Forecasted Results of JWST's NIRCam Instrument for Transiting Planet Science

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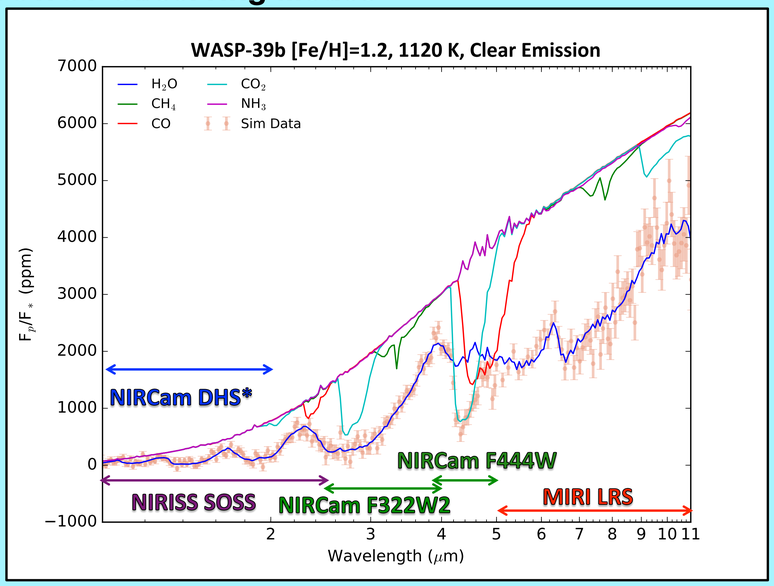
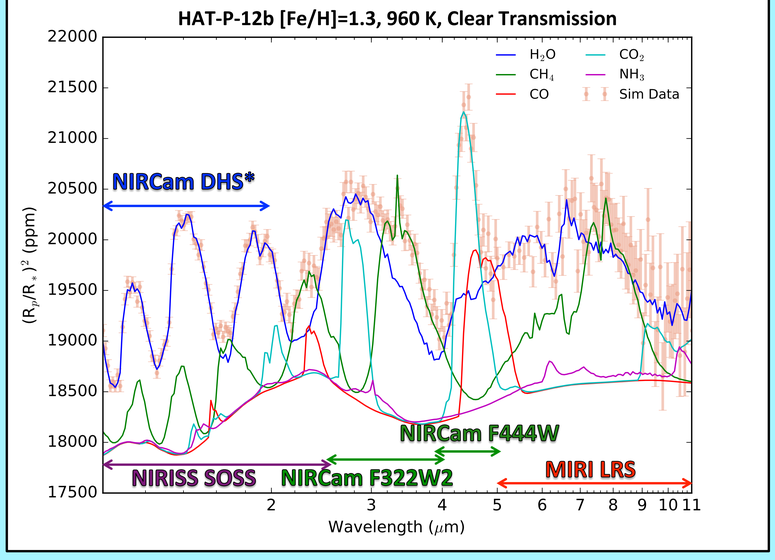
1 Introduction

The James Webb Space Telescope instrument suite will enable high precision spectroscopy at wavelengths longer than the Hubble Space Telescope (1.7 μm). The additional wavelength coverage will add CO, CO_2, CH_4, and NH_3 abundance constraints to the H_2O mixing ratios already measured by HST. We use the CHIMERA model retrieval suite[1] with simulated JWST observations[2] to assess the relative value of different modes and their expected science return.

2 JWST Observing Modes

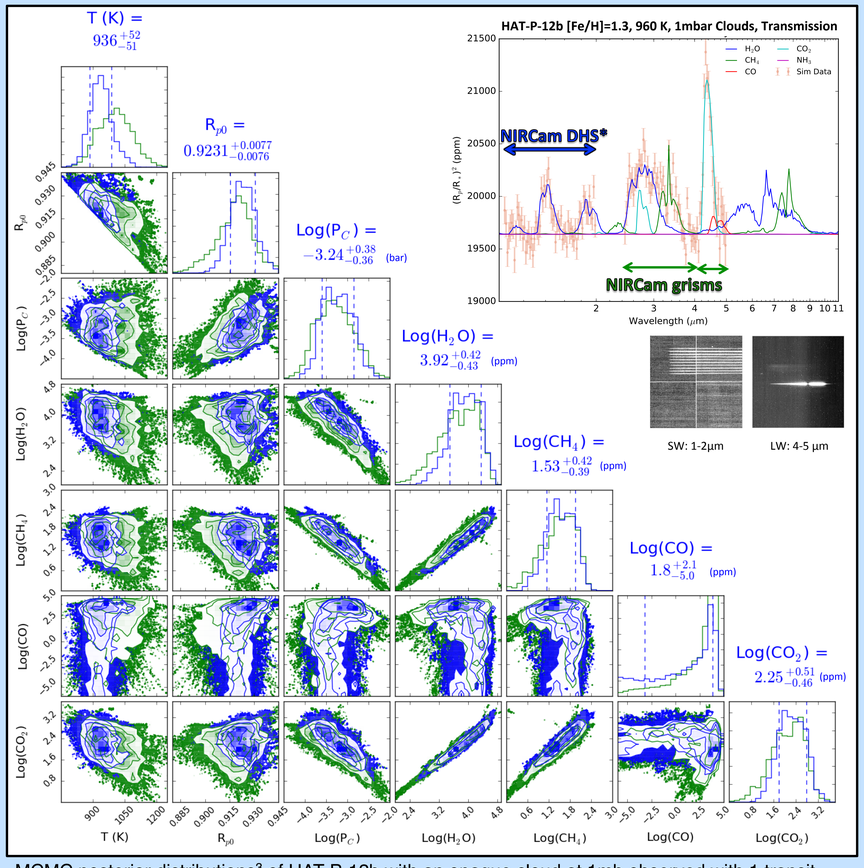


Simulated Data for 4 JWST observations (1 eclipse each) and relative contributions of high opacity molecules to the emission spectrum of WASP-39b. NIRCam's 2.5-5 μm wavelength coverage is critical to detecting carbon-bearing molecules.
*The Dispersed Hartmann Sensor (DHS), if it becomes an approved mode, obtains spectra simultaneously with the F322W2 and F444W NIRCam modes



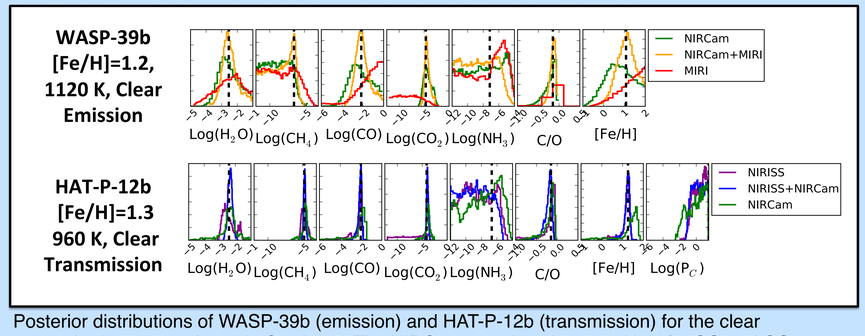
Simulated Data for 4 JWST observations (1 transit each) of HAT-P-12b in transmission for a clear atmosphere. HAT-P-12b is cool enough that CH_4 becomes detectable in all instruments.

3 Scientific Benefit of the DHS



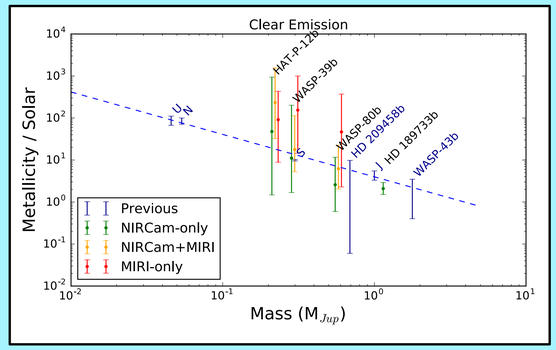
MCMC posterior distributions[3] of HAT-P-12b with an opaque cloud at 1mb observed with 1 transit with each of the NIRCam grisms and simultaneous DHS mode (blue) compared to the NIRCam grisms alone (green). The DHS, if it becomes an approved mode, improves constraints on the abundance of water and temperature and comes for free with any NIRCam grism observation. This in turn improves constraints on carbon dioxide because of the correlations between molecules. The inset plot shows the wavelengths covered by the DHS and long wavelength grisms. Example images from laboratory testing show how the short wavelength and long wavelength detectors can be run simultaneously for a single object.

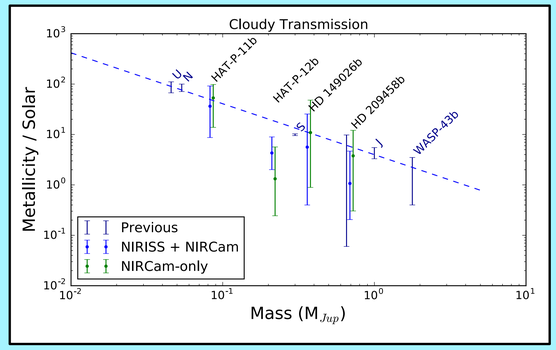
4 NIRCam Combined with MIRI and NIRISS

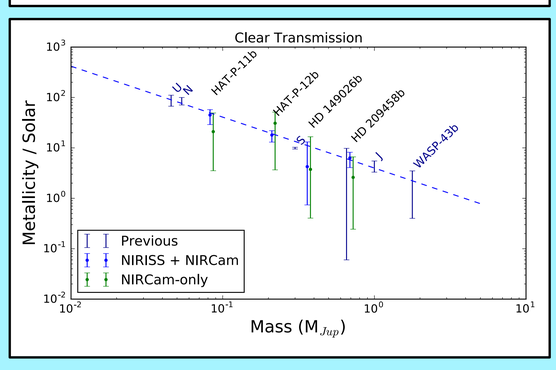


Posterior distributions of WASP-39b (emission) and HAT-P-12b (transmission) for the clear atmospheric spectra shown in Section 3. The NIRCam wavelengths are critical for CO and CO_2 abundances. As with the DHS in Section 3, MIRI and NIRISS add to the NIRCam instrument by improving H_2O and CH_4 constraints, which in turn reduce uncertainties on CO, CO_2 and the metallicity.

5 Predicted Mass-Metallicity Relations







We prescribe a linear mass-metallicity relationship in log space based upon literature measurements of Solar System bodies and hot Jupiters[4,5] and assume chemical equilibrium to estimate the initial abundances. We then retrieve the abundances and metallicities for 1 transit in each mode for each system with an MCMC fit. The highest precision metallicities are obtained by using NIRISS and NIRCam together for transmission but these measurements can be strongly affected by clouds.

6 Conclusions

The NIRCam grisms on JWST will be important tools in constraining the abundances of CO and CO_2 in exoplanet atmospheres. If the DHS mode becomes an approved mode, observers can simultaneously obtain short wavelength data with the long wavelength grisms to improve the measurement of the H_2O and other mixing ratios. Combining the NIRCam grisms with the DHS, NIRISS and MIRI modes will provide unprecedented insights about planet composition. This can in turn be used to understand planet formation and evolution of a wide variety of planets outside the solar system.

7 References

[1] Line et al. 2013, ApJ 775, 135, 2013; Line et al. ApJ 779, 3, 2013
[2] Greene et al., ApJ 817, 17, 2016
[3] Foreman-Mackey et al., PASP 125, 306, 2013.
[4] Kreidberg et al., ApJL, 793, L27, 2014
[5] Line et al., ApJ, submitted 2016