



**SURE in SFU**

Chan Siu Chung, Davy (PHYS Year 4)

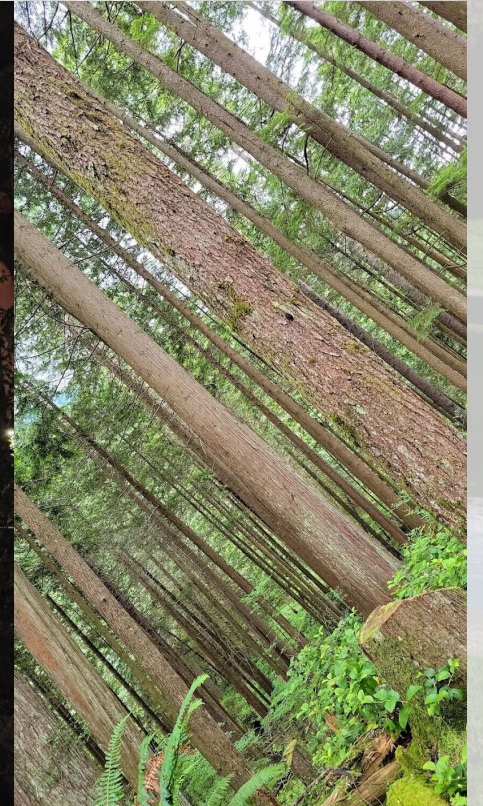


# Prof. Hoi Kwan (Kero) Lau

- Research interest: Theoretical quantum optics and quantum information science
- <https://scholars.croucher.org.hk/scholars/hoi-kwan-kero-lau>
- <https://www.sfu.ca/physics/people/faculty/hoikwanl.html>
- <https://www.sfu.ca/physics/laugroup/Home.html>

# What have I done in this summer?

- Travel!



# What have I done in this summer?

- Research - finishing tasks assigned by your supervisor
  1. Work on your research question
  2. Related-literature review
  3. Group meeting and presentation
- I have practiced...
  1. Physics and math related your research topic
  2. Presentation and communication skills
  3. Paper reading, understanding and writing skills
  4. many...

# Prof. Lau's Quantum Optics and Information Theory Group

- Theorists, NOT experimentalist (but we will work with some groups of experimentalist) .
- Consists of some PhD, MSc and undergraduate students (I was one of them!).
- Each students work on their own research questions.
- Regular group meeting. One student will prepare a presentation on a literature related to their research. The other will be the audience and learn interesting physics!

# My Research

- Area: Quantum sensing
- Qubit measurement improvement problem
- Follow up of M. Koppenhöfer, P. Groszkowski, H. K. Lau, and A. Clerk, Dissipative Superradiant Spin Amplifier for Enhanced Quantum Sensing, PRX QUANTUM 3, 030330 (2022).
- Study of single-qubit quantum channel.
- Study of the amount of information that a measurement on a qubit carries about an unknown parameter  $\theta$ .

# My Research (Cont'd)

- Lead a discussion on D. S. Wang, D. W. Berry, M. C. de Oliveira, and B. C. Sanders, Solovay-Kitaev Decomposition Strategy for Single-Qubit Channels, Phys. Rev. Lett., 111:130504, 2013.
- Sneak peek of my research
  - Math prerequisite
    - Given  $M$  any  $2 \times 2$  matrix, we can write  $M = m_0 I + \sum_{i=1}^3 m_i \sigma_i$ .
    - A map  $f: A \rightarrow B$  is a function such that for every  $a \in A$ , there is a unique object  $f(a) \in B$ .
  - Physics prerequisite
    - Density matrix for a single qubit, which is a  $2 \times 2$  matrix.
    - In open quantum system, CPTP map maps a density matrix to another. (In closed quantum system, a unitary operator maps a state to another.)
    - POVM, generalized measurement operator (need not to be projective)



# My Research (Cont'd)

- Given the density matrix for a single qubit  $\rho = \frac{1}{2} \left( 1 + \sum_{i=1}^3 n_i \sigma_i \right)$  (Bloch vector  $\mathbf{n}$ ).
- Given POVM where  $A = a_0 + \sum_{i=1}^3 a_i \sigma_i$ .
- Probability  $P = \text{Tr}(\rho A)$ .

- CPTP map: Transformed state 
$$\begin{pmatrix} 1 \\ n_1 \\ n_2 \\ n_3 \end{pmatrix} = \begin{pmatrix} ? & ? & ? & ? \\ ? & ? & ? & ? \\ ? & ? & ? & ? \\ ? & ? & ? & ? \end{pmatrix} \begin{pmatrix} 1 \\ n_1 \\ n_2 \\ n_3 \end{pmatrix}.$$

# My Research (Cont'd)

- (Cont'd) CPTP map: Transformed state 
$$\begin{pmatrix} 1 \\ n'_1 \\ n'_2 \\ n'_3 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ ? & ? & ? & ? \\ ? & ? & ? & ? \\ ? & ? & ? & ? \end{pmatrix} \begin{pmatrix} 1 \\ n_1 \\ n_2 \\ n_3 \end{pmatrix}.$$

From my literature review of *Solovay-Kitaev Decomposition Strategy for Single-Qubit Channels*, by singular value decomposition, we can write

$$\begin{pmatrix} 1 \\ n'_1 \\ n'_2 \\ n'_3 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & & & \\ 0 & & R_1 & \\ 0 & & & \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & 0 \\ ? & ? & 0 & 0 \\ ? & 0 & ? & 0 \\ ? & 0 & 0 & ? \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & & & \\ 0 & & R_2 & \\ 0 & & & \end{pmatrix} \begin{pmatrix} 1 \\ n_1 \\ n_2 \\ n_3 \end{pmatrix},$$

where rotation matrices  $R_1, R_2 \in SO(3)$ .

- Then calculate the probability with transformed density matrix.

# My Research (Cont'd)

- Some result: CPTP map cannot lower the error of measurement, but somehow may increase the amount of information that a qubit carries about itself:  $\theta$  (needs further verification and investigation)!
- From research, I have learnt
  - Presentation and report writing skills.
  - Don't rely on Mathematica too much when trying to solve a math problem. Mathematica sometimes sucks and you can obtain the result by human brain only! Train and flex your math muscle.



I had a great summer in Vancouver thanks to:

Prof. Kero Lau for having me in his research group. I got a taste of research, and this experience is invaluable for my future. Now I knew my weaknesses and become a better physics student, with more knowledge, more skills, higher efficiency, and passion. See you in Vancouver!

Dr. MC Chu and Dr Po Kin Leung for coordinating SURE.

Last but not least, thank you to the interview panel of SURE who gave me this precious opportunity!

And everyone who assisted me for the exchange travel program, and everyone I have met in Vancouver.

# Special Acknowledgment

In Vancouver, I met a few CUHK Physics alumni who are so nice and kind to me. They are

- Pak-Tik: Former member of CUHK Physics Society uncountable years ago. PhD candidate of Prof. Kero Lau's research group, who helped me a lot and gave me good advice and suggestion about my future career.
- Sora: Former president of CUHK Physics Society uncountable years ago, who is Canadian now.
- Energy: Pak-Tik's classmate, who is teaching Canadian students physics.

Thanks a million!



The background of the slide is a photograph of a large, modern university building with a courtyard and a pond. The building has a long, horizontal facade with many windows and a series of columns. In the foreground, there is a large, rectangular pond with a person sitting on the edge. The sky is blue with some clouds.

# Thank you for listening!

If you are interested, you can

- apply SURE!
- email Prof. Lau. He seems to be looking for students.

My email: [1155142374@link.cuhk.edu.hk](mailto:1155142374@link.cuhk.edu.hk)

Prof. Kero Lau's email: [hoikwanl@sfu.ca](mailto:hoikwanl@sfu.ca)