Transiting Exoplanets and Their Atmospheres in the Era of James Webb Space Telescope:

What We expected for the Systems like TRAPPIST-One/Seven Planets?

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Abstract

The recent discovery of the TRAPPIST-1 planetary system provides an extraordinary opportunity to study multiple terrestrial extrasolar planets and their atmospheres. These planets are amenable to atmospheric characterization and are likely to be extensively studied with JWST. The upcoming launch of the James Webb Space Telescope (JWST) will offer an unprecedented capability to study nearby transiting exoplanets, it is particularly important, since it will provide a large aperture, a heliocentric orbit, and a continuous wavelength coverage from 0.6 to 28 microns. It should be powerful enough to make possible detailed atmospheric characterization not only of hot Jupiters but also of smaller planets. The TRAPPIST-North Telescope Located at the Oukaimeden Observatory in Morocco contributed to the discovery of TRAPPIST exoplanetary system. We propose to present a discussion about the scientific information we expected to gather from JWST data set in the observations of the Trappist-1 system in advance of the congress that we intend to organize in Marrakech on this subject in 2020.

Introduction

Many research (Wolf (2017), Alberti et al. (2017), Turbet et al.(2017)) have been done for examining the potential habitability of Trappist-1 planets and found that Trappist-1e and 1d are a remarkable candidates for surface habitability. Based on these studies, we decided to focus our work on each of Trappist-1e and 1d planets, we use the planetary spectrum generator (PSG) to Simulate their transit spectra with different atmospheric compositions that are by definition possible outcomes of planet formation simply because they exist in our own solar system: Erath, Venus and Mars, we then use these model atmospheres to predict the observability of these planets with JWST using Pandexo tool. In May 2020 the JWST will be launched with four instruments will be operating in the 0.6-5 microns range: NIRISS, NIRCam, NIRSpec and one in the 5-28 microns range: MIRI, which will open a new area in the domain of exoplanet atmosphere characterizations, eventually studies habitable planets, using transmission and emission spectroscopy.

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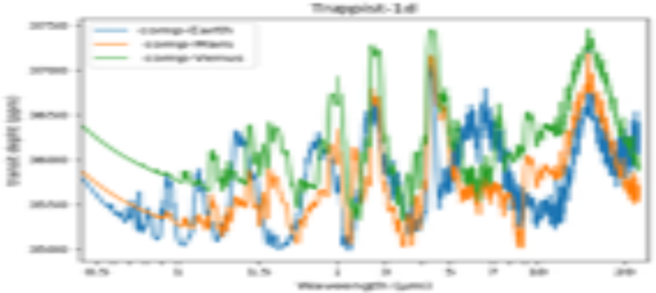
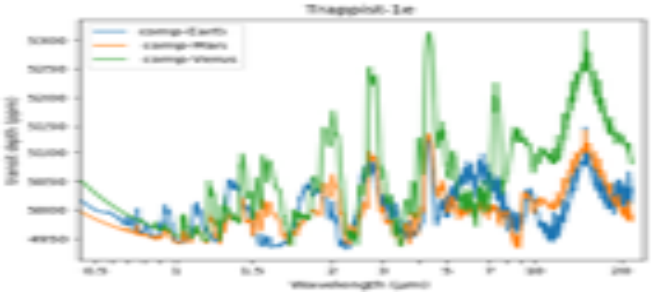
Spectra Generator

To model the planetary transmission spectra, we use the Planetary Spectrum Generator [1]. PSG is an online radiative-transfer suite for atmospheres, it is applicable to a broad range of planetary objects (planets, exoplanets…) and employs PUMAS (Planetary and Universal Model of Atmospheric Scattering) for computing spectra. Using this code we generated spectra for each of Trappist-1e and Trappist-1d planets with considering three cases of atmospheric composition , the Earth, Venus and Mars compositions.

PUMAS

- *Accurate line-by-line modeling and efficient correlated-k-synthesis for moderate resolutions*
- *Full scattering modeling of aerosols and ices*
- *Rayleigh, CIA and molecular analysis from UV to radio*
- *Layer-by-layer analysis in spherical geometry*





The Figures show transmission spectra for all planets considered for each composition (Earth, Venus, and Mars based), assuming an Earth-like surface pressure of 1 bar and cloud-free atmosphere. In each panel, the three different compositions are shown. The locations of features strongly depend on the composition of the atmosphere because of the different gases that are present.

JWST Simulator

We use PandExo [2] to simulate primary eclipse observations of Trappist-1e and 1d planets. We model the planets assuming that they will be observed by the Near InfraRed Spectrograph (NIRSpec) /G235M on JWST. The stellar spectrum used is taken from the PHOENIX models (Husser et al. 2013) for a 2511 K, solar metallicity star with a log(g) of 5.0. We set the maximum full well to 60% to achieve a duty cycle of better than 90% for all the observations.

In the calculation of noise. PandExo does not assume a systematic noise floor. Greene et al. (2016) have suggested, based on previous observations with HST and Spitzer, that the noise floor for JWST might be 20-50 ppm. This will not be truly known until well after commissioning of the telescope. The assumption to not include a noise floor does not change the conclusions presented here, so in this work, we assumed zero noise floor.

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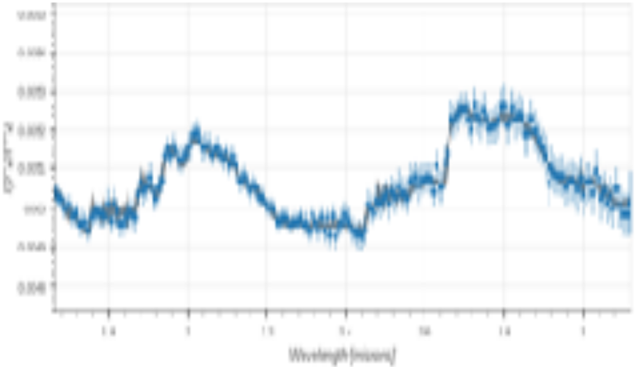
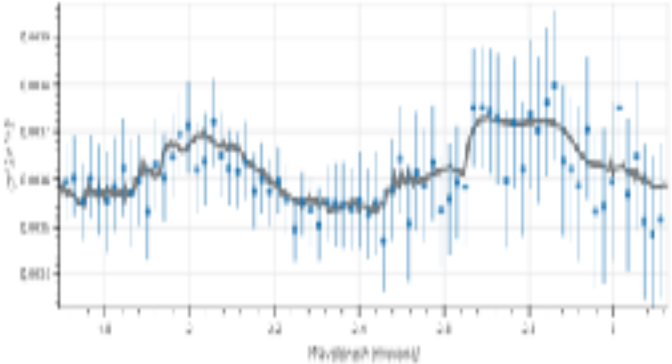


Results



The Figures, right one for trappist-1e and the left one for trappist-1d, show the simulated JWST spectra for TRAPPIST-1e and 1d, assuming a 1 bar atmosphere and Venus-like composition . The simulated data correspond to 25 NIRSpec / G235M transit observations. The features in the transmission spectra are small and thus require repeat observations for a confident detection, ranging from four to over 60 transits for the models we consider. all the planets considered would require more than 25 transits.

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References:

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