SPORK That Spectrum: Increasing Detection Significances from High-Resolution Exoplanet Spectroscopy with Novel Smoothing Algorithms

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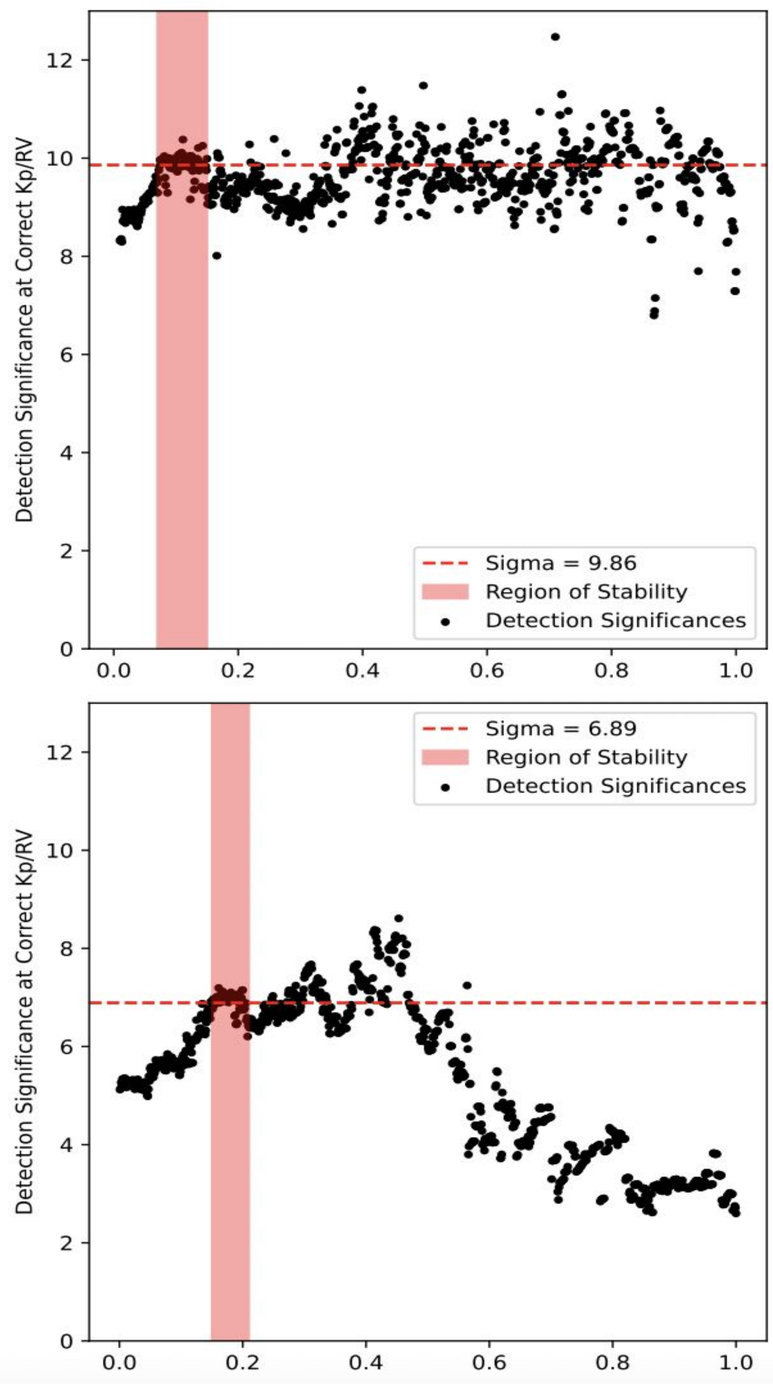
PURPOSE

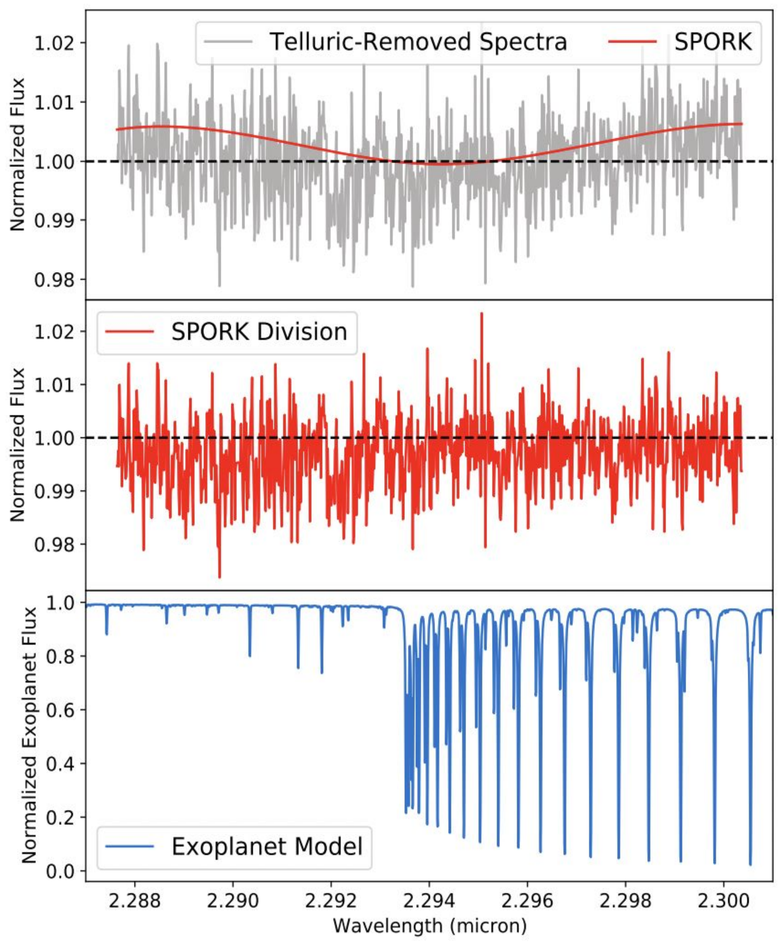
- When studying planets outside of the solar system, some of the most crucial information are found through spectroscopy.
- Extracting the planet's signal becomes difficult due to noisy signals.
- Emission spectra from CRIRES where we introduce an algorithm called SPORK (SPectral cOntinuum Refinement for telluriKs).
- We primarily focus on two hot Jupiter exoplanets: **HD 209458 b**, and **HD 179949 b.**

SPORK

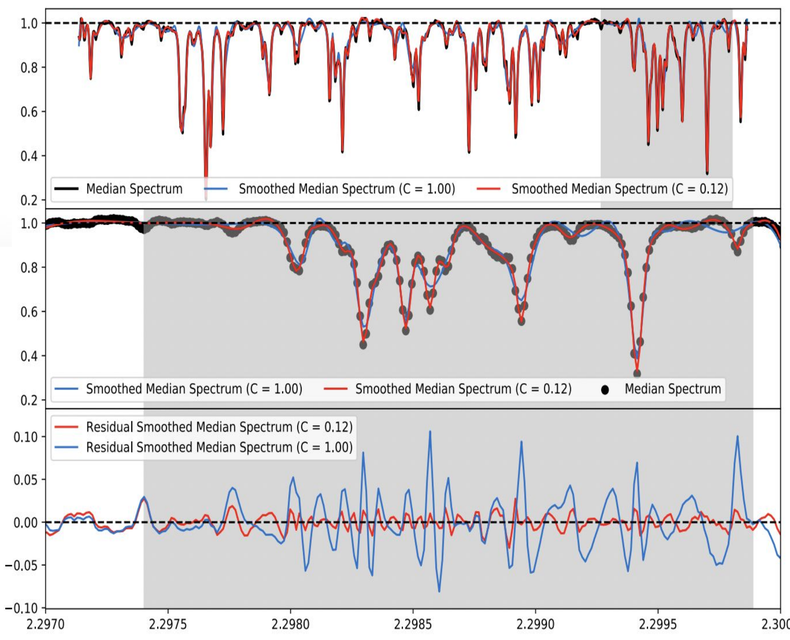
- Cross correlation is used to maximize the information from a set of spectral lines.
- We locate the host star's continuum and clip off outliers iteratively, and apply it before using a telluric removal method.
- Air mass detrending method to remove tellurics.
- SPORK itself also takes in a smoothing factor between **0** and **1** as an input.
- Apply the smoothing to the median spectrum.
- Cross correlate to extract the planet's signal.



1 Detection significance vs. smoothing factor with iterative smoothing for HD 209458 b **(top)**, and HD 179949 b **(bottom).** The region of stability is chosen to avoid over smoothing the spectrum.

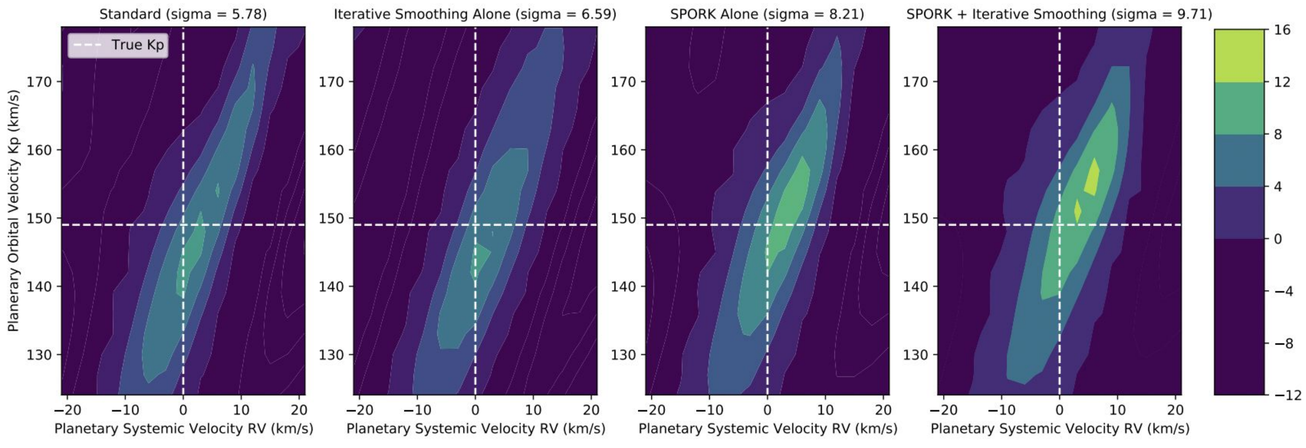


2 SPORK applied to HD 179949 b spectra after removing tellurics. **Top**: A telluric removed spectrum (grey) and fit with SPORK (red). **Middle**: The SPORK fit divided out. **Bottom**: The original model exoplanet spectrum.



3 A median spectrum of HD 209458 b and its optimally smoothed version (red) to find the **ideal smoothing factor.** The blue line represents an overfit, and the gray region highlights the closeness of the fit to the chosen factor.

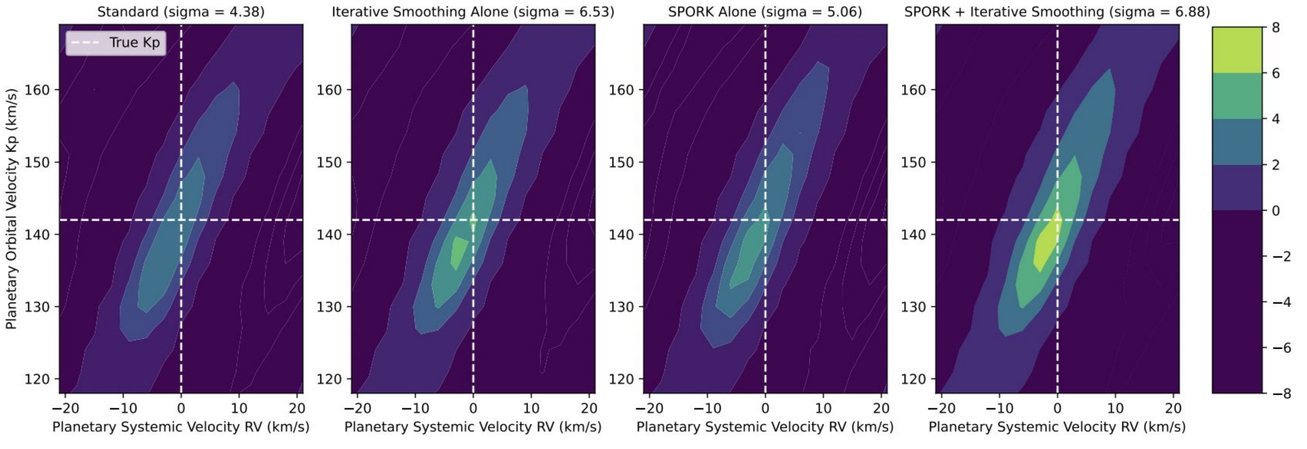
Results of SPORK on HD 209458 b & HD 179949 b



4 Exoplanet HD 209458 b, where the **detection significance increases** from a standard use at **5.78** sigma to **9.71** sigma with SPORK and iterative smoothing.

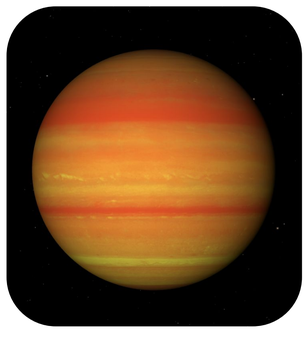
HD 209458 b

(Hypothetical Visualization)



5 Exoplanet HD 179949 b. The use of SPORK and iterative smoothing **increases the detection significance** from **4.38** sigma to **6.88** sigma.

HD 179949 b



(Hypothetical Visualization)

APPLICATIONS & USAGE

- Test SPORK before, after, and both, with telluric removal.
- Terrestrial-sized exoplanet observations can be optimal.
- It is a highly accessible technique.
- Helping to find life outside our solar system?

References: Rasmussen et al, *SPORK That Spectrum: Increasing Detection Significances from High-Resolution Exoplanet Spectroscopy with Novel Smoothing Algorithms*, 2022., NASA "Eyes on Exoplanets"