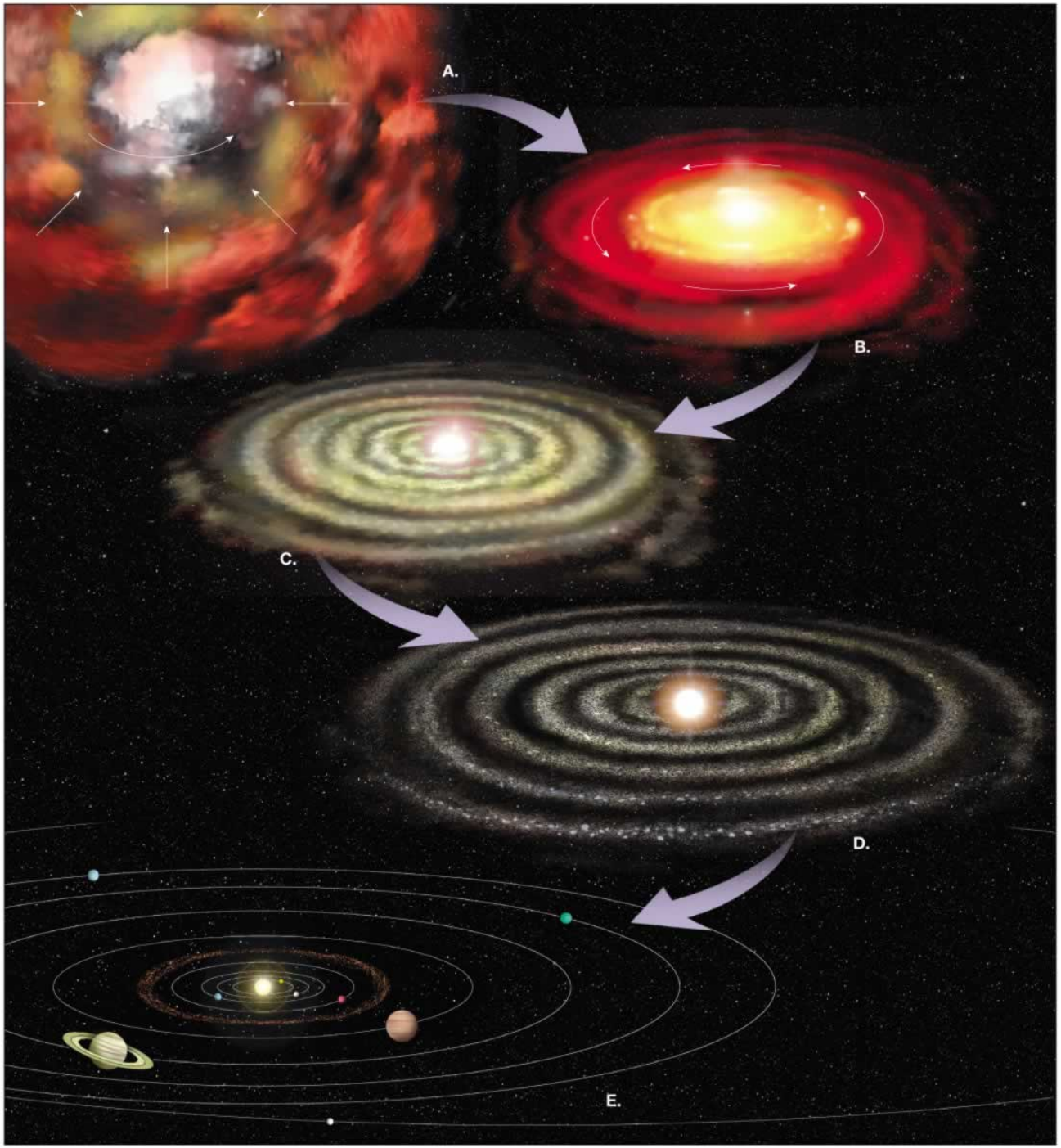
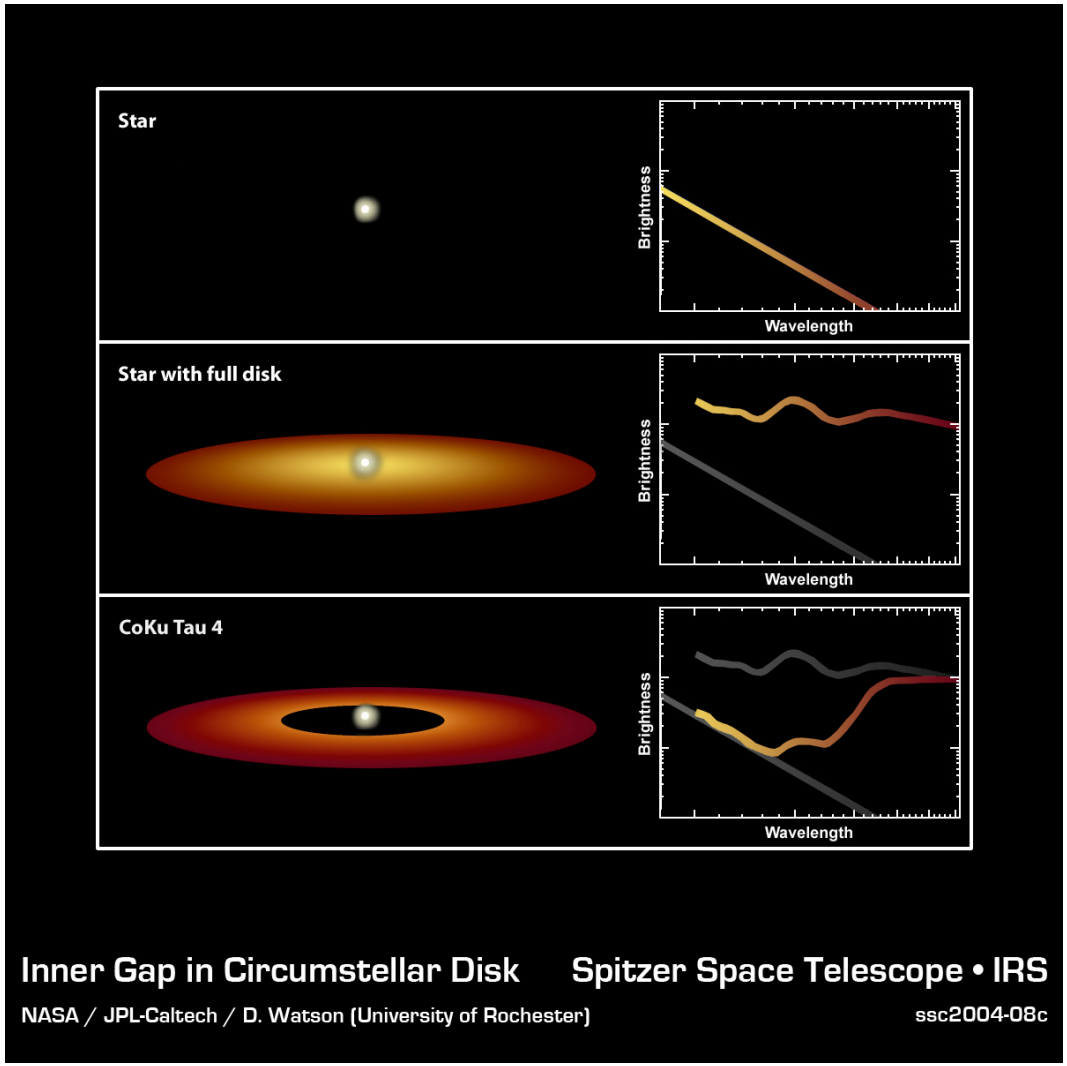
Disks evolution with the SMA


A.
B.
C.
D.
E.

Transitional or cold disks



WHAT?

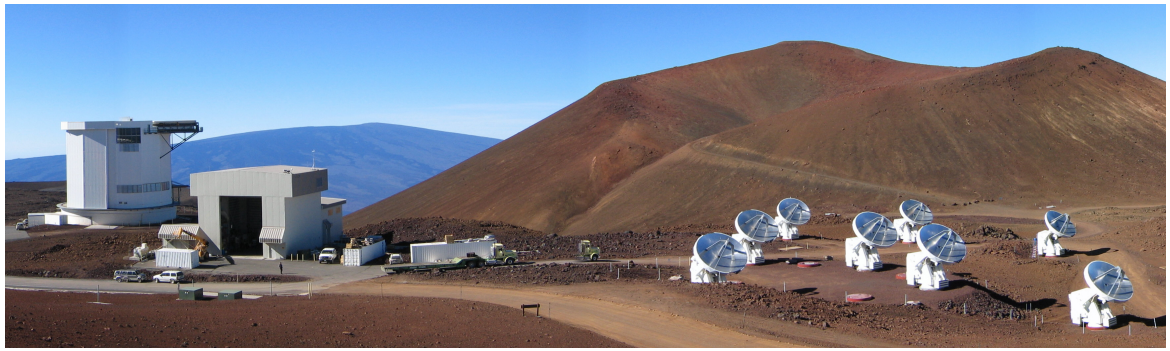
- Disks where dust clearing has begun
- Rare, presumably short-lived, phase between dusty protoplanetary disk and star with planetary system
- Identifiable through mid-IR photometry and spectroscopy (Spitzer)

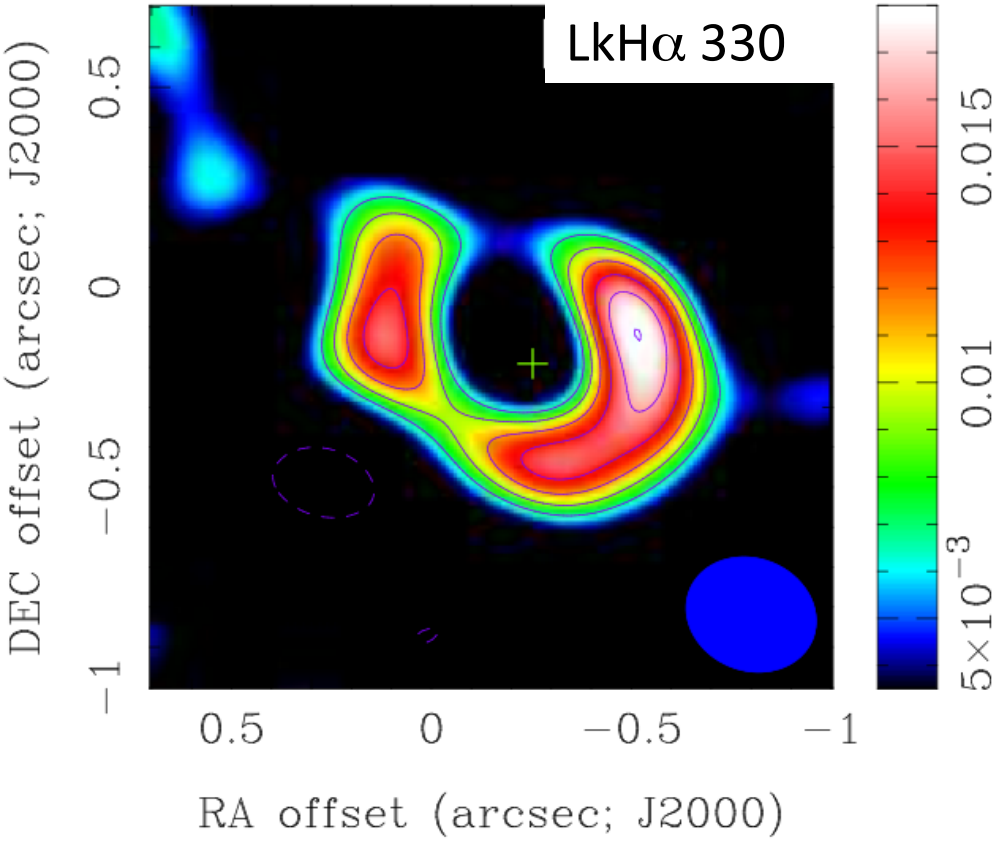
WHY?

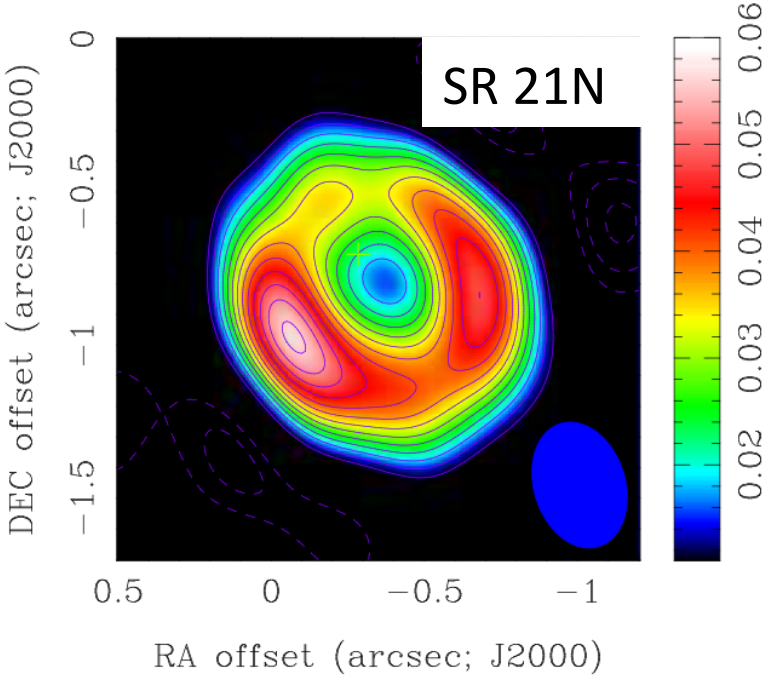
- Potentially trace young/forming planets
- Look at how disks disperse

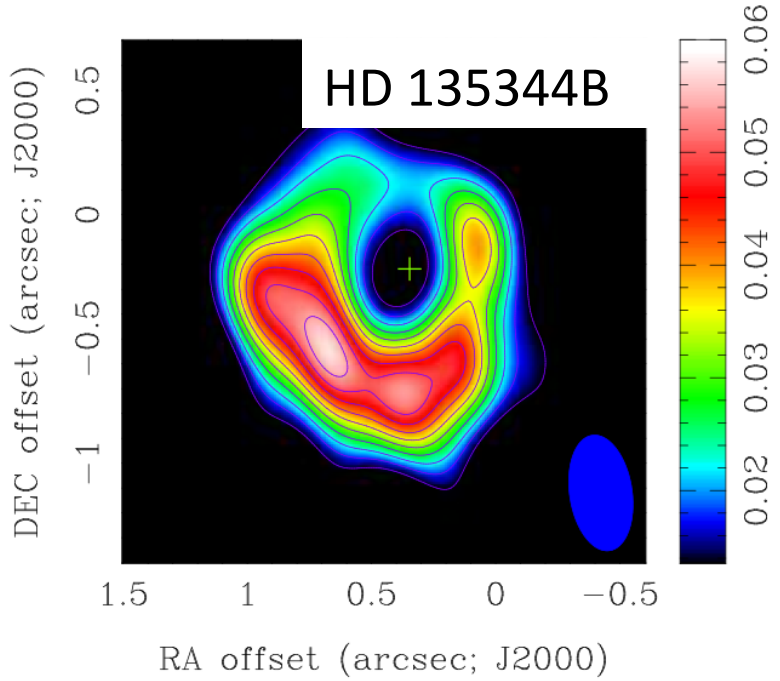
Are there disks with holes?

SMA very extended configuration



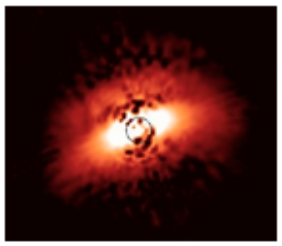






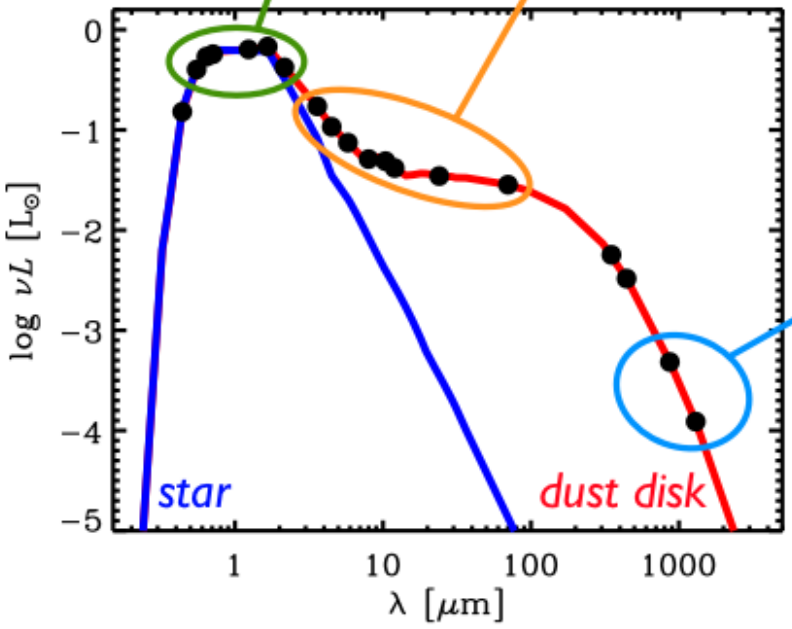
Brown et al. 2008, 2009

modeling protoplanetary disk structures



scattered light ∝ *geometry* ..... surface layers

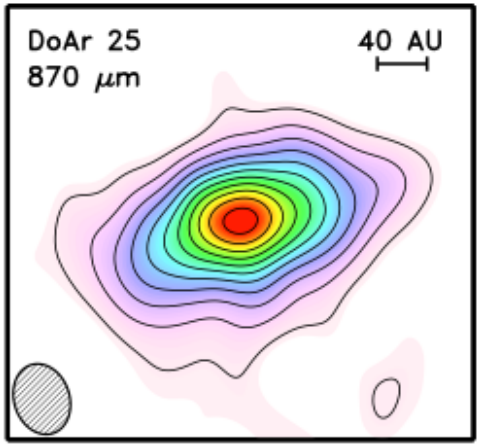
$\tau \gg 1$ ∝ $T(r)$ .....



$\tau \ll 1$ ..... midplane

∝ $\langle T \rangle$ x M

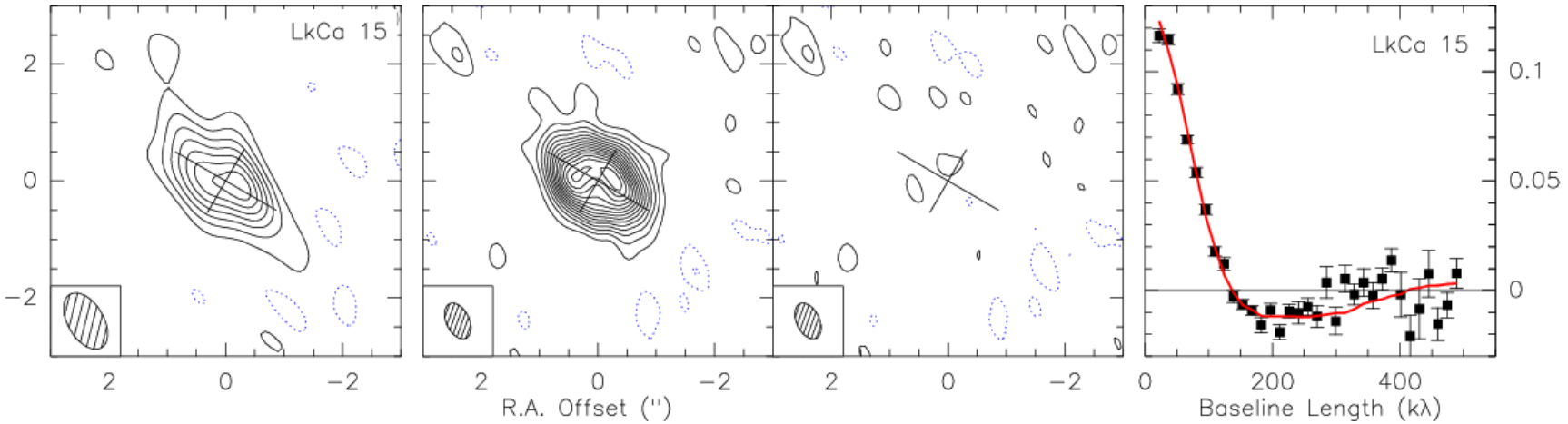
∝ $T(r)$ x $\Sigma(r)$



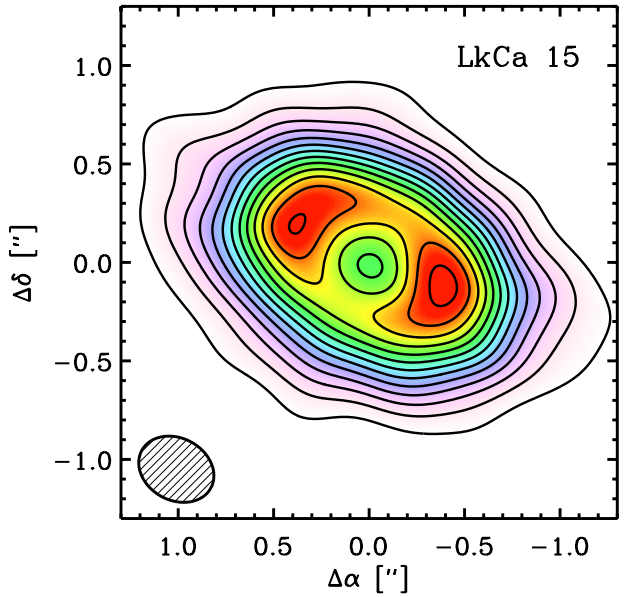
radiative transfer modeling toolkit

[Andrews et al. 2008; *HST*/NICMOS image: courtesy of G. Schneider]

Millimeter Imaging of a Cavity in LkCa 15

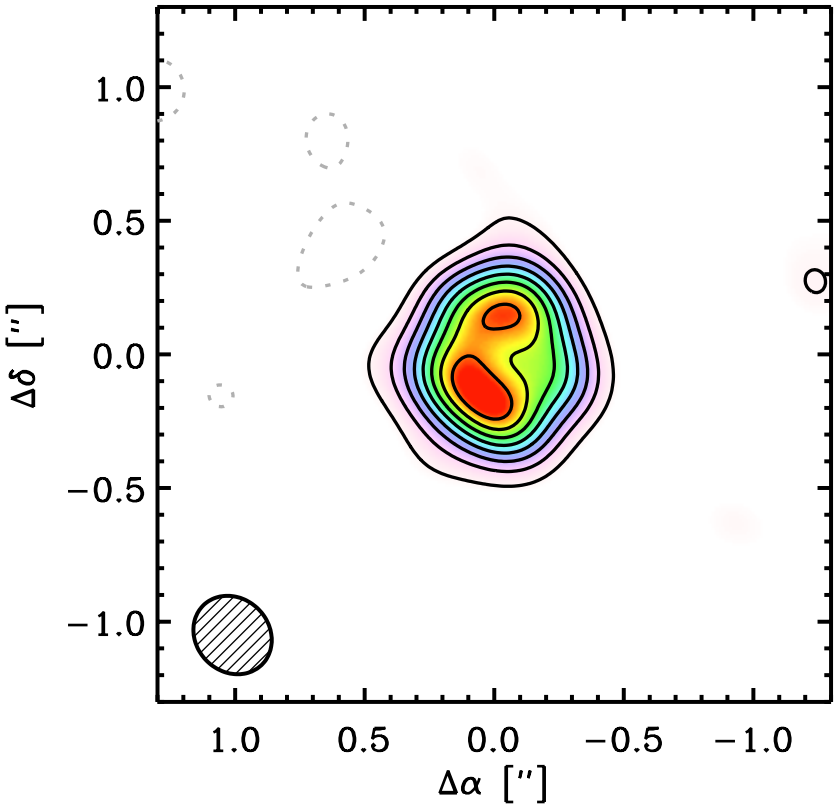


Pietu et al. 2006



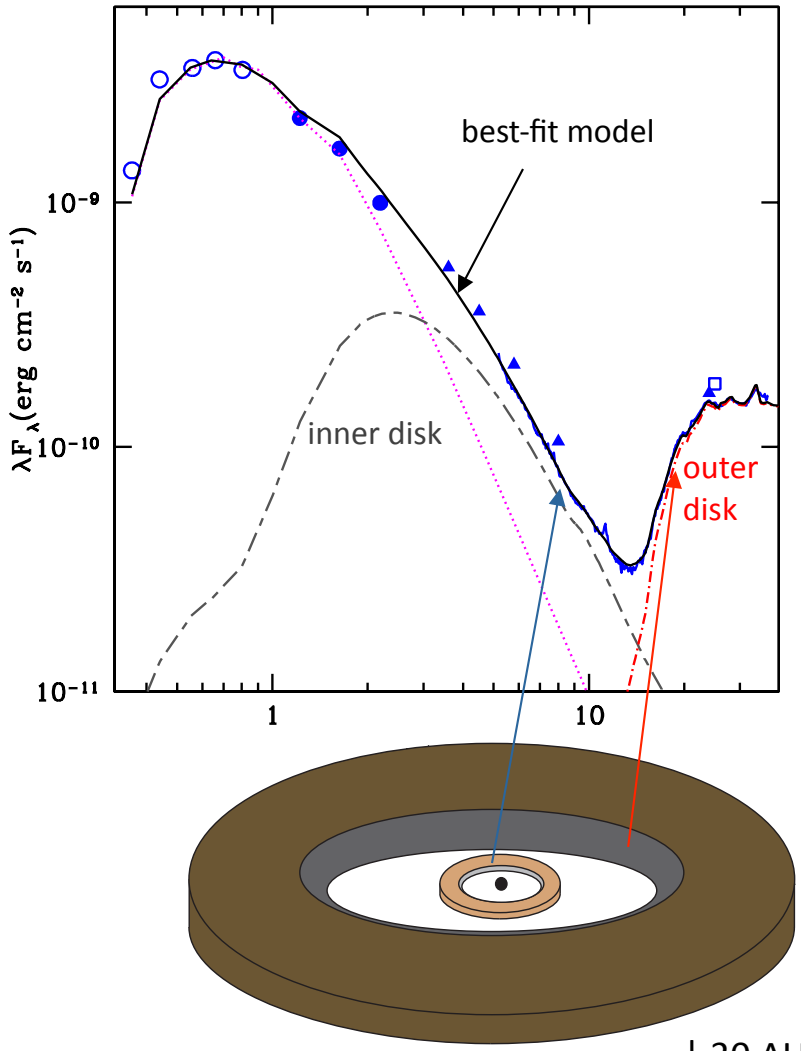
Andrews et al. 2011, Espaillat et al. (in prep)

Millimeter Imaging of a Cavity in UX Tau A



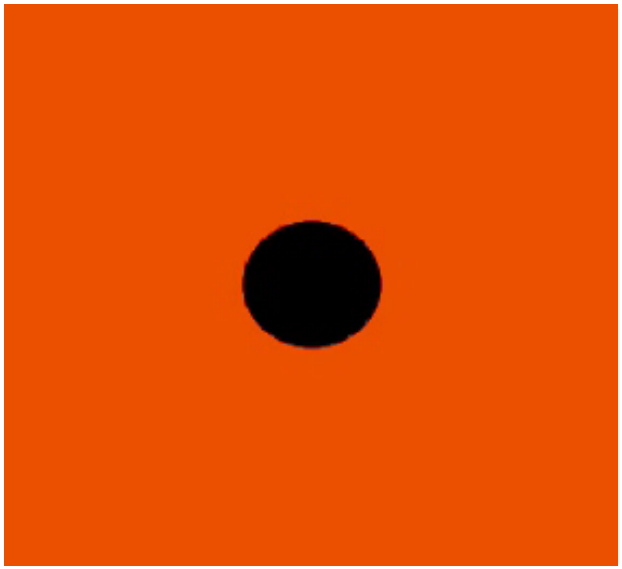
Andrews et al. 2011, Espaillat et al. (in prep)

Espaillat et al. 2007b, 2011

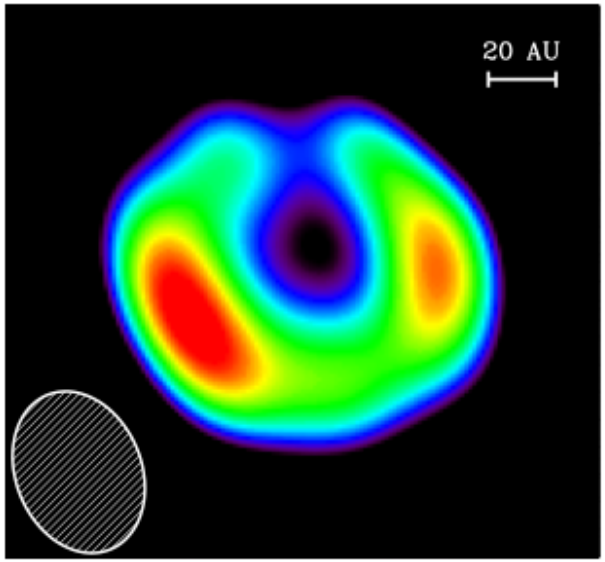


| 30 AU

signatures of planet-disk interactions



[Masset 2002]



[Andrews et al. 2011]

a giant planet opens a gap

+

intercepts the mass flow

↓

inner disk cut-off/depleted

optically thin disk "cavity"

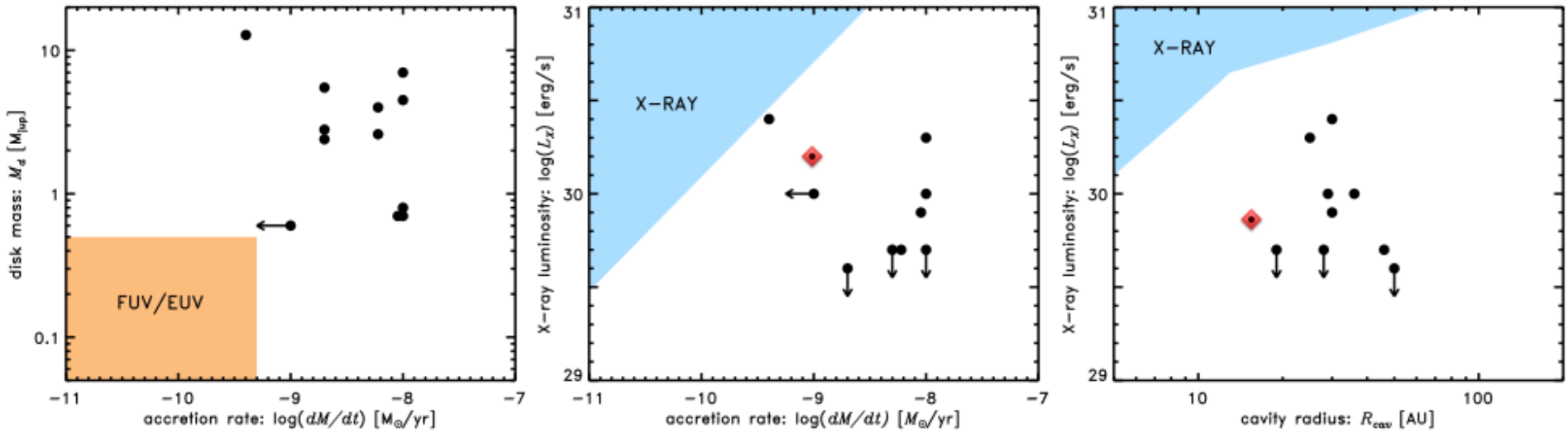
cavity radius ~ orbital period

cavity mass ~ planet mass

alternative mechanisms to open disk cavities

option 1: dispersal by winds (photoevaporation)

[Clarke et al. 2001; Alexander et al. 2006]



[Alexander & Armitage 2007; Owen et al. 2011; Andrews et al. 2011]

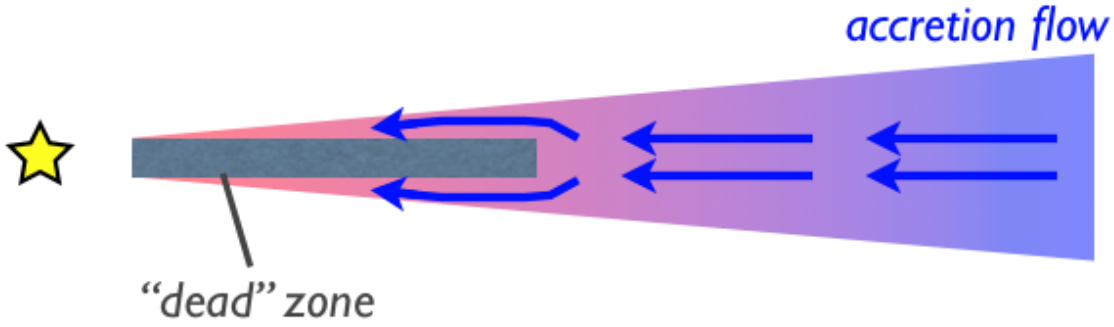
for this *kind* of transition disk, wind dispersal is ineffective

alternative mechanisms to open disk cavities

option 2: particle growth

need a very large dead zone

low ionization: quiescent: rapid growth

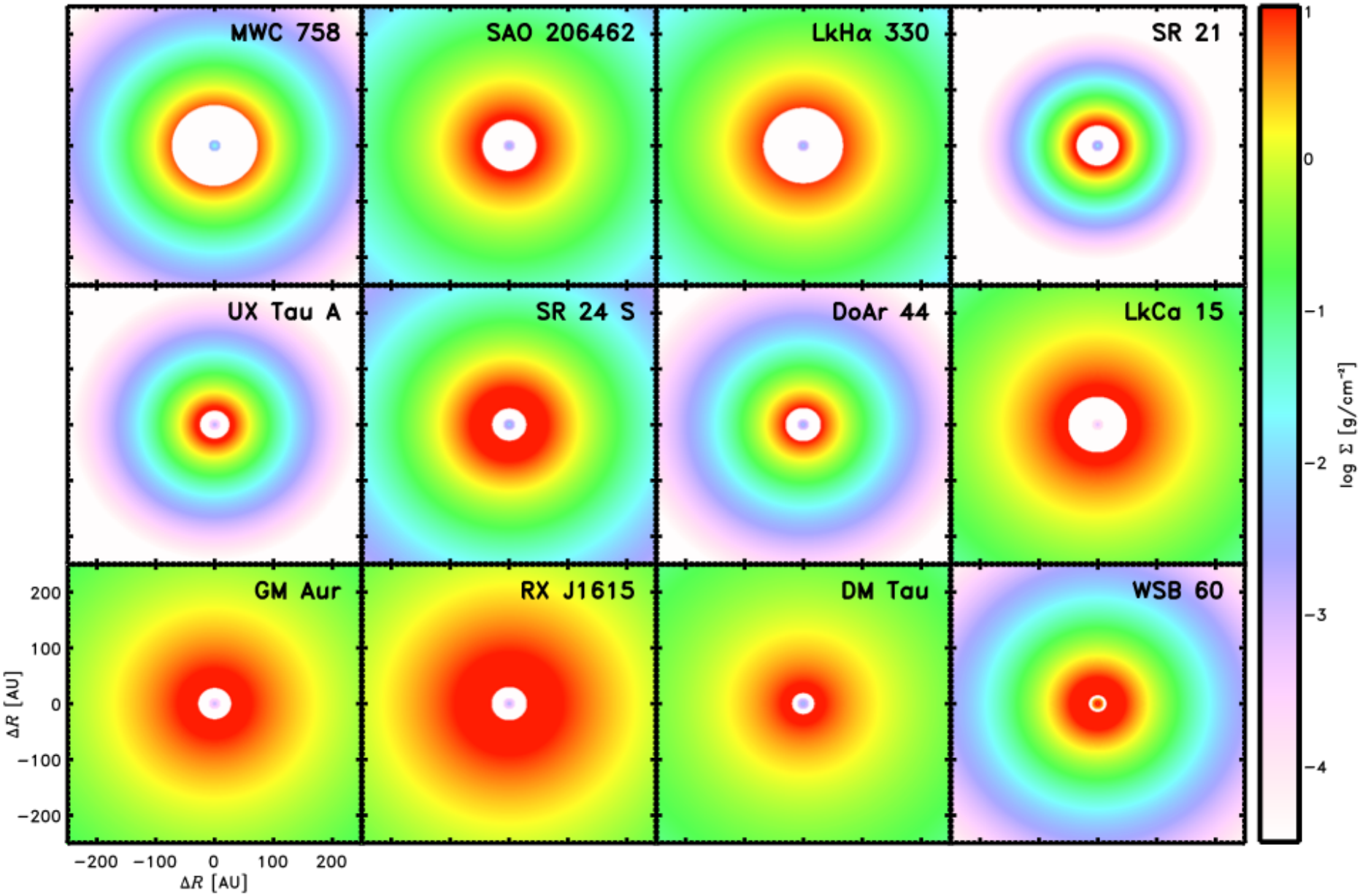


no small grains in surface flows

no fragmentation in dead zone

[Birnstiel, Andrews, & Dullemond, *in prep*]

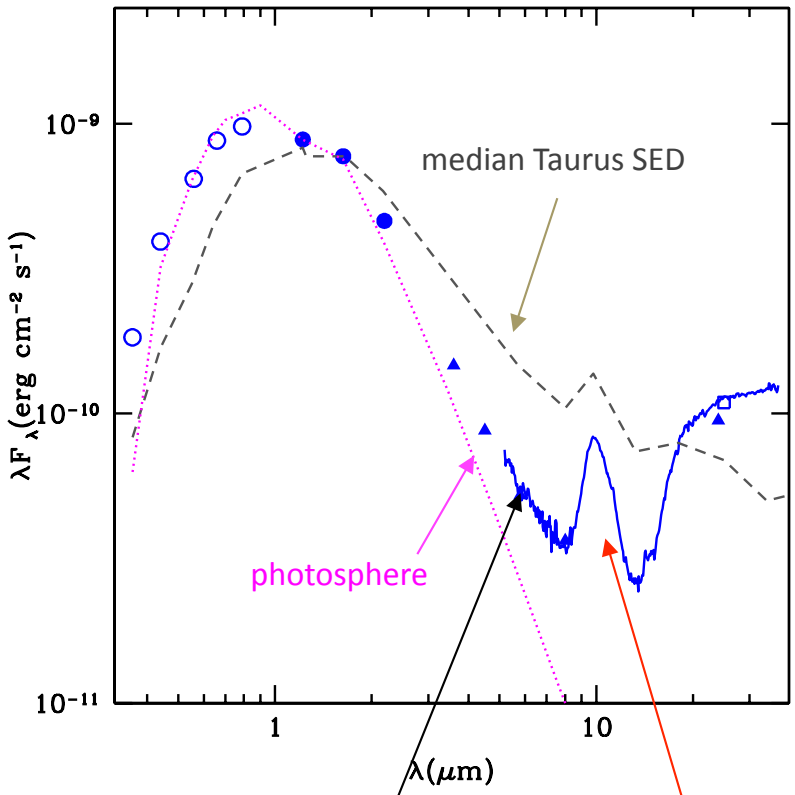
“transition” disk structures at 1 Myr



[Andrews et al. 2011]

Some Disk Holes Contain Small Dust

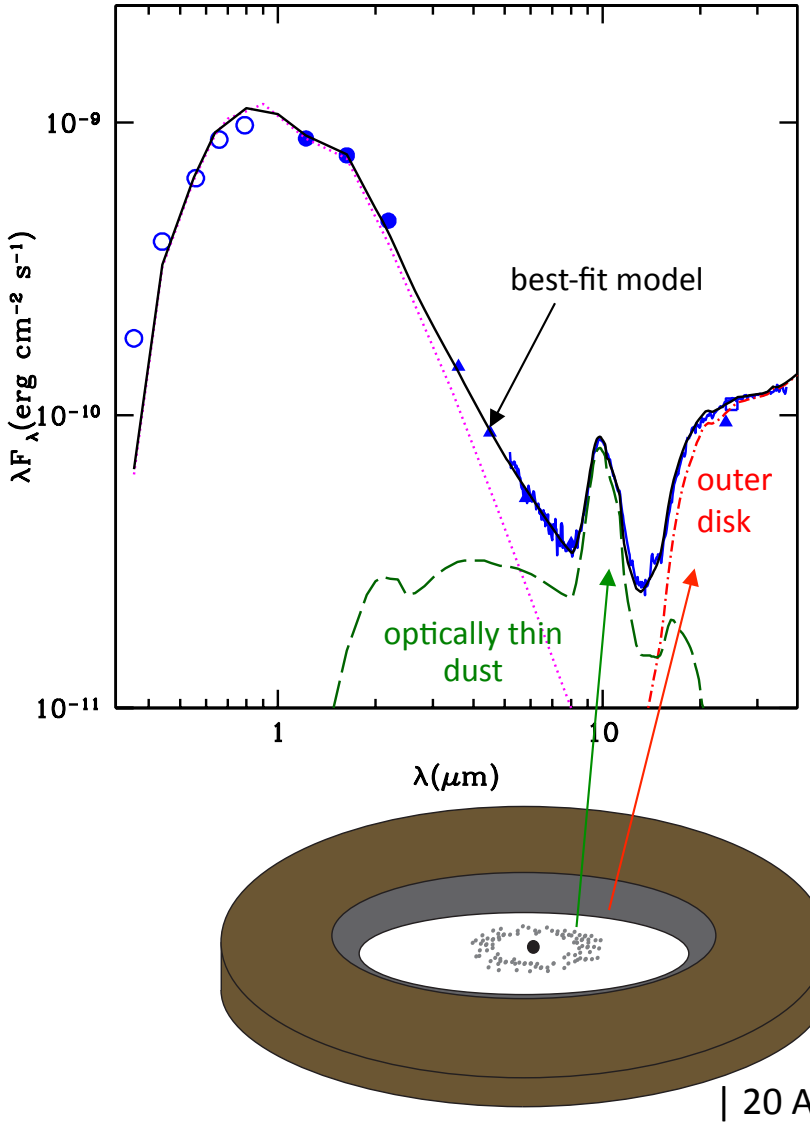
GM Aur



small near-IR excess

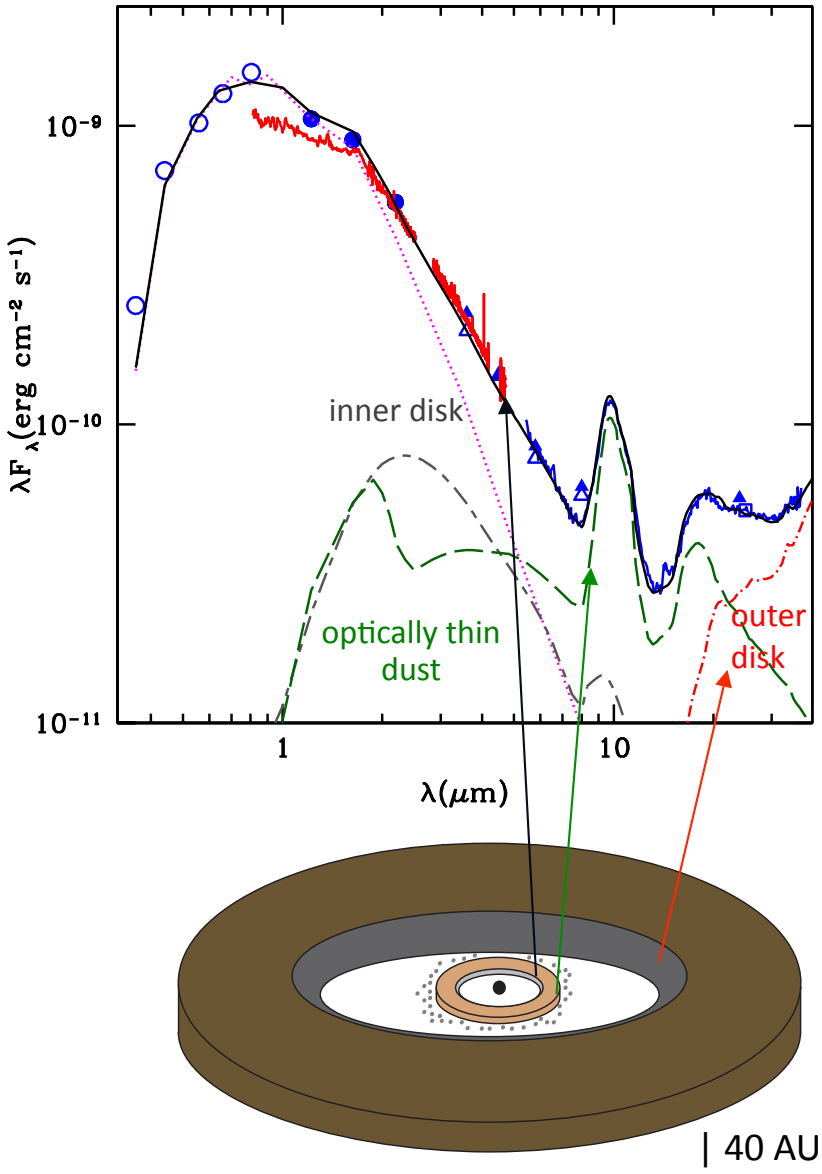
silicate emission feature

Calvet et al. 2005, Espaillat et al. 2011

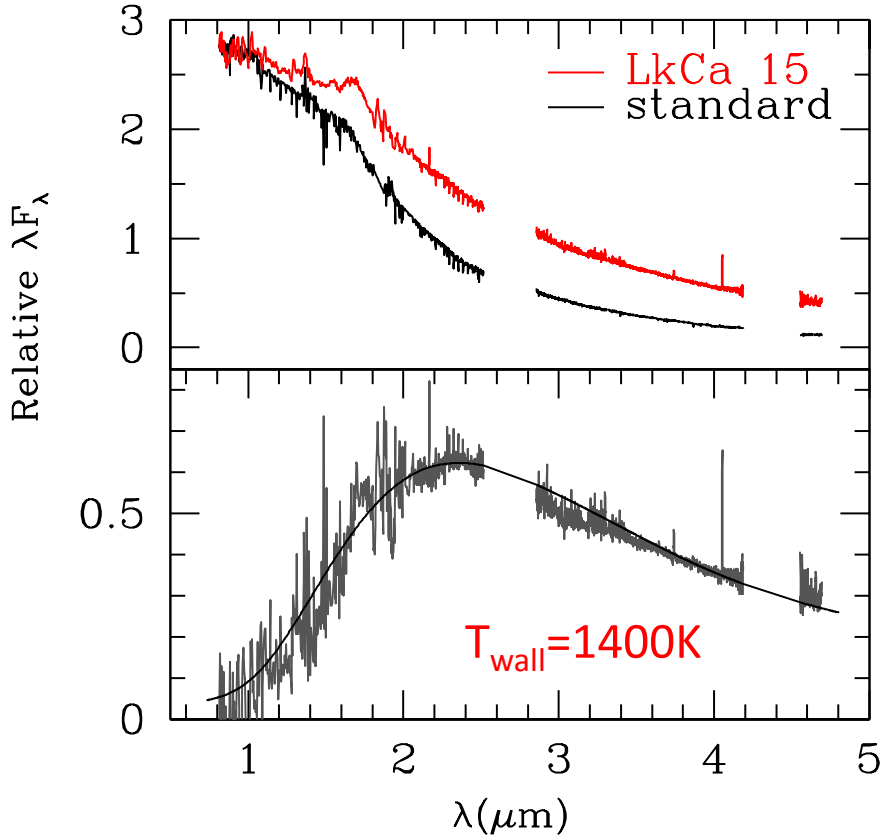


Near-IR Excess of LkCa 15 Resembles a Blackbody

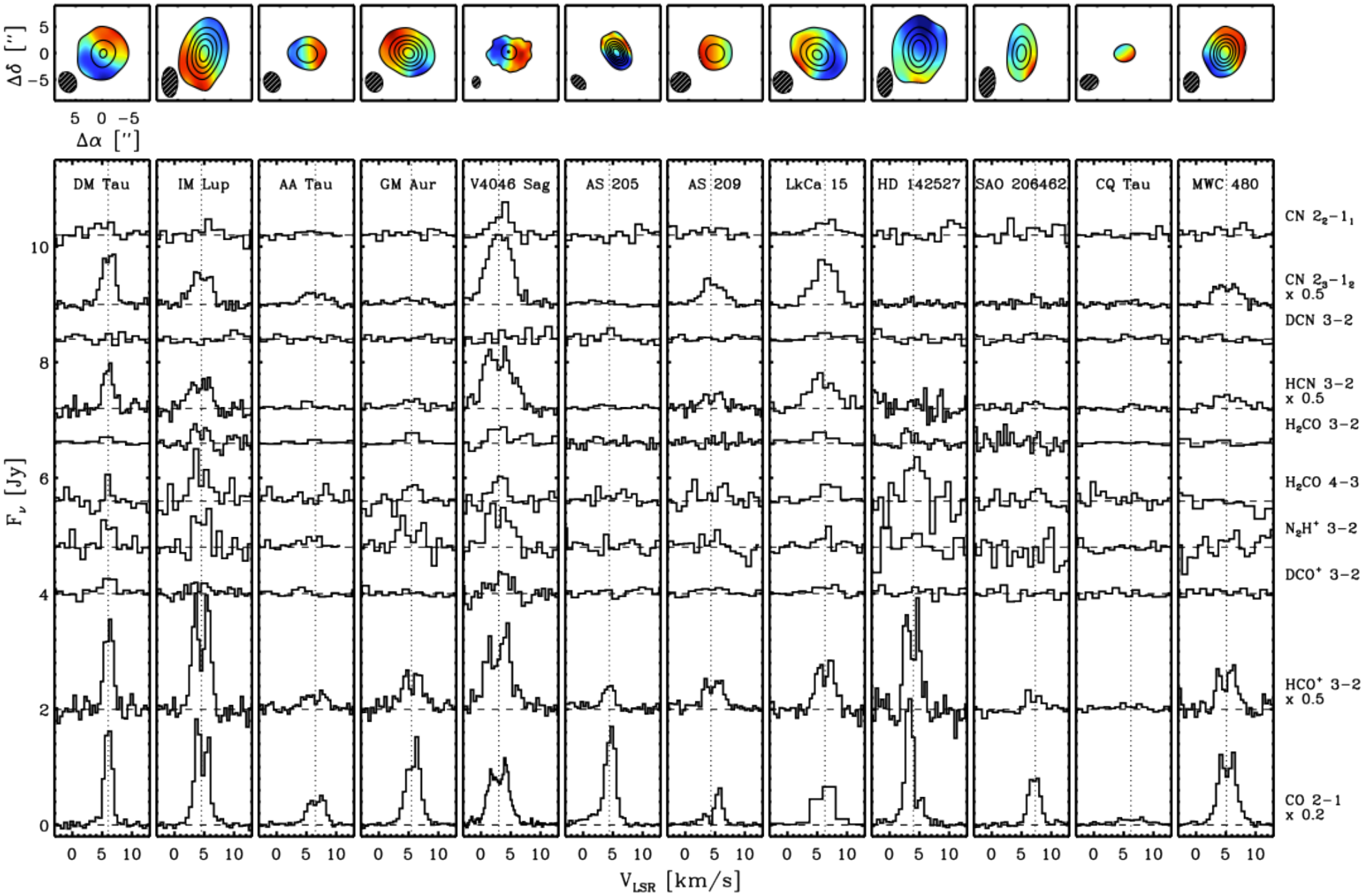
Espaillat et al. 2007b, 2010, 2011



Espaillat et al. 2008, 2010

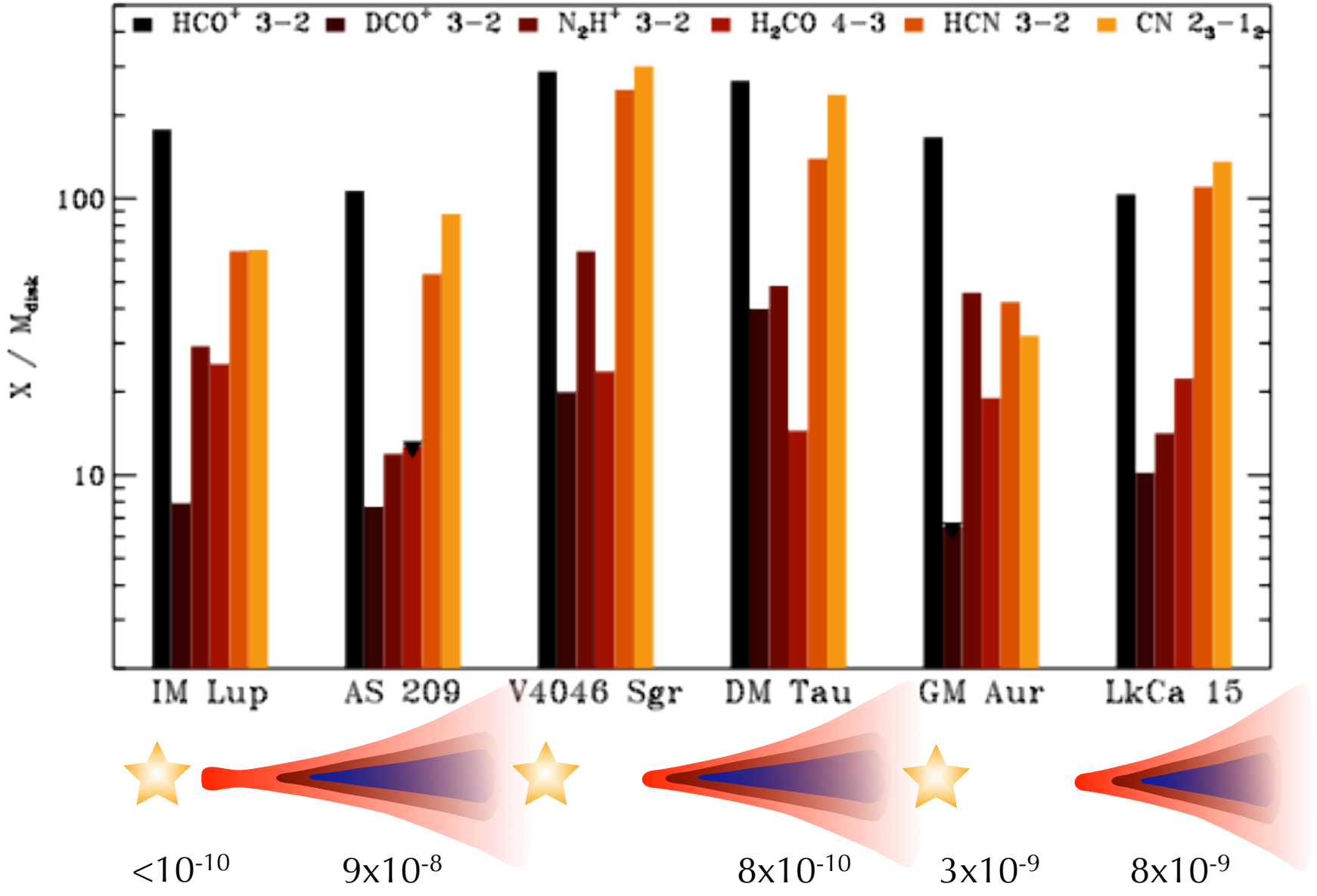


Chemical richness and source variability

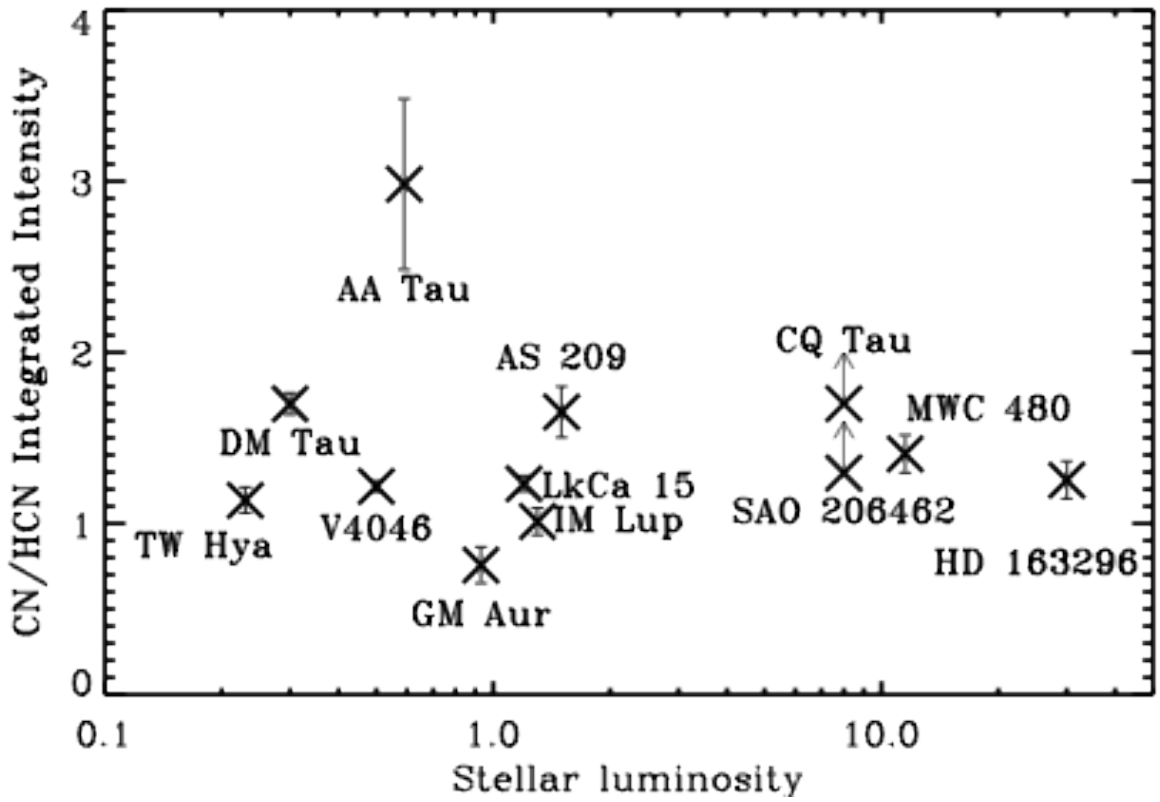


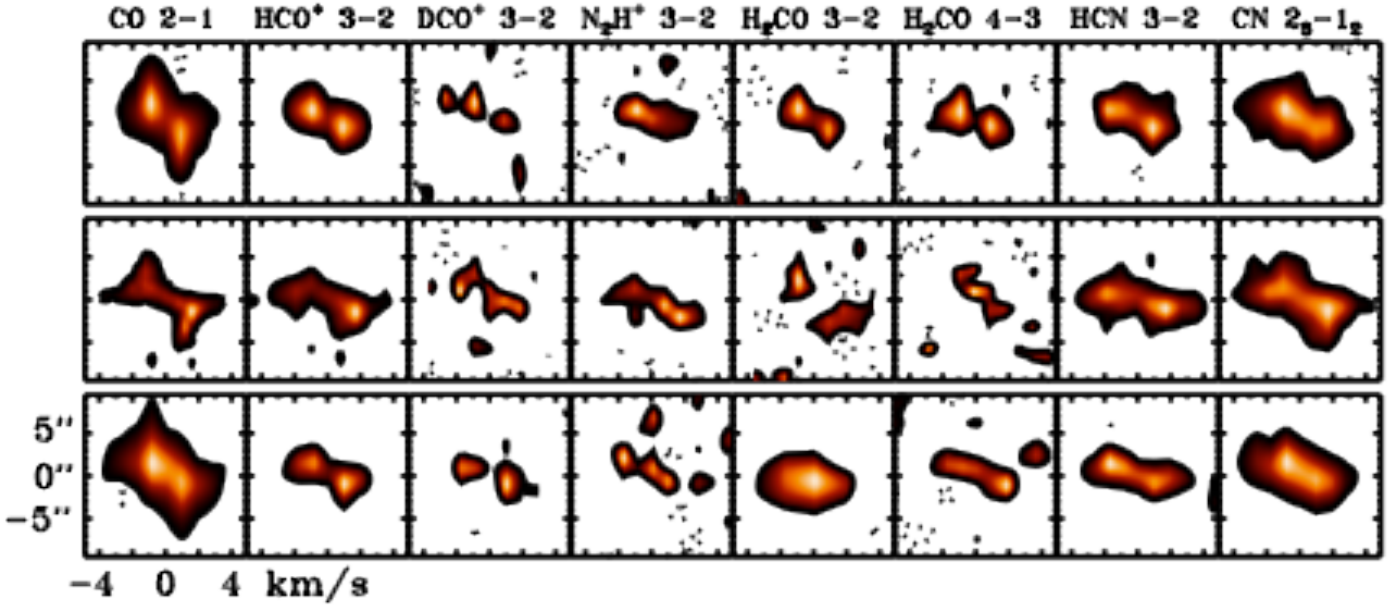
Transition vs. Full Disks:

A disconnect between the inner and outer disk



CN vs. HCN





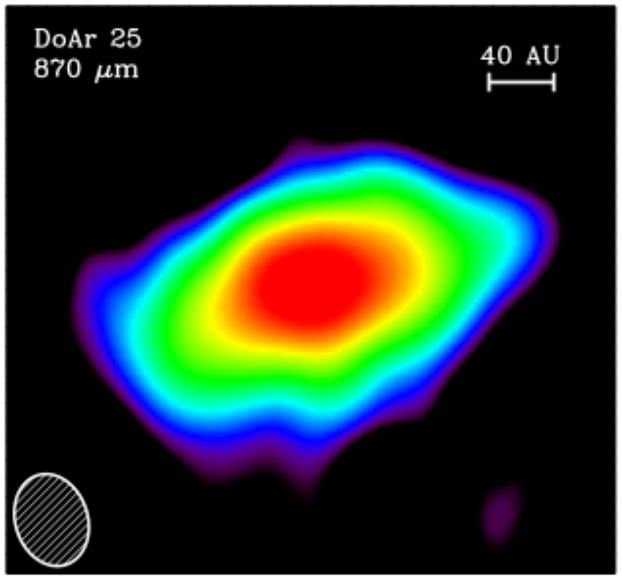
★HCN+UV→CN; CN should be abundant at high UV

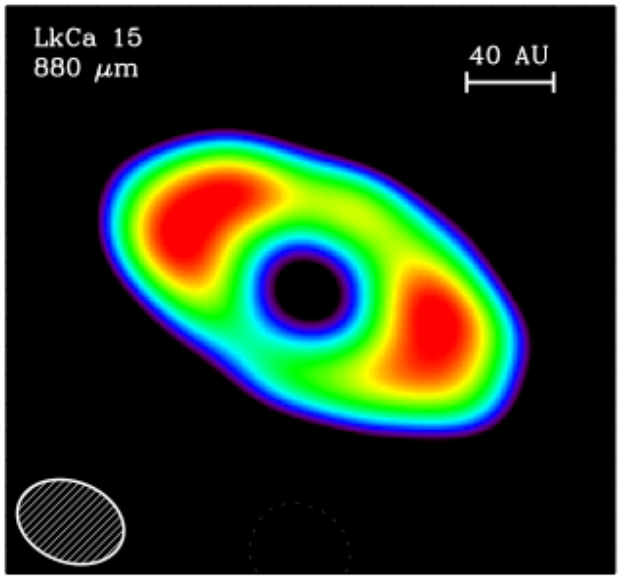
★Surprisingly constant CN/HCN emission ratio

★Disk averaged CN/HCN ratio is NOT a good radiation tracer.

★Evidence for more extended CN emission compared to HCN -- an ISRF driven outer disk chemistry?

summary: disks and planet formation





disk structures

measured dust densities in nearby disks

need state-of-the-art analysis tools

new constraints on viscous evolution

planet formation

evidence of planet-disk interactions

radio images of disks can help find planets

foreshadowing ALMA planet searches