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Unlocking JWST/NIRISS Spectra with Cross-Correlation: Detection of CO & H_2O in WASP-18b and a Better Constraint of C/O Ratio

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Spectroscopic observations of ultra-hot Jupiters (UHJs) are a primary means of understanding their origins and the formation mechanisms of their atmospheric structures. The James Webb Space Telescope (JWST), with its broad spectral coverage and high-precision instrumentation from near- to mid-infrared wavelengths, provides an ideal opportunity to probe the chemistry and physics in these extreme atmospheres using techniques such as transmission and emission spectroscopy. The JWST Early Release Science (ERS) program observations with NIRISS-SOSS provided excellent constraints for the dayside atmosphere of the UHJ WASP-18b (Coulombe et al. 2023). However, a clear carbon monoxide (CO) signal was not detected, which limited the constraints on the C/O ratio.

In this work, we apply cross-correlation techniques to the WASP-18b NIRISS SOSS dataset, successfully extracting reliable signals of CO at 4.41σ significance and H_2O at 3.39σ, where CO was unseen in previous analyses. Building on these unambiguous detections, our subsequent retrieval analysis significantly improves the constraints on atmospheric abundances, leading to a better-constrain on the C/O ratio for WASP-18b.

Our work demonstrates that the cross-correlation technique can effectively extract molecular signals from medium-resolution JWST data, enhancing the detection sensitivity for molecular species and showing the great potential of applying this method to JWST's medium-resolution spectra. By revisiting JWST archival data with this method, we can achieve a more comprehensive survey of planetary atmospheric chemistry, thereby placing precise constraints on key parameters such as planetary metallicity and C/O ratio. This work will not only maximize the scientific return of the JWST mission but also establish a new methodological foundation for theories on planetary population diversity and formation mechanisms.

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