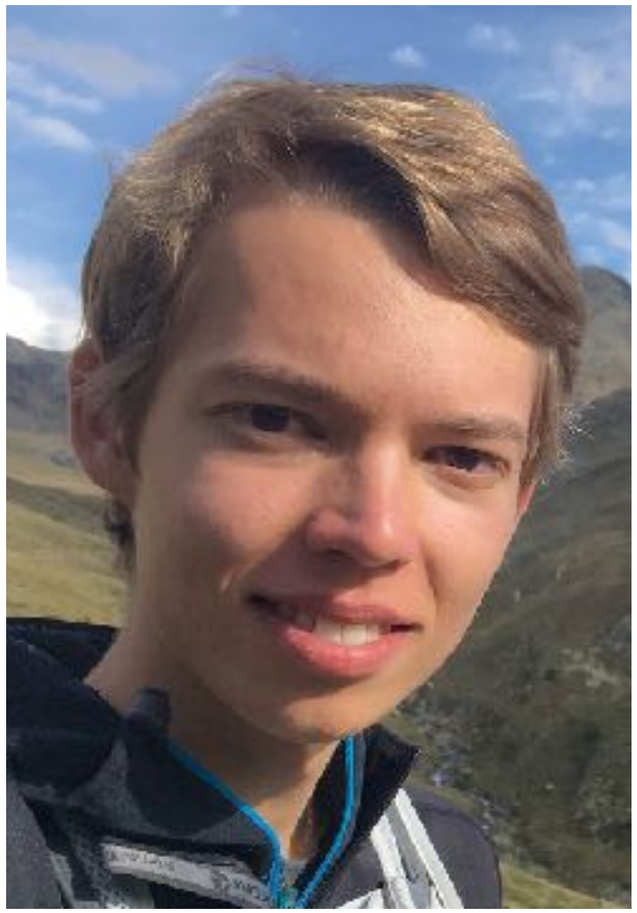
Discovering physical concepts with neural networks

Renato Renner
ETH Zurich

Machine Learning for Quantum […] Workshop 2019

joint work with …

Raban Iten



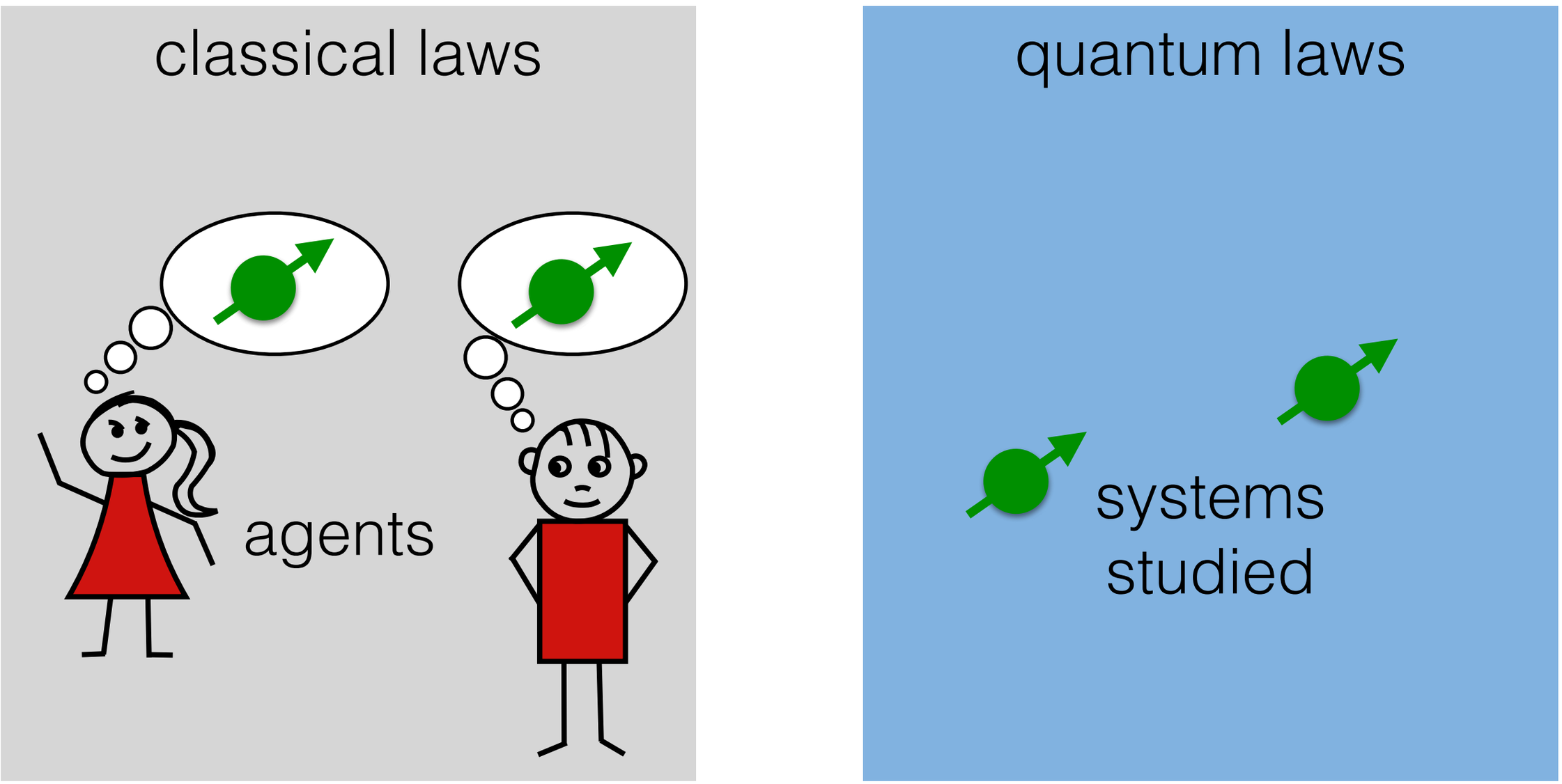
Tony Metger

Henrik Wilming

Lídia del Rio

preprint: arXiv:1807.10300

Background: How do we use quantum theory?



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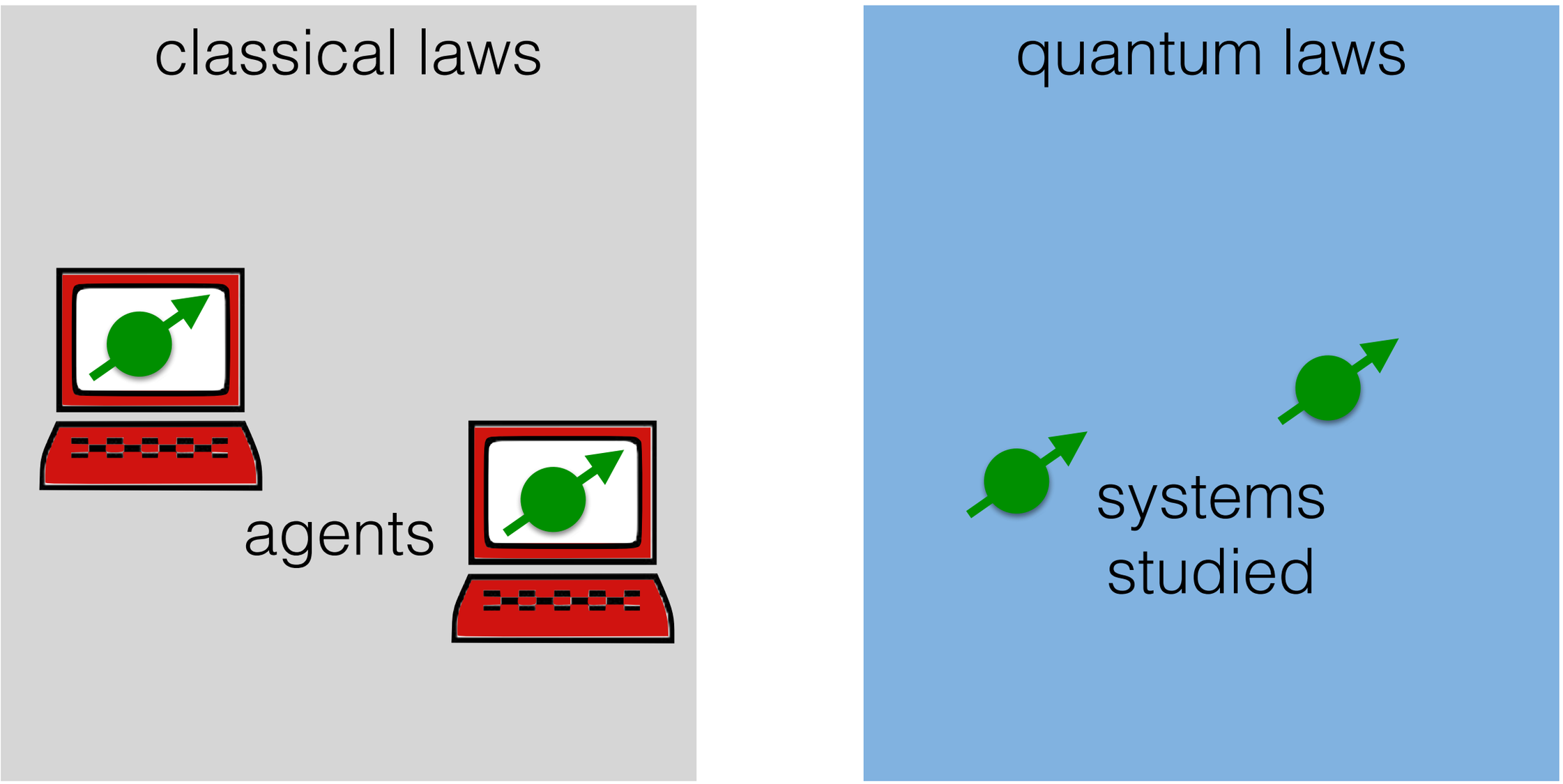

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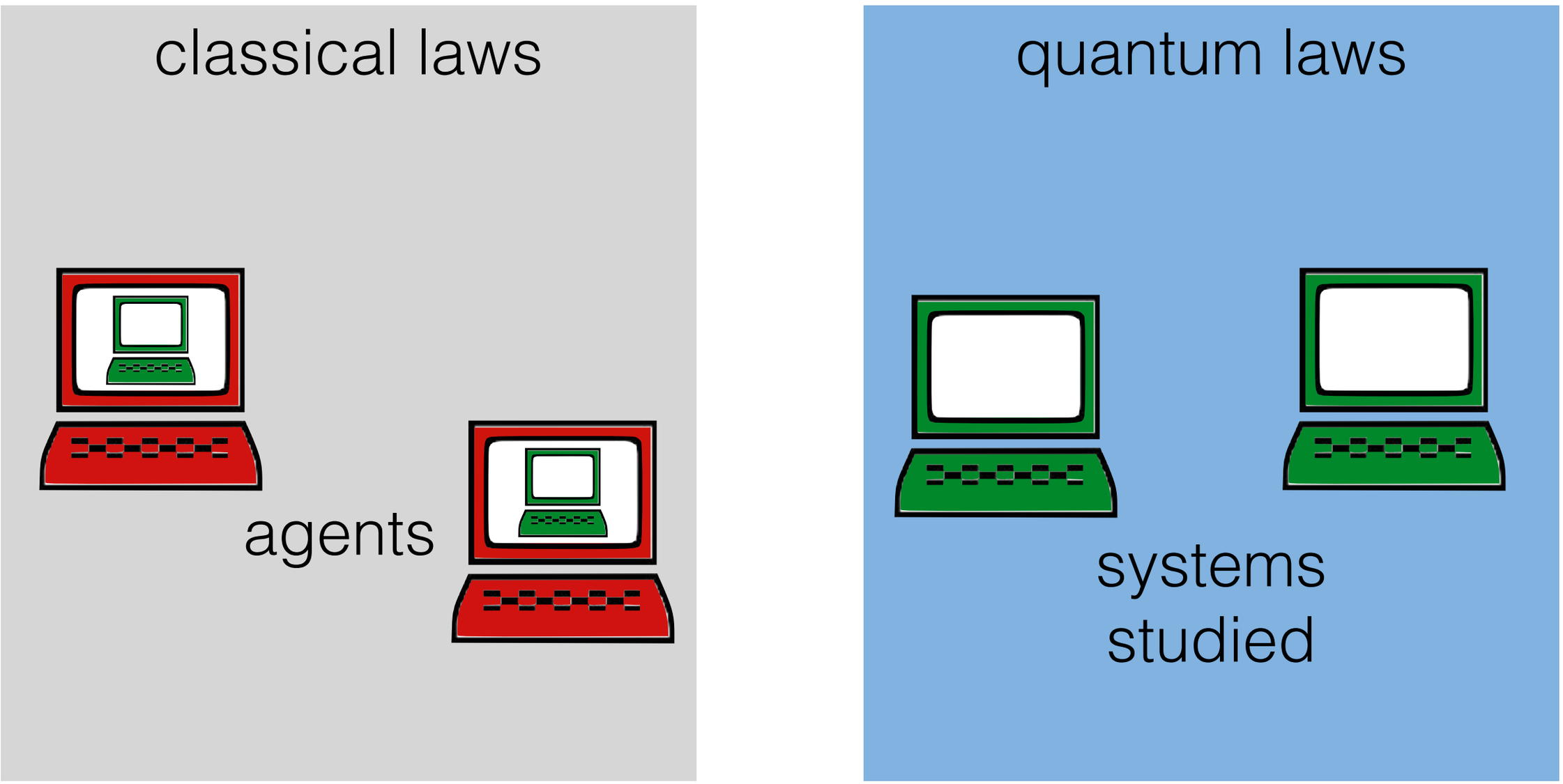
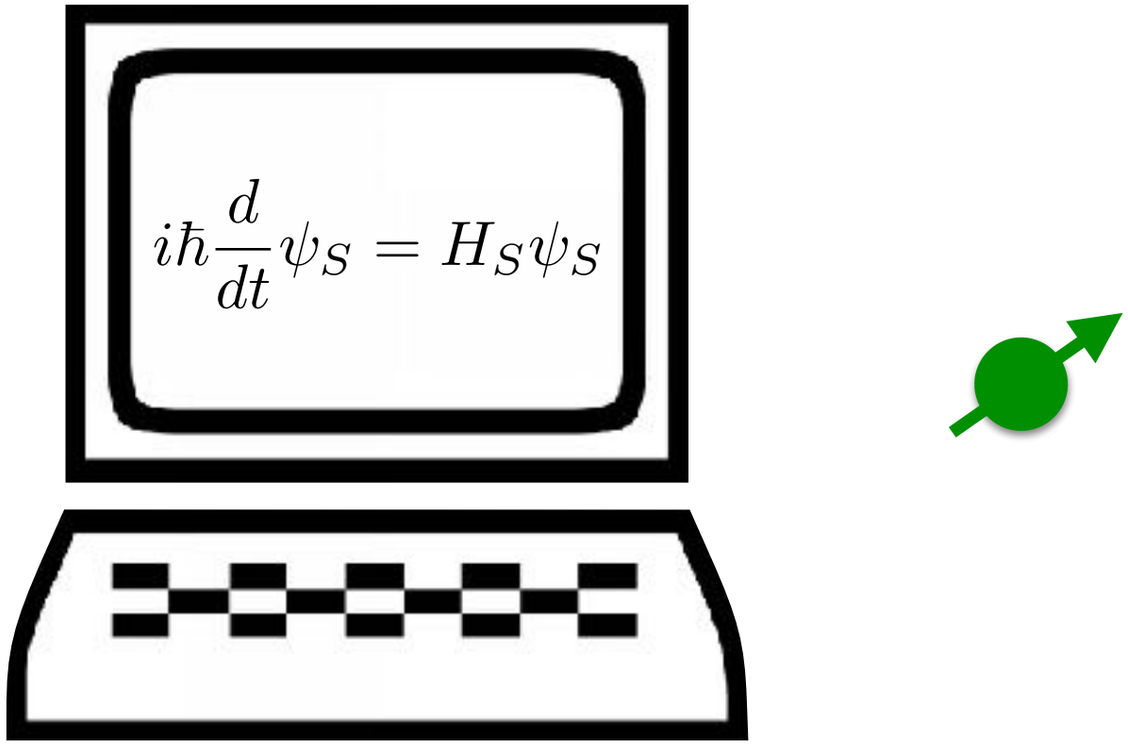
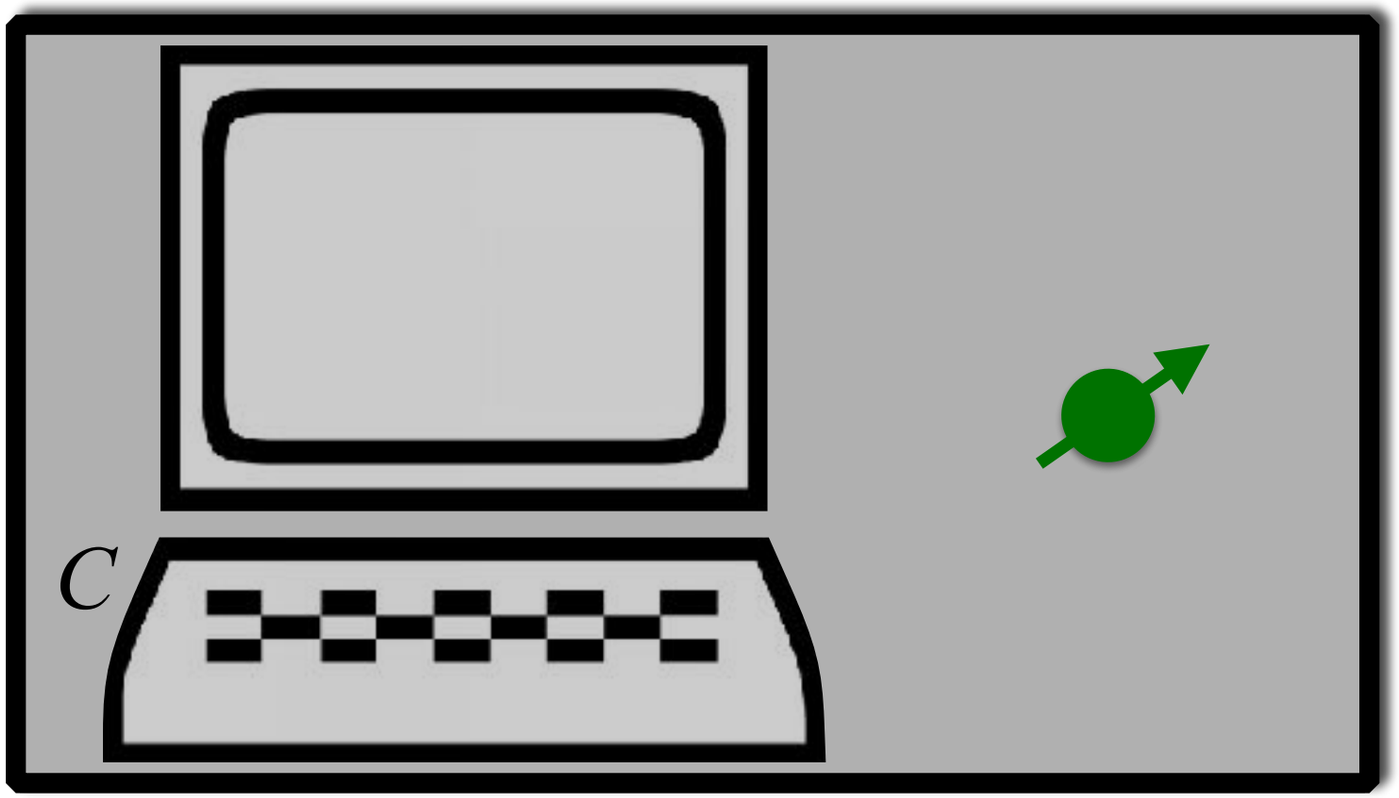


Computer as *"subject"* that uses quantum theory



Computer as *"object"* that is studied by quantum theory.

$$i\hbar\frac{d}{dt}\Psi_{CS} = H_{CS}\Psi_{CS}$$



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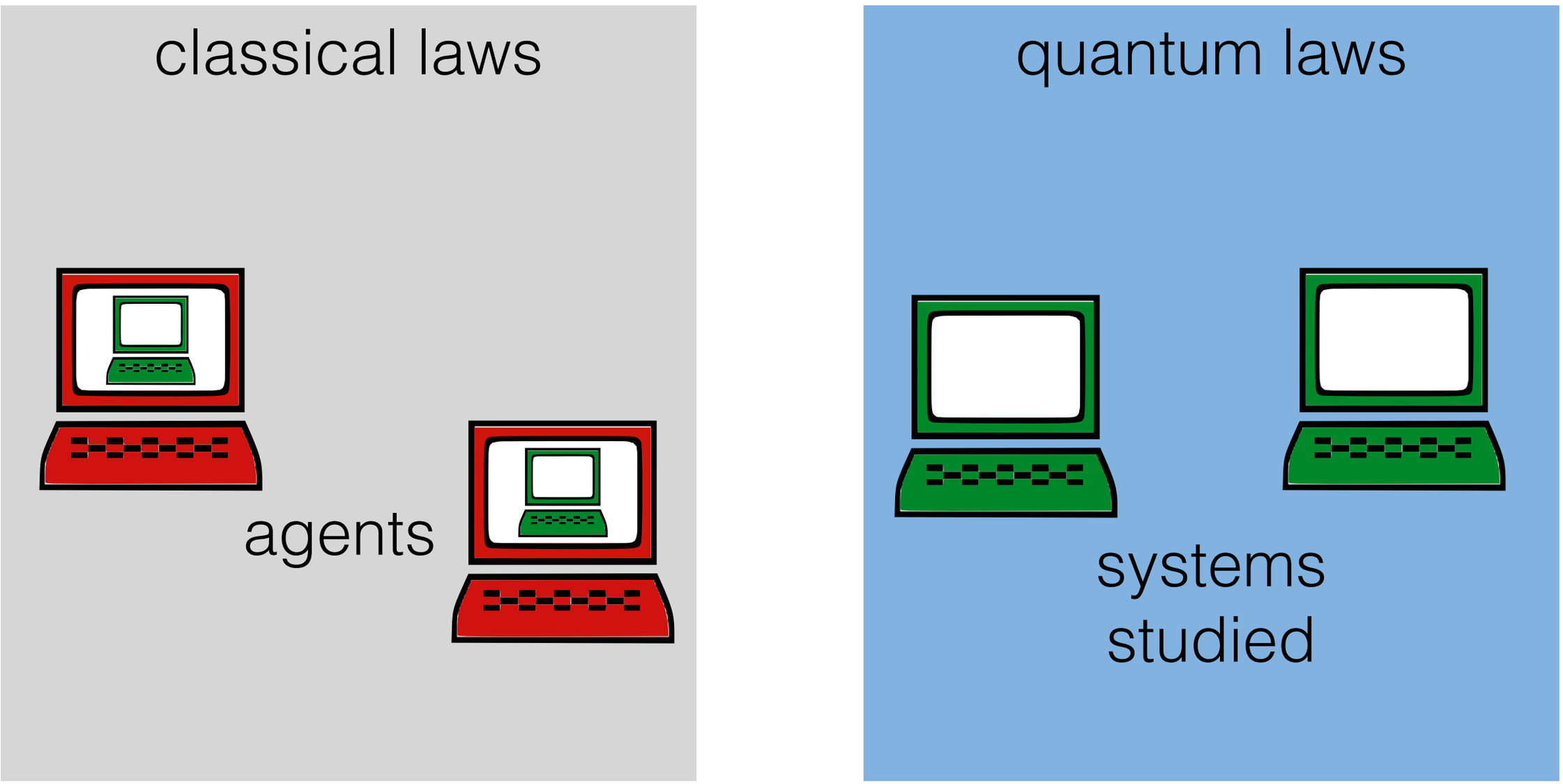

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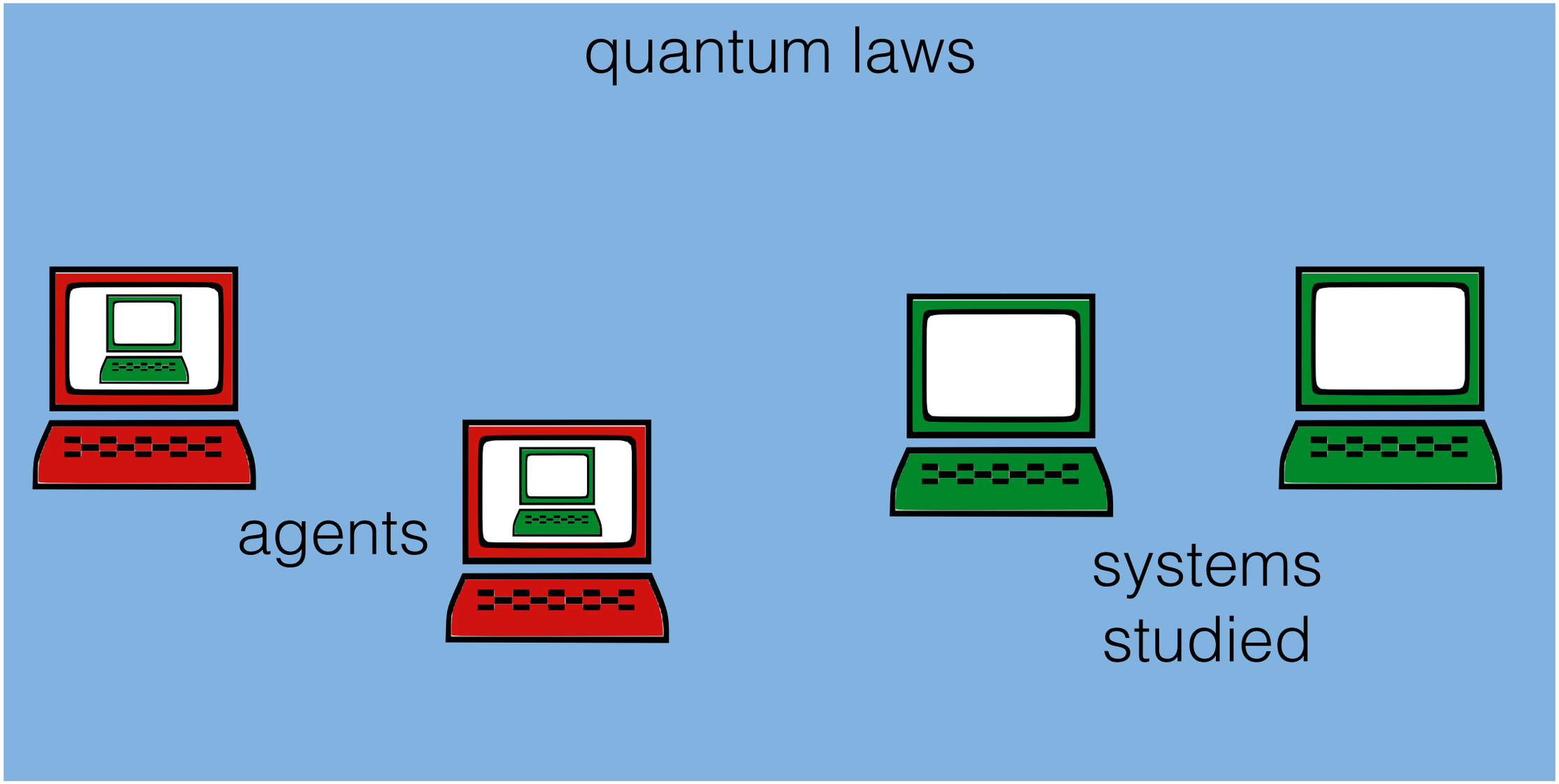
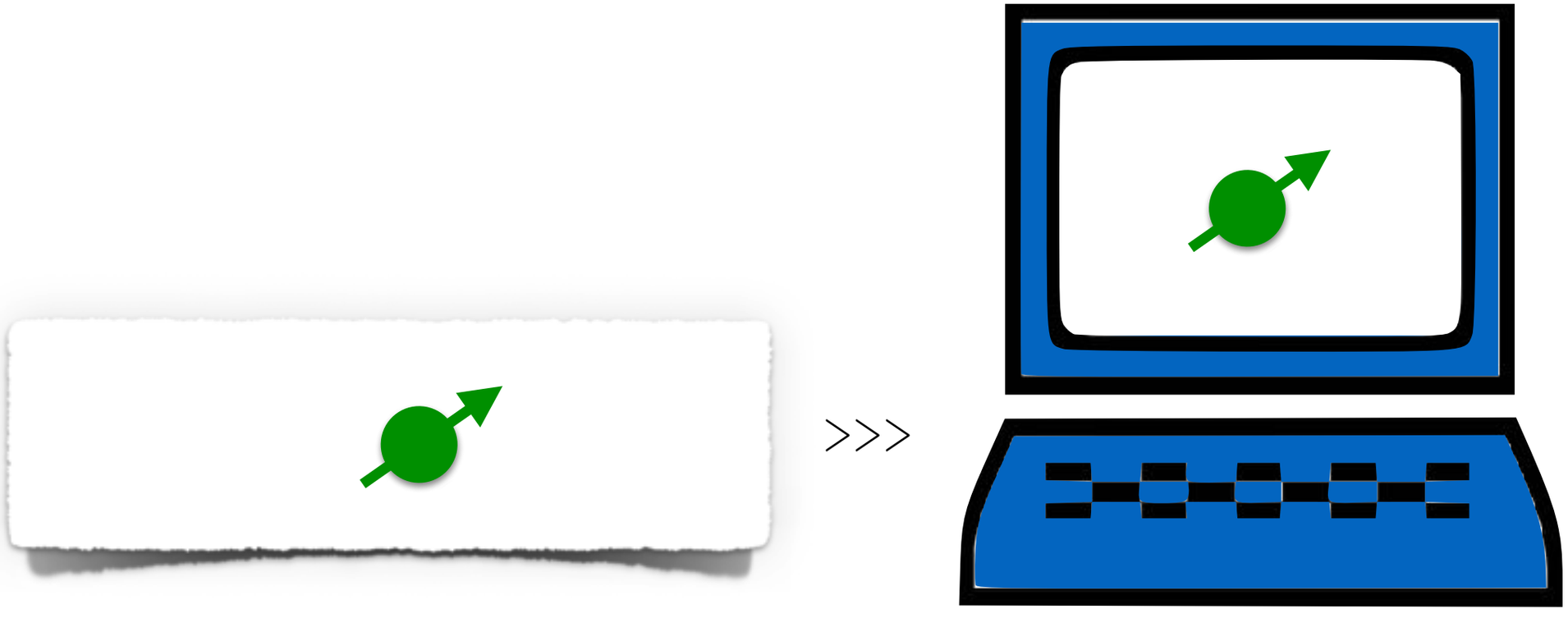
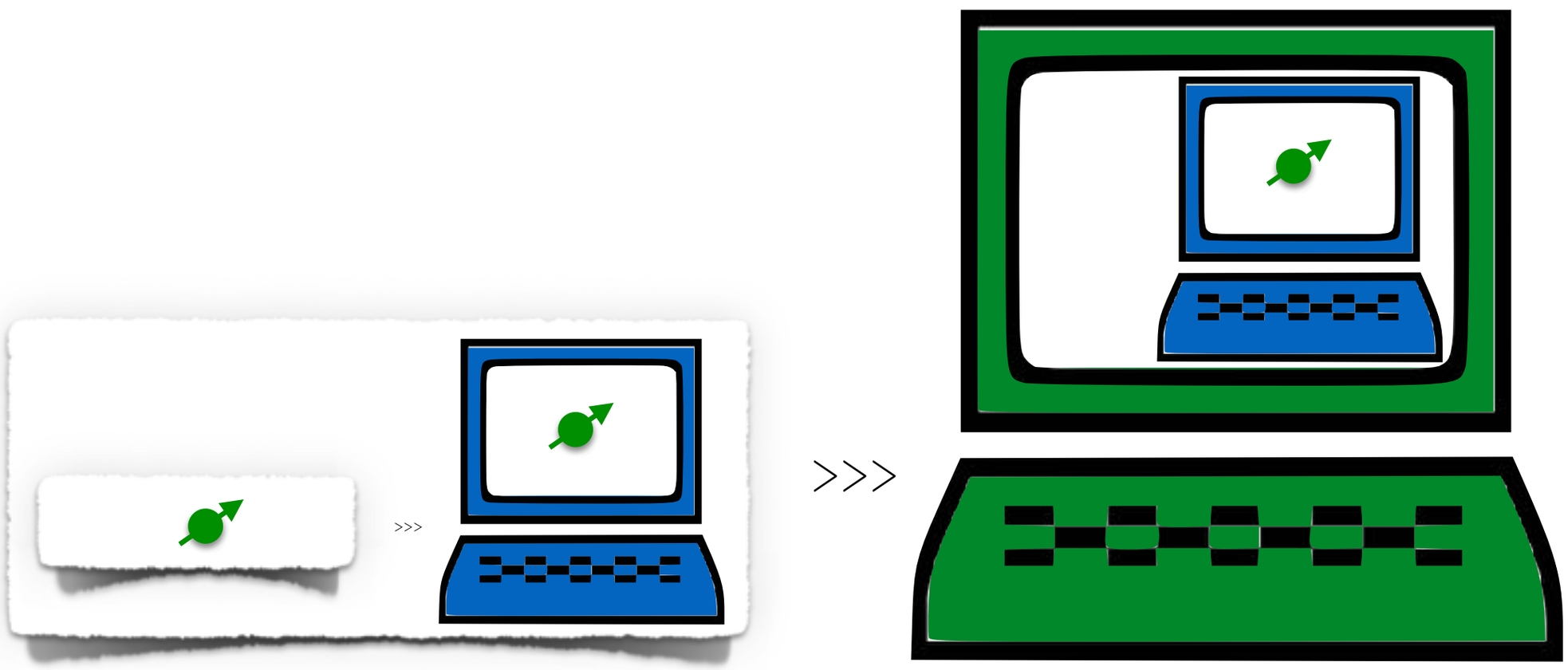
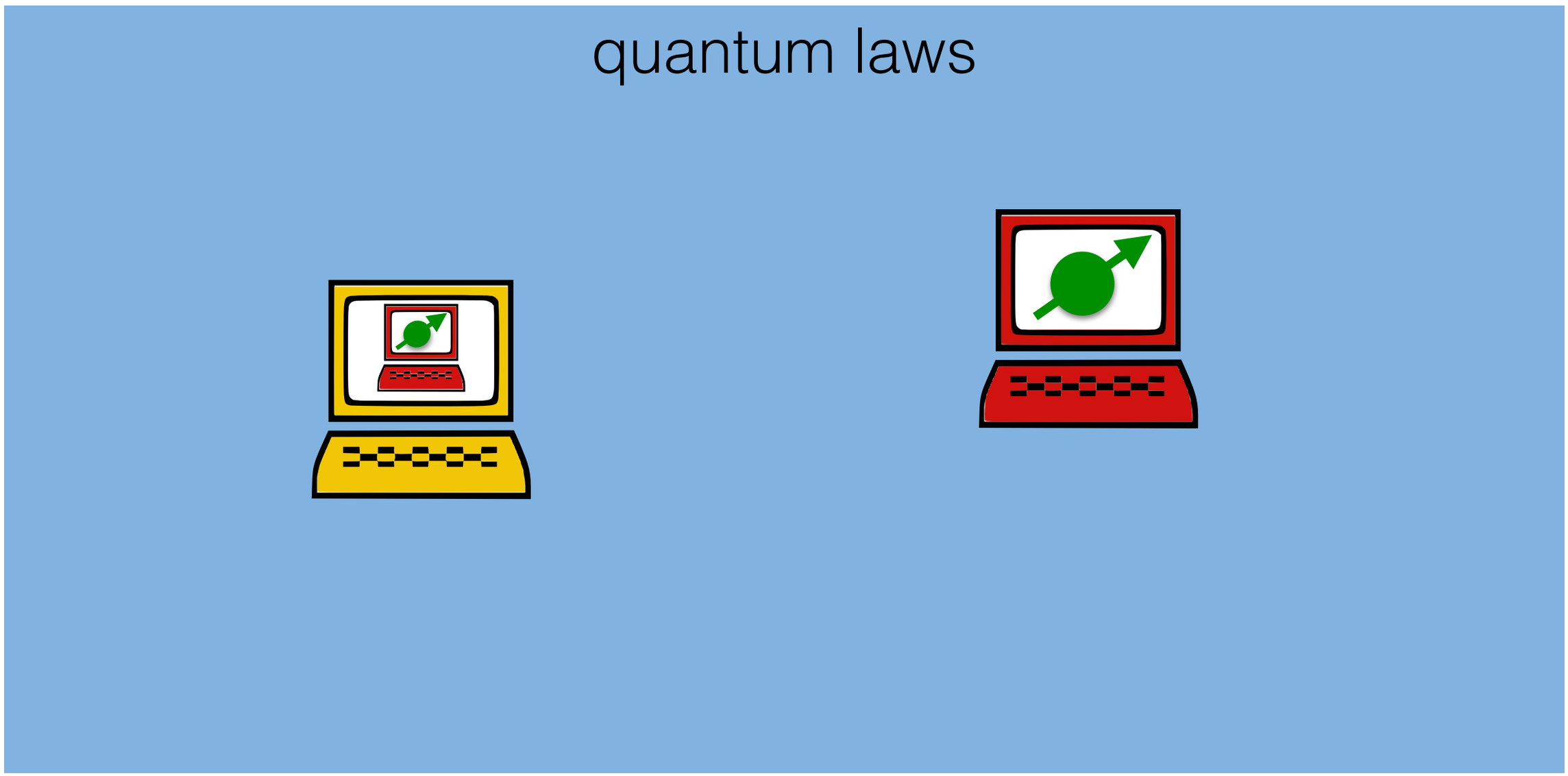






Background: Agency as a relative notion



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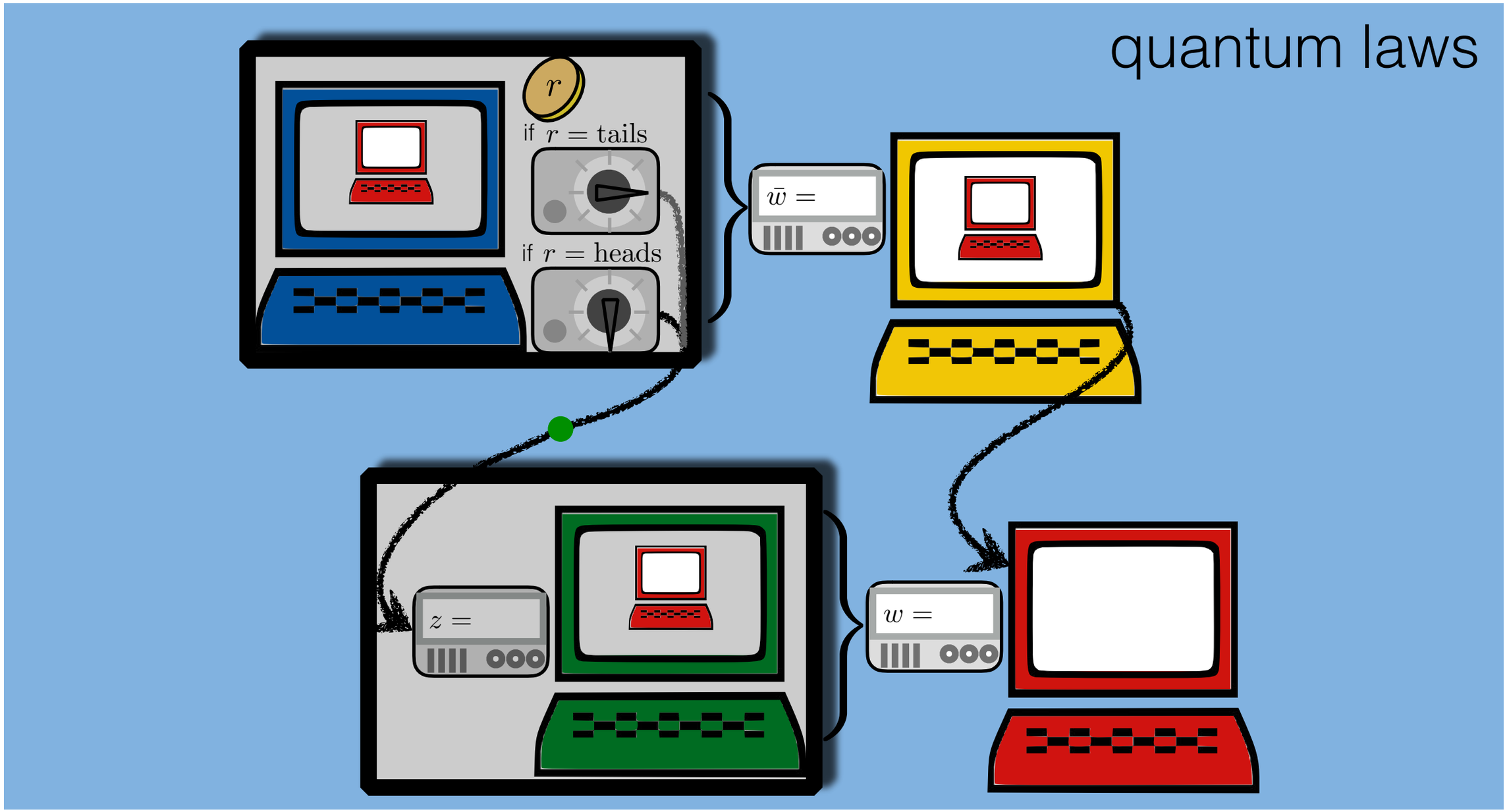
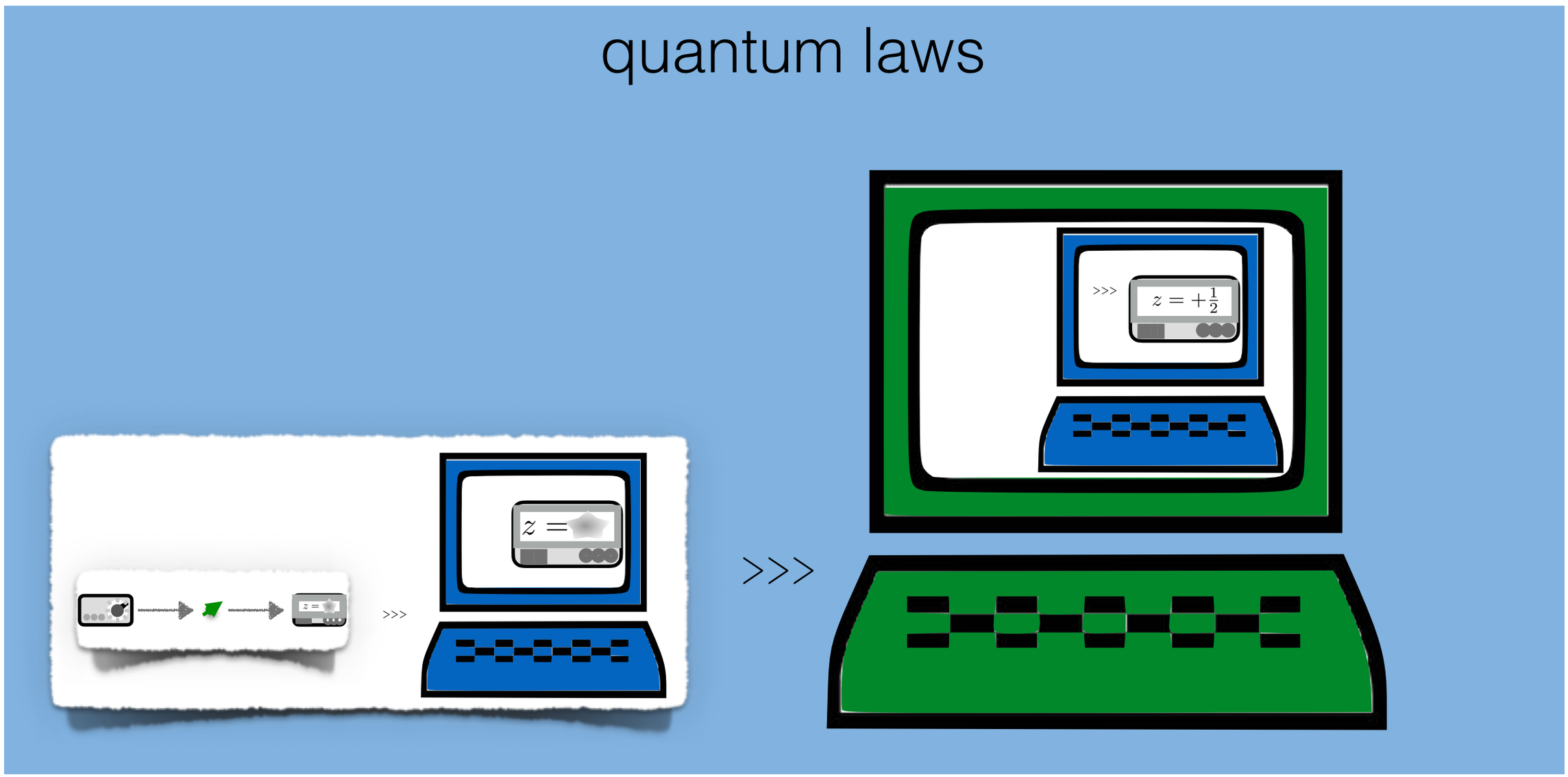


[Frauchiger and RR, Nat. Comm. 2018]: There exist scenarios where a fully quantum-mechanical treatment of the agents leads them to issue contradictory statements.

Background: The trouble

Standard quantum theory cannot in general consistently describe agents, i.e., users of quantum theory.



New Scientist

WEEKLY 23 March 2019

GAIA REBORN
The idea of Earth as one organism is back

OH MY COD!
Do you know what fish you're eating?

THE HUMAN COMPASS
How our brains detect magnetic fields

QUANTUM THEORY IS IN TROUBLE

And it looks like the problem is you

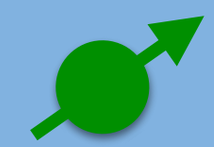
Why was the problem not noticed before?

Standard situation: agents subject to dissipation

classical laws

agent

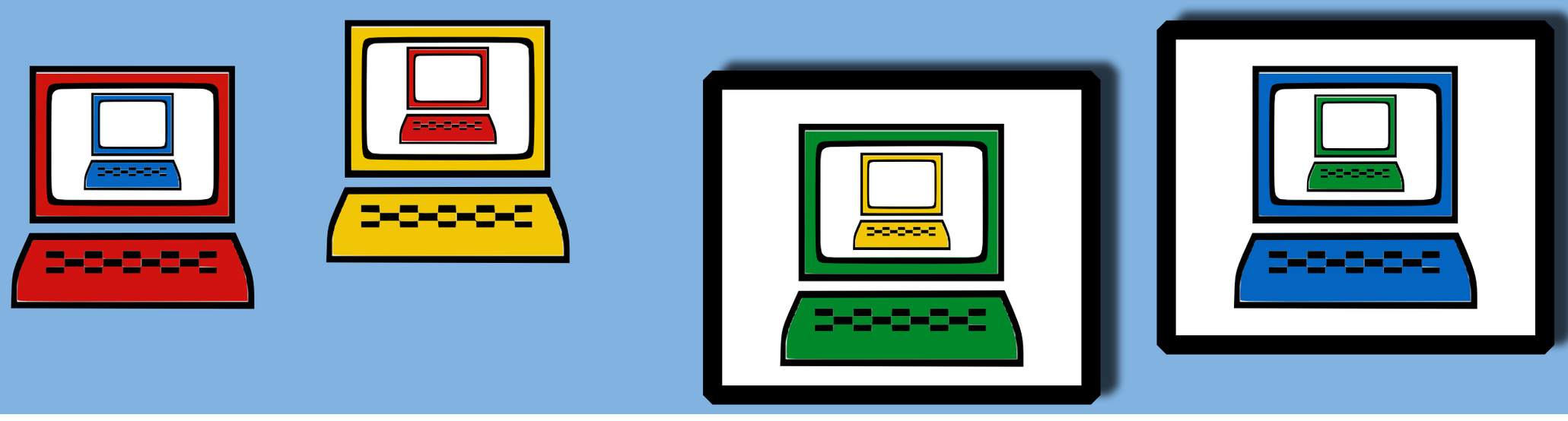
quantum laws



studied system

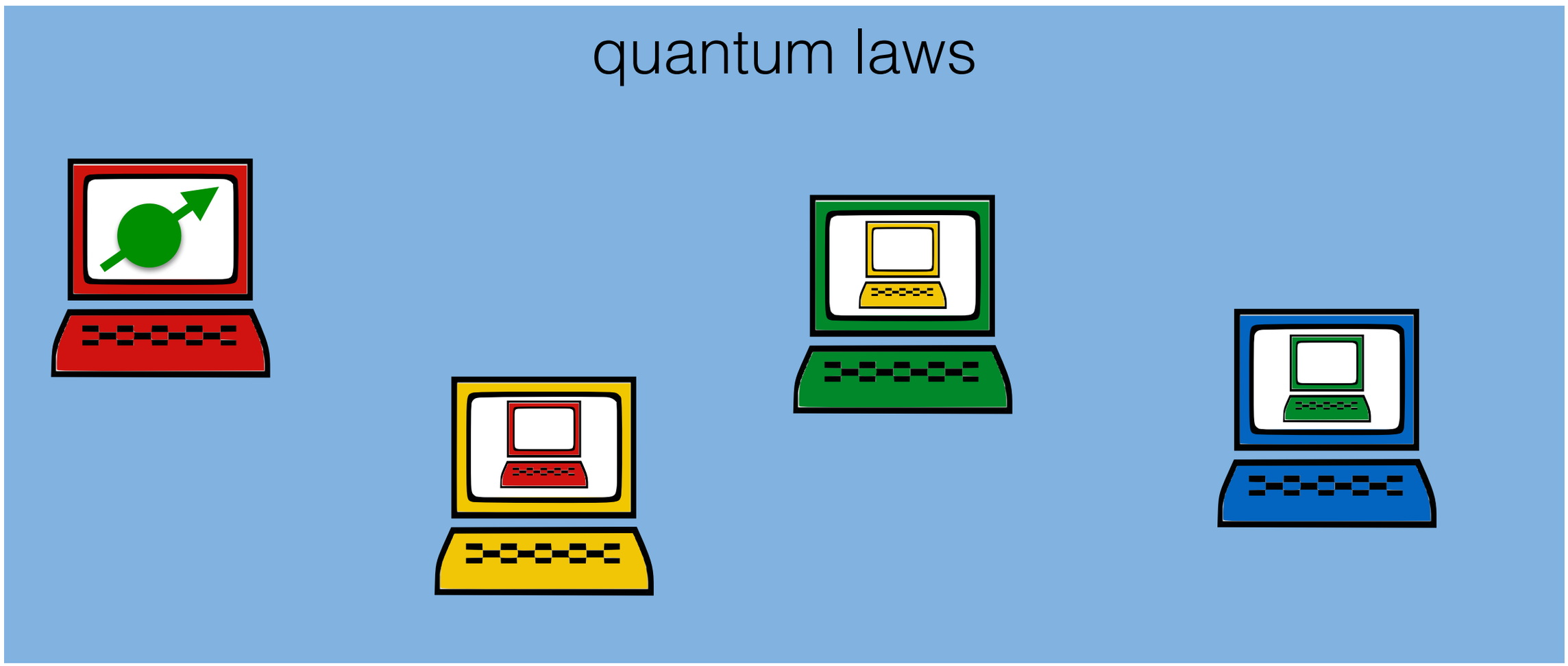
Problematic situation: systems protected from dissipation

quantum laws



Long-term program

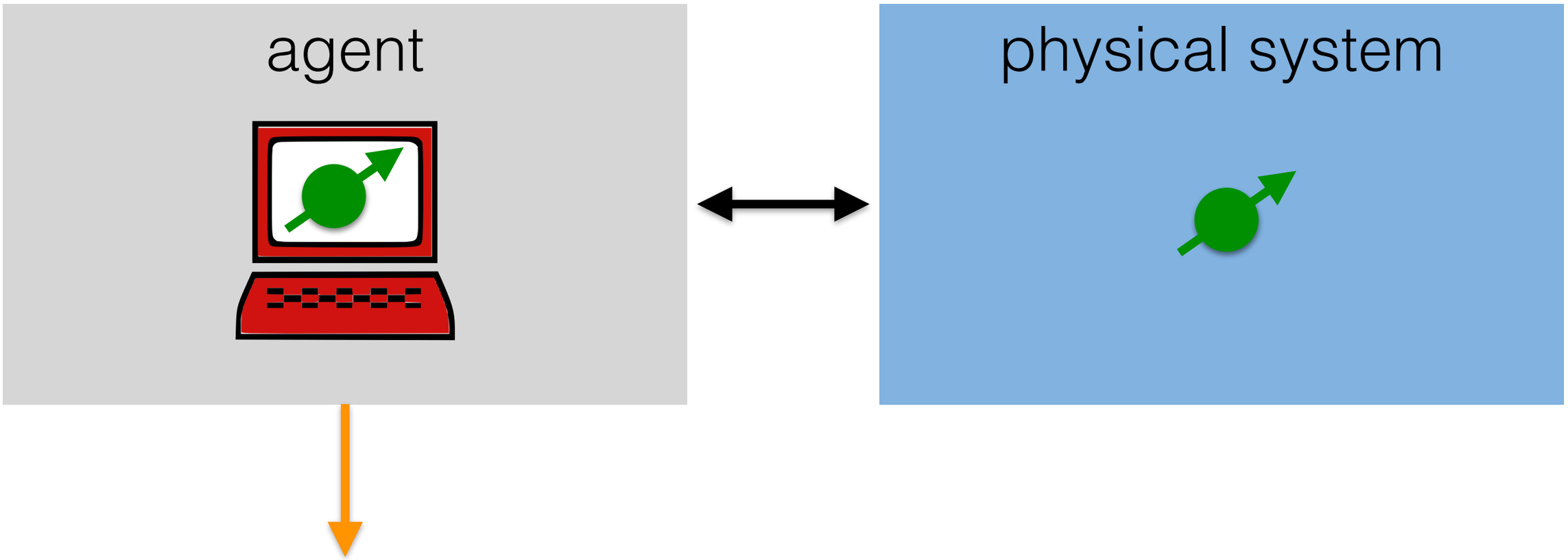
Question: How would the world be described by agents if dissipation was much slower?



Long-term program

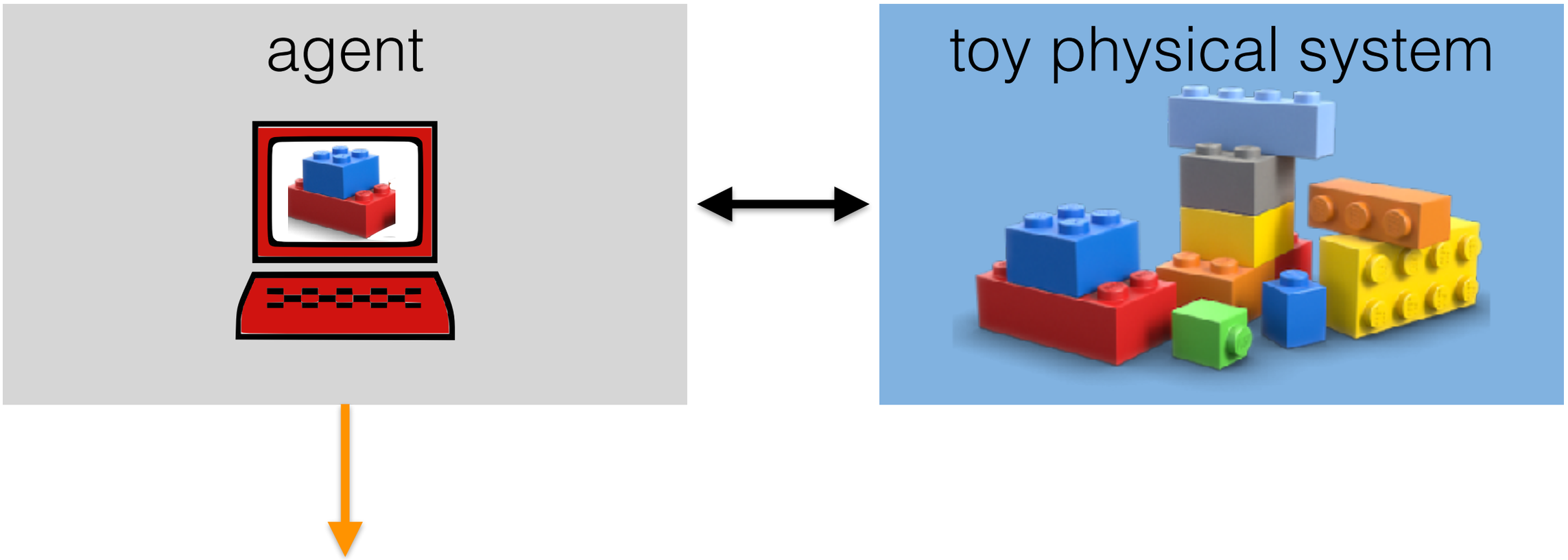
Question: Can we build agents that discover physical laws?

Question: If yes, how can we extract these laws?



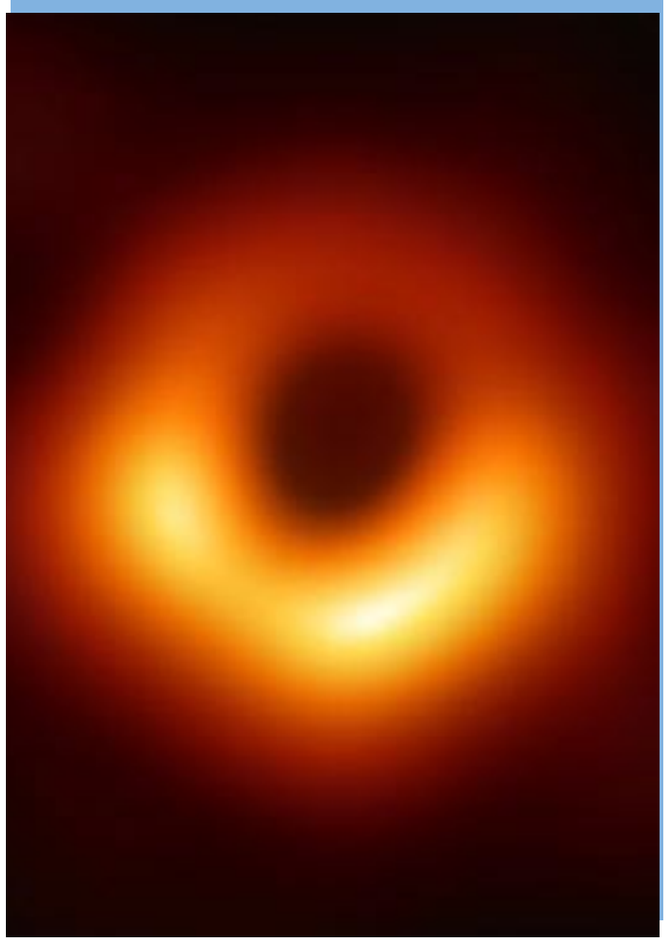
Short-term program

Question: Can we make an agent learn “physical laws” in a toy example, so that they can be extracted?

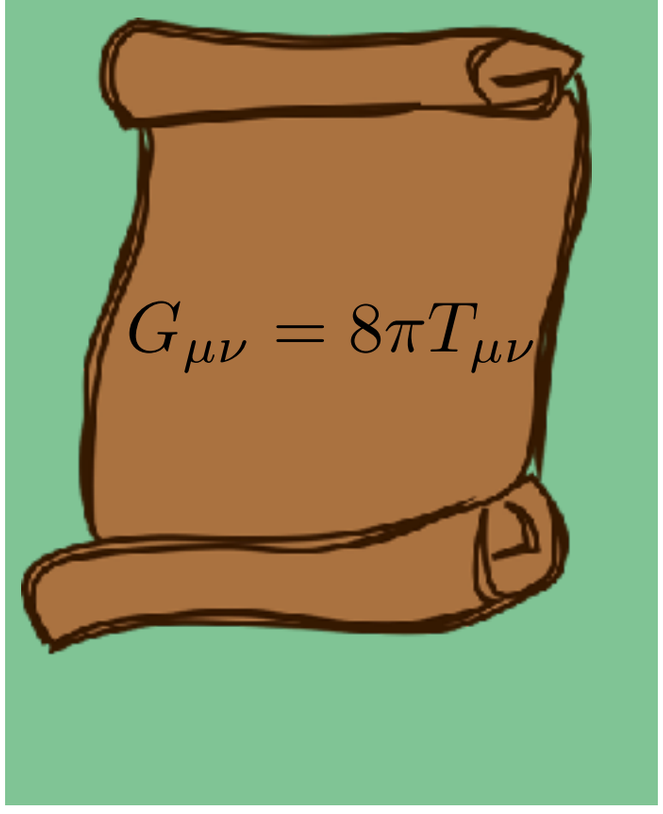


What is a physical law?

physical world



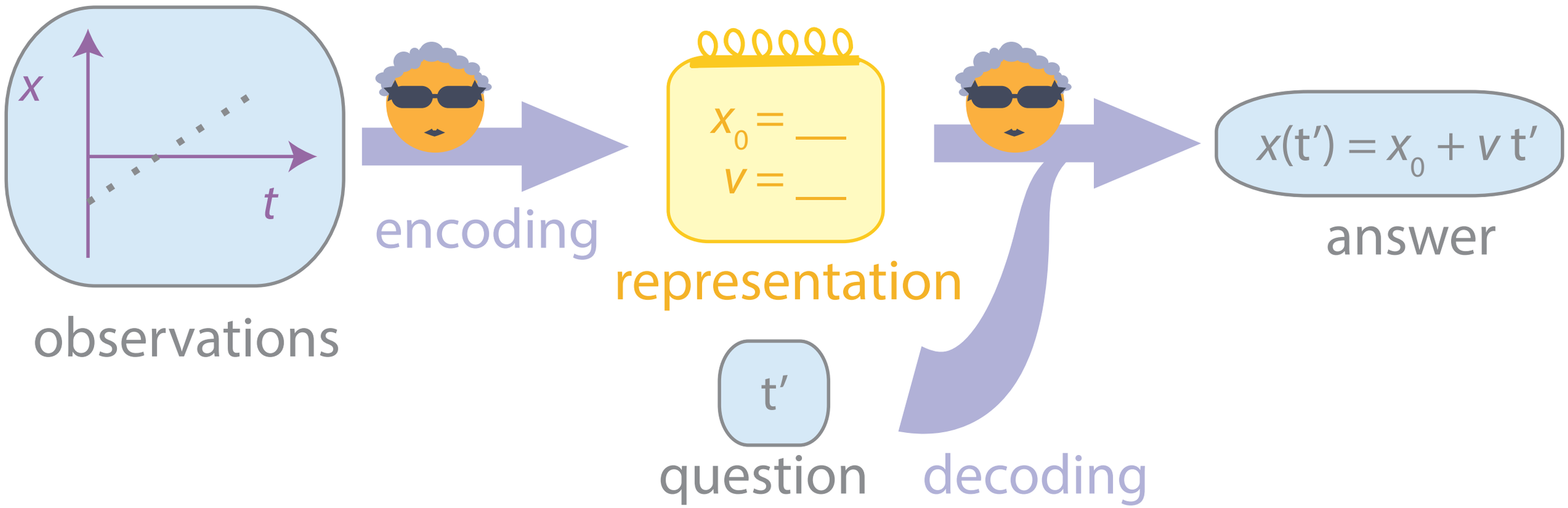
law



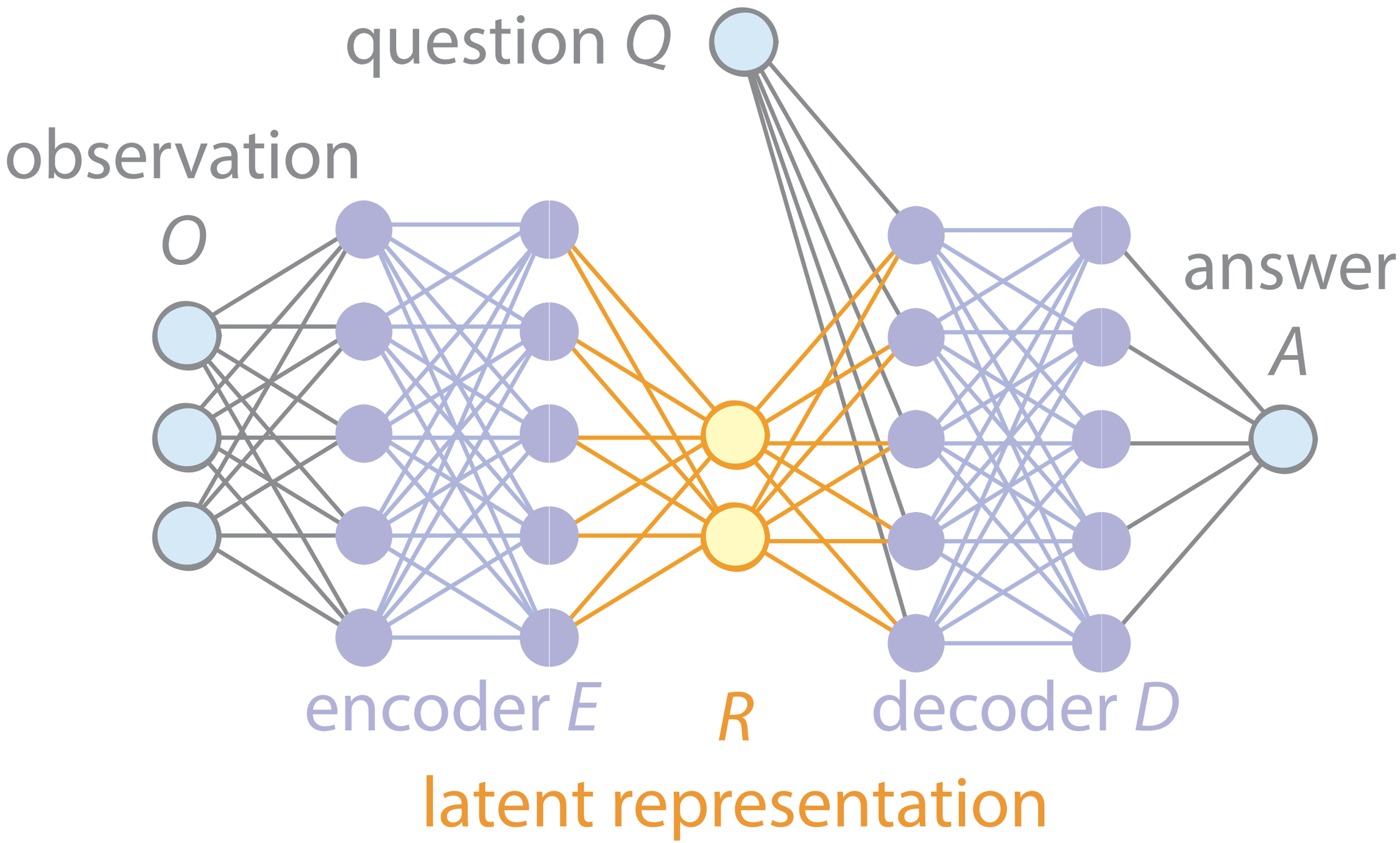
compressed description

physical world

Asking questions



SciNet


question Q
observation
O
answer
A
encoder E
R
decoder D
latent representation

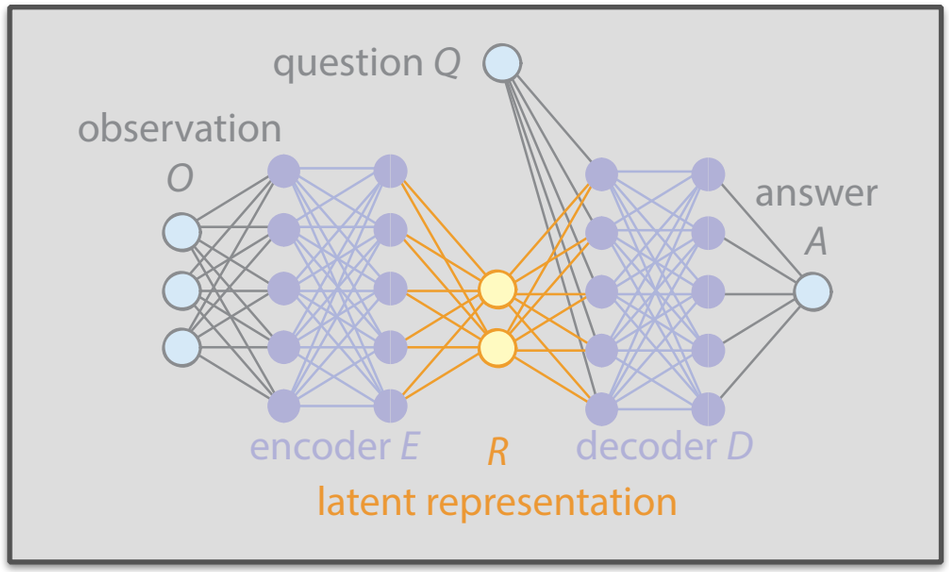
Example 1: Damped pendulum

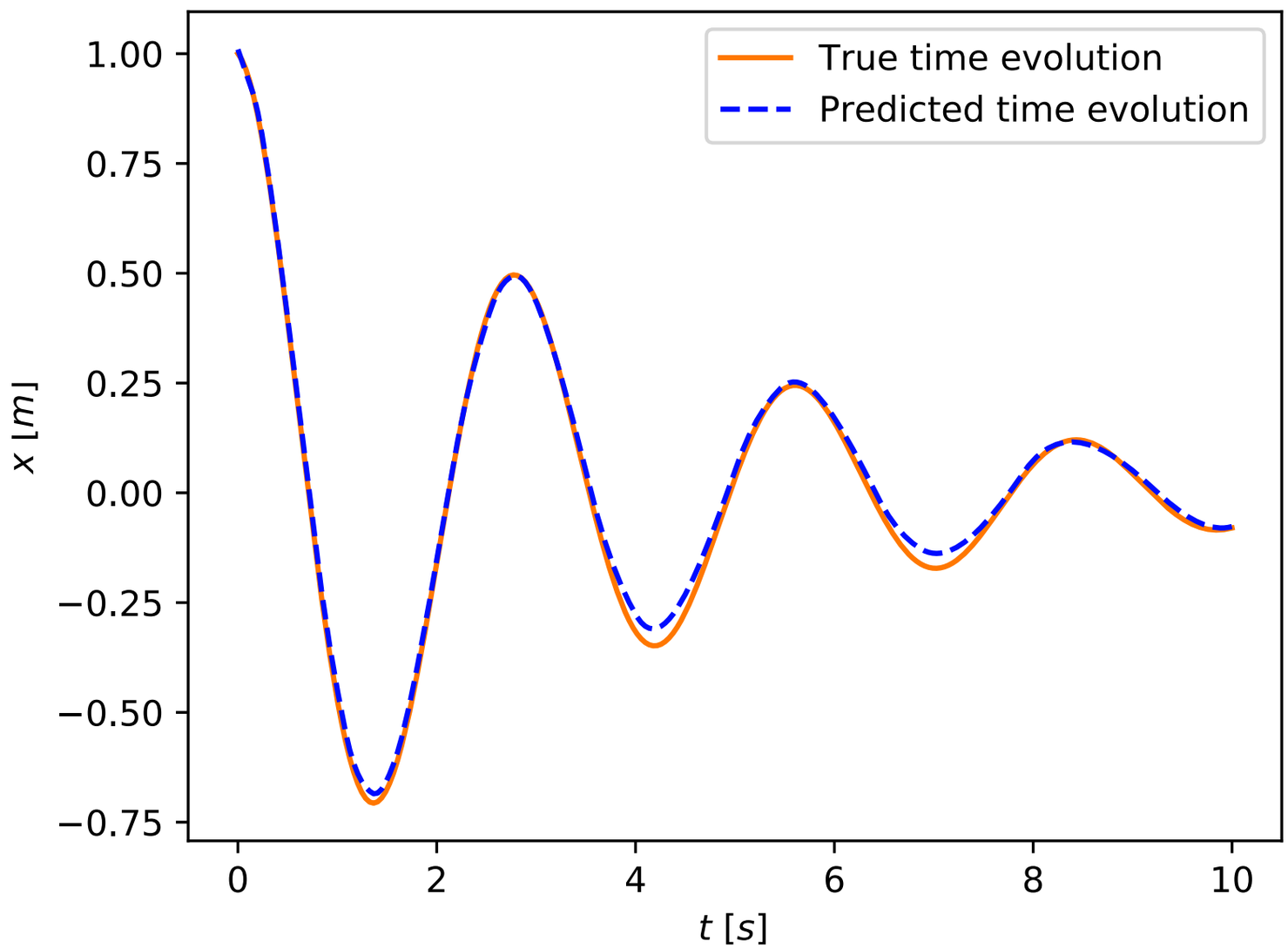
Physical model: $-\kappa x - b\dot{x} = m\ddot{x}$

"Law" defined by: κ, b

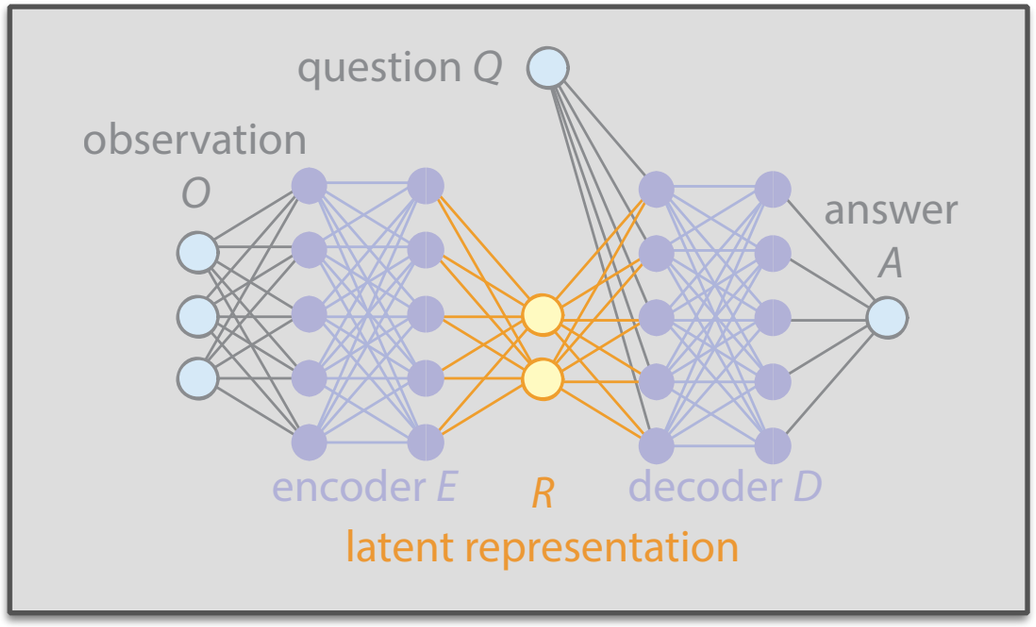
Observation: $\{x(t)\}_t$

Question: $x(t')$ for time t'

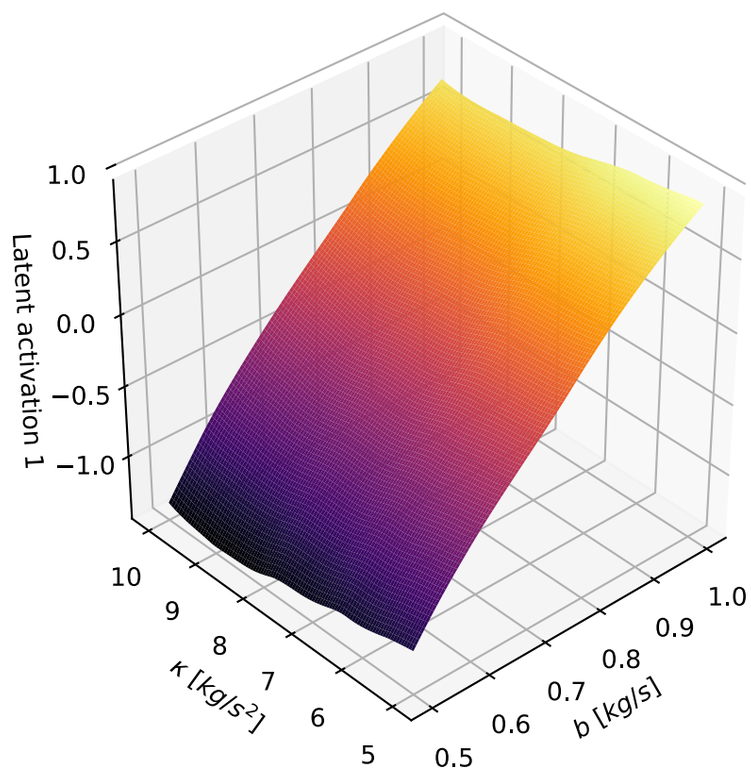




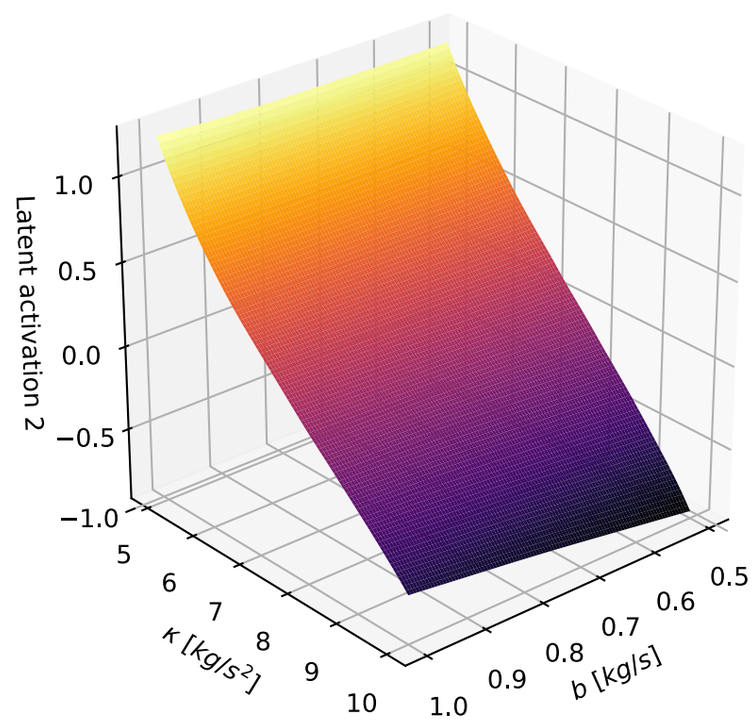
Example 1: Damped pendulum



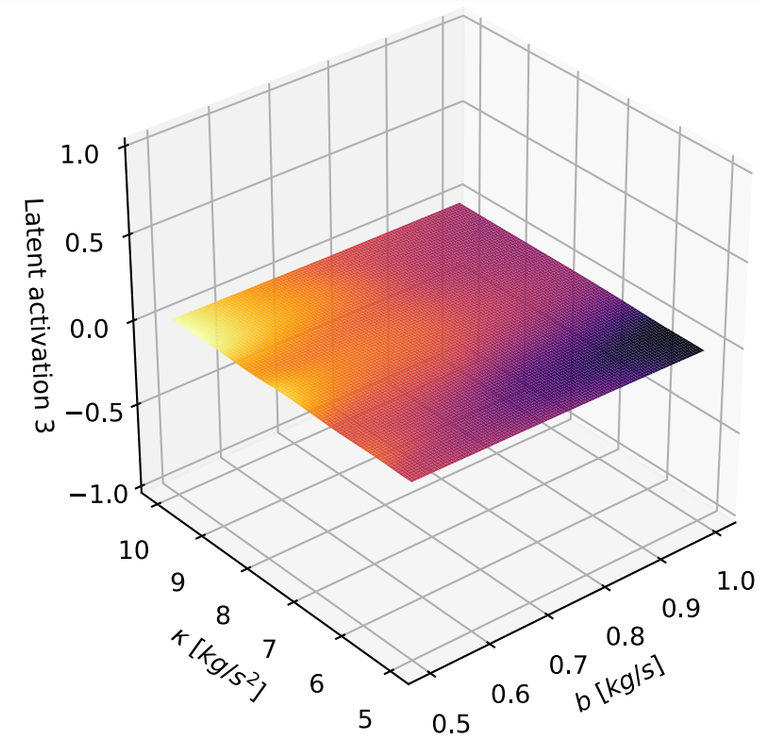
Latent representation



Latent neuron 1

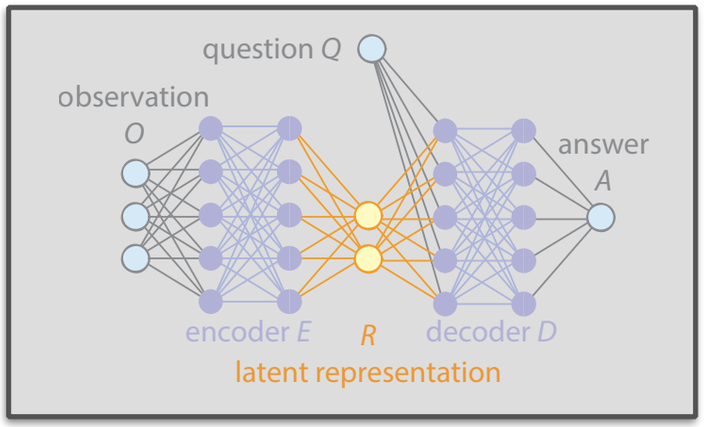


Latent neuron 2



Latent neuron 3

Example 2: Tomography of qubits



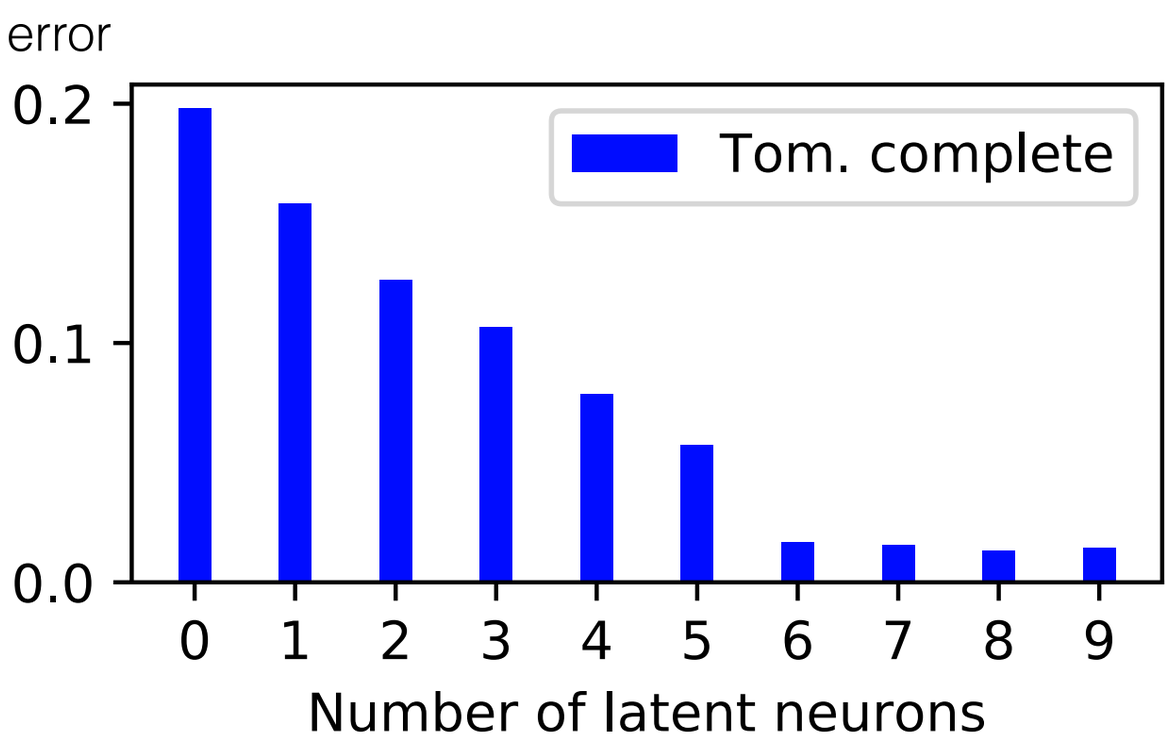
Physical model: $P(x|\psi) = |\langle \phi_x | \psi \rangle|^2$

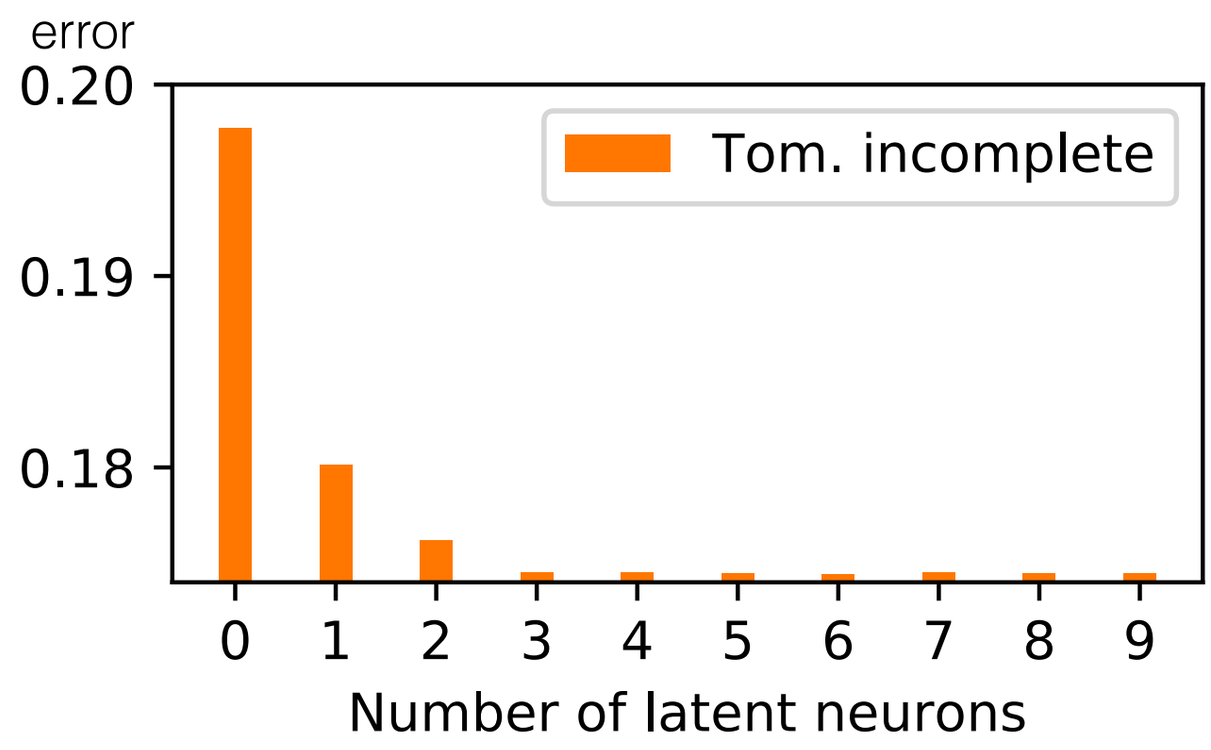
"Law" defined by: $|\psi\rangle$

Observation: $\{P(x|\psi)\}_x$

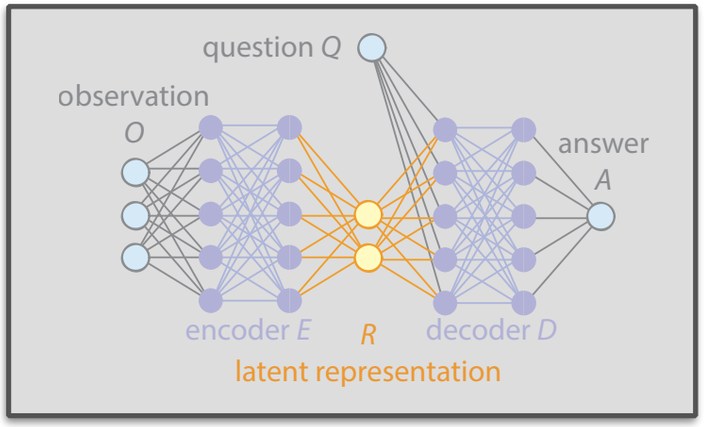
Question: $P(x'|\psi)$ for measurement x'

Latent representation

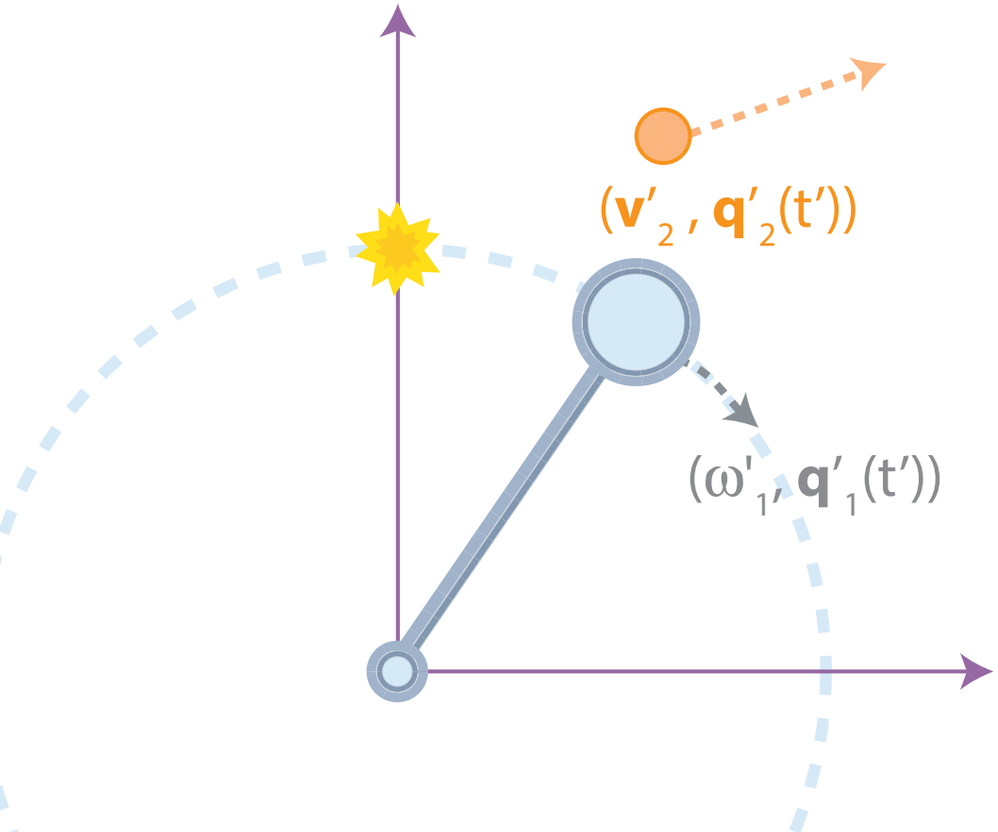




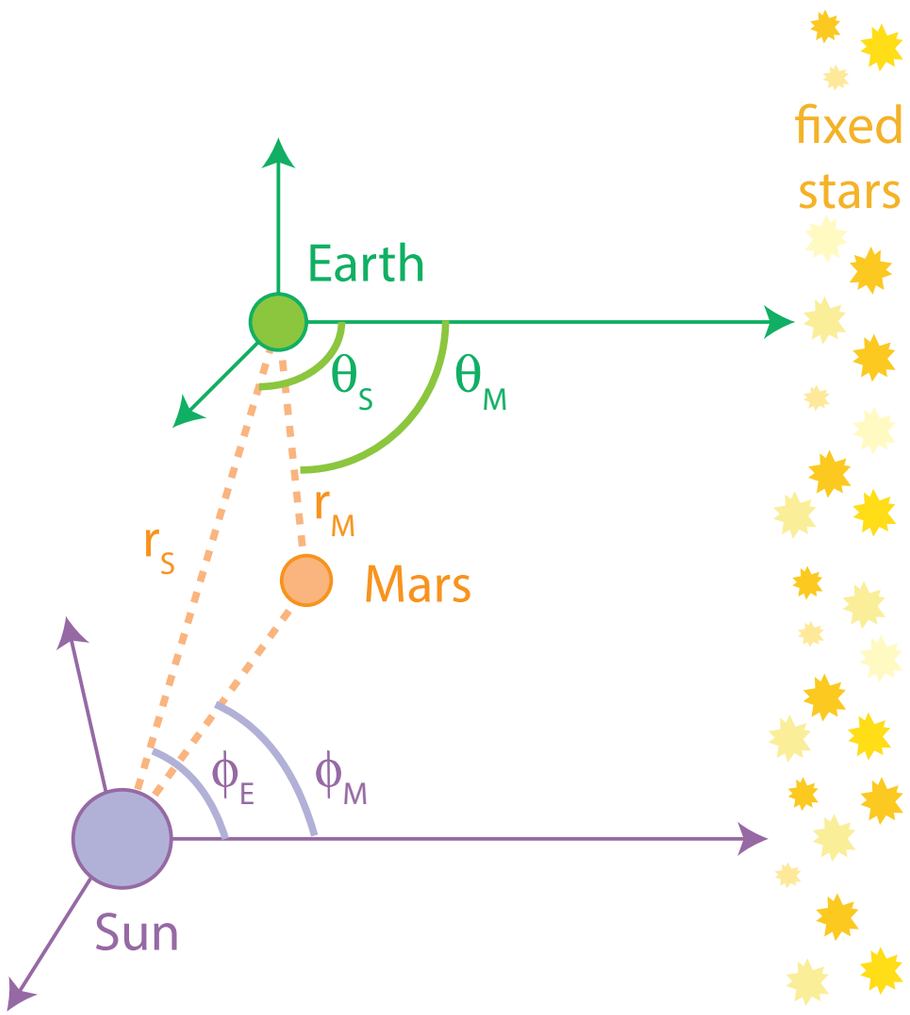
Other examples



Angular momentum conservation

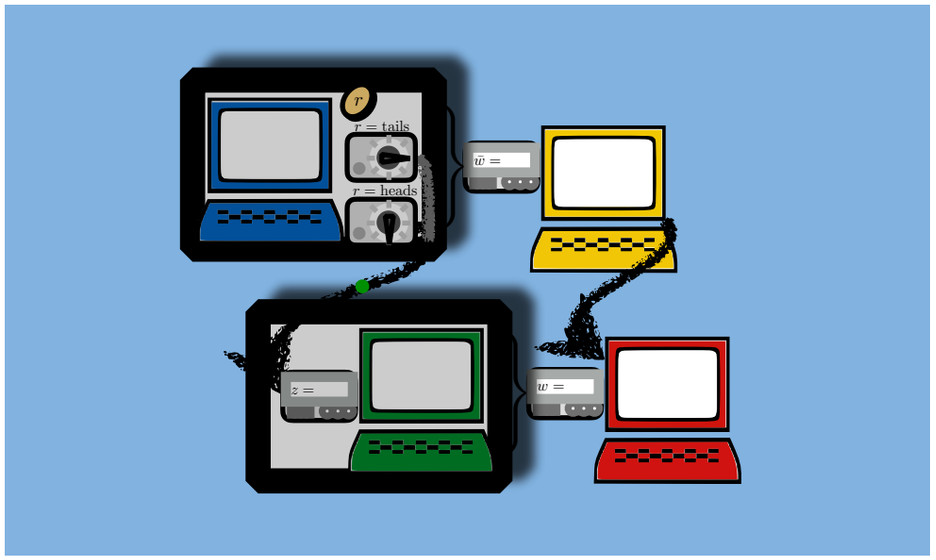


Copernicus

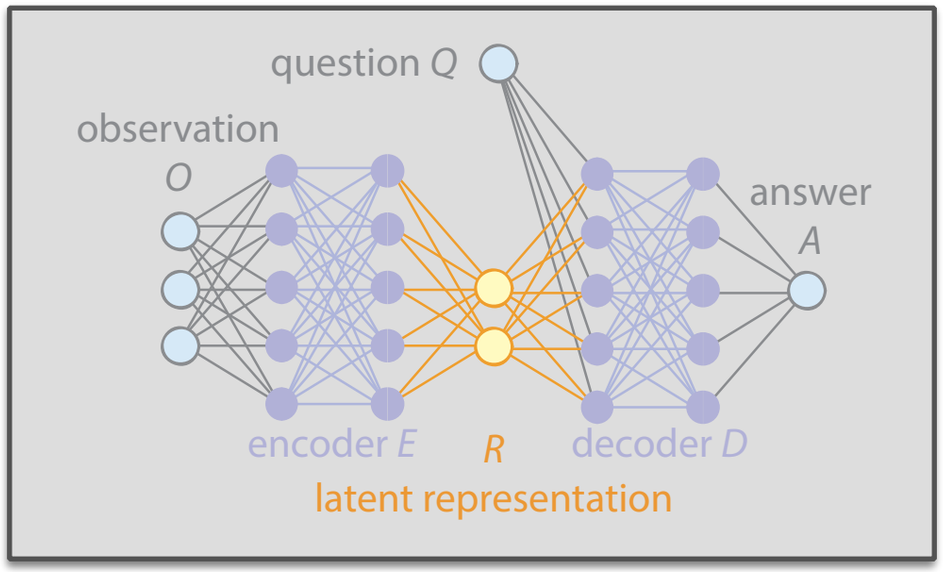


Summary

Long-term goal: Develop a variant of quantum theory that can consistently describe agents who are using the theory.



First step: SciNet, a network architecture that enables the extraction of the learned laws. (So far only tested for toy examples.)



Thank you for your attention

For more details, see

R. Iten, T. Metger, Henrik Wilming, Lidia del Rio, and RR
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arXiv:1807.10300

QSIT Quantum Science and Technology
National Centre of Competence in Research

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Swiss National Science Foundation

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Air Force Office of Scientific Research
United States Air Force