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Far from the Particle Crowd: *Shugyosha* Nambu and *Michizane* Wheeler

Rocco Gaudenzi – Max-Planck-Institut für Wissenschaftsgeschichte, Berlin – rgaudenzi@mpiwg-berlin.mpg.de
Stefano Furlan – Max-Planck-Institut für Wissenschaftsgeschichte, Berlin – sfurlan@mpiwg-berlin.mpg.de

> *Our will foretells what we will do under any circumstances. And yet these circumstances capture us in their own way. The* what *is in us, the* how *rarely depends on us, on the* why *we cannot ask questions, and rightly so we are then sent back to the* quia.
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> J.W. Goethe, *Dichtung und Wahrheit*

Abstract: In the late 1940s many physicists embrace the surging particle physics regarding it as potentially resolutive of the crisis of nuclear physics. Against this backdrop, two thinkers of peculiar taste choose otherwise. Here we trace the roots and consequences of their decisions.

Keywords: Peripheral thinking in 20th century physics, History of nuclear and particle physics, Non-reactionary conservatives

1. Introduction and methodology

In this brief communication we reconstruct, in two exemplary instances, the subtle relationship between the emergence of a collective dimension of particle physics, with its practices and objects of enquiry, and the individual dimension of two thinkers who opted to remain peripheral to it in their speculations. A dimension the consideration of which calls the attention, on the one hand, on their peculiar stance concerning the role that the experimental input should have on the pure *theoresis*; and, on the other hand, recognises the root of their long-term successes in routes independently opened in "less-suspicious" times. We are talking about the attitude and choices that, for peculiar reasons but resonant in their main aim, led the two theoretical physicists Yoichiro Nambu and John Archibald Wheeler "far from the particle crowd"; that is, to keep a certain distance from the rising trend of particle physics. A trend that, surging between the end of the 1940s and the mid-1950s and promoted by the nascent particle accelerators and high-energy cosmic rays, drew many of those who at the time would define themselves nuclear physicists into the systematic exploration of the sub-nuclear world.

Without the pretence of being exhaustive, our reconstruction proceeds from what we might call a "historical monadology", that is, a selection of the views which some representative actors developed in response to the increasingly evident *krisis*[1] faced by nuclear physics. Through this selection one can capture both the emergence of a general sentiment which regarded particle physics as the inescapable way to resolve the open problems; and two voices out of the choir – that of Nambu and Wheeler – that would be obscured by the mainstream. By adopting alternative strategies, these two voices opposed a "mild resistance" to the mainstream. While appearing as failures when assessed in the short-term, such strategies had revolutionary power in the long run.

2. Embracing particle physics

Of the three fundamental interactions that governed the microphysical world, the nuclear one was, at the turn of 1950, still in an impenetrable ambiguity. On the one hand, ever since Yukawa had advanced his enlightening conjecture in the mid-30s, the nuclear force (as well as many of the cosmic-ray phenomena) could not be discussed other than in terms of mesons; and yet, its seeming indefeasibility notwithstanding, one and a half decade of attempts later no adequate quantitative predictions had been squeezed from it. In this state of affairs, many nuclear physicists were increasingly persuaded that the problem of nuclear forces required going beyond the known nucleons and mesons, staking on particle physics for its resolution. Speaking on behalf of this majority, Enrico Fermi's introduction to nuclear forces (in his lectures held at the University of Chicago in 1949) reflected the problematic impasse and the emerging convictions: «At present the meson theories of nuclear forces are the main guides and give valuable qualitative results. However, there are serious difficulties in these theories which lead people to believe that the answer to the problem cannot be found by their further development» (Fermi 1950, p. 111). A similar, but stronger stance was echoed in Robert Marshak's lecture series held at University of Rochester and Columbia University in 1950. A former collaborator of Hans Bethe and experienced proponent of the recently confirmed two-meson hypothesis, to his students Marshak spoke of the meson theories hitherto proposed underlying their mere role as "plausible conjectures which occasionally illumine the complexities of the experimental material". And to this, he added that, in such a provisional heuristic stage, to guide the theoretical progress shall be the results from high-energy processes (the various processes featuring the production and capture of mesons), and not the traditional phenomenon of nuclear forces (and its manifestation in low-energy nuclear bound states), which had revealed itself as too speculative and thus not as insightful.

> In the task of surveying the essential results of recent meson experiments [we are restricting ourselves] to real meson processes. Omitting consideration of all nuclear phenomena (e.g., nuclear forces) which involve mesons only as virtual transitions, we have eliminated the most speculative and least satisfactory predictions of meson theory (Marshak 1952, p. 1).

[1] Here *krisis* is meant in its original, etymological, sense (*krínein*, "to decide or judge") of a situation urging for a judgement; in this case, especially one on the methodology to adopt.

The Japanese theoretical physicist Sin-Itirō Tomonaga too, after repeated attempts at the systematisation of meson theory, recognised in the new results from high-energy experiments the "instruction from Nature" necessary to guide the otherwise "powerless" human reason:

> [In settling the direction where to go next in the theory of elementary particles and nuclear forces] We are too powerless to make assumptions based only on reasoning. We must beg instruction from Nature herself. The recent development of experimental technique has […] enabled us to produce mesons in great quantity within the laboratory, and we no longer need to rely on their coming to us from the heavens to be studied. Great indeed will be the contributions of these experiments to the construction of a correct theory of elementary particles […] and the many [unresolved] aspects of the meson theory (Tomonaga 1949, p. 13).

3. Nambu and Wheeler: two *sui generis* non-reactionary conservatives

It is against this emerging collective dimension characterised by the search for a decisive hint, or at least a nudge, in the results of experimental particle physics that the reactions of Nambu and Wheeler stand out as different. Let us see in what sense this was the case and what were the short- and long-term outcomes they were led to as a consequence.

3.1. Nambu's strategy: solid-state and nuclear physics, prolegomena to a discovery

A part of the rising generation of Japanese physicists who were in their late twenties by the end of the '40s, Nambu had worked on a variety of problems, including quantum electrodynamics and some aspects of the meson theory. At the beginning of 1950, he was then appointed professor, by the cosmic-ray physicist Yuzuru Watase, in the newly founded physics department at Osaka City University as the head of a small theoretical group whose members were Satio Hayakawa, Katsuiko Nishijima, Yoshio Yamaguchi, and Tadao Nakano (Low 2005). The purpose of the group was to closely collaborate with the many experimentalists that Watase had gathered around the new high-energy cosmic-ray facilities. As it still happened in other parts of the world – and especially in economically depressed areas – Watase's idea was to do a particle physics that, if not compete with, could at least complement the works on accelerators.[2] But Nambu had a parallel agenda and, although he did spend some time between the mid of '50 and '51 leading Nakano and Nishijima on the interpretation of the puzzling *V*-shaped particle tracks which were thrilling the world of particle physics, the main research program that he pursued – individually and with some of his students – before and after that had little to do with cosmic rays and particle physics.

[2] Customary, "home-made" and comparatively inexpensive tools for particle physics, cosmic rays were the only feasible counterparts of the nascent accelerators in a country like Japan where the economic resources were low and the only existing cyclotron had been drawn in the Tokyo bay by the Allied Forces after the war. Borrowing an expression from Zel'dovich, cosmic rays were in a sense the "poor man's accelerators".

As proven at the earliest by the first note of his private notebook, dated 21st January 1950 and entitled with a Goethean echo *Dichtung und Wahrheit*, that opens the season in Osaka, Nambu's goal was to solve the problem of the nuclear forces not by searching for new underlying particles, but in terms of those which were already known and in their traditional low-energy realm: the same "old" nucleons and mesons for how they manifest themselves in the nuclear bound states. Behind his attitude lay the simple conviction that the difficulties and many unsuccessful attempts of the meson theories in quantitatively explaining the nuclear forces were due to the way these conclusions were drawn from the meson hypothesis. Before advancing "any more revolutionary" hypotheses on the nature of the basic components, in need of discussion was therefore the way in which these latter were formalised. Accordingly, the focus should not shift away from the traditional phenomena, guidance to theorisation and final discriminant; shift which Nambu instead had observed in others and in a veiled manner now criticized through the words of his student Nishijima:

> When the serious difficulty concerning the singularity of the meson potential became emphasized, […] the efforts of early meson physicists were concentrated on this problem. Recently, however, the laboratory studies of mesons were rapidly advanced, and most meson physicists are interested in the mechanism of the production and capture of π-mesons leaving the problem of "nuclear forces" [in the nuclear bound state] untouched. Still we have reasons to believe that this phenomenon, though implicitly related to the properties of mesons, will give us some information about the correct method to be employed in the meson problem [...] (Nishijima, 1951, p. 815).

This expressed the courageous intention of remaining precisely on the phenomena which Marshak, and the community of nuclear physics at large, had labelled and excluded as related to a too speculative dimension, and on which no new experimental input was indeed to be expected. Aimed at a "New Formalism", inspired by solid-state physics, to reframe the same basic phenomena, Nambu's research program moved away from the results of particle physics and its use of symmetries, that instead was soon going to increasingly motivate the most ambitious part of the theoretical physicists of the period. With great frustration, Nambu will have to close the program after four years of hard work with the admission of a failure in the original purpose that had motivated it.[3]

If this conservative program had failed in the nuclear field, it had however produced a general method to describe interacting many-body systems from the perspective of quantum field theory (Nambu, Kinoshita 1954); and in this way it had opened a route that would eventually revolutionise particle physics. As for an heterogenesis of intents, this occurred when, returning to the surface a few years later, the same method turned to be perfectly well-suited to reformulate another problem, in another field, which involved strongly interacting particles: the problem of superconductivity (Nambu

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[3] As for a twist of fate, that incursion on *V*-particles he had entertained with his students Nakano and Nishijima, and carried further by them alone, brought to the conceptualisation of strangeness as a new symmetry of physics, which in turn would lead to solve the problem of the nuclear forces through the discovery of quarks.

1960). Through this reformulation Nambu unveiled the mechanism of spontaneous symmetry breaking at work in superconductors, which, once transferred to particle physics, would explain the mechanism of mass generation in elementary particles (Nambu, Jona-Lasinio 1961).

3.2. Wheeler's "Desert Island". Tinkering with the known principles towards black holes

Partly guided by a development of earlier tendencies of his, from 1950 on John A. Wheeler embodied a point of view similar to Nambu's, though expressed with more assertive tones. At the beginning of the '50s, Wheeler, approaching his forties, had a very distinguished position in nuclear physics and, being in Princeton, certainly had no problems with staying in contact with recent developments. Already in the previous decade he had revealed a tendency towards ambitious theoretical schemes which, with a few well-established principles and an ontology as economical as possible in terms of "species" of basic entities, was simply at odds with "the pion industry" – metonym of a way of doing physics that he judged too subordinated to a superficial account of the most recent experimental results. Facing the proliferation of the "particle zoo", his aim was to think more deeply about the already well-established principles by exploring them to their extreme consequences without introducing anything new. In other words, rather than being distracted by the proliferation of experimental data and trying to accommodate them somehow *ad hoc* or phenomenologically, Wheeler sought to outline a grand view, grounded in well-established physics, capable of deriving or ordering them.[4]

It was while in the midst of this search that he matured a "conversion" which opened a new phase in his long career. Not without a gamble, he decided to look for his own path far from the particle crowd, according to a tenet that he would later put as "When I see a herd running one way, I like to march another way" (Wheeler 2000). His previous slogan and program "everything is particles" became "everything is fields" and at the core of his interests he decided to set general relativity, at the time certainly not one the most flourishing research areas. And while his "particle problem" – i.e., the attempt to account for the spectrum of particles – was still there, he now evidently was devising to attack it from a different side. Holding on to the methodology sketched above, he intended to explore to the extreme consequences the dynamical character of geometry without introducing additional elements.

It was not a coincidence then that Wheeler elaborated, articulated and even gave a name, "daring conservatism", to his own heuristic methodology right in that period of *krisis*, when he was indeed taking a chance rather than merely surviving in his established position and mindset; neither was a coincidence that, during his first travel to Japan, he found – or so he liked to believe – a resonant attitude that suggested him to expose, in a very peculiar way, his heuristic methodology (which he even thought of

[4] In a later interview, he remarked how unappealing "the missing aesthetics of modern particle physics" was to him. To confirm this, we can find in his private notebooks the draft of a talk in which he even invoked a "desert island" where he could isolate himself from the overflow of experimental news, and meditate upon the lessons of the great developments of XX-century physics (Blum, Brill 2019).

calling "Tokyo program") in front of his audience in the Japanese capital in 1953 (Blum, Brill 2019). Wheeler, creative as usual in his speeches, identifies his attitude of daring conservatism with that of *Sugawara no Michizane*, the great poet and statesman of the Heian period, noticing *inter alia*: «I did not see young men running here and there. I did not see a large organization with a computing machine. Michizane talked to young people, thought about such problems, seemed to be walking around in his spare time and did not seem to have a specific program». Although Nambu was not in the audience, he probably would have not been displeased with these words. On the contrary, with reference to that period of his life he called himself a *shugyosha*: a lonely samurai who walks around, honing his skills with the prospect of finding application – not too differently than what actually happened with his theoretical speculations.[5] Nor was Wheeler shy to state his way of proceeding to John von Neumann, as he wrote him in a 1954 letter: «I am still trying to understand elementary particles in terms of existing concepts. The general philosophy is this, how does one know what to invent, or even that any invention is necessary, until one has explored further the rich consequences of what one already has».

Daring conservatism, in this sense, was a particularly explicit instance of those critical reflections made by physicists back then, when stopping for a moment to decide which balance between *theoresis* and reliance on experimental inputs they wanted to settle for. Where did it lead Wheeler to? Among the ideas he would soon pursue, while assimilating more and more what he deemed to be the deeper lessons of general relativity, one he really got enthusiastic about was that of "geon".[6] And despite the fact that by the end of the decade the problems that geons turned out to be greater than their promises, Wheeler never abandoned them. They were, after all, a legitimate possibility allowed by general relativity and, so he thought, even if they were not going to represent directly some secret of nature, they could still be models capable of offering valuable insights into the principles that made them possible (at least mathematically) and which, according to daring conservatism, were not going to be modified. (Something similar can be said about Wheeler's "wormholes", too.) In the '60s, Wheeler had by then become one of the main authorities in general relativity, with his school as one of its hubs; his interests had been caught by gravitational collapse, and it was in the context of the soon-to-be-called black holes and of gravitational waves that the tools of analysis for geons and wormholes, developed by him and his schools, were to find fruitful and decisive application. Far from being a mere strike of luck or a way to hide a failure by nominally recycling it, this was a process which, even in its ultimate unpredictability (but, one could say echoing Einstein, that is precisely why it is called "research"), had been sought and cultivated. Another paradigmatic instance of heterogenesis of intents.

[5] Even if, obviously, the Japan of Wheeler's first impressions and fantasy was not the same as Nambu's, nevertheless, during the following decade, Wheeler's relation to that land and culture grew to be quite intense, complex and stimulating.

[6] A solution to Einstein-Maxwell equations that, in the form of a self-gravitating wave which confines itself in a certain region because of its own energy, seemed to offer a suggestion on how to derive from a pure field ontology something that resembled a "body". It was therefore meant to play a key role – as an intermediate step – in the geometrodynamical attack to the "particle problem".

3. Concluding remarks

What is the primary element that shall guide physics? What proportion between the exercise of pure theoresis and the “begging instruction from Nature” is the optimal for its advancement? While there is hardly a universal answer and a magic mix, within the limits of the considered specific historical moment – a critical one – we have seen how these matters were reckoned differently by the different actors; and how, from perpendicular beliefs as to what should lead the theoretical progress, widely different pathways and outcomes emerged. When considered in the *longue durée*, the two more strictly idiosyncratic pathways we have retraced, dictated by minoritarian choices and conservative in the short-term, turned out powerful and paradoxically revolutionary in the long-term. From the historiographical point of view, this suggests us that those somewhat unusual contributions cannot be fully assessed in a logic of sequential problem solving, but only in a logic of accretion; that is, by recognising in them the dimension – in which we interpreters should try to immerse ourselves too, as much as possible – that Wheeler used to call of the *seeker*.

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