The density of the Earth and Earth layers

While seismic refraction data can inform us of both the depth of Discontinuities in the Earth and the variation in seismic velocities with depth to good accuracy,
It is difficult to extract the density from seismic velocity alone.
The velocity equation for P and S waves also other variable
K and μ, so no unique solution.

The equation for the speed of P-waves, υ_P, is:

$$\upsilon_P = \left(\frac{K + \frac{4\mu}{3}}{\rho} \right)^{\frac{1}{2}} \qquad (1.2)$$

where K is the bulk modulus, μ is the shear modulus and ρ is the density. The equation for the speed of S-waves, υ_S, is:

$$\upsilon_S = \left(\frac{\mu}{\rho} \right)^{\frac{1}{2}} \qquad (1.3)$$

$$v_P{}^2 = \frac{K + \frac{4\mu}{3}}{\rho} \text{ and } v_S{}^2 = \frac{\mu}{\rho}$$

So:

$$\mu = \frac{3}{4}(\rho v_P{}^2 - K) = v_S{}^2 \rho$$

Rearranging gives:

$$\frac{K}{\rho} = v_P{}^2 - \frac{4 v_S{}^2}{3}$$

It still requires K

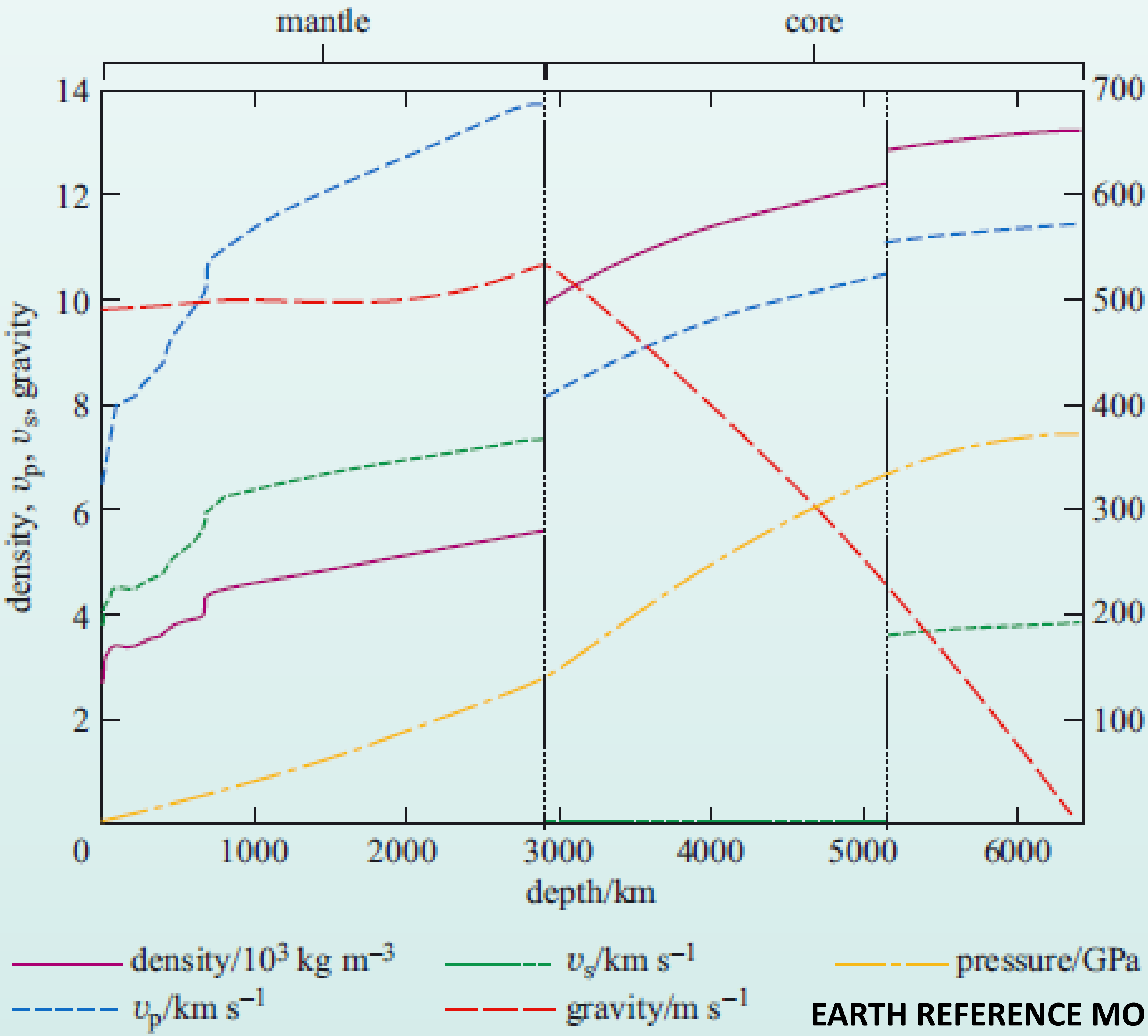
In 1923, Two geophysicist Adams and Williamsons formulated another Equation that eliminated K....considering how gravity and density would Change as a result of the mass of the overlying layers,,,,**self compression**

$$\frac{\Delta\rho}{\Delta r} = \frac{\text{change in density}}{\text{change in depth}} = \frac{\rho G m}{r^2\left(v_P{}^2 - \dfrac{4v_S{}^2}{3}\right)}$$

The integration begins at the top of the mantle by
Based on a density of 3200 kg/m3....taken from occasional
Mantle samples found at the Earth's surface.

Choosing a density for the core is more hit-and-miss...

However, constraint is that total mass cannot exceed the
Known mass of the Earth, density variation through the
Core can be determined with a degree of certainty.



EARTH REFERENCE MODEL

The density of the continents is lower than that of the oceanic
Crust –
2600-2800 kg/m3 for continent....
2800-3000 kg/m3 for oceanic crust.

Crust-mantle---boundary....called as **Mohorovicic** discontinuity....**Moho**..
Region beneath the Moho and down to 220 km referred as
Low velocity zone.

In 220-400 km, velocity increases smoothly and then hits
2 discontinuity at 410 km and 670 km...known as **Mantle transition zone**
This is a region within the mantle where the crystal structure of
The constituent minerals olivine and pyroxene are transformed
Into a dense mineral known as perovskite.

D’ denotes 670-2700 km
D’’ denotes 2700-2900 km

D’’ is marked by reduced velocity gradients compared
With the monotonic increase in seismic velocity through D’.

Core is distinguished from the lower mantle by the
Gutenberg discontinuity, named after its discoverer.

The Sun, Meteorites and bulk composition of the Earth

How the planet formed initially?

Solar system includes- asteroids, comets and planetary satellites.

2 types of planets-

1. Terrestrial planets, small rocky bodies orbiting close to the SUN (e.g Earth)
2. Gas giants- follow more distant orbits in the colder outer reaches of the Solar system.

Planetary formation is linked to the formation of stars themselves. Stars are now widely considered to form from clouds of gas, mostly hydrogen and helium,

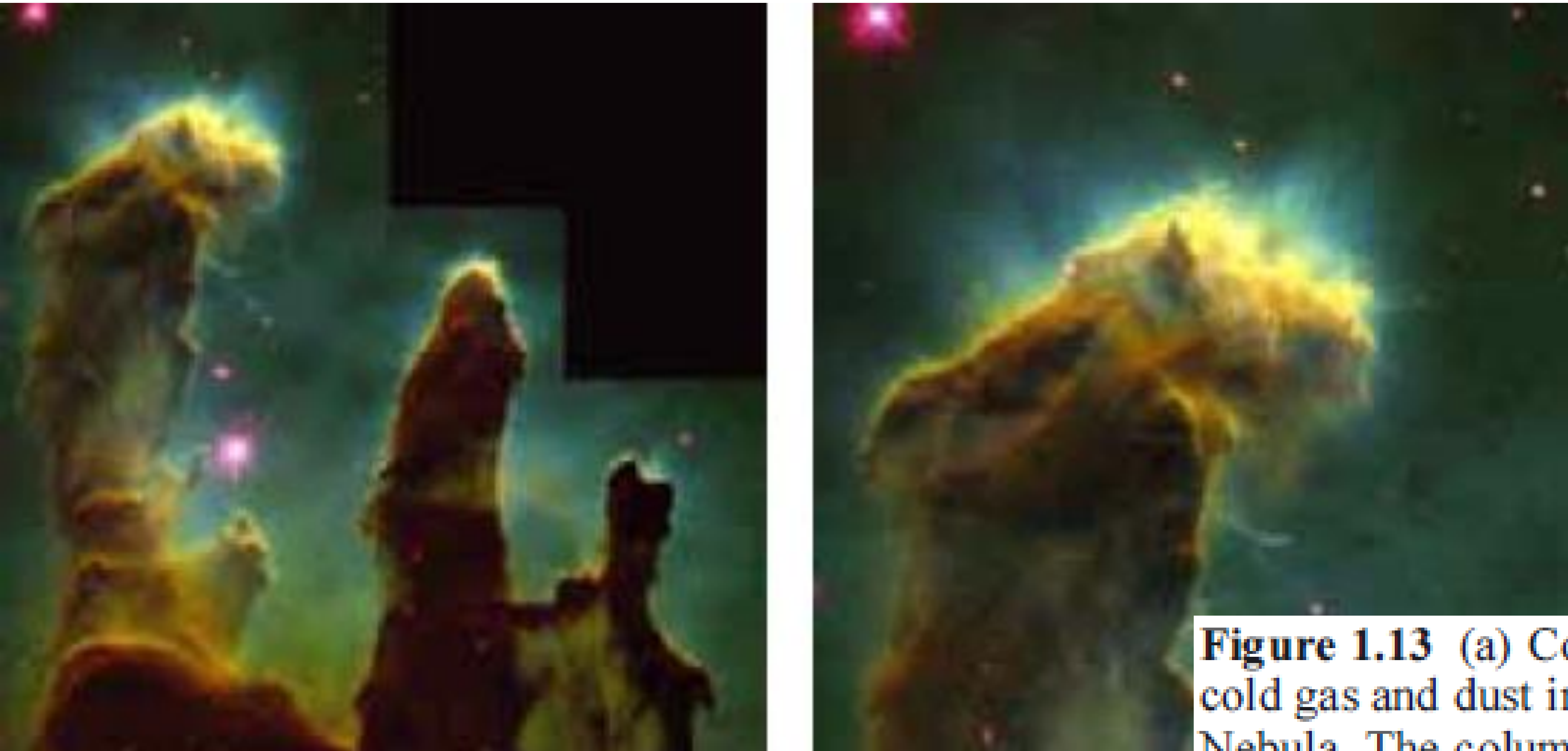


Figure 1.13 (a) Columns of cold gas and dust in the Eagle Nebula. The columns protrude from the wall of a vast cloud of molecular hydrogen and are up to four light-years long. In places the interstellar gas is dense enough to collapse under its own weight, forming young stars that continue to grow as they accumulate more and more mass from their surroundings.

The **Hubble Space Telescope** (**HST**) is a space telescope that was launched into low Earth orbit in 1990, and remains in operation. With a 2.4-meter (7.9 ft) mirror, Hubble's four main instruments observe in the near ultraviolet, visible, and near infrared spectra. The telescope is named after the astronomer Edwin Hubble.

To get some idea of the scale of the gas clouds, you
See in the diagram, individual columns are up to 4 light-years
Long and emerge from an even larger and more diffuse cloud
of gas and dust.

Small globules protruding from the
Ends of the gas ‘fingers’ that have
Been dubbed evaporating gaseous
Globules (EGGs) within which the
Density of the gas has increased to
Such an extent that the cloud is
Locally collapsing to form a star.
These EGGs are roughly the size of
Our Solar System.

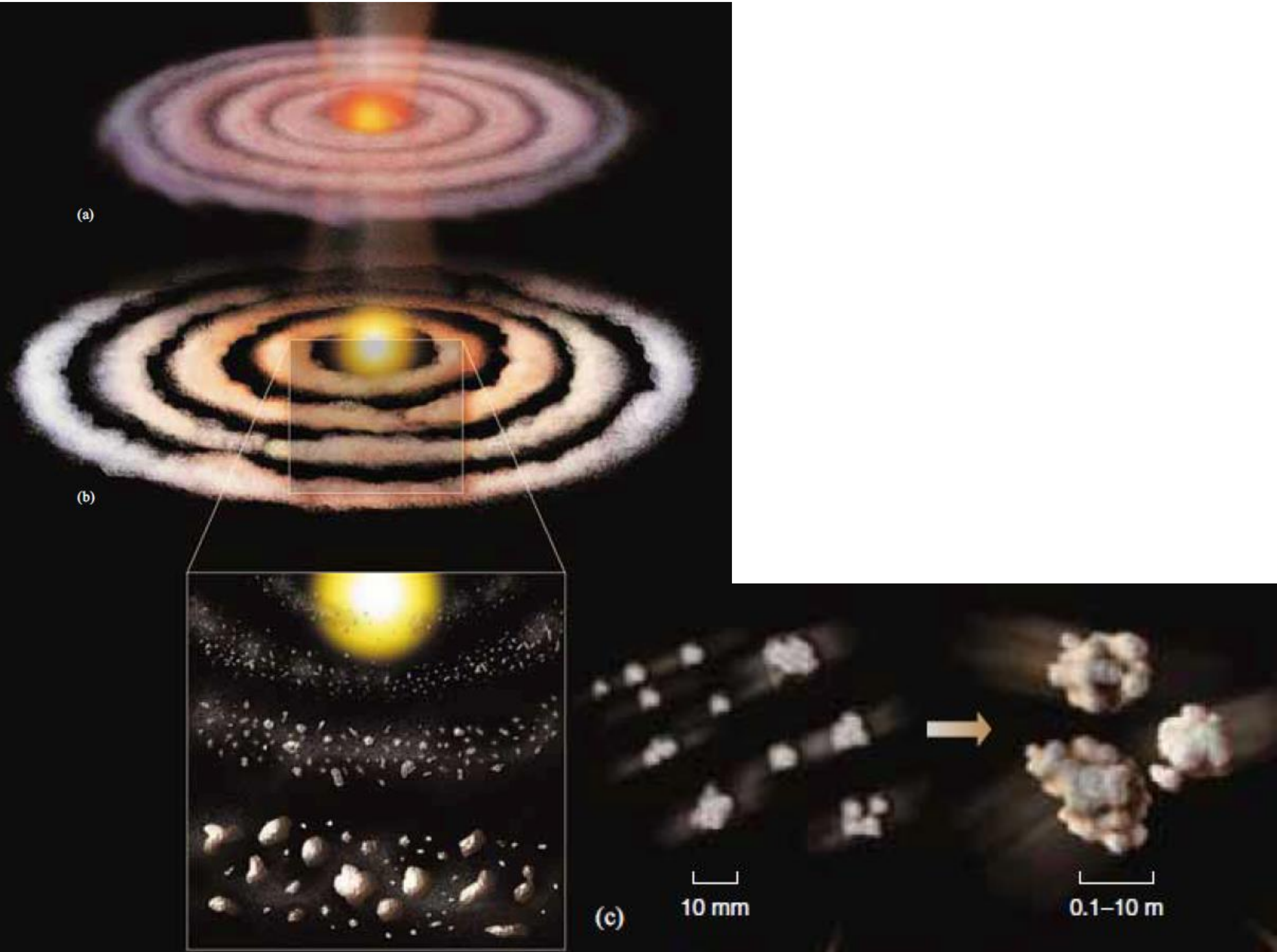
Formation of the Solar System
It all started around 4.6 Ga.

1. Condensation of the solar nebula and accretion

Gravitational collapse of an interstellar dust cloud dominated
By Hydrogen and Helium, traces of metallic and silicate dust, H2O,
CH4, NH3....

Once the sun started to shine, the heat vaporised most of the
Dust and ices and the vapour was transported further away
From the Sun by the early intense solar wind.

Condensed particle of dust stick together ....it took ~10,000 years
In the inner orbits, these clumps would have been dominated
By silicates and metal, their composition is preserved in the most
Primitive of the chondritic meteorites...

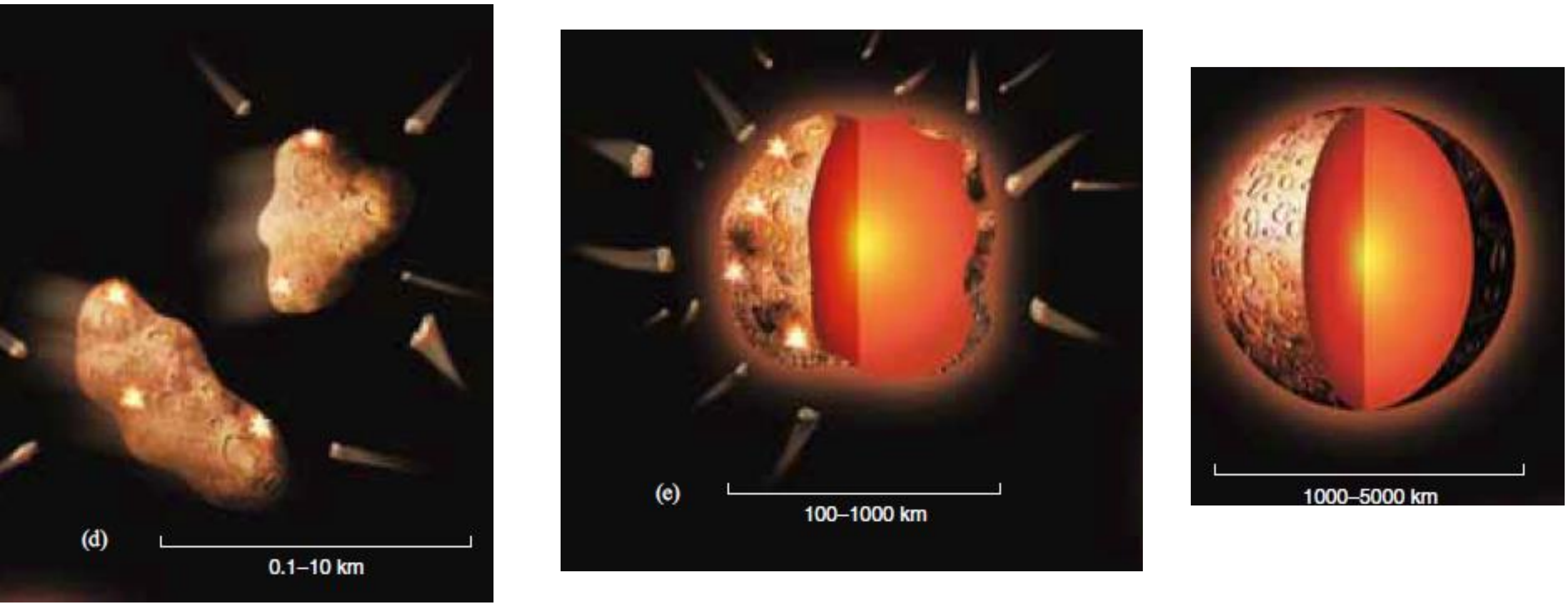

(a)
(b)
(c)
10 mm
0.1–10 m

2. Formation of Planetesimals and development of planetary embroys

Particle collision continued increasing the size of clumps
Producing a profusion of bodies ranging in size from
0.1 to 10 km in diameter, termed **planetismals** (tiny planets)

Slowly during accretion, larger bodies would begin to heat up
Because of the release of kinetic energy as smaller bodies impacted.

It is estimated that the **planetary embryos** (up to A few thousand km in size) would have swept up any remaining planetismals within a few thousand years.


(d)
0.1–10 km
(e)
100–1000 km
1000–5000 km

3. **Planetary Embryos, giant impacts and assembly of a planet**
Next stage of growth would have been slower.
Giant impacts between 2 embryos probably fragmented both
Of the impacted bodies with the debris subsequently recombining
To form a new, larger body.

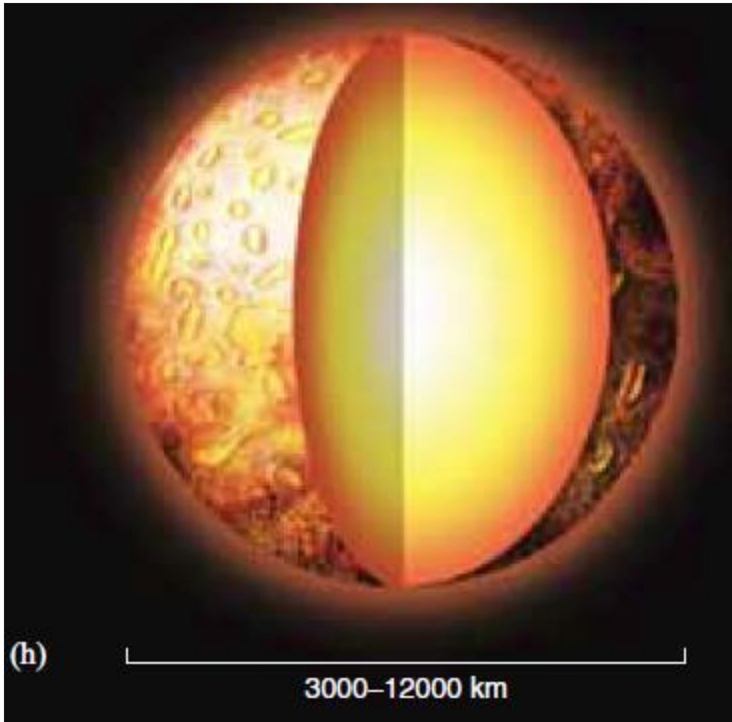
The heat released was enough to melt the newly combined mass
Creating a molten mantle of silicate material known as magma
Ocean. Metallic material sank through the
magma ocean and formed A dense
metallic core, producing a differentiated
planetary embryo.

Completion of a terrestrial planet formation

Giants impacts would have continued to take place and it Might have taken 10 Ma for the terrestrial planet to reach Half of the size and about 100 Ma to reach and build an Earth sized planet.

Once the last giant impact had occurred to form Moon.....

Of course accretion continues...
but too small to be noticeable.
Even today,,,accretion rate to the Earth today, including dust Particles is ~10*7 kg/y.



So,,,overall, we see that following steps involved
During planet formation

- -Condensation of gas to form dust particles
- -Accretion of dust to form planetismals
- -Larger collisions between planetismals to form planetary embryos
- -planetary embryos with giant impacts made planets

The composition of the Earth is related to the composition Of Solar Nebula, as most of the material from the solar Nebula condensed to form the Sun, the composition of the Earth is also related to that of the Sun.