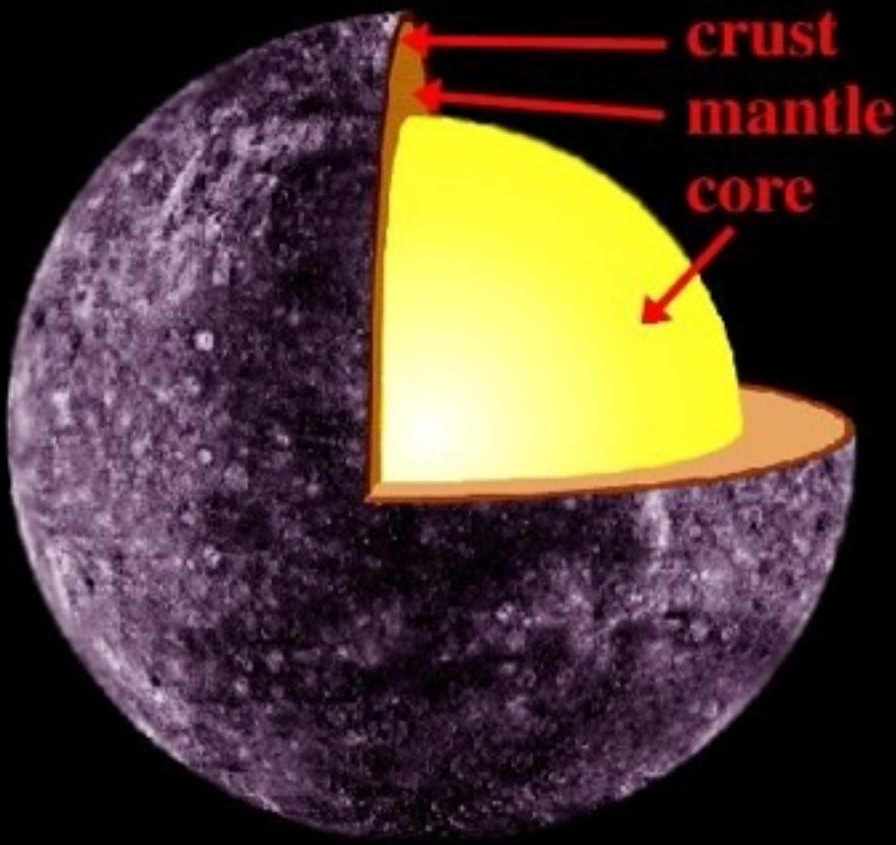
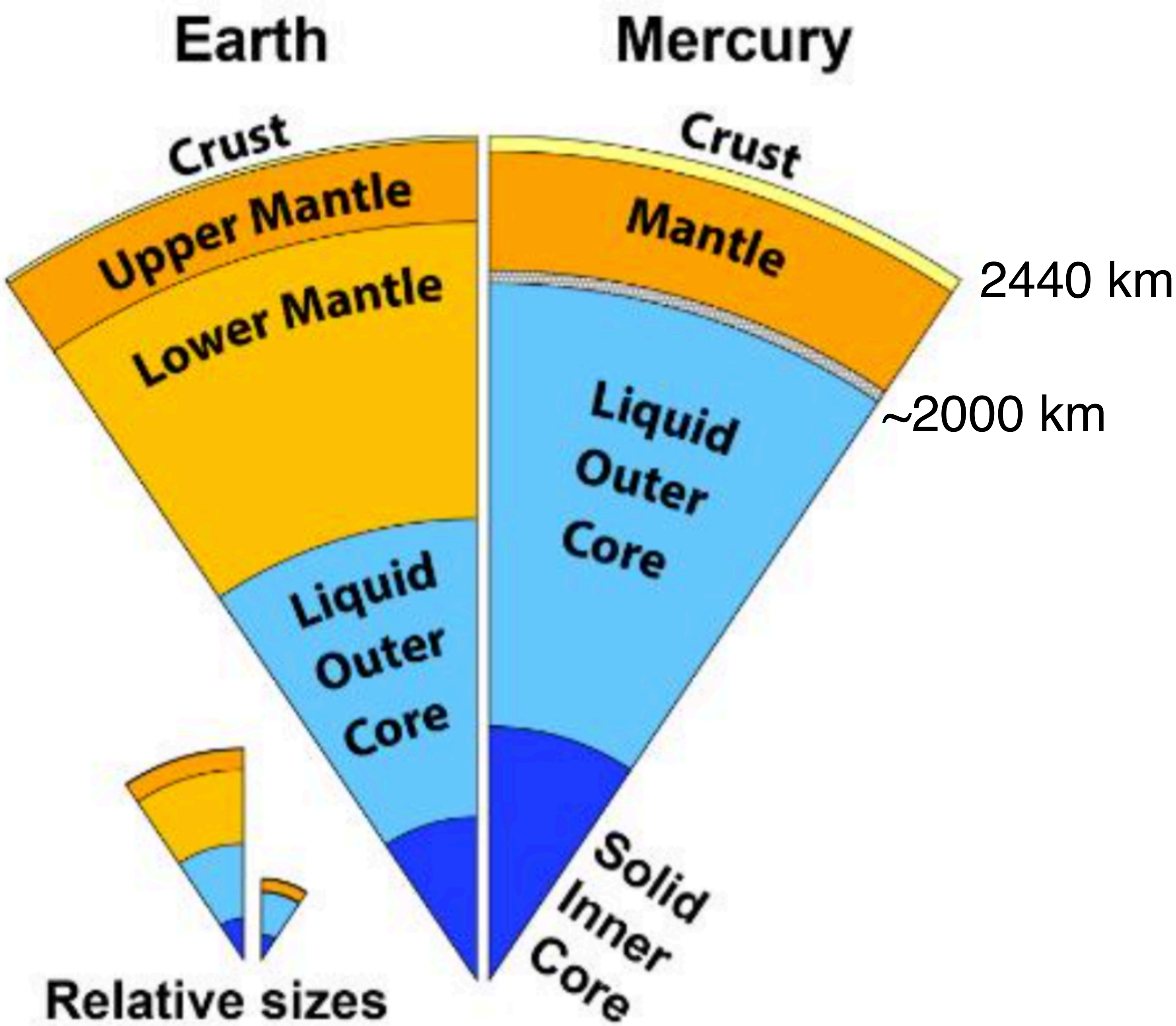


The interior structure and evolution of Mercury

COME-IN meeting
Amsterdam
10 February

Marie-Hélène Deproost

Observables



Density: very high

→ large core

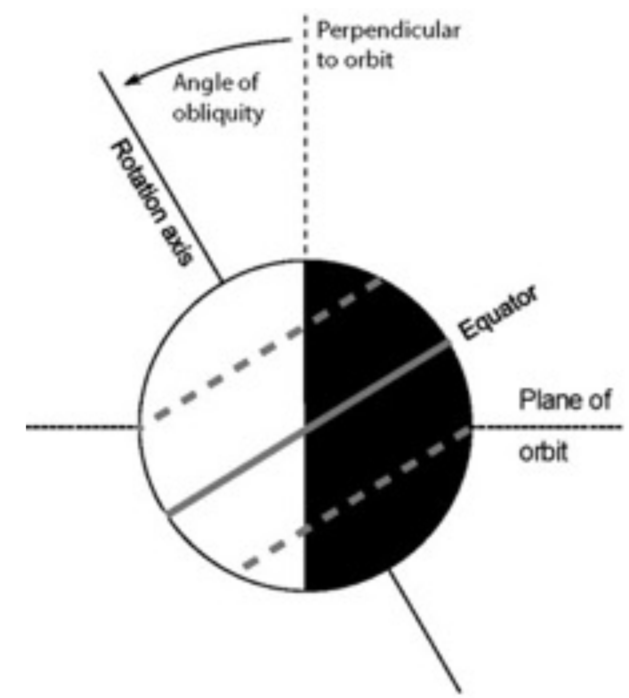
Magnetic field:

- more than 2 orders of magnitude weaker than on Earth
- strong equatorial asymmetry

→ partly liquid core + solid inner core

Observables

Rotation:



- 3:2 spin-orbit resonance
- librations:
  - observation > solid planet → liquid core
  - with grav. field: mantle polar moment of inertia
  - if solid inner core: correction
- obliquity + grav. field: planet polar moment of inertia

Moment of inertia: constraints on mass distribution
→ densities, liquid-solid interface

Tides:
mass distribution modification ⇒ grav. field modification (Love number k_2)
→ density, elasticity

Observables

Surface composition:

- surface content in iron and sulfur
- abundance of radioactive elements (K, Th, U)

$\rightarrow$ core and mantle composition

Surface features: secular cooling

- no prolonged resurfacing and near-surface alteration
- lobate scarps: contraction $\sim$ 7 km

$\rightarrow$ solid inner core, core composition, crust formation

Observables

Surface composition:

- surface content in iron and sulfur
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$\rightarrow$ solid inner core, core composition, crust formation

$\Rightarrow$ **observables alone not enough: theoretical model needed...**

Thermal evolution:
energy and entropy budgets

- inner core growth: heat generated at the inner core boundary
  $\rightarrow$ heat budget
- core dynamo:
  - liquid metal core rotating and cooling
  - energy conversion in the core $\Rightarrow$ not in heat budget
  - entropy generated

  $\rightarrow$ entropy budget

Thermal evolution: energy and entropy budgets

$$Q_{tot}(r_{cmb}) = Q_{cmb} = Q_s + Q_L + Q_g + Q_T + Q_h$$

CMB heat flow

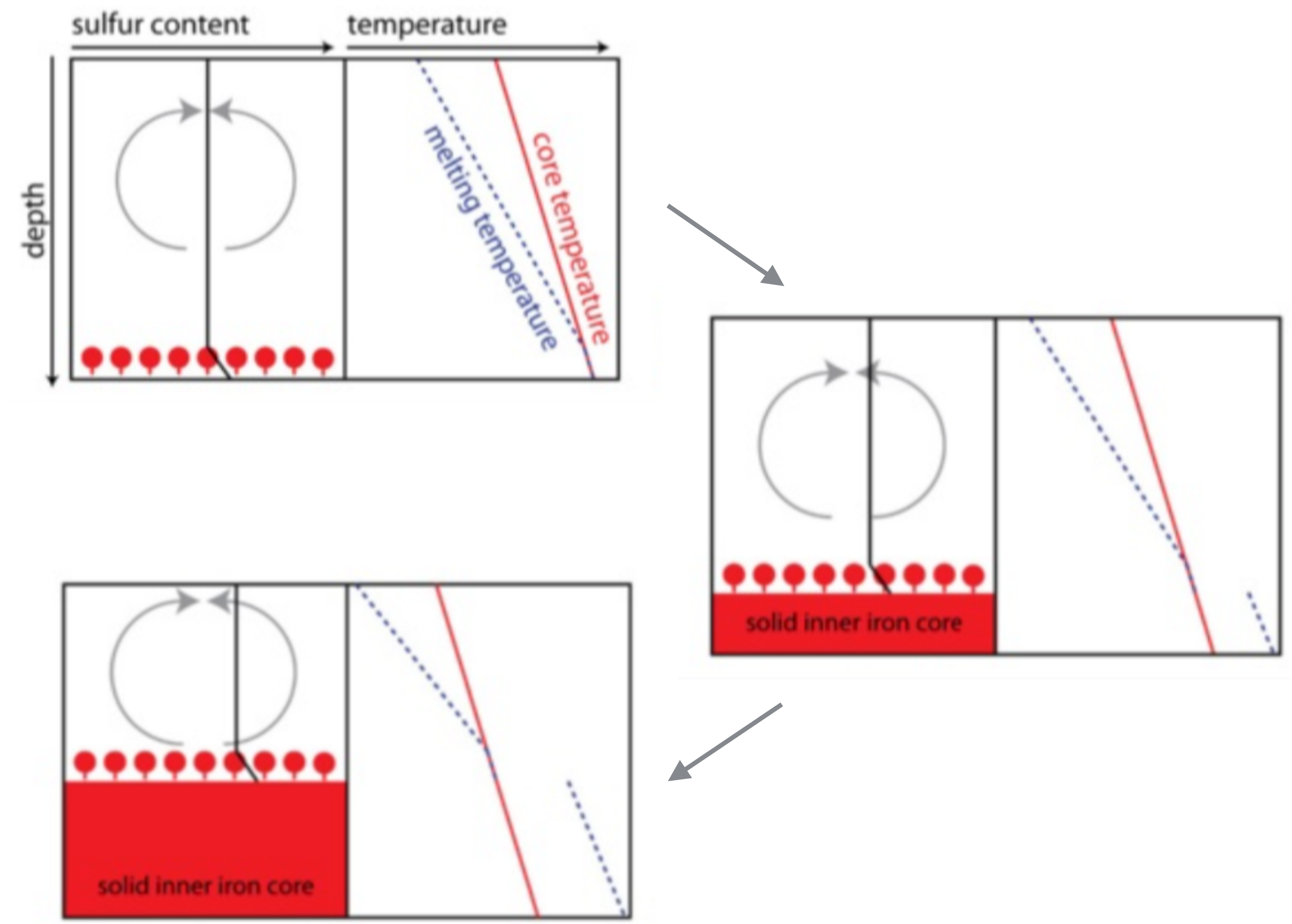
Secular cooling

Latent heat (Q_L)

Gravitational energy (Q_g)

Tidal heating (Q_T)

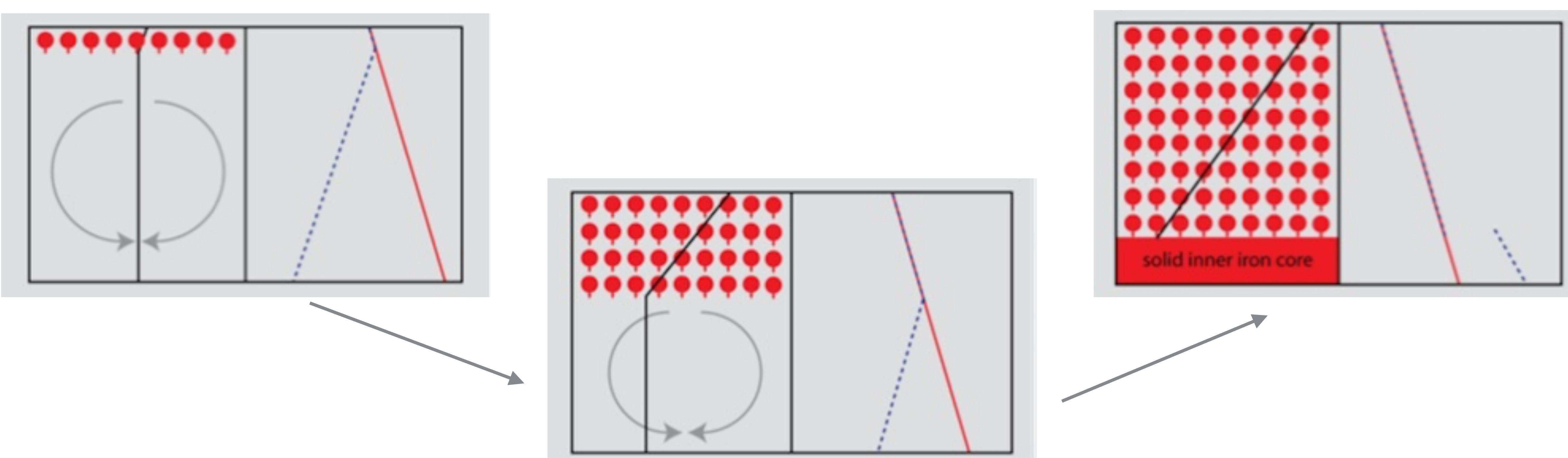
Radioactive heating



Thermal evolution: energy and entropy budgets

$$Q_{tot}(r_{cmb}) = Q_{cmb} = Q_s + Q_L + Q_g + Q_T + Q_{snow} + Q_h$$

- iron snow: $Q_{snow} = Q_{L,snow} + Q_{g,snow}$



Thermal evolution: energy and entropy budgets

$$E_J = E_s + E_L + E_g + E_T + E_h - (E_a + E_{diff})$$

Entropy available for the dynamo

Sources:

- E_s: secular cooling
- E_L: latent heat
- E_g: gravitational energy
- E_T: tidal heating
- E_h: radioactive heating

Sinks:

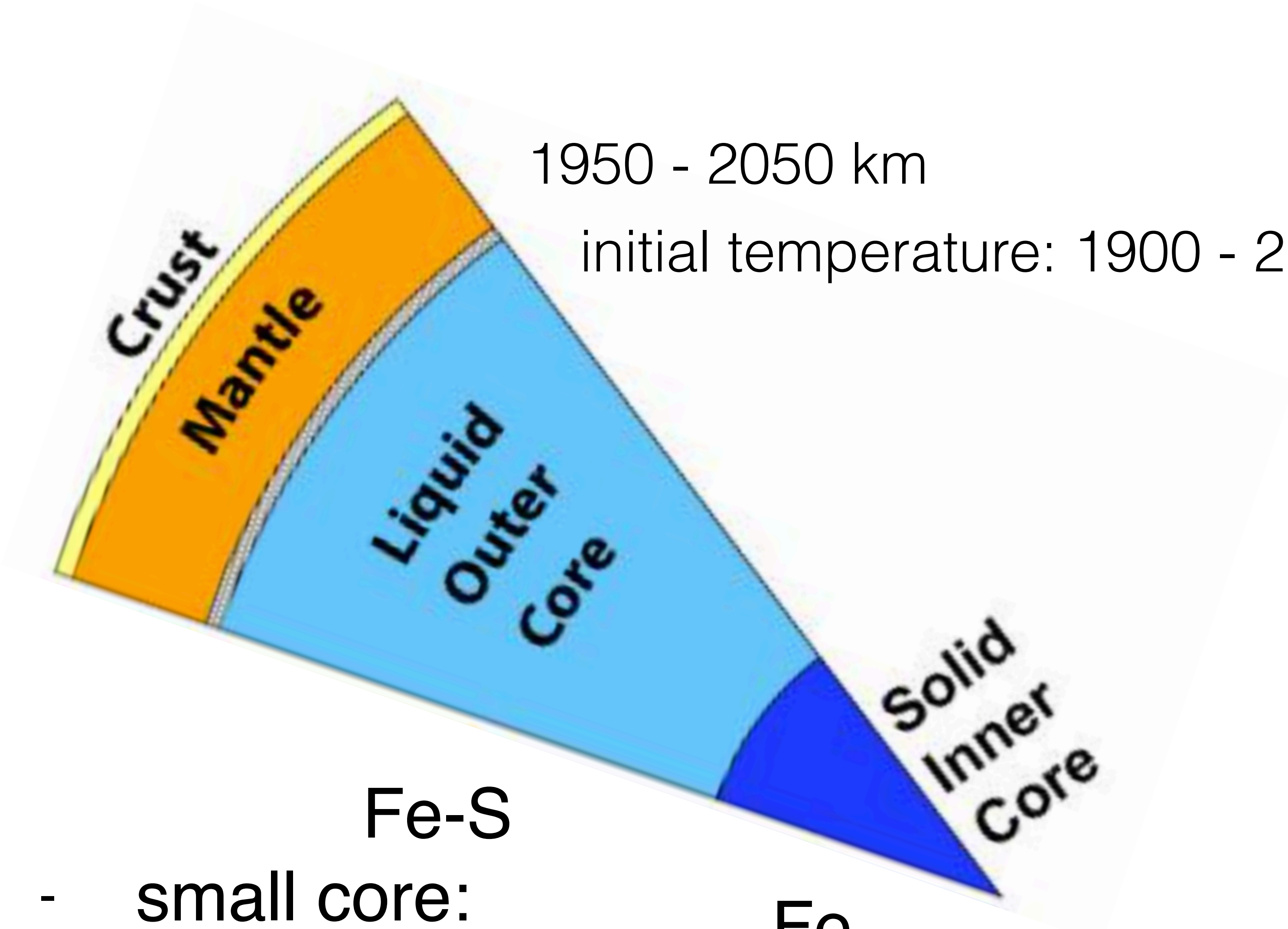
- E_a: Entropy of conduction
- E_{diff}: Entropy of molecular diffusion

Marginal dynamo: $E_J = 0$

Core model

1950 - 2050 km

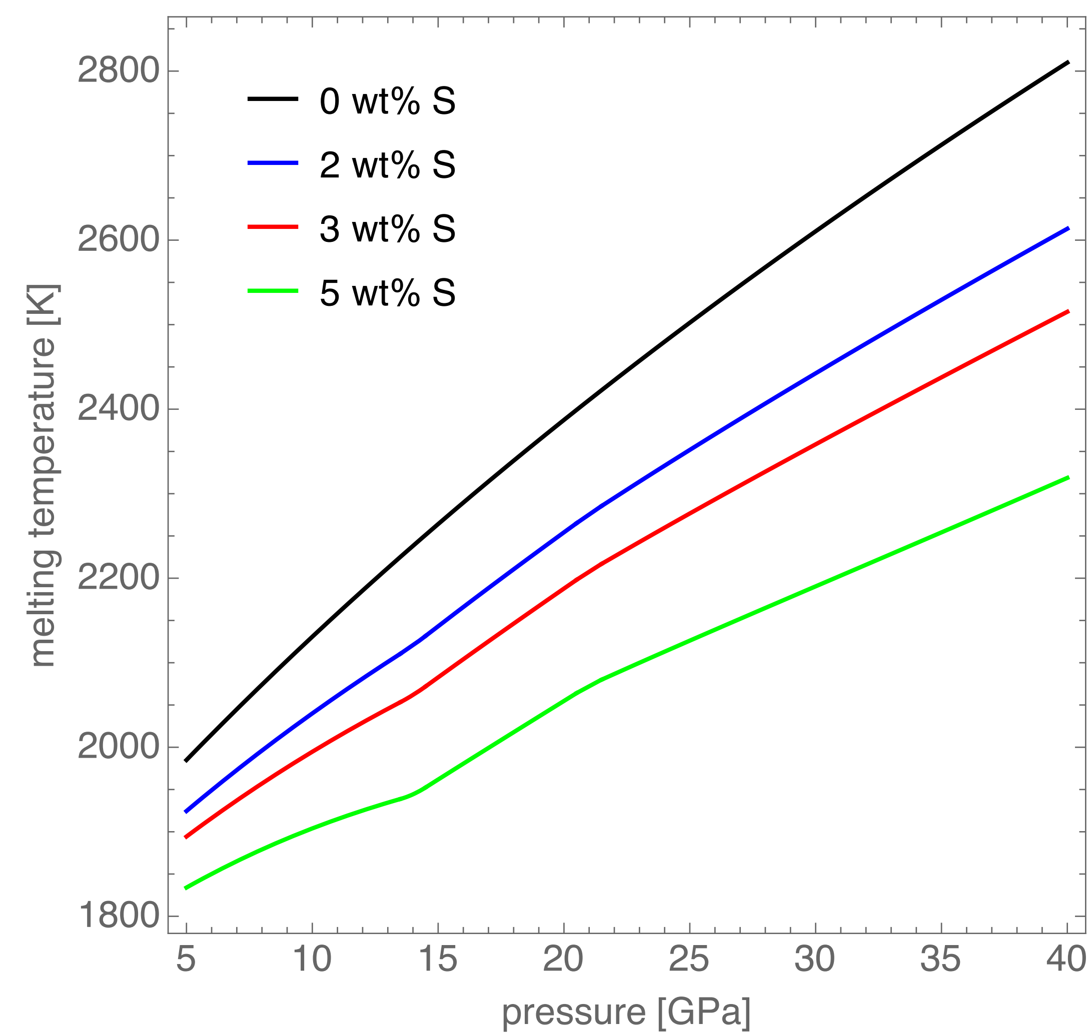
initial temperature: 1900 - 2200 K



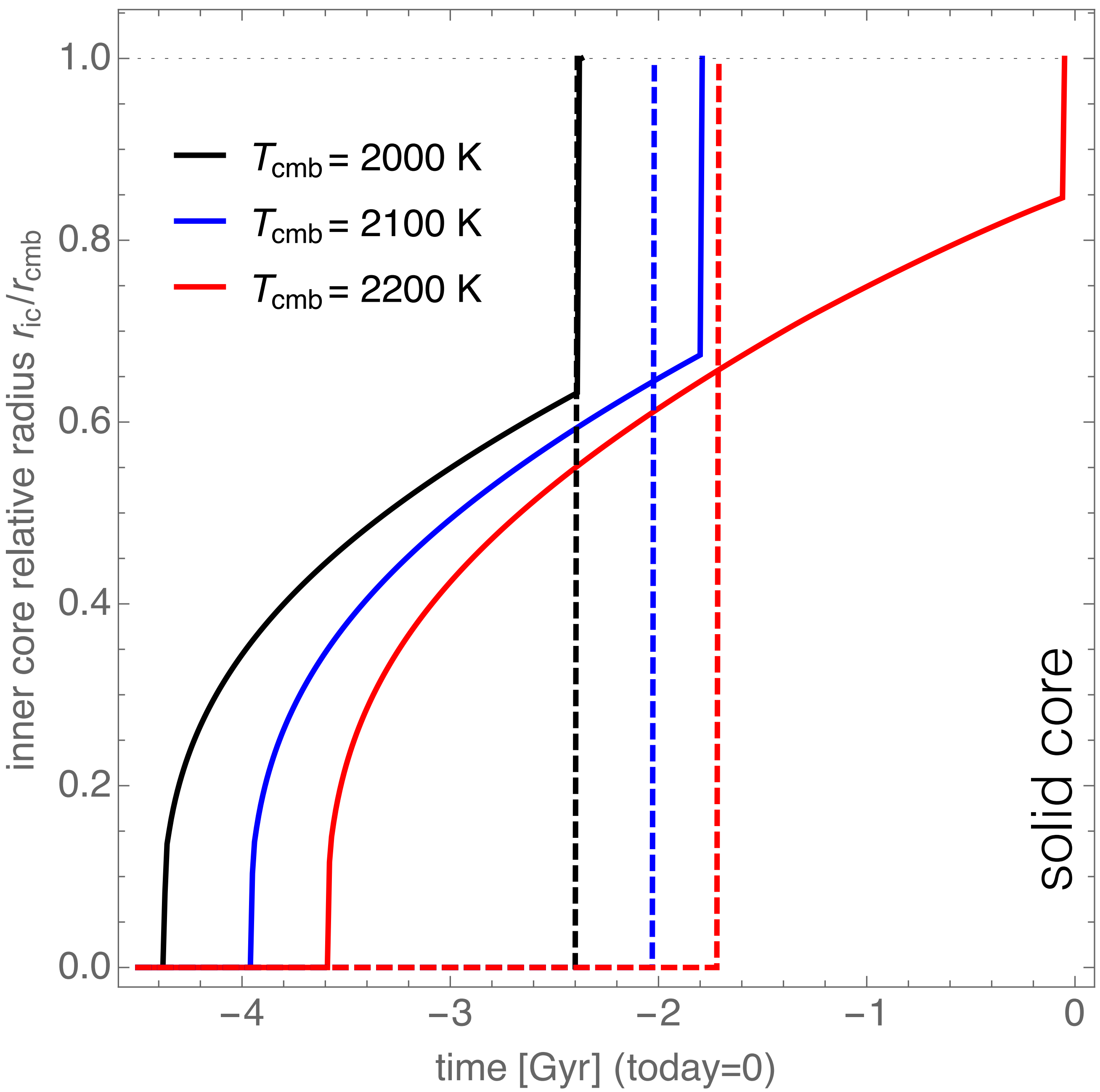
Fe-S

Fe

- small core: ~ 2-3 wt%
- large core: ~ 5 wt%



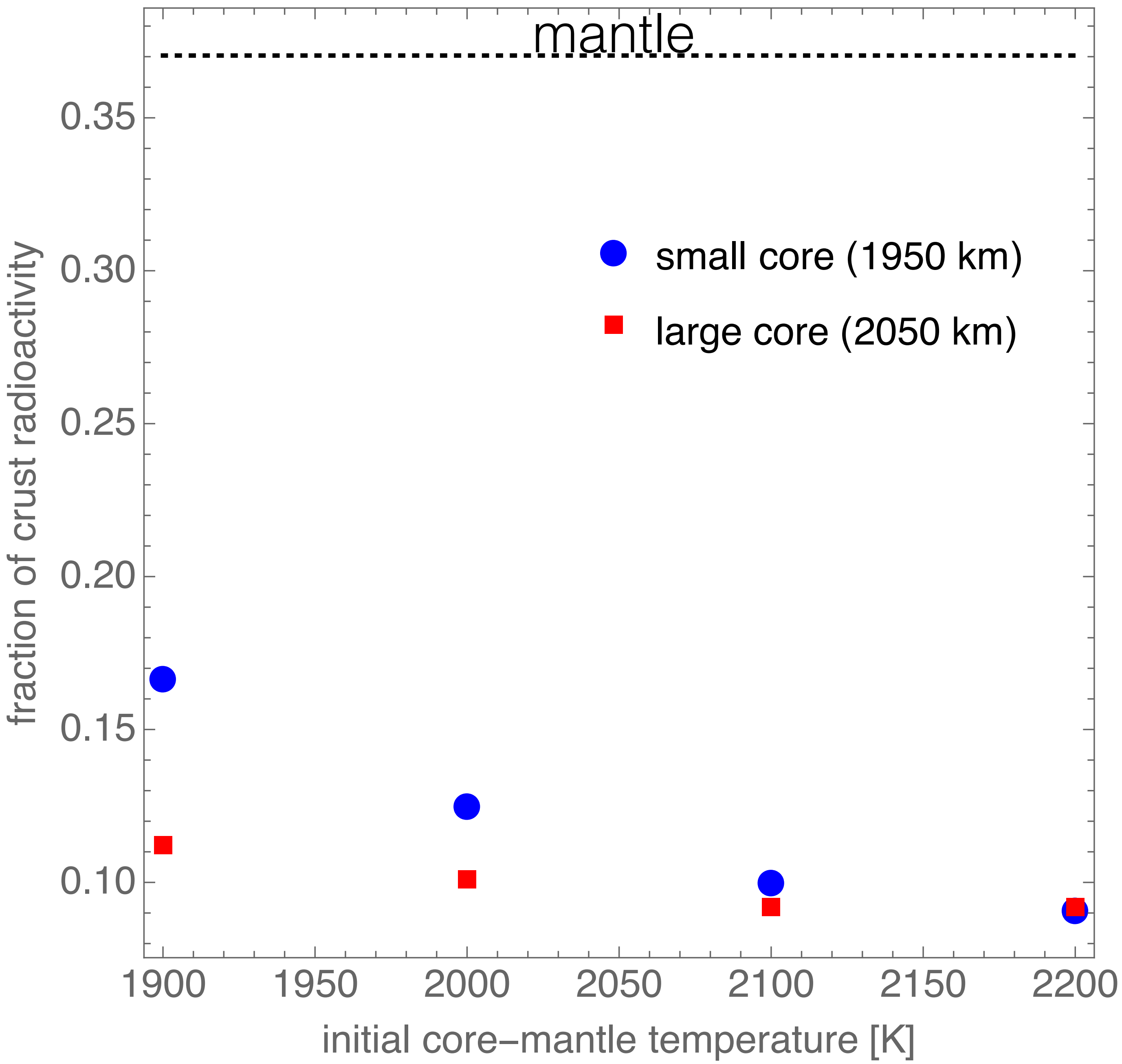
Marginal dynamo: Core melting



Solid: small core (1950 km)
Dashed: large core (2050 km)

Small core: solid iron core + iron snow
Large core: iron snow

Marginal dynamo: radioactivity

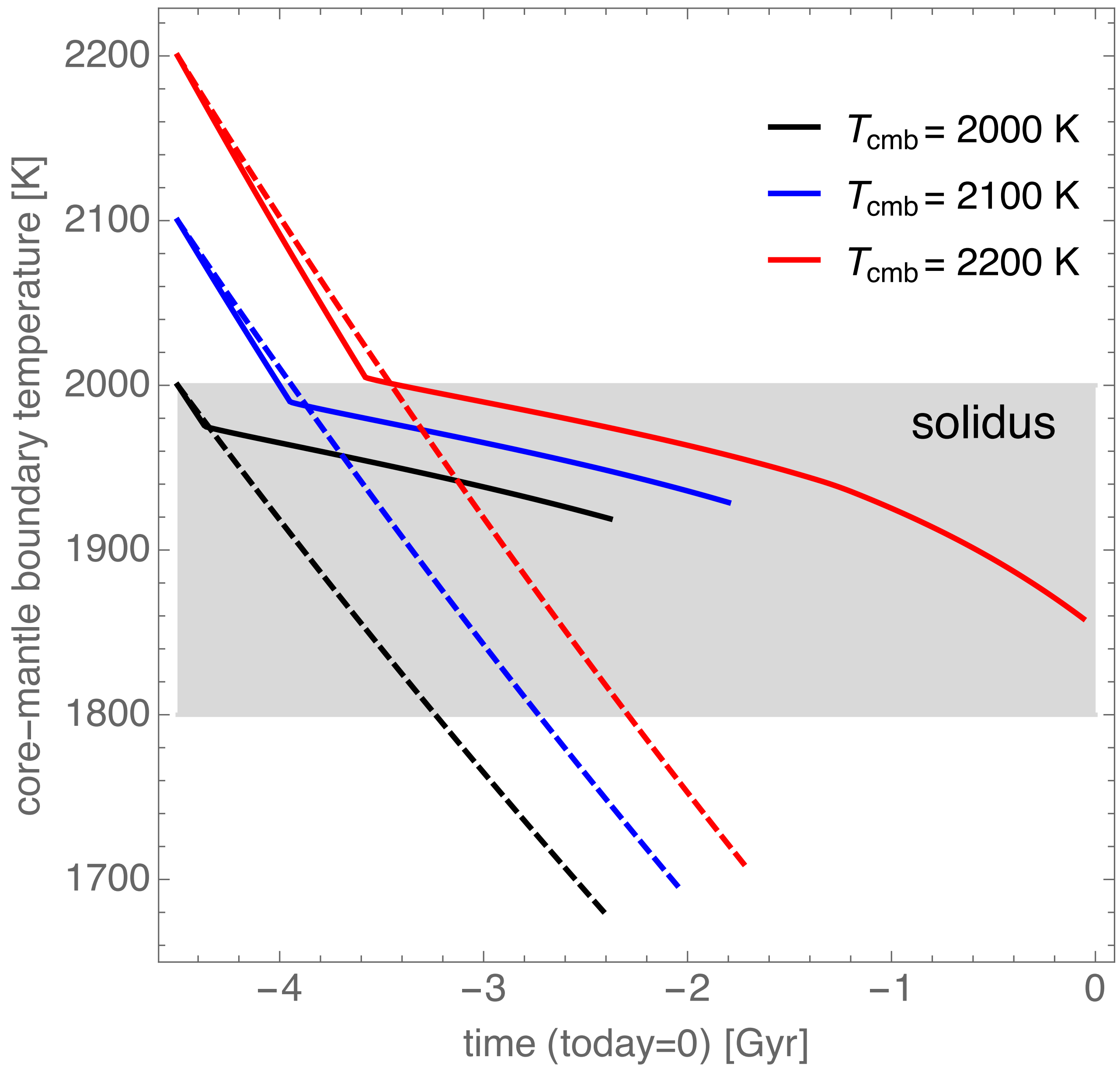


Crust radioactive element abundance:

- Uranium: 90 ppb
- Thorium: 155 ppb
- Potassium: 1288 ppm

Core: Uranium + Thorium

Marginal dynamo: core-mantle boundary temperature

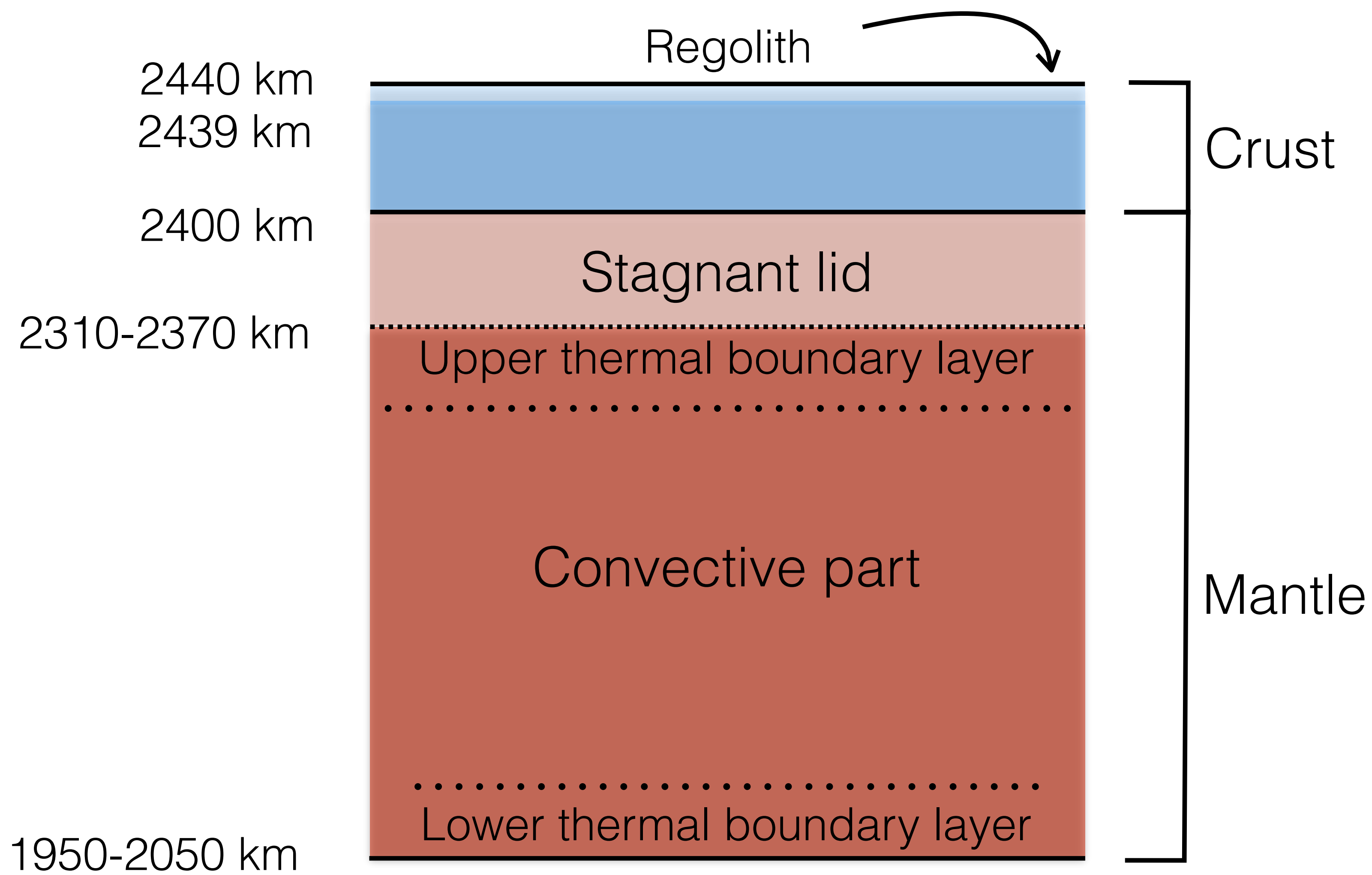


Solid: small core (1950 km)
Dashed: large core (2050 km)

Lower mantle not melted

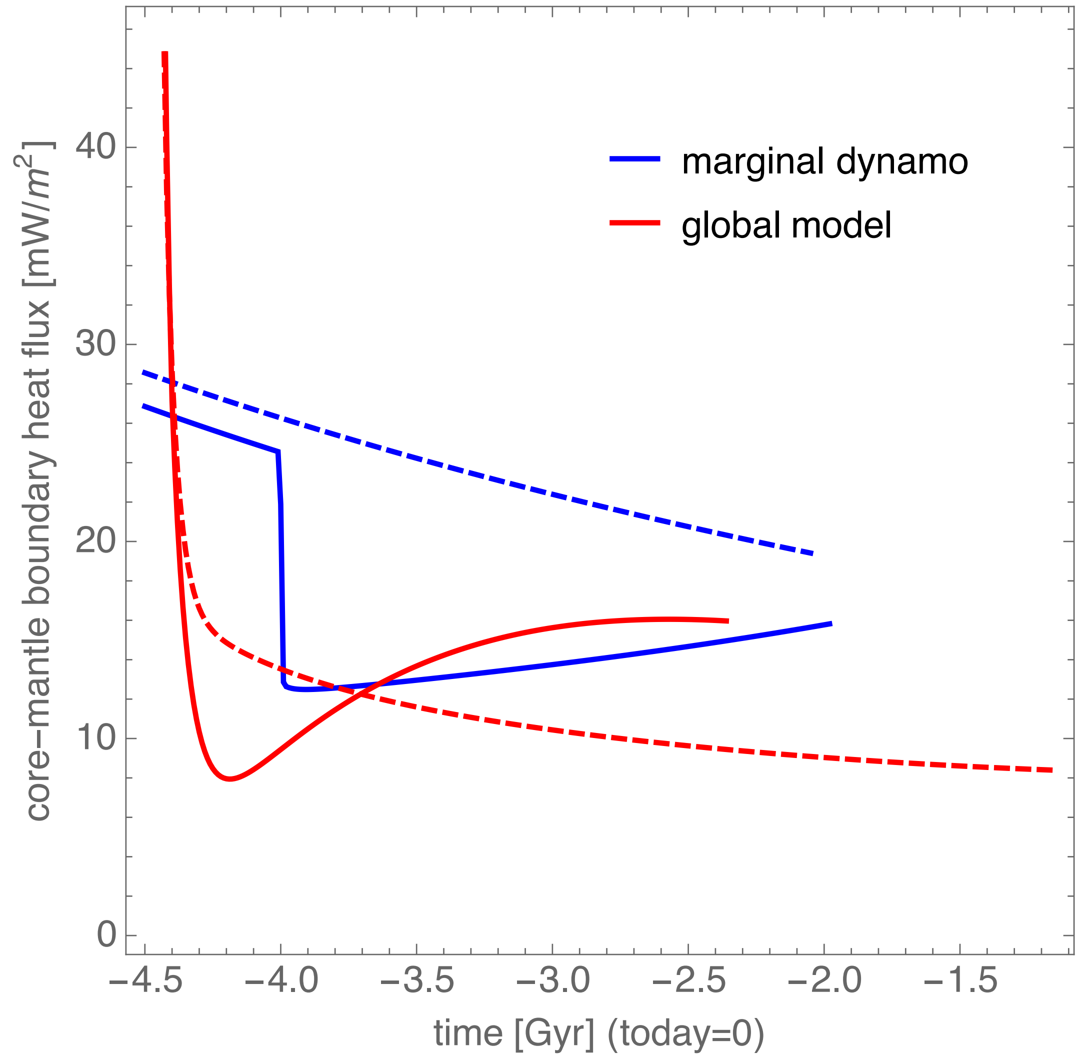
Mantle model

60% olivine
40% pyroxene



temperature: 2100 K

Global model: heat fluxes

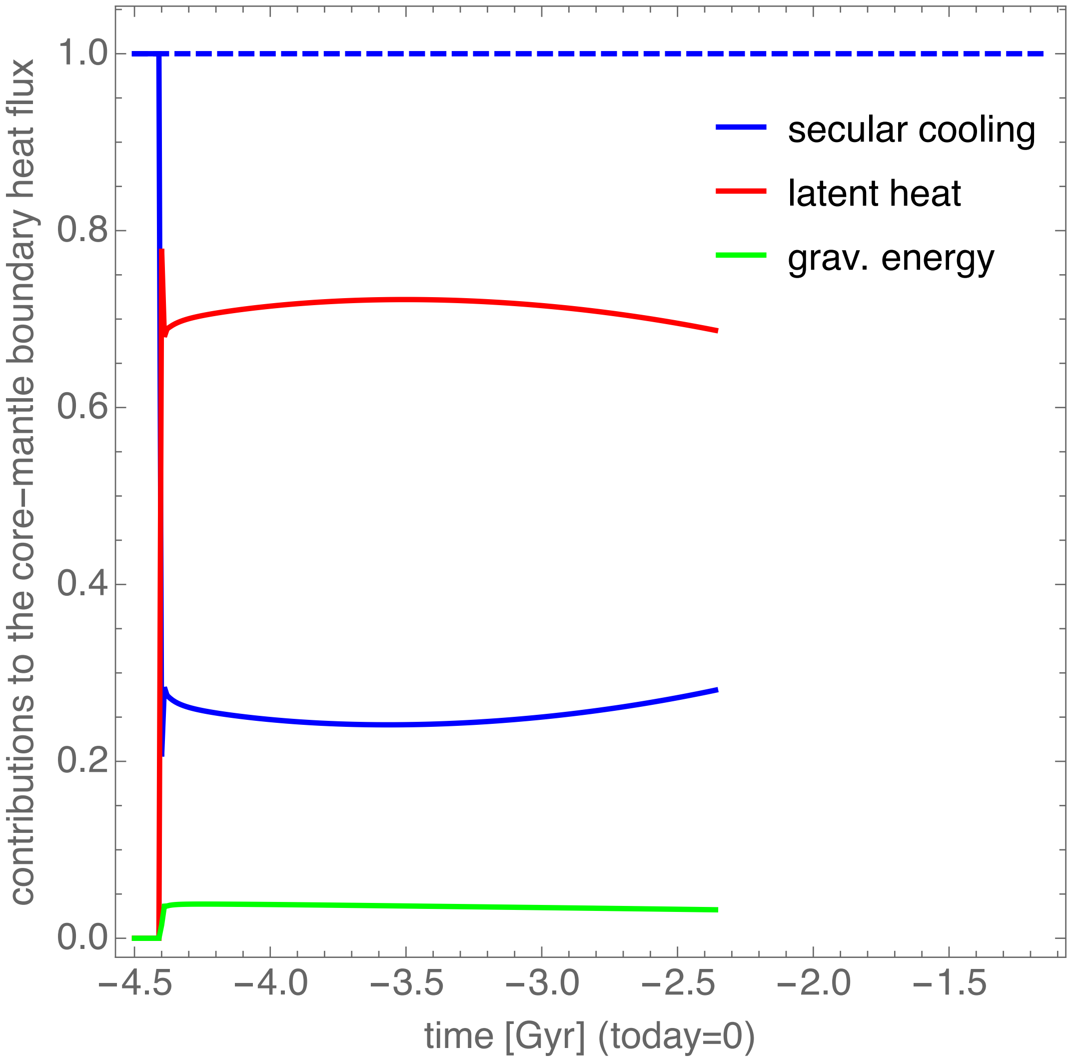


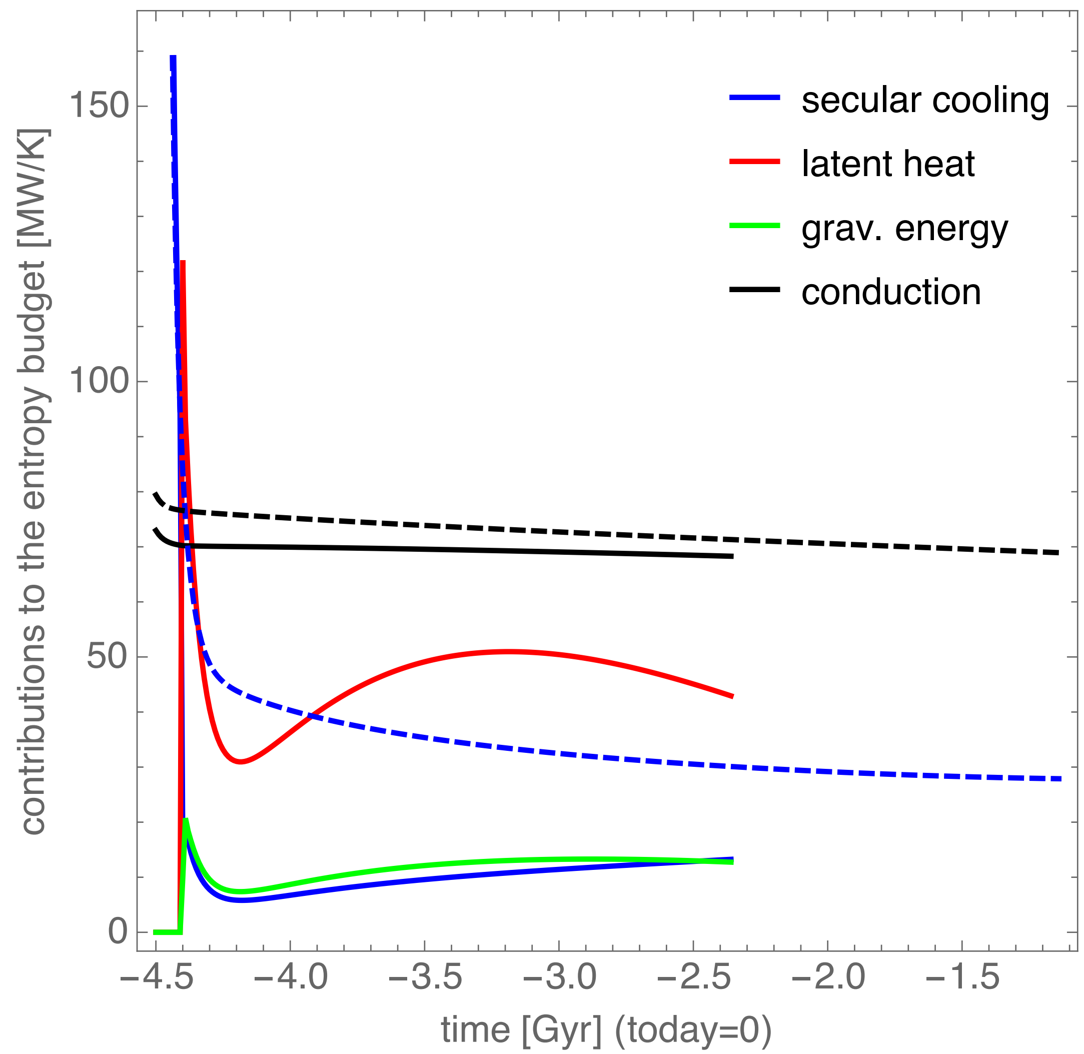
Small core:
- inner core dynamo

Large core:
- iron snow
- no dynamo
- mantle convection stops

Solid: small core (1950 km)
Dashed: large core (2050 km)

Global model: budget contributions

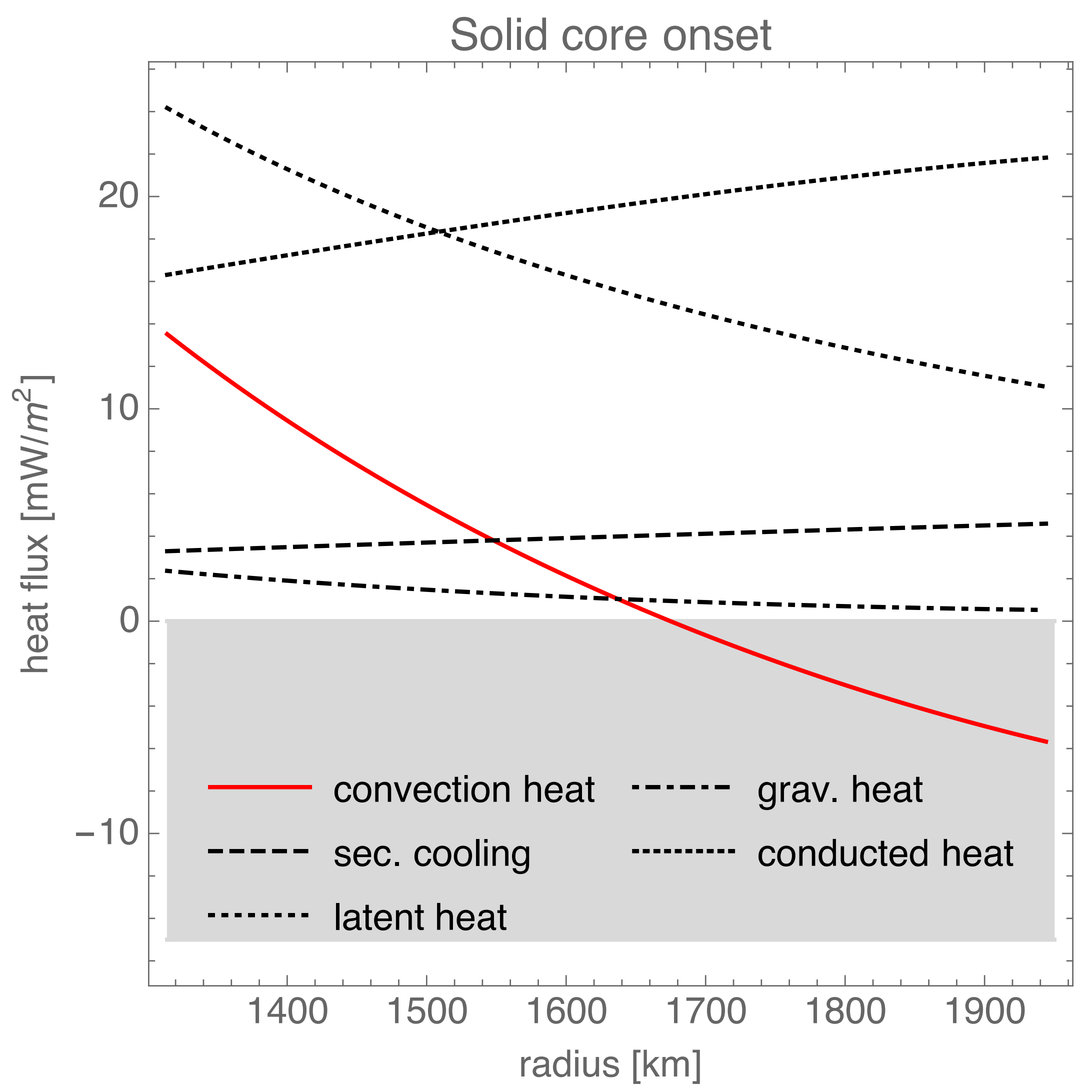




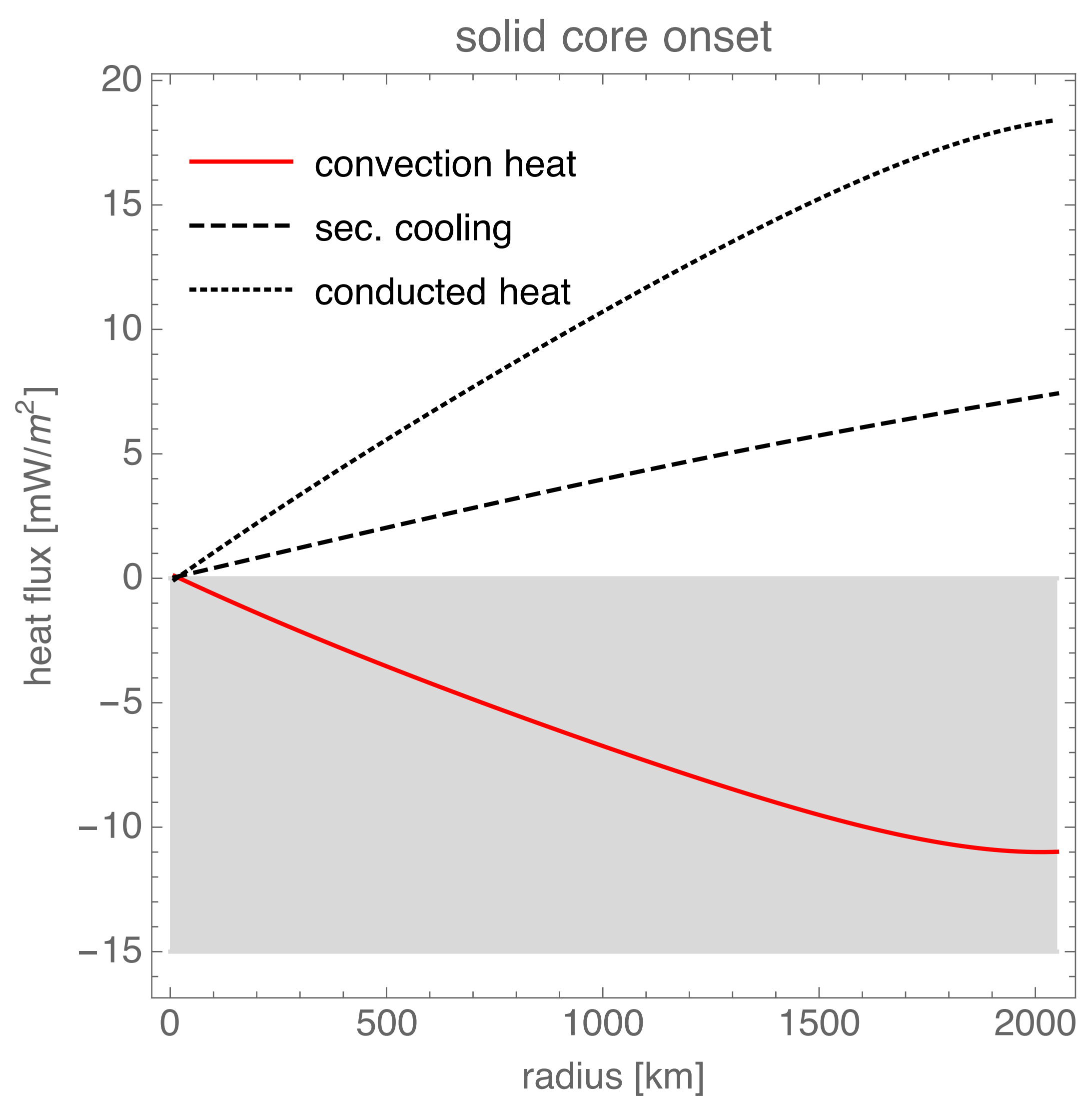
Solid: small core (1950 km)
Dashed: large core (2050 km)

Main contribution: latent heat

Global model: stratification

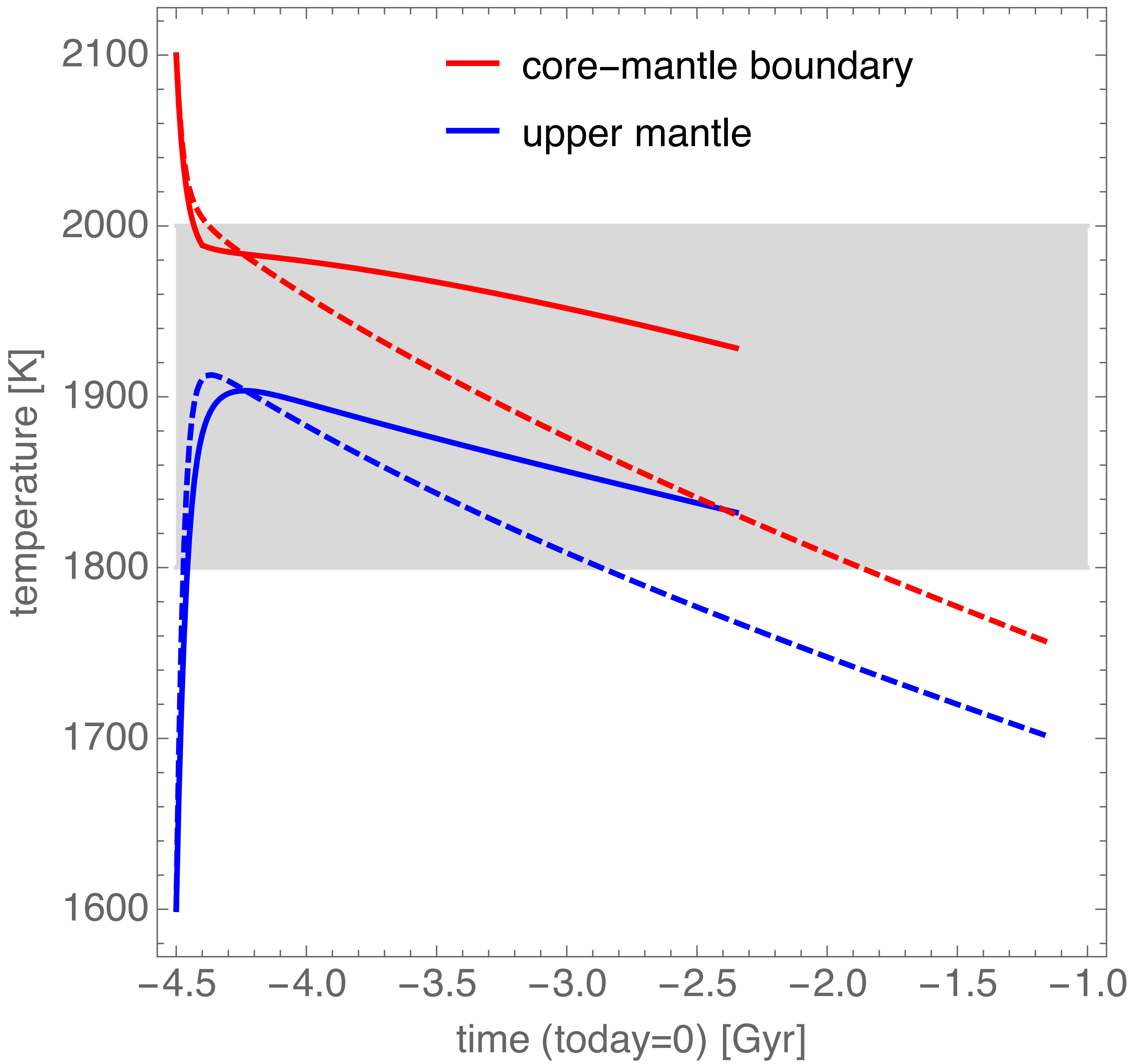


small core



large core

Global model: temperature



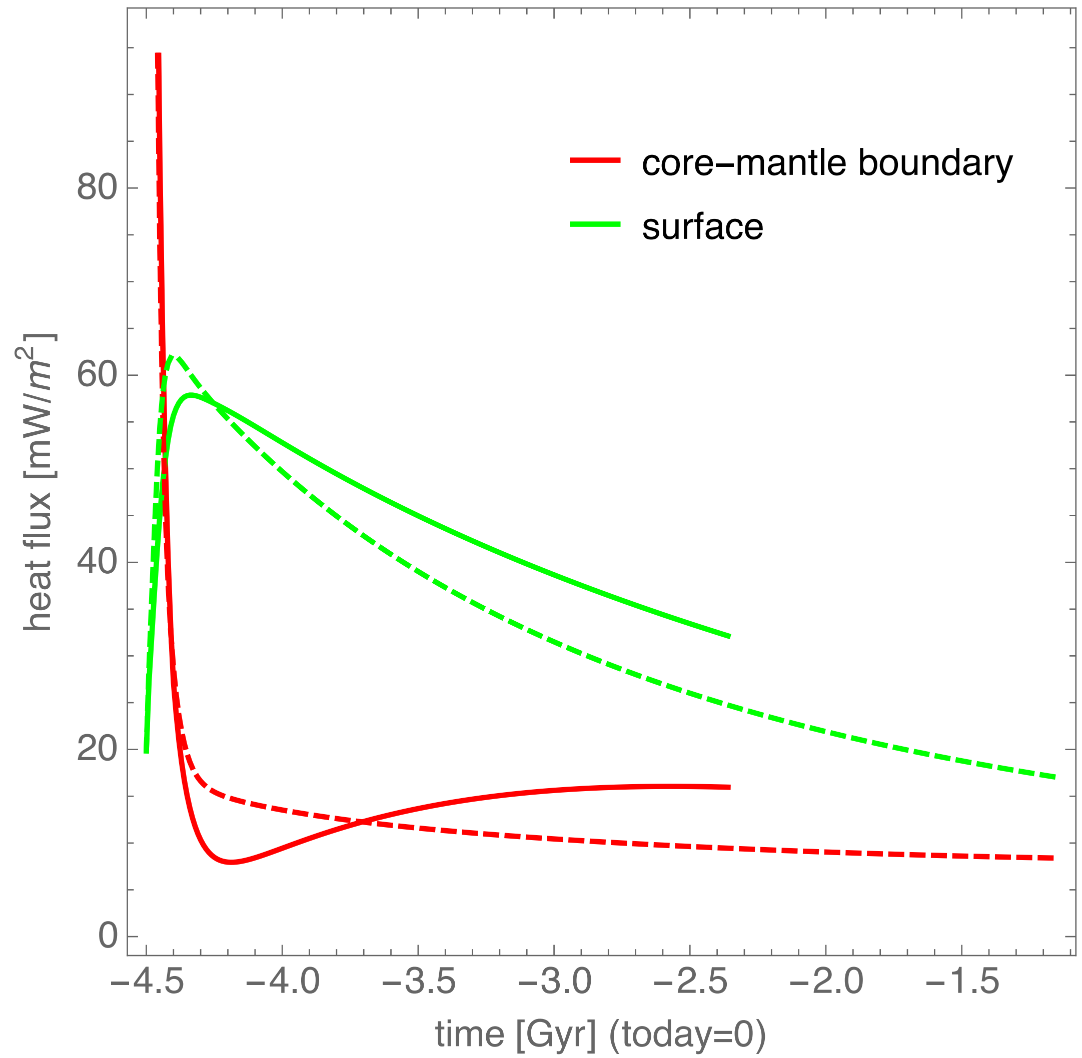
Solid: small core (1950 km)
Dashed: large core (2050 km)

Lower mantle not melted

Conclusions

Back-up

	sulfur concentration (wt)
T_{cmb} = 1900 K r_{cmb} = 1980 km	0.032776
T_{cmb} = 1900 K r_{cmb} = 2050 km	0.0570619
T_{cmb} = 2000 K r_{cmb} = 1950 km	0.0187252
T_{cmb} = 2000 K r_{cmb} = 2050 km	0.0534317
T_{cmb} = 2100 K r_{cmb} = 1950 km	0.01561
T_{cmb} = 2100 K r_{cmb} = 2080 km	0.0498513
T_{cmb} = 2200 K r_{cmb} = 1950 km	0.0151242
T_{cmb} = 2200 K r_{cmb} = 2050 km	0.0463206


core-mantle boundary
surface
heat flux [mW/m^2]
80
60
40
20
0
−4.5
−4.0
−3.5
−3.0
−2.5
−2.0
−1.5
time [Gyr] (today=0)