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A numerical study on potential driving mechanism of core convection

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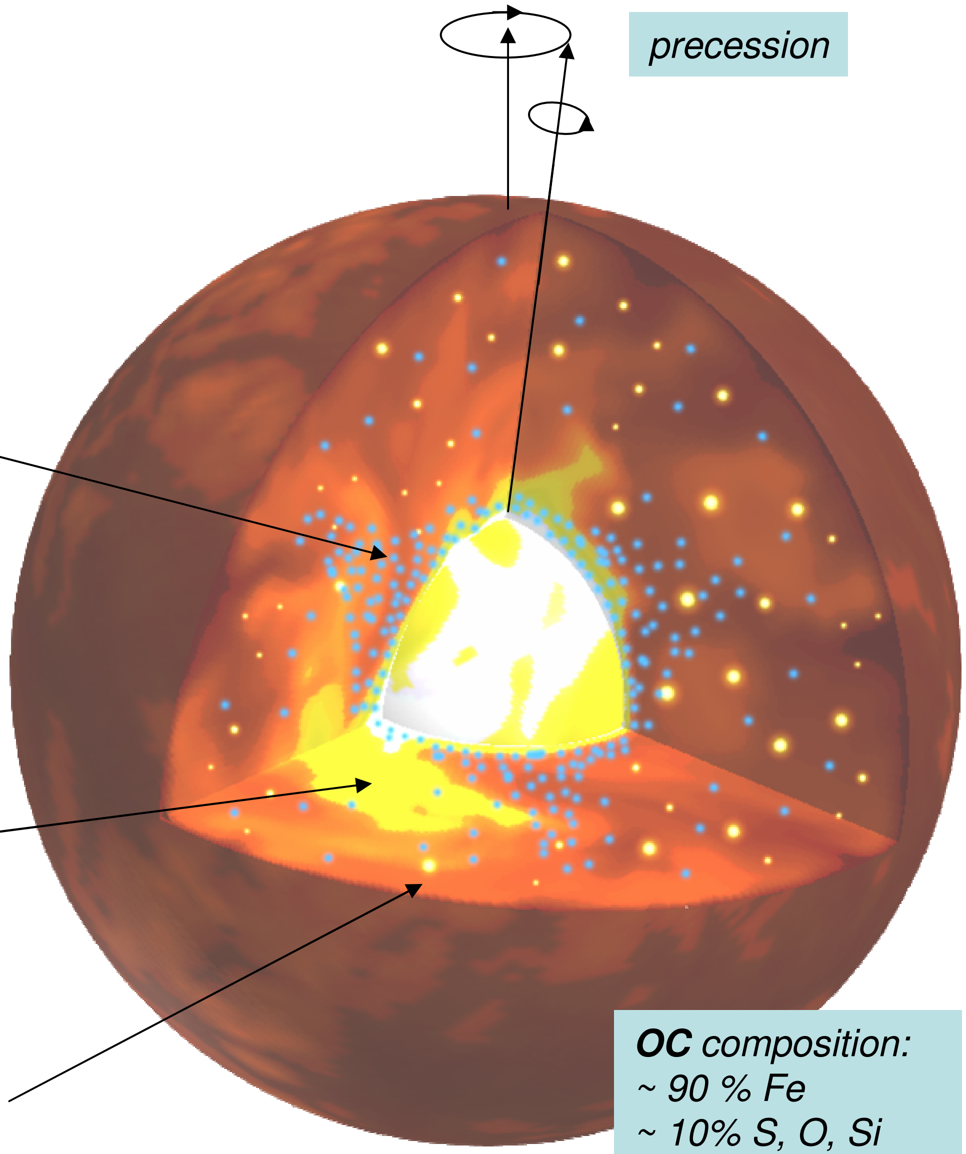
What drives the outer core?



precession

*Release of light elements at the **ICB***

Secular cooling and latent heat release

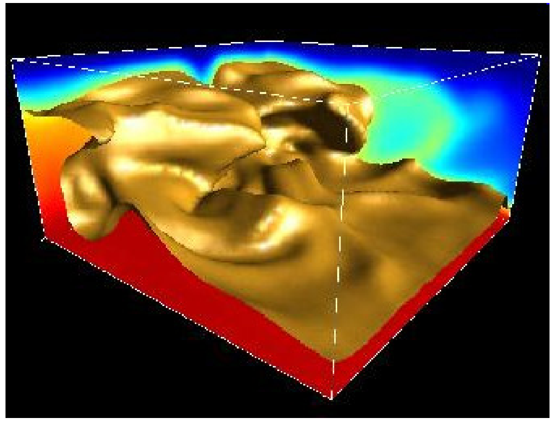
Radiogenic elements (^{40}K?)

***OC** composition:*
~ 90 % Fe
~ 10% S, O, Si

Compositional vs. thermal driving component

$$\frac{\kappa_T}{\kappa_C} \approx O(10^2)$$

i.e. temperature fluctuations diffuse much faster compared to the compositional component

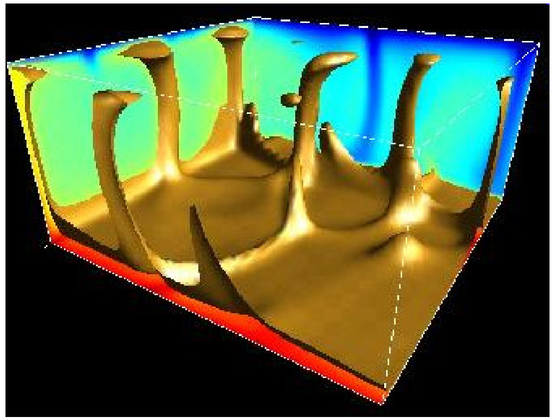


Pr=0.025

important for flow dynamics are the related Prandtl numbers

$$\Pr_T = \frac{\nu}{\kappa_T} \approx O(10^{-1})$$

$$\Pr_C = \frac{\nu}{\kappa_C} \approx O(10)$$



Pr=100.

Strong difference in the convective flow behavior between Pr<1 and Pr>1

(Breuer et al., 2004)

Questions to be clarified

I. How does thermally driven core convection distinguish from the compositionally driven case?

II. What are the effects of a coupling of both sources?

⬇

Numerical study on thermo-chemical convection in a rotating spherical shell considering different driving scenarios

purely thermally driven —— both sources ——→ purely compositionally driven

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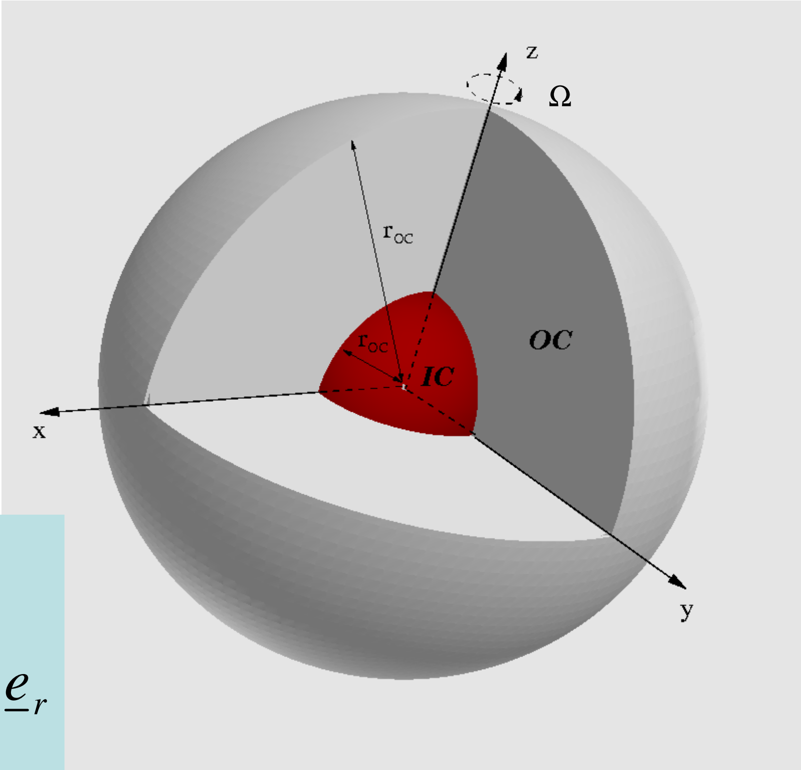
Core convection model

(Harder and Hansen, 2005)



$$\partial_t \underline{u} + \underline{u} \cdot \nabla \underline{u} =$$

$$-\nabla \tilde{p} - \frac{2}{Ek} \underline{e}_z \times \underline{u} + \nabla^2 \underline{u} + \left(Ra_T^* T + Ra_C^* C \right) \frac{r}{r_{OC}} \underline{e}_r$$

$$\partial_t T + \underline{u} \cdot \nabla T = \mathrm{Pr}_T^{-1} \nabla^2 T$$

$$\partial_t C + \underline{u} \cdot \nabla C = \mathrm{Pr}_C^{-1} \nabla^2 C$$

$$\nabla \cdot \underline{u} = 0$$

Boundary conditions:

ICB $: \underline{u} = 0, T = 1, C = 1$

CMB: $\underline{u} = 0, T = 0, C = 0$

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Considered parameters

$$\Pr_T = \frac{\nu}{\kappa_T} = 0.3$$

$$\Pr_C = \frac{\nu}{\kappa_C} = 3.0$$

$$Ek = \frac{\nu}{d^2\Omega} = 10^{-3}$$

$$Ra_T^* = \frac{\alpha_T g_0 \Delta T d^3}{\nu^2}$$

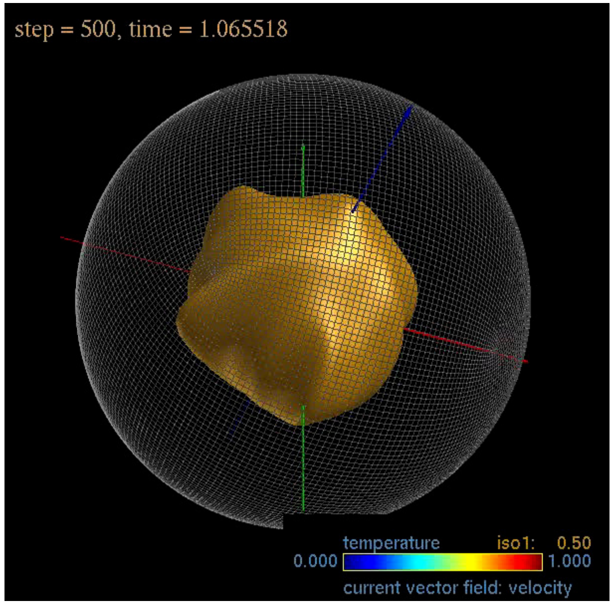
$$Ra_C^* = \frac{\alpha_C g_0 \Delta C d^3}{\nu^2}$$

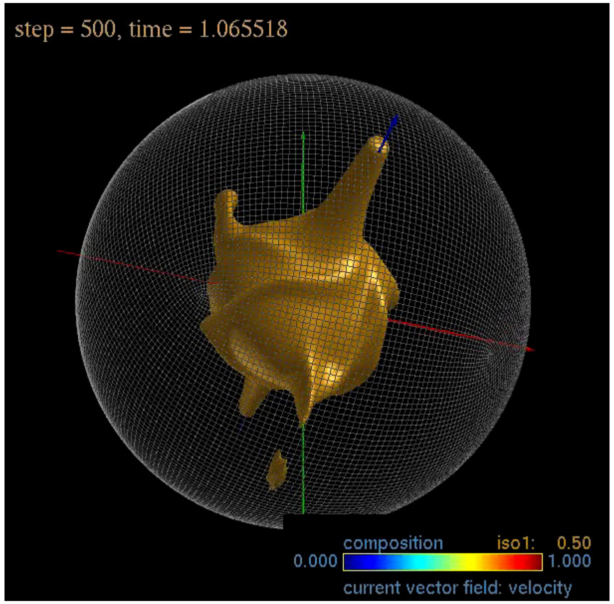
$$Ra_{tot}^* = Ra_T^* + Ra_C^* = 4.0 \cdot 10^5$$

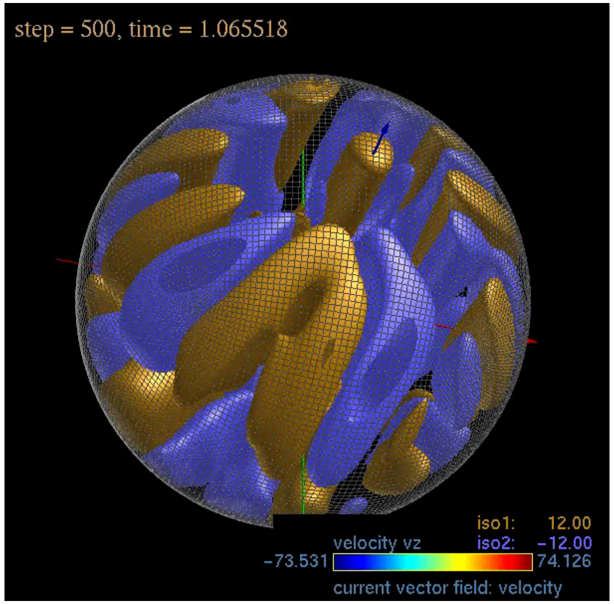
! $Ra_{tot}^* \approx 3 \cdot Ra^*{}_{crit}$ for T and $Ra_{tot}^* \approx 20 \cdot Ra^*{}_{crit}$ for C

Characteristic flow properties

temperature *composition* *vertical velocity*

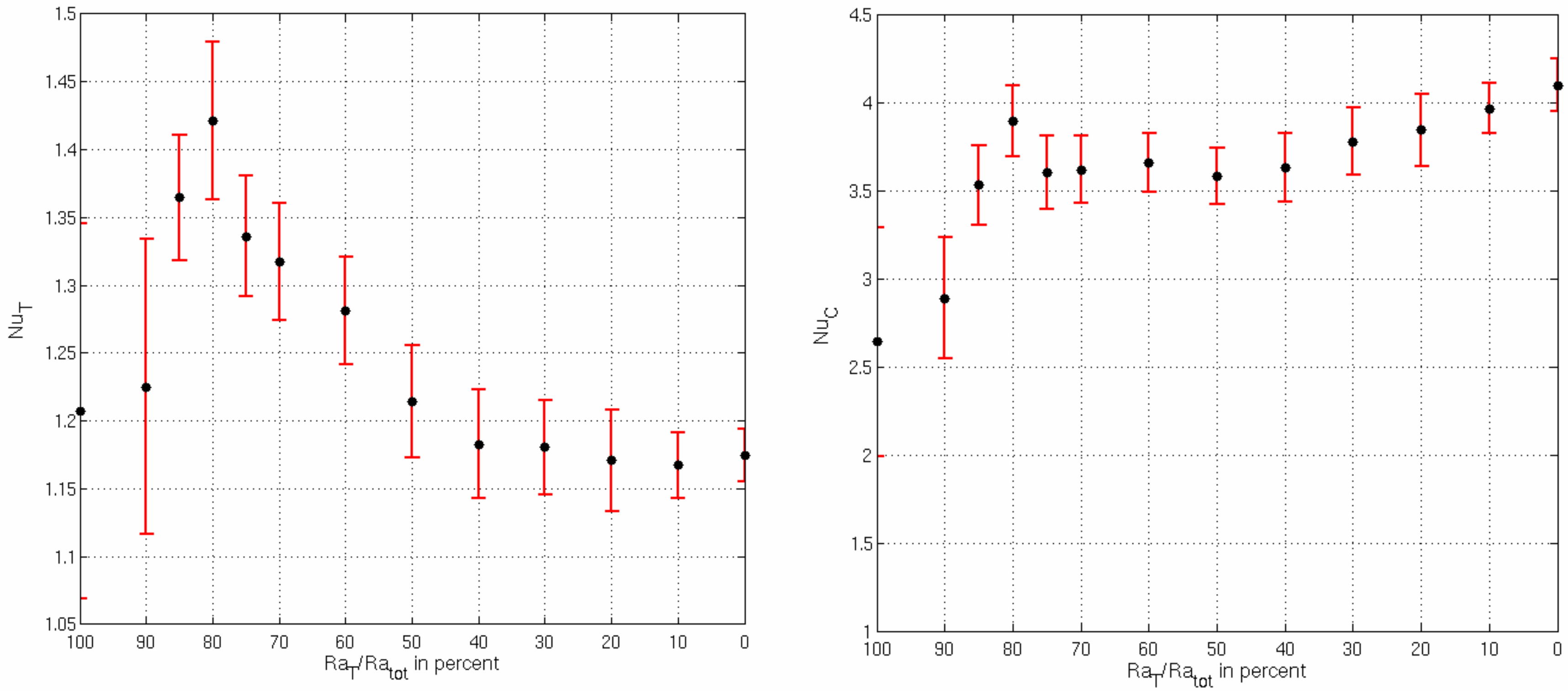




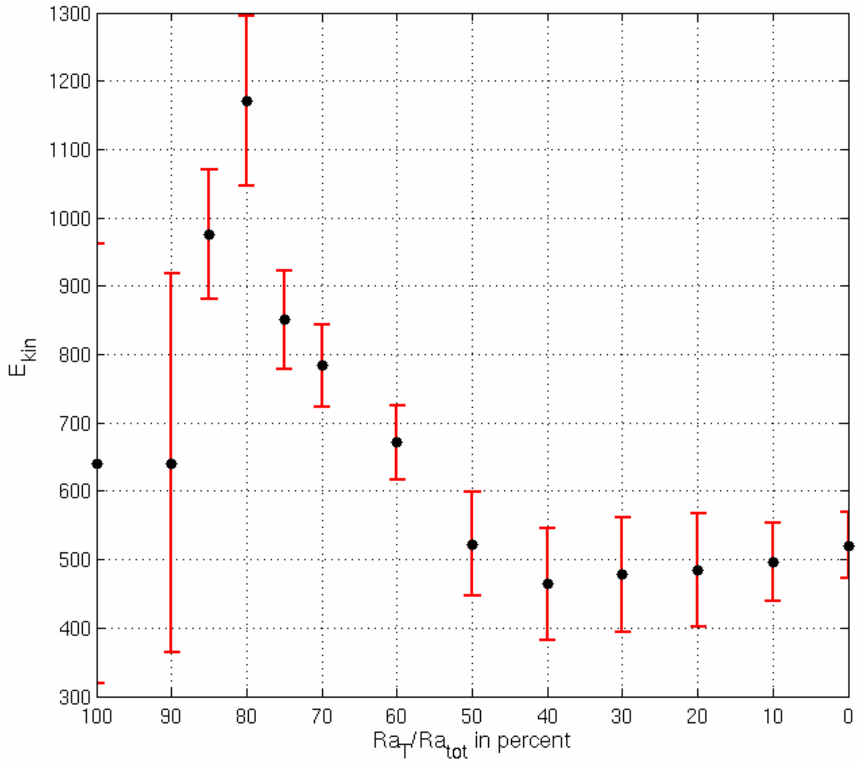


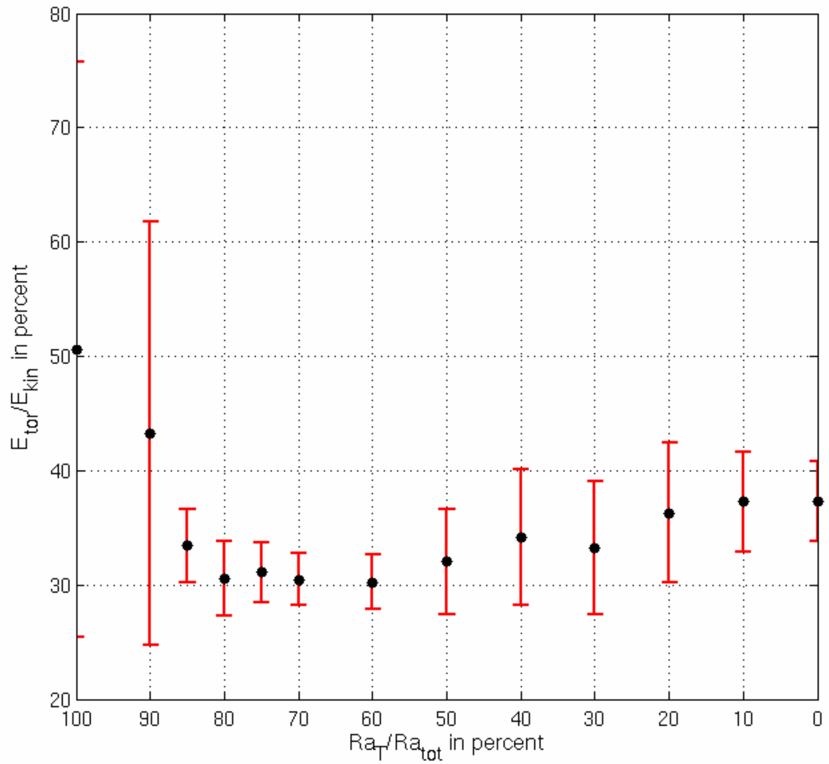
Case: $Ra_T / Ra_{tot} = 50\%$

Global parameters – transport efficiencies Nu_T, Nu_C



Global parameters – mean energy, azimuthal fraction





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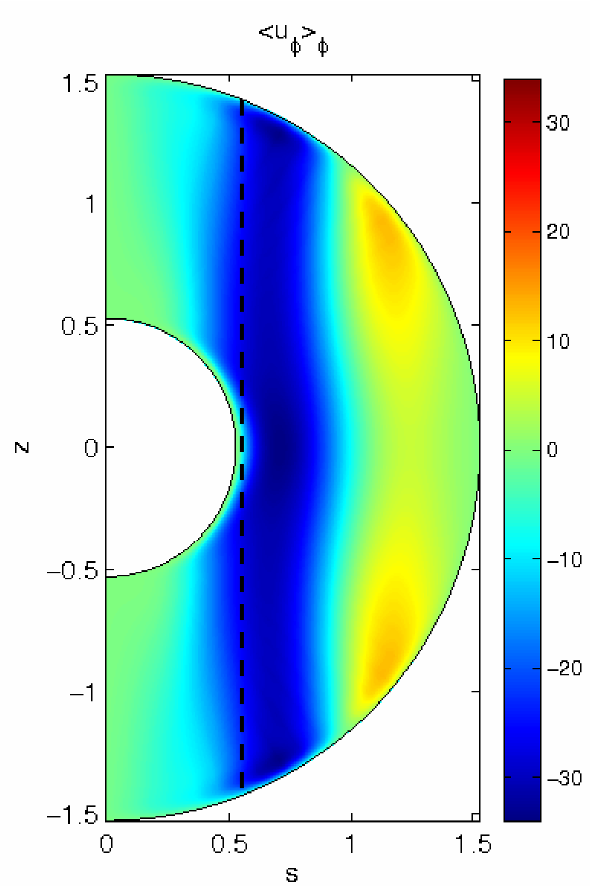
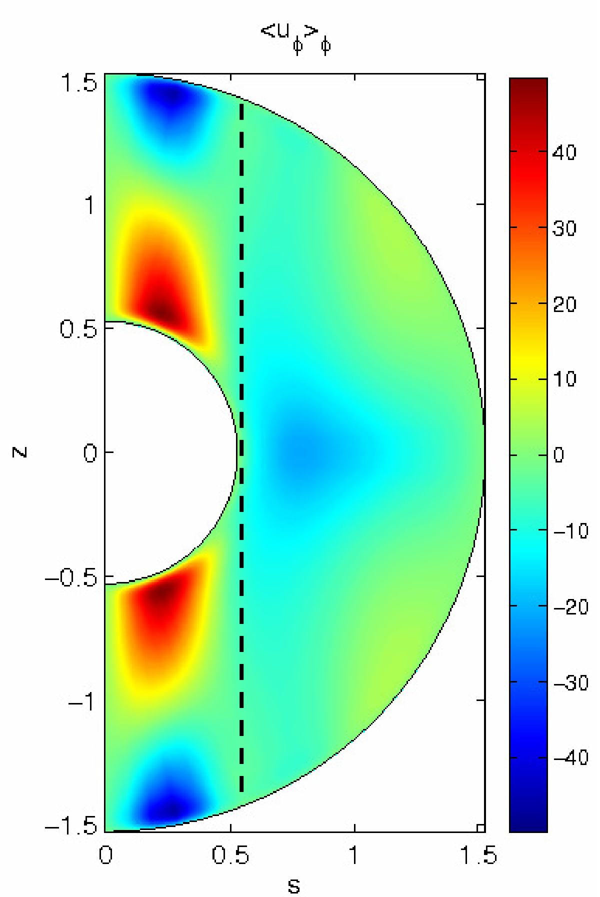
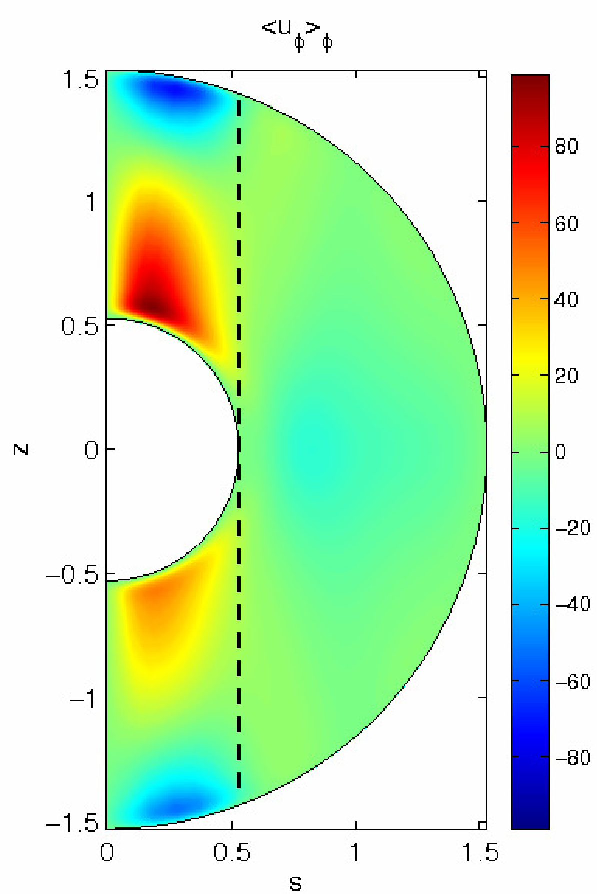
Differential rotation



$Ra_T / Ra_{tot} = 100\%$



$Ra_T / Ra_{tot} = 50\%$



$Ra_T / Ra_{tot} = 0\%$

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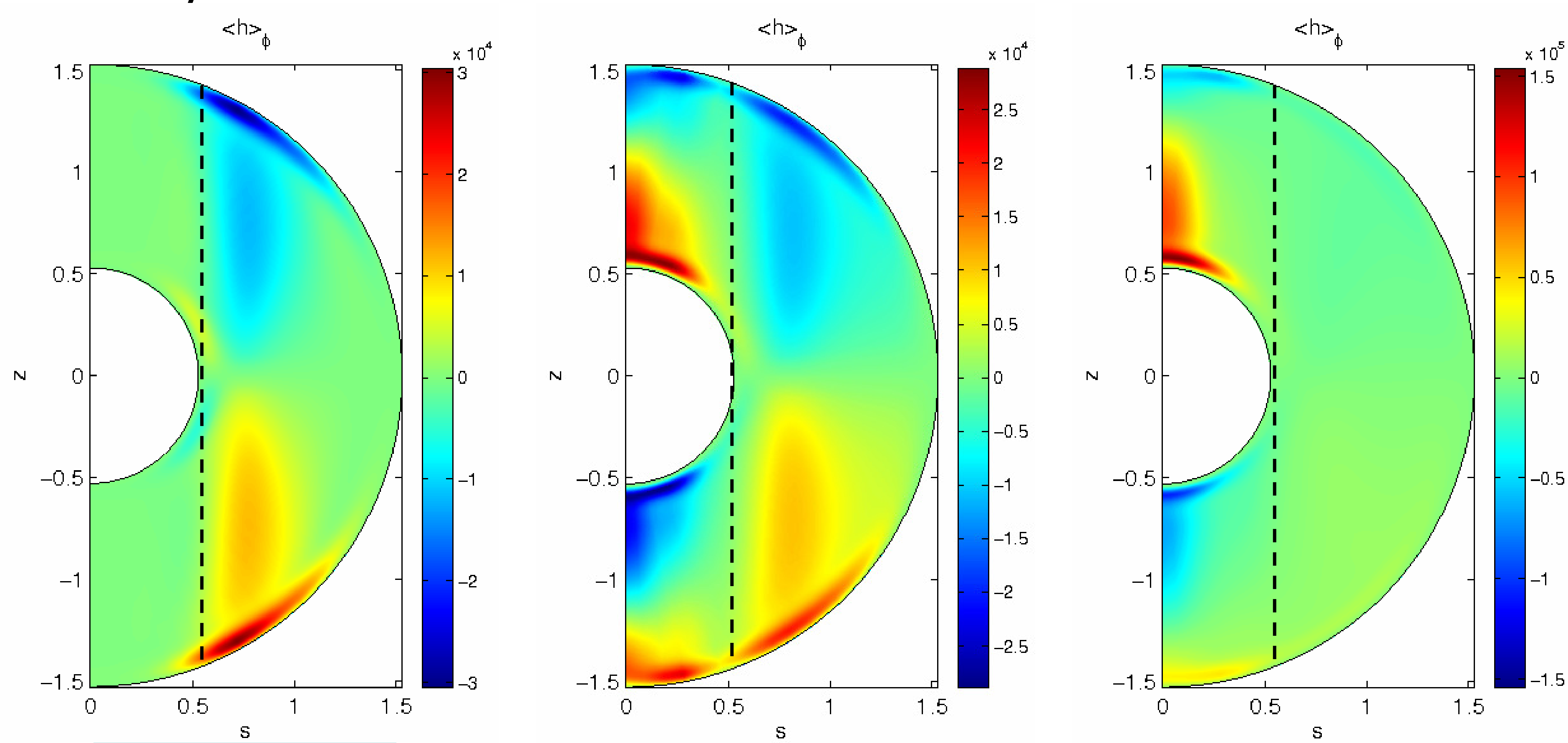
Helicity



$Ra_T / Ra_{tot} = 100\%$ $Ra_T / Ra_{tot} = 50\%$ $Ra_T / Ra_{tot} = 0\%$

Summary

Behavior of core convection depends strongly on the type of driving:

• different transport properties and efficiencies of thermal and compositional component

• different spatial distribution of differential rotation and helicity

(→ important structures for the dynamo mechanism)

Next steps:

• further investigations at more Earth-like parameters (Ra, Ek)

• consider the full dynamo problem