Introduction

The aim of this paper is to present the reconstruction of the scientific bibliography by Giuseppe Paolo Stanislao Occhialini (1907-1993) with some historical comments concerning some aspects of his own scientific production. In the very few and short biographies of him there are no specific indications at all of his bibliography. His life as a scientist, as well as his scientific bibliography, can be classified following two different, but almost overlapping, schemes: a quite spontaneous division into chronological periods, and a more awkward subject-depending division.

We can consider as a first bibliographical period the years from 1931 (when he published his first paper in Arcetri) to 1942 (when he published his last paper in São Paulo). Occhialini spent these years in Italy (at the Institute of Physics in Arcetri).
Florence), in England (at the Cavendish Laboratory in Cambridge), and in Brazil (at the University of São Paulo, and at the Biophysics Laboratory in Rio de Janeiro). His scientific production pertained to the following subjects: the study and improvement of Geiger-Müller counters starting under the supervision of Bruno Rossi; the invention and development of the controlled cloud chamber with Patrick Blackett; the confirmation of the discovery of the positron; the study of the showers of cosmic rays by means of coincidences telescopes; the invention of a new kind of plane counters to detect uni-directional weakly ionising particles.

As a second bibliographical period, we can individuate the years from 1946 (when he published his first paper with the Bristol group) to 1954 (when he pub-
lished one of his last little science papers a few months after the conference in Bag-
ères-de-Bigorre). Occhialini spent these years in England (at the Wills Laboratory in Bristol with Cecil Powell\(^\text{13}\)), in Belgium (at the Centre de Physique Nucléaire of the Université Libre de Bruxelles\(^\text{14}\)), and in Italy (at the Universities of Genoa and of Milan). Although Occhialini devoted himself again to the study of cosmic rays, we have to notice a deep change in the kind of instrumentation, the nuclear emulsions\(^\text{15}\), the Bristol group discovered the charged \(\pi\)-meson\(^\text{16}\) with. The first step of this change had its origin in Rio de Janeiro:

As soon as Italy signed the armistice, Occhialini contacted again the Brazilian research laboratories, and he started to work in the biophysics laboratory directed by C. Chagas. While he waited to come back to Europe, it was on that occasion that he met a French researcher, C. Leblond, who made physiology experiments with brain tissues that had absorbed radioactive compounds. The phenomenon that attracted Occhialini’s attention was the track left by the radioactive material there where it was absorbed. It suggested to him a new way to study elementary particles. By the use of photographic plates with sufficiently thick layers of emulsion, it could be possible to fix the track of the particles that, penetrating into the plates, excited the grains of the emulsion, and to study their physical properties.\(^\text{17}\)

Lastly, we can identify a third bibliographical period, limited to the years from 1955 to 1961 (when he signed his last paper). While nuclear emulsions\(^\text{18}\) went on being the main instrumentation of detection again, we have to notice a change in the kind of research: from a case of little science to one of big science\(^\text{19}\). Occhialini, as well as all other European physicists engaged in cosmic rays research, was «forced» to take part to some European collaborations\(^\text{20}\) – such as

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\(^{14}\) Information about Occhialini’s work in Brussels from 1948 to 1964 can be found in: U.L.B. Service des Archives. Dossier académique Occhialini 1P 745.


\(^{17}\) Archivio Occhialini 7, 1, 1, 5.


\(^{20}\) M. De Maria, M. Grilli, F. Sebastiani (eds.) (1989), *The Restructuring of Physical Sciences in Europe*
Besides classical bibliographical methods – historical references, primary cross-references, and library research – we could gain useful information with an on-line search\textsuperscript{21}. A precious source was also an incomplete index of publications\textsuperscript{22} attached to one of Occhialini’s curricula vitae conserved in Occhialini’s Archive, with his own indication of the publications he considered to be the most important ones\textsuperscript{23}. This index indicates also four papers with a contribution by Occhialini himself, but not signed by him: in the bibliographical list they are the ones numbered as [55], [58], [59], and [60].

**The Papers of the First Period (1931-1942): Arcetri, Cambridge, São Paulo**

These papers can be classified into two groups: most of them concern the study of elementary particles, both cosmic rays and particles ejected from radioactive compounds, while a few of them regard more strictly the technological development of the detection devices following the German and Florentine tradition of Geiger-Müller counters, such as in the study of the stability of the counters with non-ohmic resistances over 10 $\Omega$. Occhialini decided to develop Cosyn’s technique of saturated photocells, instead of his first proposal of thermionic valves.

In any case, they are definitely typical papers of a little science physics, as it was shortly described by Blackett:

In those days the work in the Cavendish was small science. Experiments were, on the whole, done by one person who built most of his own apparatus himself. There were some 30 research students and about 1 1/2 mechanics.24

In this first period, we have to put in evidence Occhialini’s fundamental contribution to the invention of the controlled cloud chamber and its application to the study of cosmic rays:

For it was certainly his arrival in Cambridge which stimulated my embarking on the field of cosmic rays which I have never left. And our work together in 1932-33 was a real collaboration of the happiest kind.25
One bibliographical problem concerns the paper [22]. It is listed in the above-mentioned attach to Occhialini’s *curriculum vitae* with its relative bibliographical indication, but it is not found in the *Anais da Academia Brasileira de Ciências*²⁶. In Occhialini’s Archive there is only one other mention of that paper, but it cannot help us anyway: it is a letter written by Mary Horder of the University of Bristol to Augusto Occhialini on occasion of the competitive examination for the chair of Superior Physics at the University of Cagliari:

I have just had a letter from your son, asking me to look through his papers. I have found three of those he asks for, but not the fourth, which is «Two Useful Gadgets for Wilson Chamber». I am sending the other three hoping they are the right ones. There are many people who feel that Bristol is a poorer place now that your son has gone away.²⁷

### The Papers of the Second Period (1946-1954): Bristol, Brussels, Genoa, Milan


²⁷ Horder (1948) letter from Mary Horder to Augusto Occhialini, 27th August 1948 - Archivio Occhialini 1, 1, 3.
The papers of the second period are heavily devoted to the study and application of nuclear emulsions. As we noticed before, Occhialini was involved in this detection technique in Rio de Janeiro, but he definitely applied to it when he went to Bristol, where he joined the Powell group connected to the Ilford Ltd and the Kodak. Both his work in the first and the second period lead to fundamental studies on a new elementary particle, in the latter case the charged $\pi$-meson. His role was recognised with the award of the Boys Prize by the Physical Society:

It gives me great pleasure to inform you that at its meeting on 28th April the Council of the Physical Society unanimously agreed that the sixth (1950) Charles Vernon Boys Prize be awarded to you.

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29 Wynne (1950) letter from C.G. Wynne to G. Occhialini, 1st May 1950 – Archivio Occhialini 1, 1, 5. Unfortunately, no documents about this award are still kept in the Archives of the Physical Society, now at the Institute of Physics in London.
Dr. Occhialini is distinguished by his close association with two major developments in the physics of fundamental particles, namely, the counter-controlled cloud chamber and its application to the study of pair production, and the nuclear emulsion technique leading to the identification of \( \pi \)- and \( \mu \)-mesons [...]. The remarkable achievements of this work are well known and represent the most outstanding discovery in the physics of fundamental particles in the post-war period; it was largely due to Occhialini’s enthusiasm and drive that the preliminary technique was so quickly and effectively developed.30

Although we can consider this second period still a little science time, we have to stress some aspects that lead cosmic rays physics towards a big science structure:

- the growing number of researchers and assistants involved;
- the internationalisation of the various groups of research;
- the faster technological development;
- the shift from a university laboratory to groups of laboratories;
- a functional communication network among the researchers;
- the abandonment of the model of a world made of simple elementary particles interacting only by electromagnetic forces, with the establishment of a new sub-discipline, «particle physics»31.

This peculiar change suggests a shift in the research paradigms from a post third scientific revolution one to a fourth scientific revolution one32. The growing collaboration among the researchers was at the origin of a new kind of bibliographical problem, typical of a science evolving to a big science practice:

As for the collaboration they can criticise, but you cannot do physics now if not in collaboration.33

The task of film exposure, observation, and interpretation was distributed over many individuals (and groups). Who would count as an author?34

**The Papers of the Third Period (1955-1961): Milan**


33 Occhialini (1948) letter from Giuseppe Occhialini to Augusto Occhialini, 28th April 1948 - Archivio Occhialini 1, 1, 2.


In this third period, the evolution of cosmic rays physics to big science was closed:

In Europe, the idea to realise large international collaborations to check large quantities of plates of nuclear emulsions exposed to cosmic rays prevailed. The scientific collaboration and the strong solidarity ties among the «cosmiciens» played for the community of
the European physicists an analogous role to the one that the Manhattan Project played for the American physicists.\textsuperscript{35}

The early fifties were also the time when accelerating machines more and more took the place of cosmic rays as the main source of elementary particles whose properties were to be investigated:

The G-stack project represented the extreme tentative of the European cosmiciens to defeat the large machines across the Atlantic Ocean, an extraordinary collective enterprise that marked the most important moment of the scientific season that began in the difficult post-war years.\textsuperscript{36}

While, after the mid-fifties, most of the European cosmiciens adapted themselves to the new situation and studied the elementary particles with the accelerating machines, mainly at the CERN\textsuperscript{37}, Occhialini, instead, became a leader in the new astrophysical studies in cosmic rays physics, playing a fundamental role in the birth of the European space physics scientific organisations.

\textsuperscript{35} Russo (2000) \textit{op. cit.}: 261.

\textsuperscript{36} Russo (2000) \textit{op. cit.}: 299.