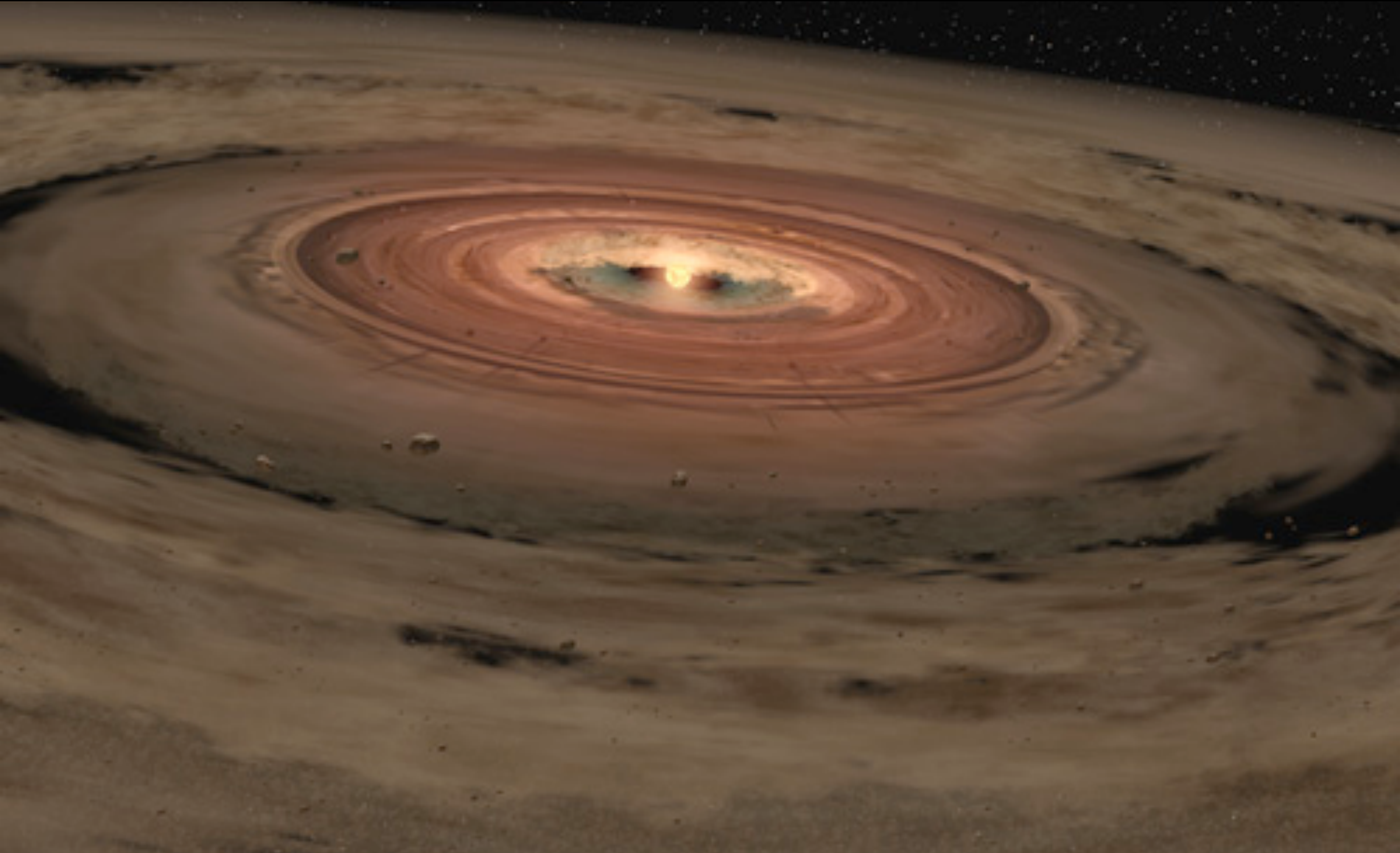
Astrophysics of Planet Formation

Lecture 4 - Terrestrial & giant planet formation



Course Outline

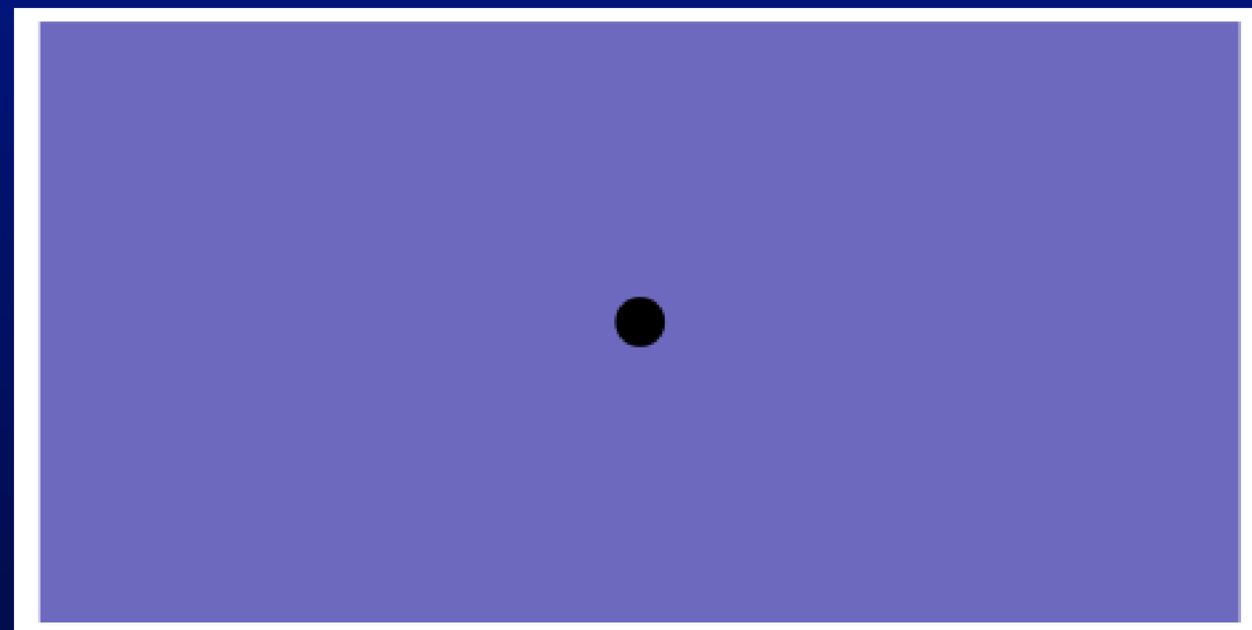
- 5 Lectures, 2 hours each (with a break in the middle!).
    1) Observations of planetary systems
    2) Protoplanetary discs
    3) Dust dynamics & planetesimal formation
    4) Planet formation
    5) Planetary dynamics
- Notes for each lecture will be placed on the course home page *in advance* - you may find it useful to annotate these as we go.
- These slides will also be posted online.
- Textbooks: Armitage - *Astrophysics of planet formation* (CUP).

  Protostars & Planets series (*V* - 2007; *VI* - 2014)

Course home-page: www.astro.le.ac.uk/~rda5/planets_2022.html

Core accretion

Figures from Armitage (2007)



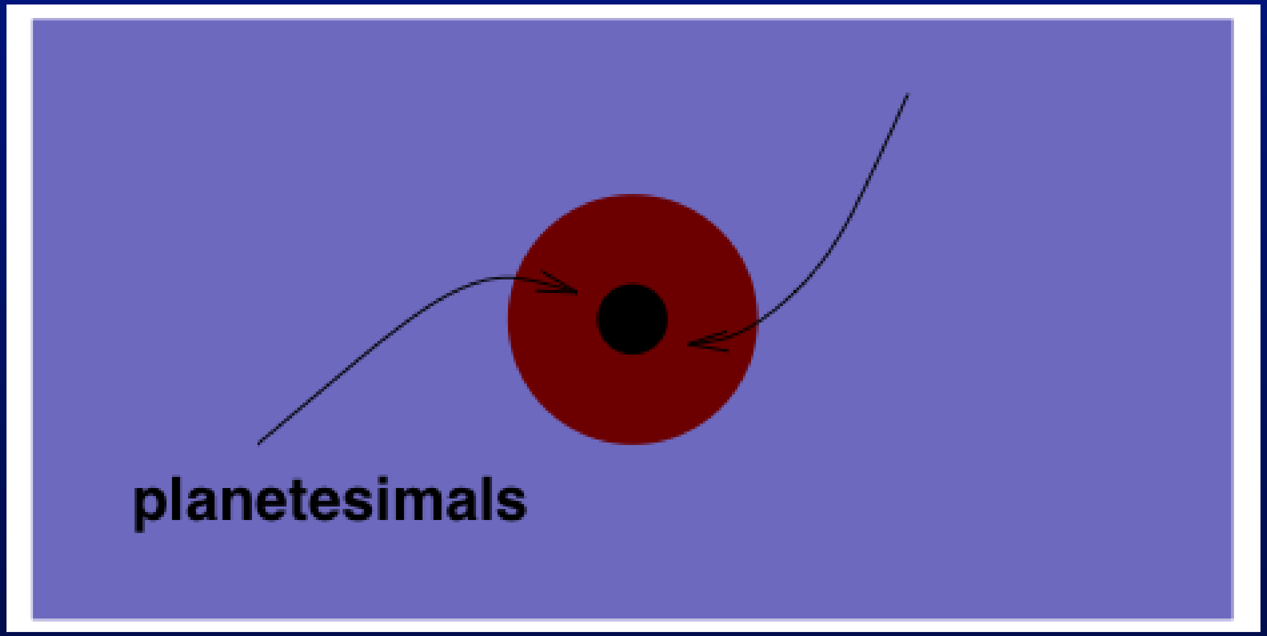
Stage I:

Formation of planetary core via collisional (runaway) growth of planetesimals.

Proceeds until core becomes massive enough to accrete gas. This happens when $v_{\rm esc} \gtrsim c_{\rm s}$.

Core accretion

Figures from Armitage (2007)



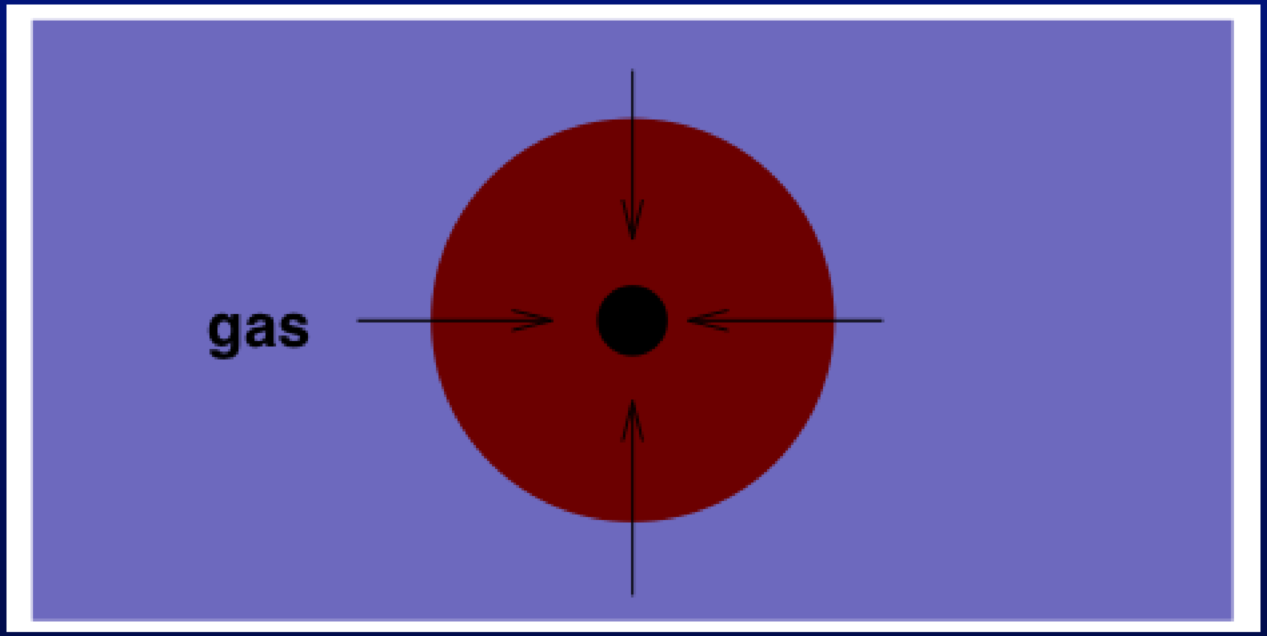
Stage II:

Concurrent accretion of gas and dust from disc.

Gas accretion is "hydrostatic" and slow, limited by the ability of the envelope to radiate away energy. The slowly increasing mass increases the size of the feeding zone and allows additional accretion of planetesimals.

Core accretion

Figures from Armitage (2007)

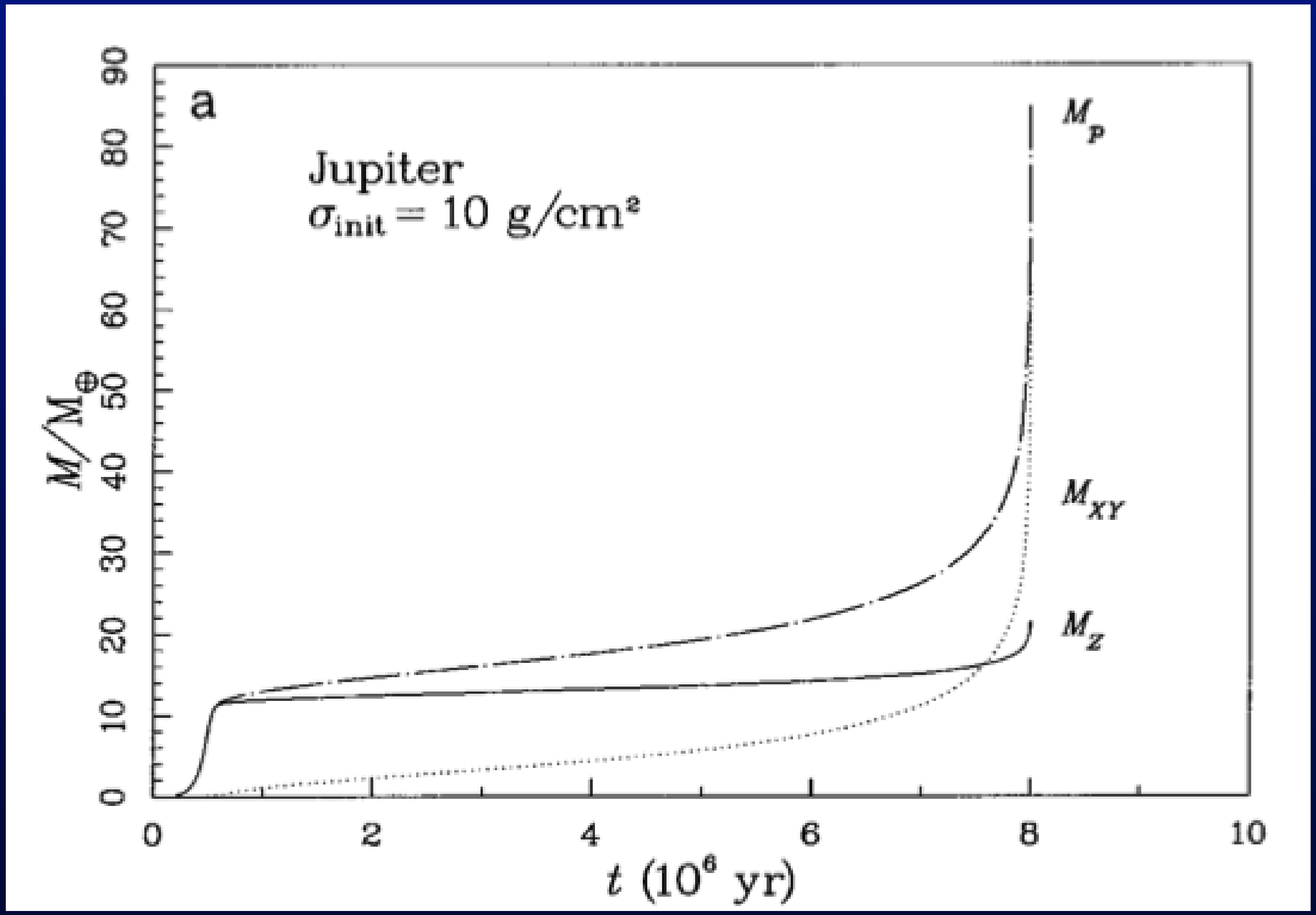


Stage III:

Runaway accretion of gas.

Once the envelope is sufficiently massive accretion is no longer "demand-limited" and the planet accretes rapidly. This phase starts when $M_{\rm env} \gtrsim M_{\rm core}$, and proceeds until the gas supply is exhausted.

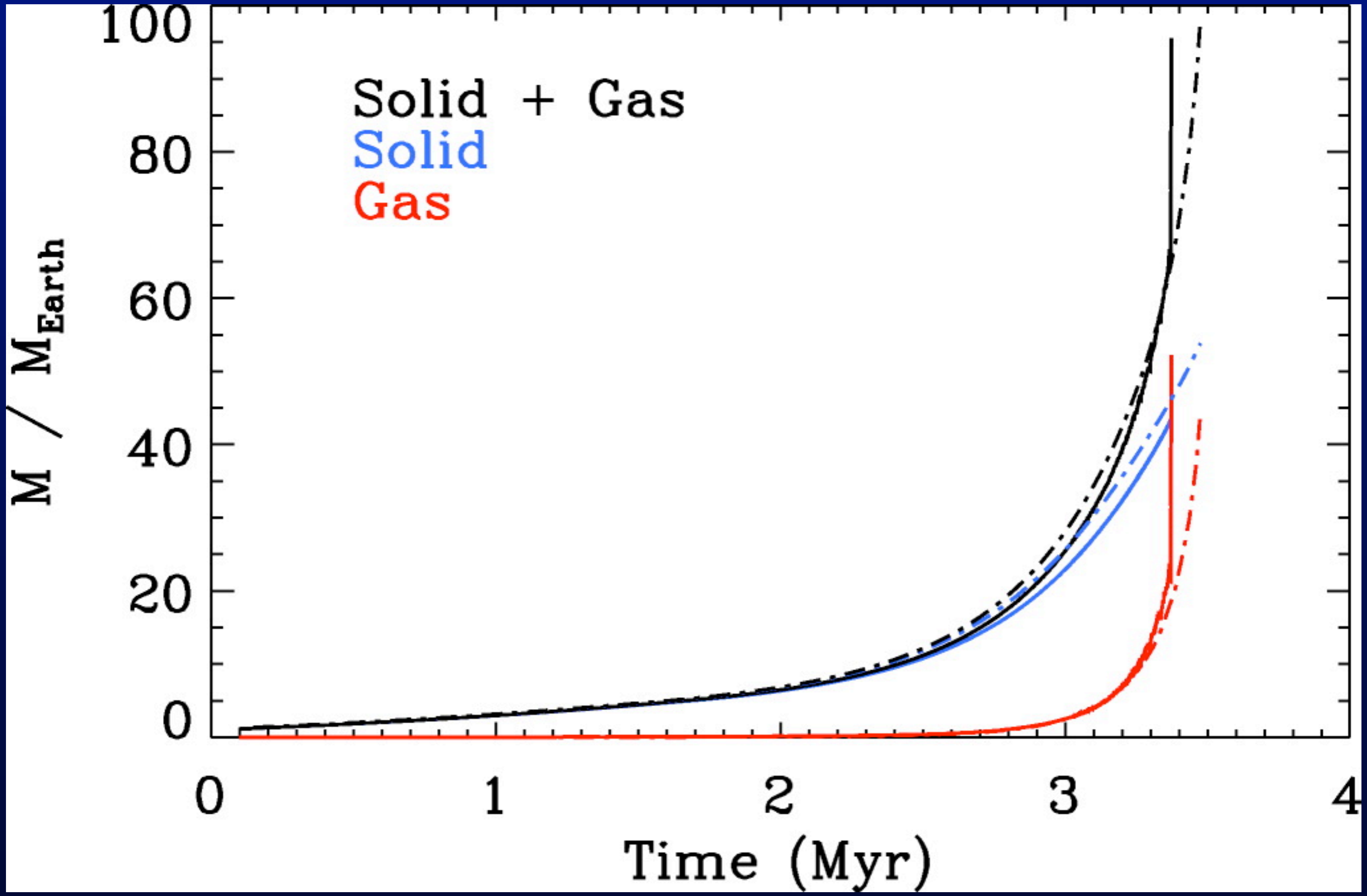
Core accretion



Pollack et al. (1996)

- Major technical uncertainty is the opacity, which determines the duration of the hydrostatic phase.
- Core accretion time-scale is uncomfortably long: approximately the lifetime of a typical disc.

Core accretion



Dodson-Robinson et al. (2008)

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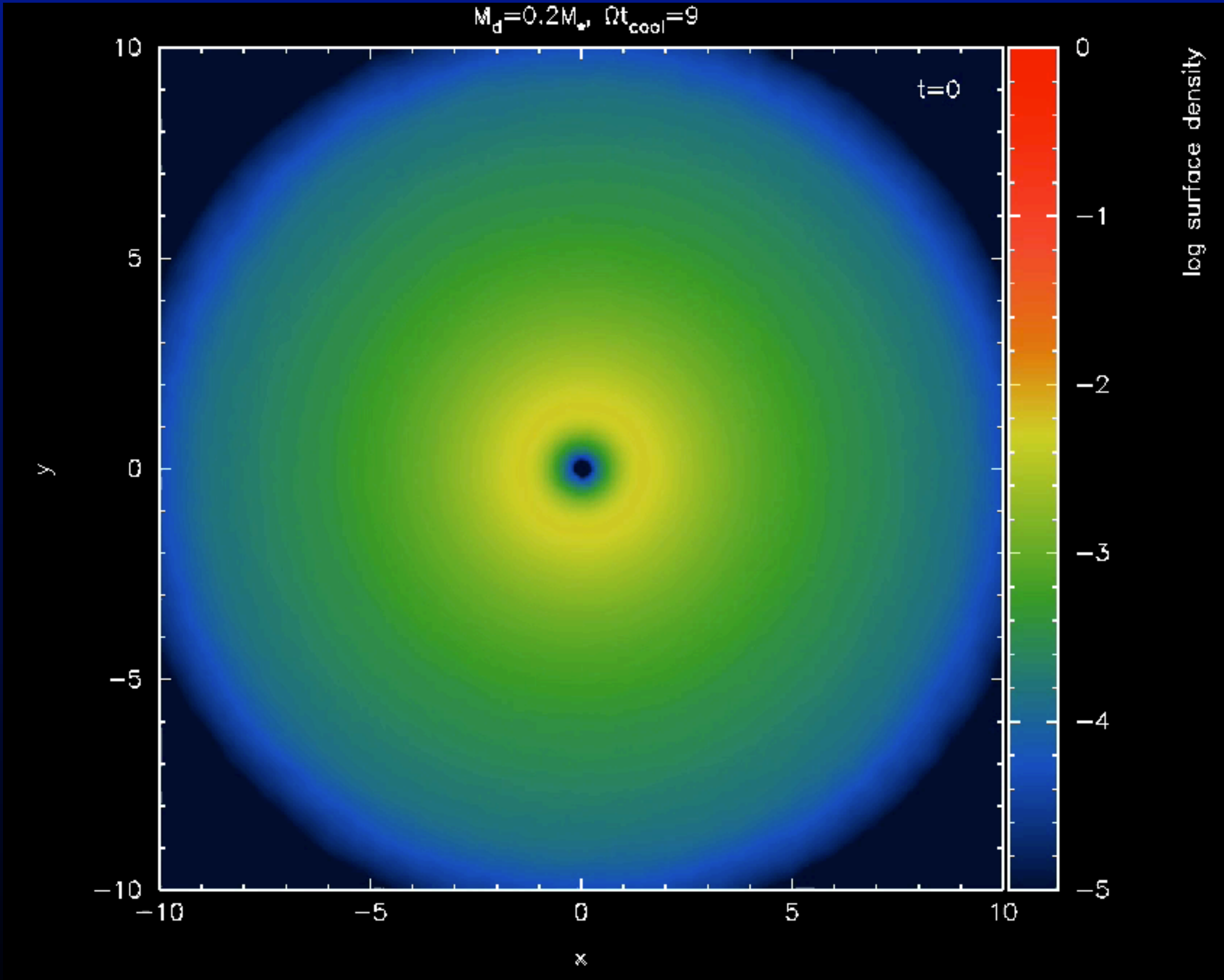
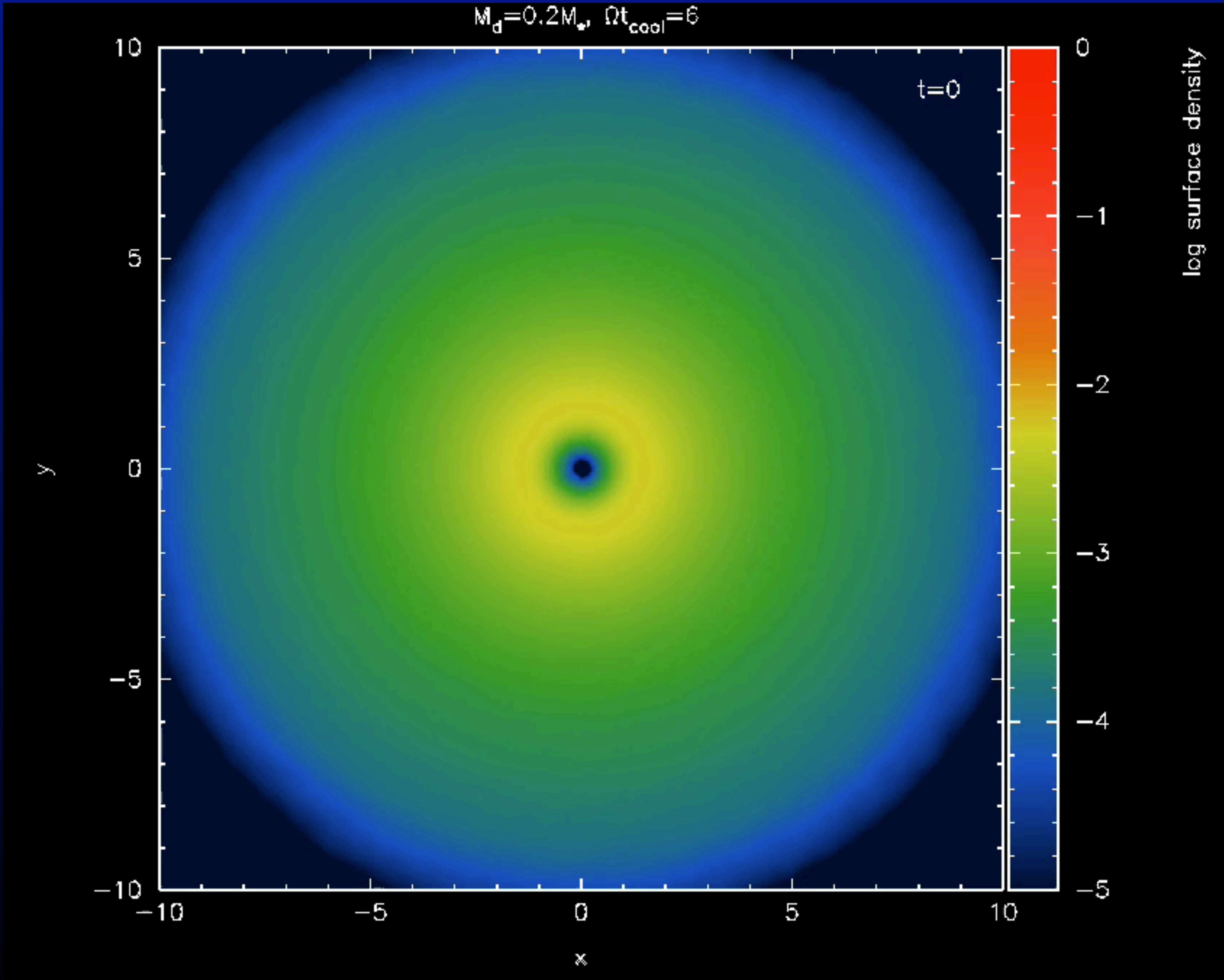


Unpublished simulation



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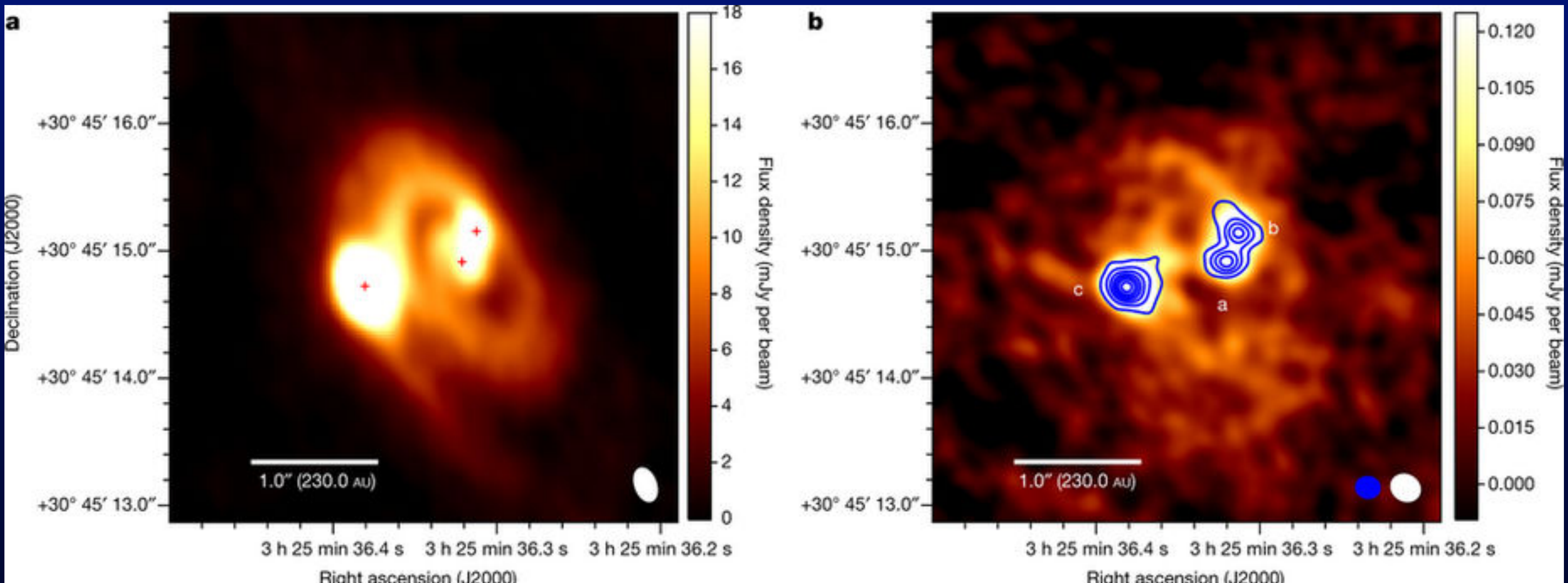
Observations of disc fragmentation



L1448-IRS3: Tobin+ (2016)

- Binary protostar with total mass ~1Msun and separation ~60AU
- Disc mass is ~0.3Msun, Q ~ 1 from ~175-300AU.
- “c” is apparently a disc fragment, with mass ~0.1Msun.

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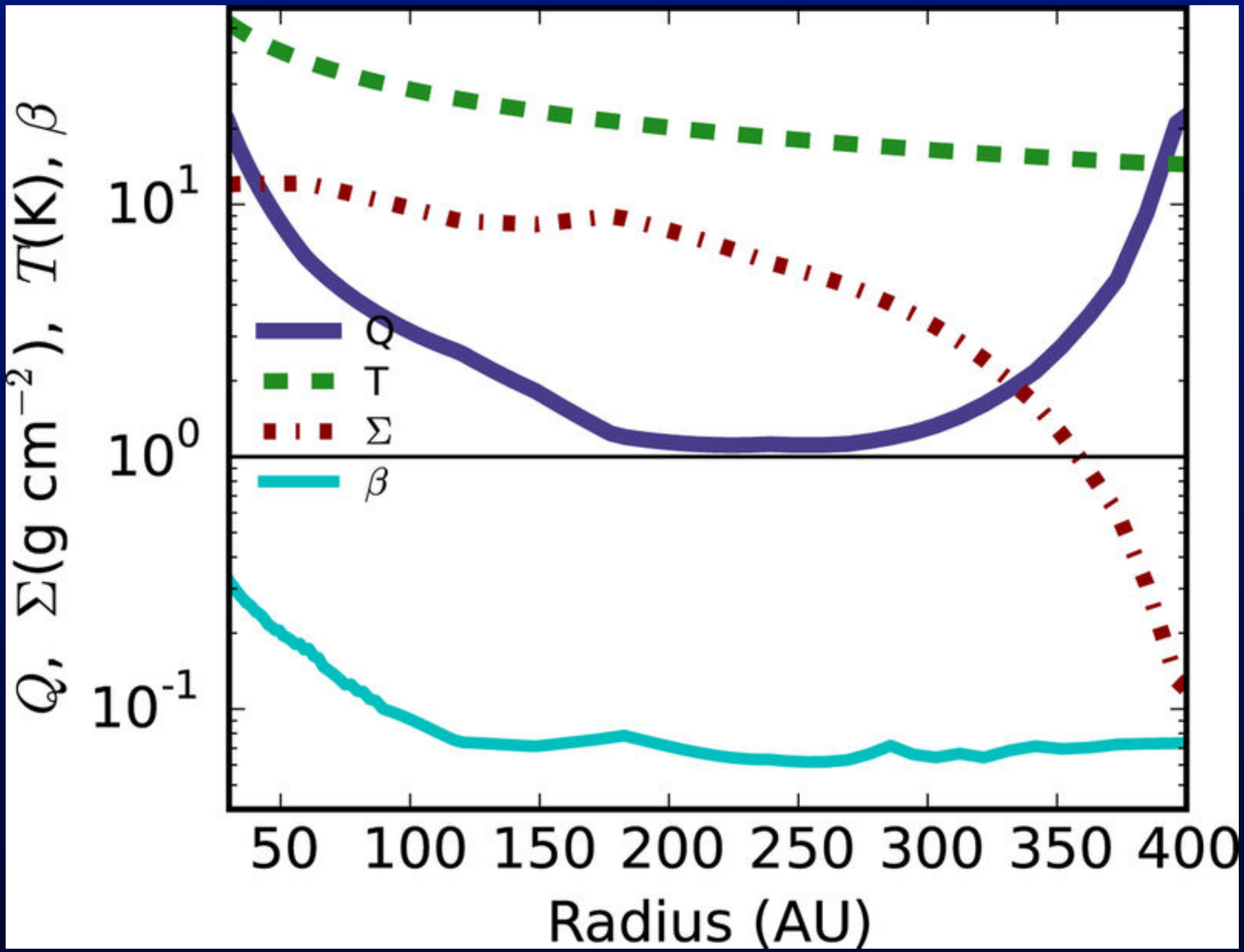

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