Abelian tensor hierarchy and Chern-Simons actions in 4D N=1 conformal supergravity

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Abstract

We consider a general framework of shift symmetric tensor gauge theories in 4D N=1 supergravity by using conformal superspace formalism. The Chern-Simons actions of tensors are expressed in a manifestly supersymmetric way.

1 Introduction

Shift symmetric tensor gauge theory in 4D N=1 SUGRA?

Gauged shift symmetry and p-form gauge fields

- Related to cancellation of U(1) gauge anomaly $\delta\phi_0 = q\theta_0 \quad \delta A_1 = d\theta_0$
- Generalized to p-form: Abelian tensor hierarchy (ATH) [de Wit & Samtleben (2005)]
  $\delta B_{p-1} = k\lambda_{p-1} \quad \delta C_p = d\lambda_{p-1}$

Chern-Simons actions

- Constructed by wedge products of gauge fields and field strengths
  $\phi_0 F_2 \wedge F_2 \quad B_2 \wedge F_2 \quad \phi_0 dC_3$
- Application: shift symmetric axion mass $-\frac{1}{2}(dC_3)^2 + g\phi_0 dC_3$ [Kaloper & Sorbo (2009)]

4D N=1 Supergravity (SUGRA)

Beyond SM, Einstein gravity, string effective theory

Construction of Chern-Simons actions of ATH in SUGRA

- ATH: express gauge transf. laws, field strengths and actions in SUGRA
- SUGRA: use conformal superspace formalism to reduce SUGRA complexity

2 Abelian tensor hierarchy in 4D global SUSY

Shift symmetric Abelian tensor gauge theory

2.1 Bosonic case

[de Wit & Samtleben (2005)]

Gauge transf. laws & field strengths shifted

	Gauge transf. laws	Field strengths
2-form	$\delta B_2 = d\lambda_1$	$H_3 = dB_2$
	shift	shift
1-form	$\delta A_1 = d\theta_0 + q\lambda_1$	$F_2 = dA_1 - qB_2$

q : constant

2.2 4D N=1 global SUSY case

[Becker et al. (2016)]

SUSY manifest: superfields & spinor derivatives

	Gauge transf. laws	Field strengths
2-form	$\delta\Sigma_\alpha = -\frac{1}{4}\bar{D}^2 D_\alpha \Lambda$	$L = \frac{1}{2i}(D^\alpha\Sigma_\alpha - \bar{D}_{\dot\alpha}\bar\Sigma^{\dot\alpha})$
	shift	shift
1-form	$\delta V = \frac{1}{2i}(\Theta - \bar\Theta) + q\Lambda$	$W_\alpha = -\frac{1}{4}\bar{D}^2 D_\alpha V - q\Sigma_\alpha$

Σ_α,Θ: chiral V,Λ: real

3 Conformal superspace

[Butter (2010)]

Reduce SUGRA complexity & SUSY manifest

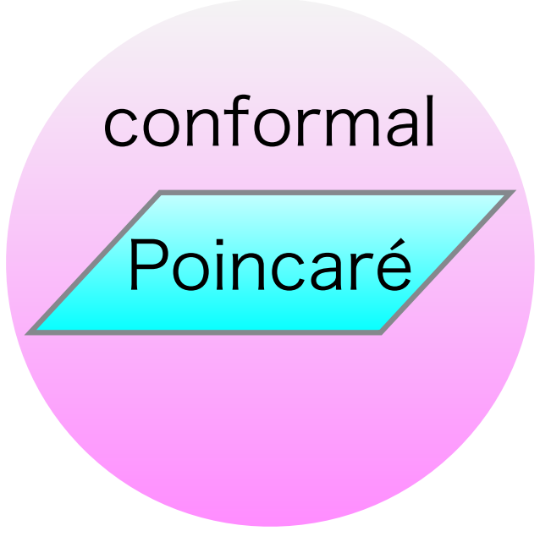
$$\boxed{\{\nabla_\alpha, \nabla_\beta\} = \{\bar\nabla_{\dot\alpha}, \bar\nabla_{\dot\beta}\} = 0, \quad \{\nabla_\alpha, \bar\nabla_{\dot\beta}\} = -2i\nabla_{\alpha\dot\beta}}$$

∇_α: superconformally covariant spinor derivative

Replace spinor derivative: $D_\alpha \rightarrow \nabla_\alpha$

Conformal SUGRA [Kaku & Townsend (1978)]

- Gauge theory of superconformal symmetry
- Larger symmetry than Poincaré SUGRA
- Gravitational complexity reduced



4 ATH in conformal superspace

Natural extension of global SUSY case

4.1 Gauge transf. laws & field strengths

Shift deformation extended

	Gauge transf. laws	Field strengths
2-form	$\delta\Sigma_\alpha = -\frac{1}{4}\bar\nabla^2\nabla_\alpha\Lambda$	$L = \frac{1}{2i}(\nabla^\alpha\Sigma_\alpha - \bar\nabla_{\dot\alpha}\bar\Sigma^{\dot\alpha})$
	shift	shift
1-form	$\delta V = \frac{1}{2i}(\Theta - \bar\Theta) + q\Lambda$	$W_\alpha = -\frac{1}{4}\bar\nabla^2\nabla_\alpha V - q\Sigma_\alpha$

Bosonic gauge fields and field strengths are expressed by superfields:

$$B_{ab} = \frac{1}{2i}((\sigma_{ab})_\alpha{}^\beta\nabla^\alpha\Sigma_\beta - (\bar\sigma_{ab})^{\dot\alpha}{}_{\dot\beta}\bar\nabla_{\dot\alpha}\bar\Sigma^{\dot\beta})| \qquad H_{abc} = \frac{1}{8}\epsilon_{abcd}(\bar\sigma^d)^{\dot\alpha\beta}[\nabla_\beta, \bar\nabla_{\dot\alpha}]L|$$

$$A_a = -\frac{1}{4}(\bar\sigma_a)^{\dot\alpha\alpha}[\nabla_\alpha, \bar\nabla_{\dot\alpha}]V| \qquad F_{ab} = \frac{1}{2i}((\sigma_{ab})_\alpha{}^\beta\nabla^\alpha W_\beta - (\bar\sigma_{ab})^{\dot\alpha}{}_{\dot\beta}\bar\nabla_{\dot\alpha}\bar W^{\dot\beta})|$$

4.2 Chern-Simons action

Constructed by gauge fields and field strengths

$$\boxed{S_{\rm CS} = \int d^4x d^4\theta E\alpha LV + {\rm Re}\left(i\int d^4x d^2\theta \mathcal{E}\alpha\Sigma^\alpha W_\alpha\right)}$$

$$\ni \alpha A_1 \wedge H_3 + \alpha B_2 \wedge F_2$$

α: real constant, E : superspace density, $\mathcal{E}$: chiral density

4.3 Superconformal & shift invariances of the CS action

Superconformal invariance

Satisfied by the Weyl weights of the superfields (for scale invariance)

e.g. Counting the Weyl weight of LV term

$$\int d^4x d^4\theta \underset{-2}{E}\alpha \underset{+2}{L}\underset{0}{V}$$

Weyl weights of superfields

$$\underset{+3}{H_{abc}} = \frac{1}{8}\epsilon_{abcd}(\bar\sigma^d)^{\dot\alpha\beta}[\underset{1/2}{\nabla_\beta}, \underset{1/2}{\bar\nabla_{\dot\alpha}}]\underset{+2}{L}| \qquad \underset{-2}{E} \leftarrow \underset{-4}{d^4x}\underset{+2}{d^4\theta}$$

$$\underset{1}{A_a} = -\frac{1}{4}(\bar\sigma_a)^{\dot\alpha\alpha}[\underset{1/2}{\nabla_\alpha}, \underset{1/2}{\bar\nabla_{\dot\alpha}}]\underset{0}{V}|$$

Shift invariance

Satisfied by the relation between the coefficients

Invariance is the same as bosonic case:

$$\delta(\alpha B_2 \wedge F_2 + \alpha A_1 \wedge H_3) = \alpha d\lambda_1 \wedge F_2 + \alpha q\lambda_1 \wedge H_3$$

5 Summary

- ATH is introduced into 4D N=1 SUGRA by using conformal superspace.
- Gauge transf. laws and field strengths are expressed in terms of the superfields.
- Shift invariant CS actions are constructed.
- Future work: application to phenmomenology e.g. inflation, anomaly cancellation in 4D,…

Appendix ATH in conformal superspace (all rank tensor & multicomponent case)

form	type	prepotentials	gauge parameters
0-form	chiral	Φ^{I_0}	Θ^{I_1}
1-form	real	V^{I_1}	Θ^{I_2}
2-form	chiral	$\Sigma_\alpha^{I_2}$	$\Theta_\alpha^{I_3}$
3-form	real	X^{I_3}	Θ^{I_4}
4-form	chiral	Γ^{I_4}	—

form	gauge transf. laws	field strengths
0-form	$\delta\Phi^{I_0} = (q^{(0)}\cdot\Theta)^{I_0}$	$\Psi_a^{I_0} = \frac{1}{2i}(\Phi^{I_0} - \bar\Phi^{I_0}) - (q^{(0)}\cdot V)^{I_0}$
1-form	$\delta V^{I_1} = \frac{1}{2i}(\Theta^{I_1} - \bar\Theta^{I_1}) + (q^{(1)}\cdot\Theta)^{I_1}$	$W_\alpha^{I_1} = -\frac{1}{4}\bar\nabla^2\nabla_\alpha V^{I_1} - (q^{(2)}\cdot\Sigma_\alpha)^{I_1}$
2-form	$\delta\Sigma_\alpha^{I_2} = -\frac{1}{4}\bar\nabla^2\nabla_\alpha\Theta^{I_2} + (q^{(2)}\cdot\Theta_\alpha)^{I_2}$	$L^{I_2} = \frac{1}{2i}(\nabla^\alpha\Sigma^{I_2} - \bar\nabla_{\dot\alpha}\bar\Sigma^{I_2\dot\alpha}) - (q^{(2)}\cdot X)^{I_2}$
3-form	$\delta X^{I_3} = \frac{1}{2i}(\nabla^\alpha\Theta^{I_3} - \bar\nabla_{\dot\alpha}\bar\Theta^{I_3\dot\alpha}) + (q^{(3)}\cdot\Theta)^{I_3}$	$Y^{I_3} = -\frac{1}{4}\bar\nabla^2 X^{I_3} - (q^{(3)}\cdot\Gamma)^{I_3}$
4-form	$\delta\Gamma^{I_4} = -\frac{1}{4}\bar\nabla^2\Theta^{I_4}$	—

form	bosonic gauge fields
0-form	$\phi^{I_0} = \frac{1}{2}(\Phi^{I_0} + \bar\Phi^{I_0})|$
1-form	$A_a^{I_1} = -\frac{1}{4}(\bar\sigma_a)^{\dot\alpha\alpha}[\nabla_\alpha, \bar\nabla_{\dot\alpha}]V^{I_1}|$
2-form	$B_{ab}^{I_2} = \frac{1}{2i}((\sigma_{ab})_\alpha{}^\beta\nabla^\alpha\Sigma_\beta^{I_2} - (\bar\sigma_{ab})^{\dot\alpha}{}_{\dot\beta}\bar\nabla_{\dot\alpha}\bar\Sigma^{I_2\dot\beta})|$
3-form	$C_{abc}^{I_3} = \frac{1}{8}\epsilon_{abcd}(\bar\sigma^d)^{\dot\alpha\alpha}[\nabla_\alpha, \bar\nabla_{\dot\alpha}]X^{I_3}|$
4-form	$D_{abcd}^{I_4} = \frac{i}{8}\epsilon_{abcd}(\nabla^2\Gamma^{I_4} - \bar\nabla^2\bar\Gamma^{I_4})|$

$q^{(p)} : I_{p+1} \rightarrow I_p$: matrix for internal d.o.f. satisfying $q^{(p)}\cdot q^{(p+1)} = 0$ (gauge invariance of field strengths)