Theoretical Galaxy Formation

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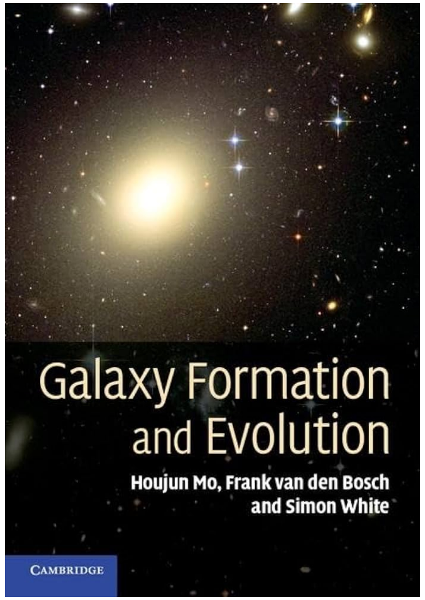
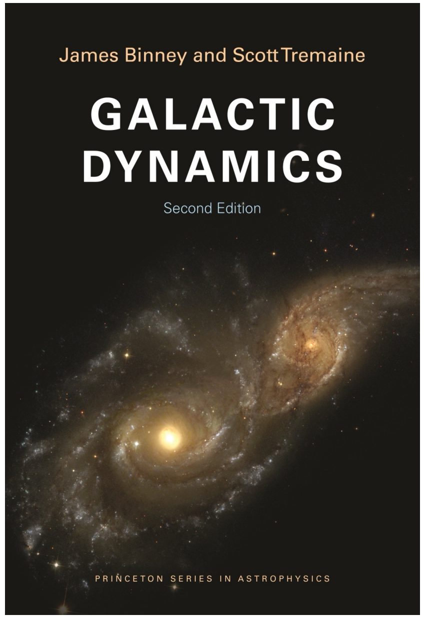
Bibliography

- Galaxy Evolution (PHYS11070)
- Galaxy Formation and Evolution (Mo, van den Bosch & White 2010, MvW)
- Galaxy Dynamics (Binney & Tremaine 2008) Chapter 9



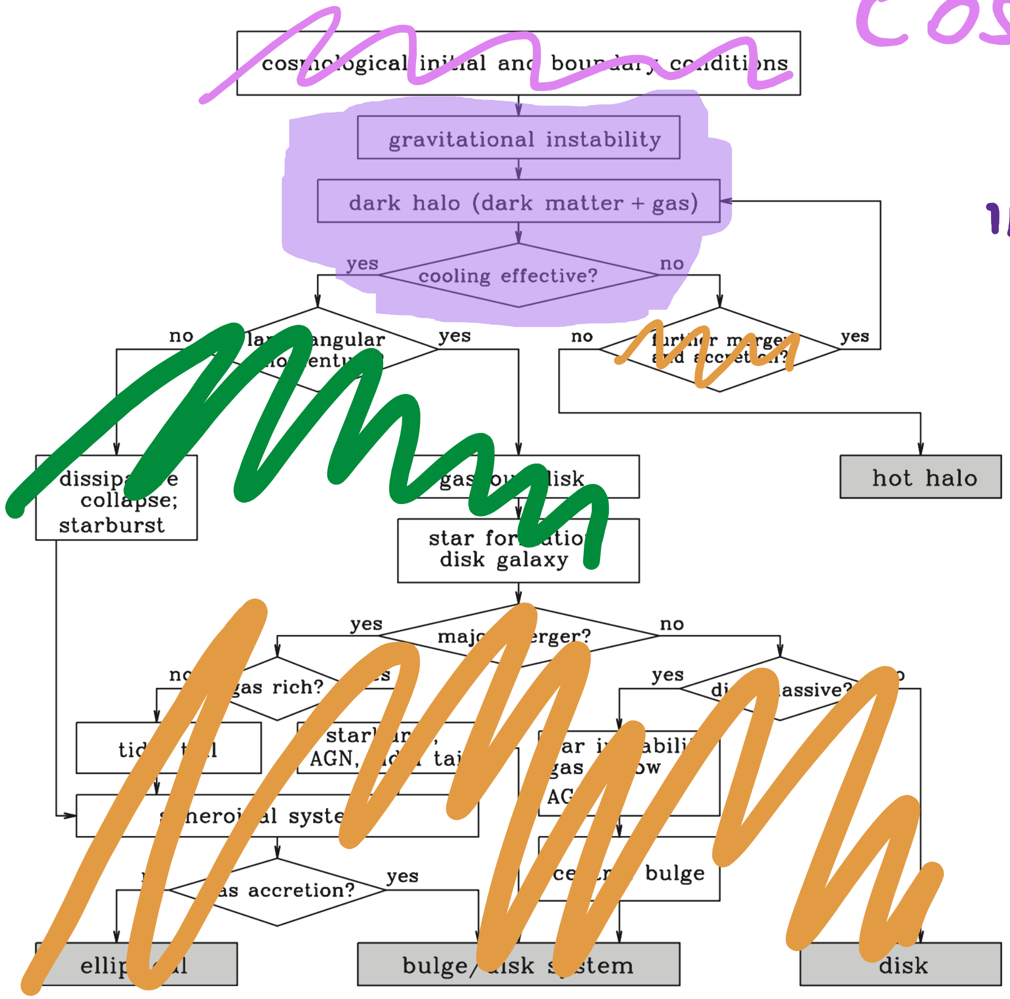


What I~~'ll~~ won't Cover

cosmology x

"Formation" ✓

morphology x



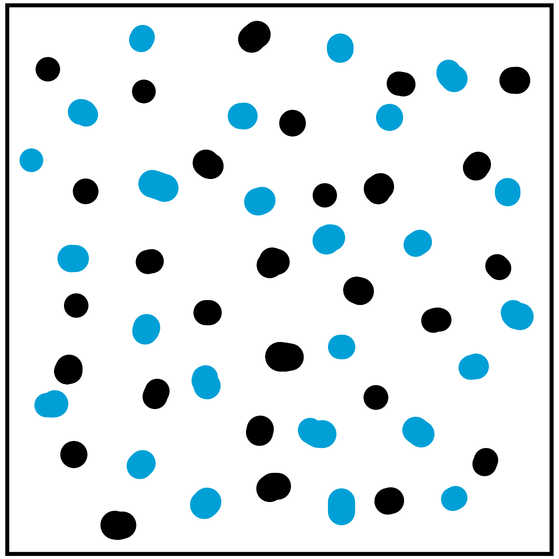
"Evolution" x

MvW; Fig. 1, p. 5

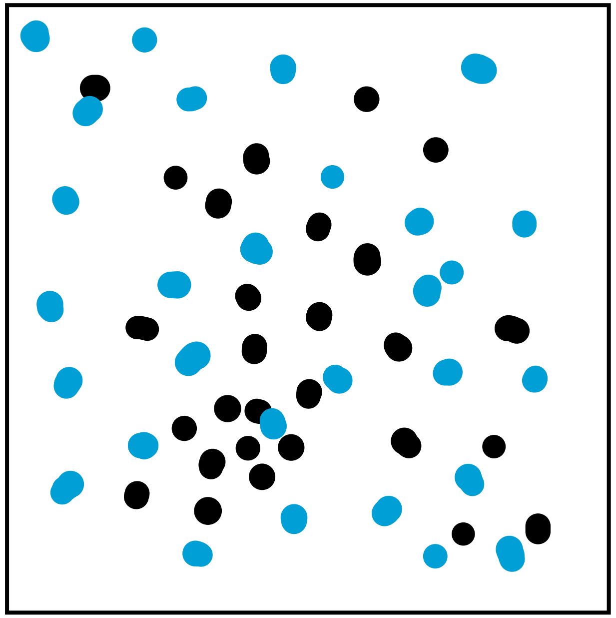
What I’ll Cover

- Perturbations in dark matter grow when baryons can’t
- Later on in time, baryons catch up
- For baryons to keep getting denser, cooling must be effective

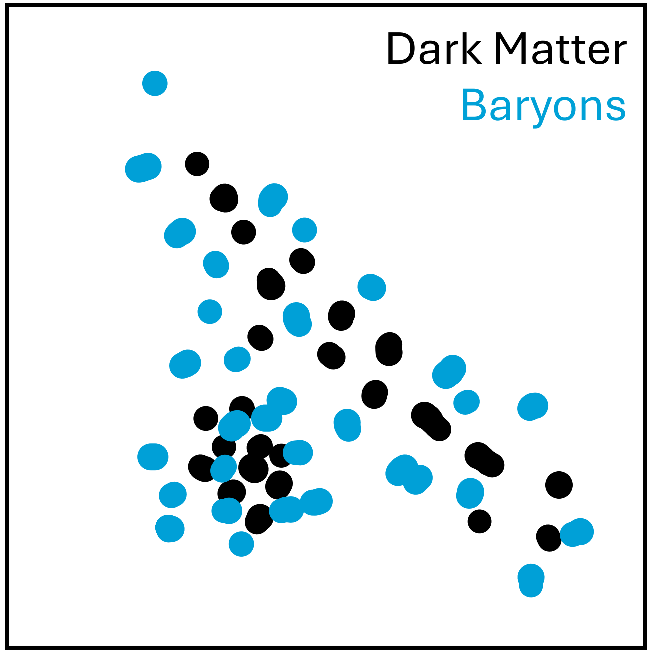
Collapse



Uniform
Uniform



Collapsing
Uniform



Collapsing
Collapsing

Collapse

Dark Matter

- Grow from *matter-radiation equality* (z~5700)
- Not effected by radiation pressure
- Can only get so dense before *virialising*

Baryons

- Grow from *surface of last scattering* (z~1100)
- *Silk Damping* stops collapse of structures smaller than a galaxy
- Can get dense enough to form stars

A question of energy

- Baryons falling into a halo will gain energy
- Hot gas can’t collapse.
- Is this an issue?

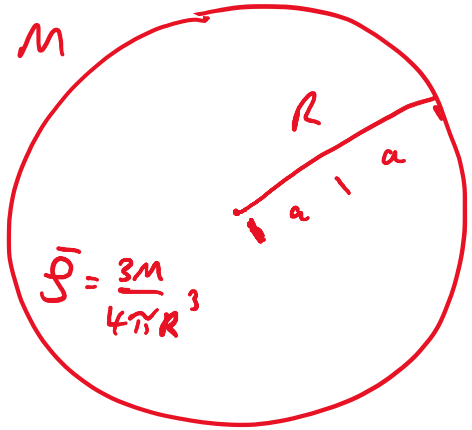
Can gas radiate away GPE?

$$\mathcal{E} \sim n k_B T$$

$$\frac{\mathcal{E}}{\dot{\mathcal{E}}} = t_{\mathrm{cool}} < t_{\mathrm{freefall}} = \sqrt{\frac{3\pi}{32 G \bar{\rho}}}$$

From QM:

$$\dot{\mathcal{E}} = n^2 \Lambda(T, \ldots)$$

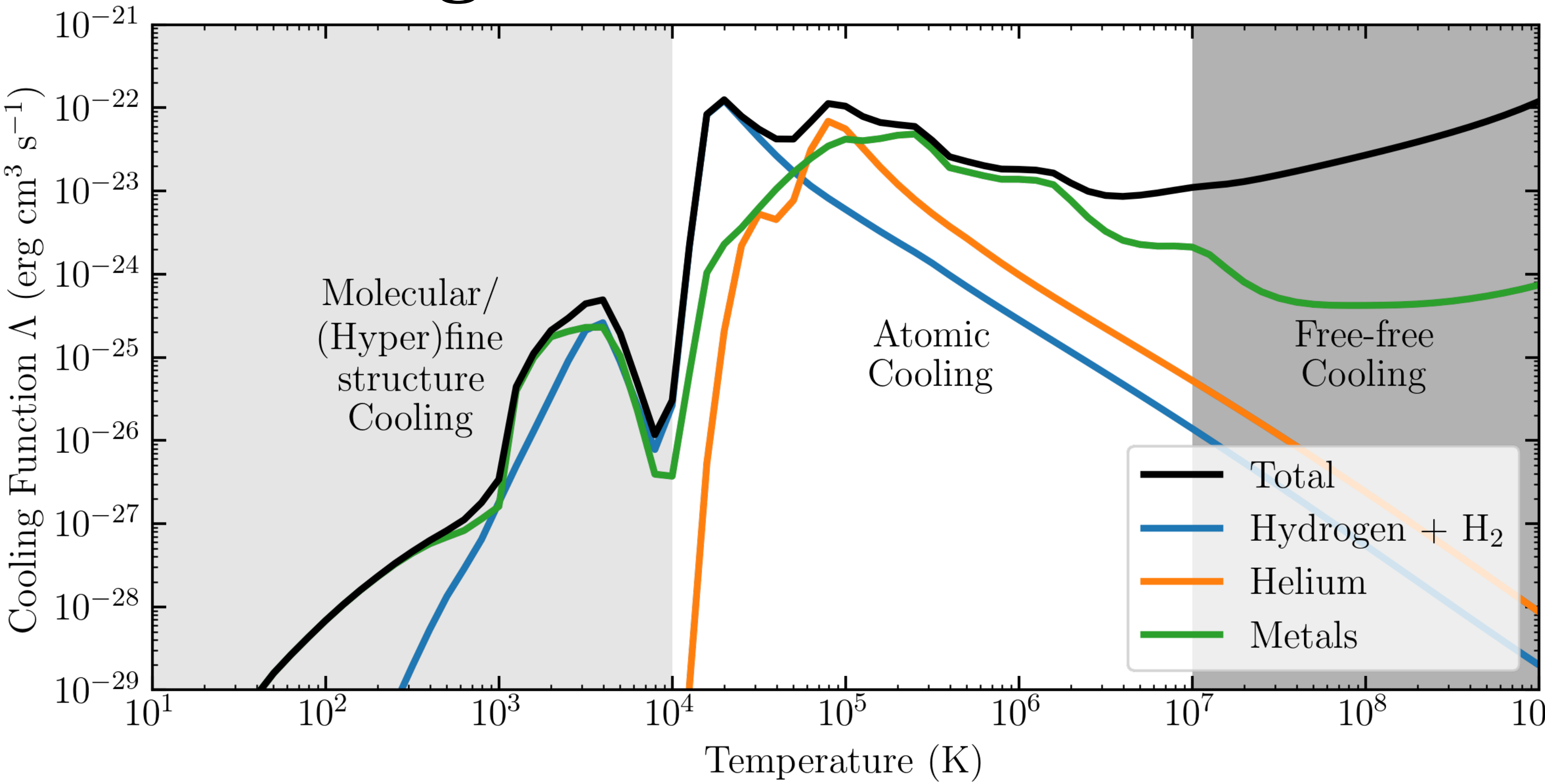


$$\bar{\rho} = \frac{3M}{4\pi R^3}$$

$$T^2 = \frac{4\pi^2}{GM} a^3$$

$$(2\, t_{\mathrm{freefall}})^2 = \frac{4\pi^2}{GM} \left(\frac{R}{2}\right)^3$$

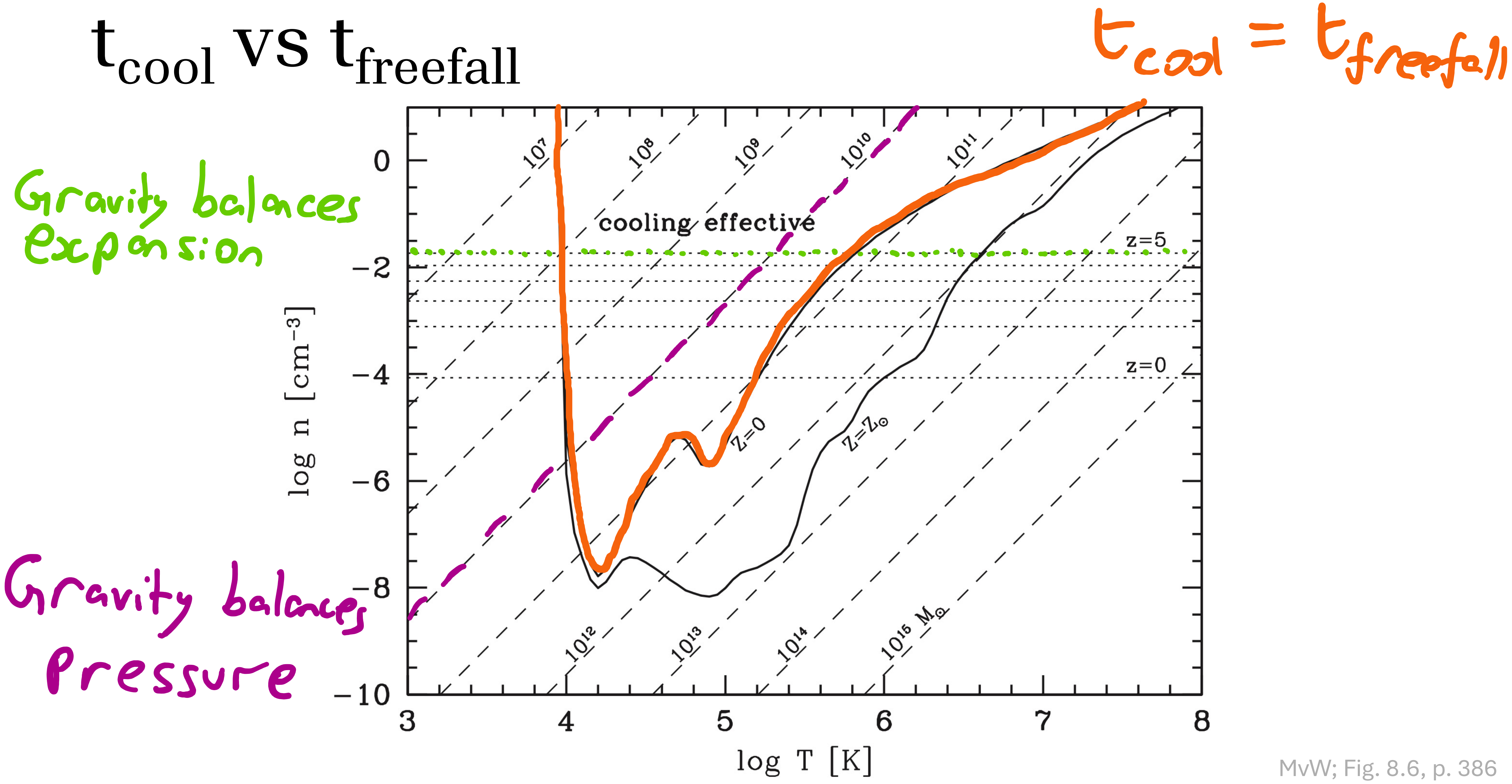
The Cooling Function, Λ



Data from Ploeckinger & Shaye (2020)

Radiation Processes in Astrophysics (PHYS11067) / MvW Appendix B for more

t_{cool} vs $t_{freefall}$



MvW; Fig. 8.6, p. 386

Summary

- Dark matter collapses into structures, then baryons fall in once they stop interacting so strongly with photons.
- If the baryons **can** radiate away the gravitational energy they gain, they will keep collapsing until they are able to form stars, and we create a galaxy.
- If they **can't** then you end up with a big cloud of hot gas that doesn't do anything.

- *What next?* Read the first chapter of Mo, van den Bosch & White; take Galaxy Evolution.