Atmospheric Physics

Lecture 19

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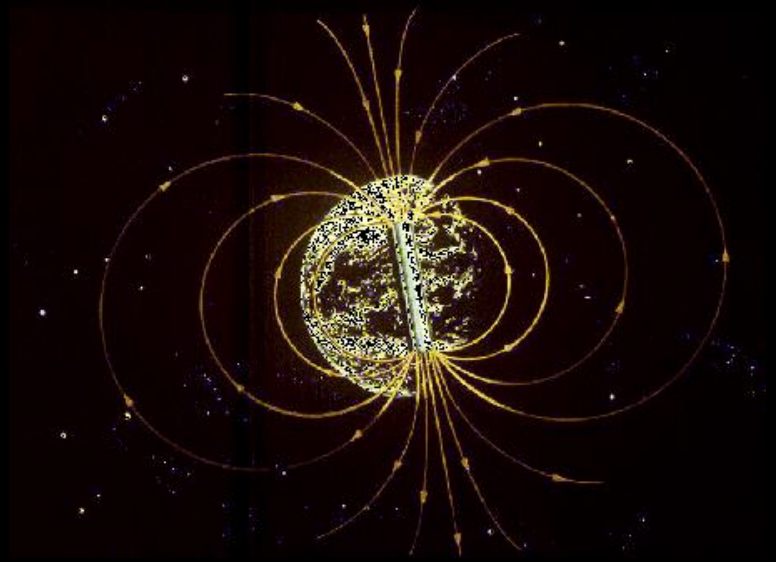
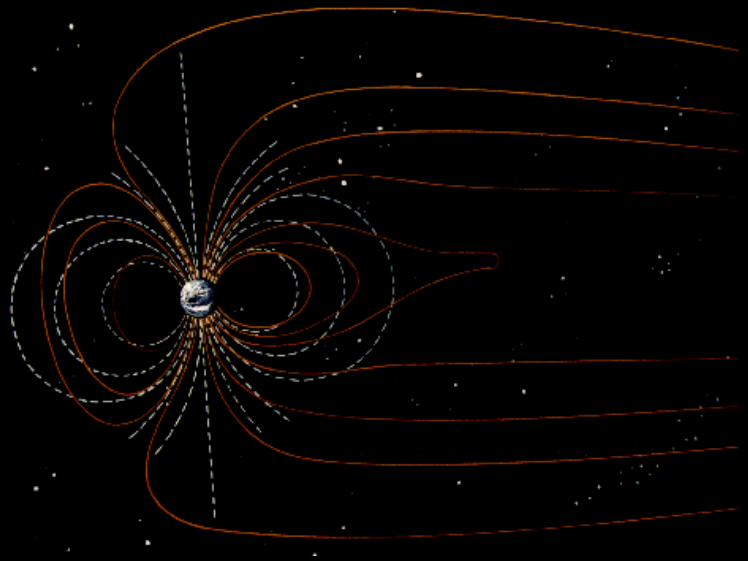
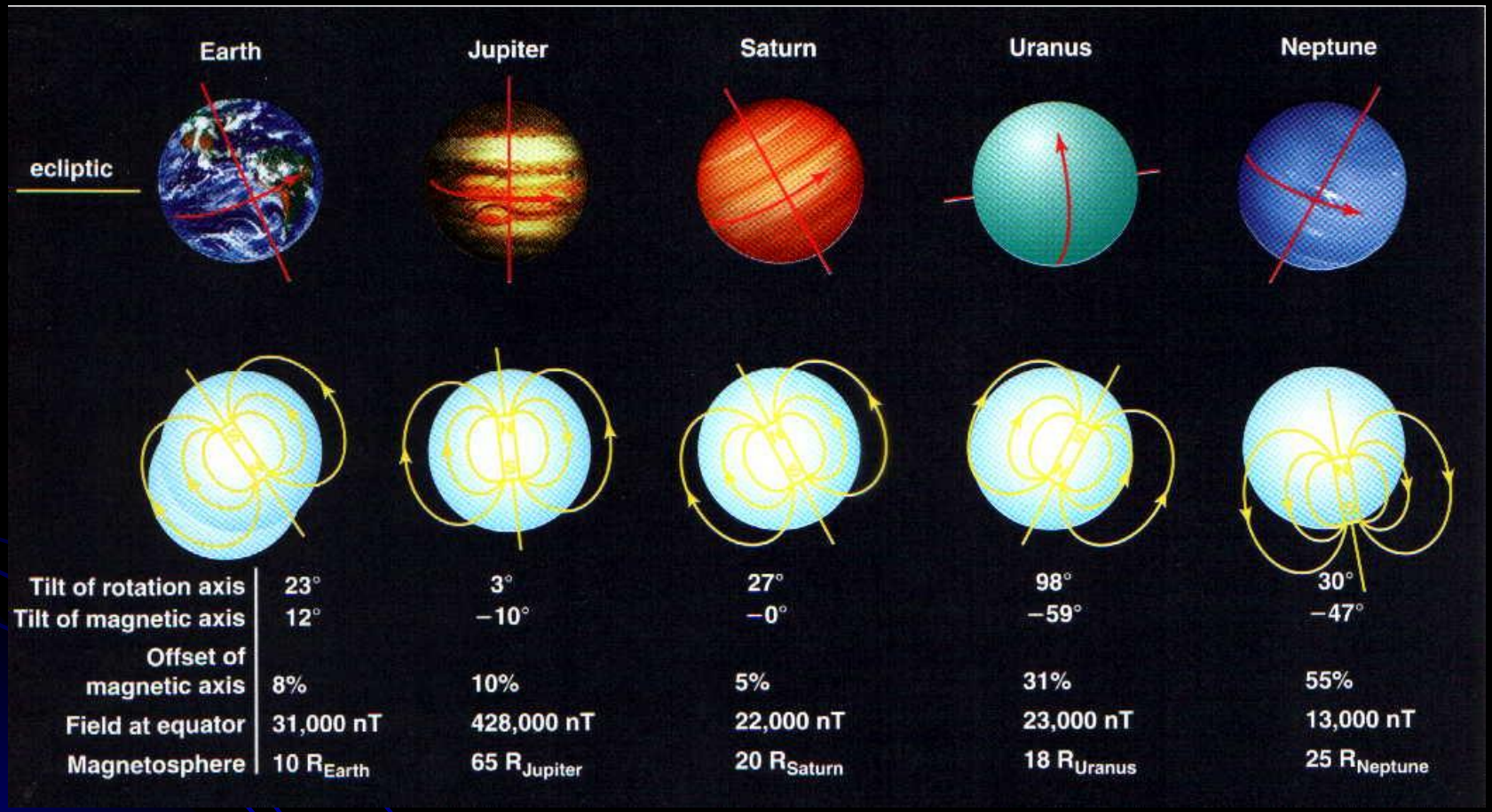
The Earth is a large magnet



The earth acts like a very large magnet. Just as a bar magnet produces field lines, so too does Earth

Our magnetic field is squashed by the solar wind.





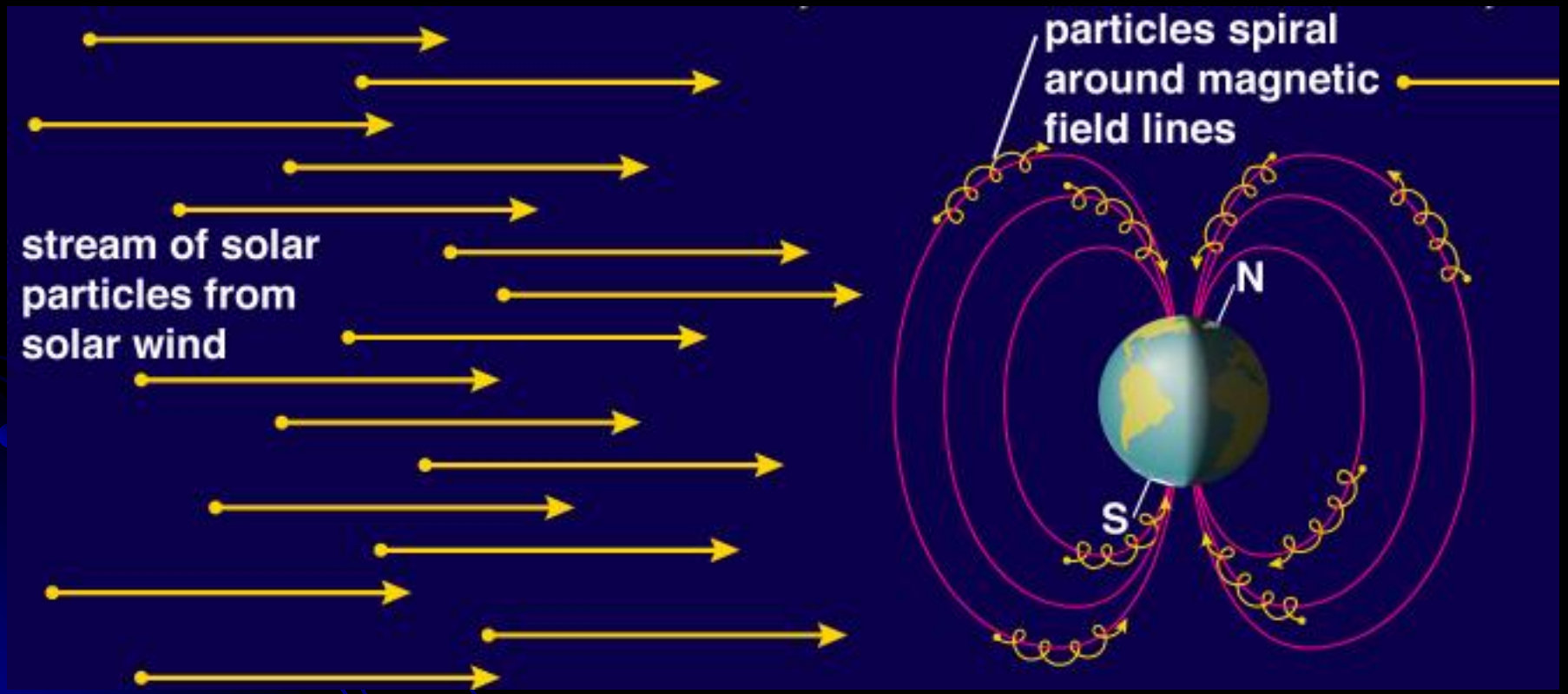
	Earth	Jupiter	Saturn	Uranus	Neptune
Tilt of rotation axis	23°	3°	27°	98°	30°
Tilt of magnetic axis	12°	−10°	−0°	−59°	−47°
Offset of magnetic axis	8%	10%	5%	31%	55%
Field at equator	31,000 nT	428,000 nT	22,000 nT	23,000 nT	13,000 nT
Magnetosphere	10 R_{Earth}	65 $R_{Jupiter}$	20 R_{Saturn}	18 R_{Uranus}	25 $R_{Neptune}$

Solar Wind

- **Sometimes the magnetic field lines can break**
- **This releases highly energetic particles from the Sun**
- **These particles escape through coronal holes and the process is known as solar wind**
- **Extends past Pluto's orbit**
- **Initial velocities of 500 km/s**

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


particles spiral
around magnetic
field lines
stream of solar
particles from
solar wind
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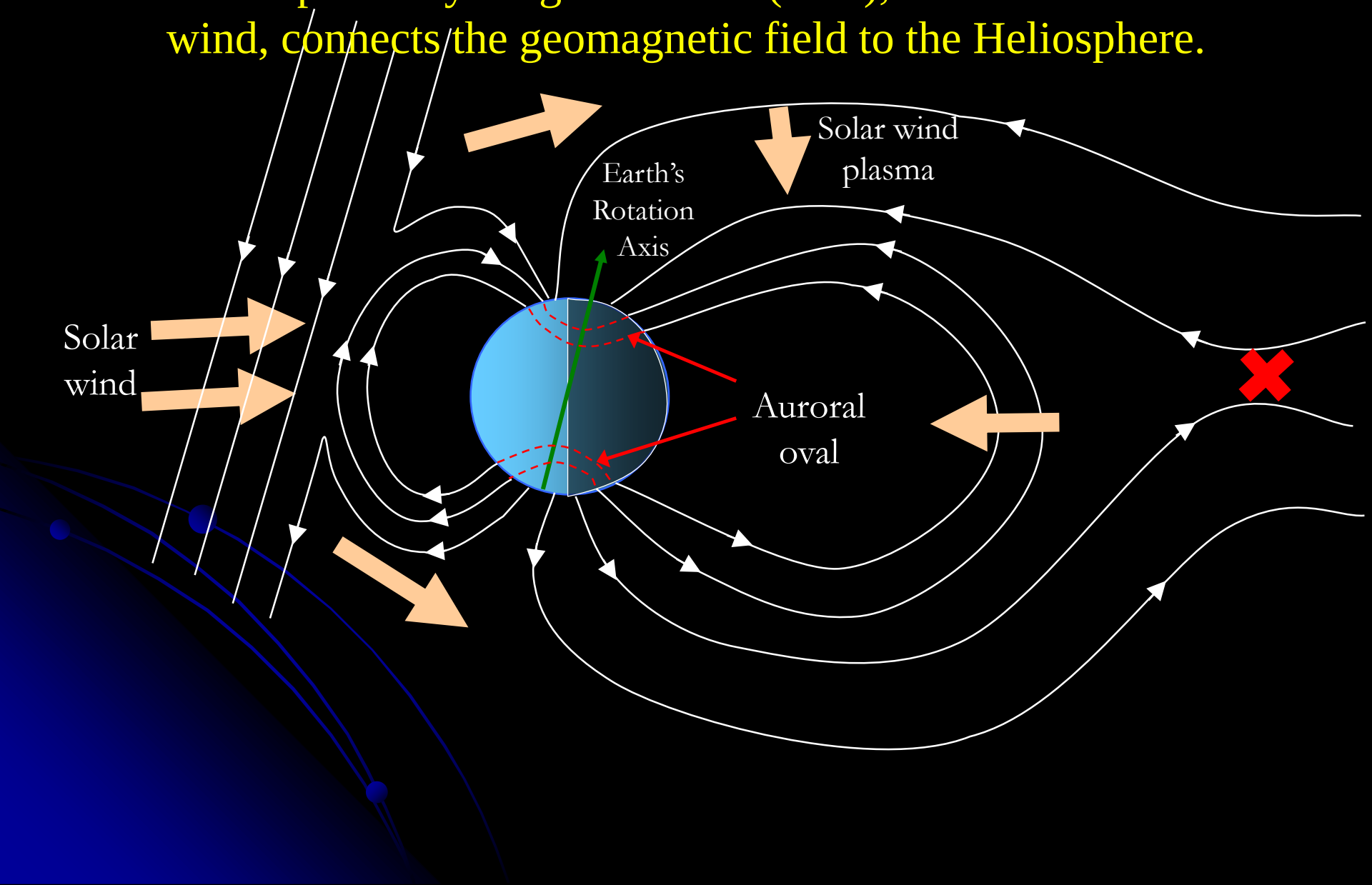
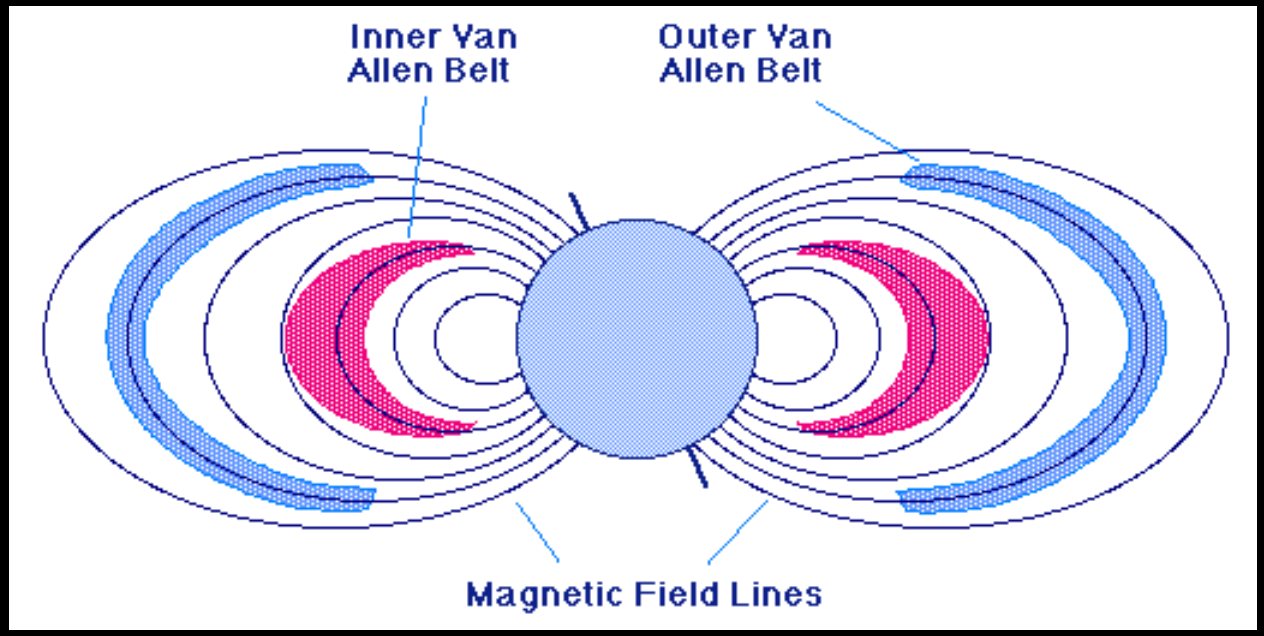
The Open Sun

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



Van Allen Radiation Belts



- The inner belt is around 1.5 R_E, mainly protons
- The outer belt at 3 – 9 R_E is trapped magnetospheric plasma

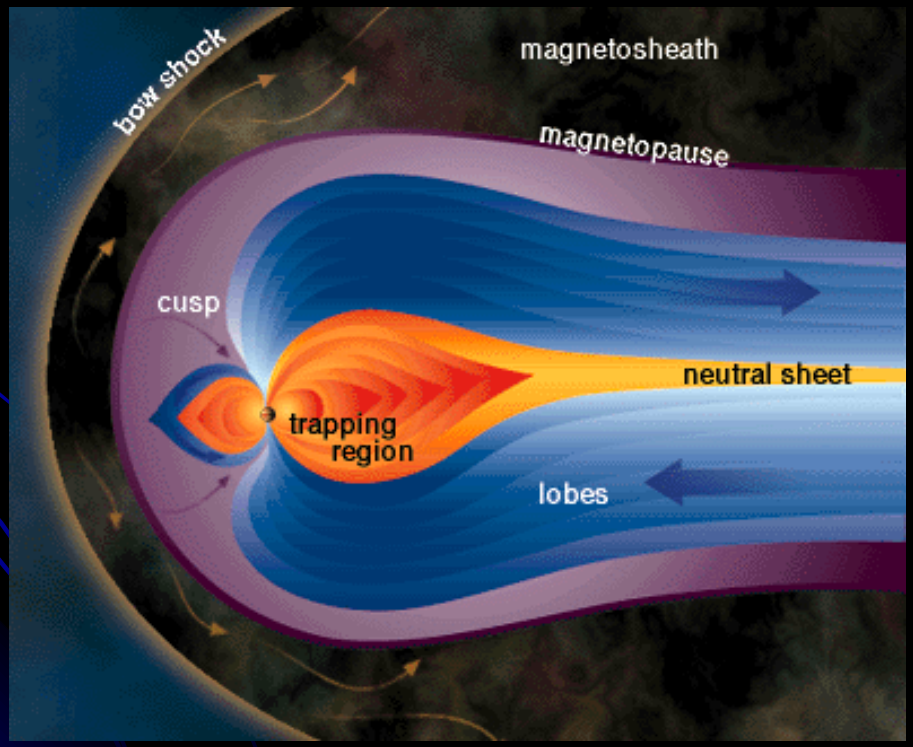
Two doughnut-shaped belts of high-energy charged particles trapped in Earth's magnetic field; they were discovered in 1958 by James Van Allen

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.

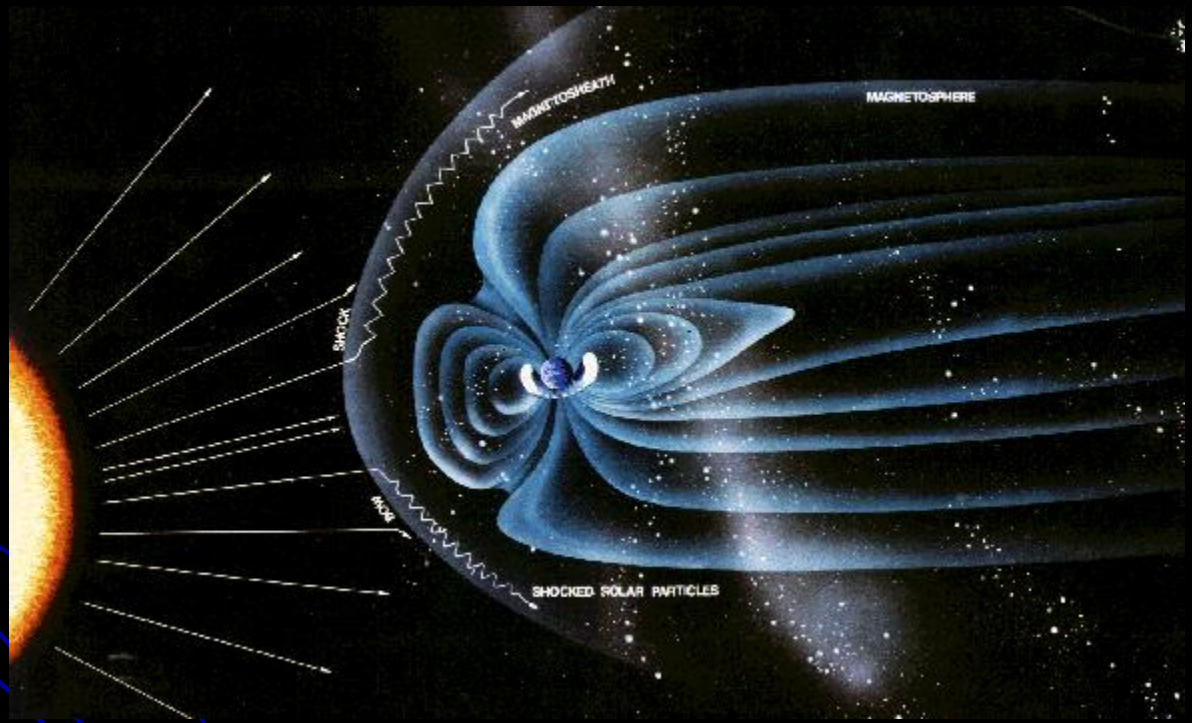
Magnetospheres

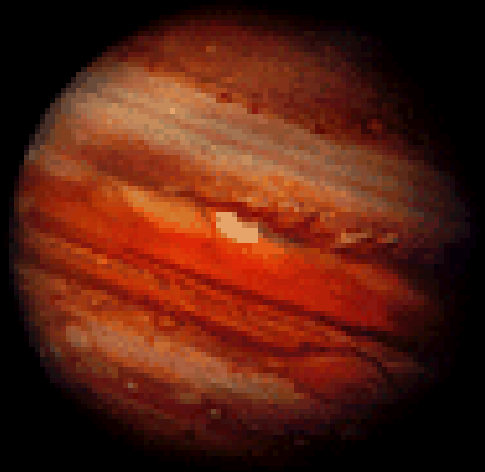
In space, the region close to Earth, just above the ionosphere, is called the magnetosphere.

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



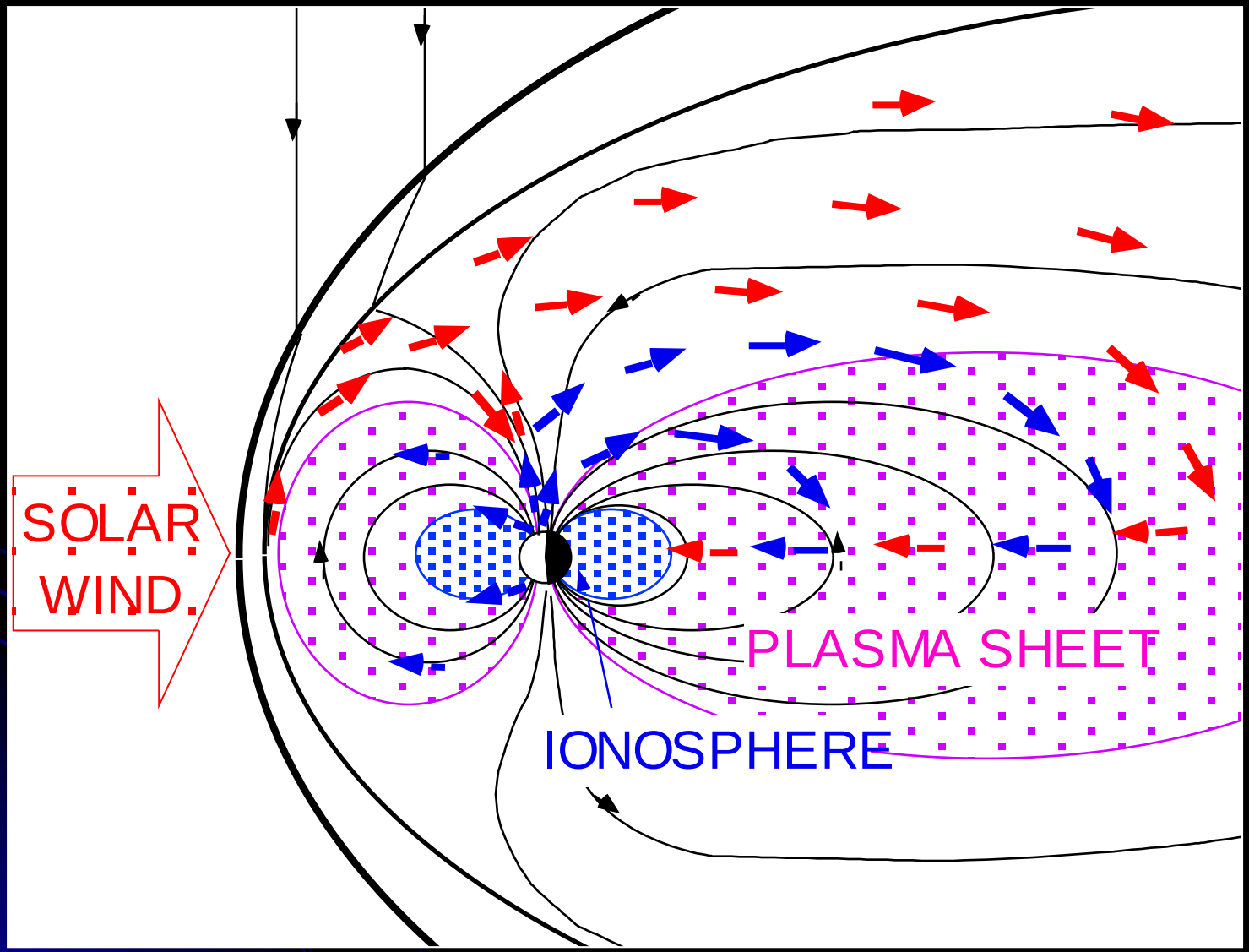
The Sun and the Earth are connected!



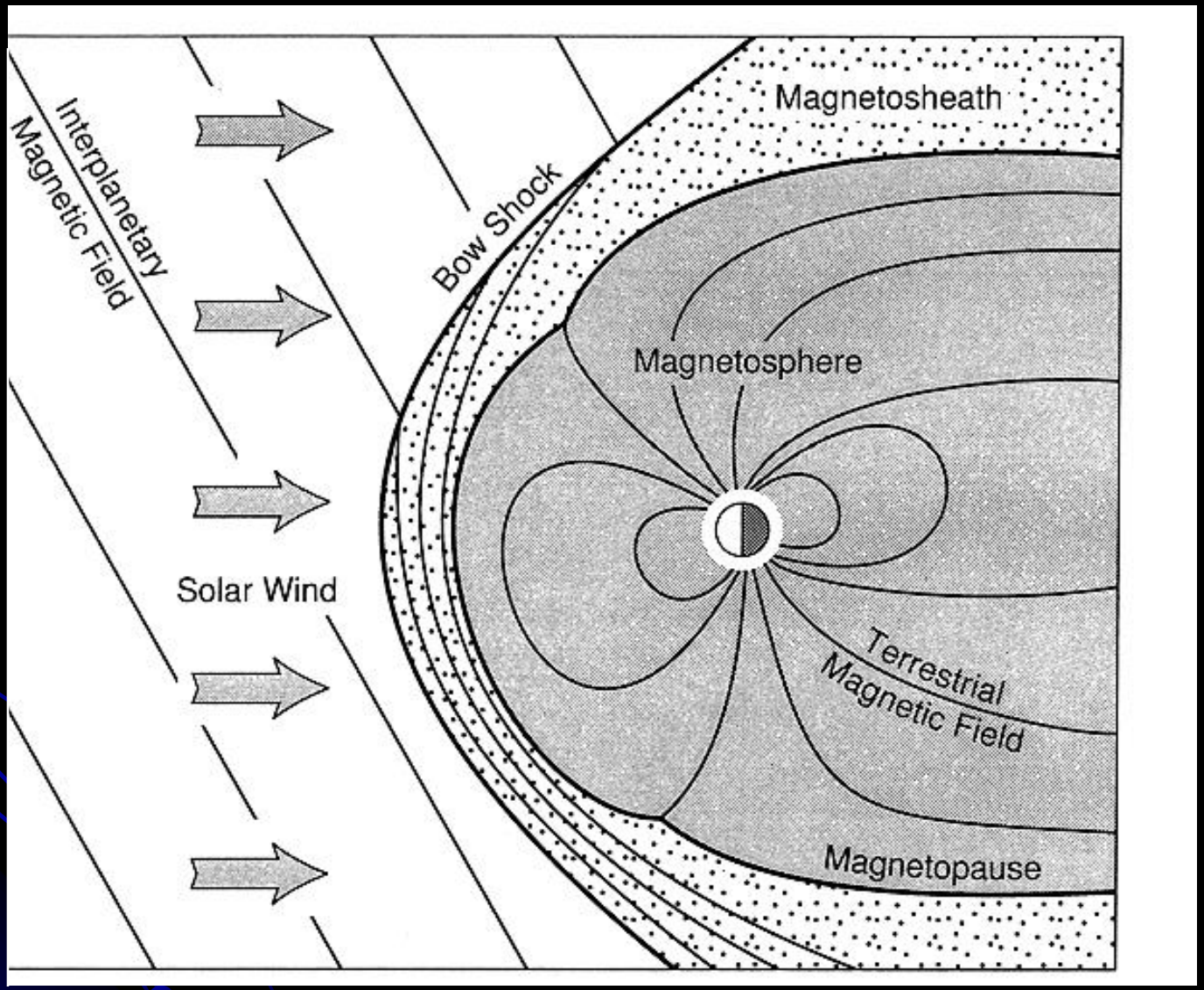


Jupiter’s magnetosphere is larger than anything else in the solar system, including the sun.

Overview: Plasma Sheet Sources



Schematic topography of solar-terrestrial environment



solar wind -> magnetosphere -> iononosphere

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**

Auroras are the result of the interaction between the Earth's magnetic field, its atmosphere, and the solar wind.

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

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 (see Fluorescence). Light emitted by the Aurora tends to be dominated by emissions from atomic oxygen, resulting in a greenish glow (at a wavelength of 557.7 nm) and - especially at lower energy levels and at higher altitudes - the dark-red glow (at 630.0 nm of wavelength). Both of these represent forbidden transitions of electrons of atomic oxygen that, in absence of newer collisions, persist for a long time and account for the slow brightening and fading (0.5-1 s) of auroral rays. Many other colors - especially those emitted by atomic and molecular nitrogen (blue and purple, respectively) - can also be observed. These, however, vary much faster and reveal the true dynamic nature of auroras.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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.

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. The curtains often show folds called "striations", which are curtain-like. When the field line guiding a bright auroral patch leads to a point directly above the observer, the aurora may appear as a "corona" of diverging rays, an effect of perspective.

Atmospheric Profile

- **Exosphere's top is at 480 km (300 mi)**
- **The atmosphere is structured. Three criteria to examine atmosphere**
  - **Composition**
  - **Temperature**
  - **Function**