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Haze formation in the atmospheres of super-Earths and mini-Neptunes

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Abstract

We have conducted a series of laboratory atmosphere simulation experiments to understand the chemistry occurring in the diversity of atmospheres expected for super-Earths and mini-Neptunes, including processes that may lead to the formation of hazes in these atmospheres. We will present the results of these experiments including production rates, particle size distributions, and gas phase chemistry [1, 2, 3, 4].

1. Introduction

Super-Earths and mini-Neptunes are the most common type of planet in our galaxy, but their atmospheres remain mostly unexplored due to a lack of solar system analogue. With the launch of the Transiting Exoplanet Survey Satellite (TESS) and the impeding launch of the James Webb Space Telescope (JWST) we are beginning in a new era in planetary atmospheric science as we will be provided with the opportunity to study previous unexplored phase space.

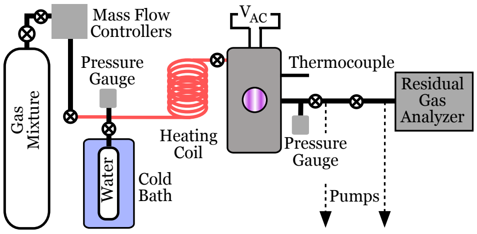

Figure 1: Schematic of the PHAZER setup configured to use the cold plasma energy source.

In preparation for these observations we have undertaken a series of laboratory simulation experiments using the Planetary HAZE Research (PHAZER) chamber (Figure 1) to study atmospheres spanning a wide range of temperatures and atmospheric compositions as shown in Figure 2.

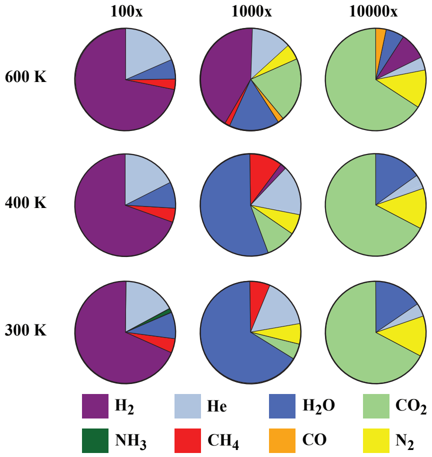

Figure 2: The experiments we will present span a range of temperatures (300-600 K) and initial gas mixtures (100 to 10,000x solar metallicity)

2. Experimental Setup

Our Planetary Haze Research (PHAZER) Chamber at Johns Hopkins University can be operated at a broad range of temperatures and pressures using a variety of reactant gases and two different energy sources. A schematic of the experimental setup is shown in Figure 1. The pressure in the reaction cell is measured and maintained at 1 mbar. The temperature of the gases and chamber are controlled by a custom heating system and measured with multiple thermocouples at the entry, exit, and inside in the chamber. While in the chamber, the reactant gases are exposed to one of two energy sources: a cold plasma generated by an AC glow discharge within the chamber or FUV photons produced by a hydrogen lamp attached to a port on the chamber. The gas phase products flow out of the chamber where they are measured by the residual gas analyzer (RGA). The solid phase products collect in the chamber; the collection technique depends on the requirements for subsequent analysis.

3. Results and Conclusions

We find that all experiments produce haze particles and that there are a wide range of production rates spanning at least three orders of magnitude, which indicates that we should expect some atmospheres to be hazy, while others should be relatively free from haze. We find that for both the cold plasma and UV energy sources the 300 K, 1000x metallicity experiments have the highest production rates [2, 4].

We see that visual inspection of the particles indicates that they will vary in optical properties as they are different colors in the optical [3].

We find that particles range from ~10 nm to 180 nm depending on the experimental conditions and that the width of the size distribution also depends on the initial conditions of the experiments [2, 3].

We find that in some cases our experiments simultaneously produce molecular oxygen (O_2) and organics. We also find that organics are produced in all experiments, even those that do not contain methane in the initial gas mixture. [1]

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