Простейшая магнитная модель геодинамо

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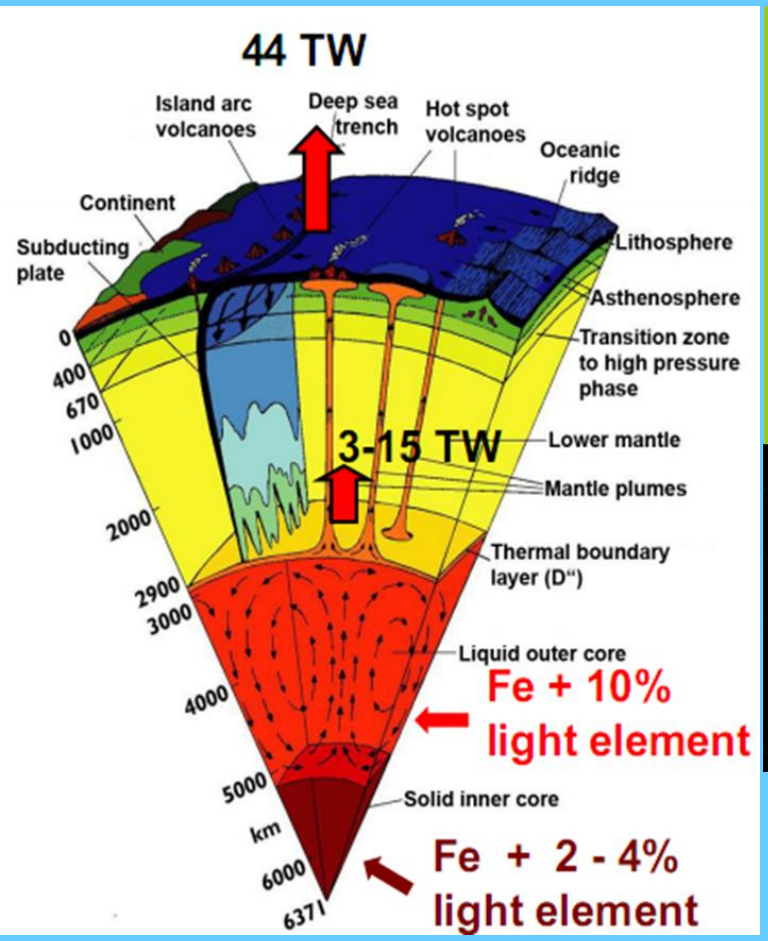
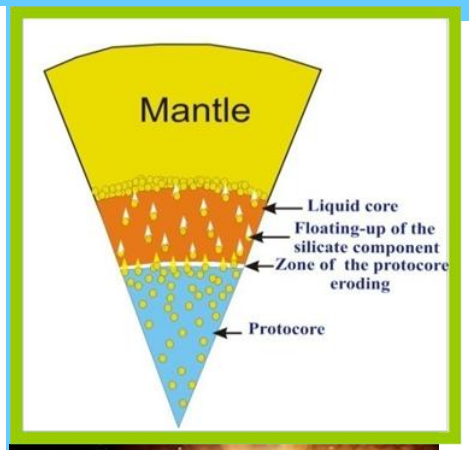
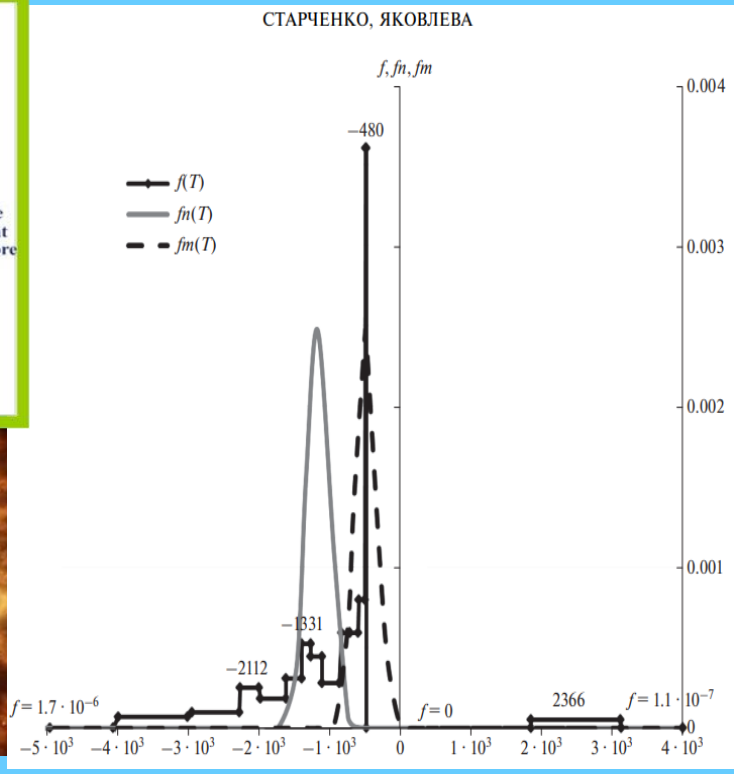






1 ТВт/M_{core}=0.5пВт/кг, 10^3лет

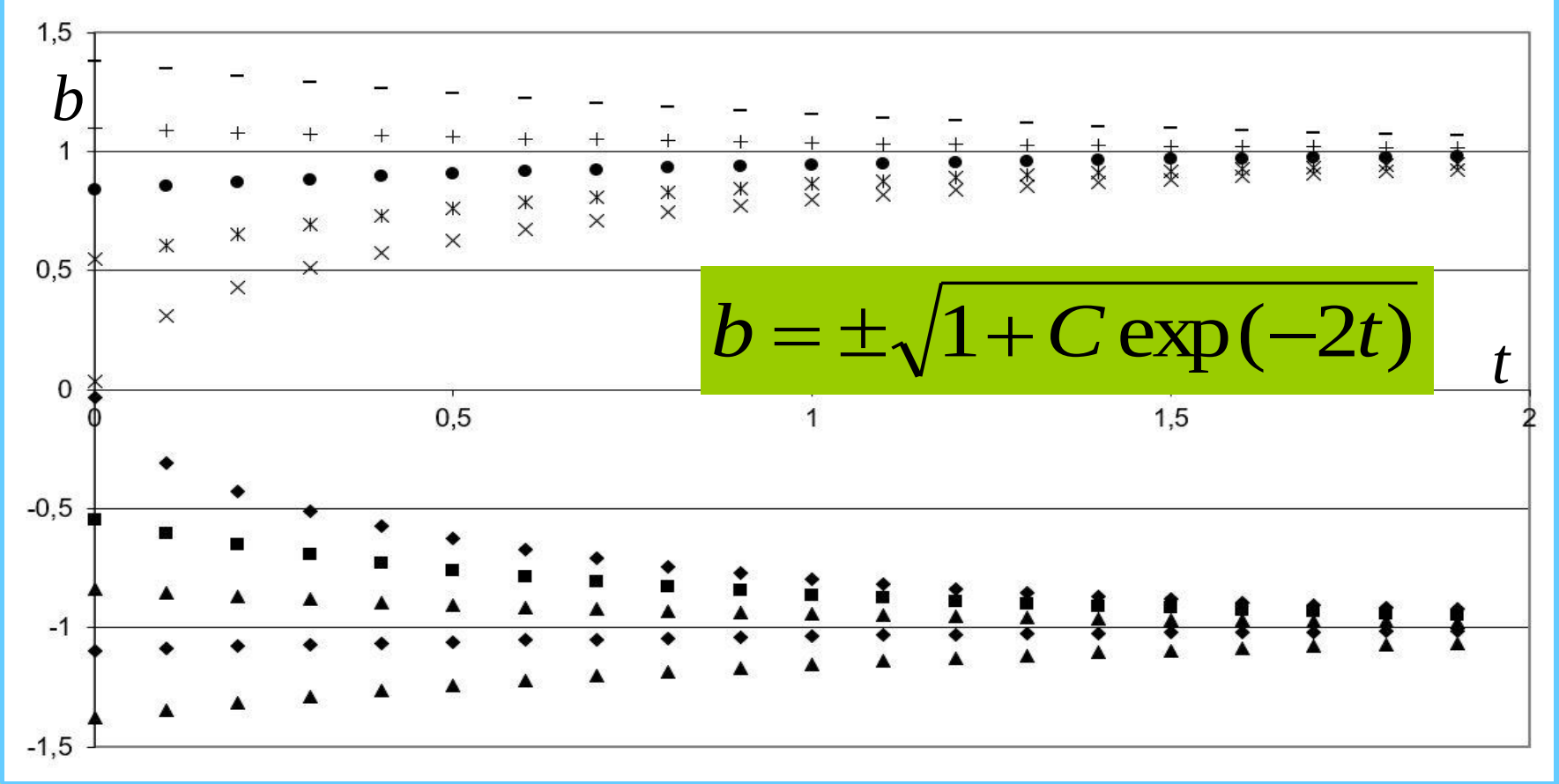
Суммируем и пренебрегаем «кинетикой» ~V^2

$$\rho \frac{d}{dt}\left(\int_0^{r_*} \frac{V^2}{2} d^3r\right) = \int_0^{r_*}\left(\rho \mathbf{A}\cdot\mathbf{V} - \frac{\mathbf{V}\times\mathbf{B}\cdot\nabla\times\mathbf{B}}{\mu_0} - \rho\nu\left|\nabla\times\mathbf{V}\right|^2\right) d^3r$$

$$\frac{d}{dt}\left(\int_0^{r_*} \frac{B^2}{2\mu_0} d^3r\right) = \int_0^{r_*}\left(\frac{\mathbf{V}\times\mathbf{B}\cdot\nabla\times\mathbf{B}}{\mu_0} - \frac{\left|\nabla\times\mathbf{B}\right|^2}{\mu_0^2\sigma}\right) d^3r$$

$$b\,db/dt = \mu_0 \rho a - b^2/T$$

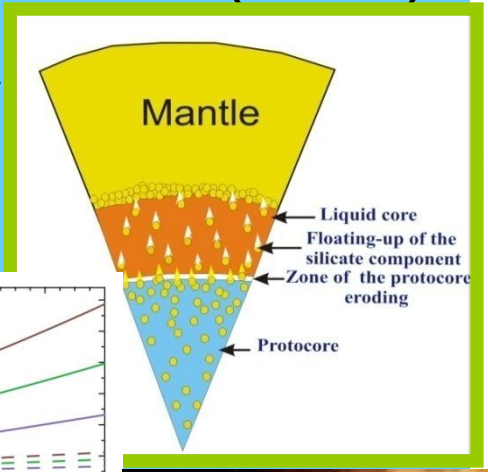
$$(T\mu_0\rho a)^{1/2} = b_s = 100\ \mathrm{G}$$

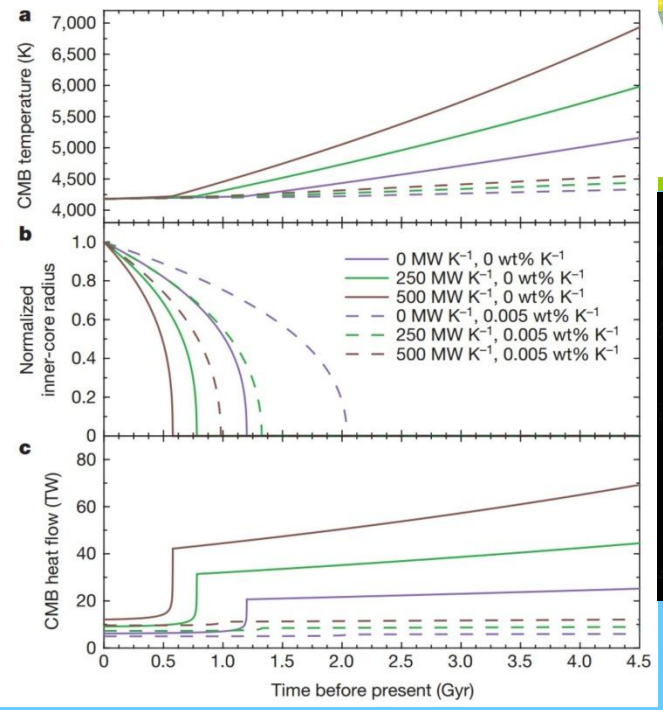


Энергетические уравнения эволюции дают магнитную модель геодинамо из 1го линейного ОДУ. В начальный момент скорость роста поля обратно пропорциональна величине начального поля. На временах порядка тысячи лет и более среднеквадратичное магнитное поле стабилизируется на уровне около 100 Гс.

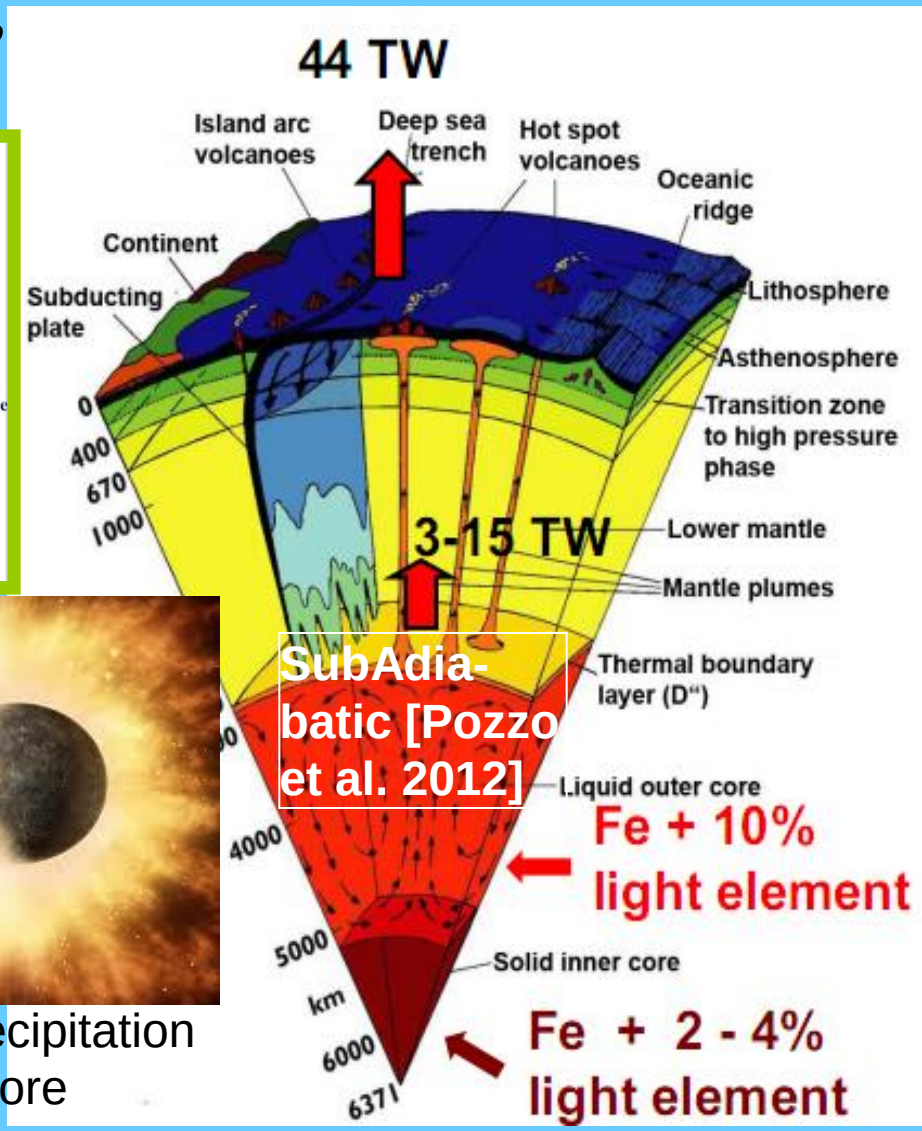
compositional CONVECTION thermal

Braginsky (1963): crystallization,
Pushkarev & Starchenko (2010):
protocore concept
+ O'Rourke &
Stevenson (2016)





magnesium precipitation
from the protocore



Velocity*Acceleration = Buoyancy Flow ≡ Convection Power/Mass

$$VA = F \quad (1)$$

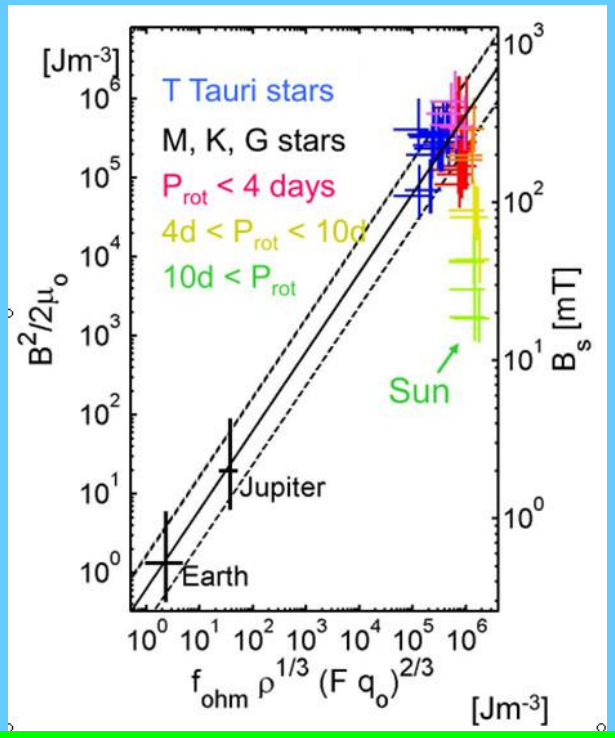
Starchenko & Jones (2002) Icarus, V.157.

$$(\mathbf{V}\times\mathbf{B})\cdot\nabla\times\mathbf{B} =$$

$$\mu\rho\mathbf{V}\cdot[\mathbf{A}$$

$$\cancel{\doteq -\nabla p - \partial\mathbf{V}/\partial t}$$

$$\cancel{+\nu\nabla\times(\nabla\times\mathbf{V})]}$$



$$E_j \equiv$$

$$<(\mathbf{V}\times\mathbf{B})\cdot\mathbf{1}_j>$$

$$= \mu\rho VAh/D$$