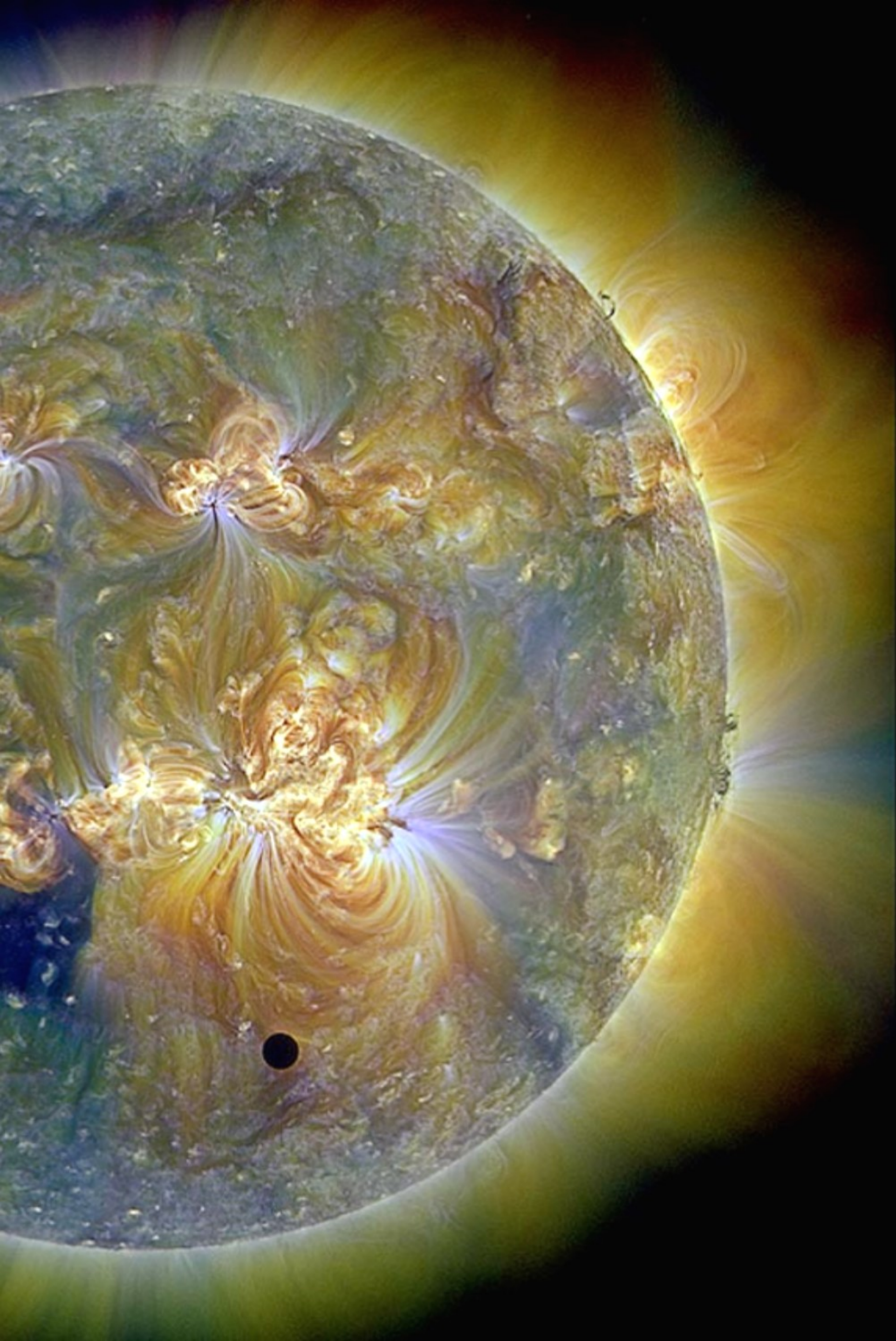
Monitoring the UV Environment of Exoplanets around M dwarfs with SPARCS

(Star-Planet Activity Research CubeSat)

Evgenya Shkolnik

and the SPARCS Mission Team



Effects of UV radiation on exoplanets orbiting M stars

- Atmospheric heating/escape by extreme-UV (EUV) photons
- Atmospheric photochemistry (e.g. photodissociation of molecules) by far-UV (FUV) and near-UV (NUV)
- Detection of an habitable and inhabited planet
  (UV can create false positives and false negatives.)

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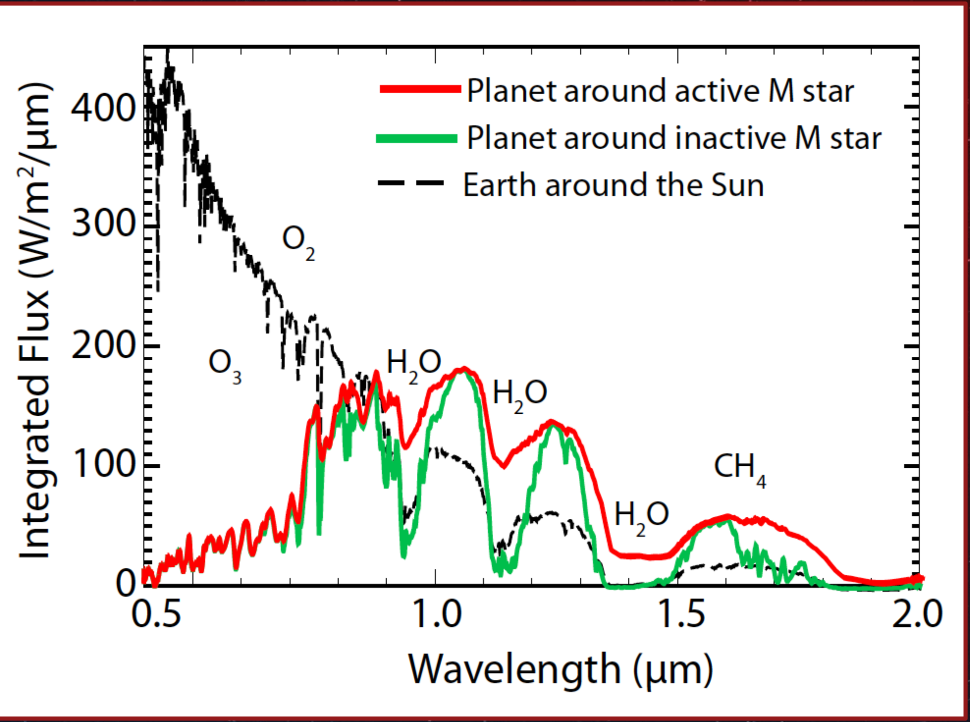

Adapted from Rugheimer et al. 2015

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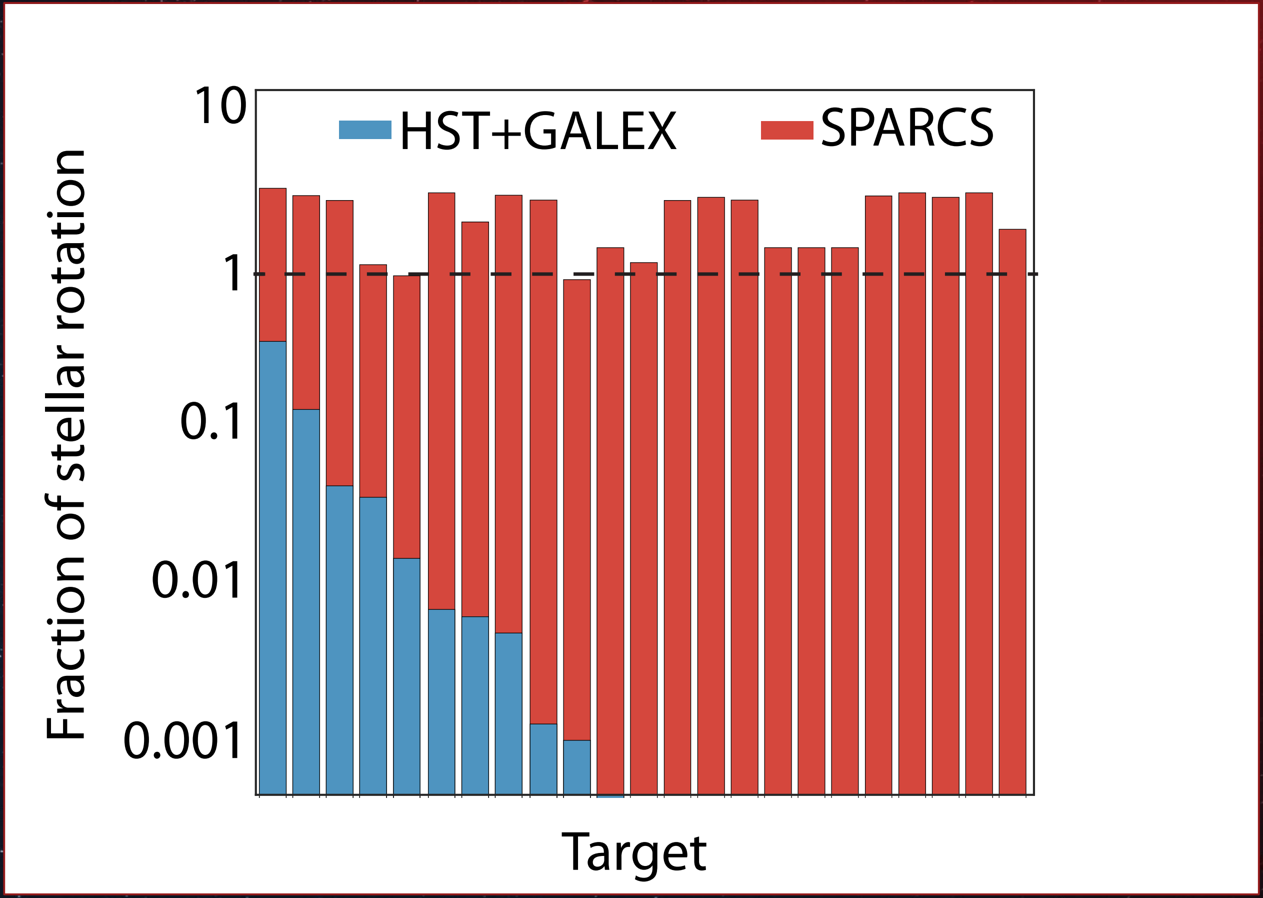
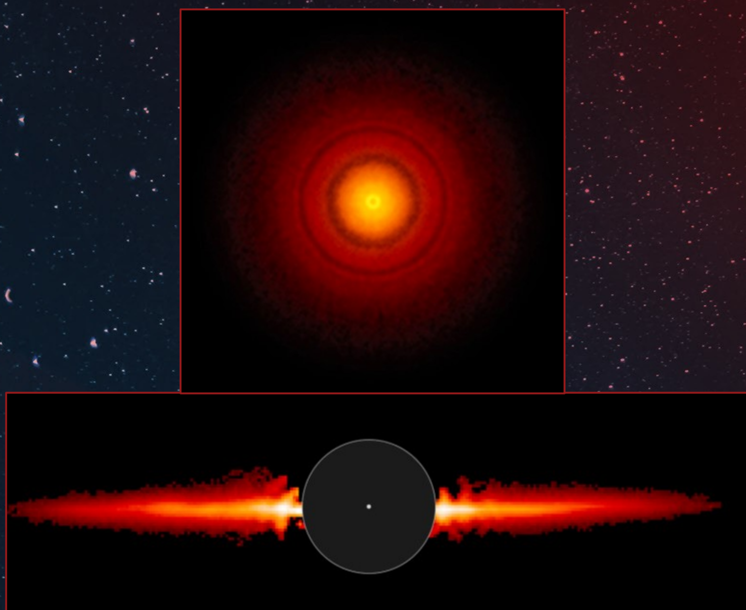
Adding the time-domain: SPARCS Monitoring Plan

Recording timescales from minutes to weeks to measure short-term flaring and long-term rotational modulation.



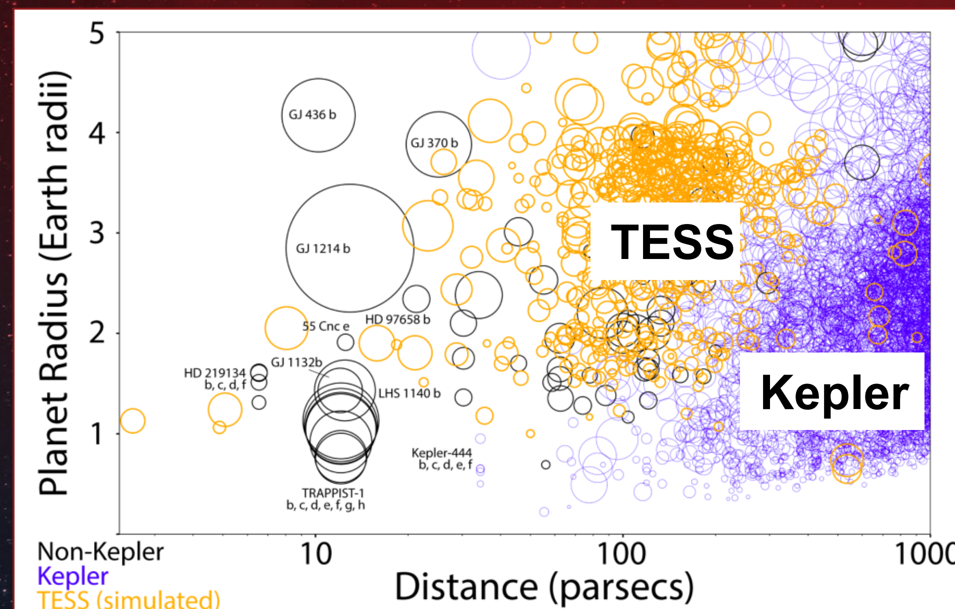
SPARCS targets

Young M stars possibly forming planets



e.g. TWA7 and AU Mic with debris disks – signposts of planets (Boccaletti et al. 2015)

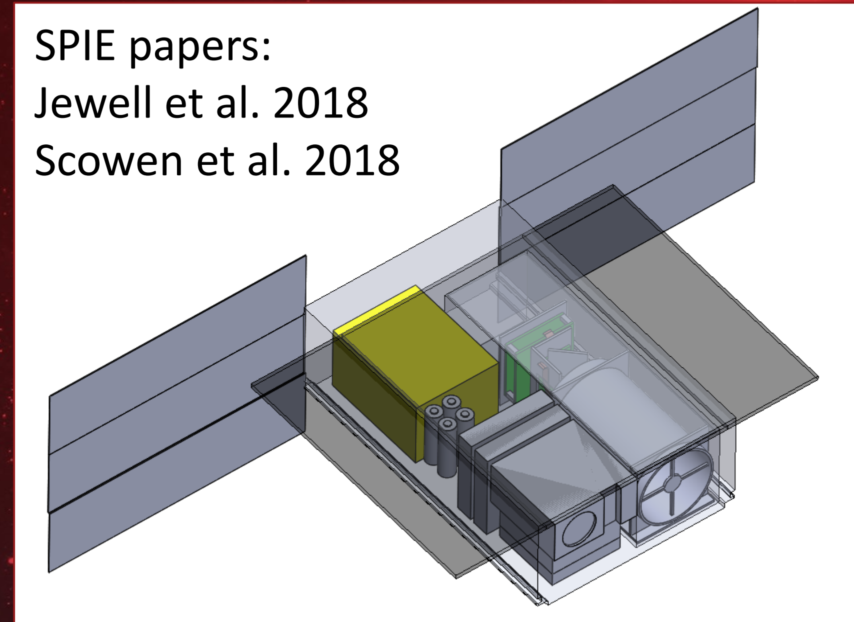
Old M dwarfs with transiting planets

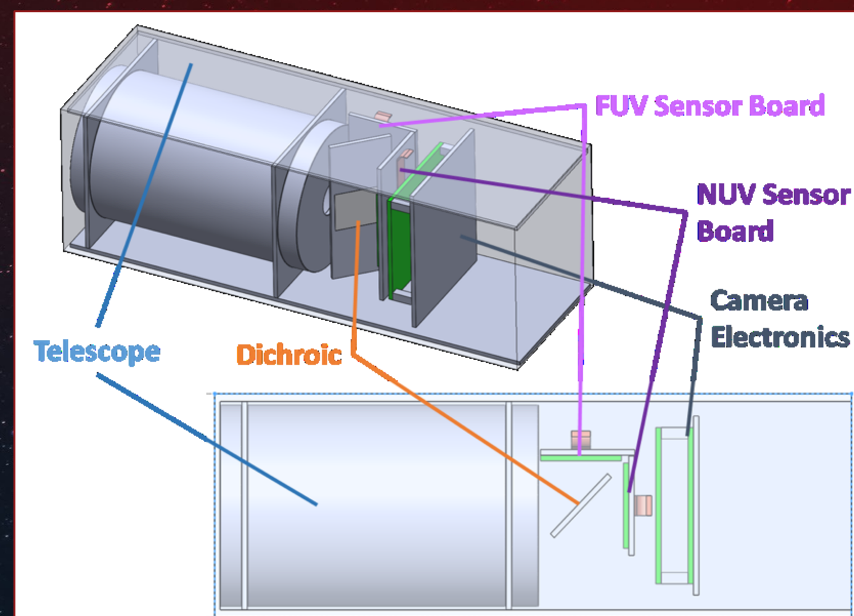


e.g. GJ 436, new TESS discoveries (Berta-Thompson et al. 2015; Barclay et al. 2018)

Overview of SPARCS

- 6U CubeSat, 9 cm telescope with a 1° FOV
- Active pointing with reaction wheels and star tracker
- UV camera with two detectors: S-FUV [153-171 nm] & S-NUV [258-308 nm]
- Photometric precision: 1% - 10%
- >1 year of dedicated monitoring of M stars from a sun-synchronous orbit





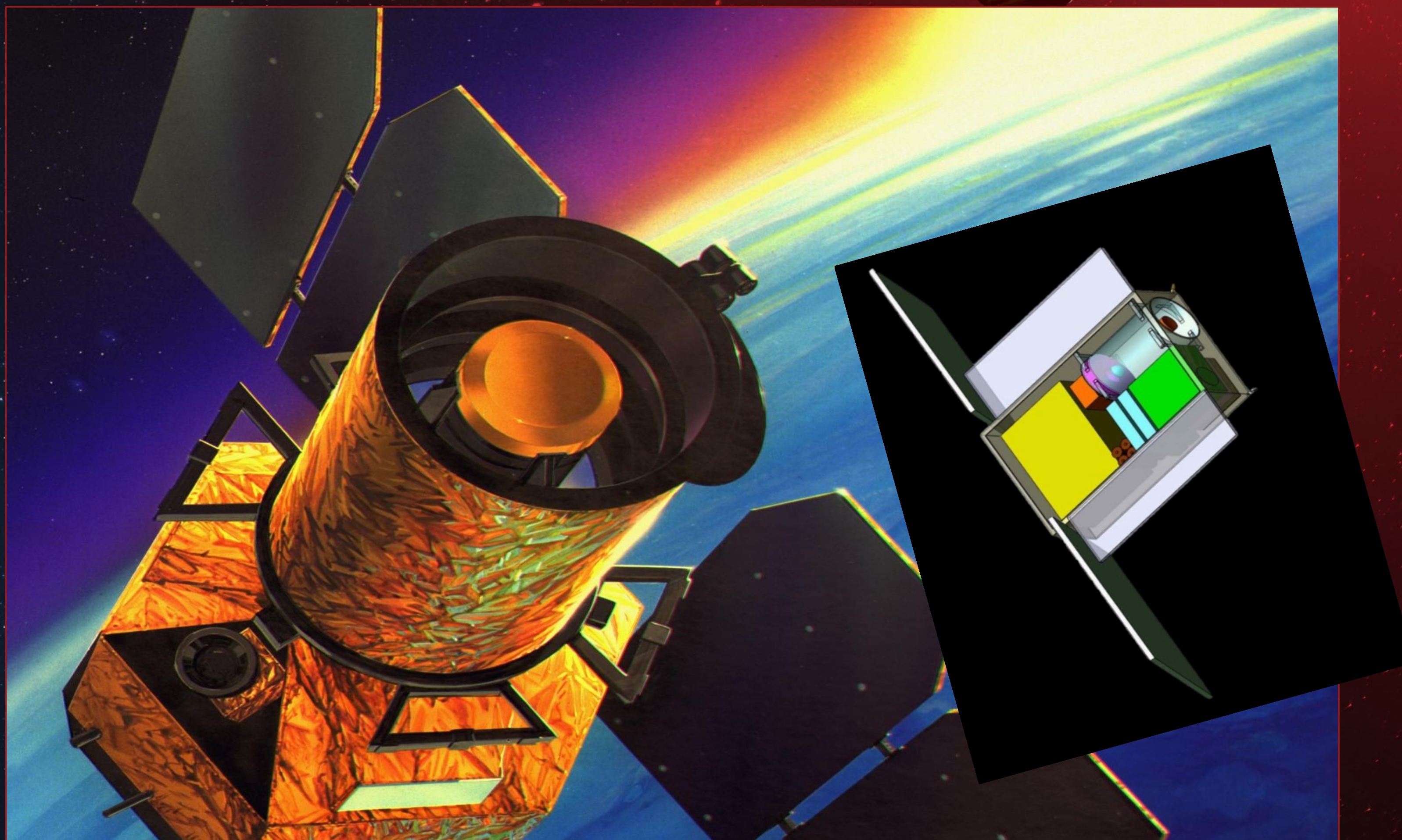
GALEX

$150M

SPARCS

$5M

(standardization, COTS, shorter build times)



~To scale

So what makes us think we can do useful UV science with SPARCS?

An interdisciplinary, creative team that can work together for years.

Principal Investigator
Evgenya Shkolnik (ASU)

Systems Engineer
Daniel Jacobs (ASU)

Payload Scientist
David Ardila (JPL)

CubeSat Telescope and I&T
Paul Scowen (ASU)
Matt Beasley (SWRI)
Connie Spittler (ASU)
Mary Knapp (MIT)

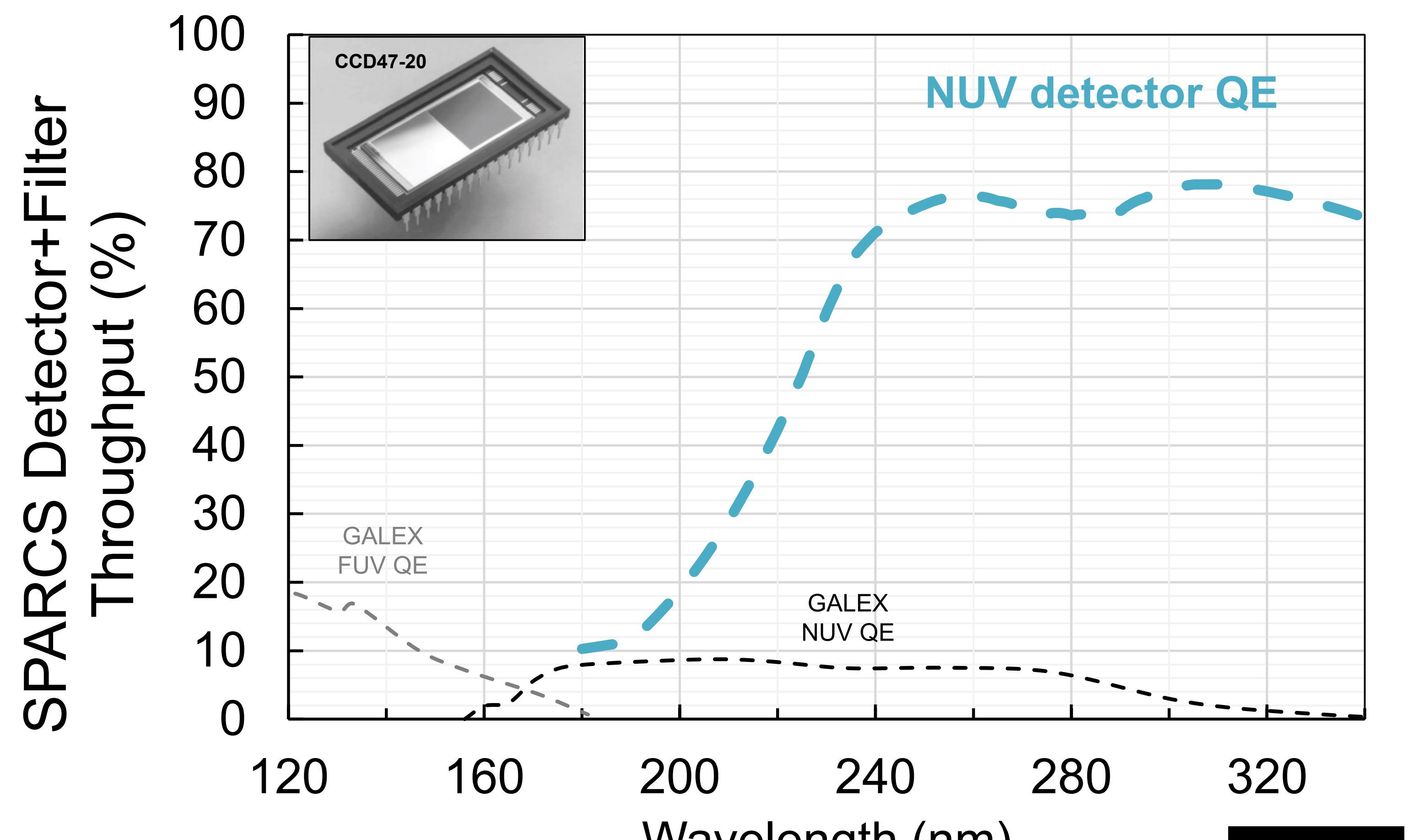
Science
Travis Barman (UA)
Varoujan Gorjian (JPL)
Joe Llama (Lowell)
Victoria Meadows (UW)
Sarah Peacock (UA)
Mark Swain (JPL)

Camera/Detector
Shouleh Nikzad (JPL)
April Jewell (JPL)

Operations/Software
Judd Bowman (ASU)
Tahina Ramiaramanantsoa (ASU)

SPARCS' technology mission: Fly high-QE, delta-doped detectors (SPARCam)

Fully-processed thinned CCDs are modified for UV enhancement by growing 2.5 nm of boron-doped silicon on the back surface.



See Nikzad et al. 2012 [redacted]

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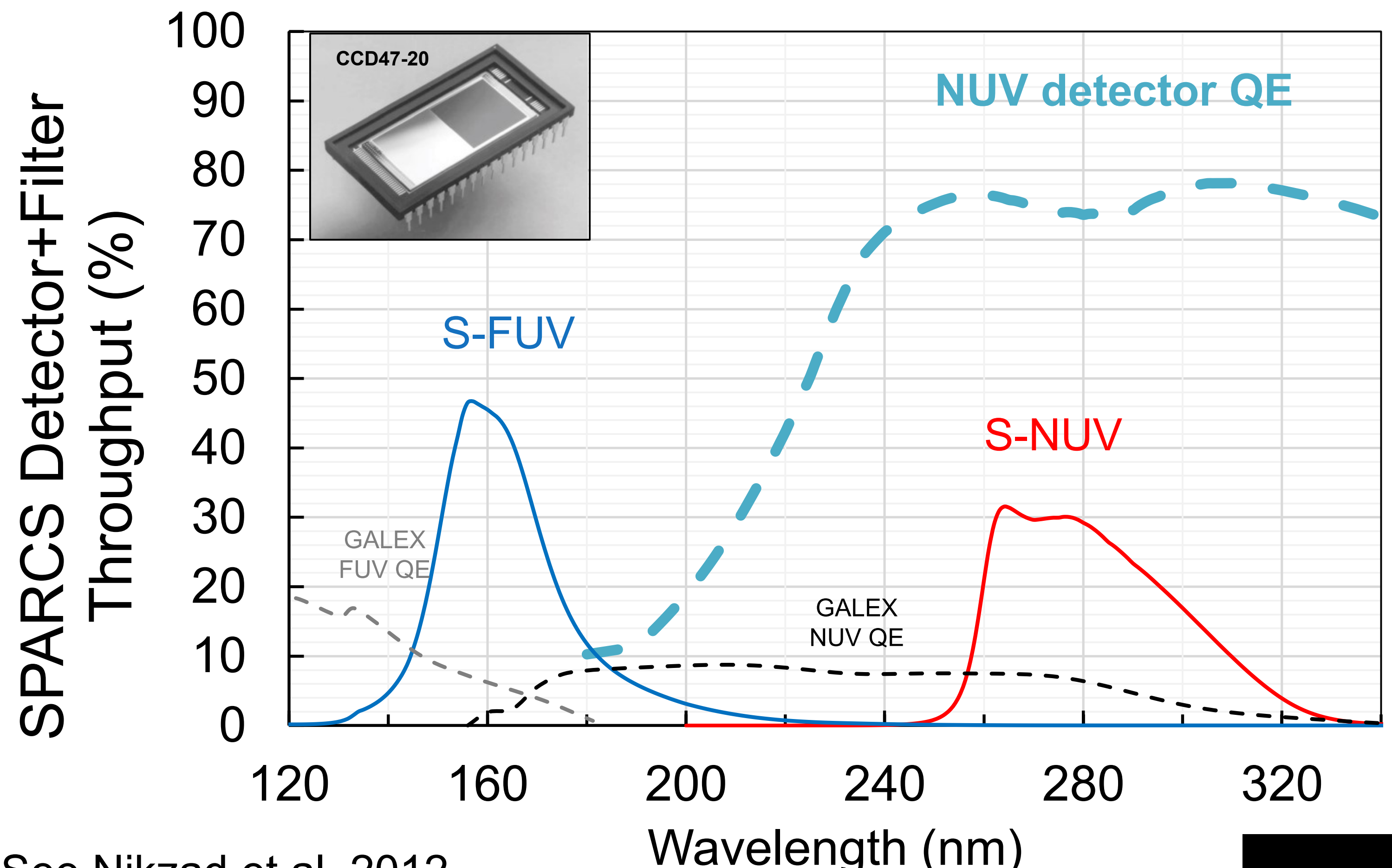
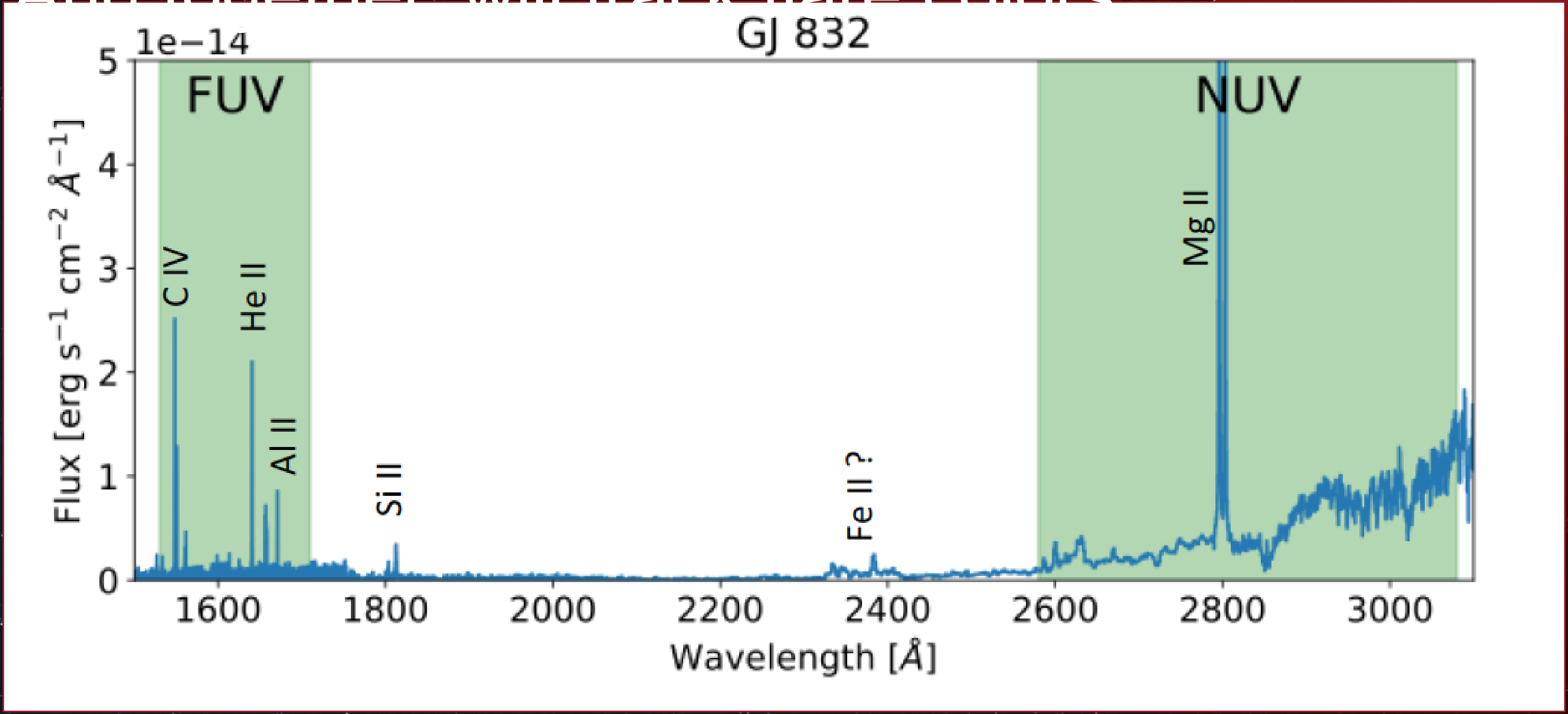


See Nikzad et al. 2012

[redacted]

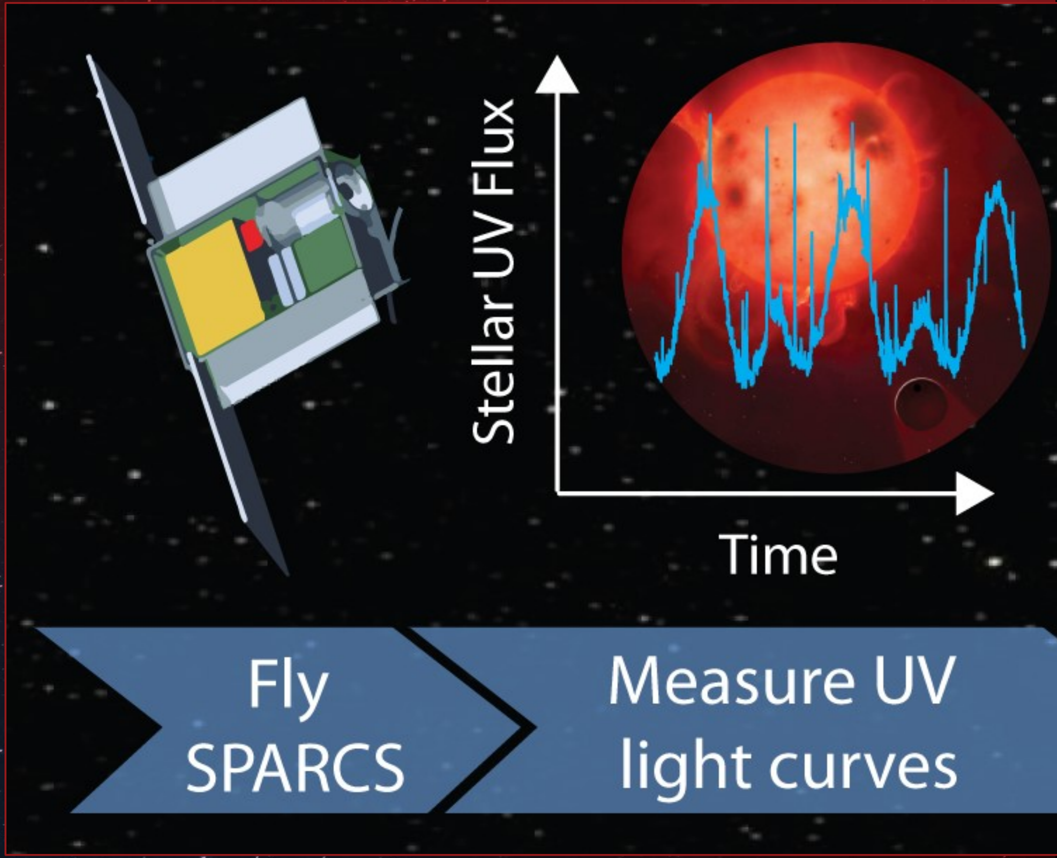
The S-FUV and S-NUV bands contain transition region and chromosphere emission lines.

And together, will track flare colors

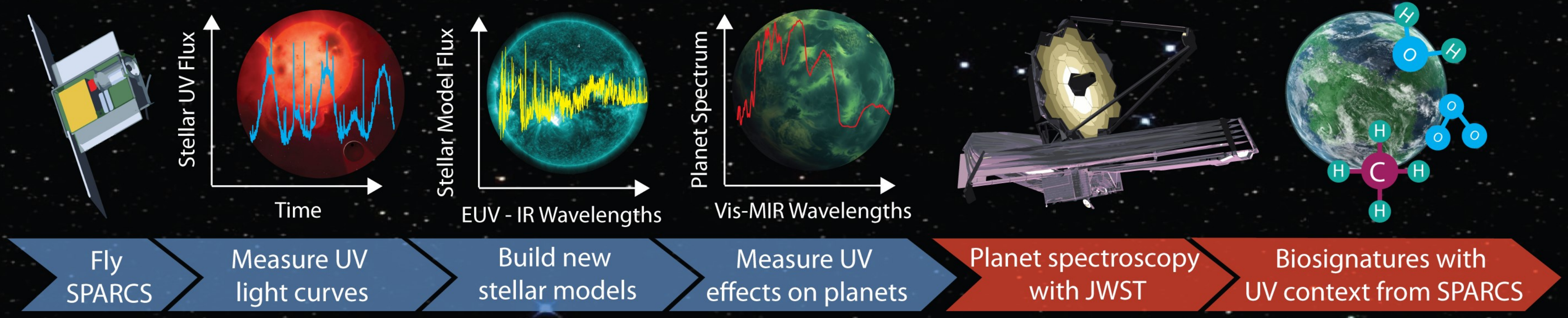


Credit: P. Loyd

SPARCS Science Plan



SPARCS Science Plan



SPARCS Timeline

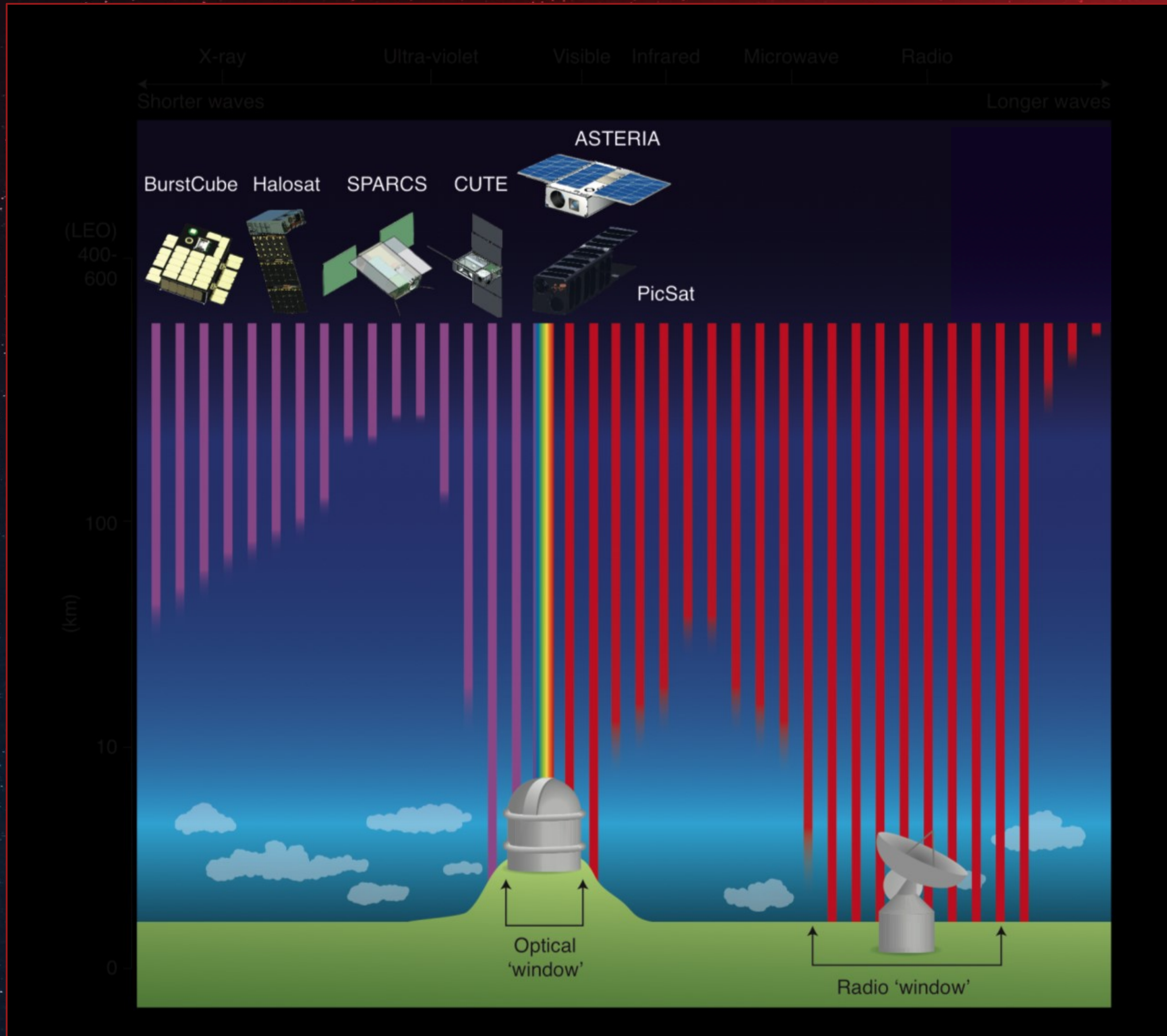
Adapted from David Oh (JPL)

Pre-Phase A	Concept Studies	Brainstorming, Trade Studies, Feasibility Study	For SPARCS: 5 months
Phase A	Concept Development		
Phase B	Preliminary Design Completion	Detailed Trade Studies, Develop System Designs and Plans	9 months
Phase C	Final Design and Fabrication	Finish Design, Build Hardware & Software, Test Subsystems	20 months
Phase D	System Integration, Test & Launch	Bring Everything Together and Test, Test, Test!	6 months
Phase E	Operations	Fly the Spacecraft, Do the Mission	≥ 12 months

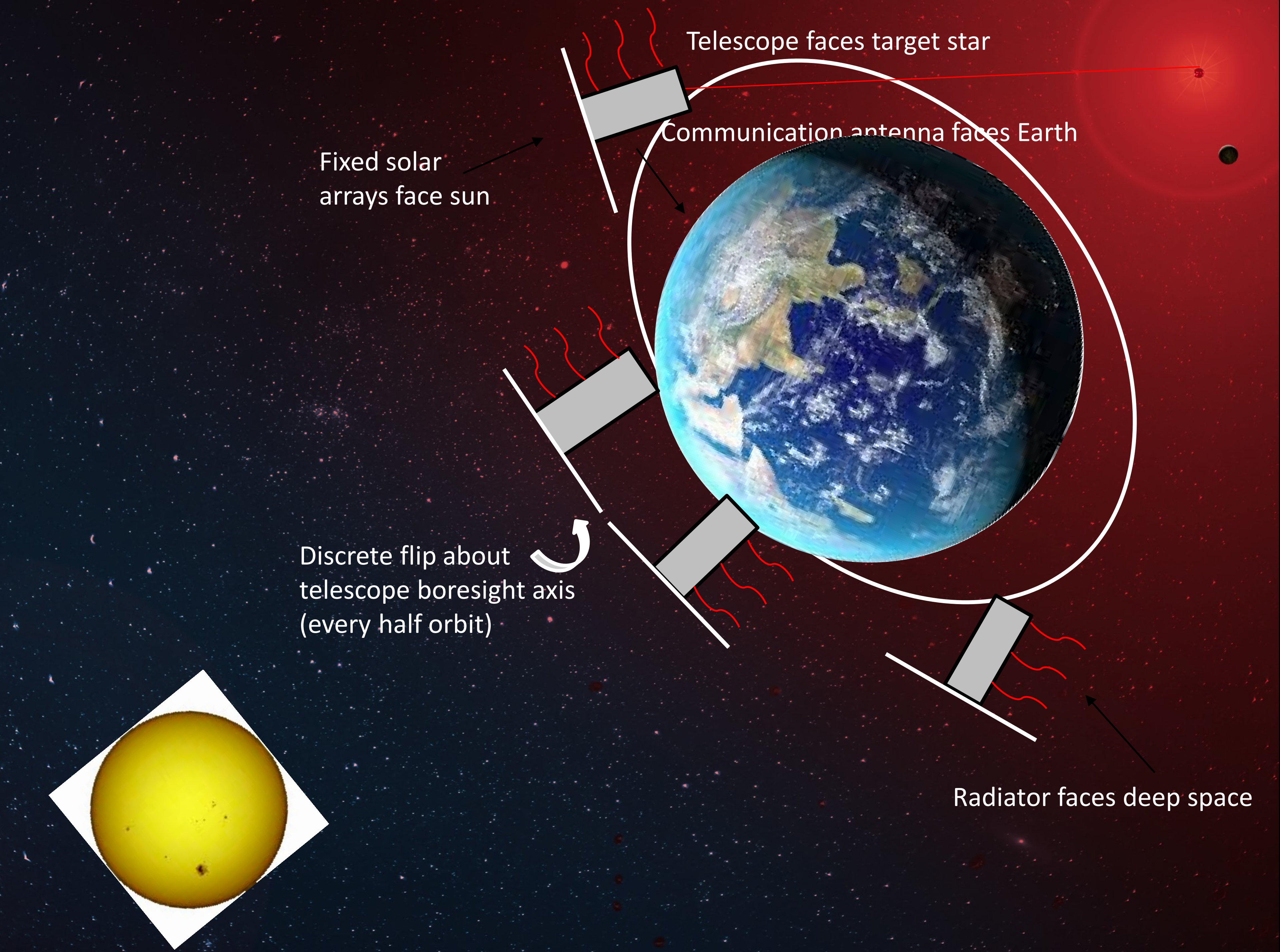
So, in the end of 2021,

SPARCS will fly....

SPARCS in Context

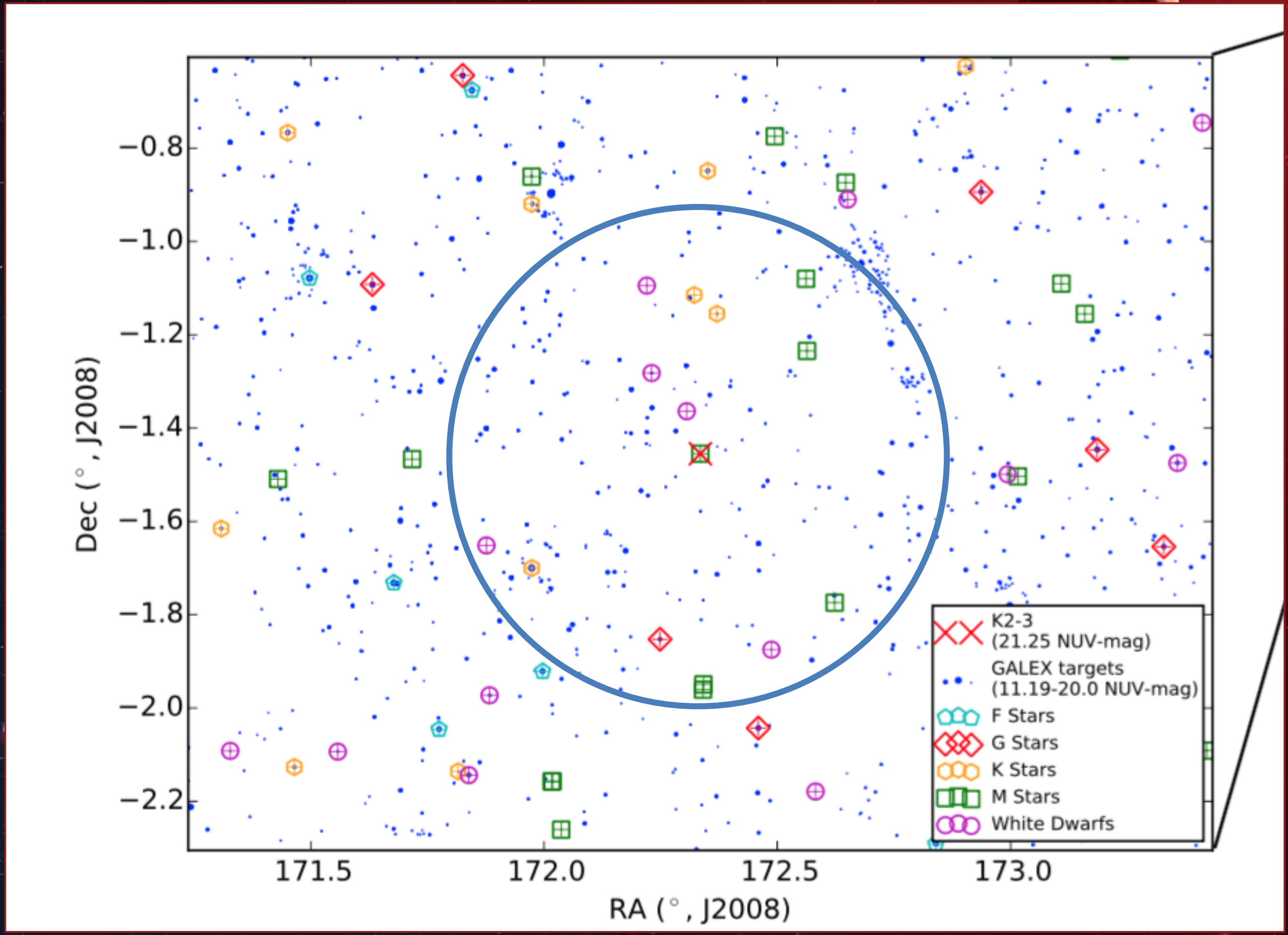


Shkolnik 2018, "On the Verge of an Astronomy CubeSat Revolution", Nature Astronomy

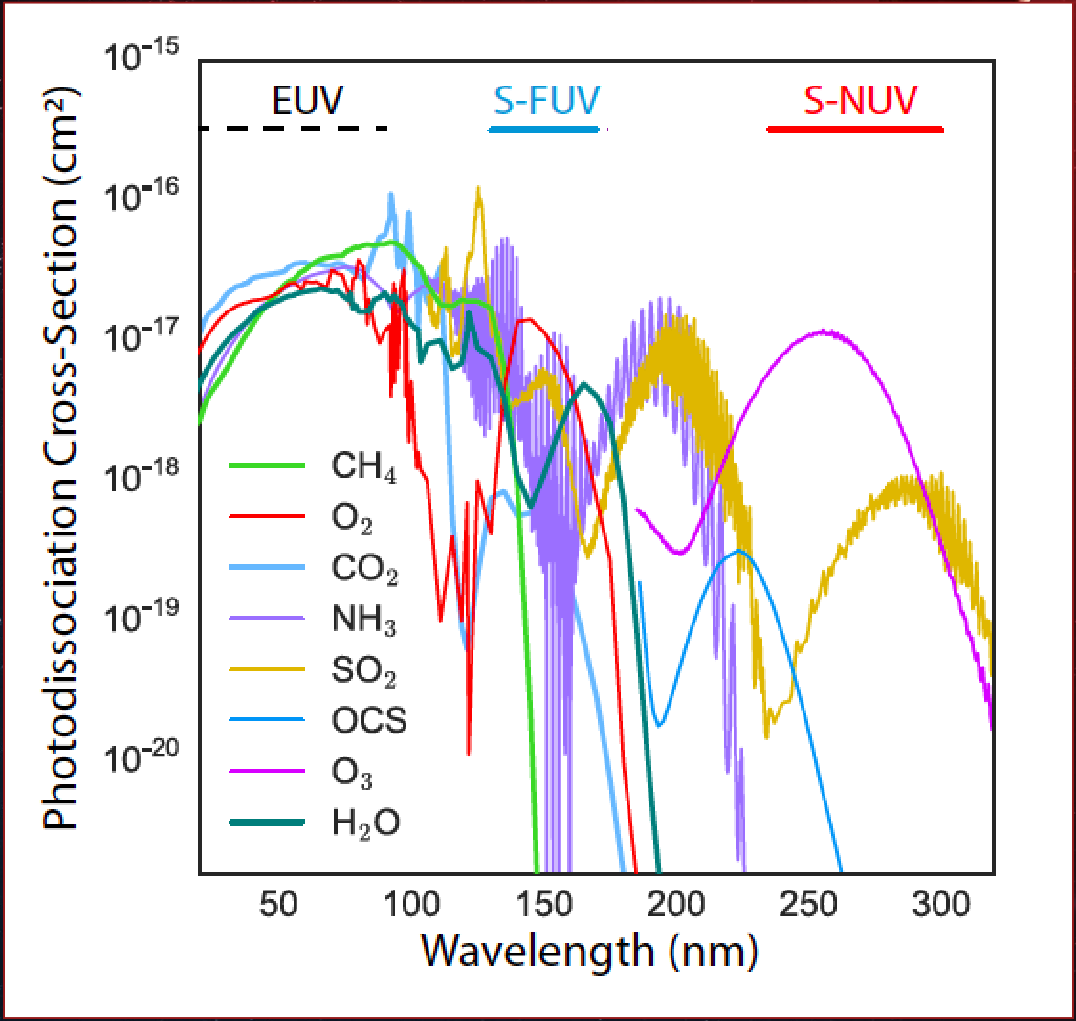


Telescope faces target star
Communication antenna faces Earth
Fixed solar arrays face sun
Discrete flip about telescope boresight axis (every half orbit)
Radiator faces deep space

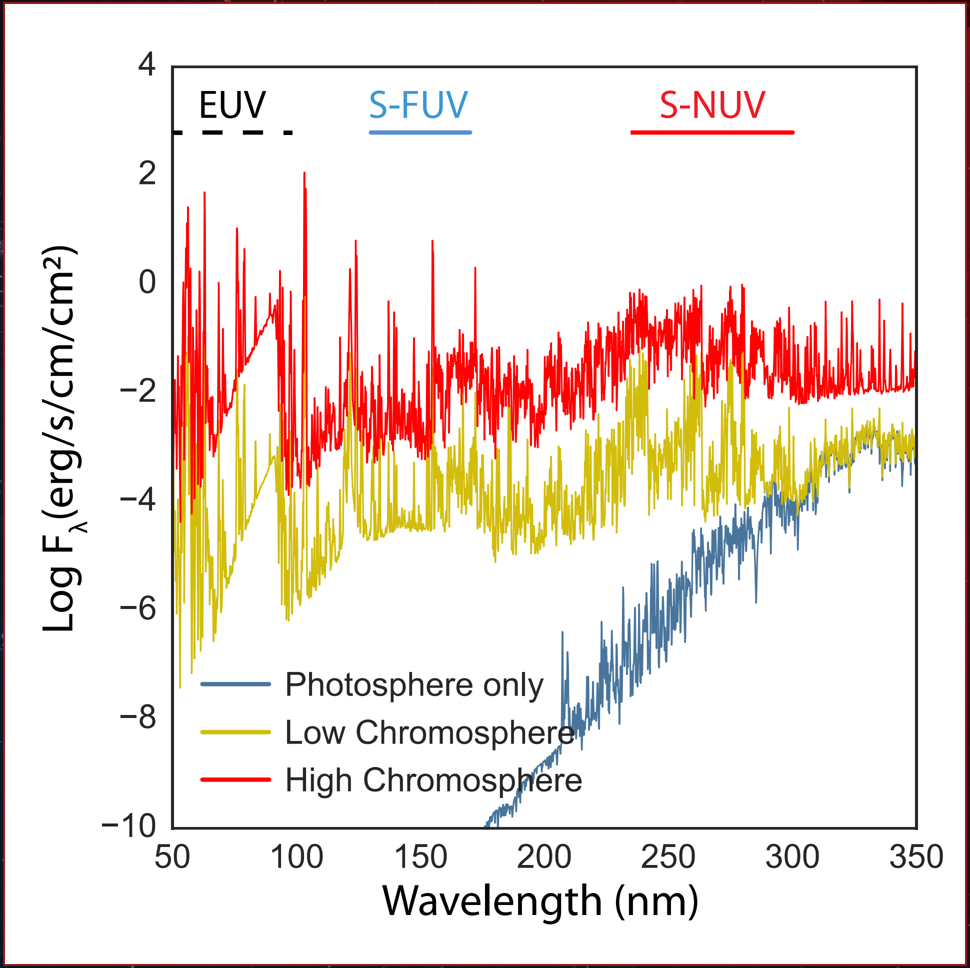
Field of View w/ Ancillary Science



UV Dissociating Wavelengths Affecting Terrestrial Planet Atmosphere Photochemistry

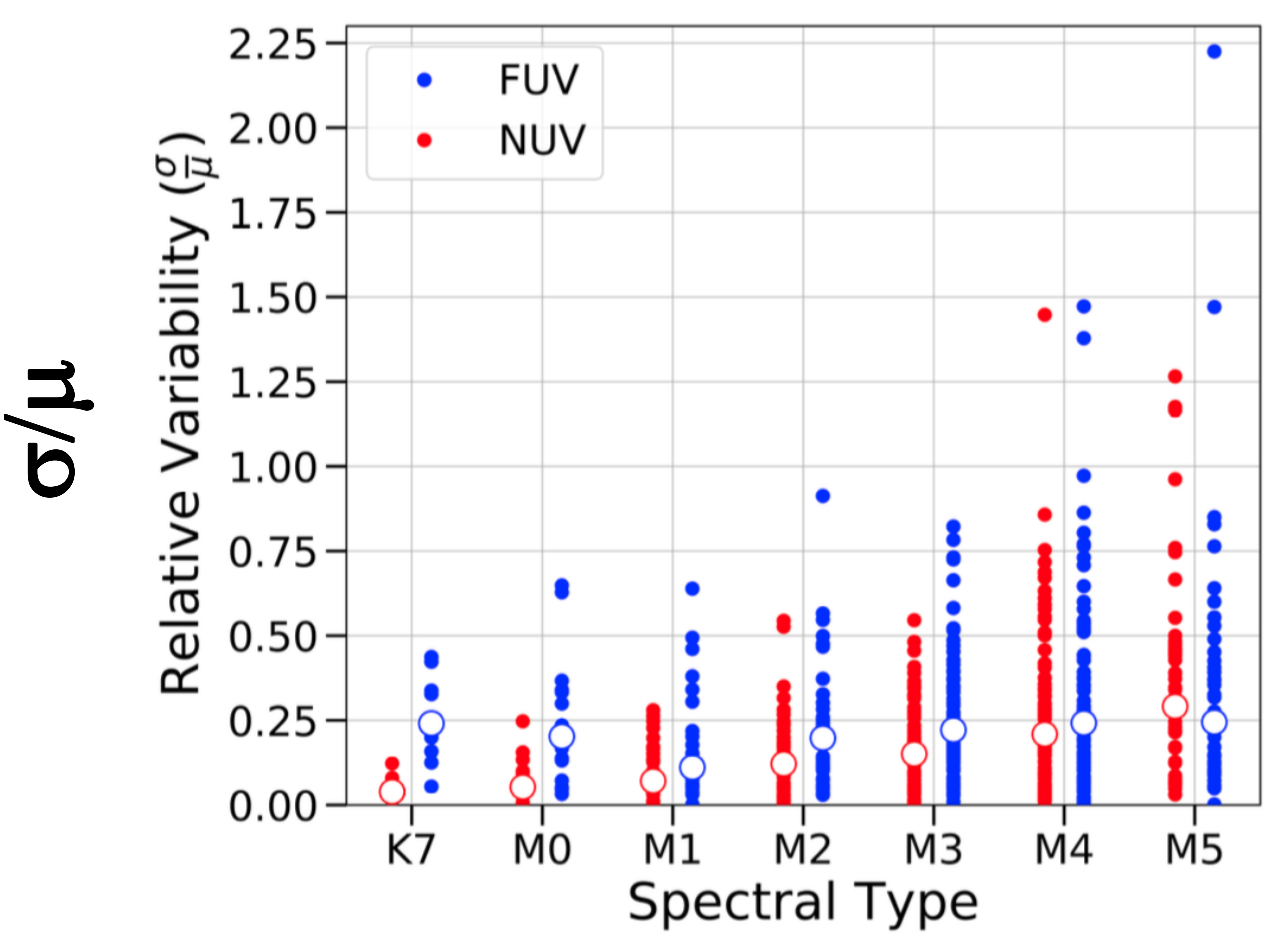


FUV and NUV wavelengths are needed to build upper-atmosphere stellar models to predict the full wavelength range.



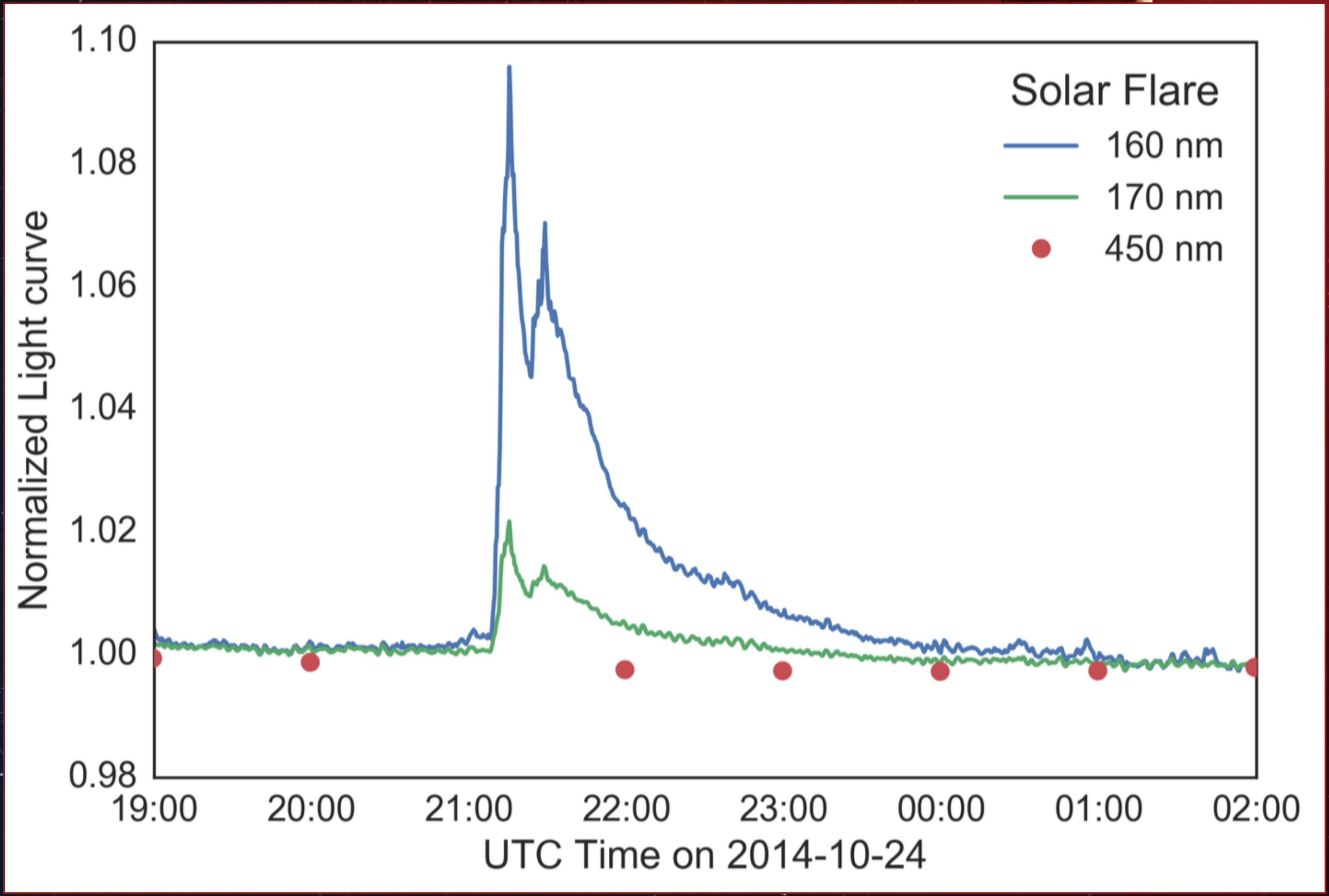
Shkolnik & Barman 2014

UV variability increases with later spectral type, but most M dwarfs have only 3 - 5 GALEX observations.



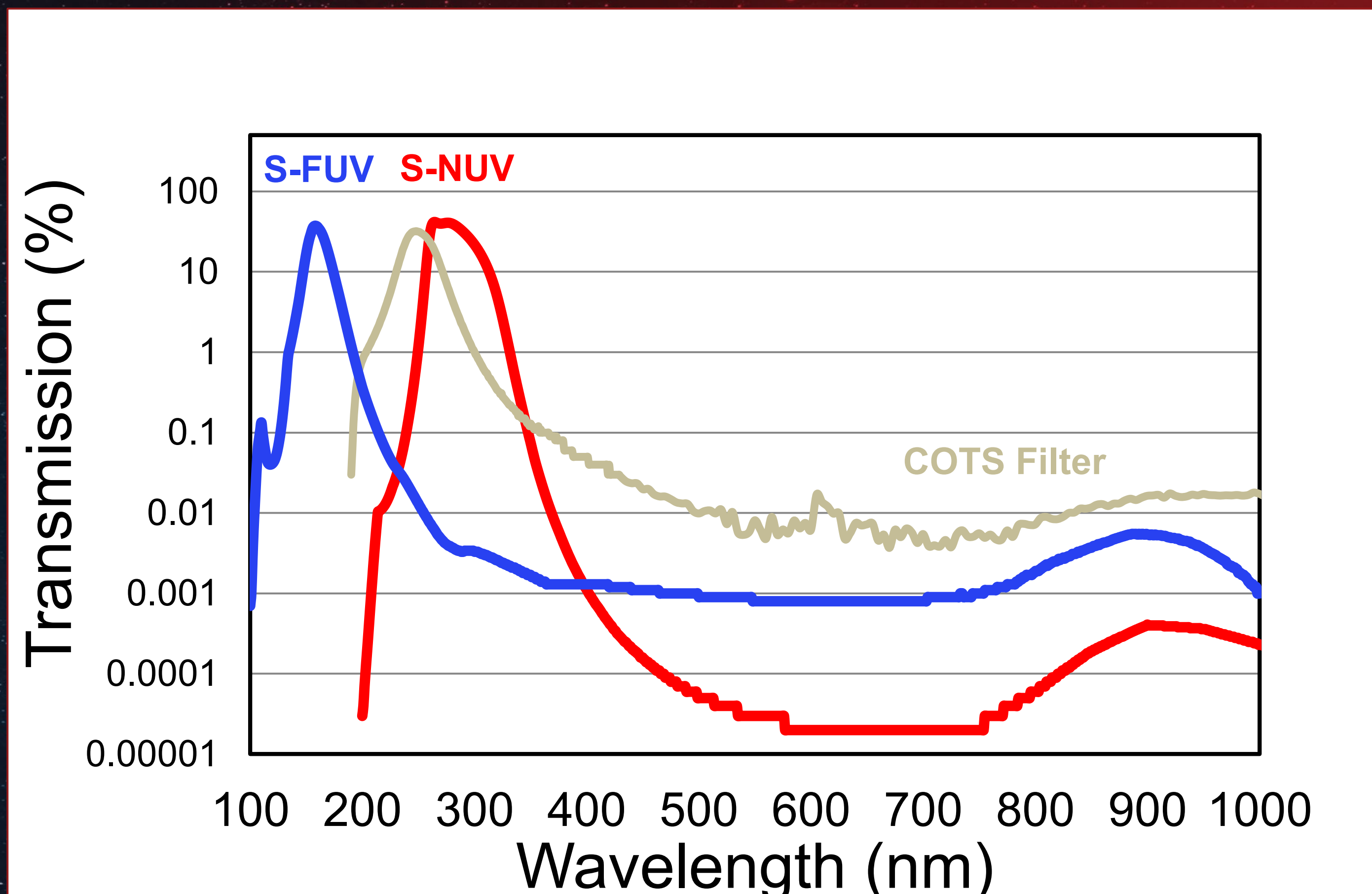
HAZMAT II; Miles & Shkolnik (2017)

The S-FUV bandpass is extremely sensitive to flare activity.



Llama & Shkolnik, in prep.

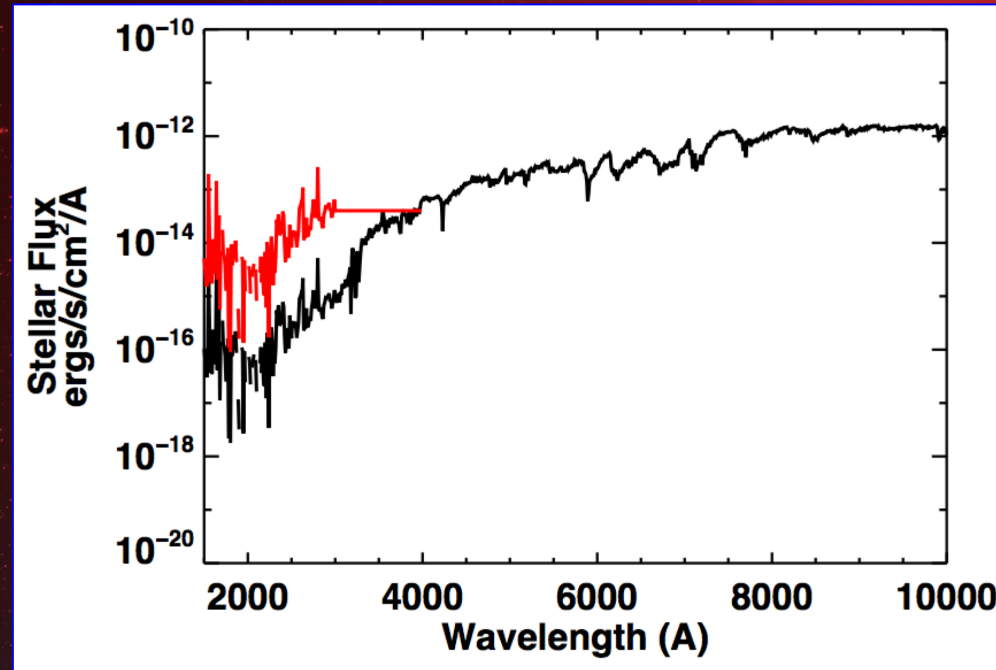
Conquering the Red Leak with Custom Filters

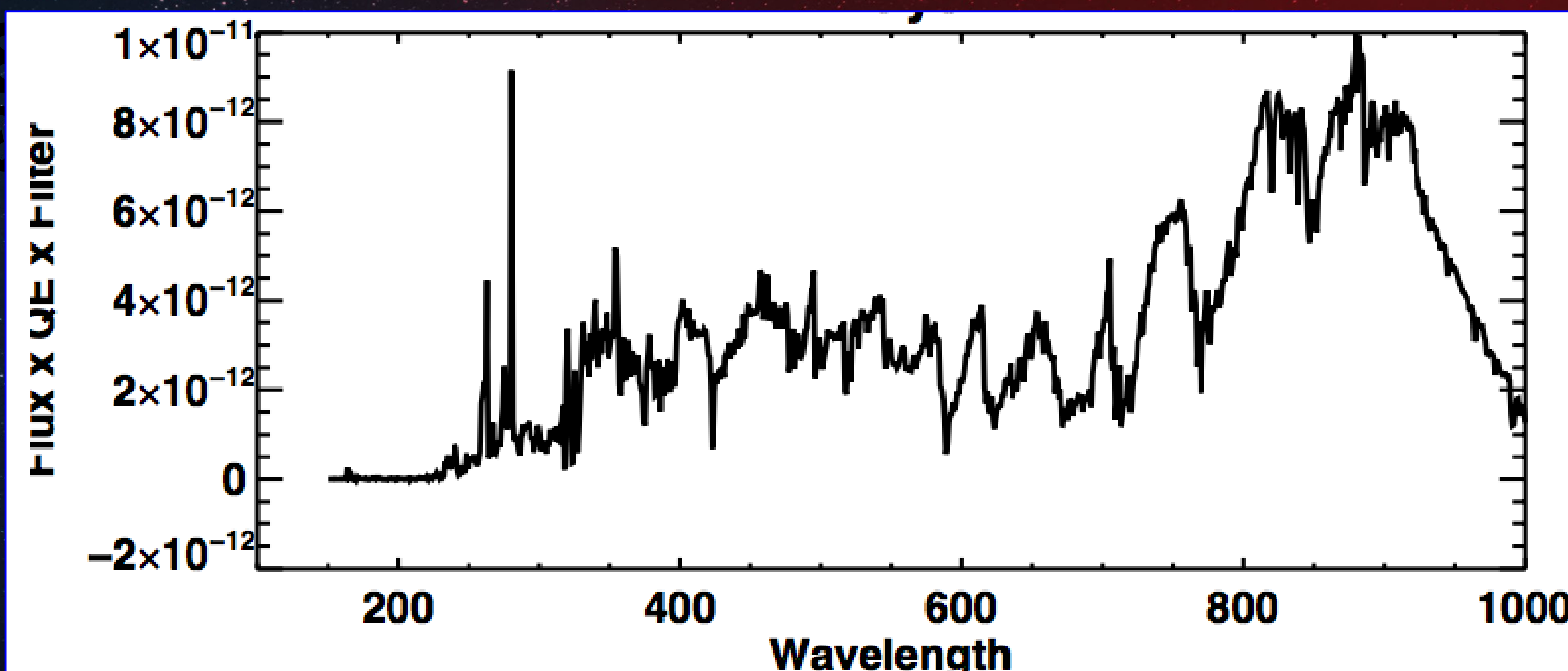


σ/μ

Conquering the Red Leak with Custom Filters

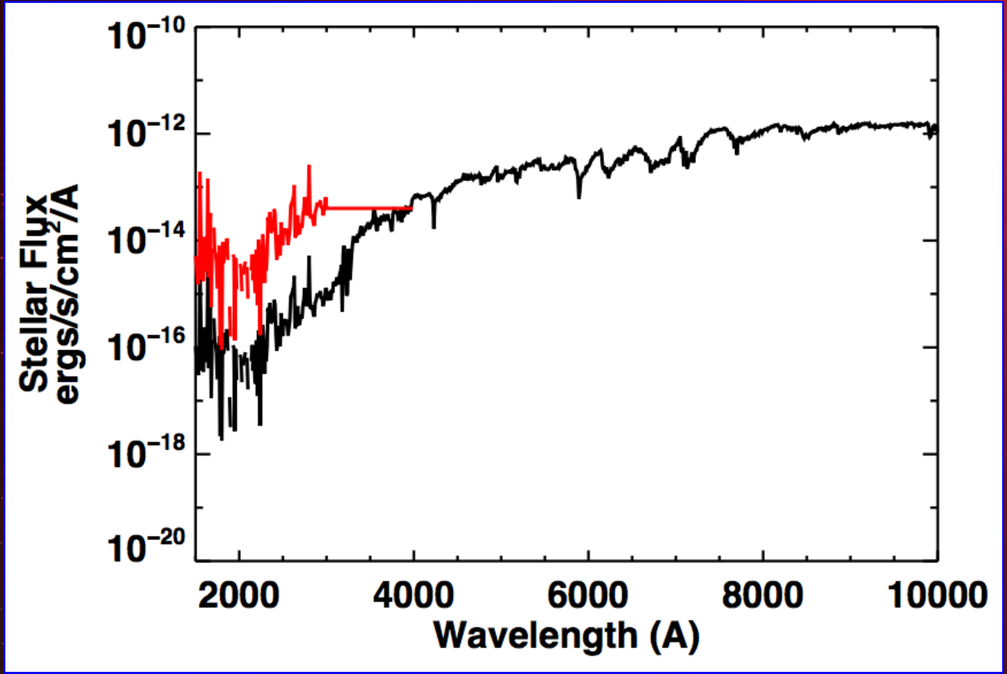
COTS filters allow stellar red photons to flood the detector.

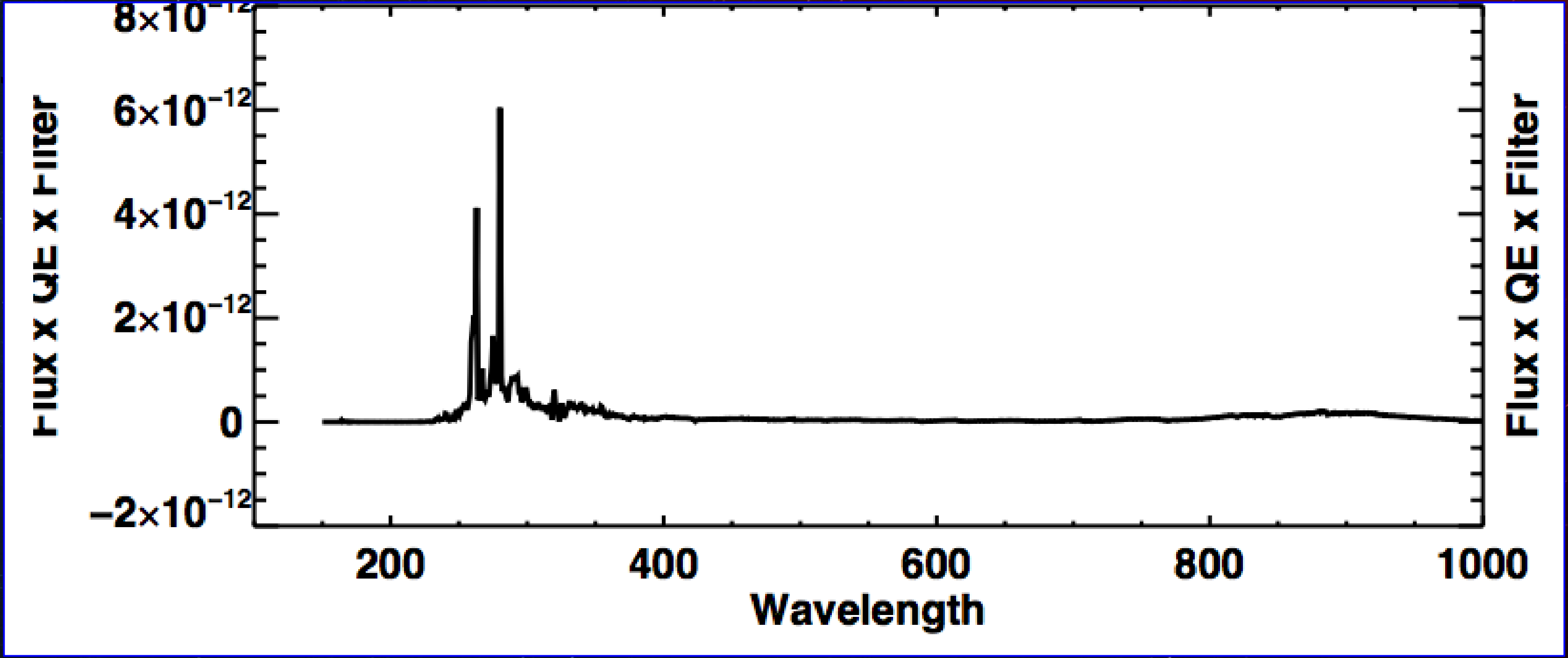




Conquering the Red Leak with Custom Filters

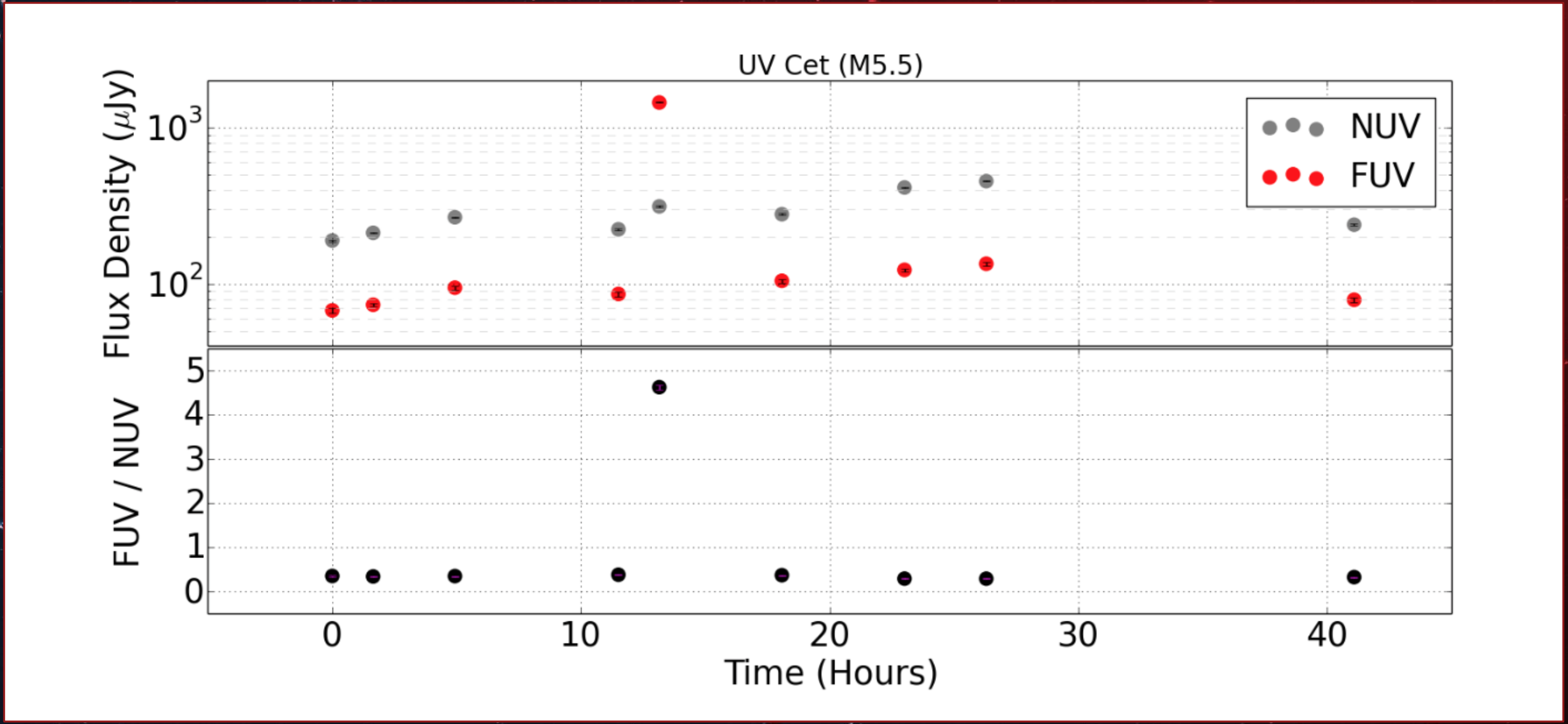
With SPARCS filters, over 90% of the detected flux is from UV wavelengths for both the active and inactive stars.





We will track flare colors (ratios) with a dichroic to monitor the FUV and NUV simultaneously.

GALEX observations of active M dwarfs, UV Cet.
FUV-to-NUV ratio can >1 during large flares.



HAZMAT II; Miles & Shkolnik 2017