Stellar Wobble by a Planet in a Disk

Limitation on Planet Detection by Astrometry

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Summary

- We consider the possibility of planet detection by astrometry.
- SIM has enough accuracy (1 μas) to detect infant planets at star forming regions.
- Light from a circumstellar disk shifts the photo-center of the star-disk system, and may interfere with the astrometry to measure precise stellar positions.
- The disk light causes a photo-center shift as large as the amplitude of the dynamical stellar wobble by a Jupiter mass planet.
- However, SIM is not sensitive to extended disk's light, so the disk's contamination to the astrometry shift is less than 1 μas.

1. SIM: Space Interferometry Mission

Launch: 2009
Baseline: 10 m
Telescopes: 33 cm
Relative Accuracy: 1 μas

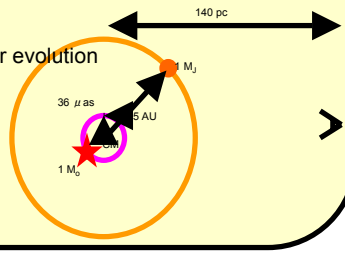
2. Stellar Wobble by a Planet

Astrometry shift by a Jupiter mass planet
- 36 μas at 140 pc > 1 μas of the SIM accuracy

Search for infant planets is possible

Taurus-Auriga molecular clouds
- ~200 T Tauri stars (Kenyon & Hartmann 1995)
- D=140 pc
- 10^5 – 10^7 yr

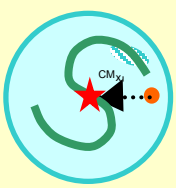
At which epoch in young stellar evolution are planets born?

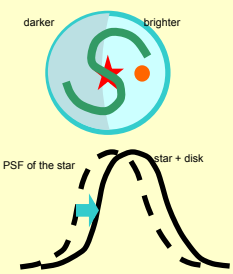


3. Disk's Contamination

Dynamically
- Shift of the mass-center

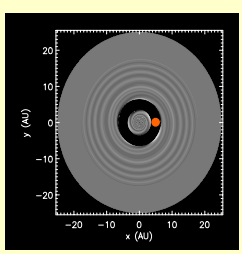
Optically
- Shift of the photo-center
- beam size >> disk's diameter





4. Density Wave Pattern

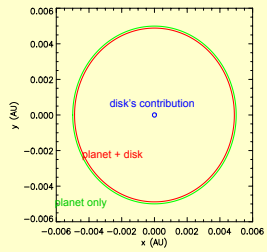
Linear calculation
2-D disks
A gap in the disk [$0.6r_p$ – $1.4r_p$]
1-10 M_J
Circular and co-planer orbits



surface density

5. Dynamical Shift

Disk's dynamical effect is negligible even for a massive (0.16 Mo) disk



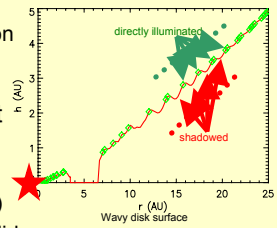
Motion of the stellar position

6. Optical Shift

Hydrostatic equilibrium in the z-direction

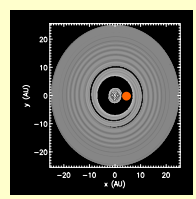
$$h = \sqrt{2\eta}/\Omega$$

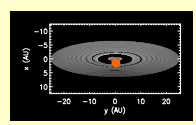
Images of the disk's scattered light



Wavy disk surface

- At optical wavelengths (400-900 nm)
- Disk surface is modeled as being solid
- Totally scattered starlight at the surface
- Illuminating and shadowing the surface

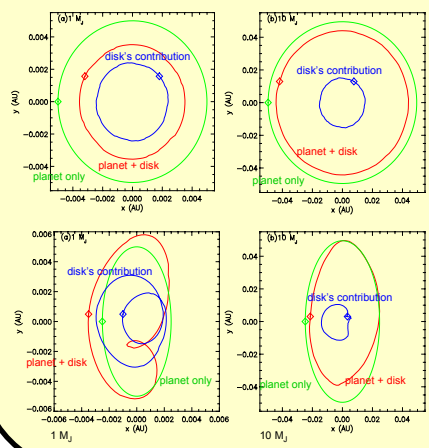




Scattered light images of disks (face-on, 75º inclined)

Wobble of the photo-center

Disk contamination is not significant if
M > 10 M_J



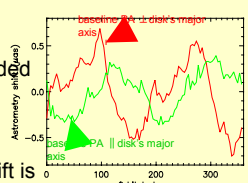
Motions of the photo-centers (Face-on, 60º inclined)

7. SIM Astrometry

SIM astrometry is not sensitive to extended sources larger than the fringe size,

$$\frac{\lambda = 0.5\mu\mathrm{m}}{b = 10\mathrm{m}} \approx 20\mu\mathrm{as} \approx 3\,\mathrm{AU}$$

Disk contamination to the astrometry shift is less than 1 μas for a 1 M_J planet.



Disk's contamination to the SIM astrometry shifts