Starspot signature on the light curve: learning about the spot distribution

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Introduction

- ✶ Starspots crossing the visible disc of a star induce periodic modulations on the light curve
- ✶ Those modulations provide information about the stellar rotation and magnetic activity
- ✶ Reinhold & Arlt (2015) proposed a method, based on the periodogram analysis, to identify the sign of the differential rotation
  - ∗ **Peak-height-ratio:**

    ratio between the heights of the 2nd and the 1st harmonics of a given rotation period (P_k), h' and h respectively

$$r_k = \frac{h'_k}{h_k}$$

$$r_k > r_{k+1} \Rightarrow P_{\rm low} = P_k \text{ and } P_{\rm high} = P_{k+1}$$
$$r_k < r_{k+1} \Rightarrow P_{\rm low} = P_{k+1} \text{ and } P_{\rm high} = P_k$$

  - ∗ **Observed relative differential rotation:**

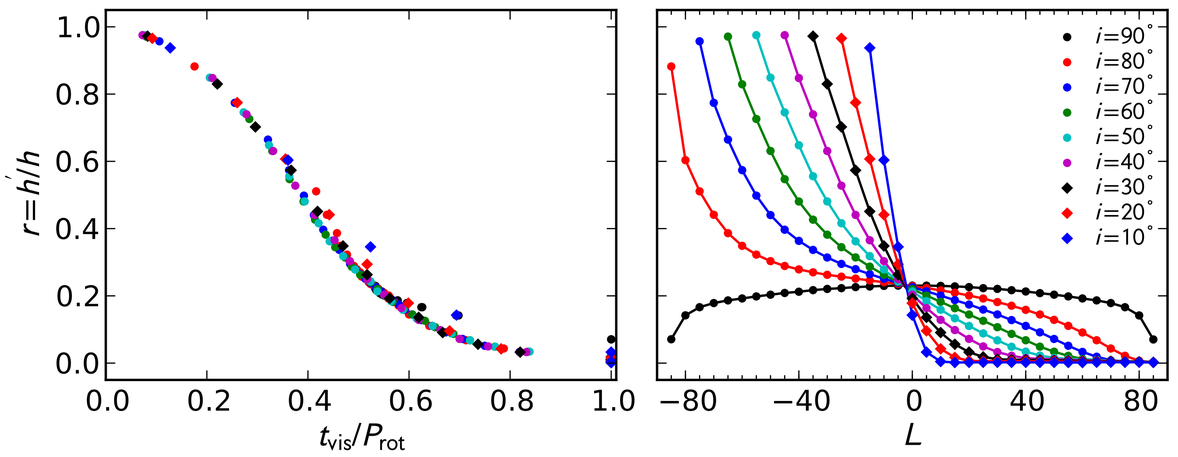
$$\alpha_{\rm obs} = \frac{P_{\rm high} - P_{\rm low}}{P_{\rm high}}$$

$$\alpha_{\rm obs} > 0 \Rightarrow \text{solar differential rotation}$$
$$\alpha_{\rm obs} < 0 \Rightarrow \text{antisolar differential rotation}$$

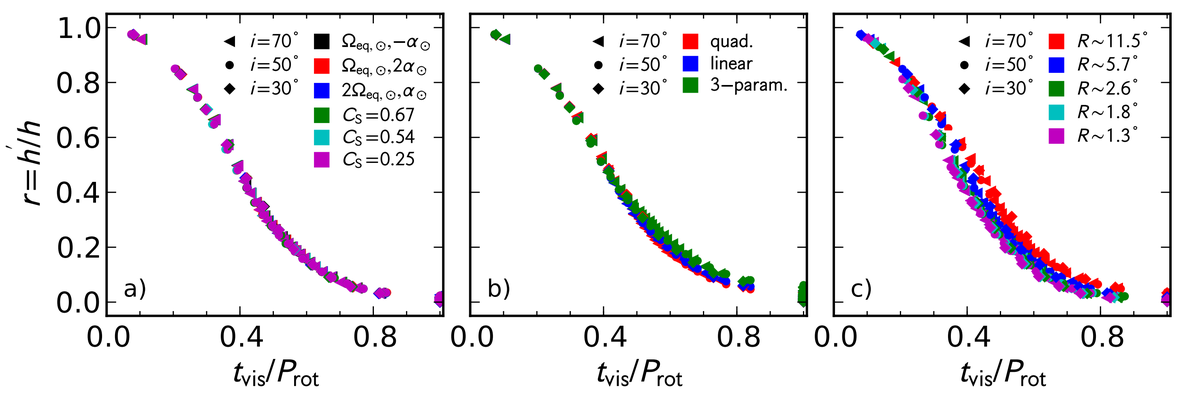
- ✶ In this work, we study in detail the peak-height-ratios and their dependency on the spot and stellar parameters
- ✶ Here, we present the first source for false-positives/negatives and observational bias

Results: Peak-height-ratios

- ✶ The peak-height-ratios, r, are essentially a function of the fraction of time the spot is visible, $t_{\rm vis}/P_{\rm rot}$
- ✶ $t_{\rm vis}/P_{\rm rot}$ is mainly determined by the inclination i and latitude L
- ✶ The relation between r and L, claimed by Reinhold & Arlt (2015), is not fully valid for $i \neq 90°$
- ✶ r is independent on the rotation rate, Ω, and spot contrast, C_S
- ✶ The limb-darkening law and spot size affect r and $t_{\rm vis}/P_{\rm rot}$

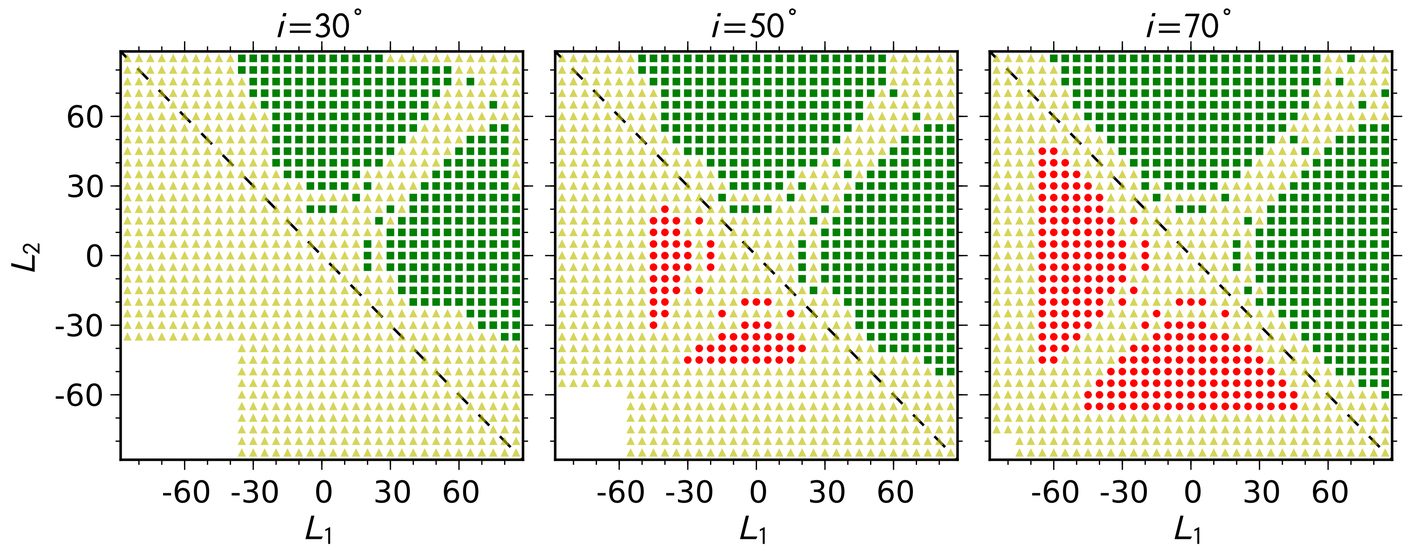


Peak-height-ratios as a function of the spot visibility time (left) and latitude (right) for different inclination angles.



r vs. $t_{\rm vis}/P_{\rm rot}$ for different i and L and different: a) contrasts and differential rotations, b) limb-darkening laws, c) and spot radii.

Results: Sign of the surface differential rotation



Sign of $\alpha_{\rm obs}$ obtained for light curves modulated by 2 spots at latitudes L_1 and L_2

Yellow: *only one rotation period is successfully detected (no information on $\alpha_{\rm obs}$ is retrieved)*

Green: *the correct sign of $\alpha_{\rm obs}$ is recovered*

Red: *false-negative for the sign of $\alpha_{\rm obs}$*

- ✶ **False-positive/negative:**
  - ∗ when P_k and P_{k+1} are associated to spots on the opposite hemisphere from the observer
  - ∗ when P_k and P_{k+1} are associated to spots at $L_k < 0$ and $L_{k+1} > 0$ (opposite and same hemisphere as the observer) and $|L_k| > |L_{k+1}|$
- ✶ **Observational bias:**
  - ∗ The modulation induced by spots at same hemisphere as the observer will be preferentially observed, specially for small i
  - ∗ This will contribute to a low rate of false-positives/negatives for the sign of $\alpha_{\rm obs}$

Conclusions

- ✶ Despite the degeneracy between stellar inclination angle and spot latitude, the peak-height-ratios provide a simple and fast way to constrain those parameters.
- ✶ This is an advantage of the method in comparison with other time consuming methods.
- ✶ If the inclination angle is known, the peak-height-ratios can actually constrain the latitudinal distribution of spots.

Santos et al. in preparation

References:

Reinhold, T. & Arlt, R. 2015, A&A, 576, A15

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