Astronomy 405
Solar System and ISM

Lecture 8
The Moon

February 1, 2013

The Moon

Highland (lighter) littered with craters

Maria (darker) lava-filled craters

Lunation

The Moon

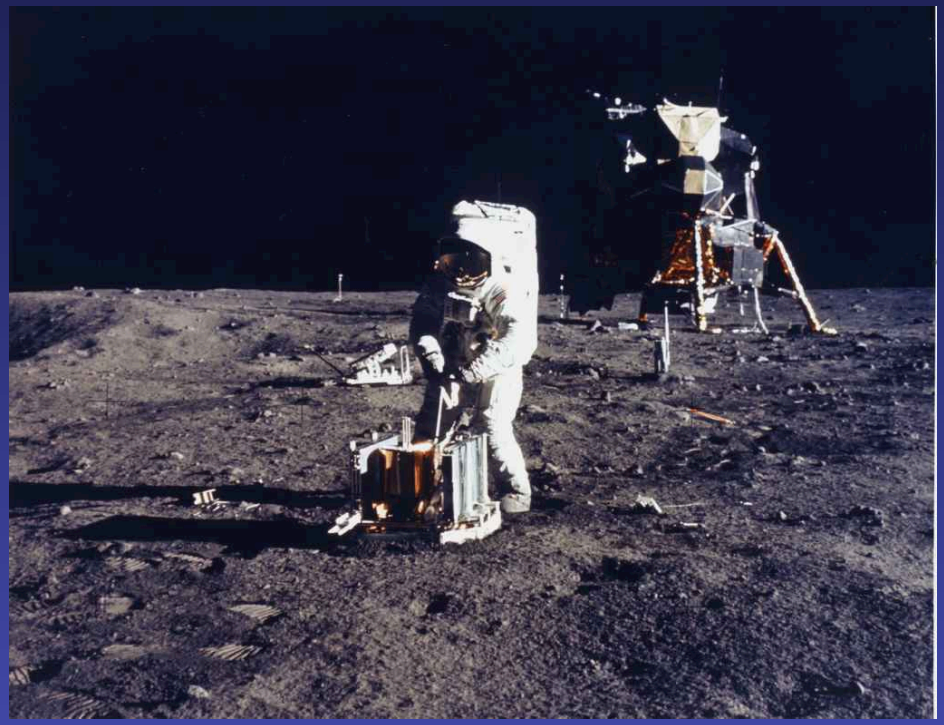
Small gravity => lost atmosphere => no weather
=> craters and footprints are preserved

Take only memory, leave only footprints. - NPS

BUT Apollo astronauts took rocks and soil from the Moon, and left seismometers on the Moon !!!

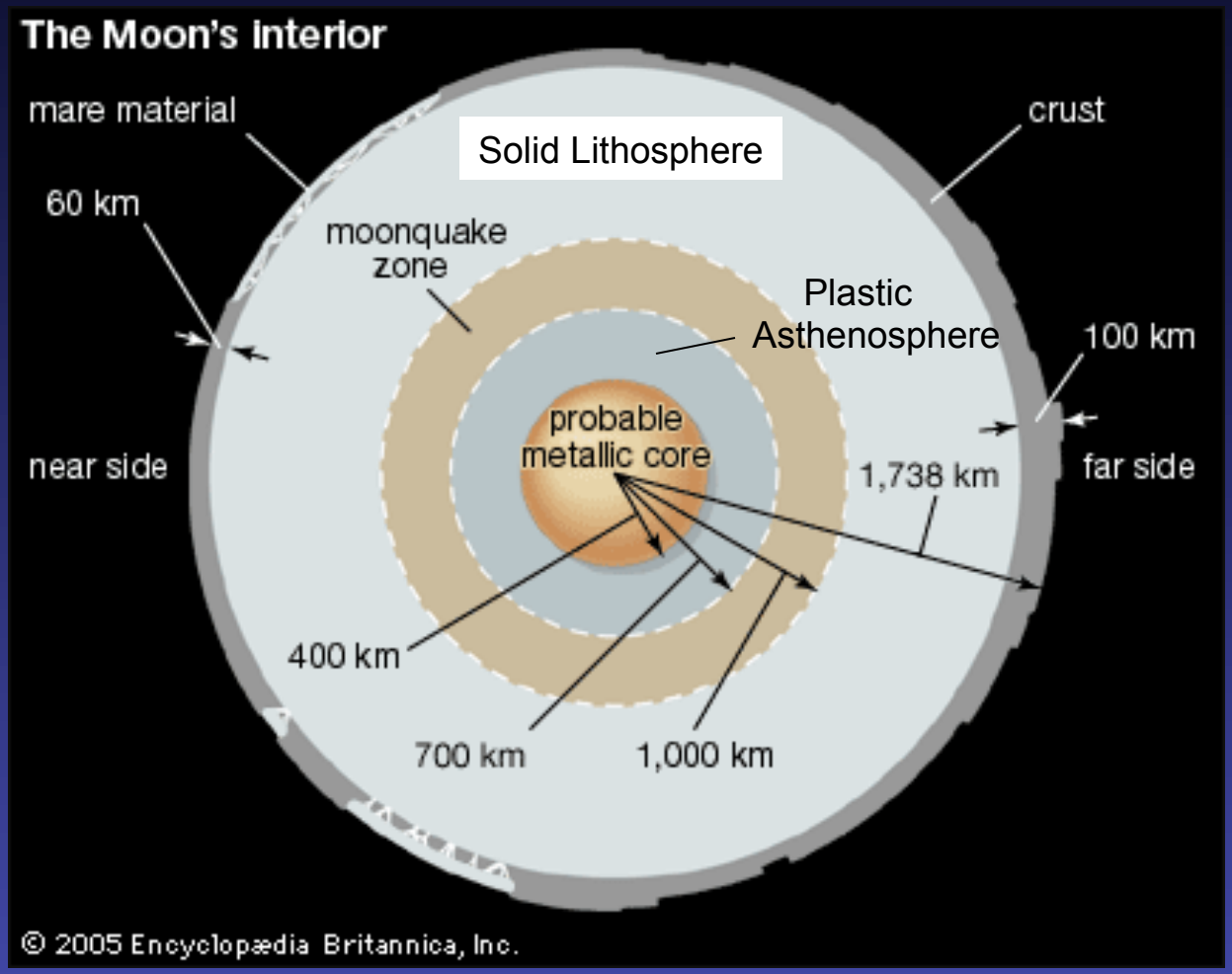
Caught in Action!!!

But…



The Moon's Internal Structure

Moonquakes were recorded. to determine the internal structure of the Moon.



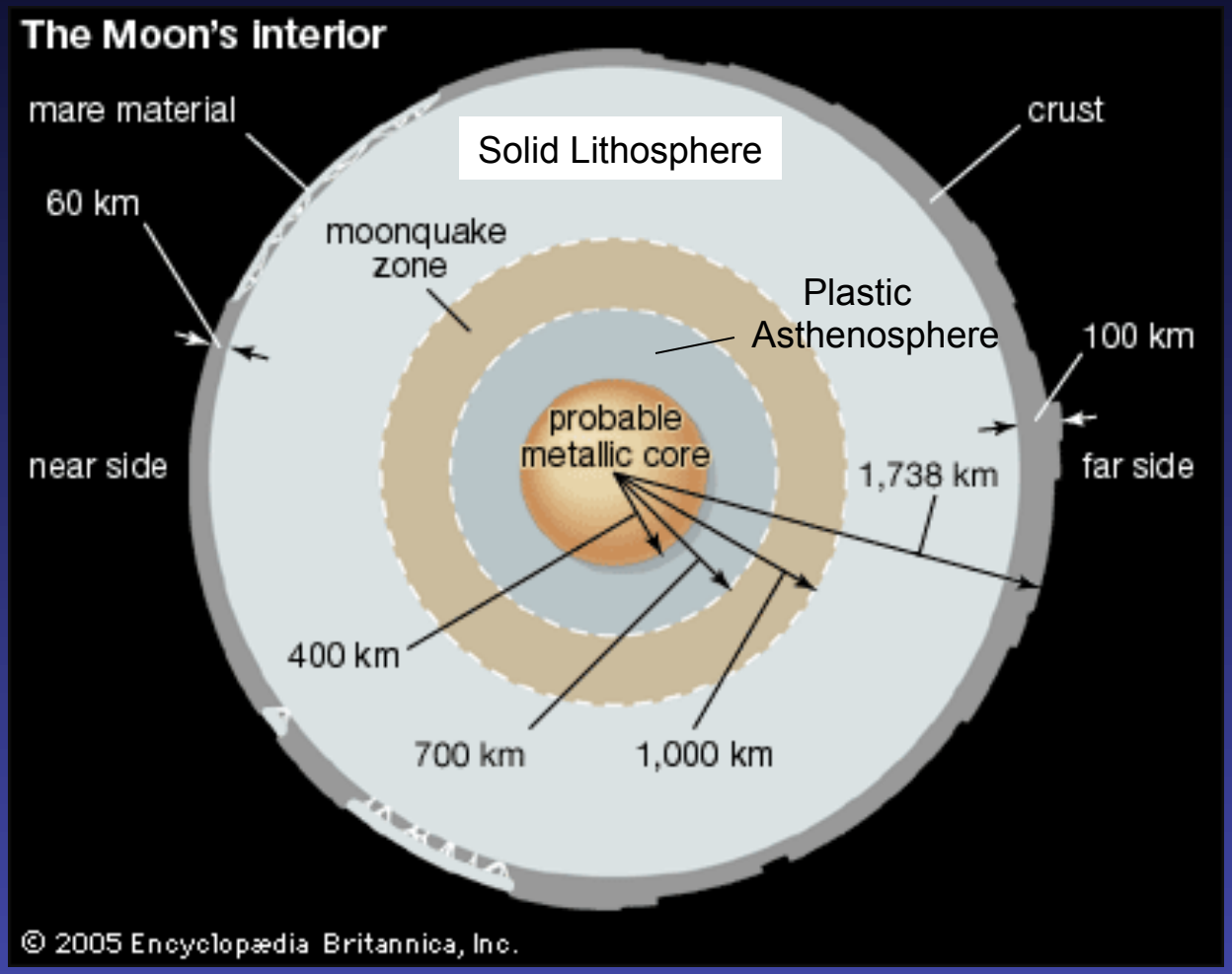
No tectonic activity.

Moonquakes originate from tidal strains caused by the Earth's gravitational pulls.

The Moon's ringing caused by meteorite hits were also detected.

The Moon's Internal Structure

Moonquakes were recorded. to determine the internal structure of the Moon.



The crust on the near side is thinner than the far side.

- only 1 mare on the far side.

- tidal forces caused the heavy side to permanently hang down toward Earth

The Moon

The Moon has no measurable global magnetic field.

Slow rotation, solid core => no magnetic dynamo

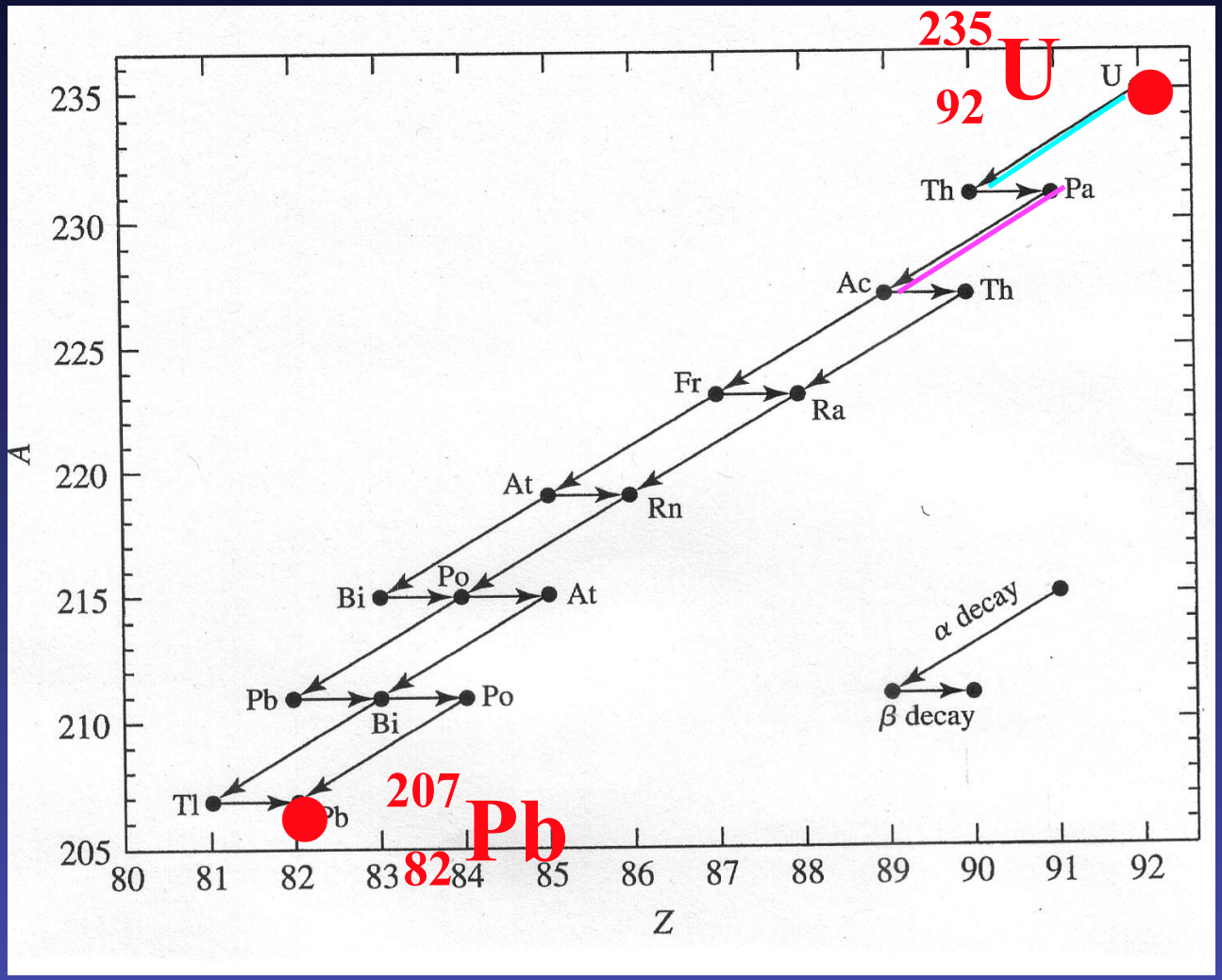
Apollo (1959-1970s) brought back 382 kg of surface rocks and soil.

Luna (Russian) brought back 0.3 kg of material.

Rocks are volcanic in origin. Basalts similar to those on Earth, rich in iron and magnesium and containing glassy structures characteristic of rapid cooling. However, lunar basalts contain no water and a lower percentage of volatiles relative to refractories.

Radioactive Dating

When rocks solidified, all isotopes were trapped inside.
Radioactive isotopes decay into stable isotopes.
Half-life of the slowest decay determined the decay rate.



7.04×10^8 yr

3.28×10^4 yr

α-particle
= He nucleus

β-particle
= electron

Radioactive Dating

Radioactive Parent	Stable Product	Half-Life (10^9 yr)
$^{129}_{53}\mathrm{I}$	$^{129}_{54}\mathrm{Xe}$	0.016
$^{235}_{92}\mathrm{U}$	$^{207}_{82}\mathrm{Pb}$	0.704
$^{40}_{19}\mathrm{K}$	$^{40}_{18}\mathrm{Ar}$	1.280
$^{238}_{92}\mathrm{U}$	$^{206}_{82}\mathrm{Pb}$	4.468
$^{232}_{90}\mathrm{Th}$	$^{208}_{82}\mathrm{Pb}$	14.01
$^{176}_{71}\mathrm{Lu}$	$^{176}_{72}\mathrm{Hf}$	37.8
$^{87}_{37}\mathrm{Rb}$	$^{87}_{38}\mathrm{Sr}$	47.5
$^{147}_{62}\mathrm{Sm}$	$^{143}_{60}\mathrm{Nd}$	106.0

Radioactive Dating

Isotope A decays into isotope B $A \rightarrow B$

The total number of atoms of A changes from $N_{A,i}$ to $N_{A,f}$ after some time t :

$$N_{A,f} = N_{A,i}\ e^{-\lambda t}$$

$$\frac{N_{A,f}}{N_{A,i}} = 1/2 = e^{-\lambda \tau_{1/2}}$$

$$\Rightarrow \lambda = \frac{\ln 2}{\tau_{1/2}}$$

$\tau_{1/2}$ is the half-life, and λ is the decay constant

Radioactive Dating

Isotope A decays into isotope B $A \rightarrow B$

The total number of atoms of A and B remain the same.

$$N_{A,i} + N_{B,i} = N_{A,f} + N_{B,f}$$

$$N_{A,f} = N_{A,i}\ e^{-\lambda t}$$

$$N_{B,f} = (e^{\lambda t} - 1) N_{A,f} + N_{B,i}$$

We can measure $N_{A,f}$ and $N_{B,f}$ but not $N_{B,i}$

We also do not know if $N_{A,i}$ was uniform in the rock.

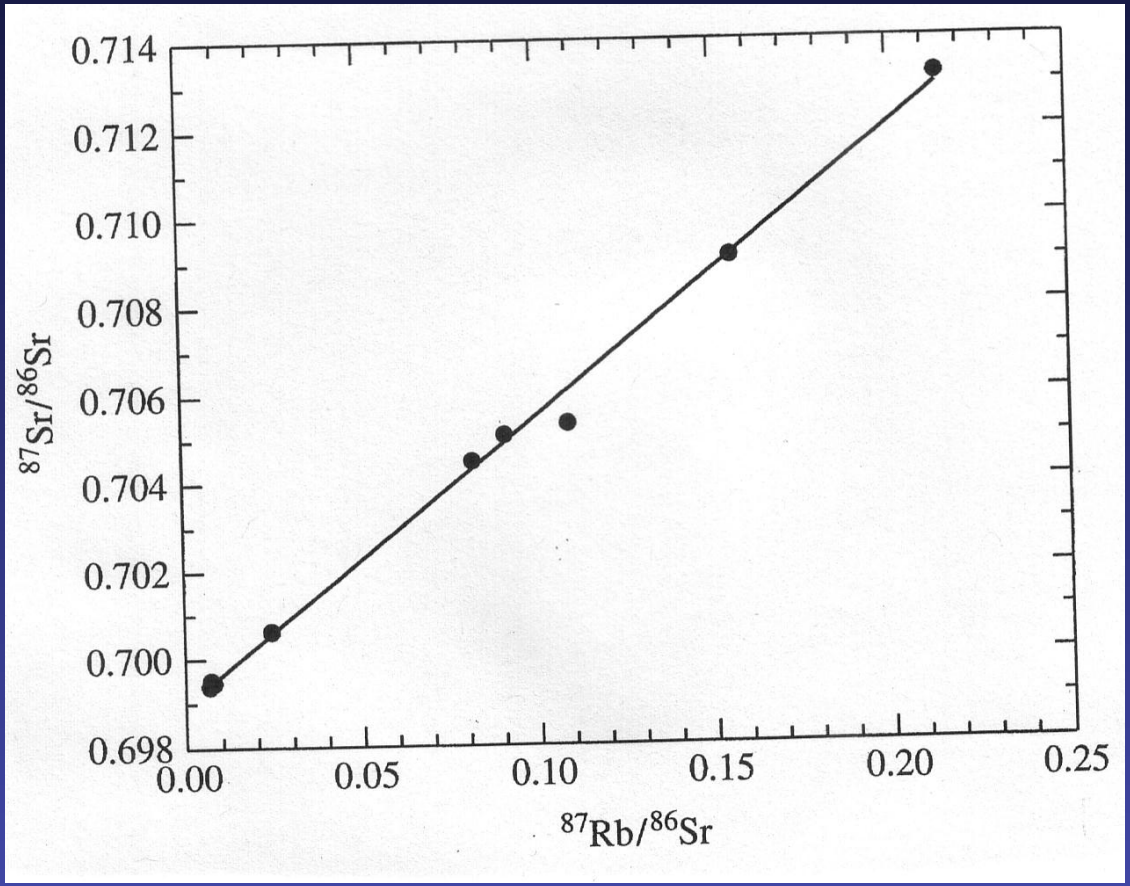
Therefore, measure stable isotope C that is chemically identical to B, and work with isotope ratios.

$$N_{C,f} = N_{C,i} = N_C$$

Ra dioactive Dating

$$N_{B,f} / N_C = (e^{\lambda t} - 1) (N_{A,f} / N_C) + (N_{B,i} / N_C)$$

Example: A = ^{87}Rb, B = ^{87}Sr, C = ^{86}Sr



Half-life = 47.5 Gyr

$\lambda = \ln 2 / 47.5\times10^{9}$
$= 0.0146\times10^{-9}$ yr^{-1}

Slope = 0.0662
$= e^{\lambda t} - 1$

$\Rightarrow t = 4.39\times10^{9}$ yr

The Formation of the Moon

Fission model (daughter model)

Earth was spinning too fast and part of it was torn off to form the Moon.

BUT, spin axes are not aligned, no water on the Moon.

Co-creation model (sister model)

Moon formed at the same time, in an accretion disk around the Earth.

BUT, lunar rocks had different compositions.

Capture model (wife model)

Moon was formed elsewhere, but was captured by Earth.

BUT, compositions are too similar, and needs a third body to brake the Moon's motion.

Collision Model
(proposed by Hartmann and Davis, simulated by Cameron and Benz)

An intruder ~ twice the mass of the present-day Mars collided with the Earth 4.6 Gyr ago.

Explains:
Moon's lack of Fe,
Similar O-isotope ratios
Earth's uncompressed mantle