The Perils of Prediction in the Physical Sciences:

Historical and Epistemological Perspectives

1st International Workshop
18-19 March 2021

Department of History and Philosophy of Science
School of Science
National and Kapodistrian University of Athens

Book of Abstracts

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List of Speakers:

Theodore Arabatzis
National and Kapodistrian University of Athens

Stathis Arapostathis
National and Kapodistrian University of Athens

Alex Broadbent
University of Johannesburg

Vasiliki Christopoulou
National and Kapodistrian University of Athens

Gregory Clancey
National University of Singapore

Radin Dardashti
University of Wuppertal

Gabriele Gramelsberger
RWTH Aachen University

Hans Hasse
University of Kaiserslautern

Matthias Heymann
Aarhus University

Stylianos Kampouridis
National and Kapodistrian University of Athens

Iraklis Katsaloulis
National and Kapodistrian University of Athens

Johannes Lenhard
University of Kaiserslautern

Miles MacLeod
University of Twente

Grigoris Panoutsopoulos
National and Kapodistrian University of Athens

Wendy Parker
Virginia Tech

Stéphanie Ruphy
Ecole Normale Supérieure – Université PSL

Léna Soler
Université de Lorraine Archives Henri Poincaré

Aristotle Tympas
National and Kapodistrian University of Athens

Program – (Eastern European Time / UTC +2)

The conference will take place online on Zoom:

Zoom Link:

https://zoom.us/j/92035551794?pwd=TVdsQ0pmWjRMRHh1bGhlOVdyL0dSUT09

March 18
12:00 – 2:00pm **Welcome / Prediction in Classical and Quantum Physics** **(Chair: Aristotle Tympas)**
Theodore Arabatzis, National and Kapodistrian University of Athens *The Perils of Prediction Project*
Léna Soler, Université de Lorraine, Archives Henri Poincaré *What Would It Be like to Be Bohmians? Predictions as Paradigm Dependent: The (Big) Difference That It Makes*
Vasiliki Christopoulou, National and Kapodistrian University of Athens *From Dimensions to Physical Laws: Lord Rayleigh's Dimensional Approach to Prediction*
3:30 – 5:30pm **Computation, Simulation, and Prediction** **(Chair: Ana Simões)**
Aristotle Tympas, National and Kapodistrian University of Athens *On Searching for One More Imaginary Particle and Missing the One Real Planet: Historiographical Considerations on Scientific Computing*
Hans Hasse & Johannes Lenhard, University of Kaiserslautern *Created by Prediction: On the History, Ontology, and Computation of the Lennard-Jones Fluid*
Stelios Kampouridis, National and Kapodistrian University of Athens *"There isn't a single solution to everything": Predictive Reliability and Hierarchy of Models in Computational Quantum Chemistry*

6.00 - 8.00pm **The Changing Fortunes of Prediction** **(Chair: Friedrich Steinle)**
Radin Dardashti, University of Wuppertal *Predictions in Fundamental Physics and the Future of Theory Assessment?*
Grigoris Panoutsopoulos, National and Kapodistrian University of Athens *The Changing Concept of Prediction in High Energy Physics: From the Standard Model to the Post-Higgs Era*
Miles MacLeod, University of Twente *Doing without Prediction: The Case of Sustainability Science*
March 19
12:30 – 2:00pm **Prediction in the Environmental Sciences** **(Chair: Theodore Arabatzis)**
Gabriele Gramelsberger, RWTH Aachen University *Cloud Parametrization Deadlock in Climate Models*
Matthias Heymann, Aarhus University *Climate Modeling and the Perils of Prediction*
3:30 – 5:30pm **Prediction in the Earth Sciences** **(Chair: Kostas Gavroglu)**
Stathis Arapostathis, National and Kapodistrian University of Athens *Dusty Predictions: Technoscientific Networks,* *Research Politics and Regional Uncertainties*
Gregory Clancey, National University of Singapore *Predictive Models and Their Markets: The Case of Seismology*
Iraklis Katsaloulis, National and Kapodistrian University of Athens *Earthquake Prediction: The Greek Case in a Global Context*
6.00 - 8.00pm **The Epistemology of Prediction** **(Chair: Hasok Chang)**
Wendy Parker, Virginia Tech *Predicting Future Weather and Climate: From Models to Expert Judgment*
Alex Broadbent, University of Johannesburg *What Is a Good Prediction?*
Stéphanie Ruphy, Ecole normale supérieure – Université PSL *Should We Still Value the Unpredictability of Scientific Inquiry?*

Abstracts

The Perils of Prediction Project

Theodore Arabatzis
National and Kapodistrian University of Athens

Successful prediction has been a central goal of the sciences, whether to anticipate future events or to test theories, models, or hypotheses. The role of prediction in the sciences has been the subject of considerable debate in the philosophical literature. Nevertheless, few studies have delved into the ways scientists actually derive and use predictions or into how prediction is entangled with the particularities of different scientific fields. The aim of the Perils of Prediction Project is to highlight the many faces of prediction in science, to illuminate its various roles in scientific practice, and to explore the perils and complications involved in the extraction of predictions from scientific knowledge. Those perils and complications are associated with the following points: First, the making of predictions is rarely a direct deduction from the premises of a scientific theory. Rather, there is a considerable gap between high-level theory and predictions of particular phenomena, a gap that is bridged by modeling, which in turn involves idealizations, and approximations. Second, it is not clear whether predictions of novel phenomena provide better epistemic support to scientific theories than explanation of already known phenomena. Third, the character and significance of prediction differ across scientific fields and time periods. Fourth, what counts as an adequate/successful prediction is occasionally up for grabs and, thereby, prediction may turn into a contested epistemic value. The project combines abstract reflection on the epistemology of prediction and concrete case-studies in which those epistemological issues are played out. The cases examined include episodes from late 19th century physics, quantum chemistry, seismology, high-energy physics, and environmental science, taking into account the ever-increasing role of computing in scientific practice.

Dusty Predictions:
Technoscientific Networks,
Research Politics and Regional Uncertainties

Stathis Arapostathis
National and Kapodistrian University of Athens

The paper studies the development of weather and dust predictions for East Mediterranean by researchers, modelers and atmospheric physicists in Greek research institutes. I follow the work and the activities of two research groups in the Physics Department of the University of Athens and in the National Observatory of Greece. Based on primary research and a series of interviews, the study unravels the co-construction of the predictive capacity of weather and dust models with the research credibility and the assetization of know-how and expertise. By following practitioners' numerical weather and dust modeling since the mid-1980s and, more specifically, the development of the SKIRON model, I argue that scientists construct their models as acts of bricolage and through the appropriation of global models of forecasting, the parametrization of local conditions and geophysical specificities. The credibility and predictive capacity of models has been co-constructed with computing infrastructures and the politics that those involved as well as with data sets from satellites and Lidar measurements. Adopting the Latourian concept of the cycle of credibility, I argue that the researchers follow an open science research strategy in order to expand their cycle of accumulation and their credibility, aiming at linking their numerical models with industrial uses and potential users of their know-how and expertise.

What Is a Good Prediction?

Alex Broadbent
University of Johannesburg

We want our predictions to be true, but do we want anything more from them than that? This paper seeks an explicit and general understanding of good prediction, of the form "X is a good prediction if …". This paper sets out central distinctions between testing and forecasting predictive contexts, between temporal and epistemic notions of prediction, and between prediction claims and activities. It also defines a subclass of predictions that are of particular interest, namely particular, important, guess-free, difficult (PIGD) predictions. These distinctions and refinements enable us to frame the question "What is a good prediction?" more precisely. Next the paper considers Erasmus's Tracking Theory of Good Prediction attractive but inadequate for PIGD predictions. Finally the paper sketches a Contrastive Theory of Good Prediction as a compatible elaboration of the Tracking Theory that deals with PIGD predictions.

From Dimensions to Physical Laws: Lord Rayleigh's Dimensional Approach to Prediction

Vasiliki Christopoulou
National and Kapodistrian University of Athens

In the nineteenth century and more so in its second half, quantification in physics became more pervasive. Based on measurement operations, dimensions of physical quantities were taken under consideration, although different claims were made about them. One such claim was that an equation would have to remain the same if the units of the quantities involved were changed. One other was that all units should be expressible in terms of the fundamental ones, namely length, mass and time, a demand interwoven with the establishment of a unified system of units. Lord

Rayleigh employed a method involving dimensions in many cases throughout his work. His approach was quite different from the aforementioned, as one key feature of his method was that it enabled predictions of physical laws, albeit not in a deductive way or in their final form. Those predictions were inherently partial, as the coefficients in physical laws could not be specified through the dimensions of the quantities involved and one should resort to experiment for their determination. At the same time, the necessary assumptions and approximations for the application of the method relied upon previous experience and involved tacit knowledge. Still, it was a method for searching from the known to the unknown. The aim of this paper is to analyze Rayleigh's dimensional approach to prediction and explore its characteristics, taking into account his personal style of research and his attitude towards the relationship between mathematics and physics.

Predictive Models and Their Markets: The Case of Seismology

Gregory Clancey
National University of Singapore

Prediction is considered by some the sine qua non of the physical sciences, or at least their intended destination. By that standard, seismology would rank among the least successful of all modern scientific projects, given its near-complete failure to predict occurrences of the phenomenon it studies – earthquakes. This is all the more striking in that, unlike many sciences, seismology is funded by governments and related institutions with the express purpose and expectation of saving whole cities and regions from catastrophe. While seismology has never succeeded in this mission, it has also never been abandoned, though its practitioners are occasionally disgraced and punished, and professionals and experts from outside repeatedly enter the field to ''try their hand'' at creating predictive models. My paper will look at how both historic and contemporary groups of seismologists have navigated this crisis at the center of their practice, drawing particularly from the example of Japan. Japan was the first nation to institutionalize earthquake prediction as an officially-sanctioned and funded role of government, yet its tragic relationship with destructive earthquakes has continued almost unmitigated into the current century. I will discuss some of the arguments and strategies Japanese scientists have used to continue practicing their discipline under the historic pressure of having failed to ensure social safety. Seismic research, I will suggest, responds to 'markets' for knowledge and safety both inside and outside of science, which calibrate and weigh prediction differently.

Predictions in Fundamental Physics and the Future of Theory Assessment?

Radin Dardashti
University of Wuppertal

Fundamental physics seems to be in a precarious situation. In particle physics you have strong disconfirmation of much of the theory landscape through recent results from the Large Hadron Collider. This leads to a situation where there are almost no predictions from theories beyond the standard model to be tested in future experiments. For theories of quantum gravity you seem to have the opposite situation: you have a multitude of proposed theories with no foreseeable experiments being able to probe the relevant energies. So, you either have theories that can't be probed or upcoming experiments that cannot rely much on theoretical predictions. In this talk I will address the various ways this situation will impact and has already impacted the research in fundamental physics and provide a perspective on theory assessment that allows to go beyond an assessment that only relies on the empirically confirmable predictions of individual theories. This perspective, which relies on the concept of theory space, will allow us to assess the apparent shift in current practice in fundamental physics as one in degree rather than in kind that can nevertheless have significant implications for what kind of knowledge fundamental physics can provide us with.

Cloud Parametrization Deadlock in Climate Models

Gabriele Gramelsberger
RWTH Aachen University

A major peril of climate modeling is the so-called "cloud parametrization deadlock". The computing resolution of global climate models is still too coarse to fully represent the effects of clouds on climate. Therefore, clouds have to be described explicitly (subscale parametrization) in climate models. But cloud parametrizations are major sources of uncertainties. In order to decrease uncertainties either results of cloud-resolving models (CRMs) can be considered offline in climate models allowing only one-way interaction (from large scale to cloud scale), or new concepts of modelling can be considered such as superparameterization, multiscale modelling, and adaptive meshing. However, these new modelling concepts are computationally expensive. The paper introduces the various modelling strategies. It discusses the current situation of the cloud parametrization deadlock and presents an entirely new idea of overcoming it by using machine learning algorithms which update climate models during simulation with observational data inputs.

Created by Prediction: On the History, Ontology, and Computation of the Lennard-Jones Fluid

Hans Hasse & Johannes Lenhard
University of Kaiserslautern

The Lennard-Jones (LJ) fluid, named after mathematician-physicist-chemist Sir John Lennard-Jones (1894-1954), occupies a special place among fluids. It is an ideal entity, defined as the flu-id whose particles interact according to the Lennard-Jones potential. This potential describes the pairwise repelling (very small distance) and attracting (van der Waals) forces with a relatively simple and mathematically tractable expression. The contribution discusses the history of the LJ fluid in three acts. Act one starts with classical mechanics and leads to the early 20th century when theoreticians like Mie, London, and Len-nard-Jones combined available data and mathematics with (theoretical) idealization. Act two welcomes the computer on the stage. Pioneering works in the 1950s and 1960s explored simulation methods to solve the "classical" equations for a large number of particles. Molecular dynamics grew into a widely used tool in both science and engineering for predicting the properties of materials. In this field, the LJ fluid acquired paradigmatic status ("the ubiquitous"). Act three offers a surprising twist. Recent work reports problems with reproducibility of LJ simulations. Although the simulations target the mathematically defined ideal object, the object that is actually simulated is different. This leads to the question of what the simulated LJ fluid actually is. Answering this "what" question requires an inquiry into the "how" question, i.e., into the methodology of simulation modeling. Viewed from the perspective of simulation, there is an underexamined layer of modeling steps that are relevant for many properties—and finally for the identity—of the simulated LJ fluid. Hence the allegedly most ideal of all fluids, created by mathematical prediction, turns out to have a bricolage character in practice.

Climate modeling and the perils of prediction

Matthias Heymann
Aarhus University

Prediction arguably pervades all aspects of our social, political and cultural lives. Its role has likely expanded during the 19th and 20th centuries to help take decisions in highly complex techno-scientific societies. Weather and climate prediction are major examples of efforts to develop and use science-based models for understanding changes in weather and climate and delivering appropriate knowledge about it. This contribution aims at investigating the case of climate modelling and the chances, challenges and perils of climate prediction. I will argue that computer-based modeling and simulation of climate contributed to changes of scientific standards and cultures, which helped increase its resources and social status, but also backfired by compromising its scientific autonomy.

“There isn’t a single solution to everything”: Predictive Reliability and Hierarchy of Models in Computational Quantum Chemistry

Stelios Kampouridis
National and Kapodistrian University of Athens

The predictive power and reliability of quantum chemical models were the product of a historical process of negotiations, controversies, and understanding of the manifold uses of predictions. The initial attempts in the 1950s and 1960s to create a general model for quantitative predictions applicable to all molecules and chemical systems proved unfeasible. Models with few approximations were computationally expensive and the calculations produced by them were not straightforward in their interpretation. Models that were computationally manageable and could be used by practicing chemists needed an extended period of testing to assess their weaknesses and strengths until their interpretation in every particular case could achieve a level of reliability. The use of empirical parameters or their avoidance in model construction further complicated the evaluation of computational methods' predictions: many thought that the inclusion of empirical parameters reduced the model into a curve-fitting exercise. As it turned out, there was not a single solution for everything. Practicing chemists had to choose between the various models according to their needs. Every model carved out a niche within which it reigned supreme and was used as a basis for assessing the value of the others. In this talk, I will argue that, by this process, a normative framework of models was created, a “hierarchy of models” as leading quantum chemist John A. Pople named it, that could produce, as a whole, predictions covering broad areas of chemistry. This normative framework was not static. As computer power increased, every model enlarged its domain of applicability. Therefore, a dynamic normative framework of models was the major outcome of computational quantum chemistry as a tool of chemical research in the early 1980s.

Earthquake Prediction: The Greek Case in a Global Context

Iraklis Katsaloulis
National and Kapodistrian University of Athens

In 1981 a group of Greek scientists presented a method which they claimed to be capable of short-term earthquake prediction, that is, a few hours to a few days before an earthquake occurs. This method was named the VAN method, after the initials of its proponents’ surnames, Varotsos, Alexopoulos, Nomicos, and its operation was based on the detection of a certain type of seismic precursors, namely electric signals. The public announcement of the method was followed by a fierce controversy about its validity, which peaked in the mid-‘90s and has still not been conclusively resolved.

Earthquake prediction has been a controversial field, where consensus on vital issues is lacking. The scientists that are involved in this field disagree on factual, theoretical and methodological grounds. The VAN method was a central episode in the broader discussion regarding earthquake prediction for almost two decades, from the beginning of the eighties to the end of the nineties.

Thus, studying the history of the controversy around the VAN method can illuminate the broader debate on earthquake prediction.

Some of the questions that arose, or were amplified, during the VAN controversy were the following: How is earthquake prediction defined? What does it mean to have an accurate earthquake prediction? What is the right strategy for pursuing earthquake prediction? Who are the experts on earthquake prediction? What is the proper procedure for the evaluation of an earthquake prediction method? In this talk I will discuss the answers that scientists have given to these questions and the arguments they have put forward in order to support them.

Doing without Prediction: The Case of Sustainability Science

Miles MacLeod
University of Twente

Prediction is well understood as a central goal of many scientific enterprises, especially those built around modeling. Many of the world's environmental problems are thought to require accurate model-based predictions to both identify them and to resolve them. However, sustainability science, as opposed to more scientifically traditional environmental science, promotes many voices and perspectives which reject approaches to environmental problems based on the construction of highly predictive models. In this paper we will consider the extent to which many views within sustainability science and attitudes towards models in particular might be understood as a reaction to the perceived lack of predictability of models, and traditional scientific norms and standards based around the production of predictive models. We will consider what the arguments are for why effort in the production of highly predictive models will not help scientifically resolve environmental challenges, stemming from the complexity of coupled human-environment systems, but also the need to engage with variable values and policy objectives, through practices such as participatory modeling. The result is that sustainability science looks non-traditional as a science in many respects which raise concerns over the degree to which sustainability science can produce robust and reliable responses to environmental problems. There may be a degree to which sound scientific practice must be in some sense tied to regulative ideal of prediction even if those predictions are limited in many respects. A normative science such as sustainability science cannot do normative work unless its models can provide some indication of future states and scenarios.

The Changing Concept of Prediction in High Energy Physics: From the Standard Model to the Post-Higgs Era

Grigoris Panoutsopoulos
National and Kapodistrian University of Athens

The concept of prediction has been a cornerstone of Physics and many philosophical studies have discussed its epistemic significance. Nevertheless, only a few of those studies have shown an interest in the dynamic role that prediction actually plays in scientific practice. Indeed, should one examine more closely the practices that have been developing in the field of High Energy Physics, it becomes apparent that prediction is a rather fluid concept, one whose character and epistemic value have been constantly shifting in response to developments in the wider scientific context. This has implications for the relationship between theory and experiment, which should be understood not as a one-dimensional process, where theory predicts and experiment confirms or falsifies, but in the context of a complex interaction that is undergoing constant transformation.In this paper I will attempt an examination of the role of prediction by focusing on three different episodes from the history of HEP: the discovery of weak neutral currents in 1973, back when the Standard Model (SM) did not yet have the acceptance and the prestige within the experimental community that it would attain during the years that followed; the discovery of W and Z bosons in 1983, when the SM was established as the only game in town in HEP, and the "Post-Higgs era", where, in the wake of the discovery of the Higgs boson, the last missing piece of the SM puzzle, and in the absence of a theory with predictions that could be validated experimentally, experiments have become, to a significant extent, independent from theoretical predictions, with the practice of exploratory experimentation gradually gaining dominance.

Predicting Future Weather and Climate: From Models to Expert Judgment

Wendy Parker
Virginia Tech

Computer simulation models are a key resource in both weather and climate prediction. In weather prediction, it is often agreed that expert judgment can 'add value' to model-based forecasts. I will suggest that the need for expert judgment in the context of climate prediction is even greater, yet its employment there seems less well accepted. I will suggest that there are both epistemic reasons – related to the type of prediction task undertaken -- and socio-political reasons for hesitancy about the use of expert judgment in climate prediction.

Should We Still Value the Unpredictability of Scientific Inquiry?

Stéphanie Ruphy
Ecole Normale Supérieure – Université PSL

On the one hand, unpredictability is traditionally valued as the hallmark of pioneering, creative research. On the other hand, there is a growing demand towards science of accountability and social responsibility (see for instance the H2020 notion of RRI (Responsible Research and Innovation)). But how can you expect science to be socially responsible – to deliver what society needs – when you cannot predict what science will deliver? I will investigate in this talk some dimensions of this prima facie tension between unpredictability and social responsibility and identify pending issues that need to be solved to improve policies of research oversight and funding.

What Would It Be like to Be Bohmians? Predictions as Paradigm Dependent: The (Big) Difference That It Makes

Léna Soler
Université de Lorraine, Archives Henri Poincaré

What difference does it make when the same (corroborated) predicted observations are embedded in two radically different physical frameworks, if not two incommensurable paradigms? The "not-so-much-difference" answer, or even the "no-difference-at-all" one, have often been endorsed. But such positions, I shall argue, greatly underestimate the weight of "the other of predictions" (i.e., of all that differs from predictions within the framework) on what is taken as physically relevant, physically acceptable, and physically established at each stage of scientific development. As a revealing case study, my argument will exploit the contrast between two presently alive, empirically equivalent theoretical frameworks in quantum mechanics: the "standard" quantum physics (SQP) learned by students for some seventy years; and an alternative physics first introduced by David Bohm in 1952 and subsequently developed in different directions by others until today (say BQP as Bohmian Quantum Physics). Although SQP and BQP predict the same observations, they are otherwise incompatible. To grasp the nature, magnitude and impacts of the differences between two predictively equivalent but incompatible frameworks like SQP and BQP, I articulate a counterfactual scenario in which the chronological and social situations of SQP and BQP are permuted. Starting from the virtual initial condition of a community of physicists educated exclusively in the BQMian framework and immersed in it all along their professional life, I attempt to come as close as possible to a perception of "what it would be like to be Bohmians" and to an experience of the gestalt switch involved when commuting to "what it is like to be SQPians". This helps to appreciate how the "same" predictions can look different. Not only do the same predicted numbers receive contradictory physical meanings, but still more consequential clashes arise at the level of epistemological evaluation: One and the same mathematical predictive algorithm, and more generally one and the same physical theory, can indeed be assessed in antagonistic ways. Taking these conclusions for granted, some epistemological issues will be briefly considered, especially in relation to the problem of theory choice.

On Searching for One More Imaginary Particle and Missing the One Real Planet: Historiographical Considerations on Scientific Computing

Aristotle Tympas
National and Kapodistrian University of Athens

This presentation aims at indicating the relevance of the historiography of scientific computing to the PYTHIA project on the perils of prediction, all the way from particle physics and quantum chemistry to seismology and climatology. Emphasis will be placed on the history of the prediction-computing connection, which will be considered in the context of the difference between the digital-hardware side and the analog-software side of computing. A comparative emphasis on the former can be found in particle physics and quantum chemistry, whereas an emphasis on the latter characterizes seismology and climatology. A further contrast can be made between the limited interest in computing in seismology, which can still perceive earthquakes as a natural phenomenon of local dimensions, and the great interest in computing in climatology, which was has been increasingly forced to take into account climate change on a global scale. I will integrate into the history of scientific computing (and thereby, indirectly, into the history of scientific prediction) a periodization scheme that takes into account: (1) the change in the use of the concept 'computer' (from human to machine computers) during the 1940s, the parallel emergence of the analog-digital demarcation, the subsequent emergence (post-1950s) of the software-hardware demarcation and the ensuing interest in software 'simulation' based on 'customized' software (as opposed to the standardized software of an 'operating system'), and long and short run changes in the means and meanings involved in the computing-modeling relationship; (2) the transition from the large computer 'mainframes' of the 1940s to, first, the 'microcomputers' of the post-1970s ('home' and 'personal' ones) and, more recently (post-1990s), the massive network of computers that gave rise to the 'internet', the 'web', and a range of 'social media'; (3) the expansive datafication that resulted from the accumulation of 'big data', in interaction with the change from the algorithms being mostly mathematical-logical-programming ones to being defined by their feeding on big data of all kinds; and (4) continuities and changes in the links between social work, computing technology and the ideology that attributes artificial intelligence to machines, from the 'postindustrial' 1970s to the '4th industrial revolution' of the 2010.

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