JWST ETC Point Spread Functions

The JWST ETC uses point spread functions (PSFs) from a precomputed library of PSFs produced by WebbPSF. (For more details on WebbPSF's optical model, check out the WebbPSF documentation pages.)

The PSF library

Each instrument aperture is represented by a precomputed set of roughly 30 PSFs, generated at log-normal wavelength intervals that span the entire wavelength range of all filters and dispersers used with that aperture. With the exception of coronagraphy, all PSFs are generated on-axis, centered on the detector, and are thus devoid of any optical aberrations that may impact real PSFs at locations far from the detector center. Given that the ETC models sources close to the center, the effect is likely to be minimal.

Coronagraphic observations have multiple sets of roughly 30 PSFs each, generated at multiple spatial locations at log-normal wavelength intervals, to account for the effects of coronagraphic spots.

The PSFs are generated to relatively small sizes—the largest are the MIRI 4QPM PSFs (used in MIRI coronagraphic imaging), which cover 8.9" on a side. Nevertheless, the PSFs cover more than 99.9% of the expected flux.

> ETC version 1.4 uses WebbPSF version 0.8.0, WebbPSF Data version 0.8.0, and POPPY version 0.8.0 to construct the PSF library for all science instruments (MIRI, NIRCam, NIRISS, and NIRSpec).

How the library is used

For a given observation, the entire set of PSFs for a given aperture are loaded into the ETC.

The scene generation process creates a spatial and wavelength cube for each source in the scene. The next step is to convolve each wavelength plane with a PSF; this PSF is produced by interpolating the set of PSFs at the specific wavelength of the cube slice. Thus, the apparent PSF in the output 2-D images is the sum of multiple wavelength-dependent PSFs, scaled by the filter throughput curve.

The model cubes for each scene are then added together to form a combined scene cube, which is then "observed" onto a detector, and results extracted by use of the strategy.

The reason that the PSF convolution is done before the combination of all of the sources is to make it easier to use a positionally-dependent PSF, which is done for coronagraphy.

Position-dependent coronagraphic PSFs

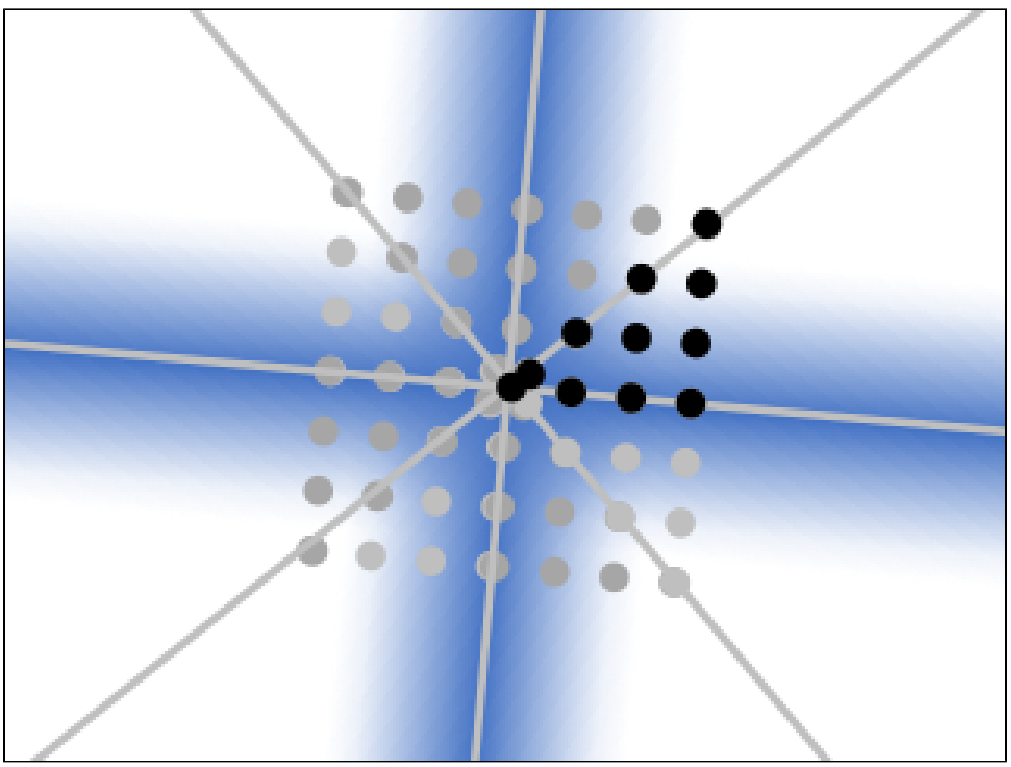
The positionally-dependent PSFs are generated in a variety of patterns to suit the shape of the occulting elements. Though they are generated for different spatial positions, they are not interpolated spatially; instead, the ETC's code selects the closest PSF to the target location. This can result in step-function behavior with various sources.

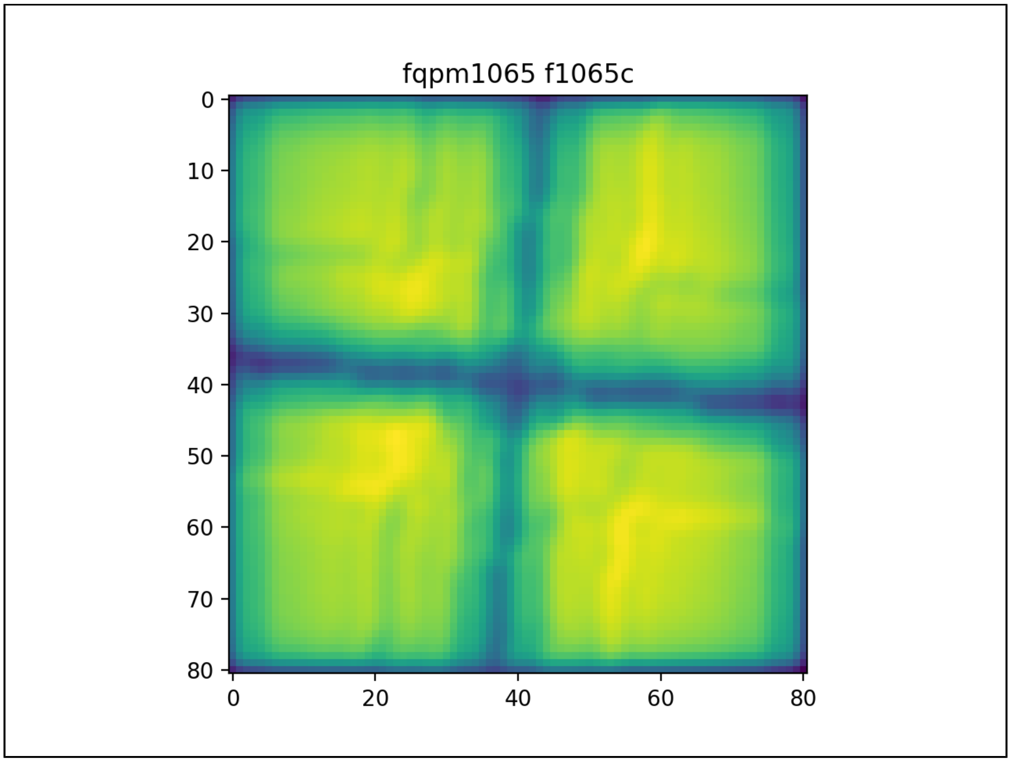
MIRI

4QPM

The MIRI 4-quadrant phase masks (4QPM) used for coronagraphic imaging are assumed to have eight-fold symmetry: they can be reflected across each of the quadrant axes and across the primary axes of the detector (which is approximately correct). PSFs were generated in a triangular shape, covering the 0%, 33%, 66%, and 99% unobscured positions. The positions take into account the roughly 5° clockwise rotation of the MIRI masks.

Figure 1. MIRI 4QPM PSF positions



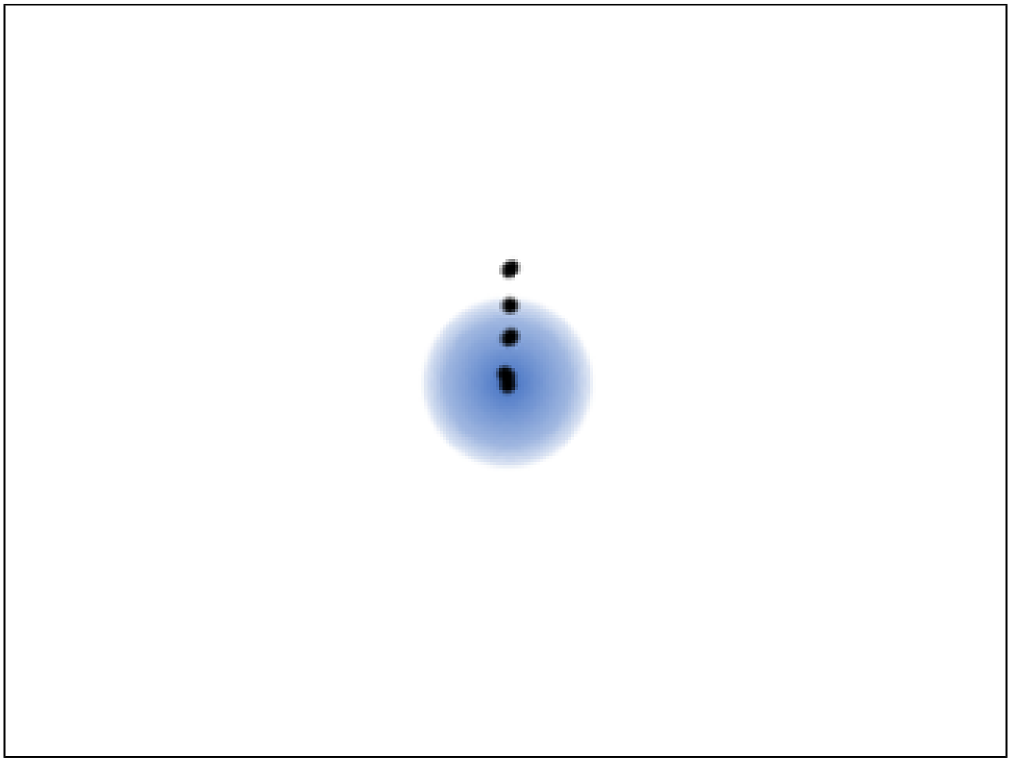


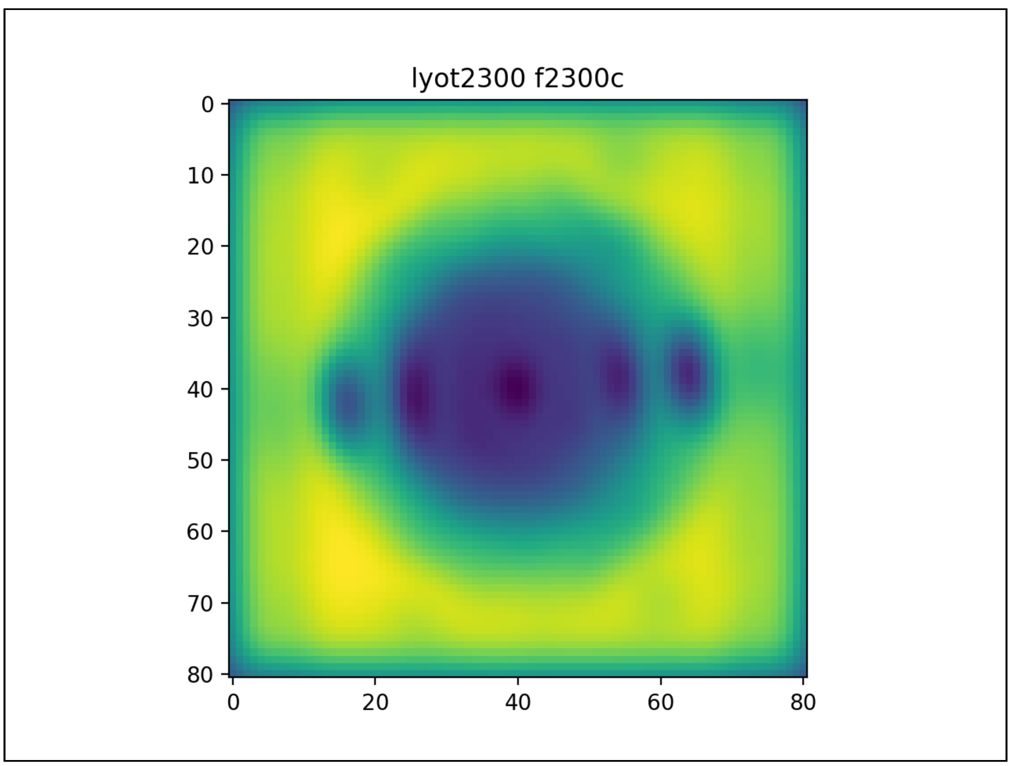
Top: A schematic view of the MIRI PSF grid and symmetry
Bottom: a dense grid of point sources run through the ETC traces out the resulting shape of the MIRI 4QPM obscuring elements

LYOT2300

The MIRI ***LYOT2300*** mask is assumed to have radial symmetry. PSFs were generated along the Y-axis, at points that are 0%, 25%, 50%, 75%, and 99% unobscured.

Figure 2. MIRI LYOT2300 PSF positions





Top: A schematic view of the MIRI PSF symmetry

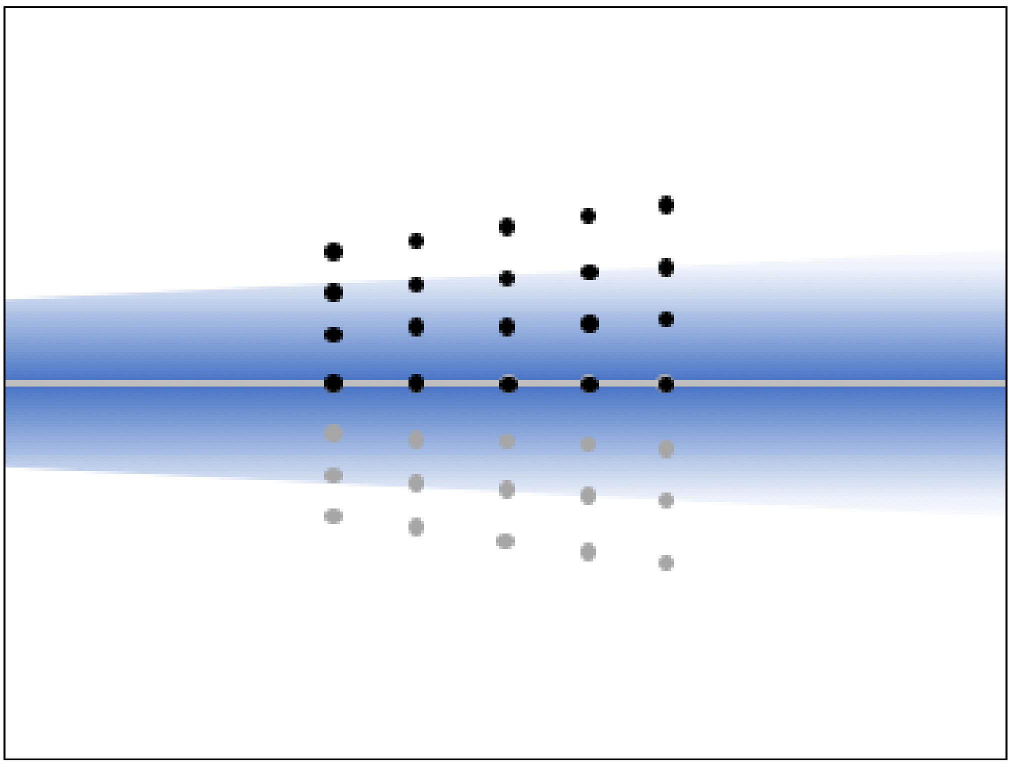
Bottom: a dense grid of point sources run through the ETC traces out the resulting shape of the MIRI LYOT2300 obscuring element

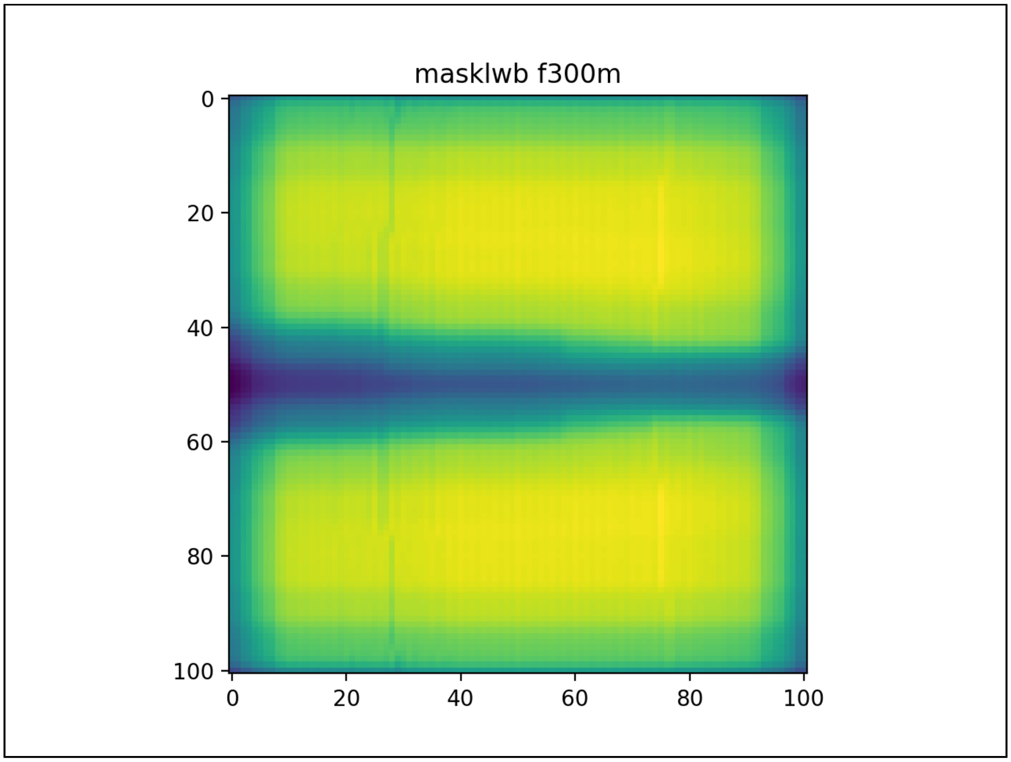
NIRCam

MASKSWB/MASKLWB

The NIRCam ***MASKSWB*** and ***MASKLWB*** masks are assumed to have vertical symmetry. They are tapered wedges (where ***MASKSWB*** tapers toward negative X, and ***MASKLWB*** tapers toward positive X), such that each filter has an optimal position along the wedge where a point source is just barely fully obscured. Sets of five PSFs were generated at the optimal position, positions 1" and 2" on either side of the optimal position, and positions above the bar that are 33%, 66%, and 99% unobscured.

Figure 3. NIRCam bar mask PSF positions



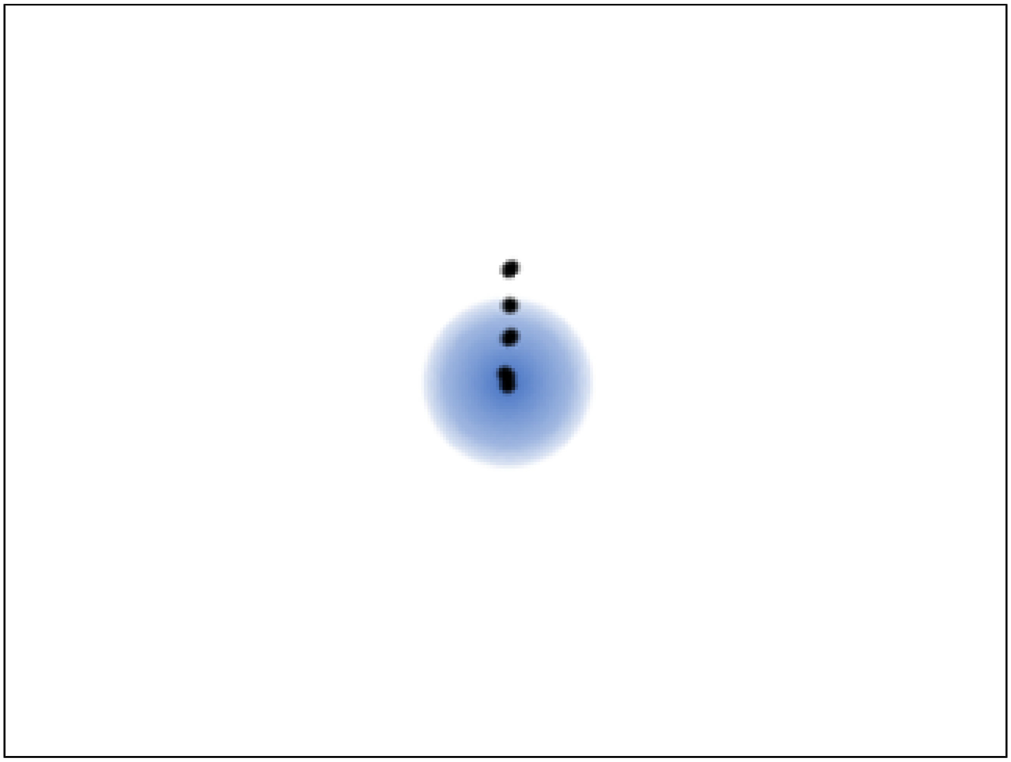


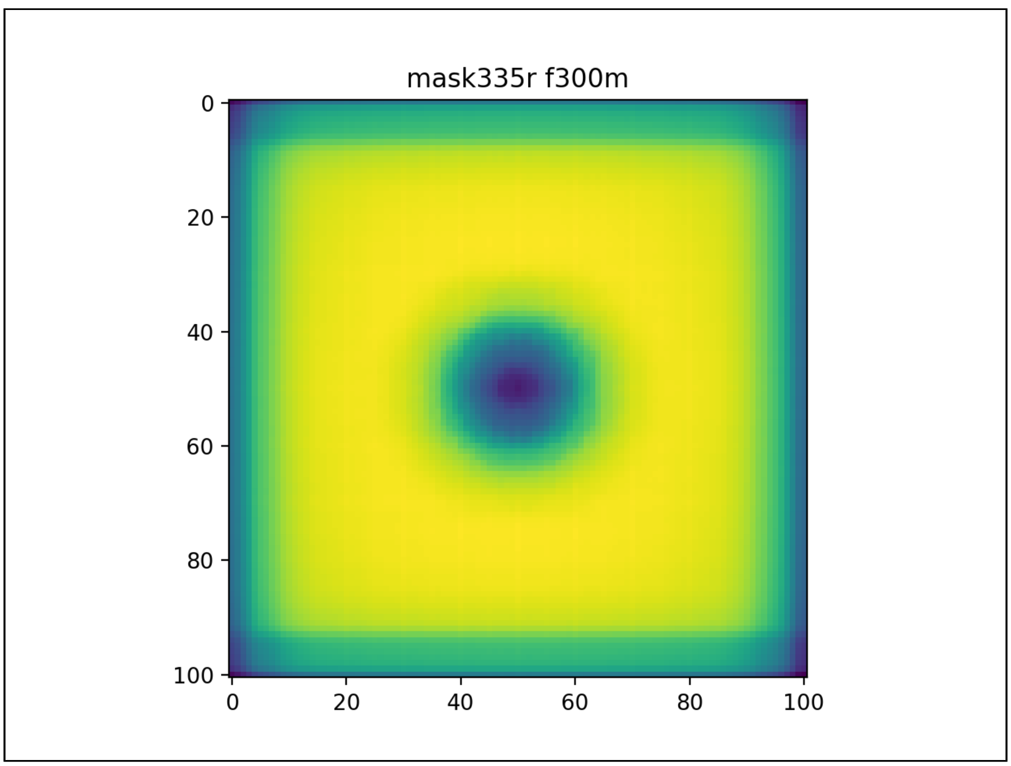
Top: A schematic view of the NIRCam MASKSWB PSF grid and symmetry (tapering toward negative X)
Bottom: a dense grid of point sources run through the ETC traces out the resulting shape of the NIRCam MASKLWB obscuring element (tapering toward positive X)

MASK210R/MASK335R/MASK430R

The NIRCam ***MASK210R***, ***MASK335R***, and ***MASK430R*** masks are assumed to have radial symmetry. PSFs were generated along the Y-axis, at points that are 0%, 25%, 50%, 75%, and 99% unobscured.

Figure 4. NIRCam round mask PSF positions





Top: A schematic view of the NIRCam symmetry

Bottom: a dense grid of point sources run through the ETC traces out the resulting shape of the NIRCam MASK335R obscuring element.