Weighing Protoplanets in Transitional Disks

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Context

- **Planet** exerts gravitational torque on the disk
- Disk **viscosity** resists opening of **annular gap**

Several **planet diagnostics**:
- Gap location, depth, and width
- **Shape of gap edges**
- Non-axisymmetric features (spiral wakes, eccentric gaps)
- Pressure bumps/dust traps

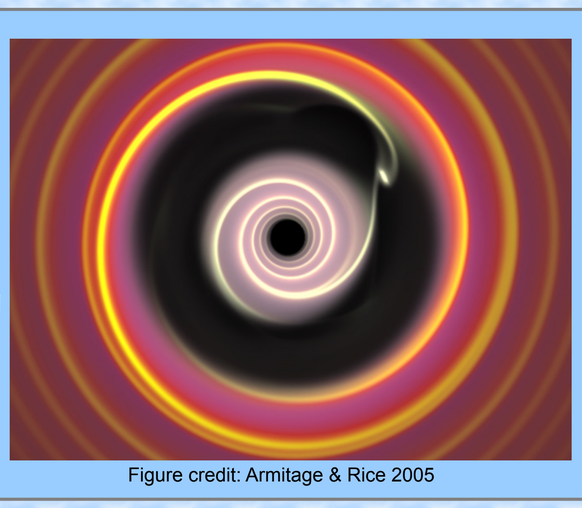
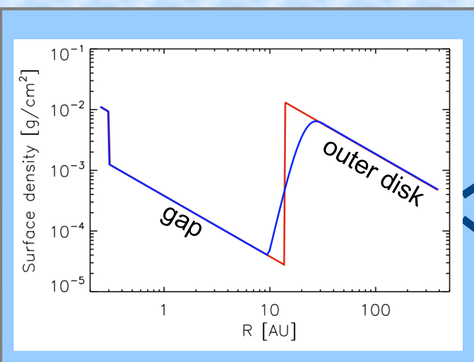
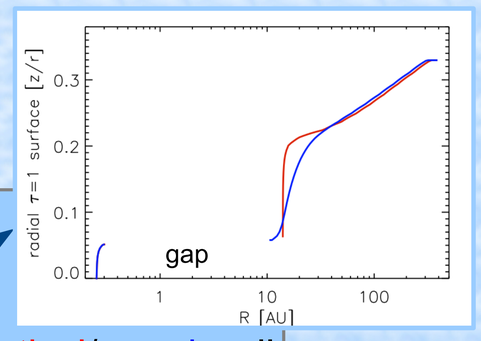


Figure credit: Armitage & Rice 2005

Method

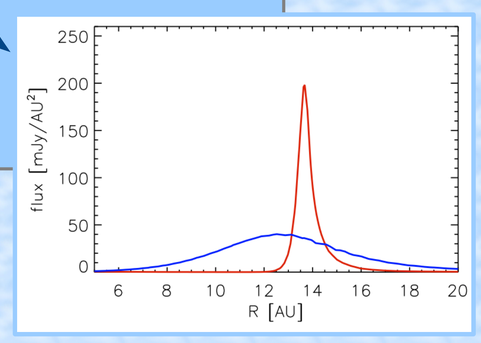


Steep/gradual increase in surface density at gap edge



Vertical/round wall

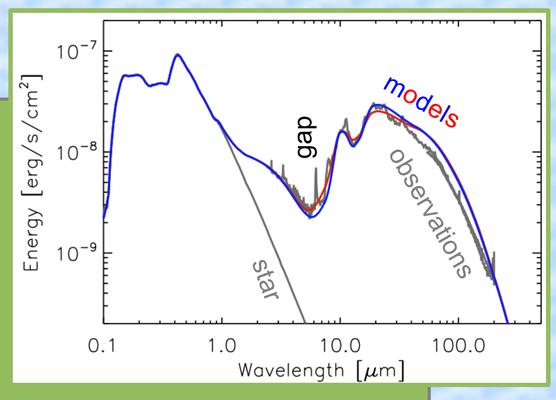
Emission peaked/ Smoothed out

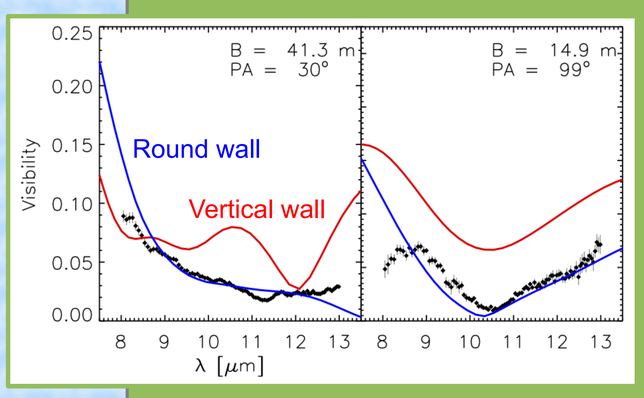


Interferometry

Disk: **HD 100546**

Radiative transfer modeling of **SED** with **MCMax** constrains:
- Scale height
- Dust temperature
- Presence of gap

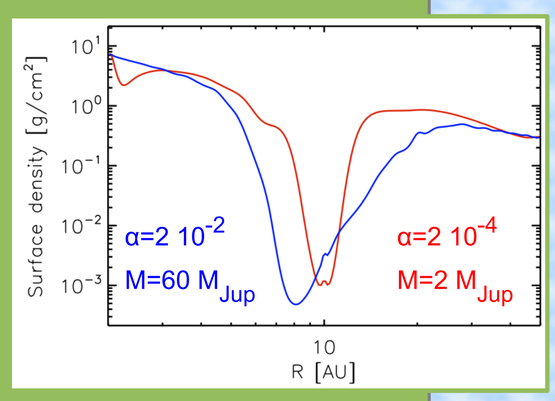




See also Panic et al. 2013

Spectrally resolved **visibilities** constrain:
- Exact wall location
- **Wall shape**
- Gap depth
- Inner disk size (0.3 AU)

Hydrodynamical modeling of **wall shape** (Fargo) constrains:
- Planet location
- **Planet mass**
- Disk viscosity (α)

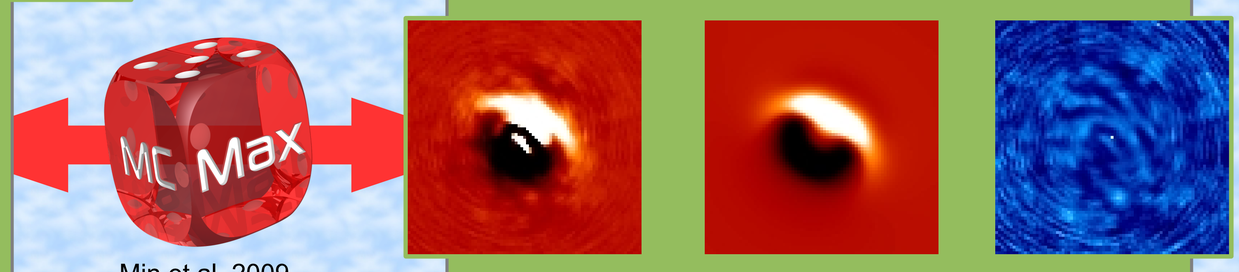


The observed gap requires a **60^{+20}_{-40} M_{Jup} brown dwarf** at 8-10 AU in a viscous disk ($\alpha > 2\ 10^{-3}$)

Imaging

Disk: **LkCa 15**

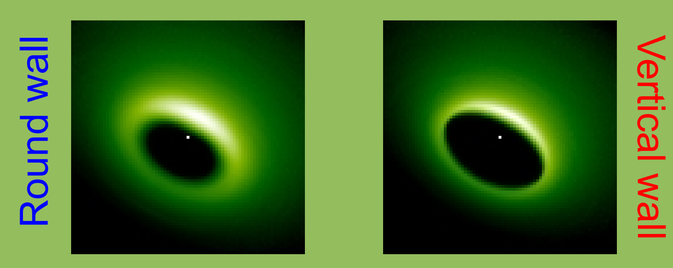
Angular Differential Imaging (ADI):
- Resolve gap edge at ~56 AU
- **Forward scattering dust** grains (g=0.7)



Min et al. 2009

K band observation | Model image + ADI | Residuals

Detect **rounded-off** disk wall



Preliminary **hydrodynamical** modeling: a **>5 M_{Jup} planet** at ~30 AU, $\alpha > 10^{-3}$

Thalmann, Mulders et al. in prep

Open questions

- **Detectable** with Sparse Aperture Masking?
- Responsible for **ejecting** the planet at 70 AU discovered by Quanz et al. 2013?

Planet mass consistent with Kraus & Ireland 2013

Location is not consistent: is it a **different planet**, or is it on an **elliptical orbit**?

Interested?

Take a preprint here
(Mulders et al. A&A accepted)

Or ask me for a copy of my thesis!
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