Quantum Gravity from a Different Perspective

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In collaboration with Ralph Blumenhagen , Andreas Deser and Erik Plauschinn

$\Delta p \cdot \Delta q \geqslant \frac{1}{2} \hbar$

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Outline

- A conception of Quantum Geometry
- Quantum Gravity from String Theory
- T-duality, fluxes and “non-geometry”
- Framework for fluxes
- Strings at low energies

Based on arXiv	1106.0316 (with Dieter Lüst) 1202.4934 1205.1522 1210.1591 1211.0030

A conception of Quantum Gravity

- general problem: quantizing general relativity gives a non-finite (non-renormalizable) theory

- at close range: spacetime is believed to be *fuzzy*

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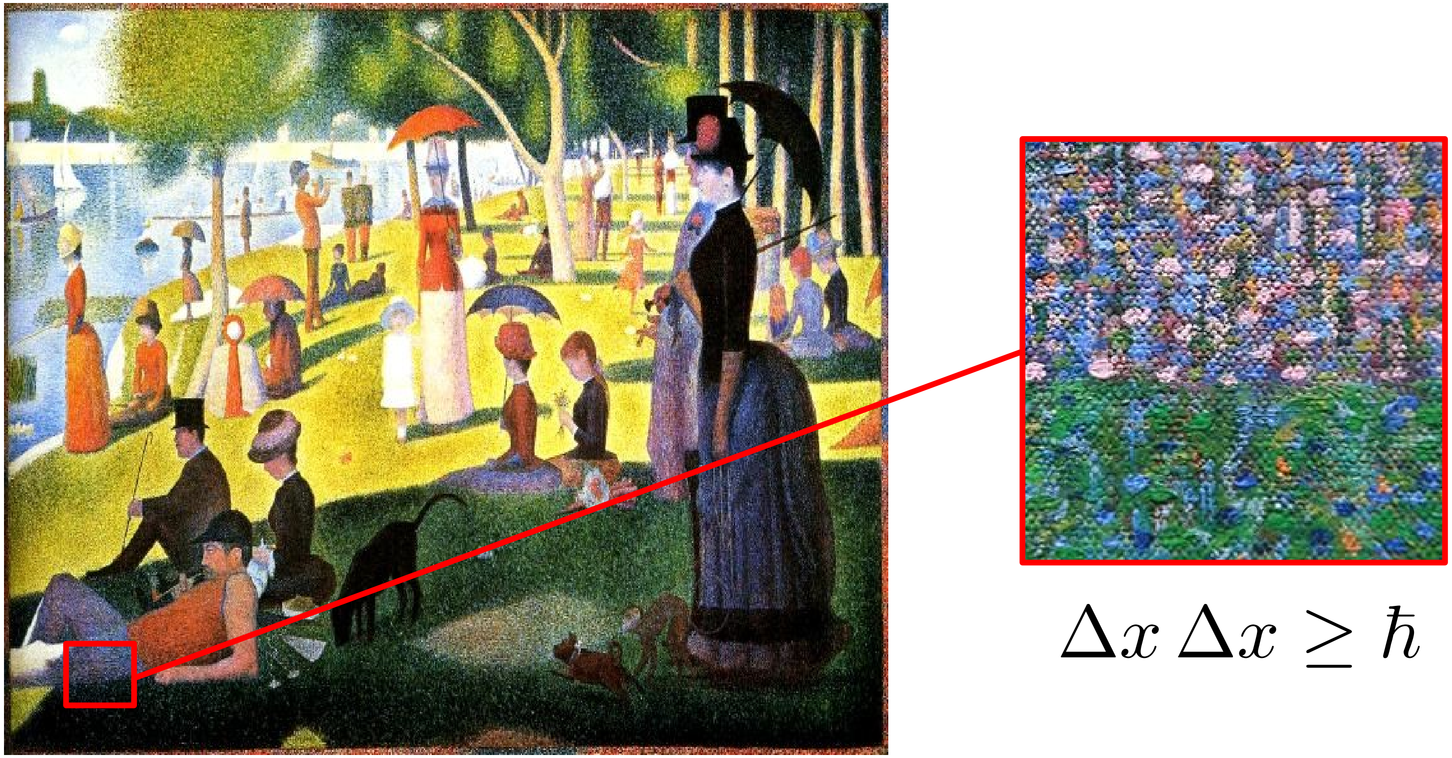

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- **Non-commutative geometry etc.**

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- and String Theory ?

Quantum Gravity from String Theory

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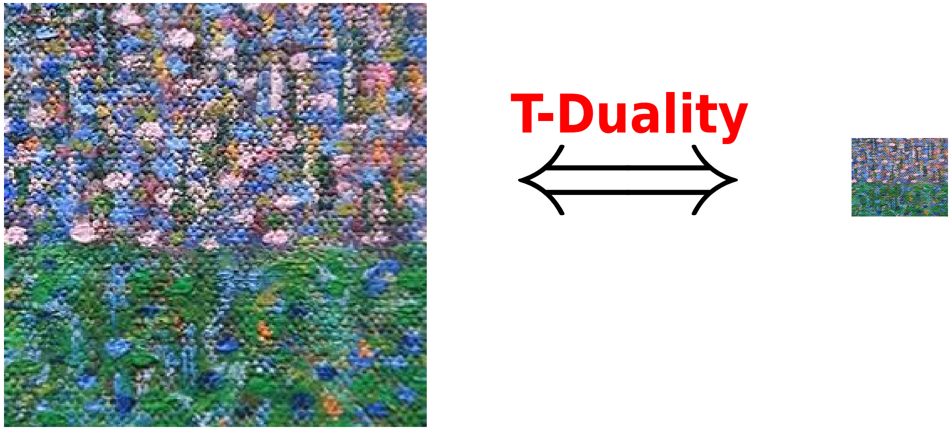
So how does the quantum geometry look like?

- String Theory is *cheating*:



T-duality, fluxes and “non-geometry”

- **basic example: 3-Torus with *H*-flux**

$$H \longrightarrow f \longrightarrow Q \longrightarrow R$$

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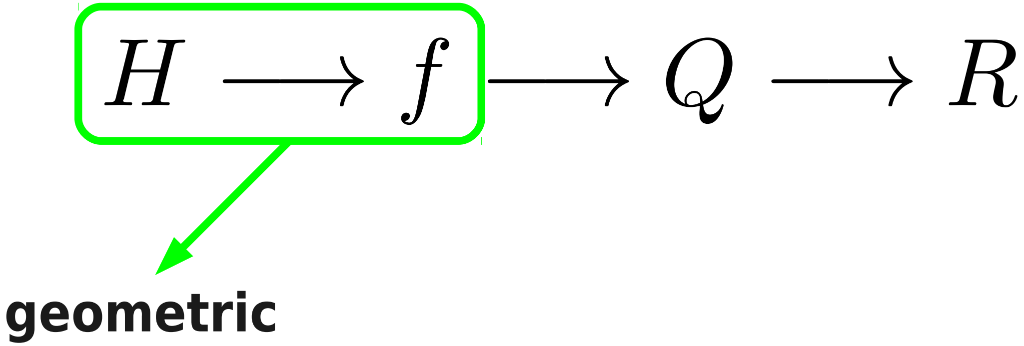

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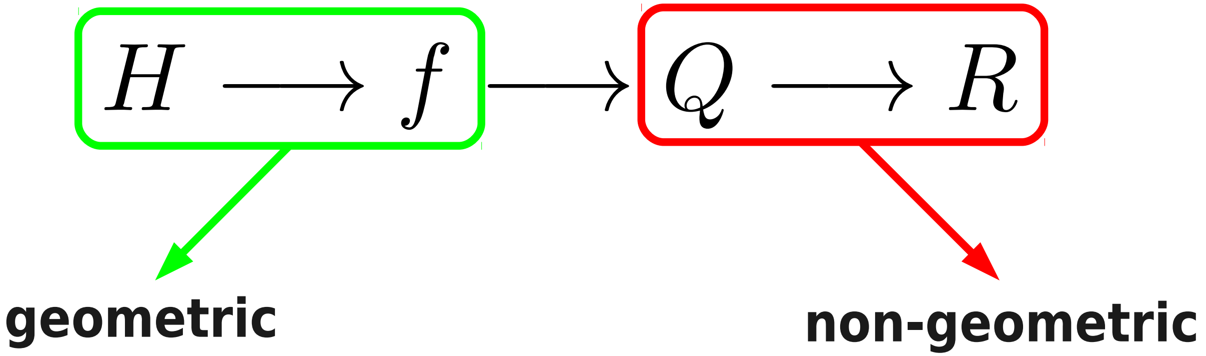

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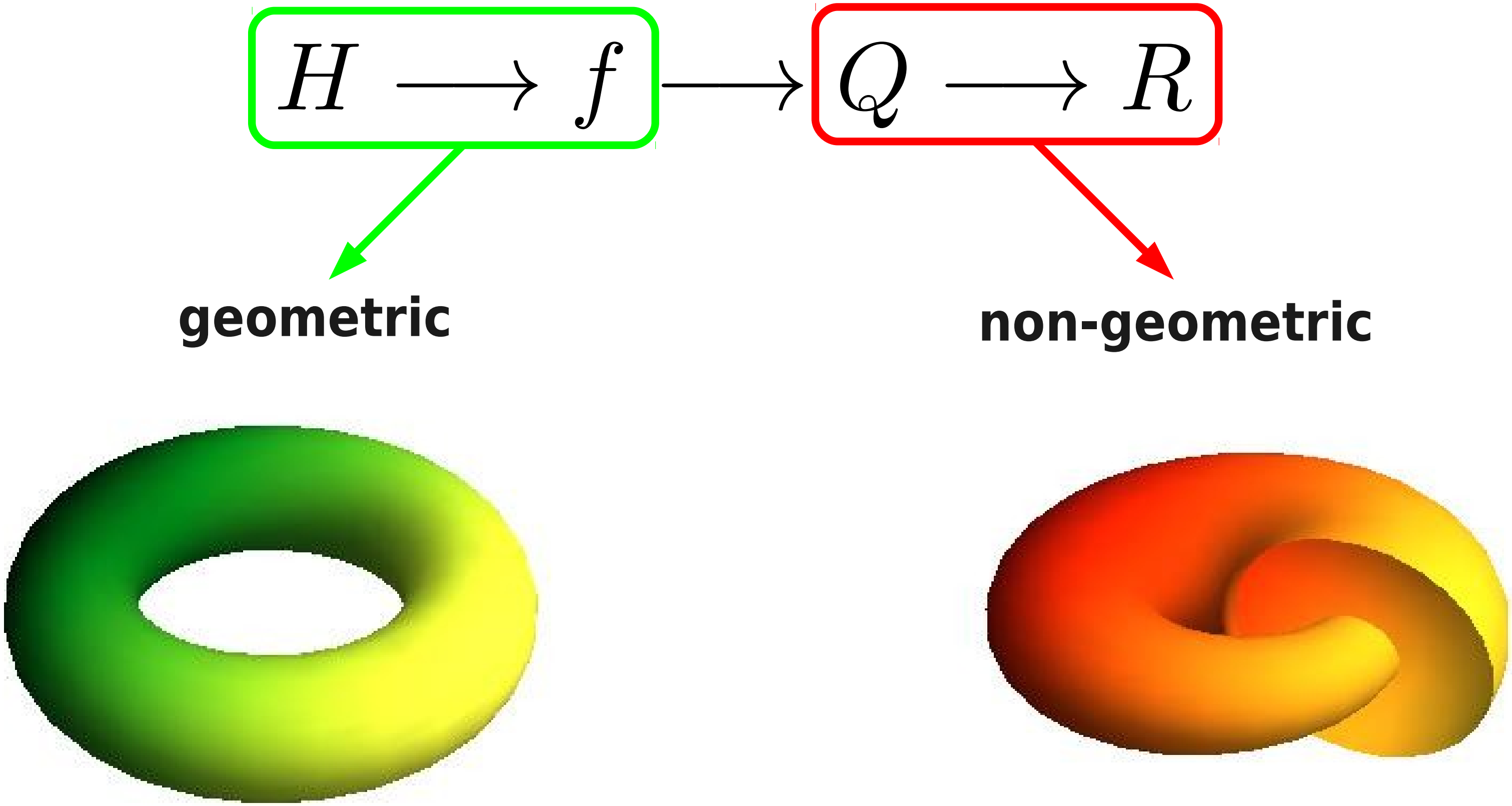

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- cannot be obtained as others
- non-geometric locally
- non-associative geometry

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- ***H*- and *R*-flux *special***

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- ***R*-flux might describe small-scale quantum geometry**

Framework for fluxes

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- **ingredients for conventional geometry (*H*-flux)**

space for points

$$M$$

space for *evolution*

$$(TM\,,\,L)$$

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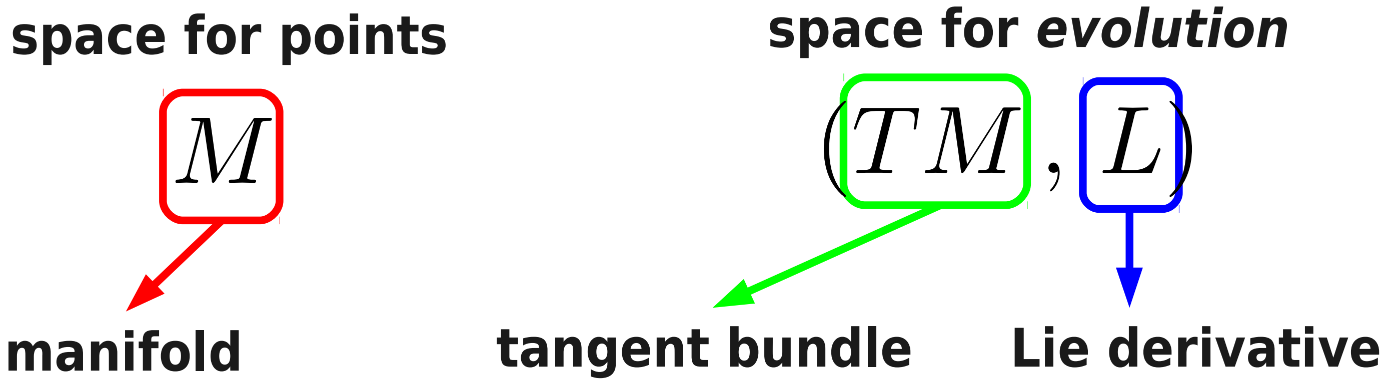

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Lie derivative

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tangent bundle **Lie derivative**

$$\boxed{\begin{aligned} L_X Y &= [X, Y]_L \\ L_X \xi &= d(\iota_X \xi) + \iota_X (d\xi) \end{aligned}}$$

describes the evolution of tensors along a path

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$$(TM, [\cdot, \cdot]_L, \partial_a)$$

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$$(TM, [\cdot,\cdot]_L, \partial_a) \implies \nabla_a, \mathcal{R}^a{}_{bcd} \;\ldots$$

  - **covariant derivative**
  - **curvature**
  - **...**

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$$\Big(\underbrace{\boxed{T^*M}}_{\text{co-tangent bundle}}, \underbrace{\boxed{[\cdot,\cdot]^H_K}}_{H\text{-twisted Koszul bracket}}, D^a\Big)$$

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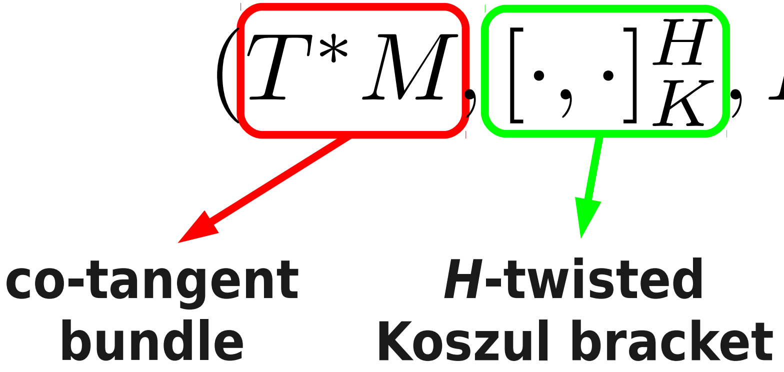

$$(\boxed{T^*M}, \boxed{[\cdot,\cdot]^H_K}, D^a)$$

co-tangent bundle

***H*-twisted Koszul bracket**

$$\boxed{[\xi,\eta]^H_K = L_{\beta^\sharp\xi}\eta - \iota_{\beta^\sharp\eta}d\xi - \iota_{\beta^\sharp\eta}\iota_{\beta^\sharp\xi}H}$$

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***anchor*: relates TM and T^*M**

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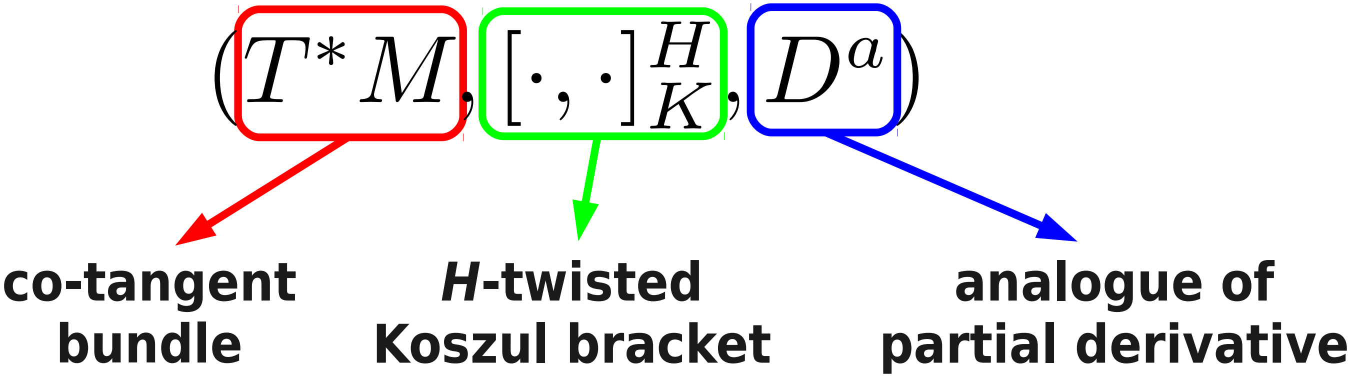

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$$\boxed{\mathrm{D}^a f = \beta^{am} \partial_m f}$$

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$$\{f,g\} = \beta(df,dg)$$

$$\{f,\{g,h\}\} + \{h,\{f,g\}\} + \{g,\{h,f\}\} = R(df,dg,dh)$$

Strings at low energies

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- **usual fields;** $(TM, [\cdot,\cdot]_L, \partial_a)$

$$S(G,B,\phi) = \int d^n x \sqrt{-|G|} e^{-2\phi} \left(\mathcal{R} - \tfrac{1}{12} H_{abc} H^{abc} + 4\partial_a \phi \, \partial^a \phi \right) + \ldots$$

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a new kind of tensor

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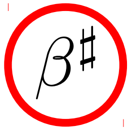

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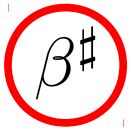

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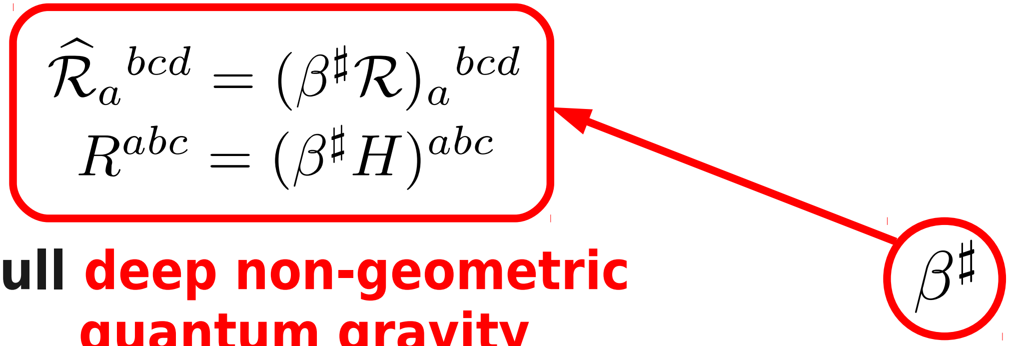

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full deep non-geometric quantum gravity

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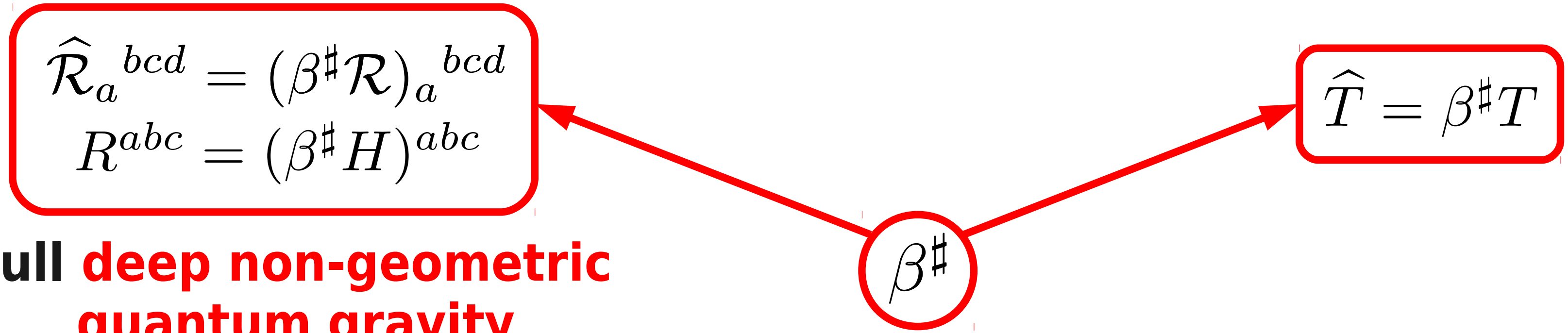

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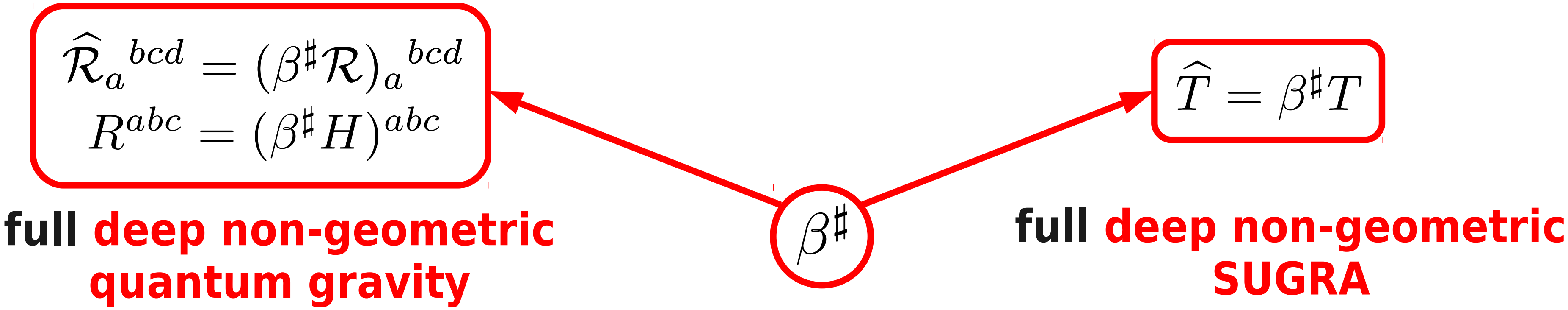

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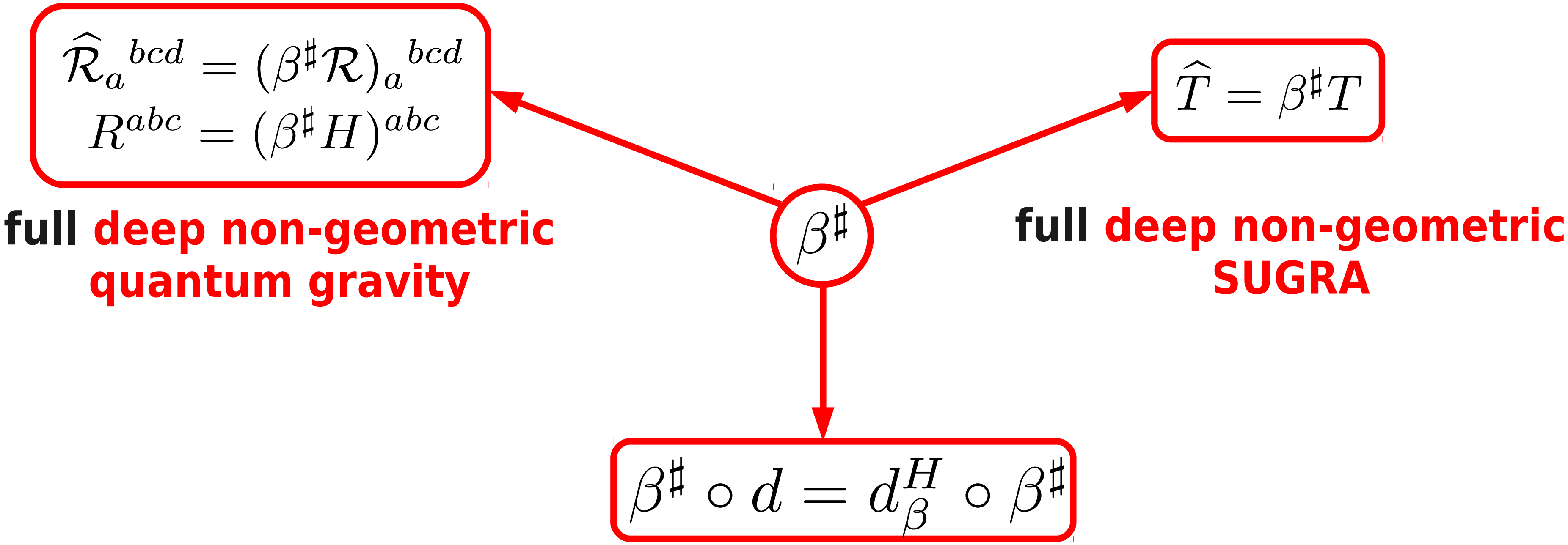

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$$\beta^\sharp \circ d = d^H_\beta \circ \beta^\sharp$$

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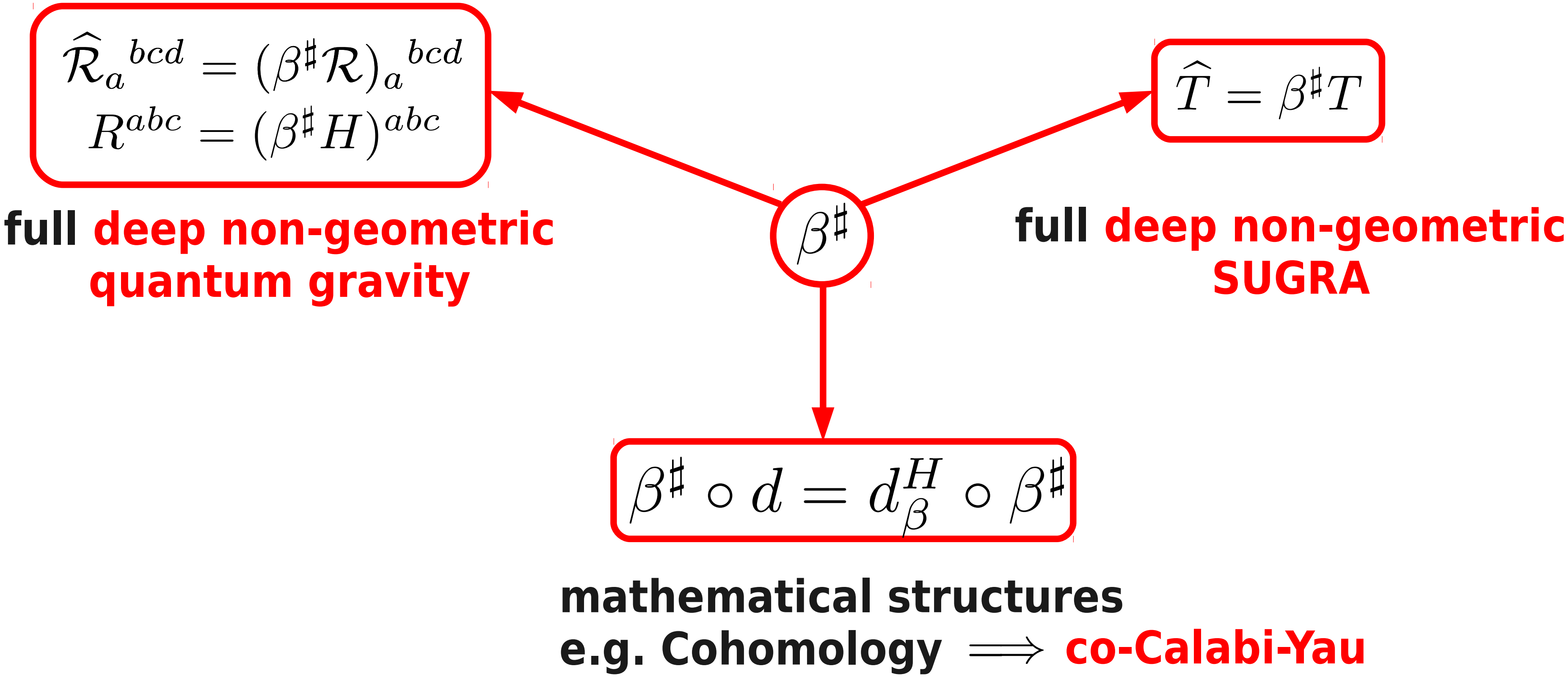

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$$\beta^\sharp \circ d = d_\beta^H \circ \beta^\sharp$$

mathematical structures
e.g. Cohomology $\Longrightarrow$ co-Calabi-Yau

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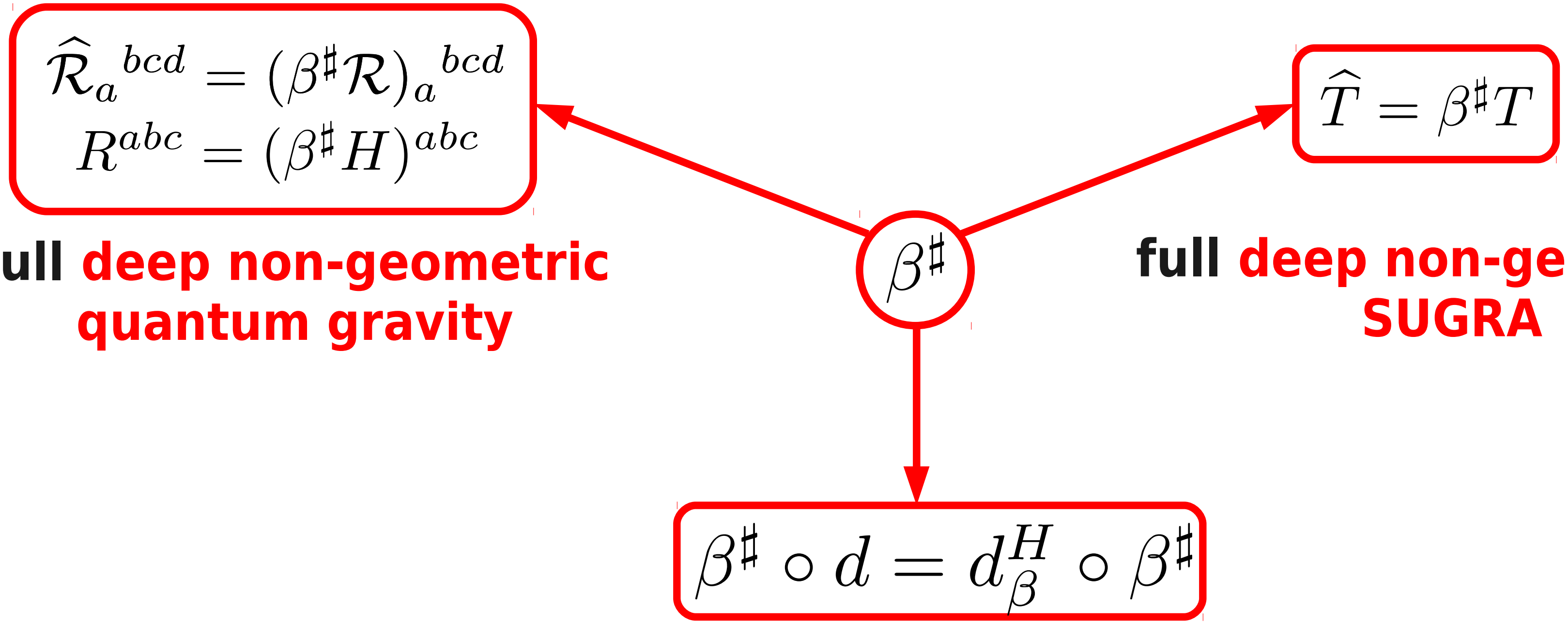

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full deep non-geometric SUGRA

$$\beta^\sharp \circ d = d_\beta^H \circ \beta^\sharp$$

mathematical structures
e.g. Cohomology $\Longrightarrow$ co-Calabi-Yau

- **EOM's are of the same form $\Longrightarrow$ non-geometric analogues**

Summary

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***H*-flux**

$$(TM, [\cdot,\cdot]_L, \partial_a)$$

***R*-flux**

$$(T^*M, [\cdot,\cdot]^H_K, D^a)$$

Summary

***H*-flux**

$$(TM, [\cdot,\cdot]_L, \partial_a)$$

conventional geometry

***R*-flux**

$$(T^*M, [\cdot,\cdot]_K^H, D^a)$$

deep non-geometry

Summary

H-flux

$$(TM, [\cdot,\cdot]_L, \partial_a)$$

conventional geometry

$$S(G, B, \phi)$$

R-flux

$$(T^*M, [\cdot,\cdot]_K^H, D^a)$$

deep non-geometry

$$\widehat{S}(\widehat{g}, \beta, \phi)$$

Summary

***H*-flux**

$(TM, [\cdot,\cdot]_L, \partial_a)$

conventional geometry

$S(G, B, \phi)$

$\beta^\sharp$

$\longleftrightarrow$

***R*-flux**

$(T^*M, [\cdot,\cdot]_K^H, D^a)$

deep non-geometry

$\widehat{S}(\widehat{g}, \beta, \phi)$

Summary

***H*-flux**

$(TM, [\cdot,\cdot]_L, \partial_a)$

conventional geometry

$S(G, B, \phi)$

$$\xleftrightarrow{\beta^\sharp}$$

***R*-flux**

$(T^*M, [\cdot,\cdot]^H_K, D^a)$

deep non-geometry

$\widehat{S}(\widehat{g}, \beta, \phi)$

THANK YOU