Title: Instructor Discussion - Beautiful Papers

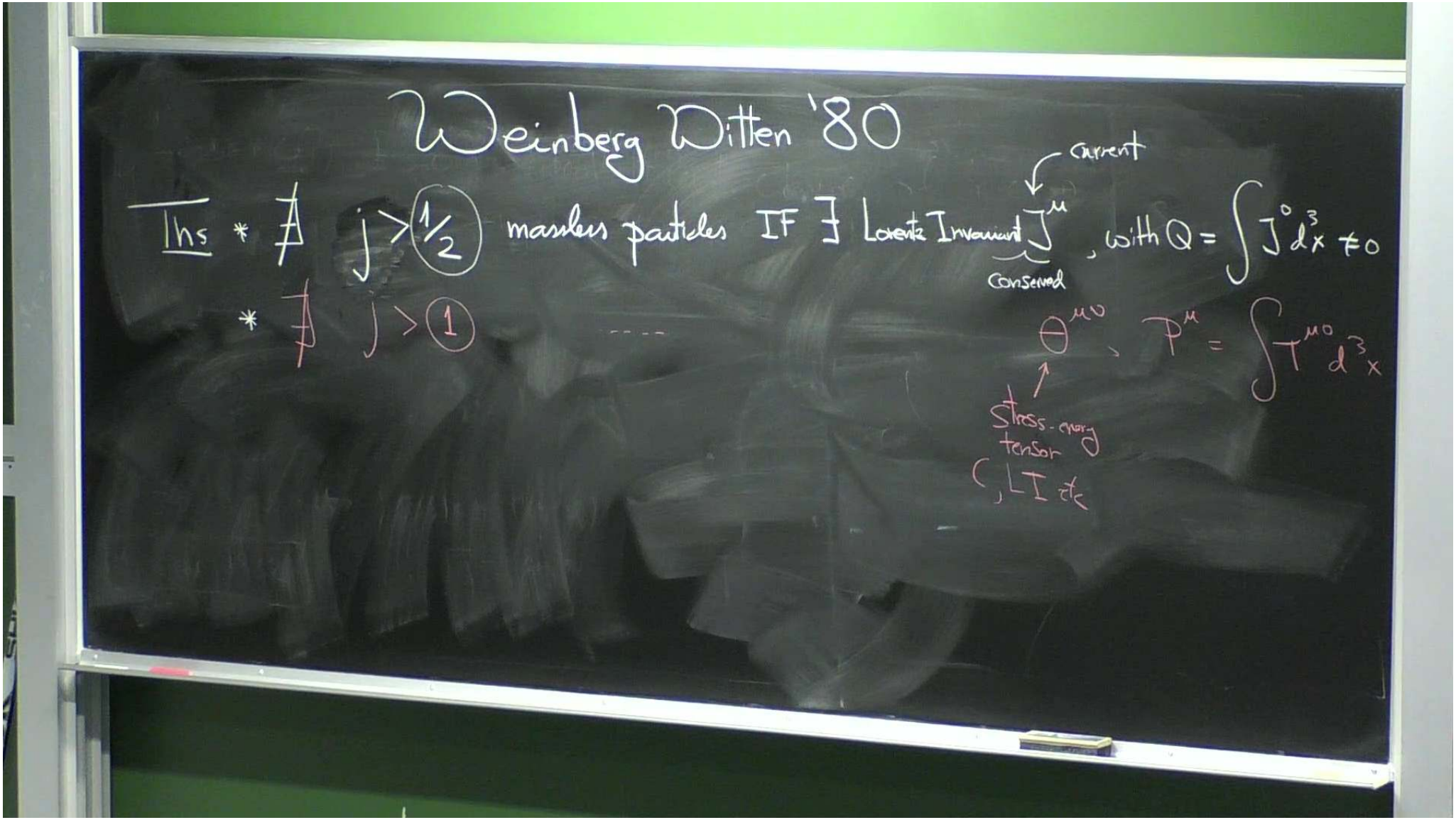
Speakers: Pedro Vieira

Collection/Series: Beautiful Papers, September 1 - November 9, 2026

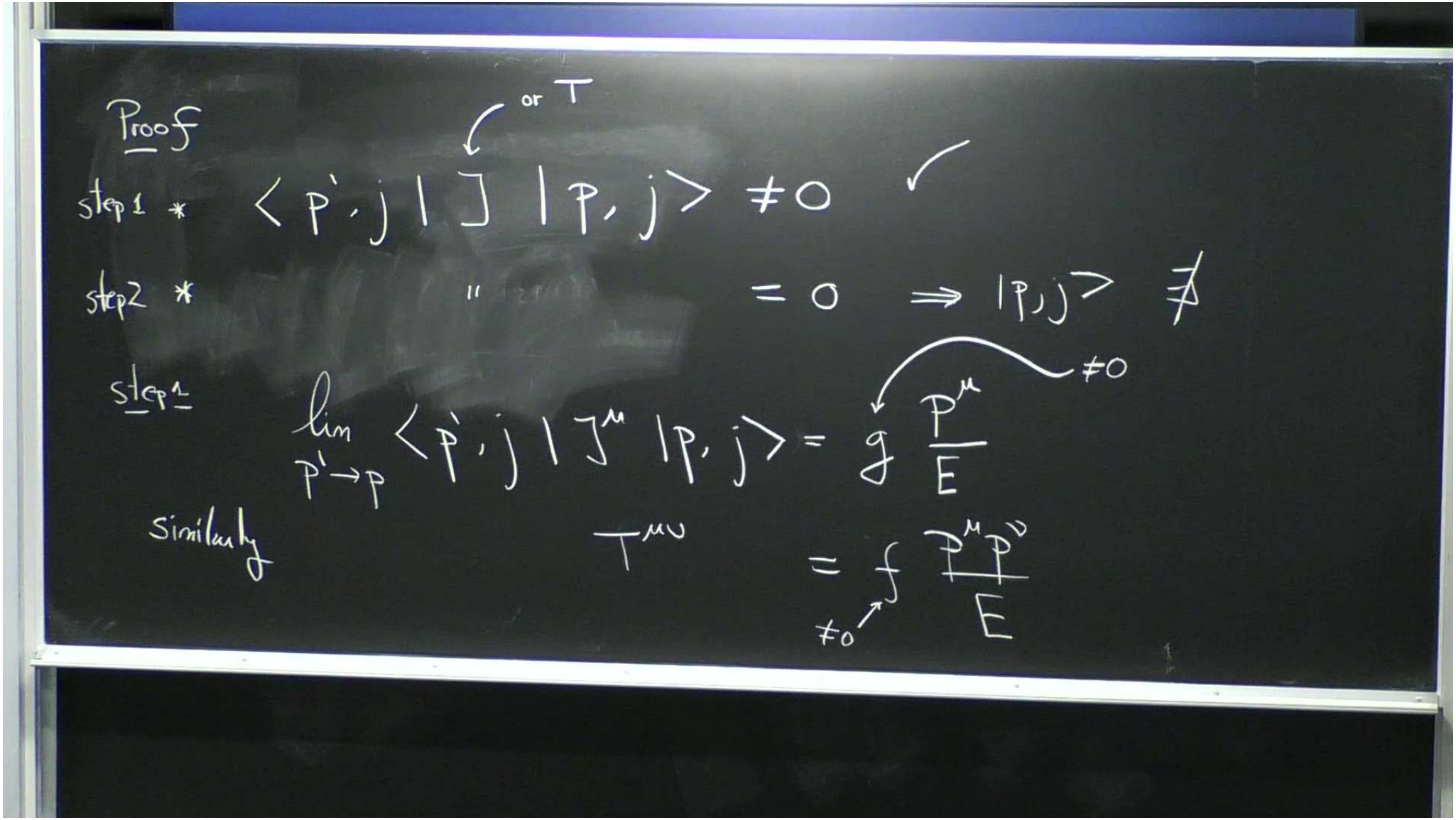
Subject: Condensed Matter, Mathematical physics, Quantum Fields and Strings, Quantum Information

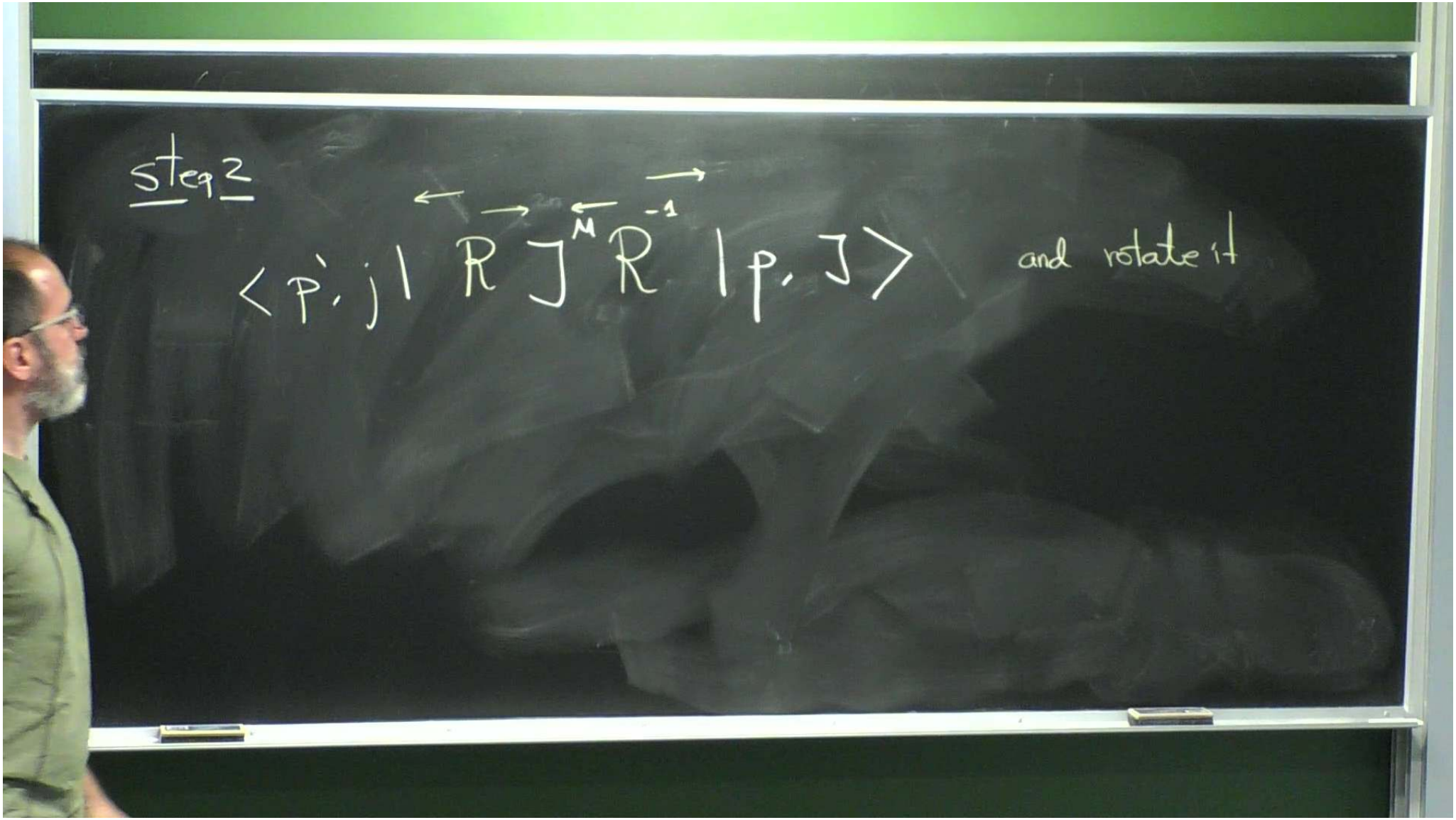
Date: September 08, 2026 - 3:00 PM

URL: https://pirsa.org/26090026


Weinberg Witten '80
Thm * ∄ j > 1/2 massless particles IF ∃ Lorentz Invariant J^μ , with Q = ∫ J^0 d^3x ≠ 0
current
conserved
* ∄ j > 1

Θ^μν , P^μ = ∫ T^μν d^3x
Stress-energy tensor
, LI etc


Proof
or T
step 1 * $\langle p', j | J | p, j \rangle \neq 0$
step 2 * $= 0 \Rightarrow |p, j\rangle \not\equiv$
step 1 $\lim_{p' \to p} \langle p', j | J^\mu | p, j \rangle = g \frac{p^\mu}{E}$
$\neq 0$
Similarly $T^{\mu\nu} = f \frac{p^\mu p^\nu}{E}$
$\neq 0$


Step 2
$\langle p', j | \overleftarrow{R}\, \overrightarrow{J}\, \overleftarrow{M}\, \overrightarrow{R^{-1}} | p, J \rangle$
and rotate it

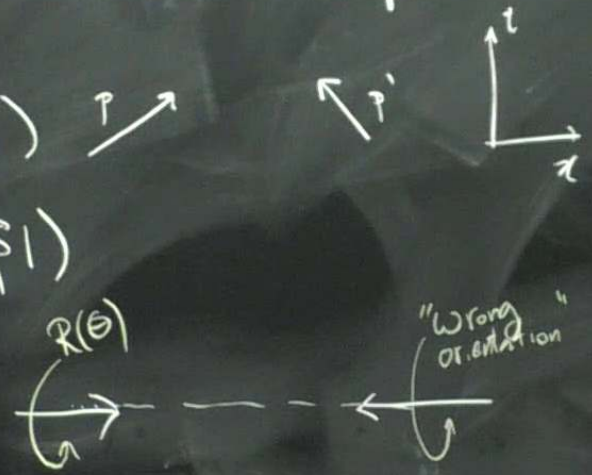
Step 2

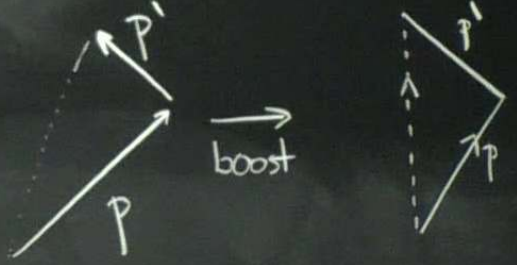
$$\langle p', j | \overleftarrow{R^{-1}} \overrightarrow{J^M} \overleftarrow{R} | p, J \rangle$$

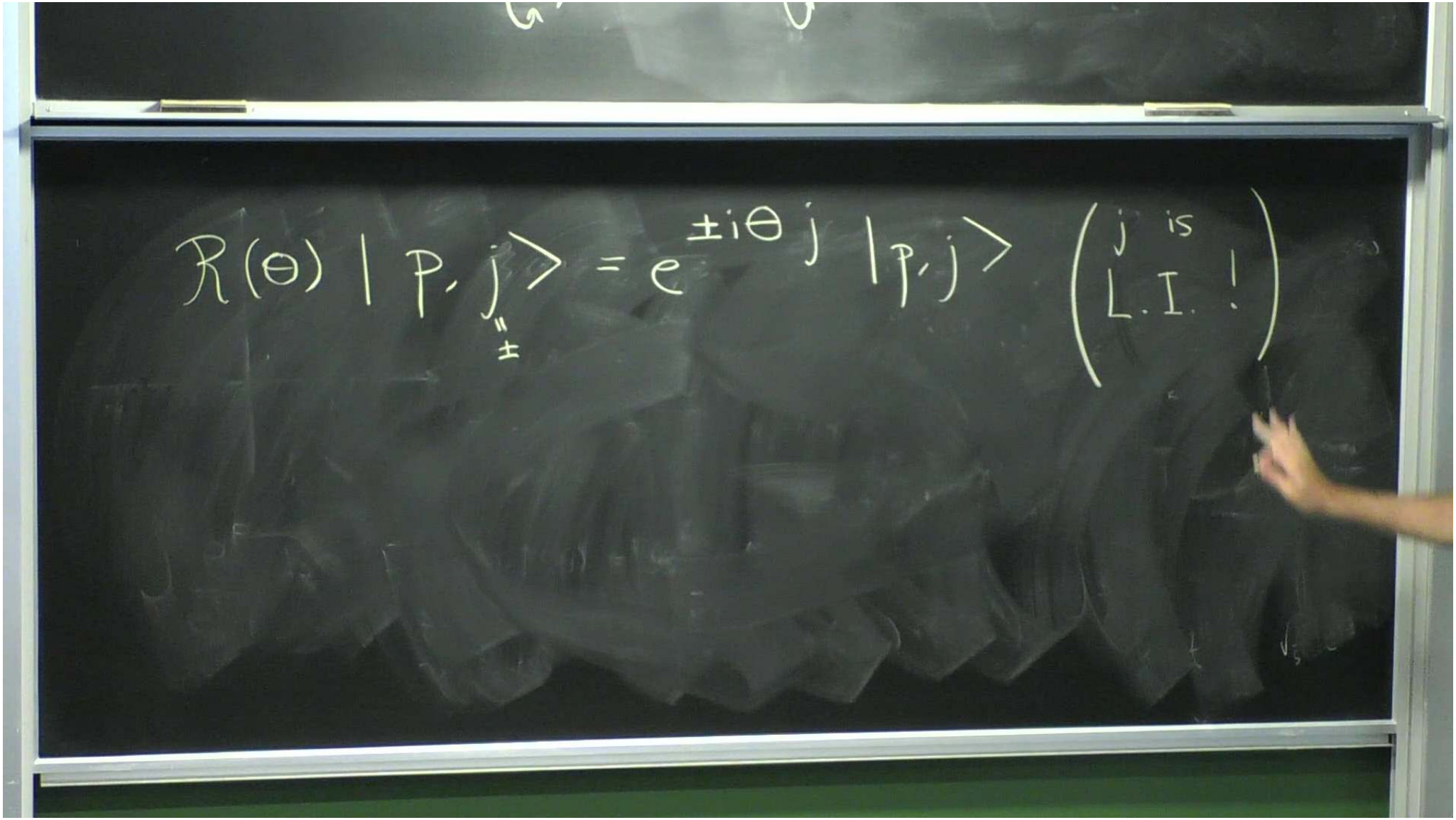
and rotate it along a nice angle

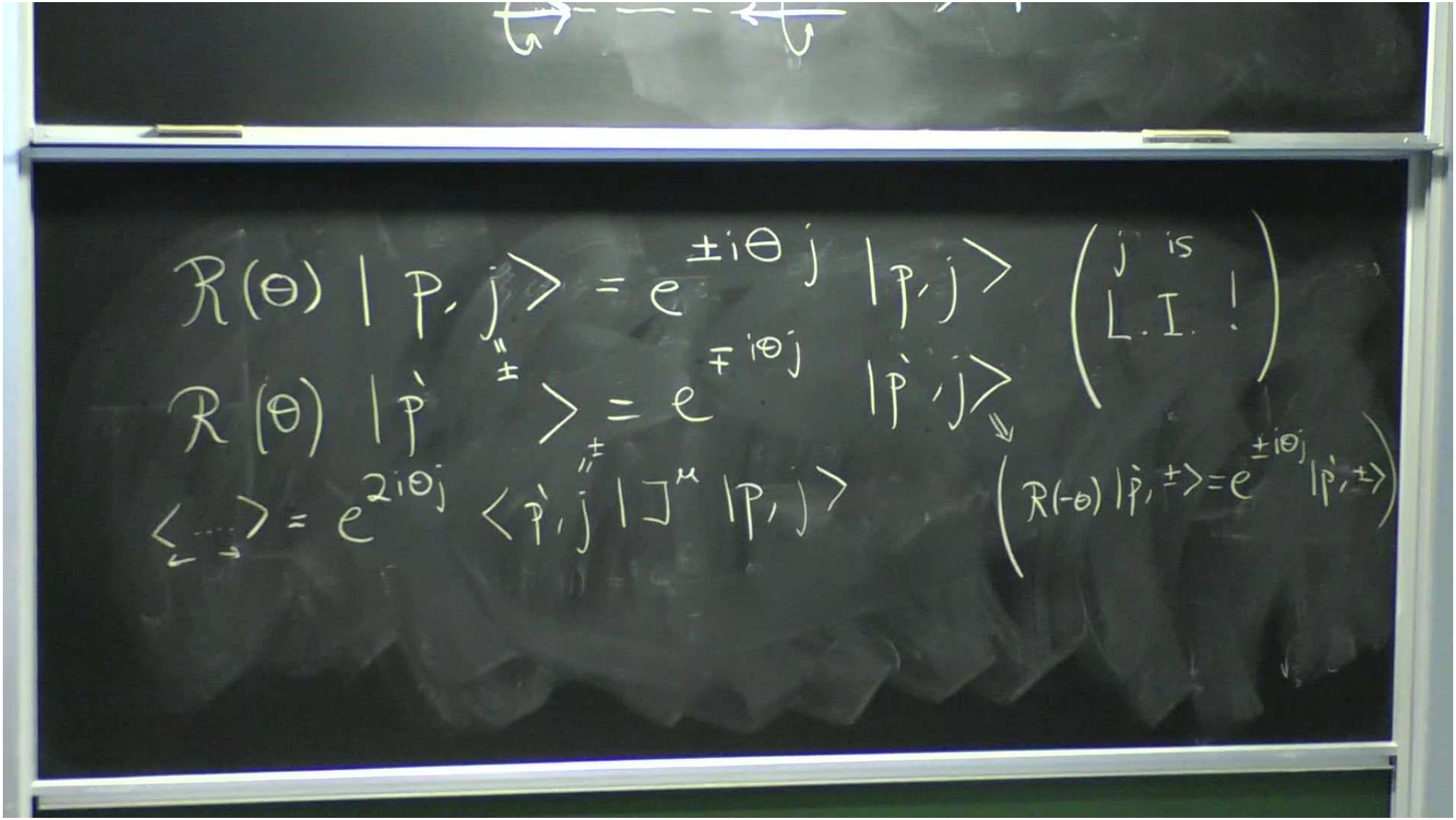
$p = (0, 0, \vec{p}, |\vec{p}|)$

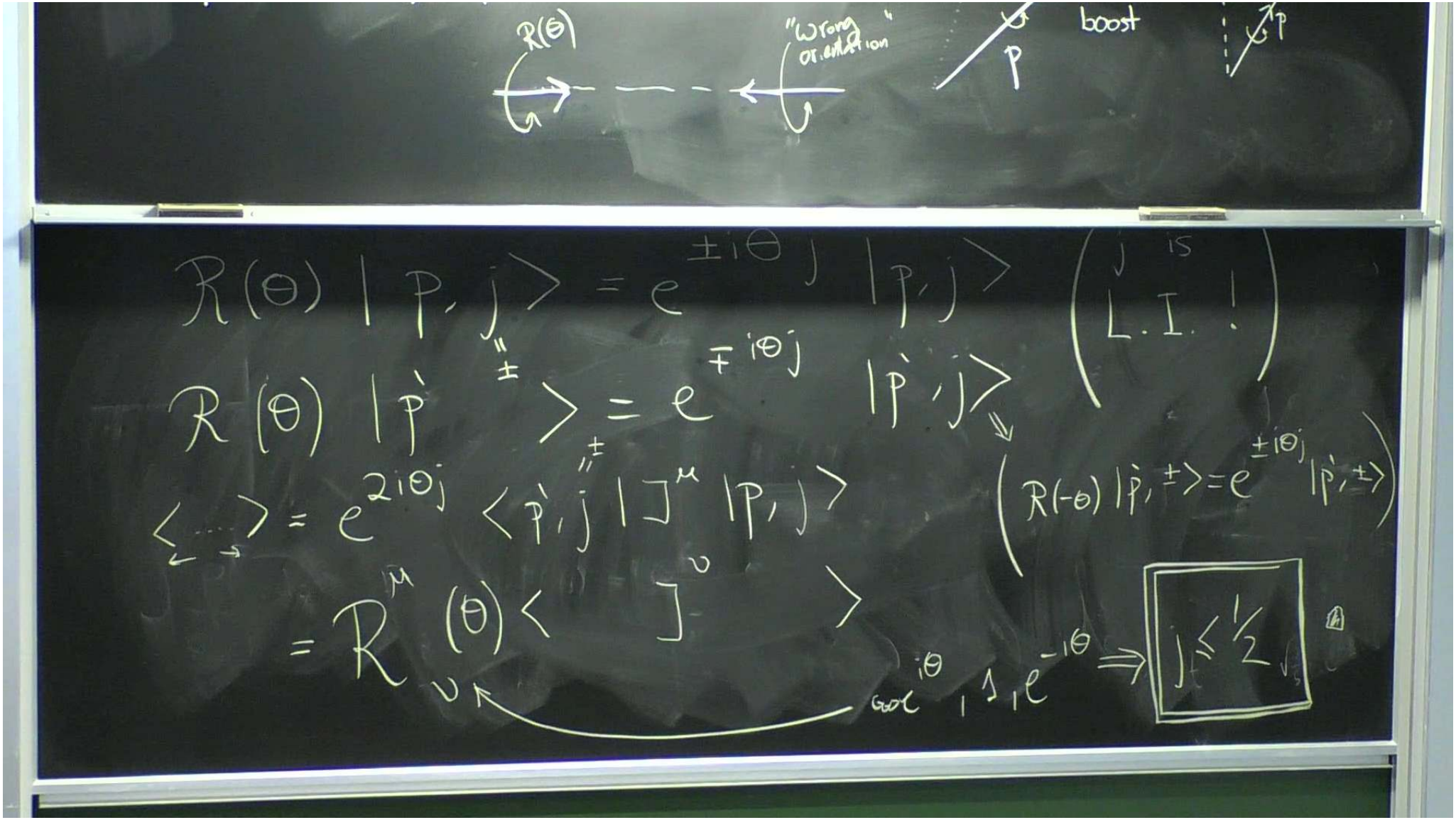
$p' = (0, 0, -\vec{p}, |\vec{p}|)$

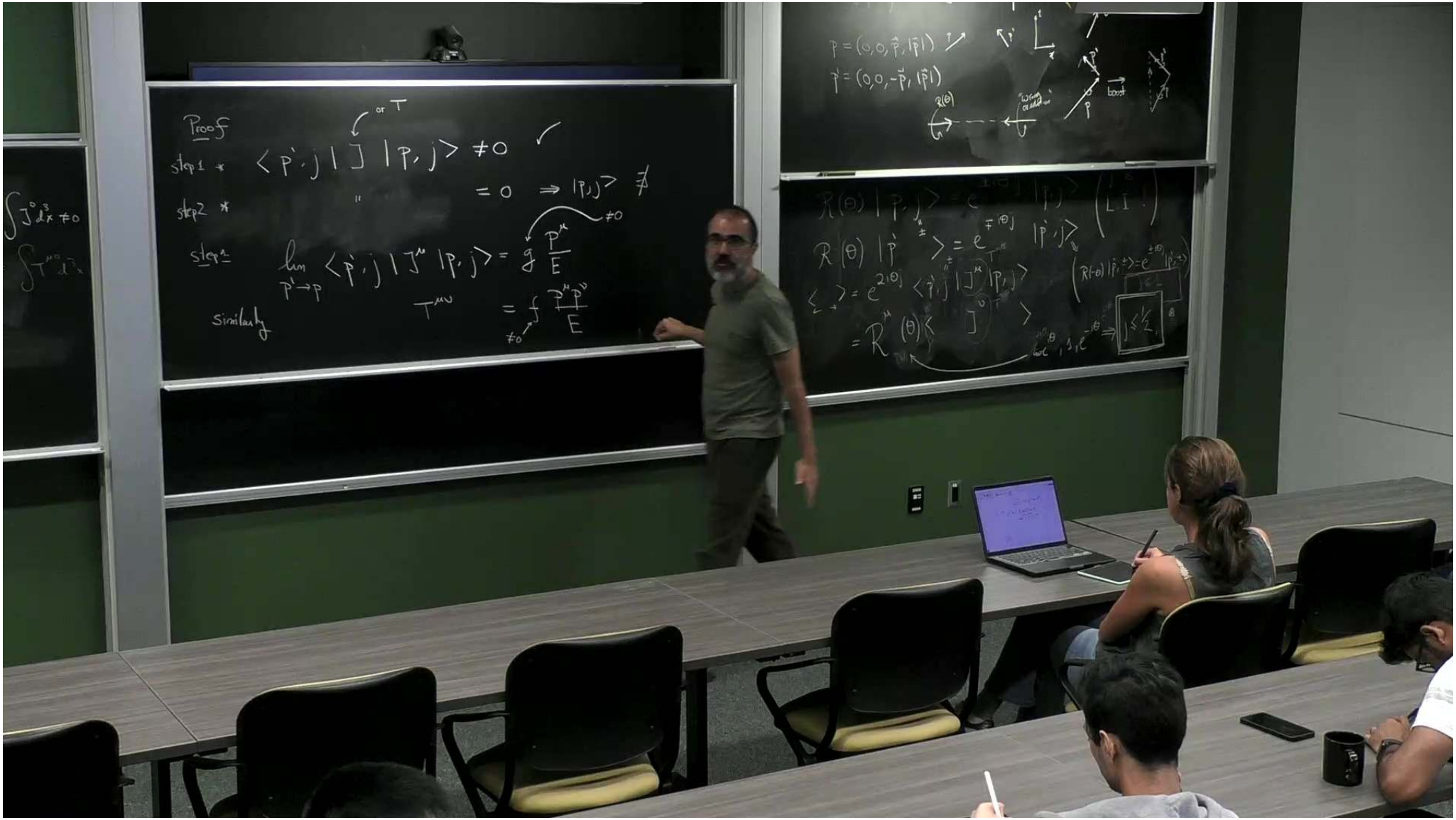


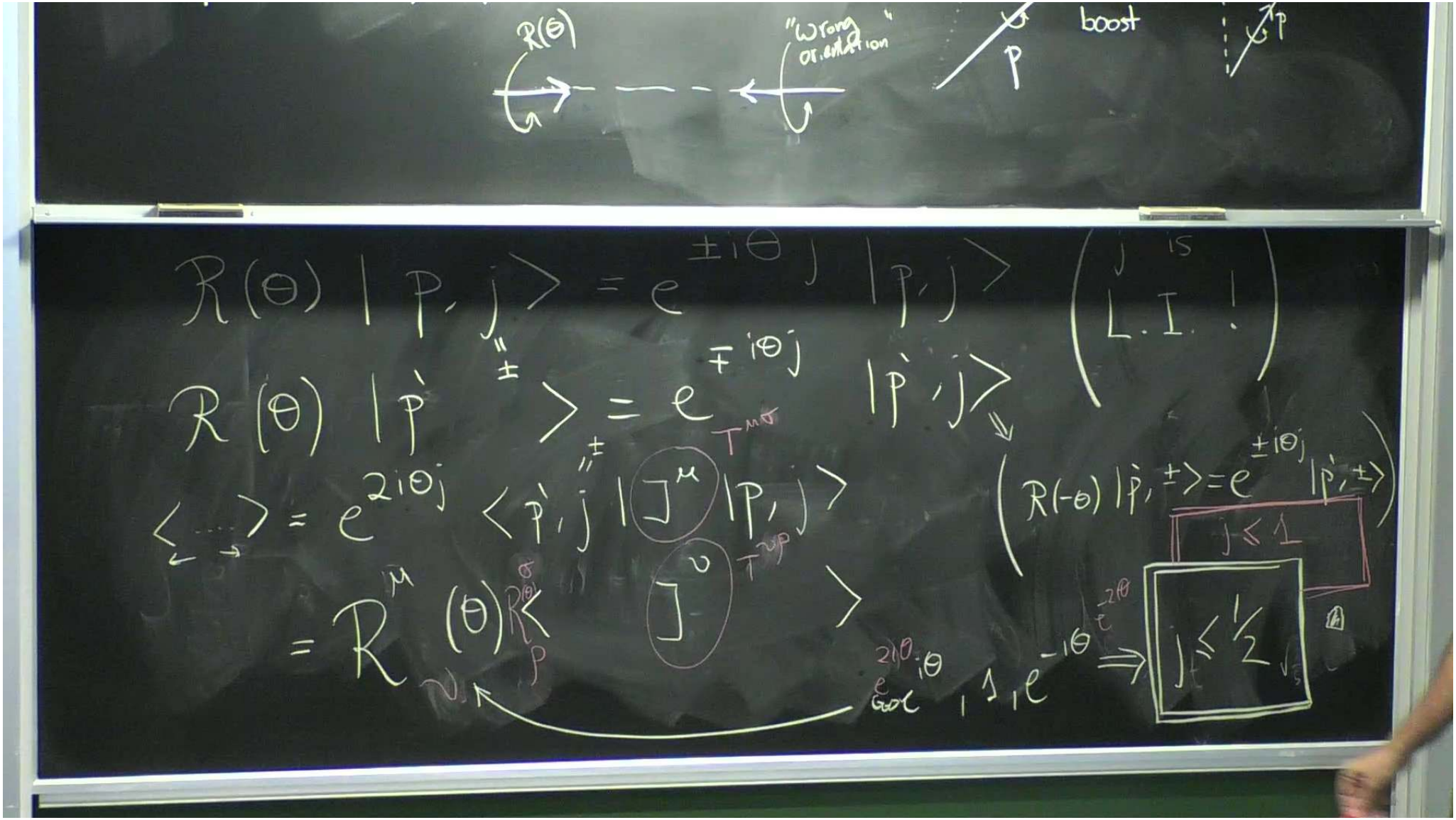


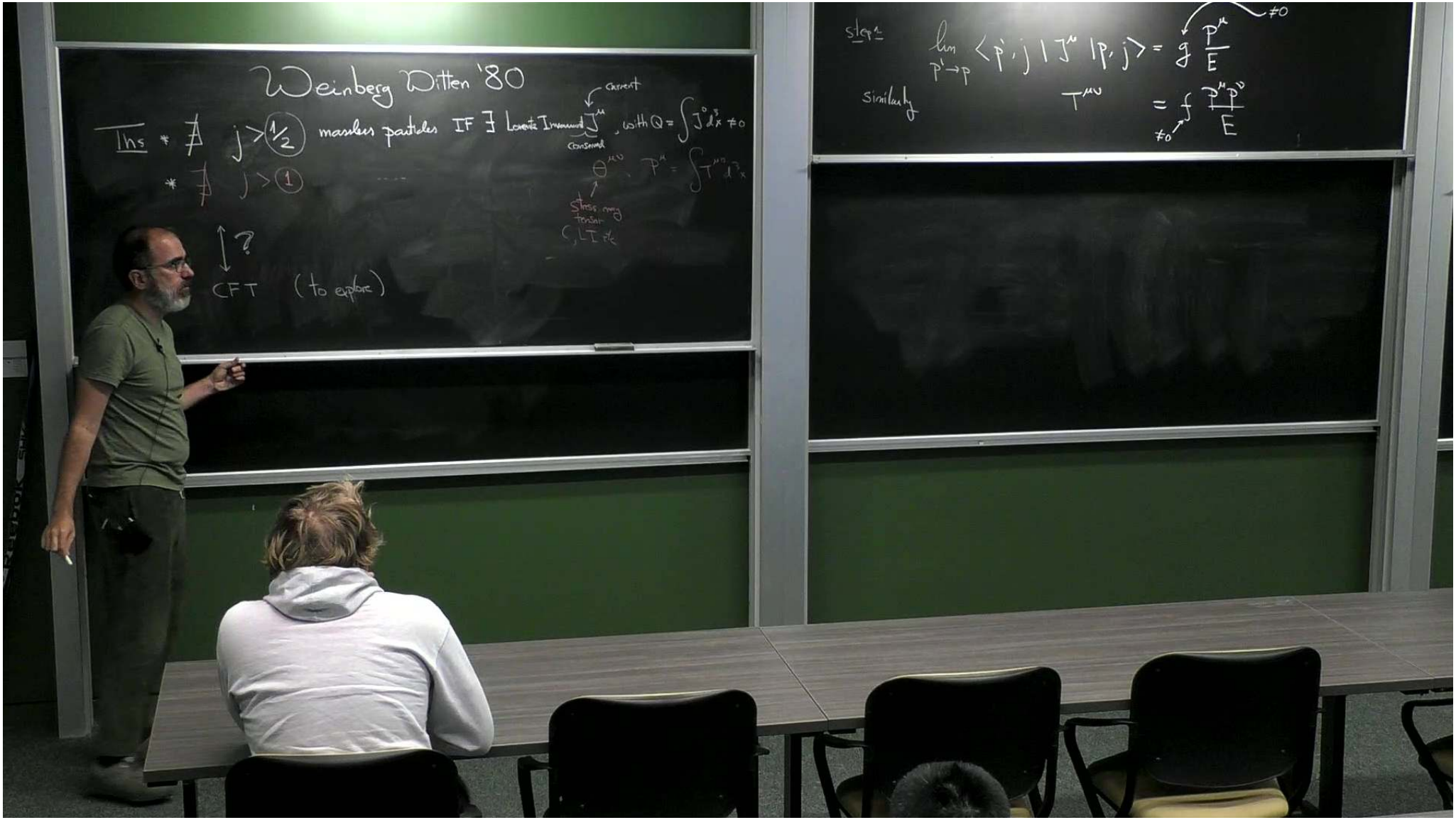

$R(\theta)\,|\,p,\underset{\pm}{j}\rangle = e^{\pm i\theta j}\,|p,j\rangle$
(j is L.I. !)

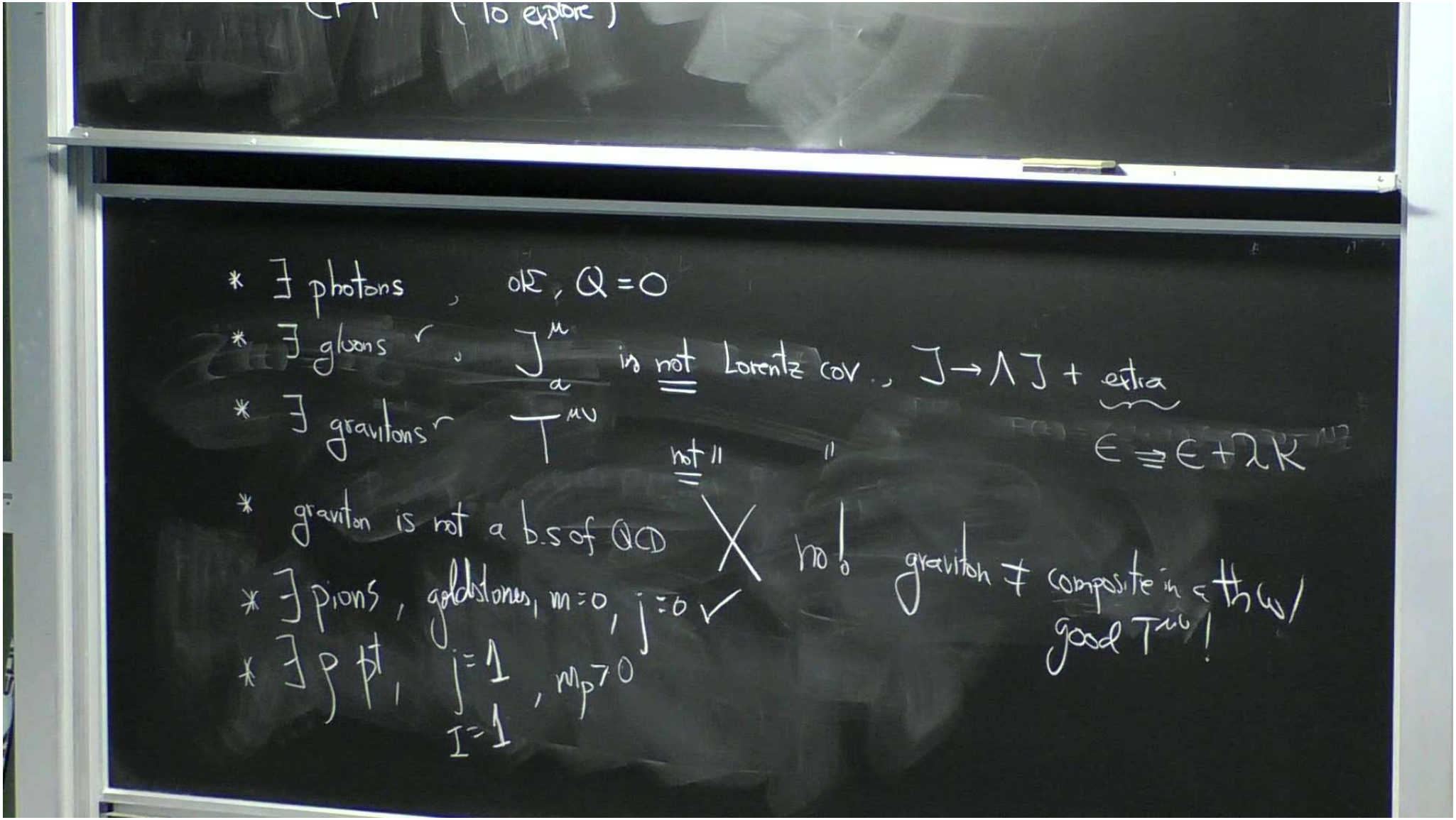

$R(\theta)\,|p,j\rangle = e^{\pm i\theta j}\,|p,j\rangle$
$(j \overset{\pm}{=} \text{is L.I.!})$
$R(\theta)\,|\vec{p}\,\rangle = e^{\mp i\theta j}\,|\vec{p},j\rangle$
$\Downarrow$
$\langle \cdots \rangle = e^{2i\theta j}\,\langle \vec{p},j|J^{\mu}|p,j\rangle$
$(R(-\theta)\,|\vec{p},\pm\rangle = e^{\pm i\theta j}\,|\vec{p},\pm\rangle)$


R(θ)
"wrong orientation"
boost
p
p
$R(\theta)\,|p,j\rangle = e^{\pm i\theta j}\,|p,j\rangle$
(j is L.I. !)
$R(\theta)\,|\vec{p}'^{\,\pm}\rangle = e^{\mp i\theta j}\,|\vec{p}',j\rangle$
$\langle\ldots\rangle = e^{2i\theta j}\,\langle p,j|J^{\mu}|p,j\rangle$
$= R^{\mu}{}_{\nu}(\theta)\,\langle\ldots\rangle$
$R(-\theta)\,|\vec{p},\pm\rangle = e^{\pm i\theta j}\,|\vec{p}',\pm\rangle$
$e^{i\theta}, 1, e^{-i\theta} \Rightarrow j \le \frac{1}{2}$


Proof
step 1 *
step 2 *
step 3 *
Similarly
boost


R(θ)
"wrong orientation"
boost
p
p
R(θ) |p, j⟩ = e^{±iθj} |p, j⟩
(j is L.I.!)
R(θ) |p'⟩ = e^{∓iθj} |p'⟩
= ±
⟨ ... ⟩ = e^{2iθj} ⟨p', j | J^μ | p, j⟩
T^{μν}
= R^μ_ν(θ) ⟨ ... J^ν ... ⟩
T^{νρ}
(R(-θ) |p', ±⟩ = e^{±iθj} |p', ±⟩)
j ≤ 1
j ≤ 1/2
e^{2iθ}, 1, e^{-iθ}, e^{-2iθ}


Weinberg Witten '80
Thm
massless particles
IF
CFT
(to explore)
step 1
Similarly


(to explore)
* ∃ photons , ok, Q=0
* ∃ gluons , J^μ_a is not Lorentz cov., $J \to \Lambda J$ + extra
* ∃ gravitons $T^{\mu\nu}$
$\epsilon \equiv \epsilon + \lambda K$
not
* graviton is not a b.s of QCD
X no!
graviton ≠ composite in extra th's / good $T^{\mu\nu}$!
* ∃ pions, goldstones, m=0, j=0
* ∃ ρ ρ', j=1, $m_\rho > 0$
I=1

Similarly $T^{\mu\nu} = f \neq 0 \; p^\mu p^\nu$ E

* Induced gravity is ok ✓

$$S[\phi, g_{\mu\nu}] \not\supset \int R$$

$$\int \mathcal{D}\phi\, e^{-S} = e^{-\int R + \cdots}$$

for (3)

* in QCD
  ∄ non-singlet massless BS with $j > 1/2$
  graviton is in a ≠ space of ≠ dim
* AdS/CFT
  $h_{\mu\nu} \sim$ no grav