LOOKING INSIDE OF EXOPLANETS

EXOPLANETARY ATMOSPHERES

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ABSTRACT

If we want to help to obtain answers to scientific key questions like, what are exoplanets made of?, why are planets as they are?, how were they formed and how did they evolve?, we have to understand their atmospheres, so to be able to build suitable exoplanetary atmospheric models. For this purpose, we are developing the necessary tools. At present, we are able to build a one dimensional equilibrium thermodynamic atmospheric model for exoplanets, that is a first approximation to their characterization. In the near future, our model will be implemented with new tools for describing disequilibrium processes and therefore will let us to reach a deeper understanding.

In this work we expose a sample of 3 exoplanets, 1 hot Jupiter and 2 hot Neptunes-like at which we build several one dimensional equilibrium thermodynamic atmospheric models. The purpose of this work is show the different variables that even in a first approximation (i.e. equilibrium thermodynamic model) seriously affect the characterization of the system.

MODELS

In this work, we build several one dimensional thermodynamic atmospheric models. This kind of models is a good first approximation for describing any atmospheric chemical composition and mixing ratios. The higher the atmospheric pressure and temperature are, the more relevant is this first approach because the timescales to reach chemical equilibrium are shorter than disequilibrium processes timescales.

We restrict our study to the most relevant elements H, He, C , N, O, because of their abundance and high trend to react. For the solar elemental abundance, we use two different references, Lodders et al. (2009) and Asplund et al. (2009), depending on the case for validation purposes with other authors. When we apply an enrichment of carbon (i.e. a C/O>0.58 approx.) we take into account a loss of 21% of O for silicate condensation (Moses et al. 2013).

With the minimization of Gibbs free energy method species can be treated independently, therefore we only need their thermodynamic data, a pressure-temperature profile and an atmosphere's elemental abundance as inputs. For our equilibrium calculations, we use our own tool that is a flexible and fast processor that execute the NASA CEA code developed by Gordon & McBride (1994) and TEA code developed by Jasmina Blecic et al. (2015).

ANALYSIS AND RESULTS

On both hot Neptune-like planets, when the atmosphere has solar metallicity, CH4 is the major carbon-bearing species. However, observations reveal that on planets Neptune-like CO represents the higher contributor to atmospheric carbon. A solution to this problem is increasing the solar metallicity and/or considering the disequilibrium processes as in Venot et al. (2014). Our investigations corroborate this as shown below which validates our work.
Also, it is important to note that when metallicity rises, there are atmospheric regions where carbon monoxide mole fraction is higher than methane regardless the temperature range in the two cases we have studied. Regarding H2O (another observed species), in the models we have developed it is the most abundant oxygen form every metallicity we have considered. By increasing the C/O, carbon monoxide can have higher molar fraction than water.
A Neptune-like atmosphere can be a reducing one if C/O increases, CH4 becoming more abundant than H2O in a wide range of pressures.

On HD 189733b, CoRot 2b and WASP-12b, unlike the Neptune cases explained above, CH4 is the major carbon-bearing species only at high pressures (i.e. low height). When metallicity rises, this tendency is maintained. Regarding oxygen, CO and H2O use to have similar mixing ratio, the H2O being the most abundant one. This tendency is noticeably reversed when C/O increases.

Hot Jupiter HD 189733b

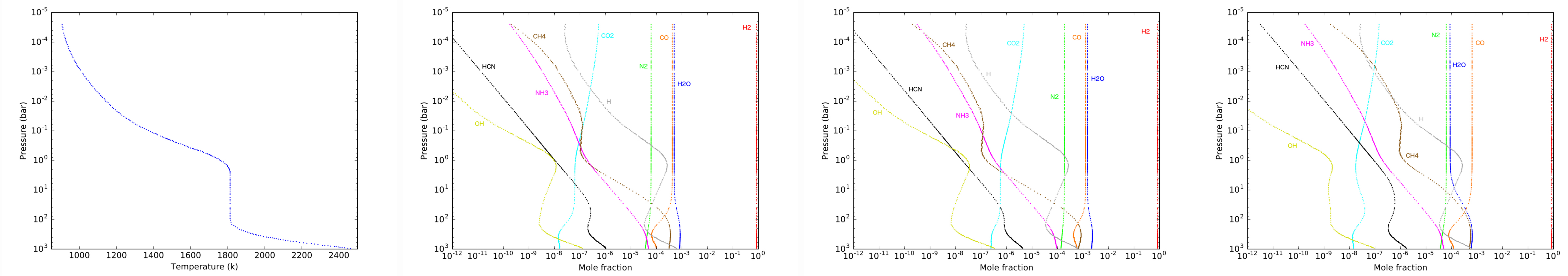

Fig. 1 - From left to right: vertical profile of temperature (Moses et al. 2013), vertical distribution of molecular abundances in our model for a) 1X solar elemental abundance, b) 3X solar elemental abundance, c) 1X solar elemental abundance and C/O=0.88. Solar elemental abundance from Lodders et al. (2009).

Hot Neptune GJ3470b

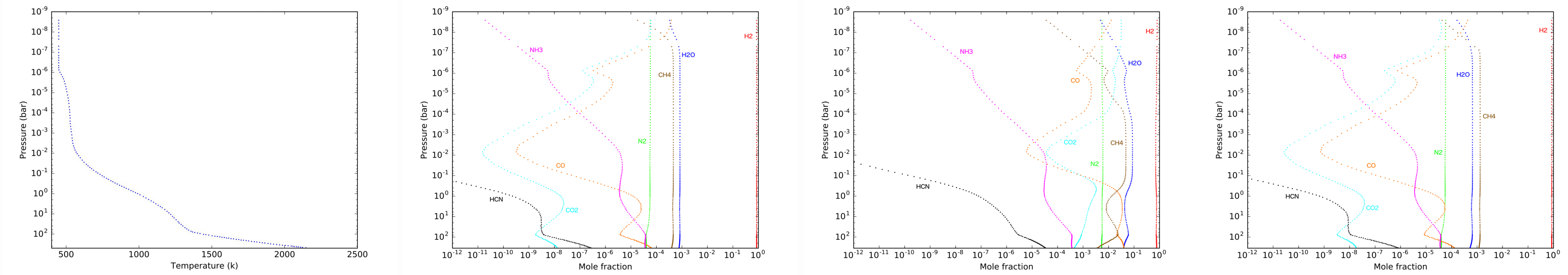

Fig. 2 - From left to right: vertical profile of temperature (Venot et al. 2014), vertical distribution of molecular abundances in our model for a) 1X solar elemental abundance, b) 100X solar elemental abundance, c) 1X solar elemental abundance and C/O=2. Solar elemental abundance from Asplund et al. (2009).

Hot Neptune GJ436b

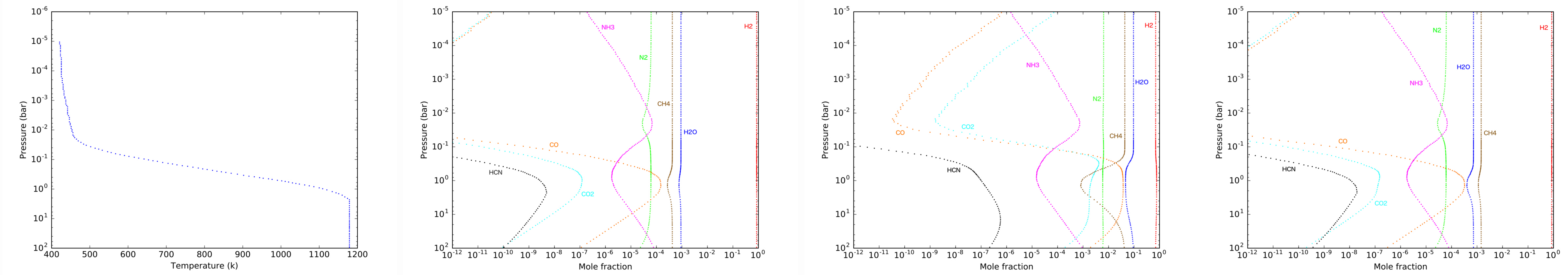

Fig. 3 - From left to right: vertical profile of temperature (Madhusudhan et al. 2011), vertical distribution of molecular abundances in our model for a) 1X solar elemental abundance, b) 100X solar elemental abundance, c) 1X solar elemental abundance and C/O=2. Solar elemental abundance from Lodders et al. (2009).

SUMMARY AND FUTURE WORK

- Although a complete atmospheric model has to take into account disequilibrium processes, one dimensional equilibrium thermodynamic atmospheric models are a good first approximation that can explain several observed planetary atmospheric spectroscopic features.
  - Metallicity and carbon-to-oxygen ratios are very relevant variables characterizing any planet deep atmosphere.

In the near future.
  - We will explore more variables that could change the atmospheric theoretical composition.
  - Our model will be implemented with new processes describing transport phenomena, photodissociation, atmospheric escape, blow-off, incoming flux, etc

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