ABSTRACT

The quest for Earth-like extra-solar planets, especially those located inside the habitable zone of their host stars, requires detection techniques sensitive enough to detect the faint signals produced by those planets. The Radial Velocity (RV), transit, and transit timing variation methods are the most used and also the most efficient methods for detecting and characterizing exoplanets. Surveys of the currently known exoplanets indicate that many of these planets orbit stars with high levels of activity. Stellar-activity features such as spots can complicate the detection and characterization of exoplanetary systems through all these methods. In this thesis, I concentrate on the problem of stellar activity for planet detection and characterization using the above mentioned methods.

The transit timing variation method is based on measuring transit timing deviation from constant period and interpreting this deviations to be due to the gravitational interaction of a perturber. Most of the methodologies which have been used to measure the transit times are model-dependent and are vulnerable to systematic errors. To overcome this problem, we proposed a model-independent method to determine the transit times through calculating the barycenter of the transit light curve.

However, the results of all the methodologies including our proposed method would be offseted in the case that the transit light curve symmetry is broken, for instance due to the overlap of the transiting planet and the stellar activity features on the stellar surface. To tackle this issue we developed a software "SOAP-T" which can simulate systems consisting of a rotating star with active zones and a transiting planet. Because this tool generates the light curves with anomalies inside, we can use these synthesis light curves to remove the anomalies in the observed transit light curves, and reproduce realistic symmetric light curves. However, in most studies which have been done on the TTV method, the impact of the stellar activity feature in the transit light curve and derived transit timing estimations have not been taken into account. We performed a quantitative study on the impact of stellar spot on the planetary parameters estimations, especially the transit timing. The results of our study show that spot anomalies might lead to an underestimation of a planet radius by about 4%. The effects on the transit duration can also be of the order of 4%, longer or shorter. Depending on the size and distribution of spots, anomalies can also produce transit timing variations with significant amplitudes (200 seconds). For instance, TTVs with signal amplitudes of 200 seconds can be produced by an Earth-mass planet in a mean-motion resonance with a Jovian type body transiting a solar-mass star in a three-day orbit, or by an Earth-mass exomoon on a Neptune mass transiting planet.

Transmission spectroscopy (multiband photometry) is the most powerful technique to explore exoplanetary atmospheres. Since the transmission spectroscopy is basically based on the high-precision transit observations at different wavelengths, one of its main limitation could be the stellar activity, which is usually taken into account only by assessing the effect of non-occulted stellar spots. We found that the anomalies inside the transit light curve at different wavelengths due to occultation of stellar spot/plage by the transiting planet can lead to a significant underestimation or overestimation of the planet-to-star radius ratio as a function of wavelength. Especially at short wavelengths, the effect can reach up to a maximum difference of 10% in the planet-to-star radius ratio, mimicking the signature of light scattering in the planetary atmosphere. Furthermore, we demonstrated that the transmission spectroscopy measurements of the active stars HD 189733b and GJ 3470b, and especially their excess of the planet radius in the bluer part of the spectra, can almost exactly be reproduced by assuming the occultation of the HD 189733b and GJ 3470b with the active region (plage) of their host star.