

# Lecture 12: The Magnetosphere & Maxwell's Equations

Last time we reviewed some observations about the earth's magnetic field and how turned to be sun (and stars in general) for further insight. We had just gotten to the observation of the variability of the solar wind - not only the 11-year sunspot cycle but also the variability in the number of sunspots in each cycle.

Sunspot <sup>reflect and are</sup> related to burning of nuclear fuel - whether

sun is "on" or "off". If on, we have sunspots,

and a strong solar wind (bulky // of charged

particles from coronosphere that stream toward <sup>the</sup> earth at

~400 km/sec + get here in 2 to 3 days (light takes 8 min)

## I. Solar Wind

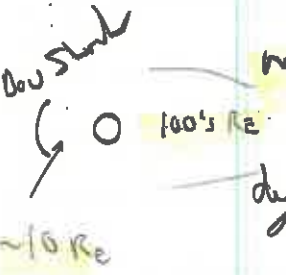
Charged solar wind particles interact with the diurnal, poloidal magnetic field of the earth

Why coronosphere is hot but sun system is cooler

I Solar Wind

charged solar wind particles interact with the dipole (polar) magnetic field of the earth, and are deflected around the earth, distorting the earth's magnetic field into a cavity called the magnetosphere.

charge in solar wind  
MAGNETOSPHERE (solar wind)



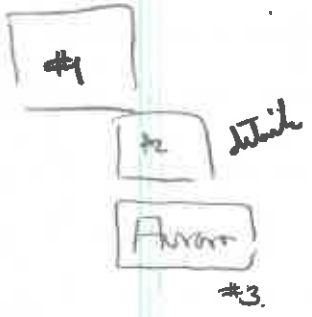
Cavity at times is like a shield which

deflects incoming solar wind particles; at times like an accelerator - accelerating ions + producing beams that produce aurora (stays back at tail).

- solar wind compresses E's magnetic field. High conductivity plasma excludes field lines from its interior. - creates wave dipole that cancels E's field.

Supersonic

400 km/sec vel of solar wind exceeds velocity of pressure waves in plasma - ∴ front of magnetosphere is a bow shock. It is an electromagnetic shock!



- small fraction of solar wind of charged particles enters the magnetosphere via the polar cusps. Goes into boundary layer (plasma mantle) and to region of neutral point (plasma sheet)

- small fraction of ions are reflected back toward sun and bow shock region is area rich in plasma physical phenomenon, RELEVANT TO STELLARATOR, TOKAMAK etc.

Solar

# Magnetosphere Dynamics

## Cyclic transfer of magnetos plasma to tail

and then back to magnetosphere is linked to

aurora. Explosive reconnection of magnetotail can push ionospheric plasma toward dayside at auroral latitudes.

Viscous drag of solar wind on magnetopause

creates Kelvin-Helmholtz (wind-over-water) instability.

Stresses are transmitted to E (to avoid magnetospheric

plasma being blown away) via <sup>closed</sup> current systems which

flow across <sup>magnet</sup> field lines, producing a force on the plasma.

This system allows stress to be transmitted to viscous shear

in the neutral atmosphere. Cause flow of ionospheric plasma

over polar cap from noon to midnight.

Potential drops along field lines occur + accelerate

electron to few keV in energy — produce Aurora. Magnetic storms are related to instabilities in the high voltage system.

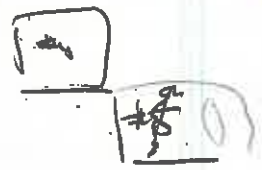
#1 + #2 go

aurora  
magnetotail  
wind drag

surface

do not know cause.

# A. Van Allen Radiation belts



Trapped ionized particles. Charged particles

milli-sec to sec

- gyrate around magnetic lines / force

sec to minutes

- bounce back + forth vertically by mirror effect of increasing magnetic field near earth.

months to hrs

- Circulate about dipole axis - eg drift around the magnetic core

Adiabatic invariants are conserved in this motion.

(not disturbed by <sup>EM</sup> waves from lightning etc).

When conserved, particles remain trapped. They are

trapped in van Allen belts. Particles in belts

are produced by decay of neutrons created by cosmic rays <sup>expanding magnetic</sup>

hitting upon atom. Particles can remain trapped for

hundreds of years

- at low energy - Electric field input and charged particle population changing variable

- "Roll" (low energy) ions, but can be same / particles

- EM noise generated by lightning (called whistlers) propagate through the magnetosphere cause particles to stick closer to magnetic field lines + increase probability of loss. (drag of radiation belt ion population).

Whistlers  
100 volts/m near  
surface sustained by  
lightning. Max drag  
afternoon thunderstorm  
in arizona.

Other EM waves also contribute to loss of charged particles in radiation belts. One is "down chorus" generated by particle beams (like chirping of birds). → Can buy low freq radio to listen to them sounds

Ionosphere

Ionosphere created by UV radiation. Low E

TEMPERATURE  
(UV radiat)

(~2000 K). Speed & plasma density. ∴ measure

radiation belts. Whistlers showed abrupt drop in plasma density (ionosphere) at about 4 R<sub>e</sub>. <sup>POP</sup> Separated region where plasma related with the earth from region where it was not the case. Plasmasphere comes from

Plasmasphere  
(Oiled  
10000 km)

ionosphere. Particles accelerated (electrically) in some fashion. ∴ Magnetosphere chemically more like ionosphere than

than or small than it



## II. Magnetic fields on other planets.

Earth is not the only planet with a magnetic field.

'Planetary' fields are diverse in nature + causes.

- **Jupiter** magnetosphere led by volcanic eruption on Io; energetic particles accelerated to eating by energies. **Extreme hazard to spacecraft. Land on moon - fried quickly!**

magnetic moment  
20,000 times that  
of E.

- **Saturn** mag field aligned along rotational axis. Daily change in strength of magnetosphere small. Rings absorb particles.

magnetic moment 600  
times E

- **Uranus** - rotation axis in ecliptic plane. but mag field 60° from rotational axis.

- **Venus** - no magnetic field. Ours looks to solar wind  $\sim R_{Venus}$  not  $10 R_{Venus}$  like E. Mag field in two coronal holes + becomes twisted into ropes

- **Mars** - probably no magnetic field.

- **Comets** - <sup>cometary</sup> solar wind shock front

### Future —

Do not know mechanism of field  
Do not understand aurora

See: <http://www-ssc.igpp.ucla.edu/SSC/External/magnetospheres.html>

## II: Connection between Sunspot, solar wind + climate change

No answer  
do Corona

- Number of sunspot changes with time
- + There have been periods when there were no suns etc (head Royal Astronomical Society in stars 1st <sup>among</sup> ~~sunspot~~ just before died).
- Ultraviolet is on solar wind is strong
- strong solar wind = strong magnetic field shield to cosmic rays
- ∴ cosmic rays <sup>like C<sup>14</sup>, O<sup>18</sup></sup> isotope, tell when sun "on" or "off"
- cosmic rays also nucleate clouds (ultrafine cloud chambers).

So "earth system" is really a system. The

inner core ties to sun-derived phenomena, and to the atmosphere + climate!

→ p 8-15 moved to L12