On the influence of stellar activity on transit timing variations

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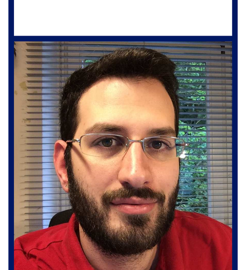


Abstract

We report the results of our study on the effects of the activity (spots) of planetary host stars, on the mid-transit time measurements of their planets. While one planet is transiting in front of the parent star, it can cross over spots. This causes deformations of the transit lightcurve, which can lead to errors in the mid-transit time determination. We investigate the dependence of this error in different parameters of the planet and the star, in an effort to identify special occasions were the effect becomes strongest.

Scientific aims

- Severeness of transit profile deformation from activity.
- Can it produce fake Time Timing Variations (TTVs)?
- How do the properties of the planet's orbit, like Period and impact factor, affect the fake TTVs?

The lightcurves

- We produce simulated lightcurves of active stars with planets and photometric accuracy equal to the lightcurves of the Kepler mission(Fig.1:left)
- The stars are always limb darkened and the spots are very cold
- The transits with the spot crossing events are normalized, to remove the activity slope. (Fig.1:right)

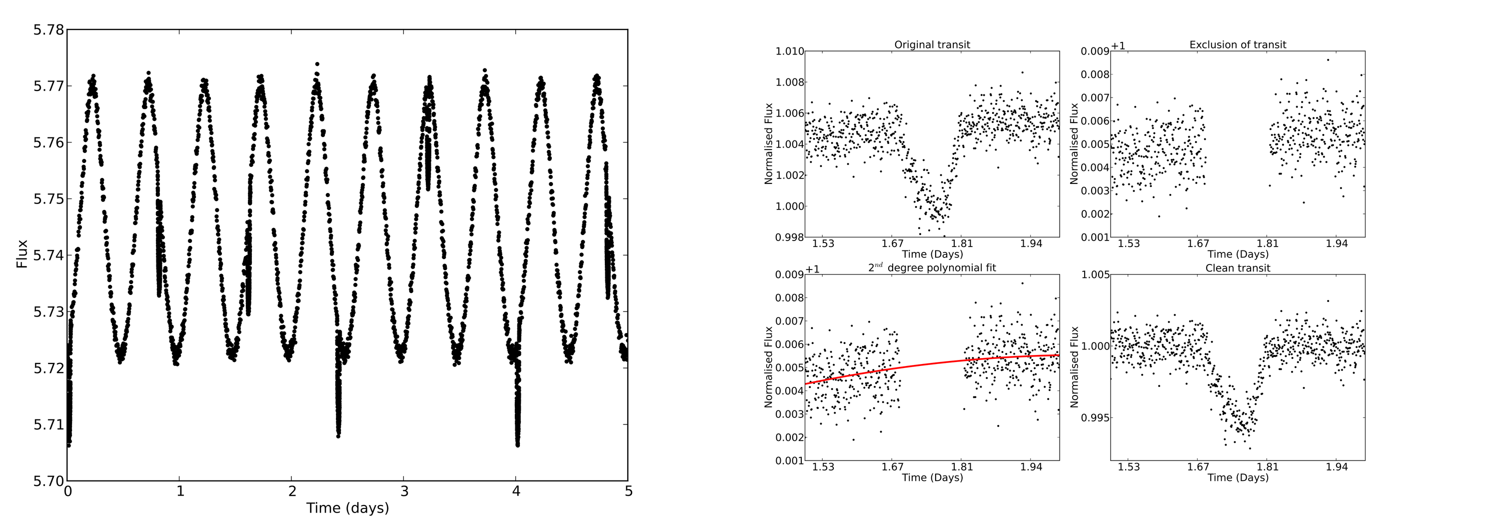


Figure 1: Left: A simulated lightcurve of a Neptune-size planet. The sinusoidal variation is caused by one spot on the host's surface. Right: The activity removal procedure of a spot affected transit.

Parameter Space

Planets

- Planets with $R_p/R_\star$ = 0.5 and 1
- Impact factors from 0 to 1
- Orbital periods from 5 to 600 days

Star

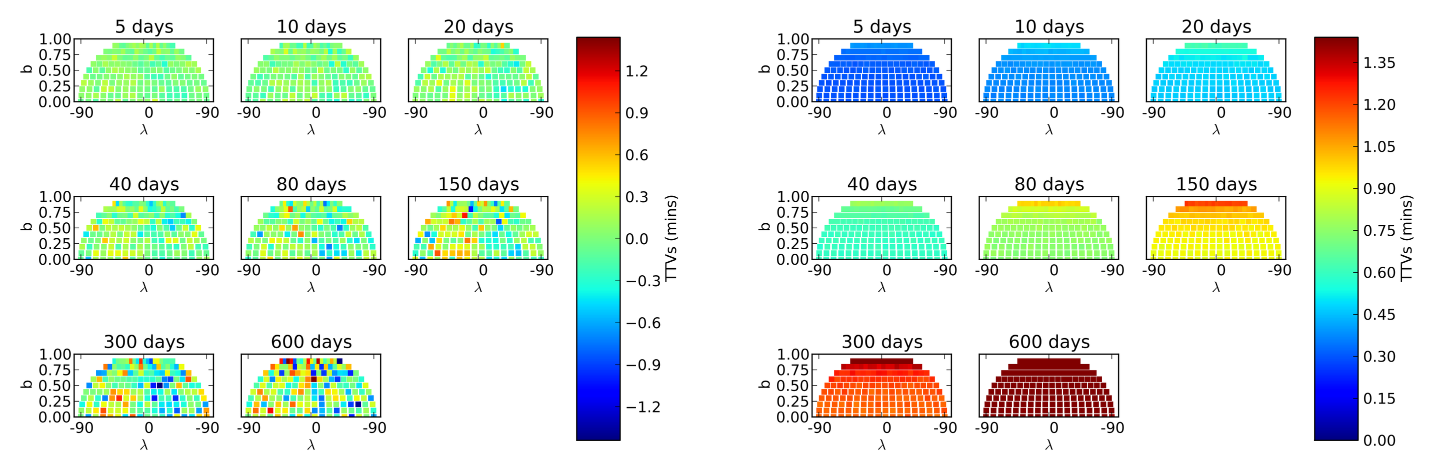
- $T_{eff} \simeq 4300$ K
- $R_\star$ = 0.7
- Linear LD = 0.7
- Quadratic LD = 0.04
- Rotational period of 10 days

Strategy

- We assume circular spots with filling fuctor of 2.5%
- For each transit the spot is placed in other position, so the spot-crossing event to cover the full longitudes spectrum
- The transit mid-times (TTVs) and their errors are then being calculated, using MCMC
- In the same fashion we calculate the TTVs for different values of transit impact factor b (Fig.2)
- While sun spots are usually appear in groups we repeat the same procedure assuming spot elongated in longitude (Fig.3)

Circular spot

$R_p/R_\star$ = 1



$R_p/R_\star$ = 0.5

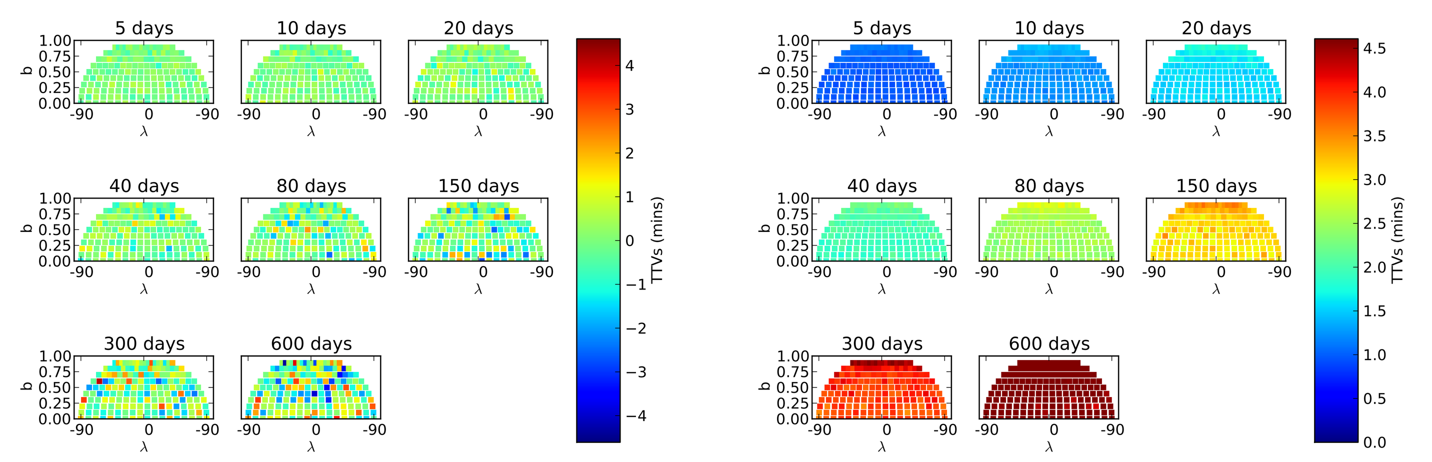
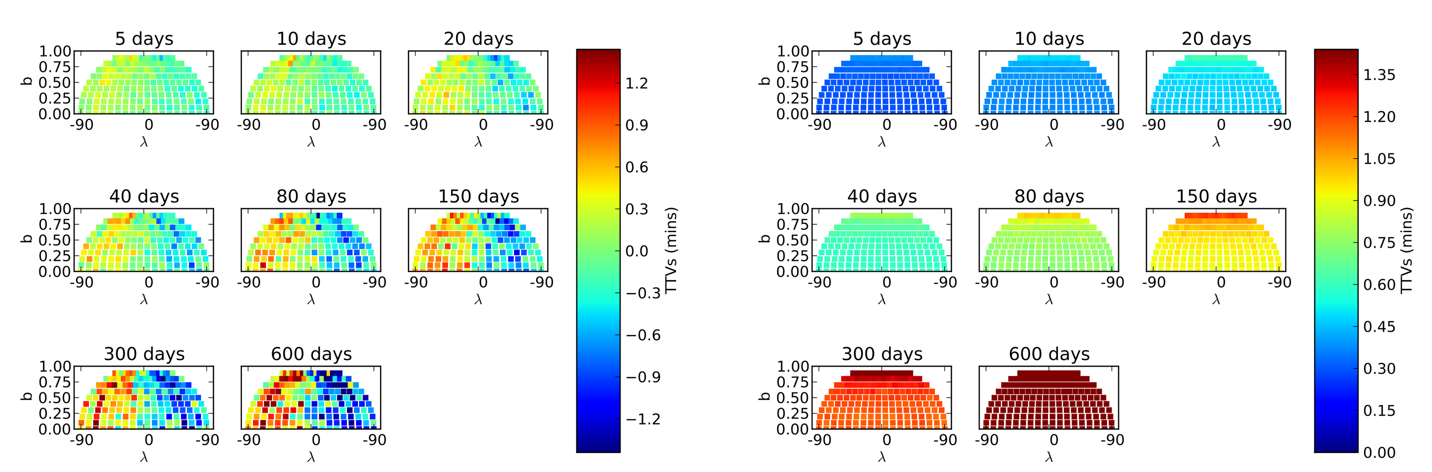


Figure 2: top: A visual representation of the measured TTVs (colormap) due to a spot-crossing event for each longitude and latitude of the observed stellar surface for a planet with radius $R_p/R_\star$ = 0.1 with periods from 5 to 600 days. On the left one can see the corresponding errors of each measurement. bottom: The same as on top for a planet with $R_p/R_\star$ = 0.05 .

Elongated spot

$R_p/R_\star$ = 1



$R_p/R_\star$ = 0.5

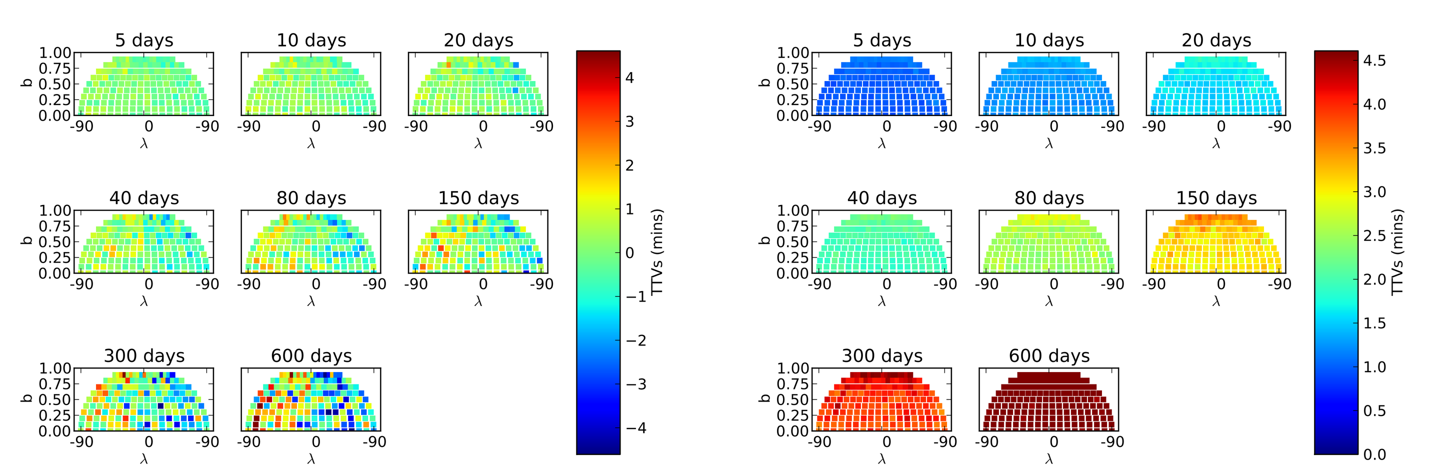


Figure 3: The same as in Fig.2 for a planets with $R_p/R_\star$ = 1 (top) and 0.05 (bottom) crossing an elongated in longitude spot

Results

- The size of the TTVs depends strongly on the transit duration time and becomes larger as the planet radius reduces
- An elongated spot or a spot group produces larger TTVs than a circular spot
- The TTVs of planets with period < 40 days are not affected from the activity by more than 0.5 min
- In every case the deformation of the transit profile is such that the TTVs measurement errors would immediately point for a spurious detection