Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions

# Supermembrane interaction with dynamical D=4 N=1 supergravity

Superfield Lagrangian description and spacetime equations of motion

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November 12, 2012

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# Introduction

- SUSY extended objects, super-p-branes, and their description
- The supermembrane action and its properties
- 2 Minimal and special minimal supergravity.
  - Supergravity in superspace. Minimal off-shell formulation.
  - Closed 4-form in SSP and supermembrane in minimal SUGRA background
  - Closed 3-form potential and special minimal SUGRA
- Oynamical generation of cosmological constant in special minimal supergravity.
  - Superfield equations of special minimal SUGRA
  - Dynamical generation of cosmological constant in sMin SUGRA
- Supermembrane supercurrent and its contribution to the supergravity superfield equations
  - Supermembrane supercurrent vector superfield J<sub>a</sub>
  - Supergravity superfield equations with supermembrane current
- 5 Spacetime component equations of the D = 4 N = 1supergravity–supermembrane interacting system
  - $WZ_{\hat{\theta}=0}$  gauge
- 6 Conclusions and outlook
  - Conclusions
  - Outlook

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## Outline

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•  $\hat{E}^a$  is the Hodge dual two form  $\hat{E}^a := \frac{1}{2} d\xi^m \wedge d\xi^n \sqrt{g} \epsilon_{mnk} g^{kl} \hat{E}_l^a$ .

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The second WZ term is given by integral of the pull–back to W<sup>3</sup> of the three form potential defined on Σ<sup>(4|4)</sup>: C<sub>3</sub> := C<sub>3</sub>(Z),

$$\begin{split} C_3 &= C_3(Z) = \frac{1}{3} dZ^{\underline{K}} \wedge dZ^{\underline{N}} \wedge dZ^{\underline{M}} C_{\underline{MNK}}(Z) := \frac{1}{3} E^{\underline{C}} \wedge E^{\underline{B}} \wedge E^{\underline{A}} C_{\underline{ABC}}(Z) \\ E^{\underline{A}} &:= (E^a, E^{\alpha}, \bar{E}^{\dot{\alpha}}) = dZ^{\underline{M}} E_{\underline{M}}^{\underline{A}}(Z) , \quad \alpha = 1, 2, \quad \dot{\alpha} = 1, 2 . \end{split}$$

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In flat superspace (SSP) E<sup>a</sup> = dX<sup>a</sup> − i(dθσ<sup>a</sup>θ̄ − c.c.), E<sup>α</sup> = dθ<sup>α</sup>, C<sub>3</sub> = c<sub>3</sub> such that h<sub>4</sub> = dc<sub>3</sub> := −<sup>i</sup>/<sub>4</sub>E<sup>b</sup> ∧ E<sup>a</sup> ∧ E<sup>β</sup>σ<sub>abαβ</sub> + c.c. is closed,

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and the action possesses a 2-parametric local fermionic κ–symmetry

$$\begin{split} i_{\kappa}\hat{E}^{a} &:= \delta_{\kappa}\hat{Z}^{M}E_{M}{}^{a}(\hat{Z}) = 0 , \qquad i_{\kappa}\hat{E}^{\alpha} = \kappa^{\alpha} = \bar{\kappa}_{\dot{\alpha}}\tilde{\gamma}^{\dot{\beta}\alpha} , \\ \bar{\gamma}_{\beta\dot{\alpha}} &= \epsilon_{\beta\alpha}\epsilon_{\dot{\alpha}\dot{\beta}}\tilde{\gamma}^{\dot{\beta}\alpha} = \frac{i}{3!\sqrt{g}}\sigma^{a}_{\beta\dot{\alpha}}\epsilon_{abcd}\epsilon^{mnk}\hat{E}^{b}_{m}\hat{E}^{c}_{n}\hat{E}^{d}_{k} , \quad \bar{\gamma}_{\beta\dot{\beta}}\tilde{\gamma}^{\dot{\beta}\alpha} = \delta_{\beta}{}^{\alpha} \end{split}$$

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•  $\kappa$ -symmetry transformations of D = 4 N = 1 supermembrane (p = 2)

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 This κ-symmetry [de Azcarraga & Lukierski 82, Siegel 83 for p=0, Green & Schwarz 84 for p=1, Achucarro, Gauntlett, Itoh and Townsend 89 for p=2, D=4] is important: it reflects the supersymmetry preserved by the ground state of the supermembrane (which is thus the 1/2 BPS state).

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- The supermembrane action in curved superspace possesses  $\kappa$ -symmetry if  $E^a$ ,  $E^{\alpha}$  and  $H_4 = dC_3$  obey the SSP SUGRA constraints.

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- For D = 4 N = 1 the SUGRA constraints are off-shell

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Supermembrane action					

$$i_{\kappa}\hat{E}^{a}:=\delta_{\kappa}\hat{Z}^{M}E_{M}{}^{a}(\hat{Z})=0, \qquad i_{\kappa}\hat{E}^{\alpha}=\kappa^{\alpha}=\bar{\kappa}_{\dot{\alpha}}\tilde{\tilde{\gamma}}^{\dot{\beta}\alpha},$$

$$\bar{\gamma}_{\beta\dot{\alpha}} = \epsilon_{\beta\alpha}\epsilon_{\dot{\alpha}\dot{\beta}}\tilde{\bar{\gamma}}^{\dot{\beta}\alpha} = \frac{i}{3!\sqrt{g}}\sigma^{a}_{\beta\dot{\alpha}}\epsilon_{abcd}\epsilon^{mnk}\hat{E}^{b}_{m}\hat{E}^{c}_{n}\hat{E}^{d}_{k} \;, \quad \bar{\gamma}_{\beta\dot{\beta}}\tilde{\bar{\gamma}}^{\dot{\beta}\alpha} = \delta_{\beta}{}^{\alpha}$$

- This κ-symmetry [de Azcarraga & Lukierski 82, Siegel 83 for p=0, Green & Schwarz 84 for p=1, Achucarro, Gauntlett, Itoh and Townsend 89 for p=2, D=4] is important: it reflects the supersymmetry preserved by the ground state of the supermembrane (which is thus the 1/2 BPS state).
- The supermembrane action in curved superspace possesses  $\kappa$ -symmetry if  $E^a$ ,  $E^{\alpha}$  and  $H_4 = dC_3$  obey the SSP SUGRA constraints.
- The supermembrane exists in the dimensions in which the H<sub>4</sub> constraints are consistent with SUGRA constraints.
- For D = 4 N = 1 the SUGRA constraints are off-shell
- $\Rightarrow$  one can write the superfield action of SUGRA,  $S_{SG}$  and the interacting SUGRA+supermembrane action  $S_{SG} + S_{p=2}$ .

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Supermembrane action					

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- $\Rightarrow$  one can write the superfield action of SUGRA,  $S_{SG}$  and the interacting SUGRA+supermembrane action  $S_{SG} + S_{p=2}$ .
- one can obtain the supergravity superfield equations with the contributions of supermembrane supercurrent(s).

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Supermembrane action					



Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Supermembrane action					

• We can obtain the supermembrane supercurrent varying the supermembrane action with respect to SUGRA superfields

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Supermembrane action					

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Supermembrane action					

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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- The standard minimal supergravity allows for the existence of such  $H_4 = dC_3$ , so that the supermembrane can propagate in the off-shell minimal SUGRA background.

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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- The standard minimal supergravity allows for the existence of such  $H_4 = dC_3$ , so that the supermembrane can propagate in the off-shell minimal SUGRA background.
- But, as we will see, the supermembrane coupling to *dynamical* supergravity implies an additional restriction on minimal supergravity supermultiplet.

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Outline					

- Introduction
  - SUSY extended objects, super-p-branes, and their description
  - The supermembrane action and its properties
- 2 Minimal and special minimal supergravity.
  - Supergravity in superspace. Minimal off-shell formulation.
  - Closed 4-form in SSP and supermembrane in minimal SUGRA background
  - Closed 3-form potential and special minimal SUGRA
- Oynamical generation of cosmological constant in special minimal supergravity.
  - Superfield equations of special minimal SUGRA
  - Dynamical generation of cosmological constant in sMin SUGRA
- Supermembrane supercurrent and its contribution to the supergravity superfield equations
  - Supermembrane supercurrent vector superfield J<sub>a</sub>
  - Supergravity superfield equations with supermembrane current
- Spacetime component equations of the D = 4 N = 7supergravity–supermembrane interacting system
  - $WZ_{\hat{\theta}=0}$  gauge
- 6 Conclusions and outlook
  - Conclusions

Intro. Supermembrane	Special min SUGRA ●OOOOO	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
Superspace SUGRA					

Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Superspace SUGRA					

• Minimal supergravity constraints and their consequences can be collected in (see [Wess & Zumino 77, Grimm, Wess & Zumino 78])

$$T^{a} := \mathcal{D}E^{a} = -2i\sigma_{\alpha\dot{\alpha}}^{a}E^{\alpha} \wedge \bar{E}^{\dot{\alpha}} - \frac{1}{8}E^{b} \wedge E^{c}\varepsilon^{a}_{bcd}G^{d} ,$$
$$T^{\alpha} := \mathcal{D}E^{\alpha} = \frac{i}{8}E^{c} \wedge E^{\beta}(\sigma_{c}\tilde{\sigma}_{d})_{\beta}{}^{\alpha}G^{d} - \frac{i}{8}E^{c} \wedge \bar{E}^{\dot{\beta}}\epsilon^{\alpha\beta}\sigma_{c\beta\dot{\beta}}R + \frac{1}{2}E^{c} \wedge E^{b}T_{bc}{}^{\alpha}$$

Intro. Supermembrane	Special min SUGRA ●OOOOO	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Superspace SUGRA					

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• These expressions for bosonic and fermionic torsion 2-forms involve main superfields  $R = (\bar{R})^*$ , and  $G_a = (G_a)^*$ , which obey  $(G_{\alpha\dot{\alpha}} := G_a \sigma^a_{\alpha\dot{\alpha}})$ 

$$\begin{split} \mathcal{D}_{\alpha}\bar{R} &= 0 , \qquad \bar{\mathcal{D}}_{\dot{\alpha}}R = 0 , \\ \bar{\mathcal{D}}^{\dot{\alpha}}\mathcal{G}_{\alpha\dot{\alpha}} &= -\mathcal{D}_{\alpha}R , \qquad \mathcal{D}^{\alpha}\mathcal{G}_{\alpha\dot{\alpha}} = -\bar{\mathcal{D}}_{\dot{\alpha}}\bar{R} \end{split}$$

Intro. Supermembrane	Special min SUGRA ●OOOOO	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Superspace SUGRA					

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$$\mathcal{D}_{\alpha}\bar{R} = 0, \qquad \bar{\mathcal{D}}_{\dot{\alpha}}R = 0,$$
  
 $\bar{\mathcal{D}}^{\dot{\alpha}}G_{\alpha\dot{\alpha}} = -\mathcal{D}_{\alpha}R, \qquad \mathcal{D}^{\alpha}G_{\alpha\dot{\alpha}} = -\bar{\mathcal{D}}_{\dot{\alpha}}\bar{R}$ 

 One more main superfields enter the decomposition of the superfield generalization of the gravitino field strength T<sub>bc</sub><sup>\u03c4</sup>(Z),

$$T_{\alpha\dot{\alpha}\ \beta\dot{\beta}\ \gamma} \equiv \sigma^{a}_{\alpha\dot{\alpha}}\sigma^{b}_{\beta\dot{\beta}}\epsilon_{\gamma\delta}T_{ab}^{\phantom{ab}\delta} = -\frac{1}{8}\epsilon_{\alpha\beta}\bar{\mathcal{D}}_{(\dot{\alpha}|}G_{\gamma|\dot{\beta})} - \frac{1}{8}\epsilon_{\dot{\alpha}\dot{\beta}}[W_{\alpha\beta\gamma} - 2\epsilon_{\gamma(\alpha}\mathcal{D}_{\beta)}R]$$
Intro. Supermembrane	Special min SUGRA ●OOOOO	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Superspace SUGRA					

### Minimal SUGRA in superspace

• Minimal supergravity constraints and their consequences can be collected in (see [Wess & Zumino 77, Grimm, Wess & Zumino 78])

$$\begin{split} T^{a} &:= \mathcal{D}E^{a} = -2i\sigma_{\alpha\dot{\alpha}}^{a}E^{\alpha} \wedge \bar{E}^{\dot{\alpha}} - \frac{1}{8}E^{b} \wedge E^{c}\varepsilon^{a}_{bcd}G^{d} ,\\ T^{\alpha} &:= \mathcal{D}E^{\alpha} = \frac{i}{8}E^{c} \wedge E^{\beta}(\sigma_{c}\tilde{\sigma}_{d})_{\beta}{}^{\alpha}G^{d} - \frac{i}{8}E^{c} \wedge \bar{E}^{\dot{\beta}}\epsilon^{\alpha\beta}\sigma_{c\beta\dot{\beta}}R + \frac{1}{2}E^{c} \wedge E^{b}T_{bc}{}^{\alpha} \end{split}$$

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$$\mathcal{D}_{lpha} ar{R} = \mathbf{0} , \qquad ar{\mathcal{D}}_{\dot{lpha}} R = \mathbf{0} , \ ar{\mathcal{D}}^{\dot{lpha}} \mathbf{G}_{lpha \dot{lpha}} = - \mathcal{D}_{lpha} R , \qquad \mathcal{D}^{lpha} \mathbf{G}_{lpha \dot{lpha}} = - ar{\mathcal{D}}_{\dot{lpha}} ar{R}$$

 One more main superfields enter the decomposition of the superfield generalization of the gravitino field strength T<sub>bc</sub><sup>\u03c4</sup>(Z),

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• It is symmetric,  $W_{\alpha\beta\gamma} = W_{(\alpha\beta\gamma)}$ , and chiral

$$ar{\mathcal{D}}_{\dot{lpha}} W^{lphaeta\gamma} = \mathbf{0} , \qquad \mathcal{D}_{lpha} ar{W}^{\dot{lpha}\dot{eta}\dot{\gamma}} = \mathbf{0} .$$

Intro. Supermembrane	Special min SUGRA O●OOOO	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
Superspace SUGRA					

Intro. Supermembrane	Special min SUGRA O●○○○○	Dynamical generation of Λ ΟΟΟ	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
Superspace SUGRA					

• The superfield generalization of the Ricci tensor is

$$egin{array}{lll} R_{bc}{}^{ac} = & rac{1}{32} (\mathcal{D}^eta ar{\mathcal{D}}^{(\dotlpha)} G^{lpha|\doteta)} - ar{\mathcal{D}}^{\doteta} \mathcal{D}^{(eta} G^{lpha)\dotlpha}) \sigma^a_{lpha\dotlpha} \sigma_{beta\doteta} & - \ & - rac{3}{64} (ar{\mathcal{D}}ar{\mathcal{D}}ar{R} + \mathcal{D}\mathcal{D}R - 4Rar{R}) \delta^a_b \;. \end{array}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Superspace SUGRA					

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• and the superfield generalization of the *l.h.s.* of the supergravity Rarita–Schwinger equation reads  $\epsilon^{abcd} T_{bc}{}^{\alpha} \sigma_{d\alpha\dot{\alpha}} = \frac{i}{8} \tilde{\sigma}^{a\dot{\beta}\beta} \bar{\mathcal{D}}_{(\dot{\beta}|} G_{\beta|\dot{\alpha})} + \frac{3i}{8} \sigma^{a}_{\beta\dot{\alpha}} \mathcal{D}^{\beta} R$ ,

Intro. Supermembrane	Special min SUGRA O●○○○○	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
Superspace SUGRA					

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• This suggests that superfield supergravity equation should have the form

$$G_a=0\;,\qquad R=0\;,\qquad ar{R}=0\;.$$

Intro. Supermembrane	Special min SUGRA O●○○○○	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
Superspace SUGRA					

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• This suggests that superfield supergravity equation should have the form

$$G_a = 0$$
,  $R = 0$ ,  $\bar{R} = 0$ .

• Indeed, these  $\Rightarrow$  'free' SUGRA equations of motion

$$R_{bc}^{\ \ ac} = 0 \;, \qquad \epsilon^{abcd} T_{bc}^{\ \ lpha} \sigma_{dlpha \dot{lpha}} = 0 \;.$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Closed 4-form and support	mombrano in minimal				

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions			
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Closed 4-form and super	losed 4 form and supermembrane in minimal SI IGRA SSP							

 The superspace of minimal supergravity allows for existence of two closed 4-forms

$$\begin{split} H_{4L} &= -\frac{i}{4} E^b \wedge E^a \wedge E^\alpha \wedge E^\beta \sigma_{ab\ \alpha\beta} - \frac{1}{128} E^d \wedge E^c \wedge E^b \wedge E^a \epsilon_{abcd} R \,, \\ dH_{4L} &= 0 \,, \end{split}$$

and its complex conjugate  $H_{4R} = (H_{4L})^*$ .

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Closed 4-form and super	membrane in minimal S	SUGRA SSP			

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• We assume  $H_4 = dC_3 = H_{4L} + H_{4R}$ .

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions			
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Closed 4-form and super	losed 4-form and supermembrane in minimal SUGRA SSP							

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- We assume  $H_4 = dC_3 = H_{4L} + H_{4R}$ .
- This knowledge is completely sufficient to study the supermembrane *in* the background of minimal D = 4,  $\mathcal{N} = 1$  supergravity.

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Closed 4-form and super	membrane in minimal S	SUGRA SSP			

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- We assume  $H_4 = dC_3 = H_{4L} + H_{4R}$ .
- This knowledge is completely sufficient to study the supermembrane *in the background* of minimal D = 4,  $\mathcal{N} = 1$  supergravity.
- Indeed,  $\delta S_{p=2} = -\frac{1}{2} \int_{W^3} *\hat{E}_a \wedge \delta \hat{E}^a \int_{W^3} \delta \hat{C}_3$ , and, when the variation are produced by  $\delta \hat{Z}^M$  only, the variations of the 'potentials' are expressed in terms of 'contractions' of the field strengths superforms  $\delta \hat{E}^a = i_{\delta} T^a$ ,  $\delta \hat{C}_3 = i_{\delta} H_4$
- (with  $i_{\delta}\hat{E}^{A} := \delta \hat{Z}^{M} E^{A}_{M}(\hat{Z})$ ,  $i_{\delta}(\Omega_{\rho} \wedge \Omega_{q}) := \Omega_{\rho} \wedge i_{\delta}\Omega_{q} + (-)^{q} i_{\delta}\Omega_{\rho} \wedge \Omega_{q}$  for any p- and q-forms).

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Closed 3-form potential a	and special minimal SU	GRA			

Basic variations and prepotentials of minimal supergravity

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions			
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## Basic variations and prepotentials of minimal supergravity

• The knowledge of  $T^a = DE^a$  and  $H_4 = dC_3$  is not sufficient when one studies the supermembaane interaction with *dynamical* supergravity.

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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#### Basic variations and prepotentials of minimal supergravity

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• in this case, 
$$\delta S_{p=2} = -\frac{1}{2} \int_{W^3} * \hat{E}_a \wedge \delta \hat{E}^a - \int_{W^3} \delta \hat{C}_3$$
 with  $\delta \hat{E}^a = \delta E^a|_{Z^M = \hat{Z}^M}$ 

and  $\delta \hat{C}_3 = \delta C_3|_{Z^M = \hat{Z}^M}$  with  $\delta E^a(Z)$  and  $\delta C_3(Z)$  expressed in terms of basic supergravity variations.

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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and  $\delta \hat{C}_3 = \delta C_3|_{Z^M = \hat{Z}^M}$  with  $\delta E^a(Z)$  and  $\delta C_3(Z)$  expressed in terms of basic supergravity variations.

• Clearly  $\delta E^a(Z)$  and  $\delta C_3(Z)$  are not arbitrary as far as  $E^a(Z)$  and  $C_3(Z)$  obey the superspace SUGRA constraints. The basic variations are free parameters of the solution of the equations stating that the constraints are preserved by variation.

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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 with  $\delta \hat{E}^a = \delta E^a|_{Z^M = \hat{Z}^M}$ 

and  $\delta \hat{C}_3 = \delta C_3|_{Z^M = \hat{Z}^M}$  with  $\delta E^a(Z)$  and  $\delta C_3(Z)$  expressed in terms of basic supergravity variations.

- Clearly  $\delta E^a(Z)$  and  $\delta C_3(Z)$  are not arbitrary as far as  $E^a(Z)$  and  $C_3(Z)$  obey the superspace SUGRA constraints. The basic variations are free parameters of the solution of the equations stating that the constraints are preserved by variation.
- The admissible variations of supervielbein read [Wess & Zumino 78]

$$\begin{split} \delta E^{a} &= E^{a}(\Lambda(\delta) + \bar{\Lambda}(\delta)) - \frac{1}{4} E^{b} \tilde{\sigma}^{\dot{\alpha}\alpha}_{b} [\mathcal{D}_{\alpha}, \bar{\mathcal{D}}_{\dot{\alpha}}] \delta H^{a} + i E^{\alpha} \mathcal{D}_{\alpha} \delta H^{a} - i \bar{E}^{\dot{\alpha}} \bar{\mathcal{D}}_{\dot{\alpha}} \delta H^{a} ,\\ \delta E^{\alpha} &= E^{a} \Xi^{a}_{a}(\delta) + E^{\alpha} \Lambda(\delta) + \frac{1}{8} \bar{E}^{\dot{\alpha}} R \sigma_{a\dot{\alpha}}{}^{\alpha} \delta H^{a} , \end{split}$$

where

$$2\Lambda(\delta) + \bar{\Lambda}(\delta) = \frac{1}{4} \tilde{\sigma}_{a}^{\dot{\alpha}\alpha} \mathcal{D}_{\alpha} \bar{\mathcal{D}}_{\dot{\alpha}} \delta H^{a} + \frac{1}{8} G_{a} \delta H^{a} + 3(\mathcal{D}\mathcal{D} - \bar{R}) \delta \mathcal{U}$$

and the explicit expression for  $\Xi_a^{\alpha}(\delta)$  is not needed for our discussion.

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Closed 3-form potential a	and special minimal SU	GRA			

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Closed 3-form potential a	nd special minimal SUC	GRA			

The above expressions for δE<sup>A</sup> in terms of δH<sup>a</sup> and (DD - R)δU can be used to obtains the superfield equations of supergravity from the superspace action [Wess & Zumino 77, 78]

$$S_{SG} = \int d^4 x ilde{d}^4 heta \; sdet(E^A_{M}) \; \equiv \int d^8 Z \; E \; .$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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• To this end one calculates the variation of superdeterminant of the supervielbein

$$\delta E = E[-\frac{1}{12}\tilde{\sigma}_{a}^{\dot{\alpha}\alpha}[\mathcal{D}_{\alpha},\bar{\mathcal{D}}_{\dot{\alpha}}]\delta H^{a} + \frac{1}{6}G_{a}\,\delta H^{a} + 2(\bar{\mathcal{D}}\bar{\mathcal{D}}-R)\delta\bar{\mathcal{U}} + 2(\mathcal{D}\mathcal{D}-\bar{R})\delta\bar{\mathcal{U}}]\delta\bar{\mathcal{U}}$$

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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- $\Rightarrow$  the expected SUGRA superfield equations  $G_a = 0$  and R = 0.

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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Closed 2 form potential a	and apopulation minimal CLU				

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- $H_4 = dC_3 = -\frac{i}{4}E^b \wedge E^a \wedge E^\alpha \wedge E^\beta \sigma_{ab\ \alpha\beta} \frac{1}{128}E^d \wedge E^c \wedge E^b \wedge E^a \epsilon_{abcd}R$ +*c.c.* is expressed in terms of SUGRA potentials.

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# Closed 3-form potential in SSP of minimal SUGRA

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• This implies certain modification of the auxiliary field sector of SUGRA,

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- This implies certain modification of the auxiliary field sector of SUGRA,
- The corresponding off–shell formulation of SUGRA which we call *special* minimal SUGRA was described by Siegel [78], Siegel and Gates [79] and Waldram and Ovrut [97]

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Qualization						
Outline						
1	Intro	duction				
	o Sl	JSY extende	d objects, super-	- <i>p</i> –branes, and their	description	
	• Th	ie supermem	brane action and	d its properties		
2	Minin	nal and spec	ial minimal supe	rgravity.		
	St	upergravity in	superspace. Mi	nimal off–shell formu	lation.	
	• Cl	osed 4-form	in SSP and supe	ermembrane in minin	nal SUGRA	
	ba	ckground				
_	• Cl	osed 3-form	potential and spe	ecial minimal SUGR/	4	
3	Dyna	imical genera	ation of cosmolog	gical constant in spe	cial minimal	
	supe	rgravity.				
	St	perfield equa	ations of special	minimal SUGRA		
	Oy	/namical gen	eration of cosmo	ological constant in s	Min SUGRA	
4		rmembrane	supercurrent and	d its contribution to th	ne supergravity	
		rfield equatio				
	St	upermembrar	he supercurrent v	vector superfield $J_a$		
_	St	upergravity su	uperfield equatio	ns with supermembr	ane current	
5		etime compo	onent equations (	of the $D = 4 \mathcal{N} = 1$		
		rgravity-supe	ermembrane inte	eracting system		
_	• W	$Z_{\widehat{ heta}=0}$ gauge				
6	Conc	lusions and	outlook			

- Conclusions

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Superfield eqs. of sMin S	UGRA				

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ ●○○	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
Superfield eqs. of sMin S	UGRA				

• In terms of prepotential approach, the special minimal SUGRA has the chiral compensator which is not a generic but a special chiral superfield, constructed from real scalar prepotential  $V = V^*$  and not from the complex one  $(\overline{D}\overline{D}V$  with  $V = V^*$  vs  $\overline{D}\overline{D}U$  with  $U \neq U^*$  in the flat superspace).

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- In terms of component formulation, in special minimal SUGRA one of two auxiliary scalars of the generic minimal SUGRA [Stelle & West 78, Ferrara & van Nieuwenhuizen 78] is replaced by a divergence of an auxiliary vector, S → ∂<sub>μ</sub>k<sup>μ</sup>.

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- This seemingly minor modification has drastic consequence already in the case of 'free' supergravity:

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- it results in the dynamical generation of cosmological constant [the effect first described in superfield context by Ogievetsky and Sokatchev [1980]].

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Dynamical generation of cosmological constant in sMin SUGRA

# Dynamical generation of cosmological constant in sMin SUGRA
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### Dynamical generation of cosmological constant in sMin SUGRA

• Substituting 
$$(\mathcal{D}\mathcal{D} - \bar{R})\delta\mathcal{U} = \frac{1}{12}(\mathcal{D}\mathcal{D} - \bar{R})(i\delta V + \frac{1}{2}\bar{\mathcal{D}}_{\dot{\alpha}}\delta\bar{\kappa}^{\dot{\alpha}})$$
, one finds

$$\begin{split} \delta S_{SG} &= \frac{1}{6} \int d^{8} Z E \left[ G_{a} \, \delta H^{a} + (R - \bar{R}) i \delta V \right] - \\ &- \frac{1}{12} \int d^{8} Z E \left( R D_{\alpha} \delta \kappa^{\alpha} + \bar{R} \bar{D}_{\dot{\alpha}} \delta \bar{\kappa}^{\dot{\alpha}} \right) \, . \end{split}$$

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• Thus special minimal SUGRA is characterized by the same vector superfield equation  $G_a = 0$ ,

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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$$R = 4c$$
,  $\overline{R} = 4c$ ,  $c = const = c^*$ .

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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### Dynamical generation of cosmological constant in sMin SUGRA

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• As far as  $R_{bc}{}^{ac} = -\frac{3}{64}(\bar{D}\bar{D}\bar{R} + DDR - 4R\bar{R})\delta^a_b + O(G_a)$  the superfield equations  $\Rightarrow$  Einstein equation with cosmological constant

$$R_{bc}{}^{ac} = 3c^2 \delta_b{}^a$$
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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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•  $-\Lambda \propto c^2$ , *c* is an arbitrary integration constant  $\Rightarrow$  *cosmological constant is generated dynamically* in the special min SUGRA.

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions			
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Dynamical generation of cosmological constant in sMin SUGRA								

# Special minimal SUGRA variations.

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Dynamical generation of	cosmological constant i	n sMin SUGRA			

### Special minimal SUGRA variations.

• Resuming the special minimal SUGRA variation of the bosonic supervielbein and three form potential read (simplified):

$$\begin{split} \delta E^{a} &= E^{a}(\Lambda(\delta) + \bar{\Lambda}(\delta)) - \frac{1}{4} E^{b} \tilde{\sigma}_{b}^{\dot{\alpha}\alpha} [\mathcal{D}_{\alpha}, \bar{\mathcal{D}}_{\dot{\alpha}}] \delta H^{a} + i E^{\alpha} \mathcal{D}_{\alpha} \delta H^{a} - i \bar{E}^{\dot{\alpha}} \bar{\mathcal{D}}_{\dot{\alpha}} \delta H^{a} ,\\ \delta C_{3} &= \frac{1}{3!} E^{C} \wedge E^{B} \wedge E^{A} \beta_{ABC}(\delta) \end{split}$$

where

$$\begin{aligned} 2\Lambda(\delta) + \bar{\Lambda}(\delta) &= \frac{1}{4} \tilde{\sigma}_{a}^{\dot{\alpha}\alpha} \mathcal{D}_{\alpha} \bar{\mathcal{D}}_{\dot{\alpha}} \delta H^{a} + \frac{1}{8} G_{a} \delta H^{a} + i/4 (\mathcal{D}\mathcal{D} - \bar{R}) \delta V ,\\ \text{and} \qquad \beta_{\alpha\beta\gamma}(\delta) &= 0 , \qquad \beta_{\alpha\beta\dot{\gamma}}(\delta) = 0 ,\\ \beta_{\alpha\dot{\beta}a}(\delta) &= i\sigma_{a\alpha\dot{\beta}} \delta V , \qquad \beta_{\alpha\beta a}(\delta) = -\sigma_{ab\ \alpha\beta} \delta H^{b} ,\\ \beta_{\alpha ab}(\delta) &= \frac{1}{2} \epsilon_{abcd} \sigma_{\alpha\dot{\alpha}}^{c} \bar{\mathcal{D}}^{\dot{\alpha}} \delta H^{d} + \frac{1}{2} \sigma_{ab\ \alpha}^{\beta} \mathcal{D}_{\beta} \delta V ,\\ \beta_{abc}(\delta) &= \frac{i}{8} \epsilon_{abcd} \left( (\bar{\mathcal{D}}\bar{\mathcal{D}} - 1/2R) \delta H^{d} - c.c. \right) + \\ &+ \frac{1}{4} \epsilon_{abcd} G^{d} \delta V + \frac{1}{8} \epsilon_{abcd} \tilde{\sigma}^{d\dot{\gamma}\gamma} [\mathcal{D}_{\gamma}, \bar{\mathcal{D}}_{\dot{\gamma}}] \delta V . \end{aligned}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A ○○●	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
Dynamical generation of	cosmological constant i	n sMin SUGRA			

### Special minimal SUGRA variations.

• Resuming the special minimal SUGRA variation of the bosonic supervielbein and three form potential read (simplified):

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where

Now we are ready to study the interacting system action S<sub>SG</sub> + S<sub>p=2</sub>.

Intro. Superm	embrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Outline						
1	Introd • SU • Th Minin	Juction JSY extended le supermem nal and speci	d objects, super- brane action and ial minimal super	<i>p</i> -branes, and their its properties gravity.	description	
	<ul> <li>St</li> <li>Cloba</li> <li>Cloba</li> </ul>	osed 4-form i ckground osed 3-form j	superspace. Min In SSP and super potential and spe	rmembrane in minim cial minimal SUGRA	nation. nal SUGRA	
3	Dyna supe • St • Dy	mical genera rgravity. perfield equa namical gene	ation of cosmolog ations of special r eration of cosmo	ical constant in spec ninimal SUGRA ogical constant in sl	cial minimal Min SUGRA	
4	Supe supe • Su • Su	rmembrane s rfield equatio ipermembrar ipergravity su	supercurrent and ns ne supercurrent v uperfield equatior	its contribution to the ector superfield $J_a$ is with supermembra	e supergravity ane current	
5	Spac supe • W	etime compo rgravity–supe $Z_{\hat{\theta}=0}$ gauge	enent equations of ermembrane inter	f the $D = 4 \mathcal{N} = 1$ racting system		

- Conclusions and outlookConclusions
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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions		
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Suparmembrane suparcurrent /-							

Supermembrane supercurrent vector superfield

Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Supermembrane superci	irrent /-				

#### Supermembrane supercurrent vector superfield

• Now we see that the  $\propto \delta H^a$  variation of the supermembrane action gives us the vector supercurrent of the form

$$\begin{split} J_{a} &= \int_{W^{3}} \frac{1}{2\hat{E}} \hat{E}^{b} \wedge \hat{E}^{\alpha} \wedge \hat{E}^{\beta} \sigma_{ab\alpha\beta} \delta^{8}(Z - \hat{Z}) - \\ &- \int_{W^{3}} \frac{i}{2\hat{E}} \left( *\hat{E}_{a} \wedge \hat{E}^{\alpha} - \frac{i}{2} \hat{E}^{b} \wedge \hat{E}^{c} \wedge \hat{E}_{\dot{\beta}} \epsilon_{abcd} \tilde{\sigma}^{d\dot{\beta}\alpha} \right) \mathcal{D}_{\alpha} \delta^{8}(Z - \hat{Z}) + c.c + \\ &+ \int_{W^{3}} \frac{1}{2 \cdot 4! \hat{E}} \hat{E}^{b} \wedge \hat{E}^{c} \wedge \hat{E}^{d} \epsilon_{abcd} \left( \mathcal{D}\mathcal{D} - \frac{1}{2} \bar{R} \right) \delta^{8}(Z - \hat{Z}) + c.c. + \\ &+ \int_{W^{3}} \frac{1}{4! \hat{E}} * \hat{E}_{b} \wedge \hat{E}^{b} G_{a} \delta^{8}(Z - \hat{Z}) - \\ &- \int_{W^{3}} \frac{1}{4! \hat{E}} * \hat{E}_{c} \wedge \hat{E}^{b} \tilde{\sigma}^{d\dot{\alpha}\alpha} \left( 3\delta^{c}_{a} \delta^{d}_{b} - \delta^{d}_{a} \delta^{c}_{b} \right) [\mathcal{D}_{\alpha}, \bar{\mathcal{D}}_{\dot{\alpha}}] \delta^{8}(Z - \hat{Z}) , \end{split}$$

where  $\hat{E} = sdet(E_M^A(\hat{Z}))$  and  $\delta^8(Z) := \frac{1}{16} \delta^4(x) \,\theta\theta \,\bar{\theta}\bar{\theta}$  is the superspace delta function which obeys  $\int d^8Z \,\delta^8(Z-Z')f(Z) = f(Z')$  for any superfield f(Z).

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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SUGRA superfield equati	ions				

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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• The supercurrent enters the vector superfield eq. of SUGRA  $G_a = J_a$  which follows from the action of the SUGRA+SM interacting system

$$S = S_{SG} + rac{1}{6}S_{
m 
ho=2} = \int d^8 Z E(Z) + rac{1}{12}\int d^3 \xi \sqrt{g} - rac{1}{6}\int\limits_{W^3} \hat{C}_3 \; ,$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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SUGRA superfield equati	ions				

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• The scalar superfield equations  $(\delta S / \delta V = 0)$  reads

$$R - \bar{R} = -i\mathcal{X}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
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• The scalar superfield equations ( $\delta S/\delta V = 0$ ) reads

$$R - \bar{R} = -i\mathcal{X}$$

• where the *real* superfield  $\mathcal{X} = \mathcal{X}^*$  is given by

$$\begin{split} \mathcal{X} &= \frac{i}{E} \int_{W^3} \hat{E}^a \wedge \hat{E}^\alpha \wedge \hat{E}^{\dot{\alpha}} \sigma^a_{\alpha\dot{\alpha}} \, \delta^8(Z - \hat{Z}) + \\ &+ \int_{W^3} \left( -\frac{\hat{E}^b \wedge \hat{E}^a \wedge \hat{E}^\alpha}{4\hat{E}} \, \sigma_{ab\alpha}{}^\beta \mathcal{D}_\beta + c.c + \frac{\hat{E}^b \wedge \hat{E}^c \wedge \hat{E}^d}{2\cdot4!\hat{E}} \, \epsilon_{abcd} \tilde{\sigma}^{a\dot{\alpha}\alpha} [\mathcal{D}_\alpha, \bar{\mathcal{D}}_{\dot{\alpha}}] \right) \delta^8(Z - \hat{Z}) + \\ &+ \int_{W^3} \left( i \frac{*\hat{E}_a \wedge \hat{E}^a}{4!\hat{E}} \left( \mathcal{D}\mathcal{D} - \bar{R} \right) + c.c. + \frac{1}{4!\hat{E}} \hat{E}^b \wedge \hat{E}^c \wedge \hat{E}^d \epsilon_{abcd} G^a \right) \delta^8(Z - \hat{Z}) \, . \end{split}$$

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SLIGRA superfield equat	ions				

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• Notice that  $\bar{\mathcal{D}}^{\dot{\alpha}} G_{\alpha \dot{\alpha}} = -\mathcal{D}_{\alpha} R$  and c.c.  $\Rightarrow$ 

 $ar{\mathcal{D}}^{\dot{lpha}} J_{lpha \dot{lpha}} = i \mathcal{D}_{lpha} \mathcal{X} \;, \qquad \mathcal{D}^{lpha} J_{lpha \dot{lpha}} = -i ar{\mathcal{D}}_{\dot{lpha}} \mathcal{X} \;.$ 

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ ΟΟΟ	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
Outline					
<ul> <li>Introd</li> <li>SL</li> <li>Th</li> <li>Minin</li> <li>Su</li> <li>Closed</li> <li>Cl</li></ul>	Juction JSY extended le supermem nal and speci upergravity in osed 4-form i ickground osed 3-form j	d objects, super- brane action and ial minimal super superspace. Mir n SSP and super potential and spe	p–branes, and their its properties gravity. imal off–shell formu rmembrane in minim cial minimal SUGR/	description Ilation. nal SUGRA	
<ul> <li>3 Dyna super</li> <li>• Su</li> <li>• Dyna super</li> </ul>	mical genera rgravity. Iperfield equa namical gen	ation of cosmolog ations of special r eration of cosmol	ical constant in spec minimal SUGRA logical constant in sl	cial minimal Min SUGRA	
<ul> <li>Super super super</li></ul>	rmembrane s rfield equatio permembrar pergravity su etime compo rgravity-supe	supercurrent and ns ne supercurrent v uperfield equation onent equations o ermembrane inter	its contribution to the ector superfield $J_a$ is with supermembrations of the $D = 4 \ \mathcal{N} = 1$ racting system	ne supergravity ane current	

- WZ<sub>∂=0</sub> gauge
   Conclusions and outlook
  - Conclusions

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
WZ a gauge					

# $\mathsf{WZ}_{\hat{ heta}=\mathbf{0}}$ gauge

• We use the general coordinate invariance to fix the Wess–Zumino (WZ) gauge on supergravity superfields

$$\begin{split} \underline{i}_{\underline{\theta}} E^{\alpha} &:= \quad \theta^{\underline{\alpha}} E_{\underline{\alpha}}^{\alpha} = \theta^{\alpha} , \qquad \underline{i}_{\underline{\theta}} E^{\dot{\alpha}} := \theta^{\underline{\alpha}} E_{\underline{\alpha}}^{\dot{\alpha}} = \overline{\theta}^{\dot{\alpha}} \\ \theta^{\alpha} &:= \theta^{\underline{\beta}} \delta_{\underline{\beta}}^{\alpha} , \qquad \overline{\theta}^{\dot{\alpha}} := \theta^{\underline{\beta}} \delta_{\underline{\beta}}^{\dot{\alpha}} , \\ \underline{i}_{\underline{\theta}} E^{\underline{a}} &:= \quad \theta^{\underline{\alpha}} E_{\underline{\alpha}}^{\underline{a}} = 0 , \quad \underline{i}_{\theta} w^{\underline{a}\underline{b}} := \theta^{\underline{\beta}} w^{\underline{a}\underline{b}}_{\underline{\beta}} = 0 \end{split}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
WZ 🔬 . gauge					

 $\mathsf{WZ}_{\hat{ heta}=0}$  gauge

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• and the local spacetime SUSY to set to zero the fermionic Goldstone field of the supermembrane,

$$\hat{ heta}^{lpha}(\xi) = 0 \qquad \Leftrightarrow \qquad \hat{ heta}^{lpha}(\xi) = 0 \;, \qquad \hat{ar{ heta}}^{\dot{lpha}}(\xi) = 0 \;.$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
WZ o gauge					

 $\mathsf{WZ}_{\hat{ heta}=0}$  gauge

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• The leading componet of supervielbein matrix has a triangular form

$$E_N{}^{\mathcal{A}}|_{\theta=0} = \begin{pmatrix} e_{\nu}^{\mathfrak{a}}(x) & \psi_{\overline{\nu}}^{\underline{\alpha}}(x) \\ 0 & \delta_{\beta}^{\underline{\alpha}} \end{pmatrix} \qquad \Rightarrow \qquad E_A{}^{\mathcal{N}}|_{\theta=0} = \begin{pmatrix} e_a^{\nu}(x) & -\psi_a^{\beta}(x) \\ 0 & \delta_{\underline{\alpha}}^{\beta} \end{pmatrix}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
WZ o gauge					

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• Relation between the leading componet of  $T^{\alpha}_{ab}$  and the true gravitino field strength

$$T_{ab}{}^{\alpha}|_{\theta=0} = 2e^{\mu}_{a}e^{\nu}_{b}\mathcal{D}_{[\mu}\psi^{\alpha}_{\nu]}(x) - \frac{i}{4}(\psi_{[a}\sigma_{b]})_{\dot{\beta}}G^{\alpha\dot{\beta}}|_{\theta=0} - \frac{i}{4}(\bar{\psi}_{[a}\tilde{\sigma}_{b]})^{\alpha}R|_{\theta=0}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
W7					

# Current superfields in the $WZ_{\hat{\theta}=0}$ gauge

• We find that the vector and scalar superfields have the following form,

$$\begin{aligned} J_{\alpha\dot{\alpha}}|_{\dot{\theta}=0} &= \frac{\theta_{\beta}\,\bar{\theta}_{\dot{\beta}}}{8} (\,3\mathcal{P}_{a}{}^{b}(x)\sigma^{a}_{\alpha\dot{\alpha}}\tilde{\sigma}^{\beta\dot{\beta}}_{b} - 2\delta_{\alpha}{}^{\beta}\delta_{\dot{\alpha}}{}^{\dot{\beta}}\mathcal{P}_{b}{}^{b}(x) \\ &-i\frac{(\theta\theta - \bar{\theta}\bar{\theta})}{32}\sigma^{a}_{\alpha\dot{\alpha}}\mathcal{P}_{a}(x) + \propto \underline{\theta}^{\wedge3} \\ \mathcal{X}|_{\hat{\theta}=0} &= -\frac{\theta\sigma^{a}\bar{\theta}}{16}\mathcal{P}_{a} + i\frac{(\theta\theta - \bar{\theta}\bar{\theta})}{16}\mathcal{P}_{a}{}^{a}(x) + \propto \underline{\theta}^{\wedge3} \end{aligned}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
WZ gaugo					

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• Where we have introduced the current pre-potential fields,

$$\begin{aligned} \mathcal{P}_{a}{}^{b}(x) &:= \int_{W^{3}} \frac{1}{\hat{e}} * \hat{e}_{a} \wedge \hat{e}^{b} \, \delta^{4}(x - \hat{x}) , \\ \mathcal{P}_{a}(x) &:= \int_{W^{3}} \frac{1}{\hat{e}} \epsilon_{abcd} \hat{e}^{b} \wedge \hat{e}^{c} \wedge \hat{e}^{d} \, \delta^{4}(x - \hat{x}) = \\ &= e_{a}^{\mu}(x) \int_{W^{3}} \epsilon_{\mu\nu\rho\sigma} d\hat{x}^{\nu} \wedge d\hat{x}^{\rho} \wedge d\hat{x}^{\sigma} \, \delta^{4}(x - \hat{x}) \end{aligned}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
WZ. gauge					

## Current superfields in the WZ $_{\hat{\theta}=0}$ gauge

• We find that the vector and scalar superfields have the following form,

$$\begin{aligned} J_{\alpha\dot{\alpha}}|_{\dot{\theta}=0} &= \frac{\theta_{\beta}\,\bar{\theta}_{\dot{\beta}}}{8} (\,3\mathcal{P}_{a}{}^{b}(x)\sigma^{a}_{\alpha\dot{\alpha}}\tilde{\sigma}^{\beta\dot{\beta}}_{b} - 2\delta_{\alpha}{}^{\beta}\delta_{\dot{\alpha}}{}^{\dot{\beta}}\mathcal{P}_{b}{}^{b}(x) \\ &-i\frac{(\theta\theta - \bar{\theta}\bar{\theta})}{32}\sigma^{a}_{\alpha\dot{\alpha}}\mathcal{P}_{a}(x) + \propto \underline{\theta}^{\wedge3} \\ \mathcal{X}|_{\hat{\theta}=0} &= -\frac{\theta\sigma^{a}\bar{\theta}}{16}\mathcal{P}_{a} + i\frac{(\theta\theta - \bar{\theta}\bar{\theta})}{16}\mathcal{P}_{a}{}^{a}(x) + \propto \underline{\theta}^{\wedge3} \end{aligned}$$

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• There is no explicit supermembrane contributions to the Rarita-Schwinger equations ,

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

• We calculate the Einstein eq. using the vector and scalar current superfields,

$$\left. R_{bc}{}^{ac} \right|_{_{\theta=0}, \ \hat{\theta}=0} \quad = \quad -\frac{3}{32} T_2 \left( \mathcal{P}_b{}^a(x) - \frac{1}{2} \delta^a_b \mathcal{P}_c{}^c(x) \right) + \frac{3}{64} (R + \bar{R})^2 |_{_{\theta=0}} \delta^a_b \, .$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

• We calculate the Einstein eq. using the vector and scalar current superfields,

$$R_{bc}{}^{ac}|_{\theta=0,\ \theta=0} = -\frac{3}{32} T_2 \left( \mathcal{P}_b{}^a(x) - \frac{1}{2} \delta^a_b \mathcal{P}_c{}^c(x) \right) + \frac{3}{64} (R+\bar{R})^2|_{\theta=0} \delta^a_b.$$

### The last term needs a separate study,

$$R - \bar{R} = -iT_2 \mathcal{X} \qquad \Rightarrow \qquad \partial_\mu (R + \bar{R})|_{\theta=0} = \frac{T_2}{16} \int_{W^3} \epsilon_{\mu\nu\rho\sigma} d\hat{x}^\nu \wedge d\hat{x}^\rho \wedge d\hat{x}^\sigma \,\,\delta^4(x - \hat{x})$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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$$|R-\bar{R}=-iT_2\mathcal{X}$$
  $\Rightarrow$   $\partial_{\mu}(R+\bar{R})|_{\theta=0}=rac{T_2}{16}\int\limits_{W^3}\epsilon_{\mu
u
ho\sigma}d\hat{x}^{
u}\wedge d\hat{x}^{
ho}\wedge d\hat{x}^{\sigma}\,\delta^4(x-\hat{x})$ 

• The solution can be written in the form,

$$R(x) + \bar{R}(x) = 8c + \frac{T_2}{16} \int_{x_0}^x d\tilde{x}^{\mu} \int_{W^3} \epsilon_{\mu\nu\rho\sigma} d\hat{x}^{\nu} \wedge d\hat{x}^{\rho} \wedge d\hat{x}^{\sigma} \,\,\delta^4(\tilde{x} - \hat{x})$$

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of $\Lambda$	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions

• It is easy to check that

$$\Theta(x,x_0|\hat{x}):=\int\limits_{x_0}^x d ilde{x}^\mu \int\limits_{W^3} \epsilon_{\mu
u
ho\sigma} d\hat{x}^
u\wedge d\hat{x}^
ho\wedge d\hat{x}^\sigma \; \delta^4( ilde{x}-\hat{x})$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
WZ o gauge					

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$$\Theta(x,x_0|\hat{x}) := \int\limits_{x_0}^{x} d\tilde{x}^{\mu} \int\limits_{W^3} \epsilon_{\mu\nu\rho\sigma} d\hat{x}^{\nu} \wedge d\hat{x}^{\rho} \wedge d\hat{x}^{\sigma} \ \delta^4(\tilde{x}-\hat{x})$$

obeys

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u
ho\sigma} d\hat{x}^
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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
WZ o gauge					

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u
ho\sigma} d\hat{x}^{
u} \wedge d\hat{x}^{
ho} \wedge d\hat{x}^{\sigma} \,\,\delta^4(x-\hat{x}) \;.$$

• Then, we can writte

$$R(x) + \bar{R}(x) = 8c + \frac{T_2}{16}\Theta(x, x_0|\hat{x})$$

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions

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ho\sigma} d\hat{x}^{
u} \wedge d\hat{x}^{
ho} \wedge d\hat{x}^{\sigma} \,\,\delta^4(x-\hat{x}) \;.$$

• Then, we can writte

$$R(x)+\bar{R}(x)=8c+\frac{T_2}{16}\Theta(x,x_0|\hat{x})$$

• And finally we obtain,

$$\begin{aligned} R_{bc}{}^{ac}(x) &= -\frac{3T_2}{32} \left( \mathcal{P}_b{}^a(x) - \frac{1}{2} \delta_b^a \mathcal{P}_c{}^c(x) \right) \\ &+ 3\delta_b^a \left( c^2 + \left( \left( \frac{T_2}{128} + c \right)^2 - c^2 \right) \Theta(x, x_0 | \hat{x}) \right) \end{aligned}$$

Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

• We can separate these contributions in three different classes

$$R_{acb}{}^{c}(x) = \eta_{ab} \, 3c^{2} + T_{2} \left( \mathcal{T}_{ab}^{sing}(x) + \mathcal{T}_{ab}^{reg}(x) \right)$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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• The first one is proportional to an arbitrary integration constant

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

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- The first one is proportional to an arbitrary integration constant
- The second one contains singular terms  $\propto \mathcal{P}_c^{\ d}(x)$

$$\begin{aligned} \mathcal{T}_{ab}^{sing}(x) &= -T_2 \frac{3}{32} \left( \mathcal{P}_{ba}(x) - \frac{1}{2} \eta_{ba} \mathcal{P}_c^{\,c}(x) \right) = \\ &= -\frac{3T_2}{32} \int_{W^3} \frac{1}{\hat{e}} * \hat{e}_a \wedge \hat{e}_b \, \delta^4(x - \hat{x}) + \frac{3T_2}{64} \eta_{ba} \int_{W^3} \frac{1}{\hat{e}} * \hat{e}_c \wedge \hat{e}^c \, \delta^4(x - \hat{x}) \end{aligned}$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

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 The last one contains regular terms proportional to the supermembrane tension,

$$\mathcal{T}^{reg}_{ab}(x) = \eta_{ab}\mathcal{T}^{reg}(x) \ , \qquad \mathcal{T}^{reg}(x) = + rac{3T_2}{64}\left(rac{T_2}{256} + c
ight)\Theta(x,x_0|\hat{x}) \ .$$
Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

• Considering the Einstein eq. in two pieces of space time separated by the supermembrane worldvolume

$$M_{+}^{4} : \qquad R_{acb}^{c}(x) = 3\eta_{ab} \left(\frac{T_{2}}{128} + c\right)^{2}$$
$$M_{+}^{4} : \qquad R_{acb}^{c}(x) = 3\eta_{ab} c^{2}$$

$$M_-^4 : \qquad R_{acb}{}^c(x) = 3\eta_{ab} c^2$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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• Where  $M^4_+$  denotes the half-space where  $\Theta(x, x_0 | \hat{x}) = 1$  $(M^4_- \to \Theta(x, x_0 | \hat{x}) = 0)$ 

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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- Two branches of spacetime have different values of cosmological constant

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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- Where  $M_{+}^{4}$  denotes the half-space where  $\Theta(x, x_{0}|\hat{x}) = 1$  $(M_{-}^{4} \rightarrow \Theta(x, x_{0}|\hat{x}) = 0)$
- Two branches of spacetime have different values of cosmological constant
- These values coincide if  $c = -\frac{T_2}{256}$ , but we do not find any reason for such choice

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

• If we search purely bosonic supersymmetric solutions ( $\psi^{\alpha}_{\mu} = 0$ ), we study Killing spinor equations ( $\delta_{\epsilon}\psi^{\alpha}_{\mu} = 0$ )

$$D\epsilon^{\alpha} + \frac{i}{8} e^{c} (\epsilon \sigma_{c} \tilde{\sigma}_{d})_{\beta}^{\alpha} G^{d}|_{\theta=0} + \frac{i}{8} e^{c} (\bar{\epsilon} \tilde{\sigma}_{c})^{\alpha} R|_{\theta=0} = 0$$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

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• Using the auxiliary field equations of motion, we obtain

Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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Using the auxiliary field equations of motion, we obtain

$$D\epsilon^{\alpha} + \frac{i}{2}e^{a}\left(\bar{\epsilon}\tilde{\sigma}_{a}\right)^{\alpha}\left(c + \frac{T_{2}}{128}\Theta(x, x_{0}|\hat{x})\right) = 0.$$

• We can split this eq. on two killing equations valid in the two different branches

Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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$$\begin{split} M_{-}^{4} &: \qquad D\epsilon^{\alpha} + \frac{i}{2}e^{a}\left(\bar{\epsilon}\tilde{\sigma}_{a}\right)^{\alpha}c = 0 \ , \\ M_{+}^{4} &: \qquad D\epsilon^{\alpha} + \frac{i}{2}e^{a}\left(\bar{\epsilon}\tilde{\sigma}_{a}\right)^{\alpha}\left(c + \frac{T_{2}}{128}\right) = 0 \end{split}$$

Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

• Applying the covariant derivative and using the Ricci identities  $DD\epsilon^{\alpha} = -\frac{1}{4}R^{ab}\epsilon^{\beta}\sigma_{ab\beta}{}^{\alpha}$ 

$$\begin{split} M_{-}^{4} : & R^{ab} \epsilon^{\beta} \sigma_{ab\beta}{}^{\alpha} = \frac{1}{4} |c|^{2} e^{d} \wedge e^{c} \epsilon^{\beta} \sigma_{cd\beta}{}^{\alpha} , \\ M_{+}^{4} : & R^{ab} \epsilon^{\beta} \sigma_{ab\beta}{}^{\alpha} = \frac{1}{4} \left| c + \frac{T_{2}}{128} \right|^{2} e^{d} \wedge e^{c} \epsilon^{\beta} \sigma_{cd\beta}{}^{\alpha} \end{split}$$

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 For purely bosonic solution preserving all SUSY the formers should be obeyed for arbitrary  $\epsilon^{\alpha}$ 

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions 00
$WZ_{\hat{ heta}=0}$ gauge					

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 These equations solve our equations of motion and describe the completely SUSY solution (At least modulo singular terms)

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

• These equations contain supermembrane contributions

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

- These equations contain supermembrane contributions
  - Indirect: Arbitrary cosmological constant generated dinamically

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

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  - Indirect: Arbitrary cosmological constant generated dinamically
  - Direct: Shift of cosmological constant on one of the sides  $\propto T_2$

Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

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Intro. Supermembrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

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- because, due to the presence of dynamical supermembrane have to restrict the local SUSY parameter by boundary conditions which clearly break 1/2 of the SUSY on W<sup>3</sup>

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
$WZ_{\hat{ heta}=0}$ gauge					

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- The SUSY parameter should also obey the boundary condition

 $W^3 = \pm \partial M^4_{\pm} : \qquad \hat{\epsilon}^\alpha = \hat{\epsilon}_{\dot{\alpha}} \tilde{\tilde{\gamma}}^{\dot{\alpha}\alpha} , \qquad \hat{\epsilon}^\alpha := \epsilon^\alpha(\hat{x}(\xi)) , \quad \hat{\bar{\epsilon}}_{\dot{\alpha}} := \bar{\epsilon}_{\dot{\alpha}}(\hat{x}(\xi)) .$ 

Intro. Supermembrane	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions OO
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Intro. Supern	embrane	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions
Outline						
3	Introd Sl Th Minin Sl Cl	duction JSY extended le supermem nal and speci lipergravity in osed 4-form i	d objects, super- brane action and al minimal super superspace. Mir n SSP and supe	p-branes, and their its properties gravity. imal off-shell formu rmembrane in minim	description lation. nal SUGRA	
3	<ul> <li>Cli</li> <li>Dyna</li> <li>supe</li> <li>St</li> <li>Dy</li> </ul>	osed 3-form   mical genera rgravity. Iperfield equa mamical gen	ootential and spe ttion of cosmolog ations of special r eration of cosmol	cial minimal SUGR/ ical constant in spec minimal SUGRA logical constant in sl	A cial minimal Min SUGRA	
4	Supe supe • St • St Space	rmembrane s rfield equatio upermembrar upergravity su setime compo	supercurrent and ns ne supercurrent v uperfield equation onent equations c	its contribution to the ector superfield $J_a$ as with supermembrations of the $D = 4 \ N = 1$	ne supergravity ane current	
		roravitv–sube	ermembrane inte	racting system		

- WZ<sub>θ=0</sub> gauge
   Conclusions and outlook
  - Conclusions

Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of Λ 000	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions ●○
Conclusions					

• We have derived the complete set of spacetime component eqs. of motion for the interacting system of dynamical D = 4  $\mathcal{N} = 1$  SUGRA and supermembrane

Intro. Supermembrane 00000	Special min SUGRA	Dynamical generation of A	Supercurrents and SUGRA eqs.	Spacetime component eqs	Conclusions ●○
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- The supermembrane current superfields simplify drastically in that gauge

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- Generically the difference of these values is proportional to the supermembrane tension, while its basic value is determined by an arbitrary constant independent on T<sub>2</sub>

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# THANK YOU FOR YOUR ATTENTION!