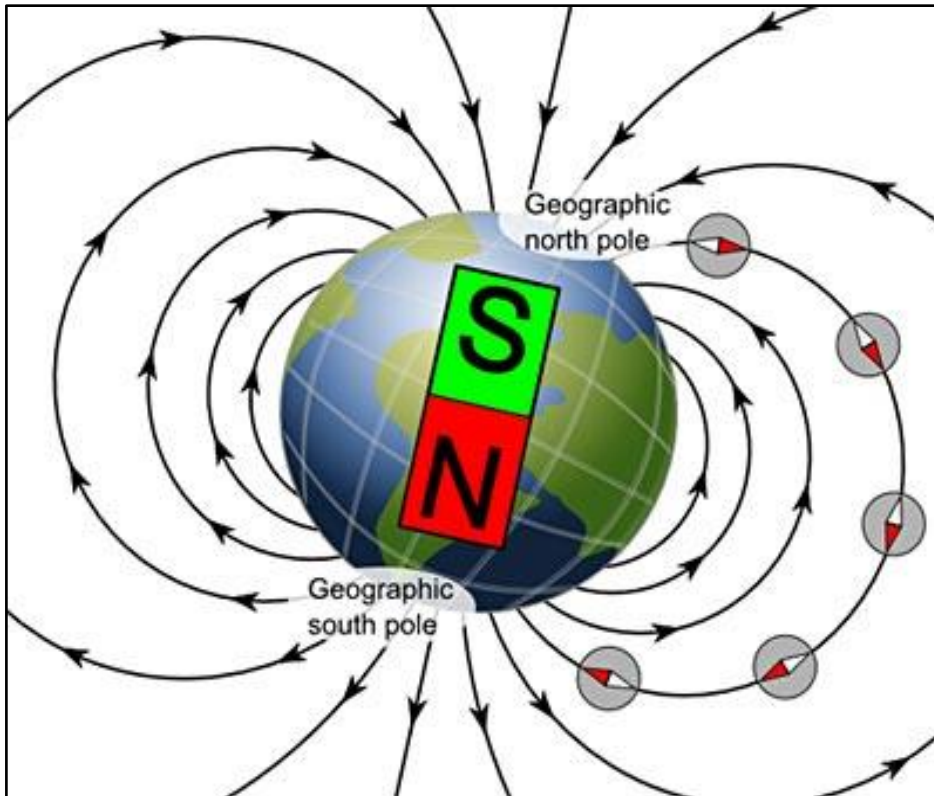
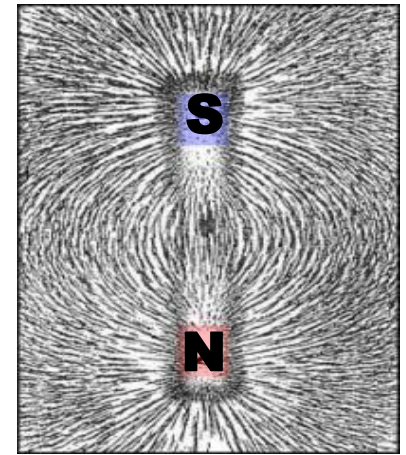


# Earth is a Magnet!

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

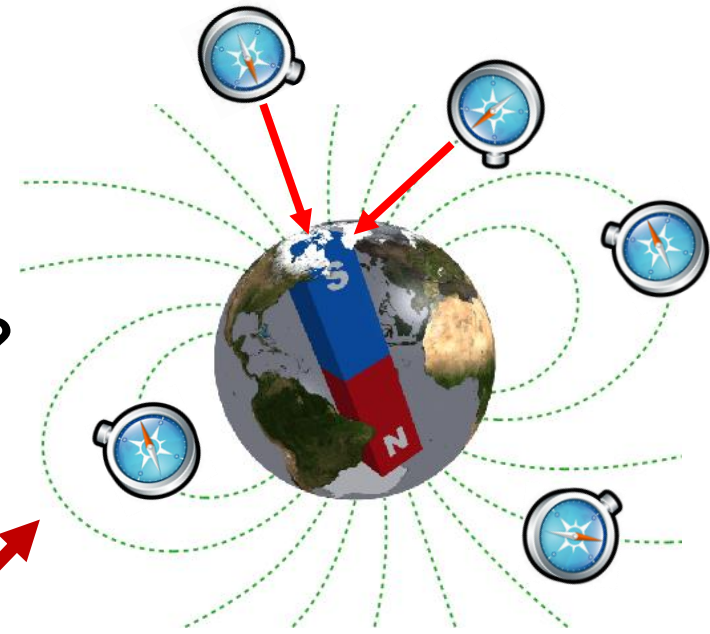


- We represent the magnetic field at any point on or above the Earth's surface by a line pointing in the direction a compass would point.
- Close to the Earth's surface, the magnetic field has a “donut” shape.

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

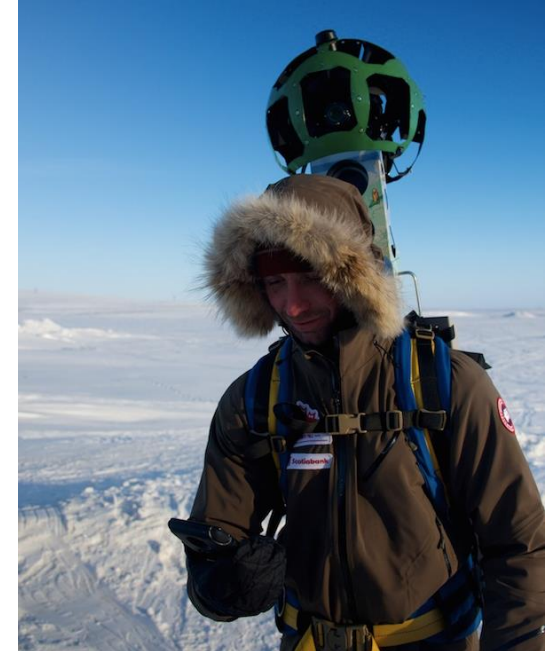
# Understanding a Compass

Question 1: what direction is North?



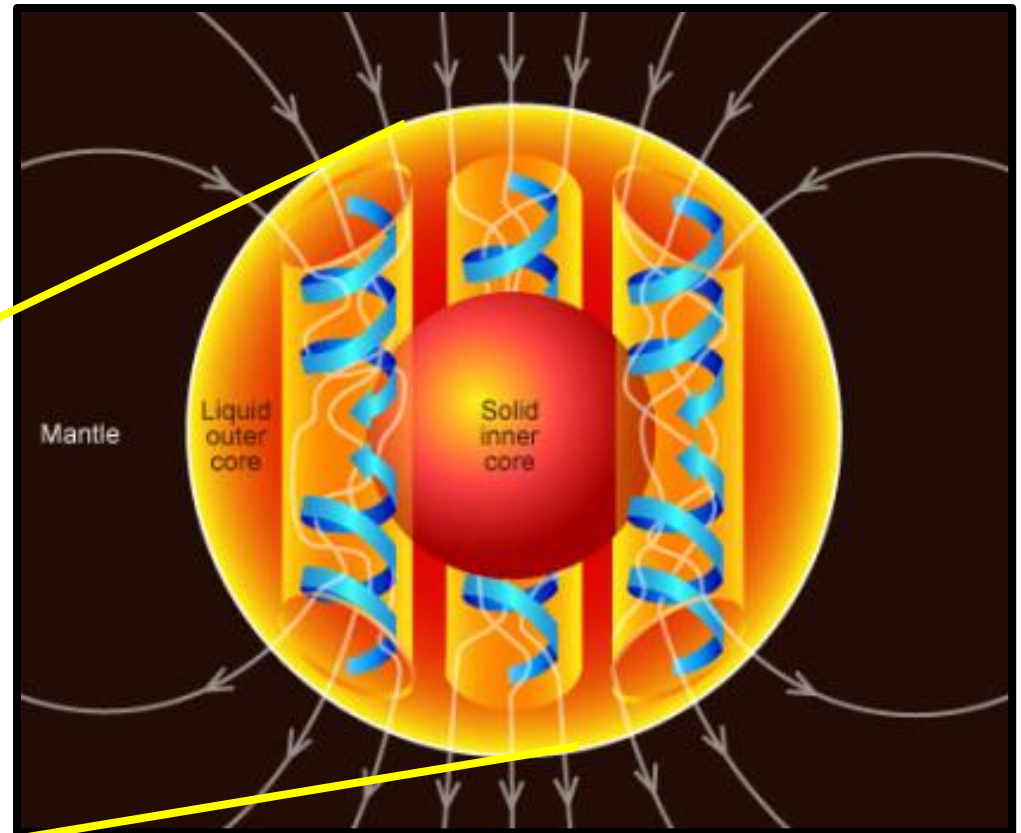
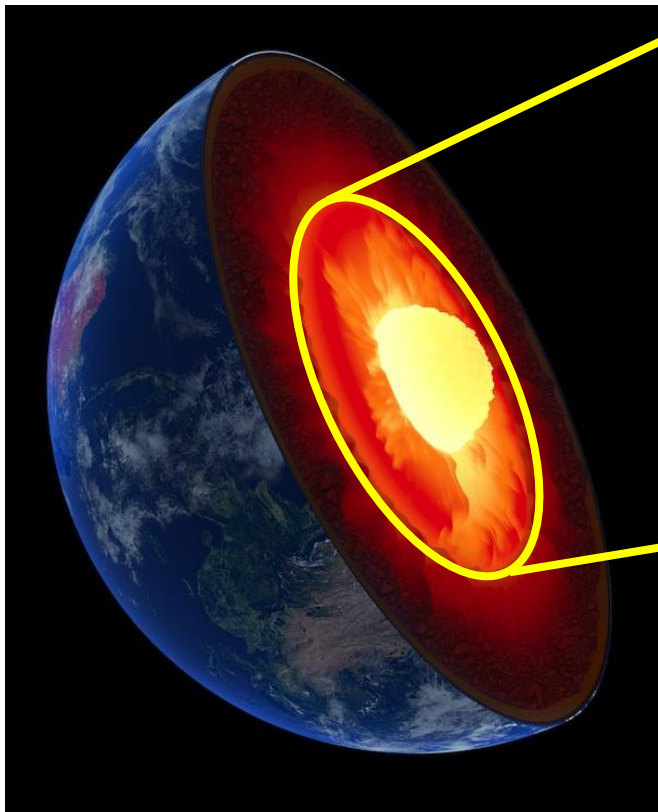
Question 2: where does a compass point at the magnetic North Pole?

**Answer:** straight down!



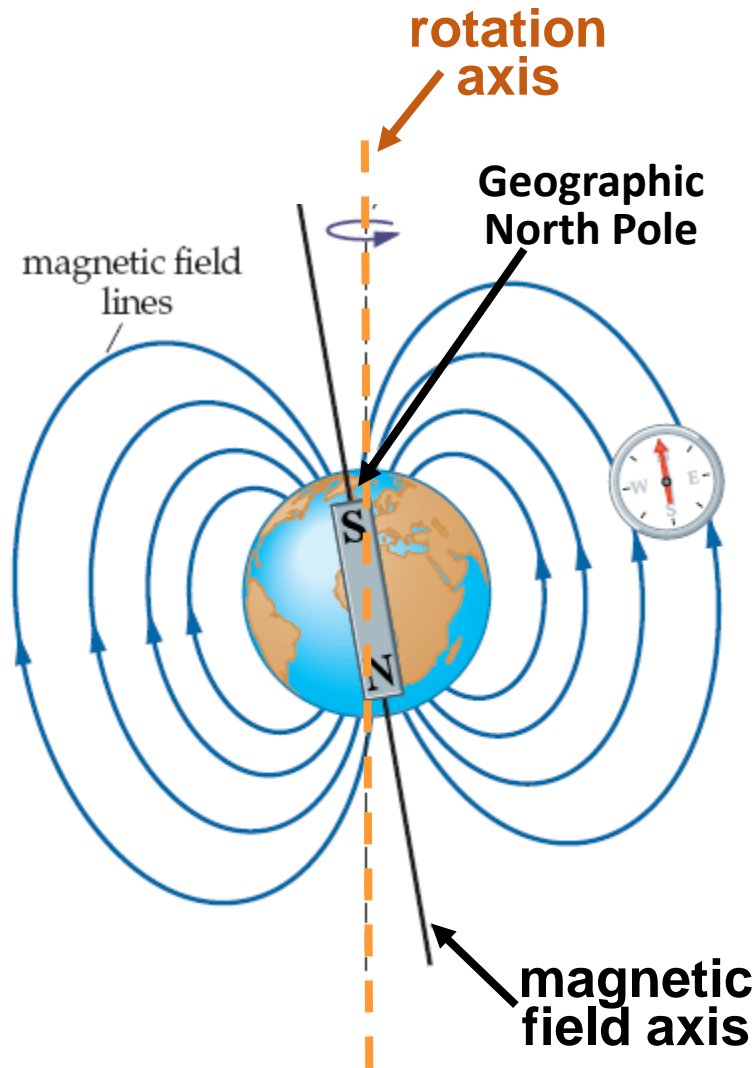
# What creates Earth's Magnetic Field?

## Geodynamo Theory



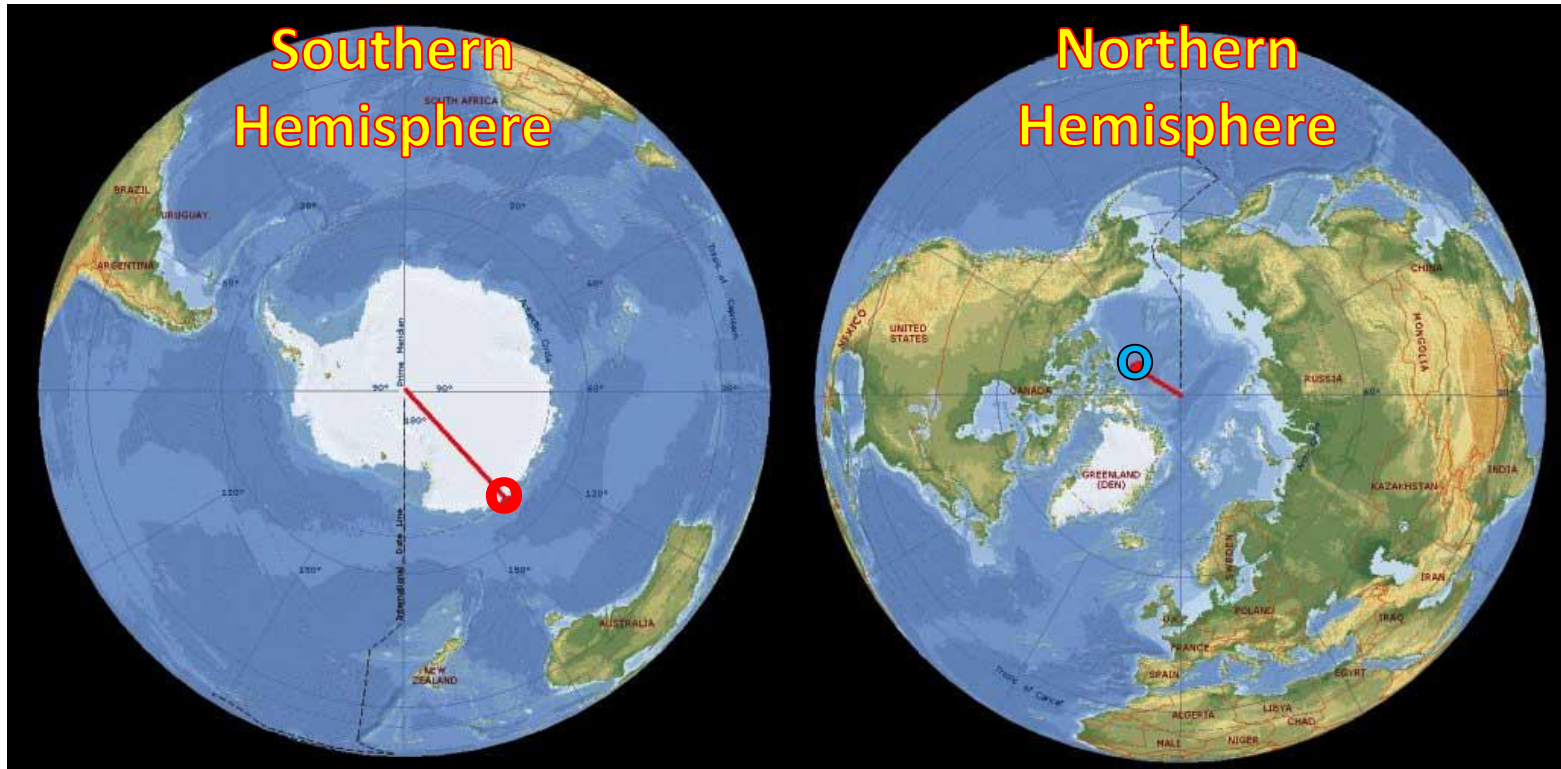
Rotating, convecting, and electrically conducting **liquid outer core** acts to induce and constantly maintain Earth's magnetic field.

# Magnetic Field Axis



- The axis of Earth's magnet and the geographical (rotation) axis **do not coincide**.
- The magnetic field axis is **tilted at  $11.5^\circ$**  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)



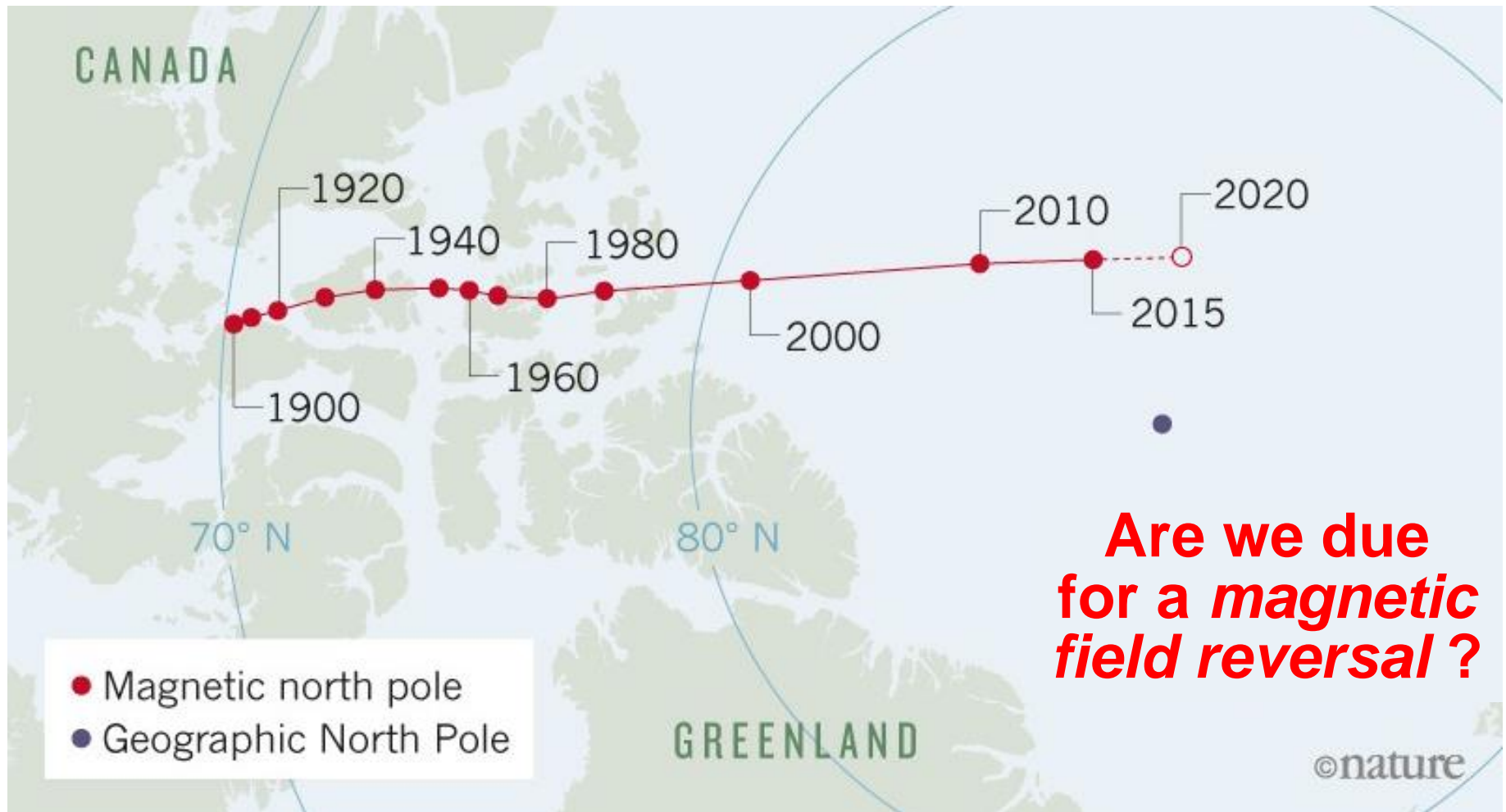
**1800 mi from True South**

**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  $\sim 50$  km ( $\sim 30$  mi) back and forth every day.

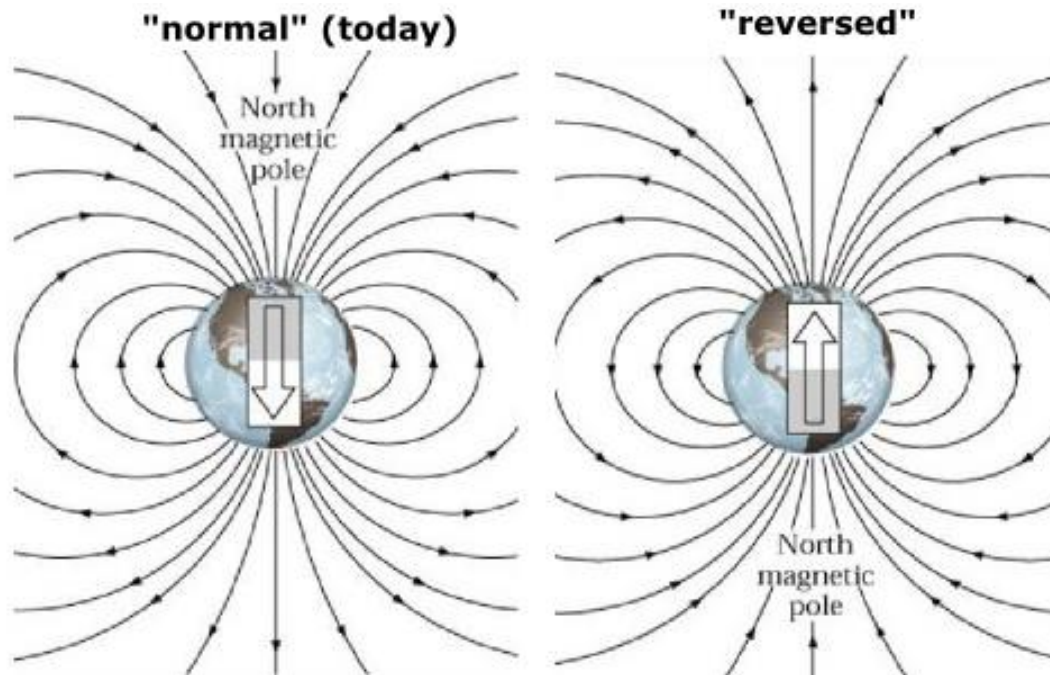
# Magnetic Poles Are Constantly Moving

The **magnetic north pole** has been **steadily moving towards Siberia, Russia** by an average 10 km per year in the 19<sup>th</sup> 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.

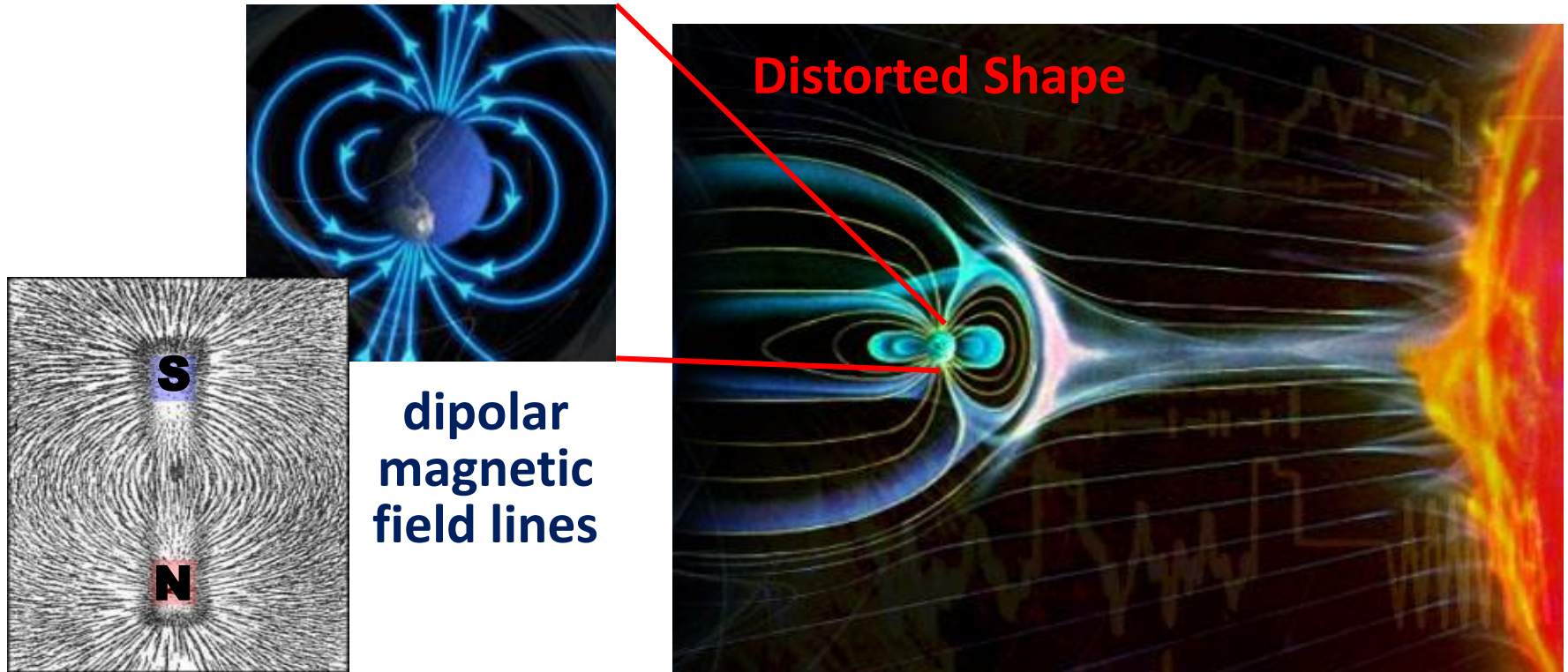


**How exactly this reversal mechanism works is still not completely understood...**

- 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**.

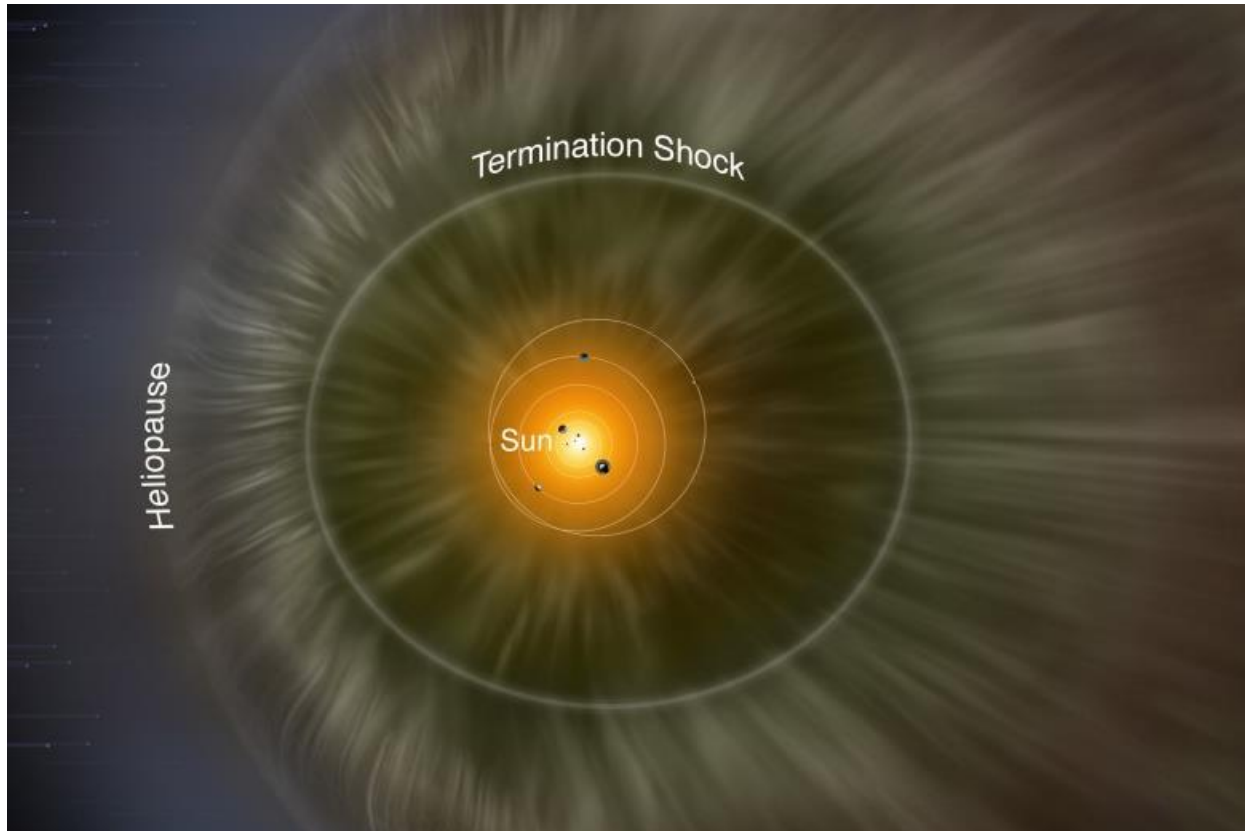


- Magnetosphere is **asymmetric**: the *sunward side* is about 10 Earth radii out but the other side stretches out in a *magnetotail* that extends beyond 200 Earth radii.



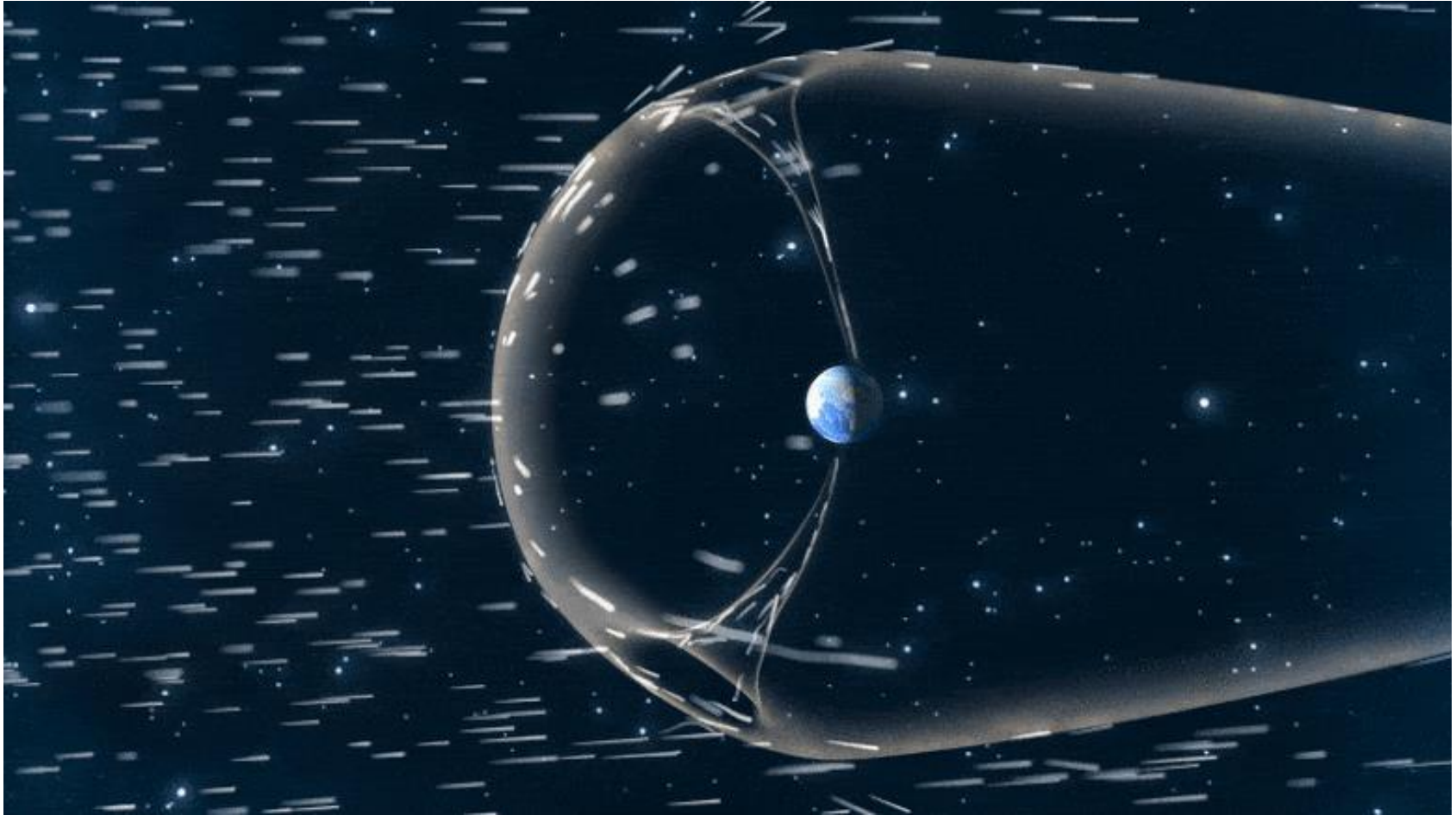
# Solar Wind

- 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  **$1.3 \times 10^{36}$  particles per second!**
- Planets with a **weak** (Venus, Mars) or **non-existent magnetosphere** are getting their **atmosphere stripped off** by the Solar Wind.

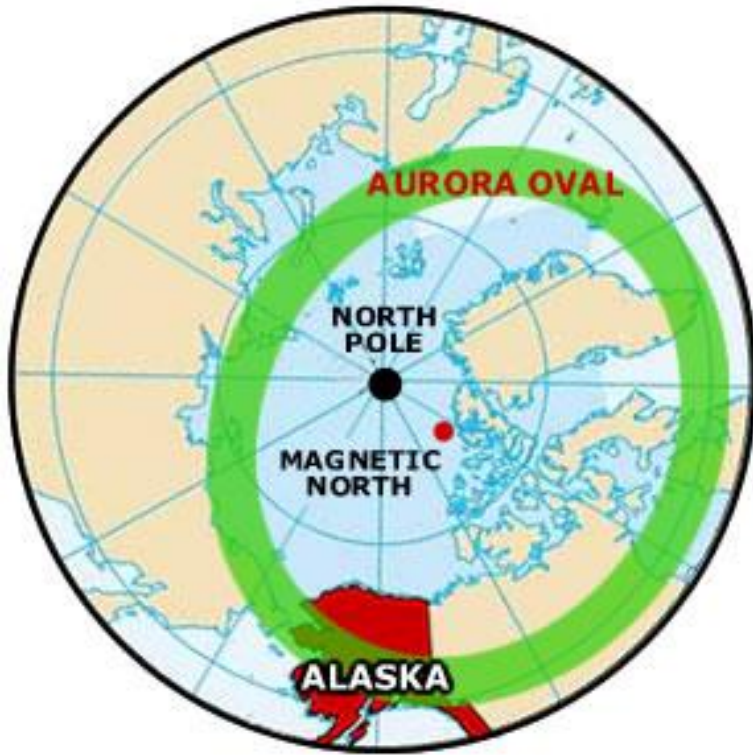
# Magnetic Shield



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!)

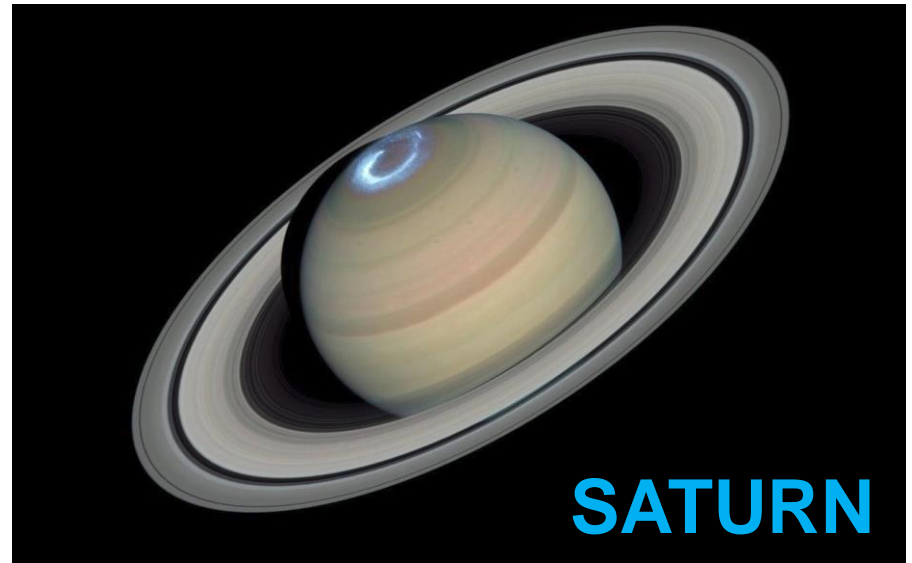
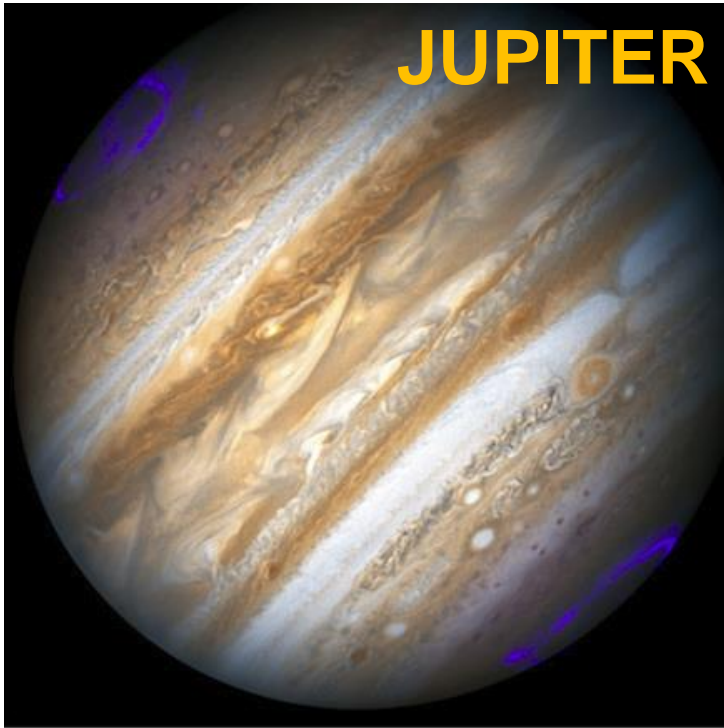
"Dance of the Spirits"



## 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>**