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Using TESS to Monitor the JWST Spectrophotometric Standards

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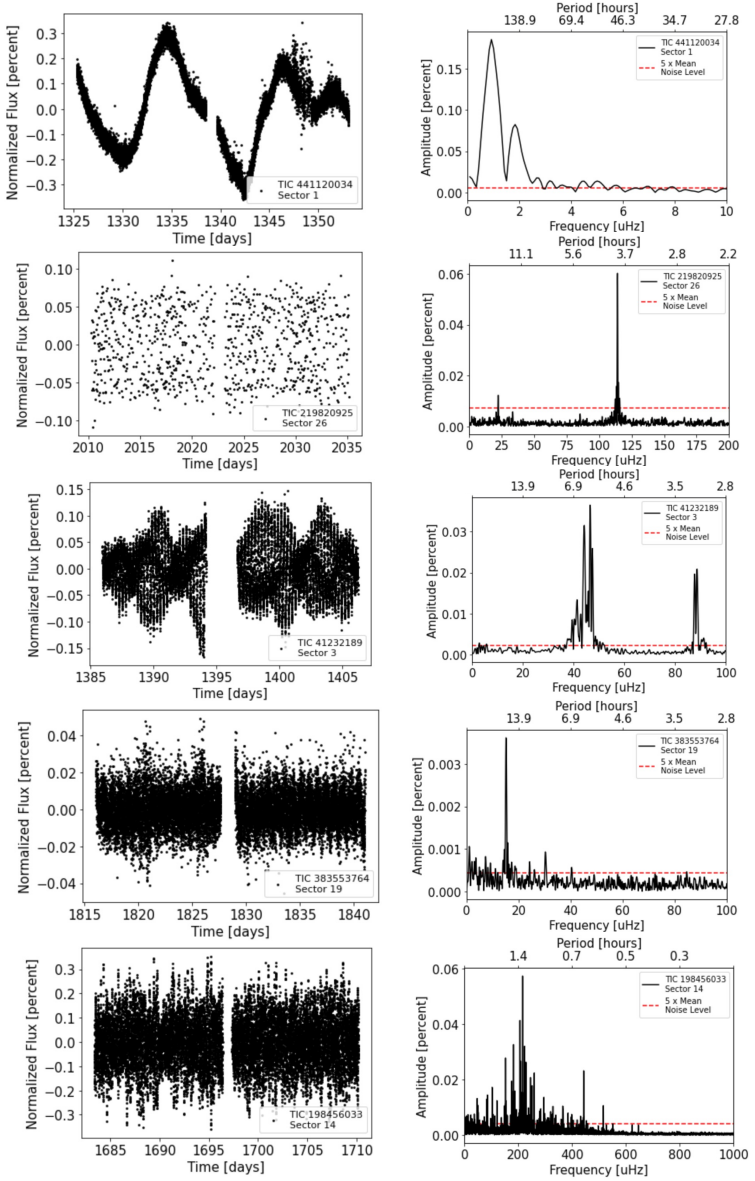
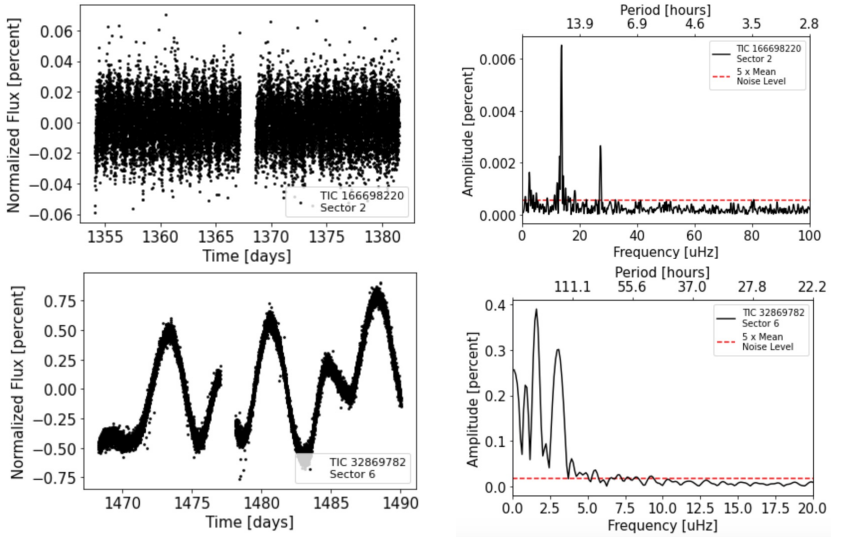
Abstract:

Calibration of the science instruments of the James Webb Space Telescope (JWST) is performed using standard stars. Their spectral types include white dwarfs, A, and G stars because they can be modeled to high accuracy. Selecting stars which are stable to within 2% allows accurate and reliable modeling [1,2]. Therefore, stars that vary in brightness because of pulsation, rotation, eclipses, flares or any other reason may need to be removed from the list of candidates. The Transiting Exoplanet Survey Satellite (TESS) has observed 34 candidate calibration stars for JWST. We examined the TESS light curves for evidence of periodic and transient phenomena and report on any detected variability. Using Lomb-Scargle periodograms, we searched for any significant periodic signals less than 15 days. We detected several variable stars in the set, and the peak-to-peak amplitudes for one were larger than 1%.

References:

1. Bohlin & Cohen 2008, Bohlin 2010
2. Gordon & Bohlin, 2012
3. Lightkurve Collaboration, 2018
4. Feinstein et al. 2019
5. Kjeldsen and Bedding, 1994
6. The Astroquery Developers, MAST, 2021
7. TESS Input Catalog (TIC)





TIC	TESS mag*	Teff* [K]	Log(g)* [cgs]	Stellar Type	Period [hours]	Periodogram Max Amp [percent]	Periodogram Noise Level [percent]	Largest Observed Flux Variation [percent]
441120034	6.2	5920	4.4	G2 V	303.48	0.1852	0.00199	0.7
219820925	6.7	7930	3.5	A6 V	2.424	0.0602	0.0027	0.22
41232189	5.8	10350	4.1	A0 V	5.976	0.0365	0.00074	0.314
383553764	4.4	9070	3.9	A1 V	18.336	0.0036	0.00014	0.095
198456033	6.4	8360	3.9	A3 V	1.296	0.0573	0.00135	0.711
166698220	5.7	7900	4.1	A6 V	20.304	0.0065	0.00019	0.129
32869782	7.3	6050	4.5	G1 V	174.168	0.3904	0.00557	1.666

Displayed above are the variable stars that were detected.
[* obtained from the TESS Input Catalog].

The full list of JWST Primary Standards can be found here: https://jwst-docs.stsci.edu/data-processing-and-calibration-files/absolute-flux-calibration

Purpose and Background:

We search for brightness variations in the set of 42 candidate stars. Any variability will reduce the precision of the spectrophotometric calibrations across instruments.

Analysis:

Using TESS 2-minute data and 30-minute full-frame images, we generated light curves of the standards [3,4]. Then, we calculated Lomb-Scargle periodograms to find any significant periodic signals in the time series data; ie. if the maximum amplitude > 5 sigma above the noise level. The mean noise level is calculated as:

$$\sigma_{noise} = \sqrt{\pi/N} * \sigma_{rms}$$

where N is the number of data points and σ_{rms} is the standard deviation of the flux values [5]. We searched for evidence that the variability was coming from another star in the photometric aperture. We started by listing the nearby stars that were brighter than TESS mag < 15 and within 200". In most cases, the target star was 4-8 magnitudes brighter than any nearby background stars. We also examined difference images to confirm that the target star was responsible for the observed signal. The reported largest observed flux variation is calculated as the difference between the maximum and minimum outlier-removed, normalized flux. When noise dominates it acts as an upper limit on the amplitude on any observed variability.

Results:

Of the 34 stars with TESS data, 7 stars show significant variability. Only TIC 32869782 had a large flux variation of 1.67 percent. This variation is large enough that it could have a negative impact on JWST calibrations.