A memory of Luciano

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Luciano Girardello Memorial

Plan of the talk

The first time I met Luciano

- I was fellow at Cern during 1972 and 1973.
- I saw an announcement of a seminar that Luciano was going to give at the University of Geneva on infinite algebras as the Virasoro algebra.
- I attended his seminar and after his seminar I got to know Luciano discussing for some time with him first about his seminar and then about our life.
- He told me that he started later than normally to work in physics, but I don't remember why.
- He was coming from Colorado where he had worked with Barut and Wyss on infinite dimensional algebras.
- While I came to the Virasoro algebra studying the DRM, they were studying infinite algebras to classify the elementary particles.
- In analogy with what is done with the group $SO(4,1)$ that is the spectrum generating algebra of all level of the hydrogen atom.
- All levels of the hydrogen atom are contained in a unique infinite dimensional representation of $SO(4,1)$.

Our only paper together

- Although Gliozzi, Scherk and Olive with the GSO projection had found the first string theory without tachyons, after 1976 practically only Green and Schwarz kept working on string theory.
- No job for those working in string theory.
- Gell-Mann writes: ... I set up at Caltech a nature reserve for endangered superstring theorists. I brought J. H. Schwarz and P. Ramond at Caltech and encouraged A. Neveu to visit. [Gell-Mann, in the Birth of String Theory, edited by A. Cappelli and al].
- The majority of people went back to field theory, either to QCD or, after the construction of 11-dim supergravity by [Cremmer, Julia and Scherk, Phys. Letters B **76** (1978) 409], there was a lot of hope of unifying gauge theories with gravity by means of a Kaluza-Klein reduction to $D = 4$.
- $\mathcal{N} = 8$ supergravity was constructed by [Cremmer and Julia, Phys. Lett. B **80** (1978) 48; Nucl. Phys. B **159** (1979) 141].

- It has 28 vector fields as in the gauge theory with a gauge group $SO(8)$.
- This group is too little to accomodate the group of the Standard Model: $SU(3) \otimes SU(2) \otimes U(1)$.
- One needs at least $SO(10)$.
- It turned out, however, that the 70 scalars lived in the coset space $\frac{E^{7/7}}{SU(8)}$
- The $SU(8)$ gauge fields are auxiliary fields without a kinetic term.
- In other words $\mathcal{N} = 8$ supergravity contains not only the elementary 28 gauge fields, but also the composite gauge fields of $SU(8)$.
- The idea by Cremmer and Julia was to use them, rather the elementary ones, to unify the Standard Model with gravity.
- How to generate a kinetic term for those gauge fields?
- A recent study of the CP^{N-1} model in $D = 2$ showed that a kinetic term can be generated in the quantum theory.

- The CP^{N-1} model had many properties in common with QCD and one could study them explicitly in the large N expansion [D'Adda, Di Vecchia and Lüscher, Nucl. Phys. B **146** (1978) 63] [Witten, Nucl. Phys. B **149** (1979) 285].
- It has the following Lagrangian:

$$L = \overline{D_\mu z^i} D^\mu z^i \;\; ; \;\; |z|^2 = \frac{N}{2f}$$

where

$$z^i = (z^1, z^2 \dots z^N) \;\; ; \;\; D_\mu z^i = \partial_\mu z^i + \frac{i}{\sqrt{N}} A_\mu z^i$$

- with no kinetic term for the gauge field.
- A kinetic term is generated in the quantum theory.
- The low-energy effective Lagrangian is given by

$$L_{eff} = \frac{\alpha^2}{8\pi m^2} + \frac{F_{\mu\nu} F^{\mu\nu}}{24\pi m^2} \Longrightarrow V(R) = \sigma R \;\; ; \;\; \sigma = \frac{12\pi m^2}{N}$$

with a confining potential generated in the quantum theory.

- Cremmer and Julia proposed that the same phenomenon could happen for the gauge bosons of $SU(8)$.
- It was shown by
  [Moore and Nelson, Phys. Rev. Lett. **53** (1984) 1519]
  that theories with scalar in a coset space $\frac{G}{H}$ have anomalies if the fermions transform according to a non-anomaly free representation.
- We assumed that the only fields contributing to the $SU(8)$ anomaly were the gravitinos and the spin $\frac{1}{2}$ fermions, we computed their contribution to the anomaly and we concluded that it was not zero
  [Di Vecchia, Ferrara, Girardello, Phys. Lett. B **151** (1985) 199].
- But this was wrong because we forgot the contribution of the 28 gauge bosons that also contribute to the anomaly as noticed by [Marcus, Phys. Lett. **157** (1985) 383].
- They cannot be in the 28 of $SU(8)$ because it is not a real representation.

- The way to proceed is to separate their field strength into a self-dual and an anti-self-dual part

$$F_{\mu\nu} - i\tilde{F}_{\mu\nu} \in 28 \quad ; \quad F_{\mu\nu} + i\tilde{F}_{\mu\nu} \in \overline{28}$$

- They are chiral fields that contribute to the $SU(8)$ anomaly and in fact they cancel the contribution of the fermion fields.
- $SU(8)$ is big enough to contain the Standard Model.
- But the idea of using $\mathcal{N} = 8$ supergravity to unify gauge theory with gravity died out soon because it did non seem possible to generate chiral fermions as in the Standard Model [Witten, Contribution to Shelter Island Conference].
- The time was then ripe to go back to string theory because both type IIB, type I and the newly constructed heterotic string all have chiral fermions.

- Working on our paper we used to work at Cern late at night.
- One day we went to the cantine at 11 pm to drink something before going to bed.
- We were served by a Spanish worker at the cantine that we knew very well.
- Then I went to bed in the foyer that was above the Theory Division.
- When next morning I went to the cantine to get my breakfast I saw a lot of police around.
- During the night the Spanish worker was killed and I don't think that the killer was ever found.
- We were all interviewed by the police and we were under a shock for long time.
- After that Cern was not anymore as before when the cantine was open all night and Cern was an open place.

More about Luciano

- It was always a pleasure to meet Luciano and discuss with him.
- I liked a lot his informal personality, his genuine interest in physics and his desire to share his ideas and his problems with others.
- Many people change when they grow up and become important, but Luciano stayed always the same as he was when he was a young post-doc.
- Sometimes I felt that he was in another world, but he was only trying to understand something in his mind.
- A few minutes later he went to the blackboard and started to discuss the problem that he had in mind.
- His informal attitude and his pleasure to discuss with everybody was particularly good for the young students and post-docs around him, as you can see for the big number of them who started their scientific career with him.
- If Milano is as it is now, this is also thanks to Luciano.