Joseph Tooby-Smith PhD.

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Skill set

* Formal verification in maths and physics: Develop and maintain 'HepLean', a project to digitalise results from high energy physics into Lean 4. One motivation behind this is to develop a new way to use AI in theoretical physics.
* Categorical methods: 5 peer-reviewed publications using (higher) category theory to understand problems in physics. More generally, a range of publications applying advanced mathematics to physics.
* Theoretical physics: PhD from University of Cambridge, Masters/Undergrad from University of Oxford.
* Computer programming: 6+ years of experience in C++, python, Mathematica and Github.
* Software development skills: Contributed to a large open-source project (Mathlib). Maintain an open-source Github repository.
* Science communication: Ran and organised many outreach events communicating science to the wider public.

Employment

PostDoc. **Reykjavik University** *(2024-current)*, Computer Science.
Postdoc-Advisor: Tarmo Uustalu

PostDoc. **Cornell University** *(2021-2024)*, High energy physics.
Position: Hans Bethe Postdoctoral Associate in the high-energy theory group in the Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)
Description: Started a program to digitalise results from high energy physics into Lean 4. Also, continued use of higher category theory in physics by studying generalized symmetries.

Education

PhD. **University of Cambridge** *(2018-2021)*, Mathematical and Theoretical Physics.
Thesis: Arithmetical, geometrical, and categorical forays into particle physics.
Description: Thesis focused on the application of techniques in mathematics to solve problems in physics, including the use of number theory, category theory and geometry.
Advisor: Ben Gripaios
Awards: Honorary Vice-Chancellors Award (2018)

MMathPhys. **University of Oxford** *(2014-2018)*, Mathematical and Theoretical Physics.
Classification: Distinction/First Class (double classification)
Awards (Christ Church College): * Scholarships (2024-2017) * Collections Prize (2016) * Clifford Smith Prize (2018) * Hooke Prize (2018)
Awards (University of Oxford): * The Scott Prize for performance in the Physics Part A examination (2016) * The Scott Prize for best performance in the MPhys Part B examination (2017) * Prize for the Best Results on the Oxford MMathPhys (2018)

Three most recent publications

Below I list my three most recent publications with a brief description. (They are not in chronological order, but in an order of importance).

* J. Tooby-Smith. HepLean: Digitalising high energy physics. In: *arXiv preprint* (2024). arXiv:2405.08863 [hep-ph].

  This paper detailed a project called "HepLean", to create a monolithic library in the theorem prover Lean 4 containing results from the area of high energy physics. High energy physics is probably the closest area of physics to mathematics. This is a project I'm continuing to work on. Most physicists use computer algebra systems (e.g. mathematica), I am planning to make Lean and the library HepLean as useable as possible for physicists.

* J. Tooby-smith. Formalization of physics index notation in Lean 4. In: *arXiv preprint* (2024). arXiv:2411.07667 [cs.lo].

  This paper follows on from HepLean. It is formalization into Lean 4 of index notation used by physicists to deal

with tensor. The motivation behind this is make it easier for physicists write results into a formal proof assistant, and thereby increasing the adoption of such methods. The method by which I formalized index notation is novel, and used in the background category theory.

* B. Gripaios, O. Randal-Williams, and J. Tooby-Smith. Smooth generalized symmetries of quantum field theories. In: *J. Geom. Phys.* 201 (2024), 105212. doi:10.1016/j.geomphys.2024.105212. arXiv:2310.16090 [hep-th].

  The area of category theory is a common language between mathematics, computer science and physics. In this paper we used a special area of category theory called higher topos theory to formulate a concept in physics called generalized symmetries. This used a generalisation of the notion of a monad (which will be familiar to functional computer scientists).

Other publications

* A. Gomes, M. Ruhdorfer, and J. Tooby-Smith. Semisimple unifications of any gauge theory. In: *Phys. Rev. D* 108.7 (2023), 075001. doi:10.1103/PhysRevD.108.075001. arXiv:2306.16439 [hep-ph].
* C. Csaki, A. Ismail, M. Ruhdorfer, and J. Tooby-Smith. Higgs squared. In: *JHEP* 04 (2023), 082. doi:10.1007/JHEP04(2023)082. arXiv:2210.02456 [hep-ph].
* B. Gripaios, O. Randal-Williams, and J. Tooby-Smith. Generalized symmetries of topological field theories. In: *JHEP* 03 (2023), 087. doi:10.1007/JHEP03(2023)087. arXiv:2209.13524 [hep-th].
* J. Davighi and J. Tooby-Smith. Flatland: abelian extensions of the Standard Model with semi-simple completions. In: *JHEP* 09 (2022), 159. doi:10.1007/JHEP09(2022)159. arXiv:2206.11271 [hep-ph].
* J. Davighi and J. Tooby-Smith. Electroweak flavour unification. In: *JHEP* 09 (2022), 193. doi:10.1007/JHEP09(2022)193. arXiv:2201.07245 [hep-ph].
* B. C. Allanach, M. Madigan, and J. Tooby-Smith. A ν supersymmetric anomaly-free atlas. In: *JHEP* 02 (2022), 144. doi:10.1007/JHEP02(2022)144. arXiv:2107.07926 [hep-ph].
* J. Tooby-Smith. Arithmetical, geometrical, and categorical forays into particle physics. In: *Preprint* (2021). doi:10.17863/CAM.72061.
* B. Gripaios and J. Tooby-Smith. Inverse Higgs phenomena as duals of holonomic constraints. In: *J. Phys. A* 55.9 (2022), 095401. doi:10.1088/1751-8121/ac4c66. arXiv:2103.08923 [hep-th].
* B. C. Allanach, B. Gripaios, and J. Tooby-Smith. Semisimple extensions of the Standard Model gauge algebra. In: *Phys. Rev. D* 104.3 (2021), 035035.
* J. Davighi, M. McCullough, and J. Tooby-Smith. Undulating Dark Matter. In: *JHEP* 11 (2020), 120. doi:10.1007/JHEP11(2020)120. arXiv:2007.03662 [hep-ph].
* B. C. Allanach, B. Gripaios, and J. Tooby-Smith. Anomaly cancellation with an extra gauge boson. In: *Phys. Rev. Lett.* 125.16 (2020), 161601. doi:10.1103/PhysRevLett.125.161601. arXiv:2006.03588 [hep-th].
* T. Cohen, N. Craig, S. Koren, M. McCullough, and J. Tooby-Smith. Supersoft Top Squarks. In: *Phys. Rev. Lett.* 125.15 (2020), 151801. doi:10.1103/PhysRevLett.125.151801. arXiv:2002.12630 [hep-ph].
* B. C. Allanach, B. Gripaios, and J. Tooby-Smith. Solving local anomaly equations in gauge-rank extensions of the Standard Model. In: *Phys. Rev. D* 101.7 (2020), 075015. doi:10.1103/PhysRevD.101.075015. arXiv:1912.10022 [hep-th].
* B. C. Allanach, B. Gripaios, and J. Tooby-Smith. Geometric General Solution to the $U(1)$ Anomaly Equations. In: *JHEP* 05 (2020), 065. doi:10.1007/JHEP05(2020)065. arXiv:1912.04804 [hep-th].
* J. Davighi, B. Gripaios, and J. Tooby-Smith. Quantum mechanics in magnetic backgrounds with manifest symmetry and locality. In: *J. Phys. A* 53.14 (2020), 145302. doi:10.1088/1751-8121/ab78ce. arXiv:1905.11999 [hep-th].

Teaching

I will be undertaking more teaching in computer science in the academic year 2024-2025.

2016	Undertook a teaching module as part of my undergraduate
2018	Demonstrator for theoretical physics part I (Department of Physics, Cambridge)
2019-2020	Supervisor for Gauge Field Theory (Department of Physics, Cambridge)
2019	Supervisor for Quantum Field Theory (DAMTP, Cambridge)
2020	Supervisor for Symmetries, Fields and Particles (DAMTP, Cambridge)

Outreach

2016-2018	Oxford Hands on Science roadshows, and committee member (2017)
2017-2018	Oxford Physics department and Christ church college open days
2017	Volunteered at Stargazing Oxford event
2019	Volunteered at Cambridge Science Festival
2019	Helped at Cambridge HEP master classes
2022	Helped at outreach events for Cornell's Centre for Materials Research

Talks

2020	Cambridge University: "Local anomalies in Z' models"
2020	Edinburgh University: "Local anomalies in Z' models"
2020	Bonn University: "Supersoft Stops"
2020	Perimeter:"A voyage through undulating dark matter and the GUTs of su(48)"
2021	Cornell University: 'Inverse Higgs Constraints'
2022	NYU: 'A study of GUTs'
2022	Chicago: 'Symmetries of field theories'
2023	Carleton: 'Gauge extensions of the Standard Model'
2023	Cornell University: 'Symmetries of field theories'
2024	Cornell University: HepLean: Digitalising high energy physics
2024	Reykjavik University: Lean and the physical sciences

Conferences

2018	British Universities Summer School in Theoretical Elementary Particle Physics
2018	Annual Theory Meeting
2018	YTF 11
2019	Young Experimentalists & Theorists Institute
2019	NExT PhD Workshop
2019	Cavendish Laboratory Graduate Student Conference (was on the Organising committee and a convener)
2022	Phenomenology 2022 Symposium: From Virtual to Real
2022	Program on New Directions in Particle Physics
2022	Generalized Global Symmetries, Quantum Field Theory, and Geometry

2023	Cornell Topology Festival
2023	Higher Structures in Functorial Field Theory
2023	Categorical Symmetries in Quantum Field Theory (Workshop)

Athletic achievements

Personal Bests: 1:59.4 (800m), 3:59.40 (1500m), 8:39.6 (3000m), 9:59.49 (3000m Steeple chase), 15:08.92 (5000m), 30:01 (10k).