A study of stellar activity modelling's impact on RV planet detection

E. Ahrer[1,2], D. Queloz[1,3], V. M. Rajpaul[1], D. Ségransan[3], F. Bouchy[3], R. Hall[1], W. Handley[1,4], C. Lovis[3], M. Mayor[3], A. Mortier[1,4], F. Pepe[3], S. Thompson[1], S. Udry[3]

Introduction

We present a comprehensive analysis of 10 years of radial velocities (RVs) obtained by the HARPS spectrograph on a K2V star, which has previously been reported to host two unconfirmed planet candidates. We use the state-of-the-art nested sampling algorithm PolyChord[1] to compare a wide variety of stellar activity models.

Activity indicators such as the bisector span (BIS) of the Cross-Correlation Function (CCF), as well as the Full Width Half Maximum (FWHM) of the CCF and the chromospheric activity indicator $\log R'_{HK}$ are used to model the activity induced RV variations.

Stellar Activity Modelling

Model	Description
Circular	Circular orbit modelling
Kepler	Eccentric orbit modelling
+ magn. cycle	Kepler + long-term magnetic activity cycle (see Fig. 1)
+ linear	Kepler + linear model (BIS, FWHM or $\log R'_{HK}$)
+ BIS P_{rot} harm.	Kepler + harmonic model based on rotation period P_{rot} (up to 4th order) simultaneously fitted to BIS
+ FF' model[3]	Kepler + spot model based on flux
Gaussian Process (GP)[4]	Simultaneous GP modelling of RVs and activity indicators (Keplerian terms for RVs)

Table 2. Overview of considered stellar activity models.

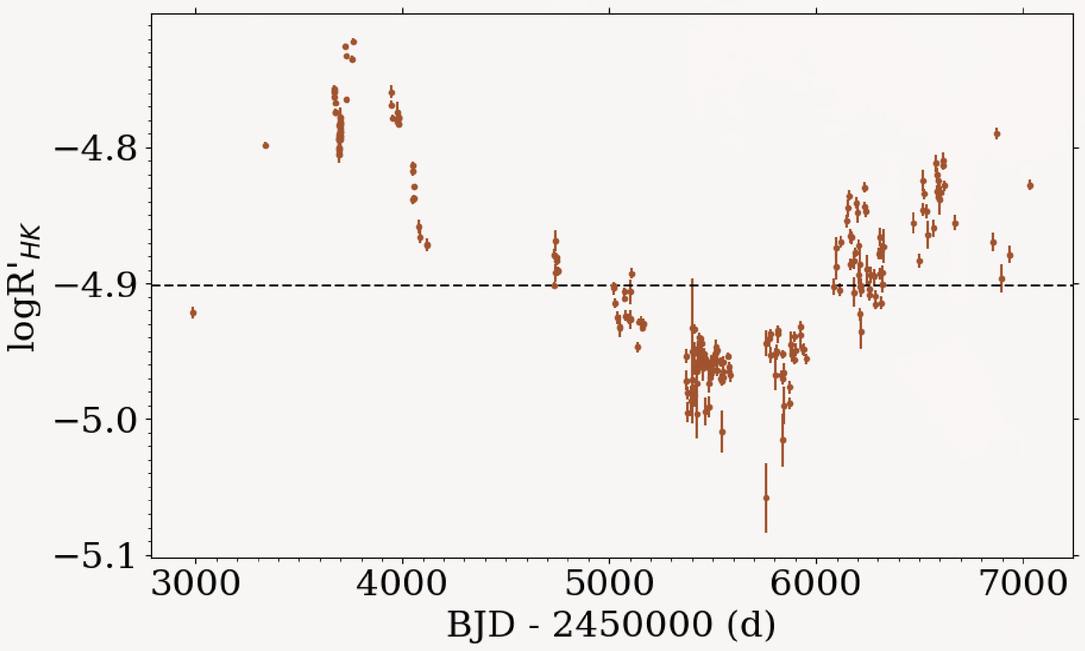

Fig 1. $\log R'_{HK}$ measurements for our test system over a span of 10 years.

Bayesian Analysis

For analysing our RV data, as well as our stellar activity indicators we use the Bayesian evidence *R* to compare our models, as shown with the Jeffreys scale in Table 1.

$\lvert\Delta \ln R\rvert$	Probability	Remark
< 1.0	< 0.750	Inconclusive
1.0	0.750	Weak Evidence
2.5	0.923	Moderate Evidence
5.0	0.993	Strong Evidence

Table 1. Jeffreys scale for the significance of Bayesian evidence comparison[2]

Conclusions

We show that the use of overly-simplistic stellar activity models that are not well-motivated physically can easily lead to spurious 'detections' of planetary signals that are almost certainly not real.

We also demonstrate the importance of considering stellar activity effects for every type of star as our test case is considered inactive with median($\log R'_{HK}$) = -4.90 (see Fig. 1), for comparison $\log R'_{HK}$ = -4.94 for the Sun at it's recent minima[5].

Our study thus underlines the importance both of exploring a variety of competing models and of understanding the limitations of one's sampling algorithm.

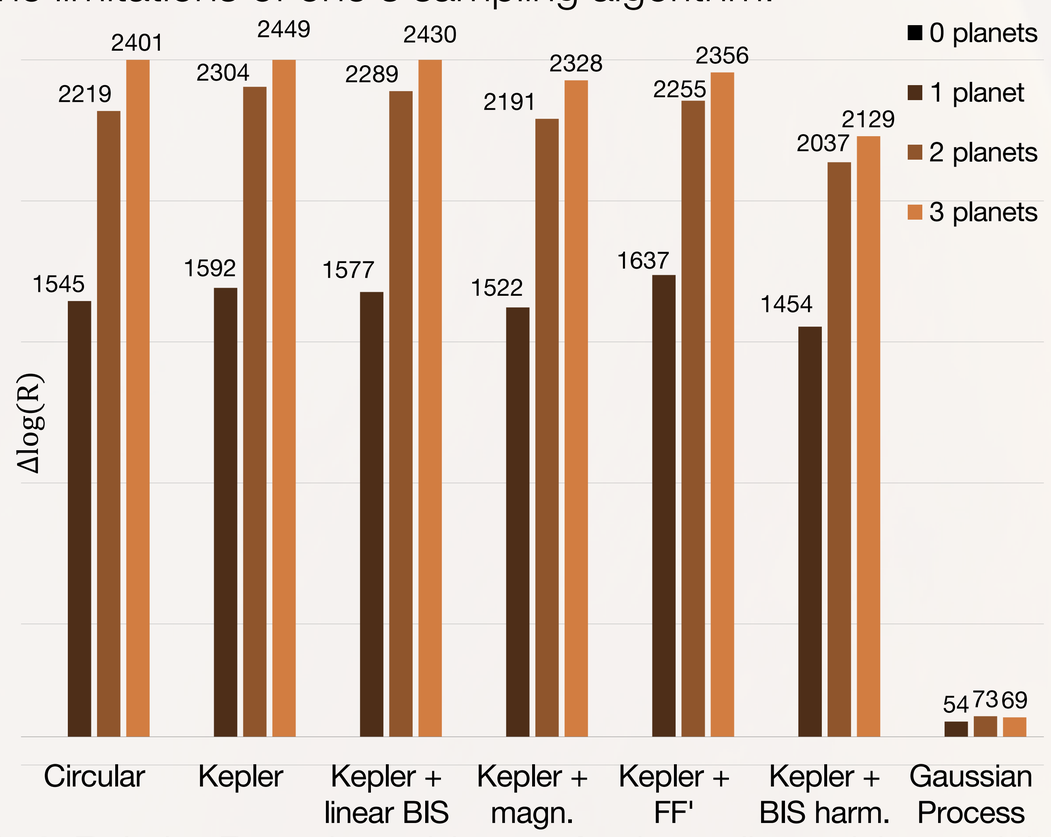

Fig 2. Relative Bayesian evidences for the stellar activity models with up to three planets, normalised to the zero-planet case in each model. Note that the GP is the only model to favour two planets (with $\lvert\Delta \ln R\rvert \sim 4$) over three and with increasing model complexity the evidence differences are decreasing.

[1] Astrophysics Group, Cavendish Laboratory, Cambridge, UK
[2] Department of Physics, University of Warwick, UK
[3] Departement d'astronomie, Université de Genève, Switzerland
[4] Kavli Institute for Cosmology, Cambridge, UK

Affiliations

eva-maria.ahrer@warwick.ac.uk **Contact me**

References

[1] Handley W. J., et al., 2015, MNRAS, 453, 4384
[2] Jeffreys H., 1983, Clarendon Press
[3] Aigrain S., Pont F., Zucker S., 2011, MNRAS, 419, 3147
[4] Rajpaul V., et al., 2015, MNRAS, 452, 2269
[5] Mamajek E. E., Hillenbrand L. A., 2008, ApJ, 687, 1264

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