EPSC Abstracts
Vol. 8, EPSC2013-288, 2013
European Planetary Science Congress 2013

Aerosol properties in exoplanet atmospheres

P. Lavvas (1), T. Koskinen (2) and R.V. Yelle (2)
(1) Groupe de Spectroscopie Moléculaire et Atmosphérique, Université de Reims, Champagne-Ardenne, France
(2) Lunar and Planetary Laboratory, University of Arizona, USA
(panayotis.lavvas@univ-reims.fr)

Abstract

The study of exoplanetary atmospheres is rapidly expanding providing new insights in the complexity addressed in the atmospheres of these distant planets. Apart from the inventories observed in these objects, recent studies suggest that subsequent products of chemical evolution such as hazes can also exist in these atmospheres. We investigate here what would be the properties of such hazes and the conditions of their formation.

1. Introduction

Primary eclipse observations of HD189733b at UV, visible and near IR wavelengths by different instruments of the Hubble Space Telescope (HST), show a rather monotonic decrease in the planet to star apparent radius with increasing wavelength, which has been interpreted as a signature of a high altitude haze [1, 2, 3]. On the other hand, observations on HD209458b at similar wavelengths demonstrate the signature of Na [4] and CO [5] in its atmosphere, which imply the lack of an optically thick haze, like in HD189733b.

Table 1: Gravity acceleration (cm s^{-2}), radius (km) and mass loss rates (in g cm^{-2} s^{-1}) from the photolysis of the main gaseous species in the atmospheres of three exoplanets.

	HD209458b	HD189733b	GJ436b
Gravity	1000	2250	1287
Radius	90000	80000	26931
Species		Mass Loss Rate	
CH_4	1.0(-17)	1.5(-12)	1.2(-12)
CO	1.2(-11)	2.2(-12)	6.5(-14)
N_2	1.3(-12)	3.0(-13)	8.8(-15)
NH_3	1.1(-9)	6.5(-9)	4.8(-9)
H_2S	3.1(-6)	9.6(-8)	9.6(-9)
SiO	6.6(-10)	1.8(-10)	1.3(-10)
Aerosols	∼1(-8)	∼1(-9)	∼1(-10)

Both for Jupiter and Saturn, hazes can be separated into two general families: photochemical aerosols and clouds [6, 7]. Photochemical aerosols are present in the stratosphere and upper troposphere of both giant planets, while clouds are formed at deeper regions. A similar stratification can be anticipated for the hazes in exoplanet atmospheres, although the chemical composition of the aerosols and the gaseous species condensing into clouds could be different. Given our current understanding for the role of aerosols in planetary atmospheres, and motivated by the above observations from hot-Jupiters, we would like to understand how aerosols would behave in exoplanet atmospheres.

2. Model

In order to investigate the properties of aerosols in extrasolar planet atmospheres, we utilize a classical aerosol microphysics model, which we modified in order to be representative of the atmospheric conditions found in EGPs. Our prototype model [8, 9] utilizes a geometrically expanding grid of particle sizes and calculates the population of each size particle by solving the continuity equation for each cell at each altitude of the simulated atmosphere, taking into account their sedimentation as well as the impact of atmospheric mixing. For EGPs, aerosol particles can thermally decompose when they reach to atmospheric regions characterized by much warmer temperatures than those at their formation region. We can treat this process as an ablation procedure of the aerosols in which case the particles loose mass at a rate that depends on the atmospheric temperature, the size of each particle, and the vapor pressure of the material they are made of. Estimates for the composition and production rate of aerosols are made based on photochemical model calculations for the chemical destruction of the main components in EGP atmospheres, and estimates of aerosol formation efficiency based on the

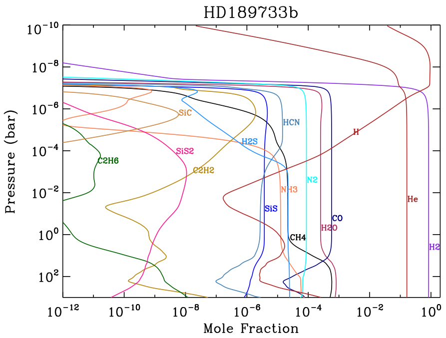

Figure 1: Photochemical model results for the main species in the atmosphere of HD189733b, as well as subsequent products of photochemistry.

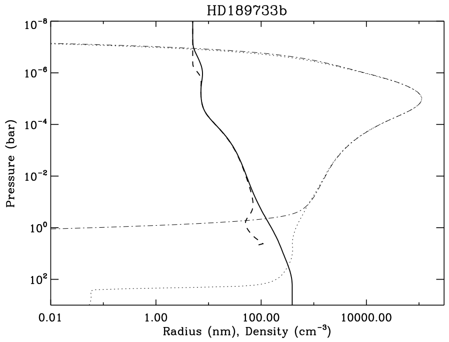

Figure 2: Aerosol microphysics results in the atmosphere of HD189733b. The different curves show the changes in the average particle radius (solid line) and density (dotted line) when ablation is not included, relative to the radius (dashed line) and the density (dash-dotted line) when the ablation process is included in the model calculations.

atmospheres of the solar system (Table 1 & Fig. 1).

3. Results

Our results suggest that ablation has a dramatic effect on the properties of aerosol particles; for HD209458b we find that particles ablate much faster than they grow through coagulation and aerosols are rapidly destroyed. Therefore, aerosol growth is inhibited in this atmosphere by the very high temperature conditions, consistent with the observations. At lower temperatures like those for exoplanet HD189733b, ablation is still active but limited to the deep stratosphere of this atmosphere (Fig. 2). For these results, we assumed that the chemical composition of the particles is similar to silicate material, thus other compositions e.g. hydrocarbons, would be even less likely to survive at these conditions. We further discuss the sensitivity of the model results on the input parameters, such as the production profile, gravity acceleration and atmospheric mixing, as well as compare the model results with observations.

References

[1] F. Pont, H. Knutson, R. L. Gilliland, C. Moutou, and D. Charbonneau. Detection of atmospheric haze on an extrasolar planet: the 0.55-1.05 μm transmission spectrum of HD 189733b with the HubbleSpaceTelescope. *MNRAS*, 385:109–118, March 2008.

[2] D. K. Sing, J.-M. Désert, A. Lecavelier Des Etangs, G. E. Ballester, A. Vidal-Madjar, V. Parmentier, G. Hebrard, and G. W. Henry. Transit spectrophotometry of the exoplanet HD 189733b. I. Searching for water but finding haze with HST NICMOS. *Astronomy & Astrophysics*, 505:891–899, October 2009.

[3] A. Lecavelier Des Etangs, A. Vidal-Madjar, J.-M. Désert, and D. Sing. Rayleigh scattering by H_2 in the extrasolar planet HD 209458b. *Astronomy & Astrophysics*, 485:865–869, July 2008.

[4] D. Charbonneau, T. M. Brown, R. W. Noyes, and R. L. Gilliland. Detection of an Extrasolar Planet Atmosphere. *The Astrophysical Journal*, 568:377–384, March 2002.

[5] I. A. G. Snellen, R. J. de Kok, E. J. W. de Mooij, and S. Albrecht. The orbital motion, absolute mass and high-altitude winds of exoplanet HD209458b. *Nature*, 465:1049–1051, June 2010.

[6] R. A. West, K. H. Baines, E. Karkoschka, and A. Sánchez-Lavega. *Clouds and Aerosols in Saturn's Atmosphere*, chapter 7. 2009.

[7] R. A. West, A. J. Friedson, D. Banfield, B. Ragent, and F. W. Taylor. *Jupiter: The planet, satellites and magnetosphere*, chapter 5. Cambridge, 2004.

[8] P. Lavvas, R. V. Yelle, and C. A. Griffith. Titan's vertical aerosol structure at the Huygens landing site: Constraints on particle size, density, charge, and refractive index. *Icarus*, 210:832–842, December 2010.

[9] P. Lavvas, C. A. Griffith, and R. V. Yelle. Condensation in Titan's atmosphere at the Huygens landing site. *Icarus*, 215:732–750, October 2011.