Kalb-Ramond Fields and the CMBR

Talk at UNICOS2014 (AULAKHFEST)

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May 13-15, 2014

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- Incorporation into warped $D = 5$ spacetime (Randall-Sundrum) $\Rightarrow$ 'antiwarping' $\rightarrow$ large B-pol ! ?

  Maity,SenGupta 2003; Maity,PM,SenGupta 2004; Chatterjee,PM 2005

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- Vector gauge parameter ξ^a has $U(1)$ type of gauge invariance ('ghosts for ghosts') Kaul 1978; Townsend 1979

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Compactification details determine $D = 4$ $\mathcal{G}_{gauge}$; for Calabi-Yau $\to E_6$

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Effective Interaction Action

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$$\Delta\Theta_{cos} \simeq 2hf_0\Delta t$$

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- BICEP2 : negligible pol plane rotation

Beyond Het String : P-violating KR Augmentation

New Augmented KR field strength

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- Has potential for generation of $\not{P}$ CMB pol anisotropy correlations from P-sym correlations

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$$\begin{aligned}\mathcal{P}_{\alpha\beta} \;&\equiv\; \frac{E_\alpha E^*_\beta}{|E_1|^2 + |E_2|^2} \\ &=\; \frac{1}{2} I_{\alpha\beta} + \xi_1(\sigma_1)_{\alpha\beta} + \xi_2(\sigma_2)_{\alpha\beta} + \xi_3(\sigma_3)_{\alpha\beta}\end{aligned}$$

Generation of $\not{P}$ CMB pol anisotropy correlations

Recall : temperature anisotropy

$$\frac{\Delta T}{T}(\vec{n}) \; = \; \sum_{l,m} a^T_{lm} \; Y^T_{lm}(\vec{n})$$

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Stokes parameter $\xi_{1,3} \in [-1, 1] \rightarrow$ lin pol. Circ pol $\xi_2 = 0$ for Thomson scattering $\Rightarrow \mathcal{P}_{\alpha\beta} = \mathcal{P}_{\beta\alpha}$

Decomposition into E , B

$$\mathcal{P}_{\alpha\beta}(\vec{n}) \;=\; \mathcal{P}^{E}_{\alpha\beta}(\vec{n}) + \mathcal{P}^{B}_{\alpha\beta}(\vec{n})\;,\; E \rightarrow grad\;,\; B \rightarrow curl$$

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Multipole Expansion of Pol tensors

$$\mathcal{P}^{(E)}_{\alpha\beta} \quad = \quad \sum_{l,m} a^{E}_{lm}\; Y^{E}_{lm,\alpha\beta}(\vec{n})$$

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If KR field dynamics appropriate, cosmic birefringence + $\not{P}$ $\Rightarrow$ generation of C_l^{TB} from C_l^{TE}

$\not{P}$ covariance from P-sym covariance

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$$C_l^{TB} \quad = \quad C_l^{TE} \sin \Delta\Theta_{cos}$$

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But even C_l^{BB} was thought earlier to be vanishingly small, so await confirmation of BICEP2

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Similarly $D=4$ Maxwell eq

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k \cdot A^{TT} = \ & 0 \ = n \cdot A^{TT} \Rightarrow A^{TT} \to 2 \text{ indep pol}
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Einstein eq

$$
R_a^b = 2G \left(F_{ac} \, F^{bc} - \frac{1}{4} \delta_a^b F^2 \right)
$$

Gravitationally induced nonlinear electrodynamics

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Known consequences : For spherically symmetric metrics $\rightarrow$ Reissner-Nordstrom black hole solution; for relatively small curvatures $\rightarrow$ gravitational lensing (light bending under gravity). Other consequence ?

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KR fields serve as sources for completely antisymmetric torsion $\rightarrow$ Einstein-Cartan sptm

Gravitationally induced nonlinear electrodynamics

$$\Box_g A^{Tb} = 2G\left(F_{ac}\, F^{bc} - \frac{1}{4}\delta^b_a F^2\right) A^{Ta}$$

Reminiscent of EM wave propagation in anisotropic media with nonlinear susceptibility

Known consequences : For spherically symmetric metrics $\rightarrow$ Reissner-Nordstrom black hole solution; for relatively small curvatures $\rightarrow$ gravitational lensing (light bending under gravity). Other consequence ?

KR fields serve as sources for completely antisymmetric torsion $\rightarrow$ Einstein-Cartan sptm

Does the projection to gauge-inert physical part of vector potential go through ? If so, F_{ab} in EC sptm is not gauge-dependent $\rightarrow$ need to explore.

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- Need to explore thoroughly gravity-induced nonlinear electrodynamics for vector potential for possible polarization effects