EPSC Abstracts
Vol. 13, EPSC-DPS2019-1879-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Simulating observations of transiting exoplanets with JWST/MIRI including instrumental systematics

Marine Martin-Lagarde (1), Pierre-Olivier Lagage (1), René Gastaud (1), Alain Coulais (1, 2), Christophe Cossou (3) and Dan Dicken (1)
(1) AIM, CEA, CNRS, Université Paris-Saclay, Université de Paris, F-91191 Gif-sur-Yvette, France, (marine.martin-lagarde@cea.fr)
(2) LERMA, Observatoire de Paris, CNRS, F-75014, Paris, France,
(3) Institut d'Astrophysique Spatiale, CNRS/Université Paris-Sud, Université Paris-Saclay, bâtiment 121, Université Paris-Sud, 91405 Orsay Cedex, France

Abstract

The launch and commissioning of the James Webb Space Telescope (JWST) in 2021 will provide game-changing astronomical observations, in particular for exoplanets. To familiarize the community with data soon after the launch of the JWST, an Early Release Science program (ERS) has been developed, including observations of transiting exoplanets. These observations include a complete phase curve of WASP43b with the JWST Mid-InfraRed Instrument (MIRI). Data challenges will be organized before the science program begins, to be well prepared for the data analysis. In that frame, we have developed tools to simulate MIRI transiting exoplanet observations, including instrumental systematics, and applied them to the ERS observation of WASP43-b.

1. Introduction

The James Webb Space Telescope, to be launched in 2021, will open new perspectives in astrophysics and especially in exoplanets observations. Twenty-five percent of the JWST observing time in the framework of GTO (Guaranteed Time Observations) and ERS (Early-Release Science) programs will be dedicated to exoplanet observations. Most of them aim at characterizing exoplanet atmospheres (vertical structure, molecular content, hazes, clouds, winds, etc.). The JWST will bring a large collecting area and a large wavelength coverage (0.5 – 28 microns), with 3 instruments in the 0.5-5 microns range (NIRISS, NIRCAM and NIRSPEC) and one instrument in the 5 – 28 microns range (MIRI). To take full advantage of the JWST capabilities when observing transiting exoplanets, relative spectro-photometry precision down to the 10 ppm level should be achieved. This is not easy and the lesson learned from Spitzer and Hubble observations is that good knowledge of the instrumental systematic effects and their corrections are necessary to infer robust conclusions on the exoplanet atmospheres from the data. As the choice of data detrending method may affect the scientific results, instrument simulators have been developed to create benchmark data for testing the data reduction pipeline of Spitzer transit observations [1] and of HST transit observations [2]. Here we present how we generate realistic MIRI-LRS observation of the WASP43 system, including the instrument systematics.

2. Methods

Several pieces of software have been developed to create synthetic data of MIRI time-series observations.

2.1. MIRISim

The instrument consortium has developed MIRISim; a simulator reproducing as accurately as possible the instrument behaviour, including its noises and systematics, for imaging and spectroscopy modes of MIRI. The consortium made it publicly available [3].

2.2. ExoNoodle

Complementary to MIRISim, we have developed ExoNoodle, a Python tool to generate time-series spectra of star-planet systems, varying over time as the planet orbits around the star. It aims at providing MIRISim with Time-Series Observations (TSO) input files. ExoNoodle is a program that calculates the spectrum expected from the star and planet(s) system at each time-step of a time-series. It comes as a Python package. Even though exoNoodle is developed with

MIRI-LRS study case, it can be easily used for other MIRI observational modes or other instruments. Special attention is taken to calculate precisely ingress and egress. It includes contributions from the spectrum coming from:

- Star spectrum;
- Stellar limb-darkening;
- Planet day and night emission spectrum;
- Planet reflection spectrum (Albedo);
- Planet transmission spectrum ($R_p/R_\star(\lambda)$).

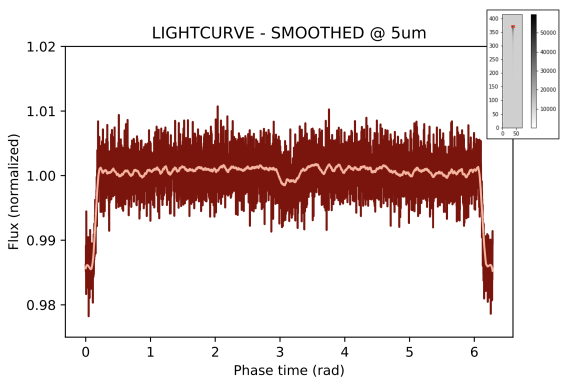

Figure 1: WASP43-b simulated time-series with [1] in dark red the raw synthetic data at 5 μm and [2] in light red, the smoothed curve. Upper right corner: a synthetic MIRI-LRS Slitless image, with the 5 μm bin box in red.

The figure 1 represents a simulation of WASP43-b time-series as it would be observed with MIRI-LRS Slitless mode. In dark red is shown the raw synthetic data corresponding to a bin around 5 μm on the image (the red box in the upper right corner). In light red, the smoothed curve is here to reveal the main transit features (transit at $t = 0$ rad and eclipse at $t = \pi$ rad). In the upper right corner, one of the simulated MIRI-LRS Slitless images is shown with the 5 μm red bin box used.

2.3. Systematics introduction

MIRISim does not include a TSO mode. Changing the source spectrum over time means to restart a new computation, at every time-step, and therefore getting rid of the systematics evolution, such as latency effects. This is why there are no systematics appearing on figure 1 data. To correct for this, we have developed a post-treatment routine, re-introducing the signal variations induced by the instrument drifts. The effect we are correcting for in this work so far are:

- The dark current variation after an anneal;
- The persistence;
- The response drift.

The intensity and the time scale of such effects depend on the flux level and thus varies along the spectrum.

3. Summary and Conclusions

These simulated data of JWST-MIRI LRS Slitless exoplanet time-series observations are being used to test and improve the data reduction and retrieval techniques the community is building, for example in the framework of the ExoplANETS-A project. They will be used in the framework of MIRI exoplanet data challenge to be conducted to prepare the transiting exoplanet ERS program.

Acknowledgements

The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement 776403. M. Martin-Lagarde is partly funded by a CNES scholarship.

References

[1] James G. Ingalls, J. E. Krick, S. J. Carey, John R. Stauffer, Patrick J. Lowrance, Carl J. Grillmair, Derek Buzasi, Drake Deming, Hannah Diamond-Lowe and Thomas M. Evans: Repeatability and accuracy of exoplanet eclipse depth measured with post-cryogenic Spitzer, The Astronomical Journal, Vol. 152, 2016.

[2] R. Varley, A. Tsiaras, and K. Karpouzas: Wayne—A Simulator for HST WFC3 IR Grism Spectroscopy, The Astrophysical Journal, Vol. 231, 2017.

[3] MIRI European Consortium, MIRISim Documentation - Release 1.0.0, March 26, 2018