INVESTIGATING THE UNEXPECTED DEPLETION OF METHANE IN CLOSE-IN SUB-NEPTUNES: FROM HUBBLE TO JAMES WEBB SPACE TELESCOPE OBSERVATIONS

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ABSTRACT

With no equivalent in the Solar-System, Sub-Neptunes and Super-Earths are the most numerous categories of planet discovered so far, but our understanding of their composition remains incomplete and, in particular, the unexpected depletion of methane in close-in atmospheres is still difficult to explain. Temperate to warm Sub-Neptunes, with an extended atmosphere orbiting nearby bright stars are excellent targets for transmission spectroscopy. In anticipation of upcoming James Webb Space Telescope observations of these targets, it is essential to perform atmospheric reconnaissance with the Hubble Space Telescope (HST), and, discriminate between a primary clear atmosphere, and, a cloudy or hazy one, for which no molecular absorbers can be detected. In the case of a clear atmosphere, it is crucial to determine which molecule is causing the detected features, to better constrain formation, and, evolution models. In this matter, it is still unclear whether water or methane should dominate the spectrum around 1.4 μm in HST WFC3 G141 wavelength range. For planets with temperatures below 600K, methane should be the main absorber around 1.4 μm, even though water could be more abundant. This result disagrees with HST WFC3 G141 observations on K2-18 b (283K) for which water was detected by two independent studies. We investigated this possible methane depletion for a new Sub-Neptune target, LTT-3780 c. This planet (2.42$R_{\oplus}$, 6.29$M_{\oplus}$, 363K) is a good target for transmission spectroscopy as its Transmission Spectroscopy Metric (TSM) reaches 112.5, more than 2.5 times the one of K2-18b. Using Exo-REM, a radiative-convective model, we simulated the atmosphere of LTT-3780 c, varying the cloud coverage and the metallicity. We showed that methane is the main absorbing species for low metallicity, while water takes over for metallicity above 300 times solar. It is possible to identify the main absorber and to assess the cloudiness of such a planet within the Hubble near-infrared wavelength range. However, one can wonder if the Hubble WFC3 is the best-suited instrument in the era of the JWST to discriminate molecular features. Using the NIRSpec G395 wavelength range, between 2.8 to 5μm, we show that methane could be detected with stronger atmospheric features.

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