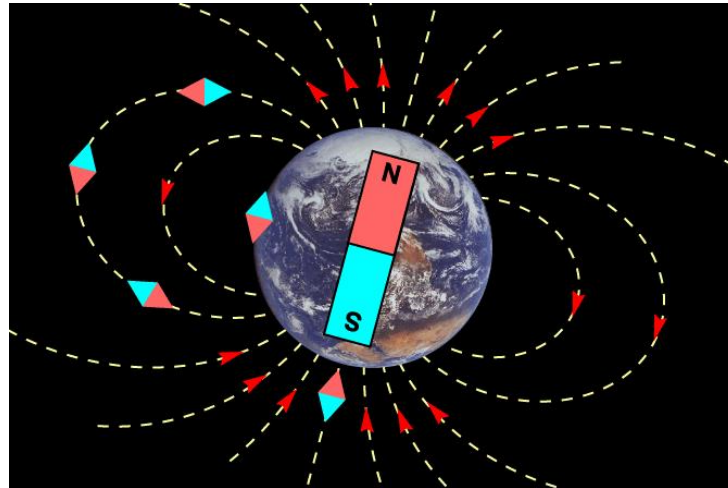
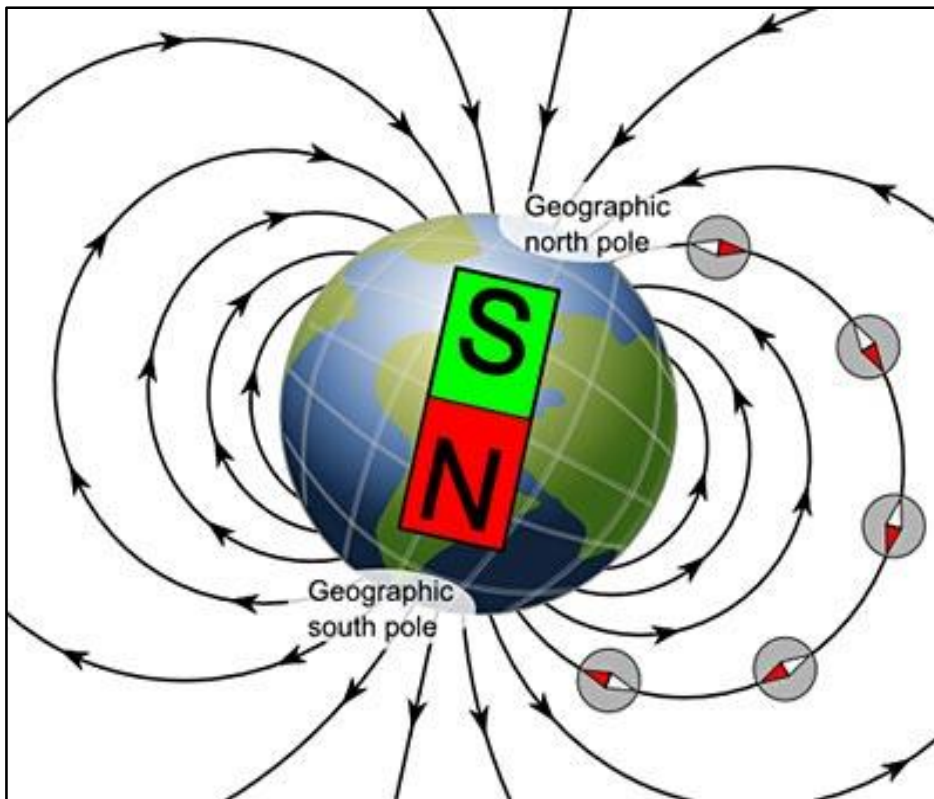


Magnetosphere



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.

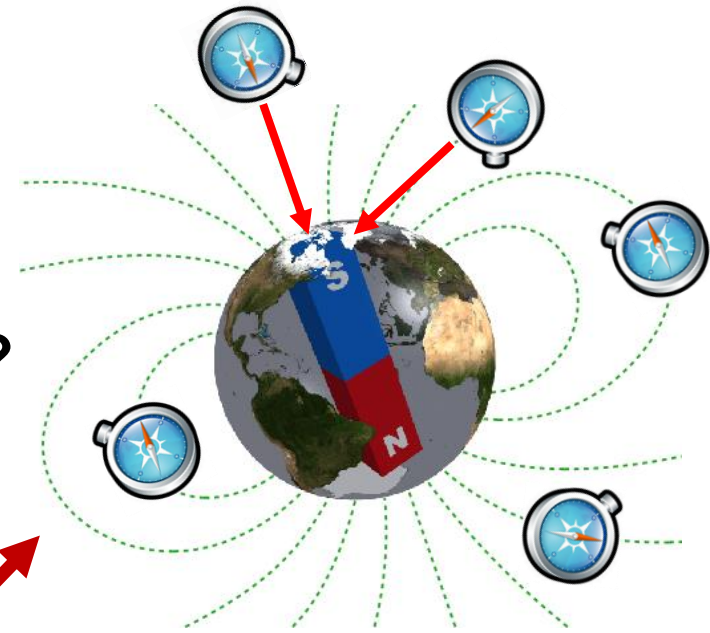
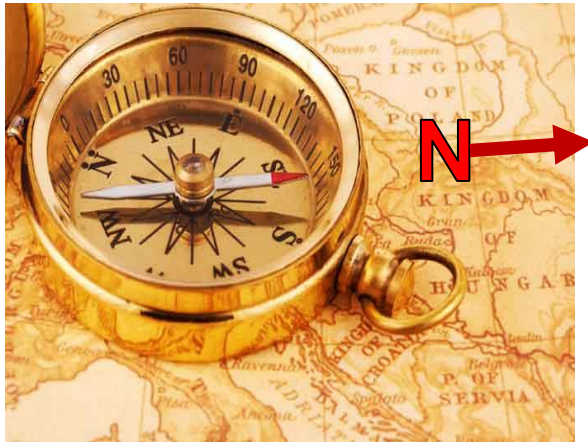


- We represent the magnetic field at any point on or above the Earth's surface by a line pointing in the direction a compass would point.
- Close to the Earth's surface, the magnetic field has a “donut” shape.

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

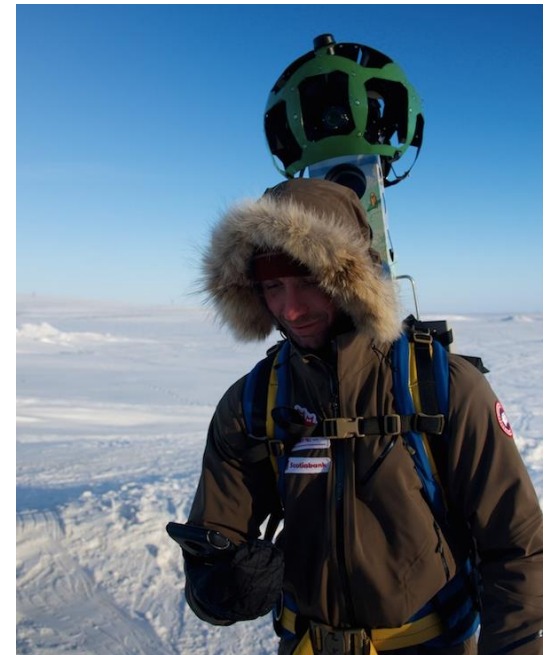
Understanding a Compass

Question 1: what direction is North?



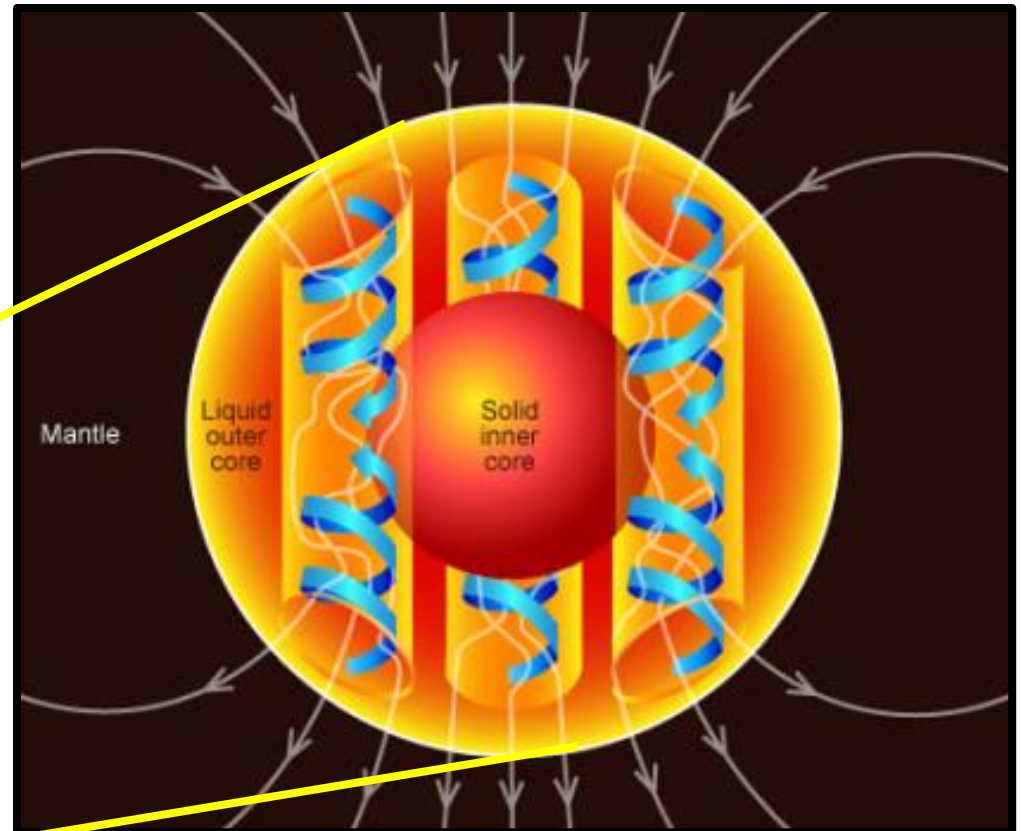
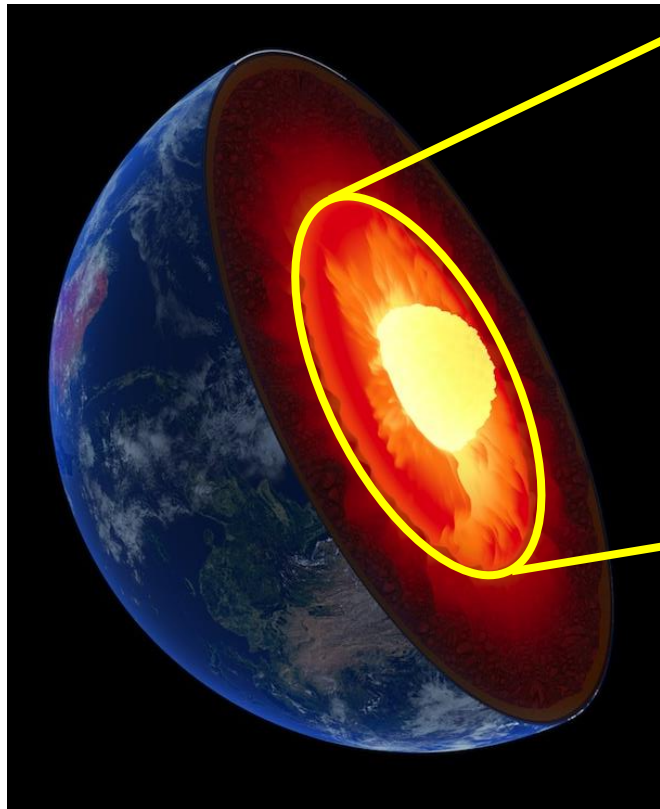
Question 2: where does a compass point at the magnetic North Pole?

Answer: straight down!



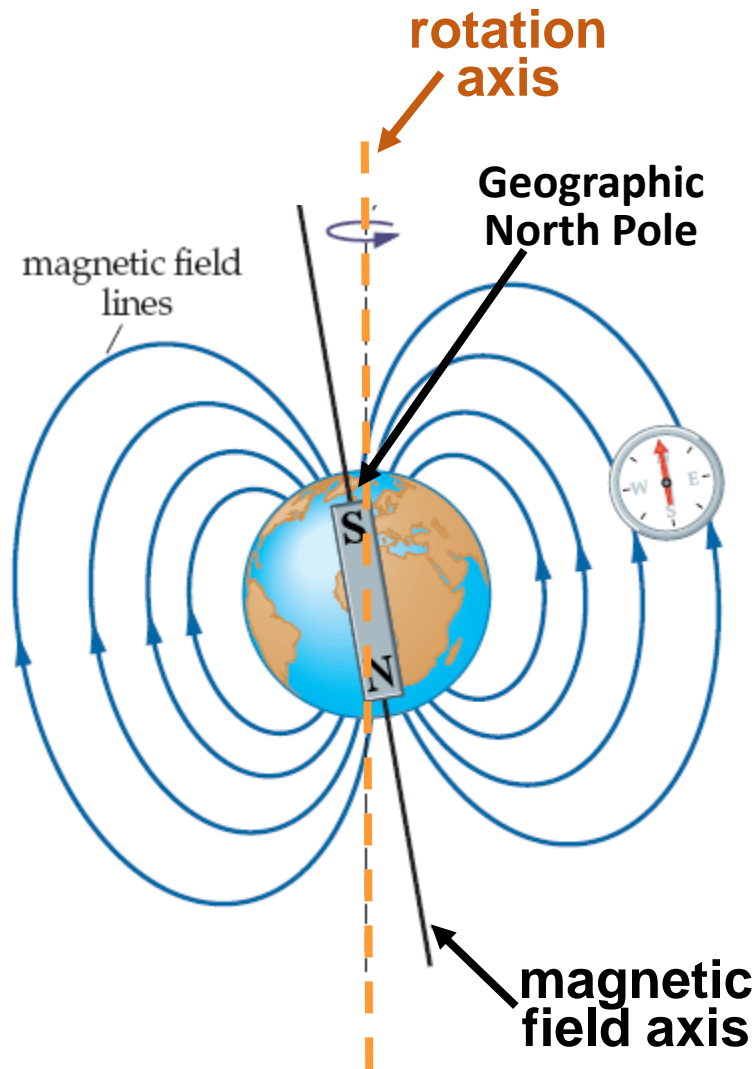
What creates Earth's Magnetic Field?

Geodynamo Theory



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

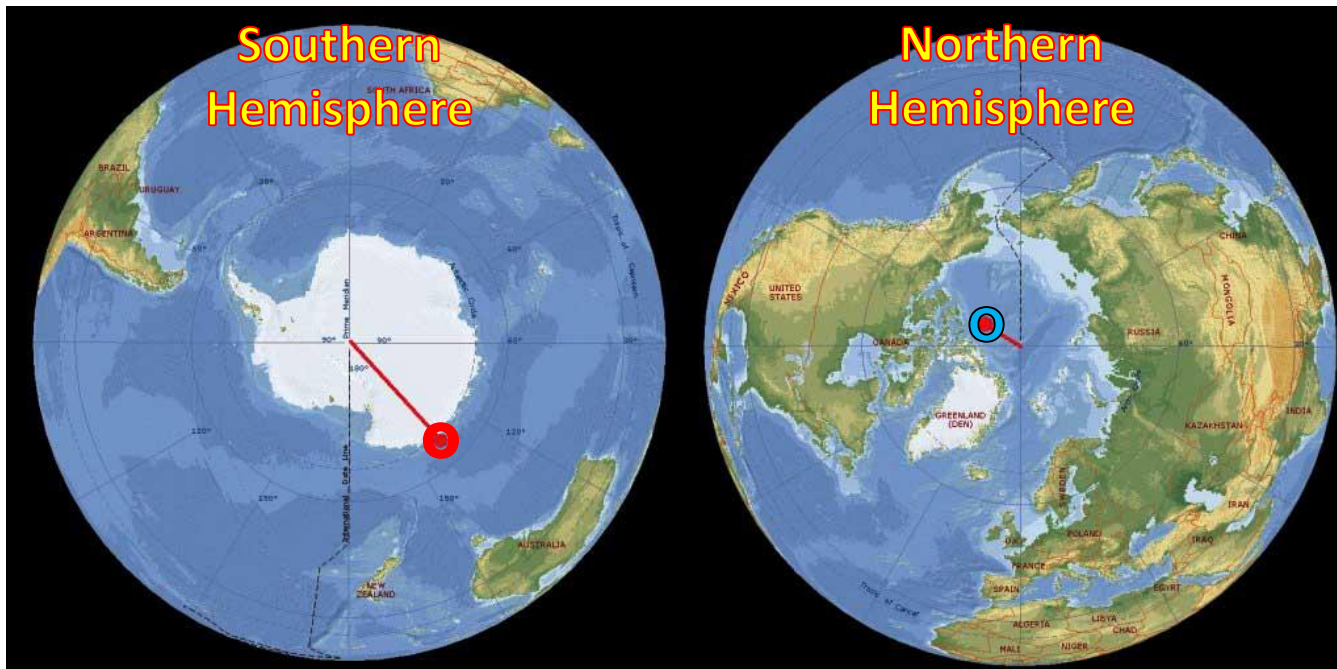
Magnetic Field Axis



- 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

- The Earth's North and South Magnetic Poles are also known as **Magnetic Dip Poles**, with reference to the vertical "dip" of the magnetic field lines at those points.



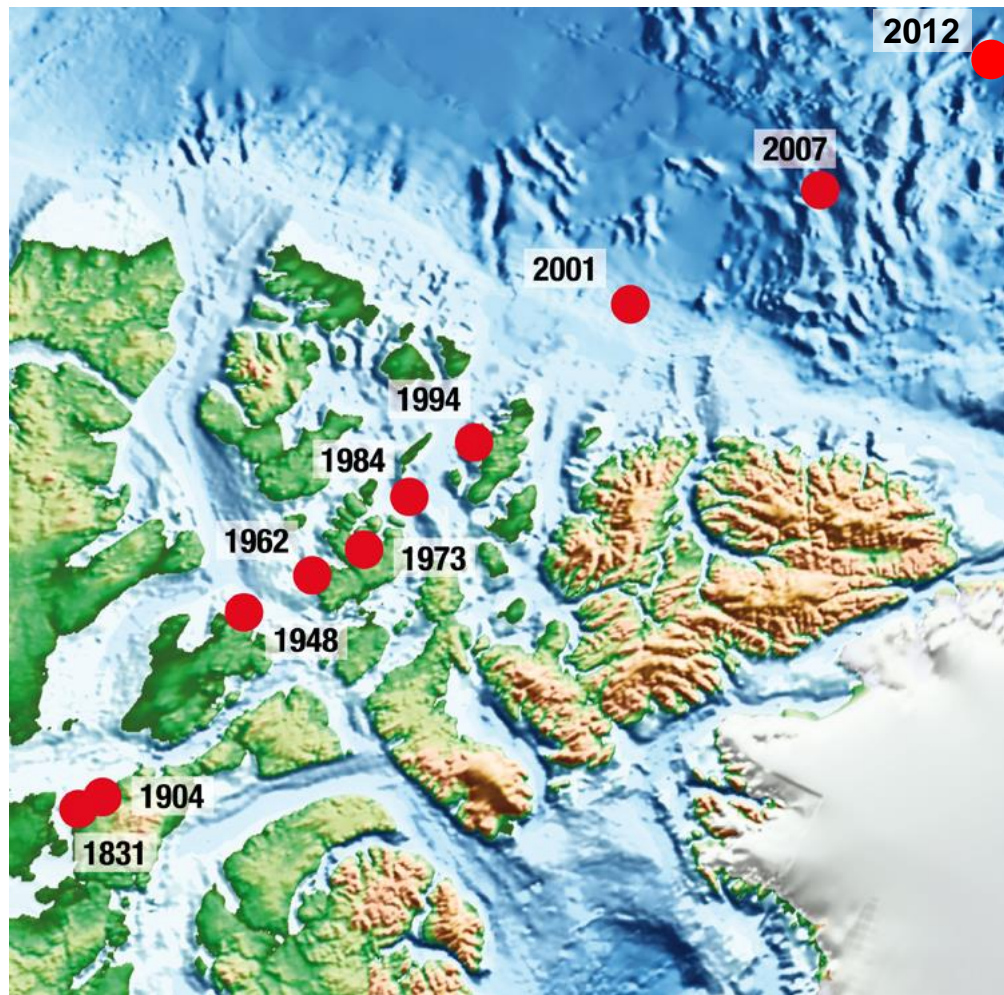
1800 mi from True South

380 mi from True North

**Magnetic
Dip
Poles
Location
(2010)**

- 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



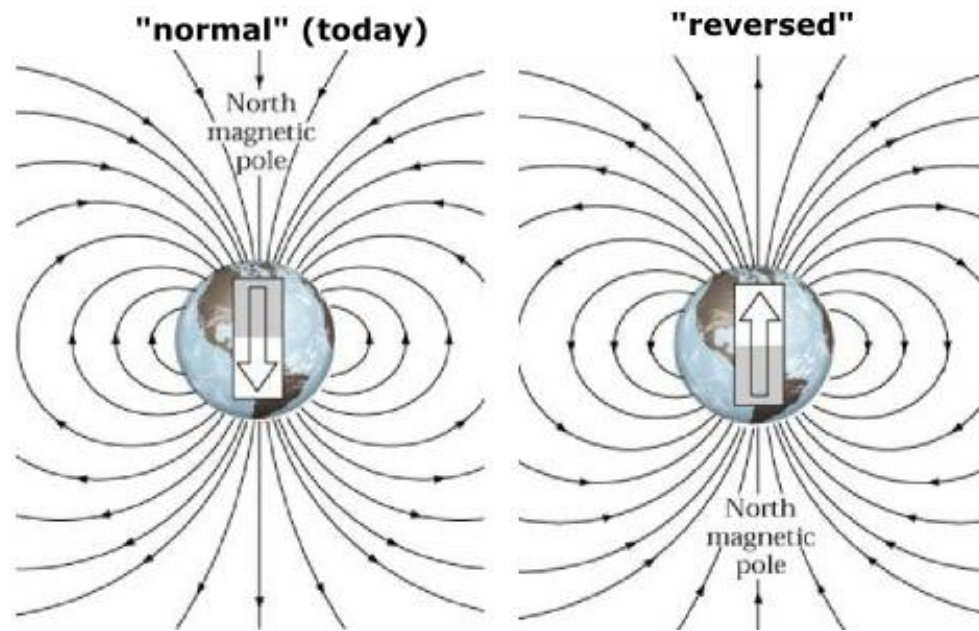
Tracking North Magnetic Pole

- The location of the **magnetic north pole** has been recorded for over 180 years: it has been **steadily moving north** by an average 10 km per year, lately accelerating to 40-50 km per year.
- The global magnetic field strength has also **weakened** by about **10%** since the 19th century.

**Are we due
for another
*field reversal?***

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** over the Earth's history.

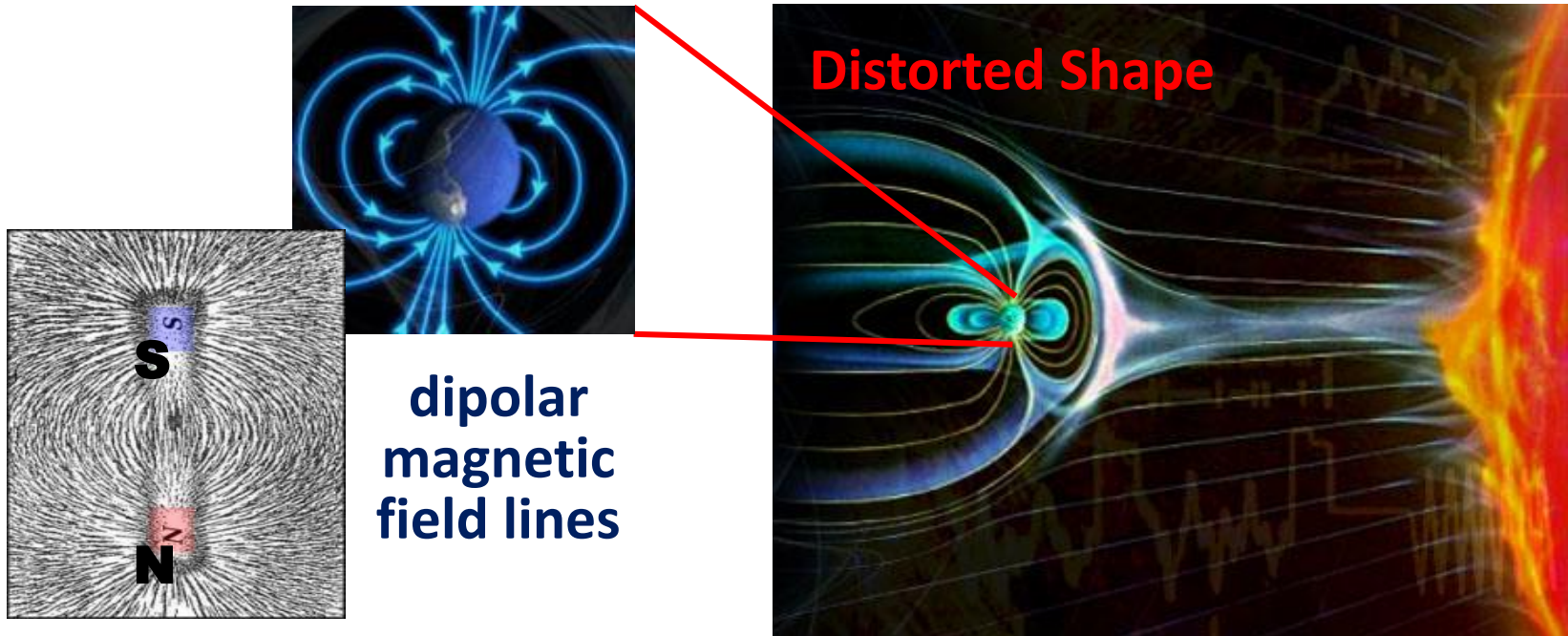


How exactly this reversal mechanism works is still not completely understood...

- 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

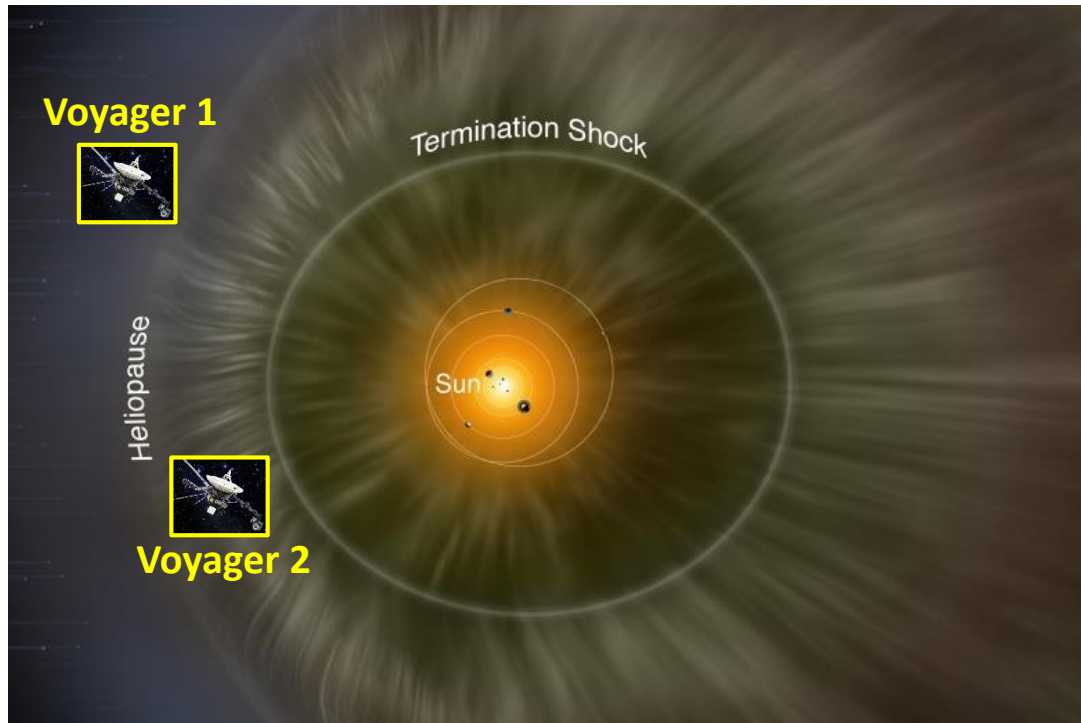
- At the Earth's surface, the Earth's magnetic field is **dipolar** - similar to that of a **bar magnet**.
- Further out, the Earth's magnetic field is **distorted by Solar Wind**.



- 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).



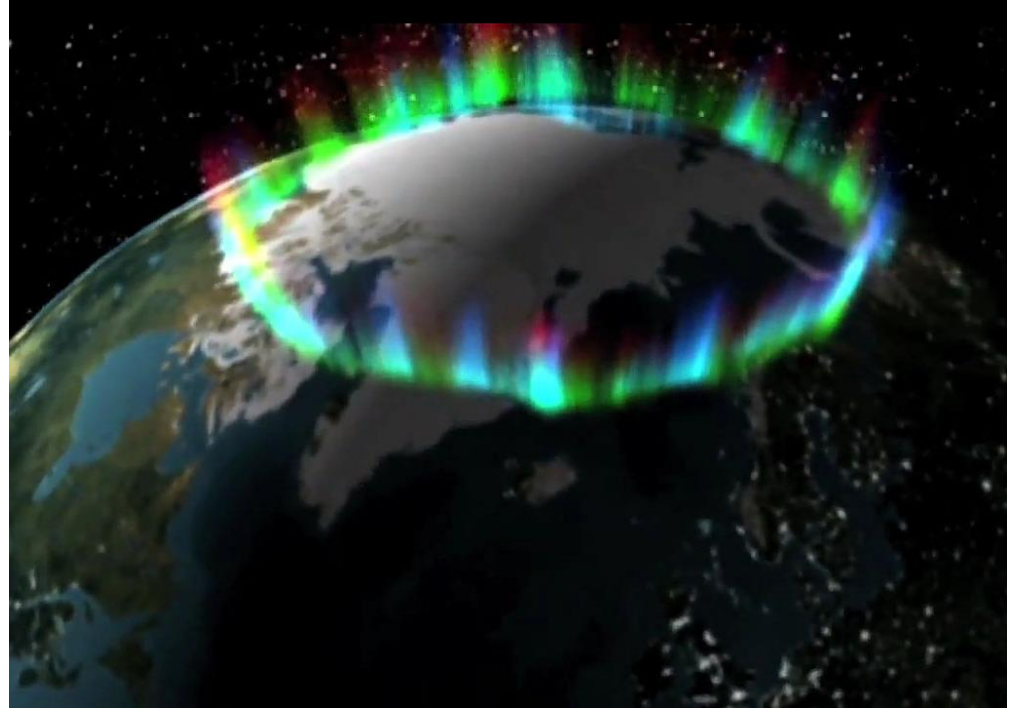
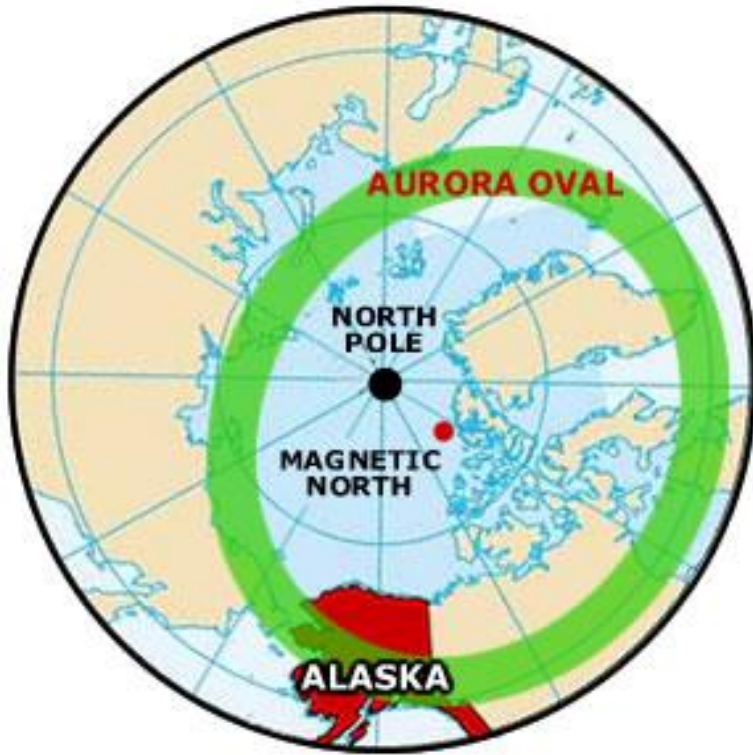
- Solar Wind consists of mostly **electrons** and **protons**.

- The stream of particles varies over time and averages **1.3×10^{36} particles per second!**

- 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!)

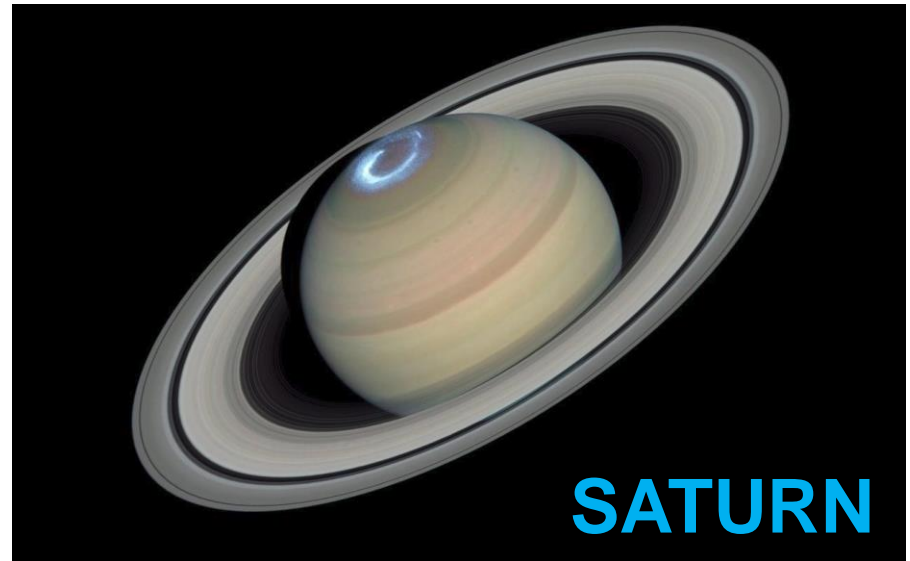
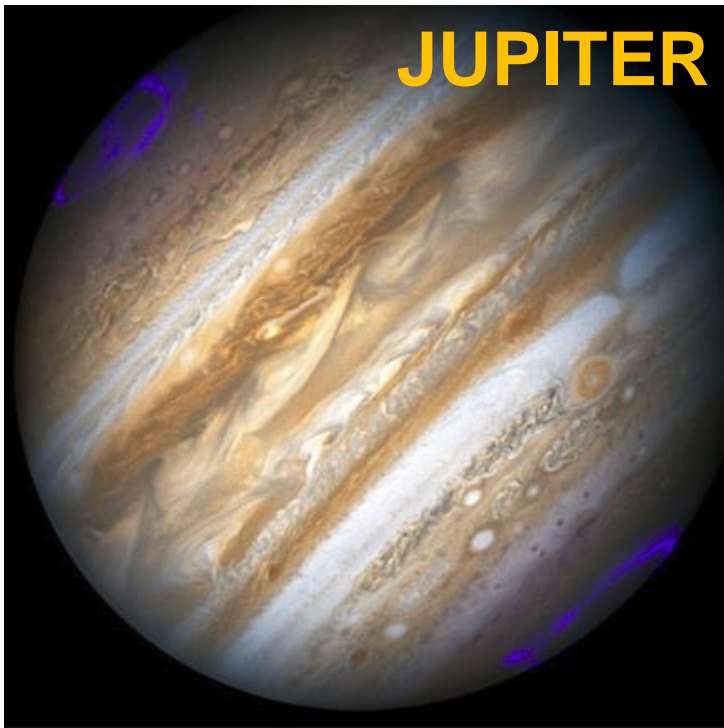
"Dance of the Spirits"



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

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

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