SPACE PHYSICS

Lecture 15

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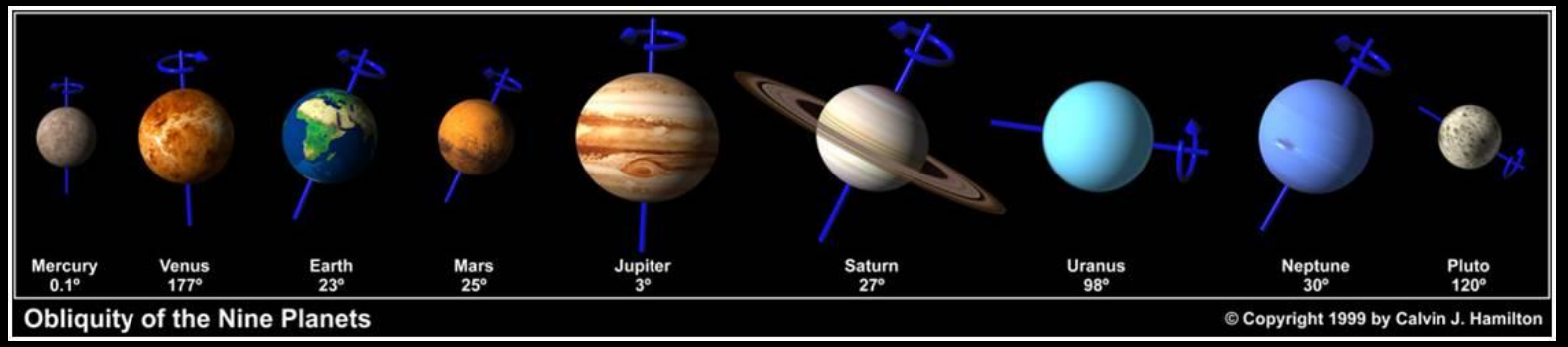
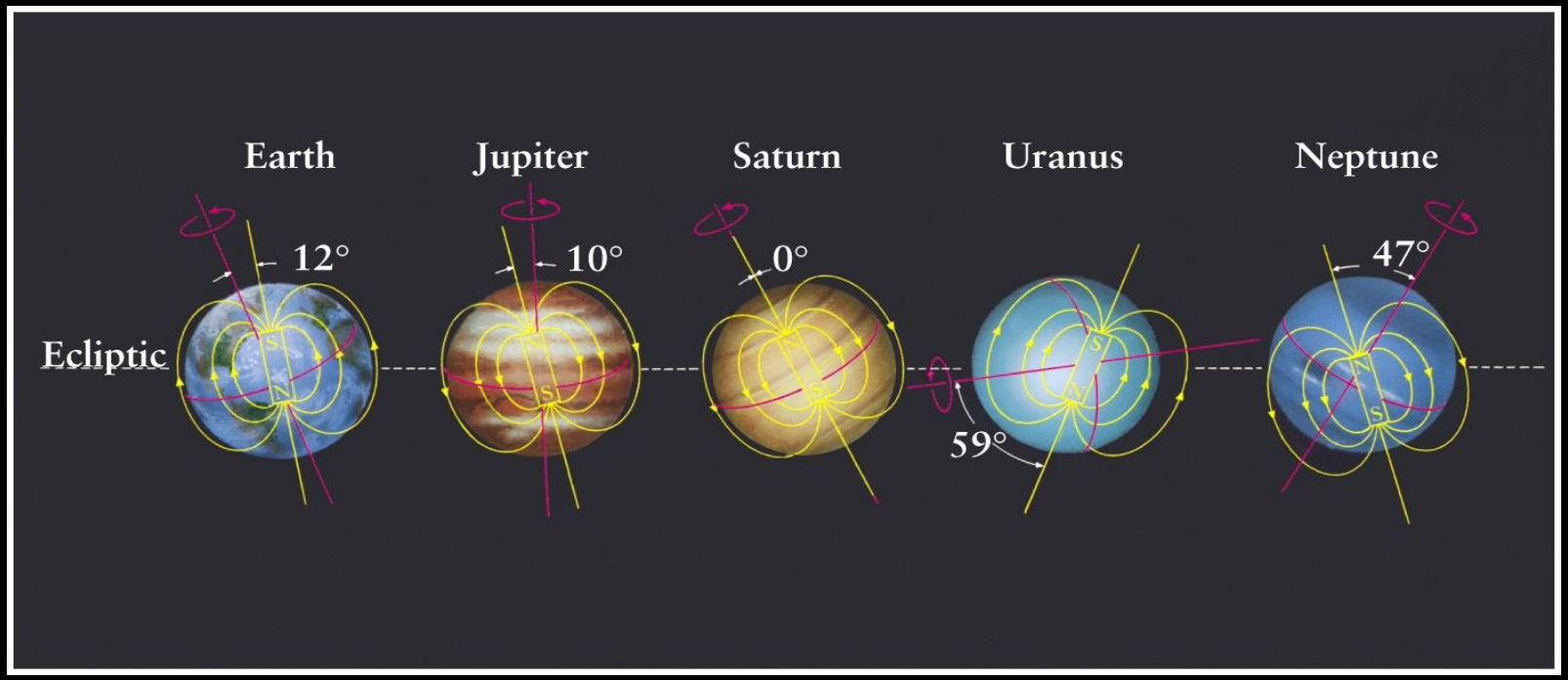
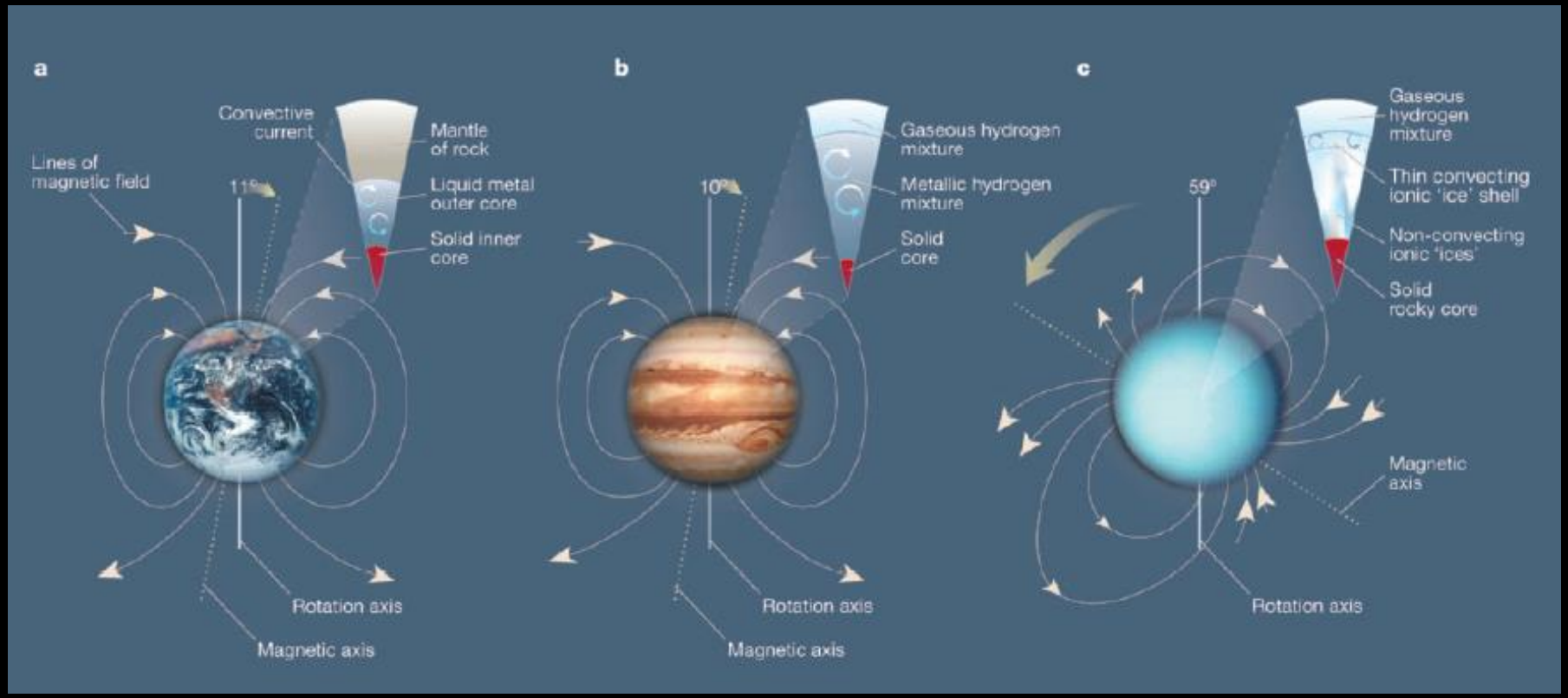
Magnetic and geographical axes





Neptune's Magnetic axis is NOT centered

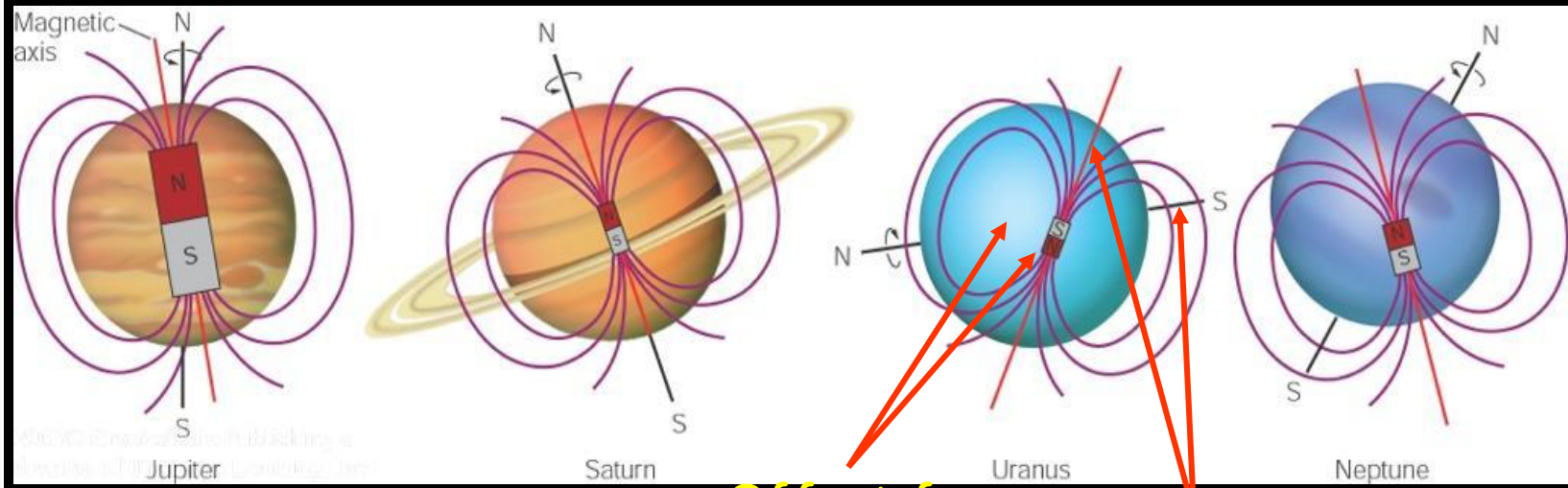
Comparison of Magnetic Fields and Interior Structures of 3 kinds of Planets



The Magnetic Field of Uranus

No metallic core → no magnetic field was expected.

But actually, magnetic field of ~ 75 % of Earth's magnetic field strength was discovered:



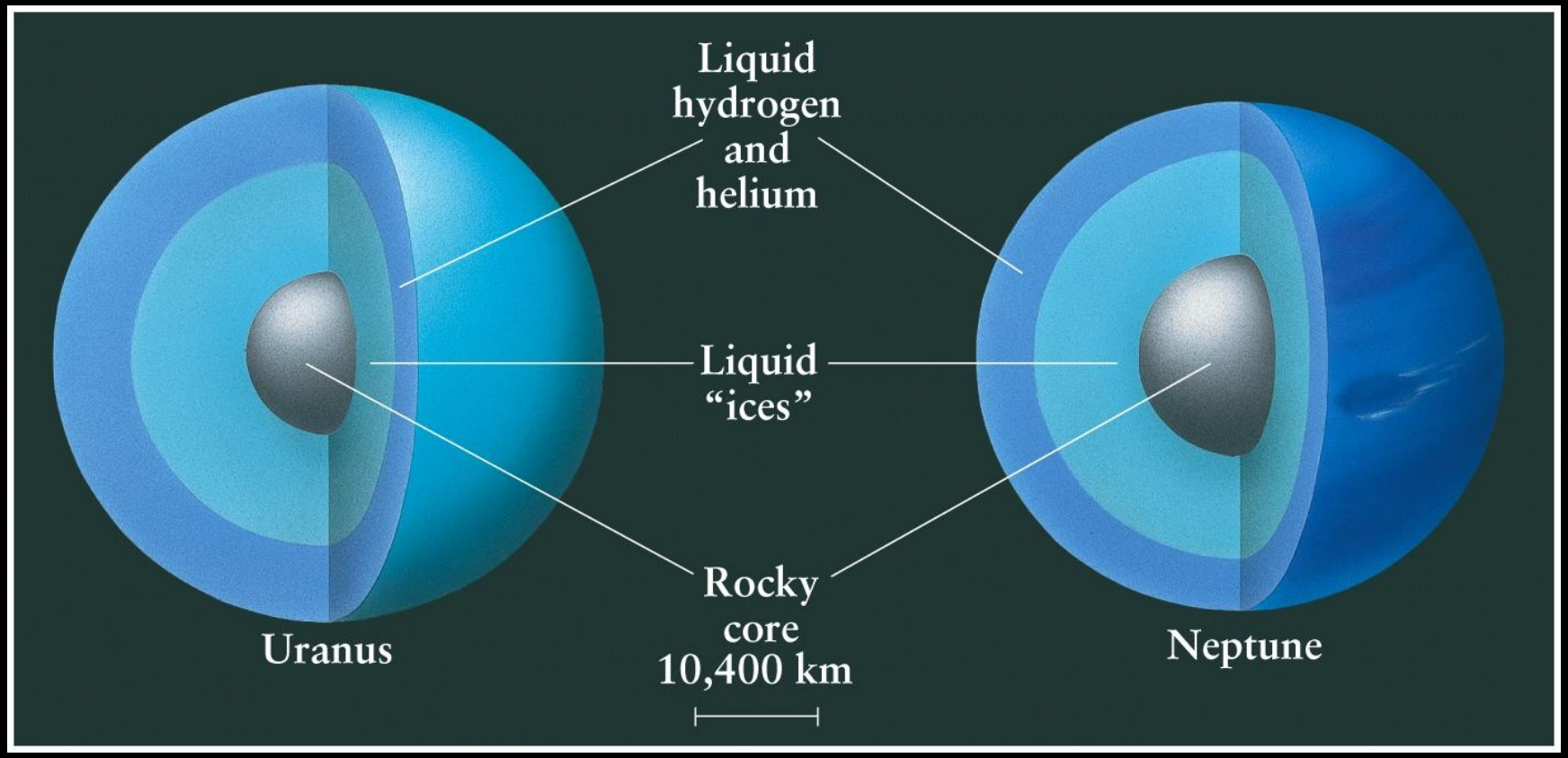
Possibly due to dynamo in liquid-water/ammonia/methane solution in Uranus' interior.

Offset from center: ~ 30 % of planet's radius!

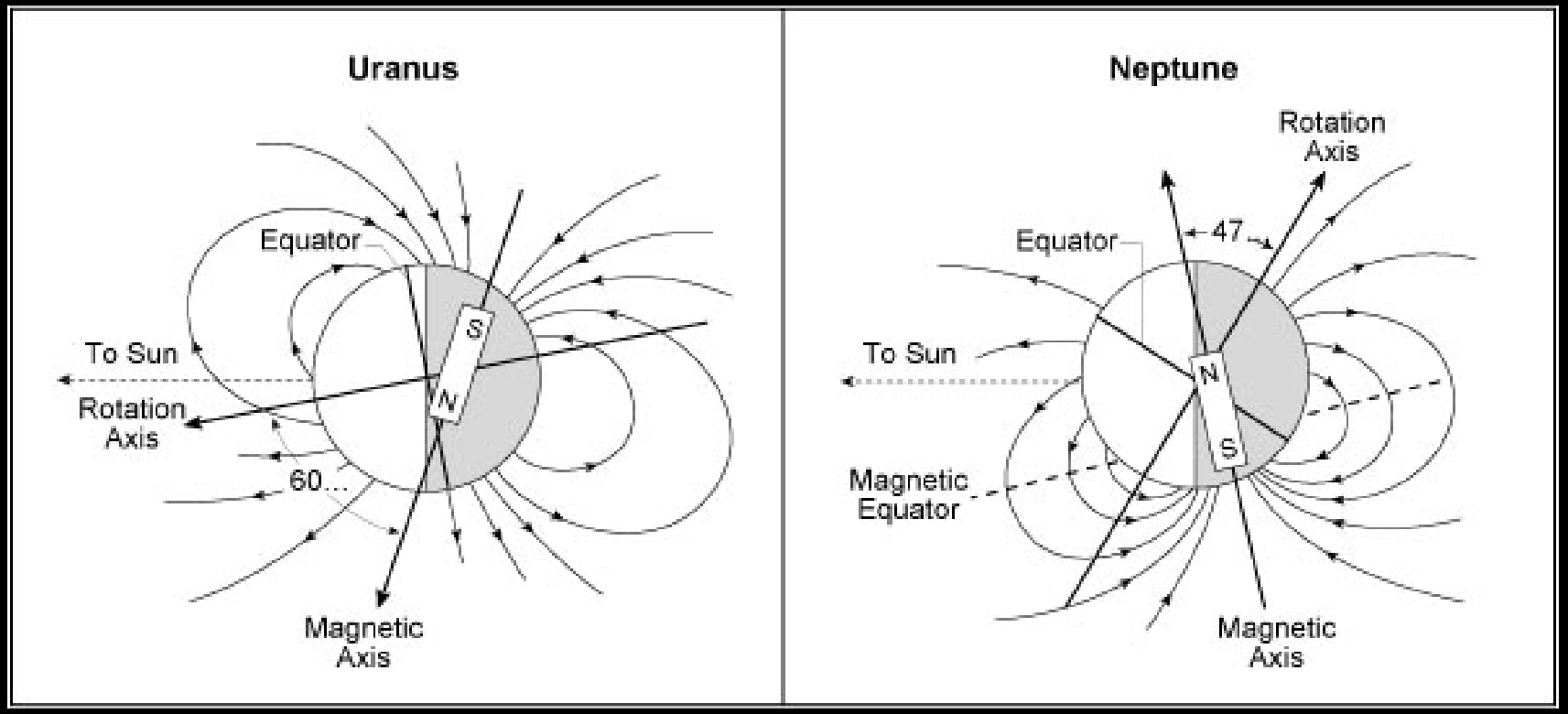
Inclined by ~ 60° against axis of rotation.

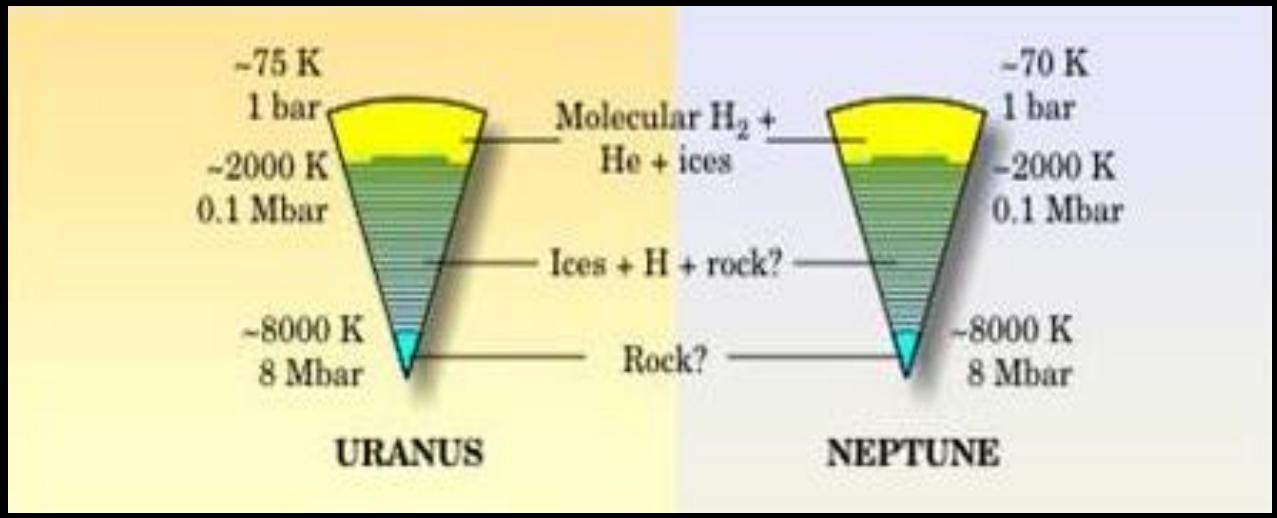
Magnetosphere with weak radiation belts; allows determination of rotation period: 17.24 hr.

Structures of Uranus and Neptune



Relatively thin atmospheres compared to Jupiter and Saturn, but still quite extensive compared to terrestrial planets

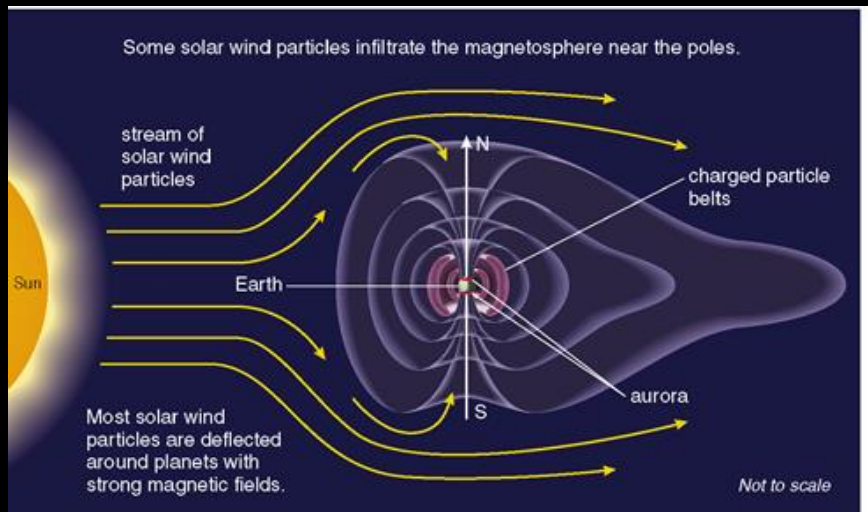

Uranus
Equator
To Sun
Rotation Axis
60...
S
N
Magnetic Axis
Neptune
Rotation Axis
Equator
47
To Sun
N
S
Magnetic Equator
Magnetic Axis

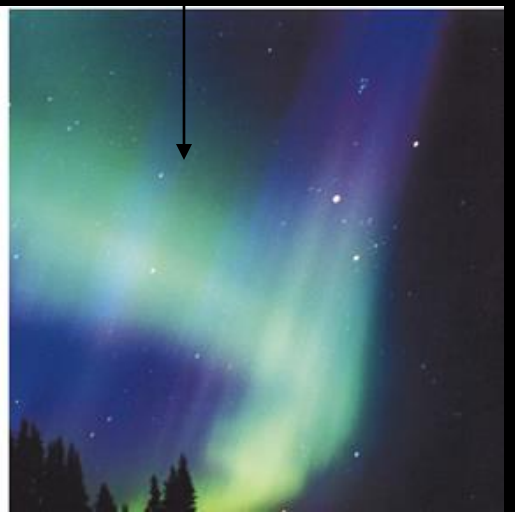

~75 K
1 bar
~2000 K
0.1 Mbar
~8000 K
8 Mbar
Molecular H_2 + He + ices
Ices + H + rock?
Rock?
~70 K
1 bar
~2000 K
0.1 Mbar
~8000 K
8 Mbar
URANUS
NEPTUNE

Earth's Magnetic Field

Another important characteristics of the Earth is its magnetic fields, which shield us from the bombardment of the high-energy charged particles, mostly from the Sun.

- The rapid rotating liquid outer metal core of Earth generate magnetic field.
- The charged particles from the Sun must move along the magnetic field lines, and are directed to the north and south polar regions. The interactions between the charged particles and the molecules of the atmosphere cause the glow of atmosphere near the north and south poles ⇒ *aurora borealis and aurora australis*
- *Without magnetic field, solar wind can strip much of the Earth's atmosphere…*

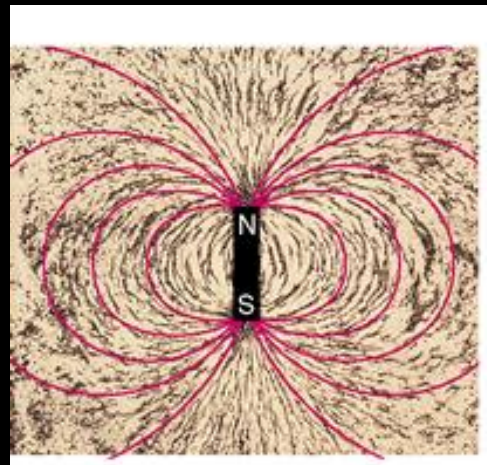


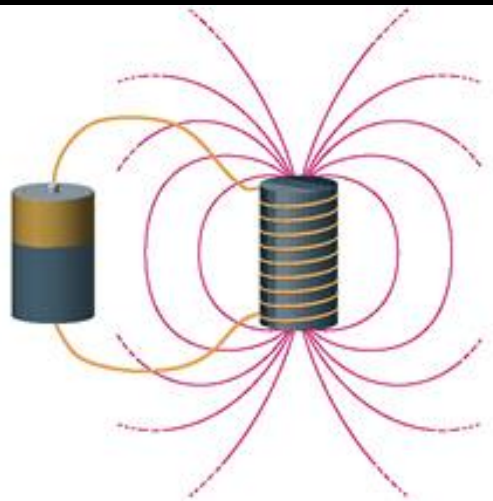


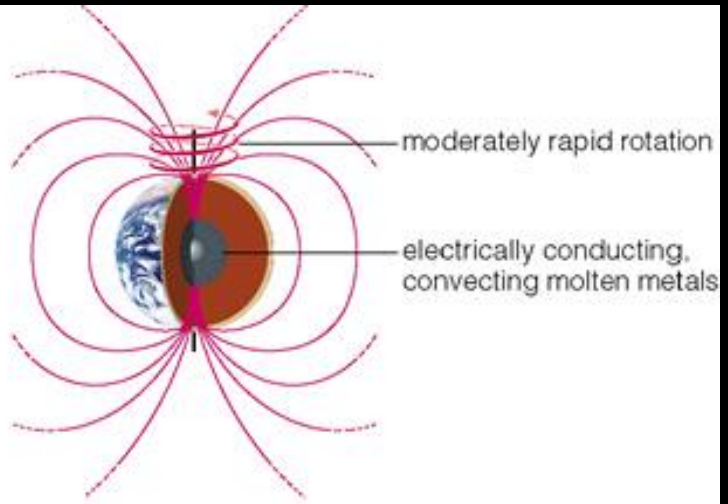
Building a Magnet

- We can generate magnetic field by circulating electric charges (running a electric current) in a spiral path.
- We do not have a complete theory of how the magnetic field of the Earth is formed yet…but generally, it is believed to form by the rotation of the Earth carries the electrically conducting molten metals in the core around, generating Earth's magnetic field.

Lines indicate points with equal magnetic field strength







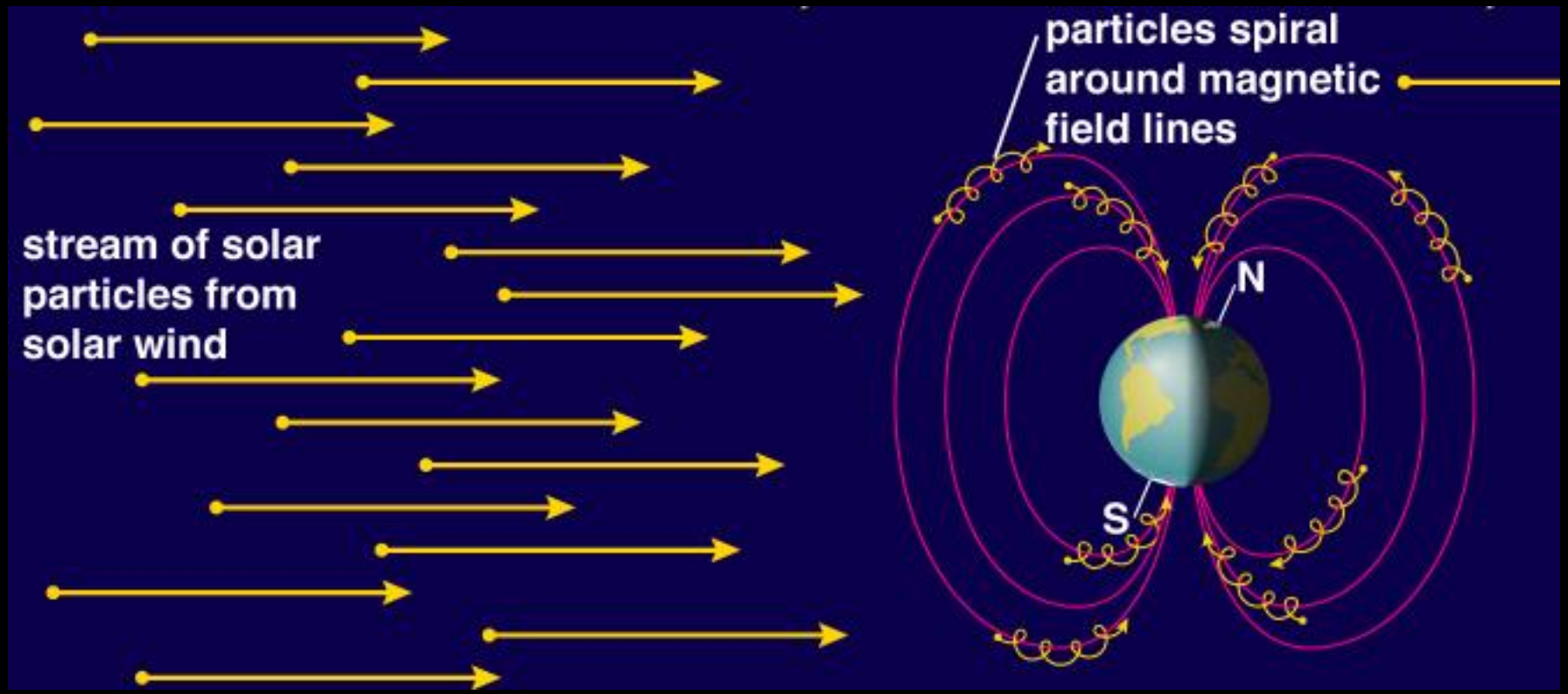
Corona and Solar Wind

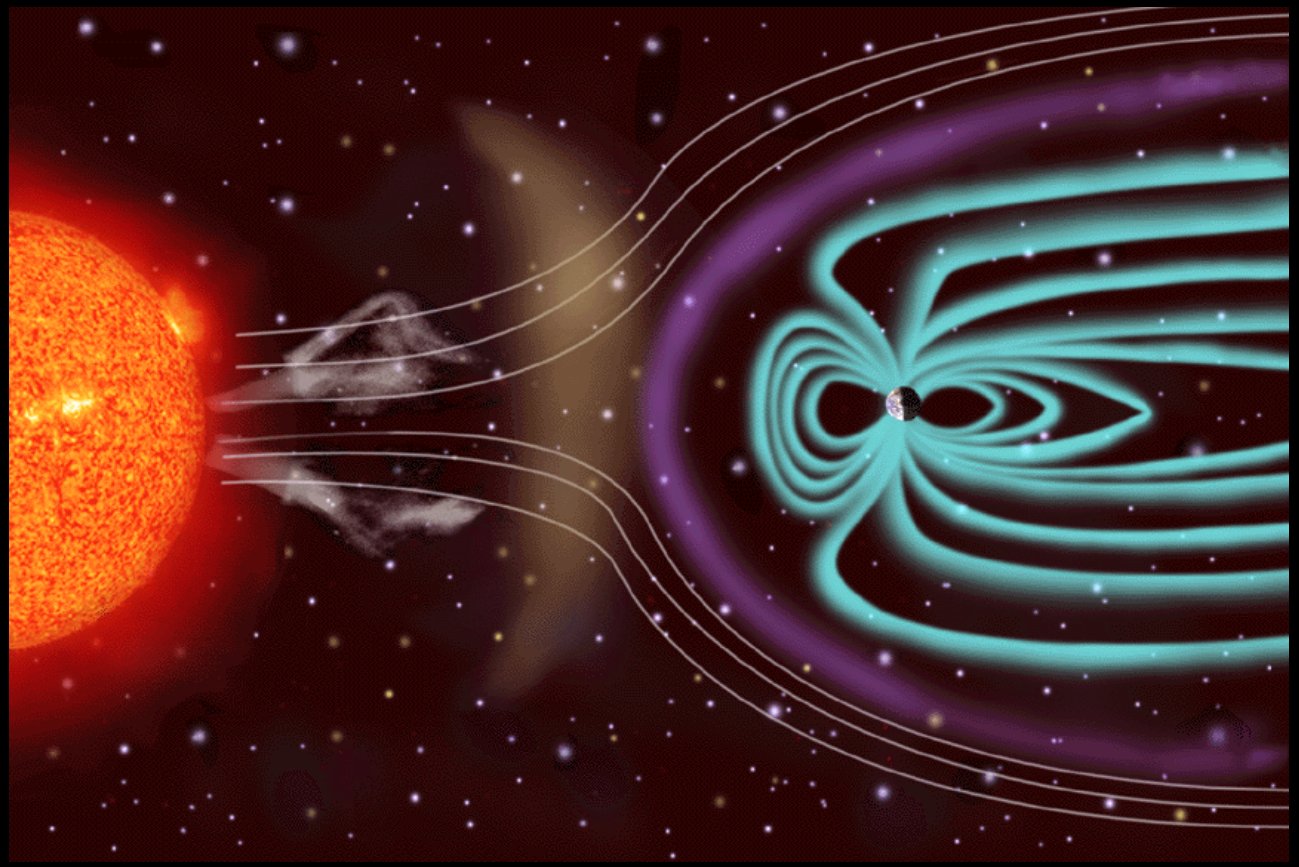
The Sun's Corona is forever expanding into interplanetary space filling the solar system with a constant flow of solar wind.

The sun's corona,or extended outer layer,is a region of plasma that is heated to over 1000000celsius.the mean velocity of these particales is about 145km/s,wich is below the solar escape velocity of 618km/s.

Solar Wind

The solar wind is a stream of charged particals-plasma-ejected from the upper atmosphere of the sun. It contains electons & protons with energies of about 1kv





Solar wind shapes the Earth's magnetosphere and magnetic storms are illustrated here as approaching Earth. These storms, which occur frequently, can disrupt communications and navigational equipment, damage satellites, and even cause blackouts. The white lines represent the solar wind; the purple line is the bow shock line; and the blue lines surrounding the Earth represent its protective magnetosphere.

Solar wind is the continuous flow of charged particles (ions, electrons, and neutrons) that comes from the Sun in every direction.

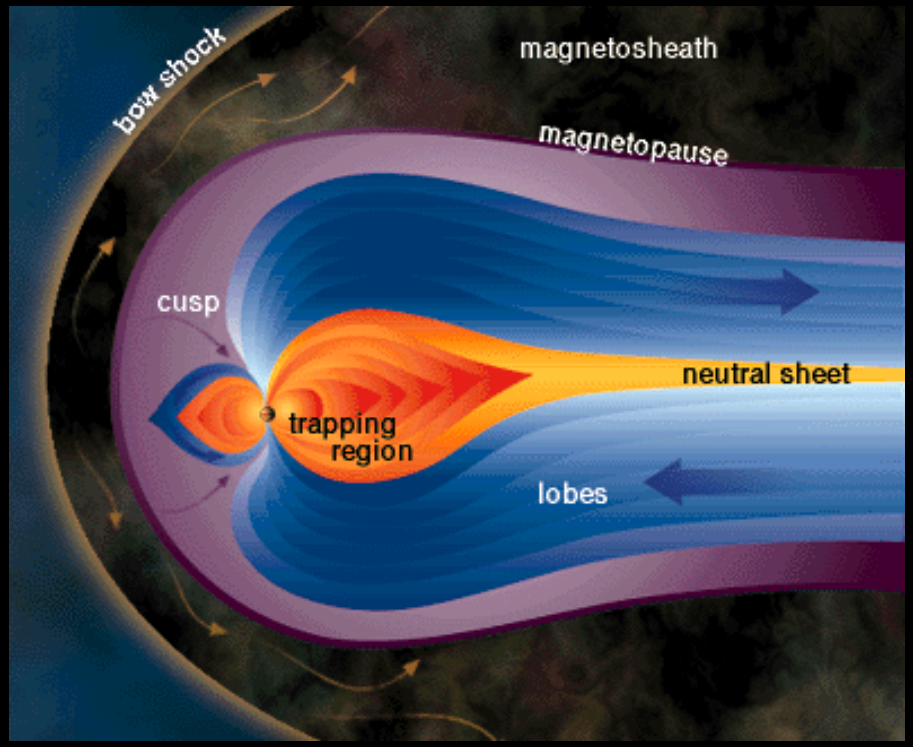
Solar wind consists of slow and fast components. Slow solar wind is a consequence of the corona's high temperature. The speed of the solar wind varies from less than 300 km/s to over 800 km/s.

As the solar wind appraches a planet the particales are deflected by lorante force this region ,known az magnetosphere,causes the particales to travel around the planet

Magnetospheres

In space, the region close to Earth, just above the ionosphere, is called the magnetosphere.

A magnetosphere is a large electromagnetic field that surrounds planets and other celestial bodies.

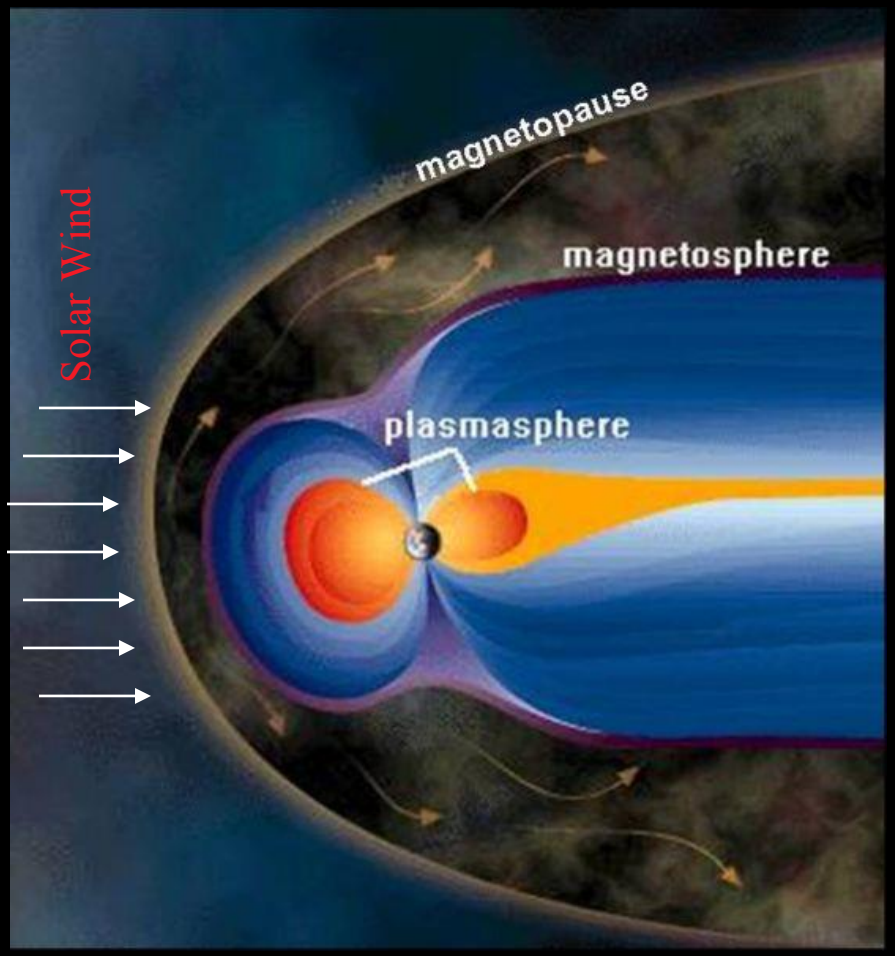


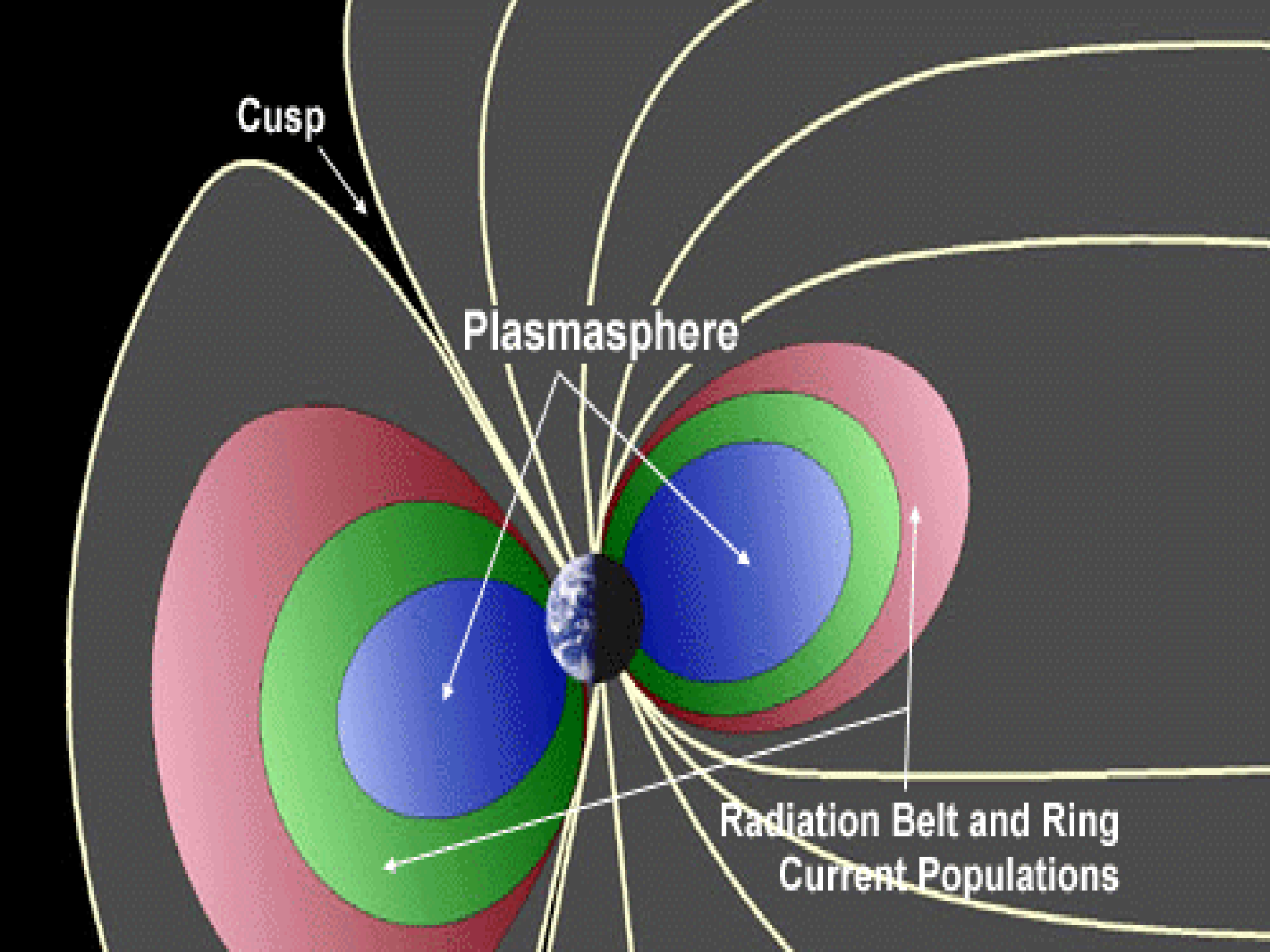
Jupiter's magnetosphere is larger than anything else in the solar system, including the sun.

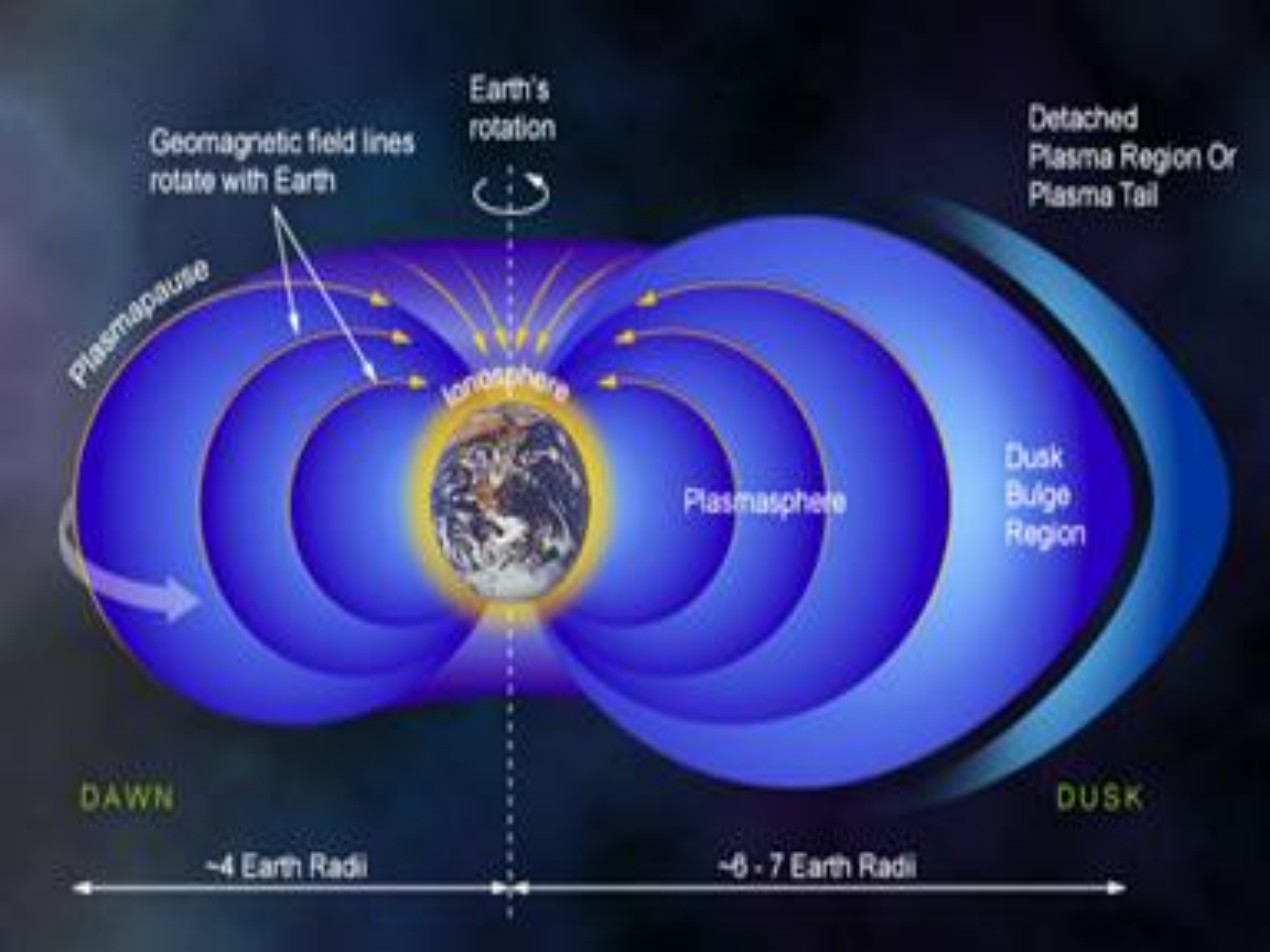
What is the Magnetosphere?

Solar wind flows past Earth and is deflected around Earth's magnetic field.

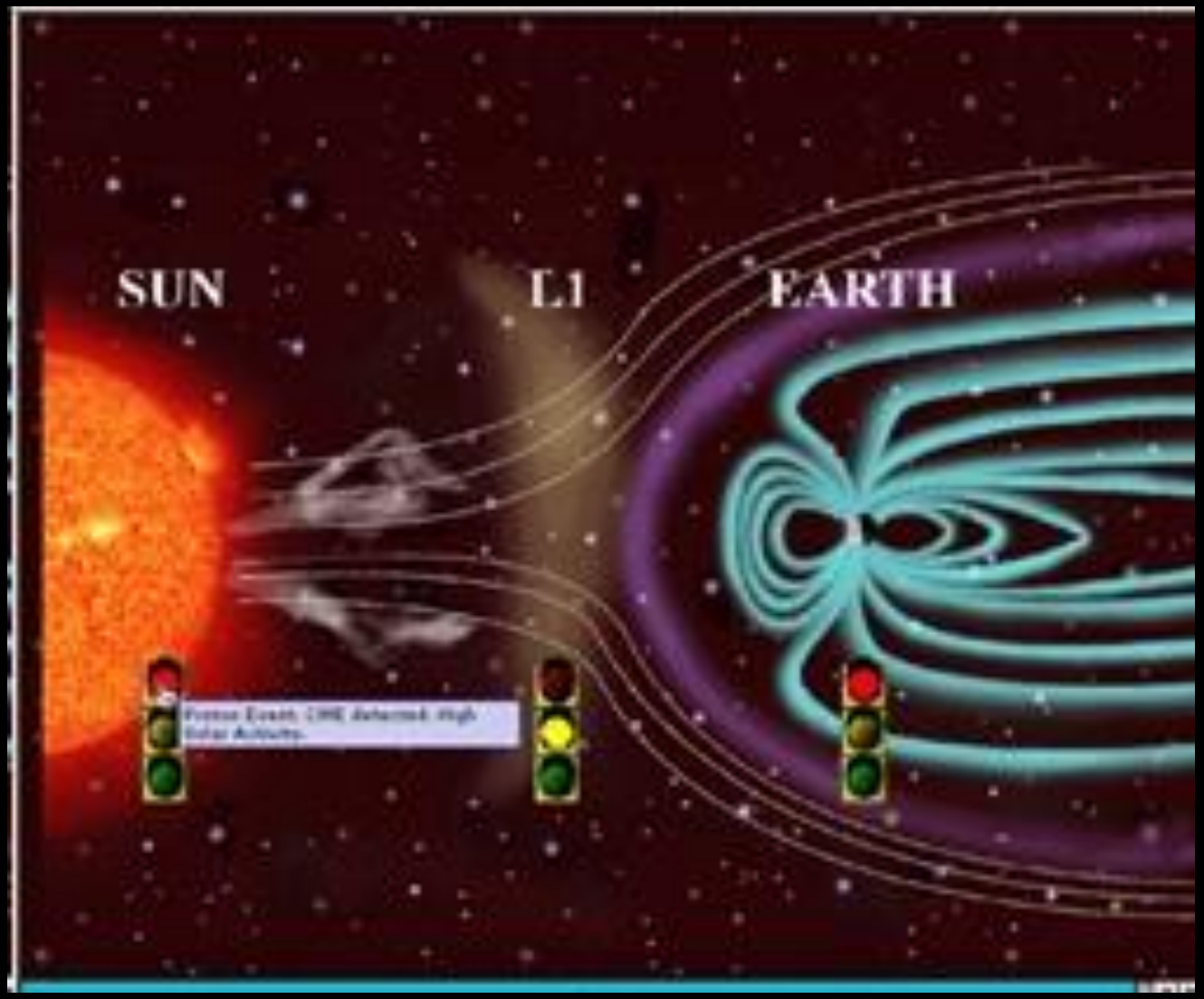
- The solar wind compresses the magnetic field on the sun-side, creating a boundary termed the *magnetopause* at ~10 R_E.
- On the night side, the solar wind-dipole field interaction results in a tail up to~60 R_E.
- The magnetosphere is the region within the magnetopause, from ~10 R_E on the sun side to ~60 R_E on the night side.
- Plasma within ~4 – 6 R_E rotates with the Earth—a region called the *plasmasphere.*



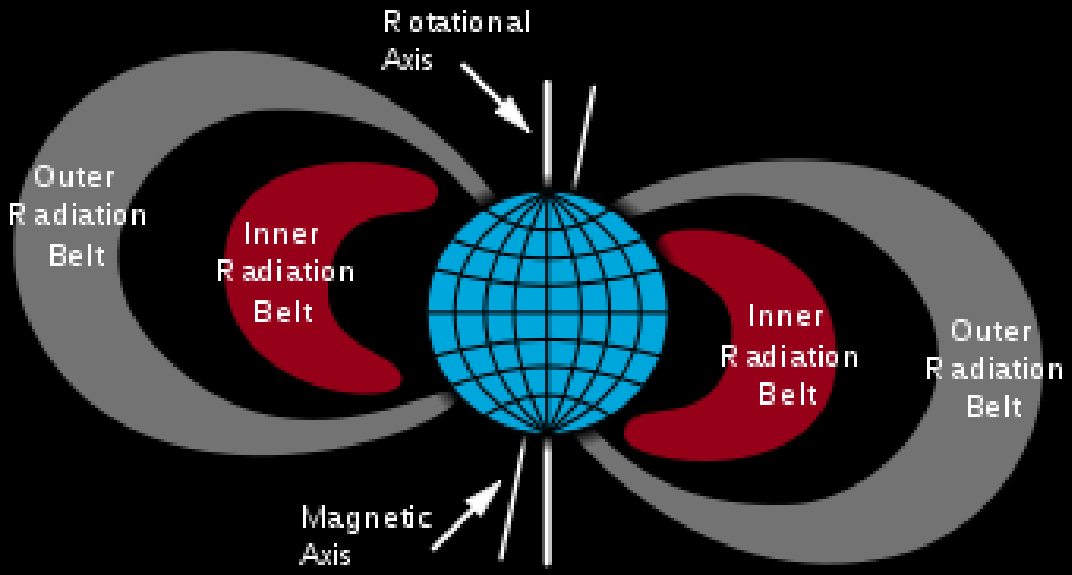

Cusp
Plasmasphere
Radiation Belt and Ring
Current Populations


Earth's rotation
Geomagnetic field lines rotate with Earth
Detached Plasma Region Or Plasma Tail
Plasmapause
Ionosphere
Plasmasphere
Dusk Bulge Region
DAWN
DUSK
~4 Earth Radii
~6 - 7 Earth Radii

The Sun and the Earth are connected!



Two doughnut-shaped belts of high-energy charged particles trapped in Earth's magnetic field; they were discovered in 1958 by James Van Allen



The inner Van Allen Belt lies about 9,400 km (1.5 Earth radii) above the equator, and contains protons and electrons from both the solar wind and the Earth's ionosphere. The outer belt is about three times further away and contains mainly electrons from the solar wind.

- "The radiation belts are regions of high-energy particles, mainly protons and electrons, held captive by the magnetic influence of the Earth. They have two main sources. A small but very intense "inner belt" (. It consists mainly a high-energy protons (10-50 MeV) and is a by-product of the cosmic radiation, a thin drizzle of very fast protons and nuclei which apparently fill all our galaxy.

- In addition there exist electrons and protons (and also oxygen particles from the upper atmosphere) given moderate energies (say 1-100 keV; 1 MeV = 1000 keV) by processes inside the domain of the Earth's magnetic field.

- Some of these electrons produce the polar aurora ("northern lights") when they hit the upper atmosphere, but many get trapped, and among those, protons and positive particles have most of the energy .

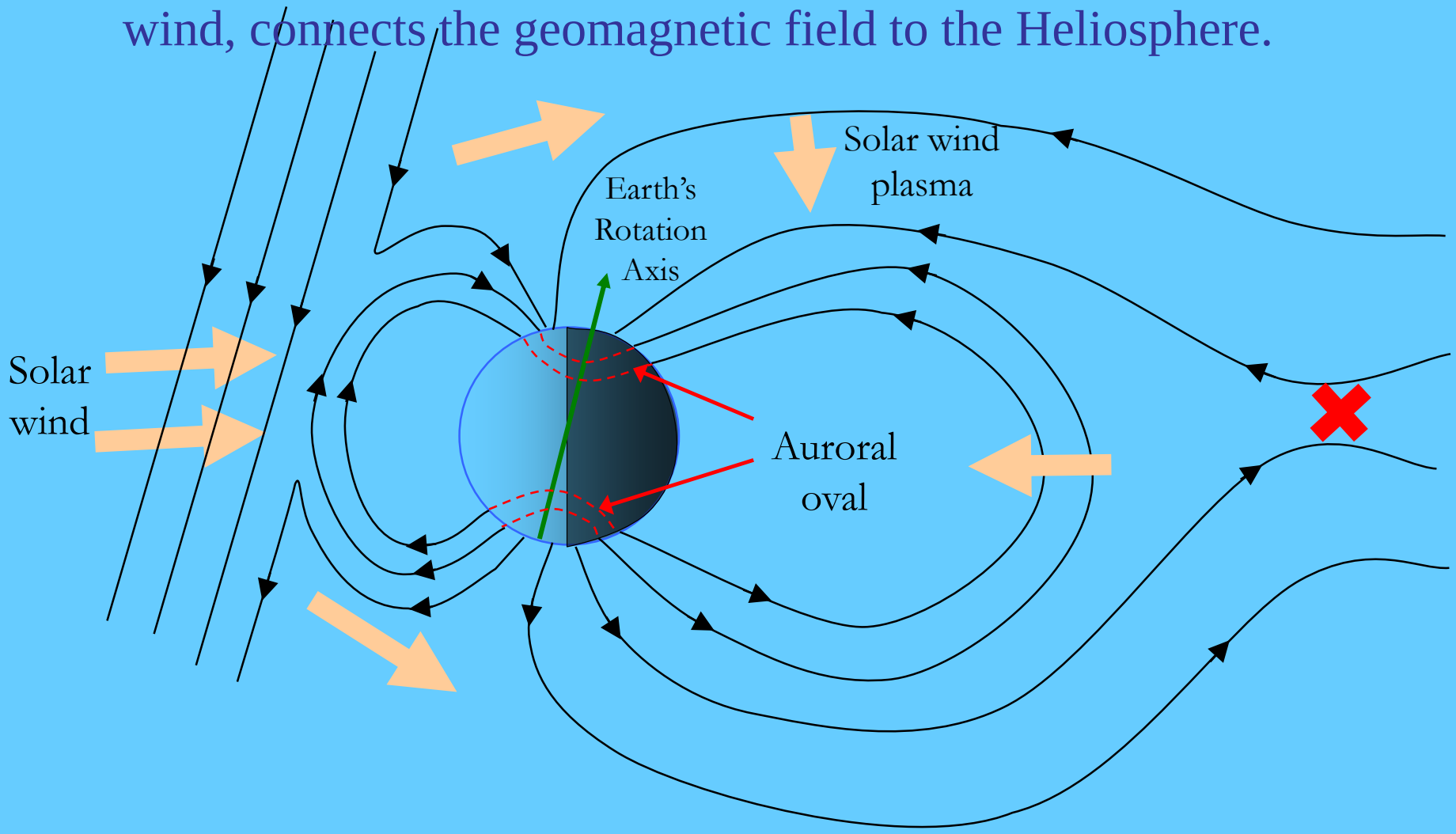
Aurora

- A result of solar wind interactions with Earth's magnetic field
- Charged particles from the Sun work their way down Earth's magnetic field lines
- Once they reach Earth's atmosphere, they interact and give off light
- The Northern/Southern lights
- More common closer to the poles

The location of auroras on Earth is strongly controlled by the Earth's magnetism

The Open Sun

The Interplanetary Magnetic Field (IMF), carried in the solar wind, connects the geomagnetic field to the Heliosphere.



Aurora

The **aurora** is a bright glow observed in the night sky, usually in the polar zone. For this reason some scientists call it a "polar aurora.

Especially in Europe, it often appears as a reddish glow on the northern horizon, as if the sun were rising from an unusual direction.

The aurora borealis most often occurs from September to October and from March to April. Its southern counterpart, **aurora australis**, has similar properties. Australis is the Latin word for "of the South".

Auroral mechanism

Auroras are now known to be caused by the collision of charged particles (e.g. electrons), found in the magnetosphere, with atoms in the Earth's upper atmosphere (at altitudes above 80 km). These charged particles are typically energized to levels between 1 thousand and 15 thousand electronvolts and, as they collide with atoms of gases in the atmosphere, the atoms become energized. Shortly afterwards, the atoms emit their gained energy as light

As well as visible light, auroras emit infrared (NIR and IR) and ultraviolet (UV) rays as well as X-rays (e.g. as observed by the Polar spacecraft). While the visible light emissions of auroras can easily be seen on Earth, the UV and X-ray emissions are best seen from space, as the Earth's atmosphere tends to absorb and attenuate these emissions.

Auroral forms and magnetism

Typically the aurora appears either as a diffuse glow or as "curtains" that approximately extend in the east-west direction. At some times, they form "quiet arcs"; at others ("active aurora"), they evolve and change constantly. Each curtain consists of many parallel rays, each lined up with the local direction of the magnetic field lines, suggesting that aurora is shaped by the earth's magnetic field. Indeed, satellites show auroral electrons to be guided by magnetic field lines, spiraling around them while moving earthwards.

Frequency of occurrence

The aurora is a common occurrence in the Poles. It is occasionally seen in temperate latitudes, when a strong magnetic storm temporarily expands the auroral oval. Large magnetic storms are most common during the peak of the eleven-year sunspot cycle or during the three years after that peak.

The origin of the aurora

The ultimate energy source of the aurora is the solar wind flowing past the Earth

Both the magnetosphere and the solar wind consist of plasma (ionized gas), which can conduct electricity. It is well known (since Michael Faraday's work around 1830) that if two electric conductors are immersed in a magnetic field and one moves relative to the other, while a closed electric circuit exists which threads both conductors, then an electric current will arise in that circuit. Electric generators or dynamos make use of this process ("the dynamo effect"), but the conductors can also be plasmas or other fluids.

Physicists say that the aurora is just a large-scale electrical discharge phenomenon in the high-altitude atmosphere, resulting from quantum leaps in oxygen and nitrogen atoms.

Energetic **electrons** streaming along geomagnetic field lines hit and excite atoms and molecules.

In the highest reaches of the atmosphere, above about a hundred kilometers, **oxygen** and **nitrogen** atoms and molecules are **energized** and/or **ionized** by energetic electrons.

The auroral light results from the **de-excitation** of these particles. The color, shape, and intensity depend on the energy of the electrons shooting downward into the upper atmosphere.

Characteristics

The aurora has a variety of **shapes, colors, and structures**, and is continuously changing in time.

After 10 to 20 minutes the activity decreases. The bands are spread out, disintegrating in a **diffuse light** all over the sky. Clouds of light are turning on and off every few to tens of seconds. Then nature's own gigantic light-show is over.

Aurora over Yellowknife, Canada.

Each torus is up to 3,500 km in diameter and a few hundred km thick. The width of the belt on the night side is up to 600 km.

Aurora in Manitoba, Canada.