TW Hya: Where’s the gap?

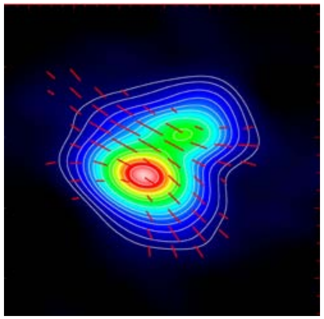
Rachel Akeson

NASA Exoplanet Science Institute

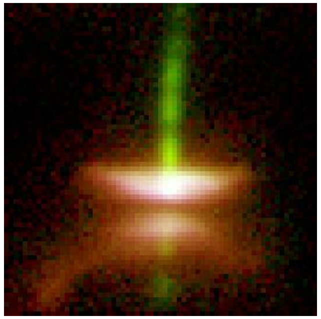
Collaborators

- Rafael Millan-Gabet
- David Ciardi
- Andy Boden
- Anneila Sargent
- Thanks to the CHARA team for the sensitivity improvements and special thanks to Chris F for battling the trees

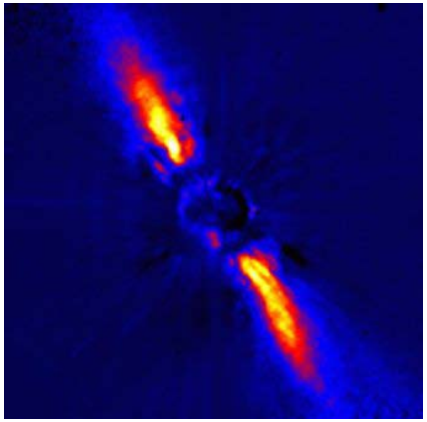
Evolution of disks



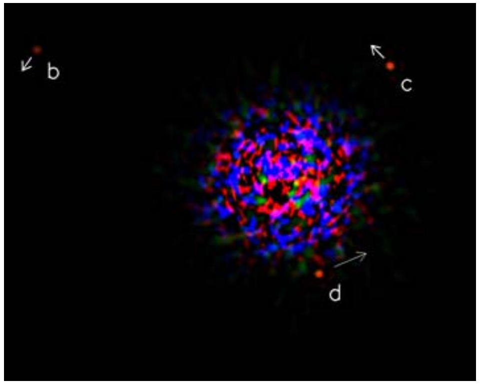
Girart et al



Burrows et al

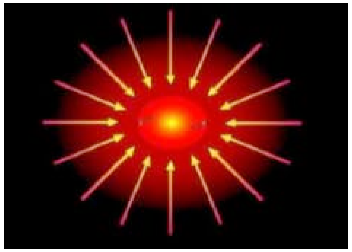


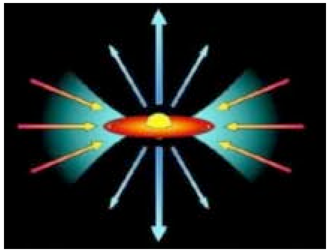
ESO

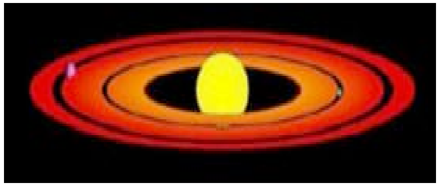


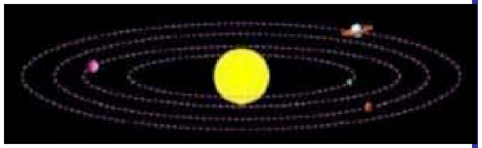
Marois et al

Protostellar collapse ala Shu





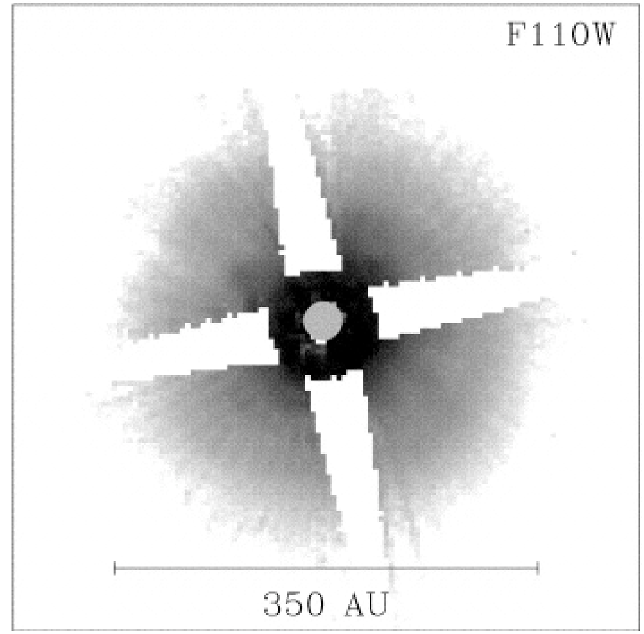




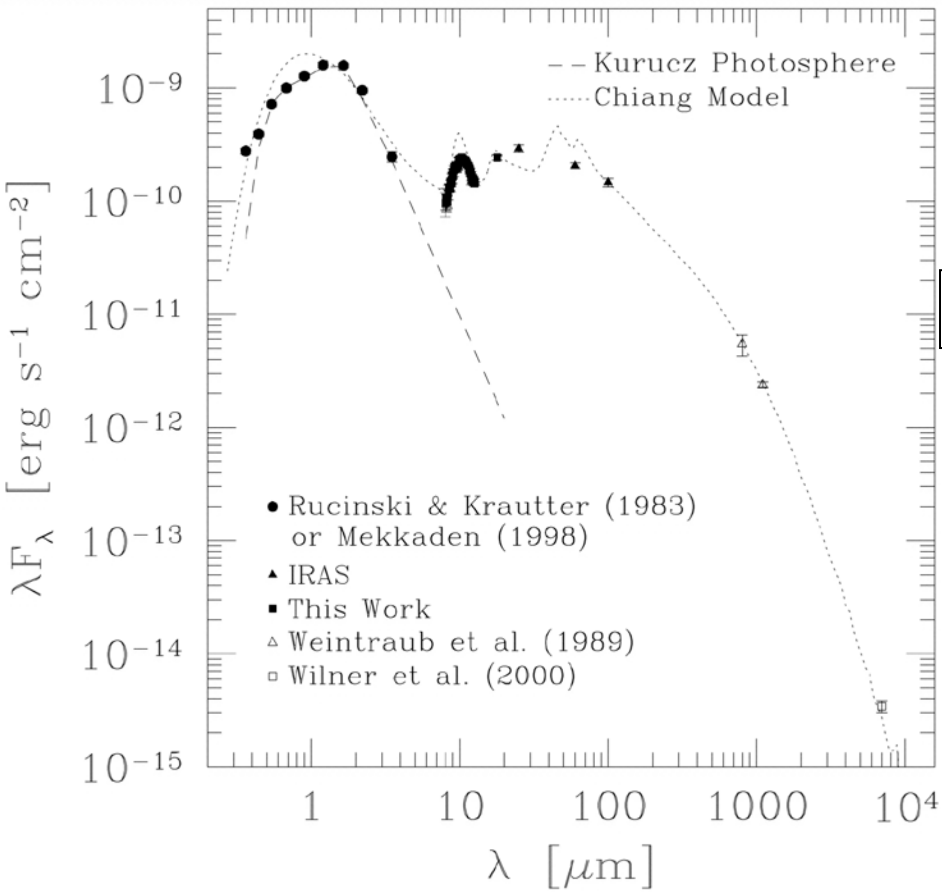
10^4 10^5 10^6 10^7 10^8 yrs

TW Hya

T Tauri star at ~50 pc



Weinberger et al



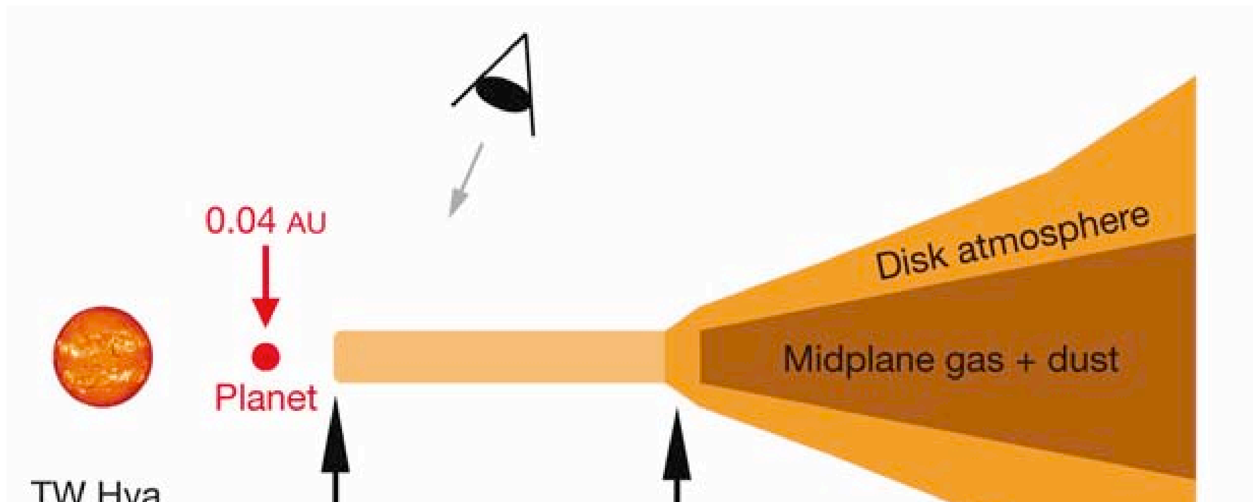
- Face-on disk
- Low accretion rate
- Age ~10 Myr

TW Hya inner hole

- Calvet et al (2002) used SED modeling and VLA 7mm images
  - 4 AU inner hole with optically thin material to produce silicate emission
  - Optically thick disk extends to at least 140 AU
- Eisner et al (2006) observed TW Hya with KI
  - Data implies sub-micron sized dust to 0.06 AU
  - Consistent with material still accreting onto central star

Is there a planet?

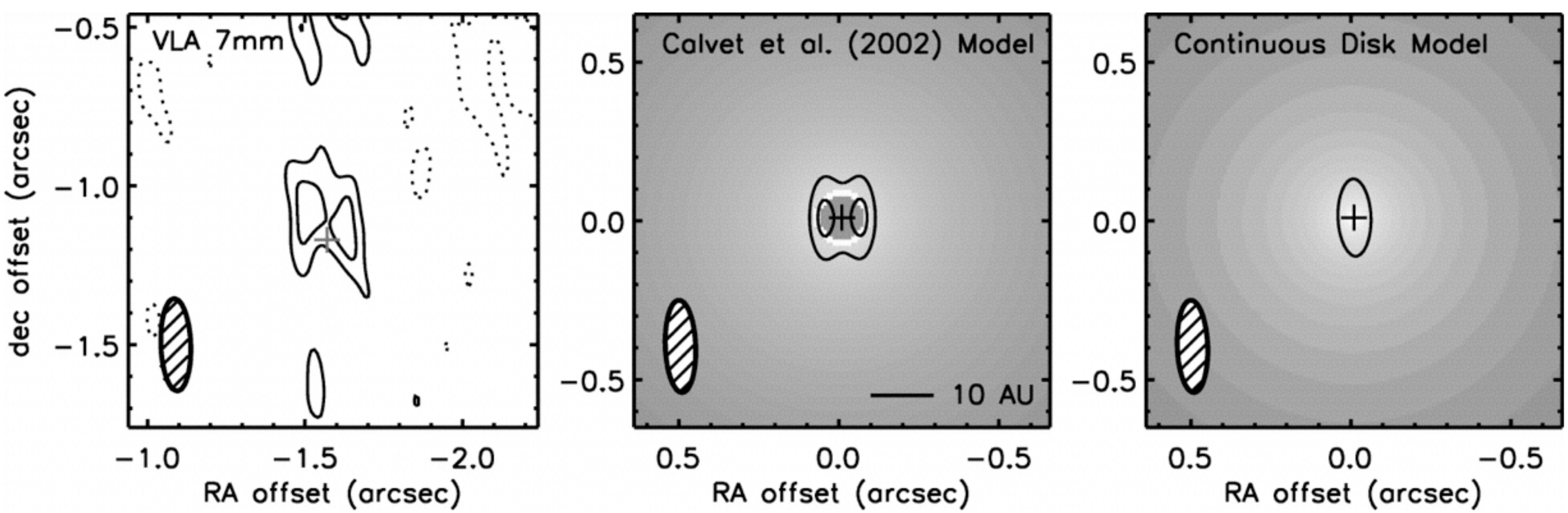
– Setiawan et al (2008) claimed a detection of a radial-velocity planet with a semi-major axis of 0.04 AU



But Huelamo et al (2008) find RV variations are due to a cool star spot

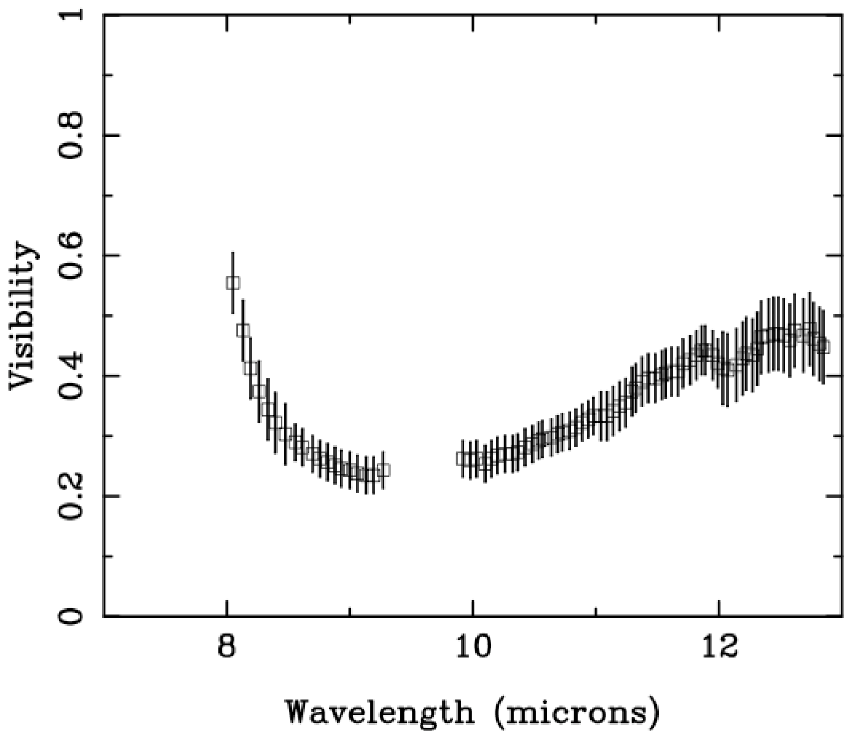
Direct confirmation of inner hole

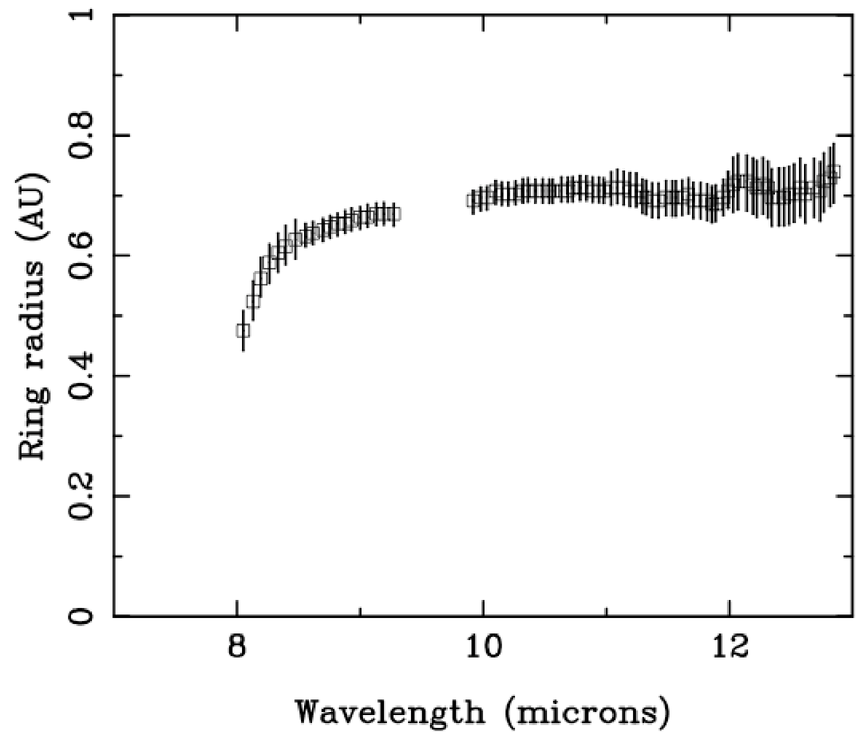
- Hughes et al (2007) re-observed with the VLA 7 mm at higher resolution
  - Emission consistent with ring at 4 AU



But in the mid-infrared…

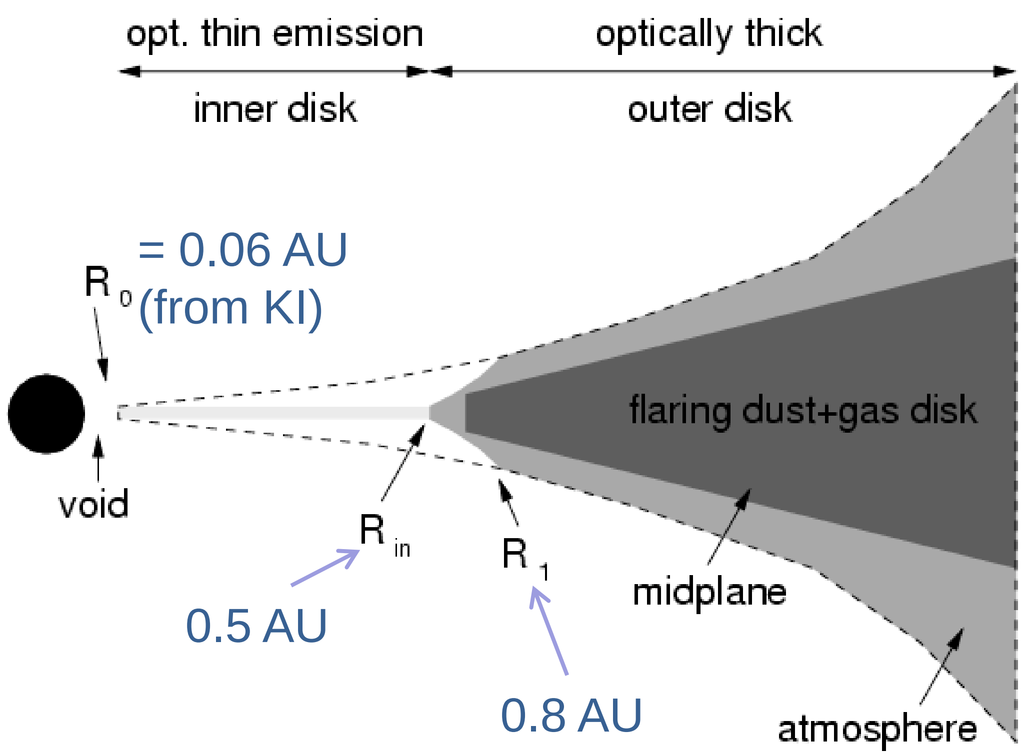
- Ratzka et al (2007) used VLTI to measure the mid-infrared size





Ratzka et al disk model

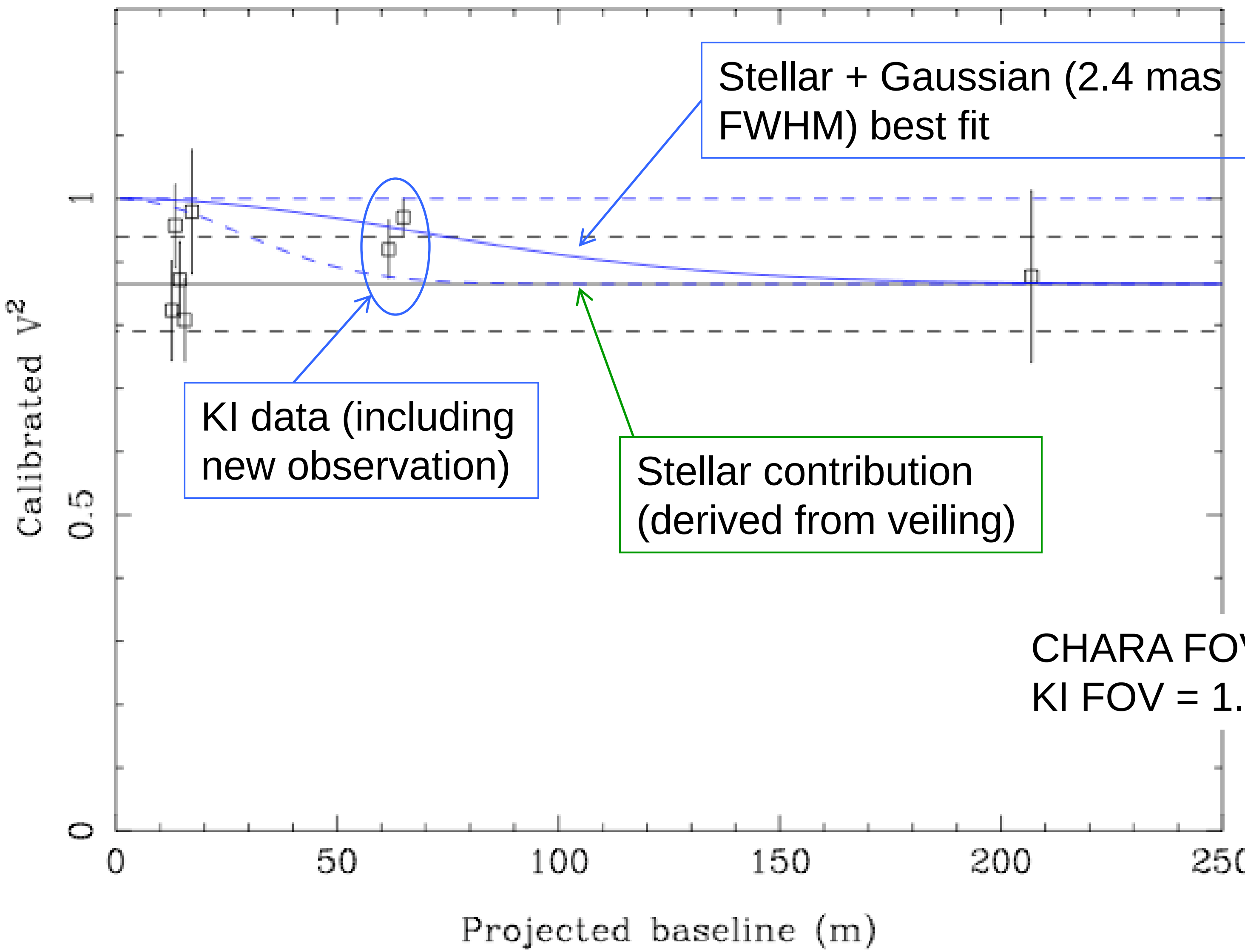
– Mid-IR emission is resolved and consistent with inner hole ***less than 1 AU*** in size



New CHARA observations: April 2009

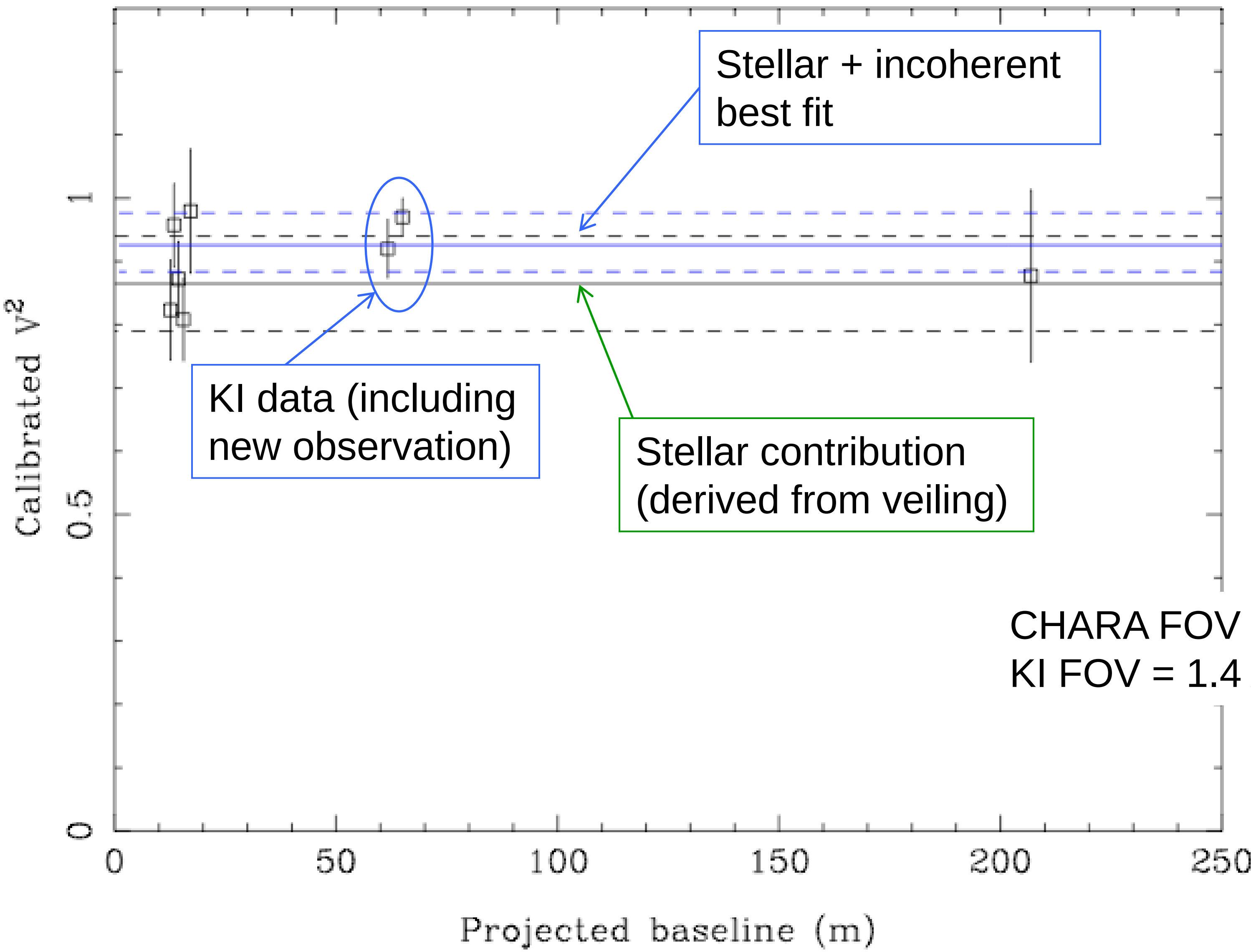
- Challenges
  - Relatively faint: K = 7.2
  - Very low declination: -34 deg (yes, we could see the trees in the camera images…)
- Chose two baselines to bracket the Keck measurement
  - Inclination not important as disk is face-on
- Issues with data
  - The source has less than 100 counts, pushing the capabilities of reduceir
  - Theo started implementing modified power spectrum background subtraction
  - Reduction shown made with new Michigan Classic pipeline

Near-IR data



CHARA FOV = 28 AU
KI FOV = 1.4 AU

Near-IR data



CHARA FOV = 28 AU
KI FOV = 1.4 AU

Near-IR results

- TW Hya is marginally resolved with no obvious baseline dependence
  - But large uncertainty in long baseline point limits how well this can be constrained
- Best fit (chisq = 1.2) for flat visibility
  - Stellar + incoherent
    - Uncertainty in near-IR SED limits determining the incoherent flux
    - Consistent with small scattering component
    - Less consistent with tracing inner hot dust

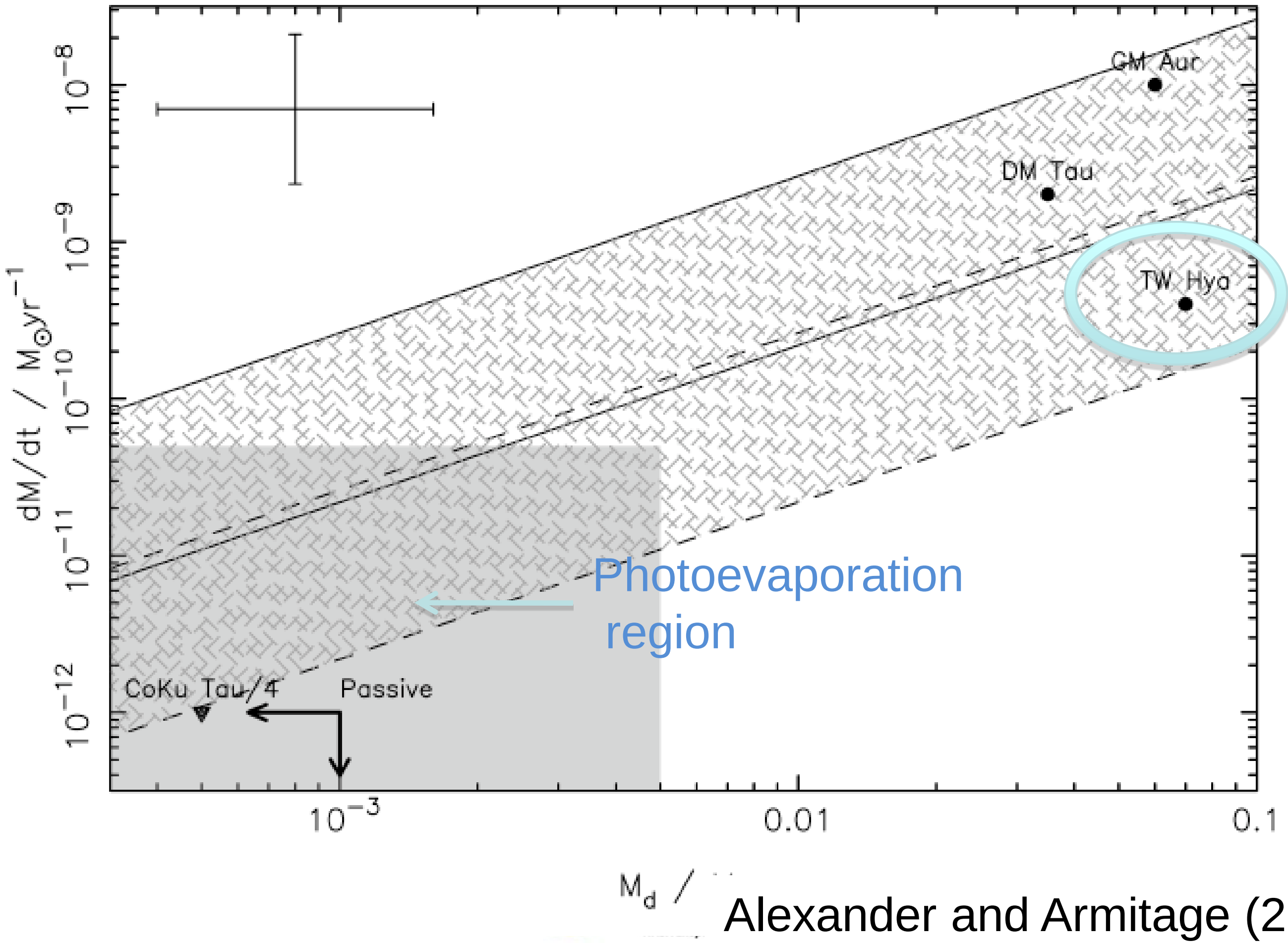
What clearing mechanism(s) are at work in the inner disk?

Inner radius of optically thick disk is NOT at the dust sublimation radius

1. Grain growth in inner disk MAYBE
   - But accretion rate much lower than "standard" T Tauri
2. Dynamical clearing by planet
   - Setiawan et al proposed planet too close
   - Inner region must have optically thin material
3. Photoevaporation PROBABLY NOT

Photoevaporation

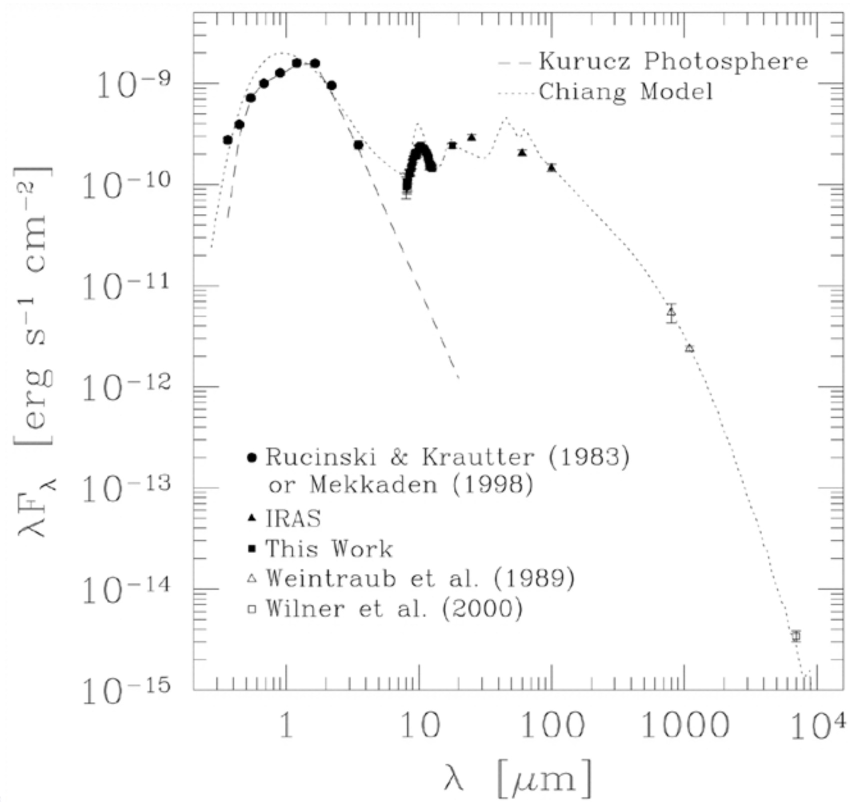
- Photoevaporation requires balance of disk mass and accretion rate



Alexander and Armitage (2007

Whole disk models

- Constrain inner disk radius/gap using spatially resolved data at 2 microns, 10 microns, and 7 mm
- Include SED as well

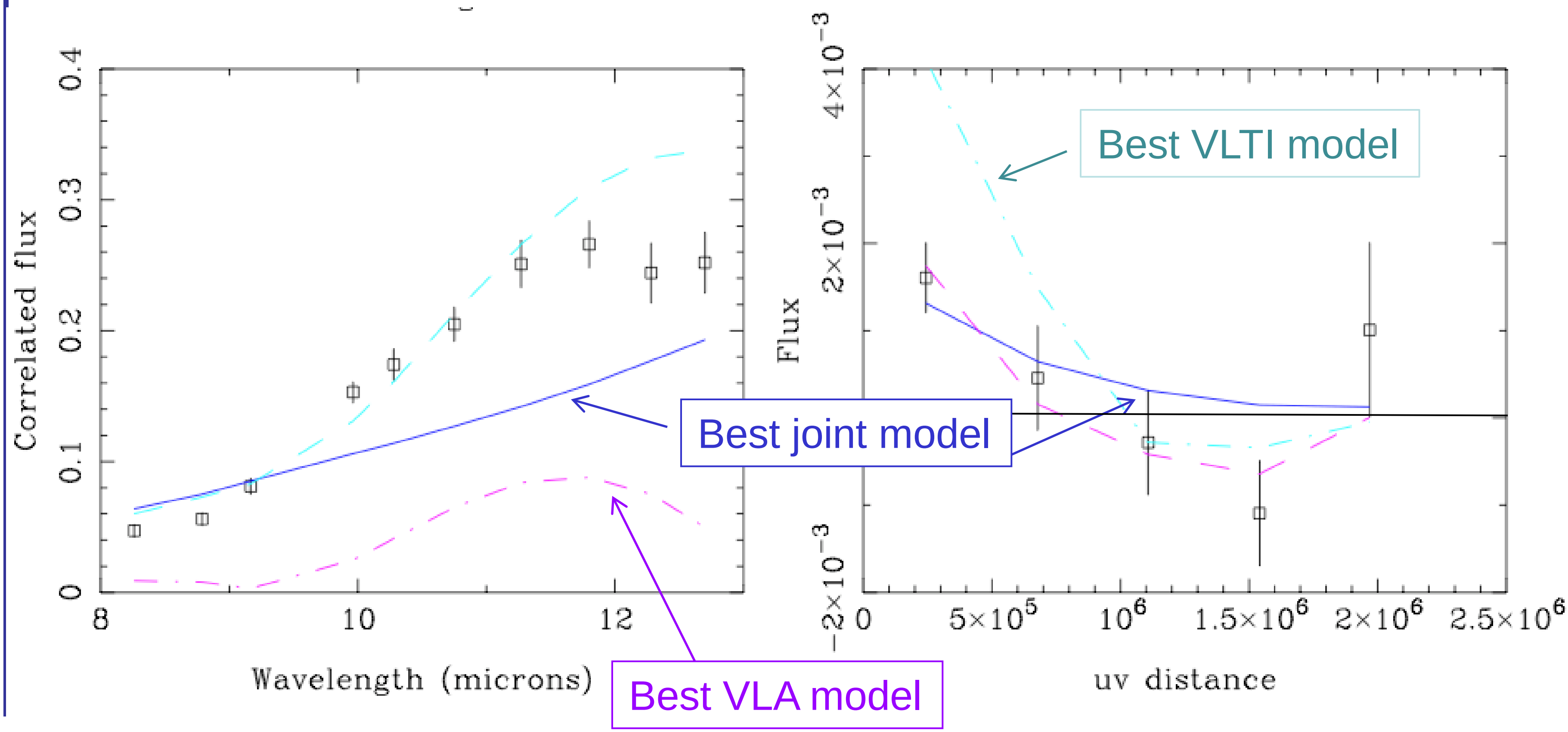


Disk model

- Flared disk
  - Use parameterization of Chiang and Goldreich 1997
- Vertically extended inner rim
  - For a face-on disk, the flux from the rim will depend on the exact shape
    - Vertical wall will have no flux
    - Rounded rim (Isella and Natta 2005) will produce flux
  - We have no data to constrain this shape, so included as a thin ring with increased flux (neglects shadowing effects)
- Fit parameters: inner and outer radius, surface density, flux ratio at rim, emissivity wavelength exponent (β)

VLTI vs VLA data

- Best fit single disk to each data set does not match other (but can match SED)



Refined model

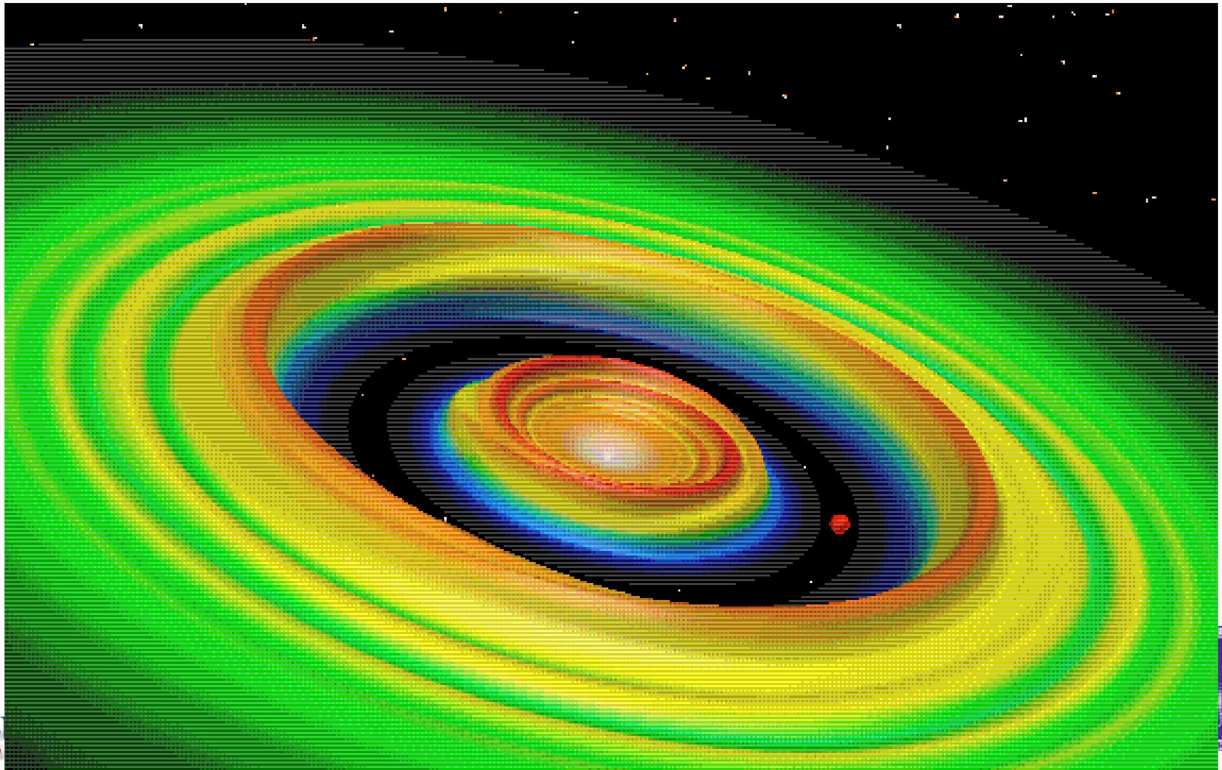
- Given limits of spatially resolved data, try adding as few parameters as possible
- Attempt 1
  - Increase flux in a ring at ~4 AU to fit VLA data
  - Results: Can not fit all data well
  - Single data set fits suggest different grain properties
- Next steps
  - Vary emissivity exponent as a function of radius
  - Try gap in disk

What could create a flux/density buildup within the disk?

- Spiral waves
  - Seen on larger scales in AB Aur
- Protoplanet
  - Eventually the planet will clear a gap, but in the initial stages the planet holds back larger grains from the inner disk (Rice et al 2006)
- Snow line
  - Grains past the snow line can form icy mantles and may grow more quickly
  - Snow line in T Tauris starts at ~5 AU and moves inward (e.g. Kennedy et al 2006)

Planet-cleared gap?

- A planet in the disk can clear a gap when the Roche radius (gravitational sphere of influence, aka the Hill radius) exceeds the disk thickness



Bryden et al 1999

Summary

- TW Hya is one of the closest examples of an accreting protoplanetary disk
  - Clearly doesn't fit a simple disk model
- Inner radius of optically thick disk not at the dust sublimation radius
  - But measured accretion requires some material going into the star
- Spatially resolved data suggest a ring with increased density (and possibly a gap) and a break in the grain size distribution