

Magnetic fields from the second order perturbation theory

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Based on **Phys.Rev.D91,123510(2015)**, Collaborator: K.Ichiki, K.Takahashi, N.Sugiyama

Magnetic fields are observed ubiquitously even on large scales.

- galaxy, cluster scales $\sim O(10^{-6})$ Gauss,
- Intergalactic scales (or voids?) $> O(10^{-22})$ Gauss

Cosmological magnetic fields = **seed fields** + dynamo mechanism

Question.

Can we generate **seed fields** in the standard cosmology?

→ 2nd order perturbation theory

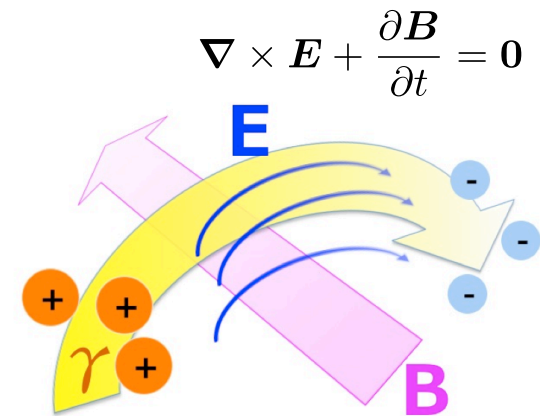
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Harrison mechanism

Primordial plasma in the early universe

- Thomson scattering induces the relative velocity between protons and electrons
- The rotational currents induce magnetic fields.



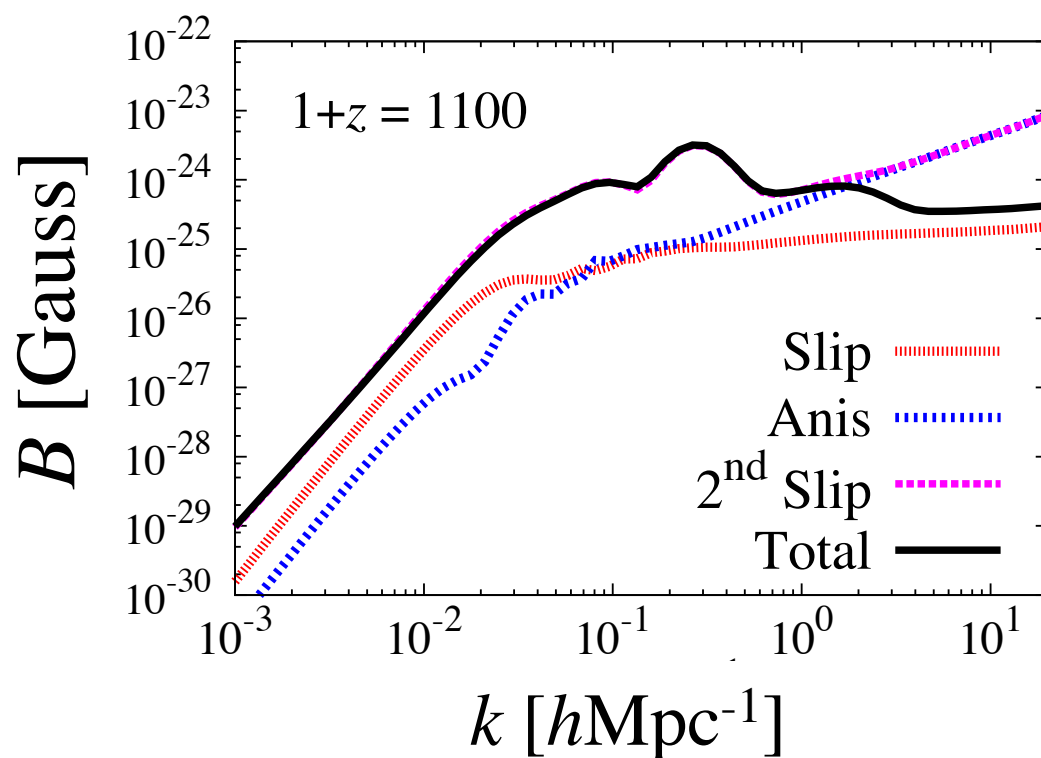
$$\frac{dB^i}{dt} = \frac{4\sigma_T \rho_\gamma^{(0)} a}{3e} \epsilon^{ijk} \left[\frac{1}{2} \delta v_{\gamma bj, k}^{(2)} - \delta_{\gamma, j}^{(1)} \delta v_{\gamma bk}^{(1)} - \frac{3}{4} \left(v_{el}^{(1)} \Pi_{\gamma j}^{(1)l} \right)_{,k} \right]$$

2nd order Slip term
Slip term Anisotropic stress

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Magnetic field spectrum at cosmological recombination:



Remark

- Bump at $k \sim 0.5 h\text{Mpc}^{-1}$
- Non-trivial cancellation!