"The Planets"
Astro/EPS C12 (CCN 17045 or 32505)

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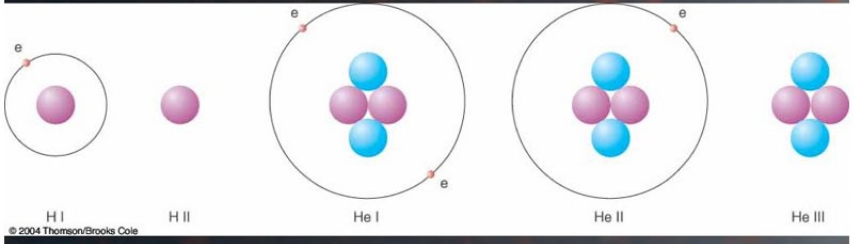
LEC: 2 LeConte TWTh, 2:40–5:00pm
Office Hours: 419 Campbell Hall,
Mon 3–4 and Tue 5–6

STAR PARTY

- 10PM TUES 12 AUG
- attendance optional (this is just for fun)
- meet at 10pm in front of Campbell Hall
- don't be late
- my cell 510-207-2236
- may be cancelled if weather is bad

CHARGED PARTICLES AND PLASMA



- ions are formed by removing or adding electrons to the neutral atom
- ions are charged particles
- PLASMA is a neutral ionized gas

MAGNETIC FIELDS

- magnetic fields are generated by moving charge (or "currents")
- RIGHT HAND RULE: if the current flows in a loop following your fingers, the magnetic field direction follows your thumb
- charged particles spiral along magnetic field lines
- charged particles can't cross magnetic field lines
- field lines must be closed
- RIGHT HAND RULE: if the current flows in one direction following your thumb, the magnetic field forms a loop following your fingers

MAGNETIC FIELDS vs PLASMAS

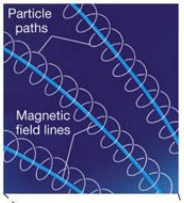
- dense plasma or conducting fluid
  - can generate strong magnetic field felt far away from source
  - within the plasma, complex interaction between currents and magnetic fields: magnetohydrodynamics
- thin plasma
  - particles follow field lines
  - magnetic fields generated by currents in the this plasma are relatively weak

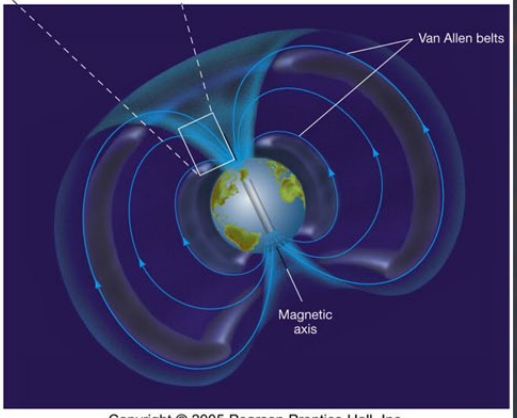
DEMONSTRATING MAGNETISM

- iron filings trace field lines
- field is strongest where field lines are closest together
- charged particles get trapped in magnetic field lines, so their flow patterns can be visualized this way

MAGNETIC DIPOLE

- a basic type of magnetic field configuration
- has a north pole and south pole
- field lines connect from south pole to north pole
- the magnet can be visualized as a current loop

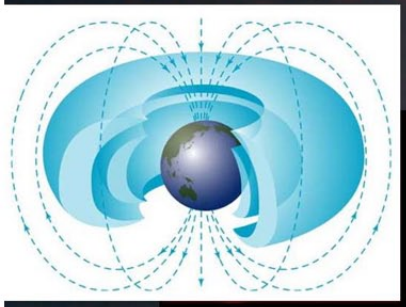


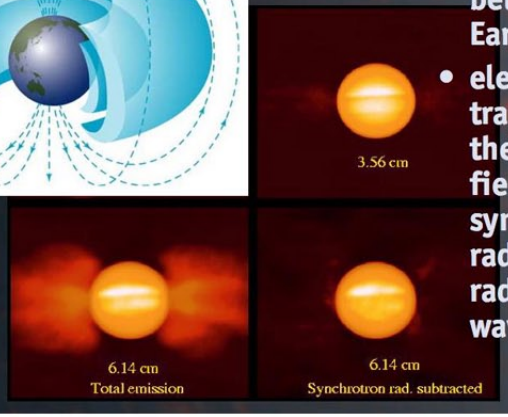


MAGNETIC FIELDS & CHARGED PARTICLES

- charged particles follow field lines
- field lines follow charged particles

RADIATION BELTS





- Jupiter has radiation belts like Earth does
- electrons trapped in the magnetic field emit synchrotron radiation at radio wavelengths

"DYNAMOS" AND MAGNETIC FIELD GENERATION

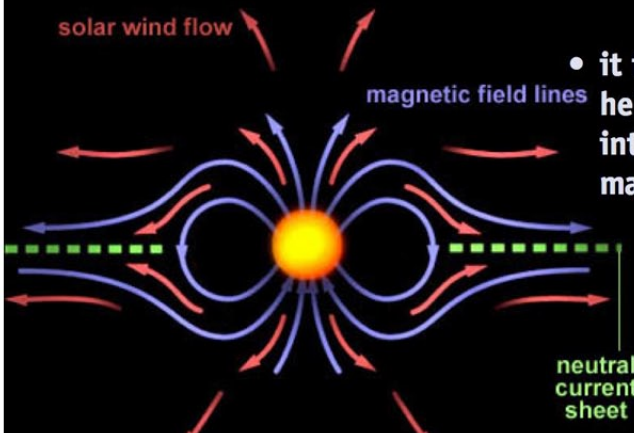
internal magnetic fields are generated when planets have two things:

- conducting fluids in the interior
  - liquid iron
  - liquid metallic hydrogen
  - ionized water
- rapid rotation

"DYNAMOS" AND MAGNETIC FIELD GENERATION

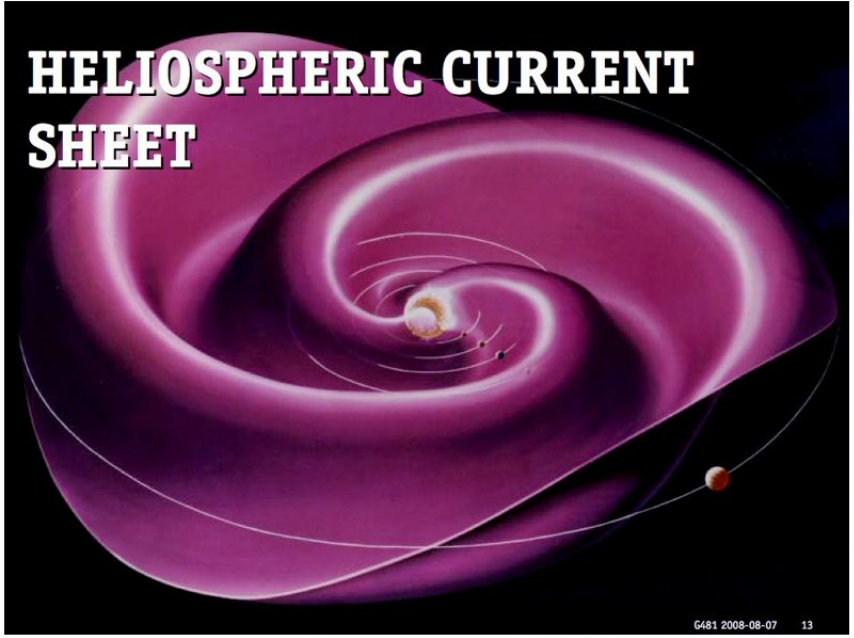
- Earth + Mercury
  - spinning liquid iron near core
- Mars
  - may have a "fossil" magnetic field preserved in some locations
- Jupiter + Saturn
  - rapidly spinning liquid metallic hydrogen
- Uranus + Neptune
  - spinning, polarized water away from core
- Sun
  - hot hydrogen plasma

SOLAR WIND/IMF

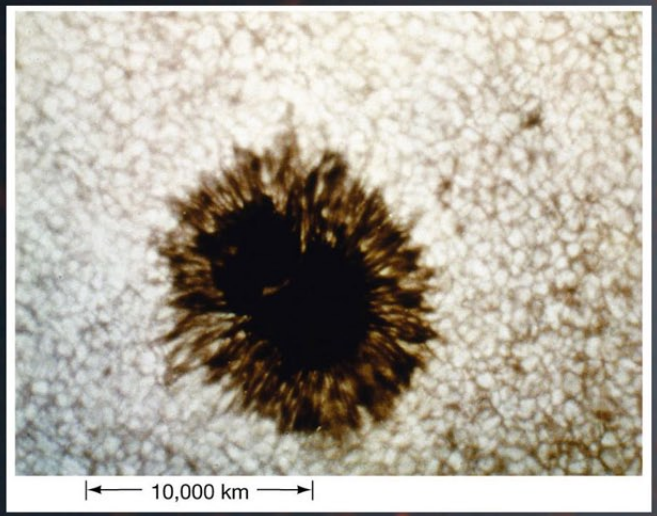


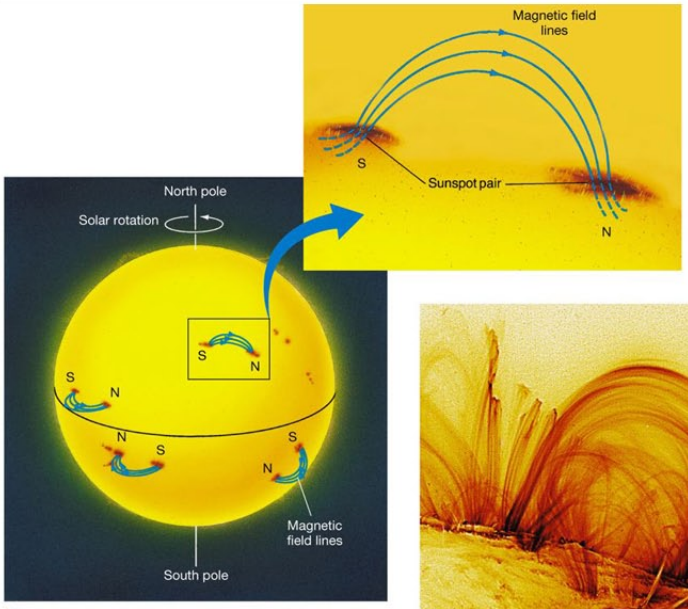
- the solar wind is a flowing plasma
- it follows and helps shape the interplanetary magnetic field

HELIOSPHERIC CURRENT SHEET

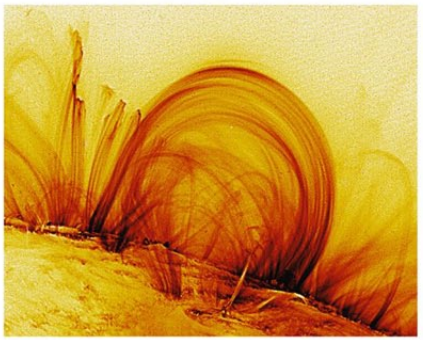


SUNSPOTS

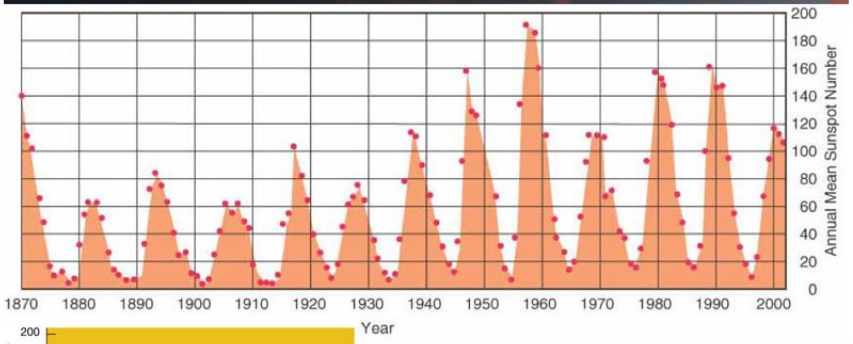


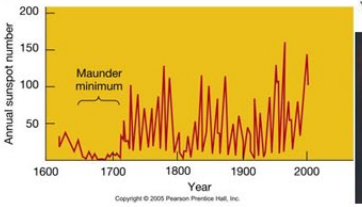


(a)



SUNSPOT CYCLE

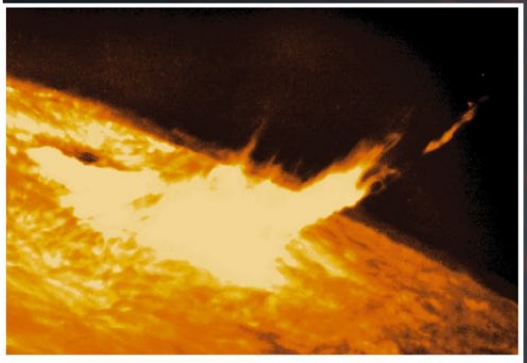


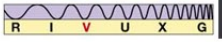


CORONA

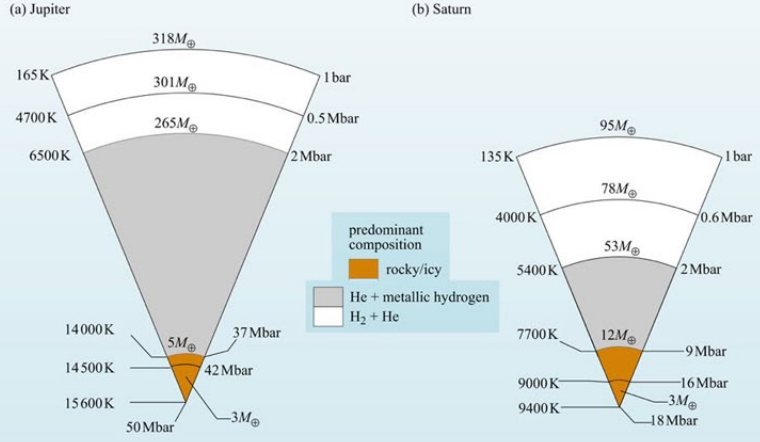
SOLAR FLARES

- 100 MK temperatures (6x hotter than the core)
- can cause problems at Earth
  - hazardous for astronauts and satellites
  - can disrupt electric power distribution grids on the surface





GIANT PLANET INTERIORS



METALLIC LIQUIDS

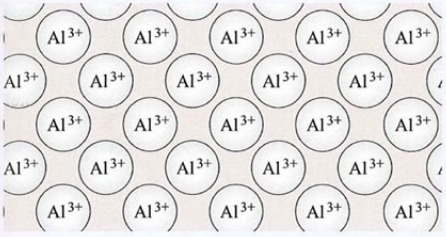


Figure 6.6 Aluminium ions (Al^{3+}) arranged as though in a crystal of aluminium. The electrons 'lost' from the atoms wander freely through the solid.

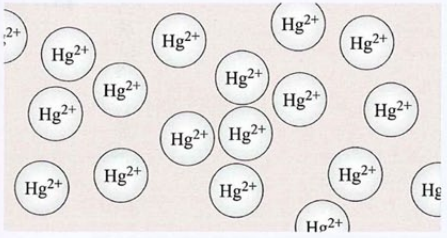
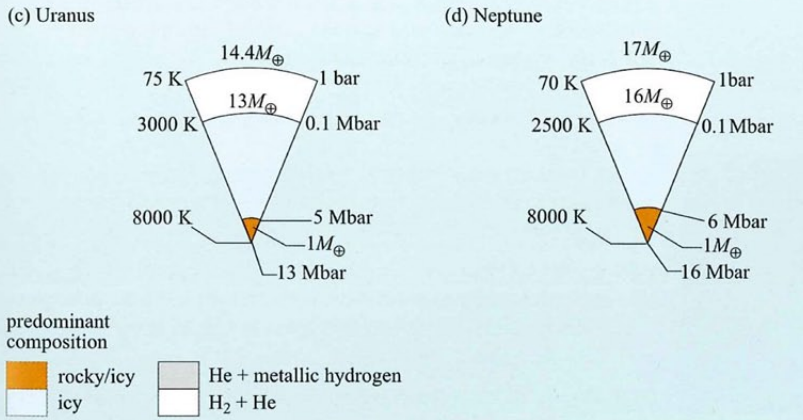
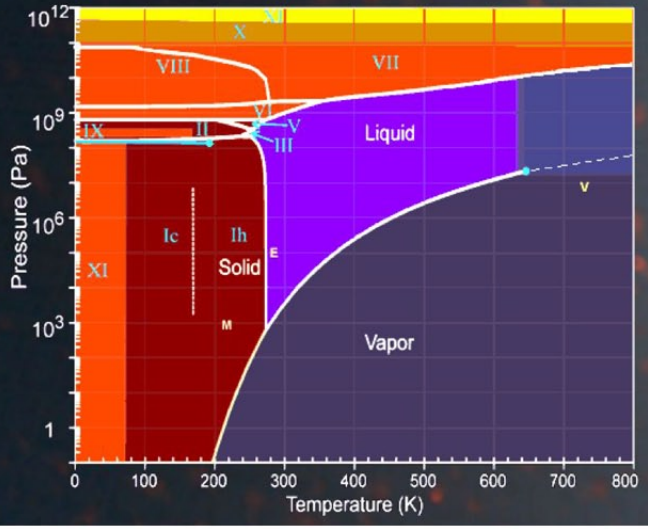


Figure 6.7 Mercury ions (Hg^{2+}) arranged as though in liquid mercury. The 'lost' electrons are free to travel through the liquid, but the arrangement of the ions is less regular than in solid aluminium.

GIANT PLANET INTERIORS

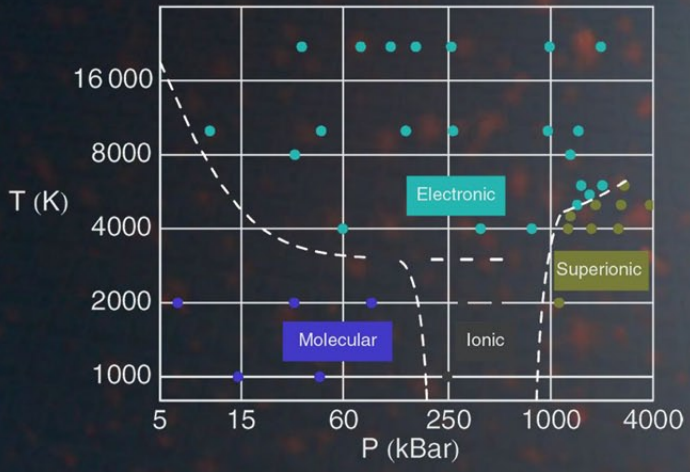


PHASES OF WATER

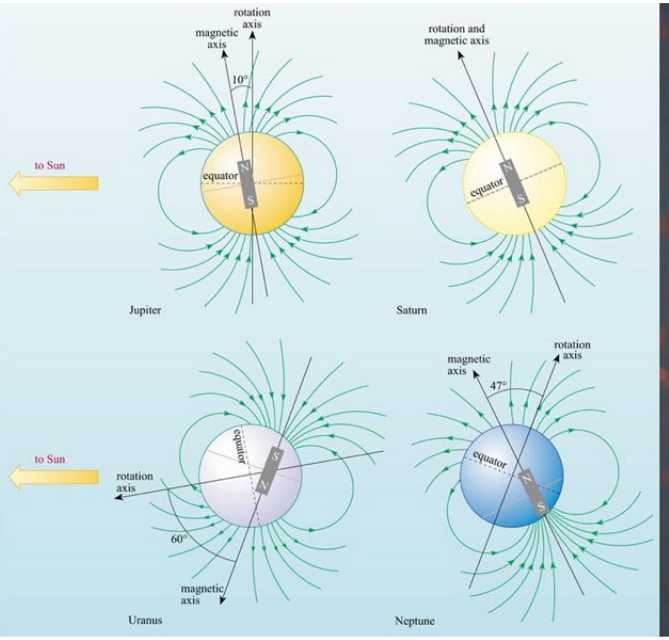


Martin Chaplin (LSBU website)

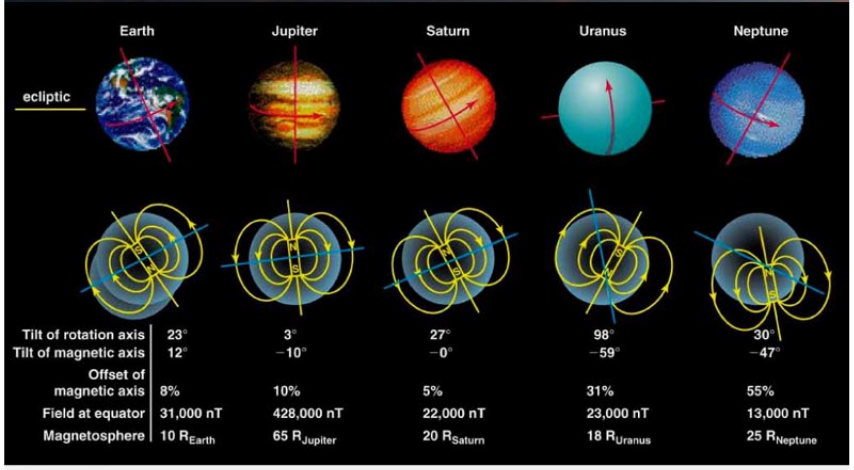
HIGH PRESSURE WATER



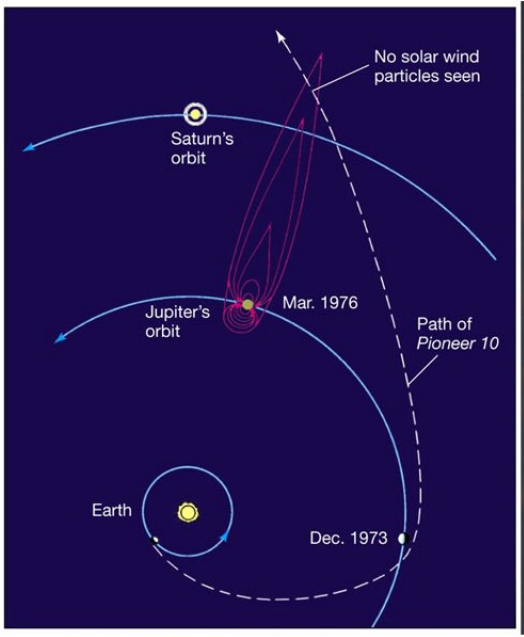
Mattsson and Desjarlais (2006), DFT



MAGNETIC FIELDS

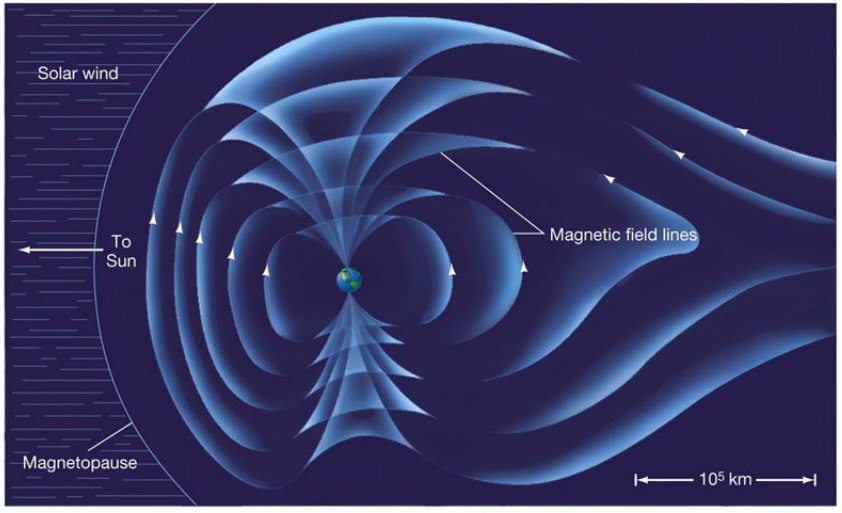


	Earth	Jupiter	Saturn	Uranus	Neptune
Tilt of rotation axis	23°	3°	27°	98°	30°
Tilt of magnetic axis	12°	−10°	−0°	−59°	−47°
Offset of magnetic axis	8%	10%	5%	31%	55%
Field at equator	31,000 nT	428,000 nT	22,000 nT	23,000 nT	13,000 nT
Magnetosphere	10 R_{Earth}	65 $R_{Jupiter}$	20 R_{Saturn}	18 R_{Uranus}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



- Jupiter's magnetosphere is the largest planetary structure in the Solar System

GEOMAGNETIC FIELD

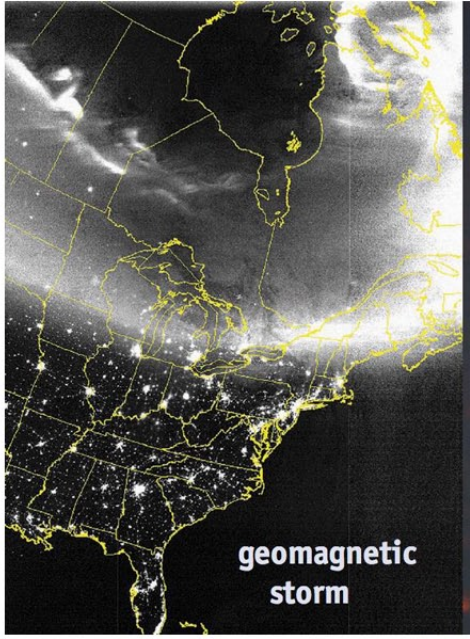


AURORAE

Dirk Obudzinski, 2004, near Davis

AURORAE

Dirk Obudzinski, 2003, near Gilroy



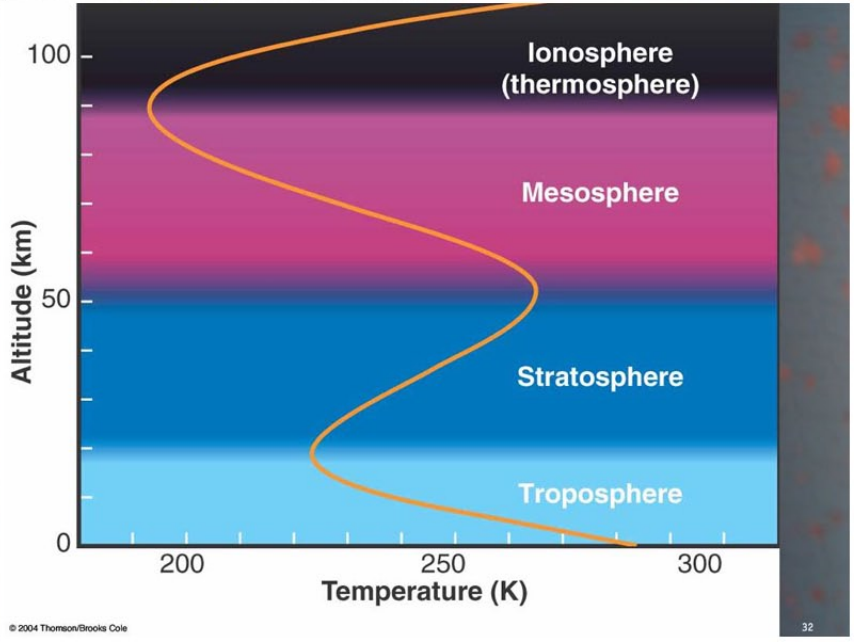
geomagnetic storm

AURORAE

normal

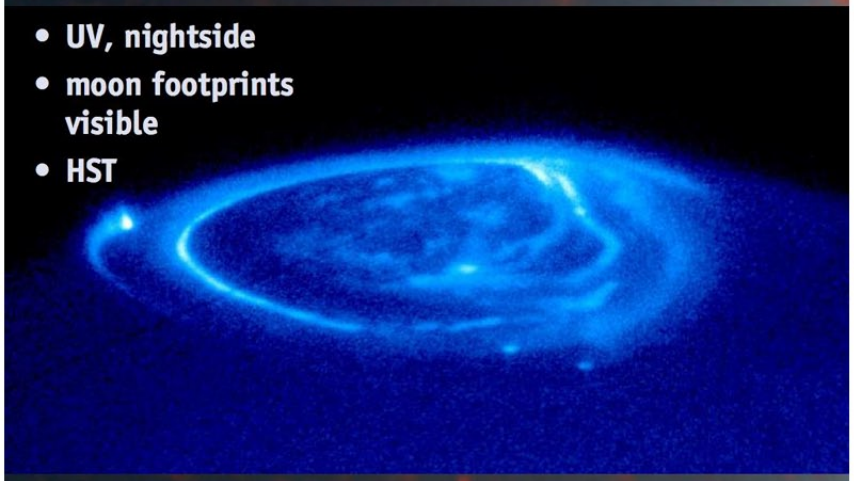
AURORAE

- Duane Clausen, Michigan 2003
- aurorae much higher than clouds



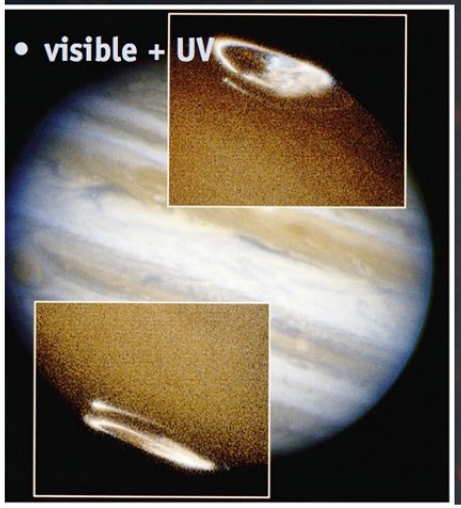
JUPITER AURORA

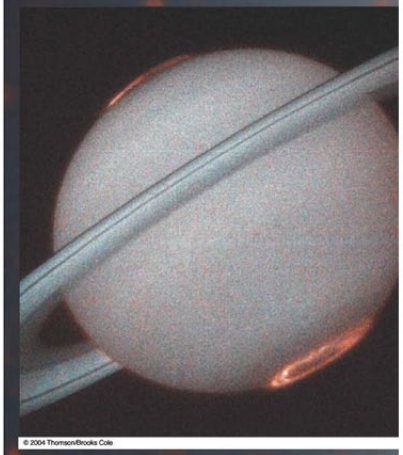
- UV, nightside
- moon footprints visible
- HST



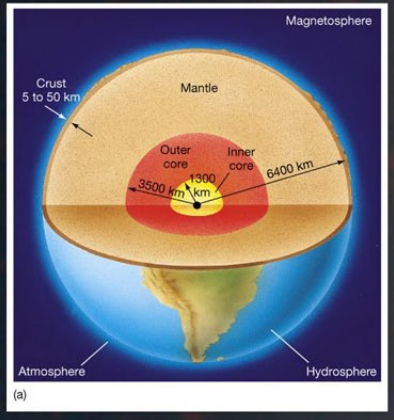
AURORAE

- visible + UV



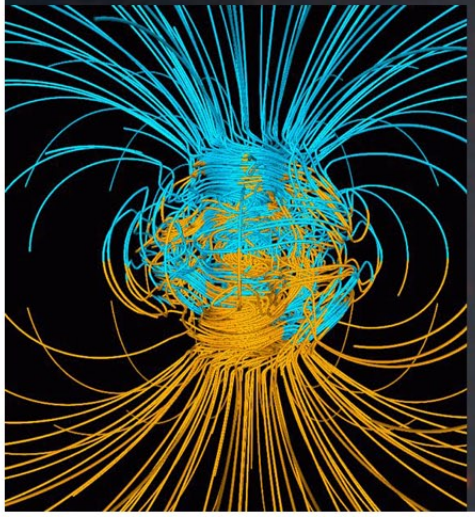


THE DYNAMO



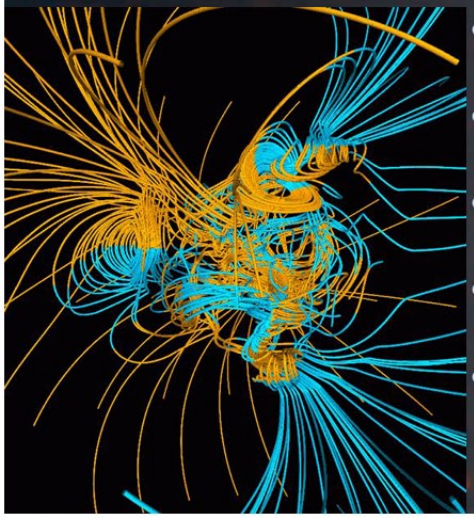
- magnetic fields are generated by moving charge
- flow in the liquid iron core is the magnetic dynamo

NORMAL DYNAMO

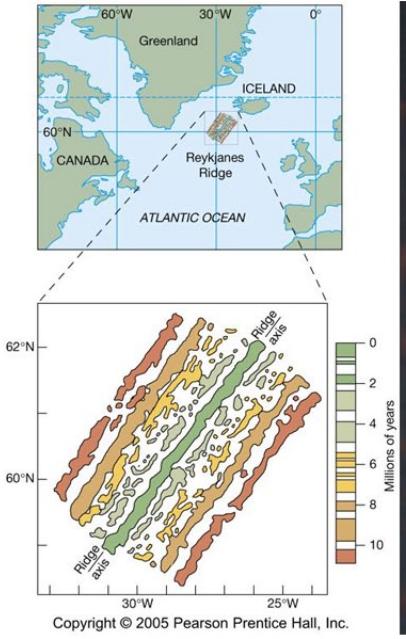


- Pittsburg / UCLA simulation
- cray C90
- mantle boundary visible
- outgoing field lines (S): yellow, incoming (N): blue

DYNAMO IN REVERSAL



- rapid, chaotic variation during reversal
- field still protects Earth
- reversal lasts ~1000 years
- happen on irregular 700,000 yr timescales
- last one 780,000 years ago



RIFT ZONE MAGNETIC RECORDS

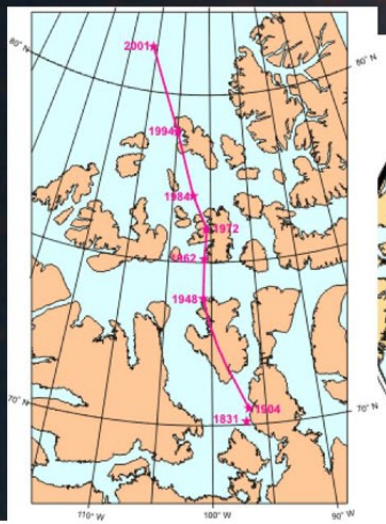
- magnetic field POLARITY (north-south direction) shows an alternating pattern near oceanic rifts

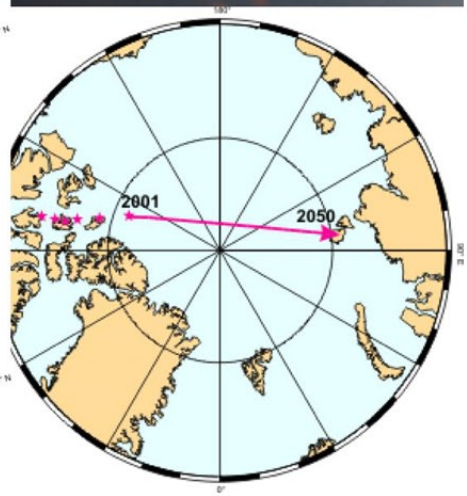
MAGNETIZED SOLIDS

- some solids can maintain a permanent magnetization
- imagine tiny frozen current loops within the solid
- "fossil" magnetic fields are trapped in some lavas as they solidify
- heating solids past their Curie temperature will erase the magnetization

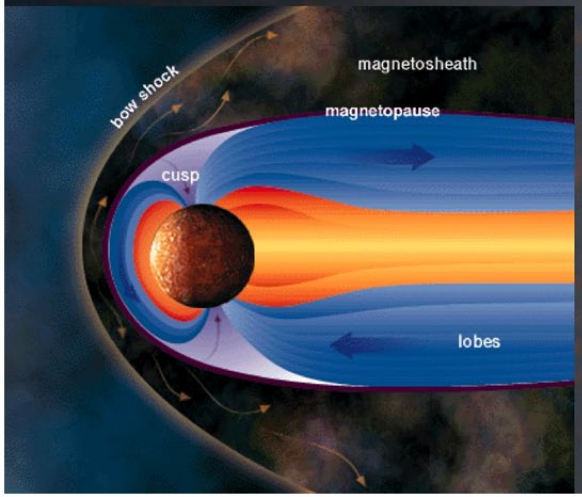
POLE ON THE MOVE

- 2001: 81° N
- 2005: 83° N



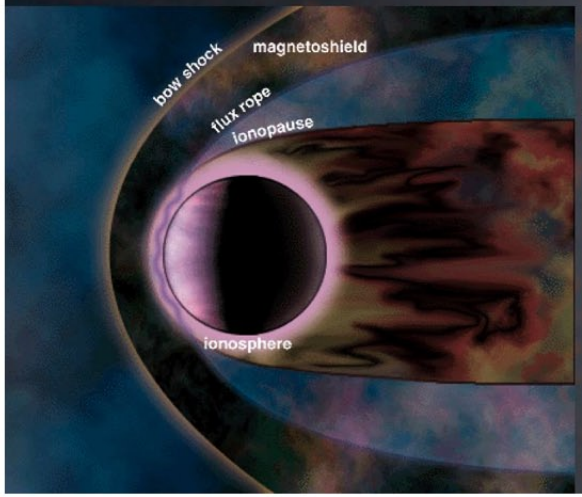


MERCURY'S MAGNETOSPHERE



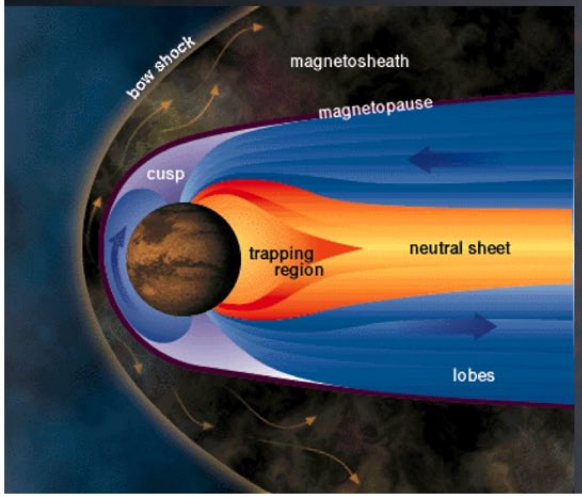
- 1% Earth's strength
- possibly a residual field
- Mercury's slow rotation and small size made this surprising

VENUS' MAGNETOSPHERE



- no intrinsic field
- probably related to lack of rapid rotation

MARS' MAGNETOSPHERE



- MGS detected a field 0.12% Earth's strength
- probably not a global field
- lack of significant field probably due to lack of liquid core

CLOUD CONTRACTION