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EMULATING JWST EXOPLANET TRANSIT OBSERVATIONS IN A TESTBED LABORATORY EXPERIMENT

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Abstract. The transit technique is used for the detection and characterization of exoplanets. The combination of transit and radial velocity (RV) measurements gives information about a planet's radius and mass, respectively, leading to an estimate of the planets density (Borucki et al. 2011) and therefore to its composition and evolutionary history. Transit spectroscopy can provide information on atmospheric composition and structure (Fortney et al. 2013).

Spectroscopic observations of individual planets have revealed atomic and molecular species such as H2O, CO2 and CH4 in atmospheres of planets orbiting bright stars, e.g. (Deming et al. 2013). The transit observations require extremely precise photometry. For instance, Jupiter transit results to a 1% brightness decrease of a solar type star while the Earth causes only a 0.0084% decrease (84 ppm). Spectroscopic measurements require still greater precision $<$30ppm.

The Precision Projector Laboratory (PPL) is a collaboration between the Jet Propulsion Laboratory (JPL) and California Institute of Technology (Caltech) to characterize and validate detectors through emulation of science images. At PPL we have developed a testbed to project simulated spectra and other images onto a HgCdTe array in order to assess precision photometry for transits, weak lensing etc. for Explorer concepts like JWST, WFIRST, EUCLID.

In our controlled laboratory experiment, the goal is to demonstrate ability to extract weak transit spectra as expected for NIRCam, NIRIS and NIRSpec. Two lamps of variable intensity, along with spectral line and photometric simulation masks emulate the signals from a star-only, from a planet-only and finally, from a combination of a planet + star. Three masks have been used to simulate spectra in monochromatic light. These masks, which are fabricated at JPL, have a length of 1000 pixels and widths of 2 pixels, 10 pixels and 1 pixel to correspond respectively to the noted above JWST instruments (see Fig. 1. Left).

From many-hour long observing sequences, we obtain time series photometry with deliberate offsets introduced to test sensitivity to pointing jitter and other effects. We can modify the star-planet brightness contrast by factors up to 10^4:1. With cross correlation techniques we calculate positional shifts which are then used to decorrelate the effects of vertical and lateral offsets due to turbulence and instrumental vibrations on the photometry (see Fig. 1. Right).

Using Principal Component Analysis (PCA), we reject correlated temporal noise to achieve a precision lower than 50 ppm (Clanton et al. 2012). In our current work, after decorrelation of vertical and lateral offsets along with PCA, we achieve a precision of $\sim$20 ppm. To assess the photometric precision we use the Allan variance (Allan 1987). This statistical method is used to characterize noise and stability as it indicates shot noise limited performance.

Testbed experiments are ongoing to provide quantitative information on the achievable spectroscopic precision using realistic exoplanet spectra with the goal to define optimized data acquisition sequences for use, for example, with the James Webb Space Telescope.

Keywords: Exoplanet transits, spectroscopy, photometry, testbed, laboratory, detectors, simulation masks, data analysis

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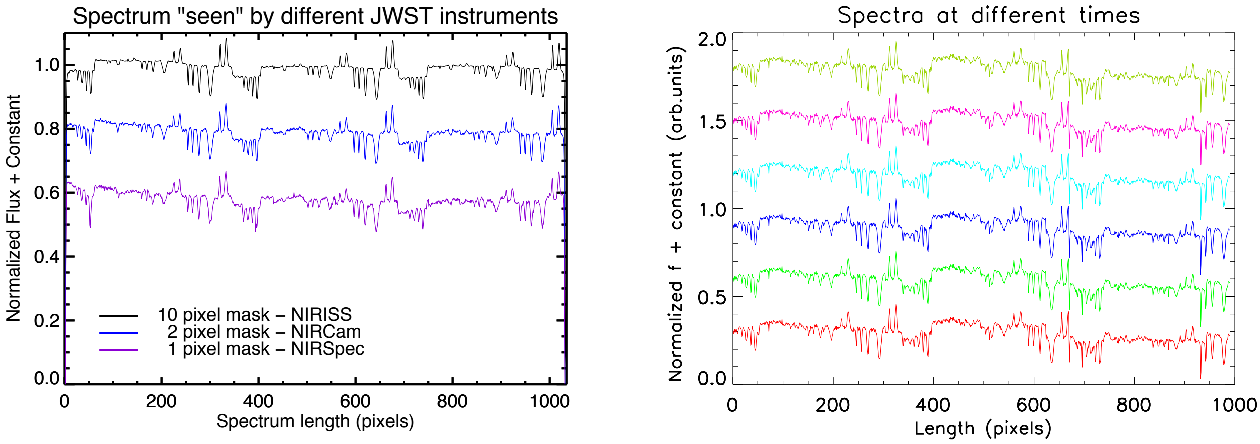

Fig. 1. Left: The detected spectrum, emulated by the three diferent masks which correspond respectively to the three following JWST instruments: NIRISS, NIRCam, NIRSpec. **Right:** Six of the synthetic spectra, produced by the 10-pixel width mask, at different times (shifted for clarity). The spectrum length is 1000 pixels. The features represent emission and absorption lines. After decorrelation of vertical and lateral offsets we achieve a precision <30 ppm.

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