YARARA : A new post-processing pipeline to improve RV

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YARARA

ABSTRACT

We developed YARARA (Cretignier et al. in prep), a new post-processing pipeline designed to provide more precise RV time-series on HARPS and HARPS-N observations even if the pipeline can be applied to any stable instrument. The pipeline is a data-driven approach based on spectra-timeseries corrections by PCA rather than RVs corrections. Such methods have proven their value for instance to correct for telluric lines (Bedell et al. 2019) and is well dedicated for stars intensively observed. YARARA is therefore in adequation with observational strategies needed to detect the exoplanets that induce signals below a few m/s in RV.

Such pipeline is made possible thanks to a new method of spectra normalisation based on an alpha-shape strategy performed by a publicly available code called RASSINE (Cretignier et al. 2020). We demonstrated that a precision better than 0.10% can typically be reached on the normalisation of HARPS spectra. RASSINE allows us to normalise all the spectra in the same way, which allows us to obtain exquisite residuals after removing a median spectrum. Those residuals can then be represented as a "river diagram" where the instrumental systematics and Earth's contaminations are more clearly visible (**Fig.1**).

YARARA contains specific recipes dedicated to the correction of: cosmics, tellurics, fringing, ghosts, stitchings and simultaneous fiber contamination. On HD10700 HARPS data, the RVs rms is reduced from 1.09 m/s down to 0.92 m/s (**Fig.2**). Since YARARA is deeply embedded in the framework of line-by-line (LBL) analysis (Dumusque 2018, Cretignier et al. 2019), it is possible to directly observe how 1-year signals are mitigated on each individual line (**Fig.3**). On HD10700, the power is reduced for a candidate planet at 600 days (Feng et al. 2017). As a comparison, running YARARA on HD10180 (Lovis et al. 2011), the 6 exoplanets are recovered. The same occurs for exoplanets injected in the spectra-timeseries, showing that YARARA is not absorbing planetary signals.

RIVER DIAGRAM OF SPECTRA-TIMESERIES

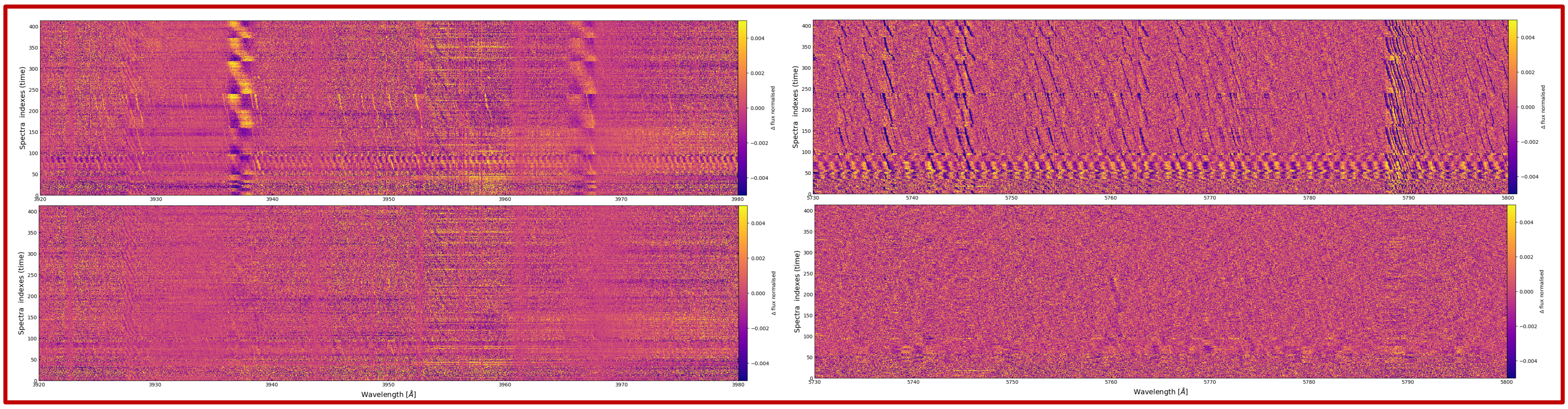

Figure 1. Top : River diagram representation of HD10700 spectra time-series before YARARA correction. **Bottom :** Same as top after YARARA processing. **Left :** Zoom in a ghost +ThAr contaminated region. **Right :** Zoom in a telluric + fringing contaminated region.

IMPROVEMENT IN RVs PRECISION

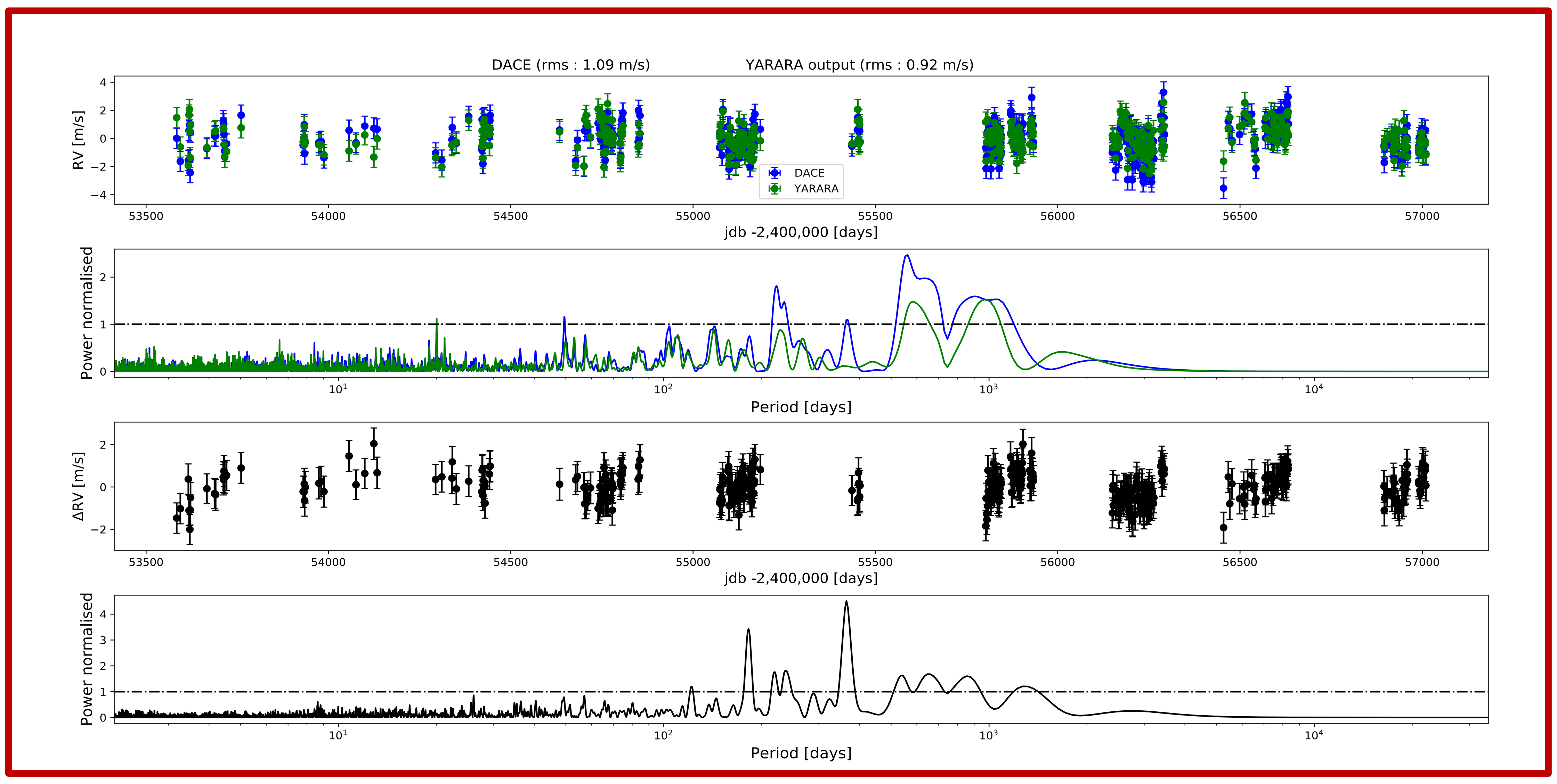

Figure 2.

First row : RV timeseries of 10 years of HARPS observations on HD10700 (Tau Ceti). RV derived from the DRS compared to RV derived after YARARA's post-processing. The rms of the RV time-series is reduced from 1.09 m/s down to 0.92 m/s.

Second raw : GLS periodogram of each RV timeseries. The horizontal dashed line represent a FAP level of 1%. A doubtful signal at 600 days (Feng et al. 2017) is highly reduced.

Third row : RV difference.

Last row : GLS periodogram of the RV difference timeseries. Power is clearly absorbed at 1-year and 1/2 a year, which is expected as YARARA corrects for telluric lines and instrumental systematics as for instance stitching effects (Dumusque et al. 2015).

1-YEAR SIGNAL SUPRESSION AS VISUALISED BY LBL RVs

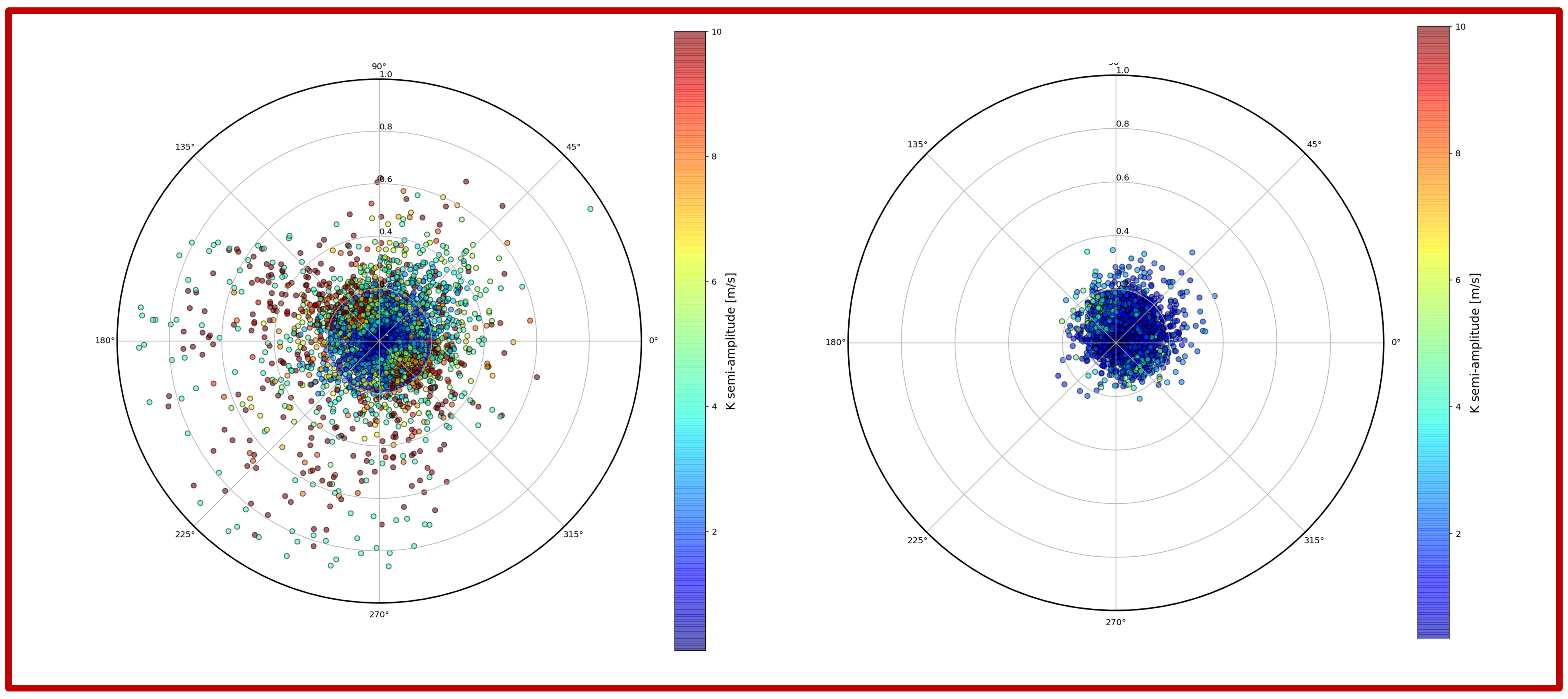

Figure 3. Polar periodogram of each individual LBL RV time-series focalised at 1-year. In comparison to a classical GLS periodogram, the polar periodogram is focalised at a fixed period (here 365 days) and show the power of the signal as the radial coordinate and the phase of the signal as polar coordinate. The color represents the semi-amplitude of the fitted sinus.

Left : LBL RVs uncorrected by YARARA. A lot of stellar lines present 1-year signals due to telluric lines or instrumental systematics. Note that 1-year signal do not produce preferentially phase for each line.

Right: LBL RVs after YARARA correction. Most of the lines have lost their 1-year signal.