Device-independent quantum information based on thermodynamics

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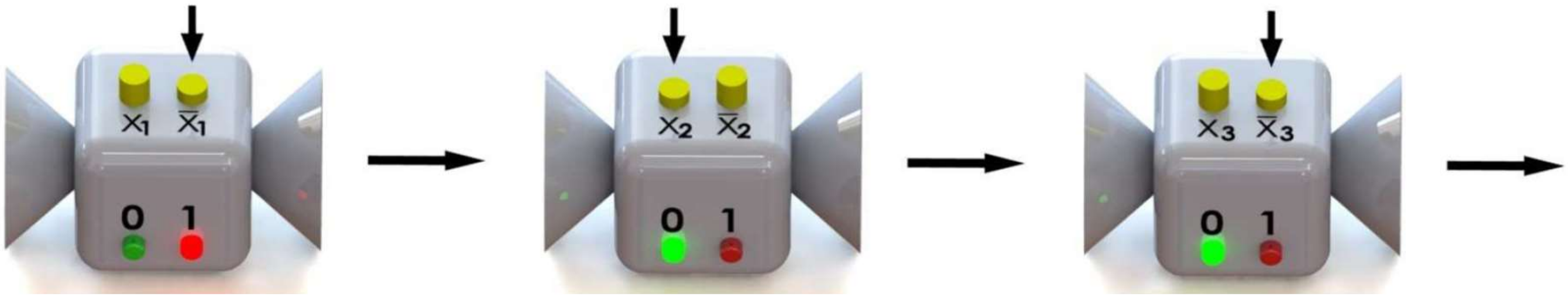
Sequential measurements on a single system



Dagomir's student

- A student in a box can simulate the quantum predictions

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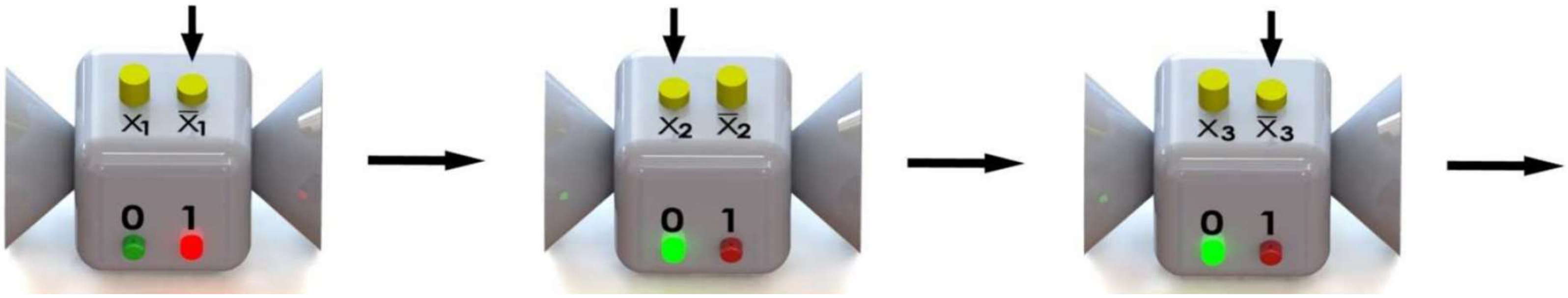

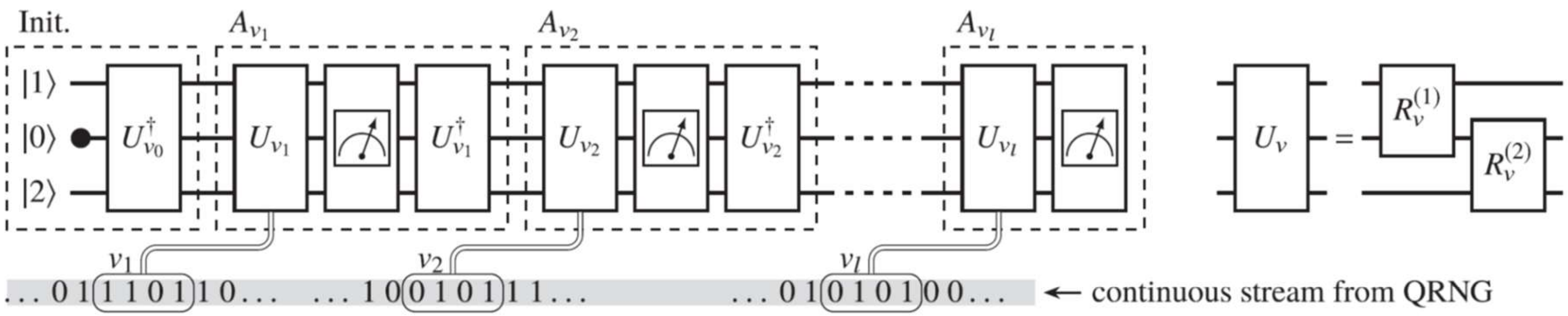

F. M. Leupold, M. Malinowski, C. Zhang, V. Negnevitsky, AC, J. Alonso, and J. P. Home, PRL **120**, 180401 (2018)

The device-independent paradigm

- Without knowing anything about the system tested
- The observation of certain correlations under certain conditions allows us to conclude that the system is truly quantum…
- Not a classical simulation of a quantum system

- We can use this to certify security, privacy…

The DI paradigm based on nonlocality

- Without knowing anything about the system tested
- The observation of nonlocal correlations under space-like conditions allows us to conclude that the system is truly quantum…
- Not a classical simulation of a quantum system

- We can use this to certify security, privacy…

The DI paradigm based on thermodynamics

- Without knowing anything about the system tested
- The observation of contextual correlations under no-heat emission conditions allows us to conclude that the system is truly quantum…
- Not a classical simulation of a quantum system

- We can use this to certify security, privacy…

Key points

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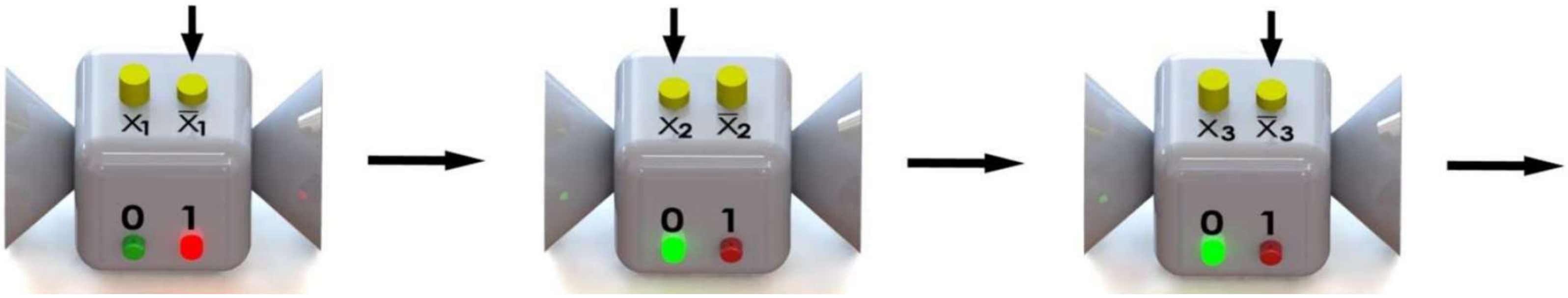
- If we can experimentally certify that the system under observation cannot be a classical device with finite memory
- Then we can use it for quantum information applications
- A classical device with finite memory has to erase its memory to allocate new information to keep simulating the quantum statistics. Due to Landauer's principle, this produces heat that depends on how much memory has to be erased (and how often has to be erased).

PRA **94**, 052127 (2016); Phys. Today **70**(2), 23 (2017); PRL **120**, 130401 (2018)

Take out message

- Sequential quantum measurements can be experimentally distinguished from classical simulations with finite-memory: the simulations produce heat not related with the measurement, but with the fact that the classical device has to erase part of its memory to allocate the information needed for the simulation

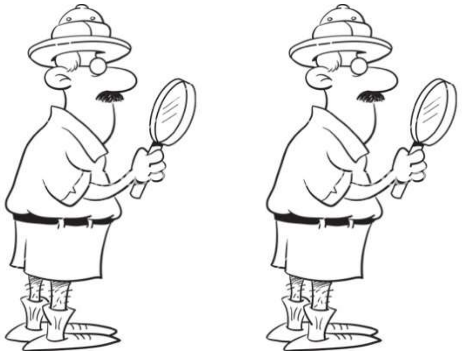
How can we be sure that there no extra heat?



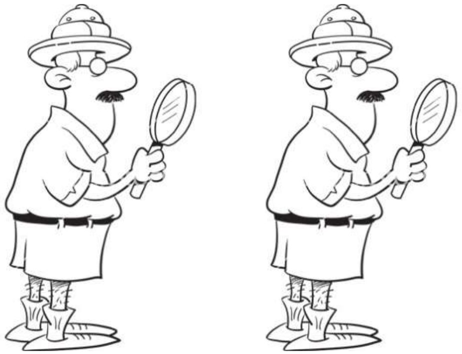
Alternative: Two maximally entangled systems

On system *A* we measure

On system *A* we measure POVMs



On system *B* we don't



If the system simulating *B* has finite memory…

System simulating *B* will emit heat!

A. Tavakoli and AC, PRA **97**, 032131 (2018)

Open questions

- Can we test the no-heat emission condition?
  - Can we perform sequential measurements on a single system, monitoring that the ion is not emitting heat?
  - Can we perform sequential POVMs on an entangled system while monitoring that its companion is not emitting heat?
- Can we compute the classical resources required for simulating the quantum predictions for sequential measurements?
  - So far: M. Kleinmann, O. Gühne, J. R. Portillo, J.-Å. Larsson and AC, New J. Phys. 13, 113011 (2011)
  - AC, M. Gu, O. Gühne, J.-Å. Larsson and K. Wiesner, PRA 94, 052127 (2016)
  - AC, M. Gu, O. Gühne and Z.-P. Xu, PRL 120, 130401 (2018)
- Can we identify applications of this thermo-based DI paradigm?