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Tales from Dubna's Oakwood: Bogoliubov, Pontecorvo, and the JINR Seminars

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Abstract: Not much has been said about the scientific milieu in which Bruno Pontecorvo worked after his emigration to the USSR (1950): the Joint Institute for Nuclear Research (JINR) in Dubna. In this paper, we begin to fill this gap by focusing on some of the distinguished scientists he interacted with, besides direct collaborations, paying particular attention to Nikolai N. Bogoliubov around 1957.

Keywords: Pontecorvo, Majorana, Neutrino, Bogoliubov, Oral community.

1. Unexpected links

The year: 1957. The place: Dubna – more specifically the Joint Institute for Nuclear Research (JINR) founded in the previous year. What do the following two men, Bruno Maximovich Pontecorvo and Nikolai Nikolaevich Bogoliubov, have in common? Little or nothing, according to collective imagination (including historiographical texts) in the West; those well-informed may just remark that they belonged to the same generation, and that they both, indeed, worked in Dubna. After all, it could be added, in '57 – as well as in the rest of their careers – they were working on quite separate topics: Pontecorvo was moving important steps towards the idea of neutrino oscillations, one of his most famed scientific contribution; and Bogoliubov, *inter alia*, was thinking about superconductivity, as attested by important papers which were to appear in print from January '58 onwards (Bogoliubov 1958a; 1958b; Bogoliubov *et al.* 1958). Why bringing these two physicists together, then? The reason is at least twofold: one related to the physical content of their research, the other concerning historiographical methodology.

Pontecorvo had come to the Soviet Union seven years earlier; even today we can see that much ink has been spilt on his migration, but certainly one cannot say the same about the *milieu* he started to work in, the physicists he interacted with, the style of doing physics he encountered there. While we hope that a more attentive contextualization of Pontecorvo's work will take place, in this short contribution we aim to offer some-

thing more "transversal", as the involvement of Bogoliubov suggests. Let us mention, therefore, a few elements that will allow to develop the intended considerations.

2. Particle physics and mixing

After the discovery of parity violation in the previous year (1956), those were hectic times for neutrino physics, in which Pontecorvo already had and still was to give some of his most remarkable contributions. We cannot follow here the whole story of neutrino theories and related developments in particle physics, but a couple of important papers and ideas must be recalled. In 1955 Gell-Mann and Pais (Gell-Mann, Pais 1955) published a seminal paper on the oscillation of kaons; in the same year, there was a follow-up in a more experimental paper by Pais, again, and Piccioni (Pais, Piccioni 1955). The reason we are interested in these is the notion of particle mixing being used – i.e., *cum grano salis*, conceiving particles (mesons, in this case) as a superposition of other "entities": what was observed was then interpreted as admixture of (other) particles and antiparticles having different lifetimes. Indeed, it was an exquisitely quantum-mechanical consequence or possibility left open by the principle of superposition.

How did Pontecorvo, after considering the violation of leptonic charge (analogous to the violation of strangeness for kaons) and following upon his musings on Majorana's famous '37 paper (Majorana 1937), come up with the notion of neutrino-antineutrino oscillation? It was clearly built upon the idea of the (Dirac) neutrino as a superposition of some entities that he was to dub "truly neutral" Majorana particles (as in the title of Bilenky, Pontecorvo 1982). Another ingredient, however, was required to make explicit not only "mixing" but "oscillations" as well: that was suggested and called (by Pais and Piccioni) "regeneration" – namely, due to the different lifetimes of the superposed particles and antiparticles, the respective population within a beam could be properly varied, thanks to the experimental setup, and the purity of the beam "regenerated". For further technical details about it, as well as concerning other developments mentioned in the following paragraphs, we redirect the reader to the original papers, of course, and to a more extended and detailed work of ours in preparation (Carini *et al.* 2021).

Now, all that may work for the mesons in question, but Pontecorvo was dealing with the neutrino, a lepton: what kind of guarantee was there that those ideas could be extended to their case? None. In fact, Pontecorvo's was an analogy in the sense of Polya (Corfield 2003, p. 83): the hope of finding a common ground. In '57 there is indeed a paper of his which can be regarded as a sort of temporary scaffolding in his attempt at transferring those ideas from mesons to leptons. The paper is titled "Mesonium and Antimesonium" (Pontecorvo 1957), where he indeed considers some still hypothetical "mesonium" as "a mixed particle", in Pontecorvo's own words, "defined as the bound system" of an electron and an antimuon (that is, leptons), which was expected to decay into a neutrino-antineutrino couple (an idea he discussed with Zel'dovich, among others, whom Pontecorvo thanks at the end of the same paper). As it often happens in the genuinely heuristic dimension of analogies, once the other side is reached the raft can

be abandoned and one moves on. So, it occurs that in another ’57 paper, published at the beginning of the following year (Pontecorvo 1958), he, more directly and in a bolder way – perhaps pushed to do so by some rumors about experimental results obtained in the West – suggests neutrino-antineutrino oscillations. Quite interestingly for whoever is trying to understand who his interlocutors were (beyond what can be seen directly from co-authorship), Pontecorvo thanks in this paper Pomeranchuk, Landau’s great disciple prematurely deceased – who, incidentally, like his master and partly in tension with him, organized in Moscow another renowned seminar. Pontecorvo also expressed his gratitude, in both papers, to Okun, with whom he had worked during the previous year on related topics. Okun, by the way, besides being interested in kaons, was certainly aware of various instances of composite models and of a variety of ideas aimed at considering, at least on an intuitive level (which was anyway clearly perceived by the physicists themselves), a particle as a system compound by other constituents. These instances were usually epitomized by De Broglie's neutrino theory of light, dating back to the ’30s, and by Fermi and Yang’s ’49 proposal (as a reaction to the “particle zoo” of those years) about mesons being non-elementary, but a composite entity held together by a binding potential (Fermi, Yang 1949). Nonetheless, of course, one has to distinguish the different strategies being employed (in their technical aspects) and their specific aims. Okun also knew, for certain, about the model proposed by Sakata – whose work, together with that of his Nagoya group, would cross paths with Pontecorvo in the following decade.

3. Resonances with superconductivity and quasiparticles?

What does Bogoliubov have to do with all of that? Clearly, the story just told is, in principle, self-sufficient staying within particle physics, and it is very well possible that historically it went like that. However, there are a few resonances that might suggest some intriguing and fruitful interaction, even if only by analogy (or by corroborating the analogy kaons/neutrinos that Pontecorvo was entertaining in his mind). Three points, in particular, deserve attention.

According to his long-standing collaborator Shirkov (2009), Bogoliubov, after getting informed about Cooper’s suggestion that the key role in superconductivity is played by *pairs* of electrons (Cooper 1956), was working on how to extend seminal techniques that he himself had developed and partly applied to the case of superfluidity a decade earlier (Bogoliubov 1947). In particular, a crucial passage was the now called Bogoliubov transformation, which maps operators of creation and annihilation into other operators of creation and annihilation, canonically, thus preserving their commutation or anticommutation relations. That also meant changing the ground state of the theory: in a sense, the physical picture is shifted from one in which there are some entities interacting in a way too complicated to deal with, to one in which there are new, composite entities (quasiparticles), “hiding” within themselves the previous interaction and thus much more convenient to treat analytically. With his theory of superconductivity, Bogoliubov (1958a; 1958b) offered another instance of mixing or superposition;

not only that, but, more importantly, his quasiparticle in that case was fermionic (a desideratum for someone trying to conceive a fermion as some kind of superposition). Moreover, the Bogoliubov transformation was in a sense developing and making explicit a strategy which *in nuce* was already present in Majorana's '37 paper, even though more formally than substantially interpreted, when Majorana was trying to get rid of Dirac's sea (which he judged as an unphysical artifice). Something similar can be said of Bogoliubov's own use of the transformation in superfluidity, which linked molecules of He-4 and elementary excitations: there was not a one-to-one correspondence between annihilation and creation operators and some specific particles, and the transformation itself seemed a mere mathematical tool, just useful to diagonalize the original Hamiltonian and to allow the application of perturbation theory, after removing divergences. In the decade that elapsed between Bogoliubov's two breakthroughs, as we have seen, the notion of mixing and similar ideas were either introduced or became much more substantial, and the same can be said of its application in his theory of superconductivity, where the composite fermionic entity is constituted by an electron and a hole and, therefore, has a straightforward physical interpretation.

If we then assume that Pontecorvo was aware of Bogoliubov's work (and we shall see in a moment that we have good reasons to do so), that example not only corroborated his intention of using some ideas of mixing for a fermionic particle such as the neutrino, but even offered him a filter to read and dig deeper into the richness of Majorana's paper, which was – as he declared many times – a decisive source of inspiration. Many (see, e.g., Wilczek 2014) have commented on how fruitfully Majorana's work was received, decades after its publication, in condensed matter physics. Here we could have, on the other hand, an early case of condensed matter physics shedding light onto a deeper reading (within particle physics) of the '37 paper.

4. Seminars, *kruzhki*, and personal bonds

As suggestive as this is, we do not even need to assume a direct contact on such a topic between Pontecorvo and Bogoliubov (at least in that precise year): after all, if those "fruitful resonances" were to be interpreted as "Pontecorvo and Bogoliubov had a conversation precisely on those ideas in 1957", the absence of Bogoliubov's name among the people Pontecorvo thanked at the end of the two papers would be quite problematic; thus, the appearance of their respective work (Pontecorvo 1958; Bogoliubov 1958a) in the same issue of the same journal would probably be just a coincidence (as, in part, surely was), an irrelevant one. Furthermore, we certainly do not intend to fall for a sort of "big names bias", ignoring all other actors and intermediaries. What we actually require – it could be said: we desire to underscore – is simply their common belonging to the texture of an oral community within which new ideas and proposals circulated quite rapidly. That is precisely why we refer to the "seminars" and try to catch through them at least some aspects of the *Lebenswelt*, so to speak, and of the practices of doing physics in Dubna around '57. In any case, we intend to consider that Pontecorvo did know

about what Bogoliubov was doing (even if he may have not actually perceived the analogy or assumed it as relevant) for two kind of reasons, personal and institutional.

Nowadays it is quite easy to take for granted the meaning of "seminars" and their existence, considering them as some sort of conference, more or less formal, with questions and answers at the end, or possibly also in-between. The German tradition of seminars that was flourishing one hundred years ago, however, was quite different: rather than being monothematic, a seminar usually saw the short presentation – by different speakers – of a number of recent results, with often heated discussions. There was, in other words, much less unidirectionality in communication and much more two-directional flow and variety of ideas. Adopted by Niels Bohr, this tradition became an essential part of that *Kopenhagener Geist* that was to be disseminated around the world, including the Soviet Union and Japan, assuming in the process different specific connotations (Hall *et al.* 2004). In the Russian case, speaking of physics, the main responsible for the import of such a tradition was Lev Landau. As some historians have underlined (Hall 2008), nonetheless, that was not a mere imitation of practices from elsewhere, since those seminars somehow were grafted into the local tradition of the *kruzhok* (Alexandrov 1997; Gordin 2008), a small "circle" of people debating ideas (circles which were to prove particularly important in the periods were the official institutions were under the strict surveillance of the regime). Someone may be reminded of the distinguished Kapitza Club in Cambridge – and Kapitza, while still in Russia, had been in turn exposed to Joffe's "seminars". More in general, these small circles represented a tradition that, already in the 19th century, saw as its nucleus someone who had spent some *Lehrjahre* in Western Europe and, back home, was able to keep together the best of the two worlds, so to speak. "Understanding the kruzhok, therefore, leads directly into the nexus between the formal structures of Western science and the social structures of the Russian intelligentsia" (Gordin 2008).

To all this we may add that, a not-always-easy relationship with Landau notwithstanding, a joint Bogoliubov-Landau seminar was held, following upon Bogoliubov's results in superconductivity; such an event, even if short-lived (Shirkov 2009), obviously must have attracted much interest. Moreover, as testified by the reminiscences of occasional visitors such as Richard M. Weiner (2007), Pontecorvo had very active interests in other people's research and ideas; Soloviev (1994), in his book on Bogoliubov, remarks the same. As for even more personal facts, Pontecorvo and Bogoliubov not only had a friendly relationship, but they were even neighbors; one of Pontecorvo's sons also translated Bogoliubov and Shirkov's textbook on quantum field theory into English (Bogoliubov, Shirkov 1982); and, quite suggestively, we may also add that, towards the end of the millennium, just after a few years since their respective passing away (with only some months in-between), two roads in a new area of Dubna were named after Pontecorvo and Bogoliubov.

Sieroka (2010) remarked how another great mathematician and physicist, Hermann Weyl, was very well aware of the way the notion of neighborhood – in its conflated meaning referred to mathematical points, physical regions, and even human contacts – turns out to be more useful and more "fundamental" than that of the single, isolated point-individual: once we discuss some ideas together with other people, with whom

we have strong intellectual ties, it is often not so meaningful to dissect and analyze what belongs to whose suggestion. As Rilke once put it beautifully in a letter, "the question concerning 'influences' is naturally possible and legitimate, and there may be cases in which the answer brings up the most surprising explanations. In the meanwhile, no matter how that question sounds, it has to be brought back to the life from which it comes and, in a sense, get dissolved into that" (Rilke 1950). We hope to have offered some guidelines in such a direction. In *Storie del bosco boemo* ("Tales of the Bohemian Woods"), the renowned translator, Slavist and writer A.M. Ripellino (1975) fancied about the mixture of essay, poem, and tale that he had tried to achieve there. Not too differently (if not for the historical grounding), in this little contribution, *Tales from Dubna's Oakwood*,[1] we have tried to send a message on at least three intertwined levels: one more related to physical contents, one about the cautionary but suggestive use of analogies in (possible) reconstructions, and one at the level of historiographical methodology, almost a plea for more attention to the traditions of seminars that were flourishing in past decades. Concerning the latter, the more one waits and the more their traces fade away: against the increasing, not seldom acritical application of ready-made tools of analysis to the history of science, it is important not to lose sight of the network of relationships and exchanges in a certain *milieu*. That is, indeed, a texture by nature volatile, often extemporary and not easy to grasp, one made of bonds that, echoing Gordin (2020), "it is the goal of history to make […] visible anew".

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[1] The oral dimension stressed above should make obvious the choice of "tales", while "oakwood" is a pun on toponymy, since "dub", in Russian, means "oak". If the aura of mystery surrounding Pontecorvo led Gadda (1952) to set his rendering of La Fontaine's fable of the raven and the fox in a forest with Pontecorvo and Klaus Fuchs, hopefully, seventy years and hundreds of speculations later, we have given a contribution to redirect the fascination around Pontecorvo into another, more interesting and lasting direction.

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