# Recovering simulated planet and disk signals using SCALES aperture masking

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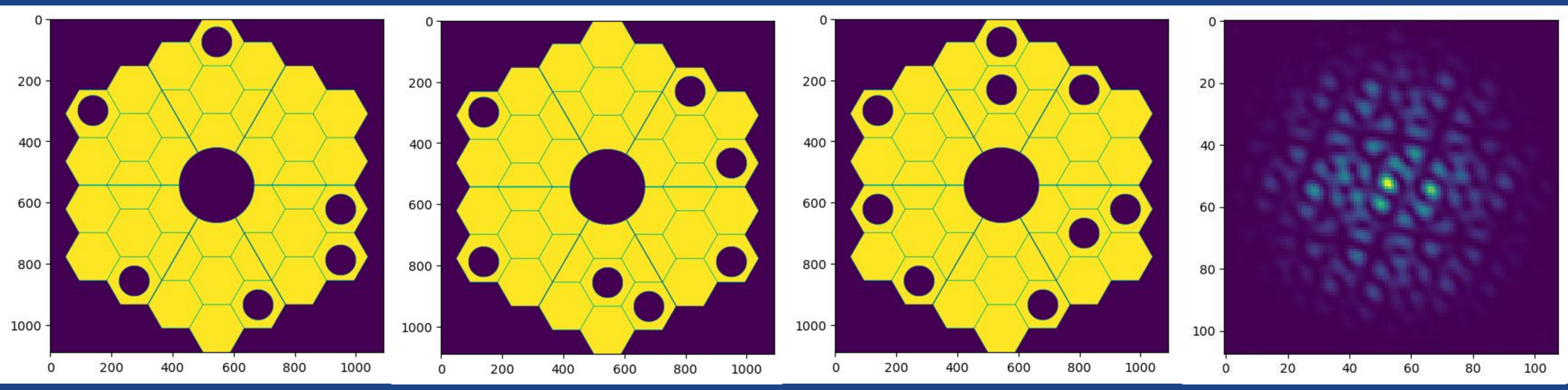
## Introduction

- **S**licer **C**ombined with an **A**rray of **L**enslets for **E**xoplanet **S**pectroscopy (**SCALES**) is an integral field spectrograph (IFS) that will see first light at W. M. Keck Observatory in 2025.
- SCALES will directly image exoplanets and protoplanetary disks in the thermal infrared from 2.0 - 5.2 μm. Other targets include supernovae and Solar System bodies.
- SCALES will image colder (and thus older) systems than have previously been studied, as the first facility-class IFS in this wavelength regime.
- Non-redundant aperture masking (NRM) is a relatively simple technique to achieve high spatial resolution imaging of high-contrast targets. The telescope aperture is made to function as an interferometer by blocking it with a mask.
- We developed a Python package to generate non-redundant mask designs. We select several designs with good Fourier coverage and test their performance by recovering planet signals from simulated SCALES images.

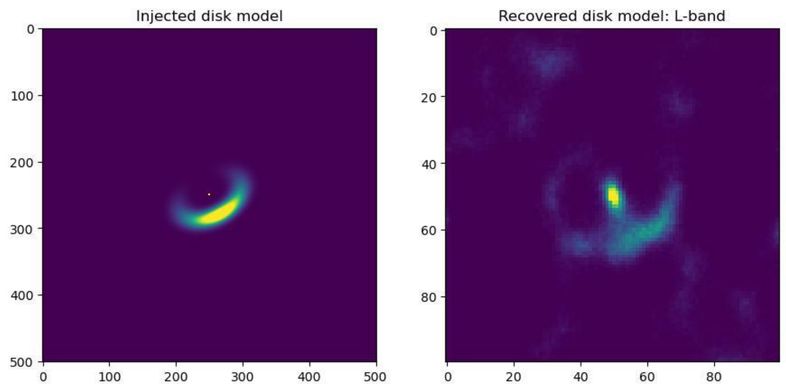
## Mask Design and NRM-artist

- Designs with more holes have better Fourier coverage and provide more throughput, assuming a fixed hole size.
- Generating more non-redundant holes becomes difficult, especially for larger hole sizes.
- NRM-artist is a nascent Python package that generates non-redundant mask designs for the Keck primary.
- Holes are randomly placed, and the (u, v) coordinates for the design are generated and checked for redundancy.
- Currently, NRM-artist does not optimize Fourier coverage or mask performance.
- A number of mask designs were generated with 6, 7, and 9 holes using NRM-artist.
- Three masks were selected based on their variety of baseline lengths, even hole distribution across the Keck aperture, and adequate (u, v) plane coverage.



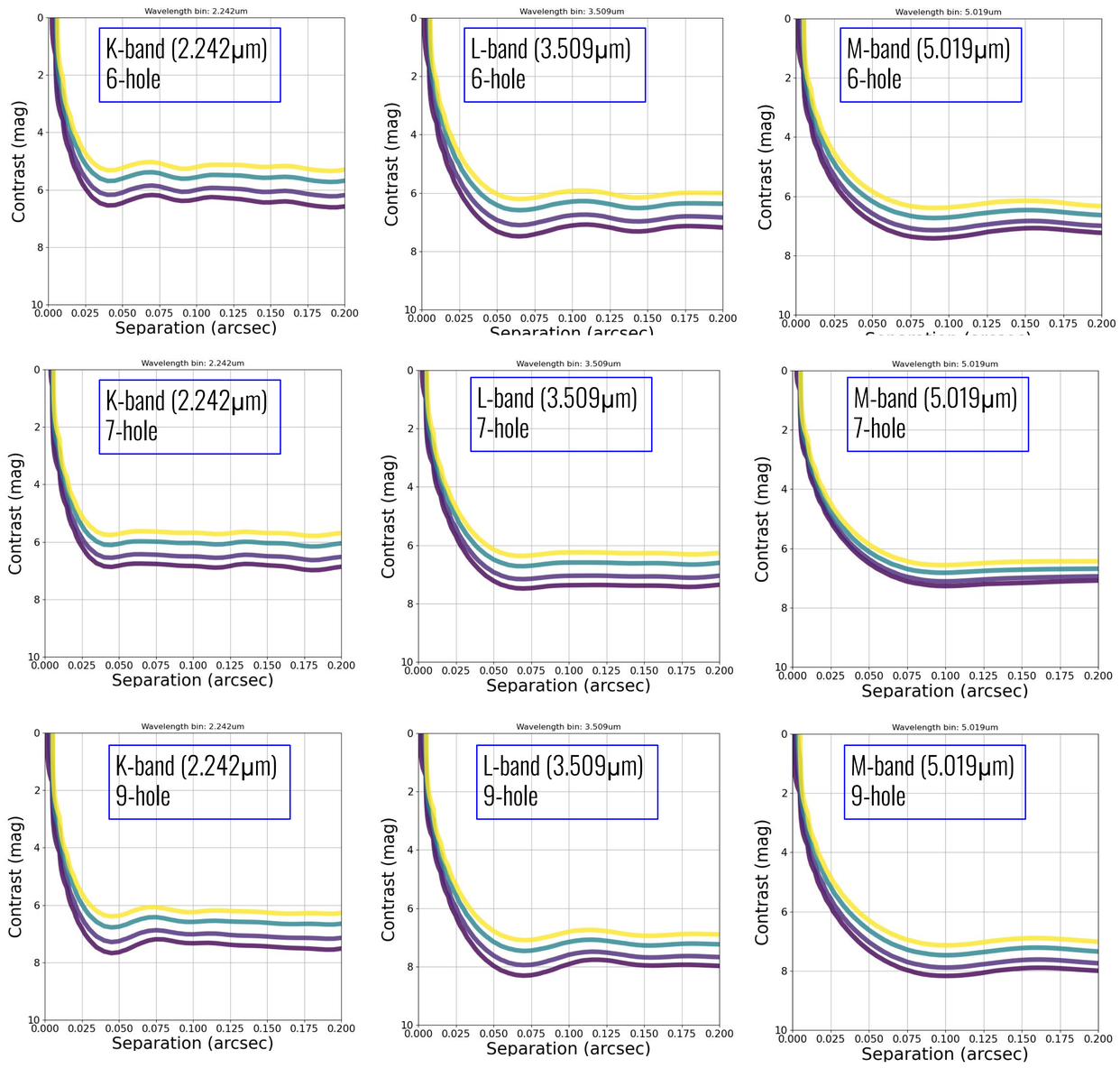
Left to right: 6-hole mask, 7-hole mask, 9-hole mask, simulated PSF of 6-hole mask at M-band.

## Signal Injection and Recovery




- Planet and disk signals were injected into raw SCALES frames and recovered. Planets were simulated with the Sonora model.
- Disk signals were generated using a geometric disk model (see Sallum et al. 2023).
- Top: injected disk signal recovered at L-band using the 7-hole mask design. Bottom: recovered planet.
- Note: FOVs differ between left and right panels.

## Contrast Curves




Above: contrast curves generated at sigma levels 1, 2, 5, and 10 for each of the three mask designs tested at SCALES low-resolution SED mode wavelength bins in K, L, and M bands.

## Future Work and Acknowledgements

- NRM-artist will be improved to run faster and more robustly. It will eventually be expanded upon for use with a wider variety of telescope apertures.
- An MCMC algorithm will be used to identify mask designs that are optimized for (u, v) plane coverage and for either extended or compact targets.
- A wider variety of targets will be injected into SCALES frames to test mask performance, with the ultimate goal of selecting final mask designs to go onto SCALES.
- The authors would like to thank Dr. Maaike van Kooten for providing the Keck/NIRC2 OPD data used to generate SCALES frames.