Simultaneous Multiwavelength Observations of the Highly Active M Dwarf YZ CMi

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1. INTRODUCTION

YZ CMi is an 11-mag M4.5Ve highly-active flare star with a rotation period of 2.77 days located at a distance of 5.9 pc (Gaia Collaboration, 2018). As part of a larger multiwavelength campaign to monitor M-dwarfs (e.g., Paudel et al. 2021 accepted; Gilbert et al. 2021 in prep), we have obtained several observations, simultaneously with TESS optical photometry (Sector 7 & 34), that include X-ray, ultraviolet, and radio data, as well as ground-based optical observations for YZ CMi. We share our preliminary results, which will also be incorporating NICER X-ray photometry and CTIO/SMARTS 1.3-m telescope observations in a near future publication (Vega et al. in prep).

2. TESS FLARE ANALYSIS OF YZ CMI

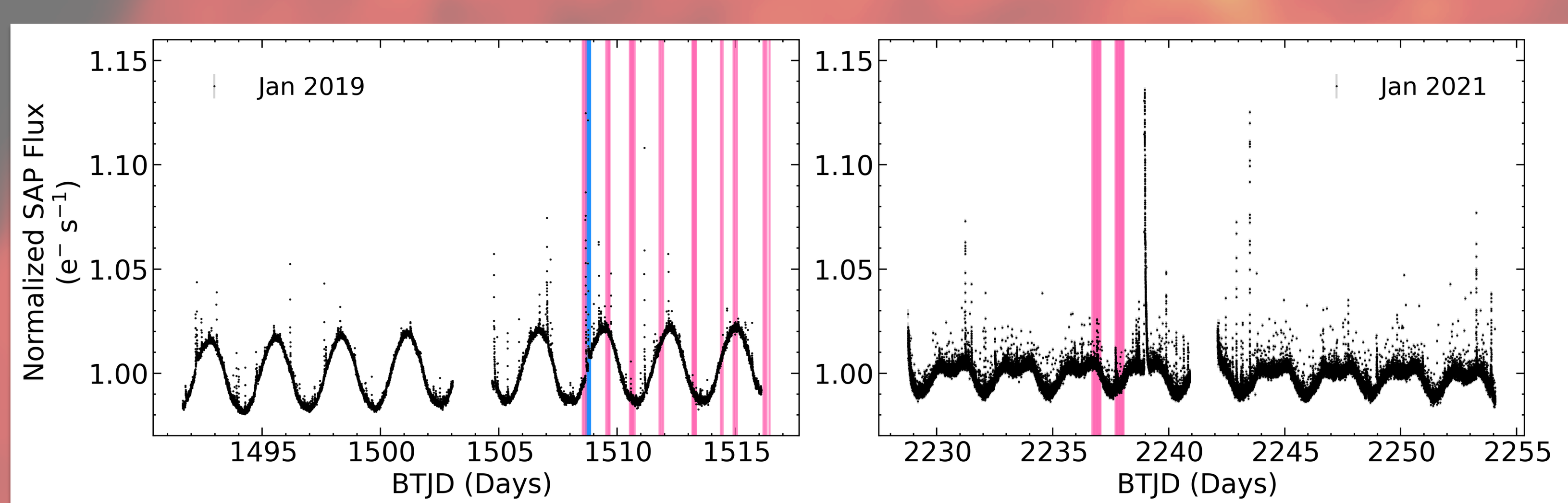
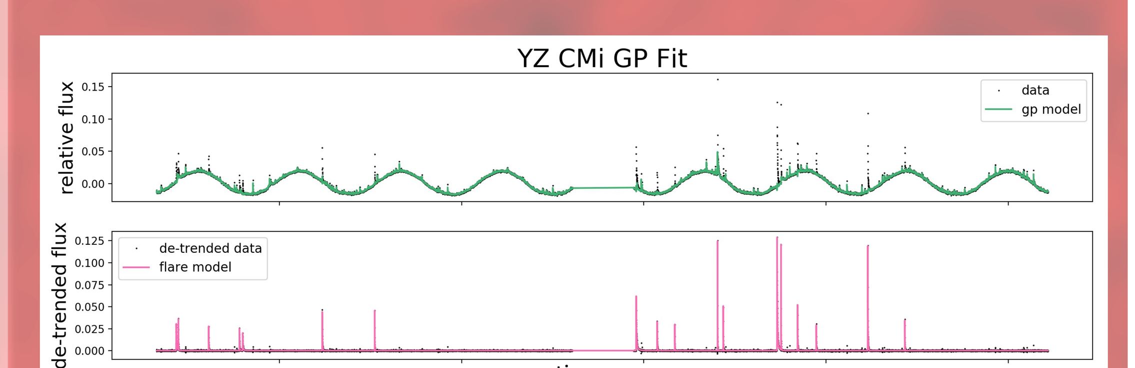
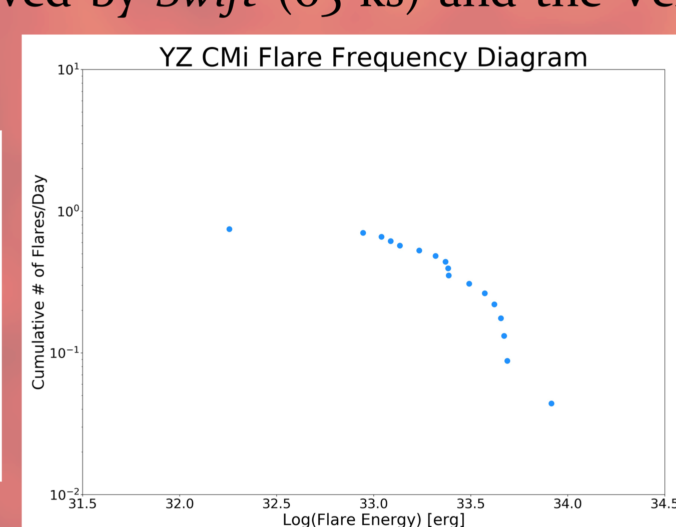


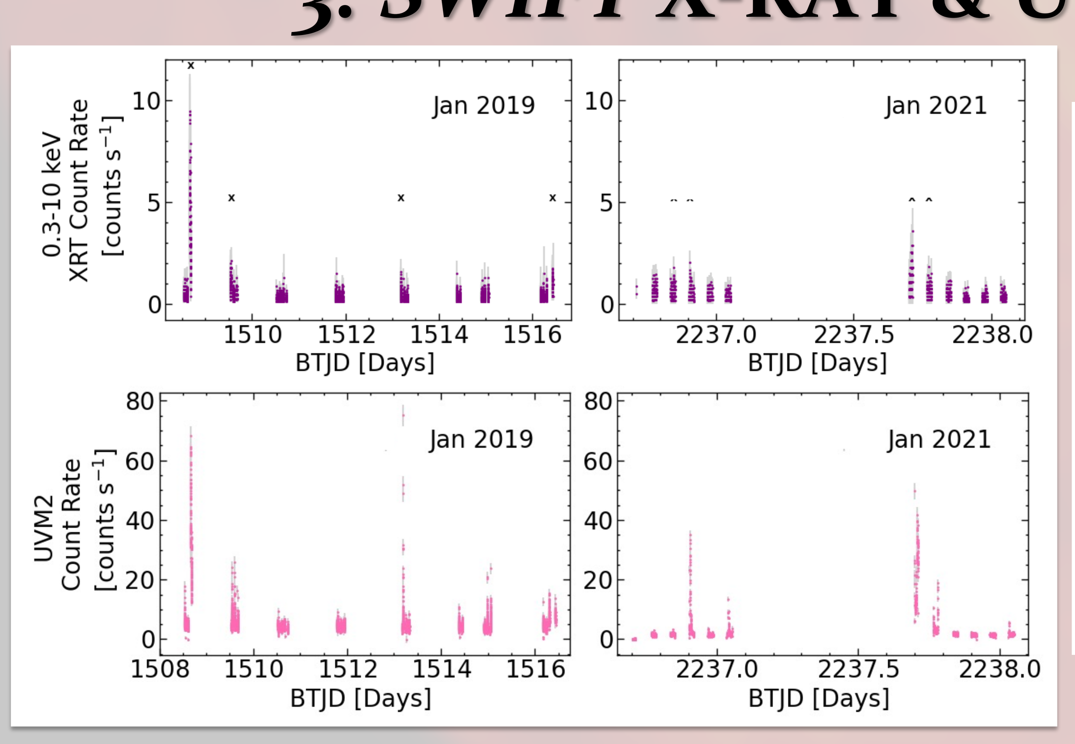
Fig: YZ CMi's TESS light curve during Sector 7 (Jan. 2019) at 2-minute cadence and in Sector 34 (Jan. 2021) at 20-second cadence, revealing spot-induced brightness changes and more-resolved flares in the 20-second cadence data. Pink and blue segments correspond to times when it was observed by *Swift* (65 ks) and the Very Large Array (5 hr), respectively.

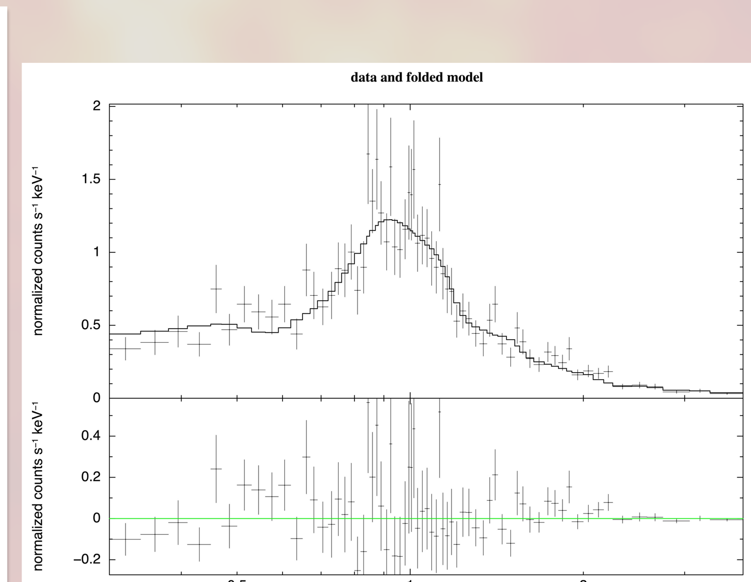




Left Fig.: First panel shows YZ CMi's TESS Sec. 7 light curve (black) and a Gaussian Process (GP) model fit of the spot modulation and long-term variability (green). Second panel shows the detrended light curve after subtracting the GP model, revealing the flares, with our flare model overplotted in pink. Right Fig.: The Flare Frequency Distribution (FFD) of YZ CMi showing 17 flares identified from our model fit in the TESS Sec. 7 optical light curve.

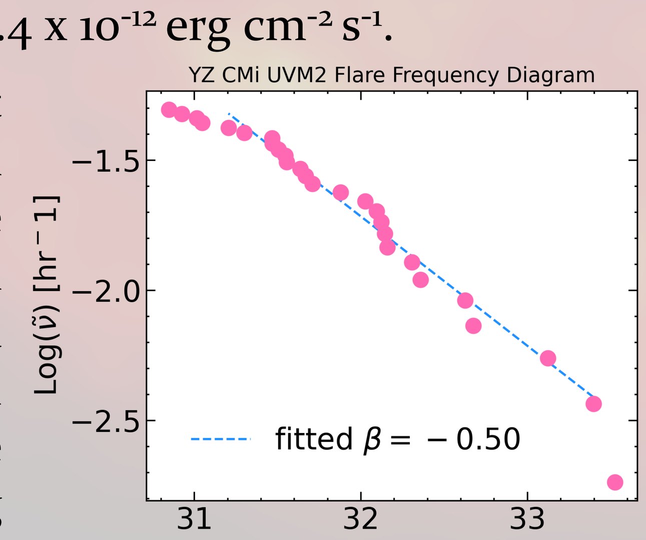
3. *SWIFT* X-RAY & UV ANALYSIS



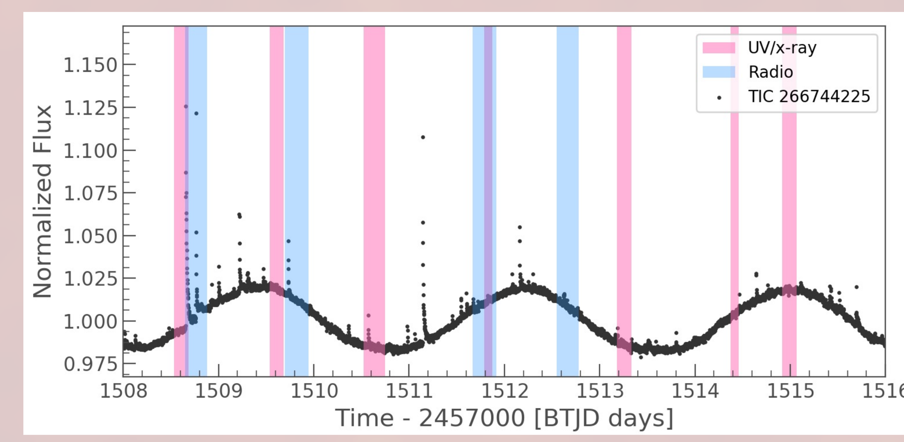


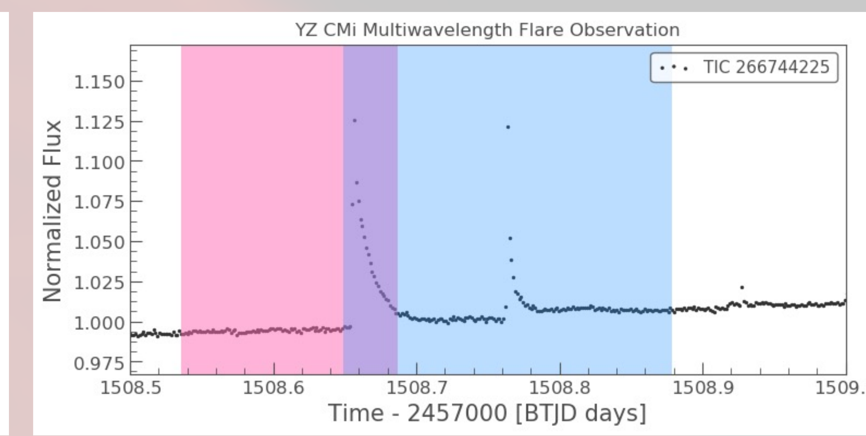
Left Fig.: YZ CMi's *Swift* X-ray (top panels) and UV (bottom panels) light curves during TESS Sec. 7 and 34. We estimate the X-ray quiescent flux in the 2019 observations to be ~ 6.6 x 10^{-12} erg $cm^{-2}s^{-1}$ in the soft X-ray band (0.3-10 keV) and the UVM2 (2250 Å; FWHM=527 Å) quiescent flux to be ~ 2.4 x 10^{-12} erg cm^{-2} s^{-1}.

Top Right: X-ray spectrum during a large flare event detected on BTJD 1508 that lasted >24 min with energy, Log(E) = >32.6 erg (see Section 4). We fit the spectrum with a two-temperature APEC model (Smith et al. 2001) and the elemental abundances from a plasma emission and photoelectric absorption model by Anders & Grevesse (1989). Lower Right: FFD of the 2019 UVM2 light curve showing 28 UV flares. Using least-square fitting we find a spectral index = -0.5.



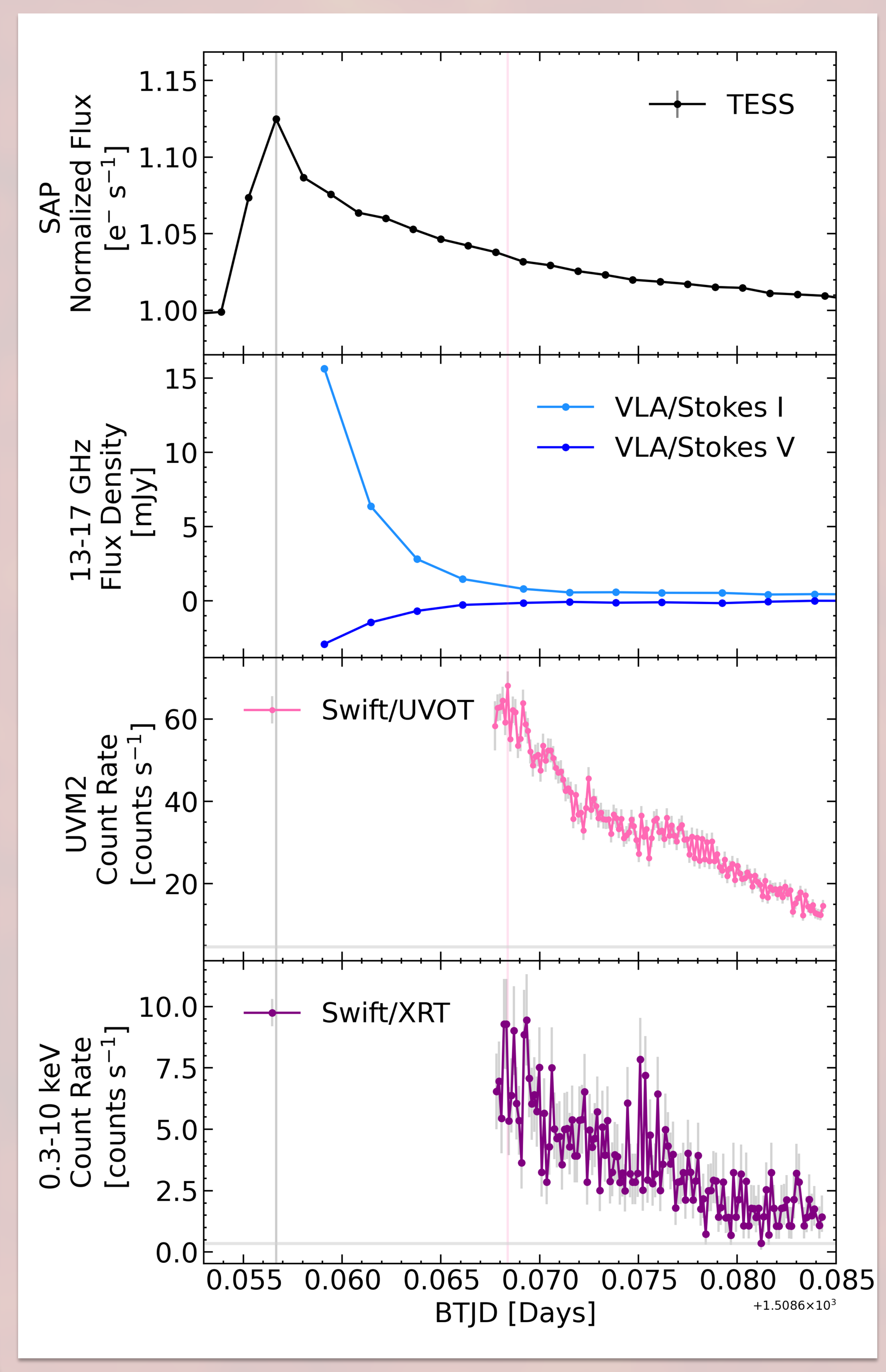
4. THE LARGE FLARE EVENT OBSERVED BY TESS, *SWIFT*, AND THE VLA





Top-Left Fig.: TESS Sec. 7 light curve zoomed-in to show the *Swift* and VLA time segments of observation.

Top-Right Fig.: *Swift* and VLA observation time segment overlapping on a TESS optical flare.



Left Fig.: Simultaneous multiwavelength light curves of the flare event.

Top panel: Optical flare from the TESS 2-min cadence light curve.
Second panel: VLA Ku band light curves of total intensity (Stokes I) and the circularly polarized (Stokes V) radio emission. Stokes I curve shows the decay phase the radio flare.
Third panel: *Swift* UVM2. 11.03-second cadence light curve. We estimate a flare energy > 7.75 x 10^{31} erg. The peak of the TESS flare and (apparent) peak of the UV flare are marked by the gray and pink vertical lines, respectively, in each panel, a difference of < 16.9 mins.
Bottom Panel: *Swift* X-ray light curve with a flux > 5.9 x 10^{-11} erg cm^{-2} s^{-1}, giving a flux ratio $F_{Flare}/F_{Quiescent}$ = 8.9.

5. SUMMARY OF PRELIMINARY RESULTS

In our multiwavelength study of YZ CMi, we have modeled and calculated the rotation period and optical flare energies from the TESS optical light curve, as well as the X-ray and UV flare energies in the *Swift* light curves during the TESS Sector 7 observations. CAVEATS: Some of the X-ray and UV flares were not observed for full duration, thus some flare energies are only lower limits.

NEXT STEPS:

- **Compare the FFD slopes of the optical, UV, and X-ray flares.**
- **Compare flux ratios (e.g., F_{XR}/F_{UV}; $F_{XR}/F_{optical}$)**
- **Finalize the analyses of the TESS Sector 34 *20-second* cadence data: measure flare morphologies, amplitudes, frequencies, and total energy budget of this more-resolved light curve.**
- **We have NICER X-ray data and CTIO/SMARTS observations for YZ CMi that were taken during TESS Sector 34.**

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BACKGROUND IMAGE Credit: NASA/SDO/Goddard • **ACKNOWLEDGEMENTS:** This work is supported by NASA; CRESST II; The Heising-Simons Foundation; TESS-*Swift* Program G03273; *Swift* Key Program 1417229 PI: T. Barclay