2020 NORTH AMERICAN ANNUAL MEETING OF THE ASSOCIATION FOR SYMBOLIC LOGIC

University of California, Irvine
Irvine, California

March 25–28, 2020

Program Committee: Liron Cohen, James Cummings, Denis Hirschfeldt (chair), Phokion Kolaitis, Maryanthe Malliaris, Toby Meadows
Local Organizing Committee: Matthew D. Foreman, Isaac Goldbring (chair), Penelope Maddy, Toby Meadows, Kai F. Wehmeier, Martin Zeman
Please see `https://sites.uci.edu/asl2020/` for additional information.

All plenary and tutorial lectures will be held at the Social Science Lecture Hall (SSLH), room 100. All special session and contributed talks will be at SSLH 100; Social and Behavioral Sciences Gateway (SBSG), rooms 1321, 1511, and 1517; Social Science Plaza B (SSPB), room 1222; and Social Science Tower (SST), room 777. The welcoming reception will be held at 7:00 on Wednesday, March 25, at the Marriott Bayview Hotel. The banquet will be held at 7:30 on Thursday, March 26 at the Wedgewood University Club (on campus). There will be an excursion to Laguna Beach after the afternoon session on Friday, March 27, with shuttles leaving from campus.

WEDNESDAY, March 25

Morning

8:00 – 9:00	Registration and coffee.
9:00 – 9:10	Opening Remarks.
9:10 – 10:00	Invited Lecture: **H. Jerome Keisler** (University of Wisconsin–Madison), *Continuous model theory revisited.*
10:00 – 10:30	Coffee.
10:30 – 12:20	Special Sessions A1, B1, D1, E1, F1, and G1. See pages 3–6.

Afternoon

2:00 – 2:50	Invited Lecture: **Jeremy Avigad** (Carnegie Mellon University), *The mechanization of mathematics.*
3:05 – 3:55	Tutorial: **Jouko Väänänen** (University of Helsinki), *A tutorial on the logic of dependence and independence, Part A.*
3:55 – 4:25	Coffee.
4:25 – 5:15	Tutorial: **Anna Zamansky** (University of Haifa), *Paraconsistent logics: a tutorial, Part A.*
5:30 – 6:20	Invited Lecture: **Rina Dechter** (University of California, Irvine), *Reasoning with deterministic and probabilistic graphical models.*
7:00 – 9:00	Welcoming Reception, Marriott Bayview Hotel.
8:00 – 11:00	ASL Council Meeting, Room SSPB 1222.

THURSDAY, March 26

Morning

8:30 – 9:00 Coffee.
9:00 – 9:50 Invited Lecture: **Benoit Monin** (University Paris-Est Créteil), *Reverse mathematics and the Ramsey's theorem for pairs.*
9:50 – 10:20 Coffee.
10:20 – 11:10 Invited Lecture: **Sandra Müller** (University of Vienna), *How to obtain lower bounds in set theory.*
11:25 – 12:15 Tutorial: **Jouko Väänänen** (University of Helsinki), *A tutorial on the logic of dependence and independence, Part B.*

Afternoon

2:15 – 3:05 Invited Lecture: **Omer Ben-Neria** (Hebrew University), *Approximating the set theoretic universe by canonical inner models.*
3:20 – 4:10 Tutorial: **Anna Zamansky** (University of Haifa), *Paraconsistent logics: a tutorial, Part B.*
4:10 – 4:40 Coffee.
4:40 – 5:30 Tutorial: **Hector Pastén** (PUC Chile), *Hilbert's tenth problem beyond the integers, Part A.*
5:45 – 6:25 Special Session A2. See pages 3–6.
5:45 – 7:05 Contributed Talks. See pages 6–6.

7:30 – 9:30 Banquet: Wedgewood University Club.

FRIDAY, March 27

Morning

8:30 – 9:00 Coffee.
9:00 – 10:50 Special Sessions A3, B2, C1, D2, and F2. See pages 3–6.
11:00 – 12:30 Special Sessions A4, C2, E2, F3, and G2. See pages 3–6.

Afternoon

2:10 – 4:00 Special Sessions B3, C3, D3, F4, and G3. See pages 3–6.

TBA – Shuttles to Laguna Beach.

SATURDAY, March 28

Morning

8:30 – 9:00 Coffee.
9:00 – 9:50 Tutorial: **Hector Pastén** (PUC Chile), *Hilbert's tenth problem beyond the integers, Part B.*
9:50 – 10:20 Coffee.
10:20 – 11:10 Invited Lecture: **Juliette Kennedy** (University of Helsinki), *Tracking the profile of natural language in foundational practice.*
11:25 – 12:15 Invited Lecture: **Alexander Razborov** (University of Chicago and Steklov Mathematical Institute), *Continuous combinatorics.*

SPECIAL SESSIONS

A. Finite Model Theory and Descriptive Complexity

(Organized by Artem Chernikov, Neil Immerman, and Scott Weinstein)

Session A1: Wednesday, March 25 in room SBSG 1517.

10:30 – 11:10 **John T. Baldwin** (University of Illinois at Chicago), *Classes of finite structures that generate strongly minimal Steiner systems.*

11:30 – 12:10 **Siddharth Bhaskar** (University of Copenhagen), *Tameness in least fixed-point logic.*

Session A2: Thursday, March 26 in room SBSG 1321.

5:45 – 6:25 **Henry Towsner** (University of Pennsylvania), *Generalizing VC dimension to higher arity.*

Session A3: Friday, March 27 in room SBSG 1511.

9:00 – 9:40 **Cibele Freire** (Wellesley College), *On the complexity of the resilience problem.*

10:00 – 10:40 **Nadja Hempel** (University of California, Los Angeles), *A property of pseudo finite groups.*

Session A4: Friday, March 27 in room SBSG 1511.

11:00 – 11:40 **Cameron Hill** (Wesleyan University), *Towards a characterization of pseudo-finiteness.*

11:50 – 12:30 **Caroline Terry** (University of Chicago), *Speeds of hereditary properties and mutual algebraicity.*

B. Forcing and Ramsey Theory

(Organized by Dana Bartosova and Assaf Rinot)

Session B1: Wednesday, March 25 in room SSPB 1222.

10:30 – 11:10 **Todd Eisworth** (Ohio University), *Prismatic ideals.*

11:30 – 12:10 **David Fernández-Bretón** (Universidad Nacional Autónoma de México), *Finiteness classes inspired by Ramsey theory in choiceless set theory.*

Session B2: Friday, March 27 in room SSPB 1222.

9:00 – 9:40 **Natasha Dobrinen** (University of Denver), *Ramsey properties of Fraïssé structures*

10:00 – 10:40 **Sean Cox** (Virginia Commonwealth University), *Canary trees and definability of the nonstationary ideal.*

Session B3: Friday, March 27 in room SBSG 1511.

2:10 – 2:50 **Thomas Gilton** (University of California, Los Angeles), *Abraham-Rubin-Shelah open colorings and a large continuum.*

3:10 – 3:50 **Dima Sinapova** (University of Illinois at Chicago), *Iteration, reflection, and Prikry forcing.*

C. Logic and Graph Limits

(Organized by Cameron Freer and Rehana Patel)

Session C1: Friday, March 27 in room SBSG 1517.

9:00 – 9:40 **Henry Towsner** (University of Pennsylvania), *Randomness in ordered graph limits.*

10:00 – 10:40 **Nathanael Ackerman** (Harvard University), *Entropy of invariant measures.*

Session C2: Friday, March 27 in room SBSG 1517.

11:00 – 11:40 **Jaroslav Nešetřil** (Charles University), *Stability and modelings.*

11:50 – 12:30 **John T. Baldwin** (University of Illinois at Chicago), *Henkin models in the continuum.*

Session C3: Friday, March 27 in room SBSG 1517.

2:10 – 2:50 **Alexander Razborov*** **and Leonardo Coregliano** (University of Chicago and Steklov Mathematical Institute), *Semantic limits of dense combinatorial objects.*

3:10 – 3:50 **Persi Diaconis** (Stanford University), *Looking backward looking forward.*

D. Model Theory

(Organized by James Freitag and Özlem Beyarslan)

Session D1: Wednesday, March 25 in room SSLH 100.

10:30 – 10:50 **Hunter Chase** (University of Illinois at Chicago), *Query learning with random counterexamples.*

11:00 – 11:20 **Allen Gehret** (University of California, Los Angeles), *Expansions of structures.*

11:30 – 11:50 **Erik Walsberg** (University of California, Irvine), *Archimedean NIP structures.*

12:00 – 12:20 **Omer Mermelstein** (University of Wisconsin–Madison), *A new ω-stable set.*

Session D2: Friday, March 27 in room SBSG 1321.

9:00 – 9:20 **Elliot Kaplan** (University of Illinois at Urbana-Champaign), *H_T-fields.*

9:30 – 9:50 **Kyle Gannon** (University of Notre Dame), *Definable convolution and enveloping semigroups.*

10:00 – 10:20 **Alexi Block Gorman** (University of Illinois at Urbana-Champaign), *Pathologies and non-preservation results in o-minimality and structures with o-minimal open core.*

10:30 – 10:50 **Caroline Terry** (University of Chicago), *A stable arithmetic regularity lemma in finite abelian groups.*

Session D3: Friday, March 27 in room SBSG 1321.

2:10 – 2:30 **Joel Nagloo** (CUNY Bronx Community College), *Model theory and the Schwarzian differential equations.*

2:40 – 3:00 **Rémi Jaoui** (University of Notre Dame), *On the solutions of general algebraic planar vector fields.*

3:10 – 3:30 **Roland Walker** (University of Illinois at Chicago), *Distality rank.*

3:40 – 4:00 **Margaret Thomas** (Purdue University), *Definable topologies in o-minimal structures.*

E. Philosophy and Logic

(Organized by Toby Meadows)

Session E1: Wednesday, March 25 in room SBSG 1511.

10:30 – 11:10 **Gabriel Uzquiano** (University of Southern California), *Singletons of classes.*
11:30 – 12:10 **Rohan French** (University of California, Davis), *Metainferences.*

Session E2: Friday, March 27 in room SBSG 1321.

11:00 – 11:40 **Thomas Barrett** (University of California, Santa Barbara), *How trivial is the trivial strategy for excising structure?*
11:50 – 12:30 **Andrew Bacon** (University of Southern California), *Fundamentality: A logical framework.*

F. Proof Theory

(Organized by Valeria de Paiva, Elaine Pimentel, and Reuben Rowe)

Session F1: Wednesday, March 25 in room SST 777.

10:30 – 11:10 **Alexander Kurz** (Chapman University), *The logic of quantale enriched categories.*
11:30 – 12:10 **Joan Moschovakis** (Occidental College), *Constructive significance of the negative interpretation of classical analysis.*

Session F2: Friday, March 27 in room SST 777.

9:00 – 9:40 **Anupam Das** (University of Birmingham), *Recent developments in non-wellfounded proof theory.*
10:00 – 10:40 **Farzaneh Derakhshan** (Carnegie Mellon University), *Infinitary proof theory of first order linear logic with fixed points.*

Session F3: Friday, March 27 in room SST 777.

11:00 – 11:40 **Dominic Hughes** (University of California, Berkeley), *First-order proofs without syntax.*
11:50 – 12:30 **Sonia Marin** (University College London), *Intuitionistic modal proof theory: something old, something new.*

Session F4: Friday, March 27 in room SST 777.

2:10 – 2:50 **Yoni Zohar** (Stanford University), *Analyticity or cut-admissibility?*
3:10 – 3:50 **Marco Gaboardi** (Boston University), *l^p norms in a linear calculus.*

G. Reverse Mathematics and Computability Theory of Ramsey-Theoretic Principles

(Organized by Damir Dzhafarov and Ludovic Patey)

Session G1: Wednesday, March 25 in room SBSG 1321.

10:30 – 11:10 **Paul-Elliot Angles d'Auriac** (Université Claude Bernard Lyon), *The reverse mathematics of Hindman's and related theorems.*
11:30 – 12:10 **Sarah Reitzes** (University of Chicago), *Reduction games, provability, and compactness.*

Session G2: Friday, March 27 in room SSPB 1222.

11:00 – 11:40 **Linda Brown Westrick** (Pennsylvania State University), *Pseudo-Borel codes in HYP.*

11:50 – 12:30 **Keita Yokoyama** (Japan Advanced Institute of Science and Technology), *Ramsey's theorem and induction axioms.*

Session G3: Friday, March 27 in room SSPB 1222.

2:10 – 2:50 **Lu Liu** (Central South University), *Logic strength of tree theorem.*

3:10 – 3:50 **Marta Fiori Carones** (Università di Udine), *(Extra)ordinary equivalences with* ADS.

CONTRIBUTED TALKS

THURSDAY, March 26

Session I: Thursday, March 26 in room SBSG 1517.

5:45 – 6:05 **Samuel Braunfeld,** *Monadic stability and growth rates of ω-categorical structures.*

6:15 – 6:35 **Caleb Camrud,** *Results in computable model theory of continuous logic.*

6:45 – 7:05 **Marcos Mazari-Armida,** *Characterizing some classes of rings via superstability.*

Session II: Thursday, March 26 in room SSPB 1222.

5:45 – 6:05 **Sean C. Ebels-Duggan,** *Logicality, Zermelo's theorem, and well-founded extensions.*

6:15 – 6:35 **Michał T. Godziszewski,** *Between the model-theoretic and the axiomatic method of characterizing mathematical truth.*

6:45 – 7:05 **Michał T. Godziszewski*, Victoria Gitman, Toby Meadows, and Kameryn J. Williams,** *On axioms for multiverses of set theory.*

Session III: Thursday, March 26 in room SST 777.

5:45 – 6:05 **Diego A. Rojas,** *Effective notions of weak convergence of measures on the real line.*

6:15 – 6:35 **Dan E. Willard,** *How the law of excluded middle pertains to the second incompleteness theorem and its boundary-case exceptions.*

6:45 – 7:05 **Joachim Mueller-Theys,** *The idea of named logic.*

Abstract of invited tutorial

▸ HECTOR PASTEN, *Hilbert's tenth problem beyond the integers*.
Department of Mathematics, Pontificia Universidad Católica, 4860 Avda. Vicuna Mackenna, Santiago, Chile.
E-mail: hector.pasten@mat.uc.cl.
Hilbert's tenth problem asked for an algorithm to decide solvability of diophantine equations over the integers. The works of Davis, Putnam, Robinson and Matiyasevich showed that the requested algorithm does not exist. However, the analogous problem remains open in a number of important cases such as the field of rational numbers, rings of integers of number fields, and the ring of complex entire functions. This tutorial aims to present some of the main techniques in this very active area of research.

▸ JOUKO VÄÄNÄNEN, *A tutorial on the logic of dependence and independence*.
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URL Address: http://www.math.helsinki.fi/logic/people/jouko.vaananen/.

Tarski defined the semantics of first order logic by giving an inductive definition of what it means for an assignment s of values to variables $x_1, \ldots x_n$ to satisfy a formula $\phi(x_1, \ldots, x_n)$ in a given model. This definition has served logic well but it is not suitable for expressing dependences and independences between the variables $x_1, \ldots x_n$. One assignment s does not contain enough information to give grounds to make the conclusion that under this assignment e.g., x_1 is totally determined by x_2, or x_5 is totally independent of x_7. The situation can be remedied by considering the satisfaction of a formula under not a single assignment, but a whole set of assignments. Such sets play a central role in dependence logic ([1]) and are called teams to emphasise their collective contribution to truth.

In the first lecture of this tutorial the elements of semantics based on teams are presented. Illuminating examples from database theory, imperfect information games, and partially ordered quantifiers are reviewed. The fundamental relationship of dependence logic to existential second order logic, fixpoint logic, non-deterministic polynomial time (NP), and polynomial time (P) is established. In the second lecture the framework developed is applied to social choice theory, quantum information theory, and biology, all major sources of examples of manifestation of dependence and independence phenomena.

[1] Jouko Väänänen, ***Dependence logic***, Cambridge University Press, 2007.

▸ ANNA ZAMANSKY, *Paraconsistent Logics: a Tutorial*.
Information Systems Department, University of Haifa, Israel.
E-mail: annazam@is.haifa.ac.il.

Perhaps the most counterintuitive property of classical logic (as well as of its most famous rival, intuitionistic logic) is the fact that it allows the inference of any proposition from a single pair of contradicting statements. A lot of work and efforts have been devoted over the years to develop alternatives to classical logic that do not have this drawback. Those alternatives are nowadays called 'paraconsistent systems', and the corresponding research area—paraconsistent reasoning.

This tutorial, based on a recently published book [1], aims to provide a methodological overview of the rich mathematical theory that exists by now concerning the most fundamental part of paraconsistent reasoning: propositional (monotonic) logics. Among those logics we will focus on those which are effective (in the sense that they are decidable, have a concrete semantics, and can be equipped with implementable analytic proof systems). We will start by defining in precise terms basic notions related to paraconsistency. Then we will describe some of the main approaches to paraconsistency: finite-valued semantics (both truth-functional and nondeterministic), logics of formal inconsistency and paraconsistent logics which are based on modal logics. These logical systems will be discussed both from semantical and proof theoretical points of view, and some of them also characterized in terms of minimality or maximality properties.

[1] A. Avron, O. Arieli, and A. Zamansky, ***Theory of effective propositional paraconsistent logics***, Studies in Logic 75, College Publications, 2018.

Abstracts of invited plenary lectures

▸ JEREMY AVIGAD, *The mechanization of mathematics*.
Department of Philosophy and Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, USA.
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In computer science, *formal methods* are used for specifying, developing, and verifying complex hardware and software systems. The word "formal" indicates the use of formal languages to write assertions, define objects, and specify constraints. It also indicates the use of formal semantics, that is, accounts of the meaning of a syntactic expression, which can be used to specify the desired behavior of a system or the properties of an object sought. For example, an algorithm may be expected to return a tuple of numbers satisfying a given constraint, expressed in some specified language, whereby the logical account spells out what it means for an object to satisfy the symbolically expressed constraint. Finally, the word "formal" suggests the use of formal rules of inference, which can be used to verify claims or guide a search.

Such methods hold great promise for mathematical discovery and verification of mathematics as well. In this talk, I will survey some applications, including verifying mathematical proofs, verifying the correctness of mathematical computation, searching for mathematical objects, and storing and communicating mathematical results.

[1] Jeremy Avigad, *The mechanization of mathematics*, ***Notices of the American Mathematical Society***, vol. 65, no. 6, pp. 681–690, reprinted in ***The Best Writing on Mathematics 2019***, Mircea Pitici, editor, Princeton University Press, Princeton, New Jersey, 2019, pp. 150–170.

▸ OMER BEN-NERIA, *Approximating the set theoretic universe by canonical inner models*.
Einstein Institute of Mathematics, Hebrew University, Jerusalem, Israel.
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The goal of the talk is to introduce the concept of approximating the set theoretic universe V using canonical inner models. We will describe several ways by which a canonical inner model M of V can approximate V, as well as applications and limitations of having such approximations. Our presentation will focus on the inner models L (the constructible universe) and HOD (hereditarily ordinal definable sets), and lead to recent results concerning Woodin's HOD-conjecture.

This is a joint work with Yair Hayut.

▸ RINA DECHTER, *Reasoning with deterministic and probabilistic graphical models*.
Donald Bren School of Information and Computer Sciences, UC Irvine.

"An important component of human problem-solving expertise is the ability to use knowledge about solving easy problems to guide the solution of difficult ones." – Minsky

A longstanding intuition in AI is that intelligent agents should be able to use solutions to easy problems to solve hard problems. This has often been termed the "tractable island paradigm." How do we act on this intuition in the domain of probabilistic reasoning?

This talk will describe the status of reasoning algorithms that are driven by the tractable islands paradigm when solving satisfaction, optimization and likelihood queries described over mixtures of deteministic (logic-based) and probabilistic graphical models. I will show how heuristics generated via variational relaxation into tractable structures, can guide heuristic search and Monte-Carlo sampling, yielding anytime solvers that produce approximations with confidence bounds that improve with time, and become exact if enough time is allowed.

▸ H. JEROME KEISLER, *Continuous model theory revisited*.
University of Wisconsin, Madison.
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We revisit two research programs that were proposed in the 1960's, remained largely dormant for five decades, and then become hot areas of research in the last decade.

The monograph "Continuous Model Theory" by Chang and Keisler, Annals of Mathematics Studies (1966) studied structures with truth values in $[0, 1]$, with formulas that had continuous functions as connectives, sup and inf as quantifiers, and equality. In Model Theory for Metric Structures, Ben Yaacov, Bernstein, Henson, and Usvyatsev, London Math. Society Lecture Note Series, vol. 350 (2008), 315–427, equality is replaced by a metric, and all functions and predicates are required to be uniformly continuous. This has led to an explosion of research with results that closely parallel first order model theory, with many applications to analysis. Here we discuss the "Expansion Theorem", which allows one to extend many model-theoretic results about metric structures to general [0, 1]-valued structures—the structures in the 1966 monograph without equality (with no uniform continuity requirement).

In the paper "Ultrapowers which are not saturated", J. Symbolic Logic 32 (1967), 23–46, I introduced a pre-ordering $\mathcal{M} \trianglelefteq \mathcal{N}$ on all first-order structures, that holds if every regular ultrafilter that saturates $\mathcal{N}$ saturates $\mathcal{M}$, and suggested using it to classify structures. In the last decade, in a remarkable series of papers, Malliaris and Shelah showed that $\trianglelefteq$ gives a rich classification of simple first-order structures. Here, we discuss analogous of $\trianglelefteq$ for general [0, 1]-valued structures, and for metric structures.

▸ JULIETTE KENNEDY, *Tracking the profile of natural language in foundational practice*.
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URL Address: http://www.math.helsinki.fi/logic/people/juliette.kennedy/.

Gödel begins his 1946 Princeton Bicentennial Lecture lecture with the concept of computation, pointing out that this concept can be given a formalism independent definition:

> Tarski has stressed in his lecture the great importance (and I think justly) of the concept of general recursiveness (or Turing computability). It seems to me that this importance is largely due to the fact that with this concept one has succeeded in giving an absolute definition of an interesting epistemological notion, i.e., one not depending on the formalism chosen. [1, p. 150].

Gödel then poses the question in the lecture, whether notions of provability and definability can be developed, which are formalism independent in the way he understands computability to be. (The question also interested Emil Post.) In this talk we offer an implementation of Gödel's suggestion, in the case of definability. The calculus we present is based on the parametric use of logics and is aimed at measuring the degree of logical entanglement or on the other hand the degree of formalism freeness in the extended constructibility setting. Developing a methodology based on the parametric treatment of a class of logics, we then consider a second calculus based on this methodology, aimed at measuring the set-theoretical commitments of a logic, and on the other hand the logical entanglements of a set-theoretical concept, through the lens of model classes. The second calculus is presented in the context of Tarski's engagement with what he called "the mathematical"—a natural language move of a different sort than that made by Gödel in his Princeton lecture, in which he asked for formalism independent notions of provability and definability.

The "parametric use of logics" standpoint, in which one is able to survey a class of logics, without being entangled in any one of them, is part of what we call the semantic point of view. In investigating the semantic point of view, we ask questions such as: does a given model class always have an implicit syntax or logic, or do we attach syntactic features to a model class arbitrarily? How stable is the syntax/semantics distinction? Is the syntax/semantics distinction sharp enough to do the foundational and philosophical work we ask it to do?

We end the talk with a look at a new paradigm in foundational practice, in which foundational formal systems are used episodically and opportunistically, for mathematical rather than for foundational purposes.

[1] KURT GÖDEL, ***Collected works***, vol. III, The Clarendon Press, Oxford University Press, New York, 1995, unpublished essays and lectures, with a preface by Solomon Feferman,

edited by Feferman, John W. Dawson, Jr., Warren Goldfarb, Charles Parsons and Robert M. Solovay.

▸ BENOIT MONIN, *Reverse mathematics and the Ramsey's theorem for pairs*.
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Every matematicien already heard his collegues of professors say things like "Theorems A and B are equivalent" or "Theorem C does not follow from theorem D". But what do we really mean by that? Indeed, from the viewpoint of classical logic, theorems are all pairwise equivalent within ZFC. Also even though it is *formally* true, no one would claim that the four color theorem implies the Fermat–Wiles theorem.

Reverse mathemetics can be seen as an attempt to put a formal meaning on our intuition about this: two theorems are equivalent if each can be deduced from the another one, using in addition only a restricted set of axioms: the ones allowing to perform "elementary transformations", that is, simply computations. The terminology itself comes from the used method to show axioms optimality: Once some axioms have been used to show a theorem T, we then try to demonstrate back these axioms from Theorem T, with the only help of the "ground axioms" allowing to perform elementary transformations: this is why these mathematics are "reversed".

A simple observation that certainly contributed to the growth of reverse mathematics, is that they are very structured: Most mathematical theorems are equivalent to one among five axiomatic systems [3] [4] linearly ordered by strength: RCA_0, WKL_0, ACA_0, ATR_0 and Π^1_1-CA_0. Among them RCA_0 is the weakest which is also the one we always take for granted: it contains the basic axioms, needed to develop the computable mathematics. The systematic equivalences of theorems with one of these five systems led to them sharing the nickname "Big Five".

One of the most studied theorem in reverse mathemetics is the Ramsey theorem for pairs—RT^2_2—which is the cornerstone of a 50 year mathematical adventure. We will try to explain what is special about this theorem, by going through the history of its related reverse mathematical results, from the non-provability of RT^2_2 within RCA_0 [1], to the separation between RT^2_2 and SRT^2_2 in ω-models [2].

[1] Ernst Specker, *Ramsey's theorem does not hold in recursive set theory*, ***Studies in Logic and the Foundations of Mathematics***, vol. 61 (1971), pp. 439–442.

[2] Benoit Monin and Ludovic Patey, *SRT22 does not imply RT22 in omega-models*, https://arxiv.org/pdf/1905.08427.pdf.

[3] Stephen G. Simpson, ***Subsystems of second order arithmetic***, Cambridge University Press, 2009.

[4] Denis R. Hirschfeldt, ***Slicing the truth: On the computable and reverse mathematics of combinatorial principles***, World Scientific, 2015.

▸ SANDRA MÜLLER, *How to obtain lower bounds in set theory*.
Institut für Mathematik, UZA 1, Universität Wien. Augasse 2-6, 1090 Wien, Austria.
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URL Address: https://muellersandra.github.io.

Computing the large cardinal strength of a given statement is one of the key research directions in set theory. Fruitful tools to tackle such questions are given by inner model theory. The study of inner models was initiated by Gödel's analysis of the constructible universe L. Later, it was extended to canonical inner models with large cardinals, e.g., measurable cardinals, strong cardinals or Woodin cardinals, which were introduced by Jensen, Mitchell, Steel, and others.

We will outline three recent applications where inner model theory is used to obtain lower bounds in large cardinal strength for statements that do not involve inner models. The first result, in part joint with J. Aguilera, is an analysis of the strength of determinacy for certain infinite two player games of fixed countable length, the second result studies the strength of a model of determinacy in which all sets of reals are universally Baire, and the third result, joint with Y. Hayut, involves combinatorics of infinite trees and the perfect subtree property for weakly compact cardinals κ.

▸ ALEXANDER RAZBOROV, *Continuous combinatorics*.
University of Chicago, USA and Steklov Mathematical Institute, Moscow, Russia.
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Any increasing sequence of finite models of an universal theory in a relational signature contains a subsequence converging in a strictly defined sense to an analytical object. It turns out that these objects possess rich and very helpful structure; in particular, they can be alternately described in many different ways using analytical, logical, algebraic or statistical languages. Two popular views of such continuous structures are known as graph limits (semantical) and flag algebras (syntactical).

In this talk we will describe the emerging theory using many examples from combinatorics, logics and other fields. Most of the talk will be devoted to the "dense regime" in which the density of elementary predicates is assumed to be a constant in $(0, 1)$ and that is rather well-understood by now. Time permitting we will also review basic concepts about very sparse regime (graphings) as well as recent interesting advances in the intermediate regime.

Part of this talk represents joint work with Leonardo Coregliano.

Abstracts of invited talks in the Special Session on
Finite Model Theory and Descriptive Complexity

▸ JOHN T. BALDWIN, *Classes of finite structures that generate strongly minimal Steiner systems*.
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In [1] we construct families of strongly minimal Steiner systems that are limits of finite structures via a 'Hrushovski Construction'. While most research into flat Hrushovki constructions focuses on the associated acl-geometry, we focus on properties of the individual theories. Changing the pre-dimension δ, the exact class $\mathbf{K}_0$ of finite structures, or the algebraicity enforcing μ-function yields striking differences. One variant construction creates strongly minimal quasigroups; another theories that have no $\emptyset$-definable binary functions (so do not eliminate imaginaries); still another creates quasigroups with associated Steiner systems with line length q for each prime power q. The finite substructures in the last example are all members of a variety (universal algebra sense) that is congruence regular, permutable, and uniform, but not residually small. The notion of (a, b)-graph from the study of 3-Steiner systems that was generalized to infinite structures by Cameron and Webb is further generalized to (partial) k-Steiner systems. Two important techniques underlie these constructions: (i) the replacement of 'substructure by an appropriate 'strong' substructure in defining the 'Fraïssé' limit and (ii) replacing hereditary classes by classes closed under union.

[1] J. Baldwin and G. Paolini, *Strongly minimal Steiner systems I*, ***The Journal of Symbolic Logic***, provisionally accepted.

▸ SIDDHARTH BHASKAR, *Tameness in least fixed-point logic*.
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We investigate classification-theoretic combinatorial properties, such as the order property, the independence property, and the strict order property, in the context of least fixed-point logic over families of finite structures. We show that each of these properties depends only on the elementary limit theory of such a family, and classify the valid entailments among them. In particular, we show that the order property is equivalent to the independence property.

McColm [2] conjectured that least fixed-point (LFP) logic collapsed to first-order (FO) logic exactly when a class of of structures is not proficient. Gurevich, Immerman, and Shelah [1] found two counterexamples. As an application of our classification, we show that any counterexample to McColm's conjecture must be "wild," in the sense that its elementary limit theory must fail any known tameness condition.

This work is joint with Alex Kruckman.

[1] Yuri Gurevich, Neil Immerman, and Saharon Shelah, *McColm's conjecture*, ***Proceedings of the IEEE Symposium on Logic in Computer Science*** (Paris), IEEE Computer Society Press, 1994, pp. 10–19.

[2] Gregory McColm, *When is arithmetic possible?*, ***Annals of Pure and Applied Logic***, vol. 50 (1990), no. 1, pp. 29–51.

▸ CIBELE FREIRE, *On the complexity of the resilience problem*.
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Various problems in relational databases, such as causality, explanations, and deletion propagation, examine how interventions in the input of a query impact the query's output. An intervention constitutes a change (update, addition, or deletion) to the input tuples. The resilience of a Boolean query is the minimum number of tuples that need to be deleted from the input tables in order to make the query false. In this talk I will present some complexity results for conjunctive queries with and without self-joins. I will define the concept of *triads* and show a complete characterization of the complexity for the class of conjunctive queries without self-joins using this structure. For the class of conjunctive queries with self-joins, structural properties beyond triads must be used, namely *chains, confluences and permutations*. A complete dichotomy has not yet been proved for this case but I will show various complexity results that indicate one might exist.

This talk is based on the following papers:

[1] Cibele Freire, Wolfgang Gatterbauer, Neil Immerman, and Alexandra Meliou, *The complexity of resilience and responsibility for self-join-free conjunctive queries*, ***Proceedings of the VLDB Endowment***, vol. 9 (2015), no. 3, pp. 180–191.

[2] ———, *New results for the complexity of resilience for binary conjunctive queries with self-joins*, ***arXiv e-prints***, (2019), arXiv:1907.01129.

▸ NADJA HEMPEL, *A property of pseudo finite groups*.
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In a joint work with Daniel Palacin, we study pseudo finite groups, i.e., infinite groups which satisfies all sentences that hold in all finite groups or equivalently an ultra product of finite groups (modulo a non-principle ultrafilter).† One might think of these groups as a "logical limit" of finite groups. In fact, studying such groups often sheets light of the limit behavior of finite groups. We show that every pseudo-finite group contains an infinite abelian subgroup. In addition, we discuss the existence of a finite-by-abelian finite index subgroup in any pseudo finite group satisfying a certain condition on centralizers.

▸ CAMERON DONNAY HILL, *Towards a characterization of pseudo-finiteness*.
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I will discuss an ongoing project to find a characterization of pseudo-finiteness for countably categorical theories in which algebraic closure is trivial. First, we'd like to identify certain primitive building blocks out of which models of pseudo-finite theories are made. Second, we'll need to understand the program for actually putting those building blocks together. The working hypothesis is, roughly, that pseudo-finite theories are certain kinds of limits of almost-sure theories (those arising from 0,1-laws for classes of finite structures). I'll also speculate that the almost-sure theories in this context are precisely the rank-1-super-simple theories.

▸ CAROLINE TERRY, *Speeds of hereditary properties an mutual algebraicity*.
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A hereditary graph property is a class of finite graphs closed under isomorphism and induced subgraphs. Given a hereditary graph property $\mathcal{H}$, the speed of $\mathcal{H}$ is the function which sends an integer n to the number of distinct elements in $\mathcal{H}$ with underlying set $\{1, \ldots, n\}$. Not just any function can occur as the speed of hereditary graph property. Specifically, there are discrete "jumps" in the possible speeds. Study of these jumps began with work of Scheinerman and Zito in the 90's, and culminated in a series of papers from the 2000's by Balogh, Bollobás, and Weinreich, in which essentially all possible speeds of a hereditary graph property were characterized. In contrast to this, many aspects of this problem in the hypergraph setting remained unknown. In this talk we present new hypergraph analogues of many of the jumps from the graph setting, specifically those involving the polynomial, exponential, and factorial speeds. The jumps in the factorial range turned out to have surprising connections to the model theoretic notion of mutual algebricity, which we also discuss.

This is joint work with Chris Laskowski.

▸ HENRY TOWSNER, *Generalizing VC dimension to higher arity*.
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The notion of bounded VC dimension is a property at the intersection of combinatorics and probability. This family has been discovered repeatedly and studied from various perspectives—for instance, in model theory, theories with bounded VC dimension are known as NIP (the theories which do Not have the Independence Property). One useful property is that graphs with bounded VC dimension are the graphs that can be always be finitely approximated in a random-free way: graphs with bounded VC dimension satisfy a strengthening of Szemeredi's Regularity Lemma in which the densities between the pieces of the partition are either close to 0 or close to 1. The generalization of VC dimension to higher arity, known in model theory as k-NIP for various k, has been less well-studied. We summarize some known facts about this generalization, including a new result (joint with Chernikov) showing k-NIP hypergraphs have a similar kind of approximation with only lower order randomness.

Abstracts of invited talks in the Special Session on
Forcing and Ramsey Theory

▸ SEAN COX, *Canary trees and definability of the nonstationary ideal*.
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A *Canary Tree* on κ is a tree T of height and size κ, without cofinal branches, such that whenever a stationary set is killed in a $< \kappa$-distributive forcing extension, T obtains a cofinal branch in that extension. The presence of such a tree implies that the nonstationary ideal on κ is $\mathbf{\Delta}_1$ definable over $(H_{\kappa^+}, \in)$. Canary trees were introduced by Mekler and Shelah, who proved that the existence of an ω_1-Canary tree was independent of ZFC. Assuming GCH, Hyttinen and Rautila generalized those results to show that if κ is the successor of a regular cardinal μ, then one can force the existence of a tree that is "Canary for" stationary subsets of $\kappa \cap \mathrm{cof}(\mu)$. We prove that much of the Hyttinen–Rautila machinery works even in the absence of GCH, and prove:

Theorem 1. *If Martin's Maximum* (MM) *holds, then there is a poset that preserves* MM *and forces* $NS_{\omega_2} \restriction A$ *to be* $\mathbf{\Delta}_1$ *definable over* $(H_{\omega_3}, \in)$, *where* A *is the maximal set in the approachability ideal* $I[\omega_2]$. *In particular,* $NS \restriction \big(\omega_2 \cap cof(\omega)\big)$ *is* $\mathbf{\Delta}_1$ *definable over* $(H_{\omega_3}, \in)$ *in the extension*.

This is joint work with Philipp Lücke.

▸ NATASHA DOBRINEN, *Ramsey properties of Fraïssé structures*.
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The Infinite Ramsey Theorem states that given $n, r \geq 1$ and a coloring of all n-sized subsets of $\mathbb{N}$ into r colors, there is an infinite subset of $\mathbb{N}$ in which all n-sized subsets have the same color. Extensions of Ramsey's Theorem to Fraïssé structures have been studied for several decades. Given a Fraïssé class $\mathcal{K}$, and a fixed $A \in \mathcal{K}$, one colors all copies of A inside of $\mathbb{K}$, the Fraïssé limit of $\mathcal{K}$. The goal is to find out for which classes $\mathcal{K}$ is there a bound $T(A, \mathcal{K})$ such that for any finite number of colors, there is a copy $\mathbb{K}'$ inside $\mathbb{K}$ in which the copies of A have no more than $T(A, \mathcal{K})$ colors. If it exists, the minimum such number is called the *big Ramsey degree* of A in $\mathbb{K}$.

The question of which Fraïssé structures have finite big Ramsey degrees gained new momentum when it was brought into focus by Kechris, Pestov, and Todorcevic (KPT) in their work finding a correspondence between the Ramsey property and extreme amenability. Answering a question of KPT, Zucker found a correspondence between Ramsey degrees for infinite structures and completion flows, providing additional motivation for this research.

In the past few years, the speaker developed the method of strong coding trees to prove that the k-clique-free Henson graphs have finite big Ramsey degrees, for each $k \geq 3$. Central to proofs is an extension of Harrington's "forcing proof" of the Halpern–Läuchli theorem to the setting of strong coding trees. These proofs are in ZFC, where the forcing is used to do a bounded search for a finite object. In this talk, we will provide an overview of these methods and their applications and modifcations to current work proving finite big Ramsey degrees for more Fraïssé structures.

▸ TODD EISWORTH, *Prismatic ideals*.
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We introduce the notion of *prismatic ideals*, and use such ideals to obtain several coloring theorems in ZFC related to the question of whether the successor of a singular cardinal can be Jónsson cardinal.

▸ DAVID FERNÁNDEZ-BRETÓN, *Finiteness classes inspired by Ramsey theory in choiceless set theory*.
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There are multiple equivalent ways of defining what it means for a set to be finite; if one drops the Axiom of Choice, then many of these are no longer equivalent. The notion of a finiteness class is a way of axiomatizing the fact that a class of sets corresponds to a certain definition of "finite", and various people have researched the intricacies of the logical relations between multiple such classes. In this talk we will introduce two new finiteness classes, closely related to Ramsey's and Hindman's theorems, and show the relations between these new classes and other previously studied ones.

This is joint work with Joshua Brot and Mengyang Cao.

▸ THOMAS GILTON AND ITAY NEEMAN, *Abraham–Rubin–Shelah open colorings and a large continuum*.
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Open Coloring Axioms may be viewed as consistent generalizations of Ramsey's Theorem to ω_1 in which topological restrictions are placed on the colorings. The first of these, denoted OCA_{ARS}, appeared in [1]. There the authors showed that OCA_{ARS} is consistent with ZFC. To ensure that the posets which add the homogeneous sets satisfy the c.c.c., they construct a type of "diagonalization" object (for a continuous coloring χ) called a *Preassignment of Colors*, which guides the forcing to add the χ-homogeneous sets.

However, the only known constructions of effective preassignments require the CH. Since a forcing iteration of $\aleph_1$-sized posets all of whose proper initial segments satisfy the CH results in a model in which $2^{\aleph_0}$ is at most $\aleph_2$, this leads naturally to the question of whether OCA_{ARS} is consistent with $2^{\aleph_0} = \aleph_3$.

We answer this question in the affirmative. In light of the CH obstacle, we only construct names for preassignments with respect to a small class $\mathcal{A}$ of CH-preserving iterations. However, our preassignments are powerful enough to work even over models in which the CH fails.

Our final forcing is built by combining the members of $\mathcal{A}$ into a new type of forcing, called a *Partition Product*. A partition product is a type of restricted memory iteration with isomorphism and coherent-overlap conditions on the memories. In particular, each "memory" is isomorphic to a member of $\mathcal{A}$.

In this talk, we will describe these ideas in more detail and sketch proofs of our construction of preassignments.

[1] U. Abraham, M. Rubin, and S. Shelah, *On the consistency of some partition theorems for continuous colorings, and the structure of $\aleph_1$-dense real ordertypes*, ***Annals of Pure and Applied Logic***, vol. 325 (1985), no. 29, pp. 123–206.

▸ DIMA SINAPOVA, *Iteration, reflection, and Prikry forcing*.
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There is an inherent tension between stationary reflection and the failure of SCH. The former is a compactness type principle that follows from large cardinals. The latter is an instance of incompactness, and usually obtained using Prikry forcing. We describe a Prikry style iteration, and use it to force stationary reflection in the presence of not SCH. Then we discuss the situation at smaller cardinals. This is joint work with Alejandro Poveda and Assaf Rinot.

Abstracts of invited talks in the Special Session on
Logic and Graph Limits

▸ NATHANAEL ACKERMAN, *Entropy of invariant measures*.
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The entropy of a probability measure on a finite set quantifies one notion of the complexity of the measure. For a finite relational language L, and a measure μ on L-structures with underlying set the natural numbers, if μ is S_∞-invariant then it is determined by its restriction to L-structures with underlying sets of the form $\{0, \ldots, n-1\}$. We can therefore canonically assign to μ its *entropy function*, En_μ, which sends each natural number n to the entropy of the restriction of μ to L-structures with underlying set $\{0, \ldots, n-1\}$.

In this talk I will discuss the relationship between the growth rate of En_μ and the language L. If the largest arity of a relation in L is k, then En_μ grows as $O(n^k)$. I will give a precise expression for the coefficient of n^k based on the hypergraphon representation of μ, and show how these notions generalize what is often called the *entropy of a graphon*. When μ comes from sampling from a Borel structure we will show that the growth rate of the entropy function is $o(n^k)$. We will also discuss lower bounds on the possible growth rates of the entropy function in this case. This generalizes work of Janson and Hatami-Norine from graphons to hypergraphons.

This is joint work with Cameron Freer and Rehana Patel.

▸ JOHN T. BALDWIN, *Henkin models in the continuum*.
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We describe Shelah's construction of atomic models in the continuum, as reformulated with Laskowski as a Henkin construction [2]. Then we discuss briefly the connection with the Ackerman–Freer–Patel [1] proof that if M is a countable structure for a relational language L with trivial definable closure then there is an invariant probability measures on the countable L-structures that concentrates on M. We explain while the sufficient conditions for the model in the continuum include those with trivial definable closure, our theorem applies more generally to obtaining a atomic model in the continuum of the first order theory of a countable atomic extendible structure admitting a formula-based geometry.

[1] N. Ackerman, C. Freer and R. Patel, *Invariant measures concentrated on countable structures*, ***Forum of Mathematics, Sigmas***, vol. 4 (2016).

[2] J. T. Baldwin and M. C. Laskowski, *Henkin constructions of models in the continuum*, ***The Bulletin of Symbolic Logic***, vol. 24 (2019), no. 1, pp. 1–34.

▸ LEONARDO COREGLIANO AND ALEXANDER RAZBOROV, *Semantic limits of dense combinatorial objects*.
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This talk is essentially a continuation of the invited talk given by one of us in which we will provide more technical details about the work on generalizing graphons/digraphons/permutons to arbitrary universal theories and connecting the resulting objects (that we call P-ons and T-ons) to flag algebras. A significant part of this generalization is quite routine but while doing it we have been able to identify several more interesting points on which we will try to concentrate:

1. our generalization also encompasses limit objects like permutons, limits of interval graphs or limits of subsets in finite vector spaces that had been originally defined quite differently
2. a simple proof of the induced removal lemma (infinite version) based on compactness in propositional logic
3. subtle differences between "perfect" T-ons and those allowing errors of measure zero.

We also may talk about the structure and classification of quasi-random objects that can be naturally defined in our framework.

▸ PERSI DIACONIS, *Looking backward looking forward*.
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de Finetti's theorem and its many variants were an early instance of graph limits (the Aldous–Hoover theorem was an answer to a statistics question). There has been wonderful progress in extensions to limit theorems of all kinds. It is natural to ask, does some of this progress feed back into the wealth of questions arising in statistics? I promise you, there are simple statistics questions that are wide open in this domain; for example, characterizing latent variable models or characterizing the mixing measures.

▸ JAROSLAV NEŠETŘIL, *Stability and modelings*.
Charles University, Faculty of Mathematics and Physics, Computer Science Institute of Charles University (IUUK), Malostranské nám. 25, 118 00 Praha 1, Czech Republic.
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We present a characterization of monotone stable classes of graphs by means of the existence of modeling limits for FO-converging sequences. Related results on sparse hierarchies will be mentioned.

This is a joint work with P. Ossona de Mendez (Paris and Prague).

▸ HENRY TOWSNER, *Randomness in ordered graph limits*.
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The structure of a graph limit—more precisely, of an ultraproduct of finite graphs—canonically induces a decomposition into a "random" part and a "structured" part, corresponding to the classical Szemerédi Regularity Lemma.

When we extend this idea to hypergraphs, we end up with a nested sequence of notions of structure: a k-graph (that is, a hypergraph of k-tuples) decomposes into a random part, a part "explained by $k-1$-ary information", a part "explained by $k-2$-ary information", and so on.

In this talk, we discuss what happens when we consider *ordered* graphs and hypergraphs. The ordering introduces a new notion of structure which is *stronger* than the usual notion of structure: an ordered graph decomposes into three parts, a "random" part, a unary part, and a part "explained by the ordering". We discuss how this perspective can be used to take theorems about k-ary hypergraphs and compare them to theorems about ordered $k-1$-ary hypergraphs.

Abstracts of invited talks in the Special Session on Model Theory

▸ ALEXI BLOCK GORMAN, *Pathologies and non-preservation results in o-minimality and*

structures with o-minimal open core.
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Model theorists have produced a myriad of results on the preservation of neostability properties and open core for expansions of o-minimal theories, from dense pairs to H-structures with an o-minimal base theory. To appreciate the success of many efforts to show that properties such as NIP, NTP2, and open core are preserved under various expansions, it is important to discuss negative results as well. There are many natural constructions in model theory, including taking model companions and expansions by definable skolem functions, that do not preserve all of the properties above. In this talk, we seek to understand why preservation fails in certain pathological cases even for the most natural constructions and expansions. We will discuss various examples, including the model companions for the expansion of some o-minimal theories by a predicate for a dense, divisible proper subgroup, which we will see need not preserve NIP, strong, or NTP2, though in some cases one, two, or all three of these properties still hold for the model companion. Other examples include the non-preservation of open core for the expansion of an o-minimal structure by a certain dense, indpenedent set, and the expansion of an o-minimal structure by a predicate and by definable skolem functions that preserves the o-minimal open core, but not o-minimality itself. We will unpack the relevance of these non-preservation results, and the open questions from [1] that they answer.

Some of the work mentioned is joint with Erin Caulfield and Philipp Hieronymi.

[1] Alfred Dolich, Chris Miller, and Charles Steinhorn, *Structures having o-minimal open core*, ***Transactions of the American Mathematical Society***, vol. 362 (2010), no. 3, pp. 1371–1411.

▸ HUNTER CHASE, JAMES FREITAG, AND KYLE GANNON, *Query learning with random counterexamples*.
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Several notions of complexity of set systems correspond both with model-theoretic dividing lines and notions of machine learning. Set systems of finite VC-dimension, which correspond to NIP formulas, are exactly those which are PAC-learnable, while set systems of finite Littlestone dimension, which correspond to stable formulas, are exactly those which are online-learnable.

In equivalence query learning, a learner attempts to learn a target set C from a set system $\mathcal{C}$ by submitting hypothesis sets H from a hypothesis class $\mathcal{H} \supseteq \mathcal{C}$. A teacher responds to the hypotheses by informing the learner that they are correct or providing a counterexample $x \in C \triangle H$. In the case where the counterexamples are chosen adversarially, bounds on learning depend on Littlestone dimension and consistency dimension; the latter is a notion of richness of $\mathcal{H}$ relative to $\mathcal{C}$ [2].

We consider the case where counterexamples are chosen randomly from $C \triangle H$, first studied in [1]. One aim of using random counterexamples is to make learning possible using hypotheses only from $\mathcal{C}$. We give bounds in this setting and describe connections with model theory.

[1] D. Angluin and T. Dohrn, *The power of random counterexamples*, ***Algorithmic Learning Theory 2017***, Kyoto, Japan, (S. Hanneke and L. Reyzin, editors), vol. 76, Proceedings of Machine Learning Research, 2017, pp. 452–465.

[2] H. Chase and J. Freitag, *Bounds in query learning*, arXiv preprint `arXiv:1904.10122`.

▸ KYLE GANNON AND ARTEM CHERNIKOV, *Definable convolution and enveloping semigroups*.
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Let T be a first order theory expanding the theory of a group, $\mathcal{G}$ a monster model of T, and G a small elementary substructure. Then, there is a natural action of $\mathrm{conv}(G)$ on the space of measures which are finitely satisfiable in G. If G is countable and NIP, we show that the Ellis semigroup of this action is isomorphic to a particular convolution algebra of Keisler measures. This is joint work with Artem Chernikov.

▸ ALLEN GEHRET, *Expansions of structures*.
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In this talk I will discuss some ideas about expanding model theoretic structures. The motivating project is the study of the differential field of logarithmic transseries, although at this level of generality there might be other applications also.

▸ REMI JAOUI, *On the solutions of general algebraic planar vector fields*.
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It is a theorem of Landis and Petrovskii from the fifties that the only algebraic solutions of a general planar algebraic vector field are always stationary. The non-stationary solutions of a general vector field are therefore given by transcendental functions but few things are known about the nature of these transcendental functions. For example, can they be expressed using only "classical" transcendental functions such as exponentials, logarithms, Weierstrass's elliptic functions?

In my talk, I will describe a stronger non-integrability result (irreducibility in the sense of Nishioka–Umemura) for general planar algebraic vector fields of degree greater or equal to three, based on a linearization technique for autonomous differential equations around their generic point.

▸ ELLIOT KAPLAN, *H_T-fields*.
University of Illinois at Urbana-Champaign.
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In this talk, I will introduce the class of H_T-fields, which are real closed H-fields equipped with additional compatible o-minimal structure. Key examples are Hardy fields of o-minimal expansions of the real field and the differential field of logarithmic-exponential transseries expanded by the total exponential function. I will discuss some results about H-fields which also hold for certain H_T-fields.

▸ OMER MERMELSTEIN, *A new ω-stable set*.
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Alluding to the title of Hrushovski's seminal "A new strongly minimal set" [1], we introduce a new ω-stable theory of rank ω^ω—that of the generic *strict gammoid/flat pregeoemtry*.

[1] EHUD HRUSHOVSKI, *A new strongly minimal set*, ***Annals of Pure and Applied Logic***, vol. 62 (1993), no. 2, pp. 147–166.

► JOEL NAGLOO, *Model theory and the Schwarzian differential equations*.
CUNY Bronx Community College, Department of Mathematics and Computer Science, Bronx, NY, 10453 And CUNY Graduate Center Ph.D. Programs in Mathematics, 365 Fifth Avenue, New York, NY 10016.
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This talk is centered around the problem of proving variants of the Ax–Lindemann–Weierstrass (ALW) theorem for analytic functions which satisfy Schwarzian differential equations. I will discuss the ALW theorem for the uniformizers of genus zero Fuchsian groups and point to the model theoretic ingredients that go into its proof. I will also explain how one can apply this result to obtain ALW theorems for other Schwarzian equations.

► CAROLINE TERRY, *A stable arithmetic regularity lemma in finite abelian groups*.
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The arithmetic regularity lemma for $\mathbb{F}_p^n$ (first proved by Green in 2005) states that given $A \subseteq \mathbb{F}_p^n$, there exists $H \leq \mathbb{F}_p^n$ of bounded index such that A is Fourier-uniform with respect to almost all cosets of H. In general, the growth of the index of H is required to be of tower type depending on the degree of uniformity, and must also allow for a small number of non-uniform elements. Previously, in joint work with Wolf, we showed that under a natural model theoretic assumption, called stability, the bad bounds and non-uniform elements are not necessary. In this talk, we present results extending this work to stable subsets of arbitrary finite abelian groups.

This is joint work with Julia Wolf.

► MARGARET E. M. THOMAS, *Definable topologies in o-minimal structures*.
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A 'definable topological space' is simply a definable set together with a definable family which forms a basis for a topology. We present some progress towards understanding the nature of topologies that are definable in o-minimal structures, related in particular to their classification and to the identification of suitable definable analogues of classical notions, such as compactness and separability, in this setting. This is based on work arising from a joint project with Pablo Andújar Guerrero and Erik Walsberg.

► ROLAND WALKER, *Distality rank*.
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Pierre Simon introduced distality to better understand unstable NIP theories by studying their stable and "purely unstable," or distal, parts separately. We introduce distality rank as a property of first-order theories and give examples for each rank m such that $1 \leq m \leq \omega$. For NIP theories, we show that distality rank is invariant under base change. We also define a generalization of type orthogonality called m-determinacy and show that theories of distality rank m require certain products to be m-determined. Furthermore, for NIP theories, this behavior characterizes distality rank m.

▸ ERIK WALSBERG, *Archimedean NIP structures*.
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I will discuss some recent work on NIP expansions of archimedean ordered abelian groups.

Abstracts of invited talks in the Special Session on Philosophy and Logic

▸ ANDREW BACON, *Fundamentality: A logical framework*.
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In explaining the notion of a fundamental property or relation, metaphysicians will often draw an analogy with languages. According to this metaphor, the fundamental properties and relations stand to reality as the primitive predicates and relations stand to a language: the smallest set of vocabulary God would need in order to write the 'book of the world'. However this analogy, if taken too literally, is fraught with paradoxes. In this talk I shall outline a general model theoretic framework for generating theories of fundamentality that draws on the abstract properties of languages as left adjoints of forgetful functors in categories of typed structures. I will then summarize some results on the consistency of higher-order theories of fundamentality that capture some of the abstract analogies between language and reality.

▸ THOMAS BARRETT, *How trivial is the trivial strategy for excising structure?*
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It is often suggested by metaphysicians, philosophers of physics, and physicists themselves that we should prefer theories that 'posit less structure'. In particular, we should try to 'excise' or 'dispense with' surplus structure from our theories. One method of excising structure that has historically received significant attention is the so-called *trivial strategy*. Suppose that we have a theory T in language L and we have identified some piece of structure—represented by a predicate symbol $p \in L$—that we want to excise. The trivial strategy tells us to simply move to the theory $T|_{L-\{p\}}$, i.e., the theory whose axioms are those consequences of T that do not use the symbol p.

The standard view about the trivial strategy — endorsed by, for example, Putnam, Field, Colyvan, and others—is that it is, as the name itself suggests, trivial. The theory $T|_{L-\{p\}}$ may not be elegant or attractive, but moving to it does successfully excise the structure p from T. My aim in this talk is to argue that this standard view is not correct. In brief, there are two main problems with the trivial strategy. First, as has been emphasized by Melia, it can be that the theory T has 'kosher' consequences—i.e., consequences that do not involve the predicate p—that the theory $T|_{L-\{p\}}$ does not have. And second, there is a large class of cases where moving to $T|_{L-\{p\}}$ simply does not excise anything from T; the two theories posit precisely the same structure. This discussion yields a modest payoff concerning the conditions under which one theory posits less structure than another.

▸ ROHAN FRENCH, *Metainferences*.
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Metainferences—inferences between inferences—have recently become a major focus for work on understanding nontransitive and nonreflexive approaches to the paradoxes of self-reference. In the present paper we'll provide a metasequent calculus, treating metainferences themselves as first class logical citizens, looking at the structural features of consequence relations between metasequents. In the process we will look at how shifting the focus from

inferences to metainferences provides some insight on the connection between Strong-Kleene logic and nonreflexive logics, as well as looking at potential revenge issues facing nonreflexive solutions to the paradoxes of self-reference.

▸ GABRIEL UZQUIANO, *Singletons of Classes*.
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Kaplan's paradox begins with the observation that Cantor's theorem rules out the satisfiability of a certain sentence in a possible worlds model for intensional logic. The sentence may be used to encode the hypothesis that for every proposition, it is possible that it, and it alone, is queried, and for Kaplan, the puzzle originally arises out of concern that logic should remain neutral with respect to it. The role of Cantor's theorem may promote the misimpression that the issue arises as a byproduct of the identification of propositions with sets of possible worlds, but we know that the negation of the sentence is a theorem of intensional logic and remains a limitative result whether or not one opts for a possible worlds model theory for intensional logic. The role of Cantor's theorem is in fact more subtle than one may have anticipated: different proofs of the theorem provide a heuristic for a battery of limitative theorems of intensional logic. These results provide specific instances of propositions for which it is not possible to be the one and only queried proposition.

Abstracts of invited talks in the Special Session on Proof Theory

▸ ANUPAM DAS, *Recent developments in non-wellfounded proof theory*.
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Non-wellfounded proof theory has become a popular alternative to systems with induction or with infinitely branching rules. The non-wellfounded approach to infinitary proof theory retains finitary branching at the cost of wellfoundedness, and usually requires some sort of global fairness condition on the infinite branches to prevent fallacious reasoning. Both well-founded and non-wellfounded infinitary proof theory have the advantage of being amenable to metalogical arguments for proof analysis (e.g., cut-elimination), but the non-wellfounded approach exhibits a further advantage: there is a natural class of 'finite' proofs, namely those whose dependency graphs are finite, known as *circular* or *cyclic* proofs.

Non-wellfounded proofs were considered early on in the history of logic, due to their association with non-standard models of arithemetic (indeed, this was one of the motivations behind Mints' continuous cut-elimination [2]). *Cyclic* proofs themselves seem to first appear in the '90s and '00s in the study of modal fixed point logics, where regular tableaux were obtained in a general way thanks to the celebrated Niwiński–Walukiewicz games [4]. In the '00s Brotherston and Simpson, inspired by that approach, constructed non-wellfounded systems of predicate logic extended by forms of inductive definitions [3]. More recently the French school of proof theory has pioneered the study of cyclic type systems, motivated by the Curry-Howard correspondence and admitting a more structural proof-theoretic treatment [6, 7].

This talk aims to give an overarching (and personal) view of the world of circular proof theory today. In particular, I will try to promote a classical viewpoint of bridging the somewhat disconnected worlds therein by means of correspondences that, in a formal sense, preserve computational content. To this end I will concentrate, as a case study, on the bridge between first-order arithmetic [5, 1] and simply typed recursive programs induced by Gödel's functional interpretation.

[1] Anupam Das, *On the logical complexity of cyclic arithmetic*, ***Logical Methods in Computer Science***, in press.

[2] Grigori Mints, *Finite investigations of transfinite derivations*, ***Journal of Soviet Mathematics***, vol. 10, no. 4, pp. 548–596.

[3] James Brotherston and Alex Simpson, *Sequent calculi for induction and infinite descent*, ***Journal of Logic and Computation***, vol. 21, no. 6, pp. 1177–1216.

[4] Damian Niwiński and Igor Walukiewicz, *Games for the μ-calculus*, ***Theoretical Computer Science***, vol. 163, no. 1, pp. 99–116.

[5] Alex Simpson, *Cyclic Arithmetic is equivalent to Peano Arithmetic*, ***Proceedings of FOSSACS '17***, (Javier Esparza and Andrzej Murawski, editors), vol. 10203, Springer-Verlag, 2017, pp. 283–300.

[6] David Baelde, Amina Doumane and Alexis Saurin, *Infinitary proof theory: the multiplicative additive case*, ***Proceedings of CSL '16*** Marseille, France, (Jean-Marc Talbot and Laurent Regnier, editors), vol. 62, Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik, 2016, pp. 42:1–42:17.

[7] Anupam Das and Damien Pous, *Non-wellfounded proof theory for (Kleene+Action)(Algebras+Lattices)*, ***Proceedings of CSL '18*** Birmingham, UK, (Dan Ghica and Achim Jung, editors), vol. 119, Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik, 2018, pp. 19:1–19:18.

▸ FARZANEH DERAKHSHAN, *Infinitary proof theory of first order linear logic with fixed points*.

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Inductive and coinductive structures are everywhere in mathematics and computer science. The induction principle is well-known and fully exploited to reason about inductive structures like natural numbers and finite lists [1]. To prove theorems about coinductive structures such as infinite trees and streams we appeal to bisimulation or the coinduction principle[2]. Pure inductive and coinductive types however are not the only data structures we are interested to reason about. In this talk I present a calculus to prove theorems about mutually defined inductive and coinductive data types. Our strategy is to use circular proofs similar to Brotherston's first order classical logic for proving inductive theorems [1]. Our calculus is an infinitary system for first order linear logic with fixed points. We allow a rich signature of fixed points including mutually defined inductive and coinductive predicates. By enforcing a condition on the derivations we ensure the cut elimination property and thus validity of them. Our main calculus is designed to reason about linear data types but we add a restricted structural context to appeal to first order theories already proven to be valid as well.

Binary session types is a particular form of session types in which each process has two endpoints. It is corresponding to subsingleton logic with fixed points by Curry-Howard interpretation. We use our logical system to show strong progress property of locally valid binary session typed processes with recursion. Strong progress theorem guarantees that a process either terminates or communicates with the outside after every finite number of steps [6]. Previously we proved strong progress property for valid binary session types by appealing to the Curry-Howard isomorphism. In this talk, I present a direct way to prove this theorem by formalizing it with mutual inductive and coinductive predicates and represent its proof as a valid derivation in our system.

[1] J. Brotherston, *Cyclic proofs for first-order logic with inductive definitions*, ***International Conference on Automated Reasoning with Analytic Tableaux and Related Methods***, Springer, Berlin, Heidelberg, pp. 78–92, 2005.

[2] D. Kozen and A. Silva, *Practical coinduction*, ***Mathematical Structures in Computer Science***, vol. 27 (2017), no. 7, pp. 1132–1152.

[3] A. Abel and B. Pientka, *Well-founded recursion with copatterns and sized types*, ***Journal of Functional Programming***, vol. 26 (2016).

[4] J. Fortier and L. Santocanale, *Cuts for circular proofs: semantics and cut-elimination*, ***Computer Science Logic 2013*** (***CSL 2013***), Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 2013.

[5] D. Baelde, A. Doumane, and A. Saurin, ***Infinitary proof theory: the multiplicative additive case***, 2016.

[6] F. Derakhshan and F. Pfenning, *Circular proofs as session-typed processes: A local validity condition*, arXiv preprint `arXiv:1908.01909`, 2019.

► MARCO GABOARDI, *l^p norms in a linear calculus*.
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It is natural to give to intuitionistic linear logic an interpretation in metric spaces, where functions are non-expansive maps. This follow a correspondence between monoidal closed categories and metric spaces, firstly studied by Lawvere. In this talk, I will discuss some of the implications that this correspondence has on the design of a linear calculus including connectives whose interpretation lies in the l^p norms family.

► DOMINIC J. D. HUGHES, *First-order proofs without syntax*.
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Proofs are traditionally syntactic, inductively generated objects. This talk reformulates first-order logic (predicate calculus) with proofs which are graph-theoretic rather than syntactic, called combinatorial proofs. The presentation will be highly accessible, with numerous pictures and examples in the spirit of a tutorial, in the hope that listeners from varied backgrounds can walk away with something memorable.

This talk is based on the arxiv paper [1], the recent culmination of a 15-year research project to extend propositional combinatorial proofs [2] with quantifiers.

Multiple sequent calculus proofs correspond to the same combinatorial proof, so combinatorial proofs provide abstract mathematical invariants of syntactic proofs, eliminating representational redundancy (such as arbitrary orderings of adjacent non-interacting sequent calculus rules). Thus the work is firmly in the spirit of Hilbert's 24th problem [3].

[1] Dominic J. D. Hughes, *First-order logic without syntax*, `arXiv.1906.11236`.

[2] ———, *Proofs without syntax*, ***Annals of Mathematics***, vol. 164 (2006), no. 3, pp. 1065–1076.

[3] Rüdiger Thiele, *Hilbert's twenty-fourth problem*, ***American Mathematical Monthly***, vol. 110 (2003), no. 1, pp. 1–24.

► ALEXANDER KURZ, *The logic of quantale enriched categories*.
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It is well known that (generalised) metric spaces are categories enriched over the quantale of the non-negative reals with addition as monoidal structure. In this talk we concentrate on enriching over finite quantales. As in the classical case of enriching over the two element lattice, it is possible to extract from the adjunction given by "homming into the quantale" a logic, which we will present in proof theoretic form.

► SONIA MARIN, *Intuitionistic modal proof theory: something old, something new*.
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Intuitionistic modal logic, despite more than sixty years of investigation [5, 4, 11], still partly escapes our comprehension. Structural proof theoretic accounts of intuitionistic modal logic have adopted either the paradigm of *labelled deduction* in the form of labelled natural deduction and sequent systems [9], or the one of *unlabelled deduction* in the form of sequent [2] or nested sequent systems [10, 1] (for a survey see [6, Chap. 3]). Both of these approaches are still under active investigation. For instance, Dalmonte *et al* recently proposed a framework for fragments of intuitionistic modal logics [3] using unlabelled sequents that they relate to a new intuitionistic version of *neighbourhood semantics*.

In this talk, we would like to give an overview of the current landscape of intuitionistic modal proof theory and illustrate how these "old and new" approaches can complement each other. We will present a refinement of the labelled approach to what we called a *fully* labelled framework [7]. Taking full advantage of the standard *birelational semantics* of intuitionistic modal logic [8], it allows us to account for intuitionistic modal logic extended with a large class of axioms.

This is based on joint work with Marianela Morales and Lutz Straßburger.

[1] Ryuta Arisaka, Anupam Das, and Lutz Straßburger, *On nested sequents for constructive modal logic*, ***Logical Methods in Computer Science***, vol. 1 (2015), no. 3, pp. 1–33.

[2] Gavin M. Bierman and Valeria de Paiva, *Intuitionistic necessity revisited*, technical report, School of Computer Sciences-University of Birmingham, 1996.

[3] Tiziano Dalmonte, Charles Grellois, and Nicola Olivetti, *Intuitionistic non-normal modal logics: A general framework*, preprint, arXiv:1901.09812, 2019.

[4] Gisèle Fischer Servi, *Axiomatizations for some intuitionistic modal logics*, ***Rendiconti del Seminario Matematico dell' Università Politecnica di Torino***, vol. 42 (1984), no. 3, pp. 179–194.

[5] Frederic B. Fitch, *Intuitionistic modal logic with quantifiers*, ***Portugaliae Mathematica***, vol. 7 (1948), no. 2, pp. 113–118.

[6] Sonia Marin, *Modal proof theory through a focused telescope*, Ph.D. thesis, Université Paris-Saclay, 2018.

[7] Sonia Marin, Marianela Morales and Lutz Straßburger, *A fully labelled proof system for intuitionistic modal logics*, preprint, hal-02390454, 2019.

[8] Gordon D. Plotkin and Colin P. Stirling, *A framework for intuitionistic modal logic*, ***1st Conference on Theoretical Aspects of Reasoning About Knowledge*** (J. Y. Halpern, editor), Morgan Kaufmann, 1986.

[9] Alex Simpson, ***The proof theory and semantics of intuitionistic modal logic***, Ph.D. thesis, University of Edinburgh, 1994.

[10] Lutz Straßburger, *Cut elimination in nested sequents for intuitionistic modal logics*, ***16th Conference on Foundations of Software Science and Computation Structures***, (F. Pfenning, editor), Springer, 2013.

[11] Duminda Wijesekera, *Constructive modal logics I*, ***Annals of Pure and Applied Logic***, vol. 50 (1990), no. 3, pp. 271–301.

▸ JOAN RAND MOSCHOVAKIS, *Constructive significance of the negative interpretation of classical analysis*.

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The Gödel–Gentzen negative interpretation translates classical arithmetic into the negative fragment of intuitionistic arithmetic, establishing their equiconsistency. The translation extends to the language and logic of analysis, with variables over numbers and number-theoretic functions, but cannot reduce classical analysis with countable choice to an intuitionistic subsystem. Bishop and Brouwer accepted countable choice, and Brouwer accepted bar induction; neither is negatively interpretable in the classically correct part B of Kleene's intuitionistic analysis I.

Assuming the classical meaning of countable choice is accurately expressed by its negative interpretation, an intuitionist can understand classical analytical reasoning by adding to B the negative translation of countable choice (which suffices to prove the negative translation of bar induction). The resulting *minimum classical extension* of B is consistent with I by Kleene's function realizability. In this sense, intuitionistic and classical analysis are compatible.

Kleene's two-sorted intuitionistic arithmetic, with constants and axioms for primitive recursive functions, proves its own negative interpretation. B adds the axiom schemas of countable choice and bar induction, each of which can be weakened in various ways. We seek to clarify the classical content of subsystems of B by finding individual axioms which precisely characterize their minimum classical extensions. Restricted double negation shift and weak characteristic function principles generally do the trick.

Solovay's original (unpublished) proof, that the subsystem S of B with bar induction and arithmetical countable choice can be negatively interpreted in two-sorted intuitionistic arithmetic with bar induction and Markov's Principle, will be presented in this talk with his permission. This result can be improved by weakening Markov's Principle to a double negation shift axiom consistent with Brouwer's creating subject counterexamples, but an open question remains.

► YONI ZOHAR, *Analyticity Or Cut-admissibility?*.
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When Gentzen introduced the first sequent calculi, LK and LJ [1], his purpose was to provide formal systems for both intuitionistic and classical logic that admit the *subformula property*, more generally called *analyticity*, which ensures that a proof of a provable sequent can always be found that contains only subformulas of it. For both calculi, this result was obtained as a corollary of a seemingly stronger property that they admit, namely cut-admissibility. Indeed, when looking at the rules of LK and LJ, it is evident that the only rule that may (locally) violate the subformula property is the cut rule. Since then, a similar process, according to which cut-admissibility is first proven and then analyticity is obtained as a corollary, has been applied for a wide variety of sequent calculi for modal, many-valued, paraconsistent, and other non-classical logics.

In this talk I will describe a (friendly) duel between cut-admissibility and analyticity. I will show that the above route to analyticity is not the only one, and will present other routes that bypass cut-admissibility. Further, I will show cases in which these other routes are simpler, and sometimes even necessary. This will be followed by a comparison between the usefulness of each property for designing and implementing efficient decision procedures for the corresponding logics. The duel will end by presenting two very large families of sequent calculi, suitable for characterizing a wide variety of logics, in which a tie is inevitable.

[1] Gerhard Gentzen, *Investigations into logical deduction*, ***American Philosophical Quarterly***, vol. 1 (1964), no. 4, pp. 288–306.

Abstracts of invited talks in the Special Session on
Reverse Mathematics and Computability Theory of Ramsey-Theoretic Principles

► PAUL-ELLIOT ANGLÈS D'AURIAC, *The reverse mathematics of Hindman's and related theorems*.
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Hindman's Theorem is a theorem from Ramsey Theory that asserts that for any coloring of the positive integers in a finite number of colors, there exists an infinite H such that any sum of distinct elements taken from H is of the same color. Its reverse mathematical study has been started by Blass, Hirst and Simpson, who gave a lower bound and a higher bound being respectively ACA_0 and ACA_0^+, where ACA_0^+ is the existence of the ω-jump of any set. These bounds leave a gap in the precise strength of the theorem.

While those axiomatic bounds have not been improved since Blass, Hirst and Simpson, and remain an important question, some advances have been made. In particular, Towsner defined a combinatorial object, the *full-matches*, that is crucial in solving the question, and whose strength is also still unknown. The existence of PA or low$_n$ full-matches to every computable coloring would show Hindman's theorem in ACA_0, but it is not even known whether there exists a computable coloring with no computable full-matches.

In this presentation, we will talk about our recent efforts on solving these questions, as well as few theorems related to Hindman's one, such as the Ordered Variable Word theorem.

This is joint work with Benoît Monin and Ludovic Patey.

▸ CHI TAT CHONG, WEI LI, LU LIU, AND YUE YANG, *Logic strength of tree theorem*.
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In this talk we show that almost all results on Ramsey's theorem for pairs generalize to tree theorem and Erdos-Moser's theorem is yet another theorem whose strength lies between RT^2_2 and ACA. We firstly describe the CJS-style Seetapun forcing for TT^1_k. Given a combinatorial principle, the sufficiency notion is a simple (usually Σ^0_1) sentence about a finite set F of initial segment of solution such that it implies that whatever the instance X looks like, one of the initial segment in F extends to a solution of X. This notion transform the proof strength analysis of a combinatorial principle into a specific combinatorial question. We show how to apply this notion on tree theorem. Lerman, Solomon and Towsner proved that ADS does not imply SCAC, we give a different way to handle ADS vs SCAC.

▸ DAMIR D. DZHAFAROV, DENIS R. HIRSCHFELDT, AND SARAH C. REITZES, *Reduction games, provability, and compactness*.
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In this talk, I will discuss joint work with Damir D. Dzhafarov and Denis R. Hirschfeldt. Our work centers on the characterization of problems P and Q such that P $\leq_\omega$ Q, as well as problems P and Q such that $\mathsf{RCA}_0 \vdash \mathrm{Q} \rightarrow \mathrm{P}$, in terms of winning strategies in certain games. These characterizations were originally introduced by Hirschfeldt and Jockusch in [1]. I will discuss extensions and generalizations of these characterizations, including a certain notion of compactness that allows us, for strategies satisfying particular conditions, to bound the number of moves it takes to win. This bound is independent of the instance of the problem P being considered. I will also discuss similar characterizations related to the intuitionistic version of RCA_0.

[1] D. R. Hirschfeldt and C. G. Jockusch, Jr.,, *On notions of computability-theoretic reduction between Π^1_2 principles*, ***Journal of Mathematical Logic***, vol. 16 (2016), no. 1650002.

▸ MARTA FIORI CARONES, *(Extra)ordinary equivalences with* ADS.
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ADS states that each countable linear order has an infinite ascending or an infinite descending chain. In reverse mathematics, it received attention as one of the many consequences of Ramsey's theorem for pairs, which is non computably true and non equivalent with WKL_0 nor with Ramsey's theorem for pairs. Indeed very few principles are known to be equivalent to ADS and among them there are no theorems of ordinary mathematics, as far as we know. Despite this, we present a couple of statements which are equivalent to ADS and to its stable version SADS. The statements were originally proved by Ivan Rival and Bill Sands [1].

The first one claims that for each infinite poset P with finite width (i.e., such that there is a fixed finite bound on the size of antichains in P) there is an infinite chain $C \subseteq P$ such that each point of P is comparable to none or to infinitely many points of C. We denote this statement (restricted to countable posets) RSpo_k, for k the width of the poset. Despite the fact that the original proof makes essential use of Π^1_1-CA_0, we prove that RSpo_k is equivalent to ADS over the base theory RCA_0, for each $k \geq 3$. We also proved that, over WKL_0, RSpo_2 is equivalent to SADS.

The second statement is a strengthening of the former one since it guarantees that each infinite poset P with finite width there is an infinite chain $C \subseteq P$ such that each point of P is comparable to none or to cofinitely many points of C. We denote this statement (restricted to countable posets) sRSpo_k, for k the width of the poset. We proved that sRSpo_2 is equivalent to ADS. On the other hand, the strength of sRSpo_k, for $k \geq 3$, remains unclear: Π^1_1-CA_0 remains the unique upper bound and ADS the lower bound.

In 1980 Ivan Rival and Bill Sands [1] proved that for each infinite poset P with finite width (i.e., such that there is a fixed finite bound on the size of antichains in P) there is an infinite chain $C \subseteq P$ such that each point of P is comparable to none or to infinitely many points of C. We denote this statement (restricted to countable posets) RSpo_k, for k the width of the poset.

Despite the fact that the original proof makes essential use of Π^1_1-CA_0, we prove that RSpo_k is equivalent to ADS over the base theory RCA_0, for each $k \geq 3$. ADS is the statement that each countable linear order has an infinite ascending or an infinite descending chain. Very few principles are known to be equivalent to ADS and among them there are no theorems of ordinary mathematics, as far as we know. Thus the equivalence between RSpo_k and ADS is, to the best of our knowledge, an interesting novelty in the field. We also proved that, over WKL, RSpo_2 is equivalent to SADS, which is ADS restricted to posets of order type ω, ω^* or $\omega + \omega^*$.

Rival and Sands actually proved a stronger version of the statement, namely that each infinite poset P with finite width there is an infinite chain $C \subseteq P$ such that each point of P is comparable to none or to cofinitely many points of C. We denote this statement (restricted to countable posets) sRSpo_k, for k the width of the poset. We proved that sRSpo_2 is equivalent to ADS. On the other hand, the strength of sRSpo_k, for $k \geq 3$, remains unclear: Π^1_1-CA_0 remains the unique upper bound and ADS the lower bound.

This is joint work with Alberto Marcone, Paul Shafer and Giovanni Soldà.

[1] Ivan Rival and Bill Sands, *On the adjacency of vertices to the vertices of an infinite subgraph*, ***Journal of the London Mathematical Society***, vol. 2 (1980), no. 3, pp. 393–400.

▸ HENRY TOWSNER, ROSE WEISSHAAR, AND LINDA WESTRICK, *Pseudo-Borel codes in HYP*.
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We show that the Borel Dual Ramsey Theorem fails in HYP, regardless of the number of partitions $k \geq 2$. Therefore, the Borel Dual Ramsey Theorem is not a statement of hyperarithmetic analysis. We also apply similar methods, namely construction of completely determined pseudo-Borel codes via decorating trees, to obtain results concerning some theorems about Borel graph coloring.

▸ KEITA YOKOYAMA, *Ramsey's theorem and induction axioms*.
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In the proof of infinite Ramsey's theorem, induction is essentially used in several places, and from the view point of reverse mathematics, it requires induction axioms in many cases. Indeed, there are many studies on the inductive strength of Ramsey's theorem [2, 3, 4]. For example, it is well-known that ACA_0 proves $\mathrm{RT}^n \rightarrow \mathrm{RT}^{n+1}$, but not $\forall n \mathrm{RT}^n$ (see e.g., [1]), where RT^n denotes Ramsey's theorem for n-tuples, and the induction for Σ^1_1-formulas is essential to fill this gap. Similarly, we will see that RT^2_2 (Ramsey's theorem for pairs and two colors) does not imply RT^2 without some induction beyond arithmetical level. On the other hand, it is also known that Ramsey's theorem behaves in a very different manner with the absence of Σ^0_1-induction [5]. In this talk, we will overview the relations between Ramsey's theorem and induction.

This is partially joint works with Kołodziejczyk/Kowalik/Wong and Slaman.

[1] Denis Hirschfeldt, ***Slicing the truth***, Lecture Notes Series, Institute for Mathematical Sciences, National University of Singapore, 2014.

[2] Peter A. Cholak, Carl G. Jockusch and Theodore A. Slaman, *On the strength of Ramsey's theorem for pairs*, ***The Journal of Symbolic Logic***, vol. 66 (2001), no. 1, pp. 1–55.

[3] Chi-Tat Chong, Theodore A. Slaman and Yue Yang, *The inductive strength of Ramsey's theorem for pairs*, ***Advances in Mathematics***, vol. 308 (2017), pp. 121–141.

[4] Theodore A. Slaman and Keita Yokoyama, *The strength of Ramsey's theorem for pairs and arbitrary many colors*, ***The Journal of Symbolic Logic***, vol. 83 (2018), pp. 1610–1617.

[5] Keita Yokoyama, *On the strength of Ramsey's theorem without Σ_1-induction*, ***Mathematical Logic Quarterly***, vol. 59 (2013), pp. 108–111.

Abstracts of contributed talks

▸ SAMUEL BRAUNFELD, *Monadic stability and growth rates of ω-categorical structures*.
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The growth rate of an ω-categorical structure M is the function counting the number of realized n-types, up to reordering the variables. Equivalenty, after quantifier elimination, it counts the number of n-isomorphism types in the hereditary class of substructures of M.

We prove that for M stable, there is a gap in the possible growth rates from slower than any exponential to faster than any exponential, corresponding to whether M is monadically stable, i.e., remains stable under any expansion by unary predicates. Together with results of Simon reducing certain questions to the stable case, this allows us to confirm some longstanding conjectures of Macpherson on the spectrum of possible growth rates.

[1] Samuel Braunfeld, *Monadic stability and growth rates of ω-categorical structures*, `arXiv preprint arXiv:1910.04380`, 2019.

[2] Pierre Simon, *On ω-categorical structures with few finite substructures*, `arXiv preprint arXiv:1810.06531`, 2018.

▸ CALEB CAMRUD, *Results in Computable Model Theory of Continuous Logic*.
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Within model theory, a natural question to be asked is "which model theoretic results have effective counterparts?" A wide range of results have been proven in this area with respect to classical logic [1]. Classical model theory, however, has limitations in its ability to intuitively reflect the continuous nature of many metric structures. In an attempt to bypass these limitations, Ben Yaacov et al. developed a model theory for continuous first-order logic [2]. Soon after, a completeness result for this logic was proven [3], and Calvert later proved a version of an effective completeness theorem utilizing probabilistic computation [4]. Resurrecting this decade-old project in a new light, we examine the effective model theoretic properties of continuous first-order logic within the framework of computable presentations. We will present a new version of the effective completeness theorem: that any decidable continuous first-order theory has a computably presentable model. We will further discuss preliminary results on complete types.

[1] V. S. Harizanov, *Pure computable model theory*, ***Handbook of Recursive Mathematics***, vol. 1, (Yu. L. Ershov, S. S. Goncharov, A. Nerode, J. B. Remmel, and V. W. Marek, editors), Studies in Logic and the Foundations of Mathematics, 138–139, North-Holland, Amsterdam, 1998, pp. 3–114.

[2] Itaï Ben Yaacov, Alexander Berenstein, C. Ward Henson, and Alexander Usvyatsov, *Model theory for metric structures*, ***Model Theory with Applications to Algebra and Analysis***, vol. 2, (Zoé Chatzidakis, Dugald Macpherson, Anand Pillay, and Alex Wilkie, editors), London Math Society Lecture Note Series, vol. 350, London, 2008, pp. 315–427.

[3] Itaï Ben Yaacov and Arthur Paul Pedersen, *A proof of completeness for continuous first-order logic*, ***The Journal of Symbolic Logic***, vol. 75 (2010), no. 1, pp. 168–190.

[4] Wesley Calvert, *Metric structures and probabilistic computation*, ***Theoretical Computer Science***, vol. 412 (2011), pp. 2766–2775.

▸ SEAN C. EBELS-DUGGAN, *Logicality, Zermelo's theorem, and well-founded extensions*.
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Väänänen and Wang [1] show that second-order models of ZFC are internally categorical (isomorphic when embedded in a common model). These methods are kin to those of *abstractionist set theory*, in which select concepts X are assigned first-order *extensions* $\check{\epsilon}X$. Jáne and Uzquiano [2] have shown that such assignments on inaccessibly large domains yield models of ZFC without the axiom of foundation, $\mathtt{ZFC}^-$.

Within these models, one can generate alternate models by reassigning extensions to different objects. Thus, each injection $p\colon \mathrm{rng}(\check{\epsilon}) \to$ the universe M (which may also include atoms) delivers another model of set theory.

It is evident from [2] that $\mathtt{ZFC}^-$ is not internally categorical. However, further application of these methods do distinguish the well-founded, for such extensions are *stable*: every injection reproduces an isomorphic copy of them.

This connects the aforementioned work with that of Russell and Tarski. Russell's arguments for his theory of types are not far off from an argument that only well-founded sets are logically respectable. Tarski proposed *permutation invariance* as a mark of the logical. The close link demonstrated between well-foundedness and stability gives an argument for Russell's conclusion usian Tarskian arguments.

[1] Jouko Väänänen and Tong Wang, *Internal categoricity in arithmetic and set theory*,

Notre Dame Journal of Formal Logic, vol. 56 (2015), no. 1, pp. 121–134.

[2] Ignacio Jáne and Gabriel Uzquiano, *Well- and non-well-founded Fregean extensions*, ***Journal of Philosophical Logic***, vol. 33 (2004), pp. 437–465.

▸ MICHAŁ T. GODZISZEWSKI, *Between the model-theoretic and the axiomatic method of characterizing mathematical truth*.
University of Warsaw, Poland and MCMP LMU Munich, Germany.

The so-called model-theoretic method of characterizing the notion of truth consists in defining a general notion of a model of a given formal language L, providing a definition of a binary relation between models of L and the sentences of L, and finally singling out a concrete model as the standard or the intended one and declaring that truth simpliciter (of sentences of L) should be understood as truth in this model. Can we really treat this model-theoretic definition of truth as the definition of (mathematical) truth (say, at least with respect to the language of arithmetic)? There are at least two serious problems with this method:

1. The first problem with is that it indeed relies on the concept of an intended or standard structure (or the class of intended structures in case of some other theories, e.g., in the case of set theory). One of the arguments aiming at distinguishing the standard or intended model of Peano Arithmetic relies on the Tennenbaum's Theorem and related results. We demosntrate how the mathematical analysis of the Tennebaum-like phenomena in the context of a recently proposed modification of the basic concepts of computable model theory suuports the view that this cannot be achieved and that not only the argument-from-Tennenbaum's-theorem doe not work, but that in the context of computable quotient presentations of first-order structures the theorem itself simply does not hold.

2. The second one is that even having forgotten about the above, we might assume that our metatheory can provide us with a determinate concept of the standard model. Then the question is: does it follow that then the concept of truth is definite, complete, determinate or absolute? In what follows, we provide an analysis of these two particular questions regarding the use of the notion of standard model in the model-theoretic characterization of the notion of mathematical truth simpliciter, leading to results that can be interpreted as delivering the following message: not only there are conceptual problems regarding the way standard models are used in the characterization, but there are philosophically justified mathematical reasons for which the appeal to standard models in truth-theoretic constructions is at least problematic, if not impossible, and therefore, if one's goal is to provide a formal theory of mathematical truth simpliciter, the axiomatic framework is the right method of doing so.

We conclude with a section describing an application of the axiomatic method of characterizing truth to set theory taken as the base theory. By using a result of Gitman and Hamkins we suggest that our result characterizing the class of models of ZF C expandable to models of the theory of the so-called Compositional Truth allows for an essentially truth-theoretic argument in favor of pluralism in philosophy of set theory.

▸ MICHAŁ T. GODZISZEWSKI, VICTORIA GITMAN, TOBY MEADOWS, AND KAMERYN J. WILLIAMS, *On axioms for multiverses of set theory*.
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Recursive saturation, introduced by Barwise and Schlipf is a robust notion, one which has proved to be important for the study of nonstandard models. In particular, it is ubiquitous in the model theory of axiomatic theories of truth, e.g., in the topic of satisfaction classes (one can show that if $M \models ZFC$ is a countable ω-nonstandard model, then M admits a satisfaction class iff M is recursively saturated). V. Gitman and J. Hamkins showed in

"A Natural Model of the Multiverse Axioms" that the collection of countable, recursively saturated models of set theory satisfy the so-called Hamkins's Multiverse Axioms. The property that forces all the models in the Multiverse to be recursively saturated is the so-called Well-Foundedness Mirage axiom which asserts that every universe is ω-nonstandard from the perspective of some larger universe, or to be more precise, that: if a model M is in the multiverse then there is a model N in the multiverse such that M is a set in N and $N \models' M$ is ω-nonstandard.'. Inspection of the proof led to a question if the recursive saturation could be avoided in the Multiverse by weakening the Well-Foundedness Mirage axiom. Our main results answer this in the positive. We give two different versions of the Well-Foundedness Mirage axiom—what we call Weak Well-Foundedness Mirage (saying that if M is a model in the Multiverse then there is a model N in the Multiverse such that $M \in N$ and $N \models' M$ is nonstandard.') and Covering Well-Foundedness Mirage (saying that if M is a model in the Multiverse then there is a model N in the Multiverse with $K \in N$ such that K is an end-extension of M and $N \models' K$ is ω-nonstandard'). I will present constructions of two different Multiverses satisfying these two weakened axioms.

This is joint work with V. Gitman. T. Meadows, and K. Williams.

► MARCOS MAZARI-ARMIDA, *Characterizing some classes of rings via superstability*.
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In his work towards proving Shelah's categoricity conjecture (a generalization of Morely's categoricity theorem), Shelah introduced limit models as a replacement for saturated models. It turns out that the uniqueness of limit models in a tail of cardinal is an important property that extends the notion of superstability to AECs and which is equivalent to superstability for first-order theories. Thus an AEC is superstable if and only if it has uniqueness of limit models in a tail of cardinals.

In this talk, we show that the model-theoretic notion of superstability can be used to characterize several well-studied classes of rings.

THEOREM 1. *Let R an associative ring with an identity element.*

- *R is left noetherian if and only if the class of left R-modules with embeddings is superstable.*
- *R is left pure-semisimple if and only if the class of left R-modules with pure embeddings is superstable.*
- *R is left perfect if and only if the class of flat left R-modules with pure embeddings is superstable.*
- *R is left artinian if and only if the class of left R-modules with embeddings is superstable and the class of flat right R-modules with pure embeddings is superstable.*

It is worth mentioning that the class of flat left R-modules is not first-order axiomatizable. Therefore, the results of this talk use in an indispensable way non-elementary notions.

This talk is based on [1] and [2].

[1] MARCOS MAZARI-ARMIDA, *Superstability, noetherian rings and pure-semisimple rings*, submitted, https://arxiv.org/abs/1908.02189.

[2] MARCOS MAZARI-ARMIDA, *On superstability in the class of flat modules and perfect rings*, submitted, https://arxiv.org/abs/1910.08389.

► JOACHIM MUELLER-THEYS, *The idea of Named Logic*.
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In first-order logic, objects need not be named. However, there are original structures that are (or even must be) completely named, for instance data structures like tables or the natural numbers, named by the numerals. This gives rise to consider named structures from the beginning—leading to a striking model theory.

Let L be any first-order language having the closed terms $T_0 \neq \emptyset$. An L-model $\mathcal{M}$ is called *named* :iff $|\mathcal{M}| = T_0^{\mathcal{M}}$, whereby $T_0^{\mathcal{M}} := \{t^{\mathcal{M}}\colon t \in T_0\}$. *If $\mathcal{M}$ is named, $\mathcal{M} \preceq T_0$*. We write $\models\!\equiv$ for $\models$ if models involved are named.

If T_0 is finite, i. e. $T_0 = \{c_1, \dots, c_n\}$, *variables and quantifiers become redundant*, like $\models\!\equiv \forall x\, \exists y\, Pxy \leftrightarrow \forall x\, (Pxc \vee Pxd) \leftrightarrow (Pcc \vee Pcd) \wedge (Pdc \vee Pdd)$; otherwise, this should be the case if suitable infinitary expressions like $\bigwedge\Phi$, $\bigvee\Psi$ are added. Then named logic will be generally *atom(ist)ic* in the sense that there is a set K_ϕ of fundamental conjunctions $\kappa := \bigwedge\Lambda$ such that $\models\!\equiv \phi \leftrightarrow \bigvee K_\phi$ for all ϕ. This shall allow reduction to (infinitary) propositional logic when identity is excluded.

Let $\mathcal{M} \models\!\equiv t \doteq s$ imply $\mathcal{N} \models\!\equiv t \doteq s$. Then, for $a = t^{\mathcal{M}}$, *Buchholz's* $\beta[a] := t^{\mathcal{N}}$ is well-defined and an algebraic epimorphism from $\mathcal{M}$ onto $\mathcal{N}$ already, viz. β is surjective and $\beta[f^{\mathcal{M}}(\vec{a})] = f^{\mathcal{N}}(\beta[\vec{a}])$. If $\mathcal{M} \models\!\equiv P\vec{t}$ implies $\mathcal{N} \models\!\equiv P\vec{t}$ in addition, β is an epimorphism, viz. $\vec{a} \in P^{\mathcal{M}}$ implies $\beta[\vec{a}] \in P^{\mathcal{N}}$. Given $\mathcal{M} \models\!\equiv \iota$ iff $\mathcal{N} \models\!\equiv \iota$ for all $\iota \in \{t \doteq s : t, s \in T_0\}$ (*algebraic* or *identitarian equivalence*), β is injective, whence β is an algebraic isomorphism. If $\mathcal{M} \equiv_{\mathrm{at}} \mathcal{N}$ (*atomic equivalence*), viz. $\mathcal{M} \models\!\equiv \alpha$ iff $\mathcal{N} \models\!\equiv \alpha$ for all atomic sentences, then, eventually, $\beta\colon \mathcal{M} \cong \mathcal{N}$. It follows that *$\mathcal{M} \equiv_{\mathrm{at}} \mathcal{N}$, $\mathcal{M} \cong \mathcal{N}$, $\mathcal{M} \equiv \mathcal{N}$ are equivalent*. *Thereby $\equiv_{\mathrm{at}}$ coincides with $\equiv_{\mathrm{alg}}$ if there are no predicate symbols*.

Let $\Lambda_{\mathcal{M}}$ consist from the atomic and negated atomic sentences $\lambda \in L$ such that $\mathcal{M} \models\!\equiv \lambda$. We have shown that *$\mathcal{N} \models\!\equiv \Lambda_{\mathcal{M}}$ implies $\mathcal{N} \equiv_{\mathrm{at}} \mathcal{M}$*, whence follows that *any named structure $\mathcal{M}$ is characterized by $\Lambda_{\mathcal{M}}$ up to equivalence and isomorphism*. Moreover, *$\Lambda_{\mathcal{M}}$ axiomatizes $\mathcal{M}$ completely*, viz. *$\Lambda_{\mathcal{M}} \models\!\equiv \sigma$ iff $\mathcal{M} \models\!\equiv \sigma$*.

Note. The fundamental germ had been missed first (in particular by G. H. Müller, which has had troublesome personal consequences). Later it was synthesized and named by Wilfried Buchholz. Conversation with Ronald Fuller during ASL-APA 2017 (Seattle) led to important insights. The *Isomorphism Theorem* is recent.

► DIEGO A. ROJAS, *Effective notions of weak convergence of measures on the real line*.
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The space $\mathcal{M}(X)$ of Borel probability measures on a computable metric space X forms a computable metric space under the Prokhorov metric [2, 3], and the Prokhorov metric is known to generate the topology of weak convergence of measures on $\mathcal{M}(X)$ (see [1]). However, the study of weak convergence of computable finite Borel measures is limited. To this end, we introduce two effective notions of weak convergence of finite Borel measures on $\mathbb{R}$. We show that a uniformly computable sequence of finite Borel measures on $\mathbb{R}$ tends to a computable measure if it converges in either notion. We also show that there is a sequence of computable measures that converges weakly but not effectively so. Finally, we show that both notions of effective weak convergence are equivalent for uniformly computable sequences of finite Borel measures on $\mathbb{R}$.

[1] Vladimir Bogachev, ***Weak convergence of measures***, Mathematical Surveys and Monographs, American Mathematical Society, Providence, RI, 2018.

[2] Peter Gács, *Uniform test of algorithmic randomness over a general space*, ***Theoretical Computer Science***, vol. 341 (2005), no. 1, pp. 91–137.

[3] Mathieu Hoyrup and Cristóbal Rojas, *Computability of probability measures and Martin-Löf randomness over metric spaces*, ***Information and Computation***, vol. 207 (2009), no. 7, pp. 830–847.

► DAN E. WILLARD, *How the law of excluded middle pertains to the second incompleteness theorem and its boundary-case exceptions*.
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This abstract will summarize and serve as a pointer to a 20-page paper that we are scheduled to publish in January-2020 at the LFCS conference. Our article [2] discusses how the Law of Excluded Middle (LXM) is germane to a quite tender border that separates the Second Incompleteness Effect from its permitted partial exceptions.

In many of our papers, we have used a language L^* where Add(x,y,z) and Mult(x,y,z) do denote two 3-way relations for formalizing addition and multiplication. Our employed analogs of arithmetic's conventional Π_1 sentences have been called Π_1^* sentences. In a context where α is a base system of proper axioms, such as Peano Arithmetic, a general goal of our research has been to determine when it is possible to develop an alternate axiom system $I_D(\alpha)$ that can recognize its own consistency under a deductive apparatus D and simultaneously prove all of α's Π_1 theorems (when they are rewritten as counterpart Π_1^* forms in the language L^*).

Our main older result in [1] was that for any consistent axiom system α , there existed an axiom system IS(α) that could simultaneously recognize addition as a total function and corroborate its own consistency under Smullyan's "semantic tableaux" deductive apparatus (denoted as "Tab"). Part of the intuition behind this evasion of the Second Inc Theorem is that IS(α) treats multiplication as a 3-way relation.

It is known that Tab deduction treats each instance of LXM as a proven theorem. Let "Xtab" denote a revision of Tab deduction that treats LXM as a schema of logical axioms (instead of as derived theorems). Also, let IS$^*(\alpha)$ denote a formalism identical to IS(α) except that the latter will attempt to recognize its self-consistency under Xtab rather than Tab deduction. Our new announced result in [2] is that Xtab deduction, which superficially resembles "Tab", is actually different and strong enough for the 2nd Inc Theorem to apply to Xtab (thus rendering IS($^*\alpha$) to be inconsistent).

In other words, the machinery of the LXM, *when promoted to becoming a set of logical axioms,* is sufficient for activating the 2nd Incompleteness Effect.

[1] Dan E. Willard, *An exploration of the partial respects in which an axiom system recognizing solely addition as a total function can verify its own consistency*, ***The Journal of Symbolic Logic***, vol. 70 (2005), pp. 1171–1209.

[2] ———, *On the tender line separating generalizations and boundary-case exceptions for the second incompleteness theorem under semantic tableaux deduction*, ***International Symposium on Logical Foundations of Computer Science***, (LFCS 2020), pp. 266–285, disseminated in Springer's LNCS series.

Abstracts of talks presented by title

▸ JOHN CORCORAN, *Reductio: indirect deduction*.
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The phenomenon of *reductio*, or indirect deduction, predates Pythagoras. Aristotle incorporated it into his syllogistic deduction system. We survey treatments given by logicians including Aristotle, the Stoics, Galen, Ockham, Saccheri, Bolzano, Boole, De Morgan, Peirce, Frege, Russell, Löwenheim, Brouwer, Tarski, and Jaskowski.

In Aristotle's syllogistic there are two separate types of deductions, direct and indirect [4].

For direct deduction, after assuming the premises and identifying the ultimate conclusion, reasoners derive intermediate conclusions one-after-the-other by epistemically immediate steps until the ultimate conclusion is achieved.

For indirect deduction, after assuming the premises and identifying the ultimate conclusion, reasoners assume-for-purposes-of-reasoning the ultimate conclusion's contradictory. Then intermediate conclusions are entered step-by-step until reaching a "contradiction": an intermediate conclusion that is the contradictory of a previous intermediate conclusion or an assumption.

Aristotle has no negation and no conjunction: his indirect deductions do not involve “intelim” rules [4, Sections 4, 7, and 8].

Several logicians down to the present era follow Aristotle in understanding reductio to involve a special type of deduction using an assumption that contradicts the ultimate conclusion [2][3].

Surprisingly, a few logicians follow Boole [1] in ignoring reductio entirely.

Moreover, many logicians take reductio as direct deduction using a special law—not as a separate type of deduction using an additional assumption. For example, Tarski takes a reductio to use what he calls the LAW OF REDUCTIO AD ABSURDUM, having two forms [6, §44]:

$$(p \rightarrow\sim p) \rightarrow\sim p$$
$$(\sim p \rightarrow p) \rightarrow p$$

Peirce also explains reductio using a special law he called the *principle of reductio ad absurdum* [5, pp. 69–70].

[1] George Boole, ***Laws of Thought***, (John Corcoran, editor), Prometheus, 1854/2003.

[2] John Corcoran, ***Review: Saccheri, G. Euclides Vindicatus (1733)***, translated by G. Halsted, Chelsea, 1986, Mathematical Reviews MR0862448.

[3] ———, *Argumentations and logic*, ***Argumentation***, vol. 3 (1989), pp. 17–43.

[4] ———, ***Aristotle's prototype rule-based underlying logic***, ***Logica Universalis***, vol. 2 (2018) pp. 9–35.

[5] Charles Peirce, ***Essential Peirce: Selected philosophical writings*** (***1867–1893***), vol. I, (Nathan Houser et al., editors), Indiana University Press, 1992.

[6] Alfred Tarski, ***Introduction to logic***, Dover, New York, 1995.

▸ JOHN CORCORAN, JUSTIN LEGAULT, AND ROBIN SMITH, *Łukasiewicz's “łinferences” and “łimplications”*.
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The first occurrence of the word ‘inference’ in Łukasiewicz [3, p. 1] is an undefined common noun: an example is given and instructively discussed. On page 2 the word ‘implication’ occurs, as a contrasting common noun, again without definition: an example is given without discussion.

This paper analyses [3] to determine the meanings these two words acquire. It also discusses meanings they previously had [1] [2].

To prevent confusion, the Polish stroke-el (Ł, lowercase ł) marks Łukasiewicz's senses.

The example łinference is:
All men are mortal,
All Greeks are men,
therefore
All Greeks are mortal.

At first this seems to be a single sentence similar to the following.

All men are mortal and all Greeks are men, therefore all Greeks are mortal.

But what explains the two extra uppercase letters, the three extra lines, and the missing conjunction? On second thought it also seems similar to the three-sentence passage.

All men are mortal.
All Greeks are men.
Therefore, all Greeks are mortal.

The łinference seems to hover between the two.

The example łimplication is:

If all men are mortal
and all Greeks are men,
then all Greeks are mortal.

This seems to be a single sentence except that it is written on three lines—something not found in ***Prior Analytics*** [4]. Łukasiewicz implies that the differences between łinferences and łimplications are crucial—without saying what the differences are.

Łukasiewicz states that none of Aristotle's syllogisms are łinferences [3, pp. 2, 21, passim]. In contrast, he states that all of Aristotle's syllogisms are łimplications [3, pp. 2, 138, passim]—in fact true łimplications [3, pp. 2, passim].

We explore several hypotheses including (1) that łinferences are premise-conclusion arguments and (2) that łimplications are universalized conditionals [1][2].

[1] JOHN CORCORAN, *Meanings of implication*, ***Diálogos***, vol. 9 (1973), pp. 59–76.

[2] ———, *Logic teaching: 21st century*, ***Quadripartita Ratio***, vol. 1 (2016), pp. 1–34.

[3] JAN ŁUKASIEWICZ, ***Aristotle's syllogistic***, Oxford University Press, 1956.

[4] ROBIN SMITH, ***Aristotle's Prior Analytics***, Hackett, 1989.

▸ JOHN CORCORAN AND JOSÉ MIGUEL SAGÜILLO, *Ex falso quodlibet, EFQ, an absurdity*.
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Classically, any proposition from which every proposition follows is one from which its own negation follows. Thus every such proposition is self-contradictory. Ostensibly, therefore, in a classical context, whoever states "from a falsehood everything [follows]", hereafter *FFE*, implies, intentionally or not, the absurdity that every falsehood is a contradiction.

Such strange views appear in the popular literature.

Aristotle implicitly contradicted FFE by observing, in particular, that the existential negative does not follow from its converse: the truth "Some animal is not a human" does not follow from the falsehood "Some human is not an animal".

Boole sharpened Aristotle's independence results by observing, in effect, that neither premise of a categorical syllogism follows from its conclusion—even if the other premise is added. Consider the following example.

Every quadrangle is a pentagon.
Every triangle is a quadrangle.
———————————
Every triangle is a pentagon.

Boole's result implies that neither premise follows from the conclusion—here chosen to be false.

No respectable classical logician has ever espoused *ex falso quodlibet*.

However, FFE has been *verbally* endorsed by classical logicians such as C. I. Lewis [1]. Some mistakenly took the FFE sentence to express a quantified-propositional-logic law corresponding to the fact that given any two propositions, the negation of the first materially implies the conditional having the first as antecedent and the second as consequent. This requires conflating the object-language negation of a given proposition with the meta-language proposition that the given proposition is false. It also requires conflating an object-language conditional with the meta-language proposition that the consequent follows logically from the antecedent. The latter mistake, of course, goes hand-in-hand with conflating logical and material consequence.

We review occurrences throughout history of the classically incorrect *ex falso quodlibet* and related slogans—including the classically correct *ex contradictione quodlibet*. We identify their various interpretations and analyze statements made with them or about them.

[1] John Corcoran, *C. I. Lewis: History and philosophy of logic*, ***Transactions of the C. S. Peirce Society***, vol. 42 (2006), pp. 1–9.