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Global fields and their L-functions

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Curriculum Vitae

Pavel Solomatin was born on May 14, 1991 in Moscow, Russian Federation. Started from 2004 he attended experimental division of the mathematical high school No. 179, with the curriculum focusing on both computer science and mathematics.

Upon graduating in 2008 he went on to obtain a bachelor diploma in pure mathematics from the National Research University Higher School of Economics (HSE). There he fell in love with number theory and defended his bachelor thesis titled “*On Arithmetic Properties of Abelian Varieties over Finite Fields*” under scientific direction of professor Alexey Zykin.

In 2012 Pavel enrolled in the master program at HSE math department, graduating in 2014 with the thesis titled “*Curves with Many Points over Finite Fields: The Class Field Theory Approach*”, which was also written under kind Alexey’s guidance. During his master studies Pavel’s research received support from the grant “*Arithmetic Properties of Abelian Varieties over Finite and Function Fields*” issued by the Russian Academy of Science. Directly after graduation in 2014 he received an ALGANT scholarship which allowed him to continue his mathematical studies as a Ph.D. candidate under scientific direction of professor Bart de Smit (Leiden University) and professor Karim Belabas (University of Bordeaux). Besides the scientific research Pavel was also devoting efforts to teaching various kinds of mathematical disciplines for graduate and undergraduate students. For this job he received the “*Best teacher 2013–2014*” award according to the choice of students from the HSE-NES joint bachelor program in economics. While staying in the Netherlands his teaching duties were related to assistance for multiple courses of the Dutch “Master in Mathematics” program, such as “Number Theory” and “Elliptic Curves”.

Starting from February 2018 he is working full-time as a software engineer at a Dutch IT-company called Ortec. There he is applying his passion for mathematics in order to improve our world.

Bibliography

- [1] Athanasios Angelakis and Peter Stevenhagen. Imaginary quadratic fields with isomorphic abelian Galois groups. In *ANTS X—Proceedings of the Tenth Algorithmic Number Theory Symposium*, volume 1 of *Open Book Ser.*, pages 21–39. Math. Sci. Publ., Berkeley, CA, 2013.
- [2] Emil Artin and John Tate. *Class field theory*. AMS Chelsea Publishing, Providence, RI, 2009. Reprinted with corrections from the 1967 original.
- [3] Andrea Bandini, Ignazio Longhi, and Stefano Vigni. Torsion points on elliptic curves over function fields and a theorem of Igusa. *Expo. Math.*, 27(3):175–209, 2009.
- [4] W. Bosma and J. Cannon. *Discovering Mathematics with Magma: Reducing the Abstract to the Concrete*. Algorithms and Computation in Mathematics. Springer Berlin Heidelberg, 2007.
- [5] Wieb Bosma and Bart de Smit. On arithmetically equivalent number fields of small degree. In *Algorithmic number theory (Sydney, 2002)*, volume 2369 of *Lecture Notes in Comput. Sci.*, pages 67–79. Springer, Berlin, 2002.
- [6] John Conway, John McKay, and Allan Trojan. Galois groups over function fields of positive characteristic. *Proc. Amer. Math. Soc.*, 138(4):1205–1212, 2010.
- [7] Gunther Cornelissen. Two-torsion in the Jacobian of hyperelliptic curves over finite fields. *Archiv der Mathematik*, 77(3):241–246, 2001.
- [8] Gunther Cornelissen, Aristides Kontogeorgis, and Lotte van der Zalm. Arithmetic equivalence for function fields, the Goss zeta function and a generalisation. *J. Number Theory*, 130(4):1000–1012, 2010.
- [9] Bart de Smit. Generating arithmetically equivalent number fields with elliptic curves. In *Algorithmic number theory (Portland, OR, 1998)*, volume 1423 of *Lecture Notes in Comput. Sci.*, pages 392–399. Springer, Berlin, 1998.
- [10] Bart de Smit and Robert Perlis. Zeta functions do not determine class numbers. *Bull. Amer. Math. Soc. (N.S.)*, 31(2):213–215, 1994.
- [11] Bart de Smit and Pavel Solomatin. On abelianized absolute Galois group of global function fields. <https://arxiv.org/abs/1703.05729>, 2017.

BIBLIOGRAPHY

- [12] Bart de Smit and Pavel Solomatin. A remark on abelianized absolute Galois group of imaginary quadratic fields. *https://arxiv.org/abs/1703.07241*, 2017.
- [13] Gunther Cornelissen; Bart de Smit; Xin Li; Matilde Marcolli; Harry Smit. Reconstructing global fields from Dirichlet L-series. *arXiv: https://arxiv.org/abs/1706.04515*, 2017.
- [14] Michael DiPasquale. On the order of a group containing nontrivial Gassmann equivalent subgroups. *Rose-Hulman Undergraduate Math Journal*, 10(1), 2009.
- [15] Kevin D. Doerksen. On the arithmetic of genus two curves with (4,4)-split Jacobians. *PhD thesis*, 2011.
- [16] Bosco Fotsing and Burkhard Külshammer. Modular species and prime ideals for the ring of monomial representations of a finite group. *Comm. Algebra*, 33(10):3667–3677, 2005.
- [17] Gerhard Frey and Ernst Kani. Curves of genus 2 with elliptic differentials and associated Hurwitz spaces. In *Arithmetic, geometry, cryptography and coding theory*, volume 487 of *Contemp. Math.*, pages 33–81. Amer. Math. Soc., Providence, RI, 2009.
- [18] László Fuchs. *Abelian groups*. Springer Monographs in Mathematics. Springer, Cham, 2015.
- [19] Carl Friedrich Gauss. *Disquisitiones arithmeticae*. Springer-Verlag, New York, 1986. Translated and with a preface by Arthur A. Clarke, Revised by William C. Waterhouse, Cornelius Greither and A. W. Grootendorst and with a preface by Waterhouse.
- [20] David Goss. *Basic structures of function field arithmetic*, volume 35 of *Ergebnisse der Mathematik und ihrer Grenzgebiete (3) [Results in Mathematics and Related Areas (3)]*. Springer-Verlag, Berlin, 1996.
- [21] Everett W. Howe, Enric Nart, and Christophe Ritzenthaler. Jacobians in isogeny classes of abelian surfaces over finite fields. *Ann. Inst. Fourier (Grenoble)*, 59(1):239–289, 2009.
- [22] E. Kani and M. Rosen. Idempotent relations and factors of Jacobians. *Math. Ann.*, 284(2):307–327, 1989.
- [23] Ernst Kani. Discriminants of Hermitian $R[G]$ -modules and Brauer’s class number relation. In *Algebra and number theory (Essen, 1992)*, pages 43–135. de Gruyter, Berlin, 1994.
- [24] Ernst Kani. Elliptic curves on abelian surfaces. *Manuscripta Math.*, 84(2):199–223, 1994.
- [25] Ernst Kani. The number of curves of genus two with elliptic differentials. *J. Reine Angew. Math.*, 485:93–121, 1997.
- [26] Irving Kaplansky. *Infinite abelian groups*. Revised edition. The University of Michigan Press, Ann Arbor, Mich., 1969.
- [27] Norbert Klingen. *Arithmetical similarities*. Oxford Mathematical Monographs. The Clarendon Press, Oxford University Press, New York, 1998. Prime decomposition and finite group theory, Oxford Science Publications.

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- [28] James R. C. Leitzel, Manohar L. Madan, and Clifford S. Queen. Algebraic function fields with small class number. *J. Number Theory*, 7:11–27, 1975.
- [29] Sidney A. Morris. *Pontryagin duality and the structure of locally compact abelian groups*. Cambridge University Press, Cambridge-New York-Melbourne, 1977. London Mathematical Society Lecture Note Series, No. 29.
- [30] M. Ram Murty. *Problems in analytic number theory*, volume 206 of *Graduate Texts in Mathematics*. Springer, New York, second edition, 2008. Readings in Mathematics.
- [31] M.R. Murty and V.K. Murty. *Non-vanishing of L-Functions and Applications*. Modern Birkhäuser Classics. Springer Basel, 2012.
- [32] Kiyoshi Nagata. Artin’s L-functions and Gassmann equivalence. *Tokyo J. Math.*, 9(2):357–364, 1986.
- [33] Władysław Narkiewicz. *Elementary and analytic theory of algebraic numbers*. Springer Monographs in Mathematics. Springer-Verlag, Berlin, third edition, 2004.
- [34] J. Neukirch. Kennzeichnung der endlich-algebraischen Zahlkörper durch die Galoisgruppe der maximal auflösbaren Erweiterungen. *Journal für die reine und angewandte Mathematik*, 238:135–147, 1969.
- [35] J. Neukirch. Kennzeichnung der p -adischen und der endlichen algebraischen Zahlkörper. *Invent. Math.*, 6:296–314, 1969.
- [36] J. Neukirch. *Algebraic number theory*, volume 322 of *Grundlehren der Mathematischen Wissenschaften [Fundamental Principles of Mathematical Sciences]*. Springer-Verlag, Berlin, 1999. Translated from the 1992 German original and with a note by Norbert Schappacher, With a foreword by G. Harder.
- [37] J. Neukirch, A. Schmidt, and K. Wingberg. *Cohomology of Number Fields*. Grundlehren der mathematischen Wissenschaften. Springer Berlin Heidelberg, 2013.
- [38] Midori Onabe. On the isomorphisms of the Galois groups of the maximal Abelian extensions of imaginary quadratic fields. *Natur. Sci. Rep. Ochanomizu Univ.*, 27(2):155–161, 1976.
- [39] Robert Perlis. On the class numbers of arithmetically equivalent fields. *J. Number Theory*, 10(4):489–509, 1978.
- [40] Dipendra Prasad. A refined notion of arithmetically equivalent number fields, and curves with isomorphic Jacobians. *Advances in Mathematics*, 312:198 – 208, 2017.
- [41] Luis Ribes and Pavel Zalesskii. *Profinite groups*, volume 40 of *Ergebnisse der Mathematik und ihrer Grenzgebiete. 3. Folge. A Series of Modern Surveys in Mathematics [Results in Mathematics and Related Areas. 3rd Series. A Series of Modern Surveys in Mathematics]*. Springer-Verlag, Berlin, second edition, 2010.

BIBLIOGRAPHY

- [42] Michael Rosen. *Number theory in function fields*, volume 210 of *Graduate Texts in Mathematics*. Springer-Verlag, New York, 2002.
- [43] Joseph J. Rotman. *An introduction to the theory of groups*, volume 148 of *Graduate Texts in Mathematics*. Springer-Verlag, New York, fourth edition, 1995.
- [44] R. Perlis. On the equation $\zeta_k(s) = \zeta'_k(s)$. *Journal of Number Theory*, Volume 9, Issue 3, Pages 342-360, 1977.
- [45] René Schoof. Nonsingular plane cubic curves over finite fields. *J. Combin. Theory Ser. A*, 46(2):183–211, 1987.
- [46] Jean-Pierre Serre. On a theorem of Jordan. *Bull. Amer. Math. Soc. (N.S.)*, 40(4):429–440, 2003.
- [47] Pavel Solomatin. L-functions of genus two abelian coverings of elliptic curves over finite fields. *arXiv: <https://arxiv.org/abs/1601.05941>*, 2016.
- [48] Pavel Solomatin. On artin L-functions and Gassmann equivalence for global function fields. *arXiv: <https://arxiv.org/abs/1610.05600>*, 2016.
- [49] Pavel Solomatin. A note on number fields sharing the list of Dedekind zeta-functions of abelian extensions with some applications towards the Neukirch-Uchida Theorem. *<https://arxiv.org/abs/1901.09243>*, 2019.
- [50] Henning Stichtenoth. *Algebraic function fields and codes*, volume 254 of *Graduate Texts in Mathematics*. Springer-Verlag, Berlin, second edition, 2009.
- [51] D. Stuart and R. Perlis. A new characterization of arithmetic equivalence. *J. Number Theory*, 53(2):300–308, 1995.
- [52] Andrew V. Sutherland. Arithmetic equivalence and isospectrality. *MIT Lecture Notes of Mini-Course in Topics in Algebra (18.708)*, 2018.
- [53] H. Toyokazu and S. Seiken. *Introduction To Non-abelian Class Field Theory, An: Automorphic Forms Of Weight 1 And 2-dimensional Galois Representations*. Series On Number Theory And Its Applications. World Scientific Publishing Company, 2016.
- [54] Michael Tsfasman, Serge Vlăduț, and Dmitry Nogin. *Algebraic geometric codes: basic notions*, volume 139 of *Mathematical Surveys and Monographs*. American Mathematical Society, Providence, RI, 2007.
- [55] Stuart Turner. Adele rings of global field of positive characteristic. *Bol. Soc. Brasil. Mat.*, 9(1):89–95, 1978.
- [56] Kôji Uchida. Isomorphisms of Galois groups. *J. Math. Soc. Japan*, 28(4):617–620, 1976.
- [57] Kôji Uchida. Isomorphisms of Galois groups of algebraic function fields. *Ann. of Math. (2)*, 106(3):589–598, 1977.

- [58] André Weil. Zum Beweis des Torellischen Satzes. *Nachr. Akad. Wiss. Göttingen. Math.-Phys. Kl. IIa.*, 1957:33–53, 1957.
- [59] André Weil. *Basic number theory*. Classics in Mathematics. Springer-Verlag, Berlin, 1995. Reprint of the second (1973) edition.
- [60] Jared Weinstein. Reciprocity laws and Galois representations: recent breakthroughs. *Bull. Amer. Math. Soc. (N.S.)*, 53(1):1–39, 2016.