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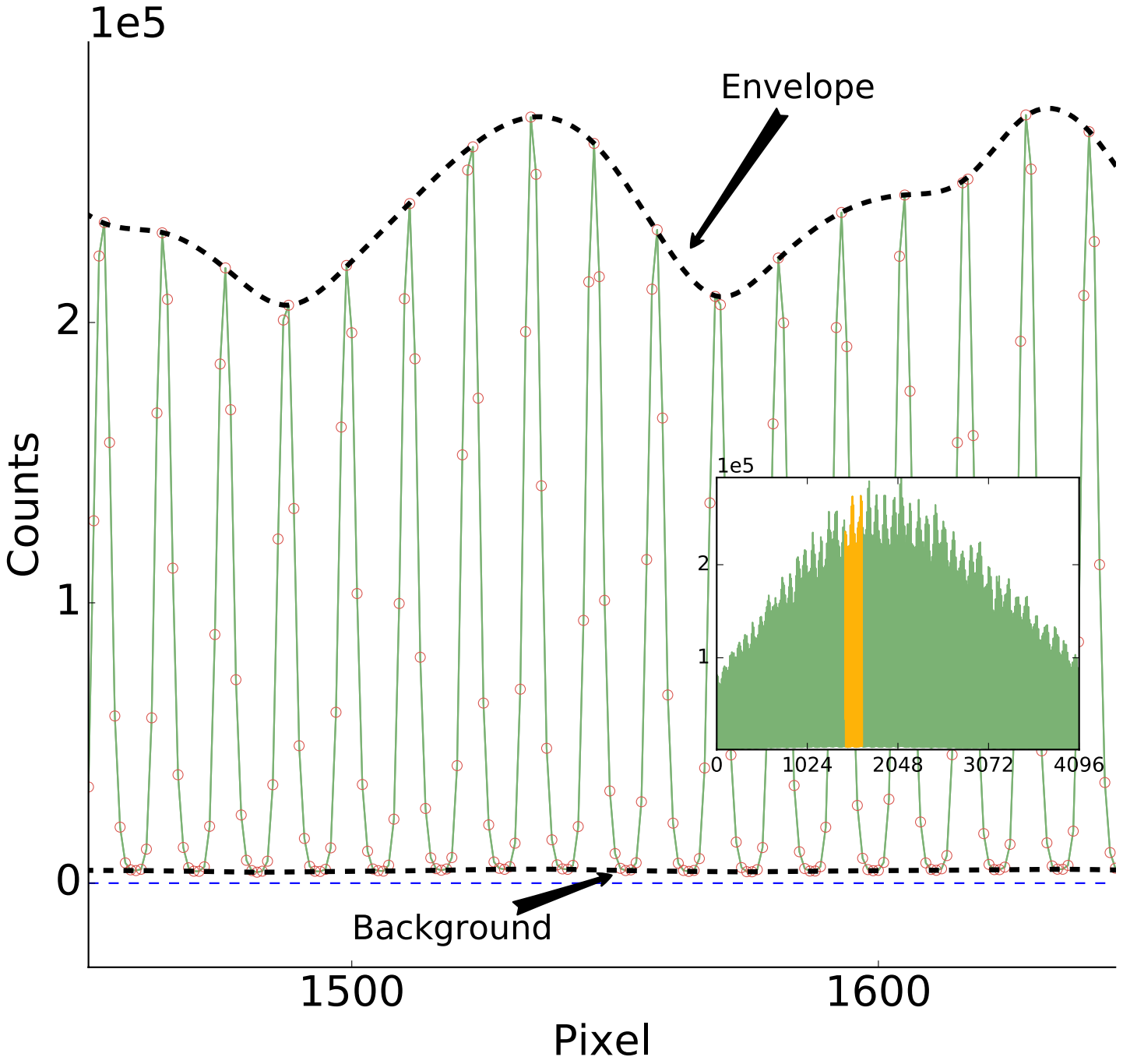
1e5
Envelope
2
1
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Counts
Background
1500
1600
Pixel
1e5
2
1
0
1024
2048
3072
4096

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Abstract

The laser frequency comb, or "Astro-Comb" (Steinmetz 2008), installed on HARPS (High Accuracy Radial velocity Planet Searcher) was repaired in October 2016 and is running under unsupervised operations since.

In this poster we analyse the comb data gathered between October 2016 and December 2016. In particular, we focus on the wavelength dependent modulation of the signal envelope and background. We are able to characterise this background with wavelength, echelle order, and time. We show that the proper evaluation of the background is essential to optimise the performances, i.e. accuracy and precision, of the system.

Which characteristics did we study?

The Astro-Comb produces a series of emission lines equidistant in frequency, such that the each line's frequency, f_n, is uniquely determined by the equation of the comb: $f_n = f_0 + n\, f_r$, where f_r=250MHz is the "repetition frequency", $f_0 < f_r$ is the "offset frequency", and n is a large integer number. Details on the Astro-Comb's design can be found in Wilken et al. (2010,2012).

The Astro-Comb shows a modulated and wavelength dependent envelope (background), identified by connecting line maxima (minima) of unknown origin.

In this work, we characterise the these two features and we determine the background's effect on the accuracy of the wavelength calibration.

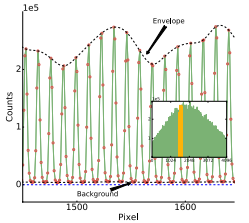
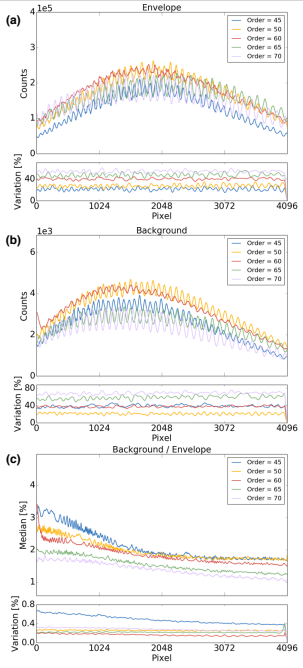


Figure 1. shows a zoom-in (large) and the entirety (inset) of the Astro-comb spectrum (green) for the 50th echelle order. Measured electron count values are shown as red circles. The envelope and background are shown as black dashed lines.



Do they change with wavelength?

The envelope and the background are shown on the top panels of Figure 2a and 2b, respectively. Both quantities show a periodic variation in intensity with wavelength within a single order, with the spacing of approximately 100 pixels increasing with pixel number. The intensity of the comb varies with echelle order, but the same periodic trend is observed. We also calculate the background to envelope ratio (B2E, hereafter) to further explore the nature of the background, shown in Figure 2c. B2E is consistently below 5% for all echelle orders.

Do they change in time?

To investigate the stability of the envelope and background with time, we analysed 513 comb observations made between October and December 2016. We calculate the median intensity and the central 68% of the intensity distribution of the envelope, the background, and the B2E for each pixel. The envelope (background) varies between 20% and 40% (30% and 80%), with no strong correlation with pixel number. B2E is stable to the 0.5% level, but shows larger variation for the bluest echelle orders, which also exhibit anti correlation with pixel number.

Are the periods the same?

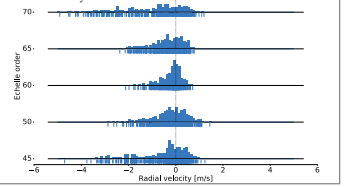
We performed a Fourier analysis of the B2E for all 513 comb observations to determine whether the envelope and background are modulated by the same function. The analysis showed that B2E has a flat spectrum, with a small feature corresponding to a period of approximately 100 pixels, consistent with data in Figure 2c. This implies that the envelope and the background shapes both have origin in the same underlying physical process.

What is the background's impact on wavelength accuracy?

Finally, we investigate the effect of the background the wavelength calibration accuracy. We calculate the difference between the comb line positions with and without background subtraction, expressed in m/s. We determine the centre of the line in the two cases and plot the results in Figure 3 for five echelle orders.

Figure 2. *(LEFT)* (a): The top panel shows median intensity of the envelope for 513 comb observations as a function of pixel number, for 5 echelle orders. The bottom panel shows central 68% of the intensity range, expressed as a percentage of the median intensity. (b): Same as (a), only for background. (c): Same as (a), only for the background to envelope ratio.
Figure 3. *(RIGHT)* Distribution of offsets between comb line centres (expressed as radial velocity) determined by fitting Gaussian profiles with and without background subtraction.

The difference varies for each echelle order and can not be explained by a simple offset. Median offset across a single spectrum is ~ 0.2 m/s. Therefore, a proper evaluation of the background is essential for wavelength accuracy.



Conclusions

Even if the source of the envelope and background in the comb spectra of HARPS are not fully understood, it is possible to characterise them in time and wavelength. The spacial and temporal behaviour suggest that they are intimately related, and of the same origin. In particular, the ratio of the background to the envelope for each order is basically stable in time and smooth in space. Nevertheless, we show that not subtracting the background signal in the data reduction would bring to non-negligible errors in the wavelength calibration.

References

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Wilken et al. 2012, Nature, 485, 611–614