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Cosmic Rays, UV Photons, and Haze Formation in the Upper Atmospheres of Hot Jupiters

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Abstract. Cosmic ray ionization has been found to be a dominant mechanism for the formation of ions in dense interstellar environments. Cosmic rays are further known to initiate the highly efficient ion-neutral chemistry within star forming regions. In this talk we explore the effect of both cosmic rays and UV photons on a model hot Jupiter atmosphere using a non-equlibrium chemical network that combines reactions from the UMIST Database for Astrochemistry, the KIDA database for interstellar and protoplanetary environments and three-body and combustion reactions from the NIST database and from various irradiated gas planet networks. The physical parameters for our model atmosphere are based on HD 189733 b (Effective Temperature of 1000 K, log g = 3.3, solar metallicity, at a distance 0.03 AU from a K dwarf). The active UV photochemistry high in our model hot Jupiter atmosphere tends to destroy these hydrocarbons, but on a time-scale sufficiently slow that PAH formation could already have taken place. In most cases, carbon-bearing species formed by cosmic rays are destroyed by UV photons (e.g. C_2H_2, C_2H_4, HC_3N). Conversely, carbon-bearing species enhanced by an active photochemistry are depleted when cosmic ray ionization is significant (e.g. CN, HCN and CH_4). Ammonia is an interesting exception to this trend, enhanced both by an active photochemistry and a high cosmic ray ionization rate.

Keywords. cosmic rays, Exoplanet: atmosphere, astrochemistry

We present the results of our work, Figures 1 and 2. Both results utilize the non-equilibrium chemical network from Walsh (2013), described in the abstract.

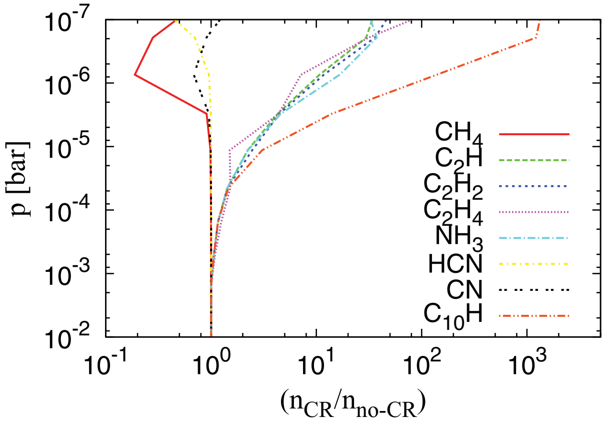

Figure 1. Ratio of abundances from our non-equilibrium chemical network when using the cosmic ray flux determined by Rimmer & Helling (2013), to the chemical abundances using a cosmic ray flux of zero. Both chemical models take their parameters from a Drift-Phoenix model atmosphere with $T_{\rm eff} = 1500$ K and $\log g = 3$ (Witte *et al.* 2009). Most small hydrocarbons such as acetylene are enhanced by more than an order of magnitude, as is ammonia, whereas methane, the cyano radical and hydrogen cyanide are depleted.

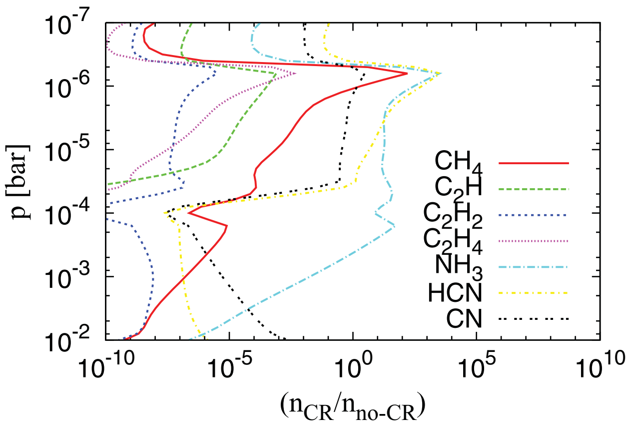

Figure 2. Ratio of abundances from our non-equilibrium chemical network when using a model hot-Jupiter p-T profile, (Hansen *et al.* 2008) to the chemical abundances using the Jupiter-like p-T profile from Moses *et al.* (2005). Both chemical models use a cosmic ray flux of zero. Ammonia, the cyano radical and hydrogen cyanide are enhanced, as is methane in a small region within the upper atmosphere. All other small hydrocarbons are depleted.

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