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

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EXOPLANETS-A
EU's H2020 programme

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Exoplanet Atmosphere New Emission Transmission Spectra Analysis

European Commission

January 2018 – March 2021

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

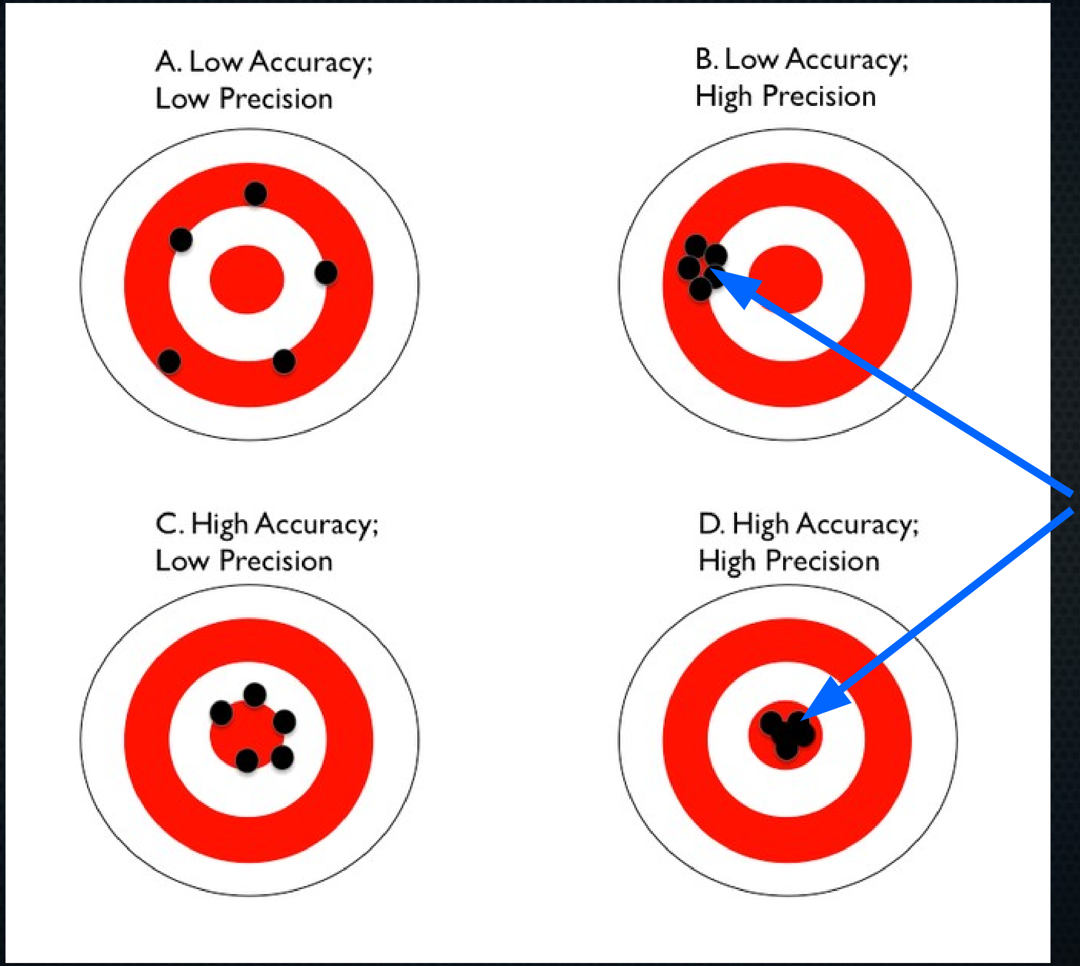
https://www.explore-exoplanets.eu/

Participant No	Participant organisation name	Country
1	Cea	France
2	Inta	Spain
3	Uleic	UK
4	Mpg	Germany
5	University College London	UK
6	Univie	Austria
7	Stichting Sron	Netherlands

Our Goals:

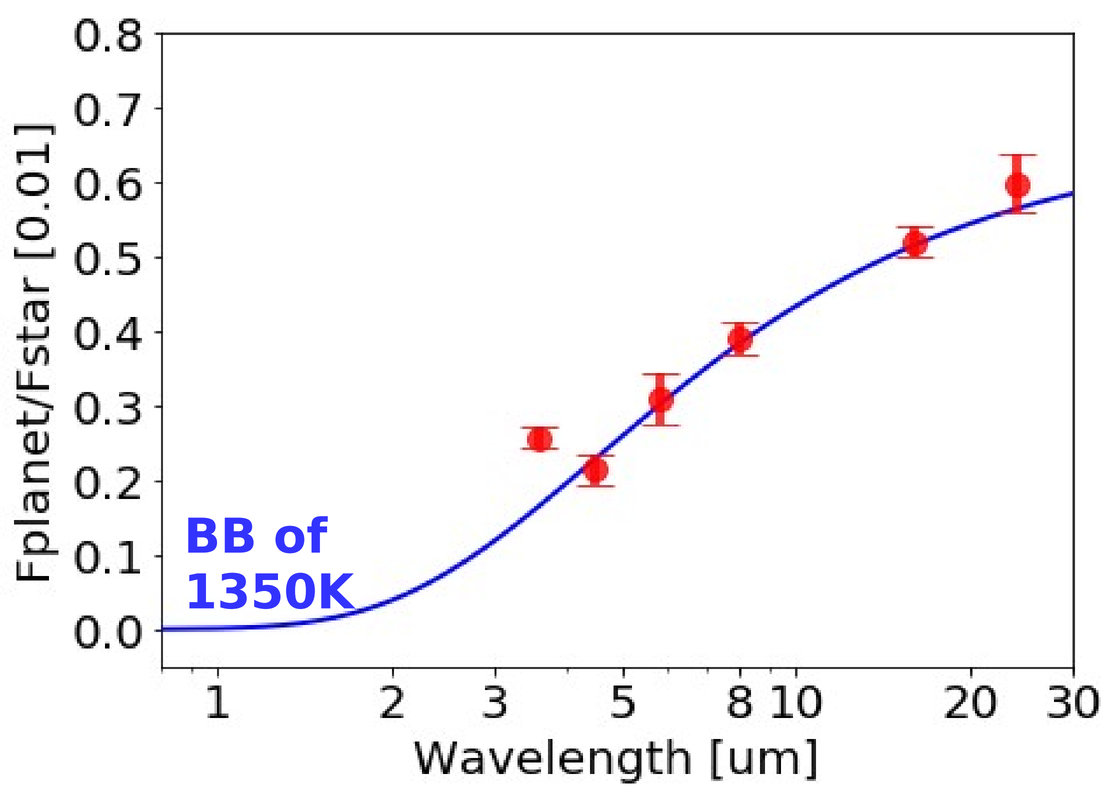
- We will develop a novel data calibration and spectral retrieval tools to exploit archival data from ESA Space Science archives (HST) combined with NASA Space Archives (Spitzer) and produce a homogeneous catalog and characterization.
- To this end, we will collect a coherent and uniform database of 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.

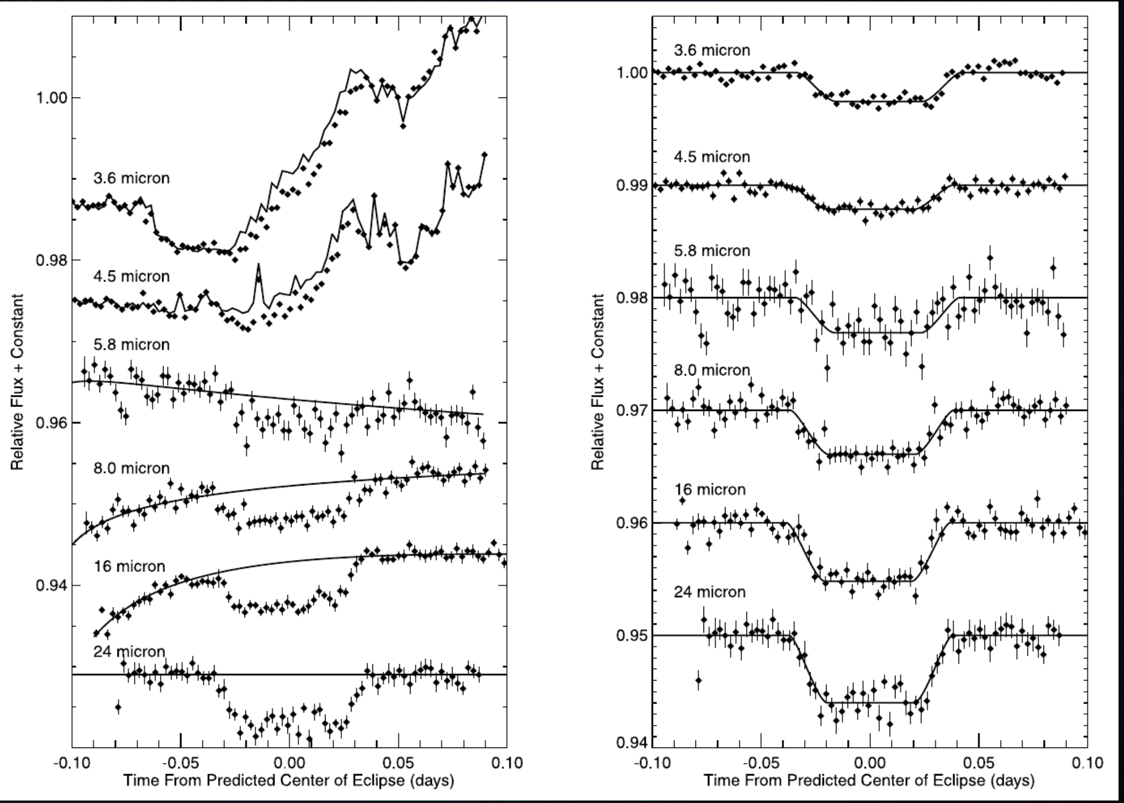
Measurement Uncertainties and Bias



Is identical if you don‘t know your target

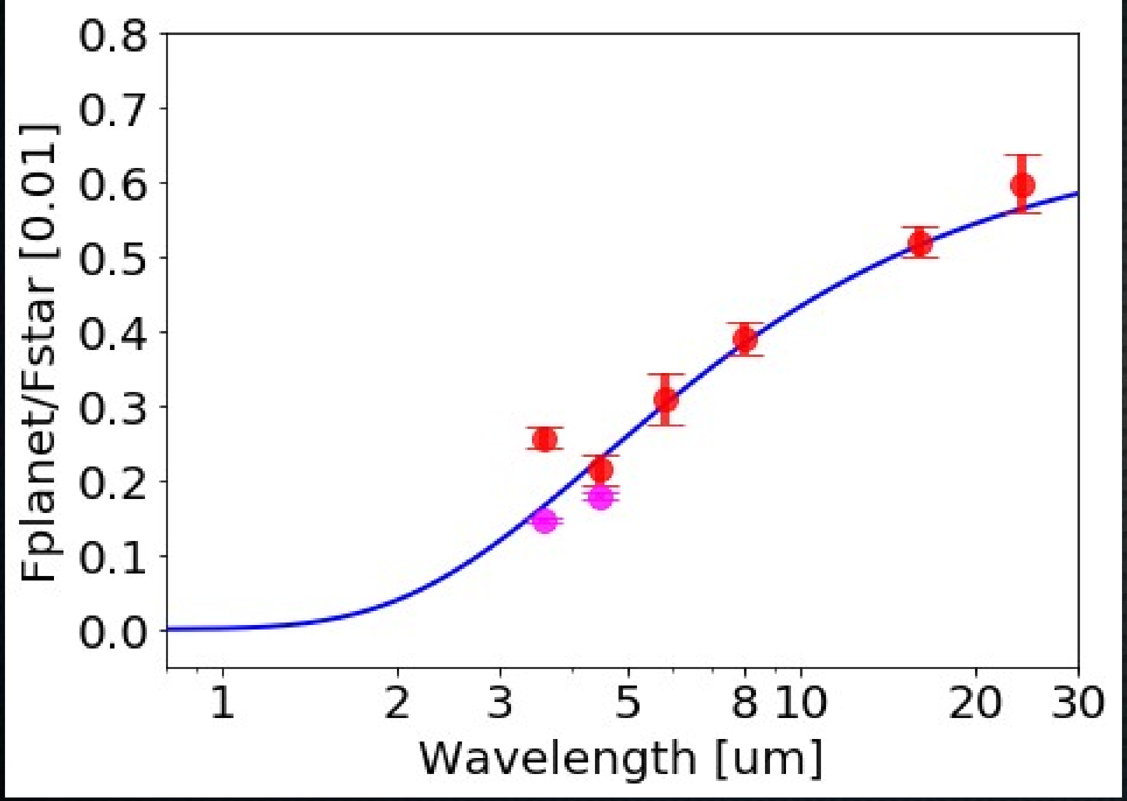
Example: Eclipse observations of HD189733 b

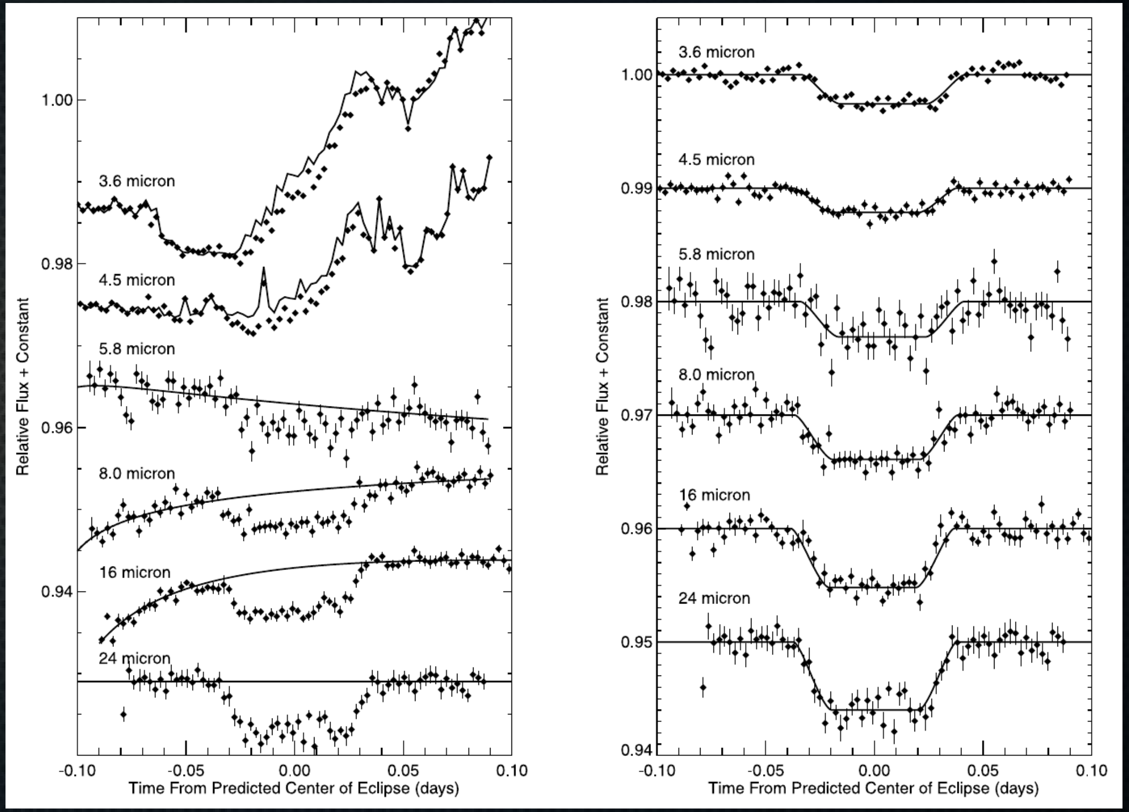




Charbonneau et al 2008

Example: Eclipse observations of HD189733 b





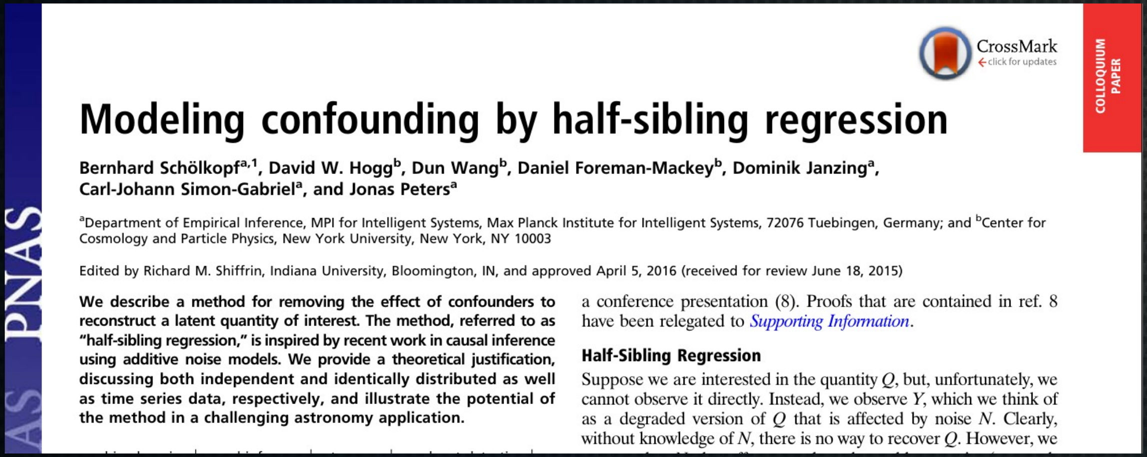
Charbonneau et al 2008 + Knudsen et al 2012

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



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COLLOQUIUM PAPER

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Modeling confounding by half-sibling regression

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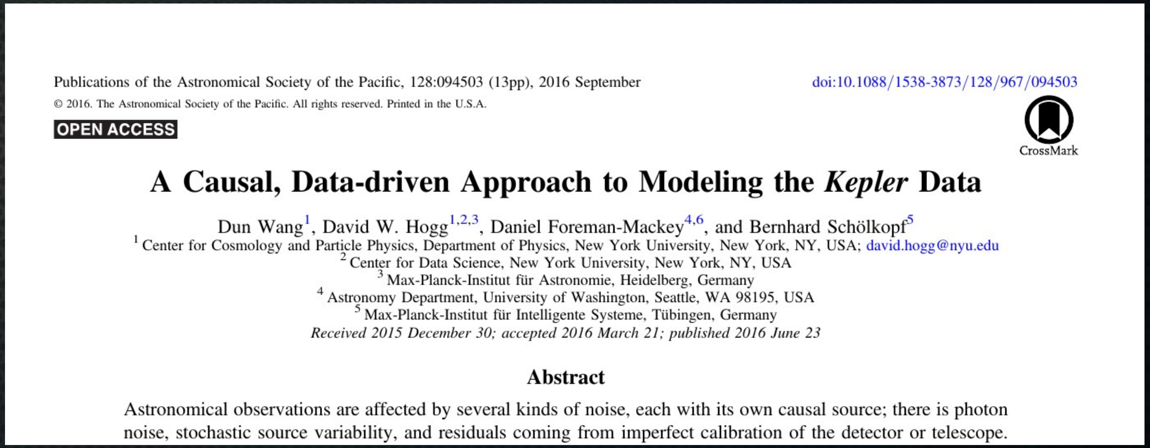
Edited by Richard M. Shiffrin, Indiana University, Bloomington, IN, and approved April 5, 2016 (received for review June 18, 2015)

We describe a method for removing the effect of confounders to reconstruct a latent quantity of interest. The method, referred to as "half-sibling regression," is inspired by recent work in causal inference using additive noise models. We provide a theoretical justification, discussing both independent and identically distributed as well as time series data, respectively, and illustrate the potential of the method in a challenging astronomy application.

a conference presentation (8). Proofs that are contained in ref. 8 have been relegated to *Supporting Information*.

Half-Sibling Regression

Suppose we are interested in the quantity *Q*, but, unfortunately, we cannot observe it directly. Instead, we observe *Y*, which we think of as a degraded version of *Q* that is affected by noise *N*. Clearly, without knowledge of *N*, there is no way to recover *Q*. However, we



Publications of the Astronomical Society of the Pacific, 128:094503 (13pp), 2016 September
doi:10.1088/1538-3873/128/967/094503

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A Causal, Data-driven Approach to Modeling the *Kepler* Data

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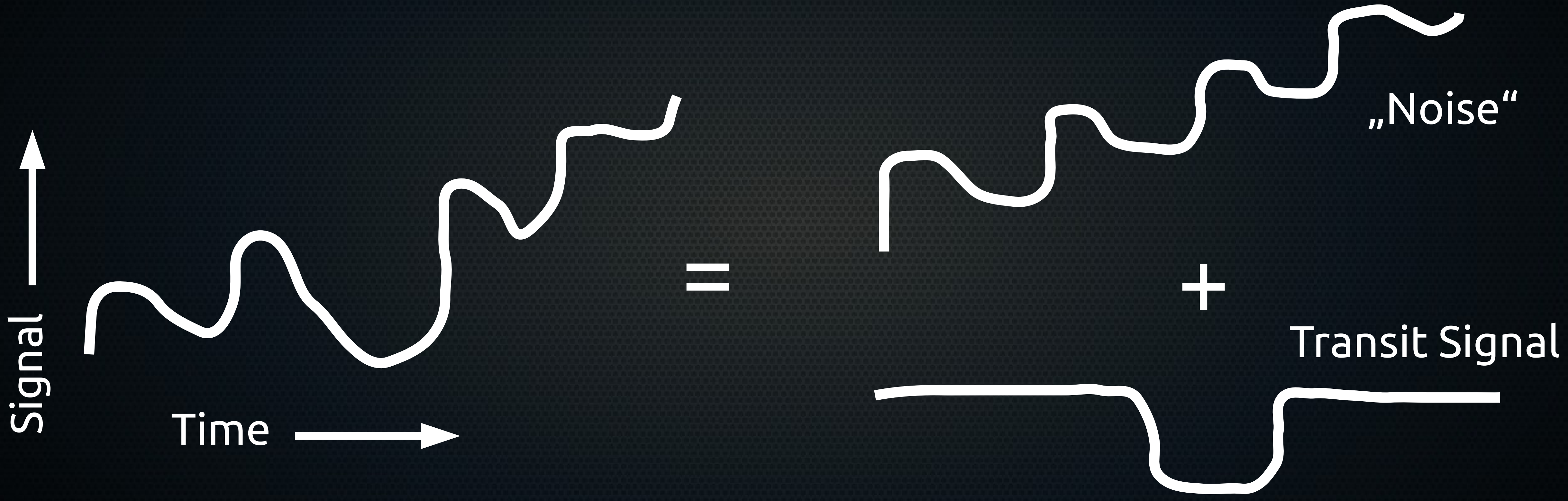
Abstract

Astronomical observations are affected by several kinds of noise, each with its own causal source; there is photon noise, stochastic source variability, and residuals coming from imperfect calibration of the detector or telescope.

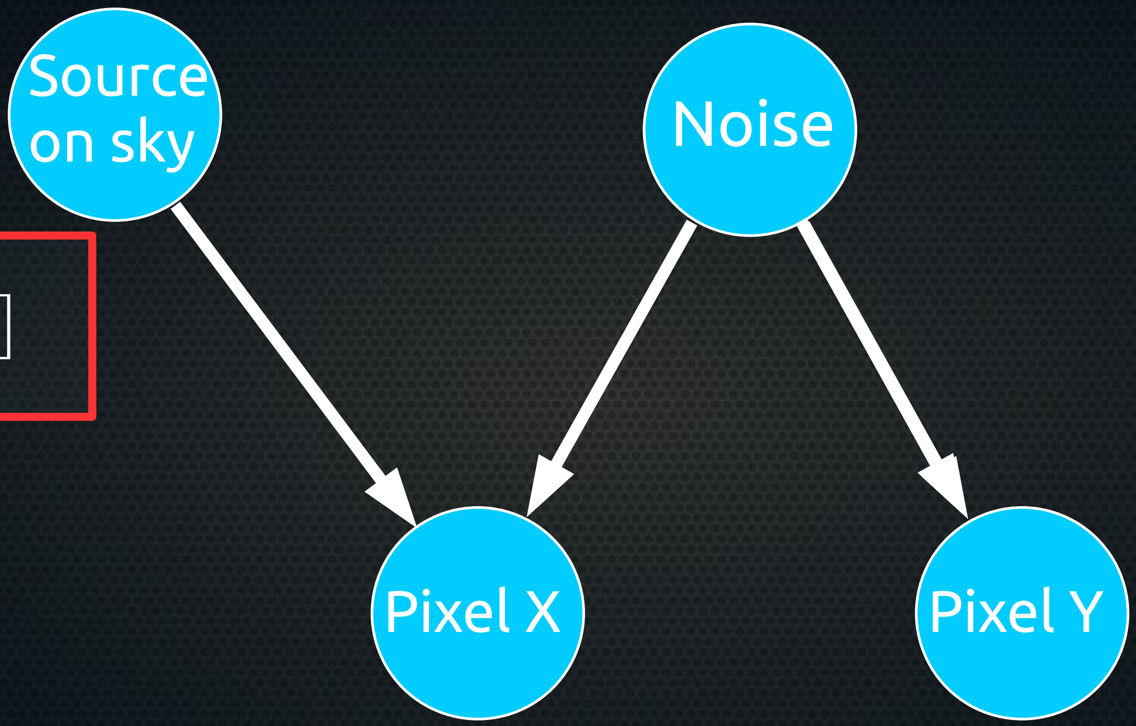
Look out for Sammland et al 2020 (submitted to A&A) for an aplication of this method to VLT/SPHERE observations.

Additive Noise Model



A Causal Noise Model

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



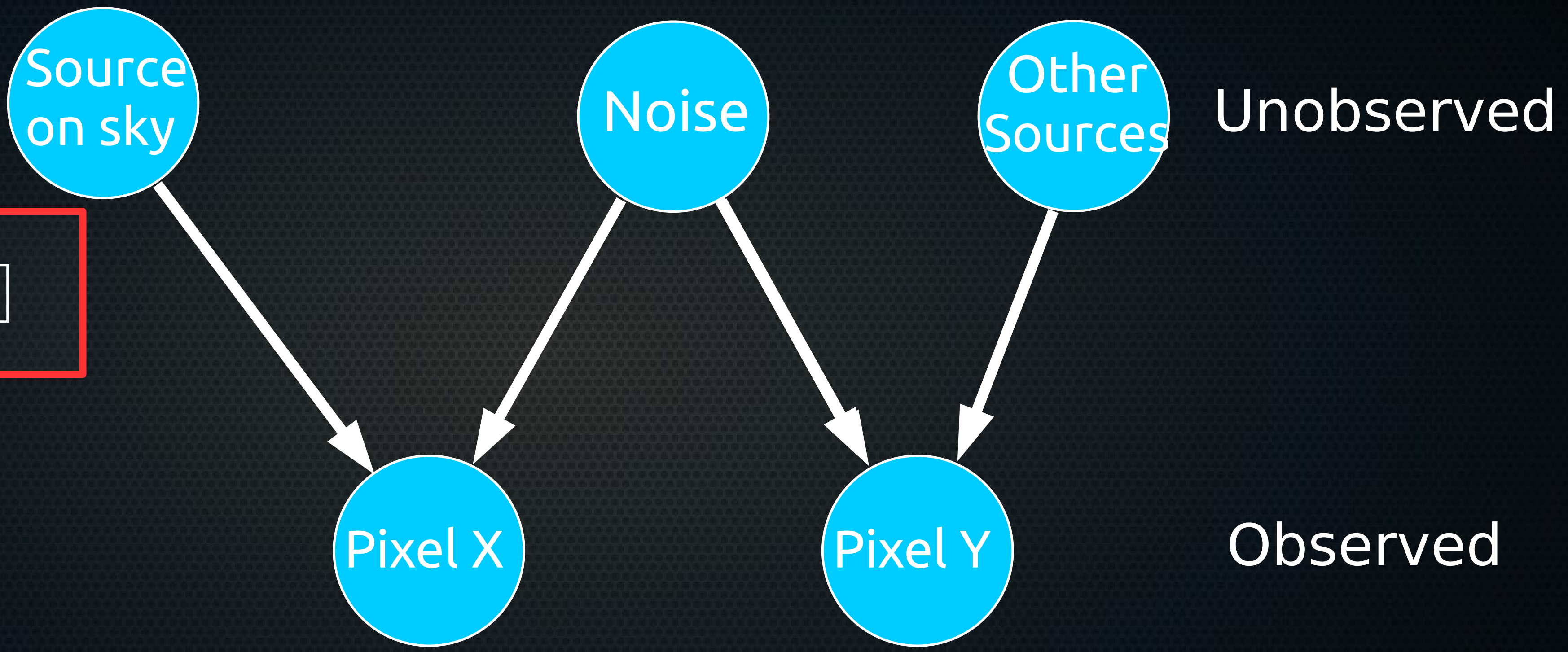
Unobserved

Observed

$$X(t) = I(t) + f(N, t) \qquad Y(t) = g(N, t)$$

A Causal Noise Model

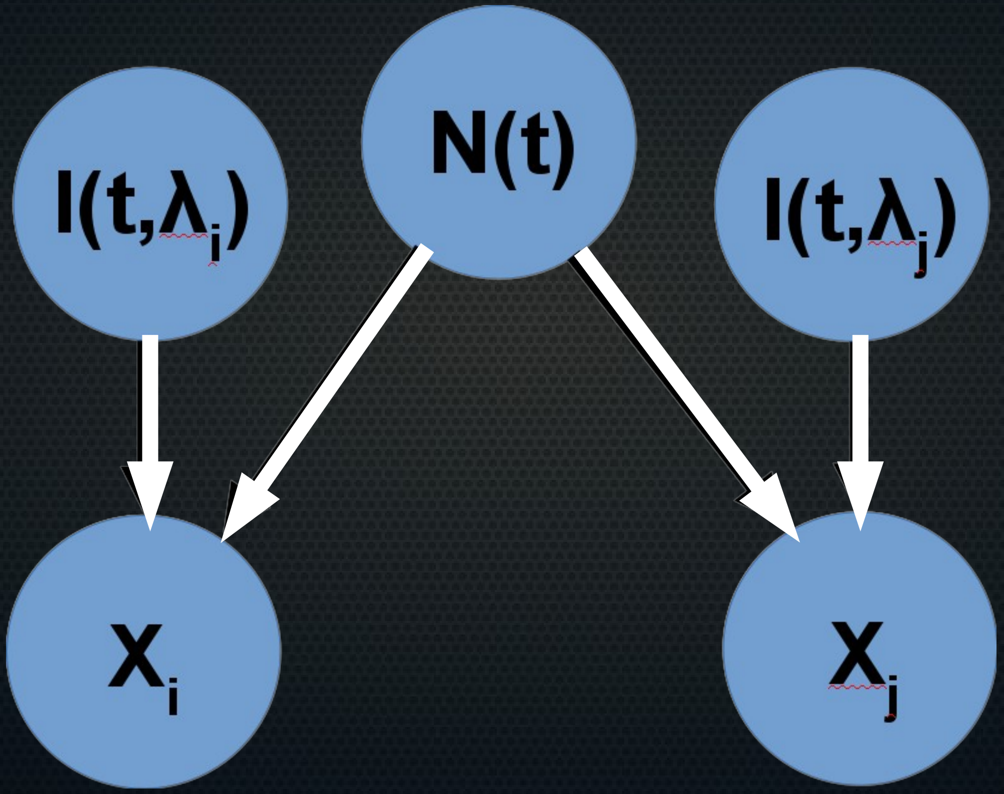
$$\hat{I} = X - E[X|Y]$$



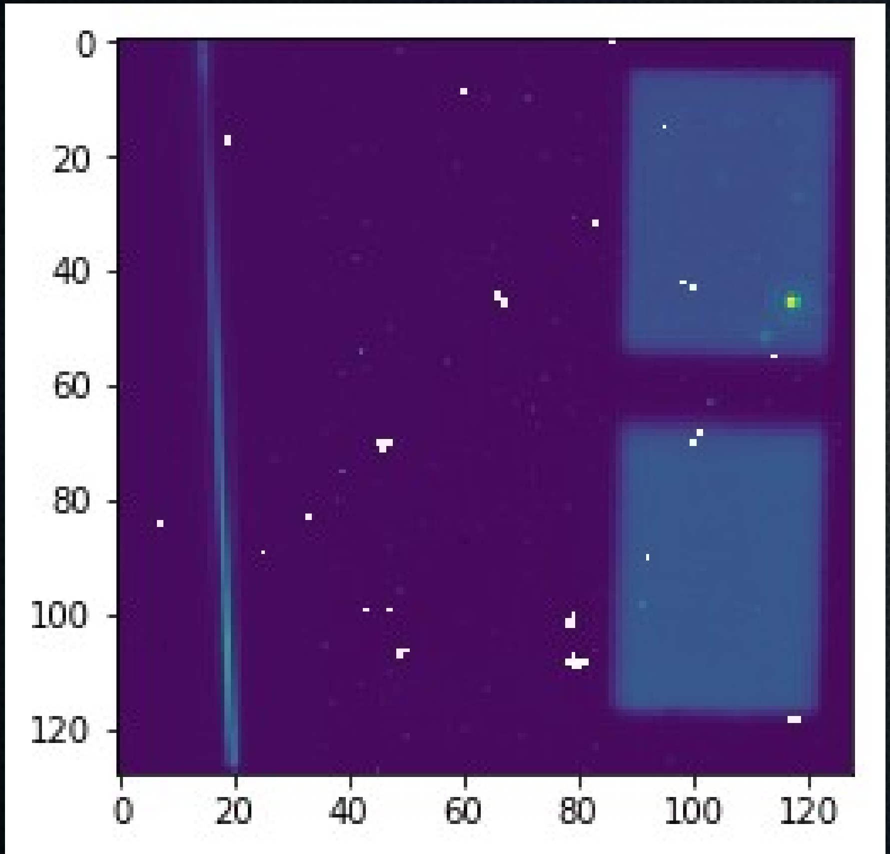
$$X(t) = I(t) + f(N, t) \qquad Y(t) = R(t) + g(N, t)$$

CASCADe :

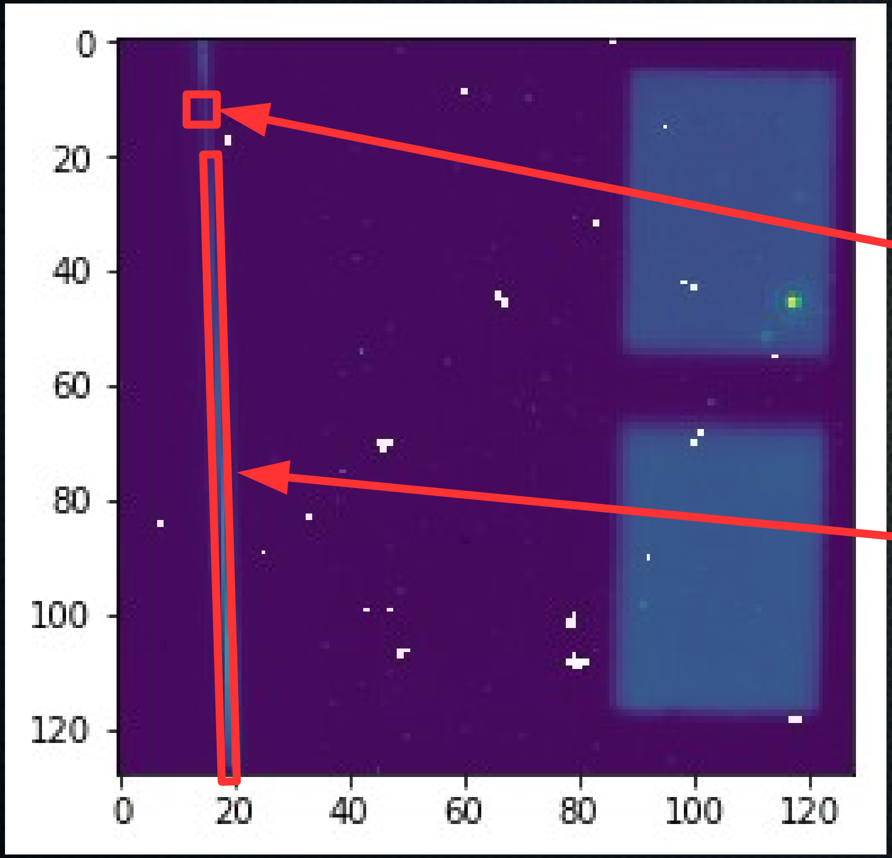
Calibration of trAnsit Spectroscopy using CAusal Data



Using CASCADe on Spitzer data



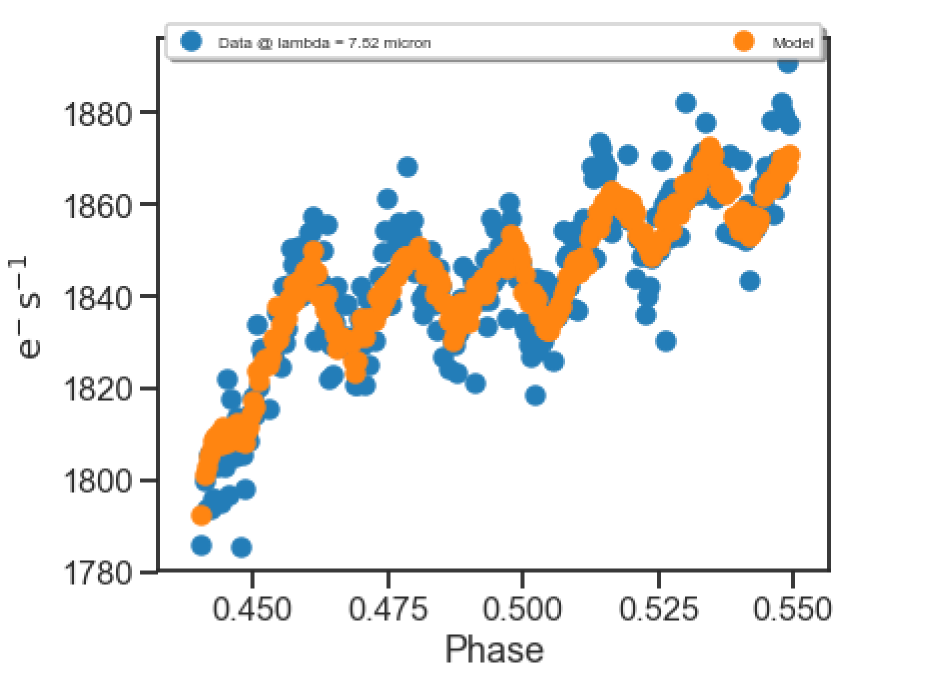
Using CASCADe on Spectroscopic Data

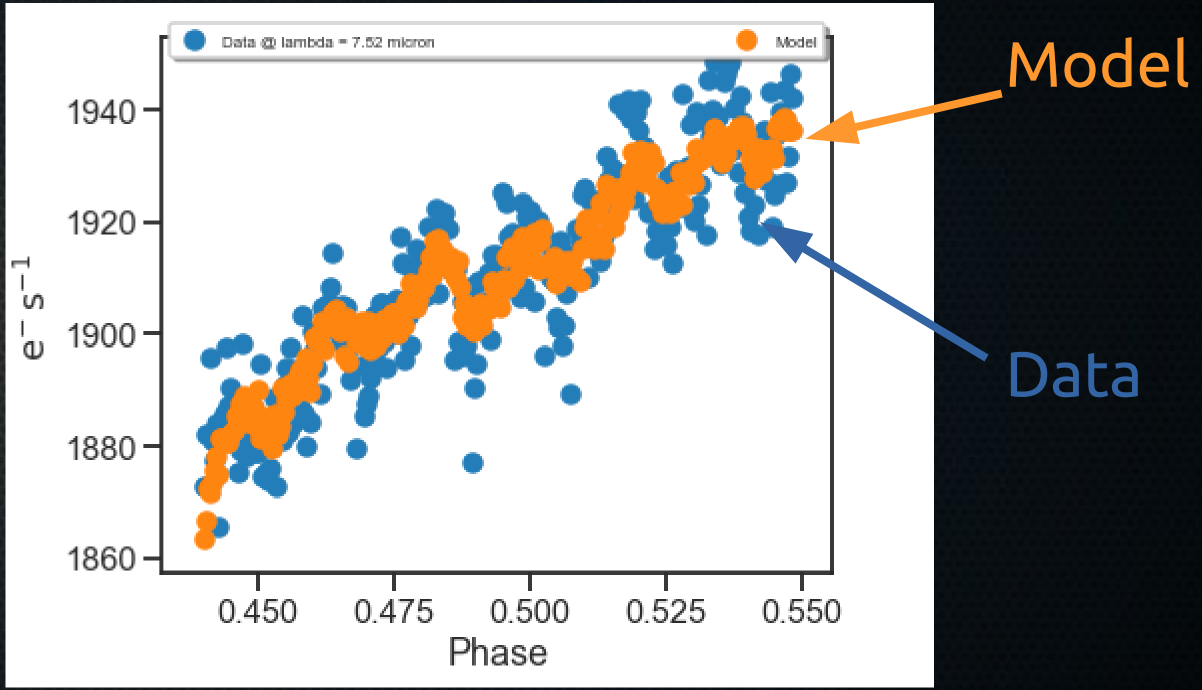


Pixel from which the signal is extracted

Pixels used to construct regression model

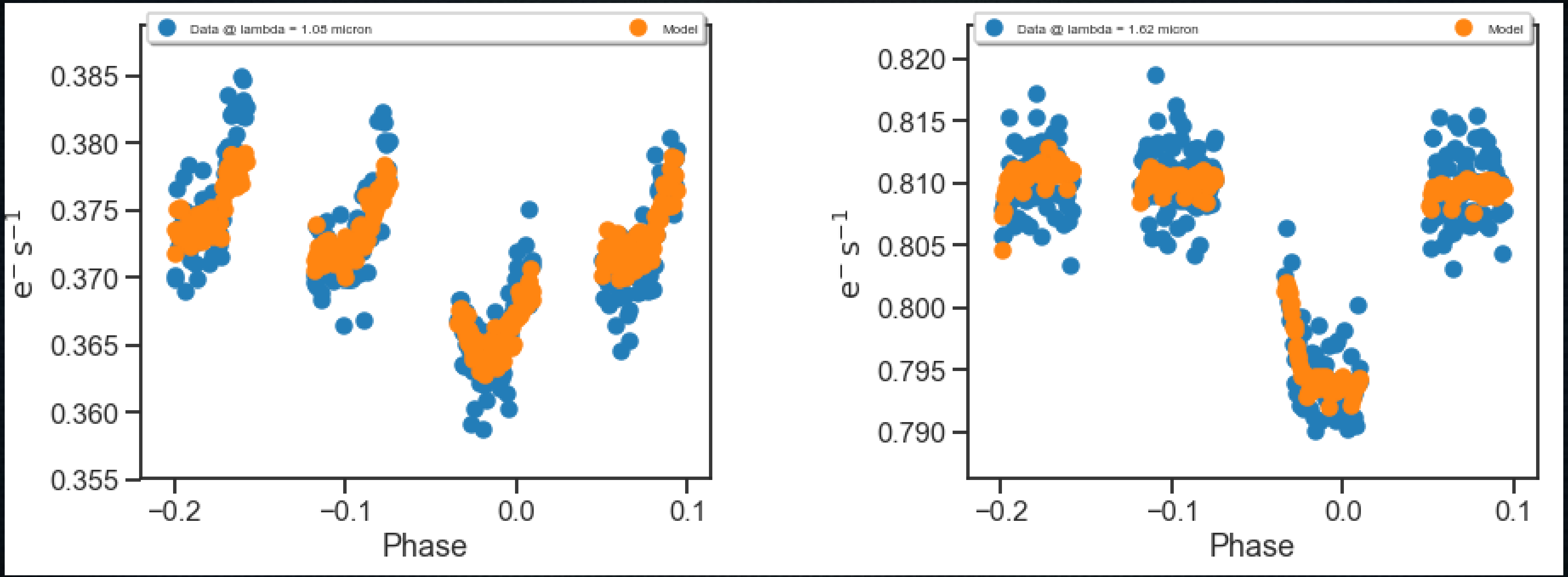
A Causal Noise Model of HD189733 b Eclipses with Spitzer





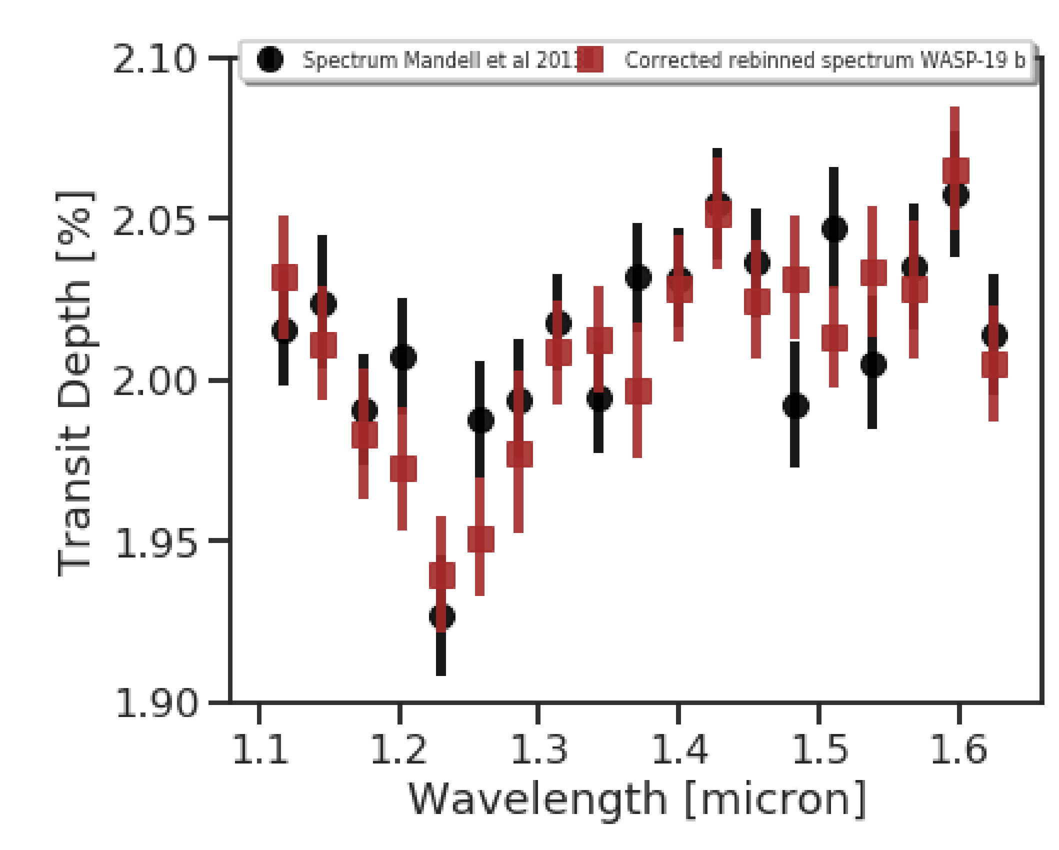
Same wavelength, two different Eclipse Observations

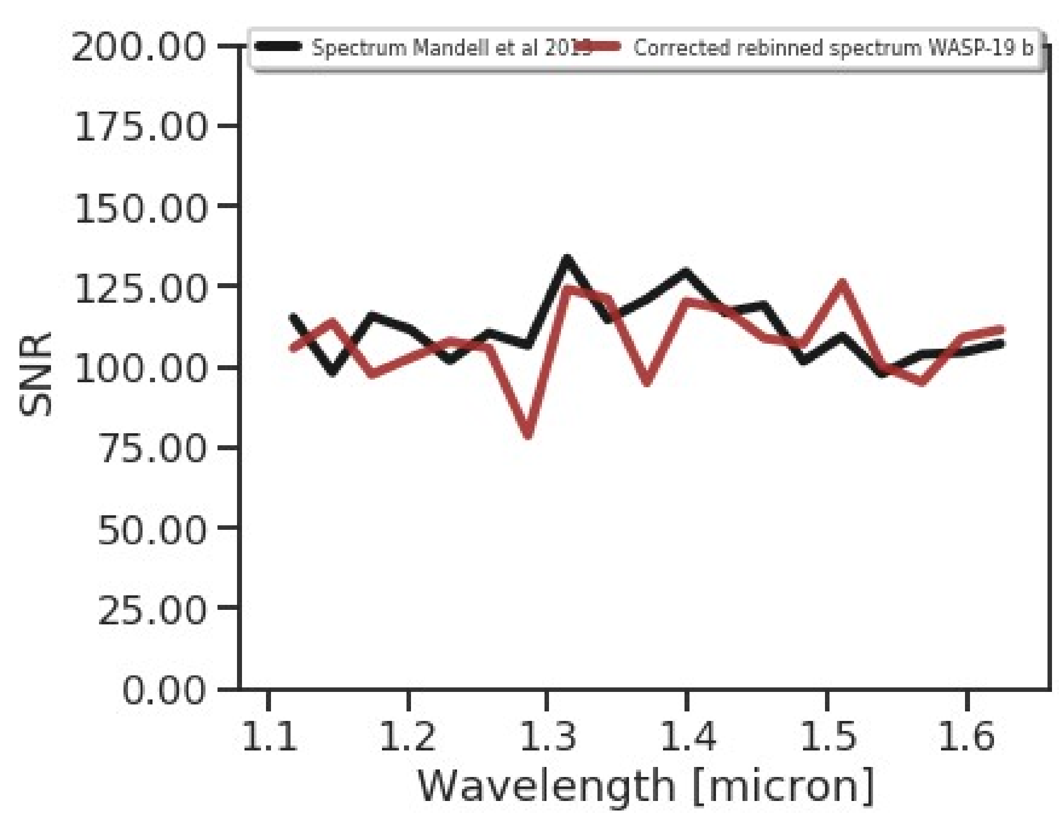
A Causal Noise Model of a WASP 19 b Transit with HST



Same Transit Observation, different wavelengths

WASP 19 b „final" transit spectrum





See also Mandell et al 2013

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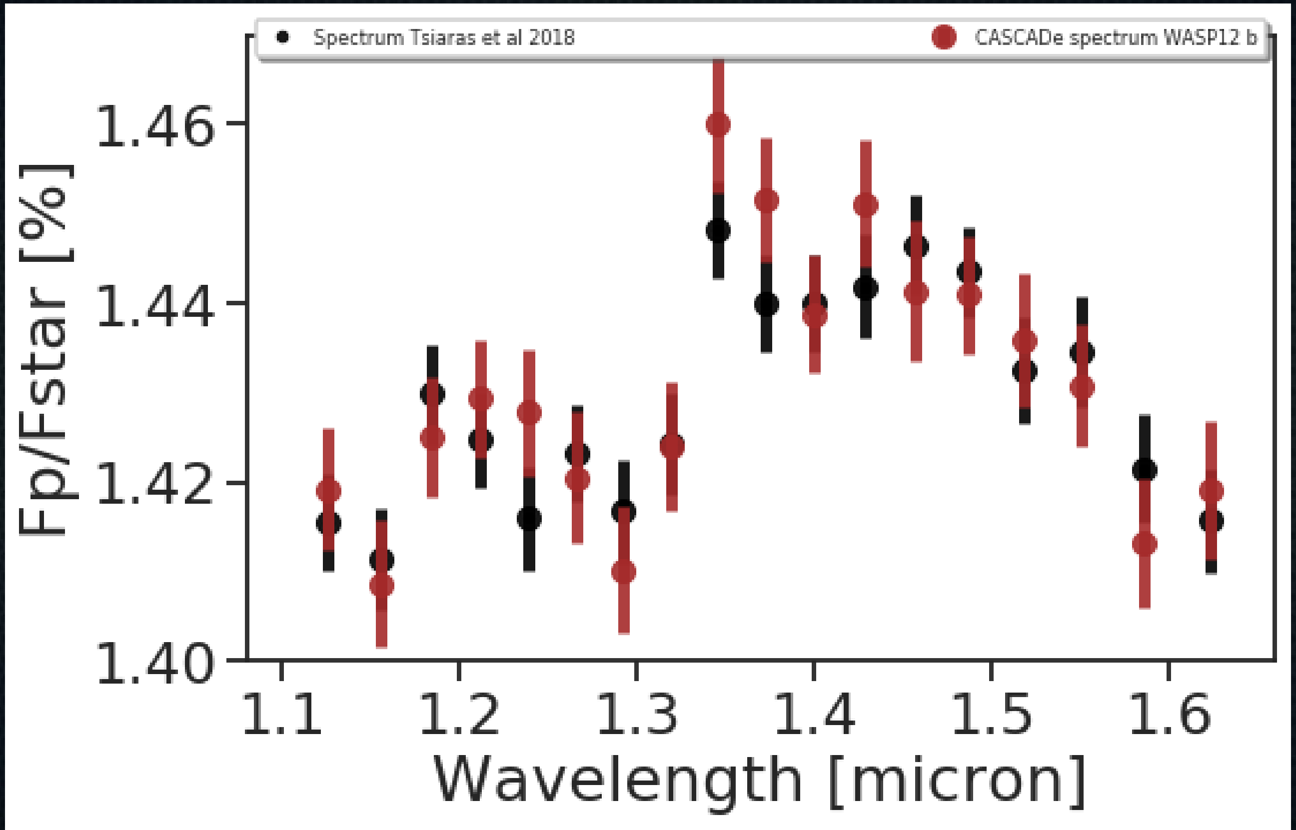
WASP 12 b „final“ Transit Spectrum



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.