

Partners and Quantum Information Capsule

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Recent works: Quantum Information Capsule and Information Delocalization

[KY, N. Watamura, M. Hotta, Phys. Lett. A 383, 12, 1255 (2019)]

[KY, M.Hotta, arXiv:1902.05675 [quant-ph]]

Where is “information” stored in quantum systems?

A fundamental and important question in

- Black hole physics... Information loss problem
- Quantum chaos... Scrambling of information

Isn't it non-trivial?

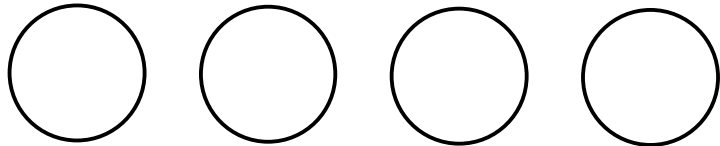
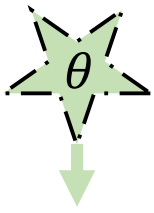
... No! Information is easily delocalized by entanglement.

Information stored in unentangled states

Write process

Local write operation

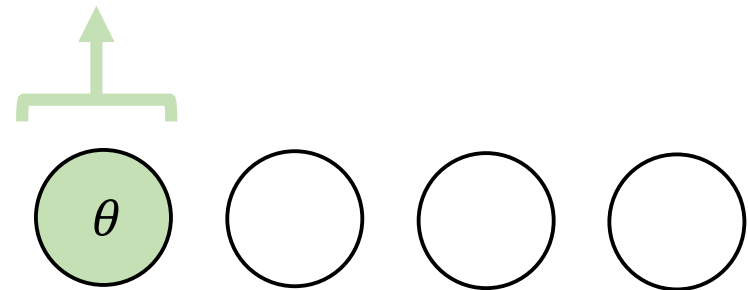
$$e^{-i\theta\sigma_z}$$



Unentangled multiple-qubit system

Read-out process

The information can be perfectly retrieved by local (swap) operation.



Information is localized

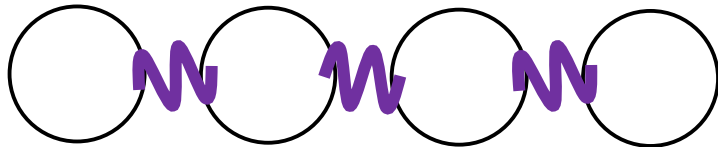
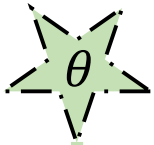
[KY, N. Watamura, M. Hotta, Phys. Lett. A 383, 12, 1255 (2019)]

Information Delocalization by Entanglement

Write process

Local write operation

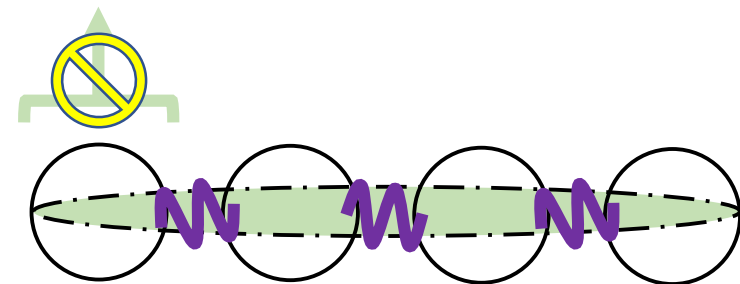
$$e^{-i\theta\sigma_z}$$



Entangled multiple-qubit system

Read-out process

The information **cannot** be perfectly retrieved by local (swap) operation.



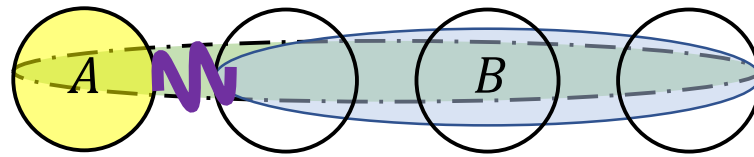
Information is delocalized

[KY, N. Watamura, M. Hotta, Phys. Lett. A 383, 12, 1255 (2019)]

Partners and Quantum Information Capsule (QIC)

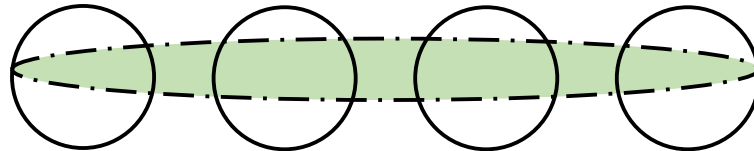
A common picture:

Two qubits AB (a pair of partners) shares the delocalized information.



New picture:

A **single** qubit (QIC) perfectly confines the delocalized information.



QIC

[[KY](#), N. Watamura, M. Hotta, Phys. Lett. A 383, 12, 1255 (2019)]

A similar analysis can be done for more general systems ,e.g., scalar fields.

[[KY](#), M.Hotta, arXiv:1902.05675 [quant-ph]]

Applications

- Tracking scrambled information by calculating the time evolution of QICs

[[KY](#), M.Hotta, arXiv:1902.05675 [quant-ph]]

- Investigating the information shared by partners in evaporating black holes
 - Collaboration with T. Tomitsuka and M. Hotta (on-going)
- Masking of information and QICs
 - Collaboration with M. Hotta (on-going)

Credits and future plans

- GPPU Points:
 - GSP: 18 (required: 20)
 - GASP: 7 (required: 10)
- Plans in near future:
 - International conference:
 - Relativistic Quantum information-North @ Taiwan, 27th May- 2nd June
 - Quantum Information and String Theory @ Kyoto, 17th- 28th June
 - Visit a laboratory
 - Shih-Yuin Lin's lab. @ Taiwan 20th - 24th May

Summary

- In entangled systems, information is delocalized.
- Two classes of carriers for delocalized information:
 - Partners: a pair of qubits/ modes
 - Quantum information capsule: a single qubit/ mode
- Calculating the time-evolutions of partners and QICs, we can track the information propagated through the system.