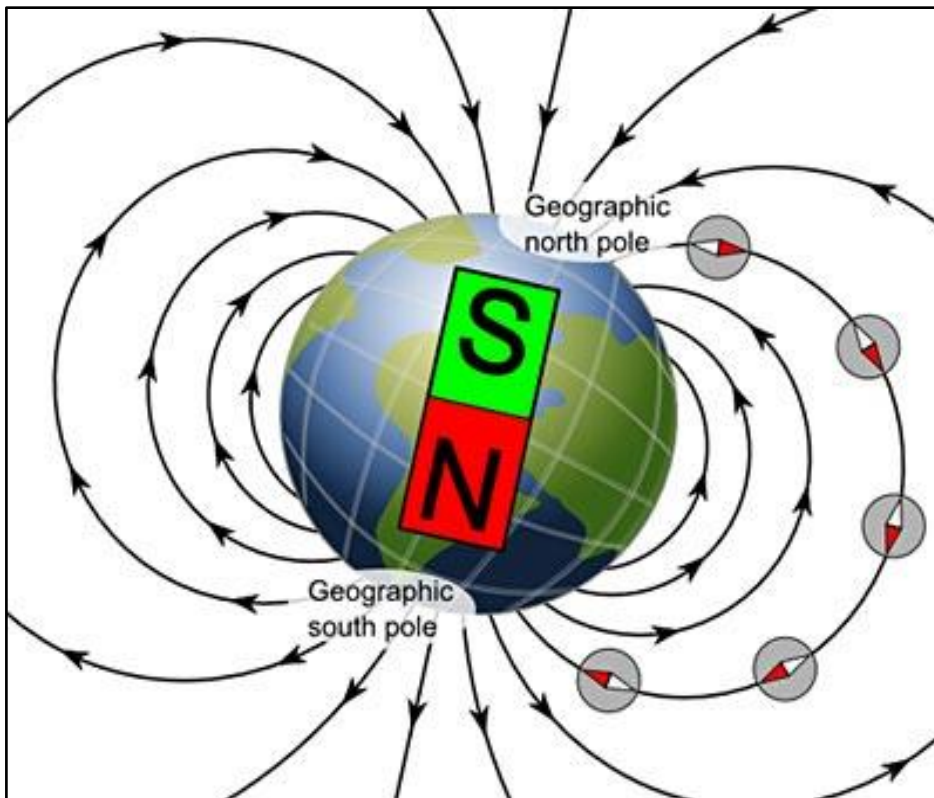
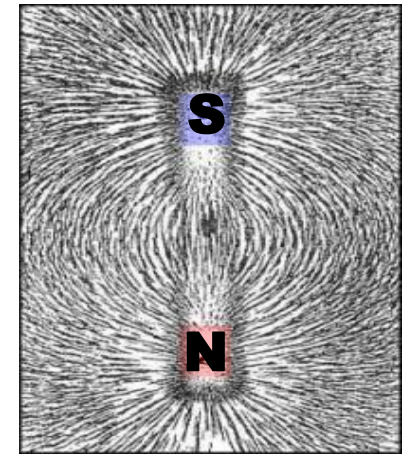


Earth is a Magnet!

The Earth acts much like a bar magnet: its magnetic field deflects compasses on the Earth's surface to point northwards.

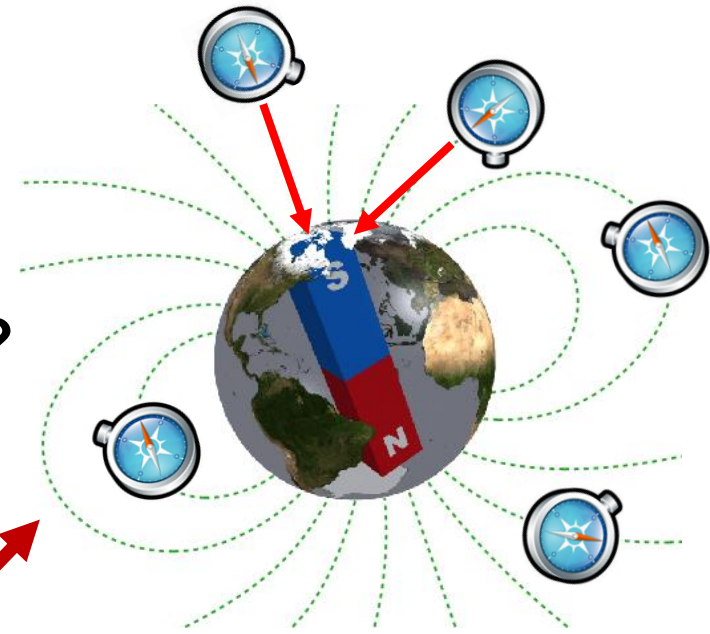


- We represent the magnetic field at any point on or above the Earth's surface by a line pointing in the direction a compass would point.
- Close to the Earth's surface, the magnetic field has a “donut” shape.

The **North Pole** of the Earth has “**south**” polarity.

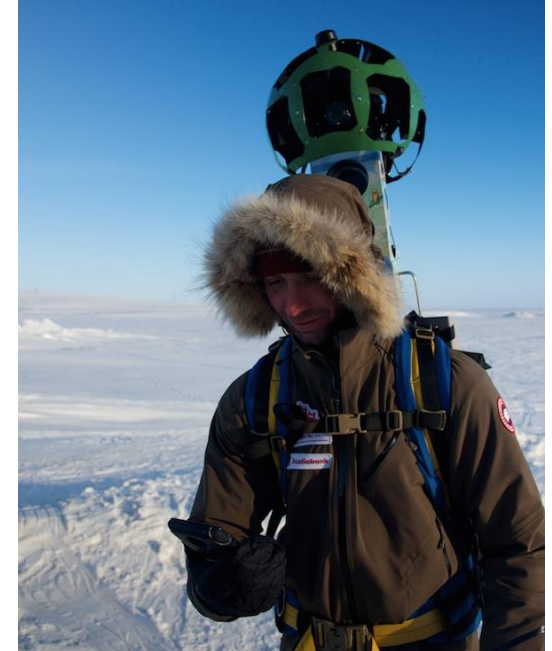
Understanding a Compass

Question 1: what direction is North?



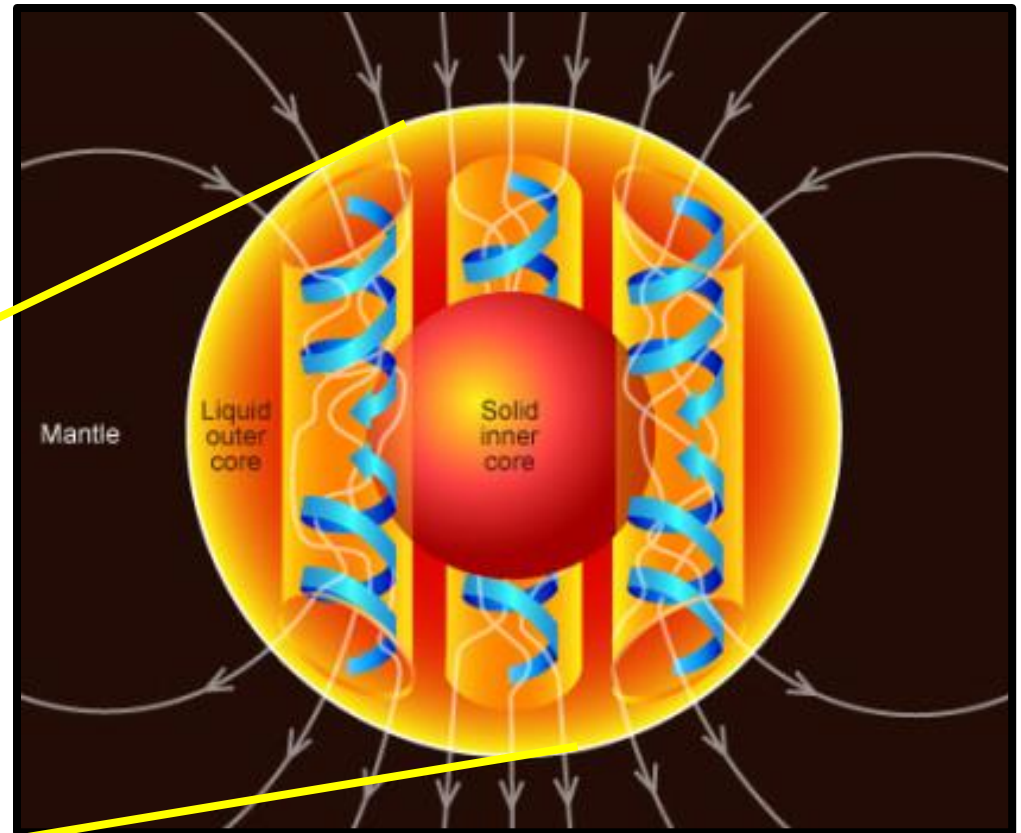
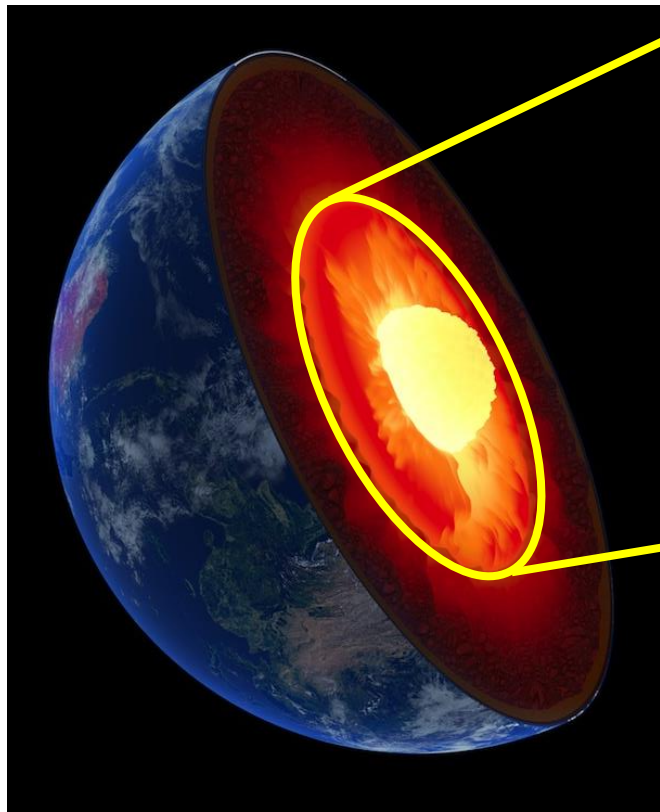
Question 2: where does a compass point at the magnetic North Pole?

Answer: straight down!



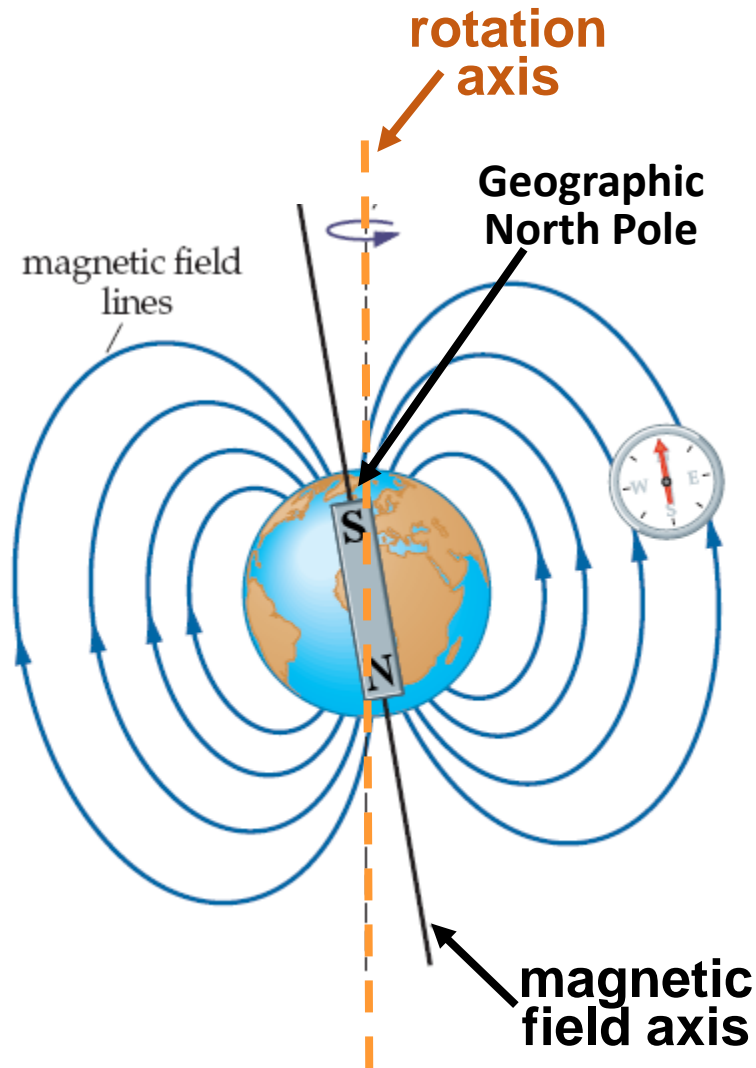
What creates Earth's Magnetic Field?

Geodynamo Theory



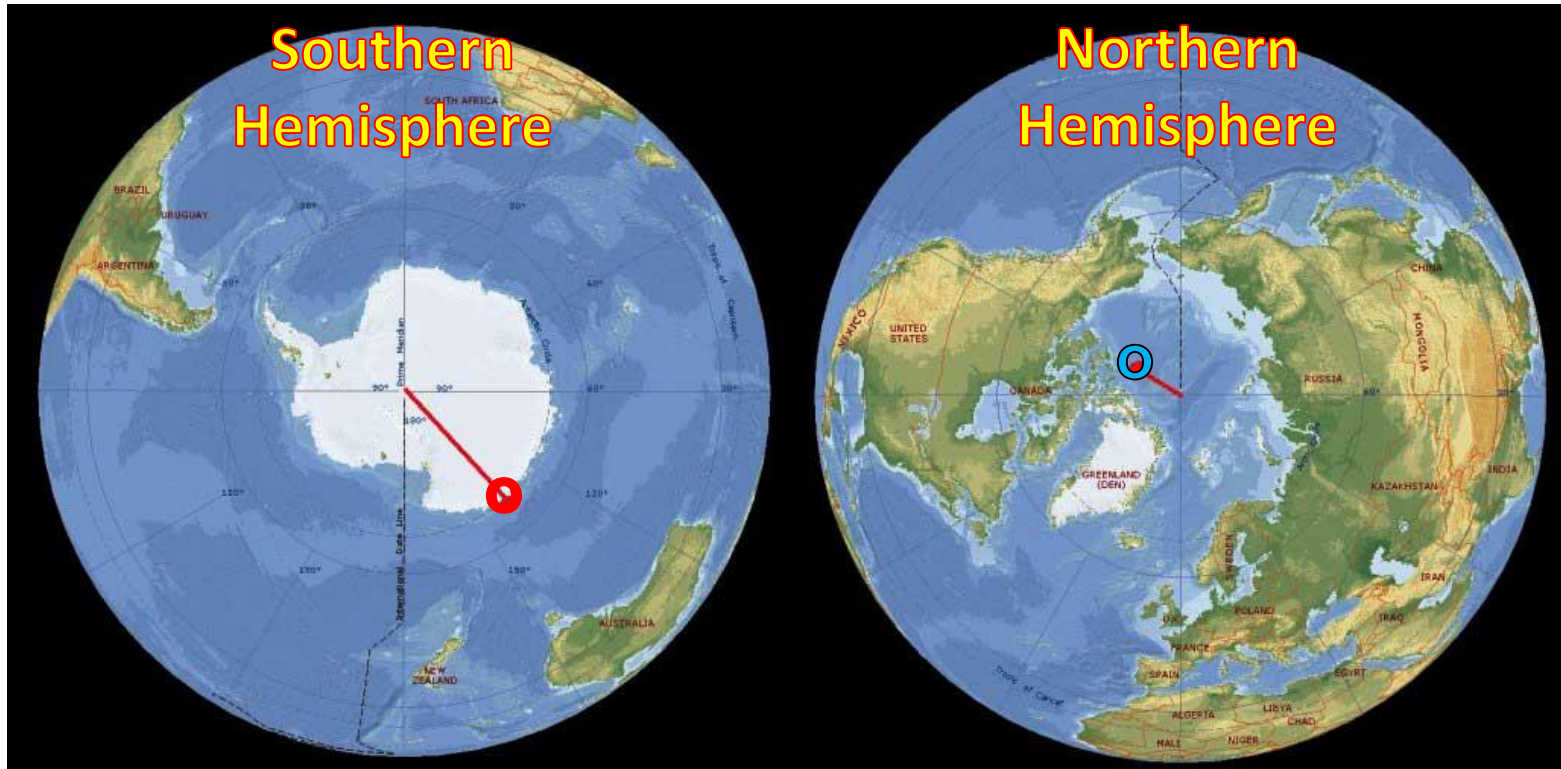
Rotating, convecting, and electrically conducting **liquid outer core** acts to induce and constantly maintain Earth's magnetic field.

Magnetic Field Axis



- The axis of Earth's magnet and the geographical (rotation) axis **do not coincide**.
- The magnetic field axis is **tilted at 11.5°** to the axis of rotation of the Earth.
- The magnetic field axis **does not pass through the center of the Earth**.
- The magnetic poles and geographic poles are **not the same**.

Magnetic Poles Location (2010)



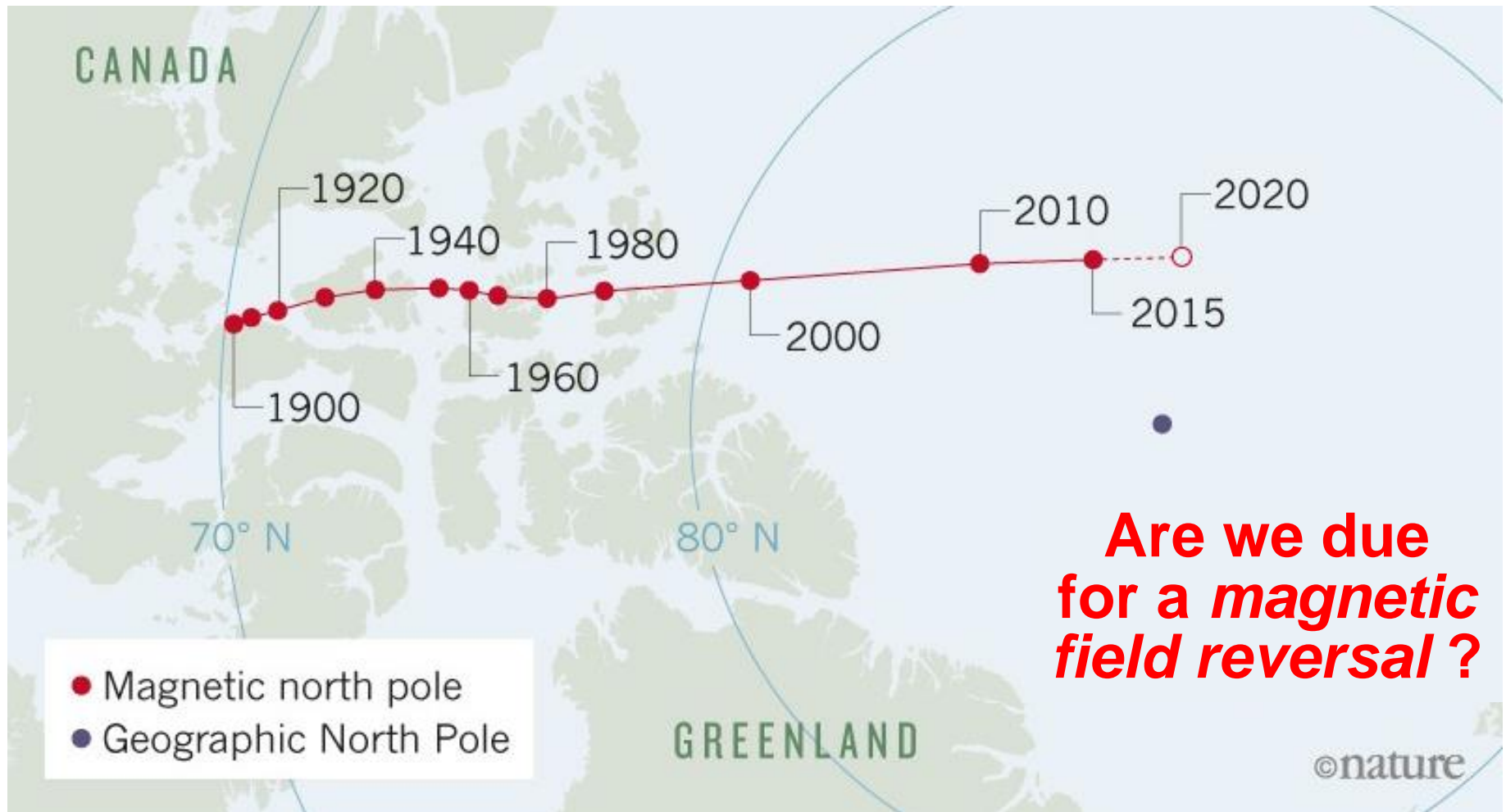
1800 mi from True South

380 mi from True North

The **positions** of the Earth's magnetic poles are **not very well defined**: they are spread over an area, wandering ~ 50 km (~ 30 mi) back and forth every day.

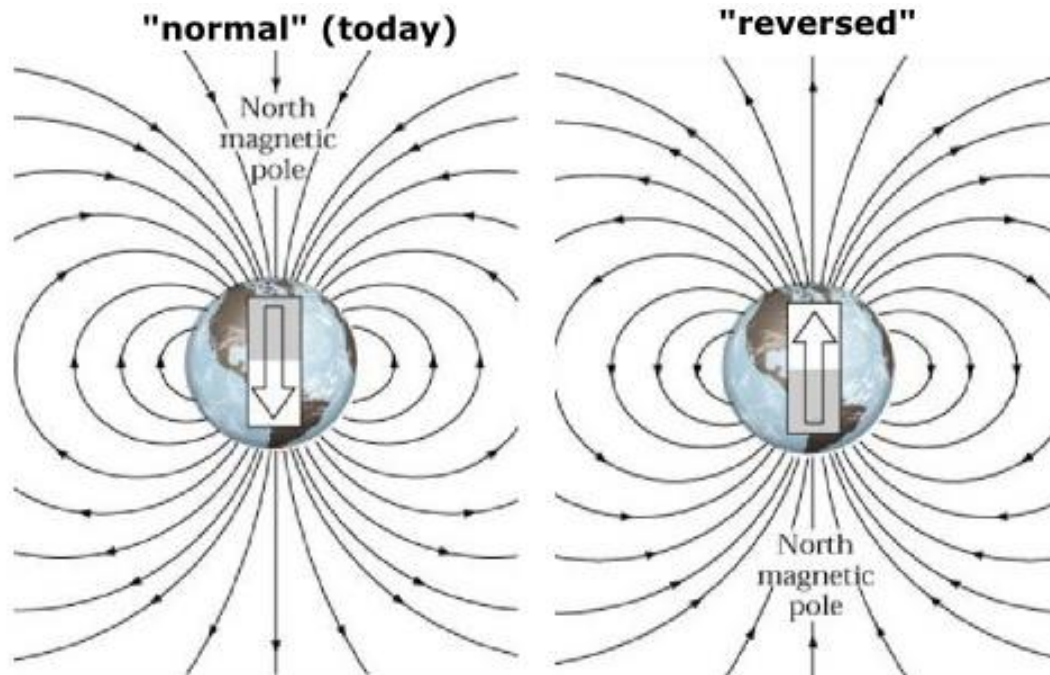
Magnetic Poles Are Constantly Moving

The magnetic north pole has been steadily moving towards Siberia, Russia by an average 10 km per year in the 19th century, lately accelerating to 40-50 km per year.



Magnetic Field Reversal

- Careful study of the magnetic structure of ancient rocks suggests that the Earth's magnetic field has **reversed its direction many times** (*evidence of at least 171 found!*) over the Earth's history.

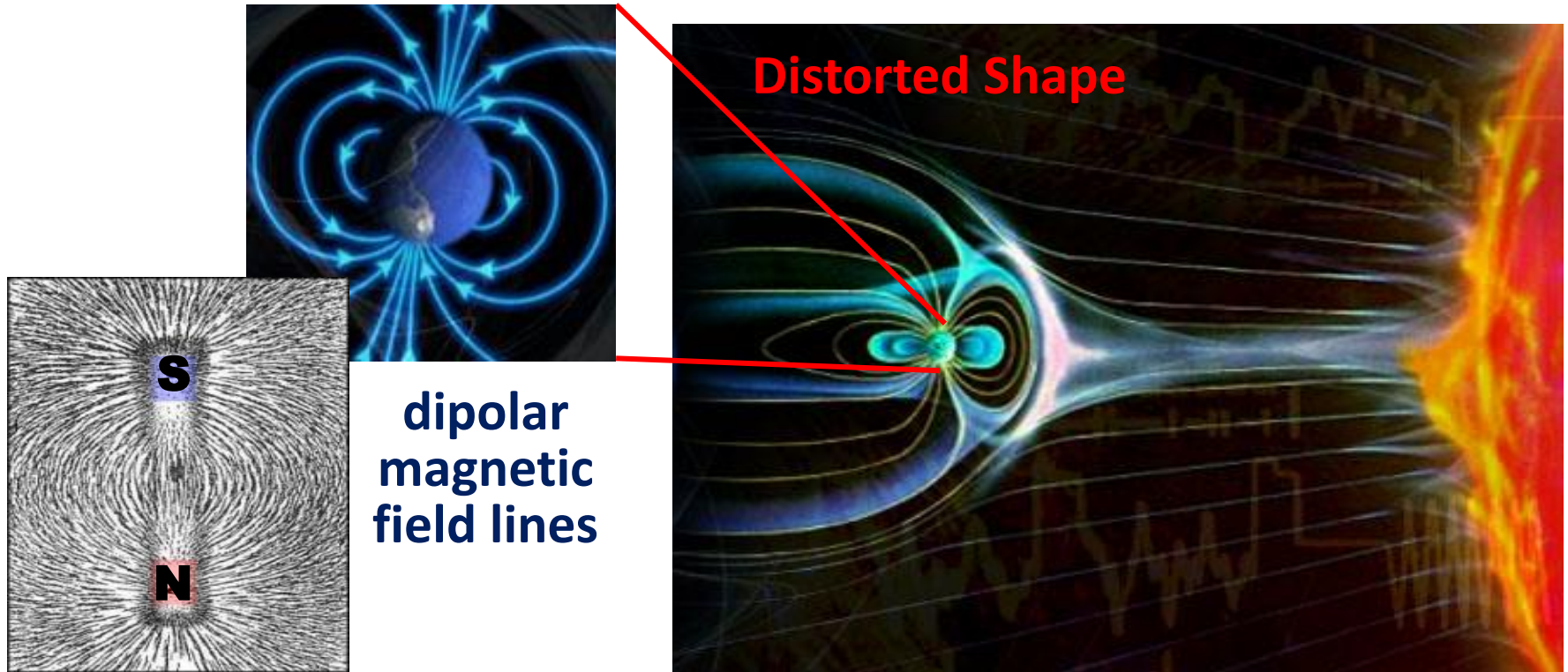


How exactly this reversal mechanism works is still not completely understood...

- Field reverses **once every 400,000 years** on average.
 - Reversal takes about 10,000 years to happen.
 - **Last reversal** was ~780,000 years ago.

Earth's Magnetic Field Shape

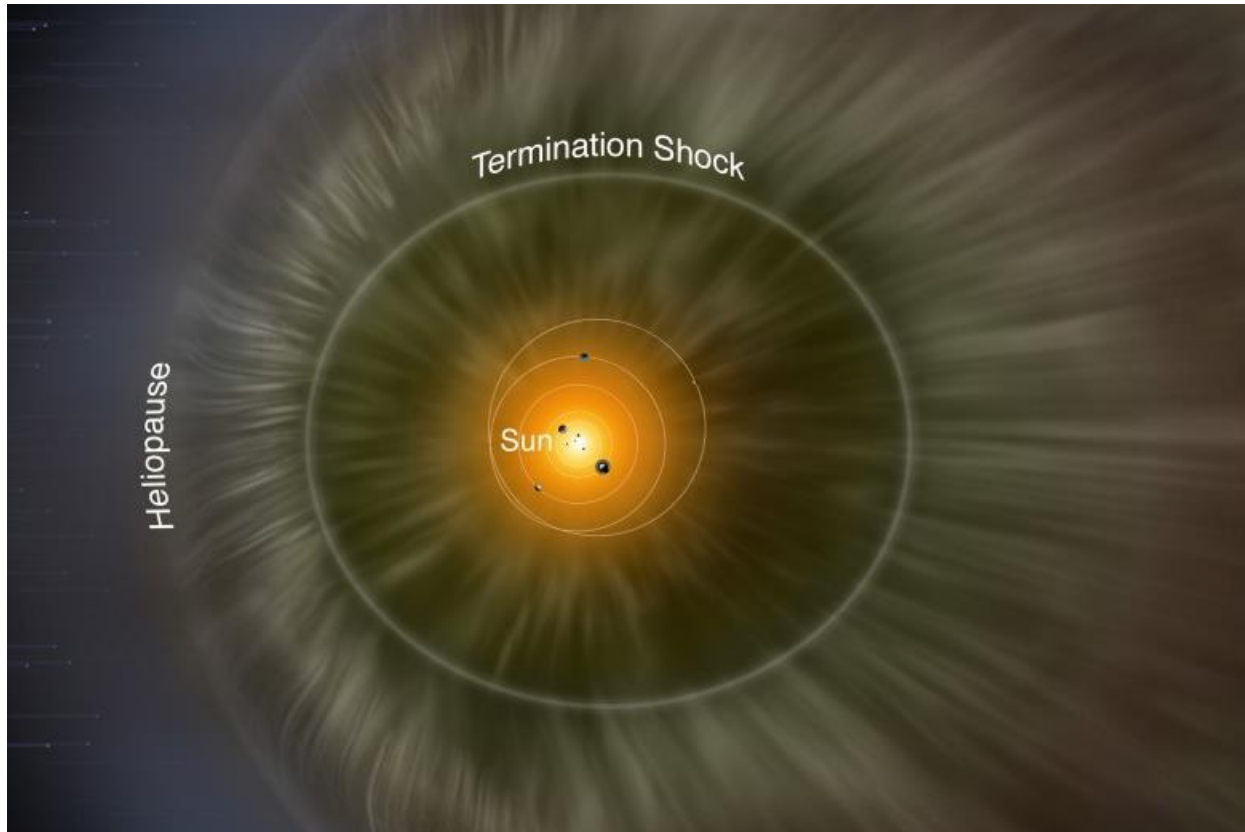
- At the Earth's surface, the magnetic field is **dipolar** - similar to that of a **bar magnet**. Further out, it is **distorted by Solar Wind**.



- Magnetosphere is **asymmetric**: the *sunward side* is about 10 Earth radii out but the other side stretches out in a *magnetotail* that extends beyond 200 Earth radii.

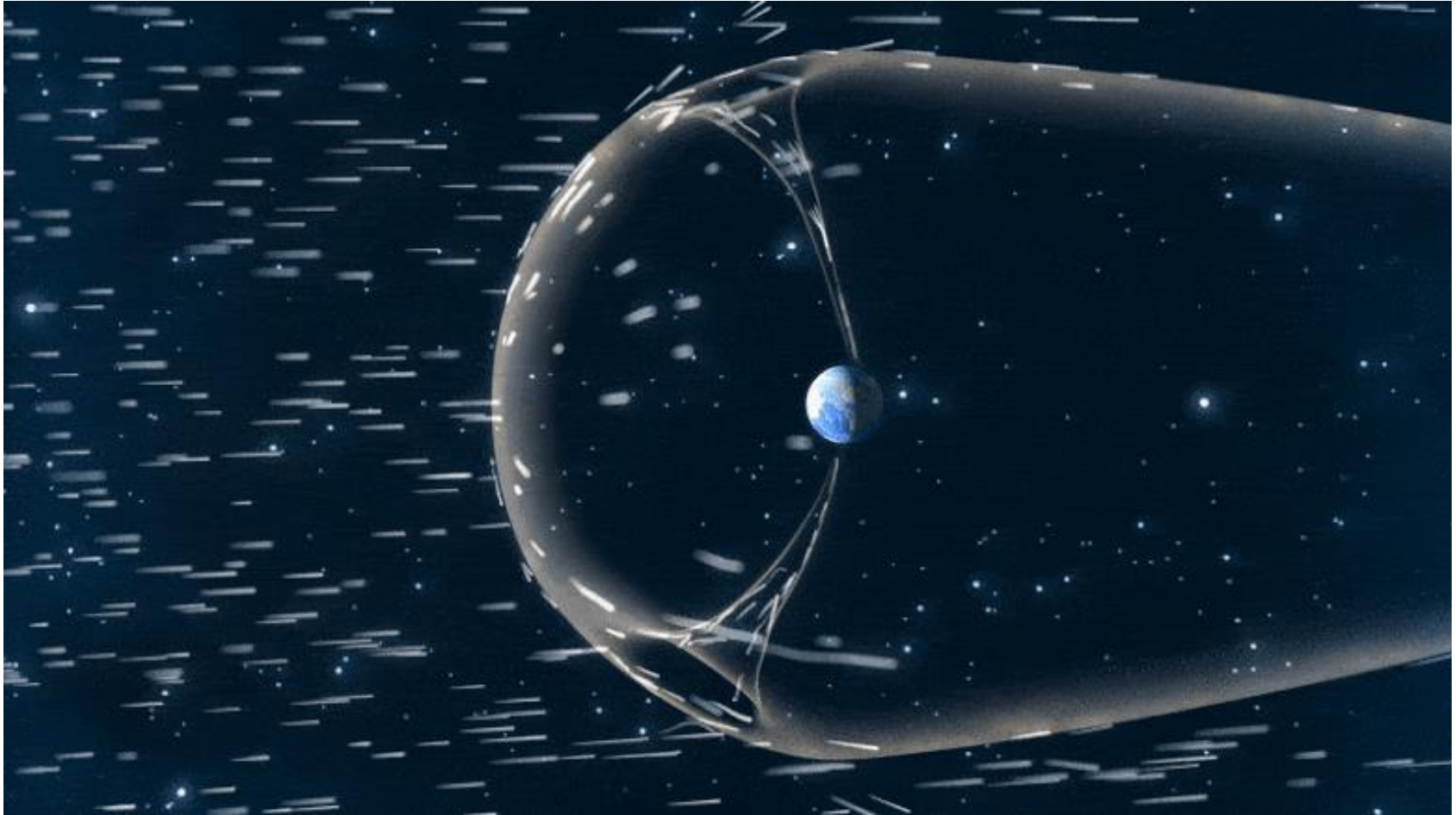
Solar Wind

- The **Solar Wind** is a stream of *plasma* released from the upper atmosphere of the Sun (photosphere and corona).



- Solar Wind consists of mostly **electrons** and **protons**.
- The stream of particles varies over time and averages **1.3×10^{36} particles per second!**
- Planets with a **weak** (Venus, Mars) or **non-existent magnetosphere** are getting their **atmosphere stripped off** by the Solar Wind.

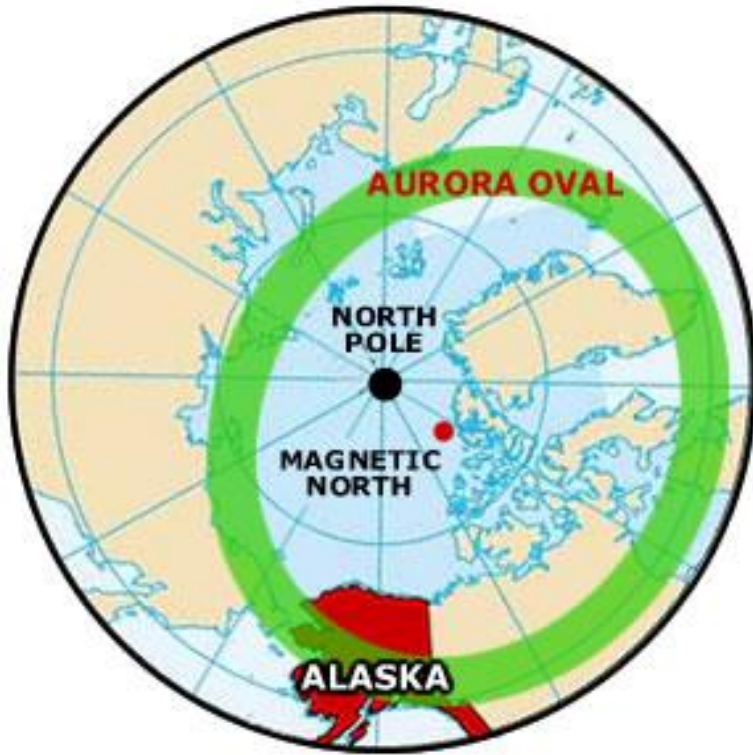
Magnetic Shield



The Earth's magnetic field deflects most of the particles away and **acts to protect life on Earth** from **Solar Wind** as well as from **cosmic ray particles** coming from deep space.

Aurora Borealis or Northern Lights

(Galileo!)



- **Generally can be observed at night in the polar regions between 60 and 72 degrees north and south latitudes, within the Arctic and Antarctic polar circles (south: *Aurora Australis*).**
- **Periods of particularly intense Solar activity, called *geomagnetic storms*, cause a lot of disturbance to the Earth's magnetic field, including auroras as far south as Hawaii (just 20°N latitude)!**

Aurora Borealis or Northern Lights

(Galileo!)

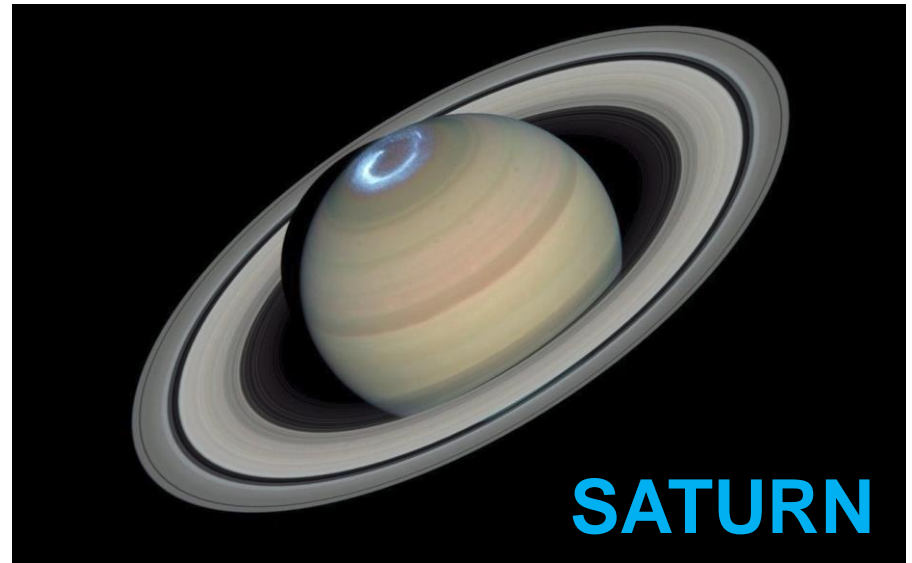
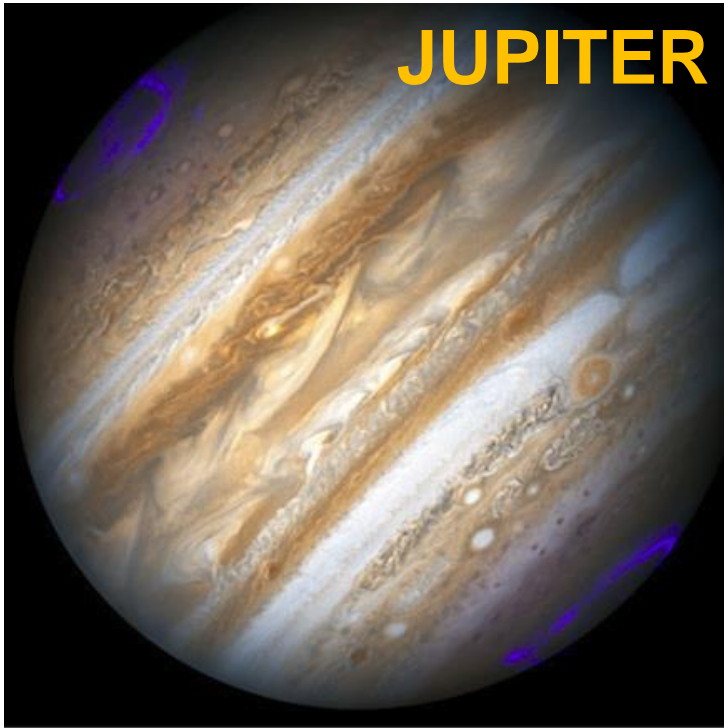
"Dance of the Spirits"



Aurora colors:

- **Red** – oxygen atoms at ~200 mi high
- **Blue** – ionized nitrogen molecules
- **Green-Yellow** – oxygen atoms at ~60 mi high – **most common!**
- **Pink/crimson/purple** – mix of the above

Aurora on other planets



Aurora Borealis Video

“Fantastic Aurora” explained:

<https://www.youtube.com/watch?v=N5utQxtma2U>

“Night of the Northern Lights”:

<https://www.youtube.com/watch?v=fVsONlc3OUY>