CMB ANISOTROPIES GENERATED BY A STOCHASTIC BACKGROUND OF PRIMORDIAL MAGNETIC FIELDS WITH NON-ZERO HELICITY

(M. Ballardini, F. Finelli & D. Paoletti, in prep. 2014)

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

"2nd Azores School on Observational Cosmology", Angra do Heroísmo, 6 June 2014

COSMOLOGICAL MAGNETIC FIELDS

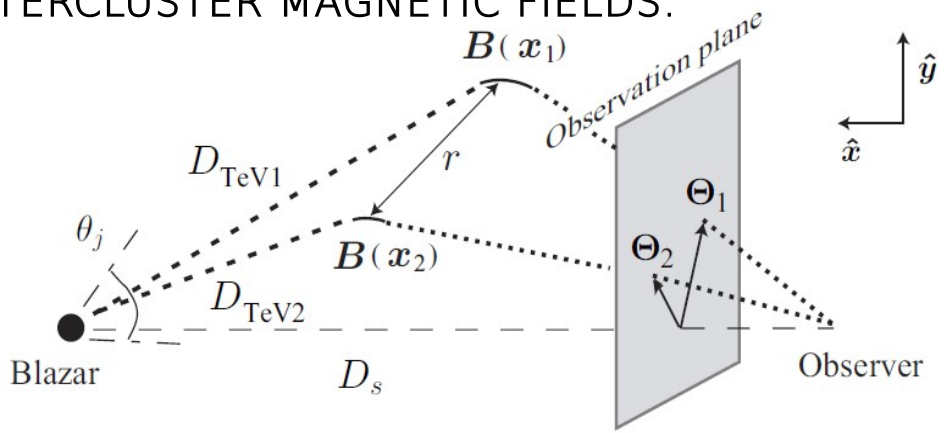
ASTROPHYSICAL ORIGIN?

- LARGE SCALE MAGNETIC FIELDS ARE COMMON FEATURES OF SEVERAL ASTROPHYSICAL OBJECTS

  Ryu (2011) for a review

PRIMORDIAL SEEDS?

- INTERCLUSTER MAGNETIC FIELDS:



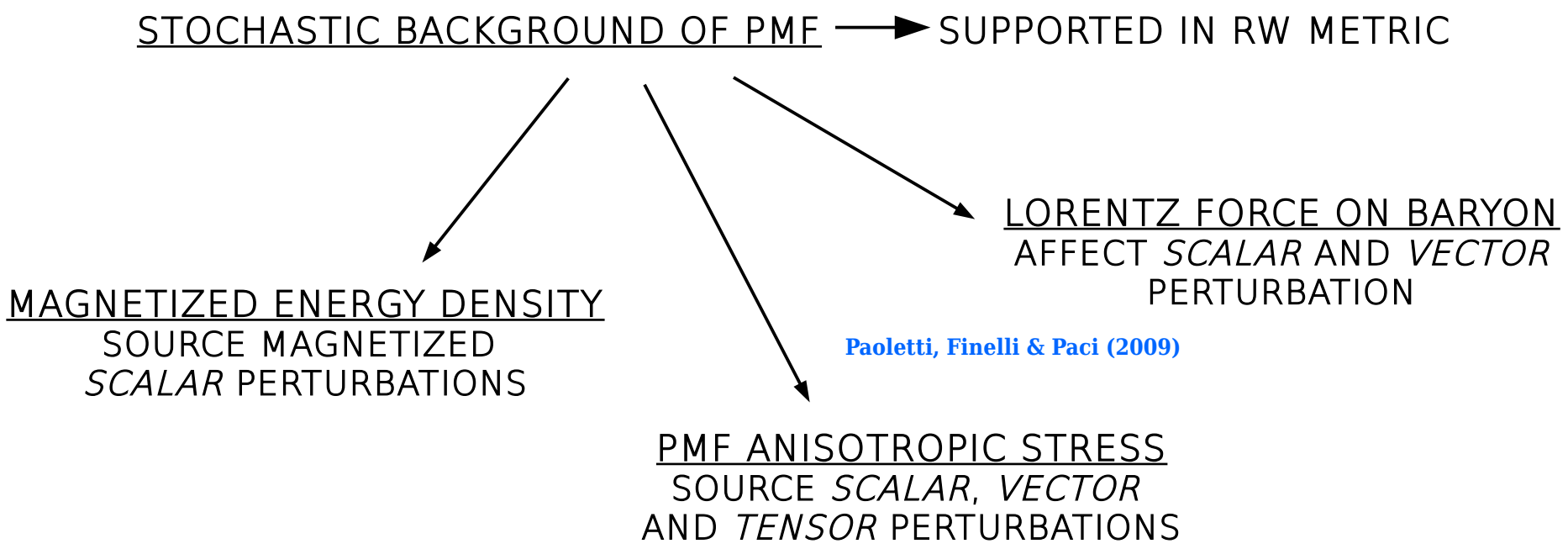
Neronov & Vovk (2010); Tavecchio et al. (2010); Tayloe et al. (2011); Vovk et al. (2012); Tashiro et al. (2013)

WHERE DO THEY COME FROM?

HYPOTHESIS OF REMNANTS MF FROM PRIMORDIAL SEEDS!!

IMPRINTS OF PMFs

- Big Bang Nucleosynthesis; **Kahniashvili et al. (2010); Grasso & Rubinstein (1995)**
- Large Scale Structure; **Shaw & Lewis (2010); Fedeli & Moscardini (2012)**
- CMB spectral distortions; **Kunze & Komatsu (2014); Ganc & Sloth (2014)**
- CMB anisotropies:



POWER-SPECTRA OF THE PMF EMT

- COMPENSATED MODES;
- INFINITE CONDUCTIVITY LIMIT (MHD) $\longrightarrow$ $\mathrm{B}(\mathrm{x},\tau)=\mathrm{B}(\mathrm{x})/a(\tau)^2$
- TWO POINT CORRELATION FUNCTION:

$$\left\langle \mathrm{B}_i(\mathbf{k})\mathrm{B}_j^*(\mathbf{h})\right\rangle \equiv \frac{(2\pi)^3}{2}\delta(\mathbf{k}-\mathbf{h})\left[\mathrm{P}_{ij}\mathrm{P}_S(k)+\imath\epsilon_{ijl}\hat{k}_l\mathrm{P}_A(k)\right]$$

- POWER SPECTRUM:

$$P_{S/A}(k)=A_{S/A}\left(\frac{k}{k_*}\right)^{n_{S/A}}\neq 0$$

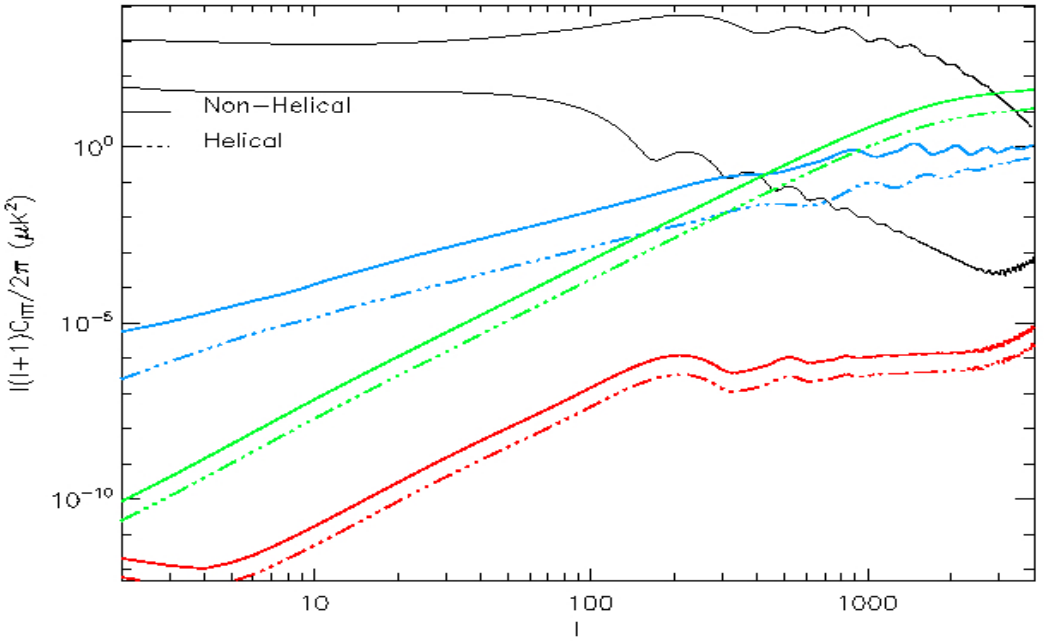
ONLY FOR $k < k_D$.

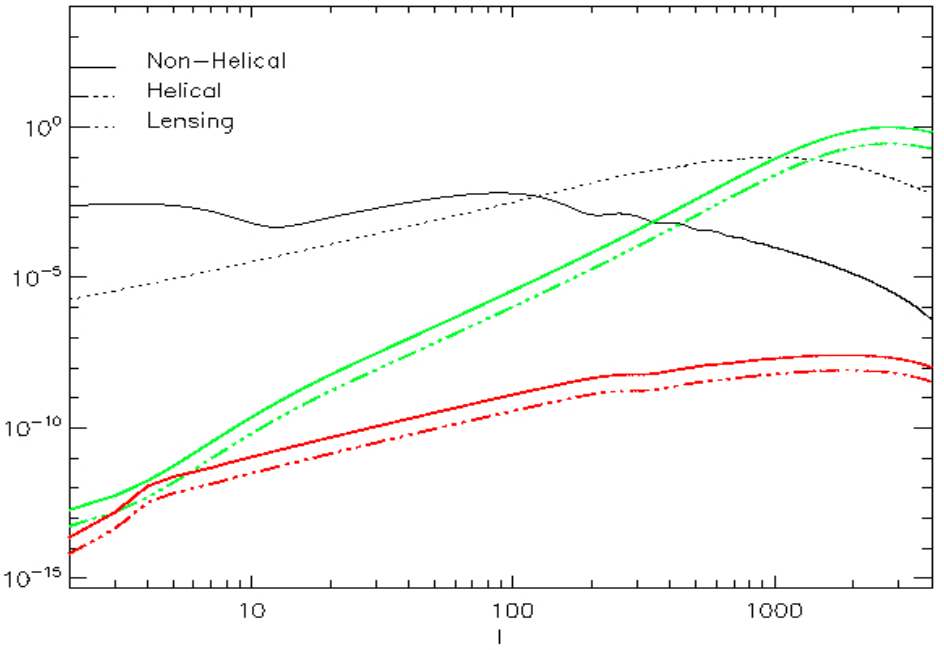
- ENERGY-MOMENTUM TENSOR:

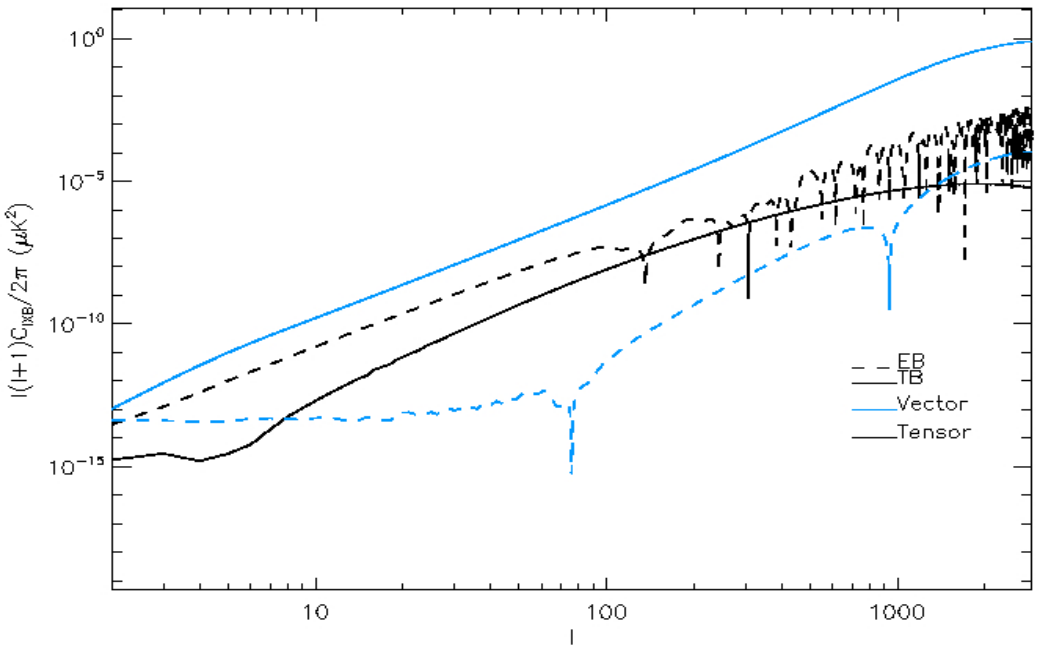
$$\begin{aligned}\langle\tau_{ab}(\mathbf{k})\tau^*_{cd}(\mathbf{h})\rangle \;=\; & \frac{1}{4(4\pi)^2}\delta(\mathbf{k}-\mathbf{h})\int d^3p\Big\{\Big[P_S(p)P_S(|\mathbf{k}-\mathbf{p}|)\Big(P_{ac}(p)P_{bd}(|\mathbf{k}-\mathbf{p}|)+P_{ad}(p)P_{bc}(|\mathbf{k}-\mathbf{p}|)\Big)\\ & -P_A(p)P_A(|\mathbf{k}-\mathbf{p}|)\big(\epsilon_{aci}\epsilon_{bdj}\hat{p}_i\widehat{(\mathbf{k}-\mathbf{p})}_j+\epsilon_{adi}\epsilon_{bcj}\hat{p}_i\widehat{(\mathbf{k}-\mathbf{p})}_j\big)\\ & +\imath P_S(p)P_A(|\mathbf{k}-\mathbf{p}|)\Big(P_{ac}(p)\epsilon_{bdi}\widehat{(\mathbf{k}-\mathbf{p})}_i+P_{ad}(p)\epsilon_{bci}\widehat{(\mathbf{k}-\mathbf{p})}_i\Big)\\ & +\imath P_S(p)P_A(|\mathbf{k}-\mathbf{p}|)\Big(\epsilon_{aci}P_{bd}(|\mathbf{k}-\mathbf{p}|)\hat{p}_i+\epsilon_{adi}P_{bc}(|\mathbf{k}-\mathbf{p}|)\hat{p}_i\Big)\Big]\\ & +\ldots\delta_{ab}+\ldots\delta_{cd}+\ldots\delta_{ab}\delta_{cd}\Big\}\,.\end{aligned}$$

Ballardini, Finelli & Paoletti, in prep. (2014)

CMB ANISOTROPIES







$B_{1Mpc} = 5$ nG
$n_S = n_A = -1$

Ballardini, Finelli & Paoletti, in prep. (2014)

CONCLUSIONS

- Computed the exact expressions for the EMT components including the helical contribution.
- Investigated the impact of a SB of PMFs with non-vanishing helicity on CMB anisotropies.
- Importance of the odd-correlators, TB and EB.

What's next?

Paoletti, Ballardini & Finelli, in prep. (2014)

- Constrain PMF with helical component with CMB data.
- Study how much initial helicity can be produced during the inflation.

$$-\frac{g}{4}\phi F^{\mu\nu}\tilde{F}_{\mu\nu}$$

THANK YOU !!