Quantum computing research in Durham QLM

Durham Institute for Data Science Launch: Numbers theme

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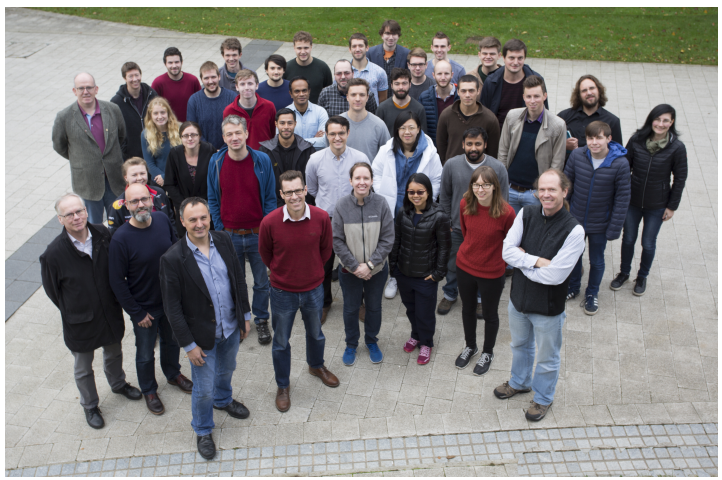
The Quantum Light and Matter (QLM) Section in Physics

- Section of physics department comprised mostly of experimental atomic and molecular physicists
- Recently re-branded from Atmol (atomic and molecular physics) to reflect changing and expanding interests
- Part of the Durham-Newcastle Joint Quantum Centre
- ∼11 PIs, ∼15 PDRAs, ∼27 postgrads



web: https://www.dur.ac.uk/qlm/, https://www.jqc.org.uk/
twitter: @DurhamQlm, @jqcDurNew, @QSUMproject

Our Group

- Two PIs

EPSRC
Pioneering research and skills

  - Viv Kendon → Reader coming to end of EPSRC established career fellowship on hybrid quantum classical computing, significant contributions on subject of quantum walks (among other things)
  - Nicholas Chancellor (me) → EPSRC UKRI innovation fellow, three year project to look at hybrid algorithms and early use cases
- One postdoc
  - Jie Chen → Non-quantum background, recruited to help develop use cases
- Four graduate students: Jemma Bennett, Laurentiu Nita, Parth Patel, and Adam Callison (Imperial)

Quantum computing

Big idea: harness the fundamental physics of discrete systems (quantum mechanics) to solve important problems

- We know it works in theory: quantum search of unstructured database with N entries in a time proportional to $\sqrt{N}$
- This is not possible without using quantum mechanics (only option without QM is random guess or exhaustive search)

(011) (010)

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- ... but how do we use real, imperfect, quantum machines to solve problems people care about

Context related to recent 'quantum supremacy*' result

Recent result posted by NASA: quantum supremacy in Google machine

What does this mean in simple language:

- Google machine appears to be *very* hard to simulate classically: evidence toward useful QC
- QS is not a demonstration of a useful application though

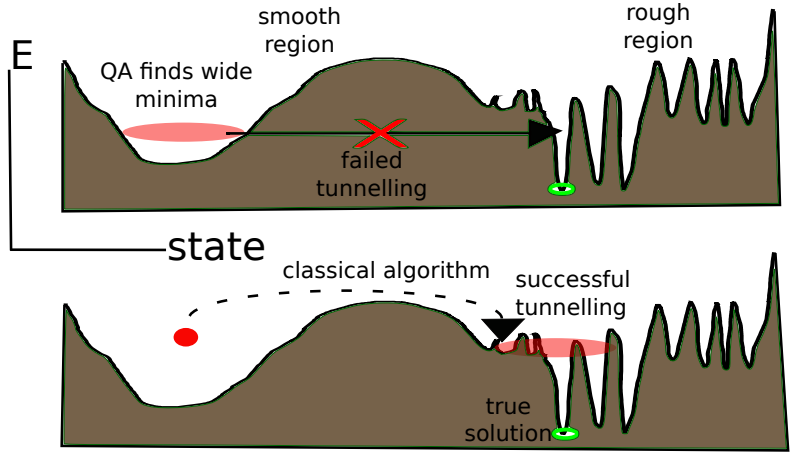
Where does our work fit with this...

- Finding useful applications is next logical step
- But we focus on a different kind of machine than the Google machine $\rightarrow$ partial explanation on next slide

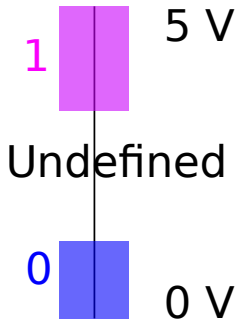
*Myself and many others in QC object to this use of the term 'supremacy' for a number of reasons, but we are kind of stuck with the term, see arχiv:1705.06768 for discussion

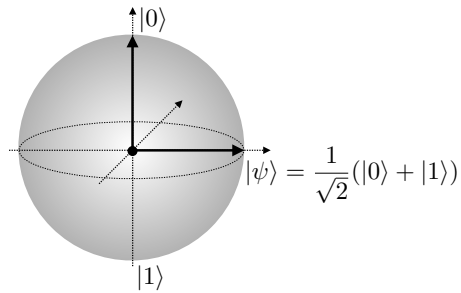
What we do...

- Study out how to use early machines in the best way possible
  $\rightarrow$ hybrid quantum/classical algorithms



- Focus on continuous time, use physical system directly to compute rather than constructing discrete 'gate' operations:
  - Why? Quantum systems are fundamentally continuous, rotations in state space rather than discrete flips





- Find what the best early use cases are for quantum computing

Why have I come here today?

Getting the most out of early quantum machines requires input from 'non-quantum' people in at least two* important ways:

1. Need to find what the best use cases are for early machines, requires domain experts who will not be experts in QC
2. Early algorithms should be hybrid quantum/classical, adding quantum to current classical state of the art, rather than "starting from zero"

This means talking to a lot of people in other disciplines (like you) to develop use cases

*probably many more actually

What makes a good early use case?

Early quantum computers may be powerful but relatively...

expensive

Needs to be a high value problem

Needs to be hard classically, otherwise why bother

small

Low processor throughput, quantum processor runs on 'small' (sub)problem (overall problem could still be high throughput)

NP-hard optimization problems and simulations of electrons are two examples which fit these criteria, there are others as well

Image: public domain taken from wikimedia commons

Take home message

If you have an interesting problem and want to explore if QC can help, come talk to us

- My email: nicholas.chancellor@durham.ac.uk
- Viv's email: viv.kendon@durham.ac.uk
- Jie's email: jie.chen@durham.ac.uk
- ARC hosing QCsig quantum computing special interest group, contact arc@durham.ac.uk to be added to the mailing list

If you just want to follow what we are doing:

- My webpage: http://nicholas-chancellor.me/
- Viv's webpage: http://kendon.info/viv
- My twitter: @NChancellorPhys