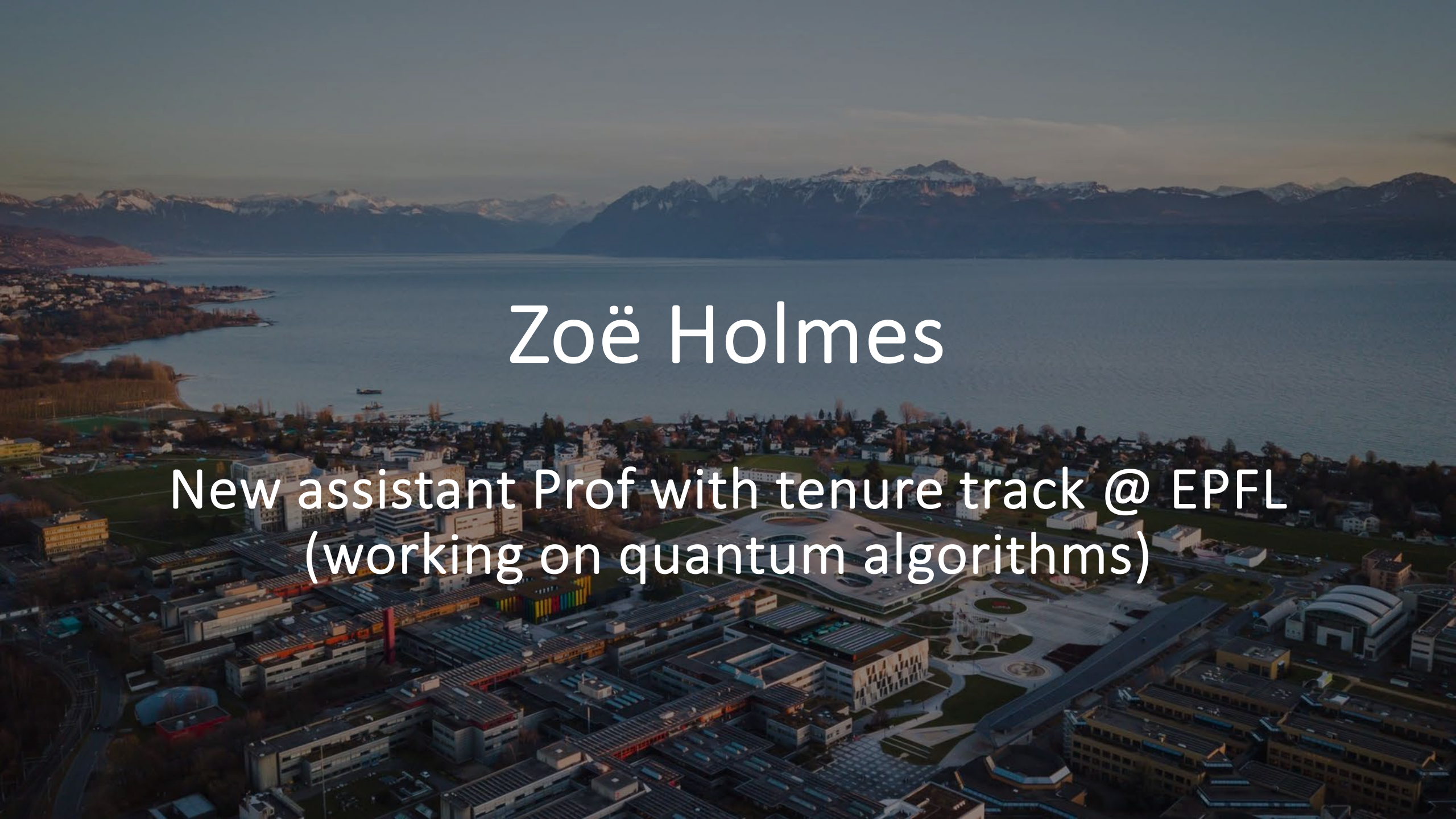

Zoë Holmes

New assistant Prof with tenure track @ EPFL
(working on quantum algorithms)

How I somehow ended up in Physics (Part 1: School)

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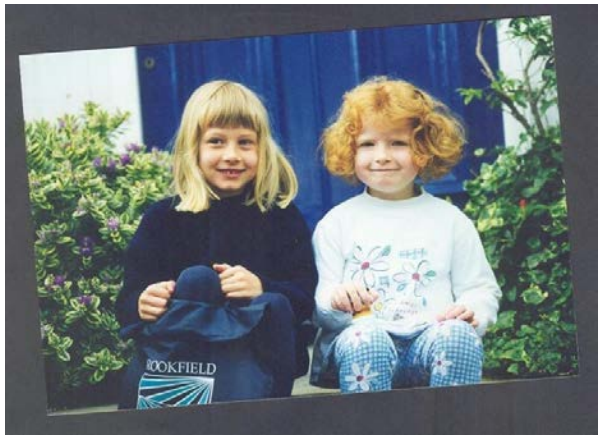

Nerdy precocious child

Could do maths and thought science was ok but didn't love it

Quite liked debating/philosophy/arguments/puzzles

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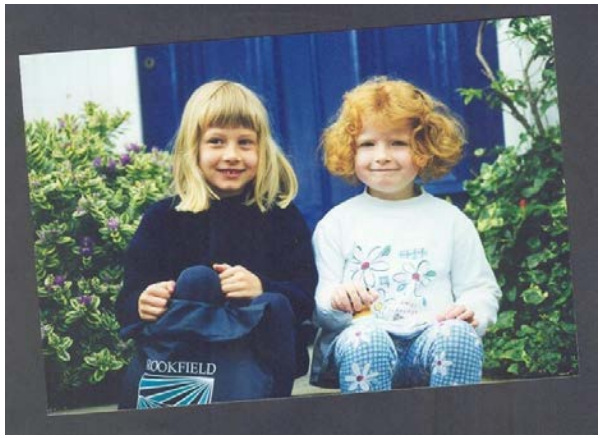

Always liked a good challenge….

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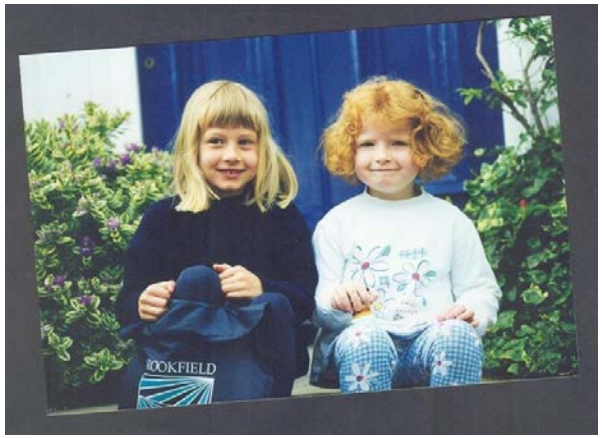

So decided to do art at GCSE

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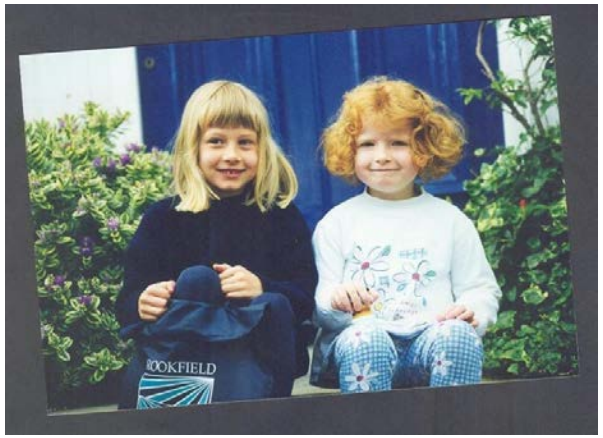

Couldn't draw at all when I started it… but then spent more time on my art GCSE than the rest of my subjects put together…

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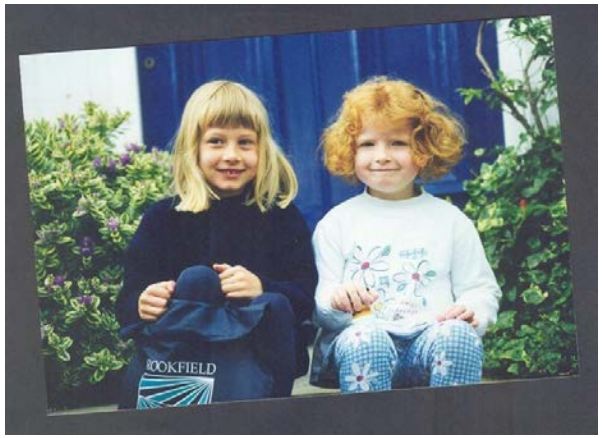

Couldn't draw at all when I started it… but then spent more time on my art GCSE than the rest of my subjects put together… and then some how got one of the top 10 marks in the UK for it

How I somehow ended up in Physics (Part 1: School)

Science wasn’t cool at my (girls) school

and I didn’t initially care much for it...

How I somehow ended up in Physics (Part 1: School)

But then had a love-hate relationship with my physics teacher aged 16

His lessons were objectively pretty boring

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And I realised I really enjoyed them….

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BUT I was still annoying in his easy classes: “Zoe should be leading the class… but isn’t….” (Physics report aged 15)

I paid very little attention 90% of the time (resulting in my own bespoke punishments)

And the remaining 10% quizzed him continually about whether or not the universe was deterministic

How I somehow ended up in Physics (Part 1: School)

But then had a love-hate relationship with my physics teacher aged 16

His lessons were objectively pretty boring

But he set harder exams

And I realised I really enjoyed them….

But I was still annoying in his easy classes : “Zoe should be leading the class… but isn’t….” (Physics report aged 15)

BUT I decided not to give up Physics aged 16 and try it for a bit longer…. (Thanks Mr Wingfield!)

How I somehow ended up in Physics (Part 1: School)

But then had a love-hate relationship with my physics teacher aged 16

His lessons were objectively pretty boring

But he set harder exams

And I realised I really enjoyed them….

But I was still annoying in his easy classes : “Zoe should be leading the class… but isn’t….” (Physics report aged 15)

And continued to enjoy it up to the age of 18….

How I somehow ended up in Physics (Part 2: Oxford)

- Studied Physics and Philosophy (thinking I'd probably soon give up the Physics part)

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I thought right I'll show him…. and then came top in the year!

(Spent the prize money on a very fancy meal…)

How I somehow ended up in Physics (Part 2: Oxford)

- Studied Physics and Philosophy (thinking I'd probably soon give up the Physics part)
- Really loved philosophy.
- But also really quite liked physics.

Physics marks were really not great in early years

Again fear of failure was a good motivation

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Again fear of failure was a good motivation

I managed to completely fail my thermodynamics mock

This kicked me into gear and in the real exam got my highest mark to that point

Things improved after that… (spent prize money on more fancy meals)

How I somehow ended up in Physics (Part 2: Oxford)

- Studied Physics and Philosophy (thinking I'd probably soon give up the Physics part)
- Really loved philosophy.
- But also really quite liked physics.
- When I started to study quantum it just clicked

  – it came more naturally, I found it really exciting

How I somehow ended up in Physics (Part 2: Oxford)

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- When I started to study quantum it just clicked
- Did a summer internship at the University of Potsdam (on the random walks of monkeys)
- Did a master's project on quantum biology with Vlatko Vedral

(both were fun but not especially successful)

How I somehow ended up in Physics (Part 2: Oxford)

- Studied Physics and Philosophy (thinking I'd probably soon give up the Physics part)
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- When I started to study quantum it just clicked
- Did a summer internship at the University of Potsdam (on the random walks of monkeys)
- Did a master's project on quantum biology with Vlatko Vedral
- Didn't initially consider applying for a PhD (was considering the civil service) until my then boyfriend suggested it…

Takeaways so far…

I really don’t think ‘I was born to be a physicist’ – I could have been happy doing a bunch of other things

For a long time didn’t occur to me that studying/a career in physics could be for me (I suspect for gendered reasons)

Takeaways so far…

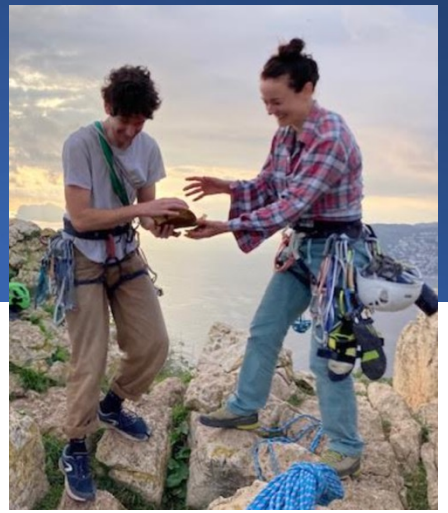
I really don’t think ‘I was born to be a physicist’ – I could have been happy doing a bunch of other things

For a long time didn’t occur to me that studying/a career in physics could be for me (I suspect for gendered reasons)

Things that got me to the PhD:

- A love of getting my teeth stuck into a good challenge / problem / argument
- Thinking quantum mechanics was really pretty cool
- Stubborness
- The odd supportive mentor
- The odd unsupportive senior figure (there’s nothing I enjoy more than proving someone wrong)

PhD: Imperial College London



- Part of the ”Controlled Quantum Dynamics – Centre of Doctoral Training”
- Gave me a nice network of colleagues who become good friends
- As well as a wider academic network that I still enjoy…
- Really enjoyed the collaborative aspect of the MRes year

Imperial College London

Guess which is the Physics building?

PhD: Physical Realisations of Quantum Thermodynamics

Coherent fluctuation relations: from the abstract to the concrete

Zoë Holmes[1], Sebastian Weidt[2], David Jennings[1,3,4], Janet Anders[5], and Florian Mintert.[1]

[1]Controlled Quantum Dynamics Theory Group, Imperial College London, London, SW7 2BW, United Kingdom.
[2]Department of Physics and Astronomy, University of Sussex, Brighton BN1 9QH, United Kingdom.
[3]Department of Physics, University of Oxford, Oxford, OX1 3PU, United Kingdom.
[4]School of Physics and Astronomy, University of Leeds, Leeds, LS2 9JT, United Kingdom.
[5]CEMPS, Physics and Astronomy, University of Exeter, Exeter, EX4 4QL, United Kingdom.

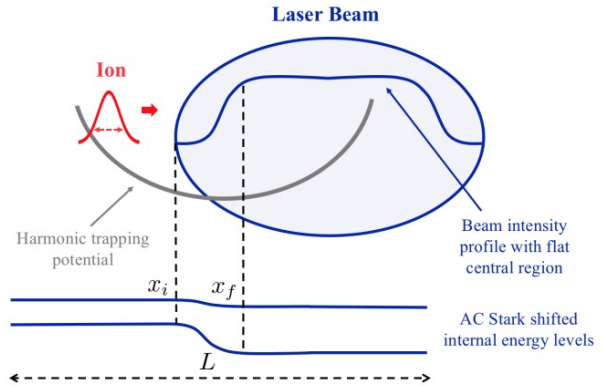


Figure 6: Sketch of trapped ion proposed implementation. The ion (red wavepacket) is at the start of the evolution stage of the forwards protocol. It is displaced in an elongated trap (grey line) that drives its evolution. An off-resonance laser beam propagates perpendicularly across one side of the trap (blue oval). The laser has an intensity profile that is sloped on the edges and flat through the center (blue line in oval). The trapped ion experiences a position dependent AC Stark shift (pair of blue lines) as it travels autonomously through the laser beam. The red dashed line indicates the spread of the ion and the black dashed line the length of the trap. The preparation and measurement stages are sketched in Fig. 7.

- An absolute slog to get out.
- Took me over 2 years!
- Working largely alone
- With three (great!) supervisors arguing like divorcing parents

$$\frac{\mathcal{P}\left(\alpha_f|\alpha_i\exp(-\chi),\gamma_i\right)}{\mathcal{P}\left(\alpha_i^*|\alpha_f^*\exp(-\chi),\gamma_f\right)}=\exp\left(-\frac{\Delta F}{k_BT}\right)\exp\left(\frac{W_q}{\hbar\omega_T}\right)$$

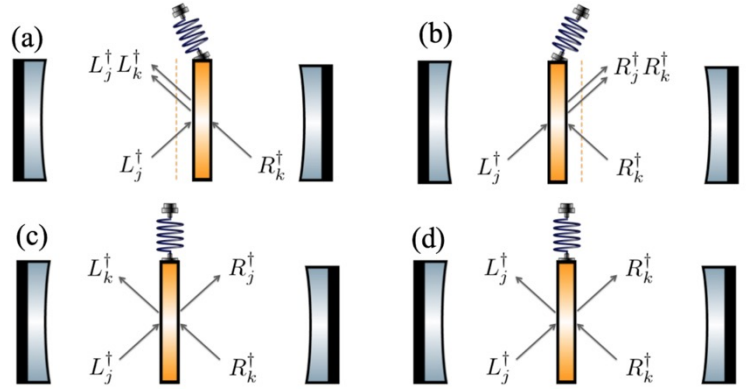
PhD: Physical Realisations of Quantum Thermodynamics

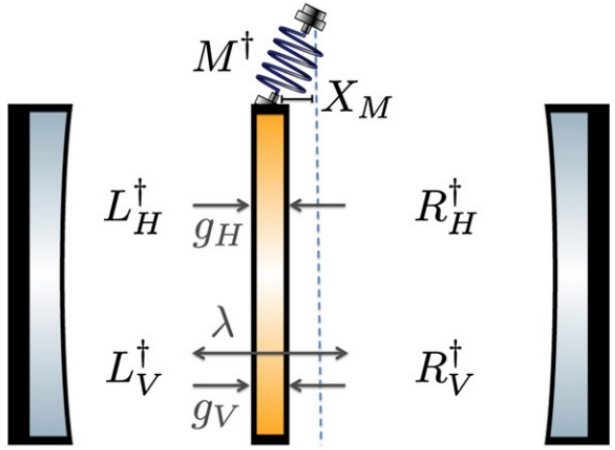
Things did improve after that

Enhanced Energy Transfer to an Optomechanical Piston from Indistinguishable Photons

Zoë Holmes, Janet Anders, and Florian Mintert
Phys. Rev. Lett. **124**, 210601 – Published 27 May 2020

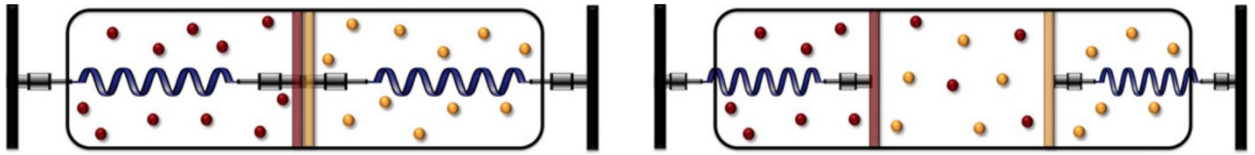
(editor's suggestion!)





Gibbs mixing of partially distinguishable photons with a polarising beamsplitter membrane

Zoë Holmes[5,1,2,3], Florian Mintert[1] and Janet Anders[2,4]



(a) Initial setup.

(b) Drawing work from mixing.

Takeaways?

PhDs can take a while to get going…

Picking the right supervisor is super important! (More important than the institution)

”Many of you will marry multiple times in your life… but you’ll only ever have one PhD supervisor… so this is the most important decision you’ll ever make”

(Prof. Terry Rudolph)

(I don’t quite agree but it is very important)

A bad initial project doesn’t mean you can’t do research

If you have multiple conflicting supervisors try and take control and lead the research yourself?

LANL Quantum Computing Summer School

Los Alamos
NATIONAL LABORATORY

10 Week Internship Program

I got to experience a completely different way of doing research…

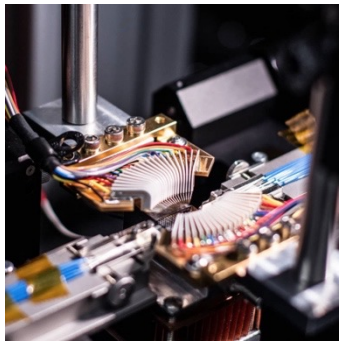
- Fast paced
- Collaborative
- Exciting

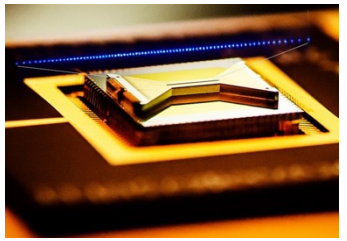
Near term quantum computing

Current/Near-term digital quantum computers are:

- Noisy (prone to errors)
- Not very big (too small for error correction/complex algorithms)

This limits their utility/means we need to be more imaginative





Making near-term quantum computers useful

- Trick to using a noisy quantum computer?

  One approach - use it as little as possible

- Key component of the algorithm will be run on the quantum computer…. but complement this with classical computing.

Hybrid Variational Quantum Computing

training data

Quantum Computation

Optimization Loop

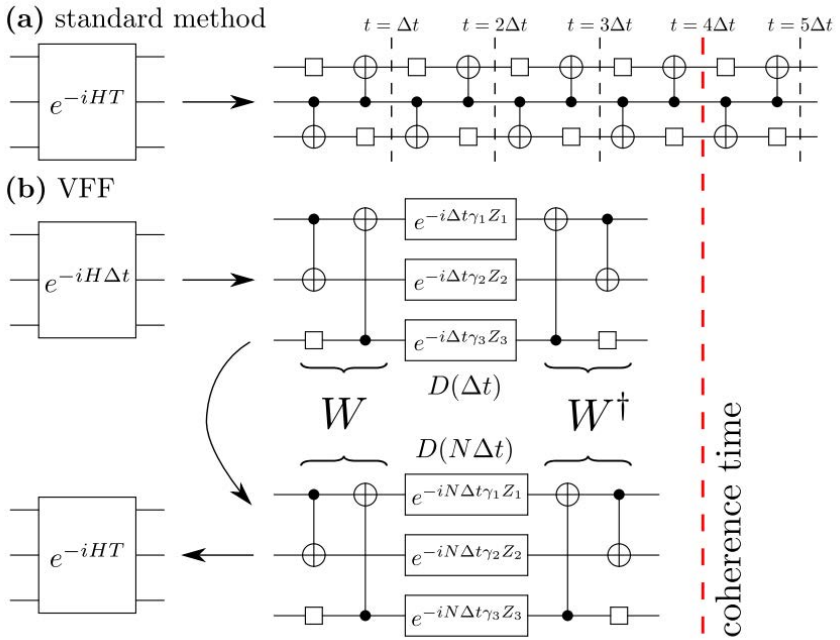
Classical Computation

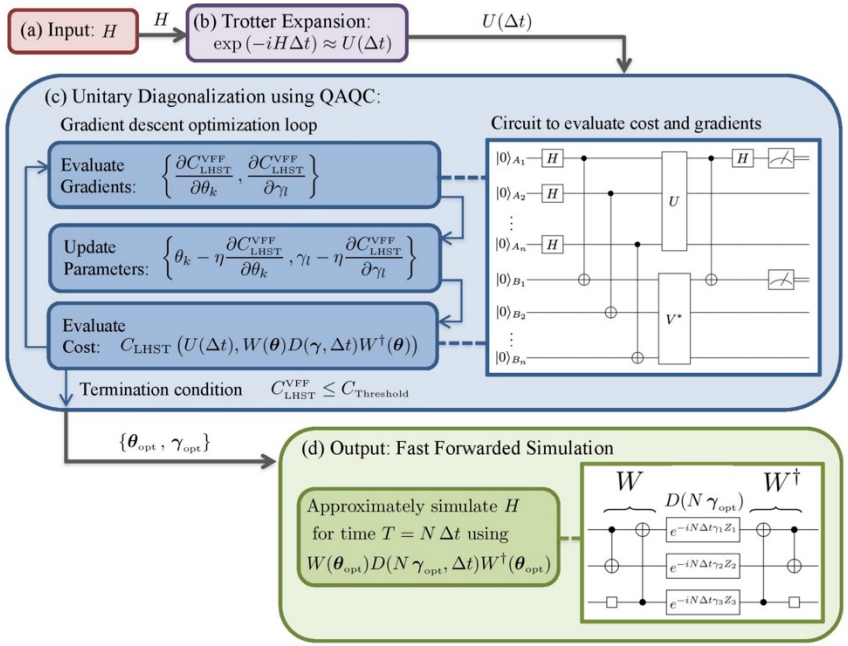
"Any method that optimizes a Quantum Neural Network (i.e. a parameterized quantum circuit) by minimizing a quantum cost function (potentially using training data)"

LANL Quantum Computing Summer School

Variational Fast Forwarding for Quantum Simulation Beyond the Coherence Time

Cristina Cîrstoiu,[1,2,*] Zoë Holmes,[1,3,4,*] Joseph Iosue,[1,5]
Lukasz Cincio,[1] Patrick J. Coles,[1,†] and Andrew Sornborger[3,‡]





Back to Imperial, then Exeter to wrap things up…

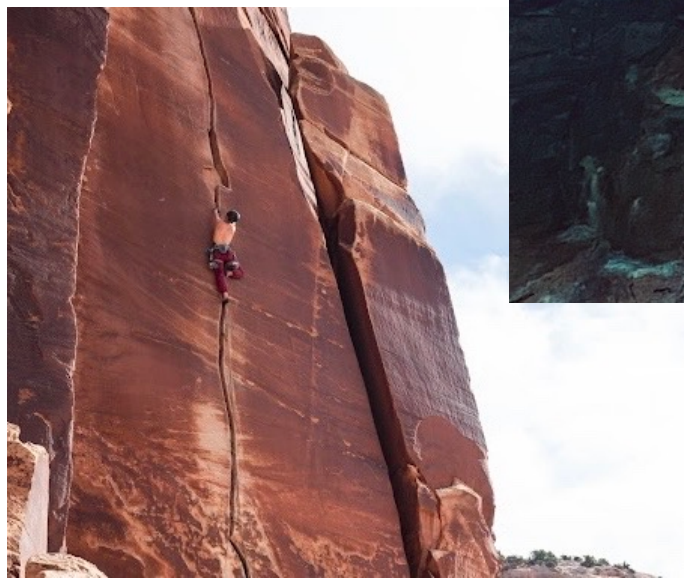
Los Alamos NATIONAL LABORATORY

Imperial College London

LANL: Post Doc (initially remote- thanks Covid)

Sheffield + the peak district

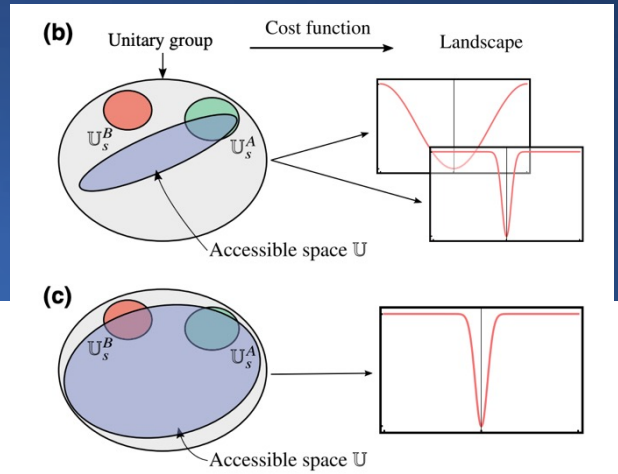
LANL: Post Doc (then in Los Alamos/Santa Fe)



LANL: The Research

- Trying to figure out how to run useful algorithms on near term quantum computers
- Quantum machine learning
- Quantum simulation
- Both analytical bounds, numerical studies and implementations on quantum computers over the cloud

Trainability in Quantum Machine Learning



Barren Plateaus Preclude Learning Scramblers

Zoë Holmes, Andrew Arrasmith, Bin Yan, Patrick J. Coles, Andreas Albrecht, and Andrew T. Sornborger
Phys. Rev. Lett. **126**, 190501 – Published 12 May 2021

Connecting Ansatz Expressibility to Gradient Magnitudes and Barren Plateaus

Zoë Holmes, Kunal Sharma, M. Cerezo, and Patrick J. Coles
PRX Quantum **3**, 010313 – Published 24 January 2022

Exponential concentration and untrainability in quantum kernel methods

Supanut Thanasilp,[1] Samson Wang,[2] M. Cerezo,[3,4] and Zoë Holmes[3,5]

Equivalence of quantum barren plateaus to cost concentration and narrow gorges

Andrew Arrasmith[1], Zoë Holmes[2,*], M Cerezo[1,3] and Patrick J Coles[1]

Learning / simulating quantum processes

Find $V(\boldsymbol{\alpha}_{\mathbf{opt}})$ such that $V(\boldsymbol{\alpha}_{\mathbf{opt}}) = U$

Parameterised unitary — Optimum parameters — Target

Out-of-distribution generalization for learning quantum dynamics

Matthias C. Caro,[1,2,3,*] Hsin-Yuan Huang,[4,5,*] Nicholas Ezzell,[6,7] Joe Gibbs,[8] Andrew T. Sornborger,[6] Lukasz Cincio,[9] Patrick J. Coles,[9] and Zoë Holmes[6]

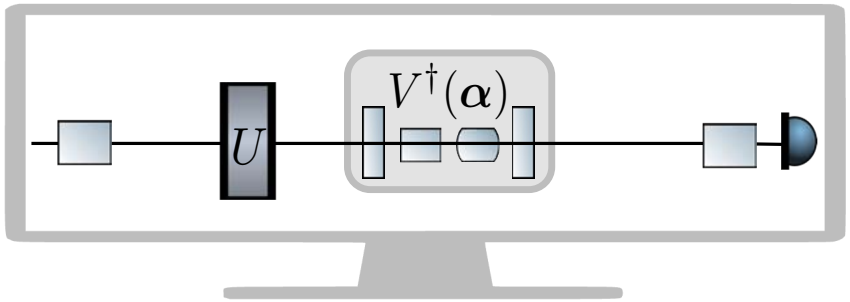
Universal Compiling and (No-)Free-Lunch Theorems for Continuous-Variable Quantum Learning

Tyler Volkoff, Zoë Holmes, and Andrew Sornborger

PRX Quantum **2**, 040327 – Published 8 November 2021

Dynamical simulation via quantum machine learning with provable generalization

Joe Gibbs,[1,*] Zoë Holmes,[2,*] Matthias C. Caro,[3,4,5] Nicholas Ezzell,[2,6] Hsin-Yuan Huang,[7,8] Lukasz Cincio,[9] Andrew T. Sornborger,[2] and Patrick J. Coles[9]



Long-time simulations for fixed input states on quantum hardware

Joe Gibbs ✉, Kaitlin Gili, Zoë Holmes ✉, Benjamin Commeau, Andrew Arrasmith, Lukasz Cincio, Patrick J. Coles & Andrew Sornborger

npj Quantum Information **8**, Article number: 135 (2022) | Cite this article

Takeaways from that chunk of my career?

I found myself in the right place at the right time working on a hot topic with low hanging fruit….

The LANL team in that period has subsequently been described to me (by a bunch of externals) as a ‘dream team’ and people have asked what was in the water…

We were just having a lot of fun and working really well collaboratively

I was very lucky to be a part of it

I was also tactical to try hard to make myself part of it

And it suited *my* style of working… intense + argumentive + fast paced
(not everyone liked it… different people have different working styles!)

Applying to EPFL

I was approached and invited to apply

I initially ignored the email assuming I was too junior and I didn't stand a chance

It was only when I mentioned it to a couple of (male) friends/colleagues – common theme here – and they said "of course you should try!" that I considered it

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I then put a lot of time into writing a decent application

And a lot of time into preparing my talk / lecture (and ran it by kind volunteers)

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I then put a lot of time into writing a decent application

And a lot of time into preparing my talk / lecture

And much to my surprise got offered the position

I celebrated with fish & chips and a mini bottle of supermarket prosecco on the pavement before driving with a friend up to the lake district to bivvy/climb for the weekend

EPFL: The Group

The Laboratory of Quantum Information and Computation:
2 PhD students in Switzerland (Manuel and Sacha)
1 PhD student in the UK (Joe)
1 Post doc (Supanut)

And have 2 new students and post docs starting this year

And a chunk of master's students/interns/visitors

EPFL: The Research

- Trying to figure out how to run useful algorithms on near term quantum computers
- Quantum machine learning (increasingly interested in its mathematical foundations)
- Quantum simulation (increasingly able to actually do interesting simulations on real hardware!)
- Both analytical bounds, numerical studies and implementations on quantum computers over the cloud

What I love about my job

- Super cheesy but genuinely the best part of my job is the people I work with.

First and foremost my new group :)

But also my old colleagues at LANL that I'm still very close to

And my broader network of collaborators (the academic community in Switzerland has been very welcoming!)

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And my broader network of collaborators (the academic community in Switzerland has been very welcoming!)

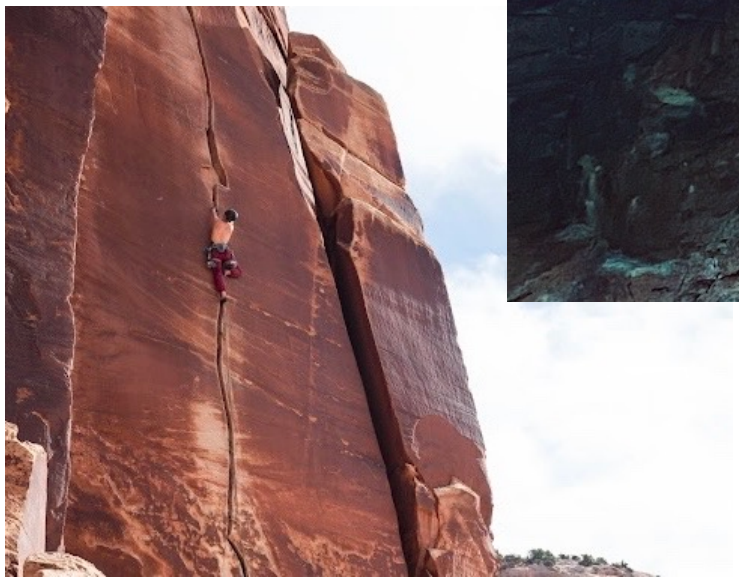
- I really really just enjoy talking and doing (quantum) physics

I like physics to be discursive, collaborative, argumentative, playful, sometimes downright silly….

Things that are important to me other than physics

CLIMBING

(Almost as dedicated to climbing as I am physics…)



Things that are important to me other than physics

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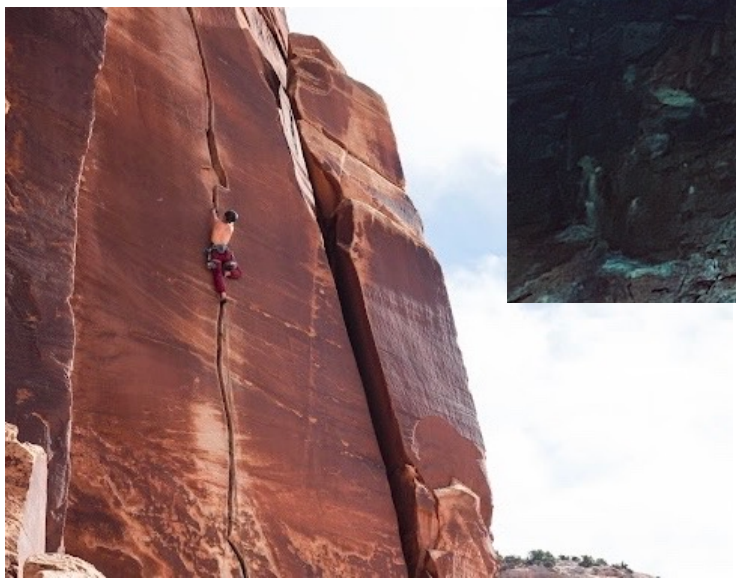
(Almost as dedicated to climbing as I am physics…)

I asked myself when I arrived in Switzerland:

What will I finish first:

My 8a project at St Loup
or
My first QML project with my new group?



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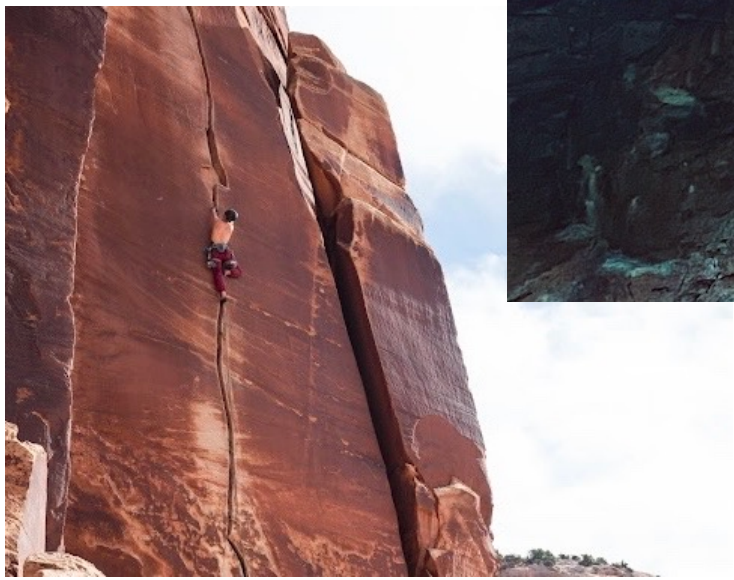

I also quite like friends, family, food, dancing, cats…

Challenges with my job

- Work life balance

I really like my work but I also like other things and need lots of sleep (9hrs!) balancing it all is a challenge….

I take a fingerboard to conferences…

Challenges with my job

- Work life balance

I really like my work but I also like other things and need lots of sleep (9hrs!)
balancing it all is a challenge….

- Feelings of inadequacy

- Stresses when projects are stuck, we've not put out any papers in a while, etc etc.

Challenges with my job

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I really like my work but I also like other things and need lots of sleep (9hrs!) balancing it all is a challenge….

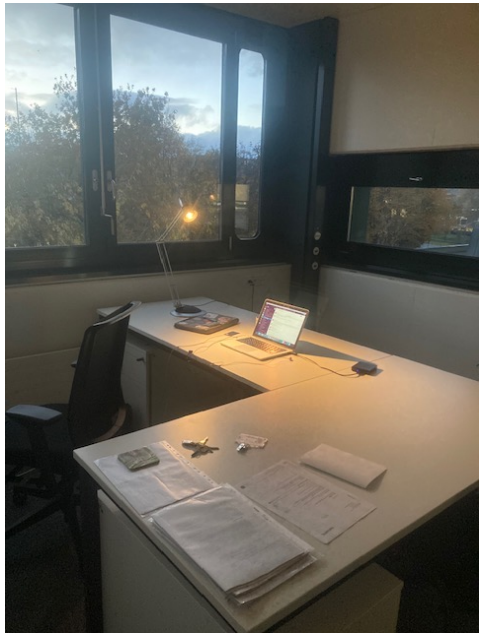
- Feelings of inadequacy

- Stresses when projects are stuck, we've not put out any papers in a while, etc etc.

The latter two I am geniunely better at these days – I accept this as part of a career in academia and try to not let it bother me

Ramblings on the similarities of physics and climbing

- Both climbing and physics can be incredibly frustrating at times (you have been bashing your head at a project for ages… you keep failing/falling… you're cold/wet/exhausted…)



Ramblings on the similarities of physics and climbing

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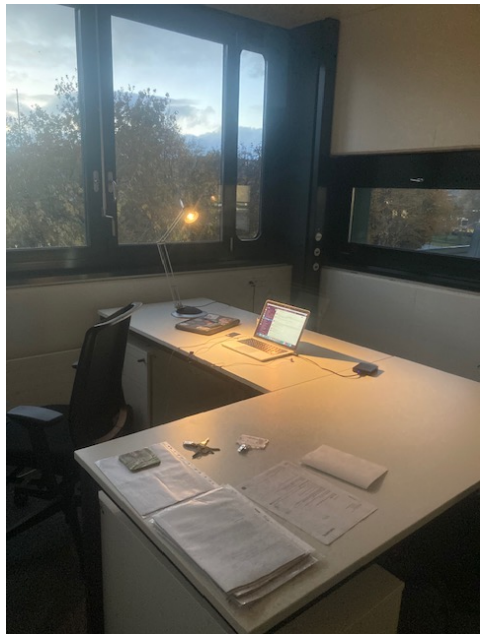
- But then you have brilliant moments where it all falls into place
- And build great relationships from struggling together
- And it gives a sense fulfillment that a more comfortable easier life wouldn't give….



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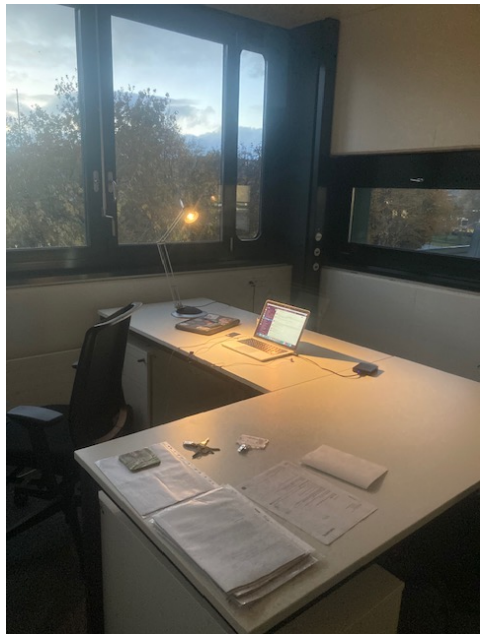

For me they are both more than 'just a job' or 'just a hobby'… and I wouldn't have it any other way

Final takeaways?

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- The ability of chug through a calculation/code something up are relatively mechanistic in comparison and can be honed through practise (a bit like drawing…)

Quantum Computing Summer School

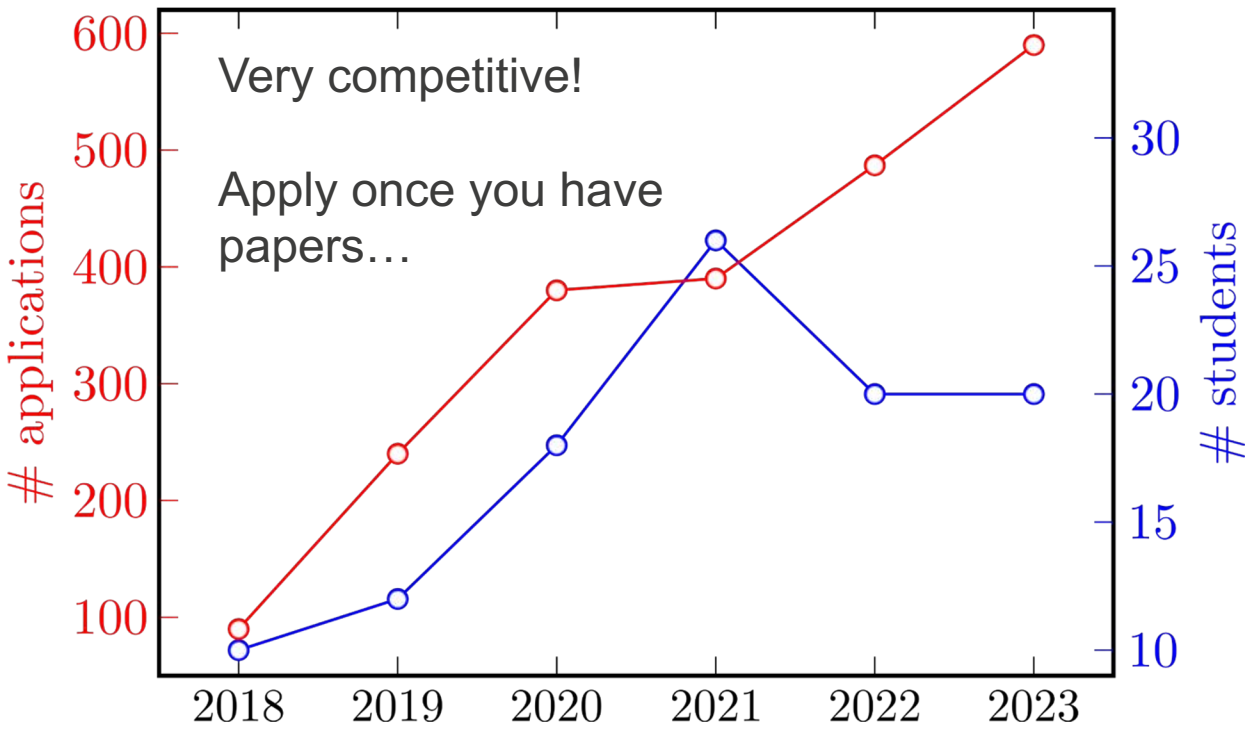
- **co-leads**
  Lukasz Cincio, T-4
  Marco Cerezo, CCS-3
  Yigit Subasi, CCS-3

- **mentors**
  A, CCS, C-IIAC, EES,
  T divs as well as UNM

- **students**
  UC Berkeley, MIT, UC Santa Barbara, Cambridge, Oxford, Waterloo, Imperial

- **format**
  at least 10 weeks, one-on-one mentor research projects

- **guest lecturers**
  Scott Aaronson (U. Texas), Andrew Childs (U. Maryland), Jay Gambetta (IBM), Mikhail Lukin (Harvard), Chris Monroe (Duke), Peter Shor (MIT)



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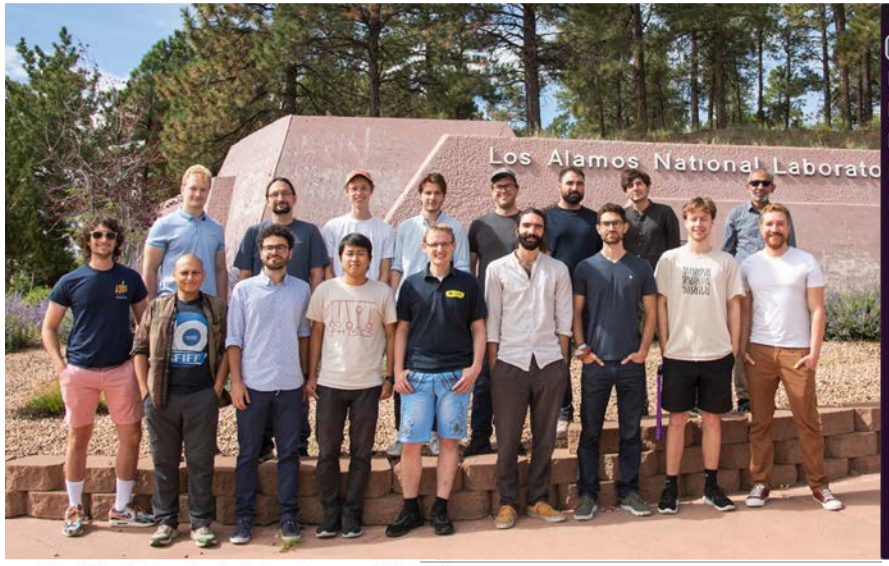

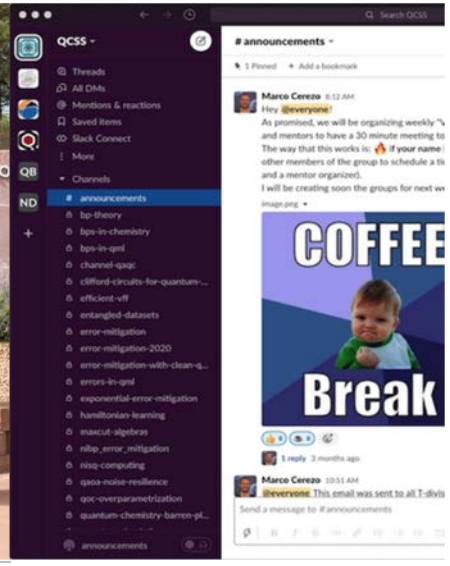

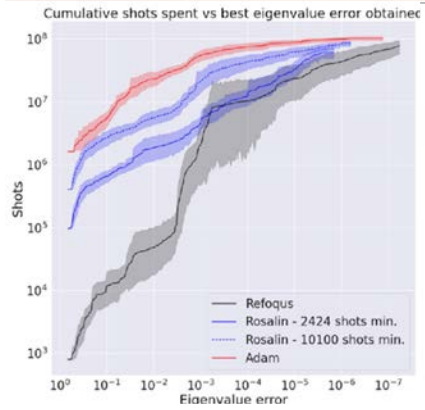

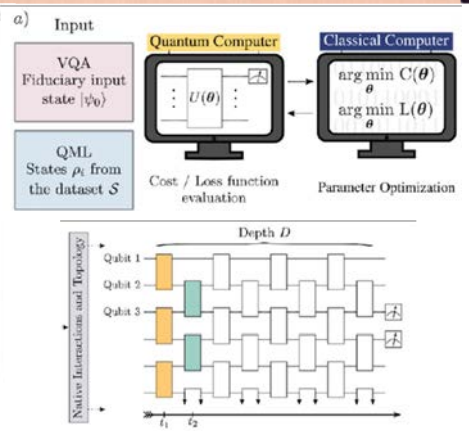

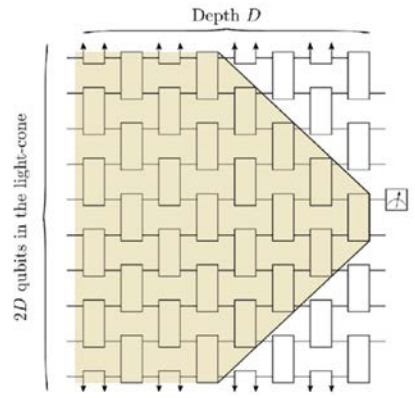

- **published over 40 papers**:
  Nature Comm., Phys. Rev. Lett., Phys. Rev. X, …
- **conferences**
  QIP, Squint, QTML, APS, …
- **media**
  vice.com, Albuquerque journal, HPCwire, phys.org, LANL STE highlights

  - *"Inside the Government's Quantum Computing Summer School"* *(vice.com)*
  - *"Preparing the Quantum Workforce of the future"* *(Albuquerque journal)*