Higher–Spin Gauge Theories

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Round Table Italy-Russia, Dubna, 18 December, 2009

Higher Spin Gauge Theories

Elementary particles are characterized by mass m and spin $s = 0, 1/2, 1, \ldots$.

Dirac (1936)

All elementary particles discovered so far are of only two types

$s = 1$: photons, gluons, W, Z

$s = 1/2$: $e, \nu, \mu, u, d \ldots$

Main goal of LHC is to discover a still hypothetical spin 0 particle: Higgs boson

Spin two graviton and spin 3/2 gravitino still have not been directly observed

The problem (at the moment, mostly theoretical): what about higher spins $s > 2$,

Higher spins are higher tensors:

$$A_n\,, \qquad g_{nm}\dots$$

- $m \neq 0$ **symmetric fields of any spin:** Singh-Hagen (1974)
- $m = 0$ **symmetric fields of any spin:** Fronsdal (1978)

$\phi_{n_1 \dots n_s}\,, \phi_{n_1 \dots n_{s-2}} \sim \varphi_{n_1 \dots n_s}$ **double traceless** $\eta^{n_1 n_2}\eta^{n_3 n_4}\varphi_{n_1 \dots n_s} = 0$

Gauge transformation:

$$\delta\varphi_{k_1 \dots k_s} = \partial_{(k_1}\varepsilon_{k_2 \dots k_s)}\,, \qquad \varepsilon^m{}_{m k_3 \dots k_{s-1}} = 0$$

Higher-spin symmetries: far going extension of SUSY

Higher-spin gauge theories far going extension of supergravity

String

String Field Theory:

Massive fields of all symmetry types

$$|\Psi\rangle \ = \ \sum \psi_{m_1 \dots m_{s_1},\, n_1 \dots n_{s_2},\, \dots} a_{-1}^{m_1} \dots a_{-1}^{m_{s_1}} a_{-2}^{n_1} \dots a_{-2}^{n_{s_2}} \dots |0\rangle$$

$$Q|\Psi\rangle \ = \ 0 \qquad \text{equations + constraints}$$

$$\delta|\psi\rangle \ = \ Q|\varepsilon\rangle \qquad \text{gauge symmetries:} \qquad \text{true+Stueckelberg}$$

Mass scale $m^2 \sim 1/\alpha'$

Tensionless limit $\alpha' \to \infty$: **All fields become massless**

High-energy symmetries?!

A HS symmetric String Theory = HS gauge theory

Unfolded Dynamics

First-order form of differential equations

$$\dot{q}^i(t) = \varphi^i(q(t)) \qquad \text{initial values:} \quad q^i(t_0)$$

Unfolded dynamics: multidimensional covariant generalization

$$\frac{\partial}{\partial t} \to d\,, \qquad q^i(t) \to W^\alpha(x) = dx^{n_1} \wedge \ldots \wedge dx^{n_p} W^\alpha_{n_1 \ldots n_p}(x)$$

a set of differential forms

Unfolded equations

$$dW^{\alpha}(x) = G^{\alpha}(W(x))\,, \qquad d = dx^{n}\partial_{n}$$

$G^{\alpha}(W)$: **function of "supercoordinates"** W^{α} **Covariant first-order differential equations**

$d > 1$: **Nontrivial compatibility conditions**

$$G^{\beta}(W) \wedge \frac{\partial G^{\alpha}(W)}{\partial W^{\beta}} \equiv 0$$

equivalent to the generalized Jacobi identities

Any solution to generalized Jacobi identities:

FDA **(Sullivan (1968); R.D'Auria and P.Fre (1982))**

Properties

- General applicability
- Manifest (HS) gauge invariance
- General coordinate invariance
- Interactions: nonlinear deformation of $G^{\alpha}(W)$
- Independence of ambient space-time

  Geometry is encoded by $G^{\alpha}(W)$
- Lie algebra cohomology interpretation: σ_{-} cohomology
- Covariant twistor transform

Achievments

Higher-spin field interactions for symmetric fields

Free fields of general type

Open problems

Spontaneous breaking of higher spin symmetries

Nonlinear theories of general (mixed symmetry) fields

Higher-spin interpretation of String Theory

Higher-spin theory of fundamental interactions

Higher Spins in Italy

SNS Pisa Augusto Sagnotti

Padova University Dmitry Sorokin

Bologna University Fiorenzo Bastianelly

Related studies:

University Tor Vergata Massimo Bianchi

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Higher Spins in Russia

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