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Towards a rapidly rotating liquid sodium dynamo experiment

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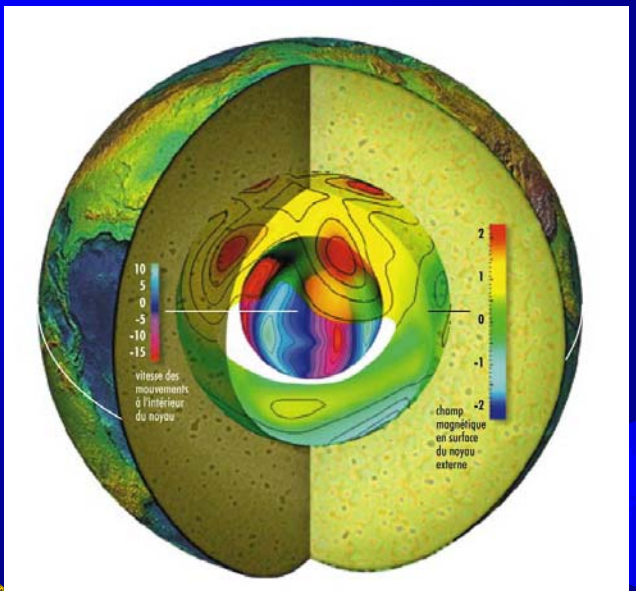
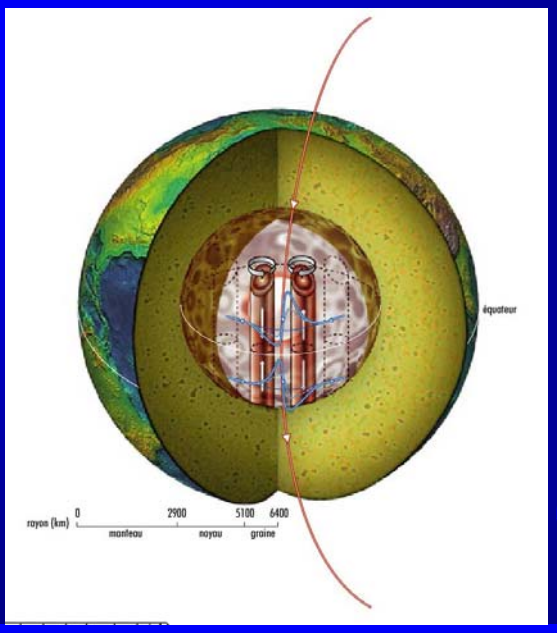
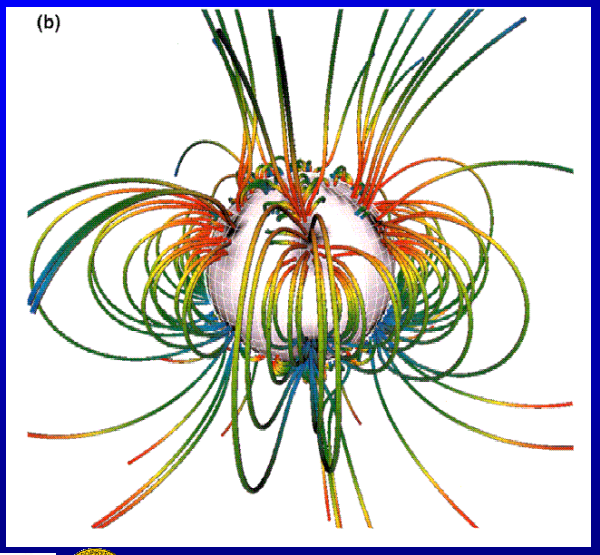
Earth's magnetic field^{++}



Dynamics of the Earth's Core

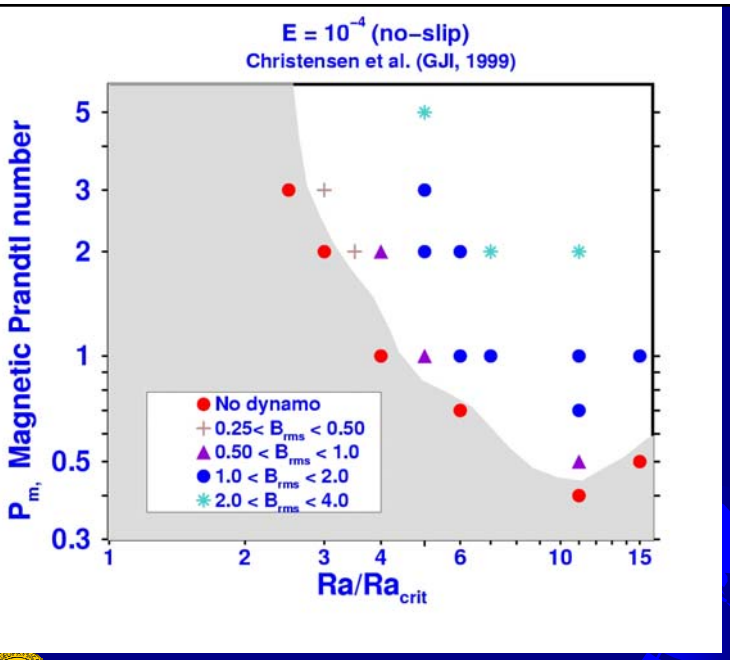


Numerical Dynamos



Kageyama and Sato

PRE, 1997



To build an experimental planetary dynamo

1. Liquid metal $P_m << 1$

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2. **Vigorous motions**

To build an experimental planetary dynamo:

$$R_m = \frac{Ua}{\eta} \approx 100 \qquad \eta = 0.1\ \mathrm{m^2 s^{-1}}$$

1. **Use liquid sodium (η)**
2. **Impose vigorous motion in a large container (U, a).**

In the core, $R_m > 100$

To build an experimental planetary dynamo:

1. **Liquid metal** $P_m << 1$
2. **Vigorous motion** $R_m = \frac{Ua}{\eta} \approx 100$
3. **Rapid rotation**

Coriolis Vs Laplace forces

Waves:

- **Rotation alone → inertial waves : [0,2] Ω**
- **Magnetic forces alone → Alfvèn waves : $\omega_a \sim (\mu_0\rho)^{-1/2}B/a$**
- $\lambda = \omega_a/\Omega = B / a\,\Omega\,(\mu_0\rho)^{1/2}$

Rapid rotation means : $\lambda << 1$

In the Earth's outer core $\lambda \sim 3.\,10^{-4}$

To build an experimental planetary dynamo:

1. **Liquid metal** $P_m << 1$
2. **Vigorous motion** $R_m = \frac{Ua}{\eta} \approx 100$
3. **Rapid Rotation** $\lambda = \frac{\omega_{Alfven}}{\Omega} << 1$
4. **Magnetostrophy**

Coriolis Vs Laplace forces

At long time scale :

Lorentz ~ Coriolis $\rightarrow \Lambda = jB/2\rho U\Omega$

Magnetostrophy means : $\Lambda \sim 1$

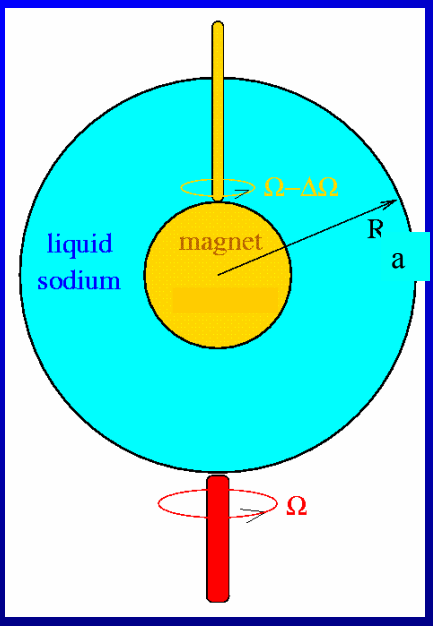
In the Earth's core, $0.1 < \Lambda < 10$

To build an experimental planetary dynamo:

1. Liquid metal $P_m << 1$
2. Vigorous motion $R_m = \frac{Ua}{\eta} \approx 100$
3. Rapid rotation $\lambda = \frac{\omega_{Alfven}}{\Omega} << 1$
4. Magnétostrophy $\Lambda \sim 1$

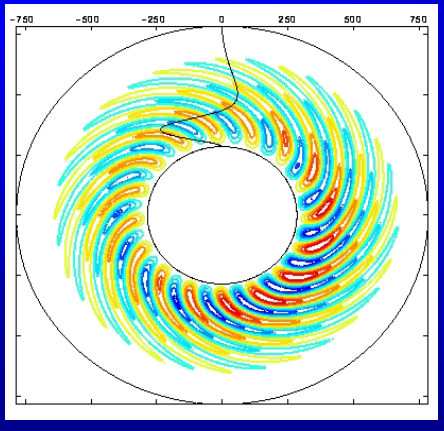
Planetary Dynamo

$$Power \approx C \frac{\rho \eta^3}{a} R_m^2 \frac{\Lambda_d^2}{\lambda^2}$$

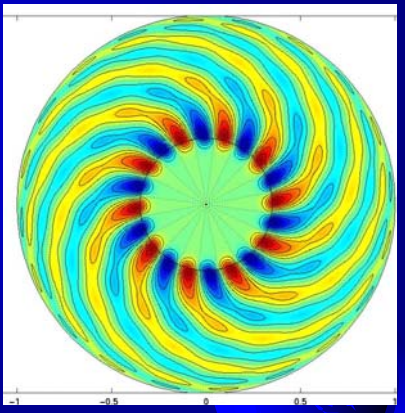


A planetary Dynamo ?

Thermal convection



Differential rotation



$E=10^{-6}$

Planetary Dynamo

$$R_m = 100$$

$$\lambda = 0.25$$

$$\Lambda_d \approx 1$$

$a = 1$ m

$Power = 600$ kW

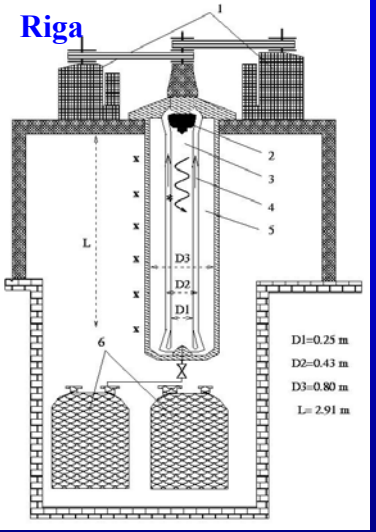
$\Omega = 450$ rpm

$\Delta\Omega = 150$ rpm

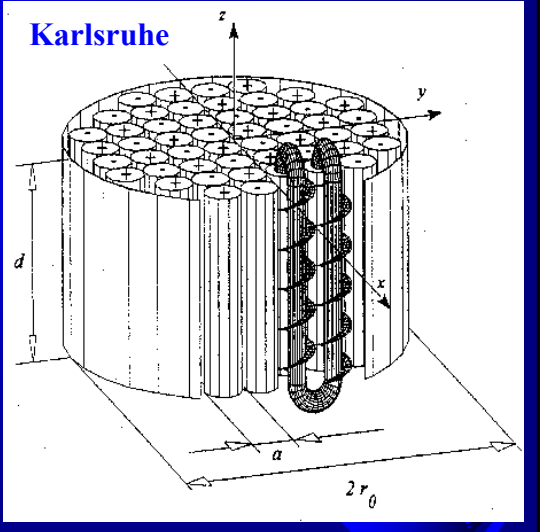
$B = 0.3$ T

Riga and Karlsruhe dynamos

Riga



Karlsruhe



DTS

$R_m < 30$

$\lambda > 0.01$

$\Lambda_i > 0.01$

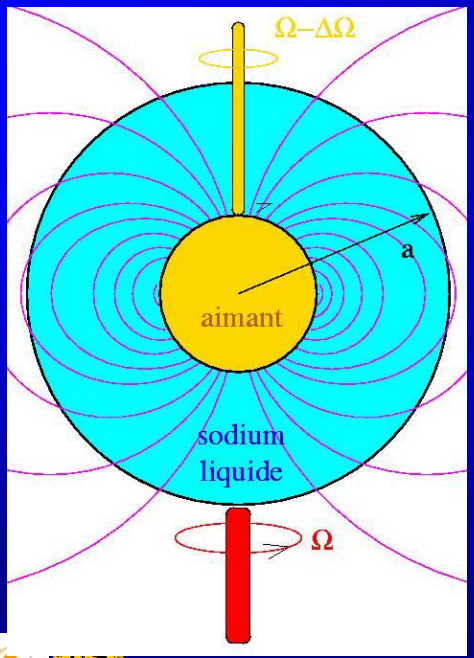
$a = 0.21$ m

Power = 20 kW

Ω = 0-2000 rpm

$\Delta\Omega = \pm$0-2000 rpm

$B = 20$ mT



DTS experiment

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$\lambda > 0.01$

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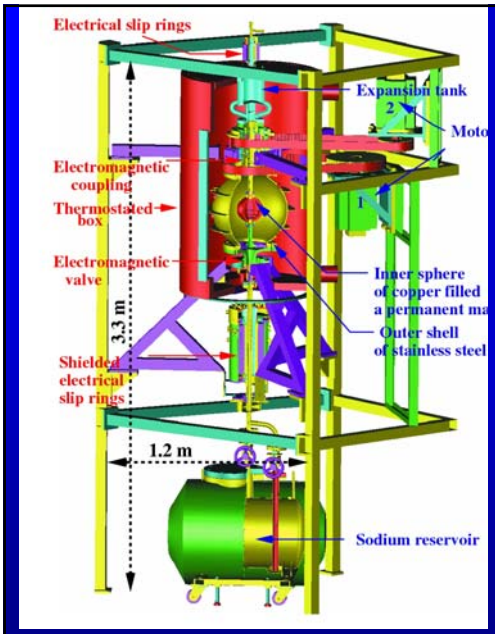

DTS : 40 liters sphere