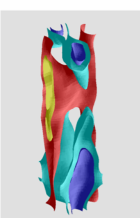
What happens if we place a pipe filled with mercury in a *(very)* strong magnetic field, and why would we do that?

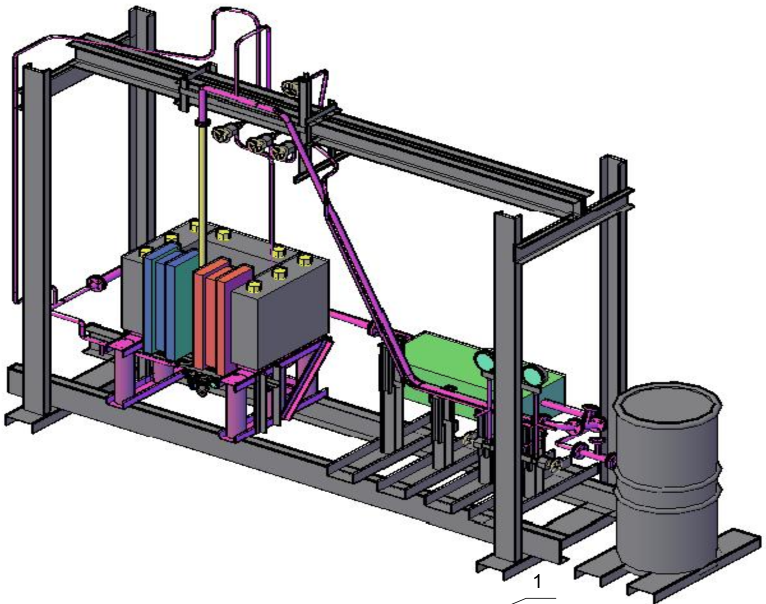
Oleg Zikanov

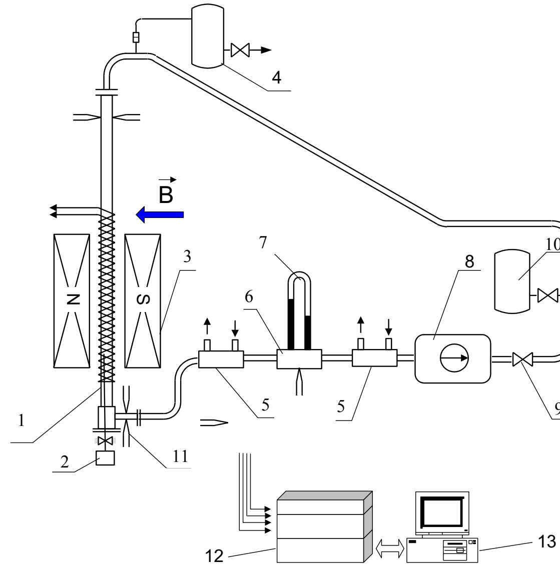


Numerical Fluid and Thermal Science Laboratory

University of Michigan Dearborn

DEARBORN





1 – Work area;

2 – Probe arm;

3 – Electromagnet;

4 – Compensation tank;

5 – Heat exchanger;

6 – Flow measurement;

7 – Pressure switch;

8 – Electromagnet pump;

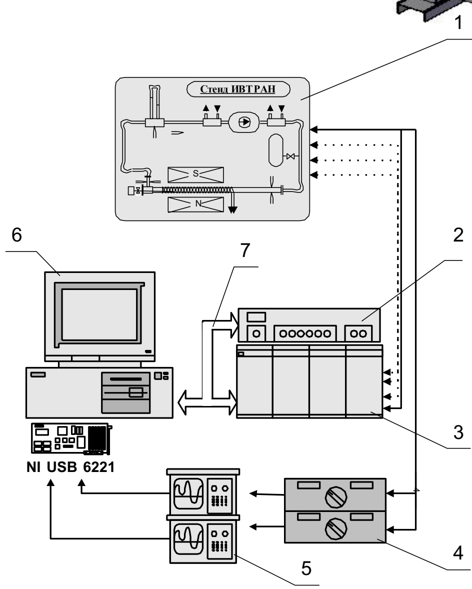
9 –Control valve;

10 – Tank with mercury;

11 – Thermocouple;

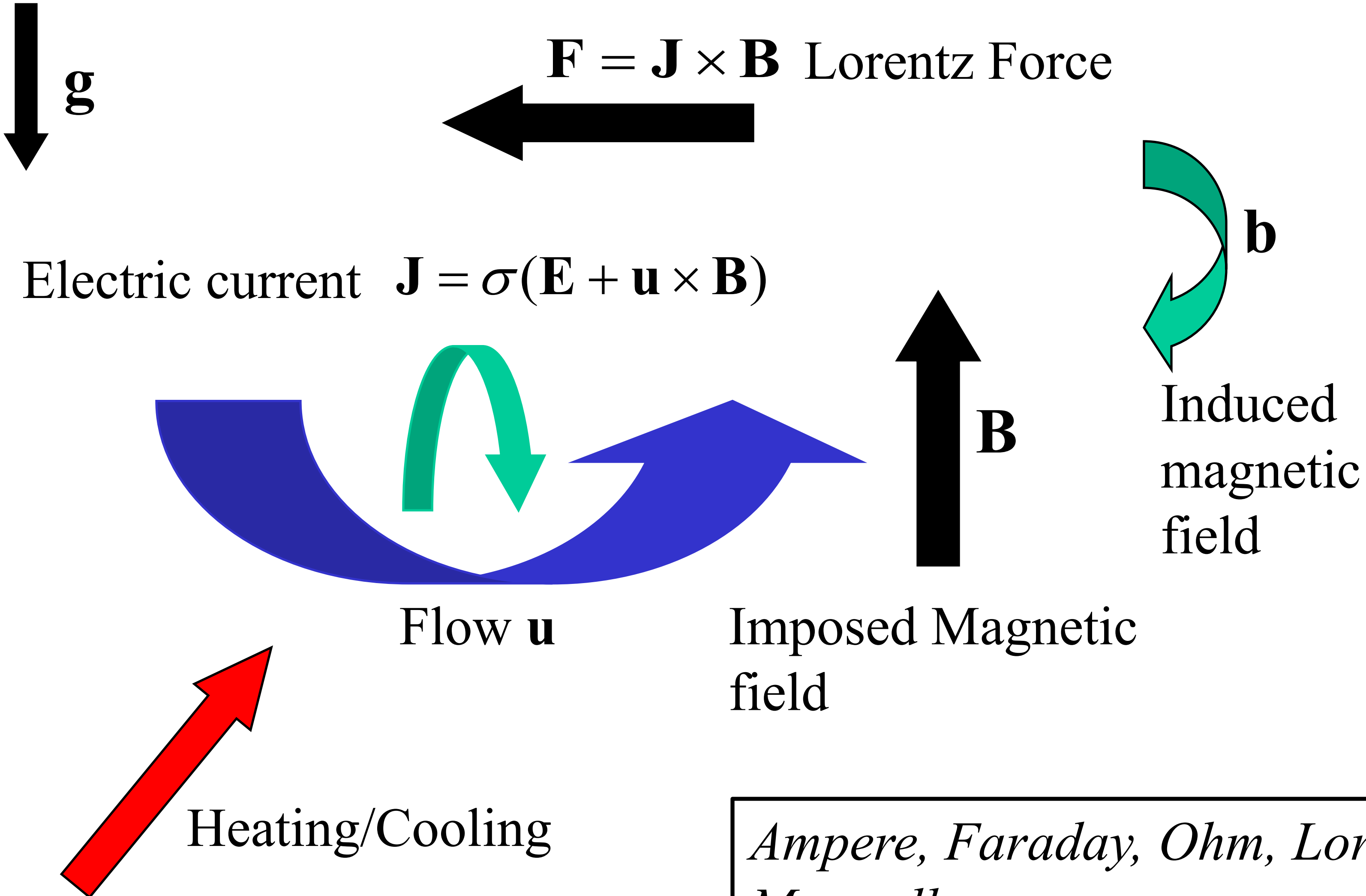
12 – Measurement instrument rack;

13 – Computer



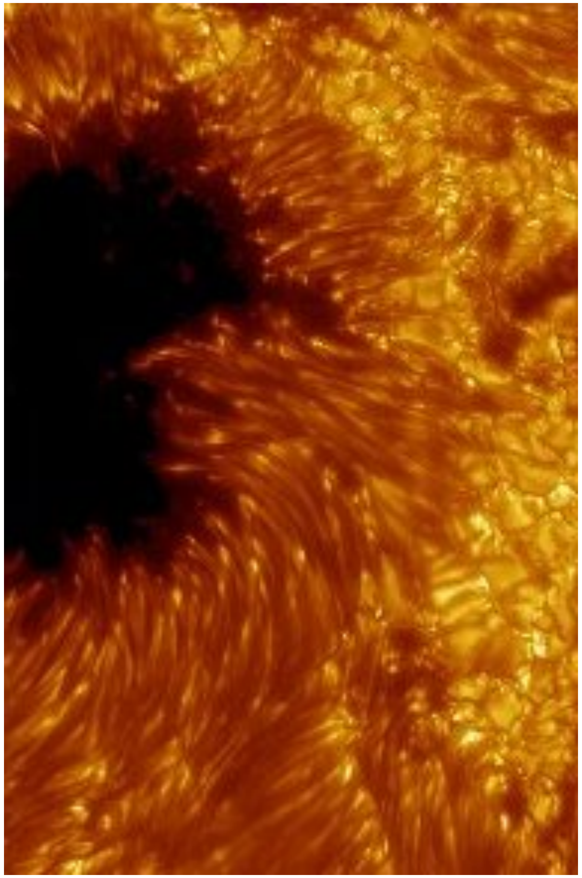
Parameter	Value
Magnetic Induction, T	1,5-2,5
Cross-size, mm	30-100
Magnet core length, mm	1000

Electrically conducting liquid

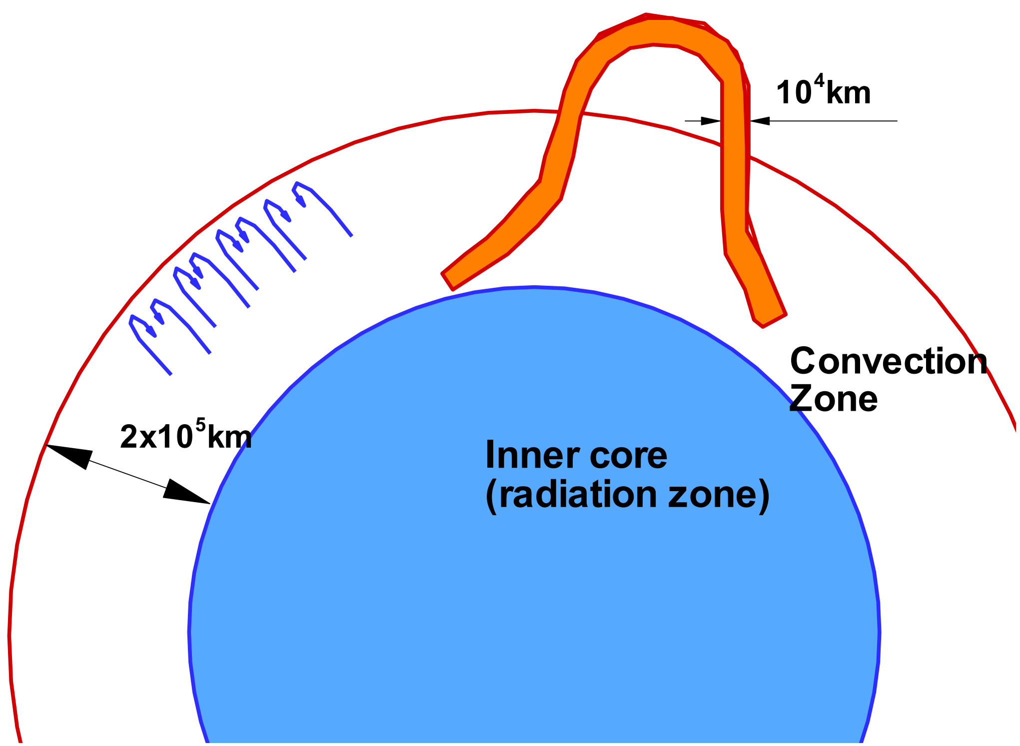


Ampere, Faraday, Ohm, Lorentz
~~*Maxwell*~~

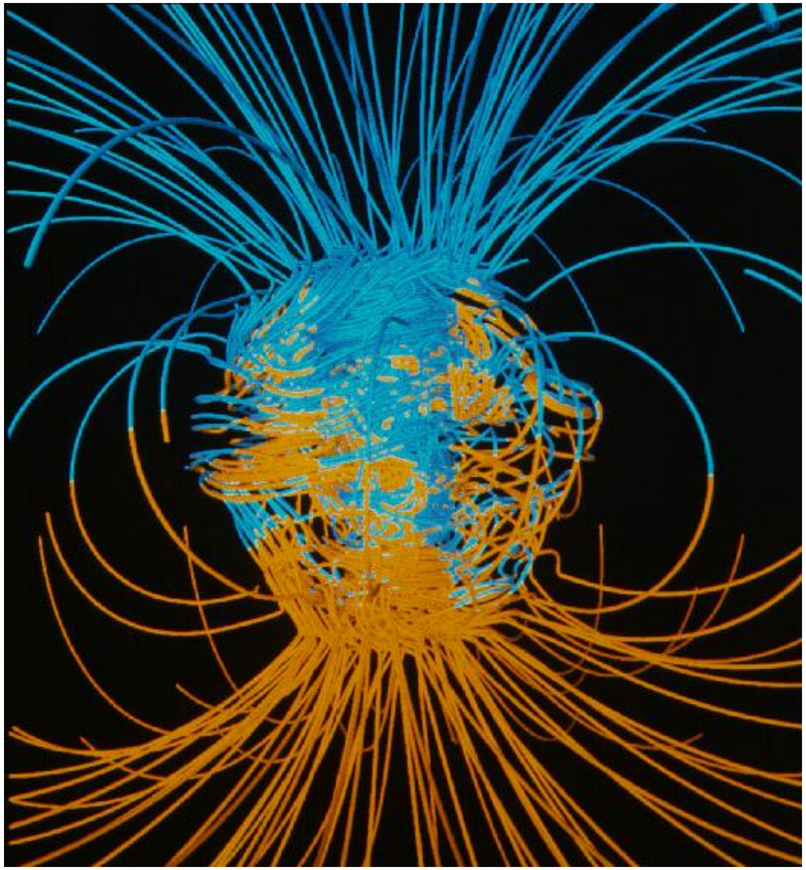
sunspots

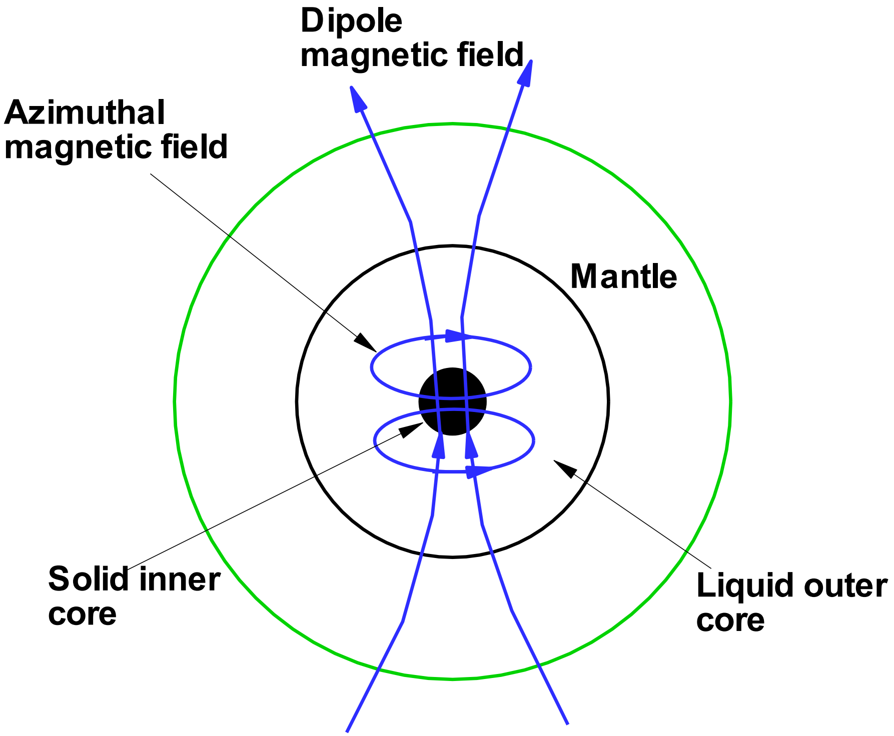


Sunspot – high resolution observations. Nature 2002



dynamo

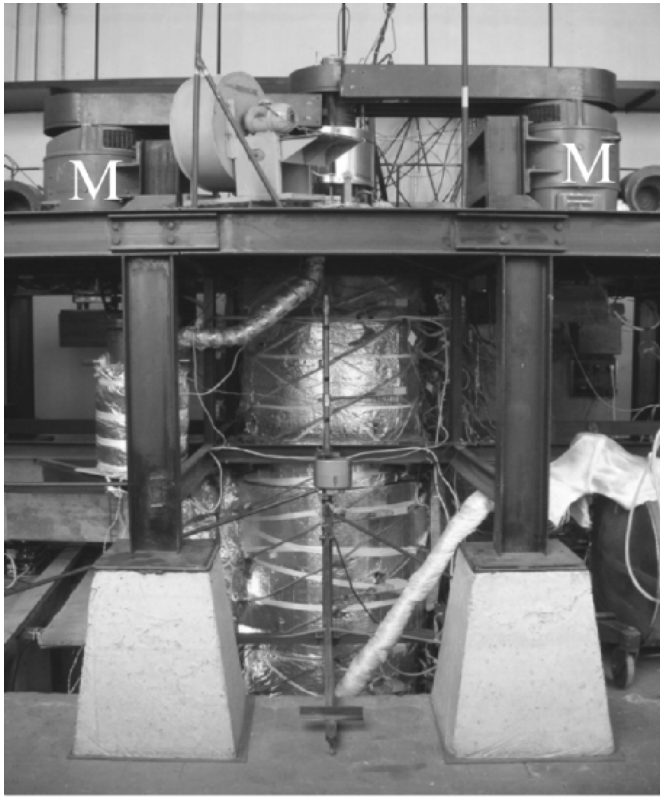


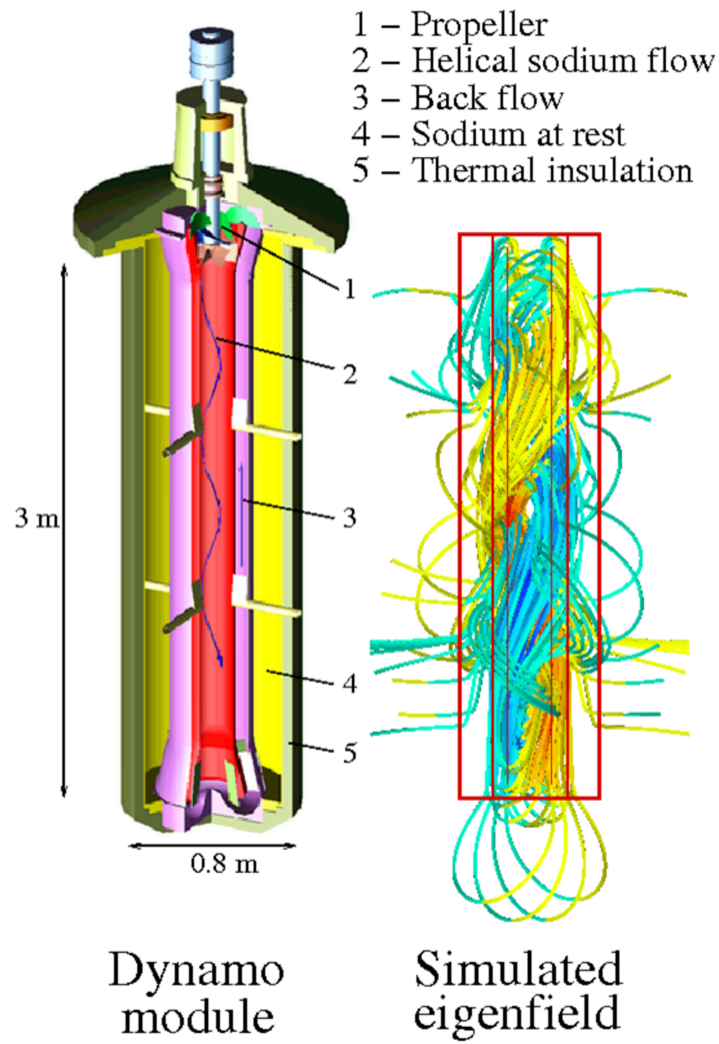


Glatzmaier, Roberts

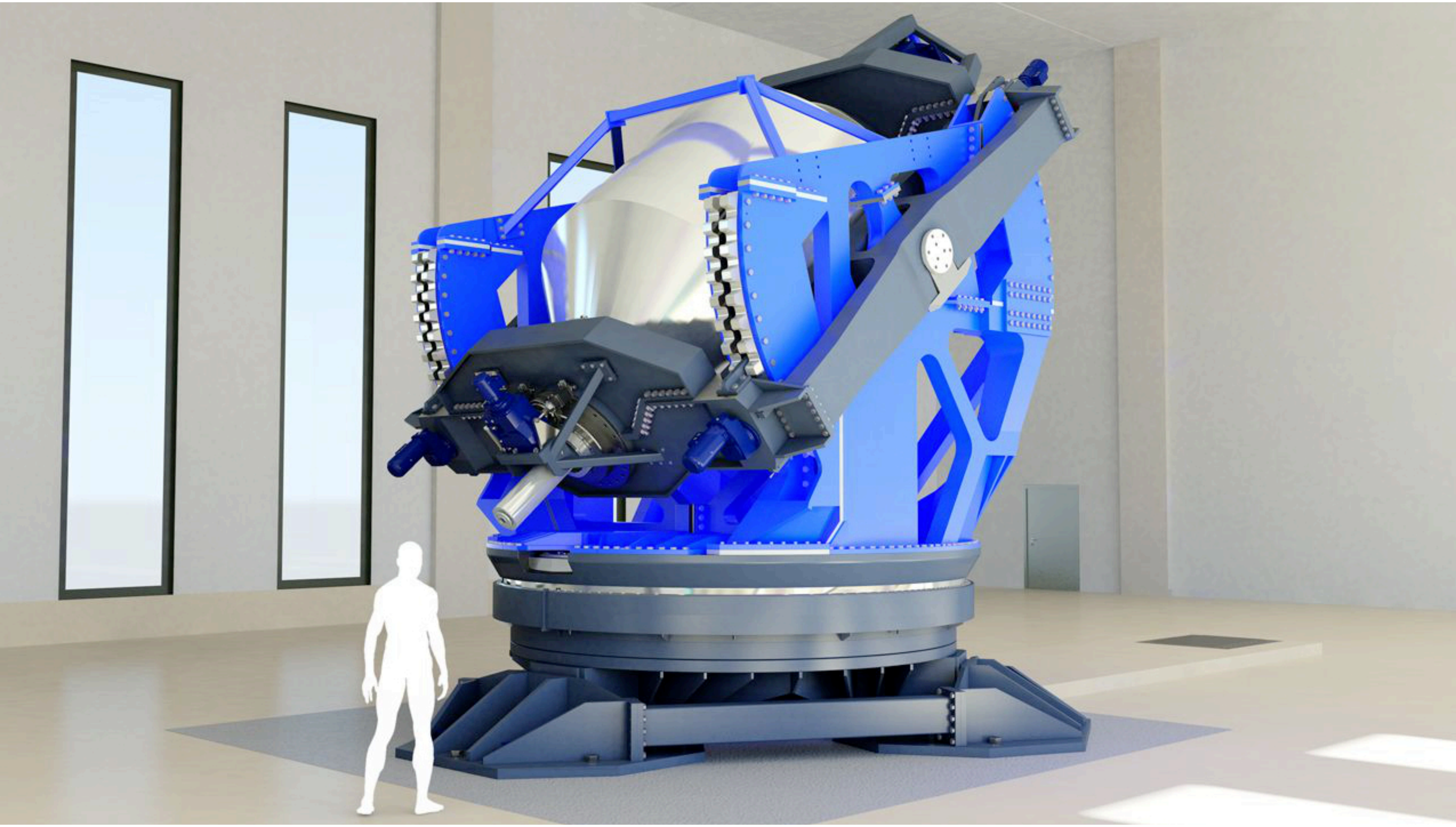
Contemp. Phys. **38**, 1997

Riga dynamo experiment, 1999



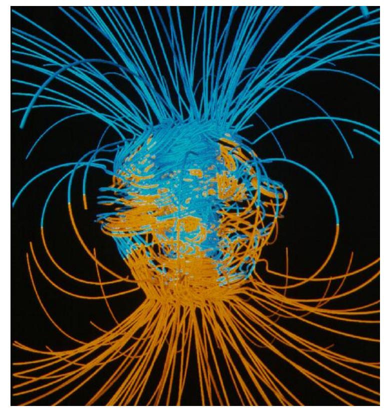


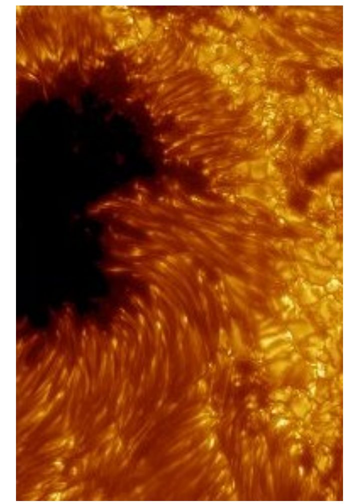
Dresden-Rossendorf dynamo experiment (*Dresdyn*)



magnetic Reynolds number – *not high enough!*

laboratory experiments are here





0.01 - 1

10^2

10^8

Re_m

$$Re_m = UL\sigma\mu$$

MHD flows at low Re_m

Diffusion-dominated solutions for magnetic field

Instantaneous adjustment of magnetic field to changes of velocity

Effect of flow on imposed magnetic field is weak

Quasi-static (inductionless) approximation

$$\mathbf{b} << \mathbf{B}_0, \qquad \mathbf{B} = \mathbf{B}_0 + \mathbf{b} \approx \mathbf{B}_0$$

$$\mathbf{J} = \sigma\left(-\nabla\phi + \mathbf{u} \times \mathbf{B}_0\right)$$

$$\mathbf{F} = \mathbf{J} \times \mathbf{B}_0$$

$$\nabla^2\phi = \sigma\nabla \cdot (\mathbf{u} \times \mathbf{B}_0)$$

effect of magnetic field on flow structure

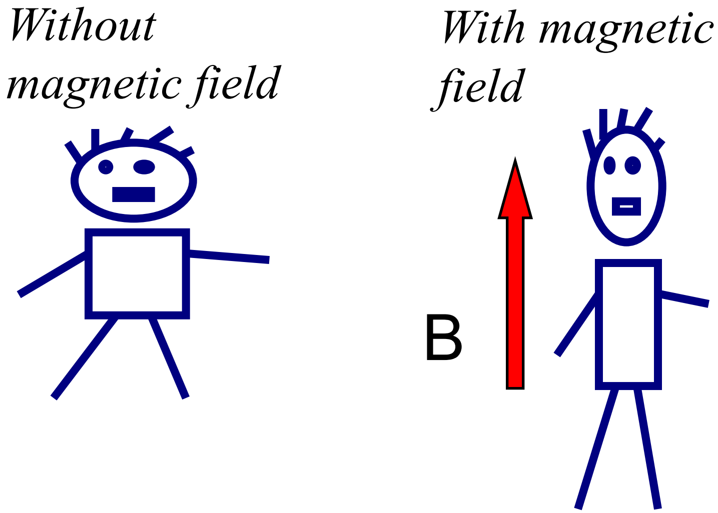
Joule dissipation of induced electric currents:

$$\frac{d}{dt}\int \frac{1}{2}\rho \mathbf{u}^2 dV = -\int \varepsilon dV - \int \mu dV$$

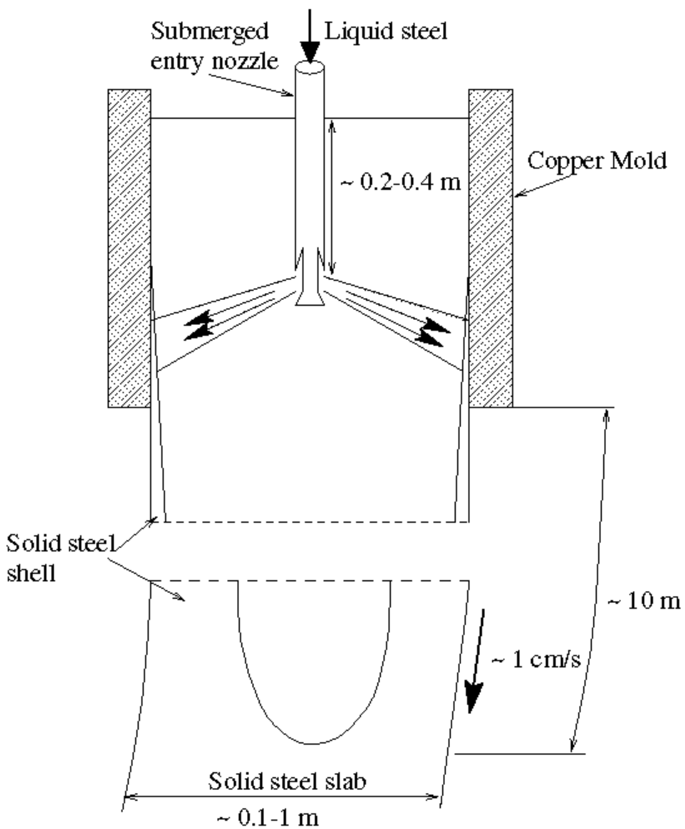
$$\mu = \frac{1}{\sigma}\int \mathbf{J}^2 dV$$

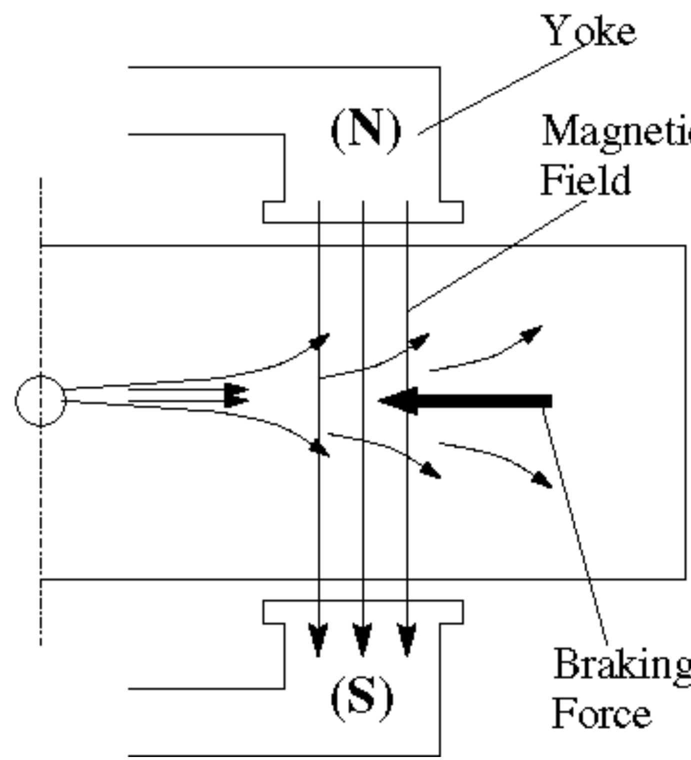
Conventional turbulence disappears in a sufficiently strong magnetic field

anisotropy of flow structures:



continuous casting of steel

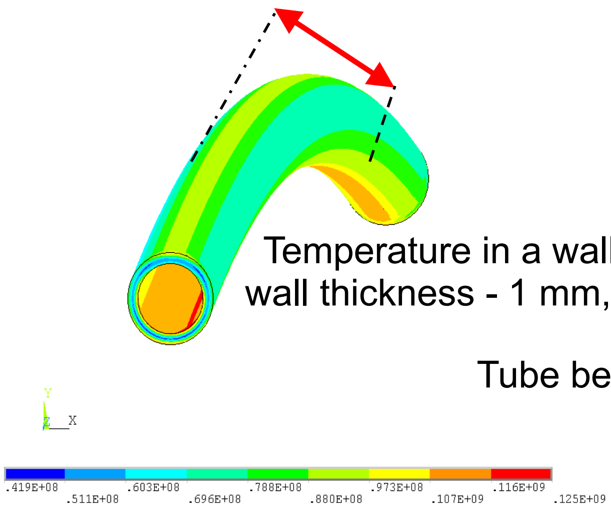




- Induction stirring and heating
- Magnetic valves
- Electromagnetic pumps
- Electromagnetic flow meters
- Microfluidic mixers
- …

combined effect of heating and magnetic field on a flow of liquid metal in a tube

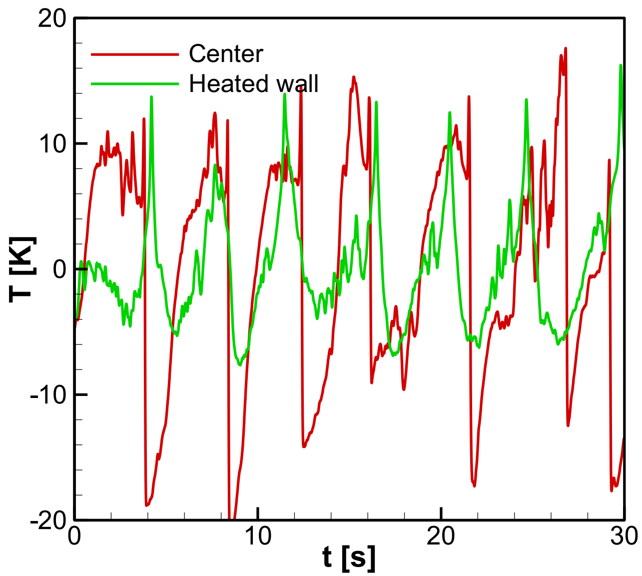
thermal stresses



Temperature in a wall (length - 1 m, wall thickness - 1 mm, steel AISI 304)

Tube bending

High-amplitude low-frequency oscillations of temperature



experiment,
Melnikov et al (2014)