The Geometry of String Theory

Matas Mackevicius

Supervisor
Thomas Mohaupt

Department of Mathematical Sciences
University of Liverpool
STRING THEORY SUMMARIZED:

I just had an awesome idea. Suppose all matter and energy is made of tiny, vibrating “strings.”

Okay, what would that imply?

I dunno.
STRING THEORY SUMMARIZED:

I just had an awesome idea. Suppose all matter and energy is made of tiny, vibrating "strings."

Okay. What would that imply?

[Diagram of stick figures]
Riemannian Geometry ought to be replaced by Generalised Geometry
Black Hole Horizons
Black Hole Horizons
Black Hole Horizons
Black Hole Horizons

$\Sigma_{KH}$
Black Hole Horizons

$g(\xi, \xi) < 0$

$\Sigma_{\text{KH}}$
Black Hole Horizons

\[ g(\xi, \xi) < c \]

\[ g(\xi, \xi) > 0 \]

\[ \Sigma_{KH} \]
Black Hole Horizons

$g(\xi, \xi) = 0$

$g(\xi, \xi) > 0$

$g(\xi, \xi) < 0$

$\Sigma_{KH}$
Black Hole Horizons

\[ g(\xi, \xi) = 0 \]
\[ g(\xi, \xi) > 0 \]
\[ g(\xi, \xi) < 0 \]

\[ \Sigma_{KH} \]

T-Duality

Spacetime Singularity

[M. Rocek, E.P. Verlinde]
Black Hole Horizons

$g(\xi, \xi) = 0$

$g(\xi, \xi) > 0$

$g(\xi, \xi) < 0$

$\Sigma_{KH}$

T-Duality

Spacetime Singularity

[Tensionless String]

[M. Medevielle, T. Mohaupt]

[T. Mohaupt]

[M. Rocek, E.P. Verlinde]
• T-Duality is inherently **topological** and does not require the notion of a metric.
Black Hole Horizons

- T-Duality is inherently **topological** and does not require the notion of a metric.

- T-Duality mixes the **metric** $g$, **Kalb-Ramond** field $B$ and the **Dilaton** $\phi$, so all these should be included in the underlying geometry.

---

**Tensionless String**  
[M. Medevielle, T. Mohaupt]

---

**Spacetime Singularity**  
[M. Rocek, E.P. Verlinde]

---

**T-Duality**

**$g(\xi, \xi) = 0$**

**$g(\xi, \xi) > 0$**

**$g(\xi, \xi) < 0$**
Approaches to Stringy Geometry

- Generalised Geometry

- Double Field Theory
Approaches to Stringy Geometry

- **Generalised Geometry** [N. Hitchin, M. Gualtieri]
- Double Field Theory
Approaches to Stringy Geometry

• **Generalised Geometry** [N. Hitchin, M. Gualtieri]

\[ E = TM \oplus T^* M, \quad X + \xi \in \Gamma(E) \]

• Double Field Theory
Approaches to Stringy Geometry

- **Generalised Geometry** [N. Hitchin, M. Gualtieri]

\[ E = TM \oplus T^* M, \quad X + \xi \in \Gamma(E) \]

\[ X \in \Gamma(TM), \quad \xi \in \Gamma(T^* M) \]
Approaches to Stringy Geometry

- **Generalised Geometry** [N. Hitchin, M. Gualtieri]

\[ E = TM \oplus T^*M, \quad X + \xi \in \Gamma(E) \]

\[ X \in \Gamma(TM), \quad \xi \in \Gamma(T^*M) \]

\[ \langle \bullet, \bullet \rangle, \quad O(D, D) \]
Approaches to Stringy Geometry

- **Generalised Geometry** [N. Hitchin, M. Gualtieri]

\[ E = TM \oplus T^*M, \quad X + \xi \in \Gamma(E) \]

\[ X \in \Gamma(TM), \quad \xi \in \Gamma(T^*M) \]

\[ \langle \bullet, \bullet \rangle, \quad O(D, D) \]

\[ [X + \xi, Y + \eta]_D = [X, Y] + \mathcal{L}_X \eta - \iota_Y d\xi \]
Approaches to Stringy Geometry

- **Generalised Geometry** [N. Hitchin, M. Gualtieri]

\[ E = TM \oplus T^*M, \quad X + \xi \in \Gamma(E) \]

\[ X \in \Gamma(TM), \quad \xi \in \Gamma(T^*M) \]

\[ \langle \cdot, \cdot \rangle, \quad O(D, D) \]

\[ [X + \xi, Y + \eta]_D = [X, Y] + \mathcal{L}_X \eta - \iota_Y d\xi \]

\[ \mathcal{G}(g, B), \quad \text{div}^g = \alpha d\phi + \text{div}^g \]

[M. Garcia-Fernandez, Jeffrey Streets]
Approaches to Stringy Geometry

• Generalised Geometry

• 
  **Double Field Theory** [Hull, Zwiebach, Hohm]
Approaches to Stringy Geometry

- Generalised Geometry

\[ X^M = (\tilde{x}_\mu, x^\mu) \]

- **Double Field Theory** [Hull, Zwiebach, Hohm]
Approaches to Stringy Geometry

- Generalised Geometry

- Double Field Theory [Hull, Zwiebach, Hohm]
Approaches to Stringy Geometry

• Generalised Geometry

• **Double Field Theory** [Hull, Zwiebach, Hohm]

\[
X^M = (\tilde{x}_\mu, x^\mu) \quad \leftrightarrow \quad \omega^\mu, p_\mu
\]

\[
\mathcal{H}_{MN} = \begin{pmatrix}
g^{-1} & -g^{-1}B \\
Bg^{-1} & g - Bg^{-1}B
\end{pmatrix}, \quad e^{-2d} = \sqrt{-g}e^{-2\phi}
\]
Approaches to Stringy Geometry

• Generalised Geometry

• **Double Field Theory** [Hull, Zwiebach, Hohm]

\[ X^M = (\tilde{x}_\mu, x^\mu) \quad \leftrightarrow \quad \omega^\mu, p_\mu \]

\[ \mathcal{H}_{MN} = \begin{pmatrix} g^{-1} & -g^{-1}B \\ Bg^{-1} & g - Bg^{-1}B \end{pmatrix}, \quad e^{-2d} = \sqrt{-g}e^{-2\phi} \]

\[ O(D, D), \quad \eta_{MN} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \]
Approaches to Stringy Geometry

- Generalised Geometry

- **Double Field Theory** [Hull, Zwiebach, Hohm]

\[ X^M = (\tilde{x}_{\mu}, x^\mu) \]

\[ \mathcal{H}_{MN} = \begin{pmatrix} g_{-1} & -g_{-1}B \\ Bg_{-1} & g - Bg_{-1}B \end{pmatrix}, \quad e^{-2d} = \sqrt{-g}e^{-2\phi} \]

Diffeomorphisms

\[ O(D, D), \quad \eta_{MN} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \]
Approaches to Stringy Geometry

- Generalised Geometry

- **Double Field Theory** [Hull, Zwiebach, Hohm]

\[
X^M = (\tilde{x}_\mu, x^\mu)
\]

\[
\mathcal{H}_{MN} = \left( \begin{array}{cc}
g^{-1} & -g^{-1}B \\
Bg^{-1} & g - Bg^{-1}B \end{array} \right), \quad e^{-2d} = \sqrt{-g}e^{-2\phi}
\]

- Diffeomorphisms

- B-Shifts

\[
O(D, D), \quad \eta_{MN} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}
\]
Approaches to Stringy Geometry

- **Generalised Geometry**

- **Double Field Theory** [Hull, Zwiebach, Hohm]

\[
X^M = (\bar{x}_\mu, x^\mu) \quad \text{↔} \quad \omega^\mu, p_\mu
\]

\[
\mathcal{H}_{MN} = \begin{pmatrix}
g^{-1} & -g^{-1}B \\
Bg^{-1} & g - Bg^{-1}B
\end{pmatrix}, \quad e^{-2d} = \sqrt{-g}e^{-2\phi}
\]

- Diffeomorphisms
- B-Shifts
- Factorized T-Dualities

\[
O(D, D), \quad \eta_{MN} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}
\]
Approaches to Stringy Geometry

- Generalised Geometry

- **Double Field Theory** [Hull, Zwiebach, Hohm]

\[
X^M = (\tilde{x}_\mu, x^\mu) \quad \leftrightarrow \quad \omega^\mu, p_\mu
\]

\[
\mathcal{H}_{MN} = \begin{pmatrix}
g^{-1} & -g^{-1}B \\
Bg^{-1} & g - Bg^{-1}B
\end{pmatrix}, \quad e^{-2d} = \sqrt{-g}e^{-2\phi}
\]

Diffeomorphisms
B-Shifts
Factorized T-Dualities
Buscher Rules
Approaches to Stringy Geometry

- Generalised Geometry

- Double Field Theory [Hull, Zwiebach, Hohm]

\[ X^M = (\tilde{x}_\mu, x^\mu) \]

\[ \mathcal{H}_{MN} = \begin{pmatrix} g^{-1} & -g^{-1}B \\ Bg^{-1} & g - Bg^{-1}B \end{pmatrix}, \quad e^{-2d} = \sqrt{-g} e^{-2\phi} \]

Diffeomorphisms

B-Shifts

Factorized T-Dualities

Buscher Rules

\[ \partial^A \partial_A \Phi = 0, \quad \partial^A \Phi \partial_A \Phi' = 0 \quad \text{Constraints} \]

(Weak) \quad (Strong)
Ricci & Scalar Curvature (Generalised Geometry)?

Original Solution

$$ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2 ds_2^2, \quad B_{\mu\nu} = 0, \quad \phi = 0$$
Ricci & Scalar Curvature (Generalised Geometry)?

Original Solution

\[ ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2 ds_2^2, \quad B_{\mu\nu} = 0, \quad \phi = 0 \]

T-Dual Solution

\[ ds'^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2 ds_2^2, \quad B'_{\mu\nu} = 0, \quad \phi' = -\frac{1}{2} \ln(|f(r)|) \]
Ricci & Scalar Curvature (Generalised Geometry)?

Original Solution

$$ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2 ds^2 \quad B_{\mu\nu} = 0, \quad \phi = 0$$

T-Dual Solution

$$ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2 ds^2 \quad B'_{\mu\nu} = 0, \quad \phi' = -\frac{1}{2} \ln(|f(r)|)$$
Ricci & Scalar Curvature (Generalised Geometry)?

Original Solution

\[ ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2ds_2^2, \quad B_{\mu\nu} = 0, \quad \phi = 0 \]

T-Dual Solution

\[ ds'^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2ds_2^2, \quad B'_{\mu\nu} = 0, \quad \phi' = -\frac{1}{2} \ln(|f(r)|) \]

\[ S_{\mu\nu} = R_{\mu\nu} - 2\nabla_\mu \nabla_\nu \phi + \frac{1}{4} H_{\mu\rho\sigma} H^\rho_\nu \rho\sigma - \frac{1}{2} e^{2\phi} \nabla^\rho (e^{-2\phi} H_{\rho\mu\nu}) \]

\[ S = R + 4\nabla^2 \phi - 4(\partial \phi)^2 - \frac{1}{12} H^2 \]
Ricci & Scalar Curvature (Generalised Geometry)?

**Original Solution**

$$ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2 ds_2^2, \quad B_{\mu\nu} = 0, \quad \phi = 0$$

**T-Dual Solution**

$$ds'^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2 ds_2^2, \quad B'_{\mu\nu} = 0, \quad \phi' = -\frac{1}{2} \ln(|f(r)|)$$

$$S_{\mu\nu} = R_{\mu\nu} - 2\nabla_\mu \nabla_\nu \phi + \frac{1}{4} H_{\mu\rho\sigma} H^{\rho\sigma} - \frac{1}{2} e^{2\phi} \nabla^\rho (e^{-2\phi} H_{\rho\mu\nu})$$

$$S = R + 4\nabla^2 \phi - 4(\partial \phi)^2 - \frac{1}{12} H^2$$
Ricci & Scalar Curvature (Generalised Geometry)?

Original Solution

\[ ds^2 = -f(r) dt^2 + \frac{dr^2}{f(r)} + r^2 ds_2^2, \quad B_{\mu\nu} = 0, \quad \phi = 0 \]

T-Dual Solution

\[ ds'^2 = -f(r) dt^2 + \frac{dr^2}{f(r)} + r^2 ds_2^2, \quad B'_{\mu\nu} = 0, \quad \phi' = -\frac{1}{2} \ln(|f(r)|) \]

\[ S_{\mu\nu} = R_{\mu\nu} - 2 \nabla_\mu \nabla_\nu \phi + \frac{1}{4} H_{\mu\rho\sigma} H^{\rho\sigma} - \frac{1}{2} e^{2\phi} \nabla^\rho \left( e^{-2\phi} H_{\rho\mu\nu} \right) \]

\[ S = R + 4 \nabla^2 \phi - 4 (\partial \phi)^2 - \frac{1}{12} H^2 \]

\[ S_{\mu\nu} = R_{\mu\nu}, \quad S = R \]

Same as original – nothing new
(sanity check)
Ricci & Scalar Curvature (Generalised Geometry)?

Original Solution

\[ ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2ds_2^2, \quad B_{\mu\nu} = 0, \quad \phi = 0 \]

T-Dual Solution

\[ ds'^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2ds_2^2, \quad B'_{\mu\nu} = 0, \quad \phi' = -\frac{1}{2} \ln(|f(r)|) \]

\[ S_{\mu\nu} = R_{\mu\nu} - 2\nabla_\mu \nabla_\nu \phi + \frac{1}{4} H_{\mu\rho\sigma} H_{\nu}{}^{\rho\sigma} - \frac{1}{2} e^{2\phi} \nabla^\rho \left( e^{-2\phi} H_{\rho\mu\nu} \right) \]

\[ S = R + 4\nabla^2 \phi - 4(\partial \phi)^2 - \frac{1}{12} H^2 \]

Same as original – nothing new (sanity check)

Divergence Free!

\[ S' = \frac{2}{r^2} - \frac{2f(r)}{r^2} - f''(r) \]
Ricci & Scalar Curvature (Generalised Geometry)?

Original Solution

\[ ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2ds_2^2, \quad B_{\mu \nu} = 0, \quad \phi = 0 \]

T-Dual Solution

\[ ds'^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2ds_2^2, \quad B'_{\mu \nu} = 0, \quad \phi' = -\frac{1}{2} \ln(|f(r)|) \]

\[ S_{\mu \nu} = R_{\mu \nu} - 2\nabla_\mu \nabla_\nu \phi + \frac{1}{4} H_{\mu \rho \sigma} H_{\nu}^{\rho \sigma} - \frac{1}{2} e^{2\phi} \nabla^\rho \left( e^{-2\phi} H_{\rho \mu \nu} \right) \]

\[ S = R + 4\nabla^2 \phi - 4(\partial \phi)^2 - \frac{1}{12} H^2 \]

\[ S' = \frac{2}{r^2} - \frac{2f(r)}{r^2} - f''(r) \]

Same as original – nothing new (sanity check)

Divergence Free!
Ricci & Scalar Curvature (Double Field Theory)?
Ricci & Scalar Curvature (Double Field Theory)?

Original Solution

\[ \mathcal{H}_{\mu\nu} = \begin{pmatrix} g^{\mu\nu} & 0 \\ 0 & g_{\mu\nu} \end{pmatrix}, \quad d = -\frac{1}{2} \ln (r^2) \]
Ricci & Scalar Curvature (Double Field Theory)?

Original Solution
\[ \mathcal{H}_{\mu\nu} = \begin{pmatrix} g^{\mu\nu} & 0 \\ 0 & g_{\mu\nu} \end{pmatrix}, \quad d = -\frac{1}{2} \ln (r^2) \]

T-Dual Solution
\[ \mathcal{H}_{\mu\nu} = \begin{pmatrix} g'^{\mu\nu} & 0 \\ 0 & g'_{\mu\nu} \end{pmatrix}, \quad d' = -\frac{1}{2} \ln (r^2) \]
Ricci & Scalar Curvature (Double Field Theory)?

Original Solution

$$\mathcal{H}_{\mu\nu} = \begin{pmatrix} g^{\mu\nu} & 0 \\ 0 & g_{\mu\nu} \end{pmatrix}, \quad d = -\frac{1}{2} \ln (r^2)$$

T-Dual Solution

$$\mathcal{H}_{\mu\nu} = \begin{pmatrix} g^{'\mu\nu} & 0 \\ 0 & g^{'}_{\mu\nu} \end{pmatrix}, \quad d' = -\frac{1}{2} \ln (r^2)$$

Graviton-Dilaton System

$$\mathcal{R} = 4\mathcal{H}^{MN} \partial_M \partial_N d - \partial_M \partial_N \mathcal{H}^{MN} - 4\mathcal{H}^{MN} \partial_M d \partial_N d + ...$$

$$\mathcal{R}_{MN} = \frac{1}{2} \mathcal{K}_{MN} - \frac{1}{2} S^P_M \mathcal{K}_{PQ} S^Q_N$$
Ricci & Scalar Curvature (Double Field Theory)?

Original Solution
\[ \mathcal{H}_{\mu\nu} = \begin{pmatrix} g^{\mu\nu} & 0 \\ 0 & g_{\mu\nu} \end{pmatrix}, \quad d = -\frac{1}{2} \ln (r^2) \]

T-Dual Solution
\[ \mathcal{H}_{\mu\nu} = \begin{pmatrix} g'^{\mu\nu} & 0 \\ 0 & g'_{\mu\nu} \end{pmatrix}, \quad d' = -\frac{1}{2} \ln (r^2) \]

Graviton-Dilaton System
\[ \mathcal{R} = 4 \mathcal{H}^{MN} \partial_M \partial_N d - \partial_M \partial_N \mathcal{H}^{MN} - 4 \mathcal{H}^{MN} \partial_M d \partial_N d + \ldots \]
\[ \mathcal{R}_{MN} = \frac{1}{2} \mathcal{K}_{MN} - \frac{1}{2} S^P_M \mathcal{K}_{PQ} S^Q_N \]
Ricci & Scalar Curvature (Double Field Theory)?

Original Solution
\[ \mathcal{H}_{\mu \nu} = \begin{pmatrix} g^{\mu \nu} & 0 \\ 0 & g_{\mu \nu} \end{pmatrix}, \quad d = -\frac{1}{2} \ln(r^2) \]

T-Dual Solution
\[ \mathcal{H}_{\mu \nu} = \begin{pmatrix} g'^{\mu \nu} & 0 \\ 0 & g'_{\mu \nu} \end{pmatrix}, \quad d' = -\frac{1}{2} \ln(r^2) \]

Graviton-Dilaton System
\[ \mathcal{R} = 4\mathcal{H}^{MN} \partial_M \partial_N d - \partial_M \partial_N \mathcal{H}^{MN} - 4\mathcal{H}^{MN} \partial_M \partial_N d + \ldots \]
\[ \mathcal{R}_{MN} = \frac{1}{2} \mathcal{K}_{MN} - \frac{1}{2} {S^P}_M \mathcal{K}_{PQ} {S^Q}_N \]

\[ \mathcal{R} = \mathcal{R}' \]
Both contain divergences
Ricci & Scalar Curvature (Double Field Theory)?

Graviton-Dilaton System

Original Solution
\[ \mathcal{H}_{\mu\nu} = \begin{pmatrix} g^{\mu\nu} & 0 \\ 0 & g_{\mu\nu} \end{pmatrix}, \quad d = -\frac{1}{2} \ln (r^2) \]

T-Dual Solution
\[ \mathcal{H}_{\mu\nu} = \begin{pmatrix} g'^{\mu\nu} & 0 \\ 0 & g'_{\mu\nu} \end{pmatrix}, \quad d' = -\frac{1}{2} \ln (r^2) \]

\[ \mathcal{R} = 4 \mathcal{H}^{MN} \partial_M \partial_N d - \partial_M \partial_N \mathcal{H}^{MN} - 4 \mathcal{H}^{MN} \partial_M d \partial_N d + \ldots \]

\[ \mathcal{R}_{MN} = \frac{1}{2} \mathcal{K}_{MN} - \frac{1}{2} S^P_M S_P^Q \mathcal{K}_{PQ} S^Q_N \]

EF Coordinates

\[ \mathcal{R} = \mathcal{R}' \]
Both contain divergences

\[ \mathcal{R}_{EF} = \mathcal{R}'_{EF} \]
Divergence Free
Ricci & Scalar Curvature (Double Field Theory)?

Original Solution
\[ \mathcal{H}_{\mu\nu} = \begin{pmatrix} g^{\mu\nu} & 0 \\ 0 & g_{\mu\nu} \end{pmatrix}, \quad d = -\frac{1}{2} \ln (r^2) \]

T-Dual Solution
\[ \mathcal{H}'_{\mu\nu} = \begin{pmatrix} g'^{\mu\nu} & 0 \\ 0 & g'_{\mu\nu} \end{pmatrix}, \quad d' = -\frac{1}{2} \ln (r^2) \]

Graviton-Dilaton System
\[ \mathcal{R} = 4\mathcal{H}^{MN} \partial_M \partial_N d - \partial_M \partial_N \mathcal{H}^{MN} - 4\mathcal{H}^{MN} \partial_M d \partial_N d + \ldots \]
\[ \mathcal{R}_{MN} = \frac{1}{2} \mathcal{K}_{MN} - \frac{1}{2} S^P_M \mathcal{K}_{PQ} S^Q_N \]

\[ \mathcal{R} = \mathcal{R}' \]
Both contain divergences

EF Coordinates
\[ \mathcal{R}_{EF} = \mathcal{R}'_{EF} \]
Divergence Free

Divergence Free!
\[ (\mathcal{R}_{EF})_{MN} = ? (\mathcal{R}'_{EF})_{MN} \]
Unique Connections, Generalised Riemann Curvature?
Unique Connections, Generalised Riemann Curvature?

- Both, in Generalised Geometry + Double Field Theory, connection is not uniquely determined.
• Both, in Generalised Geometry + Double Field Theory, connection is not uniquely determined.

• In Generalised Geometry, the Generalised Riemann curvature is not a tensor.
Unique Connections, Generalised Riemann Curvature?

• Both, in Generalised Geometry + Double Field Theory, connection is not uniquely determined.

• In Generalised Geometry, the Generalised Riemann curvature is not a tensor.

• In DFT, the Riemann curvature is not uniquely determined, contains undetermined anomalous terms coming from connections.
Unique Connections, Generalised Riemann Curvature?

- Both, in Generalised Geometry + Double Field Theory, connection is not uniquely determined.

- In Generalised Geometry, the Generalised Riemann curvature is not a tensor.

- In DFT, the Riemann curvature is not uniquely determined, contains undetermined anomalous terms coming from connections.

- Modifications can be made to the GG Riemann curvature, which makes it tensorial.

[J. Street, C. Strickland-Constable, F. Valach]
Unique Connections, Generalised Riemann Curvature?

- Both, in Generalised Geometry + Double Field Theory, connection is not uniquely determined.

- In Generalised Geometry, the Generalised Riemann curvature is not a tensor.

- In DFT, the Riemann curvature is not uniquely determined, contains undetermined anomalous terms coming from connections.

- Modifications can be made to the GG Riemann curvature, which makes it tensorial. [J. Street, C. Strickland-Constable, F. Valach]

- Connection can be uniquely determined in DFT when using Projection operators as fundamental objects. [Jeong-Hyuck Park]
Generalised Kretschmann Scalar?
Generalised Kretschmann Scalar?

- Notions of “time-like” and “space-like” no longer apply in the extended geometrical framework.
Generalised Kretschmann Scalar?

- Notions of “time-like” and “space-like” no longer apply in the extended geometrical framework.
- We need a geometric invariant to distinguish between curvature and coordinate singularities.
Generalised Kretschmann Scalar?

- Notions of “time-like” and “space-like” no longer apply in the extended geometrical framework.
- We need a geometric invariant to distinguish between curvature and coordinate singularities.
- Two approaches:
Generalised Kretschmann Scalar?

- Notions of “time-like” and “space-like” no longer apply in the extended geometrical framework.
- We need a geometric invariant to distinguish between curvature and coordinate singularities.
- Two approaches:

\[ K_{GG} = S_{\mu\nu\rho\sigma} S^{\mu\nu\rho\sigma} + \text{corrections} \]

Generalised Kretschmann Scalar
Generalised Kretschmann Scalar?

- Notions of “time-like” and “space-like” no longer apply in the extended geometrical framework.
- We need a geometric invariant to distinguish between curvature and coordinate singularities.
- Two approaches:
  
  \[ \mathcal{K}_{\text{GG}} = S_{\mu\nu\rho\sigma}S^{\mu\nu\rho\sigma} + \text{corrections} \]
  Generalised Kretschmann Scalar

  \[ \mathcal{K}_{\text{DFT}} = R_{MNPQ}R^{MNPQ} + \text{projection corrections/contractions} \]
  DFT Kretschmann Scalar
Generalised Kretschmann Scalar?

- Notions of “time-like” and “space-like” no longer apply in the extended geometrical framework.
- We need a geometric invariant to distinguish between curvature and coordinate singularities.
- Two approaches:

  \[ \mathcal{K}_{\text{GG}} = S_{\mu\nu\rho\sigma} S^{\mu\nu\rho\sigma} + \text{corrections} \]

  Generalised Kretschmann Scalar

  \[ \mathcal{K}_{\text{DFT}} = R_{MNPQ} R^{MNPQ} + \text{projection corrections/contractions} \]

  DFT Kretschmann Scalar

  Probably more doable...
Generalised Kretschmann Scalar?

- Notions of “time-like” and “space-like” no longer apply in the extended geometrical framework.
- We need a geometric invariant to distinguish between curvature and coordinate singularities.
- Two approaches:
  \[ \mathcal{K}_{GG} = S_{\mu\nu\rho\sigma} S^{\mu\nu\rho\sigma} + \text{corrections} \]
  Generalised Kretschmann Scalar
  \[ \mathcal{K}_{DFT} = R_{MNPQ} R^{MNPQ} + \text{projection corrections/contractions} \]
  DFT Kretschmann Scalar

Probably more doable...
Future Research/other ideas
Future Research/other ideas

- Complete the construction of GG and DFT geometric invariant (Kretschmann).
Future Research/other ideas

• Complete the construction of GG and DFT geometric invariant (Kretschmann).

• Explore the notions of generalised Killing vector fields and generalised Killing horizons.
Future Research/other ideas

• Complete the construction of GG and DFT geometric invariant (Kretschmann).

• Explore the notions of generalised Killing vector fields and generalised Killing horizons.

• Develop the notion of generalised Geodesic completeness.
Future Research/other ideas

• Complete the construction of GG and DFT geometric invariant (Kretschmann).

• Explore the notions of generalised Killing vector fields and generalised Killing horizons.

• Develop the notion of generalised Geodesic completeness.

• Incorporate the RR-RR sector into the generalised framework.
Future Research/other ideas

- Complete the construction of GG and DFT geometric invariant (Kretschmann).

- Explore the notions of generalised Killing vector fields and generalised Killing horizons.

- Develop the notion of generalised Geodesic completeness.

- Incorporate the RR-RR sector into the generalised framework.

- Explore these ideas of non-Riemannian background (new string solutions beyond Riemann).
Future Research/other ideas

- Complete the construction of GG and DFT geometric invariant (Kretschmann).

- Explore the notions of generalised Killing vector fields and generalised Killing horizons.

- Develop the notion of generalised Geodesic completeness.

- Incorporate the RR-RR sector into the generalised framework.

- Explore these ideas of non-Riemannian background (new string solutions beyond Riemann).

- Further applications of DFT + GG for string cosmology, black hole physics, string phenomenology.
Future Research/other ideas

- Complete the construction of GG and DFT geometric invariant (Kretschmann).
- Explore the notions of generalised Killing vector fields and generalised Killing horizons.
- Develop the notion of generalised Geodesic completeness.
- Incorporate the RR-RR sector into the generalised framework.
- Explore these ideas of non-Riemannian background (new string solutions beyond Riemann).
- Further applications of DFT + GG for string cosmology, black hole physics, string phenomenology.

Thanks for listening to my TED talk.
References