Mitigating effects of stellar activity in RV using SCALPELS

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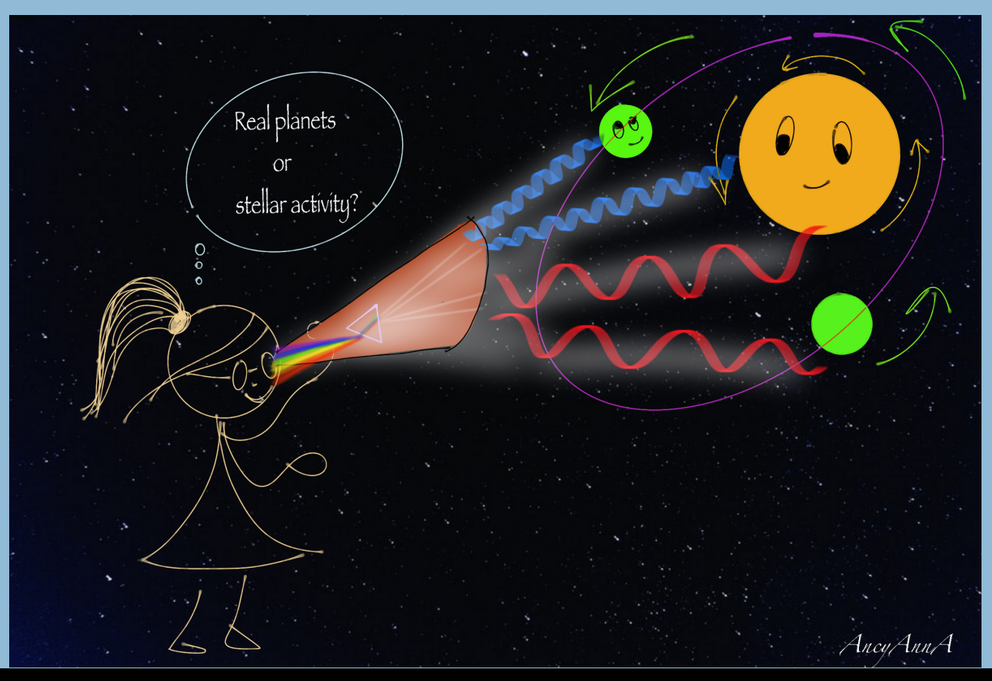
PROBLEM

- Difficulty in the mass characterisation of exoplanets with follow-up RV observations due to the contamination caused by spurious stellar activity signals. [i],[iv]
- Challenging to differentiate between a signal induced by stellar activity and a planet. [ii]



AIM

- Understand and correct for the stellar activity, to enable accurate RV detection and characterisation of exoplanets.
- Push the limits on mass determination down towards the Earth-mass regime using high-precision RV measurements combined with stellar activity characterisation.
- Detection of new low-mass planets whose RV signals were previously below the detection limit, due to activity confusion.

METHOD

A new algorithm, SCALPELS, has been developed to separate RV Doppler shifts caused by the orbital motion of planets from the apparent RV variations caused by the spectral line-shape variability aroused by stellar activity . [iii]

INTRODUCTION

We present results obtained from the application of SCALPELS to the RV data of the Sun and an active, exoplanet hosting star CoRoT-7 [vi] where we investigated the efficiency of this approach in correcting for the confusing stellar activity signals.

ANALYSIS

SCALPELS

Self-Correlation Analysis of Line Profiles for Extracting Low-amplitude Shifts.[iii]

- Decouples the effect of genuine dynamical Doppler shifts from spurious shifts caused by changes in the profile shape of cross-correlation function (CCF).
- Uses the property of auto-correlation function(ACF) of the CCF that it is invariant to translation.
- Principal modes of variability in the CCF or ACF are isolated by calculating the Singular-Value Decomposition (SVD).
- Project the RVs onto the time-domain subspace spanned by ACF's principal components -> activity or shape component $\mathbf{v}_{\parallel}$
- Project the RVs onto the orthogonal complement of this time-domain subspace -> planet or shift component $\mathbf{v}_{\perp}$

SHAPE CHANGES IN CCF PROFILE

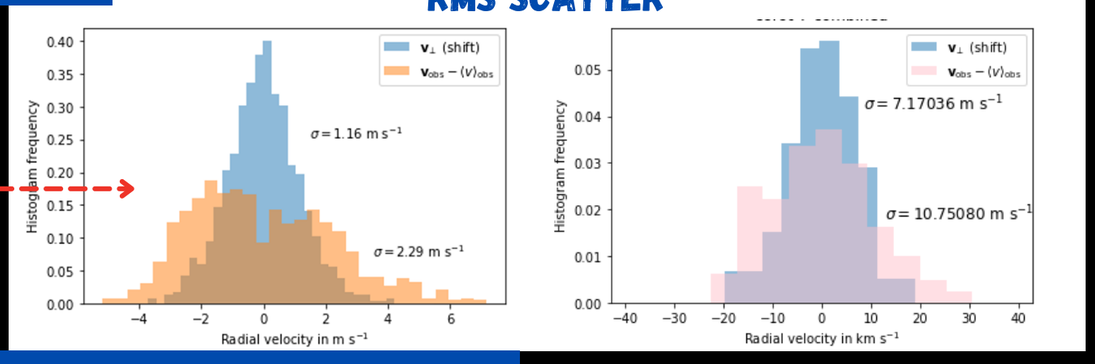
[FROM HARPS-N SOLAR TELESCOPE] [v]

The movie above depicts the variations in solar heliocentric CCF profile shape as active regions pass by. These shape changes explicitly indicate the presence of stellar activity and its effect on RVs. Contrarily, orbiting planets only induce a shift to the profile without affecting the line shape or depth.[iii]

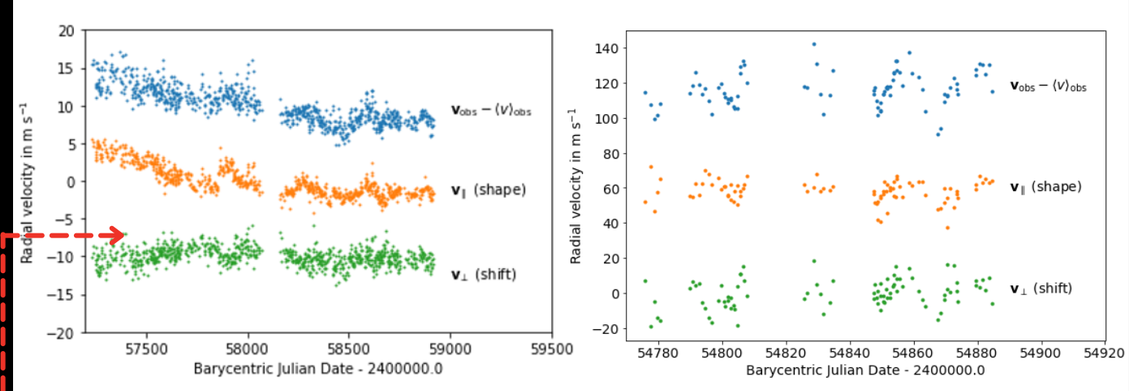
SUN

ACTIVE STAR: COROT-7

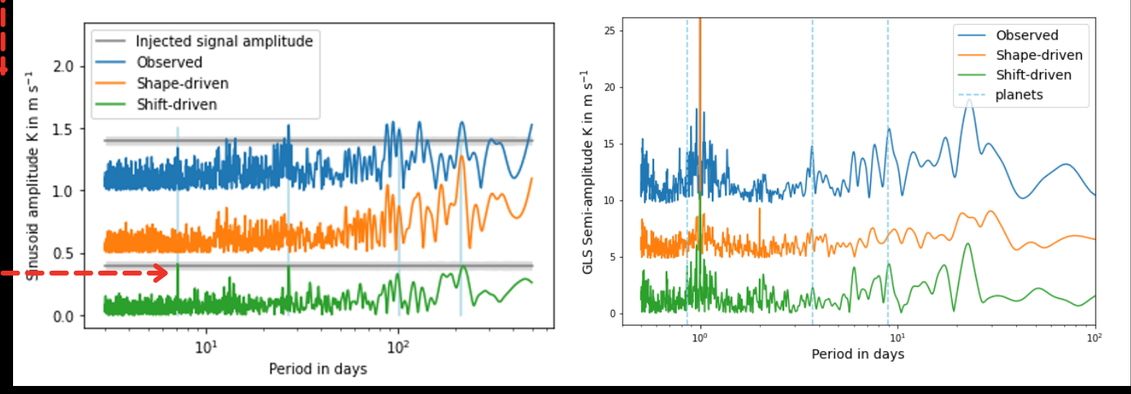
RMS SCATTER



SCALPELS SEPARATION



PERIODOGRAMS



RESULTS & FUTURE WORK

- Reduced the correlation between velocity variations due to stellar variability depending on the shape changes in spectral line shape alone, without using time-domain information .
- The local RMS scatter in RVs is reduced significantly after subtracting the SCALPELS-identified shape-driven components.
- The shape or activity-driven $\mathbf{v}_{\parallel}$ component efficiently carries the long-term activity trends away.
- Isolated injected(solar) and real(CoRoT-7) planet signals (vertical blue lines) from RVs contaminated by activity, with good precision.
- Improving the sensitivity of SCALPELS towards shift-inducing activity signals (if any) would be a breakthrough in the precise follow-up characterisation of exoplanet systems detected by TESS.

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