National Aeronautics and Space Administration

Optimizing detection and characterization of exoplanets in high-contrast Imaging data

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Program: FY22 SURP

Strategic Focus Area: Extra-solar planets and star and planetary formation

Objectives: To improve the high contrast performance of full pupil and Aperture Masking Interferometry (AMI) mode of the NIRISS instrument onboard the James Webb Space Telescope (JWST) and compare it with other techniques to find and characterize exoplanets around young stars. We explore under which conditions different techniques (e.g. AMI, Kernel Phase Imaging, or point-spread-function subtraction) provide superior contrast. We build on our Bayesian approach developed during a R&TD_ESI proposal (Ygouf & Rocha, FY 2020) to model observations with NIRISS taking advantage of wavefront sensing and control data. Our code estimates aberrations and the astrophysical object scene simultaneously (Ygouf et al. 2013) providing robust determination of source properties and uncertainties. **Background:** **D**irect detection of planets provides estimates of temperature, luminosity, and composition, which combined with dynamical masses, and system ages, place fundamental constraints on models of formation and evolution. Access to orbital radii 10-50 AU are crucial to study gas giant planets in formation to compare with gas and ice giants in our Solar System (requiring < 0.1" spatial resolution at the distance of nearby star-forming regions > 100 pc). The AMI mode on NIRISS provides spatial resolution < 0.5 λ/D (0.06" at 3.6 microns on the 6.5 meter JWST). We demonstrate the benefits of our methodology by comparing to other techniques, enable new scientific findings, and strength collaborations with the University of Michigan.

Approach and Results: We combine JWST instrument simulator, with Multinest posterior inference, and fitting code of Ygouf et al. (2023) yielding:

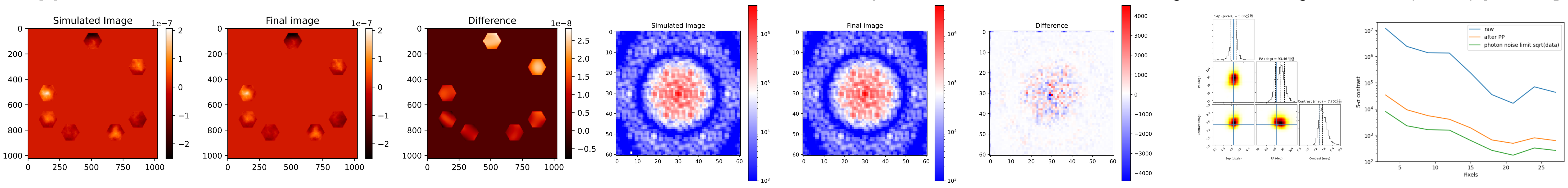

Figure 1: NIRISS AMI: Far left – simulated pupil with realistic noise, best fit model, and pupil difference in meters; middle – simulated image with realistic noise, best fit model, and difference in counts; far right – recovered source parameter probability density functions with truth values indicated, realized contrast curves compared to the photon noise limit.

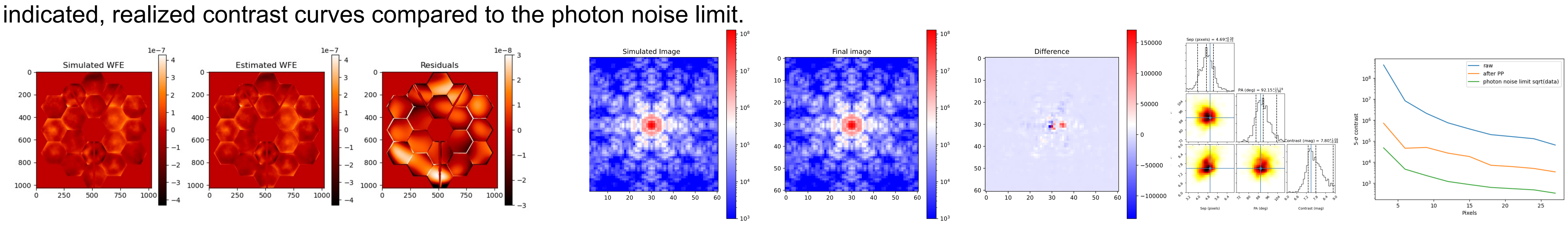

Figure 2: NIRISS FULL PUPIL: Far left – simulated pupil with realistic noise, best fit model, and pupil difference in meters; middle – simulated image with realistic noise, best fit model, and difference in counts; far right – recovered source parameter probability density functions with truth values indicated, realized contrast curves compared to the photon noise limit.

Significance/Benefits to JPL and NASA: 1) Builds JPL competitive position for access to JWST; 2) Strengthens partnership with the University of Michigan; 3) Makes more efficient use of NASA/ESA/CSA JWST observing time, potentially saving x2 in observing time for some programs; and 4) Provides algorithmic heritage which can be repurposed to improve CGI performance on the Roman Space Telescope.

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