

2 Fermi in Italy: his manuscripts

2.1 The “Fermi Archive” at the Domus Galilaeana in Pisa

As is well known, from his time in high school (1918) to his departure for Stockholm and then for the United States of America (1938), Enrico Fermi carried out intense and productive scientific research in Italy. The results obtained by Fermi in this “Italian” period are sensational. In a special Section, at the end of the volume, we provide a list of all Fermi’s publications(*) in his Italian period, including minor works such as reports to conferences and contributions to non-scientific journals, expanding the list given in “Note e Memorie” (Collected Papers) [6], correcting some mistakes in the titles, and following chronological order. In some cases these minor publications are very useful in order to understand why Fermi made his strategic physics choices and why he adopted particular formulations. Fermi’s activity in disseminating scientific culture is really stunning, as is borne witness to by the numerous articles in the “Atti delle Riunioni della Società Italiana per il Progresso delle Scienze” (Proceedings of the meetings of the Italian Society for the Progress of Science), by lectures, and by contributions to journals aimed at the general public, such as *Sapere* [F145] and *Gerarchia* [F95].

Let us briefly run through some points in Fermi’s scientific output in Italy.

Let us first recall his work in 1926 “Sulla quantizzazione del gas perfetto monoatomico” (On the Quantization of the Monoatomic Ideal Gas) [F42], regarding the foundations of the quantum statistics of an ideal monoatomic electron gas, and more generally of a gas composed of particles that obey Pauli’s exclusion principle. Fermi’s statistics are historically called Fermi-Dirac statistics, due to the publication of similar results by Paul Adrien Maurice Dirac (1902-1984) a few months later, the result of independent research [63].

In 1927 the formulation [F56] of the statistical model of the atom appeared, followed by further developments and applications. This provides a semiquantitative method of calculating various atomic properties in the field of quantum mechanics. This model, which is still of great use, including in the field of astrophysics, is called the “Thomas-Fermi” model. Indeed Llewellyn Hilleth Thomas (1903-1992) had published analogous results a few months earlier [161] as far as the formulation of the model was concerned but limited only to the fundamental level.

(*) In this volume we refer to Fermi’s publications by their number in the list, preceded by F, *i.e.* [F1], [F2] etc., to distinguish them from the ordinary bibliography.

Fermi also arrived at the formulation of a quantitative theory of the hyperfine structure of spectrum lines (1930) from which the magnetic moments of many nuclei could be deduced [F73].

Furthermore Fermi presented an extremely simple and efficient formulation of quantum electrodynamics [F85] which formed the basis of the cultural and scientific training of an entire generation of Physicists in this area.

At the end of 1933 a theory of nuclear beta decay was proposed [F115], based on the hypothesis of the existence of the neutrino and on the remarkable idea that electrons did not pre-exist in the nucleus but were created, together with neutrinos, at the moment of their emission. This would then reveal itself to be the basis of all weak interactions between elementary particles. In March 1934 came the discovery of neutron-induced radioactivity [F120, 121, 122] and later the discovery of the effect of slowing them down [F140], followed by an in depth analysis of the properties of diffusion, absorption and slowing of neutrons in various material substances. For the discovery of neutron-induced radioactivity and the effects of slowing, seen also as the crowning achievement of his previous scientific activity, Fermi was awarded the Nobel Prize for Physics in 1938.

We are lucky enough to have here in Italy, at the Domus Galilaeana in Pisa, almost all the original manuscript documents relating to this intense research activity [106].

Altogether there are 27 notebooks, 9 laboratory notebooks, about 600 cards recording data, 38 manuscripts and typescripts, 39 letters, as well as a miscellaneous collection of personal documents. Most of this material, as Edoardo Amaldi tells us, was left behind by Fermi at the Physics Institute of the University of Rome before he left Italy permanently on 6 December 1938. After Fermi's death in Chicago on 28 November 1954 Amaldi, the only one of Fermi's associates still in Rome, after consulting the President of the Accademia dei Lincei Francesco Giordani (1896-1961) and various Colleagues, including Enrico Persico (1900-1969), Franco Rasetti, Emilio Segrè, decided that this material, together with other material recovered later in the house of Fermi's sister, should be entrusted to the Domus Galilaeana in Pisa, designated in the early 1940s as the key Italian institution for the study of the History of Science. This material is still housed today at the Domus Galilaeana, in safe keeping in two sturdy safes on the first floor of the splendid *palazzo* at 26 via Santa Maria, and it constitutes the so-called "Fermi Archive".

Amaldi observed in 1959, at the end of the article in which he presented "The Fermi Manuscripts at the Domus Galilaeana" [8] to the scientific community: "I am glad that these manuscripts are now kept at the Domus Galilaeana for future generations, beside other documents of men who have also honoured mankind with their thoughts and experiments".

To complete the picture we also make a few brief references to Fermi's academic career during his Italian period. He graduated in Physics at the University of Pisa on 4 July 1922 and was awarded the Diploma of the Scuola Normale Superiore on the 7 July immediately

following. In 1925 he obtained the *Libera Docenza*(*) in Mathematical Physics. He was one of the three winners in the competition for the chair in Mathematical Physics at the University of Cagliari which concluded on 21 January 1926. He came second behind Giovanni Giorgi (1871-1950) and ahead of Rocco Serini (1886-1864). There was a head to head contest for first place between Giorgi, who received three votes from the board members Giovanni Guglielmo (1853-1935), Carlo Somigliana (1860-1955) and Roberto Marcolongo (1862-1943), and Fermi who received only two votes from the board members Vito Volterra (1860-1940) and Tullio Levi-Civita (1863-1941). According to a belief widely held in the via Panisperna group “Fermi was rather disappointed and upset by the outcome of the competition which he thought was unfair”, as claimed by Emilio Segrè in the introduction to “Note e Memorie” [6]. In fact the only advantage of coming first of the three would have been that of being appointed immediately as Professor at Cagliari, as happened to Giorgi. Instead Fermi actually renounced the privileges of his second place, very chivalrously, in order that Rocco Serini, who had come third, could be appointed at Pavia.

In any case Fermi was not left without a chair. Indeed Orso Mario Corbino (1876-1937), a powerful Senator and Director of the Physics Institute of the University of Rome, immediately managed to launch a competition for the post of Professor of Theoretical Physics at the University of Rome. It was the first competition in Italy for this discipline. The examining board, made up of Gian Antonio Maggi (1856-1937), Michele Cantone (1857-1932), Antonio Garbasso (1871-1933), Quirino Majorana (1871-1957) and Orso Mario Corbino, unanimously put Enrico Fermi in first place of the three, followed by Enrico Persico in second place, with a majority of three votes out of five, and Aldo Pontremoli (1896-1928) in third place with a unanimous vote. Fermi immediately took up his post as Professor in Rome on 1 January 1927.

By Royal Decree on 18 March 1929, proposed by the Head of Government Benito Mussolini (1883-1945), Fermi was nominated as a member of the newly created Accademia d'Italia. Great satisfaction for this event is expressed in a page of notebook No. 2 at the Domus Galilaiana where Fermi noted “A VII - 18 - 3 - 29 - INCIPIT VITA NOVA – GAUDEAMUS IGITUR!” (A New Life begins - So let us Rejoice) (Fig. 2). It is one of the very few personal displays in a research notebook of Fermi's where he echoes the words of a well-known student song: “Gaudeamus igitur, Iuvenes dum sumus; ...”. Finally Fermi received the 1938 Nobel Prize for Physics from the hands of King Gustav V in the ceremony in Stockholm on 10 December 1938.

On a more personal note, which is relevant for our understanding of later events, we recall that in a civil ceremony on 17 July 1928 Fermi married Laura Capon, a member of Rome's Jewish community, the daughter of Admiral Augusto Capon (1872-1943), an extraordinary character with firm personal convictions who was also a nationalist writer using the pseudonym Adriacus. His life was interwoven with the history of the Italian navy. Augusto Capon's life came to a tragic end following the roundup of Jews on 16

(*) Qualification entitling Fermi to teach at university level [Translator's Note].

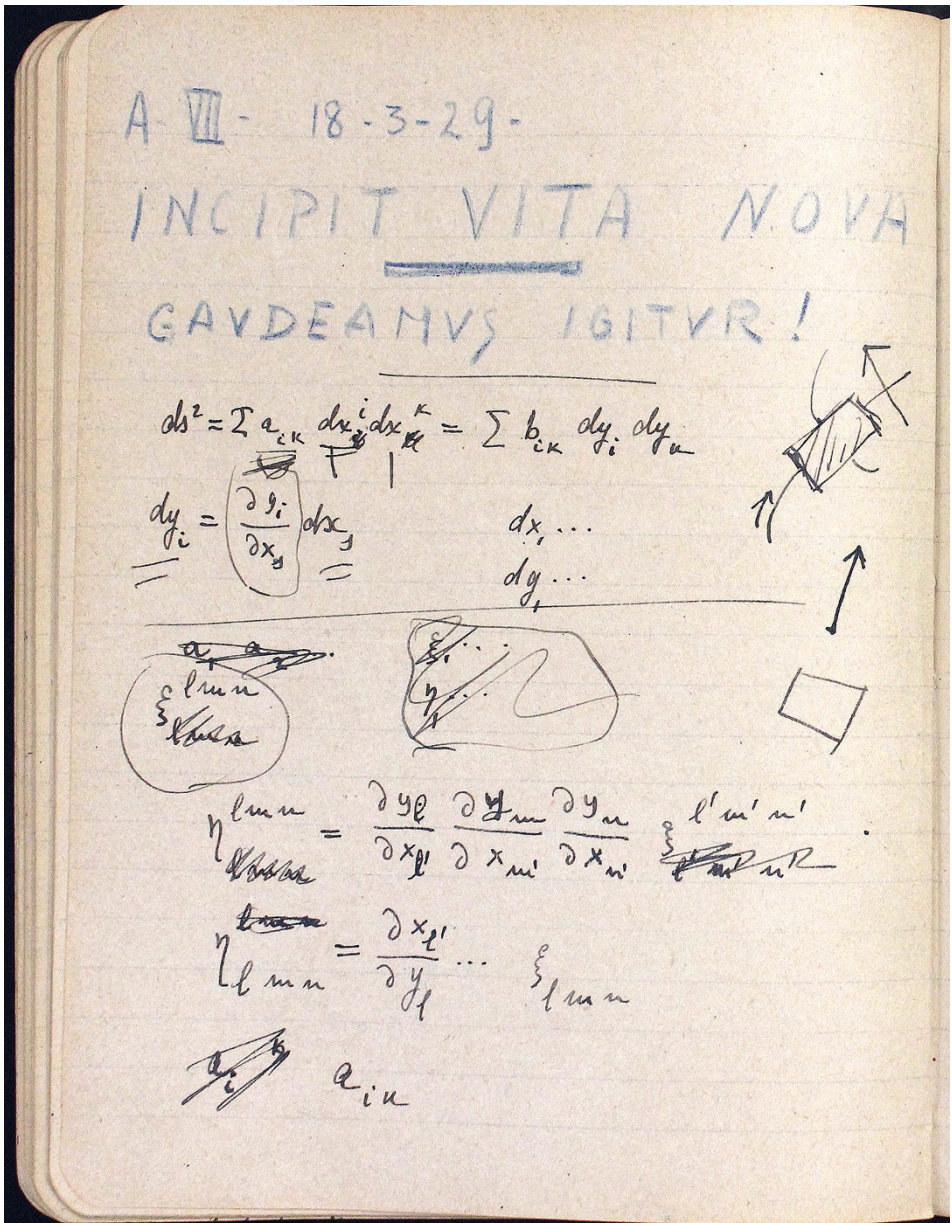


Fig. 2. – Fermi comments with satisfaction on his nomination as a member of the Accademia d'Italia (18 March 1929) - FDG.

October 1943 in Rome by the occupying German forces. Fermi's sister Maria told him about the dramatic day of Capon's arrest in a highly emotional letter, dated 4 July 1944 immediately after the liberation of Rome, which is preserved in the Fermi Archive at the University of Chicago.

Their children Nella (1931-1995), born on 31 January 1931, and Giulio (1936-1997), born on 16 February 1936, were baptized on 23 February 1936 in the church of Saint Bonosa in via Tirso according to a note in the Zanghi Archive at Sapienza University of Rome.

On the eve of their departure for Stockholm and the United States, on 5 December 1938, the Fermis also married according to Catholic rites, officiated by Monsignor Ernesto Ruffini (1888-1967), at the parish church of St. Roberto Bellarmino in Piazza Ungheria after Laura received the required baptism.

2.2 A gap in the Archive

A few years ago, when we began to study the birth and development of nuclear physics in Italy, consulting and reorganising the Fermi Archive in the Domus Galilaeana, we immediately noticed a strange gap.

The documents concerning neutron-induced radioactivity consist in all of nine laboratory notebooks and more than 600 cards of recorded data. They provide complete coverage of the experimental work carried out by Fermi and his team (Amaldi, D'Agostino, Pontecorvo, Rasetti, Segrè) in the period from 20 April 1934 until May 1935, when the research group was in practice disbanded, while Fermi's discovery of neutron-induced radioactivity was announced on 25 March 1934. So it seemed that more than a month of Fermi's research activity, in the decisive phase of the discovery, had left no written documentation. Recently however we found in Irpinia, at Avellino, two manuscript documents written by Fermi that cover exactly the period March-April 1934 and which allow us to fill in completely the gap we had met before.

It is a lined notebook of the same type as those entrusted to the Domus Galilaeana, characterized by the same brick red coloured cover and produced by the same Dutch company, together with a packet of 16 loose sheets.

The Irpinia notebook, we choose to call it that way to highlight its provenance, is lined, is made up of 78 pages and is written on both sides. The front of the notebook, which can be identified thanks to the paper mill's stamp at the bottom of the cover, is written by Fermi over 15 pages, numbered with circled numbers but without any dates, and is dedicated to problems relating to beta decay. The cover and some pages of the notebook and of the loose pages are shown in chapter 11, pp. 179-227. We indicate by Qf# the pages in the front of the notebook, by Q# the pages numbered from the back, and by S# (S#a) the front (back) pages of the loose sheets.

After the first fifteen pages, where these theoretical calculations are reported, the notebook was turned upside down so it could be used as a laboratory record for Fermi's subsequent experiments on neutron-induced radioactivity. This side of the notebook is composed of 141 pages, numbered by Fermi, with the first date, 27 March 1934, written

at the top of page 44 (!), and the last, 24 April, written on page 140. This notebook contains both the preparatory procedures for the experiments and the entries of the measurements taken during the months of March and April 1934.

So the dates, but above all the contents, allow us to identify this notebook as Fermi's first notebook on neutron-induced radioactivity and therefore the notebook of the discovery.

The loose sheets however start with the date 7 April 1934 and end on 20 April 1934 and therefore they concern the research carried out immediately after the discovery. They are written on both sides and, as we have been able to establish, were ripped out of another laboratory notebook, also on neutron-induced radioactivity, stored at the Domus Galilaeana. This notebook is identical to the Irpinia notebook, produced by the same firm, and was mainly compiled by Segrè so that it is conventionally known as the "Segrè Notebook", indicating "20-4-34" as the first date written at the beginning of the notebook. The notebook clearly shows that the first part had been forcibly ripped out. Moreover on the first page is the deep impression of some numbers, heavily traced in pencil on the last page but one of the 16 Irpinia pages.

So Fermi, after using and filling up the first Dutch notebook, presumably bought during his visit to Leiden a few years before, moved on to recording data in the second notebook. Around 20 April he tore out the 16 pages, which are the consistent continuation of the first notebook, and he passed the second notebook to Segrè so that he could record the measurements that had been assigned to him. In an initial phase these concerned the evaluation of the absorption of radiation in matter and are not directly connected to neutron-induced radioactivity.

Moreover, at the end of the last page of the bundle of 16 pages, "end of measurements / Segrè Notebook" is written. The handwriting of this note is Fermi's. Very probably Fermi intended to indicate with these words that the first phase of the research had been concluded. The results were reported in the first three publications under his name alone: the two letters to "La Ricerca Scientifica" on 25 March [F120] and in early April [F121] and the letter to Nature on 10 April [F122]. A new phase was opening up which directly involved his collaborators.

The story of the Irpinia notebook and of these 16 pages is very remarkable, as is that of their discovery.

Ever since way back in 1978, the Library of the Istituto Tecnico per Geometri "Oscar D'Agostino" in Avellino, later merged into the "De Sanctis - D'Agostino" Istituto Superiore di Istruzione Secondaria, has housed all the archive material that had belonged to Oscar D'Agostino (1901-1975), a chemist born in Avellino who had cooperated with Fermi in his research into neutron-induced radioactivity in the period 1934-1935.

This material was donated by Mrs Sofia Melograni, D'Agostino's widow, when the school was named after her husband in October 1978. On this occasion the "Oscar D'Agostino Foundation" was also established with the task of preserving this material and of offering scholarships in Oscar D'Agostino's name to particularly deserving students at the school.

Over the following years the "Oscar D'Agostino Archive" has been the subject of ex-

hibitions and of some publications, in which some parts of it have also been reproduced. A preliminary inventory was compiled by Giovanni Acocella, a scholar of the History of Physics from Avellino, connected with the “Federico II” University in Naples, and presented by him at the XXII National Conference on the History of Physics and Astronomy which was held in Genova-Chiavari on 6-8 June 2002 [2]. Following this presentation, in July the same year, since at that time we were investigating Fermi’s discovery of neutron-induced radioactivity, we joined Giovanni Acocella at Avellino in order to study in depth the contents of the D’Agostino Archive, hoping to find information about the chemical aspects of the research carried out in Rome into neutron-induced radioactivity since D’Agostino was acknowledged as the “group’s Chemist”. It was then that, to our great surprise, we discovered Fermi’s notebook and the bundle of 16 pages amongst D’Agostino’s papers. These documents had been ascribed to D’Agostino and had been classified as “Notebook No. 3” and “Notebook No. 4”, respectively. Moreover some pages of “Notebook No. 3” had already been published as “D’Agostino’s Notebook”, even if the handwriting and the contents are clearly not D’Agostino’s but Fermi’s.

It is difficult to establish why these two documents, which represent the initial missing gap in the Fermi Archive at the Domus Galilaeana, ended up in D’Agostino’s personal archive. Perhaps a possible answer is suggested by the Irpinia notebook itself which shows us, on the basis of the handwriting, that Fermi’s first collaborator after the discovery was actually D’Agostino. So one might think that D’Agostino’s initial, and as we shall see later, constant presence, above all in the early stages of the research, is a reason why these documents are now in Avellino. It is possible that they were given to D’Agostino personally by Fermi, as a testament to the contribution made by this Chemist, who is often relegated to a subordinate and marginal position in historiographical reconstructions, but whom Fermi however always recalled in his writings and thanked meaningfully. Another possibility is that after Fermi’s death the notebook and the 16 pages were handed to D’Agostino by Amaldi so that he could have a memento of the period of his collaboration with Fermi.

2.3 How to proceed

The Irpinia notebook is very important, apart from its historical significance, because it represents the only direct and structured testimony of Fermi’s discovery of neutron-induced radioactivity and it allows us to reconstruct the initial phase completely on the basis of objective documentation.

With regard to this first phase, the only document available to us was Fermi’s Letter dated 25 March 1934 to “La Ricerca Scientifica”, which at that time was the Official Journal of the recently founded Consiglio Nazionale delle Ricerche-C.N.d.R. (National Research Council), in which he announced the discovery [F120]. However this Letter is very concise, as we shall see. It only contains the essential information about the results without reference to the procedures followed. The same concision is to be found both in the second Letter to “La Ricerca Scientifica” [F121], and in the Letter to “Nature” [F122], written by Fermi immediately after the discovery, and also in the first extensive article written on the subject by Fermi and sent to “Il Nuovo Cimento” in May 1934

[F131].

Instead the Irpinia notebook affords a detailed reconstruction of all the experimental steps taken by Fermi, of his working rhythm, of his choices in methodology as well as in strategy, in the culminating phase of the discovery.

Moreover, together with the 16 loose sheets and the last 22 pages of a notebook of Amaldi's which we will discuss in chapter 8, it allows us to reconstruct the birth around Fermi of his first working group and the way it operated in this initial moment.

Finally, by analysing the Irpinia notebook, in the light of another of Fermi's laboratory notebooks stored in the Domus Galilaeana which Fermi himself named "Thesaurus Elementorum Radioactivorum" (Fig. 3), it is possible to establish the exact day and hour when Fermi discovered neutron-induced radioactivity: it was Tuesday 20 March 1934, around two o'clock in the afternoon, after a feverish night spent fine tuning the counter and the amplifier and repeated background measurements.

In any case, before proceeding with an analysis of Fermi's discovery which is the main focus of our book, we thought it was appropriate, as we have already anticipated in the introduction, to set this discovery both in the framework of the Physics of the time, giving ample space to the development of Nuclear Physics, starting with the first International Conference on Nuclear Physics organised in Rome in 1931, to the discovery by Frédéric Joliot (1900-1958) and Irène Curie (1897-1956) of alpha particle-induced radiation announced on 15 January 1934 [59], and also in the more specific context of the research carried out in Rome with regard to the atomic nucleus, from the first beginnings with the *Laurea*(*) Thesis of Ettore Majorana (1906-1939) in July 1929, to the creation of a bismuth crystal spectrograph to study gamma radiation (November 1933) and the production of a source of radium D from which polonium could be periodically extracted (December 1933), which in practice were never fully used.

(*) The *Laurea* is the degree issued by the Italian Universities that includes a research thesis and leads to the title "Dottore". It is therefore of a higher level than a Bachelor degree in American or British Universities.

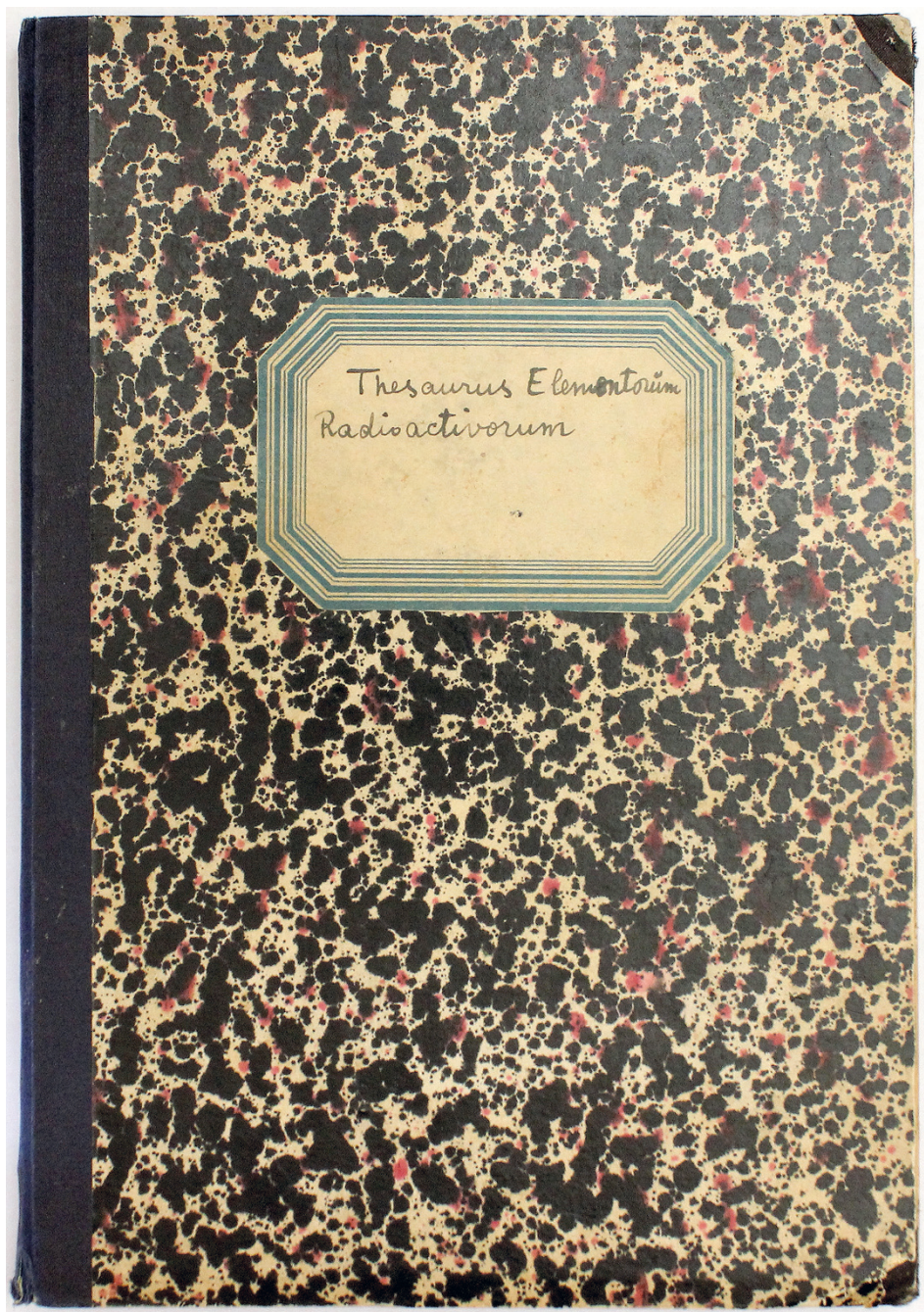


Fig. 3. – The laboratory notebook that Fermi named “Thesaurus Elementorum Radioactivorum” (1934) - FDG.

The Lost Notebook of ENRICO FERMI

The True Story of the Discovery of Neutron-Induced
Radioactivity

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