Probing the AU Microscopii Debris Disk at Close Separations with the Gemini Planet Imager

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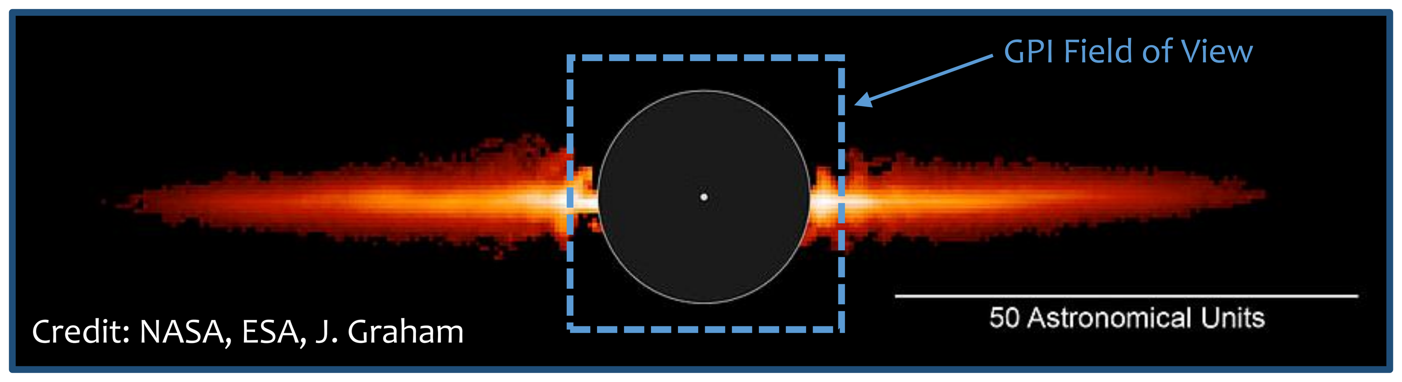
Summary:

- The Gemini Planet Imager observed AU Microscopii (AU Mic) during the commissioning of the instrument using both integral field spectroscopy and broadband imaging polarimetry.
- We detect scattered starlight from the AU Mic debris disk in both our *H*-band and *K1*-band data between ~0.2"-1.5" from the star.
- We find asymmetries in the disk morphology between ~0.5"-1.2", including a possible inner warp similar to that of β Pictoris' disk.
- With GPI spectral mode observations, we reach ~50% completeness for 2 M_{Jup} planets at 5 AU.

The Known Debris Disk Around AU Mic

- AU Mic is a young (β Pictoris moving group) and nearby (~10 pc) M-dwarf, ideal for studying planet formation.
- Its edge-on debris disk has an inner hole inside of ~40 AU (0.4") that may be carved out by planets.

HST ACS/HRC Image of AU Mic



The Gemini Planet Imager Observations

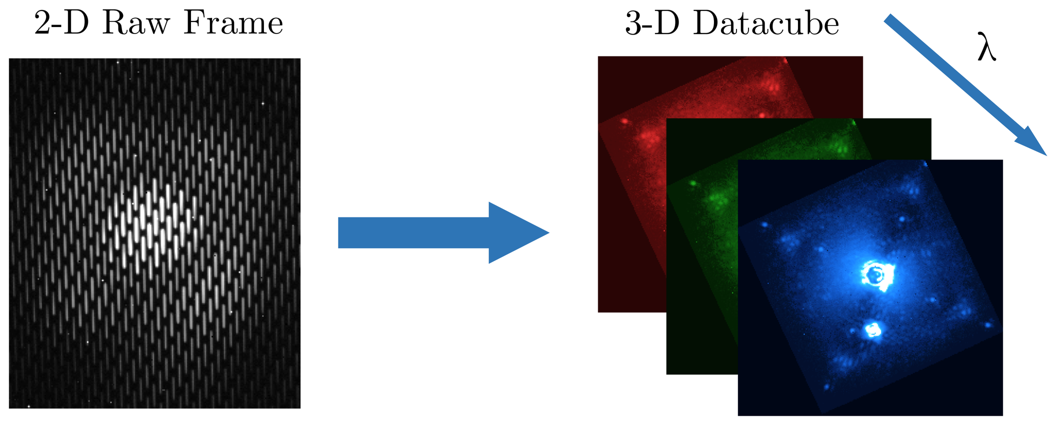
- The Gemini Planet Imager (GPI)[1] combines a high-performance AO system, a coronagraph, and an integral field unit to image planets and disks closer in to the star than ever before.
- GPI can perform integral field spectroscopy (spectral mode) with R~30-90 and broadband imaging polarimetry (polarimetry mode).
- AU Mic data taken during commissioning allows us to test the performance of GPI.
  - 2014 May 12: 27 minutes of *K1*-Band (first half of *K*-band) spectral mode with 154° of field rotation
  - 2014 May 15: 40 minutes of *H*-band polarimetry mode with 155° of field rotation

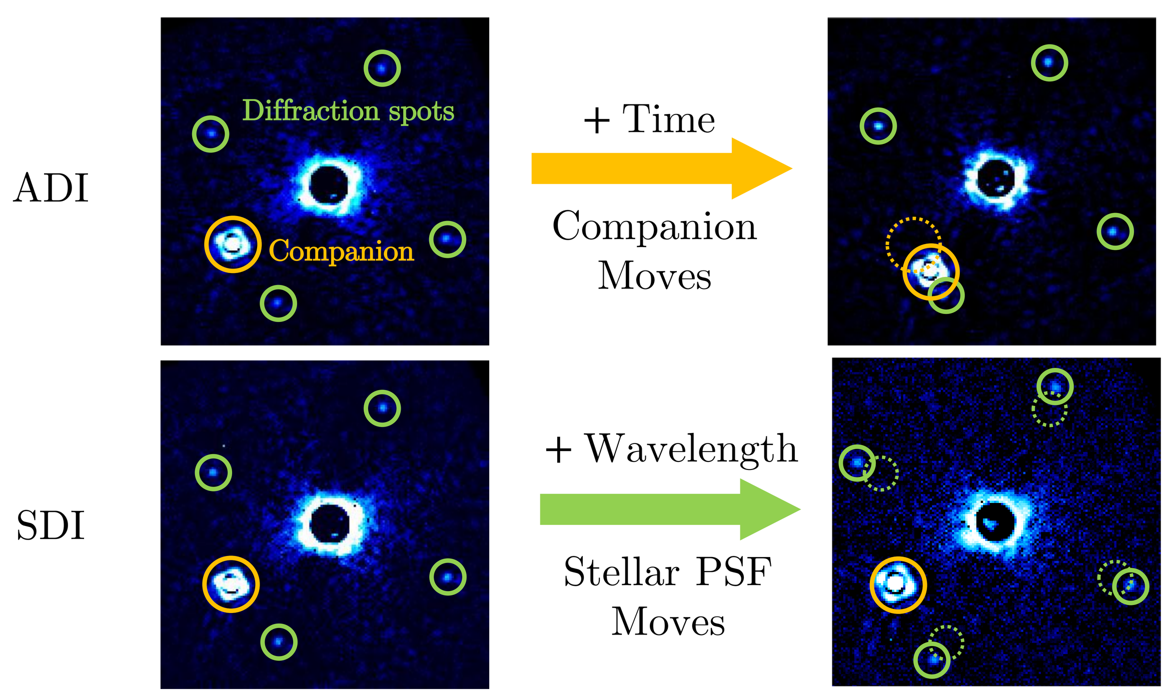
Data Reduction and PSF Subtraction

Datacube Assembly

- Done using the standard GPI Data Reduction Pipeline[2]
- Microspectra (spectral mode) and polarization spot pairs (polarimetry mode) are extracted from raw 2-D data to form 3-D datacubes.
- Fiducial diffraction spots are used to register the images and provide a relative flux calibration.

Spectral Datacube Construction





PSF Subtraction

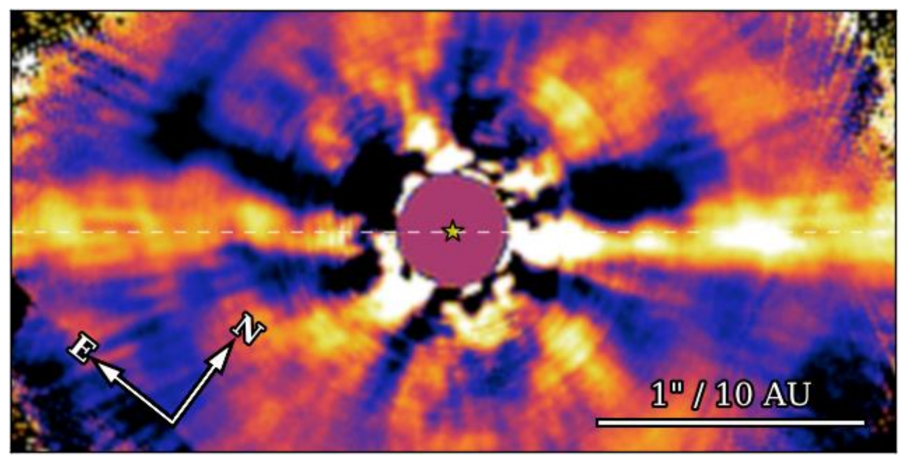
- With our total intensity polarimetry data, we used angular differential imaging (ADI) to detect the disk.
- In spectral mode to search for planets, we used both ADI and spectral differential imaging (SDI).
- Stellar point spread function (PSF) is modeled and subtracted using principal component analysis following the KLIP algorithm.[3]

References:

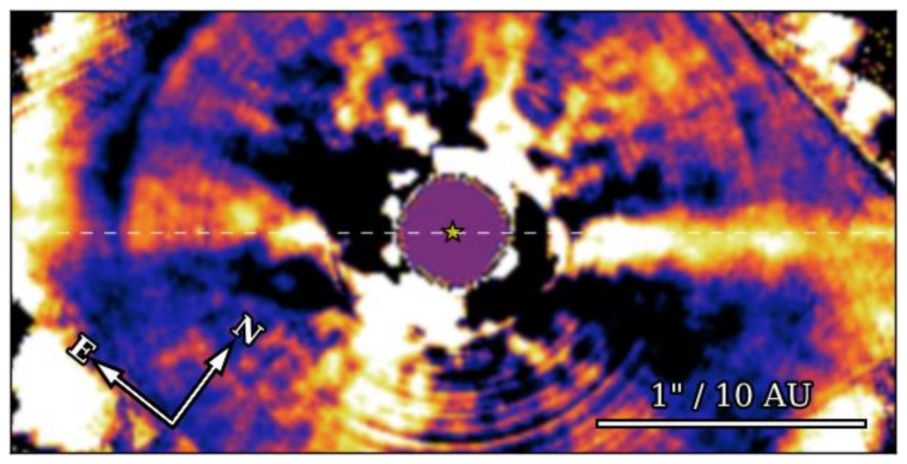
[1] Macintosh, B., Graham, J.R., Ingraham, P., et al. 2014, PNAS, 111, 35.
[2] Perrin, M.D., Maire, J. , Ingraham, P., et al. 2014, Proc SPIE, 9147.
[3] Soummer, R., Pueyo, L. , & Larkin, J. 2012, ApJ, 755, 2.
[4] Graham, J. R., Kalas, P.G., Matthews, B.C. 2007, ApJ, 654, 1.
[5] Krist, J.E., Ardila, D.R., Golimowski, D.A., et al. 2005, ApJ, 129, 2.

What Does GPI See?

H-Band Broadband ADI (40 minutes)



K1-Band ADI+SDI (27 minutes)



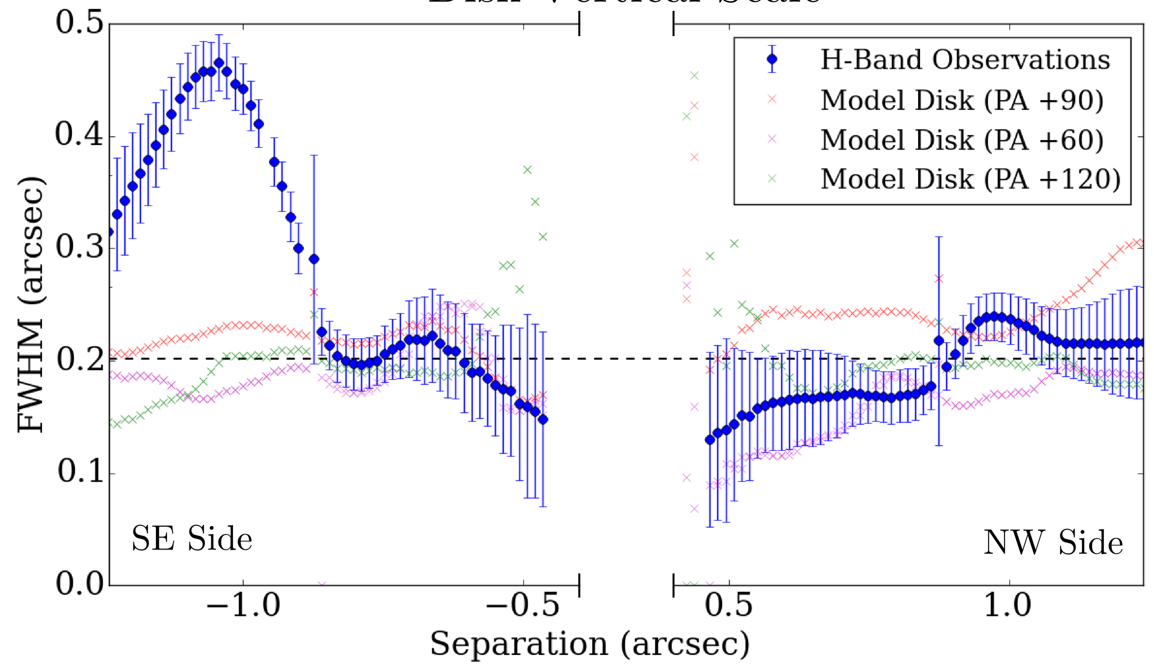
Morphology of the Debris Disk

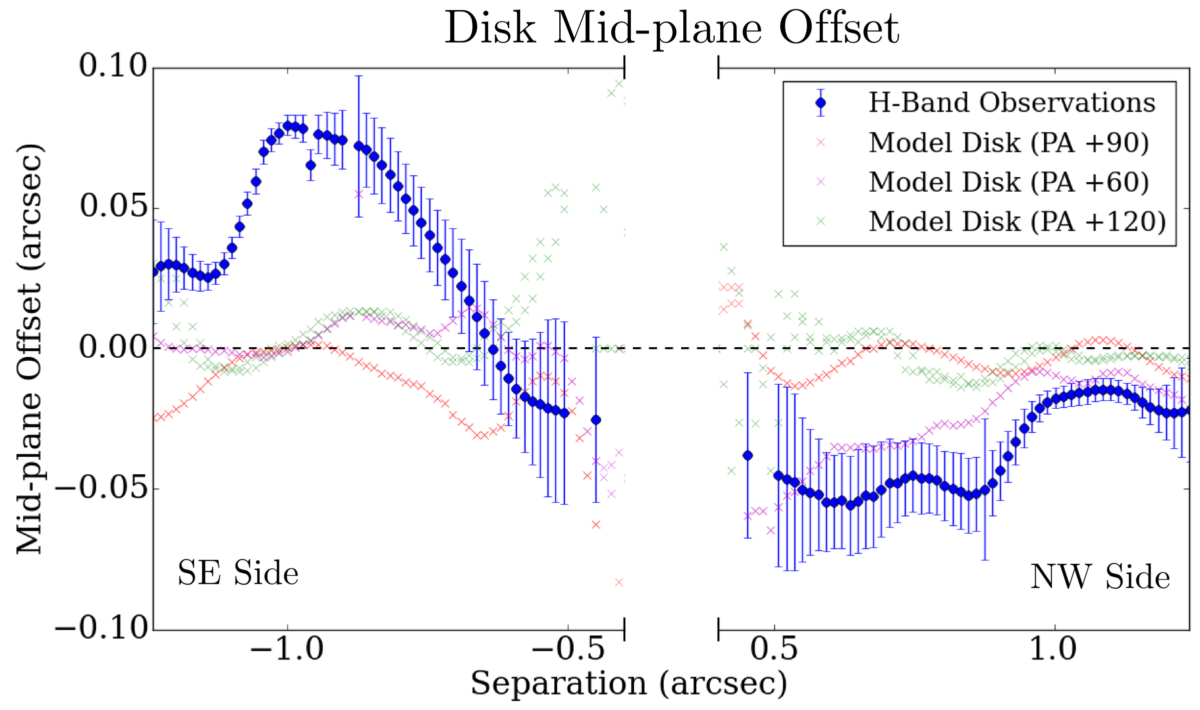
Retrieval of Disk Properties

- Full width at half maximum (FWHM) and disk mid-plane offset measured by fitting Gaussian vertical profiles.
- We account for systematic biases and measurement errors by injecting model disks into the data.
- Injected disks modelled as a ring following a porous water ice model for AU Mic[4] with an uniform scale height of 0.74 AU.[5]

Results

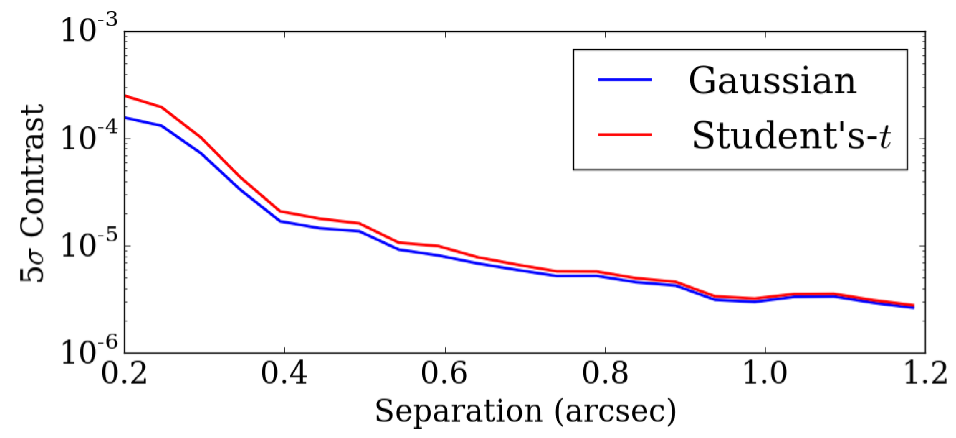
- The southeast (SE) side of the disk is more flared out at ~1" whereas the northwest (NW) side is consistent with a vertical scale height of 0.74 AU.
- There is a clear offset from the disk mid-plane on the SE side and a possible offset on the NW side.
- The disk mid-plane offsets hint at a possible warp (~2°) in the disk, possibly due to a perturbing planet like in the case of β Pictoris.



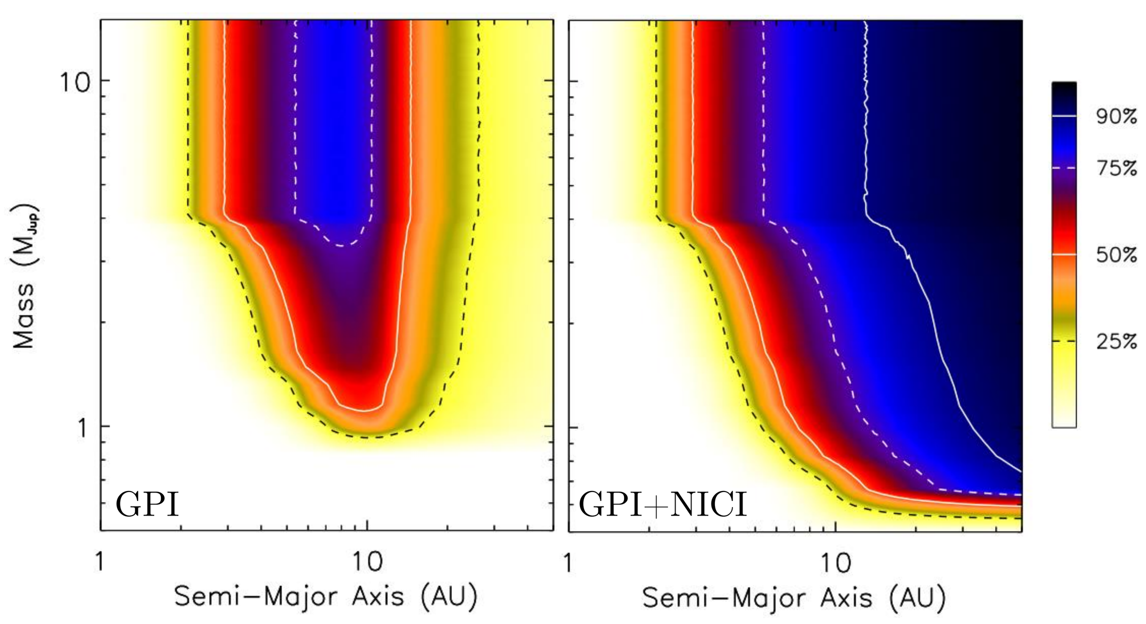


Upper Limits on Potential Planets

- Using our K1 spectral mode data, we find upper limits for "hot start" planets.
- The current data is limited by integration time and lack of sky subtraction.



Sensitivity to "Hot Start" Planets



Future Work

- Extract the surface brightness of the disk in both *H*- and *K1*-bands and quantify variations
- Measure the polarized intensity of the AU Mic disk to help constrain the composition of the disk
- Acquire longer spectral mode observations of AU Mic now that the instrument is commissioned to probe for fainter planets close in to the star

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