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Na, K, and electrons in exoplanet atmospheres

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Abstract

We describe a detailed study on the properties of Na and K atoms in extrasolar giant planets, and specifically focus on their role in generating the atmospheric free electron densities, and their impact on the transit depth observations. We focus our study on the case of HD 209458 b, and we show that photoionization produces a large electron density in the middle atmosphere that is about two orders of magnitude larger than the density anticipated from thermal ionization (Figs. 1 & 2). Our purely photochemical calculations result though, to a much larger transit depth for K than observed for this planet (Fig. 3). This conclusion does not change even if the roles of molecular chemistry and excited state chemistry are considered for the alkali atoms. On the contrary, the model results for the case of exoplanet XO-2 b are in good agreement with the available observations. In addition, we note that the differential transit depth reported for the HD 209458 b Na line based on the medium resolution observations with HST/STIS [2, 6] appears to be inconsistent with the low resolution observations [5, 4] (Fig. 4). Given these results we discuss other possible scenarios, such as changes in the elemental abundances, changes in the temperature profiles, and the possible presence of clouds, which could potentially explain the observed HD 209458 b alkali properties.

References

[1] Beaulieu, J. P., et al., 2010. MNRAS 409, 963.

[2] Charbonneau, D.,et al., 2002.Ap.J. 568, 377.

[3] Crossfield, I. J. M., et al., 2012. Ap.J. 752, 81.

[4] Deming, D., et al. 2013. ApJ. 774, 95.

[5] Knutson, H. A., et al., 2007. Ap.J., 655,564

[6] Sing, D. K., et al., 2008b. Ap.J., 686, 658.

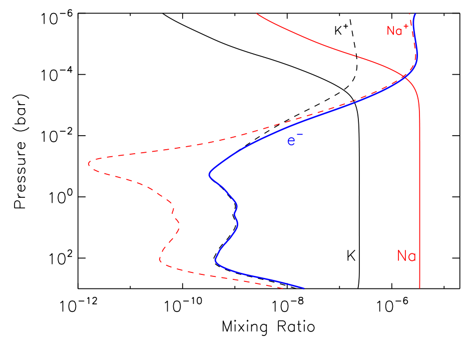

Figure 1: Vertical profiles for the mixing ratios of Na (red) and K (black) from our calculations. Solid lines show the neutral compound and dashed lines the corresponding ion. The total electron mixing ratio profile is presented by the blue line.

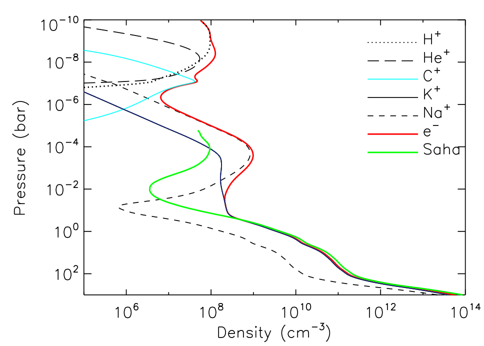

Figure 2: Calculated densities of different ions and the resulting electron density (solid red line) assuming charge balance, in the atmosphere of HD 209458 b. The green line presents the electron density assuming thermal ionization only.

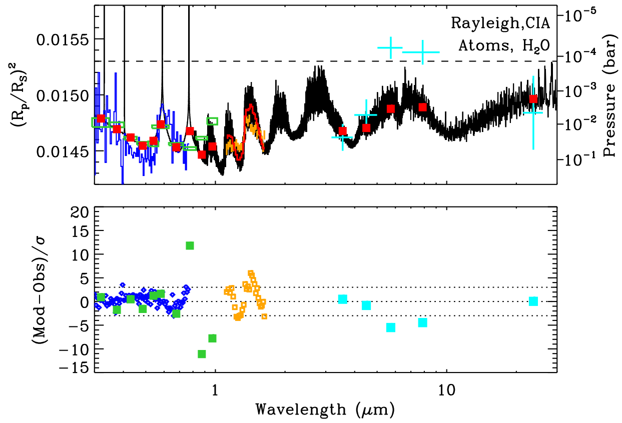

Figure 3: Transit depth calculation in the atmosphere of HD 209458 b. In the top panel, the black line is the transit depth based on our calculations including Na and K, Rayleigh scattering by H_2, collision induced absorption, and H_2O. The green boxes present the results from [4] from the re-analysis of the HST/STIS observations of [5], while the blue histogram presents the HST/STIS observations [6]. The orange lines present the HST/WFC observations [4]. The cyan cross are the Spitzer transit depth measurements from IRAC [1] and MIPS [3]. The red points and line present our calculations mapped to the resolution of the observations. The dashed line presents the cloud transit depth required to match the differential transit observations (see Fig.4), and demonstrates the inconsistent results between the medium and low resolution analyses of the STIS data. In the lower panel we present the residuals between model and observations in terms of the 1 sigma level of uncertainty in the observations. The blue points correspond to the comparison with the [6] data, the green and orange squares to the [4] data from STIS and WFC data, respectively, and the cyan squares to the Spitzer observations.

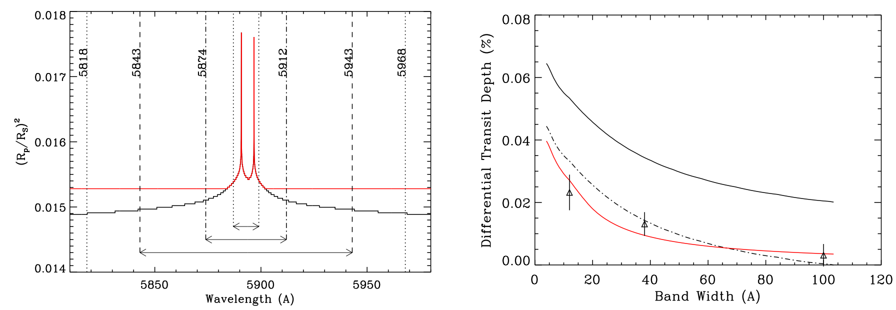

Figure 4: Top: Transit depth spectrum around the Na line core. The black line corresponds to the clear atmosphere case and the red line to the case with a cloud deck. The vertical broken lines designate the bands used by [2] for the investigation of the differential transit depth assuming band widths of 12, 38, and 100 Å(arrows). Bottom: Differential transit depth calculation performed by assuming different band widths around the Na core and comparing with the reference region bound between 5818 and 5968 Å. The solid line is the clear atmosphere case assuming the Na profile from our photochemical model, while the dash-dotted line corresponds to the clear atmosphere case but homogeneously shifted downwards by $\sim$0.02%. The red line corresponds to the differential transit depth assuming a cloud deck with a transit depth of $\sim$0.0153 around the sodium core. The symbols with the associated error bars are the differential transit depth values from the [2] HST/STIS observations.