The Extreme-uv Stellar Characterization for Atmospheric Physics and Evolution (ESCAPE) Mission Concept

Exploring the physics and evolution of potentially habitable worlds

Kevin France
University of Colorado
APAC - 24 June 2020
The liquid water “Habitable Zone”
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- F - star 
  ~2 AU

- G - star
  ~1 AU
  not to scale

- M - star
  ~0.15 AU
The liquid water “Habitable Zone”

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Not to scale
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not to scale
A more complete picture of the Habitable Zone: Stellar impacts and space weather
A more complete picture of the Habitable Zone: Stellar impacts and space weather

Which star–planet systems are conducive to the maintenance of habitable conditions? Where should NASA and its partners commit their resources?
Stellar EUV (10 – 91nm) flux: the driver of atmospheric escape

High-energy stellar photons control the atmospheric physics and chemistry of temperate, rocky planets. The EUV dominates heating of the upper atmosphere and drives escape.
EUV environment is the dominant uncertainty for exoplanet atmosphere survival

Adapted from France et al. (2016)
EUV environment is the dominant uncertainty for exoplanet atmosphere survival
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Impulsive Stellar Eruptions Drive Atmospheric Escape

Flares & CMEs

Optically Inactive M star ($P_{\text{rot}} \sim 40$ days).

- Flares may dominate EUV output of active stars
- Stellar particle bombardment drives ion escape, charge exchange, pickup/sputtering loss processes

Adapted from Loyd et al. (2018)
ESCAPE Science Objectives

1) Determine if stellar radiation environments permit habitable conditions to exist on rocky exoplanets
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2) Characterize stellar EUV evolution & flares, and their impact on habitable environments
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1) Determine if stellar radiation environments permit habitable conditions to exist on rocky exoplanets

2) Characterize stellar EUV evolution & flares, and their impact on habitable environments

3) Determine the impact of coronal mass ejections on atmospheric mass loss
The ESCAPE Science and Implementation

EUV & FUV (7 – 180 nm) spectroscopy of 200 nearby stars, including most promising exoplanet hosts

Atmospheric models using ESCAPE data as inputs quantify atmospheric loss rates and identify the most promising habitable planet targets
The ESCAPE Science and Implementation

EUV & FUV (7 – 180 nm) spectroscopy of 200 nearby stars, including most promising exoplanet hosts

Launch in spring 2025 with a 2 year primary mission
The ESCAPE Science Program

> 100 x sensitivity of EUVE:

First statistical study of EUV irradiance on planet-hosting stars
The ESCAPE Science Program

> 100 x sensitivity of EUVE:
First statistical study of EUV irradiance on important stellar/planetary timescales.

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

AU Mic data adapted from Kowalski et al.
The ESCAPE Science Program

> **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

*SDO and AIA data adapted from Mason et al. (2016)*
The study of stellar impacts on terrestrial exoplanets is an inherently interdisciplinary endeavor.

The ESCAPE science team combines experts from astrophysics, heliophysics, and planetary science.

<table>
<thead>
<tr>
<th>Principal Investigator</th>
<th>Kevin France (Colorado)</th>
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<tr>
<td>Project Scientist</td>
<td>Jeremy Drake (CfA/SAO)</td>
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<td>Instrument Scientist</td>
<td>Brian Fleming (Colorado)</td>
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</tbody>
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The ESCAPE Mission
(Euv Stellar Characterization for Atmospheric Physics and Evolution)

ESCAPE Hardware:
- Instrument, MSFC, UCB, SAO, PSU, LASP
- Instrument I&T, LASP
- Observatory I&T, Ball

ESCAPE Data:
- Processing, LASP
- Archiving, MAST
The ESCAPE Small Explorer Concept
(Euv Stellar Characterization for Atmospheric Physics and Evolution)

The ESCAPE Instrument

Primary & Secondary Mirror Module Fabrication and Alignment

Spacecraft

Detector

Gratings

Instrument Design
The ESCAPE Instrument

ESCAPE Telescope:

Primary & Secondary Mirror Module Fabrication and Alignment

Fabricated and aligned by NASA/MSFC and SAO, building on X-ray telescope heritage in APD and HPD

- Grazing incidence Hettrick–Boywer design (Gregorian)
- Electroform Nickel Reconstruction
The ESCAPE Instrument
(Euv Stellar Characterization for Atmospheric Physics and Evolution)

ESCAPE Gratings:

- Grazing and normal incidence gratings
- Electron-beam lithography
- Fabricated by Penn State, building on X-ray rocket and SAT heritage
The ESCAPE Instrument
(Euv Stellar Characterization for Atmospheric Physics and Evolution)

ESCAPE Detector:

- 125 x 40mm MCP, XDL readout, KBr photocathode
- Fabricated by SSL/UCB, building on heritage from Hubble, FUSE, EUVE, and numerous helio and PS missions
The ESCAPE Instrument
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ESCAPE Detector:

• 125 x 40mm MCP, XDL readout, KBr photocathode
• Fabricated by SSL/UCB, building on heritage from Hubble, FUSE, EUVE, and numerous helio and PS missions
• Demonstration system successfully flown on NASA rocket mission in 2019 (SISTINE)
The ESCAPE Instrument
(Euv Stellar Characterization for Atmospheric Physics and Evolution)

ESCAPE Spacecraft:

- Ball BCP 100 spacecraft
- ADCS system (< 5” pointing stability and < 30” pointing control)
- Ka and S-band comm.
- Fabricated and integrated by Ball, building on heritage from WISE, GPIM, and in development for IXPE and SPHEREx
The ESCAPE Mission
(Euv Stellar Characterization for Atmospheric Physics and Evolution)

ESCAPE explores the high-energy radiation environments of nearby habitable zones.

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The ESCAPE Mission
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ESCAPE explores the high-energy radiation environments of nearby habitable zones.

ESCAPE provides the essential stellar context for exoplanet habitability and provides a roadmap for future life-detection missions.
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(Euv Stellar Characterization for Atmospheric Physics and Evolution)

ESCAPE explores the high-energy radiation environments of nearby habitable zones.

ESCAPE provides the essential stellar context for exoplanet habitability and provides a roadmap for future life-detection missions.

High-throughput grazing incidence optical system and heritage spacecraft enables EUV observations of 200 nearby stars of a range of masses and ages to be surveyed in a 2 year mission.

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Backup Slides

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ESCAPE Science Team

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The Local ISM

The EUV *is* observable. The challenge has been an observational one, not an astrophysical one.
The ESCAPE Target Sample

Target list will be updated with new RV and transit results during Phases B – D.