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.)
Effects of UV radiation on exoplanets orbiting M stars

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Adapted from Rugheimer et al. 2015
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

SPIE papers:
Jewell et al. 2018
Scowen et al. 2018
GALEX

$150M

SPARCS

$5M

(standardization, COTS, shorter build times)
So what makes us think we can do useful UV science with SPARCS?
An interdisciplinary, creative team that can work together for years.

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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
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
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

- Fly SPARCS
- Measure UV light curves

Stellar UV Flux vs Time
SPARCS Science Plan

- Fly SPARCS
- Measure UV light curves
- Build new stellar models
- Measure UV effects on planets
- Planet spectroscopy with JWST
- Biosignatures with UV context from SPARCS
<table>
<thead>
<tr>
<th>Phase</th>
<th>Pre-Phase A</th>
<th>Phase A</th>
<th>Phase B</th>
<th>Phase C</th>
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<td>Concept Studies</td>
<td>Concept Development</td>
<td>Preliminary Design Completion</td>
<td>Final Design and Fabrication</td>
<td>System Integration, Test &amp; Launch</td>
<td>Operations</td>
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<tr>
<td>For SPARCS:</td>
<td>5 months</td>
<td>9 months</td>
<td>20 months</td>
<td>6 months</td>
<td>≥ 12 months</td>
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So, in the end of 2021, SPARCS will fly....
Telescope faces target star

Fixed solar arrays face sun

Communication antenna faces Earth

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

Llama & Shkolnik, in prep.
Conquering the Red Leak with Custom Filters

![Graph showing transmission vs. wavelength for S-FUV, S-NUV, and COTS Filter]
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