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Giuseppe Paolo Stanislao Occhialini: A cosmopolitan scientist

(1) Introduction

In this communication we will try to elucidate the topics of this Conference: "The Global and the Local", through the illustration of some aspects of the life of G. P. Occhialini, a Italian physicist who worked in England, in Brasil in Belgium and spent several months at foreign scientific institutions. At the same time he continued to entertain with his country and with his family, above all the father, a influent professor of physics at the Genoa University, strong personal and institutional connections which were fundamental for his scientific career.

Giuseppe ("Beppo") P. S. Occhialini (1907–1993) was born in Fossombrone (Pesaro Province, Italy) on December 5th, 1907, son of Raffaele Augusto Occhialini (1878–1951), a physicist, and Etra Grossi.

He studied physics at the University of Florence from 1927 on.

At the Institute of Physics in Arcetri just in 1927 had arrived Bruno Rossi and in 1928 Gilberto Bernardini arrived.

Bruno Rossi directed the research of the Arcetri group towards this new direction. At this time, he invented "Rossi's circuit" that allowed to detect the simultaneous discharge of several counters (multiple coincidences).

According to Occhialini, the Geiger-Müller counter was like the Colt in the Far West: a cheap instrument usable by everyone on one's way through a hard frontier.

Besides working with Rossi with counter-coincidence circuits, Occhialini was already interested in imaging particle detectors. At the end of the 1920s the most important instrument in this field was the Wilson chamber.

In summer 1930, Rossi went to Bothe's laboratory to learn the best use of the GM counters. In Berlin, Rossi met several important physicists of that time, among them Patrick Blackett who was an expert in the use of the cloud chamber and worked at the famous Cavendish Laboratory, in Cambridge, under the prestigious direction of E. Rutherford.

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In that occasion Rossi asked Blackett to admit at the Cavendish one of his young collaborators, so that the latter could learn the cloud chamber technique to study cosmic rays.

Occhialini was sent to Cambridge, with a letter of introduction written by Bruno Rossi, and with a CNR scholarship for three months. The first English period started so, and it lasted not three months but three years.

(2) The Cambridge period (1931–1934)

When Occhialini went to Cambridge the research at the Cavendish mainly concerned nuclear physics and was still made in a relatively simple way. The Cavendish continued a tradition of research made producing visible phenomena. It was not the case that they used scintillators, photographic plates, and cloud chambers. Very less used at the Cavendish was instead the GM counter.

The technique of cloud chamber was developed for nuclear physics applications, after Rutherford's suggestion, first shortly by Shimitzu and, then, by Blackett. The modernity of the Cavendish could only impress the young Occhialini.

He worked side by side with Blackett, and together they developed the controlled cloud chamber technique. He brought with him the technique of the coincidence counting of cosmic rays developed by Rossi. The marrying of the counter technique with the cloud chamber was an obvious step.

This marrying permitted a valuable progress in the obtaining of useful images: 76% of the photographs contained tracks of particles, and they could take one photograph every 2 minutes. In practice, the particles themselves started the controlled cloud chamber when they came into it and ionised. The controlled cloud chamber was applied to the study of cosmic rays, the subject of research that had engaged Occhialini in Arcetri.

The most important paper published by Blackett and Occhialini on their researches with the controlled cloud chamber was "Some photographs of the tracks of penetrating radiation", communicated to the Royal Society by Rutherford on February 7th, 1933. The core of the paper was the study of cosmic rays showers, with side, but absolutely not less important, items such as the positive electron (the positron) and the non-ionising links.

Blackett and Occhialini interpreted the positron according to Dirac's theory as the anti-electron whose destiny was to annihilate with an electron producing one or more photons. Positrons could also account for the apparent backwards trajectories of negative electrons from a neutron source.

The discovery of the positron has been studied in detail by Hanson in 1963 who showed that the discovery was much less linear than some hasty historical reconstruction shows.

Anyway the most important result was that Blackett and Occhialini showed that the particle they have found was the same particle discovered by Anderson in 1932 and that one hypothesized by Dirac in 1931.

In 1948, the Nobel Prize in Physics was awarded to Blackett for his contributions to the development of the Wilson method and his discoveries, made by this method, in nuclear physics and on cosmic radiation.

In his Nobel Lecture, Blackett expressed himself outspokenly by mentioning several times Occhialini's fundamental contribution to their researches in Cambridge.

In a letter to Occhialini's father, Blackett motivated his disappointment for having awarded the prize alone, without a common assignation to Occhialini himself:

> I am very happy and proud to have awarded this prize, but I would have been still happier if Beppo had been honoured at the same time. For it was certainly his arrival in Cambridge which stimulated my embarking on this field of cosmic rays which I have never left. And our work together in 1932–33 was a real collaboration of the happiest kind.

(3) Brasil (1937–1944)

In June–July 1937, Occhialini was invited by Gleb Wataghin to join him in organising a school of physics in Sao Pãulo. In August 1937, Occhialini left Italy to Brazil and was nominally admitted to the school "Dante Alighieri" in São Paulo. Actually, he became appointed professor of Experimental Physics at the University of São Paulo. There he prepared an experiment to observe large cosmic rays showers with Wilson chambers and counters.

The experiment was interrupted during the Second World War, when most of the Brazilian physicists were engaged in the researches concerning the production of sonars able to detect German U-boots. In March 1942, Brazil joined the nations fighting against Italy and Occhialini was recalled back to Italy because of the breaking of diplomatic relations.

Furthermore Brazil forbade the Italian citizens to be employed by public institutions, so that, in June 1942, Occhialini was removed from the University of São Paulo. Many Italian professors came back to Italy but the English government refused to permit Occhialini the free passage. During this period, Occhialini escaped to the Agulhas Negras (or Itatiaya) mountains, between São Paulo and Rio de Janeiro, where he worked as an alpine guide.

When Italy signed the armistice, on September 10th, 1943, he offered to fight with the United Nations, but the invasion of France delayed his arrival to England till the end of 1944.

(4) The Bristol period (1944–1948)

Blackett, at that time at the Admiralty, called Occhialini from Brazil to work with the allied project to build the atomic bomb. The suggestion to let Occhialini come to England to work in the atomic research was kept secret, mostly because of the after-effects on his family in Italy.

Occhialini's position in 1944 was not at all easy. Brazilian scientists tried to make him stay in Brazil to go on with his researches in cosmic rays physics. Similar proposals came from the Ohio University with a Rockefeller fellowship, but Occhialini preferred to wait for the safe-conduct to leave Brazil to England. But he was not admitted to join war research because of his nationality.

He arrived in Bristol in September 1945 where he had been exempted by the Secretary of State from the Special Restrictions applicable to enemy aliens under the Aliens Order. In the H. H. Wills Laboratories, they made use of nuclear emulsions, experimentally produced by Ilford and Kodak, and they exposed them at high altitude to detect the disintegration due to cosmic rays collisions against the atmosphere.

They expected to find among the disintegration products the π-meson, a particle whose existence had been predicted by Hideki Yukawa in 1935, as the particle responsible for the strong nuclear interaction. Cecil Frank Powell had been interested in the technique of nuclear emulsions from 1938 on, following a suggestion of Walter Heitler and, after the end of WW II, was also a member of the emulsion panel chaired by Joseph Rotblat. By referring to precedent works of other physicists, Powell, Occhialini, Livesey and Chilton wrote in 1946 a perfect description of the technique of photographic emulsions in nuclear and particle physics.

In 1946, the main disadvantage of the photographic emulsions lay in the wide gaps in the succession of the grains forming a track left by a particle, preventing a correct determination of the true length of the tracks. It was thus very important to be able to produce new kinds of photographic emulsions, containing higher quantities of silver bromide. The Bristol group with Cecil Waller of the Ilford invented a new kind of borax-loaded plates.

During one of his holidays as a speleologist in the caves on the Pyrénées, Occhialini exposed about two dozens of C2 Ilford emulsions on the Pic-du-Midi.

It was Occhialini, on the very night of his coming back to Bristol, who developed the emulsions after having recovered them from the one-month exposure. It was evident at once the difference between normal plates and borax-loaded ones.

As Powell remembers:

> When they were recovered and developed in Bristol it was immediately apparent that a whole new world had been revealed. The track of a slow proton was so packed with developed grains that it appeared almost like a solid rod of silver, and the tiny volume of emulsion appeared under the microscope to be crowded with disintegrations produced by fast cosmic ray particles with much greater energies than any which could be generated artificially at the time. It was as if, suddenly, we had broken into a walled orchard, where protected trees had flourished and all kinds of exotic fruits had ripened in great profusion.

Powell decided to concentrate the whole lab staff in the study of low energy normal events. In November 1946, Marietta Kurz (a member of "Cecil's beauty chorus") found the track of a meson (a π-meson) till its stopping point, and a second track, beginning from the end of the first one, of a second meson (actually: a muon), stopping in the same emulsion too. Within a few days, Irene Roberts found a similar case. These results were published on Nature a few months later, in May 1948.

> The excitement of the discovery of the π-meson was intense and the occasion was such that Occhialini of undoubted rationalistic outlook could only express his feelings by going into the R.C. Cathedral to light a candle! (Powell)

To confirm the discovery of the π-meson made on the Pic-du-Midi, the Bristol team decided that they had to get quickly other recordings of similar events to grant to their work the necessary scientific validity. Lattes found the indication of a meteorological station at high altitude on the Bolivian Andes, Chacaltaya station, with an extremely advantageous geographical position granting a cosmic rays flux 100,000 times grater than that on the Pic-du-Midi. The British government decided to finance Lattes' mission, in the conviction that the development of nuclear physics would have had political-military advantages. The first plate was developed after one month in La Paz, and Lattes found a complete track of the "double meson". All the other emulsions were developed and studied in Bristol and gave as a result about thirty tracks of "double mesons". The discovery doubtless represented an important step in the history of the comprehension of the structure of matter, and the results obtained were convincing in considering that the observed process was a fundamental one.

The first meson (the π-meson) was thus identified with Yukawa's meson, and the second meson with Anderson's meson (the muon). It was furthermore postulated the typical decay reaction of the π-meson that, to grant momentum conservation, included a neutral small mass particle (later identified with the muonic neutrino). The positive result of these researches was of course the outcome of the different contribute of various scientists and institutions. The official communication, apart from the published articles, was at the Conference on Cosmic Rays and Nuclear Physics held at the Institute of Advanced Studies in Dublin (July 5th–12th, 1947). Powell, spokesman of the Bristol team, exposed their conclusions strengthening their scientific character.

The University of Bristol officially recognised Occhialini's important contribution to the researches he made in cosmic rays physics and the development of the related technology with the award of the doctorate *honoris causa*.

The rapid development of the nuclear emulsions technique was strictly connected with a parallel development in the microscopic technique. Nuclear emulsions exposed on the Pic-du-Midi by the Bristol group, which collaborated with Cooke, Troughton & Simms, were studied by means of a reflecting microscope.

By the examination of the nuclear emulsions, Occhialini and Bates, using a reflecting microscope, reversed the normal microscopic procedure, inverted the plate, and observed through the backing glass plate. They were thus able to observe stars and heavy fragments, not visible by the ordinary technique.

The role played by Occhialini in the discovery of the π-meson was as important as that one he played in Cambridge. In this case too, Occhialini did not win the 1950 Nobel Prise in Physics awarded to Powell alone for his development of the photographic method of studying nuclear processes and his discoveries regarding mesons made with this method. The denied acknowledgement was less self-evident than in Blackett's case. Powell never quoted Occhialini in his Nobel Lecture.

In the same year when Powell was awarded the Nobel Prize, an important award of Occhialini's contribution to cosmic rays physics and the relative technology came with the Charles Vernon Boys Prize of the Physical Society of London. Powell showed a particular happiness for this award to Occhialini. This fact might contribute to see from a different point of view Powell's accusing silences on the role played by Occhialini in his researches in Bristol.

Powell, not only brought pressure to bear on the Physical Society, but suggested to award Occhialini the Nobel Prize. Actually, he wrote to Wolfgang Pauli in order to convince him to put Occhialini's name forward to the Nobel Committee in Physics. Pauli, who was a great friend of Occhialini and had admired his scientific work since the years the latter spent in Cambridge with Blackett, was happily willing to support his nomination.

(5) A new laboratory in Brussels and his return to Italy 1948–1950

Occhialini left Powell's group in Bristol and went to Brussels to work at the Centre de Physique Nucléaire of the Université Libre de Bruxelles. He worked continuously in Brussels from 1948 to

1950. Thereafter, he was appointed professor at the University of Genoa from 1950 to 1952, and at the University of Milan from 1952 on.

While teaching and making research in Italy, Occhialini continued to collaborate with the Centre de Physique Nucléaire where he spent a lot of time every year until his sabbatical year at the MIT in 1959.

The Brussels and Genoa/Milan groups in the 50's can be considered a single one group of research under the scientific leadership of Occhialini. Occhialini was called to Brussels, together with Constance Dilworth, by Max Cosyns, a friend of his speleological adventures, to give birth to a new laboratory where they could study nuclear emulsions. They also printed a new journal, the "Bulletin du Centre de Physique Nucléaire de l'Université Libre de Bruxelles".

In the Brussels laboratory they went on with the researches on the new NT2 and NT4 Kodak plates by Berriman, and G5 Ilford plates by Waller. The emulsions group, under the scientific leadership of Occhialini, became soon one of the most important groups of research on nuclear emulsions, after the one in Bristol.

While in Brussels, and then in Genoa and Milan, Occhialini played a fundamental role in the development of several groups of research in nuclear emulsions in Italy and in the birth of a European network of groups devoted to the studies of cosmic radiation. Brussels was the school where to learn the emulsion technique for Bonetti and Scarsi from Genoa, Merlin from Padua, Cortini from Rome, Levi Setti from Pavia.

A very sad fact shattered the laboratory in Brussels in 1952: the so-called winch affair. On August 14th, 1952, during a speleological exploration of the cave of Pierre-Saint-Martin, Marcel Loubens, a member of a speleological group formed by Occhialini, Cosyns, Labeyrie, Casteret and Tazieff, died while climbing to the earth's surface, since the hook connecting his cable to the winch broke and he fell for about forty meters and crashed on the rocks below. He was in his last agony two days long, assisted by Occhialini, Labeyrie and Tazieff.

The winch affair caused a tremendous internal division. Occhialini's scientific collaboration with Cosyns came so to its end. Occhialini went on to work with the Brussels emulsion group, while Cosyns had to leave Belgium and went to Paris.

Occhialini succeeded in making Brussels group again a part of the European network of laboratories that were flying stacks of plates on balloons at high altitude. Occhialini asked Powell to let the Brussels group join the collaboration organising flights of nuclear emulsions.

Occhialini was Professor of Physics at the Institute of Physics of the University of Genoa from 1949 to 1951. During 1952, Occhialini was also six months long at the Brazilian Centre of Physical Researches in Rio de Janeiro.

His travel was supported by the UNESCO and had the aim to help Lattes and Camerini in the organisation of the group of research in Rio de Janeiro and its researches made in the laboratory on Chacaltaya.

(6) An actor in the long search for strange particles

Occhialini was Professor of Physics at the Institute of Physics of the University of Milan from 1952 on, sharing his time with the emulsions laboratory in Brussels too.

The scientific production in the early 50's concerned both the study on the development and use of nuclear emulsions, and the studies on new kinds of particles.

Maybe the most important characteristic of Occhialini's studies on cosmic rays was the participation of his groups to international cooperations organising flights of balloons carrying stacks of nuclear emulsion plates at high altitude.

The prelude to the European collaborations was, in 1947–1948, the launch of balloons to expose nuclear plates at cosmic radiations at 30 km altitude. This launch was organised by Powell's group in Bristol with the collaboration of the University of Padua. The further development of the Bristol activities with the Italian groups saw the engagement of the INFN Sections of Milan, Padua, and Rome. The first great expedition, involving thirteen groups, was, in 1952, the launch from the Italian bases of Naples and Cagliari, and the following recovery of stacks of plates (with a glass support) after the landing on sea of the balloons.

All emulsions were processed in Bristol, Padua, and Rome; in October 1953, a meeting was held in Bern in order to distribute the processed plates among the different groups. The first results were discussed in an international congress held in Padua in April 1954.

The third significant experience was the launch of the so-called G-Stack from Novi Ligure, in October 1954.

The G-Stack was a single stack of emulsions with a volume of about 15 dm^3. The choice to launch a single "giant" stack came from the aim to study in the most advantageous way part of the recorded tracks in their whole length in order to obtain precise values of their energy and decay modes. The most important result of the G-Stack was the determination of the equality of the values of the masses of the then supposed different K-mesons, and the statement that the different decay modes were alternative decay processes of a same particle.

After the G-Stack, the results on elementary particles obtained by means of accelerating machines soon outnumbered the ones found in cosmic rays. In the second half of the 50's, Occhialini thus went on with his studies on elementary particles by exposing the nuclear emulsion plates to beams of particles produced by accelerating machines at the CERN or elsewhere. The conferences held by cosmic rays physicists in the early 50's were of the utmost importance in the history of physics. The 1953 International Cosmic Rays Conference held in Bagnères-de-Bigorre was an epoch-making event where "order emerges from chaos".

Researches by means of nuclear emulsions had an improvement in Milan thanks to the application of an already known principle to microscope technique. A device of this kind, a MS2 Koristka microscope, was made for Occhialini and his group by Dr. Cantù of Koristka.

A second important European collaboration followed a few time after the G-Stack Collaboration: the K^--Collaboration. The new aim was a thorough study of the interactions and decay of K^--mesons. For the publication of the three classical papers on the K^--Collaboration, Occhialini's group in Milan and Brussels was more and more involved in the studies on K^--mesons, both from cosmic radiation and artificially produced. During this period, Occhialini stopped to sign his contribution to published articles.

(7) The astrophysical period

We can consider the second half of the 50's as a "transition period" in Occhialini's scientific career. The K^--collaboration was not only a renounce to cosmic rays as the primary source of elementary particles, but was also the last great experiment made with stacks of nuclear emulsions. Even if Occhialini played an important role both in the coordination of the K^--collaboration and in the further development of new kinds of microscopes to scan nuclear emulsions, the importance of this last technique was decreasing.

As L. Scarsi remembers:

> In this transition period Beppo Occhialini continues to be a drawing leader; he coordinates the collaboration among the groups on a European scale, he continues the experimentation and the technical development on new kinds of high precision microscopes, he is engaged at close quarters in the analysis of the events due to the capture and interaction of the K^-. In this connection I remember, in Milan, the classification of the "hyperfragments" widespread among the microscopists, following the increasing difficulty of interpretation: "Normal", "G.O.K." (God only Knows), "D.O.K." (Devil only Knows) and "B.O.K." (Beppo only Knows).

The launch of the Sputnik in September 1957 prompted Bruno Rossi, at the Massachusetts Institute of Technology (MIT), to begin a series of researches in space physics on the interplanetary plasma and cosmic γ-rays.

Occhialini, accompanied by Constance Dilworth, decided to spend a sabbatical year at the MIT as Visiting Professor to rise, once back to Milan, a group of cosmic and space physics.

The Milan group of nuclear emulsions was converted to the new space adventure by means of spark chambers on balloon and satellite, in a strict collaboration with the French group in Saclay, while the cloud and bubble chamber group was sent to work at the CERN.

Occhialini was one of the founding fathers of the European space physics, as well as Pierre Auger, Robert Boyd, Marcel Golay, Bengt Hultqvist, Reimar Lüst, Harrie Massey, Bernard Peters, Pol

Swings, Hendrik van de Hulst. After the first steps of the European Preparatory Committee for Space Research (COPERS — Comité Preparatoire Europeen pour la Recherche Spatiale) in Paris, Occhialini was one among the most important members of the Council and of the Scientific and Technical Committee of the new-founded European Space Research Organisation (ESRO).

He was Chairman of the COS-Group (Advice Committee for Cosmic Rays Physics) and member of the restricted Launching Program Advisory Committee (LPAC) devoted to choose and define European space missions that were organised following the *"Street-car" principle*: each mission was a cluster of experiments proposed by the various scientific communities.

Among the different space missions organised by Occhialini too, we can remember the HEOS A1, the TD1, the HEOS A2, and the COS-B.

The COS-B satellite was launched on a Delta 2913 launcher, on August 8th, 1975. COS-B failed on April 26th, 1981. This satellite was the product of the Caravane Collaboration, formed by the Laboratory for Space Research (Leiden), the CNR Institute of Cosmic Physics and Informatics (Palermo), the CNR Laboratory of Cosmic Physics and Related Technologies (Milan), the Max-Planck Institute for Extraterrestrial Physics (Garching), the CEN Service of Physical Electronics (Saclay), the ESRO Scientific Laboratory (ESLAB) (Nordwijk). COS-B permitted to draw the first detailed γ-map of the Galaxy and to have a first catalogue of discrete sources in the range of a few 100 MeV. With COS-B, as well as other ESRO instruments, Beppo showed how he could work constructively on a supernational scale while maintaining his unique Italian character.

COS-B was launched in 1975 and soon became the first great European success in high-energy astrophysics. In 1975, ESRO and ELDO, an industrial organisation projecting European launchers, merged giving birth to the European Space Agency (ESA).

After the launch of COS-B, the new, more bureaucratic, way to manage the ESA was the beginning of the end of Occhialini's scientific activity. COS-B was Occhialini's last scientific success, even if he did not play a central role throughout the seven years the mission lasted.

In 1979 Occhialini and Uhlenbeck were awarded together the prestigious Wolf Prize, the last of a consistent series of awards (1934 Sella Prize, 1935 Vallauri Prize, 1949 Einaudi Prize, 1951 Charles Vernon Boys Prize, 1955 Feltrinelli Prize).

He was doctor *honoris causa* of the universities of Brussels (1949) and Bristol (1959), member of several scientific academies in Italy and abroad, and foreign fellow of the Royal Society. Occhialini, Bruno Rossi, and Bruno Pontecorvo died in the same period. Occhialini, in particular, died in Paris on December 30th, 1993.

(8) Conclusions

Occhialini was an eminent scientist. He made research with great attention and enthusiasm, a feeling that he transmitted to his students and collaborators. He was considered a legendary figure because of his discoveries and the vicissitudes of his life. He had a deep sense of nature's laws and was more interested in how nature actually works than in the mathematical laws describing natural phenomena.

He represents a tradition of physics in which visualisation can be considered as a legitimate alternative to the physical and mathematical models of natural phenomena. This tradition starts in the early modern science in 15th and 16th century. The newtonian approach and the development of the mathematical physics didn't obscure a tradition of visual representation which continued in physics with Von Humboldt, Faraday, Rutherford, Einstein. From the '30's of 20th century "visualisation" begun to be considered useless for the development of the physics researches.

Nevertheless, he was in wonderful relation with some theoretical physicists, such as Wolfgang Pauli. Many physicists in Europe and America consider themselves disciples of Occhialini's school of physics.

Occhialini was not only a great scientist but also a sincere humanist. He never cut his roots with the cultural environment of the central Italy which constantly fed his way of life. As Tagliaferri remembers:

> Beppo had many friends because he felt well among the people. He was sincerely interested in every human being he met, of whatever condition, and treated everybody on an equal footing. He was unselfish, kind and tender; but he reacted, even harshly, to abuses and did not forgive falsity. He did not like to speak to the public, but he talked with pleasure. He

> was a storyteller, and he hold his listeners spellbound when he talked about his discoveries in physics, his speleological explorations, the scientists and artists he met, the beauty of Tuscany and Umbria landscape, his adventures during his travels.

Occhialini had a very deep cultural life. He was so endowed of a refined sensibility to be able to quote the finest passages in Shakespeare's works by heart. His own thought was quite always original and stimulating and was the very proof of his tremendous literary and artistic culture. At the bottom of his culture there was always the human being in his multiform aspects.

In Milan, he and his wife organised once a week, particularly in winter, an informal meeting with an important physicist, and hosted friends, acquaintances, and students. These evenings spent in his home are among the best memories of the people who knew him personally.

From scientific point of view we can understand his tension between "Local" and "Global" considering the way in which he combined the phenomenological florentine tradition (Garbasso, Bruno Rossi, etc.) and Rossi's invention of counter-coincidence circuits with Cavendish experience on cloud chambers.[1]

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[1] For further details on Occhiliani see the works mentioned in the bibliography, especially Redondi P., Sironi G., Tucci P., Vegni G. (*eds.),* "The Scientific Legacy of Beppo Occhialini" (2006).