The high-mass slope of the IMF at sub-solar metallicities

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Collaborators

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The Stellar Initial Mass Function

- Main features:
  - Characteristic mass scale at ~ 0.25 - 1 $M_\odot$
  - Power law slope above this scale, with index α = 1.35 (Salpeter, 1955)
  - Possible high mass cutoff at ~ 150 $M_\odot$
- Question: does the IMF vary with metallicity?
- There's little evidence for evolution down to metallicities ~ 0.01 $Z_\odot$ (Globular clusters). But what about at lower Z?

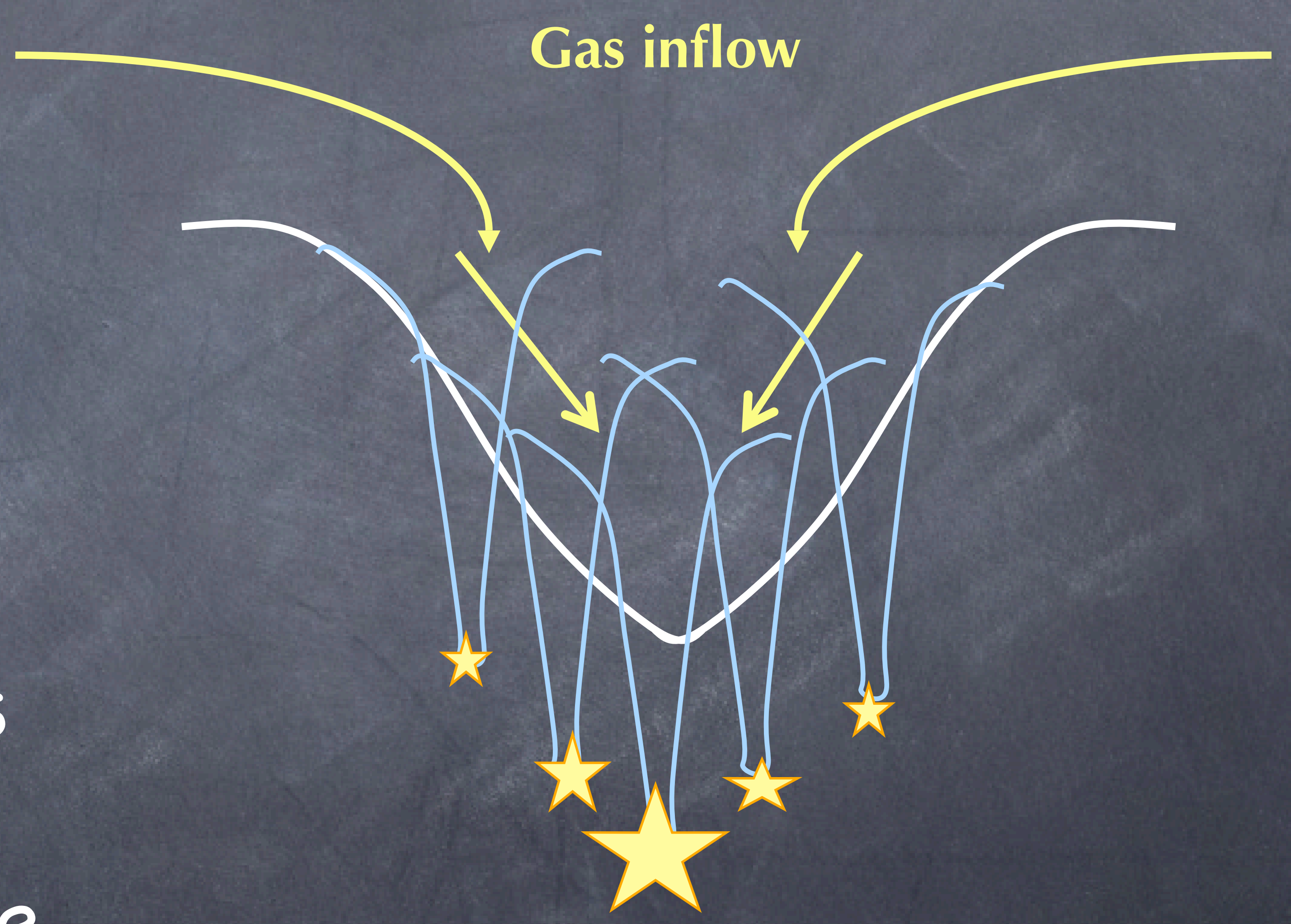
- If the gas cools quickly, then we can build up many Jeans masses of cold gas before any can collapse
- Many Jeans masses => many fragments
- Fragments compete for available gas mass, in a process called **competitive accretion**
- Larger fragments accrete faster: “the rich get richer”
- Resulting IMF has a power-law slope that is close to the Salpeter value

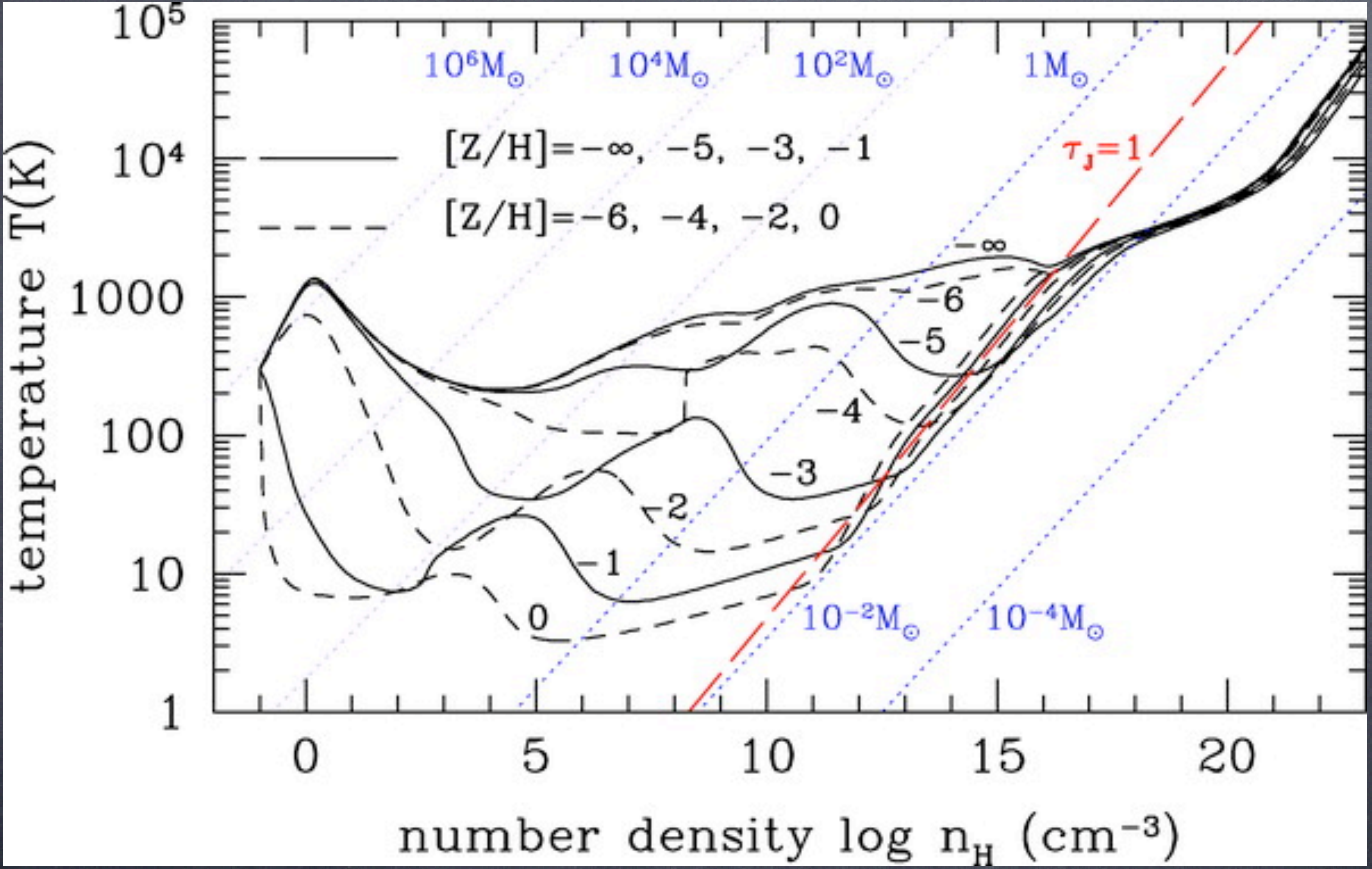
Requirements for competitive accretion

Bonnell & Bate (2006):

• Need a situation where gravity dominates the dynamics

• A collapsing, highly Jeans unstable region creates a situation where competitive accretion is **unavoidable**

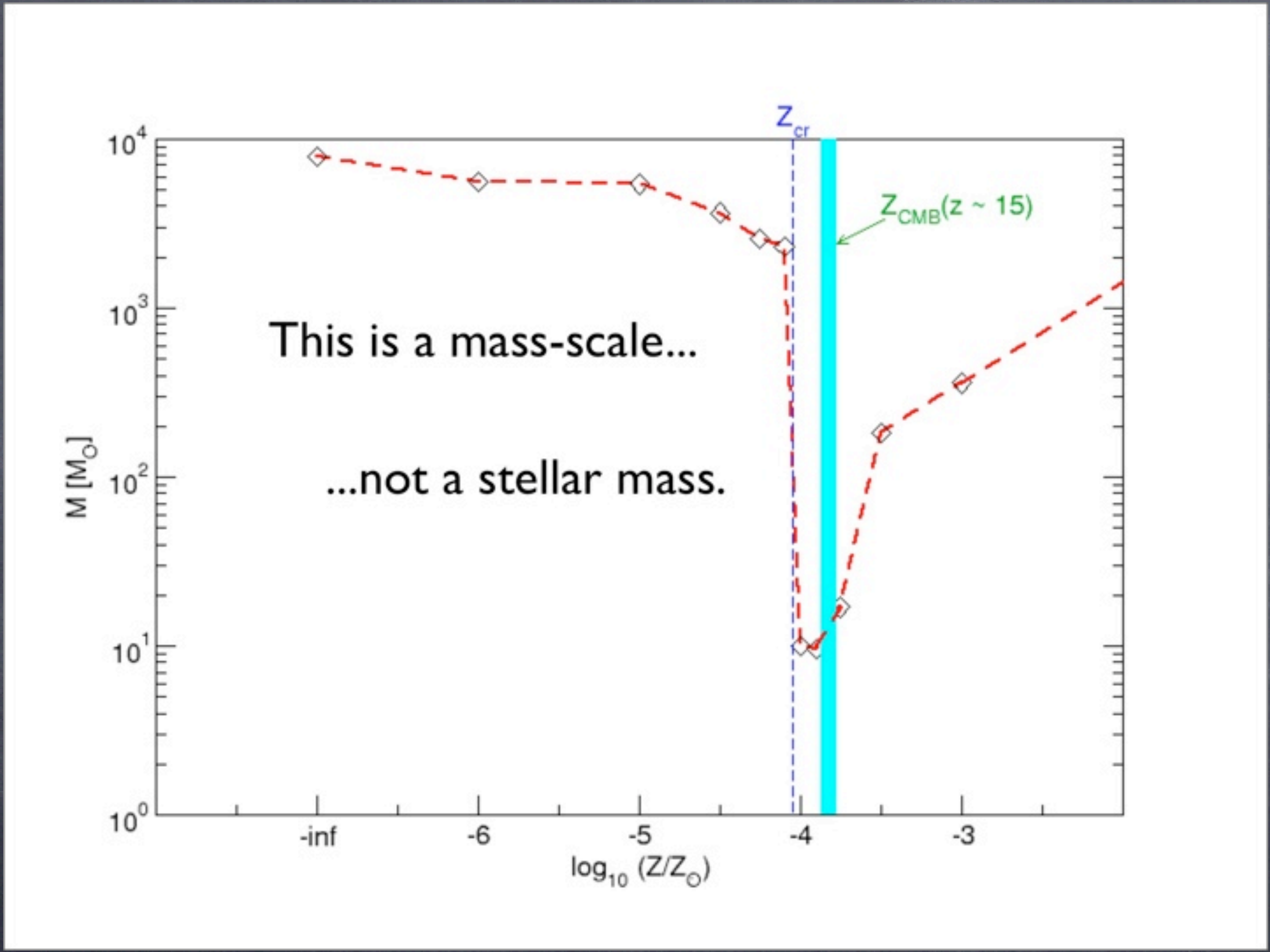




Omukai et al, 2005

- Two cooling regimes:
  - Low density, due to H_2, HD, C, O, [CO?]
  - High density, due to dust
- Both might give you fragmentation
- BUT: difficult to get low mass fragments in the low density regime

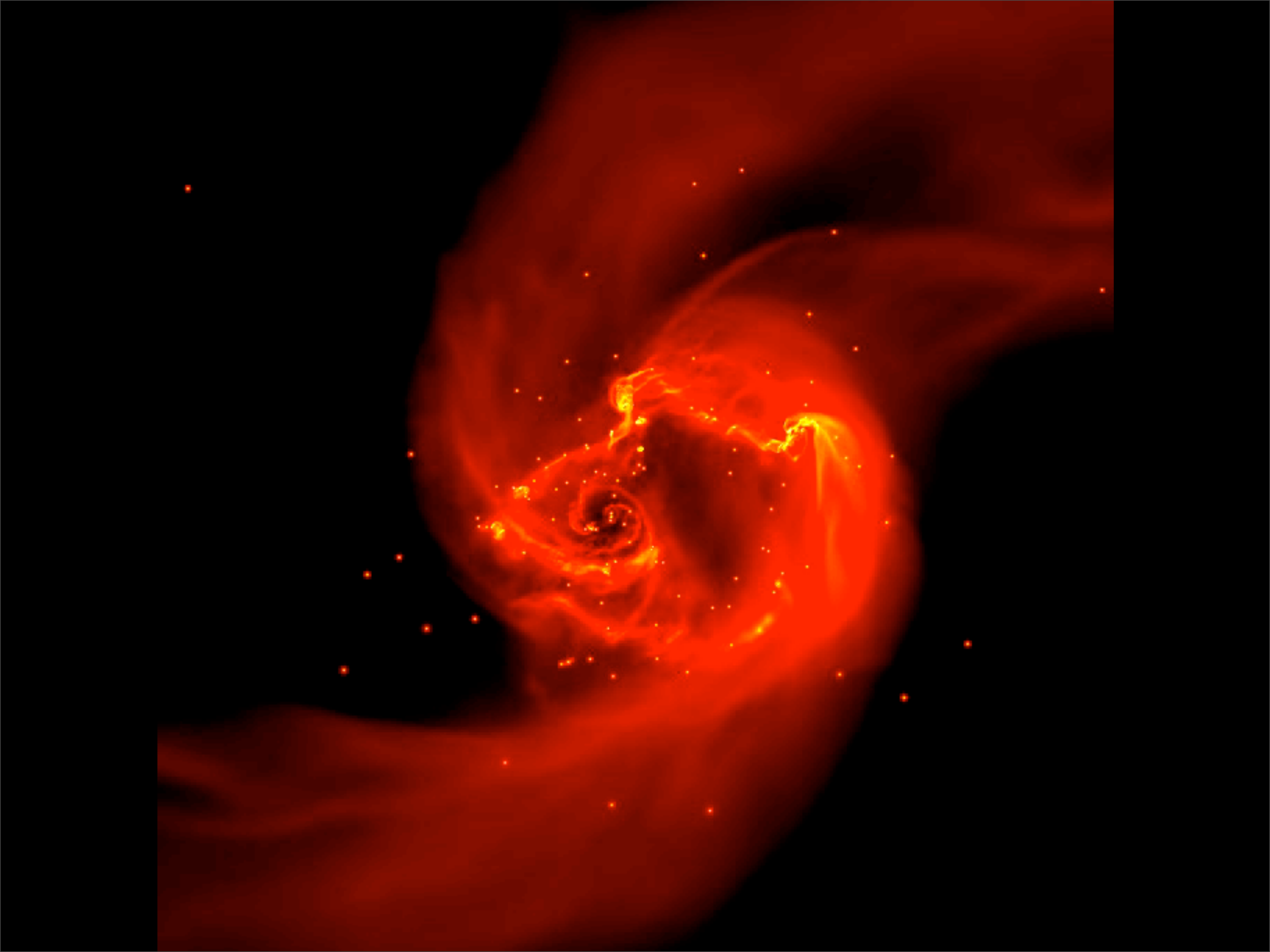
- CMB temperature floor: $T_{CMB} \sim 3\ (1 + z)$
- Once the gas reaches T_{CMB}, can't cool further, so no more fragmentation
- If cooling is too rapid, we reach T_{CMB} while still at low density => still large Jeans mass
- If cooling too slow, stay well above T_{CMB}, so again get large Jeans mass
- At high redshift, this gives us a fine-tuning problem; very limited range of metallicities that will give us low mass fragments

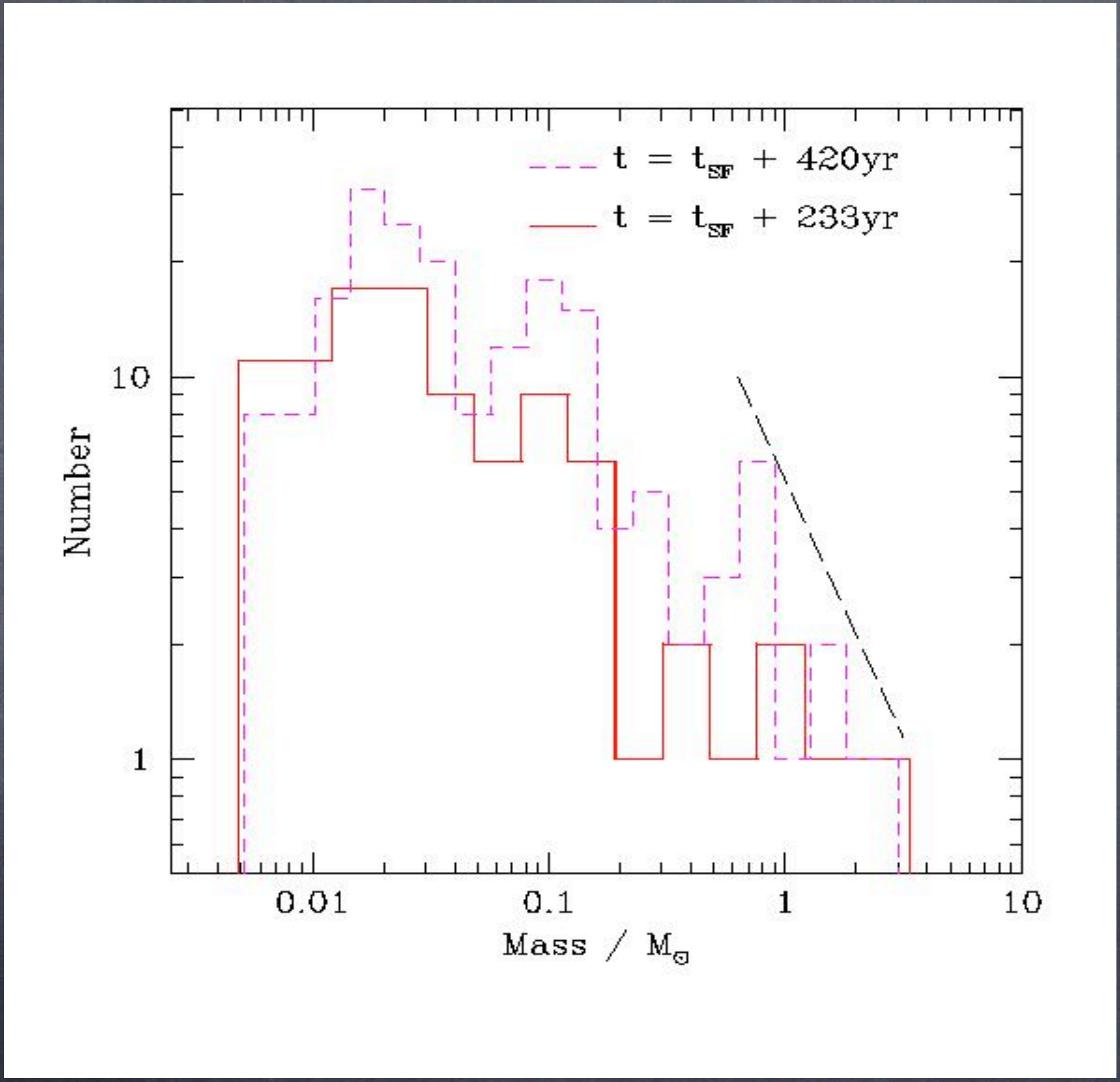


B. Smith, private communication

- Dust doesn’t have this problem
- Generally, once dust cooling becomes important, we cool to T_{dust}
- Typically, $T_{dust} > T_{CMB}$
- But cooling and fragmentation occur at much higher densities, so the Jeans mass stays low
- Sounds good, but does it actually work...?

- Clark, Glover & Klessen 2008:
  - Tabulated equation of state
  - Large particle number: $N = 2.5 \times 10^7$
  - Good mass resolution: $M_{res} = 0.002\ M_{sun}$
  - Sink particles
  - Small amount of initial rotation, turbulence

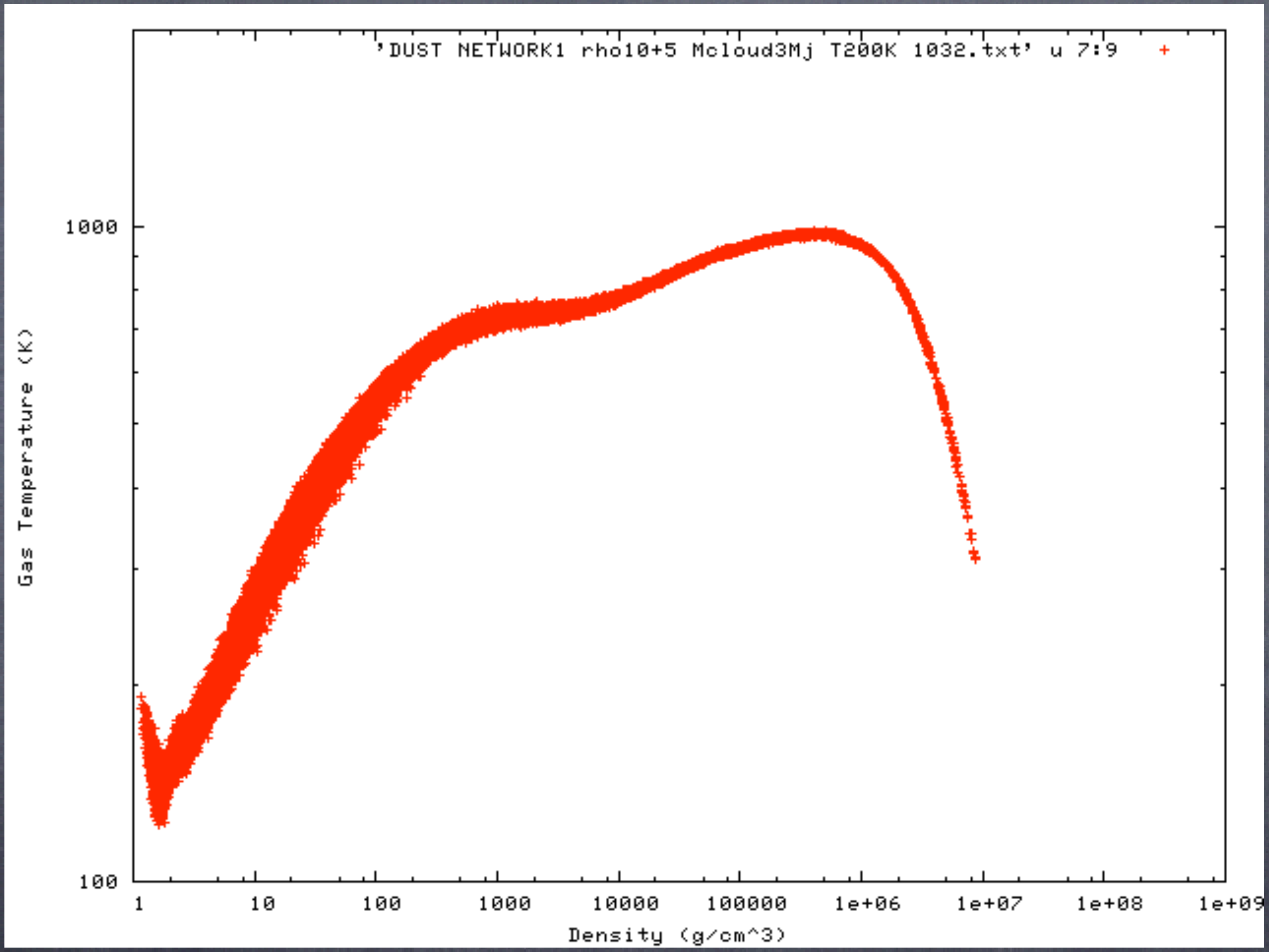




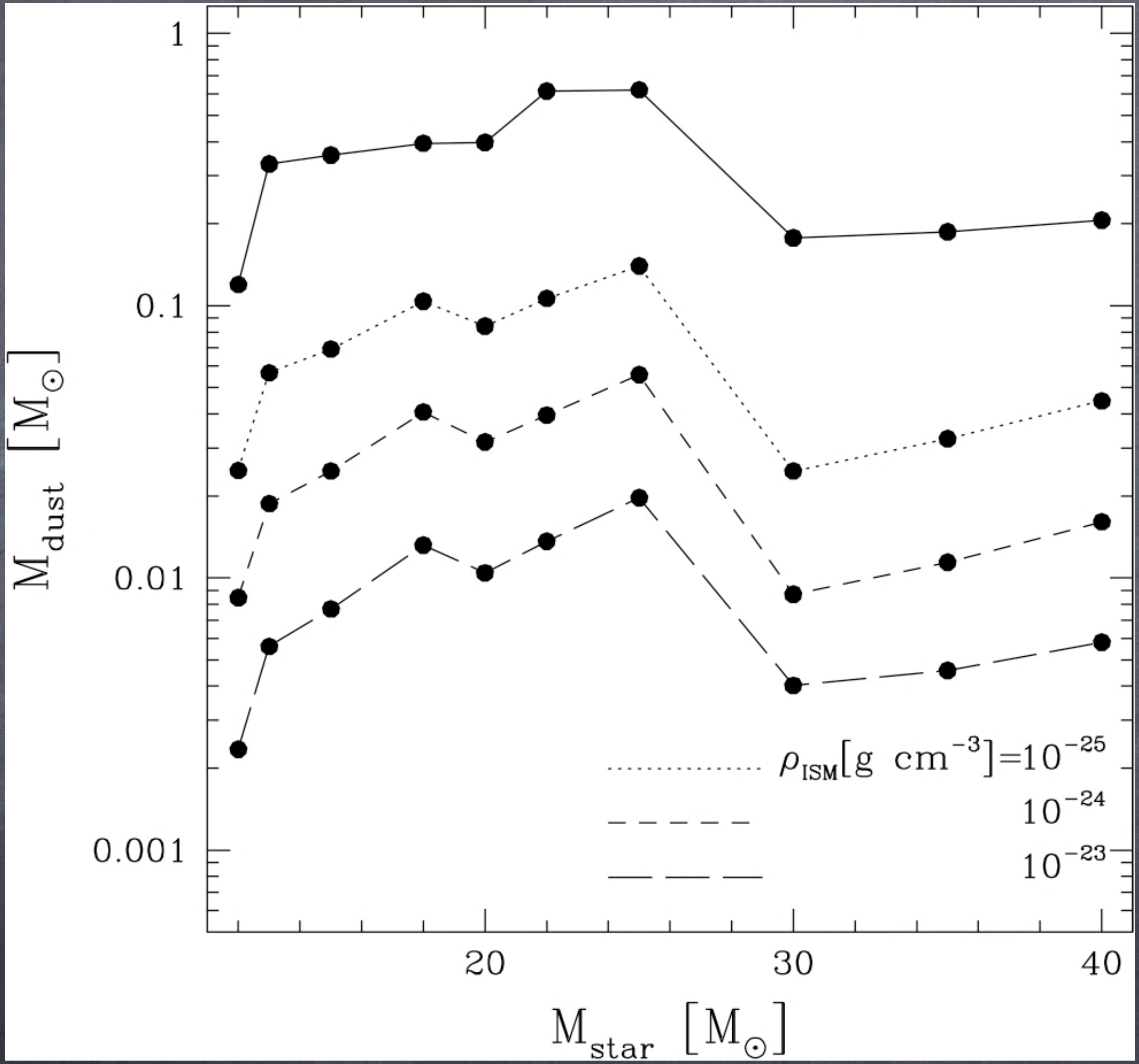
CGK08

Problems

- Are our simulations realistic?
- Do we have enough dust?
- Will radiative feedback suppress fragmentation?
- What about magnetic fields?
- Will collisions/mergers change the IMF?



Dopcke et al, unpublished



Bianchi & Schneider 2007

Conclusions

- Competitive accretion yields a power-law IMF even at very low metallicity, provided that gas can cool quickly enough
- Two cooling mechanisms => two fragmentation regimes; these may or may not coexist in practice
- CMB a big problem for producing low mass stars at high redshift by low density cooling

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- For details, see:

  http://www.ita.uni-heidelberg.de/research/klessen/positions/postdoc.shtml
- Closing date: **November 15th, 2009**