EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

NSF

ExoExplorers Webinar — 03/12/2021

M-Dwarfs

$M < 0.6\ M_\odot$

$T < 3800$ K

E.g. TRAPPIST-1, Proxima Centauri

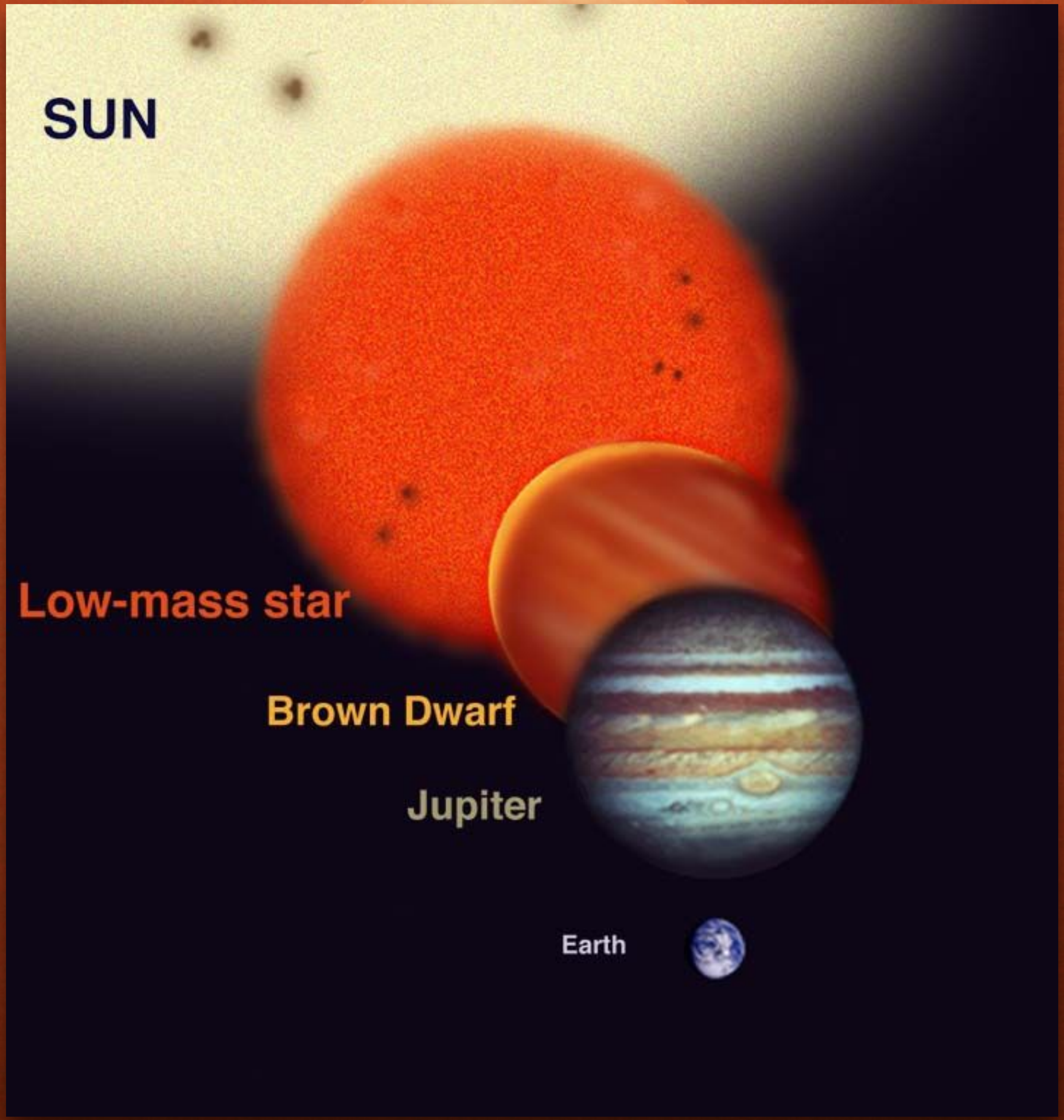
Image credit: NASA/JPL-Caltech/Spitzer

M-Dwarfs

$M < 0.6\ M_\odot$

$T < 3800$ K

E.g. TRAPPIST-1, Proxima Centauri




Habitable Zone
TOO HOT
JUST RIGHT
TOO COLD
Planet size: 1-2x Earth
Image credit: NASA

EVRYSCOPE

Close-in M-dwarf habitable zones => easy to detect Earthlike planets

Image credit: ESO/M. Kornmesser

Close-in M-dwarf habitable zones => easy to detect Earthlike planets

Complication: Flares

Image credit: ESO/M. Kornmesser

EVRYSCOPE

M-Dwarf Flares

M-dwarfs are typically active flare stars

Flares affect planetary habitability

More powerful flares => greater impact

Most powerful flares: “Superflares”

Image credit: David A. Aguilar (CfA)

EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

ExoExplorers Webinar — 03/12/2021

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

NSF

EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

ExoExplorers Webinar — 03/12/2021

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

NSF

Superflares

Stellar flares with energy $E \geq 10^{33}$ erg

Common for M dwarfs

Bright enough to see easily from Earth

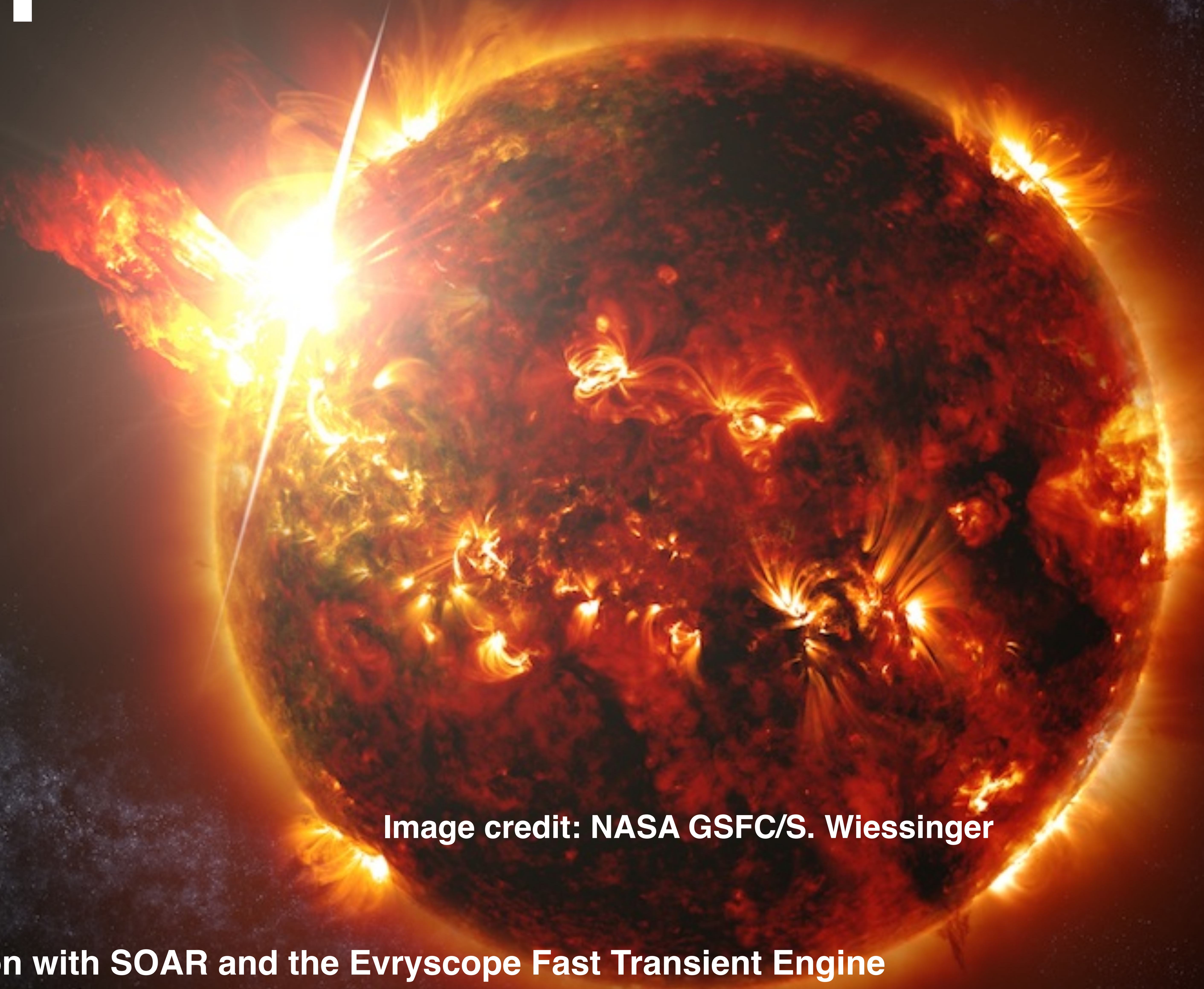


Image credit: NASA GSFC/S. Wiessinger

Superflares

High-energy particles can follow superflares

Particles interact with planetary atmospheres

Image credit: NASA/ESA/L. Calçada

EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

NSF

ExoExplorers Webinar — 03/12/2021

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

EVRYSCOPE

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

NSF

ExoExplorers Webinar — 03/12/2021

EVRYSCOPE

Exo-Aurorae

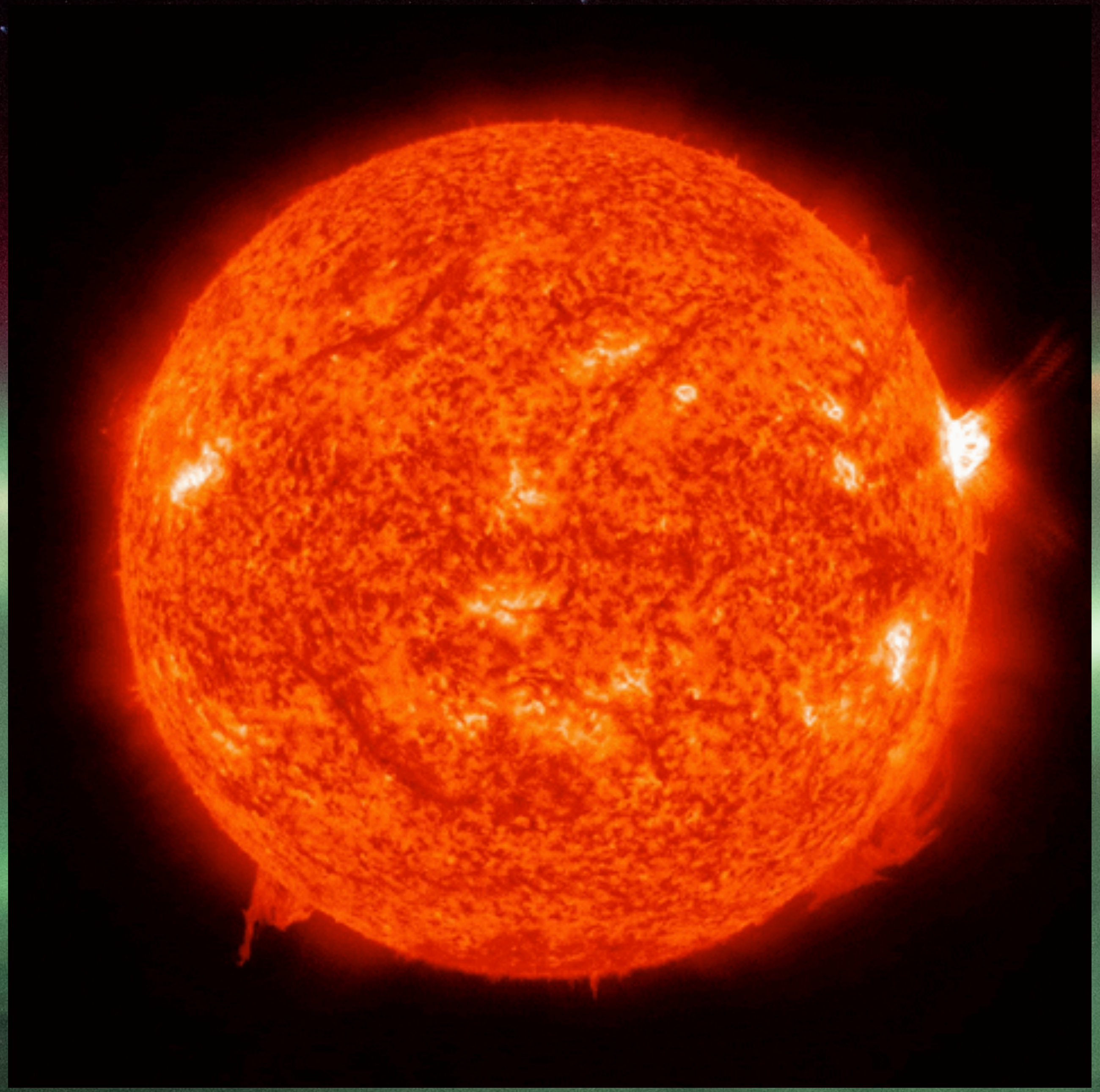
High-energy particles can follow superflares

Particles interact with planetary atmospheres

Image credit: NASA

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Exo-Aurorae



CME

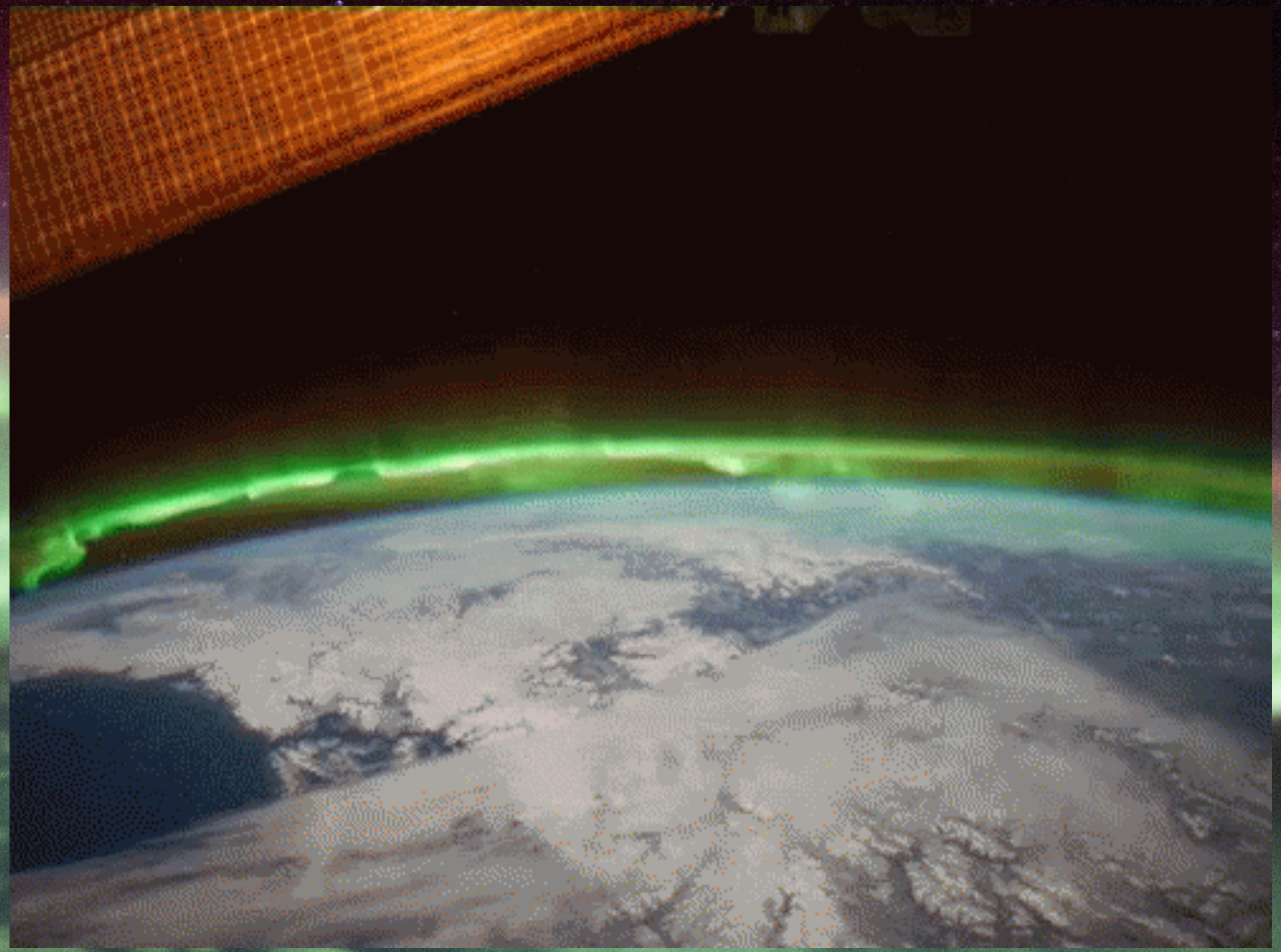


Image credit: NASA

Exo-Aurorae

Oxygen: characteristic green aurorae of Earth

Bright emission @ 5577 Å within hours of flare => exo-aurorae

Image credit: NASA

Exo-Aurorae

Oxygen: characteristic green aurorae of Earth

Bright emission @ 5577 Å within hours of flare
=> exo-aurorae

Luger et al. (2017): exo-aurorae from M-dwarf planets may be detectable

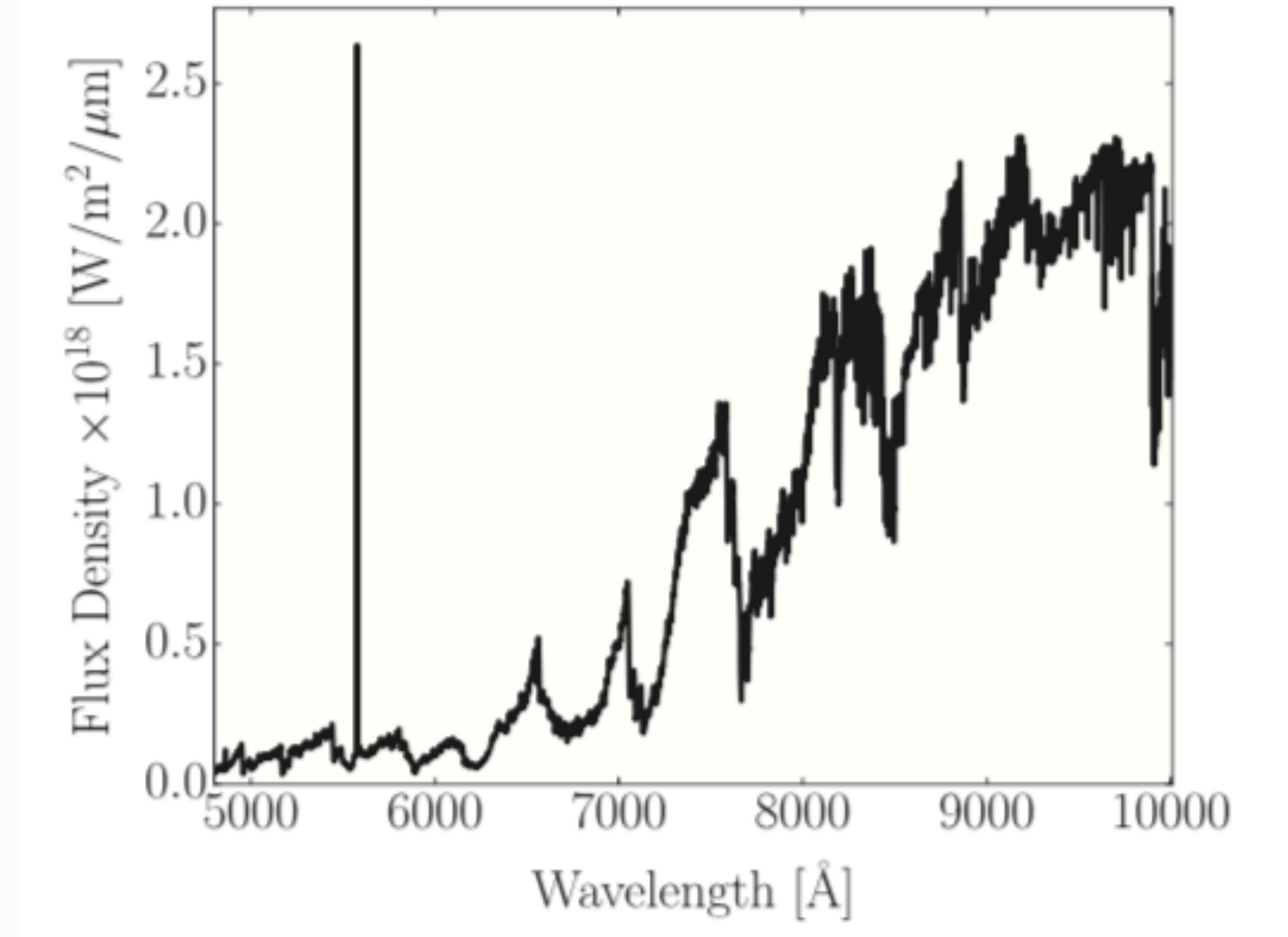


Figure 3. Simulated high-resolution visible spectrum of Proxima Cen b with a 0.1 TW O I auroral emission at 5577 Å. A gray geometric albedo of 0.3 is assumed for the planet. The spectrum is calculated at quadrature phase and scaled to the observing distance (1.302 pc).

Image credit: NASA

Exo-Aurorae

Oxygen: characteristic green aurorae of Earth

Bright emission @ 5577 Å within hours of flare
=> exo-aurorae

Luger et al. (2017): exo-aurorae from M-dwarf planets may be detectable

Challenge: Actually finding such an event

Image credit: NASA

EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

NSF

ExoExplorers Webinar — 03/12/2021

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

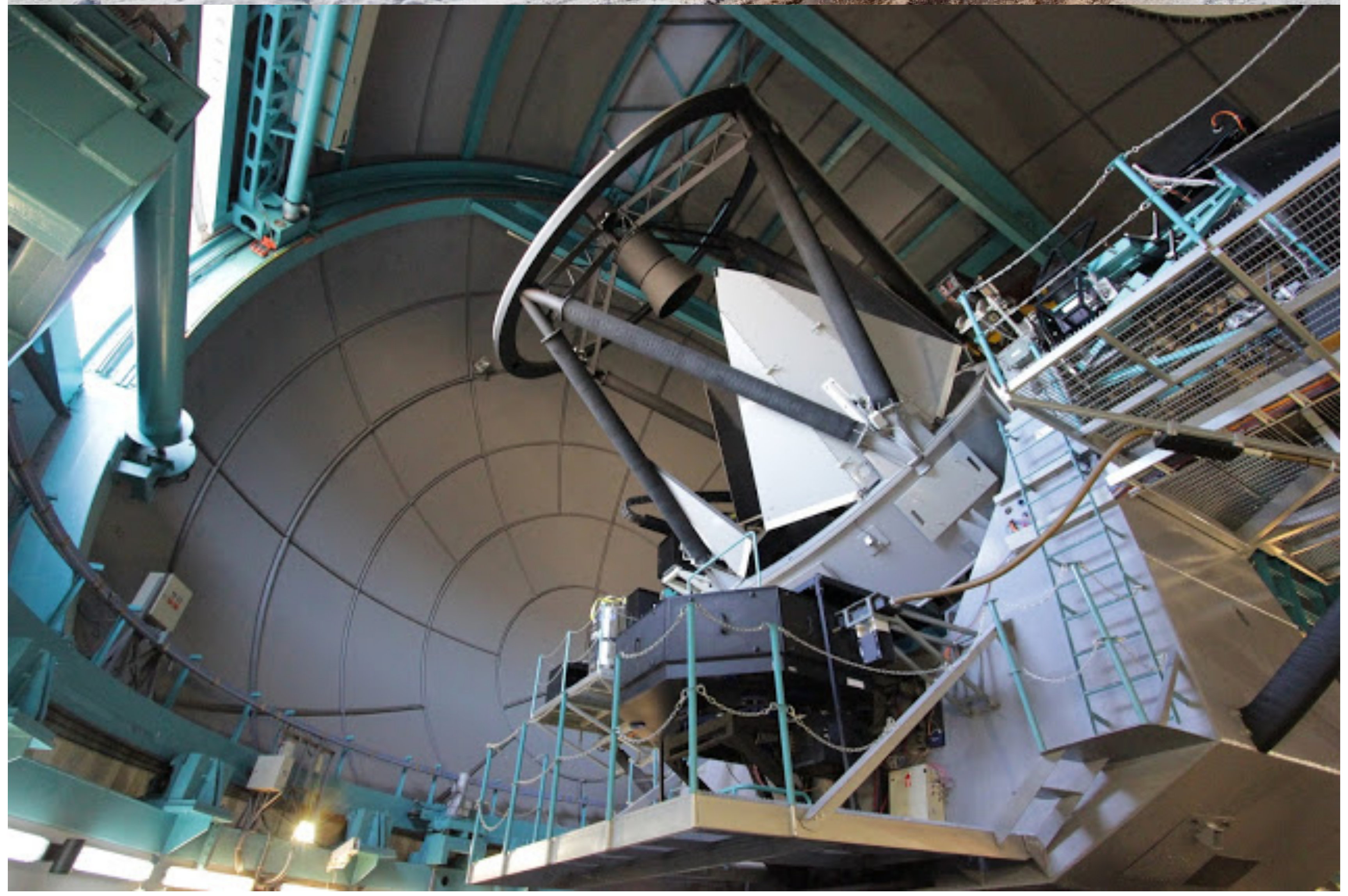
ExoExplorers Webinar — 03/12/2021

SOAR (Southern Astrophysical Research) Telescope

EVRYSCOPE

- Cerro Pachon, Chile
- 4.1 m, optical + near IR

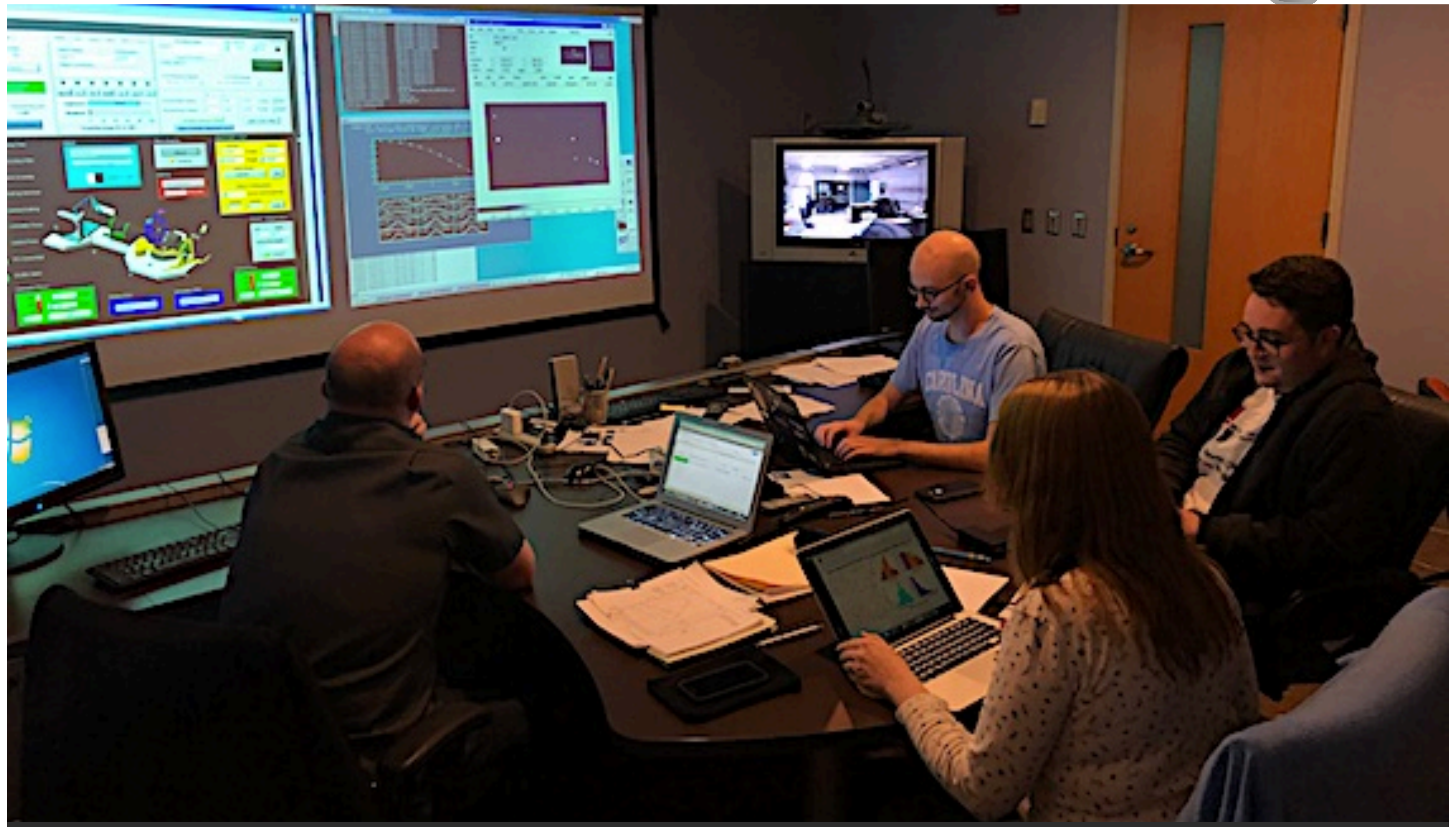
- Goodman High-Throughput Spectrograph:
  - Gratings 400-2400 L/mm (R ~ 1850-14000)
  - For more details, see Clemens et al. (2004)

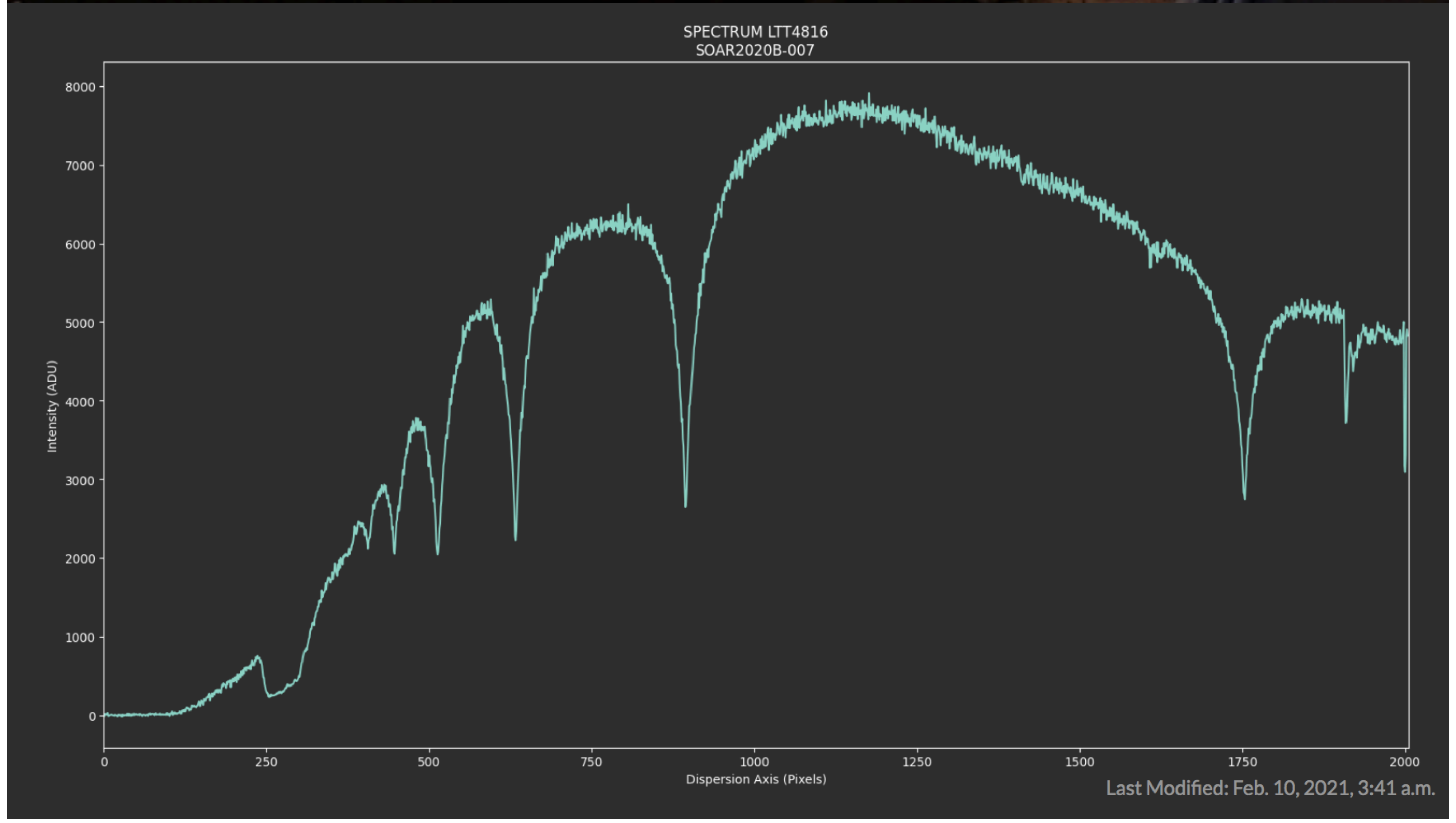


Observing with SOAR

EVRYSCOPE

- **SOAR nights allocated to UNC, split among research groups (~few per group per term)**
- **Variety of targets observed for diverse science cases in group**
- **Observations fully remote, facilitated by operators at CTIO**





Observing with SOAR

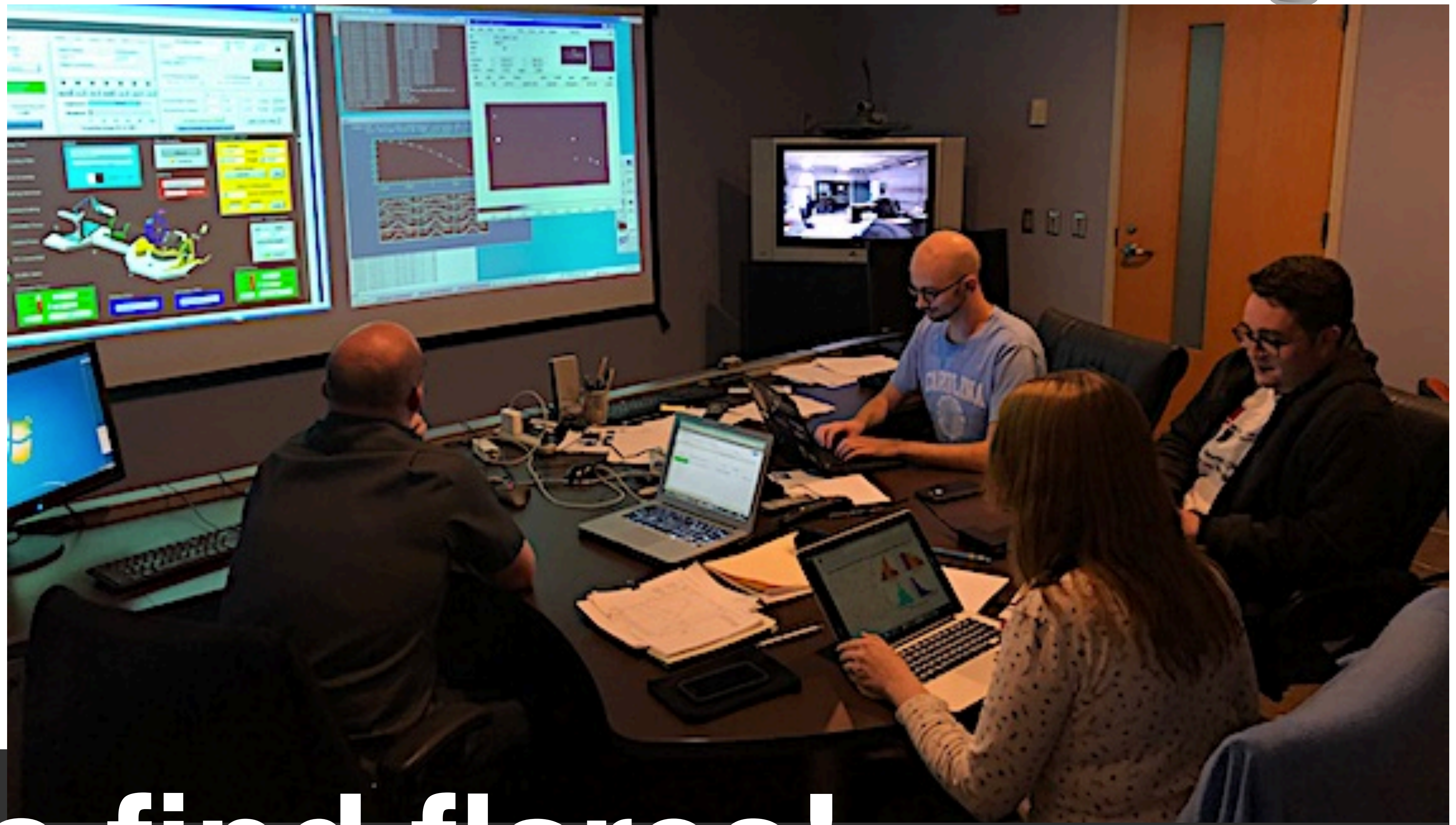
EVRYSCOPE

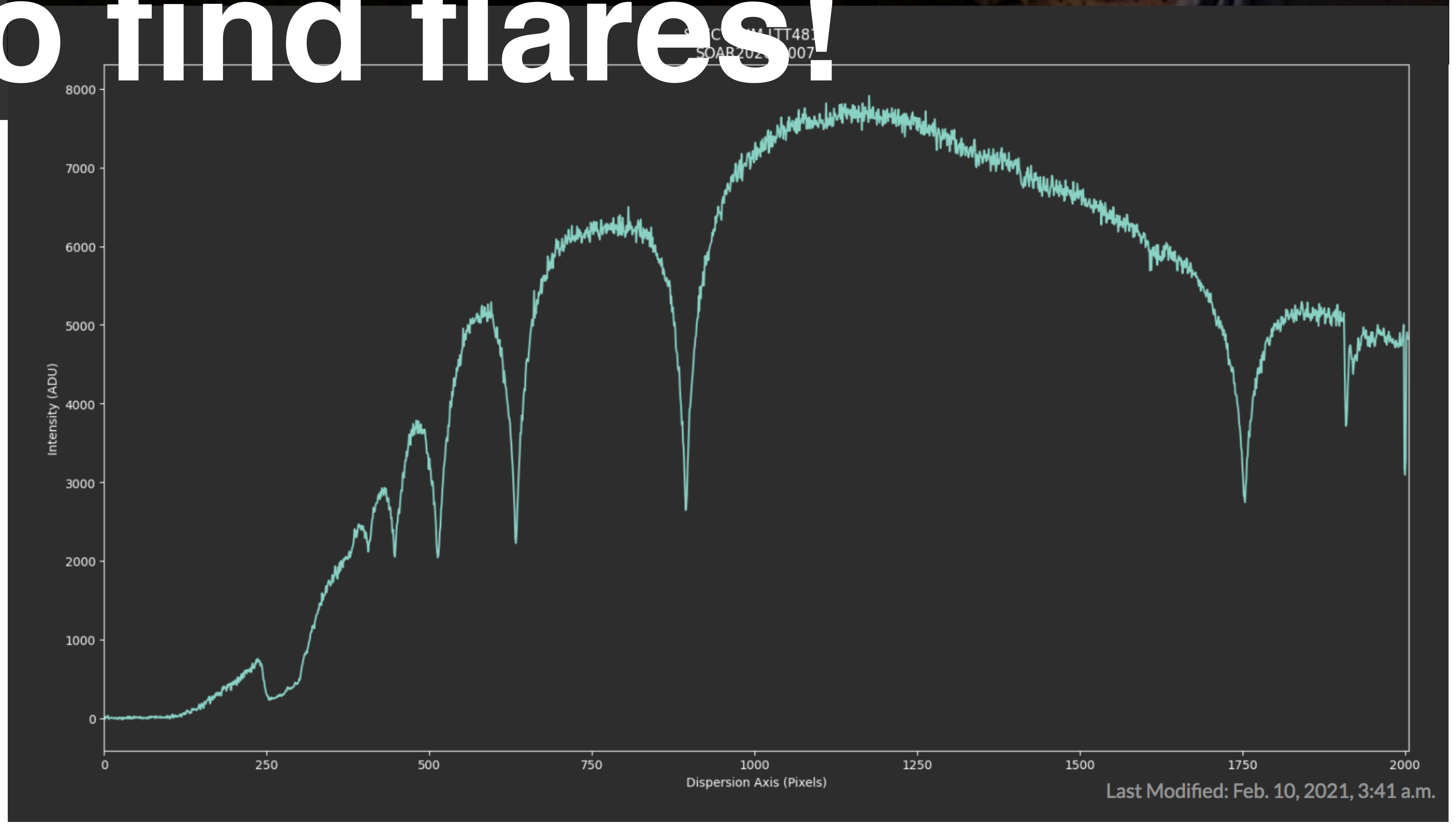
- **SOAR nights allocated to UNC, split among research groups (~few per group per term)**

But first, we need to find flares!

- **Variety of targets observed for diverse science cases in group**

- **Observations fully remote, facilitated by operators at CTIO**





Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

ExoExplorers Webinar — 03/12/2021

EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Amy Glazier, UNC Chapel Hill

Collaborators: Nicholas Law (PI), Hank Corbett, Ward Howard, Alan Vasquez Soto, Ramses Gonzalez, Nathan Galliher, Jeff Ratzloff

ExoExplorers Webinar — 03/12/2021

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

NSF

The Evryscopes

EVRYSCOPE

Evryscope-South:

- Cerro-Tololo Inter-American Observatory, Chile
- Deployed in 2015

Evryscope-North:

- Mount Laguna Observatory, California, USA
- Deployed in 2018

Evryscope-South

EVRYSCOPE

Technical specifications:

- 22 cameras
- Plate scale = 13 arcsec/pixel
- Cadence = 2 min
- Limiting mag. ≈ 16 in Sloan *g'*
- 8150 sq. deg. field of view

For more details, see Ratzloff et al. 2019

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

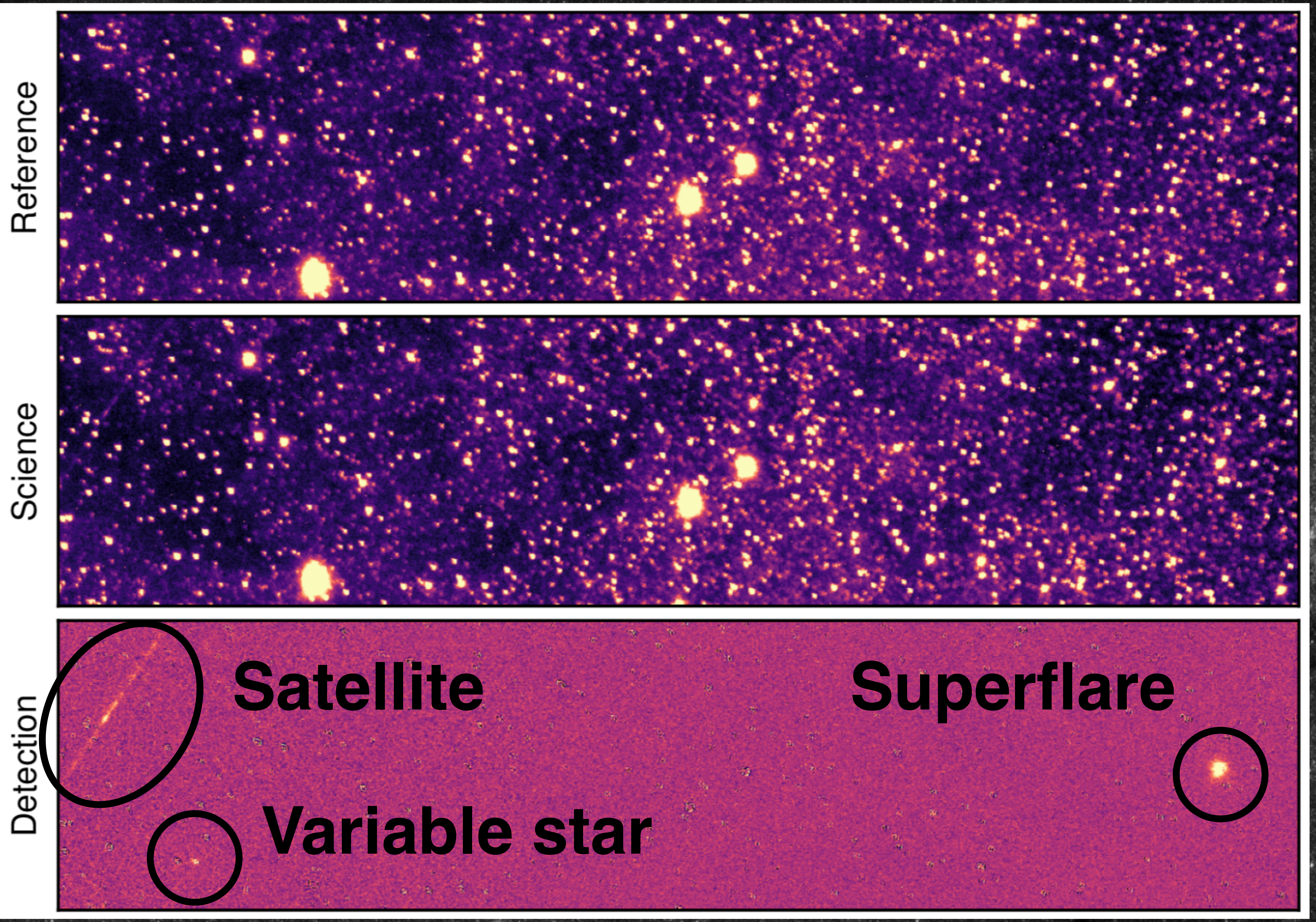
EVRYSCOPE

EFTE
Evryscope Fast Transient Engine

Subtract images taken in same pointing in real time

Automatically identify transient candidates for rapid follow-up

For more details, see Corbett et al. (2020)



EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

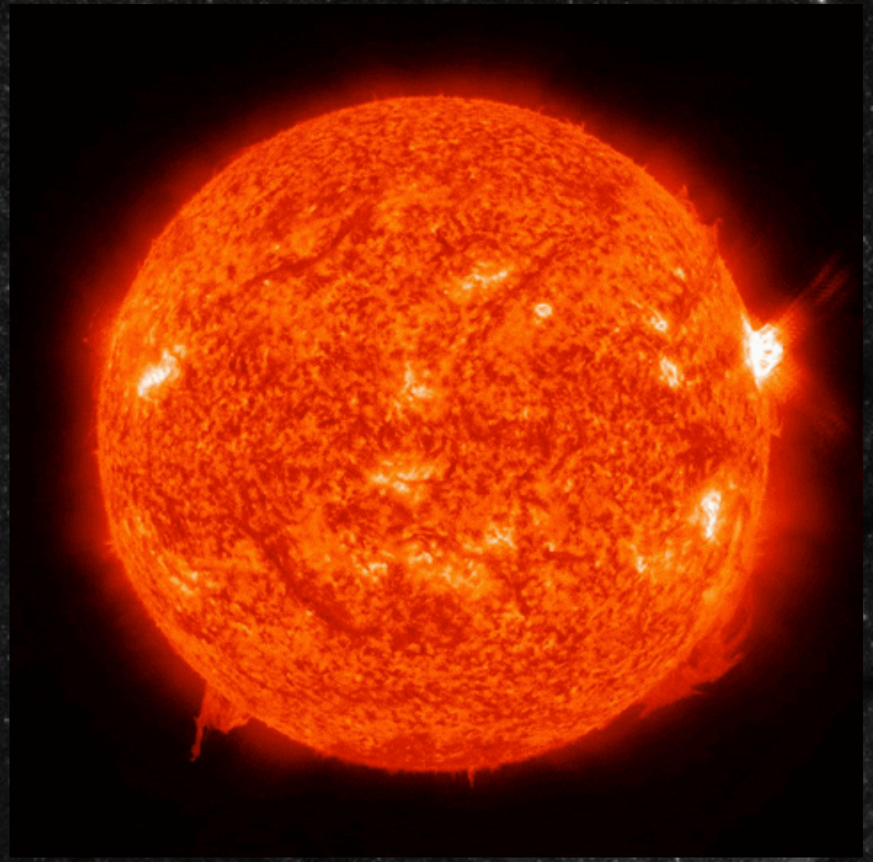
EVRYSCOPE

Constraints on Post-Superflare Exo-Auroral Emission with SOAR and the Evryscope Fast Transient Engine

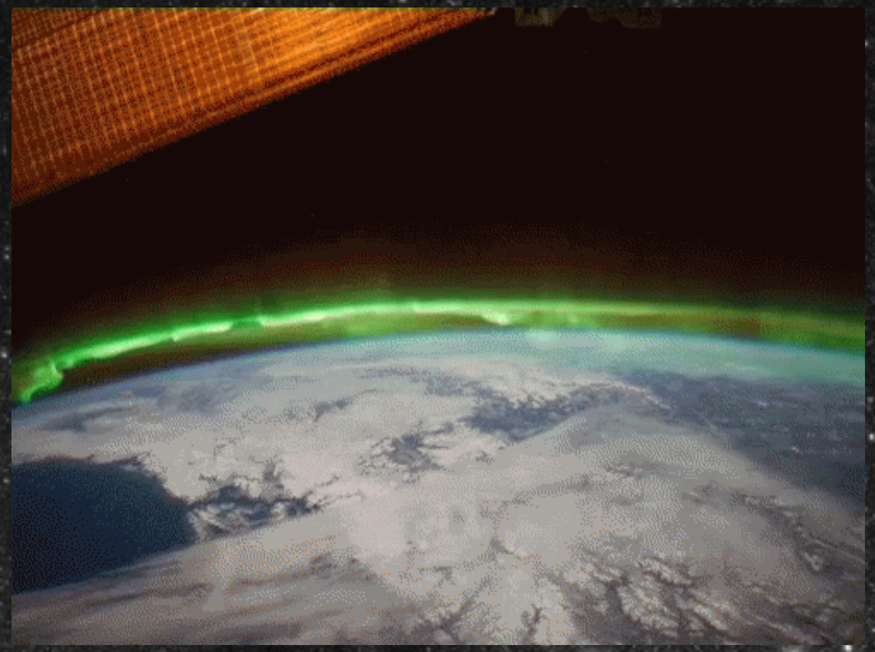
DISCLAIMER: direct detection is unlikely

DISCLAIMER: direct detection is unlikely

…but we will get upper limits to inform future surveys.



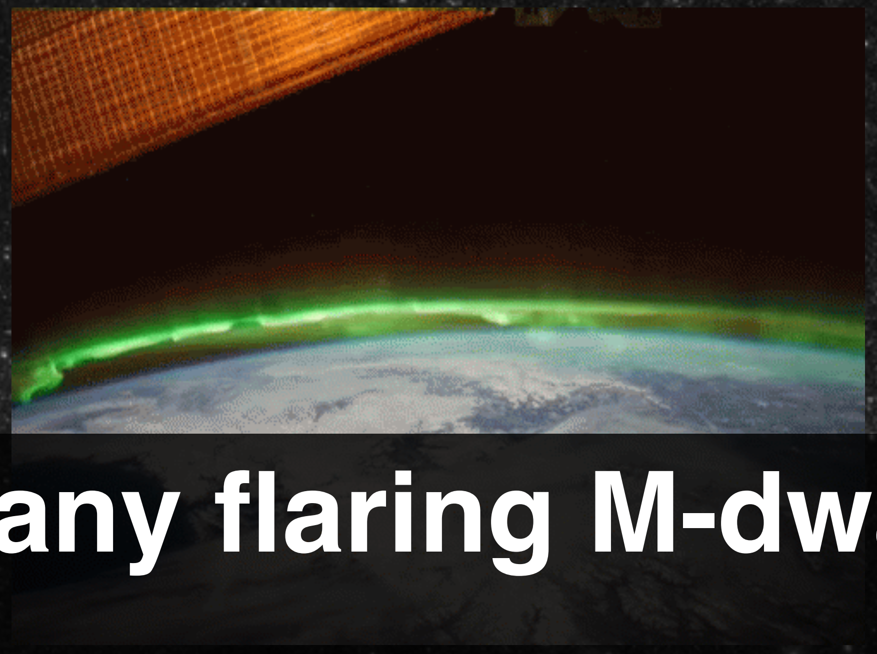
+



+

Evryscope

SOAR

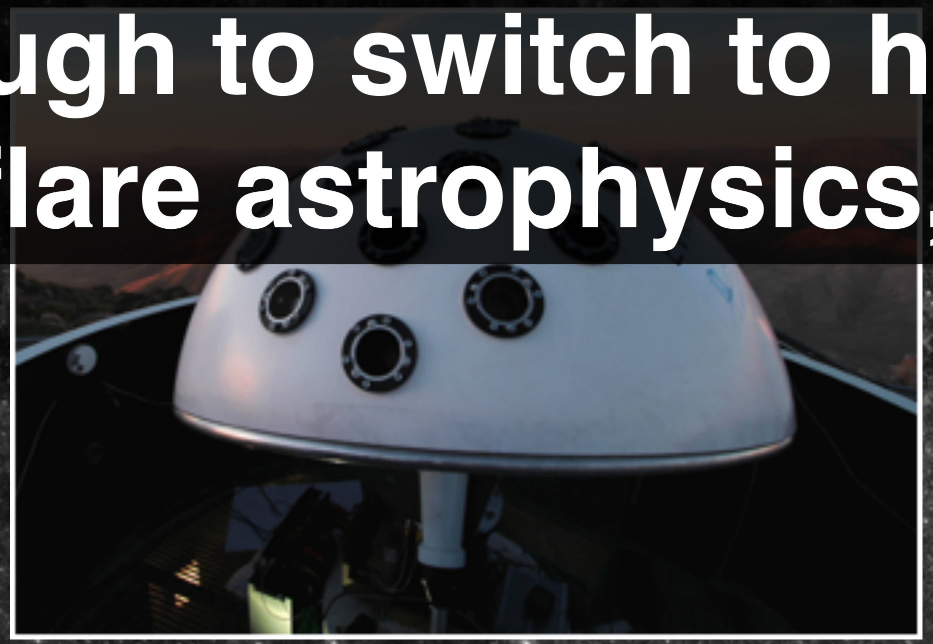


Not limited to known planet hosts: any flaring M-dwarf is good

Planets need not be transiting: can detect or characterize new planets

Rapid follow-up: can capture flare astrophysics in early stages of flare

Flexible enough to switch to high-res mid-flare: can start in low-res for overall flare astrophysics, then switch to high-res for aurorae



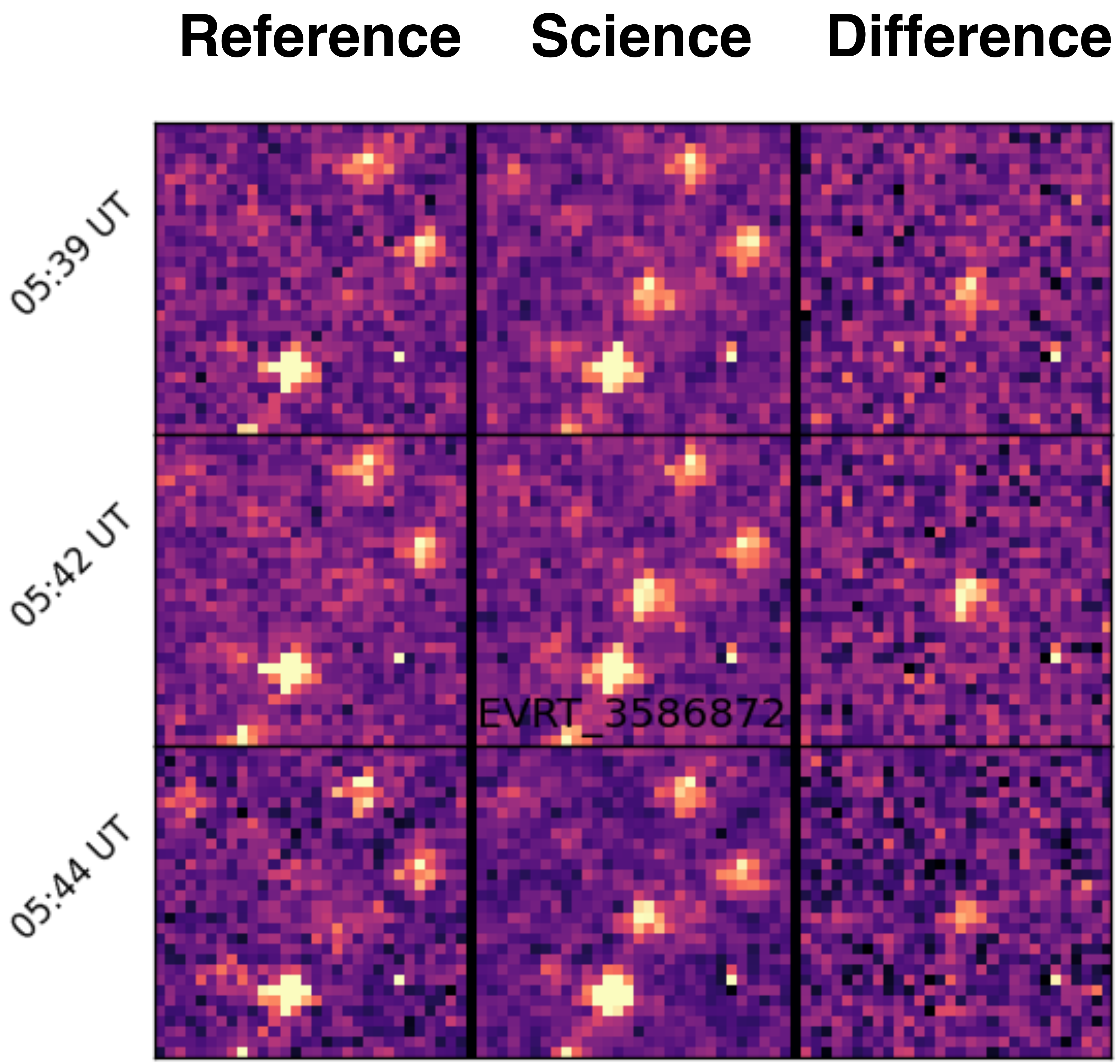
Evryscope

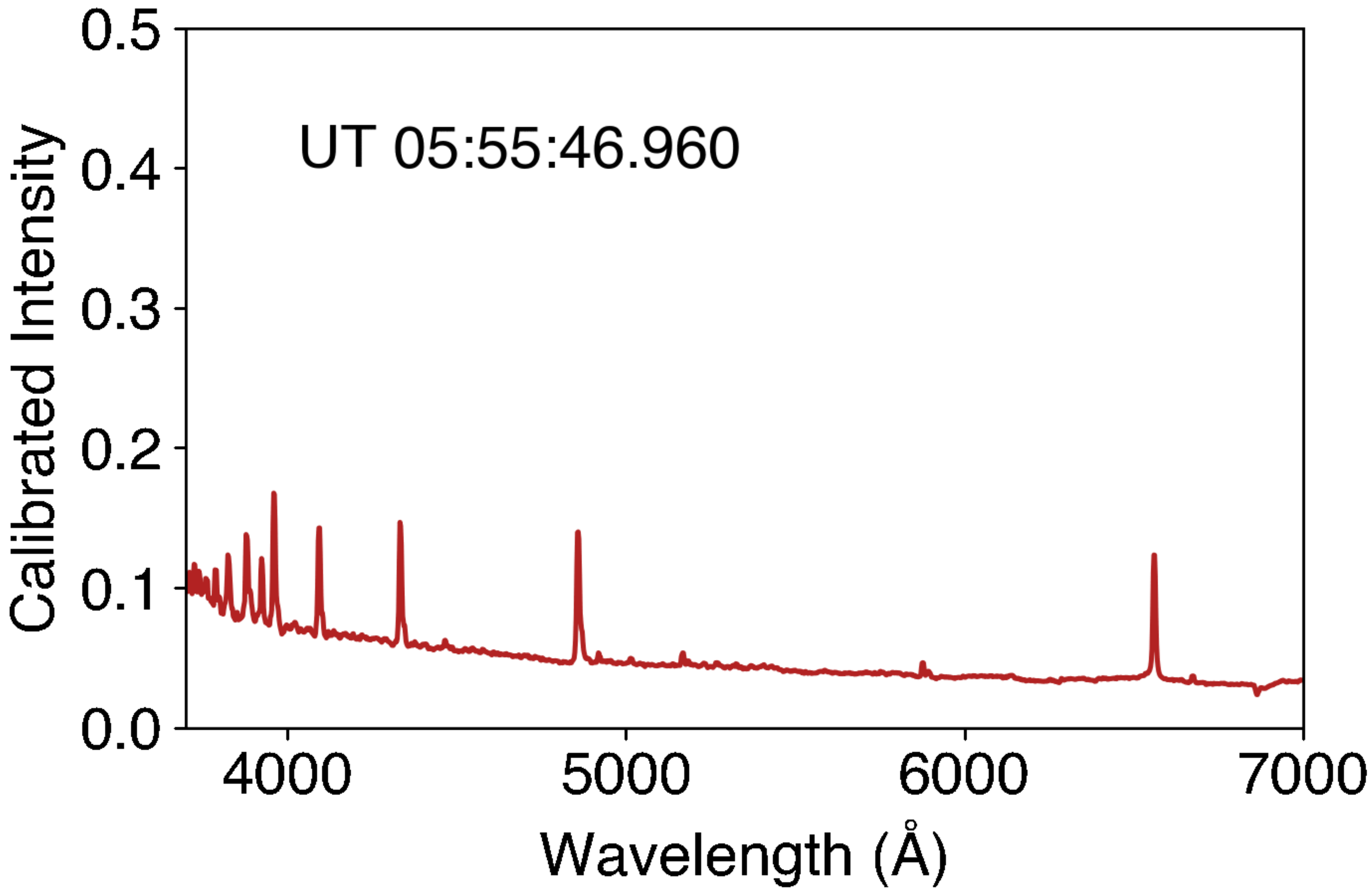
SOAR

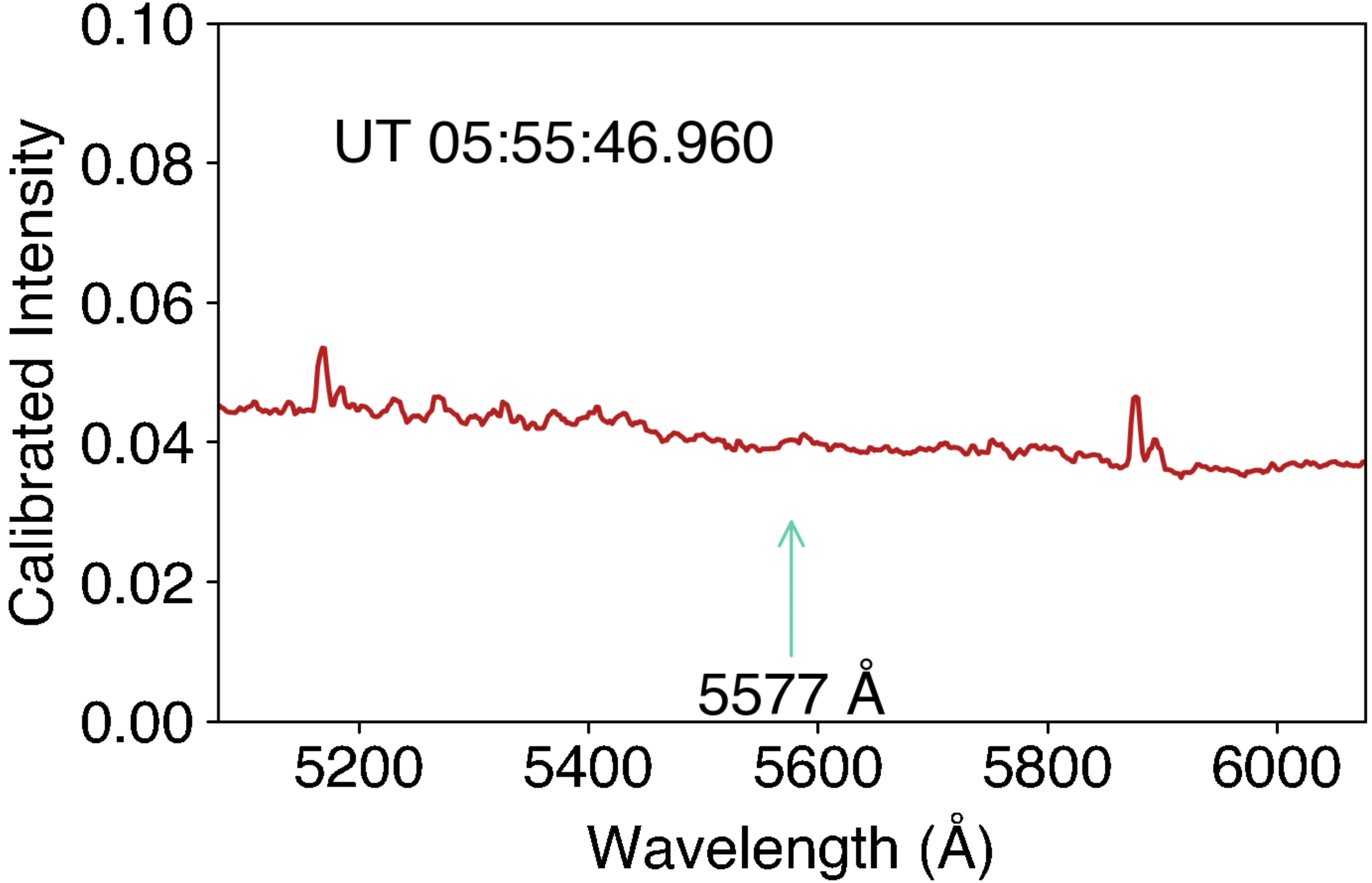
One of our first flares!

EVRYSCOPE

- February 14, 2020
- Early-to-mid M-dwarf
- On target within 15 minutes




UT 05:55:46.960
Calibrated Intensity
0.0
0.1
0.2
0.3
0.4
0.5
4000
5000
6000
7000
Wavelength (Å)

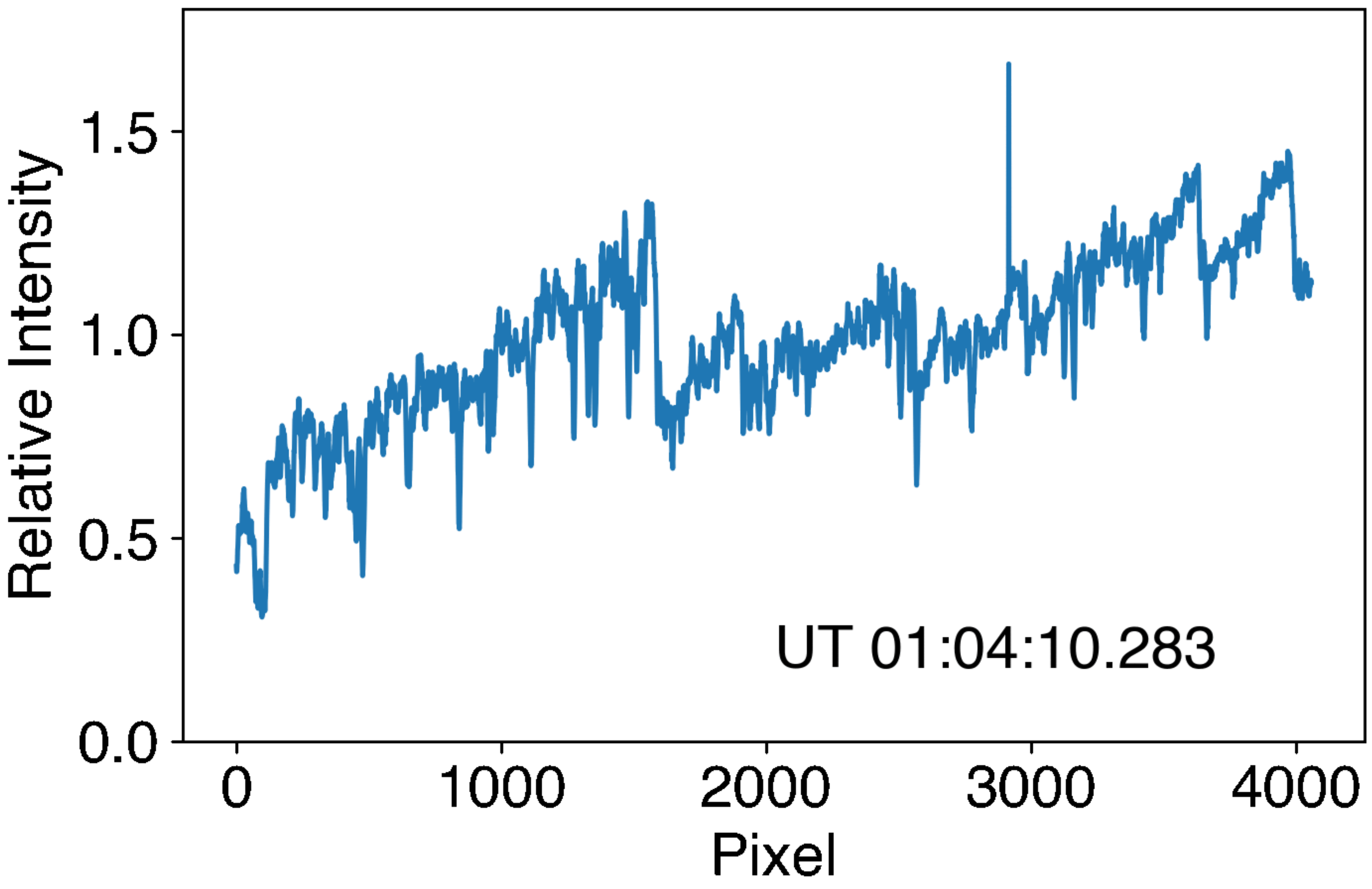

UT 05:55:46.960
Calibrated Intensity
0.10
0.08
0.06
0.04
0.02
0.00
5577 Å
5200
5400
5600
5800
6000
Wavelength (Å)

• November 24, 2020

• Non-flaring star, M-dwarf binary

• Higher resolution spectrum shows more promise—maybe even higher resolution necessary

• **Currently awaiting dark nights!**



Superflares affect M-dwarf exoplanets' habitability—and associated particle events can induce exo-aurorae

Evryscope superflare detections + rapid spectroscopic follow-up unlock capabilities for detecting exo-aurorae

Questions?

Amy Glazier
aglazier@unc.edu