Disk Instability vs. Core Accretion: Observable Discriminants

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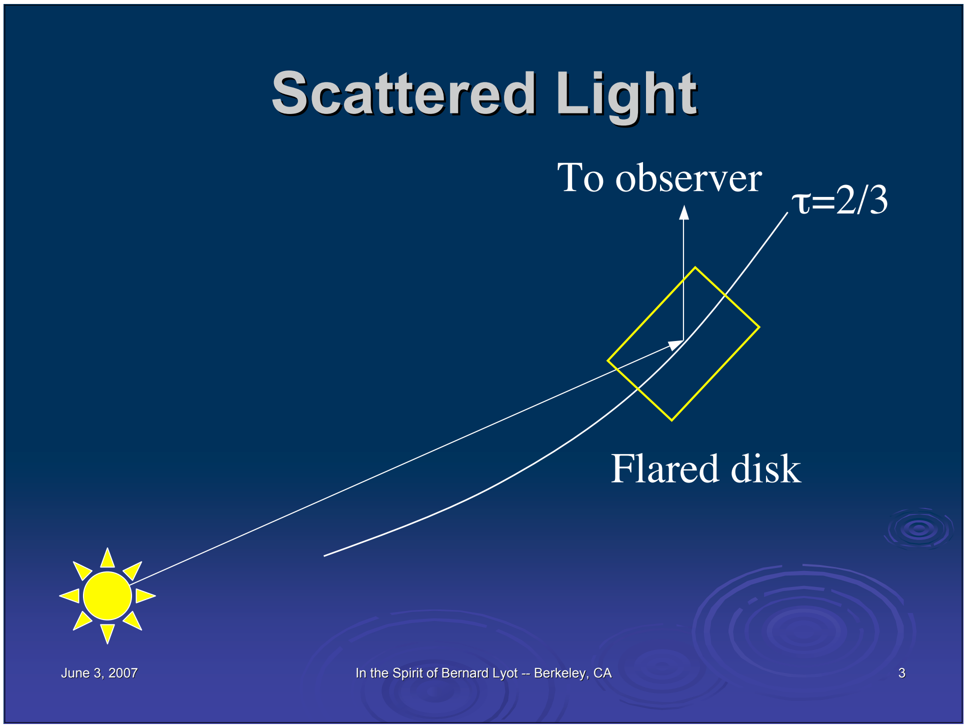
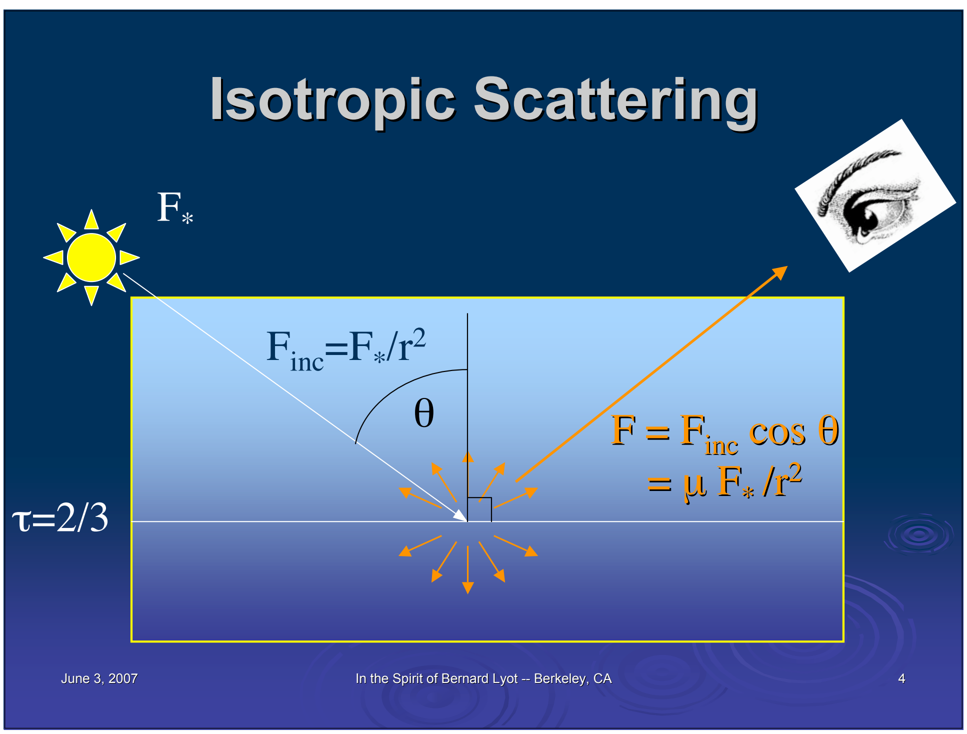
Motivation

- Disk Instability vs. Core Accretion
- Formed planet : forming planet :: smoking gun : caught in the act
- Most simulations of disk-planet interactions start with fully-formed planet
- **Push high-contrast imaging to the limit**



Scattered Light
To observer
τ=2/3
Flared disk
June 3, 2007
In the Spirit of Bernard Lyot -- Berkeley, CA
3



Isotropic Scattering
F*
Finc=F*/r2
θ
F = Finc cos θ
= μ F* /r2
τ=2/3
June 3, 2007
In the Spirit of Bernard Lyot -- Berkeley, CA
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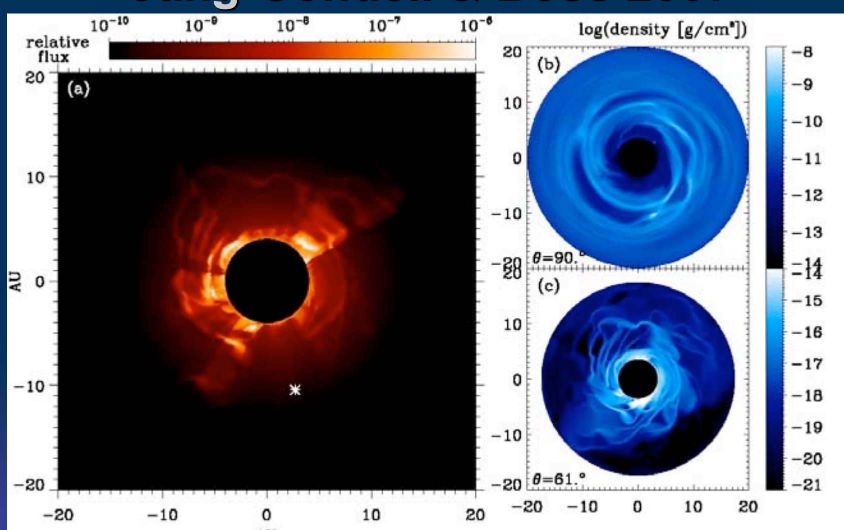
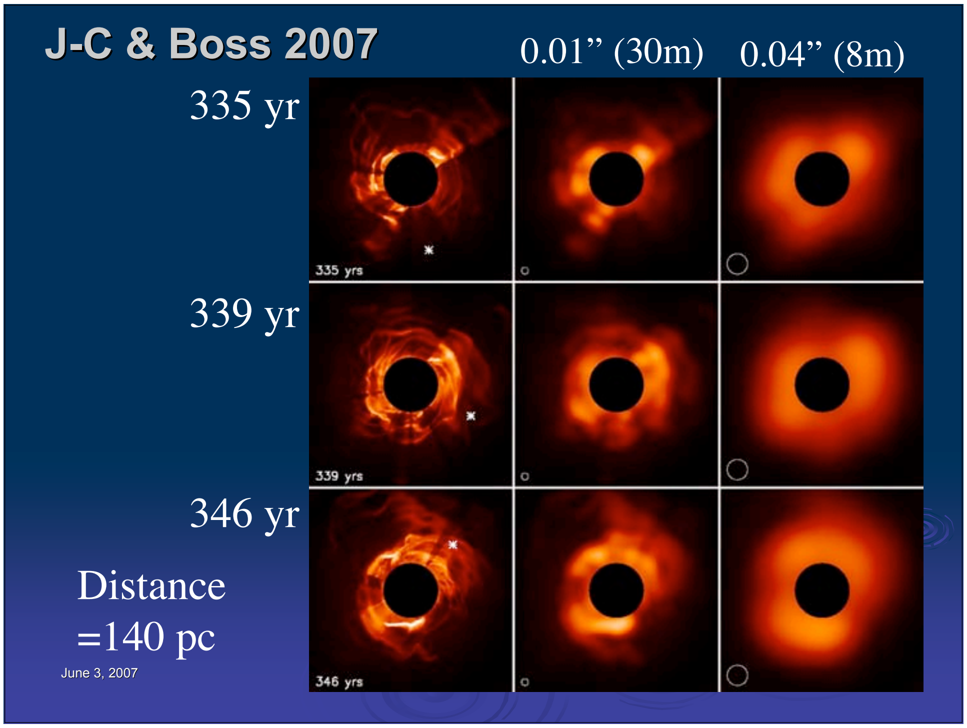
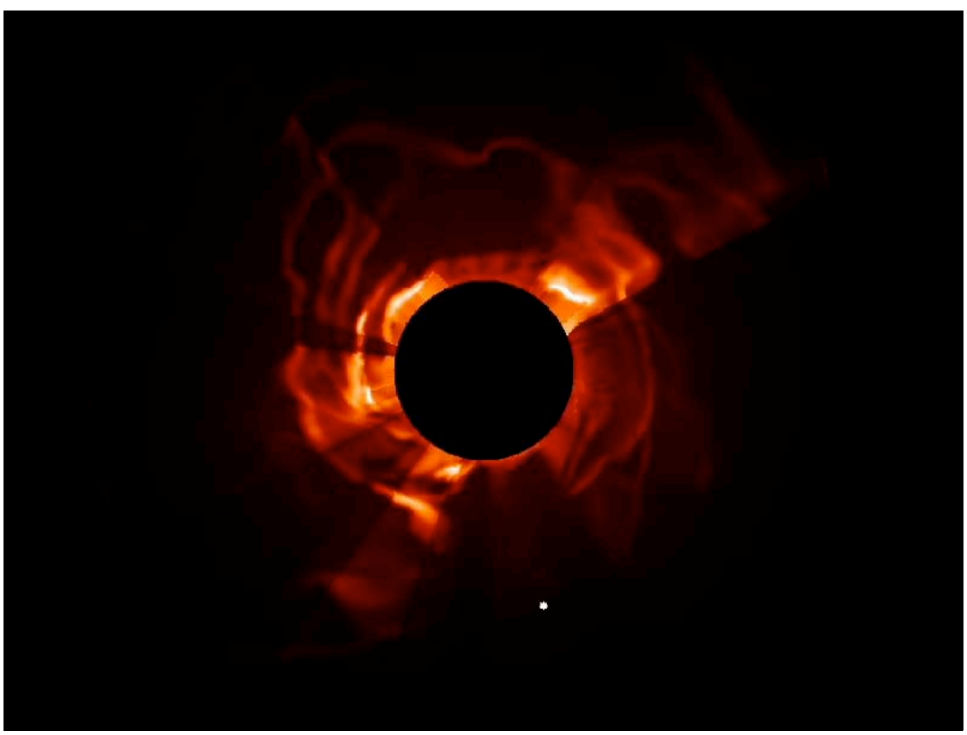
Disk Instability

- 3D hydrodynamic simulations of disk instability by Boss 2001
- Self-gravitating clump formed

Jang-Condell & Boss 2007




J-C & Boss 2007
0.01” (30m)
0.04” (8m)
335 yr
339 yr
346 yr
335 yrs
339 yrs
346 yrs
Distance
=140 pc
June 3, 2007



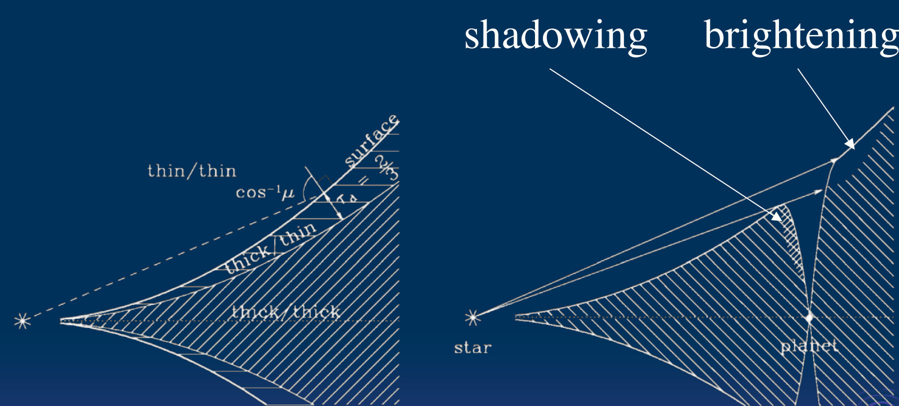
Features of Disk Instability

- Scattered light probes upper layers of disk
- Filamentary structures
- Variability over several years' time
- Need at least 0.01" resolution (GMT, TMT; ALMA)

Core Accretion

- Planet cores embedded in gaseous disks
- 10-20 Earth masses (0.03-0.06 Jupiter masses)
- Assume hydrostatic equilibrium, steady state

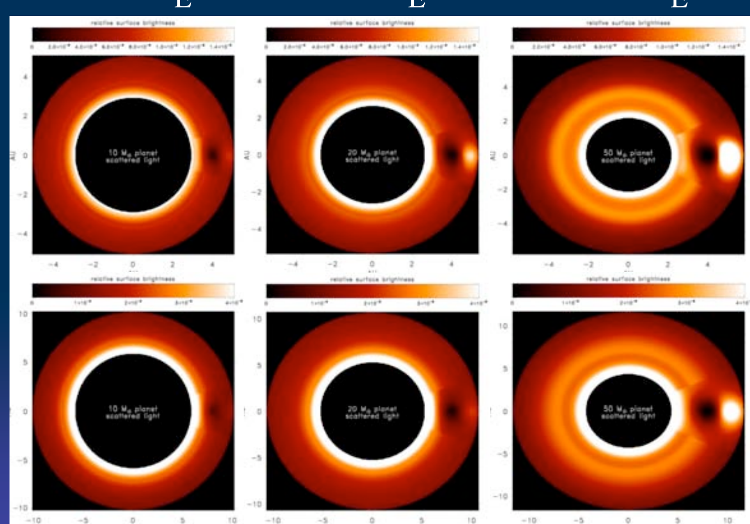
Planet Shadows



Jang-Condell & Sasselov 2003, 2004

Scattered Light

	$10\ M_E$	$20\ M_E$	$50\ M_E$
4 AU			
8 AU			



Jang-Condell, in prep

Features of Core Accretion

- Smooth overall disk
- Paired shadow/brightening at planet position
- 10^{-9} - 10^{-8} contrast ratio (surface brightness)
- Need <0.01” resolution

Comparison

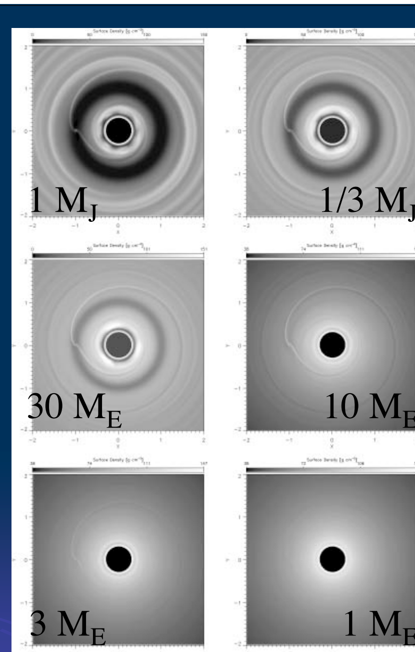
Disk Instability	**Core Accretion**
Early YSO (Class I) ~10^{-5} M_{sun}/yr Massive disk ~0.1 M_{sun}	Later YSO (Class II) ~10^{-7} M_{sun}/yr Small disk ~0.01 M_{sun}
Turbulent structure, highly variable	Quiescent, stable structure
Planet location indeterminate	Feature at planet position
Very high angular resolution <0.01” Very high contrast <10^{-8}	

Future Work

- Inclined disks
- Thermal emission, ALMA wavelengths
- Shadowing and illumination on partial gaps
- Include hydrodynamics in core accretion scenario

Partial Gaps

- Partial clearing of a gap by sub-Jupiter-mass planets
- Subject to shadowing and illumination, just as dimples
- Larger feature, more easily observed



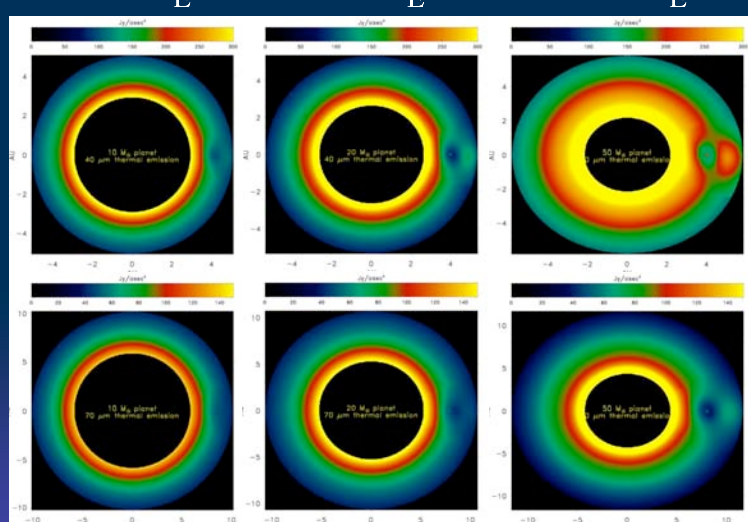
Bate, et al. 2003

Observational Challenges

- Angular resolution <0.01"
- High contrast imaging $<10^{-7}$
- Small inner working angle <0.05"
- High sensitivity

Thermal Emission

	$10\ M_E$	$20\ M_E$	$50\ M_E$
4 AU 40 μm			
8 AU 70 μm			



Jang-Condell, in prep