# Semi-parametric methods to aid in the detection and characterization of distant worlds around small stars

by

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# Abstract

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Statistical studies of the exoplanet population have provided key insights into their formation histories and evolution. Developing an understanding of the planet formation process requires both accurate and precise measurements of fundamental planetary parameters such as their masses, radii, and orbital characteristics. Planetary systems orbiting low mass stars represent superlative opportunities to characterize exoplanets in detail as they are plentiful within the solar neighbourhood and they are known to commonly host multi-planet systems of terrestrial to Neptune-sized planets that are more easily detectable than similar planets around Sun-like stars. One major deterrent to the characterization of such planets is stellar activity and its manifestation in radial velocity (RV) measurements that can mask and even mimic planetary signals.

In this thesis, I develop and implement a formalism aimed at enabling the detection and precise and accurate characterization of planetary systems around low mass stars. This formalism is based around semi-parametric Gaussian process (GP) regression models that are used to simultaneously model planets, in both RV and transit light curve observations, and the temporal covariance structure arising from stellar activity produced by magnetically active regions on the stellar surface. The GP formalism is applied to synthetic RV datasets emulating the upcoming planet detection survey using the near-infrared spectropolarimeter SPIRou and to synthetic optical and near-infrared measurements of the expected population of transiting planets discovered with TESS. I also apply the GP formalism to activity modelling in the K2-18 planetary system from which an accurate and precise planetary mass of its transiting temperate sub-Neptune is inferred along with the presence of an additional planet in the system using RV measurements from HARPS and CARMENES. Lastly, I extend the GP formalism to the treatment of stellar photometric variability and systematic effects in TESS light curves and uncover a number of candidate transiting planets around low mass stars in the first two TESS sectors.

Applications of GPs for the detection and characterization of exoplanets will prove to be a crucial tool

for developing a global understanding of planet formation and in revealing how common the conditions for life like our own are within our galaxy.

*To my wife and future children.*

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