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Research Activity

- **supergravity, strings & branes**

and also

- **cosmic billiards**
- **algebraic structures**
- **non-commutative field theories**
- **higher spin theories**
- **QCD strings for lattice**

Supergravity

- **Quantum nature of Black Holes:** Black-Hole attractors in supergravity, non-BPS Black Holes, first order formalism, role of rotation, gauged supergravities *(A. Ceresole in collaboration with Padova and Politecnico)*

- Canonical quantization of **Supermembranes** with central charges *(M.P. Garcia Del Moral in collaboration with Caracas)*

- **Cosmic biliards**, oxidation and duality groups in low dimensions (E_8, E_9, E_{10}). (*Frè*)

- **Gauging of M-theory hidden superalgeras**. (*Castellani, Frè, and Grassi → connection with pure spinors*)

Strings & Branes

- **Non-perturbative properties of gauge theories:** instanton effects using strings and branes. (***Billò, Frau, Garcia Del Moral Lerda, Pesando , also in collaboration with Copenhagen, Napoli, SISSA, Brussels and Roma Tor Vergata***)

- **Magnetized D-branes** and their effective action ***(C. Angelantonj, M. Billo, M.Frau, A. Lerda, I. Pesando, also in collaboration with Copenhagen and Napoli)***

- **Charged open strings** and their interactions. (***Sciuto also in collaboration with London***)

- Applications of **Berkovits formalism** and **pure spinors** to string theory (***Grassi, Castellani and Frè***)

- D-brane **phenomenology** and **cosmology** constructions ***(M.P. Garcia Del Moral in collaboration with Cambridge)***

Strings & Branes

- **SUSY breaking:** Metastable, Dynamical, asymmetric Scherk-Schwarz. ***(C. Angelantonj, A. Fotopoulos in Collaboration with Crete and CPHT)***

- Moduli space and D-branes of **exact CFT backgrounds** ***(A. Fotopoulos I Collaboration with CERN, Ecole Polytechnique and U. of Patras)***

- Lagrangian formulation of **Interacting Higher Spin theories** and their connection to string theory. ***(A. Fotopoulos in collaboration with U. of Crete)***

- **Nambu-Goto bosonic string model** as a description of the physics of interfaces ***(M. Billo, M. Caselle and L. Ferro)***

Non-commutative geometry

- **Non-commutative diffeomorphisms** in deformed gravity theories. (***Castellani & Aschieri***)

- **Gauge and gravity theories on finite groups**. (***Castellani & Aschieri***)

- **Gerbes** and geometry of antisymmetric fields. (***Aschieri***)

Collaborations

Many of these projects are developed in collaboration with colleagues of other universities and research centres, e.g.

Copenhagen
Paris
Leuven
London
Munchen
Valencia
Frascati
Napoli
Padova
SISSA
CERN
Crete
Brussel
Copenhagen
Utrecht
Cambridge, Edimburgh,
Caracas

INTERACTING HIGHER SPINS

Based On:

A. F., N. Irges, A. C. Petkou, M. Tsulaia e-Print: arXiv:0708.1399 [hep-th]

A. F. and M. Tsulaia Phys.Rev.D76:025014,2007

I. Buchbinder, A. F., A. Petkou, M.Tsulaia, Phys. Rev. D 74, 2006, 105018

A. F, K.L. Panigrahi, M. Tsulaia, Phys. Rev. D74, 2006, 085029

- There are two consistent theories which contain fields with arbitrary spin (all spins are required for consistency):

A: (Super)string theory – Consistent both Classically and Quantum Mechanically (in D = 26, D = 10)

Backgrounds: Flat for bosonic. Flat, pp-wave, AdS5 X S5 for Superstring

B: Higher Spin Gauge Theory (M.Vasiliev, E.Fradkin-M.Vasiliev) – Consistent Classically. Quantum Mechanically – No S Matrix on AdS

Backgrounds: AdS(D)

- HS Theory is an "analog" of SUGRA, but classical consistency requires an infinite tower of massless HS fields

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- SUGRA's are low energy limits of superstring theories.

A: Is HS gauge theory any limit (an effective theory) of String Theory???

B: Is HS gauge theory (Massless Fields) a symmetric phase of String Theory (Massive Fields)?

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- In string theory masses; $m_s \sim s/\alpha'$. Symmetric Phase $m_s \to 0$. $\alpha' \to \infty$ (High Energy) Note: In a high energy limit a string might curve only about a highly curved background, e.g. AdS with a small radius
- How to derive a gauge invariant interaction. Use BRST method. A possible way to take a BRST Charge for a bosonic string and rescale:

$$Q = \sum_{k,l=\ -\infty}^{+\infty} (C_{-k} L_k - \frac{1}{2}(k-l) : C_{-k} C_{-l} B_{k+l} :) - C_0$$

$$c_k = \sqrt{2\alpha'} C_k, \qquad b_k = \frac{1}{\sqrt{2\alpha'}} B_k, \qquad c_0 = \alpha' C_0, \qquad b_0 = \frac{1}{\alpha'} B_0$$

$$\alpha_k^\mu \to \sqrt{k} \alpha_k^\mu$$

- And take formally $\alpha' \to \infty$

$$Q = c_0 l_0 + \tilde{Q} - b_0 \mathcal{M}$$

$$\tilde{Q} = \sum_{k=1}^{\infty} (c_k l_k^+ + c_k^+ l_k), \quad \mathcal{M} = \sum_{k=1}^{\infty} c_k^+ c_k, \quad l_0 = p^\mu p_\mu, \qquad l_k^+ = p^\mu \alpha_{k\mu}^+$$

INTERACTING HIGHER SPINS

- BRST Charge is nilpotent in any Dimension Q^2 = 0. One can truncate the number if oscillators α^{μ}_{k}, c_k, b_k to any finite k without affecting the nilpotency property. To get a free lagrangian for a leading Regge trajectory expand the Fock space states

$$|\Phi\rangle = |\phi_1\rangle + c_0|\phi_2\rangle = |\varphi\rangle + c^+ \; b^+ \; |d\rangle + c_0 \; b^+ \; |c\rangle$$

- Fock vacuum

$$\alpha^{\mu}_{k}|0\rangle = 0, \quad c_k|0\rangle = 0 \quad k > 0, \qquad b_k|0\rangle \; = \; 0 \qquad k \geq 0$$

- Operator Algebra

$$[\ell_k, \ell_l] \; = \; k \; \delta_{k+l,\,0} \; \ell_0$$

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❖ Lagrangian

$$L = \sum_i \int dc_0^i \langle \Phi_i | Q_i | \Phi_i \rangle + g(\int dc_0^1 dc_0^2 dc_0^3 \langle \Phi_1 | \langle \Phi_2 | \langle \Phi_3 | | V \rangle + h.c)$$

Gauge Transformation

$$\delta |\Phi_i\rangle = Q_i |\Lambda_i\rangle - g \int dc_0^{i+1} dc_0^{i+2} [(\langle \Phi_{i+1}| \langle \Lambda_{i+2}| + \langle \Phi_{i+2}| \langle \Lambda_{i+1}|)|V\rangle]$$

Equation of Motion

$$\mathcal{Q} |\Phi\rangle = 0$$

Interaction Vertex and gauge invariance condition

$$\sum_i Q_i |V\rangle = 0 \qquad |V\rangle = V |-\rangle_{123}$$

$$|-\rangle_{123} = c_0^1 c_0^2 c_0^3 \; |0\rangle_1 \otimes |0\rangle_2 \otimes |0\rangle_3$$

where $V(\alpha_i^+, c_i^+, b_i^+, b_{i0})$ is a function of the oscillators

INTERACTING HIGHER SPINS

- The BRST invariance of |V> ensures the gauge invariance of the action and closure of the nonabelian algebra up to first order in g. One can solve this equation, taking V to be an arbitrary polynomial in $\alpha_i^{\mu+}$; b_i^+, c_i^+ with ghost number zero.

$$[\delta_\Lambda,\ \delta_\Xi]|\Phi_1\rangle = \delta_{\tilde{\Lambda}}|\Phi_1\rangle = Q_1|\tilde{\Lambda}_1\rangle \quad g(\langle\Phi_2|\langle\tilde{\Lambda}_3| + \langle\Phi_3|\langle\tilde{\Lambda}_2|)|V\rangle] + \ O(g^2)$$

$$|\tilde{\Lambda}_1\rangle = g(\langle\Lambda_2|\langle\Xi_3| + \langle\Lambda_3|\langle\Xi_2|)|V\rangle + \ O(g^2)$$

- The solution should not be BRST trivial: |V> ≠ Q|W>. The trivial one can be obtained from the free action by field redefinitions.

$$\delta\Phi_i = F(\Phi_i)$$

INTERACTING HIGHER SPINS

Finally we can find a solution inspired from String Field Theory

$$|V_3\rangle = \int dp_1\ dp_2\ dp_3\ (2\pi)^d\ \delta^d(p_1+p_2+p_3)$$

$$\times exp\left(\frac{1}{2}\sum_{i,j=1}^{3}\sum_{n,m=0}^{\infty}\alpha_{n,\mu}^{+,i}\ N_{nm}^{ij}\alpha_{m,\nu}^{+,j}\ \eta^{\mu\nu}+\sum_{i,j=1}^{3}\sum_{n\geq 1,m\geq 0}c_n^{+,i}X_{nm}^{ij}b_m^{+,j}\right)\ |-\rangle_{123},$$

Put the anzatz

$$|V\rangle = V^1 \times V^{mod}|-\rangle_{123}$$

$$V^1 = exp\ (\ Y_{ij}l^{+,ij}+Z_{ij}\beta^{+,ij}\ ) \qquad V^{mod} = exp\ (\ S_{ij}\gamma^{+,ij}+P_{ij}M^{+,ij}\ )$$

Where $\beta^{ij} = c^i b_0^j$, $\gamma^{ij} = c^i b^j$, $M^{ij} = \alpha^i\alpha^j$ and $l^{ij} = \alpha^i p^j$. Demand closure of the algebra

$$[\delta_\Lambda,\ \delta_\Xi]|\Phi_1\rangle = \delta_{\tilde{\Lambda}}|\Phi_1\rangle = Q_1|\bar{\Lambda}_1\rangle - g[(\langle\Phi_2|\langle\bar{\Lambda}_3| + \langle\Phi_3|\langle\bar{\Lambda}_2|)|V\rangle]$$

INTERACTING HIGHER SPINS

Demand BRST invariance and closure of the algebra

$$Z_{i,i+1} + Z_{i,i+2} = 0$$

$$Y_{i,i+1} = Y_{ii} - Z_{ii} - 1/2(Z_{i,i+1} - Z_{i,i-2})$$

$$Y_{i,i+2} = Y_{ii} - Z_{ii} + 1/2(Z_{i,i+1} - Z_{i,i+2}).$$

$$S_{ij} = P_{ij} = 0 \qquad i \neq j$$

$$P_{ii} + S_{ii} = 0 \qquad i = 1, 2, 3$$

$$|S|^2 = 1$$

We have actually done a field dependent deformation of the initial BRST charge

$$\left[\delta_\Lambda, \delta_\Xi\right] |\Phi_1\rangle = 0$$

$$Q' = Q + gV(\Phi)$$

$$Q'^2 = Q^2 + 2gQV(\Phi) + g^2V(\Phi)^2 = 0$$

CONCLUSIONS

- A consistent Interacting Higher Spin theory can appear from the high energy limit of Open String Field Theory.

- To do AdS along these lines one probably has to do supersymmetric case

- Even a free BRST on AdS for fermions and mixed symmetry has not yet been done