Reaching the 25 cm/s RV precision on the HARPS-N solar data through post-processing of stellar spectra

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The detection of Earth-like exoplanets in the habitable zone of Sun-like stars is today challenged by the presence of several systematics induced by 1) the instruments, 2) the Earth's atmosphere, and 3) the stellar activity (e.g. Meunier+20, Crass+21). By analyzing spectra time-series residuals, we showed that most of the known systematics produce, at the spectral level, clear signatures that are significantly different from a pure Doppler shift signal. We thus developed a post-processing framework called YARARA (Cretignier+21) to correct for those at the spectral level, before computing any RV information. Further improvements can also be obtained in the time domain by extracting new stellar activity proxies derived from spectral "shells" (Cretignier+22) or non-Dopplerian proxies using line-by-line RVs (Cretignier, in prep).

After performing a global reprocessing of the historical HARPS and HARPS-N databases for bright and well sampled targets, we demonstrate that i) the overall RV precision improves by 30%, and ii) several stars reach a floor of 80 cm/s, expected from the combination of both instrumental stability and granulations effects (Al Moulla+22), and that iii) dozens of new planetary candidate signals become significant. To highlight the performance of our framework on a single target, we will show 8 years of HARPS-N solar observations for which we are able to reach an RV rms of 80 cm/s, equivalent to the detections of 25 cm/s planetary signals.