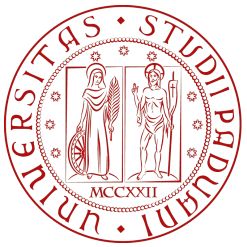

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Bruno Rossi and Italian Cosmic-Ray Physics: Padova and the Expedition to Eritrea

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"In any case, whenever technical progress opened a new window into the surrounding world, I felt the urge to look through this window, hoping to see something unexpected."

— Bruno Benedetto Rossi (upon receiving the Rumford Prize, Cambridge, 1976)

Contents

Abstract

After the discovery of cosmic rays in 1912, only in the late 1920s did physicists begin to debate the nature and origin of cosmic rays. The Venetian physicist Bruno Rossi (1905-1993) was one of the first to entirely dedicate his career to this new and fascinating subject. The people and students he collaborated with, while working in Florence first and in Padua later, were to become prominent researchers in different fields of experimental physics, both in Italy and abroad. Gathering fragmented and unpublished material, this dissertation will focus on his work during the interwar period and the influence it had on the development of physics. Particular attention will be paid also to the socio-political aspects of Rossi's life and career, as he was a Jew and thus suffered from the infamous fascist Racial Laws, which forced him and his wife to leave Italy.

1. Moments in the Life of a Scientist[1]

Let us begin by recounting the main stages of Bruno Rossi's personal and academic life, focusing on the Italian period. Most of what will be treated in this chapter can be found in [9, 22, 27, 28, 70, 71]. We refer the reader to these references for further and more detailed information.

1.1 Early life and education (1905-1927)

Bruno Benedetto Rossi was born in Venice in 1905, the eldest of three children. His father Rino Rossi (1876-1927) was from Bologna, while his mother Lina Minerbi (1868-1967)[2] was from Ferrara. After marrying, his parents had moved to Venice, where his father, as an electrical engineer, worked on the electrification of the city.

Bruno Rossi remembered that, as a child, the research of regularities and cause-effect relations were the first hint of his scientific attitude. An attitude that was soon to become a long-life commitment to the development not only of cosmic-ray physics but also of many other research fields.

Figure 1.1: Rossi's university card.

After being tutored at home until the age of fourteen, he attended the ginnasio - liceo classico "Marco Polo" in Venice. He first studied engineering at the University of Padua and then physics at the University of Bologna, where he graduated with a thesis on imperfect contacts between metals. His supervisor was the physicist Quirino Majorana (1871-1957), uncle of the more famous Ettore Majorana (1906-missing since 1938).

[1] Title of his autobiography [70].

[2] One of her siblings was the famous sculptor Arrigo Minerbi (1881-1960).

Rossi didn't keep fond memories of the physics education he received at those universities, while he very much appreciated the mathematical courses delivered by the great professors he encountered, such as Gregorio Ricci Curbastro (1853-1925) and Ernesto Laura (1879-1949) in Padua or Salvatore Pincherle (1853-1936) and Pietro Burgatti (1868-1938) in Bologna. Regarding physics, he was very grateful in those years to Orazio Specchia (1890-1961), who allowed him and other two students to freely use the laboratory of the Istituto "Augusto Righi" in Bologna, where he spent a lot of time practising with optical instruments. He also appreciated very much Rita Brunetti (1890-1942), describing her course as "*un 'vero' corso di fisica*" (cf. [70], p. 3).

1.2 *Lo spirito di Arcetri*[3] (1928-1932)

In 1928, thanks to Brunetti's presentation, Rossi became one of the assistants of the physicist Antonio Garbasso (1871-1933)[4] at the University of Florence. The Experimental Physics Institute was located among the olive trees in Arcetri, not far from the mansion where Galileo spent his last years in exile. About this period he said that "*probabilmente i quattro anni che ho passato ad Arcetri sono stati i più belli della mia vita*" (cf. [71], p. 33).

The group of colleagues and students he worked with was very young (he himself was not even 23) and, as usual in Italy at those times, quite small. This allowed them to give birth to an interweaving of both scientific collaboration and friendship which resulted in fruitful and dynamic research activities. The group was composed by Gilberto Bernardini (1906-1995), Giuseppe (Beppo) Occhialini (1907-1993), Guglielmo Righini (1908-1978), Beatrice Crinò (1913-1954), Giulio Racah (1909-1965), Lorenzo Emo Capodilista (1909-1973) and Daria Bocciarelli (1910-2006). Another positive influence in Arcetri was the astronomer Giorgio Abetti (1882-1982), director of the local observatory: Abetti and his group of astronomers were the first to put Rossi in contact with the physics of the universe. Furthermore, Abetti weekly organized a seminar gathering together physicist and astronomers, a very appreciated initiative that favoured the exchange of ideas among them.

Despite the poor instrumentation available, Rossi managed to find his way into the field he was about to give fundamental contributions to, that is cosmic rays. Indeed, in the autumn of 1929 he read and was fascinated by an article of Walter Bothe (1891-1957) and Werner Kolhörster (1887-1946) [8], who first questioned the nature of that radiation. They employed two Geiger-Müller tubes, developed by Hans Geiger (1882-1945) in 1913 and recently improved with the help of Walther Müller (1905-1979), putting materials of different composition and

[3]This is the definition used in [71] (p. 34) to describe the particular atmosphere Rossi and his colleagues enjoyed in those years at the Experimental Physics Institute of the University of Florence in Arcetri.

[4]It is worth recalling that Garbasso was also the mayor of Florence from 1920 to 1927 and then *podestà* until 1928. Being thus quite detached from research, he placed his trust in the group he was head of, supporting it economically and politically. His role can be compared to the one played by Orso Mario Corbino (1876-1938) with the so called *Ragazzi di Via Panisperna* in Rome.

Figure 1.2: Bruno Rossi, Giuseppe Occhialini, Gilberto Bernardini and Daria Bocciarelli (from left to right) outside the Experimental Physics Institute, Arcetri 1931.

size in between. If both the counters were triggered, it meant that the same ionizing particle had managed to cross them all. They found that the detected radiation was able to penetrate at least 4.1 *cm* of gold.

Since their discovery in 1912 by Victor Hess (1883-1964)[5], primary[6] cosmic rays were naturally considered as composed by gamma radiation "*per una serie di pregiudizi che oggi sarebbe difficile giustificare*" (cf. [71], p. 35). In particular, the most penetrating rays known at the time were gamma rays, whose penetrating power was thought to increase with energy and whose interactions composed only of Compton scattering[7]. Hence, cosmic rays, the most penetrating rays known, had to be of that kind. Now this hypothesis was directly challenged, as the scattered electrons, due to their charge and light mass, had weaker penetrating power than what Bothe and Kohlhörster found. The scientific community split into those who supported the so-called undulatory hypothesis, advocated by Robert Millikan (1868-1953), and those who supported the corpuscular hypothesis instead, advocated by Arthur Compton (1892-1962) and

[5]For the sake of precision, the Italian physicist Domenico Pacini (1878-1934) published in the same year a paper where he arrived to similar conclusions after analogous experiments (conducted underwater instead of up in the atmosphere). Though having been carried out even before the ones by Hess, these experiments were not as precize, thus not worth the priority of the discovery.

[6]Primary refers to the rays that hit the atmosphere coming from space, while their interactions with the latter give rise to secondary radiation, that can be collected on the surface of the Earth.

[7]Compton scattering is the process in which a photon (quantum of the electromagnetic radiation) hits an electron. As a result, the electron acquires energy and accelerates away, while the photon is deviated and looses energy.

by Rossi himself.

As just said, in this debate Bruno stood for the corpuscular hypothesis and became passionate about the issue. In just a few weeks, he developed a multiple coincidence electrical circuit[8], which permitted to partially automatize the acquisition of the measurements and discard false coincidences between various Geiger-Müller counters with more precision. Such innovation, which will also be later employed in the development of the AND circuit, was just the first of a long series, pointing out his unique experimental abilities and imagination. The circuit was to be the basic instrument adopted by physicists for cosmic-ray research in the following years, besides leading to an always growing use of electronic components in nuclear and subnuclear experimental physics.

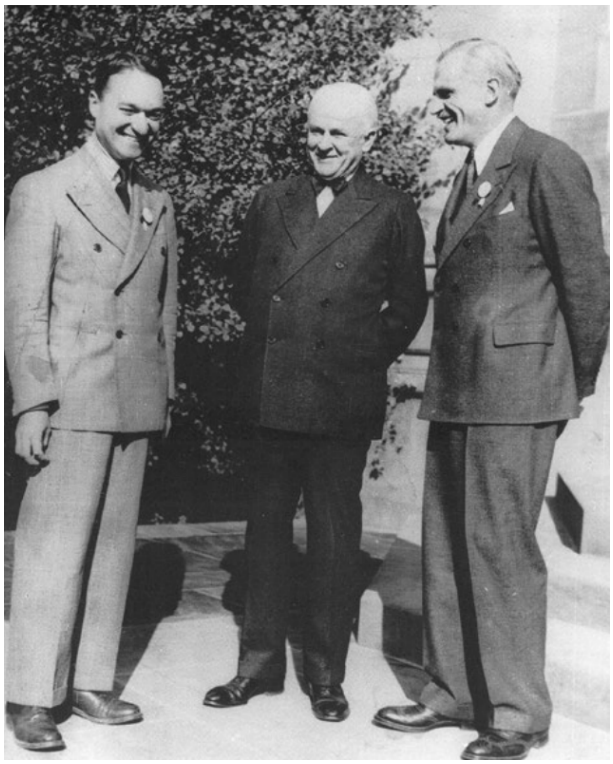


Figure 1.3: Bruno Rossi, Robert Millikan and Arthur Compton (from left to right) at the Nuclear Physics Congress of the Reale Accademia d'Italia, Rome 1931.

In 1930 Rossi asked Bothe to let him work at Reichsanstalt laboratory in Charlottenburg for a few months. So, in the summer he arrived in Germany, where Berlin was "*il cuore della fisica moderna*" (cf. [70], p. 13). There he met for the first time Patrick Blackett (1897-1974), visiting from England, who would later be of great help to him. Rossi's activity there resulted in showing that cosmic rays were even more penetrating than what was found before, and that they had some new peculiarities which were still to be understood. This strengthened Bothe and Kolhörster's results, as only charged massive particles could have such a penetrating power (only protons and electrons were known back then). As a consequence, Rossi also became

[8]Which recorded the simultaneous occurrence (coincidence) of two, three or more electrical pulses arriving from the different counters.

interested in the geomagnetic effects on the radiation, beginning to consider a possible East-West effect, that is a difference in the number of cosmic rays proceeding from East or West according to the possible charge of the primary particles originating them. Another theoretical finding was the latitude effect, according to which the cosmic-ray flux decreases while moving from large to small latitudes[9].

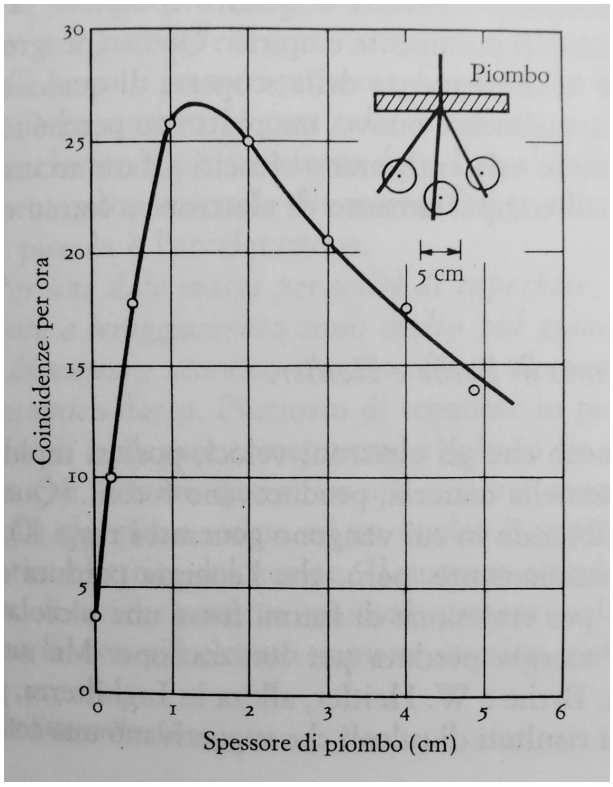


Figure 1.4: Rossi Curve and the related experimental set-up as presented in [69].

Back to Arcetri, one of the main findings was the so-called Rossi Curve. Rossi put three Geiger-Müller counters in a triangular arrangement on the same vertical plane, as shown on the top right corner in figure 1.4, so that a single particle could not pass through them all. This way, only the showers of particles stemming from the newly discovered interactions of cosmic rays with matter could be responsible for these triple coincidences[10]. The Rossi Curve is the plot of the frequency of these triple coincidences as a function of the thickness of the shielding which contains the counters (see again figure 1.4). Along with previous results, this led to the classification in two different components of cosmic rays: a soft component, which does not penetrate so much but produces a lot of showers (they were found to be photons and electrons and, after the discovery of the positron in 1932, physicist showed that also this new particle is present in the showers), and a hard component, which is more penetrating yet produces fewer

[9]This effect was to be soon studied in depth by Compton in the years 1930-32 and published from 1932 on [11]. We will come back to his experiments later on in the present dissertation, as Rossi will be involved in one of them by Compton himself.

[10]Rossi found here, and later on in similar experiments, an excess of random triple coincidences. They were due to the still unknown phenomenon of extensive air showers originated from the interactions of cosmic rays with air before reaching the apparatus.

showers (composed of particles first called mesotrons, then muons, which will only be officially discovered in 1937). We know today that his interpretation lacked the fact that those processes are mediated by pions. He actually observed showers emerging primarily from the interaction of pions with lead nuclei, or even from electrons, positrons and photons generated in turn from interactions of pions with air before reaching the apparatus. The hard component, that is muons, was instead not responsible for the showers.

His friendship with Blackett was useful to introduce Italian physicists to cloud chambers. Beppo Occhialini was looking forward to spending some time abroad, so in 1931 Rossi sent him to Cambridge. There, Blackett and Occhialini managed to create a counter-controlled cloud chamber, which eventually allowed them to visualise and photograph showers systematically for the first time. In 1932 the American physicist Carl David Anderson (1905-1991) photographed, with a less sophisticated apparatus, the track of an unknown particle with mass comparable to an electron yet with positive charge. Anderson did not recognise it as a positron at first, while Blackett and Occhialini, who were in direct contact with Paul Dirac (1902-1984) and got to observe several pictures of the new particle, confirmed that it was exactly the particle that the British physicist had predicted in his theory of the electron back in 1928. Indeed, they correctly interpreted some of the tracks as the production of electron-positron pairs. Furthermore, the very different ways in which these showers appeared (besides electron-positron pair production) opened the eyes of the physical community onto the plethora of interactions and of particles that they had the difficult task to analyze and comprehend in the decades to come.

Meanwhile, in 1931 the Reale Accademia d'Italia, chaired by Guglielmo Marconi (1874-1937), held a congress in Rome where physicists from all over the world who were interested in nuclear physics and related topics gathered together. Rossi was invited by Enrico Fermi (1901-1954) to give an introductory speech about cosmic rays, where he presented different pieces of evidence leaning toward the corpuscular hypothesis. The undulatory scenario was getting more and more unlikely as further results were published, and was to be soon completely discarded.

One of the last important results Rossi obtained in Arcetri stemmed from a productive collaboration with Enrico Fermi (1901-1954). In 1931 Rossi tried to look for the East-West effect in Florence, getting to no conclusion. Rossi and Fermi then demonstrated that it was impossible to observe it at Florence altitude and latitude, as a combination of great height above sea level and low latitude would be ideal. An expedition was thus what they needed in order to verify or disprove the effect. The place was chosen to be Asmara, the capital of the then Italian colony of Eritrea, at a height of 2370 meters above sea level and a magnetic latitude of $11°30'$ North. The expedition, highly supported by Garbasso, initially encountered difficulties due to the need of funds (which has always been a problem for scientific research in Italy) and to Rossi's imminent move to Padua, where he was appointed to the experimental physics chair. Unfortunately, this delay cost him and his group the priority of the discovery, although their results would prove to be the most precise and definitive for the question.

1.3 Padova (1933-1938)

Rossi arrived in Padua, "*una delle sedi universitarie più desiderabili d'Italia*" (cf. [70], p. 25), at the beginning of 1933, bringing with him two of his students, Sergio De Benedetti (1912-1994) and Eugenio Curiel (1912-1945). There he found other brilliant pupils, like Ettore Pancini (1915-1981) and Giampiero Puppi (1917-2006)[11].

The Consiglio Nazionale delle Ricerche (CNR) finally provided the necessary funds, so in August the expedition to Asmara could begin. In a few months, Rossi and his collaborators were able to verify both the latitude and the East-West effect. Plus, they unexpectedly ran into a new phenomenon, as detectors far away from each other registered an excess of coincidences which could not be explained by mere randomness: they had discovered extensive air showers, caused by highly energetic particles[12]. Such measurements and discoveries are perhaps the main contribution given by Rossi during his stay in Padua.

His following works still regarded cosmic-ray showers, also exploiting data taken in Arcetri, with which he further characterized the soft and hard components of the rays. Along with De Benedetti he found that the soft component was not, as someone claimed, a secondary radiation originating from the hard one, as their intensity varied differently with height. In the meantime, a new theory by Hans Bethe (1906-2005) and Walter Heitler (1904-1981) demonstrated that the soft component was made of highly energetic electrons, positrons and photons, which created the showers by means of the processes of radiation and materialization that were part of the recent theory of Quantum Electrodynamics (QED), which was settling down among the physical community [3][13]. Furthermore, the hard component turned out not to be made up of fast electrons, instead of particles with an intermediate mass between electrons and protons, from which the name mesotrons.

As Rossi recalled, "*varie circostanze ostacolarono la mia attività scientifica negli anni '30. Fra queste, la più importante fu, indubbiamente, la preoccupazione per la minacciosa situazione internazionale e per l'incipiente campagna antisemita in Italia; preoccupazione che mi impediva di concentrare la mente sulla fisica*" (cf. [70], p. 32). On the other hand, he was deeply interested in teaching, "*il mio compito più impegnativo*" (cf. [70], p. 26), for which he spent a lot of time, both preparing and delivering the lessons.

His last great effort led to the design and realization of the new building of the Istituto di fisica "Galileo Galilei", still home to the Physics and Astronomy Department. The construction took several years and resulted in a state-of-the-art institute for the time, with particular

[11] Except for Puppi, they all were convinced anti-fascists, in particular Curiel and Pancini would become partisans. This political commitment was so strong that Curiel eventually was killed by the Brigate Nere in Milan, and Pancini became a commander of the Gruppi di Azione Patriottica (GAP).

[12] In a few years Pierre Auger (1899-1993) would study them in depth and estimate the enormous energy (for the time) of $10^{15}\,eV = 1\,PeV$ for some of them. Due to such thorough analysis, Auger is commonly considered as the physicist who discovered extensive air showers.

[13] A subsequent article by Heitler and Homi Jehangir Bhabha (1909-1966) was precisely dedicated to explain the showers by means of this new theory [4].

attention not only to the experimental side, but also on the didactic and organizational side (two descriptions of the newly built institute can be found in [67] and [18]). Even though at a reduced rate, cosmic-ray research was still going on: by 1937 a 7 tons electromagnet (figure 1.5), capable of creating a 13000 gauss magnetic field, was ready and he was working on the construction of a 1 million volt accelerator. The new institute itself was indeed thought by Rossi to be a place where cosmic-ray physics research and experimental physics research in general could be finally carried out at best.

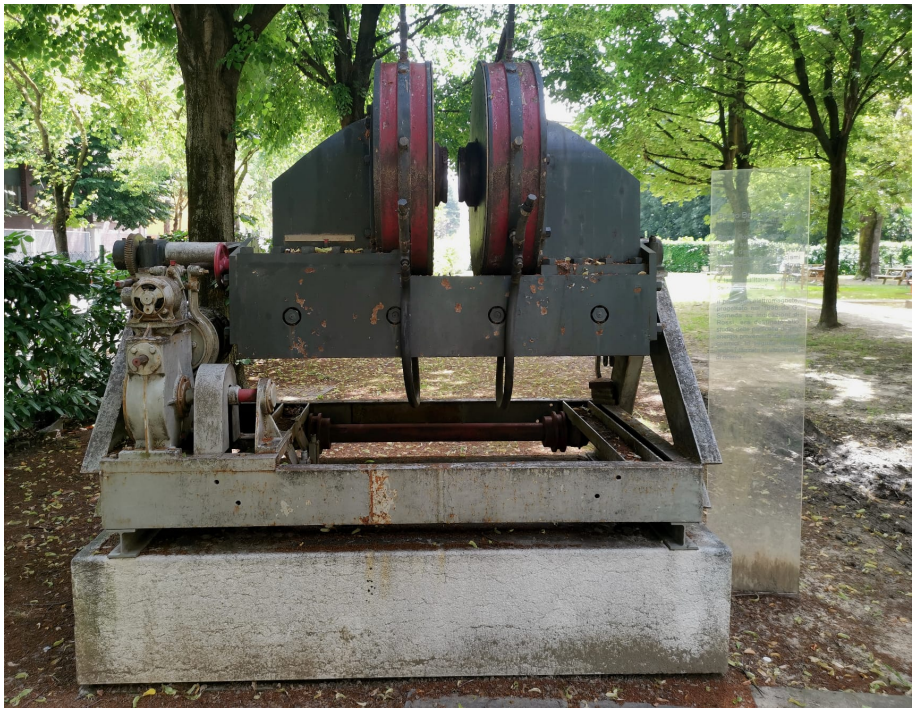


Figure 1.5: The electromagnet Rossi intended to use for his research, currently positioned in the garden outside the entrance of the Physics and Astronomy Department in Padua.

Unfortunately, his work and even his own life in Italy encountered a brutal interruption. In September 1938, shortly after Rossi met and married Nora Lombroso (1914-2009)[14], the Italian dictator Benito Mussolini (1883-1945) began to apply the Racial Laws. About the immediate consequences of them, Rossi summarised: *"appresi che, per effetto di questi decreti, non ero più un cittadino del mio paese e che, in Italia, la mia attività di insegnante e di scienziato era finita"* (cf. [70], p. 32). His wife, who demonstrated firmness and strong political interests throughout her life, convinced him that staying in Italy would have been way too dangerous. So they quickly had to find a way to leave Italy, as mobility for Jews was becoming almost impossible: he exploited what remained of the scholarship offered to visit Bothe to request some money and a passport, while Nora was able to obtain one with the help of some friends who lived in Sicily.

[14]She was granddaughter to Cesare Lombroso (1835-1909), famous for his pseudo-scientific theories in physiognomy and phrenology applied to criminology. The Lombroso family lost his prestige after the advent of fascism, due to its hostility towards the dictatorship and to its Jewish origins.

This event would mark their lives forever. Moreover, almost no one bade them farewell, something that caused Rossi, along with the reduced scientific activity he experienced there, to hardly ever speak or write about the years he spent in Padua.

1.4 Beyond Italy and later life (1939-1993)

At first the Rossis reached Niels Bohr (1885-1962) in Copenaghen, where the latter organised a conference, presumably with the aim of helping Bruno to find a job somewhere. Indeed, Blackett joined the conference and invited him to Manchester, where Rossi moved with his wife in December. There his research activity could finally start again: with Lajos (Ludwig) Jánossy (1912-1978) he confirmed with precision Bethe and Heitler's theory. Yet the war was at the doorstep, so it was better to leave for the United States, where Compton invited him to Chicago. After two weeks in New York, where the Fermis and Bethe were as well, Bruno and Nora headed to Chicago.

The hot topic concerning cosmic rays was the belief that the mesotron could be the particle mediating the strong nuclear force, as predicted by Hideki Yukawa (1907-1981)[15], which eventually proved not to be the case (it was the still undiscovered pion). After an expedition to Mt. Evans and after having developed the first Time to Amplitude Converter (TAC), Rossi confirmed the unstability of the mesotron[16], measuring a mean lifetime of 2.15 ± 0.06 microseconds, close to the current estimate.

From 1943 to 1945 he and his growing family lived at Los Alamos, as Rossi was involved in the Manhattan Project as head, along with Hans Staub (1908-1980) of the Detector Group. He stood out for his ability to develop new instrumentation, like a fast ionizing chamber, which was fundamental to study the characteristics of the explosion. A lot has been written and said about this project, so we will just mention what he wrote to his mother on 10th August 1945 to inform his family about what he had been doing there: *"E' stata certo una grande soddisfazione che i nostri sforzi abbiano servito ad accorciare la guerra, probabilmente di parecchi mesi. Ma prego il Cielo che sia questa l'ultima volta che la bomba atomica viene usata. Si è detto tante volte, dopo l'invenzione di una nuova arma, che essa avrebbe reso nuove guerre impossibili, e non è mai stato così. Ma questa volta deve essere vero, perché l'alternativa è troppo spaventosa. Ero presente alla prima prova, ed è una cosa che non si può descrivere"* [68].

After the war, he began to work at the Massachusetts Institute of Technology (MIT) of Cambridge, founding the Cosmic Ray Group, and he remained there for the rest of his career. We can briefly identify three main periods in his career at the MIT. In the first one (1945-1950) Rossi studied the nature, the origin and the spectrum of the primary cosmic rays. In the second one (1950-1960) he focused on characterizing new particles, such as heavy mesons

[15] According to his theory, the range of a force was inversely proportional to the mass of the mediator, so the mesotron seemed to fit this description.

[16] The unstability of the mesotron had already been demonstrated by Franco Rasetti (1901-2001) in 1941.

and hyperons, via cloud chambers, and then on extensive air showers using huge arrays of detectors. In the third period (1960-1980), large accelerators took the place of cosmic sources for particles, marking the end of such a short but exciting period of physical research. Rossi didn't appreciate those large machines, so he moved his interests toward space exploration. Indeed, the National Aeronautics and Space Administration (NASA) gave him and his group the opportunity to carry out research with some detectors directly put into space. In this field, he gave excellent contributions as well, first in the study of the interplanetary plasma and, more noticeably, discovering along with Riccardo Giacconi (1931-2018) the first source of X-rays coming from outside the Solar System[17].

Figure 1.6: Bruno Rossi and his wife Nora Lombroso, Cape Coral, early 1990s.

From that point on, Rossi left more and more his research activities, due also to his age, in order for the younger generation to work in the fields in which he spent his career. His intention was also to reconstruct the evolution of those fields, with the following hope: *"avrei cercato di comunicare ad altri quel senso dell'inesauribile ricchezza della natura che aveva dominato la mia vita e il mio lavoro di scienziato"* (cf. [70], p. 123). He later taught in Italy at the University of Palermo from 1974 to 1980, and spent some time every year in the Country where he was born, yet never going back to the Institute of Physics in Padua.

Throughout his life, as Nora remembered, Bruno cultivated various interests, mainly for literature, starting from Dante's Divine Comedy [5]. He thought indeed that a great scientist should often spend time in other free time activities, with the aim of being more relaxed and focused. Bruno Benedetto Rossi died on 13th April 1993 at his home in Cambridge where, after being paralyzed by a stroke, he had been accompanied in his last days by the reading of the verses he loved. His ashes rest in the monumental cemetery of the church of San Miniato al Monte, not far from Arcetri, where his great career began.

[17] This and his later works on what took the name of X-ray astronomy brought Giacconi to the Nobel Prize in 2002.

2. Organizing a scientific expedition

In this chapter we will exploit the pieces of information made available by the new documents found in Venice, plus some archivial material from the University of Padua, to reconstruct and integrate the story of the 1933 scientific expedition to Asmara, Eritrea. Specifically, we will now consider the frame in which it took place and what brought to its official start, while the following chapter will be dedicated to the travelogue itself.

2.1 Background

As mentioned before, physics was not a major part of the Italian scientific scene when Rossi began his career. Nevertheless, the few physicists present at that time were carrying out internationally appreciated research activities, both on the experimental and the theoretical side. In 1931 such question was also discussed by the Società Italiana di Fisica (SIF), on behalf of which the Italian Minister of National Education Balbino Giuliano (1879-1958)[1] wrote to the rectors of the universities concerning *"le manchevolezze gravi che in molte Università presenta l'insegnamento superiore della Fisica"* [21]. The SIF hoped that new and broader physics courses were offered to students, with the aim of *"fornire ai laureandi cognizioni sufficientemente aggiornate ai rapidi e grandi progressi che la Fisica ha fatto negli ultimi tempi"*.

The following year, Rossi came second in the competition for a chair in physics at the University of Ferrara, and the University of Padua exploited this information to offer him the position of experimental physics' professor. The university probably followed the suggestion of the SIF, alongside the opportunity offered by the recent retirement of Professor Giuseppe Vicentini (1860-1944), and was intentioned to renew this teaching, as emerges from the council meeting of the Faculty of Mathematical, Physical and Natural Sciences [75]. Just a month later, the proposal of creating a theoretical physics chair is rejected, as there are no experts in that field at the moment in the university [77].

In 1933 Rossi fully began to operate this transition. He asked and obtained the independence of the Physics Institute from the Seismological Observatory, which *"appare estraneo all'indirizzo scientifico che il nuovo titolare intende impartire all'Istituto"* [78]. Indeed, Giuseppe Vicentini, the previous holder of the Experimental Physics chair in Padua, had only focused his research activity on X-rays and seismography until his retirement in 1932. Despite being far from the new fields of physics, it should be stressed how Vicentini had been a major figure in the history of physical instrumentation and radiology. He developed in 1894 the microseismograph, a device which first allowed to measure the two different components, East-West and North-South, of seismic waves. Furthermore, just two weeks after Wilhelm Röntgen (1945-1923) announced

[1] After a few months he promulgated a law that made the oath to Fascism compulsory for every university teacher. The idea came mainly from the philosopher Giovanni Gentile (1875-1944) and from the mathematician Francesco Severi (1879-1961), but it was Giuliano who put it into law.

the discovery of X-rays, Vicentini was the first Italian physicist to reproduce the experiment, thoroughly studying the characteristics of the new mysterious rays and paving the way to the first Italian radiological applications[2].

Then Rossi asked to hire a new assistant who could dedicate his scientific and didactic activities to the Institute [78]. Finally, he requested new material to be bought via a special appropriation granted by the Ministry of National Education, probably some material he would also need for the forthcoming expedition to Eritrea [81].

The great effort and organization skills he put in this process and his capabilities both as physicist and as teacher brought him to experience a rapid cursus honorum within the university. He began to hold different physics courses, like Experimental Physics, Advanced Physics, Physics of Radiation, Electrology and Optics, for which he was reconfirmed for all the years to come. Just two years later, in 1935, he was promoted Full Professor recognizing, apart from all his qualities, his *"larga considerazione nel mondo degli studiosi"* [87].

As mentioned above, during this transition period he was beginning to work on the East-West effect and had just demonstrated, along with Fermi, that it was not possible to observe it in Italy due mainly to the large latitude [19]. An expedition to a place nearer to the geomagnetic equator was thus exactly what he needed to finally address the question properly. In the frame we have described in this paragraph, such experience would have represented an occasion for Italian physics to show its capability to carry out fundamental research programmes also in the new and challenging field of cosmic rays.

2.2 Situation of the Italian Colonies

From its birth in 1861 the Kingdom of Italy and its governments expressed the desire of acquiring some territories both in Africa and in South-Eastern Asia. Still, only starting from 1882 some territories began to be controlled by the Kingdom. It was at first a small economical area of Eritrea, yet in just two years Italians conquered the port of Massaua, leading to a process which in 1890 ended up in declaring Eritrea the first Italian colony.

By 1933, the year of Rossi's expedition, Italian colonialism had, little by a little, taken over Eritrea (1882), Somalia (1890), Libya (1911), the islands of the Dodecanese (1912) and the small Chinese concessions of Tientsin (1901). The project fascism had was even bigger: to transform Italy into an empire. The Italian Colonial Empire became reality when on 9th May 1936, as a result of the Ethiopian War (1935-1936), the king of Italy Vittorio Emanuele III (1869-1947) was proclaimed Emperor of Ethiopia (called Abissinia during colonialism). Eritrea, Somalia and Ethiopia were then united under the name of Africa Orientale Italiana (AOI).

The Empire reached its maximum extension in 1940, due to some additional territories subtracted from Britain during the Second World War. Just a year later, in 1941, the Allies

[2]Several of his instruments and X-ray films which he and his assistants processed are preserved at the Museum "Giovanni Poleni" in Padua.

defeated the Italian army in AOI. The same fate happened to Libya and the rest of the North Africa in 1943. The same year Mussolini fell, so any possibility of colonial territories definitively vanished. Eventually, after the war the Treaty of Paris (1947) stripped Italy of every colonial territory.

Figure 2.1: Map of the Italian Empire on the facade of the Palazzo del Podestà (one of the buildings composing the Palazzo Comunale) that faces Piazza delle Erbe in Padua.

Italian colonialism was partially founded, as it was for almost any other colonialism of the time, on a profound racism toward Africans. They were not considered completely humans like white people instead were. Abuse, oppression and subjugation were the favoured weapons to keep the local population under control. Indigenous people were thus not allowed to occupy administrative positions, except in some rare instances and mainly in small villages which could not be directly connected to colonial representatives. Manual work and servitude to white people were indeed the usual occupations in big cities like Asmara. Furthermore, we have to keep in mind that from 1922 to 1943 fascism took over Italy: if fascists were used to treat some categories of Italian people, like political opposers, with threats and harassments, the indigenous people received an even worse treatment in those years.

The present dissertation will focus on a very particular aspect of colonialism: how the Italian scientific community took advantage of having such new territories available. Apart from zoology and botany, which began to analyze new species and cultures, the proximity to the equator turned out to be suited for some other research fields: physics and geophysics for instance were in need of carrying out some measurements in places where the magnetic field of the Earth was strong enough. Restricting to our purposes, we will see that the CNR promoted and built a geophysical station in Mogadishu, Somalia, while it planned to build another one

in Asmara, Eritrea, which was instead never realised.

We can then argue that science helped to consolidate the colonial power, both through the institution of research centres and groups[3] and through some studies aimed to justify the superiority of white over indigenous people. Concerning such studies, which stemmed mainly from Cesare Lombroso's phrenology (we already mentioned that he was grandfather to Rossi's wife), we notice that they are closely related to the ones that were to be used against Jewish people. This way, fascism built a pseudoscientific motivation to justify its aggressive actions. In order to stress even further these arguments, some racial exhibitions were organized all around Italy.

Recently, the debate on decolonization had been extended also to physical sciences and related fields. The autonomous scientific and technological progress that occurred within some countries after they got to be politically decolonized (India, Brazil and South Africa for instance) is indeed related to how colonialism brought scientific knowledge there. Yet in doing so, the colonizing country exploited the resources and the people of the colony without recognizing them any, or little, role in this process. As a consequence, before decolonization took place, but also for some time after, chauvinism prevented locals from being part of the scientific community or even from being able to share any possible contribution. The ongoing work of historians, in our case historians of physics, is then to analyze the role played by science in the colonizing process, with the goal of getting a better understanding of its evolution all the way to its end.

2.3 Preparation

Here we will gather some of the unpublished material that was found in Venice, along with already known information, in order for us to reconstruct part of the events that made up the organization of the expedition.

As far as we have been able to understand from our research (so we expect that more could be found out) the first document telling something about the expedition to Eritrea is the report of the plenary meeting of the CNR published on *La Ricerca Scientifica* on 15th March 1933 [79]. Here they just tell that the expedition will take place, adding no more details.

The first information contained instead in the newfound Venice archive comes from a letter written by Guglielmo Marconi and sent to Emilio De Bono[4], Minister of the Colonies at the time, on 24th May 1933 [25]. Here Marconi thanked the Minister for his intention of helping to set up the preparation of the expedition. Marconi had already been in contact with both Professor Ugo Bordoni (1884-1952), head of the CNF (Comitato Nazionale per la Fisica, part of the CNR), and Dr. Ercole Vellani, head of the Office of Studies and Propoganda of the Ministry,

[3]Starting from 1931 the Italian scientific community organized the so-called Congresses of Colonial Studies, where the different kinds of scientific research connected to the colonies gathered together.

[4]He was an army general and, more noticeably, one of the four Quadriumviri of the Rome March in 1922. From 1935 to 1936 he also took part in the Ethiopian War (1935-1936).

who would find the way to proceed bureaucratically. De Bono was then informed that Rossi would lead the scientific group, alongside with an assistant and a specialized mechanic, and that the whole thing would last about three months starting from September. Marconi underlined the importance of the experiments that would be done there, and the necessity of carrying out them precisely in Asmara, place where the mission intended also to explore the possibility of building a permanent astronomical and geophysical observatory[5]. The CNR, for its part, had already contributed with 70000 lire, thus Marconi asked De Bono to invest 35000 more in order to cover also transportation, colonial indemnity and some other technical aspects.

The letter we just considered was own by Rossi due to the fact that it was sent to him by Ugo Bordoni, a fact declared by Bordoni himself in a letter to the Venetian physicist on 18th June [7]. Here Bordoni added that, as Giovanni Magrini (1877-1935)[6] told him, he was aware that Rossi had decided to substitute the mechanic with another assistant, declaring support for this decision.

De Bono answers Marconi on 27th June, referring to a previous answer of the 31st May (which we do not have), informing the scientist that everything that he asked for will be accomplished by both the Italian and colonial governments [17].

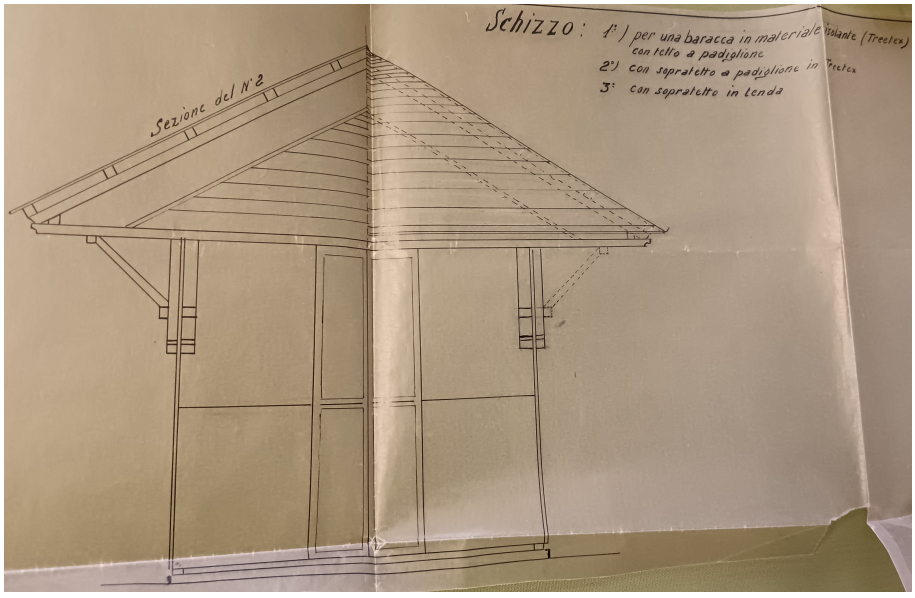


Figure 2.2: Sketch of the hut sent to Rossi by the Roman engineer.

On 29th May an engineer, who used to live in Eritrea and is now part of the Central Office of the State Property[7], sent Rossi some sketches of the hut to be built in Asmara (figure 2.2), with some indications concerning building materials and methods to assemble it properly [24].

[5]This is the first time ever that we hear about this project, which actually was never realized. As we will see, the CNR and the government will support this idea, but we only have little information about what its precise fate was, thus the matter should be investigated more.

[6]Giovanni Piero Magrini was a Physicist, scholar of hydrography and oceanography, secretary general of the CNR since its first plenary meeting in 1924.

[7]We know that his name was Luigi, yet we were not able to deduce from his signature the surname. Another useful information to identify him is the fact that he lived in Via Panisperna 78 at the time.

On 16th June Rossi informed Bordoni that a doctor, who was living in Asmara and was having a brief stay in Italy, indicated him Fort Baldissera as the best place in Asmara to perform the experiments [36]. He was now planning to write as soon as possible to the Governor of Eritrea and to the Commissario of Massaua, as communications were quite slow and they would have to leave in just two months.

On 20th June, Compton replied to a letter Rossi had sent him on 7th June (which we do not have). From Compton's words we deduce that in such letter Rossi had told him that the apparatus had arrived in Padua[8] [10]. As emerges from the recently found inventory of the materials sent from Chicago to Padua [82] and is then confirmed by Rossi himself in a letter to the custom of Genova [83] and in the paper containing the final results of the expedition (cf. [66], p. 576), the apparatus was exactly the same one used by Compton in America and by Stefan Meiring Naudé (1905-1985) in South Africa as part of the series of experiments aimed to verify and quantify the latitude effect [11]. The rest of Compton's letter of 20th June concerns the latest cosmic-ray experiments, in particular the results obtained by Luis Àlvarez (1911-1988) and Thomas Johnson (1899-1998) in Mexico City, about which Compton was sorry for not having considered and cited Rossi's previous articles on the question. Indeed, they found for the first time an eccess of positive over negative particles, yet their results were not as definitive as the ones that Rossi will obtain in Asmara. Then Compton argued that the East-West effect may be present at high altitudes even when it is not detectable at sea level, announcing a possible similar experiment to be carried out in Chicago and related to a forthcoming flight of Professor Auguste Piccard's (1884-1962) high altitude balloon. As a sidenote, Compton added his excuses for not having read until then about the results Rossi obtained in Florence back in 1930, and at the end suggested him to publish more frequently on the *Physical Review* in order for the foreign scientific community to keep acquainted with his latest results and to be able to consider them in future articles.

On the same day, Rossi wrote to Magrini [37]. While asking him about the economical aspects of the expedition, he referred to a previous one which had Somalia as destination[9]. Then he informed Magrini that Compton's apparatus was waiting in Geneva to be definitively imported to Italy. He added that it would be used for measurements both in Italy and in Eritrea[10]. The remaining bureaucracy was under control, and Rossi was going to get into touch with the Governor of Eritrea.

Then on 27th (or 25th) July Rossi wrote to commendatore Giancarlo Vallauri (1882-1957)[11]

[8] As we will see in the subsequent letter sent to Magrini, on 20th June the six boxes containing the apparatus were still at the custom in Genova (they arrived there on 1st June), so it is more likely that Rossi meant that they had reached Italy. Eventually, they will be allowed to be temporarily imported to Italy on 25th June [83].

[9] The CNR had built a geophysical station in Mogadishu, which operated from July 1932 and permitted to make several geophysical measurements [76, 80]. An in-depth analysis of the history of the Somalian station may be of interest.

[10] Yet, as far as we know, it was only unpacked and built in Asmara. This is probably due to the fact that a condition for the temporary importation was that the custom sealed with lead the battery until it was still in Italy [84].

[11] Vallauri was a scientist and a military man. Specialized in electrotechnics, he covered several major

about the possibility or not to put the hut on the roof of a building (it had been already mentioned by Marconi to De Bono when outlining the main aspects of the expedition), as it would be the best option [38]. It was now clear instead that the location of the experiments would be Fort Baldissera. The hypothetical day for the departure was at the moment 25th August. In a few days, a letter from the Società Veneziana di Navigazione a Vapore would indeed inform him that the departure was postponed to 28th August [20].

Some interesting information about how Italian physics was considered abroad emerges from what Rossi wrote to Bordoni on 31st July [39]. Rossi had to decline, due to his forthcoming expedition, an invitation to give a talk about cosmic rays at the All-Union Conference on the Atomic Nucleus, which would have taken place from 24th to 30th September at the Ioffe Institute in Leningrad (LFTI), Soviet Union (today Saint Petersburg, Russia) [74][12]. Nevertheless, he was happy for the great consideration obtained: *"mi ha fatto piacere comunque constatare che anche all'estero si comincia ad apprezzare quanto viene fatto in Italia in questo moderno campo di ricerche"*.

The last letter we have dated before the departure was sent to Magrini by Rossi on 23rd August [40]. Rossi requested Magrini support concerning a special allowance by the government. The expedition was turning out to be more expensive than expected, in particular concerning the shipments, for paying which they had to use part of the funds of the Padua's Institute of Physics. His concern is clearly expressed by the sentence *"cosicchè l'anno venturo si inizierà in condizioni economiche assai poco brillanti!"*[13]. Rossi then ended the letter asking for reassurances about the custom procedures for the material, as it could not resist to a long stay in a stock in Massaua due to the high temperature and humidity.

2.4 Ivo Ranzi

We will now dedicate this and the following section to the two assistants that joined Rossi in the expedition, Ivo Ranzi (1903-1985) and the already cited Sergio De Benedetti.

Ivo Ranzi was formed as a physicist at the University of Bologna (1925) and later obtained his teaching qualification in experimental physics during the second of two brief periods ad the University of Camerino (1928-29 and 1931-32). In 1933 he was eventually nominated effective assistant at the University of Bologna, a position he was holding when the expedition to Eritrea took place.

institutional positions, such as vice president of the Reale Accademia d'Italia from 1939 and president of the CNR from 1941 to 1943.

[12]Among the others, some physicists that took part in this conference were Abram Ioffe (1880-1960), George Gamow (1904-1968), Paul Dirac, Frédéric Joliot-Curie (1900-1958) and Franco Rasetti. Considering that also Ettore Majorana had been invited (but did not join), the organizers took into account at least three Italians, something that shows how Italian physics was gaining high consideration abroad.

[13]This situation is similar to what the Via Panisperna group was experiencing in Rome: young and prepared physicists with innovative ideas, great enthusiasm for their work among the institutions, yet only poor economic support for their research programmes.

His interests focused on the study of the recently discovered ionosphere. After Marconi made the first transatlantic radio connection in 1901, Oliver Heaviside (1850-1925) and independently Arthur Kennelly (1861-1939) hypothesized the existence of layers in the upper atmosphere that could reflect radio waves, later discovered and named Heaviside-Kennelly layers, part of the nowadays called ionosphere. Ranzi then intended to make some measurements of the thickness and characteristics of that layer near to the equator, and compare it to the same measurements made in Italy[14]. Such measurements would have been the first of that kind made by an Italian group, since the Somalian expedition was not suitable for that purpose. However, the results he had obtained before leaving for Eritrea made him already worthy of the Fondazione Querini Stampalia Prize in 1931, awarded by the Venetian Institute of Science, Literature and Arts, with the following motivation: *"per il miglior lavoro diretto a far progredire in qualche modo per via matematica o per via dell'osservazione o dell'esperimento l'interpretazione dei fenomeni relativi alla portata delle radiocomunicazioni"* (cf. [23], pp. 520-521).

Figure 2.3: This might be the only photograph of Ranzi available. From left to right: Ranzi (allegedly), Rossi and De Benedetti. Asmara, Eritrea 1933.

Apparently, Ranzi was not very enthusiast about the academical environment of the University of Bologna. Indeed, in a letter sent to his mother while he was in Asmara Rossi referred a

[14] A possible reason of why he was chosen for the expedition, except the necessity for Ranzi of having such measurements done, will be exposed later on in this section.

conversation he had with Ranzi, saying that *"Figurati che Ranzi è già tanto stufo delle continue beghe, della meschinità e dell'ostilità dell'ambiente, che accarezza l'idea di traslocare definitivamente all'Asmara colla sua famiglia, se veramente qui si farà quell'Istituto, che il Consiglio delle Ricerche avrebbe intenzione di creare"* [53].

After the expedition, Ranzi was at the center of a bad episode of racism when in 1937 he said aloud during a seminar in Arcetri that *"sentiva puzza di ebreo"* in presence of the physicist Giulio Racah, who left the room in protest (cf. [26], p. 169). What strikes the most is that Ranzi showed many times to be grateful and friendly to Rossi, who also was a Jew and with whom he had collaborated in Asmara. It was though commonly known that he was a convinced supporter of the Nazi-fascists, and that this feeling grew stronger as the racist component of the two dictatorships became heavier. Consequently, after the war he was academically and politically forced to move to Argentina, where he lived from 1948 to 1953. He eventually got to come back to Florence, where in a few years he regained most of his teaching positions. However, many aspects of his personal and academical life still remain unknown, especially considering the last years of the *Ventennio*, so further research on Ranzi could tell us more about him and the relationship between physicists and politics during that period.

Coming back to the expedition, twelve letters sent by Ranzi to Rossi from late May to the beginning of August 1933 were found in the Venice archive. Here we will consider only the information there contained which comes useful for the present dissertation.

The first letter we have was sent on 31st May 1933, containing Ranzi's initial thoughts and concerns about whether he will be confirmed or not to take part in the expedition [30]. In particular, he informed Rossi that his professor, Quirino Majorana, was favourable to his participation, still Majorana needed some more reassurances from Rossi about when they would come back to Italy. It seems like Rossi and Ranzi had already talked about the question before this letter, and that they found it better to slightly modify the reality in order for Ranzi to be accepted. Indeed, Ranzi then suggested Rossi to tell Majorana some things he made up about how he got involved in such project. Plus, he thought that it would be useful if the CNR showed his interest in the issue by giving him some economical help (about 1000 or 2000 lira) to prepare some equipment. Another interesting fact that emerges from Ranzi's words is that Rossi was soon having a colloquium with Guglielmo Marconi. Prior to having this confirmation, we could only hypothesize it (they could have only exchanged some letters and never met in those circumstances), as we saw Marconi showed his interest and support just a few days before.

It is evident from the letter we just considered that there was a complicity between Rossi and Ranzi. We know that they had known personally since their studies in Bologna: *"i miei due compagni saranno dunque il dott. De Benedetti, che si laurea ora a Firenze, ed il Prof. Ranzi, assistente di Majorana, che è stato mio compagno di scuola a Bologna"* [36]. This can support the thesis for which Rossi could have put some personal questions before the strictly academical ones concerning who had to follow him during this expedition. It would explain

in particular why they had to make up some excuses for Majorana. Another reason for this behaviour (the two alleged reasons could both be true) could be found in the scientific distance between Rossi and Majorana: the former was carrying out research in newly discovered fields, while the latter was spending years on trying to disprove the theory of relativity, so a possible involvement of one of his pupils in such research programmes was not straightforward at all.

On 5th June, Ranzi then informed that Majorana had received the letter from Rossi regarding his involvement [31]. Ranzi was looking forward to the experience in Eritrea and was already trying to help, gathering as much useful information as he could (such as the voltage and frequency of the electricity in Asmara). There could be problems in sending telegrams from Italy to Eritrea, not as much as the vice versa, but he was confident that this would have been soon overcome. Lastly, he wrote about some organizational and economical aspects[15], yet specifying about the remuneration that *"ciò non ha eccessiva importanza: l'importante per me è di aver ottenuta la possibilità di partecipare alla tua spedizione"*.

On 4th July, Ranzi wrote about a vacuum pump saying that he had not found any cheap alternative, so suggested Rossi to bring his [32]. Once again, we see the economic problems scientific research had at that time.

By the 25th July, Ranzi had completed the preparation of the experimental apparatus he was to use in Asmara [33]. He showed here also a great interest in achieving the necessary information in order to properly help Rossi in his experiments.

At the end of July Ranzi read the recent results obtained in Mexico City by Àlvarez and Johnson, commenting that Asmara is located at an even more favourable latitude, so *"c'è da attendersi un bellissimo esito delle tue ricerche: il problema è ora divenuto oltremodo affascinante: ti confesso che sono veramente entusiasta di poterci mettere un po' le mani anch'io"*. [34]

Throughout these letters, it also emerges that Ranzi went multiple times to Padua to meet Rossi and De Benedetti and to organize the expedition.

2.5 Sergio De Benedetti

Most of the information about De Benedetti's life is taken from his unpublished manuscript titled *Note Antifasciste* [14]. It is a memoir of his life and scientific activity until his escape to the USA caused by the war, with a strong accent on the political questions of the time, naturally starting from his anti-fascism.

Sergio De Benedetti began his academical studies attending the *biennio* in engineering at the University of Florence in 1929, but eventually changed his mind after Racah, who was graduating in physics, took him to see the experimental physics laboratories in Arcetri. So De Benedetti attended the last years as a pure physics' student, where Gilberto Bernardini (head

[15]Ranzi, just like De Benedetti, was an assistant. Hence, the two of them belonged to the 11th grade in the scale which would eventually confer the daily allowances once overseas. There was still the possibility for them to reach the 7th grade due to their particular scientific activity. Though, we will not consider here the evolution of these questions, extensively treated in some of the following letters.

of the Institute due to Garbasso's illness) followed his thesis project. Along with De Benedetti, his closest friend Eugenio Curiel tried to obtain the same position too, yet the circumstances only permitted Curiel to carry out his project in Padua under Rossi's guide. After initial difficulties, De Benedetti's passion for physics and its opened questions grew stronger and stronger, as emerges from his words when talking about the first time he managed to build a Geiger-Müller counter able to register the passage of cosmic rays: *"Cosa erano queste particelle velocissime che producevano una piccola scarica nei miei contatori? Di dove venivano? Come si comportavano? Tutte questioni a cui, lo sapevo bene, non avrei dato una risposta finale, ma alla cui chiarificazione avrei almeno potuto portare un qualche contributo"* (cf. [14], cap. III, p. 16).

Figure 2.4: Sergio De Benedetti inside the hut which contained the cosmic-ray detection apparatus, Asmara (Eritrea) 1933.

At the end of April 1933 De Benedetti received from Rossi the proposal of taking part in the expedition to Eritrea. Rossi had already asked Curiel, yet the latter had refused due to an inner conflict he was living at the time: he thought that physics could not fulfill his moral sense, thus he was thinking about switching to a philosophy course[16]. Rossi was so hit by Curiel's refusal that he thought to have failed his mission of instilling a passion for science, especially on such a good student (cf. [14], cap. III, p. 20).

[16]Curiel's short life, tragically ended as previously recalled, was marked by several apparently senseless choices which instead stemmed, at least in major part, from his political commitment and actions.

Before graduating in July 1933, De Benedetti spent a week in Padua to prepare the boxes with the instrumentation needed for the expedition. The old Institute of Physics in Padua, which was located in the Bo Palace, seemed to him very obsolete and he completely disliked it, except for Rossi's manners, which he said were to be always nice to him in the years to come. Then, De Benedetti came back to Padua and helped to finish the preparation. At last, the expedition could start.

After coming back from Eritrea, De Benedetti worked at the University of Padua from 1934, spending part of 1935 in Paris at the Curie Laboratories with Frédéric Joliot-Curie. Due to the Racial Laws, in September 1938 De Benedetti immigrated to France, and there he found a position as an assistant in experimental physics at the Parisian laboratories he had visited just three years before. Then the war began to spread and the Nazi-fasists arrived in Paris, so he and other jewish people, among all also the physicist Bruno Pontecorvo (1913-1993) for instance, were forced to flee. De Benedetti first went to Portugal and eventually to the USA, where he remained for the rest of his life.

In America, De Benedetti first worked at the Bartol Research Institute in Phyladelphia[17], then as a teacher for Army Air Force recruits at Kenyon College (Ohio)[18]. He briefly took part in the Manhattan Project in Dayton, Ohio, working on the trigger mechanism of the atomic bomb. After the war, he worked as a researcher in experimental physics at the Carnegie Institute of Technology (now Carnegie Mellon University) where he also taught. At last, after a career in the field of particle physics, which brought him to be the first president of the Faculty Senate of the University, De Benedetti retired in 1984.

An interesting point emerging from the letters Rossi sent from Eritrea is that Rossi and De Benedetti had a very good bond apart from their scientific collaboration. Indeed, as we will see Rossi described De Benedetti as a great assistant for the experiments in Asmara [55]. Furthermore, the two used to play tennis together whenever they had free time between their work in Eritrea [48, 55, 56, 57]. We know that later on their bond will deteriorate, to the point that De Benedetti will talk very little about Rossi in his *Note Antifasciste*. Several reasons could account for this, yet an educated guess concerns the different approach they had towards politics. De Benedetti considered politics as a major part of a scientist's life and recognized that science should not be prerogative of scientists, as in his words *"la cosa più importante che uno scienziato può fare oggi è quella di spiegare e di far apprezzare la scienza a il resto della popolazione"* (cf. [16], minute 8:30). On the other hand, as far as we can deduce from the documents, Rossi was not of that opinion and seemed to see politics as unbound from scientific research. Still, we cannot tell whether his way of thinking was similar to Fermi's one, who

[17]De Benedetti underlines in the *Note Antifasciste* the fact that ending up working with Thomas Johnson there was such a curious coincidence (cf. [14], cap. III, p. 22).

[18]This and all the subsequent information concerning De Benedetti's life after he left Europe were found in his biography written in 2015 by his daughter Vera De Benedetti Bonnet [15]. In fact, it was not possible to straightforwardly find something else about his biography, so we suggest carrying out some research about his life (all of his three children graduated at Carnegie Mellon University and could be contacted), which was so closely connected to many important figures of the history of physics.

showed almost a complete political indifference. Another aspect which supports this thesis is the lifelong friendship De Benedetti had with Bernardini instead, who, in addition to having been a mentor to De Benedetti in Arcetri, was strongly committed to politics.

2.6 The experiments

Three different experiments were carried out in Eritrea: Rossi's cosmic-ray one aimed primarily to detect the East-West effect (it will be used to do some measurements about the latitude effect and other aspects of cosmic rays too), Ranzi's one aimed to study the Heaviside layer near the equator, and Compton's one aimed to obtain a further support to the existence of the latitude effect. It is then quite useful to pass through the description of such experiments before we talk about the events which brought to their realization and to the relative consequences.

2.6.1 Rossi's experiment

The first experiment Rossi carried out was the measurement of the latitude effect, which took place during the boat trip from Italy to Eritrea. It simply employed a Geiger-Müller counter closed inside a $7\,cm$ thick lead shell, which protected it from environmental radioactivity. The shell was cardanically suspended in order for the counter to remain horizontal despite the movements of the boat. The counting procedure relied then on an automatised mechanical counter.

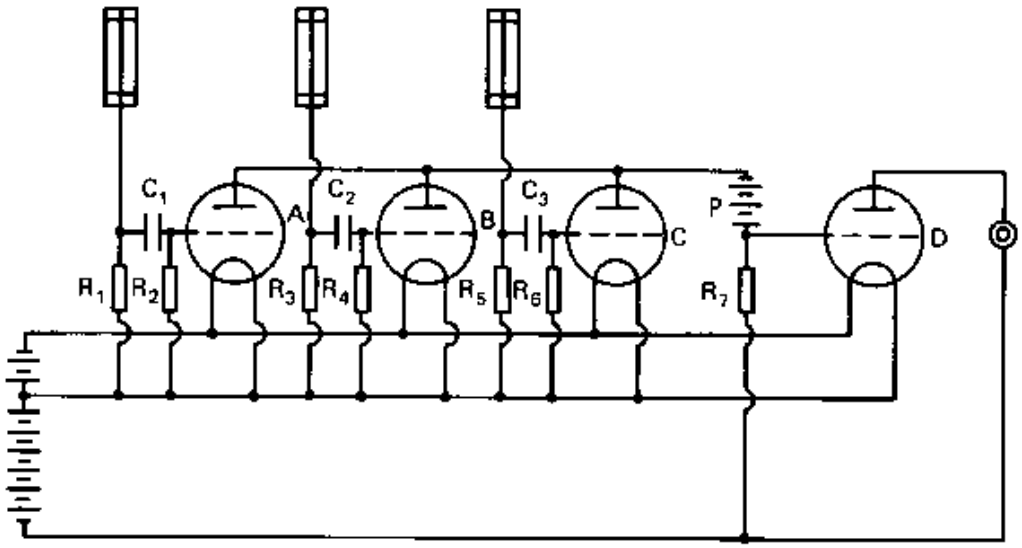


Figure 2.5: Configuration of the original (three) coincidence circuit presented by Rossi for the first time in [35].

Let's consider now how Rossi's coincidence circuit worked, as all the other experiments he carried out during the expedition were completely based on it. The circuit (figure 2.5) was composed essentially of a certain number of thermionic valves (or thermionic tubes, the circled

parts in the figure) whose functioning is the following: a heated cathode (first element at the bottom of each circle) emits electrons via thermionic emission, which can be accelerated or decelerated applying a potential difference between the cathode and a metallic grid (in the middle of the circle). The electrons can then reach, if sufficiently accelerated, the anode (at the top of the circle) thus producing a current in the part of the circuit related to that valve. Each grid is connected to the exit channel of a Geiger-Müller counter in such a way that when a particle is detected by a counter, the grid becomes positively charged and allows the current to flow from the cathode to the anode. It is then natural to see that in order for the apparatus to record a double coincidence it must employ two of these counter-valve system, or three for a triple coincidence (this is the case shown in figure), and so on. Finally, an additional valve (D), which is not connected directly to any counter, plays the role of trigger: having its grid connected in series with all the exit channels of the valves, it activates only if all the counters register the passage of a particle at the same time (a cosmic-ray interaction takes less time than the time the circuit needs to return to its initial unexcited state). A fixed voltage difference (P) helps to properly set the voltage threshold beyond which the valve D activates. Eventually, different systems can be employed to register the voltage pulses that announce the coincidence events. The precise circuit Rossi used in Asmara was slightly different, but the core structure remained the same, so this basic description is sufficient for our purposes.

Figure 2.6: The cosmic-ray "telescope" Rossi and De Benedetti used in Asmara for counting the coincidences (Museum "Giovanni Poleni", University of Padua).

Rossi intended to count the number of double coincidences between two Geiger-Müller counters, depending on the direction identified by their reciprocal position. Both the zenith

and azimuth directions were considered, even though the main objective was to look for a difference in the latter, that is the East-West effect. For the purpose he built a cosmic-ray "telescope" (figure 2.6): a rigid steel structure in which it was possible to put two counters with their axis parallel to each other and both in a horizontal position with respect to the surface of the Earth. It was also possible to modify the distance among them. This way, it could be oriented in each direction by rotating the whole system along the azimuth and zenith angle.

In Asmara, Rossi and De Benedetti used two copies of such apparatus, one for measuring the East-West effect and the other for measuring the difference along the zenith angle. They were both positioned inside the hut at Fort Baldissera and for each of them the number of coincidences was recorded by means of a mechanical counter.

Another experiment concerned the absorption of cosmic rays in lead. Two Geiger-Müller counters were put on a support similar to the "telescope", but which allowed to insert layers of lead of different thickness in between them. They were thus able to record the number of coincidences as a function of the thickness of lead travelled by the rays that were able to trigger both counters.

Last, they made a measurement related to the showers as well, similar to the one carried out in Arcetri which we had previously considered. Three Geiger-Müller counters were put beneath layers of lead of variable thickness and organised in a triangular setting with a vertex pointing down. If showers stemmed from the interaction of cosmic rays with lead (or the unknown extensive air showers occurred), all the three counters would be triggered at the same time, and a triple coincidence circuit registered such events. As a comparison, another configuration consisted in putting the counters on the same vertical line.

Further information about the apparatus and the experiments can be found in [66].

2.6.2 Ranzi's experiment

Ranzi intended to measure the height and other characteristics of the Heaviside-Kennelly layer, part of the ionosphere. In 1932, he had improved the method, developed by Gregory Breit (1899-1981) and Merle Tuve (1901-1982) in 1926, which allowed to measure such height via the registration of echoes [29]. Breit and Tuve's idea was to generate very short radio signals and then detect the reflected signal: assuming a straight path, a perpendicular reflection with respect to the Heaviside-Kennelly layer and propagation at the speed of light[19], a measure of the elapsed time between the sending of the signal and its return permitted to calculate the total distance it had travelled, therefore the maximum height reached as well.

Ranzi's upgraded apparatus, which was the same he was going to bring to Eritrea, worked just like an old valve radio. A one-valve transmitter generated the signal, which bounced on

[19]Under this assumptions we talk about apparent (or virtual) height, as they are obviously simplifications of the actual propagation and reflection of the radio wave. Afterwards, the apparent height can be converted into the real height through some corrections.

the ionosphere and was then detected by a two-valve receiver located nearby the transmitter. In order to get a better reading of the time position of the reflected wave and to extrapolate other information about the reflected waves, the receiving valve was connected to an oscillating current. The proper tuning of such frequency with respect to the frequency of the wave caused beats to occur, resulting in an oscillating figure with sharper ends, plus the apparent movement of the beats points out the phase variation of the wave. Eventually a cathode ray oscillograph was connected to the receiver and showed the trend of the voltage as a function of time. We underline that time was not directed only from left to right, like in modern oscilloscopes. Instead, the cathode ray was put into motion by means of an oscillating magnetic field, so that it oscillated back and forth repeatedly.

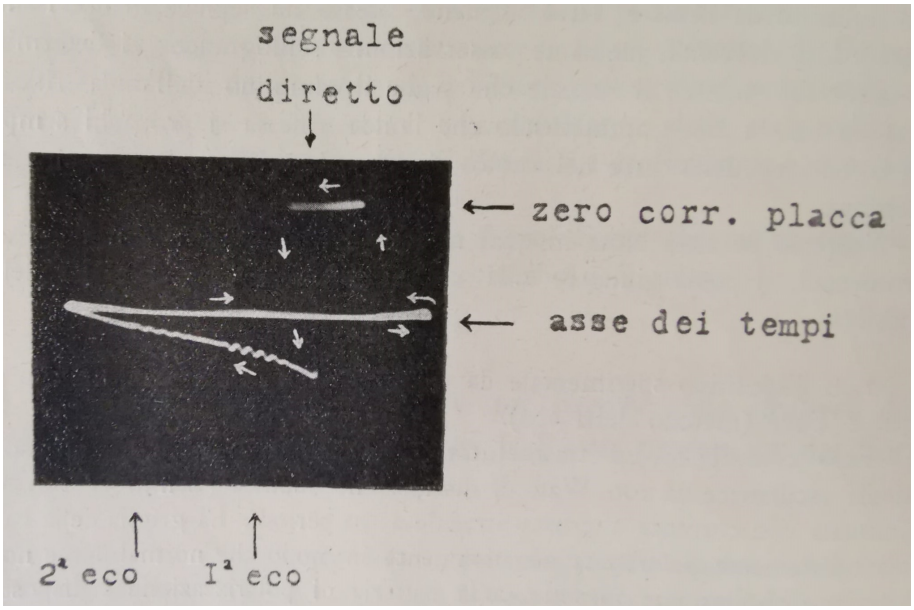


Figure 2.7: Example of detection of a reflected wave as seen on the oscillograph. The image is taken from Ranzi's 1932 original article [29].

A typical measurement consisted of two lines (figure 2.7), whose time reading is specified by the little arrows. The upper one represents the signal generated by the transmitter, which almost makes the receiving valve reach saturation. Then the pointer rapidly moves down to the lower end of the second line and begins to slowly rise. During this second phase, we can see the detection of the reflected waves, which manifests as beats over the straight line. In this case we have two echoes, being the second due to a double deflection (ionosphere-ground-ionosphere). Eventually, the pointer reaches the left side of the display, so it inverts its movement. The velocity of the displacement was tuned in such a way that the echoes appeared before the pointer turned back.

The time elapsed from emission to detection was then calculated taking into account the end of the emitted signal and the end of the echo, as the end of the emitted signal may overlap in some cases with the starting point of the echo. As previously stated, Ranzi's method allowed to measure the change of phase the wave undergoes when it reflects on the Heaviside-Kennelly

layer, thus providing additional information about the structure of the ionosphere.

2.6.3 Compton's experiment

At the beginning of the 1930s Arthur Compton published a series of papers in which he, along with other physicists[20], tried to both improve the technology of the ionization chambers and to use them to verify the latitude effect. Before going straight to the apparatus sent to Italy (and across the world), it is worth pausing on such improvements, as the idea itself of the experiment will stem partially from what he found out during this upgrading process.

At the fundamental level, Compton considered the recombination theory to be the actual theory of ionization. According to it, each cosmic ray interacts with the gas inside the chamber, causing some electrons to be scattered away from their atoms. The probability of the electron not going back to its ion and recombining with it (from which the name of the theory) can be calculated with some suitable assumptions. If recombination does not happen, the resulting electrons are then accelerated by the electric field applied to the chamber which, if large enough, will give rise to a Townsend discharge and so to a more easily detectable current signal. The other possibility that others had proposed was that cosmic rays, via interactions with the steel walls of the chamber, produced beta rays which could be then absorbed by the gas according only to its pressure.

Another important question concerned the relation between the ionization current and both the pressure of the gas inside the chamber and its temperature. Compton's idea was to compare the predictions for both theories of these relations, to see which one supported more the evidences.

In doing so, Compton also had to introduce a standard gamma-ray source, composed of around 1 mg of radium, which was left at a fixed position, typically within a meter from the center of the chamber. Being the emitted gamma rays way less energetic than cosmic rays, the presence of a proper metallic shield (composed of lead and in some configurations combined with a copper one) could let only cosmic rays through. Thus, two different confirmations of the recombination theory were obtained: the considered ratio was independent on the pressure (otherwise the electron from gamma rays should have been stopped earlier than those from cosmic rays) and the ionization current changed with temperature (not predicted by the other theory).

Furthermore, experimental tests showed that argon filled ionization chambers were able to detect weaker ionization currents, as the gas had a smaller speed of recombination.

We can now finally consider the experimental apparatus employed for the latitude effect detection (figure 2.8). It consisted of all the best components that emerged from those two years of experimentation: an argon filled ionization chamber, a radium source to be put nearby, and the other usual instruments which allowed to measure the ratio of the ionizing current stemming

[20]Ralph Bennett (1900-1994), Joyce Stearns (1893-1948) and John Hopfield (1891-1953).

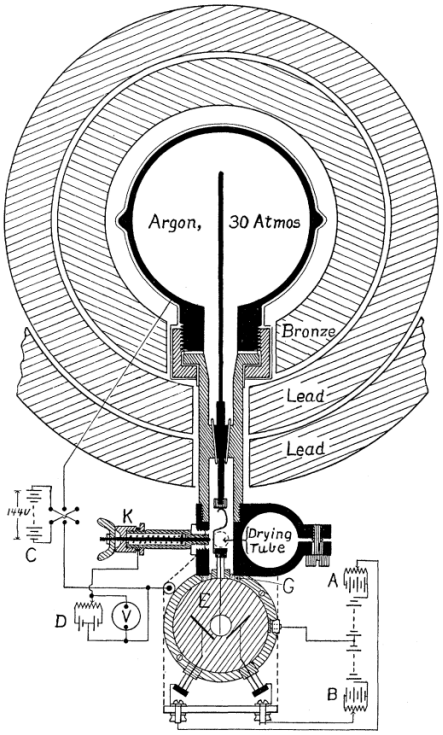


Figure 2.8: Sketch of Compton's apparatus for detecting the absolute flux of cosmic rays, as presented in [11].

only from cosmic rays over the one from cosmic rays plus radium source. As previously noticed, this was the best way to measure the flux as, being it compared to a standard radiation source, it was not dependent on temperature nor pressure, but only on the effective flux of cosmic rays hitting the chamber. A complete description can be found in [11].

3. Travelogue

Let's now consider the chronicle of the expedition itself. Almost all the information that will be presented comes from the numerous letters (around 250 pages!) Rossi wrote to his mother on a daily basis, and sent whenever possible according to the frequency of postal vessels, plus a little information coming from archival material.

The present chapter will be organized in a striclty chronological way. This is made on purpose, in order for us to help the reader easily compare the information in the bibliography. For that purpose, we specify that the word "letter" could here have two meanings depending on the source: a single letter entirely wrote in a single day, or everything that has been written in a single day but is part of a larger letter which covers more days. The ambiguity can be dissolved for each case looking at the bibliographical references.

3.1 August and September

The expedition officially began on 28th August 1933, as the boat Cortellazzo left Trieste with Rossi, De Benedetti, Ranzi and all their equipment onboard [41].

The following day they arrived in Fiume (now Croatian Rijeka, at the time part of the Kingdom of Italy) and began counting the number of cosmic-ray impulses via a Geiger-Müller counter, which had been placed in a corner of the navigation cabin [42]. After that first data taking session in Fiume, a second one was made automatically overnight during the trip to the bay of Split, where they spent the whole day counting. About this measurements Rossi wrote that *"né le vibrazioni della nave, né la radio di bordo sembra che disturbino gli apparecchi"* [43].

Leaving the bay, they left the counter on, though having had a little problem with the mechanical numerator, which seemed to have been overcome though. As they passed by the Greek coasts, Rossi noticed that the data seemed to indicate a decreasing intensity of cosmic rays while moving southward, but nothing definitive [44].

On 7th September the boat made a stop in Port Said, at the mouth of the Suez Canal, through which they sailed until they finally got to Massaua, Eritrea, two days later [45]. Here the Commissario of Massaua welcomed them and, as organized by the Government of the Colony, they were given: a car to reach Asmara, a truck to move the scientific instrumentation (except the fragile one which was moved there by train), a ticket allowing free movement by the Eritrean railway, and also three rooms in a local hotel, as they had to leave Massaua the following morning [46, 47].

During the short stay in Massaua, Rossi had his first impact with the Eritrean society. As Rossi never talked about his personal opinions about social issues and politics related to this expedition, at least not publicly nor in books, this dissertation will also focus on this unpublished aspect. He merely states that *"L'impressione più forte che ho provato è stata quella di vedere i negri 'a casa loro'"* and again *"Non sembra che finora la civiltà abbia avuto*

presa, se non su quei pochi che sono venuti più direttamente a contatto con i bianchi per ragioni del loro lavoro (camerieri, chauffeurs ecc.). Conservano quasi tutti il loro costume, molto diverso, d'altra parte, secondo le diverse razze e le diverse religioni" [47]. This shows his prejudice in considering the locals as not civilized and different from white people. Still, a profound and more rational sense of curiosity begins to emerge at the same time, almost a scientific and anthropological one, which he will show throughout his African stay.

Figure 3.1: Particular of the drawing made by Rossi's brother Ruggero (1909-1993) depicting Bruno's departure from Italy and the arrival to Africa.

The following morning, they were greeted at Asmara by Cavaliere Balì and commendatore Alberto Pollera (1873-1939)[1], two government officials. The three physicists were about to stay at the former's house, as he will be in Italy with his family for a while. There they temporarily set up a laboratory in a room near the kitchen, and were given a *"moretto"* named Salomone, the best servant of the Balì, who *"per il modesto stipendio di 50 lire al mese, ci tiene in ordine la casa, ci prepara il latte alla mattina, ci pulisce le scarpe, ci lava la biancheria più ordinaria"*, while another one named Hasfà will help them as *"uomo di fatica per le esperienze"* [46, 47]. Eventually they undertook quite a long round of institutional visits, the most important one paid to the general Archimede Mischi (1985-1970), regent of the government in absence of the marchese Riccardo Astuto dei Duchi Lucchesi (1982-1952), colonial governor of Eritrea. Everyone treated them *"con grande cordialità e .... deferenza"* [47], a typical behaviour that Rossi will notice in many other fascist colonists. Regarding the possibility of owning a weapon (specifically a *"rivoltella"*) for personal security, which he and others like Ranzi had considered before, he simply states *"non è assolutamente il caso di portarla perché la gente è più pacifica qui che in Italia"*.

[1]Balì is a term that refers to a particularly high degree within some knightly orders. Pollera was a military man and anthropologist, director of the government library and of the *sezione studi e propaganda* of the Italian government in Eritrea from 1932 to 1936.

As previously noticed, the position chosen for placing the experiments was Fort Baldissera, situated at an elevated point from which it was possible to see the whole Asmara plateau. The hut that Rossi had designed had already been built at the headquarters of the genius accordingly to his indications, and was ready to be disassembled and reassembled. The government then assured them lots of military men and indigenous to help to set up the laboratory, plus infrastructures and electricity for both the experiments and their home, everything for free [47]. This way, on Sunday 17th everything was ready, with the interior of the hut consisting of a central pole, three little tables and two stools, besides the instrumentation [48]. During the weekend they also got to socialize with some young officials, and with a topographer and lieutenant of the Alpini who helped them find the geographical and geomagnetical North relying on the coordinates of the Polar Star received from Padua [49].

Figure 3.2: The hut built near Fort Baldissera, Asmara.

On 18th September, they could finally begin the first data taking session, which consisted of some preliminary measurements [48]. Meanwhile, they finally met the Governor, who asked them what scientific research they were carrying out, and pretended to understand it. Anyway, on 19th Rossi wrote that *"Per quanto sia ancora prematuro parlare di risultati definitivi, sembra proprio che una differenza fra oriente e occidente ci sia, e abbastanza sensibile!"*. He then specified that, concerning possible results, he would like to proceed *"secondo giustizia"*, so to publish the essential parts on his own, while leaving *"qualche cosetta"* to De Benedetti. About Ranzi he just said that *"visto che farà delle misure per conto suo, penso che basti un ringraziamento"*.

During the same letter, Rossi then talked about the growing awareness he was developing about the actual lack of difference between white people and indigenous: *"Quello in cui ci sentiamo ancora un po' impacciati è nei nostri rapporti cogli indigeni. Il dover dar loro del tu, anche se portano un'uniforme piena di galloni come un generale, il doverli trattare sempre*

dall'alto in basso, il dover parlar loro con un'aria di superiorità e di degniazione ci costa una fatica enorme e non è raro il caso che infrangiamo involontariamente queste norme, che qui sono da tutti rigorosamente osservate. E poi molto spesso vien fatto di domandarsi fino a qual punto questa gente sia simile a noi; è fatto che molti sanno leggere e scrivere, alcuni fanno i dattilografi, altri guidano le automobili, ecc., ma tante volte mi fanno l'effetto più di animali ammaestrati che di uomini. Ed anche questa è una cosa che mette terribilmente in imbarazzo. Ci sono nei loro cervelli dei pensieri, delle preoccupazioni simili alle nostre? Sono capaci di provare altri sentimenti all'infuori di quelli, che sono propri anche degli animali, come l'amore per i figli o l'attaccamento al padrone?" [48]. Such racist preconceptions were in fact deep-rooted within developed countries at that time, and it is not surprising that a scientist like him was quite interested in observing the surrounding environment in order to question them in a rational way. Indeed, he suggested that further information could be collected in the countryside outside Asmara, where it was less likely to find indigenous that behaved like Europeans.

After some days of preliminary measurements, Rossi could state with more confidence that the East-West effect *"sembra ormai quasi sicuro"*, so it was time to move onto the definitive session of data taking [50]. Meanwhile, on one of those evenings he and De Bendetti took also part in the Jewish New Year's Eve celebrations, even though he had to reassure his mother that *"se vedo che è il caso, cercherò ... di tenermi in disparte!"*, probably referring to the period of increasing antisemitism they were experiencing. Some people present there informed him that the Italian government indeed treated Jewish people not as citizens but *"alla stregua degli indigeni"*.

On 24th September the main measurements began, even though some problems occurred, as in his words *"Non sono, veramente, completamente soddisfatto del funzionamento degli apparecchi; presentano alcuni fenomeni che non mi so ancora bene spiegare e che non so se dipendano dalle particolari condizioni dell'ambiente o a qualche modificazione che abbiano subito gli strumenti durante il viaggio. Ho fiducia, ad ogni modo, che tutto ciò non ostacoli seriamente le misure"* [50]. This was probably the first time ever that an experiment showed the presence of the extensive air showers phenomenon, as just a few days later Rossi will continue to face the same problem, about which we can thus argue that it was not a generic malfunctioning.

It is during this first session that he and De Benedetti began to openly criticize the colonists and their attitude. The first event that made them think about all of this was the visit of the Governor, who seemed interested and polite, yet *"pur senza discendere dall'olimpo del suo alto grado"*. He then added that *"Noi, in confidenza, abbiamo trovato che si desse un po' più arie del necessario; ma De Bendetti dice che è pagato apposta per questo; e d'altra parte, in colonia tutti, appena arrivano, diventano «grandi gente», fin l'ultimo scrivano"*. Mischi seemed to be the only exception, given his kindness and intelligence, while everyone else kept asking them stupid questions about their scientific work, concerning which Rossi hilariously said *"Ad ogni momento debbo mettere in opera tutta la mia buona volontà per trattenere il risolino"*. He

ended this critique by saying that he would never live there, being Asmara *"la più meschina e pettegola cittadina di provincia che io abbia mai conosciuto"*, where there was no support even among the same social class, so it seemed like *"la colonia sia fatta per quelli che hanno bisogno di sentirsi grandi uomini (non fosse altro che di fronte a questi poveri negri) mentre in patria sarebbero degli umili sconosciuti, che nessuno saluta per la strada"*, yet specifying that these arguments did not apply to business owners or to people who studied the area, just to colonists [50].

Two days later Ranzi began to take his measurements too, *"che hanno già dato dei risultati molto interessanti"* [50]. They also unpacked the instrumentation given by Compton, wishing to use it as soon as possible. In the meantime, they were also working on some theoretical calculations.

On 30th September, Rossi returned to the issue of what he thought was a malfunctioning, yet he left the question opened as it could also be stemmed from a new and unknown phenomenon [52].

3.2 October

On 3rd October, Rossi informed his mother that he had received some unexpected compliments from his uncles about the expedition, making him wonder if the CNR had inflated the information he sent them [52]. Actually, the CNR did not make such a thing, as the article that came out just a few days before was limited to reporting Rossi and Ranzi's telegrams without adding any comment on them [85]. However, in that telegram Rossi explicitly wrote that he obtained a value of 1.16 ± 1.25 for the ratio between the intensity of cosmic rays from West and from East, concluding that the result is *"conforme a quanto è da attendersi nel caso di una radiazione corpuscolare carica positivamente"*. Hence, it is quite normal that these words were interpreted by some as the announcement of the discovery of the East-West effect, as we are shortly going to see also for an article on the *Corriere*.

After the first week of October, they still needed more statistics, so they postponed some trips in the area [53]. At the same time, the Balì was coming back from Italy sooner than expected, so they moved to another house, a nicer and recent one, again paid by the government. During those days the Governor received an unexpected telegram from Ettore Majorana saying *"Ringrazio ospitalità, rallegrami risultati radiazione penetrante"*, about which Rossi comments on how peculiar Majorana was. He heard from Ranzi some stories concerning Majorana and the Institute of Bologna, making him rethink about his course of study: *"ho pensato che cosa sarebbe stato di me se, appena laureato, invece di andare a Firenze, fossi rimasto lì, come tanto avrei desiderato! Bisogna proprio anche di questo, ringraziare la Provvidenza; più il tempo passa, e più mi accorgo quale fortuna sia stata la mia di capitare sotto un professore come Garbasso"*. He then referred that Ranzi is considering the idea of moving in Asmara with his family, as the CNR had the intention of creating a permanent Institute there.

"Siamo diventati ormai "asmariani" autentici" Rossi stated as he and his colleagues approached one month in Asmara [53]. He was going on with the theoretical calculation, besides complaining about not having time to take a look *"né alle dispense, né a quella famosa monografia francese"*[2]. Although communication with Europe was difficult, he was still in contact with some friends and colleagues from Germany and Paris, like Maurice de Broglie (1875-1960)[3], about whom he says *"Ho scritto viceversa una bella letterina al Duca De Broglie pregandolo di pazientare ancora un po'. Speriamo che non mi mandi a quel paese!"*.

On 11th October, Rossi received a form to join the Italian Fascist Party, about which he did not add any comment[4] [54]. In this letter, he informed that they had just finished a series of measurements with the counters positioned at 45° within the lead sleeves, which results confirmed and completed the previous ones. They were about to begin other series with an angle of 30° and 15°, yet there was not enough time to proceed with even more configurations. If the CNR was actually about to set up an institute there, with Ranzi as director, maybe the latter would carry out further investigations in the future. Rossi found the government *"molto ben disposto .... se non vi sarà da mettere fuori troppi quattrini"*. Still, at the moment they had to work for about 12 hours a day, from 8 am to 8 pm, replacing one another.

From about the 12th October he finally began to have some free time to wander around the surroundings of Asmara with De Bendedetti [55]. They first visited Basciaul, the indigenous city, about which he summarized *"Nell'insieme, da questa passeggiata mi è rimasta un'impressione molto penosa; non credevo che degli uomini potessero vivere in un modo così poco umano; eppure, dopo tutto, non è detto che debbano essere più infelici degli altri"*. Then Prof. Rolando Guidotti (chief of the Eritrean Agricultural Office) took him to take a look over the experimental cultures, which Rossi found very interesting.

A few days later he read an article on the *Corriere* about their expedition, which he found a bit exaggerated [55]. Indeed, that article, published on 30th September 1933, claimed that Rossi had officially confirmed the East-West effect [51]. As the article referred to a telegram sent by Rossi to the CNR, it is obvious that it was exactly the same telegram we previously considered when talking about the article on *La Ricerca Scientifica*. So, once again, we notice that the words Rossi used to communicate his (partial) results were likely to be considered as the announcement of the discovery, especially in the eyes of a reporter. He then spent a few words on his assistants, starting from De Benedetti: *"è un ragazzo molto sveglio; ed è inoltre molto coscienzioso nelle esperienze, tanto che credo di potermi fidare completamente di lui. Discutiamo spesso insieme sull'argomento delle nostre ricerche, e vedo che ha capito ed*

[2]We have not been able, so far, to identify which monograph Rossi referred to.

[3]Not to be confused with his younger and more famous brother Louis de Broglie (1892-1987), who was a prominent figure in the development of quantum mechanics. Maurice instead worked mainly in the field of X-ray diffraction and spectroscopy. In winter 1931-32 Rossi had stayed at Maurice De Broglie's private laboratory in Paris, where he also became friends with Louis Leprince-Ringuet (1901-2000) and Pierre Auger. More information about their scientific collaboration can be found in [6].

[4]It is quite strange, as we know that he had been part of the PNF since 31st December 1932 (cf. [72], p. 76), so this could either be something useful to complete the enrollment in the Party or just a mistake.

assimilato bene il problema. Spero di riuscire a fargli un posto a Padova, perché sono convinto che farà una buona riuscita". The comment concerning Ranzi was quite different instead: *"è anche un'ottimo compagno; ma forse un po' addormentato e non ha certo la padronanza, che ormai ha conquistato De Benedetti. Giacché cerco di farmi aiutare più da De Benedetti che da lui, anche per lasciargli il tempo di fare le sue esperienze che sono, del resto, assai interessanti"*[5]. Rossi followed the suggestion he read in the writings of Giorgin, that is of measuring the asymmetry at different zenith angles. Rossi probably intended to perform another one at 60° as well.

Figure 3.3: Some handwritten data from 1st and 2nd October 1933. On the bottom there is a drawing of what it seems to be the entrance of the hut, where a camera is put in front of two Àscari in their traditional clothes (probably it represents a scene in which Rossi was taking one of his travel pictures).

It was then time to set up Compton's instrumentation, yet as he said *"Le esperienze procedono sempre bene; soltanto l'apparecchio di Compton continua a farci impazzire"* [55]. The

[5]Throughout the expedition it seems like Ranzi showed a poor attitude in collaborating and getting on well with his collegues. Indeed, he also refused the idea Rossi and De Bendetti had of slightly extend the return trip in order to visit more places. This is in accordance with the peculiarity of his character previously depicted.

problem was solved in two days time, indeed he stated *"Penso che, finalmente, funzioni discretamente e vogliamo approfittarne per liberarci di questo pensiero"*, showing how it was not their favourite activity to carry on, still obviously an important one for an important physicist too. It was positioned inside a small military tent (so small that it was not possible to stand up inside of it), at a distance with respect to the hut in order for the radium contained in the experiment not to disturb the other detectors [56]. The tent was necessary not only to protect it from direct solar radiation or rain, but also due to the red sand that would coat it in a few minutes. About all these peculiar conditions in which they had to perform this experiments he commented that, all in all, *"ci sembra quasi di essere gli eroi di un romanzo di Salgari o di Verne!"*. They will take some measurements for Compton's experiment, and then it will be moved, after a week or so, to Massaua by Ranzi, where the latter will perform some other.

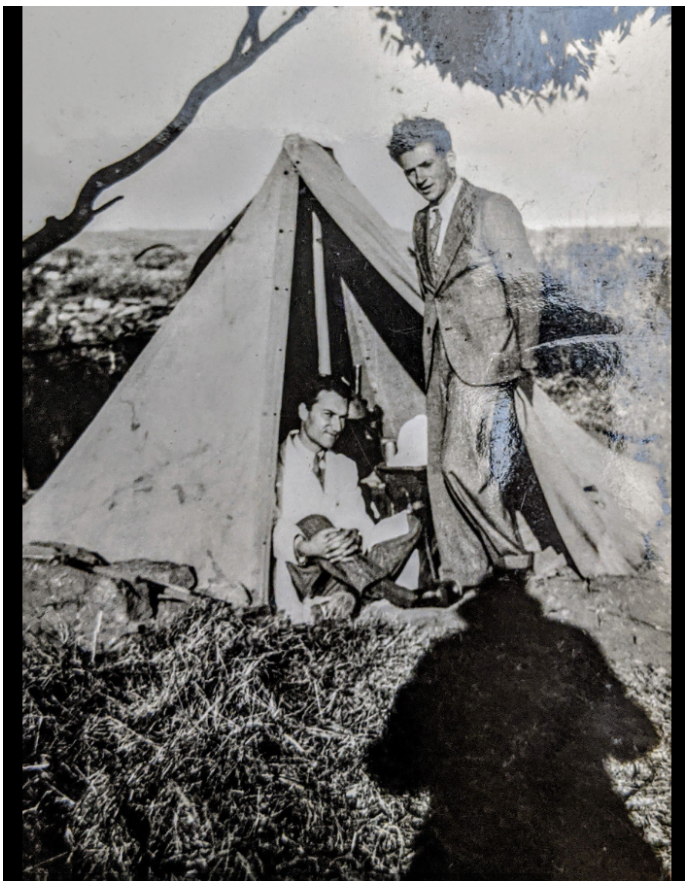


Figure 3.4: Rossi (sitting) and De Benedetti (standing) with the tent which hosted Compton's experiment. Asmara, Eritrea 1933.

On 24th October, he manifested his intention to write to the CNR considering the geophysical station, as that project *"sembra prenda consistenza"* [56]. The day before they went on a trip by car to the Western lands up to Cheren with Commissario Mosconi, one of the Government Directors, *"che stanno al Governatore come i ministri stanno al Re"*. First, they visited the Elabaret Concession hosted by Pietro Casciani (1869-1942), whose hospitality was known all around Eritrea [57]. Then they arrived in Cheren, where the Commissario of the city showed them the place.

Three days later, the first data taking in Asmara with Compton's apparatus was done, so Ranzi had to take it to Massaua to do the second one. On the other hand, *"Le esperienze principali sull'influenza del campo magnetico terrestre sono ultimate, ed hanno dato un ottimo risultato. Quanto a quei disturbi, che avevamo notato fin da principio, stiamo studiandone ora la causa"* [57]. We are missing at the moment the page of the letter that followed, in which Rossi probably argued the origin of this phenomenon. However, as we will shortly show, he came back to the same argument later, completing his considerations.

The last letter of October brings a fundamental piece of information about the new Institute of the University of Padua: *"Il progetto dell'Istituto mi era già stato mandato direttamente dagli ingegneri; mi sembra che, nell'insieme, corrisponda a quanto avevo fissato prima di partire; ad ogni modo ora lo esaminerò per bene e spero di arrivare a Padova prima dell'inizio dei lavori"* [57]. This is the first time that Rossi talked about the project, at least within the material we are taking into account. This means that he was commissioned to build a new Institute shortly after he arrived in Padua, so it took five years to have it done. Moving on to his trips in Eritrea, he showed his growing interest in exploring the surroundings by saying that *"in niente come nei viaggi, l'appetito vien mangiando: quanto più si vede, tanto più si impara a vedere e tanto più si desidera quindi di vedere. Io, per esempio, ad ogni nuovo viaggio mi accorgo di gustare e di capire sempre più il paese, gli uomini, i loro costumi"*.

3.3 November and December

The first day of November, Rossi wrote to a professor of the University of Padua (it was not possible to find out who). Rossi hoped that through his own commitment to physics and to the University of Padua (probably he was referring mainly to the construction of the new Institute and to the ongoing expedition) he could be worthy of the University itself [58]. Rossi then informed that the experiments in Eritrea were proceeding well, even though there was not enough time to study every aspect of the matter. Hence, *"sarebbe veramente desiderabilissimo poter istituire qui all'Asmara un centro di ricerche fisiche e geofisiche, come è nell'intenzione del Consiglio delle Ricerche. Il Governo sarebbe assai favorevole a questa iniziativa; bisogna vedere soltanto se si trovano i denari!"*.

On 6th November, he wrote that the day before Mosconi had brought him to the Eastern Concessions [59]. There they were hosted in the Matteoda Concession by the wife of the lawyer Carlo Matteoda, a woman of exceptional activity and energy who owned the coffee production business (the biggest of the whole colony) started by his husband before he was expelled from Eritrea. The mixture of intelligence, influence and stubbornness she embodied was probably feared by many important men, and someone even called her *"il nostro dolce tormento"*. The trip was pleasant and on the way back they could also pay a visit to a recently opened gold mine. Finally, Rossi went back to the question of the apparent malfunctioning of his experimental equipment, concerning which he had now developed the belief of having found something new:

"quel disturbo parrebbe che non fosse un disturbo ma che nascondesse un fenomeno nuovo; non so però se mi azzarderò ad annunciarlo, dato il poco tempo che ho avuto a mia disposizione per studiarlo". Even though this discovery was to reveal itself as a fundamental one in the history of physics, he considered another one to be the most important: Ranzi probably found extensive deposits of radioactive minerals in the region of Massaua. At first, he and Rossi tried to analyze a sample conserved at the local Mining Institute, bringing it close to the counters, whose impulses began to increment. So when Ranzi had to go to Massaua to carry out measurements with Compton's apparatus, he also went to the mine where the sample came from, finding that the mineral was largely present there. The element which they argued to be responsible for such radioactivity was radium, still further analysis in Italy were necessary to find out if it was the case and, more importantly, if the concentration was enough to justify an eventual project of extraction. Rossi prayed his mother not to tell anyone about this, as the CNR had not been informed yet. The letter ends with a reassurance about his still very positive economic situation, probably due to the great amount of support he and his assistants received throughout their stay in Eritrea.

During those days they were very busy for the conclusion of the experiments [59]. Rossi began to write a note in English that he intended to send to the *Physical Review* before coming back to Italy. At the same time, he had finished and sent to Padua the second part of the electrostatics notes used to carry on the course in his absence. He had also read the article on his research on *L'Illustrazione Italiana*, yet he complained that *"ci sono diversi strafalcioni! Ma è inutile, dei raggi cosmici nessuno ne capisce niente!"*.

Ranzi was about to leave on 15th November, ahead of Rossi and De Benedetti's departure, as he was not intentioned to lengthen the way back to Italy [60]. Also, a couple of trunks with some of their personal items and the boxes with all the material were to be shipped in advance. Once in Italy, Rossi's mother would collect the trunks, while Angelo Drigo (1907-1978)[6] would collect the boxes and bring them to Padua. Back to what was happening, Ranzi had just returned from Massaua, satisfied with the result that the radioactive material turned out to be quite abundant. Ranzi thus announced the discovery to the Government, and Rossi to the CNR as well. The Governor seemed very interested about the question, being also favorable to the realization of the geophysical station, *"di denari però non sembra che possa o voglia metterne fuori"*.

There is now a lack of letters that goes from the one dated 14th November to the one dated 26th November. We hope that this gap will be soon filled whenever the material will be completely available.

[6]After graduating in physics at the University of Padua in 1929, Drigo was for several years assistant to Rossi, following closely his research activity. During this period, his future wife Giulia Alocco (1910-2003) was working there as an assistant in experimental physics as well. In 1934 Drigo became professor of experimental physics, and in 1939 he succeeded Rossi as director of the Institute. From 1943 on he spent the rest of his career at the University of Ferrara, of which he was Rector from 1965 to 1972. In 1946, thanks to Enrico Fermi, he was elected member of the American Physical Society.

Compton was informed by Rossi of the results obtained with his apparatus with a letter dated 25th November [61][7]. Exploiting Compton's papers, Rossi had extrapolated some useful quantities and then had measured the intensity of cosmic rays both in Asmara and in Massaua. Furthermore, he informed the American physicist that the measurements concerning the East-West effect were in accordance with the ones made in Mexico City. It emerges then that Compton had proposed to Rossi to publish his results on the *Physical Rewiev*, so he was sending him some of the his and De Benedetti's notes with the request of submitting it to the journal[8]. In the post scriptum he added that a continued measurement of the intensity of cosmic rays during the trip from Italy to Massaua had shown a clear reduction while moving towards the equator.

On 25th November Rossi sent his data, along with a brief note, to the CNR as well, which published them on *La Ricerca Scientifica* as a preliminary report [64]. He pointed out here all the main findings, anticipating a forthcoming complete publication (which can be found in [66]).

"Questa è stata proprio una settimana campale" [62]. With this sentence Rossi began the letter written on his last full day in Asmara, underlining the great effort of their last week of work: general preparations, letters, farewell visits, packing of the material to be shipped. Nevertheless, during those months Rossi had grown attached to the place and to the physical laboratory he and his colleagues had set up in such an unusual environment, indeed telling his mother: *"Ti confesso che, quando abbiamo smontato i nostri apparecchi, mi sono accorto che a poco alla volta, mi ero affezionato al nostro laboratorio improvvisato sull'amba del forte Baldissera; ed ho pensato con un po' di dispiacere che non avrei probabilmente più rivisto quello strano panorama di collinette rosse tagliate geometricamente, che, al tramonto, secondo la loro distanza, si colorano di una tinta più o meno intensa, formando come un fantastico scenario"*. On the other hand he explained that, except for work, life there was terribly monotonous, describing a typical week:

"lunedì: il giorno prima di quello in cui arriva la posta
martedì: il giorno in cui arriva la posta
mercoledì: il giorno in cui parte la posta
giovedì: il giorno in cui si mangia l'antipasto
venerdì: il giorno in cui spara il cannone
sabato: il giorno della première al cinematografo
domenica: il giorno in cui spara il cannone e si mangia l'antipasto".

The last, quite long, letter we have talks about what happened from their departure on

[7]The letter is written in German, as Rossi did not possess a sufficient knowledge of the English language. Indeed, both Rossi and his wife had to struggle to learn English when they began to wander first around Europe and then around the US (cf. [70], p. 37 and 128).

[8]Two articles came out, one made by Rossi and another by De Benedetti [13, 65]. Even though Rossi also published the results obtained with Compton's apparatus on *La Ricerca Scientifica*, underlining the good accordance with previous publications (cf. [66], pp. 575-578), the same results were not published in these two articles.

27th November all the way to a few days before their arrival in Venice, which should have occurred on 19th December [63]. Here Rossi described the several trips he undertook during the return journey, in which he eventually fully recognized the incomparable charm of the African lands in which he had spent more than two months: *"Per la prima volta ci siamo sentiti prendere irresistibilmente dal fascino di questi paesi tropicali, nei quali lo spirito umano è completamente soggiogato dalla potenza, direi quasi dalla prepotenza della Natura. Si sente, in ogni sua manifestazione, un respiro così ampio, così solenne, come da noi, colla nostra natura addomesticata non possiamo avere più pallida idea".*

Figure 3.5: Rossi (right) and De Benedetti (left) sailing through the Red Sea, 1933.

4. Conclusions and research perspectives

In this last chapter we will gather all the main findings of this dissertation, giving some hints about what needs to be clarified or discussed in a broader context.

First, we will consider the results obtained during the expedition to Asmara, showing their impact on Rossi's carreer and on physics in general. In the light of that information, we will move to talk specifically about Rossi's scientific legacy, discussing why and how his figure has partially been forgotten and the consequent importance of a reanalysis of his life and work.

Then, we will briefly show how poor some of the biographical information about Rossi's collaborators and other people related to that period of the history of physics is, leading to the urge of a deeper analysis that would help to reconstruct some outstanding issues.

At last, we will focus on three very interesting lines of possible research which stemmed from the present project. One concerns the intention of the Italian government to bring Rossi back from the US and the issue of why this never happened. Another is about Compton's worldwide programme, whose organization is still unclear. Finally, we will reconsider the relation between Italian scientific institutions, in our case the CNR, and the colonies, as there are still many unknown aspects regarding the destiny of scientific centres which they planned to realize overseas.

4.1 Results of the expedition

In April 1934 Rossi, De Benedetti and Ranzi published the complete results on *La Ricerca Scientifica* [66]. Let's consider them in order to show how the expedition brought to unprecedented findings. It must be specified that almost all the results concerning cosmic rays were obtained removing their soft component via lead and brass shieldings, hence the effects we are about to take into account refer to the hard component (later to be identified with muons), except for one experiment.

First, they used a single Geiger-Müller counter to measure the latitude effect. Compton, as we will recall in a while, made use instead of an ionization chamber. During the boat trip, they counted the rate at which a Geiger-Müller counter recorded the passage of cosmic rays. At last, the rates at different latitudes were compared, and they clearly confirmed the decreasing trend from large to small latitudes. In the same section, he presented the two measurements of the absolute cosmic-ray flux made both in Asmara by himself and De Benedetti and in Massaua by Ranzi via Compton's ionization chamber. Such data were in accordance with the worldwide study Compton was carrying out, thus represented a confirmation of the effect. Together, the latitute effect measurements allowed Rossi to deduce a lower bound of 3 GeV for the energy of cosmic rays which manage to get to the Earth's surface.

Rossi then moved on to the most significant part of the article: the analysis of cosmic-ray flux as a function of the azimuth angle, from which the idea of organizing an expedition actually stemmed. The data supported that the charged component of primary cosmic rays was made up of mainly positively charged particles. As abovementioned, Compton and his collaborators had already arrived to the same conclusions, yet Rossi's research allowed for the first time to draw an even stronger argument: positively charged particles cannot make up only a minor part of primary cosmic rays (Compton estimated an 87% of uncharged component), rather their majority.

Concerning the dependence of the cosmic-ray flux on the zenith angle, they found that it monotonically increased as the zenith angle decreased, in accordance with their expectation. However, the trend differed from the predicted one, which was only based on the absorption of the rays in air. Nowadays, a semi-empirical formula suggests a trend for the flux, in particular the muon flux, close to the cosine squared of the zenith angle. The complex structure of air showers and of the atmosphere (for instance, we will see in a while that Ranzi himself found it difficult to interpret the results about the ionosphere) bring to the impossibility of deriving a purely analytical formula. It is then natural that Rossi could not solve the issue.

In his review, Rossi dedicated a brief *"osservazione"* to a new and unknown phenomenon he had run into while determining the random coincidences among multiple counters. We have already reported inside the travelogue how he became aware of its existence, ruling out the possibility of a malfunctioning generating it. In Asmara, he even had recorded, as a further check, an excess of random coincidences among three counters positioned on the same pane and at large distance from one another. He then hypothesized that *"parrebbe dunque [...] che di tanto in tanto giungessero sugli apparecchi degli sciami molto estesi di corpuscoli, i quali determinassero coincidenze fra contatori anche piuttosto lontani uno dall'altro"*. However, he stated that unfortunately they did not have enough time to study more in depth the question, which will bring in the following years to the identification of the so-called extensive air showers.

The only experience which was carried out without the lead sleeves around the counters concerned the study of the interaction of cosmic rays with matter. He repeated the experiment he had carried out in Arcetri, where three Geiger-Müller counters could be triggered only if showers stemmed from the interaction of cosmic rays with a layer of lead positioned above them. The results were then compared with a second repetition of the experiment in Padua after coming back from Eritrea. Such comparison showed that cosmic rays in Asmara, so in a place of great height and small latitude, showers occurred more frequently than in Padua, correctly arguing a correlation with the presence of more soft component particles in Asmara than in Padua[1]. Other considerations suggested to him that the soft component of cosmic rays was not produced by the hard one, something he was about to confirm with further experiments. Putting everything together, it was now clearer that the soft component was able to produce

[1]The soft component particles, that is electrons, positrons and photons, constitute indeed the electromagnetic part of the secondary cosmic rays and lose energy faster than the hard (muonic) component.

showers a lot more than the hard one (actually the hard one, that is muons, does not produce showers). Also, here he found an excess of random coincidences but, as previously recalled, he could not know that they were due to extensive air showers. For the sake of precision, we remember again that at the time physicists ignored the existence of pions too, whose role in the formation of showers cannot be ignored in order to fully interpret his results.

The last pages of the article contain Ranzi's results on the Heaviside-Kennelly layer, about which we only give the essential information, not being this of central importance for our purposes. He referred to two interesting observations: the presence of a peak in the ionization which occurred some time after the solar radiation peak, and some peaks in the ionization even at night. Both the phenomena indicated that the knowledge about how ionization of the upper atmosphere takes place was far from being completely understood at the time, so Ranzi encouraged further research on the topic.

4.2 On the valorization of Rossi's figure

Bruno Rossi had a prominent impact on the development of cosmic-ray physics (and other fields like particle physics too) under many different aspects. His ability to conceive innovative experimental setups, above all the coincidence circuit, and his deep knowledge of such newborn research field allowed the spread evidences which had been collected starting from 1912 to link together and unite, little by little, under a coherent interpretation scheme. It is our intention now to recall his main contributions and legacy, pointing out how they have brought to research lines which are nowadays still investigated.

Rossi's attitude to be a good teacher and scientific communicator were at the time well known. Even if he was at the beginning of his career, in 1931 at the Nuclear Physics Congress in Rome he was not afraid to publicly challenge Millikan's undulatory hypothesis for cosmic rays in favour of the more empirically sustained particle hypothesis. His arguments and exposition of the question were so convincing that, according to Rossi's biography, Compton's interest in cosmic rays, a field in which the American physicist had never worked in before, started that day (cf. [70], p. 15). Just like Compton, we can surely tell that many others were inspired by Rossi to pursue this kind of scientific research, gathering useful help for understanding the cosmic radiation. Different books, handwritten notes of his lectures and positive feedbacks about them corroborate this point of view.

Analogously to what we have just said, the entire group of Arcetri benefitted from Rossi's influence. In particular, Occhialini began his brilliant career thanks to the far-sighted intuition Rossi had in sending him to England at Blackett's side. The rest of the group undertook several experiments in cosmic-ray physics too, giving important contribution to some aspects like the production of showers.

Throughout his career, he continued to provide opportunities for scientific growth to his collaborators, paving the way for great discoveries. As an example, we have already recalled

that in 1962 along with Giacconi Rossi discovered the first source of X-rays coming from outside the Solar System. This unprecedented observation, in which Giacconi took part developing the actual method of realizing it, opened the eyes of the scientific community on the possibility of studying, by different means from usual telescopes, remote objects and their characteristics. In 2002 Giacconi received the Nobel Prize for this work with motivation "for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources". We have to give Rossi credits for it, as at the time he was coordinating the MIT group on cosmic rays and had the idea of asking the American Science and Engineering Company for support. So maybe without Rossi's commitment, the discovery would have arrived some years later.

Stepping back, the coincidence circuit is by far one of Rossi's revolutionary insights. It allowed to tremendously reduce the time window inside which two events could be said to occur at about the same time (for cosmic rays a single particle that passes through all the detectors), thus discarding a lot of noise. Unlike other attempts to realise a similar circuit, like Bothe's during the same period, Rossi's circuit allowed to register even more than double coincidences: the number of valves connected in parallel determined the number of elements whose coincidence was needed. Its technical simplicity and versatility resulted rapidly in a large scale diffusion of this method. However, Rossi could not predict that this circuit was to become one of the basic and fundamental elements of electronic computing: the AND and the OR gates are indeed the natural evolution of the coincidence and anticoincidence method.

Although Rossi's work on the East-West effect was at the time considered only as a confirmation of Àlvarez and Johnson's results, it should be stressed that it was the first experiment which clearly permitted to conclude that primary cosmic rays are made of a majority of positively charged particles. Rossi himself recalled multiple times this aspect, as the previous results could not rule out definitively the scenario in which a major part of cosmic rays is electrically neutral.

Another crucial contribution Rossi gave to cosmic-ray physics is the discovery and study of extensive air showers. Rossi was the first to notice their existence, though not having the time to accurately study them. The experimental configuration he made up in Asmara, in which three Geiger-Müller counters were positioned far from each other, can be considered as the first array of detectors aimed to study this new phenomenon. In the following years, thanks mainly to the work of Pierre Auger, research on this topic intensified. As we mentioned in the first chapter of this thesis, during the period 1950-1960 Rossi returned to study extensive air showers by means of huge arrays of detectors, the only way to reconstruct their behaviour and the energy spectrum of the primary radiation. In doing so, he and his group had to make the great change from liquid to plastic scintillators for the detectors. Big enough pieces of plastic scintillators were not available at the time, so Rossi's group had to develop them on purpose. Therefore, Rossi's work on extensive air showers went from their very first observation all the way to the big projects which allowed to fully characterize them.

Last, we cannot avoid mentioning the effort and time he put into the realization of the

new Institute of Physics of the University of Padua, to which he dedicated almost all the years he spent in Padua. Recently the University managed to name the library of the Physics and Astronomy Department after him, the first concrete acknowledgment to Rossi since its building.

This list is not intended to be complete, as much more could be added to it, but aims to give the reader a clear picture of Rossi's merits throughout his life to physics and its institutions, and to the scientific community as a whole. We think that his figure has been partially forgotten by many, and that even his contribution are nowadays considered not as fundamental as they actually are. A reason for that can be found in the instead enormous attention paid in the years to Fermi's Rome group, leaving the Arcetri group and Rossi himself in the shadow. Anyway, we hope that this dissertation could help in valorizing his life and work, suggesting carrying on this positive process.

4.3 Biographical insights

Among the several physicists and intellectuals Rossi encountered during the Paduan period, some of them possess a personal story that can help us better understand the circumstances that surrounded the physical community of the time. Nonetheless, historians have sometimes neglected to reconstruct some parts of their lives. This thesis project have now raised questions that directly need an in-depth analysis of certain biographies. It is now our concern to point out some of them.

Sergio De Benedetti (1912-1994) had a lifelong career in the field of particle physics, starting with his thesis on cosmic rays with Gilberto Bernardini at the Experimental Physics Institute of the University of Florence, and ending up as a professor of physics at the Carnegie Mellon University of Pittsburgh. Looking for information about his participation to Rossi's expedition we stumbled across his unpublished *Note Antifasciste*. In those memoirs De Benedetti gives unique pieces of information about his and his friends' (like Eugenio Curiel on whom we will dwell shortly) life under fascism. According to [2], which appears to be the only article on the subject, two versions of the memoirs exist (cf. [2] p. 100): a noted version conserved at the Archival Centre of the Scuola Normale Superiore di Pisa, and one without notes, the one we had considered, published on the website of the "Frank Mt. Pleasant" Library of Special Collections and Archive of the Chapman University of Orange, California [14]. The noted version could reveal even more parts of the backstory we are interested in. Moreover, as the only (poor) biography of De Benedetti was written and published by his daughter Vera [15], the search for documents and interviews (his three children are still alive) is fundamental to get to a complete picture of his life and his scientific and socio-political contributions.

Ivo Ranzi (1903-1985) is certainly the person whose life is most shrouded in mystery compared to the others we are considering. Apparently he was a friend to Rossi, something we deduce primarily from their letters, yet this clashes with Ranzi's growing racism, being Rossi Jewish. This is not the only controversial aspect of his life: we recalled his collaboration

with the Nazi-fascists and the fact that he allegedly made some of the documents which talked about this disappear. The fact is reported in [73], where the author, after research into the Italian Central State Archive, talks about *"i (misteriorsamente) pochi documenti d'archivio a suo riguardo* (cf. [73], p. 58). Further research needs to be carried out with the aim of unveiling most of this obscure affair.

Eugenio Curiel (1912-1945) has been cited multiple times during this dissertation, as he was close to both Rossi, his supervisor, and De Benedetti, his best friend and colleague at university. His tragic death, as he was killed by the Camicie Nere in Milan on 24th February 1945, followed several years of militancy inside the Resistenza as a partisan. Curiel's political thought and actions have been profusely discussed in different books and articles, yet there seem not to be a zoom on his academical and scientific activity, which would integrate and, hopefully, help to comprehend the history of his life. De Benedetti himself, despite knowing Curiel very well, could not fully understand his friend's decisions. Lastly, as far as we know, no one have ever taken into account the information about Curiel available inside the *Note Antifasciste*.

Figure 4.1: Photograph of Eugenio Curiel.

Carlo Anti (1889-1961) was an archaeologist, rector of the University of Padua from 1932 to 1943. During his rectorate he promoted a deep renovation of the University, which culminated with the construction of new buildings such as the *casa dello studente* "Principe di Piemonte" (1935), Palazzo Liviano (1940) and the new Institute of Physics (1937). The latter was commissioned from Bruno Rossi shortly after his arrival in Padua. Anti's attitude toward fascism was probably an optimistic one, as he seemed to focus only onto the opportunities that a strong government could offer in terms of economical and political support to Italian culture. Yet several other ambiguities suggest clarifying his role and his precise point of view. As far as

we are concerned, further information of that kind could turn out to be useful to have a better look at the academical environment in which Rossi, along all the other intellectuals who later had to flee, lived his last Italian years.

Gian carlo Wick (1909-1992) was a theoretical physicist, primarily known for his work in quantum field theory, where different concepts and rules were named after him. A close friend of Fermi and Rossi, he managed to collaborate with the former in Rome, producing significant results. In the Venice archive we found about thirty letters among Wick, Rossi and Fermi. Dated from late 1937 to mid 1938, the letters talk about Wick's academical placement and other questions. Having notice the lack of a complete biography about Wick, this new material could represent a good starting point for some research on his life.

4.4 Other considerations

At least other three questions are worth discussing, especially for the useful information that we could extrapolate from them.

The first issue concerns Rossi's non-return to Italy at the end of the war. After the Second World War came to an end, the nascent Italian Republic (the passage from monarchy to republic was decided via an institutional referendum on 2nd and 3rd June 1946), was profoundly interested in bringing back those Italian scientists who, due to both political or racial reasons, had to flee to another Country during the *Ventennio*. Italian science had been substantially destroyed by such losses and in particular physics had lost prominent exponents, among all Fermi and Rossi, with the consequent spread and weakening of their groups. It was then time for the *"anni della ricostruzione"*, so defined by Edoardo Amaldi (1908-1989) in an article dedicated to those years [1]. We know from archival material of the University of Padua that, starting from 13th October 1944, the Ministry of Public Education asked the Ministry of Foreign Affairs to contact Rossi [88]. However, still by April 1946 no one had sent such information, even though the University itself appeared to have been aware of the request. We do not know what happened next, nonetheless it is a fact that Rossi never came back to Italy if not many years later, as seen in the first chapter. It is possible that Rossi intended to remain in the US, yet some more documents could allow reconstructing the reason why it took so much time to the University and to the Ministry to contact him. Some other hypothesis regarding his academical destiny exist, such as competition for the chair of the Institute of Physics in Padua, but it is too early to jump to conclusions.

The second question concerns Compton's worldwide series of experiments. They aimed to detect the latitude effect, and counted more than a hundred single experiments, an 80ish of which were carried out by independent groups, while the rest were directly coordinated by Compton himself. Rossi, De Benedetti and Ranzi's measurements in Eritrea, made with Compton's apparatus, were nicely compatible with the previous ones which had already been obtained. However, it seems their data was never directly credited to them: the only hint we

have comes from a 1936 Compton's article, in which a black dot (a latitude effect measurement directly coordinated by Compton) is positioned in what we hypothesize to be Asmara (cf. [12], p. 73), yet without specifying who did the measurement. The same fate may have been destined to another Italian measurement of the same series, as inside De Benedetti's *Note Antifasciste* we found the following consideration: *"ero in relazione con un professore di Napoli, cui dovevo consegnare un apparecchio per lo studio dei raggi cosmici, costruito in America da A. H. Compton, e che doveva essere usato per misure in tutto il mondo [...] Arrivai con le casse dell'apparecchio americano e prima di passare l'esame lo montai riuscendo a farlo funzionare perfettamente"* (cf. [14], V, p. 1). From this we learn that another measurement was to be carried out in Naples even before the expedition took place, and indeed in the same image of Compton's 1936 article a white dot (a latitude effect measurement obtained by an independent group) is positioned where exactly Naples is (see the map reproduced from [12] in figure 4.2). No other article appears to provide further information on these measurements, so the question should be better analysed in order to comprehend how this worldwide experiment was precisely organised.

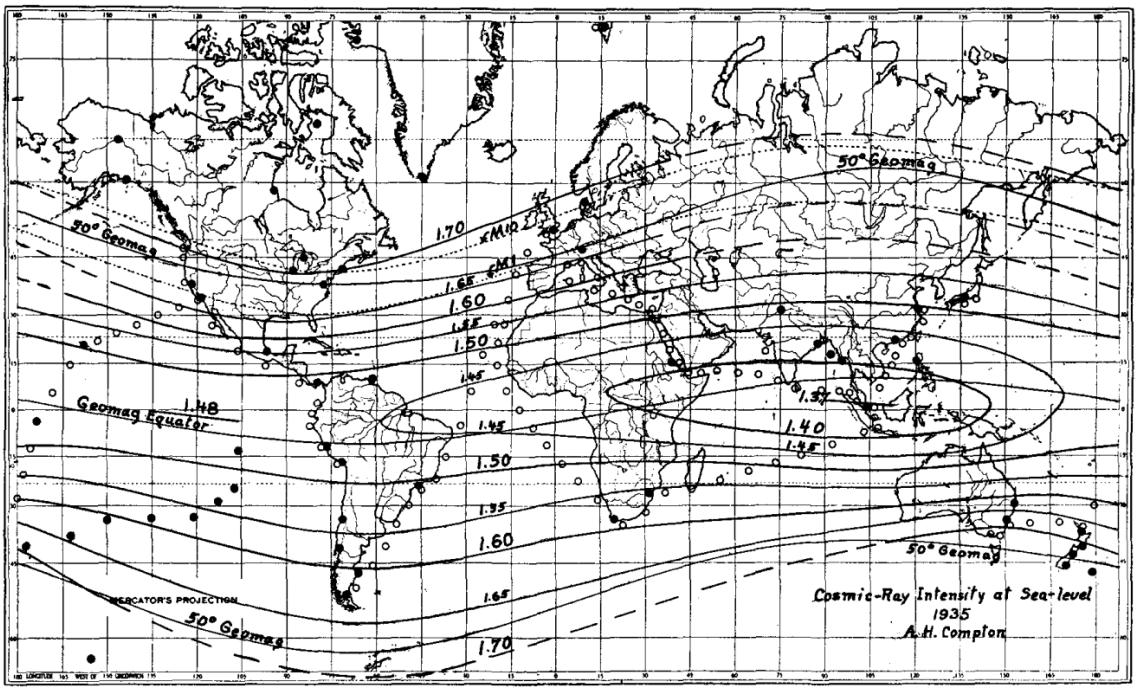


Figure 4.2: Map of the state of Compton's worldwide research programme up to 1936 [12].

The last not completely clear topic we consider are the CNR overseas research centres. We have encountered multiple times during this thesis, particularly during the travelogue, the intention of the CNR of building a physical and geophysical centre in Asmara, similarly to what had already been done in Mogadishu. In addition to what we have already showed, we report this words appeared on *La Ricerca Scientifica* while the expedition was still taking place: *"il Consiglio Nazionale delle Ricerche sta ora svolgendo pratiche per ottenere che la Stazione stessa possa continuare i suoi lavori in modo permanente nella speranza di poter giungere presto*

anche all'impianto di un Osservatorio astronomico che in quella regione avrebbe grandissima importanza per la scienza" [86]. This is actually the last time that the CNR mentioned such a project, leaving a big question mark on why it was abandoned at last. Probably economical, political and organizational reasons concurred, yet finding out more about this project would be very interesting. Indeed, connecting to what have been told about the situation of the Italian colonies, the history of the successful Somalian and of the failed Eritrean projects still have the potential of revealing an amount of information of great utility for historians of physics and for historians of the colonialism as well.

4.5 Summing up

Just like Rossi had the opportunity to look through "a new window into the surrounding world"[2], so the new documents found in Venice allowed us to look through a new window into his life and into the history of physics. What we found revealed unknown backstories which helped to better reconstruct Rossi's work during the Paduan period, especially concerning the expedition to Eritrea. On the other hand, new questions have been raised, bringing to a renewed interest in looking for more information about several aspects related to his story and to the story of the people he was in touch with as well.

The large amount of letters taken into account also represents an unprecedented source of information about his personality and inner thoughts about science and society. His comments on politics, colonialism, economical aspects of the Italian scientific institutions and many more issues give us a glimpse of his eclectic attitude. He was a thorough observer of nature and of its incomparable charm, on whose description and understanding he put effort in both a scientific and a humanist way.

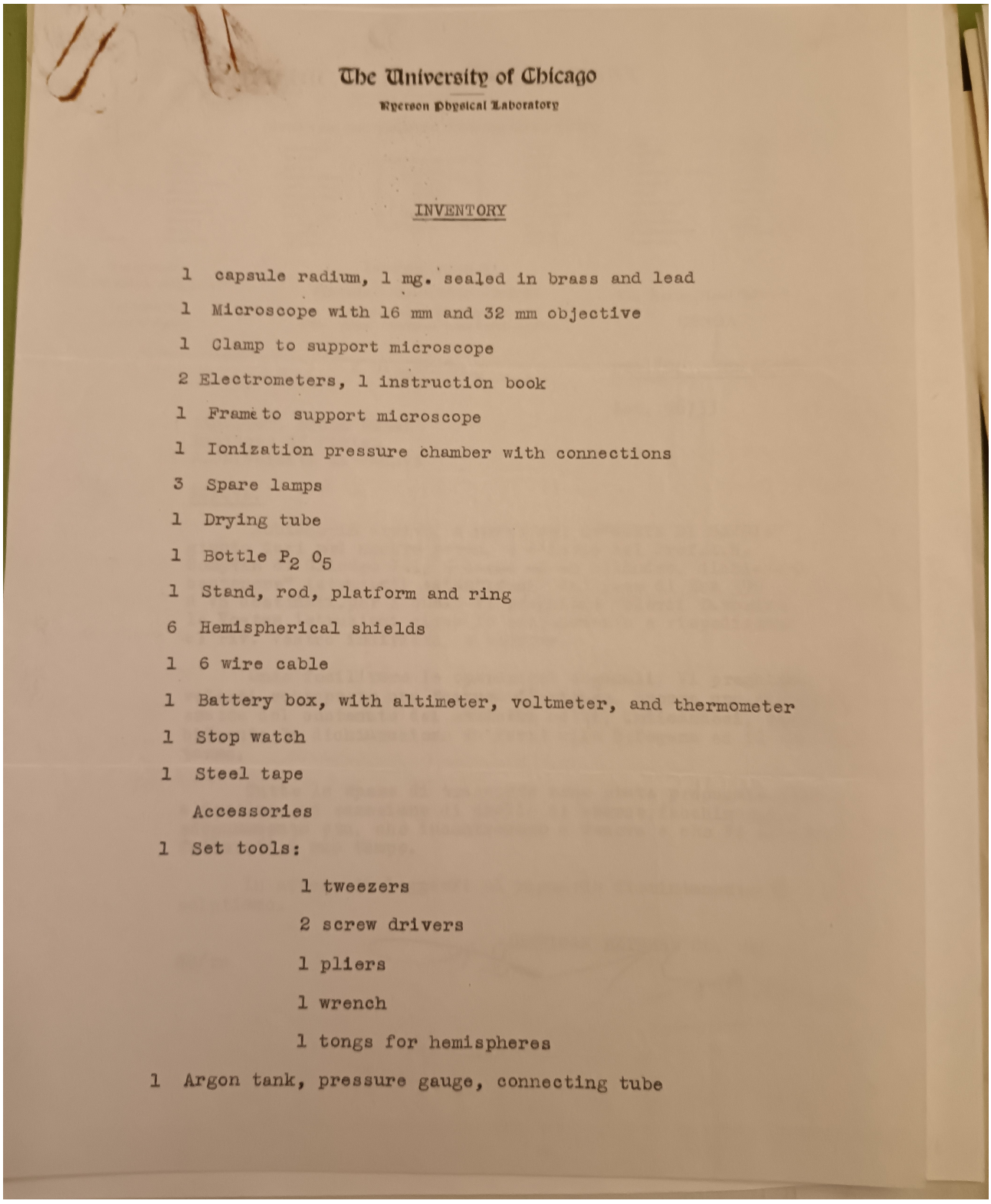
As we said, the research on these topics is not finished yet. Actually, this thesis marks just the beginning of a long work that needs to be done. Due to the restriction of a Master Degree thesis' project, we focused only on the core theme of the expedition, yet hundreds of the documents found in Venice are still waiting to be made available for a proper historical and physical analysis.

We hope that, in the following years, most of the issues hereby presented will be taken into account and given the attention we think they deserve. Indeed, the direct and indirect influence Rossi had on the huge and complex system of the history of cosmic-ray physics, and of physics itself too, is crucial to obtain a clear picture of the whole evolution of these research fields.

[2]This is part of the quote, already presented at the very beginning of this thesis, taken from the speech Rossi delivered upon receiving the Rumford Prize in 1976 in Cambridge.

A. Examples of documents

What follows is a sample of typical documents found in Venice.



The University of Chicago

Ryerson Physical Laboratory

INVENTORY

1 capsule radium, 1 mg. sealed in brass and lead
1 Microscope with 16 mm and 32 mm objective
1 Clamp to support microscope
2 Electrometers, 1 instruction book
1 Frame to support microscope
1 Ionization pressure chamber with connections
3 Spare lamps
1 Drying tube
1 Bottle $P_2 O_5$
1 Stand, rod, platform and ring
6 Hemispherical shields
1 6 wire cable
1 Battery box, with altimeter, voltmeter, and thermometer
1 Stop watch
1 Steel tape

Accessories

1 Set tools:
1 tweezers
2 screw drivers
1 pliers
1 wrench
1 tongs for hemispheres

1 Argon tank, pressure gauge, connecting tube

Figure A.1: First page of document [82].

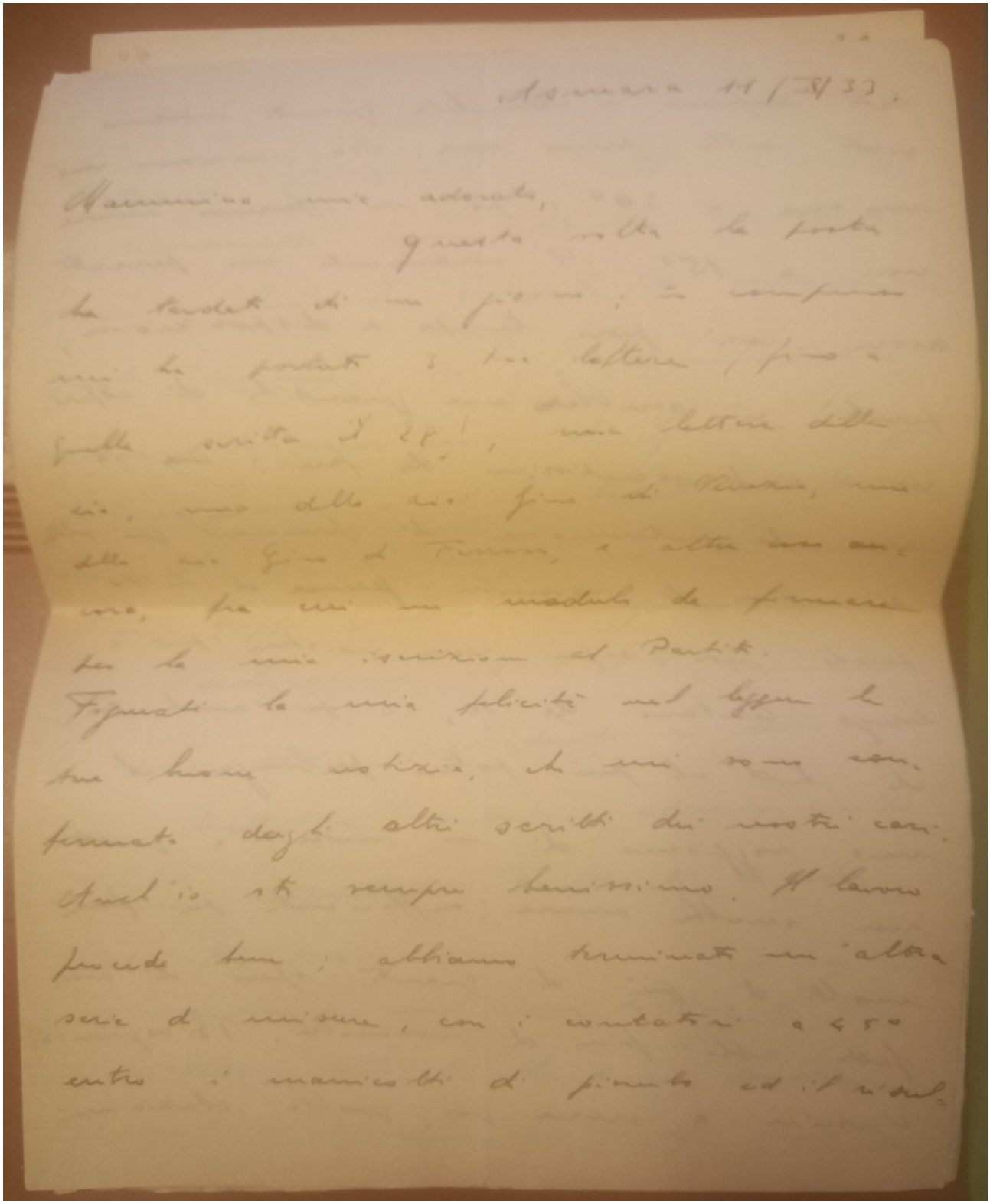
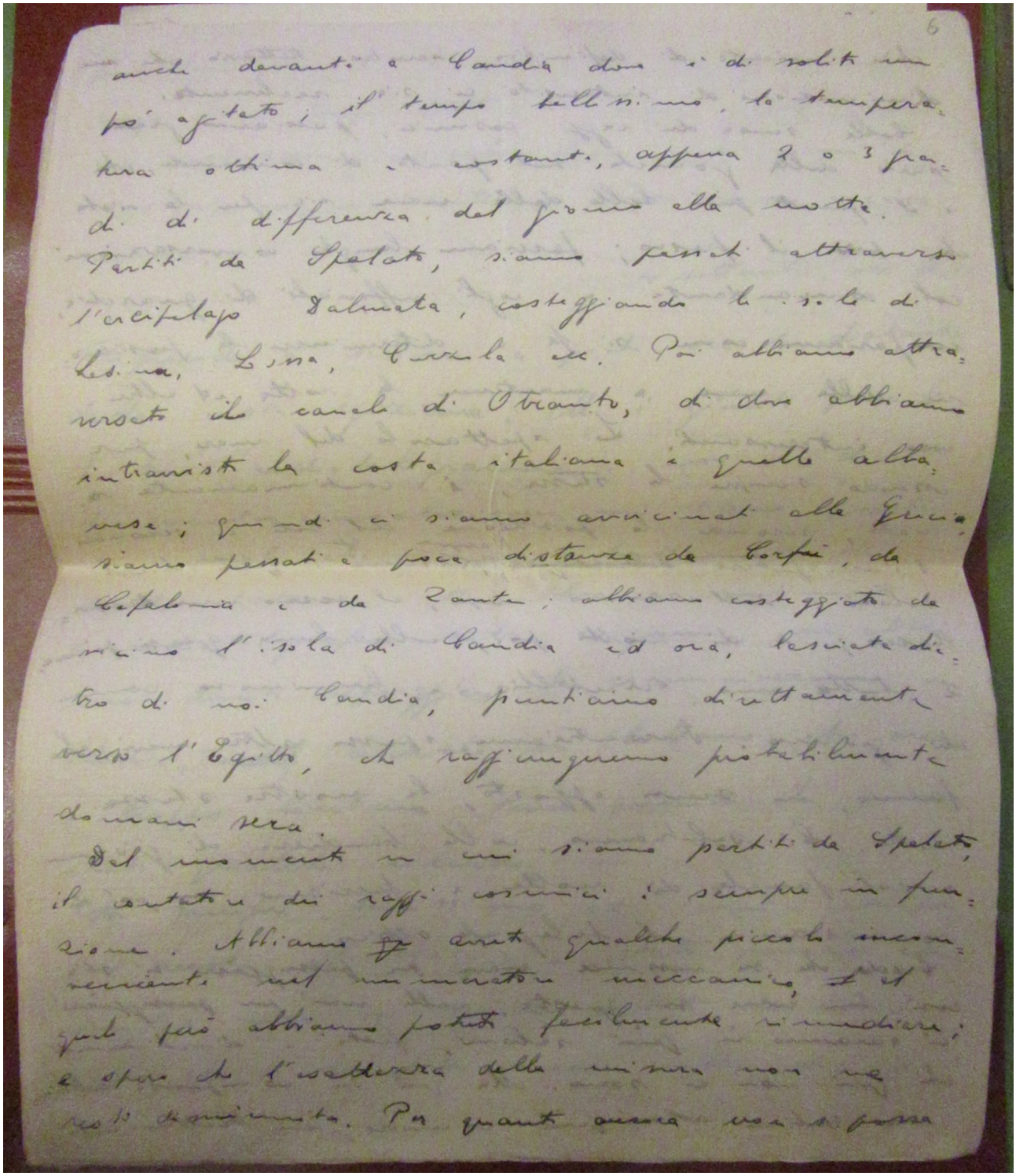
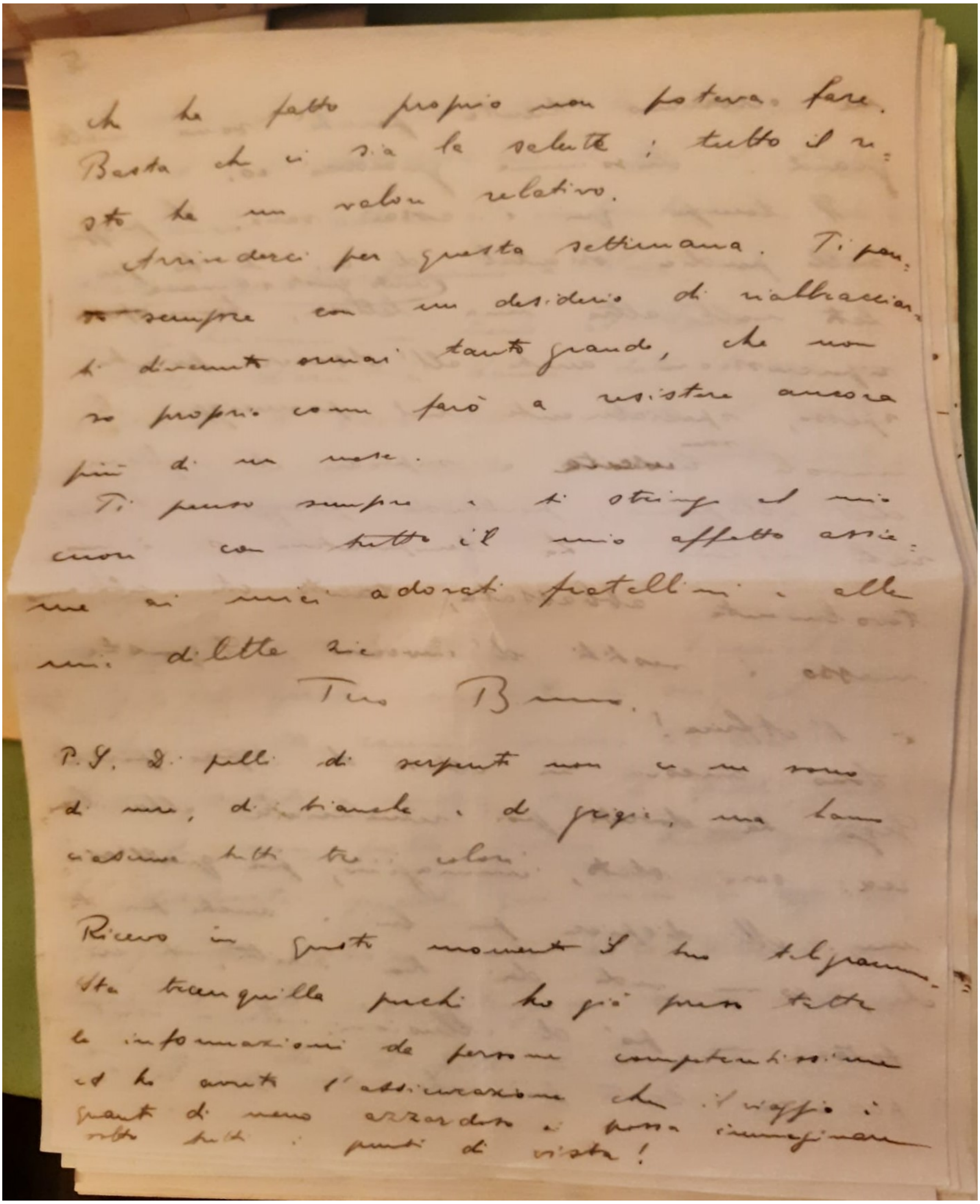


Figure A.2: First page of document [54].



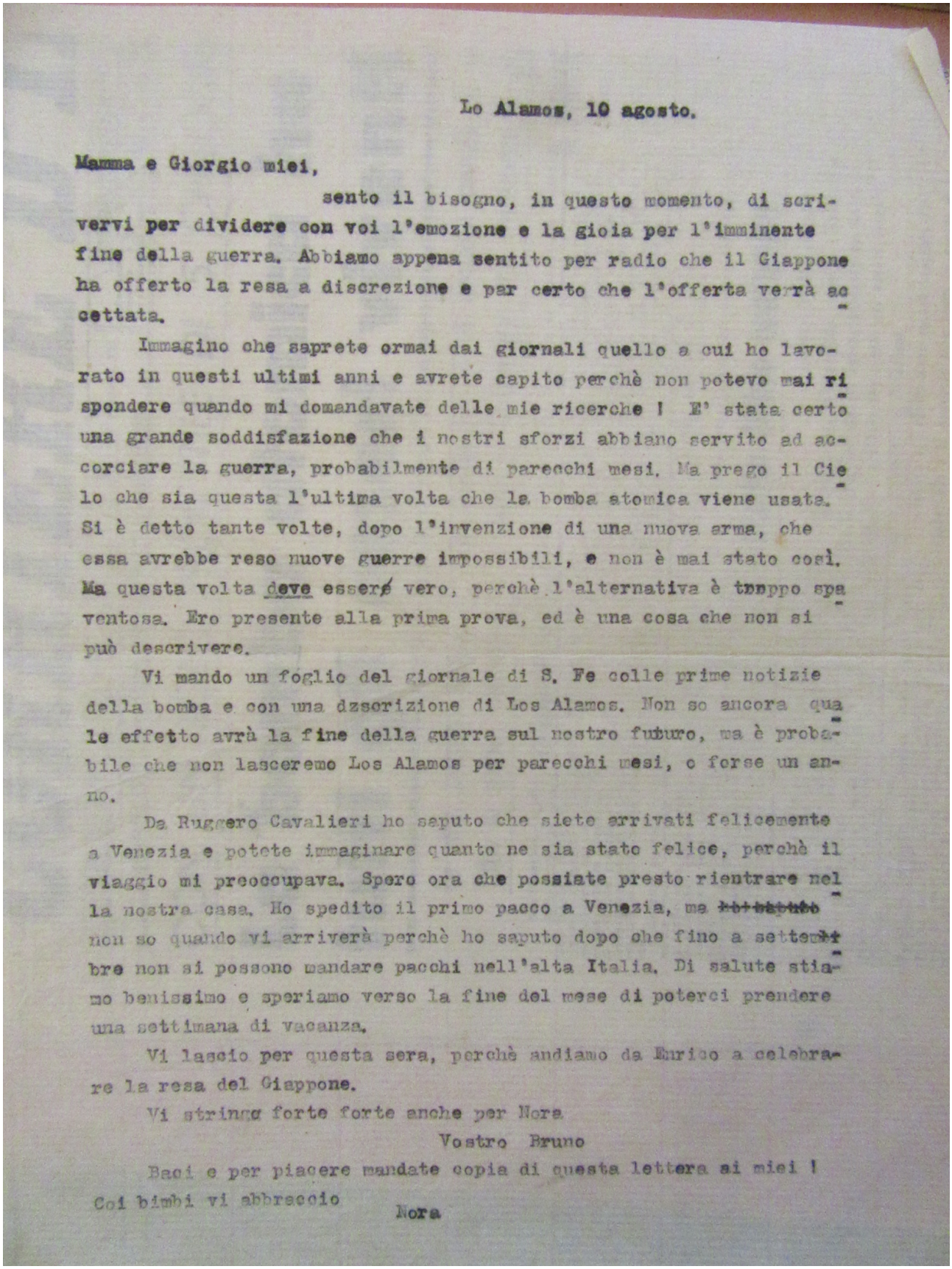
anche davanti a Candia dove è di solito un
po' agitato; il tempo bellissimo, la tempera-
tura ottima e costante, appena 2 o 3 gra-
di di differenza dal giorno alla notte.
Partiti da Spalato, siamo passati attraverso
l'arcipelago Dalmata, costeggiando le isole di
Lesina, Lissa, Curzola ecc. Poi abbiamo attra-
versato il canale di Otranto, di dove abbiamo
intravisto la costa italiana e quelle alba-
nese; quindi ci siamo avvicinati alle Ionie,
siamo passati a poca distanza da Corfù, da
Cefalonia e da Zante; abbiamo costeggiato da
vicino l'isola di Candia ed ora, lasciata die-
tro di noi Candia, puntiamo direttamente
verso l'Egitto, che raggiungeremo probabilmente
domani sera.
Dal momento in cui siamo partiti da Spalato,
il contatore dei raggi cosmici è sempre in fun-
zione. Abbiamo avuto qualche piccolo incon-
veniente nel meccanismo meccanico, ma di
volta poi abbiamo potuto facilmente rimediare;
a parte ciò l'esattezza della misura non ne
resta diminuita. Per quanto questa non si possa

Figure A.3: Sixth page of document [44].



che ha fatto proprio non poteva fare.
Basta che ci sia la salute; tutto il re-
sto ha un valore relativo.
Arrivederci per questa settimana. Ti pen-
so sempre con un desiderio di riabbracciar-
ti diventato ormai tanto grande, che non
so proprio come farò a resistere ancora
più di un mese.
Ti penso sempre e ti stringo al mio
cuore con tutto il mio affetto assie-
me ai miei adorati fratellini e alle
mie dilette zie.
Tuo Bruno.
P.S. Di pelli di serpente non ce ne sono
di nere, di bianche e di grigie, ma hanno
ciascuna tutti tre i colori.
Ricevo in questo momento il tuo telegramma.
Sta tranquilla perchè ho già preso tutte
le informazioni da persone competentissime
ed ho avuto l'assicurazione che il viaggio è
quanto di meno azzardoso si possa immaginare
sotto tutti i punti di vista!

Figure A.4: Last page of document [60].



Lo Alamos, 10 agosto.

Mamma e Giorgio miei,

sento il bisogno, in questo momento, di scrivervi per dividere con voi l'emozione e la gioia per l'imminente fine della guerra. Abbiamo appena sentito per radio che il Giappone ha offerto la resa a discrezione e par certo che l'offerta verrà accettata.

Immagino che saprete ormai dai giornali quello a cui ho lavorato in questi ultimi anni e avrete capito perchè non potevo mai rispondere quando mi domandavate delle mie ricerche ! E' stata certo una grande soddisfazione che i nostri sforzi abbiano servito ad accorciare la guerra, probabilmente di parecchi mesi. Ma prego il Cielo che sia questa l'ultima volta che la bomba atomica viene usata. Si è detto tante volte, dopo l'invenzione di una nuova arma, che essa avrebbe reso nuove guerre impossibili, e non è mai stato così. Ma questa volta deve essere vero, perchè l'alternativa è troppo spaventosa. Ero presente alla prima prova, ed è una cosa che non si può descrivere.

Vi mando un foglio del giornale di S. Fe colle prime notizie della bomba e con una dzscrizione di Los Alamos. Non so ancora quale effetto avrà la fine della guerra sul nostro futuro, ma è probabile che non lasceremo Los Alamos per parecchi mesi, o forse un anno.

Da Ruggero Cavalieri ho saputo che siete arrivati felicemente a Venezia e potete immaginare quanto ne sia stato felice, perchè il viaggio mi preoccupava. Spero ora che possiate presto rientrare nella nostra casa. Ho spedito il primo pacco a Venezia, ma ~~lo~~ non so quando vi arriverà perchè ho saputo dopo che fino a settembre non si possono mandare pacchi nell'alta Italia. Di salute stiamo benissimo e speriamo verso la fine del mese di poterci prendere una settimana di vacanza.

Vi lascio per questa sera, perchè andiamo da Enrico a celebrare la resa del Giappone.

Vi stringo forte forte anche per Nora

Vostro Bruno

Baci e per piacere mandate copia di questa lettera ai miei !

Coi bimbi vi abbraccio

Nora

Figure A.5: Document [68].

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Figure credits

Figure 1.1, Figure 2.2 and Figure 3.1: Venice, private archive.

Figure 1.2: [70], Figure 4 (after p. 32).

Figure 1.3: [70], Figure 11 (after p. 32).

Figure 1.4: [69], p. 107.

Figure 1.5: photograph taken in the garden outside the Physics and Astronomy Department in Padua.

Figure 1.6, Figure 3.4 and Figure 3.5: <https://intellettualinfuga.com/it/Rossi/Bruno - %20Benedetto/145> (last visited on 30th May 2024), courtesy of Linda Rossi.

Figure 2.1: photograph taken in Piazza delle Erbe, Padua.

Figure 2.3: <https://intellettualinfuga.com/it/Rossi/Bruno%20Benedetto/145> (last visited on 30th May 2024), courtesy of Vera De Benedetti Bonnet.

Figure 2.4: [70], Figure 24 (after p. 32).

Figure 2.5: [35], p. 636.

Figure 2.6: <https://intellettualinfuga.com/it/Rossi/Bruno%20Benedetto/145> (last visited on 30th May 2024), the apparatus is preserved at Museum "Giovanni Poleni", Padua.

Figure 2.7: [29], p. 42.

Figure 2.8: [11], p. 390.

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Figure 4.1: <https://it.wikipedia.org/wiki/Eugenio_Curiel> (last visited on 6th June 2024), public domain image.

Figure 4.2: [12], p. 73.