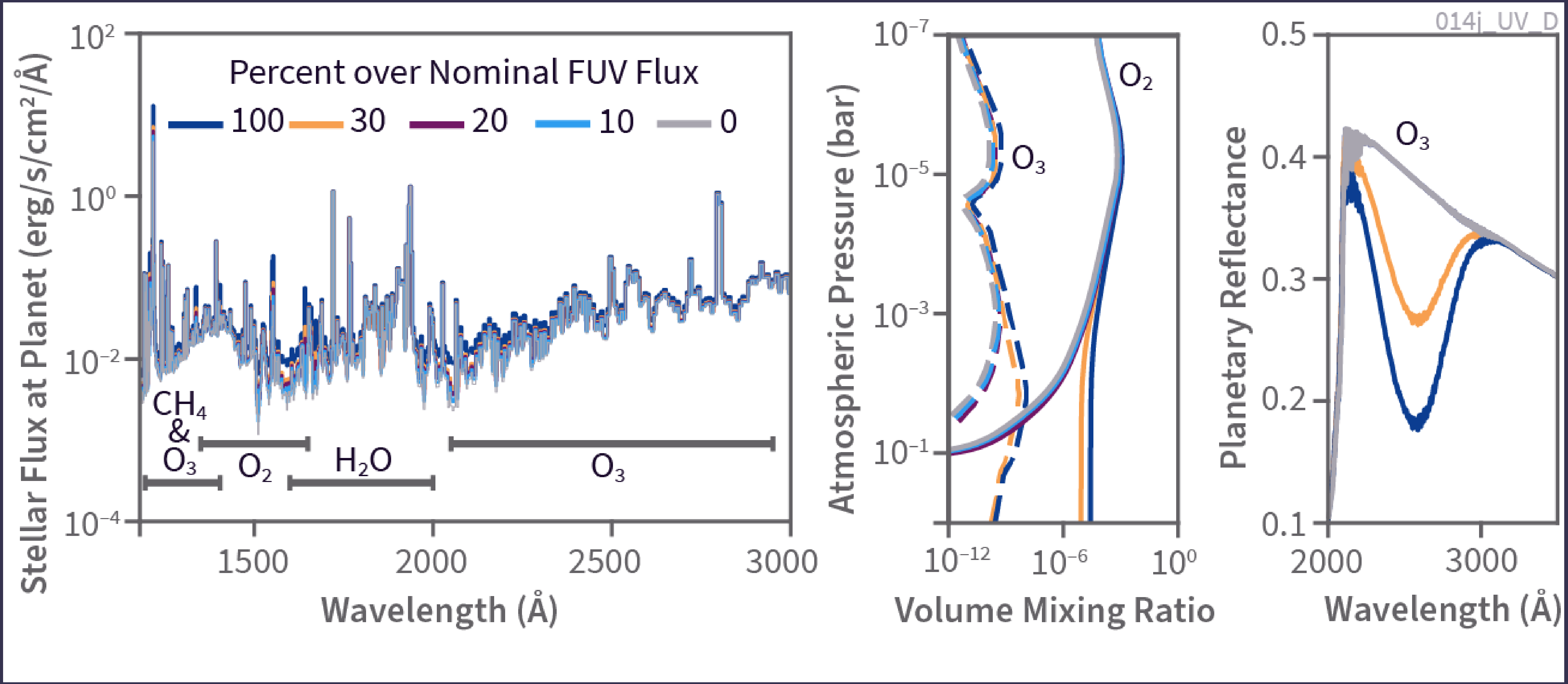
Daily flares on M stars



Challenge:

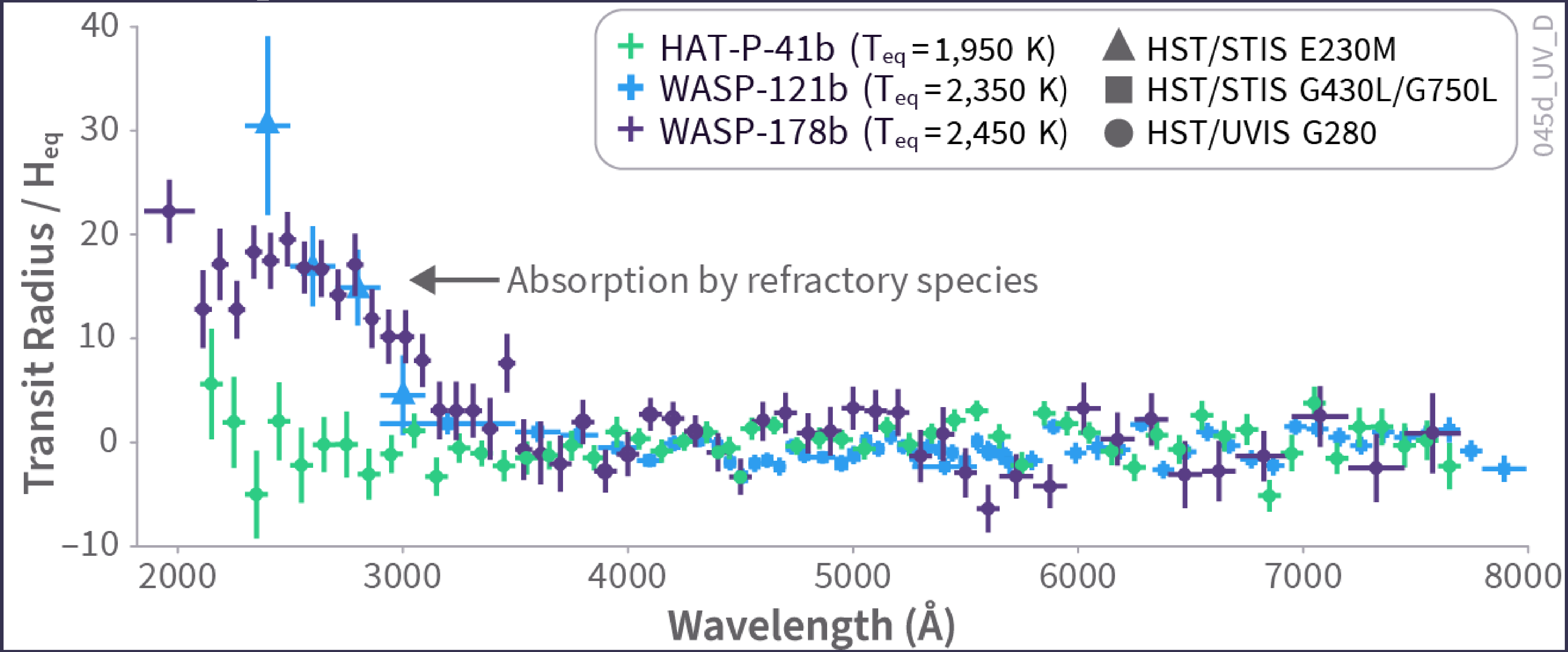
- No mode covers the full UV range simultaneously.
- STScI no longer allows UV observations of active M stars.
- HST cannot do broad population-wide studies. Need large time-investment.

UV Impacts on Earth-like Atmospheres

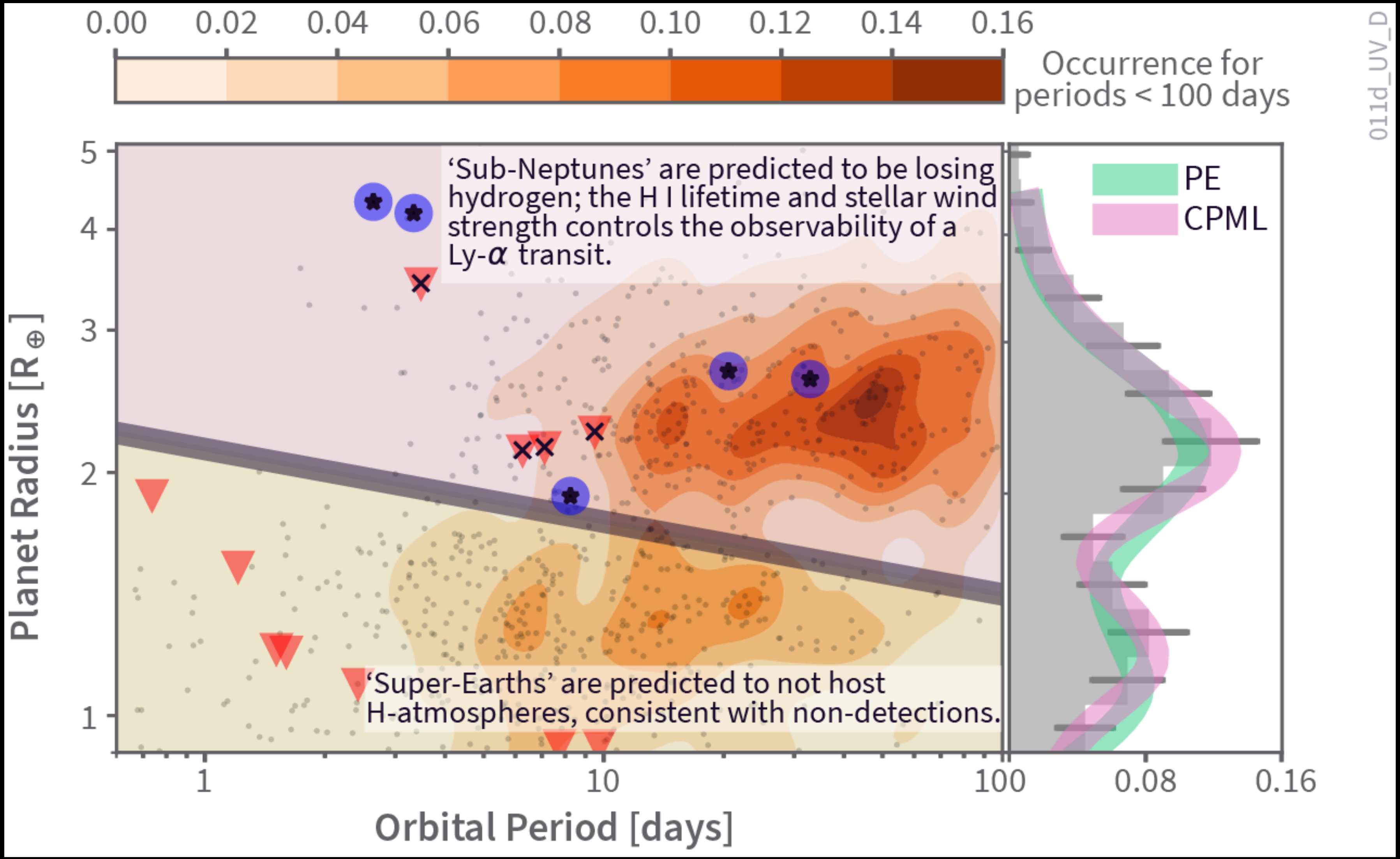


Davis et al., in prep.

Strong UV Absorption in Hot Jupiter Atmospheres

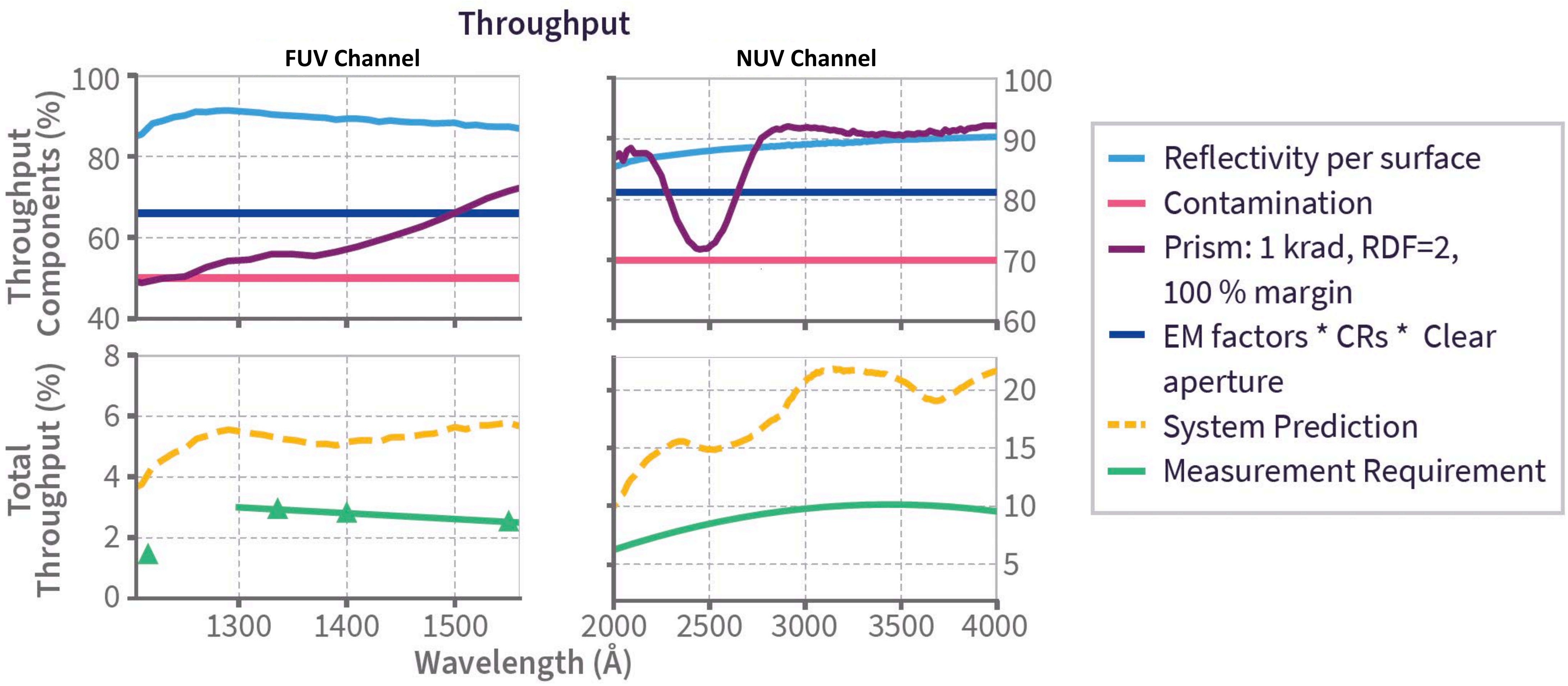


Lothringer et al. 2022



0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16
Occurrence for periods < 100 days
011d_UV_D
'Sub-Neptunes' are predicted to be losing hydrogen; the H I lifetime and stellar wind strength controls the observability of a Ly-α transit.
'Super-Earths' are predicted to not host H-atmospheres, consistent with non-detections.
Planet Radius [R⊕]
5
4
3
2
1
Orbital Period [days]
1
10
100
0.08
0.16
PE
CPML

Throughput


Throughput
FUV Channel
NUV Channel
Throughput Components (%)
Total Throughput (%)
100
80
60
40
8
6
4
2
0
1300
1400
1500
2000
2500
3000
3500
4000
100
90
80
70
60
20
15
10
5
Wavelength (Å)
Reflectivity per surface
Contamination
Prism: 1 krad, RDF=2, 100 % margin
EM factors * CRs * Clear aperture
System Prediction
Measurement Requirement

UV-SCOPE at a Glance

- Mission concept to study exoplanet atmospheres and planet habitability, in the changing environment of its host star's ultraviolet stellar activity.
- Produces a broad-purpose legacy database of time-domain ultraviolet spectra for nearly 200 stars and planets.
- Instrument: 60 cm, f/10 telescope paired to a long-slit spectrograph. Simultaneous, almost continuous coverage between 1203 Å and 4000 Å, with resolutions ranging from 6000 to 240
- To be located at the Sun-Earth L2
- Primary science mission: 34 months. Spacecraft carries enough fuel for 6 years of operations.