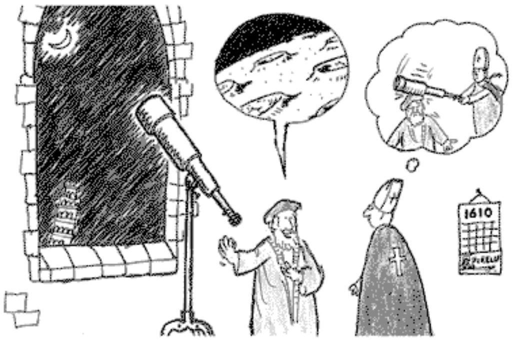
Observational ISM and Star Formation



Galileo discusses his discoveries with the church.

This Class (Lecture 17):

Stacey Alberts & Josh Dolence
(Natta et al.)

Next Class:

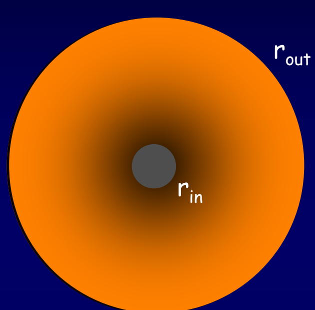
Christian Luca & Nick Hakobian
(Bergin et al.)

Music: *Blister in the Sun* – Violent Femmes

Outline

- High-Resolution Imaging of the Dust Continuum

T(r) & Σ(r) Determine F_ν



$$F_\nu \sim D^{-2} \int_{r_{in}}^{r_{out}} B_\nu[T(r)]\,(1-e^{-\tau(r)})\, 2\pi r\, dr$$

$$F_\nu \sim D^{-2} \int_{r_{in}}^{r_{out}} k\, T(r)\, \nu^2 \underbrace{\kappa_\nu \Sigma(r)}_{\tau_\nu(r)}\, 2\pi r\, dr$$

$$F_\nu \sim \nu^{2+\beta} \kappa_0 \int_{r_{in}}^{r_{out}} r^{1-q-p}\, dr \quad \sim \kappa_0 \nu^{2+\beta} r^{2-q-p}$$

$T(r) \sim r^{-q}$ $\quad 3/4 < q < 1/2$

$\Sigma(r) \sim r^{-p}$ $\quad 0 < p < 2$

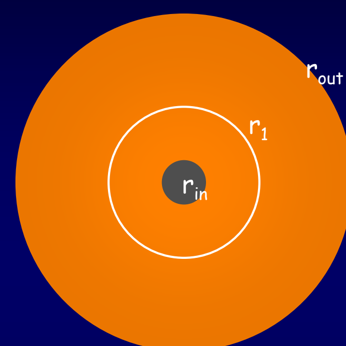
$\kappa_\nu \sim \nu^\beta$ $\quad 0 < \beta < 2$

$p = 3/2,\ q = 3/4 \quad F_\nu(1\text{ mm}) \sim r_{in}^{-1/4}$

$p = 1,\ q = 1/2 \quad F_\nu(1\text{ mm}) \sim r_{out}^{1/2}$

http://feps.as.arizona.edu/pub_presentations/kobe_2005/Kobe_nbsp_05Jul13.ppt (Steve Beckwith)

Inner Disk May Have τ >> 1



$$F_\nu \sim \int_{r_{in}}^{r_{out}} B_\nu[T(r)]\,(1-e^{-\tau(r)})\, 2\pi r\, dr$$

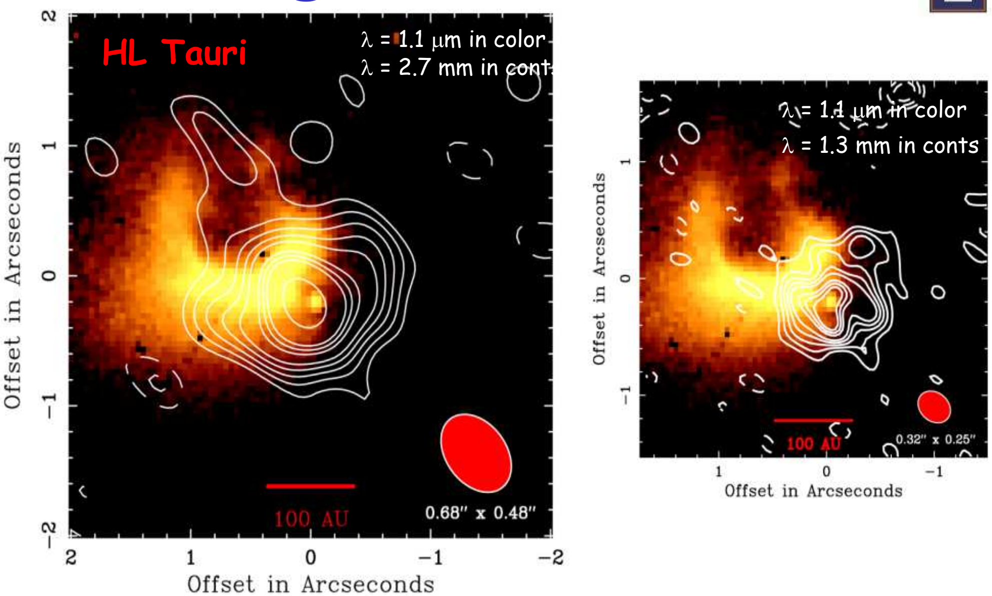
$$F_\nu \sim \int_{r_{in}}^{r_1} k\, T(r)\, \nu^2\, 2\pi r\, dr \quad (\tau > 1)$$

$$+ \int_{r_1}^{r_{out}} k\, T(r)\, \nu^2\, \kappa_\nu \Sigma(r)\, 2\pi r\, dr \quad (\tau < 1)$$

The radius at which the disk appears optically thick is a function of κ_ν, hence wavelength. The changing ratio of optically thick/optically thin regions with wavelength offsets the changes from κ_ν itself, thus causing a degeneracy of parameters (makes it difficult to derive β uniquely.)

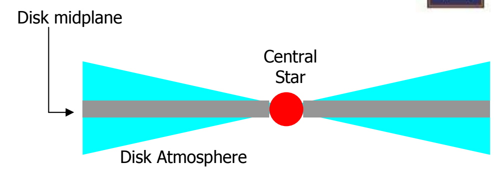
http://feps.as.arizona.edu/pub_presentations/kobe_2005/Kobe_nbsp_05Jul13.ppt (Steve Beckwith)

Tracing the Bulk Material



Stapelfeldt et al. 1995; Looney et al. 2000; Looney et al. 2007

Modeling Circumstellar Disk



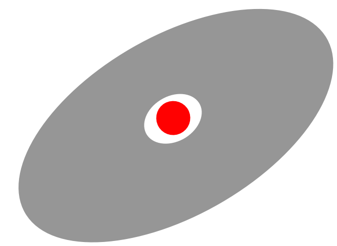
<u>Power-law disk model:</u>

- Flat Disk Midplane**:**
affects the physical structure,
dominates at the sub-mm and mm

Surface density: $\Sigma = \Sigma_0 (r/1\ \mathrm{AU})^{-p}$

Temperature: $T = T_0 (r/1\mathrm{AU})^{-q}$

Opacity: $\kappa = \kappa_0 (\nu/1200\mathrm{GHz})^{\beta}$

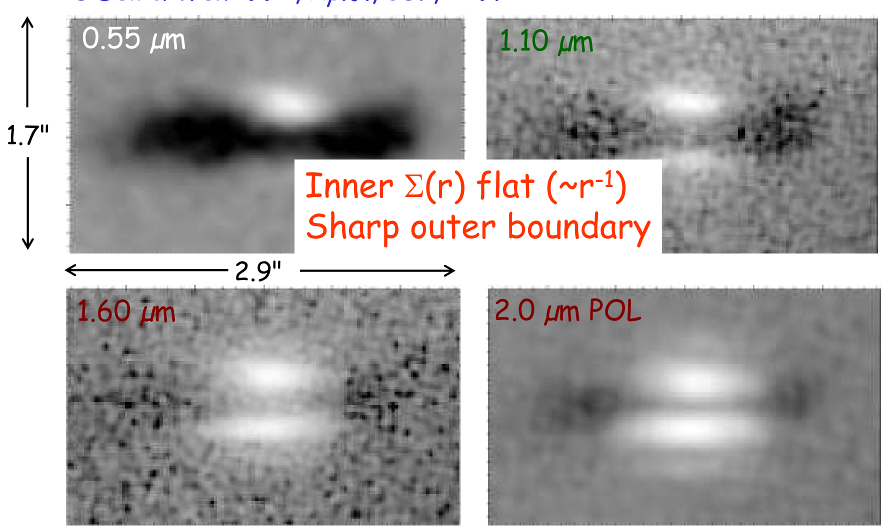


Flux $\propto \nu^{\beta} r^{-(q+p)}$

Most significant disk parameters: R_o, R_i, p, q, M_D, β

Disk Boundaries Appear Sharp

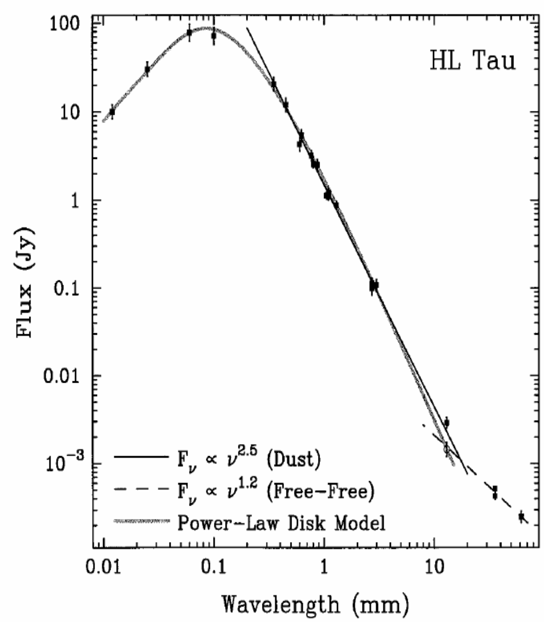
O'Dell & Wen 1992, *Ap.J.*, **387**, 229.

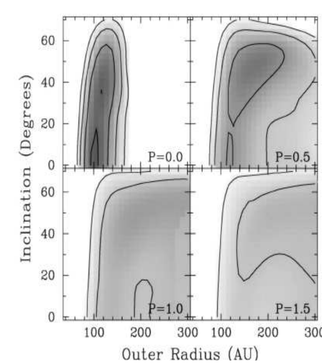


McCaughrean *et al.* 1998, *ApJL*, **492**, L157.

http://feps.as.arizona.edu/pub_presentations/kobe_2005/Kobe_nbsp_05Jul13.ppt (Steve Beckwith)

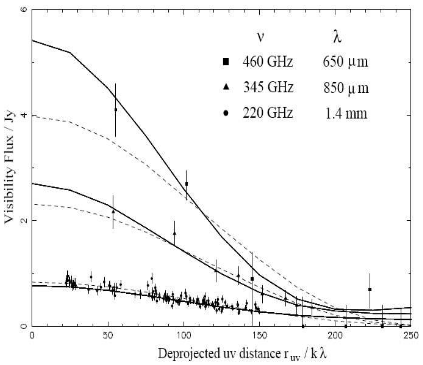
HL Tauri

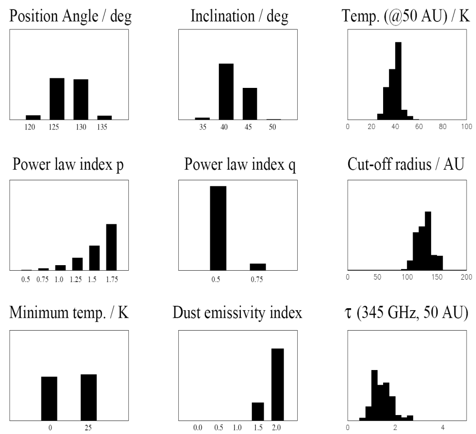




Mundy et al. 1996

HL Tauri

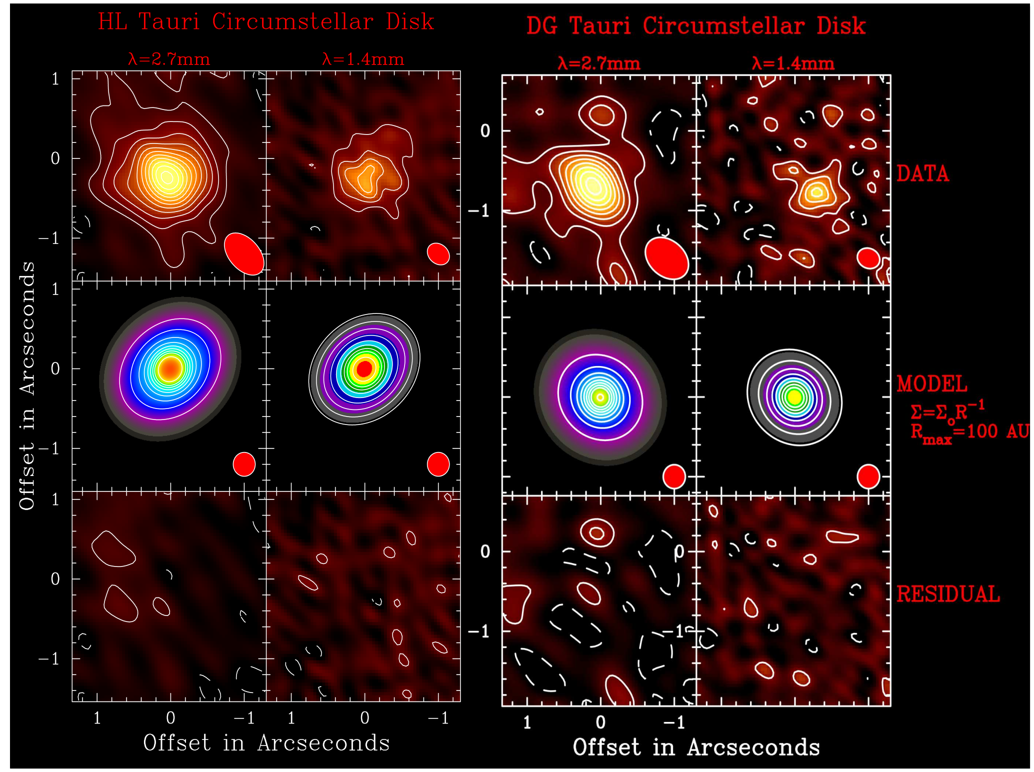




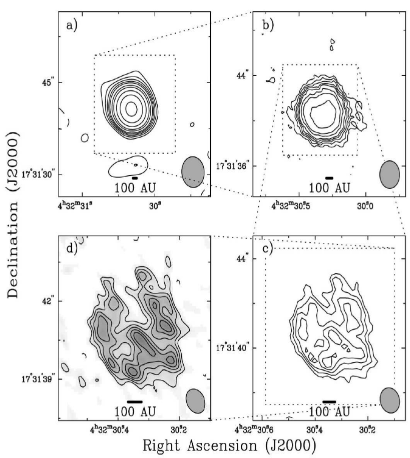
Mar 15, 2007

Astronomy 596 Spring 2007

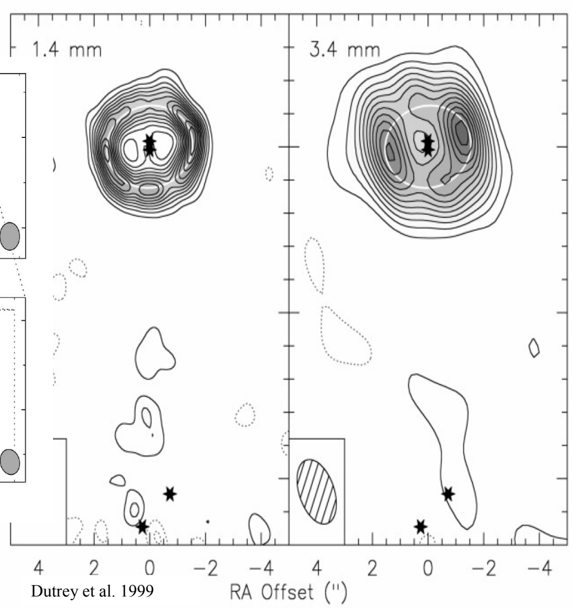
Lay et al. 1997



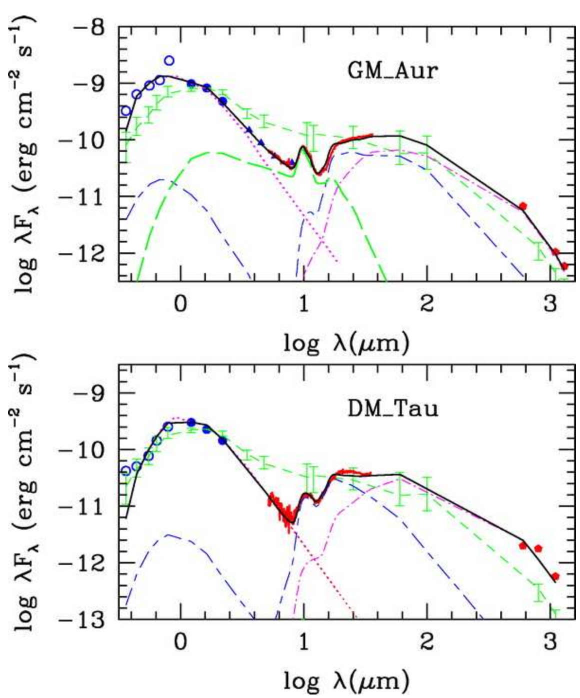
GG Tauri: Ring World



Looney et al. 2000



Dutrey et al. 1999

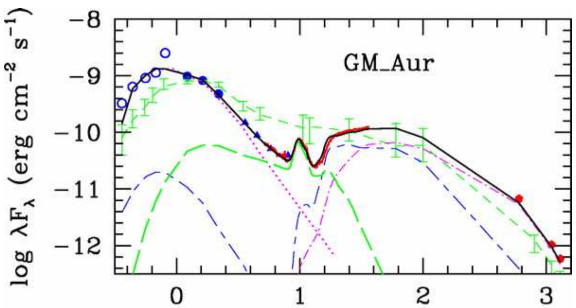


Also, very few "transitional" disks are found (that is, disks w/ inner holes):

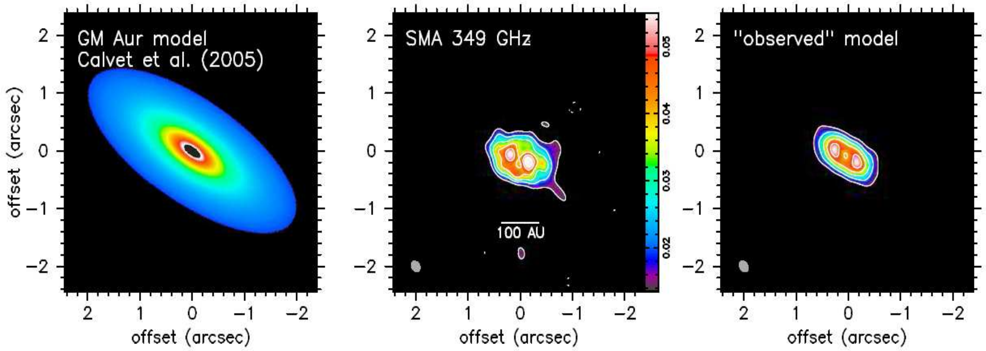
Statistics are a few to many hundreds of young stars.

Calvet et al. 2005,

http://www.gps.caltech.edu/classes/ge133/slides/lec07_16oct2006.ppt (Geoff Blake)



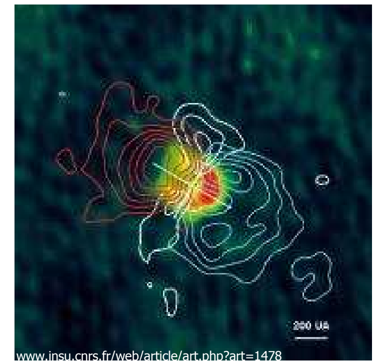
At least some disks evolve "from the inside out." Does this apply more generally, or can disks dissipate in a variety of ways?



Intermediate-Mass Stars

Jupiter-like planet candidate in the Circumstellar disk of HD 141569A (Clampin et al. 2003)

Non-Keplerian rotational disk around AB Aurigae (A. Dutrey, 2005)



BIMA Subarcsecond-Imaging of MWC 480

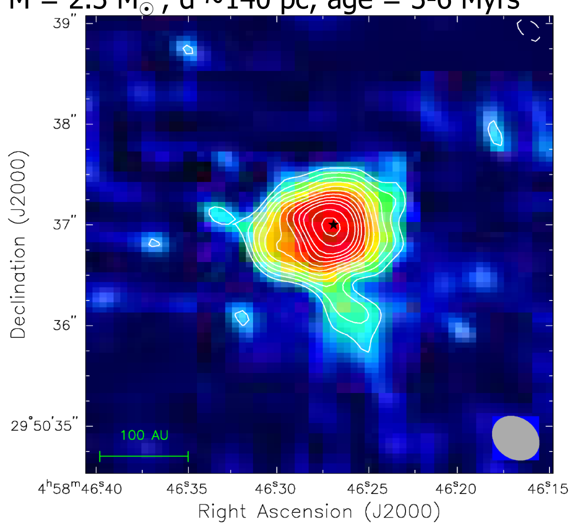
MWC 480 (HD 31648);
Herbig Ae star: sp. type = A2/3; M = 2.3 $M_\odot$; d ~140 pc; age = 3-6 Myrs

Resolving the disk:
@ λ=1.3 mm dust continuum

observations with the BIMA array:
0.32" x 0.45"

PA = 143±10 deg
Incl. = 37±5 deg
FWHM ≈ 100 AU

σ ≈ 3 mJy
Flux = 210±15 mJy
Jet-like emission = 30 mJy



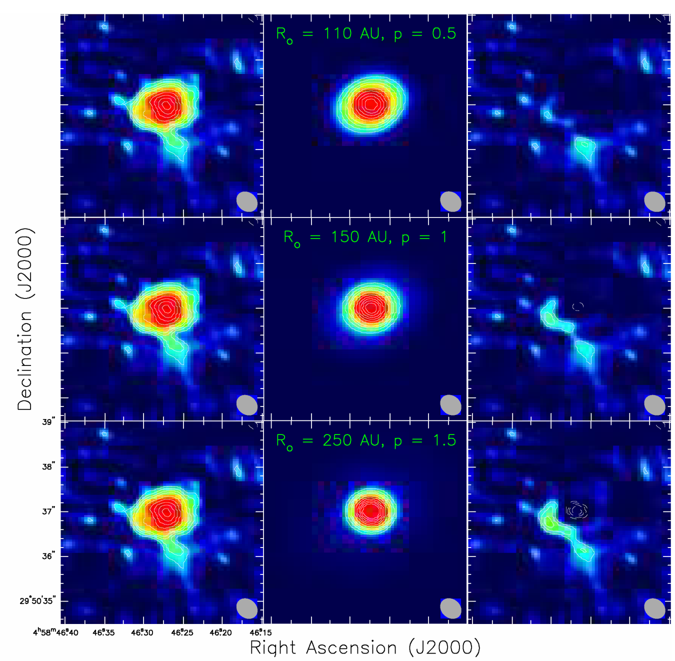
(Hamidouche et al. 2006)

Best fit models of disk observations

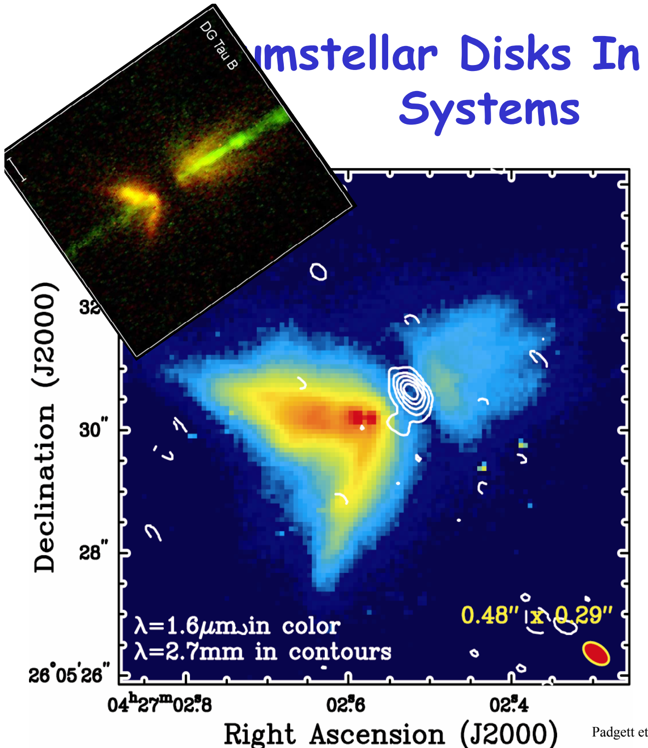
p = 0.5

p = 1

p = 1.5



umstellar Disks In T Tauri Systems



- Resolved Disks
- Small-scale continuum emission dominated (< 1″)
- Surrounded by large scale molecular disk.
- Disk masses:
  $0.001\text{-}0.1\ M_{\odot}$
- Disk radii: ~ 50-1000 AU
- Density in disk is a shallow function with radius.

Padgett et al. 1998, Looney et al. 2002