Quantum Field Theory in Naples in the Sixties

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dedicated to Pasquale Sodano
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Introduction

The very existence of an advanced research activity in quantum field theory in Naples, during the Sixties, can be seen as a kind of miracle.

Theoretical Physics is very well developed in Italy at that time. On the phenomenological side there are the strong personalities of Raffaele Raoul Gatto and Nicola Cabibbo, with their brilliant coworkers Luciano Maiani, Giuliano Preparata, Guido Altarelli, Franco

Buccella, to name a few. On a more theoretical side, starting from Regge poles one could understand that dual models, developed through an ingenious idea of Gabriele Veneziano, would provide the basic paradigm for high energy sub-nuclear physics.

These lines of research are of outstanding scientific level, and very well connected with contemporary experimental research in Frascati and at CERN.

Even without reaching the exaggerated criticism of people involved in the extreme S-matrix theory and/or the so called bootstrap theory, nevertheless there is no doubt that relativistic quantum field theory at that time is receiving very little credit as a possible general theoretical frame for elementary particle physics.

There are only few places where research on these topics are pursued in the world. One of these places is Naples.

We will analyze the historical and scientific background for this “miracle”, which gives rise to a kind of cultural “cradle” for the formation of many young people.

We follow a kind of itinerary along three topics:

- The Chair of Theoretical Physics in Naples

- Eduardo Renato Caianiello and his scientific policy

- Hiromi Umezawa in Naples, and the dynamical map

Here, I limit myself to some loose considerations. A more detailed presentation is in preparation.

The Chair of Theoretical Physics in Naples

At the beginning of the Fifties, the scientific situation at the University of Naples, as far as Physics is concerned, is not very different from what Ettore Majorana finds more than a decade before.

Ettore Majorana reaches the Royal University of Naples, as the first full Professor of Theoretical Physics, in January 1938, appointed directly by the Minister of National Education, Giuseppe Bottai, due to his "alta fama di singolare perizia" ("high reputation of singular expertise"), outside of the regular procedure of public competition. (Why Naples?)

The proposal for a direct appointment comes, on October 1937, from the selecting committee of a competition for a position in Palermo. According to the rules, the committee must select three competitors as winners in a definite order. The dream of any selecting committee is to increase the number of available positions.

The scientific production of the candidate Ettore Majorana is so outstanding, that the committee, chaired by Enrico Fermi of course, “hesitates” to follow the standard rules of comparison, and suggests to the Minister the direct appointment in “some University of the Kingdom” (but why Naples?). Then the winners are, in order, Gian Carlo Wick (Palermo), Giulio Racah (Pisa), Giovanni Gentile jr (Milan).

All details and documents about the competition can be found in our book on Majorana, coauthored by F.G. and Nadia Robotti, edited by the Scuola Normale Superiore in Pisa, 2008.

Let us read what Majorana writes to his Mother on January 11th, 1938 (from the Majorana Family archive):

"... Praticamente l'Istituto si riduce alla persona di Carrelli, del vecchio aiuto Maione e del giovane assistente Cennamo. Vi è anche un professore di fisica terrestre difficile da scoprire. ..."

("... Practically the Institute [of Physics] reduces to the person of [Antonio] Carrelli, of the old chief assistant Maione, and of the young assistant [Francesco] Cennamo. There is also a professor of Earth Physics [Giuseppe Imbò] very difficult to discover. ...")

More than ten years after, the situation is almost the same. The "old" chief assistant Maione is substituted by a new one, and there are a few other assistants. The professor of Earth Physics is still difficult to discover (for the good reason that he works mostly at the Vesuvio Observatory).

As it is very well known, Majorana disappears in March 1938, leaving the Course of Theoretical Physics without an attendant. Carrelli takes care of the Course for some years as a substitute professor (we have also his lecture notes), then Ezio Clementel, then Luigi Radicati di Brozolo as full Professor for a very short period, before moving to Pisa.

But this Chair is important, and needs to be occupied. In the meantime, a new competition for Theoretical Physics is issued by the University of Catania. In 1955, the selecting committee choses the winning “triplet”. The winners are in order: Eduardo Renato Caianiello, Marcello Cini, Fausto Fumi.

E.R. Caianiello starts his service as the effective successor of Ettore Majorana on the Chair of Theoretical Physics in Naples, on November 1956.

Eduardo Renato Caianiello and his scientific policy

We have given an account of his early scientific activity, together with some biographic information, based on original archive documents, in a chapter of the book "Imagination and Rigor" (Springer Verlag Italia, 2006). Here is a synthesis. We can see that all situations of the time recall similar situations of the present.

Born in Naples on June 25th, 1921. Attends High School at the Classical Lyceum Jacopo Sannazzaro, and enrolls in 1938 in the Course for the "Laurea" degree in Physics at the University of Naples. Drafted into the Army in 1940, during the next three years, after a military training in Pavia, participates to the War in North Africa as a volunteer, earns a War Cross, and returns to Italy with severe wounds. Then, at the end of 1943, he can resume his University studies, and finally earns the doctoral degree "Laurea in Fisica" in December 14th, 1944, discussing a research thesis by the title "Una verifica sperimentale della teoria di Debye sulla dispersione anomala nei liquidi dipolari" ("Experimental verification of Debye theory on anomalous dispersion in dipolar liquids”), under the supervision of Antonio Carrelli.

Antonio Carrelli is Professor of Experimental Physics, and Head of the Institute of Physics at the University. His scientific reputation is very high, due to important research on the Raman effect, performed in Germany at the end of the Twenties, and subsequent research on spectroscopy in the next years. The 1937 committee, for the Palermo competition where Majorana is excluded and appointed directly in Naples, includes Carrelli as an influential member. May be he is responsible for the steering of Majorana toward Naples.

After graduation, Caianiello begins his scientific career as Assistant at the Institutes of Mathematics, and Technical Physics, where he works, and publishes papers, on the integration of complete systems of first order linear equations with partial derivatives (1947), on the impulsive motion of an holonomous system with constraints (1948), and finally on the Luxenbourg effect of radio wave transmission (1948).

Then, as an important strategic decision, in June 1948, he accepts a fellowship at the MIT in Boston, and begins a brilliant scientific career at the international level. In fact, he is invited in Rochester by Robert E. Marshak, and earns a Ph.D. in Theoretical Physics, with a research Thesis on the decay and absorption of mesons (in particular about the beta decay and a possible electron decay of the π-meson, and about the spin of the μ-meson). The Thesis can be found at the archive in Rochester.

His subsequent research activity is oriented toward elementary particles. In particular, he considers a scheme of beta decay, through the emission of a virtual “vector meson”, which subsequently gives rise to an electron-neutrino pair (looks extremely modern, but of course the treatment is given inside Yukawa theory of nuclear forces, the distinction between strong and weak interactions is not completely clear yet). Then the π^- reactions in tritium. Finally there is a long series of papers dedicated to the search for the universal Fermi-type interaction.

As a curiosity, I would like to mention that he told us to have proposed at that time the possibility that parity is not conserved, with meager recognition, and absolute lack of encouragment by the Big Bosses around.

Then, there is an additional strategic decision. He decides to come back to Italy. Robert Marshak writes a very interesting letter of support (July 4th, 1951), addressed to Gilberto Bernardini, who is also returning to Italy, but intended for all interested people. In fact, a copy of the letter reaches also

Edoardo Amaldi, so that we can read it in our Amaldi archive in Rome.

Marshak remarks that the return to Italy of Bernardini, then a well established scientist, is "too bad for Columbia and wonderful for Italy", and proposes Caianiello, young but very promising, "just in case you find possible to add an American-trained theoretical physicist to your staff in Italy". Then he recalls all scientific achievements, in particular about the search for a universal Fermi-type interaction.

Caianiello receives some offers. Firstly he accepts the one from Turin (Gleb Wataghin), where he stays in 1951-1952. Then he moves to Rome, by invitation of Edoardo Amaldi, where he stays in 1952-1955. On leave of absence from Rome, he is for some period at CERN (at that time hosted in Copenhagen), and in Princeton.

While in Princeton, in 1995 Caianiello learns that he is the first winner for the professorship in Catania. Fortunately, Carrelli, with the help of Renato Caccioppoli (a great Matematician and estimator of theoretical physics), manages to call Caianiello in Naples, where he assumes his duties on November 1956, being allowed to complete his stay in Princeton.

The scientific activity during the Fifties is extremely interesting. First of all he moves his interest toward quantum field theory, may be under the influence of the success of renormalization theory, as developed by Richard Feynman, Julian Schwinger, and Sin Itiro Tomonaga.

In fact, he develops his own approach to renormalization theory, by a scheme based on recursive equations for the propagators (vacuum expectation of time ordered products of local field operators). In particular, perturbative expansions can be obtained through a repeated application of the recursion procedure. Ultraviolet divergences arises from the iteration of the recursive equations, even outside of a perturbation scheme. Then Caianiello develops his own method to cope with ultraviolet divergences. It is the so called finite part integration. It has a modular structure, and can be rigorously interpreted in the frame of distribution theory. Starting from the taming of divergences on a single integral, the method allows the control of multiple diverging integral, through very deep combinatorial methods.

Looking at the original papers, and their extensions, one can feel a sense of freshness and actuality, and appreciate the simplicity and deepness of the whole method. A modern presentation of these ideas, also with pedagogical aims, is in preparation.

After his arrival in Naples, Caianiello starts also a research program aiming at the modeling of the brain functions, through methods of theoretical physics. The first attempts are particularly fascinating. In a paper on Nuovo Cimento 1958, coauthored with V. Braitenberg, F. Lauria, N. Onesto, they introduce a system made by an array of active elements, each represented by a self-coupled nonlinear oscillator, capable of sustained oscillations. Each oscillator is coupled with the other oscillators in the array with some assigned coupling. One way of implementing the model is to assume that sensorial inputs in time are represented by changes in the parameters of the oscillators or their coupling. The outputs, effecting the muscular motor plaques, can be taken from particular variables of the system.

It is immediately recognized that this model, due to the arbitrariness in the couplings, and to their different effects on the behavior of each single oscillator, falls into the category of complex dynamical systems, as, for example, spin glasses and neural networks. Due to the work of Giorgio Parisi, and others, now we know that this class of systems are capable of hierarchical organization and behavior. Therefore, the Braitenberg,-Caianiello-Lauria-Onesto model shares a remarkable aspect of modernity, in line with the most advanced recent research topics on complex dynamical systems. Surely, it would be worth to reconsider this model, and investigate its further possibilities on the basis of recent developments in this field.

In fact, at the time, the model was very difficult to investigate, due to the lack of convenient analytical tools, and computer facilities. Therefore, Caianiello moved to a different well known celebrated model, presented in 1961 on Journal of Theoretical Biology, with a paper by the the title "Outline of a theory of thought-processes and thinking machines". Here, threshold elements are present, and the continuous electromechanical analogy is lost.

With the arrival in Naples, Caianiello starts also a prodigious activity at the organizational level. Firstly, a new Institute of Theoretical and Nuclear Physics of the University is founded, with a connected “Scuola di Perfezionamento” (“School of Higher Training”) on the same subjects. To this purpose, there is a strong support from Edoardo Amaldi, and the CNEN (Felice Ippolito), as the documents in the Amaldi archive in Rome show.

The new Institute is hosted at the “Mostra d’Oltremare” at the western outskirts of Naples, in a lively park. The “School” starts with a conference by Werner Heisenberg in 1958.

In 1958, Caianiello is also coorganizer, with Antonio Borsellino, of a Varenna School on quantum field theory, and organizer of a Varenna School on Cybernetics.

The Institute and the School make possible to rise young brilliant people to advanced research in quantum field theory (as for example Bruno Preziosi, Maria Marinaro, Alfonso Campolattaro, and others), and cybernetics (as Luigi Maria Ricciardi, Aldo De Luca, and others).

Caianiello is also concerned with the enlargement of the Faculty, with the call as Professors of Ettore Pancini, Giulio Cortini, Ruggero Querzoli. Therefore, there is a start of experimental research activity on elementary particles and nuclear physics, and a Section of the National Institute for Nuclear Physics is established in Naples. Moreover, teaching is drastically improved.

A program of long term foreign visitors is also established. At the beginning of the

Sixties, walking in the corridors of the Institute one can recognize that Norbert Wiener is approaching from the smell of his cigar.

And Hiroomi Umezawa comes also to a long visit in Naples.

During the Sixties researches in quantum field theory (I am also there, after graduation in 1964) deal with the combinatorial aspects of renormalization theory, the structure of the renormalization group, and the definition of finite part integrals through methods of analytic continuation in configuration space. In the next section we recall the contributions by Umezawa.

There is also a strong impulse on cybernetics, now evolving into the different branches of Information Science. At the end of the Sixties, Caianiello establishes a new Institute of Cybernetics, under the sponsorship of the National Council of research, hosted in Arco Felice, still farther to the West in Naples. There are also notable contribution by Umezawa on brain modeling.

Finally let us recall that at the end of the decade deep inelastic scattering buries the deviation from quantum field theory, and the standard model of elementary particles, still valid, establishes a solid quantum field theoretical basis for the sub-nuclear world.

Hiroomi Umezawa and the dynamical map

Hiromi Umezawa receives his formation in the frame of the well established Japanese

School of Theoretical Physics, with exponents as J. Yukawa, S. Tomonaga, S. Sakata. Then he moves abroad as visiting, in particular in Manchester in 1953-1955. The notable results of the early stage of his research in quantum field theory include the spectral representation for the two-point function (with S. Kamefuchi, 1951), anticipating the well known Källen-Lehmann representation, an elegant formulation of the theory of propagators, developed with A. Visconti in 1954-1955, and other results in renormalization theory.

Caianiello is able to invite him for a long period in Naples, at the beginning of the Sixties. There is no possibility for a permanent position, due to the law of the time (Italian citizenship necessary for a Chair at the University). Therefore, Umezawa after some years leaves, firstly to Milwakee, then to Edmonton. But the influence of Umezawa on the research in Naples is very strong and long lasting.

I will mention two cases.

Umezawa is involved in the building of models for memory, based on Boson condensation (in collaboration with Luigi Maria Ricciardi and Aldo De Luca). This research line is still continuing, by the efforts of other people.

The other case involves the development of a general paradigm, with numerous applications, called the dynamical map.

It is well known that the dynamical content of a quantum field theory model is given by the Heisenberg local quantum fields, depending on the space-time specifications, obeying appropriate commutation relations and nonlinear evolution equations. On the other hand, the observable content of the theory, as for example the cross sections and the masses of the stable particles, is given in terms of the asymptotic fields, which are free fields, and live in the simple Fock space of free fields.

It would be tempting to express the interacting Heisenberg fields as functions of the free asymptotic fields in their Fock space. However, there are very serious physical reasons (the so called Haag theorem) which forbid in a drastic way this natural, potentially very useful, naive procedure. Heisenberg fields do not live in a Fock space. By forcing them to do so would destroy the interaction.

Dynamical maps allow indeed to express interacting fields in “terms” of asymptotic free fields. The trick is to consider these expression in a “weak” sense, as equality for averages in suitable states, not in a strong sense as operator equalities.

This strategy is very similar to that developed in the frame of the constructive quantum field theory program of Arthur Wightman, and followers, whose foundations are laid down approximatively at the same time as the dynamical map (beginning of the Sixties).

The funny thing is that the researcher, working on dynamical maps for a specific model, has the possibility of operating naively at the intuitive level. He really thinks that he is writing expressions for the interacting fields, with their commutation relations and dynamical equations, in terms of the asymptotic free fields. Since in any case the physical content is expressed through quantum averages, he could even ignore the existence of Haag Theorem, and get correct results.

Dynamical maps are very useful in quantum field theory, and can be extended to other case, as for example in condensed state physics, and for thermal systems (quantum systems in contact with an heat reservoir).

Even the phenomenon of spontaneous breakdown of symmetry receives a very interesting formulation in the frame of dynamical maps, in the sense that the broken symmetry does not disappear completely, but gets a kind of rearrangement.

It happens that I have a copy (in the old fashioned cyano-graphic technology) of a preliminary typescript, written around 1964, explaining the strategy of the dynamical map in quantum field theory. The interesting fact is that the preprint is coauthored by Gianfausto Dell'Antonio and Hiroomi Umezawa. This adds motives to the complex relations between Umazawa and Naples, still to be completely understood.

In any case the influence of Umezawa in Naples is very strong, and continues after his departure for Milwakee and Edmonton. There is a long list of young people leaving Naples and joining for some time the research group of Umezawa, in the States (and then in Canada). I recall here Antonio Aurilia, Fernando Mancini, Giuseppe Vitiello, Pasquale Sodano, Silvana De Lillo, to name a few.

I understand that each of them, upon arrival, still under jet lag, receives a first apparently very simple research task: to develop the dynamical map for quantum electrodynamics. After many months of strenuous struggle against the difficulties of gauge invariance, infrared divergences, ultraviolet divergences, traces of Dirac gamma matrices, photon mass renormalization, four photon vertices, there is finally the advise to attempt a simpler research project. A good way to reinforce the strength of character.

My talk comes to an end. Some additional remarks are left for this evening.