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Stellar activity of Kepler 289 from transits modelling

Alexandre Araújo de Souza & Adriana Valio

[1] Universidade Presbiteriana Mackenzie; e-mail: adesouza.astro@gmail.com, adrivalio@gmail.com

Abstract. The Kepler mission launched in 2009 obtained precise photometric measurements for ~150.000 stars with nearly continuous coverage four years. More than 3800 planet candidates have been discovered via the planet transit method. When exoplanets pass in front of their host star, a portion of the start light is blocked out and a small decrease in the photon flux is measured. These changes in flux over time consist of a light curve. The relative size of the planet with respect to the host star will determine the decrease in flux during the transit. By fitting models to the light curve, various characteristics such as orbital parameters and planetary radius can be extracted. The target star of this study is Kepler-289 a star with mass of 1.08 (± 0.02), solar mass and with an age of 0.65 (± 0.44) Gyr an effective temperature of 5990 (± 38) K. The Kepler 289 has 3 planets denoted Kepler-289b, c and d. In this work, we use as technique for spot detection the planetaray transits model, which uses an exoplant as a probe in the study of spots from the light curves. Preliminary results show that the star is active with some spots seen on the 4 transits of planet Kepler-289d, the larger planet with a mass of 0.415 (± 0.053)MJup. The transit modeling of the planet Kepler-289d resulted in 9 detected spots. A Lomb Scargle periodogram of Kepler-289 light curve yeield a mean stellar rotation of 8.76 days.

Resumo. A missão Kepler lançada em 2009 obteve medições fotométricas precisas para ~150.000 estrelas com cobertura quase contínua por quatro anos. Mais de 3800 candidatos a planetas foram descobertos através do método de trânsito planetário. Quando os exoplanetas passam na frente de sua estrela hospedeira, uma parte da luz é bloqueada e uma pequena diminuição no fluxo de fótons é medida. Essas mudanças no fluxo ao longo do tempo consistem em uma curva de luz. O tamanho relativo do planeta em relação à estrela hospedeira determina a diminuição do fluxo durante o trânsito. Ajustando modelos de trânsitos à curva de luz, várias características, como parâmetros orbitais e raio planetário, podem ser extraídas. A estrela-alvo deste estudo é Kepler-289 uma estrela com massa de 1,08 (± 0,02), massa solar com uma idade de 0,65 (± 0,44) Ganos e uma temperatura efetiva de 5990 (± 38) K. A Kepler-289 tem 3 planetas denotados por Kepler-289b, c e d. Neste trabalho, utilizamos como a técnica de detecção pontual de mancha pelo modelo de trânsitos planetários, que utiliza um exoplaneta como sonda no estudo de manchas a partir das curvas de luz. Resultados preliminares mostram que a estrela é muito ativa com algumas manchas detectadas nos 4 trânsitos do planeta Kepler 289d, o planeta maior com uma massa de 0,415 (± 0,053) MJup. A modelagem das curvas de luz do trânsito do planeta Kepler-289d resultou em 9 manchas detectadas. O periodograma Lomb Scargle da curva de luz da Kepler 289 resultou em uma rotação estelar média de 8,76 dias.

Keywords. Stars: rotation – starspots – Stars: solar-type

1. Introduction

New astronomical instrumentations and space mission launches, Astronomy has daily have reported new discoveries in Astronomy about various phenomena in the universe. Such discoveries provide the emergence of increasingly accurate and effective techniques in the study of various astronomical knowledge areas. One such area is Stellar Astrophysics, an area of Astronomy dedicated to the study of stars. This area of Astronomy that is experiencing its golden era with the emergence of space missions such as CoRoT (COnvection ROtation et Transits planétaires), Kepler, TESS (Transiting Exoplanet Survey Satellite) and the future PLATO mission (PLAnetary Transits and Oscillations of stars). In this work, the highlight will be for we focus on NASA's Kepler space mission.

The method of planetary transits is one of the techniques used in the discovery of exoplanets. When transiting the host star, the exoplanet crosses the star disk in the direction of the observer causing a slight decrease in the star's brightness. This decrease in brightness allows us to infer a series of physical parameters from the planetary system, including planetary radius, orbital parameters, suche as period, semi-major axis and inclination angle.

The model of Silva (2003), was proposed for the first time to use a planet as a probe to detect the presence of spots on the surface of the star. Briefly, it consists in physically characterizing stains spots in solar stars (F, G, K) of planetary transient simulations. This method generates a two-dimensional synthesized image of the star taking into account the obscuration of your disk limb darkening.

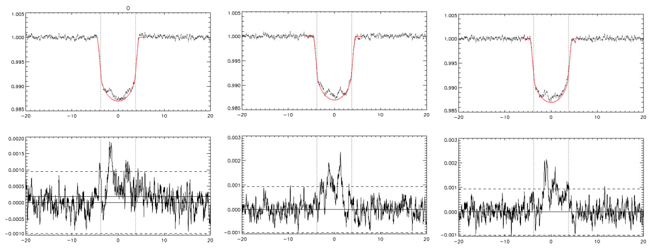

Figure 1. Kepler-289 Transit Light Curve (black line), with fit (red line). In the lower panels the residue is shown to be subtracted from the Kepler-289 star light curves model. The residue is possible to identify peaks with greater emphasis, the result of stellar eclipse spots.

2. Transit modeling

In the analysis of the Kepler-289 light curves, 3 planetary transits were detected. Each traffic transit was fit by the Silva model. The fit were made to the parameters of the planet Kepler-289 d. The transits of the other planets were not identified to be fit for fitting. The parameters for used in the fit are described listed in Table 1. Figure 1 it is possible to see show the detected transits. Initially, the resulting light curve of the model without

Table 1. Parameters of the star model without spots and the coefficients of limb obscuration darkening.

Obscuration of limbo u1 and u2	0.46 and 0.046
Radius of the planet ($R_\star$)	0.102
Orbital Semi-major axis ($R_\star$)	112.0
Angle of inclination	89.8
Period of the planet	125 days

Table 2. Table with the mean values of the physical parameters obtained from the spots with the Silva (2003) model for Kepler-289.

Radius R_p	0.56±0.15(R_p)
Intensity	0.40±0.20(I_c)
Longitude	−80° to 60°
Latitude	−20.5°
Temperature	4700 ± 800 (K)

spot on the traffic curve should be adjusted the transits in the light curve are fit by a model of a star without spots. The result of the subtraction of the light curve model is the residue where some peaks are stressed. By subtracting this model from the light curve, a residual light curve is generated where some peakes are evident. Noise residual peaks with intensities greater than 10x the noise are understood as evidencce of spots on the surface of the star where, the peaks occur when the planet crosses the star disk during its orbital period.

3. Physical parameters of the spots

From the excesses detected in the residues residuals it is possible to estimate physical parameters of the spots. These residues residuals were modeled considering the following parameters: size, intensity and location of spots on the surface of the star Kepler-289. The stellar spot is modeled as a circular disk and it is possible to obtain with:

- Spot size in units of the planetary radius R_p;
- Intensity: intensity of the spot in relation to the brightness of the center of the star;
- Position: longitude and latitude in the stellar disk.

Figure 2 shows the results of the fit of the residues residuals obtained from the Kepler-289 light curve. For a better understanding it. On the left panels, it is shown the two-dimensional image the stars with the 3 spots on the surface, and next to, and on the right panels the result of the fit with of the three peaks obtained by of the residues residuals. The mean values obtained for the spots temperature, position and intensity are listed in Table 2.

4. Determination of the rotation period of the star Kepler-289

The stellar rotation is one of the a parameter of great importance in the study of the evolution of stars. From it, it is possible to obtain information about age, angular momentum transfer, deceleration of stars in relation to the life time, magnetic fields etc. The model depicted in this work is of great effectiveness in the study of stellar rotation, as well as the differential rotation in solar type stars using the position of the spots on the surface detected by sucessive planetary transits. To obtain the average stellar rotation of the star is used obtained by applying the Lomb-Scargle Periodogram (Lomb 1976; Scargle 1982). The

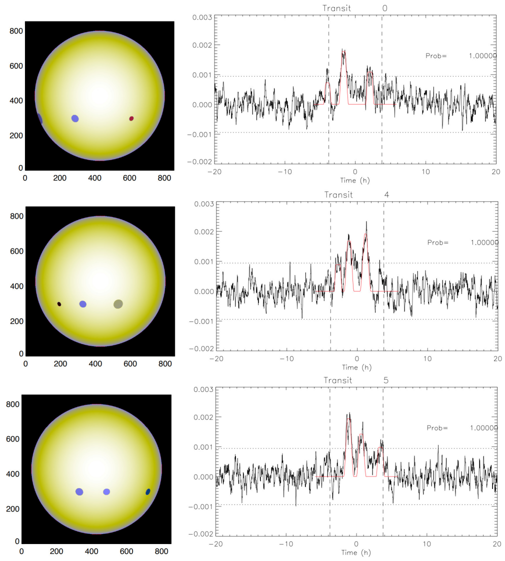

Figure 2. Two-dimensional image of a star with the presence of 3 spots on its surface and beside the model of the adjustment of the excesses presented in the red curve.

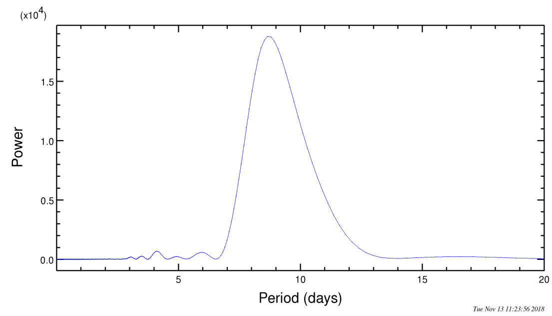

Figure 3. Lomb-Scargle periodogram with peak at 8.76 days, considered the average rotation period of star Kepler-289.

power spectrum is shown in Figure 3. In this graph we can see. This plot indicates a peak at 8.76 days, which is then adopted as the average stellar rotation period of the star.

5. Conclusion

This work aimed to report the study of studies the spots on the surface of the star Kepler 289 and also determined the average rotation period of the Kepler-289 star using the planetary transit method first proposed by Silva (2003). The results showed that the star is active. Were detected with the detection of 9 spots modeled by in the light curve of Kepler 289d exoplanet. The Unfortunately, the transits of the other planets were not detected.

References

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