

The diffusion of quantum theory and quantum mechanics in Italy (1900-1947)

Paolo Rossi - Dipartimento di Fisica dell'Università di Pisa; Sezione di Pisa dell'INFN; Centro Fermi - Museo storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Rome, Italy – Paolo.Rossi@unipi.it

Adele La Rana – University of California, Riverside; INFN Section of Rome 1, Sapienza University – Adele.LaRana@roma1.infn.it

Abstract: We examine the limited reception of quantum theory in Italy until 1925 and the evolution determined by the rise of quantum mechanics (1925) and by the establishment of the first (1926) and second (1937) university chairs of theoretical physics. A detailed analysis of the introduction of theoretical physics in all Italian universities between 1927 and 1938 is presented, specifying the teachers and the content of the courses. A detailed paper about this historical analysis has been submitted by the authors for publication in the European Physics Journal – H (La Rana, Rossi 2020-21).

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1. The limited reception of quantum theory in Italy until 1925

The introduction among Italian physicists of the concepts of early quantum theory was greatly slowed down by some structural and cultural factors (Battimelli et al. 2020)¹. First, physics as an academic discipline was greatly underpowered compared to other countries and other disciplines. Besides the chairs of experimental physics (whose number never exceeded 18 units between the end of the 19th century and 1920, rising to 21 after 1925), there were only a dozen chairs of mathematical physics, even then strongly anchored to problems far from those of theoretical physics. The situation in Germany was very different, where Theoretische Physik chairs were present since the beginning of the 20th century [Leone Robotti 2006].

Above all, we must take into account the radically empiricist orientation of contemporary Italian physicists, for whom mathematics had only the function of "putting order" in the data: the physical laws could be obtained only from the analysis of the data and not through a hypothetical-deductive process based on the formulation (and subsequent

¹ We refer to the paper (Battimelli et al. 2020) and to the paper now undergoing peer-review (La Rana, Rossi 2020-21), for archival and bibliographic references that we could not include here for reasons of space.

empirical verification) of theoretical models. As a result, there was no discussion of atomism in Italy, at least until the First World War, nor participation in the international debate that was then opposing energy and atomism [Dragoni 1989; Maiocchi 1991; Giuliani Marazzini 1994].

The first Italian theoretical study on the kinetic theory of gas dates back to 1916 and is due to Carlo Del Lungo [Del Lungo 1916]. In the pre-war period, Einstein's theory of Brownian motion was not yet recognized, and the few articles on black body did not mention Planck's theory, as in the case of Virgilio Polara [Polara 1910], or criticized it, as in the case of Luigi Puccianti [Puccianti 1912] and Raffaele Augusto Occhialini [Occhialini 1913].

The first physicists who understood the importance of mathematics in the formulation of concrete physical models in the context of atomic physics were Antonio Garbasso and Orso Mario Corbino. Garbasso was the first to consider the connection between atomic models and spectroscopy [Garbasso 1904, 1905, 1909]. Corbino already in 1908 [Corbino 1908], and then in a couple of popular articles [Corbino 1909a, 1912], described the hypothesis of quantization of energy, without however showing particular enthusiasm for what was perceived as a sort of "accounting device" (a point of view shared by Planck himself).

The topic of energy quantization found some space only after the discovery of the Stark-Lo Surdo effect. In the same issue (January 1914) of *Il Nuovo Cimento* in which Antonino Lo Surdo announced the discovery of the new phenomenon [Lo Surdo 1914], Garbasso published a note in which he related the effect to the quantization of hydrogen levels proposed by Bohr [Garbasso 1914]. Garbasso's main objective seemed to enhance the role of Antonino Lo Surdo in the debate on the priority of discovery rather than supporting Bohr's theory. The proof is that, although in this work he had preceded the same Danish pioneer, Garbasso did not return to work on these issues later, preferring to deal with classical physics.

Even in the immediate post-war period, there was little attention paid to the results obtained until then in the context of the first quantum theory, except for its implications in the field of spectroscopy. Particularly significant was the role of Rita Brunetti. She graduated in Pisa in 1913 on spectroscopy topics; in 1915, she became assistant of Garbasso, continuing to engage in spectroscopy research. From 1918, she started to interpret experimental results in the light of quantum theory; in 1921, she wrote a review article on the atomic nucleus, expressing great appreciation for Bohr's theory [Brunetti 1921]. However, it was a purely instrumental adherence, devoid of any attention to the strictly theoretical issues raised by the quantization. Paradoxically, this attitude favored a sort of passive acceptance of quantum theory. In this same spirit, when after 1925 the new quantum theory - quantum mechanics, according to the name coined by Max Born in 1924 [Born 1924] - asserted itself, it was easier for some to accept Werner Heisenberg's matrix approach than Erwin Schrödinger's wave mechanics, based on the concept of wave function and thus perceived as too theoretical and speculative.

2. The first competition for theoretical physics chairs

The first diffusion of Heisenberg and Schrödinger’s quantum mechanics and the creation of the first chairs of theoretical physics in Italy are largely parallel processes, linked to the names of the same scientists. Therefore, it is worth treating these issues in a unitary way, focusing on the physicists who won the first competition and immediately became the bearers of the new ideas in the world of Italian physics. Indeed, the spread of quantum mechanics was closely linked to the appearance on the scene of a new generation of young physicists (many of them in their thirties) open to new physical ideas developed especially in Germany. In turn, there was no direct scientific involvement of the professors already in service before 1926 in the conceptual revolution going on in those years.

The first winner, Enrico Fermi, at the end of the competition was immediately recruited by the Physics Institute of the University of Rome, where he settled in the autumn of the same year. However, his treatise *Introduction to atomic physics* [Fermi 1928] deals mainly with the old theories, and only about thirty final pages concern quantum mechanics, without any discussion on its foundations. It is singular that Fermi’s first article on the new quantum theory, which appeared in the early months of 1926 very close to the appearance of Schrödinger’s work [Schrödinger 1926], was published only in German in *Zeitschrift für Physik* with the title *Zur Wellenmechanik des Stossvorganges* [Fermi 1926b], and did not have an Italian version.

In the immediately following years, Fermi produced some significant contributions to the new theory, including the article *A statistical method for the determination of some properties of the atom* [Fermi 1927] and the work *On quantum electrodynamics* [Fermi 1929], fundamental for the development of quantum field theory. Even in the essay *Interpretation of the principle of causality in quantum mechanics* [Fermi 1930], Fermi assumed a strictly pragmatic attitude that was not attentive to the conceptual and philosophical foundations of the theory. In 1933, he formulated the theory of beta decay, but then immediately went on to deal with nuclear physics, obtaining the extraordinary experimental results that earned him the Nobel Prize.

Enrico Persico, classified as second in the competition, took immediately service at the University of Florence where he held the theoretical physics course from 1926/27 to 1929/30.

Far more interested than Fermi in the conceptual implications of the new quantum mechanics, and certainly influenced, at least indirectly, by the ideas supported at the time by neo-positivist thinkers, Persico soon intervened on the foundations of the theory. On this issue he published in *Il Nuovo Cimento* two reviews: *Wave mechanics* [Persico 1927] and *Recent viewpoints on the foundations of physics* [Persico 1928], and the article *On the relation $E = hv$ in wave mechanics* [Persico 1930], while in that period he gave no significant contributions to the applications of theory.

In 1930 Persico moved to the chair of theoretical physics of the University of Turin, where he remained until 1950, moving later to Rome.

Aldo Pontremoli was the third winner of the 1926 competition, but his call on the chair of theoretical physics in Milan met academic obstacles. The theoretical physics course was however entrusted to him for the academic year 1927/28, but at the beginning of 1928 he decided to take part in the polar expedition of Umberto Nobile and perished in the Barents Sea on May 25, 1928 during the tragedy that swept the expedition.

He had no chance of making original contributions to modern quantum mechanics. Nevertheless, the list of his publications shows that he had attention for the new theories from

their birth and carefully followed their developments, as also emerges from his article *On Rutherford's neutron* [Pontremoli 1923] and from the booklets of his lectures [Gariboldi 2020].

2. The diffusion of quantum mechanics in the main seats until the Second World War

The penetration of new ideas into the major Italian universities was not simultaneous, especially in cases where there was neither a professorship nor a theoretical physics assignment, so the treatment of wave mechanics and Heisenberg mechanics was often entrusted to higher physics or mathematical physics courses. It is therefore worth examining the individual situations separately, highlighting those in which, at the research level or even only at the educational level, there is evidence of an effective assimilation of the new concepts. It should be noted that elements of the so-called old quantum theory - quantization according to Bohr-Sommerfeld, quantization of electromagnetic radiation and black body theory - had already become part of the experimental courses in various Italian universities, in some cases already shortly after the end of the WWI. It was, of course, a phenomenological and experimental approach, in line with the widespread attitude in the community of Italian physicists. With the gradual emergence of quantum mechanics, in the second half of the 1920s, and the establishment of the first chairs of theoretical physics, the concepts of quantum mechanics slowly began to make their way into lessons alongside the first quantum theory.

In this context, it should be noted that acceptance of the existence of the new academic discipline was certainly neither immediate nor generalized. Proof of this is the fact that ten years passed before a second theoretical physics competition was launched in 1937. The 1937 competition was preceded by the attribution to Ettore Majorana (1906-1938?) of a chair for clear fame destined to Naples, and it was won by Giovanni Gentile jr (1906-1942), Giulio Racah (1909-1965) and Gian Carlo Wick (1909-1992), later called respectively in the seats of Milan, Pisa and Palermo.

We report in chronological order the universities where theoretical physics courses for university students began, covering the period until 1947, when the third theoretical physics chair competition was finally held, and the first two generations of theorists had already run out for various reasons.

2.1. Naples

The University of Naples was the first Italian academic center in which an explicitly titled "Theoretical Physics" course took place. The teacher in charge was Antonio Carrelli (1900-1980), who held lessons from the year 1925 and until 1950, with two interruptions in the 1930s. The first was between 1931 and 1932, when he first moved to Catania, having won the competition in the chair of Experimental Physics, and then to Utrecht, for a period of study; the second was in the academic year 1937-38, when the chair of theoretical physics was established and assigned to Ettore Majorana.

After Majorana's disappearance, Carrelli again lectured in parallel with the experimental physics course. It is worth noticing that, since 1925 and during the 1930s, the theoretical physics course in Naples was biennial. We do not have indications that Carrelli held quantum physics lessons within his course in the 1920s. Nevertheless, a work that well represents his attention to new developments in quantum theory at the turn of the 1920s is

Quantum theory. Critical exposition of the new physics, published in 1931 in the *Memoirs* of the Pontifical Academy of Sciences [Carrelli 1931]. Carrelli was one of the three winners of the competition *Dissertatio Critica circa theoriam quantorum in physica*, launched by the same Academy in 1929. The Academy, chaired by the Jesuit Giuseppe Gianfranceschi, had put a 10000 lire prize for the competition: half of it went to Gleb Wataghin, while Antonio Carrelli and Paolo Straneo shared the second half.

An explicitly popular text by Carrelli is *The Quantum Theory* [Carrelli 1932], in which he gives a detailed account of the present knowledge on the structure of matter, in a form accessible to all and without formulas. The first available notes of Carrelli's course are the lessons in theoretical physics for the academic year 1933-34, followed by the lectures given in 1936 [Carrelli 1936]. The 1933-34 lectures include a first part dedicated to restricted relativity, which ends with the discussion of relativistic dynamics. The second part deals with subjects of statistical physics. The quantum theory of specific heats (Einstein-Debye theory) appears at the end of the 1936 lecture notes, while the second part of the 1942 lectures [Carrelli 1942] concerns radioactivity and atomic structure.

It is interesting to note that atomic phenomenology and its interpretation in the context of Bohr-Sommerfeld's quantum theory represent the topics of the first lectures of Ettore Majorana's course in Naples in 1938, largely borrowed from the course held in Rome by Fermi in 1927-28 and attended by Majorana himself [De Gregorio Esposito 2007]. Therefore, apart from the very short parenthesis of Majorana, notions of quantum mechanics appeared in Naples in the lectures on theoretical physics only in the 1940s, a delay that reflects Carrelli's preference for topics related to the structure of matter and statistical mechanics.

2.2. Rome

As for the first reception in Rome of the old quantum theory, we saw that in 1909 Corbino wrote an article in *Il Nuovo Cimento*, entitled *The atomistic hypothesis of radiant energy* [Corbino 1909a]. In the same journal he published also an extract from a letter to Tullio Levi-Civita: *On the corpuscular nature of electric radiation* [Corbino 1909b]. His research activity in the following years was not oriented on quantum physics, but we have already underlined the importance of his political action to promote the formation of a modern physics school in Rome. Also significant is his article *The present-day crisis of physics* which appeared in 1927 in *Il Nuovo Cimento* [Corbino 1927].

Before Fermi, notions of quantum theory were present in Rome in the complementary experimental physics course held by Antonino Lo Surdo (1880-1949). Lo Surdo had obtained the Roma chair of complementary physics in January 1919 and from the academic year 1918-19 he had held the corresponding course at the «Sapienza» University. During the first year his lectures focused - as can be read from the lectures booklet - mainly on physical optics, but already from 1919-20 the course included new topics: «*the experience with Michelson's step spectroscope and the observation of the Zeeman phenomenon, emission and absorption (Kirchhoff's law), the black body*».

The lectures of the academic year 1920-21 are enriched with topics of atomic spectroscopy and quantum theory, from an experimental and phenomenological point of view. In the A.Y. 1922-23 the course was called «higher physics and complements of physics». The experiences on electromagnetic phenomena prevail. In the A.Y. 1925-26 the course program still includes the study of radioactivity, as in 1920-21, also including the experiences of Rutherford and Geiger to count alpha particles, the study of the nature of alpha particles and helium emanated from the radio.

With the establishment of the chair of theoretical physics in Rome, the corresponding course started already from the academic year 1926-27. The lectures of theoretical physics held by Fermi in 1926-27 and 1927-28 followed the evolution of the first quantum theory. Only from 1928-29 did Fermi include wave mechanics in the course, which in his *Introduction to atomic physics* occupies the last of the ten chapters [Fermi 1928].

Among the most active scholars of quantum theory in Rome we find the above mentioned Giuseppe Gianfranceschi (1875-1934), professor of astronomy (1915-26) and physics (1921-22) at the Gregorian University and president of the Pontifical Academy of Sciences since 1919 to 1934. It is no coincidence that, under his presidency, the Academy launched the competition for the best critical dissertation on new physics.

Gianfranceschi had an extremely critical attitude with respect to quantum physics since its first formulation and continued to follow its developments carefully even during the 1920s. He took part in the International Congress of Physicists, which was held in Como in 1927. There he presented his personal reflections in the discourse *The physical meaning of quantum theory* (Bologna 1928). His more mature reflections on new physics are contained in *Chapters of contemporary physics* (Rome 1932), in which he recognizes the impossibility of tracing some phenomena to the models of classical physics, but reiterates that there is still no adequate theoretical framework to explain them.

One must not forget the presence in Rome of Ettore Majorana (1906-1938?), who in addition to the important theoretical contributions had the opportunity to present three programs for theoretical courses, to be carried out as freelance teacher. The titles were *Mathematical methods of quantum mechanics*, *Mathematical methods of atomic physics*, *Quantum electrodynamics*, respectively for the academic years 1933/34, 1935/36 and 1936/37. However, he didn't actually give any of these courses.

After Fermi's departure in December 1938 and a short period in which the theoretical physics course was held by assignment by Bruno Ferretti (1913-2010), the Rome chair of theoretical physics was succeeded in 1940 by Giancarlo Wick, who thus left Padua and who held the course until 1946, when he left Italy to move to the United States.

2.3. Florence

It was a somewhat privileged seat, first for the presence of Fermi then for that of Persico. One should remember that Lo Surdo made his discovery of the effect that bears his name in 1914, when he was an assistant to the physics cabinet in Florence. Enrico Persico held the theoretical physics course in the A.Y. 1926/27, 1927/28 and 1928/29. In the first year, the course covered only topics of classical electromagnetism, while in 1927/28 Persico introduced several topics of (old) quantum physics: Rutherford's atomic model, Planck's theory of the black body, Bohr-Sommerfeld quantization, spectral series, Pauli principle. Finally, in 1928/29 the new quantum mechanics was also introduced (lectures 47-64). In 1929 Persico published the course notes with the title *Lectures on wave mechanics* [Persico 1929], collected by Bruno Rossi (1905-1993) and Giulio Racah. After Persico's departure, the theoretical physics course was entrusted to Bruno Rossi from 1931/32 to 1933/34, and subsequently to Giulio Racah from 1934/35 to 1937/38 and to Tito Franzini (1902-1989) from 1939.

2.4. Bologna

Quantum theory enters institutional courses at the Bologna University with Giulio Cesare Dalla Noce (1885-1969), who held by appointment the theoretical physics course at the University of Bologna from 1927. Being an assistant since October 1922, he became *aiuto*

(help) in 1936 and held the position until his retirement in October 1945. Dalla Noce never got full professorship. In January 1930 he introduced for the first time in his course notions of the new quantum theory, with a lecture dedicated to wave mechanics and to Heisenberg quantum theory. The assignment of theoretical physics for the academic year 1942/43 was entrusted to Bruno Ferretti, then again to Dalla Noce for the following two years, while for the academic year 1945/46 it was entrusted to Gilberto Bernardini (1906-1995), professor of experimental physics, and for the academic year 1946/47 to Leonida Rosino (1915-1997).

2.5. Milan

In the register of lectures of the complementary physics course held by Aldo Pontremoli in the academic year 1926/27 (the last one he was able to complete) we find Heisenberg's quantum mechanics on June 13 and 14, 1927 Schrödinger's wave mechanics on June 15, one year ahead of Fermi and Persico. After the disappearance of Pontremoli, in the A.Y. 1928/29 the theoretical physics course was assigned to Bruno Finzi (1899-1974), who in the last five lessons also dealt with wave mechanics and Heisenberg mechanics. Starting from the A.Y. 1929/30 for a few years the course was taught by Giovanni Polvani (1892-1970), who from 1929 was holder of the chair of experimental physics, but had always also expressed theoretical interests, then in the A.Y. 1936/37 the course was entrusted to Giovanni Gentile by appointment. In 1937 the Milan chair of theoretical physics was established and was assigned to Giovanni Gentile jr (1937-1942), the first winner of the second theoretical physics competition. In 1942-43 there was nobody in charge of the course, while the *libera docenza* in theoretical physics was attributed to Gaetano Castellfranchi (1892-1965), who wrote one of the first manuals of quantum physics in Italy [Castellfranchi 1929], re-edited in many subsequent editions, including the eighth one: *Modern physics. Atomistics and nuclear transmutations* [Castellfranchi 1946].

2.6. Turin

From 1930 also Turin had its theoretical physics chair, held by Enrico Persico until 1947. Before Persico's arrival, it is worth mentioning, at least concerning research, several articles by Gleb Wataghin (1899-1986) in *Il Nuovo Cimento* as early as 1927. His later works are published largely in the *Physical Review*. Let's recall that Wataghin was winner of half of the *Dissertatio Critica Circa theoriam quantorum in physica* award, launched by the Pontifical Academy of Sciences in 1929, with his memory *Critical Dissertation on quantum theory* [Wataghin 1932].

2.7. Pisa

Schrödinger's mechanics appeared in the course of higher physics held by Luigi Puccianti (1875-1952) already in the academic year 1927/28, and in 1928/29 the formulations of Schrödinger and Heisenberg were also presented in the course of mathematical physics held by Orazio Lazzarino (1880-1963). From 1932 to 1936 the assignment of theoretical physics was entrusted to Giovanni Gentile jr, then from 1936 to 1938 the course passed to Giulio Racah, holder of the chair from 1937, having ranked second after Giovanni Gentile in the second competition in the chair of theoretical physics. After the expulsion of Racah in 1938 due to racial laws, starting from 1939 for many years (until 1955) the teaching was entrusted to Tullio Derenzini (1906-1988) on assignment.

2.8. Padua

In the academic years 1933/34 and 1934/35 the theoretical physics course was entrusted by assignment to Bruno Rossi (owner of the local chair of experimental physics). From 1935/36 to 1937/38 Leo Pincherle (1910-1976) was in charge of it, but in 1938 he was purged, like Rossi himself, following the racial laws and emigrated to Great Britain. In 1938 the chair of theoretical physics was established and Giancarlo Wick, called from Palermo, held it until 1940, and then moved to Rome. In 1942/43 the chair was held by Gleb Wataghin, from Sassari, where he had held the physics course for the Faculty of Pharmacy.

2.8. Catania

Starting from the 1935/36 academic year, the theoretical physics course was entrusted to Orazio Specchia (1890-1961), owner of the local chair of Experimental Physics, who had the assignment until 1942, when he moved to Pavia.

2.8. Genoa

From 1936/37 in charge of the course was Paolo Straneo (1874-1968), holder of the chair of mathematical physics. Let's recall that Paolo Straneo had won a quarter of the Prize *Dissertatio Critica circa theoriam quantorum in physica*, launched by the Pontifical Academy of Sciences in 1929, for his work about quantum theory published in 1931 [Straneo 1931].

2.8. Messina

In 1936/37 and 1937/38 he was charged with the course Antonio Rostagni (1903-1988), a full professor of experimental physics, who in 1938 moved to Padua on the place left by Bruno Rossi due to the racial laws. In 1942-43 the assignment passed to Virgilio Polara (1887-1974).

2.8. Modena

Starting from the academic year 1936/37 in charge of the course was Mariano Pierucci (1893-1976), owner of the local chair of experimental physics, who kept the course of theoretical physics for eighteen years.

2.8. Palermo

In the academic year 1936/37 the theoretical physics course was entrusted by assignment to Emilio Segrè (1905-1989). Giancarlo Wick was the first to occupy the chair of theoretical physics in Palermo in 1937/38. In 1939/40 and in 1942-43 in charge of the course was Edoardo Gugino (1895-1967), ordinary of rational mechanics, while in 1940/41 the course was held by Cosimo Cannata (born 1903).

2.8. Pavia

In 1936/37 the theoretical physics course was assigned to Paolo Rossi (1878-1940). Subsequently, from 1937/38 to 1941/42, it passed to Rocco Serini, full professor of mathematical physics, selected in the Cagliari competition of 1925, and from 1942/43 to Piero Caldirola (1914-1984), who held the course until 1955.

2.8. Cagliari

In 1937/38 in charge of the theoretical physics course was Ivo Ranzi (1903-1985), who was also in charge of the experimental physics course. In 1940/41 Guglielmo Righini

(1908-1978) was in charge. In 1942-43 the course was held by Giuseppe Frongia (1908-1982), later a full professor of experimental physics in the same university.

2.8. Parma

It was the only Italian state university that, although providing a degree in physics, did not activate a course in theoretical physics until after the Second World War.

3. Appendix. The Committees of the first three competitions for theoretical physics chairs

First competition (November 1926)

Michele Cantone (1857-1932), experimental physics in Pavia (1898) and Naples (1904); Orso Mario Corbino (1876-1937), experimental physics in Messina (1905) and Rome (1908), (rapporteur); Antonio Garbasso (1871-1933), experimental physics in Genoa (1903) and Florence (1913), (president); Gian Antonio Maggi (1856-1937), mathematical physics in Pisa (1895) and Milan (1924); Quirino Majorana (1871-1957), experimental physics in Turin (1914) and Bologna (1922).

Second competition (October 1937)

Enrico Fermi (1901-1954) (president), theoretical physics in Rome (1927) and USA (1938); Antonio Carrelli (1900-1980) (secretary), experimental physics in Catania (1930) and Naples (1932); Orazio Lazzarino (1880-1963), mathematical physics in Cagliari (1920), Catania (1921), Pisa (1925); Enrico Persico (1900-1969), theoretical physics in Florence (1927), Turin (1930), Rome (1950); Giovanni Polvani (1892-1970), experimental physics in Bari (1927) and Milan (1929).

Third competition (End 1946)

Enrico Persico (1900-1969), theoretical physics in Florence (1927), Turin (1930), Rome (1950); Edoardo Amaldi (1908-1989), experimental physics in Rome (1937); Gilberto Bernardini (1906-1995), experimental physics in Camerino (1937), Bologna (1938), Rome (1946) 1946 and Scuola Normale Superiore (1964); Antonio Rostagni (1903-1988), experimental physics in Messina (1937) and Padua (1938); Rocco Serini (1886-1964), mathematical Physics in Pavia (1927).

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