WFIRST: REALISTIC SIMULATIONS OF CORONAGRAPHIC OBSERVATIONS

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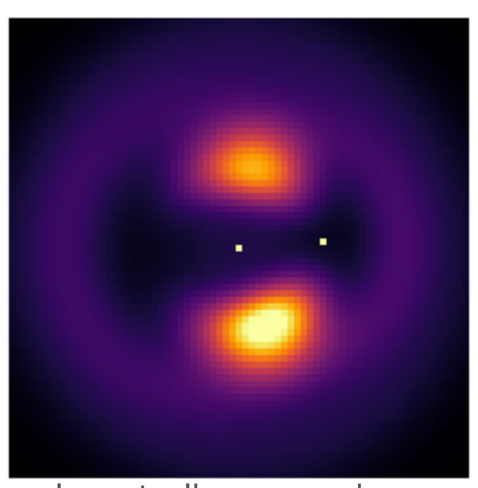
The Coronagraph and Rapid Imaging Spectrograph in Python (*crispy*)

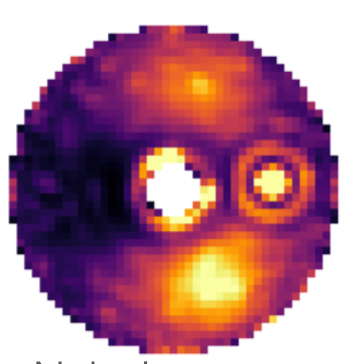
crispy (Rizzo et al. 2017) is an open-source Python package for simulating high-contrast imaging and integral field spectroscopy. The package is presently focused on space-based high-contrast instruments and mission designs. It allows the user to propagate an input flux map of the science scene all the way down to the focal plane, using pre-computed libraries of coronagraph point-spread functions. It then models the detector readout, with a stochastic approach that approximates the photon-counting operation. Finally, because the focal plane is constructed for sequences of spatial speckle realizations, the products can be post-processed in a realistic way. Everyone can see, use, and contribute to the development of ***crispy*** at:

https://github.com/mjrfringes/crispy

Software outline

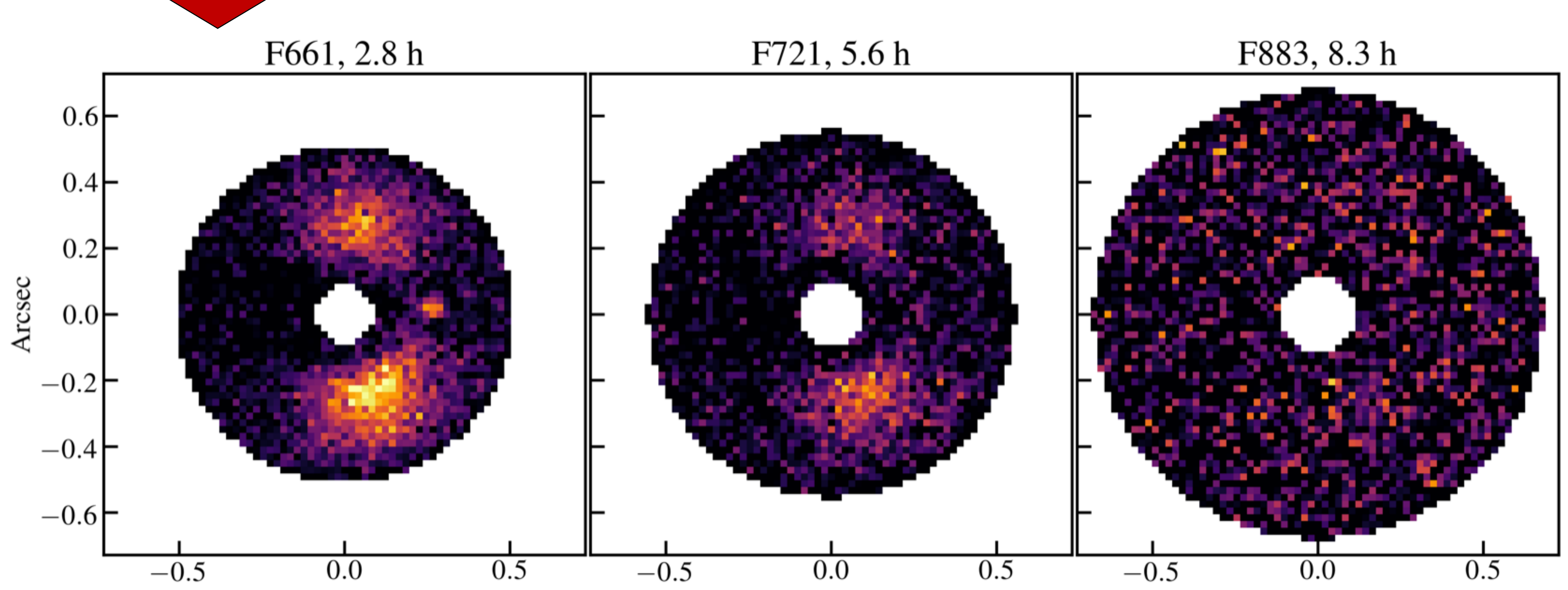


Input slice or cube



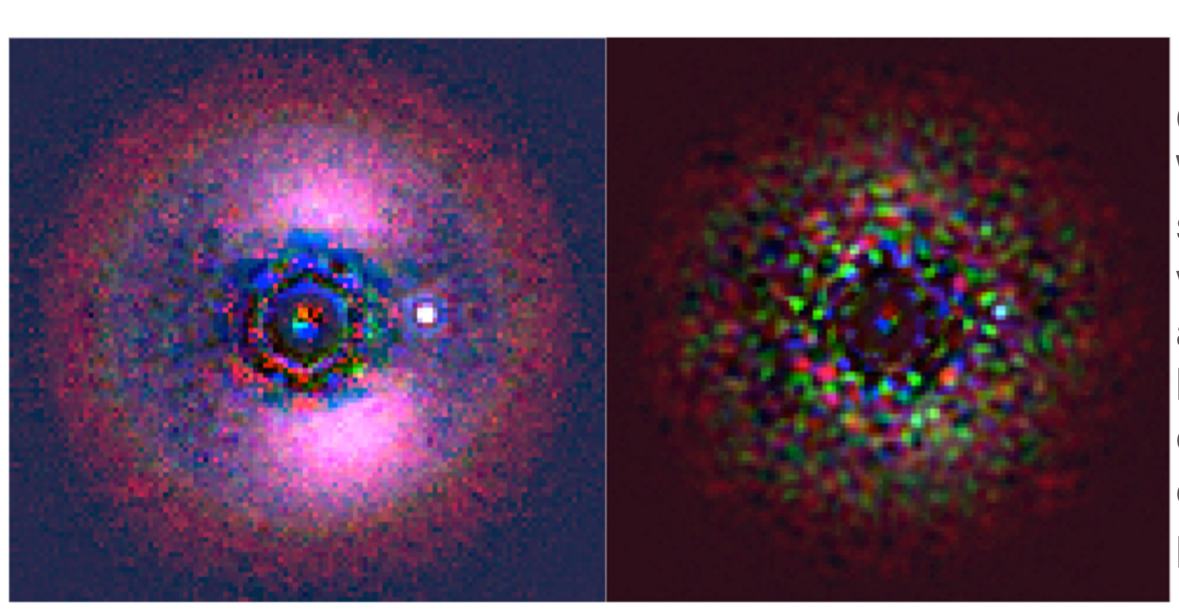
Noiseless map

1. Pick a target system of interest and a star-only reference.
   - Small cube with a planet and two dust resonant structures (left)
   - Full "Haystacks cubes" (Roberge et al 2017)
   - Input your own map
2. Propagate the target through a coronagraph/starshade model for multiple realizations of the speckle field: construct focal plane array sequences.
   - WFIRST Hybrid-Lyot Coronagraph
   - WFIRST Shaped Pupil Coronagraph
   - WFIRST starshade (simplified model)
3. Apply fully-parametric detector readout model as many times as needed to reach desired exposure time.
4. Repeat on reference star, or alternative at appropriate frequency
5. Apply post-processing routine.
   - Reference differential imaging



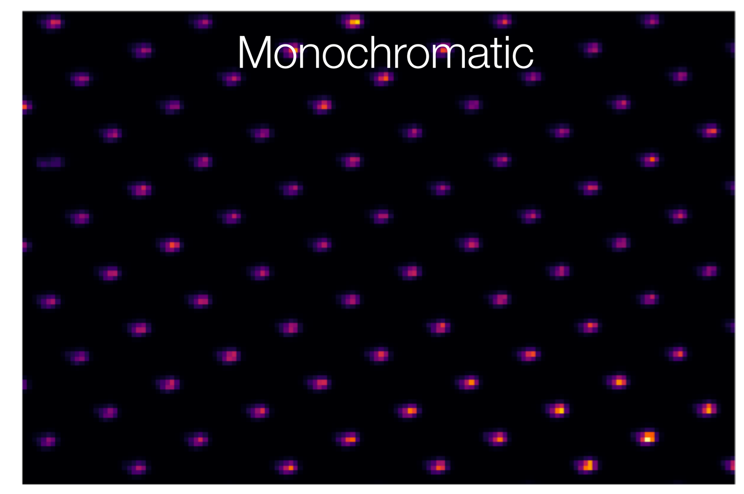
Noisy, PSF-subtracted averages for WFIRST HLC bands

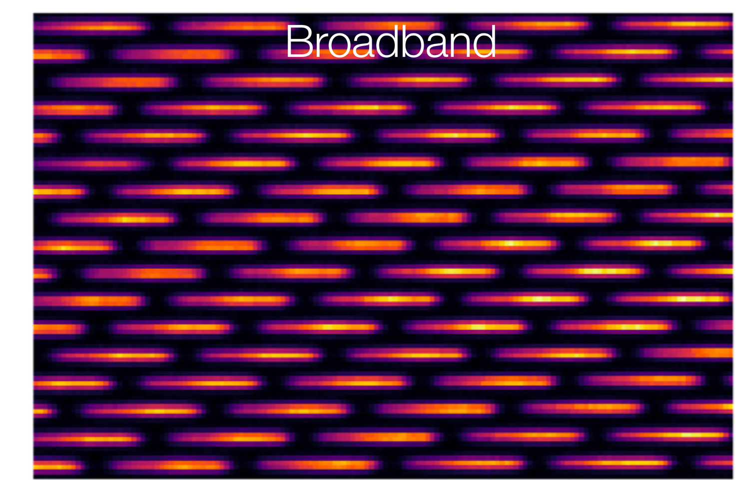
Study impact of various levels of noise

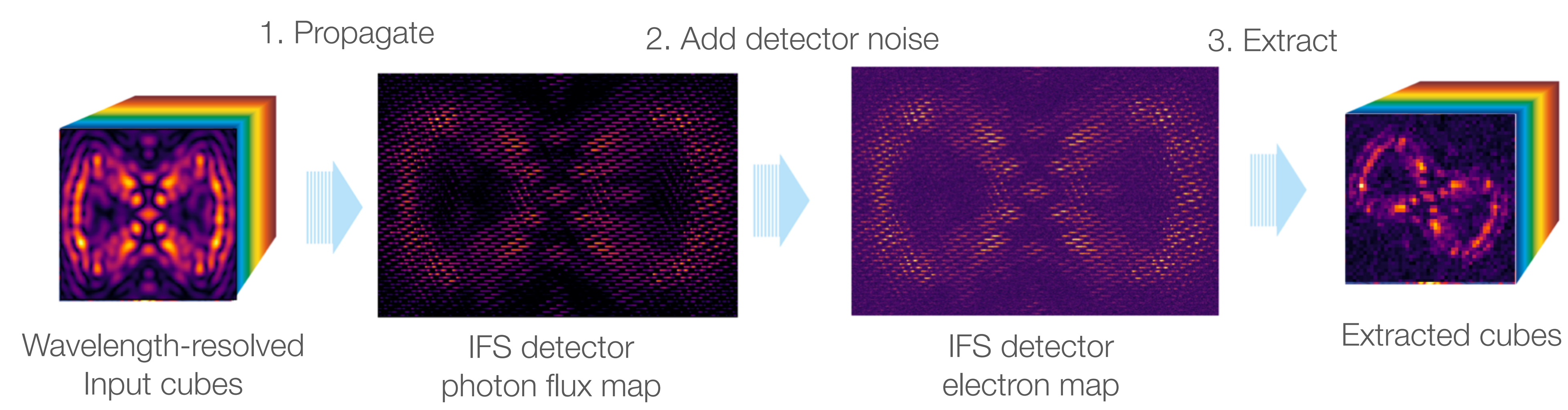


Composite RGB images using ***crispy*** WFIRST Shaped pupil disk mode simulations with two levels of r.m.s wavefront errors: 10 picometers (left) and 100 picometers (right). This can help assess the impact of certain types of noise on the system, put contraints on stability, and help prepare for new post-processing methods.

Integral field spectrograph model with *crispy*

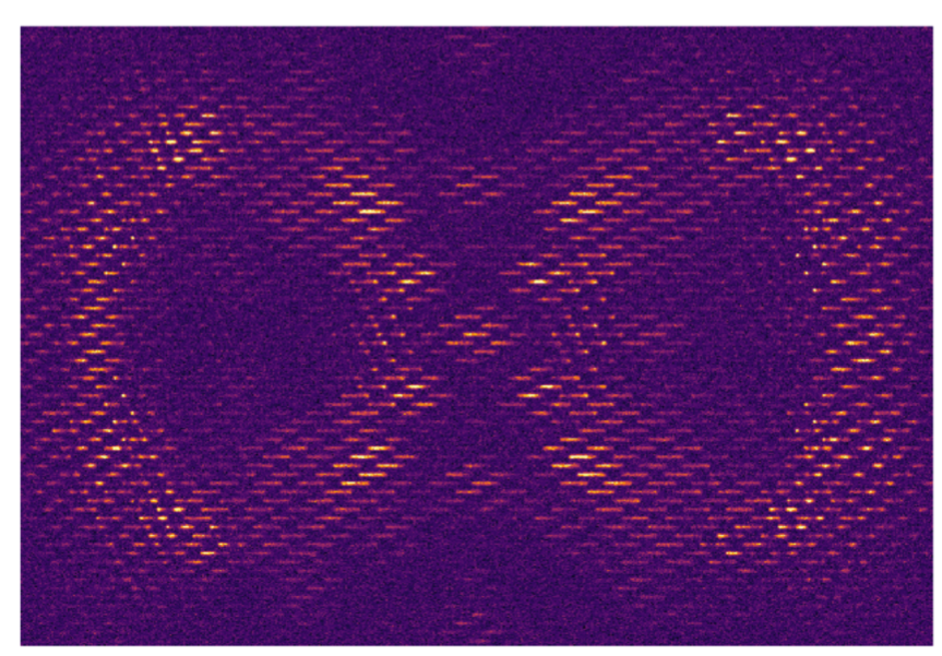


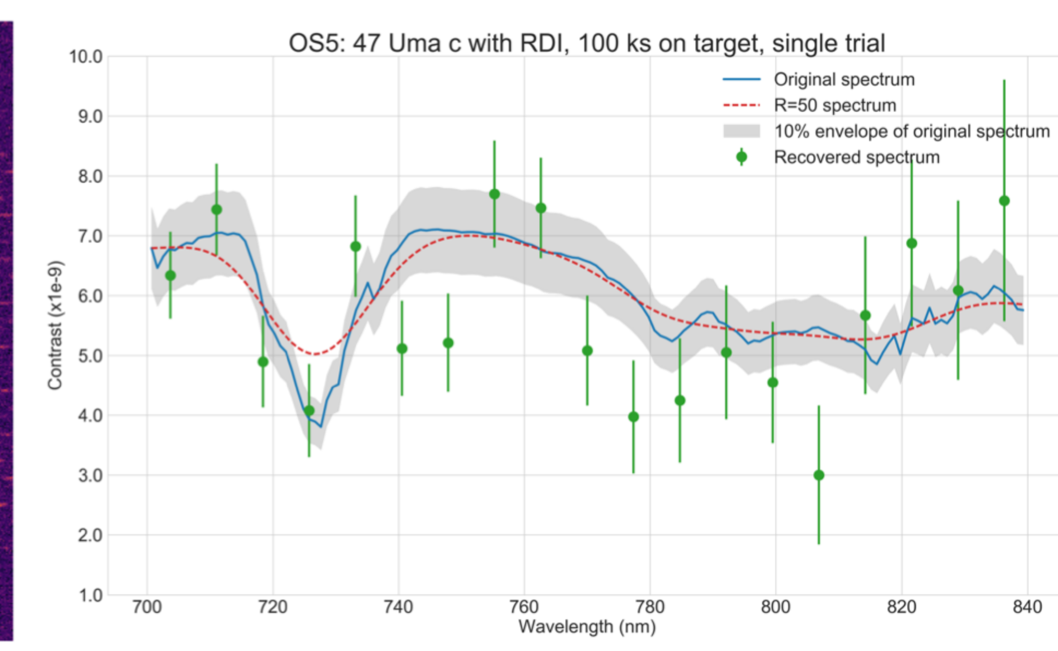




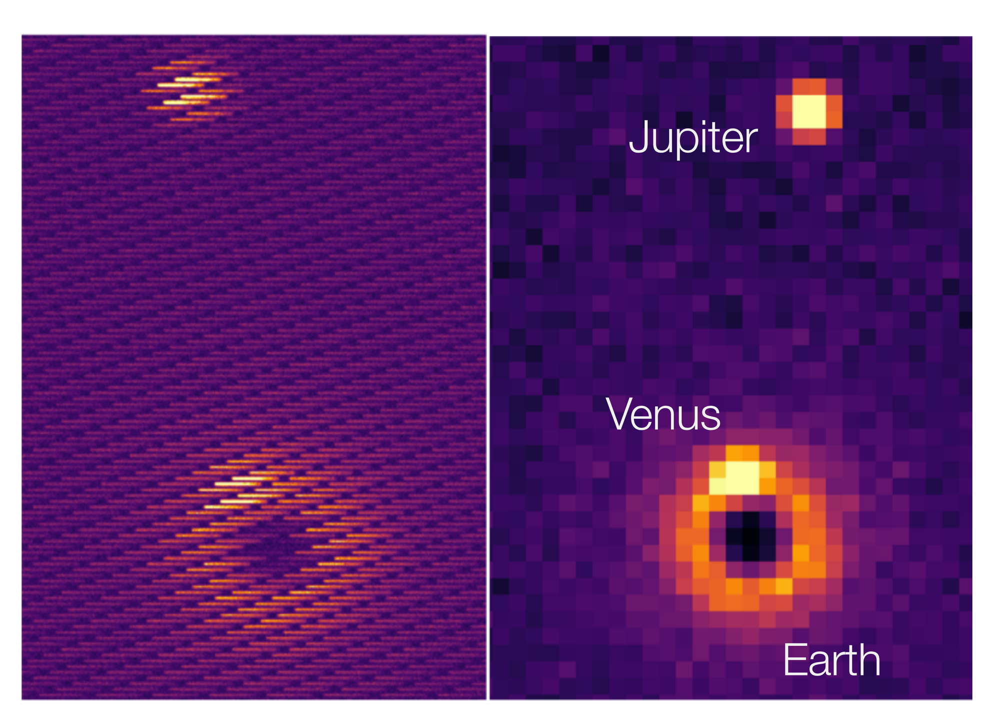
Integral field spectrograph results

Below: Simulation of the WFIRST Integral Field Spectrograph (Rizzo et al. 2017). Each line in the image (left) corresponds to the microspectrum of one single spatial element of the focal plane. This is a simulation of ~27h exposure (stack of 1000 images of 100 seconds) on the 47 Uma system, with the WFIRST Shaped Pupil Characterization Mask (bowtie). The recovered spectrum is shown on the right, and has approximately the same SNR as what is expected from parametric modeling.





Compatibility with starshade model



Simulation of a variant of the WFIRST IFS (34% bandwidth) using a Starshade, observing a Haystacks Solar System at 7pc. Starshade is modelled ideally with no leak, 75 mas inner working angle, 100 hours exposure. In this particular simulation, the Earth cannot be distinguished at good SNR from the exozodiacal light contribution.

Rizzo et al., 2017: *Simulating the WFIRST Coronagraph Integral Field Spectrograph*, SPIE

Roberge et al., 2017: *Finding the Needles in the Haystacks: High-Fidelity Models of the Modern and Archean Solar System for Simulating Exoplanet Observations*, PASP