

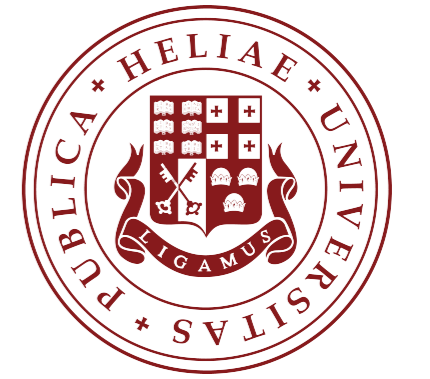
Stellar prominence oscillations and eruptions: The cases of HK Aqr and PZ Tel



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Abstract

Prominences are manifestations of magnetic fields on stars and have been detected on a handful of stars so far other than the Sun. We have selected two well known prominence-hosting stars, namely the young dMe star HK Aqr and late G type star PZ Tel, to search for prominence variability in form of oscillations. Such have so far not been detected on stars except for the Sun. Using oscillation parameters such as period and amplitude one can estimate the magnetic field strength in prominences. Moreover, prominences and Coronal Mass Ejections (CMEs) are well correlated on the Sun. This makes prominence hosting stars even more interesting as targets to search for CMEs, especially as the detection of stellar CMEs has turned out to be difficult. CMEs have impact on planetary atmospheric and stellar evolution so their investigation is of high importance. We report on the detection of prominence oscillations on HK Aqr. The estimation of oscillation parameters yielded values comparable to solar large-amplitude oscillations. However, during six nights of observations we could not detect any signature of CMEs. Assuming that CMEs produce absorption signatures similar to the prominence signatures, we show that considering the fact that CMEs/prominences are seen in absorption on these stars severely limits the number of detectable CMEs, in contrast to CMEs/prominences which can be seen in emission.

1. The target stars

We selected three nearby young fast rotating main-sequence stars. They have high levels of chromospheric and coronal activity, as reflected by their high X-ray luminosity L_X . The estimated daily number of strong ($E_X > 10^{32}$ erg) X-ray flares ranges from about ten to more than hundred [1]. On the Sun, such strong flares are tightly correlated with CMEs. Both PZ Tel and HK Aqr are known to have prominences which were discovered as absorption features moving across their rotationally broadened $H\alpha$ profiles [2, 3]. The selected stars are younger than those we monitored in a previous study [5].

star	spectral type	d (pc)	age (Myr)	P_{rot} (d)	$\log L_X$ (erg s^{-1})	N_{flare} (d^{-1})
PZ Tel	K0V	51	20	0.94	30.48	182
HK Aqr	M0Ve	22	200	0.43	29.26	13

2. Observations and data preparation

We obtained time series of optical spectra during six nights in August 2012 with the FEROS spectrograph installed at ESO's MPG/2.2m telescope in La Silla (PZ Tel, HK Aqr). The mean S/N of the spectra of each night varied between 38 and 77. To make prominences visible we generate residual spectra by subtracting an average spectrum. For stability reasons we generate different averages (for the whole series, per night, etc.).

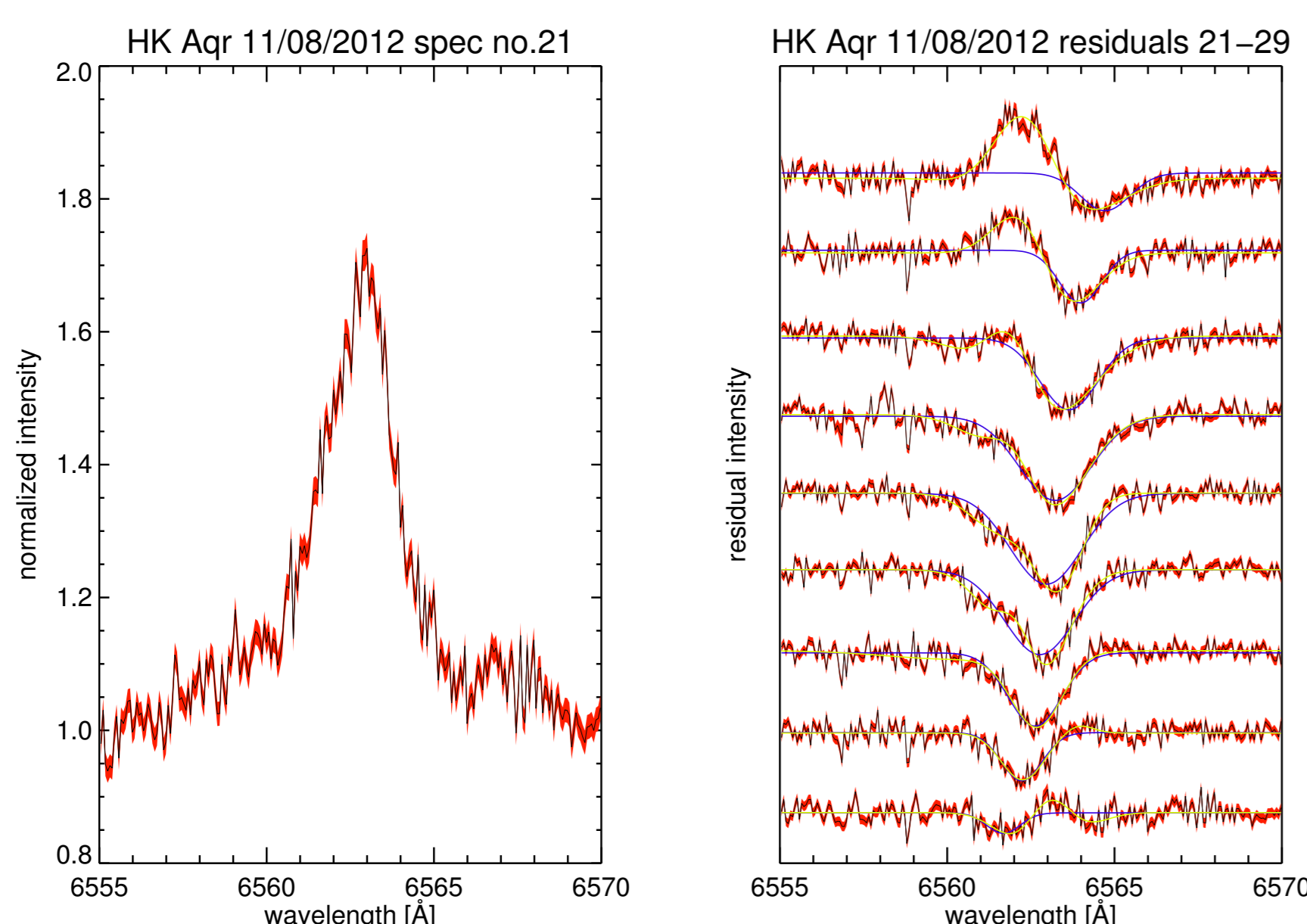


Figure 1: *Left panel:* Sample spectrum of the night of 11/08/2012. The red coloured area marks the $1-\sigma$ error. *Right panel:* Residual spectra and corresponding single and double gaussian fits from which the centers have been determined which are shown in Fig. 3 as sinusoidal motion. The red coloured are marks the $1-\sigma$ error.

3. Prominences and oscillations

We show dynamic spectra (relative intensity as a function of wavelength and rotational phase) of the region around $H\alpha$ from HK Aqr and PZ Tel. One can clearly see the dark absorption features caused by prominences travelling from the blue to the red wing due to the star's rotation. Some stable systems can be seen over several rotations (e.g. HK_08_P2, HK_11_P2, and HK_12_P1). In Fig. 2 we show the dynamic residual spectra.

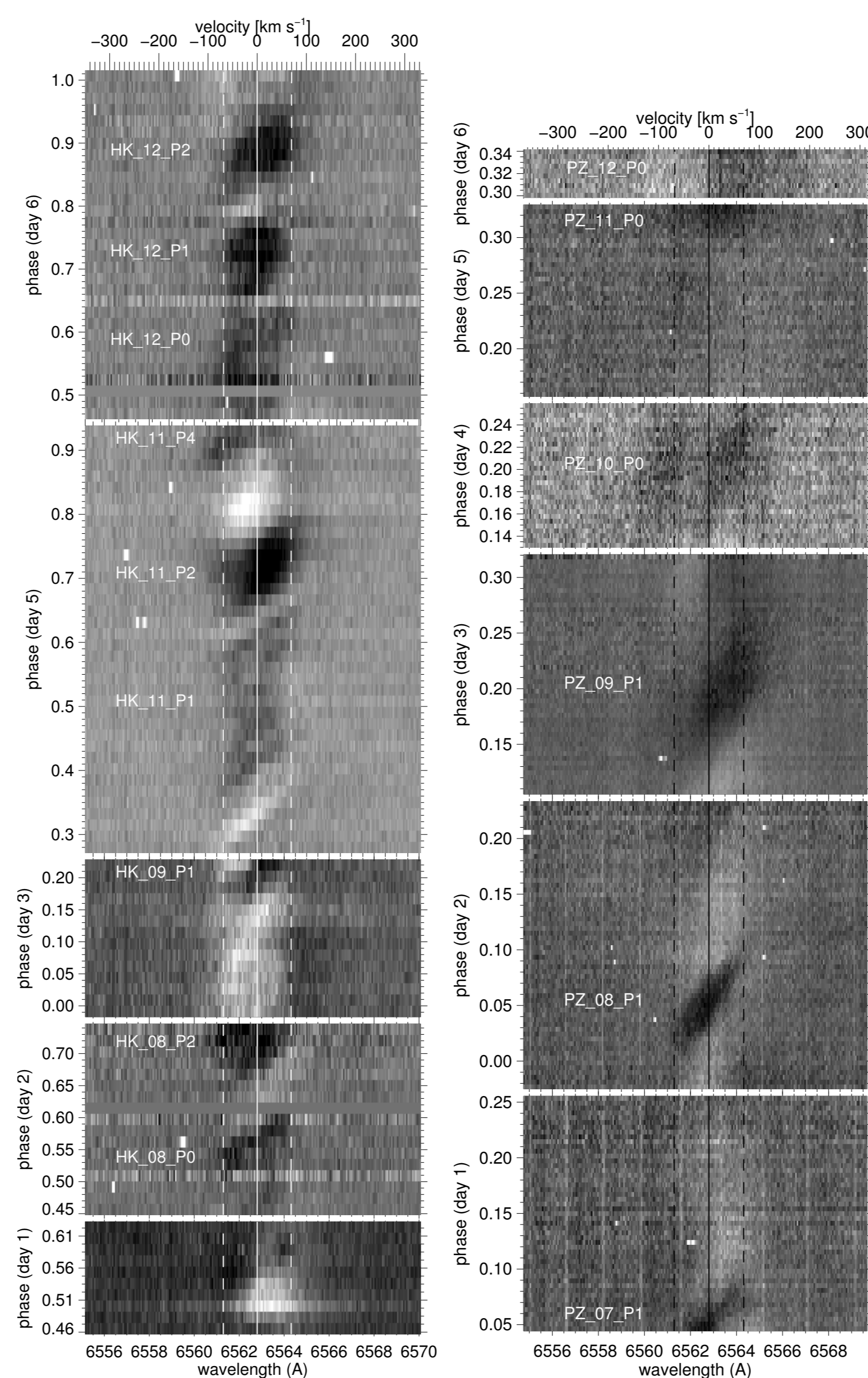


Figure 2: Dynamic residual spectra of the whole observing time of HK Aqr (left panel) and PZ Tel (right panel).

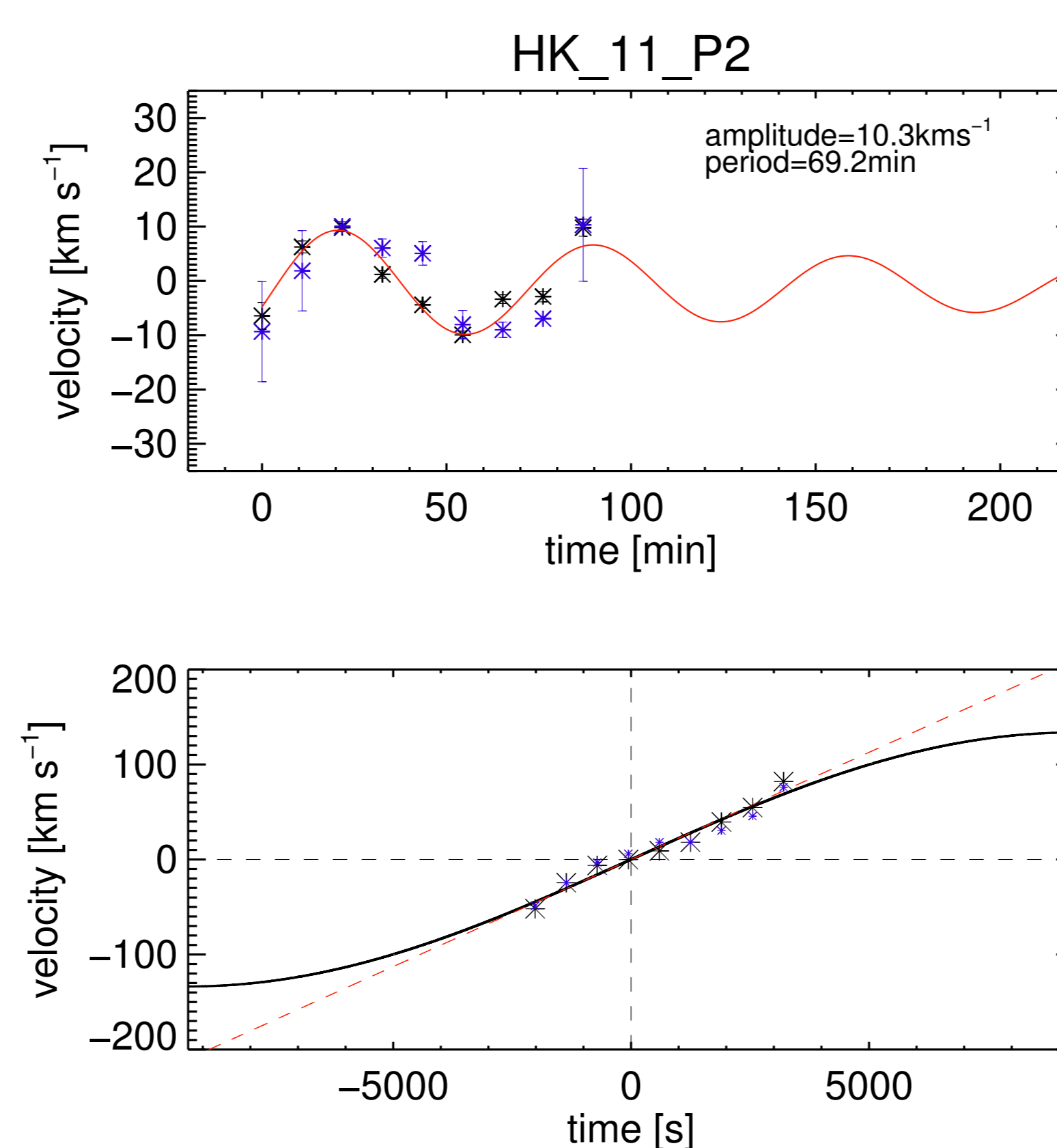


Figure 3: *Upper panel:* Motion of the center positions of the gaussian fits to the residual spectra (black asterisks: single gaussian fitting, blue asterisks: double gaussian fitting). The red solid line is a damped sinusoidal function fitted to the center positions determined from single-gaussian fitting of the residuals. *Lower panel:* Location of the center positions (black asterisks) on the rotational velocity of the co-rotating cloud.

To search for oscillations we fit the residual spectra with single gaussians. By determining center of the gaussians we are able to investigate if the variations follow a sinusoidal motion. The analysis of the HK and PZ data set has shown that only HK Aqr shows oscillations with parameters reminiscent to solar large amplitude oscillations. In Fig. 3 we show the most significant example of the whole data set namely the oscillation of prominence HK_11_P2.

4. Magnetic field of prominences

If oscillations have no transverse character (no intensity variations) then those can be interpreted in terms of Alfvén or kink waves. Using the kink speed depending on the magnetic field B_0 , the plasma density ρ_0 , which is related to the length of the prominence and the period of the first harmonic, then we can assess the magnetic field. Using the approach from Dunstone et al. [4] we derive a hydrogen plasma density of $2.9 \times 10^{-15} \text{g cm}^{-3}$. By assuming a prominence with a length of $2.7 \times 10^{10} \text{cm}$, which is one side of a square spanning the measured prominence area we derive a magnetic field strength of 0.88G which is comparable to magnetic field strength at solar coronal heights comparable to the height of prominence HK_11_P2 [6].

5. Stellar activity

Although both stars are young and active (see X-ray luminosity in Table 1) we did not find signatures of erupting prominences. This seems to be surprising at first glance. But considering that erupting prominences are also seen in absorption (only visible when they appear in front of the disk) and considering their on-disk time, we find that the probability to detect them is $\ll 1$.

References

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