

# Quantum Weirdness

Richard Shoup & Thomas Etter  
Interval Research  
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"QM is the physicists' way of saying: 'Don't ask.'" - anon

## Weirdness (?)

- Superposition - 2 or more values at once
- Interference - two-slit, beam splitter, bomb tester
- Random "collapse" - the Miracle
- Entanglement - "spooky action at a distance", EPR
- Dense coding - 2 bits transmitted by 1 qubit, crypto
- Teleportation - for real, inverse of dense coding

"I've got some grad student. He's thinking about the meaning of quantum mechanics. He's doomed." -- John McCarthy

## States vs Relations

- *Things* (variables) and *possibilities* (cases)
  - values of a var, *joint values* of several vars
- Alternatives not unique
  - Superposition:  $a|0\rangle + b|1\rangle$
- Link Theory: composite relations, case counting
  - Arithmetic, algebra of cases
  - In general, exponential size/effort

$$\begin{bmatrix} a \\ b \end{bmatrix} \quad \begin{array}{c|c} x & n \\ \hline 0 & a \\ 1 & b \end{array}$$

"An elementary particle is not an independently existing, unanalyzable entity. It is, in essence, a set of relationships that reach outward to other things." -- Henry Stapp

## Constraints & Superposition

Which two of these are most alike?

$$X^2 = +1 \Rightarrow X = \{ +1, -1 \} \quad \leftarrow$$

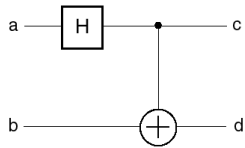
$$X^2 = -1 \Rightarrow X = \{ +i, -i \} \quad \leftarrow$$

$$S = (|0\rangle + |1\rangle) / \sqrt{2} \quad \leftarrow$$

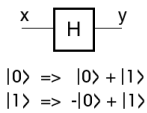
- Algebraic variable - *all possible values*
  - Not just one unknown value, e.g.  $a^2 + b^2 = c^2$
- Quantum experiment - *underconstrained* situation



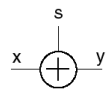
## Quantum Entanglement



$|00\rangle \Rightarrow |00\rangle + |11\rangle$   
 $|01\rangle \Rightarrow |01\rangle + |10\rangle$   
 $|10\rangle \Rightarrow -|00\rangle + |11\rangle$   
 $|11\rangle \Rightarrow -|01\rangle + |10\rangle$



$|0\rangle \Rightarrow |0\rangle + |1\rangle$   
 $|1\rangle \Rightarrow -|0\rangle + |1\rangle$



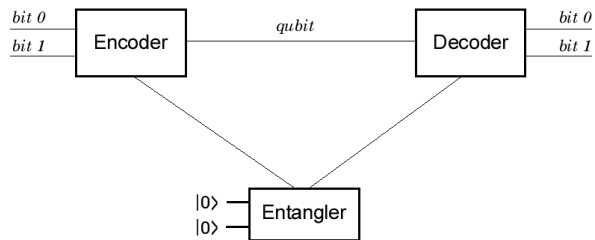
$|00\rangle \Rightarrow |00\rangle$   
 $|01\rangle \Rightarrow |01\rangle$   
 $|10\rangle \Rightarrow |11\rangle$   
 $|11\rangle \Rightarrow |10\rangle$

## Quantum Entropy

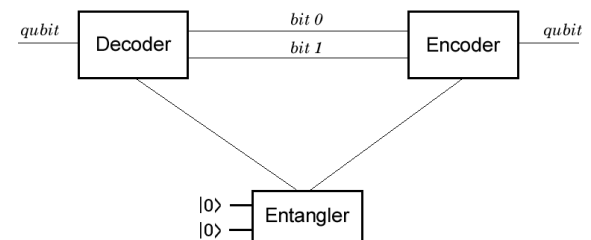
	$S_{A B}$	$S_{A:B}$	$S_{B A}$	$S_{\text{Total}}$
classical (independent)	1	0	1	2
classical (correlated)	0	1	0	1
quantum (entangled)	-1	2	-1	0

Cerf & Adami, 1996

## Quantum Dense Coding



## Quantum Teleportation



## Quantum Connectedness

*When to the new eyes of thee  
All things by immortal power,  
Near or far  
Hiddenly  
To each other linked are  
That thou canst not stir a flower  
Without troubling a star.*

*-- Francis Thompson  
in "Mistress of Vision"*