

THE SMILE OF MNEMOSYNE: JOHN WHEELER BETWEEN THE HISTORY OF SCIENCE AND ARTS

Scientia, vol. II, n. 1 (giugno 2024)
DOI: 10.61010/2974-9433-202401-004
ISSN: 2974-9433

Received 10/05/2023 | Accepted 2/09/2023 | Published online 27/05/2024

Stefano Furlan

Max-Planck-Institut für Wissenschaftsgeschichte di Berlino
e Département de Philosophie
Université de Genève
sfurlan@mpiwg-berlin.mpg.de

Sunto

John A. Wheeler (1911–2008) è una figura chiave della fisica del XX secolo, noto anche al di fuori della cerchia degli specialisti per espressioni evocative come «black hole» o «it from bit». Decisamente meno conosciuti sono i suoi interessi e le sue attività legati alla visualizzazione nelle arti (oltre che nella sua stessa fisica) e alla storia. Quest'articolo offrirà alcune linee guida per apprezzare come questi aspetti si siano andati intrecciando a fondo con le pratiche di ricerca di Wheeler a partire dagli anni '50. Inoltre, si richiamerà l'attenzione sui suoi rapporti con la cultura degli immigrati germanofoni a Princeton e si tratterà un inaspettato parallelismo con alcuni tratti del pensiero di Aby Warburg. **Parole chiave:** visualizzazione; fisica del '900; storia integrata di arti e scienze

Abstract

John A. Wheeler (1911–2008) is a leading figure of 20th-century physics, well-known even to a larger public for his evocative expressions such as «black hole» or «it from bit». Much less explored is his active engagement with visualization in the arts (as well as in his own physics) and with history. This paper intends to offer some insights into Wheeler's related activities from the 1950s on, showing how his peculiar relationship with the past and with pictures was strictly intertwined with his way of practicing science. Attention will be paid for the first time to his contacts with the German *émigrés* in Princeton and an unexpected comparison will be drawn with a few aspects of Aby Warburg's thought.

Keywords: visualization; 20th-century physics; integrated history of arts and sciences

Something must be at once defined ('bepaalt', says the Dutchman), and for a moment one believes to possess that unknown space, until somebody else pulls out the stakes again and plant them in a narrower or larger space.

– Goethe, *Wilhelm Meisters Wanderjahre*

Introduction: 'barbaric' times

During the 1950s, Erwin Panofsky repeatedly praised the scholar's «ivory tower» [Panofsky, 1957; Landauer, 2000], from whose height, so to speak, one could spot, like a sentinel, the barbarians *ad portas*. This is quite well-known already, perhaps also because of the contrast to the very different connotations that the expression 'ivory tower' has otherwise taken on. There is something that may be added, however: even if it is only a conjecture, we may have good reasons to think that, among such barbarians, Panofsky was including in his mind, at least from time to time, this man here (Fig. 1) (the one on the right – the other is simply the Mephistophelian Wolfgang Pauli, whom Panofsky actually befriended).



Fig. 1 - Copyright: Cern, Pauli-archive-pho-055.

Who is that? Panofsky's Princeton neighbor. The story goes [Panofsky, 2006] that the FBI once went to ask the eminent art historian if the man living next door seemed a trustworthy and reliable person of unsuspecting ideas: at that point, Panofsky stated without hesitation that he was a mass murderer. Now, our art historian was not freaking out entirely, nor are we dealing with an extreme or somewhat caricatured form of strained relations between neighbors; and this is not a Princeton version of some American serial killer story, either. That neighbor was not an ordinary barbarian: yes, he used to put science at the service of technical 'utility' (as opposed to the attitude of the ivory tower) and even military tasks, but, to borrow a phrase from Manzoni, he was a barbarian not without some genius. His name was John Archibald Wheeler (1911-2008): even non-specialists may have heard of him at least due to a few expressions that he adopted and, then, became part of common parlance, from 'black holes' to 'it from bit'.

This paper will address a couple of Wheeler's peculiarities, at least when compared with his fellow physicists: one is his overlooked relationship with the past, the other his use of pictures (far beyond standard scientific diagrams). We will see how the two, actually, are partly intertwined – hence the suggestive and unexpected comparison that we will sketch in the following, referring to some Warburgian motives (as the sagacious reader may have already guessed from an element of the title, followed by the reference to Panofsky). In order to do that, first of all, we have to properly situate Wheeler's activities in his era and emphasize aspects that are typically neglected by historians of recent physics.

Reacting to the Atomic Age

Besides allowing us to introduce Wheeler from an unusual angle, the above-mentioned anecdote also shows Panofsky's reaction against the Atomic Age (understandably, up to a point). He was certainly not alone in that: some eloquent pages by Michel Serres on what Hiroshima meant for his generation and its image of science [Serres, 1992] come easily to mind, but the same goes for the incipit of Erwin Chargaff's fascinating autobiography [Chargaff, 1978] or some reflections by Karl Jaspers, Günther Anders, and others [Jaspers, 1958; Anders, 1959]. In 1960 Edgar Wind, in the first of his famous lectures on *Art and Anarchy*, remarked:

So Hegel drew up his bill of particulars. As he saw it, the moment had arrived in the world's history when art would no longer be connected, as it had been in the past, with the central energies of man; it would move to the margin, where it would form a wide and splendidly varied horizon. The centre would be occupied by science – that is, by a relentless spirit of logical inquiry. The kind of science which Hegel foresaw bears no resemblance to the science of today: in that he was a bad prophet. But the place of science in our lives he foresaw correctly, and he was equally foresighted in the place he assigned to art [Wind, 1985, p. 10].

Needless to say, here we do not intend to face the *vexata quaestio* of the 'end of art' in Hegel's thought, but Wind's considerations – or, perhaps better, observations – sound quite shareable. Science, however, had not just taken a central role, but had also released some unprecedented power on the human scale, thus raising doubts and fears, not only among outsiders. For instance, even one of Panofsky's sons, Wolfgang, who was going to become a quite distinguished physicist and, by the way, was also a student of Wheeler's, did not remain indifferent to such ethical dilemmas and activated himself from within the community of physics (and also tried to problematize the situation when talking to his father, without much success) [Panofsky, 2006]¹. Wheeler too, even if he was convinced of the Cold War necessity of developing thermonuclear weapons to keep the Soviet threat at bay, meditated upon those issues in a variety of ways, not least inspired in the long-term by the visions for peace of his two mentors, Albert Einstein and Niels Bohr. He also took note of the impact of the new Promethean powers at the level of society at large, realizing that the old genre of celebrating science and his triumphs needed a

¹ «The recently aggravated tendency to consider Science as an essential element in the preparation of war and the scientist as a cog in the Military Machine cannot be dissipated other than by continuous work in which the Unions must participate actively», as Paul P. Ewald said in the IUPAP assembly of 1947 [Anon., 1992] (I wish to thank R. Lalli for this passage). Here we may also recall that Wheeler's former Ph.D. student Katharine Way, right after the war, co-edited with Dexter Masters the book *One World or None: A Report to the Public on the Full Meaning of the Atomic Bomb* [Masters, Way, 1946], in which the voice of people like Einstein, Bohr, Oppenheimer, Wigner, Compton, Szilard, and others was meant to offer a problematization of the perspectives opened by the Atomic Age to a larger public. Even if, in that case, the editors were, respectively, a physicist and a novelist, a serious scholarly comparison between this kind of documents/reactions from the sciences and the aforementioned texts from philosophers and humanists still seems missing: when are we going to see the «imperative of responsibility» by Hans Jonas and Leo Szilard's «ten commandments» discussed side-by-side?

renewal. Before getting there, however, we have to better characterize what Wheeler was up to during those years, on a plurality of levels. In his last essay, Irving Lavin, dedicating it to the *American Panofsky* [Lavin, 2019], remarked on how, for the transplanted art historian, the United States represented a context in which the regional and national boundaries that characterized his discipline in Europe were completely lifted – well, John Wheeler was going to transgress many other disciplinary boundaries, with a ‘barbaric’ injection of new energy that deserves some consideration, not just for the sake of an individual focus (however remarkable), but also because of his impact on generations of students and researchers².

Reacting to the ‘particle zoo’

In the same years as the reactions to the Atomic Age, Wheeler gradually began intertwining a more complex and intriguing vision of science. Even if we have mentioned his awareness of the need for a renewal, in communicative terms, it would be misleading to suggest that he activated himself in merely rhetorical terms: as we shall examine, his peculiar way of practicing science is strictly connected to the features that his communication skills emphasized for relatively broader audiences, so that his heuristics was vitally linked to his rhetoric and vice versa. Given these premises, the point here is not much about the technical details *per se* of Wheeler’s physical research of that period: suffices it to say that, towards the end of the 1940s, with the explosion of the so-called ‘particle zoo’ – that is, the discovery of new kinds of unaccounted particles – his previous ambitious attempts at building a comprehensive picture of nature went into a crisis [Blum, Brill, 2020]. Some new ways of doing physics, which followed the latest experimental outputs and added *ad hoc* terms here and there to accommodate the newly available phenomenology, were not congenial to Wheeler, who even went as far as to invoke a «desert island» to isolate himself from the flood of new experimental data and rather devote himself to meditating more deeply on already well-established principles, trying to explore their extreme consequences [Furlan, 2021; 2022]. This heuristic approach even received a name: «daring conservatism» (half-playful

² For the scientific ‘manpower’ that was available to someone like Wheeler in the post-war US we redirect to Kaiser, 2002.

nod to Eisenhower's slogan «dynamic conservatism»). Wheeler then began to regard one of his two great mentors, Niels Bohr, as the hero and, later, even the father of daring conservatism [Furlan, 2020a; Blum, Furlan, 2022]. Which 'principles', however, was it supposed to get applied to? To general relativity – that is, to what Wheeler considered the main legacy of his other great mentor, Albert Einstein. Wheeler would thus devote a couple of decades to trying to build everything from the geometry of general relativity, exploring its extreme implications.

It is interesting to note how, at this stage of crisis and evaluation of future strategies, Wheeler, around forty, somehow decided to reinvent his well-established career as a nuclear physicist, in an operation that was by no means obvious: as a matter of fact, after general relativity had been consecrated by the classic tests that are still illustrated every time today, it had ended up on the fringes of frontier research in physics. Wheeler would thus become a key figure, especially for the next two-three decades, of the so-called 'Renaissance of General Relativity', a phenomenon that long remained completely flattened or taken for granted in certain triumphalist narratives, but was appropriately exhumed and studied in more recent years, on the occasion of the centenary of the theory [Blum, Lalli, Renn, 2016; 2020]. In light of our preceding considerations, this also means that Wheeler conceived of his own work from that period as the development of Einstein's results, but with a methodology he claimed to have taken from Bohr: for him, the great and still open challenge of quantum gravity, namely that of reconciling general relativity and quantum physics, was thus also a personal matter, in an attempt to reconcile the legacy of his two mentors, at the same time forging his own precursors (as we all forge our precursors, to echo Borges). This was a conscious and prolonged operation over the years: «If it is true, as Thomas Mann tells us, that each one of us models his or her life consciously or unconsciously on someone who has gone before...» [Wheeler, 1980, p. 102]. One can better understand, then, why a seminal paper from that phase opens with an epigraph from Confucius, something decidedly unusual for a physics paper: «I transmit but I do not create; I am sincerely fond of the ancient» [Misner, Wheeler, 1957, p. 525]. All this has been reconstructed in some detail only in very recent years, not least thanks to the rich archives that Wheeler himself set up for posterity. The fact that he did it should not be taken as a self-aggrandizing pose: his notebooks are not afraid of showing the criticism he received from illustrious colleagues, nor is Wheeler reluctant to leave visible traces of his zetetic attempts, unlike

the fox who erases his footprints with his tail (as instead happens, for instance, in Gauss's *Nachlass* – or, much more prosaically, in all the cases of scientists simply unaware of a non-trivial historical dimension of their research). Actually, as we shall see, this sort of heuristic transparency would permeate even his late *published* works. Wheeler's archives, left to the American Philosophical Society in Philadelphia, are rather to be seen as one of the manifestations of the importance he attached to history and historiography, as well as of his 'transgenerational' concerns (as would perhaps be phrased today).

On the uses of history for life

In parallel with the physical program just outlined, there was another of Wheeler's activities worth noting, as it is even more overlooked and perhaps unexpected. Between the late 1940s and the mid-1950s, that is in the turning years after the first phase of his career, Wheeler spent rather extensive periods in Europe, notably in Paris, first, and in Leiden, where he was Lorentz Professor in 1956. In Paris, among other things, he took drawing lessons to improve his graphic skills, so important – as we shall discuss – for his way of practicing and communicating physics [Wheeler, 1994a; Hentschel, 2014; Furlan, 2024a]. It was during that period that Wheeler also became a reader of *The Paris Review*, a magazine founded in 1953 in which established writers – it would include names ranging from Eliot to Borges, from Pound to Nabokov – were interviewed with a special emphasis on their creative process: the series was in fact called *Writers at Work*³. An original thinker and skillful communicator such as Wheeler was predictably intrigued and he soon envisioned something similar in order to collect and pass on to posterity the creative experiences, heuristic strategies, and more generally the testimony of the founding figures of the new physics, who were starting to be relatively old and pass away [Wheeler, 1963]. This sense of *vanitas*, along with the need

³ It is not the purpose of the present paper, but, in terms of the Cold War scenario in the background, it is not irrelevant to add that, its apolitical appearance notwithstanding, *The Paris Review* was originally used as a cover for CIA-related activities by the magazine's founding editor Peter Matthiessen. The CIA covertly funded various magazines (for a list, see e.g. Iber, 2015), even with socialist inclinations, as a 'soft power' move to promote a kind of moderate buffer against the far left. Similar considerations, regarding both the role of the history of science in the post-war US and 'soft power' moves, can be found with partly similar overtones in van Dongen, 2020, even if putting them next to Wheeler is a new operation.

for new ways of communicating physics to a wider audience in the middle of the gloomy fears of the Atomic Age, prompted Wheeler to help set in motion the organization of one of the largest projects in the history of science, *Sources for History of Quantum Physics*, then led by Thomas Kuhn and others. Wheeler would also write a preface to the whole endeavor [Wheeler, 1971a]. The interview format (a source of much frustration for Kuhn and for the historiography he had in mind) had been suggested by Wheeler on the model of *The Paris Review* and its *Writers at Work* [te Heesen, 2020]. It is of course possible to debate whether such a medium of historical investigation, under those circumstances and after decades from the original events, was appropriate (depending also on historiographical aims), but what is certainly interesting to point out is not only the active engagement of a distinguished physicist (still very active, in terms of scientific research) such as Wheeler, but also the unified conception of the ‘works of the mind’, so to speak, that he evidently nurtured⁴. Later he would make explicit his idea of a sort of heuristic repository (and, in terms of variety of inspiration, the literary reference he would resort to speaks volumes): «Do analogies form themselves out of thin air? Does our problem click by magic into parallelism with another idea from our own area, or with a thought from quite another field? Not by magic alone, but magic plus the prepared mind, Abraham Flexner reminds us. We recall the leader of industry who went to Arthur D. Little for something in writing on the proper organization of a research laboratory. He came away with John Livingston Lowe’s inspiring book, *The Road to Xanadu*. And where could one see better than in that study of where Coleridge got his ideas how the storehouse of the imagination is stocked by conversation, story, book and observation?» [Wheeler, 1985, p. 16].

Even conceptually, Wheeler’s tentative analogical transfer of the model of *The Paris Review* was not trivial: his emphasis on the dynamic dimension of the creative process, rather than on the final product, is quite remarkable (and many historians and philosophers of physics are still blind to that, even nowadays). In this sense, the awareness that Wheeler displayed regarding the importance of archives and historical perspectives is certainly a pleasant surprise for future scholars too, but, well beyond that, he seems to have been thinking, *in nuce* at least, about some integrated history of sciences and arts. For sure,

⁴ It is not a coincidence that Wheeler was thanked for stimulating conversations in an original book – which historically integrated scientific and artistic dimensions – such as Lipking, 2014, as the author himself confirmed to me.

even thinkers such as Cassirer had tried to find a common ground, considering arts and sciences as symbolic forms, but their differences in the way of relating to the past had not been challenged as openly as Wheeler's seemingly innocent was implying. He himself was aware of that, as he commented on other occasions, although mainly to contrast his own pragmatic and 'optimistic' attitude about science and the 'pessimism' of a few humanists [Wheeler, 1962]. That is, after all, our starting point about the reactions to the Atomic Age. Nonetheless, even if we can easily concede that Wheeler's attempt has assumptions that are problematic and to be discussed, his effort deserves attention and, instead of considering it merely wishful, we may read it as an indication of Wheeler's own peculiar relationship with the past. Indeed, it should already be quite clear, at this point, that Wheeler's uses of history were actually quite multifaceted [Furlan, 2020a]: we may echo Nietzsche's famous tripartition⁵ and claim the partial co-presence of an *antiquarian* effort, aimed at the respectful and self-serving preservation of the past; a *monumental* instrumentalization, with the aim of spurring new recruits to feel involved in a great tradition and, more generally, pointing the research directions of collaborators with grand narratives; and a *critical* gaze, capable of selectively identifying, or transfiguring by analogy, certain traits that can be used in present situations. *Pace* Panofsky, his saying that a humanist is someone who rejects authority but respects tradition [Panofsky, 1974, p. 3] applied quite well to his neighbor.

Of course, their references to Panofsky are not just an ironic *leitmotiv*, but also serve the purpose of impressionistically evoking the cultural *milieu* of the German *émigrés* in Princeton, so important for Wheeler. Needless to say, a study dedicated to the impact that it had on him is totally missing, but here, for the sake of discussion, we can highlight a few further elements. It is not hard to imagine the strong impression that, also from a cultural point of view, Bohr's court – to a large extent Germanophone – must have left on the young Wheeler in Copenhagen during the mid-1930s. By the end of that same decade, after moving to Princeton, he would find again a similar context, due to the presence of his other great mentor, Einstein, and other highly distinguished German *émigrés*. As Eugene Wigner – another European refugee and longtime friend of Wheeler's – once put it, «with the coming of the Einsteins, Weyls, and Manns, Princeton began to become a little capital

⁵ Even if, obviously, the very coexistence of these three aspects already makes them quite different from Nietzsche's second *Untimely Meditation*.

of German culture in exile» [Wigner, 1990, p. 529]. The impact of all this on Wheeler has not to be related only to some of these personalities' scientific stature, which later would make Wheeler even boast a sort of continuity in a «Göttingen-Princeton tradition» [Wheeler, 1986, p. 371]. His relationship with Hermann Weyl (besides the already remarked importance of Einstein as an inner model) is an excellent example, as if there were an overall process of intensification and articulation of youthful impressions, once Wheeler came face to face with those personalities. He himself made it quite explicit: «I first knew Weyl before I first knew him. Picture a youth of nineteen seated in a Vermont hillside pasture, at his family's summer place, with grazing cows around, studying Weyl's great book, *Theory of Groups and Quantum Mechanics*, sentence by sentence, in the original German edition, day after day, week after week» [Wheeler, 1986, p. 366]⁶. While celebrating Weyl's 100th anniversary in 1985, Wheeler also recalled the long walks and conversations he had had with him on a plurality of topics – in short, everything he could learn from him, ranging from the work of Herman Hesse to Jacob Burckhardt. It is thus interesting to remark for our purposes that, while Wheeler was promoting historiographical operations in the 1950s, with an eye on the post-atomic cultural situation, great questions about mankind and history were being debated within that Princetonian enclave of German culture, as particularly rich as it was spatially delimited; in particular, we may mention the *Kreis* of Erich Kahler (1885–1970) [Frank, 2012; Corngold, 2022]. Among the distinguished names that can be included in the circle of friends around Kahler⁷ and his wife Alice, we can list Albert Einstein, Thomas Mann, Ernst Kantorowicz, Erwin Panofsky, Kurt Gödel, Hermann Broch, Hermann Weyl, Wolfgang Pauli – a good number of which Wheeler knew personally.

As George Steiner portrayed him in a tribute, Kahler «was at Rilke's side in Munich when the first world war was ending; Einstein was to be a frequent guest; without Kahler's guardian presence, Hermann Broch would, most likely, not have written *The Death of Virgil*. In short, his life is not only rich in itself, but is at work in the genius of others. To read his books, to hear him teach, is to be in immediate reach of that lineage of humanistic hope which extends from Erasmus to Goethe. Underlying the manifold of

⁶ For some glimpse of insight into Weyl's reactions to the Atomic Age, see Sieroka, 2020, p. 113. See also Sieroka, 2010, p. 161 for some remark about those of Fritz Medicus, Weyl's philosophical companion in Zürich before the great mathematician left for the US.

⁷ Not to be mistaken, in Wheeler's case, with the mathematician Erich Kähler!

Goethe's work, we experience the conviction – profoundly rational yet animate beyond reason – that certain harmonic structure initiate and energize the seeming chaos of sensible and historical life» [Steiner, 1969, p. 193]. In 1943, in the midst of the collapse of a whole world, Kahler, already in the US, published *Man the Measure: A New Approach To History*, reprinted in 1956, while in 1957 it was the turn of *The Tower and the Abyss* – the tower being that of Babel, not the ivory one [Kahler 1957; 1967 (1943)]. These two books had, among their central questions, the following: «What could be salvaged of the past? More crucially, could the concept of civilization itself be so rethought as to make less probable future crises of self-destruction? [...] The lunatic ravage of the culture in which he grew up, the pressures of loss and of exile that have marked his own life, give to Kahler's discourse its urgency and grandeur» [Steiner, 1969, p. 194]. As one may expect, in-between he also promptly commented on the Atomic Age, which however was framed within a sort of conceptual *longue durée* accompanied by a quite original perspective. Just to give a flavor with its incipit: «The appearance of the atomic bomb has not created a substantially new situation, but it has nevertheless completely changed the world. The state in which mankind finds itself today is no different from what it was before Hiroshima; it is one that long ago crept upon us unobserved. The atomic bomb has simply, at a single stroke, made it acute, perceptible to the senses, visible to all eyes. What formerly could be considered the extravagant interpretation of intellectuals, or lightly dismissed as pious warnings from podium and pulpit, has now risen up before mankind as unavoidable, menacing reality – not words, but fact. This realization is the only new element introduced by the 'Atomic Age'» [Kahler, 1946, p. 167].

The fact that Kahler published the first volume during World War II and gave that evocatively gloomy title to its 'sequel' may generate a partly misleading first impression: how the collapse of a world was reached is indeed a crucial issue to Kahler, but he was no Spengler in his tones or overtones – his narrative has a different light from the twilight of the West. His meditations are not merely backward-looking: as we may partly guess even from the quote above, his approach to history is rather to consider the vicissitudes of the human species in a unitary and organic way, examining the enduring marks they left on the human psyche. «History implies a continuity of something more than time; only if history can be seen as a one and consistent human evolution, only then has it a meaning. Otherwise it would be nothing but an incoherent mass of rising and falling powers, growing and dying peoples and individuals» [Kahler,

1967 (1943), p. 4]. *The Tower and the Abyss*, then, builds on such understanding in order to put the focus on «the transformation of the individual» – as the subtitle reads [Kahler, 1957] – that mankind was undergoing. Disruption and fragmentation on a plurality of levels were indeed taking place, but, in Kahler’s view, that was a phase of transition from the previous individual form of existence to a new supra-individual one, yet to be distinctly delineated. It would be quite suggestive to say that Wheeler tried to find his own form of supra-individual and transgenerational existence in his peculiar way of conceiving scientific activity, marked by conviviality, the dialogue with past, present and future ‘colleagues’, and the feeling of belonging to a living tradition that was flowing directly from history toward an excitingly open future. In the 1980s, besides carrying on his relentless role as animator and prompter of ideas, without any egotistical posturing, he would even try to encapsulate this view into his physics, with a special emphasis on the function of a community of observers-participants, scattered in space *and* time across the universe, not just studying it, but contributing to bringing the cosmos itself into being [Wheeler, 1990].

Of course, directly juxtaposing Kahler’s writings and these further developments of Wheeler’s ideas would be far-fetched, but, if we go back to the postwar and the 1950s, these hints are still useful to keep in mind, since, in that *milieu*, one could indeed breathe a kind of attitude toward history that was very different from the one dominating today the Anglophone *koiné*, especially in scientific areas or even history of science (which, perhaps not by chance, has so far remained blind to all these aspects of Wheeler’s thought and activities). Referring to *Man the Measure* on the occasion of Kahler’s sixtieth birthday, Thomas Mann called it «no more and no less than the novel of mankind, narrated by a poetic thinker and historical rhapsode, inspired by the deep feeling that in this gravest of human crises nothing is more urgent, nothing more vital than the knowledge of man, of his historical background and the direction of his evolution» [Frank, 2012, p. 121]: that «deep feeling» was not so remote from Wheeler’s historical pathos. Thus, even if, at least at the current state of exploration of his archives, there does not seem to have been any direct contact with Kahler’s texts, and unfortunately a list of his readings or personal books does not seem to be available, it is hard to believe that in the same Princeton no echo, however mediated, reached someone like Wheeler – curious, culturally sympathetic, attentive to history⁸.

⁸ Moreover, his wife Janette (née Latourette Hegner) had been trained as a historian.

«Zum Bild das Wort»

Wheeler, in addition to drawing ideas and anecdotes from history, as well as updating or transforming them by analogy, had a very similar attitude towards the past and its ‘untapped potential’ when it came to the use of pictures with a long tradition, which retain a powerful symbolic or rhetorical power, survive their previous contexts and get gradually charged with new meanings. This very last characterization, at this point, almost spontaneously suggests a reference that, in the beginning, would have sounded outlandish: Aby Warburg. Even in this case, it does not appear that Wheeler had any direct contact with his thought (even in the case of Panofsky, just to name one of Warburg’s associates, it is uncertain whether he had any direct familiarity with his writings, although a curious comparison between the disheveled Einstein and Dürer’s wood engravings [Wheeler, 1966, p. 9; 1968a, p. 2] may perhaps suggest so⁹). Nonetheless, there are some fascinating affinities with Warburg and we can, at least theoretically, make leverage on the latter’s ideas to highlight some peculiar features of Wheeler’s thought, mainly in terms of his relation to the past and to pictures¹⁰.

A first – and possibly not extremely deep – level is represented by Wheeler’s refunctionalization, sometimes ironic, of images from earlier centuries, such as, for example, the sibyls from Cesare Ripa’s 1603 *Iconology*, used to illustrate the inspiring «aids» of his heuristics in physics [Wheeler, 1994b, p. viii-ix]¹¹, or no

⁹ Perhaps it was actually Einstein’s own self-irony: in some 1974 handwritten notes for *Reminiscences of Einstein and Bohr* (John Archibald Wheeler Papers, American Philosophical Society Library, Philadelphia, box 80), Wheeler was marginally annotating: «Walking talking Dürer». As a merely circumstantial piece of information that we may recall here, David R. Finkelstein, who had long been interacting with Wheeler, displayed an interest for Panofsky’s celebrated work on Dürer and, much later, condensed his considerations into a curious ‘physical’ reading of the latter’s *Melencolia I* [Finkelstein, 2006]. Finkelstein was trying to link melancholy to the post-quantum mechanics situation (at least as he saw it) of knowing subjects and their separation from the world; we may add that the vibrant enthusiasm which transpires from Wheeler’s observer-participator seems instead to overcome that brooding attitude or divide.

¹⁰ As discussed elsewhere [Costa, Furlan, 2023], one can see this attempt as a way of putting in unexpected tension two authors with great dialogical potential; or as an experiment to apply to Wheeler’s case some form of analysis or considerations inspired by the *Warburg-Forschung* (undoubtedly more developed); or perhaps even as a more general suggestion about the (mediated) relevance of some of Warburg’s ideas to seemingly remote scientific fields.

¹¹ Actually, it is Wheeler who calls them «sibyls»: they were just allegories. «Sibyline» [sic] is also used elsewhere by Wheeler to convey the ambiguity, paradoxicality, openness but also depth of his bold heuristic quests: e.g. in Wheeler, 1979, p. 341, where it appears as «The Sibyline Strangenesses of the Landscape» of new physics. It may also be worth stressing that Gombrich, in the 1970s, played an important role in renewing attention to Ripa’s *Iconologia* [Laganà, 2022]. However, even

less than a phrenological diagram adapted at the end of the textbook *Gravitation* to indicate the various skills one must have ‘in one’s head’ to deal with the legacy of general relativity [Misner, Thorne, Wheeler, 1973, p. 1219]. We may also mention the tree of physics: it can be found in the draft plan of a comprehensive course Wheeler was to teach in Leiden (Fig. 2) [Wheeler, 1956a, p. 90].

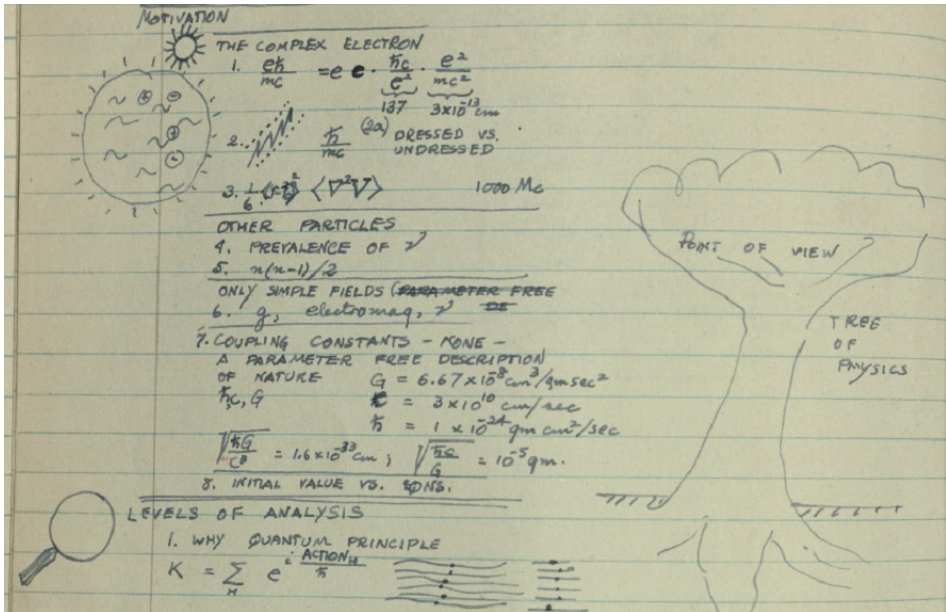


Fig. 2 - From J.A. Wheeler Papers. Copyright: American Philosophical Society Library, Philadelphia.

This is clearly an echo of the *arbor scientiarum*, but it is curious how, in the particular context of those years – the confusion deriving due to the ‘particle zoo’, the tree retains, yes, the value of a structured and in some ways hierarchical organization of knowledge, but it also appears ambiguous, with the risk of mistaking roots for branches. Out of metaphor, this misunderstanding consisted for Wheeler in considering as fundamental (as roots) many of the new particles that were being discovered, instead of considering them only as branches.

Fifteen years of intense research in geometrodynamics followed: if we now jump to the 1970s, we can see that the ideas and bold research program begun by Wheeler in the 1950s had crystallized¹², the new field of relativistic

if Wheeler already referred to the «sibyls» in the mid-1950s [Wheeler, 1956b], it was only in the anthologized version of his paper, in Wheeler, 1994b, that he resorted to Ripa’s illustrations.

¹² By this expression I do not necessarily mean that they had become commonly accepted knowledge: a number of them retained their status as conjectures or idiosyncratic suggestions. In this sense,

astrophysics was flourishing, and he, now in his sixties, was recognized as one of the top leaders also in general relativity and gravitational issues. We are all accustomed these days to cloying poses of physicists and mathematicians displaying blackboards thickly filled with symbols in the background; it is now standard iconography [te Heesen, 2019a], imitated and propagated even in a fictitious or ‘hieroglyphic’ manner on tv and whatnot. These pictures seem singularly suited to reinforce stereotypes. Now, if we instead take a look at the blackboard in Fig. 3, it is a safe bet that there is no physicist who, in the light of any standard expertise, would be able to fully illustrate its meaning, which includes Gödel, quantization, black holes and astrophysics, Leibniz’s monads. Were it not associated with Wheeler, the blackboard would be easily dismissed as the work of a madman or a ‘crackpot’¹³. If the previous picture is in black and white (as presumably was the portrayed blackboard), we should also take note of how colorful Wheeler’s blackboards could be (Fig. 4).

There is no question that even these photographs are to some extent posed, or betray, if nothing else, some awareness of being seen. Indeed, we might even say that they are pictures that are ‘watching us’: perhaps not much or not only by having some agency *à la* Bredekamp, but by means of the fact that their content breaks away from the idiosyncratic way of talking of a single scientist (such as Wheeler) and gets cloaked in a naturalistic aura. This aura is then increased by the suggestion that such pictures guard some fundamental and yet-unsolved natural enigma. ‘Quantum foam’, for instance, today is no longer just a pictorial-evocative expression of Wheeler’s conjectures or

one has to distinguish between a ‘crystallization’ resulting in notions which came to be considered standard tools and a ‘crystallization’ that just reflected Wheeler’s way of repeatedly presenting and articulating his own ideas. See Furlan, 2024a, where this distinction is discussed with reference to some considerations by P. Galison – in need of additions and clarifications – about Wheeler’s visual style. The same paper also broadens the perspective suggested by K. Hentschel in a few pages on Wheeler and the visual techniques deployed in *Gravitation* [Hentschel, 2014, p. 107-112]. It is worth adding that the by now commonplace comparison with Penrose and his diagrams, discussed also in those pages, could actually be enriched by further investigations about the graphic exchanges between Wheeler and him (and the conceptual ones, too: see some remarks in Furlan, 2020b; 2021). Anybody who has leafed through Penrose’s popular books may quite easily recognize (or at least consider as a hint) his quite peculiar shading with dots (a sort of stippling) in geometric figures – such as the one appearing in Wheeler, 1968b, p. 247, as I have also directly confirmed in conversation with Penrose himself.

¹³ Even without strictly focusing on the content, in front of a picture like that there is arguably more to be learned from Rudolf Arnheim’s work and his considerations on visualization and spatial disposition [Arnheim, 1954] than from conventional historical-philosophical texts about diagrams in physics. Also the medium itself – the blackboard – would deserve further attention. These two points will be addressed in some other publication.

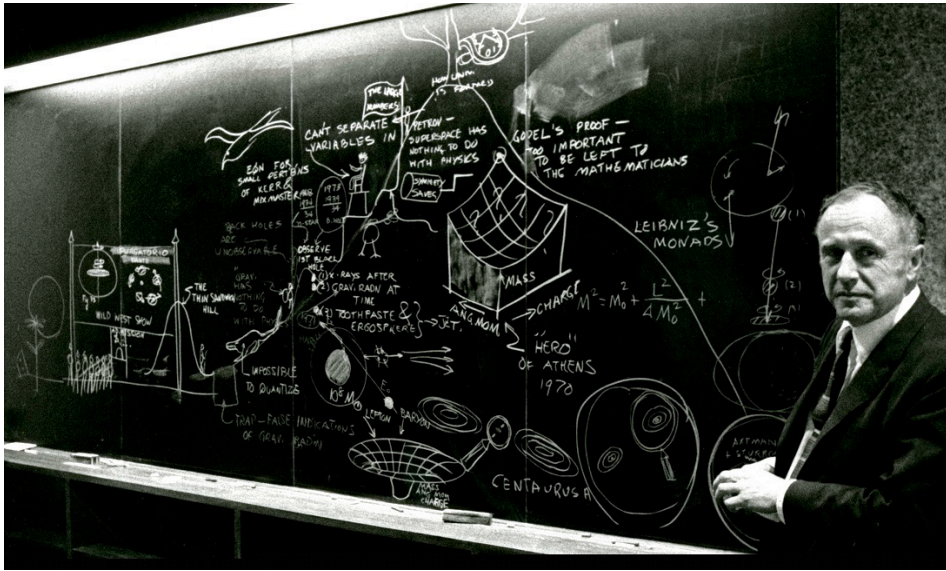


Fig.3 - John A. Wheeler, Princeton, 1970. Copyright: Johns Hopkins University Sheridan Libraries, jhu_coll-0002_14283.

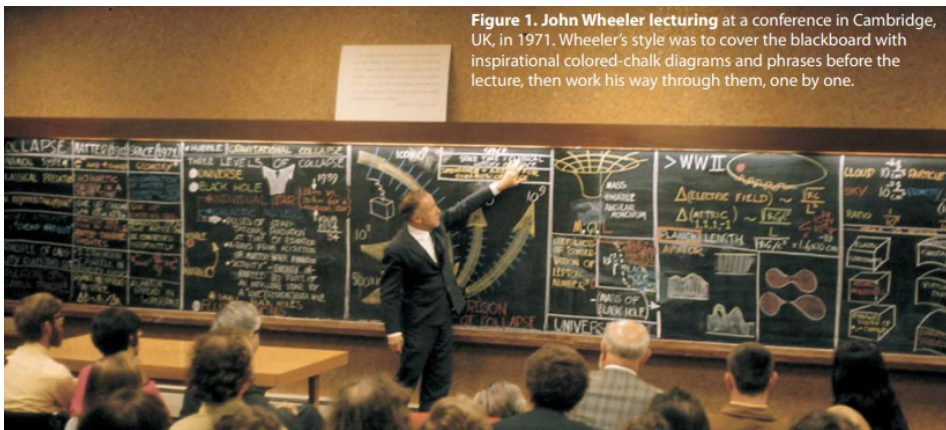


Figure 1. John Wheeler lecturing at a conference in Cambridge, UK, in 1971. Wheeler's style was to cover the blackboard with inspirational colored-chalk diagrams and phrases before the lecture, then work his way through them, one by one.

Fig. 4 - Taken from [Misner, Thorne, Zurek, 2009, p. 41]. Credit: Kip S. Thorne.

expectations about physical realms very far from experience, but has typically become something fascinating and exotic, directly conceived as being ‘out there’. The picture originally evoked by Wheeler is by now almost perceived as one of those Byzantine icons which were supposed to have descended directly from heaven and had not been made by the hand of man, the *acheiropoieta*; or at least we can say that, as often the case with painters of icons, the ‘painter’ here has faded into a kind of anonymity, after opening a supposed window onto realms hard to see. We may also be reminded of

a recent notion, proposed in very different contexts, by Andrea Pinotti: *an-icons* – that is to say, pictures which seem to deny their iconic status and hide their role as icons of something else [Pinotti, 2020]. All this, needless to say, is not entirely under the control of the originator: the way people speak of quantum foam nowadays is usually much ‘poorer’ and less phantasmagorical than Wheeler’s, who was not only thinking about quantum fluctuations of space at the smallest scales, but was dreaming of building everything out of nothing starting from such fluctuations in the vacuum [Wheeler, 1957; Blum, Furlan, 2022]. That is another reason for some serious historical-critical perspective¹⁴.

Indeed, the story of Wheeler’s dream-like imagery of foam at the smallest scales, which was of course informed by mathematical-technical aspects and constrained by them, has many strata that involve a plurality of Wheeler’s activities and interests, from the bubbles he had seen in pictures of underwater explosions (related to his military work) to the cosmological analogies he drew from the latter [Blum, Furlan, 2022], not to omit Shakespeare’s famous lines from *The Tempest* (IV, 1) about the «stuff» of dreams [Furlan, 2024b]¹⁵. There is even a sort of ‘eschatological’ dimension to it: «As surely as we now know how tangible water forms out of invisible vapor, so surely we shall someday know how the universe comes into being. We will first understand how simple the universe is when we recognize how strange it is» [Wheeler, 1978, p. 44]. In any case, it should be clear that a historical-epistemological analysis, without simplistic back-projections, is particularly important, given the peculiar situation of recent decades: (some of) the frontiers of theoretical physics are extremely speculative and in lack of empirical support, a few vague and evocative expectations are widely shared,

¹⁴ Even Wheeler, at some level, must have been aware of that and, in general, of some ‘affinity’ between the historicity of pictures and the historicity of science. It is known, after all, that also Thomas Kuhn [Kuhn, 1977, p. 340–341] spoke of Ernst Gombrich’s work as «a source of great encouragement». More or less in the same years, Wheeler too came in contact with Gombrich’s books: see e.g. the illustration in Wheeler, 1979, p. 358, taken from *Art and Illusion* and used to express the idea that what we call ‘reality’ is rather a *papier mâché* of iron posts of observation linked by theory (Wheeler’s Bohrian emphasis on paradoxes may have been another stimulus to look into that book). In 1979 Gombrich and Wheeler even met at a symposium in Kronberg [Medawar, Shelley, 1980]. Regarding some aspects of Gombrich’s legacy and scientific pictures, another far more recent reference is Skulberg, Sparre, 2023.

¹⁵ The notion of *rêverie* suffused in Bachelard’s work may not be irrelevant here. More prosaically, we may also comment that it is not surprising to discover that, in the 1970s, Wheeler taught a course called *Physics for poets* at Princeton (see e.g. John Archibald Wheeler Papers, American Philosophical Society Library, Philadelphia, folder Nold Chip, box 203).

research questions are framed in a certain way rather than in another, but who and how shaped them like that has been forgotten, while the spell persists – perhaps leading to some fruitful result, perhaps just enchanting with a mirage¹⁶. Wheeler’s communicative style and its impact – for better or worse – on the way the extreme frontiers of physics have been popularized and sensationalized in recent decades represent a topic that certainly deserves attention.

Visual exhibitions

There is no doubt that Wheeler was making operations such as the above on purpose, not out of ‘sloppiness’. Let us consider the following picture (Fig. 5), for instance, taken from a long paper [Wheeler, 1968b] which in several respects is the *summa* of his quantum geometrodynamics program.

Wheeler was in the middle of illustrating his ideas about quantum foam, the quantum fluctuations of space, the formation of wormholes and the whole tower of physics he was hoping to build upon all that, and suddenly showed this photo. He surely specified that one had to look at it «symbolically», but there was still no relation between a microscopic image of matter and what is supposed to happen to space itself at a scale twenty orders of magnitude smaller than that! It could just provide a tool of visualization or of persuasion, clearly: if we examine it today, it would be simply ridiculous and patronizing to frame it as a logical fallacy. This is an obvious example of visual rhetoric, as well as one of the many analogies that, at different levels (mathematical, visual, linguistic), Wheeler used to draw [Furlan, Gaudenzi, 2022]; but it is also interesting to compare it with the technique of *montage*. In this case, in a sense, the *montage* is only implicit, since there is no picture other than the microscopic view of matter which gets juxtaposed to it: the other picture (quantum foam) is actually evoked by the text in the nearby pages (perhaps we could then call it an *intermedial montage*). Looking at the structure of Wheeler’s papers from the 1970s on with this key of interpretation would easily highlight the strict and indissoluble intertwining between his rhetorical strategies and his heuristic suggestions, as if he were opening his workshop

¹⁶ This is indeed one of the core topics of the author’s Ph.D. dissertation, *Uprooting the Tree of Physics: John Wheeler Between Black Holes and ‘It from Bit’* (Université de Genève, 2024).

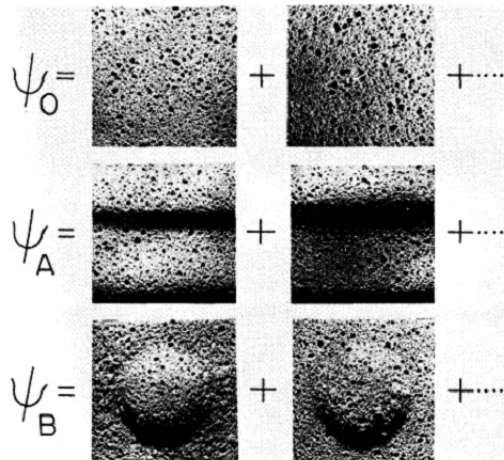


FIGURE 5. Symbolic representations of three alternative probability functions $\psi^{(3)\mathcal{G}}$. Above, ψ_0 , normal fluctuations alone; middle, ψ_A , macroscopic classical gravitational wave plus superposed fluctuations; below, ψ_B , localized excitation plus superposed fluctuations. The complex number ψ gives the probability amplitude for the occurrence of the 3-geometry ${}^{(3)\mathcal{G}}$. Those 3-geometries that contribute most to the totalized probability are highly multiply connected at the scale of the Planck length ("foamlike structure of space in the small").

Fig. 5 - Taken from Wheeler, 1968b, p. 265.

in front of everyone, instead of publishing clear-cut results. Then, let us try to make that reference to *montage* more precise, or at least to underline other features – resonant with Warburg’s – that could provide some insight.

In a late interview [Wheeler, 1994a], Wheeler played with the idea of an exhibit about images of creation from the Middle Ages and the Renaissance¹⁷: if we apply the same suggestion to his own work between the 1950s and the 1980s, it is not too far-fetched to claim that, in his ‘mental museum’, he had many such pictures of creation, largely conjured up by Wheeler himself. Some of them did find their way to even broader forms of scientific popularization, but they were first scattered by his papers, which in his last decades may resemble a *Wunderkammer*¹⁸ – but the emphatic display of variety

¹⁷ We may add that, in June 2004, during the artistic celebration called ‘The Big Nothing’ in Philadelphia, some artists at Tyler School of Art (Temple University) dedicated their show to Wheeler’s work, drawing upon the archival material he had donated to the American Philosophical Society Library (in Philadelphia as well). The name they chose was ‘Mixmaster Universe’, even if the expression actually refers to part of the work of Wheeler’s former student and collaborator Charles W. Misner [Halpern, 2017].

¹⁸ Quite exemplary in this regard are the following three papers, each one in a sense summarizing – with fireworks! – a decade of research and speculation, as well as trying to open new horizons for the future: [Wheeler, 1971b; 1979; 1990]. Needless to say, they left many readers or listeners baffled or puzzled: one of them, the renowned astronomer Jan Oort, after hearing a version of the first of

and bizarreness always goes with the strive for a deep underlying unification. The aspiration towards a Sistine Chapel-like diagram for all of physics, or the all-pervasive and almost dream-like quantum foam, a cyclic cosmology similar to an underwater explosion, the folding of space in gravitational collapse and its reverse process¹⁹, the participatory universe²⁰, an updated monadology, the alleged Chinese (Taoist) resonances of his *Physics and Austerity* program, ‘it from bit’²¹: these are just some of the ‘pictures of creation’ that Wheeler conceived and that, after they were disseminated in a sort of ‘explosion’ of his mental museum, have quite frequently become part – in varying degree and with some metamorphosis – of suggestive evocations at the frontiers of theoretical physics.

Not only do these mental ‘pictures’ mirror well-defined periods and interests of Wheeler’s long life and career, thus calling for a contextualization and a diachronic perspective, but also represent options that he occasionally pursued in parallel and that are at least in tension, when not mutually exclusive. Echoing Bohr, Wheeler used to recall over and over the need for paradoxes and clashes of concepts in order to have creative progress²². This also applies to individual papers of his late period, if we try to visualize the *tableau* of such a *montage* of ideas, so to speak. Obviously, we are not talking here about the directly visual aspects of Wheeler’s papers, as much as they can be quite richly illustrated: in that respect, they do not look like a panel of Warburg’s Atlas at all (even if one may very well think of arranging a Wheelerian exhibition like that). The focus is rather on the disposition of Wheeler’s ideas in the conceptual space outlined by these papers, in which his suggestions are partly juxtaposed, partly put in tension, partly concatenated – they are definitely not in a single chain of analytic deductions²³. In an operation similar to when, in crystallography, we

the papers above, expressed his concerns about Wheeler’s mental health to Wheeler’s wife [Furlan, 2020b].

¹⁹ This actually got ‘condensed’ in diagrams, more precisely the ‘embedding diagrams’ first devised by D. Beckedorff and Misner in 1962. For their crucial role in Wheeler’s struggle with the physics of gravitational collapse and black holes, see Furlan, 2022.

²⁰ This too actually received an ostensible picture, the quite famous capital U (U for Universe) with an eye on one of the two tops looking ‘back’ at the other [Wheeler, 1978, p. 23], like the observer who looks back into the past of the universe in a kind of autopoietic circle or, in Wheeler’s words, «a self-excited circuit».

²¹ The reconstruction and contextualization of all these ideas is not concluded yet, but the essential guidelines can be found in Furlan, 2020b; Blum, Furlan, 2022.

²² See e.g. Wheeler, 1979, p. 341.

²³ One has just to take a look again at the blackboard in (Fig. 3): it is a disposition of concepts, not a physical calculation or a series of passages in the demonstration of a theorem.

consider the reciprocal of a lattice (shifting the focus, as it were, from vertices to interstices), we must focus on the ‘intermediate spaces’ left by Wheeler and realize that they are not, trivially, a series of mistakes: the gap in-between is not a mere *non sequitur* or a formal/logical lacuna. That *Zwischenraum* is the conceptual space in which those ideas (and what they entail) are free to clash, produce transformations, or provide a field of tensions that we can try to navigate during our heuristic explorations. It is important to remark that, once again in the wake of Bohr’s example, Wheeler used to consider his suggestions as questioning, not as apodictic claims, as much as their popularization may also have the effect, as already mentioned, of turning them into some ‘oracle’ of science²⁴. In other words, Wheeler’s ‘pictures’ (in a proper sense or even as verbal evocations) must be kept in motion and in the process of clashing²⁵: in this sense, my use of the term *Zwischenraum* actually intends to mirror the role of the space between pictures in Warburg’s Atlas, always open to a new rearrangement or metamorphosis of those same pictures [Costa, 2019; 2020; te Heesen, 2019b]. In short: Wheeler is often thinking *in* (not just ‘with the aid of’) pictures, which have their own story and are subject to further metamorphoses, and his way of dealing with them is quite similar to Warburg’s attempt, in his last years, at a visual epistemology: *zum Bild das Wort* [Costa, Furlan, 2023].

Thinking in images

After what we have been saying, it would be misleading, when examining Wheeler’s pictures and their links to his physics, to assume just an illustrative-pedagogical point of view, dealing with already formulated and systematized notions. We must not forget that these suggestions concerned a research still *in fieri*, with highly speculative aspects, and that, in any case, all this visual feast required preparation: Wheeler preparing the blackboards before his lec-

²⁴ Speaking of Bohr, there is an intriguing association, at least visually, that we can make between Warburg’s panels and a couple of photographs found in Wheeler’s archives (John Archibald Wheeler Papers, American Philosophical Society Library, Philadelphia, folder Bohr #2, box 165). Their subject is a display of papers, (open) books, and pictures of Bohr, under an inscription with his name and years of birth and death (the two photographs are thus related to some celebratory event after 1962); on the back, there are Wheeler’s annotations of the various titles and the mark of the Los Alamos Photo Laboratory. For sure Wheeler, often going back to Bohr’s work in search of inspiration or analogies, kept those papers in motion!

²⁵ This is a quite different meaning that we can thus give to the term ‘iconoclash’, once made famous by Latour, 2002.

tures, carefully and with many colors, and, even before that, unearthing the right image, the proper metaphor, the effective expression – operations he did first and foremost for his own understanding, often in areas little or not at all explored («If I can't make a picture, I don't understand» [Wheeler, 1994a]). At this point, it should be clear that what I am emphasizing is rather different from the 'visualization' that is often talked about among recent historians of science. The images that constellate a heuristic path such as Wheeler's should not appear as inert products of widely shared practices or static material residues, *exuviae*, but be recognized as 'charged' poles of reasoning, indications that push in one direction instead of another, footholds for the reconstruction, and so on. They are not mere scientific diagrams, providing quantitative information: the pragmatics implied by Wheeler's graphic condensation of ideas is different, in that they do not ask the viewer to apply some standard expertise. They are not ancillary illustrations, but, indeed, as we have just said, symbolic diagrams that impress one's memory and generate thought: *imagines agentes*. Assuming this genuinely heuristic viewpoint, then, one can also better grasp the Warburgian nod present in the title of this contribution, namely *Mnemosyne*. The allusion is clearly to Memory, the Mother of the Muses, that is of the arts and sciences, as reflected in the Wheelerian way of relating to the past: a creative, productive memory²⁶. But there is also a sub-

²⁶ The above-mentioned crystallization (never definitive, never abruptly abandoned) of Wheeler's ideas makes also clear how his speeches and papers showcase a series of recurring *loci*, not entirely unlike a Brunian form of mnemotechnics. The reference to Giordano Bruno is not entirely arbitrary (even if Wheeler mentions him only in other respects), nor merely exemplary: the use of pictures in order to actually think, as well as the active and productive character of Bruno's arts of memory (not just a conservative memory), *do* resonate with Wheeler's own visual style and his indissoluble intertwining of rhetoric, heuristics, and personal experience (and not by chance Warburg was struck by Giordano Bruno as a visual thinker [Ghelardi, Targia, 2008; Johnson, 2012, p. 194-ff.]). A further affinity could be detected in the 'ascending' character that Warburg ascribed to Bruno and in Wheeler's notion of the «seekers of the larger view» [Furlan, 2024a] (or in other iconic moments such as the «staircase of physics» [Wheeler, 1975, p. 282]), but it would lead us far away from our considerations about memory and its recurring *loci*. In any case, if these may just be taken as intriguing suggestions, we can also apply some less unconventional tool to the frequently repeated elements of Wheeler's narrations and visualizations, drawing inspiration from studies such as Gruber, 1974 or Tweney, 1991. What Gruber calls the «network of enterprise» of Darwin's notebooks (an example that Wheeler certainly had in mind, as witnessed by many references to him scattered in the papers from the 1970s on), or in those of Michael Faraday, is quite close to the consistent set of Wheelerian evocations and pictures we have been talking about. The latter represent, altogether, Wheeler's evolving network of enterprise across decades of investigation on the mysteries of the universe – or, to use again an old metaphor (also dear to Bruno), the net that he used in his hunting for knowledge, his *venatio sapientiae*. All this sheds light not only on Wheeler's 'creative' adventure, but also on his compositional method; at a more mundane level, the fact that he was always involved in a variety of activities (overbusy, in a word) is undoubtedly a crucial factor that forced him into a kind of *ars*

tlar and perhaps more interesting aspect that Wheeler shares with Warburg, particularly the late Warburg of the *Atlas Mnemosyne*, as already suggested. Resorting to pictures represents for Wheeler an effort to *think in images*²⁷, just as his collections of pictures are evocations that *produce* thought and suggestions for the unexplored, not mere illustrations²⁸. In this sense, Wheeler's case is at odds with the kind of visualization studies alluded to earlier, but also with a certain scientific attitude which, of course not with all the wrongs, looks with suspicion on pictures (in a sort of iconophobia), but also on the words that accompany them by way of captions, and keeps them pedestrianly separate – and both words and pictures must then be kept all the more separate from 'formulae', needless to say. Here, in Wheeler's example, instead, we can clearly notice an intermedial (or transmedial) circulation (Fig. 6), or at the least interference, between the implicit iconicity of the mathematical formula, the skillful evocation through ordinary language, and the actual picture itself. «And as imagination bodies forth / the form of things unknown, the poet's pen / turns them to shapes, and gives to airy nothing / a local habitation and a name», to recall a few Shakespearean lines from *A Midsummer Night's Dream* (V, 1), quoted at the very end of *Gravitation*, right above the phrenological diagram [Misner, Thorne, Wheeler, 1973, p. 1219]. It is precisely that peculiar mixture that constitutes the highly original feature of both Wheeler's heuristic process and his communicative style (without of course suggesting that these elements are, in general, equally important or decisive).

In Wheeler's case, quite unusually for a recent physicist, it is crucial to emphasize the importance of ordinary language and its metaphorical power: *rebus apta verba*. In this regard, I would just like to point out something usually overlooked: even in its simplicity, the expression 'black hole' embodies an important and by no means obvious shift of attention that from the collapsing object – the star or whatever – redirects the focus towards the surrounding space and the way its curvature is altered; there is in a sense a conceptual leap, which from focusing on a sequence of states of 'something' imploding leads to a kind of 'hole'. Wheeler's initial resistance to the pioneering results on black holes (*ante litteram*) ended up putting him in the ideal position to grasp the

combinatoria of recurring elements (that is also what happens regularly today with the recycling of slides for talks and conferences, after all).

²⁷ See e.g. Gombrich, 1948.

²⁸ They are not simply «pretty pictures», to borrow the phrase quite often used in similar astrophysics-related debates (see e.g. Ventura, 2013).

importance of that conceptual obstacle and how the leap it required could be codified in a phrase of disarming concreteness and simplicity, ‘black hole’. Recalling Horace’s *Ars poetica*, we can even speak of a *callida iunctura* to emphasize how, thanks to the cunning juxtaposition of two entirely common words, ‘hole’ and ‘black’, a new meaning, well-on-point, is conveyed²⁹. We are evidently far from considering metaphorical expressions as a rhetorical frill or merely as a whimsical way of expressing oneself at the level of ordinary words.

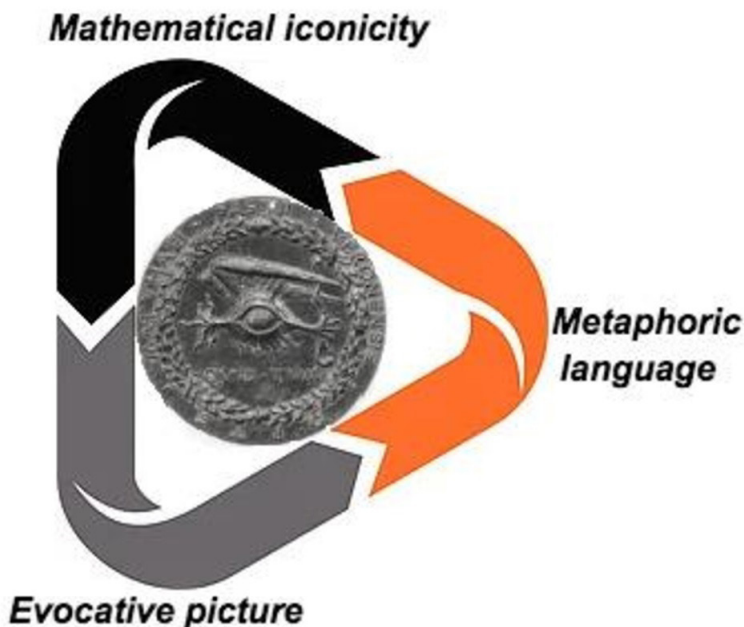


Fig. 6 - Made by the author.

²⁹ Even the story of the phrase ‘black hole’ being born when someone suggested it by shouting from the public at a conference at the end of 1967 is, in light of Wheeler’s archival material, certainly fictitious [Furlan, 2022]. The episode may have nonetheless happened and even marked the public adoption of the name, but it was already used, *with its specific meaning*, in earlier exchanges between Wheeler’s and Dicke’s groups in Princeton. Although by now it has become a dead metaphor (or an abused one), ‘black hole’, back then, nicely encapsulated, as already mentioned, the not-so-trivial shift of attention from the collapsing object to its surroundings and their geometrodynamical transformation, as discussed at length in the referenced works. This was mirrored by the change in nomenclature, from the ‘frozen stars’ of the Soviet world or Wheeler’s own ‘completely collapsed gravitational object’ to the emphasis on the ‘hole’ in space. The aspect of *callida iunctura* is also reiterated by the following simple observation: in European idioms, the phrase ‘black hole’ has been every time recreated with its corresponding very ordinary terms: *trou noir*, *gaură neagră*, *schwarzes Loch*, *bucco nero*, *μαύρη τρύπα*, *zwart gat*, *agujero negro*, *forat negre*, *чёрная дыра*, *buco negro*, and so on. The Japanese case looks like an exception, in that nobody seemed to have ventured into recreating the expression: the English sound was just ‘imported’, *burakkuhoru*. In Chinese, instead, the phrase was recreated by simply juxtaposing the character for ‘black’ and the one for ‘hole’.

In place of a conclusion: the meeting between Einstein and Warburg, and further explorations

If we go back to the early 1950s, we may find out that Wolfgang Pauli (whom we met at the very beginning) was working on an essay about Kepler and ‘archetypal’ material in his work; it was dedicated to Panofsky, whom he also thanked for discussions [Pauli, 1952]. As is well known, Pauli had quite strong ties with Jung, but his essay is not a naïve application of Jungian notions. He had been envisaging even a *Hintergrundphysik* [Pauli, 1948], which could recognize recurring ‘archetypal’ structures in the ideas of physics throughout the ages – an open project that, however, has not necessarily to be charged with more or less hypostatized archetypes in a Jungian sense³⁰. Indeed, if we just focus on pictures that enter into the physical discourse, on their metamorphoses, on their power of suggestion, as well as on their occasionally remote sources, it may be almost spontaneous to think of a Warburg-like approach. No doubt any such analysis would find fertile ground in Wheeler’s creativity, as documented by his papers and archives. Besides straightforward ‘refunctionalizations’, such as the already mentioned phrenological diagram at the end of *Gravitation*, there are more sophisticated cases: the staircase of physics [Wheeler, 1975, p. 282], for instance, can be compared with the *scala cognitionis* employed by Fludd³¹, which, in turn, comes from a long tradition going back at least to Jacob’s ladder and its interpretations [Costa, Furlan, 2023]. Wheeler’s ‘tree of physics’, as we have already seen, is another example. However, a couple of decades before Pauli wrote of a *Hintergrundphysik*, Aby Warburg himself, a little more than a year ahead of passing away, tried one move.

On September 4, 1928, Warburg met Albert Einstein for the first and only time, at the seaside resort of Scharbeutz, in the Bay of Lübeck. It was Warburg who had requested this meeting, for which he had high expectations [Bredenkamp, Wedepohl, 2015]. «Four hours of travel, four hours of conversation» – during which he showed Einstein some of the pictures of the Atlas *Mnemosyne*, where the presence of Kepler’s work immediately leaps to the eye that can recognize it. As a matter of fact, in Warburg’s view Einstein was not so much the one who dethroned Newton, but a new Kepler: a transitional figure (*Übergangstyp*) in whom an ancient background (in German, *Hintergrund*) persisted alongside

³⁰ Another whole chapter could be opened here by some compare-and-contrast with Bachelard’s attempts, for instance.

³¹ Robert Fludd was another subject of Pauli’s 1952 essay, by the way.

elements of great novelty. Kepler, by abandoning the circularity of the orbits – so entrenched in the old cosmic visions – and adopting the ellipse, which (as is well known) strongly fascinated Warburg, had initiated modernity. Einstein, similarly, with his conception of spacetime, had disclosed a new vision, which led to an *Aufhebung* (Warburg actually used the related Hegelian verb) of the previous world system. Like any *Aufhebung*, or arguably any historical process, this did not simply leave the past behind: Warburg sensed an *Urboden* or *Urgrund* still resonating in the Einsteinian vision (as in the case of Kepler) and, by showing the above mentioned series of pictures (*Bilderreihe*) to Einstein («like a schoolboy at the movies»), he was hoping to bring it to the surface.

The story of the meeting between Warburg and Einstein has been told essentially from the former's point of view. Einstein appreciated the 'exhibition' of Warburg's pictures and probed his conclusions with attentive questions, but had perplexities about the extra-physical reading of Kepler's work, nor does the exchange, overall, seem to have been symmetric. Bredekamp and Wedepohl [2015] suggest that, if we consider a 1930 article on the genesis of Kepler's ideas that was printed in the *Frankfurter Zeitung* under the title of *Albert Einstein über Kepler*, and the related drawing of elliptic orbits that appears only in the draft of the article, we can find trace of some sort of delayed and partly appreciative reply to Warburg's attempt at dialogue: after all, Einstein too presented Kepler in the light of a kind of bipolarity (two *foci*, like an ellipse) between the empirical researcher and the imaginative speculator. Maybe. Nonetheless, if we imagine who could have reacted more receptively and in tune with Warburg's ideas (or better: with his approach and use of pictures), even if some years later, Wheeler's name should now come up quite easily. Not only for the 'theoretical' reasons we have discussed in this paper, but also for the role that Warburg had assigned to Einstein: Wheeler – his creative continuator – represented in turn an *Übergangstyp*e, a living mediator between the generations of the founding figures of 20th-century physics and the age of 'it from bit'. With his own daring conservatism, Wheeler, like a two-faced Janus, was looking at the past for inspiration but also far into the future, evolving powerful guiding views. When he turned to geometrodynamics – *ubi materia, ibi geometria*³² –, he was also playing in a Keplerian fashion with correspondences between the microcosm and the macrocosm: his problem was no longer to link regular solids and planetary distanc-

³² Wheeler himself, in the first footnote of what substantially is his last synthesis [Wheeler, 1990], quotes this Keplerian motto and mentions [Pauli, 1952] as well.

es, but topological features and fundamental constants (or some of their ratios) [Blum, Furlan, 2022], in search of the central *mysterium cosmographicum*. Even quantum foam, in Wheeler's ambitions, can be seen as one such correspondence: it was not only conceived as a feature of space at the smallest scales: once gravitational collapse, tying together the large and the small, makes the universe itself undergoing collapse, quantum foam will take over. The fluctuations out of which he was trying to build everything were also the foam in which everything would ultimately pass away. If this was Wheeler's phantasmagoria during the 1960s, from the 1970s on this omnipervasive character of quantum foam and its fluctuations mutated into 'law without law' [Wheeler, 1978] – a new vision of the universe in which, to put it roughly, physical laws are not metaphysically granted from everlasting to everlasting, but rather emerge out of statistical regularities. This attempt alone is highly interesting from the point of view of the *Urgrund* Warburg was hoping to make explicit in Einstein, as if physics were undergoing another *Aufhebung*, taking another step³³. And, in any case, it may be worth noticing that Wheeler too had clearly a certain fondness for Kepler, beyond the conventional tribute to his discoveries and beyond any scientific *pruderie* – one has just to take a look at the Keplerian quotes in the compendium of Wheeler's two decades of geometrodynamical research: *Gravitation*, once again [Misner, Thorne, Wheeler, 1973, *passim*]³⁴. An examination of his archives reveals Kepler as a recurring presence even in the last period³⁵.

Beyond what we have emphasized, there would be other curious resonances to mention between Wheeler and Warburg (such as the distinctly transdisciplinary linguistic borrowings; the unhinging of 'conventional' historical narratives to reorganize knowledge and its memory³⁶; the attention to different 'forms',

³³ It is indeed the last step in Wheeler's aforesaid staircase of physics!

³⁴ It is worth underscoring how all these 'unconventional' outcrops can be found in a widespread and successful physics textbook! Of course, one must be perceptive about the rest of Wheeler's *corpus* to identify their relevance and then use his vast archives to explore what is below the tip of the iceberg. That is not to suggest the existence of an 'esoteric' Wheeler, in the sense of some full-fledged 'doctrine' of which he left some traces only for 'initiates': it would be the opposite of the heuristic transparency which, especially in his last decades, he was not afraid to manifest. Still, in his reflections, attempts at dialogue, readings and so on, there is certainly much more than meets the eye.

³⁵ See e.g. Wheeler's Research Notebook from June 1986 to September 1987 (John Archibald Wheeler Papers, American Philosophical Library, Philadelphia, volume 74), in which, on p. 82, there is mention of a quote related to Galileo and Kepler (a frequent association in Wheeler's mind) that he had asked to Owen Gingerich. Obviously the various references to Kepler would need each time a contextualization, but, as we have commented in other cases, there is a regularity with which they return, as if the name 'Kepler' (or «Galileo + Kepler») were a signpost, a mnemonic *locus*.

³⁶ That is also a fruitful 'stretching exercise' of concepts, as Wheeler's often original viewpoints can attest. «One of the most important methods I use is to imagine a historical development for our ideas

sensitive to historical enrichment but also characterized by a deep dynamic unity; the care for recurring details usually considered marginal or neglected, but which in their hands could open up distinctly new perspectives; the use – in some ways certainly idiosyncratic – of their own library as a ‘thinking machine’ [Costa, Furlan, 2023], but this goes beyond the aims of the present paper. To conclude and summarize, three levels of intertwining between arts and sciences have thus been briefly outlined. One is internal to Wheeler’s own perspective and somehow invokes a unified historiography of sciences and arts, besides calling for (or at least promoting) a historical–epistemological perspective, for instance in order to see how pictures or visual strategies get charged with specific meanings in specific contexts. Another level is actually a sort of metalevel, since it concerns the scholar who examines Wheeler’s activities and takes note of the relevance of a graphic–artistic component, imbued in his thought processes. And then yet another level, which in a sense is a bolder version of the second and could perhaps fulfill the desire expressed by Wheeler himself, concerns the fluid and transmedial dimension with which one can try to characterize, through a comparison with Warburg, Wheeler’s heuristics and rhetoric, with that peculiar form of visual thinking that distinguishes them. In a case such as Wheeler’s, all this goes well beyond the dimension of individual creativity, precisely because of the extent to which his suggestions, expectations, questions and evocations have gradually shaped those of larger communities. Regardless of the level of consideration we choose, dealing with Wheeler’s pictures in a merely analytic, singular, static way is a misrepresentation, to say the least; thanks to a Warburgian framework, instead, we can appreciate their dynamism, in terms of both their clash and their gradual metamorphosis. That, of course, is not to deny the huge differences between the two thinkers, but, while these are obvious from the very separation of their respective fields (and typical mindsets therein, at least for now), their affinities may well be worth a ‘four-hour trip’ or a similar effort.

Acknowledgments

The author wishes to thank Maria Teresa Costa, Tullio Viola, Anke te Heesen, Rossella Lupacchini, Emilie Skulberg, Margherita Melani for val-

different from what actually occurred. If we do this we see the problem from a completely new angle» [Wittgenstein, 1980, p. 37e].

uable discussions at various stages of the manuscript. This work originated within the context of the MPIWG group “Historical Epistemology of the Final Theory Program” and was completed during a stay at the Vossius Center in Amsterdam. Gratitude is also expressed to the American Philosophical Society Library in Philadelphia for its archival resources.

References

- Anders, 1959 = Anders Günther, *Der Mann auf der Brücke: Tagebuch aus Hiroshima und Nagasaki*, München, Beck, 1959.
- Anon., 1992 = Anonymous, *UIPPA-IUPAP 1922–1992. Album souvenir realized in Québec by the IUPAP Secretariat*, 1992, <<https://archive2.iupap.org/wp-content/uploads/2013/04/history.pdf>>
- Arnheim, 1954 = Arnheim Rudolf, *Art and Visual Perception: A Psychology of the Creative Eye*, Berkeley, University of California Press, 1954.
- Blum, Brill, 2020 = Blum Alexander S., Brill Dieter R., *Tokyo Wheeler or the Epistemic Preconditions of the Renaissance of Relativity*, in *The Renaissance of General Relativity in Context*, edited by Alexander S. Blum, Roberto Lalli, Jürgen Renn, Boston, Birkhäuser, 2020, p. 141–188.
- Blum, Furlan, 2022 = Blum Alexander S., Furlan Stefano, *How John Wheeler Lost His Faith in the Law*, in *Rethinking the Concept of Laws of Nature: Natural Order in the Light of Contemporary Science*, edited by Yemima Ben-Menahem, Berlin, Springer, 2022, p. 283–322.
- Blum, Lalli, Renn, 2016 = Blum Alexander S., Lalli Roberto, Renn Jürgen, *The Renaissance of General Relativity in Context*, «Annalen der Physik», 528 (2016), n. 5, p. 344–349.
- Blum, Lalli, Renn, 2020 = *The Renaissance of General Relativity in Context*, edited by Blum Alexander S., Lalli Roberto and Renn Jürgen, «Annalen der Physik», 528 (2020), n. 5, p. 344–349.
- Bredekamp, Wedepohl, 2015 = Bredekamp Horst, Wedepohl Claudia, *Warburg, Cassirer und Einstein im Gespräch*, Berlin, Wagenbach, 2015.
- Chargaff, 1978 = Chargaff Erwin, *Heraclitean Fire: Sketches from a Life Before Nature*, New York, The Rockefeller University Press, 1978.
- Corngold, 2022 = Corngold Stanley, *Weimar in Princeton: Thomas Mann and the Kahler Circle*, New York, Bloomsbury Academic, 2022.
- Costa, 2019 = Costa Maria Teresa, *Aby Warburg's Literal and Intermedial Self-*

- Translation*, in *Migrating Histories of Art: Self-Translation of a Discipline*, edited by Maria Teresa Costa, Hans Christian Hönes, Berlin, De Gruyter, 2019, p. 59-76.
- Costa, 2020 = Costa Maria Teresa, *Aby Warburgs Übersetzungswissenschaft*, «Links: Rivista di letteratura e cultura tedesca. Zeitschrift für deutsche Literatur- und Kulturwissenschaft», 20 (2020), p. 65-78.
- Costa, Furlan, 2023 = Costa Maria Teresa, Furlan Stefano, *Risalendo alla Fonte Castalia tra Arte, Storia e Scienza: Aby Warburg e John Wheeler*, in *Ad Limina. Frontiere e Contaminazioni Transdisciplinari nella Storia delle Scienze*, a cura di Elena Canadelli et alii, Milano, Editrice Bibliografica, 2023, p. 141-151.
- Finkelstein, 2006 = Finkelstein David R., *Melencolia I: The Physics of Albrecht Dürer*, 2006, <<https://arxiv.org/abs/physics/0602185v1>>.
- Frank, 2012 = Frank Joseph, *Erich Kahler and the Quest for a Human Absolute*, in Frank Joseph, *Responses to Modernity: Essays in the Politics of Culture*, New York, Fordham University Press, 2012, p. 120-135.
- Furlan, 2020a = Furlan Stefano, *Einstein's Mantle, Bohr's Shadow: Glimpses from Wheeler's Relativity Notebook III*, in *Proceedings of the 39th SISFA Conference*, Pisa, Pisa University Press, 2020, p. 221-227.
- Furlan, 2020b = Furlan Stefano, *Merging Labyrinths: Leibniz in J.A. Wheeler's Quest*, «Studia Leibnitiana», 52 (2020), p. 123-155.
- Furlan, 2021 = Furlan Stefano, *John Wheeler Between Cold Matter and Frozen Stars: The Road Towards Black Holes*. Berlin, Max-Planck-Institut für Wissenschaftsgeschichte, 2021.
- Furlan, 2022 = Furlan Stefano, *Pursuitworthiness Between Daring Conservatism and Procrastination: Wheeler and the Path Towards Black Holes*, «Studies in History and Philosophy of Science», 96 (2022), p. 174-185.
- Furlan, 2024a = Furlan Stefano, *Aesthetics of Visionaries and Engineering: John Wheeler between Black Holes and 'It from Bit'*, forthcoming in «Physis», 2024.
- Furlan, 2024b = Furlan Stefano, *Down the Maelström: John A. Wheeler between Cosmic Imagery and the Roots of Quantum Gravity*, forthcoming, 2024.
- Furlan, Gaudenzi, 2022 = Furlan Stefano, Gaudenzi Rocco, *The Earth Vibrates with Analogies: The Dirac Sea and the Geology of the Vacuum*, «Studies in History and Philosophy of Science», 93 (2022), p. 163-174.
- Gherardi, Targia, 2008 = Ghelardi Maurizio, Targia Giovanna, *Nachlass ABY WARBURG. Giordano Bruno*, «Cassirer Studies», 1 (2008), p. 13-58.
- Gombrich, 1948 = Gombrich Ernst H., *Icones Symbolicae: The Visual Image in Neo-Platonic Thought*, «Journal of the Warburg and Courtauld Institutes», 11 (1948), p. 163-192.

- Gruber, 1974 = Gruber Howard E., *Darwin on Man: A Psychological Study of Scientific Creativity*, New York, E.P. Dutton, 1974.
- Halpern, 2017 = Halpern Paul, *The Quantum Labyrinth: How Richard Feynman and John Wheeler Revolutionized Time and Reality*, New York, Basic Books, 2017.
- Hentschel, 2014 = Hentschel Klaus, *Visual Cultures in Science and Technology: A Comparative History*, Oxford, Oxford University Press, 2014.
- Iber, 2015 = Iber Patrick, *Literary Magazines for Socialists Funded by the CIA, Ranked*, 2015, <<https://www.theawl.com/2015/08/literary-magazines-for-socialists-funded-by-the-cia-ranked/>>.
- Jaspers, 1958 = Jaspers Karl, *Die Atombombe und die Zukunft des Menschen*, München, Piper & Co Verlag, 1958.
- Johnson, 2012 = Johnson Christopher D., *Memory, Metaphor, and Aby Warburg's Atlas of Images*, Ithaca NY, Cornell University Press, 2012.
- Kahler, 1946 = Kahler Erich, *The Reality of Utopia*, «The American Scholar», 15 (1946), n. 2, p. 167-179.
- Kahler, 1957 = Kahler Erich, *The Tower and the Abyss: An Inquiry into the Transformation of the Individual*, New York, Braziller, 1957.
- Kahler, 1967 = Kahler Erich, *Man The Measure: A New Approach To History*, Cleveland, The World Publishing Company, 1967 [1943].
- Kaiser, 2002 = Kaiser David I., *Scientific Manpower, Cold War Requisitions, and the Production of American Physicists after World War II*, «Historical Studies in the Physical and Biological Sciences», 33 (2002), p. 131-159.
- Kuhn, 1977 = Kuhn Thomas S., *The Essential Tension*, Chicago, University of Chicago Press, 1977.
- Laganà, 2022 = Laganà Annalisa, *Ernst H. Gombrich e il recupero dell'Iconologia di Cesare Ripa negli anni Settanta del Novecento: alcune congiunture*, «Fontes: rivista di iconografia e storia della critica d'arte», 3 (2022), p. 181-195.
- Landauer, 2000 = Landauer Carl, *Deliberating Speed: Totalitarian Anxieties and Postwar Legal Thought*, «Yale Journal of Law & the Humanities», 12 (2000), p. 171-248.
- Latour, 2002 = Latour Bruno, *What is Iconoclasm? or Is there a world beyond the image wars?*, in *Iconoclasm, Beyond the Image-Wars in Science, Religion and Art*, edited by Bruno Latour, Peter Weibel, Cambridge MA, MIT Press, 2002, p. 14-37.
- Lavin, 2019 = Lavin Irving, *American Panofsky*, in *Migrating Histories of Art: Self-Translation of a Discipline*, edited by Maria Teresa Costa, Hans Christian Hönes, Berlin, De Gruyter, 2019, p. 91-97.

- Lipking, 2014 = Lipking Lawrence, *What Galileo Saw: Imagining the Scientific Revolution*, Ithaca NY, Cornell University Press, 2014.
- Masters, Way, 1946 = Masters Dexter, Way Katharine, *One World or None: A Report to the Public on the Full Meaning of the Atomic Bomb*, New York Whittlesey House, McGraw-Hill, 1946.
- Medawar, Shelley, 1980 = *Structure in Science and Art*, edited by Peter Medawar and Julian Shelley, Amsterdam, Excerpta Medica, 1980.
- Misner, Wheeler, 1957 = Misner Charles W., Wheeler John A., *Classical Physics as Geometry*, «Annals of Physics», 2 (1957), n. 6, p. 525-603.
- Misner, Thorne, Wheeler, 1973 = Misner Charles W., Thorne Kip S., Wheeler John A., *Gravitation*, San Francisco, W.H. Freeman, 1973.
- Misner, Thorne, Zurek, 2009 = Misner Charles W., Thorne Kip S., Zurek Wojciech H., *John Wheeler, Relativity, and Quantum Information*, «Physics Today», 62 (2009), p. 40-46.
- Panofsky, 1957 = Panofsky Erwin, *In Defense of the Ivory Tower*, «The Centennial Review of Arts & Science», 1 (1957), n. 2, p. 111-122.
- Panofsky, 1974 = Panofsky Erwin, *Meaning in the Visual Arts*, New York, The Overlook Press, 1974.
- Panofsky, 2006 = Panofsky Wolfgang, *Interview by M. Schaaf and H. Spitzer, 6 July 2006*, in *Zur Verleihung der Ehrensensatorwürde der Universität Hamburg an Prof.Dr.Dr.h.c.mult. Wolfgang K.H. Panofsky am 6. Juli 2006*, Hamburg, Hamburg University Press, 2006, p. 41-79.
- Pauli, 1992 = Pauli Wolfgang, *Moderne Beispiele zur 'Hintergrundphysik' [1948]*, in Pauli Wolfgang, Jung Carl G., *Ein Briefwechsel, 1932-1958*, edited by C.A. Meier, C.P. Enz, M. Fierz, Berlin, Springer, 1992, p. 176-192.
- Pauli, 1952 = Pauli Wolfgang, *Der Einfluss archetypischer Vorstellungen auf die Bildung naturwissenschaftlicher Theorien bei Kepler*, in Jung Carl G., Pauli Wolfgang, *Naturerklärung und Psyche*, Zürich, Rascher, 1952, p. 109-167.
- Pinotti, 2020 = Pinotti Andrea, *Towards An-Iconology: The Image as Environment*, «Screen», 61 (2020), n. 4, p. 594-603.
- Serres, 1992 = Serres Michel, *Éclaircissements. Cinq entretiens avec Bruno Latour*, Paris, Editions François Bourin, 1992.
- Sieroka, 2010 = Sieroka Norman, *Umgebungen: Symbolischer Konstruktivismus im Anschluss an Hermann Weyl und Fritz Medicus*, Zürich, Chronos, 2010.
- Sieroka, 2020 = Sieroka Norman, *Unities of Knowledge and Being – Weyl's*

- Late “Existentialism” and Heideggerian Phenomenology, in *Phenomenological Approaches to Physics*, edited by H.A. Wiltsche, P. Berghofer, Berlin, Springer, 2020, p. 107-122.
- Skulberg, Sparre, 2023 = Skulberg Emilie, Sparre Martin, *A Black Hole in Ink. Jean-Pierre Luminet and ‘Realistic’ Black Hole Imaging*, «Historical Studies in the Natural Sciences», 53 (2023), n. 4, p. 389-424.
- Steiner, 1969 = Steiner George, *A Note In Tribute To Erich Kahler*, «Salmagundi», 10 (1969), p. 193-195.
- te Heesen, 2019a = te Heesen Anke, *‘The Way of the Scientist.’ Ikonografie der Unmittelbarkeit*, in *Gesichter der Wissenschaft. Repräsentanz und Performanz von Gelehrten in Porträts*, edited by Christian Vogel, Sonja E. Bökel, Göttingen, Wallstein Verlag, 2019, p. 161-178.
- te Heesen, 2019b = te Heesen Anke, *Exposition Imaginaire. On Aby Warburg’s Use of Display Panels*, in *Image Journeys: The Warburg Institute and a British Art History*, edited by Joanne W. Anderson, Mick Finch, Johannes von Müller, Passau, Dietmar Klinger Verlag, 2019, p. 13-28.
- te Heesen, 2020 = te Heesen Anke, *Thomas S. Kuhn, Earwitness: Interviewing and the Making of a New History of Science*, «Isis», 111 (2020), n. 1, p. 86-97.
- Tweney, 1991 = Tweney Ryan D., *Faraday’s Notebooks: The Active Organization of Creative Science*, «Physics Education», 26 (1991), p. 301-306.
- van Dongen Jeroen, 2020 = van Dongen Jeroen, *In Europe*, «Physics in Perspective», 22 (2020), n. 1, p. 3-25.
- Ventura, 2013 = Ventura Anya, *“Pretty Pictures”: The Use of False Color in Images of Deep Space*, «InVisible Culture: An Electronic Journal for Visual Culture», 19 (2013), <<https://ivc.lib.rochester.edu/pretty-pictures-the-use-of-false-color-in-images-of-deep-space/>>
- Wheeler, 1956a = Wheeler John A., *Relativity Notebook IV*, archival material in *J.A. Wheeler Papers*, Philadelphia, American Philosophical Society, 1956.
- Wheeler, 1956b = Wheeler John A., *A Septet of Sibyls: Aids in the Search for Truth*, «American Scientist», 44 (1956), p. 360-377.
- Wheeler, 1957 = Wheeler John A., *On the Nature of Quantum Geometrodynamics*, «Annals of Physics», 2 (1957), n. 6, p. 604-614.
- Wheeler, 1962 = Wheeler John A., *El Adelanto de la Ingeniería y la Configuración de Nuestro Futuro*, «El Farol», 200 (1962), p. 23-48.
- Wheeler, 1963 = Wheeler John A., *A Few Links in the Charismatic Chain*, in *Proceedings of the First Eastern Conference on Theoretical Physics*, edited by M.E. Rose, New York, Gordon and Breach, 1963.

- Wheeler, 1966 = Wheeler John A., *Quality of Collegueship - Central Theme of a University*, «Princeton Alumni Weekly», 66 (1966), p. 8-9.
- Wheeler, 1968a = Wheeler John A., *Einsteins Vision*, Heidelberg, Springer, 1968.
- Wheeler, 1968b = Wheeler John A., *Superspace and the Nature of Quantum Geometrodynamics*, in *Battelle Rencontres, 1967 Lectures in Mathematics and Physics*, edited by Cécile DeWitt-Morette, John A. Wheeler, New York, W.A. Benjamin, 1968, p. 242-307.
- Wheeler, 1971a = Wheeler John A., *Sources for History of Quantum Physics*. Preface, 1971, <<https://www.amphilsoc.org/guides/ahqp/>>.
- Wheeler, 1971b = Wheeler John A., *From Mendeleev's Atom to the Collapsing Star*, in *Atti del Convegno Mendeleeviano 1969*, edited by Mario Verde, Torino, Accademia delle Scienze, 1971, p. 189-233.
- Wheeler, 1975 = Wheeler John A., *The Universe as Home for Man*, in *The Nature of Scientific Discovery*, edited by Owen Gingerich, Washington DC, Smithsonian Institution Press, 1975, p. 261-296.
- Wheeler, 1978 = Wheeler John A., *Frontiers of Time*, Center for Theoretical Physics, Austin, 1978.
- Wheeler, 1979 = Wheeler John A., *Beyond the Black Hole*, in *Some Strangeness in the Proportion: A Centennial Symposium to Celebrate the Achievements of Albert Einstein*, edited by Harry Woolf, Boston, Addison-Wesley, 1979, p. 341-375.
- Wheeler, 1980 = Wheeler John A., *Albert Einstein 1879-1955 A Biographical Memoir*, Washington DC, National Academy of Sciences, 1980.
- Wheeler, 1984 = Wheeler John A., *Ideas*, in *Proceedings of the Annual Meeting at Houston, December 7 and 8, 1984*, Austin, The Philosophical Society of Texas, 1985, p. 11-18.
- Wheeler, 1986 = Wheeler John A. *Hermann Weyl and the Unity of Knowledge*, «American Scientist», 74 (1986), n. 4, p. 366-375.
- Wheeler, 1990 = Wheeler John A., *Information, Physics, Quantum: The Search for Links*, in *Proceedings of the 3rd International Symposium Foundations of Quantum Mechanics in the Light of New Technology*, edited by Shun-ichi Kobayashi et alii, Tokyo, The Physical Society of Japan, 1990, p. 310-336.
- Wheeler, 1994a = Wheeler John A., *Interview by K.W. Ford, 3 January 1994*, 1994, <<https://www.aip.org/history-programs/niels-bohr-library/oral-histories/5908-3>>
- Wheeler, 1994b = Wheeler John A., *At Home in the Universe*, College Park, American Institute of Physics, 1994.

Wigner, 1990 = Wigner Eugene P., *I was Einstein's Younger Friend*, in *Ein Haus für Albert Einstein – Erinnerungen, Briefe, Dokumente*, edited by Michael Grüning, Berlin, Verlag der Nation, 1990, p. 529.

Wind, 1963 = Wind Edgar, *Art and Anarchy*, Evanston, Northwestern University Press, 1985 [1963].

Wittgenstein, 1980 = Wittgenstein Ludwig, *Vermischte Bemerkungen*, Oxford, Blackwell, 1980.

