

INTRO TO QUANTUM COMPUTING

Week 24 Lab

# NEAR-TERM QUANTUM ALGORITHMS

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# PROGRAM FOR TODAY

- Announcements
- Canvas attendance quiz
- Pre-lab zoom feedback
- Lab content
- Post-lab zoom feedback

# ANNOUNCEMENTS

- The last course activity is a panel discussion on Sunday May 9 at 2 p.m. EDT
- We **highly encourage** you to attend the live panel! It will feature several experts in the field of quantum computing, including Scott Aaronson, Clarice Aiello, Will Oliver, and Spiros Michalakis
- This is your chance to ask all your questions!

# ANNOUNCEMENTS

- **Schrodinger's Chat** will stream on twitch over the summer.
- First stream on **Saturday, May 22<sup>nd</sup> at 10 a.m. EDT**
- Follow us on [twitch.tv/qubitbyqubit](https://twitch.tv/qubitbyqubit) ←

# CANVAS ATTENDANCE QUIZ

- Please log into Canvas and answer your lab section's quiz

**Lab Number: 1 | Quiz Password: 4869**

- **Give your TA some feedback!** Indicate your level of agreement with these statements:
  - My TA helped make the course a great experience
  - My TA helped me feel like I belong in the field of quantum computing
  - I see my TA as a STEM role model
- **This quiz is not graded but counts for your lab attendance!**

*Student@qubitbyqubit*

# PRE-LAB ZOOM FEEDBACK

On a scale of 1 to 5, how would you rate your understanding of this week's content?

- 1 – Did not understand anything
- 2 – Understood some parts
- 3 – Understood most of the content
- 4 – Understood all of the content
- 5 – The content was easy for me/I already knew all of the content

**In lecture this week, we discussed near-term quantum algorithms with a focus on QAOA**

# LEARNING OBJECTIVES FOR LAB 24

- Understanding near-term quantum algorithms }
  - Optimization problems
  - QAOA ←
  - Case study – Portfolio optimization ←
- Learning how to continue growing beyond this course }
  - Making sense of code
  - Self-teaching and bootstrapping

# CODING IN THE REAL WORLD

- When trying to implement your own code, you'll often find tutorials, documentation, someone else's implementation, etc.
- These implementations are usually messy/don't do exactly what you want
- How should you start?
- Today, we'll try to make sense of a pre-written implementation of QAOA





# STATUS OF QUANTUM COMPUTERS

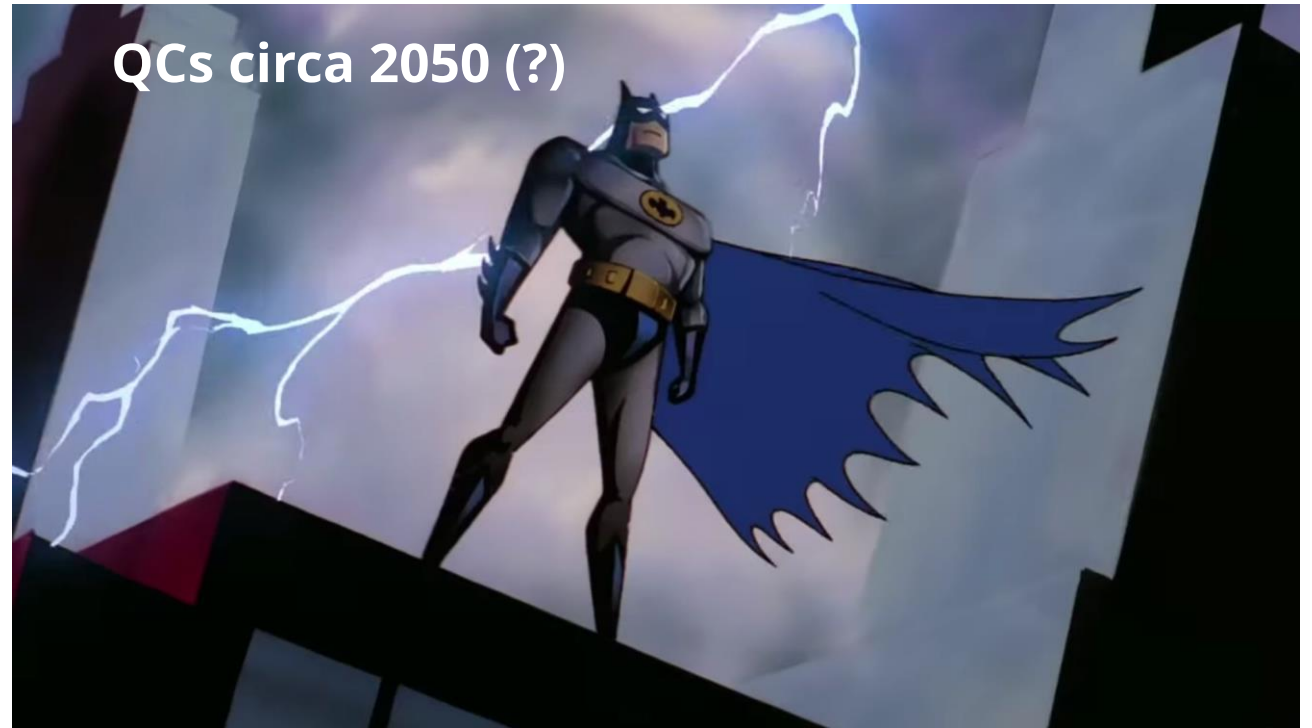
Current	Planned	Needed (for Shor's/Grover's)
65 noisy qubits  IBM	1,000 <u>noisy</u> qubits  (by 2023)	~10,000 <u>error-free</u> qubits

Handwritten annotations:

- An arrow points from the word "noisy" in the Planned column to the word "error-free" in the Needed column.
- An arrow points from the word "noisy" in the Planned column to the word "physical" below it.
- An arrow points from the word "error-free" in the Needed column to the word "logical" below it.
- A bracket is drawn under the IBM logo in the Current column.

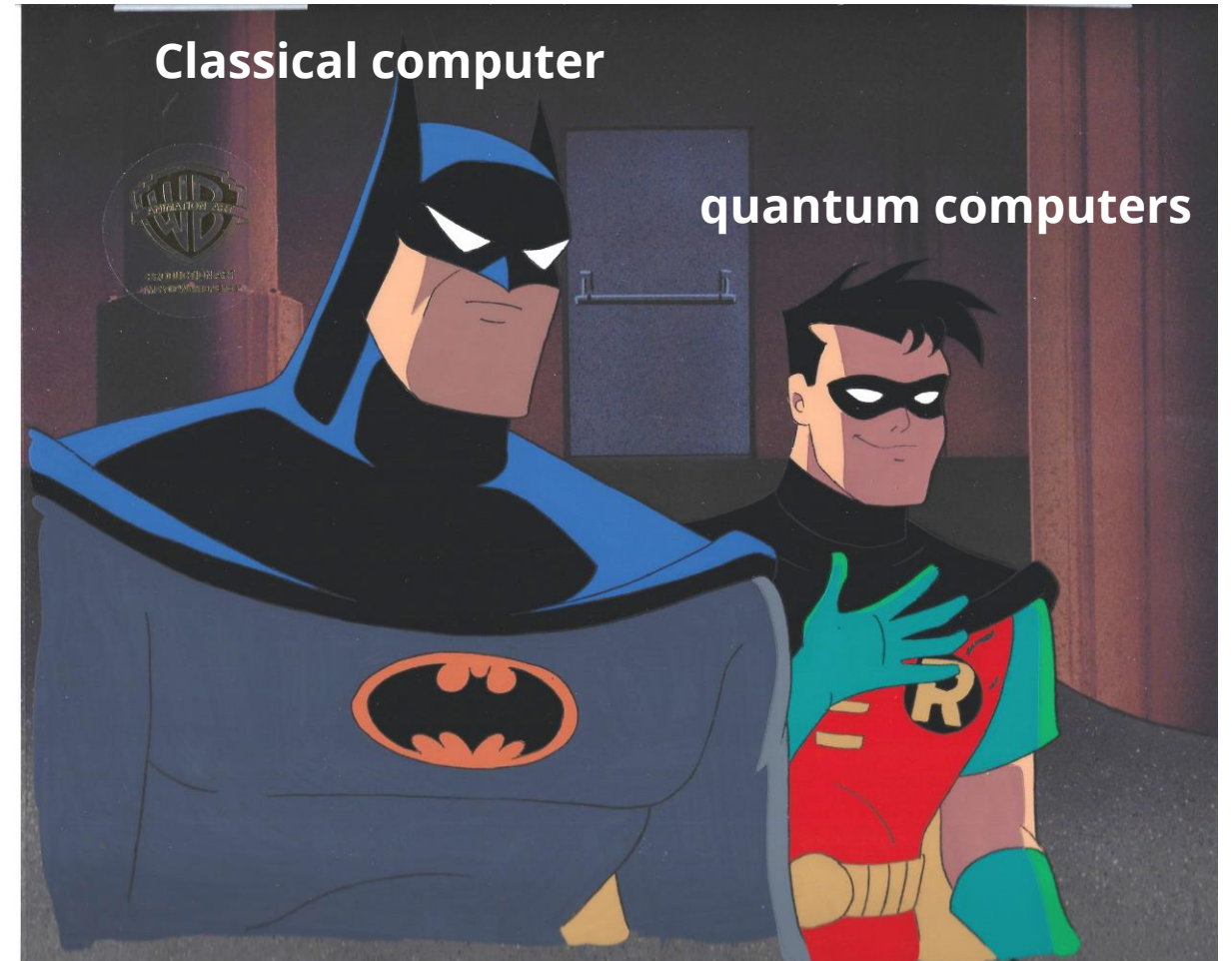
# NEAR-TERM QUANTUM ALGORITHMS

- We would like quantum computers to do Shor's, Grover's etc., but the technology is not there yet
- What can we do with the QCs we have right now/ will have within the next 5 years?



# NEAR-TERM QUANTUM ALGORITHMS

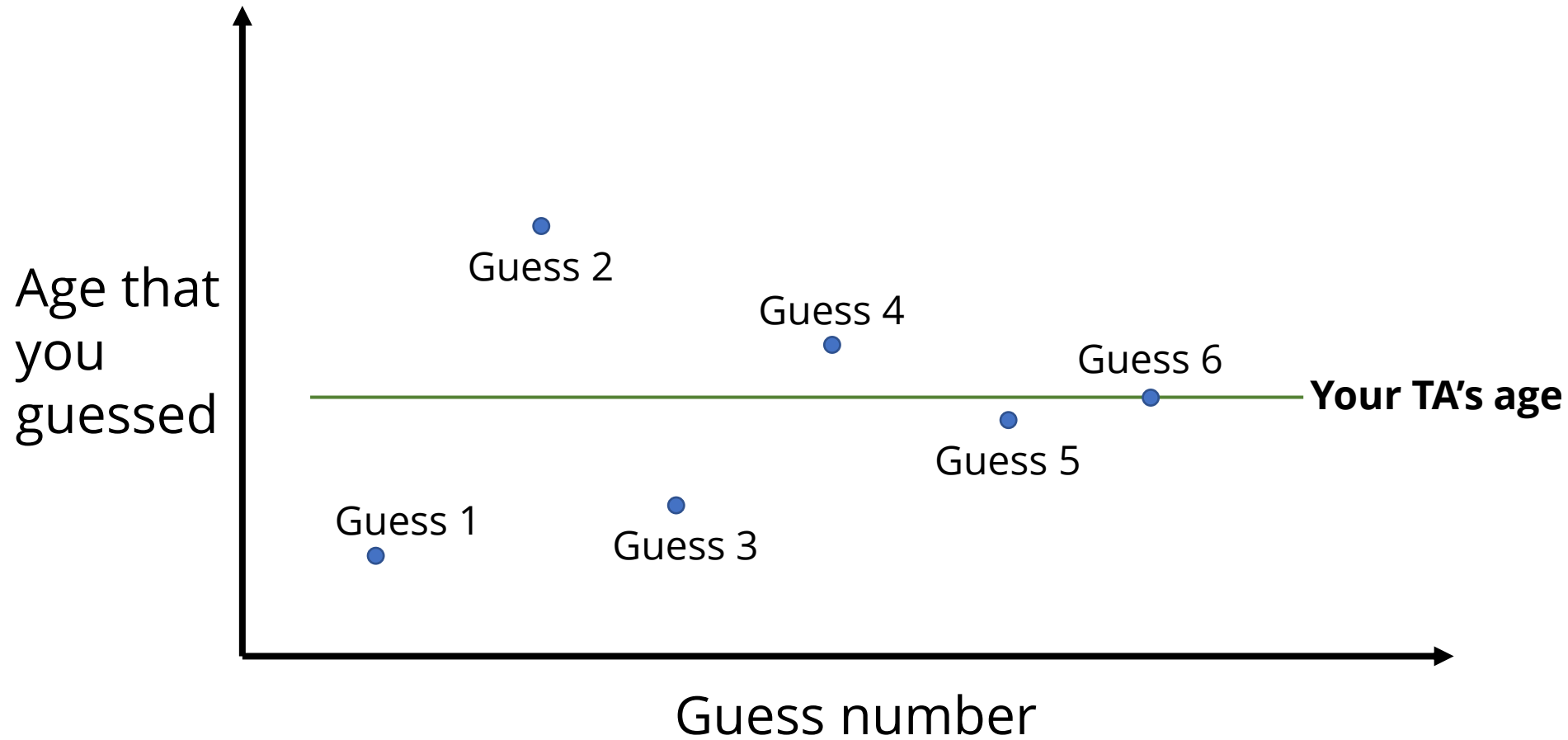
- Can we use them in combination with classical computers?
- Quantum computers do the part of the job that is difficult for classical computers, and classical computers do the rest
- Hybrid, near-term algorithms



# HYBRID ALGORITHMS GAME

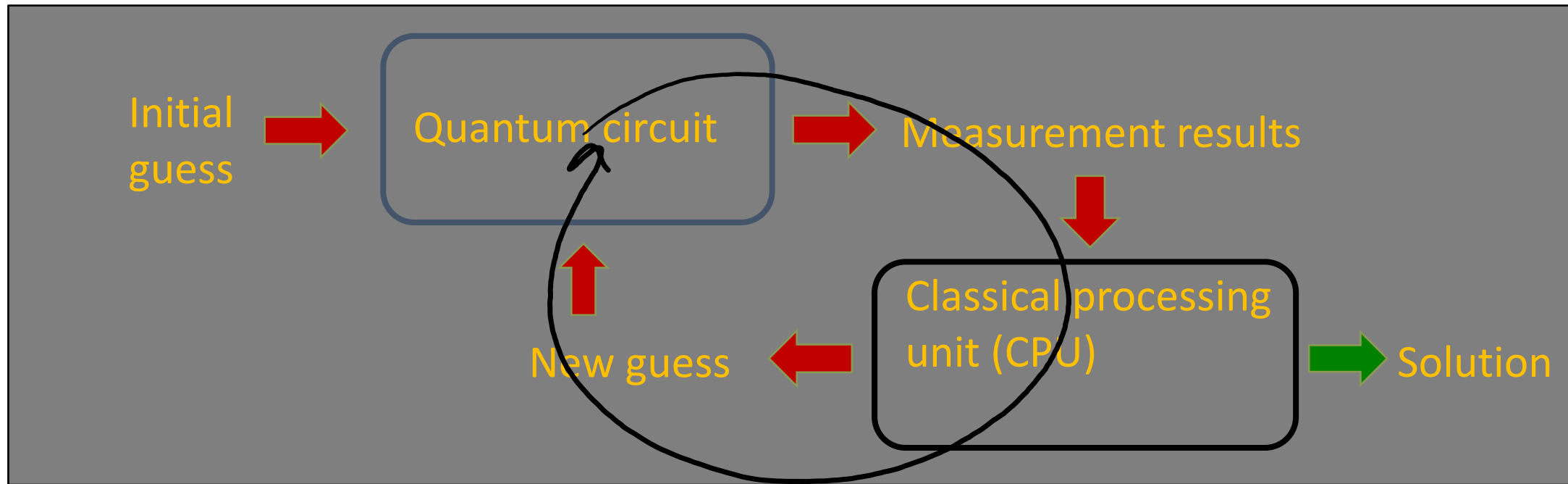
- Guess your TA's <sup>height in cm</sup>~~age~~! Guess a number, and your TA will tell you if you should go higher or lower
- **You're the quantum computer** – you make and update guesses to solve the problem
- **Your TA is the classical computer** – they listen to your guess and tell you in which direction to move for your next guess until you hit the right solution
- **Optimization problems** are an exciting application of near-term quantum algorithms

# CONVERGING TO AN OPTIMUM



# HYBRID ALGORITHMS

## Quantum Approximate Optimization Algorithm (QAOA)



# FINANCE – PORTFOLIO OPTIMIZATION

- You are a stock trader, and you would like to see what the best selection of stocks (portfolio) would have been for a given day
- **Question:** How many possible combinations of <sup>50</sup>~~20~~ stocks can we make from the <sup>5,000</sup>~~3,300~~ listed stocks (the number of stocks listed on NASDAQ)?
- This is something classical computers do today. However, as number of choices gets bigger, the optimal solution gets harder to find – need more computing power

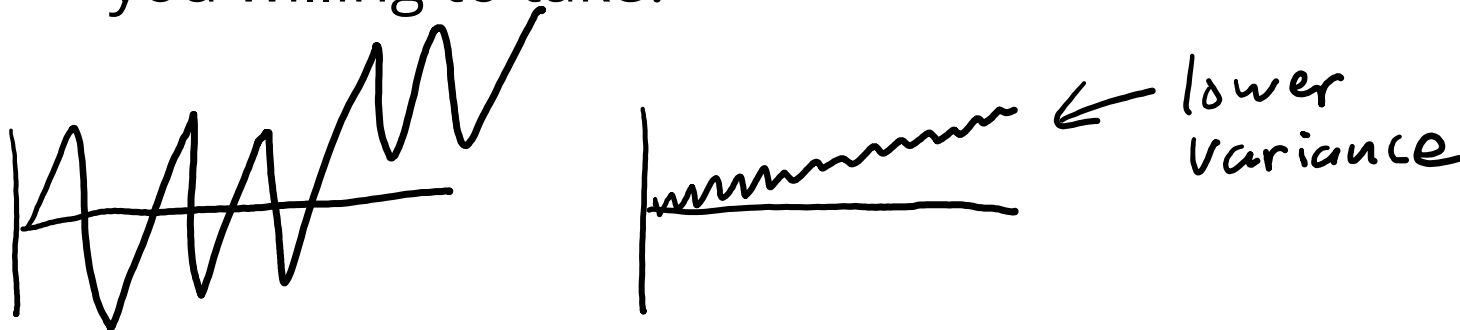
# PORTFOLIO OPTIMIZATION

- Let's make a simple version of this problem
- You have 5 stocks to choose from  $\binom{5}{2}$ 
  - Total number of assets (stocks) = 5
- You can only hold a certain number of stocks in your portfolio
  - Budget (max. number of stocks you can hold) = 2
- Your goal is to **maximize your returns**, given your budget and the amount of risk you're willing to take
- What information do you need to pick these stocks?



# PORTFOLIO OPTIMIZATION

- You would probably want to look at the historical performance of the stock
- What is the average return on the stock?
  - Greater average return means that you can expect to make more money, on average
- What is the variance in that return?
  - The more the variance, the higher the risk (and reward)! How much risk are you willing to take?



# PROCESS OF OPTIMIZATION

1. Create a **cost function**, which is one function that incorporates all our important variables, including:
  - ✓1) Average return
  - ✓2) Variance in return (amount of risk you're willing to take)
  - ✓3) Budget constraints and penalties for going over budget
2. Convert this cost function into a quantum operator (so that the classical and quantum computers can communicate)
3. Implement the operator in a circuit, and measure the outcome (**quantum computing step**)
4. Based on the measured outcome, adjust the quantum operator (**classical computing step**)
5. Repeat steps 3 and 4 until the change in measured outcome is below a threshold → the algorithm has **minimized** the cost function
6. Display the final solution

$f(x)$

↑  
possible solution

# LET'S CODE!

- Today, we'll look at an implementation of QAOA for portfolio optimization
- We'll try to make sense of what's going on in the implementation. We won't be able to understand everything within the lab time – this is normal!
- Fully understanding every step of the entire algorithm, and every line of code, would take hours/days of work
- This is an active research area, and these implementations are being developed right now!

# CODING IN THE WILD

Useful steps in developing code:

- Find open-source code for a similar problem (qiskit textbook/github) ✓
- Run code, check that it works ✓
- See what you can change ✓
- Search for documentation (google/stack exchange) ✓
- Establish dependencies- which part of the code depends on other parts? }
- Removing fluff – get to a minimum working example }

# KEY TAKEAWAYS

- Near-term quantum algorithms (such as VQE and QAOA) aim to use quantum computing resources that are currently available/will be available in the next few years to solve useful problems
- As you make progress in quantum computing, you will come across tutorials/other implementations. Making sense of them is a useful skill, and the process is messy and takes patience
- Google/stackoverflow/qiskit slack are resources to find if issues you've encountered have been solved/are being solved

# FURTHER READING AND RESOURCES

- [Intro to QAOA and VQE](#)
- [Original QAOA paper](#)
- [Qiskit textbook page on QAOA](#)
- [QC in the news](#)

# POST-LAB ZOOM FEEDBACK

**After this lab**, on a scale of 1 to 5, how would you rate your understanding of this week's content?

- 1 – Did not understand anything
- 2 – Understood some parts
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