Working Group on Philosophy of Physics
Arbeitsgruppe Philosophie der Physik (AGPhil)

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Overview of Invited Talks and Sessions

(Lecture hall AGPhil-H14)

Invited Talks

AGPhil 2.1	Mon	16:15–17:00	AGPhil-H14	**To G or not to G: J. H. Poynting and the gravitational constant in the 19th century** — •Isobel Falconer
AGPhil 4.1	Tue	14:00–14:45	AGPhil-H14	**Hypothetical Waveforms and Unmodeled or Pipeline Searches in Gravitational Wave Astronomy** — •Lydia Patton
AGPhil 5.1	Tue	16:15–17:00	AGPhil-H14	**Portrait of a Black Hole: Objectivity and the Imaging of M87* by the Event Horizon Telescope** — •Peter Galison
AGPhil 5.2	Tue	17:00–17:45	AGPhil-H14	**When is a black hole spacetime "as large as it can be"?** — •Juliusz Doboszewski
AGPhil 6.1	Wed	14:00–14:45	AGPhil-H14	**Spacetime Conventionalism Revised: Tidal Forces and Weyl Curvature** — •Karim Thébault, Ufuk Tasdan
AGPhil 7.1	Wed	16:15–17:00	AGPhil-H14	**On an inferential role of spacetime in particle physics** — •Tushar Menon

Sessions

AGPhil 1.1–1.4	Mon	11:00–13:00	AGPhil-H14	**Symmetry and Geometry**
AGPhil 2.1–2.3	Mon	16:15–18:00	AGPhil-H14	**History and Philosophy of Gravity**
AGPhil 3.1–3.3	Tue	11:30–13:00	AGPhil-H14	**Black Holes I**
AGPhil 4.1–4.3	Tue	14:00–15:45	AGPhil-H14	**Gravitational and Electromagnetic Waves**
AGPhil 5.1–5.3	Tue	16:15–18:15	AGPhil-H14	**Black Holes II**
AGPhil 6.1–6.4	Wed	14:00–16:15	AGPhil-H14	**Foundations of Gravity**
AGPhil 7.1–7.4	Wed	16:15–18:30	AGPhil-H14	**Symmetries and Principles**
AGPhil 8	Wed	18:30–19:30	AGPhil-MV	**Annual Meeting of the AGPhil**
AGPhil 9.1–9.4	Thu	11:00–13:00	AGPhil-H14	**Quantum Mechanics I**
AGPhil 10.1–10.4	Thu	14:00–16:00	AGPhil-H14	**Quantum Mechanics II**
AGPhil 11.1–11.5	Thu	16:15–18:45	AGPhil-H14	**Time and Temperature**
AGPhil 12.1–12.4	Fri	11:00–13:00	AGPhil-H14	**Processes, Events and Time**

Annual General Meeting of the Working Group on Philosophy of Physics

Wednesday 18:30–19:30 AGPhil-MV

- Report
- Plans for 2022/23
- Miscellaneous

AGPhil 1: Symmetry and Geometry

Time: Monday 11:00–13:00 Location: AGPhil-H14

AGPhil 1.1 Mon 11:00 AGPhil-H14

A Proposal for a Metaphysics of Self-Subsisting Structures — •Antonio Vassallo[1] and Pedro Naranjo[1,2] — [1]Faculty of Administration and Social Sciences, Warsaw University of Technology, Plac Politechniki 1, 00-661 Warsaw, Poland — [2]Faculty of Philosophy, University of Warsaw, Krakowskie Przedmieście 3, 00-047 Warsaw, Poland

We present a new metaphysical framework for physics that is conceptually clear, ontologically parsimonious, and empirically adequate. This framework relies on the notion of self-subsisting structure, that is, a set of fundamental physical elements whose individuation and behavior are described in purely relational terms, without any need for a background spacetime. Although the specification of the fundamental elements of the ontology depends on the particular physical domain considered –and is thus susceptible to scientific progress–, the structural features of the framework are preserved through theory change. The kinematics and dynamics of these self-subsisting structures are technically implemented using the theoretical framework of Pure Shape Dynamics, which provides a completely relational physical description of a system in terms of the intrinsic geometry of a suitably defined Riemannian space, called shape space.

AGPhil 1.2 Mon 11:30 AGPhil-H14

Arguments from scientific practice in the debate about the physical equivalence of symmetry-related models — •Joanna Luc — Jagiellonian University, Kraków, Poland

In the recent philosophical literature, several counterexamples to the interpretative principle that symmetry-related models are physically equivalent have been suggested (Belot 2013, Belot 2018, Fletcher 2020). Arguments based on these counterexamples can be understood as arguments from scientific practice of roughly the following form: because in scientific practice such-and-such symmetry-related models are treated as representing distinct physical situations, these models indeed represent distinct physical situations. I will argue that if we are exclusively interested in models understood as representing entire possible worlds (not their subsystems), arguments from scientific practice should involve some additional assumptions to guarantee that they are relevant for models understood in this way. However, none of the examples presented in the literature satisfy all these additional assumptions, which leads to the conclusion that arguments from scientific practice based on these examples do not undermine the interpretative principle that different symmetry-related models represent the same possible world. An important ingredient of my argumentation is the distinction between implicit and explicit modes of representing in physics; symmetry-related models understood as representing subsystems are in some contexts physically inequivalent only because they represent implicitly some physical object (associated with a reference frame).

AGPhil 1.3 Mon 12:00 AGPhil-H14

A new view of the history of electromagnetic theory. An alternative formulation to Maxwell — •antonino drago — via Benvenuti 3, 56011 Calci, Italy

The exceptional role played by electromagnetic theory within the history of classical physics is stressed and characterized. The notion of incommensurability between different approaches explains why this case-study constitutes a hard subject for the historians of physics and hence why in the past they were content to consider as the decisive event of this history the birth of Maxwell equations. The usual historical account on the completion of electromagnetic theory is contested; electromagnetic theory has to be considered a completed theory not before the requirement of a symmetric explanation of electromagnetic induction between moving bodies was fulfilled. Actually in a retrospective view from the introduction of Lorentz*s group some scholars have suggested new foundations of electromagnetism. Among these new foundations I recognize in a recent one (Diener et al. 2013) a substantial anticipation of an alternative formulation to Maxwell-Hertz-Lorentz one. I improve it in a formal way according to an interpretation of the foundations of the electromagnetism as constituted by the choices on two basic dichotomies: one about two kinds of mathematics, and another about two kinds of logic.

AGPhil 1.4 Mon 12:30 AGPhil-H14

The Spatially of the Universe in Einstein*s paper *Geometry and Experience* — •Taimara Passero — University of São Paulo, São Paulo, Brazil.

The aim of this talk is to present and discuss the role of Euclidean geometry in Einstein*s argument concerning the spatially of the Universe. Albert Einstein analyzes this topic in the paper *Geometry and Experience*, given as a public address on January 27, 1921 at the Prussian Academy of Sciences. In the first part of his paper, Einstein distinguishes between *purely axiomatic geometry* and *practical geometry*. In the second part, Einstein discusses whether the Universe is spatially finite or not. He presents a beautiful argument to illustrate the theory of a finite Universe by means of a mental picture using his notion of practical geometry. To obtain this, Einstein goes from the thinking and visualization offered by Euclidean geometry to acquire a mental picture of the spherical geometry. This process leads him to conclude that *the human faculty of visualization is by no means bound to capitulate to non-Euclidean geometry*.

AGPhil 2: History and Philosophy of Gravity

Time: Monday 16:15–18:00 Location: AGPhil-H14

Invited Talk AGPhil 2.1 Mon 16:15 AGPhil-H14

To G or not to G: J. H. Poynting and the gravitational constant in the 19th century — •Isobel Falconer — University of St Andrews, UK

The increasing precision of gravitational measurement is sometimes given as a reason for the acceptance of the gravitational constant, G, in the late 19th century. However, as late as the 1890s, John Henry Poynting, the doyen of British workers on gravitation, persistently refused to cast measurement of the gravitational constant as his experimental aim; he preferred to present it as measurement of the mean density of the Earth. Despite his detailed analysis, in his Adams Prize Essay of 1894, of the improvements in experimental method that were enabling ever more precise measurement, he similarly interpreted all previous measurements as of the mean density of the earth. His reservations about G alert us to the mathematical, physical and metaphysical interpretative work involved in the shift that had occurred during the previous 100 years, from expressing the laws of physics as ratio equations to expressing them as functional relationships between algebraic symbols that denoted the numerical values of physical quantities.

This talk will encompass gravitational work in Britain, France, and Germany, in exploring the introduction of G into physics and some of the questions raised by Poynting's reservations about G as a useful physical construct.

AGPhil 2.2 Mon 17:00 AGPhil-H14

The Renaissance of General Relativity in the 1960s — •Dennis Lehmkuhl — Lichtenberg Group for History and Philosophy of Physics, Institute of Philosophy, University of Bonn

This talk will focus on the development of new mathematical methods during the 1960s that allowed for new ways of understanding the solution space of the Einstein equations, and subsequently for new avenues to work on cosmology. The focus will be on the classification schemes for vacuum solutions developed by Petrov, Penrose, and Pirani, as well as the global methods developed during the work on the singularity theorems by Penrose and Hawking. Building on this, the talk will outline how both the singularity theorems themselves and the new methods developed in proving them have influenced subsequent work on cosmology.

AGPhil 2.3 Mon 17:30 AGPhil-H14

Holistic Eliminative Reasoning for Astronomy and Astrophysics — •Shannon Sylvie Abelson — Indiana University Bloom-

ington, IN, United States

I argue that a promising epistemology for astronomy and astrophysics (A&A) involves a certain kind of eliminative reasoning. Unlike the traditional conceptions of such reasoning that propose to eliminate rival theories or models based upon quality of evidence, I build upon work by Paul Horwich (1982), Patrick Forber (2011), and Elisabeth Lloyd (2013; 2015) to argue that it is particular model assumptions (variables, parameters, etc.) that are weighed and eliminated. Rather than a veridical comparison between theory predictions and individual observational results, holistic eliminative reasoning has a web-like structure. Elimination is the end result of a multi-step reasoning program that holistically evaluates the introduction of a proposed assumption into the state space of previously accepted evidence. In particular and where possible, model assumptions should cohere with our well-confirmed pictures of dynamical processes and the mechanisms that underlie them. Holistic elimination then becomes a project of capturing dynamical accuracy. These ideas have been explored in the context of biology and genetics (see Lloyd, Lewontin, and Feldman (2008), Forber (2011) and Ratti (2015)), but have not been extended to A&A. I outline how this epistemic framework can be applied to competing dynamical pictures of the mechanisms and conditions underlying the evolutionary histories of black holes, including gas accretion, intermediate mass black hole mergers, and direct-collapse black hole models.

AGPhil 3: Black Holes I

Time: Tuesday 11:30–13:00 Location: AGPhil-H14

AGPhil 3.1 Tue 11:30 AGPhil-H14

No membrane at the black hole horizon? — •Marco Sanchioni — Via Timoteo Viti 10, Department of Pure and Applied Sciences, University of Urbino, Italy

Since the discovery of Hawking radiation (Hawking, 1976), it has been ac- accepted among physicists, and later on also by philosophers (Wallace, 2018), that black holes are thermodynamic objects in the total sense. To have a statistical mechanical underpinning of black hole thermodynamics, as is the case for thermodynamics of ordinary things, it has been argued that a quantum membrane should be posited at the black hole horizon. This paper is an inquiry on the status of the quantum membrane paradigm in light of recent theoretical results on black hole physics obtained within the research program of semiclassical gravity (Penington et al., 2019; Almheiri et al., 2020) and ultimately grounded on the ER=EPR proposal (Maldacena and Susskind, 2013). However, we do not discuss the problematic aspect of such a research program, which would be a project on its own, and our result is thus conditional to its validity. In particular, the paper starts an investigation on the picture of black holes that underlies these new calculations. The main result of this paper is that, within the central assumption on the validity of semiclassical gravity, the quantum membrane paradigm should be abandoned.

AGPhil 3.2 Tue 12:00 AGPhil-H14

Stellar gravitational collapse, singularity formation and theory breakdown — •Kiril Maltsev — Heidelberg Institute for Theoretical Studies / University of Heidelberg

A critical examination of the main physical arguments against the prediction of gravitational singularity formation in stellar core collapse is given, restricted in scope to a historically oriented survey of the decades spanning in between the Schwarzschild 1916 solution and the Penrose 1965 theorem. We first review the 3 definitions (missing point(s), infinite curvature, and geodesic incompleteness) of what a singularity is, and argue that its prediction is problematic for GR, indicating breakdown of Lorentzian geometry, only insofar as infinite curvature is concerned. In contrast, geodesic incompleteness is its innovating hallmark, which is not meaningfully available in Newtonian gravity formulations (infinite density, and infinite gravitational force) of what a gravitational singularity is. The Oppenheimer-Snyder 1939 solution derives the formation of locally infinite curvature and of incomplete geodesics, while Penrose's 1965 theorem concerns the formation of incomplete (null) geodesics only. We assess as the most robust curvature pathology formation counter-argument Markov's derivation of an upper bound on the quadratic curvature invariant from a ratio of natural constants, in connection with Wheeler's conjecture that the Planck scale is ultimate. Finally, we recall Landau's objection to fermionic infinite density point mass formation, which still provides strong reasons to believe that by the least an intermediate state towards the final fate of gravitational collapse must be a bosonic configuration.

AGPhil 3.3 Tue 12:30 AGPhil-H14

Alice meets Bob! or: The association of infinity and finiteness within the Schwarzschild metric — •René Friedrich — Strasbourg

The Schwarzschild metric is the basic description of a gravitational field, but it is more than that: It provides us with some hints about the way how the universe is working. One main feature of the Schwarzschild metric is the association of finite and infinite time structures, and it includes even proposals for the solution of the so-called "information paradox" of black holes and the supposed "breakdown of general relativity" near singularities.

AGPhil 4: Gravitational and Electromagnetic Waves

Time: Tuesday 14:00–15:45 Location: AGPhil-H14

Invited Talk AGPhil 4.1 Tue 14:00 AGPhil-H14

Hypothetical Waveforms and Unmodeled or Pipeline Searches in Gravitational Wave Astronomy — •Lydia Patton — Virginia Tech, Blacksburg, Virginia, USA

The multiple theoretical and instrumental advances in gravitational wave astronomy (GWA) have allowed for the construction of an increasingly flexible platform for discovery. This paper will investigate novel research methods being constructed on the ground in GWA. It will begin by evaluating the comparison of and contrast between two methods of analysis: the construction of waveforms that incorporate hypothetical parameters for new searches (EOB and novel extended EOB methods), and the use of unmodeled and pipeline-based searches of existing data. In both cases, varying hypothetical assumptions or models allows for more flexible, broad search methods. The question then is how to move from the broader a priori models to the detection of an event. We will examine several recent papers to reconstruct how these broader methods can be used to support novel detection, and examining how search and detection methods work together in this context.

AGPhil 4.2 Tue 14:45 AGPhil-H14

What Gravitational Waves Really Teach Us about Energy — •Samuel Fletcher — University of Minnesota, Twin Cities, Minneapolis, USA

Gravitational wave solutions to the Einstein field equation of general relativity are commonly regarded as examples proving how gravity in general relativity transmits energy from a source body to a distant body. The famous 1955 Feynman sticky bead thought experiment illustrates the reality of this phenomenon by imagining two beads generating heat in a rod on which they slide with friction, due to their changing proper distance in the presence of the waves. I argue that while this lesson is not entirely wrong, it is much too simplistic. It does not reconcile its conclusion with the fact that conservation of local energy-momentum, in the sense that appears in the field equation, prevents energy transmission across a vacuum. Thus "energy transmission" must employ a different concept of energy, raising the possibility of pluralism with regard to the energy concept. Another (compatible) possibility is that gravitational waves, rather than transmitting energy, facilitate the transformation between different types or stores

of energy locally. Key to these possibilities is analysis of the Weyl tensor. Time permitting, I discuss these possibilities' implications for a re-evaluation of the scope of Mach's Principle, the idea that the distribution of matter determines the geometry of spacetime.

AGPhil 4.3 Tue 15:15 AGPhil-H14

Absorbing the Arrow of Electromagnetic Radiation — Mario Hubert and •Charles Sebens — California Institute of Technology, Pasadena, CA, USA

We argue that the asymmetry between diverging and converging electromagnetic waves is just one of many asymmetries in observed phenomena that can be explained by a past hypothesis and statistical postulate (together assigning probabilities to different states of matter and field in the early universe). The arrow of electromagnetic radiation is thus absorbed into a broader account of temporal asymmetries in nature. We give an accessible introduction to the problem of explaining the arrow of radiation and compare our preferred strategy for explaining the arrow to three alternatives: (i) modifying the laws of electromagnetism by adding a radiation condition requiring that electromagnetic fields always be attributable to past sources, (ii) removing electromagnetic fields and having particles interact directly with one another through retarded action-at-a-distance, (iii) adopting the Wheeler-Feynman approach and having particles interact directly through half-retarded half-advanced action-at-a-distance. In addition to the asymmetry between diverging and converging waves, we also consider the related asymmetry of radiation reaction.

AGPhil 5: Black Holes II

Time: Tuesday 16:15–18:15 Location: AGPhil-H14

Invited Talk AGPhil 5.1 Tue 16:15 AGPhil-H14

Portrait of a Black Hole: Objectivity and the Imaging of M87* by the Event Horizon Telescope — •Peter Galison — Black Hole Initiative, Harvard University, Cambridge, Mass. United States

In thousands of atlases depicting the working objects of scientific inquiry–from skeletons, clouds, and plants, to crystals, elementary particles, and stars, physicians and scientists across many domains worked out what counted as scientific objectivity. This long-term history, with its various takes on what a reliable image should be, converged in the yearslong struggle of the Event Horizon Telescope (EHT) to produce a picture of a black hole robust enough to make public. As a member of the imaging group, I was part of this effort–offering an occasion for the direct interaction of philosophy and physics as we in the collaboration thought through the different forms of images in consideration: ideal images, mechanically objective images, and expert judgment images. On April 10, 2019, the team released the first image of a black hole, an image viewed within a very few days by more than a billion people. This is a talk about how the EHT team of some 200 scientists came to assess as objective the glowing, crescent-like ring around the supermassive black hole M87*.

Invited Talk AGPhil 5.2 Tue 17:00 AGPhil-H14

When is a black hole spacetime "as large as it can be"? — •Juliusz Doboszewski — University of Bonn (Lichtenberg Group for History and Philosophy of Physics) — Black Hole Initiative, Harvard University

Multiple conditions have been proposed in the literature aiming at capturing the idea that a general relativistic spacetime is "as large as it can be". I will consider some of them in the context of particular black hole spacetimes, including standard solutions, regular black holes, and fully evaporating black holes. The emerging landscape is not just subtle but also surprising. Interesting connections arise between these issues and certain versions of the cosmic censorship conjecture. Philosophical consequences involve a notion of a time machine and impact the viability of metaphysical principles such as the principle of sufficient reason.

AGPhil 5.3 Tue 17:45 AGPhil-H14

A Role for the 'Fauxrizon' in the Semiclassical Limit of a Fuzzball — •Mike D. Schneider — University of Illinois at Chicago, Chicago IL, USA

Recent remarks by Huggett and Matsubara ("Lost Horizon? - Modeling Black Holes in String Theory", 2021) indicate that a 'fauxrizon' (portmanteau of 'faux horizon'), such as is relevant to understanding astrophysical black holes according to the fuzzball proposal within string theory (and perhaps in firewall proposals, more generally), might ultimately solve the familiar black hole evaporation paradox. I clarify, with general upshots for quantum gravity research, some of what this suggestion would amount to: namely, identification of intertheoretic constraints on global spacetime structure in semiclassical models of fuzzballs.

AGPhil 6: Foundations of Gravity

Time: Wednesday 14:00–16:15 Location: AGPhil-H14

Invited Talk AGPhil 6.1 Wed 14:00 AGPhil-H14

Spacetime Conventionalism Revised: Tidal Forces and Weyl Curvature — •Karim Thébault and Ufuk Tasdan — University of Bristol

Our goal in this paper is to better understand the physical interpretation of tidal forces and Weyl curvature in general relativity by considering novel articulations of thesis of 'spacetime conventionality'. We will first consider a specific rendition of the conventionality thesis in the context of the debates regarding the status of energy conservation and the effects of tidal forces. This will then, in turn, motivate a discussion of the two most physically important forms of curvature - Ricci and Weyl - which can be isolated in general relativity, focusing upon the extent to which such formal distinction may be employed to articulate an entirely non-conventional analysis of the causal origin of tidal forces. We next consider the idea that the Ricci vs. Weyl curvature distinction can be further deployed to anchor a conventionalism-proof distinction between 'pure geometric' Weyl curvature and 'matter-energy-coupled' Ricci curvature. To foreshadow our main conclusion, what we find is that the complex of couplings between Ricci curvature and stress-energy, via the Einstein equation, and Weyl and Ricci curvature, via the Bianchi identity, leads us away from such attractively clean distinctions. Finally, we will outline some open questions and possible lines of future work as an envoi.

AGPhil 6.2 Wed 14:45 AGPhil-H14

Perturbing the hole argument — •John Dougherty — Munich Center for Mathematical Philosophy, LMU Munich

The recent literature on the hole argument has seen a reappraisal of its mathematical aspects. According to this reappraisal, as Halvorson and Manchak succinctly put it, there are two mathematical claims that might be thought to underwrite the hole argument, and neither in fact does. The claim that there are isomorphic but distinct Lorentzian manifolds is trivial, and the claim that there is a diffeomorphism that spoils the determinism is false. In this paper I argue that at least one version of the hole argument is underwritten by a third mathematical claim: that the configuration space of general relativity is "natural", which is to say that it depends functorially on the base manifold. This claim is nontrivial in the sense that it is not true in many theories, such as those containing spinor fields. But it is true in a tensorial theory like general relativity. And it underwrites the version of the hole argument that analogizes general covariance to the "gauge" nature of general relativity as it is used in perturbative contexts such as calculations concerning gravitational radiation and semiclassical effects.

AGPhil 6.3 Wed 15:15 AGPhil-H14

A Case for Further Inquiry into Spin and Gravity — •Zachary Hall — Stanford University

I present an undiscussed instance of the tension between the background-dependent formalism of quantum theory and the background-independence of classical general relativity. Notably, the issue is subject to empirical testing, for which reason it also holds interest for those who eschew background-independent methods or interpretations in gravitational theory. The issue is that the representations of spin-states in quantum theory depend prima facie on an embedding of those states in a flat background geometry. This raises the question of whether we should continue using a background geometry in representing spin-states in a world with gravitation. The empirical questions are apparent with knowledge of how experimentalists align (a) preparing and measuring devices of spin-states undergoing no non-gravitationally induced precession and (b) measuring devices in multiple wings of experiments on spin-entangled states. The aligning procedure is operational, meaning that the question of how the aligned measurement axes should be represented in the spacetime has been so-far uninvestigated. While some may be inclined to think that they should be represented with the Christoffel symbols and path information of the system, it is not clear that this is the only acceptable solution a priori.

AGPhil 6.4 Wed 15:45 AGPhil-H14

On the relation between Unruh and Hawking radiation — Ignacio Araya[1] and •Siddharth Muthukrishnan[2] — [1]ICEN, Universidad Arturo Prat, 1110939, Iquique, Chile — [2]HPS, University of Pittsburgh, Pittsburgh, PA, USA 15260

It is often said that Hawking radiation just is a kind of Unruh radiation. In this work, we clarify the ways in which Hawking radiation can and cannot be seen as a kind of Unruh radiation. Hawking radiation is analogous to Unruh radiation in that the Schwarzschild metric near the horizon is isomorphic to the Rindler metric, which allows us to employ the derivation of Unruh radiation to obtain Hawking radiation. But the isomorphism is restricted to the near-horizon region. This observation leads to the way in which Hawking radiation is not a kind of Unruh radiation: the analogy between them is not due to the equivalence principle. One might think that because observers near – but outside of – the horizon of a black hole are equivalent, via the equivalence principle, to an accelerating observer in empty space, Hawking radiation observed by a hovering observer outside a black hole just is the kind of Unruh radiation that an accelerating observer in empty space would see. We argue that this is an incorrect way of thinking of Hawking radiation. Indeed, this would imply that hovering observers outside gravitating bodies that are not black holes – such as stars and planets – would also observe Unruh/Hawking radiation, and this is not the case. Throughout we emphasize the ways in which Hawking and Unruh radiation can be seen as varieties of geometric radiation, i.e., radiation generated by the structure of a metric containing horizons.

AGPhil 7: Symmetries and Principles

Time: Wednesday 16:15–18:30 Location: AGPhil-H14

Invited Talk AGPhil 7.1 Wed 16:15 AGPhil-H14

On an inferential role of spacetime in particle physics — •Tushar Menon — Faculty of Philosophy, University of Cambridge, Sidgwick Avenue, Cambridge CB3 9DA

Here is a plausible claim from particle physics: the states in a gauge multiplet correspond to (possibly distinct) configurations of the same type of particle. Take, for example, the spin-up and spin-down states (with respect to some axis) of an electron in an SU(2) multiplet. But surely, one might worry, not all such formal unifications count. Consider an electron-neutrino doublet, which is also an SU(2) multiplet. It seems less straightforward (or correct!) to consider these two be two states of the same type of particle. But why?

Consider what we might call the Redhead-Weingard thesis: two or more states in a multiplet of the gauge group of a quantum field theory are ontologically unified if they transform into each under the action of a spacetime transformation. The Redhead-Weingard thesis seems to generate the intuitively correct verdict in a number of cases, including the two SU(2) cases presented above. In ordinary relativistic QFTs, it works because the question of what structure counts as spatiotemporal is settled pretheoretically. But this fact conceals a contingent fact that is tacitly assumed across much theorising about spacetime: that spacetime plays the same inferential role regardless of the theoretical framework within which it is employed. The primary goal of this talk is to demonstrate this contingency by discussing how these roles come apart in supersymmetric quantum field theories.

AGPhil 7.2 Wed 17:00 AGPhil-H14

Cassirer and Weyl on the Constitutive Structure of Physical Theory — •Noah Stemeroff — University of Bonn

Though representative of divergent philosophical and intellectual traditions, both Ernst Cassirer and Hermann Weyl held that a given mathematical framework must always serve as a necessary presupposition of scientific thought (within a broadly Kantian position). Neither thought that this framework was fixed, a priori, as it was for Kant. However, in allowing for the revision of the constitutive framework of scientific thought, both were forced to face the spectre of a pervasive relativism. In response, each suggested that the relativist abolition of the standard of objectivity does not entail the abolition of the difference in value and performance of various scientific theories. On this view, scientific theories do not stand apart in their relation to the world, to be judged solely on their own merits, but rather as part of a progressive series. In this context, Cassirer and Weyl both highlighted the fundamental role that group theory played as a constitutive feature of our understanding of objectivity through the progress of science. In this paper, I will examine the differing views of Cassirer and Weyl concerning the constitutive role of group theory in physical enquiry, and what lessons we can draw from this history concerning modern debates on the methodology of physics.

AGPhil 7.3 Wed 17:30 AGPhil-H14

Naturalness and the Heuristic Role of Scientific Principles — •Enno Fischer — Bergische Universität Wuppertal, Interdisziplinäres Zentrum für Wissenschafts- und Technikforschung

The naturalness principle roughly demands that a theory should not involve independent parameters that are finely tuned. This principle was employed heavily over the last 40 years by theoretical physicists as a guideline for developing theories of beyond the Standard Model physics (BSM). However, since experiments at the Large Hadron Collider (LHC) have not found conclusive signs for new physics, the significance of naturalness arguments has been questioned and it has been suggested that high-energy physics has reached the "dawn of the post-naturalness era."

I argue that an explanation of the current shift in attitude towards naturalness can be given if we acknowledge that the naturalness principle has experienced epistemic support through the theories it has inspired. I argue that the potential coherence between major BSM proposals and the naturalness principle led to an increasing degree of credibility of the principle. The absence of new physics at the LHC has undermined the potential coherence and has led to the principle's current loss of significance. On the basis of this account I assess the heuristic role of naturalness as a guiding principle in high-energy physics and draw some tentative conclusions about the role of principles in the context of scientific progress.

AGPhil 7.4 Wed 18:00 AGPhil-H14

A neo-Kantian approach to the epistemology of the LHC flavour anomalies — •Alex Seuthe — Technische Universität Dortmund

Large scale experiments at the LHC, like the LHCb experiment, seek to answer questions about the fundamental structure of matter and the nature of the cosmos. Since the discovery of the Higgs boson and correspondingly of all predicted particles of the Standard Model, the field is faced with an open horizon for gaining knowledge. In flavour physics, various anomalies in $b \to s\ell^+\ell^-$ decays have been attracting attention in recent years. Although the single measurements are not yet statistically significant for a discovery, the overall picture might hint at possible extensions or modifications of the Standard Model. So far, only little epistemological reflection on the scientific process related to these anomalies has been presented. In my talk, I suggest a first attempt utilizing Ernst Cassirer's concept of science as a series process towards the limit of reality. Here, the experimental anomalies and theoretical explanatory models, including specific models or

model-independent effective theories, stand in an alternating series of cognitions, oriented towards the ideal of reality as a regulative principle.

AGPhil 8: Annual Meeting of the AGPhil

Time: Wednesday 18:30–19:30 Location: AGPhil-MV

Annual Meeting of the AGPhil

AGPhil 9: Quantum Mechanics I

Time: Thursday 11:00–13:00 Location: AGPhil-H14

AGPhil 9.1 Thu 11:00 AGPhil-H14

A Heuristic Route to Nonlinear Quantum Mechanics — •Alireza Jamali — 3rd Floor - Block No. 6 - Akbari Alley - After Dardasht Intersection - Janbazane Sharghi - Tehran - Iran

It is known since Madelung that the Schrödinger equation can be thought of as governing the evolution of an incompressible fluid, but the current theory fails to mathematically express this incompressibility in terms of the wavefunction without facing problem. In this paper after showing that the current definition of quantum-mechanical momentum as a linear operator is neither the most general nor a necessary result of the de Broglie hypothesis, a new definition is proposed that can yield both a meaningful mathematical condition for the incompressibility of the Madelung fluid, and nonlinear generalizations of Schrödinger and Klein-Gordon equations. The derived equations satisfy all conditions that are expected from a proper generalization: simplification to their linear counterparts by a well-defined dynamical condition; Galilean and Lorentz invariance (respectively); and signifying only rays in the Hilbert space.

AGPhil 9.2 Thu 11:30 AGPhil-H14

Evidence for Interactive Common Causes. Resuming the Cartwright-Hausman-Woodward Debate — •Paul M. Näger — University of Münster, Germany

The causal Markov condition (CMC), which is a central principle of causal modelling, requires that conditional on a common cause the correlation between its effects vanishes (the common cause screens off the correlation). Since Salmon (1978) presented the first counterexamples, joined by van Fraassen (1980, 1982) and Cartwright (1988 and many more), there is a debate about whether there are also common causes that fail to screen off (interactive common causes, ICCs), violating the CMC. Since indeterminism is a necessary requirement, the most serious candidates for ICCs refer to quantum phenomena. In her seminal debate with Hausman and Woodward, Cartwright early on focussed on unfortunate non-quantum examples (chemical factory). Especially, Hausman and Woodward's redescriptions of quantum cases saving the CMC remain unchallenged. This paper takes up this lose end of the discussion and aims to resolve the debate in favour of Cartwright's position. It systematically considers redescriptions of ICC structures, including those by Hausman and Woodward, and explains why these are inappropriate, when quantum mechanics (in a dynamic collapse interpretation) is true. It first shows that all cases of purported quantum ICCs are cases of entanglement and then, using the tools of causal modelling, it provides an analysis of the quantum mechanical formalism for the case that the collapse of entangled systems is best described as a causal model with an ICC.

AGPhil 9.3 Thu 12:00 AGPhil-H14

Aristotelian Grounding for GRW's Flash Ontology — •Ryan Miller — University of Geneva, Switzerland

The flash (i.e., event) ontology for the GRW objective-collapse formulation of quantum mechanics (Goldstein et al., 2012) has become popular for maintaining both a primitive ontology in 4D spacetime (Allori et al., 2014; Allori, 2015; Tumulka, 2017) and serious Lorentz invariance (Tumulka, 2009; Petrat & Tumulka, 2014a, 2014b; Tumulka, 2021). Valia Allori's (Allori et al., 2008; Allori, 2016) straightforward reading of this ontology suggests that the flashes are fundamental, grounding both the other elements of the theory and our everyday macro-scale ontology. This view has come under pressure on both points, however: Tim Maudlin (1997, 2010, 2011, 2019) argues that the GRW wavefunction cannot be wholly grounded in the flashes, while Elizabeth Miller (forthcoming) argues that flashes are an inadequate ground for everyday macro-scale ontology.

I suggest resolving these difficulties with the GRW flash ontology by grounding the flashes in entangled macro-objects. On this Aristotelian proposal, macro-objects like Schrodinger's cat maintain the entangled wavefunction that governs their micro-scale powers, realized in flash events. Because entangled particle families flash together (Maudlin, 2011), the density of micro-events will support macro-observations without the GRW parameters departing from observed values (Feldmann & Tumulka, 2012). Neo-Aristotelian grounding is thus attractive for GRW's flash ontology.

AGPhil 9.4 Thu 12:30 AGPhil-H14

Does the weak trace show the past of a quantum particle in an unperturbed system? — •Jonte R Hance[1], John Rarity[1], and James Ladyman[2] — [1]Quantum Engineering Technology Laboratories, Department of Electrical and Electronic Engineering, University of Bristol, Woodland Road, Bristol, BS8 1US, UK — [2]Department of Philosophy, University of Bristol, Cotham House, Bristol, BS6 6JL, UK

We investigate the weak trace method for determining the path of a quantum particle in an unperturbed system. Specifically, looking at nested interferometer experiments, when internal interferometers are tuned to destructive interference, we show that the weak trace method gives misleading results. This is because the methods used experimentally to obtain the weak value of the position operator necessarily perturb the system, hence, in some cases the assumption that weak coupling being equivalent to no coupling is incorrect. Further, even if we assume there is no disturbance, there is no reason to associate the weak value of the spatial projection operator with the classical idea of 'particle presence', especially if it has features which go against the classical ideas associated with a particle being present (i.e. a particle having a single, continuous path). Experiments performed that are claimed to support the interpretation simply show the effects of this coupling acting as measurement, rather than tapping into the underlying reality of what happens in a quantum system when no-one is looking.

AGPhil 10: Quantum Mechanics II

Time: Thursday 14:00–16:00 Location: AGPhil-H14

AGPhil 10.1 Thu 14:00 AGPhil-H14

How to distinguish between indistinguishable particles — •Michael te Vrugt — Institut für Theoretische Physik, Center for Soft Nanoscience, Philosophisches Seminar, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany

A long and intense debate in philosophy is concerned with the question whether there can be haecceistic differences between possible worlds, that is, nonqualitative differences that only arise from different de re representations. According to haecceitism, it can give rise to a different situation if the positions of two qualitatively identical parti-

cles are exchanged, while according to anti-haecceitism, this is not the case. It has been suggested that classical statistical mechanics might provide evidence for one of these positions. However, most philosophers of physics argue that it does not. In this work [1], I show that order-preserving dynamics, a novel method from statistical mechanics developed for the description of nonergodic systems, changes this situation: It is intrinsically haecceistic and makes different experimental predictions than non-haecceistic alternatives. Thereby, it provides an empirical argument for the existence of modality de re.

[1] M. te Vrugt, British Journal for the Philosophy of Science (forthcoming), https://doi.org/10.1086/718495

AGPhil 10.2 Thu 14:30 AGPhil-H14

Who's afraid of retrocausation? A retrocausal explanation of Bell-type correlations — •Matthias Ackermann — Leibniz University Hanover

Bell's theorem is commonly understood to have demonstrated that the observed statistics in quantum experiments rule out a 'locally causal' explanation. However, almost always the temporal aspect of 'local causality' seems to be implicitly assumed, rather than explicitly defined. Recent work by Wharton and Argaman (2020) does just that and with it offers a retrocausal framework that accounts for the correlations at the cost of an explicit relaxation of the usually implicit arrow-of-time—thus, the argument goes, operationally saving Bell-compatible locality. This work assesses their proposal based on the central aspects of causal modelling (Pearl, 2009) and an influential no-go theorem by Wood and Spekkens (2015). Taking seriously the relaxation of the standard past-to-future description of physical systems, one can defend causal fine-tuning from being deemed 'unnatural' (Wood and Spekkens, 2015) or 'unsatisfactory' (Allen et al., 2017). Although Wharton and Argaman's (2020) retrocausal model indeed does fall victim to fine-tuning, this is due to an assumed underlying symmetry. The main finding is that taking these underlying symmetry considerations seriously lets one reasonably entertain the possibility that causes and signals do not necessarily co-occur. It is concluded that the framework of classical causal modelling is too restrictive of a framework to be home to and therefore to capture the notion of retrocausality.

AGPhil 10.3 Thu 15:00 AGPhil-H14

Configuration Space Realism and Fundamentality — •Gabrielle Kerbel[1] and Nina Emery[2] — [1]University of Michigan — [2]Mount Holyoke College

The central question of quantum ontology is: what does the wavefunction represent? According to configuration space realism, the wavefunction represents a field (the 'wavefunction field') in a high-dimensional space (what we call 'cf-space'). According to the standard version of configuration space realism, which we call configuration space fundamentalism, the wavefunction field and cf-space are fundamental. We present a novel version of configuration space realism, called configuration space non-fundamentalism, according to which the wavefunction field and cf-space are non-fundamental. Instead, the wavefunction field and cf-space depend on three-dimensional space and the entities therein. We argue that configuration space non-fundamentalism should be taken at least as seriously as configuration space fundamentalism. Along the way we show how choosing between these different versions of configuration space realism will encourage metaphysicians and philosophers of physics alike to confront significant questions about the structure of grounding relations, the importance of locality and separability, and the nature of supervenience and scientific explanation.

AGPhil 10.4 Thu 15:30 AGPhil-H14

Change and Time in Quantum Mechanics — •Brittany Gentry — Utah State University, Logan, USA

While it is apparent that leading physical theories such as Relativity Theory and standard interpretations of Quantum Mechanics do not posit a real, or fundamental, time, the search for real time persists. One reason for continuing to posit real time is the concern that time is necessary to change. Examples of this concern as well as confusing claims that may lead others to that concern abound in philosophy of physics, even from physicists who agree that real time is unnecessary to physical theories. To address that concern, this paper argues that one way to separate time and change is to understand time as a construct that we use to slice up 4-dimensional Hilbert space into 3-dimensional space for the purpose of further distinguishing differences in the basic stuff occupying Hilbert space–namely, particles. On such a view, changes are the differences in positions that we observe in the stuff of Hilbert space and time is a construct that we sometimes place on this space to articulate these differences–and this conception of our QM models allows us to conceive of changes in a way that is independent of time. Time is a helpful feature of the model that we apply at certain levels, but not essential to the existence of the changes that we study. It leaves unaddressed the question of whether changes are real or apparent. However, this explanation makes progress in tidying up concerns regarding time in QM by removing the confusions surrounding the relationship between time and change.

AGPhil 11: Time and Temperature

Time: Thursday 16:15–18:45 Location: AGPhil-H14

AGPhil 11.1 Thu 16:15 AGPhil-H14

Taking seriously the problem of time of quantum gravity — •Alvaro Mozota Frauca — Autonomous University of Barcelona

In this paper I raise a worry about the most extended resolutions of the problem of time of canonical quantizations of general relativity. The reason for this is that these resolutions are based on analogies with deparametrizable models for which the problem can be solved, while I argue in this paper that there are good reasons for doubting about these resolutions when the theory is not deparametrizable, which is the case of general relativity. I introduce an example of a non-deparametrizable model, a double harmonic oscillator system expressed by its Jacobi action, and argue that the problem of time for this model is not solvable, in the sense that its canonical quantization doesn't lead to the quantum theory of two harmonic oscillators and the standard resolutions of the problem of time don't work for this case. I argue that as general relativity is strongly analogous to this model, one should take seriously the view that the canonical quantization of general relativity doesn't lead to a meaningful quantum theory. Finally, I comment that this has an impact on the foundations of different approaches to quantum gravity.

AGPhil 11.2 Thu 16:45 AGPhil-H14

quantum gravity and time's arrow: why primitivism should leave the floor to (local) reductionism — •luca gasparinetti — Venice, Italy

According to some primitivist approaches about the debate on time's arrow, spacetime is characterized by an intrinsic and global anisotropy of time, i.e., the temporal direction is a primitive and no further analyzable feature of the universe's geometry (Earman 1974 and Maudlin 2007). However, in several approaches to quantum gravity (e.g., causal set theory, loop quantum gravity, string theory), most philosophers of physics, e.g., Huggett (2021), Le Bihan (2021), Wüthrich (2018), state that spacetime disappears at the fundamental level and emerges in some sense from a non-spatiotemporal structure. Thus, the following question arises: given the disappearance of spacetime from the fundamental structure, what are the consequences for the primitivist approach about time's arrow?

In this paper, I argue that primitivism about time's arrow is seriously challenged by what quantum gravity theorists state about spacetime. More specifically, since spacetime is emergent, the direction of time, if it exists, reduces on a more fundamental asymmetry. It follows that if time's arrow is not primitive, the primitivist approach is false in the context of a theory of quantum gravity. Hence, I conclude that quantum gravity theorists have at their disposal only (local) reductionism, i.e., time's arrow is an extrinsic and, local or global, anisotropy of time.

AGPhil 11.3 Thu 17:15 AGPhil-H14

On the Status of Temperature and Thermodynamics in Relativity — •Eugene Y. S. Chua — University of California San Diego, La Jolla, CA

The project to understand black holes thermodynamically (i.e. black

hole thermodynamics) was motivated by how stationary black holes can be characterized by laws analogous to the laws of classical thermodynamics. Taking this analogy seriously as evidence that black holes are thermodynamical seems to require that thermodynamics be relevant in the large-scale relativistic regime, viz. that there is a relativistic thermodynamics to speak of. However, an unresolved debate from the 1960s over the (lack of a) canonical Lorentz transformation for a central thermodynamic concept - temperature (and heat) - undermines this very assumption by asking whether thermodynamics could be relativized at all. By examining this debate, I argue that temperature, like absolute simultaneity, is not relativistic. We can readily judge simultaneity within a frame, just as co-moving observers can readily discern a system's temperature. However, the debate suggests there is no fact of the matter about the temperature of a moving object, just as there is no absolute sense that two objects moving relative to one another are simultaneous with each other. This pushes back against the idea that classical thermodynamics should be extended into the relativistic regime. The upshot for black hole thermodynamics: the thermodynamical analogy should not be taken too seriously.

AGPhil 11.4 Thu 17:45 AGPhil-H14

The physical reality of a directed time — •Grit Kalies — HTW University of Applied Sciences, Dresden, Germany

Irreversibility has occupied philosophers and physicists for centuries. While quantum mechanics and special and general relativity interpret processes as reversible, thermodynamics describes every macroscopic process as irreversible. This divergence is called "Paradox of Time" [1].

In the 19th century, Max Planck was searching for a genuine irreversible microscopic process and refused to accept Ludwig Boltzmann's purely statistical interpretation of the second law of thermodynamics, which does not describe irreversibility at the quantum level [2]. Later, Boltzmann's interpretation was accepted.

Recent studies [3-7] show that Boltzmann and Clausius could not yet formulate the second law comprehensively due to the limited data available. As a result, physics was founded on symmetry principles. And yet: it exists, the irreversible process at the quantum level. The second law of thermodynamics can be further developed and understood as a fundamental law of nature, i.e. time symmetry is excluded.

[1] I. Prigogine, I. Stengers: Das Paradox der Zeit, Piper, München, Zürich, 1993; [2] L. Boltzmann, Sitzungsber. kaiserl. Akad. Wiss. Wien 66 (1872) 275-370; [3] G. Kalies: Vom Energieinhalt ruhender Körper, De Gruyter, Berlin, 2019; [4] G. Kalies, Z. Phys. Chem. 234 (2020) 1567-1602; [5] G. Kalies, Z. Phys. Chem. 235 (2021) 849-874; [6] G. Kalies: Back to the roots: The concepts of force and energy, Z. Phys. Chem. (2021) 1-53, DOI: 10.1515/zpch-2021-3122; [7] G. Kalies: On the unification of mechanics and thermodynamics, submitted (2021).

AGPhil 11.5 Thu 18:15 AGPhil-H14

Breaking Symmetry in Scientific Explanation — •Benjamin Faltesek — Texas A&M University, College Station, TX, USA

The causal asymmetry problem plagues argument-form accounts of scientific explanation such as Kitcher*s unificationism. Such accounts require explanations to be sound and have some additional property; for Kitcher, the additional property is unifyingness: theory A is more unifying than theory B iff A explains more phenomena than B using as many or fewer ultimate facts and argument forms than B.

The causal asymmetry problem is that such accounts cannot distinguish good from bad explanations when there is an equation among the premises. An argument pattern that explains the length of a building*s shadow from the building*s height, for instance, can equally well explain the building*s height from the length of its shadow. Each explanation is equally sound and unifying, but the latter goes against causal dependence.

I propose a solution without relying on causal intuitions. For any explanation with an equation premise, the equation has a term E such that if E takes the value 0, the system at issue in the explanation cannot exist. This is not true of the other terms C. E represents the effect of the system, the phenomenon to be explained. I provide a schema for constructing explanatory argument forms that avoids the causal asymmetry problem by conditionalizing equations on the Cs.

AGPhil 12: Processes, Events and Time

Time: Friday 11:00–13:00 Location: AGPhil-H14

AGPhil 12.1 Fri 11:00 AGPhil-H14

Die Erfindung der Zeit — •Helmut Hille — Fritz-Haber-Straße 34, 74081 Heilbronn

Die Zeit ist nicht nur Physikern und Philosophen ein Rätsel, das sie in immer neuen Anläufen zu entschlüsseln versuchen. Richtig ist, sie als Dimension zu bezeichnen, nämlich die des (zeitlichen) Nacheinanders, neben den 3 räumlichen Dimensionen des Neben-, Über- und Hintereinanders. Das räumliche Erleben geschieht dadurch, dass das Gehirn die 2-dimensionalen Bilder der Wahrnehmung * es gibt keine anderen! * so überlagert, dass ein räumlicher Eindruck entsteht. Gleiches geschieht mit den gerichteten Schallwahrnehmungen der beiden Ohren beim Stereohören. So wie ferner das Gehirn das Farbensehen zur besseren Unterscheidung von Objekten erfunden hat, wo gar keine Farben sind, so hat es auch das Zeiterleben erfunden, obwohl alle Dinge nur in der Gegenwart existieren, die zeitlos ist. Jeder Moment ist so gegenwärtig wie jeder andere, Die Rolle des Beobachters in allen Wahrnehmungen kann also gar nicht überschätzt werden. Trotzdem wird sie so wenig verstanden, weil das Gehirn das so will. Es möchte ungestört arbeiten können, weshalb es sich bedeckt hält. Es kann hier mit Hilfe der Neurophilosophie* gezeigt werden, wie es zum Zeiterleben kommt, das für unser Menschsein unverzichtbar ist. *Verbindung von Ergebnissen der Hirnforschung mit philosophischen Fragen

AGPhil 12.2 Fri 11:30 AGPhil-H14

Alfred North Whitehead und die Philosophiegeschichte — •Christian Thomas Kohl — Daumstr.105, 13599 Berlin

Jede Philosophie bezieht ihre Farbe von der geheimen Lichtquelle eines Vorstellungshintergrunds, der niemals ausdrücklich in ihren Gedankenketten auftaucht

Vorstellungshintergrund. Ein Vorstellungshintergrund kann auch aus Vorurteilen und oberflächlichen Klischees bestehen oder aus einer Mischung von allem. In der Mathematikgeschichte ist manchmal von Axiomen oder von Grundsätzen die Rede. Als Physikhistoriker wende ich mich vor allem der Geschichte der Physik zu, meinem eigenen Hintergrund. Innerhalb einer physikalischen Theorie ist eine These ein Satz, der bestätigt werden soll.

AGPhil 12.3 Fri 12:00 AGPhil-H14

Events, structures and processes — •Hans Jürgen Pirner — Institut für Theoretische Physik, Heidelberg

What are events? To answer this question, the talk analyzes physical and mental events. A singular event like the heat catastrophe of 2003 becomes meaningful when one relates it to the evolution of the climate. Structures emerge when events repeat themselves or when the experimenter makes them repeatable. In this way, physicists discovered the standard model of elementary particles, the cosmic microwave radiation and condensates of ultracold atoms. In general, events are parts of processes i.e. chains of events as will be shown for the birth of galaxies. In the university, researchers in separate faculties investigate physics and philosophy. This talk attempts to bridge this gap. By using the concept of event one understands reality from both perspectives. The author discusses Whitehead's philosophy and gives examples of how to structure events. Phenomena in the brain or in artificial intelligence show the interaction of nature and mind. Paradoxical results in decisions and in cognition interpret the connection we are looking for. If events are fundamental, a deep insight into the interaction of nature and mind opens up.

AGPhil 12.4 Fri 12:30 AGPhil-H14

Heisenberg*s loop of knowledge and a mathematical model of the *thing in itself*: Circles theory — •Mohammed Sanduk — Department of Chemical and Process Engineering, University of Surrey, Guildford, GU2 7XH, UK

In philosophy of microscopic physics, Heinsberg introduced two concepts. The first concept is for the *nature in itself* and *nature as appears*. The observation can be regarded as a transformation from *nature in itself* to *nature as appears*. In the second one, Heins-

berg, unlike Kant, opened a possibility to have a mathematical model for the *thing in itself*. This process may be a type of another transformation. It is a transformation from observable nature to nature in itself. These two concepts may form a loop of knowledge in microscopic nature. In an attempt to explain the complex harmonic oscillator (microscopic thing as appears), this loop has been adopted. This attempt led to develop a theory *circles theory*. This theory is not in quantum mechanics. The theory shows the process of the two transformations. The wave function has a form of complex harmonic oscillator. In spite of the fact that this theory is not in quantum mechanics, the results of transformations show a good similarity to relativistic quantum mechanics.