What I have recently learnt

Boding Ouyang
oybdooo@mail.ustc.edu.cn

University of Science and Technology of China

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Tutor:Jiuhou Lei(USTC), Tong Dang(USTC), Binzheng Zhang(HKU)

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Declaration

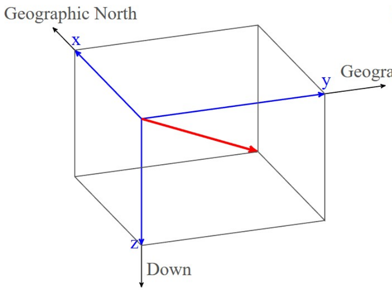
Because I am lacked of experience in scientific writing, my references format is not correct.

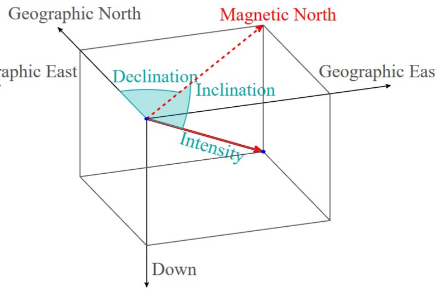
I will change it when I am experienced in it.

Because I am not hard enough during Lunar New Year, a lot of points are not prepared.

New Section
Magnetic Field

Magnetic Field Characteristics



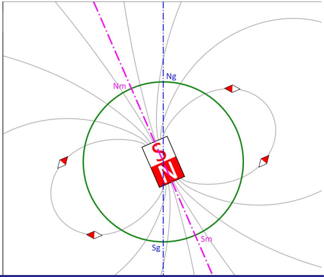


Magnetic Field Model

Dipole Model

- $$B_r = -\frac{2M_B}{r^3}\sin\theta$$
- $$B_\theta = \frac{M_B}{r^3}\cos\theta$$
- $$B_\phi = 0$$

r: radial length θ: latitude ϕ: longitude



Magnetic Field Model

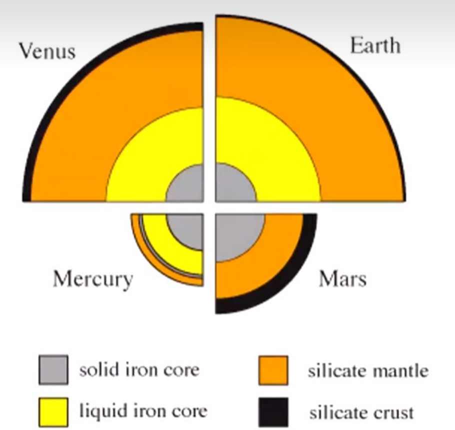
Spherical Harmonics

- $$V = a \sum_{n,m} [A_n^m (\frac{a}{r})^{n+1} + B_n^m (\frac{r}{a})^n] Y_n^m(\theta, \phi)$$
- $$B_r = -\frac{\partial V}{\partial r}$$
- $$B_\theta = -\frac{1}{r} \frac{\partial V}{\partial \theta}$$
- $$B_\phi = -\frac{1}{r \sin\theta} \frac{\partial V}{\partial \phi}$$

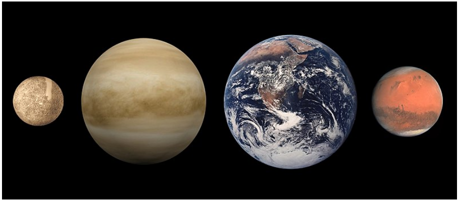
modeling based on measurement data.

Terrestrial Planet

Terrestrial planet interiors to same scale



Why there are difference between them?



Common view:

Planetary magnetic field is the key factor to control planetary environment.

Magnetic Field

$$Solar\ \ Wind(external\ \ source)$$

$$\Updownarrow$$

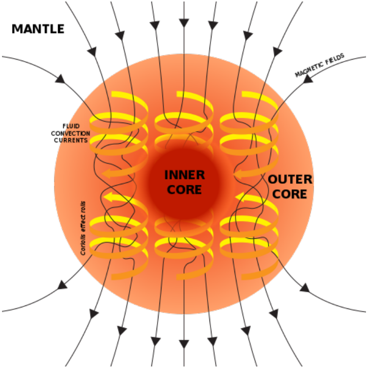
$$Planetary\ \ Space\ \ Environment$$

$$\Updownarrow$$

$$Planet\ \ Interior(internal\ \ source)$$

material and energy exchange and sphere coupling

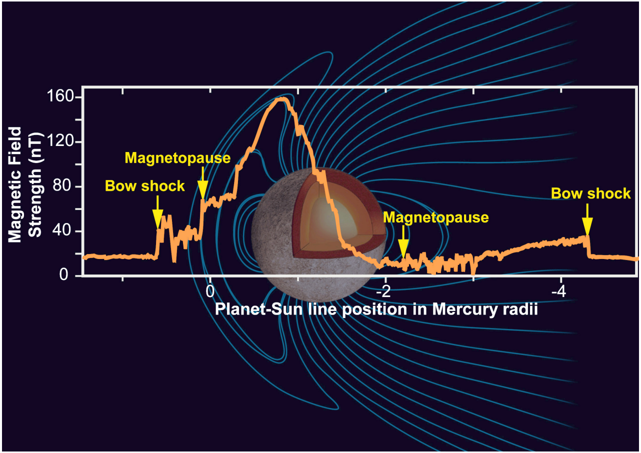
Magnetic Field——Formation



Convection currents of fluid metal in the Earth's outer core, driven by heat flow from the inner core, organized into rolls by the Coriolis force, create circulating electric currents, which generate the magnetic field.

Magnetic Field——Mercury

- Low-intensity
- Global



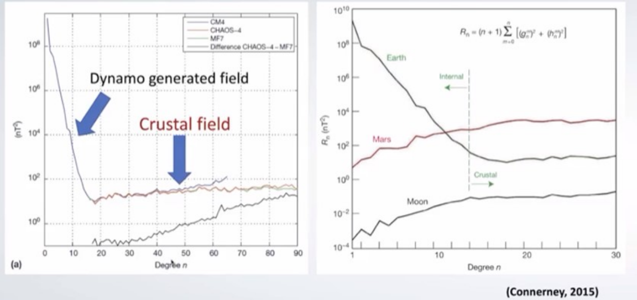
Magnetic Field——Venus

- No observed signatures of magnetic fields
- Because of the high temperature on the surface, we cannot make sure whether Venus has dynamo before

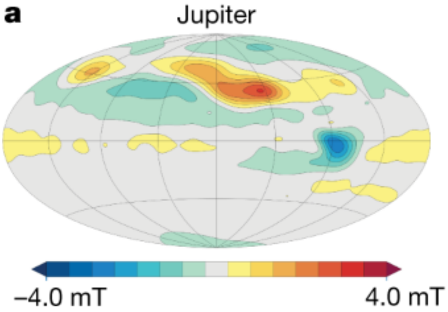
Magnetic Field——Mars and the Moon

- Lack global scale magnetic fields
- Have no active dynamo now
- But they must had dynamo in the past when the crust acquired intense remanent magnetization

Why?



- Has strongest magnetic field among planets in the Solar System



Magnetic Field——Ganymede(the third satellite of Jupiter)

- Although it is a satellite, its magnetic field is similar to Mercury
- But its magnetic field is in the range of jovian magnetosphere

Saturn's magnetic field is extremely axisymmetric!!!

Dipole tilt less than 0.007 degrees!!!

New Section

Ionosphere

Ionosphere

- Ionosphere is the ionized part of the upper atmosphere of Earth.
- about $60 \sim 1000 \ km$

Ionosphere Continuity Equation

The Boltzmann equation (first moment) :

$$\frac{\partial n_j}{\partial t} + \nabla \cdot (n_j V_j) = Q_j - L_j$$

n_j:density V_j:average speed
Q_j:generation rate L_j:loss rate

Charge conservation law:

$$n_e = \sum n_i, L_e = \sum L_i, Q_e = \sum Q_i$$

e:electron i:ion

$$\therefore \nabla \cdot \vec{j} = 0$$

$$\vec{j} = e(\sum n_i V_i - n_e V_e)$$

It shows that the current density field in plasma is solenoidal field.

Ionosphere Production & Loss of Ions

Production of Ions :

1. Solar electromagnetic radiation
2. Energetic particle
3. Meteoroid

Loss of Ions :

1. Ionic chemical reaction
2. Recombine with electrons

New Section
Magnetosphere

Magnetosphere——Formation

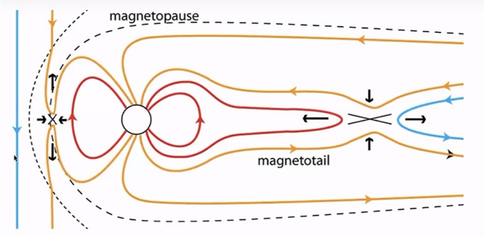
Requirement:

- Solar Wind
- Planet Magnetic Field

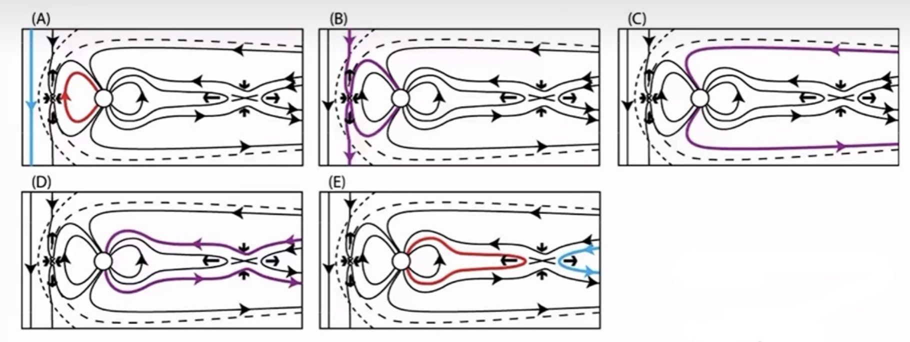
But... How???

Dungey Cycle

1. Solar wind transfers magnetic field near the planet.(**Magnetic Freezing**)
2. Planetart magnetic field near to magnetopause connect to solar wind magnetic field, the planetary magnetic field is open(**Magnetic Reconnection**)
3. At the nightside magnetotail reconnects to the open planetary magnetic field, the planetary magnetic field is closed(**Magnetic Reconnection**)

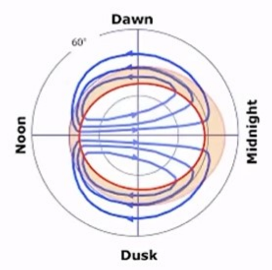


Magnetosphere——Formation



Dungey Cycle

- forms plasma convection from dayside to nightside
- forms **polar cap** consists of open field lines at high latitude



New Section
Simulation

Simulation——Catalogue

- MHD Simulation(Big Scale, Low Computation)
- Mixed Simulation(Ion Scale, High Computation)
- Particulate/Kinetic Theory Simulation(Electron Scale, Extremely High Computation)

I will describe MHD Simulation in this report.

MHD Simulation——Ideal MHD Equations

Conservation of mass:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

Conservation of momentum:

$$\frac{\partial \rho \mathbf{u}}{\partial t} = -\nabla \cdot [\rho \mathbf{u}\mathbf{u} + (P + \frac{1}{2}B^2)\bar{\mathbf{I}} - \mathbf{B}\mathbf{B}]$$

Conservation of energy:

$$\frac{\partial E_P}{\partial t} = -\nabla \cdot [\mathbf{u}(E_P + P)] - \mathbf{u} \cdot \nabla \cdot (\frac{B^2}{2}\bar{\mathbf{I}} - \mathbf{B}\mathbf{B})$$

Conservation of magnetic flux:

$$\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \mathbf{E}$$

Ohm's Law

$$\mathbf{E} + \mathbf{u} \times \mathbf{B} = 0$$

Thanks

Thank you for listening!