ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY

JcUVa

Arizona State University

Probing M Dwarf Flares with Far Ultraviolet Spectroscopy

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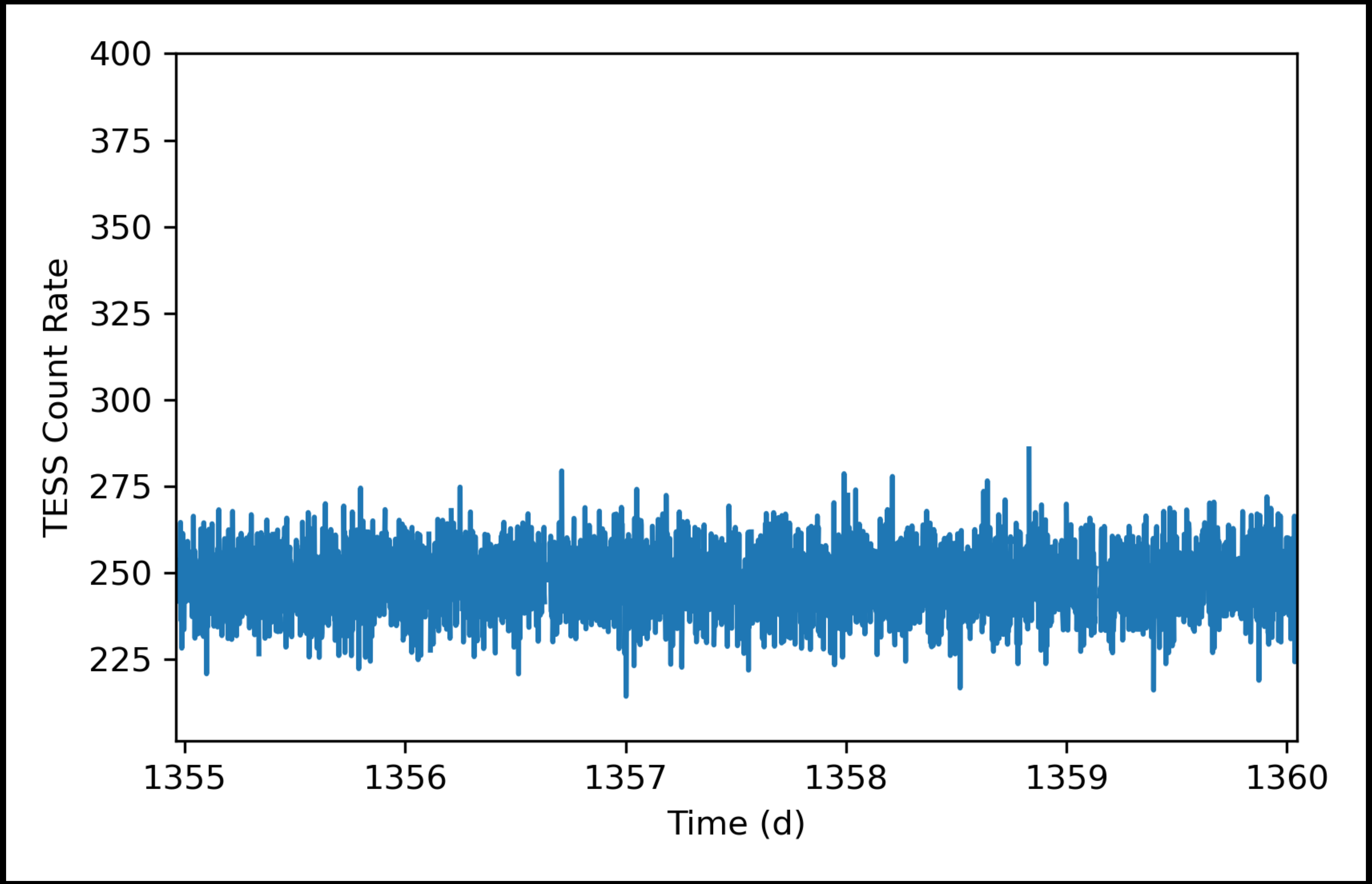
These choice results are the fruit of several large, collaborative efforts!

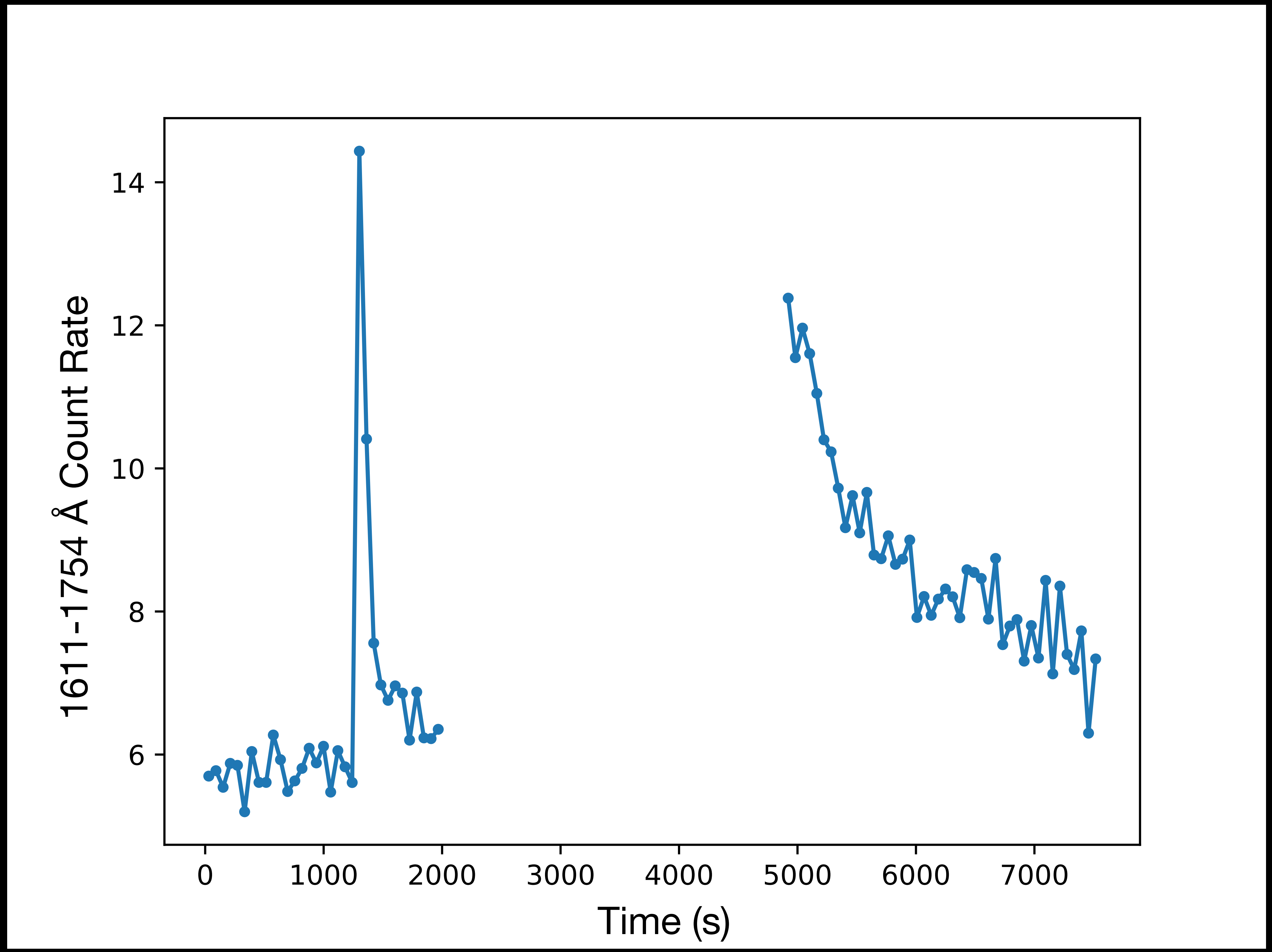
This “poster” aggregates some key results of several programs I have had the good fortune to work on:

- MUSCLES, (begun by France et al. (2014), flare results in Loyd et al. (2018b))
- HAZMAT, (begun by Shkolnik et al. (2014), flare results in Loyd et al. (2018a))
- Multi-wavelength Proxima Centauri observational campaign, MacGregor et al. (2020 in prep)

Common (several per day) M dwarf flares are much easier to detect in the UV than the optical.

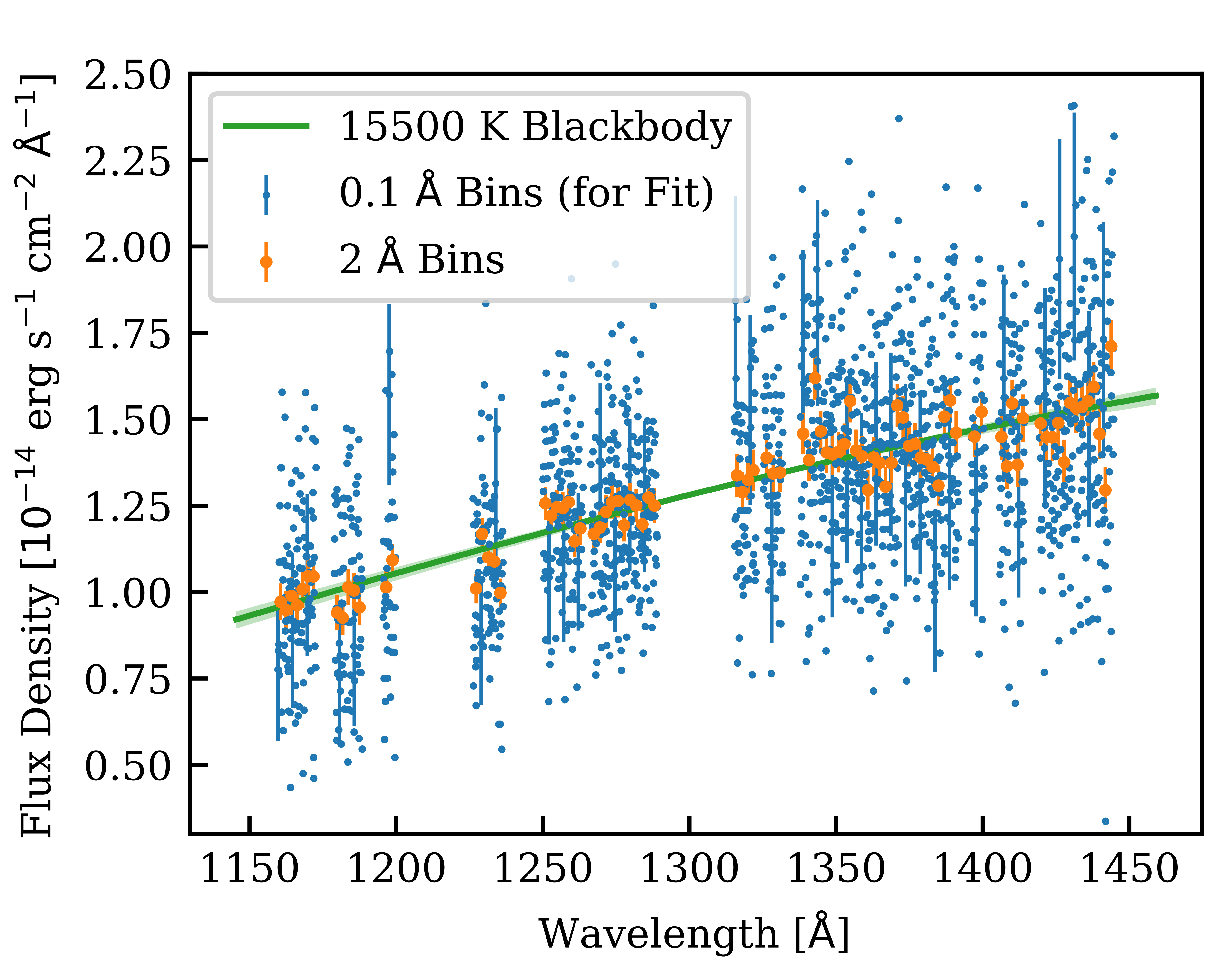


In 27 d of *TESS* observations, the M dwarf planet host GJ 887 looked entirely quiescent (Jeffers et al. 2020).



Yet in just a few hours of far UV observations of HST, the same star looked like this (Loyd et al. 2020b).

Time-resolved UV spectroscopy has revealed that continuum (“white light”) emission from strong M dwarf flares can reach temperatures of 15,000 - 40,000 K (Loyd et al. 2018a, Froning et al. 2019, MacGregor et al. 2020), exceeding previous constraints from U band spectroscopy (e.g. Kowalski et al. 2016).

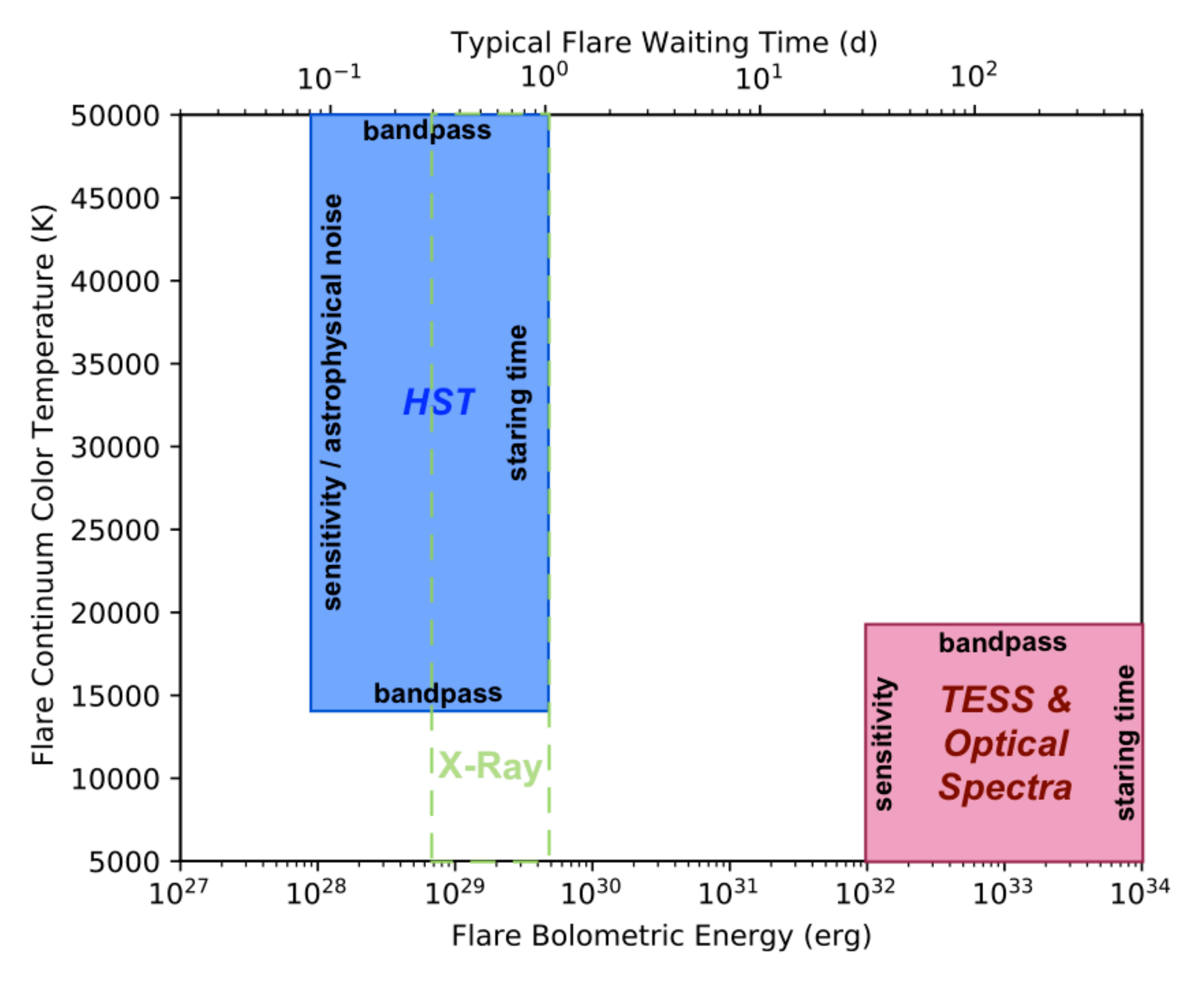


Right: *Fit to continuum emission from the “Hazflare” (Loyd et al. 2018a).*

UV observations provide a unique discovery space for M dwarf flares in energy, occurrence rate, and color temperature.

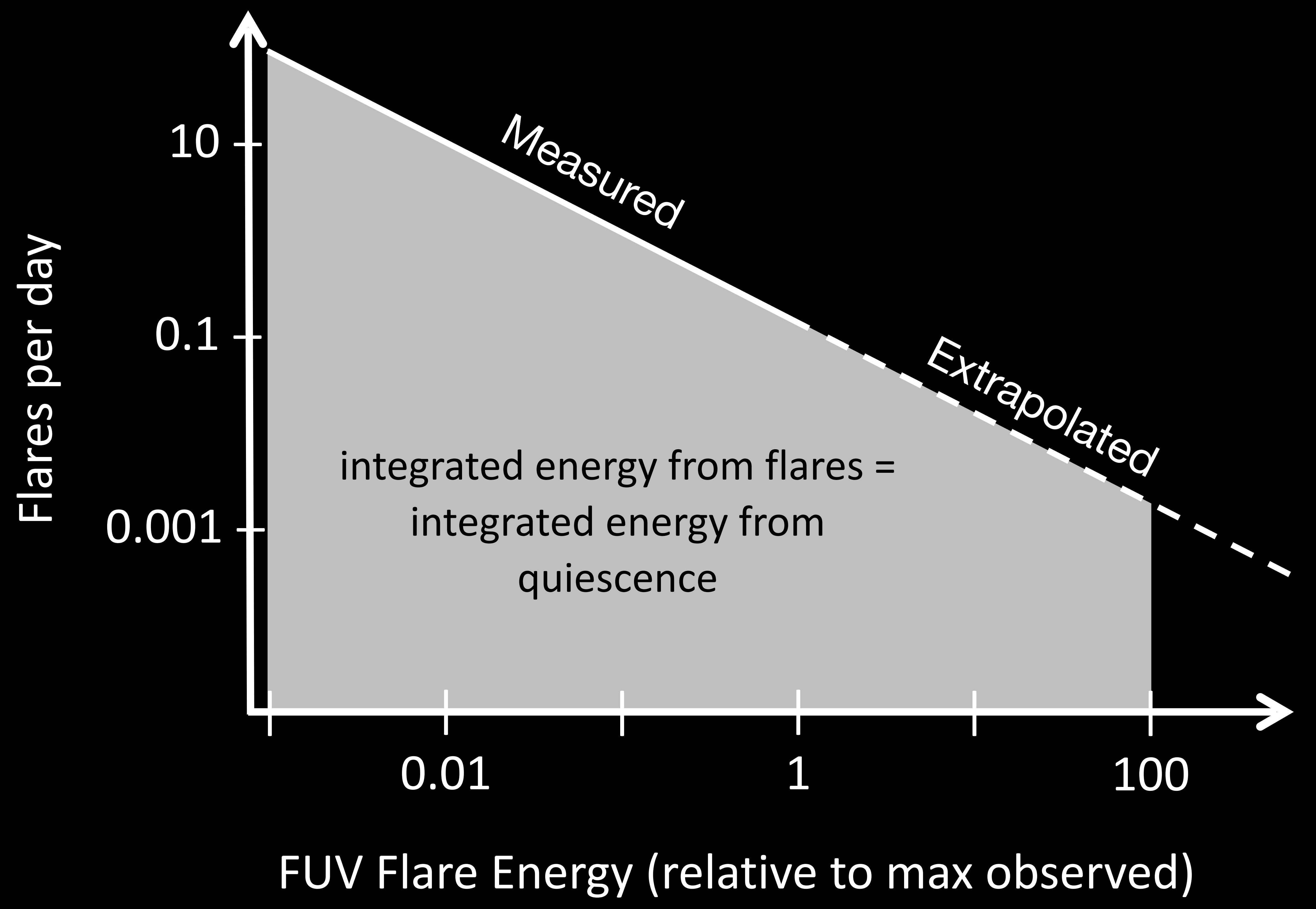
Right: (Very) Approximate boundaries of M dwarf flare discovery space in the X-ray, UV, and optical/IR.

The optical sensitivity limit is typical of TESS (Günther et al. 2020) and the X-ray sensitivity is based on observations presented in Loyd et al. (2018b). Note that X-ray data do not constrain the continuum color temperature and waiting times are for a field age M dwarf.



Flares could be responsible for more far UV emission from M dwarfs at all ages than quiescent emission alone (Loyd et al. 2018a,b).

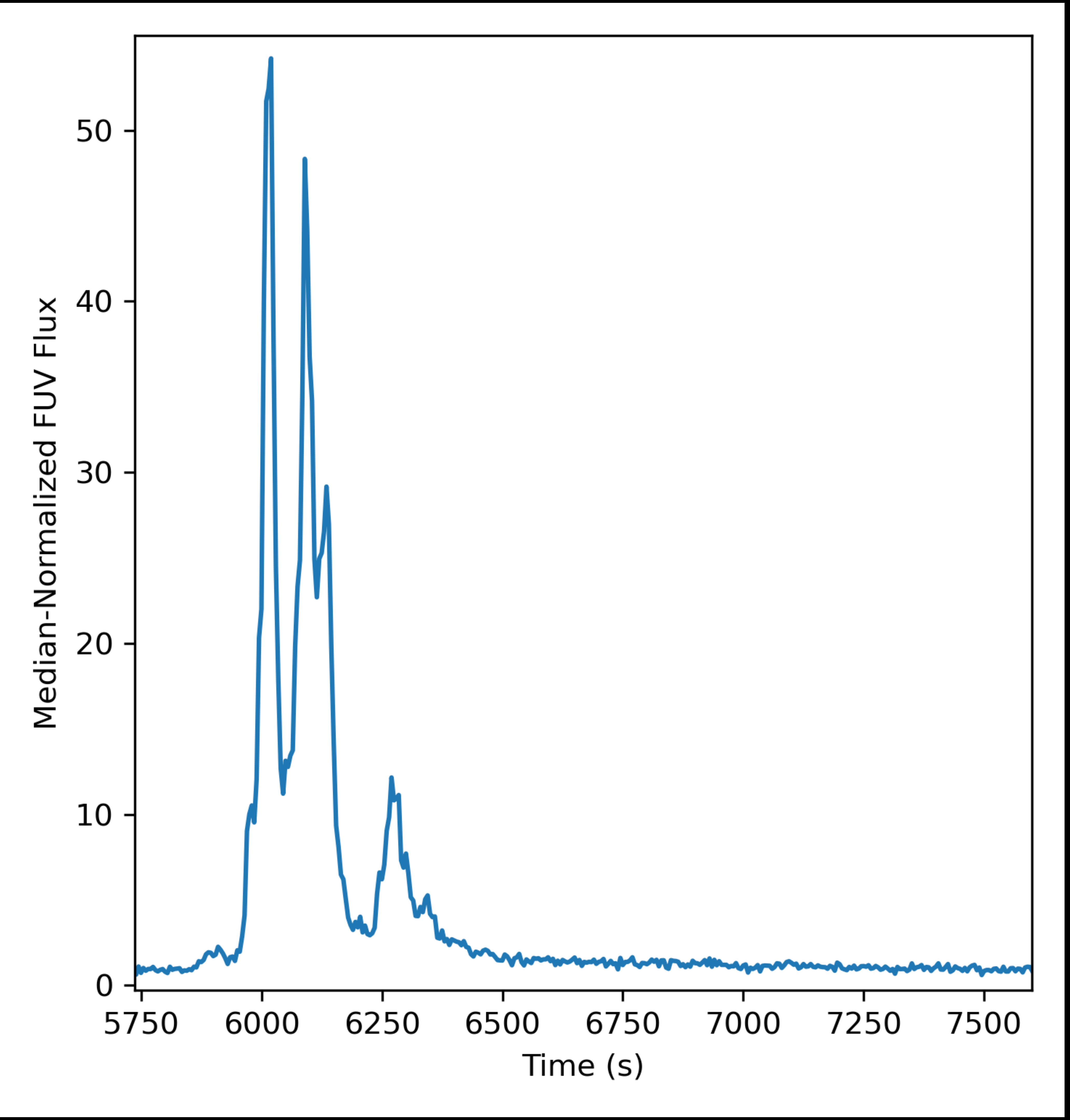
Far UV photons drive photochemistry in planetary atmospheres, meaning this “missing” UV emission could have important chemical consequences to the thin atmospheres of rocky planets.



Loyd et al. 2018b

On young, activity-saturated M stars, EUV emission that closely traces the FUV emission of superflares like the Hazflare shown to the right could thermally erode an Earth-like atmosphere on timescales of hundreds of Myr (Loyd et al. 2018a).

On top of this, flare-enhanced atmospheric loss from nonthermal mechanisms like ion pickup can be even more effective, capable of stripping a 1-bar atmosphere from planets orbiting even some of the oldest M dwarfs (France et al. 2020).



Takeaways

- UV observations can probe weaker and potentially hotter flares than optical and IR observations.
- For M dwarfs, flares could be responsible for emitting more far-UV photons than quiescence.
- M dwarf flares are likely a key factor in the retention and chemistry of exoplanet atmospheres.