The Horizon-2020 ExoplANETS-A project: Advancing transit spectroscopy

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+
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Exoplanet Atmosphere New Emission Transmission Spectra Analysis

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Total budget of 2.2M euro, of which 1.5 M euro financed by the EU.

https://www.explore-exoplanets.eu/

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<th>Participant No</th>
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Our Goals:

- We will develop a novel data calibration and spectral retrieval tools to exploit archival data from ESA Space Science archives (HST) combined with NASA Space Archives (Spitzer) and produce a homogeneous catalog and characterization.

- To this end, we will collect a coherent and uniform database of the relevant properties of host stars from ESA Space Science archives (XMM, Gaia), combined with international space mission and ground-based data.

- These exoplanet and host star catalogs will be accompanied/interpreted with models to assess the importance of star–planet interactions.

- In addition to the delivery of high level data products, our state of the art tools will be ready for rapid exploitation of data from the James Webb Space Telescope.
Measurement Uncertainties and Bias

A. Low Accuracy; Low Precision

B. Low Accuracy; High Precision

C. High Accuracy; Low Precision

D. High Accuracy; High Precision

Is identical if you don’t know your target
Example: Eclipse observations of HD189733 b

Charbonneau et al 2008
Example: Eclipse observations of HD189733 b

Charbonneau et al 2008 + Knudsen et al 2012
Removing Instrument Systematics

Two options:

• Create a detailed instrument model which includes all effects
  – Will most likely require substantial calibration observations
  – Can be time dependent (not captured in model)
  – Might not be complete

• Use a „data driven“ approach
  – All necessary information to calibrate the data contained in the data itself
  – Needs substantially less calibration observations
  – Automatically takes care of time variations.
  – Is generic !
Using Causal Data Structures to Calibrate Timeseries Observations

Look out for Sammland et al 2020 (submitted to A&A) for an application of this method to VLT/SPHERE observations.
Additive Noise Model

\[ \text{Signal} = \text{Transit Signal} + \text{"Noise"} \]
A Causal Noise Model

\[ \hat{I} = X - E[X|Y] \]

\[ X(t) = I(t) + f(N,t) \]

\[ Y(t) = g(N,t) \]
A Causal Noise Model

\[ \hat{I} = X - E[X|Y] \]

\[ X(t) = I(t) + f(N, t) \]

\[ Y(t) = R(t) + g(N, t) \]
CASCADe:
Calibration of trAnsit Spectroscopy using CAusal Data
Using CASCADe on Spitzer data
Using **CASCADe** on Spectroscopic Data

- **Pixel from which the signal is extracted**
- **Pixels used to construct regression model**
A Causal Noise Model of HD189733 b Eclipses with Spitzer

Same wavelength, two different Eclipse Observations
A Causal Noise Model of a WASP 19 b Transit with HST

Same Transit Observation, different wavelengths
WASP 19 b „final“ transit spectrum

See also Mandell et al 2013
WASP 12 b „final“ Transit Spectrum

See also Tsiaras et al 2018; based on HST WFC3 observations in „scanning mode“ of 3 transits.
CASCADe

• Can handle spectroscopic data from different observatories, with different instruments and observing modes (includes JWST).
• Performs optimal extraction, precise image registration and rebinning to construct spectral timeseries.
• Current version only for fixed $T_0$
• Public release of the code and documentation planned before end of H2020 funding period.
• Uniform catalog of HST and Spitzer spectra and analysis results is being created.