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# Exoplanets characterisation with the JWST and particularly MIRI

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## Abstract

The use of the James Webb Space Telescope (JWST) and especially its Mid-Infrared instrument, MIRI, to characterize the atmosphere of exoplanets is discussed. Both transit observations and direct imaging observations are considered.

## 1. Introduction

The detection of exoplanets, the measurement of their mass and radius, and thus the determination of their mean density, are well on track with several dedicated space and ground-based facilities in operation or planned (TESS, CHEOPS, PLATO,…).

The next step to progress in the field of exoplanets is the study of their atmosphere (chemical composition, vertical structure, two-D map, variability, …). Such a study is interesting to test atmospheric/climate models in a wide range of parameter values. It is also a way to break degeneracies in the determination of exoplanet internal structure from the mean density alone, to provide clues to planet formation (C/O ratio),... Such studies have started with observations from Spitzer and HST, and from ground-based telescopes. Nevertheless, the field is still in its infancy; a breakthrough in the domain is expected thanks to the JWST.

## 2. The JWST and its instrumental suite

The JWST is an InfraRed (IR) telescope of large diameter (6.5m to be compared to 0.8m for Spitzer) to be launched in October 2018 by an Ariane rocket. It is a NASA program with the participation of the European Space Agency (ESA) and the Canadian Space Agency (CSA). Observations in the 0.6 -28 microns range will be possible thanks to four instruments. Three of the four instruments, NIRCAM (PI. M. Rieke), NIRIS (PI R. Doyon) and NIRSPEC (PI P. Ferruit), are dedicated to imaging, coronagraphic or spectroscopic observations in the near IR (up to 5 microns); one, MIRI (European PI: G. Wright, US PI: G. Rieke), is dedicated to observations in the mid-IR (5-28 microns). For a recent status of the JSWT, see for example [3].

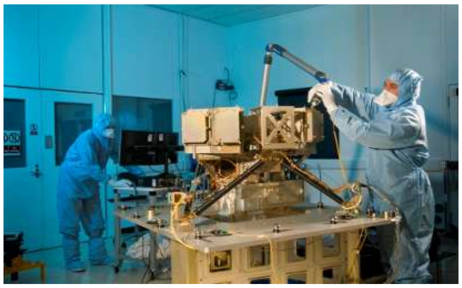

Figure 1: The JWST MIRI instrument in the RAL facility (UK) in 2012. The instrument features two main modules: an integral field spectrometer (on top) and an imager (at the bottom). For information about MIRI see [7]. (Copyright: Stephen Kill, STFC)

## 3. The JWST and the exoplanets

It should first be pointed out that the JWST is not a mission dedicated to exoplanets. Four science fields have been put forward: *First Light & Reionization, Assembly of Galaxies, Birth of Stars and protoplanetary systems, Planets and Origin of Life.* The JWST is an observatory and observing time will be granted through Time Allocation Committees. We can anticipate that the observing pressure will be high.

The capability of the JWST to observe primary and secondary transits of exoplanets has been recently (March 2014) discussed during a meeting at Passadena and the reader is referred to the paper resulting from the meeting [1] and the references there-in.

Note that the JWST will not do "all" and there is a strong scientific case for a space mission with a 1m class IR telescope dedicated to a statistical study of the atmosphere of hot to warm giant, Neptune like or super-Earth exoplanets ([6] and the Ariel M4 proposal to ESA, see also [4]).

# 4. MIRI and the exoplanets

Given its wavelength coverage (5 to 28 microns), MIRI is well suited to study exoplanets down to "temperate" one. Several strong molecular features from $H_20$, $CH_4$, $CO_2$, $NH_3$, HCN, $C_2H_2$… are present in the mid-IR region. Strong dust features (Silicates) are also present around 10 microns. Two observing techniques will be used: transit (primary and secondary) observations and direct imaging observations. These techniques probe two different classes of exoplanets. Due to observational bias, the exoplanets observed by direct imaging are **young** giant exoplanets orbiting **far** from their host star. The transit technics probe a larger mass range (from Earth mass to giant), but is limited to exoplanet in relatively close orbit around their host star; (the probability of transit decreases with the distance of the planet to the star).

## 4.1 Direct imaging

Since the beginning of the conception of MIRI, a coronagraphic mode has been included. Thanks to the use of 4 quadrants phase mask, an inner angle as low as Lambda/D is obtained [2]. The observations can be made at three wavelengths (10.65, 11.4 and 15.5 microns), which have been chosen to detect the $NH_3$ feature at 10.65 microns, which can probe the temperature of the object. MIRI observations will pioneer the field. Indeed no observation of direct imaged exoplanets has been done so far above 5 microns. Spitzer suffers from a lack of angular resolution and ground-based observations suffer from a lack of sensitivity.

The list of imaged planetary mass companions is so far limited, but will rapidly grow, now that GPI on Gemini and SPHERE on VLT are in operation. After the discovery of a planetary mass object on a wide orbit around the Young M3 Star GU Psc [5], the search for similar objects is quite active. For those exoplanets far enough from their host star, slit spectroscopic observations with the Low Resolution Spectroscopic (LRS) mode of MIRI (R about 100 in the 5-12 microns range) can be undertaken to determine the composition of the atmosphere. We are also considering using the Medium Resolution Spectroscopic (MRS) mode to obtain spectra at higher spectral resolution (R about 3000) or at wavelengths longer than 12 microns.

## 4.2 Transit observations

The observation of exoplanet transits was not foreseen at the beginning of MIRI. In the course of the instrument development, this aspect has been taken into account by adding a new observing mode: slitless LRS observations with only part of the array read to push further away the saturation limit.

# 5. Summary and Conclusions

The JWST will be a great facility to enter fully in the field of exoplanets atmosphere characterization. The observations will be difficult; for example, some transit observations will require reaching the 10 ppm level. However we can be optimistic as, the JWST in orbit at L2 will be very stable, its jitter will be as low as 7 mas (1 sigma) and a lot of knowledge on the instrument behavior and particularly the detectors, will be acquired prior to launch.

# Acknowledgements

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