Direct Imaging of Fine Structures in Giant Planet Forming Regions of the Protoplanetary Disk around AB Aur

by

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AB Aur

- Prototype young intermediate-mass star (Herbig Ae/Be star)
- $D = 144$ pc, $M = 2.4\pm0.2\ M_\odot$, age = $4\pm1$ Myr
- Disk radius $\sim 450$ AU, disk mass $\sim 20\ M_J$
  - “Spiral structure” in the outer part ($r \geq 200$ AU) of the disk is seen in the near-IR (Fukagawa et al. 2004)
  - A possible point source in a “dip” of the $PI$ (polarized intensity) image in the inner disk region (Oppenheimer et al. 2008)
De-projected near-IR image of AB Aur (Fukagawa et al. 2004)
Advantages of $PI$ imaging

Total intensity and $PI$ images of HD 107146 and AB Aur
(Oppenheimer et al. 2008)
HiCIAO

• High Contrast Instrument for the Subaru Next Generation Adaptive Optics – HiCIAO, a flexible camera that can be configured into different modes (Tamura et al. 2006)

• For this study:
  – AO + coronagraph + dual-beam polarimetry
  – $H$-band (1.6 micron)
HiCIAO

- *P* image
- Inner working angle = 22 AU
- Spatial resolution = 9 AU
- Focus on the inner regions (*r* < 50 AU)
  - The detailed structure of the inner disk is crucial to test the theories of planet formation & migration (e.g., migration due to planet-planet scattering or gravitational instability?).
Observation

- Observed under the program SEEDS (Strategic Explorations of Exoplanets and Disks with Subaru; Tamura et al. 2009)
- FOV: 10” by 20” (with a circular occulting mask of 0.3” in diameter)
- Integration time: 189.6 s
- $PI$ is calculated as $PI=\sqrt{Q^2+U^2}$
Magnified view of the inner $PI$ image
• No point-like sources are detected in the dips → upper limits of the planetary mass:
  – $5 \sim 6 \, M_J$ in Dip A, or $7 \sim 9 \, M_J$ in the inner ring
    (consistent with numerical simulations)
Discussion

• What caused the non-axisymmetric structure of AB Aur disk?
  – GI (gravitational instability)?
  – Perturbation induced by inner low-mass planets?
  – MRI (magneto-rotational instability)?

• Future investigation
  – Time variability of the structures
  – The deviation of the pattern speed from the local rotational speed would be smoking-gun proof of the existence of the planet
  – In the case of MRI, the timescale of variability is on the order of the local rotational timescales
Discussion

• The existence of a planet in the AB Aur system, whose age is only 3 ~ 5 Myr, may pose a unique constraint on the planet-forming timescale (e.g., gas-accretion may take about 10 Myr).
Thank you!