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Direct Imaging Spectroscopy of Substellar Companions with JWST

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JWST has opened the door to spectroscopy of directly imaged exoplanets beyond 3 microns, offering a new landscape for measuring their fundamental properties, assessing atmospheres, and using them to test planet formation theories. Direct imaging of exoplanets has revealed a population of Jupiter-like objects that orbit at large separations (~ 10 - 100 AU) from their host stars. These planets, with masses of ~ 2 - $14 M_{\text{Jup}}$ and temperatures of ~ 500 - 2000 K, remain a mystery for the two main planet formation models—core accretion and gravitational instability. Observations that probe elemental abundances in the atmospheres of these young gas giants can shed light on their formation. We present results from cycle 1 programs that have pioneered the use of the NIRSpec IFU to obtain higher resolution spectra of substellar companions close to Sunlike stars. For the brown dwarf companion HD 19467 B, NIRSpec IFU G395H spectra show detections of CO, CO₂, CH₄, and H₂O. We forward model the moderate resolution ($R \sim 2,700$) spectra from 3-5 microns using custom atmospheric model grids to constrain the abundances of these molecules, the C/O ratio, and non-equilibrium chemistry. For the multi planet system YSES-1, with two young Jovian planets at wide separations from a Sunlike star, we have obtained one of the most comprehensive datasets of a multi-planet system ever imaged with spectral coverage of both companions from 1-12 microns using NIRSpec and MIRI, revealing many spectral features and allowing direct spectral comparison of sibling planets in unprecedented detail. These spectra show a direct detection of silicate clouds in the 6 M_{Jup} exoplanet, YSES-1 c. Ongoing detailed atmospheric modeling will better constrain C/O ratios, non-equilibrium chemistry, and cloud composition, increasing our understanding of substellar atmospheres and formation. These observations have demonstrated the superb capabilities of the NIRSpec IFU to achieve detailed spectral characterization of substellar companions directly seen even at high contrast close to bright host stars.