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MODELING JWST DETECTORS IN THE PANDEIA ENGINE

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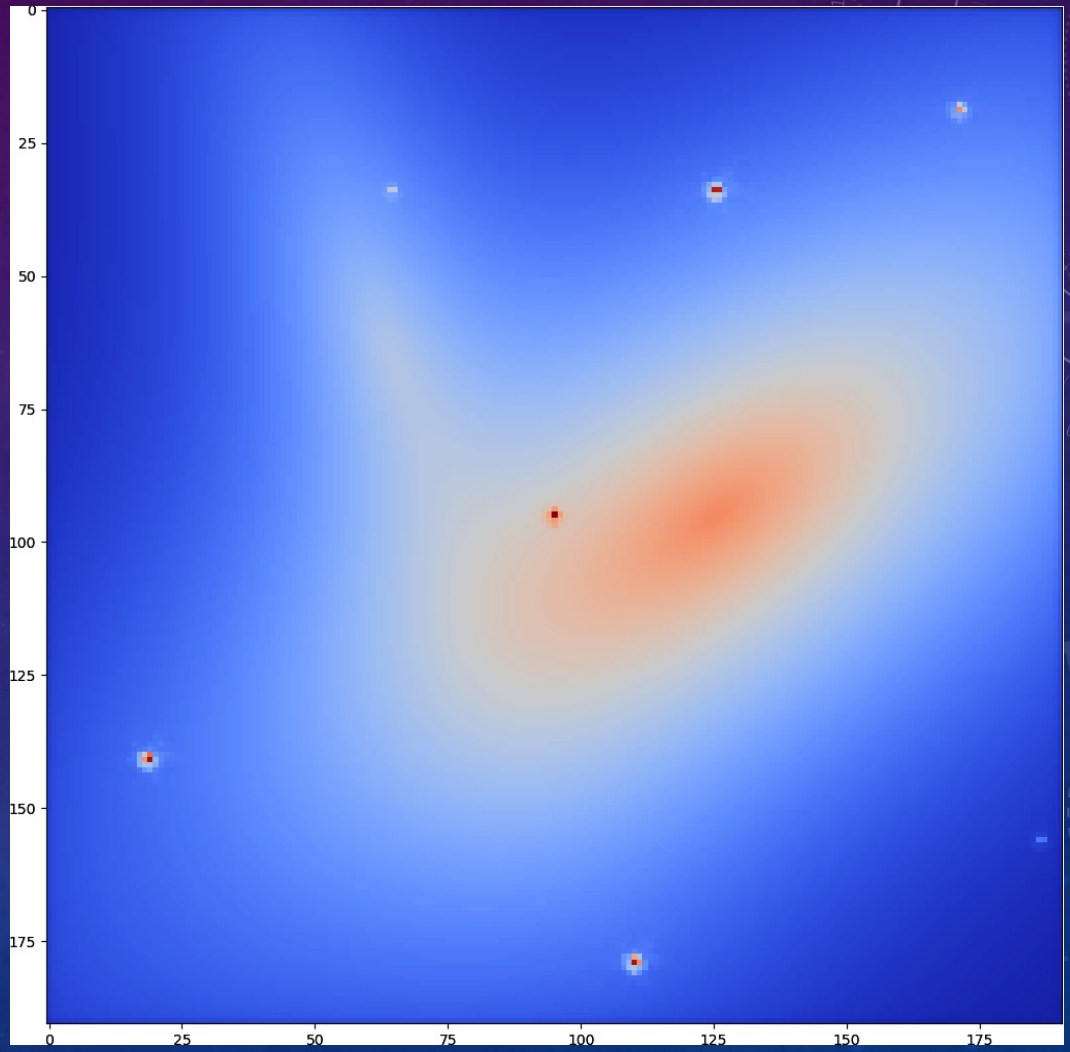
WHAT IS PANDEIA?

- Python-based
  - Numpy
  - Scipy
  - Astropy
  - Synphot
- 3-dimensional Exposure Time Calculator
  - Small scenes (~3-40 arcsec)
  - Not a simulator
  - SNR Accuracy ~10%
- Modular
  - James Webb Space Telescope
  - Nancy Grace Roman Space Telescope (WFI)



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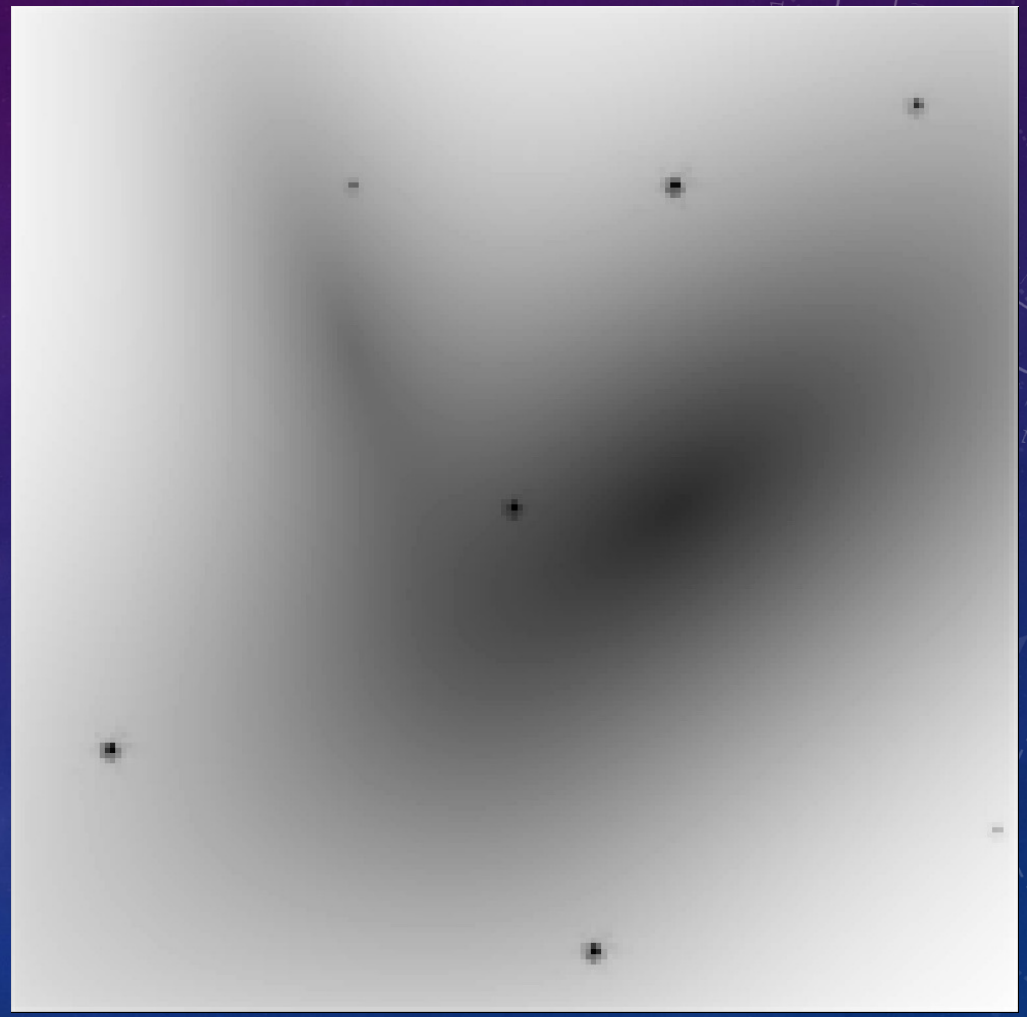
HOW DOES IT WORK?

- Build a scene out of sources
  - SED
  - 2D Parameterized Shape
    - Position, orientation
  - Normalization
  - Lines
  - Extinction



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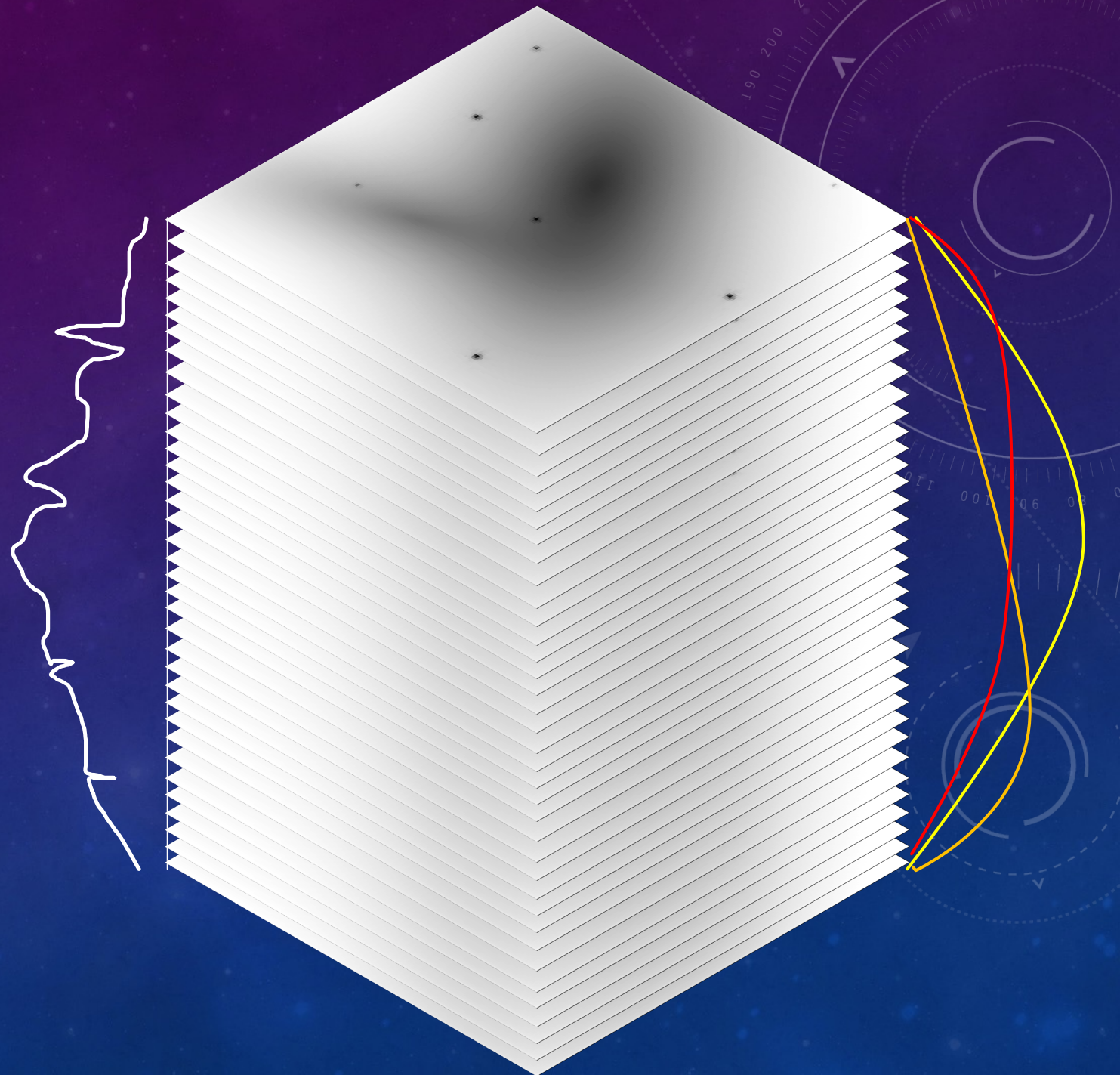
HOW DOES IT WORK?

- Create 2D profiles for each source
- Multiply each source profile by its spectrum
- Add the source cubes together
- Convolve with PSFs
- Multiply by instrument and detector throughputs



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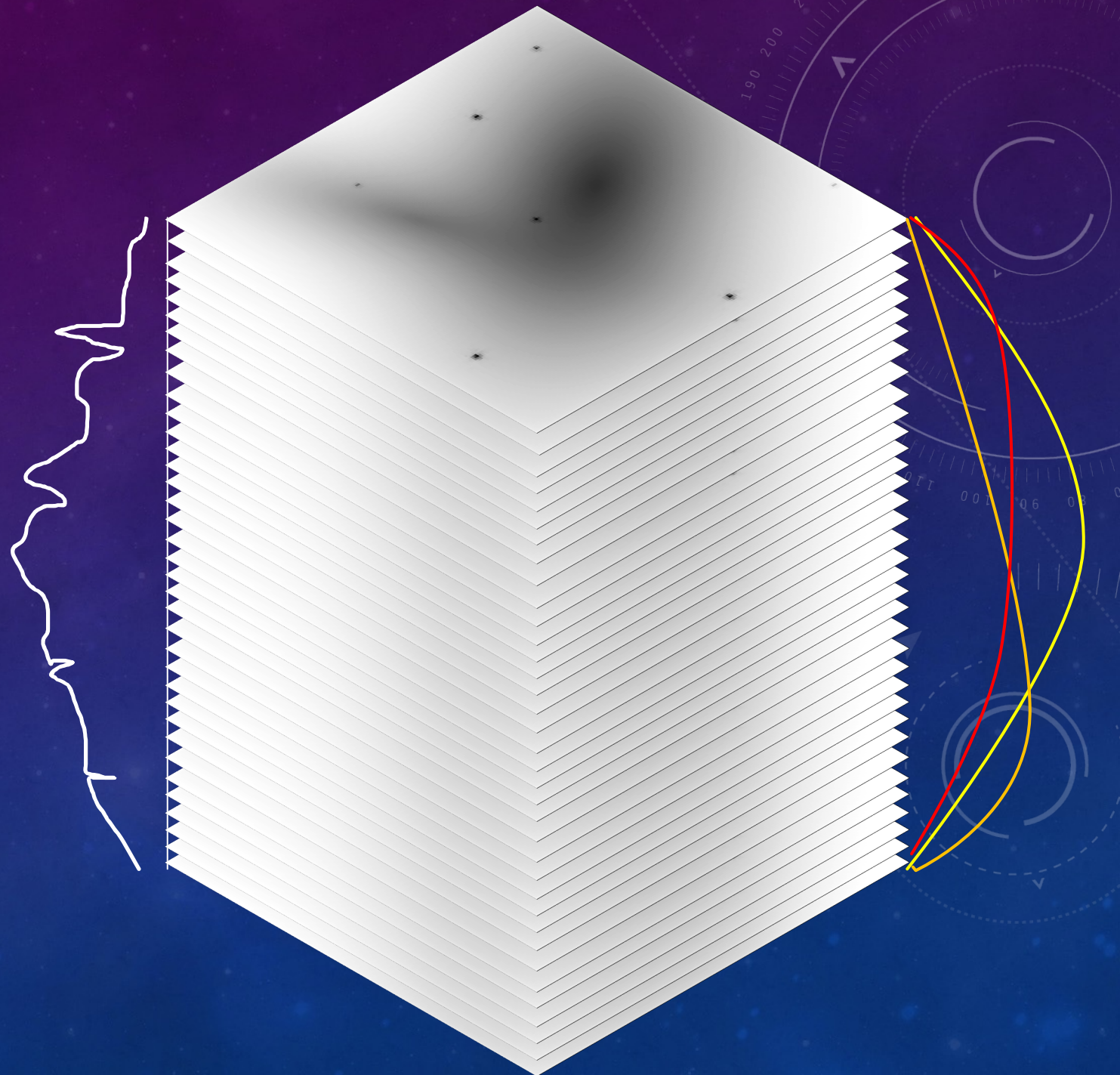
IMAGING

- Integrate over the cube



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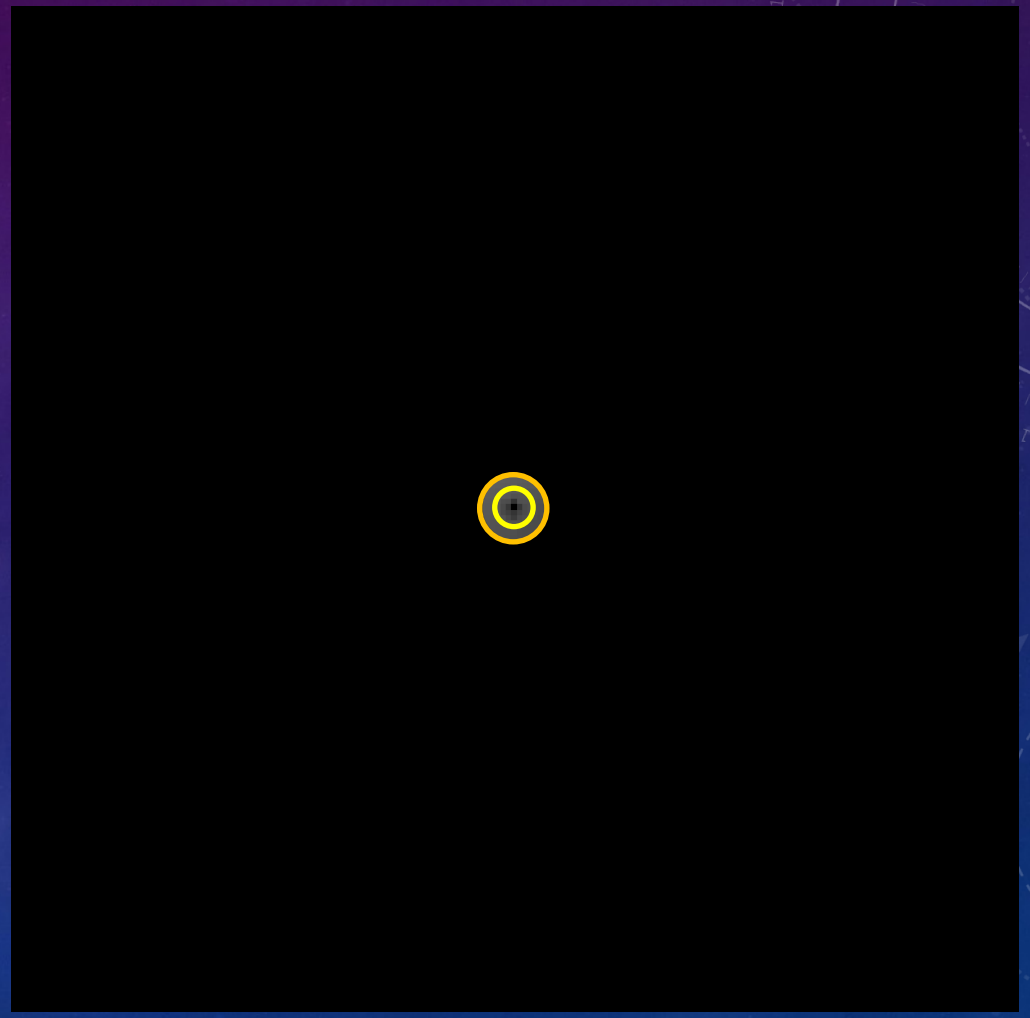
HOW DOES IT WORK?

- Construct masks for aperture and sky annulus



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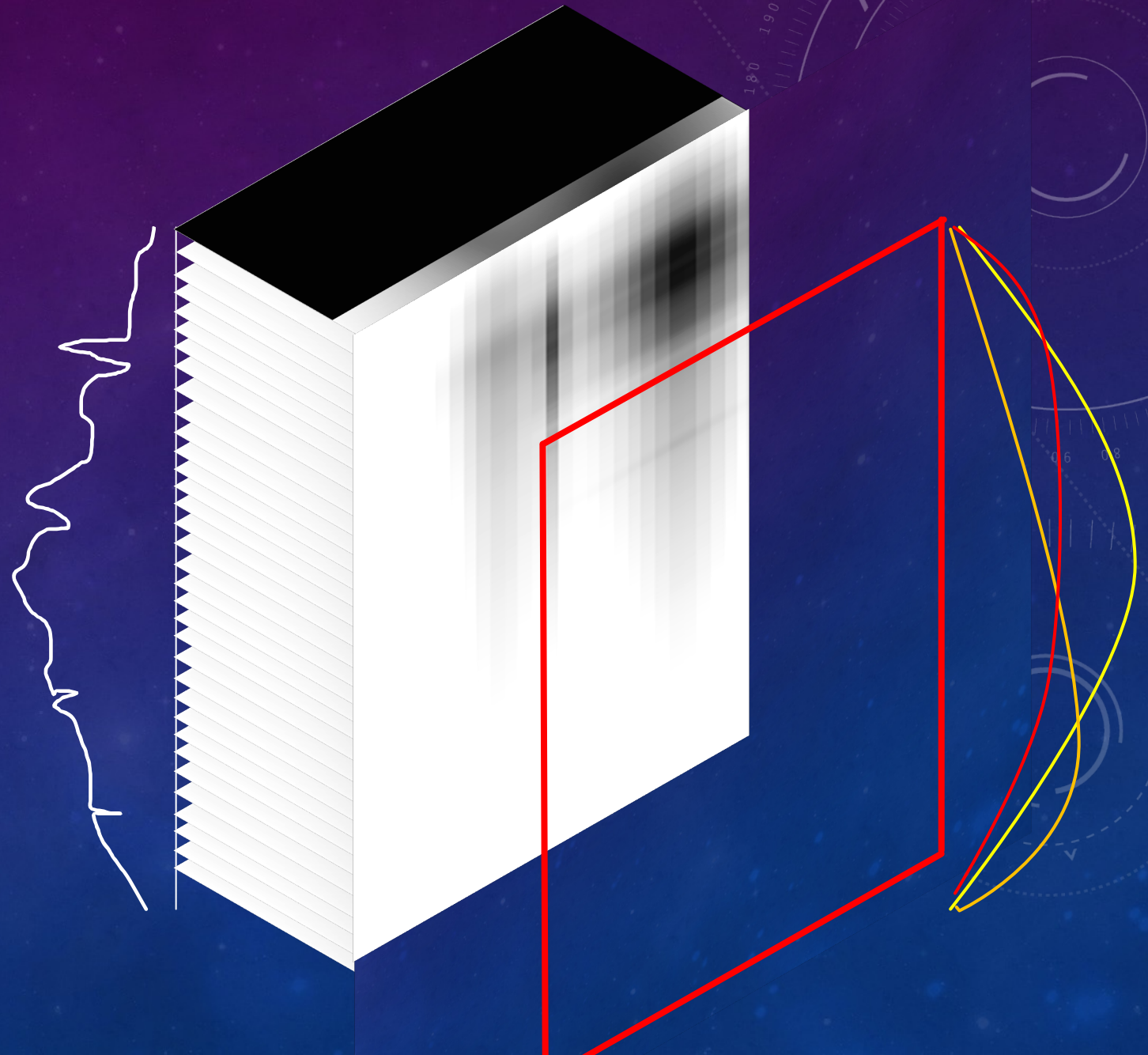
SLIT SPECTROSCOPY

- Mask out any slits
- Integrate in one of the spatial directions



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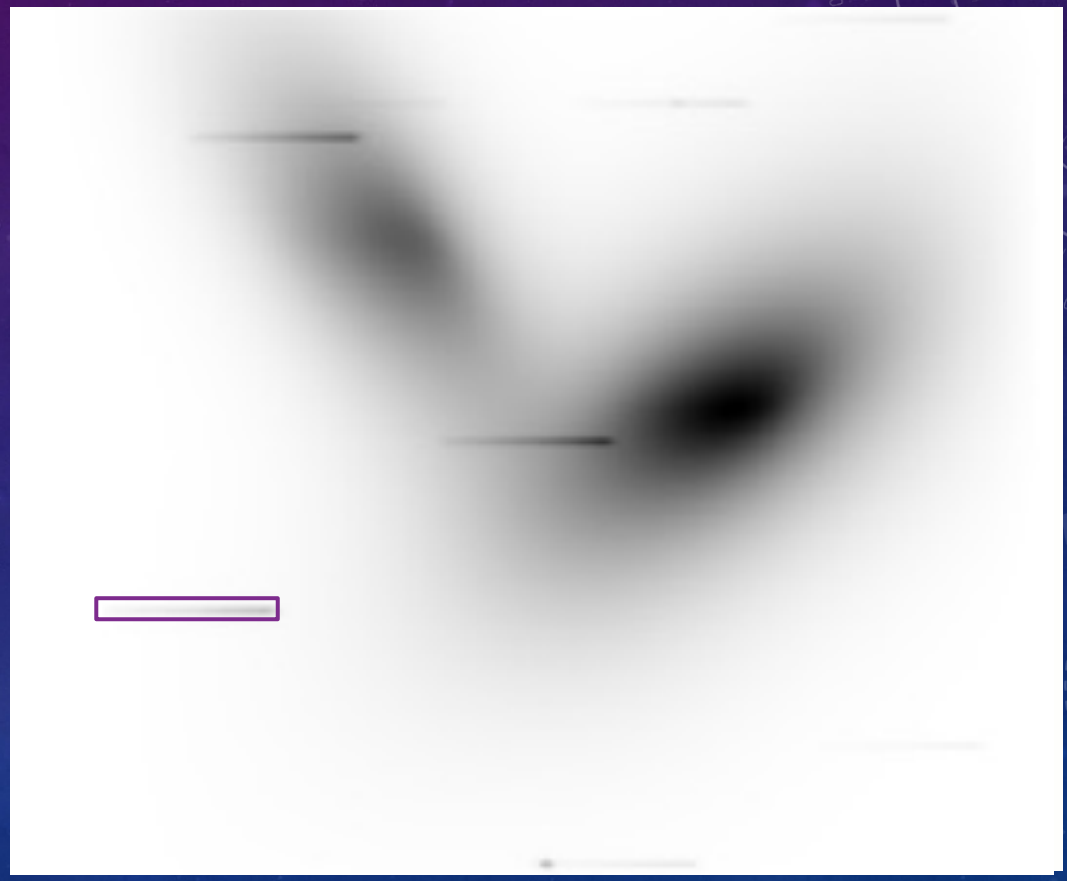
SLITLESS/MULTIORDER

- Shift and add wavelength slices



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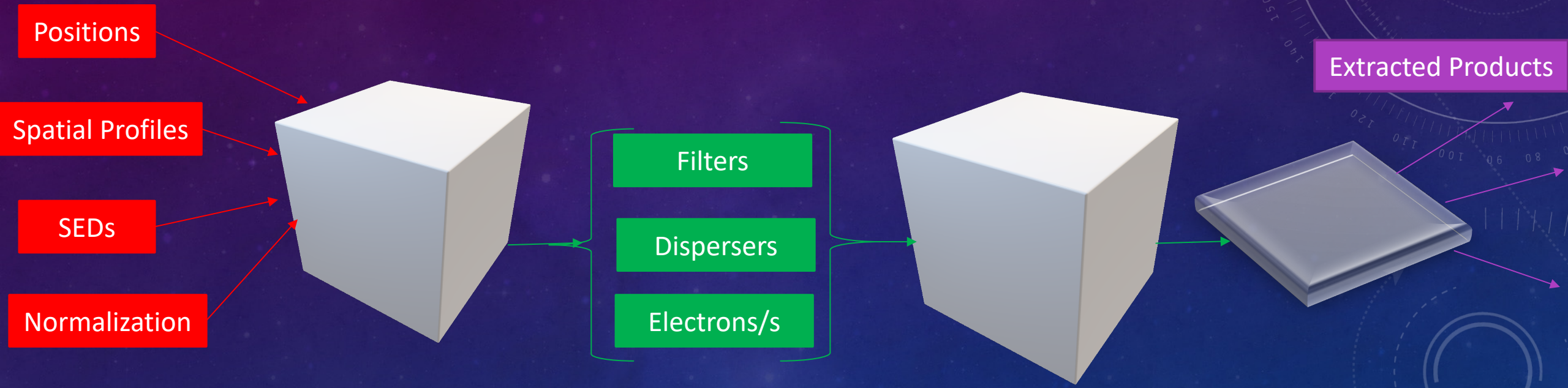
THE PANDEIA ENGINE OPERATES ON ITS OWN GENERATED SCENE CUBE



The extraction (analysis) stages know nothing about where, precisely, the flux is coming from

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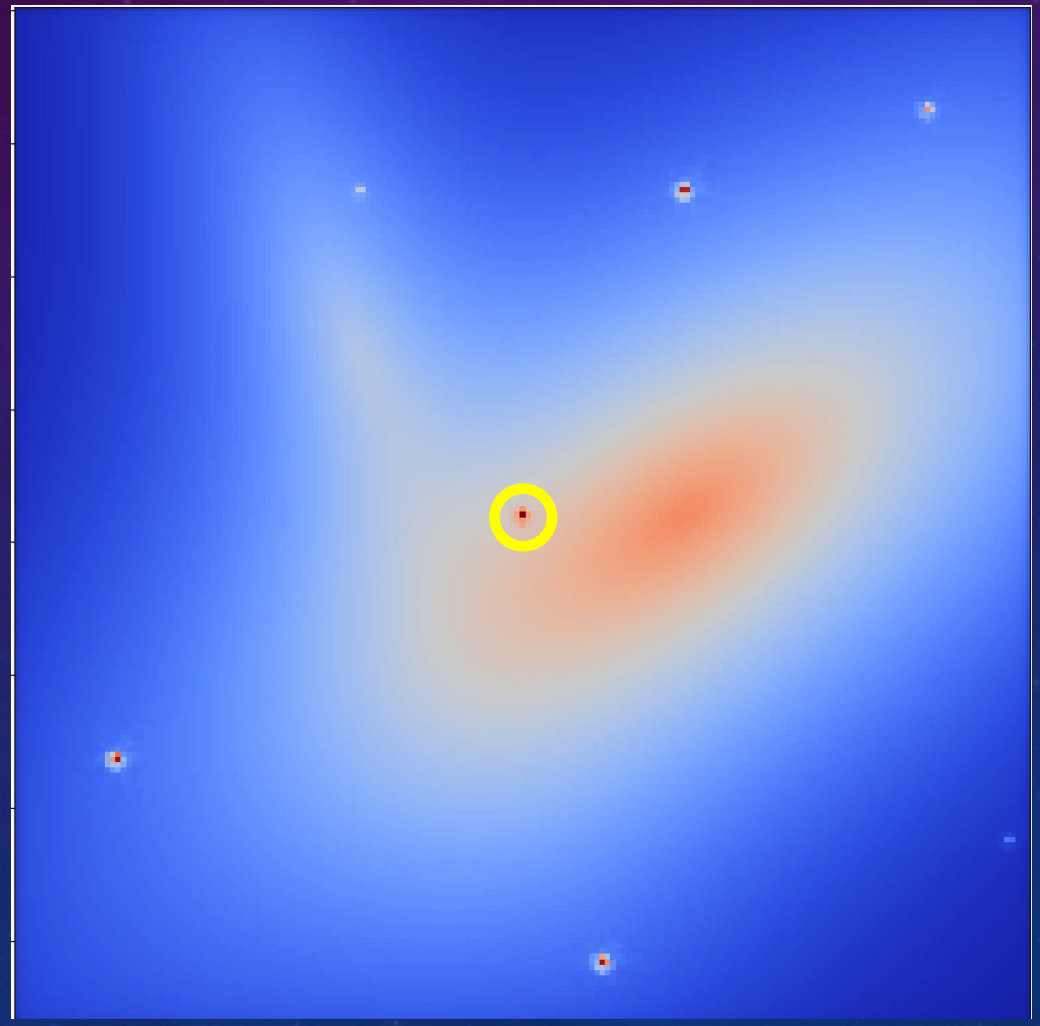
EFFECT: OVERLAPPING SOURCES



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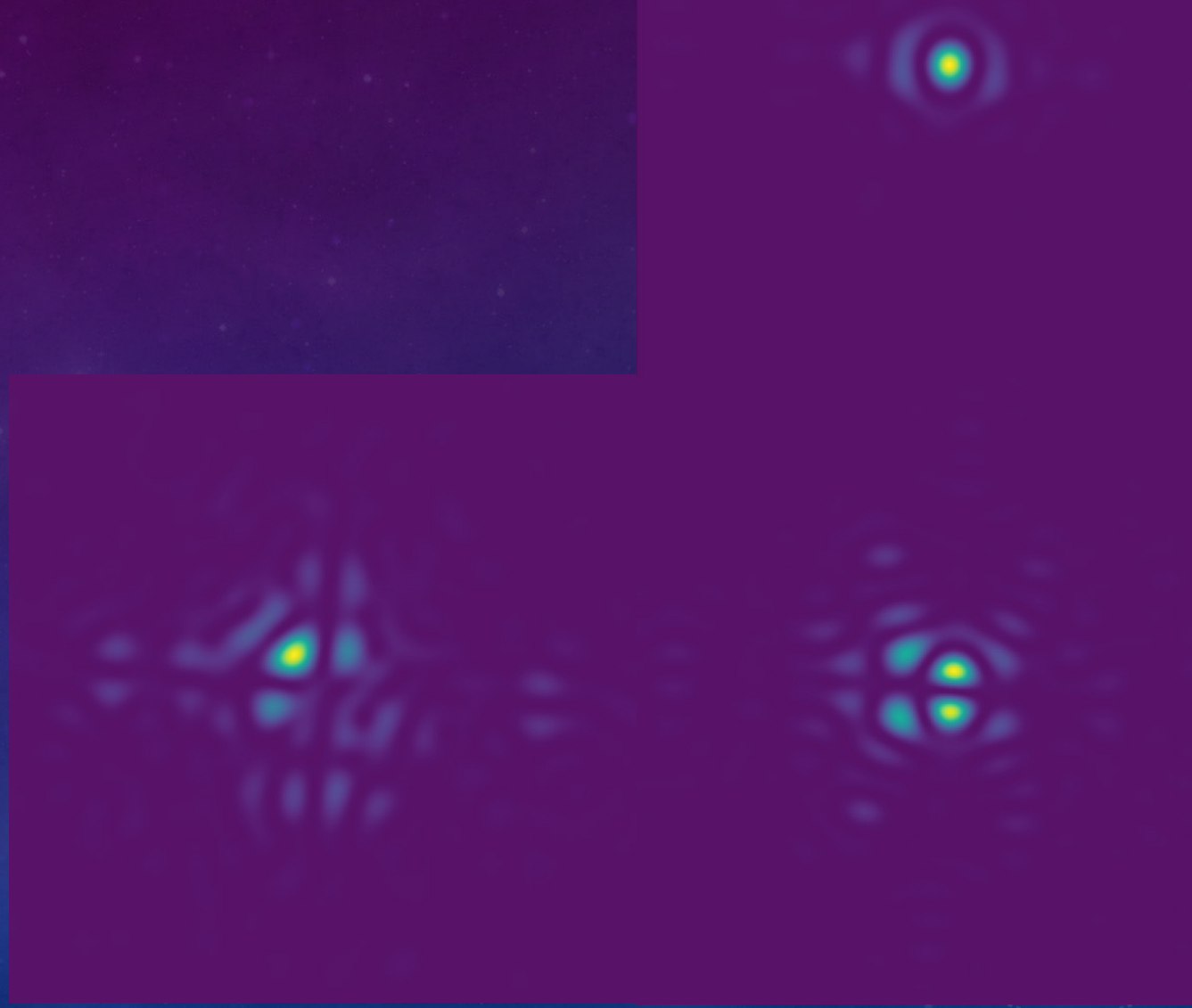
EFFECT: CORONAGRAPHS

- Sets of spatially distinct PSFs (produced by WebbPSF) covering the setup wavelengths

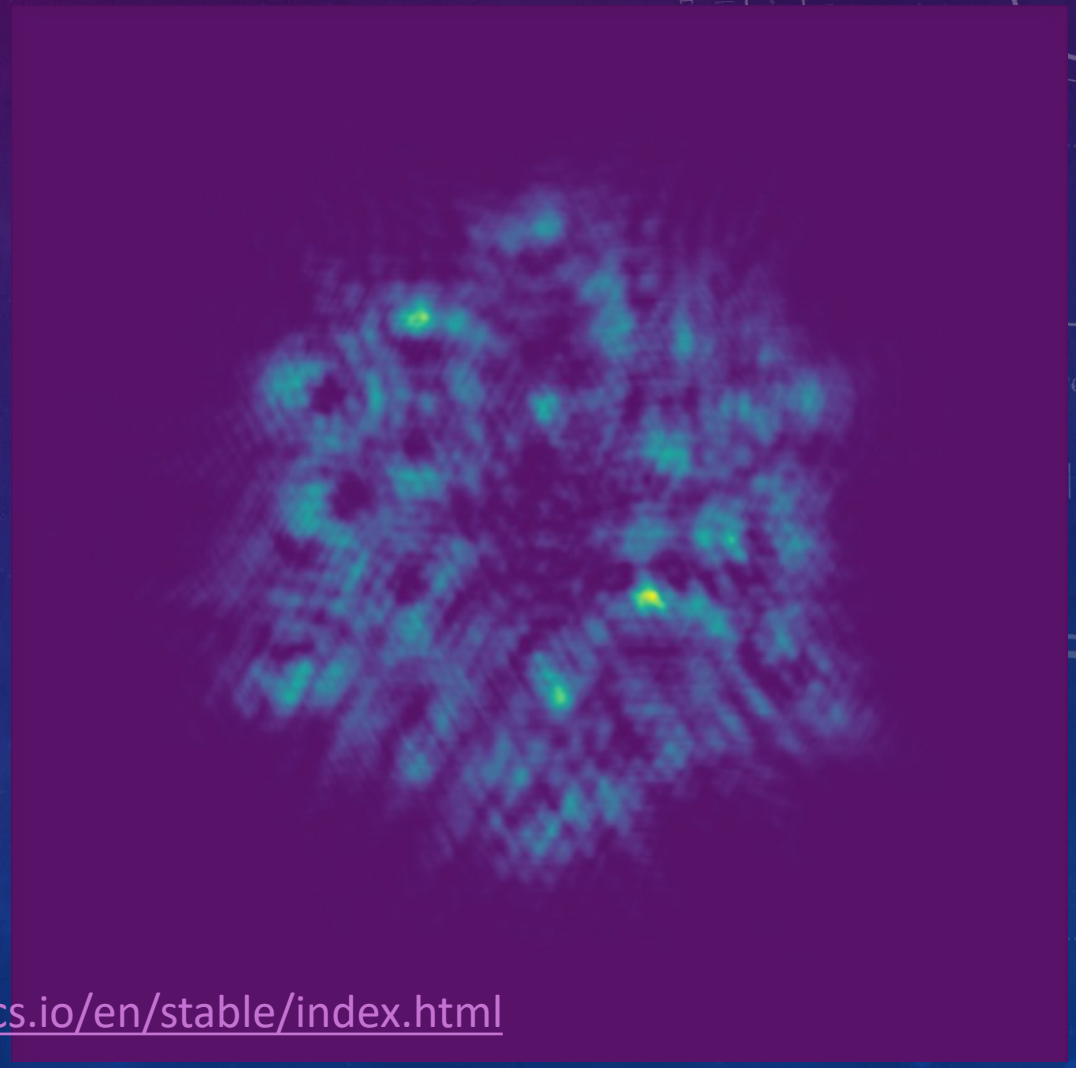
1. Split up sources into groups by which spatial PSF location best applies to them
2. Create a cube for each group of sources
3. Convolve each cube by the appropriate set of PSFs
4. Merge into a single cube.



WebbPSF: https://webbpsf.readthedocs.io/en/stable/index.html

OTHER OPTICAL ELEMENTS (WEAK LENSES, PUPIL MASKS)

- Included in special sets of PSFs.



WebbPSF: https://webbpsf.readthedocs.io/en/stable/index.html

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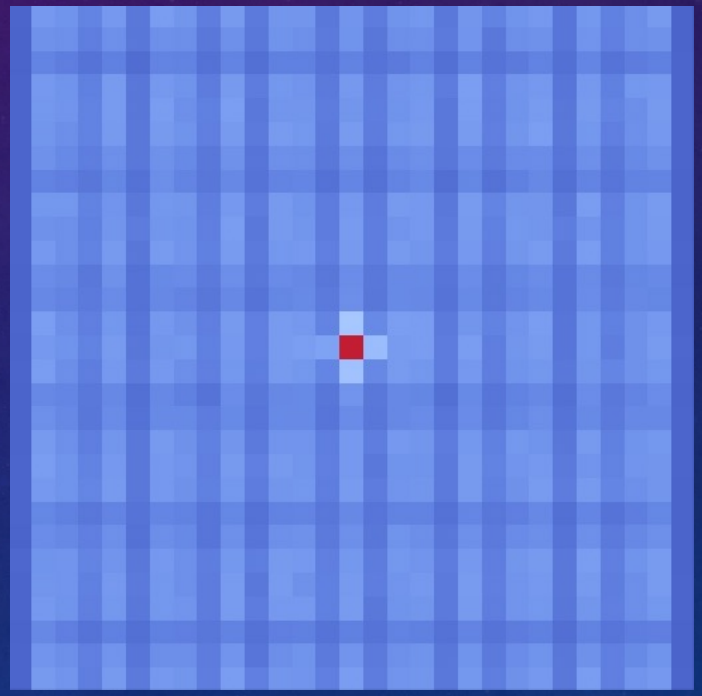
EFFECT: MICRO-SHUTTER ASSEMBLY (AND OTHER SLITS)

- Create an image mask for the slit arrangement, save just the unmasked portions of the cube for further processing.



EFFECT: MULTIACCUM READOUTS

- “Up-the-ramp” sampling
- The Exposure time is built up out of groups, integrations, and exposures
- Each group is built out of frames, reset frames, and skipped/dropped frames (a readout pattern)
- Frame times (and reset times) depend on the subarray used.
- Configured for JWST readout patterns on H2RG and SiAs detectors

- Exposure time: wall time to execute the exposures (including resets and dropped frames)
- Saturation time: time between the last reset and last read of the pixel in a single integration. (affects saturation)

EFFECT: (PARTIAL) SATURATION

- Per-Pixel saturation
- Compute the number of groups before the pixel saturates.
  - If a pixel saturates before the integration ends, we can use the groups recorded before that point to get a (somewhat noisier) measure of the signal.
  - If a pixel saturates within the first two groups, the pixel is considered fully saturated and we do not recover an electron rate.

EFFECT: CORRELATED READNOISE

- Correlated Readnoise depends on the actual number of groups (usefully) read out, not the total exposure time.

EFFECT: SPECIAL TARGET ACQUISITION RAMP CALCULATIONS

- Target acquisition is built on a special processing mode that uses only three groups – typically at the beginning, middle, and end of the ramp – to better mimic the spacecraft's onboard target acquisition process

EFFECT: COSMIC RAYS

- We are not concerned with specific cosmic rays (these are for *planning* observations)
- Cosmic Rays are treated more or less like saturation – as a reduction in the number of useable groups, per pixel.
- Depends on pixel size, an estimate of cosmic ray event rate at L2, and an estimate of how many pixels each event interacts with.
- Statistically, when a pixel is hit by a cosmic ray, you lose half the ramp (all groups before the cosmic ray hit are still usable)

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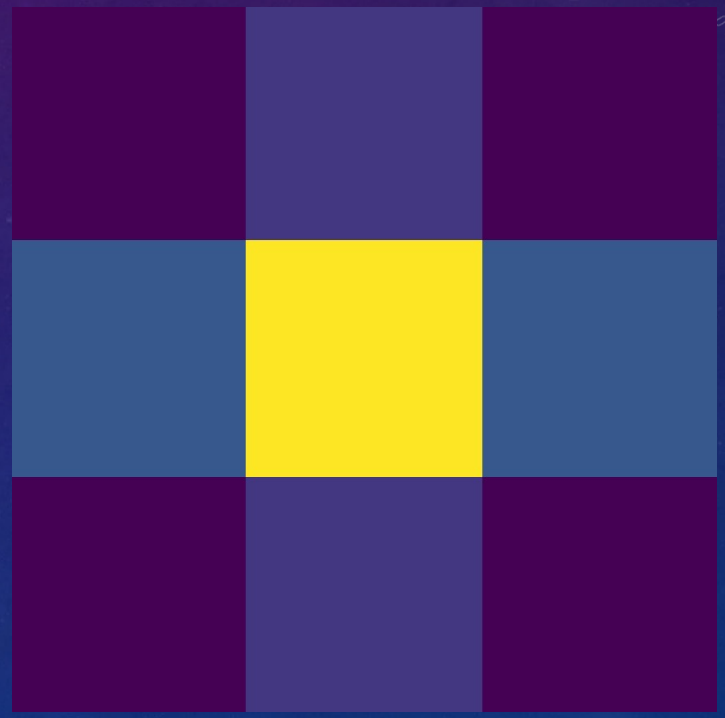
EFFECT: INTER-PIXEL CAPACITANCE

- A small kernel is convolved with the projected 2D detector image to mimic the effects of inter-pixel capacitance



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EFFECTS WE DO NOT IMPLEMENT

- Field Distortions (assume all are perfectly on-axis)
- Defocus (except weak lenses)
- Spatially-variable versions of detector effects such as read noise, IPC, or dark current

- CTE inefficiency
- Frame reset effects
- Detector Nonlinearity and Brighter-Fatter Effect
- NIRISS AMI extraction does not perform interferometry

- Slit diffraction effects
- Bad Pixels

- The same PSF sets apply to an entire extended object, even in Coronagraphy modes

PANDEIA IS NOT A SIMULATOR

NOISE AND CONTAMINATION SOURCES

- Background
  - Extragalactic background
  - Galactic cirrus
  - Zodiacal Light
  - Stray Light
- The target source
- Cosmic Rays (as reductions in # of useable groups, affecting poisson noise)
- Telescope
  - Thermal Emission
- Detector
  - Correlated Read noise
  - Dark current
  - Flat field noise
  - Target (poisson)

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CONFIGURATION

- Instruments are defined by JSON files
- Inputs are hierarchical Python dictionaries (we save in JSON format)
  - Configuration (of instrument and detector)
  - Scene (a list of source definitions)
  - Strategy (how to extract the flux)
- With the exception of the ‘calculation’ dictionary (not configurable on the web) users do not control detector effects, they are determined by instrument specialists.


```
{
    "background": "minzodi",
    "background_level": "benchmark",
    "calculation": {
        "effects": {
            "saturation": null
        },
        "noise": {
            "crs": null,
            "ffnoise": null
        }
    },
    "configuration": {
        "detector": {
            "nexp": 1,
            "ngroup": 100,
            "nint": 1,
            "readout_pattern": "slowr1",
            "subarray": "full"
        },
        "instrument": {
            "aperture": "ch2",
            "disperser": "short",
            "filter": null,
            "instrument": "miri",
            "mode": "mrs"
        }
    },
    "scene": [
        {
            "position": {
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                "x_offset": 0.0,
                "y_offset": 0.0
            },
            "shape": {
                "geometry": "point"
            },
            "spectrum": {
                "extinction": {
                    "bandpass": "j",
                    "law": "mw_rv_31",
                    "unit": "mag"
```

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WHERE TO FIND PANDEIA

- The Web Interface: https://jwst.etc.stsci.edu
- The Standalone Python module:
  - https://outerspace.stsci.edu/display/PEN/Pandeia+Engine+News
  - https://pypi.org/project/pandeia.engine/