CIARAN HUGHES

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CAREER

2016 – Current **Fermilab (USA) – Research Associate in Theoretical Physics - Lattice QCD and QIS Scientist**

Being a post-doctoral researcher at Fermilab has extended my experience as a scientist. During my time at Fermilab I have built upon and further advanced my doctoral work by non-perturbatively excluding the existence of a $bb\bar{b}\bar{b}$ bound tetraquark from within QCD (with the data made publicly available), thereby excluding the existence of such a state. In my most recent work, my collaborators and I empirically computed the amount of qubit resources needed to perform a SU(2) gauge theory on a digital quantum computer. Additionally, being surrounded by experimentalists and theoretical physicists (from different fields) has widened how the scope of my work relates to the physics community at large. For example, I am involved in the Fermilab/MILC nucleon physics programme and in a R&D experiment at Fermilab. I also research how quantum information science may aid as a future prospect for a range of physics calculations. More recently I have developed a quantum computing course for school kids aged from 15-18, due to be published as a book by Springer Dec. 2020.

2012 – 2016 **University of Cambridge (UK) – PhD in Applied Mathematics and Theoretical Physics**

My PhD investigated physics involving b-quarks using a first-principles framework called Lattice QCD. One aim of my research programme was to understand strong force phenomena by calculating quantities that are both timely and which have tangible impact. These calculations needed to be both accurate and precise in order to be useful when compared against experimental results and were made possible given the effective and efficient methodologies that I utilised. These methodologies included (but are not limited to) a state-of-the-art HISQ formalism for sea u, d, s and c-quarks, one of the most accurate non-relativistic b-quark formalisms and correctly taking into account multiple aspects of the theoretical calculation. This body of work includes:

- Calculating matching coefficients for one of the most accurate non-relativistic b-quark formalisms
- Computing the most accurate 1S bottomonium hyperfine splitting to date
- Performing the only accurate first-principles theoretical calculation of the $\Upsilon(2S) \to \eta_b(1S)\gamma$ decay

2011 – 2012 **University of Cambridge (UK) – Master of Advanced Study, Mathematics**

2008 – 2011 **National University of Ireland, Maynooth – B. Sc. (First Class Hons.) Theoretical Physics and Pure Mathematics.** Ranked highest.

EDUCATIONAL TEXTBOOKS

First Curriculum Teaching USA High School Students Quantum Computing (Made Freely Available)

2019 *Quantum Computing as a High-School Module*,
C. Hughes et. al., weblink:arxiv:1905.00282[ed-ph]

MEDIA PRESENCE

2020 https://science.osti.gov/-/media/_/pdf/about/pcast/202006/PCAST_June_2020_Report.pdf My quantum computing course is highlighted on page 17 of the USA president's report on advancing STEM.

2020 https://www.livescience.com/quantum-computing-students-online-course.html

2020 https://news.fnal.gov/2020/06/fermilab-scientists-publish-quantum-computing-course-for-high-school-students/

PUBLICATIONS

h-index: 9. 14 peer-reviewed publications within theoretical and computational particle-physics, quantum computing, education, and computational chemistry. Can be found open-source at weblink here.

2020 Y. Lin, A. Meyer, S. Gottlieb, **C. Hughes**, A. Kronfeld, J. Simone & A. Strelchenko, *Computing Nucleon Charges with Highly Improved Staggered Quarks*, arxiv:2010.10455[hep-lat] (Under Review)

2020 *Teaching Quantum Computing to High-School Students*, **C. Hughes** Joshua Isaacson, Anastasia Perry, Ranbel Sun, & Jessica Turner, weblink:arxiv:2004.07206[ed-ph] (Under review)

2019 Y. Lin, A. Meyer, **C. Hughes**, A. Kronfeld, J. Simone & A. Strelchenko, *Nucleon Mass with Highly Improved Staggered Quarks*, arxiv:1911.12256[hep-lat] (Under Review)

2019 E. Eicthen, **C. Hughes**, *Exploring S-Wave Threshold Effects in QCD: A Heavy-Light Approach*, arXiv:1911.02024 [hep-lat], Phys. Let. B 802, 135250

2018 C. T. H. Davies, J. Harrison, **C. Hughes**, R. R. Horgan, G. von Hippel & M. Wingate, *Improving the Kinetic Couplings of NRQCD*, arXiv:1812.11639[hep-lat], Phys. Rev. D 99, 054502

2018 D. Hackett, K. Howe, **C. Hughes**, W. Jay, E. Neil & J. Simone, *Digitizing Gauge Fields: Lattice Monte Carlo Results for Future Quantum Computers*, arXiv:1811.03629[quant-ph], Phys. Rev. A 99, 062341

2017 **C. Hughes**, C. T. H. Davies & C. J. Monahan, *New methods for B meson decay constants and form factors from lattice NRQCD*, arXiv:1711.09981[hep-lat], Phys. Rev. D97, 054509

2017 **C. Hughes**, E. Eichten & C. T. H. Davies, *The Search for Beauty-fully Bound Tetraquarks Using Lattice Non-Relativistic QCD* , arXiv:1710.03236[hep-lat], Phys. Rev. D 97, 054505

2015 **C. Hughes**, R. J. Dowdall, C. T. H. Davies, R. R. Horgan, G. von Hippel & M. Wingate, *Hindered M1 Radiative Decay of* $\Upsilon(2S)$ *from Lattice NRQCD*, arXiv:1508.01694[hep-lat]. Phys. Rev. D. 92, 094501.

2015 R. J. Dowdall, C. T. H. Davies, T. Hammant, R. R. Horgan & **C. Hughes**, *Erratum: Bottomonium hyperfine splittings from lattice NRQCD including radiative and relativistic corrections*, arXiv:1309.5797 [hep-lat]. Phys. Rev. D 92, 039904.

2014 **C. Hughes**, D. Mehta & D. Wales, *An inversion-relaxation approach for sampling stationary points of spin model Hamiltonians*, J. Chem. Phys. 140, 194104.

2014 D. Mehta, **C. Hughes**, M. Kastner & D. Wales, *Potential energy landscape of the two*

-dimensional XY model: Higher-index stationary points, J. Chem. Phys. 140, 224503.

2013 **C. Hughes**, D. Mehta, J. Skullerud, *Enumerating Gribov Copies on the Lattice*, Annals of Physics 331, 188-215.

2013 D. Mehta, **C. Hughes**, M. Schrock, D. Wales, *Potential Energy Landscapes for the 2D XY Model: Minima, Transition States and Pathways*, J. Chem. Phys. 139, 194503.

SELECTED RESOURCES SECURED

2020-Current ALCF Exascale Allocation: Staggered nucleon axial form factor, Fermilab
2019-Current USQCD Type-C allocation: (Co-PI) Machine Learning Highly-Dimensional Probability Density Functions using Renormalised Flows (using TensorFlow)
2018-Current DOE allocation: Track 2-Quantum Information Science for Quantum Field Theory
2018-2019 USQCD Type-A allocation: (Co-PI) Staggered nucleon axial form factor, Fermilab
2018 USQCD Type-C allocation: (Co-PI) Lattice for Quantum Computing, Fermilab
2012 Cambridge Home and European Scholarship for pursuit of PhD. Value: £18,000
2008 All-Ireland Scholarship for Pursuit of Undergraduate Degree. Value: €20,250

INVITED TALKS

Oct 2020 USA National Education Partnership, Closed Session Panelist (Remote)
Invite from White House Office of Science and Technology and NSF
Sep 2020 Theory Review: Exotic Spectroscopy, Beauty Conference 2020 (Remote)
Jun 2020 Workforce Development Panelist, Quantum Economic Development Consortium, USA
May 2019 Lattice BSM, USA
Jan 2019 Argonne, USA
Dec 2018 University of Maryland, USA
Aug 2018 Quark Confinement, Maynooth, Ireland
Jan 2018 Fermilab, USA
Dec 2017 Exotic Hadron Spectroscopy, Edinburgh, Scotland
Dec 2017 Wayne State University, Detroit, USA
Nov 2017 Quarkonium Workshop, Beijing, China
Apr 2017 University of Iowa, Iowa, USA
Feb 2017 Argonne, USA
Jan 2017 Fermilab, USA
Nov 2014 Quarkonium Workshop, CERN, Switzerland
Oct 2014 Department of Physics and Astronomy, University of Glasgow, UK

SELECTED PROFESSIONAL SERVICE

2020 Lobbyist to Congress on behalf of Fermilab UEC
2020 Reviewer for IEEE Transactions on Education
2020 Reviewer for JHEP
2018 R&D experiment measuring efficiency of photomultiplier tubes for DUNE, Fermilab
2017 Fixing dsg-hardware on Fermilab Supercomputer
2016 – 2018 Theoretical Physics Seminar Organiser, Fermilab
2014 – 2015 Graduate Seminar Series Organiser, DAMTP, University of Cambridge
2013 – 2014 Graduate Director, Post-Masters Consultancy Programme, Centre for Mathematical Sciences, Cambridge
2008 – 2011 President, Undergraduate Student Mathematics Society

TEACHING EXPERIENCE

2018	Lead Supervisor of two highschool teachers; developed a Quantum Computing course
2013 – 2015	Supervisor for Cambridge Masters course: The Standard Model
2014 – 2015	Supervisor for Cambridge Masters course: Symmetries, Fields and Particles
2010 – 2011	Tutor During Undergraduate Degree
2008 – 2011	Tutor to Second Level Students

SELECTED OUTREACH

2020	Night of Ideas at Chicago Field Museum, USA
2019	Chicago Public Schools Science Fair Judge, USA
2017 - Current	DØ and Tevatron Public Tour Guide, Fermilab, USA
2018	Saturday Morning Physics, Fermilab, USA
2017	Outreach During Fermilab Open Day, Fermilab, USA
2015	Outreach During Science Week, Centre for Mathematical Sciences, Cambridge

FURTHER EDUCATION

2019	Machine Learning, MOOC course through coursera
2018	Fundamentals of the Blockchain, Bangkok, Thailand
2014	Programming with GPU's, Cambridge, UK
2013	Autumn Academy on High Performance Computing, Cambridge, UK
2014	Effective Communication Techniques: Verbal, University of Cambridge Training Service
2013	Effective Communication Techniques: Written, University of Cambridge Training Service

SELECTED PRESENTATIONS

Jun 2019	QIS/HEP Workshop @ Aspen, Colorado, USA
Jul 2018	University of Boulder, Colorado, USA
May 2018	Multi-Scale Problems Using Effective Field Theories, INT, Seattle, USA
Jul 2017	International Lattice Conference, Granada, Spain
Jul 2016	International Lattice Conference, Southampton, UK
Jul 2014	International Lattice Conference, Columbia University, USA
Jun 2014	DAMTP, University of Cambridge, UK
Aug 2013	Poster presented at DiRAC Day, University of Leicester, UK
Jun 2013	Poster presented at the International Lattice Conference, University of Mainz, Germany

COMPUTATIONAL SKILLS

End-To-End Statistical Analysis of Noisy Data using Bayesian Statistics
High-Performance/Distributed Computing, with SQL Databases
Innovating Novel Solutions/Ideas for Stakeholder Needs
End-to-end Deployment of Optimised TensorFlow Models: Full pipeline of data generation to machine learning prediction
Extensive Use of Python, Tensorflow, Modern Fortran, C++, Bash scripting
Supercomputers, MPI, OPEN MP, GPU Programming, html

ACADEMIC AWARDS

2011	De Brun prize (highest mark in undergraduate mathematics)
2011	Hamilton prize (highest mark in undergraduate mathematical physics)
2010	Hamilton prize (presented by Royal Irish Academy). Value: €1,000
Other	McMahon prize (2010), Stokes prize (2009), Delort prize (2009), Entrance scholar (2008) Value: €1,000