

Evolution of the thermally stratified layer in Mercury's outer core

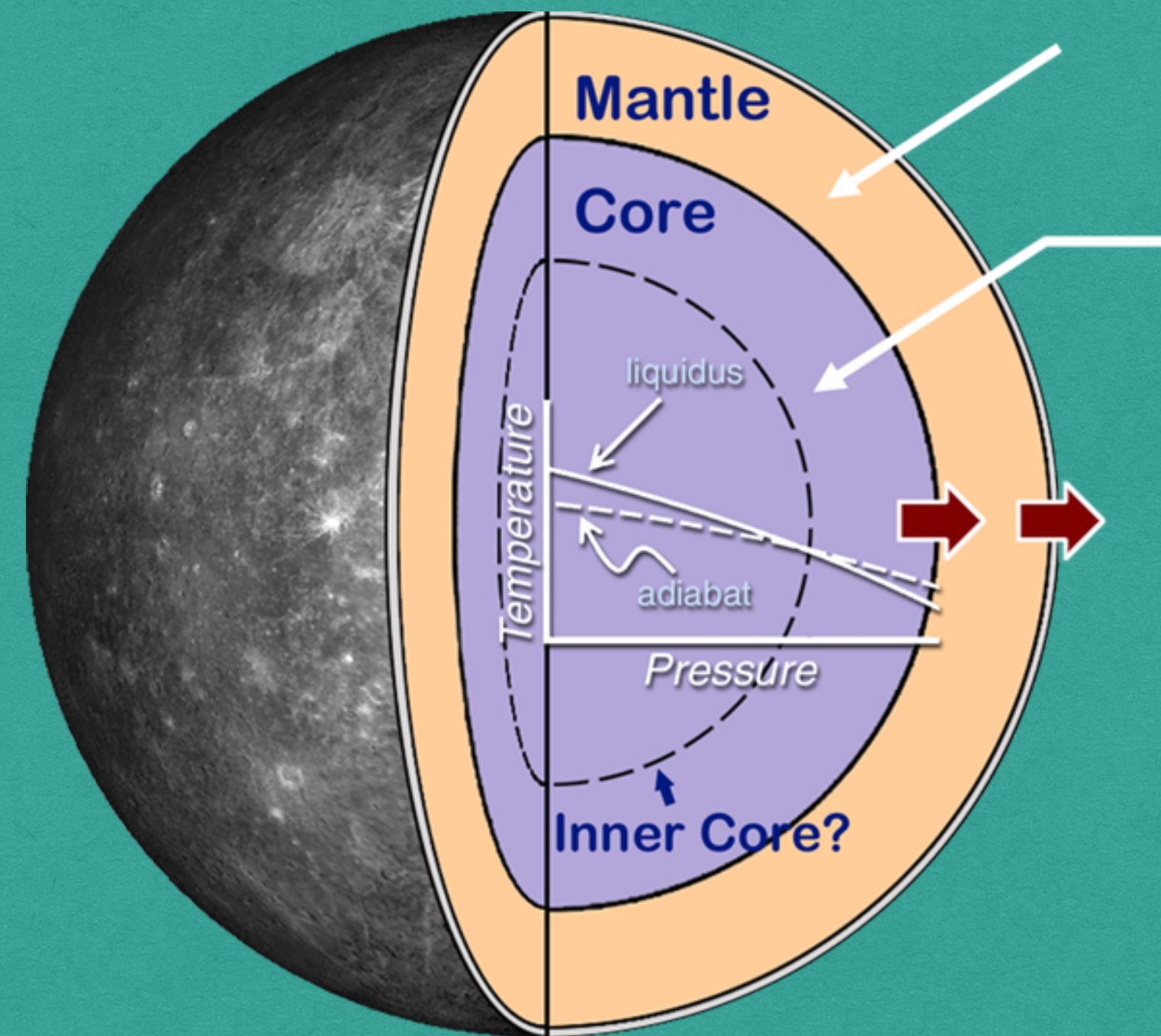
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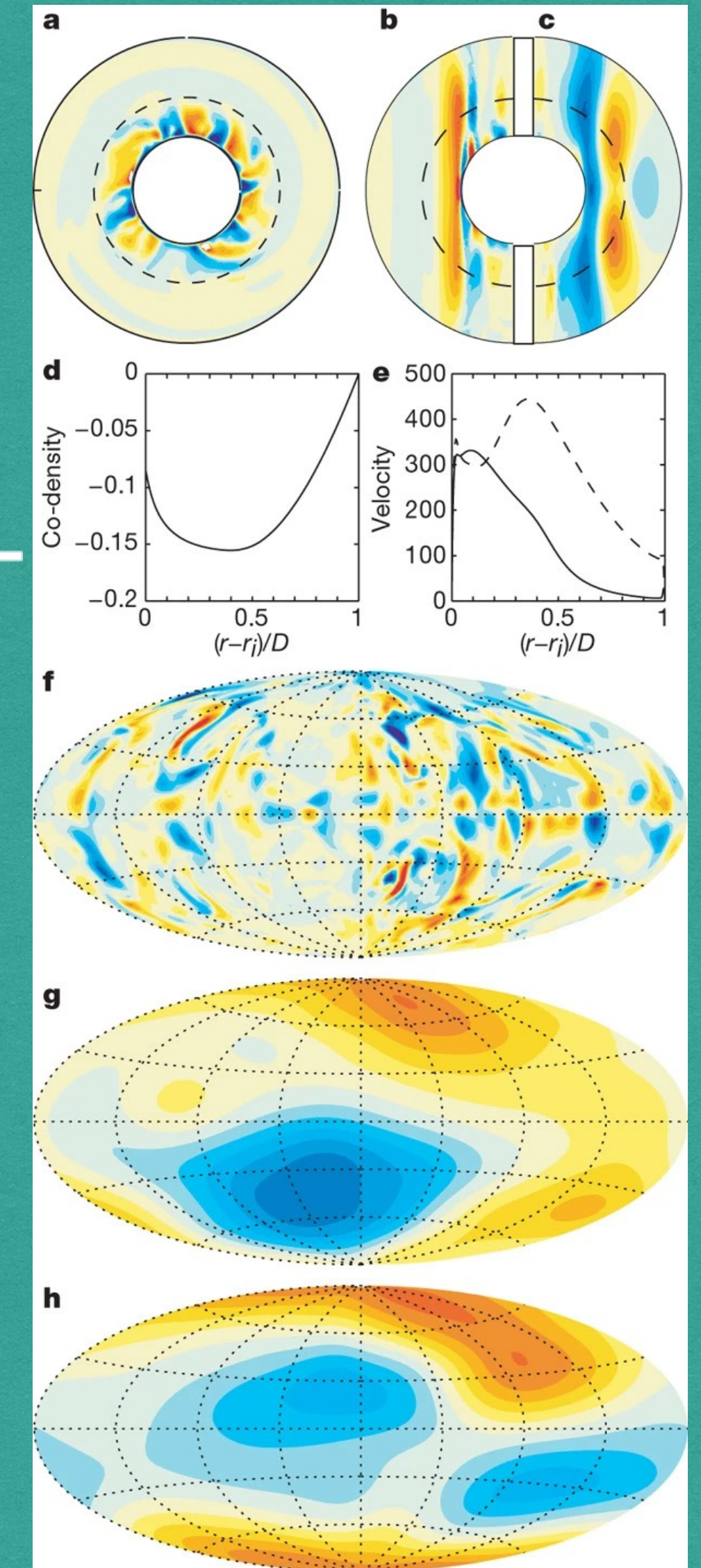
²Institute of Astronomy, KU Leuven, Leuven, Belgium

Mercury's interior structure

- Partitioning of light elements Si and S
- Dynamo models indicate that a stably stratified layer is needed to explain the observed magnetic field
- Insight into the evolution of the stratified layer requires coupled mantle-core evolution models



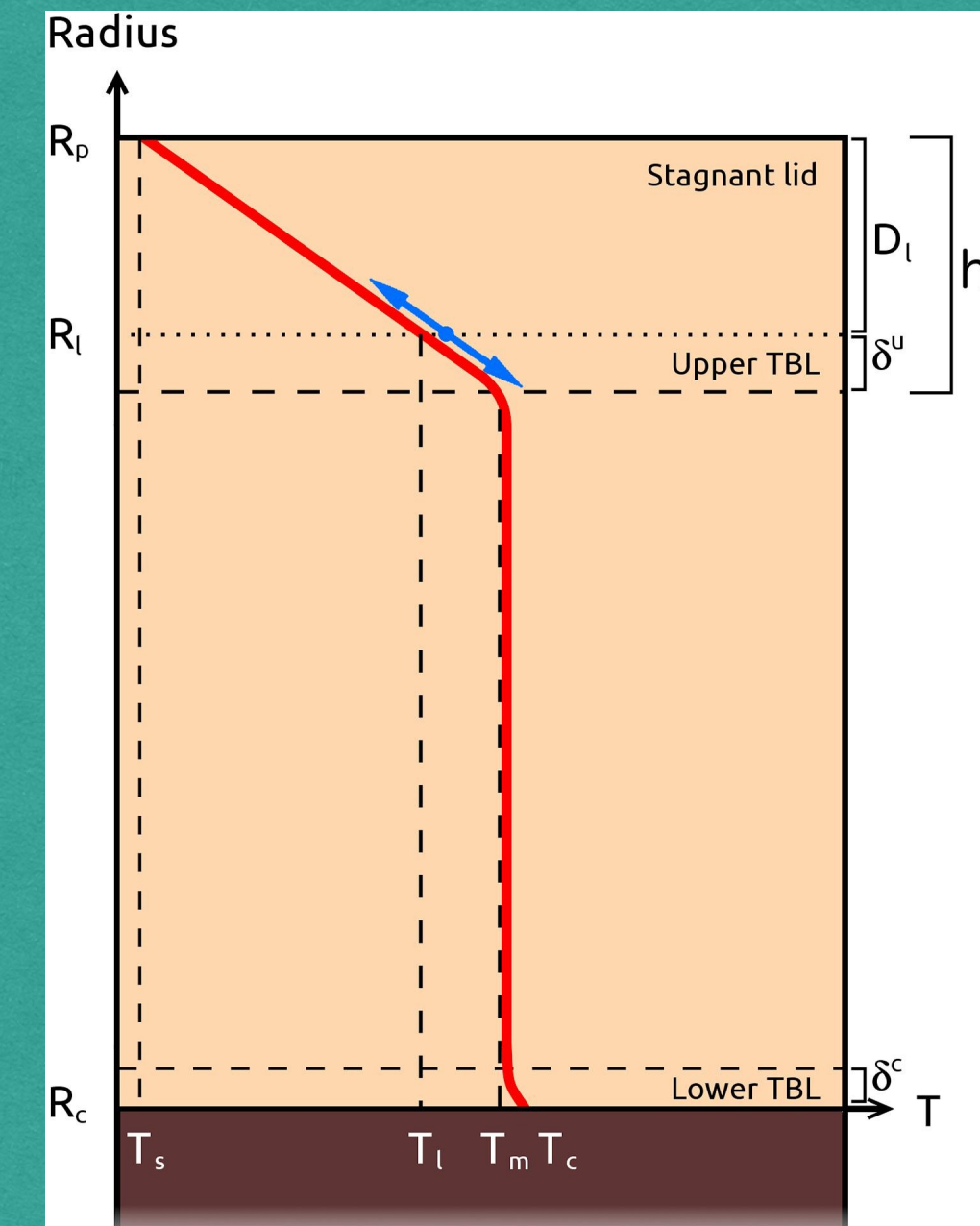
<https://luna1.diviner.ucla.edu/~jpierre/mercury/posters/Poster-11/poster-11.html>



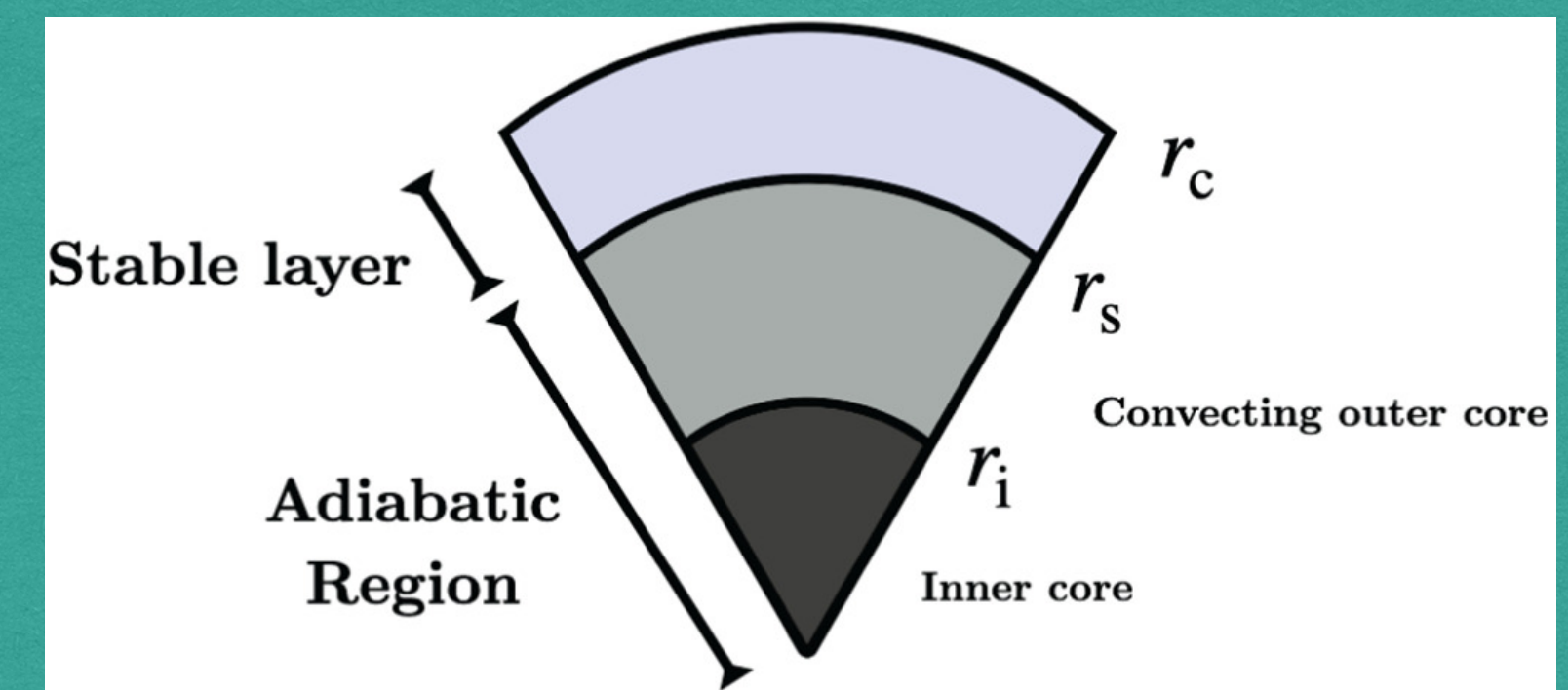
Christensen, U. A deep dynamo generating Mercury's magnetic field. *Nature* **444**, 1056–1058 (2006)

Model set-up

- 1-D mantle model based on Thiriet et al. 2019
 - Separate modelling of convective mantle and stagnant lid
 - Two key scaling parameters α and β
- 1-D core model based on Greenwood et al. 2021
 - Stable layer evolution
 - Inner core growth



M. Thiriet, D. Breuer, C. Michaut, A.-C. Plesa.
Phys. Earth Planet. Inter., 286 (2019), pp. 138-153

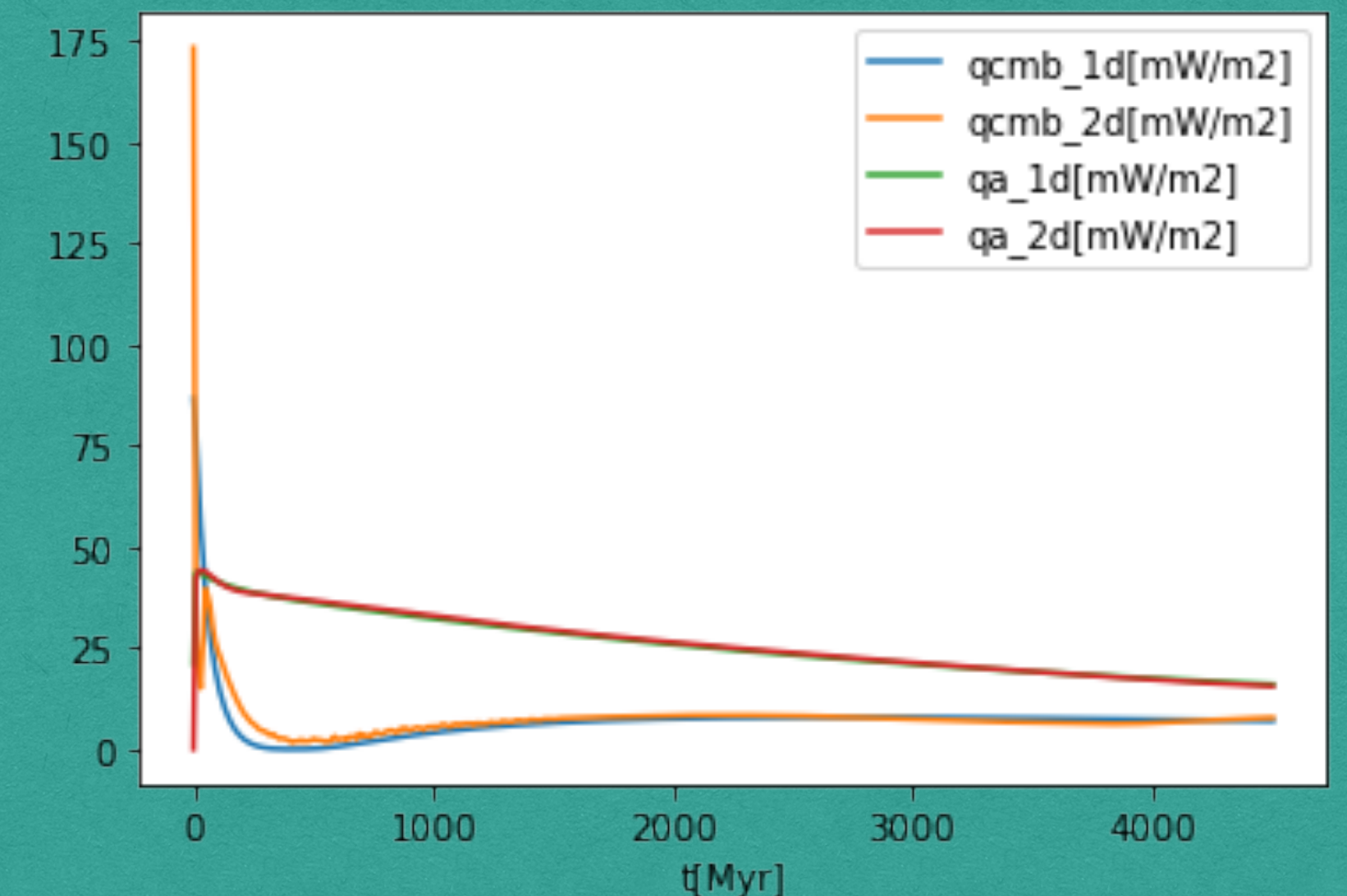
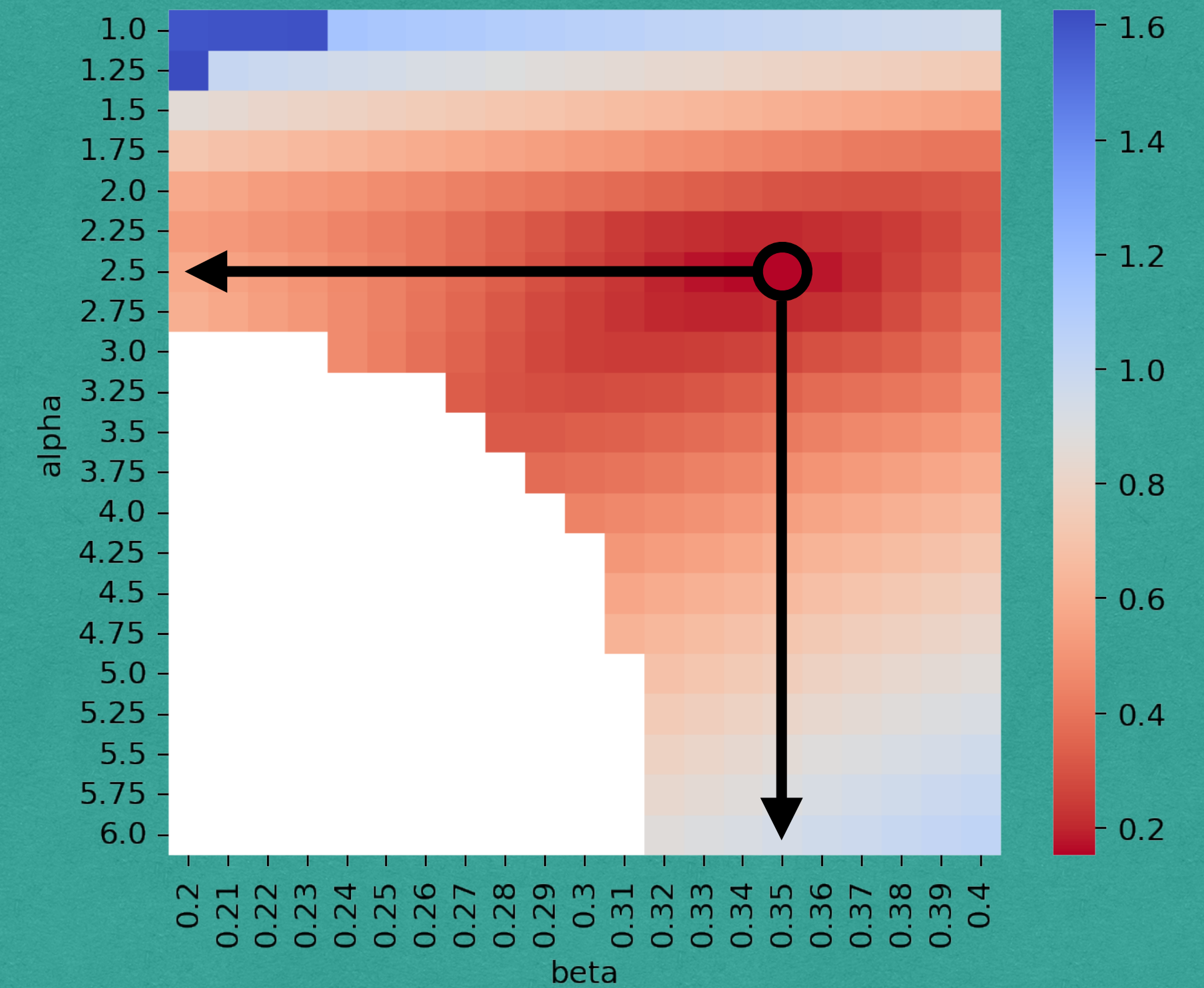


S. Greenwood, C.J. Davies, J.E. Mound.
Phys. Earth Planet. Inter., 318 (2021), p. 106763

Scaling parameters for the mantle

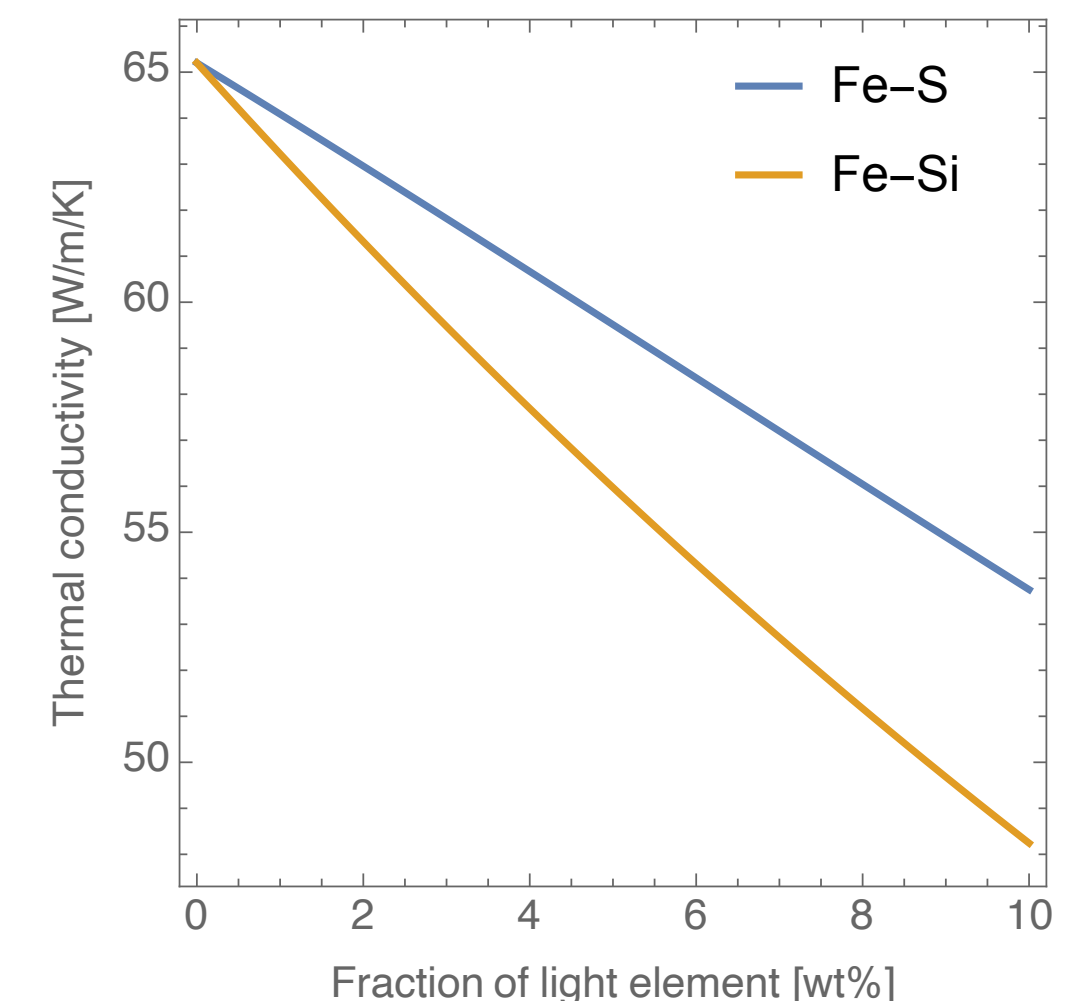
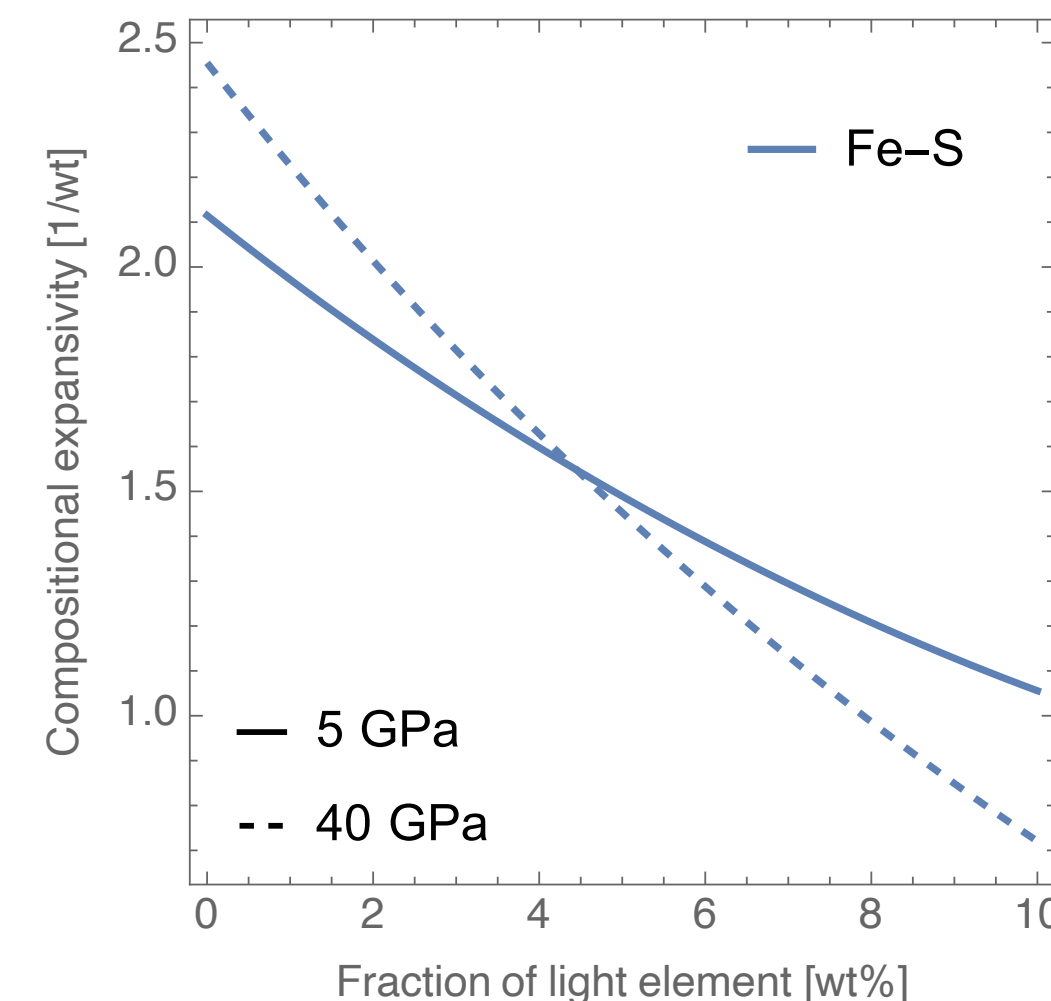
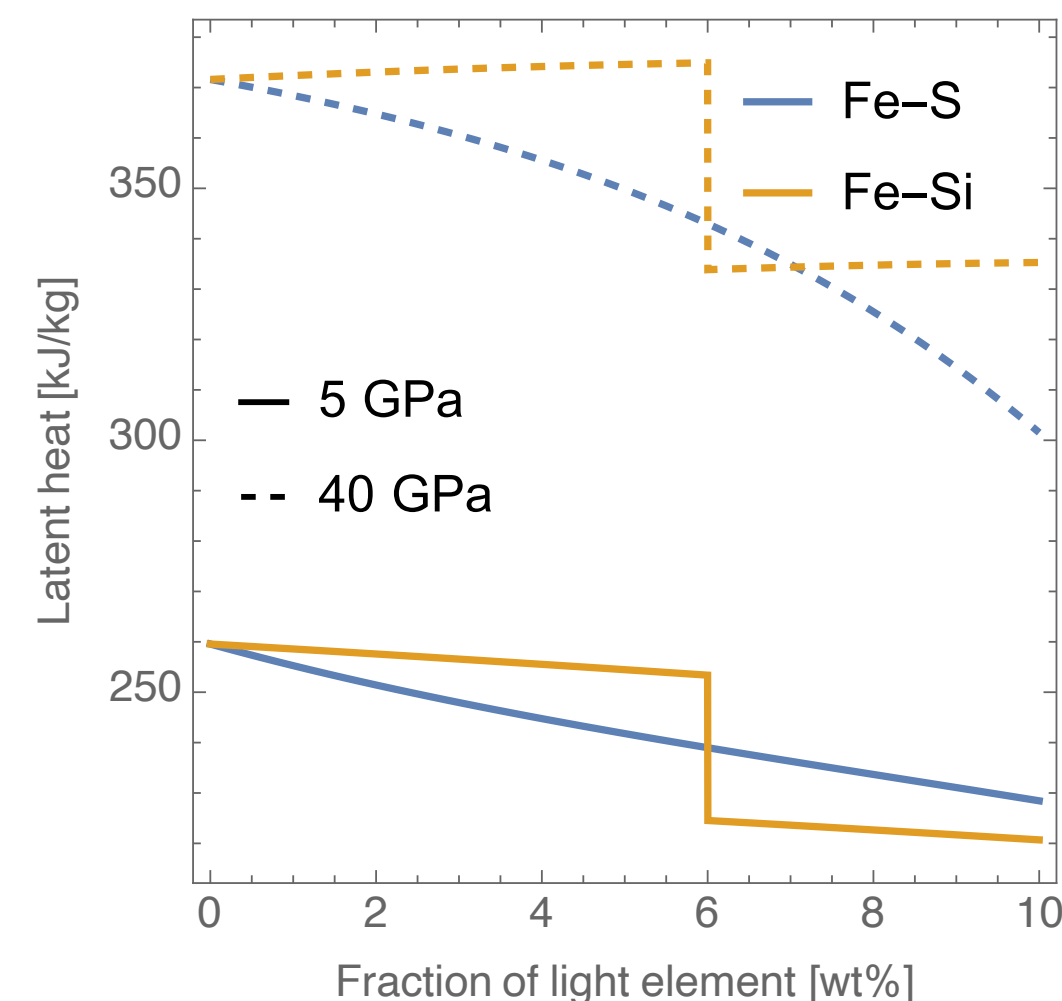
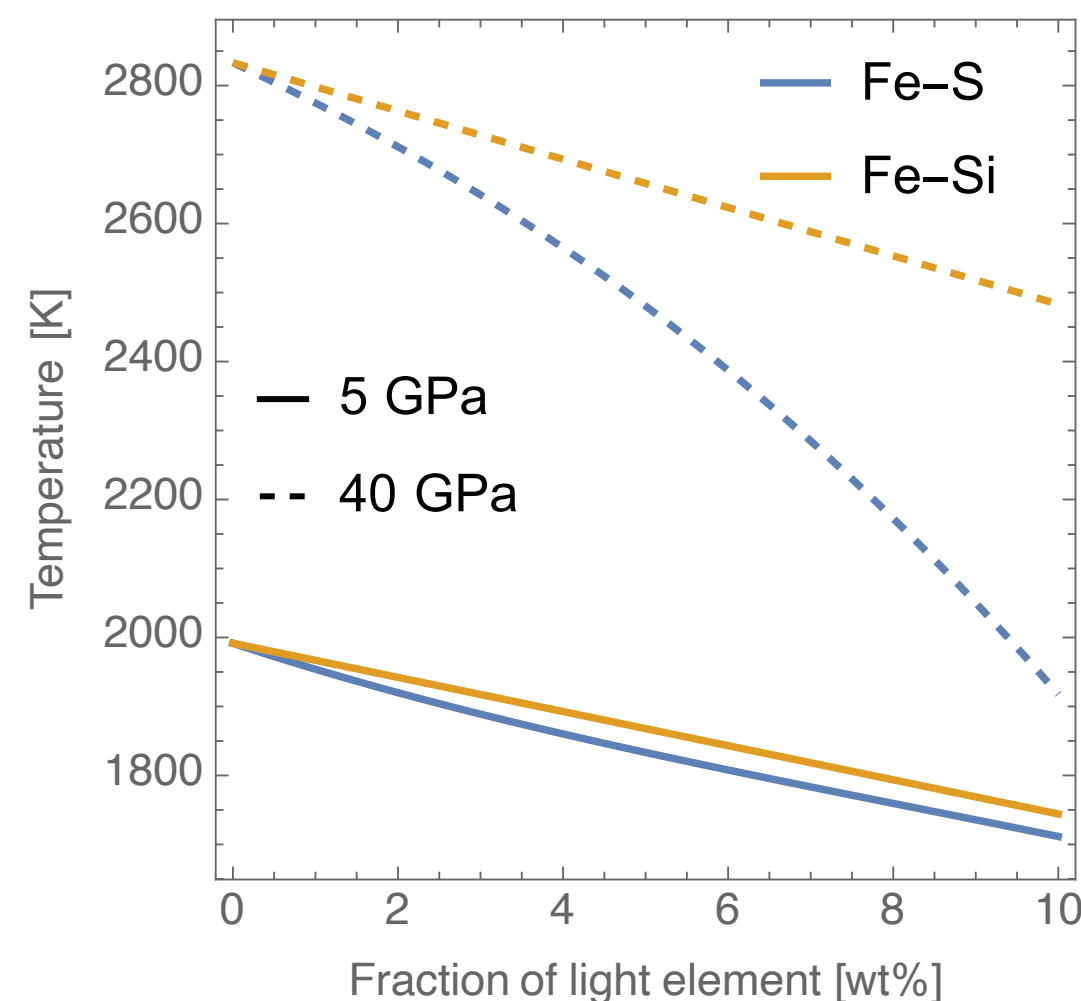
- Choosing scaling parameters to minimise difference between 2D (Gaia) and 1D model based on
 - qcmb
 - qa
 - T profile in the mantle
 - Timing of cessation of convection
- Error calculation (Thiriet et al., 2019)
 - At each time step, error on T profile is calculated in each of the 100 vertical shells, using shell volume as weight

$$W_{error} = \frac{1}{n} \sum_n \frac{|parameter^{2D} - parameter^{1D}|}{W_{scale}}$$



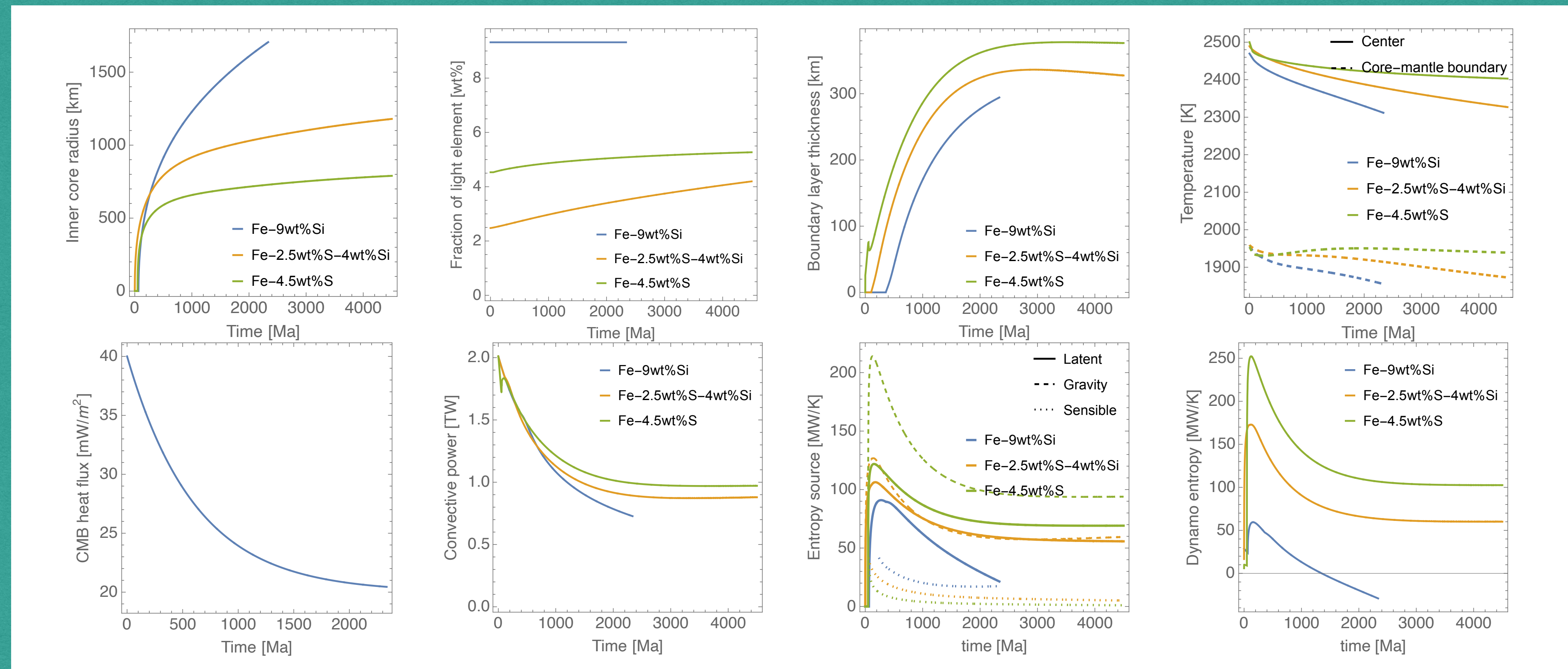
Core thermodynamic and transport properties

- Thermodynamic properties are computed from Fe-S-Si equations of state (Terasaki et al 2019) and Fe-S (e.g. Rivoldini et al 2011, Hillert 1975) and Fe-Si (Edmund et al. 2022) melting temperature
- Thermal conductivity from electrical conductivity (Wagle et al 2019) using Wiedemann-Franz relation with Sommerfeld value for the Lorenz number



Thermal evolution of the core only

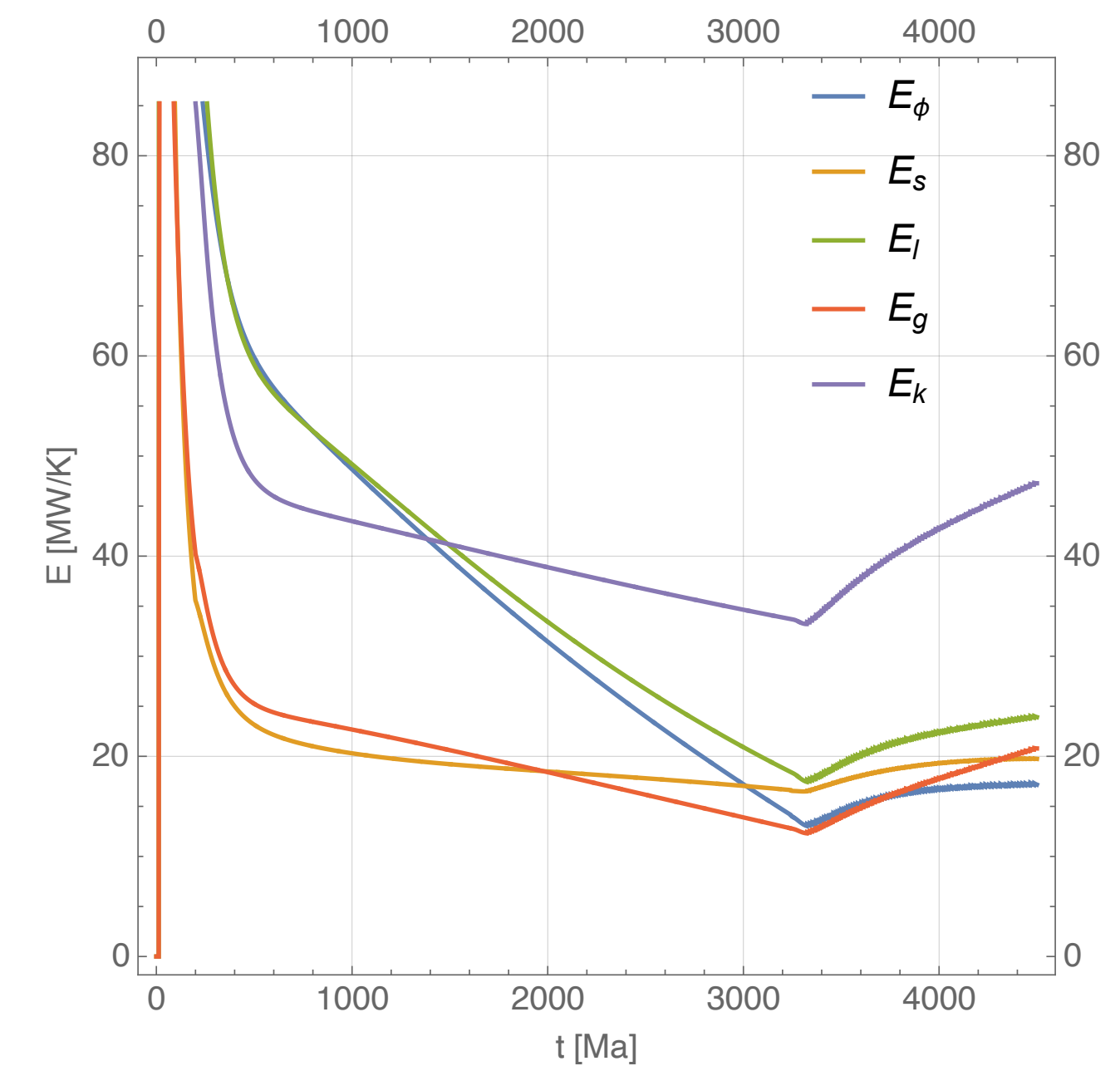
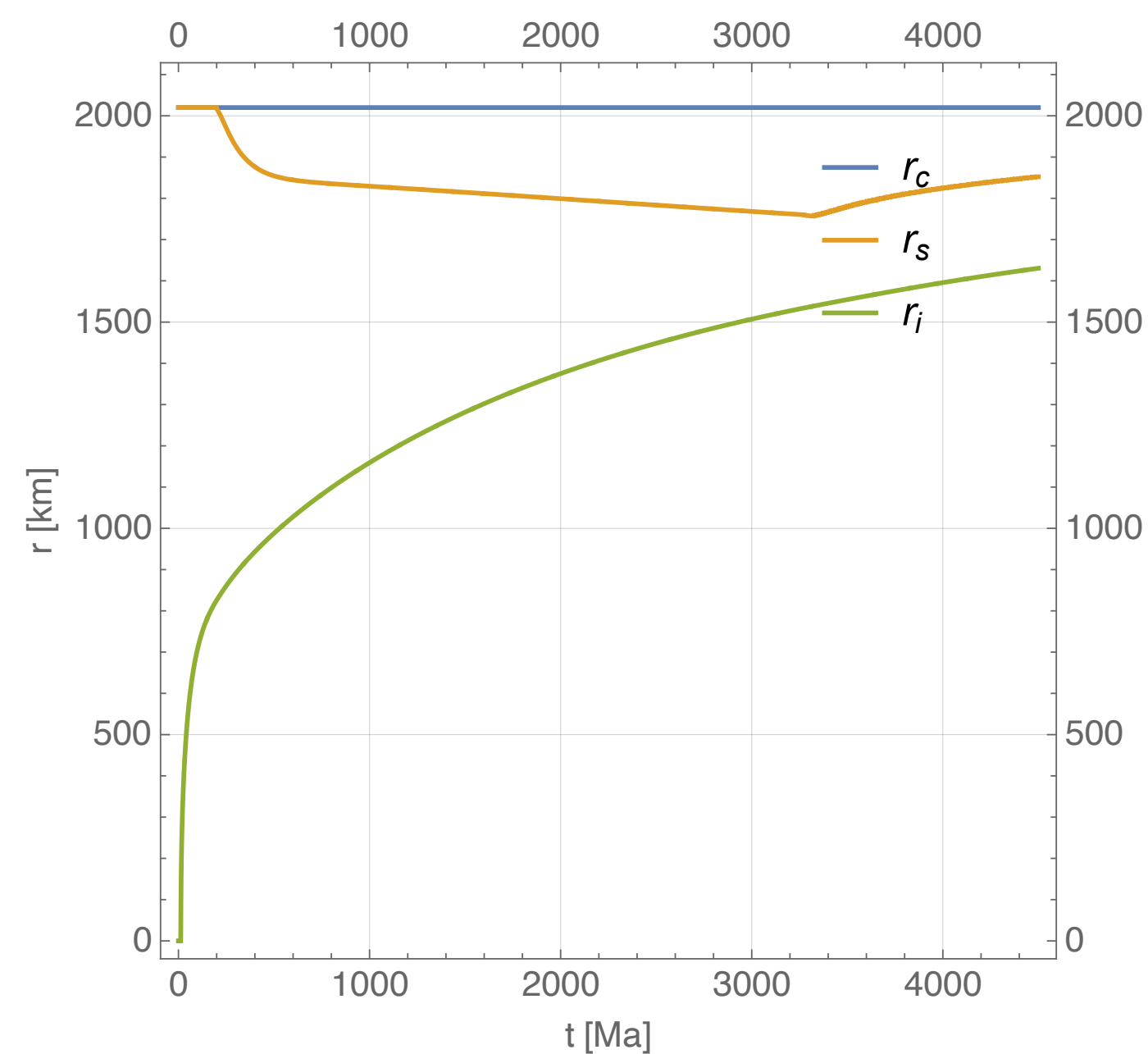
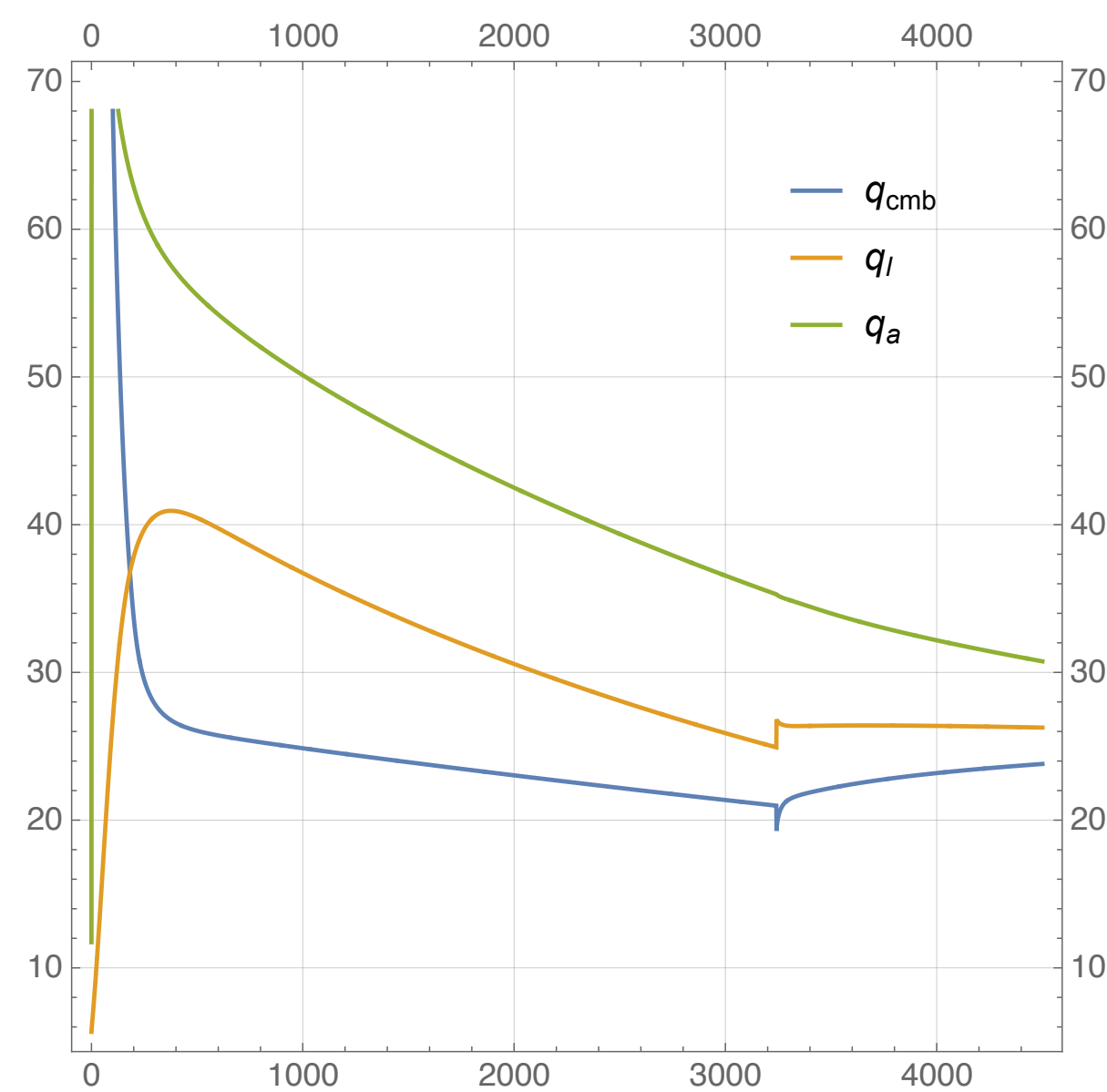
- Comparable boundary layer thickness because of comparable convective power
- Present day dynamo unlikely for models without S in the core



$r_{\text{cmb}} = 2000 \text{ km}$, $T_{\text{cmb}}(t=0) = 1955 \text{ K}$, exponentially decreasing CMB heat flow with $q_{\text{cmb}}(t=2\text{Gyr}) \sim 20\text{mW/m}^2$

Thermal evolution of Mercury (mantle coupled to core) for an Fe-S core

- An increased cmb heat flow related to cessation of mantle convection reduces the thermally stratified layer and promotes dynamo generation (Guerrero et al., 2021)



Summary

- A certain amount of S helps in producing a present-day dynamo using our composition and depth dependent thermodynamic properties
- Our 2.5wt%S+4wt%Si model produces a present-day inner core of ~1200km, and an entropy available for ohmic dissipation of ~60mW/K
- Our preliminary results show that the cessation of mantle convection decreases the thickness of the thermally stratified layer and increases the chance of dynamo generation