Title: Journal club: Frauchiger-Renner no-go theorem for single-world interpretations of quantum theory

Date: Jun 15, 2016 04:00 PM

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Abstract: <p>In this talk I will go over the recent paper by Daniela Frauchiger and Renato Renner, "Single-world interpretations of quantum theory cannot be self-consistent" (arXiv:1604.07422).

The paper introduces an extended Wigner's friend thought experiment, which makes use of Hardy's paradox to show that agents will necessarily reach contradictory conclusions - unless they take into account that they themselves may be in a superposition, and that their subjective experience of observing an outcome is not the whole story.

Frauchiger and Renner then put this experiment in context within a general framework to analyse physical theories. This leads to a theorem saying that a theory cannot be simultaneously (1) compliant with quantum theory, including at the macroscopic level, (2) single-world, and (3) self-consistent across different agents.

In this talk I will (1) describe the experiment and its immediate consequences, (2) quickly review how different interpretations react to it, (3) explain the framework and theorem in more detail.

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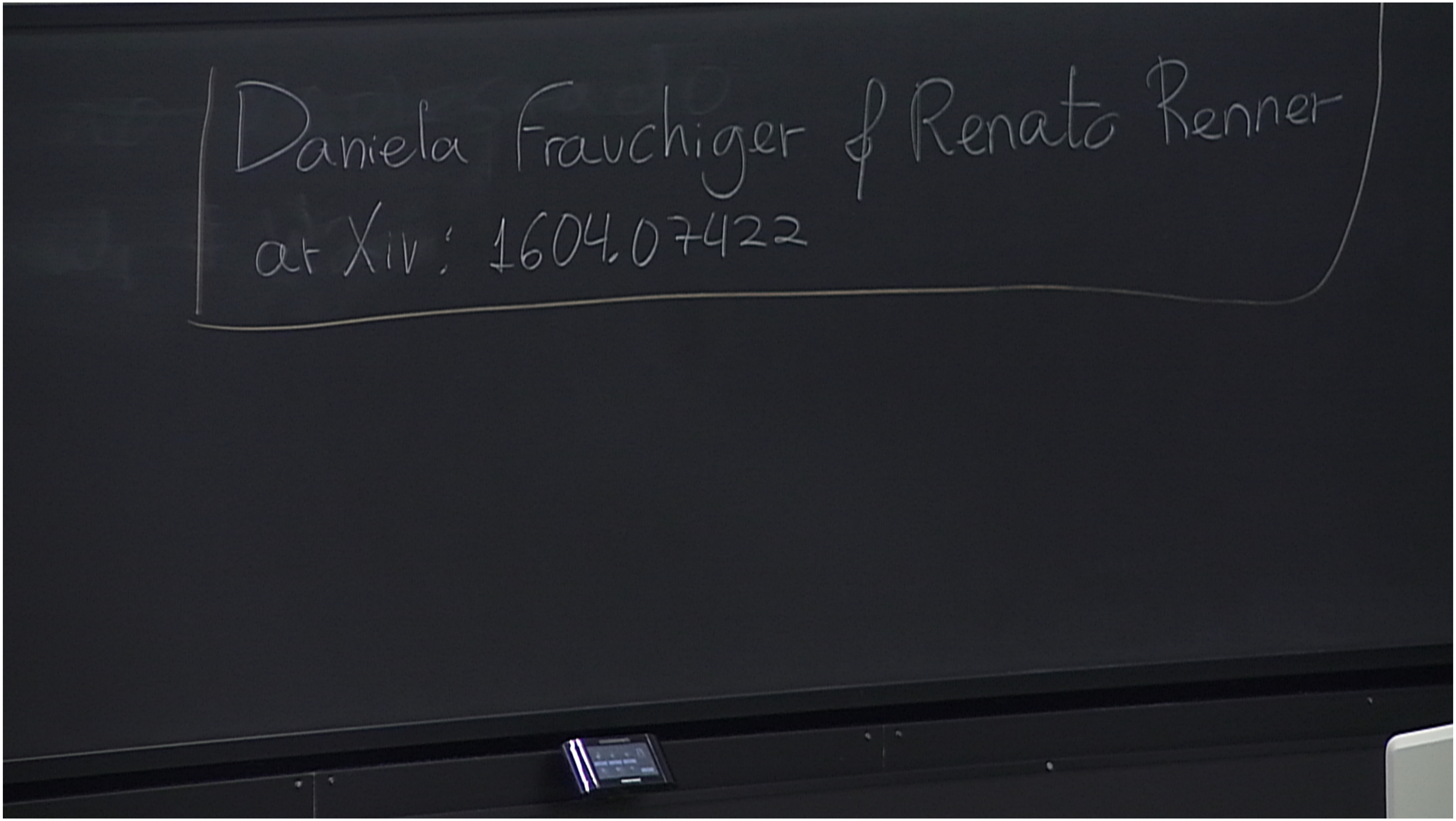
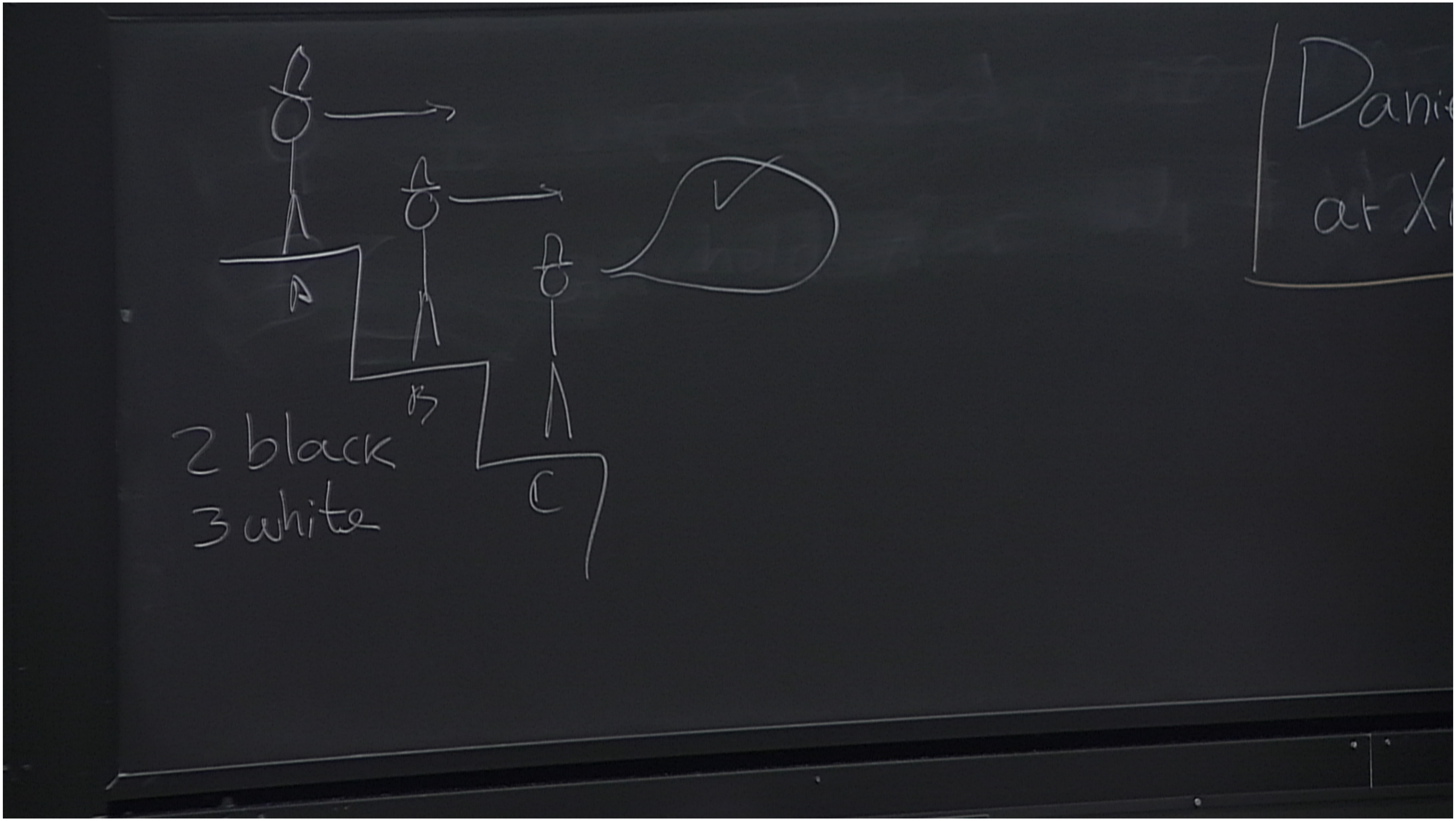
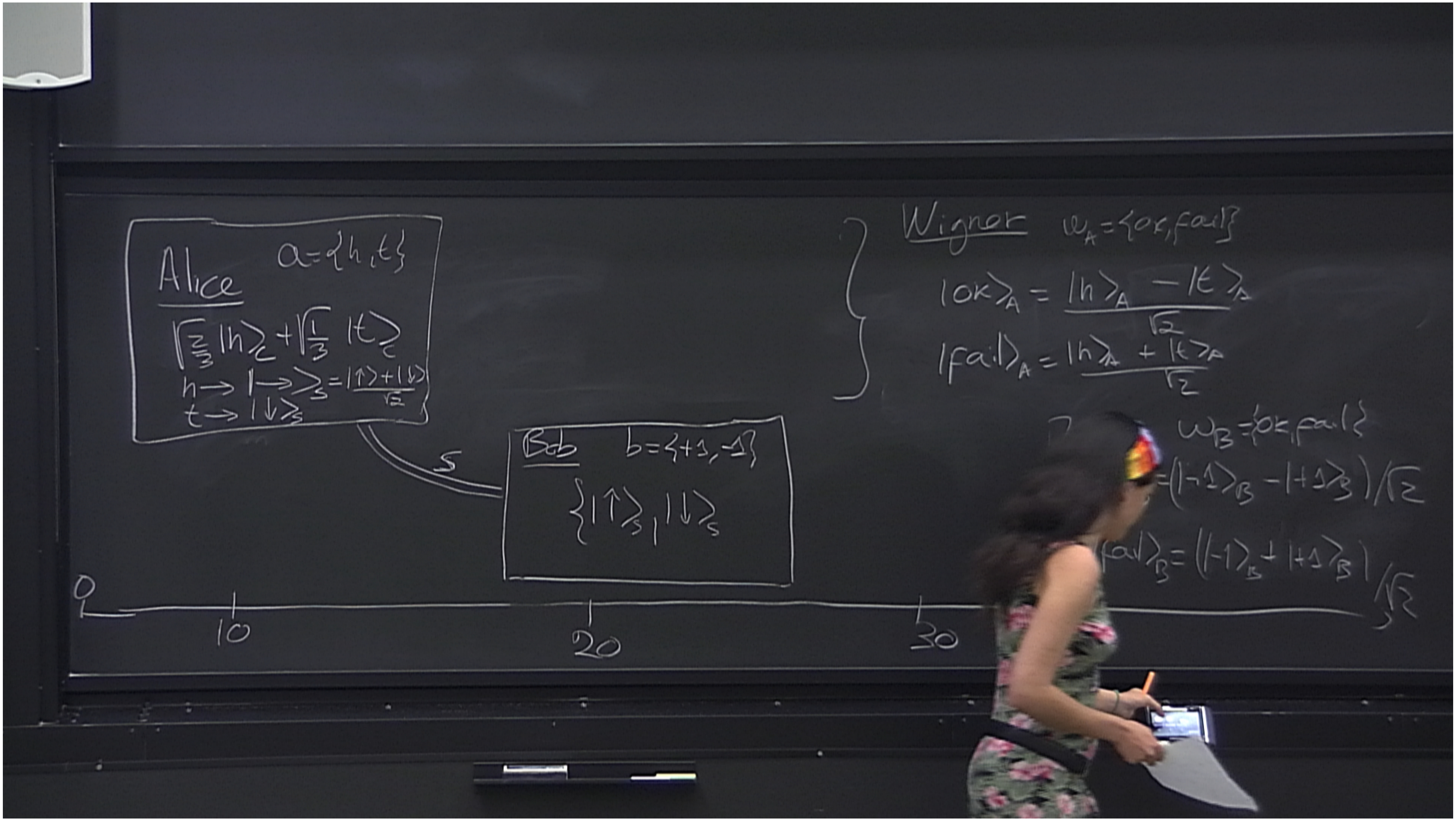

Daniela Frauchiger & Renato Renner
arXiv: 1604.07422


A
B
C
2 black
3 white


Alice a={h,t}
√(2/3) |h>_c + √(1/3) |t>_c
h → |→>_s = (|↑> + |↓>)/√2
t → |↓>_s
Bob b={+1,-1}
{|↑>_s, |↓>_s}
s
Wigner w_A={ok,fail}
|ok>_A = (|h>_A − |t>_A)/√2
|fail>_A = (|h>_A + |t>_A)/√2
w_B={ok,fail}
=(|-1>_B − |+1>_B)/√2
|fail>_B = (|-1>_B + |+1>_B)/√2
0
10
20
30

$$A = C \otimes A' \qquad B = S \otimes B'$$

$\underline{t=0}$

$$\left(\sqrt{\tfrac{2}{3}}\,|h\rangle_C + \tfrac{1}{\sqrt{3}}\,|t\rangle_C\right)|\perp\rangle_{A'}\,|\perp\rangle_S\,|\perp\rangle_{B'}$$

$\underline{t=10}$

$$\left(\sqrt{\tfrac{2}{3}}\,\overbrace{|h\rangle_C\,|h\rangle_{A'}}^{|h\rangle_A}\,|\rightarrow\rangle_S + \sqrt{\tfrac{1}{3}}\,\overbrace{|t\rangle_C\,|t\rangle_{A'}}^{|t\rangle_A}\,|\downarrow\rangle_S\right)|\perp\rangle_{B'}$$

$\underline{t=20}$

$$\sqrt{\tfrac{2}{3}}\,|h\rangle_A\,\frac{\overbrace{|\uparrow\rangle_S\,|+1\rangle_{B'}}^{|1\rangle_B} + \overbrace{|\downarrow\rangle_S\,|-1\rangle_{B'}}^{|-1\rangle_B}}{\sqrt{2}} + \sqrt{\tfrac{1}{3}}\,|t\rangle_A\,|\downarrow\rangle_S\,|-1\rangle_{B'}$$

$$\frac{1}{\sqrt{3}}\left(|h\rangle_A|+1\rangle_B + |h\rangle_A|-1\rangle_B + |t\rangle_A|-1\rangle_B\right)$$

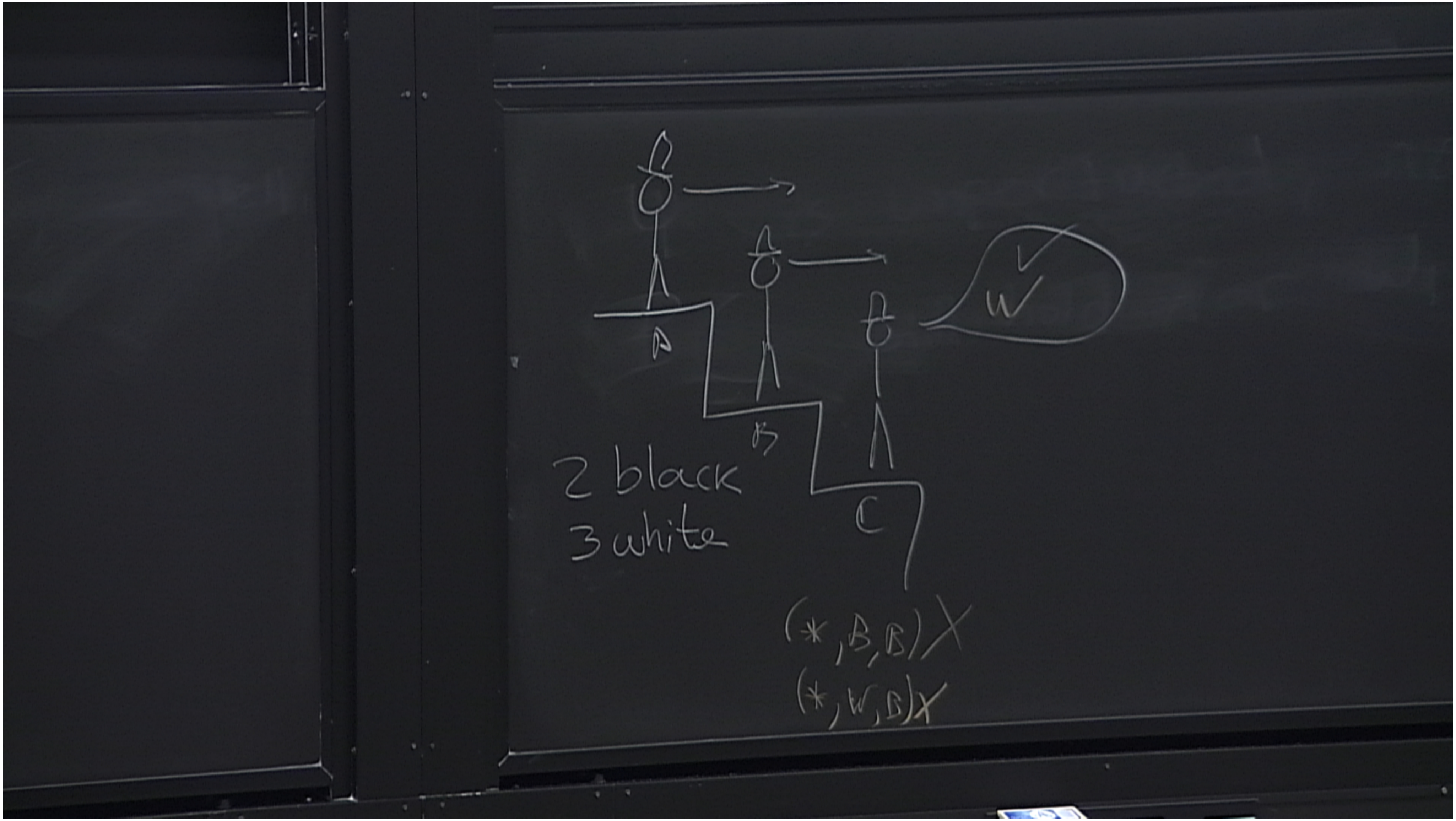
$$|h\rangle_A|fail\rangle_B \qquad |fail\rangle_A|-1\rangle_B$$

$1\rangle_{B'}$

$$\frac{1}{\sqrt{3}}\left(\underbrace{|h\rangle_A|+1\rangle_B + \mathrlap{\underbrace{}_{|fail\rangle_A|-1\rangle_B}}|h\rangle_A|-1\rangle_B}_{|h\rangle_A|fail\rangle_B} + |t\rangle_A|-1\rangle_B\right)$$

$$= \ldots\ldots \frac{1}{\sqrt{12}}|ok\rangle|ok\rangle + \ldots\ldots$$

$1\rangle_{B'}$


A
B
C
2 black
3 white
W
(*, B, B)
(*, W, B)

$=\{+1,-1\}$

$|\downarrow\rangle_S$

<u>Wigner</u> $w_A = \{ok, fail\}$

$$|ok\rangle_A = \frac{|h\rangle_A - |t\rangle_A}{\sqrt{2}} \qquad w_A = ok \longrightarrow b = +1$$

$$|fail\rangle_A = \frac{|h\rangle_A + |t\rangle_A}{\sqrt{2}}$$

$w_B = \{ok, fail\}$

$$|ok\rangle_B = \left(|-1\rangle_B - |+1\rangle_B\right)/\sqrt{2} \qquad w_B = ok$$

$$|fail\rangle_B = \left(|-1\rangle_B + |+1\rangle_B\right)/\sqrt{2}$$

30 40

Alice

$\sqrt{\frac{2}{3}}\,|h\rangle_C + \sqrt{\frac{1}{3}}\,|t\rangle_C$

$h \to |\rightarrow\rangle_S = \frac{|\uparrow\rangle + |\downarrow\rangle}{\sqrt{2}}$

$t \to |\downarrow\rangle_S$

$a = h \to w_B = \text{fail}$

S

$b = +1 \to a = h$

Bob $b = \{+1, -1\}$

$\{|\uparrow\rangle_S, |\downarrow\rangle_S\}$

0 10 20

$a = \{h, t\}$

$+\sqrt{\frac{1}{3}}\, |t\rangle_C$

$|\rightarrow\rangle_S = \frac{|\uparrow\rangle + |\downarrow\rangle}{\sqrt{2}}$

$|\downarrow\rangle_S$

$_B = \text{fail}$

S

$\frac{\sqrt{2}}{\sqrt{3}}\, |h\rangle_A\, |\rightarrow\rangle_S + \frac{1}{\sqrt{3}}\, |t\rangle_A\, |\downarrow\rangle_S$

$b = +1 \rightarrow a = h$

Bob $\quad b = \{+1, -1\}$

$\{|\uparrow\rangle_S, |\downarrow\rangle_S\}$

Wign

$|\text{ok}$

$|\text{fa}$

black
white

(*, , B) X
(*, W, B) X

$$|h\rangle_A |\rightarrow\rangle_S + |t\rangle_A |\downarrow\rangle_S$$

Reject QT

- can't measure macro
- can, but $\neq$ QT
- can, but not observers

Reject SW

- more than 1 outcome is "real"

Reject SC

- (QBism?)