Radial Velocity dependence on line formation temperature

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Hi, I'm Khaled!
I'm a 2nd year PhD student at the University of Geneva.
I work with high-resolution spectra of the Sun in order to understand how stellar activity impacts radial velocities.
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Introduction

In order to reach a radial velocity (RV) precision of ~10 cm/s required to detect Earth-twins around Sun-like stars, we need to understand and mitigate the effects of stellar variability. Previous studies [1,2] have shown that individual spectral lines are affected differently. Here, we present a novel approach to measure how RVs depend on line formation temperatures, which could shed light on the shifts and asymmetries induced by active regions and convective motion.

Method

- We use spectral synthesis with `PySME` [3] to derive the average formation temperature, denoted $T_{1/2}$, of each wavelength point for HARPS-N solar observations.
- Only unblended and accurately synthesized spectral lines are selected.
- We then compute the RVs for line segments based on their formation temperature, which can be seen as a proxy for formation depth.

Results

- Our method is applied on a time interval when the Sun shows a heightened level of activity, as seen in e.g. the Ca H & K index.
- By increasing the number of temperature bins, we observe that the measured RVs have varied sensitivity to stellar activity.
- Most notably, we find a strong activity signal at half the rotational period of the Sun for line segments formed at the very coolest layer of the solar photosphere.

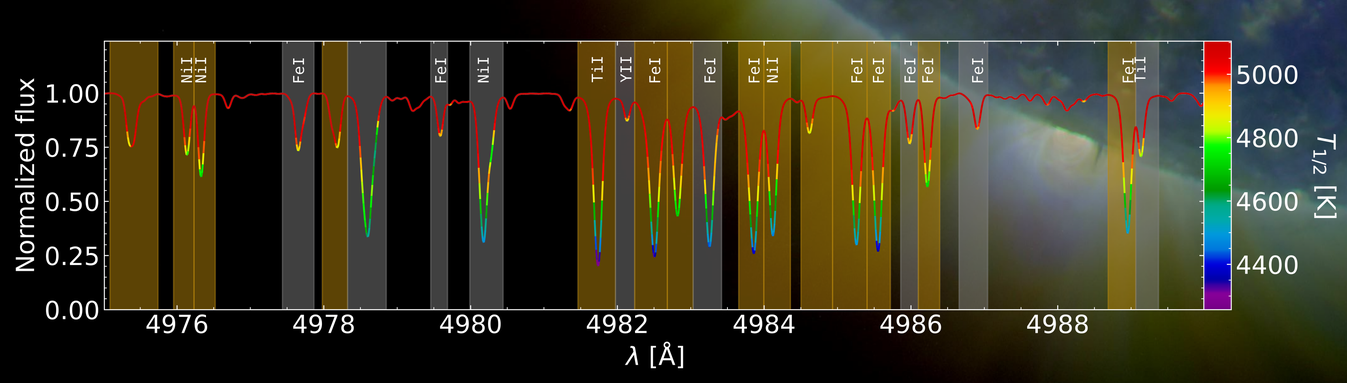

Fig. 1. Spectral window color-coded according to the average formation temperature, $T_{1/2}$. The shaded areas indicate whether a spectral line is selected (yellow) or rejected (grey). The labels above some spectral lines specify the element and ionization of identified lines.

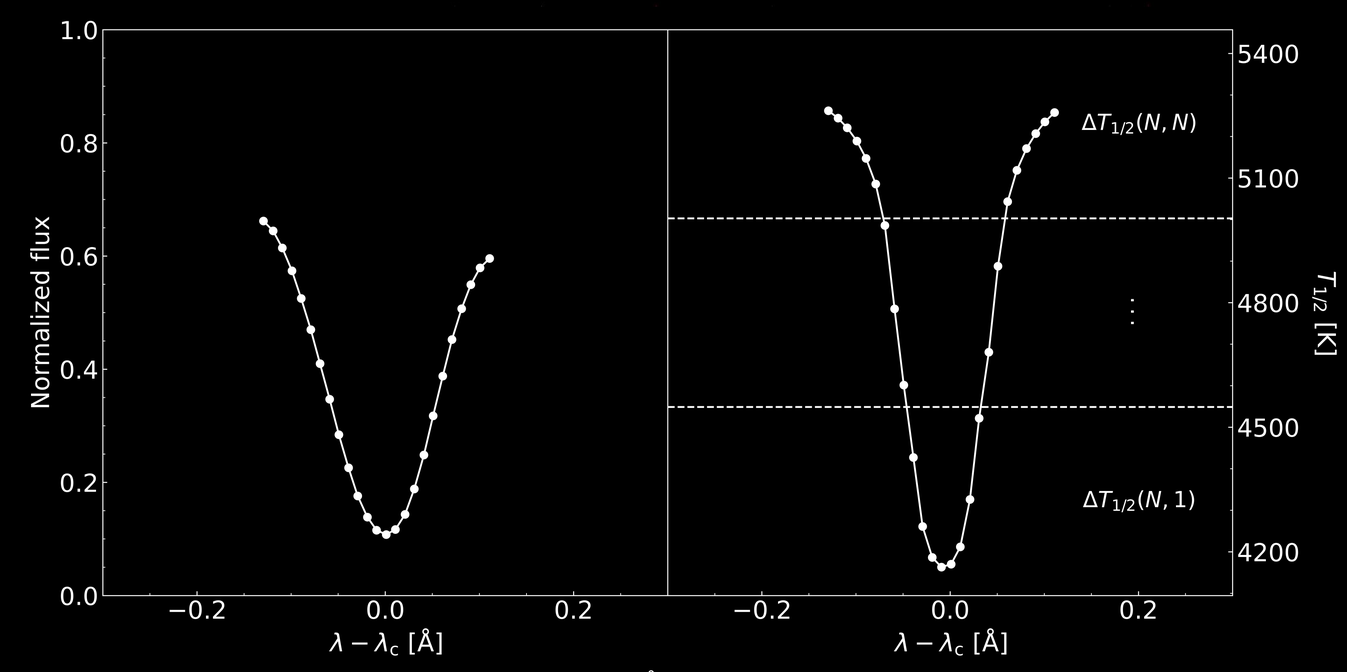

Fig. 2. Left: Flux profile of a solar Ti II line at 4337.92 Å. Right: Average formation temperature of each line point. The horizontal lines show the total temperature range for all identified lines divided into N equal bins.

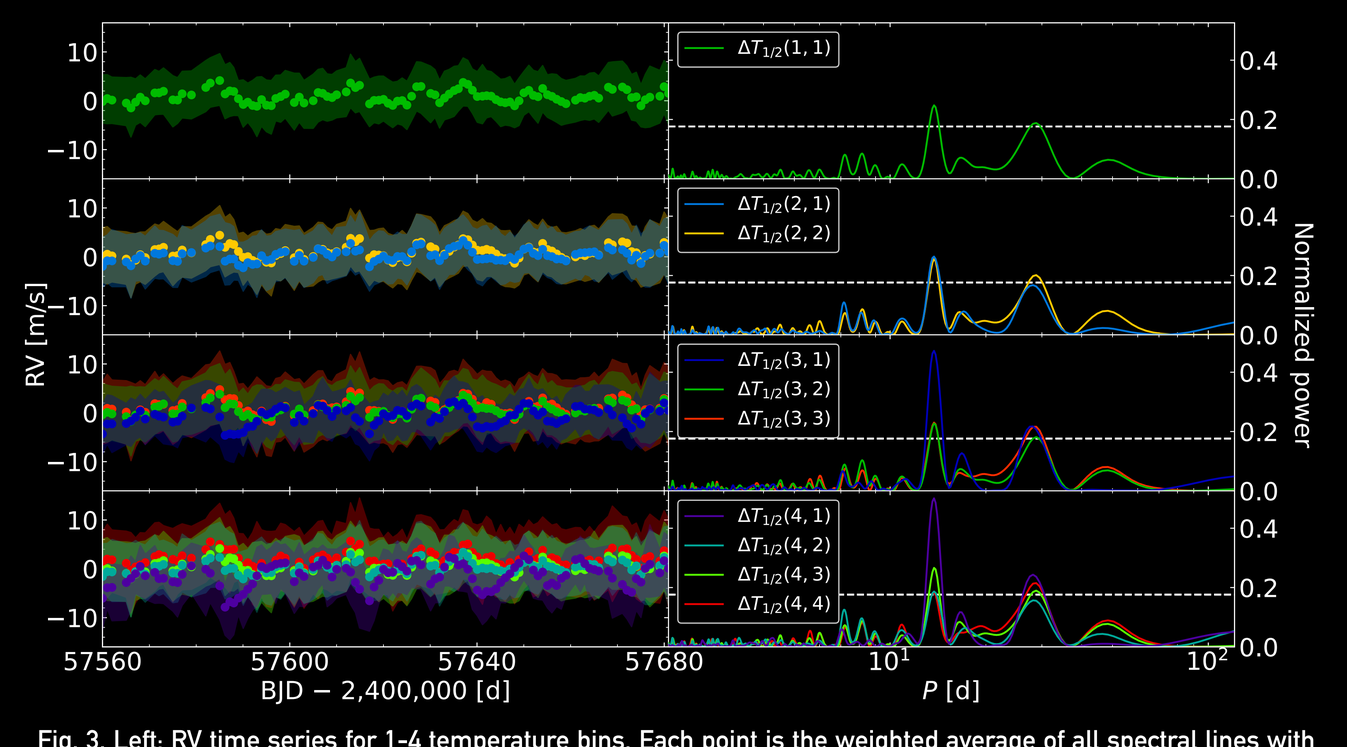

Fig. 3. Left: RV time series for 1-4 temperature bins. Each point is the weighted average of all spectral lines with RV values for a given bin. The shaded area represents the 16th to 84th percentile. Right: Periodograms of the time series, with the dashed lines showing the 1% false-alarm probability.

Up next...

- Can the temperature-binned RVs be linked to different types of stellar activity (e.g. spots, faculae, granulation patterns)?
- What is the detection limit of an injected planet for different configurations of temperature bins?

Find out more about this project and my other research topics on my website. Scan the QR code 👉 or browse onto almoulla.github.io

References

[1] Dumusque 2018, A&A, 620, A47 [2] Cretignier et al. 2020, A&A, 633, A76 [3] Available at https://github.com/AWehrhahn/SME

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