# Data analysis tools for exoplanet imaging with JWST

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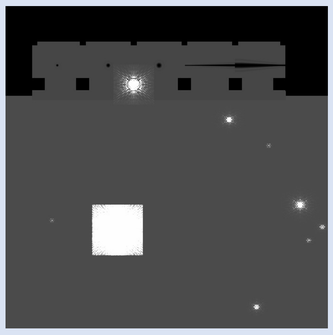
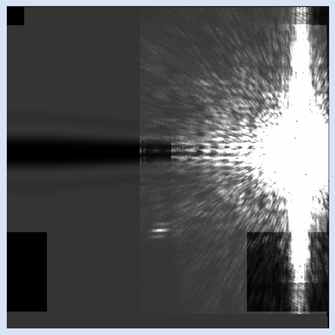
## NIRCCoS & pyNRC — Simulate NIRCam coronagraphy data

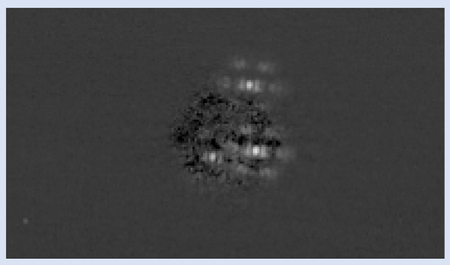
We developed powerful tools to simulate NIRCam coronagraphy observations and to push them through the official JWST data reduction pipeline. As an input for the simulations, only the APT files and a simple configuration file are required. Companion locations are automatically drawn from whereistheplanet (Wang et al. 2021) and companion magnitudes are automatically estimated using species (Stolker et al. 2020a/2020b). **Use NIRCCoS to simulate data for your own NIRCam coronagraphy program or proposal!**



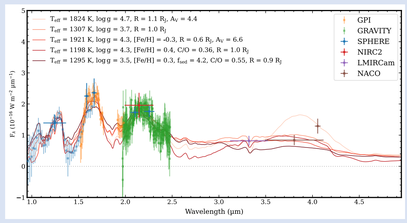
Full frame NIRCam Astrometric Confirmation image with the coronagraphic masks at the top.



HR 8799 behind the narrow end of the bar mask coronagraph (noiseless image).



JWST pipeline (i.e., KLIP) reduced HR 8799 round mask image (end-to-end simulation with realistic noise model).




Atmospheric model fits to the available spectrophotometry of HR 8799 e done with species. There are significant differences between the models in the L- and M-bands where NIRCam photometry will yield precise constraints.

Publicly available with documentation on GitHub:
https://github.com/kammerje/NIRCCoS

## spaceKLIP — Analyze NIRCam & MIRI coronagraphy data

We developed a dedicated pipeline to reduce NIRCam and MIRI coronagraphy data with pyKLIP (Wang et al. 2015). As an input for the pipeline, only a simple configuration file is required. The pipeline cleans bad pixels, performs an image registration to co-align the individual frames, performs PSF subtraction using pyKLIP, computes contrast curves, and extracts the photometry and astrometry of any detected companions using forward-modeling. **Use spaceKLIP to analyze your own NIRCam or MIRI coronagraphy data!**

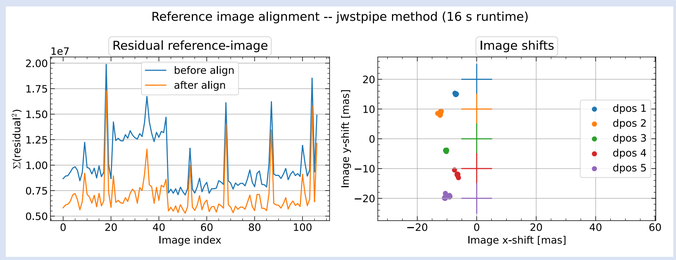
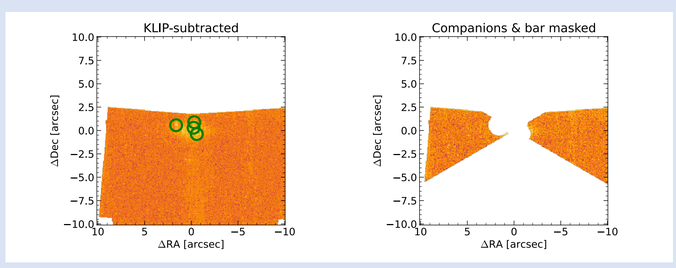
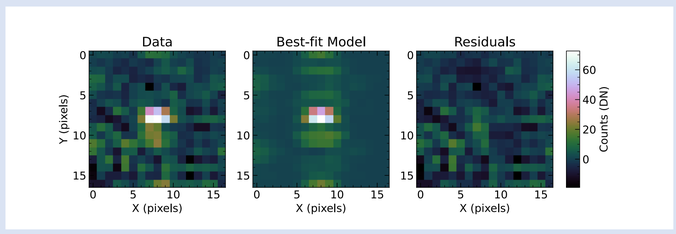



Image registration on simulated HR 8799 bar mask data recovers the injected pointing errors and small-grid-dithers. This step is important to get the best possible KLIP performance.




Known companions and the bar mask are masked out before the contrast curves are computed. It is also possible to compute calibrated contrast curves using injection and recovery tests.

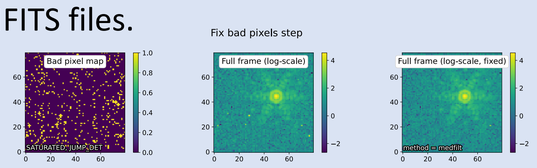



MCMC fit of the forward-modeled PSF of HR 8799 d to find the companion photometry and astrometry. The residuals are shown on the right.

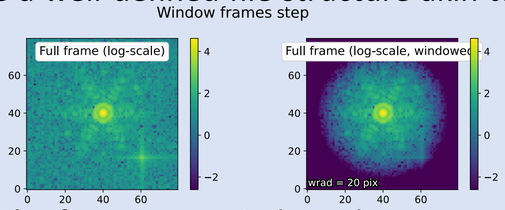
Publicly available with documentation on GitHub:
https://github.com/kammerje/spaceKLIP

## KPI3Pipeline — Extract kernel-phases from NIRCam & NIRISS data

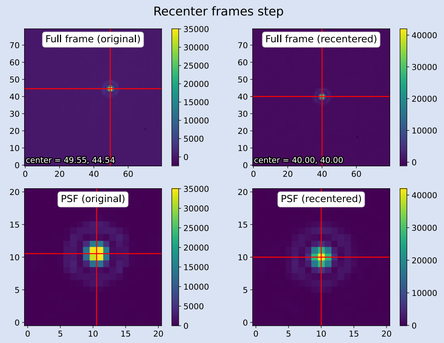
We developed a state-of-the-art JWST stage 3 pipeline for extracting kernel-phases from clear pupil NIRCam and NIRISS images. **This KPI3Pipeline can be interfaced similar as the official JWST stage 3 pipelines** for e.g. coronagraphy or aperture masking interferometry and is based on XARA (Martinache 2010/2013). It outputs kernel-phase FITS files which have a well-defined file structure akin to OIFITS files.



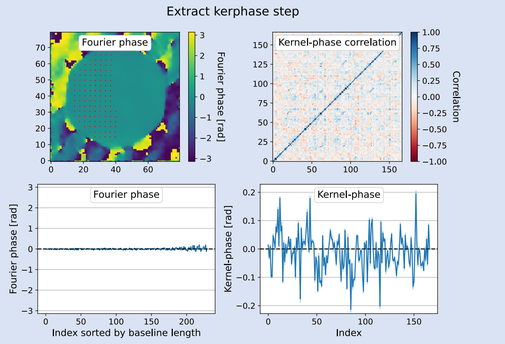

1) Bad pixels are cleaned.




3) The frames are windowed.




2) The frames are re-centered.

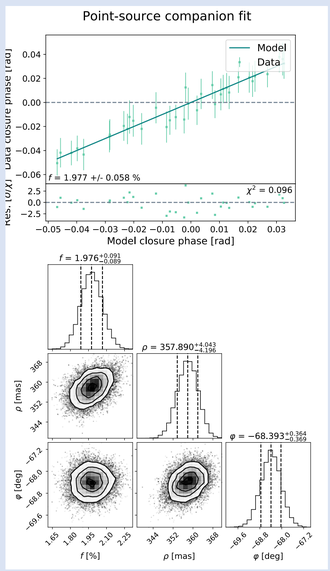



4) Kernel-phases are extracted.

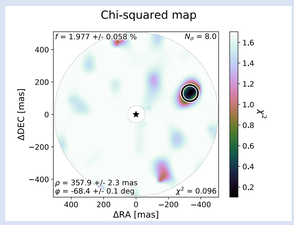
Publicly available with tutorial on GitHub:
https://github.com/kammerje/xara/tree/develop

## fouriever — Companion search & calibration for interferometry

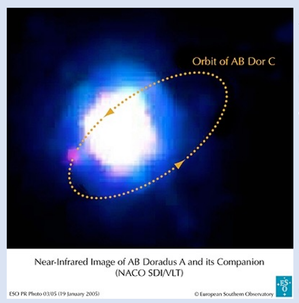
My fouriever toolkit can be used to search for companions and estimate detection limits in kernel-phase (KPFITS), aperture masking (OIFITS), and long-baseline interferometry (OIFITS) data. It can also be used to estimate error correlations and take them into account in the model fitting procedure. Furthermore, fouriever enables calibrating the data using Karhunen-Loève projection. **Use fouriever to analyze your own interferometry data!**




Point-source companion fit to simulated NIRISS AMI data of AB Dor. Fouriever plots data vs. model (top) and runs an MCMC fit to estimate the parameter uncertainties (bottom).

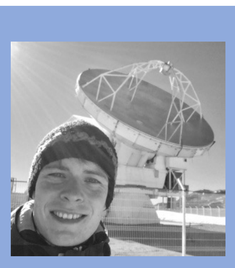



The chi-squared map reveals the detection of a companion (AB Dor C).




The detection is consistent with the orbital motion of AB Dor C (well, it is simulated data after all :-D).

Publicly available with tutorial on GitHub:
https://github.com/kammerje/fouriever



I'm a postdoc interested in high-resolution imaging of exoplanets and brown dwarfs. **I'm leading two JWST Cycle 1 programs** on kernel-phase and aperture masking interferometry. I'm also heavily involved with several JWST GTO and ERS programs that will use coronagraphy to observe exoplanets. From the ground, I'm doing high-contrast observations with the GRAVITY interferometer and the SPHERE planet imager. I'm also working on yield estimates for the LUVOIR mission and I'm one of the Team 3 (instrument science) leaders of the LIFE Collaboration.

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