EPSC Abstracts
Vol. 13, EPSC-DPS2019-1429-1, 2019
EPSC-DPS Joint Meeting 2019


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

# Studying Venus-like atmospheres with a GCM to address observational prospects of close-in orbit hot rocky exoplanets.

**Gabriella Gilli** (1,2), Martin Turbet (3), Jeremy Leconte (4) Nuno Santos (1,5), Sebastien Lebonnois (6), Franck Lefèvre (7) Pedro Machado (1,2)
(1) Instituto de Astrofisica e Ciências do Espaço (IA), Portugal (2) FCiências.ID, Lisbon, Portugal (3) Geneva Astronomical Observatory, Switzerland (4) LAB/CNRS, University of Bordeaux, France (5) Dep. de Física e Astronomia, Facultade de Ciências, Univ. Do Porto, Portugal (6) LMD/IPSL, Paris, France (7) LATMOS/IPSL, Paris, France (Email: ggilli@oal.ul.pt)

## Abstract

A new era for characterization of Earth-like exoplanet atmospheres by transmission spectroscopy will be opened by the James Webb Space Telescope (JWST), scheduled for launch in 2021, and ARIEL, one of the three candidate missions selected by the ESA due for launch in 2028. In the perspective of detecting and characterizing more and more close-in-orbit hot terrestrial exoplanets transiting nearby small stars (e.g best Earth-size targets for transmission spectroscopy studies), the atmosphere of Venus is one of the most relevant cases to address observational prospects.

We propose here to use Venus-like atmosphere templates based on a state-of-the art Venus General Circulation Model (GCM) [1, 2] with the goals of: 1) studying how the planet's atmosphere modifies the observable and 2) showing the potential and limitation of detecting spectral molecular signatures during a transit of Venus-like planet around a M star. In particular, we will focus here on theoretical transmission spectra of Venus-analogue exoplanet atmosphere as observed by forthcoming space-based satellites.

## 1. Introduction

The study of extra-solar planet atmospheres is nowadays seen as the new frontier in Astrophysics,crucial for typifying planets in the habitable zone. More than 5700 confirmed extra-solar planets have been discovered so far with very large ranges of masses, sizes and orbits, and huge steps have been taken in their characterization: from rocky terrestrial planets around cool stars to gaseous giants close to their parent star. However, the essential nature of these exoplanets remains largely mysterious. To tackle this challenge, major efforts are devoted to 1) find closest exoplanet targets with the strongest atmospheric signature 2) develop 3D theoretical tools to predict realistic climates. Current atmospheric characterization techniques address the study of extrasolar planet atmosphere mainly from four different viewpoints 1) transmission spectroscopy 2) phase variation 3) occultation spectrophotometry 4) reflected light. For the first technique most favorable targets are planets transiting nearby small stars: Venus is considered an invaluable proxy for the atmosphere of Earth-size planet. We propose here to use Venus-like atmosphere templates based on a state-of-the art Venus General Circulation Model (GCM) [1, 2] to support and optimize the observations of the new forthcoming hot terrestrial targets.

## 2. Venus-like atmosphere templates from 3D simulations

The interest of modeling Venus-like is twofold: 1) the presence of clouds, notably the sulfur-bearing aerosols, are known to produce a high albedo at visible wavelength, therefore increasing the chances to detect reflected light 2) detecting the presence of clouds and their in-homogeneous spatial distribution is paramount for addressing the questions of atmosphere formation and life survival at short orbital distances. On top of that, the reflected light is very promising observable to determine bulk temperature of a planet during daytime, therefore constraining models.
At the same time, telluric exoplanets with a dense atmosphere are the most challenging to characterize with transmission spectroscopy, because of the small atmospheric scale height and thus compact atmospheres [3], and consequently small signal. Clouds effectively increase the apparent radius of the planet, and the transiting spectrum gives information only about the atmospheric components existing above the cloud layer (∼70 km on Venus). In the case of Venus, the most remarkable spectral signature is that of Mie scattering caused by $H_2SO_4$ droplets in upper haze

(70-90 km).

In this work we will take advantage of an improved version of a ground-to-thermosphere (0-150 km) Venus General Circulation Model (the IPSL-VGCM) to show the potential and limitation of detecting spectral molecular signatures during a transit of Venus-like planet around a M star. Spectroscopic features in the IR are easier to detect for a M star than those in the visible, due to the peak of the stellar flux in the infrared. The IPSL-VGCM is currently the only GCM coupled with a photochemical model, which allows to compute self-consistently temperature and composition of the Venus atmosphere up to 150 km [2]. It now includes an improved radiative transfer scheme, an update cloud model and it takes into account of the latitude variation of the cloud structure, based on the recent Venus Express observations, as described in [5, 1]. Globally averaged profiles (e.g spatially and temporally) extracted from the state-of-the-art IPSL Venus GCM provide realistic templates of the atmosphere of Venus, as shown in the Figure 1.

## 2.1. 3D or 1D atmospheric models?

Considering the geometry of transmission spectroscopy and the lack of spatial resolution of observations of a transiting exoplanet, simplified single-column model atmosphere calculations used in current studies provide reasonable mean profiles for planets with very dense atmosphere and/or rapid rotation. However, for slowly rotating planets (the targets of this study) or synchronized exoplanets, large-scale temperature contrast can be treated correctly only with 3D models [6]. A comparison with previous 1D model studies will be also performed here.

## 2.2. Theoretical Transmission spectra

Theoretical studies of transmission spectroscopy using Venus as a proxy [4] showed that no molecular signatures can be detected below the top of the cloud deck, set at an altitude of 70 km [7]. Most of the lower atmosphere cannot be probed in transmission mainly due to the Rayleigh and Mie scattering and aerosol absorption in the UV-visible. However, we expect to detect absorption features of $CO_2$, CO and $H_2O$ in the IR. The impact of the planet radius, planet mass, orbital distances, stellar flux, etc. on the detectability of those spectral features will be explored. For this purpose we plan to use a 3D radiative transfer model able to generate transmission spectra of atmospheres based on 3D atmospheric structures, following [8].

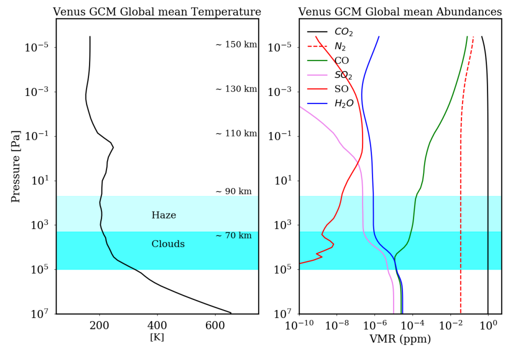


Figure 1: Atmospheric global mean profiles extracted from an improved version of the IPSL Venus GCM [1] extended up to 150 km as in [2]. *Left*: Pressure-Temperature mean profile. Approximate altitudes in km are indicated for reference. Cloud and haze location is approximately shown with shaded blue areas. *Right*: Gas mixing ratio profiles of the main molecular compounds in the Venus atmosphere.


# Acknowledgements

GG has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Slodowska-Curie grant agreement No 796923. This work was supported by FCT/MCTES through national funds and by FEDER - Fundo Europeu de Desenvolvimento Regional through COMPETE2020 - Programa Operacional Competitividade e Internacionalização by these grants: UID/FIS/04434/2019; PTDC/FIS-AST/32113/2017 & POCI-01-0145-FEDER-032113; PTDC/FIS-AST/28953/2017 & POCI-01-0145-FEDER-028953.


# References


[1] Garate-Lopez I. and Lebonnois S. 2018, Icarus, Vol. 314, Pg. 1-11

[2] Gilli et al. 2017, Icarus, Vol. 281, Pg. 55-72

[3] Ehrenreich et al. 2006, A&A, Vol. 448, Pg. 379-393

[4] Ehrenreich et al. 2012, A&A, Vol. 537, Pg. L2

[5] Lebonnois et al. 2016, Icarus, Vol. 278, Pg. 28

[6] Leconte et al. 2013, A&A, Vol. 554, Pg.A69

[7] Ignatiev et al. 2009, JGR, Vol. 114, E13

[8] Caldas et al. 2019, A&A, Vol. 623, Pg.A161