ASTR 405
Planetary Systems
Exoplanet Interiors: Terrestrial Planets

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Supplementary Readings: **terrestrial-planet-interiors.pdf** on Canvas

Terrestrial Planet Interiors by Sotin et al.

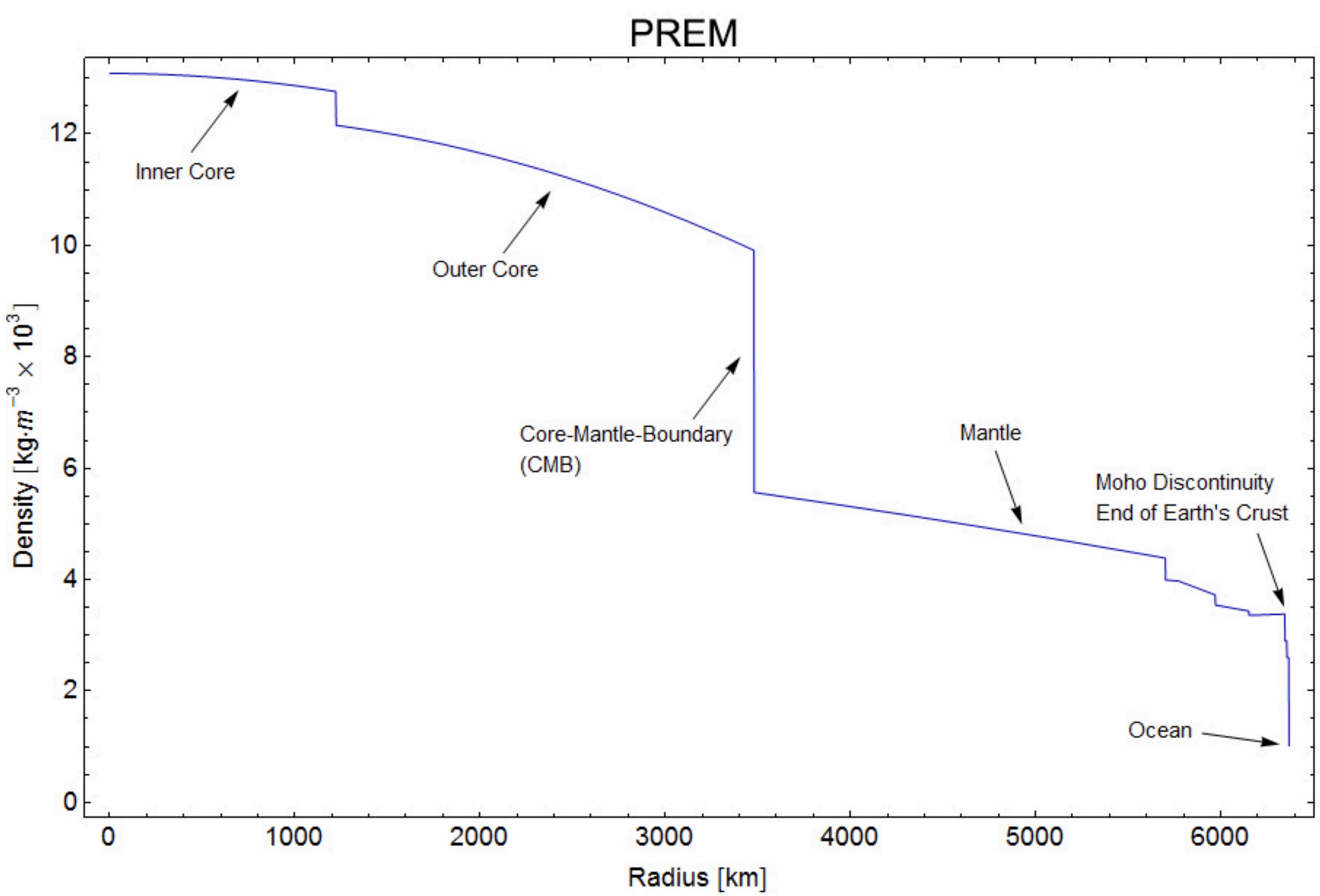
Module III: Exoplanet Atmospheres, Interiors, and Characterization

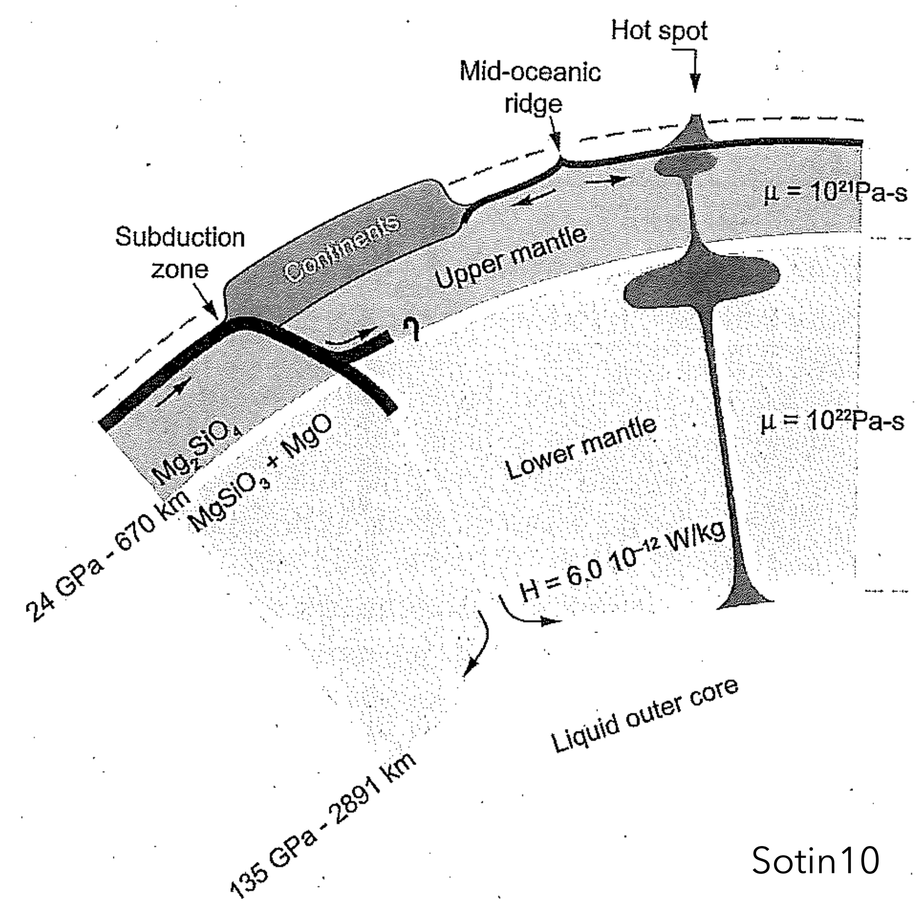
- **Exoplanet Characterization**
  - Transmission, emission & phase curves → atmospheric composition, P-T profile
  - Rossiter–McLaughlin effect → spin–orbit angles
- **Atmospheric Physics**
  - Hydrostatic structure and P-T profiles
  - Thermodynamics: convection, lapse rate, and radiative balance
  - Composition and clouds: metallicity, C/O ratio, disequilibrium chemistry
  - Atmospheric loss and the cosmic shoreline
- **Planetary Interiors**
  - Giant planets: phase diagram of hydrogen, central pressure, Hot Jupiter radius inflation
  - <u>Terrestrial planets: heat transport, cooling, and mass–radius relation</u>

Earth’s Interior Structure

Earth’s solid components can be broken into five primary layers, from the surface inward: 1) crust, 2) upper mantle, 3) lower mantle, 4) liquid metal outer core, and 5) solid inner core.

Preliminary Reference Earth Model (PREM)





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Heat Transfer & Cooling Timescale

In solid rocks, heat is transported by conduction, the diffusion of thermal energy from high to low temperature through vibrations of the crystal lattice.

Fourier's law states that the conductive heat flux $\mathbf{F}$ is proportional to the thermal conductivity k and temperature gradient:

$$\mathbf{F} = -k\frac{dT}{dz},$$

where the thermal conductivity k has units of $\mathrm{W\,m^{-1}\,K^{-1}}$.

For rocky planets,

- Total thermal energy: $U = \rho c_p V T$
- Conductive heat loss: $F = kT/h$ and $L = F\,4\pi R^2$
- Cooling timescale: $\tau = U/L$

In-Class Activity

Cooling Timescale of Earth

Rocky Planet Mass-Radius Relation

- Small rocky planets (<1.7 $R_\oplus$) mostly follow an Earth-like composition.
- Larger planets show diverse densities: some rocky, others needing ices or H/He envelopes.
- Sub-Neptunes are compositionally degenerate, consistent with either water worlds or rocky cores plus thin gas.