A study of flares on EV Lacertae using simultaneous multi-wavelength data

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Abstract

We present the first results from our large program studying nearby active flaring M dwarfs using multi-wavelength datasets. We focus on the flaring M dwarf EV Lac, which has been known as a flare star for at least 65 years. We acquired data of EV Lac using 5 different observatories: NASA's TESS mission, NASA's Neil Gehrels Swift Observatory (*Swift*), NASA's Neutron Interior Composition Explorer (NICER) and two ground based telescopes (University of Hawaii 2.2-m (UH88) and Las Cumbres Observatory Global Telescope (LCOGT) Network), to span a comprehensive, simultaneous wavelength coverage of flaring events. We identified 56 flares in the TESS light curve, 9 flares in the *Swift UVM2* light curve, 14 flares in the NICER X-ray light curve, and 1 flare in the LCOGT light curve. However, we did not identify flares in the *Swift* XRT light curve or UH88 spectrum. We find that the FFDs of TESS and NICER flares have comparable slopes, β_T = -0.67±0.09 and β_N = -0.65±0.19, and that the FFD of UVOT flares has a shallower slope (β_U = -0.38±0.13). Our results will be useful to model and estimate the impacts of strong flares on the atmospheres of planets orbiting M dwarfs.

About EV Lacertae (GJ 873, LHS 3853

- It is a young dM3.5e star at a distance of 5.05 pc.
- Its age is estimated to be in the range of 125 - 800 Myr.
- It has very strong magnetic field of ∼4 kG, and covers >50% of the stellar surface.
- It is known to produce flares frequently in X-ray, UV, optical and radio wavelengths.

TESS light curve

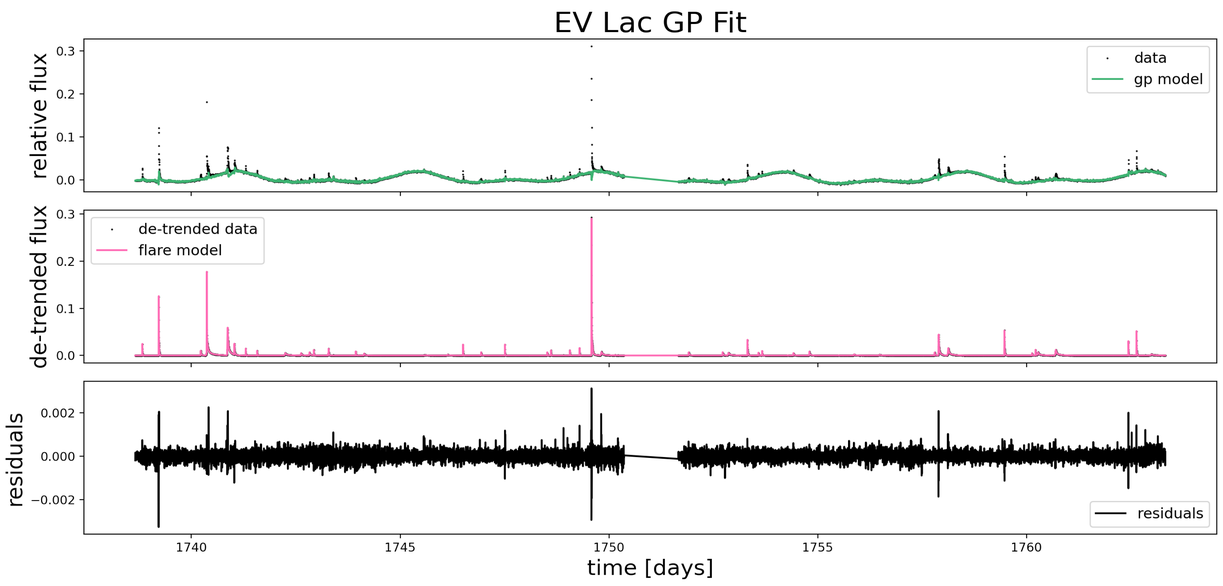

Figure: TESS light curve obtained during Sector 16 (11 Sep, 2019 - 07 Oct, 2019). The top panel shows the raw light curve (black) and spot rotation fit (green). The middle panel shows the detrended light curve after subtracting the variable feature induced by spots. We overplot flare model (pink). The bottom panel shows the residual plot obtained after subtracting both rotation and flare model from raw light curve. We identify 56 flares in this light curve (Paudel et al. 2021, submitted).

NICER X-ray light curve

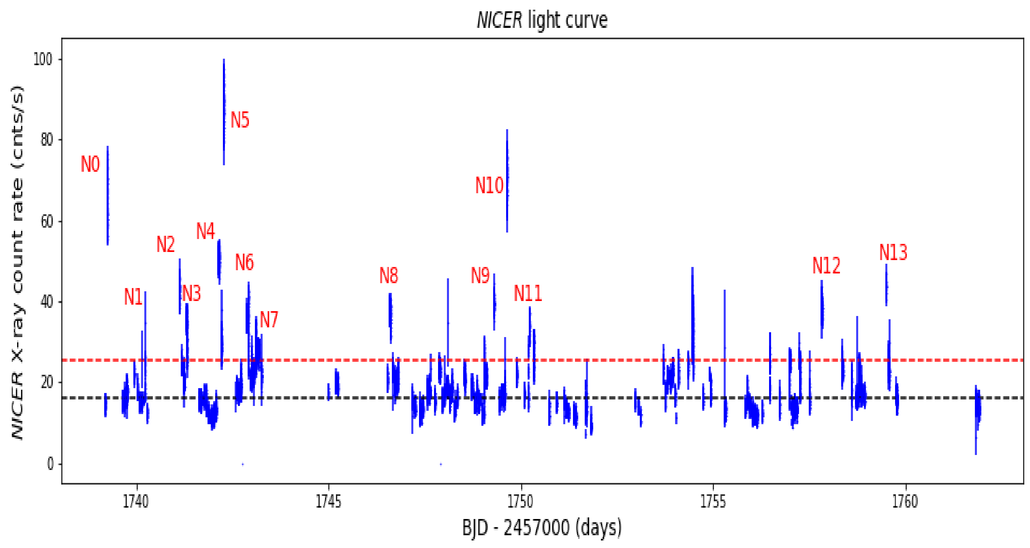

Figure: NICER X-ray light curve of EV Lac obtained simultaneously with TESS. The total exposure time is ∼100 ks. We identify 14 flares in this light curve, but none of them were observed for full duration. In this light curve, some events have single point brightening or are due to background signal. The black dashed horizontal line corresponds to the quiescent level (M_N), and the red dashed line corresponds to M_N+2.5σ value of count rate (Paudel et al. 2021, submitted).

Swift X-ray light curve

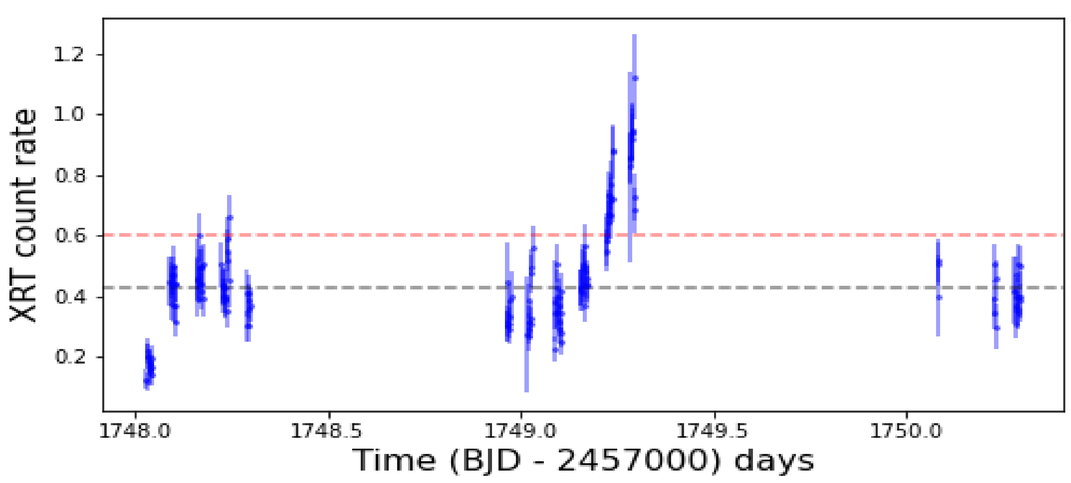

Figure: *Swift* XRT lightcurve of EV Lac obtained simultanously with TESS. The cadence size is 120 s and the total exposure time is ∼40 ks. The black and red dashed lines correspond to median and median+1σ count rate. We cannot confirm that the increase in X-ray level at t ∼1749.3 d is due to a flare (Paudel et al. 2021, submitted).

Flares observed by *Swift*/UVOT

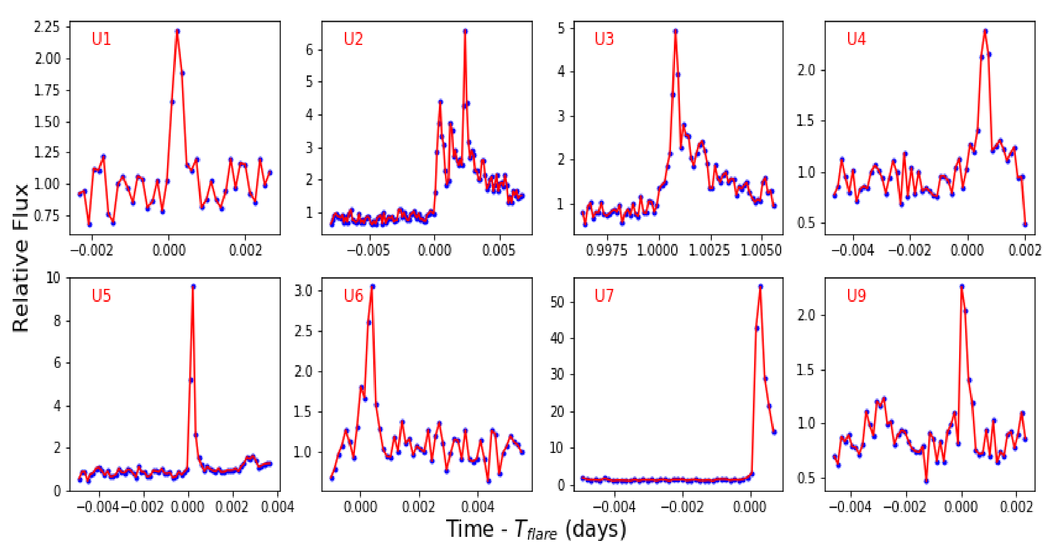

Figure: Swift/UVOT observed 9 flares during an exposure time of ∼40 ks. The blue dots in each plot represent the observed fluxes and the red line is just the connecting line. The time in the X-axis is centered at T_0 which is the TESS time when a given flare started. The cadence size is 11.033 s. One of the flares (U8) whose decay only phase was observed is not shown here (Paudel et al. 2021, submitted).

Comparison of FFDs in X-ray, UV and optical wavelengths

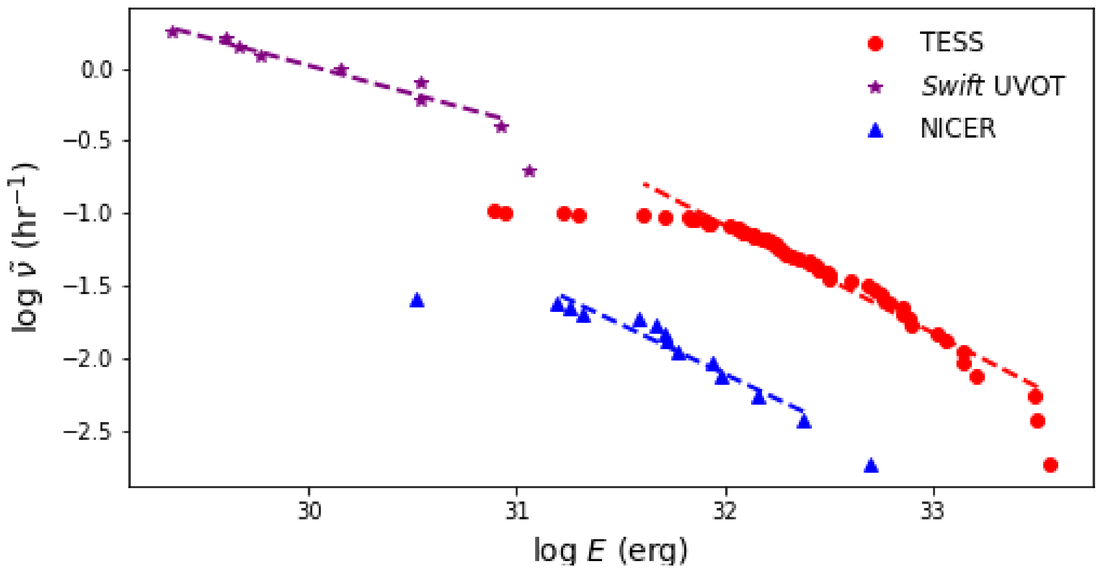

Figure: Comparison of FFDs of flares observed by TESS (red), NICER (blue), and *Swift*/UVOT (purple). The dashed lines represent the fitted line corresponding to the power-law distribution of flares in a given band. The NICER X-ray flare energies are just the lower limits because the flares were not observed for full duration (Paudel et al. 2021, submitted).

Conclusions

- We identified 56 white light flares in the TESS light curve, with estimated energies in the range log E_T (erg) = (30.5 - 33.2). We identified 9 UV flares in the *Swift*/UVOT light curve, with estimated energies in the range log E_{UV} (erg) = (29.3 - 31.1). 3 of the UV flares were not observed for full duration. Likewise, we identified 14 X-ray flares in the NICER light curve, with estimated minimum energies in the range log E_N (erg) = (30.5 - 32.3). We also identified 1 flare in the LCOGT light curve, which has an estimated energy of log E_L (erg) = 31.6.
- We did not identify flares in *Swift* X-ray light curve and UH88 spectrum.
- Using least-squares fitting, we find that the FFDs of TESS and NICER flares have comparable slopes, β_T = -0.67±0.09 and β_N = -0.65±0.19, and that the FFD of UVOT flares has a shallower slope (β_U = -0.38±0.13.

Acknowledgement

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