LIGHT CURVE ANALYSIS WITH KEPLER

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Abstract The Kepler and CoRoT space telescopes are monitoring thousands of stars with an unprecedented precision leading the way into a new age of astronomy. Originally intended to detect extrasolar planets, they furthermore provide the opportunity to look for stellar variability which is our main focus. Currently, our work focuses on the 306 exoplanet candidate host stars released on June 15, 2010. We present statistics on how many of them show periodic photometric variability, providing preliminary rotation periods. Furthermore, two different spot modeling techniques are introduced. In the future, our work will focus on spot evolution and differential rotation.

Motivation

The main sources of periodic stellar variability are binarity, surface oscillations, and rotation (due to star spots). We are interested in studying rotation-induced variability on Kepler stars. To find these periodicities we are using the Lomb-Scargle periodogram and different spot modeling techniques. Our main goals are to estimate stellar rotational periods and their evolution over time, especially considering differential rotation (Fig.1).

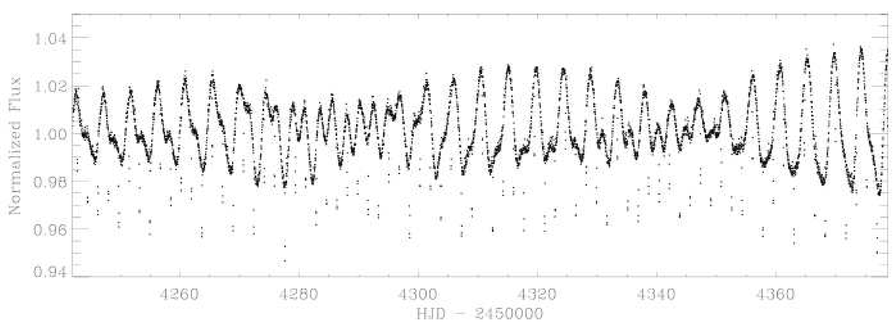

Figure 1: Corot-2 light curve showing differential rotation

P = 1.02 ± 0.02 d

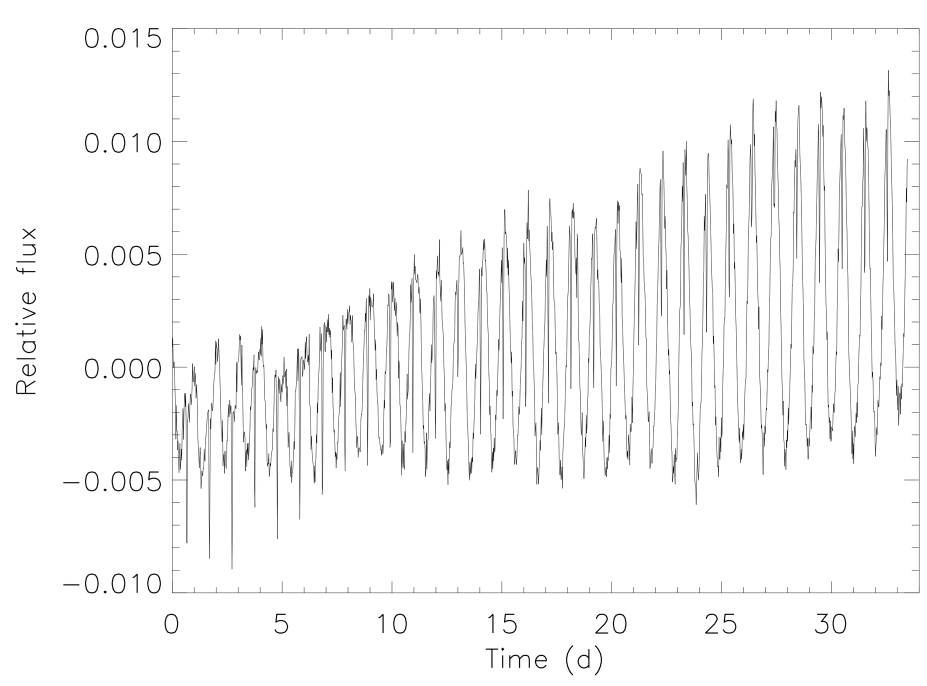

Figure 2: Light curve of the star with Kepler-ID: 5115978, $T_{\rm eff}$ = 5976 K, $\log g$ = 4.427, KEP-Mag: 15.20 and the shortest detected period, probably due to pulsations.

Sample

Our sample consists of the 306 exoplanet candidate host stars having transit events in their light curves. Since we are interested in stellar rotational periods, we selected a subsample of 24 "active" stars from the whole data set that have periodogram power greater than 70 and periods up to 17 days. These restrictions account for the facts that the light curve should show by eye a believable periodicity and that at least two full cycles are observed. The period distribution of our subsample is shown in Fig.6. A statistical overview of the whole sample can be found in [1, 2].

Lomb-Scargle periodogram

The Lomb-Scargle periodogram [4] is a powerful spectral analysis tool for unevenly sampled data. It decomposes the data into a series of sines and cosines and one obtains peaks with different powers depending on the goodness of the fit. The periods we found are always associated to the highest peak of the periodogram. The period errors were calculated by overplotting the highest peak with a Gaussian and calculating the half of the FWHM. They should be considered as upper limits.

P = 11.19 ± 1.57 d

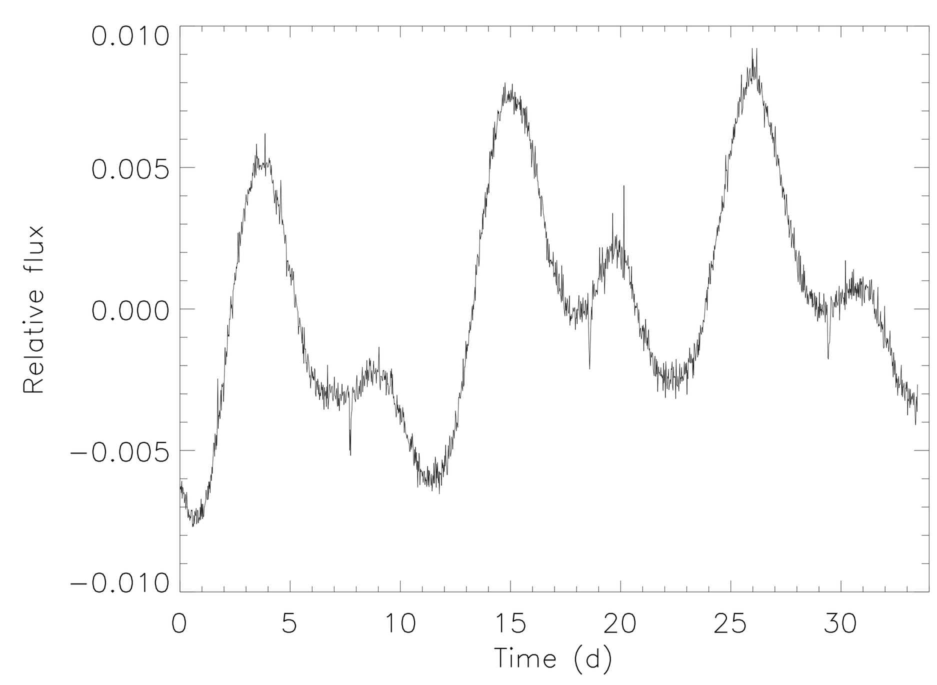

Figure 3: Light curve of the star with Kepler-ID: 8505670, $T_{\rm eff}$ = 4214 K, $\log g$ = 4.608 and KEP-Mag: 15.06

P = 11.19 d, Power = 100.7

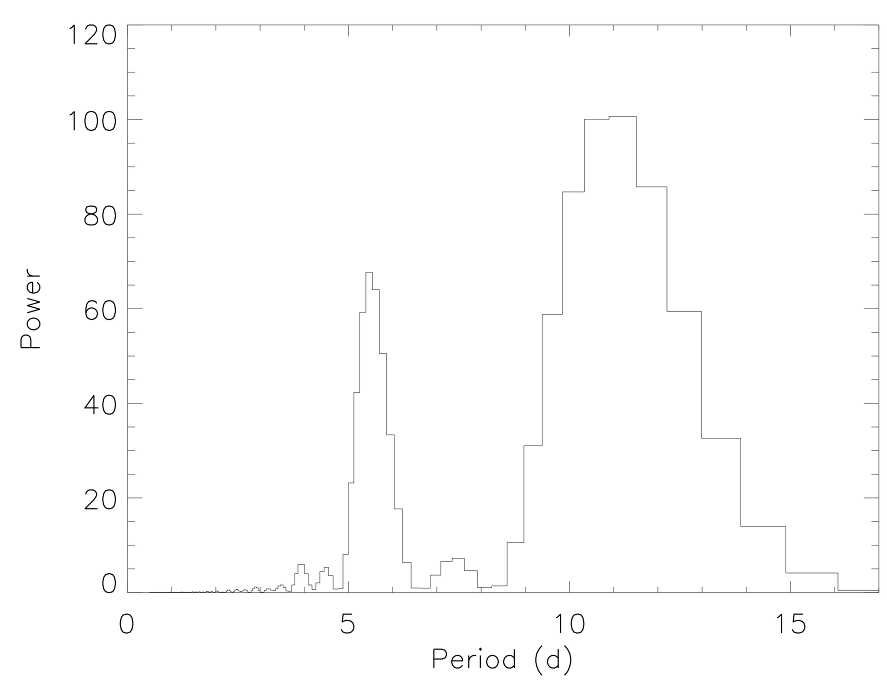

Figure 4: Periodogram of light curve from Fig. 3 with two significant periods.

Light curves

The Kepler Quarter 1 (Q1) data was released to the public on June 15, 2010. It has a time span of ~ 33.5 days and a cadence of ~ 30 minutes. In Fig. 2 & 3 two Kepler light curves are presented showing by eye clear periodicity. We divided each one by its median and subtracted unity. Unfortunately, in almost all Kepler light curves a linear trend is seen likely caused by the instrument so all calculations we did are based on the so-called raw data. The values of the unique Kepler-ID, $T_{\rm eff}$, $\log g$ and apparent magnitude are taken from the Kepler Input Catalogue (KIC).

Spot modeling

Assuming the flux variations are due to spots, one has to be very careful to assign these periods as true stellar rotational periods because star spots use to change their size and position, some are created, others disappear during a cycle. Therefore, explicit spot modelling needs to be done. We are using the two different algorithms CHEETAH and MODSTAR. The first one fits a light curve with spots of different size and position based on the paper of Eker [3]. MODSTAR works the other way round: Spots are placed on an rotating star which produces a light curve.

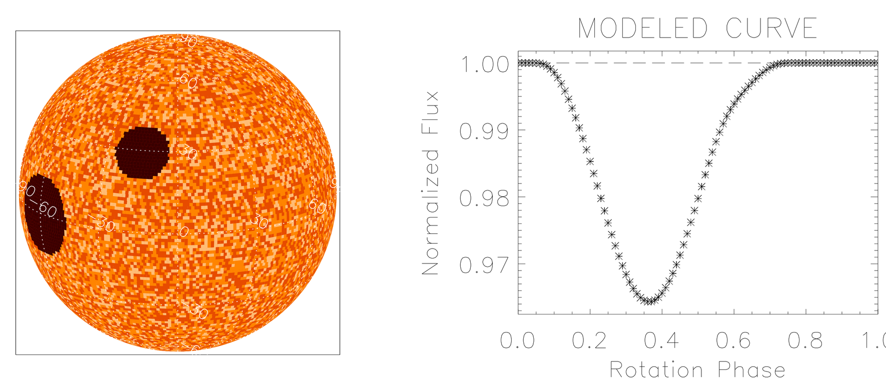

Figure 5: Simulated star with two circular spots and the resulting light curve using MODSTAR.

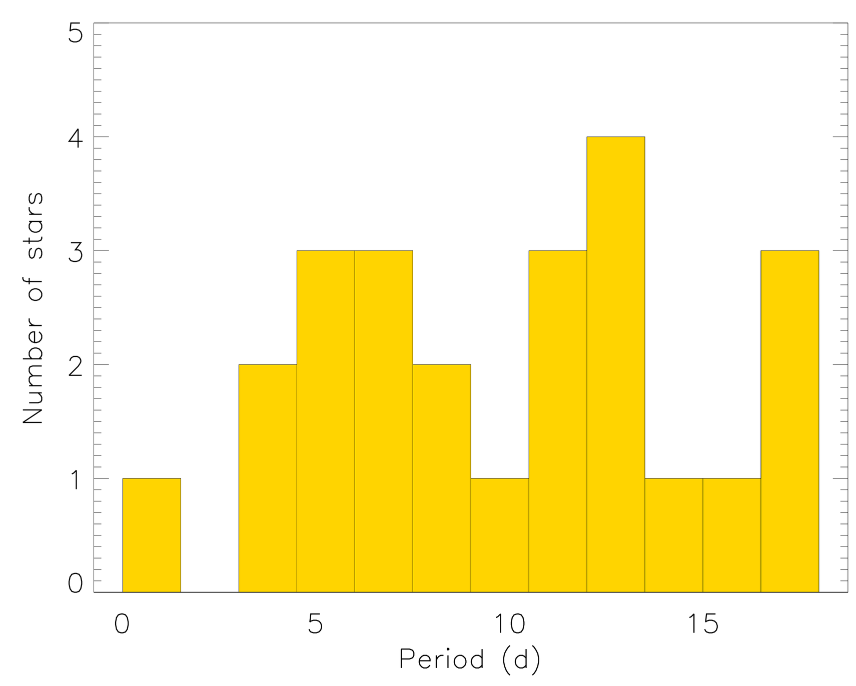

Figure 6: Period distribution of the 24 active stars. Most of the periods are believed to be stellar rotational periods but in some cases it is possible that just the half period was detected.

Summary & Future work

Using the Lomb-Scargle periodogram, we selected some active stars from our sample and determined preliminary periods and their errors. Most of the periods are believed to be stellar rotational periods but in some cases it is possible that just the half period was detected. The light curve in Fig.2 shows some kind of beat frequency. The duration of the signal indicates that it is probably due to pulsations. But also differentially rotating stars curves of similar shape (s. Fig.1). Therefore, our future work will focus on the evolution of periods over time, especially considering differential rotation. As more data becomes available we will also look for activity cycles.

References

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[3] Z. Eker. Modeling light curves of spotted stars erratum. 1994.

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