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Editorial

From history of physics to "history for physics"

Introduction to the EPJ H special issue on "History for Physics: Contextualizing modern developments in the foundations of quantum theory"

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On history of physics

All human activity has a history. This can be understood in the straightforward sense that there exists a past in which things were and happened differently and which can be studied for its own intrinsic value. In addition, we can take the position that our past has conditioned our present in various ways and that the traces we can still find of that past therefore hold valuable keys to a better understanding of our present activities. If we further assume that physics is not just the current state of our physical theories, but is itself a human activity—a social and intellectual practice that produces these theories—we can use historical analysis as an epistemological tool for a better understanding of these theories.

The study of history, especially the history of science and in particular the history of physics, can take many different forms—one of the beauties and strengths of the field. The particular approach to history we advocate here is one that we see as complementary to physical reasoning. Its epistemological focus concerns physics itself: its theories as well as its practice. For this reason, our target audience encompasses not only historians of physics but also physicists themselves.

To clarify, we consider any legitimate history of physics to be necessarily independent of any attempt at instrumentalization from within the field of physics itself. Examples of such instrumentalization include the distortion of historical narratives in order to legitimize current research programs or the presentation of supposedly historically informed scientific views. Another example is the overemphasis on the contributions of certain individuals (or groups) to the effect of erasing others. Additionally, determining what counts as an interesting historical question should, of course, not be dictated by current trends within physics. Thus, while we see our epistemological aim as complementary to, and in some sense intertwined with, physics, the history of physics must remain an intellectually independent endeavor.

Nevertheless, we maintain that the history of physics should inherently address the implications of contemporary physics. This is because historical analyses allow for critical engagement and independent logical analysis based on factual evidence, which can be extremely useful in clarifying fundamental conceptual and programmatic issues. Unlike a philosopher, who might ask, "What ought to exist?" in a normative sense, a historian asks, "What has existed?" and "How did it develop into what it is now?" in an empirically informed sense. On this basis, we are then free to draw conclusions about how historical knowledge enhances our understanding of contemporary theories.

On a more personal level, it can be challenging to quantify the internal transformative power of discovering a previously unknown, and possibly surprising, historical origin of a theory, concept, or debate. Or, the moment of enlightenment when one realizes that a familiar concept has not always been that way, but that it has been changed by all kinds of influences over time. Or that a concept that has always seemed odd to oneself has actually been debated since it was first introduced, highlighting that concepts within science are in fact not free of human value judgements. These kinds of insights shift our perspective on what is perceived as eternally given and externally determined, and what, in turn, can be seen as historically contingent and thus open to critique and rethinking.

In this sense, the practice of history can be empowering. It can restore agency to the individual researcher within the highly specialized and formally as well as programmatically determined enterprise of contemporary physics. This is particularly true for technically informed history, where an engagement with the technical details allows for

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an even deeper understanding of the development of theories. Such an analysis can enable researchers to reclaim those theories, or aspects thereof, from their often unknown and unconscious past.

These are only some of the reasons how awareness of the history of physics can be useful. To truly appreciate the benefits of historical analysis and the depth of understanding it can bring, one needs to engage with it. And we hope that this special issue, with its unique format of "tandem papers", combining a contemporary physics problem with its historical analysis, and jointly authored by a physicist and a historian, will be received as providing rich material for that purpose.

On developing "history for physics"

The term "History for Physics" was coined by us, the guest editors of this special issue, back in 2018. At the time, we had been wondering what we could do to help polish the image of the history of physics among physicists and make it more renown at the same time. Being convinced of the essential and interdisciplinary value of history for physics, we soon thought to organize a symposium (hinting at the word's old meaning of a convivial gathering) to bring together physicists and historians of physics for mutual exchange. To foster genuine collaboration and engagement between members of these respective fields and to demonstrate the kinds of fruits this collaborative work can bear, we put central the idea of "tandem talks". From our first announcement poster[1] we quote:

> This symposium aims at demonstrating the importance of the history of physics within physics itself. To forward this agenda, the core format will be that of tandem talks. Each tandem will pair two presentations, one given by a physicist on a historically relevant research topic in quantum foundations, the other given by an historian of physics providing the historical context to that same topic.

Let us stress at this point that with the term "History for Physics", the name might be misleading, we, again, do not endorse a Whiggish history of physics, nor do we promote historically uninformed narratives that merely serve to legitimize current research agendas. As previously discussed, we view the history of physics as a necessarily independent intellectual endeavor. One, that we nevertheless wish to see as an integral part of physics practice.

The title of our symposium was then chosen to be "History for Physics: Quantum Foundations", held at the Faculty for Physics of the University Vienna on September 23–24, 2019. The subtitle "Quantum Foundations" specified it to actually be the first out of two symposia that we then ended up organizing. The second one was called "History for Physics: Quantum Gravity" and was held at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) in Potsdam on November 28–29, 2019. It was important to us that the venues for both symposia would be physics institutes, to grant low level access. Vice versa, of course, this also provided an opportunity for historians of physics to visit renown physics institutes.

In a similarly "tandem" manner, we were fortunate to have been very generously supported, both financially and administratively, by an institute for the history of science, the Max Planck Institute for the History of Science (MPIWG) in Berlin, and by an institute for physics, the Institute for Quantum Optics and Quantum Information (IQOQI) in Vienna. We want to use this occasion to once more express our deep gratitude and appreciation.

The events themselves were, as we perceived it, a great success. On the one hand, we were able to announce invited tandem talks given by world renown scholars: In Vienna, these were David Kaiser with Christopher Fuchs, and Olival Freire Jr. with Daniel Greenberger. In Potsdam, we had Alexander Blum with Hermann Nicolai and Thiago Hartz with Claus Kiefer engaging with this new format. To complement this, for each symposium we published an open call for contributions, for both, tandem talks and single history of physics contributions. This way, we were lucky to schedule two additional tandem talks and five single history talks at the Vienna symposium, and four additional single history talks at the Potsdam event. To contextualize and reflect on our endeavor, we further organized a panel discussion on "the relevance of the history of physics for research and education and its current realization within academic structures" for each symposium. In Potsdam, this was further kicked off by three inspiring impulse talks by esteemed colleagues. The full list of speakers and panelists, in fact the full program of both symposia including links to the recorded talks, is documented on the website of the MPIWG.[2] We extend our sincere thanks to all the speakers and audience members for the stimulating talks and discussions, making both events truly exceptional.

After these two symposia had been held so successfully, a continuation was definitely an option. However, other projects, the amount of organization involved, publication pressure, unstable job situations and, not to forget, a global pandemic unfortunately did not allow for this so far. Consequently, the "History for Physics" symposium series thus came to a hold at some point. Eventually however, picking up an encouraging suggestion by Olival Freire Jr., we developed a concept for a special issue on the "History for Physics" theme. A special issue, we thought, would expand our theme to the textual level, potentially giving it a higher visibility. It would further be

[1] https://www.mpiwg-berlin.mpg.de/sites/default/files/2019-06/hfp-vienna.pdf.
[2] https://www.mpiwg-berlin.mpg.de/event/history-physics.

inclusive also for people who had not participated in one of our events. With the invaluable guidance from Olival Freire Jr. and Alexander Blum, we are now grateful that our concept has found a home at EPJ H, which really seems a natural place for such a thematic issue. We owe special thanks to James Wells, editor-in-chief at EPJ H, for his immediate enthusiasm about our plan and for encouraging us to submit a formal proposal, which was thankfully approved in September 2021.

The special issue was given the title "History for Physics: Contextualizing modern developments in the foundations of quantum theory", specified again with a subtitle—to keep it topical and in hopeful anticipation for a potential continuation of our concept in one way or another. As the title suggests, we see this issue as a direct, textual, continuation of the theme of our symposia. That is, we still aim to "bridg[e] contemporary topics in physics with their historical context" and "to draw attention to the history of physics as a subject of study and research for the active practitioner in physics; but also [hope] to encourage historians of physics to engage with contemporary questions in physics, to possibly draw from this inspiration, or recognize need, for further historical research," as we wrote in the official call for papers published on November 15, 2021.[3]

Central to carrying over the "history for physics" theme to a special issue format is, of course, the adaptation of the tandem talk concept to a concept of tandem articles. A tandem article should accordingly consist of "two parts; a part written by a historian of physics and a part written by a physicist. Both of these parts are supposed to treat one and the same aspect of a foundational issue involving quantum theory in a broad sense. In their respective parts, each author treats this aspect from their own respective perspective: The physicist contributes to the description of the state of the art of an open problem or debated phenomenon related to quantum physics, whereas the historian provides an appropriate historical account related to this actual case. The two parts, when being joined, should in particular present a form of togetherness. However, the precise shaping and proportioning of the parts are left to the authors." As we outlined in that same call for papers.

Reactions to this call were quite immediate and throughout positive; some even excited and congratulatory. When presenting our concept to EPJ H, we had argued that "experience showed us that a sufficient amount of [physicists and historians of physics] are indeed very open, and in fact in principle enthusiastic, to collaborate with each other. And we think that a special issue of this kind would provide a very rare opportunity and strong motivation for this potential to actually materialize [...]". And we were truly happy that the responses to our call once more seemed to confirm our perception. What did surprise us, though, and which seems worth noting here, was the significantly predominant amount of feedback and expressions of interest from physicists, despite our considerable efforts to systematically distribute the call among historians as well. This indicates to us that the common belief that physicists are generally uninterested in engaging with the academic study of their history does not hold true. Instead, we claim that there is in fact a large untapped reservoir of genuine interest in, and perhaps even a need for, serious scholarly engagement with the history of physics that lies underneath and awaits chance and support for its enhancement.

To facilitate the formation of tandems, we had offered our assistance in finding a matching partner in the call for papers. An offer that was also primarily taken up by physicists. However, despite our great efforts, in most cases it was simply impossible to find a historian knowledgeable in the field of study of the respective physicists. To provide some statistics: out of all the responses, six physicists and one philosopher of science requested assistance in finding a tandem partner, but all attempts were unsuccessful. Additionally, three other physicists and two historians/philosophers of science expressed interest and indicated they would find their own tandem partner, but they, too, did not succeed. On top of that, we contacted three physicists whose contribution we would have loved to receive, but none of these attempts resulted in a successful tandem match. In two of these cases, it was us who had to admit that we weren't able to find a matching historian after all. In the third case the contacted person themselves assured us they would find a tandem partner, which, however, did not materialize as well.

Of course, with a larger network and a better overview of who is doing research on what specific topic in the history of physics (which appears to be a general issue, reflecting the scattered and individualistic nature of our field) we might have been more successful in finding a greater number of matching tandem partners. However, based on the responses we received, our impression is that there is actually a general lack of historians of physics whose basic education in physics and mathematics is advanced enough to tackle the history of the contemporary topics in physics. This seems to be an alarming systematic deficiency of our field. To counteract this, we believe it is necessary to make greater efforts to train interested (mathematical) physicists in historical methodology, preparing them to contribute to the contemporary history of physics. Particularly, since this kind of training is becoming increasingly demanding. Yet the field of history of physics seems to be contracting and wrapping up rather than expanding to meet these challenges. We thus share the sentiment that a serious and coordinated effort by all actors in the field is essential to counteract this trend.

Eventually, we were able to form six tandems in addition to the six tandems that had formed on their own. However, as they worked toward the original deadline of July 31, 2022, these tandems encountered an unforeseen hurdle related to the complexity of this collaborative work. Beyond the usual challenges of teamwork, the historical

[3] https://www.epj.org/open-calls-for-papers/86-epj-h/2240-epjh-special-issue-history-for-physics-contextualizing-modern-developments-in-the-foundations-of-quantum-theory.

component often turned out to be much more complex than anticipated, with the relevance and connections to the contemporary sections proving quite intricate. These difficulties, among others, resulted in multiple extensions of the official deadline. By spring 2023, we decided to dispense with the deadline altogether, allowing each tandem all the time needed to complete their papers, and opting to publish them on a rolling basis. Unfortunately, by that time, about half of the initial tandems had disbanded, leaving us with an uncertain number of tandem papers—somewhere between six and eight—for our issue. The reasons for this significant loss were at the same time common and individual. In neither case, however, it seemed that the format itself was the reason the tandem projects could not be completed successfully.

It is regrettable, of course, that we are not able to present the papers that ultimately did not materialize. Nevertheless, we are still incredibly excited and proud to feature six in our view marvelous tandem papers authored by a total of 12 individuals in this very first special issue of this kind. We are truly grateful to every tandem that was willing to undertake such an unconventional project with us. We now hope that our readers will glean insight and inspiration from these papers and come to recognize the value of the history of and for physics.

On the individual (tandem) papers of the issue

Each article of our issue stands alone in terms of content and can thus be read independently. What they all have in common, however, is a focus on the foundations of quantum theory and their integration both of historical and contemporary components in various ways. In their individual efforts to interpret the tandem paper format, the authors of our special issue have sought insightful ways to combine historical work with the current state of the art. As a result, they have utilized these two components differently and thus have drawn distinct conclusions. Some authors find that as our current debates evolve, also our assessment of the work done in earlier times evolves, which is therefore never completed. Others observe that we are currently entering what appears to be a new phase of a specific research field. Still others suggest that integrating historical analysis with current knowledge opens up new avenues for exploring conceptual foundations.

To provide a glimpse into the content and scope of the papers in the issue, as well as the ways in which they integrate history and current research, they are briefly presented below in the order of their publication.

In **"Matrix mechanics mis-prized: Max Born's belated nobelization"** historian of science **John Heilbron** and physicist **Carlo Rovelli** explore why Max Born's contributions to quantum mechanics were seemingly underrecognized by the Nobel Committee in 1954. However, this paper does not seek to provide a definitive judgment on the matter. Rather, it argues that the ongoing debates and developments regarding the interpretation of quantum mechanics require an equally ongoing reevaluation of the work of its founders. This, in turn, may also inform contemporary debates. With this in mind, the authors' historical analysis distinguishes the contingencies that influenced the Nobel Committee's decision process from Born's demonstrable achievements and concludes that Born arguably deserves more credit than he is usually given. This finding is complemented by a discussion of recent ideas on the interpretation of quantum mechanics and how they relate to the ideas of the consolidating quantum mechanics of the 1920's. Their verdict: The early success of wave mechanics seems to have been an obstacle to understanding because of its—from today's perspective—misleading emphasis on the role of quantum states. To illustrate this thesis and its central points, an imaginary "counterfactual" historical narrative was devised in which wave mechanics was not discovered.

Analogue modeling, the comparison of foreign or experimentally rather inaccessible objects to better known systems, has proven to be a very fruitful approach in physics. In **"Analogue gravity and the Hawking effect: historical perspective and literature review"** historian of physics **Carla R. Almeida** and physicist **Maxime J. Jacquet** review the history of analogue reasoning as applied to the understanding of black holes. The authors offer a periodization of this historical development, distinguishing between what they call the Formative Years (until 1974), the Testimonial Years (1974–2008), and the Empirical Years (2008–2017). They argue that these periods differ in their objectives for using analogue reasoning. Whereas in the Formative Years, analogies were used merely to visualize foreign features of the theory, in the Testimonial Years there was a shift toward using analogies as tools to evaluate whether a particular theoretical feature—Hawking radiation—could actually be true. The Empirical Years then witnessed mainly experimental efforts to observe the Hawking effect in the laboratory. The paper concludes with a reflection on contemporary research on analogue gravity noting the potential consolidation of a new phase of analogous research, the so-called Autonomous Phase. This phase is characterized by its apparent independence from the original astrophysical problems and its use of reverse-analogue approaches to uncover new phenomena in condensed matter.

In **"Note on episodes in the history of modeling measurements in local spacetime regions using QFT"**, historian and philosopher of physics **Doreen Fraser** and physicist **Maria Papageorgiou** spotlight historical origins of contemporary local measurement theories within QFT. While QED employs an asymptotic measurement framework to predict scattering amplitudes, some currently discussed formalisms for QFT more generally focus on measurements in local spacetime regions, which is considered useful for relativistic quantum information (RQI) and quantum gravity. The authors start with an introduction to contemporary work done in a detector-based approach pursued in the RQI community and a framework for algebraic quantum field theory developed within mathematical physics. From this starting point they revisit the respective historical roots which they find to be rather different from each other. Finally, by analyzing how the contemporary work builds on the identified historical origins, they conclude that the reason it has taken so long to make substantial progress on the problem of local measurements in QFT is the need for a refined understanding of A) the principles of relativistic quantum theory and B) the practical issues related to the representation of probes and their interactions with quantum fields in relativistic spacetime.

Feynman diagrams are a calculative tool that graphically represent interaction processes among fundamental particles, which are generally quite difficult to determine with standard QFT tools. In **"The development of computational methods for Feynman diagrams**" historian of science **Jean-Philippe Martinez** and physicist **Robert Harlander** explore how the need for more and more complex Feynman diagrams has prompted serious efforts to the end of their algorithmic evaluation. A specific emphasis is placed on the development of early computer programs, which would turn out to play an essential role in testing the validity of QED at higher orders at the turn of the 1960s and 1970s and would also prompt significant change in the practice of handling Feynman diagram computations. The authors complement their historical analysis with a comprehensive overview of the current state of the algorithmic evaluation of Feynman diagrams, outlining the key algorithmic concepts developed over time. Both, the historical and the overview part anticipate each other by putting central technical challenges faced in both the early and the present stage of the development. Combining the historical and contemporary analysis, the authors find that the current capability of programs to compute Feynman diagrams match many of the initial hopes and expectations from the early 70's. However, various limitations indicate that a conceptual theoretical shift might become necessary sooner or later for QFT related calculations.

In **"The Quantum Theory Of Gravitation, Effective Field Theories, and Strings: Yesterday And Today."**, historian of physics **Alessio Rocci** and physicist **Thomas Van Riet** discuss how the effective field theory (EFT) approach was, and still is, negotiated within theoretical physics. By providing historical landmarks of the connection between EFT and approaches to quantize gravity within the period 1930-1994, they argue that while EFT techniques were at first developed to be applied within particle physics, work on attempts to quantize general relativity significantly influenced the process that led to the contemporary understanding of the Standard Model and general relativity as an EFT. These developments also had a decisive influence on string theory, originally seen as a theory of quantum gravity. The authors demonstrate how more traditional EFT strategies anticipated early ideas that string theory is the correct fundamental theory containing general relativity as part of the Standard Model in the low-energy regime. They conclude by connecting this historical research to a review of contemporary times by outlining how the relationship between string theory and the EFT approach qualitatively changed in the 2000s, when string theory transitioned from the so-called Landscape problem to the Swampland program.

Historian and philosopher of physics **James Fraser** and mathematical physicist **Kasia Rejzner** have teamed up for their article **"Perturbative Expansions and the Foundations of Quantum Field Theory"**. Therein, they provide an overview of mathematical engagement with the conceptual foundations of perturbative QFT. Scrutinizing the reception of several divergence difficulties that arose within the perturbative formalism, they distinguish two main responses to these difficulties that developed in the 1950's and 60's. On the one hand, an attempt to develop non-perturbative formulations of the theory: axiomatic QFT; and on the other hand, mathematical work on the foundations of the series expansion itself: causal perturbation theory. The authors manage to bridge this historical analysis to contemporary physics by situating perturbative algebraic QFT within this historical development: a contemporary approach that brings causal perturbation theory and axiomatic QFT together by establishing relationships between certain results of the respective approaches. In light of this historical analysis of the tradition of mathematical work on perturbative QFT, they finally argue that currently that the gap between the physicist's and the mathematician's formulations of QFT is not as wide as is often thought, opening up new ways of approaching QFT from a foundational point of view.