β-supergravity: geometric framework, NS-branes and Bianchi identities with non-geometric fluxes

André Betz

Max-Planck-Institute for Physics Munich

based on work with David Andriot
arXiv: 1306.4381 and 1402.597

XXVI Workshop Beyond the Standard Model
Bad Honnef, March 10, 2014

Nongeometric fluxes in 4d and 10d

Nongeometric fluxes in NSNS sector: $Q_a{}^{bc}$, R^{abc}

Nongeometric fluxes in 4d and 10d

Nongeometric fluxes in NSNS sector: $Q_a{}^{bc}$, R^{abc}

4d gauged supergravities

Nongeometric fluxes in 4d and 10d

Nongeometric fluxes in NSNS sector: $Q_a{}^{bc}$, R^{abc}

4d gauged supergravities

appearance:

- embedding tensor

Nongeometric fluxes in 4d and 10d

Nongeometric fluxes in NSNS sector: $Q_a{}^{bc}$, R^{abc}

4d gauged supergravities

appearance:

- embedding tensor
- structure constants in the gauge algebras

Nongeometric fluxes in 4d and 10d

Nongeometric fluxes in NSNS sector: $Q_a{}^{bc}$, R^{abc}

4d gauged supergravities

appearance:

- embedding tensor
- structure constants in the gauge algebras
- T-duality invariant super/scalar potential

Shelton, Taylor & Wecht '06
Dabholkar & Hull '02, '05

Nongeometric fluxes in 4d and 10d

Nongeometric fluxes in NSNS sector: $Q_a{}^{bc}$, R^{abc}

4d gauged supergravities

appearance:

- embedding tensor
- structure constants in the gauge algebras
- T-duality invariant super/scalar potential

Shelton, Taylor & Wecht '06
Dabholkar & Hull '02, '05

advantage:

- moduli stabilization

Nongeometric fluxes in 4d and 10d

Nongeometric fluxes in NSNS sector: $Q_a{}^{bc}$, R^{abc}

4d gauged supergravities

appearance:

- embedding tensor
- structure constants in the gauge algebras
- T-duality invariant super/scalar potential

Shelton, Taylor & Wecht '06
Dabholkar & Hull '02, '05

advantage:

- moduli stabilization
- find dS solutions

Shelton, Taylor & Wecht '05
Micu, Palti & Tasinato '07
Danielsson, et al '12, '13
Damian, et al '13

Nongeometric fluxes in 4d and 10d

Nongeometric fluxes in NSNS sector: $Q_a{}^{bc}$, R^{abc}

4d gauged supergravities

appearance:

- embedding tensor
- structure constants in the gauge algebras
- T-duality invariant super/scalar potential

Shelton, Taylor & Wecht '06
Dabholkar & Hull '02, '05

advantage:

- moduli stabilization
- find dS solutions

Shelton, Taylor & Wecht '05
Micu, Palti & Tasinato '07
Danielsson, et al '12, '13
Damian, et al '13

How does the picture look like in 10d?

Nongeometric fluxes in 4d and 10d

10d supergravities

Nongeometric fluxes in 4d and 10d

10d supergravities

appearance:

- non, there is just standard supergravity

$$\mathcal{L}_{\mathrm{NSNS}} \equiv e^{-2\phi}\sqrt{|g|}\left(\mathcal{R}(g) + 4(\partial\phi)^2 - \frac{1}{2}H^2\right)$$

  - with NS-fluxes $f^a{}_{bc}$, H_{abc} (and possible RR-flux F)

Nongeometric fluxes in 4d and 10d

10d supergravities

appearance:

- non, there is just standard supergravity

$$\mathcal{L}_{\mathrm{NSNS}} \equiv e^{-2\phi}\sqrt{|g|}\left(\mathcal{R}(g) + 4(\partial\phi)^2 - \tfrac{1}{2}H^2\right)$$

  - with NS-fluxes $f^a{}_{bc}$, H_{abc} (and possible RR-flux F)
- but, related to T-dual configurations of geometric vacua
  - e.g. 2 T-dualities on the torus with H-flux
  - metric g and b-field b experience monodromies

Hellerman, McGreevy & B. Williams '02
Dabholkar & Hull '02
Flournoy, Wecht & Williams '04

Nongeometric fluxes in 4d and 10d

10d supergravities

appearance:

- non, there is just standard supergravity

$$\mathcal{L}_{\text{NSNS}} \equiv e^{-2\phi}\sqrt{|g|}\left(\mathcal{R}(g) + 4(\partial\phi)^2 - \tfrac{1}{2}H^2\right)$$

  - with NS-fluxes ${f^a}_{bc}$, H_{abc} (and possible RR-flux F)
- but, related to T-dual configurations of geometric vacua
  - e.g. 2 T-dualities on the torus with H-flux
  - metric g and b-field b experience monodromies

Hellerman, McGreevy & B. Williams '02
Dabholkar & Hull '02
Flournoy, Wecht & Williams '04

advantages of β-supergravity:

- 10d solutions and possible compactifications

Nongeometric fluxes in 4d and 10d

10d supergravities

appearance:

- non, there is just standard supergravity

$$\mathcal{L}_{\mathrm{NSNS}} \equiv e^{-2\phi}\sqrt{|g|}\left(\mathcal{R}(g) + 4(\partial\phi)^2 - \tfrac{1}{2}H^2\right)$$

  - with NS-fluxes $f^a{}_{bc}$, H_{abc} (and possible RR-flux F)
- but, related to T-dual configurations of geometric vacua
  - e.g. 2 T-dualities on the torus with H-flux
  - metric g and b-field b experience monodromies

Hellerman, McGreevy & B. Williams '02
Dabholkar & Hull '02
Flournoy, Wecht & Williams '04

advantages of β-supergravity:

- 10d solutions and possible compactifications
- uplift of 4d gauged supergravities with nongeometric fluxes

Nongeometric fluxes in 4d and 10d

10d supergravities

appearance:

- non, there is just standard supergravity

$$\mathcal{L}_{\mathrm{NSNS}} \equiv e^{-2\phi}\sqrt{|g|}\left(\mathcal{R}(g) + 4(\partial\phi)^2 - \tfrac{1}{2}H^2\right)$$

  - with NS-fluxes $f^a{}_{bc}$, H_{abc} (and possible RR-flux F)
- but, related to T-dual configurations of geometric vacua
  - e.g. 2 T-dualities on the torus with H-flux
  - metric g and b-field b experience monodromies

Hellerman, McGreevy & B. Williams '02
Dabholkar & Hull '02
Flournoy, Wecht & Williams '04

advantages of β-supergravity:

- 10d solutions and possible compactifications
- uplift of 4d gauged supergravities with nongeometric fluxes

How do we make non-geometric fluxes appear in 10d?

Reformulation of $\mathcal{L}_{\mathrm{NSNS}}$

basic idea:

field redefinition $(g_{mn}, b_{mn}, \phi) \leftrightarrow (\tilde{g}_{mn}, \beta^{mn}, \tilde{\phi})$

Andriot, Larfors, Lüst & Patalong '11

Reformulation of $\mathcal{L}_{\mathrm{NSNS}}$

basic idea:

field redefinition $(g_{mn}, b_{mn}, \phi) \leftrightarrow (\tilde{g}_{mn}, \beta^{mn}, \tilde{\phi})$

Andriot, Larfors, Lüst & Patalong '11

motivation:

- β related to nongeomtric fluxes Q and R

Grange & Schäfer-Nameki '06, '07
Graña, Minasian, Petrini & Waldram '08

Reformulation of $\mathcal{L}_{\text{NSNS}}$

basic idea:

field redefinition $(g_{mn}, b_{mn}, \phi) \leftrightarrow (\tilde{g}_{mn}, \beta^{mn}, \tilde{\phi})$

Andriot, Larfors, Lüst & Patalong '11

motivation:

- β related to nongeomtric fluxes Q and R

  Grange & Schäfer-Nameki '06, '07
  Graña, Minasian, Petrini & Waldram '08

- reparametrization of the gen. metric and the dilaton in GCG

$$\mathcal{H} = \begin{pmatrix} g - bg^{-1}b & -bg^{-1} \\ g^{-1}b & g^{-1} \end{pmatrix} = \begin{pmatrix} \tilde{g} & \tilde{g}\beta \\ -\beta\tilde{g} & \tilde{g}^{-1} - \beta\tilde{g}\beta \end{pmatrix}, \quad e^{-2d} = \begin{cases} e^{-2\phi}\sqrt{|g|} \\ e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|} \end{cases}$$

Reformulation of $\mathcal{L}_{\mathrm{NSNS}}$

basic idea:

field redefinition $(g_{mn}, b_{mn}, \phi) \leftrightarrow (\tilde{g}_{mn}, \beta^{mn}, \tilde{\phi})$

Andriot, Larfors, Lüst & Patalong '11

motivation:

- β related to nongeomtric fluxes Q and R

  Grange & Schäfer-Nameki '06, '07
  Graña, Minasian, Petrini & Waldram '08

- reparametrization of the gen. metric and the dilaton in GCG

$$\mathcal{H} = \begin{pmatrix} g - bg^{-1}b & -bg^{-1} \\ g^{-1}b & g^{-1} \end{pmatrix} = \begin{pmatrix} \tilde{g} & \tilde{g}\beta \\ -\beta\tilde{g} & \tilde{g}^{-1} - \beta\tilde{g}\beta \end{pmatrix}, \quad e^{-2d} = \begin{cases} e^{-2\phi}\sqrt{|g|} \\ e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|} \end{cases}$$

result of direct calculation (rewritting):

$$\tilde{\mathcal{L}}_0 = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\Big(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 - \tfrac{1}{2}R^2 + 4\mathrm{lines}(\partial, \tilde{g}, \beta)\Big), \; R^{mnp} = 3\beta^{q[m}\nabla_q\beta^{np]}$$

Andriot, Hohm, Larfors, Lüst & Patalong '12

Reformulation of $\mathcal{L}_{\mathrm{NSNS}}$

basic idea:

field redefinition $(g_{mn}, b_{mn}, \phi) \leftrightarrow (\tilde{g}_{mn}, \beta^{mn}, \tilde{\phi})$

Andriot, Larfors, Lüst & Patalong '11

motivation:

- β related to nongeomtric fluxes Q and R

  Grange & Schäfer-Nameki '06, '07
  Graña, Minasian, Petrini & Waldram '08

- reparametrization of the gen. metric and the dilaton in GCG

$$\mathcal{H} = \begin{pmatrix} g - bg^{-1}b & -bg^{-1} \\ g^{-1}b & g^{-1} \end{pmatrix} = \begin{pmatrix} \tilde{g} & \tilde{g}\beta \\ -\beta\tilde{g} & \tilde{g}^{-1} - \beta\tilde{g}\beta \end{pmatrix}, \quad e^{-2d} = \begin{cases} e^{-2\phi}\sqrt{|g|} \\ e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|} \end{cases}$$

result of direct calculation (rewritting):

$$\tilde{\mathcal{L}}_0 = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\Big(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 - \tfrac{1}{2}R^2 + 4\text{lines}(\partial, \tilde{g}, \beta)\Big), \quad R^{mnp} = 3\beta^{q[m}\nabla_q\beta^{np]}$$

Andriot, Hohm, Larfors, Lüst & Patalong '12

- also derived from a manifest diffeo. invariant $\mathcal{L}_{DFT}(\mathcal{R}, \check{\mathcal{R}})$

Reformulation of $\mathcal{L}_{\text{NSNS}}$

basic idea:

field redefinition $(g_{mn}, b_{mn}, \phi) \leftrightarrow (\tilde{g}_{mn}, \beta^{mn}, \tilde{\phi})$

Andriot, Larfors, Lüst & Patalong '11

motivation:

- β related to nongeomtric fluxes Q and R

Grange & Schäfer-Nameki '06, '07
Graña, Minasian, Petrini & Waldram '08

- reparametrization of the gen. metric and the dilaton in GCG

$$\mathcal{H} = \begin{pmatrix} g - bg^{-1}b & -bg^{-1} \\ g^{-1}b & g^{-1} \end{pmatrix} = \begin{pmatrix} \tilde{g} & \tilde{g}\beta \\ -\beta\tilde{g} & \tilde{g}^{-1} - \beta\tilde{g}\beta \end{pmatrix}, \quad e^{-2d} = \begin{cases} e^{-2\phi}\sqrt{|g|} \\ e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|} \end{cases}$$

result of direct calculation (rewritting):

$$\tilde{\mathcal{L}}_0 = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\left(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 - \tfrac{1}{2}R^2 + 4\text{lines}(\partial, \tilde{g}, \beta)\right), R^{mnp} = 3\beta^{q[m}\nabla_q\beta^{np]}$$

Andriot, Hohm, Larfors, Lüst & Patalong '12

- also derived from a manifest diffeo. invariant $\mathcal{L}_{DFT}(\mathcal{R}, \check{\mathcal{R}})$

Can we actually see and learn more about the Q-flux from generalized geometry?

$O(d,d) \times \mathbb{R}^+$ structures and a generalized vielbein with β

- generalized tangent bundle E in GCG

$$E \cong TM \oplus T^*M$$

Hitchin '02 & Gualtieri '04

$O(d,d) \times \mathbb{R}^+$ structures and a generalized vielbein with β

- generalized tangent bundle E in GCG

$$E \cong TM \oplus T^*M$$

Hitchin '02 & Gualtieri '04

- conformal split frames with b

$$e^{-2d}\ \mathcal{E}_A = \begin{cases} e^{-2d}\ \mathcal{E}_a = e^{-2\phi}\sqrt{|g|}\ (\partial_a + b_{ab}e^b) \\ e^{-2d}\ \mathcal{E}^a = e^{-2\phi}\sqrt{|g|}\ e^a \end{cases} \quad , \quad \mathcal{E} = \begin{pmatrix} e & 0 \\ e^{-T}b & e^{-T} \end{pmatrix}$$

Coimbra, Strickland-Constable & Waldram '11

$O(d,d) \times \mathbb{R}^+$ structures and a generalized vielbein with β

- generalized tangent bundle E in GCG

$$E \cong TM \oplus T^*M$$

Hitchin '02 & Gualtieri '04

- conformal split frames with b or β

$$e^{-2d}\ \mathcal{E}_A = \begin{cases} e^{-2d}\ \mathcal{E}_a = e^{-2\phi}\sqrt{|g|}\ (\partial_a + b_{ab}e^b) \\ e^{-2d}\ \mathcal{E}^a = e^{-2\phi}\sqrt{|g|}\ e^a \end{cases} \quad , \quad \mathcal{E} = \begin{pmatrix} e & 0 \\ e^{-T}b & e^{-T} \end{pmatrix}$$

Coimbra, Strickland-Constable & Waldram '11

$$e^{-2d}\ \tilde{\mathcal{E}}_A = \begin{cases} e^{-2d}\ \tilde{\mathcal{E}}_a = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\ \partial_a \\ e^{-2d}\ \tilde{\mathcal{E}}^a = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\ (\tilde{e}^a + \beta^{ab}\partial_b) \end{cases} \quad , \quad \tilde{\mathcal{E}} = \begin{pmatrix} \tilde{e} & \tilde{e}\beta \\ 0 & \tilde{e}^{-T} \end{pmatrix}$$

$O(d,d) \times \mathbb{R}^+$ structures and a generalized vielbein with β

- generalized tangent bundle E in GCG

$$E \cong TM \oplus T^*M$$

Hitchin '02 & Gualtieri '04

- conformal split frames with b or β

$$e^{-2d}\ \mathcal{E}_A = \begin{cases} e^{-2d}\ \mathcal{E}_a = e^{-2\phi}\sqrt{|g|}\ (\partial_a + b_{ab}e^b) \\ e^{-2d}\ \mathcal{E}^a = e^{-2\phi}\sqrt{|g|}\ e^a \end{cases} \quad , \quad \mathcal{E} = \begin{pmatrix} e & 0 \\ e^{-T}b & e^{-T} \end{pmatrix}$$

Coimbra, Strickland-Constable & Waldram '11

$$e^{-2d}\ \tilde{\mathcal{E}}_A = \begin{cases} e^{-2d}\ \tilde{\mathcal{E}}_a = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\ \partial_a \\ e^{-2d}\ \tilde{\mathcal{E}}^a = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\ (\tilde{e}^a + \beta^{ab}\partial_b) \end{cases} \quad , \quad \tilde{\mathcal{E}} = \begin{pmatrix} \tilde{e} & \tilde{e}\beta \\ 0 & \tilde{e}^{-T} \end{pmatrix}$$

  - fibration of the generalized bundle

$O(d,d) \times \mathbb{R}^+$ structures and a generalized vielbein with β

- generalized tangent bundle E in GCG

$$E \cong TM \oplus T^*M$$

Hitchin '02 & Gualtieri '04

- conformal split frames with b or β

$$e^{-2d}\ \mathcal{E}_A = \begin{cases} e^{-2d}\ \mathcal{E}_a = e^{-2\phi}\sqrt{|g|}\ (\partial_a + b_{ab}e^b) \\ e^{-2d}\ \mathcal{E}^a = e^{-2\phi}\sqrt{|g|}\ e^a \end{cases} \quad , \quad \mathcal{E} = \begin{pmatrix} e & 0 \\ e^{-T}b & e^{-T} \end{pmatrix}$$

Coimbra, Strickland-Constable & Waldram '11

$$e^{-2d}\ \tilde{\mathcal{E}}_A = \begin{cases} e^{-2d}\ \tilde{\mathcal{E}}_a = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\ \partial_a \\ e^{-2d}\ \tilde{\mathcal{E}}^a = e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}\ (\tilde{e}^a + \beta^{ab}\partial_b) \end{cases} \quad , \quad \tilde{\mathcal{E}} = \begin{pmatrix} \tilde{e} & \tilde{e}\beta \\ 0 & \tilde{e}^{-T} \end{pmatrix}$$

  - fibration of the generalized bundle

- a generalized connection on $TM \oplus T^*M \times \mathbb{R}^+$

$$D_A V^B = \partial_A V^B + \hat{\Omega}_A{}^B{}_C V^C$$

Generalized connections with non-geometric fluxes

- generalized covariant derivative for b

$$\begin{cases} (D_a V^B)e^{-2d}\ \mathcal{E}_B = e^{-2d}\left((\nabla_a v^b)\mathcal{E}_b + (\nabla_a v_b)\mathcal{E}^b - \frac{1}{3}H_{abc}v^c\mathcal{E}^b - \lambda_a V^B\mathcal{E}_B\right) \\ (D^a V^B)e^{-2d}\ \mathcal{E}_B = 0 \end{cases}$$

Generalized connections with non-geometric fluxes

- generalized covariant derivatives for b or β

$$\begin{cases} (D_a V^B)e^{-2d}\ \mathcal{E}_B = e^{-2d}\left((\nabla_a v^b)\mathcal{E}_b + (\nabla_a v_b)\mathcal{E}^b - \frac{1}{3}H_{abc}v^c\mathcal{E}^b - \lambda_a V^B\mathcal{E}_B\right) \\ (D^a V^B)e^{-2d}\ \mathcal{E}_B = 0 \end{cases}$$

$$\begin{cases} (D_a V^B)e^{-2d}\ \tilde{\mathcal{E}}_B = e^{-2d}\left((\nabla_a v^b)\tilde{\mathcal{E}}_b + (\nabla_a v_b)\tilde{\mathcal{E}}^b - \lambda_a V^B\tilde{\mathcal{E}}_B \right) \\ (D^a V^B)e^{-2d}\ \tilde{\mathcal{E}}_B = e^{-2d}\left(-(\check{\nabla}^a v^b)\tilde{\mathcal{E}}_b - (\check{\nabla}^a v_b)\tilde{\mathcal{E}}^b + \frac{1}{3}R^{abc}v_c\tilde{\mathcal{E}}_b - \xi^a V^B\tilde{\mathcal{E}}_B\right) \end{cases}$$

Generalized connections with non-geometric fluxes

- generalized covariant derivatives for b or β

$$\begin{cases}(D_a V^B)e^{-2d}\ \mathcal{E}_B = e^{-2d}\left((\nabla_a v^b)\mathcal{E}_b + (\nabla_a v_b)\mathcal{E}^b - \frac{1}{3}H_{abc}v^c\mathcal{E}^b - \lambda_a V^B\mathcal{E}_B\right)\\ (D^a V^B)e^{-2d}\ \mathcal{E}_B = 0\end{cases}$$

$$\begin{cases}(D_a V^B)e^{-2d}\ \tilde{\mathcal{E}}_B = e^{-2d}\left(\ (\nabla_a v^b)\tilde{\mathcal{E}}_b + (\nabla_a v_b)\tilde{\mathcal{E}}^b - \lambda_a V^B\tilde{\mathcal{E}}_B\ \right)\\ (D^a V^B)e^{-2d}\ \tilde{\mathcal{E}}_B = e^{-2d}\left(-(\check{\nabla}^a v^b)\tilde{\mathcal{E}}_b - (\check{\nabla}^a v_b)\tilde{\mathcal{E}}^b + \frac{1}{3}R^{abc}v_c\tilde{\mathcal{E}}_b - \xi^a V^B\tilde{\mathcal{E}}_B\right)\end{cases}$$

$$Q_c{}^{ab} = \partial_c\beta^{ab} - 2\beta^{d[a}f^{b]}{}_{cd}\ , \qquad R^{abc} = 3\beta^{d[a}\nabla_d\beta^{bc]}$$

Generalized connections with non-geometric fluxes

- generalized covariant derivatives for b or β

$$\begin{cases} (D_a V^B)e^{-2d}\ \mathcal{E}_B = e^{-2d}\left((\nabla_a v^b)\mathcal{E}_b + (\nabla_a v_b)\mathcal{E}^b - \frac{1}{3}H_{abc}v^c\mathcal{E}^b - \lambda_a V^B\mathcal{E}_B\right) \\ (D^a V^B)e^{-2d}\ \mathcal{E}_B = 0 \end{cases}$$

$$\begin{cases} (D_a V^B)e^{-2d}\ \tilde{\mathcal{E}}_B = e^{-2d}\left(\ (\nabla_a v^b)\tilde{\mathcal{E}}_b + (\nabla_a v_b)\tilde{\mathcal{E}}^b - \lambda_a V^B\tilde{\mathcal{E}}_B\ \right) \\ (D^a V^B)e^{-2d}\ \tilde{\mathcal{E}}_B = e^{-2d}\left(-(\check{\nabla}^a v^b)\tilde{\mathcal{E}}_b - (\check{\nabla}^a v_b)\tilde{\mathcal{E}}^b + \frac{1}{3}R^{abc}v_c\tilde{\mathcal{E}}_b - \xi^a V^B\tilde{\mathcal{E}}_B\right) \end{cases}$$

$$Q_c{}^{ab} = \partial_c\beta^{ab} - 2\beta^{d[a}f^{b]}{}_{cd}\ , \qquad R^{abc} = 3\beta^{d[a}\nabla_d\beta^{bc]}$$

Q-flux enters in connection

$$\omega_Q{}_a{}^{bc} = \frac{1}{2}\left(Q_a{}^{bc} + \eta_{ad}\eta^{ce}Q_e{}^{db} + \eta_{ad}\eta^{be}Q_e{}^{dc}\right)$$

Generalized connections with non-geometric fluxes

- generalized covariant derivatives for b or β

$$\begin{cases} (D_a V^B)e^{-2d}\ \mathcal{E}_B = e^{-2d}\left((\nabla_a v^b)\mathcal{E}_b + (\nabla_a v_b)\mathcal{E}^b - \frac{1}{3}H_{abc}v^c\mathcal{E}^b - \lambda_a V^B\mathcal{E}_B\right) \\ (D^a V^B)e^{-2d}\ \mathcal{E}_B = 0 \end{cases}$$

$$\begin{cases} (D_a V^B)e^{-2d}\ \tilde{\mathcal{E}}_B = e^{-2d}\left((\nabla_a v^b)\tilde{\mathcal{E}}_b + (\nabla_a v_b)\tilde{\mathcal{E}}^b - \lambda_a V^B\tilde{\mathcal{E}}_B \right) \\ (D^a V^B)e^{-2d}\ \tilde{\mathcal{E}}_B = e^{-2d}\left(-(\check{\nabla}^a v^b)\tilde{\mathcal{E}}_b - (\check{\nabla}^a v_b)\tilde{\mathcal{E}}^b + \frac{1}{3}R^{abc}v_c\tilde{\mathcal{E}}_b - \xi^a V^B\tilde{\mathcal{E}}_B\right) \end{cases}$$

$$Q_c{}^{ab} = \partial_c\beta^{ab} - 2\beta^{d[a}f^{b]}{}_{cd}\ , \quad R^{abc} = 3\beta^{d[a}\nabla_d\beta^{bc]}$$

Q-flux enters in connection

$$\omega_Q{}_a^{bc} = \frac{1}{2}\left(Q_a{}^{bc} + \eta_{ad}\eta^{ce}Q_e{}^{db} + \eta_{ad}\eta^{be}Q_e{}^{dc}\right)$$

new covariant derivative based on β

$$\check{\nabla}^a v^b = -\beta^{ac}\partial_c v^b + \omega_Q{}_c^{ab}v^c\ , \quad \check{\nabla}^a v_b = -\beta^{ac}\partial_c v_b - \omega_Q{}_b^{ac}v_c$$

Calculation of $\tilde{\mathcal{L}}_\beta$ and the equations of motion

- $\tilde{\mathcal{L}}_\beta$ with nongeometric fluxes $Q_a{}^{bc}$ and R^{abc}

$$-\frac{1}{4} S \epsilon^+ = \left(\gamma^a D_a \gamma^b D_b - \overline{\eta^{ab}} D_{\overline{a}} D_{\overline{b}} \right) \epsilon^+$$

Calculation of $\tilde{\mathcal{L}}_\beta$ and the equations of motion

- $\tilde{\mathcal{L}}_\beta$ with nongeometric fluxes $Q_a{}^{bc}$ and R^{abc}

$$-\frac{1}{4} S \epsilon^+ = \left(\gamma^a D_a \gamma^b D_b - \overline{\eta^{ab}} D_{\overline{a}} D_{\overline{b}} \right) \epsilon^+$$

$$S = e^{2d} \; \tilde{\mathcal{L}}_\beta + e^{2d} \; \partial(\dots)$$

Calculation of $\tilde{\mathcal{L}}_\beta$ and the equations of motion

- $\tilde{\mathcal{L}}_\beta$ with nongeometric fluxes $Q_a{}^{bc}$ and R^{abc}

$$-\frac{1}{4}S\epsilon^+ = \left(\gamma^a D_a \gamma^b D_b - \overline{\eta^{ab}} D_{\overline{a}} D_{\overline{b}}\right)\epsilon^+$$

$$\tilde{\mathcal{L}}_\beta = e^{-2d}\left(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 + 4(\beta^{ab}\partial_b\tilde{\phi} - \mathcal{T}^a)^2 + \mathcal{R}_Q - \frac{1}{2}R^{acd}f^b{}_{cd}\eta_{ab} - \frac{1}{2}R^2\right)$$

Calculation of $\tilde{\mathcal{L}}_\beta$ and the equations of motion

- $\tilde{\mathcal{L}}_\beta$ with nongeometric fluxes ${Q_a}^{bc}$ and R^{abc}

$$-\frac{1}{4}S\epsilon^+ = \left(\gamma^a D_a \gamma^b D_b - \overline{\eta^{ab}} D_{\overline{a}} D_{\overline{b}}\right)\epsilon^+$$

$$\tilde{\mathcal{L}}_\beta = e^{-2d}\left(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 + 4(\beta^{ab}\partial_b\tilde{\phi} - \mathcal{T}^a)^2 + \mathcal{R}_Q - \frac{1}{2}R^{acd}{f^b}_{cd}\eta_{ab} - \frac{1}{2}R^2\right)$$

  - new scalar curvature for the Q-flux (analogue to f-flux)

$$\mathcal{R}_Q = 2\eta_{ab}\beta^{ad}\partial_d {Q_c}^{bc} - \eta_{cd}{Q_a}^{ac}{Q_b}^{bd} - \frac{1}{2}\eta_{cd}{Q_a}^{bc}{Q_b}^{ad} - \frac{1}{4}\eta^{ad}\eta_{be}\eta_{cf}{Q_a}^{bc}{Q_d}^{ef}$$

Calculation of $\tilde{\mathcal{L}}_\beta$ and the equations of motion

- $\tilde{\mathcal{L}}_\beta$ with nongeometric fluxes $Q_a{}^{bc}$ and R^{abc}

$$-\frac{1}{4}S\epsilon^+ = \left(\gamma^a D_a \gamma^b D_b - \overline{\eta^{ab}} D_{\overline{a}} D_{\overline{b}}\right)\epsilon^+$$

$$\tilde{\mathcal{L}}_\beta = e^{-2d}\left(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 + 4(\beta^{ab}\partial_b\tilde{\phi} - \mathcal{T}^a)^2 + \mathcal{R}_Q - \frac{1}{2}R^{acd}f^b{}_{cd}\eta_{ab} - \frac{1}{2}R^2\right)$$

  - new scalar curvature for the Q-flux (analogue to f-flux)

$$\mathcal{R}_Q = 2\eta_{ab}\beta^{ad}\partial_d Q_c{}^{bc} - \eta_{cd}Q_a{}^{ac}Q_b{}^{bd} - \frac{1}{2}\eta_{cd}Q_a{}^{bc}Q_b{}^{ad} - \frac{1}{4}\eta^{ad}\eta_{be}\eta_{cf}Q_a{}^{bc}Q_d{}^{ef}$$

- its equations of motion

Calculation of $\tilde{\mathcal{L}}_\beta$ and the equations of motion

- $\tilde{\mathcal{L}}_\beta$ with nongeometric fluxes $Q_a{}^{bc}$ and R^{abc}

$$-\tfrac{1}{4}S\epsilon^+ = \left(\gamma^a D_a \gamma^b D_b - \overline{\eta^{ab}} D_{\overline{a}} D_{\overline{b}}\right)\epsilon^+$$

$$\tilde{\mathcal{L}}_\beta = e^{-2d}\left(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 + 4(\beta^{ab}\partial_b\tilde{\phi} - \mathcal{T}^a)^2 + \mathcal{R}_Q - \tfrac{1}{2}R^{acd}f^b{}_{cd}\eta_{ab} - \tfrac{1}{2}R^2\right)$$

  - new scalar curvature for the Q-flux (analogue to f-flux)

$$\mathcal{R}_Q = 2\eta_{ab}\beta^{ad}\partial_d Q_c{}^{bc} - \eta_{cd}Q_a{}^{ac}Q_b{}^{bd} - \tfrac{1}{2}\eta_{cd}Q_a{}^{bc}Q_b{}^{ad} - \tfrac{1}{4}\eta^{ad}\eta_{be}\eta_{cf}Q_a{}^{bc}Q_d{}^{ef}$$

- its equations of motion
  - e.o.m for $\tilde{\phi}$ ($S = 0$)

Calculation of $\tilde{\mathcal{L}}_\beta$ and the equations of motion

- $\tilde{\mathcal{L}}_\beta$ with nongeometric fluxes $Q_a{}^{bc}$ and R^{abc}

$$-\frac{1}{4}S\epsilon^+ = \left(\gamma^a D_a \gamma^b D_b - \overline{\eta^{ab}} D_{\bar{a}} D_{\bar{b}}\right)\epsilon^+$$

$$\tilde{\mathcal{L}}_\beta = e^{-2d}\left(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 + 4(\beta^{ab}\partial_b\tilde{\phi} - \mathcal{T}^a)^2 + \mathcal{R}_Q - \frac{1}{2}R^{acd}f^b{}_{cd}\eta_{ab} - \frac{1}{2}R^2\right)$$

  - new scalar curvature for the Q-flux (analogue to f-flux)

$$\mathcal{R}_Q = 2\eta_{ab}\beta^{ad}\partial_d Q_c{}^{bc} - \eta_{cd}Q_a{}^{ac}Q_b{}^{bd} - \frac{1}{2}\eta_{cd}Q_a{}^{bc}Q_b{}^{ad} - \frac{1}{4}\eta^{ad}\eta_{be}\eta_{cf}Q_a{}^{bc}Q_d{}^{ef}$$

- its equations of motion
  - e.o.m for $\tilde{\phi}$ $(S=0)$
  - Einstein equation $(R_{(ab)}=0)$

$$\frac{1}{2}R_{a\bar{b}}\gamma^a\epsilon^+ = [\gamma^a D_a, D_{\bar{b}}]\epsilon^+$$

$$\frac{1}{2}\mathcal{R}_{ba} - \frac{1}{2}\eta_{e(a}\eta_{b)g}\check{\mathcal{R}}^{ge} + \frac{1}{8}\eta_{ae}\eta_{bg}\eta_{if}\eta_{cd}R^{igc}R^{dfe}$$
$$+\nabla_b\nabla_a\tilde{\phi} - \eta_{e(a}\eta_{b)g}\check{\nabla}^g(\check{\nabla}^e\tilde{\phi}) - \eta_{e(a}\eta_{b)g}\check{\nabla}^g\mathcal{T}^e = 0$$

Calculation of $\tilde{\mathcal{L}}_\beta$ and the equations of motion

- $\tilde{\mathcal{L}}_\beta$ with nongeometric fluxes $Q_a{}^{bc}$ and R^{abc}

$$-\tfrac{1}{4}S\epsilon^+ = \left(\gamma^a D_a \gamma^b D_b - \overline{\eta^{ab}} D_{\bar{a}} D_{\bar{b}}\right)\epsilon^+$$

$$\tilde{\mathcal{L}}_\beta = e^{-2d}\left(\mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 + 4(\beta^{ab}\partial_b\tilde{\phi} - \mathcal{T}^a)^2 + \mathcal{R}_Q - \tfrac{1}{2}R^{acd}f^b{}_{cd}\eta_{ab} - \tfrac{1}{2}R^2\right)$$

  - new scalar curvature for the Q-flux (analogue to f-flux)

$$\mathcal{R}_Q = 2\eta_{ab}\beta^{ad}\partial_d Q_c{}^{bc} - \eta_{cd}Q_a{}^{ac}Q_b{}^{bd} - \tfrac{1}{2}\eta_{cd}Q_a{}^{bc}Q_b{}^{ad} - \tfrac{1}{4}\eta^{ad}\eta_{be}\eta_{cf}Q_a{}^{bc}Q_d{}^{ef}$$

- its equations of motion
  - e.o.m for $\tilde{\phi}$ ($S = 0$)
  - Einstein equation ($R_{(ab)} = 0$) $\qquad \tfrac{1}{2}R_{a\bar{b}}\gamma^a\epsilon^+ = [\gamma^a D_a, D_{\bar{b}}]\epsilon^+$

$$\tfrac{1}{2}\mathcal{R}_{ba} - \tfrac{1}{2}\eta_{e(a}\eta_{b)g}\check{\mathcal{R}}^{ge} + \tfrac{1}{8}\eta_{ae}\eta_{bg}\eta_{if}\eta_{cd}R^{igc}R^{dfe}$$
$$+\nabla_b\nabla_a\tilde{\phi} - \eta_{e(a}\eta_{b)g}\check{\nabla}^g(\check{\nabla}^e\tilde{\phi}) - \eta_{e(a}\eta_{b)g}\check{\nabla}^g\mathcal{T}^e = 0$$

  - e.o.m for β ($R_{[ab]} = 0$)

Has been worked out in terms of the nongeometric fluxes!

NSNS Bianchi identities without sources

- Bianchi identity for H-flux in standard supergravity

$$\mathcal{D}A = 2e^{\phi}(\mathrm{d} - H\wedge)(e^{-\phi}A)\ , \qquad \mathcal{D}^2 = 0 \ \Leftrightarrow \ \mathrm{d}^2 = 0 \ \mathrm{and}\ \mathrm{d}H = 0$$

NSNS Bianchi identities without sources

- Bianchi identity for H-flux in standard supergravity

$$\mathcal{D}A = 2e^{\phi}(\mathrm{d} - H\wedge)(e^{-\phi}A)\,, \qquad \mathcal{D}^2 = 0 \;\Leftrightarrow\; \mathrm{d}^2 = 0 \text{ and } \mathrm{d}H = 0$$

- Dirac operator for $Spin(d,d) \times \mathbb{R}^+$ structure

$$\mathcal{D}\Psi = \Gamma^A D_A \Psi = \Gamma^A\left(\partial_A + \tfrac{1}{4}\Omega_{ABC}\Gamma^{BC} - \tfrac{1}{2}\Lambda_A\right)\Psi$$

NSNS Bianchi identities without sources

- Bianchi identity for H-flux in standard supergravity

$$\mathcal{D}A = 2e^{\phi}(\mathrm{d}{-}H\wedge)(e^{-\phi}A)\ , \qquad \mathcal{D}^2 = 0 \ \Leftrightarrow\ \mathrm{d}^2 = 0 \text{ and } \mathrm{d}H = 0$$

- Dirac operator for $Spin(d,d) \times \mathbb{R}^+$ structure

$$\mathcal{D}\Psi = \Gamma^A D_A \Psi = \Gamma^A\left(\partial_A + \tfrac{1}{4}\Omega_{ABC}\Gamma^{BC} - \tfrac{1}{2}\Lambda_A\right)\Psi$$

- Bianchi identities for Q- and R-flux in β-supergravity

$$\mathcal{D}A = 2e^{\tilde{\phi}}(\nabla_a \cdot \tilde{e}^a \wedge -\check{\nabla}^a \cdot \iota_a + \mathcal{T} \vee +R\vee)(e^{-\tilde{\phi}}A)\ ,$$

NSNS Bianchi identities without sources

- Bianchi identity for H-flux in standard supergravity

$$\mathcal{D}A = 2e^{\phi}(\mathrm{d} - H\wedge)(e^{-\phi}A)\ , \qquad \mathcal{D}^2 = 0 \ \Leftrightarrow\ \mathrm{d}^2 = 0 \text{ and } \mathrm{d}H = 0$$

- Dirac operator for $Spin(d,d) \times \mathbb{R}^+$ structure

$$\mathcal{D}\Psi = \Gamma^A D_A \Psi = \Gamma^A\left(\partial_A + \tfrac{1}{4}\Omega_{ABC}\Gamma^{BC} - \tfrac{1}{2}\Lambda_A\right)\Psi$$

- Bianchi identities for Q- and R-flux in β-supergravity

$$\mathcal{D}A = 2e^{\tilde{\phi}}(\nabla_a \cdot \tilde{e}^a \wedge - \check{\tilde{\nabla}}^a \cdot \iota_a + \mathcal{T}\vee + R\vee)(e^{-\tilde{\phi}}A)\ ,$$

$$\mathcal{D}^2 = 0 \ \Leftrightarrow\ \begin{cases} \partial_{[b} f^a{}_{cd]} - f^a{}_{e[b} f^e{}_{cd]} = 0 \\ \partial_{[a} Q_{f]}{}^{de} - \beta^{g[d}\partial_g f^{e]}{}_{af} - \tfrac{1}{2} Q_g{}^{de} f^g{}_{af} + 2 Q_{[a}{}^{g[d} f^{e]}{}_{f]g} = 0 \\ \partial_a R^{ghi} - 3\beta^{d[g}\partial_d Q_a{}^{hi]} + 3 R^{d[gh} f^{i]}{}_{ad} - 3 Q_a{}^{d[g} Q_d{}^{hi]} = 0 \\ \beta^{g[d}\partial_g R^{abc]} + \tfrac{3}{2} R^{g[da} Q_g{}^{bc]} = 0 \end{cases}$$

Blumenhagen, Deser, Plauschinn & Rennecke '12

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$NS5-\mathrm{brane}$

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$$NS5-\mathrm{brane} \xrightarrow[\mathrm{T-duality}]{smearing} KK-\mathrm{mono.}$$

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$$NS5\mathrm{-brane} \xrightarrow[\mathrm{T-duality}]{smearing} KK\mathrm{-mono.} \xrightarrow[\mathrm{T-duality}]{smearing} Q\mathrm{-brane}$$

Hassler, Lüst '13

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$$NS5-\text{brane} \xrightarrow[\text{T}-\text{duality}]{\textit{smearing}} KK-\text{mono.} \xrightarrow[\text{T}-\text{duality}]{\textit{smearing}} Q-\text{brane} \xrightarrow[\text{T}-\text{duality?}]{\textit{smearing}} R-\text{brane?}$$

Hassler, Lüst '13

sourced corrected Bianchi identities for NS-branes

- chain of NS-branes

$$NS5\mathrm{-brane} \xrightarrow[\mathrm{T-duality}]{smearing} KK\mathrm{-mono.} \xrightarrow[\mathrm{T-duality}]{smearing} Q\mathrm{-brane} \xrightarrow[\mathrm{T-duality?}]{smearing} R\mathrm{-brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ \qquad\qquad \downarrow \int \end{cases}$$

sourced corrected Bianchi identities for NS-branes

- chain of NS-branes

$$NS5\mathrm{-brane} \xrightarrow[\mathrm{T-duality}]{smearing} KK\mathrm{-mono.} \xrightarrow[\mathrm{T-duality}]{smearing} Q\mathrm{-brane} \xrightarrow[\mathrm{T-duality?}]{smearing} R\mathrm{-brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \end{cases} \qquad \downarrow \int$$

sourced corrected Bianchi identities for NS-branes

- chain of NS-branes

$$NS5\text{−brane} \xrightarrow[\text{T−duality}]{smearing} KK\text{−mono.} \xrightarrow[\text{T−duality}]{smearing} Q\text{−brane} \xrightarrow[\text{T−duality?}]{smearing} R\text{−brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \\ f_Q = const - 2q\pi \ln r_2 \\ \end{cases} \downarrow \int$$

sourced corrected Bianchi identities for NS-branes

- chain of NS-branes

$$NS5-\mathrm{brane} \xrightarrow[\mathrm{T-duality}]{smearing} KK-\mathrm{mono.} \xrightarrow[\mathrm{T-duality}]{smearing} Q-\mathrm{brane} \xrightarrow[\mathrm{T-duality?}]{smearing} R-\mathrm{brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \\ f_Q = const - 2q\pi \ln r_2 \\ f_R = const - 2q\pi^2 |r_1| \end{cases} \downarrow \int$$

sourced corrected Bianchi identities for NS-branes

- chain of NS-branes

$$NS5\mathrm{-brane} \xrightarrow[\mathrm{T-duality}]{smearing} KK\mathrm{-mono.} \xrightarrow[\mathrm{T-duality}]{smearing} Q\mathrm{-brane} \xrightarrow[\mathrm{T-duality?}]{smearing} R\mathrm{-brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \\ f_Q = const - 2q\pi \ln r_2 \\ f_R = const - 2q\pi^2 |r_1| \end{cases} \downarrow \int \implies \quad \Delta_i f = c\ \delta^{(i)}(r_i)$$

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$$NS5\mathrm{-brane} \xrightarrow[\mathrm{T-duality}]{\textit{smearing}} KK\mathrm{-mono.} \xrightarrow[\mathrm{T-duality}]{\textit{smearing}} Q\mathrm{-brane} \xrightarrow[\mathrm{T-duality?}]{\textit{smearing}} R\mathrm{-brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \\ f_Q = const - 2q\pi \ln r_2 \\ f_R = const - 2q\pi^2 |r_1| \end{cases} \downarrow \int \implies \quad \Delta_i f = c\ \delta^{(i)}(r_i)$$

- source corrected Bianchi identities

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$$NS5\text{−brane} \xrightarrow[\text{T−duality}]{\textit{smearing}} KK\text{−mono.} \xrightarrow[\text{T−duality}]{\textit{smearing}} Q\text{−brane} \xrightarrow[\text{T−duality?}]{\textit{smearing}} R\text{−brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \\ f_Q = const - 2q\pi \ln r_2 \\ f_R = const - 2q\pi^2 |r_1| \end{cases} \downarrow \int \implies \quad \Delta_i f = c\ \delta^{(i)}(r_i)$$

- source corrected Bianchi identities

$$\partial_{[a} H_{bcd]} - \frac{3}{2} f^e{}_{[ab} H_{cd]e} = \frac{C_H}{4}\ \epsilon_{4\perp abcd} \delta^{(4)}(r_4)$$

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$$NS5\mathrm{-brane} \xrightarrow[\mathrm{T-duality}]{smearing} KK\mathrm{-mono.} \xrightarrow[\mathrm{T-duality}]{smearing} Q\mathrm{-brane} \xrightarrow[\mathrm{T-duality?}]{smearing} R\mathrm{-brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \\ f_Q = const - 2q\pi \ln r_2 \\ f_R = const - 2q\pi^2 |r_1| \end{cases} \downarrow \int \Longrightarrow \quad \Delta_i f = c\ \delta^{(i)}(r_i)$$

- source corrected Bianchi identities

$$\partial_{[a} H_{bcd]} - \frac{3}{2} f^e{}_{[ab} H_{cd]e} = \frac{C_H}{4}\ \epsilon_{4\perp abcd} \delta^{(4)}(r_4)$$

$$\partial_{[b} f^a{}_{cd]} - f^a{}_{e[b} f^e{}_{cd]} = \frac{C_K}{3}\ \epsilon_{3\perp bcd}\ \epsilon_1{}^{||a} \delta^{(3)}(r_3)$$

Villadoro & Zwirner '07;

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$$NS5\mathrm{-brane} \xrightarrow[\mathrm{T-duality}]{smearing} KK\mathrm{-mono.} \xrightarrow[\mathrm{T-duality}]{smearing} Q\mathrm{-brane} \xrightarrow[\mathrm{T-duality?}]{smearing} R\mathrm{-brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \\ f_Q = const - 2q\pi \ln r_2 \\ f_R = const - 2q\pi^2 |r_1| \end{cases} \downarrow \int \implies \qquad \Delta_i f = c\ \delta^{(i)}(r_i)$$

- source corrected Bianchi identities (for the Q-brane)

$$\partial_{[a} H_{bcd]} - \frac{3}{2} f^e{}_{[ab} H_{cd]e} = \frac{C_H}{4}\ \epsilon_{4\perp abcd}\delta^{(4)}(r_4)$$

$$\partial_{[b} f^a{}_{cd]} - f^a{}_{e[b} f^e{}_{cd]} = \frac{C_K}{3}\ \epsilon_{3\perp bcd}\ \epsilon_1{}^{||a}\delta^{(3)}(r_3)$$

$$\partial_{[a} Q_{b]}{}^{cd} - \beta^{g[c}\partial_g f^{d]}{}_{ab} - \frac{1}{2} Q_g{}^{cd} f^g{}_{ab} + 2 Q_{[a}{}^{g[c} b^{d]}{}_{f]g} = \frac{C_Q}{2}\ \epsilon_{2\perp ab}\ \epsilon_2{}^{||cd}\delta^{(2)}(r_2)$$

Villadoro & Zwirner '07;

sourced corrected Bianchi identities for *NS*-branes

- chain of *NS*-branes

$$NS5\text{−brane} \xrightarrow[\text{T−duality}]{\textit{smearing}} KK\text{−mono.} \xrightarrow[\text{T−duality}]{\textit{smearing}} Q\text{−brane} \xrightarrow[\text{T−duality?}]{\textit{smearing}} R\text{−brane?}$$

Hassler, Lüst '13

- smearing warp factors and Poisson equations

$$\begin{cases} f_H = const + \frac{q}{r_4^2} \\ f_K = const + \frac{q\pi}{r_3} \\ f_Q = const - 2q\pi \ln r_2 \\ f_R = const - 2q\pi^2 |r_1| \end{cases} \downarrow \int \implies \quad \Delta_i f = c\ \delta^{(i)}(r_i)$$

- source corrected Bianchi identities (for the Q-brane)

$$\partial_{[a} H_{bcd]} - \frac{3}{2} f^e{}_{[ab} H_{cd]e} = \frac{C_H}{4}\ \epsilon_{4\perp abcd} \delta^{(4)}(r_4)$$

$$\partial_{[b} f^a{}_{cd]} - f^a{}_{e[b} f^e{}_{cd]} = \frac{C_K}{3}\ \epsilon_{3\perp bcd}\ \epsilon_1{}^{||a} \delta^{(3)}(r_3)$$

$$\partial_{[a} Q_{b]}{}^{cd} - \beta^{g[c} \partial_g f^{d]}{}_{ab} - \frac{1}{2} Q_g{}^{cd} f^g{}_{ab} + 2 Q_{[a}{}^{g[c} b^{d]}{}_{f]g} = \frac{C_Q}{2}\ \epsilon_{2\perp ab}\ \epsilon_2{}^{||cd} \delta^{(2)}(r_2)$$

Villadoro & Zwirner '07; Chatzistavrakidis, Gautason, Moutsopoulos & Zagermann '13

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2=0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2=0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

source corrected Bianchi identities by Poisson equation

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2{=}0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

source corrected Bianchi identities by Poisson equation

Further results:

- dimensional reduction to 4d

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2=0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

source corrected Bianchi identities by Poisson equation

Further results:

- dimensional reduction to 4d
- analysis of pure NSNS solutions with Minkowski background

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2=0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

source corrected Bianchi identities by Poisson equation

Further results:

- dimensional reduction to 4d
- analysis of pure NSNS solutions with Minkowski background
- consistent class of (non)geometric backgrounds with isometries

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2 = 0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

source corrected Bianchi identities by Poisson equation

Further results:

- dimensional reduction to 4d
- analysis of pure NSNS solutions with Minkowski background
- consistent class of (non)geometric backgrounds with isometries

Outlook:

- SUSY transf. in β-supergravity using Dirac operator $\mathcal{D}$

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2{=}0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

source corrected Bianchi identities by Poisson equation

Further results:

- dimensional reduction to 4d
- analysis of pure NSNS solutions with Minkowski background
- consistent class of (non)geometric backgrounds with isometries

Outlook:

- SUSY transf. in β-supergravity using Dirac operator $\mathcal{D}$
- extend to other sectors and look for new solutions

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2{=}0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

source corrected Bianchi identities by Poisson equation

Further results:

- dimensional reduction to 4d
- analysis of pure NSNS solutions with Minkowski background
- consistent class of (non)geometric backgrounds with isometries

Outlook:

- SUSY transf. in β-supergravity using Dirac operator $\mathcal{D}$
- extend to other sectors and look for new solutions
- possible R-brane? even codim. 0 NS-brane?

Conclusion & Outlook

Conclusion:

Q-flux enters a new covariant derivative $\check{\nabla}$ in β-supergravity

$\mathcal{D}^2=0 \Leftrightarrow$ sourceless Bianchi identities with nongeometric flux

source corrected Bianchi identities by Poisson equation

Further results:

- dimensional reduction to 4d
- analysis of pure NSNS solutions with Minkowski background
- consistent class of (non)geometric backgrounds with isometries

Outlook:

- SUSY transf. in β-supergravity using Dirac operator $\mathcal{D}$
- extend to other sectors and look for new solutions
- possible R-brane? even codim. 0 NS-brane?
- corresponding branes in DFT localized in winding coordinates