National Aeronautics and Space Administration

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

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Program: FY23 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 our results 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 NIRISS observations 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 10-100 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 strengthen collaborations with the University of Michigan.

Approach and Results: Combining JWST instrument simulations, the Multinest posterior inference, and a fitting code (cf. Ygouf et al., 2023): yielding:

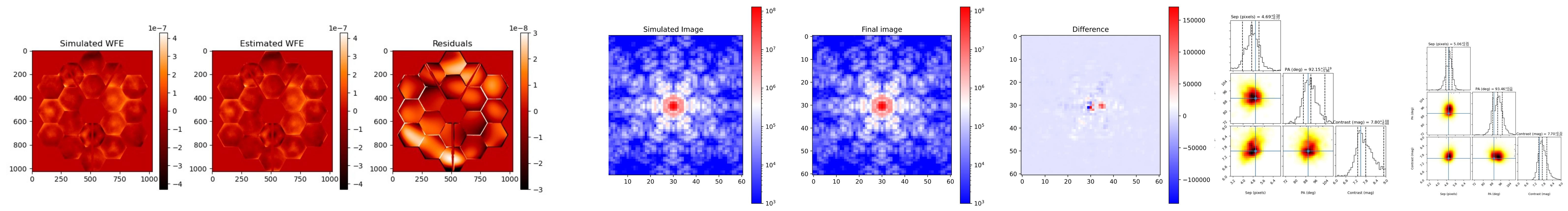

Figure 1: NIRISS: Left 3 panels – simulated full pupil with realistic noise, best fit model, and pupil difference in meters; middle 3 panels – simulated full pupil image with realistic noise, best fit model, and difference in counts; right 2 panels – recovered source parameter probability density functions with truth values indicated for both full pupil and AMI (farthest right).

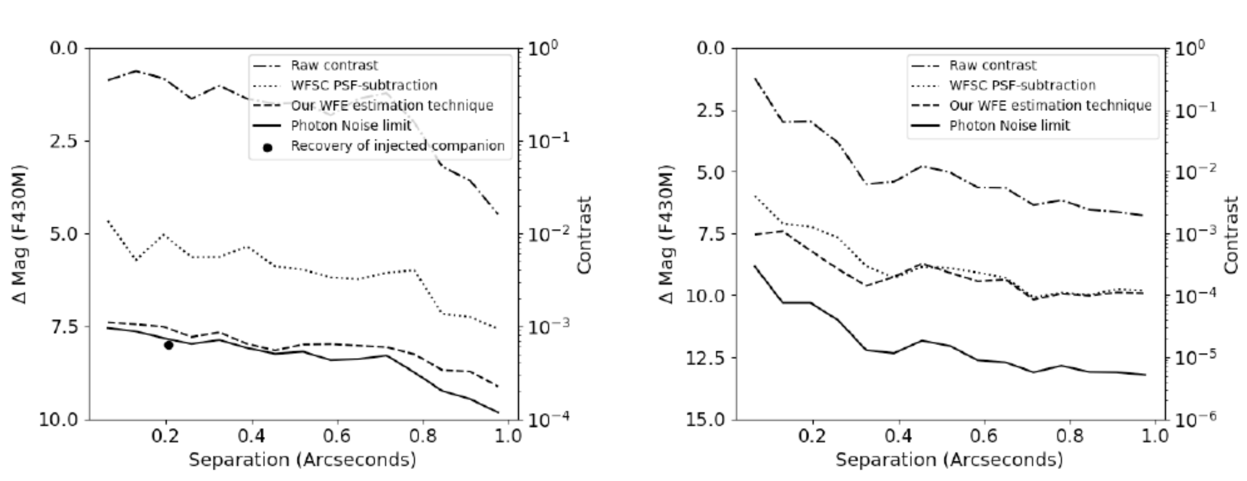

Figure 2: Left is 5 sigma contrast in magnitudes relative to the host star for AMI comparing the raw PSF to standard PSF-subtraction, our estimation technique, and the photon noise limit (with injected companion parameters indicated); Right is the full pupil case where our technique improves upon PSF subtraction within 0.4" (from De Furio et al. submitted).

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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www.nasa.gov

Clearance Number:
Poster Number: RPC# SP21016
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Publications:

De Furio et al. (submitted; response to referee nearly done)

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