Tributes

Volume 23

Infinity, Computability, and Metamathematics Festschrift celebrating the 60th birthdays of Peter Koepke and Philip Welch

Volume 13

Proofs, Categories and Computations. Essays in Honour of Grigori Mints Solomon Feferman and Wilfried Sieg, eds.

Volume 14

Construction. Festschrift for Gerhard Heinzmann Solomon Feferman and Wilfried Sieg, eds.

Volume 15

Hues of Philosophy. Essays in Memory of Ruth Manor Anat Biletzki, ed.

Volume 16

Knowing, Reasoning and Acting. Essays in Honour of Hector J. Levesque. Gerhard Lakemeyer and Sheila A. McIlraith, eds.

Volume 17

Logic without Frontiers. Festschrift for Walter Alexandre Carnielli on the occasion of his $60^{\rm th}$ birthday

Jean-Yves Beziau and Marcelo Esteban Coniglio, eds.

Volume 18

Insolubles and Consequences. Essays in Honour of Stephen Read.

Catarina Dutilh Novaes and Ole Thomassen Hjortland, eds.

Volume 19

From Quantification to Conversation. Festschrift for Robin Cooper on the occasion of his 65^{th} birthday

Staffan Larsson and Lars Borin, eds.

Volume 20

The Goals of Cognition. Essays in Honour of Cristiano Castelfranchi Fabio Paglieri, Luca Tummolini, Rino Falcone and Maria Miceli, eds.

Volume 21

From Knowledge Representation to Argumentation in AI, Law and Policy Making. A Festschrift in Honour of Trevor Bench-Capon on the Occasion of his 60th Birthday

Katie Atkinson, Henry Prakken and Adam Wyner, eds.

Volume 22

Foundational Adventures. Essays in Honour of Harvey M. Friedman Neil Tennant, ed.

Volume 23

Infinity, Computability, and Metamathematics. Festschrift celebrating the 60th birthdays of Peter Koepke and Philip Welch

Stefan Geschke, Benedikt Löwe and Philipp Schlicht, eds.

Tributes Series Editor Dov Gabbay

dov.gabbay@kcl.ac.uk

Infinity, Computability, and Metamathematics

Festschrift celebrating the 60th birthdays of Peter Koepke and Philip Welch

edited by

Stefan Geschke Benedikt Löwe Philipp Schlicht

© Individual authors and College Publications 2014. All rights reserved.

ISBN 978-1-84890-130-8

College Publications Scientific Director: Dov Gabbay

Managing Director: Jane Spurr

http://www.collegepublications.co.uk

Originally published online by Templeton Press http://www.foundationaladventures.com

Cover design by Laraine Welch

Printed by Lightning Source, Milton Keynes, UK

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form, or by any means, electronic, mechanical, photocopying, recording or otherwise without prior permission, in writing, from the publisher.

Table of Contents

Table of Contents
Prefacevii–viii
Publications by Peter Koepkeix-xiv
Publications by Philip Welchxv-xx
Doctoral studentsxxi
A note on powers of singular strong limit cardinals A. Apter
The consistency of a club-guessing failure at the successor of a regular cardinal D. Asperó
A survey of axiom selection as a machine learning problem J. C. Blanchette, D. Kühlwein
The lost melody phenomenon <i>M. Carl</i>
Modelling the usage of partial functions and undefined terms using presupposition theory
M. Cramer
The foundation axiom and elementary self-embeddings of the universe A. S. Daghighi, M. Golshani, J. D. Hamkins, E. Jeřábek89–112
Sets of good indiscernibles and Chang conjectures without choice

vi Table of Contents

An ordinal λ -calculus $T.\ Fischbach,\ B.\ Seyfferth$
Coding over core models SD. Friedman, R. Schindler, D. Schrittesser
Extender based forcings, fresh sets and Aronszajn trees M. Gitik
On ground model definability V. Gitman, T. A. Johnstone
On the automorphisms in the Gitik-Koepke construction V. Kanovei
On compactness for being λ -collectionwise Hausdorff $M.\ Magidor$
Cardinal sequences for superatomic Boolean algebras J. C. Martínez
One-dimensional Σ -presentations of structures over $\mathbf{HF}(\mathbb{R})$ A. $Morozov$
Remarkable cardinals R. Schindler
The weak ultimate L conjecture <i>W. H. Woodin</i>

Preface

In the year 2014, Peter Koepke and Philip Welch turned sixty and we celebrated this festive occasion with a scientific workshop in their honour. The workshop speakers included students, collaborators, colleagues, and friends of Peter and Philip whose research was influenced by them.





Peter and Philip have more in common than their age. Both were professors at the University of Bonn; Peter for many years and Philip as a Mercator Professor during the academic year 2002/3. Both were strongly influenced by Ronald Jensen early in their scientific careers. Philip got his D.Phil. in 1979 from the University of Oxford under the supervision of Robin Gandy with a thesis on combinatorial principles in Jensen's core model, with Jensen being in Oxford from 1978 to 1979. Peter received his doctoral degree from the University of Freiburg under Jensen's supervision with a dissertation titled "A Theory of Short Core Models and Some Applications". Peter and Philip continued working in set theory, but they also got interested in other subjects in logic: infinite time computation is another of these interests that they shared. In the last two decades, their interests became increasingly interdisciplinary: Philip started working with philosophers on theories of truth and Peter collaborated with linguists on natural language proofs. Three joint publications witness their common interests.

This Festschrift was handed over to Peter and Philip on 23 May 2014 during the Colloquium and Workshop "Infinity, computability, and metamathematics: Celebrating the 60th birthdays of Peter Koepke and Philip Welch", which took place from 23 May to 25 May 2014 at the Hausdorff Center for Mathematics (HCM) at the *Rheinische Friedrich-Wilhelms-Universität*

Bonn. The workshop and the production of the book were funded by the HCM. We received nineteen submissions for this Festschrift which were thoroughly refereed according to the standards of our field; nineteen referees helped us with this in very short time (we received the first submissions in late September 2013 and needed to submit the volume for production in April 2014; readers who know the usual glacial pace of mathematical publishing can appreciate how fast this is) and in the end, seventeen papers were accepted for publication in the Festschrift. As is traditional, we included lists of the publications and doctoral students of Peter and Philip in this preface to document their important role in our community. We are very happy to see five of the doctoral students among the authors of papers in this Festschrift. We should like to thank all authors and referees for their collaboration in producing this interesting book and hope that Peter and Philip will enjoy it.

April 2014, Hamburg, Amsterdam, and Bonn

S. G. B. L. P. S.

Publications by Peter Koepke

- [1] Peter Koepke, Karen Räsch, and Philipp Schlicht. A minimal Prikrytype forcing for singularizing a measurable cardinal. *Journal of Sym*bolic Logic, 78(1):85–100, 2013.
- [2] Peter Koepke and Benjamin Seyfferth. Towards a theory of infinite time Blum-Shub-Smale machines. In S. Barry Cooper, Anuj Dawar, and Benedikt Löwe, editors, How the World Computes, Turing Centenary Conference and 8th Conference on Computability in Europe, CiE 2012, Cambridge, UK, June 18-23, 2012, Proceedings, volume 7318 of Lecture Notes in Computer Science, pages 310–318, Heidelberg, 2012. Springer-Verlag.
- [3] Moti Gitik and Peter Koepke. Violating the singular cardinals hypothesis without large cardinals. *Israel Journal of Mathematics*, 191(2):901–922, 2012.
- [4] Peter Koepke and Julian J. Schlöder. Transition of consistency and satisfiability under language extensions. *Formalized Mathematics*, 20(3):193–197, 2012.
- [5] Peter Koepke and Julian J. Schlöder. The Gödel completeness theorem for uncountable languages. Formalized Mathematics, 20(3):199–203, 2012.
- [6] Peter Koepke and Philip D. Welch. A generalised dynamical system, infinite time register machines, and Π₁-CA₀. In Benedikt Löwe, Dag Normann, Ivan Soskov, and Alexandra A. Soskova, editors, Models of Computation in Context, 7th Conference on Computability in Europe, CiE 2011, Sofia, Bulgaria, June 27–July 2, 2011, Proceedings, volume 6735 of Lecture Notes in Computer Science, pages 152–159. Springer-Verlag, 2011.
- [7] Marcos Cramer, Peter Koepke, and Bernhard Schröder. Parsing and disambiguation of symbolic mathematics in the Naproche system. In James H. Davenport, William M. Farmer, Josef Urban, and Florian Rabe, editors, Intelligent Computer Mathematics, 18th Symposium, Calculemus 2011, and 10th International Conference, MKM 2011, Bertinoro, Italy, July 18-23, 2011. Proceedings, volume 6824 of Lecture Notes in Computer Science, pages 180–195. Springer-Verlag, 2011.

- [8] Peter Koepke and Philip D. Welch. Global square and mutual stationarity at the \aleph_n . Annals of Pure and Applied Logic, 162(10):787–806, 2011.
- [9] Arthur W. Apter and Peter Koepke. The consistency strength of choiceless failures of SCH. *Journal of Symbolic Logic*, 75(3):1066–1080, 2010.
- [10] Merlin Carl, Tim Fischbach, Peter Koepke, Russell Miller, Miriam Nasfi, and Gregor Weckbecker. The basic theory of infinite time register machines. Archive for Mathematical Logic, 49(2):249–273, 2010.
- [11] Marcos Cramer, Peter Koepke, Daniel Kühlwein, and Bernhard Schröder. Premise selection in the Naproche system. In Jürgen Giesl and Reiner Hähnle, editors, Automated Reasoning, 5th International Joint Conference, IJCAR 2010, Edinburgh, UK, July 16-19, 2010, Proceedings, volume 6173 of Lecture Notes in Computer Science, pages 434–440. Springer-Verlag, 2010.
- [12] Marcos Cramer, Bernhard Fisseni, Peter Koepke, Daniel Kühlwein, Bernhard Schröder, and Jip Veldman. The Naproche project, controlled natural language proof checking of mathematical texts. In Norbert E. Fuchs, editor, Controlled Natural Language, Workshop on Controlled Natural Language, CNL 2009, Marettimo Island, Italy, June 8-10, 2009, Revised Papers, volume 5972 of Lecture Notes in Computer Science, pages 170–186. Springer-Verlag, 2010.
- [13] Merlin Carl and Peter Koepke. Interpreting Naproche—An algorithmic approach to the derivation-indicator view. In Alison Pease, Markus Guhe, and Alan Smaill, editors, *Proceedings of the International Symposium on Mathematical Practice and Cognition: A symposium at the AISB 2010 Convention*, pages 7–10. Society for the Study of Artificial Intelligence and the Simulation of Behaviour, 2010.
- [14] Peter Koepke. Ordinal computability. In Klaus Ambos-Spies, Benedikt Löwe, and Wolfgang Merkle, editors, Mathematical Theory and Computational Practice, 5th Conference on Computability in Europe, CiE 2009, Heidelberg, Germany, July 19-24, 2009. Proceedings, volume 5635 of Lecture Notes in Computer Science, pages 280–289. Springer-Verlag, 2009.
- [15] Peter Koepke and Benjamin Seyfferth. Ordinal machines and admissible recursion theory. *Annals of Pure and Applied Logic*, 160(3):310–318, 2009.

- [16] Jip Veldman, Bernhard Fisseni, Bernhard Schröder, and Peter Koepke. From proof texts to logic. In Christian Chiarcos, Richard Eckart de Castilho, and Manfred Stede, editors, Von der Form zur Bedeutung: Texte automatisch verarbeiten, From Form to Meaning: Processing Texts Automatically, Proceedings of the Biennial GSCL Conference 2009, pages 137–146. Gunter Narr, 2009.
- [17] Peter Koepke and Russell Miller. An enhanced theory of infinite time register machines. In Arnold Beckmann, Costas Dimitracopoulos, and Benedikt Löwe, editors, Logic and Theory of Algorithms, 4th Conference on Computability in Europe, CiE 2008, Athens, Greece, June 15-20, 2008, Proceedings, volume 5028 of Lecture Notes in Computer Science, pages 306–315, Heidelberg, 2008. Springer-Verlag.
- [18] Arthur W. Apter and Peter Koepke. Making all cardinals almost Ramsey. Archive for Mathematical Logic, 47(7-8):769–783, 2008.
- [19] Peter Koepke and Ryan Siders. Register computations on ordinals. *Archive for Mathematical Logic*, 47(6):529–548, 2008.
- [20] Peter Koepke and Ryan Siders. Minimality considerations for ordinal computers modeling constructibility. *Theoretical Computer Science*, 394(3):197–207, 2008.
- [21] Peter Koepke. Forcing a mutual stationarity property in cofinality ω_1 . Proceedings of the American Mathematical Society, 135(5):1523–1533, 2007.
- [22] Peter Koepke. Gödel's completeness theorem with natural language formulas. In Thomas Müller and Albert Newen, editors, Logik, Begriffe, Prinzipien des Handelns, Logic, Concepts, Principles of Action, pages 49–63. mentis, 2007.
- [23] Peter Koepke. Ordinals, computations, and models of set theory. In Reinhard Kahle and Isabel Oitavem, editors, *Days in Logic '06, Two Tutorials*, volume 38 of *Texts on Mathematics*, pages 43–78. Universidade de Coimbra, 2006.
- [24] Peter Koepke and Philip Welch. On the strength of mutual stationarity. In Joan Bagaria and Stevo Todorcevic, editors, Set theory, Centre de Recerca Matemàtica, Barcelona, 2003–2004, Trends in Mathematics, pages 309–320. Birkhäuser Verlag, 2006.
- [25] Peter Koepke and Martin Koerwien. Ordinal computations. *Mathematical Structures in Computer Science*, 16(5):867–884, 2006.

- [26] Arthur W. Apter and Peter Koepke. The consistency strength of \aleph_{ω} and \aleph_{ω_1} being Rowbottom cardinals without the axiom of choice. Archive for Mathematical Logic, 45(6):721–737, 2006.
- [27] Sy-David Friedman, Peter Koepke, and Boris Piwinger. Hyperfine structure theory and gap 1 morasses. *Journal of Symbolic Logic*, 71(2):480–490, 2006.
- [28] Peter Koepke. Computing a model of set theory. In S. Barry Cooper, Benedikt Löwe, and Leen Torenvliet, editors, New Computational Paradigms, First Conference on Computability in Europe, CiE 2005, Amsterdam, The Netherlands, June 8-12, 2005, Proceedings, volume 3526 of Lecture Notes in Computer Science, pages 223-232, Heidelberg, 2005. Springer-Verlag.
- [29] Peter Koepke. Infinite time register machines. In Arnold Beckmann, Ulrich Berger, Benedikt Löwe, and John V. Tucker, editors, Logical Approaches to Computational Barriers, Second Conference on Computability in Europe, CiE 2006, Swansea, UK, June 30-July 5, 2006, Proceedings, volume 3988 of Lecture Notes in Computer Science, pages 257–266, Heidelberg, 2006. Springer-Verlag.
- [30] Peter Koepke and Ralf Schindler. Homogeneously Souslin sets in small inner models. Archive for Mathematical Logic, 45(1):53–61, 2006.
- [31] Peter Koepke. Turing computations on ordinals. *Bulletin of Symbolic Logic*, 11:377–397, 2005.
- [32] Peter Koepke. Simplified constructibility theory: minicourse Helsinki, March 2005, volume 5 of Graduate texts in mathematics. University of Helsinki, 2005.
- [33] Patrick Braselmann and Peter Koepke. A formal proof of Gödel's completeness theorem. *Formalized Mathematics*, 13:5–53, 2005.
- [34] Peter Koepke and Marc van Eijmeren. A refinement of Jensen's constructible hierarchy. In Benedikt Löwe, Boris Piwinger, and Thoralf Räsch, editors, Classical and new paradigms of computation and their complexity hierarchies, volume 23 of Trends in Logic, pages 159–169. Kluwer Academic Publishers, 2004.
- [35] Peter Koepke and Bernhard Schröder. ProofML—eine Annotationsprache für natürliche Beweise. *LDV-Forum*, 18(3), 2003.
- [36] Vladimir Kanovei and Peter Koepke. Deskriptive Mengenlehre in Hausdorffs *Grundzügen der Mengenlehre*. In Egbert Brieskorn, Srishti D.

- Chatterji, Moritz Epple, Ulrich Felgner, Horst Herrlich, Mirek Hušek, Vladimir Kanovei, Peter Koepke, Gerhard Preuß, Walter Purkert, and Erhard Scholz, editors, Felix Hausdorff, gesammelte Werke. Band II. "Grundzüge der Mengenlehre", pages 773–787. Springer-Verlag, 2002.
- [37] Peter Koepke. The category of inner models. Synthese, 133(1-2):275–303, 2002.
- [38] Peter Koepke and Bernhard Schröder. Natürlich formal. In Gerd Willée, Bernhard Schröder, and Hans-Christian Schmitz, editors, Computerlinguistik—Was geht, was kommt? Computational Linguistics—Achievements and Perspectives, volume 4 of Sprachwissenschaft, Computerlinguistik und Neue Medien, pages 186–191. Gardez!-Verlag, 2003.
- [39] Peter Koepke. An iteration model violating the singular cardinals hypothesis. In S. Barry Cooper and John K. Truss, editors, Sets and proofs. Invited papers from Logic Colloquium '97 (European Meeting of the Association for Symbolic Logic) held in Leeds, July 6-13, 1997, volume 258 of London Mathematical Society Lecture Note Series, pages 95–102. Cambridge University Press, 1999.
- [40] Peter Koepke. Extenders, embedding normal forms, and the Martin-Steel theorem. *Journal of Symbolic Logic*, 63(3):1137–1176, 1998.
- [41] Sy D. Friedman and Peter Koepke. An elementary approach to the fine structure of **L**. Bulletin of Symbolic Logic, 3(4):453–468, 1997.
- [42] Peter Koepke. Embedding normal forms and Π₁-determinacy. In Wilfrid Hodges, Martin Hyland, Charles Steinhorn, and John K. Truss, editors, Logic: from foundations to applications. Proceedings of the Logic Colloquium held as a part of the European Meeting of the Association for Symbolic Logic at the University of Keele, Staffordshire, July 2029, 1993, Oxford Science Publications, pages 215–224. Oxford University Press, 1996.
- [43] Peter Koepke. Metamathematische Aspekte der Hausdorffschen Mengenlehre. In Egbert Brieskorn, editor, Felix Hausdorff zum Gedächtnis, Band I, Aspekte seines Werkes, pages 71–106. Vieweg, 1996.
- [44] Peter Koepke and Juan Carlos Martínez. Superatomic Boolean algebras constructed from morasses. *Journal of Symbolic Logic*, 60(3):940–951, 1995.

- [45] Peter Koepke. An introduction to extenders and core models for extender sequences. In H.-D. Ebbinghaus, J. Fernandez-Prida, M. Garrido, D. Lascar, and M. Rodríquez Artalejo, editors, Logic Colloquium '87. Proceedings of the colloquium held at the University of Granada, Granada, July 2025, 1987, volume 129 of Studies in Logic and the Foundations of Mathematics, pages 137–182. North-Holland, 1989.
- [46] Peter Koepke. On the elimination of Malitz quantifiers over Archimedian real closed fields. Archive for Mathematical Logic, 28(3):167–171, 1989.
- [47] Peter Koepke. On the free subset property at singular cardinals. *Archive for Mathematical Logic*, 28(1):43–55, 1989.
- [48] Hans-Dieter Donder, Peter Koepke, and Jean-Pierre Levinski. Some stationary subsets of $\wp(\lambda)$. Proceedings of the American Mathematical Society, 102(4):1000–1004, 1988.
- [49] Peter Koepke. Some applications of short core models. *Annals of Pure and Applied Logic*, 37(2):179–204, 1988.
- [50] Peter Koepke. The consistency strength of the free-subset property for ω_{ω} . Journal of Symbolic Logic, 49(4):1198–1204, 1984.
- [51] Hans-Dieter Donder and Peter Koepke. On the consistency strength of "accessible" Jónsson cardinals and of the weak Chang conjecture. *Annals of Pure and Applied Logic*, 25(3):233–261, 1983.

Publications by Philip Welch

- [1] Philip D. Welch. Transfinite machine models. In Rod Downey, editor, Turing's Legacy, Developments from Turing's Ideas in Logic, volume 42 of Lecture Notes in Logic, pages 493–529. Association for Symbolic Logic, 2014.
- [2] Philip D. Welch. Turing's mathematical work. In Rafał Latała, Andrzej Ruciński, Paweł Strzelecki, Paweł Światkowski, Dariusz Wrzosek, and Piotr Zakrezewski, editors, European Congress of Mathematics, Kraków, 2-7 July, 2012, pages 763–777. EMS Publishing House, 2014.
- [3] Philip Welch. Some observations on truth hierarchies. Review of Symbolic Logic, 7(1):1–30, 2014.
- [4] Philip D. Welch. Truth and Turing. In S. Barry Cooper and Jan van Leeuwen, editors, *Alan Turing: his work and impact*, pages 202–205. Elsevier, 2013.
- [5] Philip D. Welch. Towards the unknown region: On computing infinite numbers. In S. Barry Cooper and Jan van Leeuwen, editors, *Alan Turing: his work and impact*, pages 109–116. Elsevier, 2013.
- [6] Leon Horsten and Philip Welch. The aftermath. *Mathematical Intelligencer*, 35(1):16–20, 2013.
- [7] Leon Horsten, Graham E. Leigh, Hannes Leitgeb, and Philip Welch. Revision revisited. *Review of Symbolic Logic*, 5(4):642–665, 2012.
- [8] Philip D. Welch. Some reflections on Alan Turing's centenary. European Mathematical Society Newsletter, 85:32–38, 2012.
- [9] Peter Koepke and Philip D. Welch. A generalised dynamical system, infinite time register machines, and Π₁¹-CA₀. In Benedikt Löwe, Dag Normann, Ivan Soskov, and Alexandra A. Soskova, editors, Models of Computation in Context, 7th Conference on Computability in Europe, CiE 2011, Sofia, Bulgaria, June 27–July 2, 2011, Proceedings, volume 6735 of Lecture Notes in Computer Science, pages 152–159. Springer-Verlag, 2011.
- [10] Philip D. Welch. Truth, logical validity and determinateness: a commentary on Field's Saving truth from paradox. Review of Symbolic Logic, 4(3):348–359, 2011.

- [11] Philip D. Welch. Discrete transfinite computation models. In S. Barry Cooper and Andrea Sorbi, editors, *Computability in Context, Computation and Logic in the Real World*, pages 371–410. World Scientific, 2011.
- [12] Ian Sharpe and Philip D. Welch. Greatly Erdős cardinals with some generalizations to the Chang and Ramsey properties. *Annals of Pure and Applied Logic*, 162(11):863–902, 2011.
- [13] Victoria Gitman and Philip D. Welch. Ramsey-like cardinals II. *Journal of Symbolic Logic*, 76(2):541–560, 2011.
- [14] Philip D. Welch. Determinacy in strong cardinal models. *Journal of Symbolic Logic*, 76(2):719–728, 2011.
- [15] Sy-David Friedman and Philip D. Welch. Hypermachines. *Journal of Symbolic Logic*, 76(2):620–636, 2011.
- [16] Philip D. Welch. Weak systems of determinacy and arithmetical quasi-inductive definitions. *Journal of Symbolic Logic*, 76(2):418–436, 2011.
- [17] P. Koepke and Philip D. Welch. Global square and mutual stationarity at the \aleph_n . Annals of Pure and Applied Logic, 162(10):787–806, 2011.
- [18] Philip D. Welch. Σ^* fine structure. In Matthew Foreman and Akihiro Kanamori, editors, Handbook of set theory. Vol. 1, pages 657–736. Springer-Verlag, 2010.
- [19] Philip D. Welch. Relativistic computers and transfinite computation. In Cristian S. Calude, José Félix Costa, Nachum Dershowitz, Elisabete Freire, and Grzegorz Rozenberg, editors, Unconventional Computation, 8th International Conference, UC 2009, Ponta Delgada, Azores, Portugal, September 7-11, 2009. Proceedings, volume 5715 of Lecture Notes in Computer Science, pages 37-41. Springer-Verlag, 2009.
- [20] Volker Halbach and Philip Welch. Necessities and necessary truths: a prolegomenon to the use of modal logic in the analysis of intensional notions. *Mind*, 118(469):96–100, 2009.
- [21] Philip D. Welch. Games for truth. Bulletin of Symbolic Logic, 15(4):410–427, 2009.
- [22] Leon Horsten and Philip Welch. Erratum: The undecidability of propositional adaptive logic. *Synthese*, 169(1):217–218, 2009.

- [23] Philip D. Welch. Characteristics of discrete transfinite time Turing machine models: halting times, stabilization times, and normal form theorems. *Theoretical Computer Science*, 410(4-5):426–442, 2009.
- [24] Philip D. Welch. The extent of computation in Malament-Hogarth spacetimes. British Journal for the Philosophy of Science, 59(4):659–674, 2008.
- [25] Sy-David Friedman, Philip Welch, and W. Hugh Woodin. On the consistency strength of the inner model hypothesis. *Journal of Symbolic Logic*, 73(2):391–400, 2008.
- [26] Philip D. Welch. Bounding lemmata for non-deterministic halting times of transfinite Turing machines. *Theoretical Computer Science*, 394(3):223–228, 2008.
- [27] Philip D. Welch. Ultimate truth vis à vis stable truth. Review of Symbolic Logic, 1(1):126–142, 2008.
- [28] Agustin Rayo and Philip D. Welch. Field on revenge. In J. C. Beall, editor, *Revenge of the Liar, New Essays on the Paradox*, pages 234–249. Oxford University Press, 2008.
- [29] Philip D. Welch. Turing unbound: transfinite computation. In S. Barry Cooper, Benedikt Löwe, and Andrea Sorbi, editors, Computation and Logic in the Real World, Third Conference on Computability in Europe, CiE 2007, Siena, Italy, June 18-23, 2007, Proceedings, volume 4497 of Lecture Notes in Computer Science, pages 768-780. Springer-Verlag, 2007.
- [30] Leon Horsten and Philip Welch. The undecidability of propositional adaptive logic. *Synthese*, 158(1):41–60, 2007.
- [31] Philip Welch. Non-deterministic halting times for hamkins-kidder turing machines. In Arnold Beckmann, Ulrich Berger, Benedikt Löwe, and John V. Tucker, editors, Logical Approaches to Computational Barriers, Second Conference on Computability in Europe, CiE 2006, Swansea, UK, June 30-July 5, 2006, Proceedings, volume 3988 of Lecture Notes in Computer Science, pages 571–574, 2006.
- [32] Peter Koepke and Philip Welch. On the strength of mutual stationarity. In Joan Bagaria and Stevo Todorcevic, editors, Set theory, Centre de Recerca Matemàtica, Barcelona, 2003–2004, Trends in Mathematics, pages 309–320. Birkhäuser Verlag, 2006.

- [33] Philip Welch. On the transfinite action of 1 tape turing machines. In S. Barry Cooper, Benedikt Löwe, and Leen Torenvliet, editors, New Computational Paradigms, First Conference on Computability in Europe, CiE 2005, Amsterdam, The Netherlands, June 8-12, 2005, Proceedings, volume 3526 of Lecture Notes in Computer Science, pages 532–539. Springer-Verlag, 2005.
- [34] Volker Halbach, Hannes Leitgeb, and Philip Welch. Possible worlds semantics for predicates. In Reinhard Kahle, editor, *Intensionality*, volume 22 of *Lecture Notes in Logic*, pages 20–41. Association for Symbolic Logic, 2005.
- [35] Kai-Uwe Kühnberger, Benedikt Löwe, Michael Möllerfeld, and Philip Welch. Comparing inductive and circular definitions: parameters, complexity and games. Studia Logica, 81(1):79–98, 2005.
- [36] Philip D. Welch. Some open problems in mutual stationarity involving inner model theory: A commentary. Notre Dame Journal of Formal Logic, 46(3):375–379, 2005.
- [37] Philip D. Welch. Post's and other problems of supertasks of higher type. In Benedikt Löwe, Boris Piwinger, and Thoralf Räsch, editors, Classical and new paradigms of computation and their complexity hierarchies, volume 23 of Trends in Logic, pages 223–237. Kluwer Academic Publishers, 2004.
- [38] Philip D. Welch. On the possibility, or otherwise, of hypercomputation. British Journal for the Philosophy of Science, 55(4):739–746, 2004.
- [39] Philip D. Welch. On unfoldable cardinals, ω -closed cardinals, and the beginning of the inner model hierarchy. Archive for Mathematical Logic, 43(4):443–458, 2004.
- [40] Joel David Hamkins and Philip D. Welch. $P^f \neq NP^f$ for almost all f. Mathematical Logic Quarterly, 49(5):536–540, 2003.
- [41] Volker Halbach, Hannes Leitgeb, and Philip Welch. Possible-worlds semantics for modal notions conceived as predicates. *Journal of Philosophical Logic*, 32(2):179–223, 2003.
- [42] Philip D. Welch. On revision operators. *Journal of Symbolic Logic*, 68(2):689–711, 2003.
- [43] David Asperó and Philip D. Welch. Bounded Martin's maximum, weak Erdős cardinals, and ψ_{AC} . Journal of Symbolic Logic, 67(3):1141–1152, 2002.

- [44] Philip D. Welch. On possible non-homeomorphic substructures of the real line. *Proceedings of the American Mathematical Society*, 130(9):2771–2775, 2002.
- [45] Benedikt Löwe and Philip D. Welch. Set-theoretic absoluteness and the revision theory of truth. *Studia Logica*, 68(1):21–41, 2001.
- [46] Philip D. Welch. On Gupta-Belnap revision theories of truth, Krip-kean fixed points, and the next stable set. *Bulletin of Symbolic Logic*, 7(3):345–360, 2001.
- [47] John Vickers and Philip D. Welch. On elementary embeddings from an inner model to the universe. *Journal of Symbolic Logic*, 66(3):1090–1116, 2001.
- [48] Philip D. Welch. Eventually infinite time Turing machine degrees: infinite time decidable reals. *Journal of Symbolic Logic*, 65(3):1193–1203, 2000.
- [49] John Vickers and Philip D. Welch. On successors of Jónsson cardinals. Archive for Mathematical Logic, 39(6):465–473, 2000.
- [50] Philip D. Welch. Some remarks on the maximality of inner models. In Samuel R. Buss, Petr Hájek, and Pavel Pudlák, editors, Logic Colloquium '98, Proceedings of the Annual European Summer Meeting of the Association for Symbolic Logic held at the University of Economics, Prague, August 9-15, 1998, volume 13 of Lecture Notes in Logic, pages 516–540. Association for Symbolic Logic, 2000.
- [51] Philip D. Welch. The length of infinite time Turing machine computations. *Bulletin of the London Mathematical Society*, 32(2):129–136, 2000.
- [52] Philip D. Welch. Minimality arguments for infinite time Turing degrees. In S. Barry Cooper and John K. Truss, editors, Sets and proofs. Invited papers from Logic Colloquium '97 (European Meeting of the Association for Symbolic Logic) held in Leeds, July 6-13, 1997, volume 258 of London Mathematical Society Lecture Note Series, pages 425–436. Cambridge University Press, 1999.
- [53] John R. Steel and Philip D. Welch. Σ_3^1 absoluteness and the second uniform indiscernible. *Israel Journal of Mathematics*, 104:157–190, 1998.
- [54] Philip D. Welch. Determinacy in the difference hierarchy of co-analytic sets. *Annals of Pure and Applied Logic*, 80(1):69–108, 1996.

- [55] Philip D. Welch. Countable unions of simple sets in the core model. Journal of Symbolic Logic, 61(1):293–312, 1996.
- [56] Philip D. Welch. Characterising subsets of ω_1 constructible from a real. Journal of Symbolic Logic, 59(4):1420–1432, 1994.
- [57] Philip D. Welch. Some descriptive set theory and core models. *Annals of Pure and Applied Logic*, 39(3):273–290, 1988.
- [58] Philip D. Welch. Coding that preserves Ramseyness. Fundamenta Mathematicae, 129(1):1–7, 1988.
- [59] Philip D. Welch. Doing without determinacy-aspects of inner models. In Frank R. Drake and John K. Truss, editors, Logic colloquium '86, Proceedings of the colloquium held at the University of Hull, Hull, July 13-19, 1986, Dedicated to the memory of R. L. Goodstein, volume 124 of Studies in Logic and the Foundations of Mathematics, pages 333-342. North-Holland, 1988.
- [60] Philip D. Welch. Minimality in the Δ_3^1 -degrees. Journal of Symbolic Logic, 52(4):908–915, 1987.
- [61] Philip D. Welch. The reals in core models. *Journal of Symbolic Logic*, 52(1):64–67, 1987.
- [62] Philip D. Welch. The natural hierarchy and quasihierarchy of constructibility degrees. *Journal of Symbolic Logic*, 51(1):130–134, 1986.
- [63] Philip D. Welch. Comparing incomparable Kleene degrees. Journal of Symbolic Logic, 50(1):55–58, 1985.
- [64] Philip D. Welch. On Σ₃¹. In Gert H. Müller and Michael M. Richter, editors, Models and Sets, Proceedings of the Logic Colloquium held in Aachen, July 18-23, 1983, Part I, volume 1103 of Lecture Notes in Mathematics, pages 473–484. Springer-Verlag, 1984.
- [65] Aaron Beller, Ronald B. Jensen, and Philip D. Welch. Coding the universe, volume 47 of London Mathematical Society Lecture Note Series. Cambridge University Press, 1982.

Doctoral students

Peter Koepke's doctoral students

- Ralf-Dieter Schindler Rheinische Friedrich-Wilhelms-Universität Bonn 1996
- Florian Rudolph Rheinische Friedrich-Wilhelms-Universität Bonn 2000
- 3. Jochen Löffelmann Rheinische Friedrich-Wilhelms-Universität Bonn 2001
- 4. Sandra Quickert Rheinische Friedrich-Wilhelms-Universität Bonn 2002
- Merlin Carl Rheinische Friedrich-Wilhelms-Universität Bonn 2011
- 6. Ioanna Dimitriou Rheinische Friedrich-Wilhelms-Universität Bonn 2011
- Marcos Cramer Rheinische Friedrich-Wilhelms-Universität Bonn 2013
- 8. Benjamin Seyfferth Rheinische Friedrich-Wilhelms-Universität Bonn 2013

Philip Welch's doctoral students

- John Vickers
 University of Bristol 1993
- 2. Ian Sharpe University of Bristol 2007
- 3. Richard Pettigrew University of Bristol 2008
- 4. Barnaby Dawson University of Bristol 2009