10 Years of Stellar Activity for GJ 1243

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Abstract

The flaring M4 dwarf GJ 1243 has become a benchmark for studying stellar flare and starspot activity thanks to the exceptional photometric monitoring archive from the Kepler mission. New light curves from the Transiting Exoplanet Survey Satellite (TESS) mission for this star allow precise stellar activity characterization over more than a decade timescale. We have carried out the first flare and starspot analysis of GJ 1243 from over 50 days of data from TESS Sectors 14 and 15. Using 133 flare events detected in the 2 minute cadence TESS data, we compare the cumulative flare frequency distributions, and find the flare activity for GJ 1243 is unchanged between the Kepler and TESS epochs. Two distinct starspot groups are found in the TESS data, with the primary spot having the same rotational period and phase as seen in Kepler. The phase of the secondary spot feature is consistent with the predicted location of the secondary starspot and measurement of weak differential rotation, suggesting this secondary spot may be long-lived and stable in both latitude and longitude. As expected for this highly active star, the constant spot and flare activity reveal no sign of solar-like activity cycles over 10 yr. However, we highlight the unique ability for Kepler and TESS to use flare rates to detect activity cycles.

Unified Astronomy Thesaurus concepts: M dwarf stars (982); Stellar flares (1603); Starspots (1572)

1. Introduction

The rapidly rotating, magnetically active, M4 star GJ 1243 is perhaps one of the best characterized flare stars over the past decade. Four years of nearly continuous 30 minute cadence observations by the Kepler mission (Borucki et al. 2010) found prominent starspots for GJ 1243 (Kepler ID 9726699) rotating with a period of 0.59 days (Savanov & Dmitrienko 2011), and with indications of very slow starspot evolution due to weak differential rotation (Davenport et al. 2015; Giles et al. 2017). Kepler also obtained 11 months of “short-cadence” (1 minute) monitoring, which were ideal for characterizing the flare activity for this star (Hawley et al. 2014; Silverberg et al. 2016), amassed the largest catalog of homogeneously observed flares for any star besides the Sun (Davenport et al. 2014). During the Kepler original mission, GJ 1243 was observed for four years, from 2009 May until 2013 May. As the brightest single flaring M dwarf in the Kepler field, GJ 1243 has become the benchmark flare star studied by exoplanet-searching telescopes. Continuing to measure the flares and starspots from this important Kepler star will allow us to characterize the long-term behavior of surface magnetic activity for fully convective stars, as has been done for very few stars in the past (e.g., V374 Peg Vida et al. 2016).

The Transiting Exoplanet Survey Satellite (hereafter, TESS; Ricker et al. 2014), in many ways the successor to Kepler, has recently revisited GJ 1243 (TESS ID 273589987). Short-cadence (2 minute) light curves for GJ 1243 are available from Sectors 14 and 15 (2019 July 18 through 2019 September 11), providing the most detailed light curve for this star since the end of the Kepler mission, and giving a 10 yr total observing baseline since the first Kepler data for this star became available (30 minute cadence data from Kepler Quarter 0 in 2009).

The decade timescale of precision photometric monitoring using the combined Kepler–TESS data enables a host of new stellar activity studies. Most notably, this provides stellar activity estimations (e.g., starspot amplitudes, rotation rates, and flare activity levels) on a timescale that is comparable to the Sun’s ∼11 yr activity cycle. As Scoggsins et al. (2019) has recently highlighted, variations in flare rates determined with missions like Kepler and TESS are a promising method for detecting stellar activity cycles, since the flare rate for the Sun is observed to vary by roughly an order of magnitude between solar maximum and minimum (e.g., Veronig et al. 2002; Aschwanden & Freeland 2012). Long-term monitoring of starspot modulations and rotation periods may also provide indications of stellar magnetic activity cycles (e.g., Messina & Guinan 2002; Nielsen et al. 2019; Morris et al. 2019), or differential rotation (Reinhold et al. 2013). While rapidly rotating M dwarfs like GJ 1243 and V374 Peg are not expected to show solar-like activity cycles, the variance of their surface magnetic activity over longer timescales—especially in precision estimates such as flare rates using space-based photometry—has been relatively unexplored.

Here we explore the starspot and flare activity for GJ 1243 using a combination of light curves from Kepler and TESS that span a 10 yr baseline. As we do not have continuous monitoring over this 10 yr baseline, the Kepler and TESS data instead provide point-in-time measurements of the flare and starspot activity for GJ 1243. We introduce the TESS short-cadence data in Section 2. In Section 3 we define our sample of flares from TESS and compare the flare rate with the benchmark from Kepler. As in Kepler, two distinct starspot regions are found in the TESS light curves, and we explore their evolution over the past decade in Section 4. Finally we conclude with a look ahead at the promising future for stellar activity studies combining Kepler and TESS data in Section 5, and provide a brief summary of our results in Section 6.

2. TESS Short Cadence Data

TESS is a space-based, exoplanet-searching telescope that was launched in 2018. Over the course of the primary two-year
mission, TESS will survey ~85% of the entire night sky with at least 27 days of continuous observation in search of transiting exoplanets around the brightest nearby stars (Ricker et al. 2014). To date, TESS has confirmed 45 new exoplanets and identified more than a thousand objects of interest⁴, while simultaneously studying the astrophysics of more than 200,000 stars with short-cadence (2 minute) data. The data from TESS Sectors 14 and 15 from mid-2019 (and again partially in mid-2020 with Sector 26) provide a unique opportunity to revisit the original Kepler field. By combining the data from both missions we can characterize stellar activity for GJ 1243 on a decade timescale.⁴

We use the short-cadence data from sectors 14 and 15, totaling 50.47 days of 2 minute observations. We are using the PDCSAP_FLUX light curves provided by the TESS mission directly, and require the Quality flag be set to 0 to ensure the highest fidelity data possible. Light curves for both Sector 14 and 15 are shown in Figure 1, with our detected flares (described below) highlighted.

Figure 1. TESS Sector 14 and 15 light curves for the rapidly rotating, flaring M dwarf, GJ 1243. Using FBEYE we identified 133 flare events (orange) over the 54 days of 2 minute cadence observations. For visual clarity we have not shown the full range of the largest detected flares, which reach amplitudes of 23%.

3. Comparing Flare Activity

To gather a sample of flares from the TESS data, we examined the short-cadence (2 minute) light curve for Sectors 14 and 15 using FBEYE (Davenport et al. 2014). This flare finding suite was originally designed to manually build a pristine flare sample for GJ 1243 with Kepler. In FBEYE the light curves are first smoothed with an iterative three-pass approach using a variable sized smoothing kernel based on Friedman (1984). This is designed to remove slow variability primarily from the starspots and preserve the flares. Candidate flare epochs with fluxes greater than 2.5σ above the smoothed light curve are then highlighted for the user. As Davenport et al. (2014) illustrate, while this automated step reliably detects the peaks of large flares, it is not optimized to find all small events, nor accurately separate the graduate decay phase of the flare from the underlying starspot variability. A by-eye validation of the entire 50.47 day light curve is then performed in FBEYE, which recovered a total of 133 flare events.

Rather than flare energies, FBEYE provides the equivalent duration for each event, defined as the integral of the flare in zero-registered normalized flux, which has units of seconds (see Hunt-Walker et al. 2012). The energy for each flare is then determined by multiplying the equivalent duration by the star’s luminosity. Following Davenport (2016), we determined the luminosity for GJ 1243 in both the Kepler and TESS bandpasses. The Kepler and TESS absolute magnitudes were estimated by matching the g – J color of GJ 1243 to a 1 Gyr, solar metallicity PARSEC isochrone (Bressan et al. 2012). We explored isochrones with ages up to 5 Gyr, and they did not significantly change the resulting luminosity estimates for GJ 1243. These AB magnitudes were converted to fluxes and set to a distance of 10 pc to determine the luminosity of the star in each filter. We find log $L_{\text{Kep}} = 30.68 \pm 0.04$ erg s$^{-1}$, and log $L_{\text{TESS}} = 31.06 \pm 0.04$ erg s$^{-1}$. Uncertainties in the luminosity were estimated numerically, by resampling the observed g – J color 1000 times using a Gaussian kernel with a standard deviation equal to the observed g – J errors, and finding the standard deviation of the resulting luminosity estimates from the isochrone. The Kepler luminosity used here is very close to the log $L_{\text{Kep}} = 30.67$ erg s$^{-1}$ that Hawley et al. (2014) found by convolving spectrophotometric data from Kowalski et al. (2013) with the Kepler bandpass. Hawley et al. (2014) claim a conservative uncertainty on log $L_{\text{Kep}}$ of ±0.2, but noted that when using flux-calibrated spectral observations from possibly nonphotometric conditions they get estimates on the luminosity that were 0.15–0.7 dex lower. We also attempted to use flux-calibrated reference spectra to estimate the luminosity for GJ 1243 in both the Kepler and TESS bandpasses. As shown in Figure 2, each filter curve was convolved with an M4 NUV–NIR spectral template from Davenport et al. (2012), which was normalized to the flux-calibrated optical spectrum for GJ 1243 from Reid et al. (1995). We find log $L_{\text{Kep}} = 30.04$ erg s$^{-1}$ and log $L_{\text{TESS}} = 30.35$ erg s$^{-1}$—about 0.6 dex lower than our isochrone estimates above, but with a comparable difference in

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⁴ As of 2020 April, https://tess.mit.edu/publications/.

⁵ Kepler Quarter 0 was observed in 2009 May.
luminosity between the filters. Reid et al. (1995) also note their spectral library is observed under potentially nonphotometric conditions, and so our spectrophotometric luminosity estimate here is also consistent with the results from Hawley et al. (2014). We emphasize that the specific luminosity value used for the Kepler bandpass does not impact our results in comparing the flare activity between Kepler and TESS for GJ 1243, since we have estimated the luminosity in both bands consistently. Rather, we urge caution when comparing specific flare rates between studies that use differing methods for determining stellar luminosity (e.g., spectrophotometry versus isochrone or model fits), since this can result in large (>0.5 dex) variations in the implied specific flare rate.

Since the Kepler and TESS filter curves shown in Figure 2 cover different wavelength regions, we also briefly explored how comparable the flare energies determined using these two filters would be. We convolved a 10,000 K blackbody curve with each filter, since this is a typical flare temperature assumed when estimating flare energies. Though the Kepler filter is centered closer to the peak wavelength of this blackbody curve, the TESS filter’s substantially wider wavelength coverage results in a 2.4% larger flux response. Given typical uncertainties in the distance estimation and flux calibration for nearby stars, this indicates TESS and Kepler have remarkably similar flare energy yields, and are well suited for comparison.

Flare frequency distribution (FFD) diagrams have been used to compare the occurrence rate of flares on stars as a function of flare energy (e.g., Lacy et al. 1976; Shibayama et al. 2013). This reverse sorted, cumulative flare distribution, characteristically shows many small energy events and very few high energy flares. Given their stochastic occurrence, FFDs help us understand the rate of flares over many orders of magnitude in event energy. Scoggins et al. (2019) used both FFDs and the integrated flare energy metric, \( L_{\text{fl}}/L_{\text{Kep}} \) introduced by Lurie et al. (2015), to find flare activity variations within Kepler data. \( L_{\text{fl}}/L_{\text{Kep}} \) is a more robust measurement, as it averages over uncertainties in individual event energies, but assumes fixed observing conditions throughout the sample. As our flare data for GJ 1234 comes from two telescope surveys with substantially different apertures and observing baselines, FFDs are the best parameter space for comparing our flare activity levels (see Section 3 of Davenport et al. 2019).

Figure 3 shows the FFDs from the TESS and Kepler observations. The differences in turn over rates between the two data sets is correlated with the amount of data collected. The FFD for the TESS data includes 50.47 days worth of 2 minute observations, while the Kepler data spans 11 months of short-cadence, 1 minute monitoring. The apparent change in slope and rapidly increasing uncertainties at lower event energies are due to low signal-to-noise flares that have growing incompleteness in their recovery (Davenport 2016). For large energy flares we become limited by the observing duration, and are dominated by Poisson counting errors.

Error bars shown for the FFDs in Figure 3 were produced following the approach of Davenport et al. (2016) and Howard et al. (2018). The uncertainty in the cumulative flare rates (y-axis) were computed using the 1σ confidence intervals for event counting statistics determined from the Poisson distribution by Gehrels (1986). Their Equation (7) provides a simple analytic approximation to determine the uncertainty for counting a number of events (in this case, flares) even for small numbers of events (e.g., for the rare large energy flares). Uncertainty in the flare energies was computed using the same approach used in computing errors for spectral line equivalent widths, following Equation (6) from Vollmann & Eversberg (2006). This uses the flare’s total duration, the equivalent duration (analogous to the equivalent width), and the signal-to-noise ratio of the light curve. These energy errors have the expected behavior (i.e., errors decrease for higher energy events). Errors for the smallest flares cataloged increase dramatically as shown in Figure 3, indicating these smallest events are statistically indistinguishable from noise. The combination of these occurrence rate and event energy uncertainties gives a characteristic “bow-tie” appearance to the FFD.

The FFD is typically modeled using a power-law distribution, which has been shown to extend with a fixed slope over 10 orders of magnitude in flare energy for solar-type stars from “nanoflares” to “superflares” (Shibayama et al. 2013; Maehara et al. 2015). As noted in Scoggins et al. (2019), stars with significant differences in the power-law offset (i.e., the
intercept in log–log space) would indicate changes in flare activity levels. A star whose flare activity level changed over a few years timescale may be undergoing activity cycles. We fit both the Kepler and TESS data with a linear model in log–log space. Within the resulting error uncertainties we find the FFDs for both the TESS and Kepler data are the same, revealing no sign of a stellar activity cycle over this decade. Our resulting power-law fit for the TESS data was

\[ \log_{10}(\nu) = -0.95 \pm 0.02 \times \log_{10} E + 29.4 \pm 0.7, \]

and for the Kepler FFD data was

\[ \log_{10}(\nu) = -0.942 \pm 0.001 \times \log_{10} E + 29.27 \pm 0.04. \]

The larger uncertainties of the TESS data are to be expected, given the lower signal-to-noise of the light curves and the shorter duration of observation. However, it is encouraging that TESS can effectively characterize the ongoing flare activity level of Kepler stars.

4. Comparing Starspots

Four years of nearly continuous monitoring for GJ 1243 from Kepler revealed the presence of two distinct starspot features, which appear as slowly evolving quasi-sinusoidal modulations in the light curve (e.g., Figure 1). Davenport et al. (2015) produced a detailed tracing of the phase (or equivalently, longitude) of both starspot features over the entire Kepler data set. They noted the primary spot was approximately stable in both phase and amplitude, while the secondary feature evolved on a timescale of hundreds of days. Forward modeling of the Kepler light curve suggested the primary spot was located at a high latitude, while the secondary spot was at a lower latitude. Interestingly, during the final two years of Kepler data, the secondary spot appeared to evolve almost monotonically in phase, which Davenport et al. (2015) interpreted as the signature of differential rotation of a long-lived spot feature.

The combined Kepler–TESS 10 yr light curve allows us to improve the rotation period estimation for GJ 1243. Using a Lomb–Scargle periodogram, we measured the rotation period to be \( P_{\text{rot}} = 0.5925974 \) days, \( 1.2 \times 10^{-6} \) days longer than the estimate from Davenport et al. (2015). To estimate an uncertainty on this period measurement, we use the analytic approximation developed by Mighell & Plavchan (2013) for Kepler eclipsing binaries. Scaling their expression with the 10 yr baseline of observations between Kepler and TESS (e.g., following their Figure 5), we estimate an uncertainty of \( \sigma_P = 1 \times 10^{-7} \) days. Similarly, the Davenport et al. (2015) period from 4 yr of Kepler data had an uncertainty of \( \sigma_P = 4 \times 10^{-7} \) days. We note that the error approximations from Mighell & Plavchan (2013) assume a truly constant periodic source and continuous data, and are therefore likely underestimated. We consider the difference between the rotation period for GJ 1243 from Davenport et al. (2015) and this current work to therefore be negligible (~2.8\( \sigma \)), but report the updated period estimate here for the benefit of future studies.

In Figure 4 we reproduce the phase versus time evolution map of flux from Davenport et al. (2015) for the 4 yr Kepler long-cadence (30 minute) data, as well as the new TESS Sector 14 and 15 short-cadence data. All data have been put onto the Kepler Barycentric Julian Date time. The Kepler long-cadence data has been normalized by the per-quarter median flux value using the Lightkurve package. Pixel color and shade encode the flux of the star as a function of time and rotational phase. The primary starspot is seen as a dark band (i.e., lower normalized flux in Figure 1) centered at Phase = 0.

Note that we have increased the relative flux response of the TESS data here by a factor of 2 to approximately match the starspot amplitude seen in Kepler. This difference in spot amplitude is expected due to the redder wavelength center of the TESS filter (e.g., Figure 2), which leads to a lower spot-to-star contrast ratio (i.e., spots are higher amplitude at bluer wavelengths).

To analytically trace the positions of the starspots over the 10 yr baseline, we have split the combined Kepler–TESS light curve into 40 day bins of time, and fit the phase-folded data within each bin with two Gaussian curves. The center phase of the primary and secondary spots are shown as circles in Figure 4. Modeling with Gaussian curves can cause blending and result in lower velocity amplitudes (this is often the case when decomposing multiple radial velocity peaks in spectroscopy). The same effect can be seen here, with the two peaks blending together, causing the primary starspot position to “wiggle” in phase due to blending with the secondary spot.

Davenport et al. (2015) estimated the surface shear due to differential rotation by measuring a monotonic change in phase of the secondary starspot relative to the primary. Specifically, they focused on the clear evolution in the secondary spot seen in Figure 4 from time \(~950\) to \(~1400\) days. We note that if this evolution is propagated backwards in time, the spot feature around time \(~450\) days appears to be in sync as well. However, as Davenport et al. (2015) found, the differential rotation evolution of this particular starspot does not correctly align with the secondary spot feature observed at phase \(\approx 0.5\) in the first \(~300\) days of the Kepler data.

We updated the phase evolution estimate from Davenport et al. (2015) to include this earlier starspot, shown as a continuous blue line in Figure 4. As Davenport et al. (2015) illustrate, the negative slope of this line indicates a spot moving faster than the rotation period used to phase-fold the data. The actual slope of the linear fit is the inverse of the rotation lap time \(1/\theta_{\text{lap}} = -1.5393 \times 10^{-3}\), which can be converted to a rotation shear of \(\Delta \Omega = 2\pi/\theta_{\text{lap}} = -0.00967\) rad day\(^{-1}\), somewhat stronger than measured previously by Davenport et al. (2015).

We then propagated this updated differential rotation rate from Kepler to the new TESS observations, and find the secondary spot is at a phase consistent with the predicted phase. In Figure 5 we also find the secondary spot appears to move slightly in phase between TESS Sector 14 and Sector 15 with the same shear rate seen in Kepler, while the primary feature remains at a fixed longitude. As seen in Kepler, the secondary spot in TESS also has approximately the same amplitude in the light curve, indicating these starspots (or starspot groups) have roughly equal surface filling factors (areas).

The consistent location and evolution in phase of the secondary starspot seen in TESS as compared with Kepler has two possible interpretations: (1) this feature is the same starspot observed in the latter years of the Kepler mission, which has not changed significantly in latitude (i.e., change the differential rotation rate) or size relative to the primary spot. (2) The secondary spot seen in TESS is a newer feature than the one observed with Kepler and is coincidentally aligned with the

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5 Here we used the final Data Release 25 version of the long-cadence Kepler data.
predicted phase, but is likely at the same latitude since it exhibits the same differential rotation rate. Since we lack monitoring of GJ 1243 throughout the 6 yr gap between the Kepler and TESS missions, it is impossible to show that a secondary starspot has remained consistent in its phase evolution throughout that time. As the secondary spot seen in the first 300 days of Kepler also does not appear to be in sync with this phase evolution, we prefer the latter interpretation, that the secondary starspot seen in TESS is coincidentally in phase with the feature found in Kepler.

5. Discussion

Using a combination of data from the Kepler and TESS missions we have analyzed space-based precision photometry spanning a 10 yr baseline for the benchmark active M dwarf, GJ 1243. Our study of flaring and starspot behavior in these light curves sheds new light on the active lives of low-mass stars and opens the door to searching for slow changes in flare rates due to activity cycles, or surface magnetic field topology via starspot modulations.

From the new sample of 133 flares from the 2 minute light curves in TESS sectors 14 and 15, we found the flare rate for GJ 1243 has not appreciably changed over the decade timescale. The raw number of flares detected per day is lower in TESS compared to Kepler, but this is simply due to the lower signal-to-noise in TESS, while the star’s actual activity level was unchanged. The signal-to-noise of the Kepler 1 minute cadence light curve is $\sim 6 \times$ higher than that of the TESS 2 minute data for GJ 1243. For comparison, the maximum rate of flaring recovered (i.e., for the smallest energy events shown in Figure 3) is $\sim 8 \times$ higher in Kepler than in TESS, which is well aligned with the expected difference in flare yields between the surveys.

As Davenport et al. (2019) notes, the FFD is the most robust parameter space to compare flare activity levels between different stars or between observations of a given star with different noise levels or observing duration. The flare census for GJ 1243 shows no significant variation in either the gross flare rate, or the FFD slope, indicating the same physical process is at work. We also find that flare energies computed using the Kepler and TESS filters are comparable, making FFD comparisons between these missions a prime tool in searching for flare rate variations.

The light curve for GJ 1243 shows a two-starspot morphology in both the Kepler and TESS data, with a rotation period and primary starspot feature that has remained unchanged over 10 yr. The nearby, rapidly rotating, flaring M4 dwarf V374 Peg is the most natural comparison star for our long-term space-based starspot monitoring of GJ 1243. Over 16 yr of ground-based monitoring, Vida et al. (2016) found the two starspots for V374 Peg have remained effectively stationary in longitude and with constant amplitude (area coverage). This starspot stability is consistent with previous measurements of a strong dipolar magnetic field from Zeeman–Doppler imaging for V374 Peg (Morin et al. 2008). The long-term stability of the primary starspot in the new TESS data for GJ 1243 lends support to the interpretation that this feature represents a large polar spot “cap,” possibly due to a strongly
dipolar magnetic field that is slightly misaligned with the rotation axis.

The secondary starspot for GJ 1243 has once again been observed to have weak differential rotation. While this secondary spot in TESS is perhaps coincidentally in phase with the evolution seen in Kepler, the 10 yr spot map (Figure 4) indicates the surface is dominated by two very large, and very slowly evolving features. The presence of two such large and stable active regions poses interesting questions about the surface topology of the magnetic field for GJ 1243. We believe this benchmark star is a prime candidate for continued photometric monitoring, as well as follow-up spectro-polarimetric observations to constrain the surface magnetic field structure as was done for V374 Peg (Morin et al. 2008) and other late-type M dwarfs like GJ 1245B (Morin et al. 2010).

Hawley et al. (2014) found with Kepler that GJ 1243 showed now correlation between rotation phase and the flare rate or flare energy. This was interpreted as flares occurring in active regions across the entire star, rather than concentrated near the starspots. Using the TESS flare data we again find no indication of rotational phase correlation with flare occurrence or energy. By contrast, Roettenbacher & Vida (2018) have recently found that small flares do seem to occur coincidentally with major starspot groups for predominantly higher mass flare stars (G through M) in Kepler. They interpret this difference as a fundamental change in the surface magnetic topology, in agreement with dynamo models for convective stars (Yadav et al. 2015) that predict active regions (i.e., flares) are spread across the star’s surface.

The constant flare rate and starspot properties for GJ 1243 broadly indicate that the star either lacks a solar-like activity cycle, or the timescale for such a cycle is much longer than 10 yr. The latter interpretation is in conflict with the traditional view that long activity cycles correlate with slow rotation (Böhm-Vitense 2007). However, a lack of an activity cycle is not surprising given the possible young age for GJ 1243 (Silverberg et al. 2016), and that the star is rapidly rotating and well within the “saturated” dynamo activity regime where cycle behavior is not expected (e.g., see Testa et al. 2015). GJ 1243 is a fully convective star, and it is also unknown if solar-like activity cycle behavior can arise in stars across the fully convective boundary. Yadav et al. (2016) have shown simulations that generate activity cycle behavior for fully convective stars, but only those that are slowly rotating. Recently, Bustos et al. (2019) found a candidate for such behavior using long-term spectroscopic monitoring for the slowly rotating (~109 day) M4 dwarf, GL 447A. Long-term flare monitoring for all active stars like GJ 1243, including V374 Peg (TIC 283410775, observed in Sector 15), is now possible with TESS. As Scoggins et al. (2019) note, this continuing flare rate census on decades timescales will be a valuable metric for detecting activity cycles for many stars.

6. Summary

We have presented new flare rates and starspot tracing for the active M dwarf GJ 1243 from the TESS mission. Comparing with similar data from the Kepler mission allows an analysis of magnetic activity on a decade timescale. Both the flaring and starspot behavior appear unchanged, indicating no sign of an activity cycle. The primary starspot is found to be stable in phase, while the secondary starspot feature continues to show signs of weak, solar-like differential rotation.

We have found the flare rates and FFDs of M dwarfs between Kepler and TESS are easily compared, despite the significantly longer stare time and larger aperture of the former. The wider bandpass of the TESS filter results in a slightly larger (~2.4%) observed energy for a given flare as compared to Kepler—well within the nominal error budget of most flare energy estimates.

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