Quantum Steering
IN THE GAUSSIAN WORLD

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Outline

• Quantum Information

• Entanglement & Hierarchy of $Q$ Correlations

• Quantum Steering
Some history

- **'82:** Signalling faster than light? The “no-cloning” theorem.  
  (Wootters & Zurek)

- **'85:** A computing machine that obeys the QM laws was shown to be faster than any classical one. (D. Deutsch)
  - Parallelism
  - Interference

- **'94:** Two enormously important problems were found to be solved efficiently on a quantum machine:
  - Find prime factors of an integer (RSA)
  - “discrete log” problem
  (P. Shor)

- **'95:** Shannon’s information theory was extended to the Quantum domain  
  (B. Schumacher)
After ’95 . . .

Quantum Information field

EXPLODED

Since then...
Quantum Correlations

Cryptography

Channel Superactivation

Metrology

Super-dense coding

Communication

Error-Correcting Codes

Schemes for fault-tolerant Computation

Gravitational waves

Exploit

Relativistic Information
What is “QUANTUM CORRELATIONS”?

- Distant systems A & B
- Non-interacting
- State $\rho_{AB}$
- Measure both A & B

The probability of getting $A \rightarrow a$ & $B \rightarrow b$ is:

[Correlation function] $P(a, b|A, B; \rho_{AB})$
CLASSES OF Q. CORRELATIONS

- Discord
- Entanglement
- Steering
- Non-locality
Entanglement

Steering

Non-locality

|φ⟩ = \frac{1}{\sqrt{2}} (|00⟩ + |11⟩)

If \( P(a, b|A, B; \rho_{AB}) \) cannot be expressed as:

\[ \neq \sum_{\lambda} p_\lambda \ P(a|A; \rho_{\lambda, A}) \ P(b|B; \rho_{\lambda, B}) \]

\[ \neq \sum_{\lambda} p_\lambda \ P(a|A; \lambda) \ P(b|B; \rho_{i, B}) \]

\[ \neq \sum_{\lambda} p_\lambda \ P(a|A; \lambda) \ P(b|B; \lambda) \]

Independent of Hilbert space

Obey Uncertainty relations
Wherever there is **independence** from Hilbert space...

...It corresponds to a **device-independent** entanglement detection.
Steering: 1-side device independence
Nonlocality: Total device independence

**Device independent Quantum Cryptography**

(A. Acin et al., PRL 98 230501, 2007)
An important gap . . .

Perfectly manipulated in the lab

Gaussian States

X Lack a measure of steerability (Strength)
X Detailed study of their steering properties

Thank you!