Transition Disks as Disk Evolution and Planet Formation Laboratories

2012 Sagan/Michelson Fellows Symposium

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Caltech

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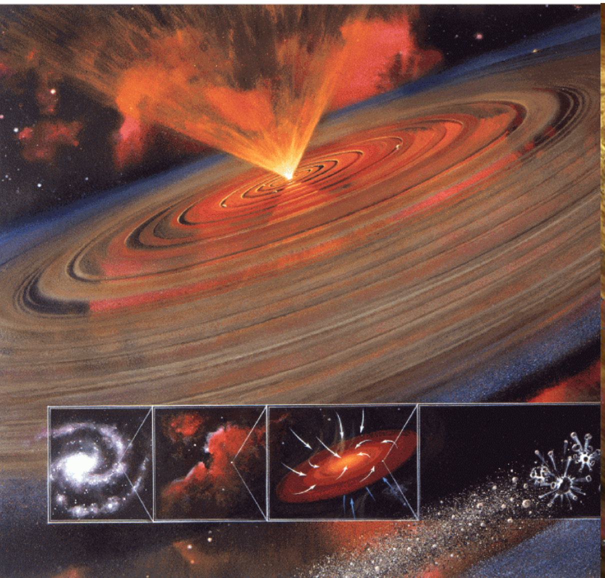
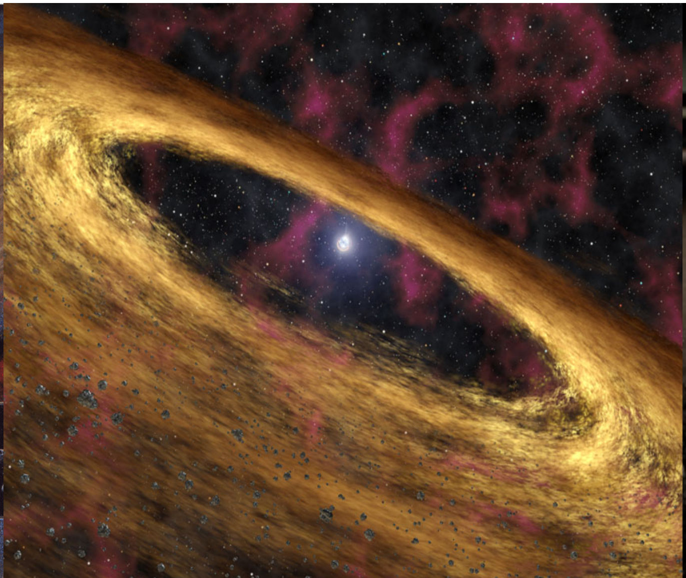
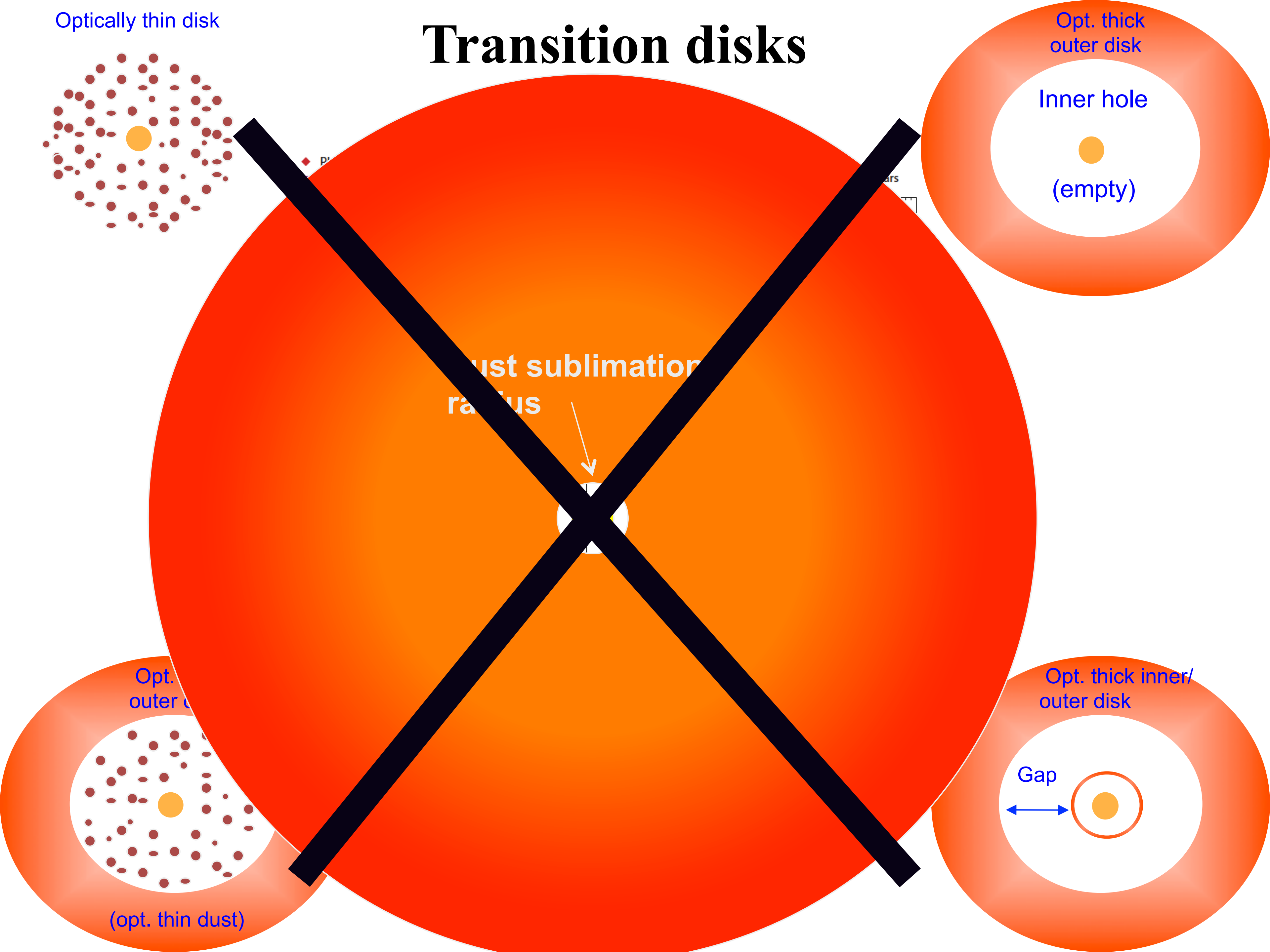
U. Hawaii, 2010 Sagan Fellow

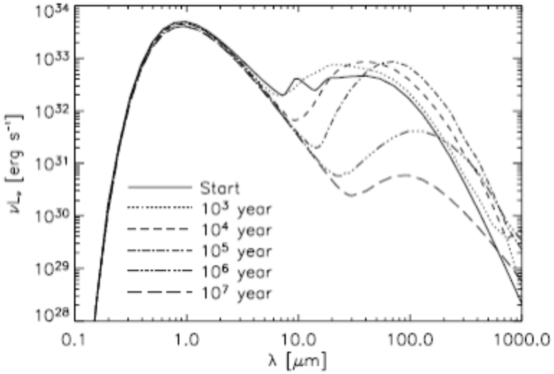




Transition disks

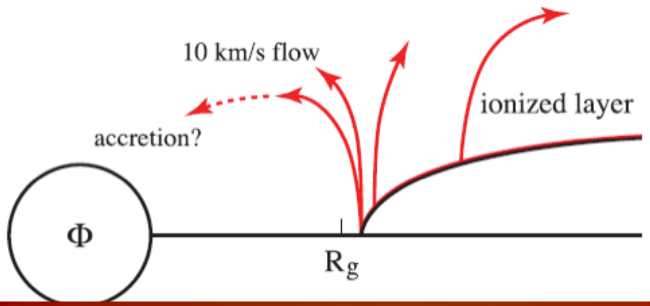


Dullemond & Dominik (2005)

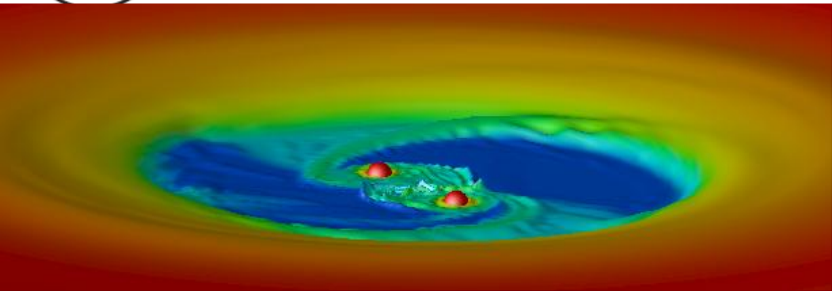


Magnetospheric accretion

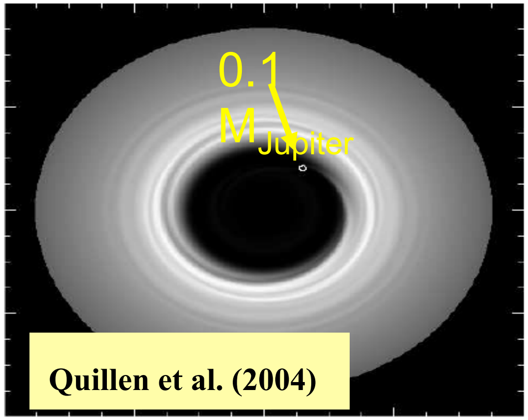
Grain growth/dust settling



Photoevaporation

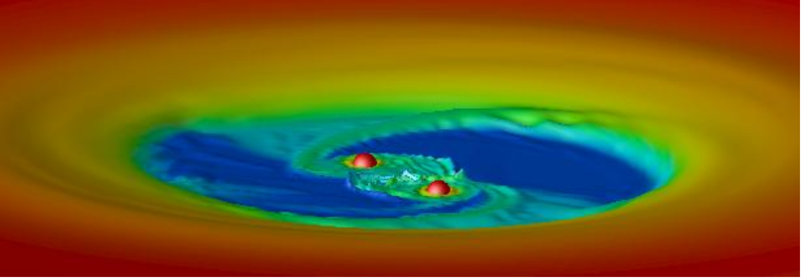


Close binaries

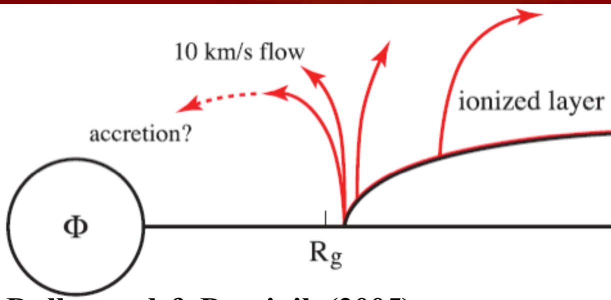


Quillen et al. (2004)

Embedded planet

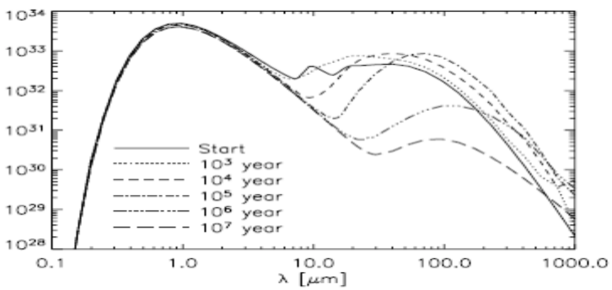


• Close binaries: identify with AO+RV

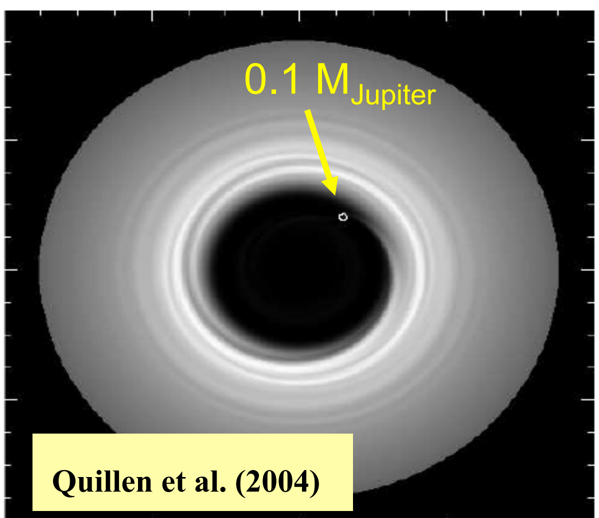


Dullemond & Dominik (2005)

• Photoevaporation: negligible accretion and low-disk masses



• Grain growth: high accretion rates, large disk masses



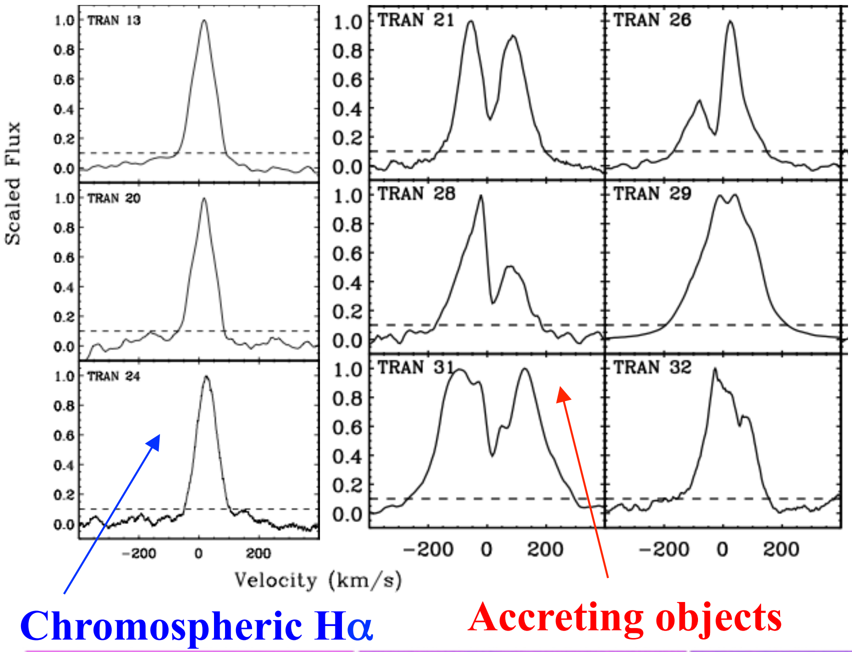
Quillen et al. (2004)

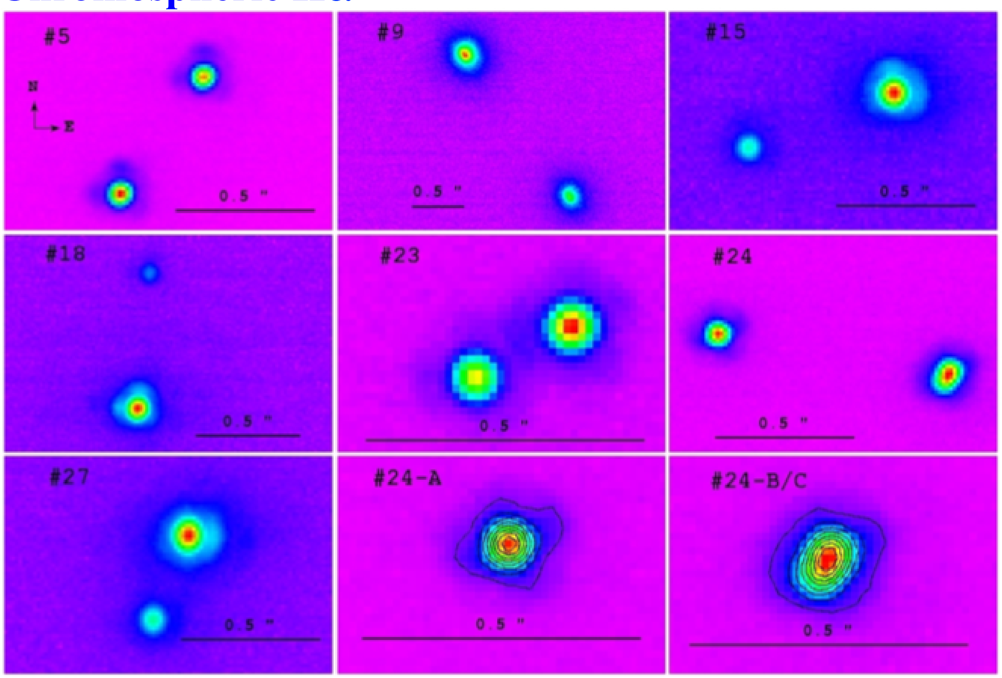
• Giant Planet formation: low/moderate accretion rates and moderate/high disk masses

•Accretions rates, disk masses, and multiplicity information can help to distinguish among processes!

Disk characterization survey
(with U. Valparaiso, Chile)

$$Log(M_{acc}(M_{\odot}/yr)) = -12.89(\pm 0.3) + 9.7(\pm 0.7) \times 10^{-3} \Delta V(km/s)$$





Observations:

•ACCRETION RATES

High Resolution Optical Spec.
CFHT/Magellan telescopes

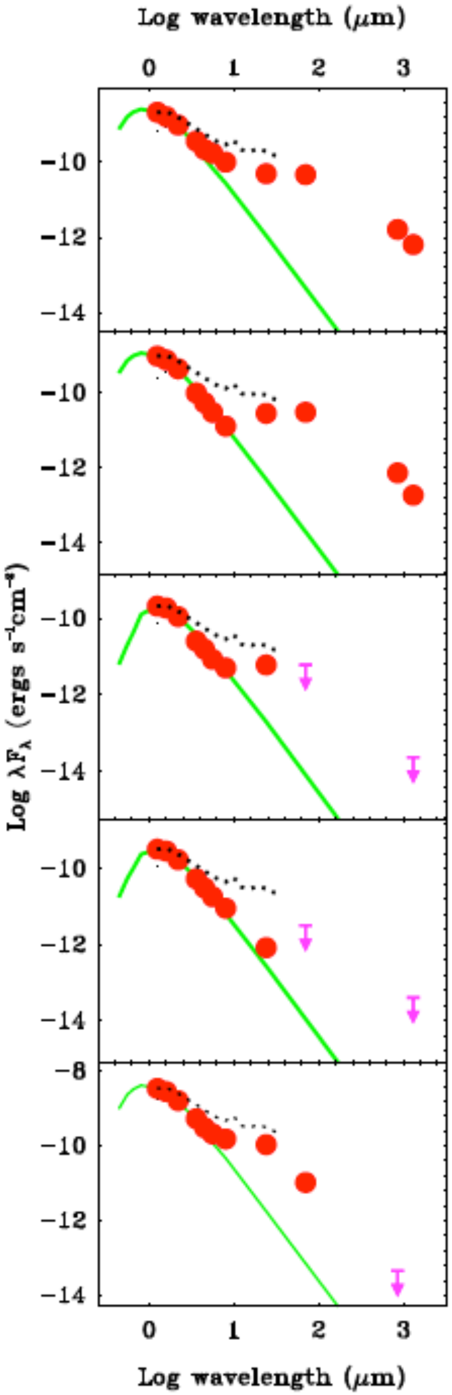
• BINARIES (r > 7-8 AU)
Gemini/VLT AO Imaging: 0.06'' resolution

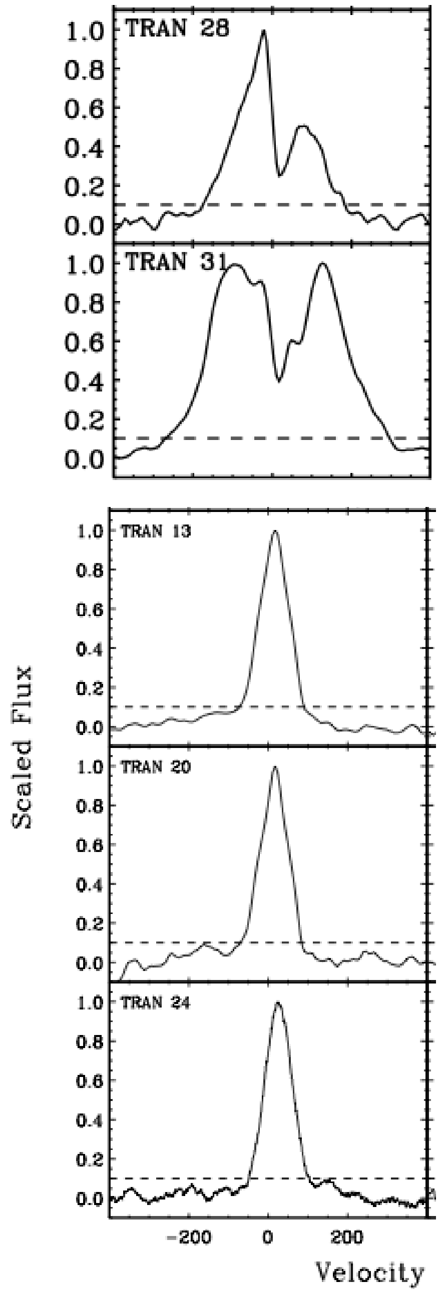
• DISK MASSES (Sub)millimeter Photometry: SMA/JCMT/APEX

$$M_{DISK} = 1.7 \times 10^{-1}[(\frac{F_{\nu}(1.3mm)}{mJy}) \times (\frac{d}{140pc})^2] M_{JUP}$$

Used accretion rates, multiplicity, disk masses + SED morphology and fractional disk luminosity (L_{disk}/L_{star}) to classify sample.

Classification



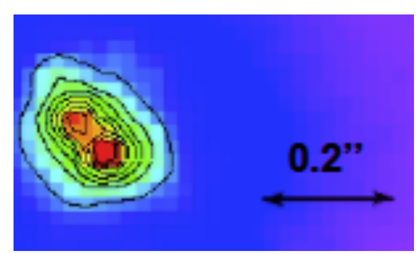


Accretion + falling mid-SED — **Grain-growth dominated disk**

Accretion + rising mid-SED — **(giant) planet-forming disk**

Lack of Acc. + low disk mass + L_{disk}/L_{star} > 1E-3 — **Photoevaporating disk**

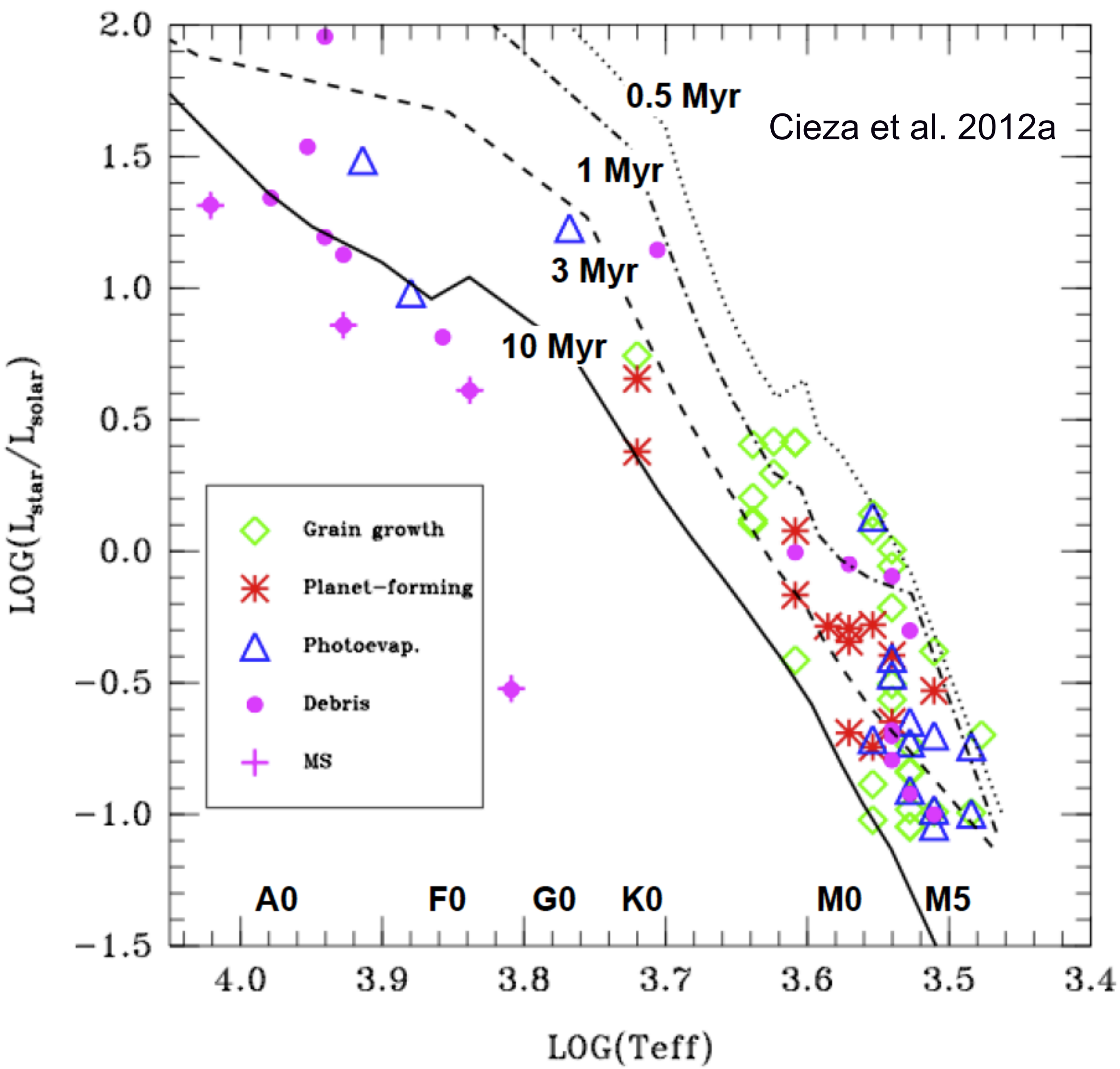
Lack of Acc. + low disk mass + L_{disk}/L_{star} < 1E-3 — **Debris disk**



Circumbinary disk

The Nature of Transition disks III.

Now have 74 transition objects that have been selected, characterized, and classified in an homogenous way.

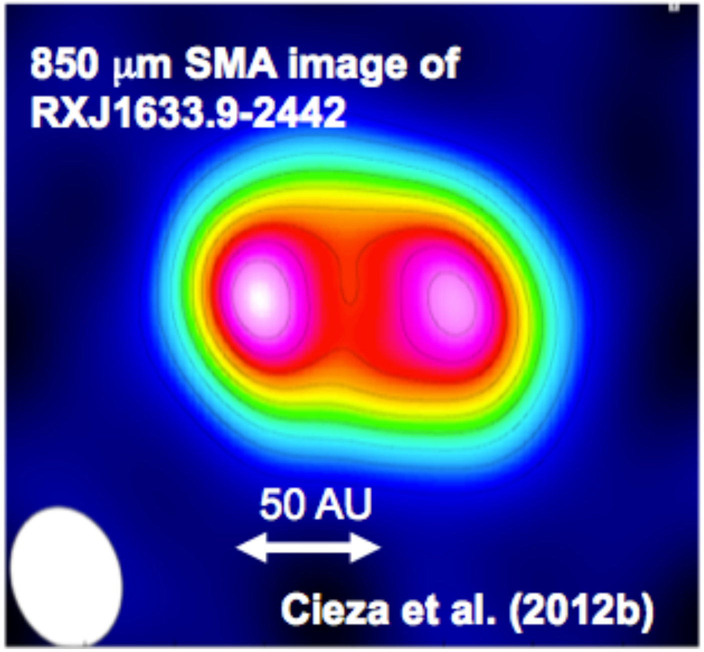


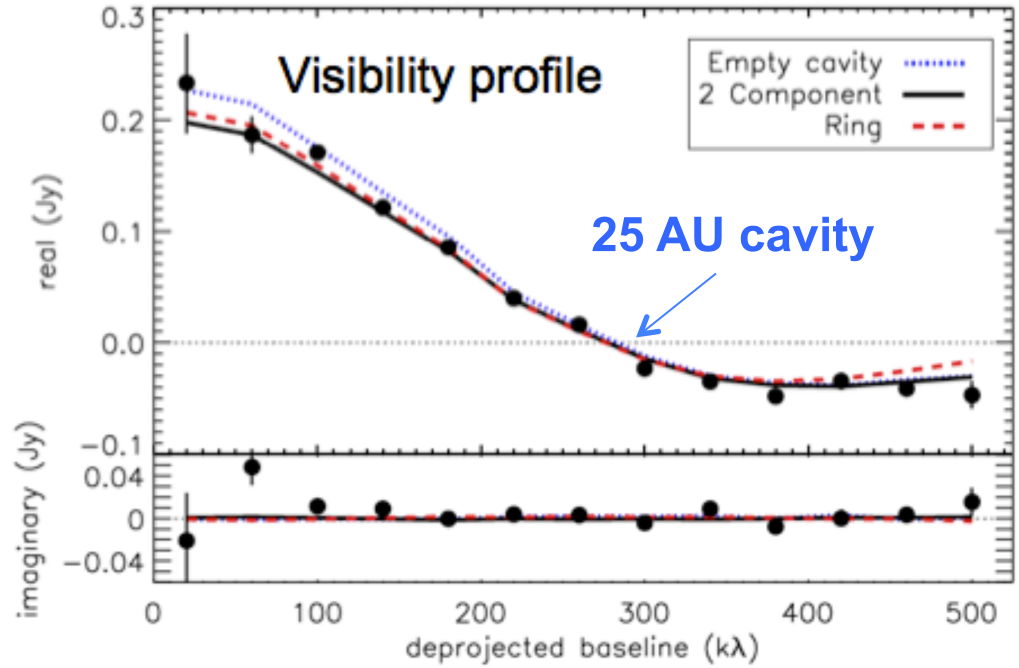
Conclusions

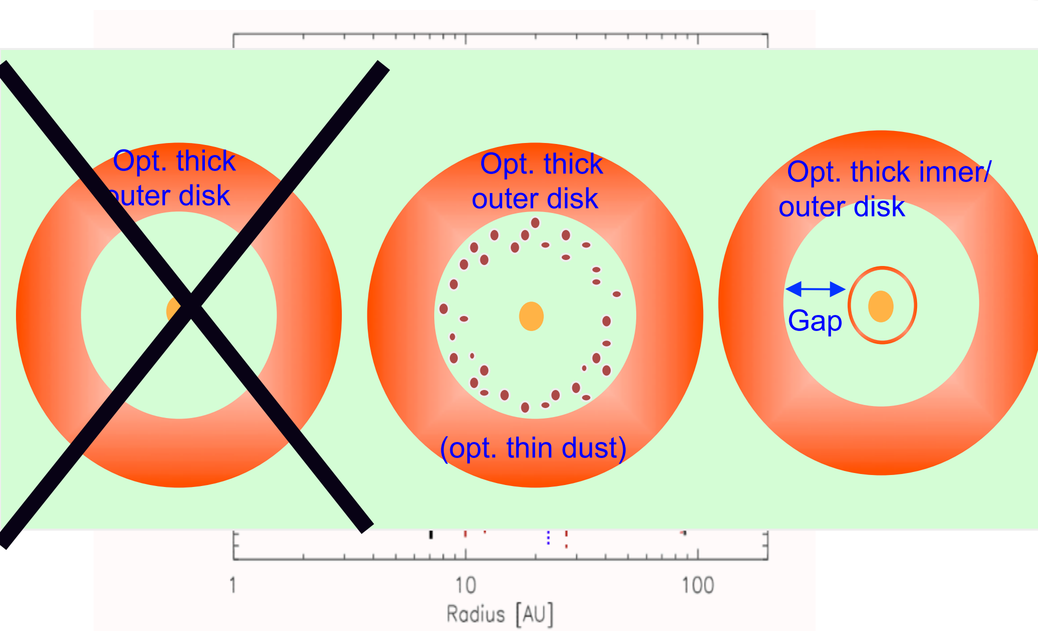
- Debris/photoevaporating disk candidates are more common around hotter stars
- Grain growth-dominated disks account for ~40% of our sample of transition disks around K and M-type stars
- The incidence of circumbinary disk candidates in our sample of transition objects is low (< 10%)
- The incidence of PFD candidates is significantly lower than occurrence of giant planets (~20% of TD and ~4% of all disks).
- The age distribution of PFD candidates favors a 3 to 5 Myr formation timescale
- Transition objects are invaluable disk evolution and planet formation laboratories.

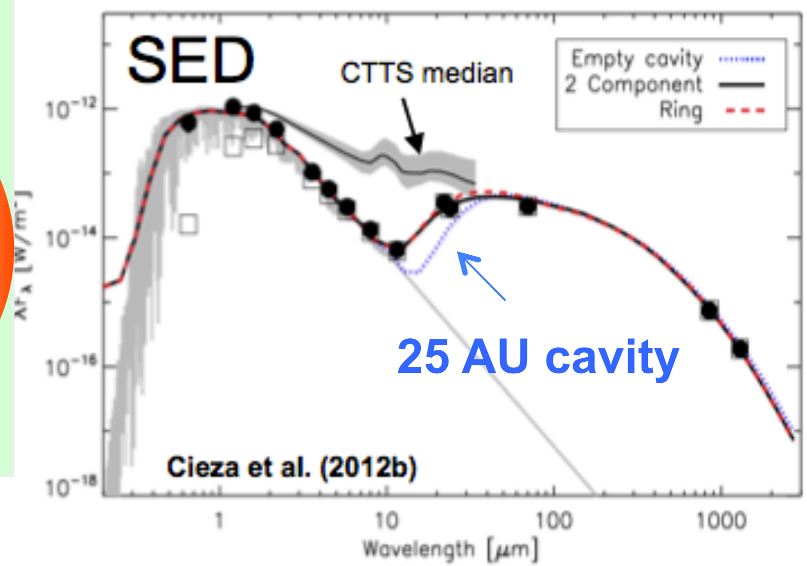
Already working on many follow up projects

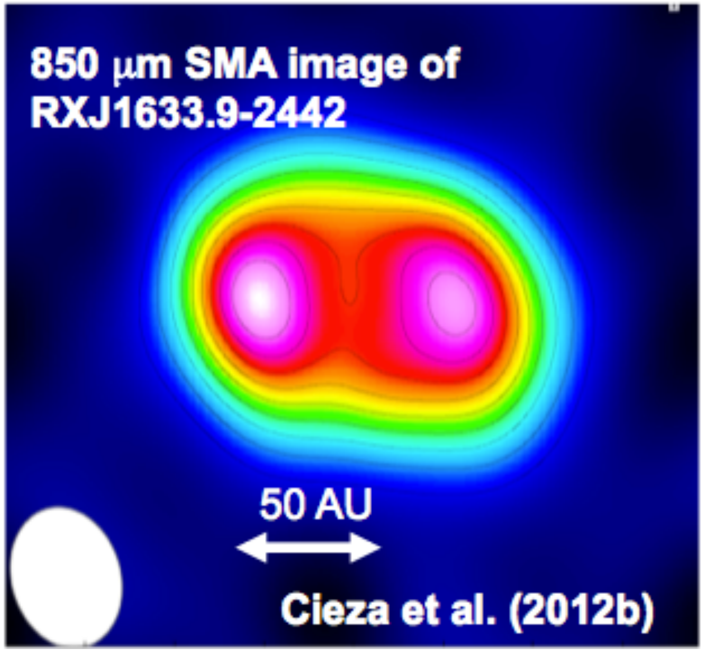
Modeling of SED + SMA images



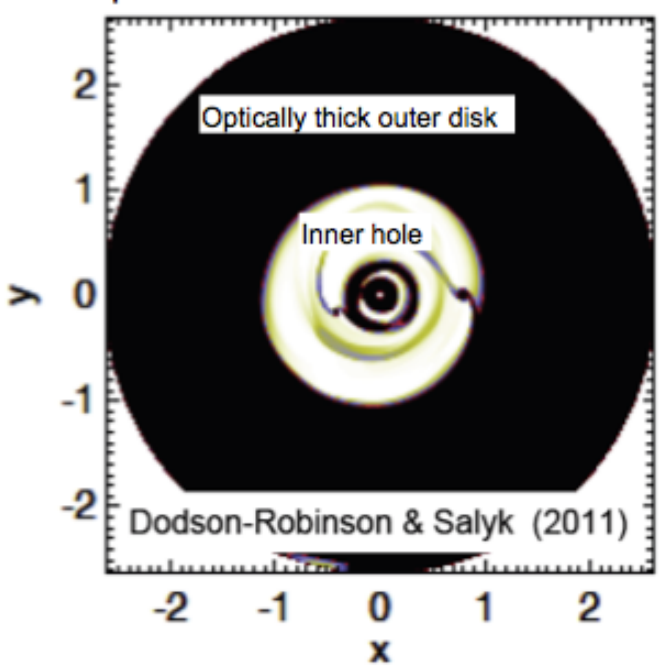


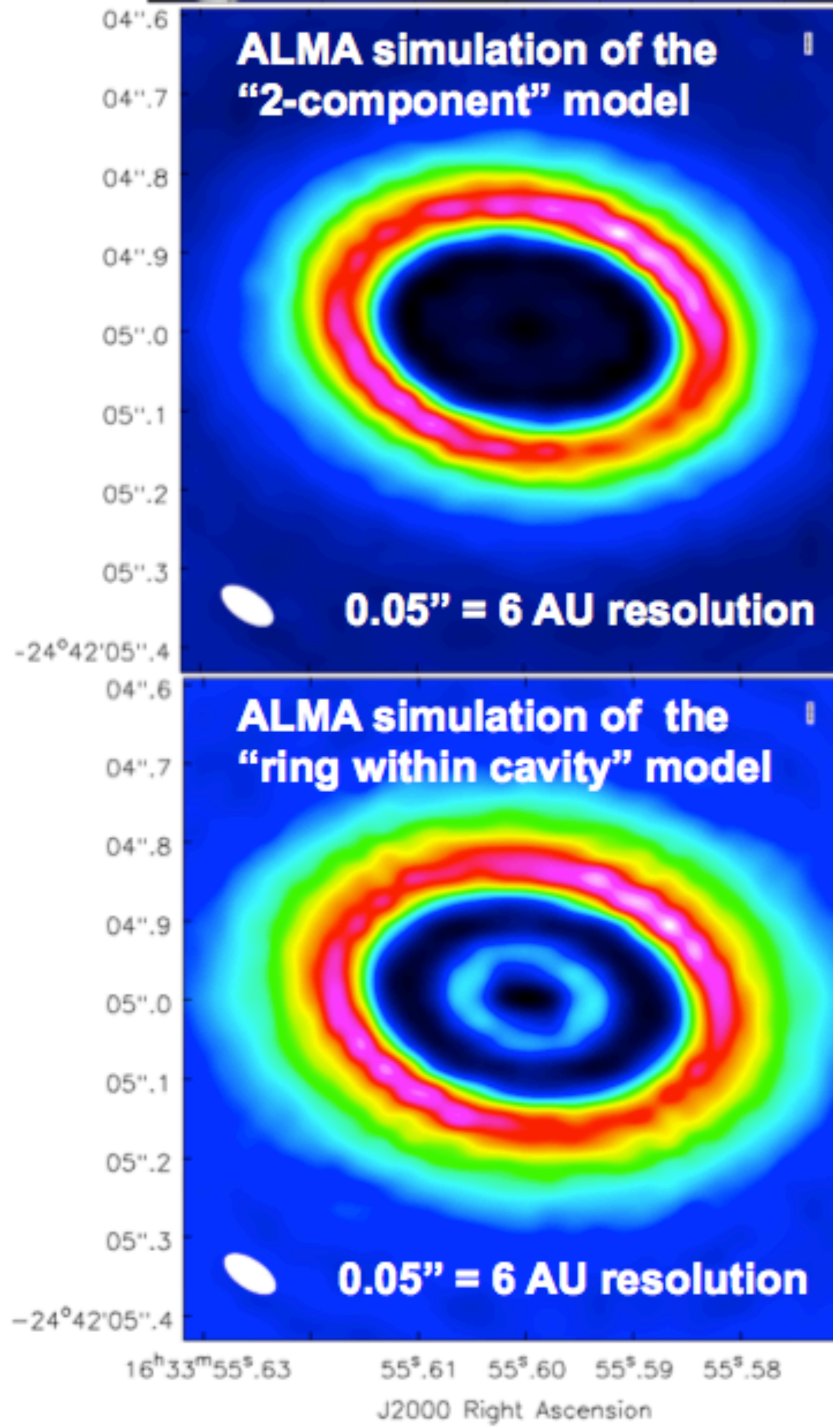






Hydrodynamic simulation of 3 planets embedded in disk





ALMA Cycle-0 observations of transition disks

(with Univ. of Valparaiso, Chile)

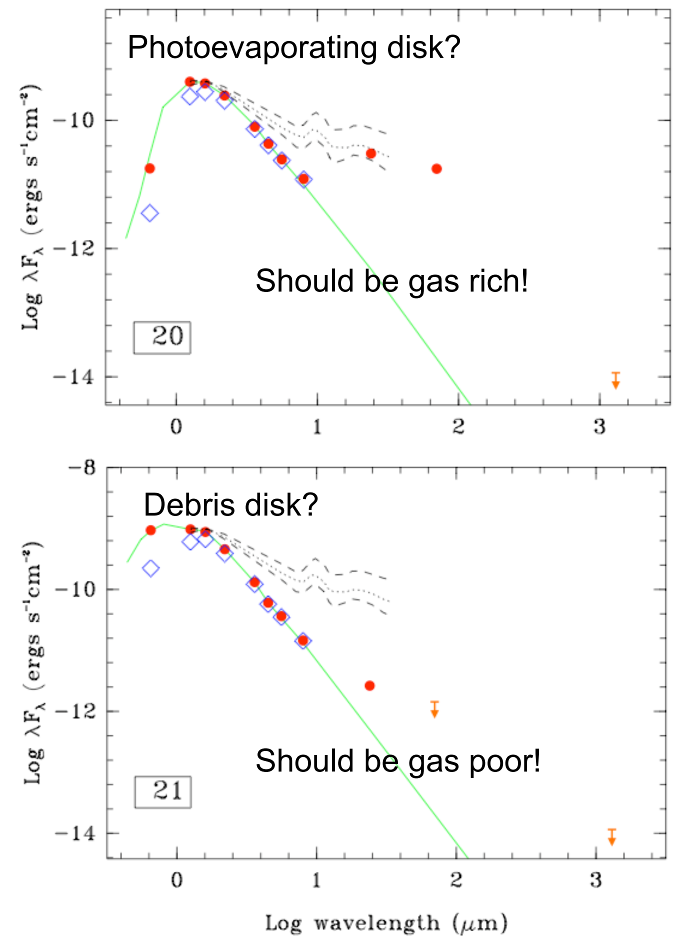
Short baselines, but huge sensitivity improvement!

- **Deep continuum and CO line observations of transition disks.**

1) Firmly distinguish primordial photoevaporating disks from debris disks

2) Estimate gas masses (and dust to mass gas ratio)

3) Estimate grain sizes (from submm slopes) as a function of evolutionary stage.



Thanks!

Questions?