Chapter 4
Giovanni Gentile Junior. Physics as an Intellectual and Spiritual Adventure

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Abstract In 1936, the arrival of the young theoretical physicist Giovanni Gentile Jr. at the Institute of Physics of Milan University directed by Giovanni Polvani, opened novel horizons both in terms of the choice of research topics in the field of modern physics and of modernization of teaching. Gentile's solid education at the Pisan school of physics and mathematics in the 1920s and his relationships with Fermi's school in Rome and later with the great German school of theoretical physics through Schrödinger, London, Heisenberg and Sommerfeld, as well as his special friendship with Ettore Majorana, became the premises on which to build a stimulating research environment with the consequent formation of a new generation of theorists in contact with the international scientific community. The unique partnership between Polvani and Gentile, rooted in a deep human, cultural and scientific affinity, immediately resulted in an effective revitalizing impulse both for the Milan Institute of Physics and for Gentile Jr.'s personal research path. Despite his brief passage in Milan—barely five years before his premature death in 1942—Gentile planted a few seeds of renewal that flourished after the war, contributing to the rebirth and revival of Italian physics almost destroyed by Mussolini's racial laws and the dramatic consequences of the war.

4.1 Introduction

Upon his arrival in 1929 at the Milan University, Giovanni Polvani was extremely determined not only to give new life to the Institute of Physics he had been called to direct, but also to make it a center for modern physics that could compete with other traditionally prominent Italian institutes such as those at the Pisa University o and the Regio Istituto Fisico of the ancient University La Sapienza in Rome, whose experimental tradition could by that time boast the presence of Enrico Fermi, who had won in 1926 the first competition ever announced in Italy for theoretical physics along with Enrico Persico and Aldo Pontremoli. The latter, who had been appointed to the newly created chair of this discipline assigned to the Milan University, had disappeared in May 1928 during the polar expedition on the airship Italia organized by Umberto Nobile. After such a dramatic event, only two professors of theoretical

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physics were left in Italy. The chair in Florence was occupied by Persico, Fermi's brotherly friend, who was an outstanding teacher and gave at the time a great contribution to the spread of modern physics holding one of the first courses in Italy on quantum mechanics. He mentored among others Bruno Rossi, Gilberto Bernardini, Giuseppe Occhialini, Giulio Racah and Daria Bocciarelli, before moving to Turin in 1931. In parallel, after the masterful work on the quantum statistics that bears his name, Fermi in Rome gathered a few brilliant new recruits, who would in different ways give great contributions to the advancement of physics in Europe and the United States. After having formulated in 1933 his masterpiece, the theory of nuclear beta decay [1], the following year Fermi conducted the well-known experiments on artificial radioactivity induced by neutrons [2] first alone and later with his formidable team, including Franco Rasetti (his old friend and collaborator since when they were both students in Pisa), Emilio Segrè (who would be awarded the Nobel Prize in Physics for the discovery of the antiproton), Edoardo Amaldi (who with Gilberto Bernardini would promote the reconstruction and renewal of Italian and European physics after the war) and Bruno Pontecorvo (who became a brilliant physicist, later named "Mr Neutrino" for his successful work on neutrino theory). Ettore Majorana was also part of this group, although in a more detached and irregular way.

By 1935–1936, while Fermi's group was already beginning to disperse after the brief, albeit successful research season, Polvani was continuing to exert his efforts to promote the growth of his Institute in Milan. In his determination to strengthen its academic staff with a theoretical physicist, Polvani aspired to have at his side the young theorist Giovanni Gentile Junior, who had graduated in the fall of 1927 from the Pisa University, where Polvani had a teaching position at the Institute of Physics directed by Luigi Puccianti before he moved to Milan. Gentile was born in Naples on 6 August 1906, the day after the birth, in Catania, of Ettore Majorana, of whom he would later become a great friend. He was the son of the homonymous idealist philosopher, Giovanni Gentile, an extremely influential figure in the fascist period, deeply involved both intellectually and politically in Mussolini's regime, and thus, to distinguish the son from the famous father, his name was usually followed by Junior, but family and friends affectionately called him Giovannino, an appropriate appellation for a notoriously kind-hearted person.

Polvani's desire dated back to a few years earlier, when the young theoretician had obtained his teaching qualification, the "Libera docenza", once back from his post-graduation stay in Berlin—where he had contacts with Erwin Schrödinger and Fritz London and other illustrious physicists, notably Einstein—and in Leipzig, where he had worked under the guidance of Werner Heisenberg. But Polvani's initial aspiration to have Gentile with him in Milan had not been realized, because Gentile had responded positively to his old professor Puccianti's offer of a teaching assignment in Pisa. Giovannino had agreed to such request, probably for more than one reason. On the one hand it would have been difficult to refuse Puccianti's invitation, moreover, for a young man at the beginning of his career the University of Pisa was much more prestigious than that of Milan. On the other hand, one can easily imagine that Gentile also felt a subtle satisfaction in returning as a professor to the places where he had been a student. For his part, Polvani did not want to insist, "out of a regard for our common master" [3, 156]. Moreover, at that time Gentile's father was director of the Scuola Normale Superiore, and so his influential presence seemed to suggest the appropriateness of this choice, also because the powerful senator would certainly make every effort to support Puccianti's initiatives aimed at improving the situation of physics in Pisa.

But Puccianti, by now elderly, turned out to be rather lazy and not even remotely as dynamic as Polvani, thus making the situation definitively uninteresting and so Gentile in agreement with his father, made himself available to accept a new invitation from Polvani in 1936. In his obituary of the young colleague who died too prematurely when he was just under 36 years of age, Polvani recalled [3, 156],

> [...] In this way, an aspiration that was, after all, in both of us was fulfilled: to come together in didactic and scientific collaboration.

These few words, even in their simplicity, express the profound sense of the human and intellectual partnership between Polvani and Giovanni Gentile Junior, that had already begun when the latter was a student at the University of Pisa and Polvani a young professor at the Institute of Physics directed by Luigi Puccianti.

Polvani had the far-sighted vision of placing side by side with the experimental tradition to which he himself belonged, the novelty deriving from the nascent Italian theoretical school, which at that time was represented by a very small group of young people who, although having as a reference the luminous example of Fermi and Persico, were finding their own style of research pursuing the novel frontiers of physics, a discipline which was still growing explosively after the revolutionary developments that had characterized the first twenty years of the twentieth century. This new generation of physicists, such as Gian Carlo Wick, Giulio Racah, Gleb Wataghin, later became highly regarded at international level, even if, unfortunately, they ended up lending their work as scholars and teachers very often, if not entirely, abroad. Post-war Italy became in fact singularly lacking in theoretical physicists first because of the diaspora due to the racial laws and then, after World War II, because of the attraction exerted by international centers that offered better prospects or, in the case of Gentile and Majorana, to their early disappearance from the Italian scene, which dramatically interrupted the path they had started.

Gentile faced with enthusiasm the role of responsibility that Polvani was offering him and in perfect harmony with his ancient professor deeply committed to both educational and scientific levels, projecting himself into the future on the front of the formation of new recruits and alongside Polvani in the requalification and development of the Institute. In seeking his own way, either independently or under the impetus of a new and dynamic Italian scientific community that for the first time was strongly in tune with the great innovations coming from the international panorama, Gentile shared his experience with a series of original personalities who, in different ways, contributed to the consolidation of such turning point for Italian physics. At the same time, as a beloved and generous teacher, Gentile was instrumental in the continuation of such outstanding tradition.

His intellectual and scientific experience was closely intertwined with philosophical, historical and epistemological interests. The breadth of his cultural horizons is also evidenced, among other things, by his affective and intellectual association with leading figures, respectively, of physics and philosophy of those years, such as the already mentioned Ettore Majorana and Gentile's brotherly friend Delio Cantimori, of which there is a substantial and precious trace in the correspondence. In Majorana's case, this correspondence is of special relevance, considering that, apart from the real family letters—and the interesting scientific exchange with his uncle Quirino—this series is the only known direct evidence of the private life of the brilliant physicist. Gentile and Majorana were full of cultural curiosities and strongly attracted by the increasing level of abstraction that characterized some aspects of the new physics and by their formal elegance. Both considered physics as an intellectual adventure and a fascinating challenge, also by virtue of its unique conceptual difficulties deeply embedded in the revolutionary new developments that had characterized the first two decades of the twentieth century. They themselves, during the 1930s, would make their contribution to such a profound renewal of the physical sciences.

This breadth of horizons and the rich interweaving of interests drove Gentile, in parallel with his commitment more closely aimed at research and teaching, to spend a large part of his time in writing essays focused on the breakthroughs of twentieth century physics and in the preparation of volumes addressed to the general public and high-school teachers. In this constant desire to integrate physics into the cultural panorama of the country, Gentile was certainly ahead of his time and can be compared to an illustrious exponent of Italian scientific and cultural life such as the mathematician Federigo Enriques, who, since the beginning of the century, had moved in the context of a vast and articulated plan in which reflection on the nature of scientific knowledge and on its cultural role was a central element [4]. The history of intense "meditation", the evolution of Gentile's thought as a philosopher and a scientist which makes manifest the cross-fertilization of knowledge in different areas, can only be retraced through the entirety of his writings, as well as from his correspondence, from which his search for a cultural unity of knowledge is emerging.

In 1940 he published, among others, his first paper on intermediate statistics, followed by applications to the peculiar properties of liquid helium and to the phenomenon of Bose–Einstein gas condensation. These works constitute his major theoretical contribution of his Milanese period and still today an important scientific legacy that testify his farsightedness in the choice of research topics. In his honor, the particles subject to intermediate statistics are called "Gentilions", to distinguish their properties from those of the "bosons" and "fermions". At this time of his life Gentile was not yet 36 years old, full of initiatives and plans for the future. Then, quite unexpectedly, a septicemia ended his young life on 30 March 1942.

Despite his brief passage at the Institute of Physics in Milan—barely five years—Gentile planted a few seeds of renewal that sprouted and flourished after the war, contributing to the rebirth and revival of Italian physics almost destroyed by the racial laws and the dramatic consequences of the war.

It is my deepest wish to dedicate this chapter to Enrico Gentile, the son of Gentile Jr., who with extraordinary commitment and high sense of filial love has dedicated himself for many years to the study and understanding of the cultural, spiritual and scientific world of his father's figure constantly also promoting related historical studies

and making every effort to ensure that all the papers and the documentation concerning his research work and personal life, as well as copies of the correspondence, were gathered together and properly preserved in an archive and made available to scholars. In this passionate form, he was able to deeply reacquaint himself with the figure of a father he had not been so fortunate to know due to the latter's dramatic death when he was only a few months old. To him goes my fond memory of many years of constant and intense discussion and close collaboration during my work of analysis and organization of his father's papers he donated to the 'Edoardo Amaldi Archives' of the Physics Department at Sapienza University of Rome.

Last but not least, I am very grateful to Alessandra Gentile for her most helpful comments on this contribution.

4.2 A New Generation of Theoretical Physicists in Italy

With his dissertation in theoretical physics, the first theoretical thesis in Italy, on which he worked in complete autonomy from the late spring of 1927, Giovanni Gentile Jr., became part of the advanced research of the time, which presented not only radically new problems from the physical point of view, but also the formidable challenge of new mathematical formalisms. Gentile studied the consequences of the Schrödinger's equation, the partial differential equation expressing the wave-like nature of atomic particles, which proved its power providing the solution for the energy levels of the hydrogen atom, that were found to be in accord with experimental data. Tackling a topical research theme, "a new form of quantum theory" published by Schrödinger in December 1926 [5], Gentile shows his ability to master the necessary mathematical tools integrating them perfectly with the physical analysis. On the other hand, as he himself pointed out, after attending for two years the university courses in Pisa as a student of mathematics, it was experimental physics that fascinated him and induced him to switch to the physics course. The next step had been the discovery of modern physics, which he arrived at through the initial topic of his thesis, the Stark-Lo Surdo effect, which was assigned to him by Polvani himself. This effect, discussed at length by Schrödinger in his third article of 1926, certainly attracted Gentile's attention towards quantum theory and in particular towards its wave-mechanical formulation provided by Schrödinger and applied to the simplest atom, hydrogen, having a single electron orbiting the nucleus. The temporary departure from Pisa of Polvani, who had won a competition for a chair of Experimental Physics in Bari, induced Gentile to take the decision to fully devote himself to the theoretical aspects of the problem, that he also tried to discuss from the point of view of the involved epistemological implications. His constant attention toward the foundations of the new quantum mechanics and the philosophical aspects of science in general was an attitude that characterized his research activity since then. It is in any case remarkable that in this decision he was not opposed by Puccianti, director of the Institute, made tolerant probably thanks to the influential figure of Gentile's father, who on the other hand had an enormous respect for his son's aspirations toward theoretical physics, and for his enthusiasm that made this discipline—still entirely new to the Italian academic world—appear far closer to philosophy than the experimental aspects of physics.[1] In those years a thesis in theoretical physics in a certain sense was not even conceivable in Italy, since this discipline was not included in the university curriculum. And indeed, on 26 November 1927, when Giovanni Gentile and his friend and colleague Gilberto Bernardini graduated in physics at Pisa University with 110 cum laude, Fermi, Persico and Pontremoli had just won the first national competition for theoretical physics, and were settling on their respective chairs in Rome, Florence, and Milan.

Since December of that year, after rejecting the possibility of working with Vasco Ronchi, who was about to found the the Institute of Optics in Florence, Gentile made a brief stay in Rome, as an assistant to Orso Mario Corbino, starting his scientific career under the best auspices. At that time Fermi, Rasetti and the small group of young people who were beginning to gather around them, were tackling atomic physics with very advanced techniques. With his first published work Gentile successfully went as far as touching on topics concerning the atomic nucleus, a domain still virtually unknown, and thus a completely novel research subject even in Rome (and in general in Italy and other research centers in the rest of the world). He discussed a model just formulated by Ernest Rutherford for the nuclear structure, whose theoretical basis Gentile showed to be without foundation [8]. Such work testified the growing interest of Fermi and Rasetti for the nuclear realm, which they considered the new frontier, while they continued to investigate the atomic electronic structure using the successful Thomas–Fermi statistical model. The structure of the nucleus would have been clarified only in 1932, with the demonstration of the existence of the neutron, a constituent of the nucleus hypothesized by Rutherford and long sought by his collaborators, in particular by James Chadwick [9].

During those six months in Rome Gentile became a good friend of Ettore Majorana, for whom he felt a deep affection and extreme admiration. Gentile was bringing in the Roman Institute a taste for the philosophical reflection on the new physical theories that was completely foreign to that environment and that most probably was at the root of his intellectual fellowship with Ettore Majorana, which naturally involved many other aspects, such as the passion for theater, or cultured readings. In this sense Gentile represented a rather lonely voice, able to deal with the awareness of a scientist and the animus of the philosopher very complex issues with which physicists such as Niels Bohr and Werner Heisenberg, whom he admired unconditionally, were confronted. We don't have much evidence to reconstruct what was the nature of their "elective affinities" [10]. What we know is that the series of letters written by Majorana to his friend Gentile represent the only known extra-familiar correspondence. With Ettore, at the time still a student, Gentile wrote the second [11] of his three papers on problems of atomic and nuclear physics presented at the Reale Accademia dei Lincei [12]. As some of these letters testify, the close collab-

[1] For an in depth discussion of the very special relationship between Giovanni Gentile Junior and his father see the beautiful contribution written by Gabriele Turi [6]. See also Roberto Maiocchi's biographical entry in the *Dizionario Biografico degli Italiani* [7].

oration between Gentile and Majorana continued during the following years, even if they did not publish any joint paper, most probably because of academic reasons, suggesting to write single-authored articles. Their shared interests can also be found in some of their articles. Majorana's pioneering paper *Relativistic Theory of Particles with Arbitrary Intrinsic Momentum* [13] was the first attempt to develop a relativistically invariant linear theory for particles with arbitrary spin, both integer and semi-integer, in which all mass eigenvalues are positive. Such constraint was introduced by Majorana in order to eliminate the negative-energy solutions characterizing the Dirac equation, which were considered an embarrassing result before the discovery of the positive electron in 1932. This requirement led Majorana to a remarkable pioneering achievement: the first ever development and application of the unitary infinite-dimensional representations of the Lorentz group. In 1939 and 1940 Gentile returned on these issues writing two very elegant works about the representations of the inhomogeneous Lorentz group [14], and a relativistic theory for particles with arbitrary spin, à la Majorana but in the light of new results obtained by Dirac [15]. And actually, since the beginning of their friendship, they had both a deep interest in group theory—that Gentile had learned in Pisa from one of the greatest Italian experts, the mathematician Luigi Bianchi—and its application to quantum physics.[2]

After six months in Rome, Gentile left for 18 months of military service. In the meantime, his friend Majorana had been working on his dissertation. He graduated in July 1929 with a thesis entitled *La teoria quantistica dei nuclei radioattivi* (The quantum theory of radioactive nuclei). It was the very first theoretical work on nuclear physics in Rome and the first in this field in Italy. In their dissertation topics the two young men were indeed both pioneers in every respect.[3]

In the fall of 1929 Gentile won a fellowship for further study abroad and went first to Berlin at the Institute of Theoretical Physics directed by Erwin Schrödinger. There he came in contact with the great German physicists of the time—such as Planck and Einstein—still in an era before the advent of the Nazi regime. Gentile

[2] Both Majorana and Gentile had in their personal libraries the first editions of the books by Hermann Weyl (*Gruppentheorie und Quantenmechanik*, 1928) and Eugene Wigner (*Gruppentheorie und ihre Anwendung auf die Quantenmechanik der Atomspektren*, 1931) as well as Luigi Bianchi's *Lessons on the theory of finite continuous groups of transformations*, Andreas Speiser's *Theorie der Gruppen von Endlicher Ordnung* and Bartel van der Waerden's *Die Gruppentheoretische Metode in der Quantenmechanik*. Majorana's investigations on group theory are largely present in his personal papers, preserved in his personal papers at Domus Galilaeana in Pisa. On Majorana and Gentile's interest in group theory see [16]. See also [17] for the onset of group theory in the new quantum mechanics.

[3] As mentioned in Majorana's letter to Gentile of 22 December 1929 (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1) a copy of his dissertation was requested by Johann Kudar, then in Berlin: "As soon as I will have confirmation of your new address, I will send you some of the well-known works of Fermi, as well as, for necessary deference to the desire expressed by the illustrious Kudar, the only copy in my possession of my dissertation." And actually, starting from January 1929, Kudar published a series of articles discussing the connection between quantum mechanics and radioactive decay, topics that were very close to Majorana's dissertation. A copy of Majorana's dissertation can be found in Gentile's papers, Box 7.

was stimulated by Fritz London to work on the valence bond theory [18], at a time when the latter had recently published with Walter Heitler his classic paper on the homopolar bond [19]. In April 1930 Gentile moved to Leipzig and worked under the direction of Werner Heisenberg until early August. Heisenberg's institute was a world-class research center, especially attractive for brilliant young physicists who came from all over the world. During his stay in Leipzig 1930, Gentile wrote in collaboration with Felix Bloch a work on magnetic phenomena of crystalline lattices that became fundamental for the theory of metals [20]. Heisenberg, like Fermi, was only five years older than Gentile and Majorana, who would visit Leipzig himself in 1933. Although Heisenberg was already very famous as one of the founders of the new quantum mechanics, he was quite informal and had a passion for chatting about physics with his collaborators, making them feel part of such a unique era of which he had been one of the protagonists. He was also an excellent pianist and a person endowed with great classical culture and deep interest in philosophy. Such characteristics, along with his boyish appearance, made him extremely fascinating in the eyes of the young Italians (Fig. 4.1). Moreover, as Bloch himself recalled [21, p. 26], one of Heisenberg's great qualities as a teacher was "his immensely positive attitude towards any progress and the encouragement he thereby conferred."

These months in Germany were a formative experience that left a deep and lasting mark on the young Gentile. He was back in Leipzig in January–March 1931, and on 12 November he took the free teaching (the "Libera Docenza") in theoretical physics.

Fig. 4.1 Heisenberg's Institute in Leipzig, 1931. Front row (L-R): George Placzek (sitting on desk), Rudolf Peierls and Werner Heisenberg; back row (L-R): Giovanni Gentile Jr., Gian Carlo Wick, Felix Bloch, Viktor Weisskopf and Fritz Sauter. Copyright: Alessandra Gentile

4.3 At Pisa University with Luigi Puccianti

In 1932, called by Luigi Puccianti, Gentile obtained a position in theoretical physics in Pisa. However, the environment at Puccianti's Institute for Physics turned out to be not very stimulating, after the impact with Fermi's lively group in Rome and in particular after the beginning of his friendship with Ettore Majorana and the later interaction with the great German theoretical school. Gentile lost his way as a physicist and had a period of poor scientific production, accompanied by an existential crisis.[4] The analogy with the case of Ettore Majorana is striking: after his return in August 1933 from his stay with Heisenberg in Leipzig—whom he deeply admired and spoke about enthusiastically in his letters to the family—Majorana no longer attended the Institute in Via Panisperna and did not publish anything until his masterly work: *The symmetrical theory of the electron and the positron* [23].[5]

Nevertheless, in these years of scientific stagnation Gentile devoted himself with passion to his cultural interests and to his epistemological reflections on physics, with which he had already been confronted at the time he was writing his thesis. In discussing the philosophical thought of Bohr, Heisenberg and Pascual Jordan, who he considered to all intents and purposes modern thinkers, he systematically dedicated himself to the diffusion of their ideas on modern physics with his activity of high popularization of science. In those years, he wrote also several entries on physics topics for the *Enciclopedia Italiana*, which he accepted with enthusiasm "because they dealt with classic questions of physics that are always of lively interest".[6] This group of essays was later published in a booklet entitled *Questioni Classiche di Fisica* [26]. The first one dealt with the "Experimental Method", to which Gentile attached great importance, as it related to the concept of the complex relationship between theory and experiment, which as a theoretical physicist concerned him very closely.[7] These texts were a manifestation of Gentile's cultural commitment to reflections on scientific culture—and its dissemination—with particular attention to modern physics, that in Italy was emerging in those years thanks to the pioneering work and institutional commitment of figures such as Enrico Fermi in Rome, Enrico Persico in Florence and Turin, Bruno Rossi in Florence and later in Padua, and their students and collaborators. Polvani's contribution to this panorama—especially because of the

[4] The last published work during his stay in Pisa is *Sopra la teoria della Rimanenza e della curva di Magnetizzazione*, submitted in December 1933, but of course it was related to research work arising from Heisenberg's deep interest in ferromagnetism [22].

[5] Nevertheless, Majorana continued to pursue his research interests and every year proposed free courses at the University of Rome submitting extremely advanced programs, but without any outcome [25]. Moreover, he was never offered any academic position during this period [24].

[6] Curriculum Vitae, G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[7] In this regard, see also [27]. Gentile's deep interest and involvement in reflecting on the epistemological and scientific implications raised by the theories that had profoundly revolutionized physics from the beginning of the twentieth century, were discussed by Maiocchi in the biographical entry dedicated to Gentile [7].

continuity he provided between the pre-war and post-war period—was to prove essential also in the reconstruction and revival of Italian Physics after the tragedy of World War II.

In Pisa Gentile already showed clear signs of his dedication to teaching. The lecture notes of his course in Theoretical Physics he edited at the end of the academic year 1933–1934, extremely advanced for the time, were published under the title *Lezioni di Meccanica Quantistica* [Lectures of Quantum Mechanics] [28]. They would deserve a more thorough analysis, in any case they are of extraordinary modernity with respect to the programs of physics courses of the time. Interestingly, they included sections dedicated to group theory, similarly to Majorana's proposed topics in his free courses.[8]

That was the time when Fermi's group in Rome was carrying out the fundamental experiments on neutron-induced radioactivity, which paved the way to the study of the structure of the atomic nucleus and eventually to the discovery in the late 1930s of the phenomenon of nuclear fission by Otto Hahn and Fritz Strassmann, an event that marked the transition to a completely new era in human history. Between 1934–1935, following the announcement of a competition by a publishing house for a monograph on modern nuclear physics, Gentile once again seized the opportunity to write a book that, if it could not entirely satisfy the interest of a physicist, could at least be useful to the chemist or engineer and in general to the cultured person who wished to know the fundamental ideas and concepts about nuclear physics and which are, so to speak, the basic tools in this research field [29]. Gentile immediately sent a copy of the book *Fisica Nucleare* to his friend Ettore Majorana, who on 20 June 1937 wrote words of appreciation: "[…] nothing similar has been seen in Italy long since, nor will it be seen so soon. It should really get into everyone's hands."[9]

Gentile's stay in Pisa lasted until 1936, when, according to Polvani's account [3, p. 149], "[…] following a new invitation from me to come to Milan, he accepted."

4.4 Finally Professor in Milan

In 1935–1936 Polvani finally succeeded in having the two degree courses in Physics and Mathematical Physics instituted and with the arrival of Gentile, by the academic year 1936–1937, it seemed that he had "touched the sky with a finger"[10]:

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[8] In the hapter on magnetic moments and vector model of the atom, Gentile introduces the fundamental concepts of reducible and irreducible representations of a group, concepts which are then used for the determination of the group representations of rotations and infinitesimal rotations and the selection rules for spectral emission. At that time no theoretical physics course included this kind of teaching.

[9] G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[10] From the text of the speech given by Polvani for the inauguration of the new seat of the Institute of Physics on 10 February 1964 [30, p. 38].

> […] the fundamental teachings, in addition to my own of experimental physics, were now in place. Gentile and Bolla were respectively in charge of Theoretical Physics and Higher Physics and Giacomini was in charge of Electrical Measurements […]. In short, it seemed that after six years of hard work, things were finally on a path of calm and profitable activity. In a word, the school of Physics was beginning to flourish…"

In October 1936, Gentile was put in charge of the Calculus of Probability and Theoretical Physics courses. He took his mission as a teacher extraordinarily seriously, as was in his nature. But he was also critical of himself, as he later wrote to his fiancée, Maria Vincenza Bartalini, a young scholar of art history, known as Nani[11]:

> I'm a bit too logical when I'm teaching, this gives a somewhat harsh tone to my reasoning. But my pupils love me and are passionate about me. This is already something, don't you think?
>
> I now have, for example, to think about a student who is doing his thesis with me. He can't get past certain difficult points. If I don't solve these difficulties, who can help him? Thus, we have to get down to work…

In that period Gentile edited new lecture notes, of which apparently only one copy exists, preserved in the library of Milan University.[12] The passion for teaching and the awareness of working alongside Polvani on the construction and consolidation of what was becoming an important center of Italian physics, soon led Gentile to find new motivations for his theoretical research. In Milan, Gentile brought atomic and nuclear physics, subjects with which he had come into contact during his six-month stay in Rome, immediately after graduation, and which he continued to study in Germany, also exploring novel paths following Heisenberg's research interests, such as ferromagnetism or the conductivity of metals, which prepared his mind for later even more challenging research topics.

One of his students was Carlo Salvetti, who had enrolled in physics in parallel with the arrival of Gentile in Milan[13]:

> My first interest was mainly in theoretical studies. As a student I had done very well, first with Polvani and then with Giovanni Gentile […] The textbooks were almost all German. He taught the Probability calculus course, but then he also taught metal theory. Really beautiful! I took the exam on electrons in metals …

Later Edoardo Amaldi would recognize in Gentile one of the most effective and enthusiastic teachers of their young scientific community [31]:

> Animated by a lively enthusiasm for research, he knew how to push and guide his students in their work, inspiring in them a very high respect for science and a deep love for culture.

Salvetti also recalled the feeling of having contacts with the international world of modern physics[14]:

[11] Gentile to Vincenza Bartalini, 2 and 22 February 1938. All excerpts from the letters to Nani, still kept by the family, are reproduced with kind permission of Alessandra Gentile.

[12] He was helped by his student Piera Pinto, who would later marry her fellow student Carlo Salvetti.

[13] C. Salvetti, interview by L. Bonolis, Rome, 18 July 2002.

[14] C. Salvetti, interview by L. Bonolis, Rome, 18 July 2002.

> There was a good atmosphere there, starting from the third year in particular, because there was Giovannino Gentile, who was instrumental in renewing the environment. He animated the group with seminars, inviting some physicists [...] including Piero Caldirola. And then also some mathematicians, especially those with a physical orientation, such as rational mechanics, and also mathematical physicists. These were seminars on theoretical physics...I learned a lot from these seminars. Gentile had probably learned this practice in Rome from Fermi and then certainly in Germany, where there was a great tradition in this sense [...] At that time there was a predominantly German culture, but I don't think only in Milan. In fact, the seminar participants came mainly from Germany and Holland. It seems to me that Thursday was the day when Gentile asked us students do seminars. Either he invited people from outside or he had us undergraduates do it. In my third year I had to give a very difficult seminar on the atom and the nucleus: on the Heisenberg-Majorana theory of the nucleus—with all the forces of exchange of nucleons—and, thus, for example, from the classical works to the Heisenberg-Majorana model...There were a lot of discussions! Yes, it was all really nice, indeed!

Gentile's interest in the foundations of physics led him in the second half of the 1930s to implement an ambitious publishing project dedicated to fundamental themes of the discipline, inspired by a similar work edited by the great mathematician Federigo Enriques, *Questioni riguardanti le matematiche elementari* [32].[15]

In Milan, Gentile's epistemological-philosophical interests well complemented with Polvani's growing commitment to the historical dimension of the physical sciences, that Gentile himself shared thoroughly.[16] The synergy resulting from the combined influence of Gentile's philosophical views on science and Polvani's commitment to the history of science cannot be undervalued, as there is no doubt that it exerted a deep impact on Gentile Jr.'s father, the philosopher Giovanni Gentile, who in 1939, during the centennial symposium of the Society for the Advancement of Science, launched the idea to create an institution destined to collect the relics of Galileo Galilei, the father of the experimental method. The project would lead to the foundation of the *Domus Galilaeana* in Pisa, the first institution devoted to the History of Science—whose first activities were also based on Polvani's extraordinary historical work on the physicists Antonio Pacinotti, Ottaviano Fabrizio Mossotti, Alessandro Volta—and of which the latter was also president for many years.

It is crucial at this point to emphasize how Gentile's reflections on the philosophical problems connected with atomic and nuclear physics, as well as with the methods of classical physics, were stimulated at that time also by his parallel involvement in the experimental research activities that were being carried out at the Physics Insti-

[15] Due to his early death in March 1942, when the first volume of *Questioni di Fisica* was nearly ready, Gentile was unfortunately unable to complete his project himself and the first volume was published by Sansoni after the war, edited by Bernardini and Polvani [33]. For this collection of essays Gentile had secured the collaboration of leading Italian physicists. Related papers and correspondence are in G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[16] Gentile helped Polvani to write an historical essay on the Italian contribution to physics during the years 1839–1939 [34]. See also, for example an unpublished manuscript on the evolution of the energy concept in its different aspects written with Vanna Tongiorgi, who later married Cocconi and was his collaborator in cosmic-ray studies (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 4).

tute and which he personally dealt with from a theoretical point of view. As Polvani recalled [3, p. 157],

> In that year in my institute Professor [Giuseppe] Bolla […] was studying experimentally the dependence of the polarizing effects of slits on their depth: and he found that the behaviour of very deep slits is totally and unexpectedly different from that, already discovered by Fizeau and interpreted by Rayleigh, relating to slits of very small depth, such as can be obtained by scratching very thin metallic films deposited on glass. The theoretical interpretation of the phenomenon, although clearly part of classical optics, was obscure and fraught with difficulties. Gentile immediately took an interest in the question, to which he soon made a new and substantial contribution […] in an extensive and beautiful work.

Gentile's article "Per la teoria degli effetti polarizzanti delle fenditure. Diffrazione della luce da due cilindri paralleli e indefiniti" [For the theory of polarizing effects of slits. Diffraction of light from two parallel indefinite cylinders] [35], attracted the attention of Arnold Sommerfeld, one of the deans of German physics, the beloved teacher and mentor of an entire generation of German theoretical physicists, notably Werner Heisenberg and Wolfgang Pauli. On June 23, 1937, Sommerfeld wrote Gentile a very long letter[17]:

> Dear colleague, since for 40 years I am struggling, and uselessly, with the problems of 'slits' I was very interested in your solution of the problem […]

Contacts between Sommerfeld and Gentile dated back at least to 1935, when Gentile arranged for Sommerfeld to be invited to give a seminar at the Scuola Normale Superiore on the theory of electrons in metals, one of the very first successful applications of quantum statistics developed by Fermi in 1926 and independently by P. A. M. Dirac.[18]

Gentile published his work on the theory of polarizing effects of slits privately, as a small volume for the Sansoni publishing house [35], which at the time belonged to his family.[19] The reason was that he was in a hurry, as it was his intention to use it for the national competition in theoretical physics, the announcement of which had appeared in the Official Gazette on 15 March 1937.

4.5 The 1937 National Theoretical Physics Competition: A Challenge for Gentile and Polvani

The national competition for a full professorship in theoretical physics was announced by the University of Palermo, where Emilio Segrè, Fermi's first student in Rome, had occupied the chair of Experimental Physics. It was the second in Italy in this discipline after the one won in 1926 by Fermi, Persico and Pontremoli.

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[17] G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[18] Gentile had been also asked at the time to write Sommerfeld's biographical entry for the *Enciclopedia Italiana* (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1).

[19] Giovanni Polvani, who had this article reprinted in *Il Nuovo Cimento* after the author's death [36], paid great attention to it in his account of Gentile's scientific career.

The deadline for submitting applications for the competition had been set by the Official Gazette at 15 June. Soon after, in an undated message, Gentile's father, who must have already received the news through unofficial channels, wrote to him a telegraphic message[20]:

> Competitors for Theoretical Physics. Gentile, Majorana, Racah, Wick, Pincherle, Wataghin. News received at this moment. Best wishes!

Three positions for 5 competitors, of which at least three of them (Majorana, Racah, and Wick) made the situation very delicate and not without risk for Gentile, who did not have many scientific publications to his credit.

Towards the end of August, Gentile received a letter from Majorana mentioning the competition[21]:

> Dear Gentile,
>
> I thank you for your letter and for your study on polarizing slits which I received some time ago. Although the subject is not familiar to me, I could see that your preparation is solid and complex even in this field of classical physics.
>
> As you must have guessed, I am still in Monteporzio, and I too look up to the sky (at the sea from afar) and I can see every day how the weather forecasts fail. I also cultivate astronomy.
>
> I think your deliberate distrust of Fermi, who spoke of you with the most sincere sympathy, is unjustified. As for the other members of the commission, either I have never seen them, or I have not seen them since ancient times. But it seems to me that at least one of them should have the authority and the will and the duty to testify for Giovanni Gentile[…]

In this last sentence Majorana implied that Giovanni Polvani was among the members of the commission, chaired by Enrico Fermi and including also Antonio Carrelli, Orazio Lazzarino and Enrico Persico.

Anxiety in Gentile's family was sky-high. Senator Gentile was even firmer than his son in his determination that Giovannino should be among the winners of the competition, and in fact another ten years would elapse before a new theoretical physics competition would be announced. On the other hand, since the beginning of his son's career, Gentile senior had intervened behind the scenes guiding his son's choices, but also using his influence as an academic, senator of the kingdom, director of the *Enciclopedia Italiana*, one of the most influential personalities in the cultural world of fascism. The family style was very patriarchal, but left room for deep union and affection within the family, as is amply testified by the family correspondence.[22] At the same time, he did so with a deep conviction of the value of his son, whose challenge of becoming a physics scholar he deeply admired and whom he felt was culturally and intellectually very close to him.

Giovannino was eventually included in the winning trio, from which he had risked being excluded mainly because of the presence of his own friend Ettore Majorana—whose scientific production was of an unquestionably high level— and because both

---

[20] Brief undated note (Giovanni Gentile Foundation for Philosophical Studies, Archive, Sapienza University, Rome).

[21] Majorana to Gentile, 25 August 1937 (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1).

[22] Giovanni Gentile Foundation for Philosophical Studies, Archive, Sapienza University, Rome.

Wick (first classified) and Giulio Racah, were ahead of him in terms of scientific work. The solution was to have Majorana appointed full professor "independently of the competition rules" because of "high and well-deserved reputation", excluding his nomination from the final triplet of winners.[23]

Everyone could certainly be satisfied with this epilogue, which in the final analysis made it possible to secure four chairs for theoretical physics in Italy, after ten years during which only Fermi and Persico had remained the only full professors in a discipline that at the end of the 1930s had yet to acquire a stable status in Italy.

4.6 The Beginning of Cosmic-Ray Research in Milan

On 27 January 1938, Gentile wrote to his fiancée Nani[24]:

> […] tomorrow I shall speak and give my, at least for you, famous lecture. I am as if absorbed in certain thoughts — which I like after all. An intellectual love this mine …".

The lecture he gave at the Mathematical and Physical Seminar in Milan, entitled "On the Limits of Electrodynamics and the New Experimental Results on Cosmic Radiation" was related to the recent discovery of the so-called mesotron of cosmic rays, a new elementary particle which was of great interest to theoretical physicists, as it could be the key to explain the apparent failure, at the high energies of cosmic-ray phenomena, of quantum electrodynamics, the quantum field theory of the interactions of charged particles with the electromagnetic field.

The subject, on which Gentile wrote a couple of articles [38, 39],[25] was also discussed in a letter written to Gentile by Gilberto Bernardini, who had been interested in cosmic-ray studies since his arrival in Florence, where he collaborated with Bruno Rossi, the pioneer of cosmic ray studies in Italy. When Rossi left Italy, Bernardini continued to cultivate research on cosmic rays, contributing to maintain in Italy the excellence of the research tradition started by Rossi. In this undated letter, which was certainly written in 1937, Bernardini was mentioning the recently formulated theory explaining the underlying processes and mechanisms of electromagnetic showers initiated by high-energy cosmic rays interacting with nuclei in the high atmosphere and producing cascades of photons, electrons and positrons. But in particular it clarified that such a theory could be reconciled with the observed phenomenology related to the penetrating component of cosmic rays hypothesizing the existence of a charged particle of both signs and mass intermediate between those of the electron and proton. One such a particle had been detected in 1936 by Carl D. Anderson and Seth Neddermeyer in cosmic-ray showers and named "mesotron". Because of

[23] For details on the competition see [37].

[24] Such personal correspondence is kept by the family.

[25] Both contain a post-script related to Heisenberg's work on similar topics that Gentile had discussed in June 1938. See also his article in *Scientia* [40] as well as his Preface and Appendix to the Italian translation of Jordan's book on twentieth century physics published by Sansoni [41].

its mass, it was thought to be the particle postulated by Hideki Yukawa in 1935 as the mediator of the strong force binding protons and neutrons in atomic nuclei.[26] Bernardini would have liked Gentile to make some calculations on the interactions of cosmic rays with the atmospheric layer at about 200 km height, which might be of "some interest."[27] Bernardini's high-altitude experiments would later give impulse to the researches carried out in Rome during the war by Marcello Conversi, Ettore Pancini and Oreste Piccioni, that eventually showed how the mesotron of cosmic rays could not be the particle hypothesized by Yukawa, because it interacted too weakly with nuclear matter, a remarkable experiment inaugurating "modern particle physics" [43, p. 241]. The identification of this particle, clarifying the mechanisms of the electromagnetic cascades in cosmic-ray processes brought such studies into the limelight as a fundamental instrument in the investigations of interactions at the nuclear level. Such topics aroused great interest in theoretical physicists such as Heisenberg, Hans Bethe, Homi Bahbha, and Fermi himself, who not by chance decided to work more actively on cosmic rays between 1937 and 1938.

Invited by Edoardo Amaldi, the recently graduated Giuseppe Cocconi, spent six months at the Physics Institute of Sapienza University in Rome where he worked with Fermi and Bernardini at the construction of a Wilson chamber to study the mesotron's decay modes. He was still in Rome when Majorana mysteriously disappeared. Cocconi completed the Wilson chamber in Milan where, since August 1938, laid the foundations for research in cosmic rays which were instrumental in training a new generation of physicists many of whom—including himself—would become particle physicists during the transition from cosmic-ray studies to high-energy physics with accelerators in the 1950s.

4.7 Ambitions to Launch "big science" at the Institute

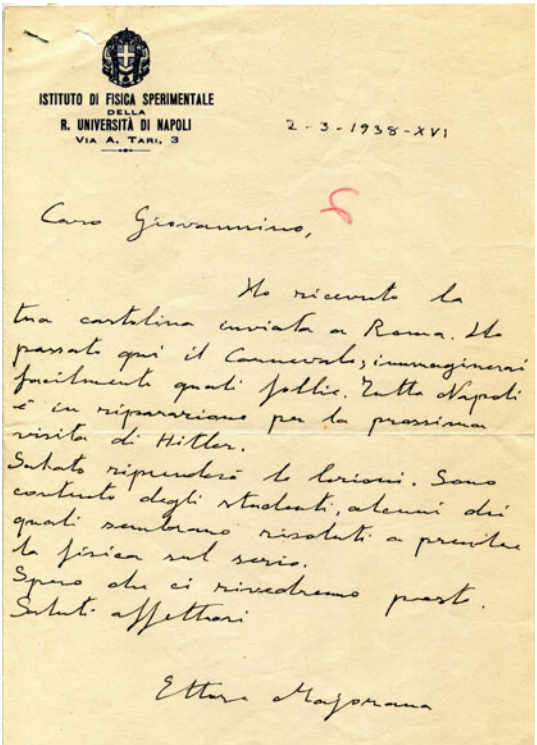
Between February and March Gentile's letters to his fiancée provide a glimpse into the lights and shadows of his life as a researcher and educator, but also into his inner solitude[28]:

> You asked me what is the meaning of that "boat waiting for the wind". You see, the shallows are those moments when we do nothing and we are dissatisfied with ourselves and everyone else. We look around us and see nothing but disappointment and regrets for lost opportunities. Then at a certain moment the work resumes — behind a cue, behind an inspiration that in general we can't quite figure out how strong it is in us. Doesn't this happen to you?
>
> [...] I'm certainly more relaxed now. Maybe because I'm starting to like Milan and maybe because I'm starting to see the fruits of my labors. Efforts, sometimes without a light to illuminate them; because in every activity there's always something that's just a job. Today, for example, I exhausted myself for half a day to verify a formula, given by a guy. There was a mistake in the sign, and it took a lot to get it out!

[26] For a wide discussion on such issues see Galison's article [42].

[27] G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[28] Gentile to Nani, 22 February and 3rd March 1938 (family papers).



ISTITUTO DI FISICA SPERIMENTALE
DELLA
R. UNIVERSITÀ DI NAPOLI
VIA A. TARI, 3

2-3-1938-XVI

Caro Giovannino,

Ho ricevuto la tua cartolina inviata a Roma. Ho passato qui il Carnevale; immaginerai facilmente quali follie. Tutta Napoli è in riparazione per la prossima visita di Hitler.
Sabato riprenderò le lezioni. Sono contento degli studenti, alcuni dei quali sembrano risoluti a prendere la fisica sul serio.
Spero che ci rivedremo presto.
Saluti affettuosi

Ettore Majorana

Fig. 4.2 Majorana's last letter to Gentile Jr sent from Naples on 3rd March 1938 (Copyright: Archive Physics Department, Sapienza University, Rome)

In that same March 1938, Majorana wrote from Naples—where he had his chair of theoretical physics—what turned out to be the last letter to his friend before his mysterious disappearance (Fig. 4.2).[29]

> Dear Giovannino,
>
> I received your postcard sent to Rome. I spent the Carnival here, you can easily imagine what follies. All of Naples is being repaired for Hitler's next visit.
>
> I will be resuming classes on Saturday. I'm pleased with the students, some of whom seem determined to take physics seriously.
>
> I hope we will see each other again soon. Warm greetings
>
> Ettore Majorana.

The following May Hitler visited Italy for a week. By that time, Austria had been incorporated into the German Reich, and Hitler's demand for annexation of the Sudetenland was setting the stage for the invasion of Czechoslovakia and later of Poland, which in turn would trigger the start of World War II.

[29] Majorana to Gentile, 2 March 1938 (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1).

In an undated letter—most probably written around May 1938, when the rumor circulated that Majorana had locked himself up in a convent—Gilberto Bernardini wrote to Gentile:

> Dear Giovanni,
>
> as you can imagine the news about Majorana were a real joy to me. It is not very nice maybe, but on the other hand it is not as tragic as we thought and we can be happy about it.
>
> I am also pleased with the news that you are going to Germany and I very much approve of your initiative. When you will be back we will agree for a real collaboration.
>
> Once in Heidelberg, you should do me the favor of asking Bothe in which period the Institute is closed during the summer. And, possibly, when you know, write to me. As I told you, I have received money from the Academy and I would like to go to Bothe, who is currently the smartest person in Europe.
>
> By the way, Bothe has put on a magnificent Van der Graaff. Now in Italy, and in Milan, a Van der Graaff would be just right and would have the advantage of costing relatively little (about 200.000 liras) […]
>
> See you soon Giovannino. Many affectionate greetings from your
>
> Gilberto

In the meantime, in April 1938, the Ministry of National Education, had in fact approved Gentile's request for a grant to be used for a study trip in Germany and Switzerland, that would include visiting laboratories where the first high-energy accelerators had been built in order to explore nuclear complex reactions in elements of intermediate and heavy atomic weight. This meant particles with energies well beyond those obtained by decay products of radioactive elements, such as those used by Fermi and his group in Rome or by the couple Irène Curie and Frédéric Joliot in Paris, for example. Apart from studies of nuclear processes performed by means of very high energy particles provided by cosmic rays, these investigations could be carried out by means of the first accelerators that were being developed at the time. However, there were very few of them around the world. By the mid 1930s, Walther Bothe's Institute for Physics at the Kaiser Wilhelm Institute for Medical Research in Heidelberg was the first in Germany to build a Van de Graaff band generator, and later, during the war, a cyclotron. This explains Gilberto Bernardini's enthusiasm for Gentile's opportunity of visiting Bothe's laboratory. Bernardini, now a professor in Bologna, often went to Rome to continue his experimental work there and together with Amaldi he later presented the ambitious project to build a cyclotron which could be used also as a research tool. They were not funded and at the moment cosmic rays continued to ensure the daily research life at the Roman Institute for Physics.

4.8 Back to Germany for a Strategic Trip

After several years Gentile remembered Germany with nostalgia. He missed the scholarly contact with the prominent figures he had known early in his career, the international context, as he wrote to his fiancée in May 1938:

I'm going back to Germany as if following an impulse that had been in my soul for many years. I like those cities. I like those wide, rich rivers […]

I am restless, I like my job, too, and I would like to do it well […]

My chess game? I am playing it with all of myself, otherwise it would be a trivial matter. But it's not only science, it's the whole life […] I'm going to Germany to get a little bit out of my scientific loneliness in Milan. I want to see what others are doing and talk with them.

In October, after a very satisfactory tour, during which he also had the opportunity to strengthen the intellectual ties that already bound him to the great German physicists, Gentile sent his report to the Ministry, in which he illustrated with passion, conviction and energy his very clear and ambitious ideas on what the Institute's objectives for the near future should be in terms of accelerator facilities for the study of the nucleus and related processes.[30]

I was in Munich with Prof. Sommerfeld, with whom I had the opportunity to discuss one of my works on diffraction of light and further work on different topics.

Then I went to Heidelberg, where I visited the Kaiser Wilhelm Institute, of which the director is Prof. Bothe. I was prompted to make that visit by the desire to question this professor about the possibility of building a van de Graaff machine of easy operation with which to start in our Institute of Physics in Milan researches of nuclear physics. Because I am convinced that also in our University of Milan the students themselves, as well as the professors, must be able to have the possibility to participate with a serious scientific work to the researches in this field. Our Institute of Physics in Milan, of recent formation, does not lend itself to modest research in classical physics, which have a relative usefulness and an interest almost of school exercises […]

From Heidelberg I moved on to Leipzig, where I stayed about four weeks: until the end of the German academic year. Leipzig was my main destination because I wanted to discuss the problems I am particularly interested in with Prof. Werner Heisenberg, with whom I had already worked in my previous trip to Germany in the years 1930–31 […]

From Leipzig I went to Berlin to visit the Kaiser Wilhelm Institute for Physics, whose director is Prof. Debye. In this Institute, besides a large high voltage plant, I was able to visit a very low temperature plant. The field of low temperatures would be the other field of physics in which would be useful to start the research for a serious scientific work. But I found that for such research the financial effort that a scientific institute would have to tackle would be much more relevant.

At the end of this report I can not help but note that if it is convenient in a nation to concentrate in a few institutes of high-level research the necessary means, even a University such as that of Milan cannot be satisfied with an Institute of Physics such as the existing one in which students often have to hear from a teacher about research done elsewhere and that they will not be able, I do not say to continue, but not even to repeat. In such conditions it becomes very difficult to initiate students in experimental work. On the other hand in nuclear physics, after the period of the first non-systematic researches, relatively inexpensive means have been devised for further research. My trip to Germany has confirmed me in this idea and I hope to present to His Excellency, in agreement with my colleagues, a well-defined program of research to submit to your high approval and obtain the necessary means.

[30] G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

By November 1938, Gentile was in full swing, and ready to begin a new academic year, as we learn from letters to his fiancée Nani, where he communicated his daily life and his reflections[31]:

> […] Today I had my first class this year—the audience increases and the work increases—I don't mind. I do care that in our University our institute counts for something, and on the other hand the students encourage us to start again every year the usual work, finding it new and fresher. Otherwise, imagine the boredom of repeating, or at most, to work scientifically always in the same situation.
>
> […] I have been very pleased with these five first lessons (if you've done well, afterwards you feel at least peaceful, if everything didn't go well, a sort of uneasiness remains, difficult to overcome […]
>
> I could read your last letter only in the afternoon, as I was invited at twelve o'clock to a banquet that the Marelli Factory gave in honor of Fermi […]

Those were Fermi's last days in Italy, before leaving for Stockholm to be awarded the Nobel Prize in Physics 1938 "for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons." In 1938, after the promulgation of the infamous racial laws by the Mussolini government, that threatened his own family, Fermi decided to emigrate to the United States immediately after the Nobel Prize ceremony in December. The second fundamental reason for Fermi's emigration was that he was refused funding for his project to establish a large national institute for radioactivity and nuclear research. This was due first of all to the loss of protection by Orso Mario Corbino (who had supported Fermi in particular having the chair for theoretical physics established in Italy and continued to do so during the years as director of the Physics Institute of via Panisperna) and by Guglielmo Marconi (Fermi's supporter as head of the National Research Council), who died both in 1937. Such circumstances were greatly exacerbated because of the growing economic commitment that was looming for Mussolini's Italy, which by that time was even more closely hooked to Hitler's chariot of conquest. The racial laws greatly affected the physics community, many were obliged to emigrate, others, such as Rasetti, decided to leave the country for political reasons.

In late 1938, while physicists in Rome were living with the sad realization that Fermi would never return from Stockholm, Polvani had taken Salvetti with him to visit the Guglielmo Marconi Institute of Physics in the new premises of La Sapienza University[32]:

> I was then in my third year and I was one of the most promising students […] Polvani dreamed of making a new institute because we were in the old building of the Rectorate, absolutely unsuitable for a scientific institute, so he wanted to go and see for himself and he took me with him. I don't know why, maybe because I was working at his lecture notes at that moment. At that time we were very few and he invited me to see two institutes that had been inaugurated quite recently.

[31] Gentile to Nani, 18–19 November and 1st December (family papers).

[32] C. Salvetti, interview by L. Bonolis, Rome, 18 July 2002.

> We went to Rome to see the Guglielmo Marconi Institute of Physics, brand new, just completed. He was interested in seeing how they had organized the structure, the services, the distribution, the teaching part, the research area…
>
> We paid another visit to Bruno Rossi's institute in Padua! A wonderful institute! He had made trips to Germany to visit other research institutes and had designed it down to the smallest detail; it was really a model institute. Then with the racial laws, shortly after completing it, he was thrown out! We arrived soon after, the institute was entirely new, brand new!

These events first, and the war soon after would deeply mark the fate of Italian physics for the next ten years.

4.9 Creating the Premises for Post-war Renewal

The 1939 year began with a happy event—on January 3 Giovannino married Maria Vincenza Bartalini—and ended with his appointment as extraordinary professor of theoretical physics in December (Fig. 4.3). In the meantime, he was following the thesis work of several students, who were working on research topics that interested him closely and on which he himself published articles.[33]

Gentile's influence on the philosophical and epistemological front is clearly visible in his former student Vittorio Somenzi, who later became professor of philosophy of science at the University Sapienza in Rome and was one of the first in Italy to study cybernetics and the emerging artificial intelligence, addressing from a philosophical point of view issues such as the relationship between mind-brain and mind-machine, which he introduced in the context of Italian studies.[34]

In fact, Salvetti himself, would have preferred to do a theoretical thesis with Gentile, but he had become very close to Polvani and thus did an experimental dissertation on the electronic amplification circuits to be used for the detection of phenomena related to the newly discovered phenomenon of nuclear fission, as suggested by Giuseppe Cocconi.[35]

> Cocconi and I had read the article sent in December 1938 by Hahn and Strassmann on fission, published in January 1939, and we were so excited—he especially, I did not understand it well at the time—that he insisted with Polvani that I should do an experimental thesis on uranium fission, but studying it from a physical point of view. It was about what a lot of physicists

[33] See for example Elisa Bonauguri's dissertation on the vector model of the atom, discussing the properties of the group of rotations as an expression of the spherical symmetry of the electron cloud, part of which was published in 1939 [44]. See also Gentile's article on the same topic [45]. After Gentile's death, in order to honor the memory of her teacher and his inspiring guide, Teresa Magri Materossi published part of her dissertation discussed in 1941 with the title *The problems of Lecher wires or propagation of electromagnetic waves along parallel wires*, in a special issue of *Il Nuovo Cimento* dedicated to Gentile [46].

[34] Somenzi's work, inspired by Gentile, was related to a theory on superconductivity formulated by Sommerfeld's collaborator Heinrich Welker [47, 48]. Somenzi's personal papers are preserved at the Physics Department of Sapienza University of Rome.

[35] The title was *Il metodo dell'amplificatore proporzionale a lampada per lo studio delle particelle elementari*. I am grateful to Leonardo Gariboldi for providing the exact title of Salvetti's thesis.

Fig. 4.3 Giovanni Gentile Jr. in Tuscany, at Forte dei Marmi, August 1939. Copyright: Alessandra Gentile

> had done since January in America, and before them in Copenhagen, that is to confirm the existence of fission with physical and not chemical methods. So they made me build—I did not know anything about electrons—a proportional amplifier. In Rome they gave me the design of their amplifier, the one they used at the Istituto Superiore di Sanità for the work with the accelerator of the Institute. So I built a linear accelerator—I had to get an electronic valve from Holland—and I also built an ionization chamber to detect fission products. I enjoyed it very much! It was a differential chamber, as it was called then, and I had to measure the range…so that went on for a long time. I couldn't see the fission products because I had some uranium salts—so that wasn't the problem—and I also had some beryllium, but it was a long time before the polonium discs for alpha radiation came from Rome. It was before the war, so the problem was that they had a big demand…With the polonium disks I would have done neutrons in reactions (α, n). For understandable reasons in that very turbulent period, I arrived at the degree without having been able to make measurements on fission products, but I obtained extremely beautiful curves of ionization of α particles! So beautiful that I graduated with an experimental thesis in June 1940 with 110 cum laude. And I had made an ionization chamber that was a dream! […] But I was not a 'war graduate'! I graduated at 3 o'clock in the afternoon of June 10. Then, at 5 o'clock we left to hear Mussolini's speech…one of his oceanic rallies…It was the announcement of the declaration of war…[36]

Difficult times began for the institute, but luckily as Salvetti recalled, they at least managed until 8 September 1943 to receive the *Physical Review*, which arrived through Switzerland even during the war. Between 1940–1941, the journal contained some articles by Donald Kerst in which he described the betatron, a new accelerating machine, in which electrons could reach relativistic speeds thus producing high-energy X rays once the beam was directed at a metal plate and which could thus be used also for medical therapy [50–52]. Especially after his trip to Germany, Gentile had become strongly interested in accelerators, and thus suggested the subject to Giorgio Salvini, who had taken the examination of theoretical physics with him in 1941 and wanted to write a theoretical thesis. However, while his work was

---

[36] After the discovery of nuclear fission announced at the beginning of 1939, a main topic of the utmost interest among physicists became the neutron cross section, which was directly involved in the mechanism of the nuclear chain reaction. In this regard, Gentile's student Carlo Borghi wrote a dissertation completed in 1940 on the neutron cross section and Compton effect, which resulted in a work published in the issue of *Nuovo Cimento* including articles honoring Gentile's memory [49]. Borghi would be in charge of the Calculus of Probability course after Gentile's death.

in progress (*Electron acceleration with magnetic induction pulses*), he received a telegram announcing that Gentile had tragically passed away. Salvini completed his dissertation in 1942, while he was still a soldier. Gentile however was no more there to enjoy another successful accomplishment of one of his students[37]:

> But today, sixty years after his death, I know how much scientific wisdom there was in him, how much originality of thought, how much desire to know, and above all how much ability to inspire his students to science. I am among those who benefited from him, who felt his drive and his generous trust.

Salvini was one of the first in Italy to have a unique knowledge about accelerators, a circumstance that determined his future role in the process of renewal of Italian physics after the war.[38] In 1946, with Carlo Salvetti, Giuseppe Bolla, and the engineer Mario Silvestri, Salvini promoted the foundation of CISE (Centro Italiano Studi Esperienze), the first Italian research facility dedicated to the peaceful development of nuclear energy, where a Cockcroft-Walton accelerator was operating since 1951. After conducting research on cosmic rays in Milan and for some time in US, Salvini became a professor in Pisa and then in Rome. When he was only 33 years old, thanks to his skills in particle and nuclear physics and his dynamic personality, as suggested by Amaldi and Bernardini he was appointed by the newly founded National Institute for Nuclear Physics (INFN) to lead the construction of an electron synchrotron. This new generation accelerator, the first powerful Italian accelerator went into operation in 1959 at the National Laboratories especially built in Frascati to host such machine. As director of the Frascati Laboratories, Salvini fully supported the proposal made in February 1960 by the Austrian-born physicist Bruno Touschek to explore the particle-antiparticle annihilation processes as a fundamental tool for studying the subnuclear universe. Touschek himself had begun his career working on the theory of a betatron built in Germany during the war, and had graduated in 1946 with a dissertation on this topic. The matter-antimatter collider AdA built in Frascati under Touschek's leadership, ushered a new era in high-energy physics [55].

In a sense, the small seed planted by Gentile fully developed following unexpected paths and flourished through cross-fertilization with other brilliant minds. At that time, Gentile and Polvani's pre-war dream of a high-energy facility was realized in Milan at the Institute for Physics with a cyclotron, which was built starting from 1960 and took its first data in 1965.

Carlo Salvetti, for his part, became Polvani's assistant and then professor at the Institute of Physics. He was one of the fathers of nuclear energy in Italy: in the 1950s he directed the realization of the Nuclear Center of Ispra and then became Director of Research of the International Atomic Energy Agency (IAEA); later he was Vice-President of the National Committee for Nuclear Energy (CNEN), continuing to be a leading figure in the promotion of Italian and European pacific use of nuclear energy.

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[37] G. Salvini, interview by L. Bonolis, Rome, 25 November 2004, 6 February 2005.

[38] See G. Salvini, interview by L. Bonolis, February–May 1998, Rome, in [54] and personal recollections in [53]. Salvini's personal papers are preserved at the Archives of the Physics Department of Sapienza University, Rome.

4.10 The Intermediate Statistics and Its Relevant Applications

Since the 1920s, Polvani had written about the kinetic theory of gases and later had been actively interested in quantum physics and quantum statistics of a monoatomic gas (the physical system discussed by Fermi to formulate his quantum statistics), issues on which he wrote articles between 1928–1933.[39] He also extended his research on the theory of gases to a gas of photons [62], in an article where he explicitly mentioned the three statistics (the classic Maxwell–Boltzmann, the Bose–Einstein and the Fermi–Dirac) and in particular Léon Brillouin's recent article discussing the three of them and the possibility of their unification, also implying the case of an intermediate statistics [63].[40] At the beginning of 1940, during one of their usual fruitful exchanges of ideas, probably touching such issues, Polvani asked Gentile the following question [56, p. 101]:

> But, purely on theoretical grounds, wouldn't one think that a statistics could be formulated in which the maximum number of occupation of a quantum state is any integer and positive number d? In particular if $d = 1$ we would have the Fermi statistics, if $d = \infty$ the Einstein statistics; for any d we would have the intermediate statistics between Einstein and Fermi.

In order to answer such a challenging question, Gentile formulated the law of statistical distribution of a quantized gas consisting of a finite number of indistinguishable particles for which it was assumed that in each quantum state there can be at most *a finite and determined number of particles*. The so-called intermediate statistics, was a natural alternative to the two well-known quantum statistics models: the Bose–Einstein statistics and the Fermi–Dirac statistics [57]. Fermions, such as electrons—having half-integer spin—have the property that at most one can occupy each quantum state while Bose–Einstein statistics allows any number of particles having integer values of spins, named bosons, to occupy the same quantum state. Both are in turn fundamentally different from the Maxwell–Boltzmann statistics that is applied in classical mechanics to systems of distinguishable particles. In this latter case, not only individual particles can be tracked, but there is no restriction in the number of particles that can occupy any state accessible to the system.

The impetus given by Polvani to address the problem of intermediate statistics was briefly recalled by Carlo Salvetti himself, who began to work on Gentile's statistics soon after he graduated in 1940.[41] The episode was also mentioned by Piero Caldirola in a memorial lecture on Polvani.[42] At the time, Caldirola, who was professor in Pavia, took an interest in the intermediate statistics and started a scientific correspondence

[39] See for example [58–60] and his famous "Il Diavolo e la Termodinamica" [61].

[40] Brillouin's article was later cited by Gentile [64, p. 493], who criticized Brillouin's method as not proper to treat the case of an intermediate statistics.

[41] C. Salvetti, interview by L. Bonolis, Rome, 18 July 2002. See also [65, p. 123]. Polvani, too, later recalled how he had challenged Gentile to investigate such a problem [3, p. 157].

[42] Manuscript given to the author by the late Carlo Salvetti in 2002.

with Gentile during the Summer of 1941,[43] related to an article he was writing on a more general formulation of the problem within quantum field theory [66].

By the end of December 1940, Gentile had ready his first article on the new quantum statistics, which began with the following observation:

> Whoever considers the two quantum statistics of Bose-Einstein and of Fermi–Dirac is naturally led to wonder which properties remain and which are modified, when we do not make any more the particular hypothesis (of Fermi-Dirac) that in an elementary cell there can be at most one particle, or the other, no less special, (of Bose-Einstein) that there can be any number, even infinite.

Gentile concluded his first article thanking his friend "Prof. G. Polvani for interesting discussions on this topic" [64].[44] After showing that from his general expression for the energy distribution of the particles one could derive the individual known distributions for bosons, fermions and for particles following Maxwell–Boltzmann classical statistics, Gentile showed that "intermediate" particles—as he named them—could exist that do not follow the two well established quantum statistics. With his new statistics, according to which the maximum occupation number of a level of energy was given by a finite number that could assume any integer value d between the two limiting cases, $d = 1$ (Fermi–Dirac statistics) and $d = \infty$ (Bose–Einstein), Gentile was launching an entirely new research field at the Institute that would be further developed between 1941 and 1942 with its remarkable applications to the exotic properties of liquid helium. And indeed, soon after, Gentile investigated the possibility of applying his statistics to the "the study of behaviour of matter at very low temperatures. A study that in recent years has led to the discovery of new, wonderful phenomena presented by liquid helium, phenomena that, for their uniqueness can only be compared to those, for many respects still so mysterious, of superconductivity in metals" [56, p. 96].

Only a couple of years before, between 1937 and 1938, the existence of superfluidity of liquid helium, and some related totally anomalous properties, had emerged as the result of research carried out by different scientists [70]. It was discovered that helium-4, a stable isotope of helium—the most abundant on Earth—has almost no viscosity at temperatures near absolute zero and can thus flow through the finest capillaries with no apparent resistance and give origin to the so called fountain effect, due to its capacity of flowing without friction even up the sides of its container. The phenomenon of superfluidity, is related to the phenomenon of condensation in which atoms behave like a gas of bosons thus leading to the so-called Bose–Einstein condensate, a new state of matter first predicted by Einstein in the mid 1920s. At temperatures very close to absolute zero a large fraction of bosons occupy the lowest quantum state giving rise to a strange and quite anomalous behaviour.

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[43] "Most illustrious Professor, I would like to report some results that I have reached after some considerations on the intermediate quantum statistics with the prayer for your judgment." Caldirola to Gentile, 18 July 1941 (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1).

[44] Gentile's statistics have been discussed in [67, 68]. For an outline of Gentile's work on the new statistics and its impact see also [69].

The fascinating and unique properties of liquid helium, as a manifestation at a macroscopic scale of the microscopic properties of such unusual quantum-mechanical system, were certainly striking. They clearly required a radically new interpretation and the nature of superfluid helium as a collection of bosons suggested Gentile the use of his intermediate statistics as a natural tool to find a theoretical explanation for the observed surprising phenomena [71]. Sommerfeld himself was especially intrigued by the possibility of using Gentile's statistics for liquid helium to get better results if compared with Bose–Einstein statistics. He gave a seminar in München that he closed with the words: "Gentile and I believe that the mystery of Helium II can be solved by the new statistics, which combines the statistics of Bose–Einstein and Fermi under a unified point of view" [72, p. 154].

The already mentioned correspondence with Caldirola in summer 1941 was also focused on such further relevant applications, on which the latter wrote later a new article [73].[45] Caldirola, who became professor of theoretical physics first in Pavia and then, in 1949, in Milan on the chair left vacant after Gentile passed away, had a leading role in the creation of the Italian theoretical school of solid state physics. Caldirola's early works on the intermediate statistics are never mentioned in his biographical sketches, but his discussions with Gentile and debates within the Institute about the physical foundations of the intermediate statistics and its wider implications in the context of the quantum theory of many-particle systems certainly had a role in orienting his interest in new research fields, different from the Italian dominating culture of nuclear and particle physics, which owed its prominence to the great tradition of studies established by Fermi and Rossi, and their collaborators.[46]

Those early research activities involved also Carlo Salvetti [77], who sent a draft of his second article to Sommerfeld [78], who in turn cited it in his own paper on liquid helium [79]. But as a follow up of this first burst of interest, others would explore the subject during the war and early post-war years, also stimulated by Sommerfeld [80–84].[47] Gentile's statistics proposed in a thermodynamical context was extended and developed during the years in very different realms, and in his honor such particles were named Gentilions, to distinguish them from the usual bosons and fermions.[48]

In January 1941, Gentile had become full professor of Theoretical physics at the Milan University (Fig. 4.4), but he did not live enough to enjoy the satisfaction for this achievement and continue his relevant investigations as he passed away after only one year, on 30 March 1942.

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[45] See also [74] and the review article on classical and quantum statistics [75].

[46] Caldirola revisited the subject of intermediate statistics in 1975, in a review article on the exclusion principle in which he recalled the debate that flourished at the time in the Milanese school and discussed its subsequent evolution and possible applications to modern physics [76].

[47] Antonio Borsellino, at the time working at Politecnico in Milan, demonstrated the incompatibility of Gentile's statistics with quantum field theory [85].

[48] See [86] and references therein.

Fig. 4.4 Giovanni Gentile Jr. with his wife Maria Vincenza Bartalini and their first daughter Erminia. Milan 1941. Copyright: Alessandra Gentile

Gentile's last article on the intermediate statistics and liquid helium appeared one month after his death [87]. Just a few days earlier he had felt delighted and proud of having invited Sommerfeld to lecture at the Seminario Matematico e Fisico in Milan.[49] In remembering the late "young friend" and his scientific legacy, Sommerfeld began his obituary with the following words [72, p. 151]:

> He was an outstanding scholar. Especially his last works secured him a prominent position in theoretical physics.

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