Searching For Planets in Their Infancy: A Survey of the Taurus Star Forming Region

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I. Searching for Exoplanets with Direct Imaging

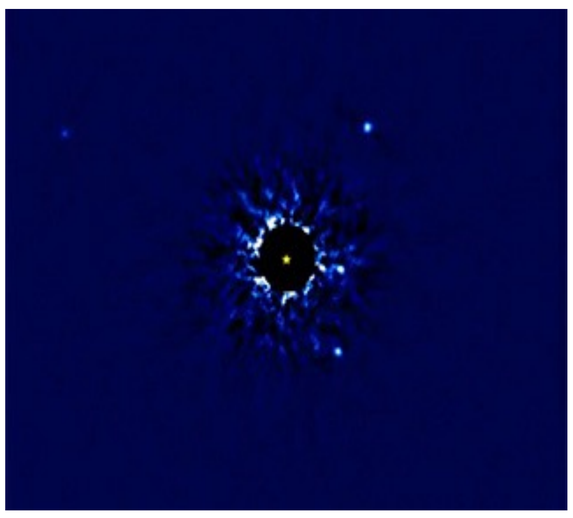


Fig 1: The HR 8799 system with four directly imaged exoplanets.

(Credit: Jason Wang and Christian Marois)

- Direct imaging is the most common method of detecting young exoplanets, using adaptive optics to detect photons from the planets themselves (Fig 1).
- Coronagraphs and various post-processing techniques are used to suppress the light of host stars which obscure nearby exoplanets.
- Reference star differential imaging (RDI): Images of reference stars are used to build a model point-spread function (PSF) using principal component analysis (PCA). This model is then subtracted away from the target image.

II. Super-RDI Can Improve on Traditional Post-Processing Methods

- PCA generally performs better with a larger library of reference images [1].
- Using image similarity metrics to select reference frames can improve RDI performance [2].
- Super-RDI: an optimized version of the Reference star differential imaging (RDI) method, where reference images are chosen using image similarity metrics and reference library size and number of principal components are chosen to maximize sensitivity [3].

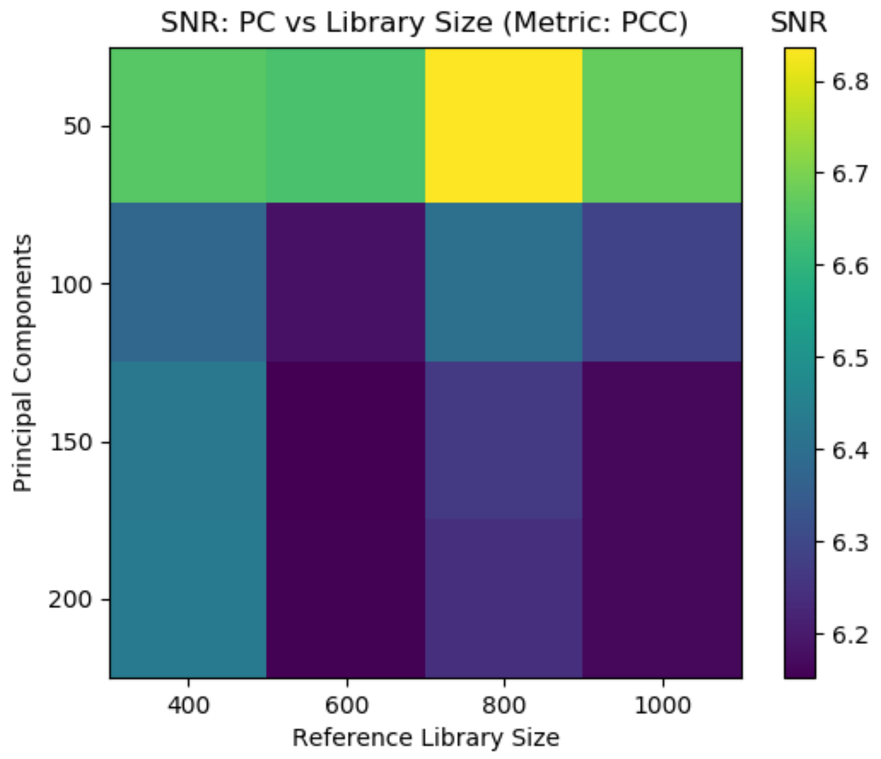
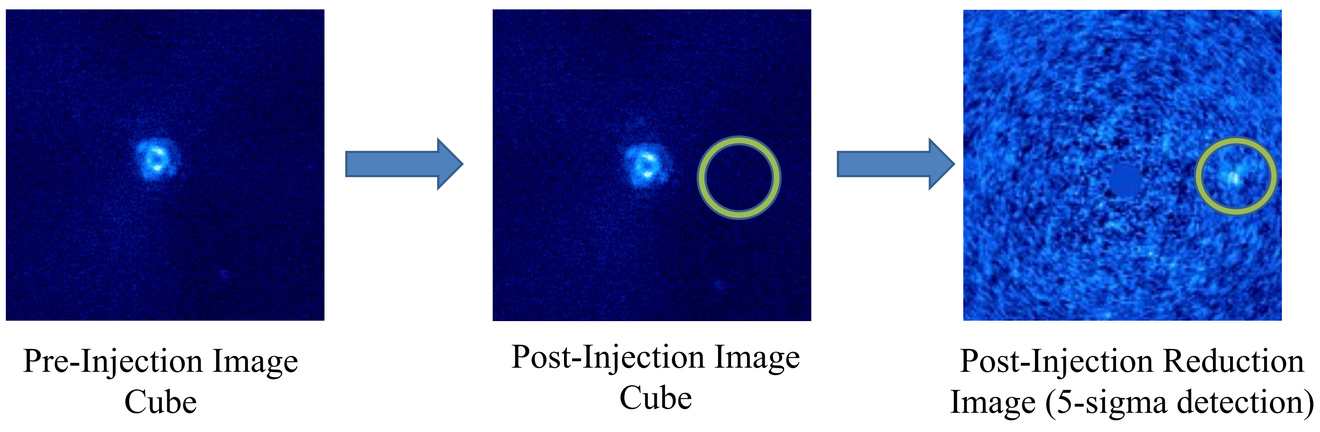


Fig 3: S/N ratio from Super-RDI reductions for HBC359 (2017/09/28), with PCC metric, varying reference library size and principal components

III. Optimizing Super-RDI to Find Exoplanets in the Taurus Star Forming Region

- We have images taken with the vector vortex coronagraph in L' with NIRC2/Keck of 100 members of the Taurus star forming region. We use Super-RDI in search for young planets.
- We seek to determine the optimal reference library size (l), number of principal components (p), and image similarity metric (m) that yields the greatest sensitivity.
- Our reference library spans nearly five years of observations and around 8000 images, combining this Taurus survey (PI: Bryan) with another vector vortex survey (PI: Mawet).
- Through injection-recovery tests, we inject fake planets with known signal-to-noise ratio (SNR) into a target dataset, reduce the data using Super-RDI and specified parameters (l, p, m), then calculate the SNR of the injected companion in the final image (Fig 2). We want to find the parameters that maximize the SNR in reductions.



Pre-Injection Image Cube

Post-Injection Image Cube

Post-Injection Reduction Image (5-sigma detection)

Fig 2: HBC359, 2017/11/09. Reductions with Super-RDI, Parameters used: library size = 1000, image metric = PCC, principal components = 100

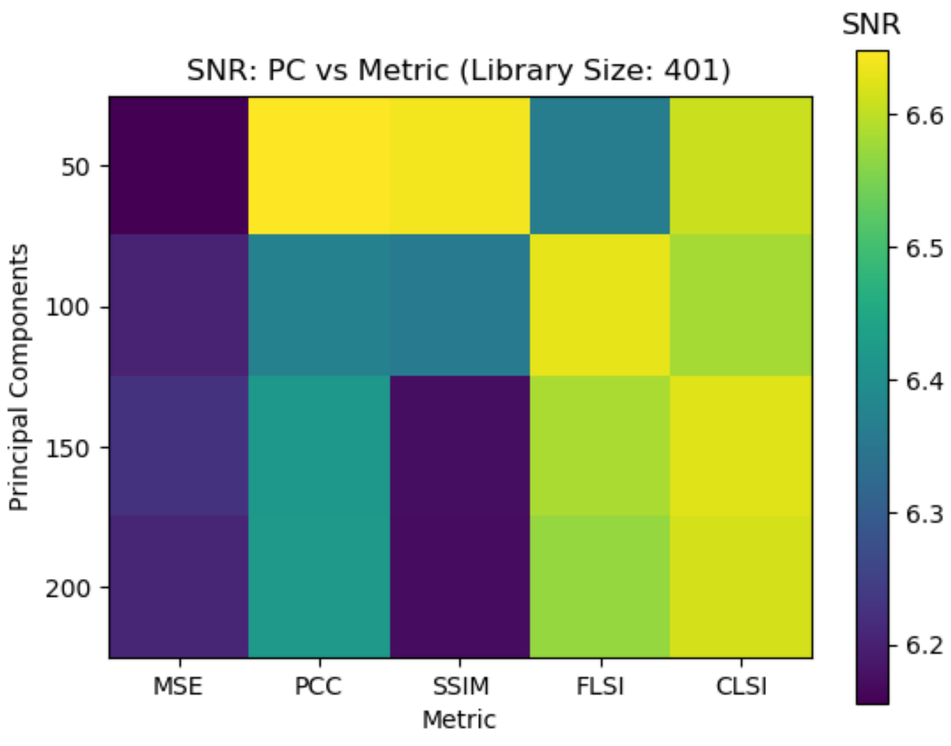


Fig 4: S/N ratio from Super-RDI reductions for HBC359 (2017/09/28), with 401 reference library size, varying similarity metrics and principal components

IV. Preliminary Results Show Improvements in SNR

- We have started to explore the (l, p, m) parameter space for a single system, HBC 359. With larger library sizes, fewer principal components, and using the PCC similarity metric, we have found increases of ~10% in SNR (Figs. 3-4). We expect further improvements when we explore more of the parameter space.
- Future work includes finding and using optimized parameters to run Super-RDI over entirety of Taurus dataset to generate a list of candidate companions.

V. References

1. Soummer et al. 2014, Five Debris Disks Newly Revealed in Scattered Light From the Hubble Space Telescope Nicimos Archive, The Astrophysical Journal Letters
2. Ruane et al. 2019, Reference star differential imaging of close-in companions and circumstellar disks with the NIRC2 vortex coronagraph at WM Keck Observatory, The Astronomical Journal
3. Sanghi et al. 2021, SUPER-RDI: Improving Exoplanet Detection Limits at Small Angular Separations with the Keck/NIRC2 Imager (unpublished)