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On the transit Ly-α signatures of terrestrial planets in the habitable zones of M dwarfs

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We model the transit signatures in the Lyman-alpha (Lyα) line of an Earth-sized planet orbiting in the habitable zone of the M dwarf GJ 436. We estimate the transit depth in this line for an exo-Earth with three types of atmospheres: a hydrogen-dominated atmosphere, a nitrogen-dominated atmosphere, and a nitrogen-dominated atmosphere with an amount of hydrogen equal to that of the Earth. For all types of atmospheres, we calculate the in-transit absorption a planetary transit would produce in the stellar Lyα line. We use a Direct Simulation Monte Carlo (DSMC) code to model the planetary exospheres and corresponding absorption. The code allows to include several species and traces neutral particles and ions. It includes several ionization mechanisms, such as charge exchange with the stellar wind, photo- and electron impact ionization, and allows to trace particles collisions. At the lower boundary of the DSMC model we assume an atmosphere density, temperature, and velocity obtained with a hydrodynamic model for the lower atmosphere. We show that for a small rocky Earth-like planet orbiting in the HZ of GJ 436 only the hydrogen-dominated atmosphere is detectable with the Space Telescope Imaging Spectrograph (STIS) on board the Hubble Space Telescope (HST). Neither a pure nitrogen atmosphere nor a nitrogen-dominated atmosphere with an Earth-like hydrogen concentration in the upper atmosphere are detectable. In this case, the main source of atmospheric hydrogen is charge exchange with the stellar wind. Our results indicate that Earth-like terrestrial planets with hydrogen-dominated atmospheres can be observed in the Lyα line if they orbit very nearby stars, or if several observational visits are available.