Boletim da Sociedade Astronômica Brasileira, **32**, no. 1, 80-81

TESS photometric observations of HD 17051

Light curve extraction and rotation period determination

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Abstract. In this work, we have done a light curve re-extraction from the Full Frame Images (FFIs) of TESS, which are taken every 30 minutes. To achieve that, we created a tool that deals with each subsector of the FFIs that contains our target, we calibrated the fluxes and applied a customized mask to the target. We report a rotational period of 7.73 days which is in the range of the previous works that report the period of rotation between 5 an 8.6 days.

Resumo. Neste estudo fizemos uma re-extração das curvas de luz das FFIs (Full Frame Images), que são registradas a cada 30 minutos, pois, a máscara automática do TESS apresenta certa contaminação de estrelas de fundo. Para isso, desenvolvemos uma ferramenta que trata dos subsetores que contêm nosso alvo a partir do FFI, criamos uma máscara customizada para o alvo, calibramos os fluxos e normalizamos a série temporal para análise. Nós reportamos um período rotacional de 7.73 dias para esta estrela, o que está dentro da faixa dos períodos já publicados que reportam períodos entre 5 e 8.6 dias.

Keywords. first keyword – second keyword – third keyword

1. Introduction

The Transiting Exoplanet Survey Satellite (TESS) mission will observe more than 2000 bright stars covering all the sky, and these observations will have a vast impact on stellar rotation and magnetic activity studies. An interesting object to study with TESS is Iota Horologii (HD 17051) because its period of rotation is difficult to be determined due to its intense magnetic activity and complicated spots dynamic. Even though this star had been studied by numerous authors, there is no consensus for its rotational period, which fluctuates between 5 and 8.6 days. As this is a bright star, it was defined as a primary target to be observed. TESS team extracted the light curve from the target pixel automatically and that light curve passed through a pipeline that deals with the correction of systematics and trends of the light curve. This automatic correction, most times, can delivery an incorrect conclusion about the rotational modulation of the star because the field of the mask can contain contaminations and/or the automatic reduction can create false trends (see figure 1. In this work, we have done a re-extraction of the light curve from the Full Frame Images (FFIs) from TESS for the target HD 17051 (ι Hor). To achieve that, we created a tool that deals with each subsector of the FFIs that contains our target, we calibrated the fluxes and applied a customized mask to the target.

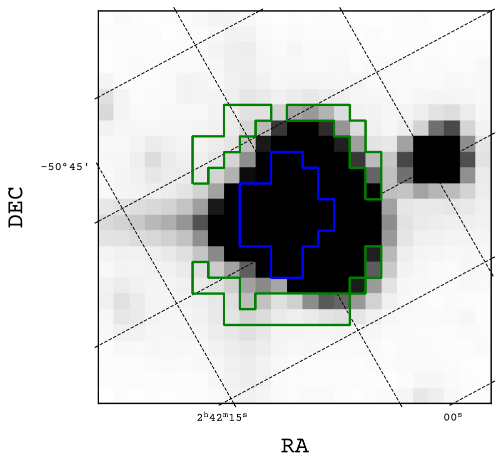

Figure 1. HD 17051 Target Pixel from sector 3. The green line is the background sky defined automatically by TESS. The blue line is the target defined by TESS.

2. ι Hor

ι Hor (HR 810, HD 17051, HIP 12653), is a $V = 5.4$ mag young solar-type star visible in the Southern Hemisphere sky, which is known to host a planet. Analysis of high-precision radial velocity data by Kürster et al. (2000) first suggested the presence of a $\simeq 2\,M_{\rm Jup}$ minimum-mass planet at $\simeq 1$ AU from the star (see also Zechmeister et al. 2013). At the time of its discovery, this planet had the most Earth-like orbit known. Exoplanets in the Hyades appeared elusive (Paulson et al. 2004) until recent discoveries (Quinn et al. 2014; Mann et al. 2016). If a true Hyades member, ι Hor would add significantly to the planet statistics of this cluster. Note, however, that planet-host stars in open clusters are not particularly rare (e.g., Brucalassi et al. 2014; Malavolta et al. 2016).

3. Methods

We extracted the light curve directly from the Full Frame Images (FFIs) from the TESS archive by downloading two 12 x 12 arcmin Target Pixels (TP from the FFI) from https://mast.stsci.edu/tesscut/TIC with coordinates RA: 40.63944368 DEC: -50.80029339 and ID TIC 166853853. The HD 17051 was observed in two sectors of TESS, sectors 2

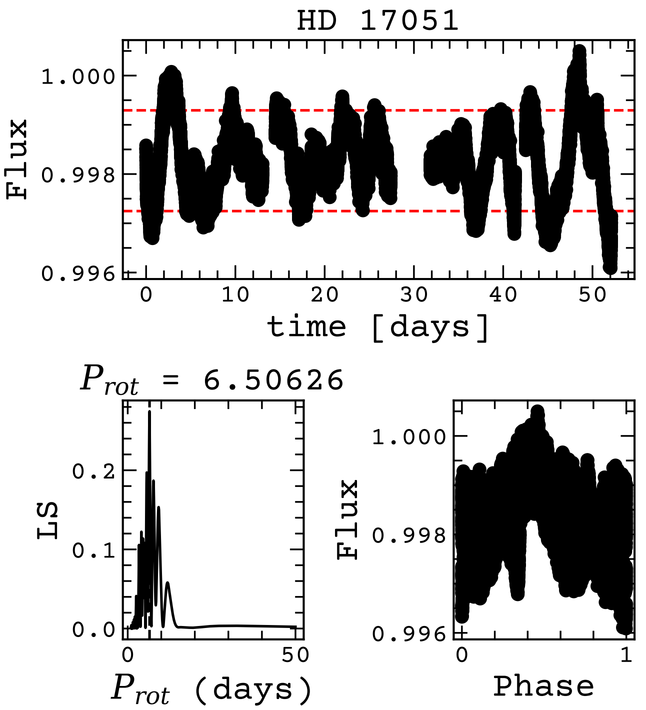

Figure 2. Analysis of HD 17051 from automatic light curve from TESS. Top panel: raw light curve with red dashed lines as the standard deviation. Bottom left panel: Lomb Scargle periodogram. Bottom right panel: Phase at the found period.

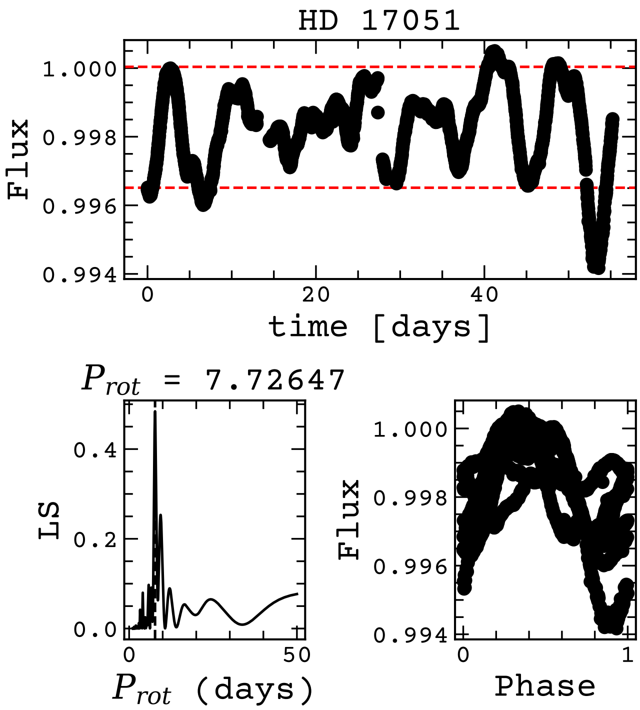

Figure 3. Analysis of HD 17051 from the re-extractioned light curve. Top panel: raw light curve with red dashed lines as the standard deviation. Bottom left panel: Lomb Scargle periodogram. Bottom right panel: Phase at the found period

and 3. Each TP has 35 x 35 pixels and is rotated by an angle with each other. This Rotation means that we can not use the same mask for the light curve extraction. We applied custom masks to each TP and extract the flux in 2 x 1245 data flux points from '$FLUX$' in the .fits files that contain our target. We then applied a background mask to the overall uniform background spread around the target with the same number of pixels selected to the target. The error comes from "$FLUX_{ERR}$". To account for the numerous systematics that generates discontínuities and outliers on the light curve, after eliminating the invalid data of the flux array, we proceed with the following reduction equation:

$$Flux_i = [F_i - Fb_i] - mean[F_i - Fb_i] + mean[F_i] \quad (1)$$

where $Flux_i$ is all final point data flux, F_i is each "$FLUX$" from the mask and Fb_i is each background flux also from "$FLUX$". This simple equation corrects all overall variations that the TP could pass since evaluate and subtract the variation of the hole TP.

The array for $Flux_i$ is then appended together with the relative error and the time is the "$TIME$" from the .fits summed with the "$BJDREFI$" plus the "$BJDREFF$" also found in the .fits file. A final file with Time, Flux and Err is then saved in a .txt file to be analyzed afterward. This .txt file contains the light curve for the two sectors of this target but there are still some small jumps and discontinuities due to the concatenation of the two sectors. We corrected these discontinuities by linear detrending on the affected portions of the light curve to fit the tendency of the curve, thus creating a more reliable light curve than the automatic extraction performed by the TESS pipeline.

4. Analysis of HD 17051

After the normalization and detrending of the time series, we get the final light curve presented in the top panel of figure 3. To determine the period of rotation, we applied a Lomb-Scargle (LS) to the light curve and folded the curve with the period detected. The result of the analysis and the phase are presented in figures 2 and 3. Figure 2 shows the analysis from the automatic pipeline from TESS. We can clearly see that the light curves on the top panels of figure 2 and figure 3 are different, as the first one returns a P_{rot} = 6.51 and the second one returns P_{rot} = 7.43

5. Summary and conclusions

From our analysis, we can clearly see that the automatic pipeline of TESS can generate false tendencies on the final light curve. These tendencies can modify the overall aspect of the light curve, thus changing the Rotation Period detected by the Lomb Scargle periodogram. After the re-extraction, TESS light curve produces our rotational period which agreed with the previous determination found in the literature.

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