A small survey of the magnetic fields of planet-hosting stars

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Introduction

Magnetic fields have a profound influence on the evolution of stars and on the environment of the planetary systems surrounding them. The stellar magnetic field is a key component in the star's spin-down and in the modulation of stellar winds. Stellar magnetic field maps are used as initial conditions for modelling stellar winds and thus the particle environment of planetary systems. As an extension to the BCool survey (Marsden et al., 2014), we chose a series of planet-hosting solar-type stars and using the NARVAL spectropolarimeter, attempted to measure the magnetic fields of these stars.

Our aim was to find targets for further spectropolarimetric observations and mapping, but also to see if the presence of planetary systems had any impact on the magnetic field of the host star. We observed 19 stars during late 2014 and early 2015.

The Longitudinal Magnetic Field

The mean longitudinal magnetic field, B_ℓ (or $\langle B_Z \rangle$) is the line-of-sight component of the stellar magnetic field integrated over the visible disc of the star. B_ℓ can be obtained from the Stokes I and Stokes V least squares deconvolution (LSD) profiles (Figure 1). From Donati et al. (1997); Mathys (1989), for the given velocity (v, in km s^{-1}) space:

$$B_\ell = -2.14 \times 10^{11} \frac{\int vV(v)dv}{\lambda_0 g_0 c \int [I_c - I(v)]dv} \quad (1)$$

where B_ℓ is in gauss, λ_0 and g_0 are normalization parameters (Marsden et al., 2014). c is the speed of light in km s^{-1} and I_c is the continuum level of the Stokes I LSD profile and is normalised to 1.

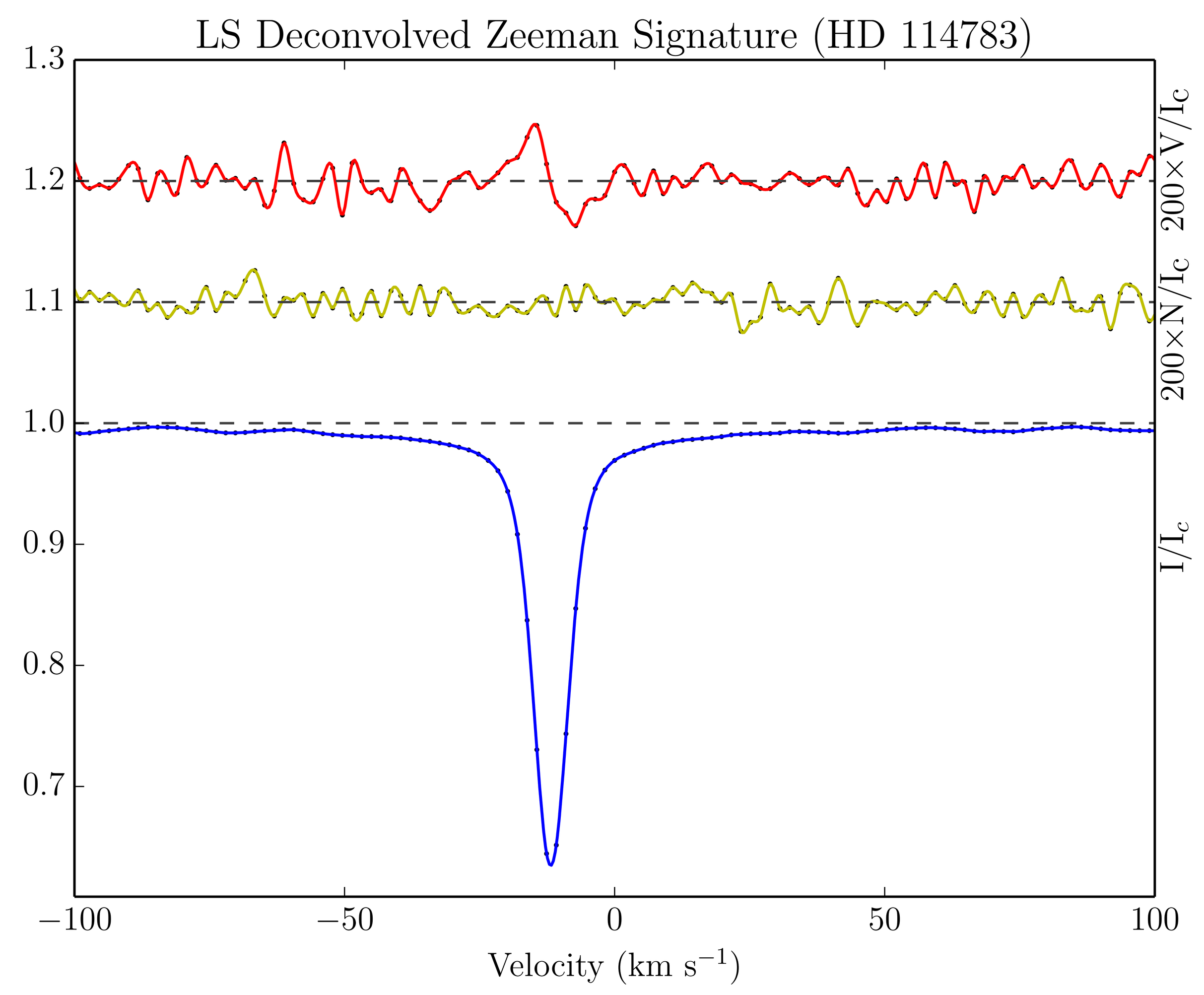

Figure 1: Least Squares Deconvoution profiles for one of our sample stars, HD 114783. The upper line (in red) is the Stokes V profile, expanded 200 times and shifted up by 0.2. The centre line (yellow) represents the LSD null profile also expanded by 200 and shifted up 0.1. The lower line (in blue) shows the Stokes I (intensity) LSD profile. For this star, a magnetic field is definitely detected. These profiles are used to determine the longitudinal magnetic field (Eqn. 1).

Additional measurements

We also determined the star's activity proxies (Ca II H&K or S-index (Wright et al., 2004), Ca II infrared triplet and Hα indices) and the star's approximate radial velocity. Using these activity proxies, we were able to investigate possible relationships between the longitudinal magnetic field of our targets and their overall activity (e.g. Figure 2). Marsden et al. (2014) illustrated positive relationships between magnetic field strength and rotation, magnetic field strength and activity and an inverse relationship between magnetic field strength and age. We confirm that our sample of planet-hosting stars conforms to these relationships.

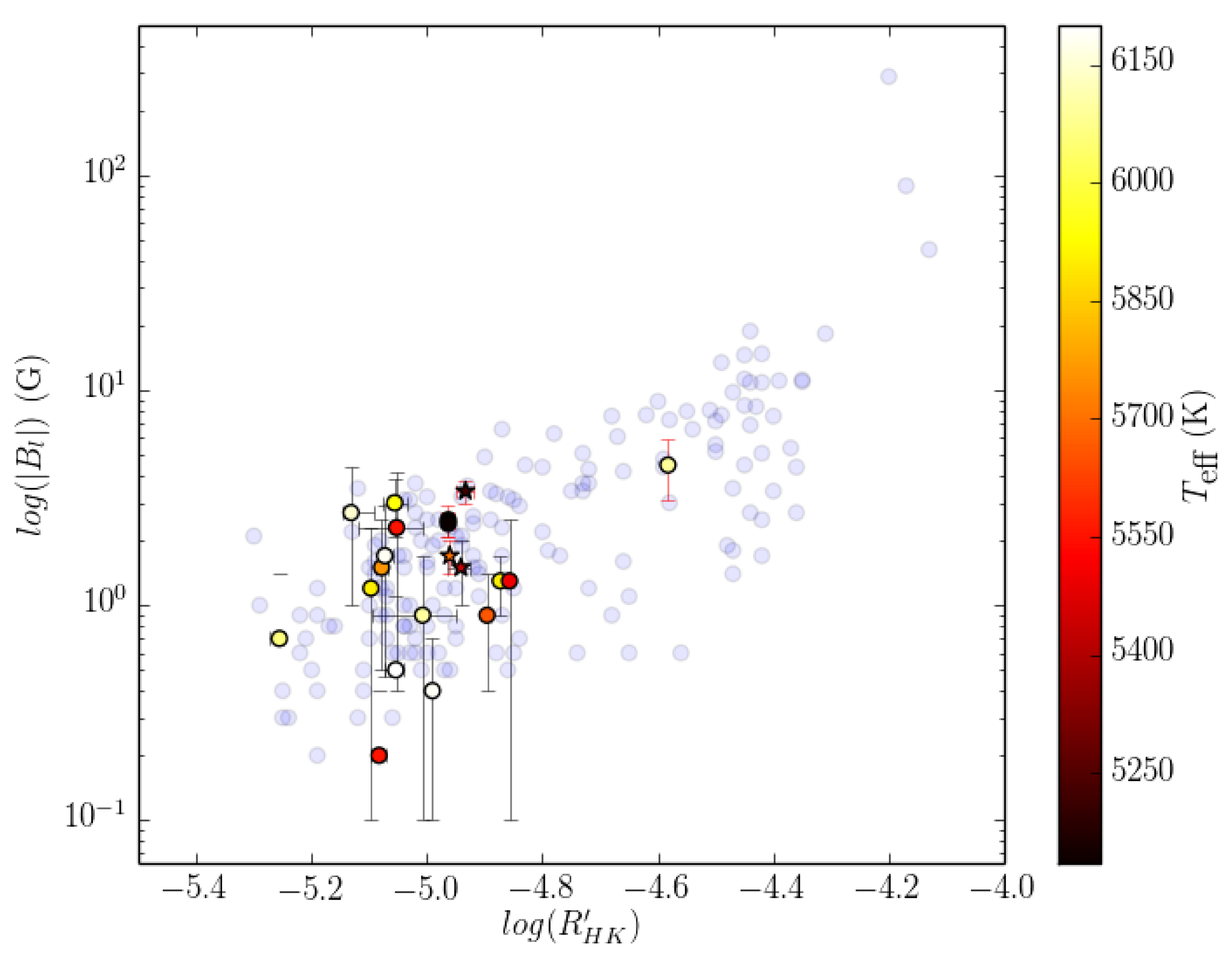

Figure 2: Plot of log(maximum measured$|B_\ell|$) vs R'_{HK}. The blue circles represent the BCool survey of solar-type stars (Marsden et al., 2014). Star-shaped points represent subgiants. The circles are coloured according to effective temperature. We show that the relationship between chromospheric activity and magnetic field intensity for planet-hosting stars is consistent with that of the population of solar-type stars in general.

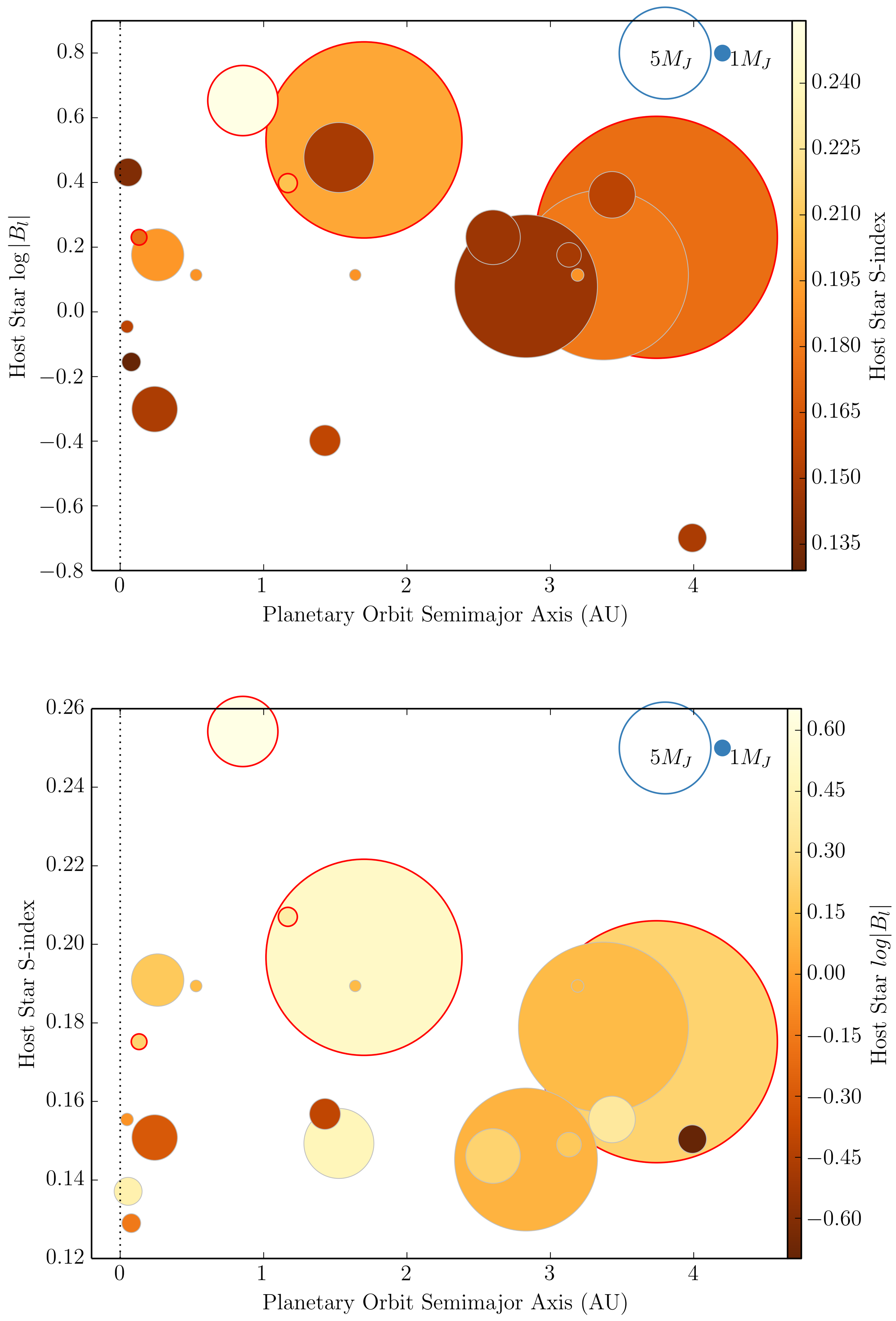

Figure 3: S-index and log(B_ℓ) shown against the semimajor axis of planetary orbits. The fill colours of the circles represent the S-index (upper panel) and log(B_ℓ) (lower panel). The radius of circles are proportional to planetary masses. Red edges to the circle indicates the host star had a magnetic detection.

Potential Planetary Influences on Magnetic Fields of the Host Star

In Figure 3, we present the configuration of the planetary systems and their relationship with the activity proxy (S-index) and the magnetic field (log($|B_\ell|$)). In both the panels, each circle represents a planet and its centre point on the x-axis at represents the semimajor axis of the planet's orbit. In the case of systems with more than one planet, each planet is represented, with all planets in a system having the same y-axis value. The size of the circles is proportional to the planetary mass.

There appears to be no correlation between the magnetic field strength and the planetary configuration. There are several planets which would warrant the colloquial appellation of "hot Jupiter", which would be the most likely candidates for star-planet interaction (SPI) , whether through tidal effects, magnetic interaction, or other posited SPI mechanisms. However, the presence of these planets do not result in any detectable trend towards higher activity or higher measured longitudinal magnetic field.

It is noted that the sample is small, and while there are some hot Jupiters none of them are at the higher end of the mass range, nor are the more massive planets particularly close to the host star. Given the correlations between stellar parameters and the strength of the stellar magnetic field detailed by Marsden et al. (2014), it is clear that any effect of SPI on the stellar magnetic field or activity, if it exists, is too subtle to detect in our sample.

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BCool: http://bcool.ast.obs-mip.fr

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