

An easy way to reduce and analyze light curves from the Kepler mission

L. de Almeida¹ & J-D. do Nascimento¹

¹ Universidade Federal do Rio Grande do Norte e-mail: dealmeida.l@fisica.ufrn.br

Abstract. LEGUME (Light Curve General Use Made Easy) is a tool written in Python that deals with basic routines for acquire, reduce and analyze raw light curves. Our tool reduces the light curves from the Kepler mission, and do basic analysis for the determination of periods of rotation, extraction of transits signals and basic characterization of the systems. Because it is written in Python, our tool can be easily implemented in more specific routines.

Resumo. LEGUME (do inglês: Light curvE General Use Made Easy) é uma ferramenta escrita em Python que lida com rotinas básicas de aquisição, redução e análise de curvas de luz cruas. Nossa ferramenta faz a redução das curvas de luz da missão Kepler e também análises básicas para determinação de períodos de rotação, extração dos trânsitos e caracterização básica dos sistemas. Por ser escrito em Python, nossa ferramenta pode ser facilmente implementada em outras rotinas mais específicas de análise.

Keywords. Methods: data analysis – Stars: rotation – binaries: eclipsing – Planets and satellites: detection

1. Introduction

In the context of exoplanet detection and determination of star rotation, astronomers need to work directly with light curves obtained from terrestrial and space telescopes. The Kepler mission publicly discloses its entire data from its mission (Batalha et al. 2013), which comprises a wide variety of raw light curves, and one may spend some time to reduce and analyze all those data, because of the flux counting differences in each quarter, slope trends and systematic errors, even in the pre-reduced light curve. LEGUME is available to the entire scientific community through github¹ and we encourage its use for introduction in reduction and analysis of time series.

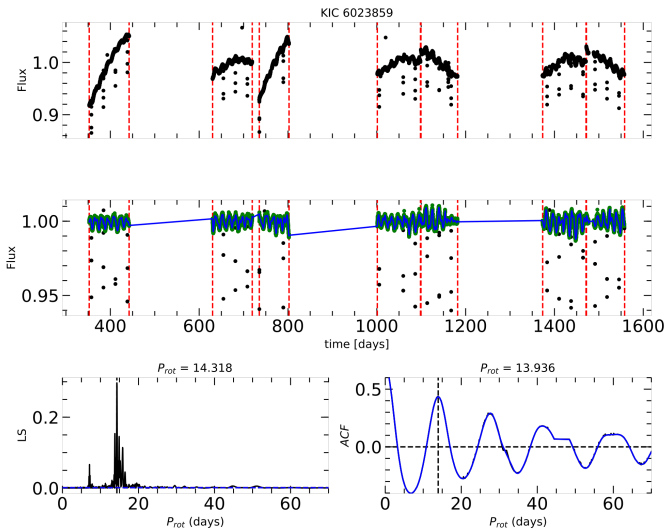


FIGURE 1. Top panel: Shows the raw *SAP_FLUX* from a example Kepler star (KIC 6023859) with quarters delimitation in dashed red. Lower panel: Rotation modulation in solid blue, considered data to run the P_{rot} LS in green dots and raw *PDC_FLUX* in white dots.

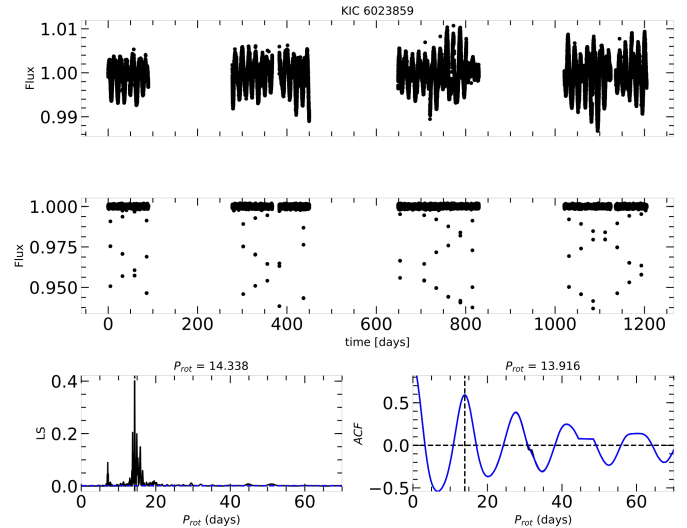


FIGURE 2. Top panel: polynomial adjust over the *SAP_FLUX*. Lower panel: Detrended *SAP_FLUX* over the *PDC_FLUX* for comparison.

2. The LEGUME tool

The LEGUME tool only needs the KIC ID of the star, and the initial and final quarters as input, to display a window with the first basic auto reduction. In this first step, the tool presents the *SAP_FLUX* data for comparison, and a pre-analysis of the *PDC_FLUX* data, with the separation between the light curve modulation and the transit signal (if there is any). All plots shown are automatically separated by quarters as shown in the Figure 1.

After that, LEGUME offers a range of controls to adjust and reduce the light curve according to the user's needs. If you want to analyze a planetary transit or eclipsing binaries (EB), it can be done by adjusting the parameters to plot the phase in a specific period or by adjusting one automatically. If you want to analyze the rotation of the star, you can adjust the type of fit and level for the rotation modulation. For comparison, the user can also force

¹ <https://github.com/monolipo/Light-Curve-Python-Analysis-Tool>

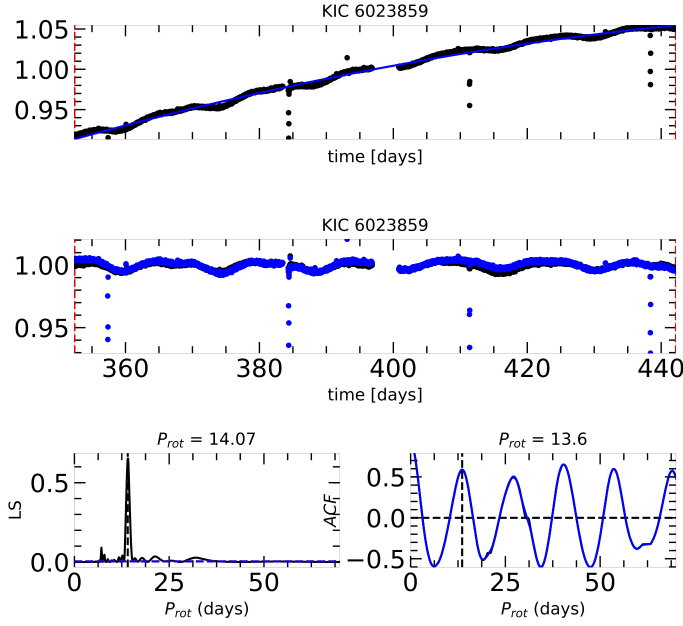


FIGURE 3. Top panel: Range selection to validate periodicity by the user. Lower left panel: Lomb-Scargle of the modulation with true period in white dashed and validation period in dashed red. Lower right panel: Auto Correlation Function with validation period in dashed red.

a polynomial correction on the raw *SAP_FLUX* light curve to compare the fidelity of the pre-reduction over the *PDC_FLUX* as shown in Figure 2.

The user can also test and validate the period found by Lomb-Scargle and ACF by clicking on the region representing a period, and interactively checking the calculated period on the same plot as seen in Figure 3. All of these subroutines are accessed through intuitive keyboard shortcuts, and at the end of the analysis, you can save the figures and print the analyzes of each light curve in a specific folder. These interactive analyzes accumulate to compile a final result of the reduction comprising the star rotation, separated from the transit signal (planetary or EB) and the periodogram in LS and ACF of stellar rotation as shown in the Figure 4.

3. The installation

You will need to have installed git software. You can verify if you already have it by typing in a terminal:

```
$which git
```

From a new terminal create a directory dedicated for this tool with the name *LIGHTCURVETOOL*, and from it, clone this github files from the link available in manuscript.

This will download the code and instructions. The most simple way to have all the needed packages is to install a full python distribution using for example Anaconda. If you already have Anaconda installed, you still may need to install the 3.6 version and some packages. To verify if you have anaconda installed, just look at the answer of 'which python' command in a terminal. If it points to a directory which name contains 'anaconda', it means that you already have anaconda installed. If you don't have anaconda installed: The anaconda package is available following this link: <https://www.continuum.io/downloads>. LEGUME uses the python 3.6 package. If you already have an

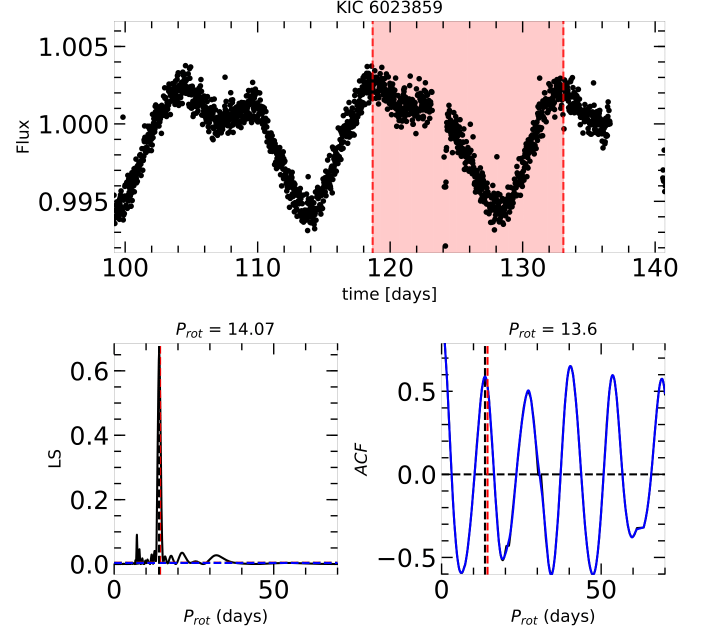


FIGURE 4. Final composition of the reduction and analysis using LEGUME. First panel: isolated modulation of the rotation. Second panel: only the binary signal without rotation. Third panel: LS and ACF periodogram of the rotation.

anaconda distribution installed for python2: you only need to install a 3.6 environment, by writing the following in a terminal:

```
$conda create --name py3k6 python=3.6
    matplotlib scipy numpy ipython h5py
    astropy pymysql pytest ipykernel
$source activate py3k6
$python kernel install --user
```

This will install the main libraries needed to work with LEGUME (Astropy Collaboration et al. 2013; Jones et al. 2001; Foreman-Mackey 2018). Now you can test your installation. Once all the above is done, you can open a terminal and go to the directory where we have downloaded the code using git.

4. Conclusion

LEGUME has the purpose of facilitating the introduction of new astronomers in the reduction and analysis of light curves. This tool is free and available through <https://github.com/monolipo/Light-Curve-Python-Analysis-Tool>. All steps for installation and use are in the documentation attached to this website.

References

- Batalha, N. M., Rowe, J. F., Bryson, S. T., et al. 2013, *VizieR Online Data Catalog*, 220
- Foreman-Mackey, D. 2018, *Astrophysics Source Code Library*, ascl:1807.027
- Astropy Collaboration, Robitaille, T. P., Tollerud, E. J., et al. 2013, *A&A*, 558, A33
- Jones, E., Oliphant, T., Peterson, P. et al, 2001, *Open source scientific tools for Python*