NOT-SO-RED DAWN OF RED DWARF

FLARE MODEL TO STUDY EXOPLANET ATMOSPHERES

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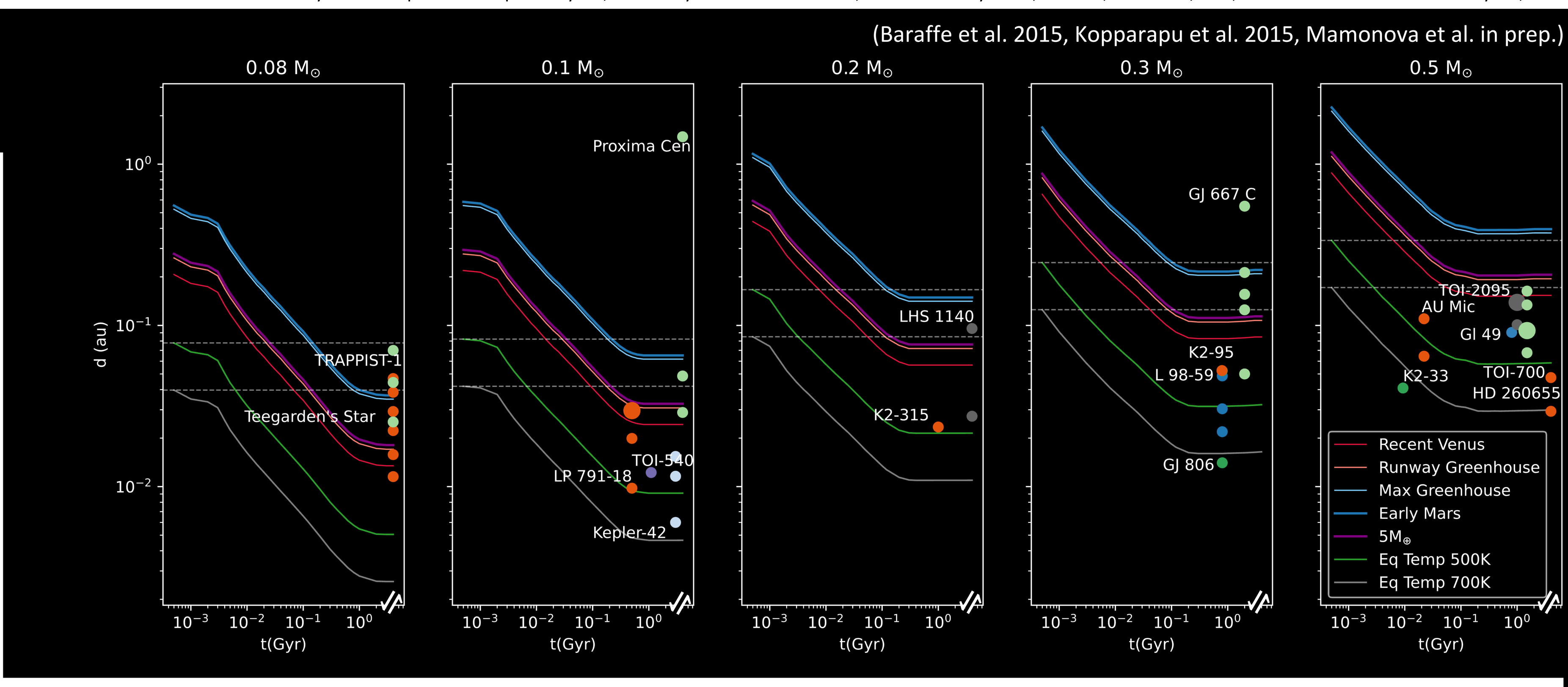
BACKGROUND

40% OF M DWARF STARS COULD HAVE A PLANET OR PLANETS IN THE HABITABLE ZONE:
Current observational biases favour dim stars for detecting short–period transiting planets. M stars' abundance makes them preferential targets in the hunt for habitable worlds.

(Baraffe et al. 2015, Kopparapu et al. 2015, Mamonova et al. in prep.)

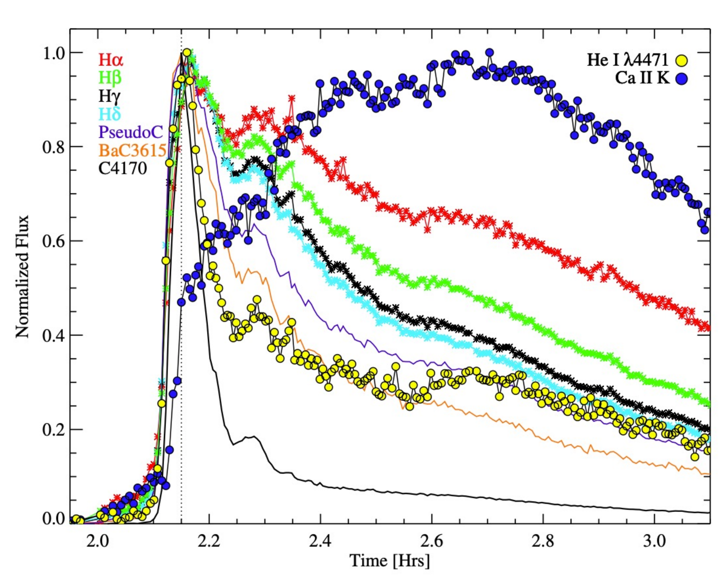


Evolutionary model of habitable zone movement for M dwarfs

IF M STARS CAN HOST HABITABLE WORLDS IS AN OPEN QUESTION :
Stars of that type have strong chromospheric activity and frequently produce flares. Flaring may alter and erode planetary atmospheres but it may also deliver the UV radiation necessary to facilitate prebiotic chemistry processes. UV radiation is otherwise negligible in these stars.

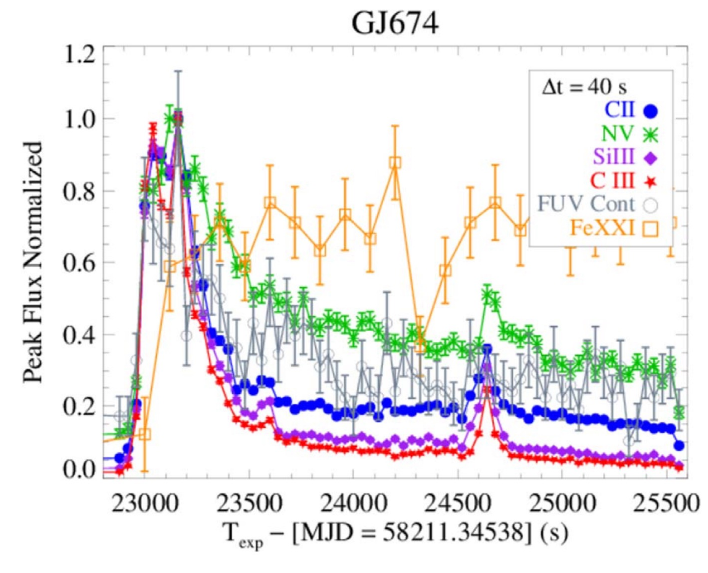
M DWARF FLARES ARE SPECTRALLY AND TEMPORALLY COMPLICATED

(Kowalski et al. 2013)



Flare evolution in several optical lines

(Froning et al. 2019)



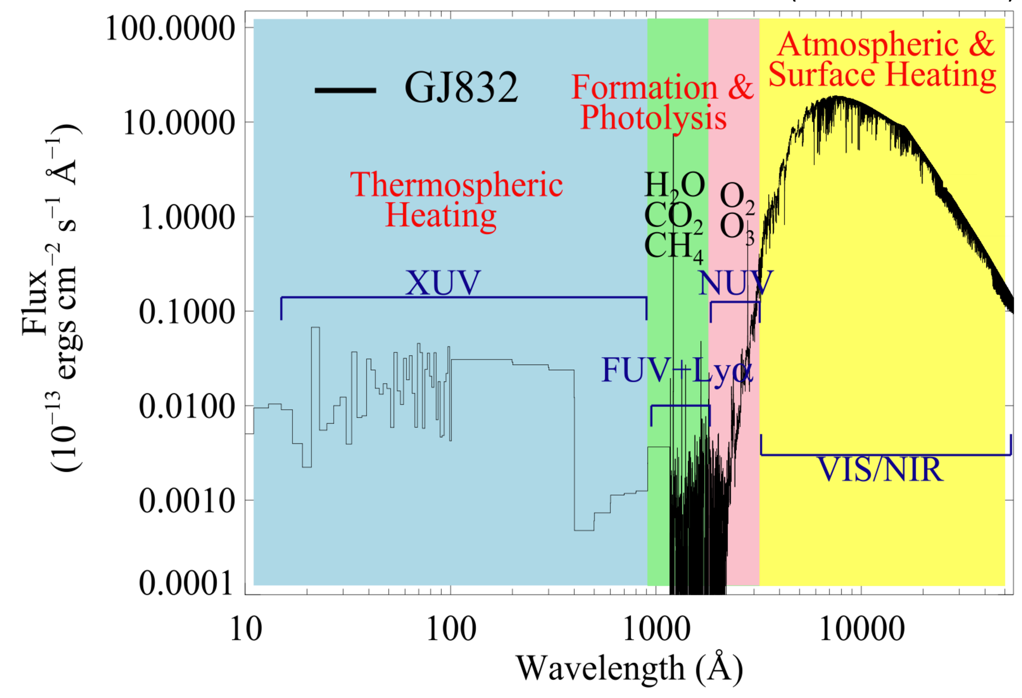
Flare evolution in several FUV lines

FLARES OBSERVED IN SPECTRAL DOMAIN :
Most X-ray and UV flare observations have been limited to single targets such as the panchromatic flare data AD Leo and EV Lac. MUSCLES survey used HST UV spectra and X-ray SED (Chandra + XXM) of 11 M/K dwarf planet hosts, and characterized several key FUV emission lines.

FLARES OBSERVED IN TEMPORAL DOMAIN :
Visible wavelength range observations recently benefited from long–period missions, such as Kepler and TESS.

HOW STELLAR HIGH-ENERGY ENVIRONMENT AFFECTS PLANETS

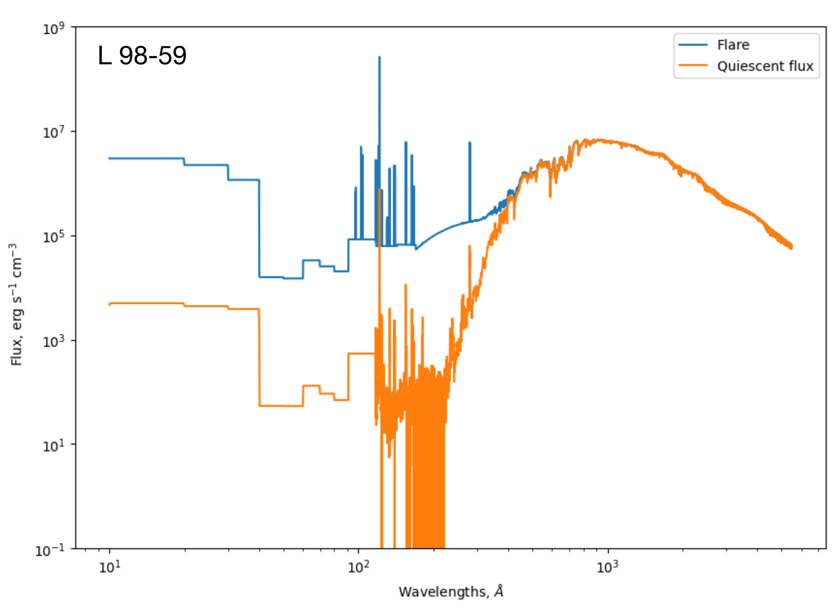
(France et al. 2016)



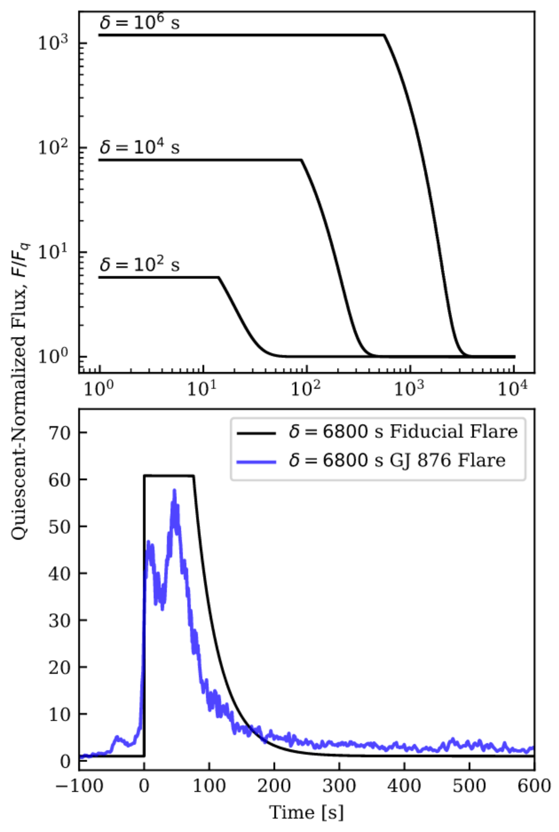
TEMPORALLY RESOLVED MODEL OF FLARE ACTIVITY OF M-DWARF HOST STAR

PREVIOUS WORK

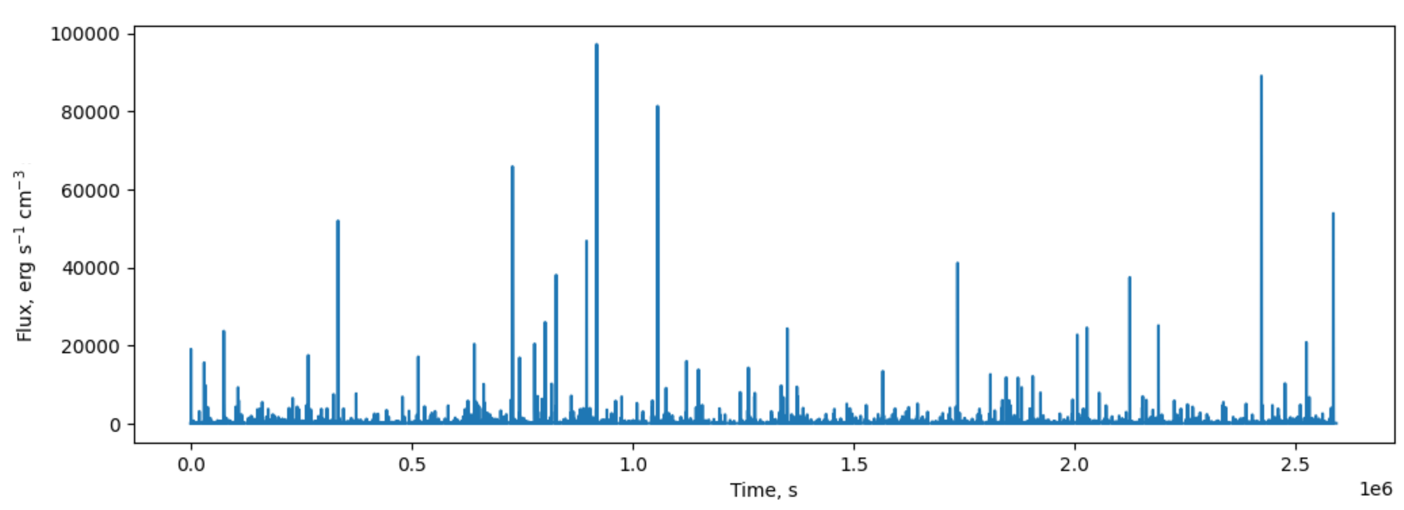
Simulated flare spectra based on MUSCLES observations, roughly scaling relations for emission lines



(Loyd et al. 2018)

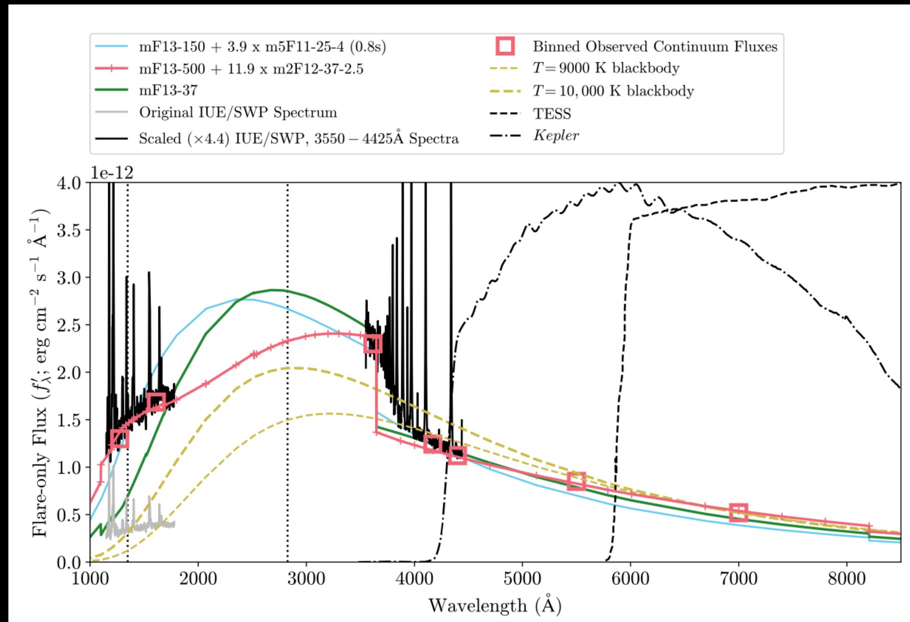


'FIDUCIAL FLARE' MODEL:
Spectre: Observed and unobserved FUV+ Blackbody+ approximate the contribution of the EUV to flares using observations of FUV transition-region emission.
Temporal model of a flare: a boxcar followed by an exponential decay.
FFD and Light curves: A power-law fit to the cumulative FFD of flares aggregated from all stars has an index of −0.76, large flares are energetically more important than small ones.



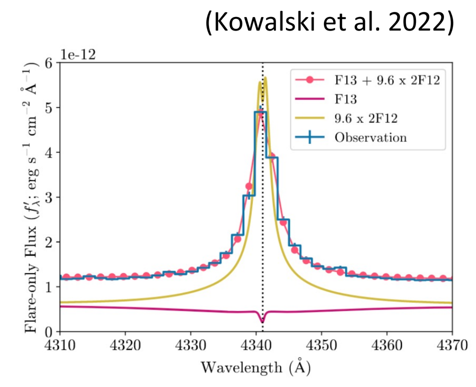
Light curves are based on measured flare statistics

THIS WORK

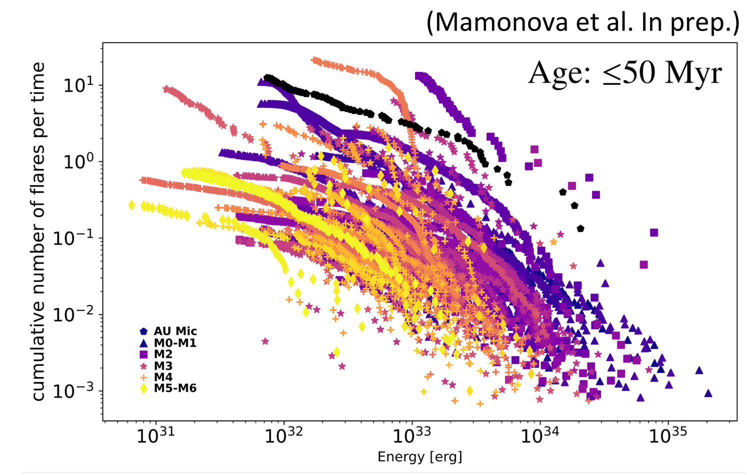


Models of the early-impulsive phase of the Great Flare of AD Leo

(Kowalski et al. 2022)



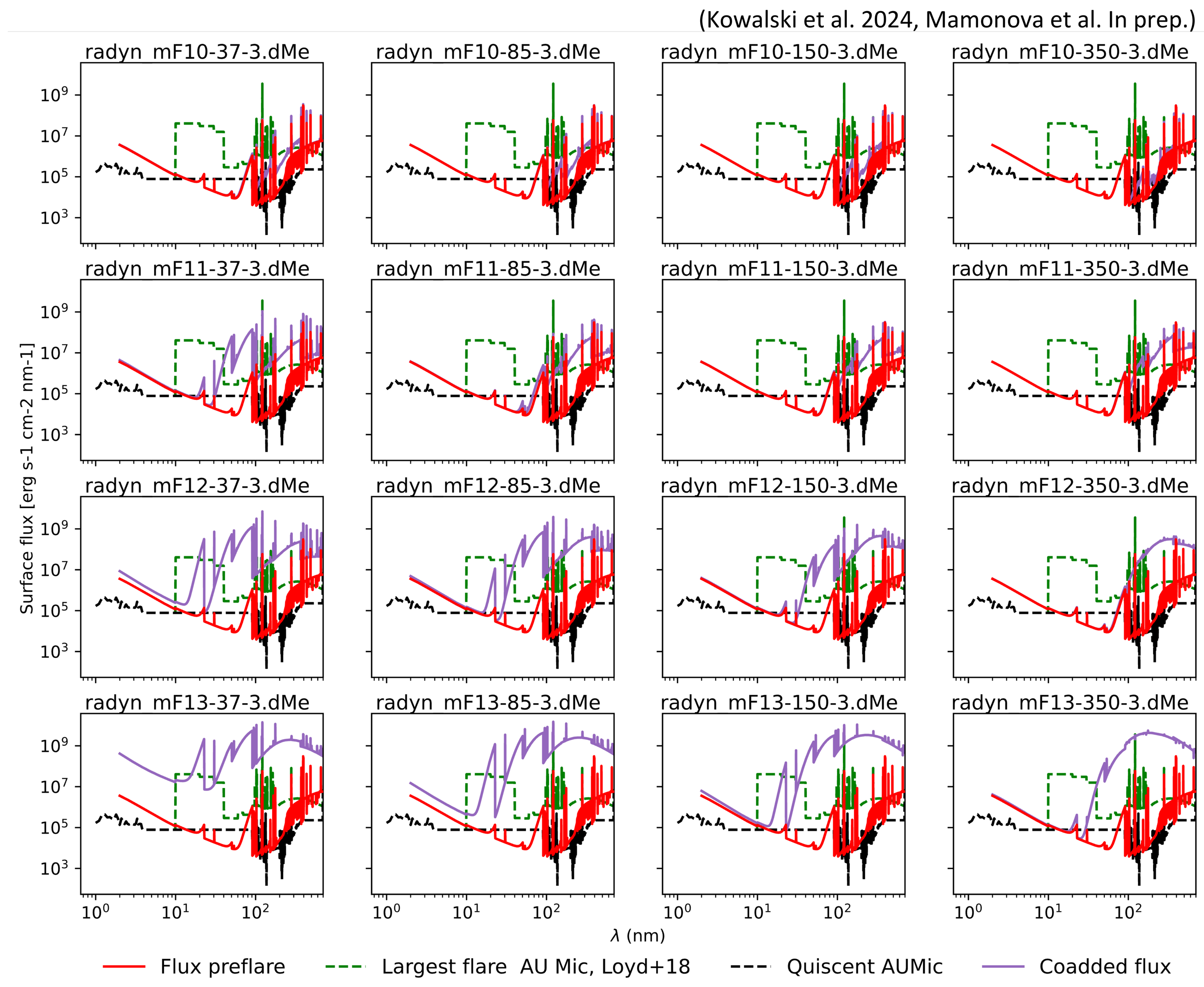
(Mamonova et al. In prep.)



Flare energy distribution for YMG sample of M dwarfs

'YMDF', YOUNG M DWARF FLARE MODEL:
Spectre: the stellar atmosphere models overcome the lack of flare observational constraints <120nm and 180 – 350nm. The physical process modelling is based on solar observations. Models are validated by comparing with flare temporal profiles and spectral line shapes in M dwarf flare observations.
Temporal model of a flare: can be based on differences in small and large flare events observed in Kepler and TESS photometry
FFD and Light curves: We obtained a sample of M dwarfs in Young Moving Groups. Cumulative FFDs show underestimation in the frequency of flares with energies of approximately 10^{32} erg/s for late M dwarfs and 10^{33} erg/s for early M dwarfs

(Kowalski et al. 2024, Mamonova et al. In prep.)



Grid of atmosphere models for reproducing flares in AU Mic

References: Baraffe I., Homeier D., Allard F., Chabrier G., 2015, A\&A, 577, A42. doi:10.1051/0004-6361/201425481; Kopparapu R., Wolf E.T., Haqq-Misra J., Jun Y., Kasting J., Mahadevan S., Terrien R., 2015, ESS; Kowalski A.F., Hawley S.L., Wisniewski J.P., Osten R.A., Hilton E.J., Holtzman J.A., Schmidt S.J., et al., 2013, ApJS, 207, 15. doi:10.1088/0067-0049/207/1/15; Froning C.S., Kowalski A., France K., Loyd R.O.P., Schneider P.C., Youngblood A., Wilson D., et al., 2019, ApJL, 871, L26. doi:10.3847/2041-8213/aaffcd; Loyd R.O.P., France K., Youngblood A., Schneider C., Brown A., Hu R., Segura A., et al., 2018, ApJ, 867, 71. doi:10.3847/1538-4357/aae2bd; France K., Loyd R.O.P., Youngblood A., Brown A., Schneider P.C., Hawley S.L., Froning C.S., et al., 2016, ApJ, 820, 89. doi:10.3847/0004-637X/820/2/89; Kowalski A.F., 2022, FrASS, 9, 351. doi:10.3389/fspas.2022.1034458; Kowalski A.F., Allred J.C., Carlsson M., 2024, arXiv, arXiv:2404.13214. doi:10.48550/arXiv.2404.13214; Mamonova et al. (in prep).

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