

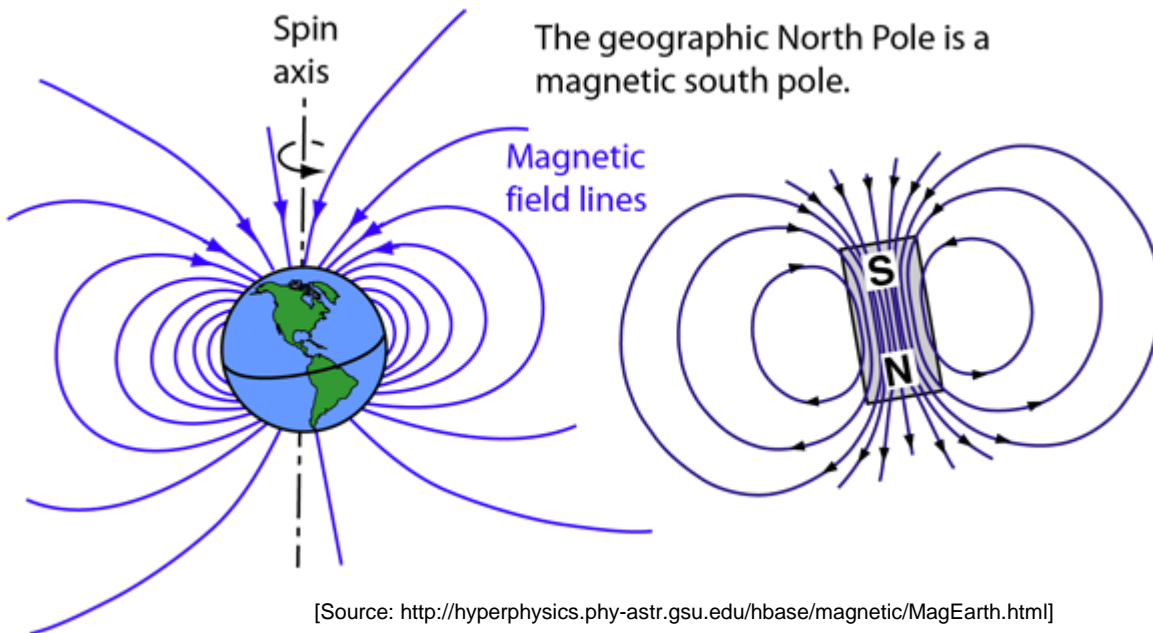
Today's Topics

Friday, October 11, 2019 (Week 6, lecture 18) – Chapter 8.

1. Magnetosphere
2. Atmosphere

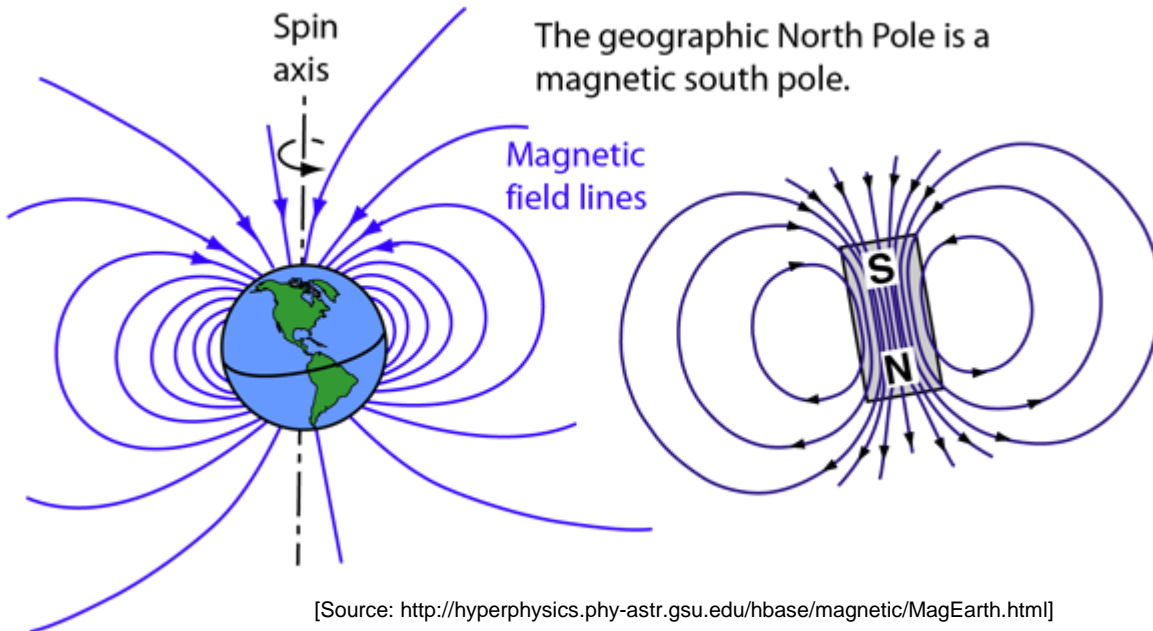
Earth's Magnetic Field

- 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.



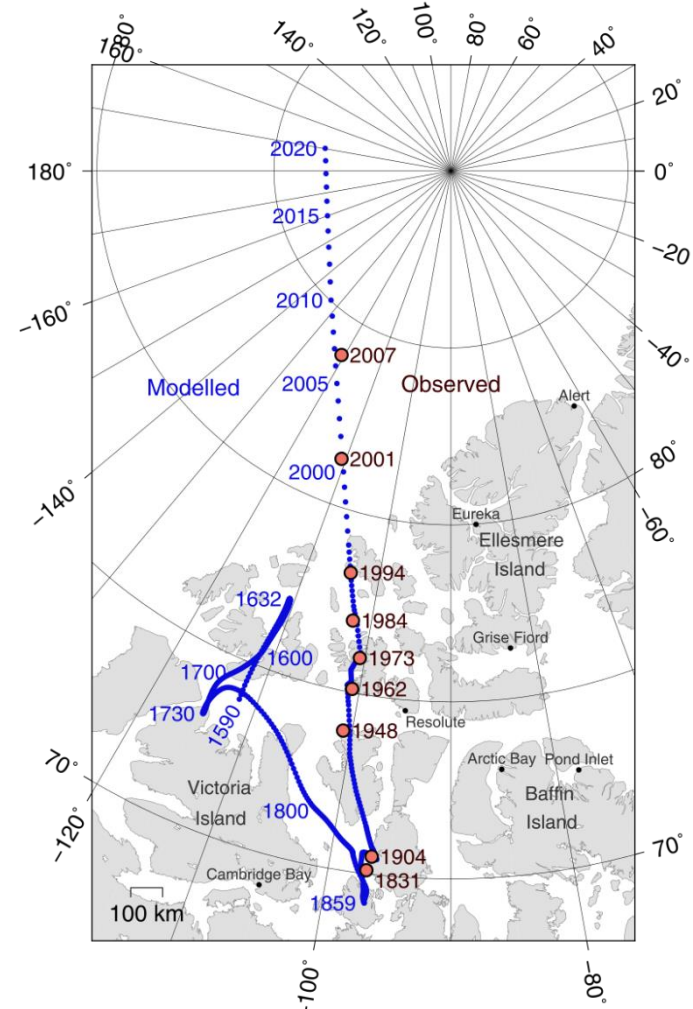
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- The magnetic pole **drifts** over time and **flips** on a time scale of 0.1 – 1 million years.



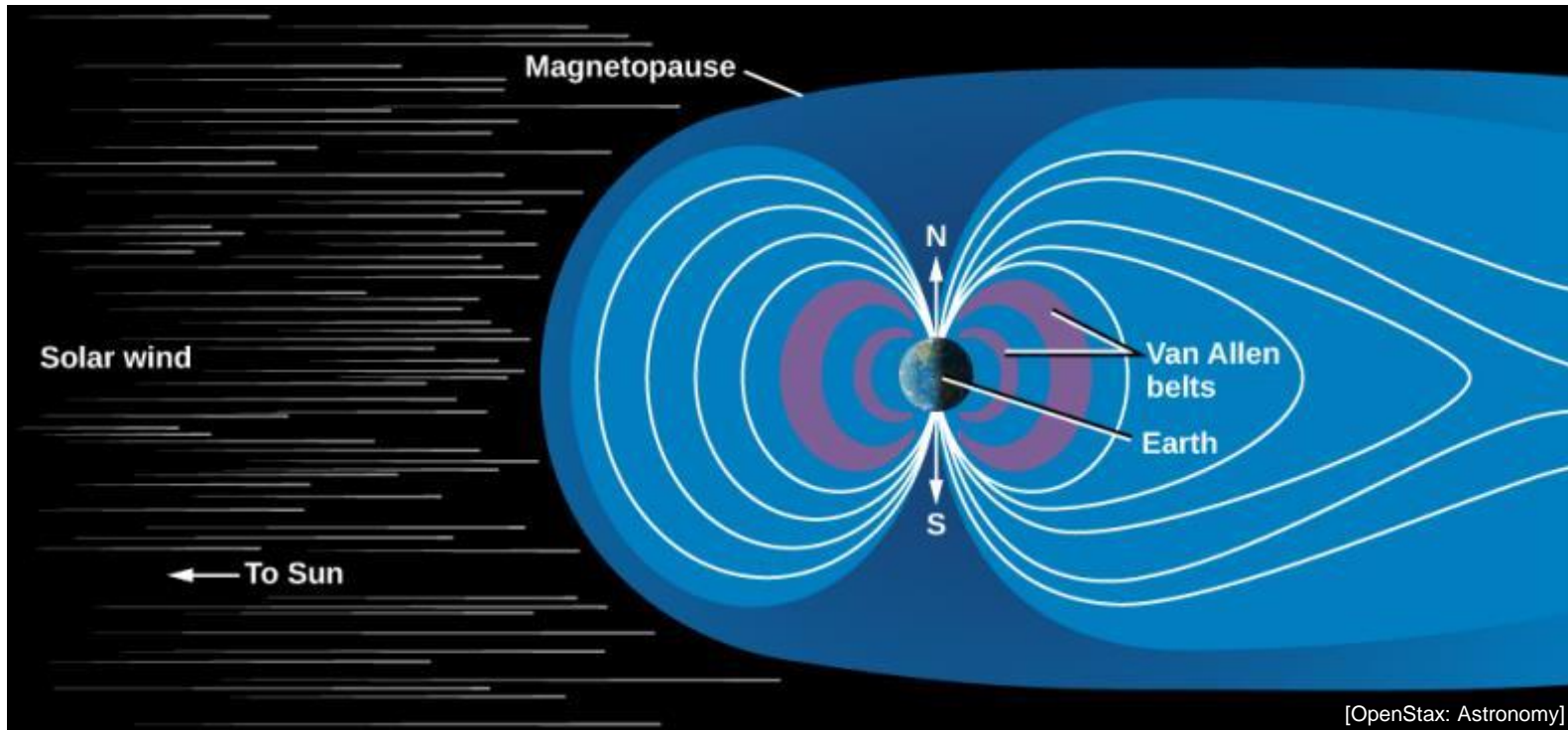
[Source: <http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/MagEarth.html>]

Earth's magnetic north vs time



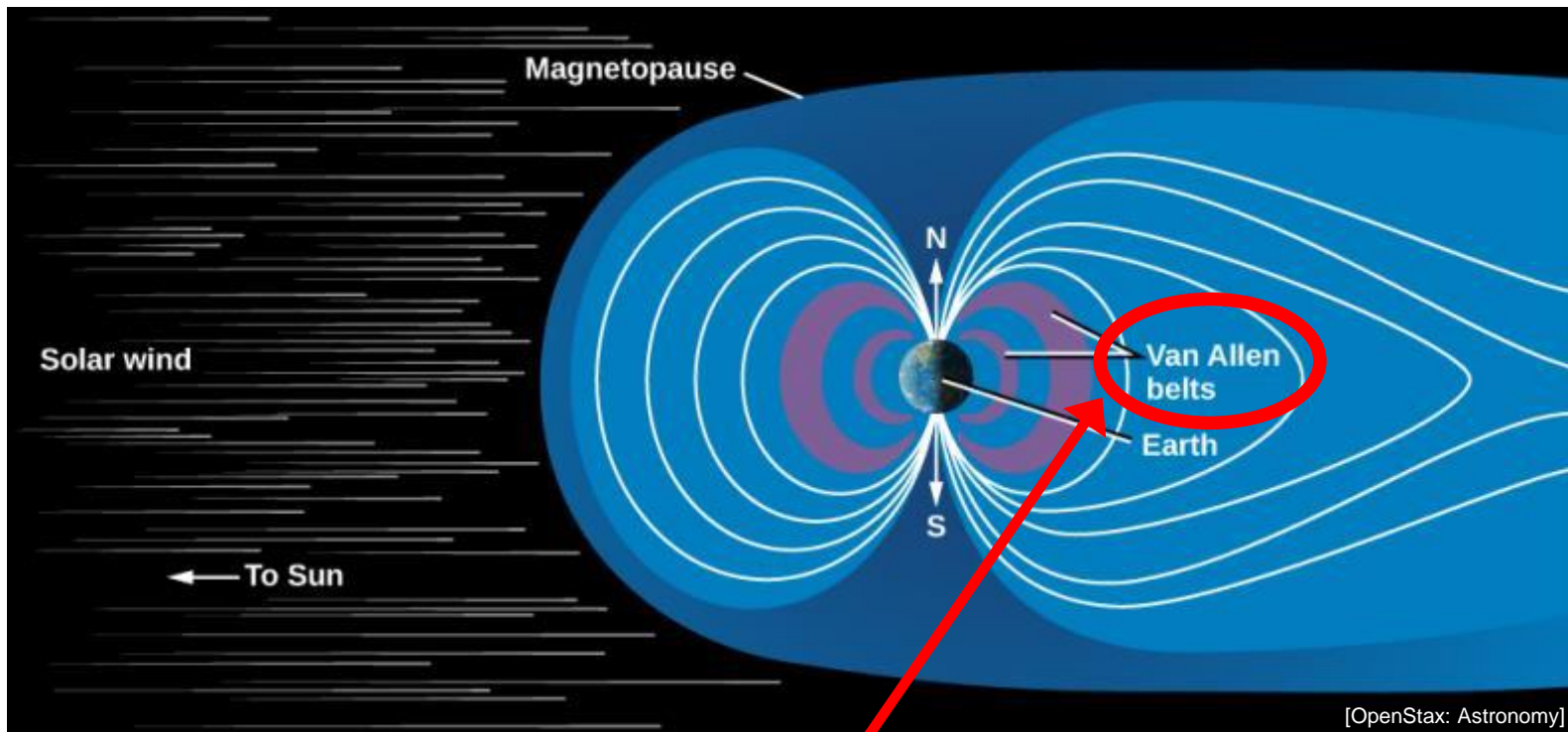
[Wikipedia: By Cavit - Own work: Observed pole positions taken from Newitt et al., "Location of the North Magnetic Pole in April 2007", Earth Planets Space, 61, 703–710, 2009 Modelled pole positions taken from the National Geophysical Data Center, "Wandering of the Geomagnetic Poles" Map created with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

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

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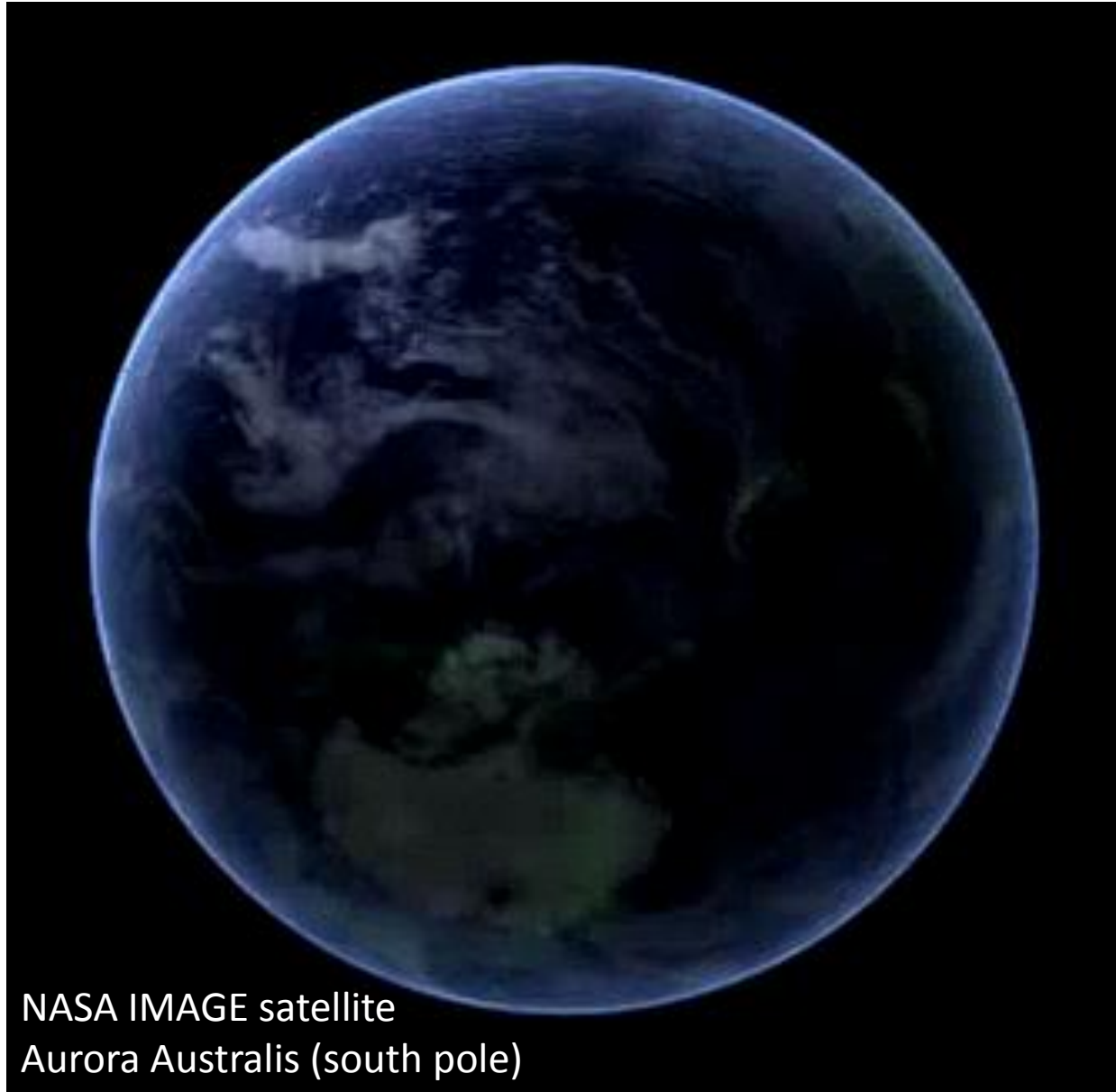
Aurora Borealis



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).

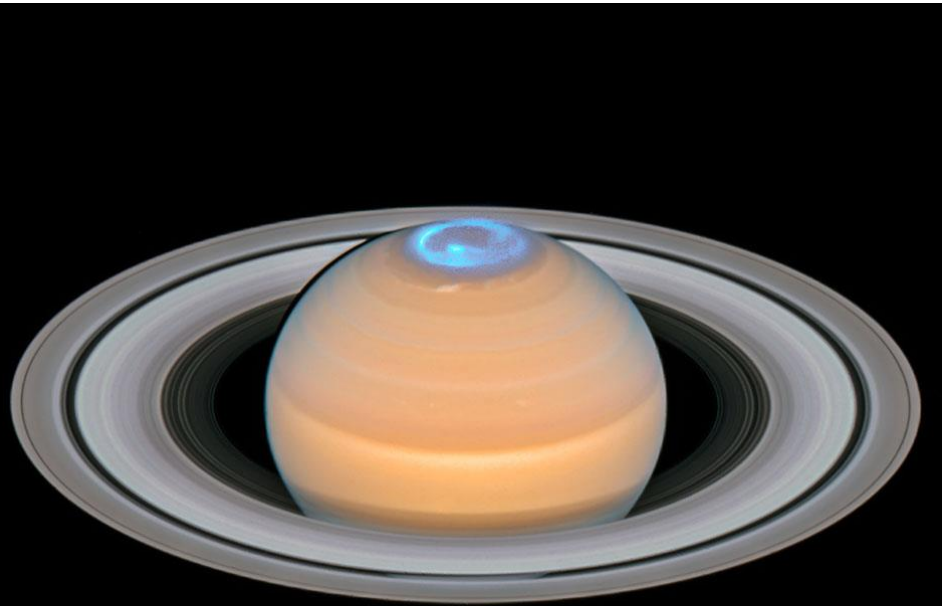
Aurora Australis



NASA IMAGE satellite
Aurora Australis (south pole)

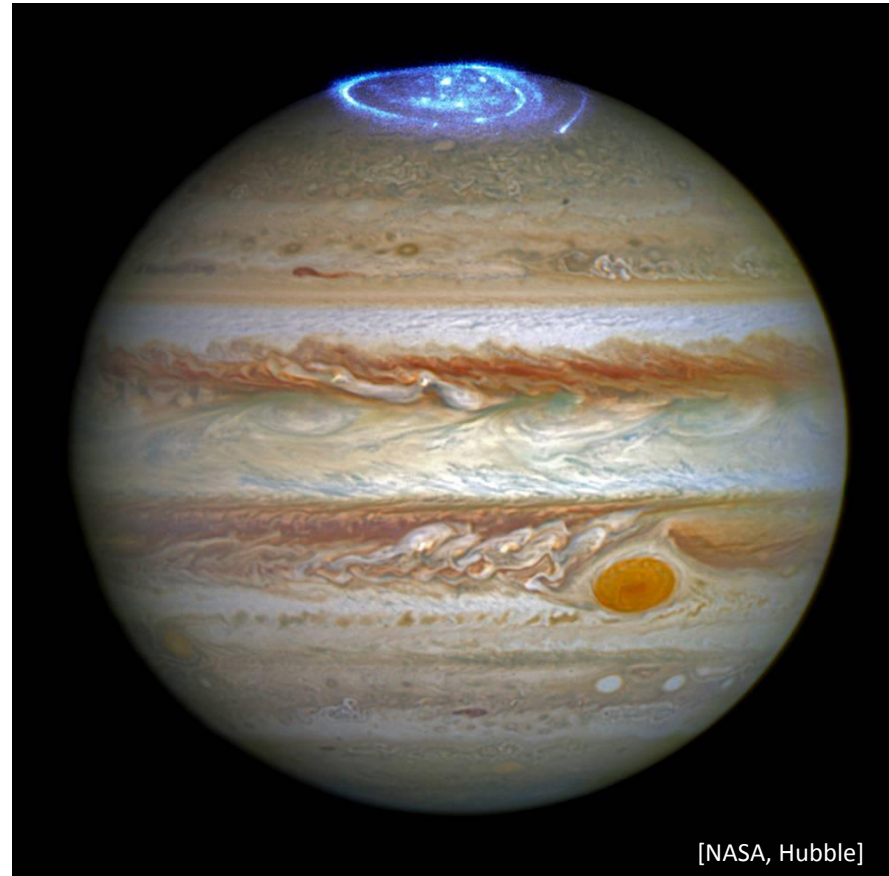
Aurora on Jupiter and Saturn

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



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

ESA/Hubble, NASA,
A. Simon (OSFCI & OPAL Team),
J. DePasquale (STScI) & L. Lamy (Obs. Paris)



[NASA, Hubble]

Earth's Atmosphere

The atmosphere forms the outer layer of the planet.

- It's what you see from outer space.
- It's where most of life is (plus oceans).
- It's where we live.

Primary Composition

78 % nitrogen gas (N_2)

21 % oxygen gas (O_2)

1 % argon gas (Ar)

0.04% carbon dioxide gas (CO_2)

0-4% water vapor (H_2O) – variable

Trace gases

Neon (Ne)

Helium (He)

Methane (CH_4)

Krypton (Kr)

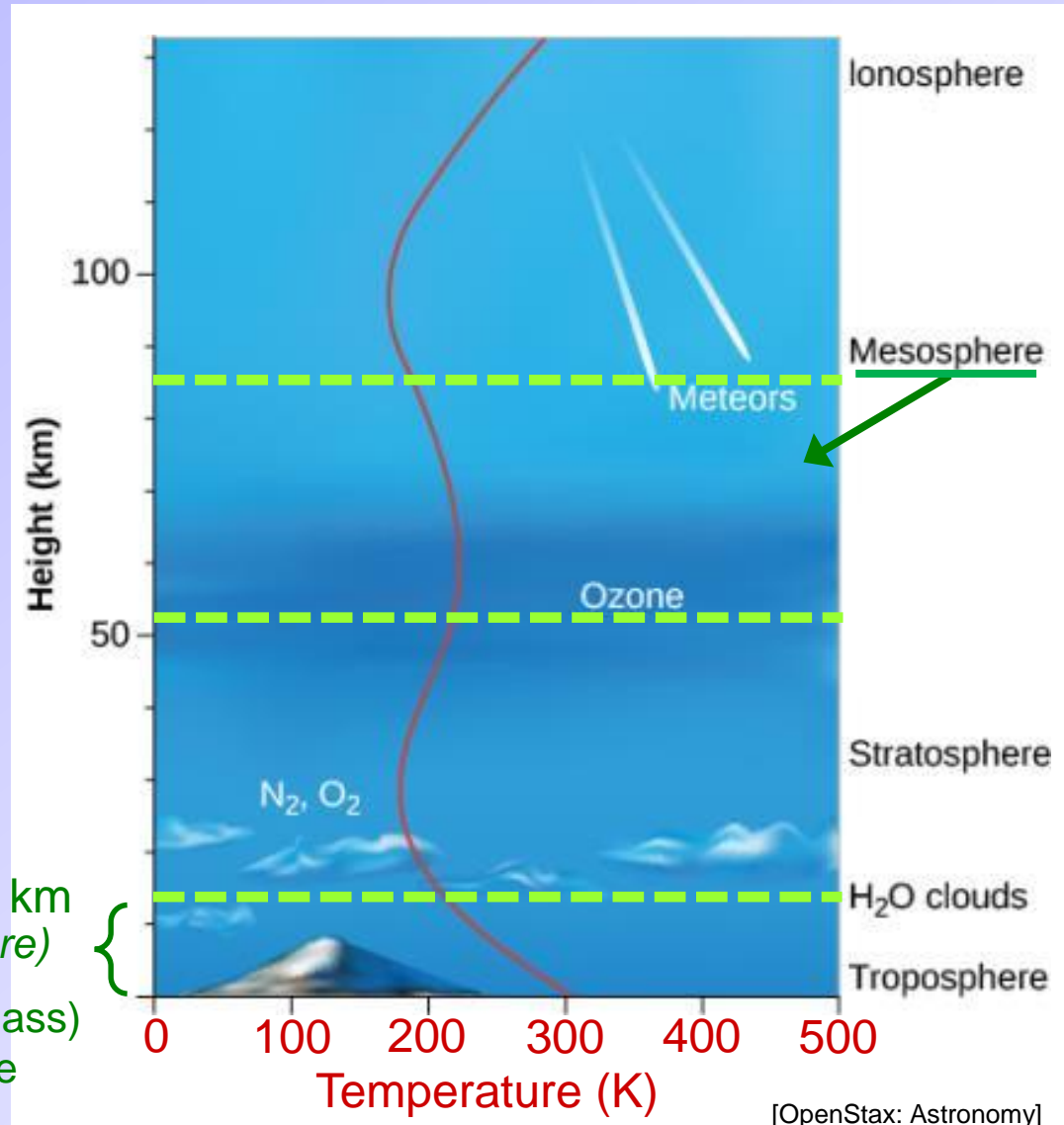
Ozone (O_3)



[OpenStax: Astronomy]

Earth as seen from Apollo 17

Structure of the Atmosphere



Troposphere: 0-12 km
(passenger jets fly here)

- 80% of atmosphere is here (by mass)
- Most weather events happen here

Structure of the Atmosphere

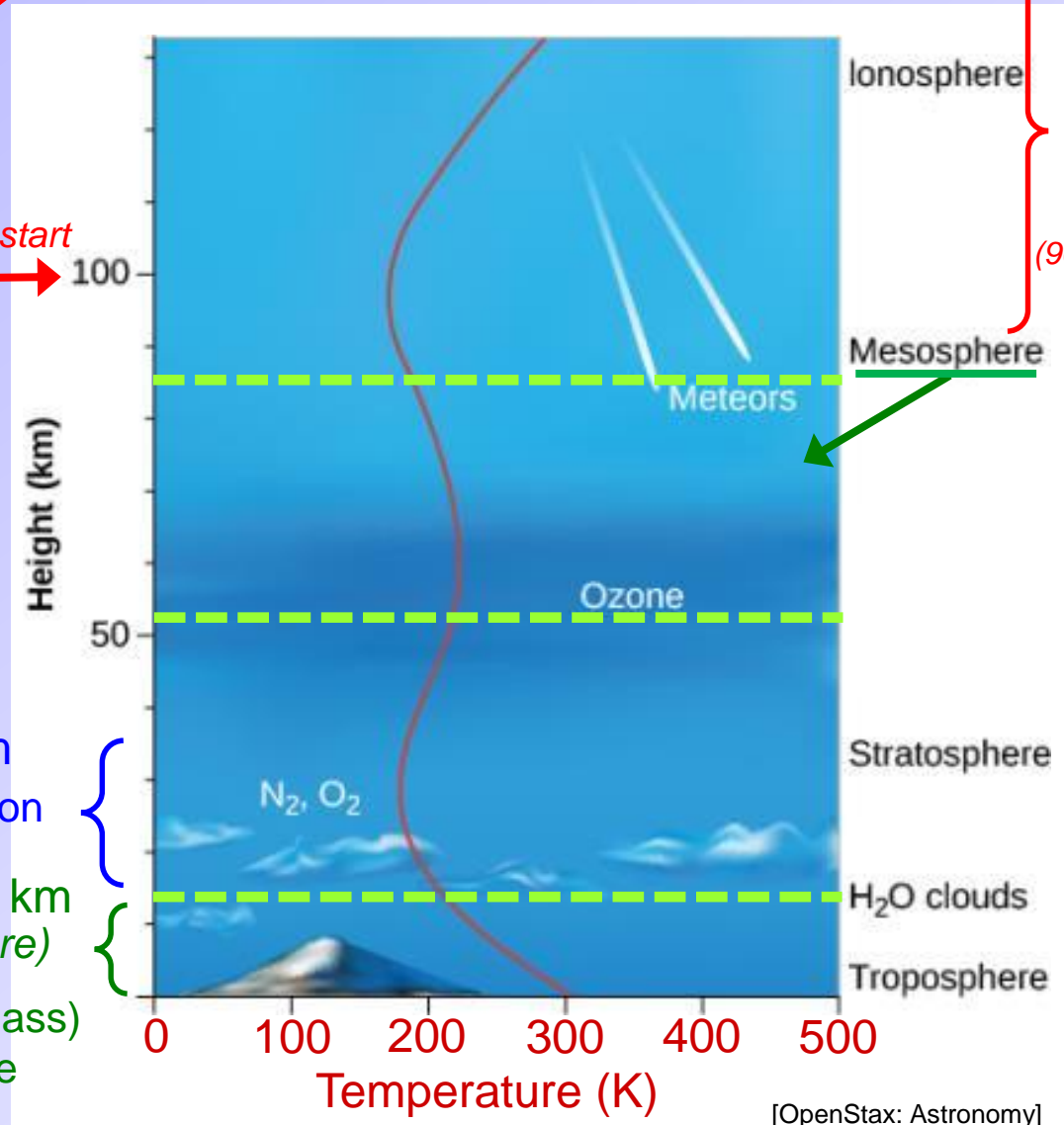
International Space Station orbits at 400 km

Often defined as start of "outer space" →

Ozone layer: 15-35 km
→ Blocks most UV radiation

Troposphere: 0-12 km
(passenger jets fly here)

→ 80% of atmosphere is here (by mass)
→ Most weather events happen here



Aurora occurs here (90-150 km)

Structure of the Atmosphere



Origin of Atmospheric Gases

Nitrogen (N₂): 78 %

Outgassing from Earth interior via volcanoes

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Radioactive decay of potassium-40.

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[OpenStax]



[Tom Greene, CW foundation]



[Walmart.com]

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→ CO₂ reacts when dissolved in water: reaction with calcium → limestone.



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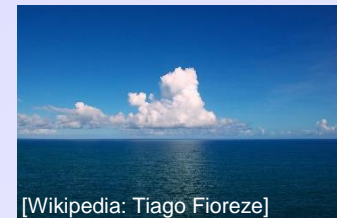
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Water (H₂O): 0-4 %

Water vapor comes primarily from **ocean evaporation**.
→ Water is mildly reactive, excellent catalyst.



Ozone (O₃): trace quantities

Ozone is created-destroyed by **UV light**: $O_2 + UV \rightarrow 2O$, $O_2 + O \rightarrow O_3$, $O_3 + UV \rightarrow O_2 + O$

Comparison with Venus & Mars



Venus



Earth



Mars

Nitrogen	3.5 %	78 %	2.6 %
Oxygen	trace	21 %	0.17 %
Argon	0.005 %	1 %	1.9 %
Carbon dioxide	96.5 %	0.04 %	95 %
water	trace	0-4 %	0.03 %



Earth's atmosphere is not CO₂ because of *life*

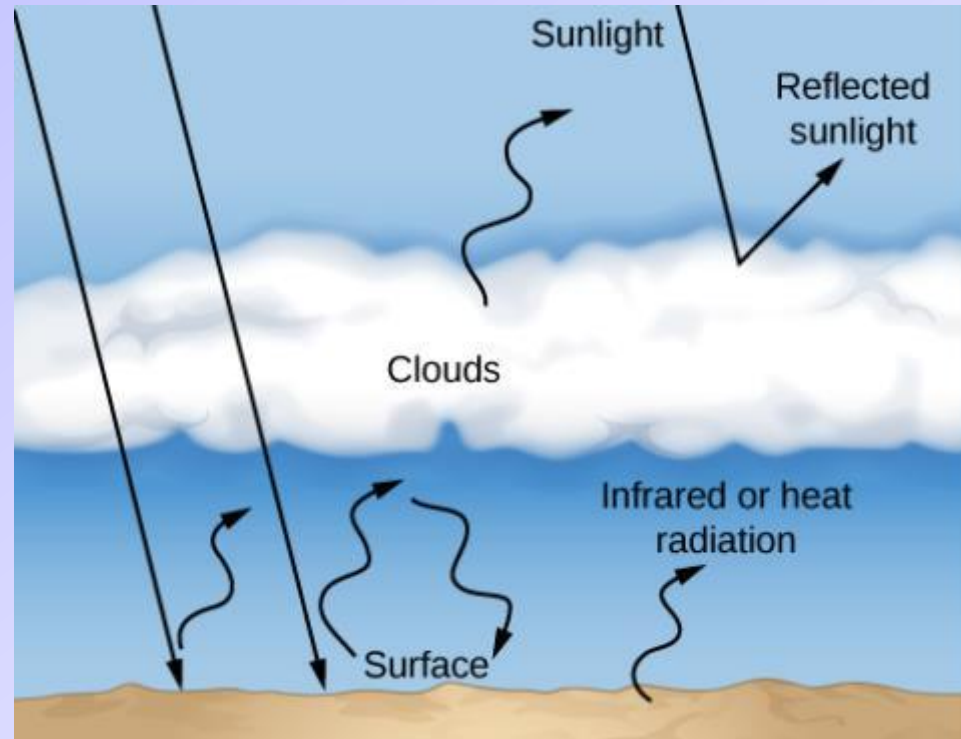
The Martian and Venusian atmospheres are dominated by carbon dioxide.

Atmospheric Temperature

The Greenhouse Effect

How it works:

- **Sunlight** penetrates atmosphere and *heats surface*.
- The heated surface re-radiates in the **infrared**.



Atmospheric Temperature

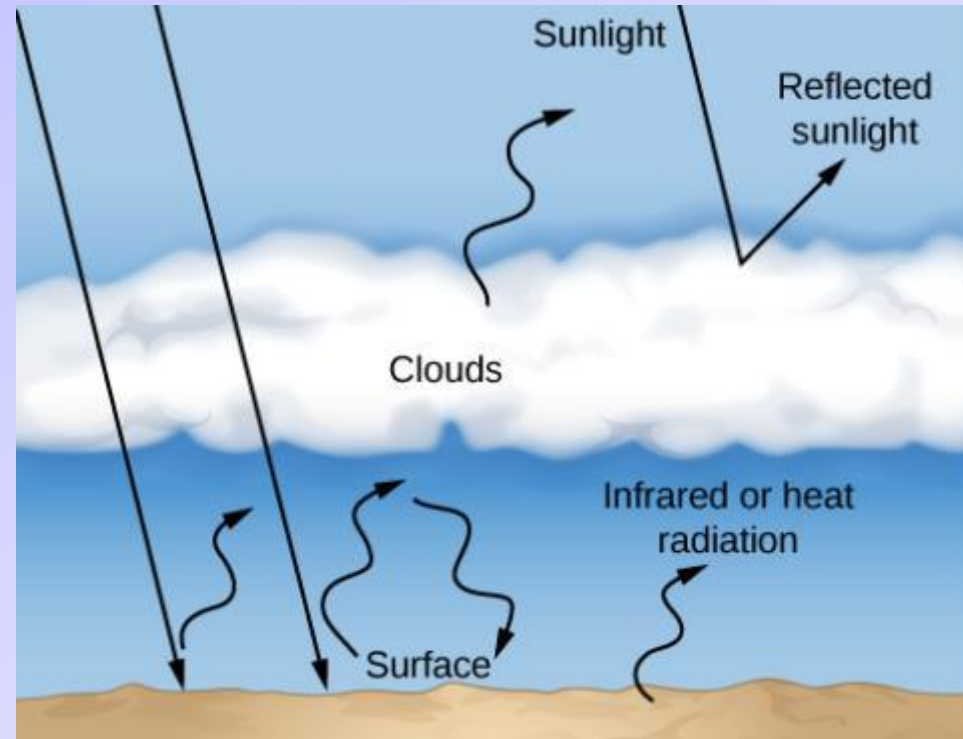
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→ **Infrared light is trapped** in lower atmosphere and has difficulty exiting the planet.

Note: **Clouds** also help block the re-radiation of infrared radiation.



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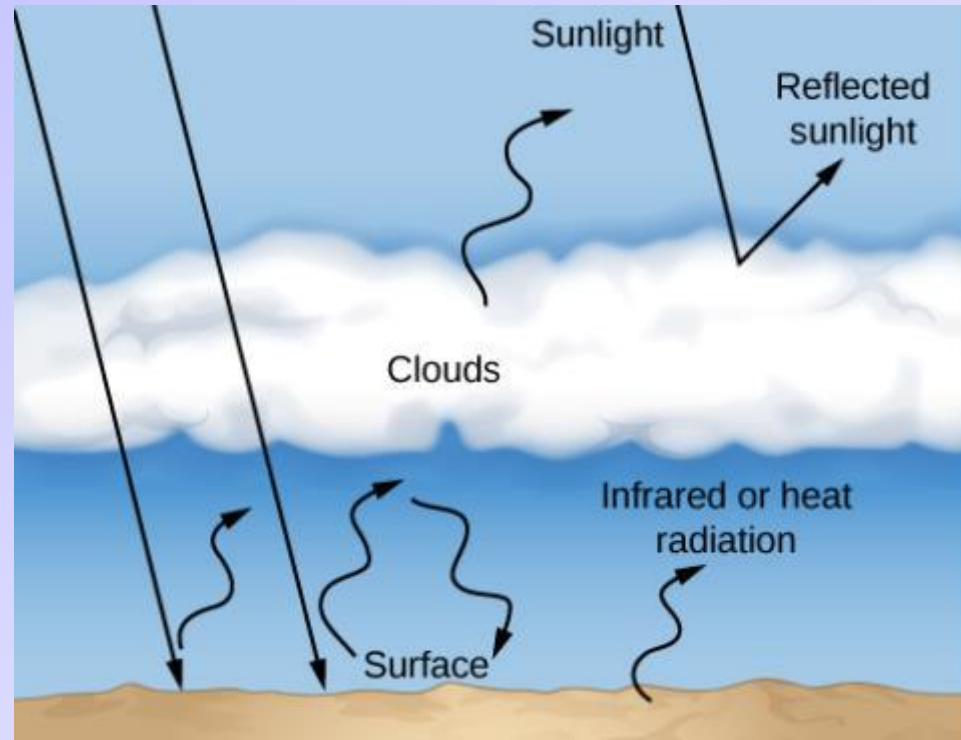
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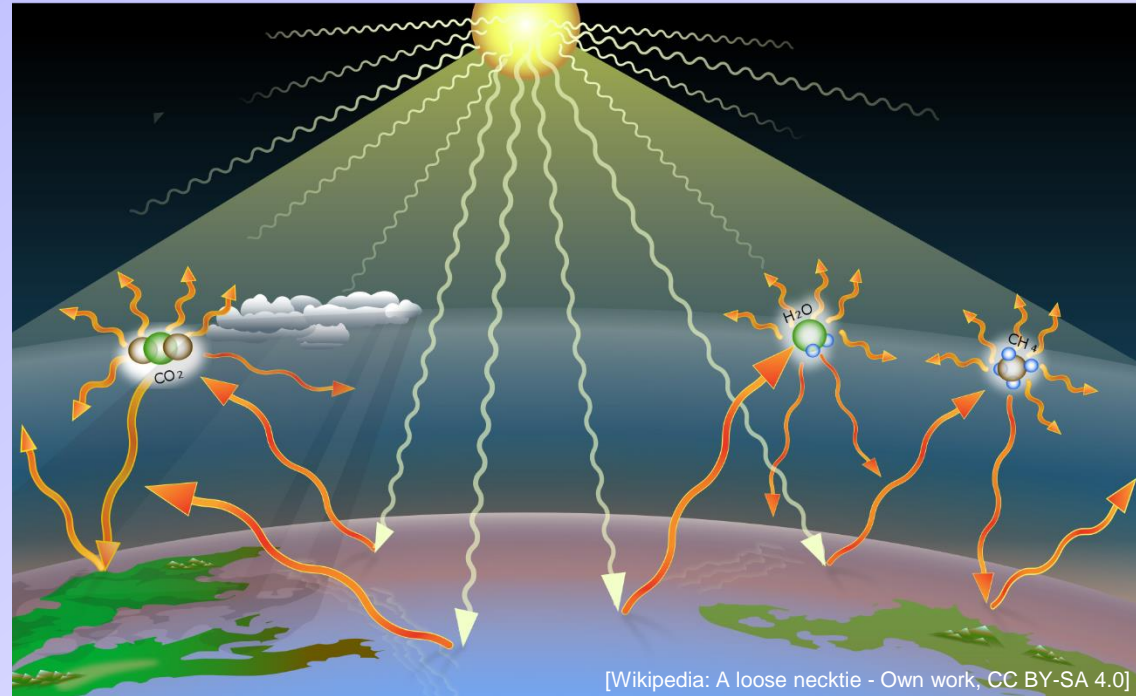


➔ Solar energy/radiation leaves more slowly and the atmosphere heats up.

Greenhouse Gases

Primary Greenhouse Gases on Earth

- Water, H_2O (+ clouds)
→ contribution: 36-72 %
- Carbon dioxide, CO_2
→ contribution: 9-26 %
- Methane, CH_4
→ contribution: 4-9 %
- Ozone, O_3
→ contribution: 3-7 %






Other greenhouse gases

- Nitrous oxide (N_2O)
- Chlorofluorocarbons (CFCs).

The Greenhouse Effect

comparison with Mars & Venus

	 [NASA] Venus	 [NASA] Earth	 [ESA] Mars
Temperature with <u>greenhouse effect</u>	470° C	15° C	- 50° C
Temperature without <u>greenhouse effect</u> (estimate)	- 40° C	- 16° C	- 56° C

*low temperature predicted
because of high albedo.
i.e. it's fairly reflective*

*Greenhouse effect is small
because Mars has a thin
atmosphere.*