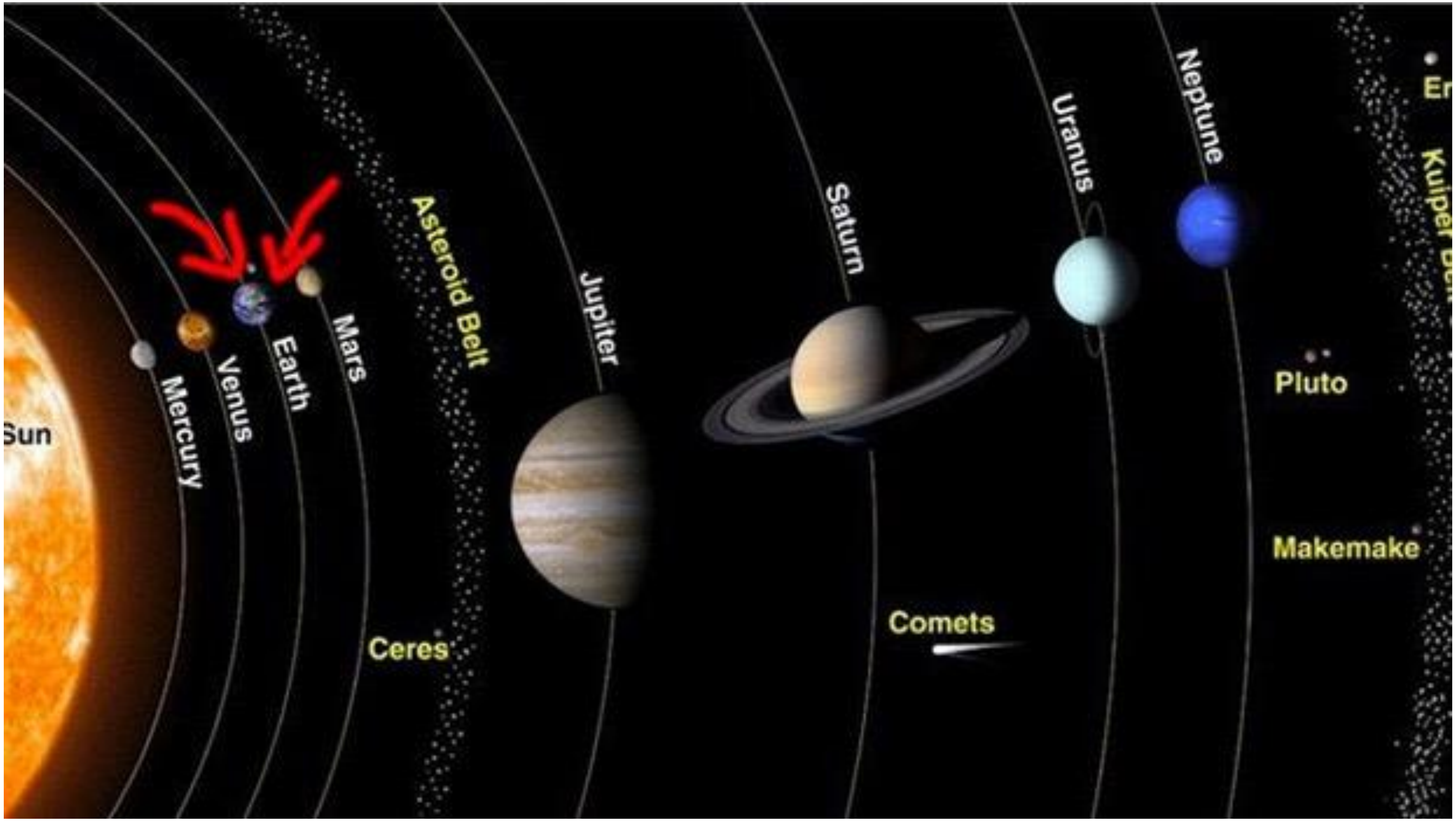
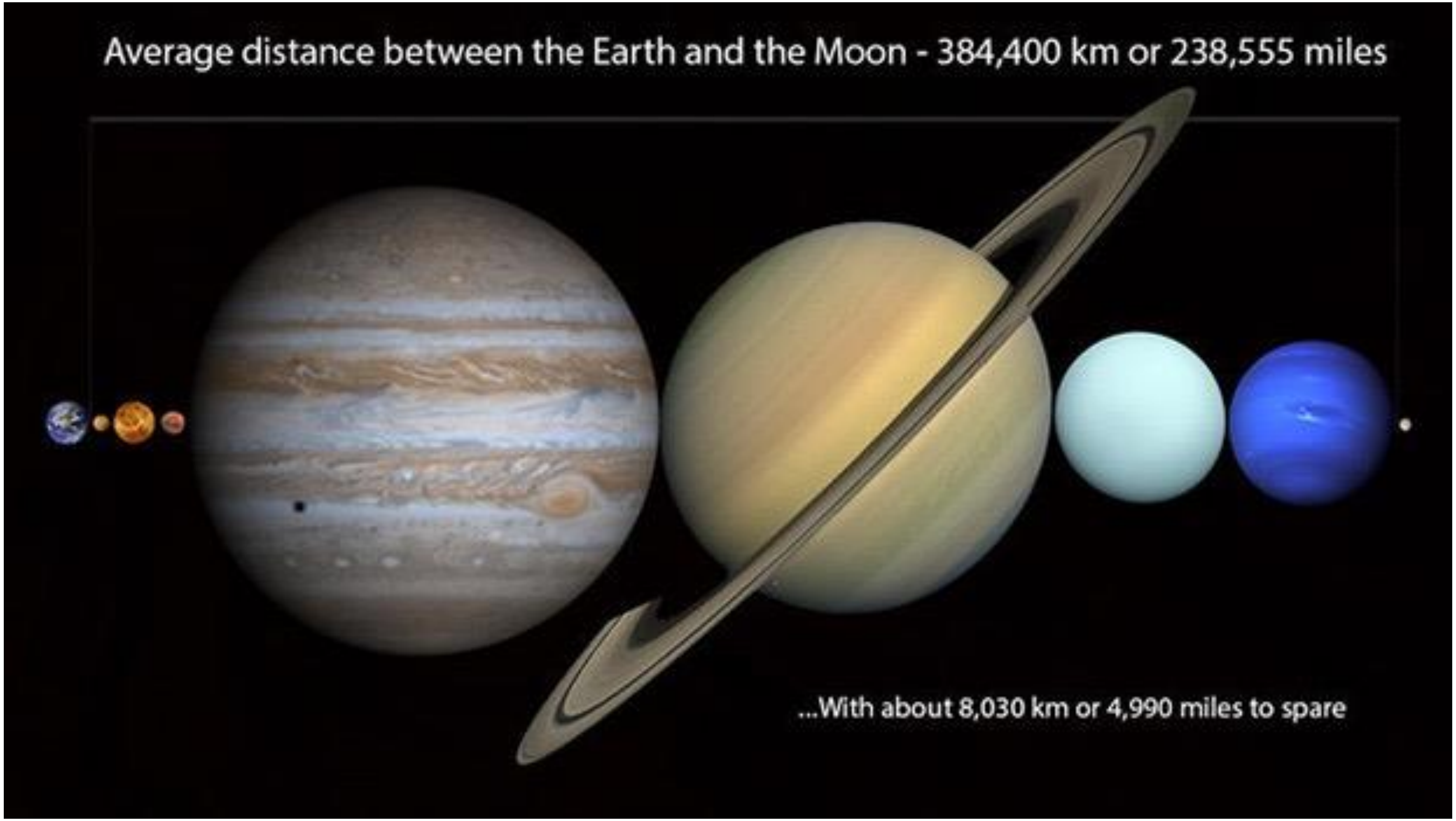
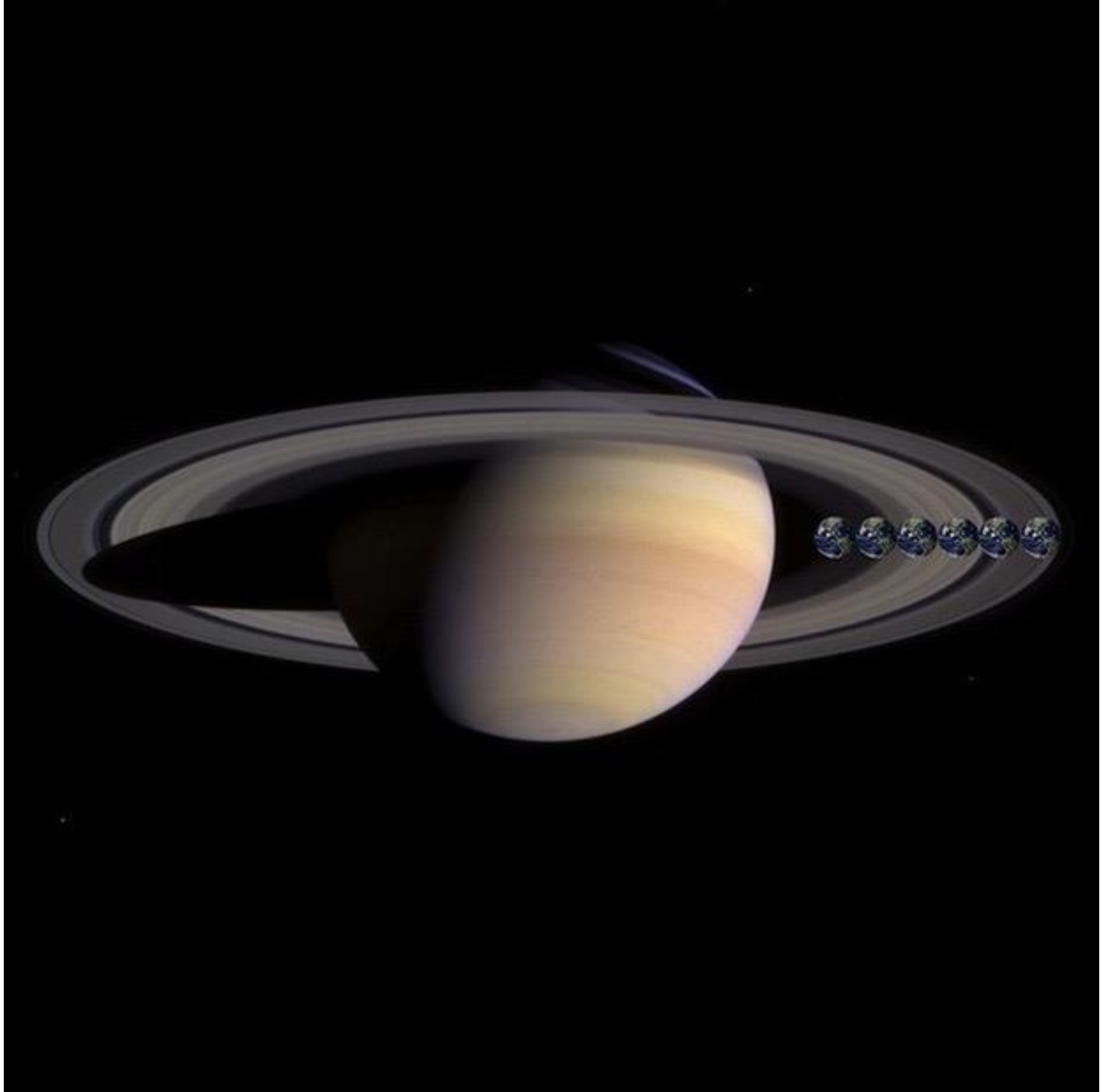
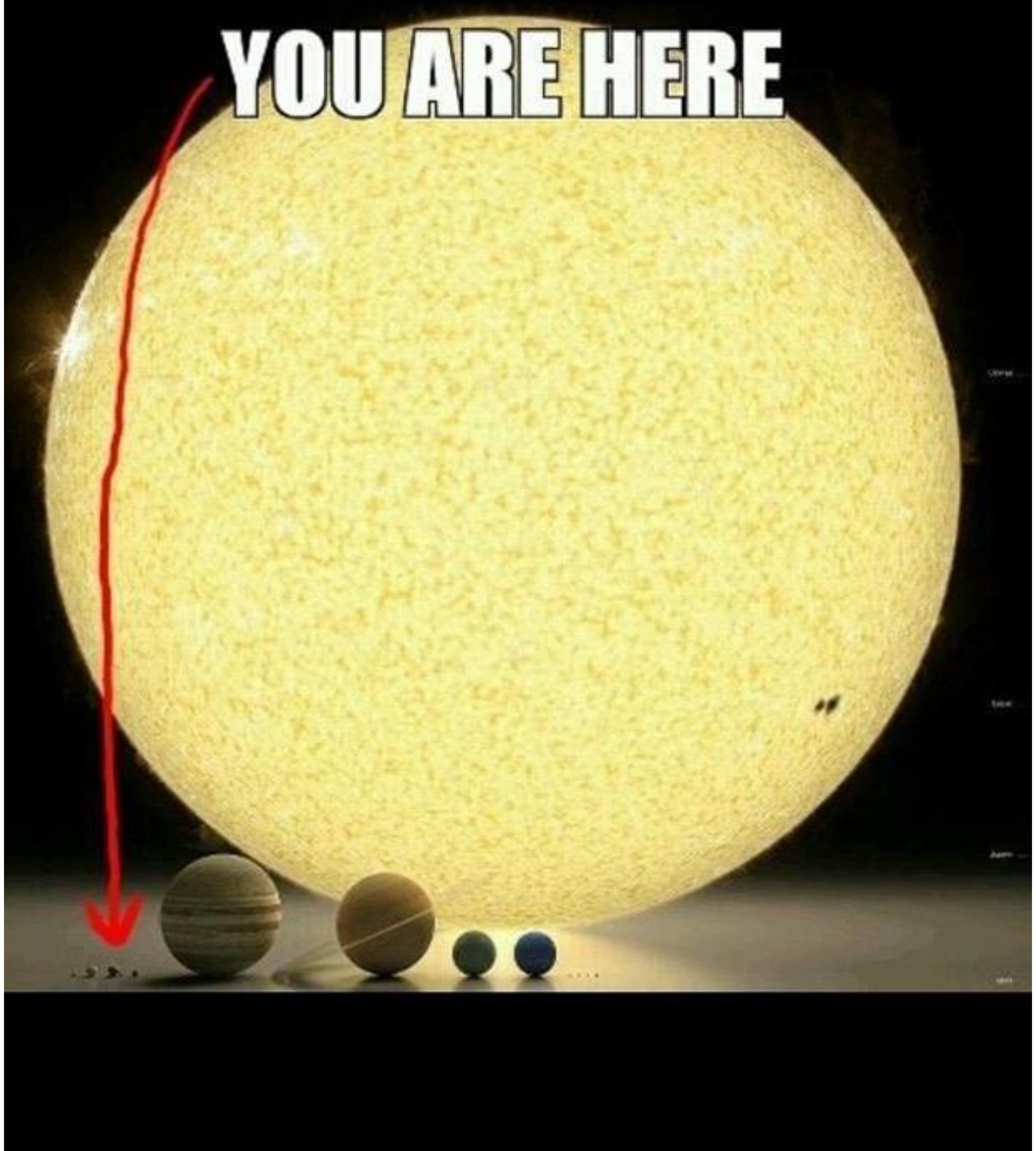
The Earth is a special place. It is the only place in the Universe where we are sure we can survive and thrive and, as far as we know, the only place where life has evolved.


Sun
Mercury
Venus
Earth
Mars
Asteroid Belt
Ceres
Jupiter
Saturn
Comets
Uranus
Neptune
Pluto
Makemake


Average distance between the Earth and the Moon - 384,400 km or 238,555 miles
...With about 8,030 km or 4,990 miles to spare




YOU ARE HERE


Solar image by John Brady

Talk about Earth

1. Special Planet
   Right environment, Temperature, Atmosphere, water

How it looked before,,,,,means how it evolved as seen today

Not only weather and climate but internal forces-

a. Endogenic forces (Volcanic activity , Earth Quakes, plate tectonics)
b. Exogenic forces (weathering/erosion and deposition by fluvial, glacial, wind etc..)

shaping of landscape...

you will be introduced to your home planet. The first part explores very briefly what is unique about the Earth when compared with the Moon and other terrestrial planets: Mercury, Venus and Mars.

The second part investigates the structure of the Earth: how it is divided into core, mantle and crust, and the evidence on which that division is based.

Finally, the lines of evidence concerning the composition of the Earth and its constituent layers are drawn together from various sources, such as meteorites and samples of the mantle.

Many things happening on earth (at different time scale)
Our aim is to –

1. Describe and analyzing the way the solid earth works....

2. Composition of the Earth and its constituent layers

3. Evolution of the Earth from a cloud of gas & dust via ocean of magma to a breathable atmosphere.

So,,,, we try to learn in the first part-

1. Introduction to the Home Planet—Earth
2. Comparison of Earth with moon
3. Structure of the Earth

Planet Earth is UNIQUE-

Most of the aspects are taken for granted-

Characteristics of the Earth-
Water + Oxygen

MARS- water locked in ice caps....
presence of water in the past
CO_2, N_2, atmosphere,,,,

VENUS- Thick atmosphere but CO_2 + SO_2
temperature intolerable

Mercury and Moon- Dry, no atmosphere

Earth Interacting Systems

ATMOSPHERE- Envelope of gases that surrounds the earth

HYDROSPHERE- Water on the planet includes all types – ocean, lake, rivers etc....

GEOSPHERE- solid Earth

BIOSPHERE- all forms of Life

We are interested in GEOSPHERE and how it interacts with atmosphere
Hydrosphere and biosphere...

CLASS-2

Surface Features-
THE MOON-

Apollo Missions in 1960 and 70’s found several pictures and described MOON to be as old as Earth ~4.4 Ga
Exceptional ------not because of its age....but size...

It is the largest satellite, if compared to the parent body...

GANYMEDE and CALLISTO – satellite of Jupiter
TITAN- satellite of Saturn
Slightly larger than the moon but much smaller to moon, if compared to the parental body
Phobos and Deimos are satellite of Mars but have been captured from Asteroid belt.

Moon has 2 different surfaces

1. Highland (elevated regions like continents)-
   Pale coloured, dense covering of Impact crater

2. Maria- (Latin for ‘sea’)- depressions like sea
   Darker flatter region with fewer crater

It has been found that crater are due to impact of meteorites and is proportional to the age of the surface

Means---- highlands are older than maria......

Radiometric dating suggests that highlands are ~4.4 Ga and Maria are ~3.8-4.2 Ga........confirming the above hypthesis..

Also maria is mostly basaltic in composition
Highlands- Anorthosite (rich in plagioclase feldspar~90%;
10% mafic minerals, uncommon rock on earth)

Hence-
Moon experienced intense meteoritic bombardment in its
Early history, later declined during maria formed.

What happened to other planets-

Mercury- appear similar to the moon with a highly cratered ancient surface

Mars- different surfaces of Mars appear similar to those of moon

Hence assuming a similar impact history to the moon, Mars has given ~3.8 Ga age, however, absolute ages are yet to known.

Venus- lower cratering density suggesting a much younger surface age

Impact crater on earth are rarely known as moon suggesting Young surface

Oldest terrestrial rock are almost 3.9 Ga old on earth
Ocean rocks < 200 Ma

The period of time on earth, between its formation at 4.55 Ga
And the age of the earliest rocks at earth is 3.9 Ga,,,is known as
"HADEAN"...

HADEAN records are obtained from other planets and
Meteorites...

Lack of terrestrial records during HADEAN is due to
Weathering process + erosion

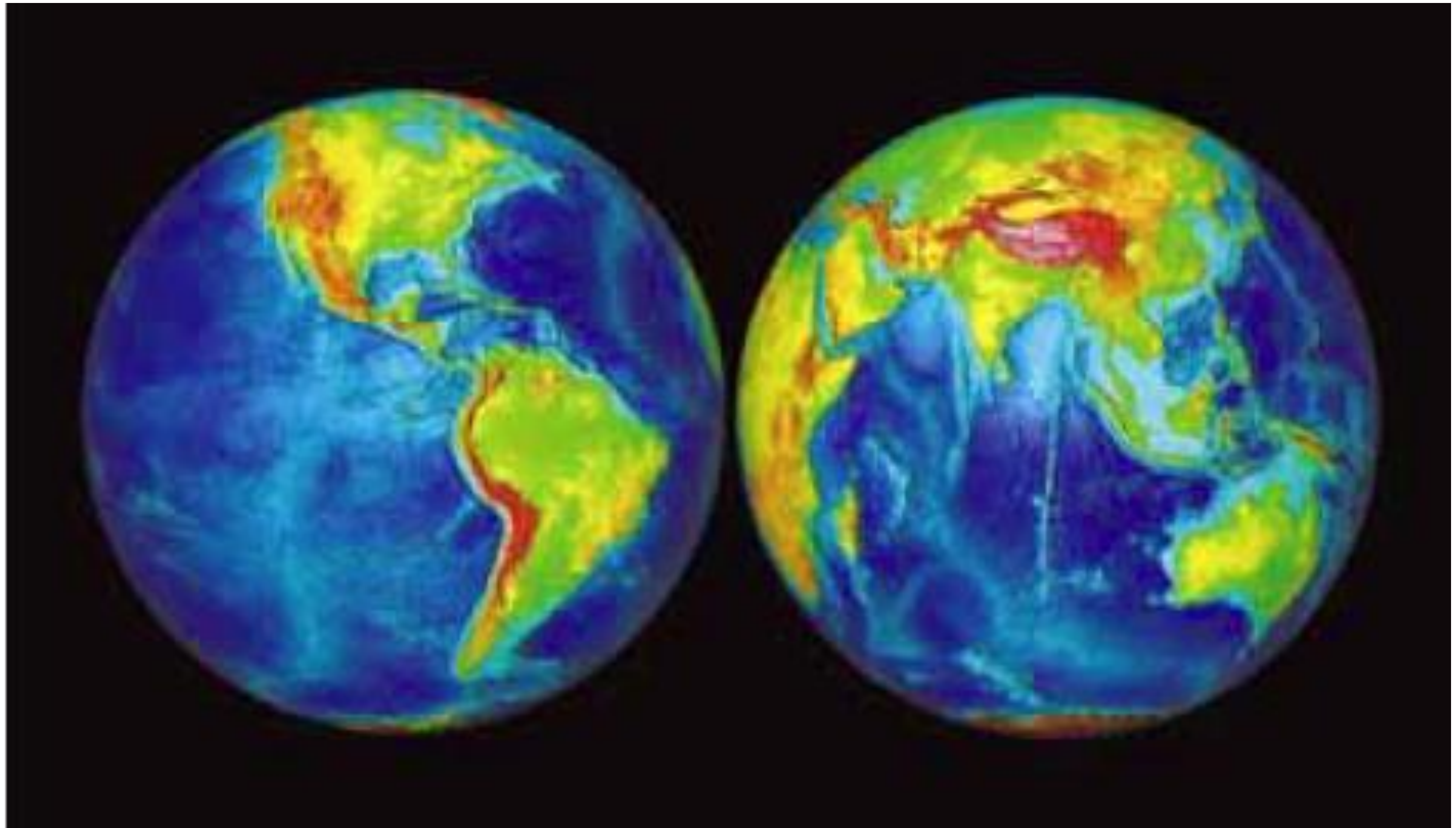
MARS is also having this but atmosphere is very thin and
Ephemeral nature preserves very old record of surface.

VENUS – no hydrosphere...so young surface of Venus needs
Another explanation...

Another concept was coined of heat holding in the core
Earth & Venus---same size....
Venus-....plate tectonic???
No

Topographic features of Earth and other planets

The surfaces of the Earth, Venus and Mars in false colours to denote the topography of each planet. Shades of blue represent depressions or basins with elevations below the mean altitude of the surface while shades of red denote highlands.



Earth

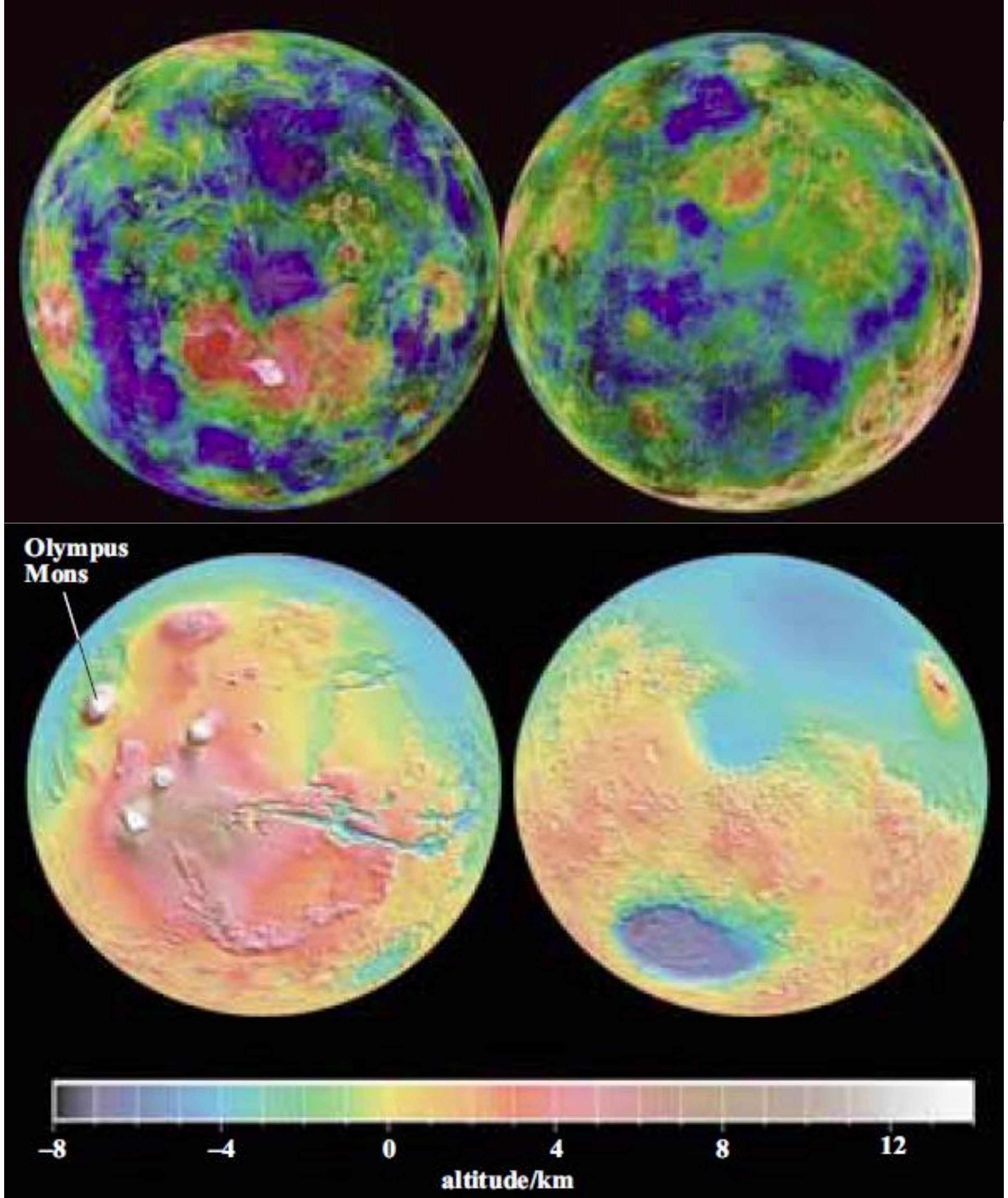


Figure 1.4 False-colour images of (a) Venus and (b) Mars, colour-coded to provide elevation information across the total topographic range of each planet. The blue (e.g. circular region in centre of left Venus image) denotes areas 1–2 km below the mean surface elevation (mse); green denotes 0–1 km below mse; yellow denotes 0–1 km above mse and red denotes areas 1–2 km above mse. Higher elevations are in shades of pink to white (small area below centre of left Venus image). The total topographic range on the image of Venus is much less than that of Mars. (NASA)

The structure of the EARTH-
Study of Earthquakes- Seismic waves,,,,seismology
Provide information on the structure of the earth..

Seismic waves-

1. P waves (body wave, compression and dilation, sound waves)
2. S waves (body wave, motion is in perpendicular direction of wave)
3. Love and Rayleigh – confined largely to the surface of the Earth and most destructive..... but they do not provide information about the interior of the Earth...... Hence not considered here.

The speed of a seismic wave is related to the physical properties of the medium through which the wave travels. In general, the wave speed is a function of two properties – the **elastic modulus** and the density – and is of the form:

$$\text{speed} = \left(\frac{\text{elastic modulus}}{\text{density}} \right)^{\frac{1}{2}} \tag{1.1}$$

For example- in air- speed of sound is 330 m/second
In steel- 6000 m/second
Young modulus- 9.2 x 10^10, density = 8.1 x 10^3 kg/m3

Elastic modulus is a measure of strain occurs in a material
When subjected to a given amount of stress, and is defined
as the ratio of stress to strain
BULK modulus relates to compressibility of a medium
SHEAR modulus relates how rigid the medium is

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

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

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:

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

- Can you see why υ_P is greater than υ_S?

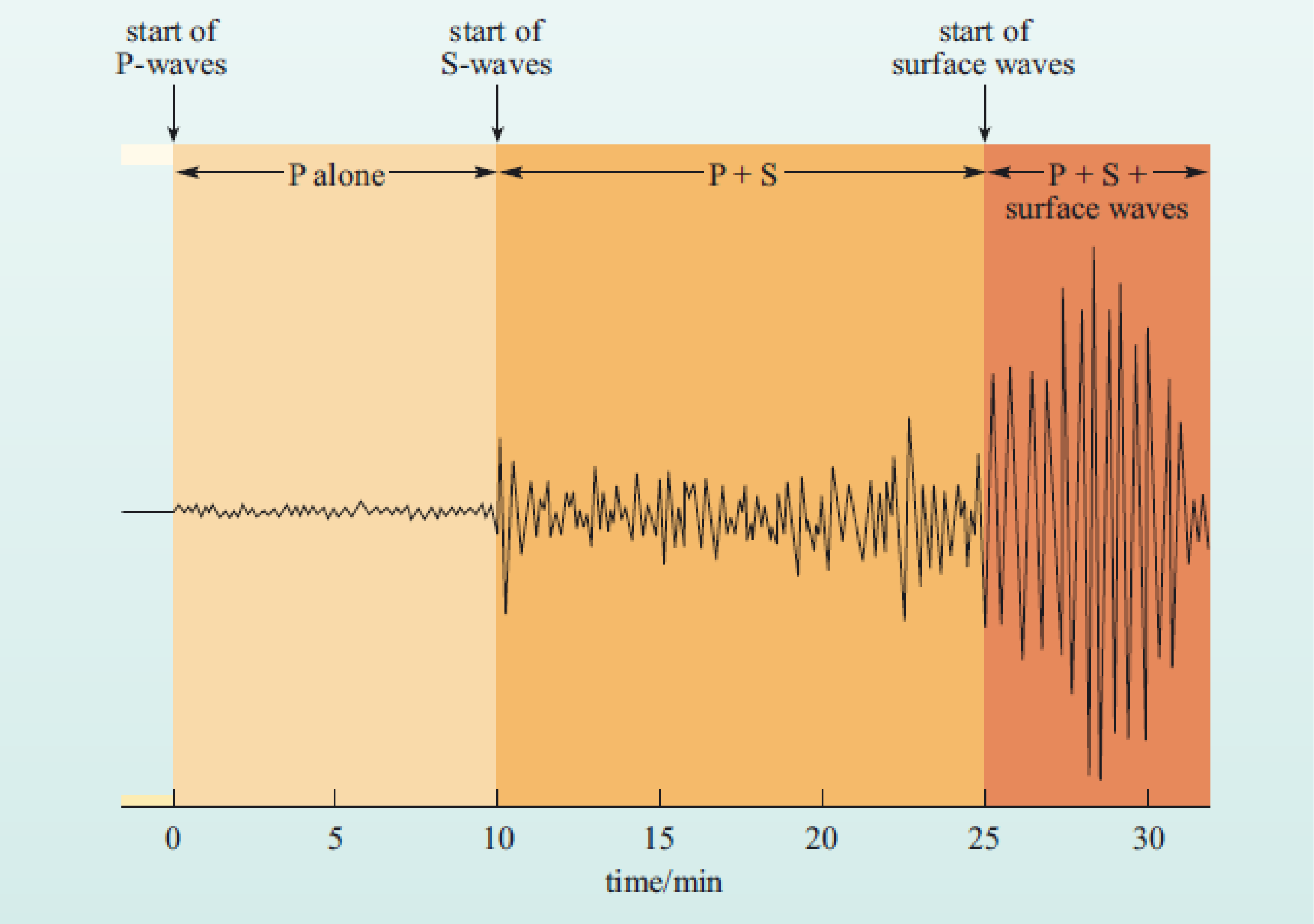
Can you see why v_P is greater than v_S?

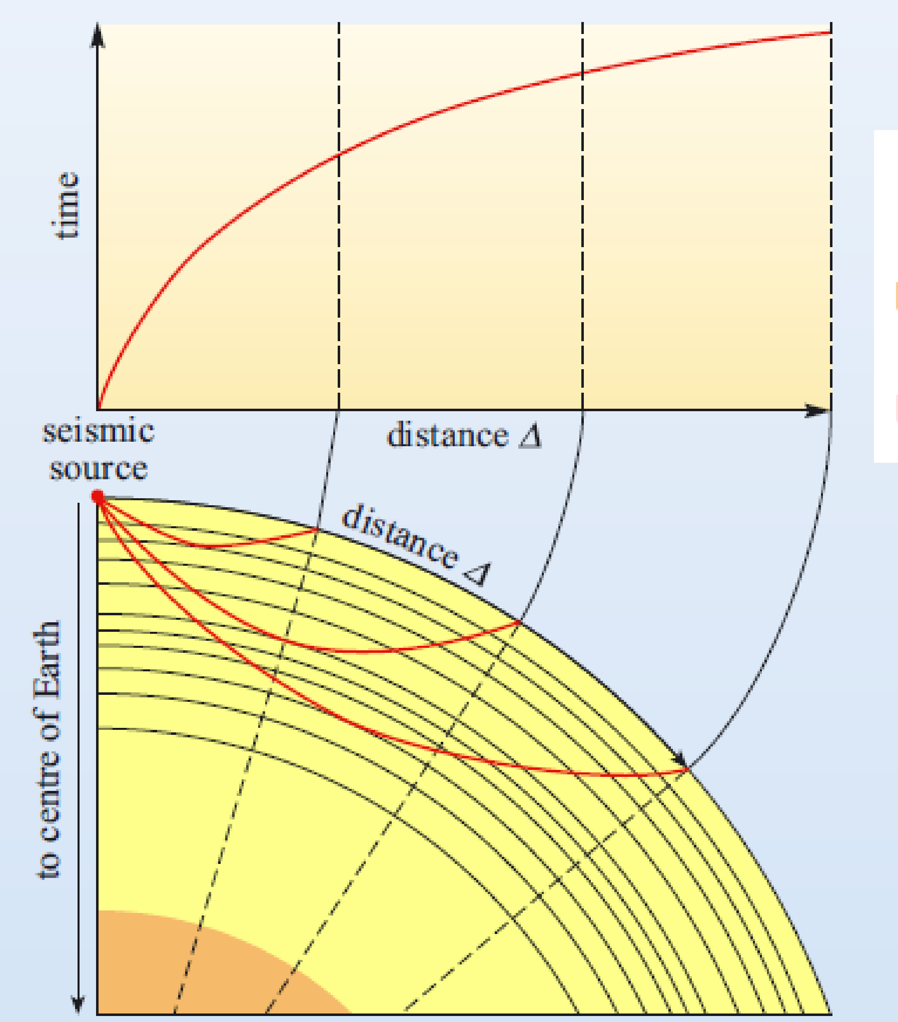
- Given that both K and μ are positive numbers, $K + \frac{4\mu}{3}$ is always greater than μ, so v_P will be greater than v_S.

- What do Equations 1.2 and 1.3 infer about P- and S-wave speeds in liquids of similar densities to solids?

Given that a liquid has no rigidity (it occupies the shape of any containing vessel), it cannot be deformed. Hence μ must be zero. Therefore, liquids cannot transmit S-waves. Also, for a given density, the P-wave velocity is lower in a liquid than in a solid.

Difference in the arrival time of P and S waves can be calculated
To compute the distance of earthquake from the seismogram,
an instrument to measure the earth quake waves.

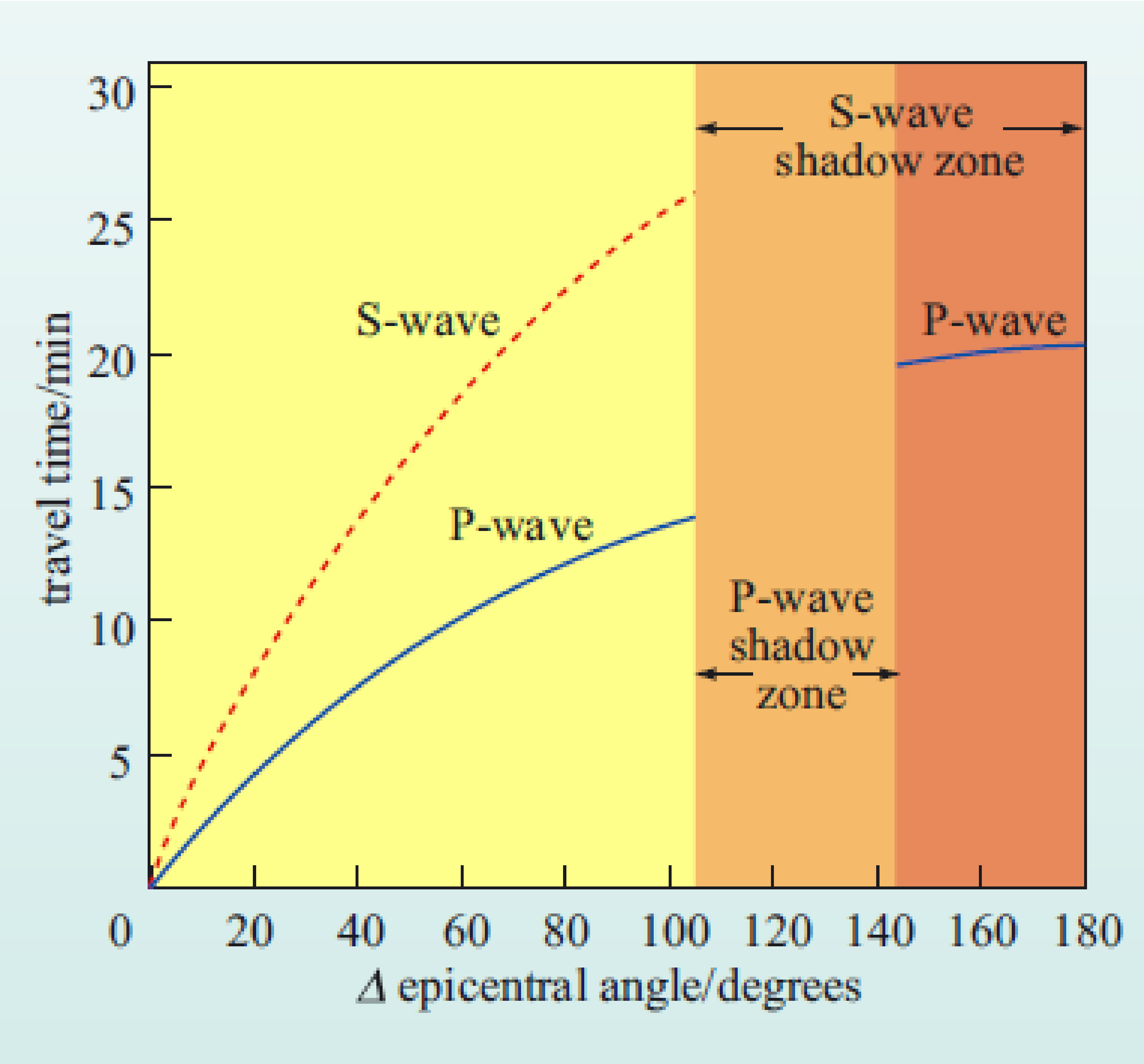




$\frac{v_1}{v_2} = \sin i$, i.e. $\sin r = 1$, meaning that $r = 90°$.

- What do you think happens to the wave path when it strikes a boundary at the critical angle?
- It is reflected rather than refracted.

- Imagine the Earth consists of a series of thin concentric shells each with a seismic velocity slightly greater than the one above. What will be the shape of the ray path?
- The ray path will be refracted to a shallower angle at each boundary and curve back towards the surface.

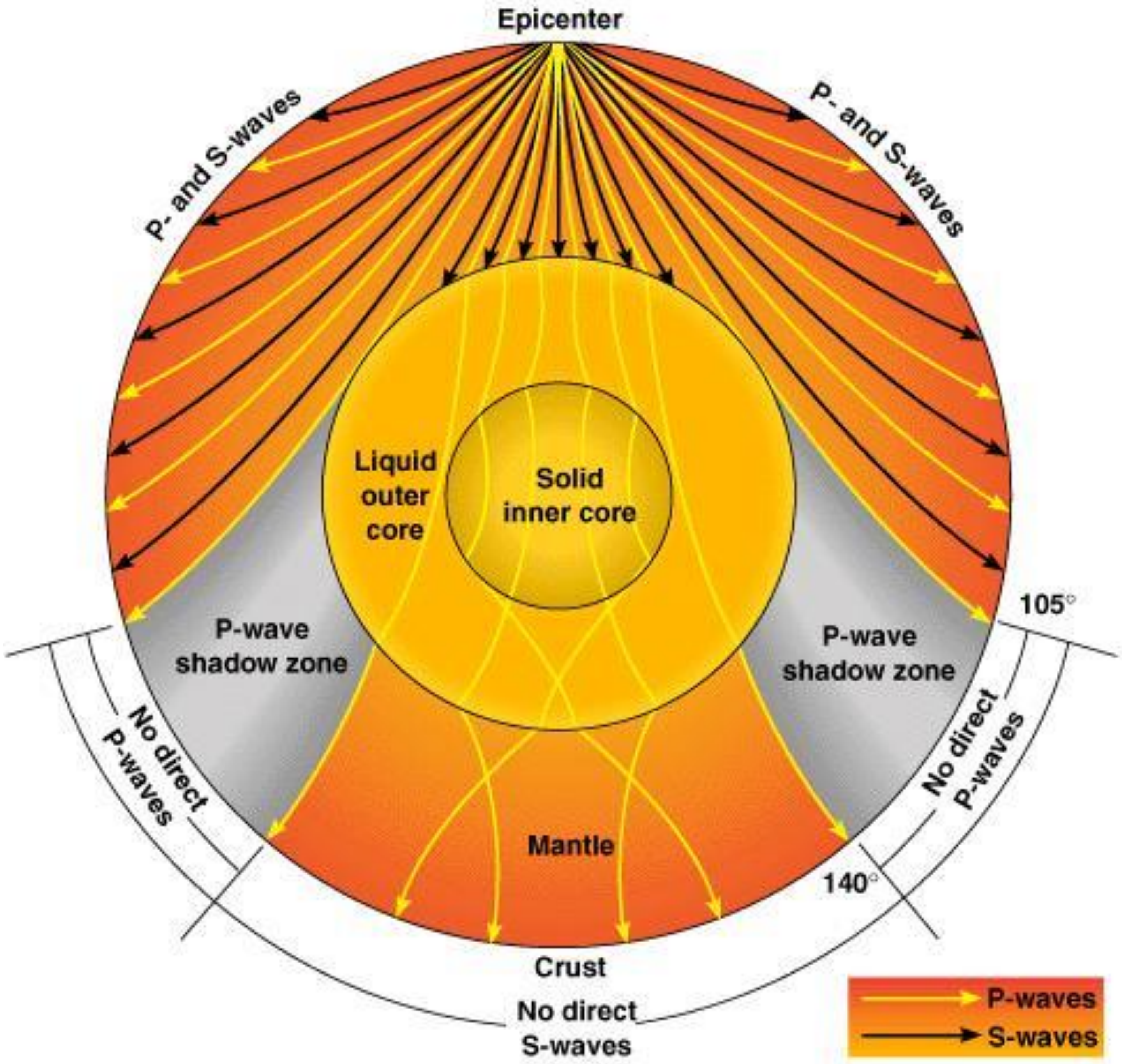


The distance of seismic receiver from a seismic source can be Measured in km but is usually expressed in terms of angle subtended At the centre of the Earth.

A plot of arrival times for different seismic Waves against delta (the epicentral angle) known as travel time curve

Arrival time of P wave disappear after the extended angle
Of 105o but it again re appear after 142o,,,,,however, S waves
Do not appear again after 105o.

The areas of the Earth's surface at these epicentral angles where there are no seismic waves are known as **shadow zones** and they are more or less the same for any earthquake, no matter where on the Earth it originates. This simple observation shows that the internal structure of the Earth must be radially symmetric.



Epicenter
P- and S-waves
P- and S-waves
Liquid outer core
Solid inner core
P-wave shadow zone
P-wave shadow zone
105°
No direct P-waves
No direct P-waves
Mantle
140°
Crust
No direct S-waves
P-waves
S-waves

all the seismologist has to go on are the arrival times of P- and S- waves and a reasonable knowledge of the seismic velocities of various rock types as they occur at the Earth's surface. The process of converting these data into information on the internal structure of the Earth is complex and was originally achieved using a laborious mathematical procedure known as **inversion**. (The

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

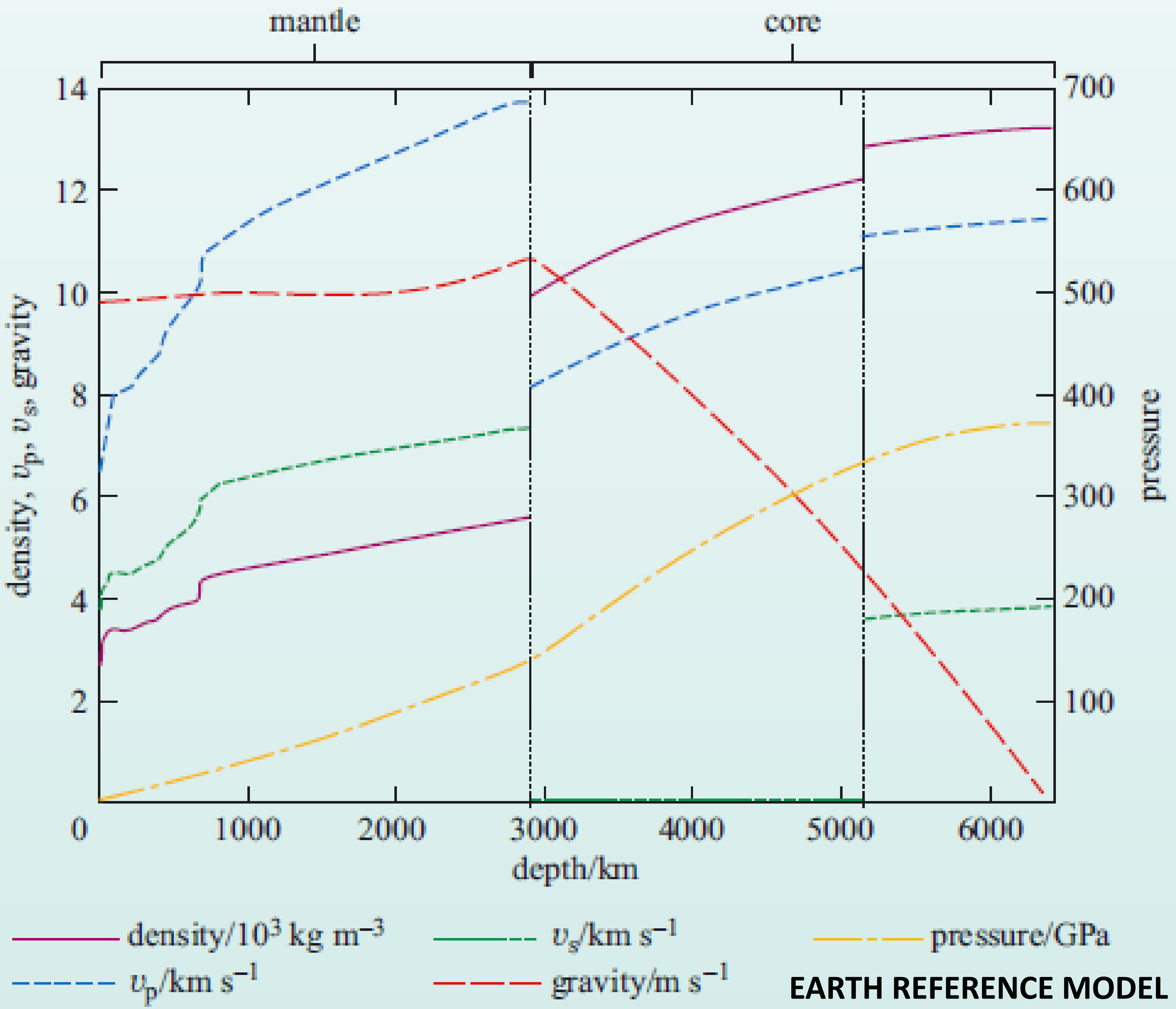
In 1923, Two geophysicist Adams and Williamsons formulated another Equation that eliminated K....considering how gravity and density would Change as a result of the mass of the overlying layers,,,,**self compression**

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

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.