– Transition Disks –

Grain Growth, Planets, or Photoevaporation?

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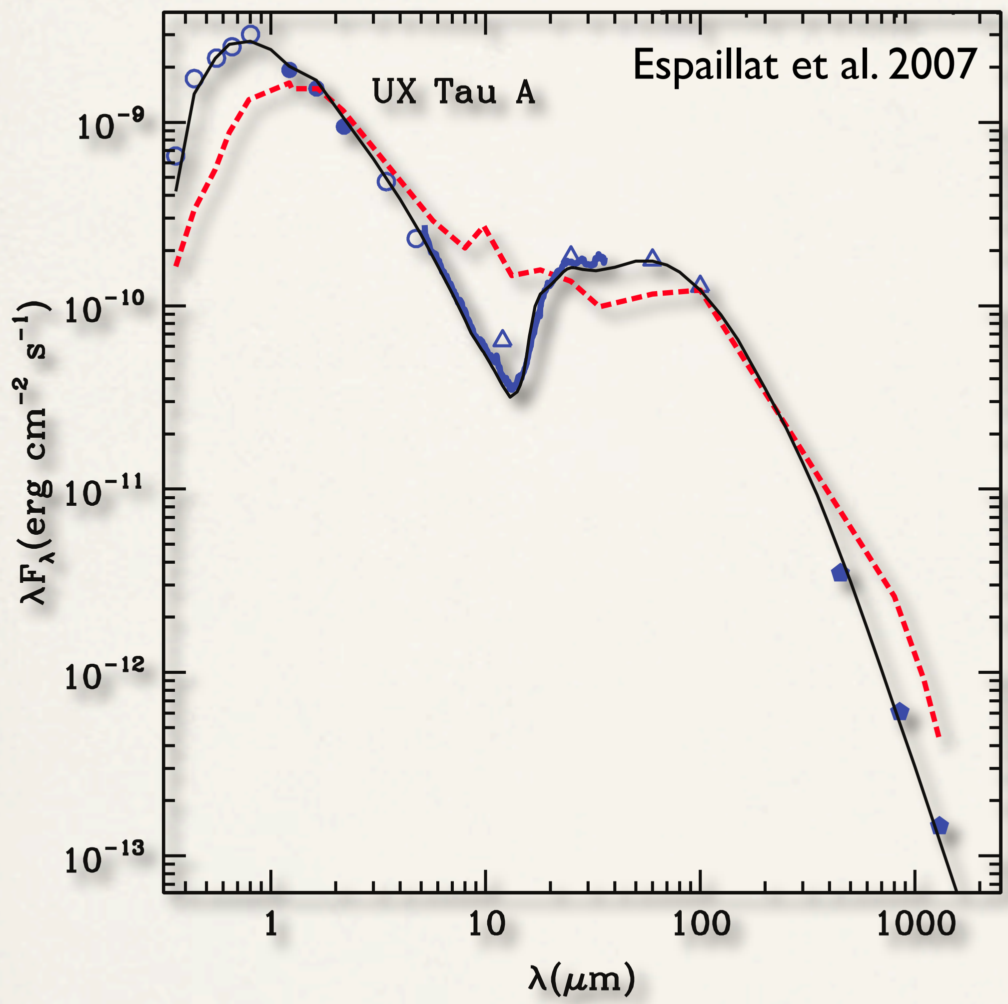
Instabilities and Structures in Protoplanetary Disks

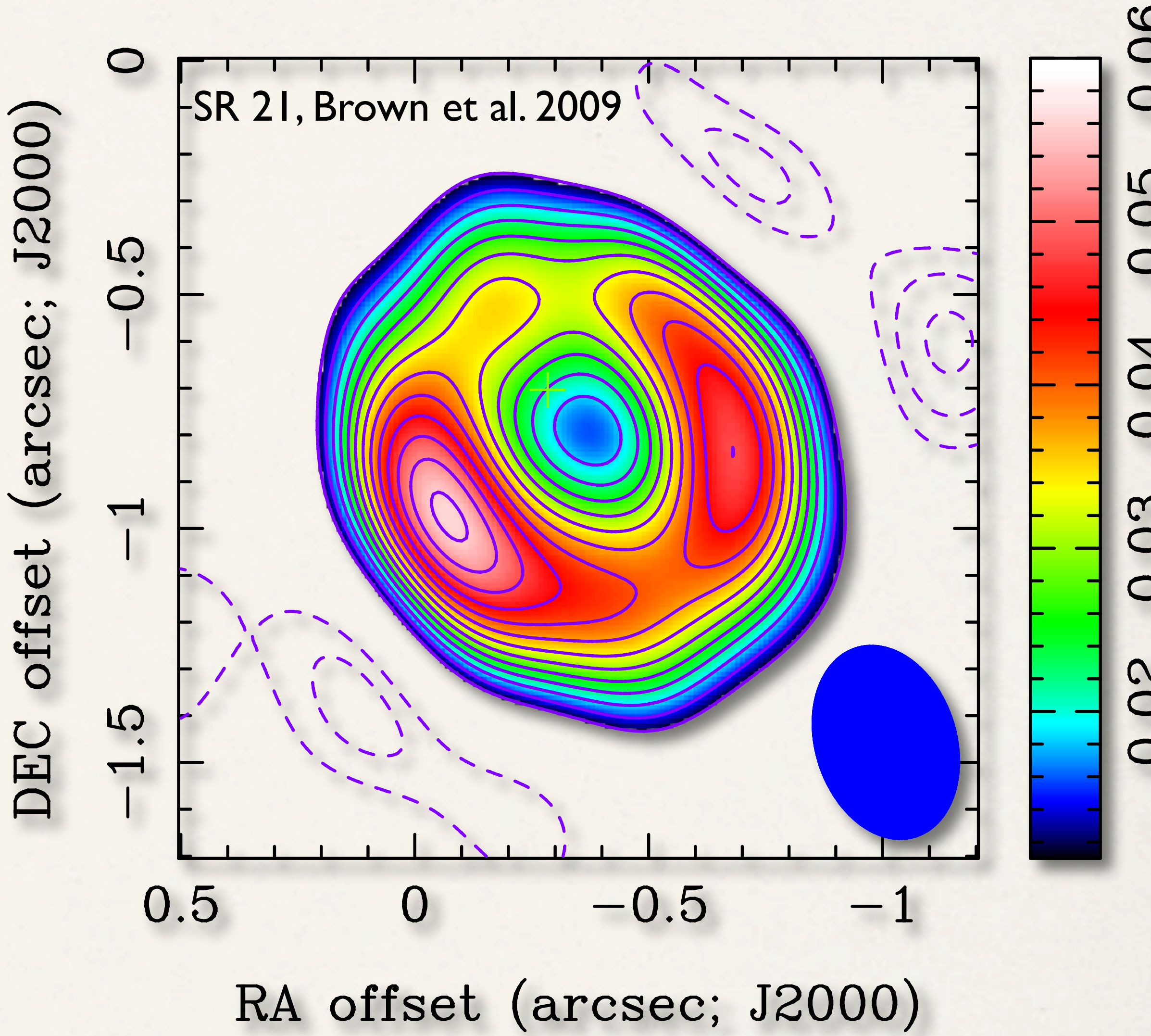
– Outline –

- Photoevaporation
- Grain Growth
- Planets & Instabilities

– Photoevaporation –

– Features of Transition Disks –

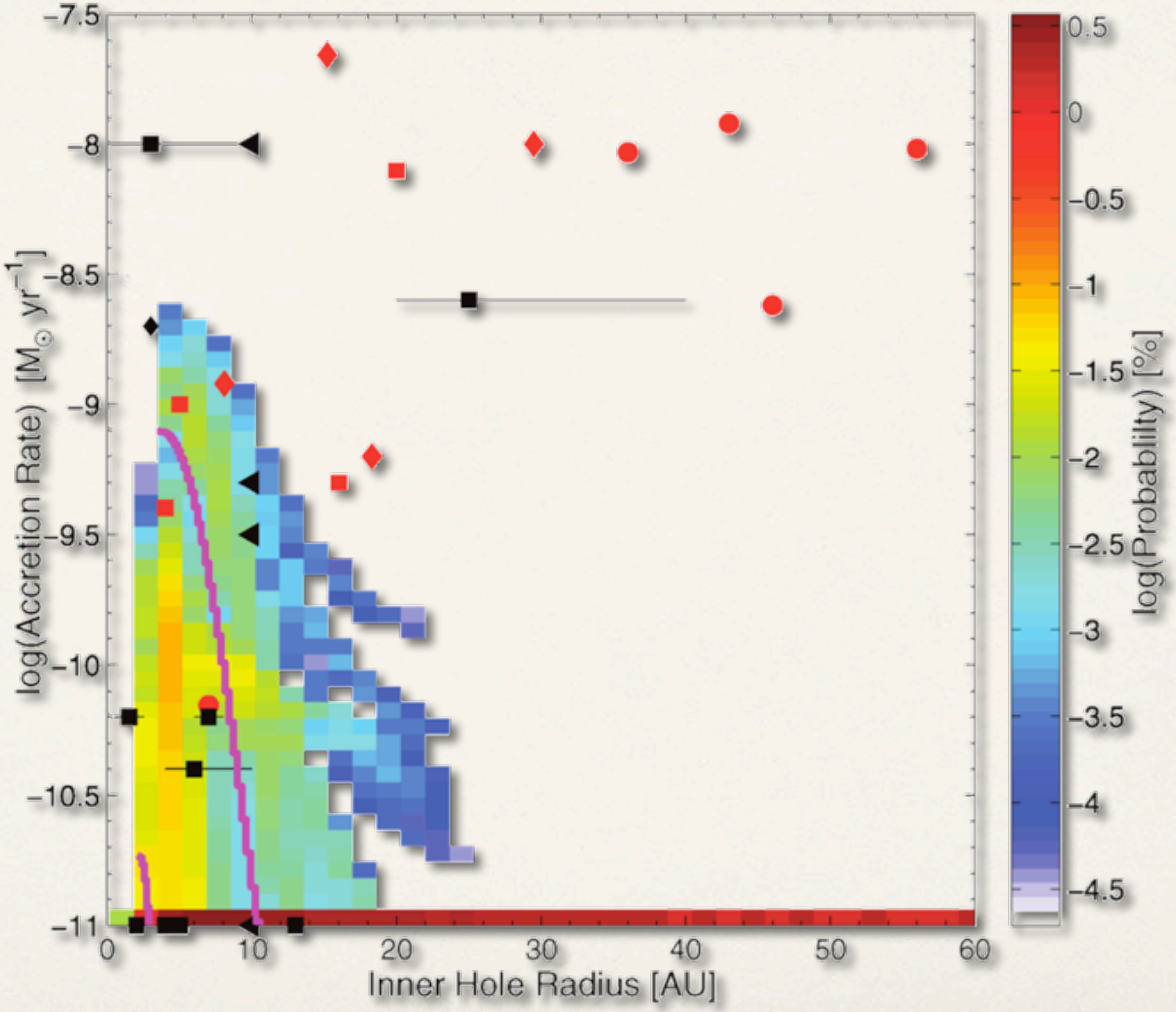




- not all TDs have a TD-like SED
- transition disk fraction*: > 1/3
- median hole size: 35 AU
- wide range of accretion rates

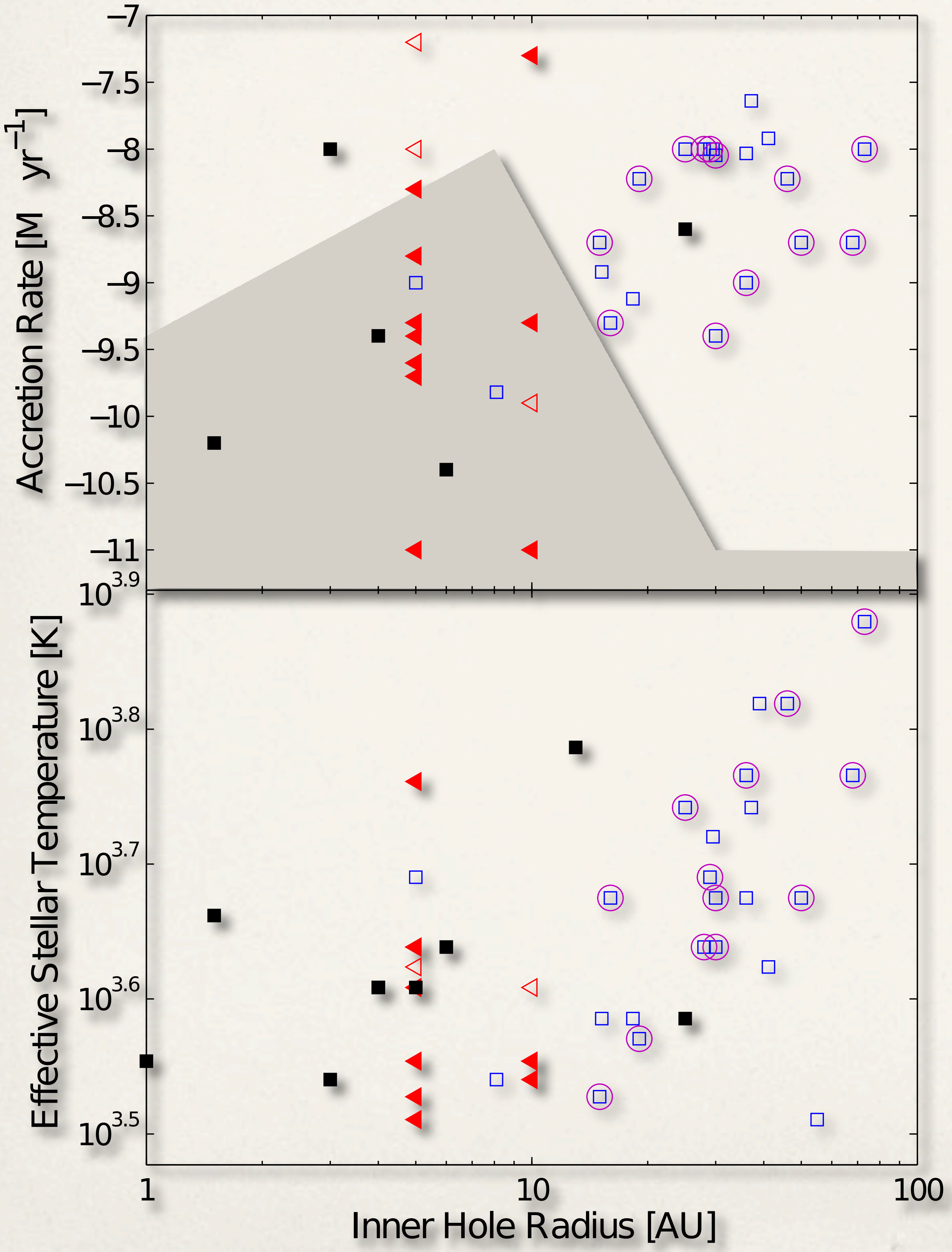
* for mm-bright disks.
See Andrews et al. 2011

– Photoevaporation –



Owen et al. 2011

– Two Populations? –



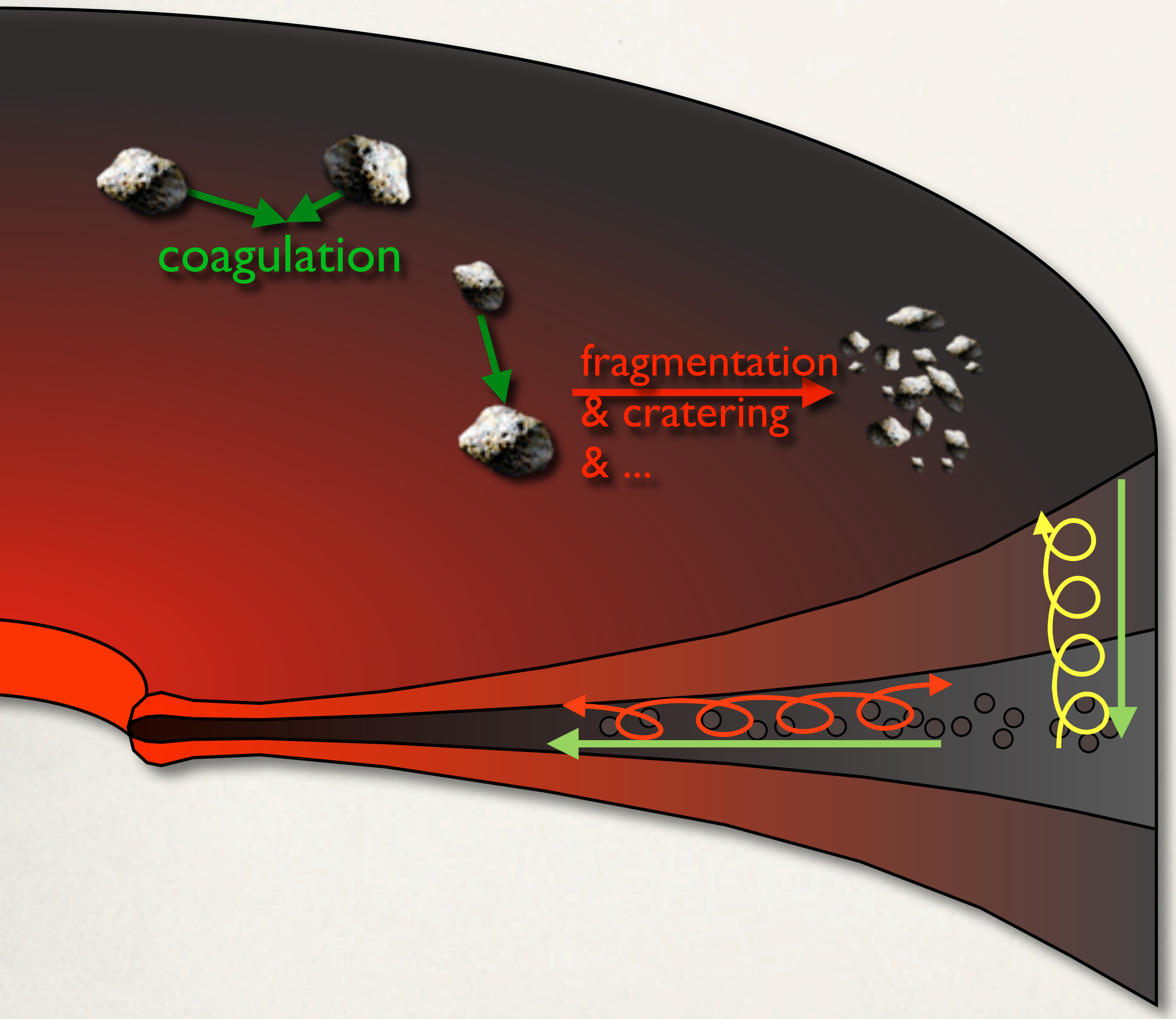
Owen & Clarke 2012:

"Transition discs in the **bright mm sub-sample have systematically higher accretion** rates than those in the faint mm sub-sample, along with being systematically weighted to earlier spectral types."

– Grain Growth –

(*alone*)

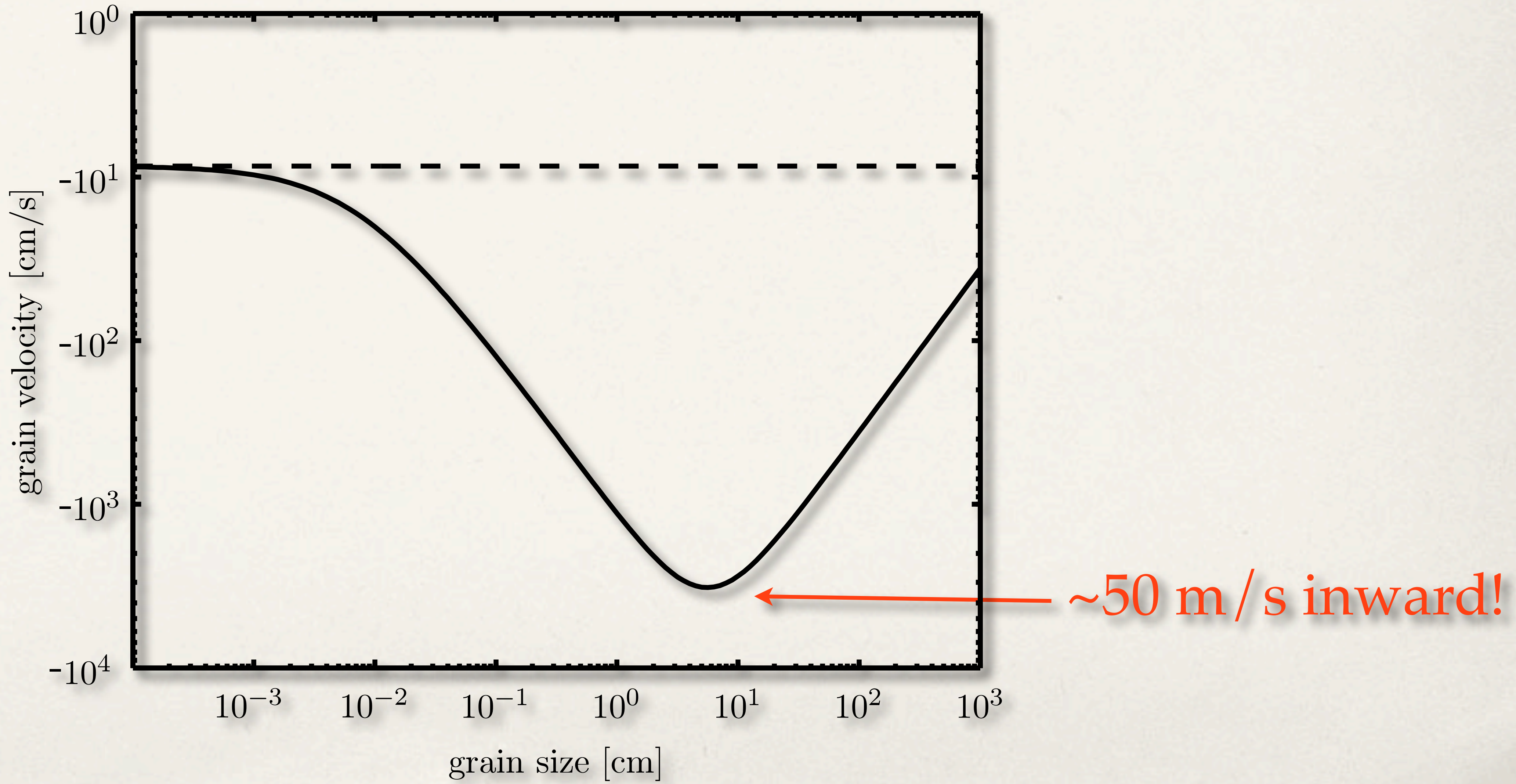
– Dust Evolution in a Nutshell –



- **Vertical Evolution**
  turbulent mixing, settling, dead zones, …
- **Radial Evolution**
  radial drift, radial mixing, gas drag, turbulent concentration, pressure traps, photophoresis,...
- **Dust Size Evolution**
  sticking, bouncing, fragmentation, compaction, erosion, evaporation, condensation, ...

– Dust Evolution in a Nutshell –

- Rule 1: the larger the grain, ...
  - ... the larger its *inward drift velocity*
  - ... the larger the *turbulent collision velocity*



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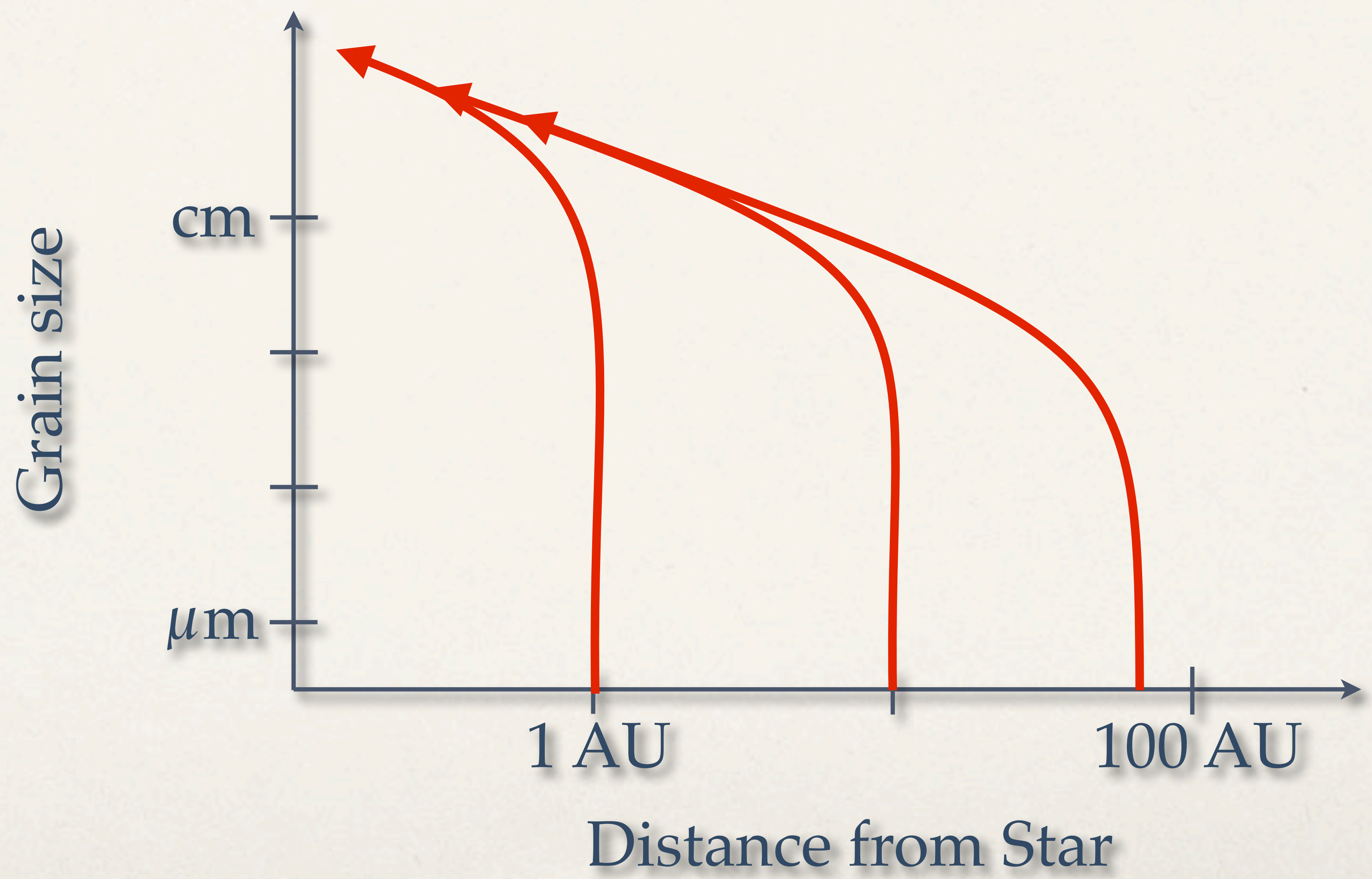
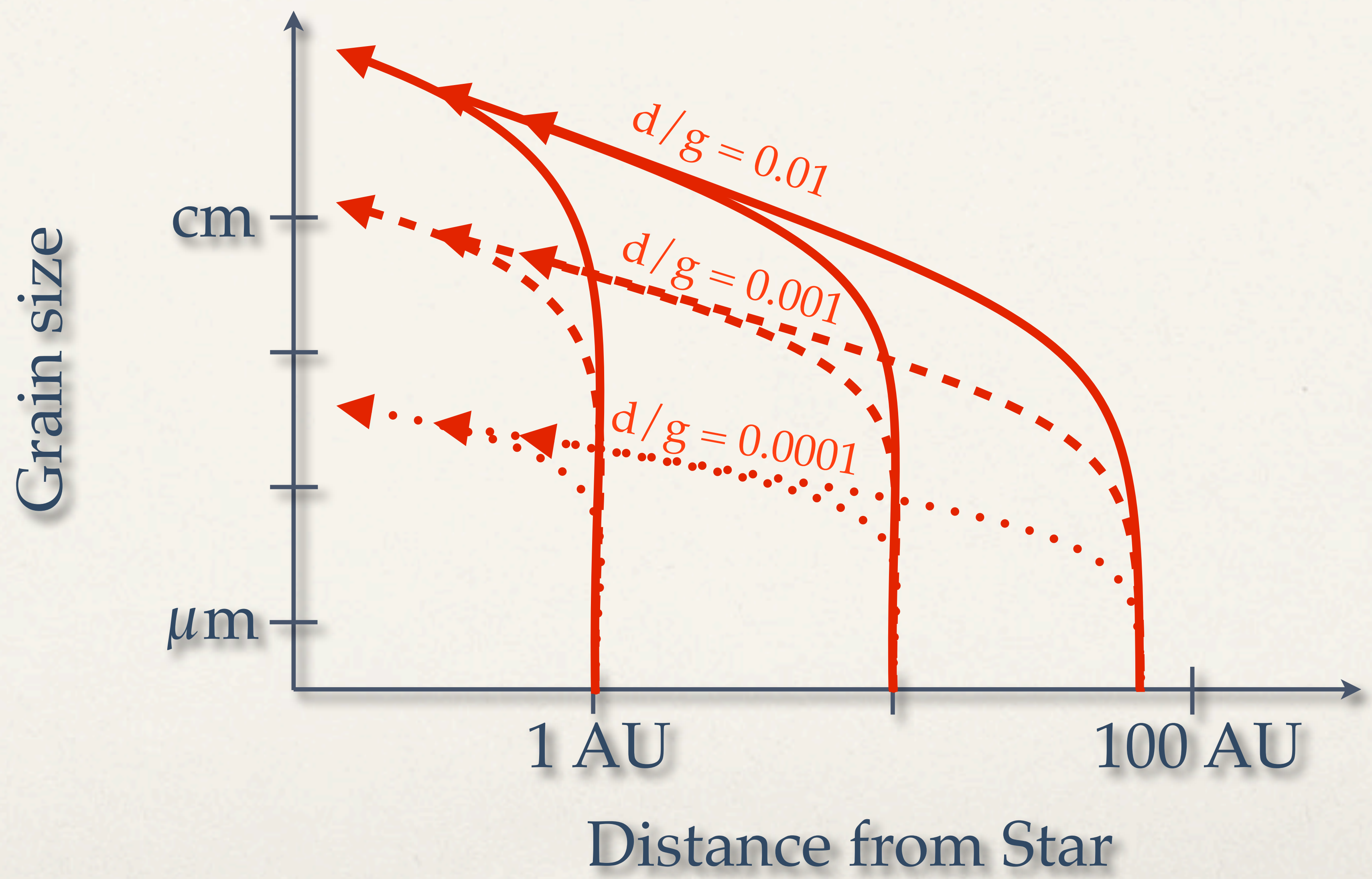


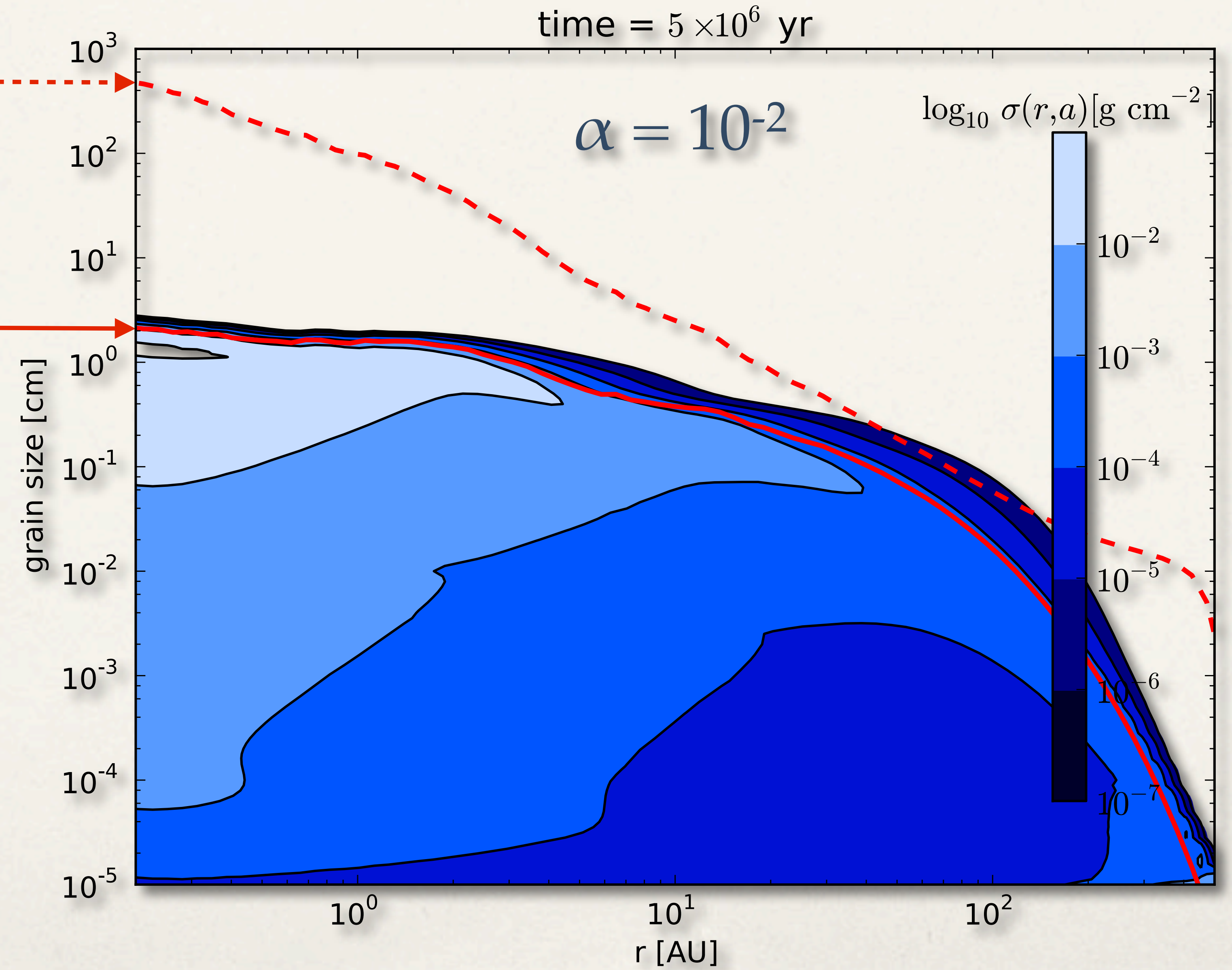
– Dust Evolution in a Nutshell –

- Rule 2: lower dust-to-gas ratio = slower growth



– Applying the Rules –

- fragmentation barrier (impact velocity too high)
- drift barrier (scales with Σ_{dust})



Birnstiel, Andrews, Ercolano 2012

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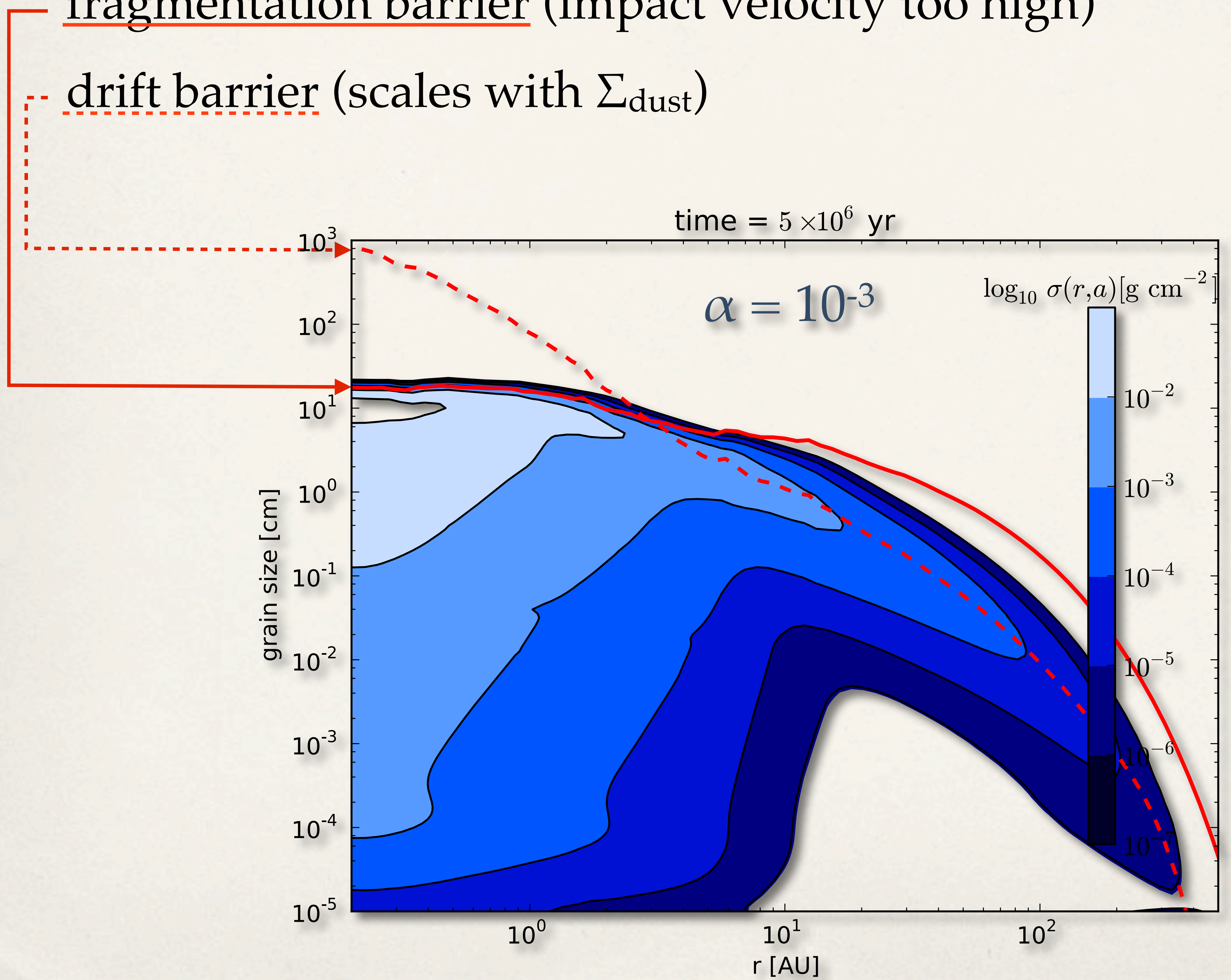

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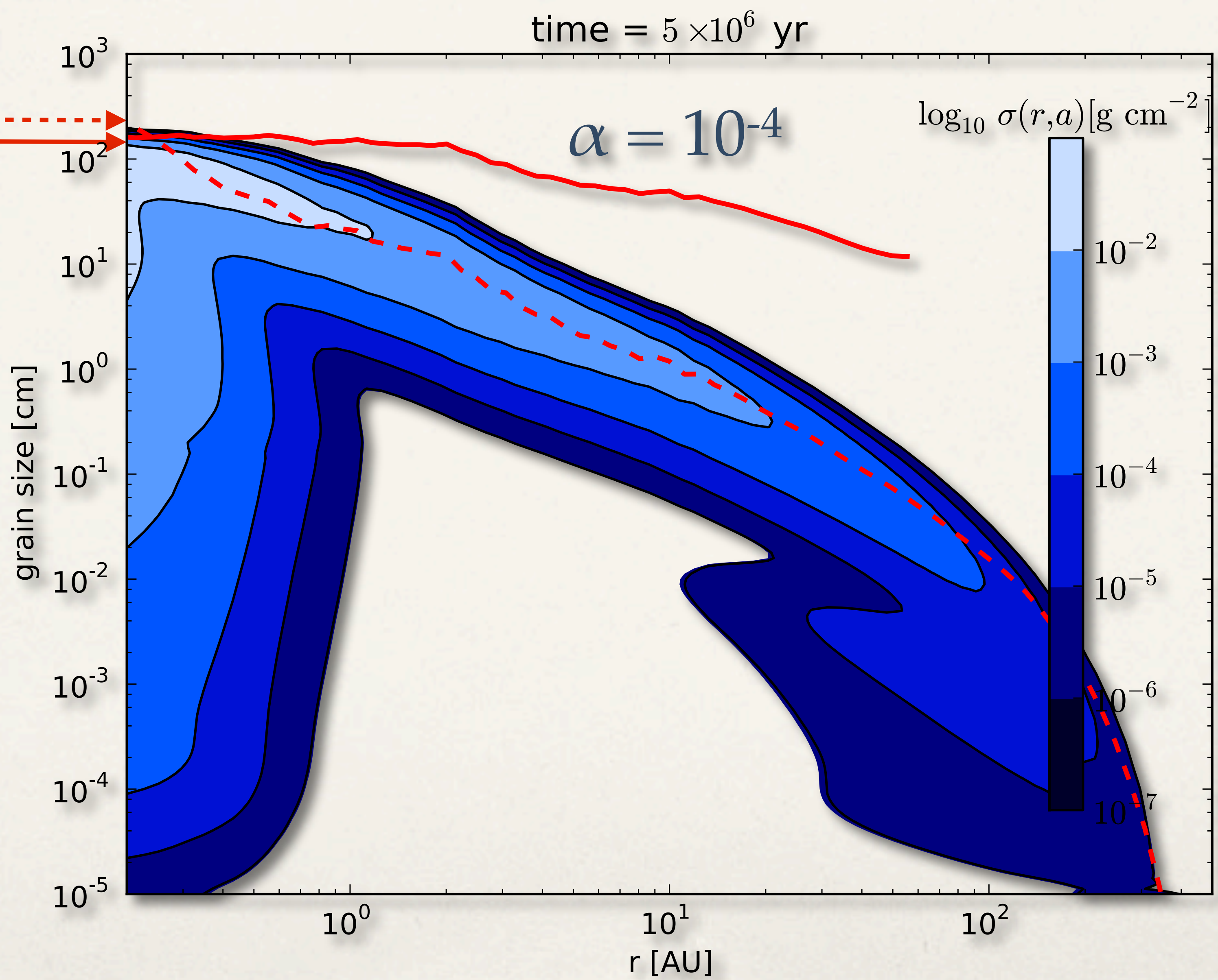

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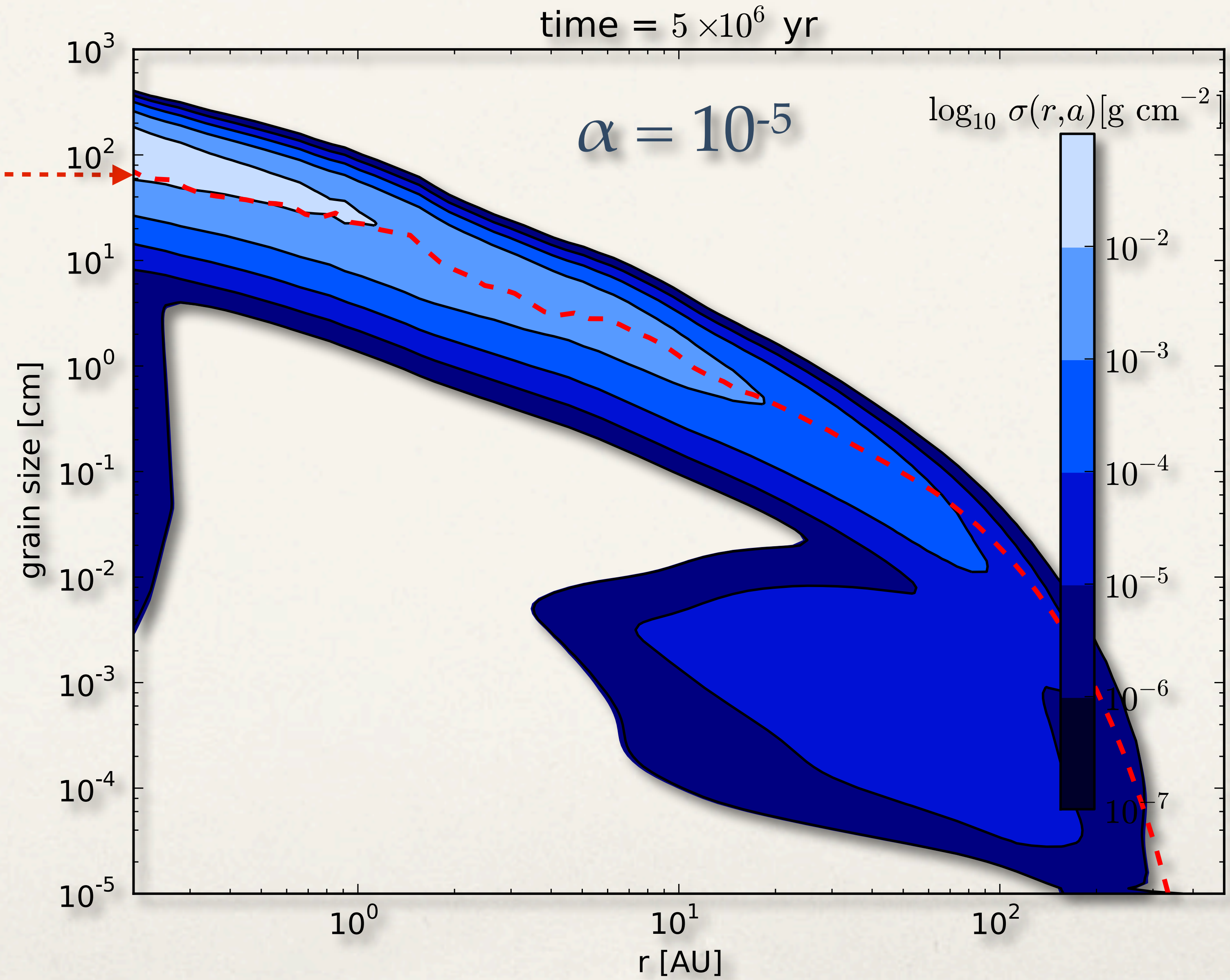

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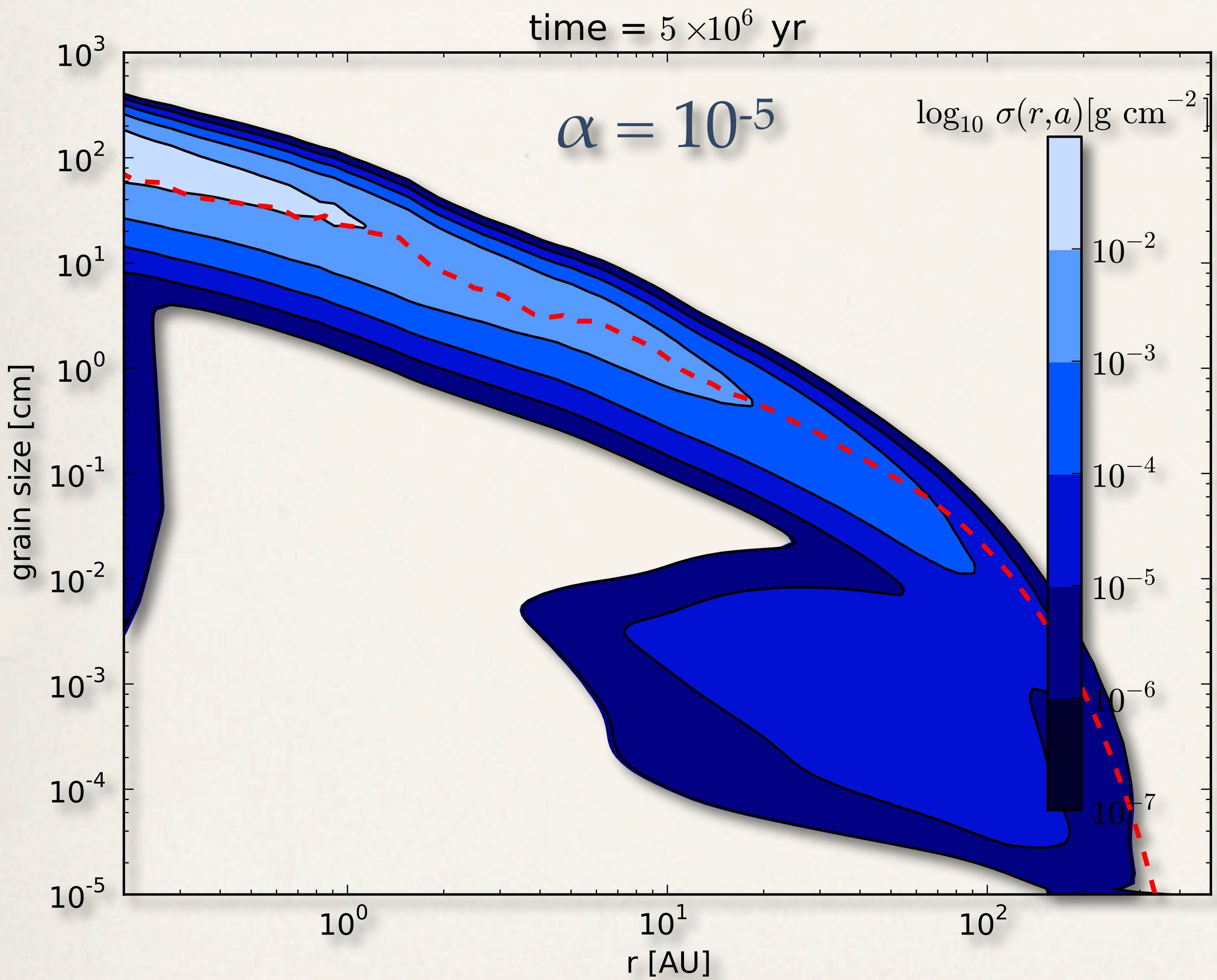
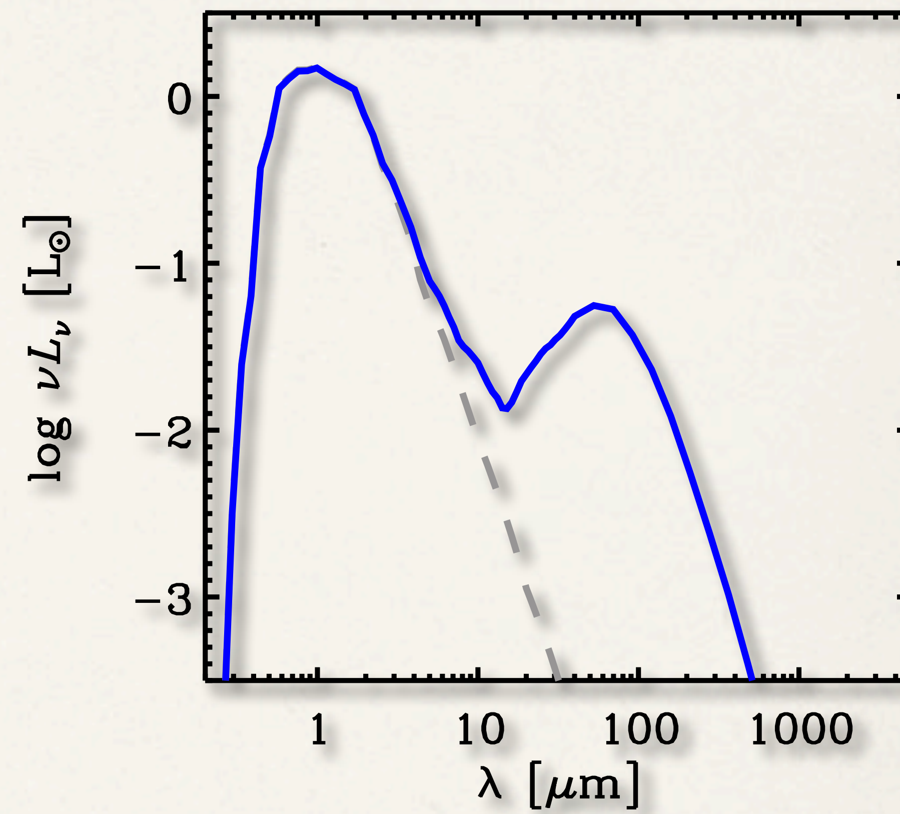
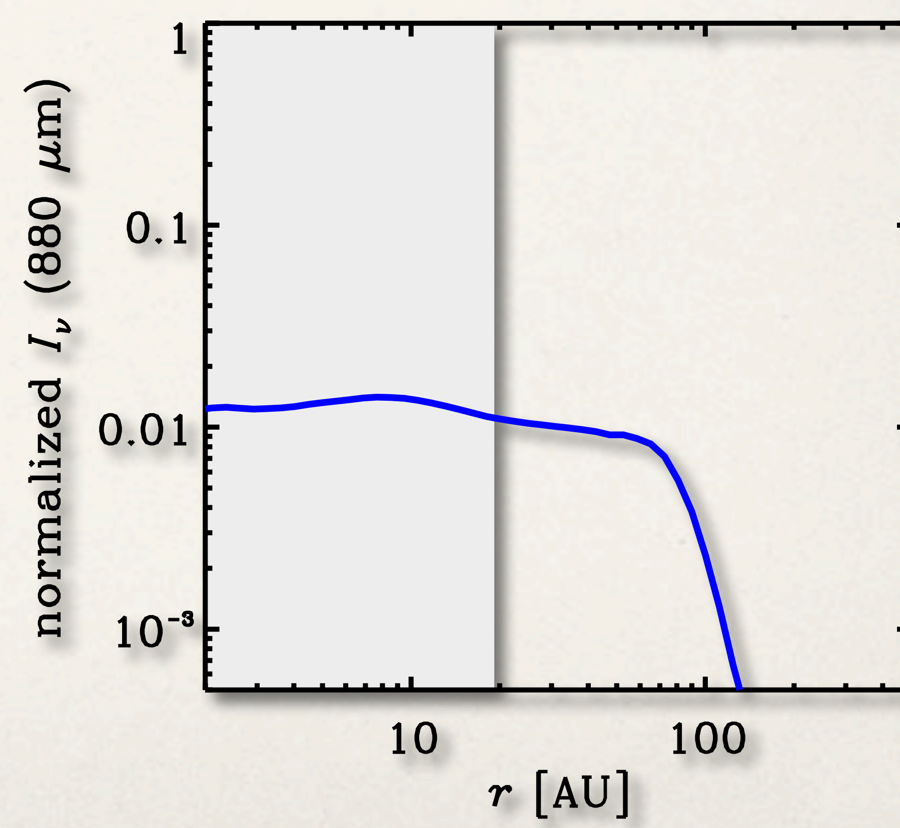


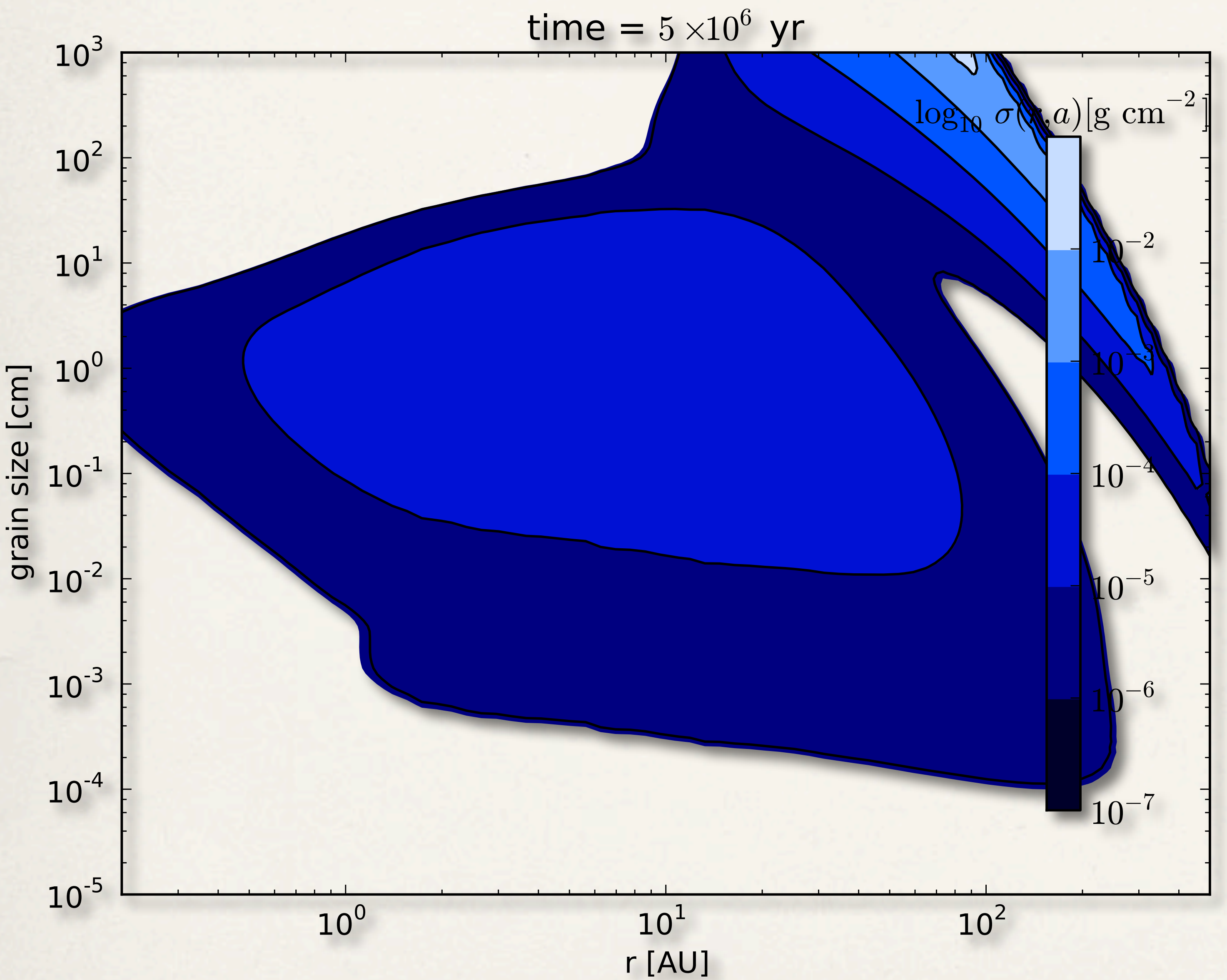


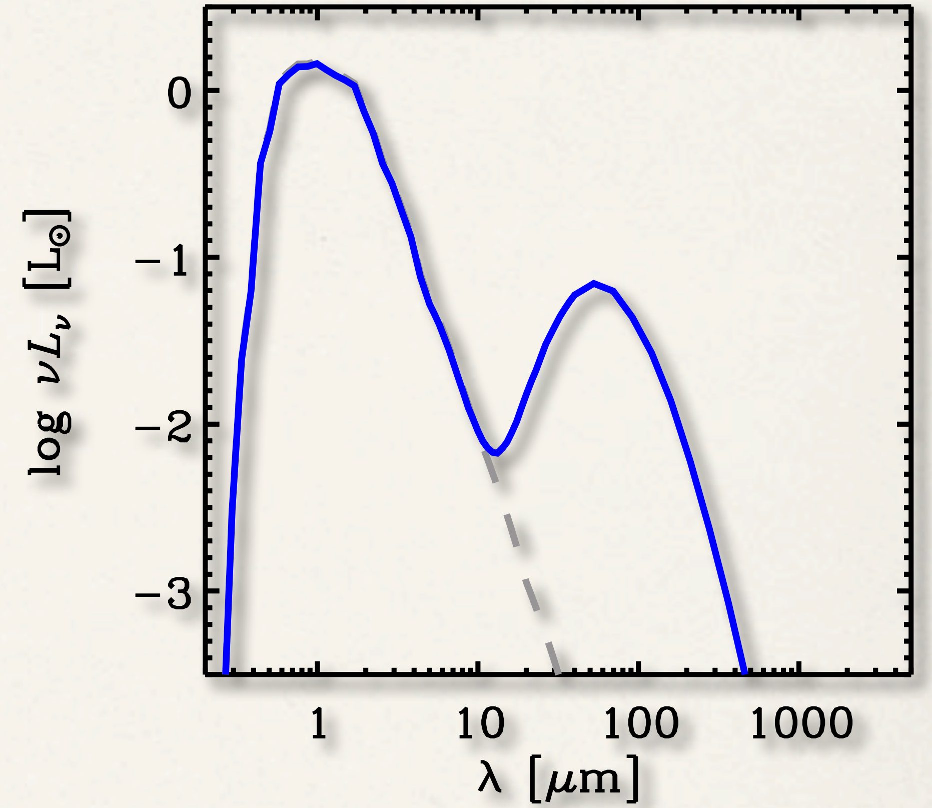


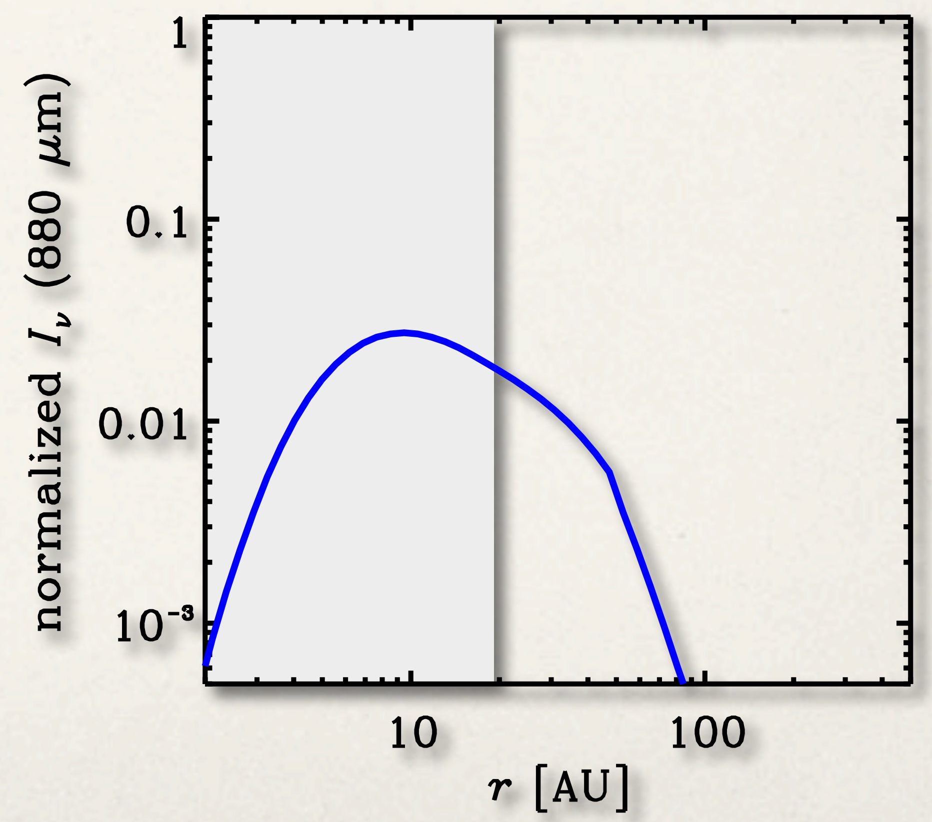
⇒ surface density profiles from first principles

Birnstiel, Klahr, & Ercolano 2012

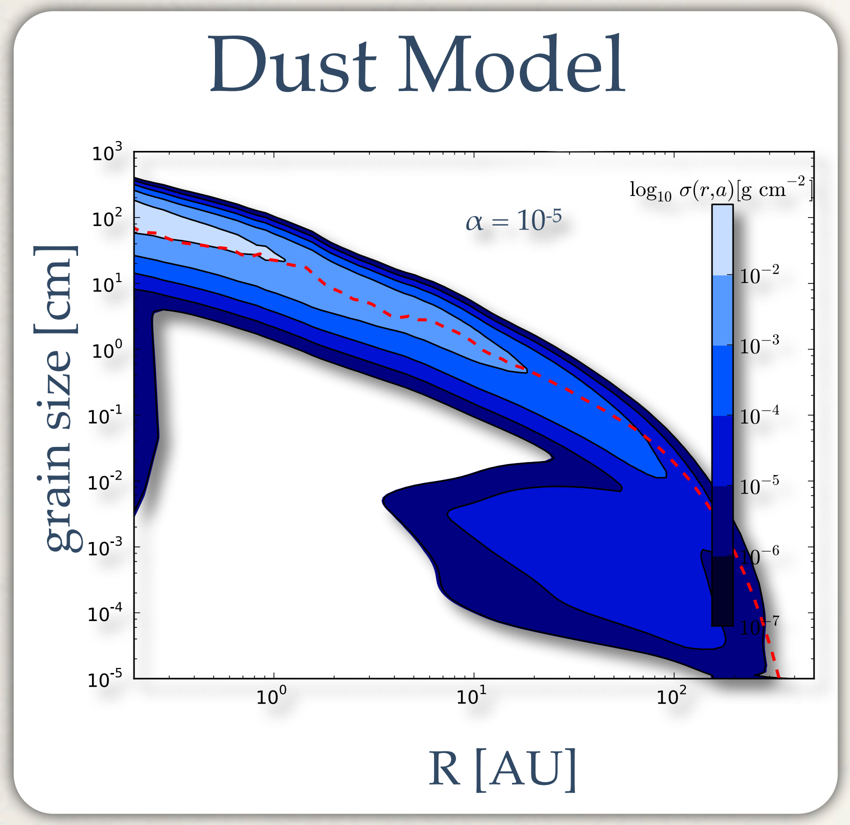
– No Drift, No Fragmentation –

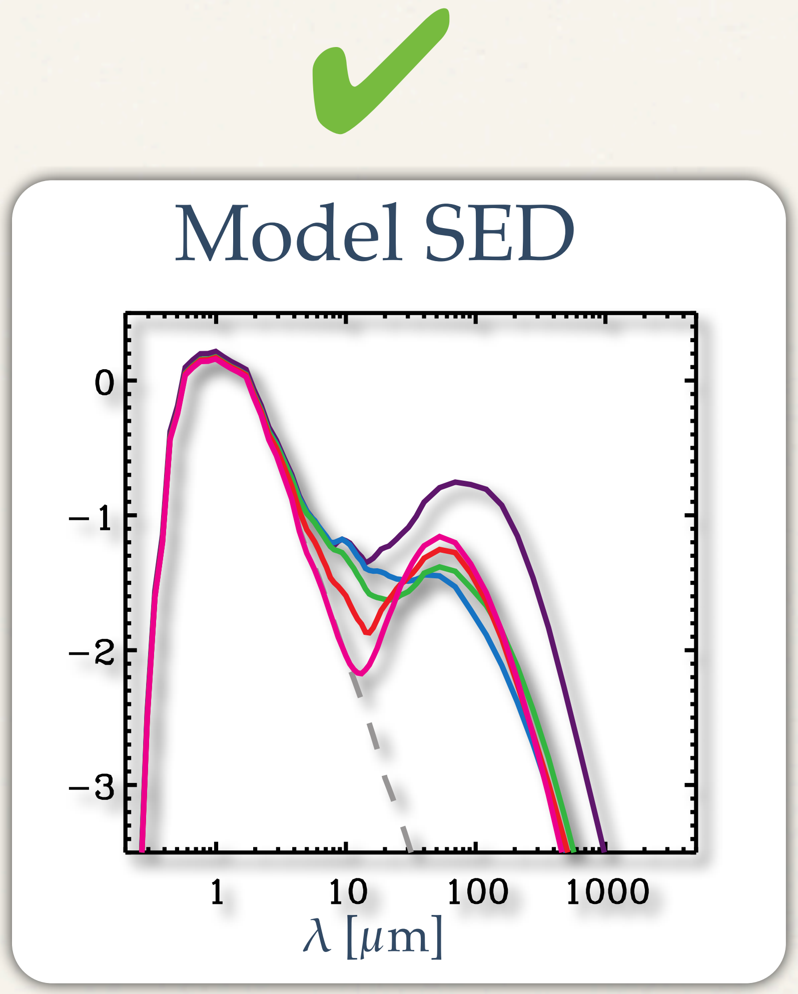


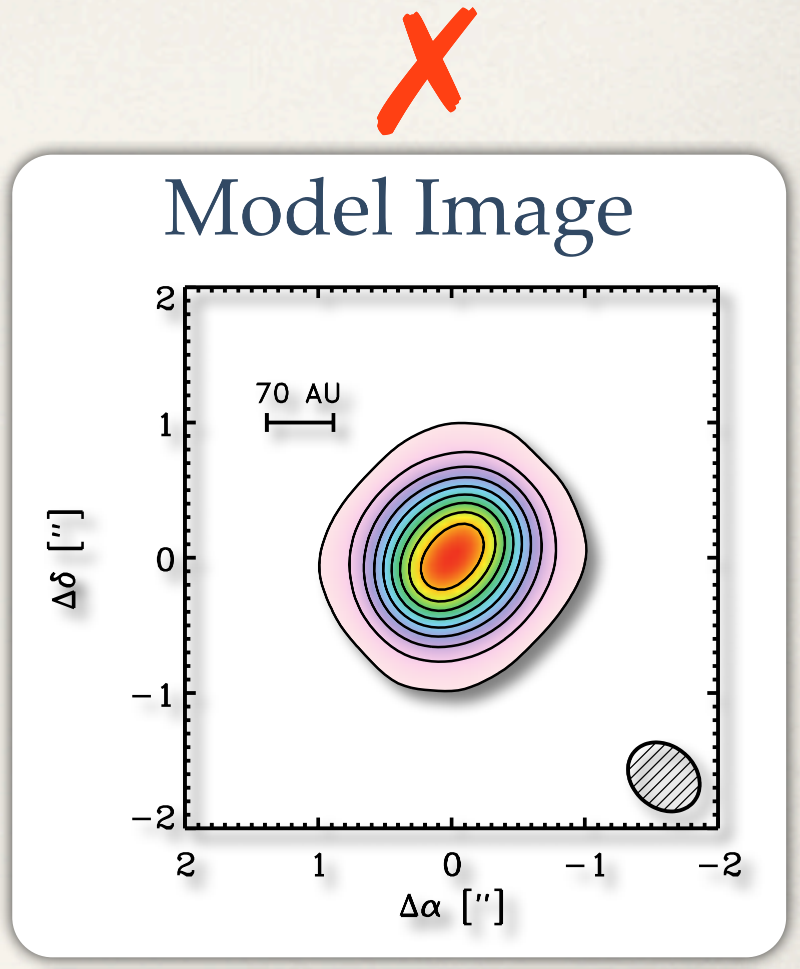


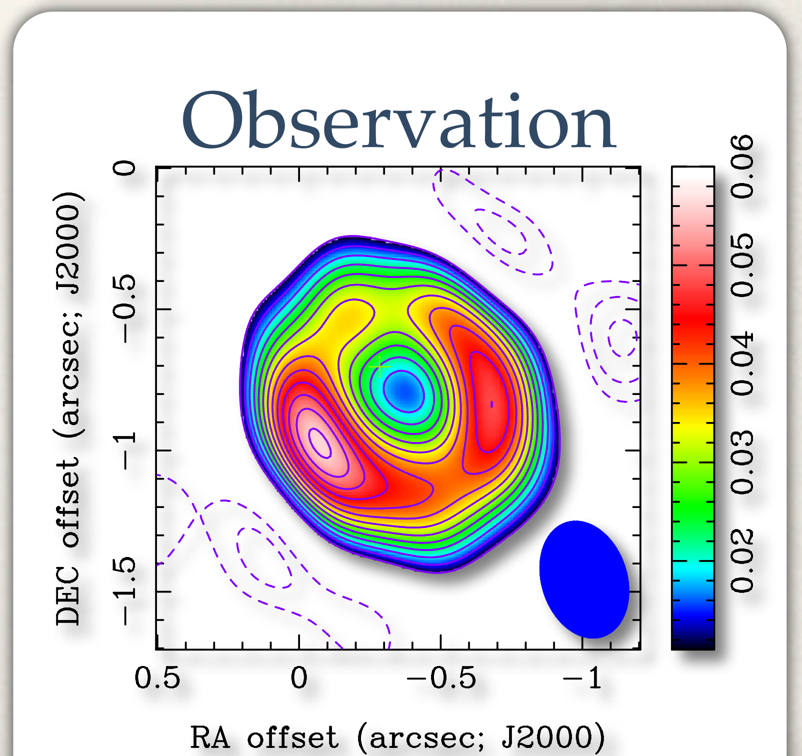


– Observations –







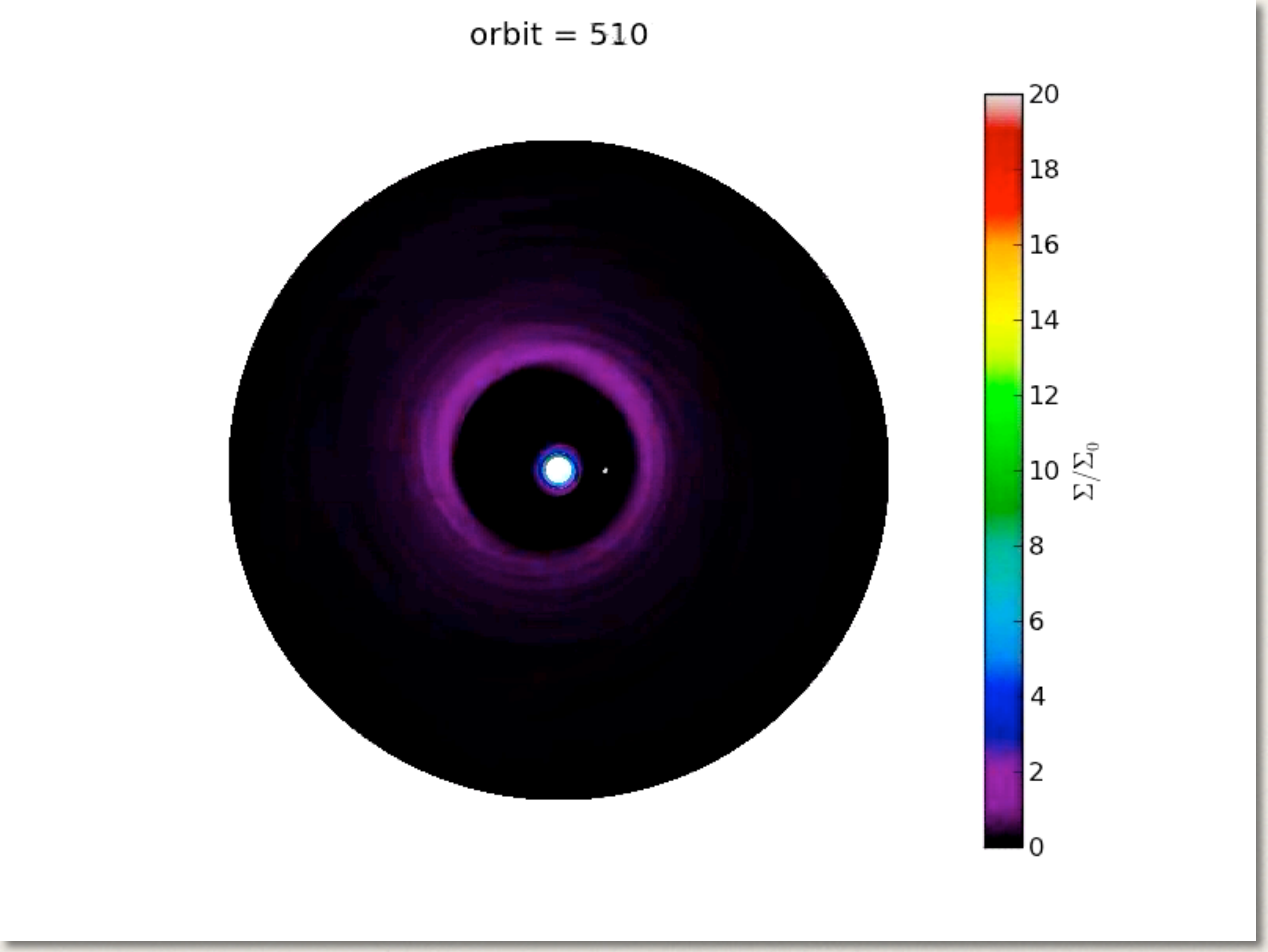


Brown et al. 2009

Birnstiel, Andrews, Ercolano 2012

– Planets & Instabilities –

– Planet in a Disk –



Pinilla, Birnstiel et al. 2012

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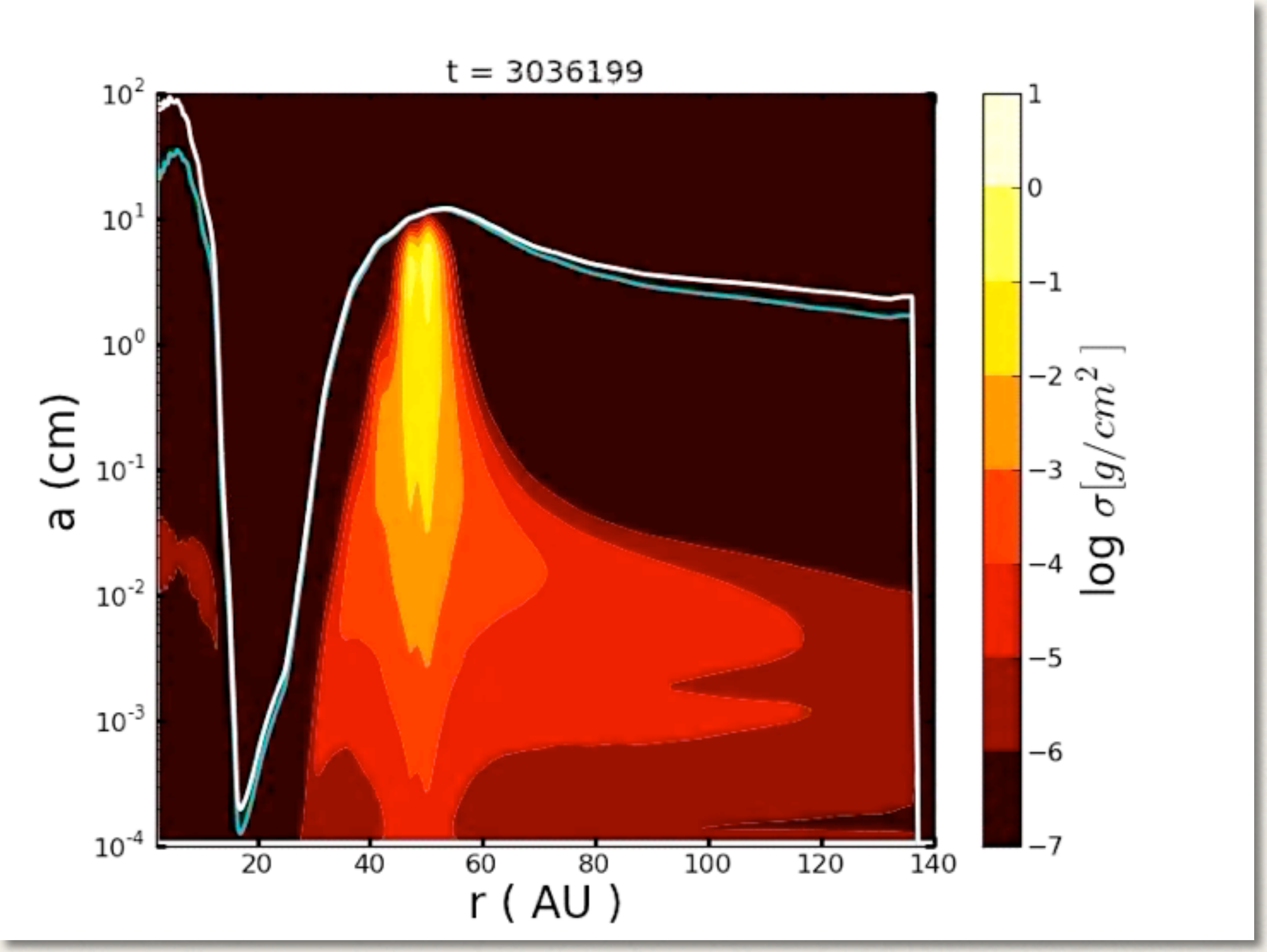

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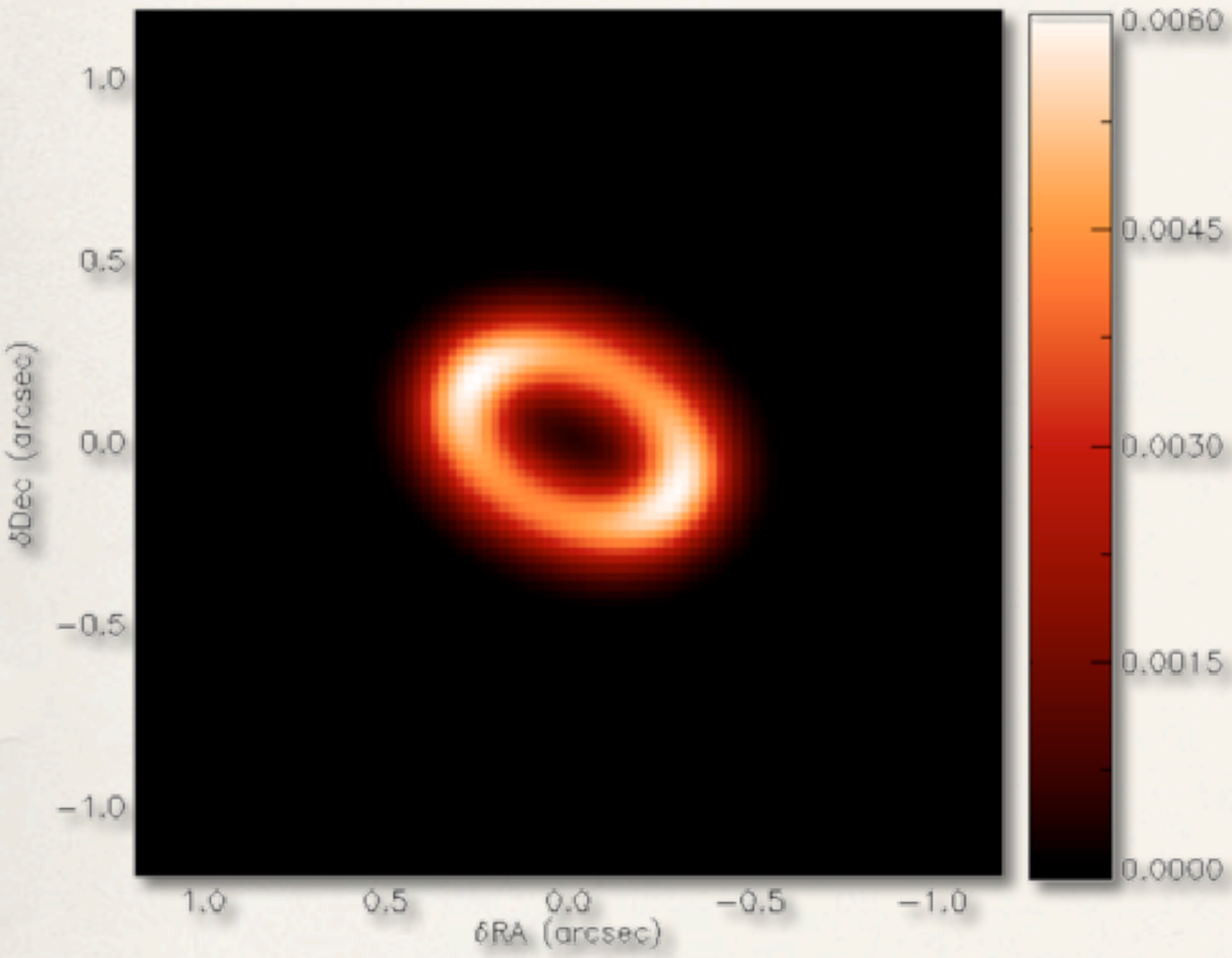
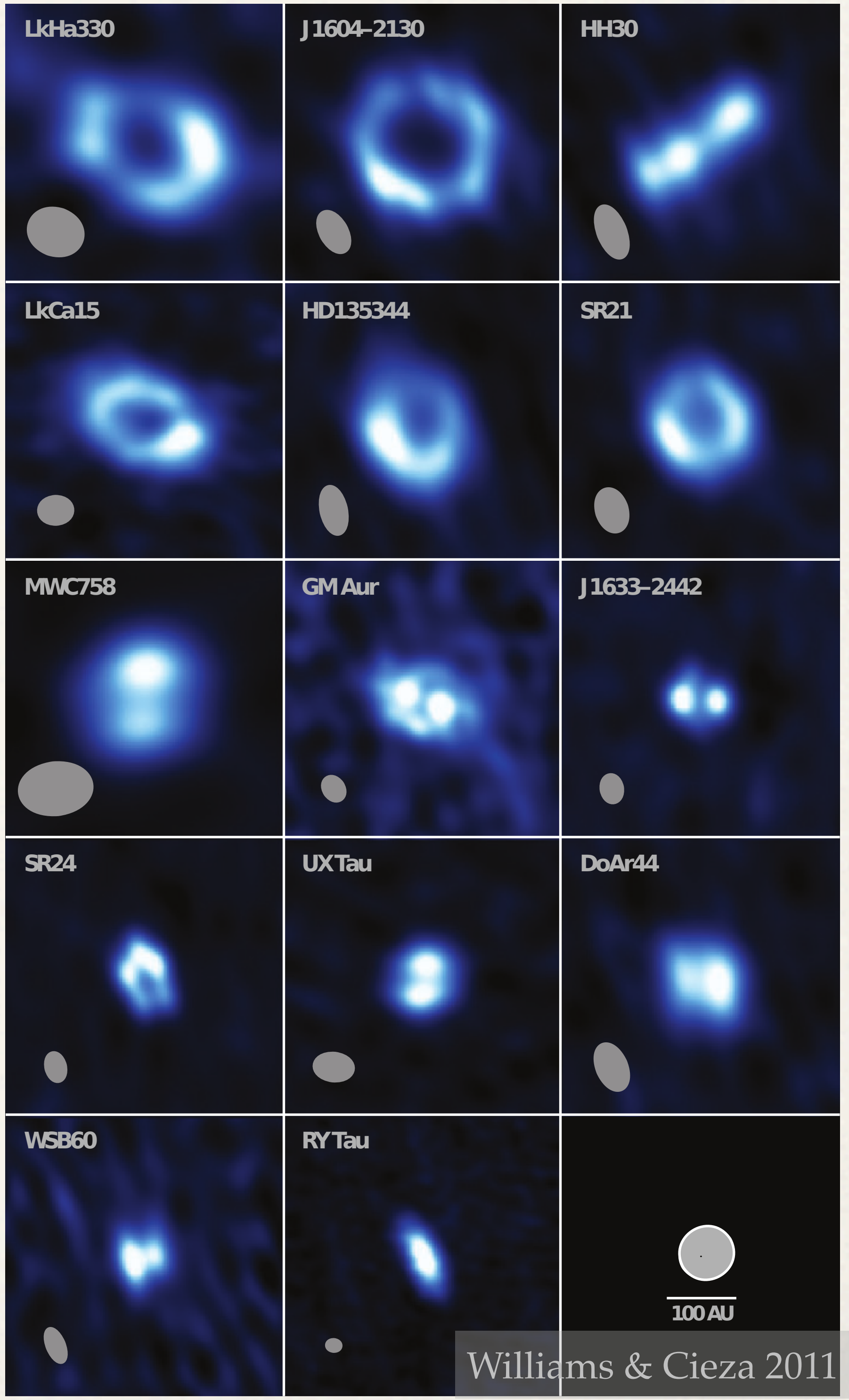
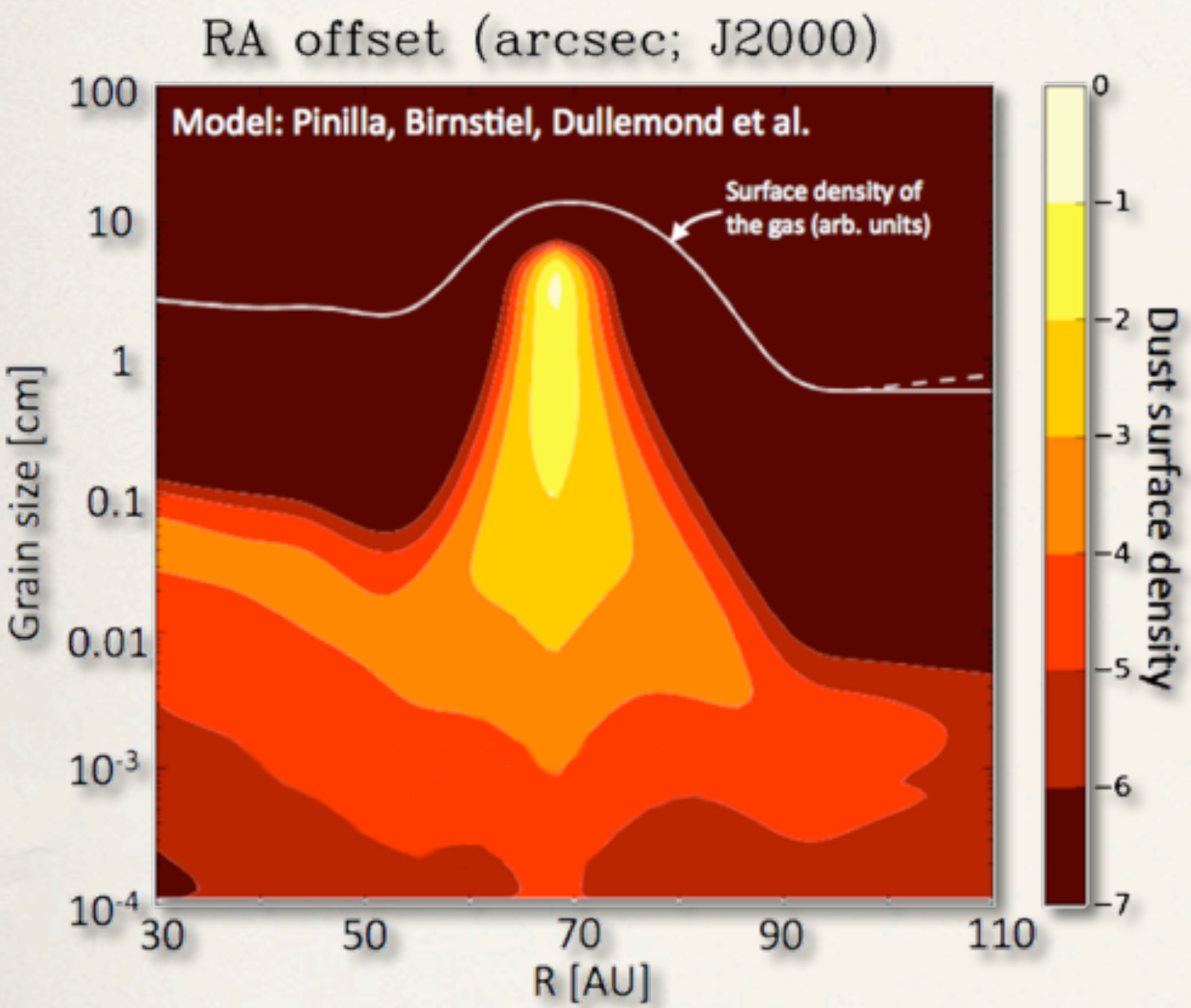
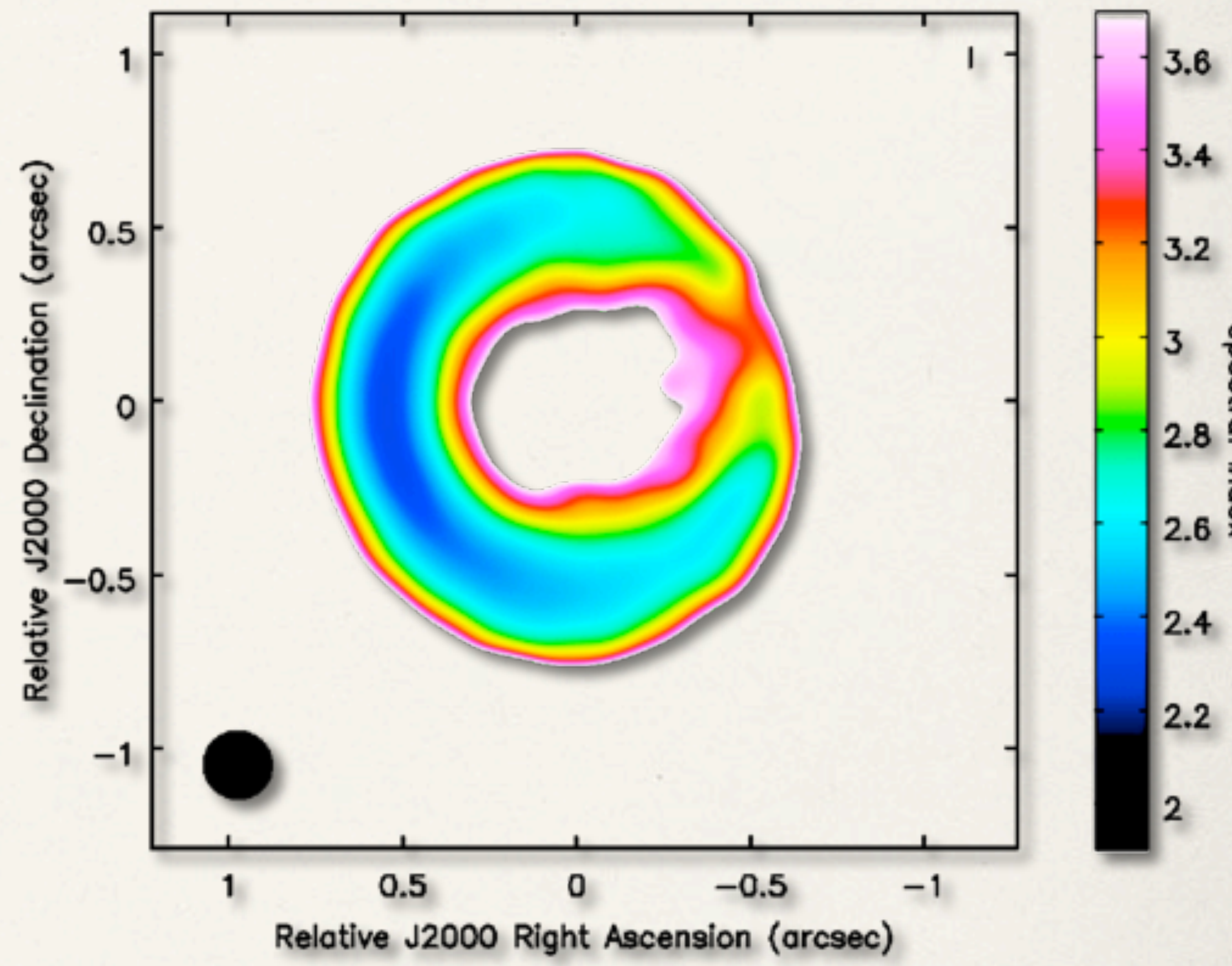




Pinilla, Birnstiel et al. 2012

– Rosby Wave Instability –





Birnstiel, Dullemond, Pinilla, in prep.
Gas profile from Regaly et al. 2012

Summary

- Photoevaporation
  - ✔ possibly explains small holes
  - ✗ high accretion rates
  - ✗ large cavities
- Grain Growth
  - ✔ high accretion rates
  - ✔ IR dips in SED
  - ✗ large cavities
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