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SEISMIC AND ROTATIONAL CHARACTERIZATION OF STARS IN PLATO OBSERVATION FIELDS USING MULTI-SECTOR TESS DATA

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Abstract.
NASA's TESS has conducted high-precision photometric observations for the past seven years, covering more than 95% of the sky and providing an extensive dataset of light curves for studying stellar oscillations and measuring rotation. TESS light curves, however, are affected by discontinuities, systematics, and sector-to-sector flux variations, which complicate the measurement of global seismic parameters as well as of long rotation periods. The upcoming ESA PLATO mission will continuously monitor stars in the Southern Hemisphere (LOPS2) for at least two years, overlapping with regions already observed by TESS. This overlap provides a unique opportunity to pre-characterize PLATO targets using existing TESS data. Using the `PYTADaCS` package, we corrected TESS light curves to mitigate systematics and derive reliable measurements. Focusing on stars in the PLATO fields, we measured $\nu_{\max}$ for 23,000 giant stars and obtained rotation periods for approximately 9,000 stars in LOPS2, providing a valuable dataset to inform PLATO's observation strategy and optimize target selection.

Keywords: PLATO, TESS, Asteroseismology, Stars: rotation

1 Introduction

The PLAnetary Transits and Oscillations of stars (PLATO; Rauer et al. 2014) space mission is designed to detect and characterise a large number of exoplanetary systems, including terrestrial exoplanets orbiting bright, solar-type stars in their habitable zones. During its nominal four-year mission, PLATO will continuously monitor two pre-selected fields for at least two years each during the Long-duration Observation Phase (LOP). Due to telemetry constraints, PLATO cannot download full-frame images at high cadence; instead, a significant part of the photometric analysis will be performed onboard, requiring targets to be selected in advance. The target samples are divided into four main categories: P1 includes at least 15,000 F5–K7 dwarfs and subgiants with $V \leq 11$ and photometric noise < 50 ppm; P2 includes at least 1,000 of the same types with $V \leq 8.5$ and photometric noise < 50 ppm; P4 covers at least 5,000 M dwarfs with $V \leq 16$; and P5 includes about 245,000 F5–K7 dwarfs and subgiants with $V \leq 13$ (Nascimbeni et al. 2025). For these targets, PLATO is expected to measure mass, radius, and age with high accuracies of 5%, 10%, and 10%, respectively.

NASA's Transiting Exoplanet Survey Satellite (TESS; Ricker et al. 2014) has been conducting high-precision photometric observations for the past seven years, covering more than 95% of the sky. By the end of Cycle 7,

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around 90% of this coverage included multiple-sector observations, which encompass the two main PLATO observation fields (LOPS2 and LOPN1). The continuous viewing zones of TESS also partially coincides with the PLATO LOP fields. This enables characterisation of stars within the PLATO fields of view using TESS data, thereby facilitating the construction of a preliminary target catalogue in preparation for the PLATO mission.

It is well established that TESS data can be used for seismic characterization of giants (Campante et al. 2016; Stello et al. 2022; Hon et al. 2022; Lund et al. 2025) and to measure stellar rotation (Claytor et al. 2024; Hattori et al. 2025). Several pipelines, including SPOC (Caldwell et al. 2020), QLP(Huang et al. 2020), Eleanor (Feinstein et al. 2019) perform simple aperture photometry on TESS Full Frame Images (FFIs) to produce light curves (LCs). While primarily designed for exoplanet science, these pipelines can be adapted and fine-tuned for characterization of giants and measurement of rotation. The Quick Look Pipeline (QLP) pipeline, for example, has already produced over 21 million LCs from FFIs, which can be leveraged for our studies. QLP already contains 1.3 million LCs for stars in each of LOPN1 and LOPS2. Figure 1 shows the number of stars and the total sector coverage for targets present in QLP (up to sector 90) in the PLATO LOP fields.

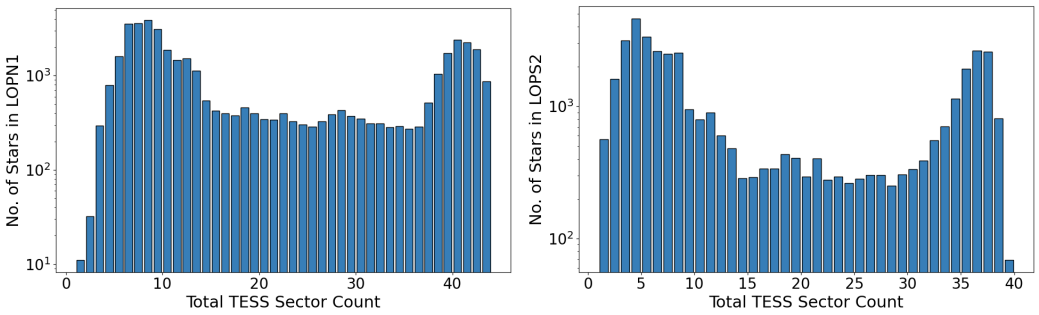

Fig. 1. Number of stars and sector coverage of QLP catalog stars in the PLATO observation fields. Left: LOPN1; Right: LOPS2

2 Seismic Characterization

Giant stars with deep convective envelope have turbulent motions which produce an acoustic noise that can stochastically drive (and damp) resonant mode oscillations. These oscillation patterns are like solar like oscillators in which power spectrum is modulated by a broad bell-shaped envelope whose maximum is at a frequency often called ν_{max}, the frequency of maximum oscillation power, and also shows a pattern of modes with nearly regular frequency spacings between consecutive overtones having the same spherical degree (l) called large frequency separation ($\Delta\nu$). These global seismic properties can be directly related to stellar mass and radius through scaling relations (Kallinger et al. 2014; Mathur et al. 2011).

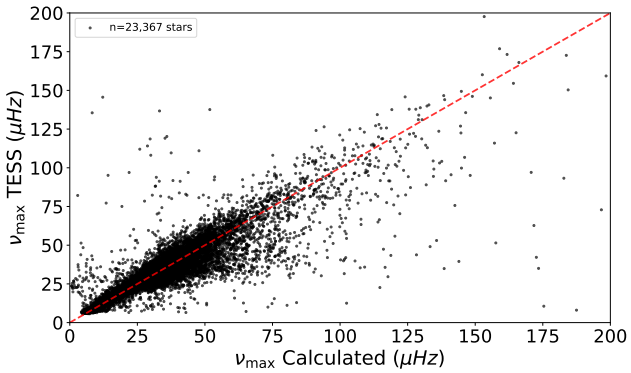

Fig. 2. Comparison of measured $\upsilon_{\max}$ from QLP light curves with theoretical $\upsilon_{\max}$ calculated from $T_{\rm eff}$ and $\log g$ for stars with consistent $\upsilon_{\max}$ values between the pipelines.

As a first step in selecting giant stars, we cross-matched all stars in the QLP catalog with Gaia and extracted those with Gaia XGBoost $T_{\rm eff}$ and $\log g$ parameters (Andrae et al. 2023), selecting stars in the ranges 3000 K $< T_{\rm eff} <$ 6000 K and $0 < \log g < 4$. For these giants, we applied the `PyTADaCS-S` pipeline (García et al., in prep.), which is optimized for seismic stars. Global seismic parameters, $\nu_{\rm max}$ and $\Delta\nu$, were derived using both the A2Z pipeline (Mathur et al. 2010) and a neural network approach (Hon et al. 2018). These pipelines employ different methods to measure global parameters and are sensitive to different TESS systematics. We measured $\nu_{\rm max}$ for 23,000 stars, with consistent results between the two pipelines. Figure 2 shows the measured $\nu_{\rm max}$ compared to the theoretical $\nu_{\rm max}$ calculated from $T_{\rm eff}$ and $\log g$.

3 Rotational Characterization

Low-mass stars with convective outer layers sustain internal dynamos that generate magnetic fields and magnetic cycles through the interaction of differential rotation and convection. As magnetic fields emerge at the photosphere, they produce stellar spots, and their decay and dispersion gives rise to faculae. The evolution of these surface magnetic features induces variations in stellar light curves, which can be used to measure the surface rotation period, $P_{\rm rot}$. We cross-matched the stars in the QLP catalog with the PIC catalog (LOPS2PICv2.10) and selected stars with 3200 K $< T_{\rm eff} <$ 6000 K that were observed in two or more consecutive sectors. We further restricted the sample to stars showing variability exceeding 3σ above the TESS noise. The final sample contains 32,000 stars.

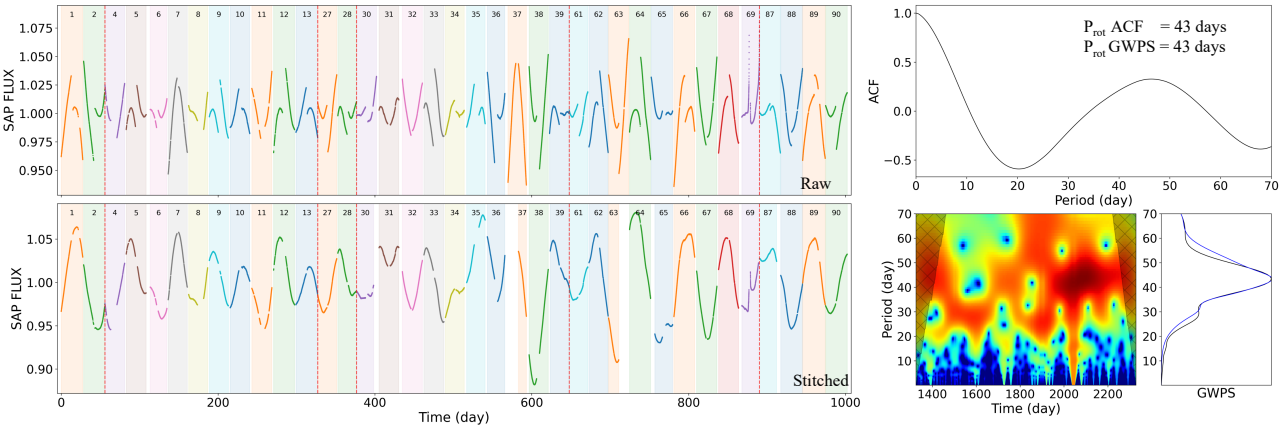

Fig. 3. Top: QLP TESS raw (top) and stitched light curve (bottom). P_{rot} measured using ACF (top) and wavelets (bottom).

TESS light curves, with 27 days of observation per sector, contain both intra- and inter-sector data gaps. These gaps occur approximately every 14 days (due to downlink operations) and every 27 days (at sector boundaries). Uncorrected light curves can still be used to detect short rotation periods ($P_{\rm rot} < 14$ days), but they severely limit our ability to measure longer rotation periods ($P_{\rm rot} > 14$ days). Additionally, TESS light curves have varying mean flux levels, or are normalized differently by the pipelines (Figure 3), making it difficult to construct long-baseline light curves and reliably measure long rotation periods. To address this, we use the light curve stitching module in `PyTADaCS-R`, which employs a Bayesian approach to align sector-normalized light curves. Proper stitching significantly improves the detection of long-period rotation signals. Rotation periods are then measured using Lomb-Scargle periodograms, autocorrelation functions, and wavelet power spectra methods from the star-privateer package (Breton et al. 2021, 2024). When processing millions of stars, a fraction of light curves inevitably exhibit calibration issues. Moreover, depending on the stellar activity cycle, the amplitude of rotation signals can vary and sometimes fall below TESS noise levels. These problematic cases must be identified and flagged.

Thousands of stars in the PLATO field were visually inspected to identify rotation periods and systematics. A random forest classifier was then trained on this set to distinguish between rotating stars, non-rotating stars, and systematics. To validate the classifier, we applied it to *Kepler* stars with known rotation periods (Santos et al. 2019, 2021). Figure 4 (left) compares TESS-derived periods (from multiple methods) with *Kepler* reference values. The unfiltered results exhibit strong systematics, such as artificial 14-day stripes caused by TESS gaps

and other artifacts, leading to a reliability of approximately 50%. After applying the classifier, these systematics are significantly reduced, improving the reliability to 81%.

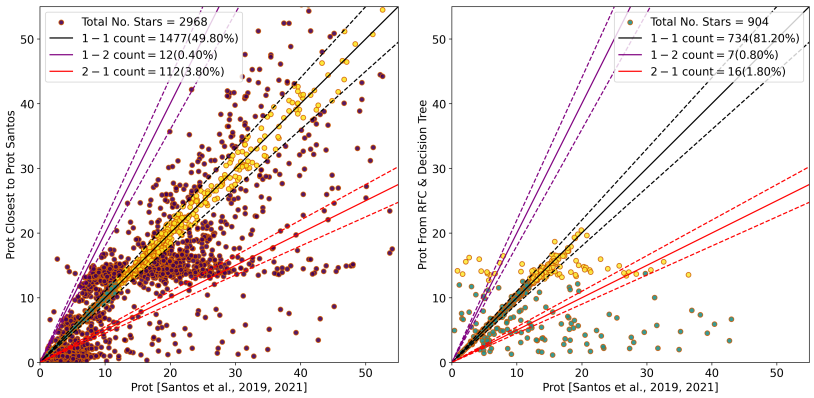

Fig. 4. (Left) Closest rotation periods from TESS using multiple methods compared to *Kepler* rotation periods. The red color represent stars outside 10% error, stars with short rotation in green and stars with long rotation in yellow. (Right) Rotation periods from TESS after applying the random forest classification

We analysed 32,000 stars in PLATO LOPS2 field using star-privateer and a random forest classifier, resulting in 9,000 stars with reliable rotation periods. The resulting period distribution is bimodal, consistent with intermediate period gap corresponding to stalling of magnetic braking (Gordon et al. 2021; McQuillan et al. 2014). However, due to a lack of long-period examples ($>$ 20 days) in the visually inspected training set, the classifier tends to reject such cases. A more balanced and representative training sample is needed to improve recovery of longer rotation periods.

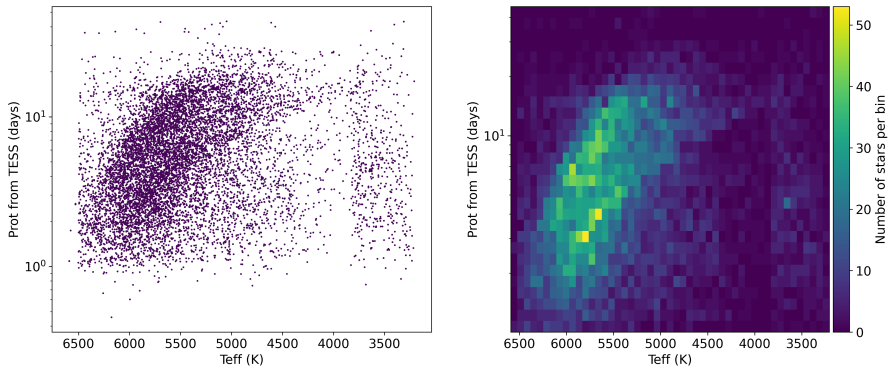

Fig. 5. Measured rotation periods ($P_{\rm rot}$) as a function of effective temperature.

4 Conclusions

QLP TESS light curves were re-calibrated using the `PyTADaCS` package to study seismic stars and measure stellar rotation periods. We measured $v_{\rm max}$ for 23,000 giants and obtained reliable rotation periods for 9,000 stars in the PLATO LOP fields. These results provide a valuable dataset to inform PLATO's observation strategy, optimize target selection, and leverage existing TESS data to enhance the mission's scientific yield.

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