Mysteries of the Moon

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"Sky and Telescope" Cruise, 2010

- Why is there only one planet with an Earthlike Moon?
- Why is the Moon about the same apparent size as the Sun ?
- Why is the nearside different from the far side?
- Why does the moon have magnetic rocks?
- Why are there moonquakes?
- Is the moon dry?
- Anything you would like explained?

Q. Why is there only one planet with an Earthlike Moon?

- What about Mercury , Venus and Mars?
- What about the satellite systems of the giant planets?

A. A moon forming event for Earth is quite likely. Mercury is too close to the Sun (and also small). Mars is too small to have a large moon. The giant planets had disks of gas from which “miniature solar systems” could form. So the real puzzle is Venus.

Why Venus has no Moon

- Being closer to the Sun is not a sufficient explanation (though solar tides do matter)
- The slow retrograde rotation of Venus begs the question, but should form part of the answer.
- If a moon forming event for an Earth sized planet is likely then the real question becomes *How did Venus lose it's moon?*
- I have studied this question with two Caltech undergrads: Alex Alemi (now grad student at Cornell) and Nick Butler (current junior at Caltech

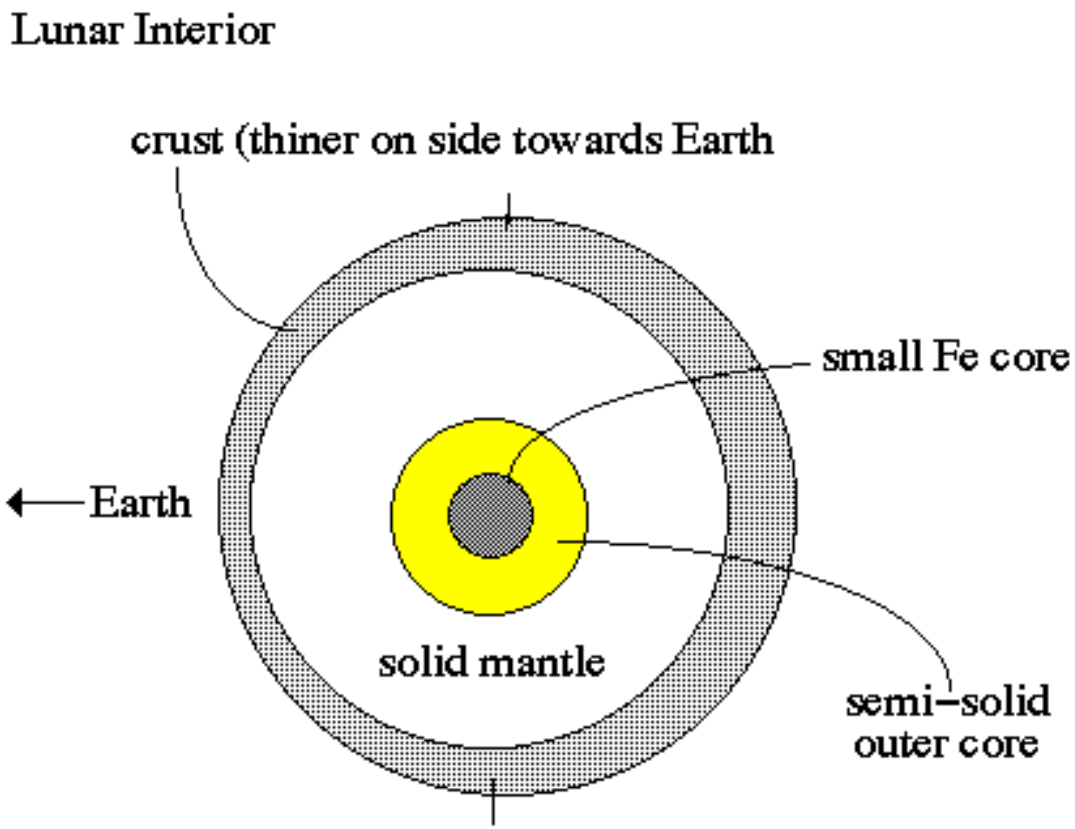
Two Possible Scenarios

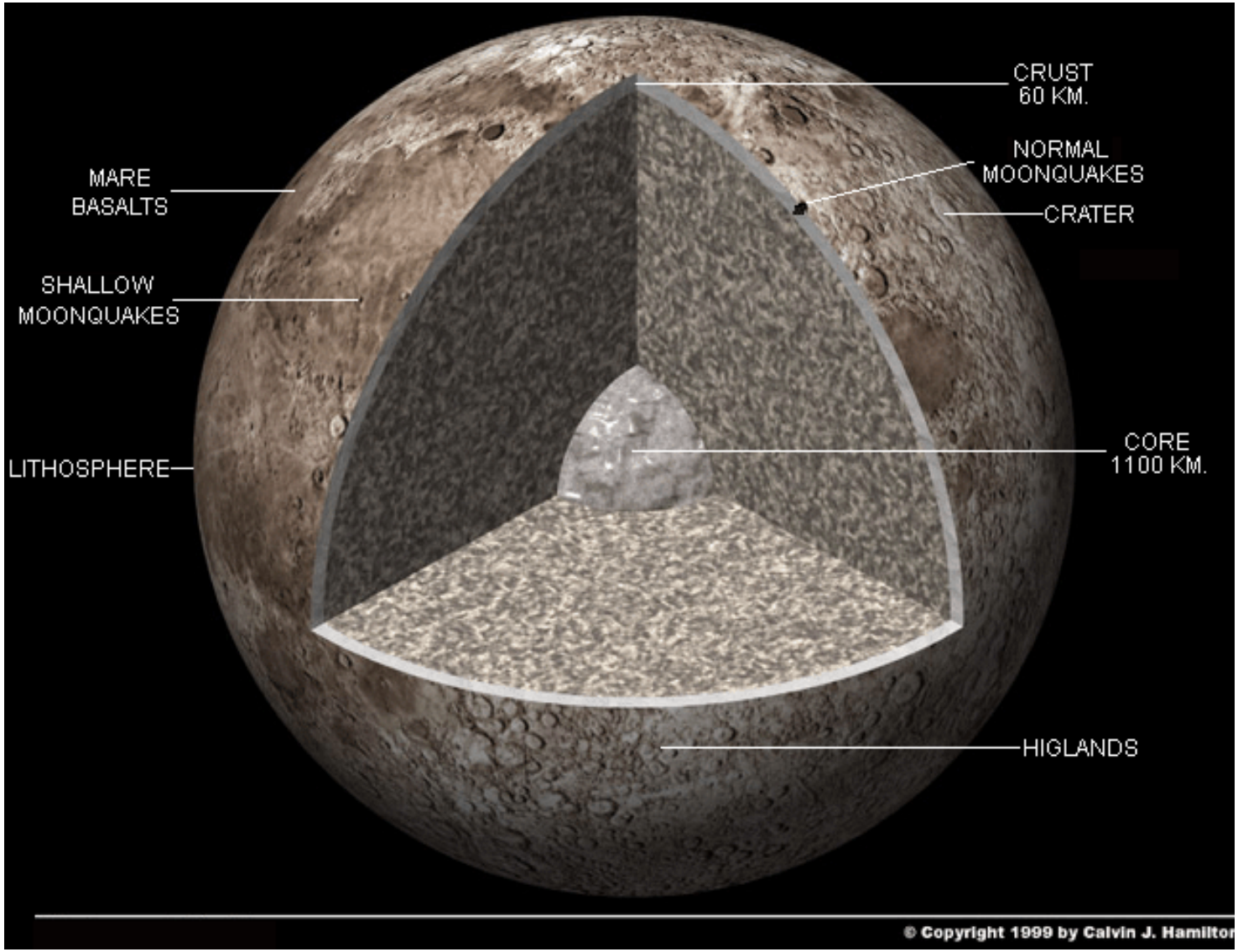
- Scenario 1: Venus moon formed; will spiral outward (just like Earth's moon) but then a collision on Venus reduced or reversed Venus spin so that the tidal evolution reversed… Moon crashed into Venus (in the first 100 Ma or solar system history)
- Scenario 2: As above but the moon is scattered to an escape trajectory by a marauding (Mars sized) interloper. It will then subsequently crash into Venus or something else (or even get ejected from the solar system.)

Why is the Moon about the same Apparent size as the Sun ?

- The close similarity must be a matter of chance but….
- The approximate similarity is to be expected because
  - The size of our Sun in the sky is about right given the need to have ~300K at Earth orbit (assuming the sun is a rather ordinary main sequence star)
  - The apparent size of the moon is affected by tidal evolution and that depends on the mass (& therefore size)… a smaller moon stays closer (appears proportionately larger) and a larger moon goes further.

Internal Structure




CRUST
60 KM.
NORMAL
MOONQUAKES
CRATER
MARE
BASALTS
SHALLOW
MOONQUAKES
LITHOSPHERE
CORE
1100 KM.
HIGLANDS
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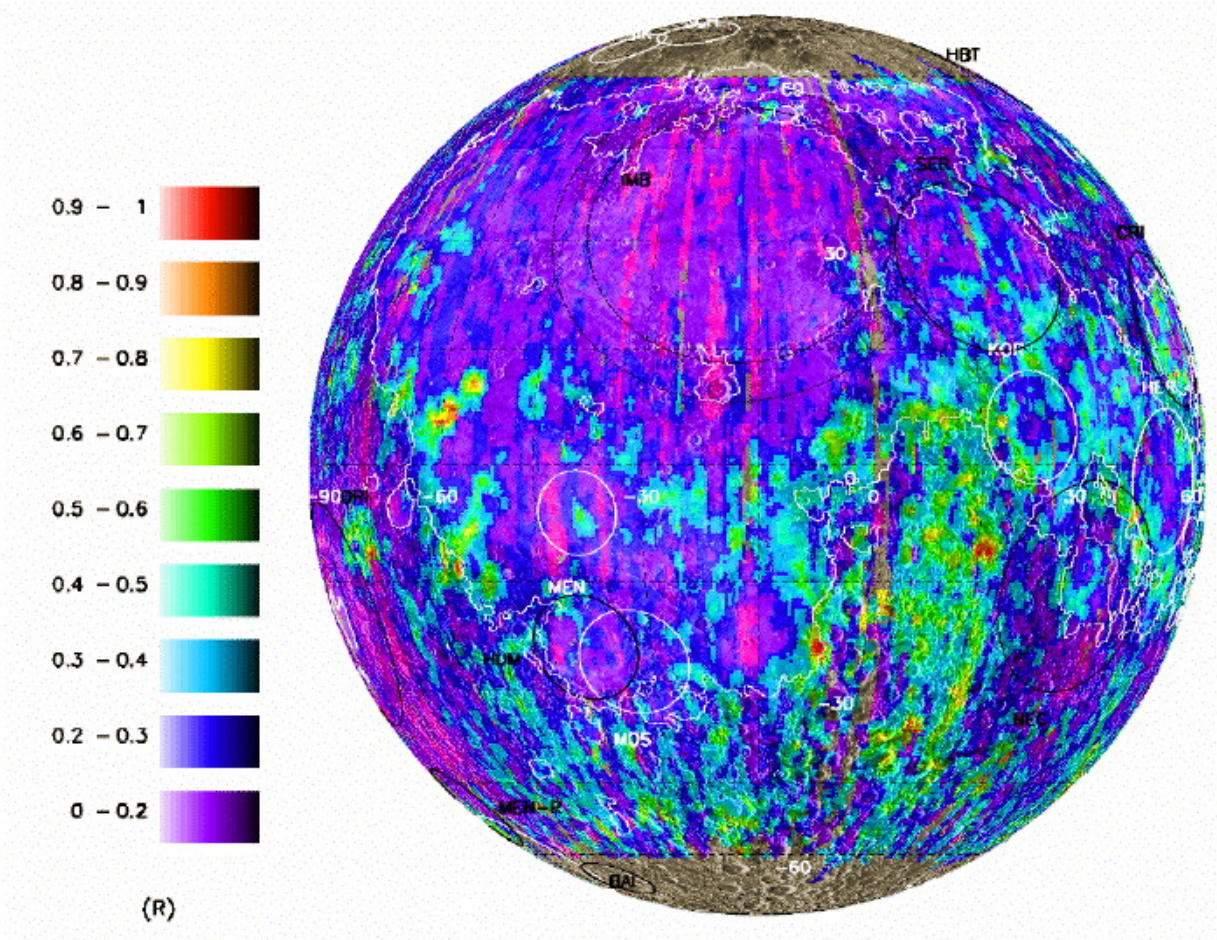
But why is the Farside crust thicker??

- We don't know!
- It might have something to do with early tidal heating and how the crust thickened over a magma ocean
- It might be a fundamental asymmetry at depth . Not just the crust. South Pole Aiken Basin is largely devoid of Mare basalt and yet it has excavated to the mantle.
- Hemispheric asymmetries exist elsewhere.. e.g., Mars has different north and South hemispheres. Earth also asymmetric (but not ancient structure).

Moonquakes

- Many Moon quakes are triggered by tides.
- Important because they tell us about internal structure
- They can also be triggered externally. Even small impacts (producing a flash of light detectable from Earth) can trigger detectable quakes.
- This motivates advocacy for sending a single seismometer (much better than the Apollo instrument) to the moon. A pair would even be better but a network is not mandatory.

Lunar Magnetism (Crustal, Near Side)



Four Categories of Fields

- Large Fields , predominantly dipolar

  Earth, Ganymede, Jupiter, Saturn, maybe Mercury
- Large Fields, predominantly non-dipolar

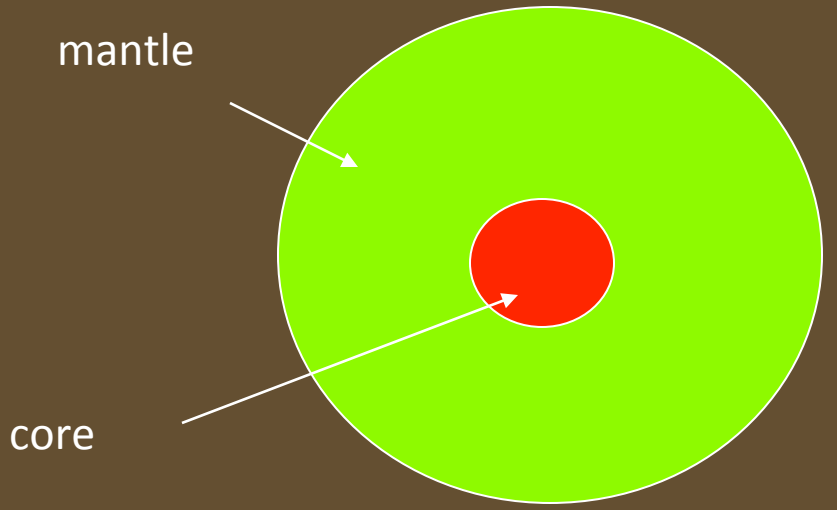
  Uranus, Neptune
- Small Fields arising from Crustal magnetism; possible past dynamos

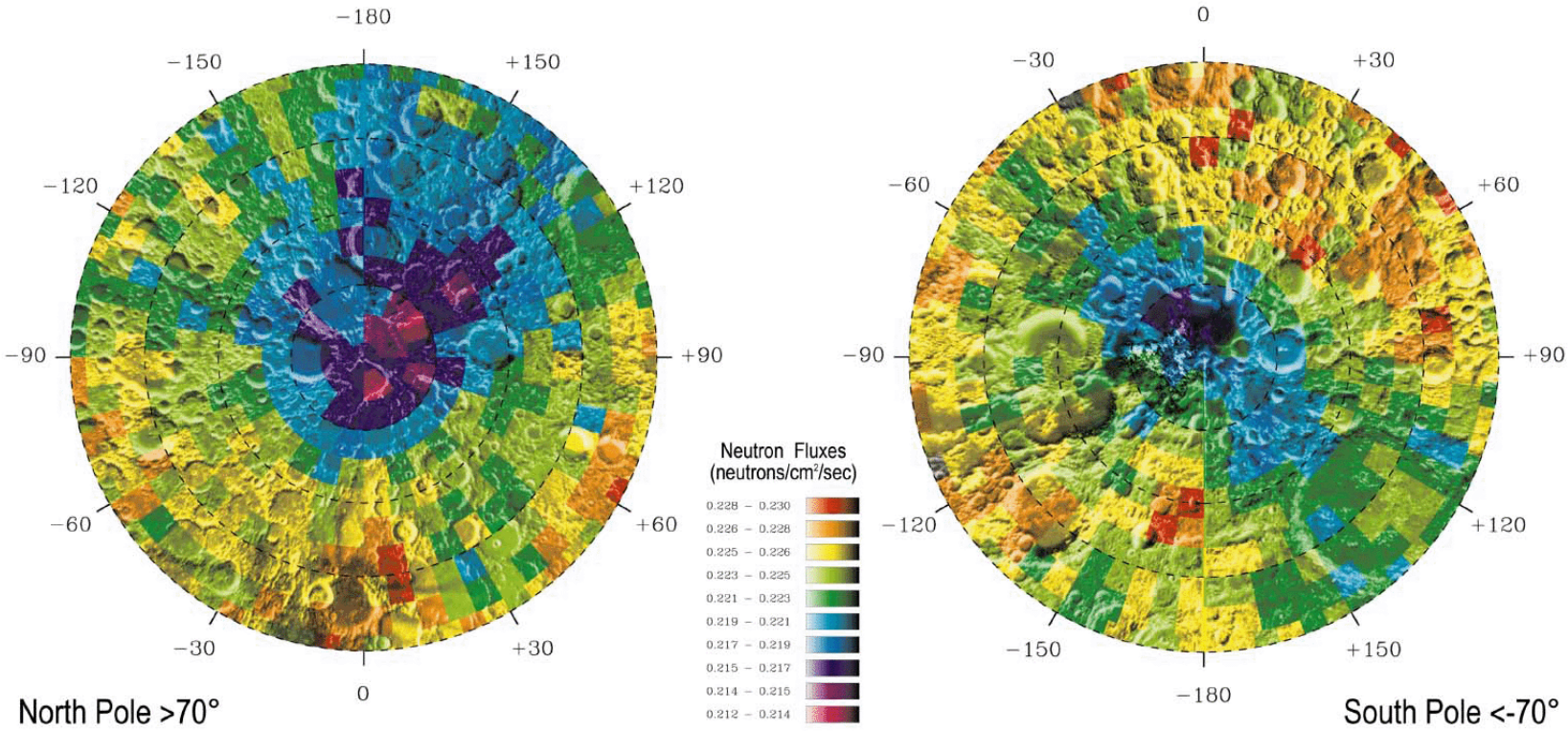
  Moon, Mars, Venus?
- Small fields arising from induction (time-varying external field)

  Io?, Europa, Callisto

Moon

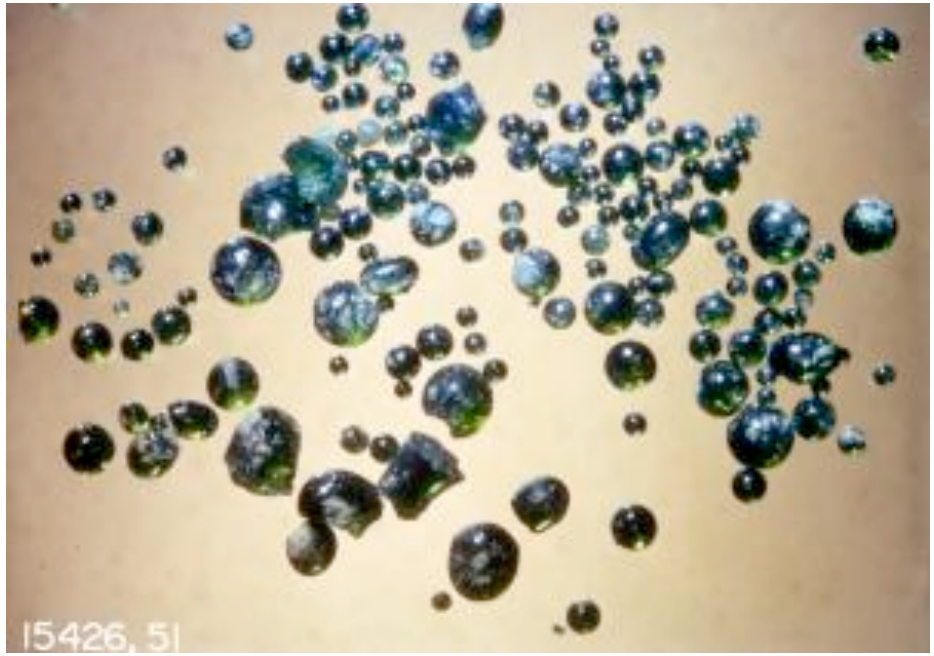
1. Small, partly liquid core suggested by response to 18.6 yr nutation. Also consistent with moment of inertia, EM induction and geochemistry.
2. No global dipole but has localized magnetization, especially at the antipodes of impact basins (suggesting a role for impacts and acquired > 3Ga ago.
3. A possible special case… mechanically driven dynamo?




−180
−150
+150
−120
+120
−90
+90
−60
+60
−30
+30
0
North Pole >70°
Neutron Fluxes
(neutrons/cm²/sec)
0.228 – 0.230
0.226 – 0.228
0.225 – 0.226
0.223 – 0.225
0.221 – 0.223
0.219 – 0.221
0.217 – 0.219
0.215 – 0.217
0.214 – 0.215
0.212 – 0.214
0
−30
+30
−60
+60
−90
+90
−120
+120
−150
+150
−180
South Pole <-70°

Water *Inside* the Moon?

- There is a lot of water inside Earth (a glassful per ton)
- There is water inside volcanic glasses from the moon. (But a factor of ten less).
- Delivered by impacts?



- Why is there only one planet with an Earthlike Moon?
  - Partly chance (Venus lost its moon)
- Why is the Moon about the same apparent size as the Sun ?
  - Partly chance but also understandable from basic physics
- Why is the nearside different from the far side?
  - Lowest energy state. But the way that they differ is not understood.
- Why does the moon have magnetic rocks?
  - Ancient dynamo because core and mantle rotate separately
- Why are there moonquakes?
  - Tides (but also the moon is not completely dead)
- Is the moon dry?
  - Controversial, but impacts (e.g., comets) might deliver water
- Anything you would like explained?