

CORRELATION AS A RESOURCE

THE ROLE OF REDUNDANT CORRELATED RECORDS IN THE EMERGENCE OF OBJECTIVE CLASSICAL REALITY

Vishal Johnson^{1,2,†} Ashmeet Singh³ Torsten Enßlin^{1,2}

November 26, 2025

¹Max-Planck-Institut für Astrophysik, Garching ²Ludwig-Maximilians-Universität, München ³Whitman College, Walla Walla

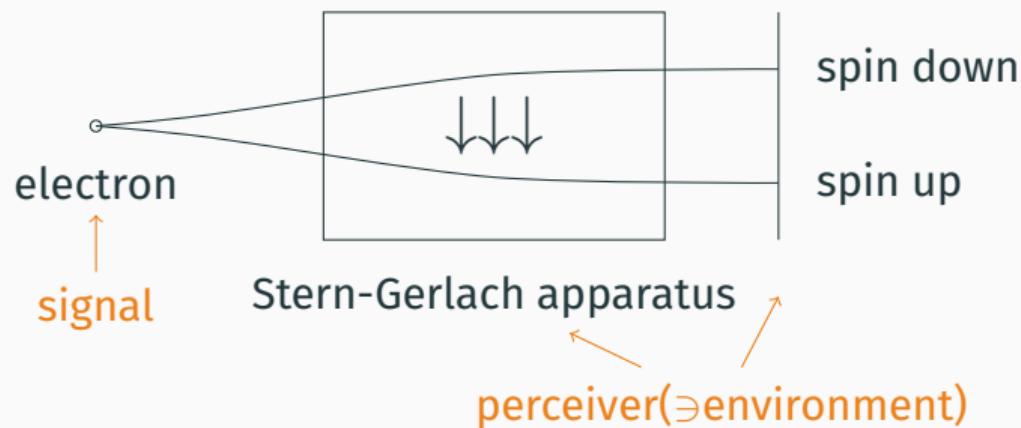
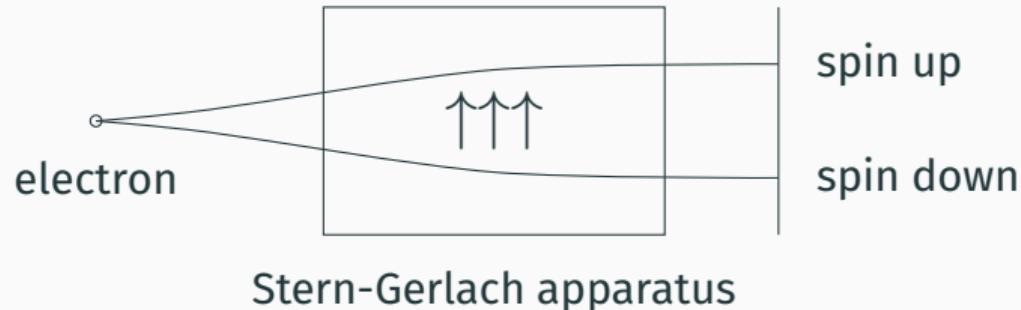
† vishal@mpa-garching.mpg.de

Quantum25



MOTIVATION

MOTIVATION: STERN GERLACH



OBJECTIVE CLASSICAL REALITY

Definition (Objective Classical Reality¹)

The state of a signal s exists objectively if multiple observers (o_α) can probe the signal independently and without disturbing it.

↑
jointly called perceiver

¹Horodecki, R., Korbicz, J. K., and Horodecki, P. Phys. Rev. A. Mar. 2015.

NO-GO THEOREM

No-GO THEOREM

not all true:

1. unitary quantum mechanics holds universally ✓
2. for $|\phi\rangle \in \Phi \subseteq \mathcal{H}_p$

$$\mathcal{U}_{s \rightarrow p}^{\text{meas}} |\psi\rangle_s |\phi\rangle_p = \sum \mathbb{P}_m |\psi\rangle_s |\mathcal{P}_{m\phi}\rangle_p \text{ (objective classical reality)} \quad (1)$$

3. measurement outcomes distinguishable: ✓

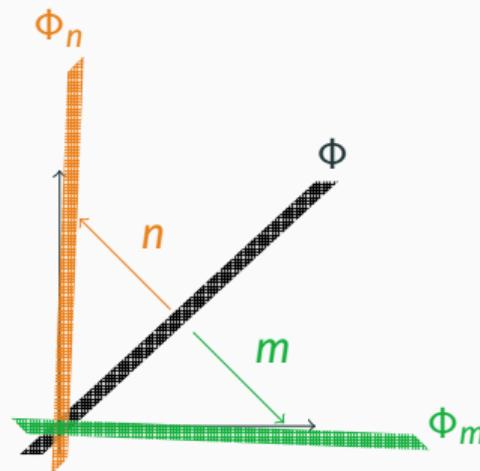
$$\langle \mathcal{P}_{m\chi} | \mathcal{P}_{n\phi} \rangle = \delta_{mn} \langle \mathcal{P}_{m\chi} | \mathcal{P}_{m\phi} \rangle \quad (2)$$

4. finite dimensional Hilbert spaces ✓
5. arbitrary initial state ($\Phi = \mathcal{H}_p$) ✗

NO-GO THEOREM: SIMPLE ARGUMENT

outcome m subspace: $\Phi_m = \{|\mathcal{P}_{m\phi}\rangle \forall |\phi\rangle \in \Phi\}$

$$m \neq n \implies \Phi_m \perp \Phi_n$$



$$\implies \Phi \subset \mathcal{H}_p$$

QUDIT MEASUREMENT PROCEDURE

CORRELATED PERCEIVER

signal: $\mathcal{H}_s = \mathbb{C}^d$

perceiver: $\mathcal{H}_p = (\mathbb{C}^d)^{\otimes N}$

$$\mathbb{C}^d \sim \Phi \ni |\phi\rangle_p = \sum_l \phi_l |l\rangle_{p_1} |l\rangle_{p_2} \dots |l\rangle_{p_N} \quad (3)$$

TRANSFERRING CORRELATION (IMPRINT)

$$\begin{aligned}\mathcal{I}_{a \rightarrow b} |m\rangle_a |n\rangle_b &= |m\rangle_a |n + m\rangle_b \\ \mathcal{I}_{a \rightarrow b}^{-1} |m\rangle_a |n\rangle_b &= |m\rangle_a |n - m\rangle_b\end{aligned}\tag{4}$$

QUDIT MEASUREMENT PROCEDURE

$$\begin{aligned} |\psi\rangle_s |\phi\rangle_p &= \sum \psi_m \phi_l \ |m\rangle_s |l\rangle_{p_1} |l\rangle_{p_2} \dots |l\rangle_{p_N} \\ &\quad \downarrow \mathcal{I}_{s \rightarrow p_1} \\ &|m\rangle_s |l+m\rangle_{p_1} |l\rangle_{p_2} \dots |l\rangle_{p_N} \\ &\quad \downarrow \mathcal{I}_{p_2 \rightarrow p_1}^{-1} \\ &|m\rangle_s |l+m-l\rangle_{p_1} |l\rangle_{p_2} \dots |l\rangle_{p_N} \\ &\hookrightarrow \left(\sum \psi_m |m\rangle_s |m\rangle_{p_1} \right) \left(\sum \phi_l |l\rangle_{p_2} \dots |l\rangle_{p_N} \right) \end{aligned} \tag{5}$$

repeating:

$$\left(\sum \psi_m |m\rangle_s |m\rangle_{p_1} \dots |m\rangle_{p_K} \right) \left(\sum \phi_l |l\rangle_{p_{K+1}} \dots |l\rangle_{p_N} \right) \tag{6}$$

correlation is a resource!

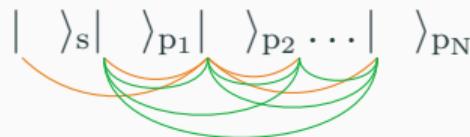
NUMERICAL RESULTS

CORRELATION PROXY

pairwise correlations : level of agreement of measurement outcomes

$$C_\alpha : \sum \text{pairwise correlations with qudit } \alpha \quad (7)$$

$$C_p : \sum_{\alpha \in \text{per}} C_\alpha$$

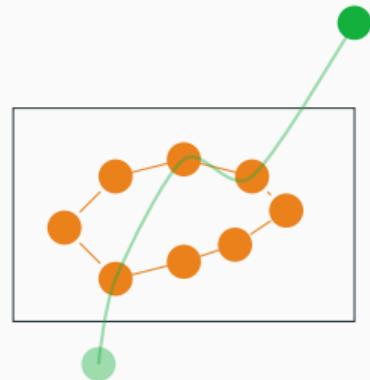


compare initial C_p with final C_s !

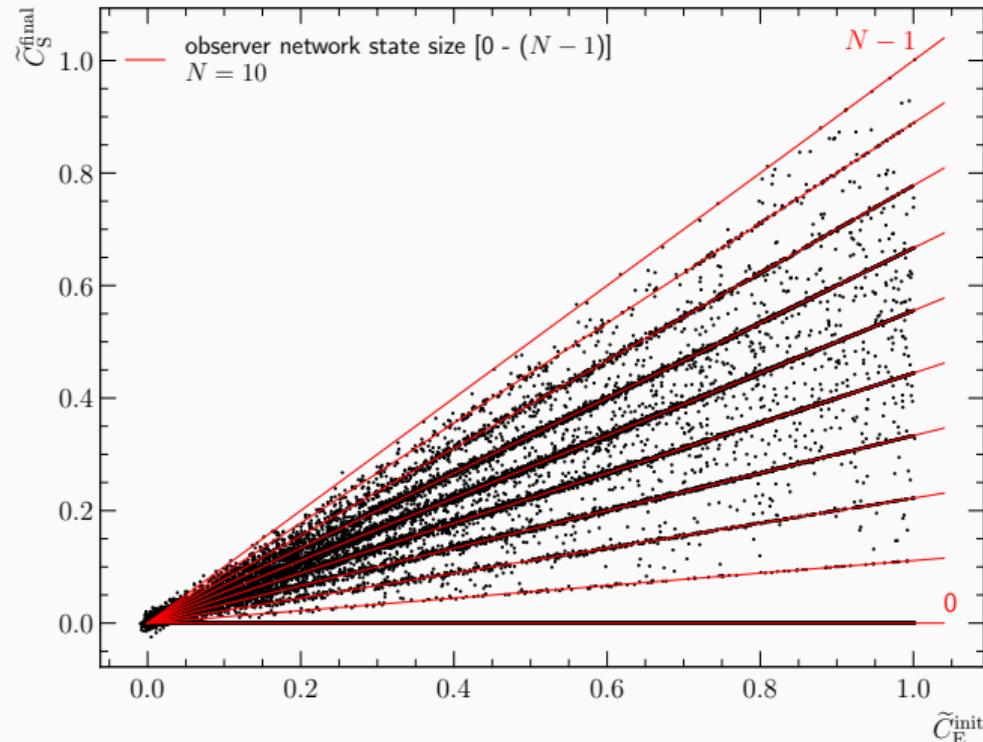
SIMULATION PROCEDURE

$$\mathcal{H}_s = \mathbb{C}^2$$

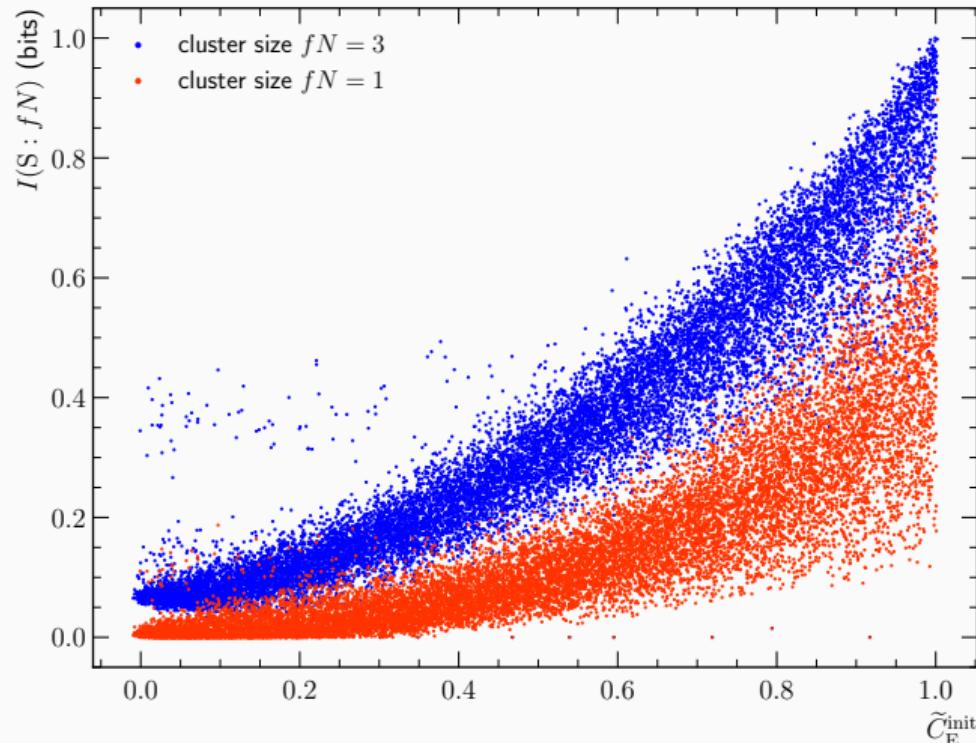
$$\mathcal{H}_p = (\mathbb{C}^2)^{\otimes N}$$



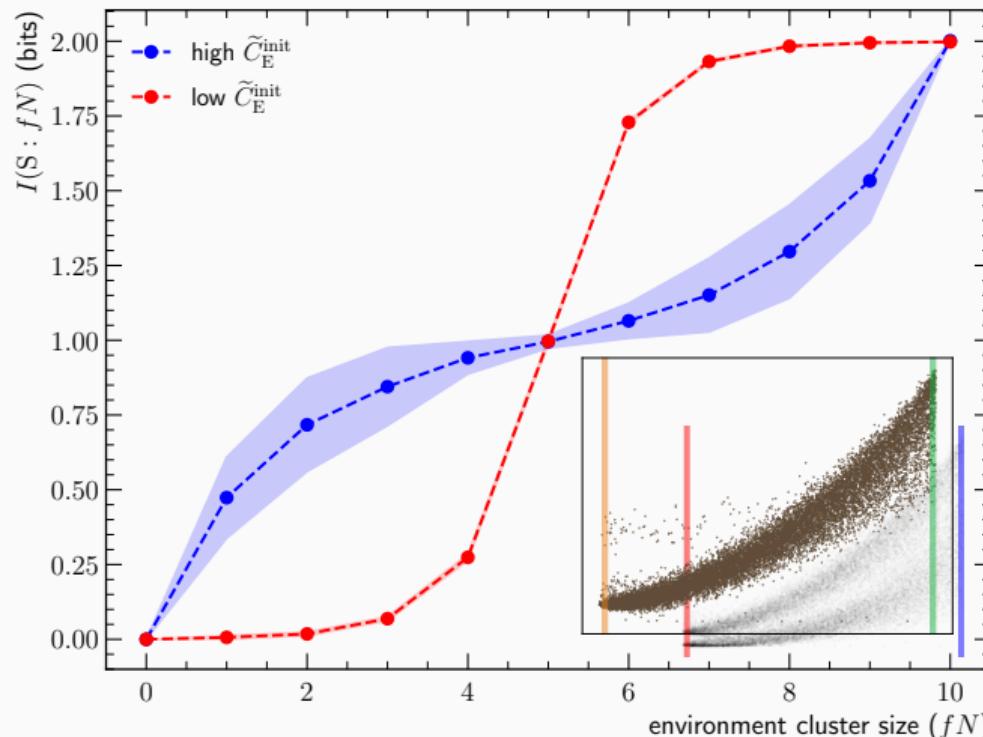
SIMULATION RESULTS: C_S VS C_P



SIMULATION RESULTS: MUTUAL INFORMATION VS $-C_p$



SIMULATION RESULTS: MUTUAL INFORMATION PLATEAU?



SUMMARY

SUMMARISING

- special initial state for perceiver
- correlation is a resource
- simulations confirm hypothesis
- how did correlation emerge?
- experimental confirmation?

THANKS! ANY QUESTIONS?
