ASYMMETRIC EVOLUTION OF THE MOON

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1. An asymmetric distribution of lavas and heat producing elements

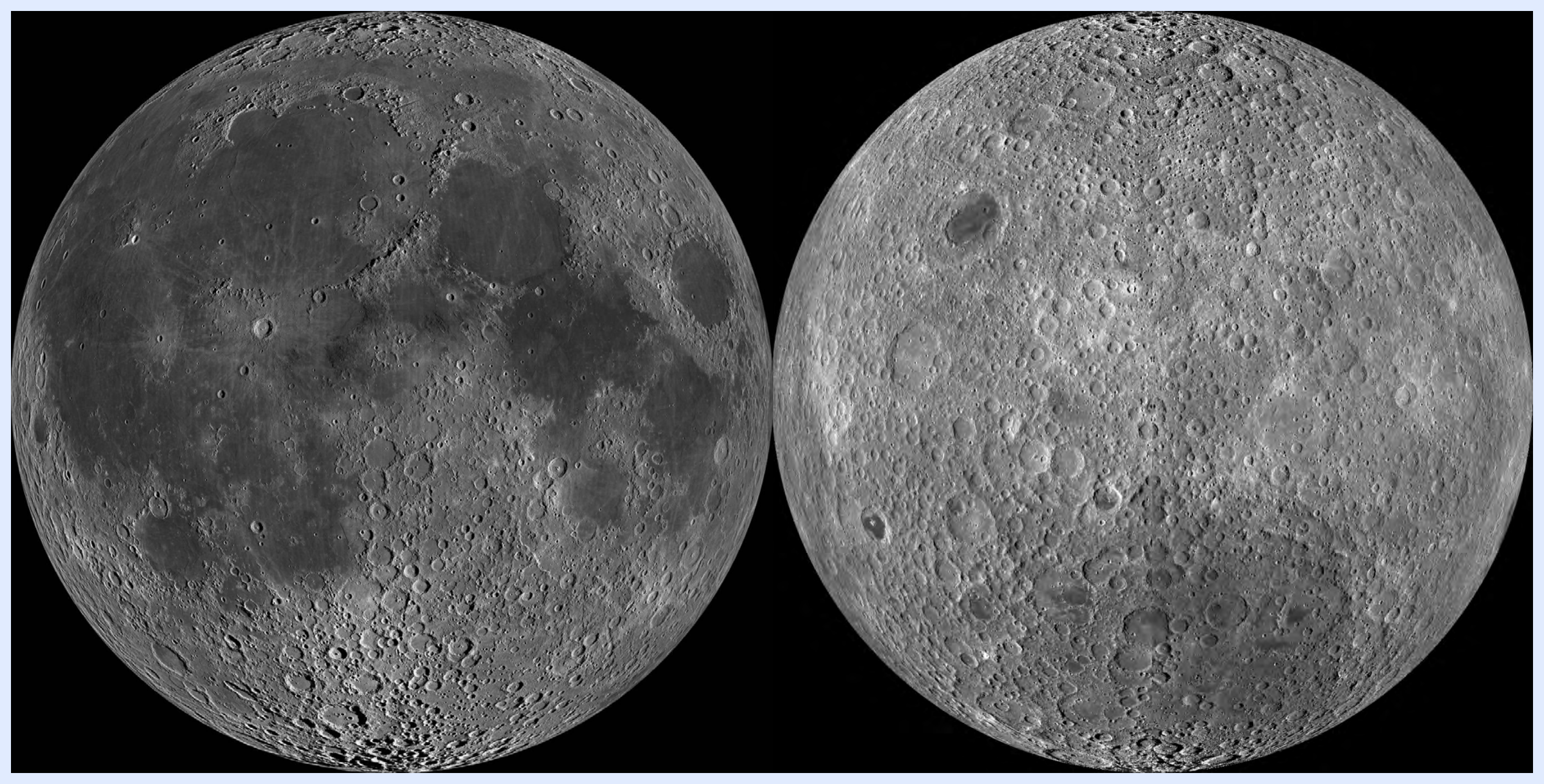
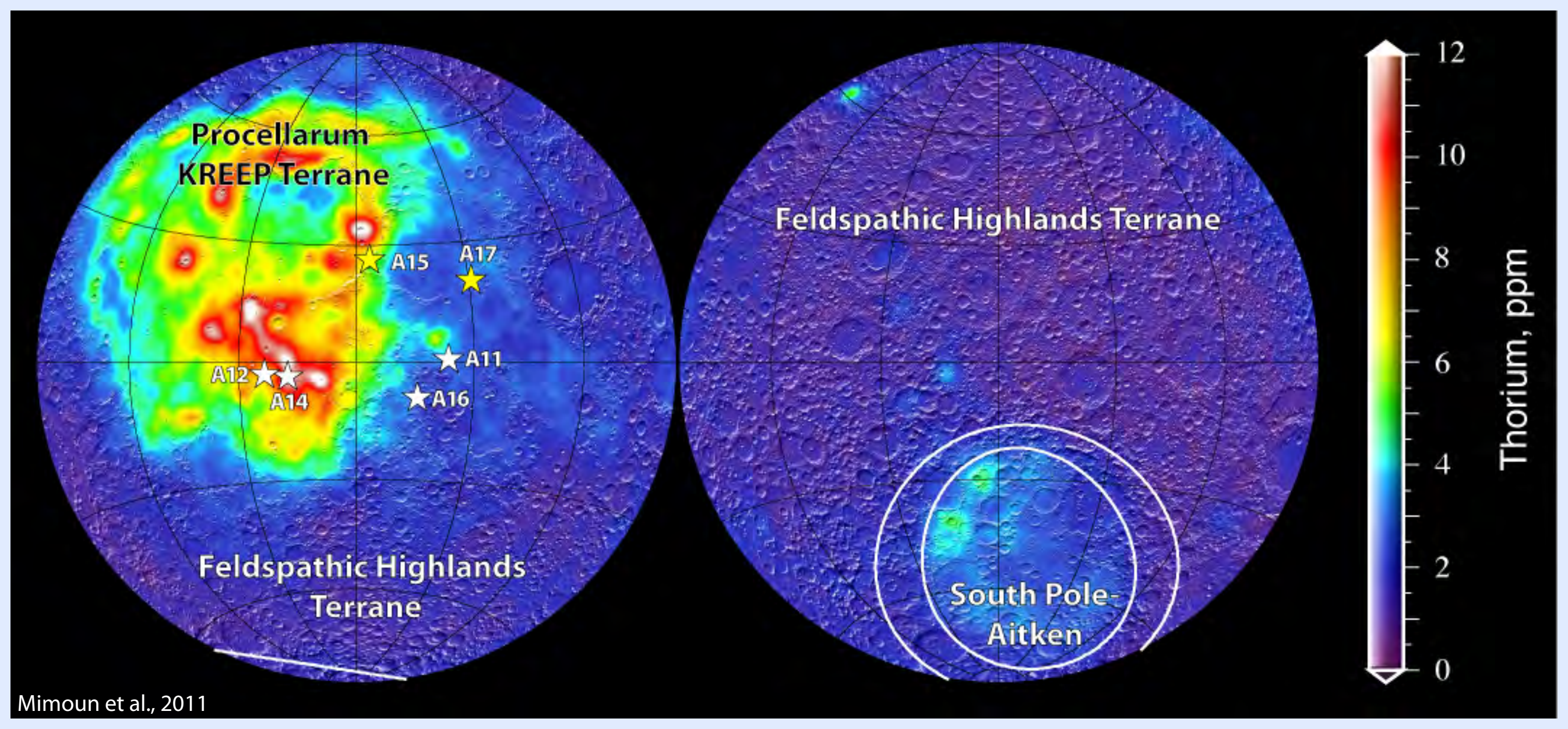


Fig. 1: Lunar nearside and farside as seen by the LROC WAC. ~17% of the surface is covered by lavas, ~95% of which are on the nearside in the Procellarum KREEP Terrane (PKT).



Mimoun et al., 2011

Fig. 2: Global thorium map of the Moon from Lunar Prospector. The highest concentrations on the nearside correspond to high standing crust that was not flooded by mare basalts.

High concentrations of heat sources within the crust in the PKT region

(1) Mare basalts at the lunar surface are concentrated in the Procellarum KREEP Terrane (see Fig. 1).
(2) There is a similar asymmetry in heat producing elements distribution (see Fig. 2).
(1)+(2) suggest that the higher heat production in this province is responsible for melting the underlying mantle.

This indicates the presence of a layer enriched in heat sources (KREEP) below the PKT which would have a tremendous impact on thermal evolution [1,2]. In this project, we study the effect of this layer on the lunar history and its possible present day measurable consequences.

2. Thermo-chemical convection model

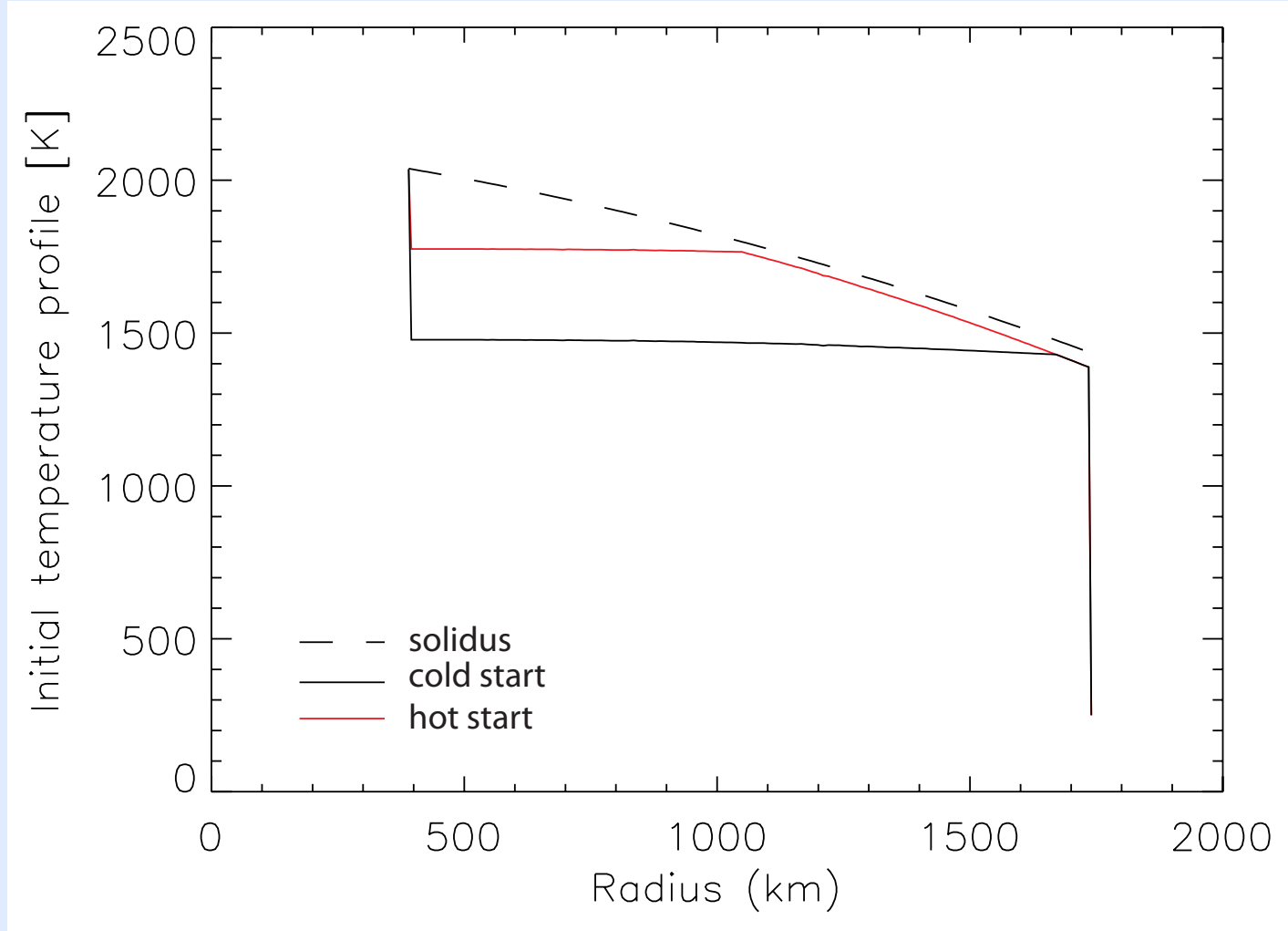
a. Main features (program name: GAIA, [3])

- 2D cylindrical and 3D spherical thermo-chemical convection
- 10-20 km radial resolution, 20-60 km lateral resolution
- solves equations of conservation of mass, energy and momentum under the Boussinesq approximation
- inertial forces are neglected (viscosity >> thermal diffusivity)
- newtonian rheology (stress and strain are proportional)

b. Important parameters

- initial temperature profile

Two temperature profiles are investigated as pictured on the right : « cold » corresponds to an adiabatic profile while « hot » follows the solidus up to a given depth and then the adiabat.



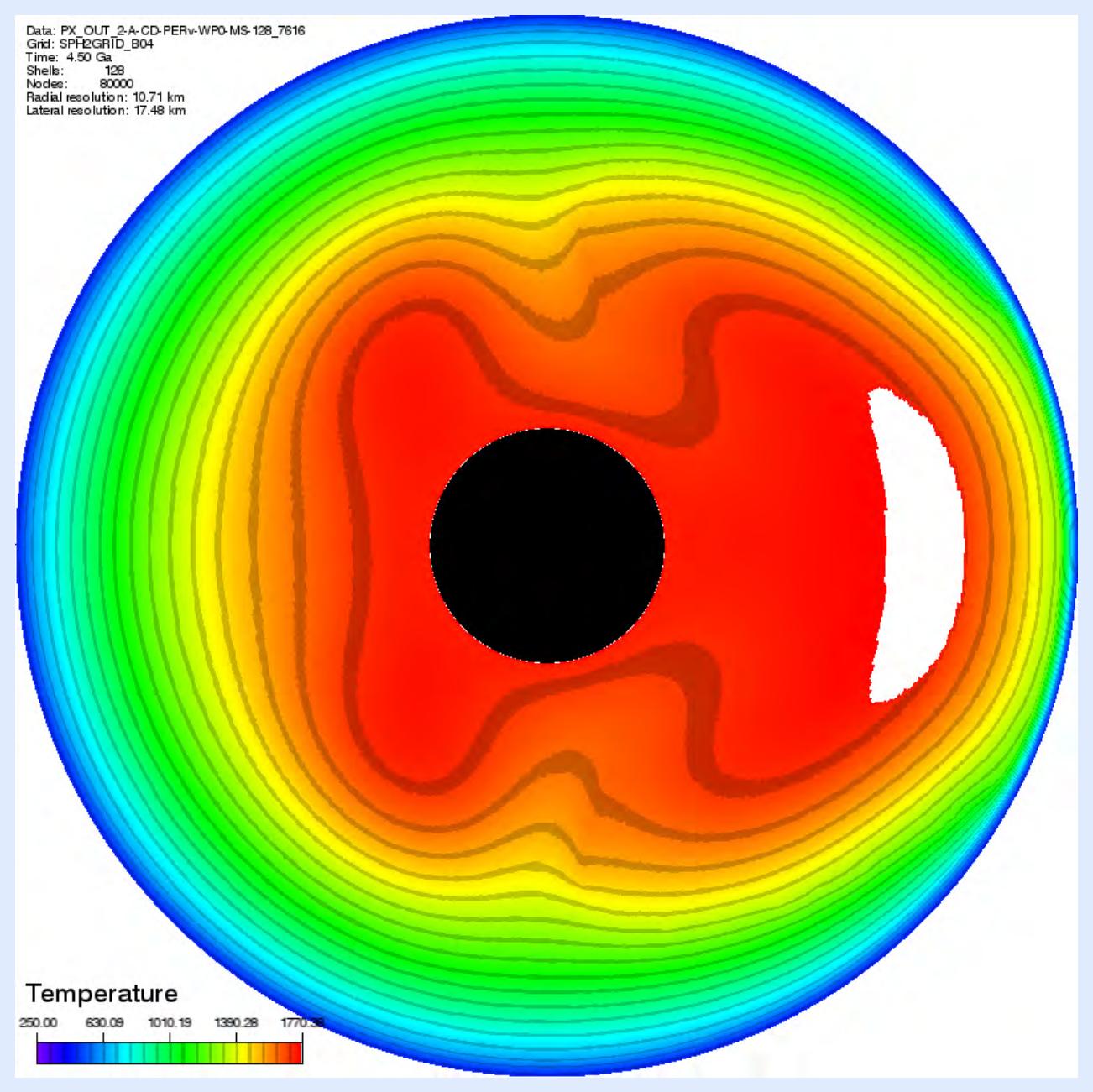
- heat sources distribution

The Moon bulk uranium content has been estimated to lie between Earth's value (20ppb) and nearly twice that amount (35ppb) [4]. We define the KREEP layer to be 20 km thick and to lay below a 50 km crust. We use [5]'s values for heat sources concentrations and study two end-member cases.

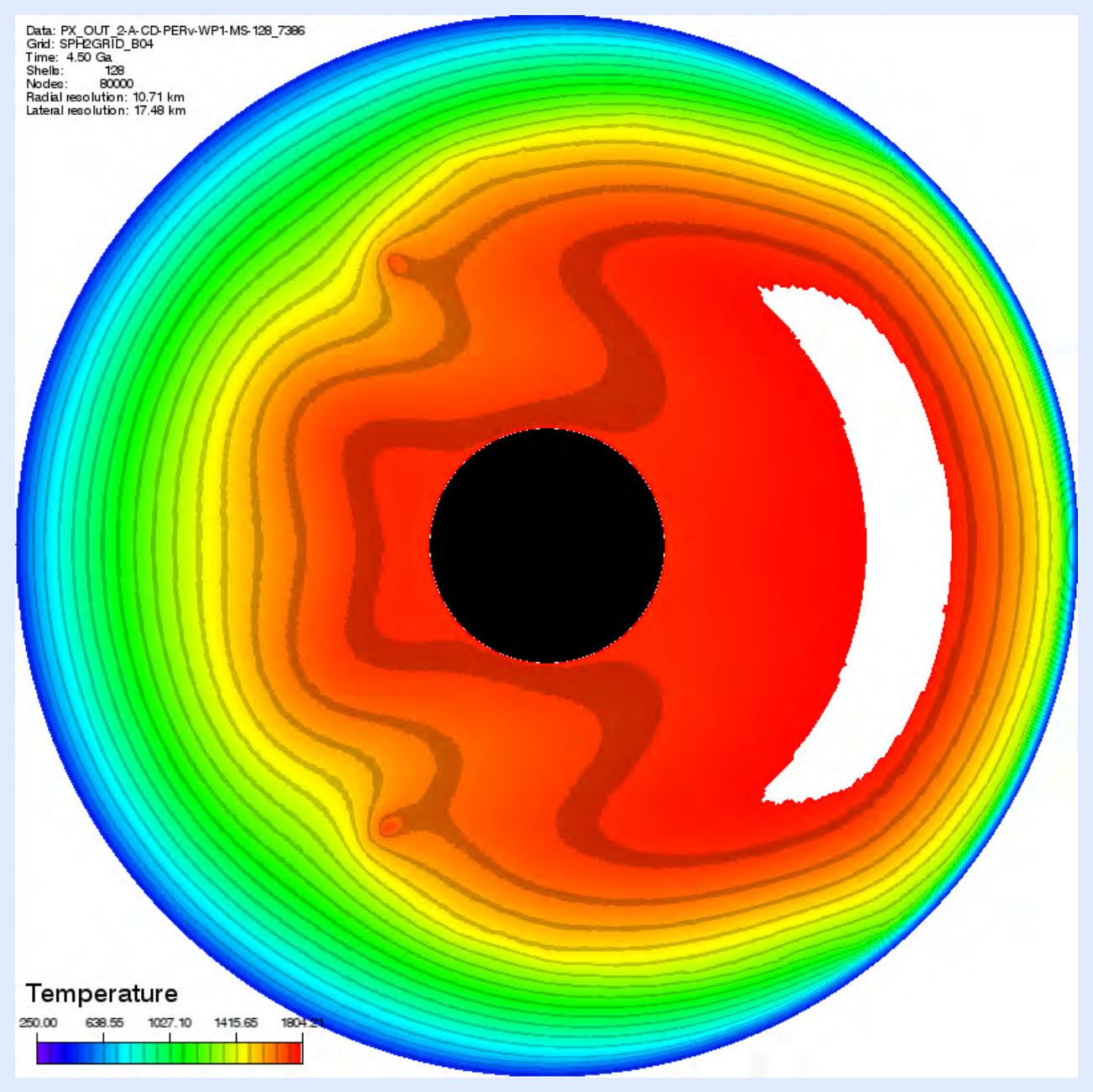
	PKT size	bulk U	concentrations
case 1	40°	22ppb	U mantle : 6.8ppb U KREEP: 3.4ppm U crust: 0.14ppm K/U = 2000, Th/U = 4
case 2	80°	37ppb	

3. Heat sources are localized in one region: what are the consequences?

1) Predicted present day temperature anomaly



Case 1: Present day temperature anomaly below the PKT when its angular size is 40°. The white region is the current meltzone.



Case 2: Present day temperature anomaly below the PKT when its angular size is 80°. The white region is the current meltzone.

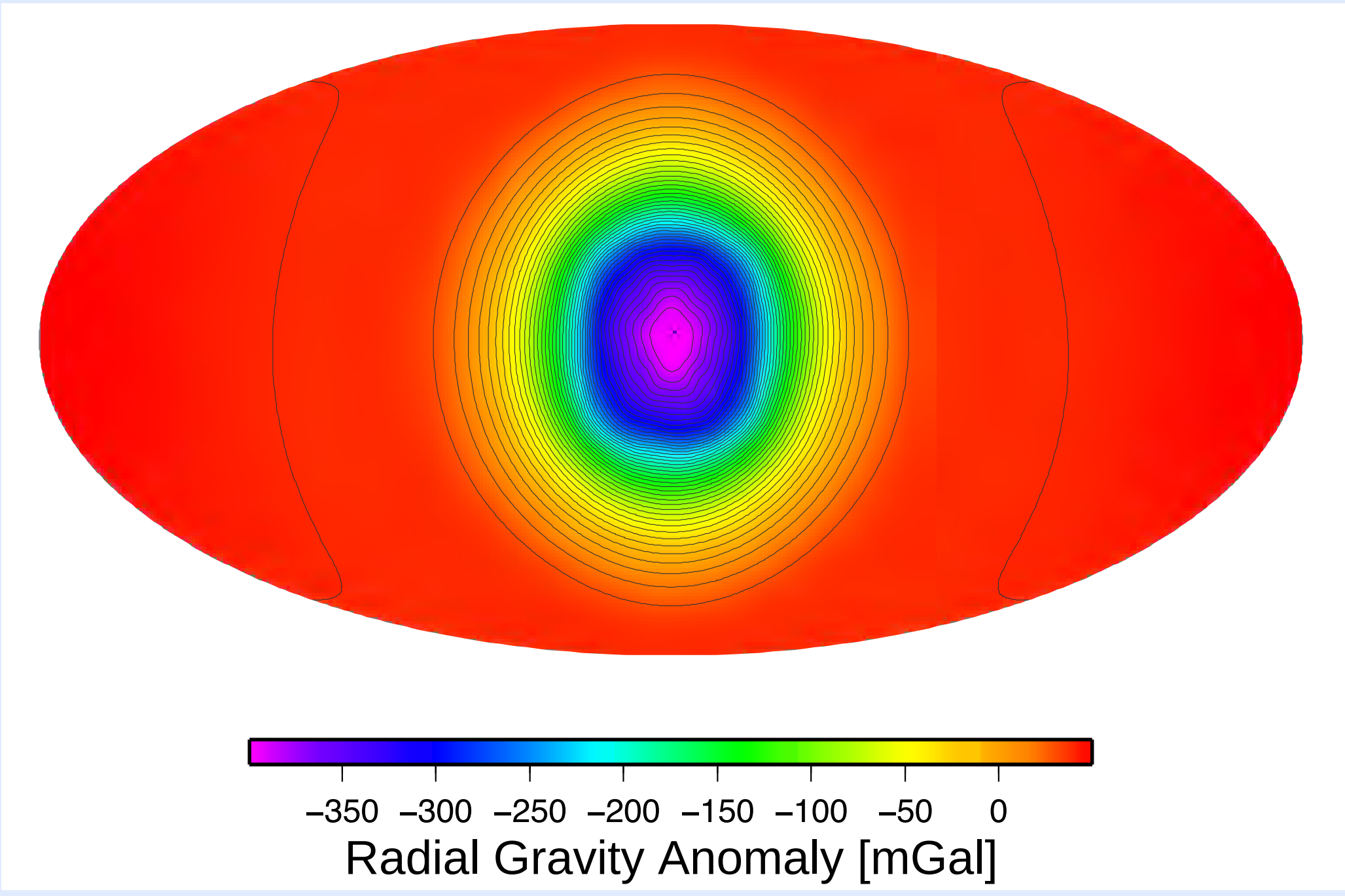


Fig. 3: Radial gravity anomaly due to the low density region (high temperature) below the PKT, with an initial anomaly size of 40°. The opposing effect of dense lavas at the surface is not taken into account and would cancel most of this negative anomaly.

2) CMB heat flow & magnetic history

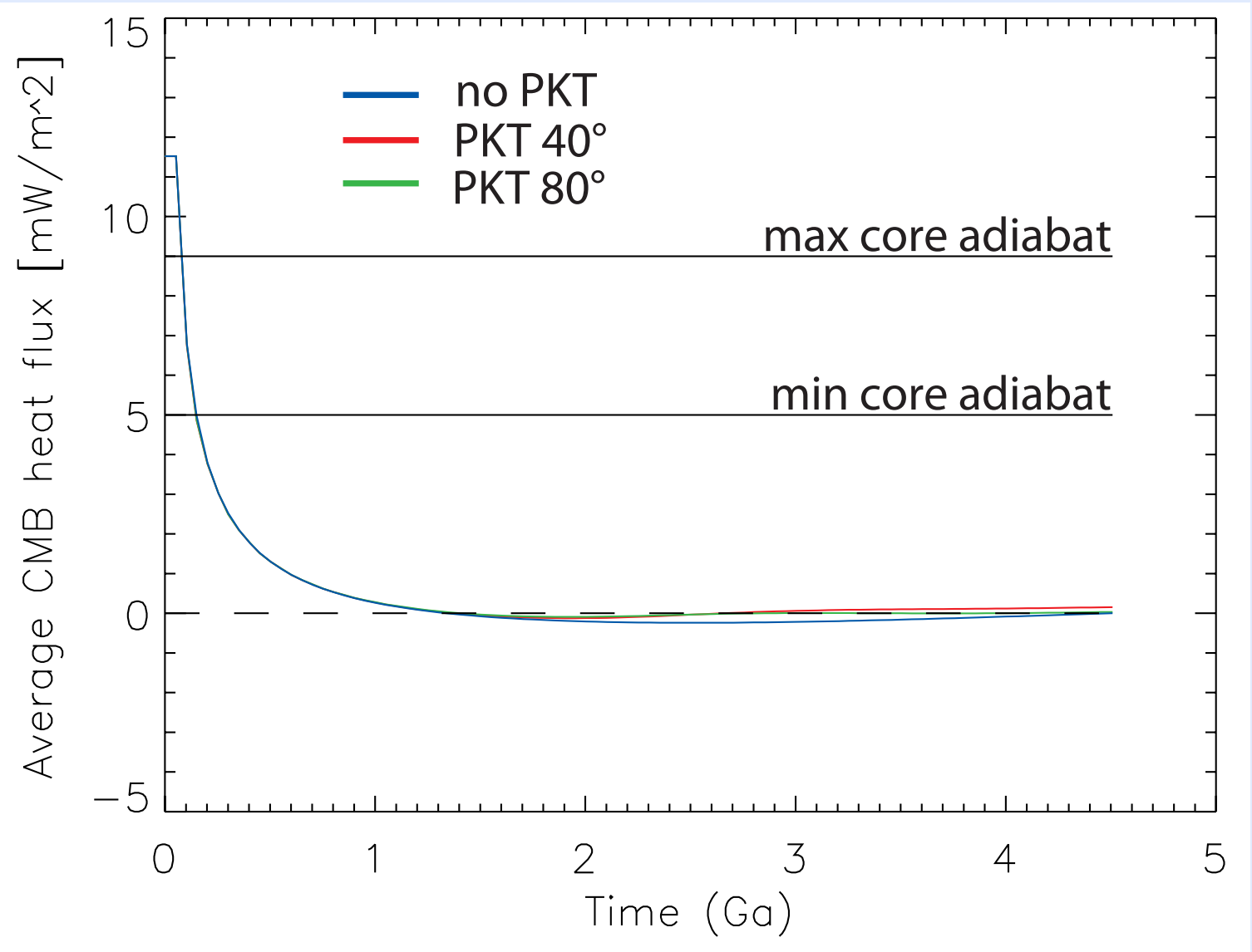


Fig. 4: Average heat flux out of the core as a function of time for different scenarios and an initially cold start. A dynamo might exist for the first 200 Ma.

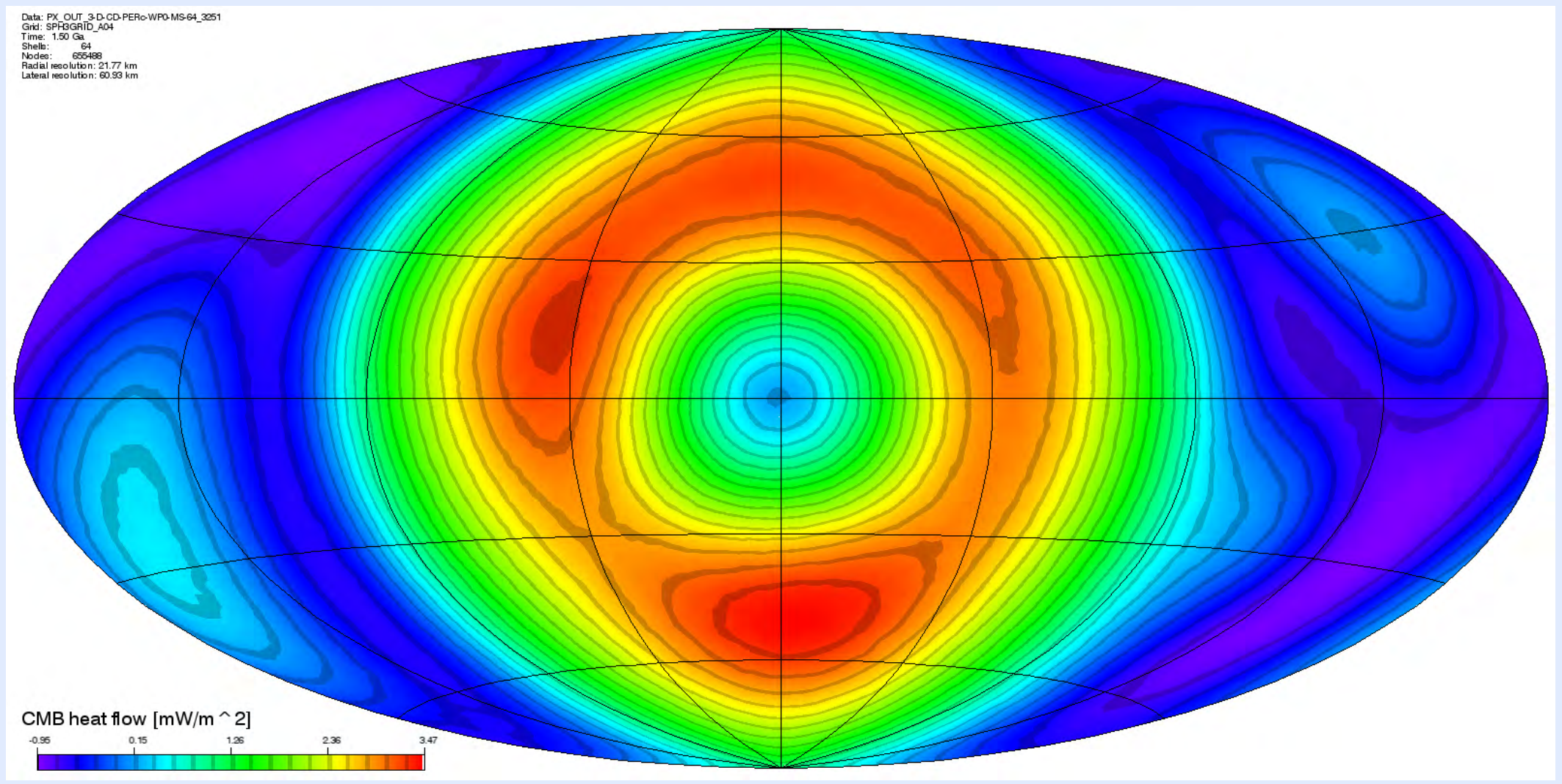


Fig. 5: CMB heat flow pattern after 1.5 Ga in the case of a « hot » initial temperature profile. [6] show that a degree-1 heat flux variation at the CMB could influence the magnetic field strength and morphology.

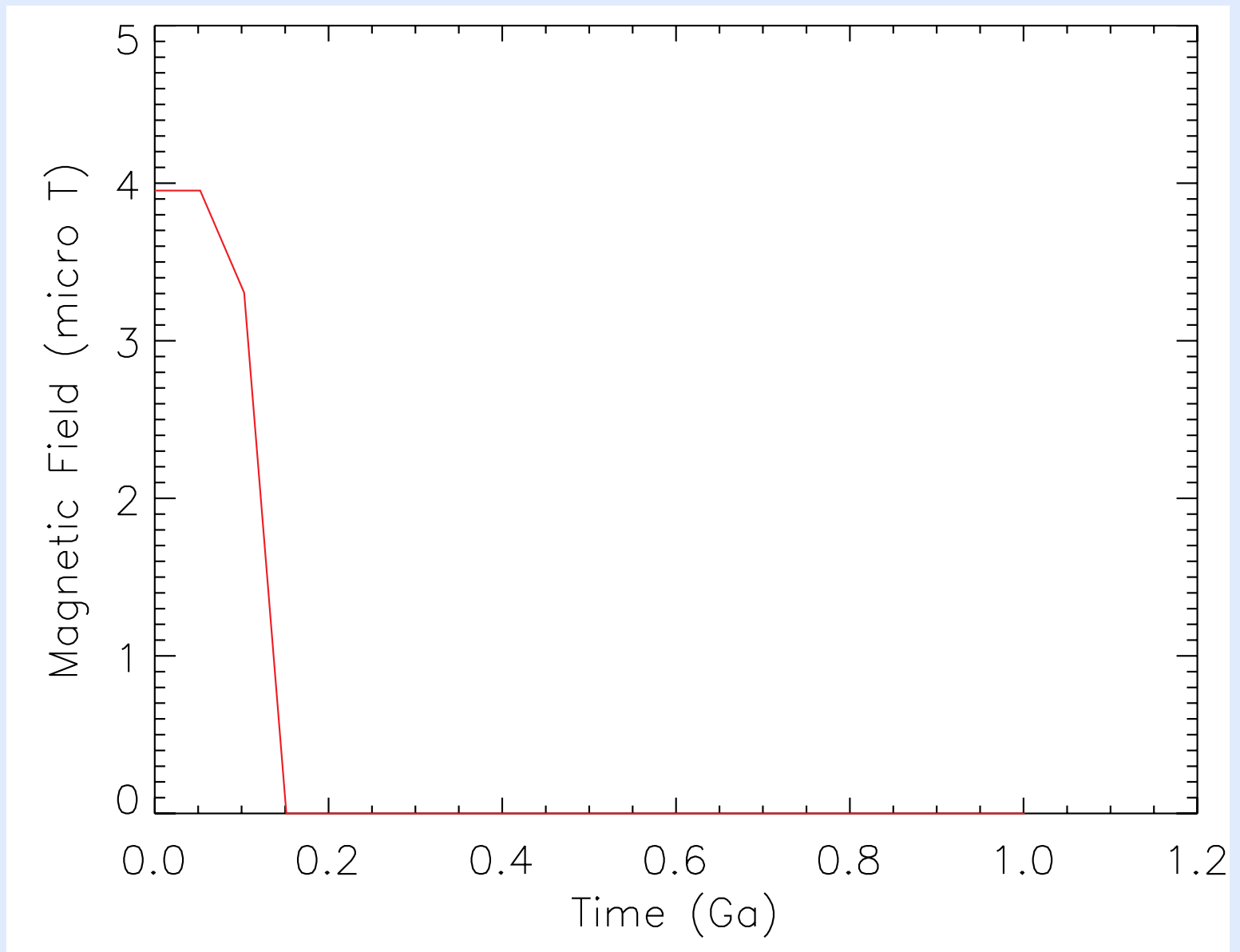


Fig. 6: Estimated surface magnetic field as a function of time using scaling laws from [7] and an initially cold start.

4. Conclusions

The consequences of localizing heat sources in the PKT are **numerous** and **long lasting**.

- melt is produced mainly on the nearside hemisphere consistent with the distribution of mare basalts.
- a temperature anomaly beneath the PKT is still present today.

These results in turn have interesting implications on **direct observables**.

- The temperature anomaly could influence seismic wave velocities and electrical conductivity
- The temperature anomaly also induces a density anomaly which, when taken into account, could reduce current crustal thickness estimates.
- The heat flow pattern at the CMB is deeply affected by this overheating region and could have an influence on the magnetic field.

Future investigations

Different mantle rheologies, crustal thickness inversion, magnetic field estimates, deep mantle low velocity zone origin.

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