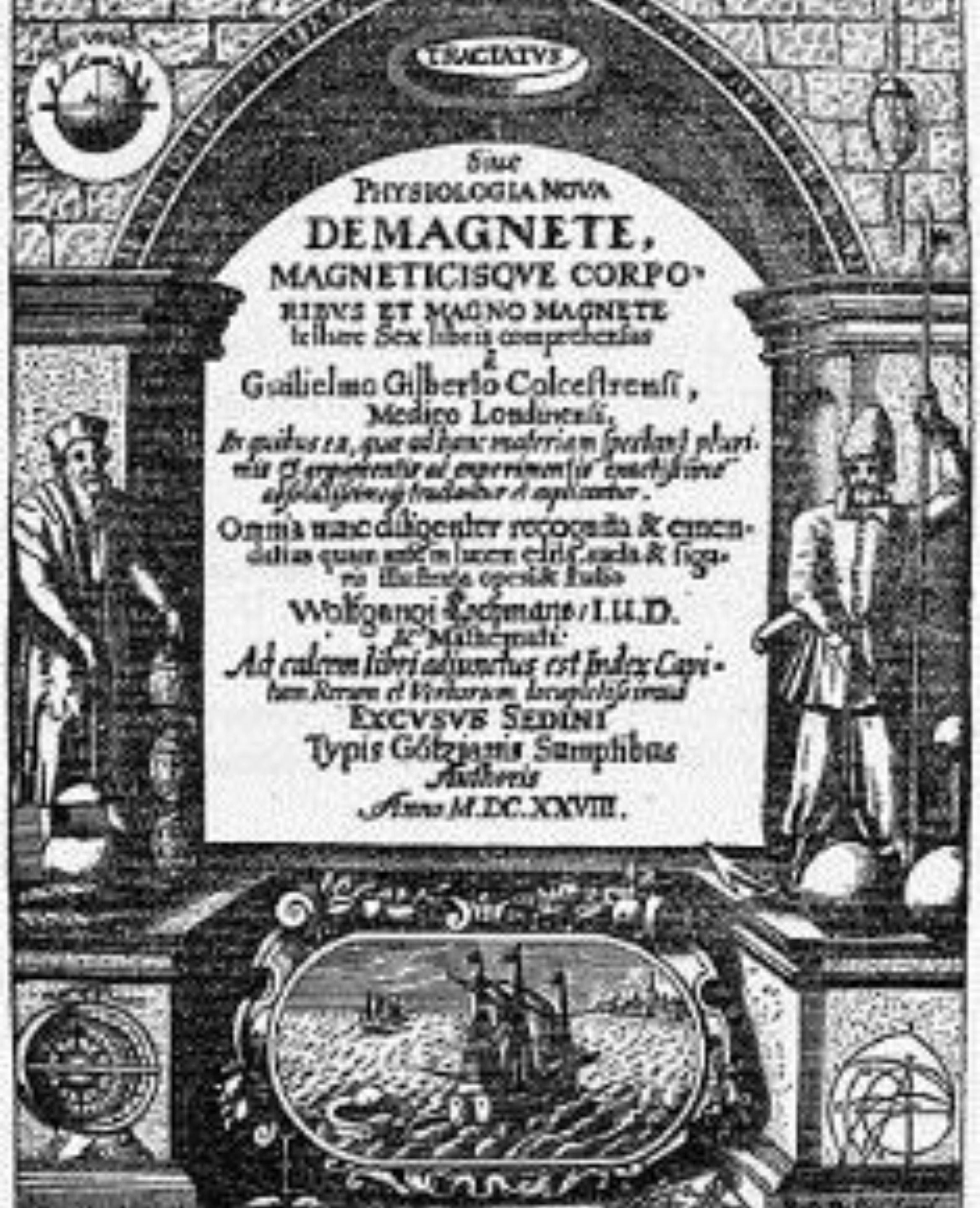
Lecture 33

- Earth magnetic field
- Magnetosphere
- Rare collisions
- Current systems

Last time…

- Eddington approximation
- 20% error near the surface compared with the *formal solution*
- Heat conduction and heat diffusion
  - $T^{5/2}$ law
- magnetic diffusivity different
  - $T^{-3/2}$ law
- Hydrostatic corona


TRACTATVS
Siue
PHYSIOLOGIA NOVA
DE MAGNETE,
MAGNETICISQVE CORPORIBVS ET MAGNO MAGNETE
Guilielmo Gilberto Colcestrensi,
Medico Londinensi,
Wolfgangi Lochmanis I.U.D.
EXCVSVS SEDINI
Typis Götzianis Sumptibus
Authoris
Anno M.DC.XXVIII.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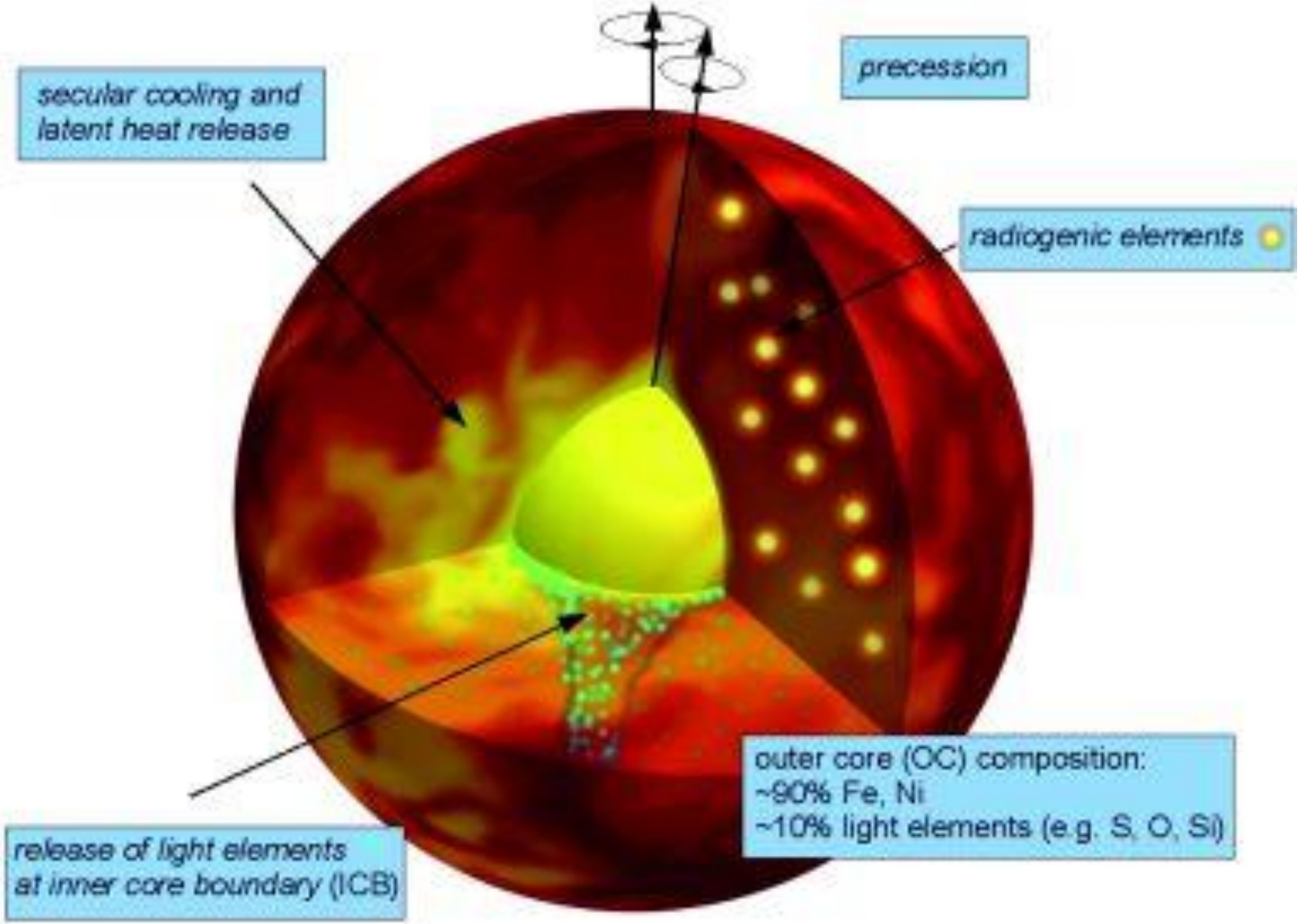
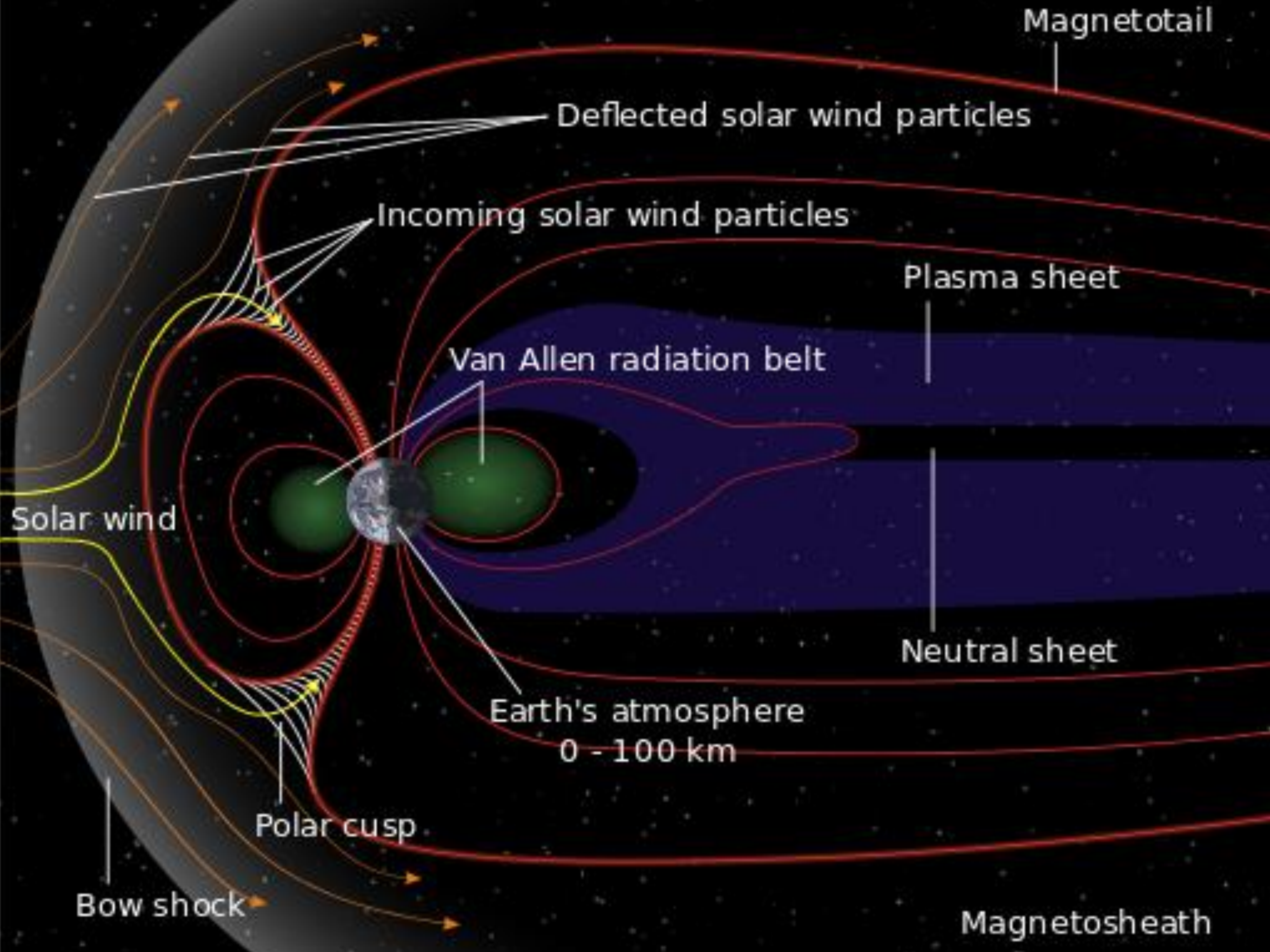


secular cooling and
latent heat release
precession
radiogenic elements
outer core (OC) composition:
~90% Fe, Ni
~10% light elements (e.g. S, O, Si)
release of light elements
at inner core boundary (ICB)

Earth's magnetic field

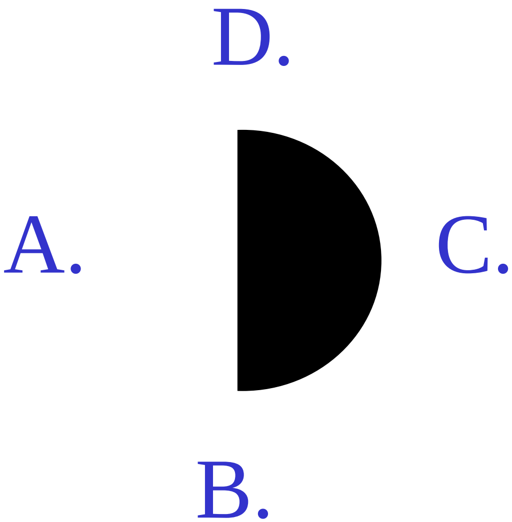
- William Gilbert (1600) "de Magnete"
  - Non-cyclic, but chaotic variations
  - Similar to but different from the Sun
- Energy source: compositional convection
  - Alternatively: Earth's precession
- Confined by solar wind → magnetosphere


Magnetotail
Deflected solar wind particles
Incoming solar wind particles
Plasma sheet
Van Allen radiation belt
Solar wind
Neutral sheet
Earth's atmosphere
0 - 100 km
Polar cusp
Bow shock
Magnetosheath

Moon's orbit?

A. 10 R_E?
B. 20 R_E?
C. 50 R_E?
D. 100 R_E?
E. 200 R_E?

View from the North: where is East



Earth's magnetosphere

- Solar wind
- Bow shock
- Polar cusp
- Van Allen Belts
- Earth's atmosphere
- Plasma sheet, neutral sheet
- Magnetosheath
- Magnetotail

Properties

- Surrounded by currents → magnetopause
- Excludes solar wind from magnetosphere
- Currents permanent, but highly variable
- Inner field: closed, but very stretched
- Particles: cosmic rays, Sun, ionosphere
- Collisions rare
- Conductivity?

Collisions rare: conductivity

A. is high
B. is low
C. is unchanged?

Lect. 32: electric conductivity

Acceleration until collision

$$\frac{m_{\rm e}\mathbf{V}}{\tau_{\rm ei}} = e\mathbf{E} \qquad \tau_{\rm ei} = \frac{T^2}{n_{\rm e}v_{\rm e}} \propto \frac{T^{3/2}}{n_{\rm e}}$$

conductivity

$$\mathbf{J} = n_{\rm e}e\mathbf{V} = \underbrace{\frac{n_{\rm e}e^2}{m_{\rm e}}\tau_{\rm ei}}_{\sigma}\mathbf{E}$$

Mean-free path

$$\ell = \frac{1}{n\sigma_{\rm cross}} \propto \frac{T^2}{n}$$

magnetic diffusivity

$$\eta = \frac{1}{\mu_0\sigma} \sim T^{-3/2}$$

Heat diffusivity

$$\chi \sim \ell v_{\rm e} \sim T^{5/2}$$

Note: $n_{\rm e}$ cancels!

Collisions rare: heat conduction?

A. is high
B. is low
C. is unchanged?

Lect. 26: Heat conduction

Frequent collisions: electric, kinetic, and thermal energies similar

$$k_\mathrm{e}\frac{e^2}{r} \sim \tfrac{1}{2} m_\mathrm{e} v_\mathrm{e}^2 \sim k_\mathrm{B} T$$

$$k_\mathrm{e} = \frac{1}{4\pi\varepsilon_0}$$

permittivity

Coulomb (1736-1806)

Coulomb cross-section

$$\sigma_\mathrm{cross} = \pi r^2 = \pi\left(\frac{k_\mathrm{e} e^2}{k_\mathrm{B} T}\right)^2$$

Mean-free path

$$\ell = \frac{1}{n\sigma_\mathrm{cross}} \propto \frac{T^2}{n}$$

Heat diffusivity

$$\chi \sim \ell v_\mathrm{e} \sim T^{5/2}$$

Also true for viscosity $\nu \sim \ell v_\mathrm{e} \sim T^{5/2}$

Collisions rare: ratio $Pr_M = \nu/\eta$?

A. is high
B. is low
C. is unchanged?

$$\nu / \eta \sim \frac{T^{5/2} / n}{T^{-3/2}} \sim T^4 / n$$

Laboratory for Atmospheric and Space Physics

About | Missions & Projects | Science | Engineering | Mission Operations & Data Systems | Education

Missions & Projects

- All
- Past
- Present
- Future

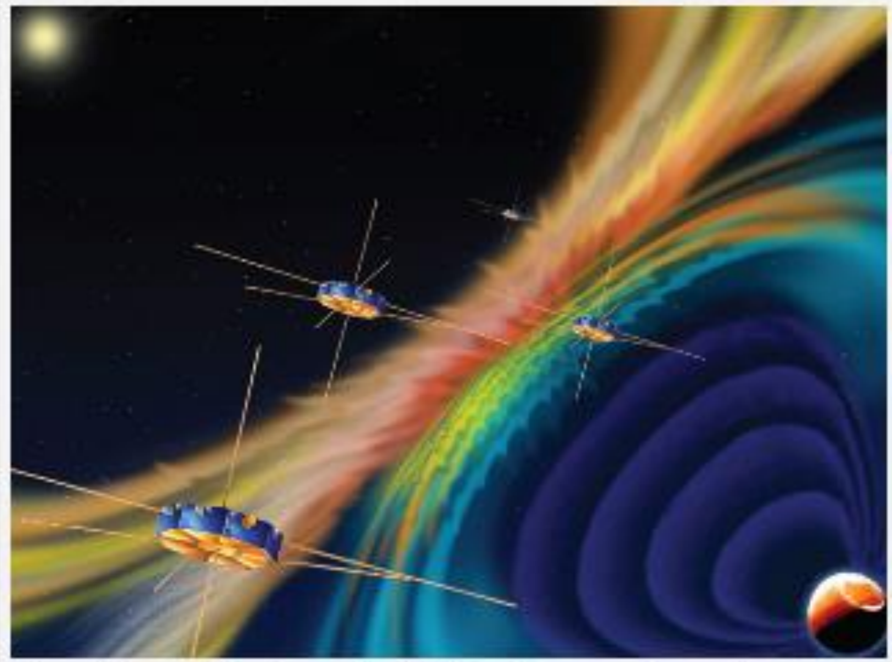
LASP Rocket Program

- Current Launch Status
- Introduction to Scientific Rockets
- Early History of Rocketry at LASP
- LASP Rocket Projects of Note
- Rocketry Multimedia Gallery

Quick Facts: Magnetospheric MultiScale (MMS)

Mission Introduction

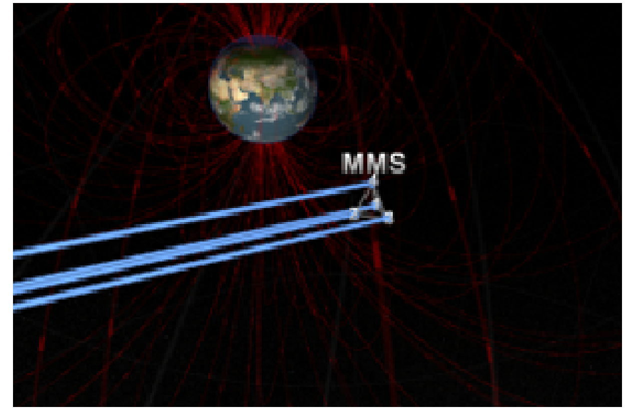
The Magnetospheric Multiscale (MMS) mission is a Solar Terrestrial Probes Program mission within NASA's Heliophysics Division. The MMS mission, consisting of four identically instrumented spacecraft, uses Earth's magnetosphere as a laboratory to study magnetic reconnection, a fundamental plasma-physical process that taps the energy stored in a magnetic field and converts it—typically explosively—into heat and kinetic energy in the form of charged particle acceleration and large-scale flows of matter.



An artist's rendition shows the MMS as it sweeps through a magnetic reconnection event caused when the solar wind meets Earth's magnetic fields. (Courtesy SwRI)

The four MMS spacecraft carry identical suites of plasma analyzers, energetic particle detectors,

The Magnetospheric Multiscale Mission



Project Description:
MMS investigates how the Sun's and Earth's magnetic fields connect and disconnect, explosively transferring energy from one to the other in a process that is important at the Sun, other planets, and everywhere in the universe, known as magnetic reconnection. Reconnection limits the performance of fusion reactors and is the final governor of geospace weather that affects modern technological systems such as telecommunications networks, GPS navigation, and electrical power grids. Four identically instrumented spacecraft measure plasmas, fields, and particles in a near-equatorial orbit that will frequently encounter reconnection in action.

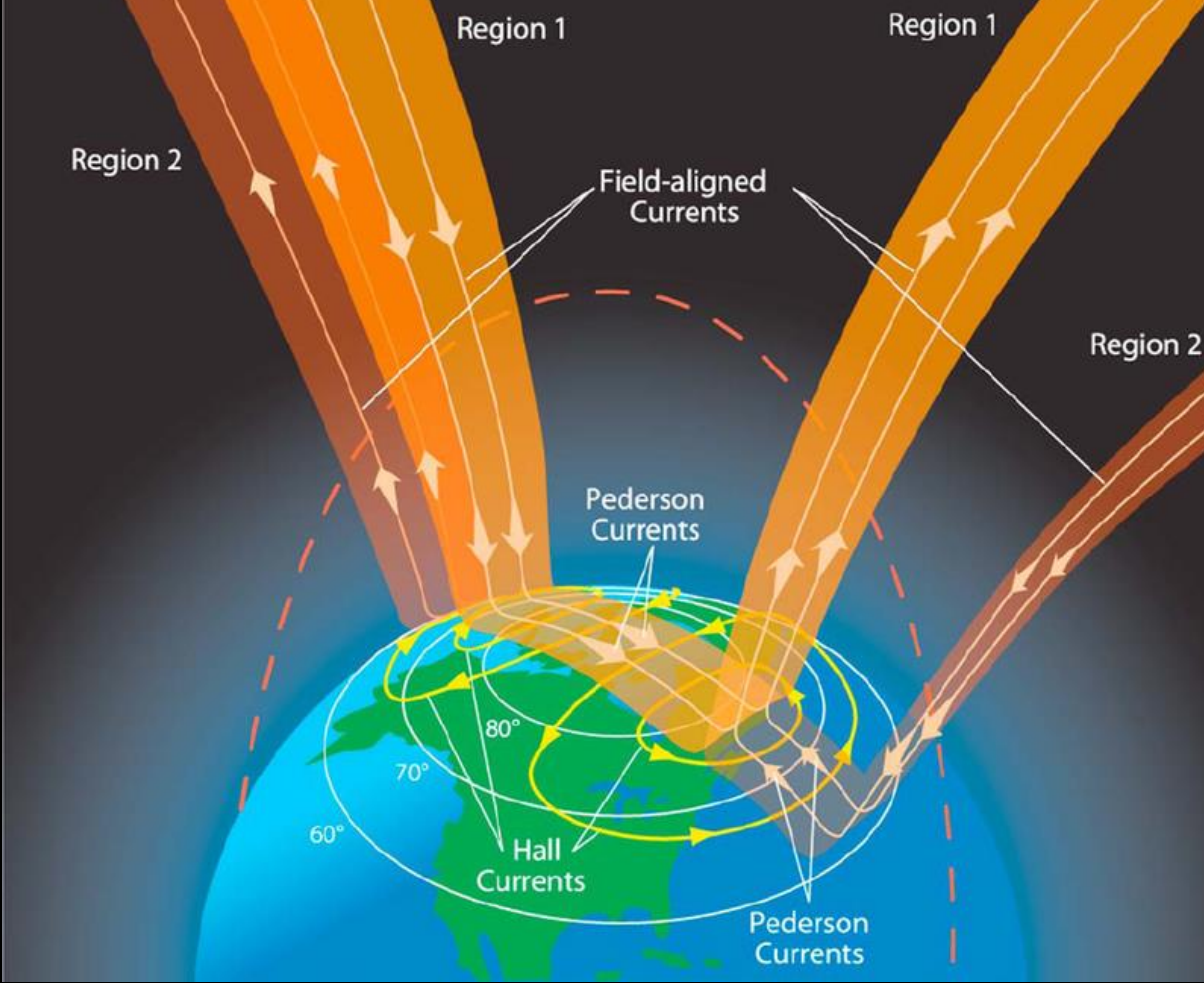
Science Goals:
MMS reveals, for the first time, the small-scale three-dimensional structure and dynamics of the elusively thin and fast-moving electron diffusion region. It does this in both of the key reconnection regions near Earth, where the most energetic events originate.

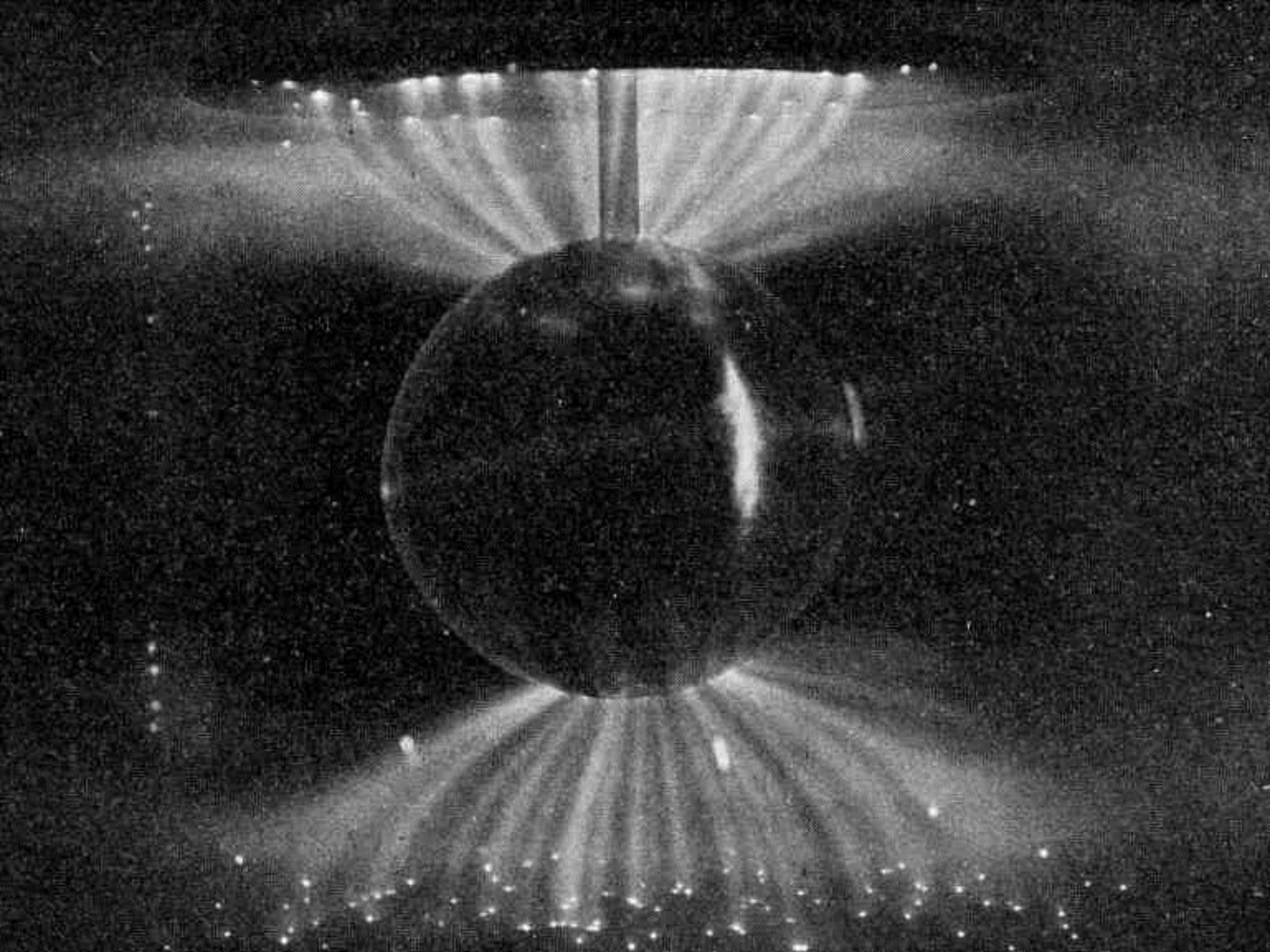
LASP Roles

- LASP serves as the mission Science Operations Center (SOC), which includes science operations planning, instrument command sequence development, and science analysis support
- Science data for all MMS measurements is hosted at LASP and centrally disseminated to the science community
- LASP Director, Dan Baker, serves as the SMART (Solving Magnetospheric Acceleration, Reconnection, and Turbulence) Science Operations Center Lead

LASP Instruments

LASP built several key components to the MMS FIELDS investigation instruments. This includes the door and preamplifier assemblies for the Spin-plane Double Probe (SDP) electric field instrument, the Axial Double Probe (ADP) electric field instrument including booms, sensors, and preamplifiers, and the Digital Signal Processor (DSP) electronics that support onboard capture and processing of the ADP, SDP, and Search Coil Magnetometer (SCM) electric and magnetic field measurements.


Region 1
Region 1
Region 2
Field-aligned Currents
Region 2
Pederson Currents
80°
70°
60°
Hall Currents
Pederson Currents



What we learned today

- Earth magnetic field
  - Outer core (liquid iron)
- Magnetosphere
- Rare collisions
  - σ high, η low, ν large, Pr_M large
- Current systems