PREPARING EXOPLANET TRANSIT SPECTROSCOPY OBSERVATIONS WITH JAMES WEBB SPACE TELESCOPE

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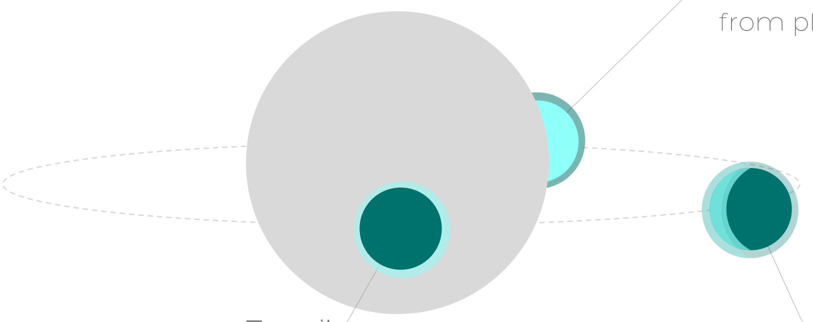
CONTEXT



EXOPLANETS' ATMOSPHERE

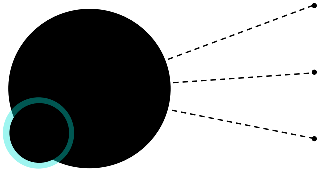
- Learn about the nature and diversity of exoplanets
- Understand the physics and chemistry at work
  (not present in the solar system / early solar system)
- Constraint planet formation (metallicity, C/O)
- Ultimately search for bio-signatures (eg. O_3)

Molecule	$\Delta\nu = 2B_0$ cm^{-1}	λ (S_{max}) 2–5 µm	S_{max} cm^{-2} am^{-1}	R 2–5 µm	λ (S_{max}) 5–16 µm	S_{max} cm^{-2} am^{-1}	R 5–16 µm
H_2O	29.0	2.69 (ν_1, ν_3)	200	130	6.27 (ν_2)	250	55
HDO	18.2	3.67 ($\nu_1, 2\nu_2$)	270	150	7.13 (ν_2)		77
CH_4	10.0	3.31 (ν_3)	300	300	7.66 (ν_4)	140	130
CH_3D	7.8	4.54 (ν_2)	25	280	8.66 (ν_6)	119	150
NH_3	20.0	2.90 (ν_3)	13	170	10.33	600	50
		3.00 (ν_1)	20		10.72 (ν_2)		
PH_3	8.9	4.30 (ν_1, ν_3)	520	260	8.94 (ν_4)	102	126
					10.08 (ν_2)	82	110
CO	3.8	4.67 (1-0)	241	565			
CO_2	1.6	4.25 (ν_1)	4100	1470	14.99 (ν_2)	220	420
HCN	3.0	3.02 (ν_3)	240	1100	14.04 (ν_2)	204	240
C_2H_2	2.3	3.03 (ν_3)	105	1435	13.7 (ν_5)	582	320
C_2H_6	1.3	3.35 (ν_7)	538	2300	12.16 (ν_{12})	36	635
O_3	0.9				9.60 (ν_3)	348	1160

Table 5 Main molecular signatures and constraints on the spectral resolving power. $\Delta\nu$ is the spectral interval between two adjacent J-components of a band. S_{max} is the intensity of the strongest band available in the spectral interval. R is the spectral resolving power required to separate two adjacent J-components

Tinetti et al. AAR 2013

TRANSIT SPECTROSCOPY

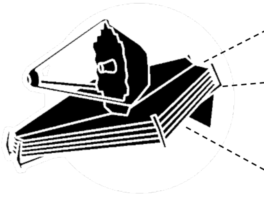


- Planet crossing the line of sight
- Tracking of the system spectrum changes over time
- Planet's atmosphere features accessible

Emission | Absorption | Albedo

CONTEXT

THE JAMES WEBB SPACE TELESCOPE



- Launch mid-2021
- 4 instruments (0.5 - 28μm)

  NIRISS | NIRCAM | NIRSPEC | MIRI
- Precision needed up to 10 ppm of signal

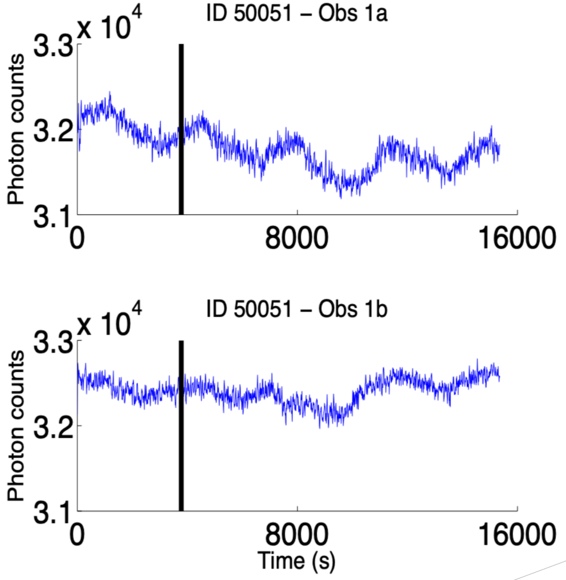
  relative spectro-photometric precision needed over about 10 hours

PREPARATION FOR DATA RETRIEVAL

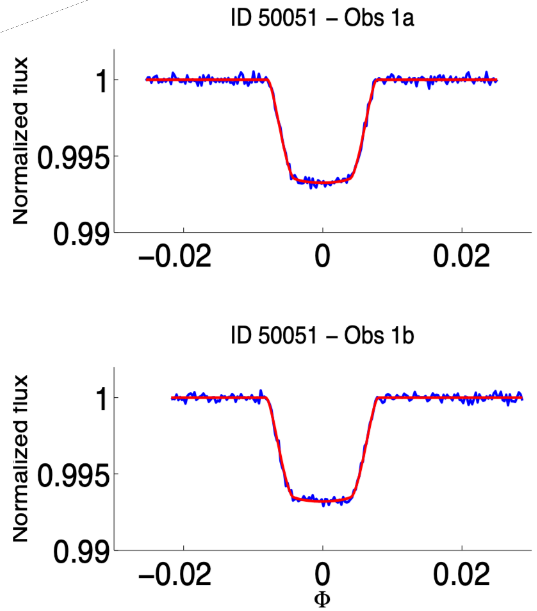
- Challenging measures
- Need new methods and preparation
- Need tests and challenges

SYNTHETIC DATA !

EXOPLANETS-A



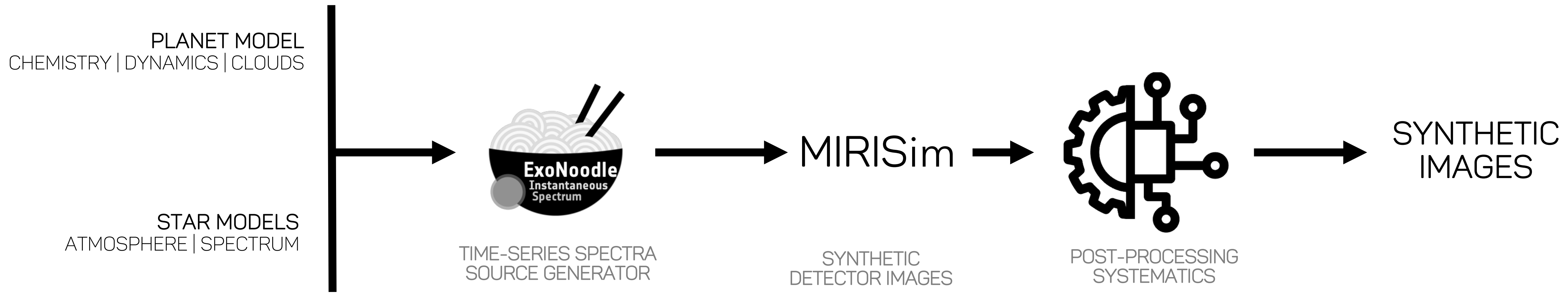
RAW LIGHTCURVES



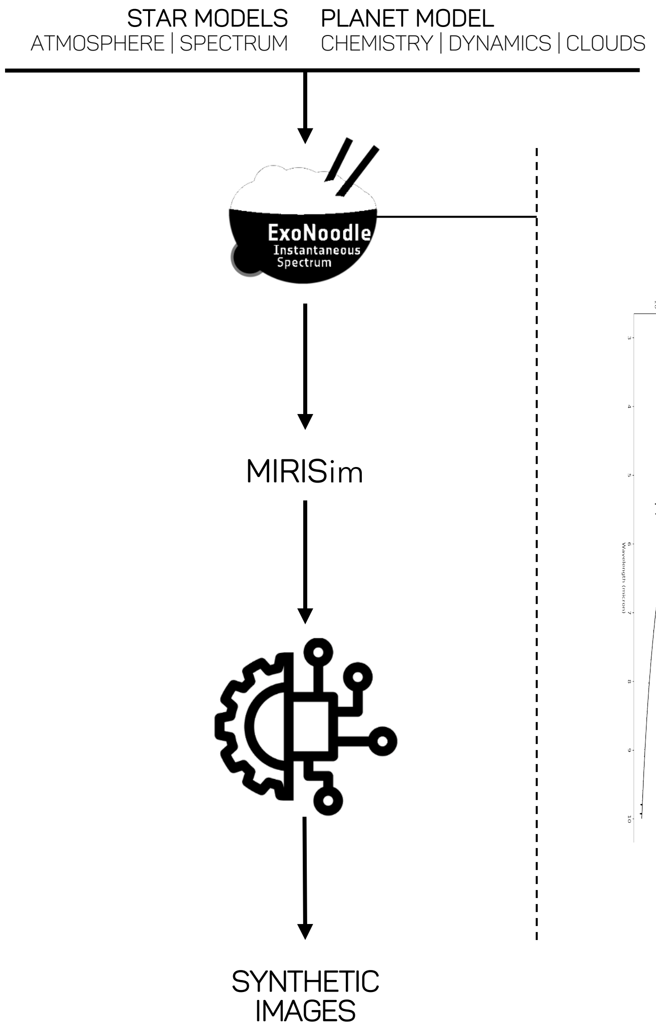
DETRENDED LIGHTCURVES + MODELS

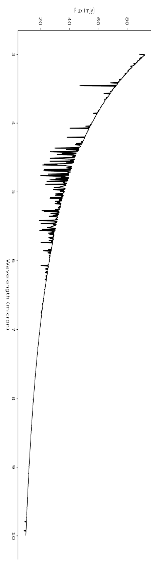
Morello et al. 2015

METHOD

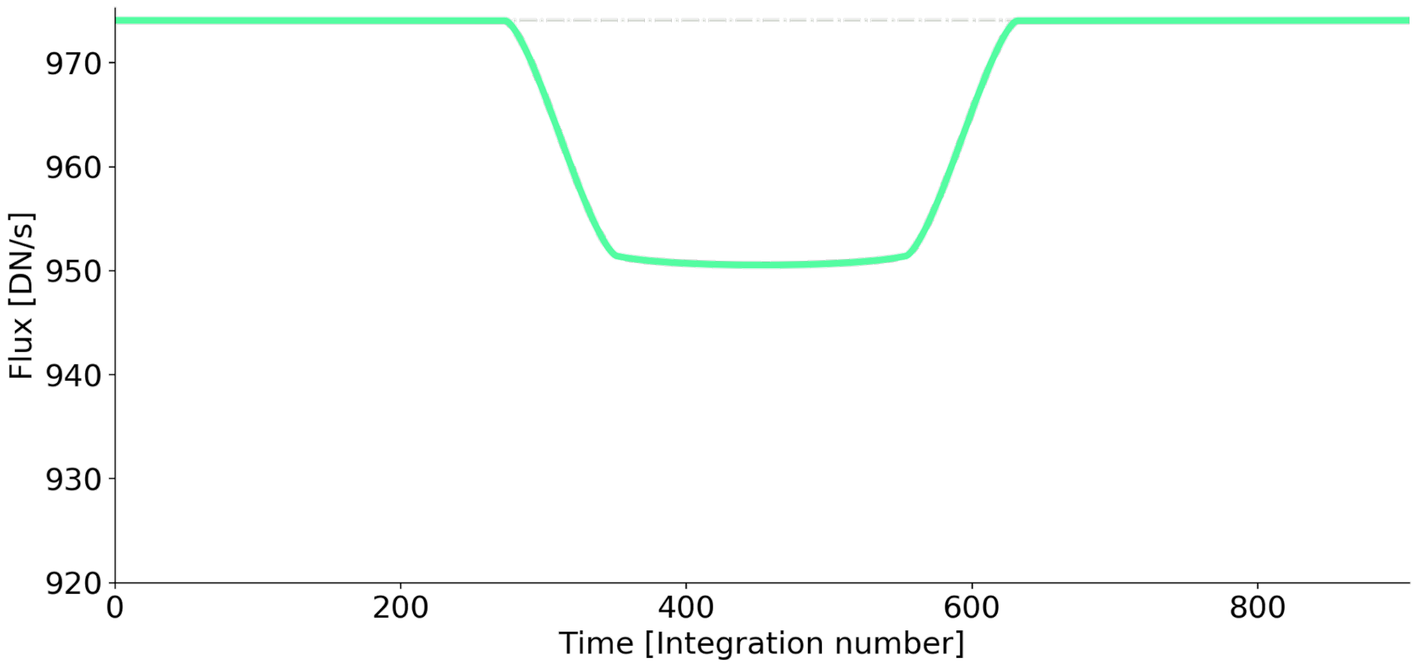

PLANET MODEL
CHEMISTRY | DYNAMICS | CLOUDS
STAR MODELS
ATMOSPHERE | SPECTRUM
ExoNoodle
Instantaneous
Spectrum
TIME-SERIES SPECTRA
SOURCE GENERATOR
MIRISim
SYNTHETIC
DETECTOR IMAGES
POST-PROCESSING
SYSTEMATICS
SYNTHETIC
IMAGES

METHOD

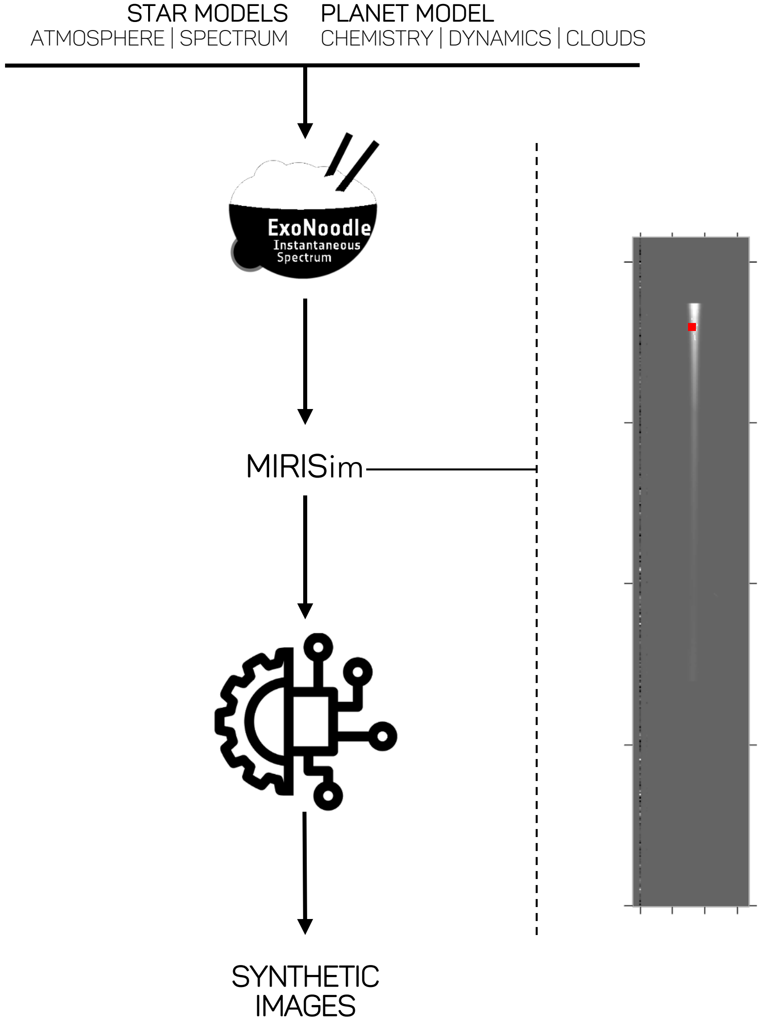




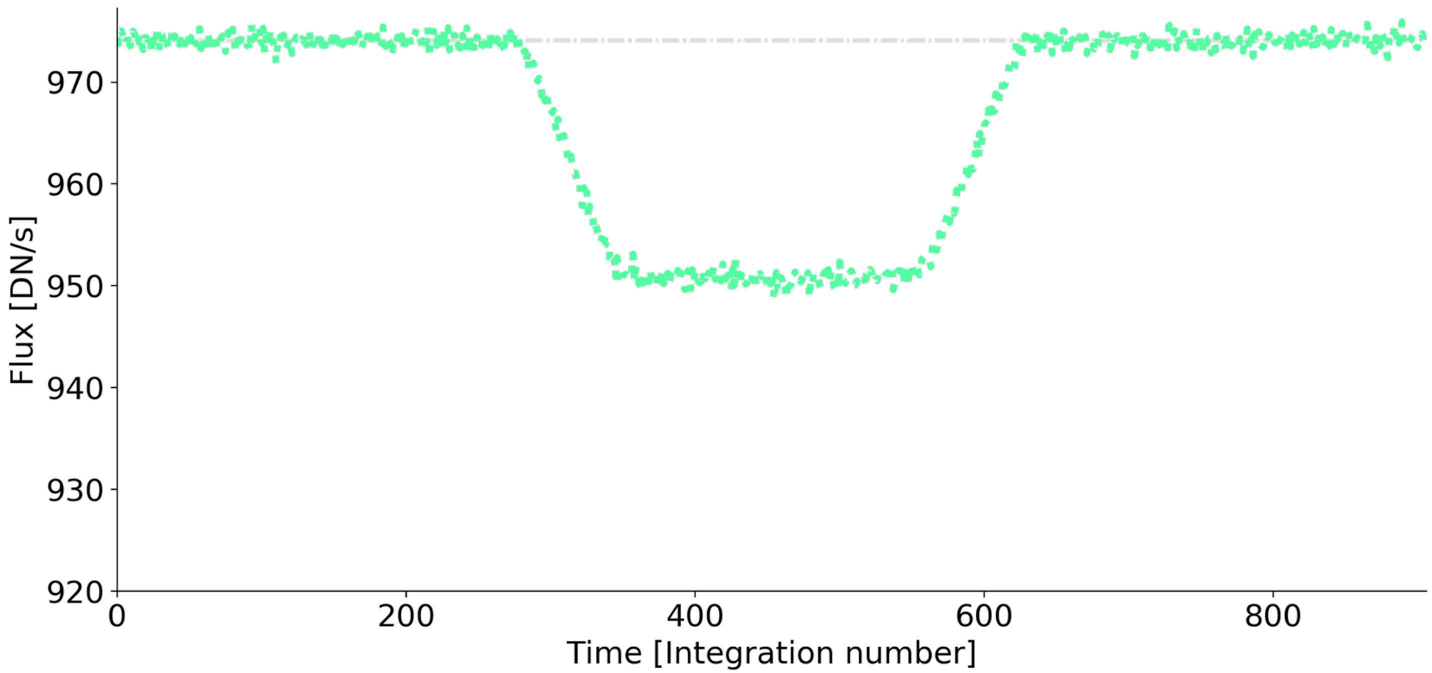
TIME-SERIES SPECTRA SOURCE GENERATOR



METHOD



SYNTHETIC DETECTOR IMAGES



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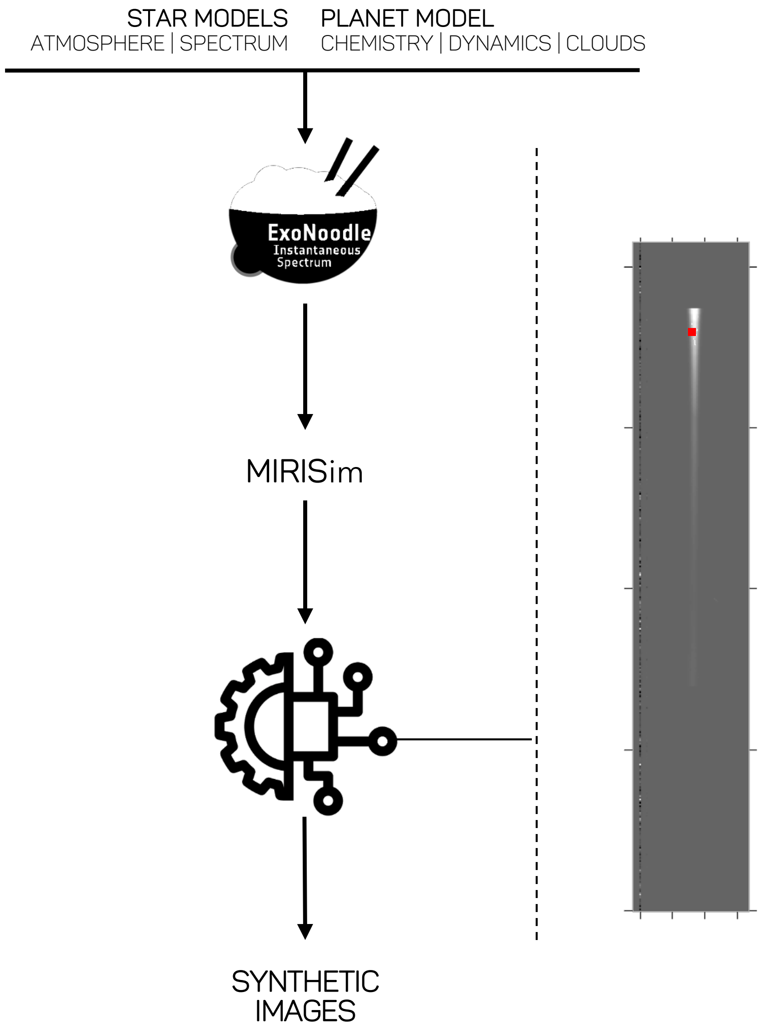
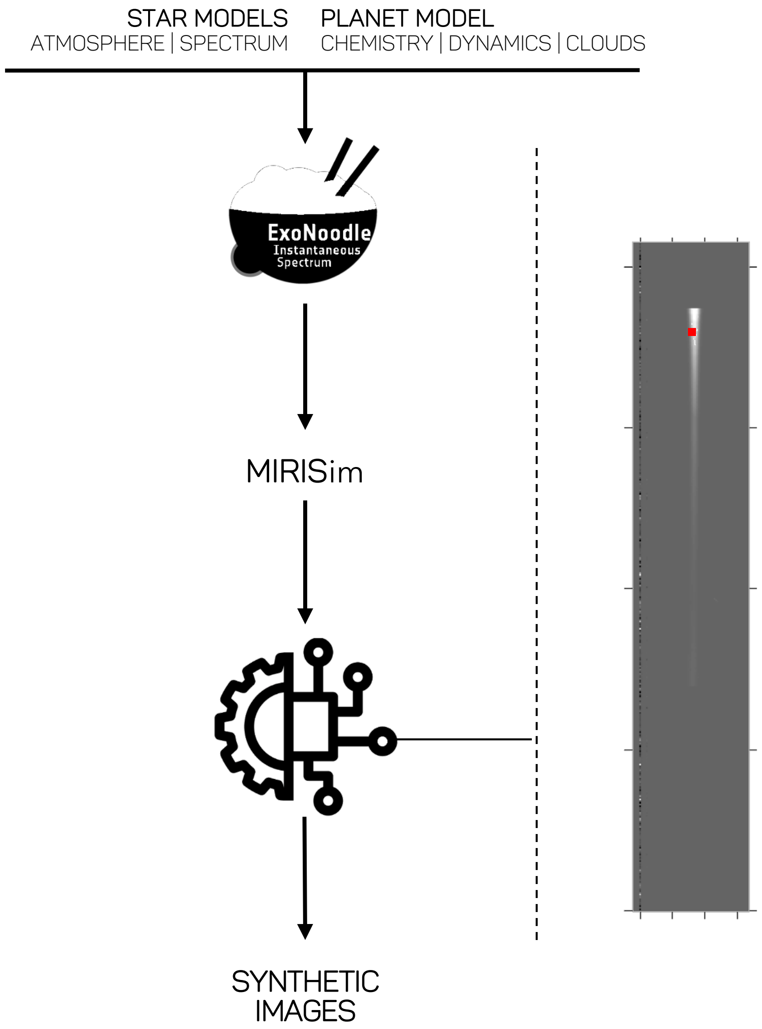


POST-PROCESSING IMAGES FOR SYSTEMATICS

From ground tests on MIRI detectors, we selected the systematic effects likely to be important for transit spectroscopy observations to include in MIRISim results as post-treatment:

Response Drift | Idle Recovery | Anneal Recovery

METHOD



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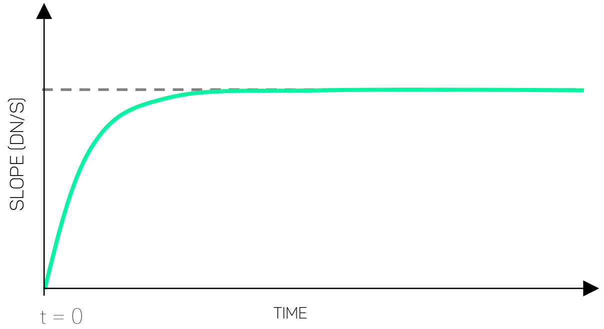
$$\dot{S}_{corrected}(t) = \dot{S}_0 + \left(a_1 \times e^{-\frac{t}{\alpha_1}} + a_2 \times e^{-\frac{t}{\alpha_2}}\right)$$



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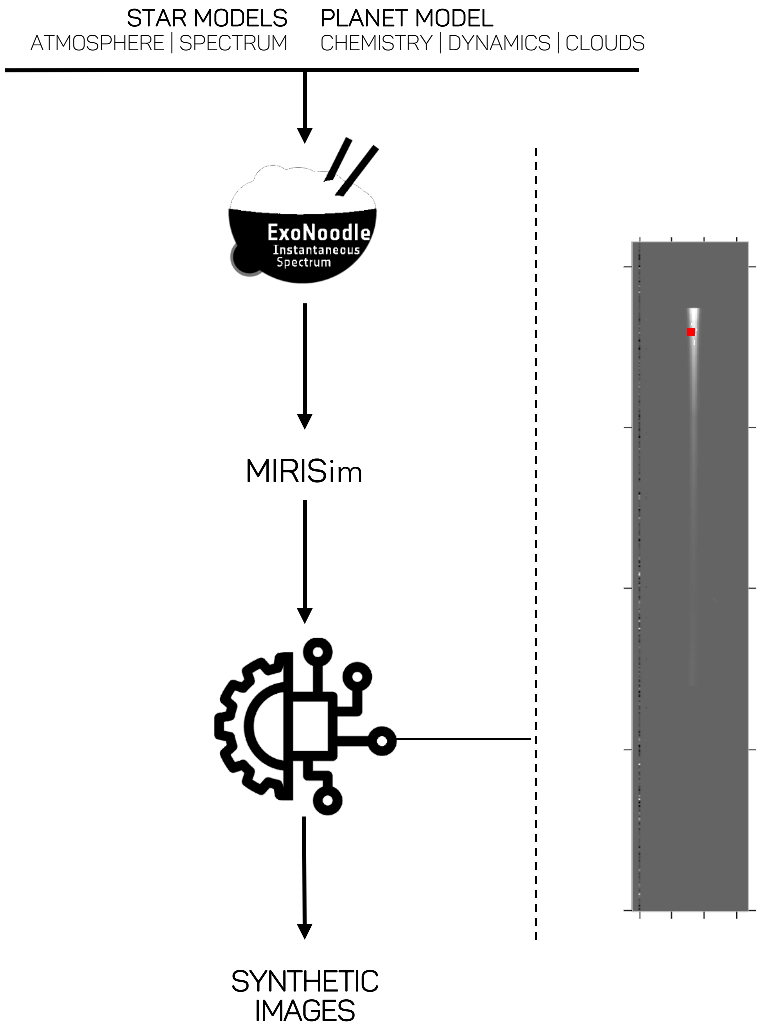

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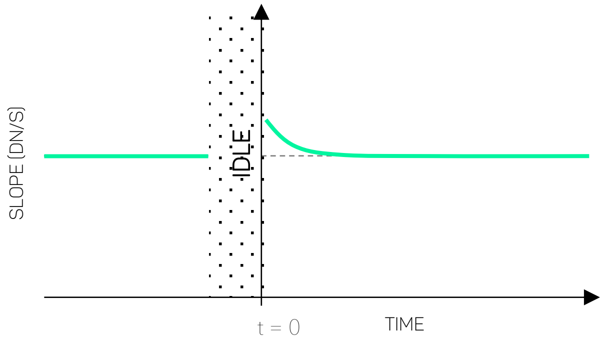
$$\dot{S}_{corrected}(t) = \dot{S}_0 + \left(c \times e^{-\frac{t}{\gamma}}\right)$$



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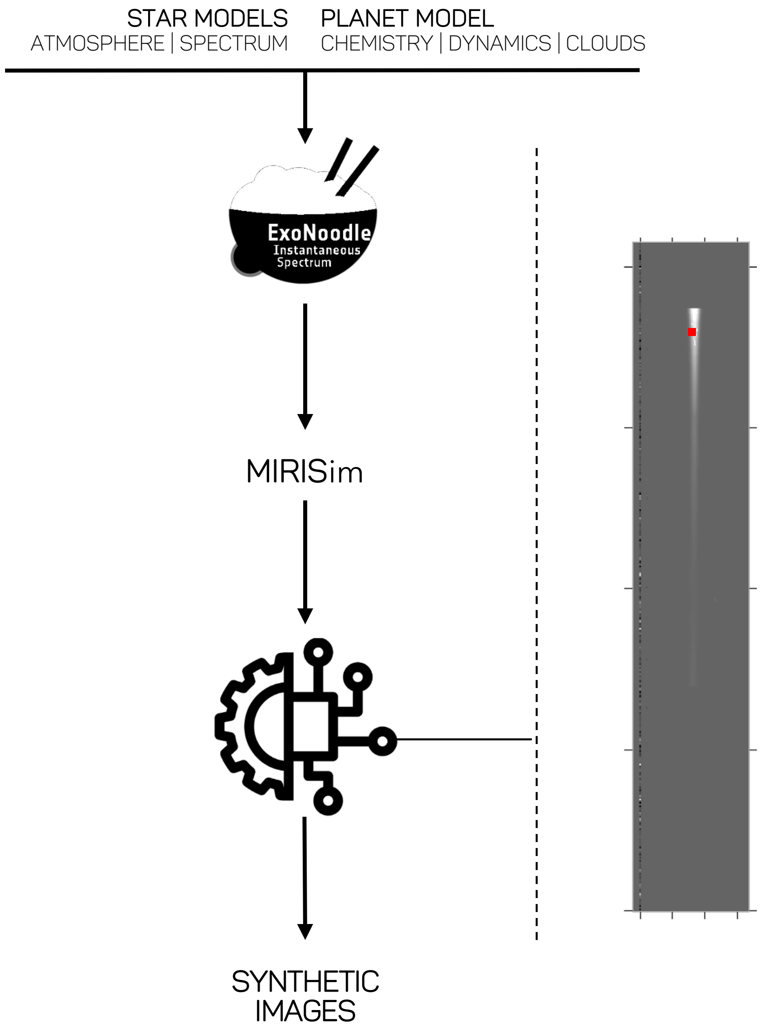

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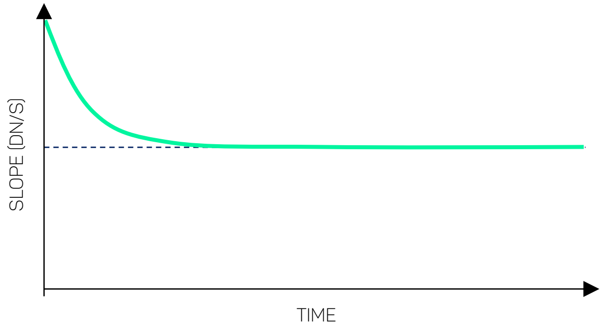
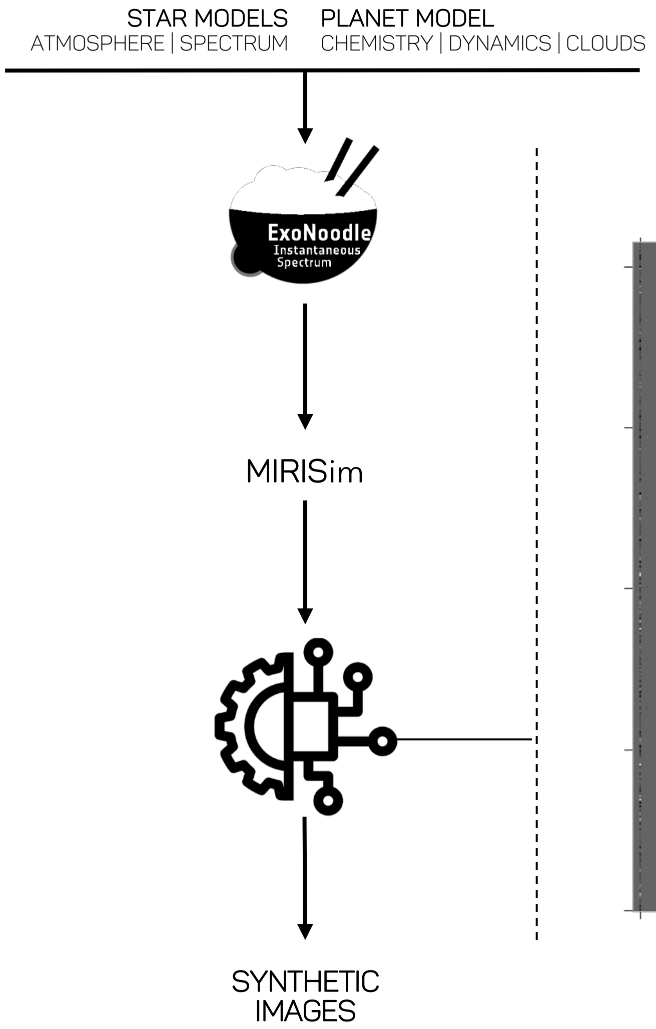
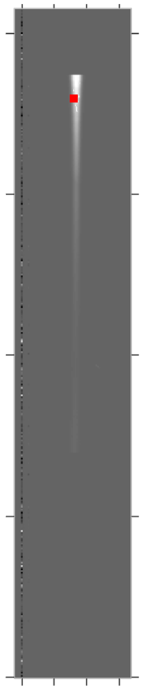
Response Drift | Idle Recovery | Anneal Recovery

$$\dot{S}_A(t) = b_1 \times e^{-\frac{t+t_A}{\beta_1}} + b_2 \times e^{-\frac{t+t_A}{\beta_2}}$$



RESULTS





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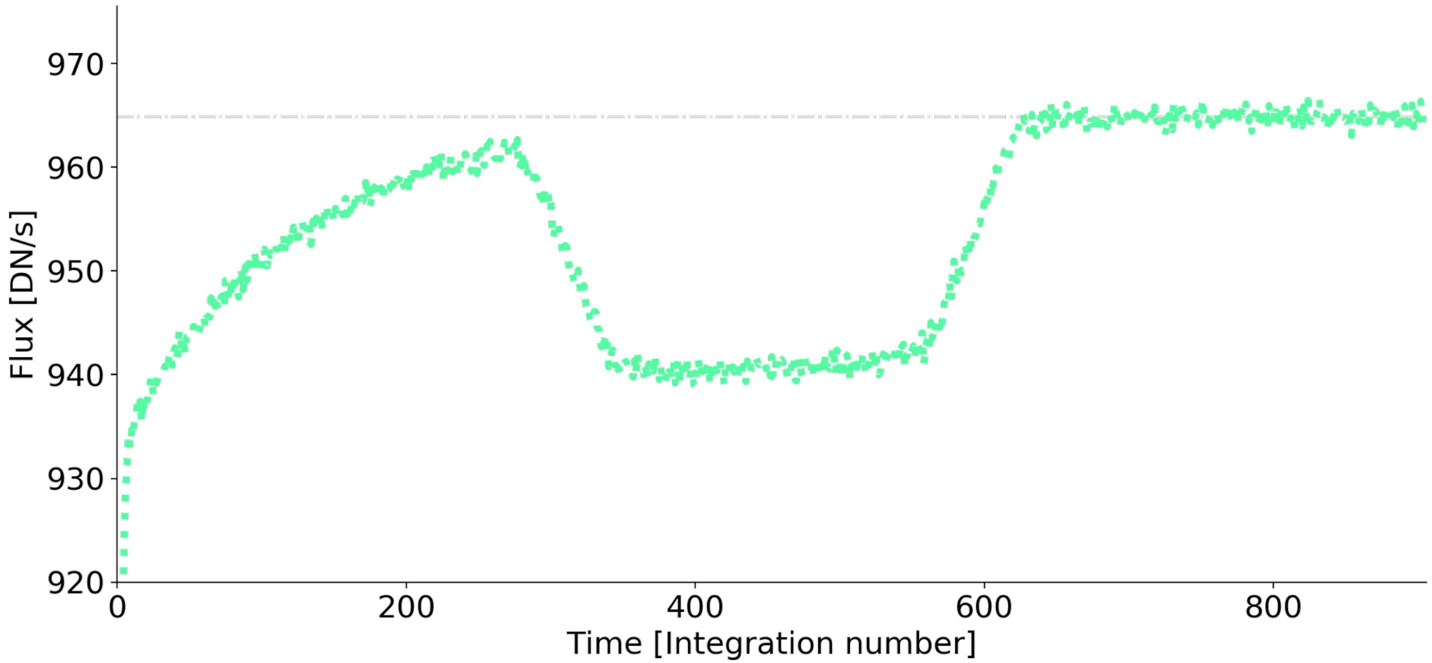
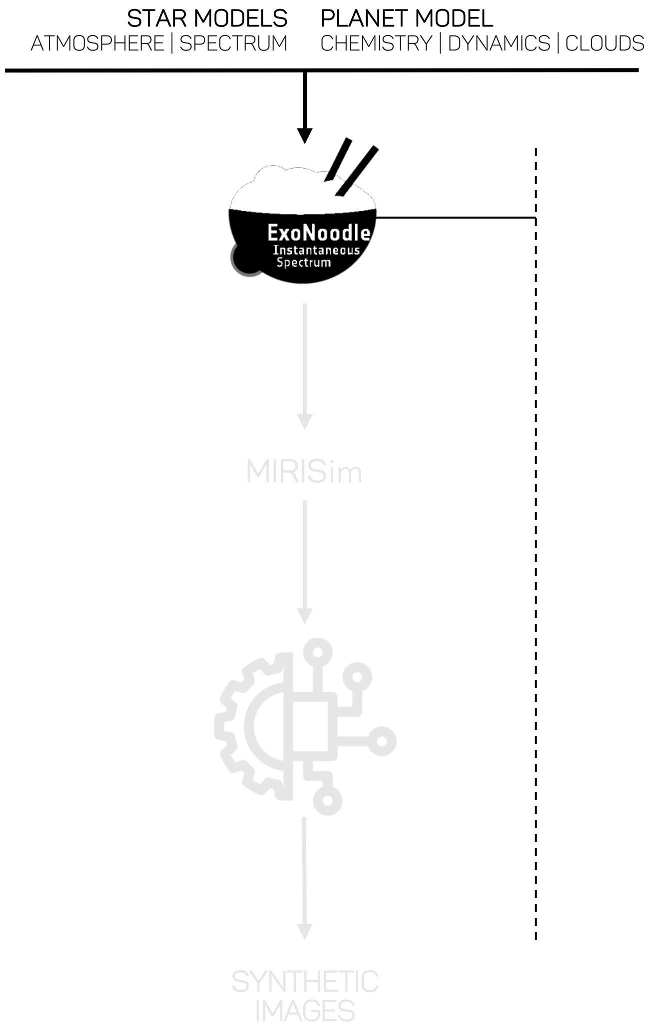
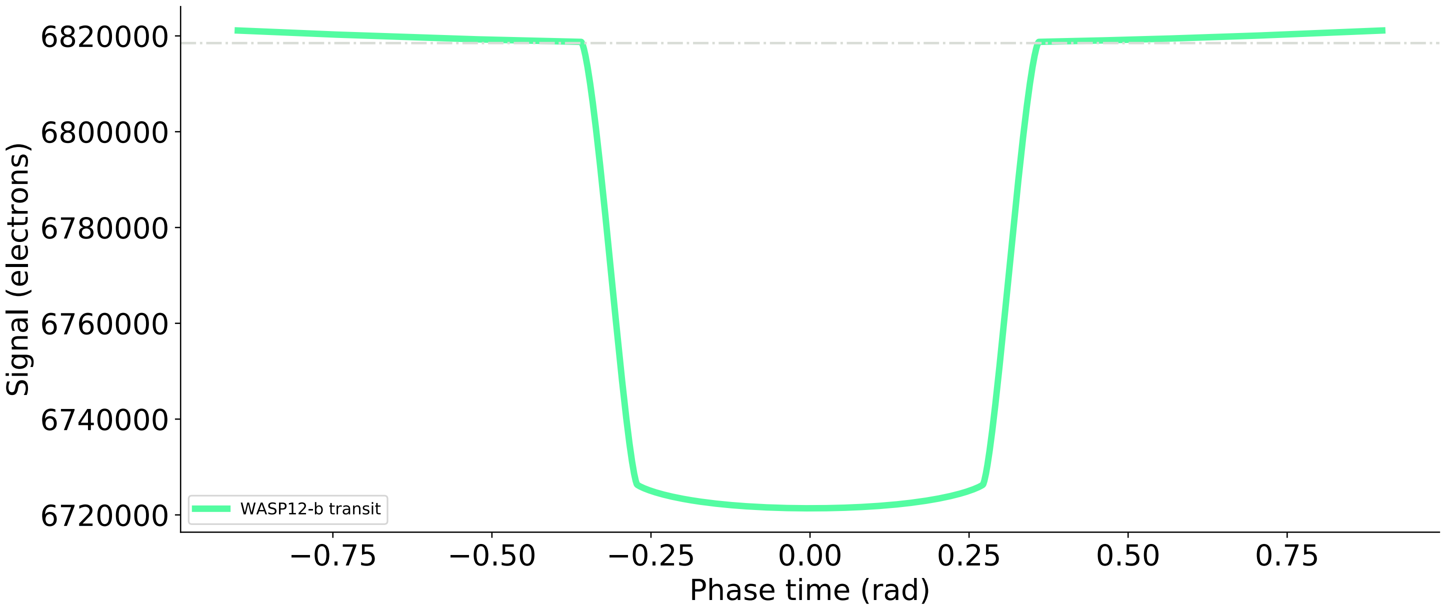


RESULTS



EXONOODLE – ASTROPHYSICAL SIMULATIONS



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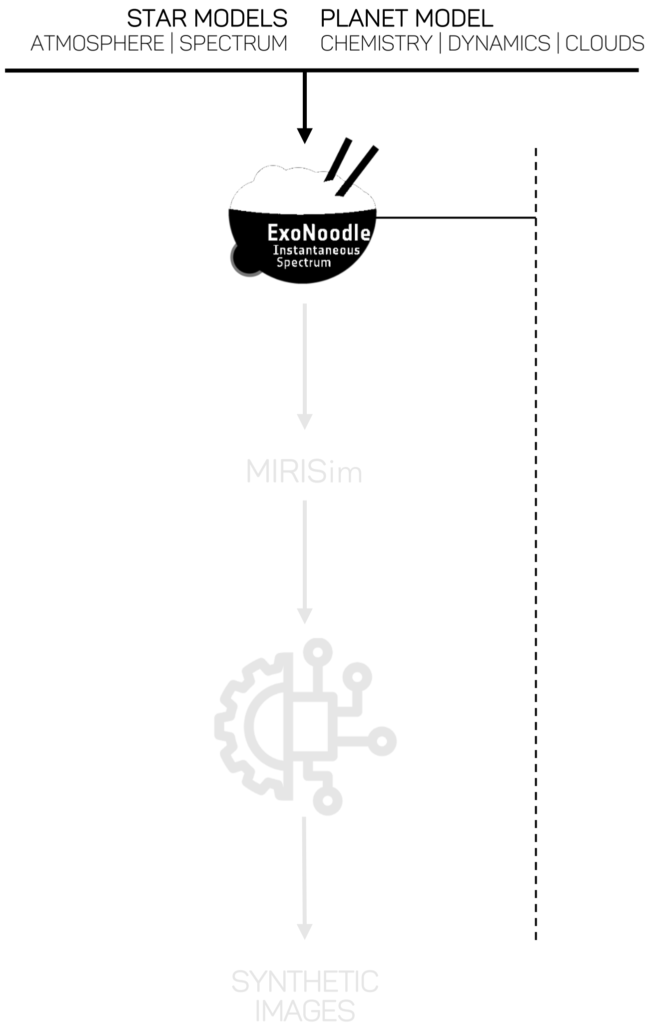

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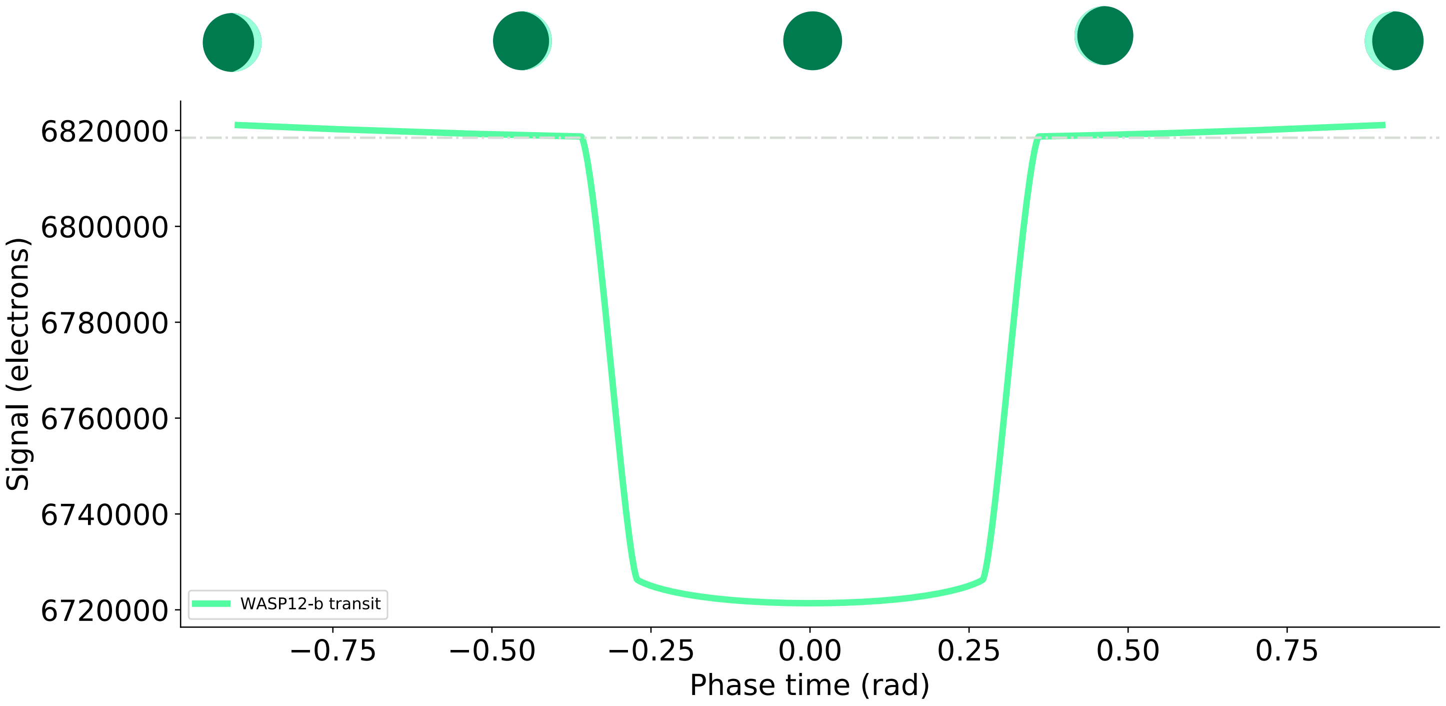

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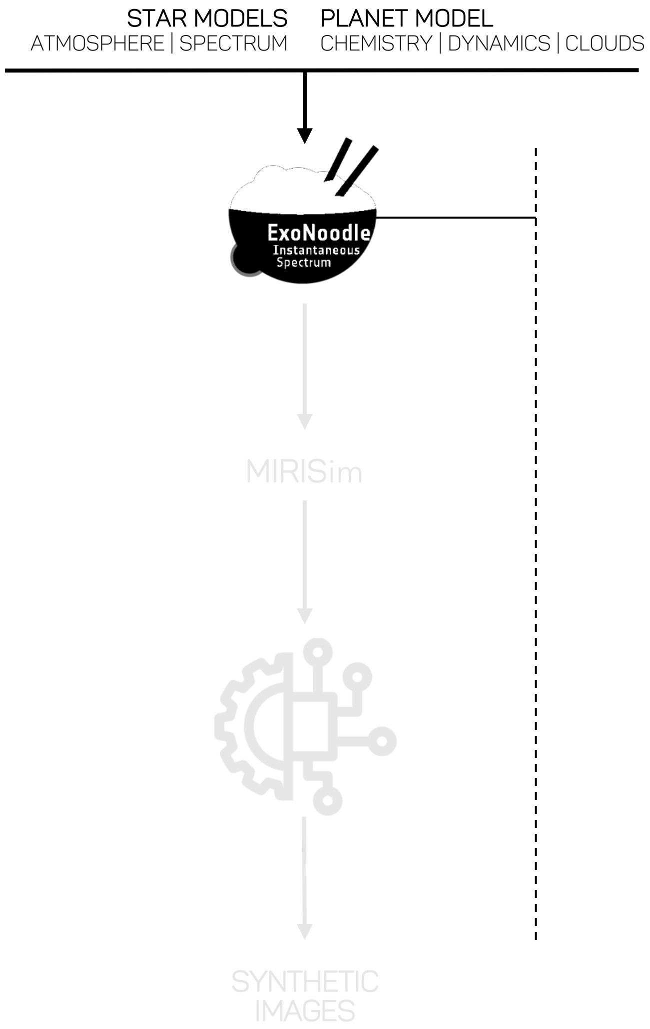

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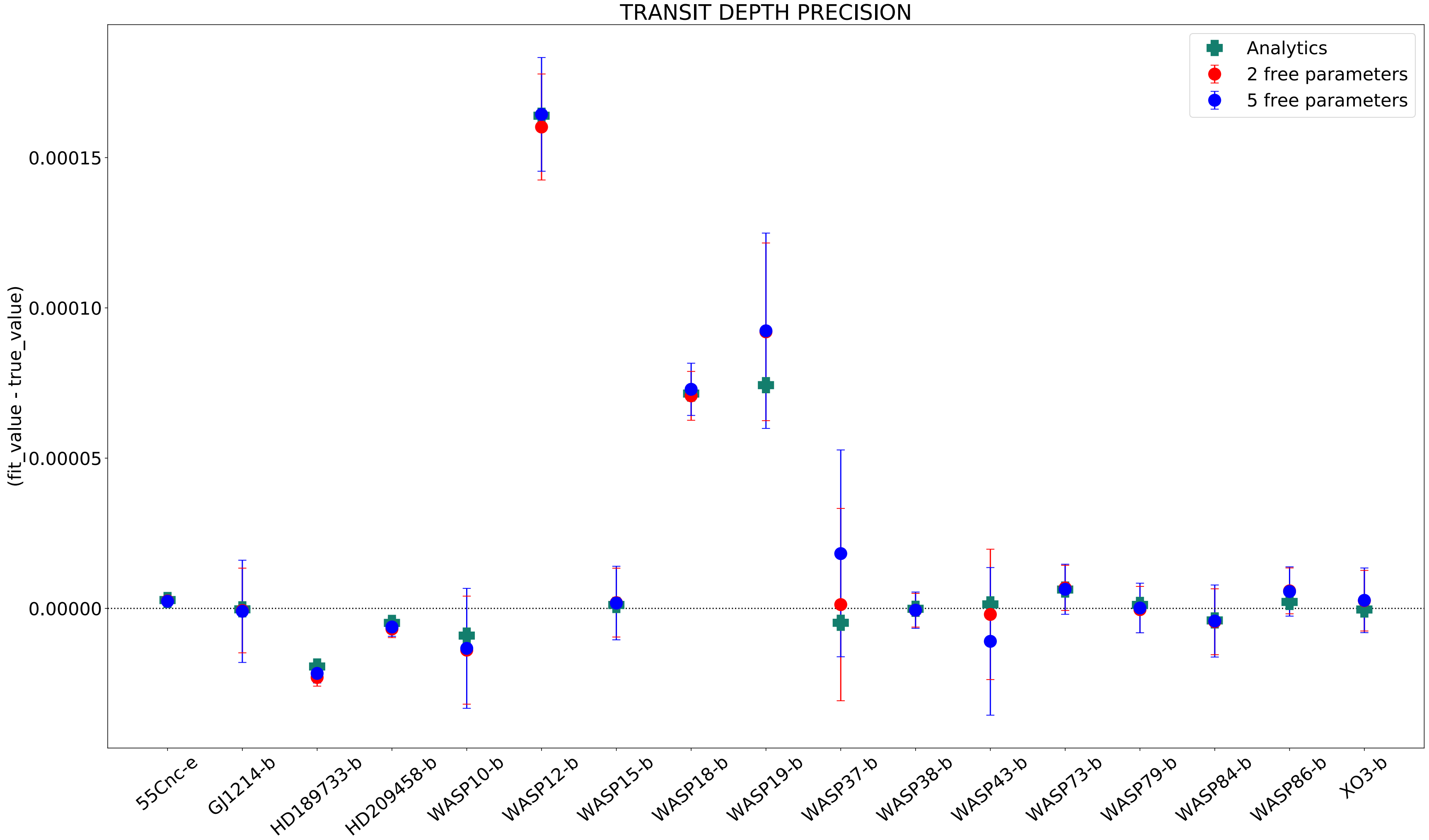
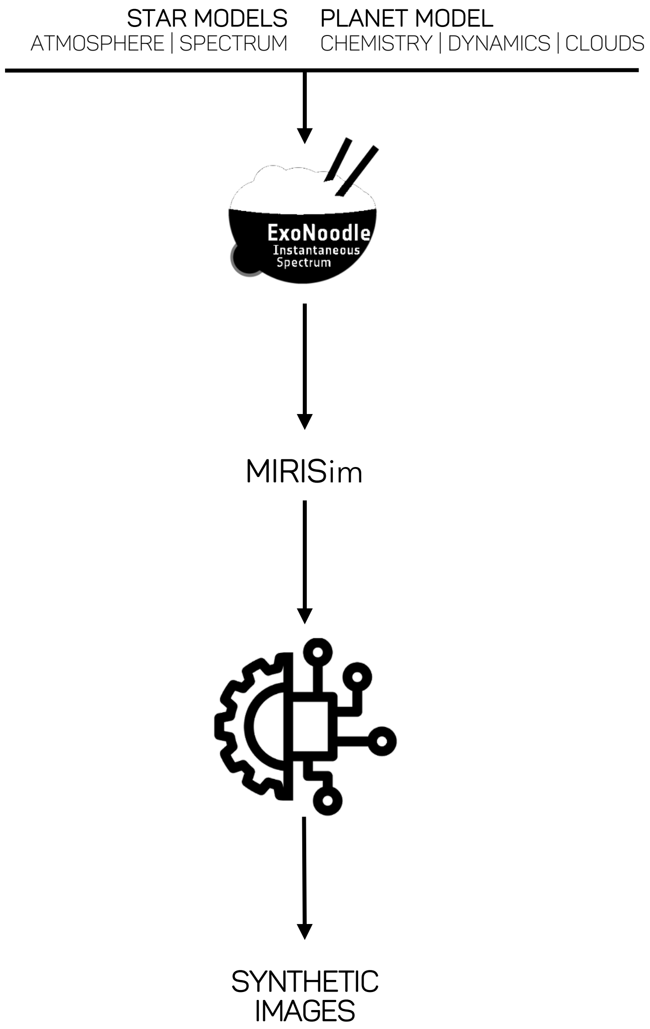


WRAP-UP



Generate detailed synthetic time-series observations of transiting exoplanets with MIRI-LRS.

· EXONOODLE

- Create time-series of exoplanetary system spectrum.
- Test of out-of-transit hypothesis induced biases in transit depth measurement.
- Release early 2020, ongoing beta-tests - Martin-Lagarde et al. *in prep*

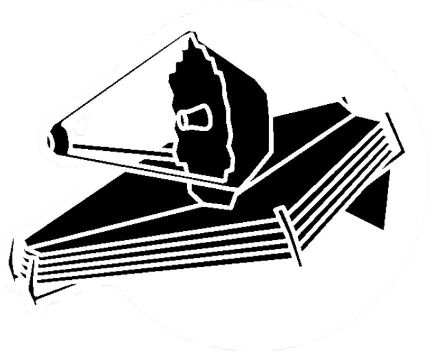
· INTRODUCTION OF SYSTEMATICS IN MIRI TSO SIMULATIONS

- Modelling with MIRI-JPL ground tests and heritage of Spitzer.
- Release 2020 - Martin-Lagarde et al. *in prep*

· PERSPECTIVE

- JWST MIRI-ERS data challenge
- New effects (Latency, Detector temperature variations)

PREPARING EXOPLANET **TRANSIT SPECTROSCOPY** OBSERVATIONS WITH **JAMES WEBB** SPACE TELESCOPE



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