The effect of stellar spots on high precision transit light curve

Mahmoudreza Oshagh*,**[1], Nuno C. Santos*,**, Isabelle Boisse*, Gwenael Boue***, Marco Montalto*, Xavier Dumusque****, Nader Haghighipour*****

Centro de Astrofísica da Universidade do Porto

*Centro de Astrofísica da Universidade do Porto, Portugal
** Departamento de Fisica e Astronomia, Faculdade de Ciencias, Universidade do Porto, Portugal
*** Department of Astronomy and Astrophysics, University of Chicago, USA
****Observatoire de Geneve, Universite de Geneve, Switzerland
*****Institute For Astronomy, University of Hawaii-Manoa, USA
1: moshagh@astro.up.pt

U.PORTO
FACULDADE DE CIÊNCIAS UNIVERSIDADE DO PORTO

Introduction

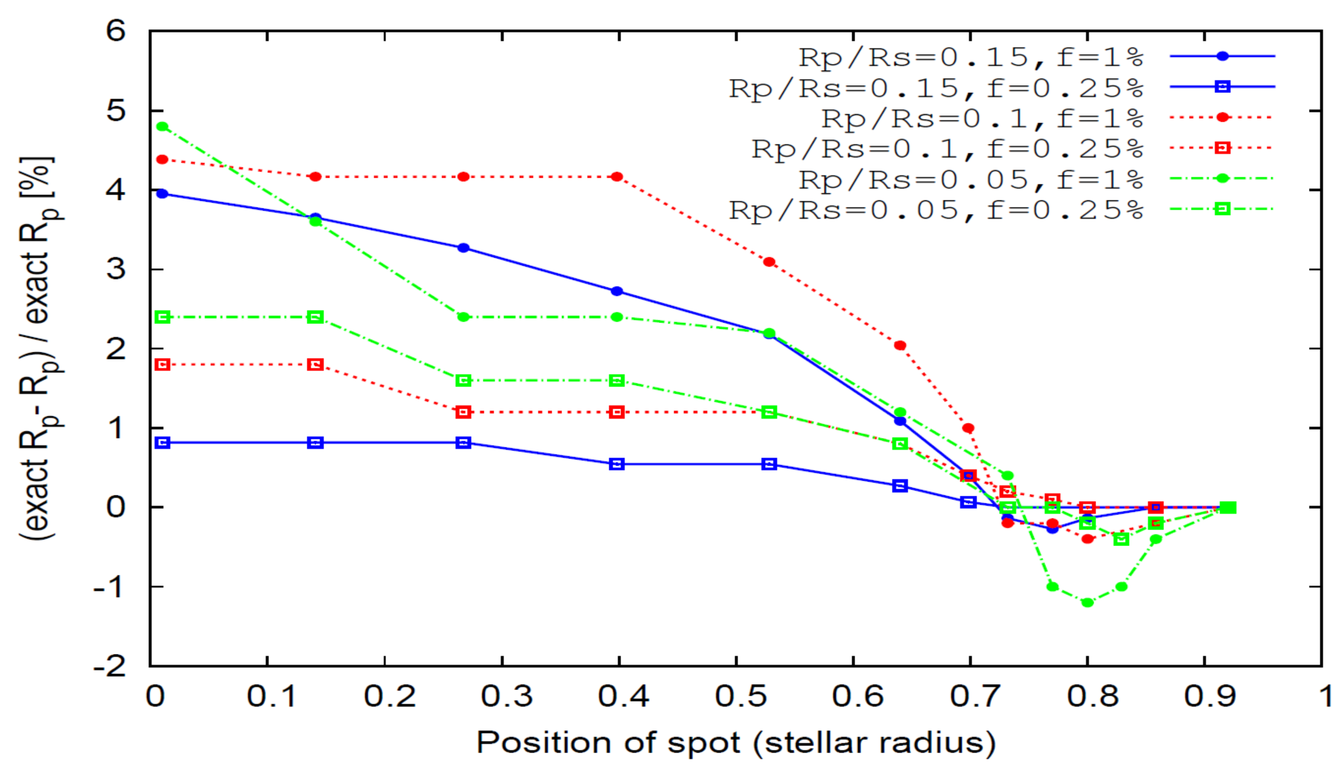
In many cases, exoplanets are orbiting stars which show high levels of chromospheric activity. The first results of the Kepler Space telescope suggest that more than 50% of the observed stars in Kepler field of view are more active than the Sun (Basri et al. 2010). Those active stars present activity features such as spots on their surface (Berdyugina 2005). These stellar spots could affect the determination of the planetary system properties, through both photometric and spectroscopic observations (e.g Boisse et al. 2009, 2011; Czesla et al. 2009). For instance, the overlap between the transiting planet and stellar spots produces anomalies in the transit light curve. Those anomalies may lead to the wrong estimation of some planetary system's parameters (e.g. planet radius). They can also cause offsets in the transit timing measurement which lead to the detection of false positive signals (Czesla et al. 2009; Sanchis-Ojeda et al. 2011; Sanchis Ojeda & Winn 2011; Oshagh et al. 2012).

SOAP-T

In this study we used "SOAP-T", a publicly available code [www.astro.up.pt/exoearths], which generates the expected radial velocity signal and light curve for a system consisting of a rotating spotted star with a transiting planet. This tool can be used to study the anomalies inside transit light curves and the Rossiter-McLaughlin effect, to better constrain the orbital configuration and the properties of planetary systems, as well as the properties of active zones of their host stars. A Detailed description of the code and some tests are presented in Oshagh et al. 2013.

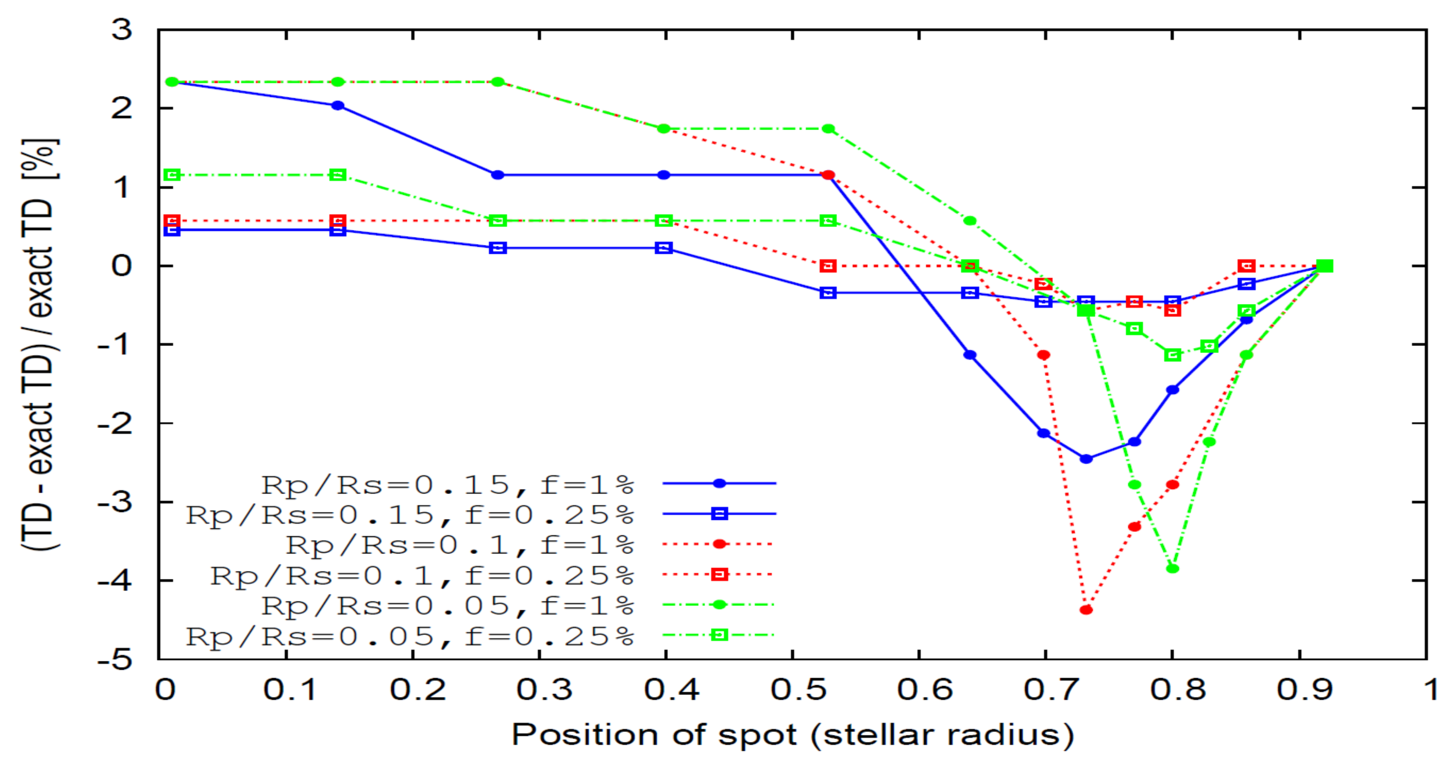
For our simulations, we consider a rotating late-type spotted star with the rotational period of 9 days and quadratic limb darkening coefficients of u1= 0.29 and u2= 0.34. The star harbors a planet with period of 3 days.

Effect of stellar spots on transit depth



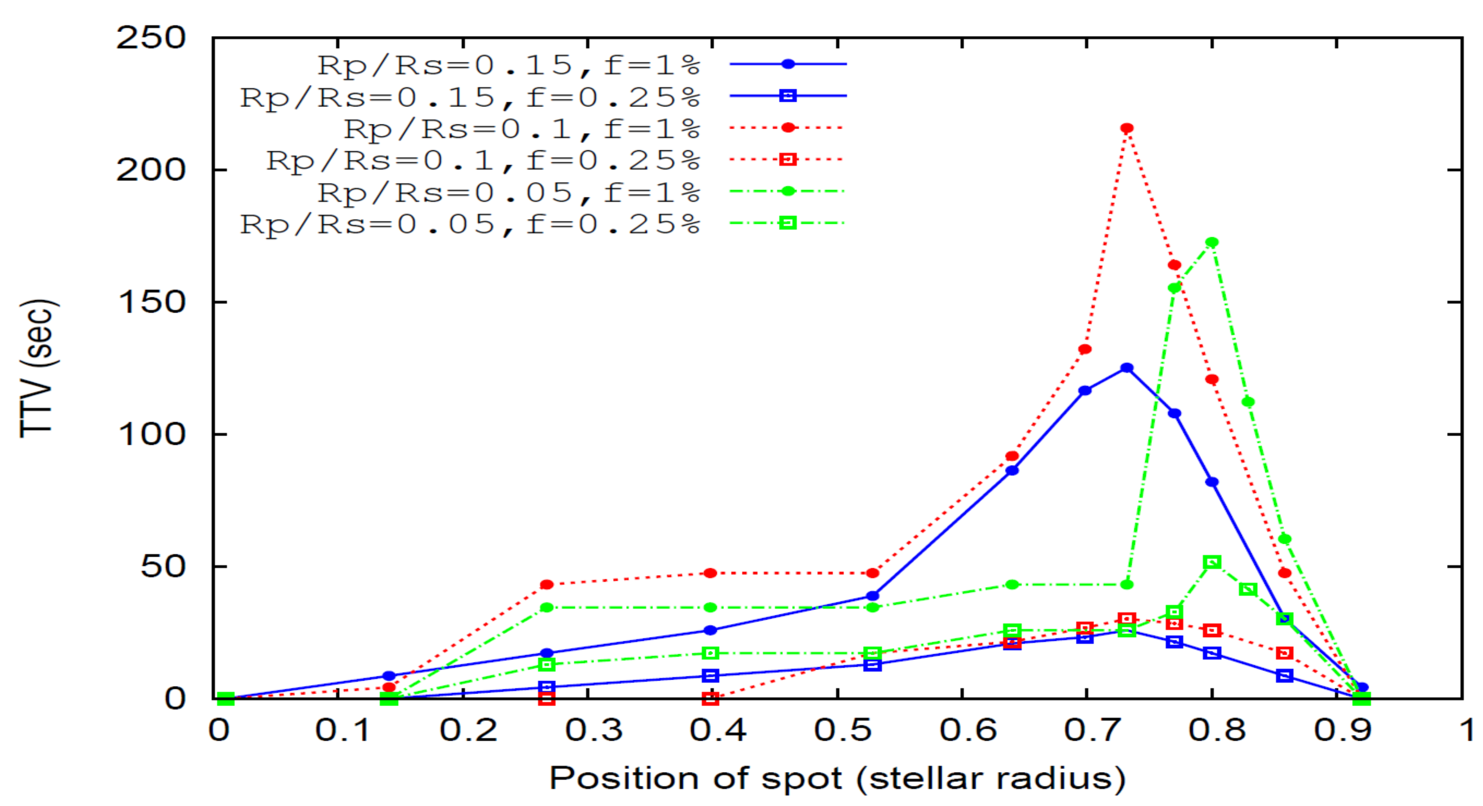
As shown in the figure, as long as the spot's anomaly moves toward the middle of transit light curve (which means overlap occurrence move from the limb to the center of stellar disk), the fitted transit's depth values (which correspond to the radius of planet in stellar radius unit) become smaller. For instance, in the case of a transiting planet with a size of Rp/Rstar = 0.05 and a spotted star with the spot's filling factor of 1%, the anomaly in the light curve can affect the fitted value of radius of planet to be 4% smaller than its actual value.

Effect of stellar spots on transit duration



As shown in this figure, the transit duration of a transit light curve affected by spot anomaly can be shorter or longer, depending on where the anomaly appears. These results shown in these figure are in agreement with the result reported by Barros et al. (2013) in the case of WASP-10 system. For one of the extreme cases, the transit duration of a transiting planet with size of Rp/Rstar = 0.1 overlap with a spot with filling factor of 1% can be estimated at maximum 4%, longer or shorter.

Effect of stellar spots on transit timing



This figure shows that the maximum value of TTVs appears when the transiting planet overlaps the spot while the spot is located 0.7 stellar radius from center of star, which shows strong agreement with results presented by Barros et al. (2013). Moreover as the result shows, in the case of a transiting planet with Rp/Rstar = 0.1 overlapping with a spot with filling factor of 1%, the maximum value of TTV which is due to anomaly in transit light curve can reach the order of 200 seconds. This amplitude of TTVs could be interpreted as the TTV signal either produced by an Earth like planet on a Jovian planet transiting a star every three days while the Earth like is in mean motion resonance with Jovian planet (Boue et al. 2012), or produced by the Earth mass exomoon on the Neptune size transiting planet (Kipping 2009).

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