EPSC Abstracts
Vol. 8, EPSC2013-125-1, 2013
European Planetary Science Congress 2013

The CH_4/CO ratio of the hot Uranus GJ 3470b

Olivia Venot (1), Marcelino Agúndez (2,3), Franck Selsis (2,3), Nicolas Iro (4), Marcell Tessenyi (5)
(1) Instituut voor Sterrenkunde, Katholieke Universiteit Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium (olivia.venot@ster.kuleuven.be) (2) Univ. Bordeaux, LAB, UMR 5804, F-33270, Floirac, France, (3) CNRS, LAB, UMR 5804, F-33270, Floirac, France, (4) Theoretical Meteorology group, Klimacampus, University of Hamburg, Grindelberg 5, 20144, Hamburg, Germany, (5) University College London, Department of Physics and Astronomy, Gower Street, London WC1E 6BT, UK

Abstract

Transit spectra have recently allowed to characterise the atmosphere of smaller planets than hot Jupiters, i.e. (sub-)Neptune size planets. For instance, the Neptune size planet GJ 436b and the mini Neptune or super-Earth GJ 1214b both orbiting around M dwarf stars. These planets have interesting differences with respect to hot Jupiters. First, because the host M dwarf star is smaller and cooler than a solar-type star, the planet is less severely heated, resulting in planetary effective temperatures below 1000 K. It is interesting to note that transit spectra of GJ 436b indicates that its atmosphere is poor in methane [1, 2, 3], yet this species is predicted to be the major carbon reservoir at thermochemical equilibrium. Although such interpretation has been disputed [4], if the poor methane content of GJ 436b's atmosphere is real, there must be an important disequilibrium process, which so far has not been identified. A detailed chemical model by [5], considering thermochemical kinetics, vertical mixing, and photochemistry, concluded that CH_4 should be the major carbon-bearing molecule in GJ 436b's atmosphere under most plausible conditions.

A second important difference with respect to hot Jupiters is that the lower mass of (sub-)Neptune planets allows to expect an elemental atmospheric composition significantly enriched in heavy elements, even an atmosphere not dominated by H and He but by CO_2, H_2O, or some other compounds [6]. In the case of GJ 1214b, its flat transmission spectrum indicates that the planet atmosphere either is hydrogen dominated but contains clouds or hazes, or consists mostly of water vapour [7, 8, 9, 10, 11, 12]. The possibility of a hydrogen dominated atmosphere for GJ 1214b has been explored through chemical modelling by [13], who found that methane would be the major carbon reservoir, just as the findings of [5]'s model on the atmosphere of GJ 436b, and that photolysis of CH_4, which could lead to the formation of hazes, would take place at heights substantially higher than required by the observations.

The recent discovery of the transiting hot Uranus GJ 3470b [14] provides a new promising candidate for follow-up characterisation of its atmosphere and for a better understanding of the atmospheric chemistry of (sub-)Neptunes. Here we aim at studying its atmospheric composition through a chemical model which considers thermochemical kinetics, vertical mixing, and photochemistry. The chemical network has been adapted from combustion modelling and is described in [15]. The atmosphere model relies on some key input information such as the elemental composition, the vertical profile of temperature and eddy diffusion coefficient, and the stellar ultraviolet flux, which are badly constrained. In order to explore to some extent the sensitivity of the atmospheric chemical composition to these uncertain parameters we have varied them around some standard choices and computed a grid of 17 models. In most cases, the CH_4/CO ratio is above 1, as what is predicted by chemical equilibrium. But we found that when the metallicity increases (i.e. solar metallicity $\times 100$) some models lead to a CH_4/CO ratio under unity. We will present you these results, together with the corresponding synthetic spectra. This result is very interesting because most of exoplanet atmospheres observed so far seem to have CH_4/CO ratio opposite from the equilibrium calculation, but no chemical model succeed to find the set of parameters that leads to this result. A very high metallicity seems to be a solution to explore as it is very likely for these atmospheres.

Acknowledgements

O.V. acknowledges support from the KU Leuven IDO project IDO/10/2013. M.A. and F.S. acknowledge support from the European Research Council (ERC Grant 209622: E_3ARTHs). Computer time for this study was provided by the computing facilities MCIA (Mésocentre de Calcul Intensif Aquitain) of the Université de Bordeaux and of the Université de Pau et des Pays de l'Adour.

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