Today's Topics

Monday, September 28, 2020 (Week 6, lecture 17) – Chapter 8.

A. Earth as a Planet

B. Interior of Earth

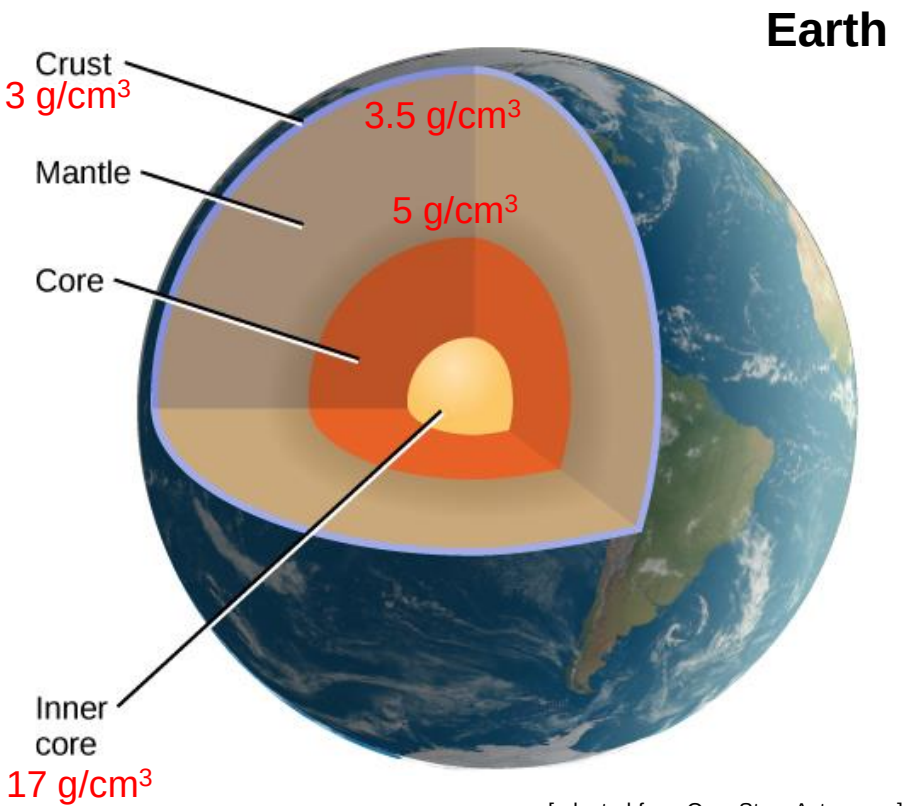
C. Magnetosphere

Earth as a Planet

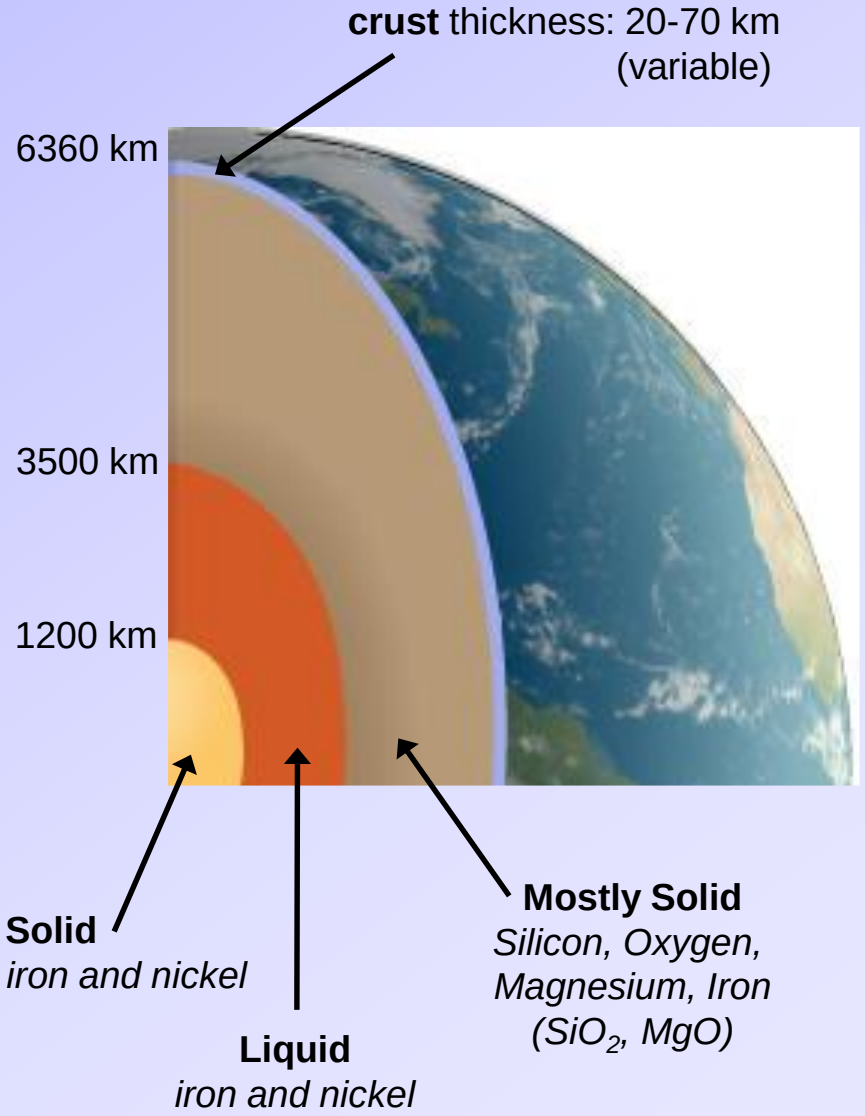
- Interior of Earth
  - → Geology
- Magnetosphere
  - → Aurora.
- Atmosphere
  - → Life's effect on Earth.
  - → Greenhouse effect.
- Asteroids impacts

Earth as seen from Apollo 17

Earth's Interior



[adapted from OpenStax: Astronomy]



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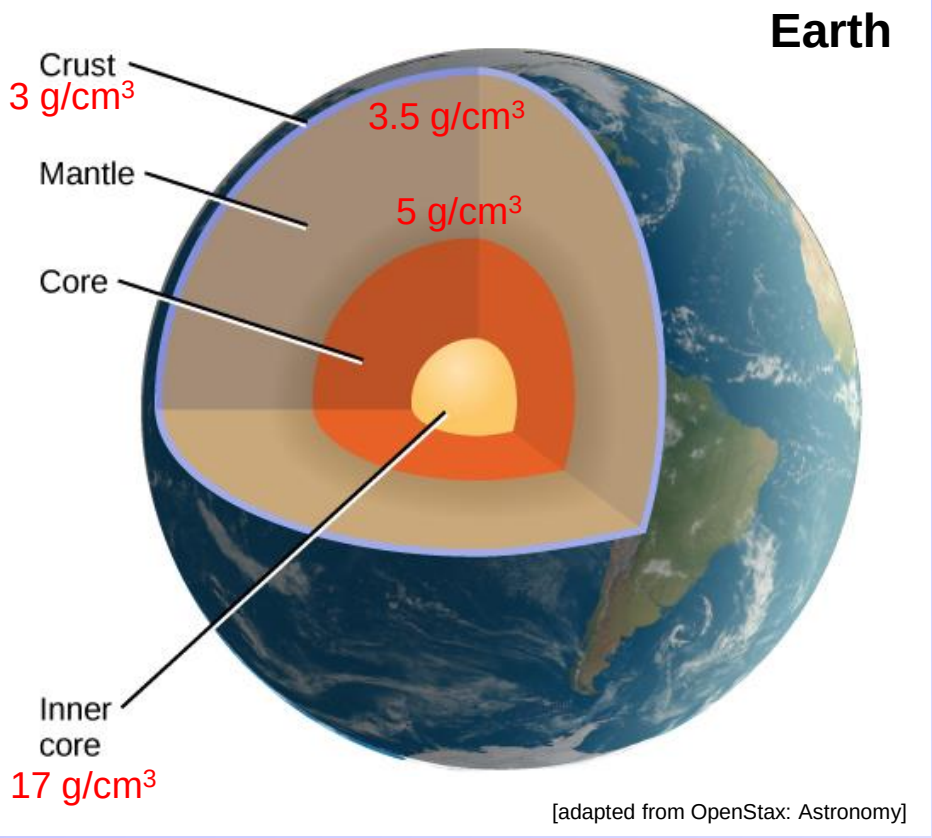

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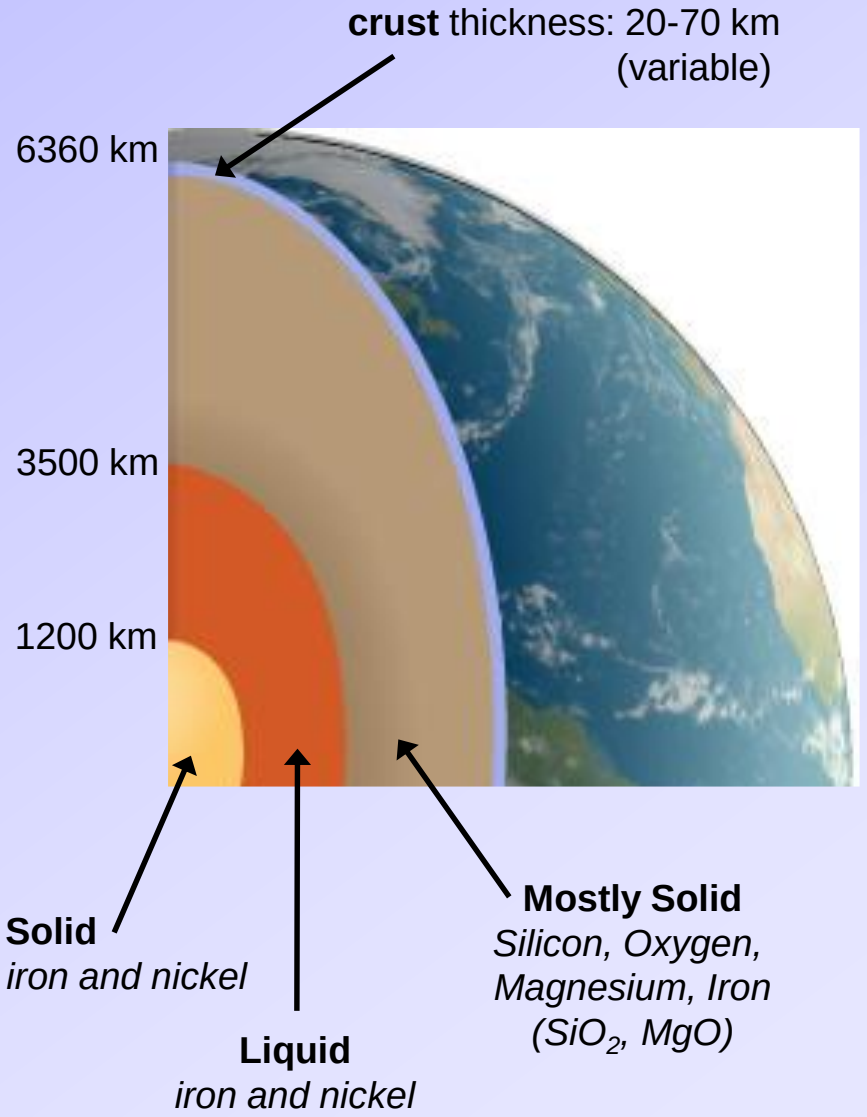
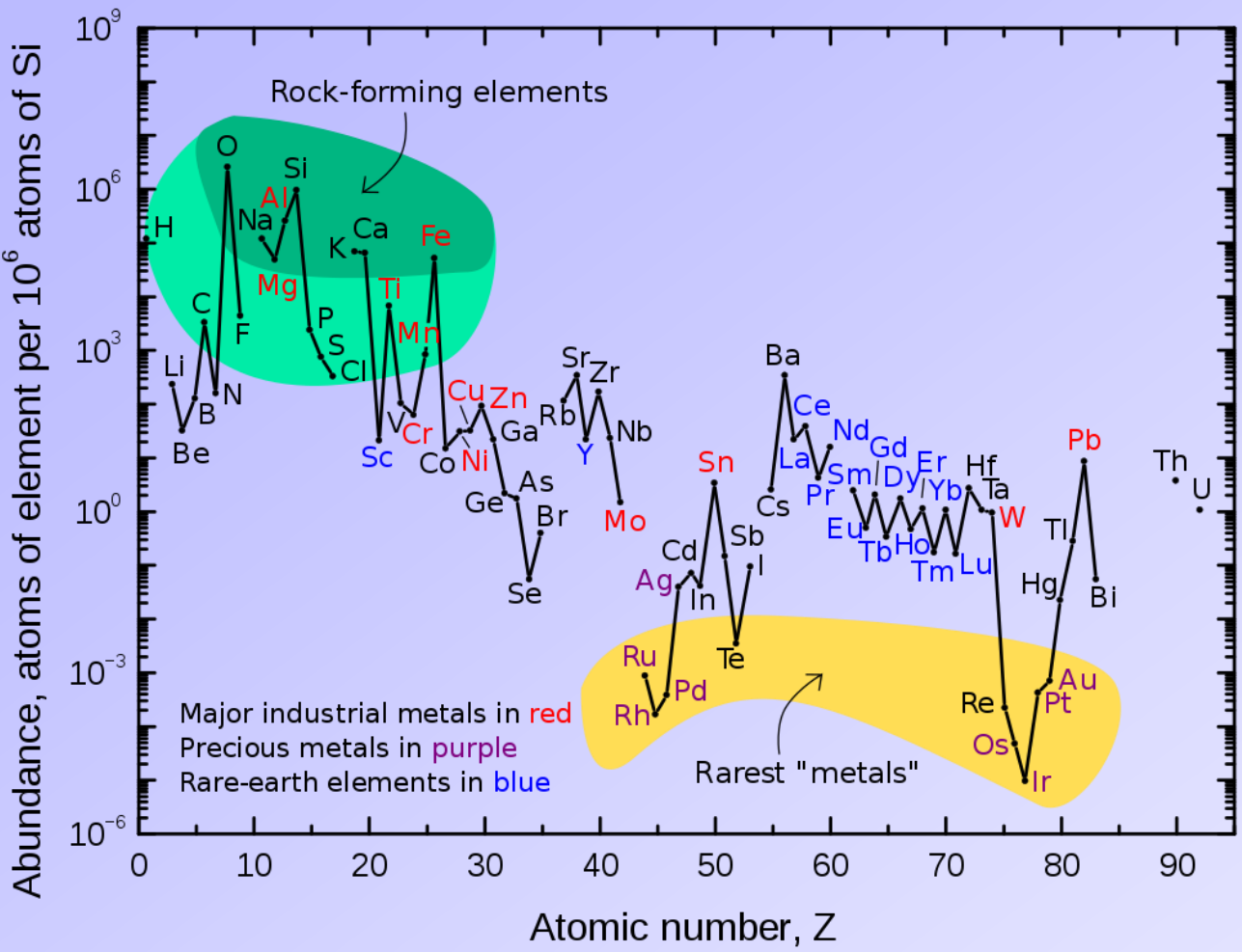


Where does the Earth's interior heat come from ?

- Residual heat from formation of planet.
- Radioactive decay (uranium, thorium, K-40).
- *Differentiation (denser material sinking).*

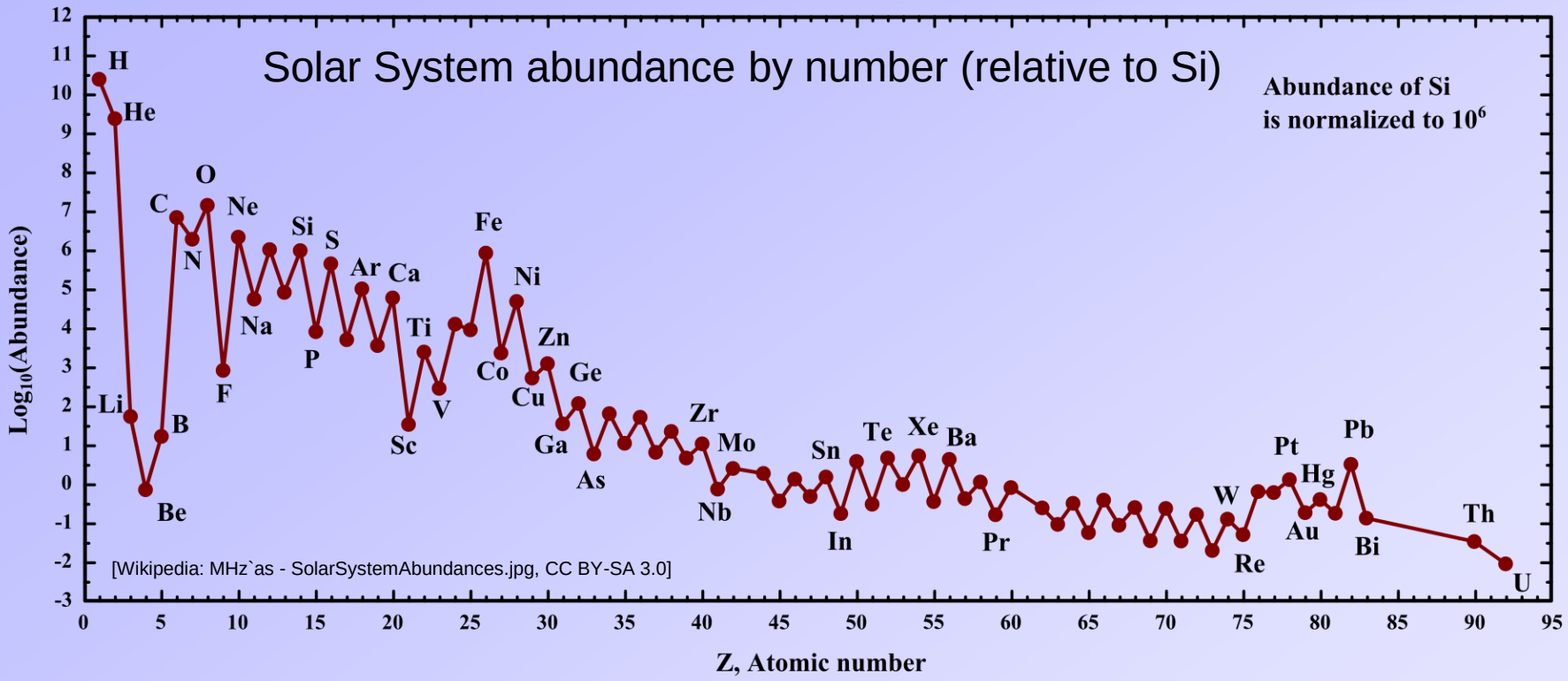
Elements in Earth's Crust



- Lots of **oxygen** and **silicon**.
- Some <u>hydrogen</u>.
- Not much <u>helium</u>.
- Decent amounts of **iron** and **aluminum**.
- *Significantly less heavy elements (past Fe = iron)*

[Wikipedia: Gordon B. Haxel, Sara Boore, and Susan Mayfield from USGS; vectorized by User:michbich - http://pubs.usgs.gov/fs/2002/fs087-02/]

Solar System's Elements



- Dominated by **hydrogen** (H) and **helium** (He).
- Very little lithium (Li), beryllium (Be), and boron (B).
- Decent amounts of **carbon** (C), **oxygen** (O), and **nitrogen** (N).
- *Steady decline in abundance for heavier elements.*
- Significant amounts of **iron** (Fe) and some **nickel** (Ni).

Measuring Earth's Interior

- How can we determine what's underneath the crust?
  - → Ground penetrating radar can go about 30 m deep.
  - → The deepest holes that we have drilled are ~12 km deep.
  - → Earth's crust is roughly 20-70 km thick.
- Drilling our way to an answer is really hard !!!

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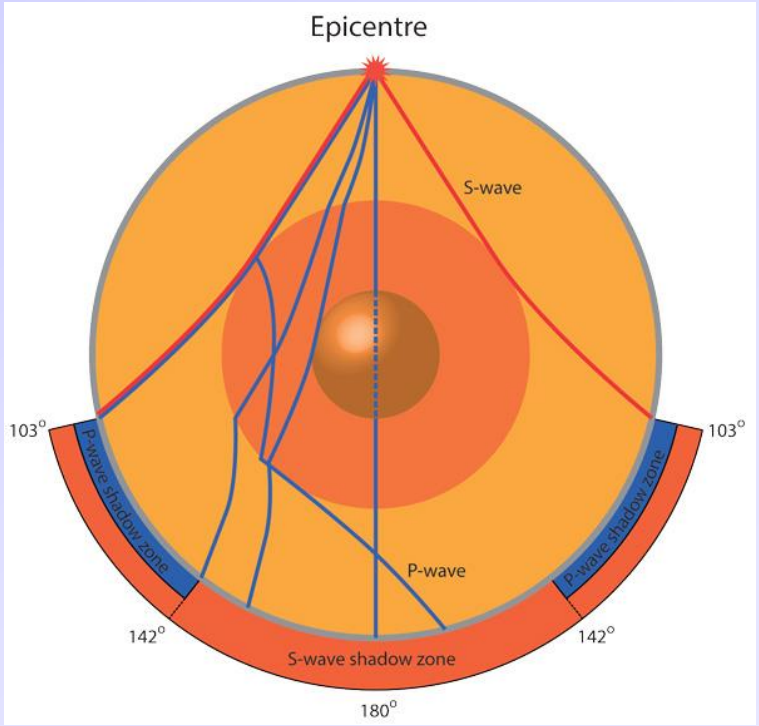
Answer: Seismic waves

- The **shadowing** and **deviation** of seismic waves by the Earth's interior can be used to probe it.
- Seismic waves are **vibrational waves.**
  → *Primary waves are **compression** waves.*
  → *Secondary waves vibrate **perpendicular** to propagation.*
- They are generated by **earthquakes** or large explosions.



[Source: https://www.bgs.ac.uk/discoveringGeology/hazards/earthquakes/structureOfEarth.html]

Earth's Crust: Tectonic Plates

[OpenStax: Astronomy]

- Earth's crust is broken in up into **tectonic plates** that "drift" on top of mantle.
- Plates are generated in **rifts zones** (←→) and removed in **subduction zones** (→←).

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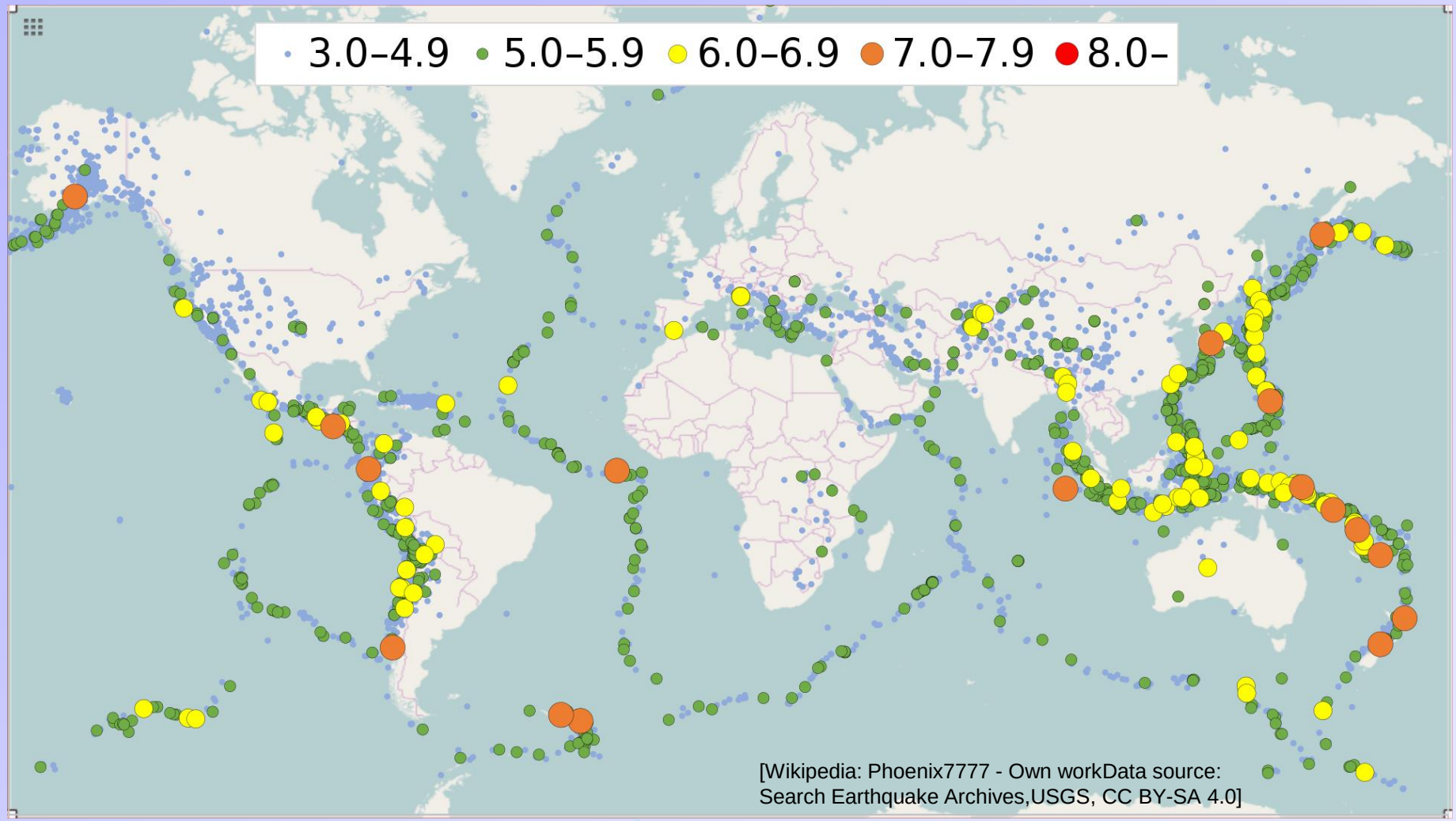
- Plates are generated in **rifts zones** (←→) and removed in **subduction zones** (→←).
- These zones typically show **mountain growth** and **volcanic activity**.
- Alfred Wegener first proposed theory in 1910-15: idea was slow to gain acceptance.

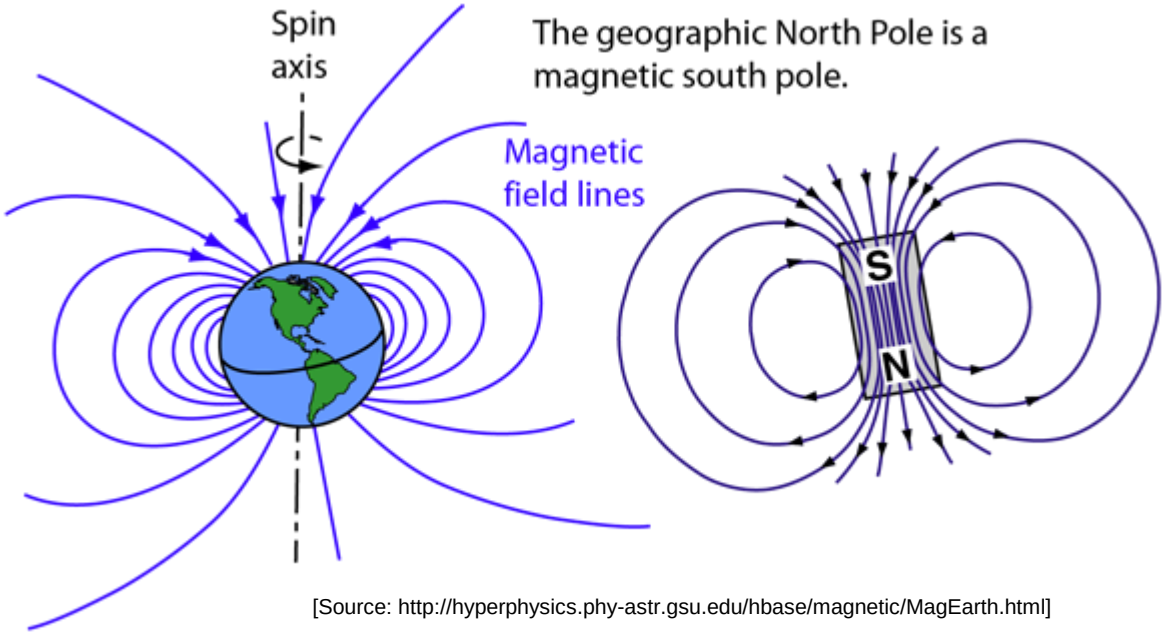
Map of Earthquakes in 2016



Earthquakes and volcanoes typically occur at tectonic plate boundaries

Earth's Magnetic Field

- Earth has a magnetic field generated by **electrical current in its core**.
- The magnetic is **not** aligned with Earth's rotation axis.
- 0.3-0.5 Gauss at surface.



[Source: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/MagEarth.html]

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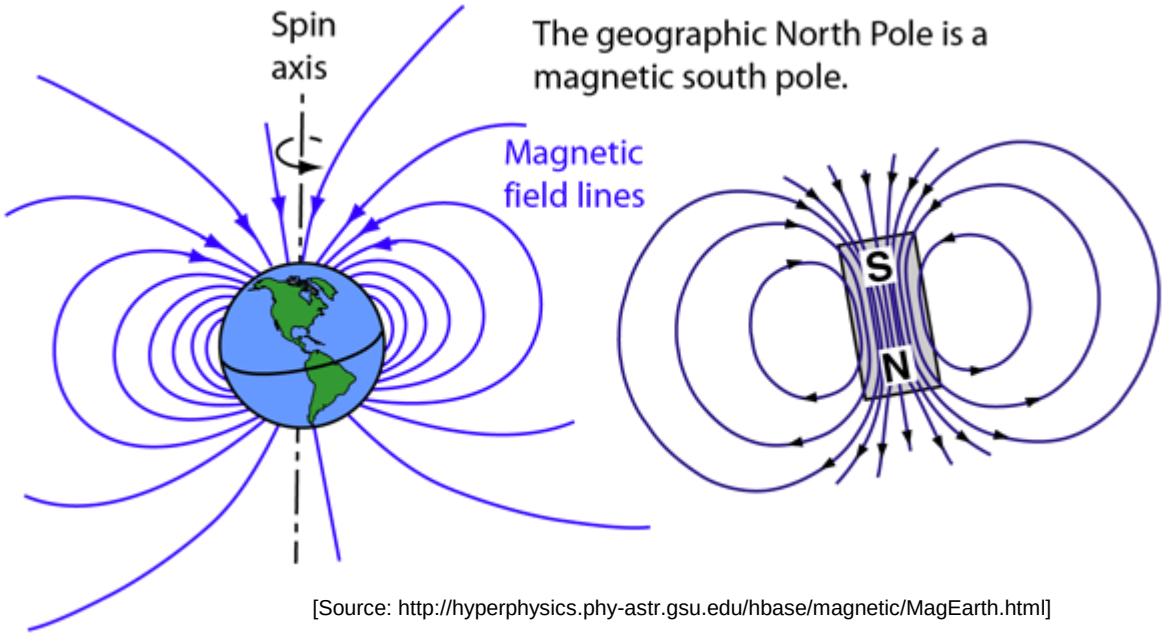
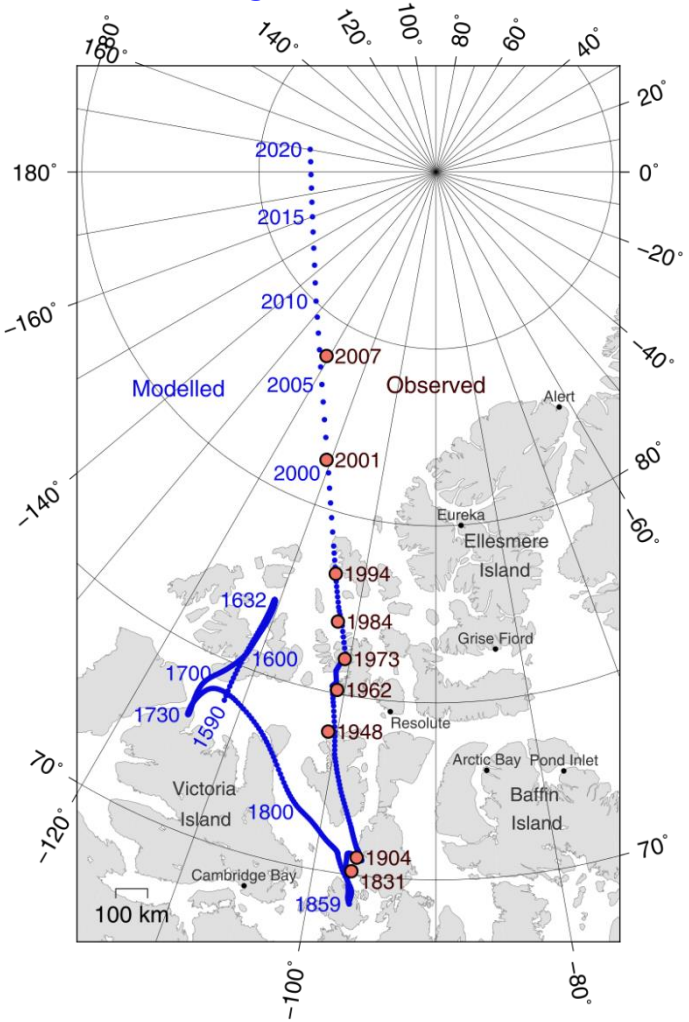
- The magnetic pole **drifts** over time and **flips** on a time scale of 0.1 – 1 million years.



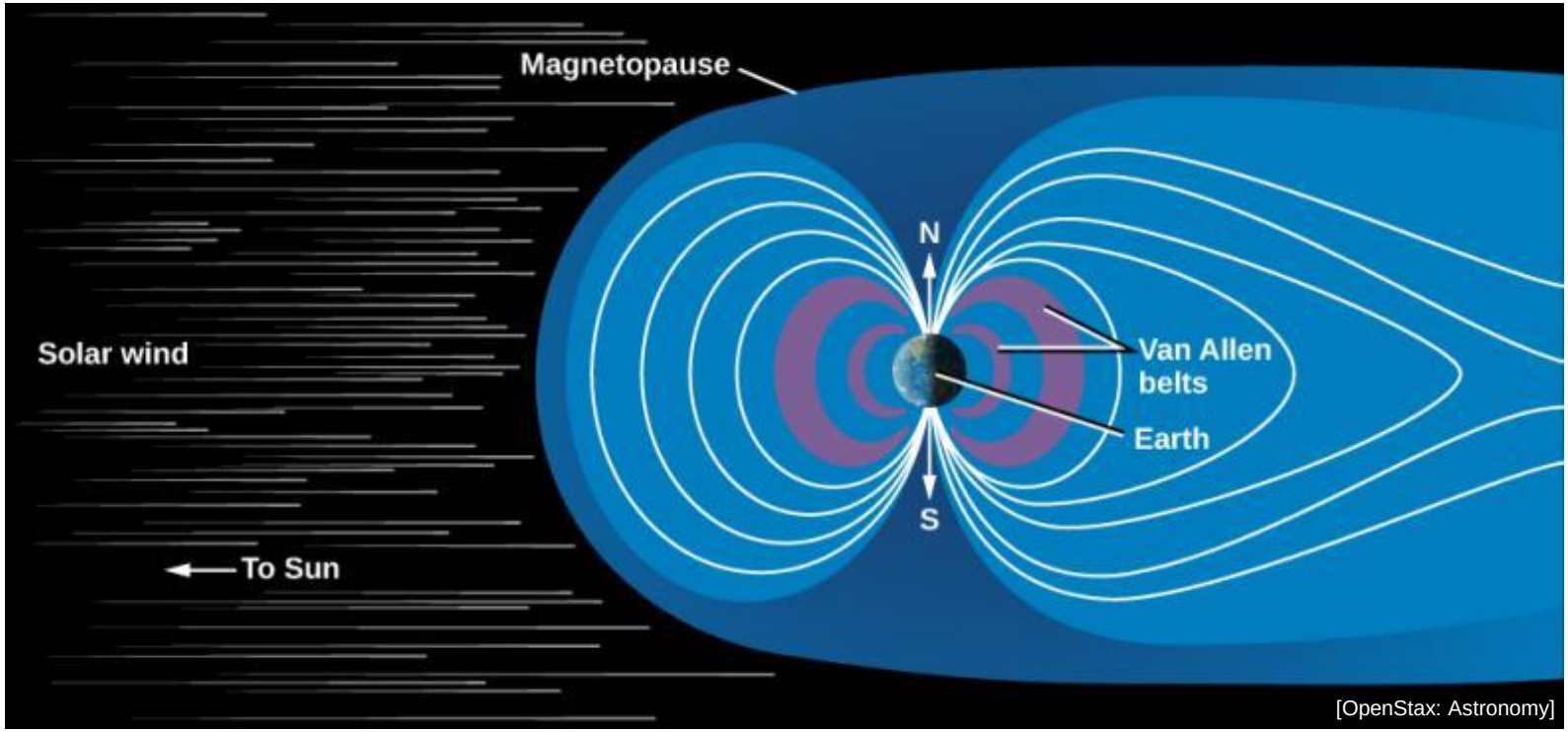
[Source: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/MagEarth.html]

Earth's magnetic north vs time



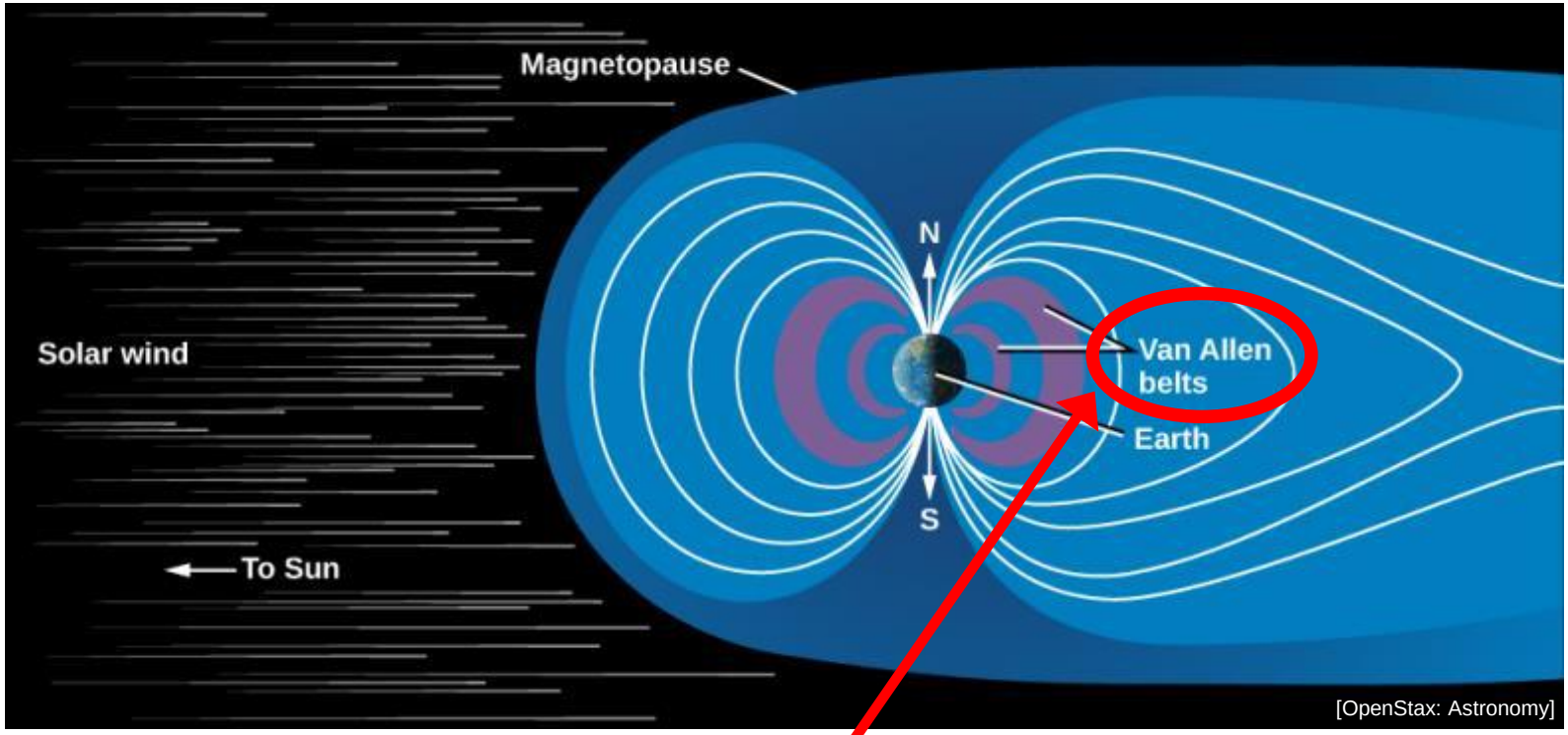
[Wikipedia: By Cavit - Own work:
Observed pole positions taken from Newitt et al., "Location of the North Magnetic Pole in April 2007", Earth Planets Space, 61, 703–710, 2009 Modelled pole positions taken from the National Geophysical Data Center, "Wandering of the Geomagnetic Poles"Map created with GMT, CC BY 4.0]

Magnetosphere



- Earth's magnetic field **screens** the planet from **charged particles** emitted by the Sun (i.e. **solar wind**).
- The Earth's magnetic field **deflects** the charged particles into **spiral trajectories** and slows them down.

Magnetosphere



Charged particles are trapped by magnetic field in the Van Allen radiation belts.

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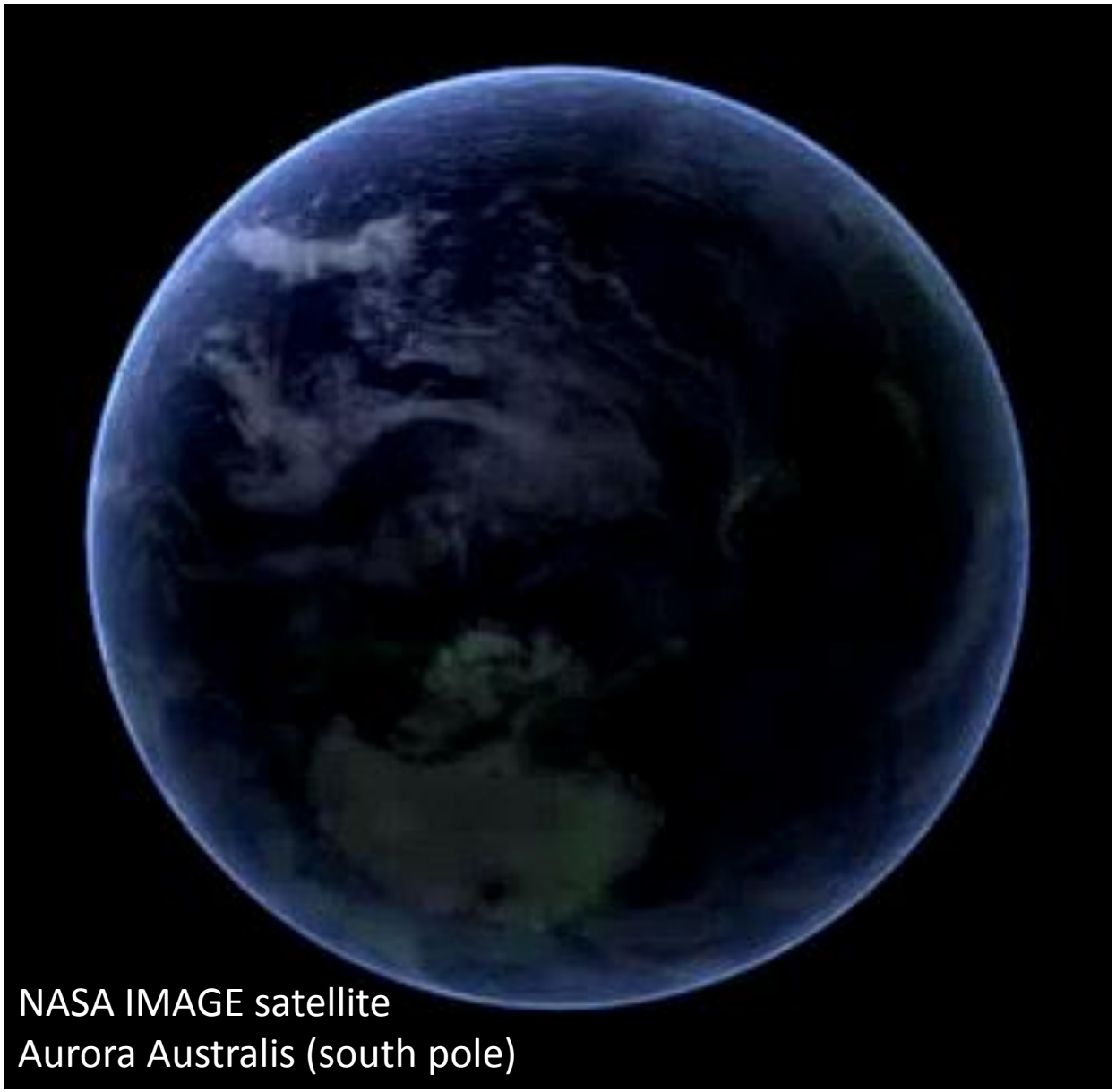
Aurora Borealis

Basic physics

- Solar wind charged particles are directed by the Earth's magnetic field into the atmosphere.
- Atmosphere molecules/atoms are ionized, excited, and generate light (red: H, green: O).

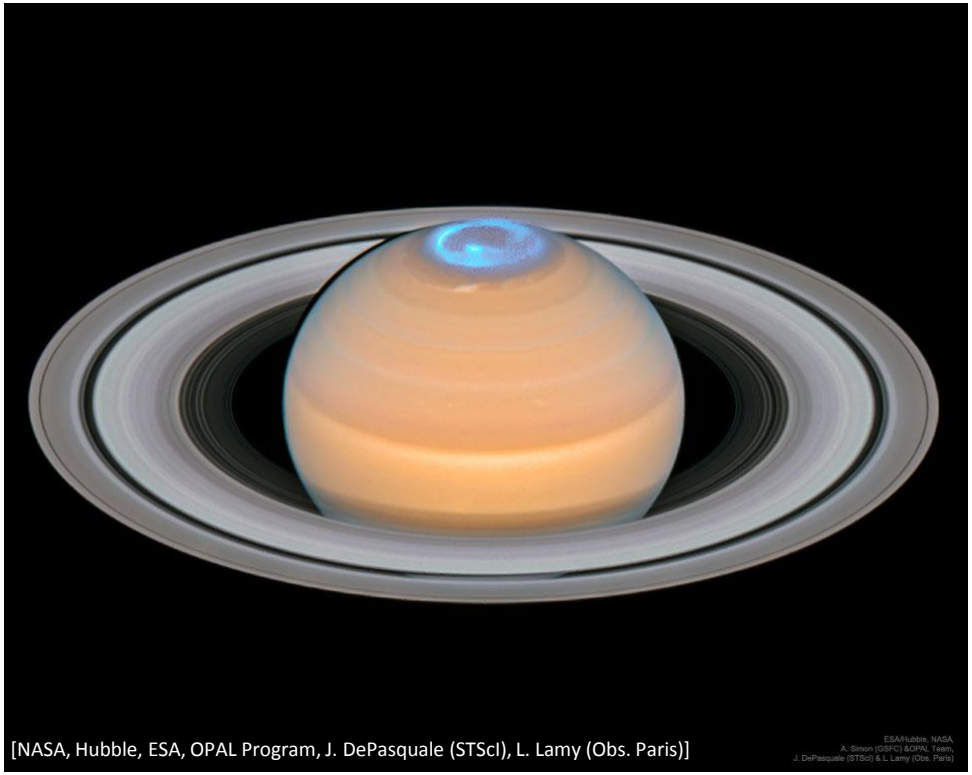
Aurora Australis



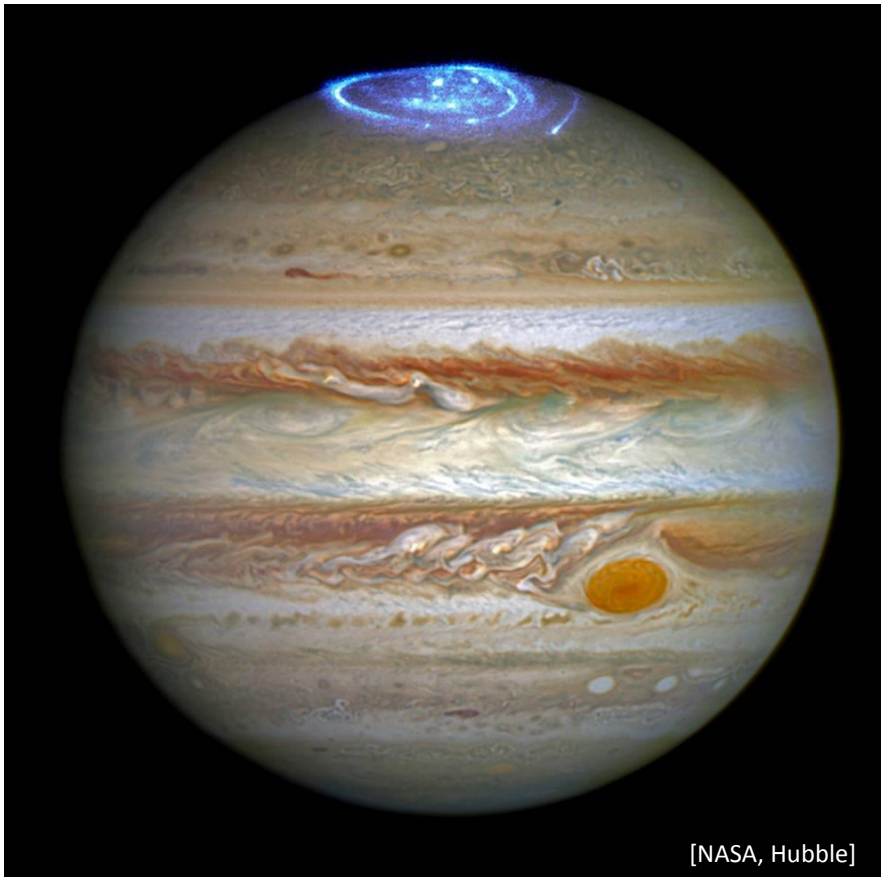
NASA IMAGE satellite
Aurora Australis (south pole)

Aurora on Jupiter and Saturn

Hubble Space telescope images: UV image overlaid on an optical image



[NASA, Hubble, ESA, OPAL Program, J. DePasquale (STScI), L. Lamy (Obs. Paris)]



[NASA, Hubble]