An exploration of methods to remove telluric signatures from exoplanet transit observations

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In this master thesis I explore multiple approaches to remove telluric features from the transit observations for several exoplanets with the PEPSI high-resolution spectrograph at LBT. Comparing the performance of different approaches will remain an important task, because high-resolution spectroscopy for exoplanets will continue to be performed from the ground for the foreseeable future.

I. Introduction

The atmosphere of our Earth causes absorption and emission features in spectroscopic observations - so-called telluric lines - that need to be removed from observations with:

- Physical models of the Earth atmosphere that use a synthetic telluric line atlas based on a LBLRTM and an atmospheric pressure profile, such as Molecfit [1].
- Statistical approaches analysing the variability of the observed spectra throughout the observation, such as Sysrem [2], or our approach described here [3].

II. Methodology

- For our statistical approach we analyzed the behaviour of each individual spectral pixel throughout ca. 50 transit spectra collected with PEPSI during a given night.
- We approximated each pixel's changes in flux with a low-order polynomial (smoothing spline interpolation) and then divided each value on that pixel light curve through its own spline, thus correcting for overall trends that are changing slowly over the night.
- The magnitude of telluric features depends on observation angle and air mass above, thus spectral pixels near telluric absorption/emission lines will show a slow variation in fluxes. Short-term variabilities, esp. during transit, should not be picked up by the smoothing spline and therefore be preserved.

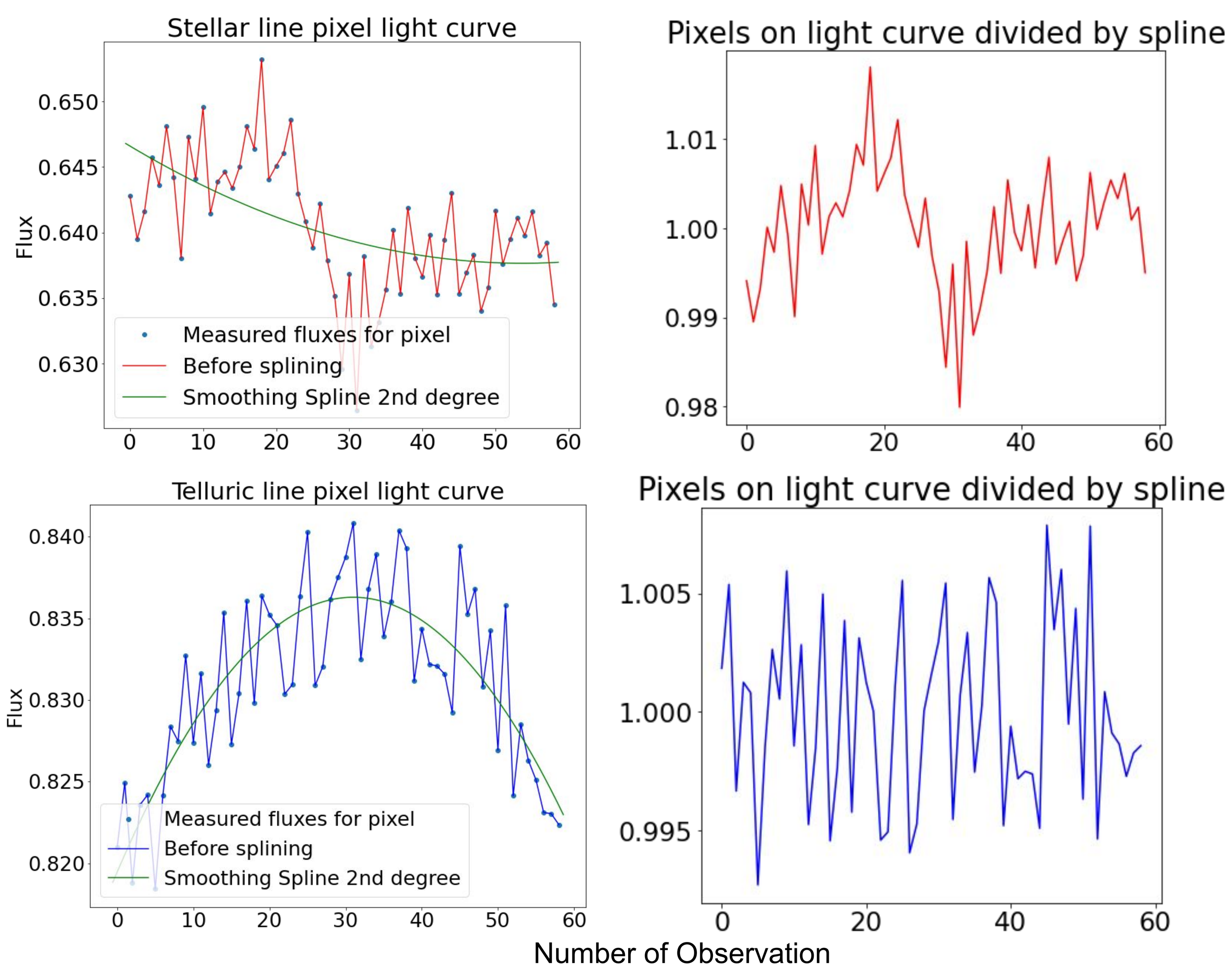

Fig. 1. Left: shows the typical light curve for pixels across several observations (locations in spectrum, see Fig. 2). From top to bottom: light curve of a pixel in a stellar line, showing the Rossiter-McLaughlin feature and the spline fit; light curve of a pixel in a telluric line and its spline fit. Right: pixel light curves for same pixels after dividing each pixel through its own spline.

III. Preliminary Results

- With this approach we can remove tellurics from the exoplanet transmission spectrum efficiently, while leaving stellar features and exoplanetary signals mostly intact.

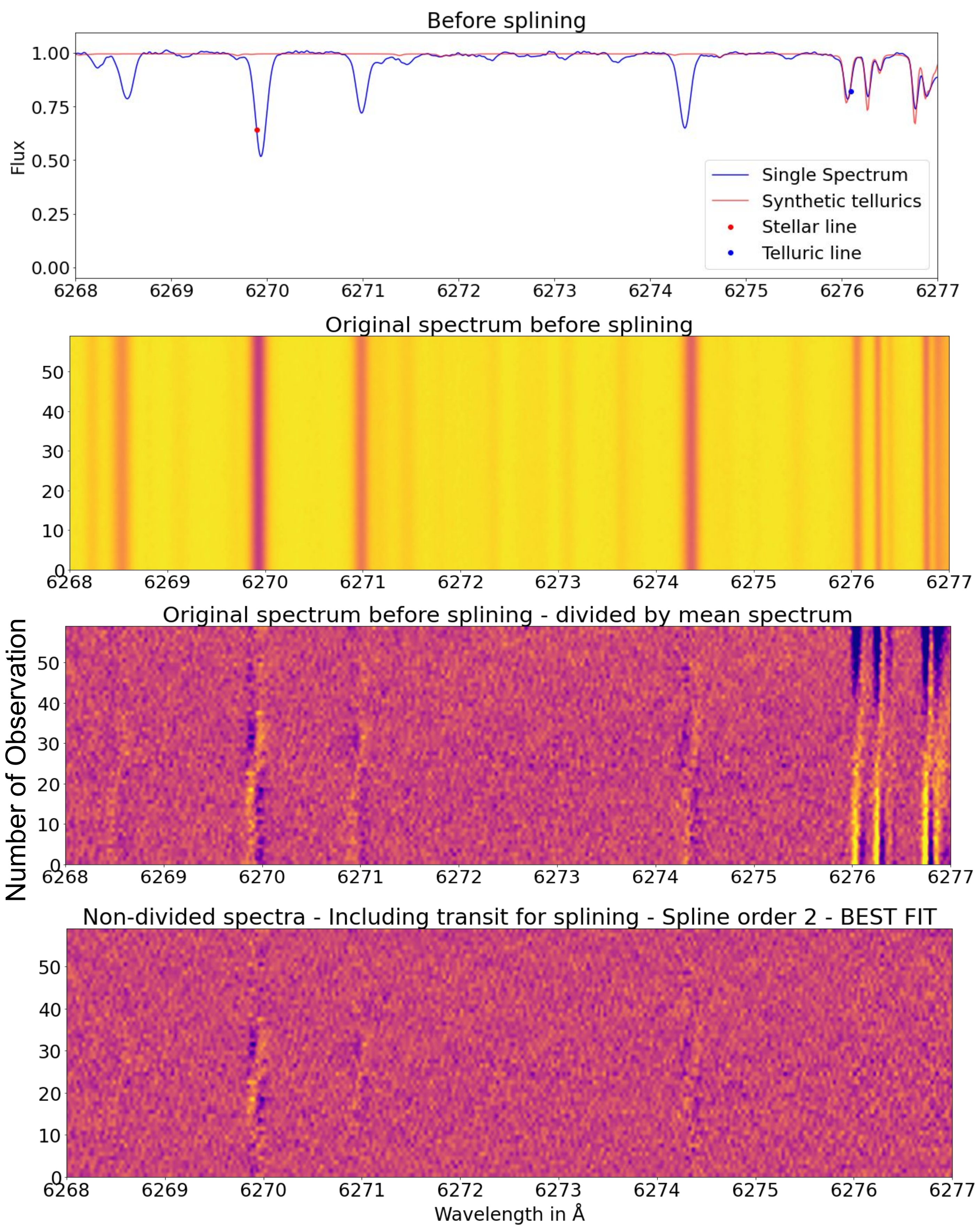

Fig. 2. Results for HD18973. From top to bottom: A single original spectrum (blue) with known positions of telluric features (red) and locations of pixels near stellar/telluric lines given in Fig. 1; the time series of spectra displayed as a 2D spectrum; the 2D spectrum divided by the mean spectrum; the 2D spectrum after removing slowly-changing features with a low-order spline fit.

IV. Next steps

- Quantitative analysis of telluric, stellar and planetary features.
- Comparison to approaches with physical models of Earth atmosphere - i.e. ESO's molecfit tool - and additional local atmospheric data.
- In-depth analysis of transit data on exoplanets HD189733b and HD63433b and their potential atmospheric features.

References

[1] Kausch et al. 2015, A&A 576, id.A78, 17 pp.
[2] Tamuz et al. 2005 MNRAS 356 4 1466-1470
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