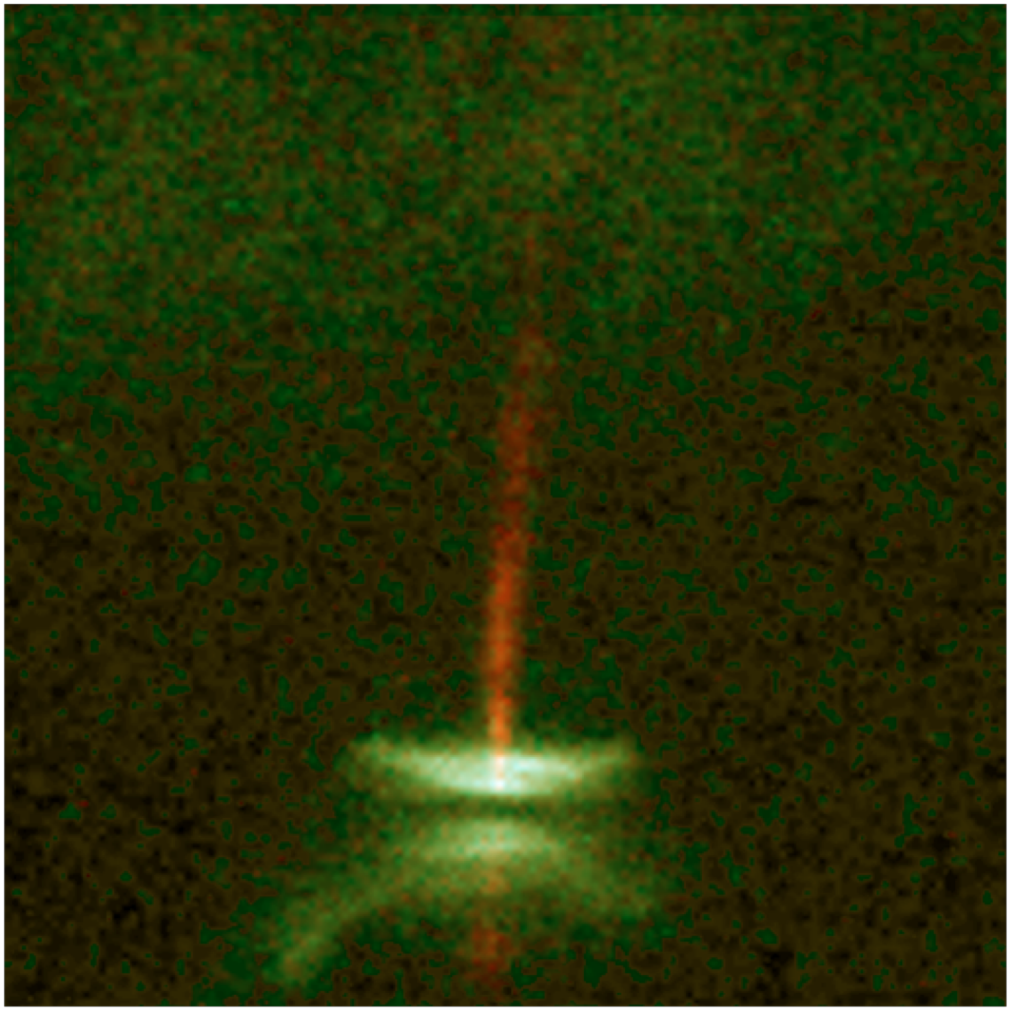
Planet Formation

- Proto-planetary discs
- Grain growth
- Snow line
- Terrestrial planet formation
- Jovian planet formation

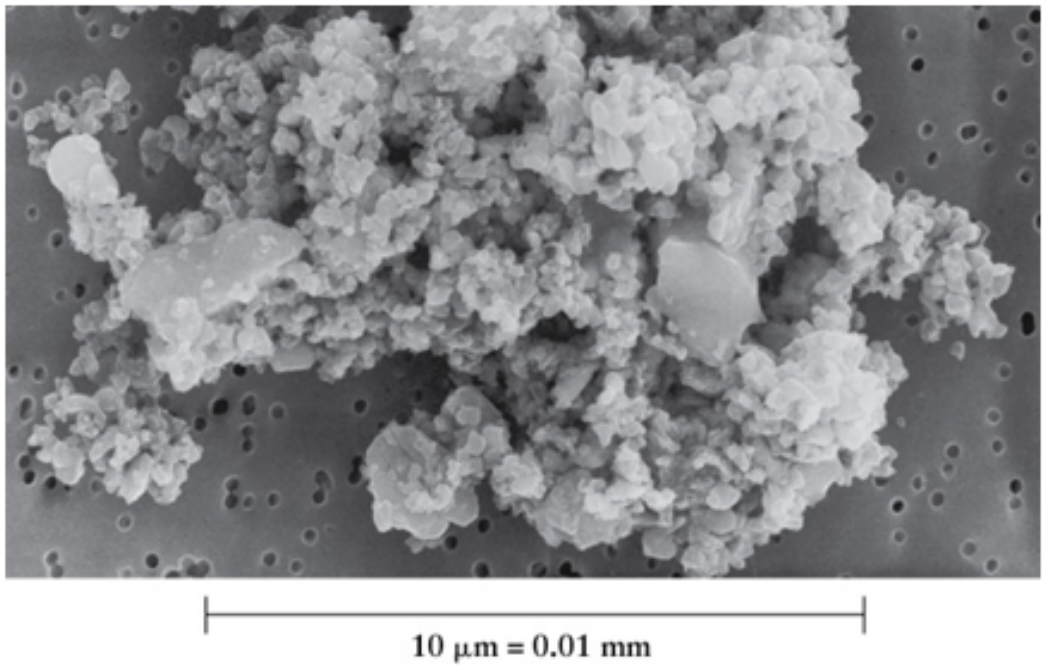
Proto-planetary discs

- The accretion discs that form stars are also the sites of planet formation

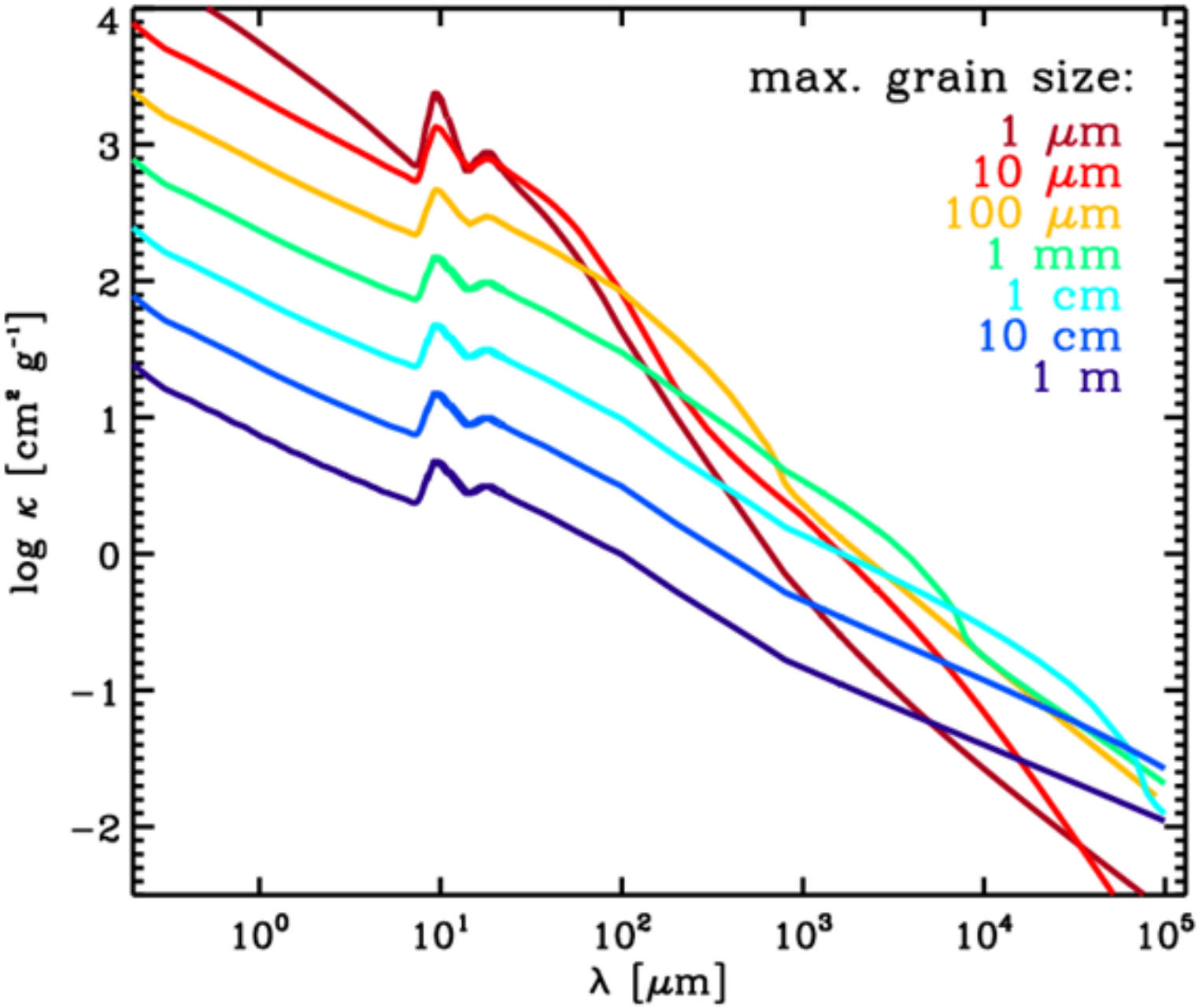


Grain Growth

- In the dense mid-plane of the proto-planetary disc the dust grains collide and some stick together – coagulate
- Held together by chemical bonds

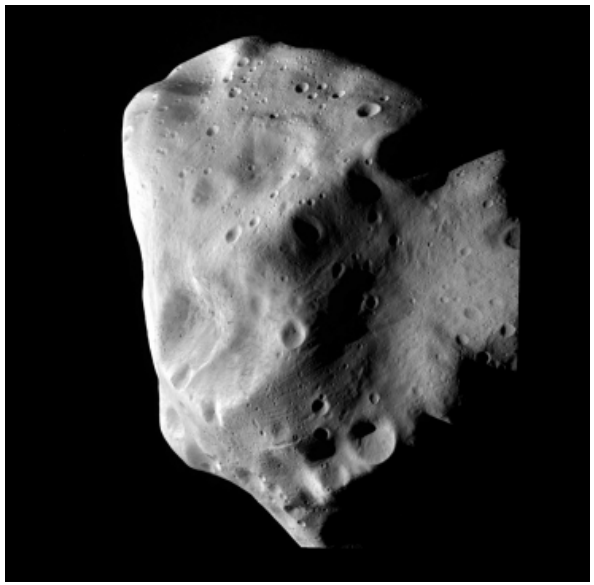


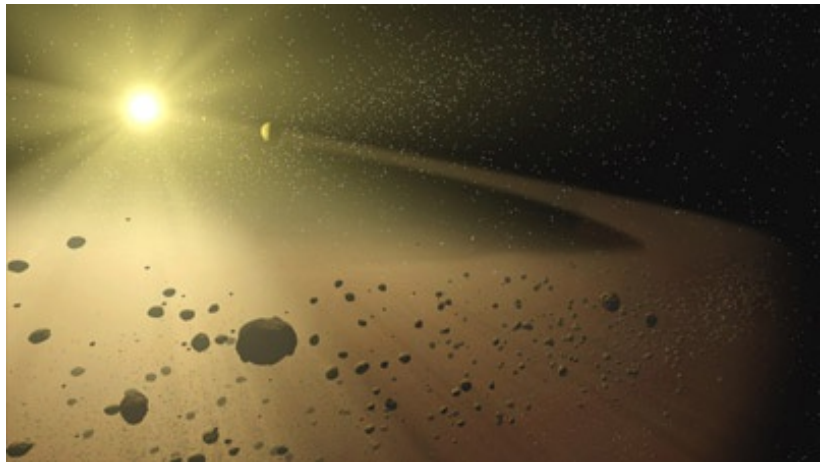
Interplanetary dust grain
Brownlee, U. Washington


max. grain size:
1 μm
10 μm
100 μm
1 mm
1 cm
10 cm
1 m
log κ [cm² g⁻¹]
λ [μm]
4
3
2
1
0
−1
−2
10⁰
10¹
10²
10³
10⁴
10⁵

Planetesimals

- Over a few million years these grains grow from a few microns to about a kilometre in size
- These are called planetesimals and are similar to asteroids
- Held together by gravity





NASA

Snow Line

- In the outer regions where temperatures are <200 K, ices coat the rocky grains made up of water, ammonia and methane frozen out from the gas phase
- In the inner regions the ices sublimate and the grains are bare silicate and carbon

- The dividing line between the rocky and icy grains is the snow line (frost/ice line)

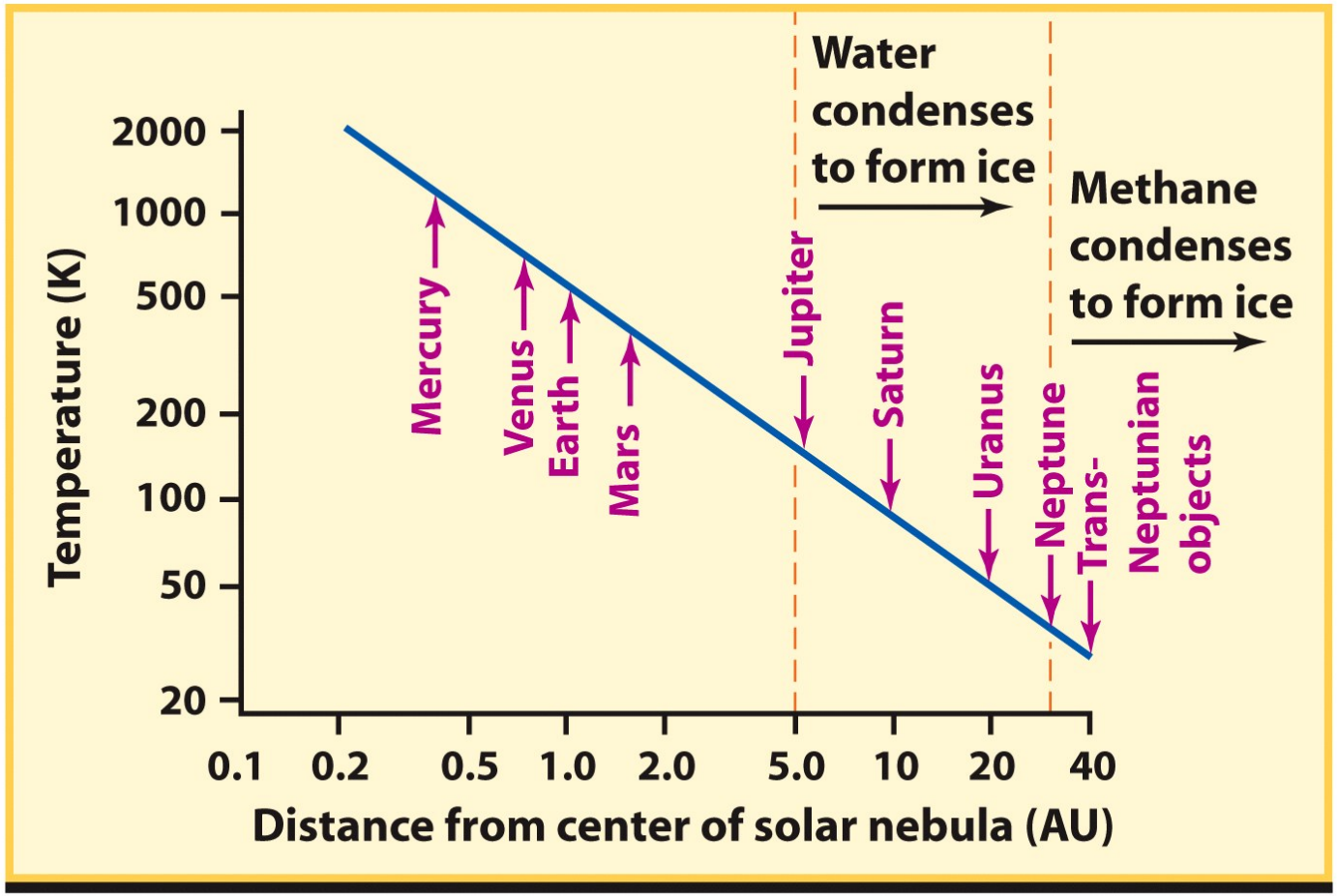
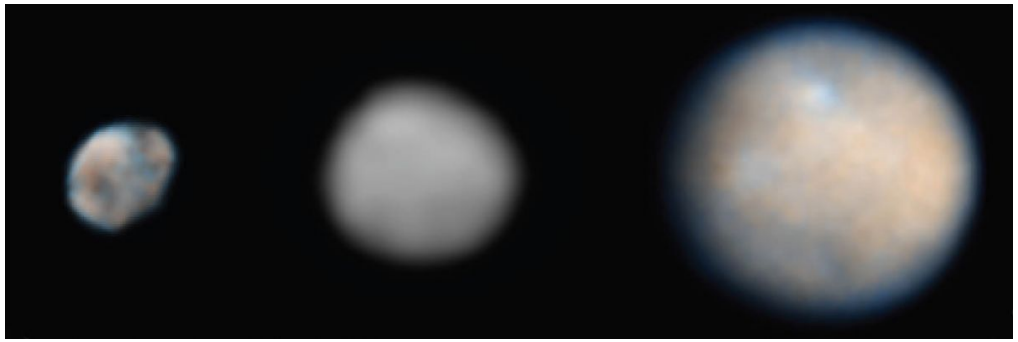


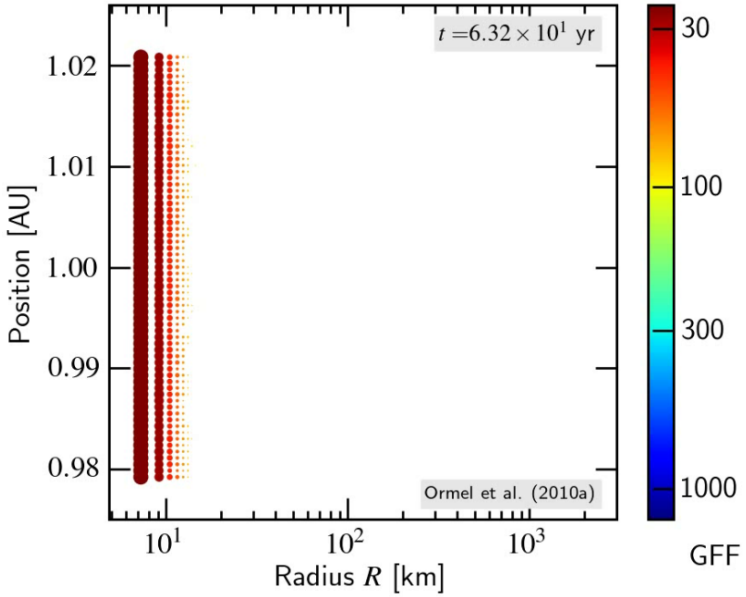
Figure 8-10
***Universe*, Ninth Edition**

Proto-Planets

- Planetesimals have enough gravity to attract each other, collide and merge
- This forms proto-planets with sizes similar to the Moon and dwarf planets



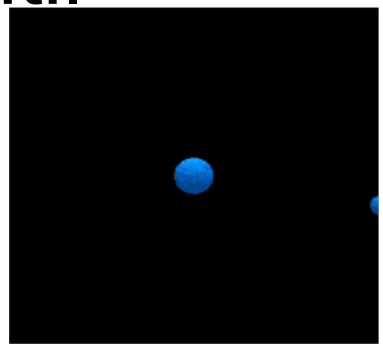
Vesta, Pallas and Ceres
sciencewise.anu.edu.au

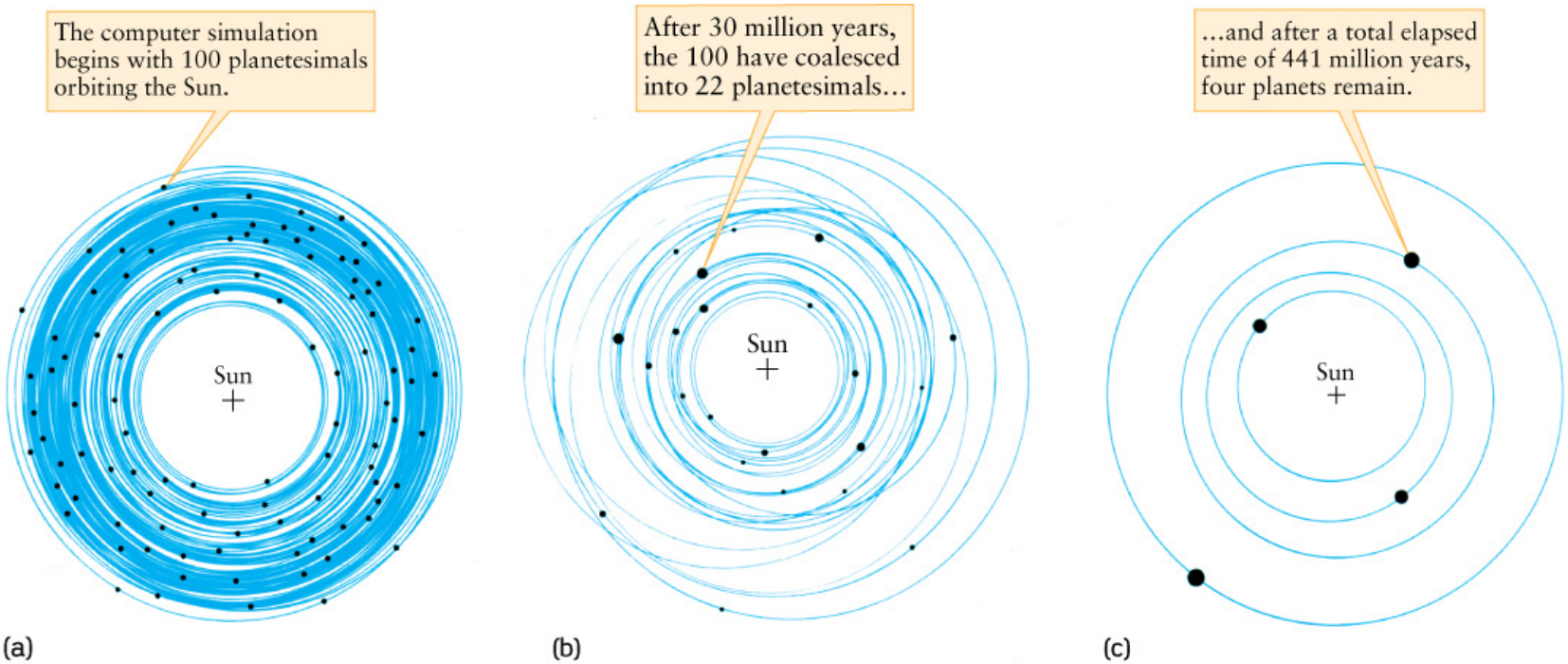


Ormel et al. (2010)

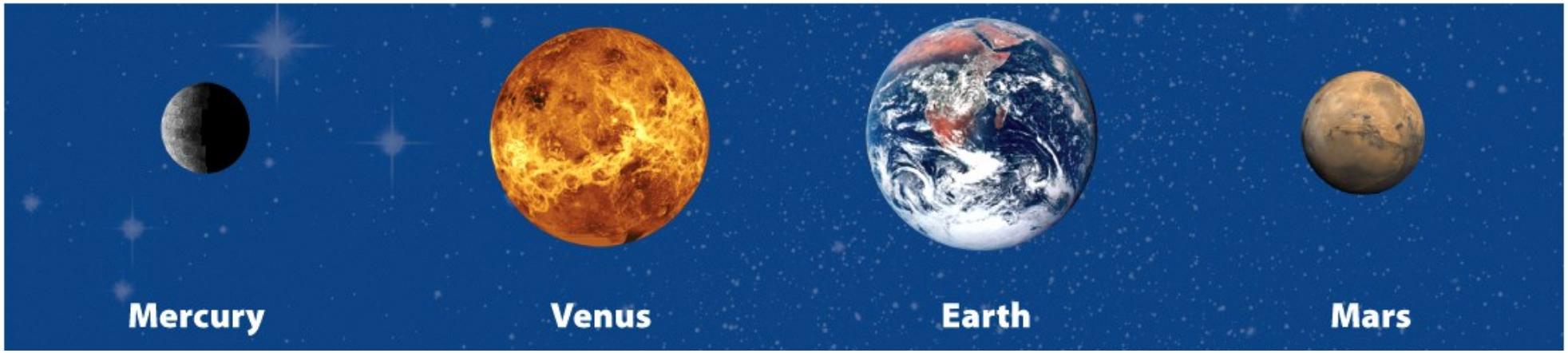
Terrestrial Planets

- Collisions & interactions continue until the neighbourhood of the largest bodies are cleared, i.e. a planet





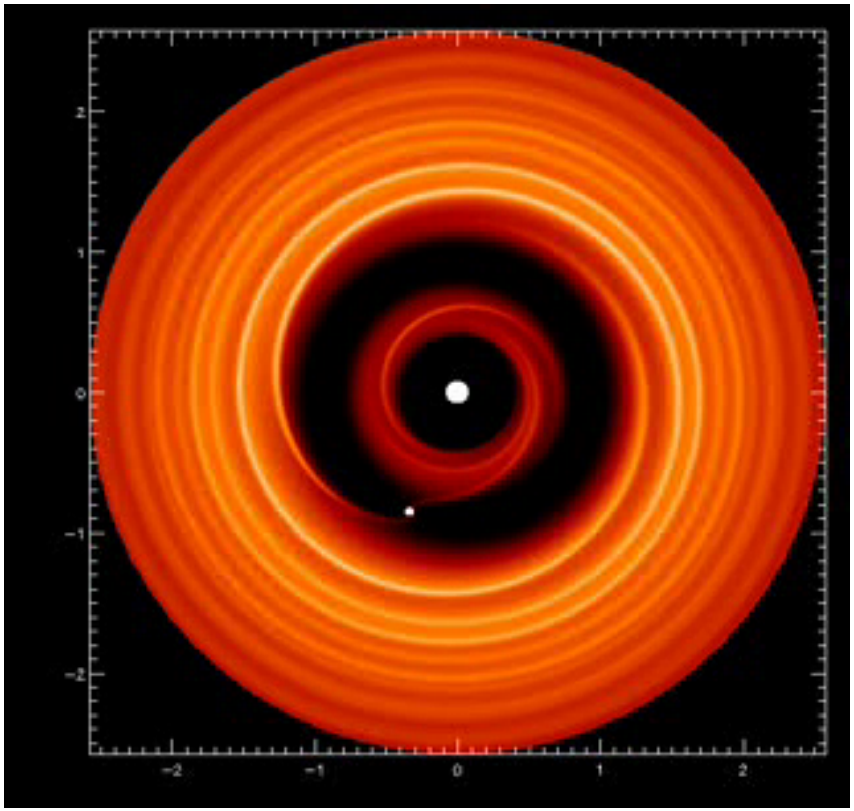
- Results in the rocky terrestrial planets
- These inner solar system planets never get massive enough to capture the hot gas from the accretion disk

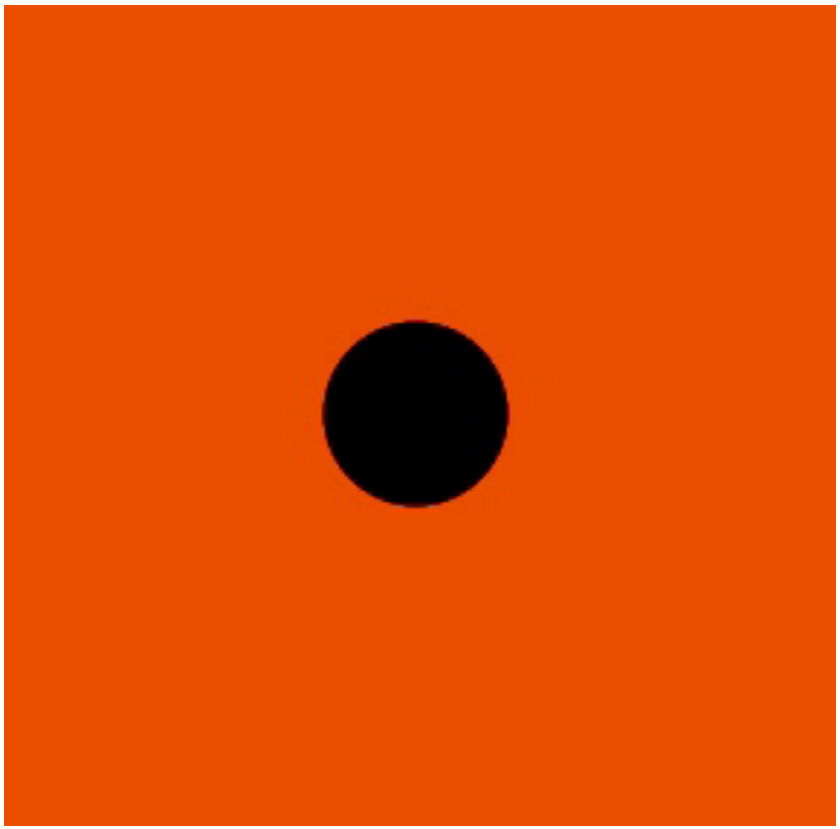


Jovian Planets

- Outside of the snow line the icy grains stick together more easily and there is a larger mass of solid material
- Here the rocky cores can build to about 10 times the Earth's mass
- The gas in the disc is also cooler and easier to capture – core accretion model

- Rapid gas capture opens a gap in the disc
- Multiple gas giants stop accreting when gaps merge

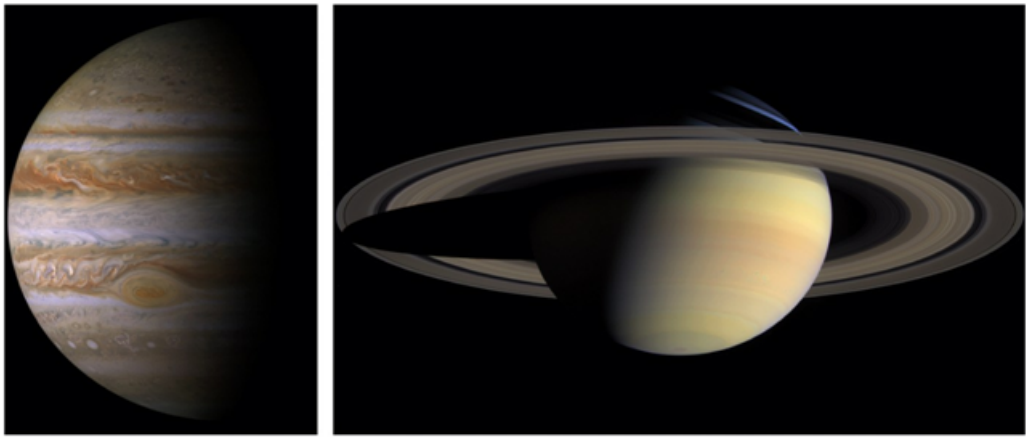




www.maths.qmul.ac.uk/~rpn/projects/mhd/

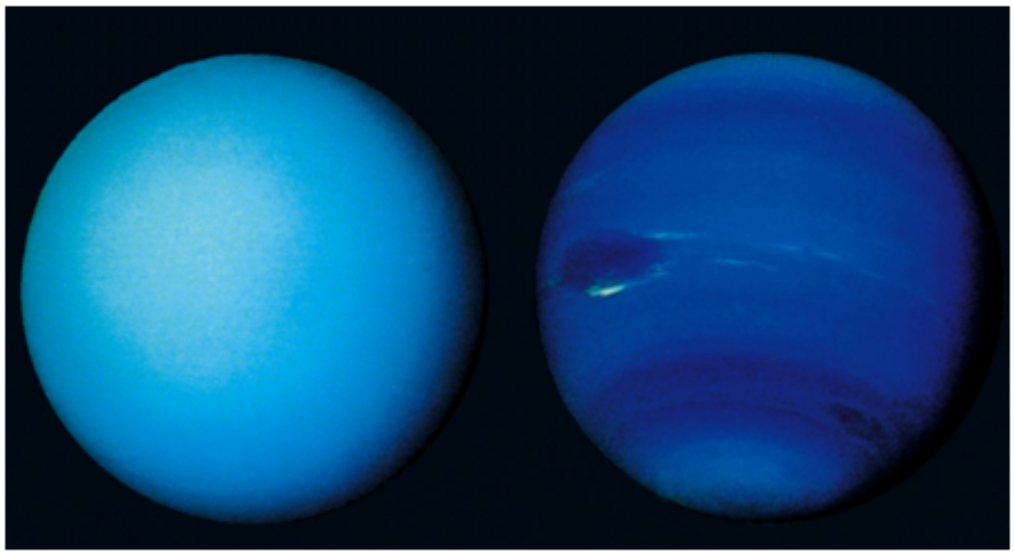
www.maths.qmul.ac.uk/~masset/moviesmpegs.html

- This leads to formation of the massive gas giants Jupiter and Saturn



Chapter 12 Opener
Universe, Ninth Edition

- Further out there is less gas available and here the ice giants Uranus and Neptune formed



Small Bodies

- Jupiter cleared most of the rocky planetesimals near it leaving the asteroids
- Icy planetesimals outside the Jovian planets were scattered outwards to form the Kuiper Belt
- Planetesimals that closely encountered the Jovian planets were flung out into the Oort cloud

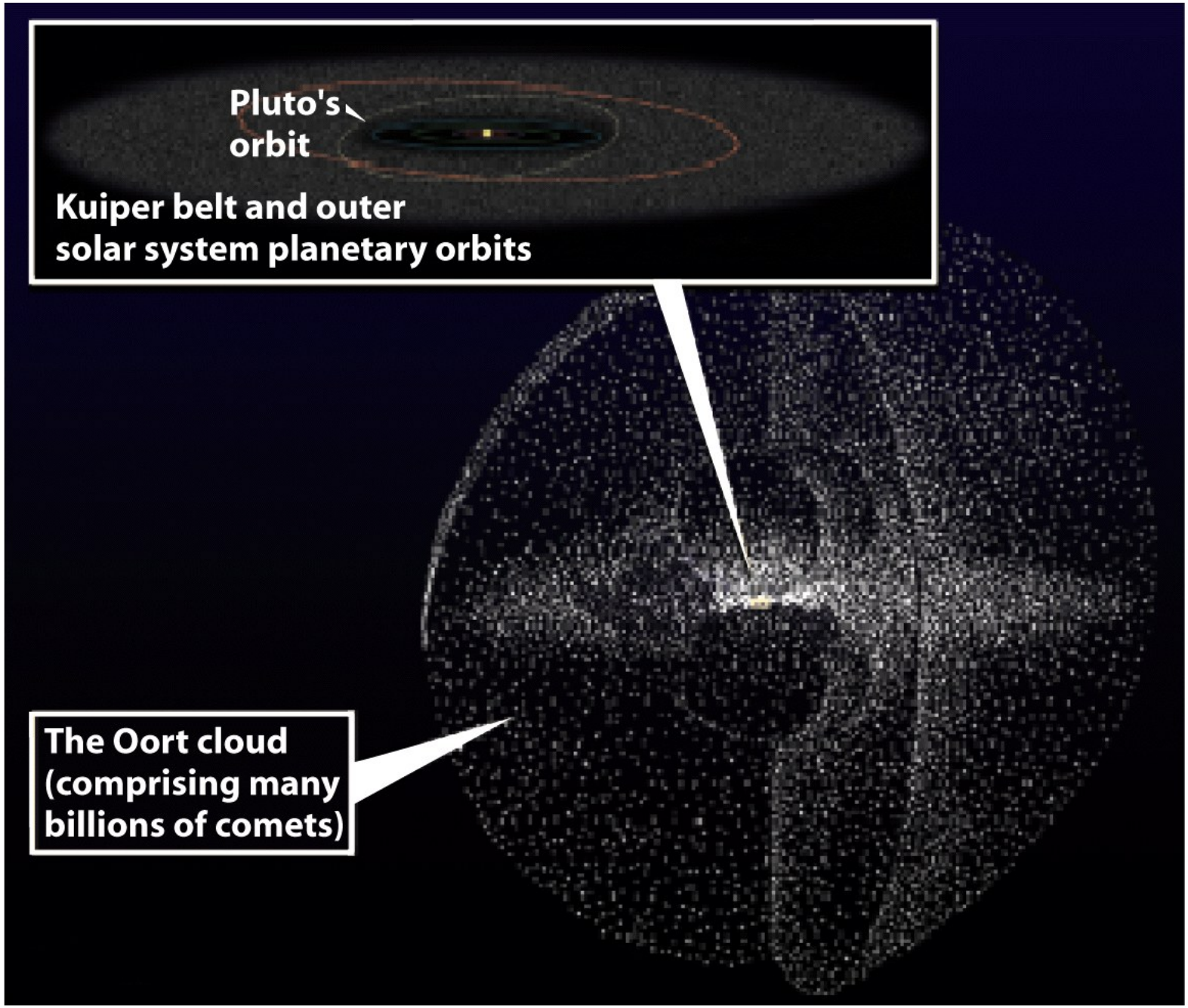


Figure 15-27
***Universe*, Ninth Edition**

Summary

- Planet formation in a disc is a natural by-product of star formation
- Dust grains enable molecular clouds to cool and collapse and planets to form
- The main features of the solar system are explained by the core accretion model
- Rocky planets form inside the snow line
- Jovian planets form outside the snow line