ExoSim2

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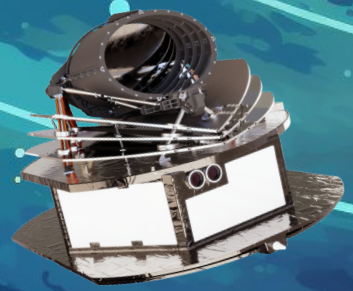

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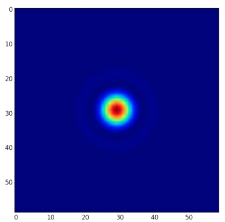
Why do we need an end-to-end time-domain simulator?

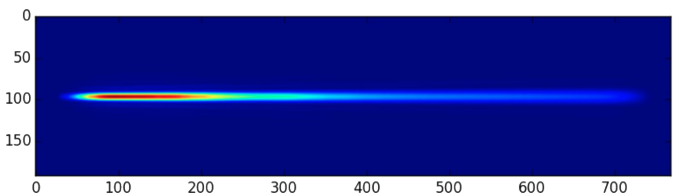
- To prepare the data reduction pipeline
- To assess the impact of known instrumental and astrophysical systematics on the final measurements
- To develop different methods for the scientific interpretation of measurements

ExoSim

https://github.com/ExoSim/ExoSimPublic

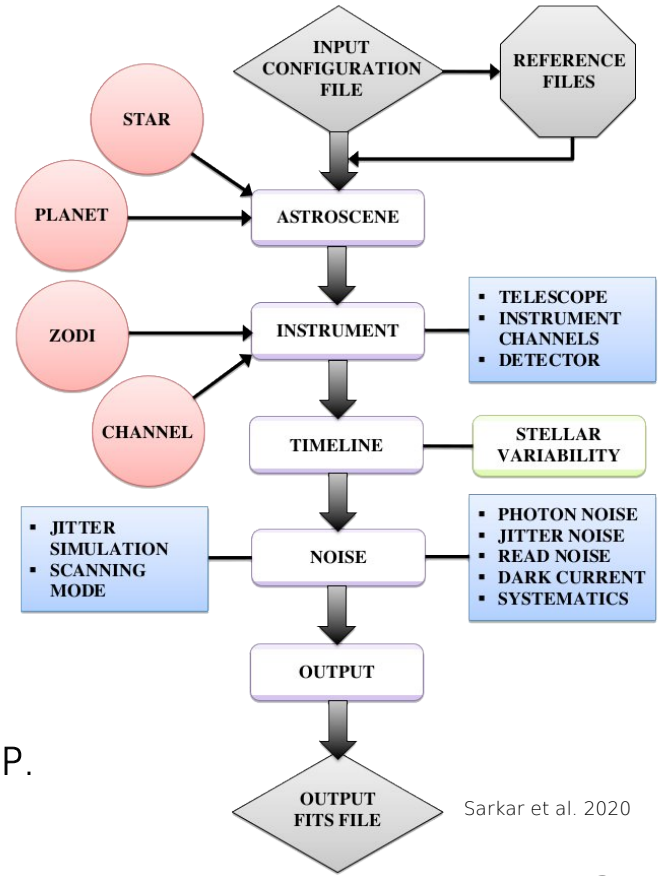
End-to-end time domain simulator for transiting exoplanet observations.





Already validated and used for

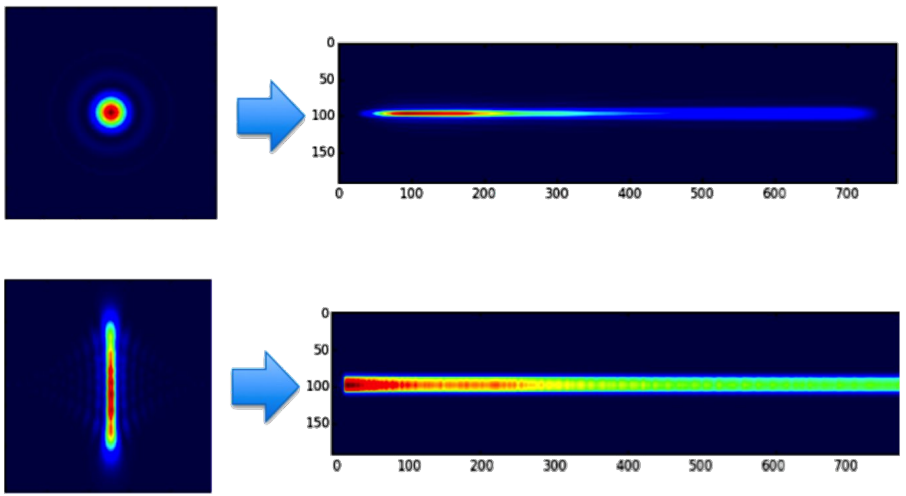
- HST
- Ariel
- JWST (*Jexosim*, Sarkar et al 2019, 2020)



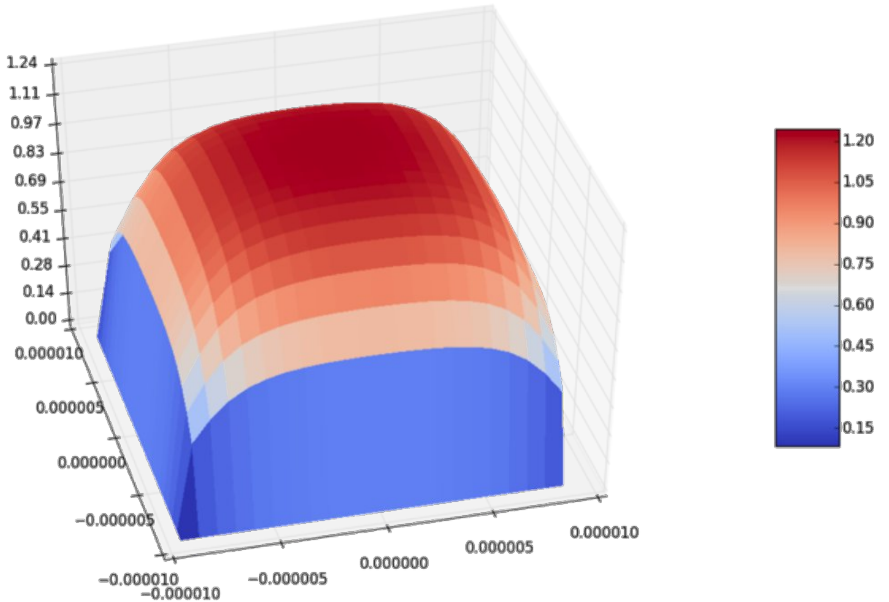
Sarkar et al. 2020

It requires a data reduction pipeline to analyse the data: AdaRP.

Details are important for Realistic simulations



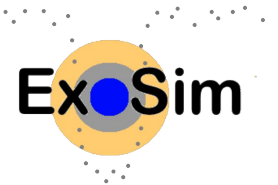
Spectral images in ExoSim, produced from the co-addition of 2-D PSFs..



2-D pixel response function used to simulate intra-pixel variation in responsivity.

Why ExoSim2?

- ExoSim was developed for Python 2.7 (lot of deprecated packages), difficult to install and use (no documentation), hard to maintain, customize and add new features (need to hack the code)



- We need a simulator that can
  - Grow with the Ariel mission
  - Be maintained in a 10 years time scale
  - Allow the user to add new functionalities

The code

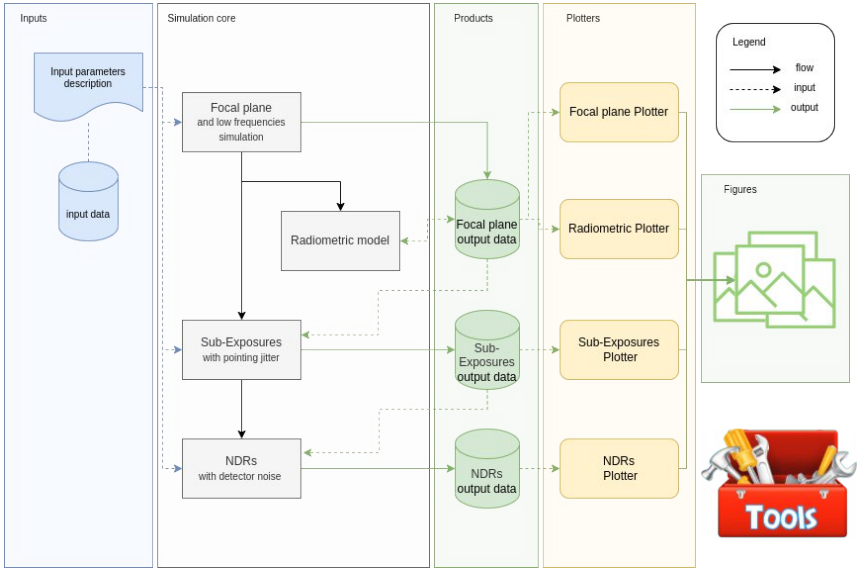
This refactored version is

- easier to use than its predecessor
- largely customizable
- completely written in Python
- tested against Python 3.9+ (`"hello future!"`),
- follows the object-oriented philosophy.
- fast (~3 min for a 10h simulated observation… on 40 cores)

It comes with

- an installer
- documented examples
- a comprehensive guide

and **almost every part of the code can be replaced by a user-defined function**, which allows the user to include new functionalities to the simulator



Stats

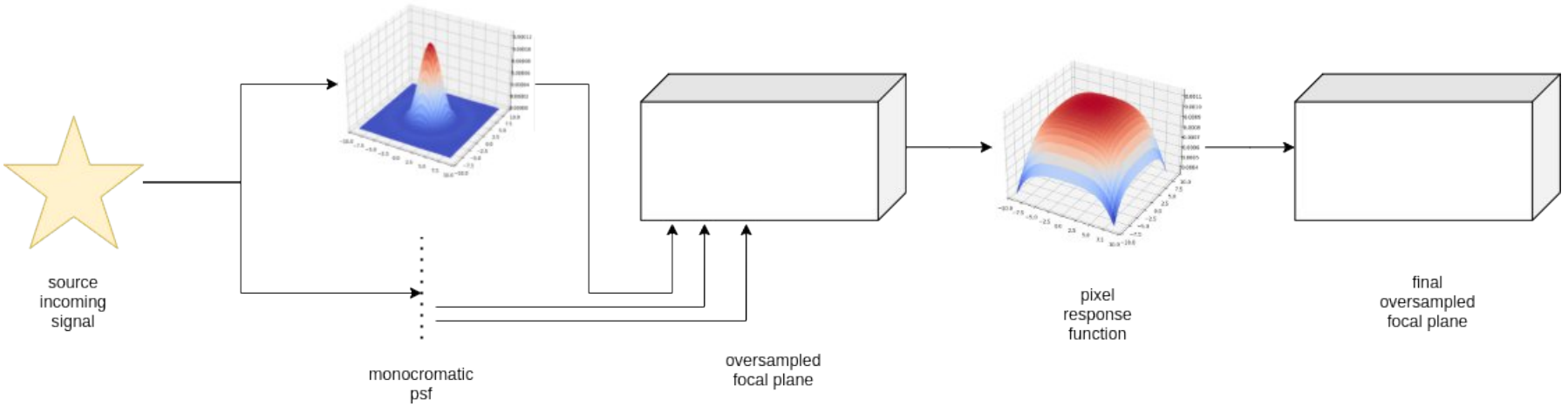
29,518 Python lines

12,760 lines → (>250 PDF pages)

94% code tested

`pip install exosim`

Populate focal plane



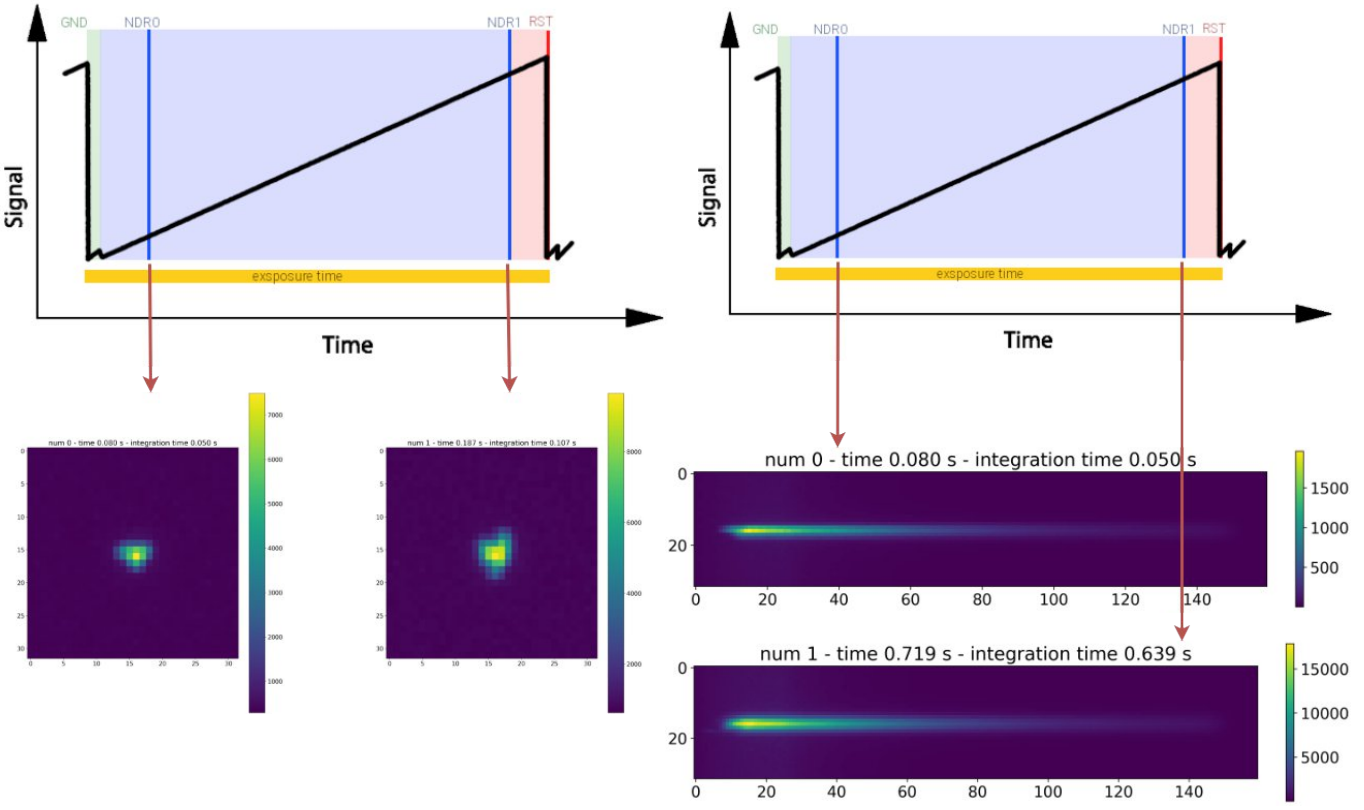
The focal plane is built considering

- The wavelength and time dependent efficiency
- The wavelength and time dependent signals from the sources
- The wavelength and time dependent PSFs
- The intra-pixel response function

Sampling the ramp with Sub-Exposures

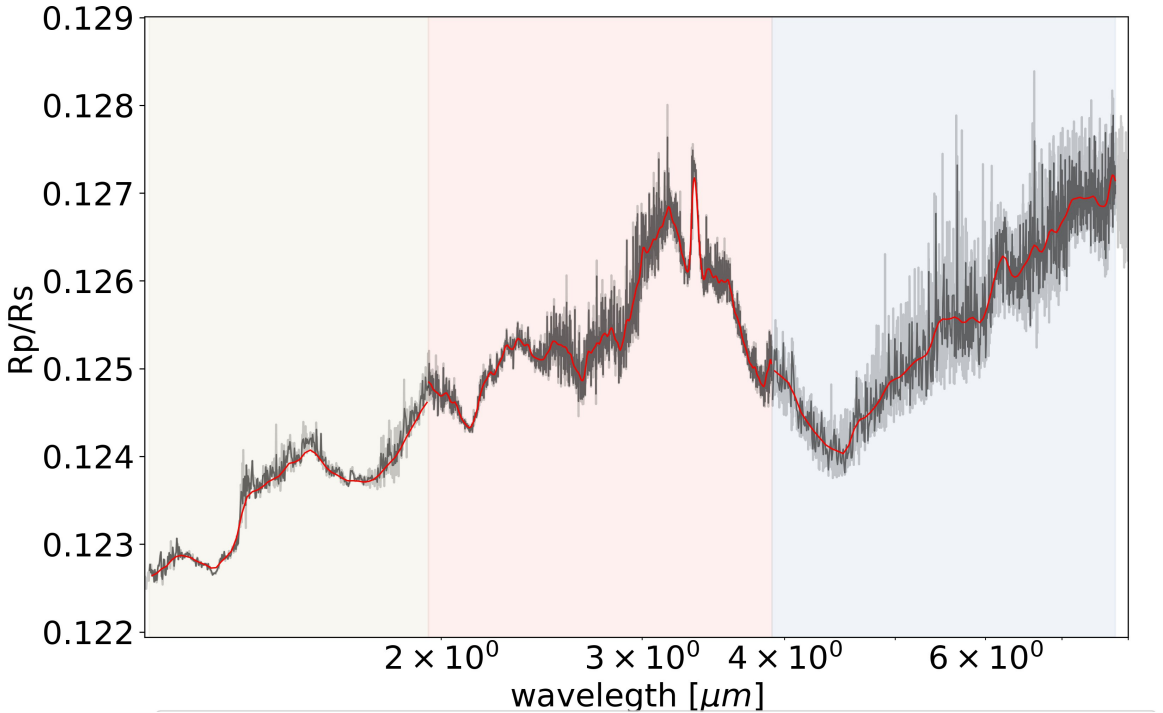
ExoSim2 includes a module for the ramp sampling.

Here, given the static focal planes, we can introduce the high frequency time effects, as the pointing jitter or astronomical signal.

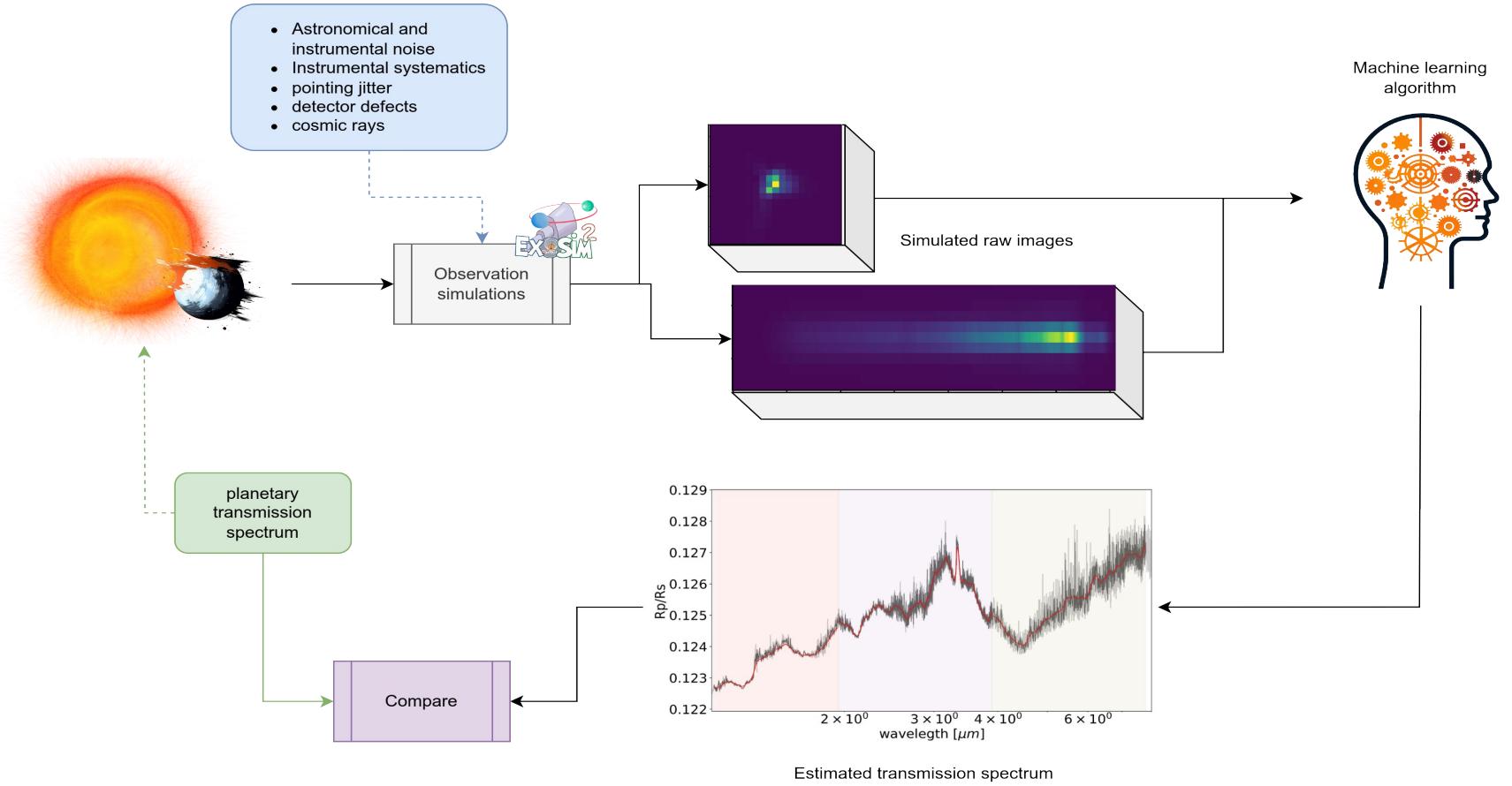


Astronomical signal

Time and wavelength dependent astronomical signals (as transit light curves) can be injected in ExoSim and will be convolved with the instrument line shape.



Data challenge 2024 and 2025



Take home messages

- ExoSim 2 is a platform: it does not simulate the physics but it applies the injected models. Every model must be tested before use.
    - Pointing Jitter simulations for Ariel;
    - Altitude variation (atmosphere, LoS etc.) for EXCITE;
    - Detector effects (linearity, persistence, dark current, etc.)

•ExoSim 2 is as correct and accurate as the input models are: you can simulate any instrument, as long as your input models are correct and representative.

- Example of use case. ExoSim can be used to test a JWST pipeline by injecting the noise models into ExoSim as external functions and comparing the results against the real data.

Thank you