Towards the hottest terrestrial planet atmospheres : 3D climate modeling and perspectives for observations

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Because primary- and secondary-transit spectroscopy is biased towards short period orbits, EChO targets will have a higher equilibrium temperature than the Earth. However, between a temperate, water-ocean bearing Earth-like planet and a hot, lava-ocean bearing CoRoT7-like object, terrestrial atmospheres can undergo many transitions and exhibit very different climate and dynamical regimes. These regimes can manifest themselves by different masses and compositions of both the atmosphere and the potential clouds that can form. Being able to predict these properties, and in particular the location of the clouds, is critical to understand transit observations that can probe very specific areas of a planet.

Here, we will present a suite of results of a 3D climate model characterizing some of the climate regimes that can be encountered as the flux received by a planet is increased. This model notably includes a versatile radiative transfer code to simulate any atmospheric cocktail of gases, aerosols and clouds for which optical data exist.

We will first discuss how three dimensional models can give completely new perspectives on the problem of the runaway greenhouse effect that determines the inner limits of the classical habitable zone of Earth-like planets. Indeed, we will show that both intrinsic 3D effects and clouds have a stabilizing feedback on the climate and thus push this inner edge closer to the star than usually inferred from 1D models.

For planets that are even closer to the star, and thus tidally synchronized, our results suggest that a runaway state with a dense steam atmosphere is not the only possible equilibrium state. Indeed, we will show that, tanks to the permanent cold trap present on the night side, a climate moist bistability can exist, and such planets could instead form a thick ice cap on the night side, leaving thin and dry atmosphere. Both scenarios would yield very distinct observable features. In particular, we will discuss how the presence of clouds on tidally locked terrestrial exoplanet could strongly affect the shape of the light curve.

Finally, turning to the hottest objects, we will present simulations of an hypothetically thin atmosphere that could exist around planets exhibiting a hot magma ocean on the day side. We will discuss what would be the observable signature of such atmospheres, and what limits on the atmospheric mass could be inferred from the light curve.