Improved Detection of Superflares on Solar-Type Stars

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Abstract

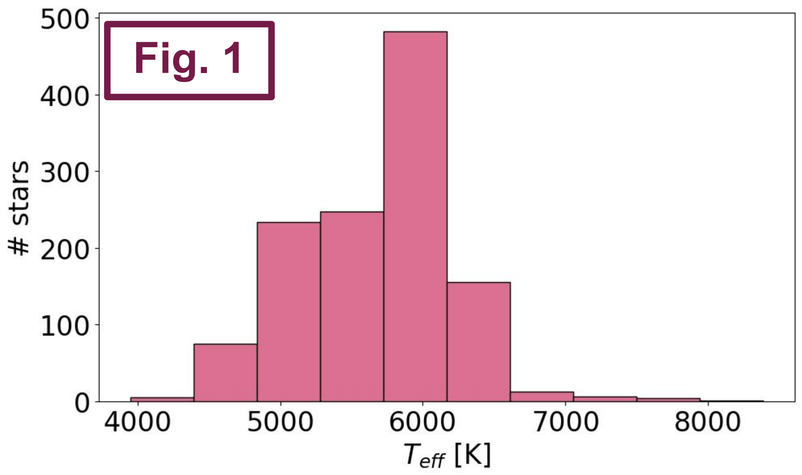
- Superflares are energetic eruptions on stars with energies exceeding 10^{32} ergs.
- Understanding the frequency of such events is crucial for assessing their likelihood on the Sun and their role in stellar magnetic activity evolution.
- We developed a Python-based, automated flare detection pipeline (`findflare`) to identify and characterize stellar flares.
- In this study we have looked at G-type stars observed by TESS.

Methodology

- Optical photometric flux time-series from TESS is used.
- **Fast Rotation Check (FRC)** is performed by computing the Generalized Lomb-Scargle periodogram. False Alarm Probability (FAP) of the most significant peak must be less than 0.1 to be classified as fast-rotating. Pipeline is sensitive to stars with rotation period less than 14 days.
- For **Gaussian-Process (GP)** rotation modelling, we use sum of two simple harmonic oscillator kernels. After subtracting the model FRC is performed if rotation is found GP is executed again. Once the final GP model solution is obtained it is subtracted from the lightcurve.
- **Flare Detection Criterion** is used to detect flares.
- After a flare is detected, the quiescent (non-flaring) stellar flux is subtracted and the integral under the flare event is calculated to reveal the total flare energy in the TESS bandpass.

Stellar Sample

- We looked at Sector 4 observations of TESS.
- Observed stars were cross matched with SIMBAD database which resulted in **1239 G-type stars**.
- Effective temperature (Teff) distribution of the stars is shown below (Fig. 1)



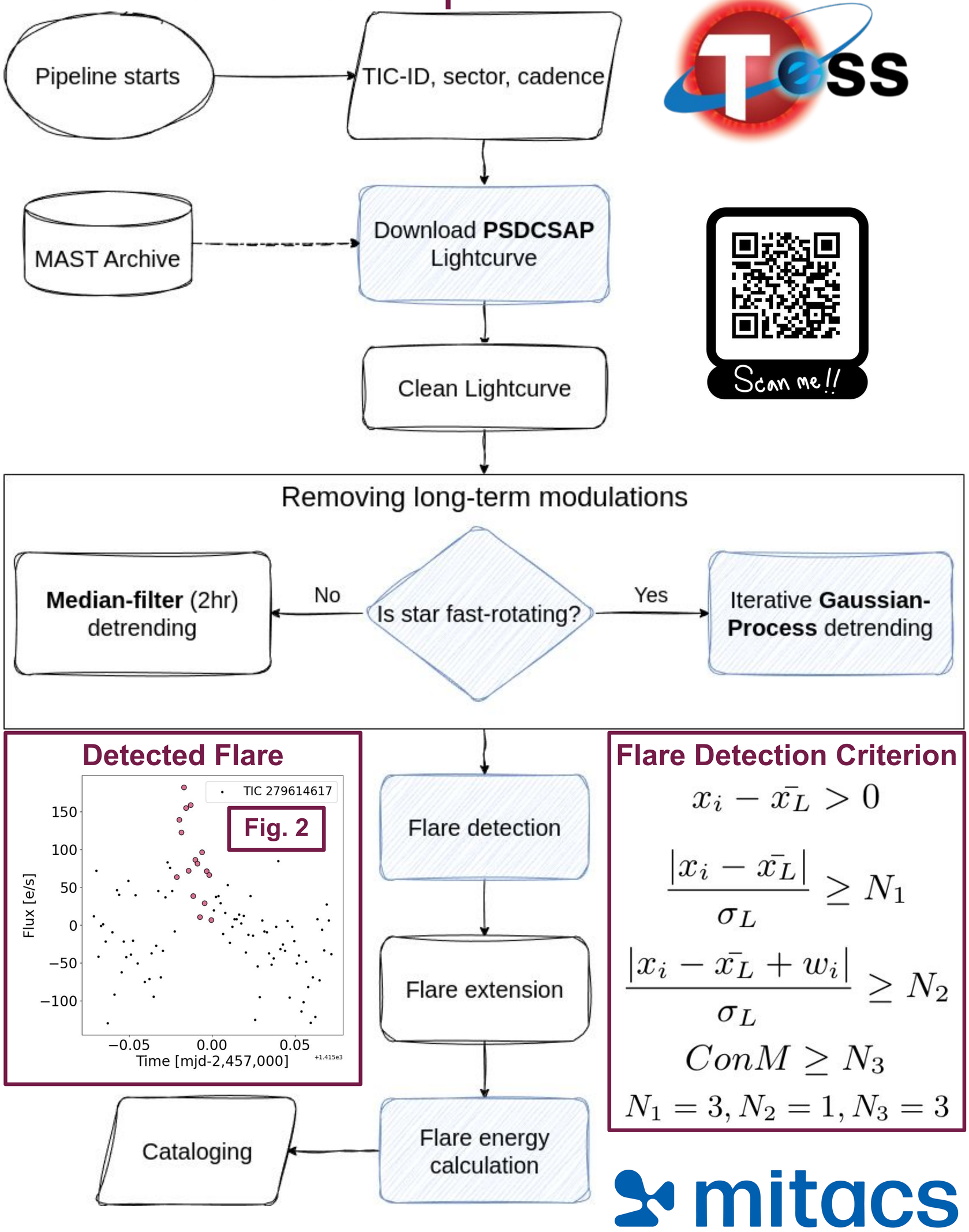
Results

- We detected a total of 389 flare events on 165 stars.
- Clear rotation was detected for 517 stars with periods ranging from 0.25 to 14 days.
- Flare occurrence rate was found to be 0.017 d^{-1} on cool stars (Teff < 5600 K) and 0.008 d^{-1} on hot stars (Teff > 5600 K).
- Flare occurrence rate was found to be 0.026 d^{-1} for stars with clear rotation and 0.001 d^{-1} for stars with unclear rotation.
- We found flares with TESS bandpass energies ranging from $10^{32.7}$ to $10^{35.9}$ ergs.

Conclusion

- Flare occurrence rate clearly suggests that cool stars are more flaring than hot stars.
- Stars with faster rotation period are found to be significantly more flaring than slow rotating stars.
- Increased flaring rates can be explained by enhanced magnetic activity of the star.
- We plan to extend our analysis to other TESS sectors, increasing statistical significance.

Flare Detection Pipeline



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References:
1) Medina et al. 2020, ApJ, 905:107
2) Chang et al. 2015, AJ, 150:27
3) Maehara et al. 2012, Nature
4) Ilin et al. 2022, MNRAS, 513
5) Davenport et al. 2014, ApJ, 797:122

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