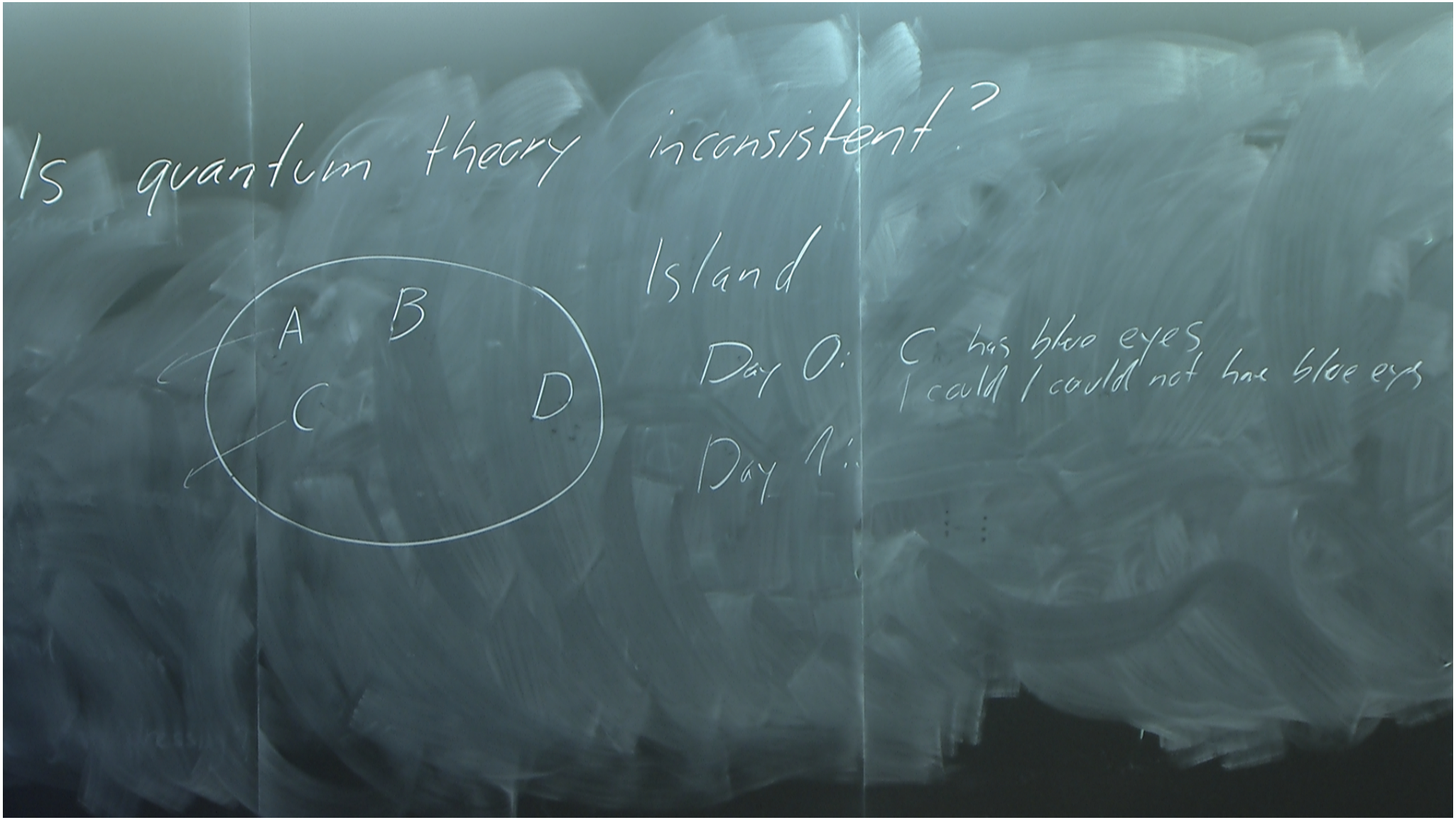
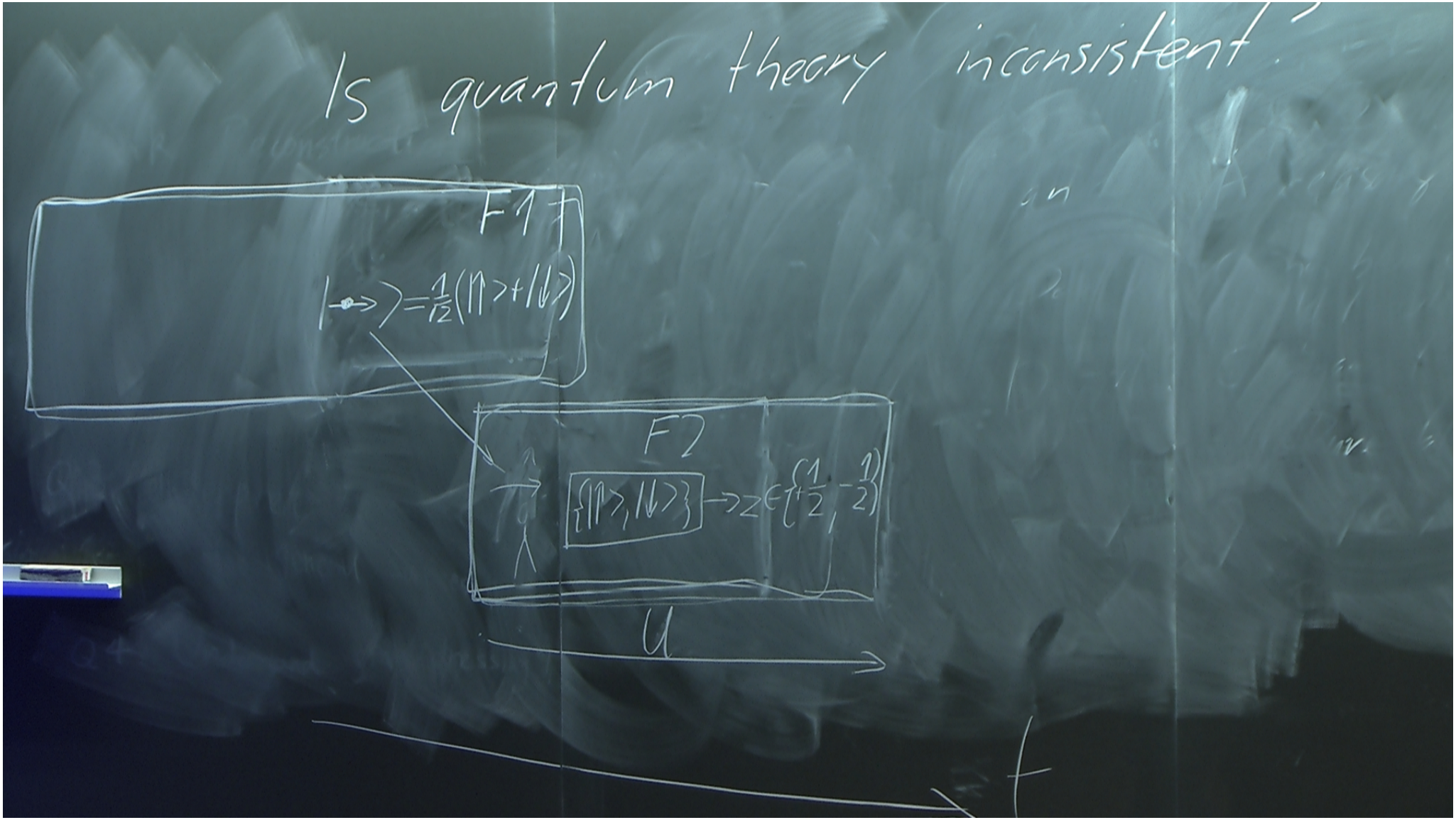
Title: An Extension of the Wignerâ€™s Friend Gedankenexperiment

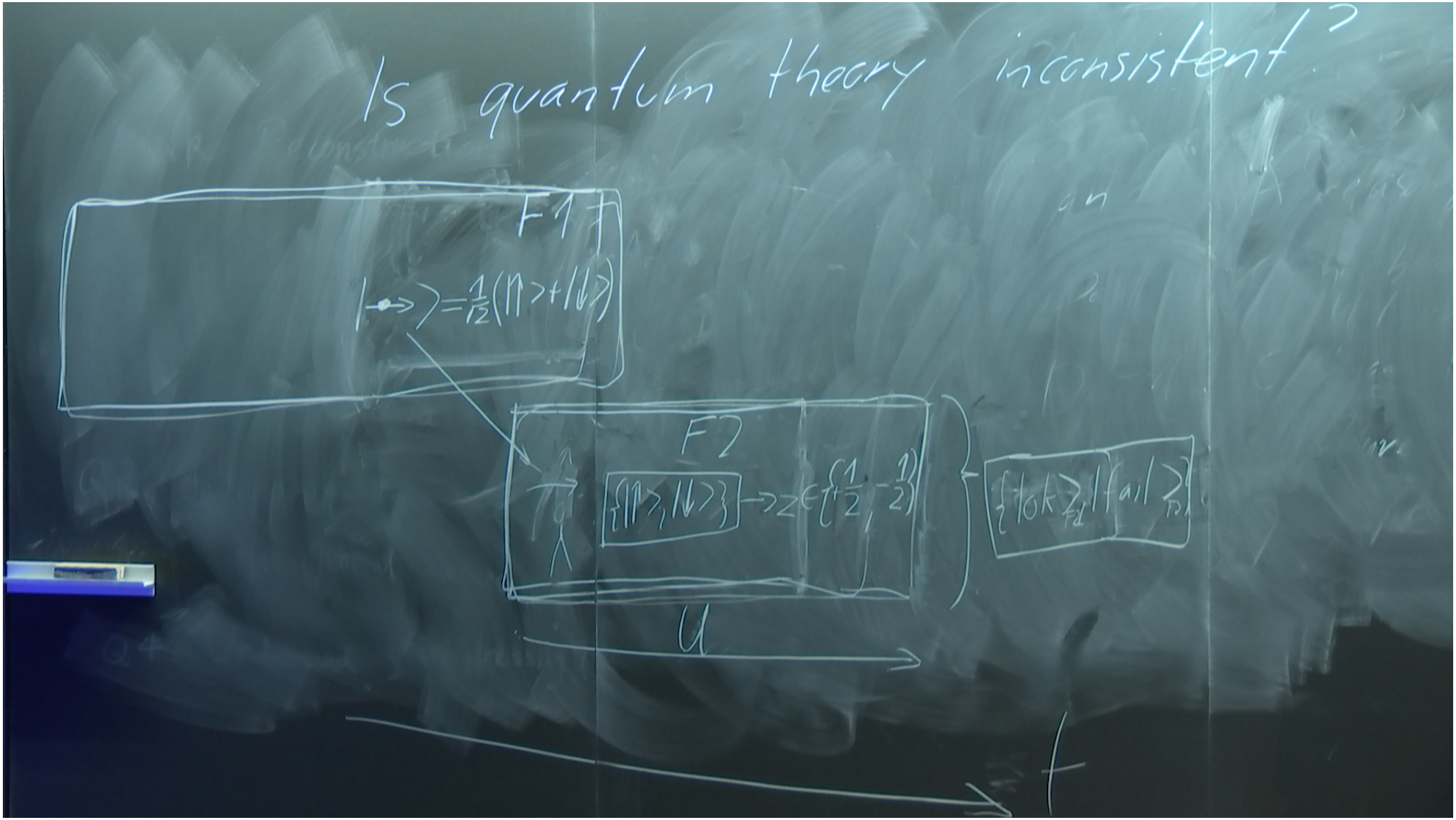
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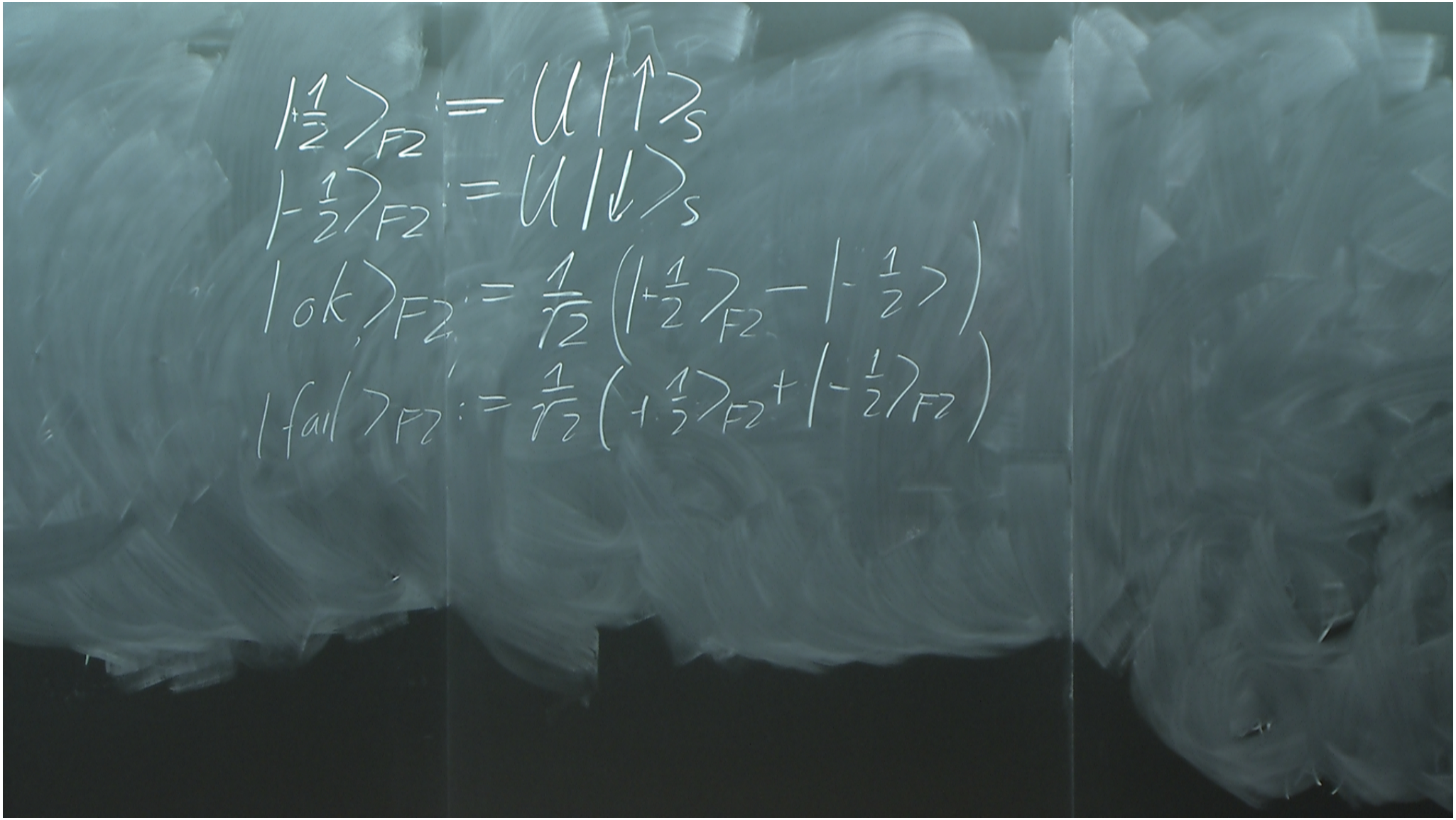
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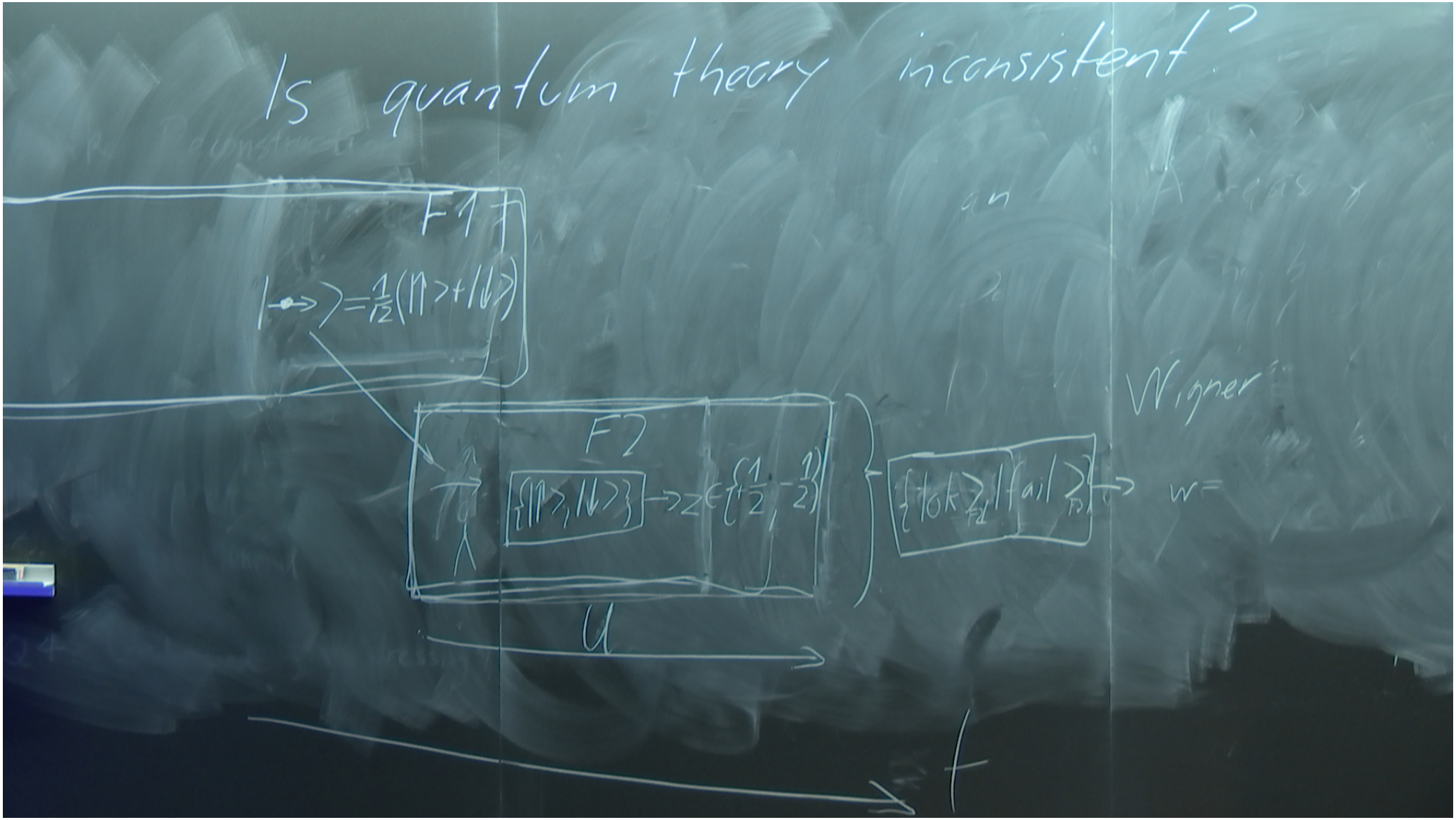
Abstract: In this talk I consider the following principle that one may impose on any physical theory T:
"If an agent uses T to describe a system which includes another agent who herself uses T then no logical contradictions should arise.â€•
I then propose a gedankenexperiment, which can be regarded as an extension of the Wignerâ€™s Friend experiment, to test whether this principle holds for quantum mechanics. The conclusion is that this is indeed the case for â€œplain" quantum theory, but that the principle is violated by many of its common interpretations and extensions.


Is quantum theory inconsistent?
Island
A
B
C
D
Day 0:
C has blue eyes
I could I could not have blue eyes
Day 1:


Is quantum theory inconsistent?
F1
$|\rightarrow\rangle = \frac{1}{\sqrt{2}}(|\uparrow\rangle + |\downarrow\rangle)$
F2
$\{|\uparrow\rangle, |\downarrow\rangle\} \rightarrow z \in \{\frac{1}{2}, -\frac{1}{2}\}$
U


Is quantum theory inconsistent?
F1
F2
U


$|+\frac{1}{2}\rangle_{F2} := U|\uparrow\rangle_S$
$|-\frac{1}{2}\rangle_{F2} := U|\downarrow\rangle_S$
$|ok\rangle_{F2} := \frac{1}{\sqrt{2}}\left(|+\frac{1}{2}\rangle_{F2} - |-\frac{1}{2}\rangle\right)$
$|fail\rangle_{F2} := \frac{1}{\sqrt{2}}\left(|+\frac{1}{2}\rangle_{F2} + |-\frac{1}{2}\rangle_{F2}\right)$


Is quantum theory inconsistent?
F1
F2
Wigner
U

$$|+\tfrac{1}{2}\rangle_{F2} := U|\uparrow\rangle_S$$

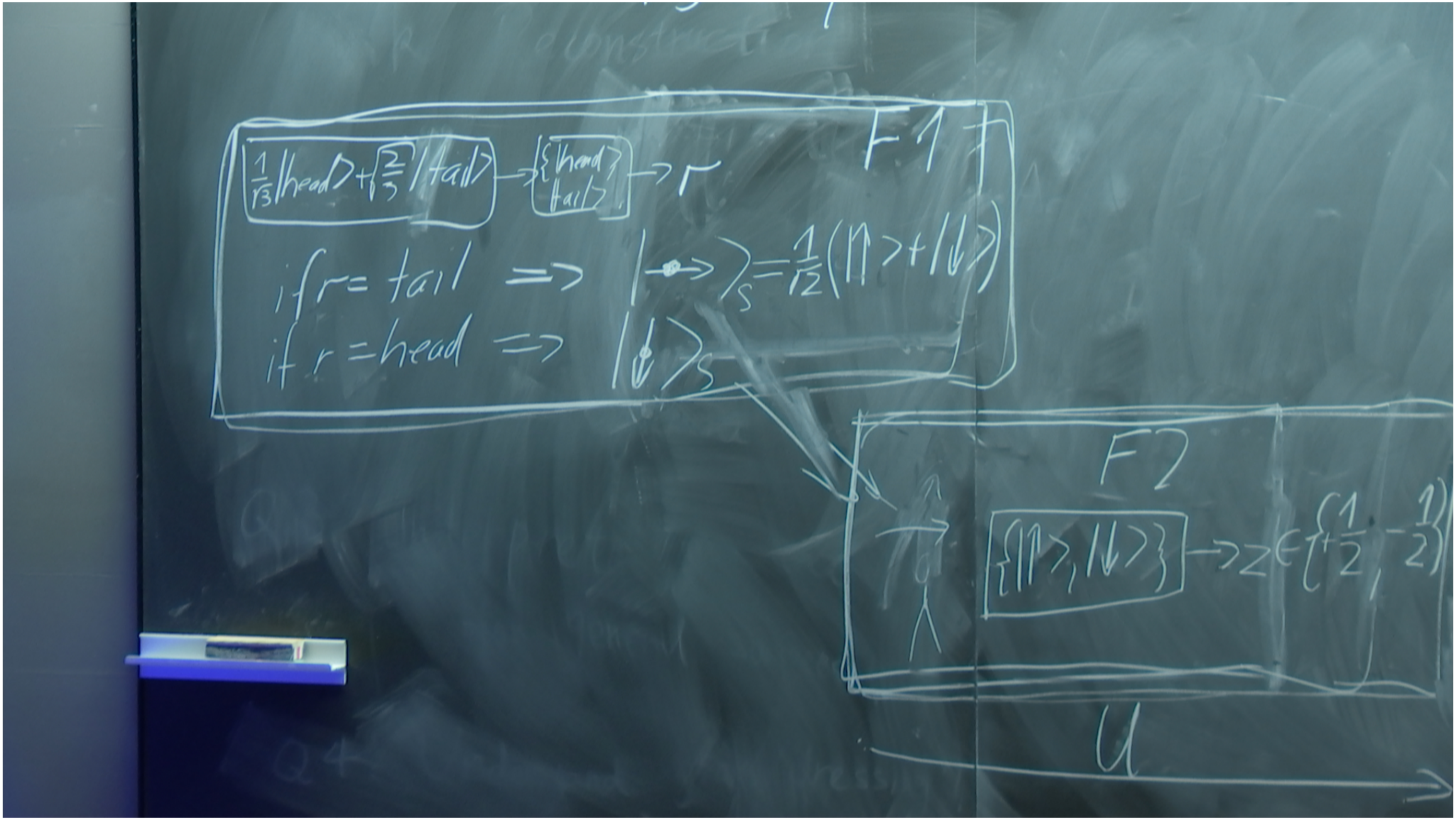
$$|-\tfrac{1}{2}\rangle_{F2} := U|\downarrow\rangle_S$$

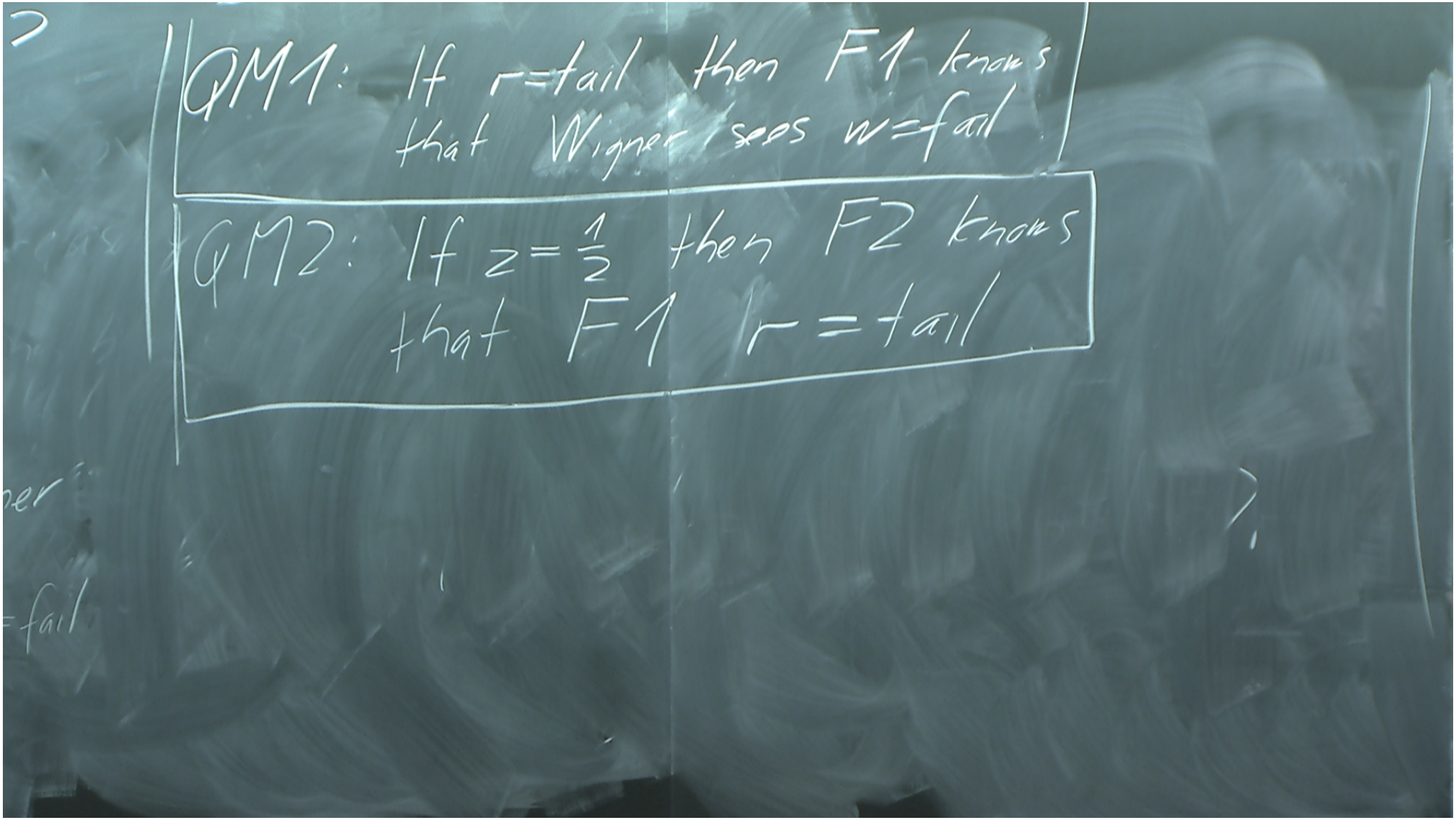
$$|ok\rangle_{F2} := \frac{1}{\sqrt{2}}\left(|+\tfrac{1}{2}\rangle_{F2} - |-\tfrac{1}{2}\rangle\right)$$

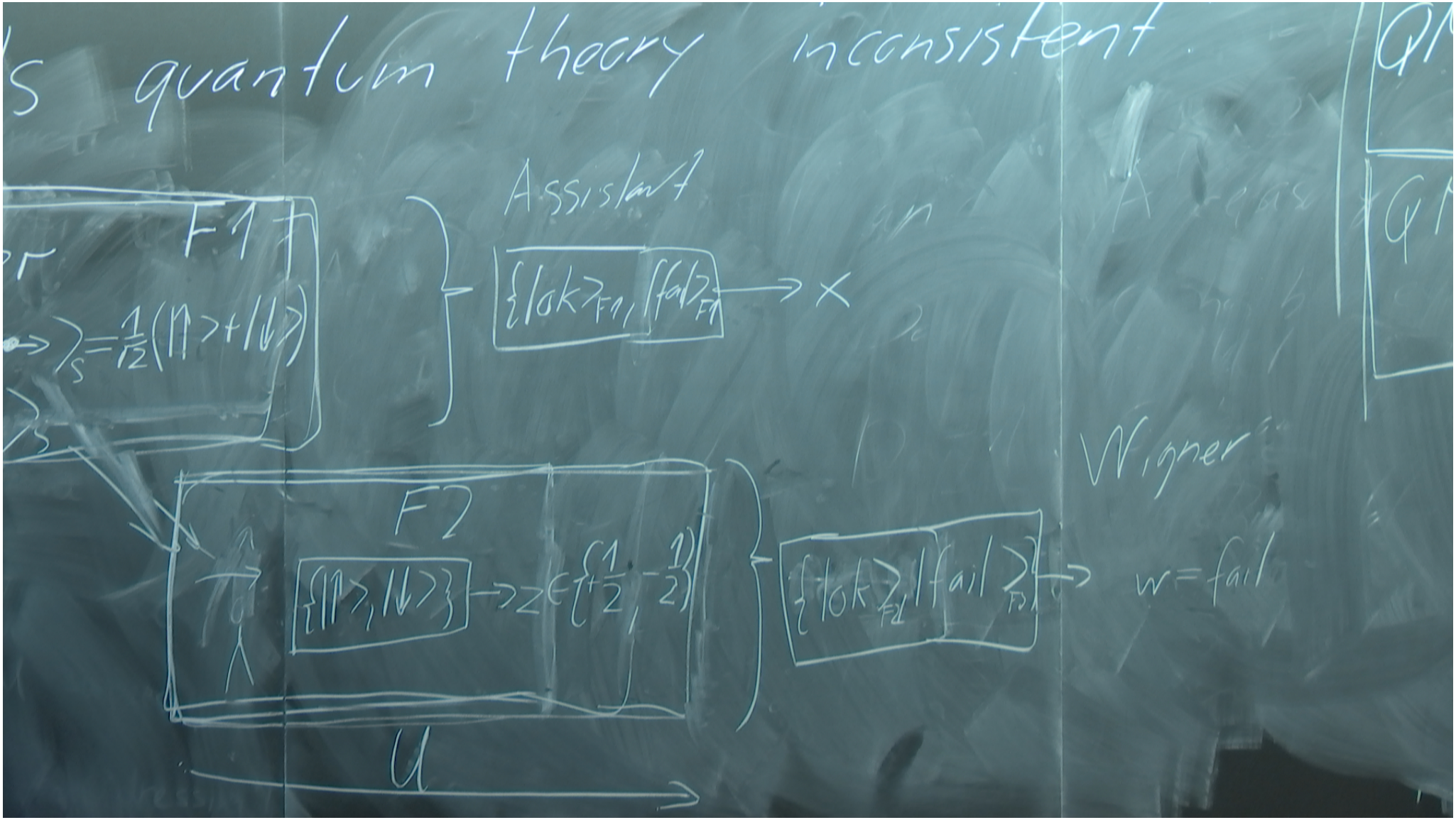
$$|fail\rangle_{F2} := \frac{1}{\sqrt{2}}\left(+\tfrac{1}{2}\rangle_{F2} + |-\tfrac{1}{2}\rangle_{F2}\right)$$

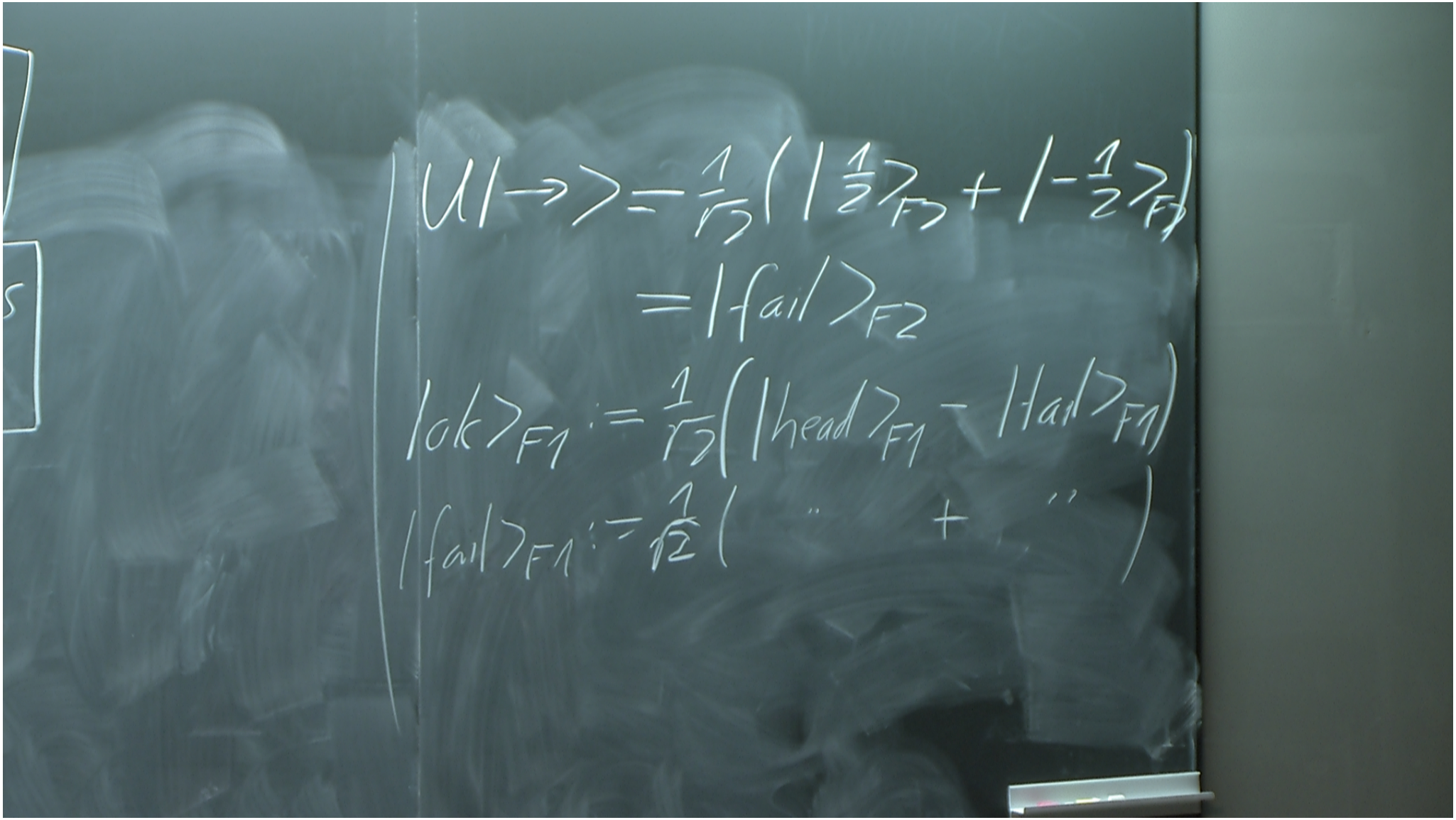
$$U|\rightarrow\rangle = \frac{1}{\sqrt{2}}\left(|\tfrac{1}{2}\rangle_{F2} + |-\tfrac{1}{2}\rangle_{F2}\right)$$

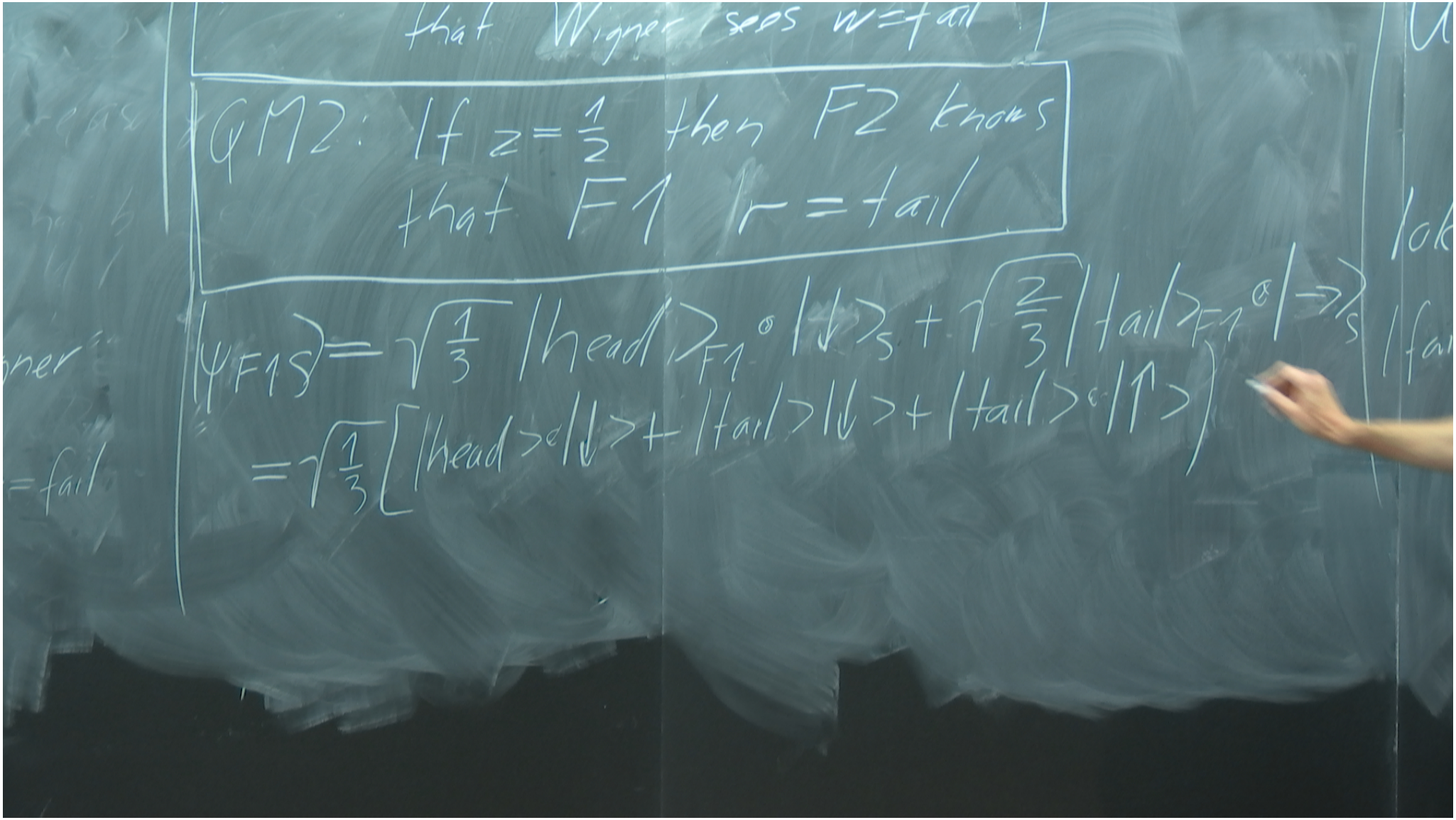
$$= |fail\rangle_{F2}$$

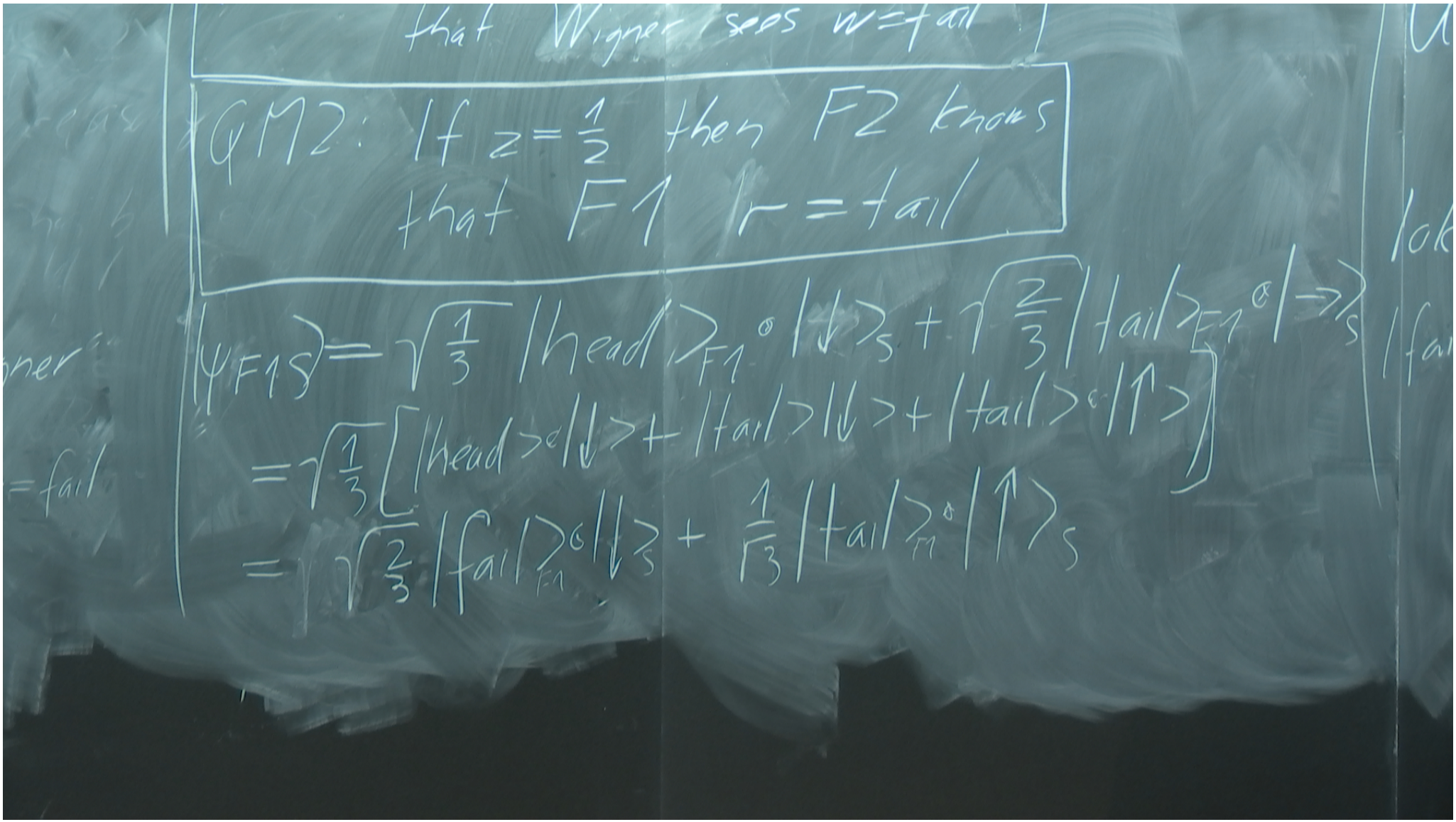

F1
if r = tail =>
if r = head =>
F2
U

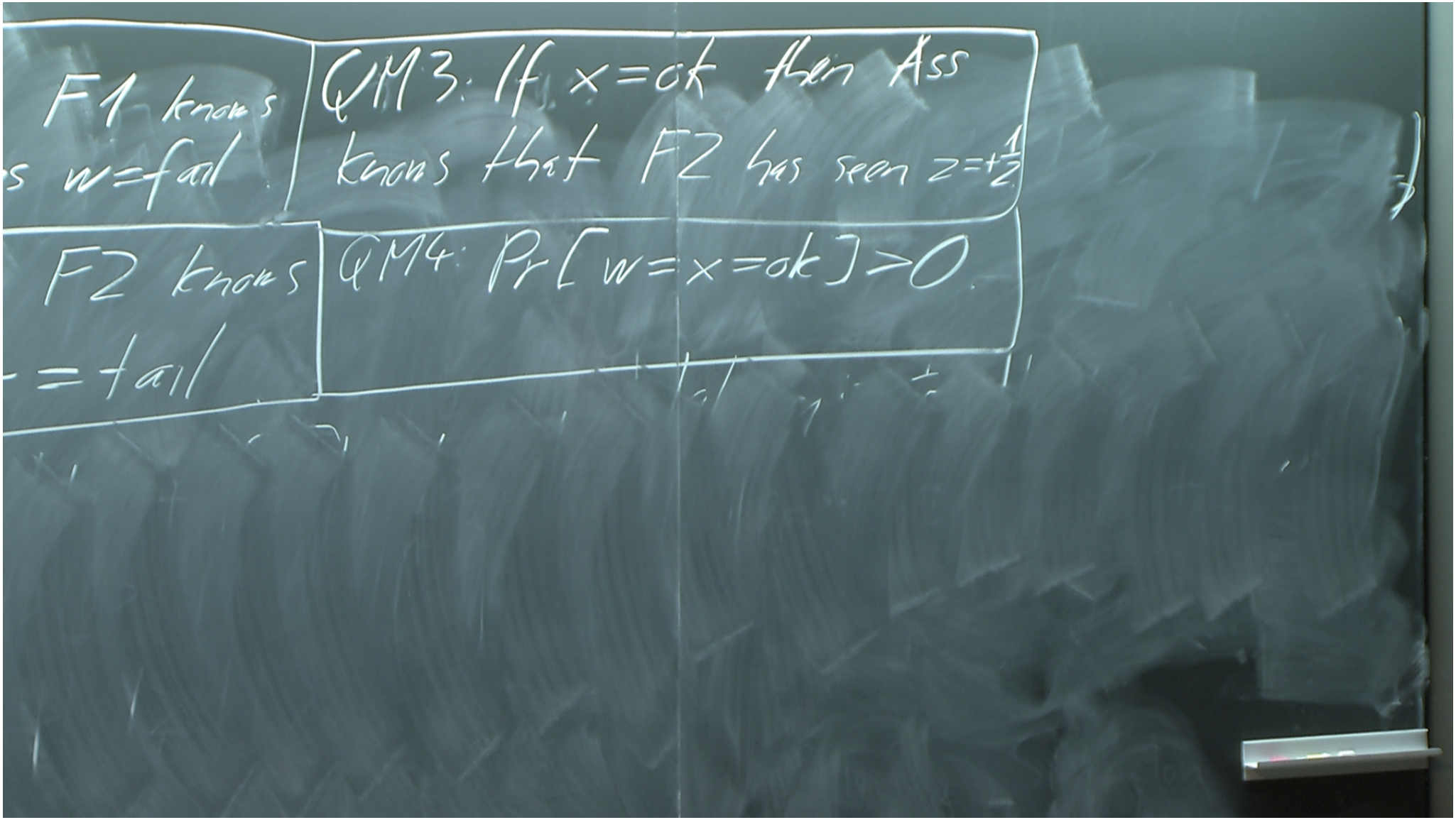

QM1: If r=tail then F1 knows that Wigner sees w=fail
QM2: If z=1/2 then F2 knows that F1 r=tail


s quantum theory inconsistent
F1
Assistant
F2
Wigner
w=fail
U


$|1\rangle = \frac{1}{\sqrt{2}}\left(|\tfrac{1}{2}\rangle_{F2} + |-\tfrac{1}{2}\rangle_{F2}\right)$
$= |fail\rangle_{F2}$
$|ok\rangle_{F1} := \frac{1}{\sqrt{2}}\left(|head\rangle_{F1} - |tail\rangle_{F1}\right)$
$|fail\rangle_{F1} := \frac{1}{\sqrt{2}}\left(\quad + \quad \right)$


that Wigner sees w=tail
QM2: If z=1/2 then F2 knows that F1 r=tail
|ψF1S⟩=√1/3 |head⟩F1 ⊗ |↓⟩S + √2/3 |tail⟩F1 ⊗ |→⟩S
=√1/3 [|head⟩⊗|↓⟩+|tail⟩|↓⟩+|tail⟩⊗|↑⟩)

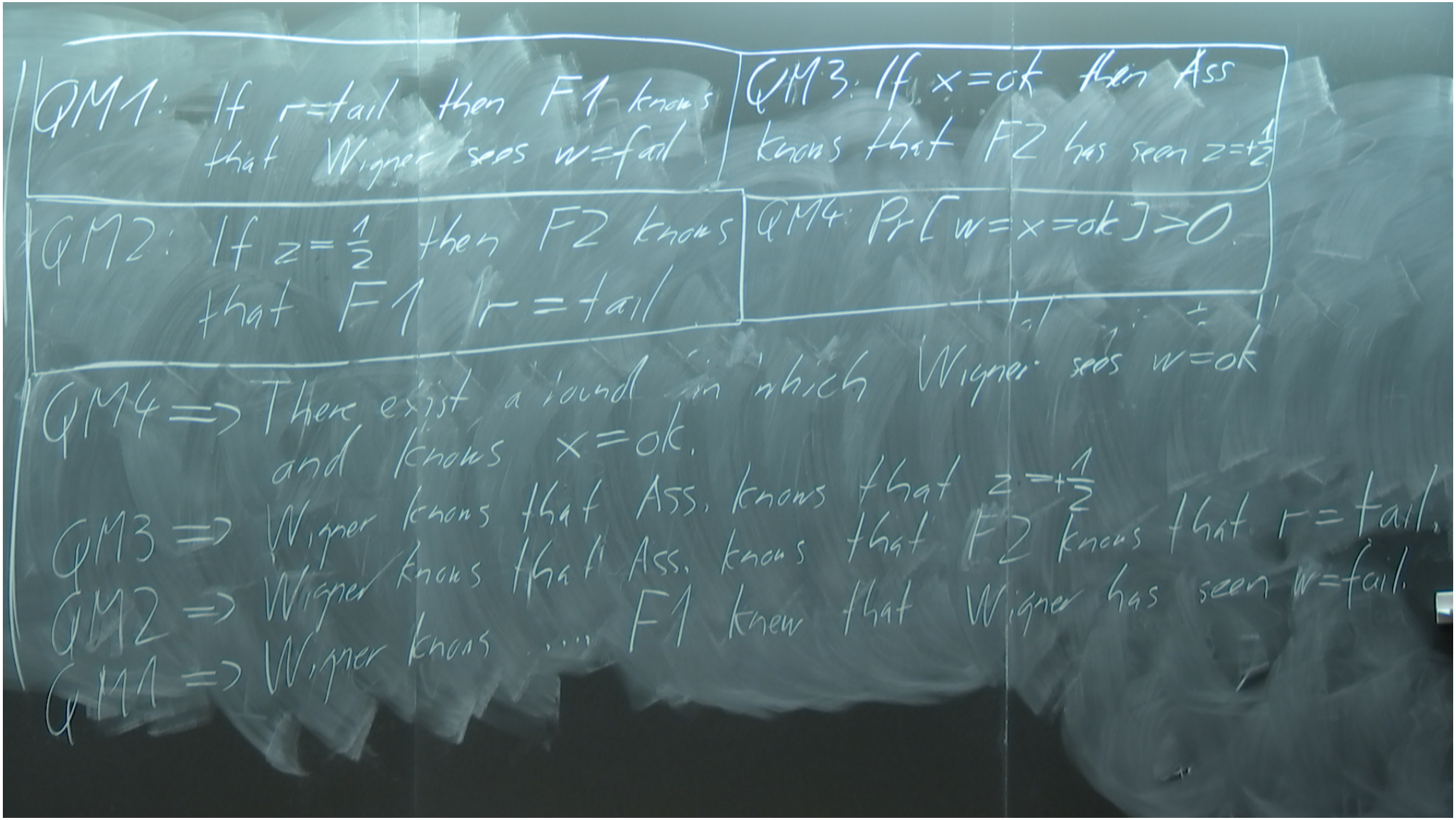

that Wigner sees w=fail
QM2: If z=1/2 then F2 knows that F1 r=fail
|ψF1S⟩ = √1/3 |head⟩F1 ⊗ |↓⟩S + √2/3 |tail⟩F1 ⊗ |→⟩S
= √1/3 [|head⟩⊗|↓⟩ + |tail⟩|↓⟩ + |tail⟩⊗|↑⟩]
= √2/3 |fail⟩F1 ⊗ |↓⟩S + 1/√3 |tail⟩F1 ⊗ |↑⟩S

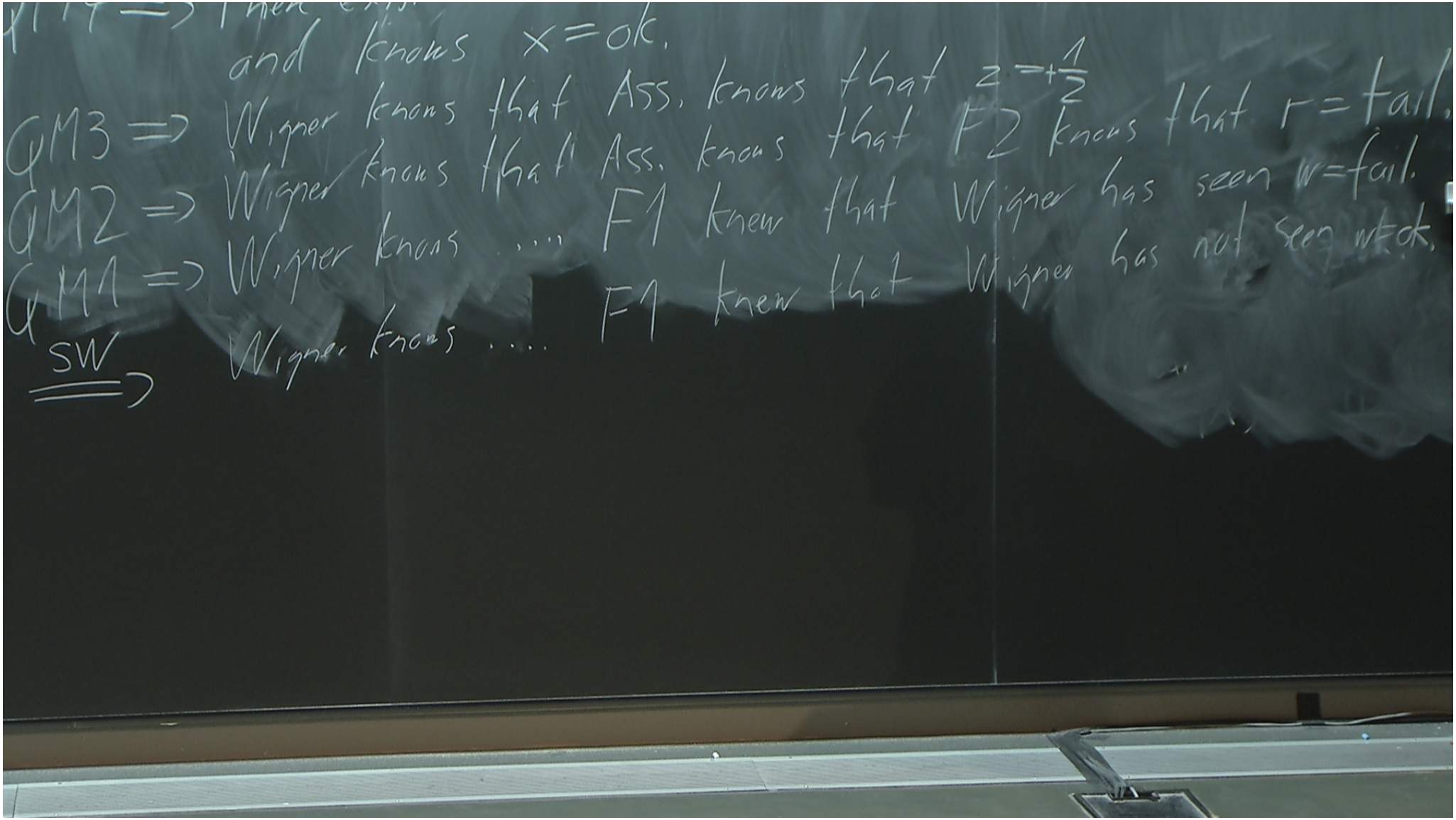

F1 knows
s w=fail
QM3: If x=ok then Ass
knows that F2 has seen z=±1/2
F2 knows
=tail
QM4: Pr[w=x=ok]>0

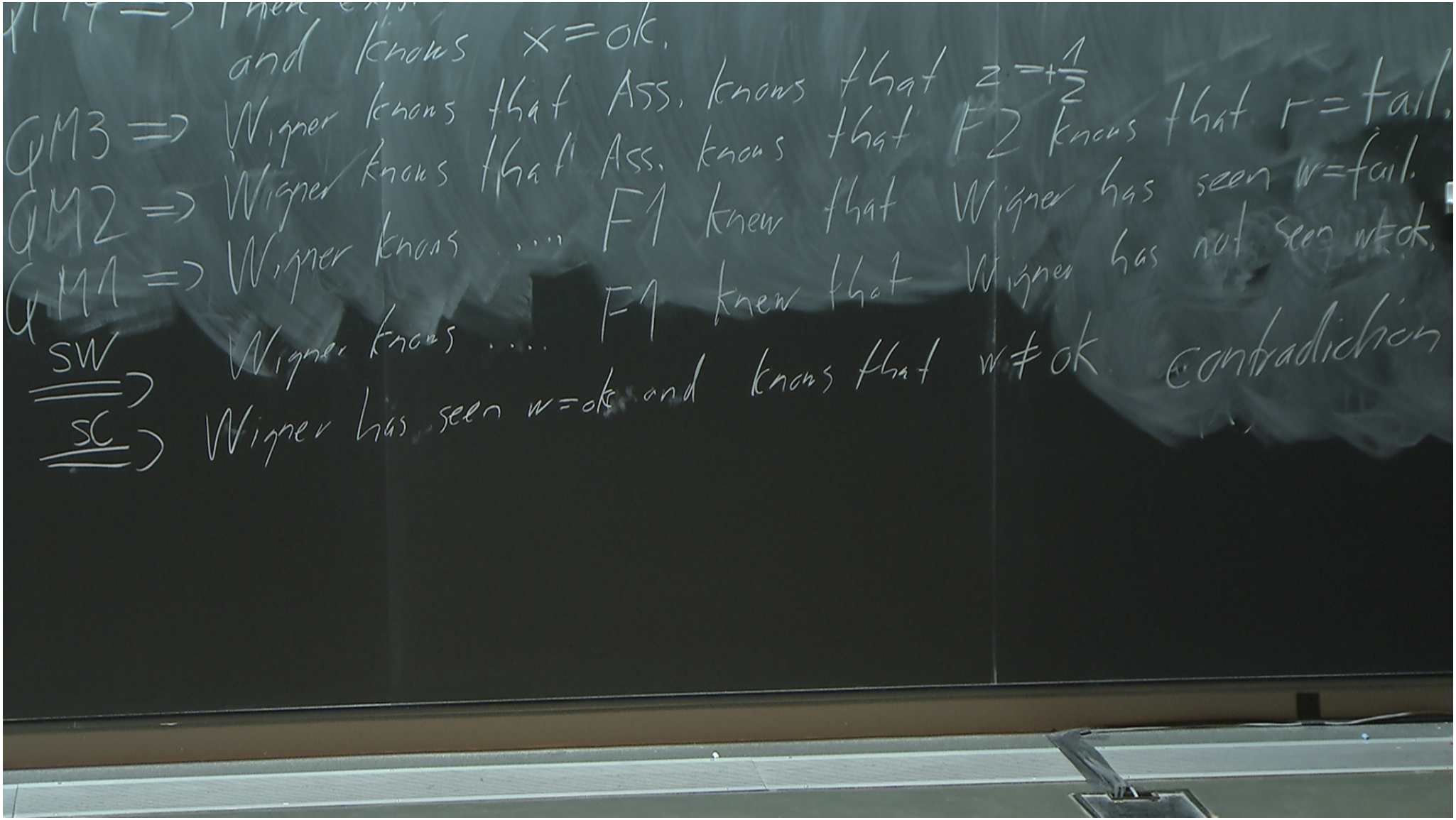
QM2: If $z=\frac{1}{2}$ then F2 knows that F1 $r=$ tail

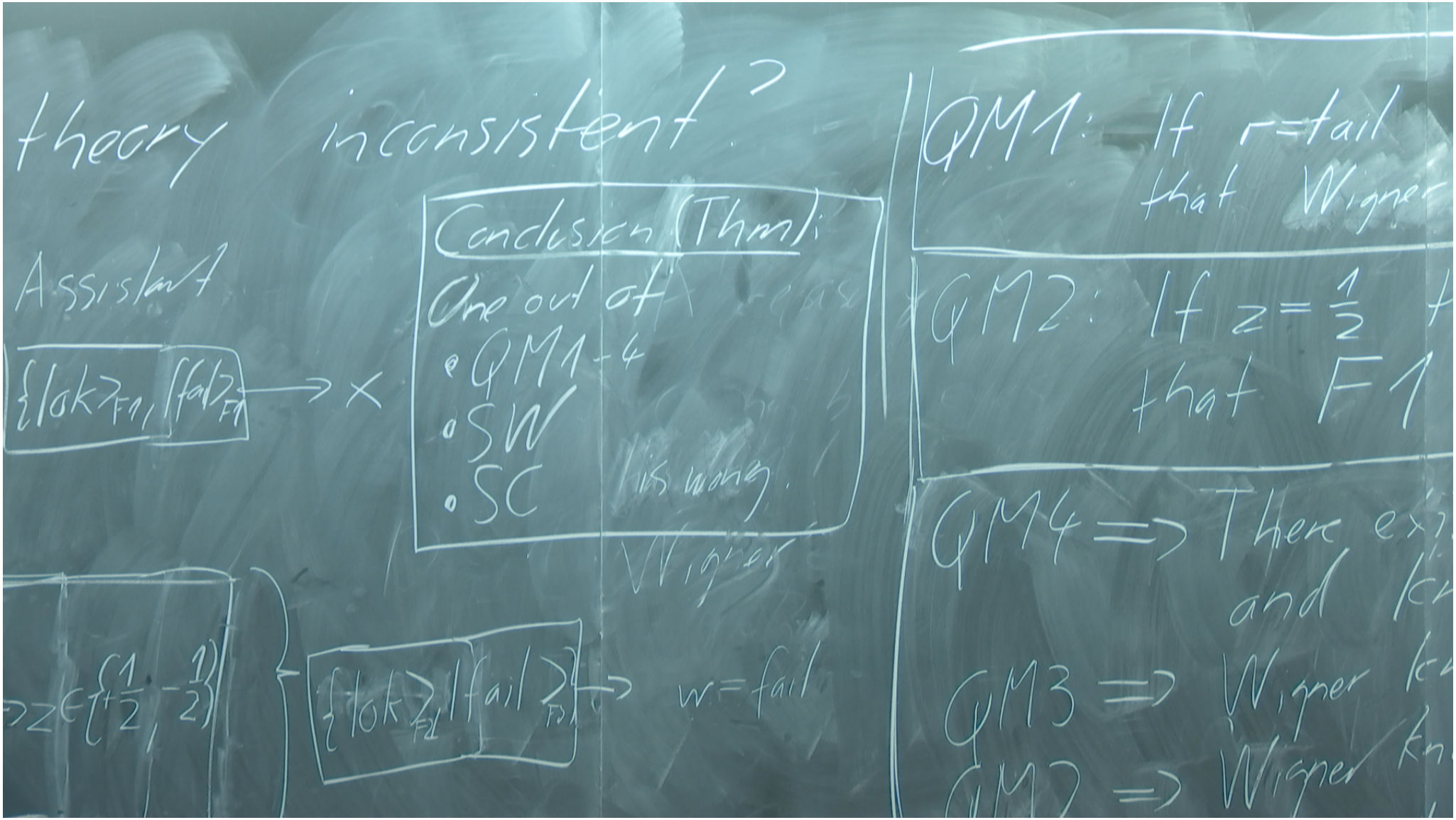
QM4: $Pr[w=x=ok]>0$.

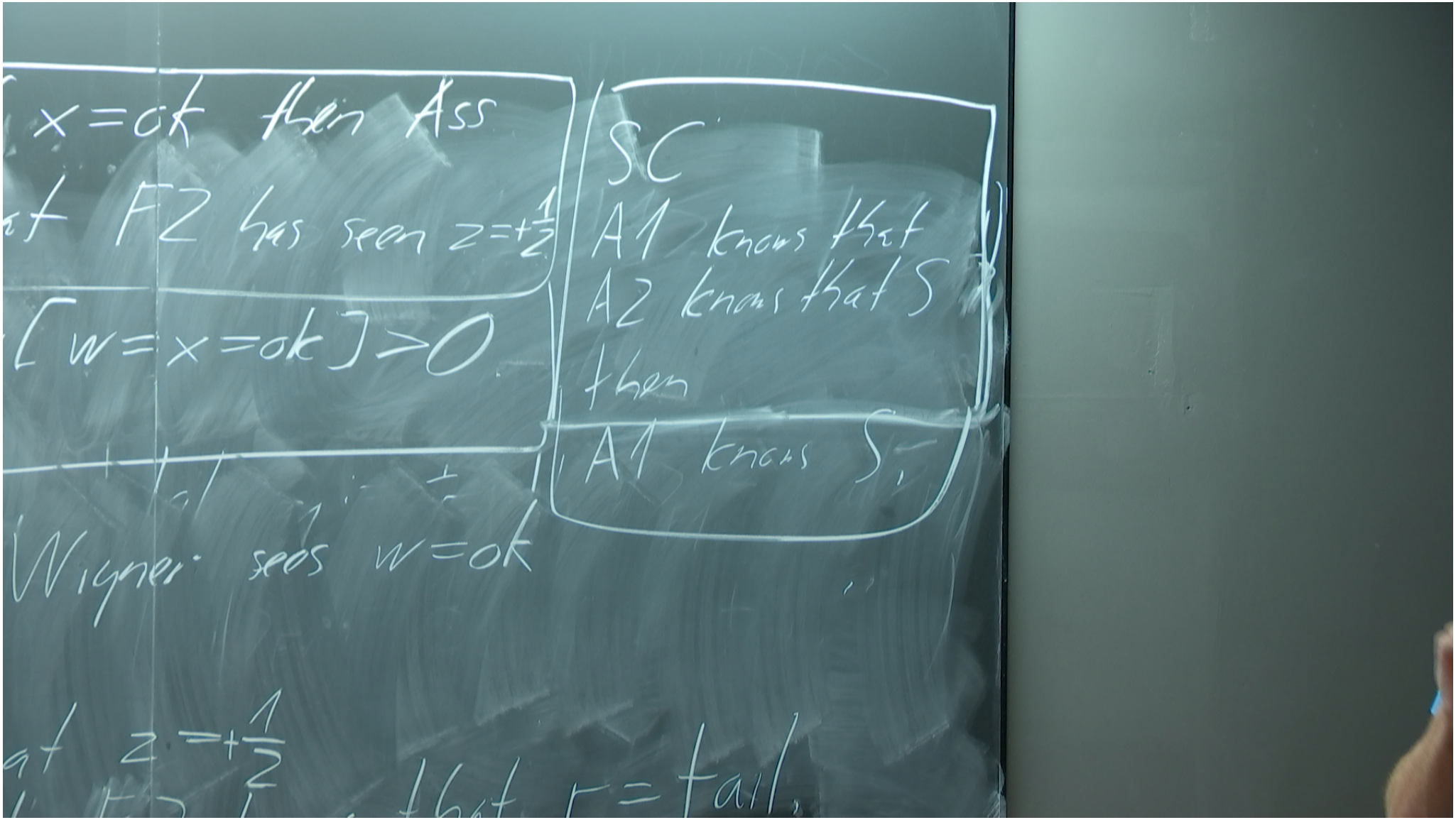
QM4 $\Rightarrow$ There exist a round in which Wigner sees $w=ok$ and knows $x=ok$.


QM1: If r=tail then F1 knows that Wigner sees w=fail
QM2: If z=1/2 then F2 knows that F1 r=tail
QM3: If x=ok then Ass knows that F2 has seen z=+1/2
QM4: Pr[w=x=ok]>0
QM4 => There exist a world in which Wigner sees w=ok and knows x=ok.
QM3 => Wigner knows that Ass. knows that z=+1/2
QM2 => Wigner knows that Ass. knows that F2 knows that r=tail.
QM1 => Wigner knows ... F1 knew that Wigner has seen w=fail.


and knows x=ok.
QM3 ⇒ Wigner knows that Ass. knows that z=+1/2
QM2 ⇒ Wigner knows that Ass. knows that F2 knows that r=fail.
QM1 ⇒ Wigner knows ... F1 knew that Wigner has seen w=fail.
Wigner knows .... F1 knew that Wigner has not seen w≠ok.
SW ⇒


and knows x=ok.
QM3 ⇒ Wigner knows that Ass. knows that z=+1/2
QM2 ⇒ Wigner knows that Ass. knows that F2 knows that r=fail.
QM1 ⇒ Wigner knows ... F1 knew that Wigner has seen w=fail.
Wigner knows ... F1 knew that Wigner has not seen w≠ok.
SW ⇒
Wigner knows .... F1 knew that Wigner has not seen w≠ok.
SC ⇒ Wigner has seen w=ok and knows that w≠ok ☹ contradiction


theory inconsistent?
Assistant
Conclusion (Thm):
One out of
• QM1-4
• SW
• SC
is wrong.
Wigner
QM1: If r=fail
that Wigner
QM2: If z=1/2
that F1
QM4 => Then
and
QM3 =>
QM2 =>
w=fail


x=ok then Ass
SC
A1 knows that
A2 knows that S
then
A1 knows S,
[w=x=ok]>0
Wigner sees w=ok
z=+1/2
r=tail