TULLIO REGGE

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TULLIO REGGE passed away on 23 October 2014. One of the most brilliant and creative minds of the twentieth century left the world stage after a long physical decline that was the cause of deep sorrow for all of his friends, colleagues, former co-workers, and, of course, relatives. The influence of his ideas and the legacy of his imaginative physical-mathematical constructions will stay with us forever. New generations of scientists, sometimes not even aware of it, will develop constructions whose very conception would be inconceivable without Regge's creations. Those who knew Tullio personally, those who interacted with him scientifically and/or in other human and cultural activities, will never forget his original, multifaceted, and intriguing personality.

Having been among his closest co-workers and, in some sense, his disciple, I can summarize Tullio's deep originality and at the same time formulate what, from my point of view, is the greatest praise of his personality by saying that he always did great things while never taking them too seriously. He had the curiosity and the imagination of a child—a very clever child—and just as all children do, he played. His games were of very high complexity and based on highly innovative conceptions, yet for him, they were just games—sophisticated intellectual games that attracted his attention and stimulated his creativity. The moment they appeared to be useful—the moment they unveiled their academic texture, becoming the basis for the development of a structured area of research into which other scientists entered around the world—was the moment Tullio's creatures completely lost the interest of their father, and his mind turned to other directions, looking for new and exciting games. In his autobiography, "*L'Infinito Cercare*," published in Italian a couple of years before his death, Tullio summarized this very attitude of his by saying that in his life, he opened many doors just to see what was inside, and when he soon got tired with the contents of that room, he easily found a new one that consented to be opened by him.

Tullio Regge was born in Torino on 11 July 1931. His family, of peasant origins, had its deep rural roots in North Eastern Piedmont in the village of Borgo d'Ale, administratively belonging to the Province of Vercelli. This area is not too far from the territory of the Duchy of Milan, yet it continuously fell under the rule of the House of Savoy since 1374, which makes it definitely and strongly Piedmontese. Like most other Italian intellectuals coming from Piedmont, Tullio was both proud of and ironical about his regional roots. Quite often, in his always rich storyteller conversation, he dropped some dialectical popular saying, which invariably reflected the Piedmontese national character that, in a rather unique assortment, combines the habit of understatement and

subtle irony toward all high-brow topics with an extremely serious industriousness. Tullio's father, Michele, was a self-taught building surveyor, who deprived of a structured school education nonetheless had a very much widespread range of intellectual interests and was propelled by an inner inexhaustible curiosity. This curiosity he transmitted to both his sons, especially the second born: Tullio. Tullio's mother, Lidia, who spoke only dialect, was a typical careful, affectionate, sound, and laborious housewife. She suffered from a variant of the same disabling disease that reduced her son to a wheelchair in the second half of his life. Her variant of the disease was less aggressive and slower with respect to her son's, and when I met her about 30 years ago, she could still walk around by herself, although with crutches. Tullio and I were driving back to Torino from Trieste where we had attended one of the very first International Centre for Theoretical Physics Spring Schools on Supergravity and Superstrings. We stopped in Borgo d'Ale and had lunch at Tullio's mother's place. She had prepared fish soup for us, which is quite unusual for a Piedmontese housewife who, typically, has no inclination for seafood, yet it was a really delicious soup that I still remember after so many years. The Regges are people that can surprise you at any moment!

I also remember, on that occasion, discussing the common geographical origins of our families (on my father's side, my great-grandparents came from Vercelli and one uncle Frè was parson of Moncrivello, 16 kilometers from Borgo d'Ale) Tullio put forward the theory that the Regge family name comes from the root *de Rege*, namely from the denomination of those people who worked on royal feuds. It is possible, but I have no idea whether it is true: Tullio probably also had no real documental basis for his statement, yet it was a plausible and elegant explanation and for him was more than sufficient until he happened to open a new door and discover something more interesting.

The general attitude of Tullio Regge toward science is best exemplified by the history of what has been one of his earliest scientific contributions, to which his family name was immediately attached, winning him the worldwide fame that led to his appointment at the Princeton Institute for Advanced Studies (IAS): I am, of course, referring to *Regge poles*. His first achievement dates back to 1957 when he was only 26. It consists of the discovery of a subtle mathematical property of potential scattering in non-relativistic quantum mechanics, namely that (a) the scattering amplitude can be thought of as an analytic function of the angular momentum that admits an extension to the complex plane, and (b) the positions of the poles determine power-law growth rates for the amplitude. Easily extended to the relativistic case, Regge poles opened a new era in scattering theory and provided the framework in which, 10 years later, Veneziano introduced dual amplitudes and gave birth to String Theory.

For more than a decade, Regge poles, Regge trajectories, Regge daughters, intercepts, and the like were the common language of high-energy physicists all over the world. Seminars were given and conferences were organized, both in the West and in the East, where such terms were ubiquitous, yet Tullio was not taking great part in this intellectual festival, his mind being mostly concentrated on other issues.

As Tullio mentions in his autobiography, when he was 8 or 9, his father gave him as a present a small telescope, which sparked his strong interest in astronomy that lasted the rest of his life. His father also contributed significantly to the development of Tullio's early interest in mathematics and other branches of science by means of other frequent presents, namely many books of all possible types that he bought at the Balon, Torino's flea market. However as for university education, at the beginning Tullio's father was inflexible and pretended that Tullio should enroll at the Politecnico of Torino, Faculty of Engineering. The self-taught building surveyor probably dreamt of a son properly educated as a civil engineer! There Tullio found himself at ease with physics and mathematics but was suffering from the educational emphasis on drawing, which apparently he hated. Later in his life, when the age of computers had finally come, Tullio changed his mind about drawing and took great pleasure in creating capricious, surrealistic views based on algorithms of algebraic geometry; cubic-ruled surfaces were his special passion, and he used to distribute them to his friends and colleagues in small, signed, color printouts.

Once, an exhibition of his mathematical paintings was organized in Torino. I was present at the gallery opening and I was looking with a smile at one of these creations that was very familiar to me since I had seen it many times either in Tullio's office or his home, where we frequently sat down to work together. The intriguing array of aerostats flying away toward the point at infinity was familiar to me, but the title given to such a painting was quite new and unexpected: *Committee of Experts*. On his crutches, Tullio came closer to me and whispered into my ear: "Pietro, now listen to the comments of the Critic. In these lines converging to infinity you detect the *weltanschauung* of the artist." However, all this happened later. As a student at the Politecnico, Regge did not like drawing and finally he managed to escape to the university where, with his father's consent, he enrolled as a second-year physics major.

In the '50s, Torino Institute of Physics was a special place in the general scientific landscape because of the presence of an absolutely remarkable personality: Gleb Wataghin. Born in 1899 in the Russian Empire, probably a fellow student of Mikhail Bulgakov in the Kiev Gymnasium masterly evocated by him in "The White Guard," Gleb

had arrived in Torino in 1919 fleeing from the Bolshevik Revolution. There he graduated in both physics and mathematics, was an early contributor to the development of Quantum Mechanics and Quantum Field Theory, became professor, and, from there, in 1934 emigrated once again to Brazil, fleeing this time from Fascism and the upcoming war. In South America, he started a new university and developed the physics of cosmic rays. After the war, he came back to Torino, and with great vigor and enthusiasm, he developed both experimental and theoretical particle physics with aid from Mario Verde, who in 1952 became Tullio's thesis advisor.

After his laurea in Torino, Tullio earned his Ph. D. from Rochester University in upper New York, where he met both his future wife, Rosanna Cester, and John A. Wheeler, with whom in 1957 he wrote a very important paper that is universally considered as the starting point in the theory of black-hole perturbations. The Regge-Wheeler equation for the evolution of perturbations of the Schwarzschild metric is founded on an intelligent decoupling, in the spherical harmonic expansion, of the physical from the fake degrees of freedom due to gauge and has provided a prototype for all subsequent treatments of similar problems. In this way, before the Regge poles, Tullio was already vindicating his early passion for astronomy by giving a mile-stone contribution to the theory of invisible stars. These invisible stars, as we now firmly know, are actually quite visible through the gigantic phenomena associated with their surrounding plasma. The same year (1957) the Regges (Tullio and Rosanna had in the meantime married) went for a semester to Munich where Tullio met with Heisenberg and developed all those calculations and conceptions that finally led to the poles. The incredible fortune of the poles and their ubiquitous presence in the high-energy physics of the '60s I already mentioned. I also mentioned that the capricious and fertile mind of their inventor was already polarized elsewhere.

Indeed, in the early 1960s, Tullio introduced the *Regge Calculus*, a simplicial formulation of General Relativity where space-time is approximated by gluing together polyhedra. Regge calculus was the first instance of discretization of a gauge theory, suitable for numerical simulation, and an early relative of *lattice gauge theories*. Once again Tullio's deep originality showed up in the discovery and clever use of subtle analytical properties of unsuspected objects, at first sight pertaining to different provinces of physics and mathematics. The proposed object of study was gravity and the discretization of curved manifolds. The Clebsch-Gordan coefficients of the rotation group, the so-called "three j coefficients," seemed to have nothing to do with it, yet in the symmetries

of these and in their analytic continuation, Tullio discovered the key to finding a new formulation of three-dimensional gravity, which he established together with Ponzano in what is now universally known as the *Ponzano-Regge model*.

In 1962, Tullio Regge became Full Professor of Relativity at the University of Torino, and in 1964, after 1 year spent at the IAS, he was offered by Oppenheimer to become a full member of the institute. He remained there with his family until 1978, when he left and came back to fill his Relativity Chair in Torino. That very same year, as a young post-doc coming back from a yearly appointment at Caltech, I met Tullio for the first time and started working with him on topics related to the recently discovered Supergravity.

Tullio Regge received the Dannie Heineman Prize for Mathematical Physics in 1964, the Città di Como Prize in 1968, the Albert Einstein Award in 1979, and the Cecil Powell Medal in 1987. In 1996, he was awarded the Dirac Medal by the International Centre of Theoretical Physics in Trieste.

He was elected in the lists of the Italian Communist Party to the European Parliament in 1989, where he finished his term in 1995. After that, he was called to a special chair by the Politecnico di Torino, where he taught until his retirement.

After leaving he left the Relativity Chair empty, I had the great honor and deep satisfaction to be appointed to it in 1996; so I left the International School of Advanced Studies of Trieste where I had spent 6 happy and stimulating years to take on my humble shoulders the responsibility of Tullio's teaching legacy.

Tullio was also a full member of the *Accademia dei Lincei* and a public figure in Italy for his frequent participations in TV debates on various problems ranging from energetics to bioethics. He was also an appreciated writer of original popular books and articles. Great interest was raised by the publication of his dialogues with Primo Levi; this text was edited by the renowned scientific journalist and writer Piero Bianucci.

Personally I am very much indebted to Tullio for what he taught me during our common period of intensive scientific interaction. Above all, he instilled in my mind the importance of the zeroth law to evaluate the results of one's own calculations, (i.e., the principle of the beauty of numbers and the final formulae). If I calculated something and my coefficients were one, one-half, one-third, or maybe three, Tullio said that there was a chance that I was right. If my result involved a 17 or, even worse, a 23, then Tullio told me that I had better redo everything from the start and he did not even want to look at my computations. Although you might learn a lot from him, he was the very antithesis of an academic professor. He had no ambition to create his own school; educate people

who would consider him their master; or perpetuate his thoughts, approaches, and philosophies. He was ever the freelancer, working for the pleasure of his own mind: he just had friends who might share his intellectual adventures or create new ones by posing to him their unsolved problems. He let himself be involved in any new physical or mathematical problem you presented to him. For instance, his contributions to the theory of superfluidity of liquid helium and vorticity are well known, and when fullerene was discovered in 1996, he was quite excited. About 15 years before, together with Mario Rasetti, Tullio had published a paper titled "Dimer Covering and Ising Model on Lattices Homogeneous Under the Icosahedral Group," where a geometrical structure identical with that of the fullerene molecule had been mathematically constructed as the substratum of an exactly solvable Ising model. The two authors had then advanced the hypothesis that molecules of such a type and with such a symmetry could indeed exist in nature. It was for them a source of great emotions to witness their actual discovery and in such a simple form: just 60 carbon atoms. What Tullio and Mario had actually done 15 years before was differently motivated and typical of Regge's way of doing science: finite group theory had been the key to solve such an Ising spin model, and the existence of that key had been the only reason to consider it. Tullio hilariously referred to the whole story as the "soccer ball."

Starting from there, with his latest brilliant collaborator (i.e., Riccardo Zecchina), Tullio embarked on a new scientific adventure: the exact solution of Ising models constructed on two-dimensional surfaces of increasing genus, namely with more and more handles. Regge's intuition was that in the limit of infinite genus, the carrying two-dimensional surface would approximate three dimensions leading to the almost one-century delayed analytic solution of the three-dimensional Ising model.

The only condition that had to be fulfilled to make a problem attractive to Tullio was that it should be mathematically inspiring and that a person's motivations were purely intellectual. By explaining to him the relevance of an issue, the far-reaching consequences for theoretical or experimental physics of its possible solution, or telling him how many distinguished scientists had considered such a problem as important, was the surest way to kill his interest in what you proposed. He would rather show you his latest intriguing computer drawing, generated by some curious algebraic surface, or he would shower you with a never-ending sequence of anecdotes, of which he was a superb and unparalleled master. He had a strong sense of humor and liked to make fun of everyone, yet always in an intelligent, friendly way that was never malicious. Addressing science as a game, the

favorite targets of his jokes were all of those who took themselves and the things they did seriously.

We will all miss Tullio Regge's creativity and his ability to not only invent new concepts but also provoke unexpected visions and ideas in the minds of his collaborators who always were his affectionate friends.

Elected 1982

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