Title: Rob Spekkens ISSYP Keynote - Can Quantum Correldatins be Explained Causally

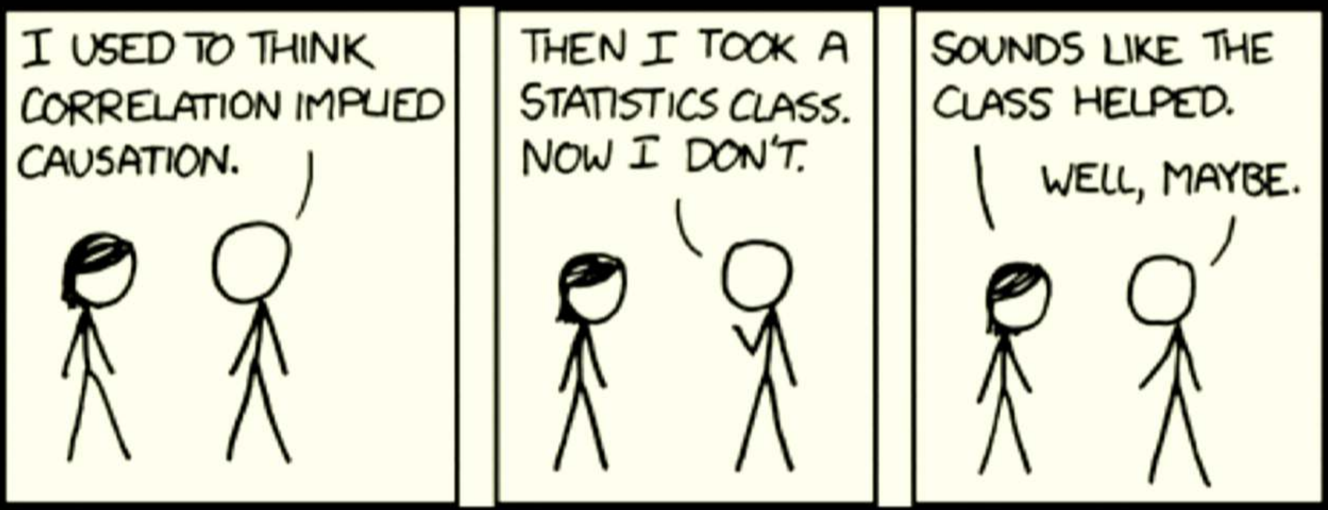
Date: Jul 20, 2016 10:30 AM

URL: http://pirsa.org/16070066

Abstract:

Can Quantum Correlations Be Explained Causally?

Rob Spekkens
Perimeter Institute



From XKCD comics

ISSYP 2016

Simpson's Paradox

P(recovery | drug) > P(recovery | no drug)

Simpson's Paradox

P(recovery | drug) > P(recovery | no drug)

P(recovery | drug, male) < P(recovery | no drug, male)

Simpson's Paradox

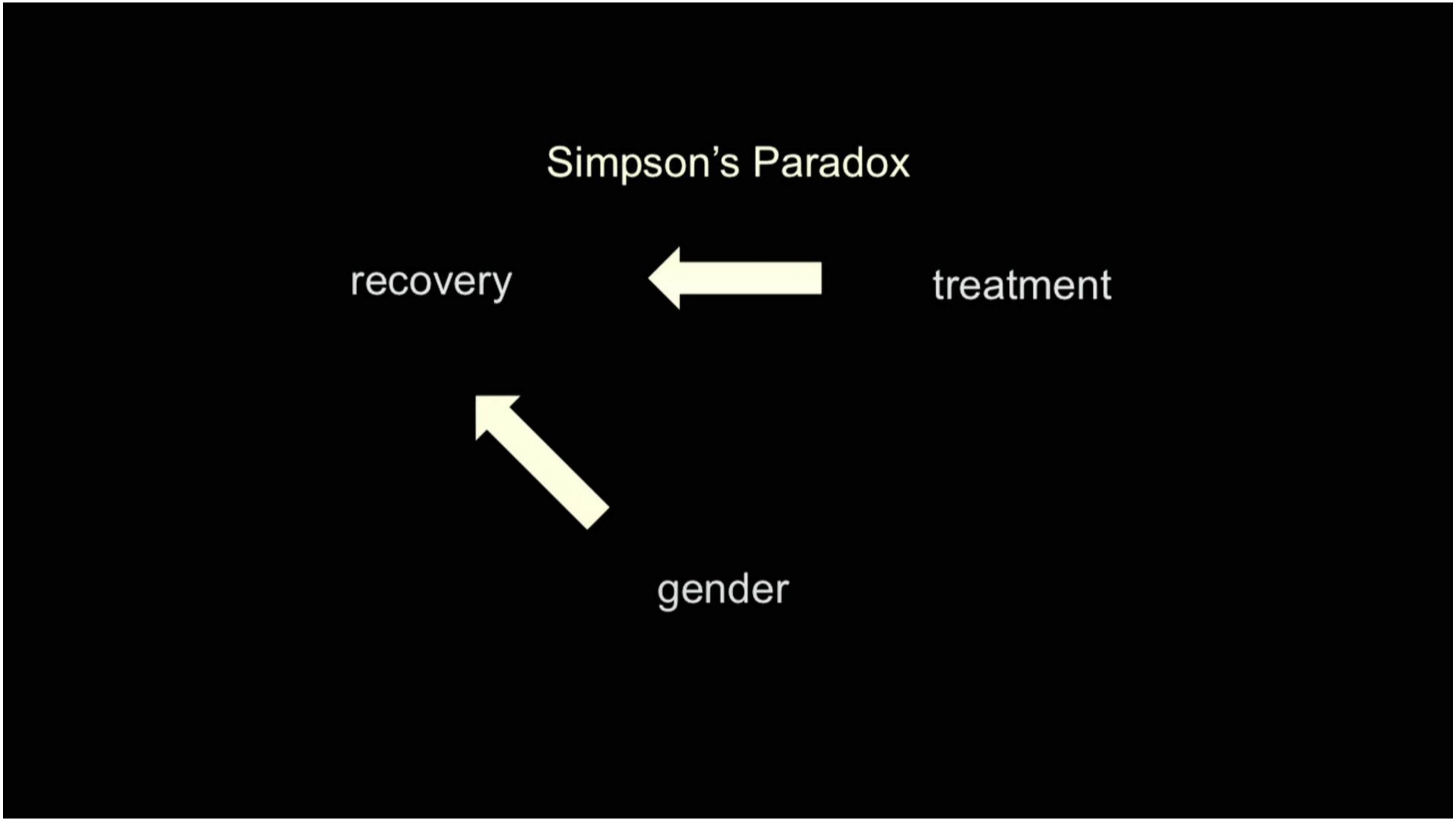
P(recovery | drug) > P(recovery | no drug)

P(recovery | drug, male) < P(recovery | no drug, male)

P(recovery | drug, female) < P(recovery | no drug, female)

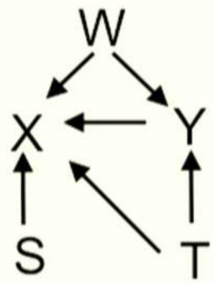
Recovery probability

	drug	no drug
male	180/300 = 60%	70/100 = 70%
female	20/100 = 20%	90/300 = 30%
combined	200/400 = 50%	160/400 = 40%


Simpson's Paradox
recovery
treatment
gender

Causal Model

Causal Structure	Causal-Statistical Parameters



$P(W)$

$P(S)$

$P(T)$

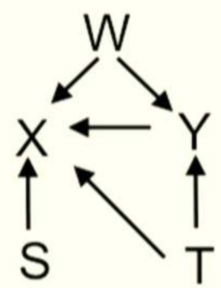
$P(X|S,T,W,Y)$

$P(Y|T,W)$

$$P(X,Y,W,S,T) = P(X|S,T,W,Y)P(Y|T,W)P(W)P(S)P(T)$$

Causal Model

Causal Structure



Causal-Statistical Parameters

$P(W)$

$P(S)$

$P(T)$

$P(X|S,T,W,Y)$

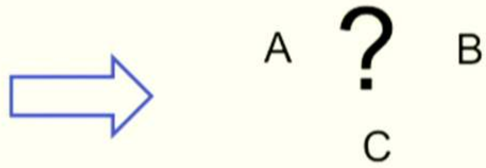
$P(Y|T,W)$

$$P(X,Y,W,S,T) = P(X|S,T,W,Y)P(Y|T,W)P(W)P(S)P(T)$$

$P(A, B, C)$

A is independent of B

$P(A, B) = P(A)P(B)$



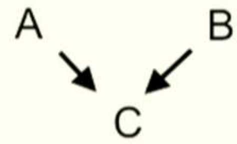
no other independence relations

$P(A, B, C)$

A is independent of B

$P(A, B) = P(A)P(B)$

no other independence relations

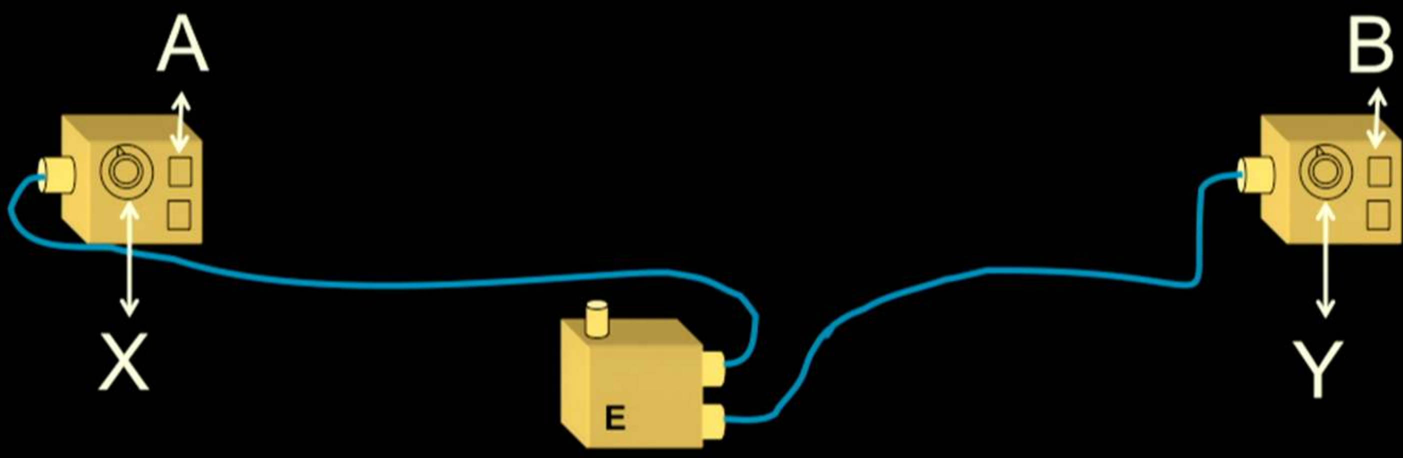


$P(A)$

$P(B)$

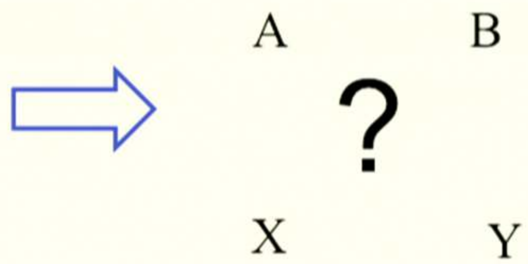
$P(C|A, B)$

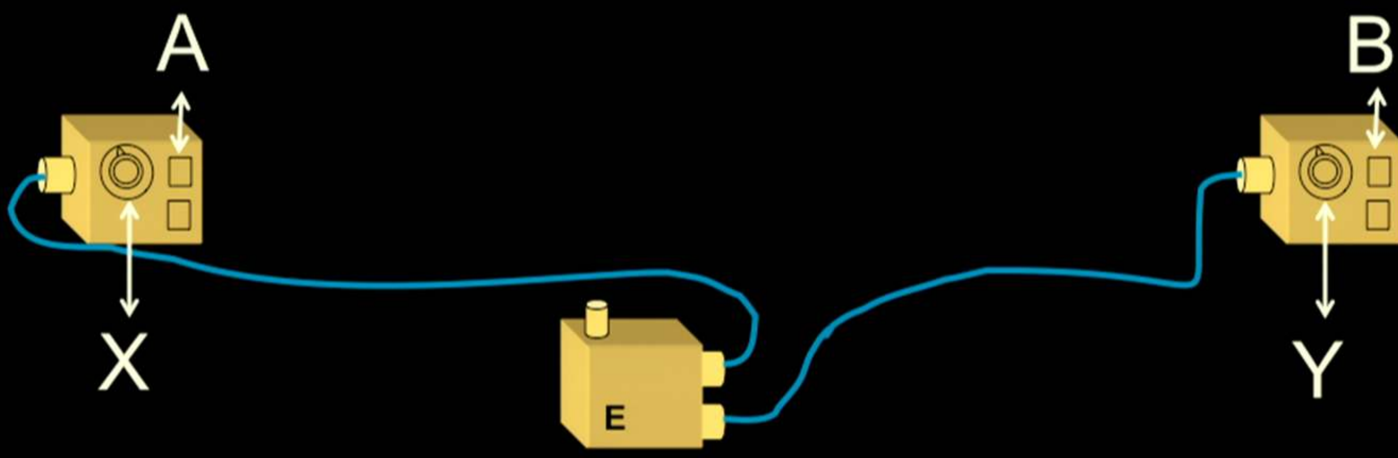
$$P(A, B, C) = P(C|A, B)P(A)P(B)$$



P(A,B|X,Y)

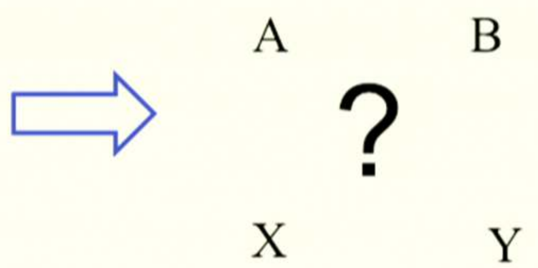
	A=0, B=0	A=0, B=1	A=1, B=0	A=1, B=1
X=0, Y=0	0.427	0.073	0.073	0.427
X=0, Y=1	0.427	0.073	0.073	0.427
X=1, Y=0	0.427	0.073	0.073	0.427
X=1, Y=1	0.073	0.427	0.427	0.073





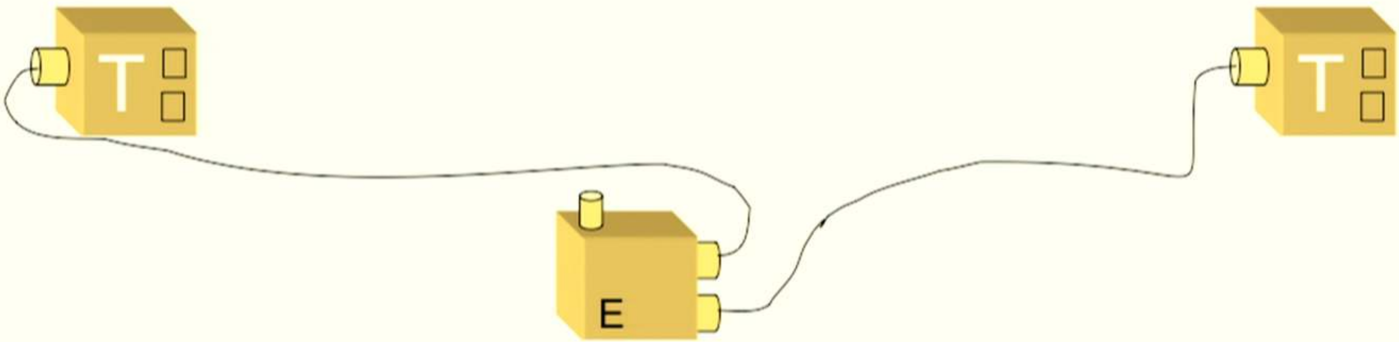
P(A,B|X,Y)

	A=0, B=0	A=0, B=1	A=1, B=0	A=1, B=1
X=0, Y=0	0.427	0.073	0.073	0.427
X=0, Y=1	0.427	0.073	0.073	0.427
X=1, Y=0	0.427	0.073	0.073	0.427
X=1, Y=1	0.073	0.427	0.427	0.073



Bell's theorem

John S. Bell
(1928-1990)


T
E
T

There are two possible measurements, H and T, with two outcomes each: green or red

Suppose which of H or T occurs at each wing is chosen at random

Scenario 1

1. Whenever the same measurement is made on A and B, the outcomes always agree

   H and H
   or
   T and T

2. Whenever different measurements are made on A and B, the outcomes always disagree

   H and T
   or
   T and H

There are two possible measurements, H and T,
with two outcomes each: green or red

Suppose which of H or T occurs at each wing is chosen at random

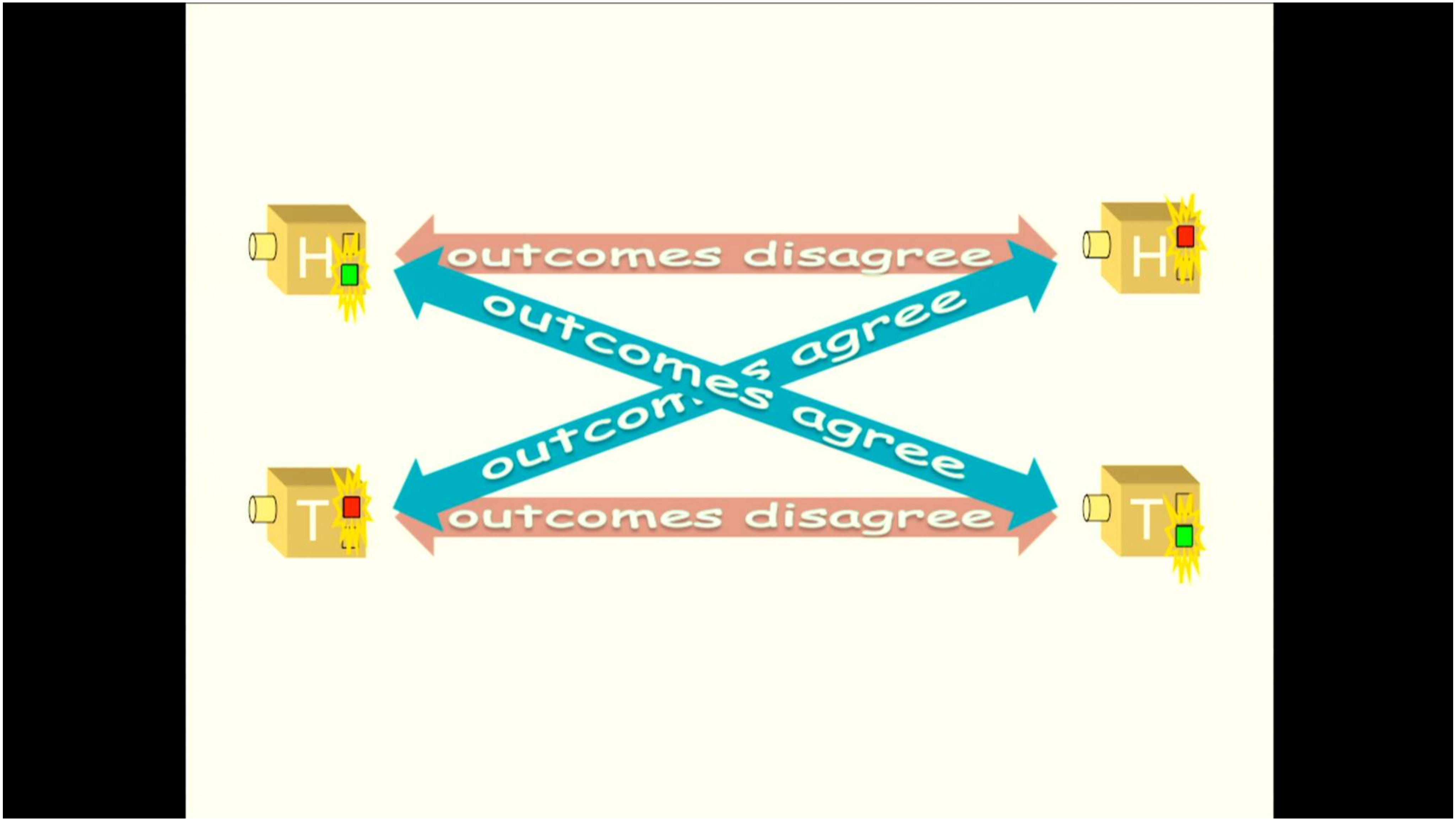
Scenario 2

1. Whenever the same measurement is made on A and B, the outcomes always disagree

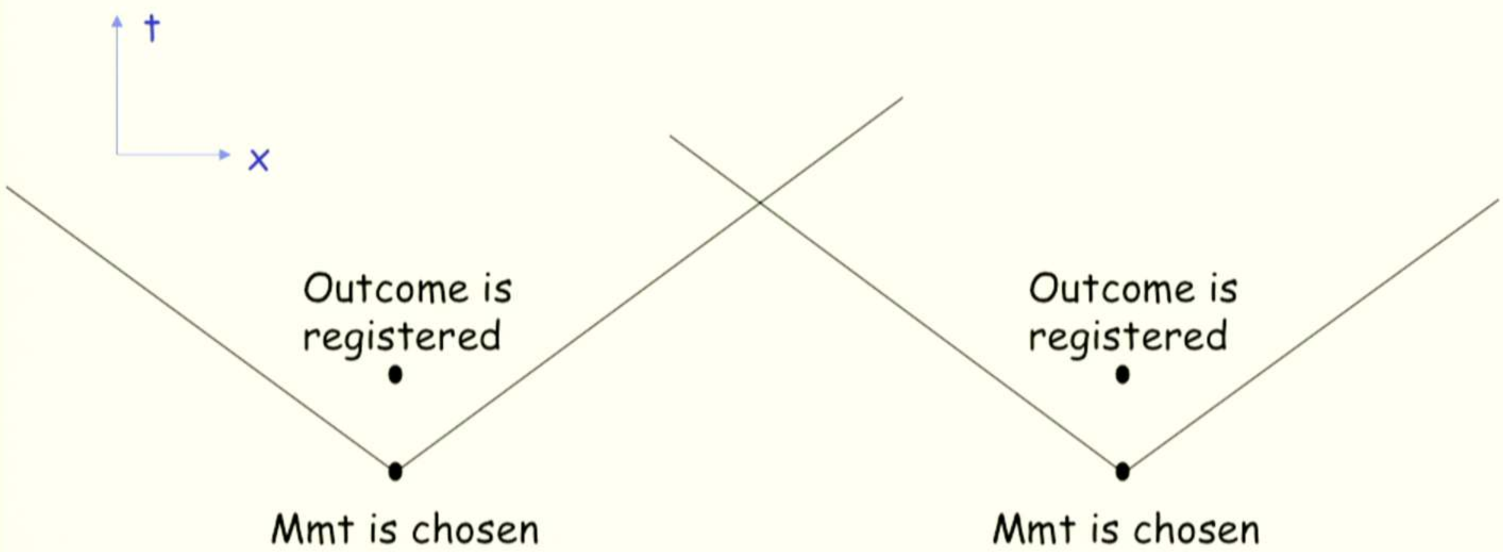
   H and H
   or
   T and T

2. Whenever different measurements are made on A and B, the outcomes always agree

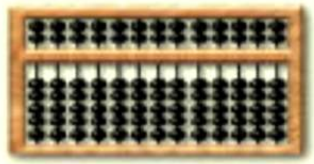
   H and T
   or
   T and H


H
H
outcomes disagree
outcomes agree
outcomes agree
T
T
outcomes disagree

Tension with the theory of relativity



Information theory

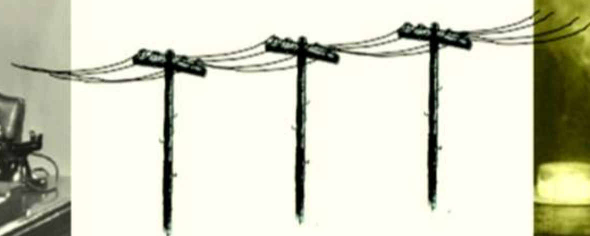


Computation

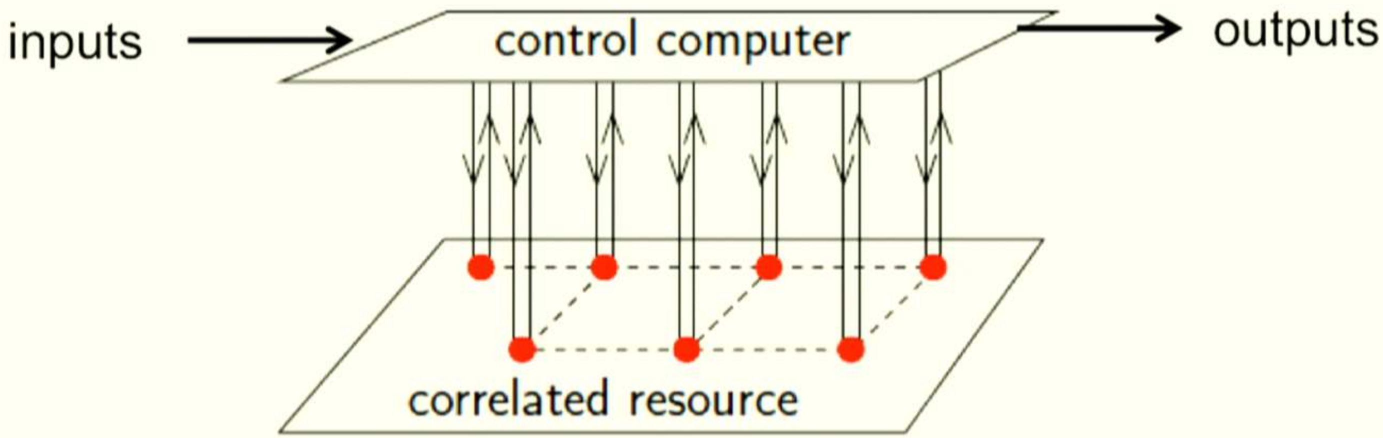
- factoring
- Searching a database

Communication

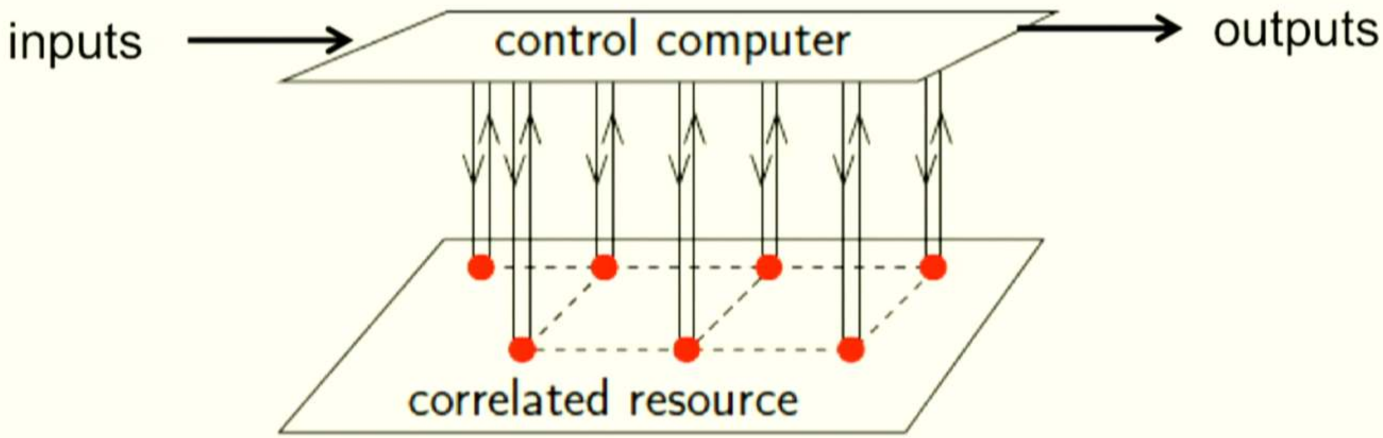
- data compression
- overcoming noise



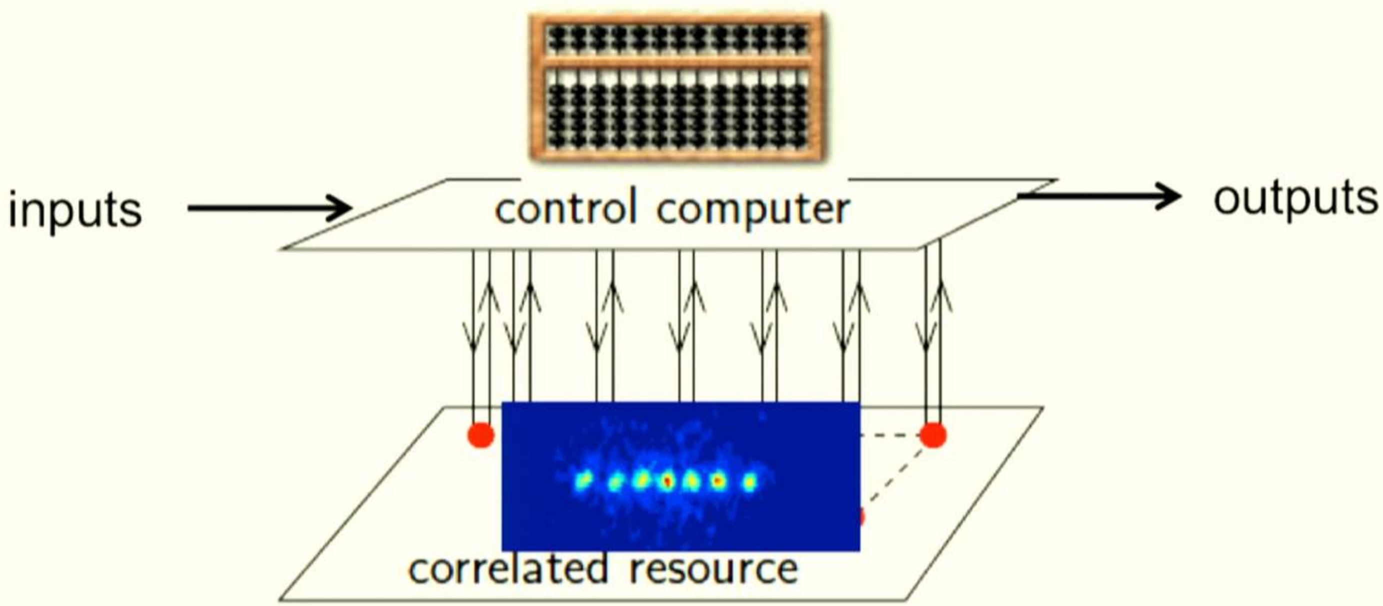
Quantum advantages for computation

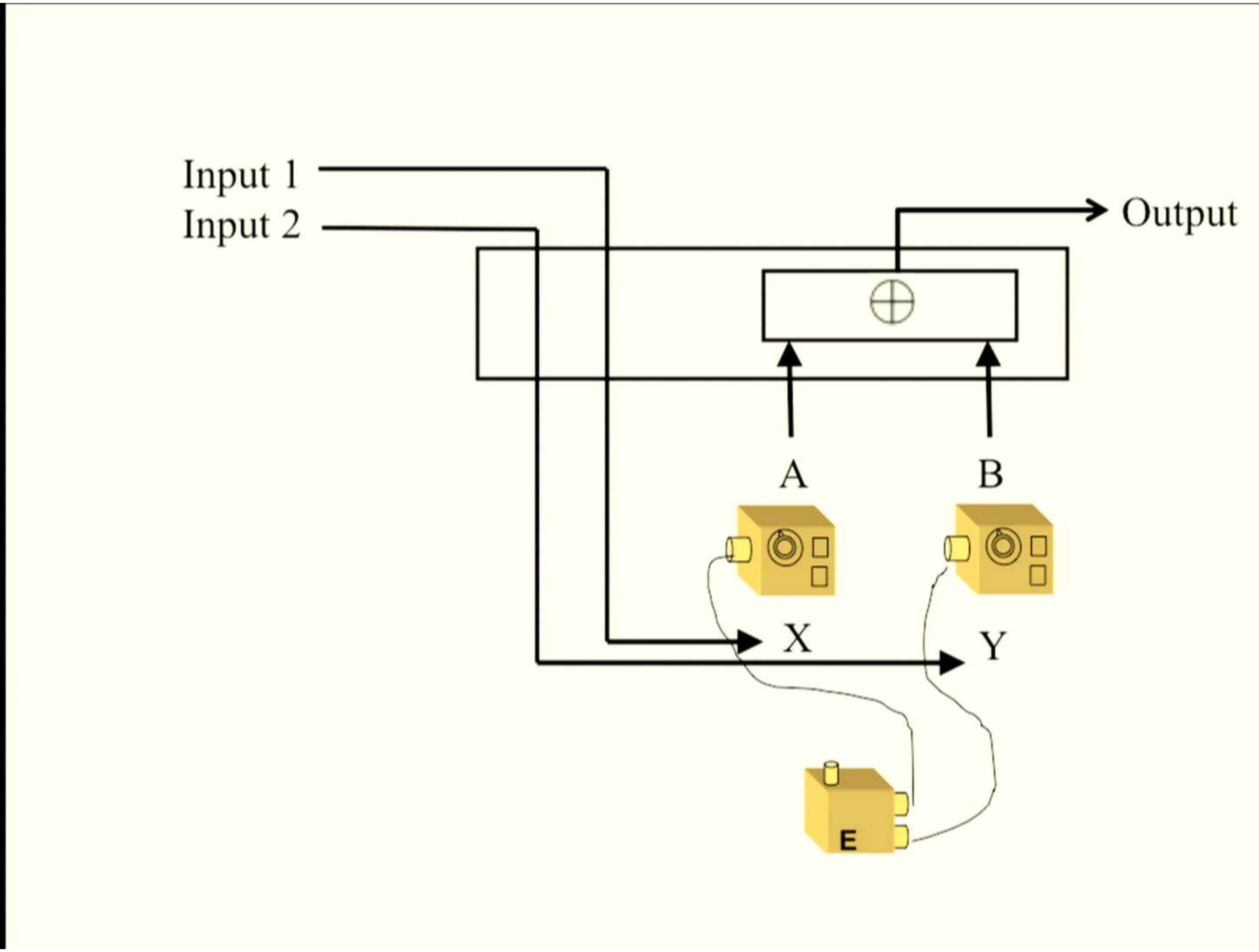


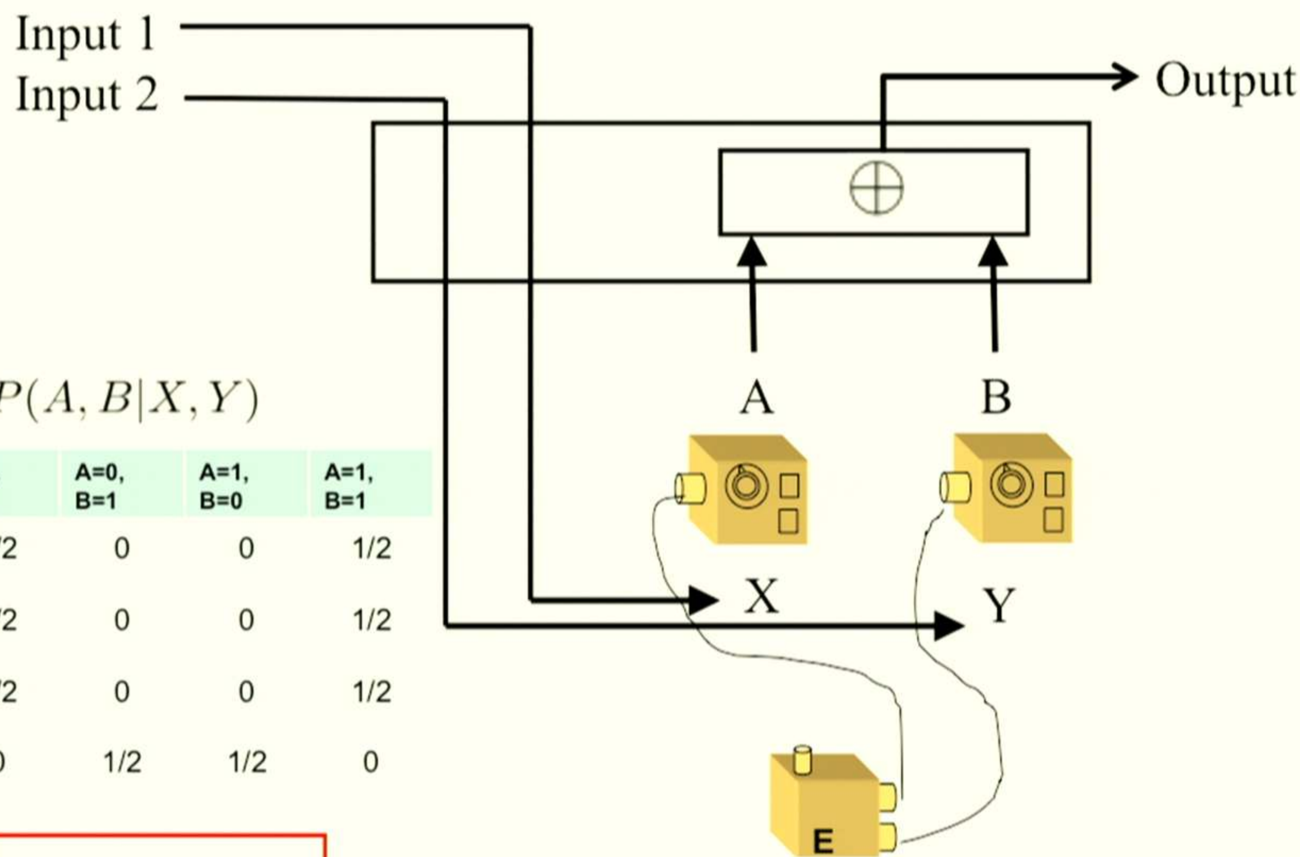
Quantum advantages for computation



Quantum advantages for computation




Input 1
Input 2
Output
A
B
X
Y
E



$$P(A, B|X, Y)$$

	A=0, B=0	A=0, B=1	A=1, B=0	A=1, B=1
X=0, Y=0	1/2	0	0	1/2
X=0, Y=1	1/2	0	0	1/2
X=1, Y=0	1/2	0	0	1/2
X=1, Y=1	0	1/2	1/2	0

$$A \oplus B = XY$$