Non-Relativistic Strings and Non-geometric Backgrounds in DFT

Charles M. Melby-Thompson
Fudan University, Shanghai

APCTP: Duality and Novel Geometry in M-theory

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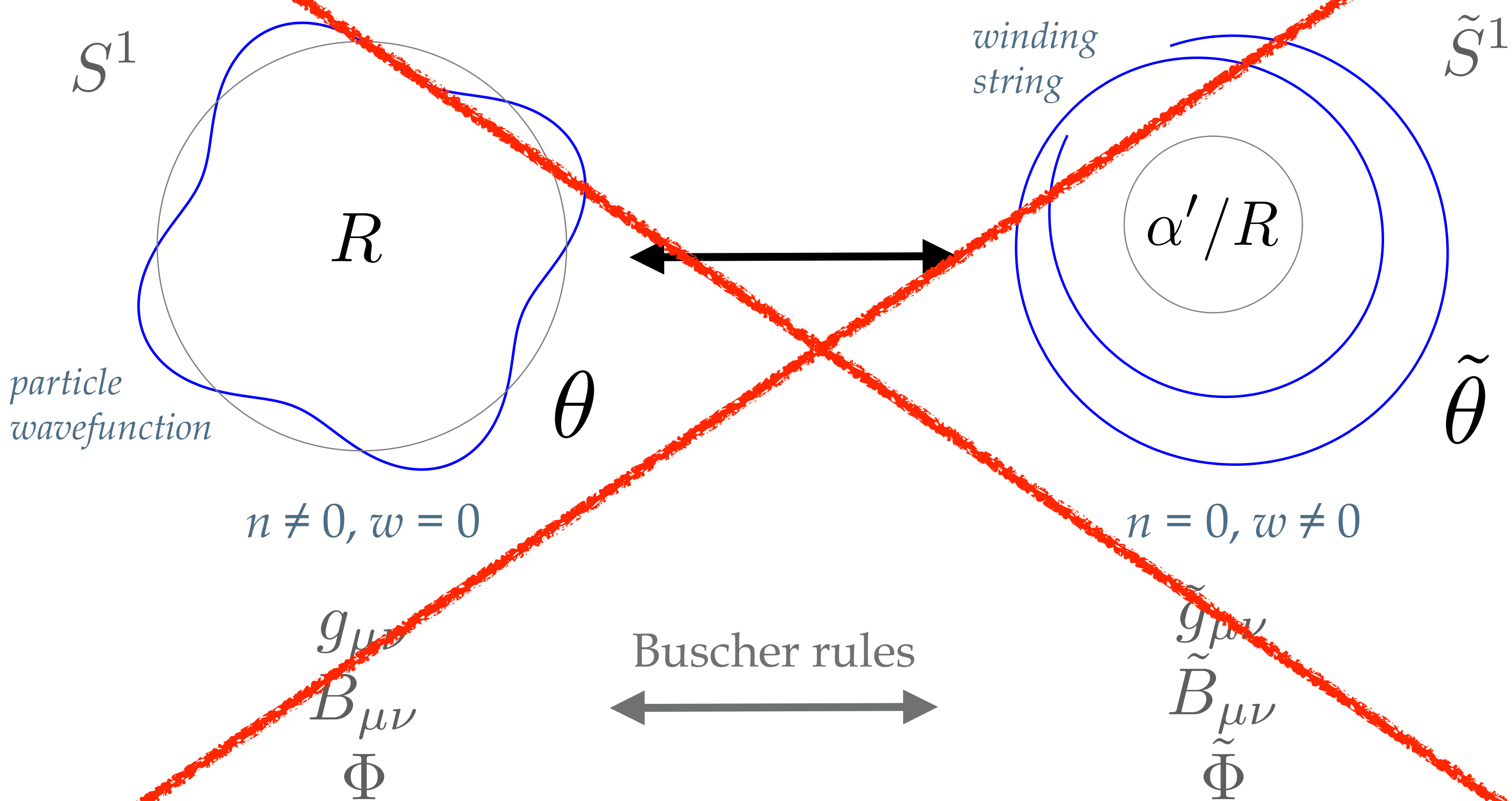
Based on arXiv:1508.01121
with S.M. Ko, R. Meyer, and J.-H. Park

What is Double Field Theory?

Idea: Make T-duality manifest (n ⟷ w)



Generalization to T^D : $O(D, D; \mathbb{Z})$ duality group

DFT: Quick Review

Doubled spacetime: $X^M = (\tilde{x}_\mu, x^\mu)$

Canonical inner product $J_{MN} = \begin{pmatrix} 0 & \delta^m_n \\ \delta^n_m & 0 \end{pmatrix}$ used to raise/lower indices

Coordinate patches glued using **generalized diffeomorphisms**.

infinitesimally: $\delta_\xi Y^M = \xi^N \partial_N Y^M - Y^N \partial_N \xi^M + Y^N \partial^M \xi_N$

Too many coordinates
$\Longrightarrow$ impose "section condition": $\begin{cases} \partial_M \partial^M \Phi(X) = 0 \\ \partial_M \Phi_1(X) \partial^M \Phi_2(X) = 0 \end{cases}$

Always choose $\dfrac{\partial}{\partial \tilde{x}_\mu} = 0$

Geometry: **DFT dilaton** $e^{-2d} = \sqrt{-g}e^{-2\Phi}$ and **generalized metric**

$$\mathcal{H}_{MN} = \mathcal{H}_{NM} = \begin{pmatrix} g^{-1} & -g^{-1}B \\ Bg^{-1} & g - Bg^{-1}B \end{pmatrix} \in O(D,D)$$

T-duality group *O(D,D)* acts by $\tilde{\mathcal{H}}_{MN} = \mathcal{O}_M{}^P \mathcal{O}_N{}^Q \mathcal{H}_{PQ}, \; \mathcal{O}^M{}_N \in O(D,D)$

DFT: Geometry and Non-Geometry

Standard geometry

$$\mathcal{H}_{MN} = \begin{pmatrix} g^{-1} & -g^{-1}B \\ Bg^{-1} & g - Bg^{-1}B \end{pmatrix}$$

Transition functions don't mix x^μ and $\tilde{x}^\mu$ non-trivially.

Non-geometry (e.g. "T-folds")

Locally geometric, but transition functions mix x^μ and $\tilde{x}^\mu$.

Example on torus: Going once around one circle, glue others using T-duality.

Also R fluxes, …

Hellerman, McGreevy, Williams;
Hull, Dabholkar
Shelton, Taylor, Wecht

Locally non-Riemannian spaces

Generalized geometries (with a sector) of the form

$$\mathcal{H}_{MN} = \begin{pmatrix} 0 & N_\mu{}^\nu \\ (N^T)^\mu{}_\nu & S_{\mu\nu} \end{pmatrix}$$

exist and are non-trivial *O(D,D)* elements!

Lee, Park

Locally Non-geometric Background

Fundamental string soliton background:

K.-H. Lee & J.-H. Park
arXiv:1307.8377

$$ds^2 = f^{-1}(-dt^2 + (dx^1)^2) + (dx^2)^2 + \cdots + (dx^9)^2\,,$$

$$B = (f^{-1} - \hat{c})dt \wedge dx^1\,, \qquad e^{-2\phi} = f\,e^{-2\phi_0}\,,$$

$$f = 1 + \tfrac{Q}{r^6}\,, \qquad r^2 = \textstyle\sum_{a=2}^{9}(x^a)^2\,,$$

x^1 compact,
$0 < \hat{c} < 2$

Apply T-duality

$$\mathcal{O}_A{}^B = \begin{pmatrix} 0 & 0 & \eta^{\alpha\beta} & 0 \\ 0 & \delta^i{}_j & 0 & 0 \\ \eta_{\alpha\beta} & 0 & 0 & 0 \\ 0 & 0 & 0 & \delta_i{}^j \end{pmatrix} \Longrightarrow$$

$$\mathrm{d}s^2 = \tfrac{1}{\hat{c}(2-\hat{c}f)}\left(-\mathrm{d}t^2 + (\mathrm{d}x^1)^2\right) + (\mathrm{d}x^2)^2 + \cdots + (\mathrm{d}x^9)^2$$

$$B = -\tfrac{1-\hat{c}f}{\hat{c}(2-\hat{c}f)}\,\mathrm{d}t \wedge \mathrm{d}x^1\,,$$

$$e^{-2\phi} = e^{-2\phi_0}\hat{c}(2-\hat{c}f)\,.$$

and take $\hat{c} \longrightarrow 0$.

Obtain generalized metric:

$$\mathcal{H}_{MN} = \begin{pmatrix} 0 & 0 & \mathcal{E}^\alpha{}_\beta & 0 \\ 0 & \delta^{ij} & 0 & 0 \\ -\mathcal{E}_\alpha{}^\beta & 0 & f\eta_{\alpha\beta} & 0 \\ 0 & 0 & 0 & \delta_{ij} \end{pmatrix}$$

inverse metric component vanishes(!)

Non-relativistic Strings

J. Gomis and H. Ooguri
hep-th/0009181

Introduce $x^\alpha = (t, x^1)$ and wrap x^1 on radius R circle.

Use metric $ds^2 = c^2 (dx^\alpha)^2 + (dx^i)^2$ and constant B field $B_{01} = B$.

Dispersion relation:

$$\frac{1}{c^2}(E + \frac{wRB}{\alpha'})^2 = k^2 + c^2 \left(\frac{wR}{\alpha'}\right)^2 + \frac{1}{c^2}\left(\frac{n}{R}\right)^2 + \frac{2}{\alpha'}(N + \tilde{N} - 2)$$

Note that $c \longrightarrow \infty$ limit doesn't make sense.

But if we set $B = c^2 - \mu^2$ (with μ a constant) then limit exits:

$$E = \mu \frac{wR}{\alpha'} + \frac{\alpha' k^2}{2wR} + \frac{N + \tilde{N} - 2}{wR}$$

(Also take string coupling to infinity, $g_s^2 = c^2 g_0^2$)

Resulting theory is non-relativistic: spectrum is invariant under Galilean transformations, …

Non-relativistic Strings

J. Gomis and H. Ooguri
hep-th/0009181

Need a worldsheet theory.

Action in original background ($\gamma = x^1 + t,\ \bar{\gamma} = x^1 - t$, $G = c^2$)

$$S = \frac{1}{4\pi\alpha'} \int d^2z \left((G-B)\partial\gamma\bar{\partial}\bar{\gamma} + (G+B)\partial\bar{\gamma}\bar{\partial}\gamma + 2\partial X^i \bar{\partial} X^i\right)$$

Non-relativistic limit is singular. (!?)

Try Lagrange multipliers: write

$$S = \frac{1}{2\pi\alpha'} \int d^2z \left(\beta\bar{\partial}\gamma + \bar{\beta}\partial\bar{\gamma} - \frac{2}{G+B}\beta\bar{\beta} + \frac{1}{2}(G-B)\partial\gamma\bar{\partial}\bar{\gamma} + \partial X^i \bar{\partial} X^j\right)$$

Limit now exists:

$$S = \frac{1}{2\pi\alpha'} \int d^2z \left(\beta\bar{\partial}\gamma + \bar{\beta}\partial\bar{\gamma} + \frac{\mu}{2}\partial\gamma\bar{\partial}\bar{\gamma} + \partial X^i \bar{\partial} X^i\right)$$

Sigma model has $c = D$, is unitary, etc… but also is Galilean invariant.

GO Limit of Double Field Theory

Start with same configuration: $ds^2 = G(dx^\alpha)^2 + (dx^i)^2,\ B_{01} = G - \mu$

Doubled geometry:

$$\mathcal{H}_{AB} = \begin{pmatrix} \frac{1}{G}\eta^{\alpha\beta} & \frac{G-\mu}{G}\mathcal{E}^\alpha{}_\beta \\ -\frac{G-\mu}{G}\mathcal{E}_\alpha{}^\beta & 2\mu\,\eta_{\alpha\beta} \end{pmatrix}$$

Limit $G \longrightarrow \infty$ exists!

Takes locally non-geometric form:

$$\mathcal{H}_{AB} = \begin{pmatrix} 0 & \sigma_\alpha{}^\beta \\ \sigma^\alpha{}_\beta & 2\mu\eta_{\alpha\beta} \end{pmatrix}$$

Dilaton in GO string: $g_s^2 = G g_0^2$

DFT dilaton: $e^{-2d} = g_s^{-2} G = g_0^{-2}$

GO limit gives a good DFT background.

GO vs. DFT: Sigma Models

K.-H. Lee & J.-H. Park
arXiv:1307.8377

DFT sigma model: $\mathcal{L} = -\frac{1}{2}\sqrt{-h}h^{ab}D_aX^MD_bX^N\mathcal{H}_{MN}(X) - \epsilon^{ab}D_aX^M\mathcal{A}_{bM}$

Worldsheet gauge field: $A^M = (A_\mu, \tilde{A}^\mu)$

Generalized 1-form: $DX^M = dX^M - \mathcal{A}^M$

Section condition: $\tilde{\partial}^\mu = 0 \implies \tilde{A}^\mu = 0$

Non-Riemannian background: *(t, x¹)* sector in conformal gauge

$$\mathcal{L}_{0,1} = -2\partial_-\gamma A_+ + 2\partial_+\bar{\gamma}\bar{A}_- - f(\partial_+\gamma\partial_-\bar{\gamma} + \partial_+\bar{\gamma}\partial_-\gamma)$$

Identify: $A_+ = \beta \qquad A_- = -\bar{\beta} \qquad f = 2\mu$

Wick rotation ➯ Gomis-Ooguri string!

Gomis-Ooguri β fields are the DFT gauge field
=> DFT is the natural geometric framework in which to understand the GO string

Symmetries

Galilean-invariant spectrum: $$E = \mu \frac{wR}{\alpha'} + \frac{\alpha' k^2}{2wR} + \frac{N + \tilde{N} - 2}{wR}$$

$\Longrightarrow$ should realize Bargmann algebra (central extension of Galilean algebra)

Realized in DFT by doubled diffeomorphisms:

$$H = -\partial_t \qquad Q = -\partial_1$$

$$P_i = -\partial_i \qquad \text{Mass number:} \quad N = -\tilde{\partial}^1$$

$$M_{ij} = -(x^i \partial_j - x^j \partial_i) \qquad \text{Boosts:} \quad B_i = -t\partial_i - x^i \tilde{\partial}^1$$

Closes onto Bargmann algebra under C-bracket (up to trivial generators):

$$[\xi, \eta]_{\mathrm{C}} = \xi^A (\partial_A \eta^B) \partial_B - \eta^A (\partial_A \xi^B) \partial_B - \frac{1}{2} \xi_A (\partial^B \eta^A) \partial_B + \frac{1}{2} \eta_A (\partial^B \xi^A) \partial_B$$

Schrödinger Backgrounds

Split spacetime as: $x^\mu = (x^\alpha, x^m) \qquad x^i = (x^m, u)$

DFT coordinates: $X^A = (\tilde{x}_\alpha, x^\alpha) \qquad X^I = (\tilde{x}_i, x^i)$

$$\mathcal{H}_{AB} = \begin{pmatrix} 0 & \sigma^\alpha{}_\beta(u) \\ \sigma_\alpha{}^\beta(u) & \mathcal{H}_{\alpha\beta} \end{pmatrix}, \qquad \mathcal{H}_{IJ} = \begin{pmatrix} u^2\,\delta^{ij} & 0 \\ 0 & u^{-2}\,\delta_{ij} \end{pmatrix}, \qquad \mathcal{H}_{AI} = 0\,,$$

$$\mathcal{H}_{\alpha\beta} = \begin{pmatrix} -\frac{1}{u^{2z}} & 0 \\ 0 & u^{4-2z} \end{pmatrix}, \qquad \sigma^\alpha{}_\beta(u) = (\sigma_\beta{}^\alpha(u))^T = \begin{pmatrix} 0 & -u^2 \\ -\frac{1}{u^2} & 0 \end{pmatrix}.$$

Generalized isometries:

Schrödinger conformal algebra

$$H = -\partial_t\,, \qquad D = -zt\partial_t - x^m\partial_m - u\partial_u - (z-2)x^1\partial_1$$

$$P_m = -\partial_m\,, \qquad B_m = -t\partial_m - x^m\tilde{\partial}^1\,,$$

$$N = -\tilde{\partial}^1\,, \qquad M_{mn} = -(x^m\partial_n - x^n\partial_m)\,.$$

$$C = -t^2\partial_t - tx^m\partial_m - tu\,\partial_u - \frac{1}{2}(x^2+u^2)\tilde{\partial}^1 \quad (z = 2 \text{ only})$$

Applications to non-relativistic holography?

Fluctuations

O. Hohm, C. Hull, B. Zwiebach [arXiv:1006.4823]
I. Jeon, K. Lee, J. H. Park [arXiv:1105.6294]

Work in the semi-covariant formalism.

DFT action: $$\mathcal{L} = \tfrac{1}{8}e^{-2d}\left[(P^{AC}P^{BD} - \bar{P}^{AC}\bar{P}^{BD})S_{ABCD} - 2\Lambda\right]$$

$$S_{ABCD} := \tfrac{1}{2}(R_{ABCD} + R_{CDAB} - \Gamma^{E}{}_{AB}\Gamma_{ECD}) \qquad \bar{P}_{AB} = \tfrac{1}{2}(\mathcal{J}_{AB} - \mathcal{H}_{AB})$$

$$\nabla_P P_{MN} = \nabla_P \bar{P}_{MN} = \nabla_M d = 0 \qquad P_{AB} = \tfrac{1}{2}(\mathcal{J}_{AB} + \mathcal{H}_{AB})$$

Quadratic action: S.M. Ko, R. Meyer, CMT, J.H. Park [arXiv:1508.01121]

$$\mathcal{L}_{\text{eff.}} := e^{-2d}\left[\tfrac{1}{2}(P-\bar{P})^{AB}\partial_A\delta d\,\partial_B\delta d - \tfrac{1}{2}\partial_A\delta d\,\nabla_B\delta P^{AB} + \tfrac{1}{8}\delta P^{AB}(\bar{\Delta}_A{}^C P_B{}^D - \Delta_A{}^C \bar{P}_B{}^D)\delta P_{CD}\right]$$

Linearized EOM:

$$(P^{AB} - \bar{P}^{AB})\nabla_A\partial_B\delta d - \tfrac{1}{2}\nabla_A\nabla_B\delta P^{AB} \equiv 0\,,$$

$$P_A{}^C\bar{P}_B{}^D\nabla_C\partial_D\delta d + \tfrac{1}{4}(P_A{}^C\bar{\Delta}_B{}^D - \Delta_A{}^C\bar{P}_B{}^D)\delta P_{CD} \equiv 0$$

with

$$\Delta_A{}^B := P_A{}^B P^{CD}\nabla_C\nabla_D - 2P_A{}^D P^{BC}(\nabla_C\nabla_D - S_{CD})$$

$$\bar{\Delta}_A{}^B := \bar{P}_A{}^B \bar{P}^{CD}\nabla_C\nabla_D - 2\bar{P}_A{}^D \bar{P}^{BC}(\nabla_C\nabla_D - S_{CD})$$

New Quadratic Differential Operator

Two more operators: $\mathfrak{D}_A{}^B = \Delta_A{}^B - P_A{}^B P^{CD} S_{CD}\,,\qquad \bar{\mathfrak{D}}_A{}^B = \bar\Delta_A{}^B - \bar P_A{}^B \bar P^{CD} S_{CD}$

Covariant $\Leftrightarrow$ commutes with generalized Lie derivative. Use:

$$(\delta_X-\hat{\mathcal{L}}_X)\Gamma_{CAB} = 2\big[(\mathcal{P}+\bar{\mathcal{P}})_{CAB}{}^{FDE} - \delta_C^F\delta_A^D\delta_B^E\big]\partial_F\partial_{[D}X_{E]}\,,$$

$$(\delta_X-\hat{\mathcal{L}}_X)\nabla_C T_{A_1\cdots A_n} = \sum_{i=1}^{n} 2(\mathcal{P}+\bar{\mathcal{P}})_{CA_i}{}^{BFDE}\partial_F\partial_{[D}X_{E]}T_{A_1\cdots A_{i-1}BA_{i+1}\cdots A_n}\,,$$

$$(\delta_X-\hat{\mathcal{L}}_X)S_{ABCD} = 2\nabla_{[A}\left((\mathcal{P}+\bar{\mathcal{P}})_{B][CD]}{}^{EFG}\partial_E\partial_{[F}X_{G]}\right) + 2\nabla_{[C}\left((\mathcal{P}+\bar{\mathcal{P}})_{D][AB]}{}^{EFG}\partial_E\partial_{[F}X_{G]}\right)\,.$$

Following contractions give new quadratic tensorial differential operators:

$$\mathfrak{D}_A{}^C\bar P_{B_1}{}^{D_1}\cdots\bar P_{B_n}{}^{D_n}T_{CD_1\cdots D_n}\,,\qquad \bar{\mathfrak{D}}_A{}^C P_{B_1}{}^{D_1}\cdots P_{B_n}{}^{D_n}T_{CD_1\cdots D_n}$$

$$\Delta_A{}^C\bar P_{B_1}{}^{D_1}\cdots\bar P_{B_n}{}^{D_n}T_{CD_1\cdots D_n}\,,\qquad \bar\Delta_A{}^C P_{B_1}{}^{D_1}\cdots P_{B_n}{}^{D_n}T_{CD_1\cdots D_n}$$

Fluctuations in GO Background

Background

$$\mathcal{H}_{MN} = \begin{pmatrix} 0 & 0 & \mathcal{E}^{\alpha}{}_{\beta} & 0 \\ 0 & g^{ij} & 0 & 0 \\ -\mathcal{E}_{\alpha}{}^{\beta} & 0 & f\eta_{\alpha\beta} & 0 \\ 0 & 0 & 0 & g_{ij} \end{pmatrix}$$

Expand linearly in fluctuations:

$$\mathcal{H}_{AB} \mapsto \mathcal{H}_{AB} + h_{AB},\ d \mapsto d + \psi$$

Constraint $\mathcal{H}_{AC} J^{CD} \mathcal{H}_{DB} = J_{AB}$ means:

$$h^{\alpha\beta} = -\sigma^{\alpha}_{\gamma} h^{\gamma\delta} \sigma^{\beta}_{\delta}\,, \qquad h^{\alpha}{}_{\beta} = -\sigma^{\alpha}_{\gamma} h^{\gamma}{}_{\delta} \sigma^{\delta}_{\beta} - f \sigma^{\alpha}_{\gamma} h^{\gamma\delta} \eta_{\delta\beta}\,,$$

$$h^{\alpha i} = -\sigma^{\alpha}_{\beta} h^{\beta}{}_{j} g^{ji}\,, \qquad h_{\alpha\beta} = -\sigma^{\gamma}_{\alpha} h_{\gamma\delta} \sigma^{\delta}_{\beta} - f \sigma^{\gamma}_{\alpha} h_{\gamma}{}^{\delta} \eta_{\delta\beta} - f \eta_{\alpha\gamma} h^{\gamma}{}_{\delta} \sigma^{\delta}_{\beta} - f^2 \eta_{\alpha\gamma} h^{\gamma\delta} \eta_{\delta\beta}\,, \qquad (\sigma^{\alpha}_{\beta} = \mathcal{E}^{\alpha}{}_{\beta})$$

$$h_i{}^j = b_{ik} g^{kj}\,, \qquad h_{\alpha i} = -f \eta_{\alpha\gamma} h^{\gamma j} g_{ji} - \sigma^{\beta}_{\alpha} h_{\beta}{}^{j} g_{ji}\,,$$

$$h^i{}_j = -g^{ik} b_{kj}\,, \qquad h^{ij} = -g^{im} h_{mn} g^{nj}\,,$$

Gauge-fixing: gauge parameter $\xi^M = (\tilde{\lambda}_\mu, \lambda^\mu)$

Use λ^α to fix $h^{\alpha}{}_{\beta} = -\frac{1}{2} f \hat{h} \sigma^{\alpha}_{\beta}$

Use $\tilde{\lambda}_\alpha$ to fix $h_{\alpha\beta} = 0$.

Use $\tilde{\lambda}_i$ and λ^i to fix $h_{\alpha i} = 0$.

Expand in plane waves:

$$h_{AB}(x) = h_{AB} e^{ip_+ x^+ + ip_- x^- + ik_i x^i}$$

Fluctuations in GO Background

Transverse/ longitudinal decomposition

$$h_{ij} = h^{\perp}_{ij} + k_i\zeta^{\perp}_j + k_j\zeta^{\perp}_i + (k_ik_j - \frac{1}{D-2}k^2 g_{ij})\rho + \frac{1}{D-2}h g_{ij}\,;$$

$$b_{ij} = b^{\perp}_{ij} + k_i\chi^{\perp}_j - k_j\chi^{\perp}_i\,,$$

$$h_i{}^{\alpha} = h_i^{\perp\alpha} + k_i\phi^{\alpha}\,,$$

$$k^i h^{\perp}_{ij} = k^i b^{\perp}_{ij} = k^i\zeta^{\perp}_i = k^i h_i^{\perp\alpha} = 0$$

Result: No normalizable fluctuating modes!

$$\mathcal{E}_{\psi} = 2p_+p_-\hat{h} + 2k^2(p_-\phi^- - p_+\phi^+) + \frac{1}{D-2}k^2[h - (D-3)k^2\rho + 4(D-2)\psi]\,,$$

$$\mathcal{E}^{-+} = k^2\hat{h}\,, \qquad \mathcal{E}^{-}{}_{+} = 2p_+(k^2\phi^- + p_+\hat{h})\,,$$

$$\mathcal{E}_{-+} = fk^2(p_-\phi^- - p_+\phi^+ + \frac{1}{4}f\hat{h}) + 8p_+p_-\psi\,, \qquad \mathcal{E}_{-}{}^{+} = 2p_-(k^2\phi^+ - p_-\hat{h})\,,$$

$$\mathcal{E}_{-i} = p_-k^m(h_{mi} - b_{mi}) + 2p_-^2h_i^- + \frac{f}{2}k^2h_i^{\perp+} + 4p_-k_i\psi\,, \qquad \mathcal{E}^{-}{}_{i} = -k^2h_i^{\perp-} + p_+k_i\hat{h}\,,$$

$$\mathcal{E}_{i+} = p_+k^m(h_{mi} + b_{mi}) - 2p_+^2h_i^+ - \frac{f}{2}k^2h_i^{\perp-} + 4p_+k_i\psi\,, \qquad \mathcal{E}_i{}^{+} = -k^2h_i^{\perp+} - p_-k_i\hat{h}\,,$$

$$\mathcal{E}_{ij} = \frac{1}{2}k_i\left[2p_-h_j^- + g^{mn}k_m(h_{nj} - b_{nj})\right]$$
$$- \frac{1}{2}k_j\left[2p_+h_i^+ - g^{mn}k_m(h_{ni} + b_{ni})\right] - k^2(h_{ij} - b_{ij}) + 2k_ik_j\psi.$$

Complete equations of motion

T-Dual Fluctuations

Apply T-duality transformation

$$(\mathcal{O}_A{}^B) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}$$

Resulting configuration is geometric:

$$ds^2 = -f\,dt^2 + 2\,dt\,dx + (dx^i)^2$$

— light-cone compactification.

Choose gauge: $h_{0\mu} = b_{0\mu} = 0$

Equation of motion reduce to

$$\mathcal{E}_\psi = p^\mu p^\nu h_{\mu\nu} - 4p^2\psi = 0\,,$$

$$\mathcal{E}_{(\mu\nu)} = p^\lambda p_{(\mu} h_{\nu)\lambda} - p^2 h_{\mu\nu} + 2p_\mu p_\nu \psi = 0\,,$$

$$\mathcal{E}_{[\mu\nu]} = p^\lambda p_{[\mu} h_{\nu]\lambda} + p^2 b_{\mu\nu} = 0.$$

Gives (D-1)(D-3) modes with dispersion

$$E = \frac{1}{2} f p_\theta + \frac{\vec{k}^2}{2p_\theta}$$

in accordance with expectations.

Reproduces the $N = \tilde{N} = 1$ sector of Gomis-Ooguri string with $wR \mapsto \alpha' p_\theta$.

Summary

- Double Field Theory: Manifestly T-duality invariant description of geometric, globally non-geometric, and locally non-geometric backgrounds
- Gomis-Ooguri string: worldsheet theory for a Galilean-invariant target spacetime
- Gomis-Ooguri limit gives non-singular configuration in DFT which is "locally non-Riemannian"
- Gomis-Ooguri worldsheet theory a special case of DFT sigma model
- Fluctuation spectrum in GO background and its dual match

Outlook

- Quantum properties of non-relativistic sigma model in curved spacetime
- Applications to holography?
- Insights on action formulation of Newtonian gravity

Thank you!