The beginning of Edoardo Amaldi's interest in gravitation experiments and in gravitational wave research

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Abstract: The research activity in gravitational wave (GW) detection in Rome started in 1970, promoted by Guido Pizzella and Edoardo Amaldi. Unpublished documents[1] allowed establishing that Edoardo Amaldi's first interest in experiments on gravitation dates back to the late 1950s, about twelve years before. Connected to the major international physicists, Amaldi was attentively following the renewed and increasing activity of research on gravitation, which was taking place in the international scientific community, both from the theoretical and the experimental point of view, since the second half of the 1950s. Today many historians of physics identify the new attitude of the scientific community towards Einstein's theory of gravitation, in the 1950s and 1960s, as the "renaissance" of General Relativity. The coeval letters and archival documents in Amaldi's archive show how his contacts with relativists were progressively growing. Starting from the middle of the 1960s, a clear will appears of beginning an experimental activity for detecting gravitational radiation in Rome.

Keywords: Gravitation, General Relativity, Gravitational Waves, Edoardo Amaldi, Bruno Touschek, Robert Dicke, Dmitri Ivanenko, Robert Wheeler, Joseph Weber, Livio Gratton, Remo Ruffini

1. Introduction

It is perhaps not widely known outside the GW community that one of the most important gatherings in the field is named after Edoardo Amaldi. The first "Edoardo Amaldi Conference on Gravitational Waves" was organized in Frascati in 1994 by Eugenio Coccia; the second one, in 1997, took place in Geneva at CERN, with a massive participation of the GW community. During the CERN conference, the GW International

[1] The unpublished documentation cited in the present paper comes mainly from: Edoardo Amaldi's Archives, Department of Physics "G. Marconi", Sapienza University of Rome; Archives of the Rectorate of Sapienza University of Rome, Professors' personal folders; Archives of the National Research Council (CNR), via dei Taurini (Rome).

Committee (GWIC) was born, under the chairmanship of Barry Barish, and it was decided that the next conference would be held in Caltech in 1999 (Coccia 2013). Since then, the Edoardo Amaldi Conference on GWs takes place every two years in a different part of the world and concerns all the aspects of GW research, from theoretical models of astrophysical sources to detection and signal processing.

2. The birth of the GW detection team in Rome: the known history

Amaldi was the father of GW detection in Italy and had a key role in the promotion of GW research. He himself recounts the origins of the GW experimental activity in Rome in an internal note of the Institute of Physics (Amaldi 1975):

> The idea of starting an experiment aiming to detect GW in Rome was stimulated by the Course on Experimental Tests of Gravitational Theories held in summer 1961 at the Scuola Internazionale E. Fermi in Varenna, where the problem was discussed by J. Weber. The program remained rather vague for practical reasons until 1968, when W. Fairbank spent a few months in Rome at G. Careri's low temperature laboratory. When Fairbank mentioned his intention of starting the development of a low temperature gravitational antenna, Careri who was informed for long time of the interest of E. Amaldi in the subject, suggested a first direct contact. This was the beginning of the collaborations between the groups of Stanford (W. Fairbank), Louisiana State University (W. Hamilton) and the Istituto di Fisica of Rome. Already at this stage a number of conversations with R. Ruffini stimulated the beginning of these researches.

The activity in Rome officially started in September 1970, when Guido Pizzella, Edoardo Amaldi's assistant, came back from the University of Iowa, where he had been working with James Van Allen, and proposed to Amaldi to begin an experiment in this field. The interest in GWs had been growing in the scientific community since the end of 1960s, stimulated by the works of Joseph Weber, the father of GW resonant bars detectors, who published several papers claiming to have detected gravitational radiation, by the room temperature resonator set up in his laboratory at the University of Maryland.[2] Furthermore the discovery of pulsars in 1968 provided an attractive candidate as GW source (Hewish et al. 1968).[3]

The roman group was originally composed by: Edoardo Amaldi, Massimo Cerdonio, Renzo Marconero, Ivo Modena and Guido Pizzella. It was the first team in Italy working at GW detection and one of the first to be born in Europe.

While W.D. Allen at the University of Reading and P.S. Aplin in Bristol were constructing room temperature Weber type detectors, the roman group shared with William Fairbank from Stanford University and William Hamilton from Louisiana State Univer-

[2] Weber (1967) reported the first possible gravitational wave signals in the paper, describing occasional mechanical excitations of the detector well above mean thermal-noise excitations. The paper was soon followed by (Weber 1968a) and (Weber 1969). Weber's papers turned on a lively scientific debate, stimulating the birth of GW detection groups in other parts of the world.

[3] In August, few months later the announcement of the discovery of pulsars Joseph Weber published the paper (Weber 1968b).

sity, the idea of building low temperature facilities. The Rome-Stanford-Louisiana collaboration envisaged the construction of three cryogenic detectors, cooled to 0.003 K, to be installed in the three locations and working in coincidence.

The story narrated by Amaldi and what comes after are known and have been recounted in different occasions and articles by the protagonists. The present paper traces instead the unpublished story that comes before these events, highlighting the evolution of Amaldi's first approaches to gravitation experiments and locating it in the framework of the renaissance of General Relativity.

3. Brief portrait of a science man

Edoardo Amaldi (1908-1989) has been one of the main actors of the rebirth of Italian and European Physics after the Second World War. A true statesman of science, as Carlo Rubbia has defined him, he has been the first Secretary General of CERN, during the delicate phase which brought to the definitive affirmation of the European Laboratory project and the final ratification of the member states (1952-1954). In the following years he gave a fundamental contribution also to the foundation of the European Space Research Organization, born in 1964, which merged in the European Launcher Development Organization during the 1970s to form the European Space Agency.

As a scientist, Amaldi grew up at the school of Enrico Fermi, being one the boys of via Panisperna, the young team of physicists who, under the guide of the Italian genius, explored the properties of nuclei, discovering the efficacy of slow neutrons in producing radioactivity. The Italian racial laws promulgated in 1938 and the war dispersed the legendary group. Amaldi was the only Panisperna boy to remain in Italy; only thirty years old, he was left with the role of leading the research activity in Rome.

At the end of the war, Amaldi was a thirty-six year old man who had taken on his shoulders the responsibility of keeping in life Italian physics.

As a scientist and experimentalist, Amaldi devoted his efforts in many fields of fundamental physics: nuclear and subnuclear physics, cosmic rays, space research, and finally the experiments for detecting GWs, his main scientific interest in his last twenty years. As his colleagues and collaborators assert, it was mainly his quest for fundamental physics which triggered his interest in gravitational radiation.[4]

4. The renaissance of General Relativity and the birth of relativistic Astrophysics

Between the early 1920s and the 1950s Einstein's theory of gravitation experienced what Jean Eisenstaedt has called "the low watermark of General Relativity" (Eisenstaedt 1989), in which there was a substantial decline of interest in the theory. In contrast with special relativity, which "was turning out to be an everyday tool of physi-

[4] This statement was made separately by Guido Pizzella, Ivo Modena, Bruno Bertotti, Fulvio Ricci and Remo Ruffini in the interviews granted to the authors of this paper during 2015.

cists", general relativity (GR) had very poor connection with experiments and "lead to too small a number of empirical predictions". The progress made was relatively slow and due to the research of isolated theoretical physicists and mathematicians. Furthermore, the coming of World War II contributed to delay the constitution of a self-organized community of researchers working on gravitational problems.

Finally, during the 1950s, the gravitationalists began to coordinate themselves in a specific community, promoting the organization of periodical conferences, starting from the Conference for the Jubilee of Relativity Theory in 1955, in Bern. This conference is often referred to as GR0. The second conference was held in 1957 in Chapel Hill (North Carolina) and was devoted to the role of gravitation in physics (GR1). The third one, the Conference on Relativistic Theories of Gravitation (GR2), was organized two years later in Royaumont (Paris). The International Committee on Gravitation and Relativity was formed shortly before.

Starting from the 1950s, the theory of General Relativity began to gain momentum for several complex interconnected reasons, including a diffused recognition that the resolution of problems related to GR was essential for different research fields, such as quantum gravity, unified field theories, and cosmology.

At the same time a growing interest in gravitation experiments was emerging. The main actor of the revival of experimental tests of gravitational theories was Robert Dicke, in Princeton. In the same University, the theoretical counterpart was John Wheeler.

It was not by chance that Joseph Weber spent the academic year 1955-56 at the Institute for Advanced Study in Princeton, where he dipped himself in GR as a fellow student of Wheeler (Weber, Wheeler 1957). Weber's ideas about the detection of GWs were enunciated for the first time at the Royaumont conference in 1959 (Weber 1962).

Furthermore, during the 1960s the new astronomical discoveries, such as quasars (1963), cosmic microwave background (1964), and pulsars (1967), strongly contributed to assign to GR a fundamental role in interpreting physical phenomena. It was the birth of relativistic astrophysics.

Many historians of physics define the period spanning from the Bern Conference of 1955 to the early 1970s, as the epoch of renaissance of General Relativity (Blum 2015).

5. Amaldi's growing interest in Gravitation

The new born International Committee on Gravitation and Relativity, chaired by André Lichnerowicz and Marie-Antoinette Tonnelat, entered the agenda of the International Union of Pure and Applied Physics (IUPAP) in 1960. As the President of IUPAP,[5] Amaldi wrote a letter[6] on this occasion to Dmitri Ivanenko, well-known relativist and member of the committee, in which he states:

[5] Amaldi was in charge as the President of IUPAP between 1957-1960.
[6] E. Amaldi to D. Ivanenko, 22 of August 1960.

> I think this is a right moment for a wider development of the research activity on gravitation and general relativity.

By the end of 1950s, Amaldi was clearly aware of the new lymph that was flowing in the field of GR. He was attentively following the renewed interest of the scientific community in the experimental tests of General Relativity, in particular Robert Dicke's program of precision tests on the equivalence of inertial and gravitational mass. In February 1960 he had sent indeed a letter to Dicke, asking him preprints and internal notes about the results of his experiments. At the end of July, only three weeks before his letter to Ivanenko, Amaldi wrote again to Dicke telling him he would like to visit his laboratory in Princeton on the following September, after the Rochester Conference held in August.[7] The visit took place on September 3. The American experimental physicist welcomed in Princeton Amaldi and his young colleague Giuseppe Fidecaro.[8] The latter recounts that Dicke discussed his experiments with them for a couple of hours, in front of a big blackboard and afterwards they went to visit the laboratory.[9]

However, more than one year before Amaldi himself together with his colleague Mario Ageno had begun a few experiments concerning gravitation. On Saturday 31 January 1959, Amaldi took an interesting note in his diary, concerning the possibility of looking for an effect of the gravitational field on the beta disintegration. As Amaldi writes, the idea had come from a discussion with Bruno Touschek, the father of the first electron-positron collider AdA, on the morning of Wednesday 28 January. Bruno Touschek raised the question of whether the decay constant of the various beta decay nuclei was the same everywhere in the Universe, irrespective of the value of the local gravitational field. In a paper published by the Accademia dei Lincei (Ageno 1966), Amaldi and Ageno wrote:

> Touschek was prompted to raise this question by the fact that in the history of physics it had happened several times that an apparent deviation from a conservative law was found, on close examination, to be the result of the perturbation caused by an external field […]. Could not the non-conservation of parity observed for the weak interaction have a similar origin?

Already one week later, the first experiment had been set up and accomplished; it was based on the equivalence principle, according to which a centrifugal field generated by a rotation is locally equivalent to a gravitational field, produced by a proper distribution of masses. Amaldi and Ageno accelerated a sample of beta radioactive source inside a centrifuge, measuring its activity repeatedly as a function of time, before and after centrifugation.

They discovered only later that other researchers in the world were dealing with the same problem (Chien-Shiung Wu 1959). Amaldi's and Ageno's experiments, accom-

[7] E. Amaldi to R. Dicke, 28 July 1960.
[8] It was possible to identify the date of the visit to Dicke through Amaldi's diaries. Amaldi used to keep very detailed diaries of his activities, so it was possible to find his accurate notes and drawings about Dicke's discussion.
[9] Email from Giuseppe Fidecaro to Ugo Amaldi and to the authors of this paper, 6 July 2015.

plished at the "Istituto Superiore di Sanità" in Rome, continued in the following years, but their results were never published on international reviews.

However, Amaldi discussed the beta decay issue with outstanding physicists from different institutes for several years. On the 19 of January 1960, few days before the inauguration of CERN's first accelerator, the Proton Synchrotron (PS), he talked in Geneva with Christian Møller about the half life of centrifugated π.[10] In November 1964 he wrote to John Synge asking him whether to publish or not their results.[11] He continued to think about the centrifuge experiments in the following years, as witnessed by the letters he wrote in 1973-74 to Møller and to Francis Perrin, sending them a copy of the 1966 paper (Ageno 1966) and asking their opinion.

Another important stimulus towards gravitation experiments came to Amaldi from Dmitri Ivanenko, who visited Italy during January and February of 1960. On the 26 of January, few days after Amaldi's discussion at CERN with Møller, Ivanenko gave a talk at the Institute of Physics in Rome, entitled "Remarks on transmutation of matter into gravitation" (Amaldi 1962). As shown by his diaries, Amaldi was present. He had come back from CERN on January 21 and would go back in Geneva on February 3 for the PS inauguration (February 5). He wrote down some very interesting annotations about Ivanenko's talk. The Russian physicist had developed a quantum-gravity model predicting transmutations of ordinary particles in a graviton, by analogy with creation and annihilation of electron-positron pairs in an electromagnetic quantum. Amaldi followed attentively his reasoning and noted (in Italian) in his diary:

> It is necessary to study gravitational waves, because it is not sure they exist.

This was the kind of issue in fundamental physics capable of tickling the interest of a tenacious experimenter as Amaldi.

Finally, as recounted in the internal note at the beginning of this paper, Amaldi participated in the Varenna School on the Experimental Tests of Gravitational Theories (19 June-1 July), directed by Møller. Among the lecturers were Bruno Bertotti (Laboratorio Gas Ionizzati, Frascati), Herman Bondi (King's College, London), Robert Dicke (Princeton University) and Joseph Weber (University of Maryland).

Among his notebooks, there is one specifically dedicated to this Varenna School; he was present in the days 27, 28 and 29 June. Strangely, it does not contain any reference to Weber's talk about GW detection. Instead, accurate annotations about Bertotti's topics are found (Bertotti 1962). Furthermore, the exchange of letters between Amaldi and Weber is very poor, considering that Weber is the father of gravitational wave detection and taking into account the importance Amaldi attributed to his 1961 encounter with him, as reported in the mentioned note of 1975. During the Sixties there was only one short letter written by Weber to Amaldi, on the 15 of September 1967: Weber invited Amaldi to visit his laboratories at the University of Maryland; as learned from the documents explored so far, this did not happen until March 1980.

[10] The information comes, as usual, from Amaldi's diaries.
[11] E. Amaldi to J.L. Synge, 21 November 1964.

Besides Amaldi's quest for fundamental physics, the new astronomical discoveries, such as quasars (1963) and pulsars (1968), triggered his interest in gravitational radiation. Together with multiwave astronomy, cosmic rays, particles from the solar wind, and neutrinos, gravitational-wave astronomy might open another window on the universe.

And, indeed, during the 1960s Amaldi promoted the opening up of new lines of research in Rome, like space science, plasma physics and astrophysics, calling back at the Institute of Physics scientists as Livio Gratton, for whom the first chair of astrophysics in Rome was established in 1962 (Gratton 2013); encouraging the training abroad of young researchers as Guido Pizzella; stimulating synergies among different expertise and actively contributing to the creation of dedicated laboratories as the Ionized Gas Laboratory in Frascati.[12]

As a young student, Remo Ruffini had a privileged role in those early years. In 1967 Amaldi strongly supported his application for a European Space Research Organization (ESRO) fellowship, which would allow him spending two years in USA. In his letter of July 7 to Reimar Lüst (who was about to become the Vice President of ESRO, in 1968), Amaldi explained that Ruffini would work both "experimentally (Dicke) and theoretically (Wheeler) at Princeton" and would spend "some time at the Maryland University (Weber)", training on gravitation. Amaldi's explicit aim was to set up "an experimental group working in this field at the return of Ruffini":

> Just to mention one possible line of research, we are considering the possibility of establishing coincidences between detectors of gravitational waves placed at large distances (one in USA and one in Italy).

In a previous letter dated April 14 to CNR, concerning a six-months fellowship of Ruffini in the USA, Amaldi had written explicitly that "the aim of creating an experimental group on gravitation has a great interest for this Institute and in particular for me personally». He believed Ruffini had "the right qualities in order to make this effort with good perspectives of success".

On February 9 of the following year, Ruffini wrote a letter to Amaldi attaching an activity report he had prepared for ESRO, in order to support the renewal of his fellowship for a second year at Princeton University. Here there is a paragraph particularly significant for our story:

> Researches on gravitation are not by any means new at Rome University. Quite apart from earlier work on gravitation theory of Tullio Levi Civita and Enrico Fermi, significant investigation has been carried out in this field in the past few years (measurement of muon and beta decay in non-inertial frames; theory of superdense stars; theory of gravitational radiation).

As we know, the story went differently with respect to Amaldi's expectation: Remo Ruffini had an important role in stimulating the beginning of the research activity in

[12] The Ionized Gas Laboratory was instituted in Rome, where it remained for the first three years and then was displaced in Frascati.

GW in Rome and the start-up of the contacts between the American and the Roman groups, but he was not the man who actually founded the experimental group. That man was definitely Guido Pizzella, who undertook with courage, enthusiasm and perseverance the leadership of the new scientific adventure.

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