Broadcasting quantum information

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Superbroadcasting

Buscemi

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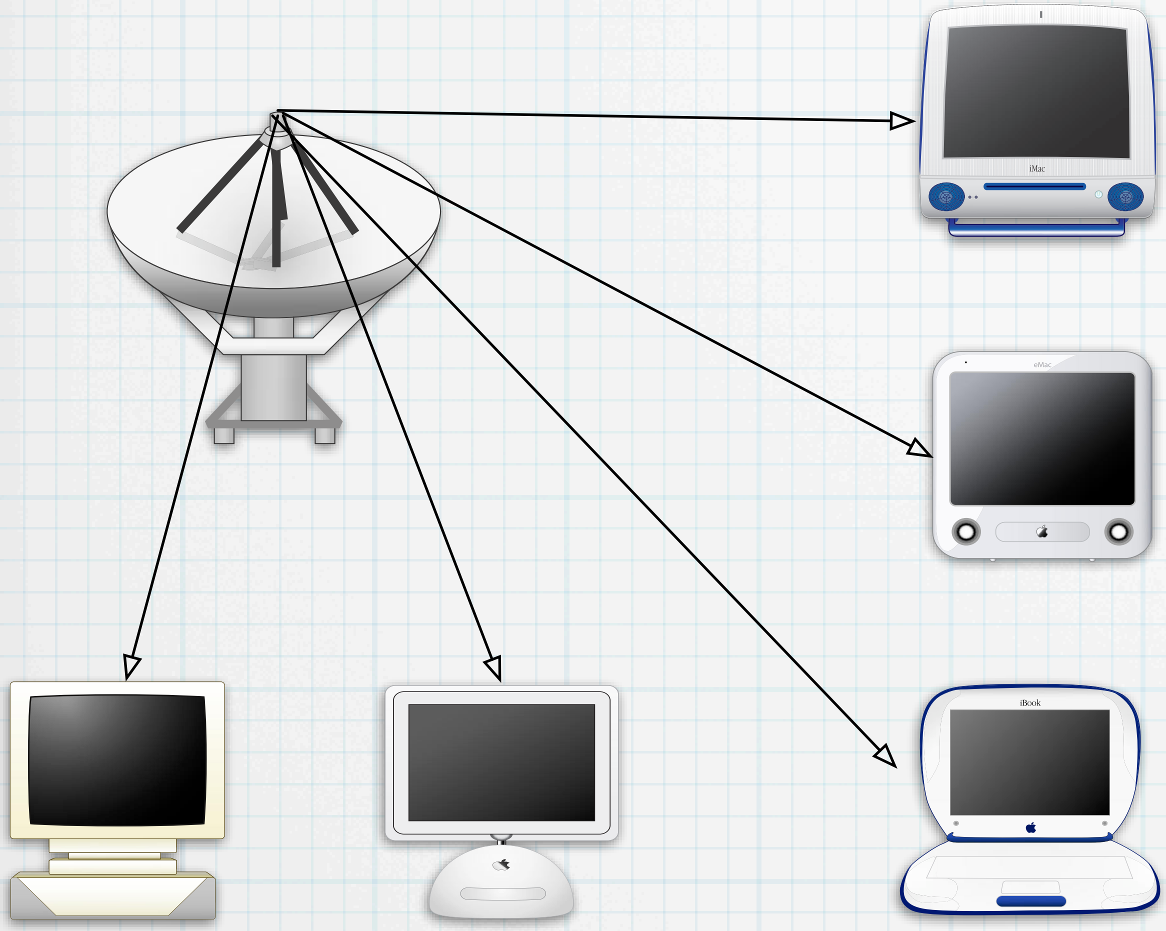
Macchiavello

Perinotti

G. M. D'Ariano, C. Macchiavello, and P. Perinotti,
Superbroadcasting of mixed states, Phys. Rev. Lett. **95** 060503 (2005)

F. Buscemi, G. M. D'Ariano, C. Macchiavello, and P. Perinotti,
(in preparation)

Broadcasting



"Information" is by its nature **broadcastable**.

What about when information is ***quantum***?

- Distributed quantum computation
- Quantum secret sharing
- Quantum game-theoretical contexts...

Broadcasting quantum information can be done only in a limited fashion

No cloning theorem

$$N \text{ inputs} \Rightarrow M \text{ outputs}$$

$$\underbrace{|\psi\rangle \otimes \ldots \otimes |\psi\rangle}_{N} \Longrightarrow \underbrace{|\psi\rangle \otimes |\psi\rangle \otimes \ldots \otimes |\psi\rangle}_{M}, \quad \forall |\psi\rangle \in \mathsf{H}$$

For $M>N$ the transformation cannot be achieved isometrically, whence it cannot occur with unit probability.

$$|E\rangle \otimes \underbrace{|\psi\rangle \otimes \ldots \otimes |\psi\rangle}_{N} \otimes |\omega_1\rangle \otimes \ldots \otimes |\omega_{M-N}\rangle \Longrightarrow |E_\psi\rangle \otimes \underbrace{|\psi\rangle \otimes |\psi\rangle \otimes \ldots \otimes |\psi\rangle}_{M}$$

$$|\langle\varphi|\psi\rangle|^N \Longrightarrow |\langle E_\varphi|E_\psi\rangle||\langle\varphi|\psi\rangle|^M$$

Cloning/Broadcasting

$$N \text{ inputs} \Rightarrow M \text{ outputs}$$

$$\begin{array}{rcl} R_{out} = & \rho \otimes \rho \otimes \ldots \otimes \rho & \quad \text{"}cloning\text{"} \\ \mathrm{Tr}_{123\ldots M-1}[R_{out}] = & \mathrm{Tr}_{23\ldots M}[R_{out}] = \rho & \quad \text{"}broadcasting\text{"} \end{array}$$

- For pure states ideal broadcasting coincides with the *quantum cloning.*
- For mixed states there are infinitely many joint states that correspond to the same local state.

No-broadcasting

- For mixed input states the ***no-cloning theorem*** is not logically sufficient to forbid ideal broadcasting

- The ***impossibility of ideal broadcasting*** has been proved in the case of one input copy and two output copies for ***non mutually commuting density operators*** [H. Barnum, C. M. Caves, C. A. Fuchs, R. Jozsa, and B. Schumacher, Phys. Rev. Lett. **76** 2818 (1996)]

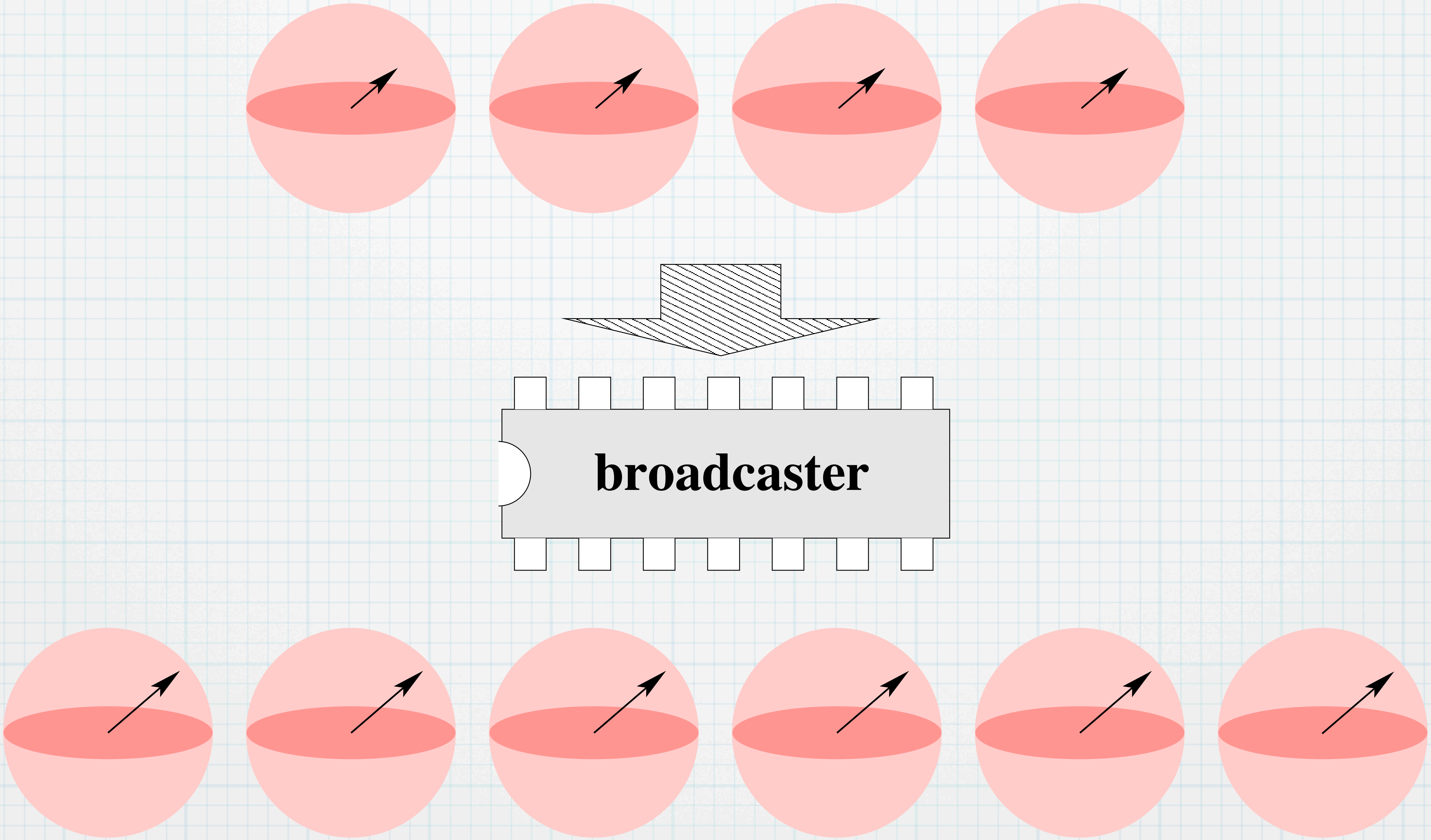
Is this a generalization of the no-cloning theorem to mixed states?

Superbroadcasting

The answer is no!

- *The no broadcasting theorem does not generalize to multiple input copies!*
- For sufficiently many input copies *it is even possible to purify the state while broadcasting!*
- ***broadcasting + purification: "superbroadcasting".***

Universally covariant superbroadcasting



$$\rho_{\boldsymbol{n}} = \frac{1}{2}(I + r\boldsymbol{n} \cdot \boldsymbol{\sigma})$$

Universally covariant superbroadcasting

shrinking/stretching factor $p(r) = r'_{opt}(r)/r$

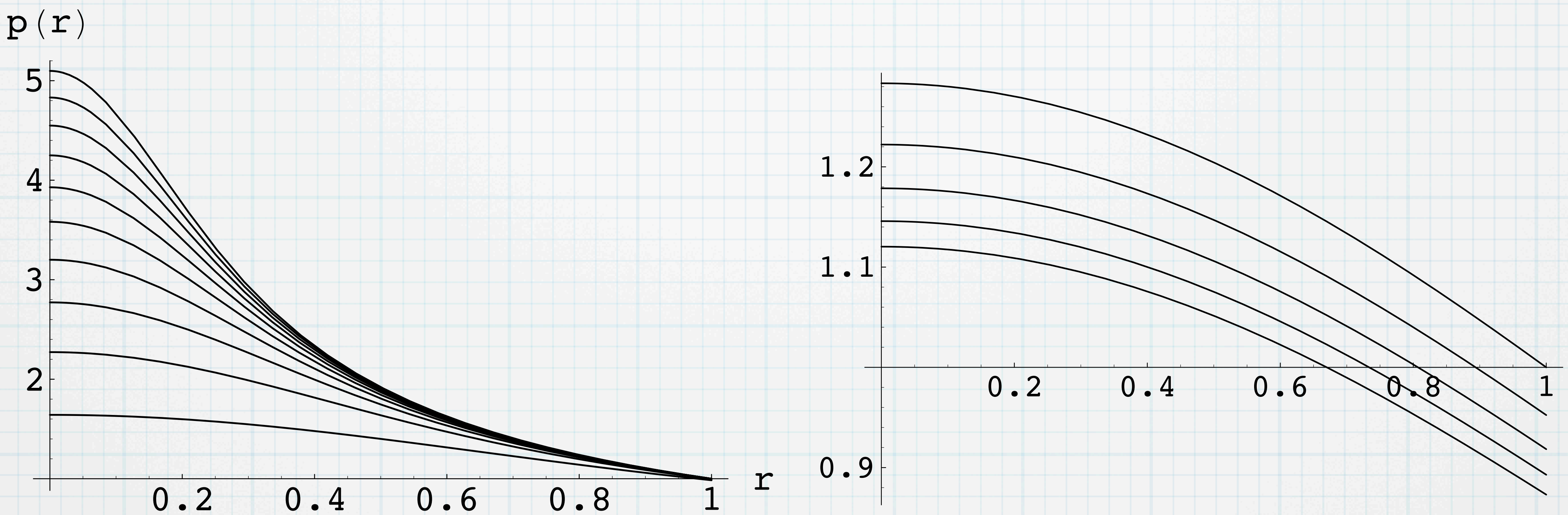
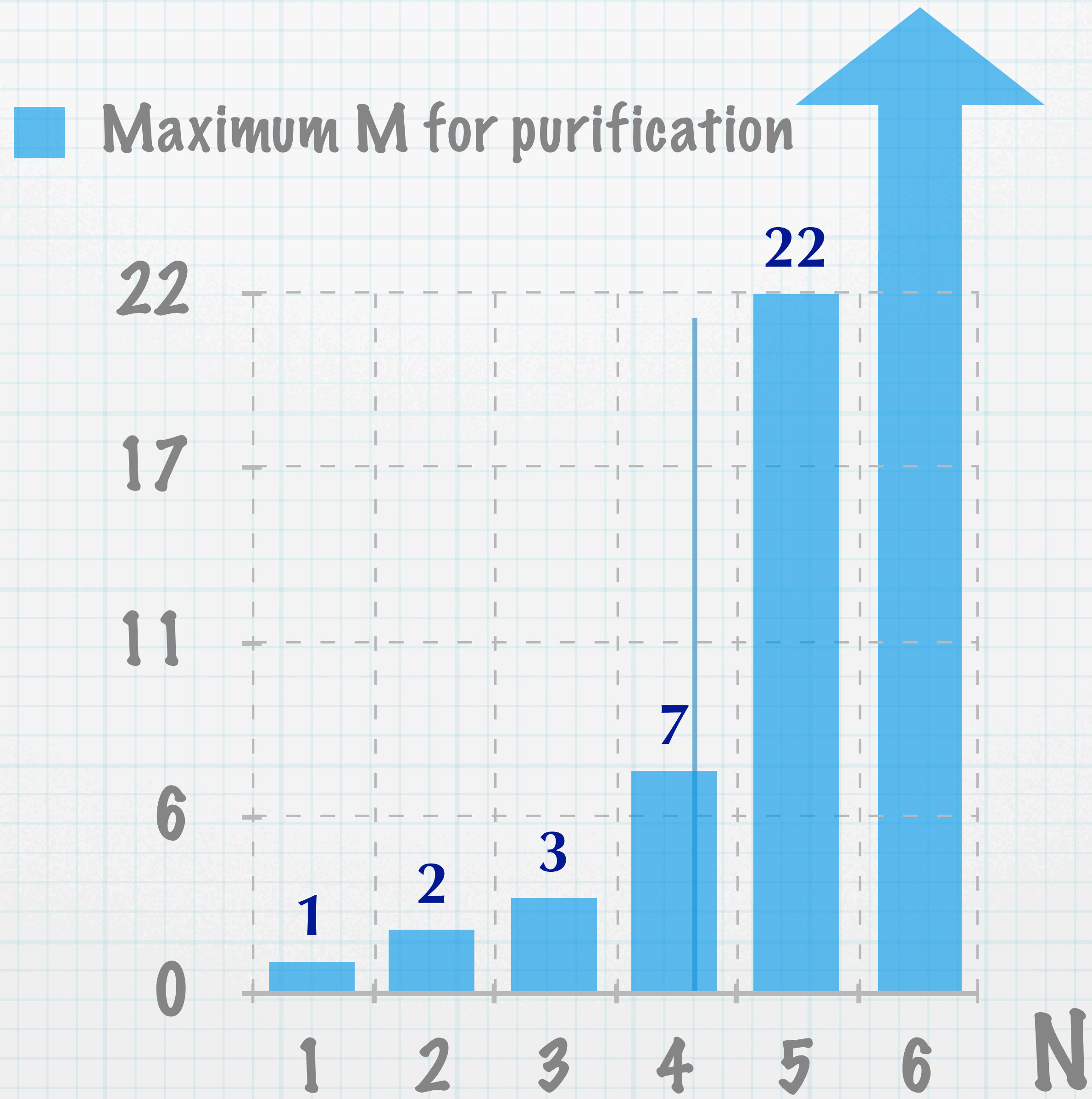


FIG. 2: The stretching factor $p(r)$ versus r. On the left: for $M = N + 1$ and $N = 10, 20, 30, 40, 50, 60, 70, 80, 90, 100$ (from the bottom to the top. On the right: for $N = 5$ and $5 \leq M \leq 9$ (from the top to the bottom).

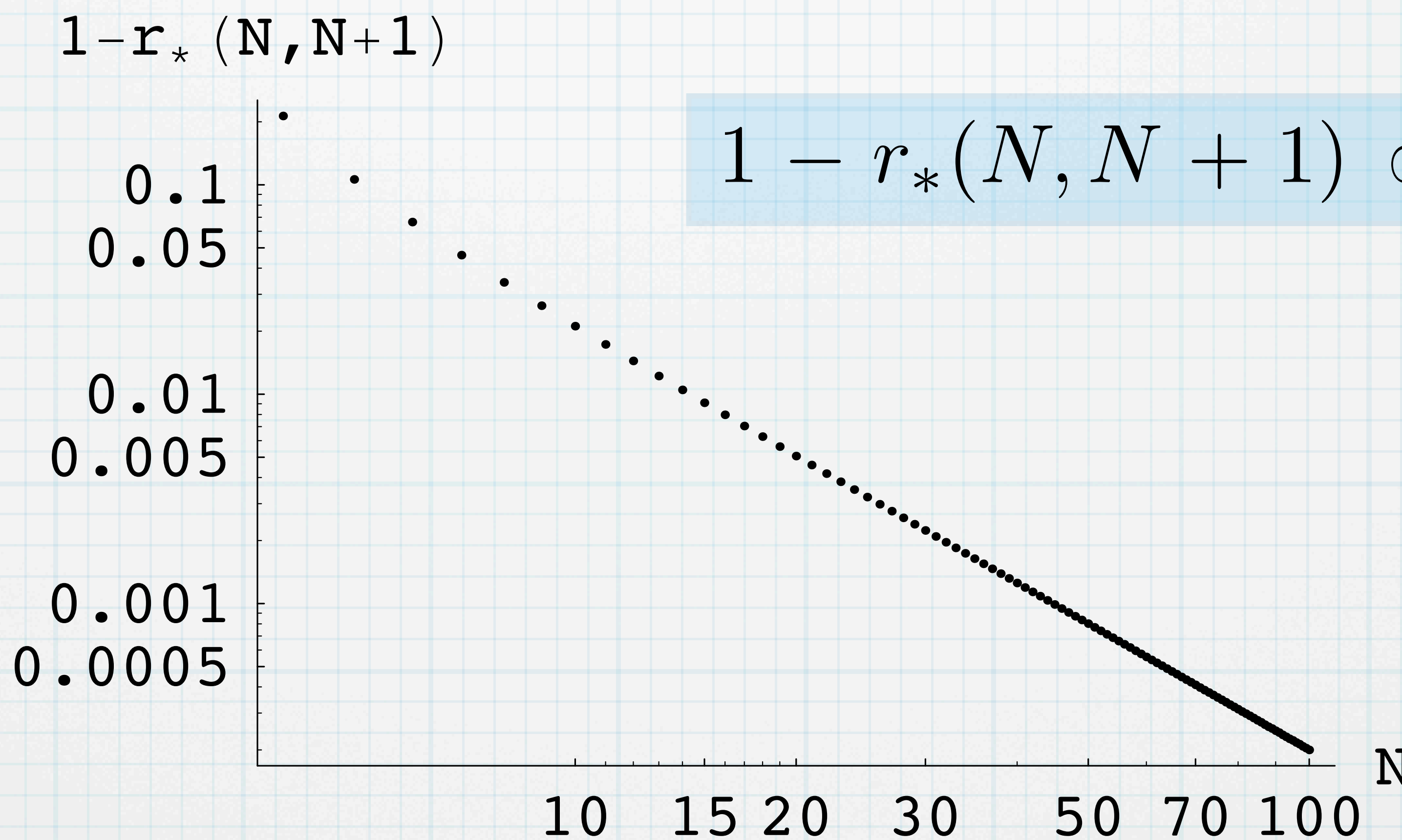
Universally covariant superbroadcasting



Universally covariant superbroadcasting

shrinking/stretching factor $$p(r) = r'_{opt}(r)/r$$

$r_*(N, M)$ *maximum purity for purification*



$$1 - r_*(N, N+1) \propto 2N^{-2}$$

FIG. 3: Logarithmic plot of $1 - r_*(N, N+1)$ versus N. $r_*(N, M)$ denotes the maximum purity for which one can have superbroadcasting from N to M copies.

Universally covariant superbroadcasting

- For pure states the optimal superbroadcasting map is the same as the optimal universal cloning [R. F. Werner, Phys. Rev. A **58** 1827 (1998)].
- For $M<N$ it corresponds to the optimal purification map [J. I. Cirac, A. K. Ekert, and C. Macchiavello, Phys. Rev. Lett. **82** 4344 (1999)].
- Therefore, the superbroadcasting map generalizes and ***interpolates optimal purification and optimal cloning***.

skip derivation

GNS representation

cyclic vector $|I\rangle\rangle \in \mathsf{H} \otimes \mathsf{H}$

$\Psi \in \mathsf{HS}(\mathsf{K}, \mathsf{H}), \qquad |\Psi\rangle\rangle = (\Psi \otimes I)|I\rangle\rangle$

transposition

$$|\Psi\rangle\rangle = (\Psi \otimes I)|I\rangle\rangle = (I \otimes \Psi^{\intercal})|I\rangle\rangle$$

complex conjugation

$$X^* \doteq (X^{\intercal})^{\dagger}$$

$$(|v\rangle\langle v| \otimes I)|I\rangle\rangle = |v\rangle|v^*\rangle$$

$$|\Psi\rangle\rangle = \sum_{nm} \Psi_{nm}|n\rangle \otimes |m\rangle.$$

$$(A \otimes B)|C\rangle\rangle = |AC\,B^{\intercal}\rangle\rangle$$

$$\langle\langle A|B\rangle\rangle \equiv \mathrm{Tr}[A^{\dagger}B].$$

GNS simplified

Choi-Jamiolkowski

Choi-Jamiołkowski correspondence

$$\mathscr{M}(\rho) = \mathrm{Tr}_{\mathrm{in}}[(I_{\mathrm{out}} \otimes \rho^{\mathsf{T}})R_{\mathscr{M}}] \quad \mathscr{M} : \mathsf{S}(\mathsf{H}_{\mathrm{in}}) \to \mathsf{S}(\mathsf{H}_{\mathrm{out}})$$

$$R_{\mathscr{M}} = \mathscr{M} \otimes \mathscr{I}(|I\rangle\rangle\langle\langle I|) \in \mathsf{B}(\mathsf{H}_{\mathrm{out}} \otimes \mathsf{H}_{\mathrm{in}})$$

$$|I\rangle\rangle = \sum_{n=1}^{d} |n\rangle_{\mathrm{in}} \otimes |n\rangle_{\mathrm{in}} \in \mathsf{H}_{in} \otimes \mathsf{H}_{in}$$

Broadcasting *N--->M:*

$$\mathsf{H}_{\mathrm{in}} = \mathsf{H}^{\otimes N}$$

$$\mathsf{H}_{\mathrm{out}} = \mathsf{H}^{\otimes M}$$

$$\mathsf{H} = \mathbb{C}^2$$

Trace preserving condition:

$$\mathrm{Tr}_{\mathrm{out}}[R_{\mathscr{M}}] = I_{\mathrm{in}}$$

Covariance and invariance constraints are easier to handle

$$\mathscr{M}(U_g \rho U_g^\dagger) = W_g \mathscr{M}(\rho) W_g^\dagger \Leftrightarrow [W_g \otimes U_g^*, R_{\mathscr{M}}] = 0$$

$$\mathscr{M}(T_h \rho T_h^\dagger) = \mathscr{M}(\rho) \Leftrightarrow [I \otimes T_h^*, R_{\mathscr{M}}] = 0$$

$$V_k \mathscr{M}(\rho) V_k^\dagger = \mathscr{M}(\rho) \Leftrightarrow [V_k \otimes I, R_{\mathscr{M}}] = 0$$

Conjugation/covariance

"conjugation": $CUC^\dagger = U^*$

$$C \equiv (i\sigma_y)^{\otimes N} \qquad \tilde{Q} \doteq CQ^\intercal C^\dagger$$

$$S_{\mathscr{B}} \doteq (I_{\text{out}} \otimes C) R_{\mathscr{B}} (I_{\text{out}} \otimes C^\dagger)$$

$$\mathscr{B}(Q) = \mathrm{Tr}_{\text{in}}[(I_{\text{out}} \otimes \tilde{Q}) S_{\mathscr{B}}]$$

Completely positive trace-preserving map from states of N qubits to states of M qubits that is invariant under permutations of input copies and of output copies and unitarily covariant

$$\Pi_\sigma \mathscr{B}(\Pi_\tau \rho \Pi_\tau^\dagger) \Pi_\sigma^\dagger = \mathscr{B}(\rho)$$

$$[\Pi_\sigma \otimes \Pi_\tau, S_{\mathscr{B}}] = 0$$

$$\mathscr{B}(U^{\otimes N} \rho^{\otimes N} U^{\dagger \otimes N}) = U^{\otimes M} \mathscr{B}(\rho^{\otimes N}) U^{\dagger \otimes M}$$

$$[U^{\otimes (M+N)}, S_{\mathscr{B}}] = 0$$

Schur-Weyl duality

We exploit the Schur-Weyl duality

$$[\mathbb{SU}(d)^{\otimes N}, \mathbb{P}_N] = 0$$

$$\mathcal{H}^{\otimes N} \equiv \bigoplus_{\nu} \mathcal{H}_{\nu} \otimes \mathcal{H}_{d_\nu}$$

$U_g^{(\nu)}$

$\Pi_\sigma^{(d_\nu)}$

$\mathbb{SU}(2)$

$$\mathsf{H}^{\otimes L} = \bigoplus_{j=\langle\langle L/2 \rangle\rangle}^{L/2} \mathsf{H}_j \otimes \mathbb{C}^{d_j}$$

H_j *representation* space

$\mathbb{C}^{d_j}$ *multiplicity* space

$$d_j = \frac{2j+1}{L/2+j+1} \binom{L}{L/2+j}$$

operators invariant under $U_g^{\otimes L} : \oplus_{j=\langle\langle L/2 \rangle\rangle}^{L/2} I_j \otimes W^{(j)}$

operators invariant under $\mathbb{P}_L : \oplus_{j=\langle\langle L/2 \rangle\rangle}^{L/2} Z_j \otimes I_{d_j}$

Input states

$$\tilde{\rho}^{\otimes N} = (r_+ r_-)^{N/2} \bigoplus_{l=\langle\langle N/2 \rangle\rangle}^{N/2} \sum_{n=-l}^{l} \left(\frac{r_-}{r_+}\right)^n |ln\rangle\langle ln| \otimes I_{d_l}$$

(Schur-Weyl duality)

$$\rho = \frac{1}{2}(I + r\boldsymbol{k}\cdot\boldsymbol{\sigma}) \qquad r_\pm \doteq \tfrac{1}{2}(1 \pm r)$$

[J. I. Cirac, A. K. Ekert, and C. Macchiavello, Phys. Rev. Lett. **82** 4344 (1999)]

Maps characterization

$$\mathcal{H}^{\otimes(M+N)} = \bigoplus_{j=\langle\langle M/2\rangle\rangle}^{M/2} \bigoplus_{l=\langle\langle N/2\rangle\rangle}^{N/2} \mathcal{H}_j \otimes \mathcal{H}_l \otimes \mathbb{C}^{d_j} \otimes \mathbb{C}^{d_l}$$

invariance of $S_{\mathscr{B}}$

under $\mathbb{P}_M \times \mathbb{P}_N$

$$S_{\mathscr{B}} = \bigoplus_{j=\langle\langle M/2\rangle\rangle}^{M/2} \bigoplus_{l=\langle\langle N/2\rangle\rangle}^{N/2} S_{jl} \otimes I_{d_j} \otimes I_{d_l}$$

invariance of $S_{\mathscr{B}}$

under $U_g^{\otimes(N+M)}$

$$S_{\mathscr{B}} = \bigoplus_{j=\langle\langle M/2\rangle\rangle}^{M/2} \bigoplus_{l=\langle\langle N/2\rangle\rangle}^{N/2} \bigoplus_{J=|j-l|}^{j+l} s_{j,l,J} P_J^{(j,l)} \otimes I_{d_j} \otimes I_{d_l}$$

Convex structure

$$S_{\mathscr{B}} = \bigoplus_{j=\langle\langle M/2\rangle\rangle}^{M/2} \bigoplus_{l=\langle\langle N/2\rangle\rangle}^{N/2} \bigoplus_{J=|j-l|}^{j+l} s_{j,l,J} P_J^{(j,l)} \otimes I_{d_j} \otimes I_{d_l}$$

$P_J^{(j,l)}$ orthogonal projector over the irreducible representation *J* coming from the couple *j,l*

$s_{j,l,J}$ positive coefficients

trace-preserving condition:

$$\sum_{j=\langle\langle M/2\rangle\rangle}^{M/2} \sum_{J=|j-l|}^{j+l} d_j s_{j,l,J} \frac{2J+1}{2l+1} = 1\,, \quad \forall \langle\langle N/2\rangle\rangle \leq l \leq \frac{N}{2}$$

broadcasting maps make a convex set, with the *extreme points* classified by the functions φ and Φ corresponding to a given choice

$$j = \varphi_l\,,\ J = \Phi_l\,, \quad \langle\langle M/2\rangle\rangle \leq \varphi_l \leq M/2\,,\ |\varphi_l - l| \leq \Phi_l \leq \varphi_l + l$$

Extremal maps

extremal *broadcasting maps*:

$$S_{\mathscr{B}}^{(\varphi,\Phi)} = \bigoplus_{l=\langle\langle N/2\rangle\rangle}^{N/2} \frac{2l+1}{2\Phi_l+1}\frac{1}{d_{\varphi_l}} P_{\Phi_l}^{(\varphi_l,l)} \otimes I_{d_{\varphi_l}} \otimes I_{d_l}$$

$$\mathscr{B}_{\varphi,\Phi}(\rho^{\otimes N}) = (r_+ r_-)^{N/2} \bigoplus_{l=\langle\langle N/2\rangle\rangle}^{N/2} \frac{2l+1}{2\Phi_l+1}\frac{d_l}{d_{\varphi_l}}$$

$$\times \sum_{n=-l}^{l} \left(\frac{r_-}{r_+}\right)^n \mathrm{Tr}_l[(I_{\varphi_l} \otimes |ln\rangle\langle ln|) P_{\Phi_l}^{(\varphi_l,l)}] \otimes I_{d_{\varphi_l}}$$

Extremal maps

The output state can be written

$$\mathscr{B}_{\varphi,\Phi}(\rho^{\otimes N}) = (r_+ r_-)^{N/2} \bigoplus_{l=\langle\langle N/2\rangle\rangle}^{N/2} \frac{2l+1}{2\Phi_l+1}\frac{d_l}{d_{\varphi_l}}$$

$$\times \sum_{n=-l}^{l}\left(\frac{r_-}{r_+}\right)^n \sum_{m=-\varphi_l}^{\varphi_l} \langle \Phi_l m + n | \varphi_l m, l n\rangle^2 \boxed{|\varphi_l m\rangle\langle\varphi_l m| \otimes I_{d_{\varphi_l}}}$$

We are now interested in the single-site output

Let's focus attention on this term

Single-site output

Change from Wedderburn to qubit representations

$$|jm\rangle \otimes |1\rangle = |jm\rangle \otimes |\Psi_-\rangle^{\otimes \frac{M}{2}-j}$$

$$\mathrm{Tr}_{j-\frac{1}{2}}[|jm\rangle\langle jm|] = \frac{1}{2}I + \frac{m}{2j}\boldsymbol{k}\cdot\boldsymbol{\sigma}$$

$$|jm\rangle\langle jm| \otimes I_{d_j} = \frac{d_j}{M!}\sum_{l\in\mathbb{P}_M} \pi_l X_j \pi_l^\dagger$$

$$X_j = |jm\rangle\langle jm| \otimes |1\rangle\langle 1|$$

$$\rho'_{(\varphi,\Phi)}(r) = (r_+ r_-)^{N/2} \sum_{l=\langle\langle N/2\rangle\rangle}^{N/2} \frac{2l+1}{2\Phi(l)+1} d_l \sum_{m=-\varphi(l)}^{\varphi(l)}$$

$$\times \sum_{n=-l}^{l} \left(\frac{r_-}{r_+}\right)^n \langle \Phi(l)m + n|\varphi(l)m, ln\rangle^2 \frac{1}{2}\left(I + \frac{2m}{M}\boldsymbol{k}\cdot\boldsymbol{\sigma}\right)$$

Derivation

The single-site output state $\rho' = \mathrm{Tr}_{M-1}[\mathscr{B}(\rho^{\otimes N})]$

commutes with σ_z

As a figure of merit we consider

$$p(r) \doteq \frac{r'}{r} = \frac{1}{r}\,\mathrm{Tr}[\sigma_z \otimes I^{\otimes(M-1)}\mathscr{B}(\rho^{\otimes N})]$$

Using permutation invariance it turns out that

$$p(r) = \frac{2}{Mr}\,\mathrm{Tr}[J_z^{\mathrm{tot}}\mathscr{B}(\rho^{\otimes N})]$$

Derivation

For extremal maps we have

$$p(r) = \frac{2}{Mr} \sum_{l=\langle\langle N/2 \rangle\rangle}^{N/2} (r_+ r_-)^{N/2-l} d_l \frac{\Phi_l(\Phi_l+1) - \varphi_l(\varphi_l+1) - l(l+1)}{l(l+1)} \sum_{n=-l}^{l} n r_-^{l+n} r_+^{l-n}$$

Since $\sum_{n=-l}^{l} n r_-^{l+n} r_+^{l-n} \leq 0$ $\Phi_l\,,\ \varphi_l$ must minimize

$$\Phi_l(\Phi_l+1) - \varphi_l(\varphi_l+1) - l(l+1)$$

Scaling factor

The solution is

$$\varphi_l = \frac{M}{2}\,,\ \Phi_l = \frac{M}{2} - l$$

corresponding to

$$p(r) = -\frac{M+2}{Mr} \sum_{l=\langle\langle N/2 \rangle\rangle}^{N/2} (r_+ r_-)^{N/2-l} \frac{d_l}{l+1} \sum_{n=-l}^{l} n r_-^{l+n} r_+^{l-n}$$

End

Violation of data-processing theorem?

- ***Superbroadcasting doesn't mean more available information about the original input state***.
- This is due to ***detrimental correlations between the broadcast copies***, which does not allow to exploit their statistics.
- From the ***point of view of each single user*** our broadcasting protocol is a purification in all respects (for sufficiently mixed states). The process transfers noise from the local states to the correlations between them.

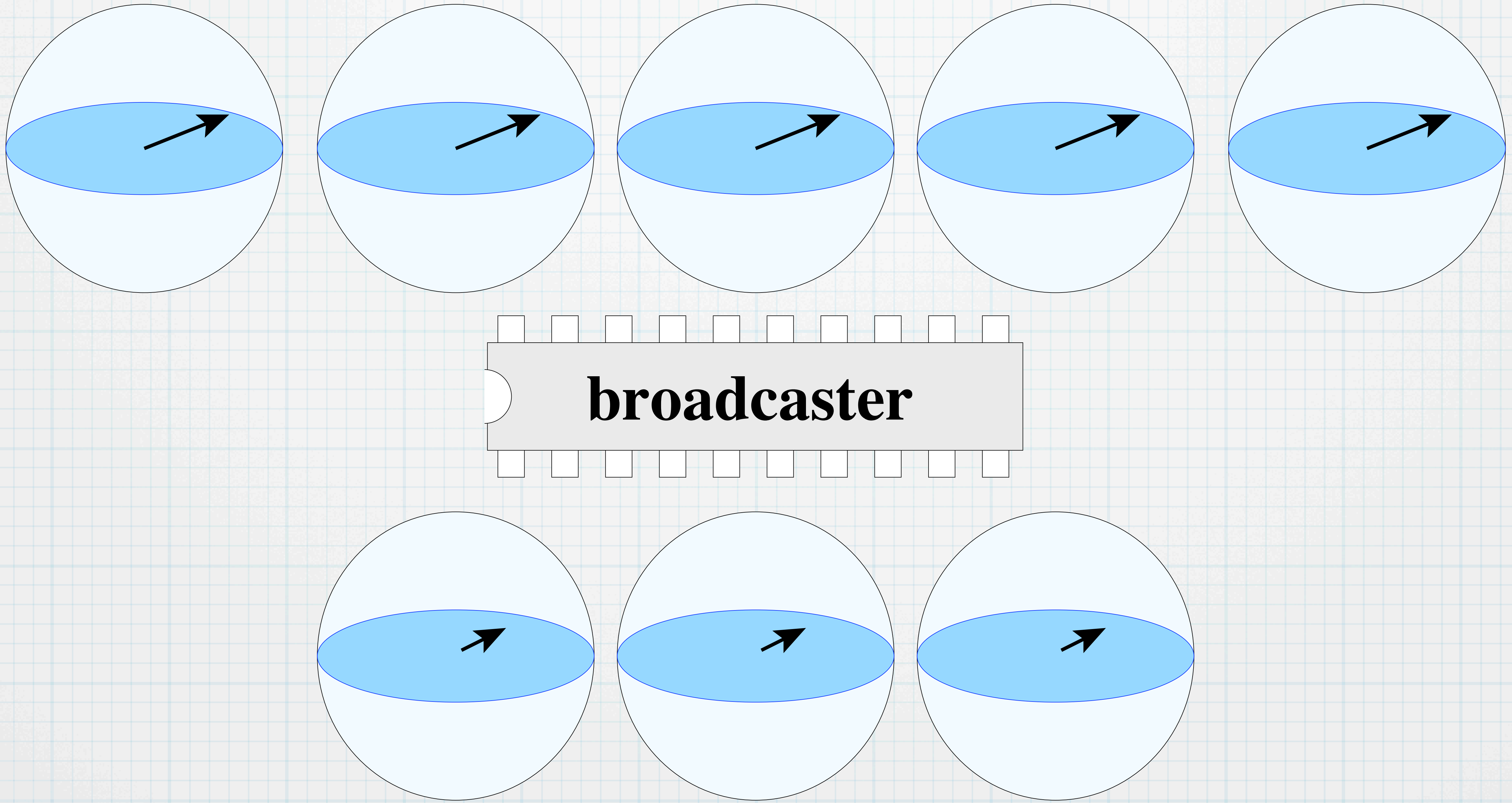
Violation of data-processing theorem?

G. M. D'Ariano, Rafał Demkowicz-Dobrzanski
and P. Perinotti, in progress

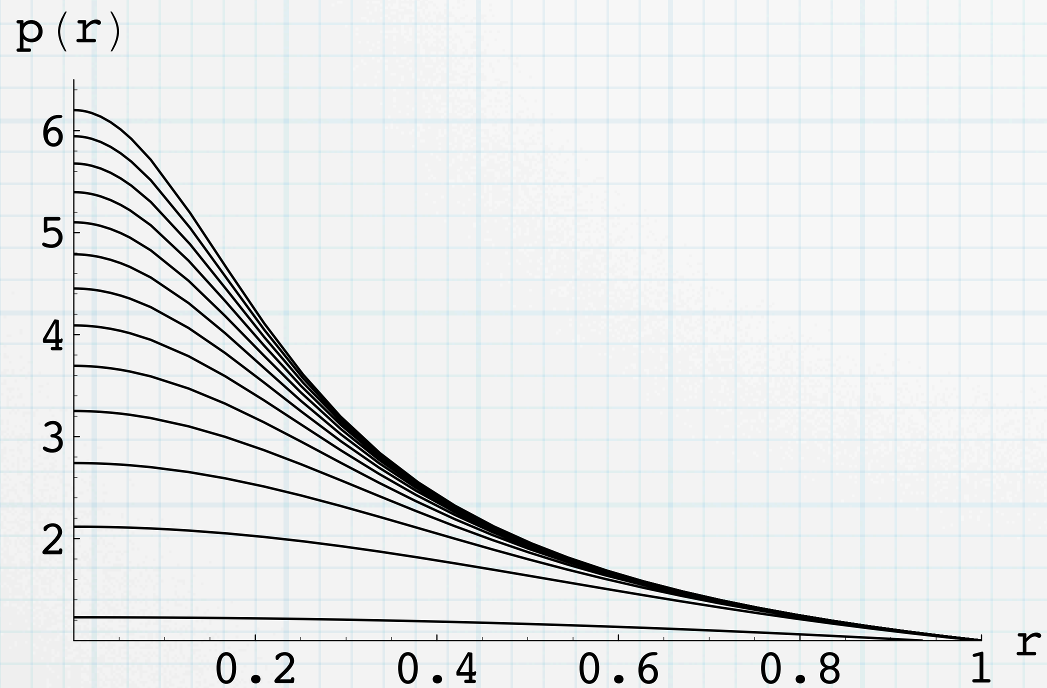
Optimal universal covariant superbroadcasting actually preserves the information about the original input state.

Rafał Demkowicz-Dobrzanski

Phase-covariant s.b.

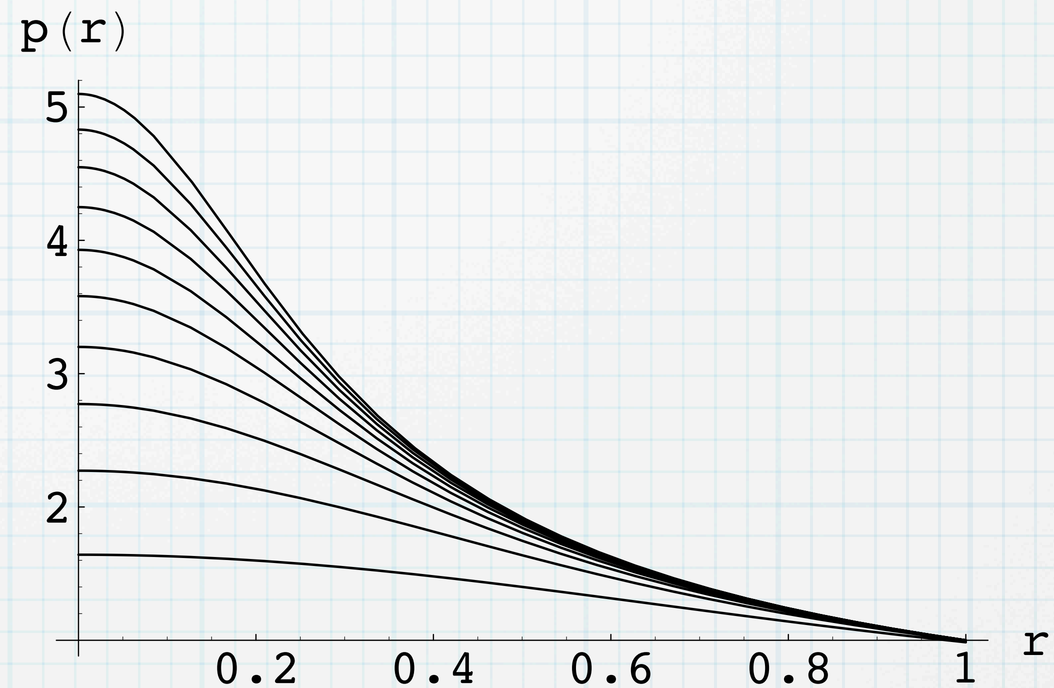


Comparison



phase-covariant case

$$M = N + 1\,, \quad 4 \leq N \leq 100$$

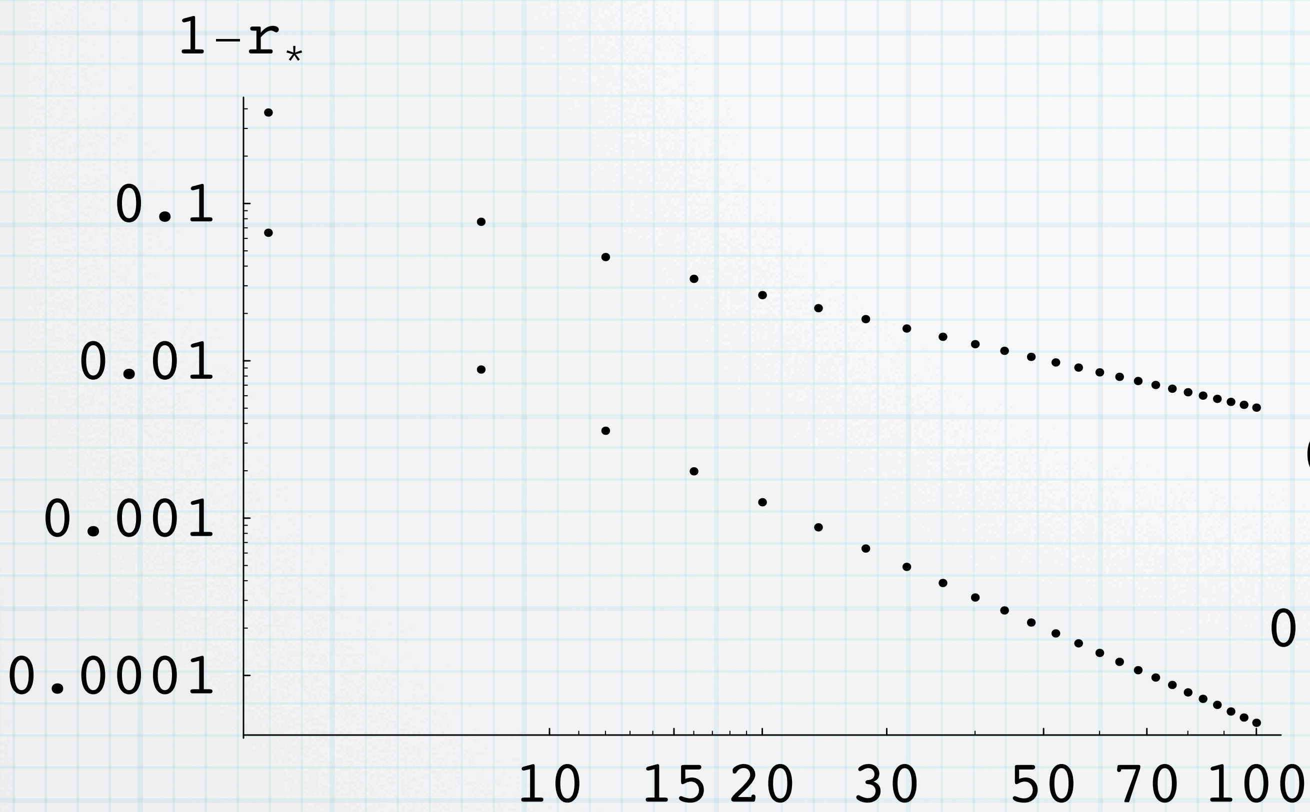


universal case

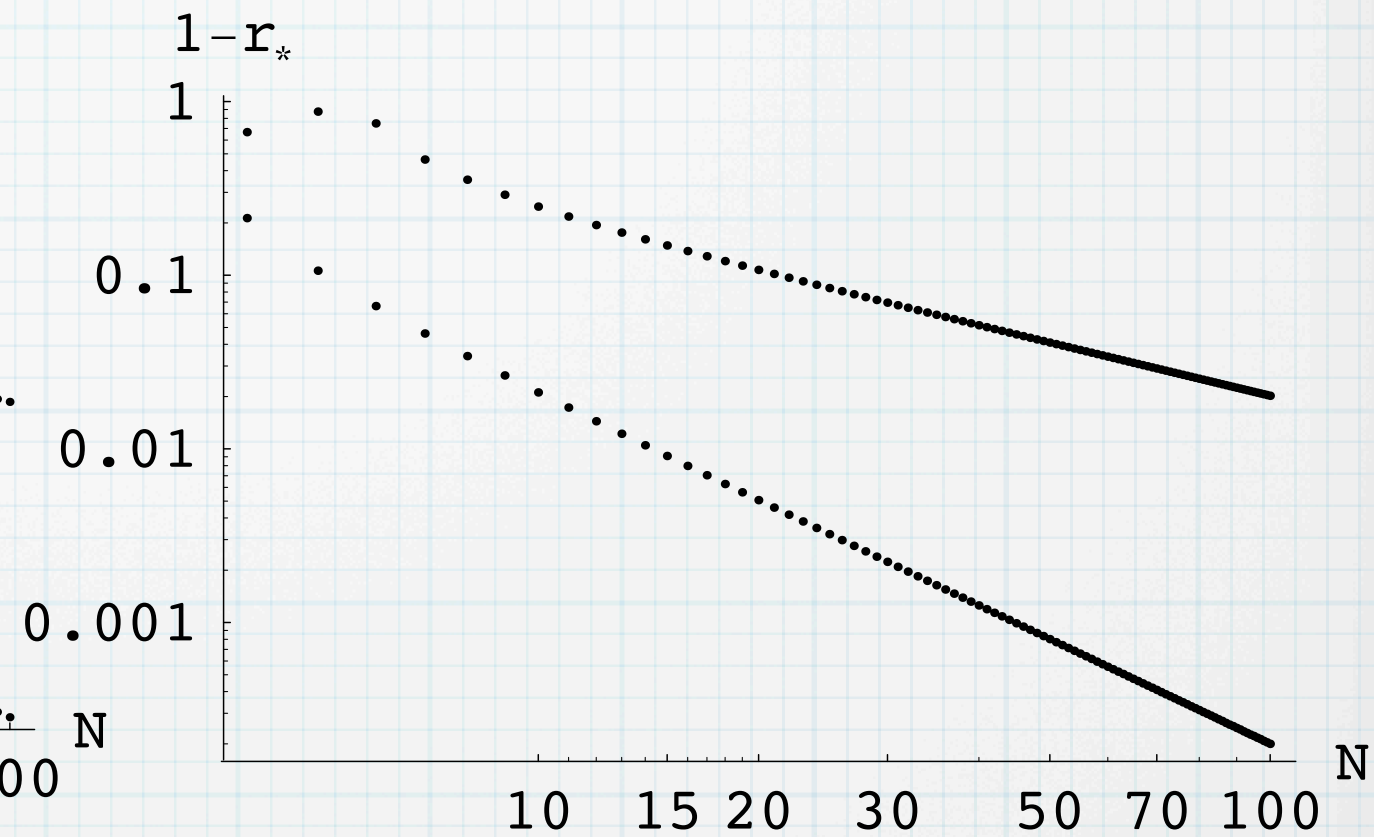
$$M = N + 1\,, \quad 10 \leq N \leq 100$$

The purification is higher in the phase-covariant case than in the universal case, since the set of input states is smaller

Comparison



phase-covariant case



universal case

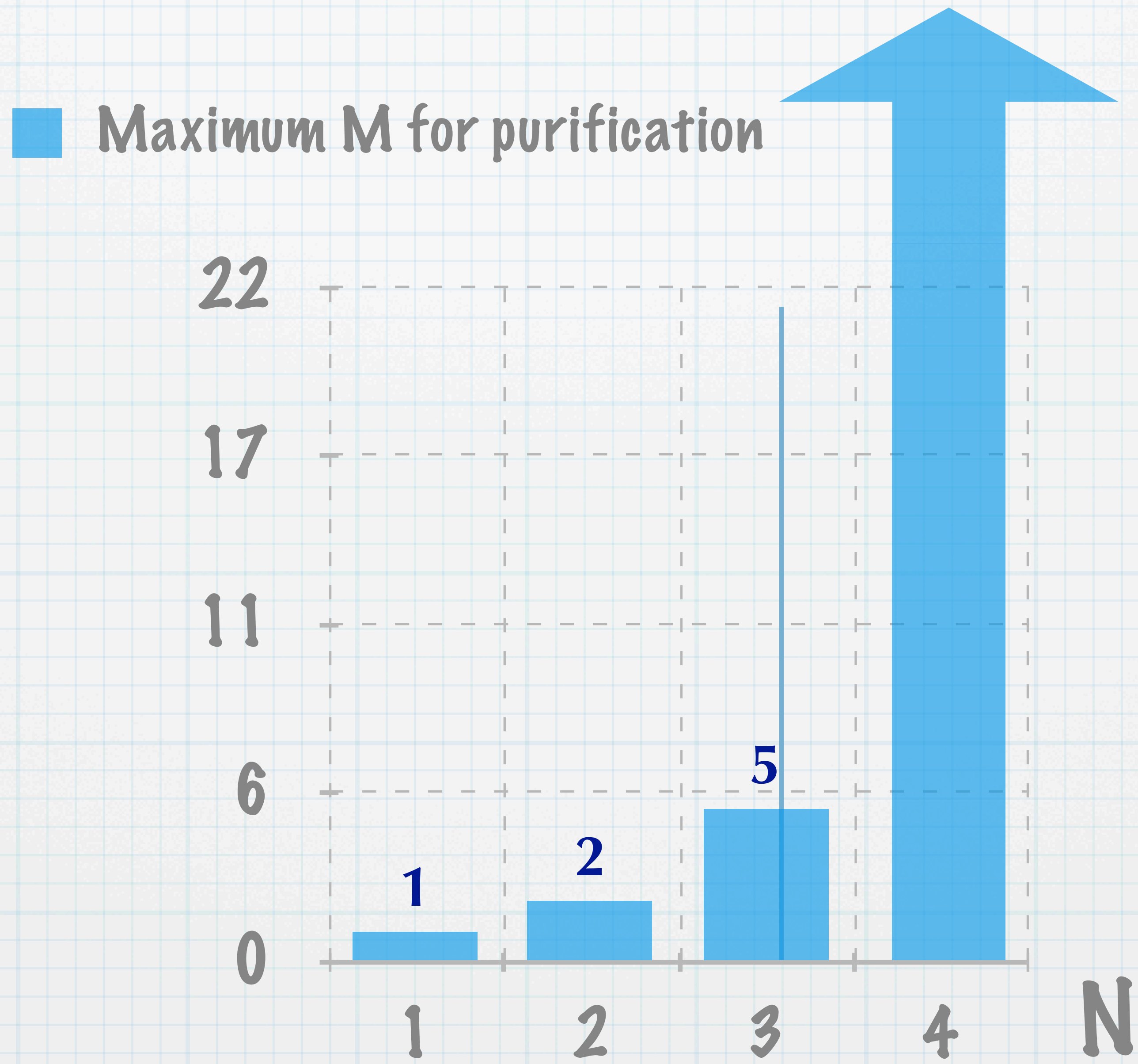
$$1 - r_*(N, N+1) \simeq \frac{2}{3} N^{-2}$$

$$1 - r_*(N, \infty) \simeq \frac{1}{2} N^{-1}$$

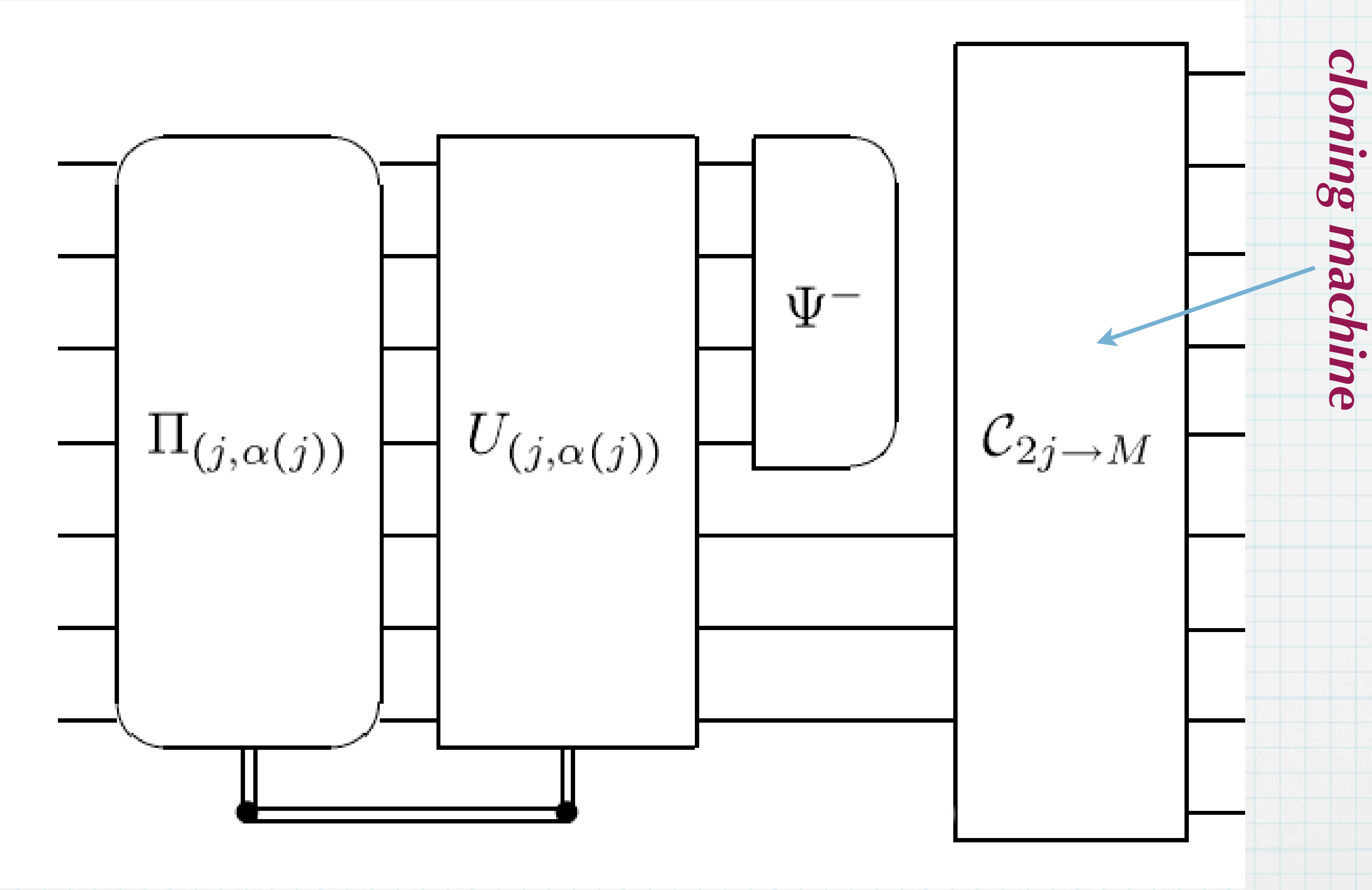
$$1 - r_*(N, N+1) \simeq 2N^{-2}$$

$$1 - r_*(N, \infty) \simeq N^{-1}$$

Phase-covariant s.b.



Realization scheme



$$\Pi_{(j,\alpha(j))} = I_{2j+1} \otimes |\alpha(j)\rangle\langle\alpha(j)|$$

$$\rho_{(l,\chi)} = (r_+ r_-)^{N/2} \left(\frac{r_+}{r_-}\right)^{J_z^{(l)}} \otimes |\chi\rangle\langle\chi|;$$

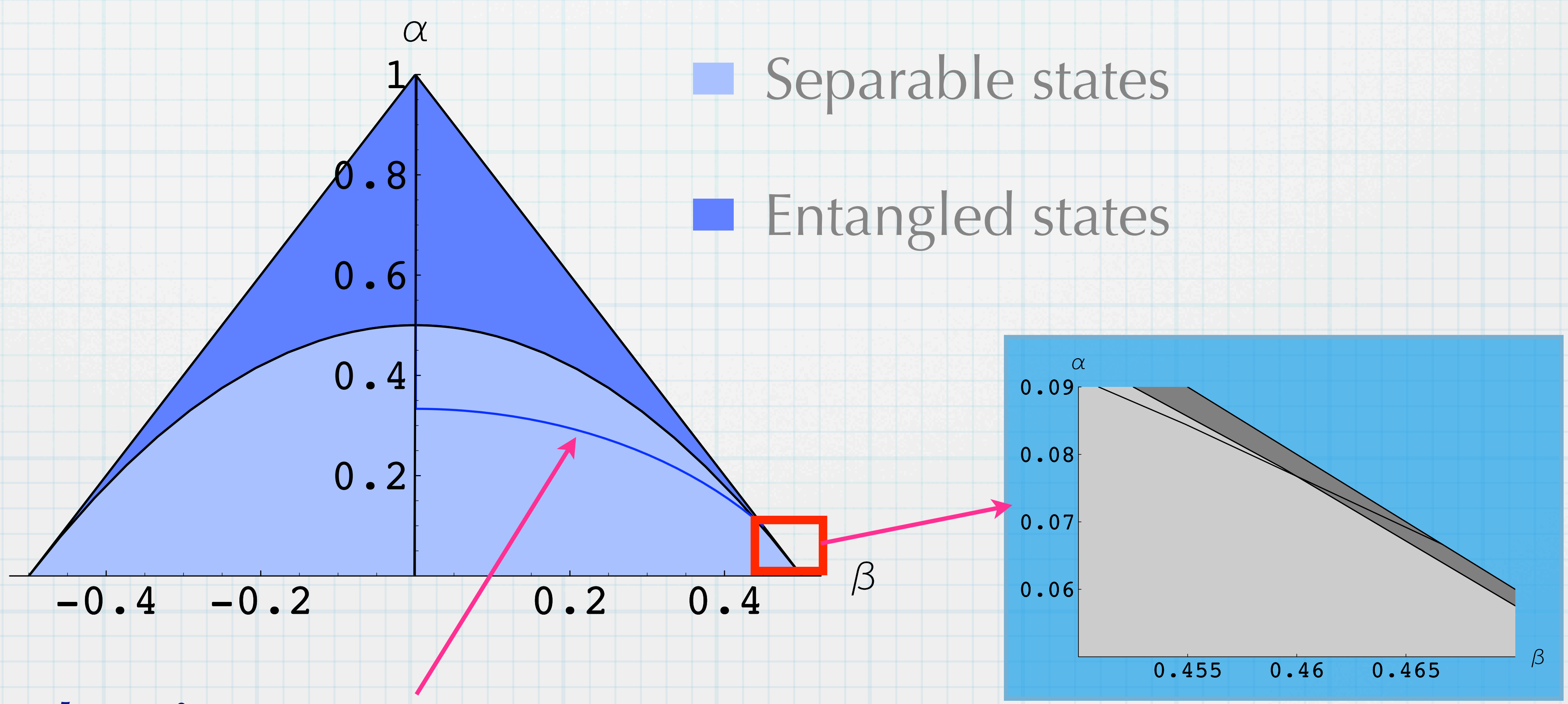
$$U_{(l,\chi)}\rho_{(l,\chi)}U^\dagger_{(l,\chi)} = (r_+ r_-)^{N/2} \left(\frac{r_+}{r_-}\right)^{J_z^{(l)}} \otimes |\Psi^-\rangle\langle\Psi^-|^{\otimes \frac{N-2l}{2}}$$

The role of correlations

Universal broadcasting: symmetric 2-sites output states commuting with $J_z^{(1)}$

Parametrization of bipartite symmetric states:

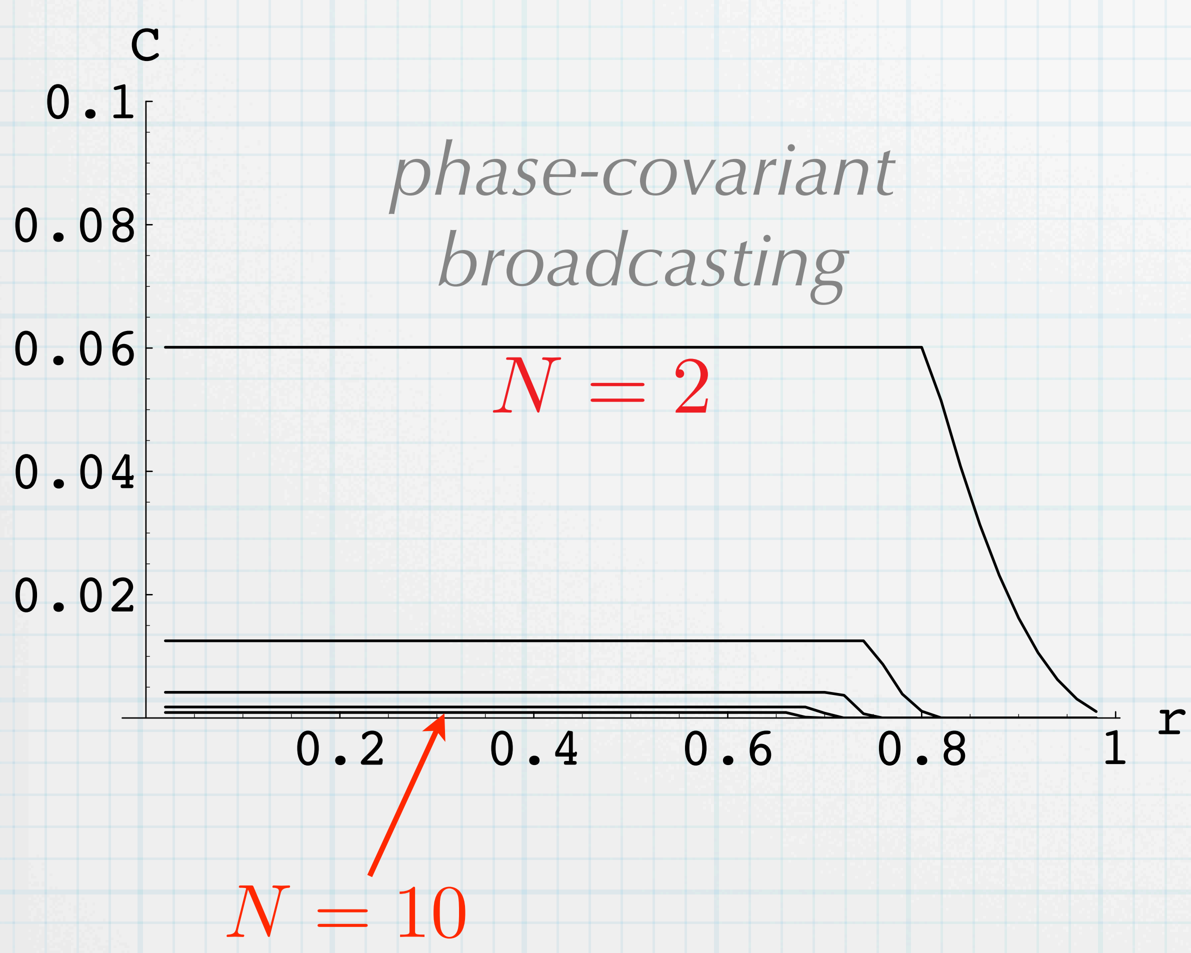
$$\rho^{(2)} = \alpha I^{(1)} + \beta J_z^{(1)} + \frac{1-3\alpha}{2} {J_z^{(1)}}^2$$

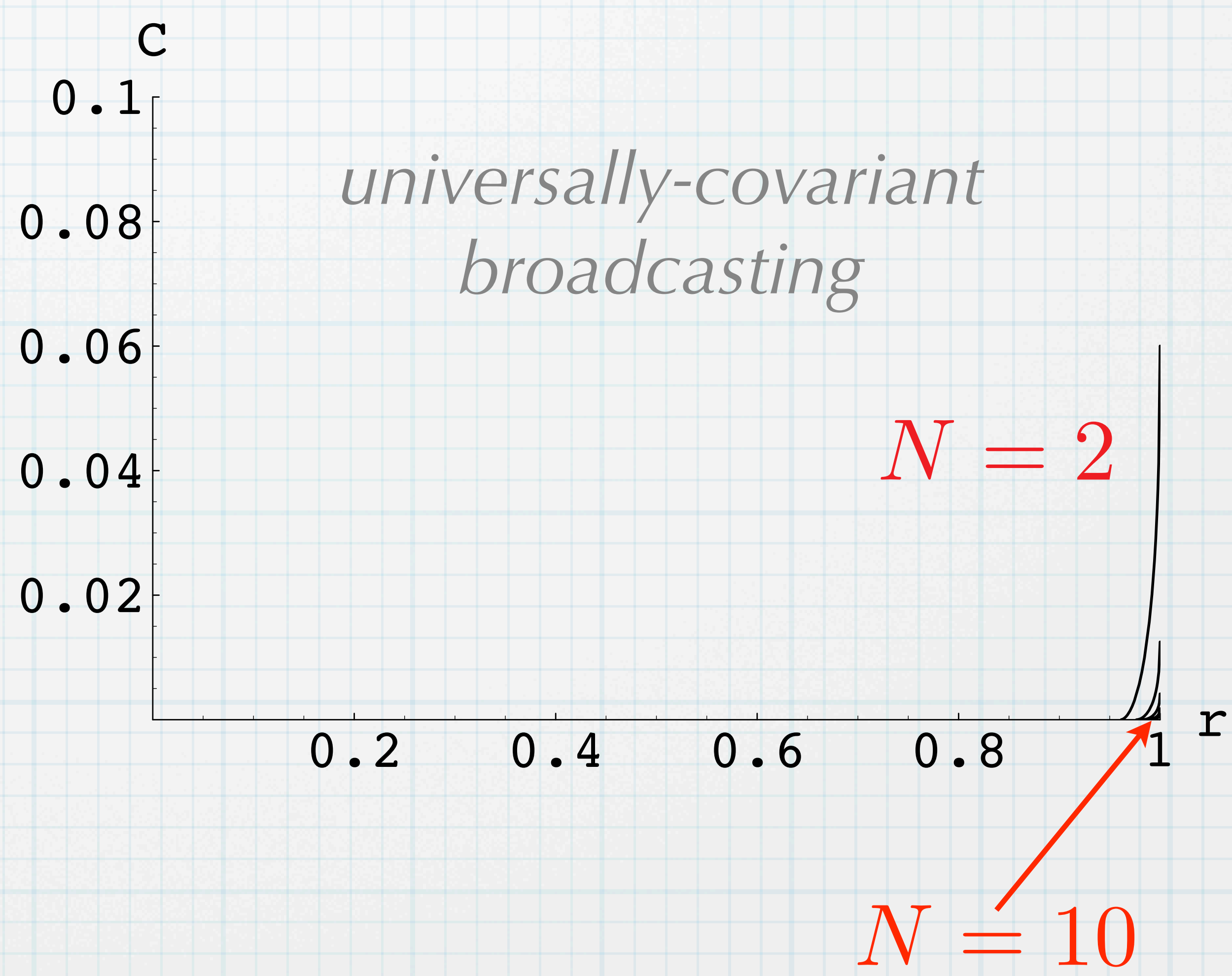


Universal broadcasting output states (4-->5)

The role of correlations

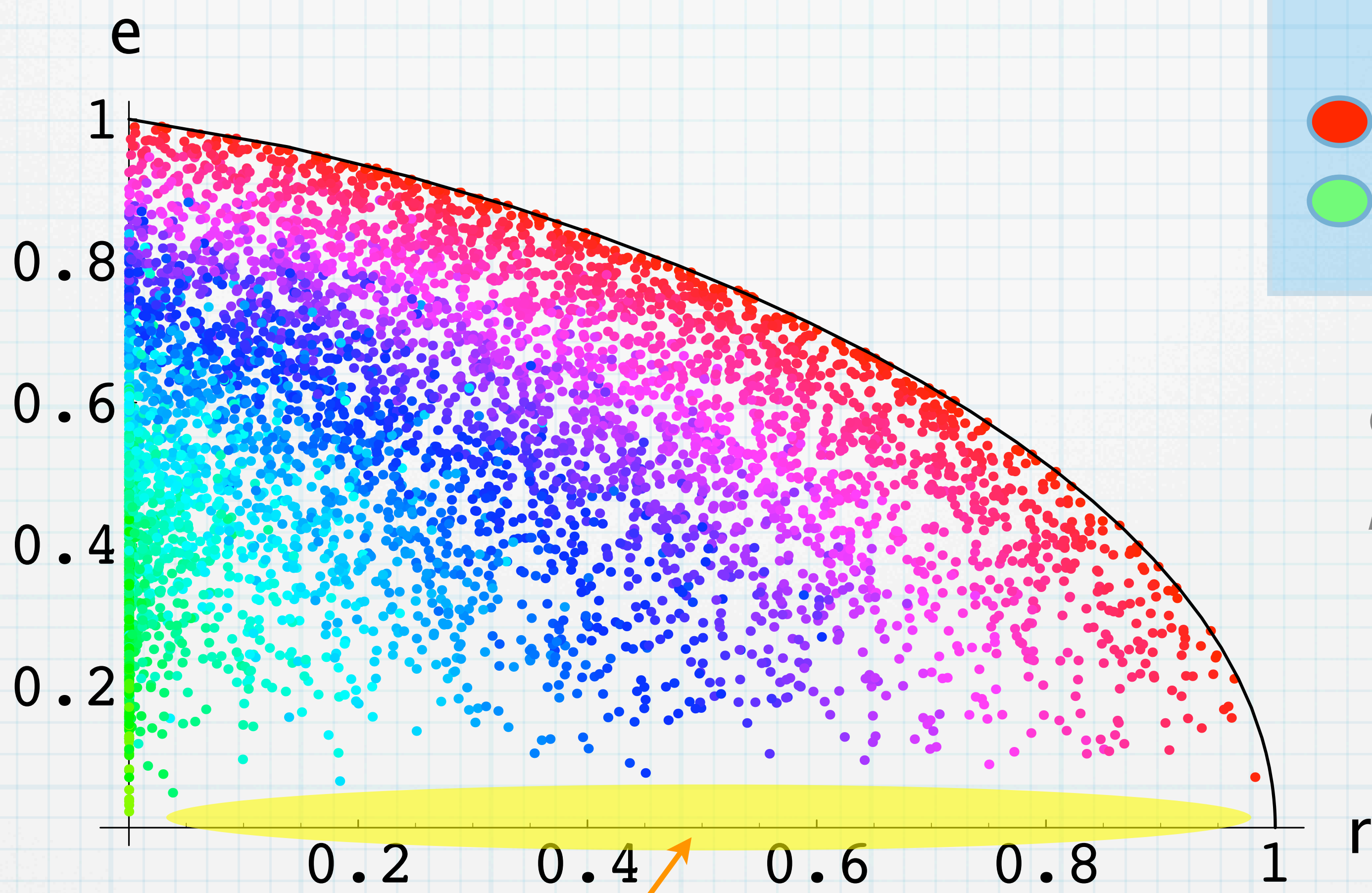
Two-sites output *concurrence C* versus the input Bloch vector length *r* for $N \rightarrow N+1\,, \qquad 2 \leq N \leq 10$





The role of correlations

permutation invariant bipartite joint states



joint states

more pure

more mixed

e: concurrence

r: local purity

output states of superbroadcasting

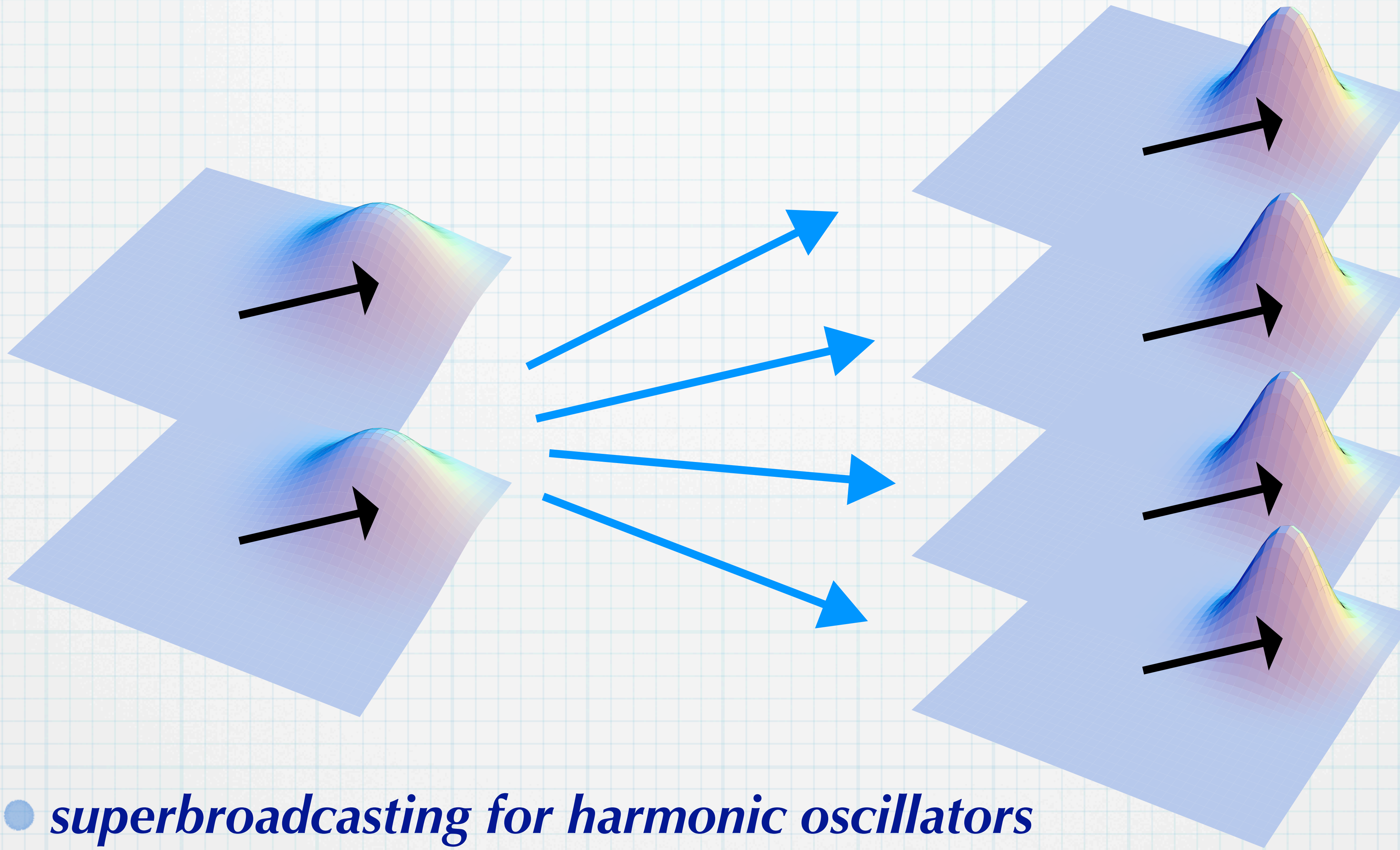
The role of correlations

Is superbroadcasting *classical*?

- The classical procedure (measurement + preparation) leads only to the same scaling factor as the superbroadcasting for $M=\infty$ (F. Buscemi, G. Chiribella, G. M. D'Ariano, C. Macchiavello, and P. Perinotti, in preparation)
- The protocol for practical achievement of the superbroadcasting map involves Werner cloning map in some stage ----> *quantum* correlations

CV superbroadcasting

G. M. D'Ariano, P. Perinotti, and M. F. Sacchi, in preparation

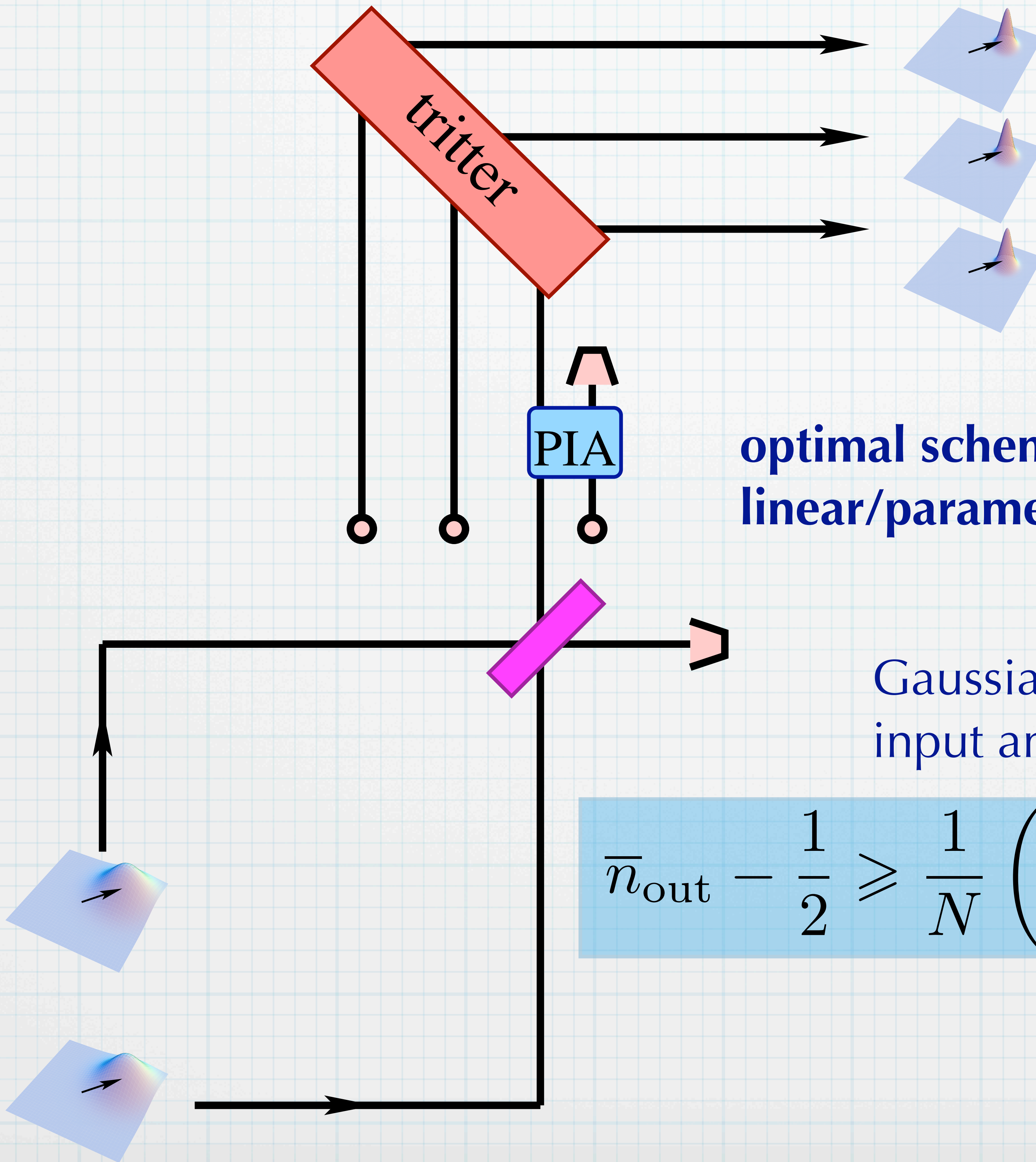


- ***superbroadcasting for harmonic oscillators***
- feasible for any displaced noisy state
- covariant under the Weyl Heisenberg group of translations on the phase space

Sacchi

CV superbroadcasting

G. M. D'Ariano, P. Perinotti, and M. F. Sacchi, in preparation

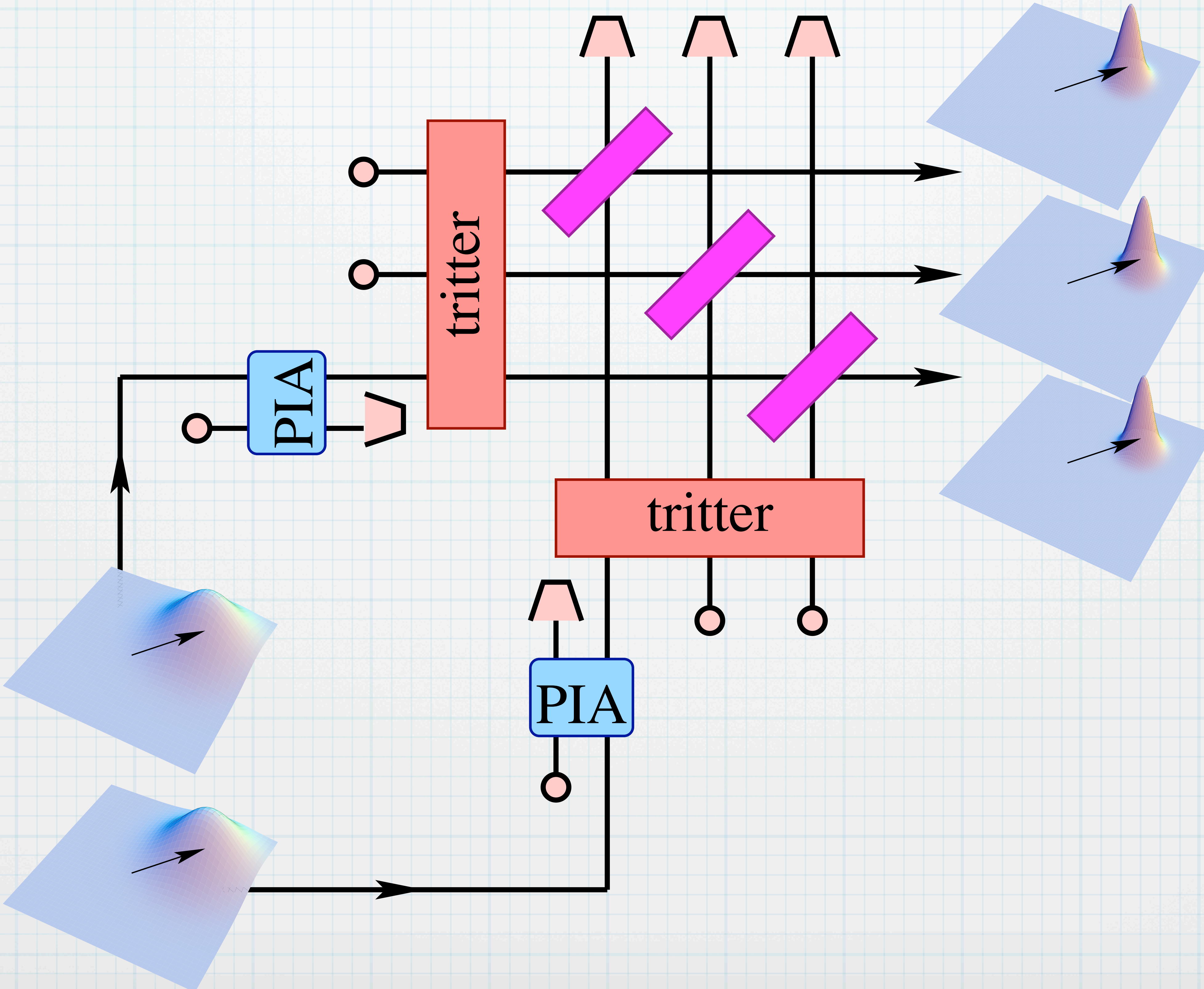


optimal scheme for thermal noise uses linear/parametric optics

Gaussian variances at the input and at the output:

$$\overline{n}_{\mathrm{out}} - \frac{1}{2} \geqslant \frac{1}{N}\left(\overline{n}_{\mathrm{in}} - \frac{1}{2}\right) + \frac{1}{N} - \frac{1}{M}$$

CV superbroadcasting



G. M. D'Ariano, P. Perinotti, and M. F. Sacchi, in preparation

CV superbroadcasting

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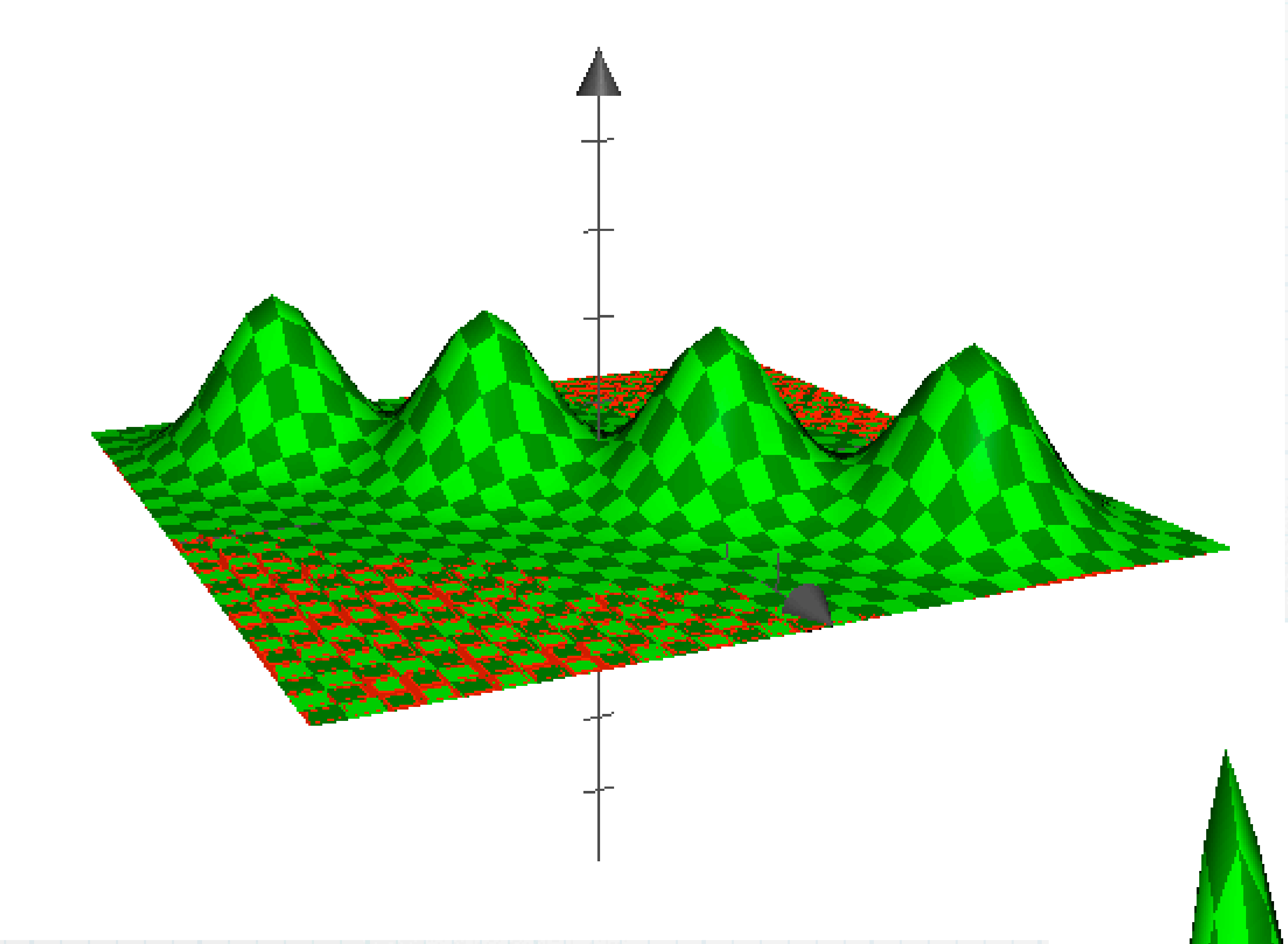
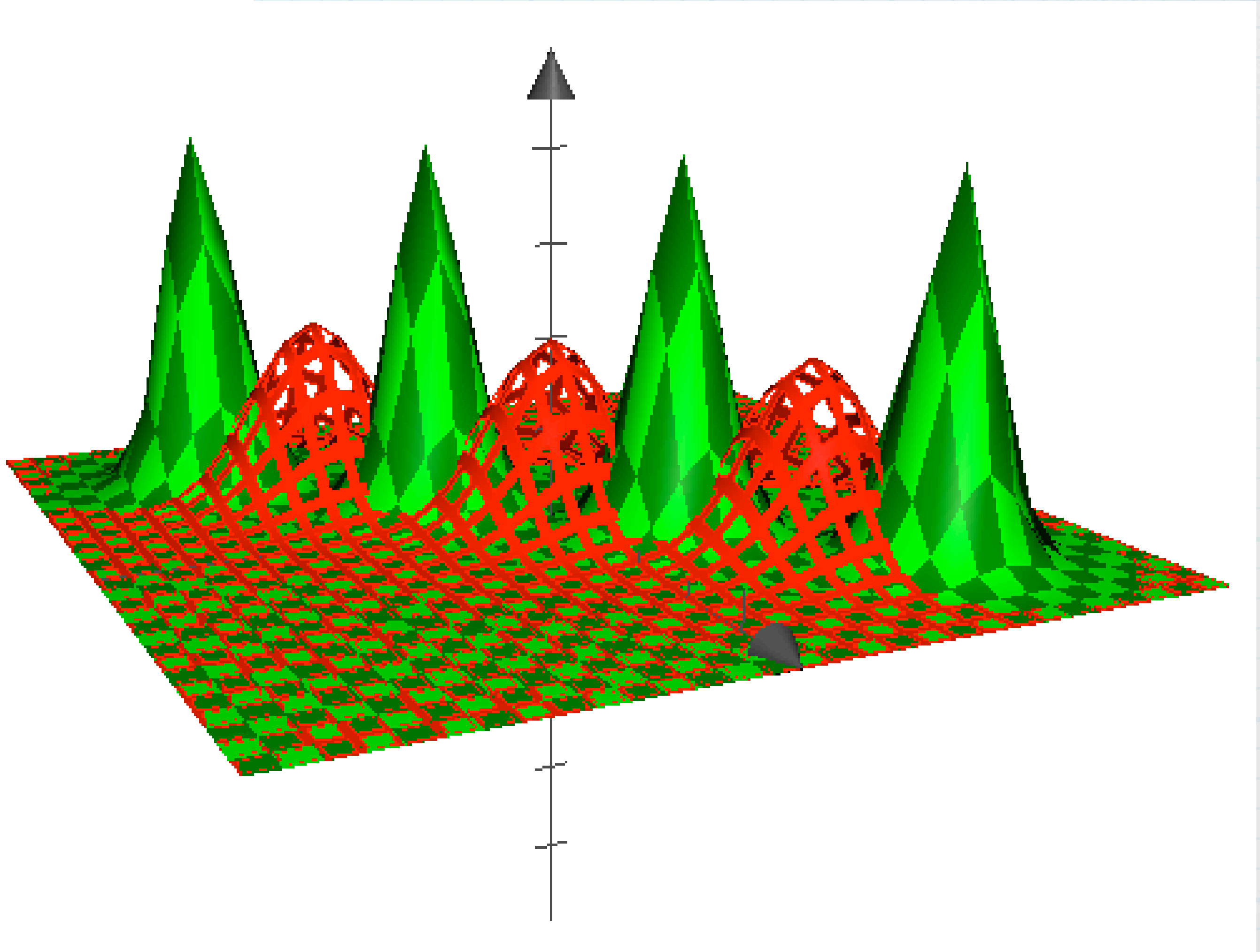
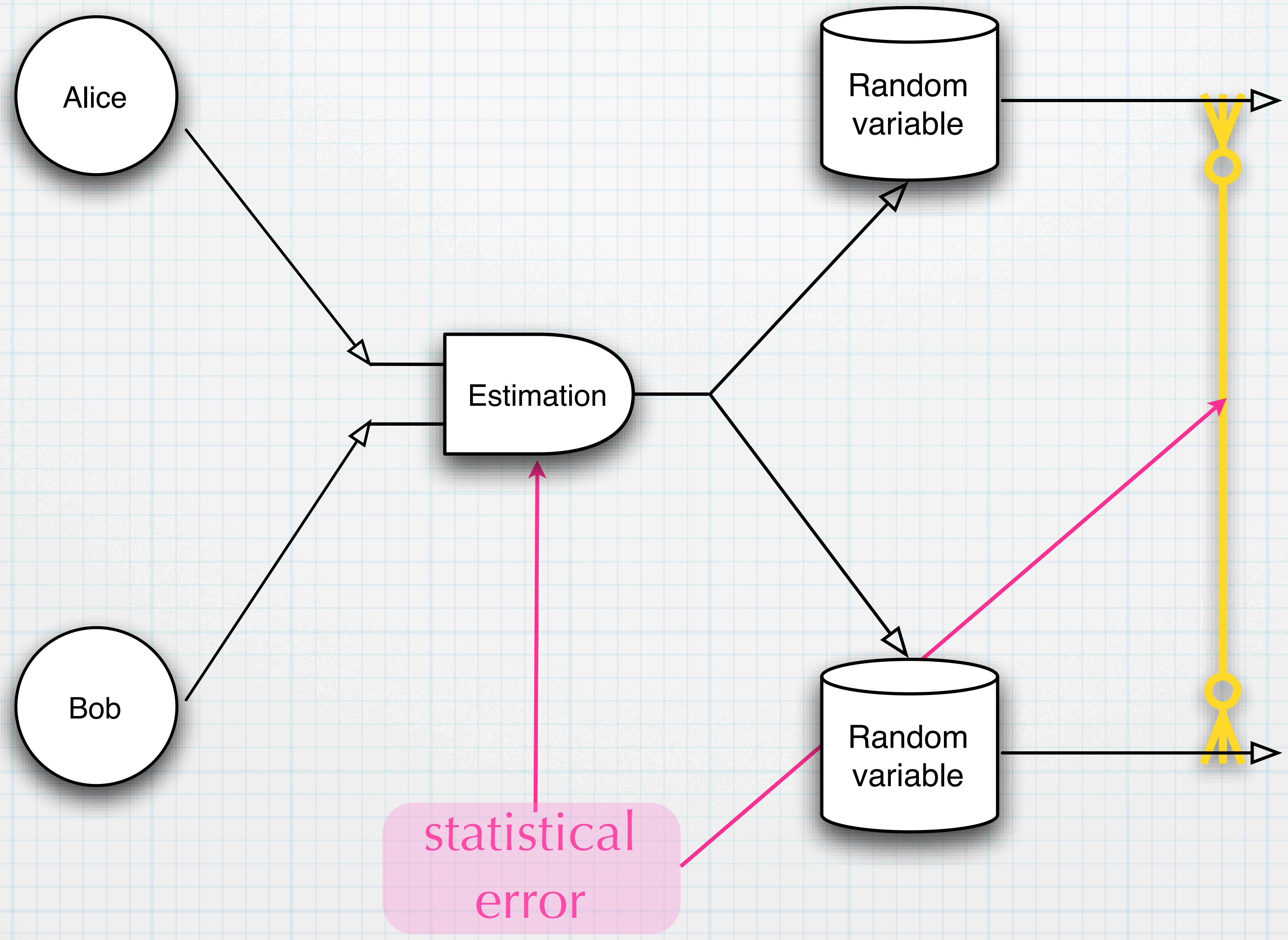


Pushing noise into correlations!

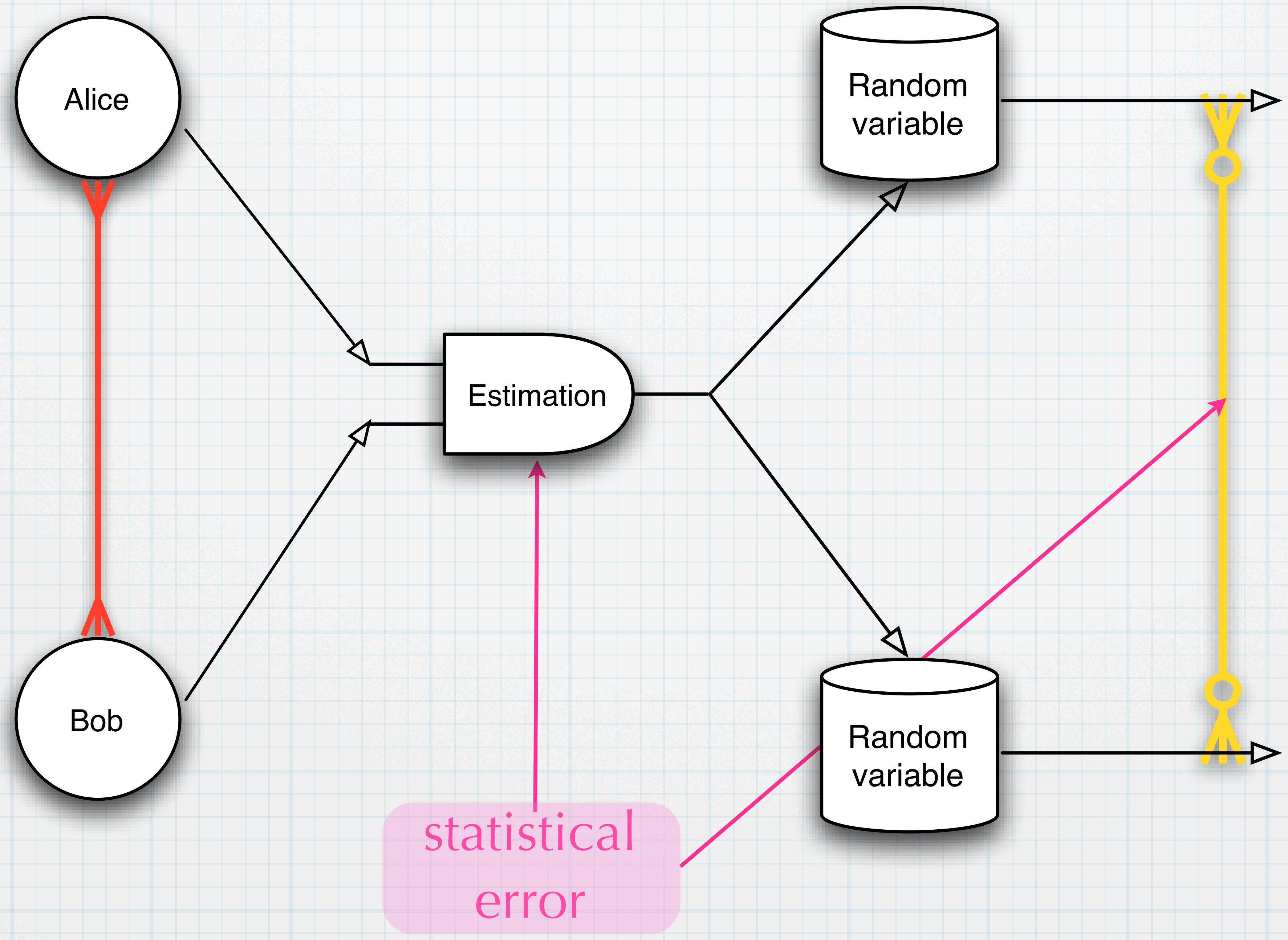
reducing thermal noise while creating correlations



Purification



Decorrelation



Decorrelation

- Classical decorrelator for $p_m(X,Y)$, X,Y random variables with

$$\langle X\rangle = \langle Y\rangle = m, \quad p_m(X,Y) \neq p_m(X)p_m(Y).$$

data processing:

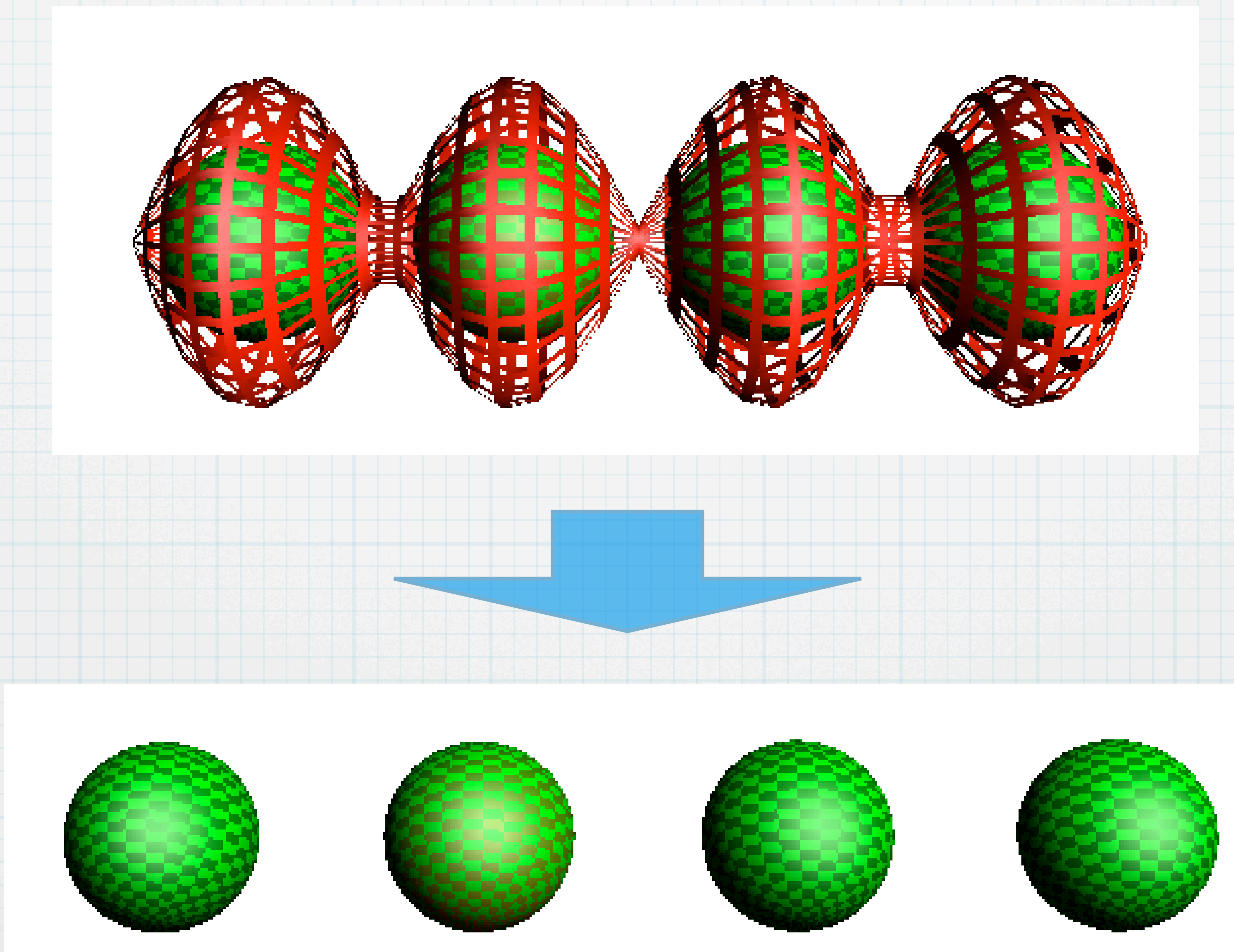
$$\forall m \begin{cases} X' = X'(X,Y), & \langle X'\rangle = m \\ Y' = Y'(X,Y), & \langle Y'\rangle = m \end{cases} \qquad p_m(X',Y') = p_m(X')p_m(Y').$$

- Quantum decorrelator $\mathscr{D}$ for $R \neq \mathrm{Tr}_2[R] \otimes \mathrm{Tr}_1[R]$

$$\mathscr{D}(U_g^{\otimes 2} R U_g^{\otimes 2\dagger}) = U_g \rho U_g^\dagger \otimes U_g \rho U_g^\dagger \ \ \forall g \in \mathbf{G}.$$

Decorrelation

It is possible ***to decorrelate a state*** by reducing the purity at each use and/or reducing the number of uses.



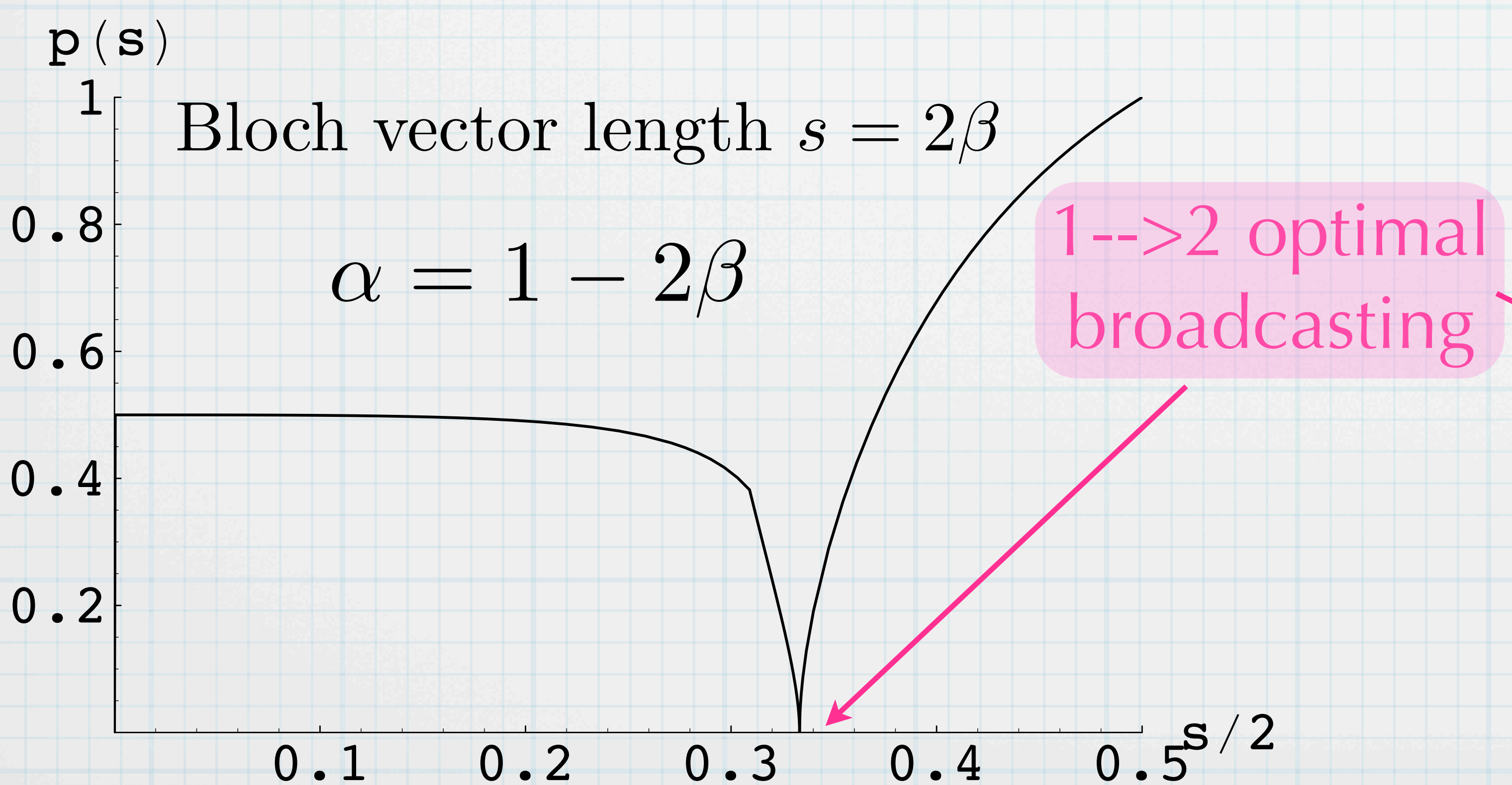
G. M. D'Ariano, Rafał Demkowicz-Dobrzanski and P. Perinotti, in progress

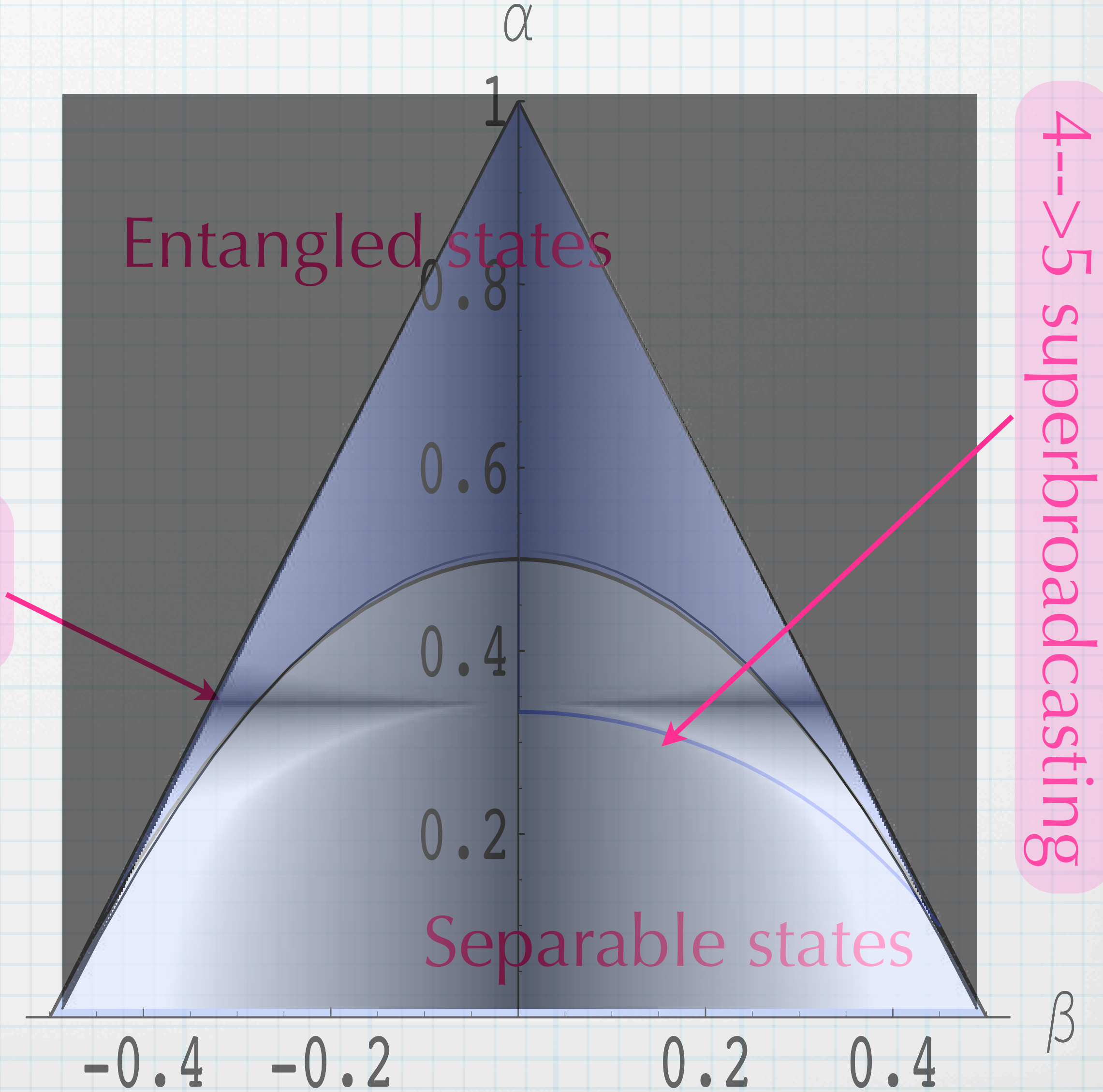
Decorrelation

- Quantum mechanically perfect decorrelation is possible!

bipartite symmetric states

$$\rho^{(2)} = \alpha I^{(1)} + \beta J_z^{(1)} + \frac{1-3\alpha}{2} J_z^{(1)2}$$



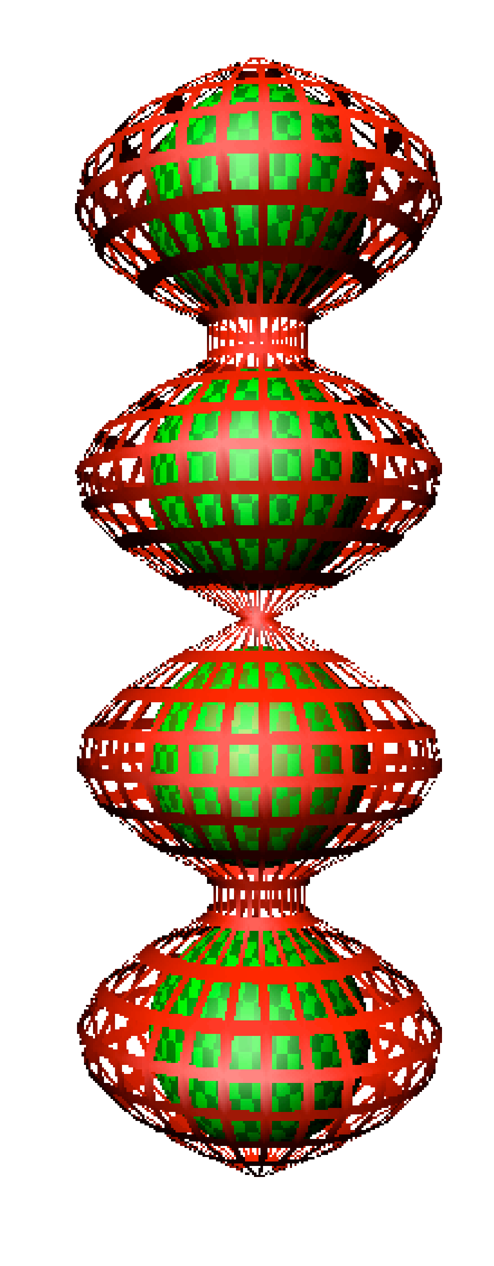


Marginal estimation

- Quantum mechanically the optimal joint state for estimation of local marginal states is a correlated state [R. Demkowicz-Dobrzanski, Phys. Rev. A **71** 062321 (2005)]
- Such joint states can be decorrelated perfectly
- [classically, the optimal joint probability for estimation of marginals is uncorrelated ...]

Summary

- It is possible to purify while broadcasting for sufficiently many input copies
- It is easier to superbroadcast starting from larger numbers of input copies and from more mixed states
- The minimum number of input copies depends on the set of input states
- Optimal broadcasting is achieved by a projection followed by a conditioned unitary and a optimal cloning
- Information on the single-site input state is preserved
- Superbroadcasting corresponds to pushing the noise of single uses into their correlations
- CV superbroadcasting is feasible
- Decorrelation quantum mechanically is possible



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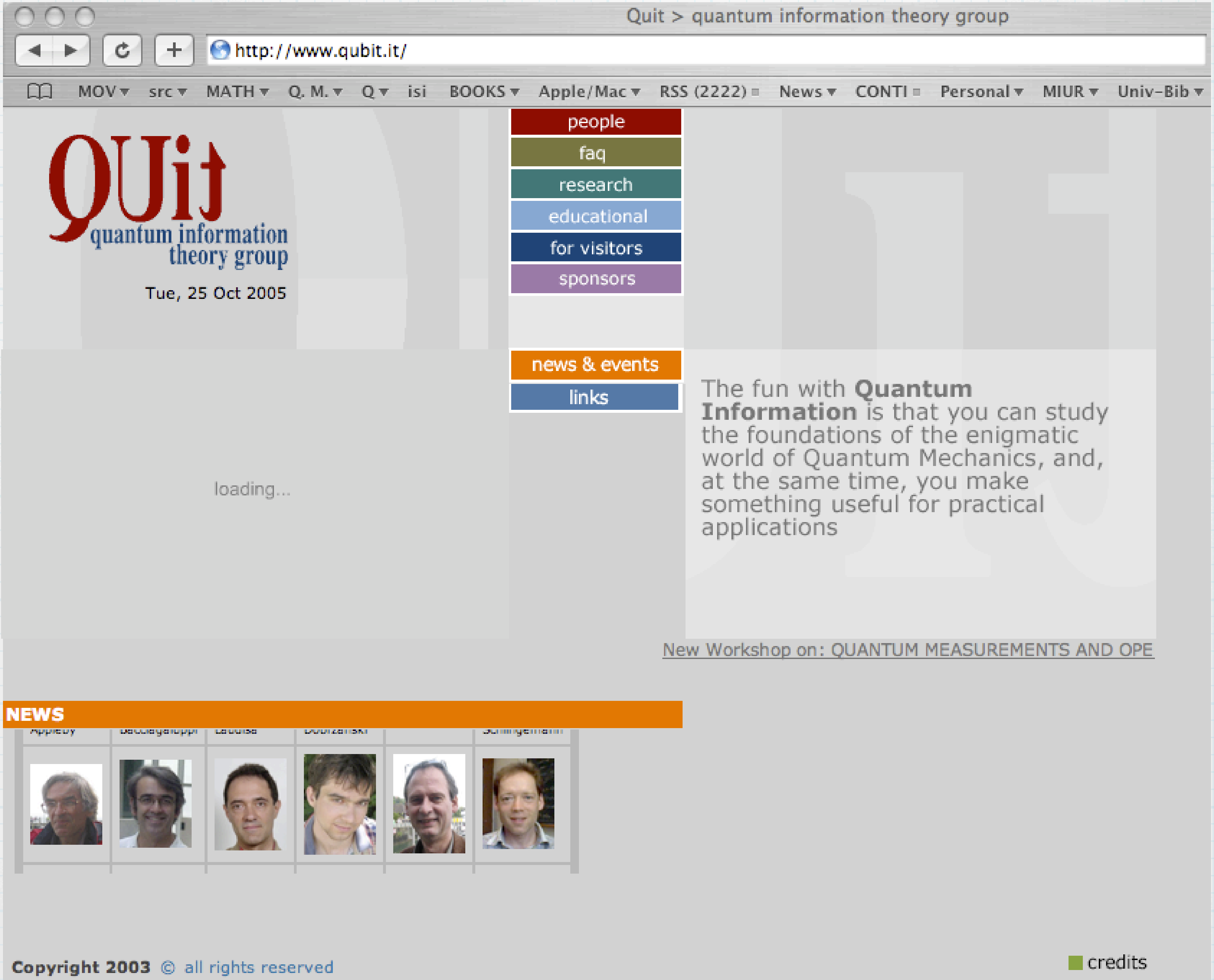
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