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Infrared Spectroscopy of the Exoplanets CoRoT-2b, XO-1b, HD 209458b Using the Wide-Field Camera-3 On the Hubble Space Telescope

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Exoplanetary transmisison spectroscopy requires exquisite precision of measurement. Due to telluric water vapor, reliable detections of water vapor in exoplanets is practical only with space-based instruments, such as the Wide Field Camera 3 (WFC3) on the Hubble Space Telescope (HST). With this work, we present HST WFC3 grism spectroscopy of two hot Jupiters, HD209458b and XO-1b in transit, and one very hot Jupiter, CoRoT-2b, in secondary eclipse, in the wavelength range of 1.1-1.7 μm. We search for water absorption or emission in the infrared spectra of these exoplanetary atmospheres. Until recently, results from observations in other infrared bands using both space-based and ground-based telescopes have given either conflicting results, due to differing analysis methodologies, or unclear results, due to model degeneracies left unbroken by insufficient data. Our new high-precision spectra, using WFC3 in both spatial-scan and non-scan mode, resolve some of these ambiguities.

A major source of uncertainty in results from NICMOS was the strong instrumental signatures that are difficult to reliably remove. For the observations of CoRoT-2b, we are able to correct the much weaker WFC3 systematics to significantly better precision than was possible with NICMOS. Further, the observations of HD209458b and XO-1b use the new spatial scanning mode for greater photon-collecting efficiency. We introduce a new analysis technique that derives the exoplanetary transmission spectrum without the necessity of explicitly decorrelating instrumental effects, and achieves photon-limited precision even at the high exposure levels collected in spatial scan mode. We validate our method by injecting a synthetic signal into an early stage of the analysis, and recovering it at the correct amplitude. We evaluate our precision using two independent error analyses to measure "red" noise. Both methods indicate that our results are nearly photon-limited at a resolving power of $\lambda/\delta\lambda \sim 70$.

In presenting these three planetary spectra, we show some of the first clearly featured exoplanetary spectra as seen with HST WFC3, with a definitive detection of the 1.4 μm water band. The water absorption we measure in transit is considerably weaker than claimed in some previous investigations. We demonstrate that the spectrum is not contaminated by stellar activity. Our current detections allow us to complete the puzzle presented by previous datasets and analyses and characterize the nature of the atmospheres of these extreme worlds.