Title: Robert Spekkens: The riddle of the quantum sphinx: quantum states and category mistakes

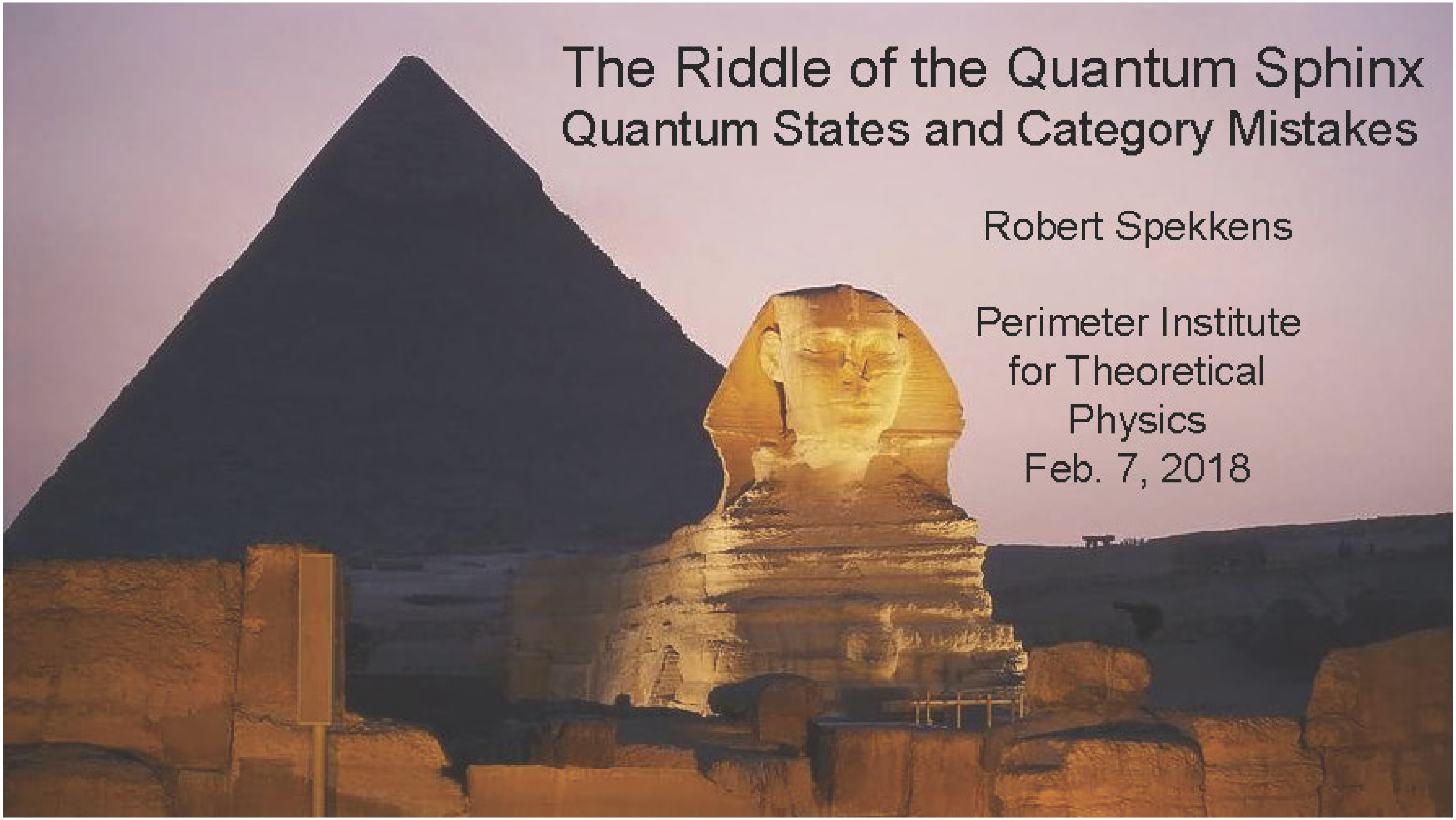
Date: Feb 07, 2018 07:00 PM

URL: http://pirsa.org/18020008

Abstract: <p>Science is like puzzle-solving. Making sense of quantum theory is a particularly thorny kind of brain-twister, with more than its fair share of mysteries. If you are stuck on a puzzle, it may be because you have made a false assumption about the nature of some entity that is absolutely central to the whole business. If so, you have made a category mistake: you are not just wrong about what this entity is, but about what sort of thing it is.</p>

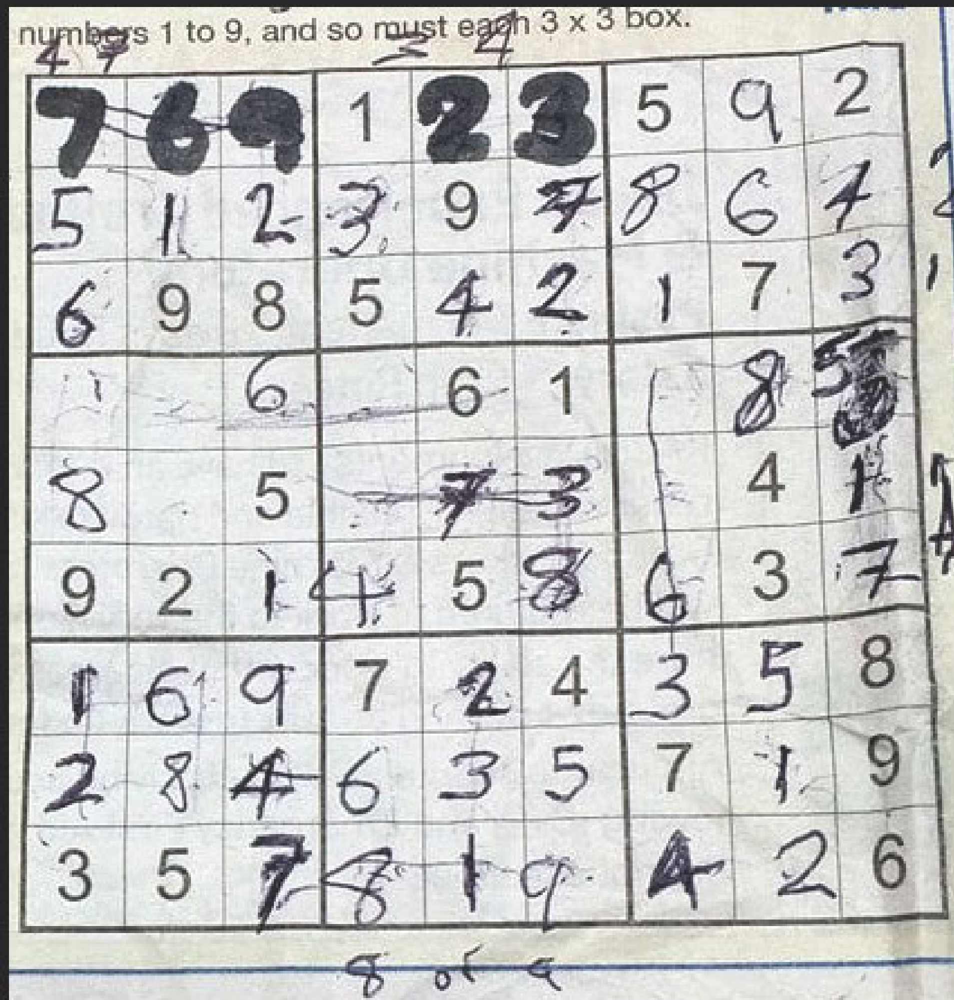
<p>In his Public Lecture at Perimeter Institute, Robert Spekkens will explain why he believes that many quantum mysteries are a result of a category mistake concerning the nature of quantum states. Along the way, he will address some idiosyncratic questions, such as: What did Plato have to say about Heisenbergâ€™s uncertainty principle? What do poorly implemented clinical drug trials have to do with "spooky action at a distance"? And, most importantly, what did the successful deciphering of Egyptian hieroglyphs teach us about the interpretation of quantum theory? </p>

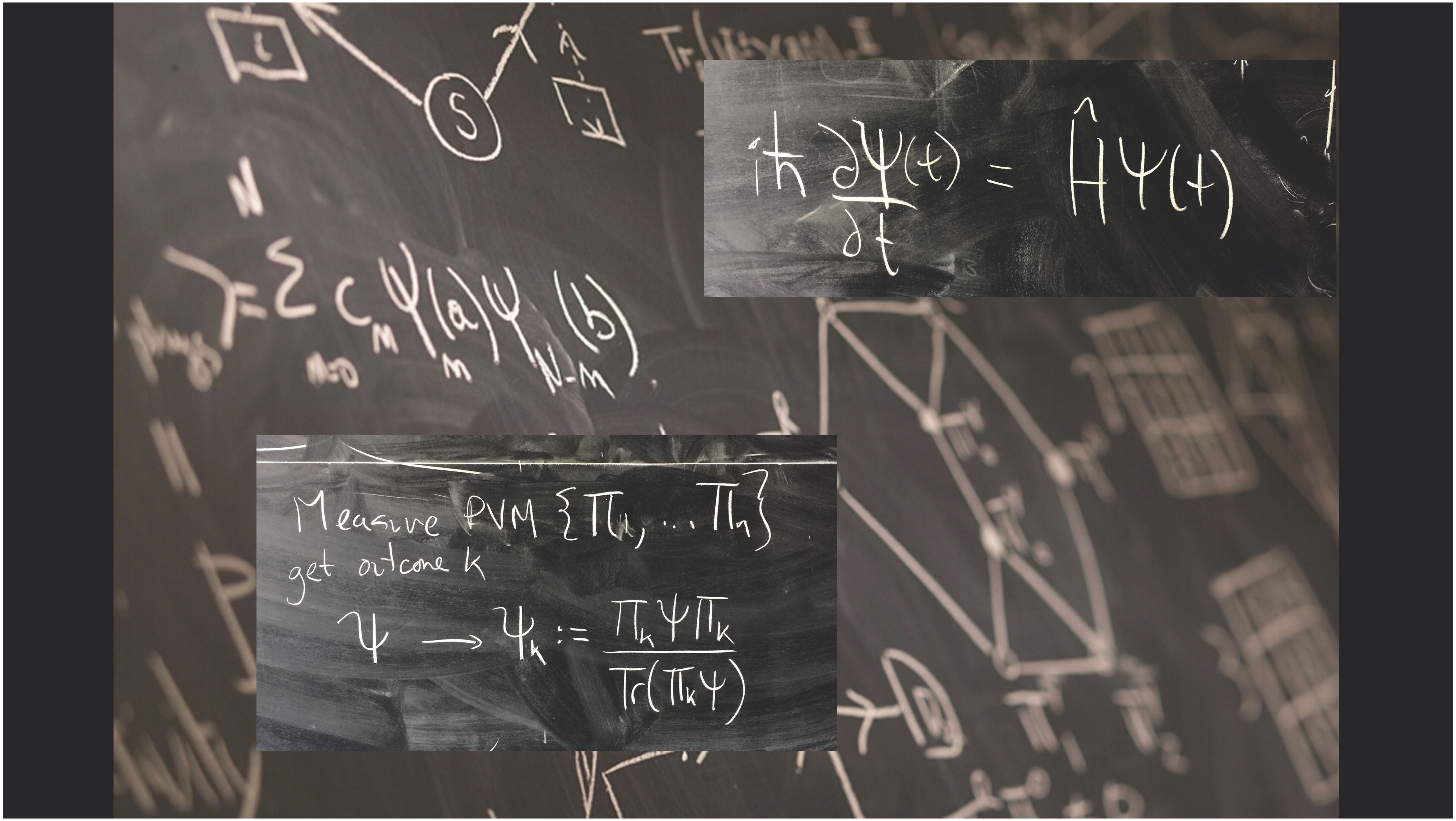
<p>Spekkens is a faculty member at Perimeter Institute whose research examines the foundations of quantum theory. He co-edited the book Quantum Theory: Informational Foundations and Foils, and he is a Project Leader of the international research collaboration "Quantum Causal Structures.â€• In 2012, he won first prize in the Foundational Questions Institute (FQXi) essay contest "Questioning the Foundations: Which of Our Assumptions Are Wrong?" He lives in Waterloo with his wife and three-year-old son.</p>

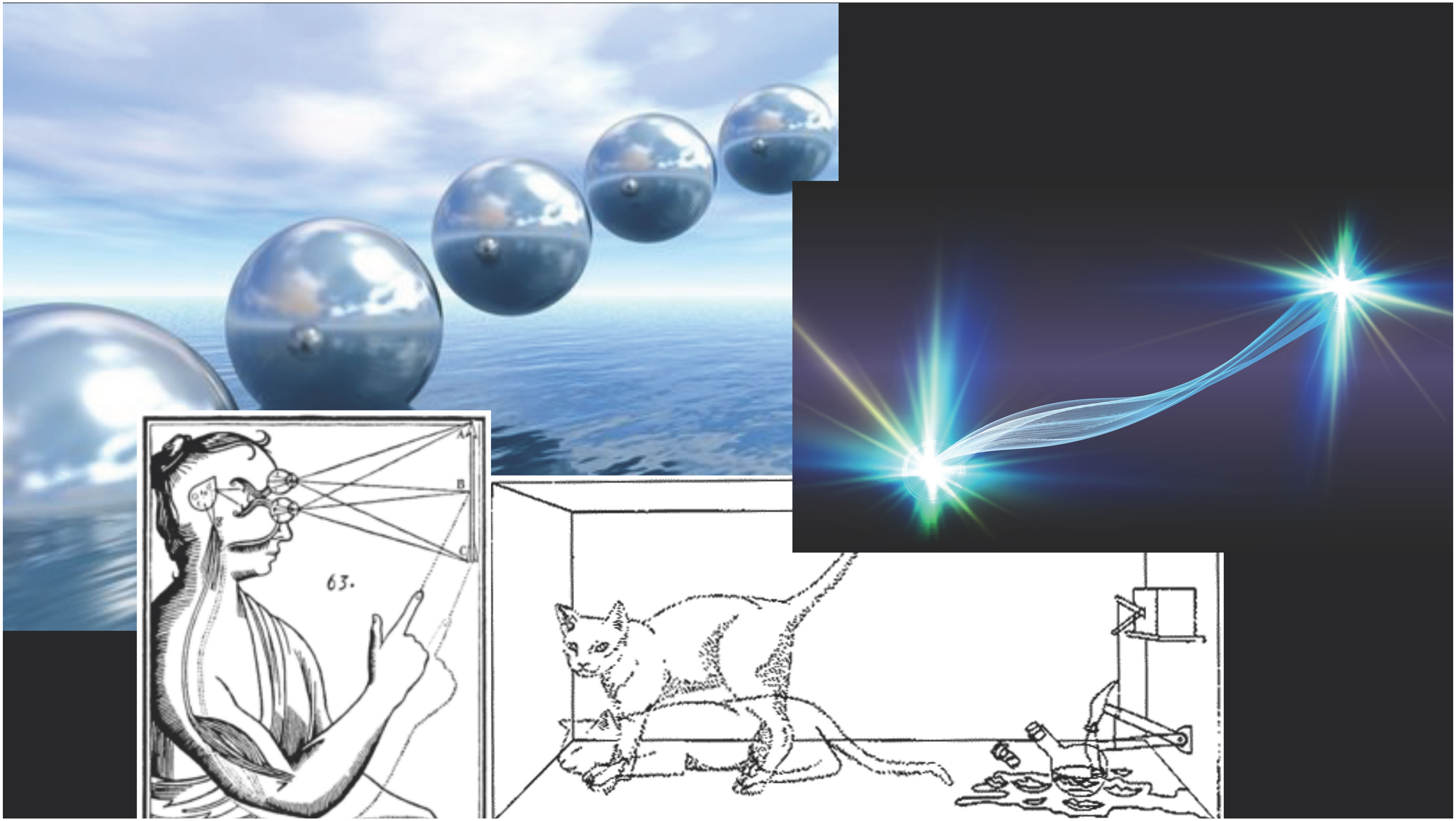

The Riddle of the Quantum Sphinx
Quantum States and Category Mistakes
Robert Spekkens
Perimeter Institute
for Theoretical
Physics
Feb. 7, 2018

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

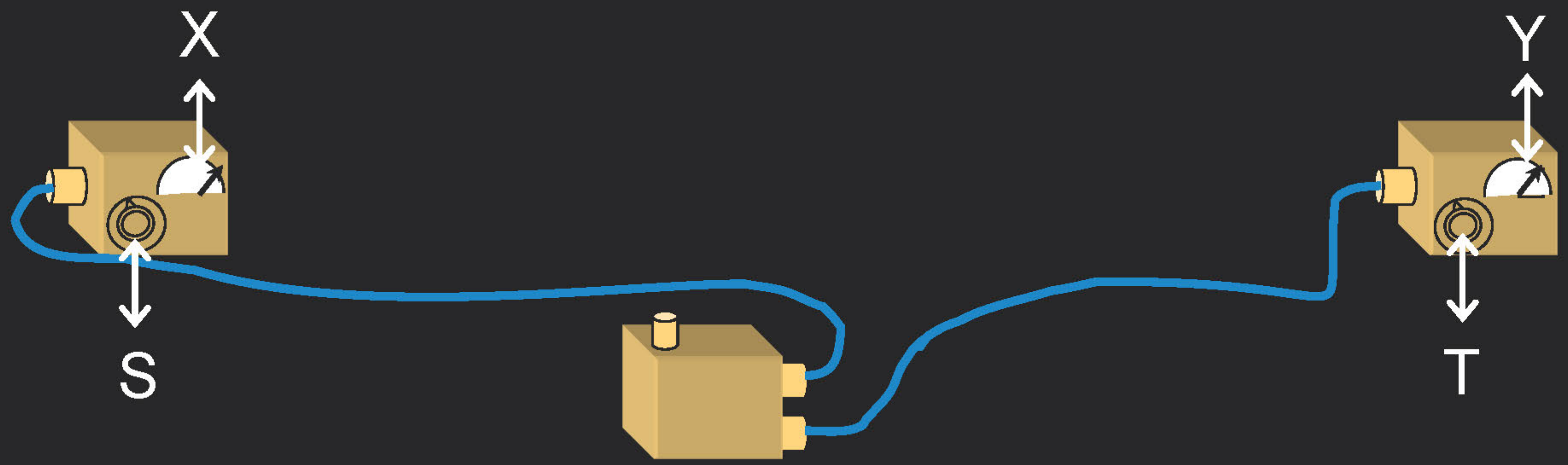
5	3	4	6	7	8	9	1	2
6	7	2	1	9	5	3	4	8
1	9	8	3	4	2	5	6	7
8	5	9	7	6	1	4	2	3
4	2	6	8	5	3	7	9	1
7	1	3	9	2	4	8	5	6
9	6	1	5	3	7	2	8	4
2	8	7	4	1	9	6	3	5
3	4	5	2	8	6	1	7	9


numbers 1 to 9, and so must each 3 x 3 box.


$i\hbar \frac{\partial \Psi(t)}{\partial t} = \hat{H}\Psi(t)$
Measure PVM $\{\Pi_1, \ldots \Pi_n\}$
get outcome k
$\Psi \longrightarrow \Psi_k := \frac{\Pi_k \Psi \Pi_k}{Tr(\Pi_k \Psi)}$


63.

$$\psi$$



P(X,Y|S,T)

	X=0, Y=0	X=0, Y=1	X=1, Y=0	X=1, Y=1
S=0, T=0	0.427	0.073	0.073	0.427
S=0, T=1	0.427	0.073	0.073	0.427
S=1, T=0	0.427	0.073	0.073	0.427
S=1, T=1	0.073	0.427	0.427	0.073

Simpson's Paradox

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)

Simpson's Paradox

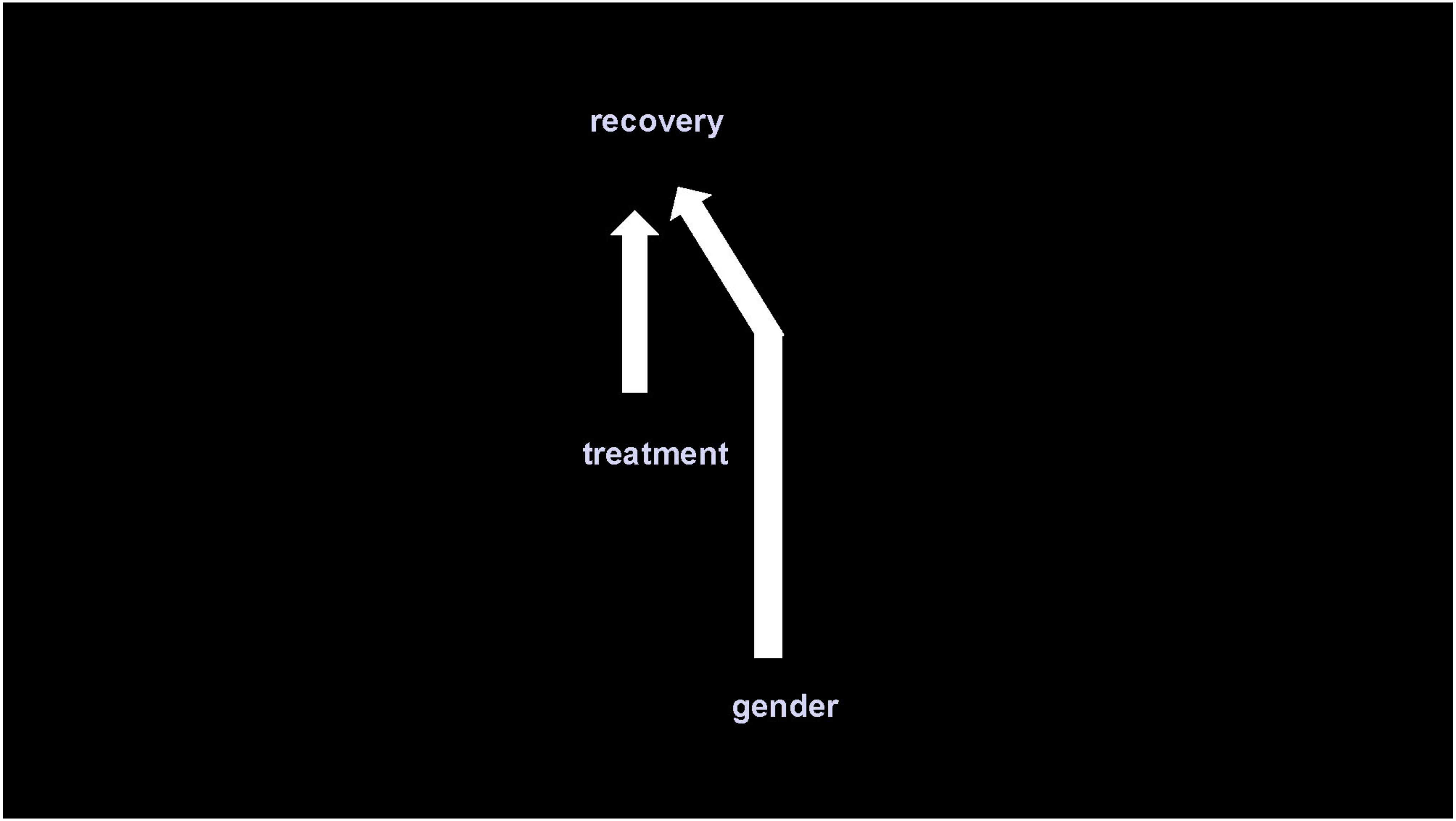
P(recovery | drug) > P(recovery | no drug)

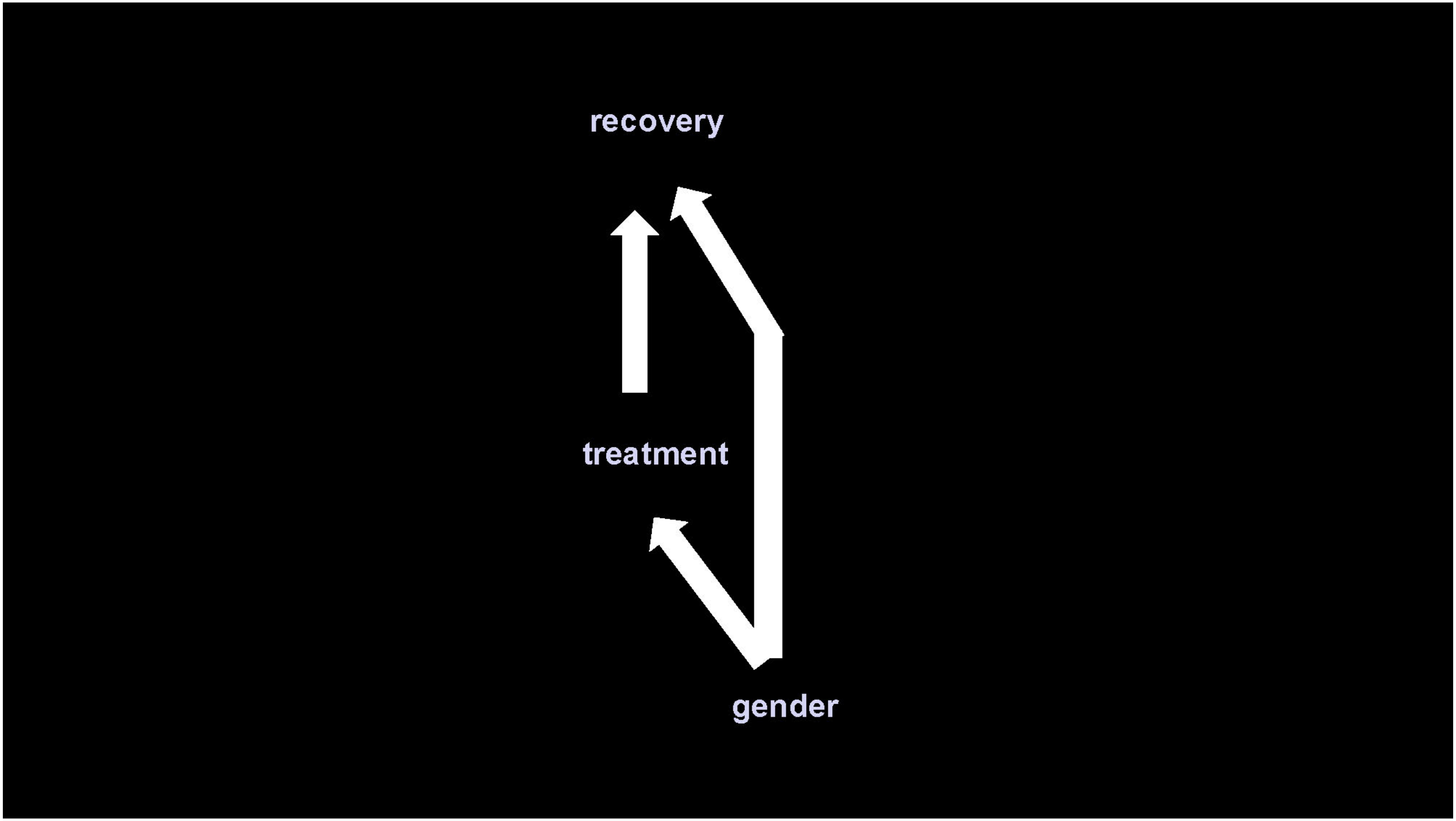
P(recovery | drug, male) < P(recovery | no drug, male)

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

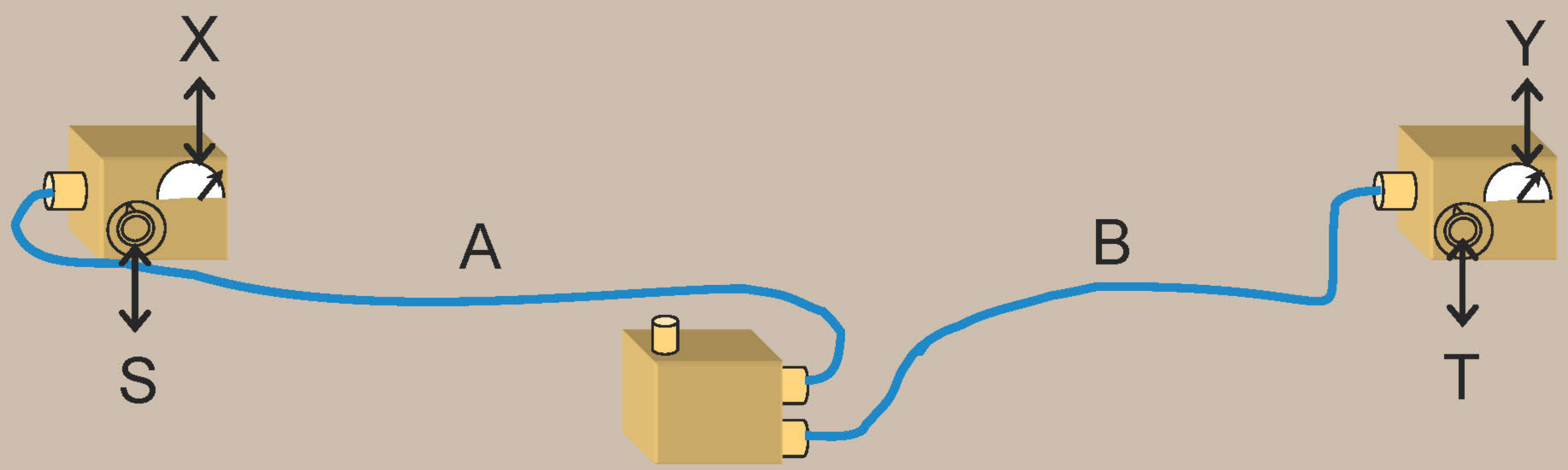
Recovery probability

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


recovery
treatment
gender

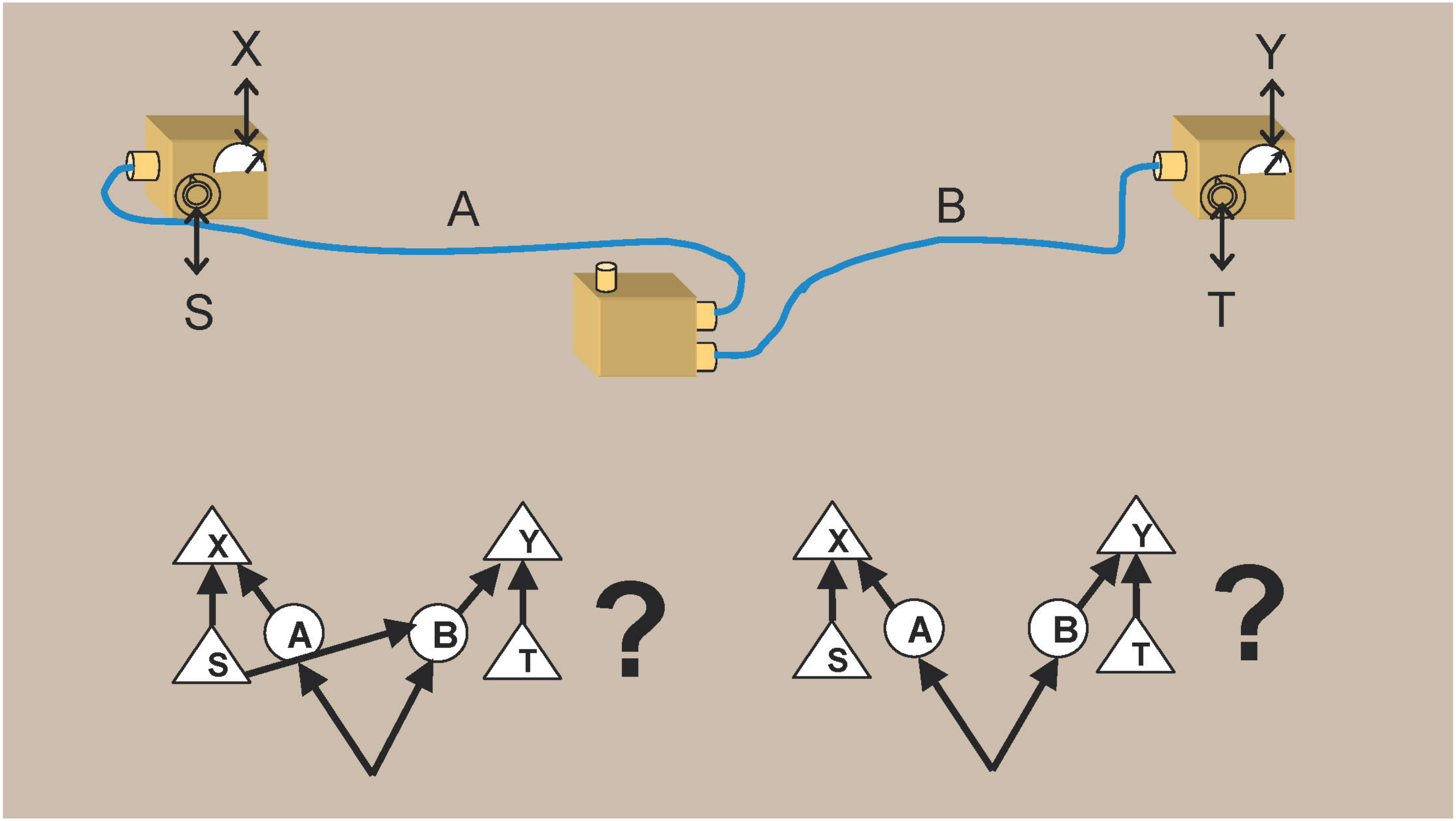


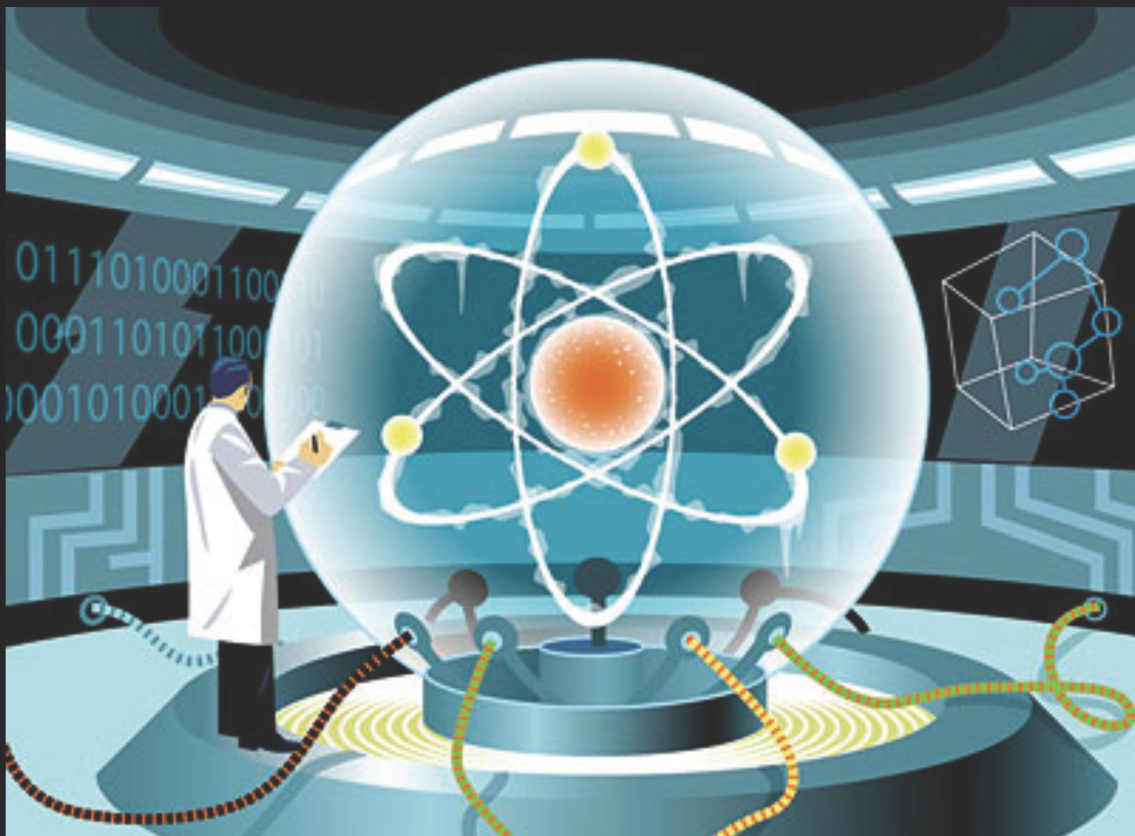
recovery
treatment
gender

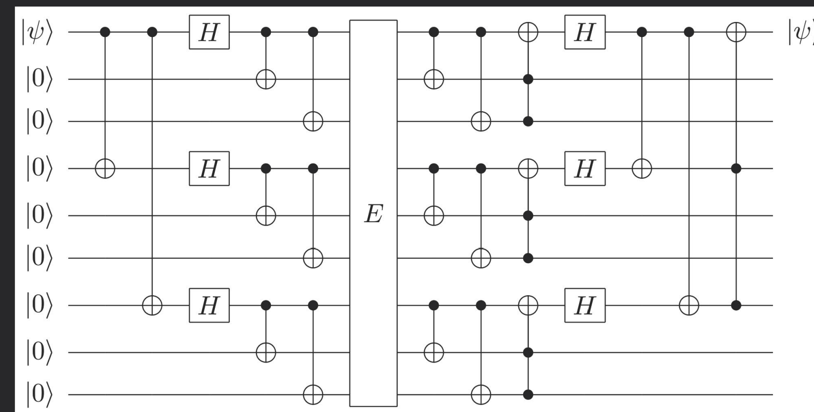


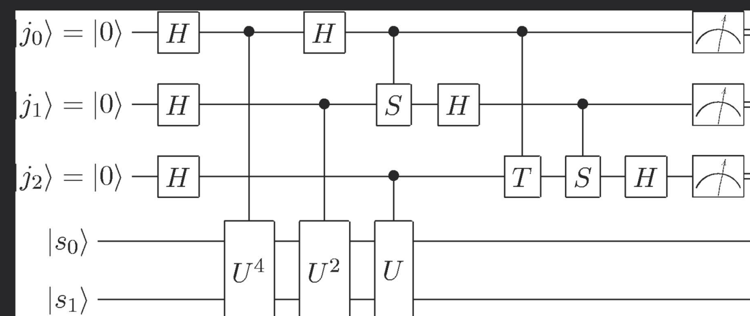
P(X,Y|S,T)

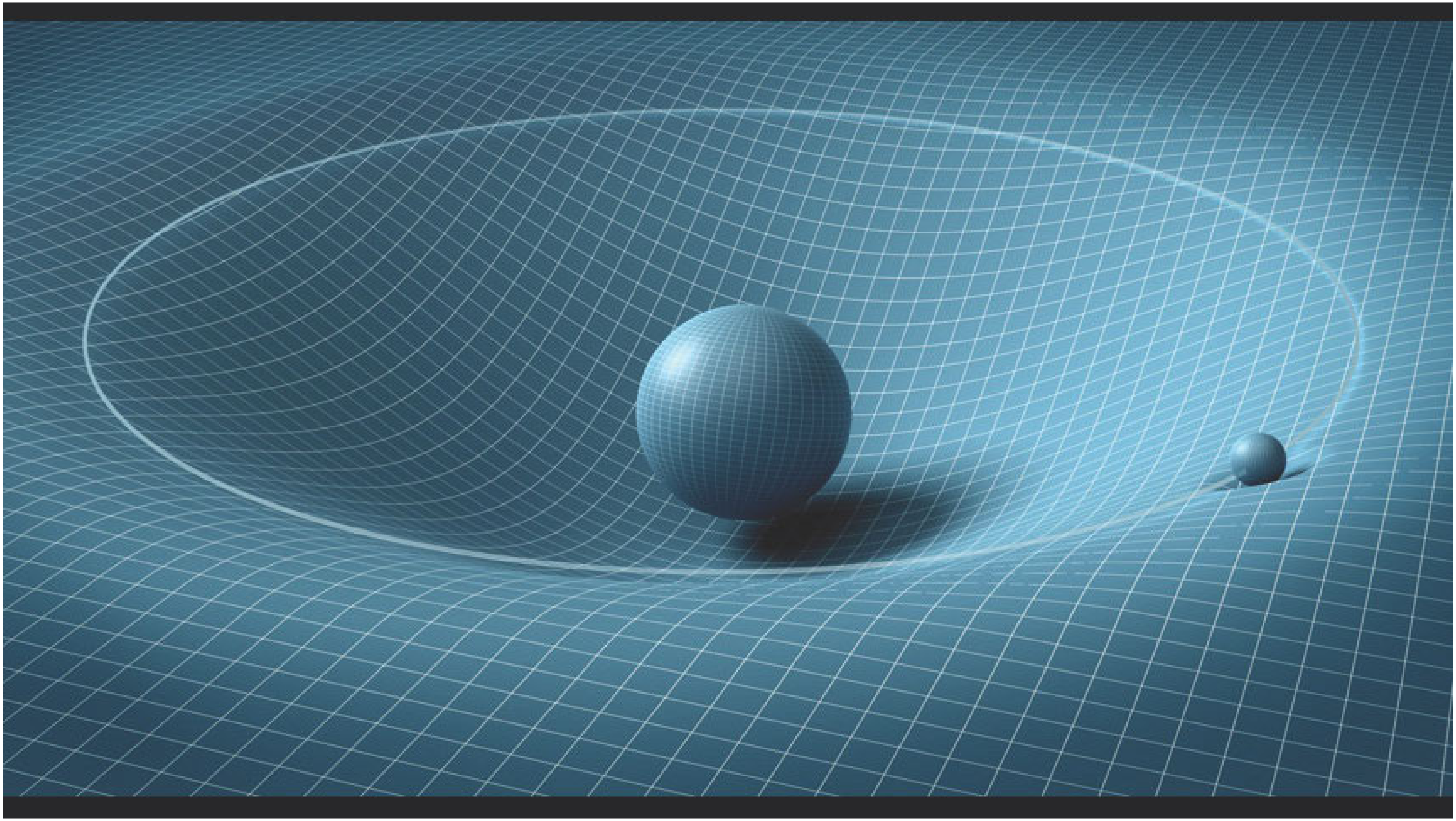
	X=0, Y=0	X=0, Y=1	X=1, Y=0	X=1, Y=1
S=0, T=0	0.427	0.073	0.073	0.427
S=0, T=1	0.427	0.073	0.073	0.427
S=1, T=0	0.427	0.073	0.073	0.427
S=1, T=1	0.073	0.427	0.427	0.073


X
Y
A
B
S
T
X
Y
A
B
S
T
?
X
Y
A
B
S
T
?



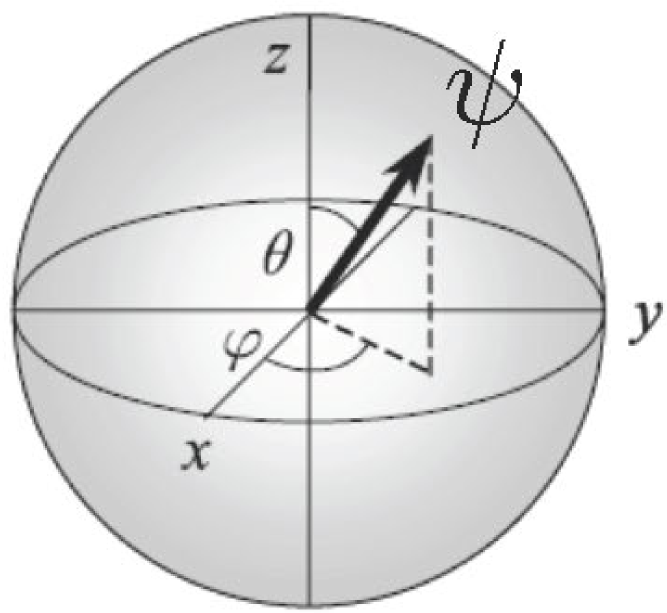

$|\psi\rangle$
$|0\rangle$
H
E
T
S


$|j_0\rangle = |0\rangle$
$|j_1\rangle = |0\rangle$
$|j_2\rangle = |0\rangle$
$|s_0\rangle$
$|s_1\rangle$
H
U^4
U^2
U
S
T



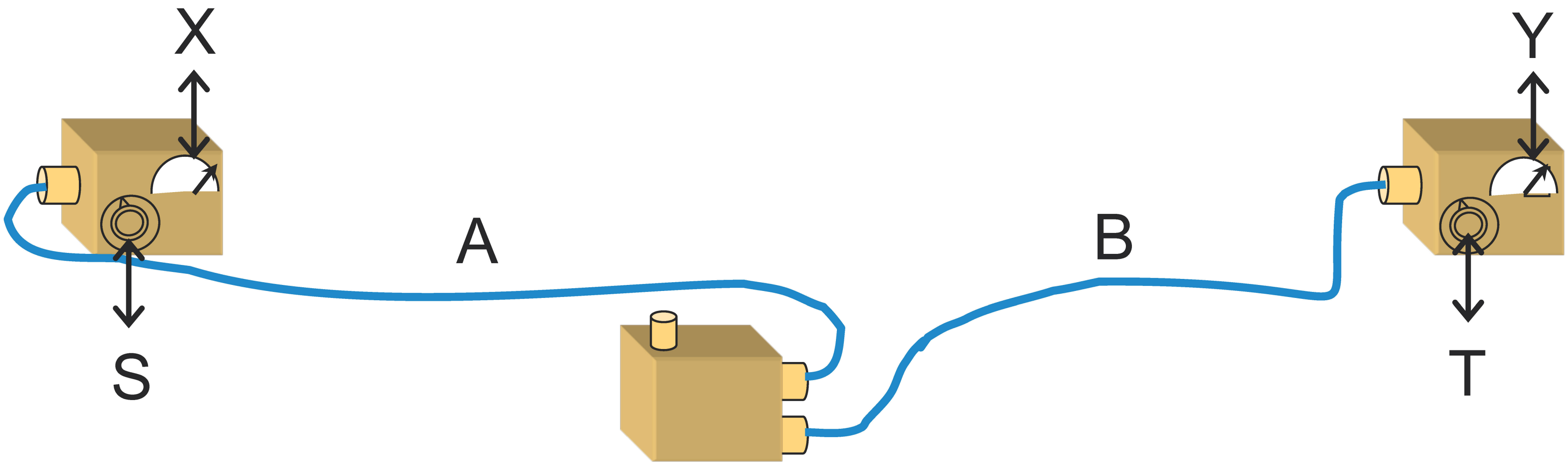
$$\psi$$

$$\psi = (0.866, 0.321, 0.383)$$



今日の天気

温度	18
風速	8
降水確率	0.50



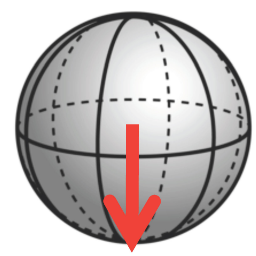
Set $S=0$

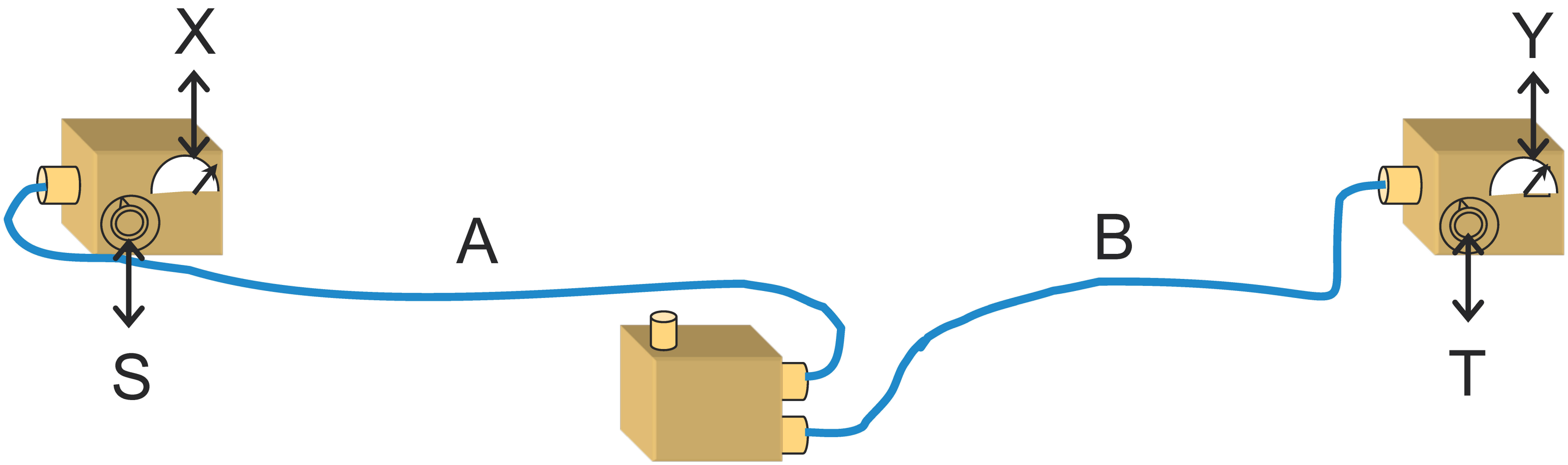
get $X=0$

B collapses to $\psi_{0,0}$

get $X=1$

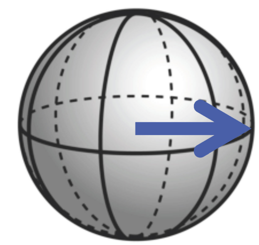
B collapses to $\psi_{0,1}$



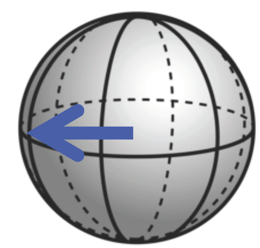


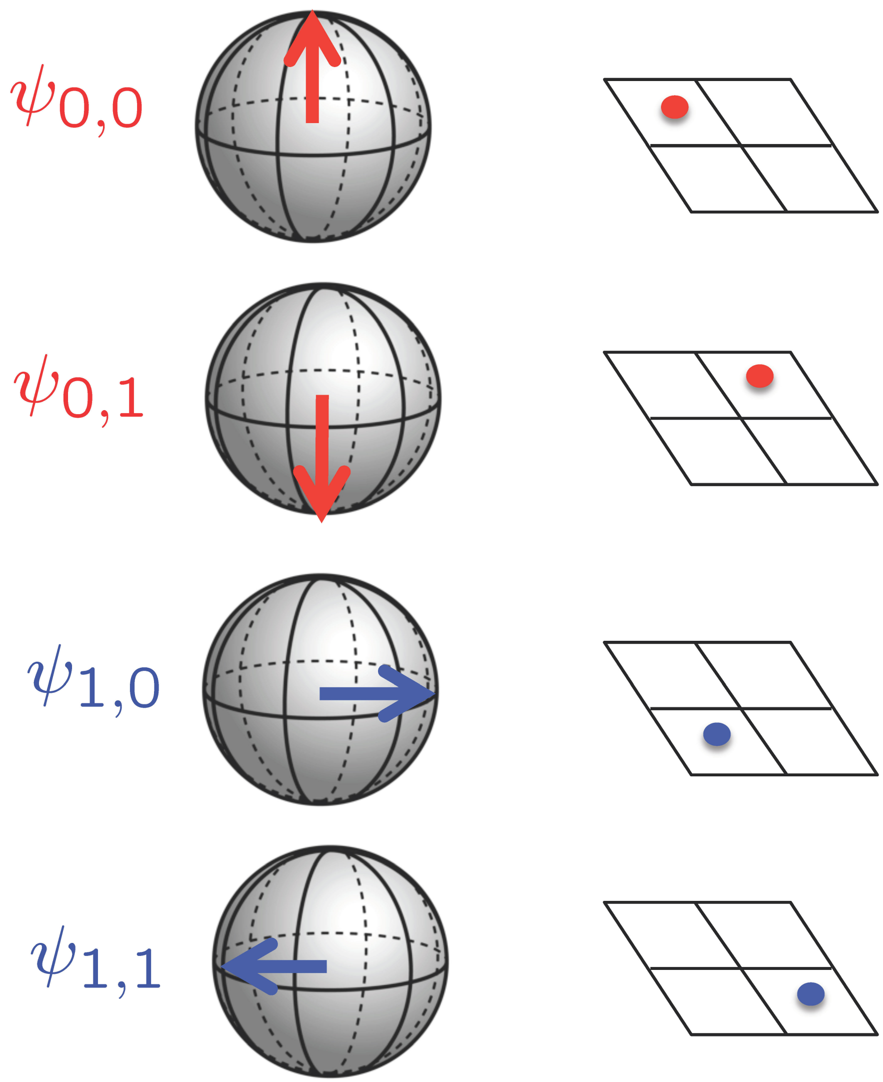
Set S=1

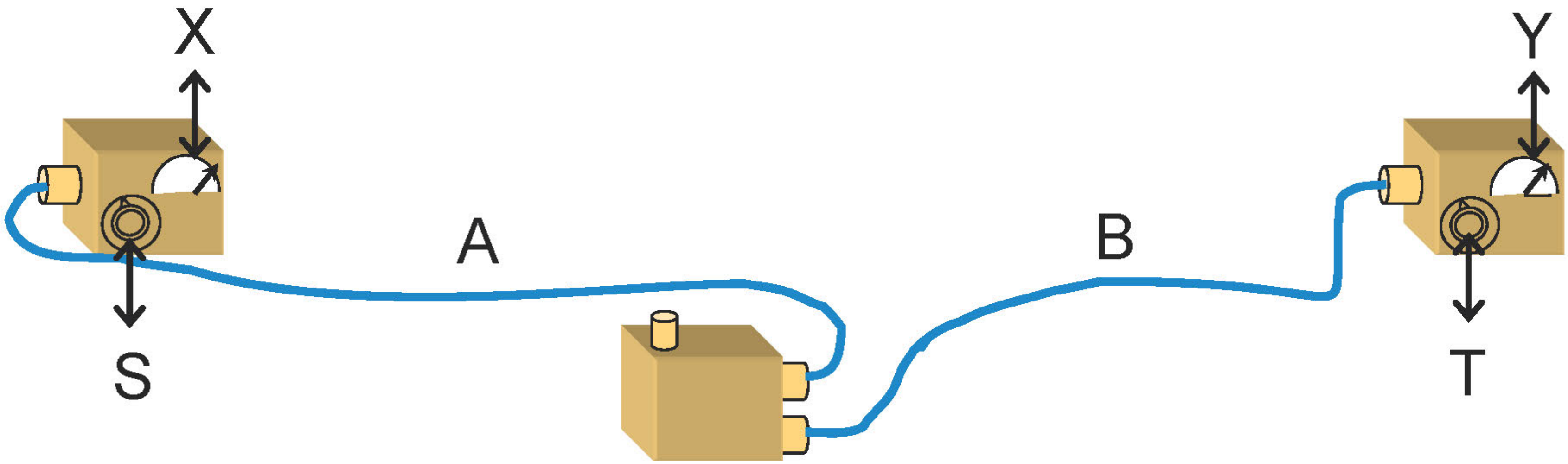
get X=0 B collapses to $\psi_{1,0}$



get X=1 B collapses to $\psi_{1,1}$

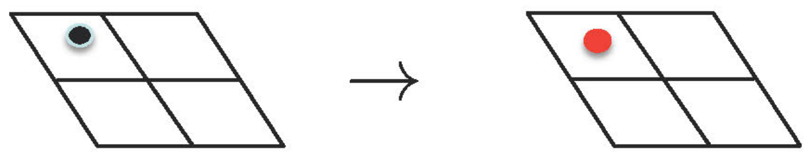



$\psi_{0,0}$
$\psi_{0,1}$
$\psi_{1,0}$
$\psi_{1,1}$

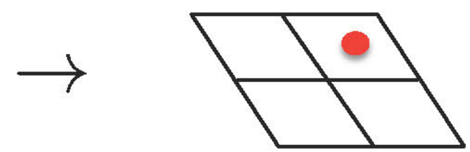


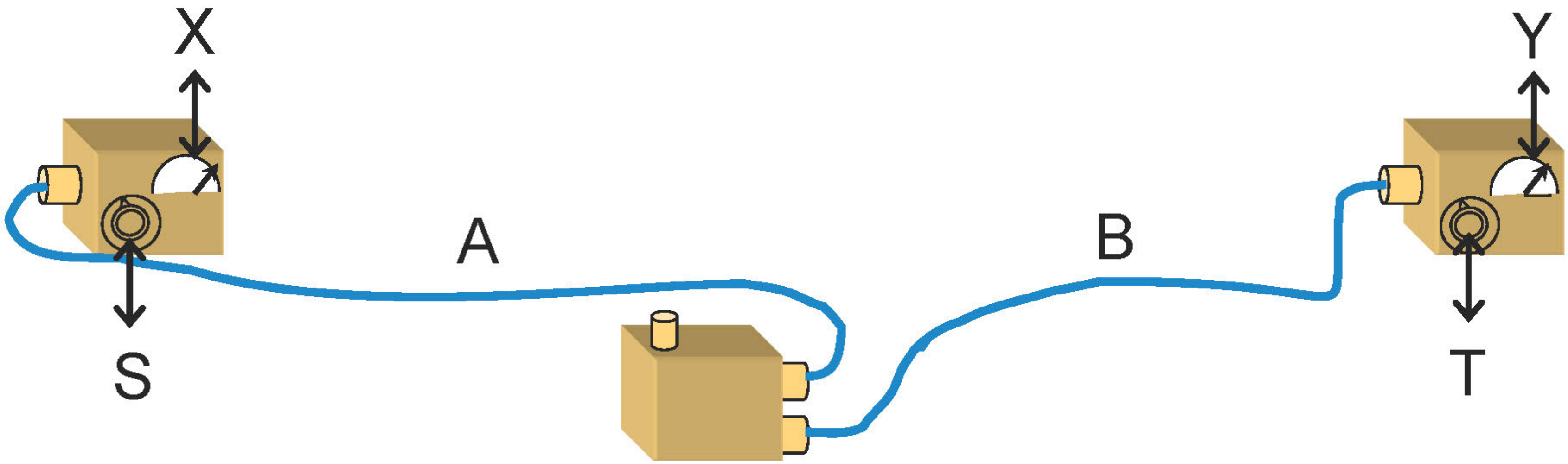
Set S=0

get X=0



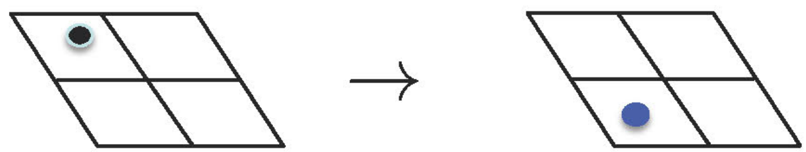
get X=1



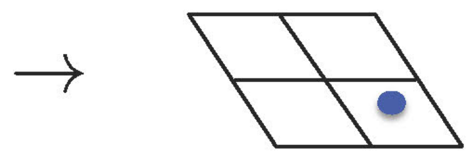


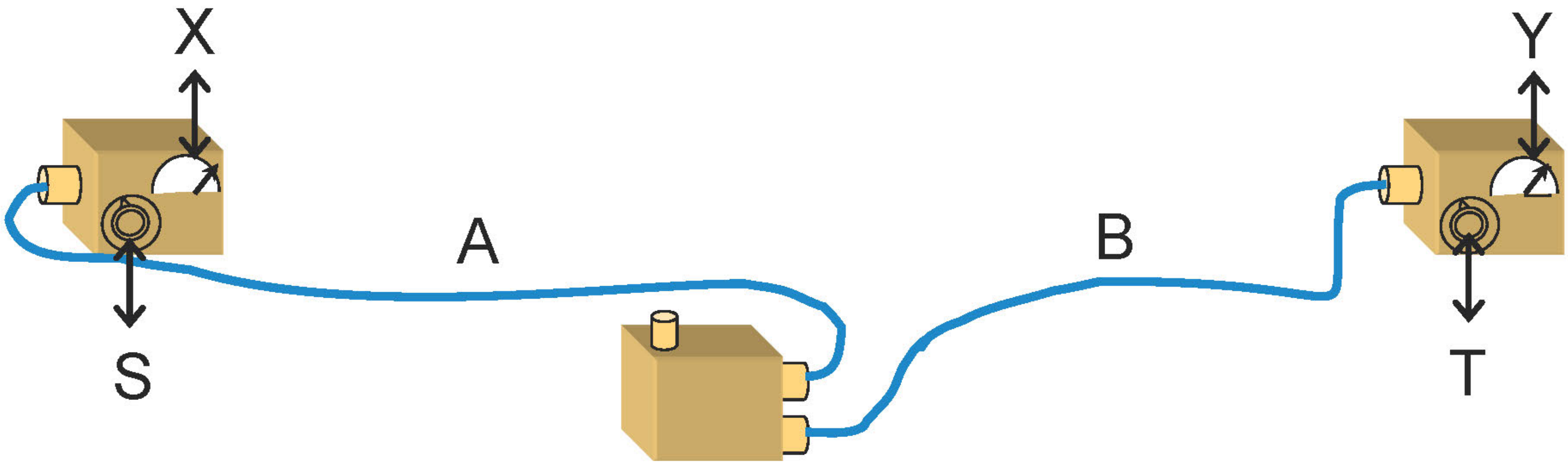
Set S=1

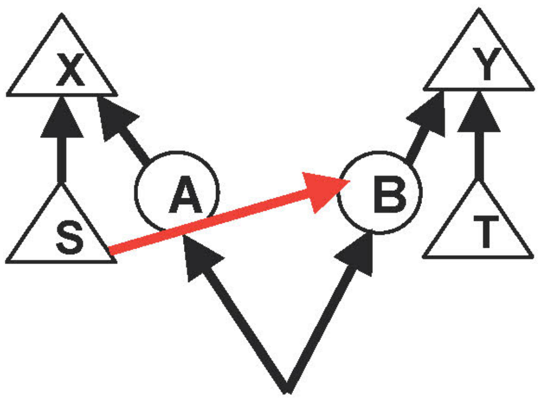
get X=0



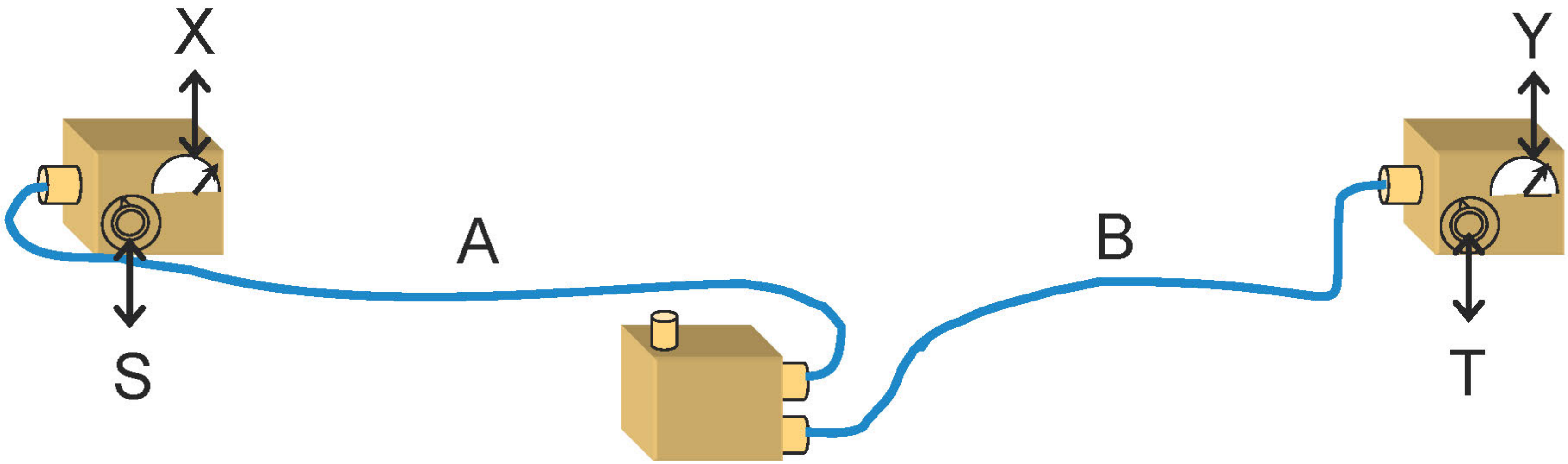
get X=1

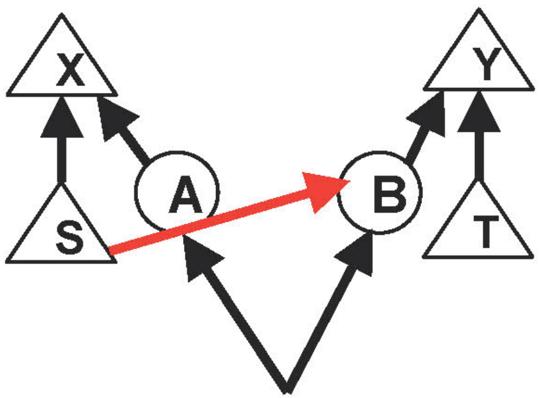


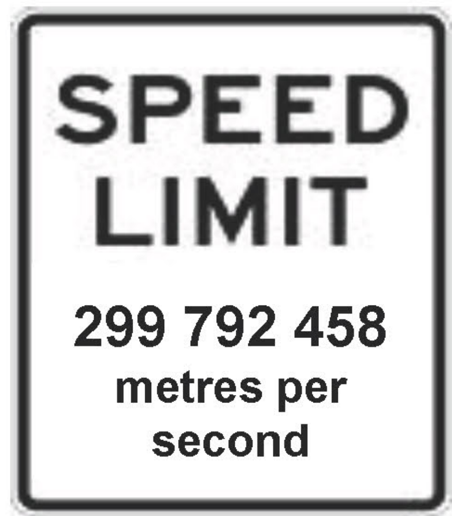




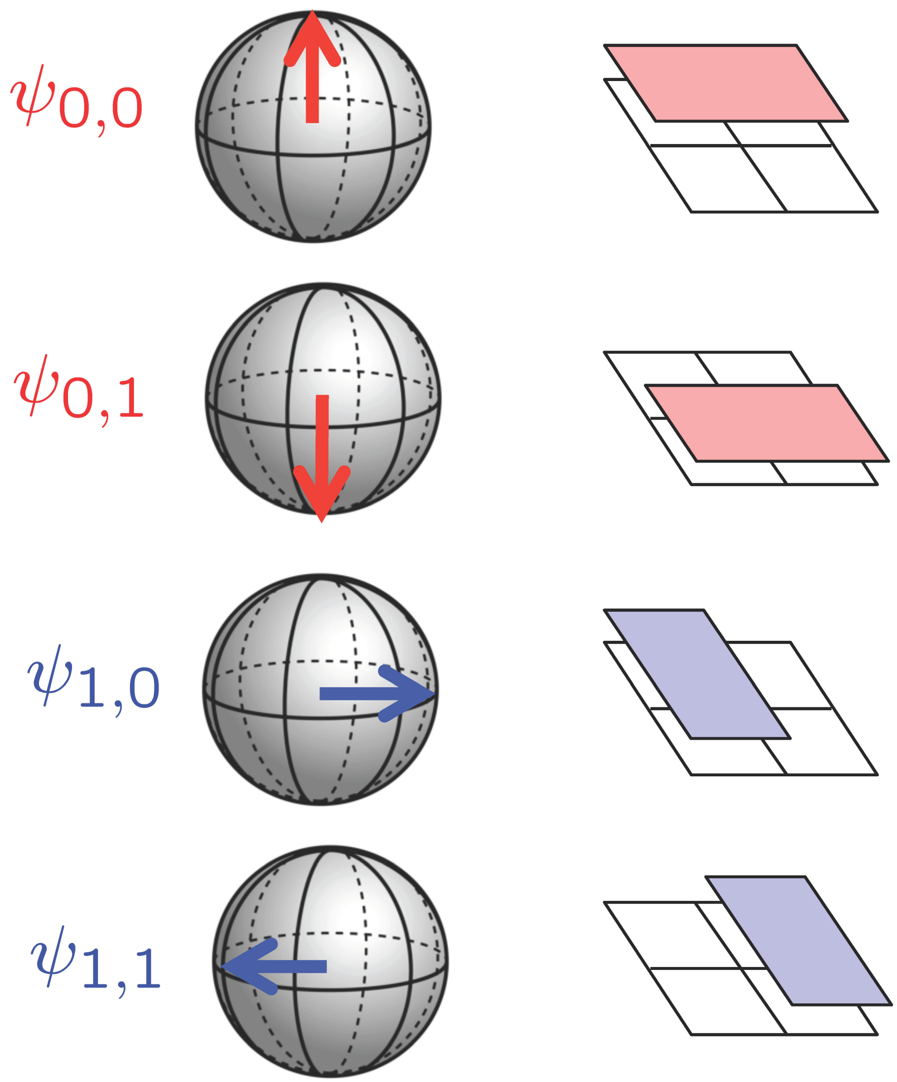
Like “treatment influences recovery”

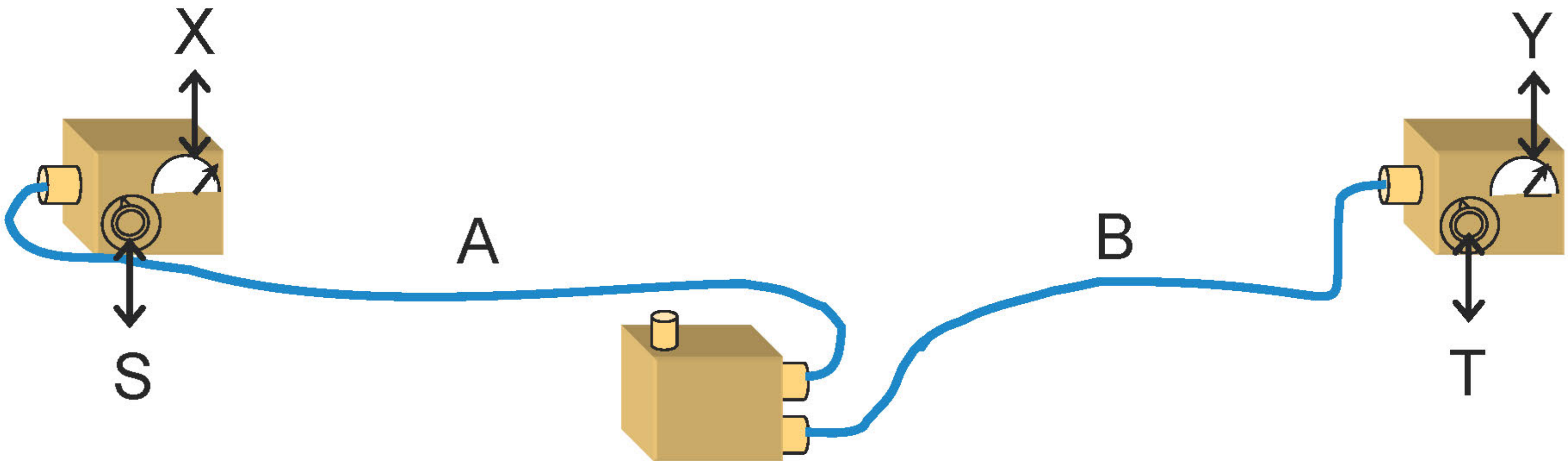






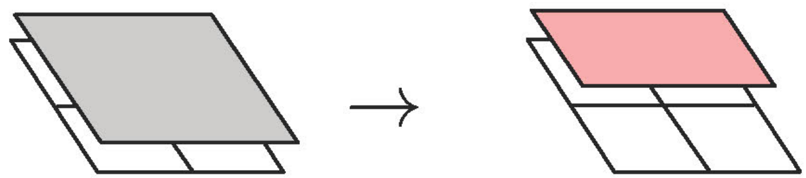
Spooky


$\psi_{0,0}$
$\psi_{0,1}$
$\psi_{1,0}$
$\psi_{1,1}$

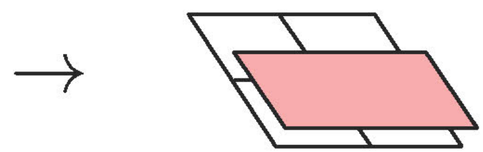


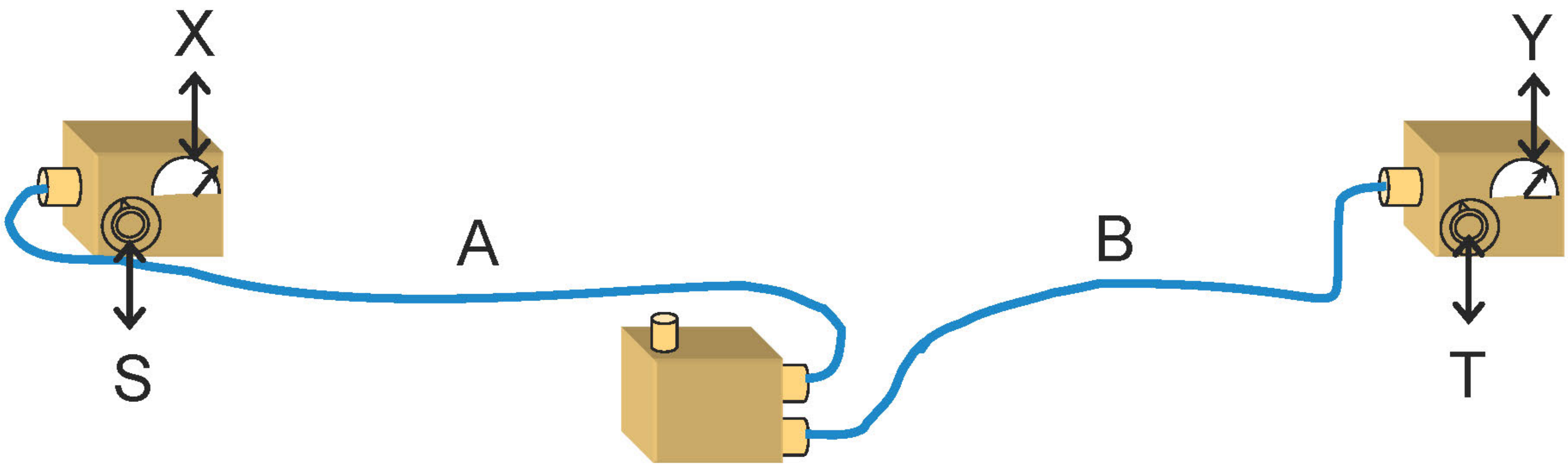
Set S=0

get X=0



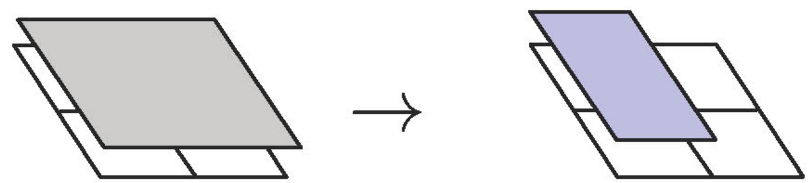
get X=1



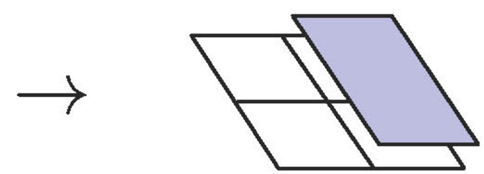


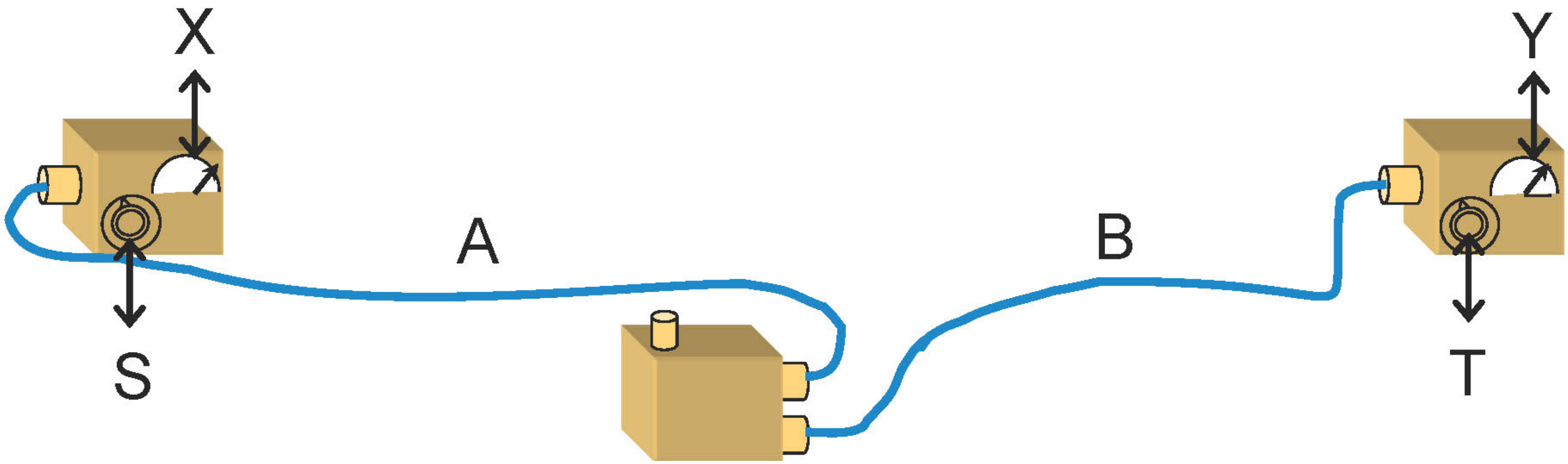
Set S=1

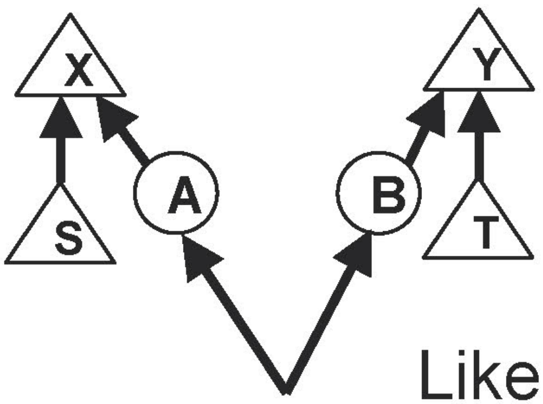
get X=0



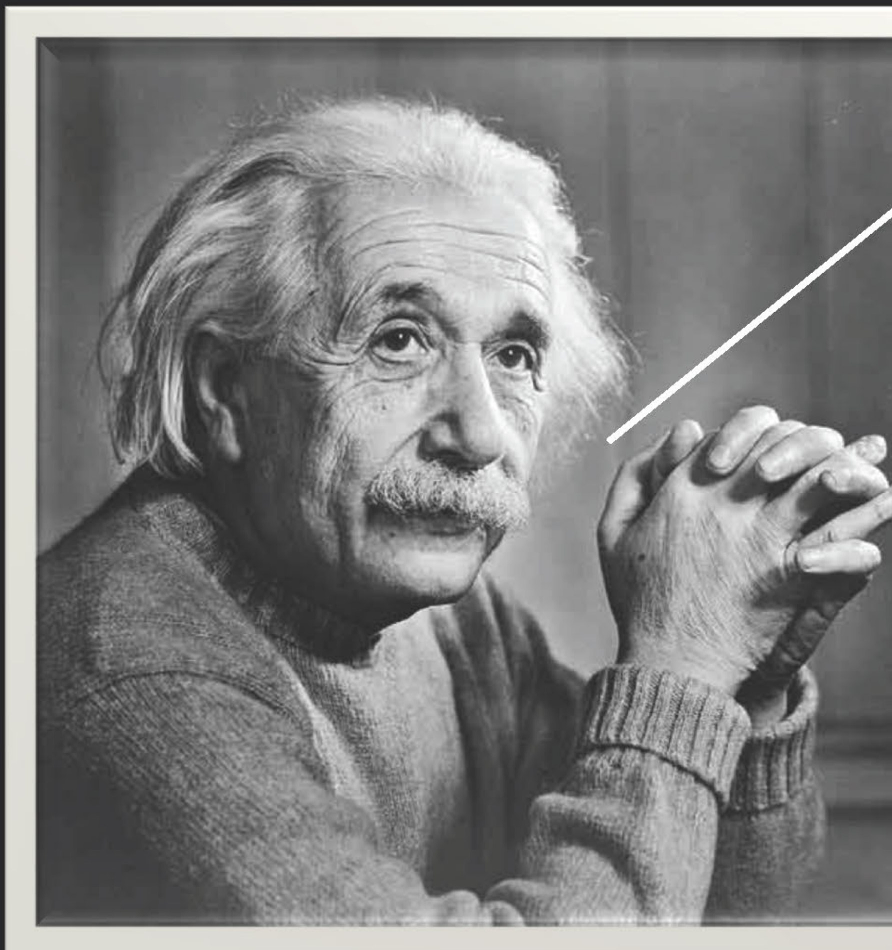
get X=1





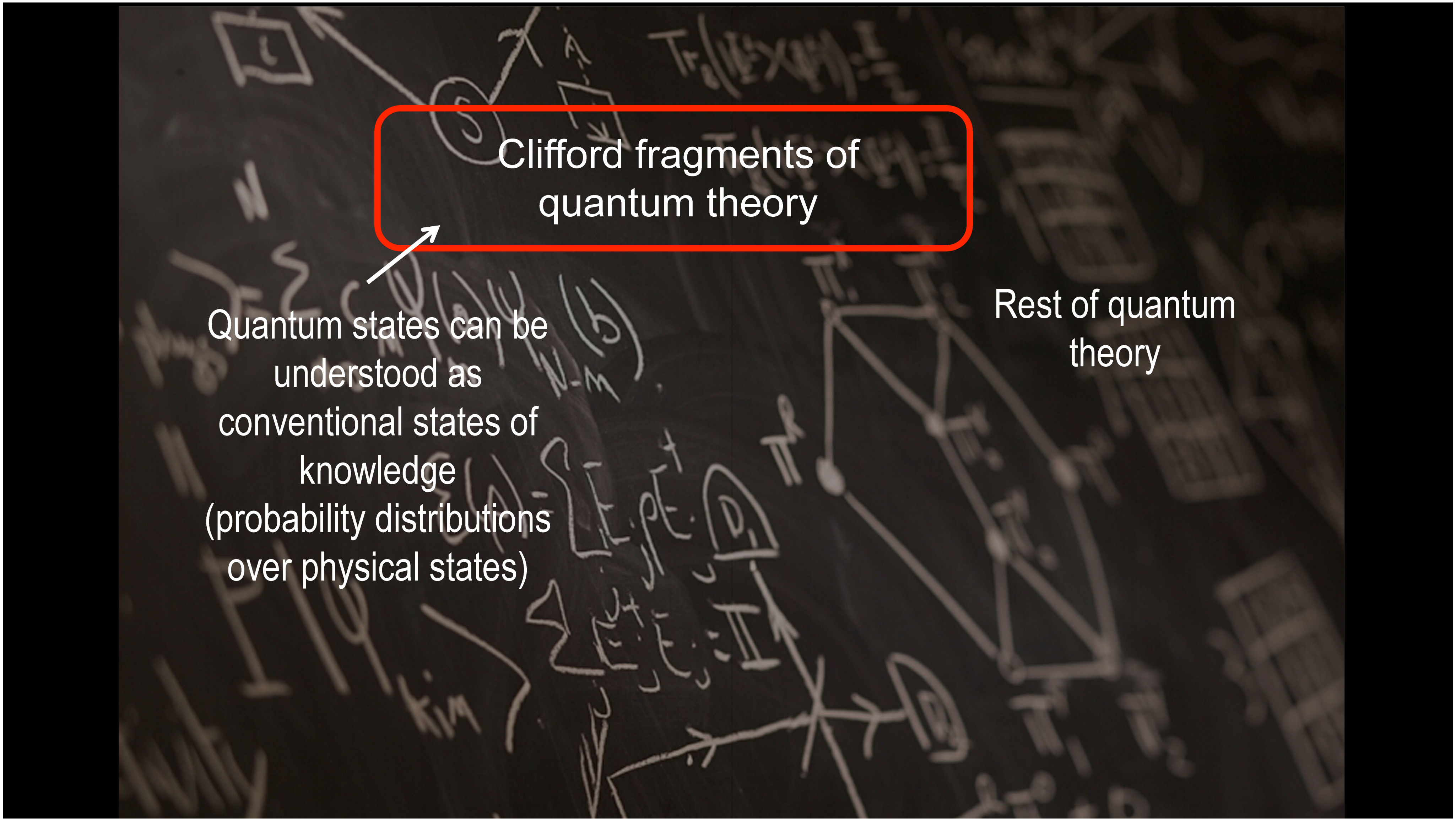


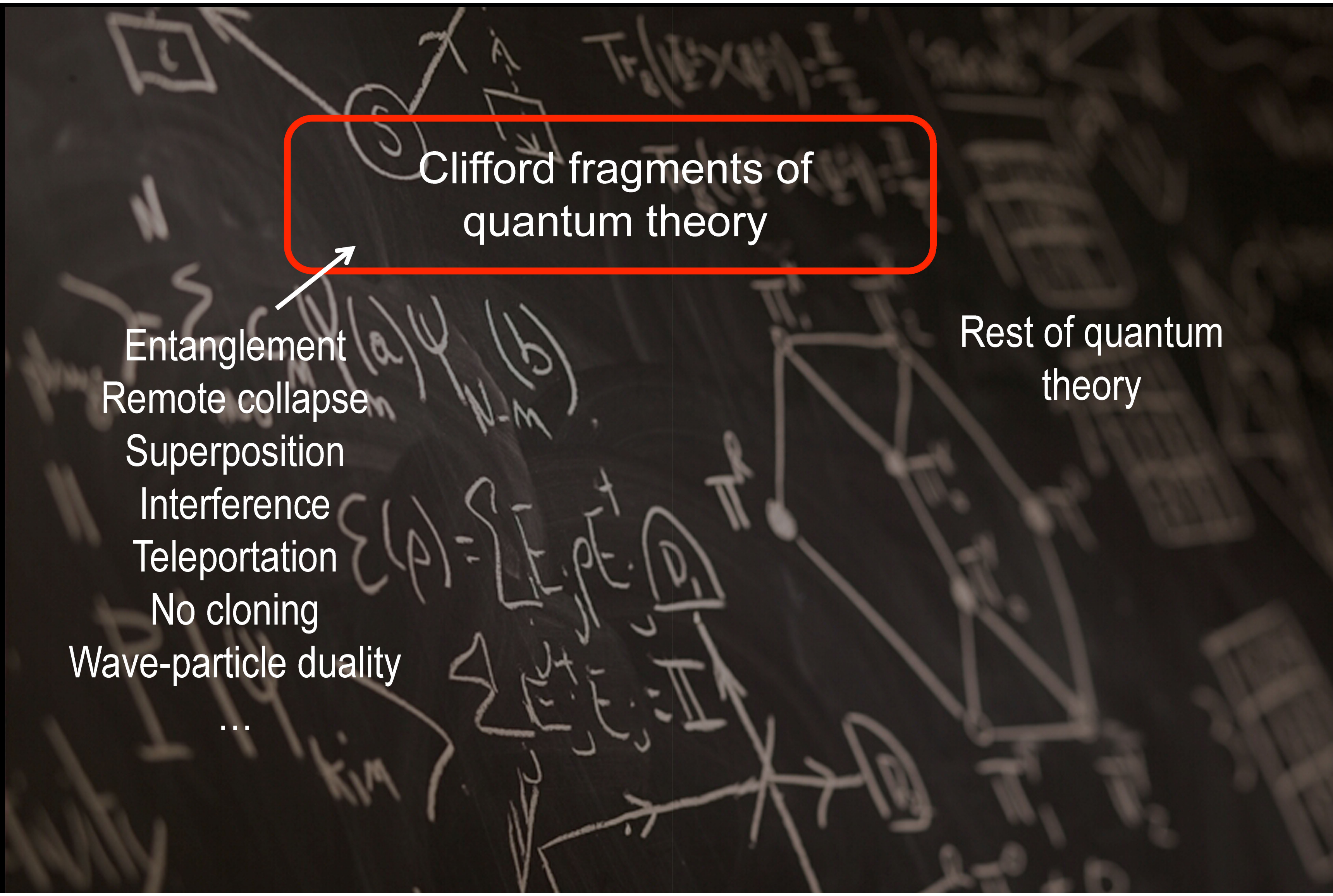
Like “treatment informs us about recovery”



"ψ_2 does not describe the totality of what "really" pertains to the partial system 2, rather only what we know about it in this particular case."

"I incline to the opinion that the wave function does not (completely) describe what is real, but only […] maximal knowledge regarding that which really exists."


Clifford fragments of quantum theory
Quantum states can be understood as conventional states of knowledge (probability distributions over physical states)
Rest of quantum theory

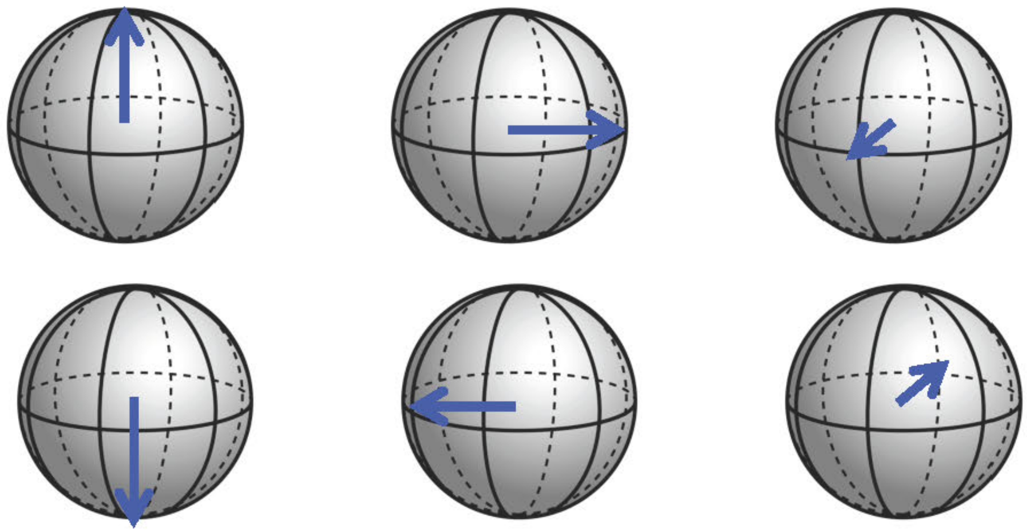


Clifford fragments of quantum theory

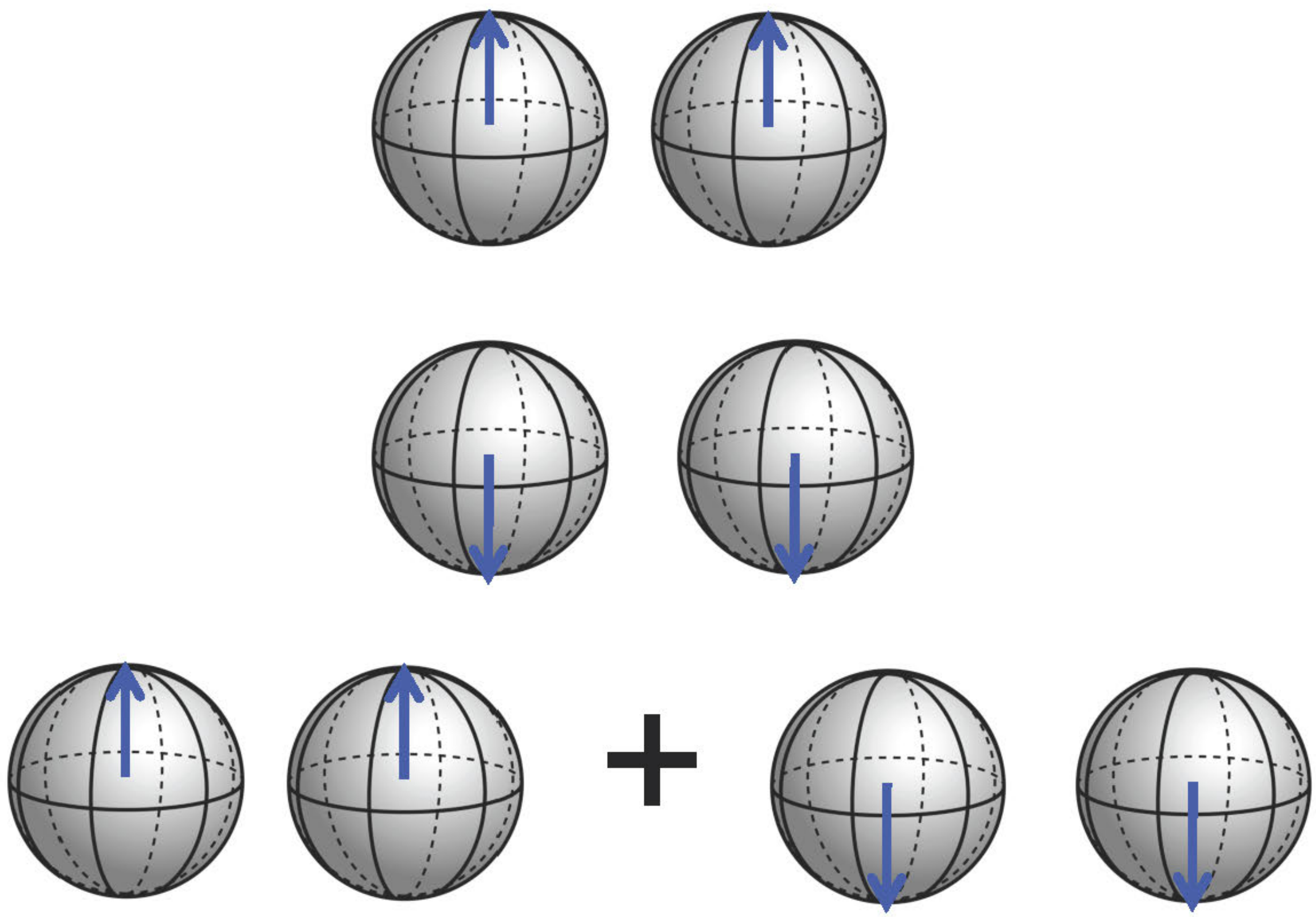
Entanglement
Remote collapse
Superposition
Interference
Teleportation
No cloning
Wave-particle duality
…

Rest of quantum theory

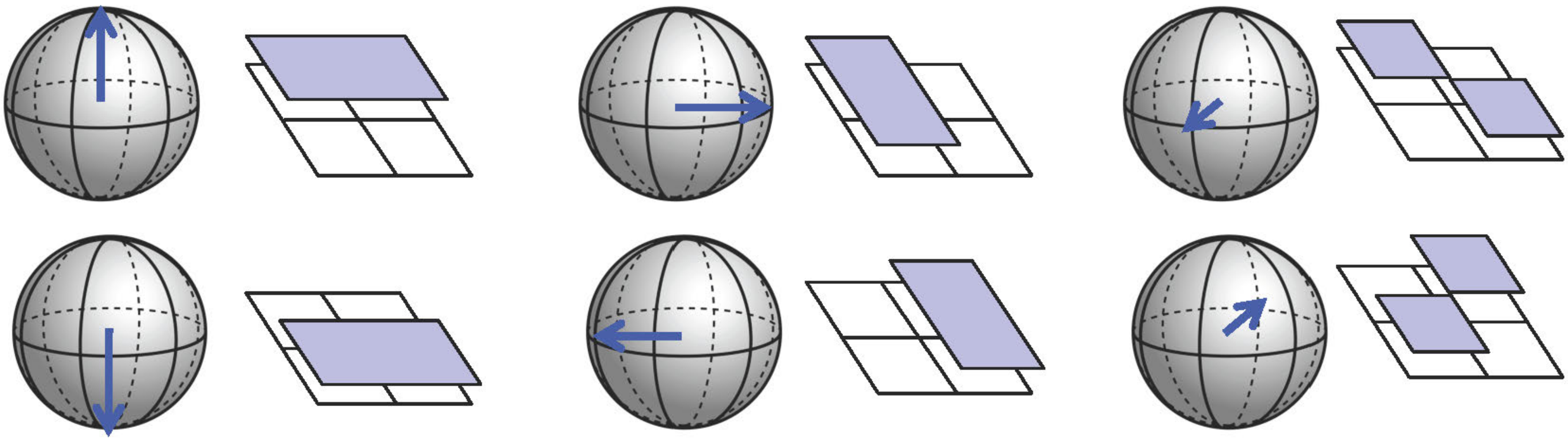
1 qubit in the Clifford fragment of quantum theory



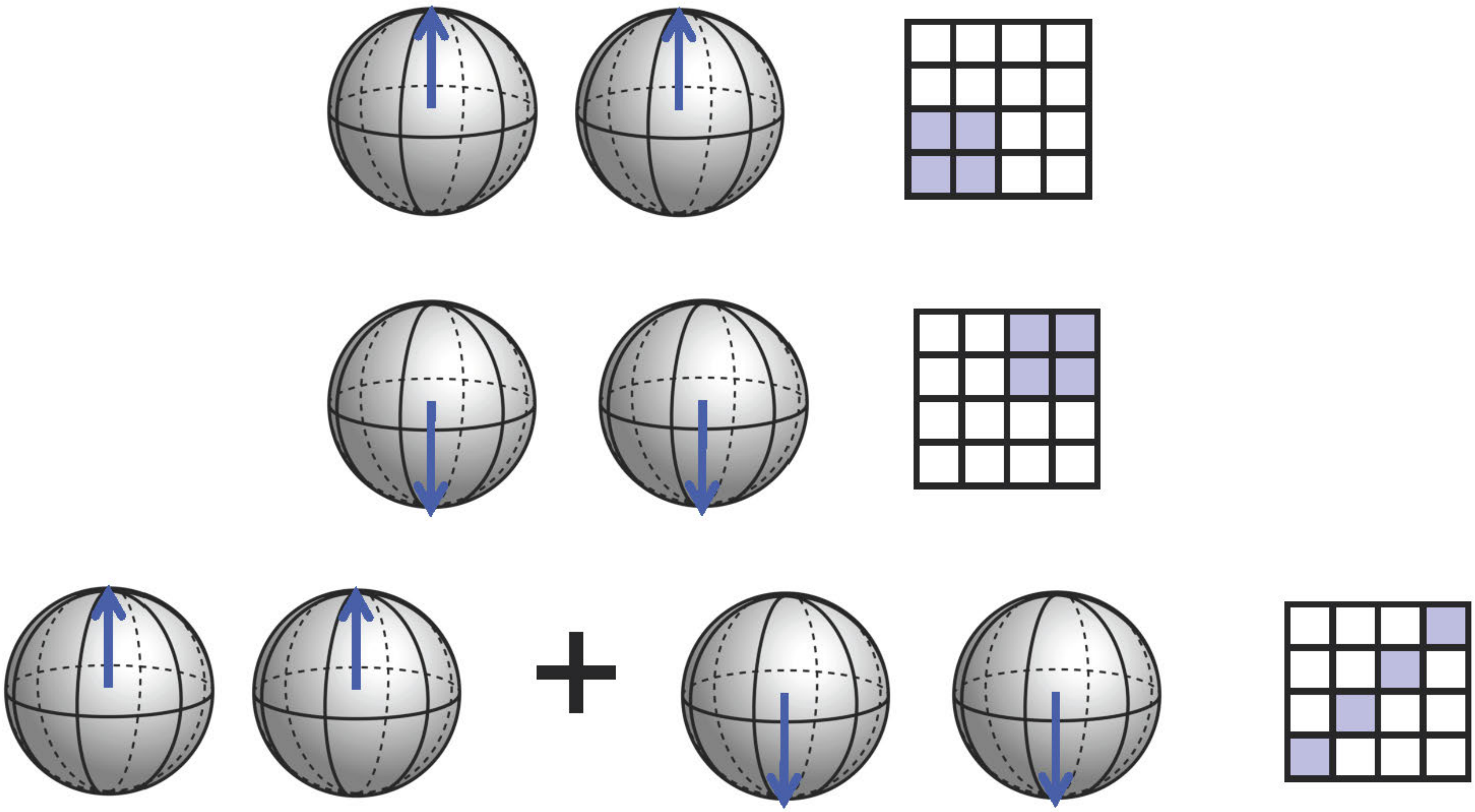
2 qubits in the Clifford fragment of quantum theory



Modelling 1 qubit in the Clifford fragment

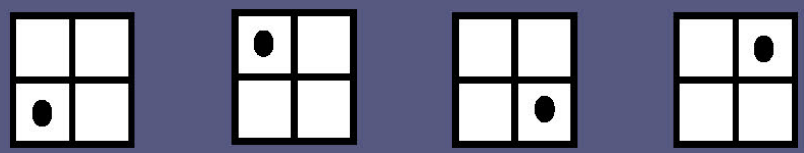


Modelling 2 qubits in the Clifford fragment

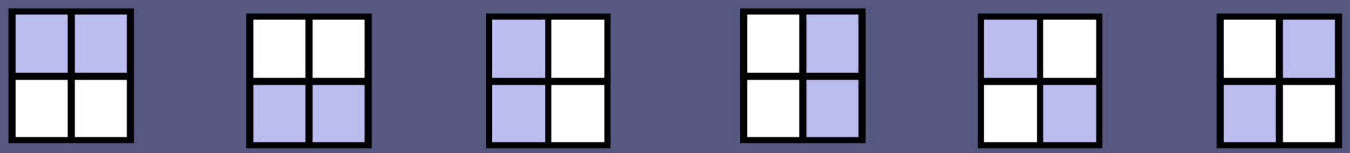


Modelling 1 qubit in the Clifford fragment

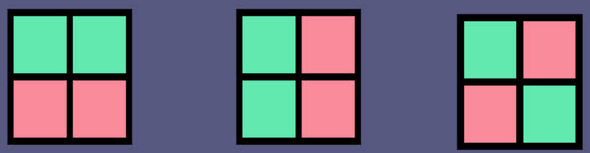
physical states



states of maximal knowledge

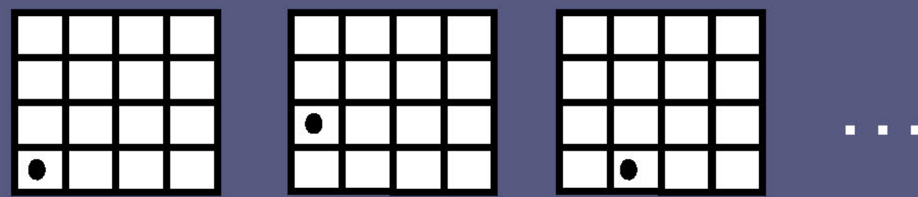


measurements

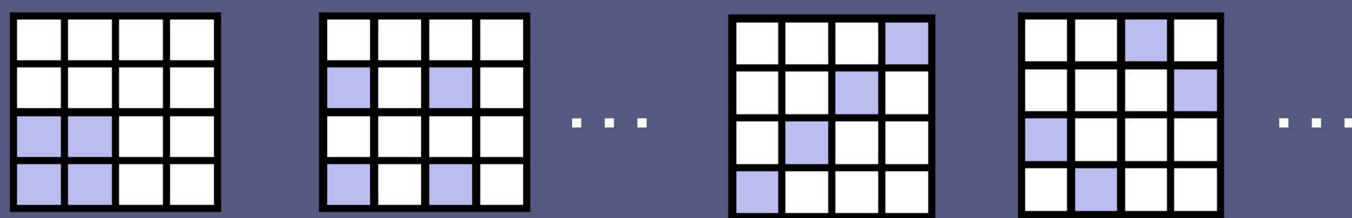


Modelling 2 qubits in the Clifford fragment

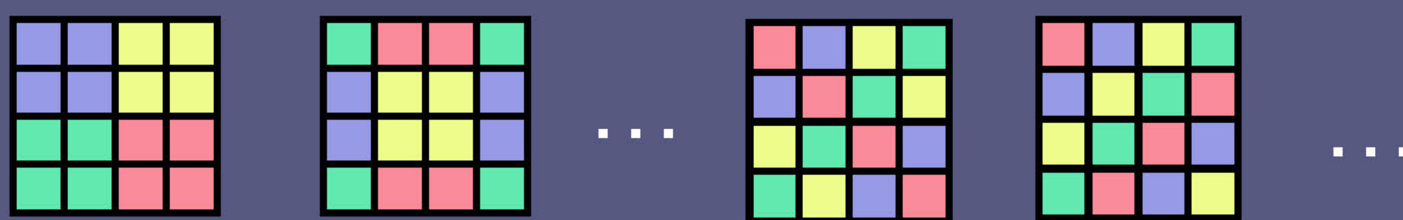
physical states

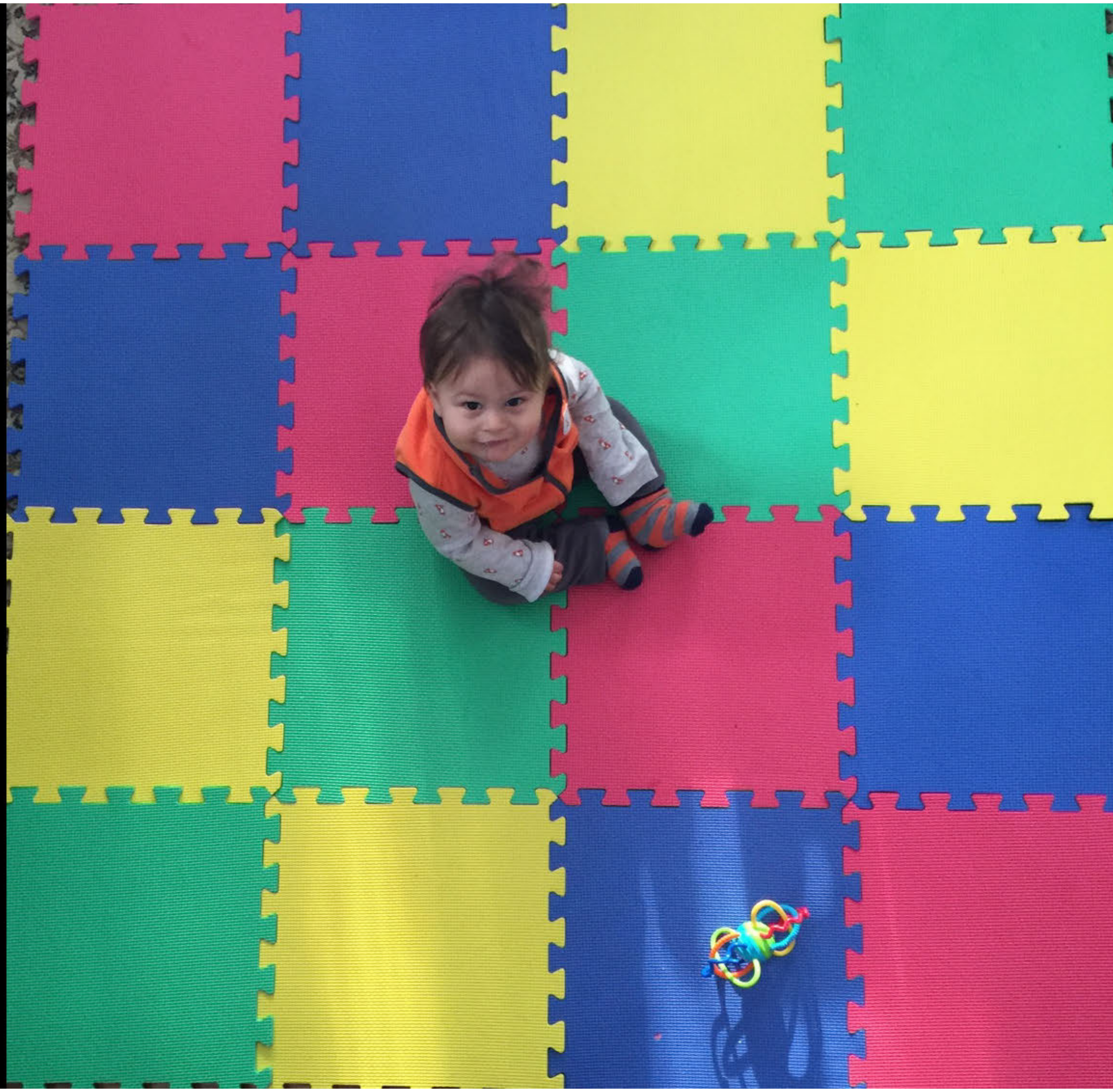


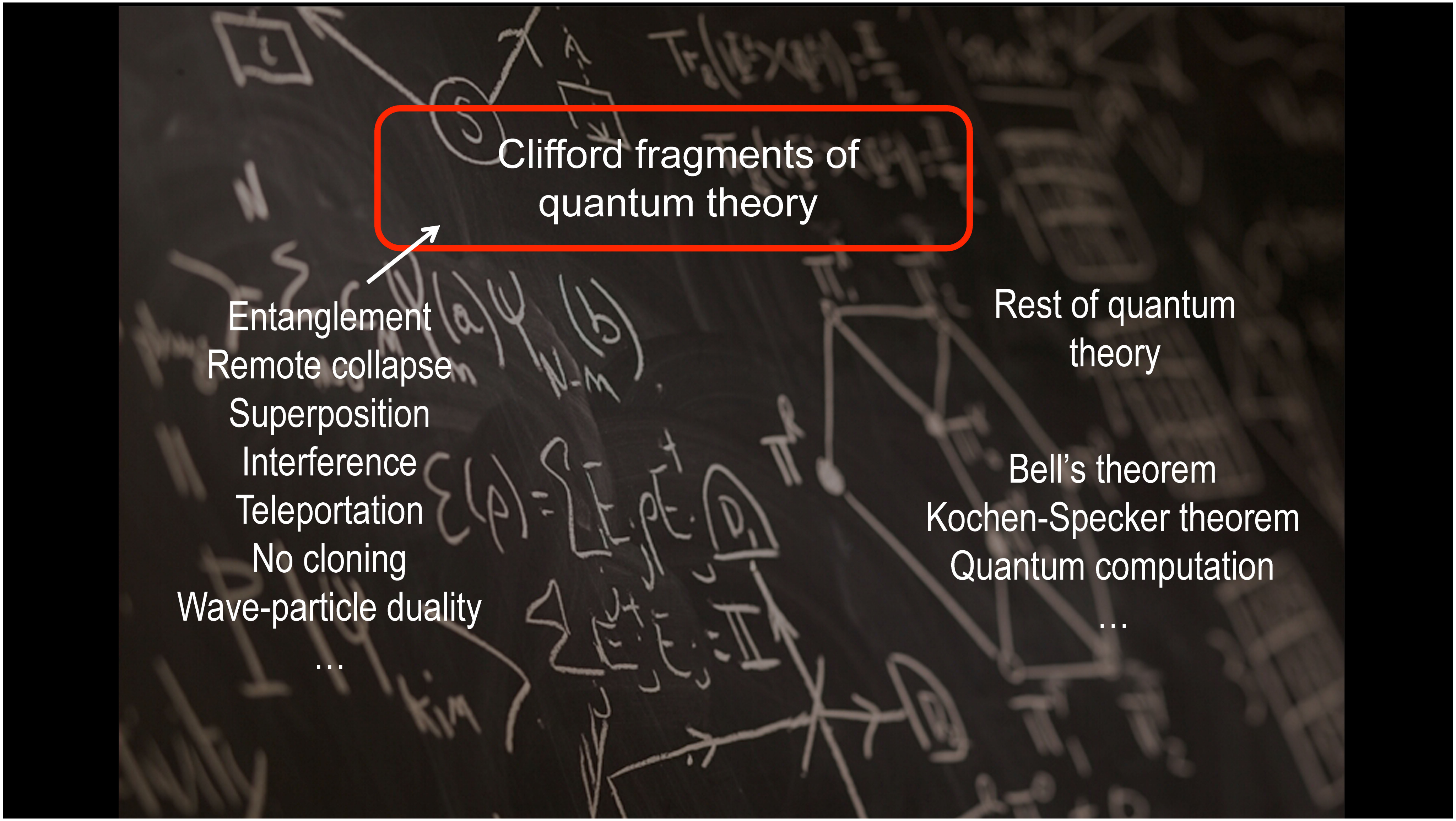
states of maximal knowledge

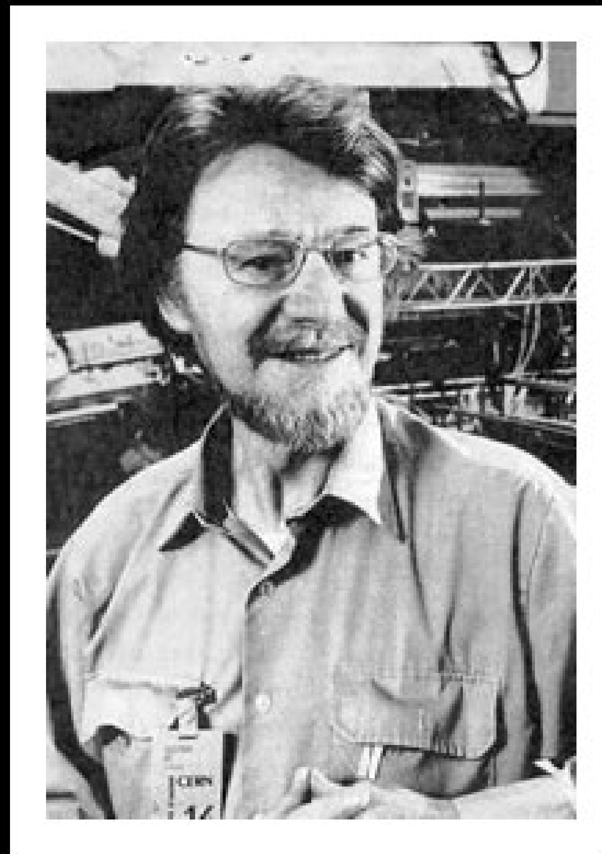


measurements

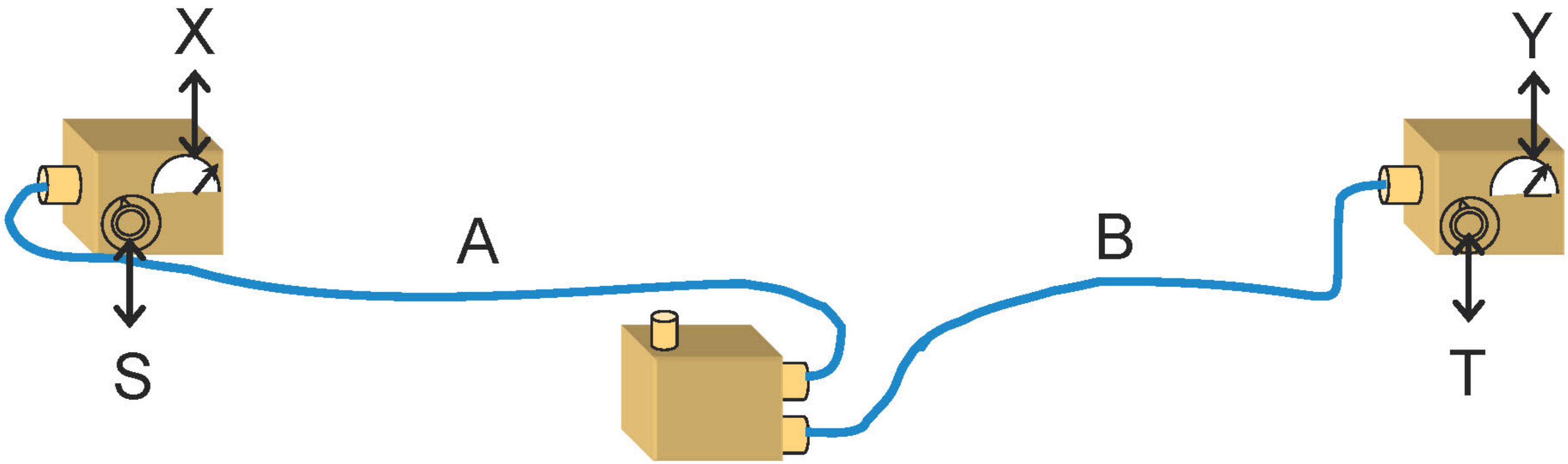





Clifford fragments of quantum theory
Entanglement
Remote collapse
Superposition
Interference
Teleportation
No cloning
Wave-particle duality
…
Rest of quantum theory
Bell's theorem
Kochen-Specker theorem
Quantum computation
…

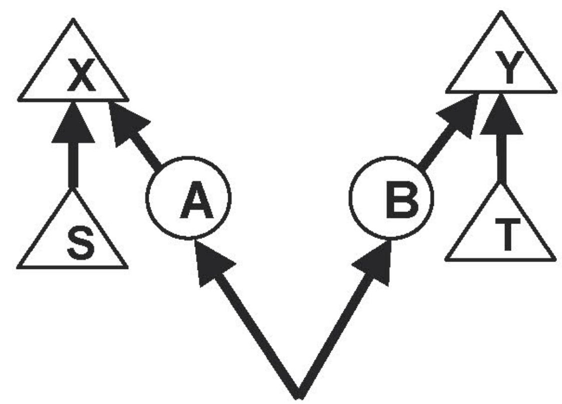


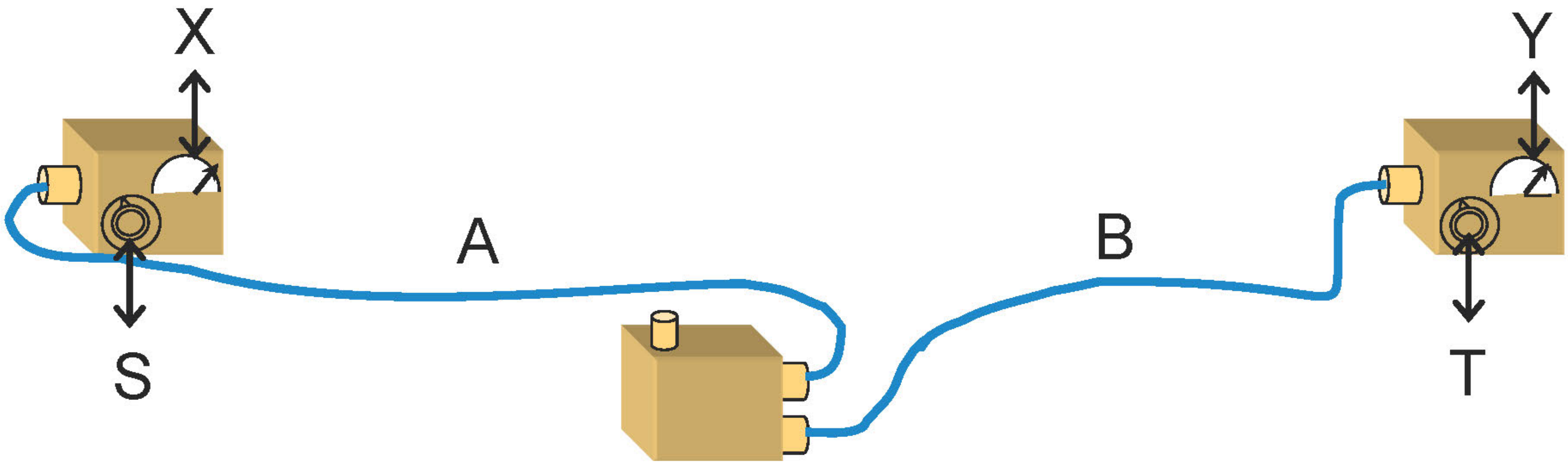
John S. Bell
(1928-1990)



P(X,Y|S,T)

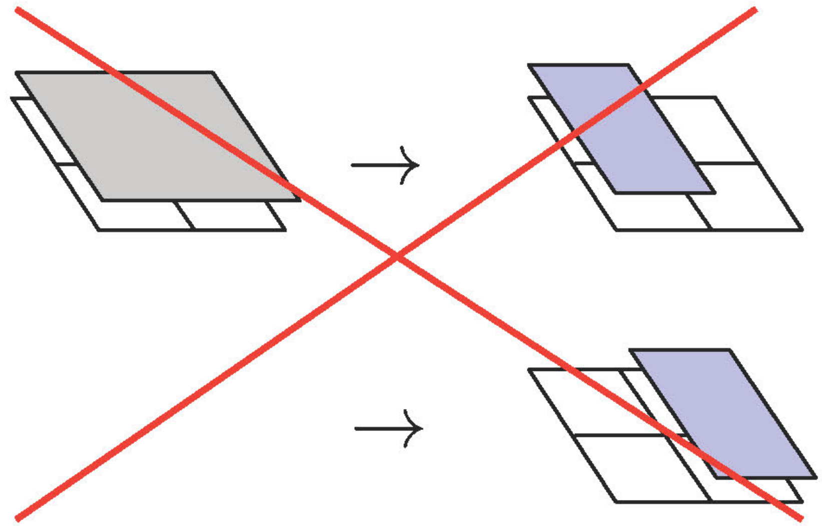
	X=0, Y=0	X=0, Y=1	X=1, Y=0	X=1, Y=1
S=0, T=0	0.427	0.073	0.073	0.427
S=0, T=1	0.427	0.073	0.073	0.427
S=1, T=0	0.427	0.073	0.073	0.427
S=1, T=1	0.073	0.427	0.427	0.073

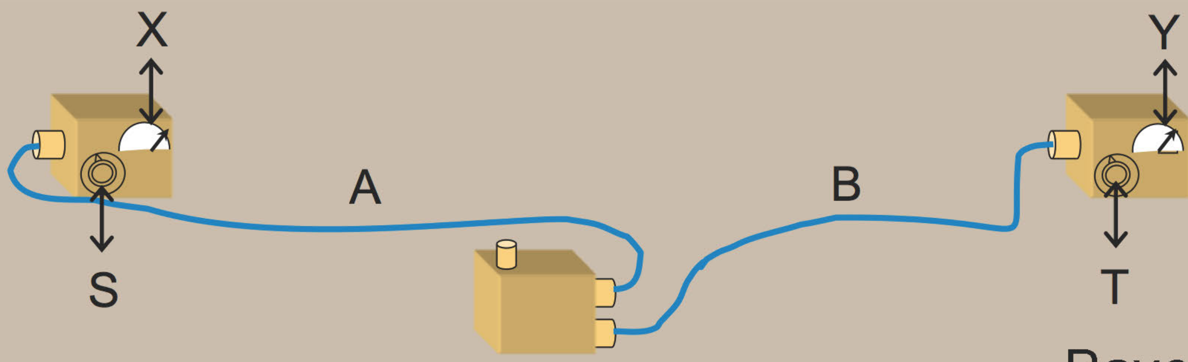




P(X,Y|S,T)

	X=0, Y=0	X=0, Y=1	X=1, Y=0	X=1, Y=1
S=0, T=0	0.427	0.073	0.073	0.427
S=0, T=1	0.427	0.073	0.073	0.427
S=1, T=0	0.427	0.073	0.073	0.427
S=1, T=1	0.073	0.427	0.427	0.073





Bayesian updating

$$P(B) \to P(B|SX)$$

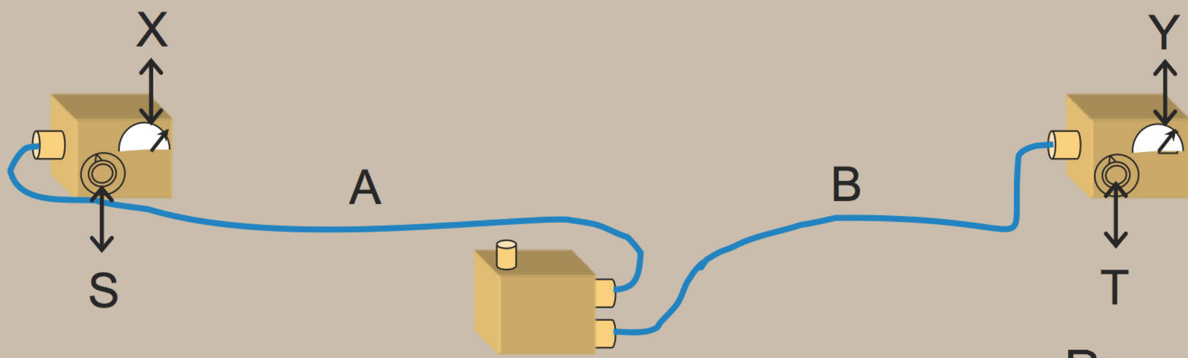
Bayesian updating

$$\psi_B \to \psi_{B|SX}$$

Given:

$P(AB)$

$P(X|AS)$



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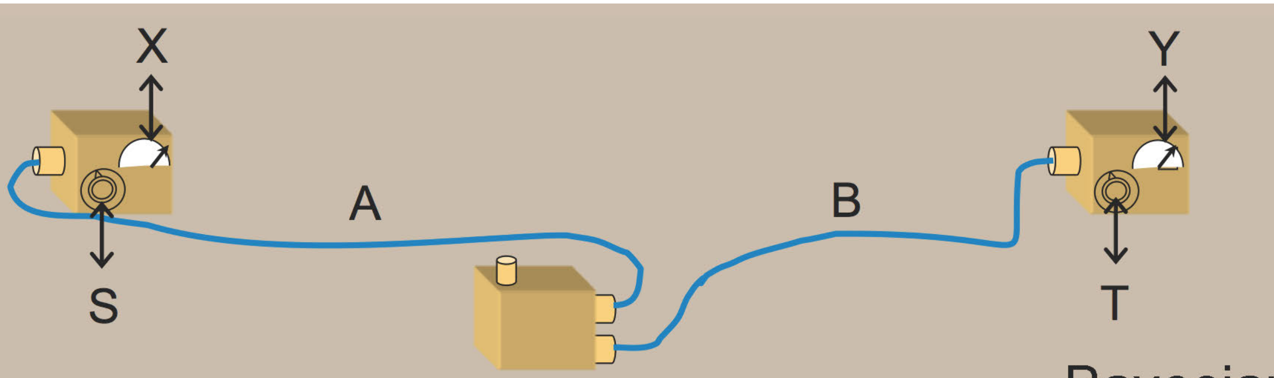


Bayesian updating

$P(B) \rightarrow P(B|SX)$

Bayesian updating

$\psi_B \rightarrow \psi_{B|SX}$

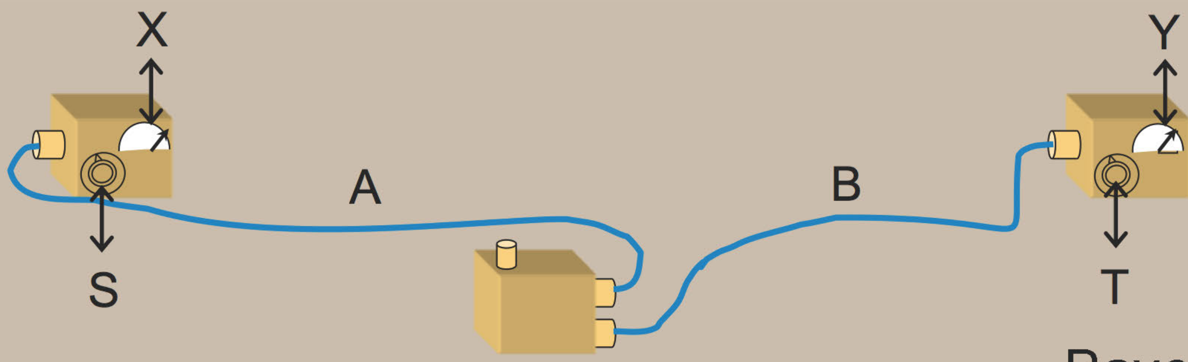
Bayesian inversion

$$P(A|SX) = \frac{P(X|AS)P(A)}{P(X|S)}$$

Given:

$P(AB)$

$P(X|AS)$



Bayesian updating

$$P(B) \to P(B|SX)$$

Bayesian updating

$$\psi_B \to \psi_{B|SX}$$

Bayesian inversion

$$P(A|SX) = \frac{P(X|AS)P(A)}{P(X|S)}$$

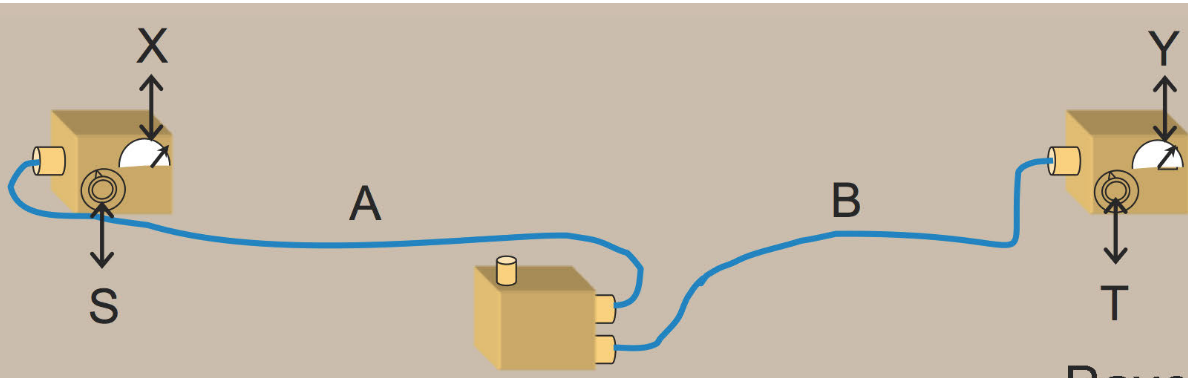
Conditional from joint

$$P(B|A) = \frac{P(AB)}{P(A)}$$

Given:

$P(AB)$

$P(X|AS)$



Bayesian updating

$$P(B) \to P(B|SX)$$

Bayesian updating

$$\psi_B \to \psi_{B|SX}$$

Bayesian inversion

$$P(A|SX) = \frac{P(X|AS)P(A)}{P(X|S)}$$

Conditional from joint

$$P(B|A) = \frac{P(AB)}{P(A)}$$

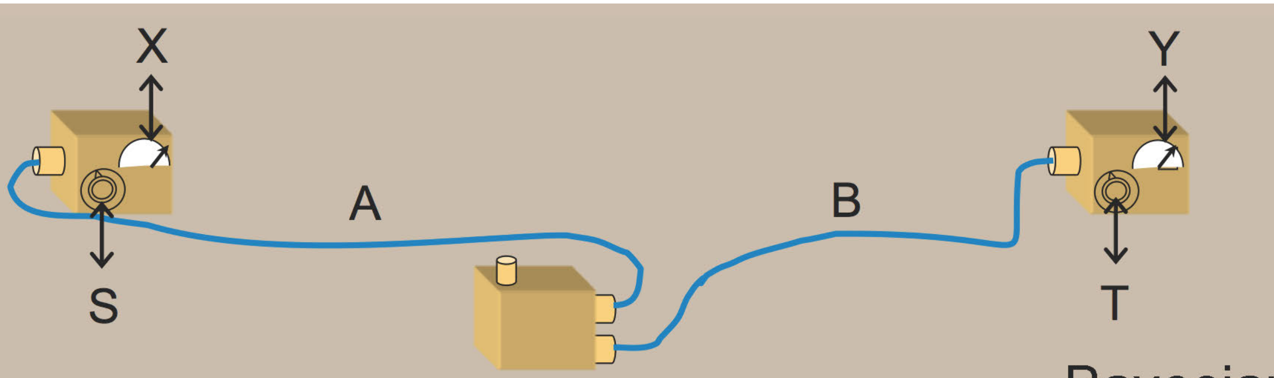
Belief propagation

$$P(B|SX) = \sum_A P(B|A)P(A|SX)$$

Given:

$P(AB)$

$P(X|AS)$



Given:

ψ_{AB}

$\psi_{X|SA}$

Bayesian updating

$$P(B) \to P(B|SX)$$

Bayesian updating

$$\psi_B \to \psi_{B|SX}$$

Bayesian inversion

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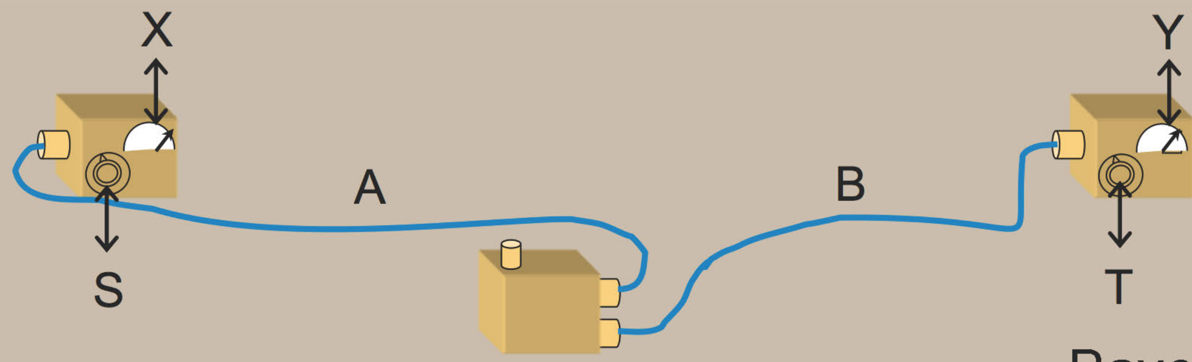

Given:

ψ_{AB}

$\psi_{X|SA}$

Bayesian updating

$$P(B) \to P(B|SX)$$

Bayesian updating

$$\psi_B \to \psi_{B|SX}$$

Bayesian inversion

$$P(A|SX) = \frac{P(X|AS)P(A)}{P(X|S)}$$

Bayesian inversion

$$\psi_{A|XS} = \psi_{X|AS} \star \psi_A \psi_{X|S}^{-1}$$

Conditional from joint

$$P(B|A) = \frac{P(AB)}{P(A)}$$

Belief propagation

$$P(B|SX) = \sum_A P(B|A)P(A|SX)$$

Given:

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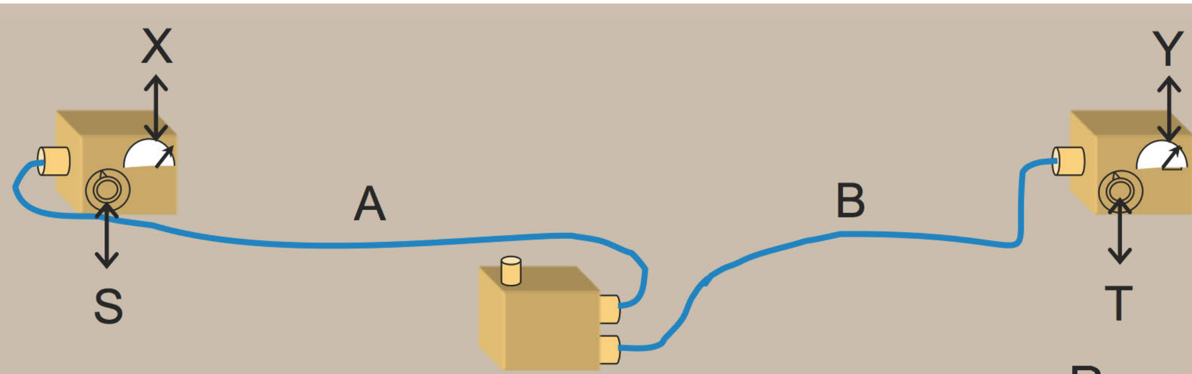
$P(X|AS)$



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Conditional from joint

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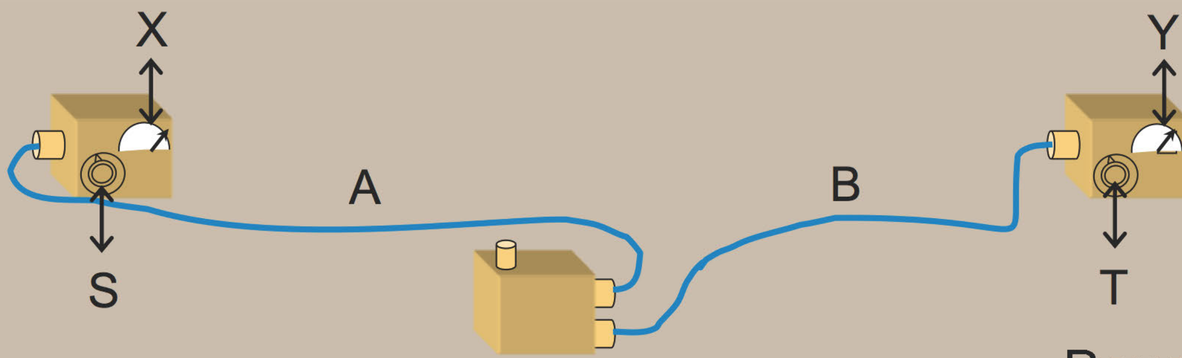

Given:

ψ_{AB}

$\psi_{X|SA}$

Bayesian updating

$P(B) \to P(B|SX)$

Bayesian updating

$\psi_B \to \psi_{B|SX}$

Bayesian inversion

$$P(A|SX) = \frac{P(X|AS)P(A)}{P(X|S)}$$

Bayesian inversion

$$\psi_{A|XS} = \psi_{X|AS} \star \psi_A \psi_{X|S}^{-1}$$

Conditional from joint

$$P(B|A) = \frac{P(AB)}{P(A)}$$

Conditional from joint

$$\psi_{B|A} = \psi_{AB} \star \psi_A^{-1}$$

Belief propagation

$$P(B|SX) = \sum_A P(B|A)P(A|SX)$$

Belief propagation

$$\psi_{B|SX} = \mathrm{tr}_A(\psi_{B|A}\psi_{A|SX})$$

Clifford fragments of quantum theory

Quantum states can be understood as conventional states of knowledge (probability distributions over physical states)

Rest of quantum theory

Quantum states must be understood as more exotic states of knowledge


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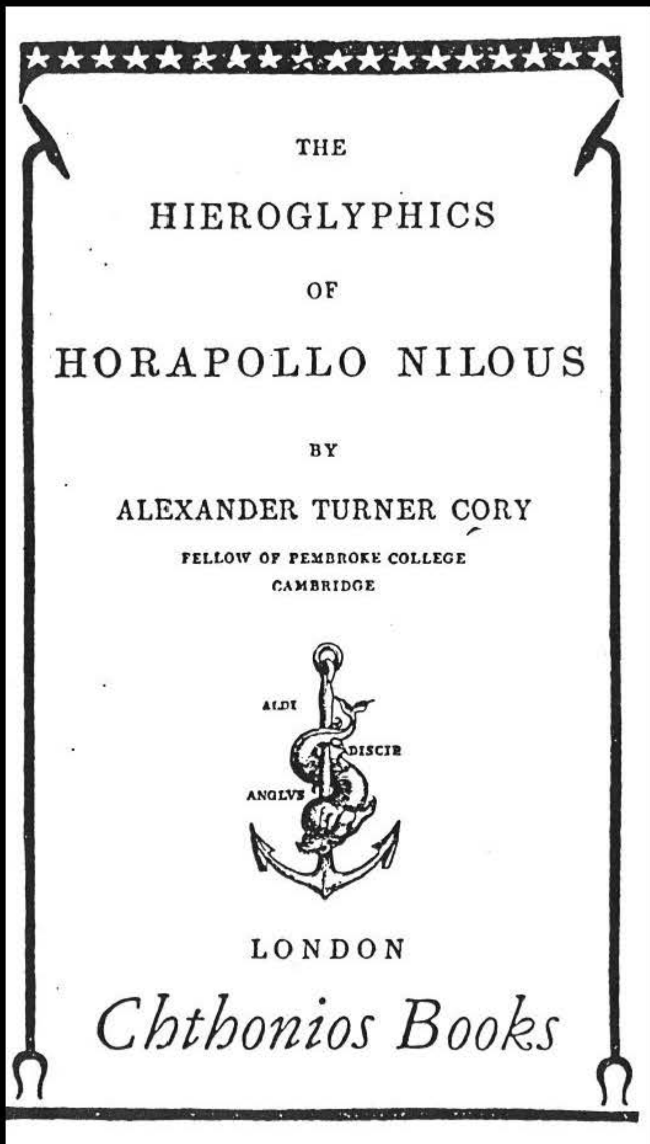

THE

HIEROGLYPHICS

OF

HORAPOLLO NILOUS

BY

ALEXANDER TURNER CORY

FELLOW OF PEMBROKE COLLEGE
CAMBRIDGE

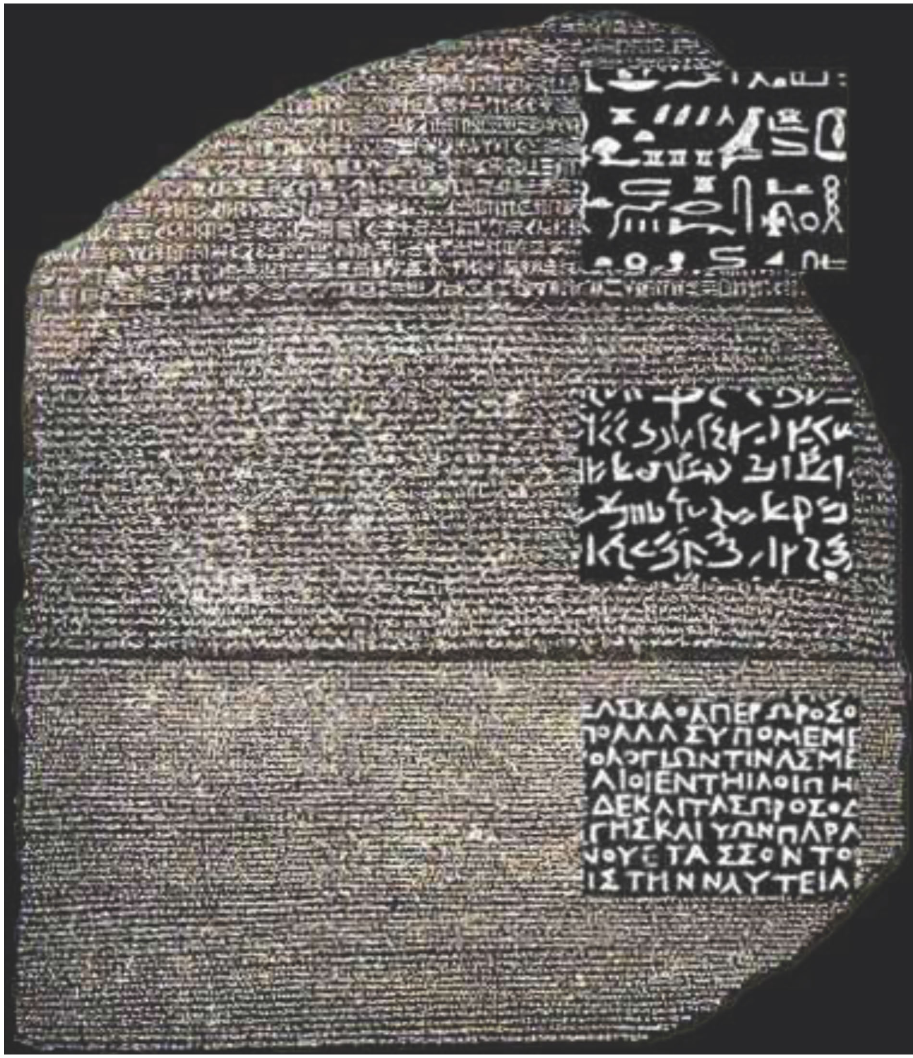
ALDI DISCIP ANGLVS

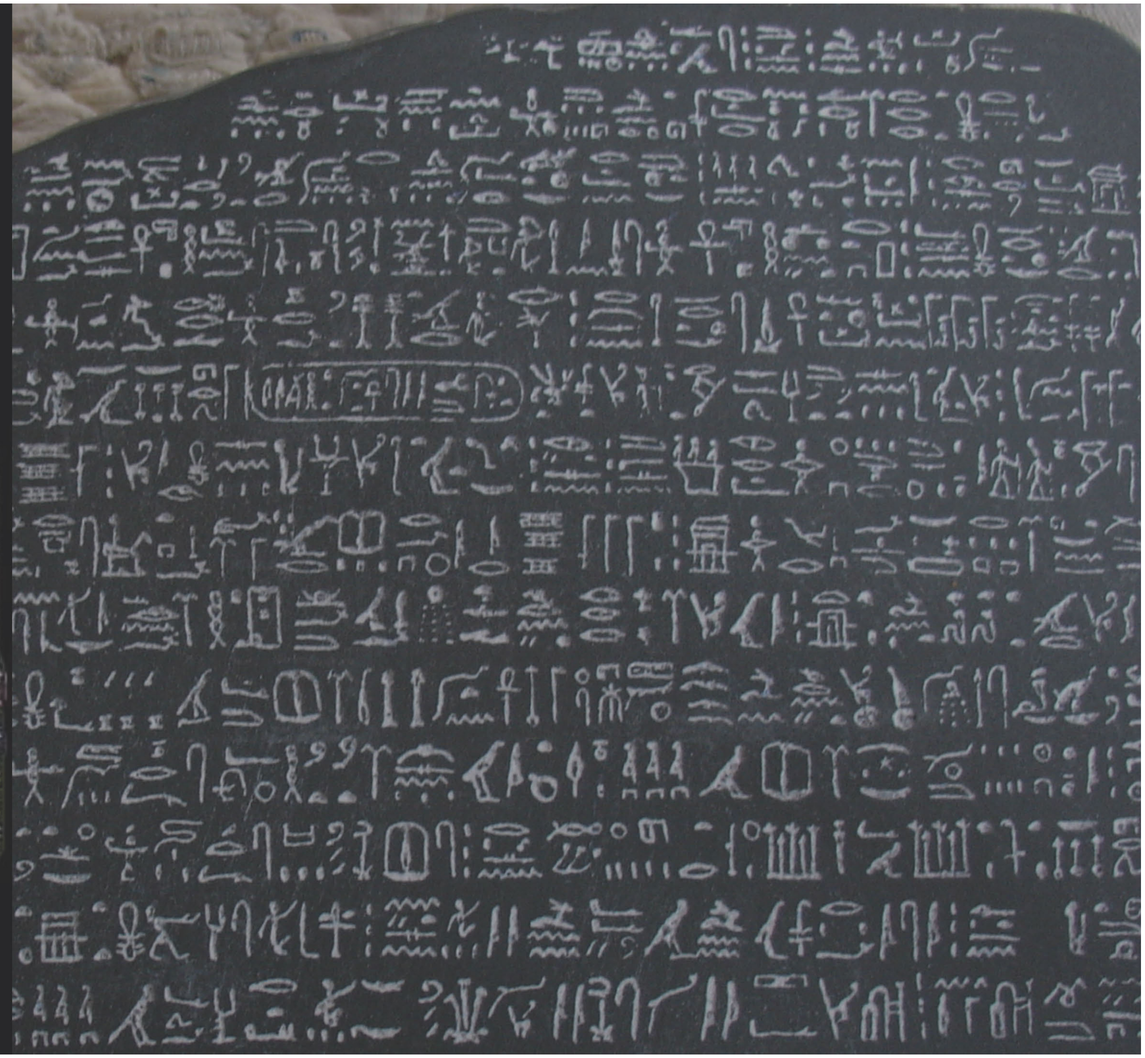
LONDON

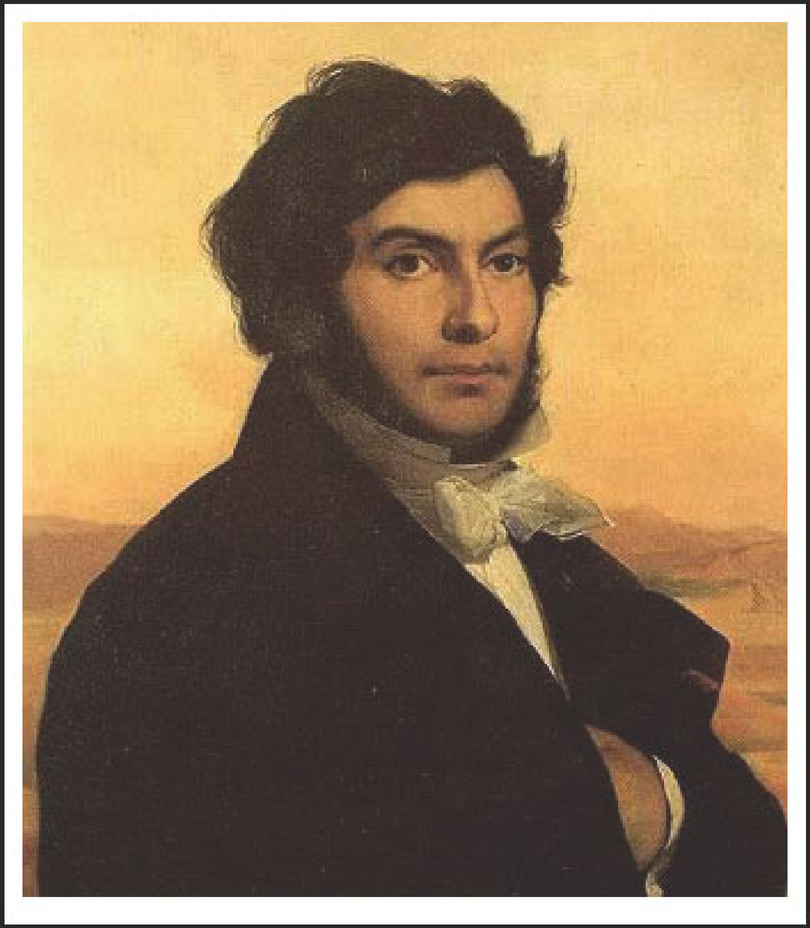
Chthonios Books

- A Man Fond of Dancing
- A Mystic Man
- A Man that is Burnt with Fire
- A Blind Man
- One Who is Fond of His Father
- A Woman That Hates Her Husband
- Children Plotting Against Their Mothers
- A Man Who Sickens Under the Reproach of Accusation
- A King who Keeps Himself Apart, and Shows No Mercy to Delinquencies
- A Man Who Has Been Succeeded in His Property by a Son Whom He Hated

“The beneficent generative force commanding through supernal and infernal dominion, augments the flow of sacred humours emanating from above.”--Kircher

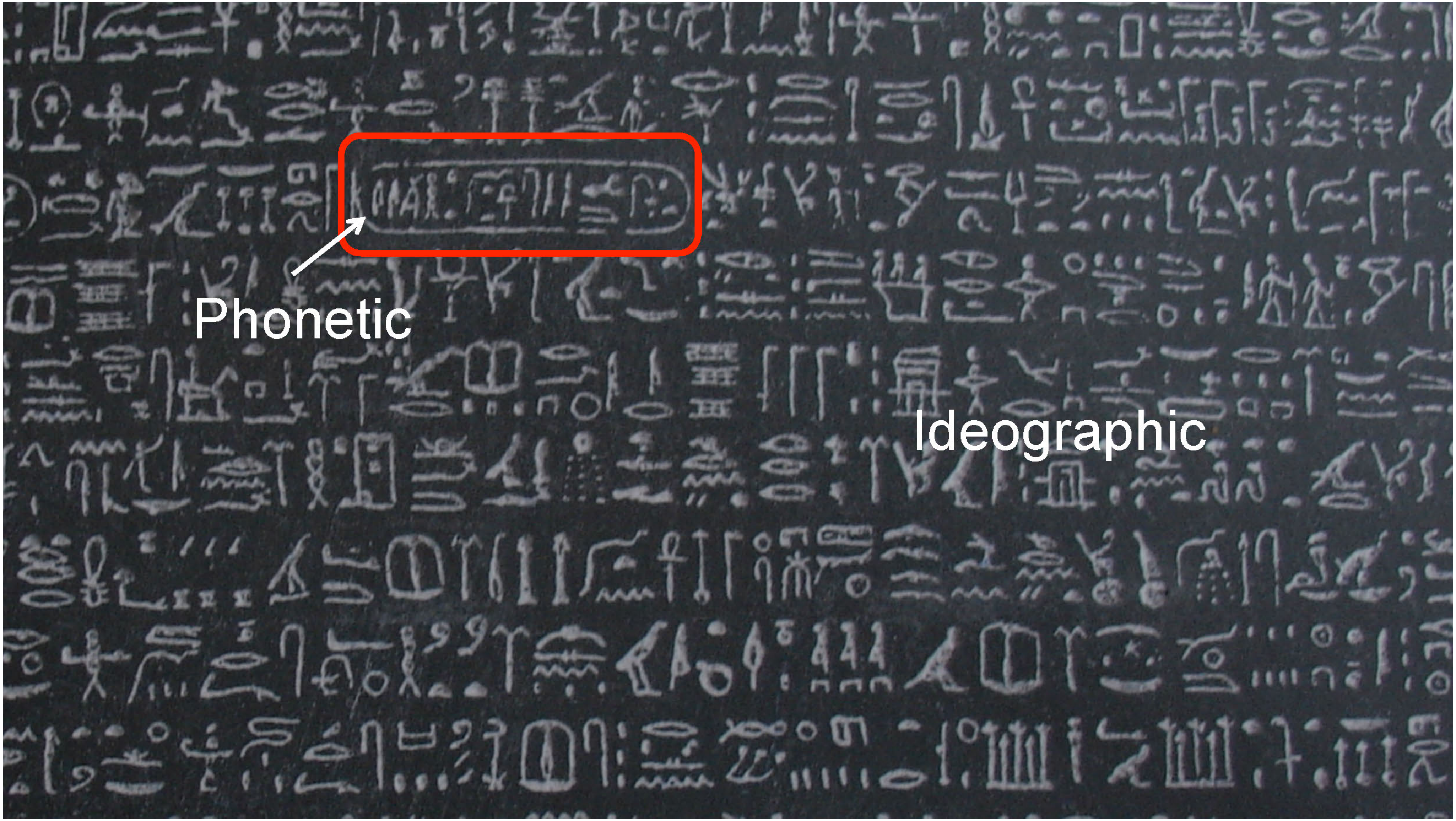


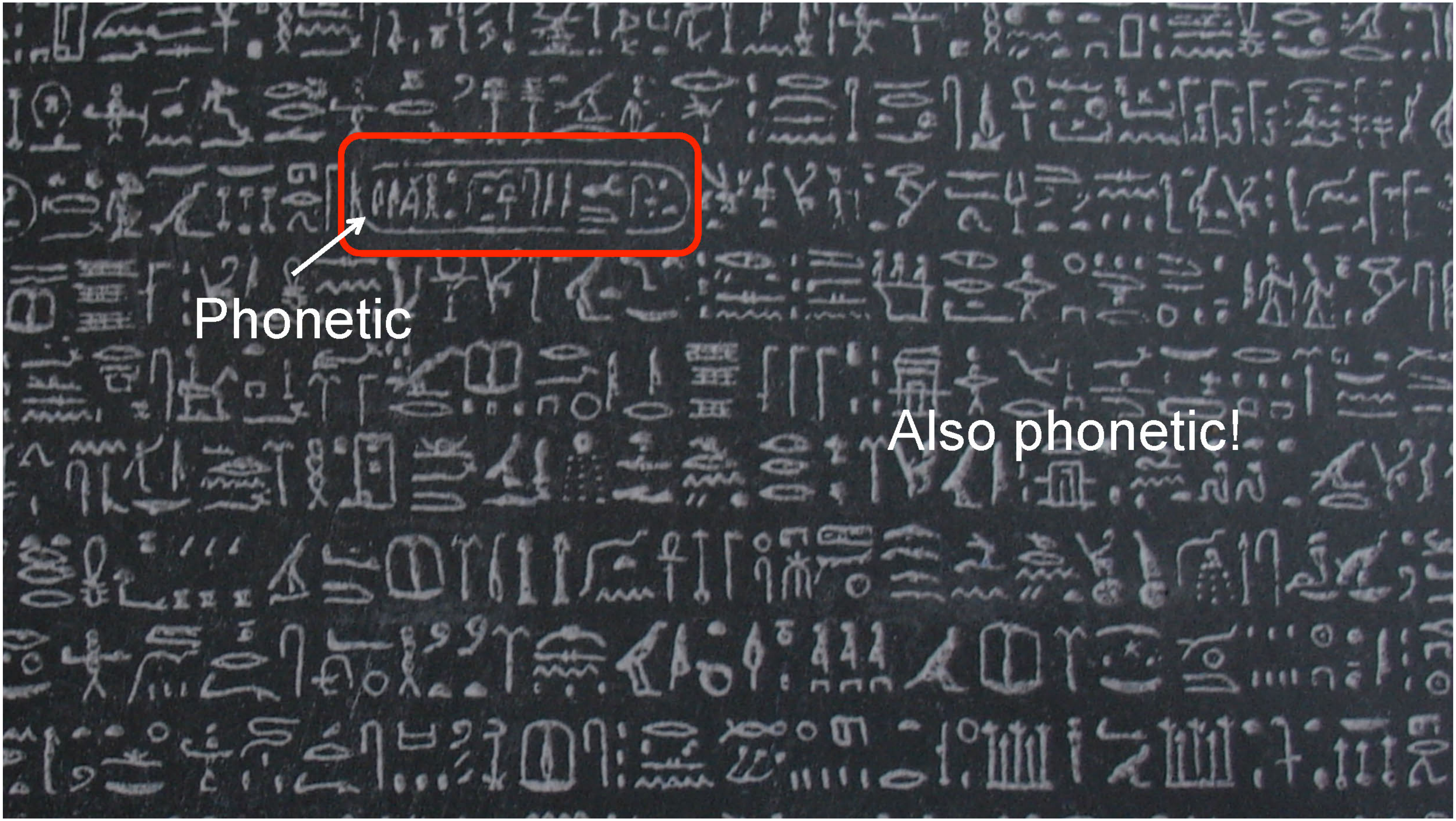




Jean-Francois Champollion
(1790-1832)


P T O L M Y S
C L E O P A T R A


Phonetic
Ideographic

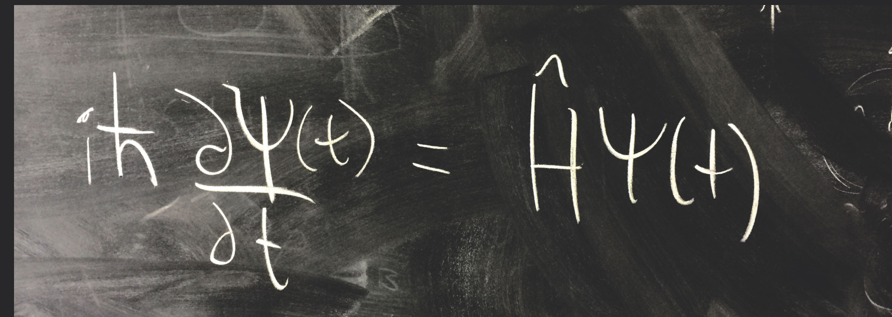

Phonetic
Also phonetic!

“The everlasting Caesar Domitian”

hieroglyphs are ideograms

“a Man Who Has Been Succeeded in His Property by a Son Whom He Hated”

“the flow of sacred humours emanating from above”

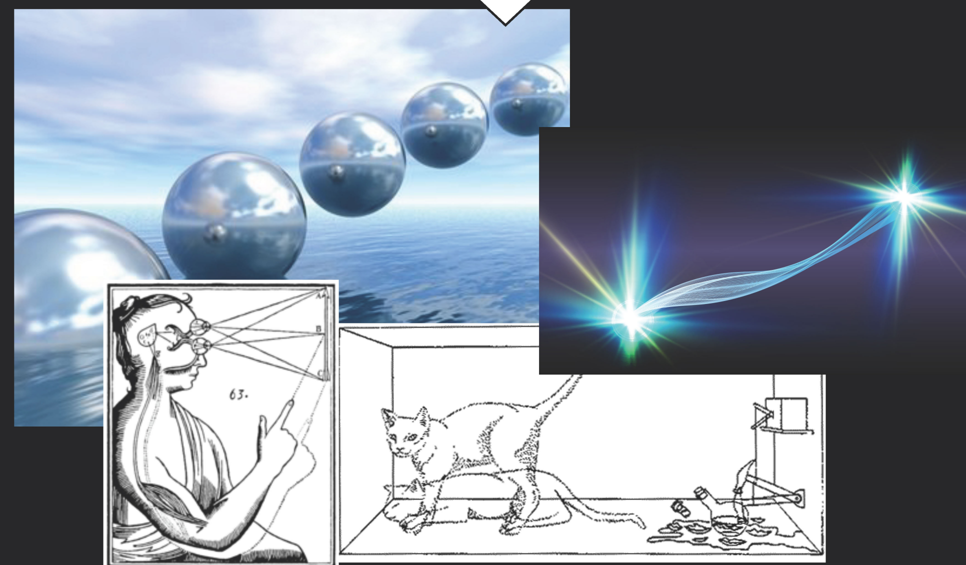


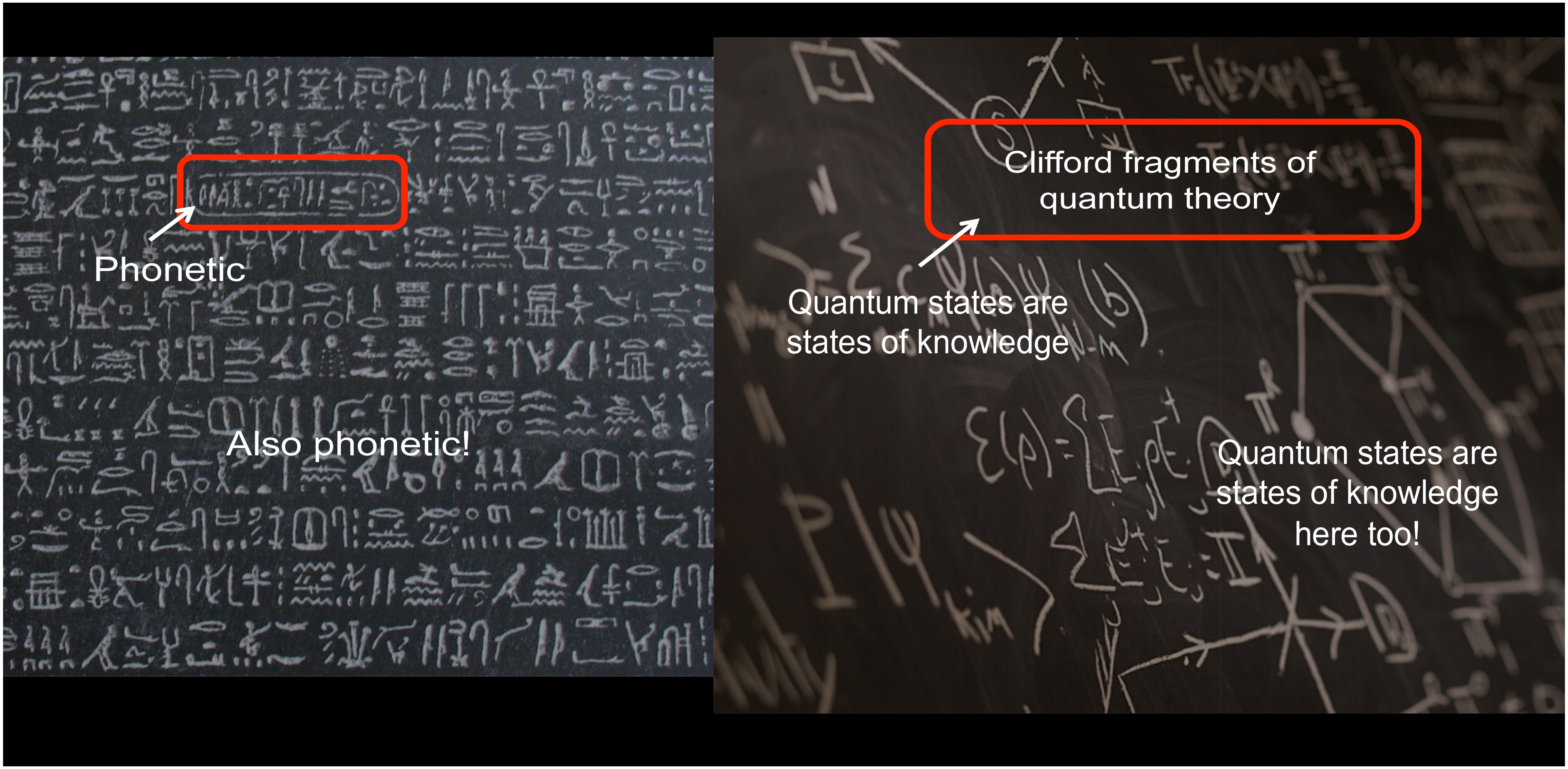
hieroglyphs are ideograms

Quantum states represent reality

“a Man Who Has Been Succeeded in His Property by a Son Whom He Hated”

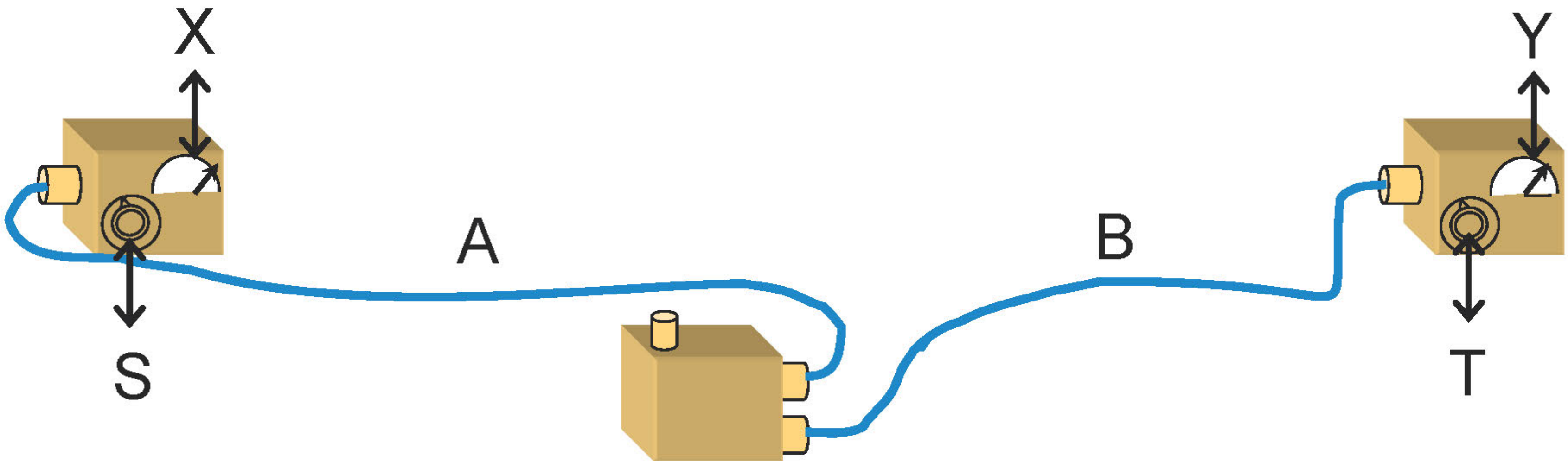
“the flow of sacred humours emanating from above”




Phonetic
Also phonetic!
Clifford fragments of quantum theory
Quantum states are states of knowledge
Quantum states are states of knowledge here too!

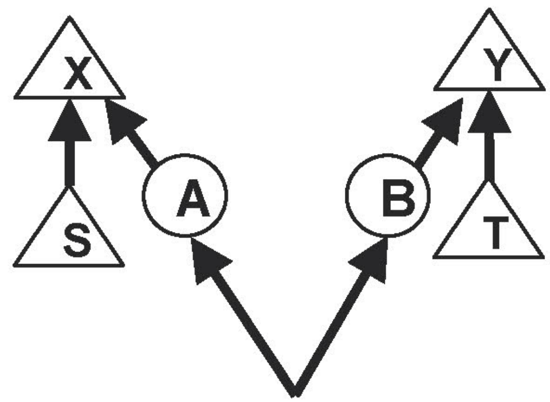
	Ideographic script	Phonetic script
Synonyms that are not homophones		mɒm
		mʌm
Homophones that are not synonyms		bɑːk
		bɑːk

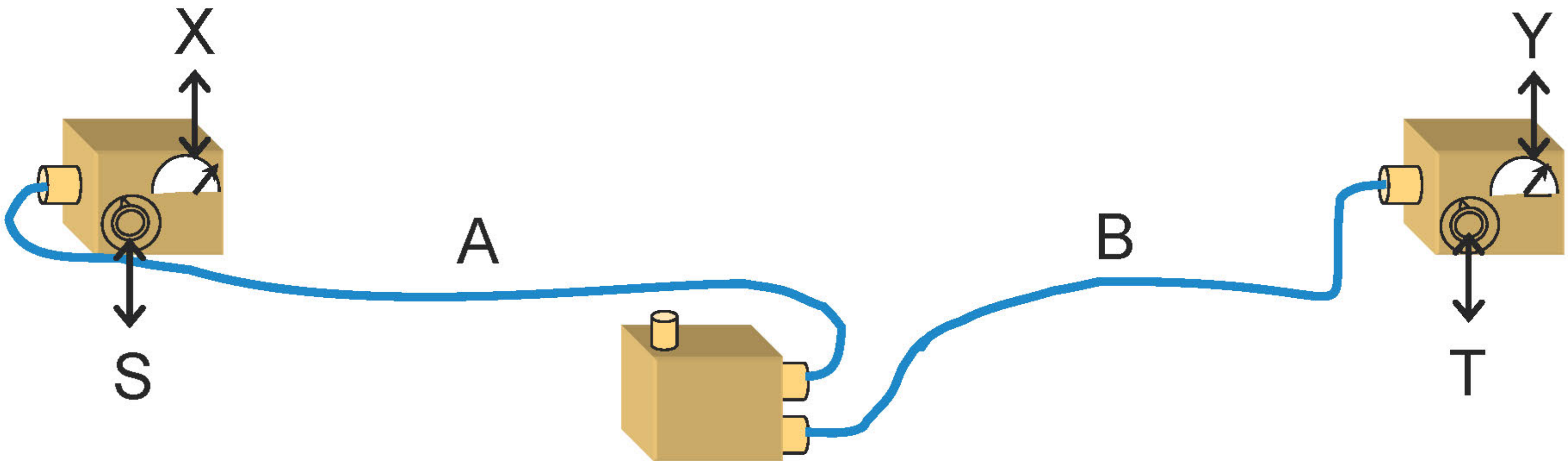
	Airport signs are ideographic	English script is phonetic
Synonyms that are not homophones		mom
		mum
Homophones that are not synonyms		bark
		bark



P(X,Y|S,T)

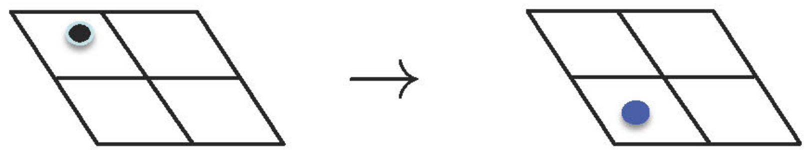
	X=0, Y=0	X=0, Y=1	X=1, Y=0	X=1, Y=1
S=0, T=0	0.5	0	0	0.5
S=0, T=1	0.5	0	0	0.5
S=1, T=0	0.5	0	0	0.5
S=1, T=1	0	0.5	0.5	0





Set $S=1$

get $X=0$ $\rightarrow$



get $X=1$ $\rightarrow$