Disks@EVLA

Grain Growth and Substructure in Protoplanetary Disks

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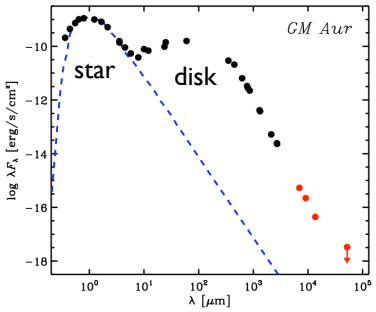
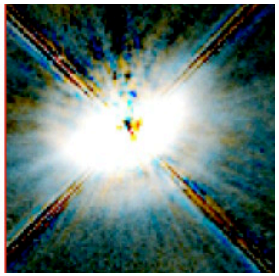
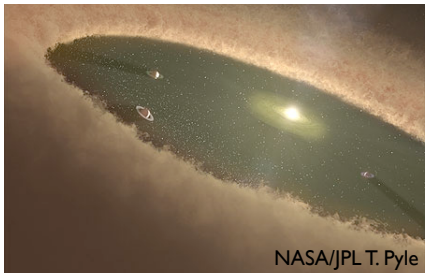
From Dust to Planets

T Tauri & HAe stars
age 1-10 Myr
100's at ~140 pc







Planetesimal formation

Planet formation

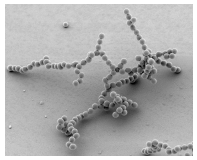
Collisional agglomoration

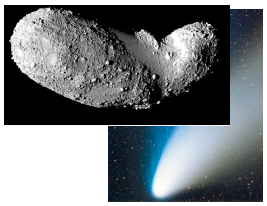
???
(collective effects)

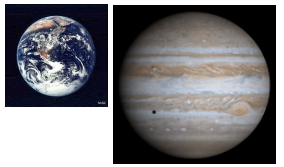
Gravity-assisted growth

Gas capture

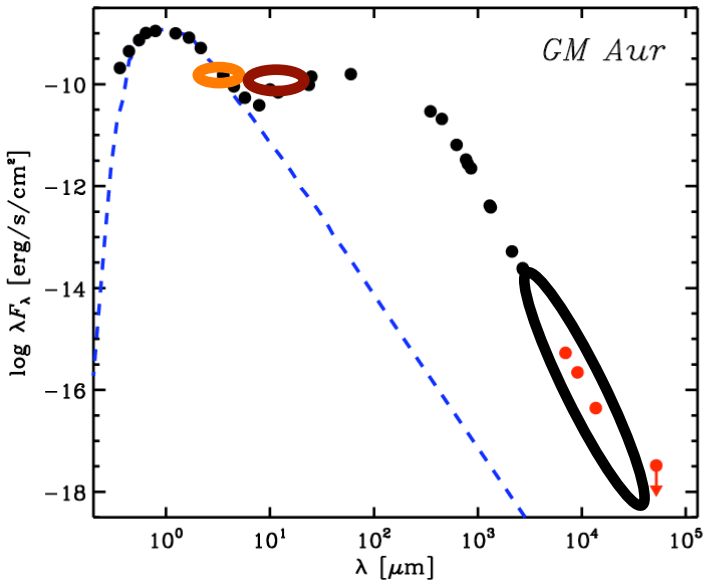
1μm 1mm 1m 1km 1000km

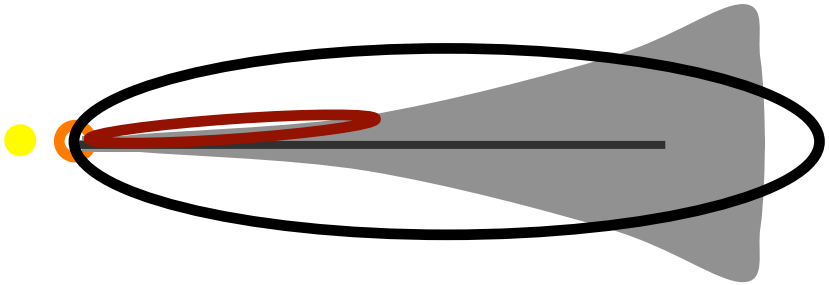






Protoplanetary Disk Dust Emission





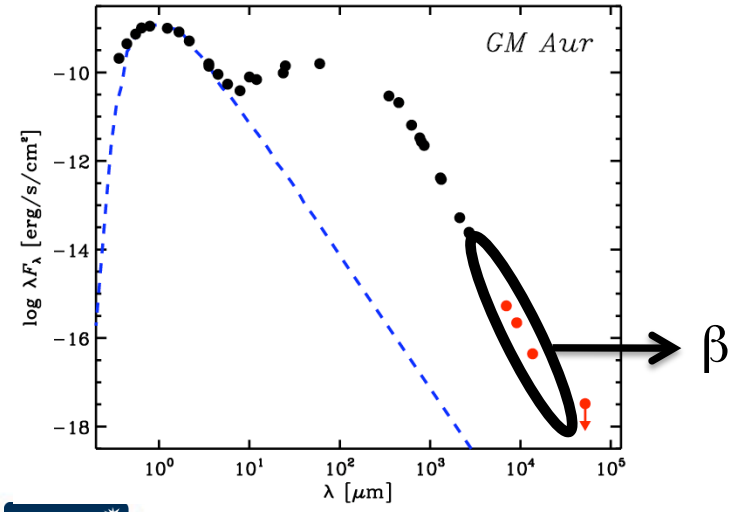
- mm/cm wavelengths
  - avoid high opacities *mass tracer*
  - sensitive to cold dust *including mid-plane*
  - sensitive to large dust *grain growth*
  - contrast with star *planet-forming region*
  - subarcsec imaging with high sensitivity *EVLA!*
  - sometimes ionized gas

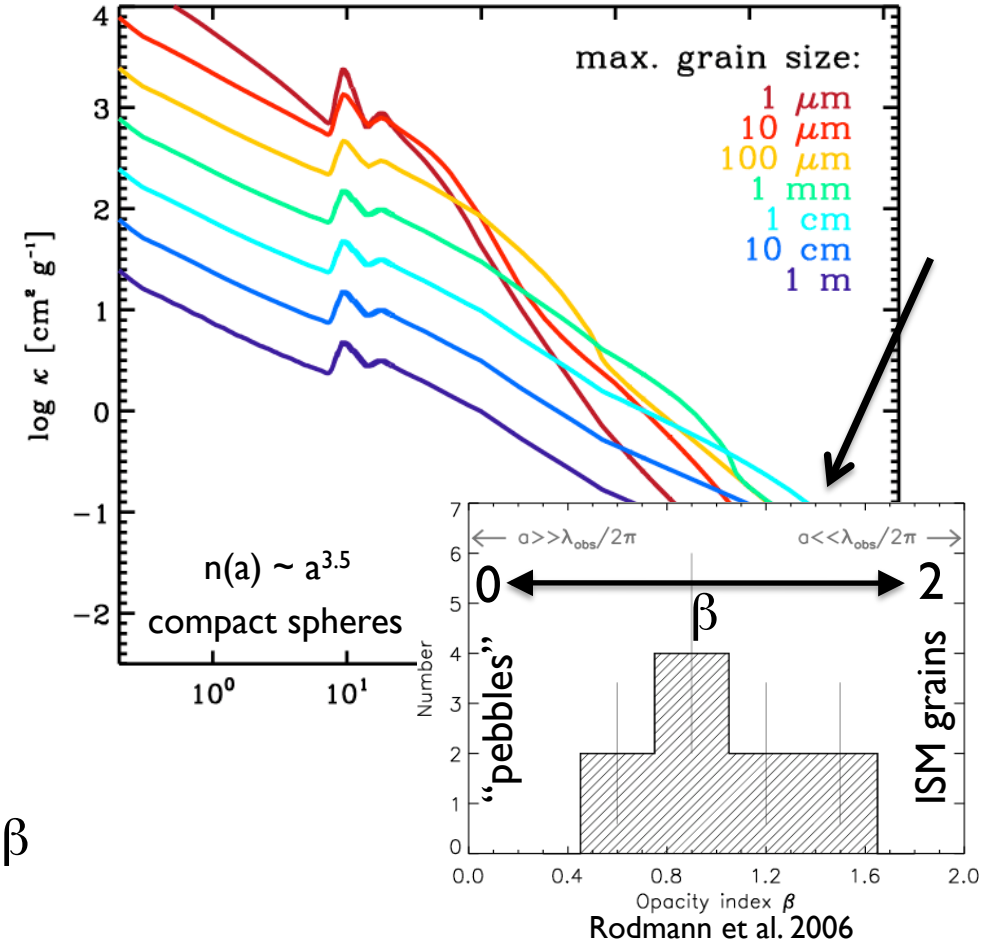
Spectral Signatures of Growth

- mm/cm emissivity $\kappa \sim \lambda^{-\beta}$
- β diagnostic of max size

- if optically thin, R-J

  $F \sim \kappa \Sigma T \sim \lambda^{-(\beta + 2)}$

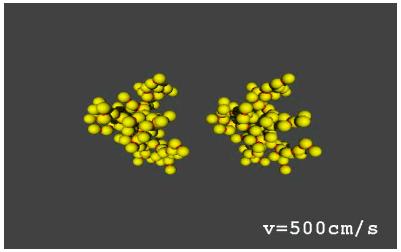




Rodmann et al. 2006

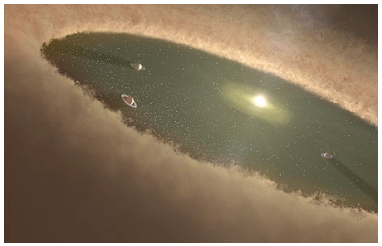
EVLA Observations

- photometry survey
  - D/DnC/C arrays, ongoing
  - 60+ nearby disks at 7/9/13/50 mm
  - spectral indices for grain growth
  - statistics, e.g. star properties, environment

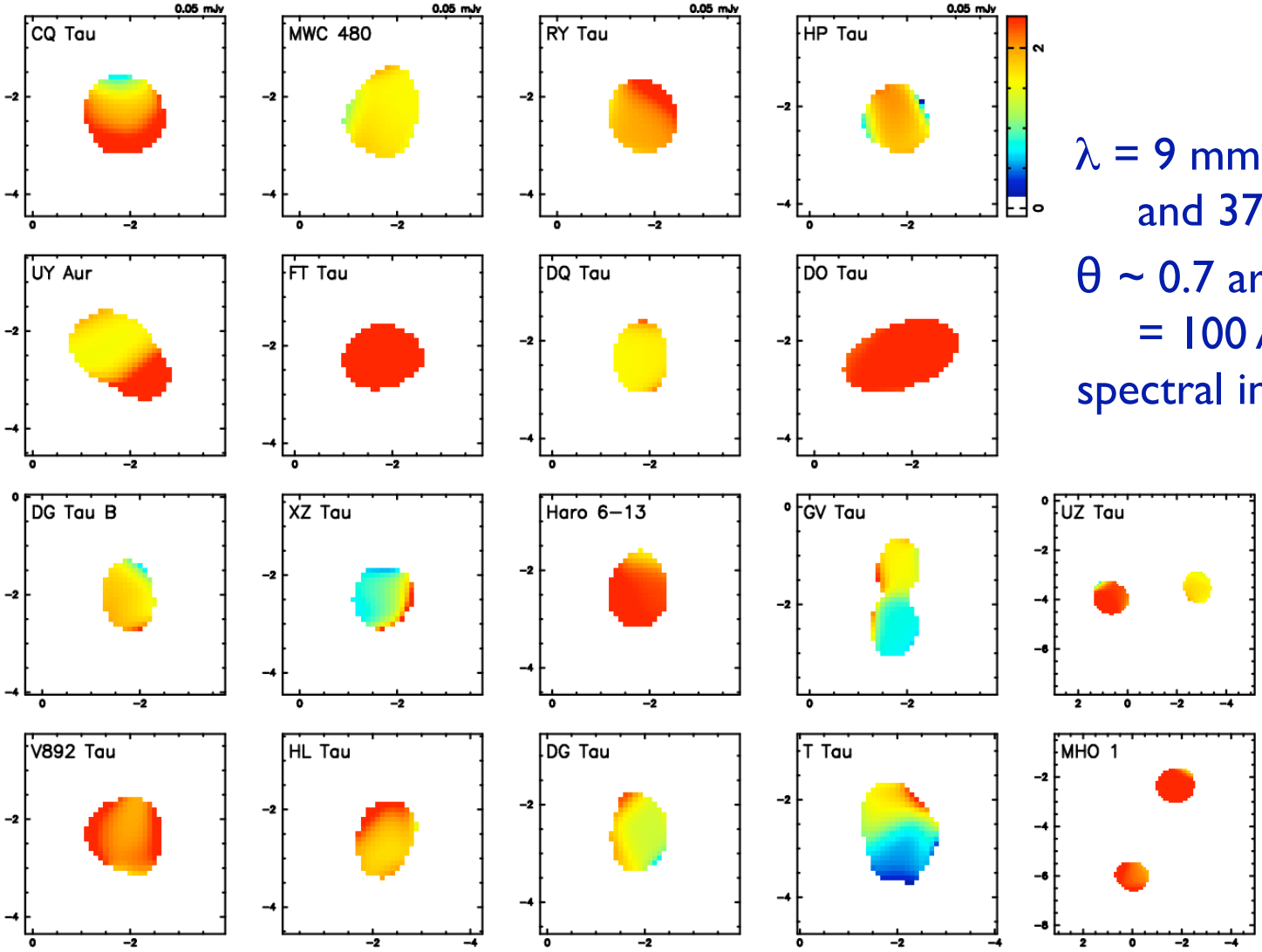


C. Dominik

- image subsets at higher resolution, to 50 mas = few AU
  - C/CnB/B/BnA/A arrays, coming soon
  - locate large grains
  - surface density structure
  - evidence for disk-planet interactions


NASA/JPL T. Pyle

Example Taurus Images (Preliminary)



λ = 9 mm (30.5 and 37.5 GHz)

θ ~ 0.7 arcsec = 100 AU

spectral indices

Some Early Analysis

- compare with Birnstiel et al. 2010 models
  - self-consistent calculation of grain size distribution, coagulation/fragmentation and irradiated disk structure
  - predict mm/cm fluxes and spectral index β

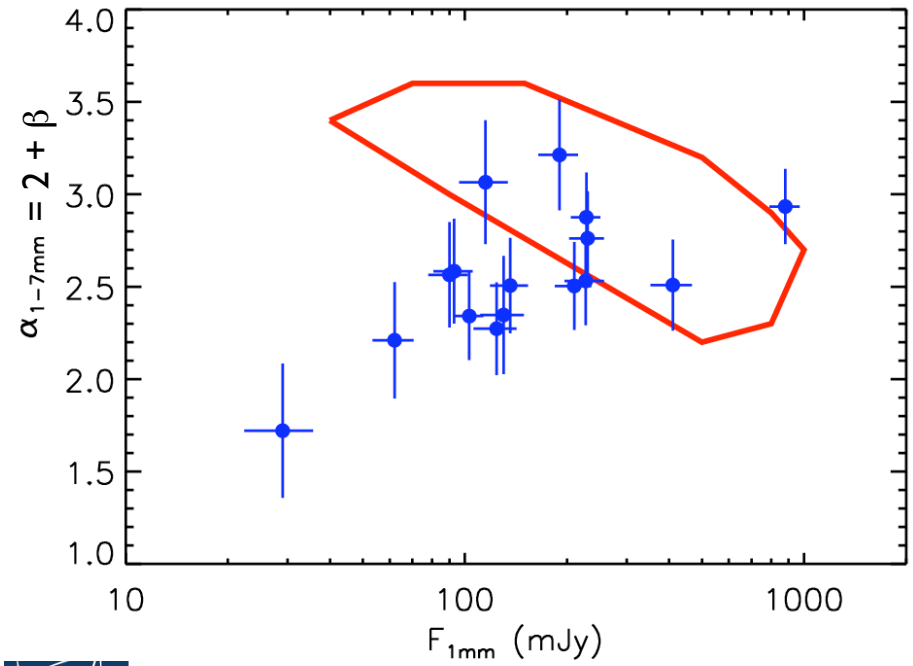


Table 1. Parameters of the model grid.

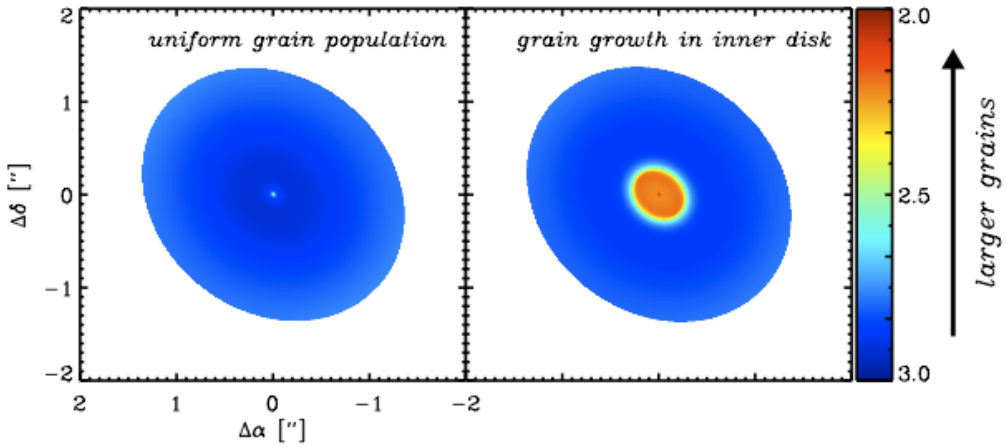
Parameter		Values			
M_{disk}	$[M_\odot]$	5×10^{-3}	$\mathbf{1 \times 10^{-2}}$	5×10^{-2}	1×10^{-1}
α_t		$\mathbf{5 \times 10^{-4}}$	1×10^{-3}	5×10^{-3}	–
u_f	[m/s]	1	**3**	10	–
f_{vac}	[% vol.]	**10**	30	50	–
ξ		1.0	**1.5**	1.8	–

Notes. M_{disk} is the total disk mass, α_t is the turbulence parameter, u_f is the critical collision velocity, f_{vac} is the grain volume fraction of vacuum, and ξ is the index of the distribution of fragments. The parameters of the fiducial model are highlighted in bold face.

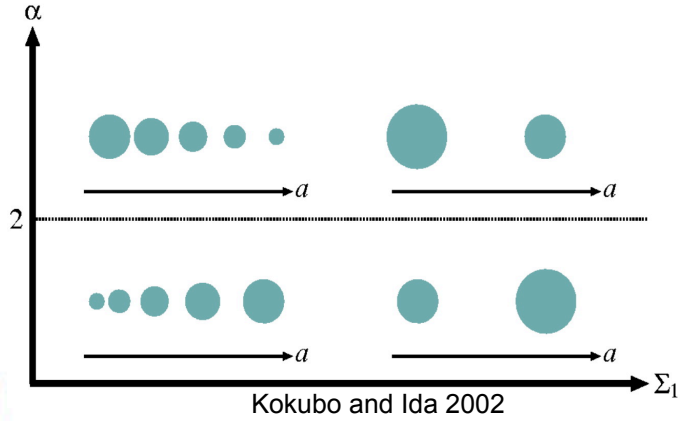
- β's agree, mm fluxes don't…
- growth to larger sizes? different initial conditions?

Resolved Disk Colors and Structure

efficient grain growth at highest densities?

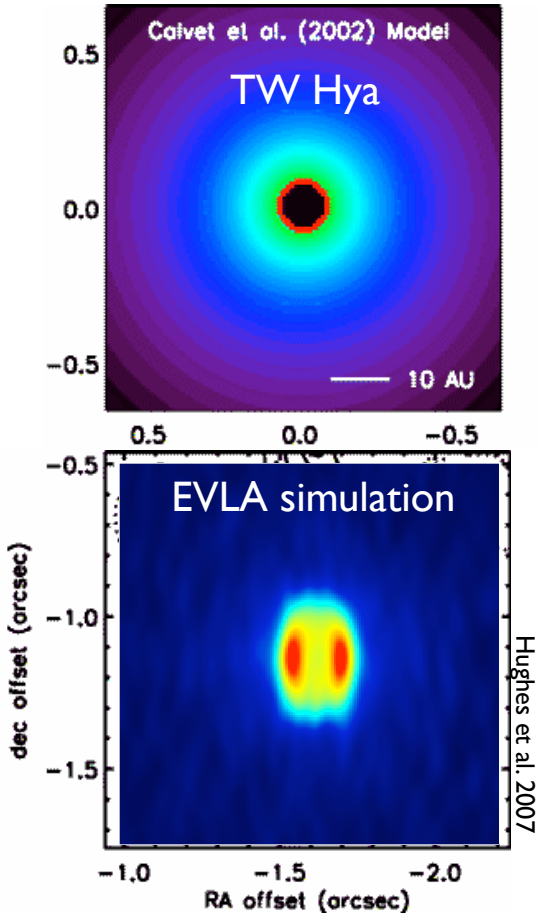


surface densities and initial conditions?



Kokubo and Ida 2002

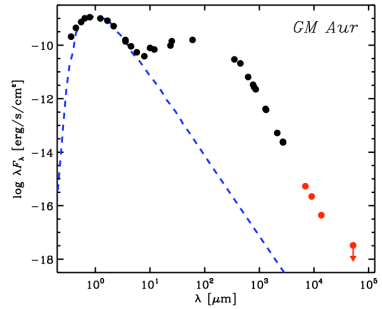
disk-planet interactions?

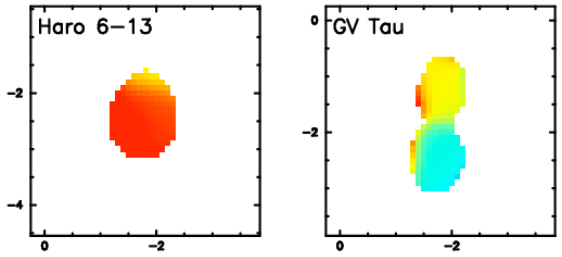


Disks@EVLA: Summary

- grain growth and substructure in protoplanetary disks
- last observable link in chain from ISM to planets

- photometry of 60+ disks at 7/9/13/50 mm
  - spectral indices reveal large grains
  - reduction and modeling underway
- imaging of subsets, to 50 mas = few AU
  - expect resolved mm/cm colors
  - surface densities, disk-planet features





- thanks to EVLA commissioning team!