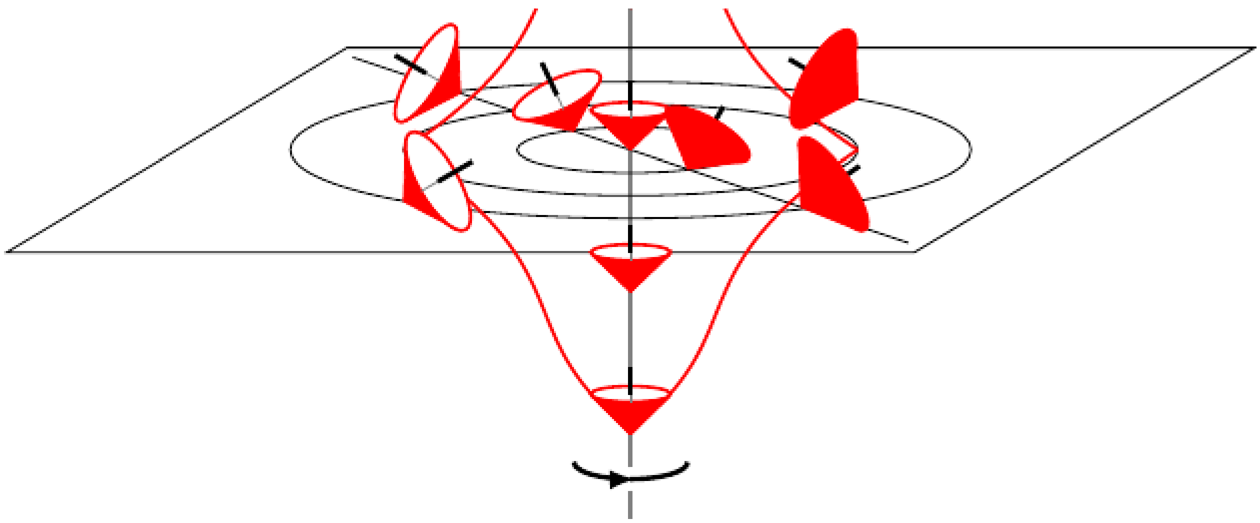
Logic, Relativity and Beyond
3rd International Conference

Honoring Hajanl Andreká's 70th Birthday

23 August – 27 August 2017

$$\mathfrak{M}_{\text{Gödel}} \models \mathit{GenRel}$$

$$\mathit{GenRel} \not\models \neg\exists \mathit{CTC}$$



Volume of Abstracts

Alfréd Rényi Institute of Mathematics 2017

Logic, Relativity and Beyond
3rd International Conference

August 23-27, Budapest 2017

There are several new and rapidly evolving research areas blossoming out from the interaction of logic and relativity theory. The aim of this conference series, which take place once every 2 or 3 years, is to attract and bring together mathematicians, physicists, philosophers of science, and logicians from all over the word interested in these and related areas to exchange new ideas, problems and results. The spirit of this conference series goes back to the Vienna Circle and Tarski's initiative Logic, Methodology and Philosophy of Science. We aim to provide a friendly atmosphere that enables fruitful interdisciplinary cooperation leading to joint research and publications. This 3rd conference is also dedicated to honoring Hajnal Andréka's 70th birthday.

Topics include (but are not restricted to):

- Special and general relativity
- Axiomatizing physical theories
- Foundations of spacetime
- Computability and physics
- Relativistic computation
- Cosmology
- Relativity theory and philosophy of science
- Knowledge acquisition in science
- Temporal and spatial logic
- Branching spacetime
- Equivalence, reduction and emergence of theories
- Definability theory
- Concept algebras and algebraic logic
- Cylindric and relation algebras

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https://www.renyi.hu/conferences/lrb17/

The 3rd Logic, Relativity and Beyond International Conference will take a place in **Alfréd Rényi Institute of Mathematics** in Budapest (HU 1053 Budapest, Reáltanoda u. 13-15).

Invited Speakers:

- Jeremy Butterfield (University of Cambridge)
- Gyula Dávid (Eötvös Loránd University)
- Gábor Etesi (Budapest University of Technology and Economics)
- Gábor Hofer-Szabó (MTA Research Centre for the Humanities)
- John Byron Manchak (University of California)
- Tomasz Placek (Jagiellonian University)
- Yde Venema (University of Amsterdam)

Program Committee:

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- Mohamed Khaled (MTA Rényi Institute)
- Koen Lefever (Vrije Universiteit Brussel)
- Attila Molnár (Eötvös Loránd University)
- Péter Németi (Independent)

Schedule and Program

Wednesday, August 23

13:20-14:20	Registration	
14:20-14:30	Opening by **Péter Pál Pálfy** Director of the Institute	
14:30-15:30	**Jeremy Butterfield** and **Feraz Azhar** The observer in cosmology, classical and quantum	Chair: **Gergely Székely**
15:30-16:00	coffee break	
16:00-16:30	**Mohamed Khaled** Beyond Gödel's incompleteness theorem	
16:30-17:00	**Valentin Shehtman** On Kripke completeness of some modal predicate logics	
17:00-17:30	**Simon Kramer** Quantum logic as classical logic	
17:30-19:00		
19:00-22:00	Welcome Party on a boat that will start at 19:00 from Vigadó tér. We go together to the boat from the institute at 18:00. The boat will stay at Olimpia park between 19:30 and 21:00. Finally, after a 1 hour river trip it will dock at Vigadó tér at 22:00. Birthday greeting by **Péter Prőhle**.	

Thursday, August 24

10:00-10:30	**Anthony Sudbery** Many-valued temporal logic for quantum mechanics	Chair: **Thomas Benda**
10:30-11:00	**Antonino Drago** Non-classical logic and special relativity	
11:00-11:30	coffee break	
11:30-12:00	**Gergely Székely**	

	Should the principle of relativity speak only about reference frames instead of coordinate systems?	
12:00-12:30	**Jean-Claude Falmagne** On a meaningful axiomatic derivation of the Doppler effect and other scientific equations	
12:30-13:00	**Dániel Berényi**, **András Leitereg** and **Gábor Lehel** Applications of structured recursion schemes	
13:00-14:30	Lunch break	
14:30-15:30	**Tomasz Placek** On non-isometric extensions of some GR space-times– a branching perspective	Chair: **Koen Lefever**
15:30-16:00	coffee break	
16:00-17:00	**Gyula Dávid** Relativistic dynamics - Novobatzky's effect and the pre-relativistic Newton's equation	
17:00-17:30	coffee break	
17:30-18:00	**Judit Madarász** A mathematical logic based approach to isotropy, homogeneity and special principle of relativity	
18:00-18:30	**Michele Friend** Physical phenomena as eigenforms	
18:30-19:00	**Joanna Luc** Are non-Hausdorff space-times physically reasonable?	

Friday, August 25

10:00-10:30	**Adam Catto** Towards a formal theory of digital physics: digital multiverses	Chair: **Judit Madarász**
10:30- 11:00	**György Szondy** Beyond the event horizon - Weyl's forgotten cosmology	

11:00-11:30	coffee break	
11:30-12:00	**György Darvas** The nature of mass in logical perspective	
12:00-12:30	**Petr Švarný** A big ball of wibbly wobbly	
12:30-13:00	**Petr Jizba** Statistical origin of special and doubly special relativity	
13:00-14:30	Lunch break	
14:30-15:30	**Gábor Etesi** On the stability of relativistic computing devices	Chair: **Péter Németi**
15:30-16:00	break	
16:00-16:30	**Juliusz Doboszewski** On some curious features of white holes	
16:30-17:00	**Aleksandra Samonek** Goal directed proofs and diagrams suitable for applications in the philosophy of science	
17:00-17:30	coffee break	
17:30-18:00	**Koen Lefever** and **Gergely Székely** Comparing classical mechanics and relativity theories in first order logic	
18:00-19:00	**Hajnal Andréka** and **István Németi** How different are classical and relativistic spacetimes?	

Saturday, August 26

10:00-10:30	**Branislav Vlahovic** and **Maxim Eingorn** Non-inflationary geometrical solution of horizon problem	Chair: **Mohamed Khaled**
10:30-11:00	**Péter Pósfay**, **Antal Jakovác** and **Gergely G. Barnaföldi** Connection between neutron star observeables and the quantum nature of nuclear matter	

11:00-11:30	coffee break	
11:30-12:00	**Tarek Sayed Ahmed** Atom-canonicity in varieties of relation and cylindric algebras with applications to omitting types modal logic	
12:00-12:30	**Sándor Jenei** Structure theorem for a class of group-like residuated chains à la Hahn	
12:30-13:00	**Szabolcs Mikulás** Axiomatizing domain algebras	
13:00-14:30	Lunch break	
14:30-15:30	**Yde Venema** Dualities in algebraic logic	Chair: **Samuel Fletcher**
15:30-16:00	coffee break	
16:00-17:00	**Gábor Hofer-Szabó** Local causality in algebraic field theories	
17:00-17:30	coffee break	
17:30-18:00	**Péter Juhász** and **Gergely Székely** Some ideas on resolving causal paradoxes of time travel	
18:00-18:30	**Daniel Saudek** Time: real, but local - robust time asymmetry on an ontology of substances and powers	
18:30-19:00	**Márton Gömöri** and **László E. Szabó** Derivation of the transformation laws for the electrodynamic quantities from electrodynamics without presuming covariance	

Sunday, August 27

10:00-10:30	**Áron Szűcs** Theory of temporal extension in special relativity, and a possible explanation for ”jumpy” light beam photography	Chair: **Attila Molnár**
10:30-11:00	**Peter Ván**	

	Galilean and special relativistic fluids	
11:00-11:30	coffee break	
11:30-12:00	**Thomas Benda** Continuity of time, movement, and locality	
12:00-12:30	**Yaroslav Grushka** Changeable sets and their possible applications to the foundations of physics	
12:30-13:00	**Marcoen Cabbolet** Incorporating relativity in categorical models of abstract physical theories	
13:00-14:30	Lunch break	
14:30-15:30	**John Byron Manchak** Some "no hole" spacetime properties are unstable	Chair: **Michele Friend**
15:30-16:00	break	
16:00-16:30	**Samuel Fletcher** Approximate space-time symmetries	
16:30-17:00	**Atriya Sen**, **Naveen Sundar Govindarajulu** and **Selmer Bringsjord** Inaugural steps in a computational study of time travel	
17:00-19:00		
19:00-22:00	Conference dinner The dinner will be in Café Vian (Bisztró Bazilika) which is about 15 minutes walking distance from the institute. We go to the restaurant from the institute at 18:30.	

Contents

Contributed Talks

Invited Talks

The observer in cosmology, classical and quantum

Jeremy Butterfield and Feraz Azhar

We review conceptual issues about the role of the observer in cosmology, both classical and quantum. We proceed in three stages. First, we discuss the various ways in which the observer contributes to the scope, and indeed content, of physical knowledge, in ways that are not special to cosmology and, besides, are indifferent between classical and quantum physics. Second, we discuss the role of the observer in classical physics, especially in classical cosmology: i.e. in a cosmology for a classical (not quantum) world. Thus this second stage considers issues about selection effects. Third, we discuss the role of the observer in quantum physics in general: and especially in quantum cosmology. Here we focus attention on the research programme of Hartle, Hawking and Hertog, especially the relation of their proposed no-boundary state to inflation, and to selection effects.

Relativistic dynamics - Novobatzky's effect and the pre-relativistic Newton's equation

Gyula Dávid

The concepts of relativistic dynamics (relativistic mass, energy, momentum, force, power etc.) are subjects of frequent misunderstandings, overstatements and simple mathematical failures. The origin of these problems stems from the ignorance of the fact that in relativistic dynamics the rest mass of a particle may change under the influence of an external force. This important effect is less known since it is missing in the most frequently discussed case, namely the electromagnetic interaction. But this is valid for every kinds of forces occuring in special relativity theory except the electromagnetic force. The general theorem about the varying rest mass was discovered in 1950 by Károly Novobátzky, in Budapest, and his result was applied to special systems by George Marx in the early fifties. Now we present a systematic treatment of the relativistic dynamics of a mass point based on a covariant variational formalism which includes the physics of the varying rest mass. This algorithm leads automatically to the correct equations of motion for a mass point moving in scalar, vector and/or tensor fields. We emphasize that the effective rest mass of a particle is identical to the Hamiltonian derived from the covariant Lagrangian. We show the mathematical equivalence of different scalar models namely the Higgs scalar theory, Nordstrom's covariant scalar gravitational theory and the exotic example of Marx which describes a motion exceeding the speed of light. Paradox of Marx raises the question whether a physical theory can lead to physically unacceptable consequences even though it's mathematical syntax is correct. Finally we show that the exact equations of relativistic dynamics can be written in non-relativistic, three dimensional form as well, using only the 3D physical quantities of the newtonian mechanics. This form of equations is analogous to the original Maxwell's equations of electrodynamics which were semantically equivalent to their relativistic form despite of the fact that their discovery preceeded the birth of relativity by half a century.

On the stability of relativistic computing devices

Gábor Etesi

A recently accepted mathematical model of non-Turing computations is based on the concept of Malament–Hogarth space-times. However a Malament–Hogarth space-time is always non-globally hyperbolic and conversely, all sufficiently nice non-globally hyperbolic space-times are conformally equivalent to a Malament–Hogarth one. Consequently non-Turing computation in the general relativistic scenario is deeply linked with global hyperbolicity. R. Penrose' strong cosmic censor conjecture (SCCC) proposes that a physically relevant non-globally hyperbolic space-time never can be stable. Therefore, if the SCCC holds true, general relativistic non-Turing computing devices never can be stable as physical systems. In this context we will discuss a recent generic counterexample to the SCCC based on special properties, called exotica", of smooth structures which exist precisely in four dimensions. This counterexample opens up the possibility to construct physically Malament–Hogarth space-times which are stable against small perturbations as well.

Local causality in algebraic field theories

Gábor Hofer-Szabó

The talk has two aims. First, we implement Bell's notion of local causality into the framework of algebraic field theories, a framework rich enough to integrate probabilistic and spatiotemporal concepts. Second, we relate Bell's notion of local causality to other locality and causality concepts such as the Common Cause Principle, local primitive causality, no-signaling, stochastic Einstein locality, Causal Markov Condition, the EPR scenario and Bell's inequalities.

Some "no hole" spacetime properties are unstable

John Byron Manchak

Here, we show a strong sense in which the “no hole” spacetime property of effective completeness is not stable; an effectively complete spacetime can be can be arbitrarily “no hole” to spacetimes without this property.

On non-isometric extensions of some GR space-times – a branching perspective

Tomasz Placek

One focus in the debate over determinism of GR has been the initial value problem. By the celebrated Choquet-Bruhat and Geroch (1969) theorem, an initial data set admits a unique, up to isometry, maximal Cauchy development. By definition, this is a maximal globally hyperbolic space-time satisfying Einstein’s Field Equations and appropriately related to the initial data set. The theorem does not prohibit the existence of multiple non-isometric developments of an initial data set that are not globally hyperbolic. Such multiple developments are extensions of a maximal globally hyperbolic space-time; the most studied examples of this sort are non-isometric extensions of the Gowdy polarized space-time or of the Taub-NUT space-time. Since non-isometric extensions of a maximal globally hyperbolic space-time have isometric regions (i.e., isometric to the original maximal globally hyperbolic space-time), they witness indeterminism of GR, in the sense of J. Butterfield’s (1989) definition of determinism.

Non-isometric extensions present a conundrum for a branching-style analysis of indeterminism, however. Given the presence of closed timelike curves, the branching framework needs to be generalized beyond Belnap’s (1992) theory by relaxing the postulate of antisymmetric causal ordering. With this relaxation accomplished we still facewhat seems to be the main problem: since branching is committed to thinking in terms of “little” objects facing alternative possible future evolutions, the challenge is to find in GR candidates for little objects with bifurcate alternative possible paths. Here a feature of Taub-NUT as well as of the polarized Gowdy space-times can help: each can be extended to a non-Hausdorff manifold, whose maximal Hausdorff sub-manifolds are identifiable with the (non-isometric) extensions of the original space-time. The non-Hausdorff manifold thus can be viewed as providing a modal format that accommodates all possible GR space-times developing from a given initial data set. This instinctled Müller (2013) and Placek (2014) to develop a “topological” version of branching, in which a possible history is identified with a maximal Hausdorff sub-manifold of a base manifold (typically non-Hausdorff). On this analysis, non-isometric extensions of a maximal globally hyperbolic space-time come out as alternative possible histories, providing evidence for indeterminism, in agreement with the verdict of Butterfield’s (1989) definition. But with this topological turn, do we have candidates for locate objects with bifurcate alternative possible paths? The non-Hausdorff manifold encompassing non-isometric extensions of the Taub-NUT space-time (or non-isometric extensions of the polarized Gowdy space-time) contains no bifurcate geodesics. Even more generally, Hájíček’s (1971) theorem suggests that there are no bifurcate curves in these manifolds. We thus face a dilemma: on the one hand, since the extensions are non-isometric Hausdorff manifolds, it looks as if GR were indeterministic. On the other hand, since no curve bifurcates in a non-Hausdorff manifold encompassing the non-isometric extensions, it looks as if no object had alternative possible evolutions, which prompts one to say "determinism". But how can the world be both globally indeterministic and locally deterministic?

References

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[3] Choquet-Bruhat, Y. and Geroch, R. (1969). Global aspects of the Cauchy problem in general relativity. Communications in Mathematical Physics, 14: 329-335.

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[6] Placek, T. (2014). Branching for general relativists. In Müller, T., editor, Nuel Belnap on indeterminism and free action, pages 191-221. Springer.

Dualities in algebraic logic

Yde Venema

Algebraic logic is, in short, the study of logic by universal algebra means. A key tool in the field is provided by categorical dualities that extend Stone's representation theorem for Boolean algebras and provide many interesting links between the worlds of algebra and topology. In the talk I will review a well-known, simple instance of such a duality, in the setting of modal logic. After a gentle introduction of the main constructions, which go back to the seminal work of Jonsson and Tarski, I will discuss some examples showing how concepts on one side of the duality are represented on the other side. I will finish the talk by discussing modal duality from the perspective of coalgebra, the general theory of state-based evolving systems.

Contributed Talks

Atom-canonicity in varieties of relation and cylindric algebras with applications to omitting types modal logic

Tarek Sayed Ahmed

Fix $2 < n < \omega . L_n$ denotes first order logic restricted to the first n variables and for any ordinals $a < \beta, (R)CA_a$ denotes the class of (representable) cylindric algebras of dimension a_1, and $\mathrm{Nr}_a\mathrm{CA}_\beta$ denotes the class of a-neat reducts of CA_β. Certain CA_n s constructed from relation algebras having an n-dimensional cylindric basis are used to show that Vaught's Theorem (VT) looked upon as a special case of the omitting types theorem (OTT) fails in the m-clique guarded fragment (CGF_m) of L_n, when $m \geq n+3$. For infinitely many values of $n \leq k < m \leq \omega$, there is an atomic, countable and complete L_n theory T such that the type of co-atoms (of the formula algebra Fm_T) is realizable in every $m-$ square model of T but cannot be isolated using I variables. Here ' m-squareness' is the locally well behaved clique-guarded semantics of CGF m; an m-square model is l-square, but the converse may be false. The limiting case, an ω-square model, is an ordinary model. This is proved algebraically by constructing a countable, atomic and simple algebra $A \in RCA_n \cap Nr_nCA_{\mathrm{l}}$ whose minimal completion (CmAtA) does not have an m-square representation, a fortiorti $\mathrm{CmAtA}^2 \notin \mathrm{SNr}_n\mathrm{CA}_\mathrm{m}\,(\supseteq \mathrm{RCA}_n)$. Canonical logics between K^n and $\mathrm{S5}^\mathrm{n}$ are barely canonical; they cannot be axiomatized by canonical, a fortiori Sahlqvist formulas. Di-completeness and elementary characterization are proved for $S5^n, L_n$ and CGF_m for all $m \geq n$. For $m \geq n+3, CGF_m$ is not Sahlqvist; this is also algebraically proved by showing that SNr_nCA_m is not atom-canonical. VT is proved for some guarded fragments of L_n and OTTs are proved with respect to standard semantics for L_n theories that have quantifier elimination; it is shown that $< 2^\omega$ many non-principal types can be omitted in case they are maximal. In the course of our investigations purely algebraic results are obtained. For example we show that the class of CA_n S satisfying the so-called Lyndon conditions coincides with the class of atomic algebras in $\mathrm{El_C Nr_n CA_\omega}$, where El denotes elementary closure and $\mathrm{S_C}$ denotes the operation of forming complete subalgebras. We also show that any class K satisfying $\mathrm{Nr}_n\mathrm{CA}_\omega \cap \mathrm{CRCA}_n \subseteq \mathrm{K} \subseteq \mathrm{S_C Nr}_n\mathrm{CA}_{n+3}$, where CRCA_n denotes the class of completely representable CA_n S, is not elementary. Entirely analagous results are obtained for relation algebras. Our overall purpose is twofold. Apart from presenting novel ideas of applying algebra to logic, we present our new results in both algebraic and modal logic in an integrated format.

How different are classical and relativistic spacetimes?

Hajnal Andréka and István Németi

This is part of an ongoing joint research with Madarász, J. and Székely, G. This research was inspired by László E. Szabó's paper [S].

We take classical (Newtonian, or pre-relativistic) spacetime to be the geometry determined by the Galilean transformations. In more detail: Let the universe of the structure CST be four-dimensional real space R4 together with the binary relation of simultaneity, ternary relation of collinearity, and quaternary relation of orthogonality, where four points are said to be orthogonal iff they are distinct and the first two points and the other two points are pairwise simultaneous and they determine orthogonal lines in the Euclidean sense. Let CST represent classical spacetime.

Relativistic spacetime is the geometry determined by the Poincaré transformations. In more detail: The universe of the structure RST is four-dimensional real space R4 and its relations are collinearity and Minkowski-orthogonality (or, equivalently, the only binary relation of light-like separability). Let RST represent special relativistic spacetime.

The question whether two structures are identical except for renaming of basic notions is a central topic in definability theory of mathematical logic. It is formulated as whether the two structures are definitionally equivalent or not (see e.g., [Ho]).

Clearly, CST and RST are not definitionally equivalent in the traditional Tarskian sense, since in CST one can define a nontrivial equivalence relation (the simultaneity), while in RST one cannot define any nontrivial equivalence relation on the universe. However, in "modern" definability theory of mathematical logic one can define new universes of entities, too (cf e.g., [H], [M] or [BH]). In this extended modern sense, in RST one can define a new universe with nontrivial equivalence relations on it (e.g., one can define a field isomorphic to R4). In fact, both spacetimes can be faithfully interpreted into the other. In the following, by definitional equivalence we always mean definitional equivalence in the modern sense. Definitional equivalence of two theories is a mathematical notion expressing "identiy of" theories. Two theories are definitionally equivalent iff there is a one-to one and onto correspondence between the defined concepts of the two theories such that this correspondence respects the relation of definability. The same notion is applicable to structures.

Theorem 1. CST and RST are not definitionally equivalent.

To prove Theorem 1, it is enough to prove that the automorphism groups (i.e., groups of symmetries) of CST and RST are not isomorphic. The automorphism group of CST is the general inhomogeneous Galilean group, where "inhomogeneous" means that we include translations and "general" means that we include dilations. Analogously, the automorphism group of RST is the general inhomogeneous Lorenz group. The two automorphism groups are not even definitionally equivalent. This follows from the following theorem which seems to be interesting in its own. It sais that the abstract automorphism groups of the two spacetimes contain exactly the same "content" as the geometries themselves, they "do not forget structure".

Theorem 2. (i) CST is definitionally equivalent to its automorphism group as well as to the inhomogeneous Galilean group. (ii) RST is definitionally equivalent to its automorphism group as well as to the inhomogeneous Lorenz group.

Similar investigations can be found, e.g., in [E], [EH] and [P].

References:

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Continuity of time, movement, and locality

Thomas Benda

In this paper, it is argued that movement, the continuity of a line, continuous flow of time and locality in an intuitive sense cannot be formalized, so that logical axiomatizations of spacetime and kinetic theories have to be made without accounting for them.

Movement in space is part of our daily experience and we naturally take its possibility for granted. Yet Zeno's Arrow Paradox suggests that movement is impossible since, at any given moment, the supposedly flying arrow is at rest. Calculus is usually thought to come to the rescue. It provides a way to deal with changes of functions;in this case, of spatial position over time—over as small domains as desired. It does so by allowing to calculate distances covered during tiny time intervals to any desired accuracy. Thereby, however, calculus accounts for no more than the outcome of movement, distances covered in a time intervals. We rather think of movement as gradual change of location, a smooth transition. We apparently have a pre-conception of transition. A movie, shot with the traditional technology of a film, appears realistic if it is composed of a sufficiently rapid sequence of still pictures. We do not reduce our watching experience to snapshots taken at high frequency, but the latter simulates what we aim to see: movement.

Similarly, a child, drawing a line, does not consider it as a totally ordered set of points, as calculus suggests, but as an entity by itself, which we naturally call ”continuous”. Continuity in this sense, the continuity of a drawn line, is readily distinguished from what is called ”continuity” in calculus. The former knows no individual stages and is naturally intuited, whereas the latter supposedly comes about by a composition of infinitely many extensionless individuals. Yet in any infinite arithmetic, zero remains the neutral element of multiplication, so that no juxtaposition of points will produce an extended line.

Transition and change without leaps, of which movement is an example, are recurrent features of the physical world. We perceive them to occur in space over time, that is, we perceive a spatially arranged, constantly changing physical world, where the parameter of change is introduced as time. Describing time in logical and mathematical terms is less straightforward than it seems. If time is composed of individual entities–defined as those entities pairs of which are able to be identical or distinct–t1, t2, ... , that is, a set, then it has to be totally ordered. To establish homogeneity of time, time needs an algebraic structure and physical laws have to be invariant against time translation. To enable a transition to begin or to continue from some stage, it has to be well-ordered. To describe gradual transition, there have to be pairs of neighbors. Otherwise, any given t1, t2 fail to be neighbors and we are able only to describe a leap, but not a transition from t1 to t2. Real numbers do not satisfy all of those requirements and, seemingly, no set does, which, if we take our intuition of leap-less change serious, leaves us at postulating time as truly continuous in above sense of the continuity of a drawn line.

Accounting for locality, prima facie unexpectedly, suffers from the same problem. Locality does not allow unmediated leaps of physical magnitudes, e.g., wave amplitudes, between spatial points. But again, any mathematical characterization of space as R^3 or spacetime as R^4 excludes locality in this sense. It still admits locality according to a standard definition as causal dependence of any physical magnitude at some given spatial location x1 from as near a spatial location x2 as desired and from no more distant location. In the light of Relativity Theory, usually a condition is added that stipulates a minimum elapsed time for said causal dependence to work. However, the standard definition of locality is motivated by an idea of gradual spatial transition, yet does not answer that motive. Instead, it accounts just for leaps of causality between spatial points, which may lie as close to each other as desired. According to it, the famous EPR experiment of splitting a particle p into two particles p1, p2 and having the spin of p2 collapse instantly upon measuring the spin of p1 would, if performed early enough after the splitting of p, reveal non-locality only insofar as leaps of causality occur in zero time intervals, but not because of spatial leaps of causality. But it is the latter that conflicts with our intuition of locality.

We are left with the alternative of either discarding above intuitions about movement, continuity and locality, which is the standard way of dealing with the problem, or stipulating true temporal or spatial continuity. The latter, however, by not admitting individual stages, precludes a logical and mathematical characterization of time and space, respectively. Any axiomatizations of spacetime and kinetic theories rely on logical and mathematical characterizations and thus beg the question of continuity thereof. That is enough for pragmatic purposes, but leaves ontological questions unanswered. In the face of said dilemma, it seems reasonable to stick with temporal continuity and give up on spatial continuity and thus on both movement and locality in above intuitive sense.

Applications of structured recursion schemes

Dániel Berényi, András Leitereg and Gábor Lehel

Recursive structures are quite common in various areas of science, especially where expressions of a certain grammar are involved, like in natural languages, programming languages or generally in formal systems. Analysis, transformation and reasoning is closely tied to the structure of these expressions but at the same time the actual operations to be carried out at different levels of the recursive structure may vary considerably. Category theory provides a set of tools that can naturally represent and deal with exactly these constructs. In this work, we review the formulation of recursion schemes over such structures and highlight two use cases: one related to programming language compilation and another one in machine learning.

Incorporating relativity in categorical models of abstract physical theories

Marcoen Cabbolet

Recently the Elementary Process Theory (EPT) has been developed: this is an example of an abstract physical theory. This talk focuses at the general method by which an abstract physical theory can be proven to agree with existing knowledge of the physical world. First it will be argued that the one existing tool, specifying a set-theoretic model of an abstract physical theory, is inadequate to prove agreement with relativity. Next, the new notion of a categorical model of an abstract physical theory T is introduced by identifying a model of T with a small category, whose objects are set-theoretic models of T, and whose arrows are model isomorphisms. It is then explained how such a categorical model of T can incorporate relativity in a natural way. Finally, a notion of agreement between an abstract physical theory and existing knowledge is defined using Rosaler's concept of empirical reduction. Concluding, specifying a categorical model of an abstract physical theory is a new formal technique in theoretical physics, which can be applied in a research program aimed at demonstrating agreement of such a theory with existing knowledge of the physical world.

Towards a formal theory of digital physics: digital multiverses

Adam Catto

We discuss the foundations of digital physics and its implications. The foundations of digital physics are expanded, and an analogue of the many-worlds interpretation of quantum mechanics under the digital physics formalism is presented, in addition to a more ”economical” multiverse theory, which takes into account resource availability and discusses a naive account of universe likelihood. We also address some problems in the epistemology of physics along the way, which help to lay an epistemic groundwork and provide motivation for the feasibility of pursuing a digital theory of physics.

The nature of mass in logical perspective

György Darvas

Latest discoveries in physics prioritise mass and issues concerning gravitation. Mass is a central notion in the general theory of relativity (GTR). My paper will concentrate on the nature of mass and discuss two related logical (pseudo- or real) problems. The easier one is the question on the difference between equivalence and identity - having treated by me in more details in earlier publications. Referring to the solution of this first problem prepares a more relevant logical problem, namely, that of the conservation of mass.

The equivalence principle is one of the main pillars of GTR. The equivalence principle states the equivalence of the gravitational and inertial masses. At the same time it does not mean that gravitational and inertial masses were identical. The equivalence principle states that the inertial mass and the gravitational mass of a test body are proportional, and (as we fixed the factor of proportion to "1") are measured on the same scale. Nevertheless, they should be considered not identical properties. Identical things cannot be equivalent: equivalence is a quantitative relation between qualitatively different (non-identical) entities. Only different things can be compared and proven to be equivalent. One needs to have two different qualities to claim they are of equivalent quantities. Therefore, gravitational mass and the inertial mass are qualitatively different entities that proved to be equivalent (at least at rest) in the measure of their effects. The paper will list a few consequences of the non-identity of the equivalent masses. We note that the isotopic field-charge (IFC) theory assumes the two kinds of masses to be different physical properties (that behave in different ways during a velocity boost), and considers them as isotopic IFC-s of the gravitational field.

Next, we investigate the conservation of mass. It has been assumed an apparently unproblematic question, without any open problem in connection with it. The picture is not so simple in the light of the difference between the two isotopic twin siblings of masses.

How did we conclude the mass conservation? In classical mechanics, we had empirical evidences for the conservation of energy. We had also empirical evidences for the conservation of mass (in general). Then three new issues entered the scene. (i) A proportionality between the quantity of energy and the measured quantity of mass was established. We have got also (ii) a proportionality between the measured quantities of the gravitational mass and the inertial mass. Finally we have got (iii) a principle of equivalence. Thus, we concluded from the conservation of energy the conservation of mass, and through the proportionality between the two kinds of masses, applying the equivalence principle, we extended the conservation to all kinds of masses.

Let us reconsider this logic. We must mention in advance the problem that in (i), originally, the energy was not the potential or the kinetic energy, rather the internal energy of a system, and the mass in the equation E=mc2 was identical with the gravitational mass. (We will refer to quotations from Einstein.) The conservation of the energy (like other mechanical quantities) was concluded from the integration of the equations of motion. In modern treatment we can obtain it by the variation of the Lagrangian for the geometric invariances. The conserved energy that we got, is proportional to the mass of the investigated system or the whole universe. To which mass? To the gravitational mass. (Here we will refer again to a few classical papers.) Where do we deduce from, that the full mass is conserved? We conclude it from the principle of equivalence. What does the principle of equivalence say us? It says, that (a) the effects of the two types of mass are indistinguishable. Moreover, we knew earlier that (b) the measured mass of a given object can behave both like gravitational mass and inertial mass, and (c) the measured quantities of these two masses are equal (at least in rest). These statements together are logically inadequate to conclude the conservation of the full mass.

If we assume, that the inertial and gravitational masses are two qualitatively different properties of matter, (at least, on the basis of the above clue), we have no reason to make any statement on the conservation of the inertial mass. The quantities of the two masses are equal, but they are supposed to be not identical. (Here we refer again to some classical papers.) This means, that we concluded the conservation of the gravitational mass (from the conservation of the energy), and we have good reason to state that this conserved amount gravitational mass is in its quantity equivalent to a certain amount of inertial mass. No more. It does not follow from this conclusion, that there are no other quantities of inertial mass in our universe, what are not without doubt conserved. I do not state, that there are certainly such non-conserved (inertial) masses. I state only, that all the above conclusions did not provide evidence for it. It has not been proven. (E.g., let's imagine a dance school. Boys and girls attend this school. The music starts and all the boys invite to dance a girl. The observer registers that all boys have found a partner. Then we read the record. Can we state that there were no more girls in the school?)

If we want to find evidence for the conservation of the full mass (both the gravitational and inertial), similar to the electromagnetics and the conservation of the electric charge, we should turn to the four-potential of the gravitational field and the energy-momentum tensor introduced in general relativity. In this course, there is irrespective that the mass is a quite different-property 'charge' of the field equations, quite different bosons mediate their interactions, and quite different Lagrangians govern their states and interactions, than the electric charges in the electromagnetic field. The common feature between them is the role of a central (1/r) scalar potential plus a kinetic part, and that we should expect some gauge invariance as a result of the four-potential. This latter did not follow from classical mechanics. The phenomenon is subject of field theory and GTR.

More precisely, in other words: when we concluded the conservation of the mass solely from the gravitational potential, we ignored any possible contribution by the kinetic part of the Hamiltonian (while the full Hamiltonian was generated by the full energy-momentum tensor in the GTR). The case is similar to that, when we derived the conservation of the electric charge - in classical electrodynamics - from the Maxwell equations alone, we derived an invariance solely from a transformation in the Coulomb field, so we concluded the conservation of the Coulomb charge (and not all electric charges). Thus - in classical electrodynamics - we did not couple it with a transformation in the gauge field.

This latter "imperfection" has been corrected by the coupled gauge transformation in QED. (In a proper gauge theory, symmetry transformations leave the total Hamiltonian invariant, and do not the kinetic and the potential components of the energy separately.) That gauge transformation was generated by the rest of the electromagnetic field tensor, and it led to the conservation of the full electric charge (Coulomb plus Lorentz types). Similar "correction" is to be done in case of the conservation of mass, by extending the derivation of the conservation to the full energy-momentum tensor in order to get conservation of the full mass.

This extension demands the consideration of the two kinds of masses, what is subject of the IFC theory. The IFC theory discusses, how the distinction between gravitational and inertial masses modifies physical equations. Their difference has not been reflected in the traditional physical equations. It makes itself apparent at high velocities relative to the observer, where the two kinds of masses differ also in their quantities. There was shown that they are subject to a hypersymmetry (conservation of a property called the isotopic field-charge spin, IFCS) that can transform them into each other (i.e., to rotate the IFCS in an abstract gauge field, where they can occupy two positions). That symmetry guarantees to keep the covariance of our physical equations. The hypersymmetry is broken at lower velocities (lower kinetic energies). Therefore, at least near to rest, one can observe the two IFC of the gravitational field equivalent. This indistinguishability was formulated as an equivalence principle. However, as we saw, equivalence - observed among limited conditions - did not mean identity. We put masses in physical equations marking the gravitational and inertial masses by different notations. Thus, we modify the equations (incl. the gravitational) that leads to novel conclusions at high velocities, while it does not result changes near to rest.

On some curious features of white holes

Juliusz Doboszewski

White holes are defined as time reversed counterparts of black holes. Whereas black holes have received a lot of attention from physicists and philosophers alike, their white hole counterparts have been less lucky, and are often seen as unphysical. I will discuss three reasons for dismissing white holes as physical possibilities: (1) that nothing resembling a white hole has ever been observed; (2) indeterminism associated with white holes; and (3) violations of the second law of horizon thermodynamics. Then I will provide additional reason for being suspicious about white holes: (4) if white holes are possible, so should be white hole splitters - that is, time reversed counterparts of spacetime metrics describing black hole mergers. White hole splitters raise new conceptual challenges. First, there is no natural white hole analogue of emitted energy: in contrast with the black hole merger event (which emitts gravitational waves during the merging process), gravitational waves (and associated mass) have to be sucked-in from the outside in the splitter event. Second, there is a physical reason for two black holes to merge: they are highly massive objects which interact gravitationally. In case of a single white hole splitting into two white holes no such interaction is available, and accounting for the split seems to be much more difficult. Possibility of white hole splitters becomes particularly interesting in the context of the black hole fireworks scenario (Rovelli and Vidotto [2014], Haggard and Rovelli [2015]), which aims to provide a non-singular, non-perturbative theory of quantum black holes. Black hole fireworks is a variant of the cosmological quantum bounce scenario: a black hole "explodes" by transitioning to a white hole at certain point during the semi-classical evaporation phase. I will argue that features (1) and (2) from the list above are accounted for in black hole fireworks, but features (3) and (4) are not. I will discuss whether the concern (3) could be expressed using some version of the generalized second law, and few hypothetical ways of accounting for (4) (small probability of the split, inhomogeneities within the white hole being responsible for the split, re-examination of time-reversal invariance of Einstein's field equations). I will argue, however, that none of these ways is satisfactory.

Non-classical logic and special relativity

Antonino Drago

In his Autobiography Popper tells that his conception of science fallibilism started from a reflection on the birth of special relativity.[1] His reflections are unawarely expressed by means of doubly negated propositions whose corresponding affirmative propositions lack of evidence (DNPs), hence the law of the double negation law fails; this fact states that they pertain to the intuitionist logic.[2] An inspection of Einstein's celebrated 1905 paper shows that he also made unawarely use of DNPs (around 63). Moreover, he claimed that his theory is not a deductive one, but a "principle theory"; yet, he has insufficiently defined this model of organization of a theory. In addition, it is well-known that his paper is insufficient under some aspects, including its consistency.

The present paper rationally re-constructs the birth of special relativity according to Einstein's original intentions. A comparative study of all non-deductive theories shows that their ideal model tackles a problem whose method of resolution is discovered by means of an inquiry illustrated by DNPs, which compose indirect proofs concluding a universal predicate; this is then changed in a postulate according to Einstein's proposition: "We will raise this conjecture [i.e. the universal DNP] (the substance of which will be hereafter called the [axiom-]principle of relativity to the state of a [affirmative] postulate".[3]

The first problem is to complete the. birth of electromagnetic theory through two steps. The first step is to state through Einstein's indirect proof that c is insuperable and then obtain Lorentz's group by choosing the suitable geometry among the four basic geometries which have been characterized by Poincaré.[4] The second step is to estavblish in Einstein's heuristic way (i.e. through DNPs) Lorentz' invariance of Maxwell's equations. The specific birth of special relativity occurs when one undergoes the classical mechanics to Lorentz' group. The invariants of classical mechanics are then obtained by following a heuristic suggestion of Levy Leblond.[5]

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On a meaningful axiomatic derivation of the Doppler effect and other scientific equations

Jean-Claude Falmagne

The mathematical expression of a scientific or geometric law typically does not depend on the units of measurement. This makes sense because measurement units have no representation in nature. Any mathematical model or law whose form would be fundamentally altered by a change of units would be a poor representation of the empirical world. This paper formalizes this invariance of the form of the laws as a "meaningfulness" axiom. In the context of this axiom, relatively weak, intuitive constraints may suffice to generate standard scientific or geometric formulas, possibly up to some numerical parameters. We give several example of such constructions, with a focus of the Doppler effect and some other relativistic formulas.

Approximate space-time symmetries

Samuel Fletcher

Approximate symmetry is widely invoked in contexts from space-time geometry to effective field theories, but it is rarely fully explicated. Such an explication, in the case of space-time symmetries, is the goal of this presentation, which reveals a surprising number of complexities. The mathematics involved can be subtle, and requires conceptual input regarding which properties (directly observable or not) are relevant in comparing approximate symmetry-related space-times, how different those properties can be while still preserving approximate symmetry, and what it means, in the case of local space-time symmetries, for two symmetry transformations to be similar to one another. This in turn sheds light on the direct empirical significance (DES) of space-time symmetries, for being approximable is certainly sufficient for DES and—under the right conditions—it may be necessary, too.

Physical phenomena as eigenforms

Michele Friend

In quantum mechanics, there is a difference between a value-attributing proposition and a state-attributing proposition. The difference is important for making sense of the curious 'fact' that sometimes in quantum mechanics we are able to numerically distinguish objects from one another although all of their properties are the same. Leibniz's law tells us that two objects are the same iff they share all of their properties. The curious fact seems to violate Leibniz's law of identity. It does not.

One way of dealing with this is modally. Van Fraassen is an example of someone who chooses this route. But we can be more precise than just adding a modal operator to (potential) properties. Following Kraus and Arenhart (2017, 172) we can think of the difference mathematically, or logically, in the following way: it is analogous to the difference between absolute (invariant) notions and relative notions in set theory. An example of a relative notion is the cardinality of the reals in a first-order theory. Skolem's "paradox" is that a first -order theory attributes the same cardinality to the reals as it does to the natural numbers, thus, apparently violating Cantor's diagonal proof. The reason Skolem's paradox is not thought to be problematic is that we can tell the difference in the cardinality if we step outside the theory and look "in" on the notion of cardinality of the reals from a larger (second-order) theory. Skolem's paradox is only one example. In mathematics, what counts as an absolute notion and what counts as a relative notion depends on the pair: object-theory and meta-theory.

I should like to extend the thoughts of van Fraassen and the mathematical modelling of the curious fact suggested by Kraus and Arenhart. The extension is to the contemplation of several, (i.e., more than two) mathematical theories, each modelling some phenomena. We see the several theories in play when we learn about the relativity theories in the way suggested by the Andréka-Németi group.

If we individuate mathematical theories by their axioms, and close each under some operations, then the Andéka-Németi group develop several theories to capture, or describe, or understand, or model, the various phenomena of the relativity theories. In their approach, we do not have one object theory and one meta-theory. We actually have several object theories, and sometimes several meta-theories. The phenomena being captures can then be thought of as eigenform: a fixed point under a transformation from one theory to another. It is exactly under the scrutiny of a phenomenon from several theories and view-points that we come to understand the phenomenon in question. This extension speaks to a pluralist mathematical approach.

Derivation of the transformation laws for the electrodynamic quantities from electrodynamics without presuming covariance

Márton Gömöri and László E. Szabó

It is common in the literature on classical electrodynamics and relativity theory that the transformation rules for the basic electrodynamic quantities are derived from the pre-assumption that the equations of electrodynamics are covariant against these “unknown” transformation rules. Consequently, the statement that the equations of electrodynamics are covariant remains a question begging until we have an independent verification of the transformation laws. In this paper we present a derivation of the transformation laws that does not rely on the assumption of covariance. The basic idea is what J. S. Bell calls ”Lorentzian pedagogy” according to which the laws of physics in any one reference frame account for all physical phenomena, including what a moving observer must see when she performs measurement operations with moving measuring devices. Accordingly, we derive the transformations of the electrodynamic quantities on the basis of the equations of electrodynamics assumed to hold in one single inertial frame, and the precise operational definitions of the fundamental electrodynamic quantities. The result is satisfying: the transformation rules obtained are identical with the textbook transformations derived from covariance. However, the analysis sheds new light on the operational meaning of the transformation rules of physical quantities, on the empirical semantics of electrodynamics, and on the status of the covariance principle.

Changeable sets and their possible applications to the foundations of physics

Yaroslav Grushka

This paper is devoted to study of coordinate transforms in abstract kinematic changeable sets. Investigations in this direction may be interesting for astrophysics, because there exists the hypothesis, that in large scale of the Universe, physical laws (in particular, the laws of kinematics) may be different from the laws, acting in the neighborhood of our solar System.

Structure theorem for a class of group-like residuated chains à la Hahn

Sándor Jenei

Hahn’s famous structure theorem states that totally-ordered Abelian groups can be embedded in the lexicographic product of real groups. Our main theorem extends this structural description to order-dense, commutative, group-like residuated chains, which has only finitely many idempotents. It is achieved via the so-called partial-lexicographic product construction (to be introduced here) using totally-ordered Abelian groups, as building blocks.

Statistical origin of special and doubly special relativity

Petr Jizba

In this talk I will show how a Brownian motion on a short scale can originate a relativistic motion on scales that larger than particle's Compton wavelength. I start by discussing complex dynamical systems whose statistical behavior can be explained in terms of a superposition of simpler underlying dynamics of the so-called superstatistics paradigm. Then I go on by showing that the combination of two cornerstones of contemporary physics, namely Einstein's special relativity and quantum-mechanical dynamics is mathematically identical (when analytically continued to Euclidean regime) to a complex dynamical system described by two interlocked processes operating at different energy scales. The combined dynamic obeys special and doubly special relativity even though neither of the two underlying dynamics does. This implies that Einstein's special relativity might well be an emergent concept in the quantum realm. To model the double-stochastic process in question, I consider quantum mechanical dynamics in a background space consisting of a number of small crystal-like domains varying in size and composition, known as polycrystalline space (or Voronoi tessellation). There, particles exhibit a Brownian motion. The observed relativistic dynamics then comes solely from a particular grain distribution in the polycrystalline space. In the cosmological context such distribution might form during the early universe's formation. Salient issues such as Hausdorff dimensions of path-integral trajectories, connection with Feynman chessboard model and implications for quantum field theory and cosmology (leptogenesis) will be also briefly discussed.

Related articles:

[1] P. Jizba and F. Scardigli, Special Relativity Induced by Granular Space, Eur. Phys. J. C (2013) 73: 2491

[2] P. Jizba and F. Scardigli, The emergence of Special and Doubly Special Relativity, Phys. Rev. D (2012) 86: 025029

[3] P. Jizba and H. Kleinert, Superstatistics approach to path integral for a relativistic particle, Phys. Rev. D (2010) 82: 085016

Some ideas on resolving causal paradoxes of time travel

Péter Juhász and Gergely Székely

Time travel is an interesting topic and we agree with its extensive scientific literature, see, e.g., [1-5], on that the subject worth not being exiled to the realm of mere science fiction. As it is heavily debated whether it is consistent with our actual scientific theories or not and under what conditions is it possible at all, we believe it is useful to pursue deeper understanding. The first part of the talk is going to cover the two kinds of temporal paradoxes: causal loops and consistency paradoxes (e.g., the Grandfather paradox). Both of them are problematic from the point of view of causality. Focus will be on the latter by investigating hopeful ideas of handling them such as using branching spaces times or developing a general method to find a self-consistent model for every possible initial data.

In the course of seeking for a better understanding of time traveling scenarios a new framework has been elaborated which makes possible to "handle paradoxes in the object level" and measure distance between setups. These tools allow to search for self-consistent solutions by an iterative way which is basically a fix point problem. In the talk this framework will be presented and a local counterexample showing that the technique is not working in general. Some ideas to fix the method will also be shown.

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Beyond Gödel's incompleteness theorem

Mohamed Khaled

In 1931, Kurt Gödel proved his first incompleteness theorem which is considered to be one of the most important results in modern logic. This discovery revolutionized our understanding of mathematics and logic, and had strong impacts in mathematics, physics, psychology, theology and some other fields of philosophy. It also plays a part in modern linguistic theories, which emphasize the power of language to come up with new ways to express ideas. Gödel's incompleteness theorem states that a complete and consistent list of axioms that extends arithmetic" and is enumerated by an effective method (an algorithm or a computer program) can never be created. Gödel's work depends on arithmetic inside the theories at issue, and it was a task to loosen this marriage to study the same phenomena for arbitrary logics. Although the natural numbers play an essential role in its proof, the statement of the incompleteness theorem is in fact talking only about complete and consistent theories. Thus, replacing arithmetic with a suitable formula, in the logic in the question, yields a meaningful property for arbitrary logics, it is called Gödel's incompleteness property (GIP).

Gödel's incompleteness property is closely connected to undecidability for arbitrary logics. Indeed, Gödel's incompleteness property for a logic that has a recursively enumerable" set of formulas implies that this logic is in fact undecidable. Otherwise, one can use the decidability algorithm together with the enumeration algorithm to find complete and consistent theory extending any consistent formula. But there are several interesting decidable logics, so GIP fails automatically for these logics. However, if we replace enumerated by an effective method" with finitely axiomatizable" in GIP, then the so obtained weak Gödel's incompleteness property (wGIP) is still a property worth investigating for these decidable logics. Both wGIP and GIP are about the quality of expressive power, not about the strength of expressive power, just as decidability is not about smallness but about "how easy to define". The credit for defining GIP and wGIP goes back to István Németi in 1985.

The problem of investigating GIP and wGIP is not trivial, it is very involved and usually requires new techniques as well as tricky use of the known techniques. In this talk, we aim to present our latest results in this direction. We will also show what kind of logic-properties we used to achieve these results. Then, we will raise some conjectures that give a complete characterizations of these incompleteness properties. For instance, we claim that any arbitrary logic (that has a propositional part) lacks wGIP on finite languages if it has the finite model property and there is a 'derived' unary connective δ such that, for any formula φ, either $\models \delta(\varphi)$ or $\models \neg\delta(\varphi)$. An interesting conjecture, due to Zalán Gyenis, states that GIP and wGIP are equivalent for undecidable logics. Another surprising claim, at least for those who are familiar with these properties, is that wGIP may fail for some version of FOL on an infinite language. We will support these conjectures by comparing them, not only to the known results concerning these properties, but rather to the techniques used to prove these results.

Quantum logic as classical logic

Simon Kramer

We propose a semantic representation of the standard quantum logic QL within a classical, normal modal logic, and this via a lattice-embedding of orthomodular lattices into Boolean algebras with one modal operator. Thus our classical logic is a completion of the quantum logic QL. In other words, we refute Birkhoff and von Neumann's classic thesis that the logic (the formal character) of Quantum Mechanics would be non-classical as well as Putnam's thesis that quantum logic (of his kind) would be the correct logic for propositional inference in general. The propositional logic of

Quantum Mechanics is modal but classical, and the correct logic for propositional inference need not have an extroverted quantum character. One normal necessity modality $\Box$ suffices to capture the subjectivity of observation in quantum experiments, and this thanks to its failure to distribute over classical disjunction. The key to our result is the translation of quantum negation as classical negation of observability.

Comparing classical mechanics and relativity theories in first order logic

Koen Lefever and Gergely Székely

The current talk discusses the completion of the research presented at the previous Logic, Relativity and Beyond Conference (LRB15). We then presented a definitional equivalence between special relativity theory extended with a primitive ether concept and classical kinematics with inertial observers which are restricted to slower than light speeds.

By establishing a definitional equivalence between classical kinematics with inertial observers which are restricted to slower than light speeds and classical kinematics without that restriction, we can now make a stronger claim:

Ether is the only concept that has to be removed from classical kinematics. However, removing ether from classical kinematics also leads to a change of the notions of space and time, which in the framework of our research is handled by the translation function.

We also discuss the properties of ether-observer-independent formulas, and how those properties are being used to simplify formulas which are generated by the translation function.

Finally, we will present our plans for further research, extending our results from kinematics to dynamics and from special relativity theory to general relativity theory.

Are non-Hausdorff space-times physically reasonable?

Joanna Luc

Which of mathematical constructions can be regarded as representing (possible) physical space-times? The answer to this question is provided by physical theories like General Relativity. According to this theory physical space-time is represented by a differential manifold which satisfies Einstein's equations. However, usually not all solutions of these equations are treated as representing physical space-times in the proper sense - additional conditions of 'physical reasonability' are imposed. They can occupy various levels of the theory: they can be accommodated as a part of definition of differential manifold (like the Hausdorff condition, second countability, connectedness, paracompactness), they can take a form of additional constraints on the energy-momentum tensor (conservation law and various energy conditions), on metric (its signature) or on global structure of space-time (causality conditions, lack of some types of singularities, lack of 'holes'). There is no consensus which of these conditions really should be imposed and it seems that there is no simple general argument here. In my talk I would like to concentrate on one of the above conditions, namely the Hausdorff condition. I would describe examples of space-times which do not satisfy this condition, discuss some of their properties and consider arguments for and against taking them as physically reasonable.

One of the simplest examples of non-Hausdorff manifold is the following: take two copies of real numbers (each of them forms a manifold) and identify them up to some point, excluding this point. More advanced examples are described in the physical literature: some extensions of Misner space-time, of Taub-NUT space-time and of Gowdy polarized space-time are non-Hausdorff (see e.g. Hawking and Ellis 1973, Chruściel and Isenberg 1991). All of these non-Hausdorff manifolds are obtained as quotient structures made from other manifolds which satisfy the Hausdorff condition. For the purposes of illustration, I will sketch the construction of non-Hausdorff extensions of Taub-NUT space-time.

The interesting fact is that the first of the examples of non-Hausdorff manifolds admits bifurcate geodesics and all of the mentioned more advanced examples do not admit them. This is because non-Hausdorffness is a necessary but not sufficient condition for presence of such geodesics. The details of connection between non-Hausdorffness and bifurcating curves are analysed in (Hajicek 1971a, Hajicek 1971b, Clarke 1976). Two main results are as follows: the necessary and sufficient condition for a manifold constructed by gluing together Hausdorff manifolds to admit bifurcate curves of the second kind (that is, a pair of curves which agree up to some point, excluding this point) is that the gluing be continuously extendable; a connected 4-dimensional Riemannian manifold which is non-Hausdorff either is not strongly causal or admits bifurcate curves of the second kind. Some extensions of Taub-NUT space-time are non-Hausdorff but the gluing is not continuously extendable, so in this case non-Hausdorffness does not imply existence of bifurcate geodesics.

In the literature the presence of bifurcating geodesics is the main argument invoked against non-Hausdorff space-times. The reason is that in such cases the equation of geodesics does not have a unique global solution (although local uniqueness is still satisfied) and that is the breakdown of determinism because geodesics are assumed to be (potential) worldliness of free test particles. However, as we have seen, in many non-Hausdorff space-times there are no bifurcate geodesics and therefore some physicist consider liberalizations of the Hausdorff condition. For example, (Hawking and Ellis 1973:174) allow for these non-Hausdorff space-times which do not admit bifurcating geodesics; similarly (Geroch 1968: 465) allows for non-Hausdorff space-times in which every geodesic has a unique extension and every curve has no more than one end point.

There are also other arguments against non-Hausdorff space-times, put forward in (Earman 2008) and (Penrose 1979). Earman firstly invokes some mathematical theorems which depend on the Hausdorff condition: every compact set of a topological space is closed and if a sequence of points of a topological space converges, the limit point is unique. His second, more physical worry is about local and global conservation of energy. In order to properly formulate local conservation law, energy-momentum tensor should be continuous and differentiable. However, this entails that when energy 'travels' along bifurcate curve, it has to take both branches, because if it went along only one of them, the tensor on another one would be discontinuous. But then global energy conservation would be violated. The third Earman's argument concerns existence and uniqueness of maximal solutions of Einstein's equations (given the appropriate initial data) - the theorem which guarantees them relies on the Hausdorff condition. The uniqueness result fails if non-Hausdorff branching is allowed - we may attach non-Haussdorffly additional branches at some given moment of time. The fourth and most philosophical Earman's argument can be summed as follows: both types of branching (on the level of geodesics and of the whole space-time) include a kind of arbitrariness connected with indeterminism. As concerns geodesics branching, he asks rhetorically: "how would such a particle know which branch of a bifurcating geodesic to follow?", suggesting that there is no good answer to this question. As concerns space-time branching, he claims that we need some physical theory that prescribes the dynamics of branching - there should be something that determines which of possible branches are realised. Branching cannot, according to Earman, be regarded as explanatory term; quite the opposite - it requires explanation in other terms.

Some of Earman's objections turn out to be harmless if we carefully interpret branching structures as representing possible evolutions, where at most one of branches can be actualised. For example, there is no problem with discontinuity of energy-momentum tensor: in actual reality it is wholly contained in one branch and the discontinuity concerns only branches which are not realised. The more subtle issue is indeterminism on the level of geodesics (curves followed by free test particles) and space-times which is allowed in some non-Hausdorff cases. There are some principal objections against it: lack of control, lack of factor which determinates the actual evolution (Earman 2008) or breaking "classical causality conception coinciding with determinism" (Hajicek 1971). However, it seems that all of these objections come down to simple rejection of indeterminism, which begs the question.

The only known attempt to use non-Hausdorff space-times to model indeterministic processes can be found in (Penrose 1979). His idea is to model quantum mechanics in Everett's interpretation by non-Hausdorff branching. Penrose rejects this idea as implausible but for the reasons connected with details of Everett interpretation, not with properties of non-Hausdorff space-times. Non-Hausdorff space-times are not well examined, so we do not have enough information to settle the issue of their physical reasonability. However, we can conclude that the known partial results cannot be taken as a basis for discrediting these space-times and that the idea to use such non-Hausdorff manifolds to model indeterministic processes within General Relativity is still not explored enough.

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A mathematical logic based approach to isotropy, homogeneity and special principle of relativity

Judit Madarász

We formalize the isotropy of space, the homogeneity of space and time, and the special principle of relativity theory in first-order logic (FOL) and we investigate their interrelationships. Rindler and Dixon in their relativity theory textbooks claim that "the principle of relativity is equivalent to the isotropy (of space) and the homogeneity (of space and time)". We analyze this statement within the scope of FOL.

This is only a sample of our approach (see the references in [1]) to the logical analysis of space-time theories in the axiomatic framework of modern mathematical logic. The aim of our research is to build a flexible hierarchy of axiom systems (instead of one axiom system only), analyzing the logical connections between the different axioms and axiomatizations. We try to formulate simple, logically transparent and intuitively convincing axioms. The questions we study include: What is believed and why? - Which axioms are responsible for certain predictions? - What happens if we discard some axioms? - Can we change the axioms, and at what price?

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Axiomatizing domain algebras

Szabolcs Mikulás

We look at various versions of domain algebras and provide a survey of axiomatizability results. We also present a finite axiomatization for the variety generated by representable upper semilattice-ordered domain–range semigroups.

Connection between neutron star observeables and the quantum nature of nuclear matter

Péter Pósfay, Antal Jakovác and Gergely Gábor Barnaföldi

The recent discovery of the gravitational waves provides a new method to study the interior of compact astrophysical objects, such as neutron stars. The high-accuracy measurements of neutron star mass gives constraint for the nuclear models of compact stars interior, which may further restricted by the gravitational wave data. Neutron star mergers, which are the most common predicted sources of gravitational waves, are very sensitive to the nuclear equation of state and different phases of high-density nuclear matter. Investigation of these compact star ”fingerprints” are one of the most active areas of this field. Equation of state zoo of the compact star interior has wide variety. Especially, the applied models have strong impact on the final observables of the objects. We study the effect of quantum fluctuations on these physical observables, using the Functional Renormalization Group (FRG) method in effective field theories of the nuclear matter. Within this framework we explored the effect of the running self interaction coupling in a simple model of Fermions coupled to a fluctuating scalar field. We calculated the phase diagram and the equation of state in this model, and compared the results to mean field and one-loop calculations [1]. We calculated the mass-radius relation for a static, spherically symmetric compact star corresponding to our model, which was compared to other results as well. Here we present our results and the latest extended models from Refs. [1,2], on the effect of quantum fluctuations in neutron star mass and radii.

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Goal directed proofs and diagrams suitable for applications in the philosophy of science

Aleksandra Samonek

In this paper we raise the following general question: how can humans reach proofs of various forms?

Time: real, but local - robust time asymmetry on an ontology of substances and powers

Daniel Saudek

Philosophy of science faces a dilemma: On the one hand, there seems to be an obvious, undeniable difference between the past, which is fixed and unchangeable, and the future, which is open and can be influenced. On the other, relativity theory shows that no "cut" between past and future can be made through spacetime in an observer-independent way.

The aim of my contribution is to provide a rigorous, non-circular foundation of local temporal asymmetry along the worldlines of objects, thereby resolving the above dilemma. This is done through the following steps: 1. Simple assumptions are made about substances and their powers. It is assumed that for each substance, there are different states, characterized by different properties. 2. These states can then be ordered through an operational criterion which does not make use of temporal concepts, but nevertheless yields the familiar ordering relation "before" between events. That is, the local temporal order can be defined non-circularly. 3. It is then possible to define a local quantification of change with the help of a recurring standard change affecting a substance. In other words, the local temporal parameter is based on an Aristotelian concept of time. 4. Finally, an epistemic assumption is made: properties in substances can be used to infer the truth-values of propositions with the help of a set of rules for such inference.

Using these steps, I proceed to show that the local past cannot be changed in principle, since the notion of doing so generates a contradiction. No such contradiction arises for the local future. We thus obtain a branching local worldline, so that the conflict between relativity theory and common sense dissolves. In short, times A-theoretical structure is real, but local.

Inaugural steps in a computational study of time travel

Atriya Sen, Naveen Sundar Govindarajulu and Selmer Bringsjord

We explain inaugural steps in a new, formal, computational study of the possibility of 'time travel,' the ultimate goal of which is to conclusively settle, by machine-verified proof, whether or not human time travel to the past is possible.

On Kripke completeness of some modal predicate logics

Valentin Shehtman

We present some new completeness results for modal predicate logics in the standard Kripke semantics. The proof is based on the technique developed earlier by S.Ghilardi, G.Corsi and D. Skvorstov, but now we arrange it in a game-theoretic style.

Many-valued temporal logic for quantum mechanics

Anthony Sudbery

I discuss the problems of probability and the future in the Everett-Wheeler understanding of quantum theory. To resolve these, I propose an understanding of probability arising from a form of temporal logic: the probability of a future-tense proposition is identified with its truth value in a many-valued logic. I construct a lattice of tensed propositions, with truth values in the interval $[0, 1]$, and derive logical properties of the truth values given by the usual quantum-mechanical formula for the probability of histories.

A big ball of wibbly wobbly

Petr Švarný

Time can have many shapes and forms, it is as a famous doctor said a "big ball of wibbly wobbly... time-y wimey... stuff". There are many views on time and this is true for the scientific community, be it physicists, logicians or philosophers (for example see (Dainton, 2016)).

In this paper, we present a first step in the project of unifying time or at least temporal logics. In a similar way as the project in fuzzy logics (Behounek & Cintula , 2006), we try to find some common grounds to the myriad of different time approaches (or as in (Barbour, 2000) even the lack of it), categorize them and present a common way how to work with them. We do this at first informally and thereafter we propose possible ways how to achieve a formal categorization. We aim to allow transitions between these categories that would formally relate the different temporal representations in a similar way as the well known system of relations between modal logics. We draw inspiration especially from similar unifying projects in logics using coalgebras as in (S. Baron, 2015). We focus on scientific representations of time. Nevertheless, in order to test our temporal categorization, we peak into popular culture for unorthodox, possibly contradictory, time representations and use them as another testing ground of our approach.

Should the principle of relativity speak only about reference frames instead of coordinate systems?

Gergely Székely

Rindler claims that "the principle of relativity is equivalent to the isotropy (of space) and the homogeneity (of space and time)" [2., p.40]. Contrary to this claim there is a construction of an anisotropic extension of the standard model of special relativity which still satisfies the principle of relativity [1., construction proving Theorem 2]. Of course, the contradiction is only apparent since something else is meant by 'the principle of relativity' in [1] and [2]. Even the mathematical language of the two frameworks are different.

Still, these examples show that there are (at least) two inequivalent formulation of the principle of relativity. It seems natural to ask which one is the 'true one'?

Since the principle of relativity is an informal idea and ideas can clearly be formulated several different ways, the right question is not which formulation is the 'true one', but how do the different formulations are related to one another.

We will use a logic based axiomatic framework of the Andréka–Németi group and Rindler's distinctions between inertial frames and inertial coordinate systems to investigate the connection between these two versions of the principle of relativity. We will see that the principle of relativity in [2] is understood for coordinate systems and the construction in [1] satisfies the principle of relativity understood for reference frames.

Based on Galileo's ship argument, we will also argue that the original intuition behind the principle of relativity is better reflected if we formulate it for reference frames only.

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Beyond the event horizon - Weyl's forgotten cosmology

György Szondy

100 years ago, in 1917 Hermann Weyl had written his comments on the General Relativity. In order to understand better the geometry of the Schwarzschild solution and the line element ds^2, he calculated the rotation ellipsoid in Euclidean space which has the same line element as the plain surface of Φ. He pointed out, that Schwarzschild solution has two outer ($r > r_g$) parts and no inner parts at all. To make it more obvious he transformed the Schwarzschild solution to isotropic coordinates and analyzed the results, as we did in our previous presentation on LRB15. In isotropic coordinates he refers the $r' > 2r_g$ region as the outer, while the $r' < 2r_g$ as the inner part. In the inner part "when r' decreases to zero", the circumference of a circle "starts increasing again and increases over all limits". Using this view for the collapse of a massive object we can observe the formation of the inner region (inner universe). We will introduce the analytical calculation and the simulation of the simplest case of massive body collapse - a simulation of a theoretical Big Bang.

Theory of temporal extension in special relativity, and a possible explanation for "jumpy" light beam photography

Áron Szűcs

In 2014 the author published a paper, which proposes the theory of temporal extension for fundamental particles as a key to intuitively interpret and understand quantum symmetries and related quantum and relativistic phenomena:

http://iopscience.iop.org/article/10.1088/1742-6596/563/1/012031/meta

In this new paper the connection between the theory of temporal extension of fundamental particles and physical objects and special relativity is discussed further. The paper highlights the advantages of the theory for providing an intuitive picture of relativity in a simple quasi-Euclidian approach. Extending the previous paper's simple demonstration of time dilatation, in this paper length contraction and the twin paradox are also demonstrated in an intuitive way utilizing temporal extension theory.

Since 2014, two papers from different authors have measured the travel of light beams by "fast photography" with substantially different methods. In both presented videos the light beams travel in an apparently "jumpy pattern", speeding up and decelerating periodically. As the two methods of photography are fundamentally different, but their result is similar in the sense that both light beams appear to travel in a "jumpy" fashion, this phenomenon might have a physical meaning.

The temporal length theory enables a logical and straightforward explanation for this phenomenon. It can be a direct consequence of the rotation of "4D photons" along a plane which includes the temporal direction, or along the plane which includes the two spatial directions perpendicular to the direction of travel.

The paper will suggest ways to distinguish between these alternatives in future experiments and will point out some curious temporal effects which could be observed with targeted measurements. These might have consequences for the development of new triggering techniques in particle accelerators in search for new physics.

Reference 1: nature.com/articles/ncomms7021 (video)

Reference 2: advances.sciencemag.org/content/3/1/e1601814.full (video)

Galilean and special relativistic fluids

Peter Ván

In this presentation the basic notion of the Galilean relativistic theory, the third order four-tensor is generalised in a special relativistic framework and the corresponding fluid theory is compared to the non-relativistic versions, and also to analogous divergence type special relativistic theories.

Non-inflationary geometrical solution of horizon problem

Branislav Vlahovic and Maxim Eingorn

The concordance cosmological model and an appropriate inflationary scenario describe the Universe very well. However, there are strict constraints on the shape of the inflaton potential. We propose an alternative interpretation of the cosmic microwave background (CMB) uniformity. We demonstrate that within the LambdaCDM model supplemented in the spherical space with an additional perfect fluid with the constant parameter $-1/3$ in the linear equation of state, there is an elegant solution of the horizon problem without inflation [1]. Under the proper parameter choice, light travels between the antipodal points during the age of the Universe. Thus, one can suggest that the observed CMB radiation originates from a very limited spatial region. We reach the agreement with the supernovae data and show that changing the amplitude of the initial power spectrum, one can adjust the proposed cosmological model to the CMB anisotropy, and that the discussed change is inside the experimentally allowed constrains.

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