PROCEEDINGS OF SCIENCE

Rehovoth 1967-1968. Strings vs Quarks or How composite are the Hadrons?

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Nice reminiscences from 2 fantastic determinant years, the fruitful interaction with Héctor and his group, the friendship that thus developed and a bit of reference to our research

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1. Héctor's visit to Argentina

The task assigned to me by the organizers turned out to be easy. I had to reminisce about the years 1967-1968 in Rehovoth and I soon realized that those 2 years have left a vivid trace on me. This is due obviously to the many interesting people I met there and most among them Héctor. I will concentrate specifically on the "other work", the one less famous that does not refer to the saturation of Superconvergence/Finite Energy Sum Rules which instead will be covered by Gabriele.

But let me start one year earlier when Héctor came to Buenos Aires, just after his wedding with Helen. He came with her to the Department of Physics in the University of Buenos Aires and, should I confess, on our first encounter I was so impressed by 'exotic' Helen that I did not pay too much attention to the husband. He then gave us a course on his recent interests in Physics (the N/D bootstrap he was studying with Diu and Gervais in Paris) and there I discovered him. There was so much joyful energy, so much self-confidence on his way of telling us about physics, so much urgency because some fundamental discoveries were there waiting for us. Although Buenos Aires was as far geographically from the North as it has always been the Department of Physics was in that period an excellent research institution. Still Héctor's optimism and enthusiasm made a difference and totally convinced me.

Héctor was on his way from Paris to Rehovoth. On leaving Buenos Aires he left me an interesting problem that mixed N/D bootstrap ideas and electromagnetic corrections. I was about to finish my PhD (with C. G. Bollini) but, due to some family problems, I was not in a hurry so instead I worked intensely on Héctor's idea. Then, the "Noche de los Bastones Largos" happened. The military decided to save our 'Christian Essence' by toppling down a democratic government and chastising the University professors, students and personnel who did not seem to fully appreciate their efforts. From one day to the next all professors resigned, the University disappeared and I finished writing my thesis at home. Then I got a letter of invitation from the Weizmann Institute, I defended my thesis on the 25th January 1967 and two days later I was on my way to Israel.

2. The arrival to Rehovoth

In Rehovoth I met some remarkable people: Igal Talmi, Zvi Lipkin, A. Rinat and then Héctor's group: Gabriele who had invited Marco Ademollo from Florence and Mordechai Milgrom. Those were nice times. Every morning I would walk thru the orange groves and arrive early to the Institute. I would learn some Italian well mixed with English, submerge in vivid discussions on Physics and then follow the rituals. There was the break at the mail arrival. For Héctor, doing science was always a social activity that required enormous attention to the information flow. Indeed it is not surprising that he became later so involved in the making of scientific journals. He would get very excited, both positively or negatively, with news coming on the mail or ideas exposed in preprints. For us science was a game played not only with Nature, trying to uncover its secrets, but also with other people, trying to exploit their new advances and of course trying to anticipate them to the next round of discoveries.

Héctor had been working following two alternative hypothesis the Quark Model and the Bootstrap. These two approaches were not talking to each other at the time. As Héctor himself has

written elsewhere the goal was to connect both pictures defining some kind of degree of compositeness for the hadrons, which on the language of today turns out to be how soft they are. When I arrived Gabriele and Héctor were trying to understand the role of fixed singularities in the angular momentum plane that appeared in the saturation of Current Algebra Sum Rules[2]. It was known that in scattering processes like $\gamma + hadron \to \mu + hadron$, where γ and μ are two generic elementary particles with spins σ_γ and σ_μ respectively, that interact weakly with the hadrons, there would appear a fixed pole in the angular momentum plane in the t-channel of value $\sigma_\gamma + \sigma_\mu - 1$. What happens if the μ particle is composite and how did the result depended on the degree of compositeness was our question. There was a difficult but deep article by Mandelstam on the *Nuovo Cimento*[3] where consistency between Unitarity and Analyticity were used to derive a host of results on the Angular Momentum Plane singularities. We realized that most of his results could be derived in a simplistic model where the in-out particles in a scattering process where supposed to be replaced by ladder diagrams. Then complicating enough the ladders, basically making the stringers (i.e. the components of the particle) themselves composite, we could simulate different degrees of compositeness. The conclusions were quite nice: the scattering amplitude would asymptotically contain -non-necessarily leading- terms decaying like integer powers in s^p with $p = \sigma_\gamma + \sigma_\mu - n$ but n grows as the particles were assumed more composite, making them more irrelevant.

2.1 An aside: the war

Just an anecdote, we reached some of these results during the 1967 war in the basement of the Weizmann. Héctor and I stayed in the Institute and were charged with the defense of the premises with the following heroic instructions: in case of an attack 1) rush to the refuge as soon as the alarm fires 2) stay there until the 'ceased' alarm would go off; 3)leave the refuge and look around to check whether there had been any damages; 4) in that case call the firemen.

I have very nice memories of that week. As anyone who has interacted with Héctor knows, it was difficult to keep him still. During that week I had the privilege of the exclusivity. We talked about many things, obviously including the Middle East situation but not excluding other subjects. Héctor was a fine humanist: suspicious of the powerful, sympathetic with the less privileged. He could not stand any form of pomposity or arrogance particularly if coming from colleagues. But at the same time he was always trying to discover real talent in young people. His criticisms were hard and sharp and were not hidden. I know some people considered him too outspoken. I would like to say two things on this respect: 1) I do not remember a single instance of a controversy where at the end I would be on the opposite side of him. Obviously we could both be wrong 2) in an ecosystem like Academia where the norm is not to criticize your fellow Héctor and people like him are an absolute vital necessity.

3. Summer 1967

The Summer came and as it was customary at the Weizmann everybody left to visit other Institutions. I first visited Florence, invited by Ademollo, then Copenhagen and finally the three of us (Gabriele, Héctor and myself) reunited at CERN invited by Daniele Amati. I remember vividly Gabriele arriving one day very excited with the suggestion that the reaction $\pi + \pi \to \pi + \omega$ was the perfect frame to study Finite Energy Sum Rules Bootstrap. With hindsight that apparently small

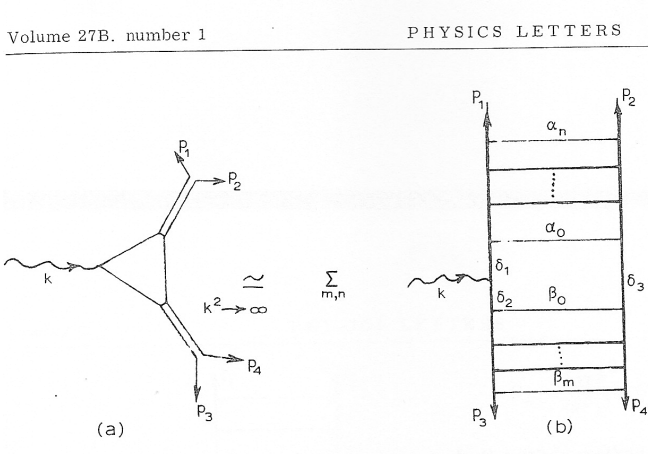

Figure 1: from reference [4].

suggestion was perhaps the most crucial step opening the way towards the results derived in the following Academic Year that eventually converge on the Veneziano Model. But again I should not digress from my assigned subject.

At CERN Amati and Jengo joined us to study the asymptotic behavior of hadron form factors. We used the same simplistic model and obtained an intuitive and satisfactory picture on how the degree of compositeness affects the decay in q^2. This is the first published example of what became known as counting rules [5].

It is important to stress the simultaneity of this line of research with the one on Finite Energy Sum Rules Bootstrap because it shows that at every moment we were thinking about hadrons as particles composed of some kind of partons (though the word was to be coined a bit later) and that we also knew that extreme bootstrap could be just an approximation. Let me quote a sentence of the article [4]

"...if the asymptotic behavior continues to be power-like then quarks?"

On a different tonality and to confute those skeptics that deny the existence of progress in Physics I am reproducing in Figure 1 one of the pictures from that same article. Notice the wobbly nature of the alleged photon. Compare now with photons produced more recently, perhaps in one of Héctor's many Journals. Progress becomes evident .... unless perhaps we were anticipating the photino, the well known wimpy photon?

4. Back to Rehovoth

On our return to Israel, many things happen to me personally that are irrelevant 42 years after. Hector's group enlarged with the acquisition of Adam Schwimmer and Mordechai Bishari. New friends became part of his constellation. Let me mention in particular a german physicist Gunther von Gehlen and an argentinian one Ruben Pasmanter. Dinners at Helen and Hector's house were now entertained by a precocious Marco who was learning simultaneously 3 languages and suddenly discovering that his father's mother language was still another one.

On the scientific side we wrote the final version of reference [4]. In fact I remember that year as a year fully occupied in the actual writing of papers. Physics was going so smoothly that we

didn't have to make too much effort to derive interesting results. We had many visits. Fubini, Gell-Mann, Sakita were among them. As a consequence all of us got an offer for the next 2 years. In fact those two years opened us many opportunities in the successive years and in addition engendered long lasting friendships.

I owe that much to Héctor.

References

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