Fast Quasi-Periodic Pulsations in M Dwarf Flares Observed by TESS

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Dozens of hypotheses for the origin of quasi-periodic pulsation (QPP) have been proposed, but limited observational data means that we are not yet able to test those hypotheses. QPPs with periods of seconds or minutes are commonly observed on the Sun, but the vast majority of QPPs observed on other stars have dominant periods in the range of tens to hundreds of minutes.

Van Doorsselaere et al. (2016) posited that the longest-period QPPs (>30 min.) are only observed on stellar flares because solar flares are too short to sustain larger oscillations, but that the same mechanisms govern both. Cho et al. (2016) found that the ratio of damping time to period in X-ray was similar in stellar and solar QPPs, even though the periods of stellar QPPs tended to be an order of magnitude longer, "consistent with the scalings found for standing slow magnetoacoustic and kink modes in solar coronal loops." The review of QPPs by McLaughlin et al. (2018) notes that white light and hard X-ray flare light curves tend to behave similarly, which raises the question of whether the ratio observed on long period QPPs in the X-ray also holds for short ones in white light. If it does not, it may suggest that different mechanisms are at work in the stellar and solar cases or that a different mechanism is at work for long and short period stellar QPPs, either of which would be an interesting result.

On a sample of 56 flares with QPPs observed in Kepler short cadence mode, Pugh et al. (2016) found that QPP behavior was uncorrelated with many stellar parameters and flare energies; this suggests that the QPP behavior is dominated by local rather than global stellar properties. However, all but one detection in that sample had a period >10 minutes (with the one at ~5 minutes). Members of this team have also identified a QPP on a flare on GJ 65 with a period of 49s, has an energy of ~1031 erg. [Fleming, et al., in prep] (Energies of flares in GALEX and TESS bandpasses are comparable to an order of magnitude. [Osten and Wolk (2015)])

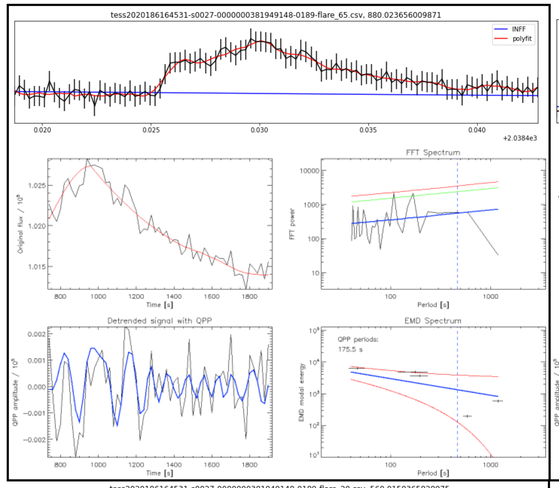
The TESS 20-second cadence mode, made available in Cycle 3, provides a new opportunity to examine the visible lightcurve morphology of flares at <1 minute resolution. This team requested that a number of nearby M dwarfs be targeted for 20-second coverage in TESS Cycle 3. Fifteen of these were observed in Sector 27, and 85 particularly large flares were found on five of the stars. We have identified 9 quasi-periodic pulsations in this sample with periods between 120 and 520 seconds. They appear to the right.

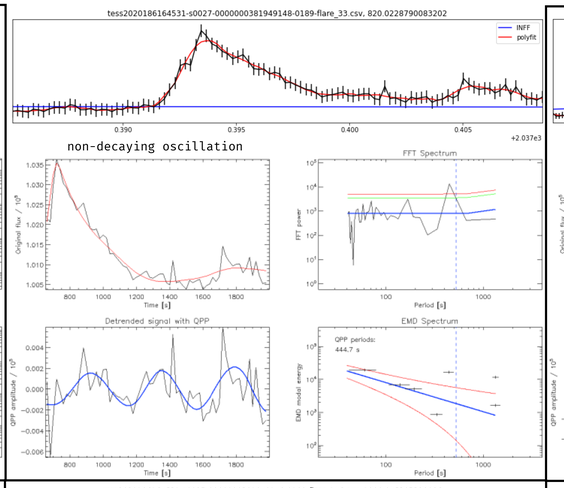
These are flares for which signatures of a QPP were detected simultaneously by two methods---Fourier and EMD. This approach is a synergy of methods defined as TVD, CEP, DYK, and TEM in Broomhall, et al. (2019).

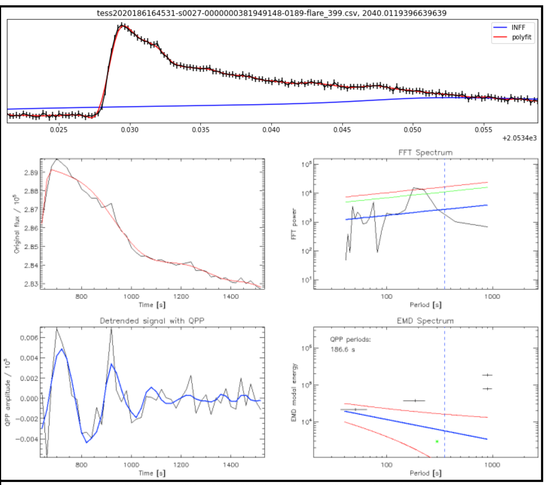
Although the majority are classic QPP signals with the amplitude smoothly decaying in a few oscillation cycles, a few of the QPP events show rather unexpected behaviour, with either stable or intermittently varying amplitude, as noted.

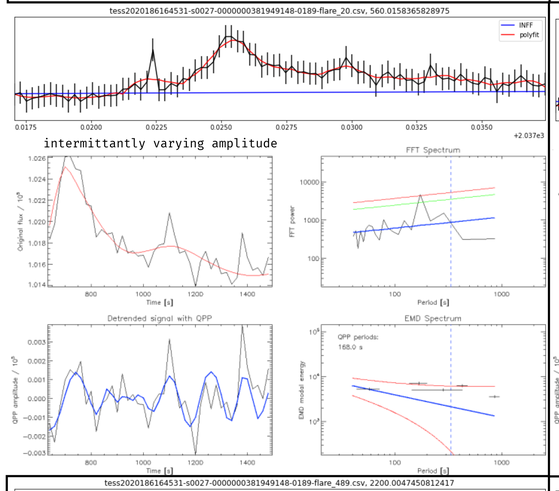
The main goal of our request to observe these targets in TESS 20-second mode was to determine whether short-period QPPs could be observed in TESS and, if so, how common they were. We have confirmed that these can be observed in TESS. They also seem to be somewhat common, and just how much so should quickly become obvious as more 20-second light curves of active M dwarfs become available. These observations suggest that the small number of prior examples of short-period extrasolar QPPs might have been a selection effect of the relatively long observational cadence of previous surveys, and that we will soon be able to make correlational studies between stellar properties and short-period QPP behavior in order to constrain mechanisms for these interesting phenomena.

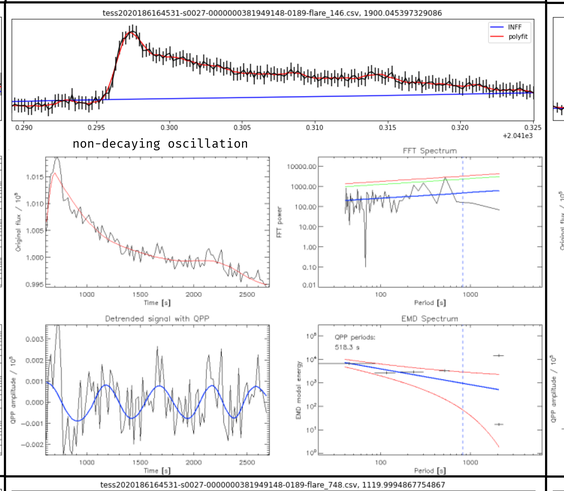
+ Broomhall, Anne-Marie, et al. "A blueprint of state-of-the-art techniques for detecting quasi-periodic pulsations in solar and stellar flares." The Astrophysical Journal Supplement Series 244.2 (2019): 44.
+ Cho, I-H., et al. "Comparison of damped oscillations in solar and stellar X-ray flares." The Astrophysical Journal 830.2 (2016): 110.
+ McLaughlin, J. A., et al. "Modelling quasi-periodic pulsations in solar and stellar flares." Space Science Reviews 214.1 (2018): 45.
+ Osten, Rachel A., and Scott J. Wolk. "Connecting flares and transient mass-loss events in magnetically active stars." The Astrophysical Journal 809.1 (2015): 79.
+ Pugh, C. E., et al. "Statistical properties of quasi-periodic pulsations in white-light flares observed with Kepler." Monthly Notices of the Royal Astronomical Society 459.4 (2016): 3659-3676.
+ Van Doorsselaere, Tom, Elena G. Kupriyanova, and Ding Yuan. "Quasi-periodic pulsations in solar and stellar flares: an overview of recent results (invited review)." Solar Physics 291.11 (2016): 3143-3164.

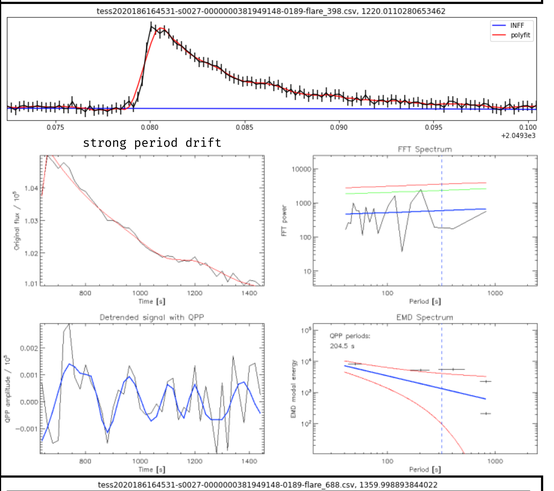


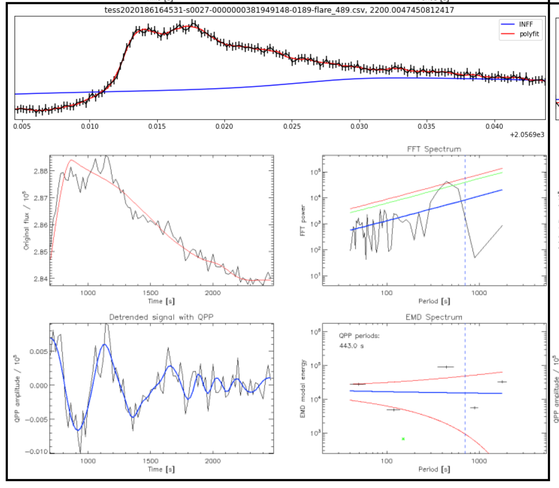


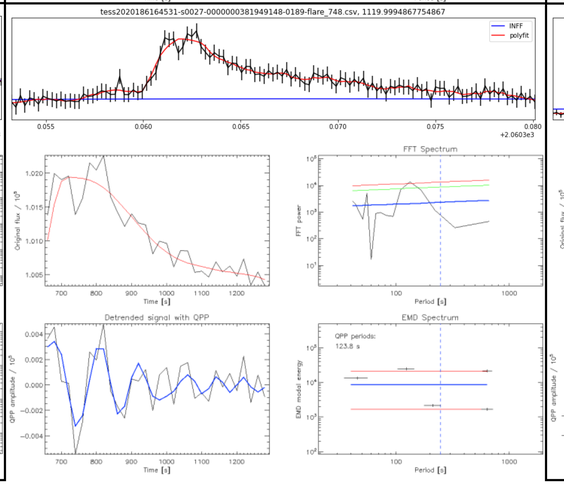


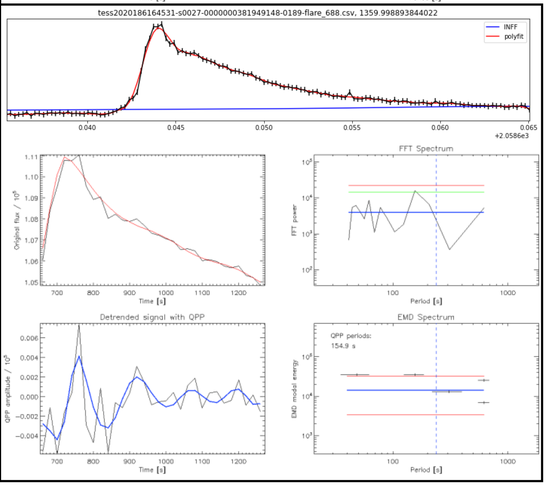












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