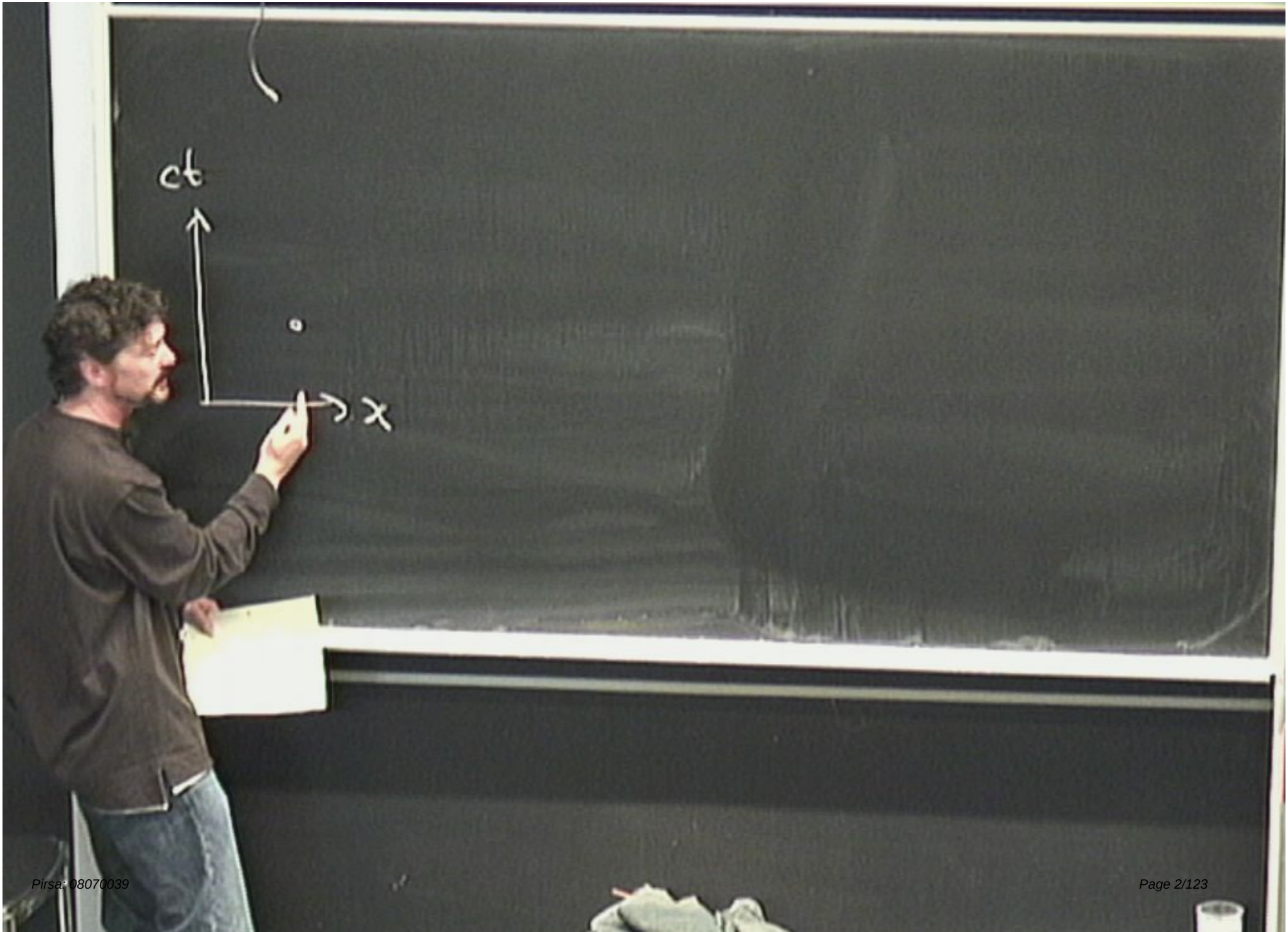
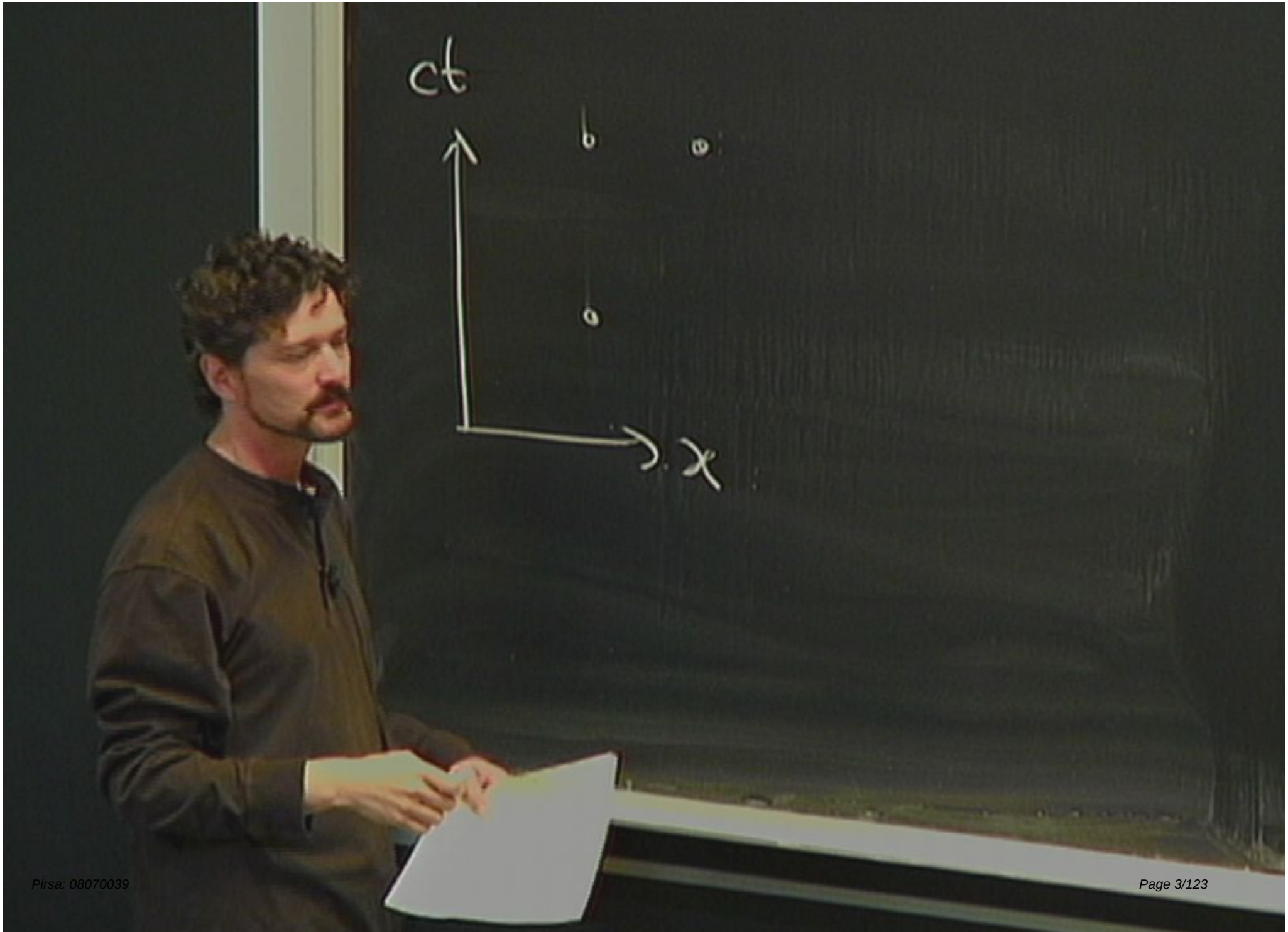
Title: Relativity 3

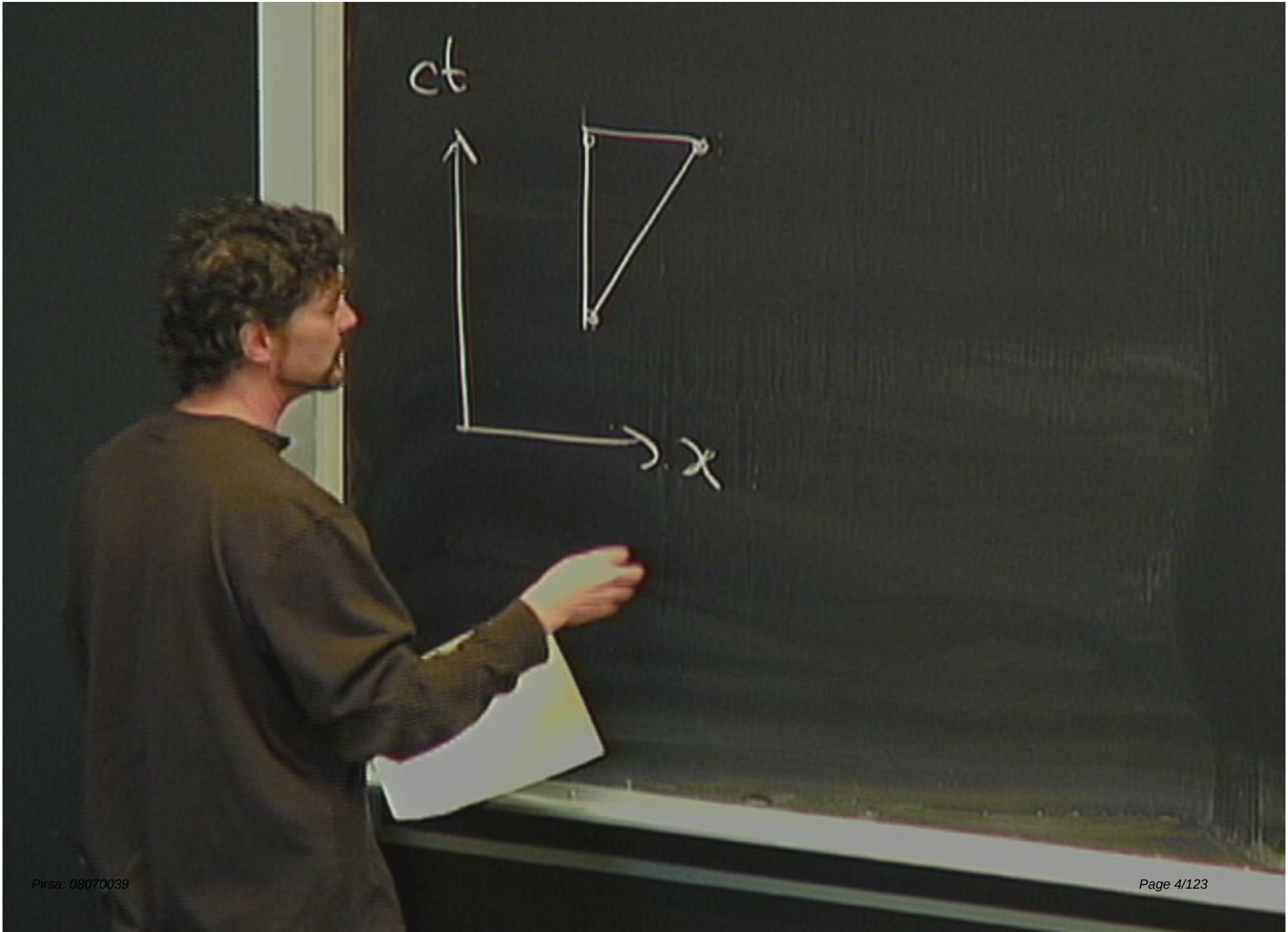
Date: Jul 26, 2008 09:00 AM

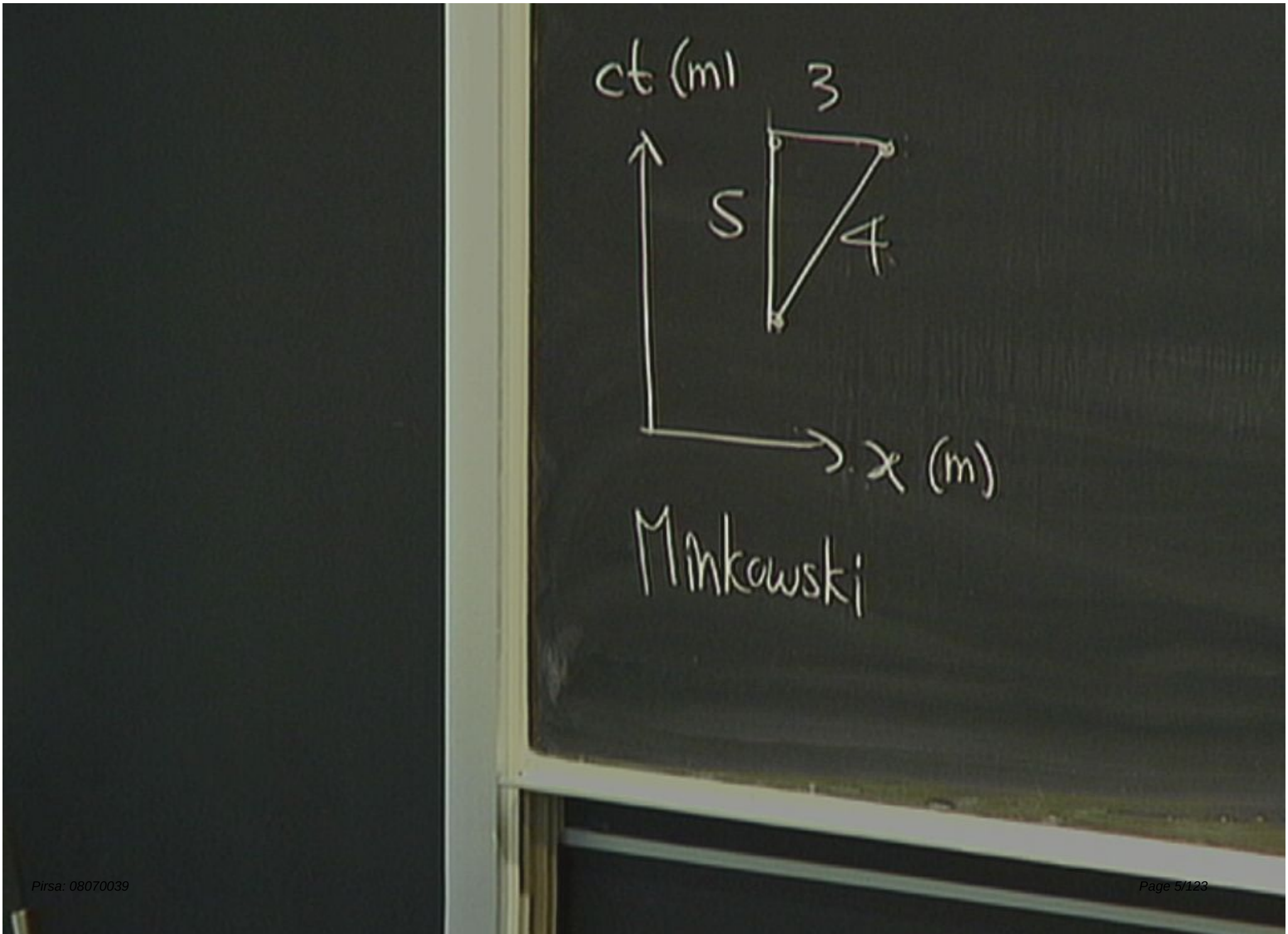
URL: http://pirsa.org/08070039

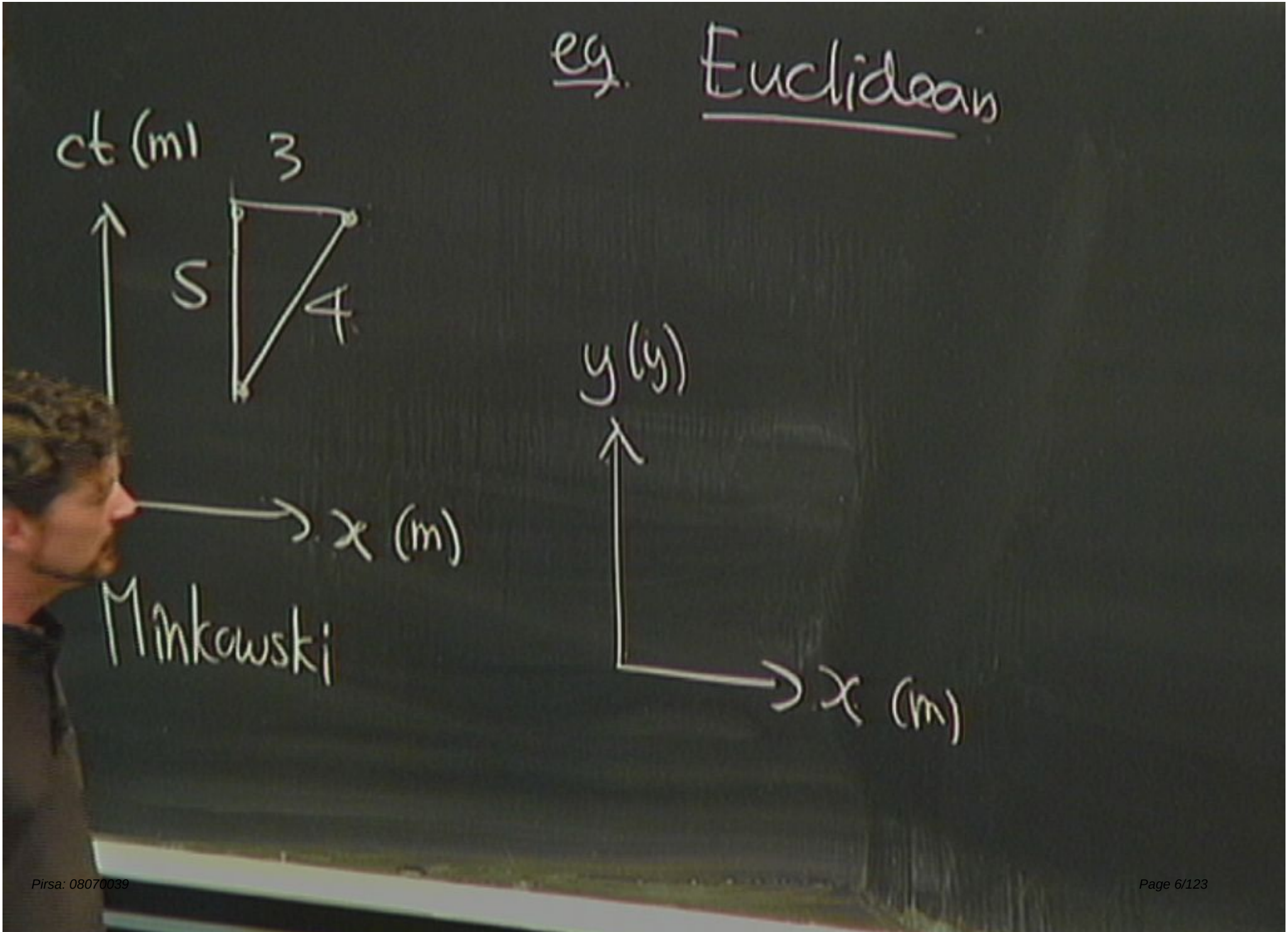
Abstract:

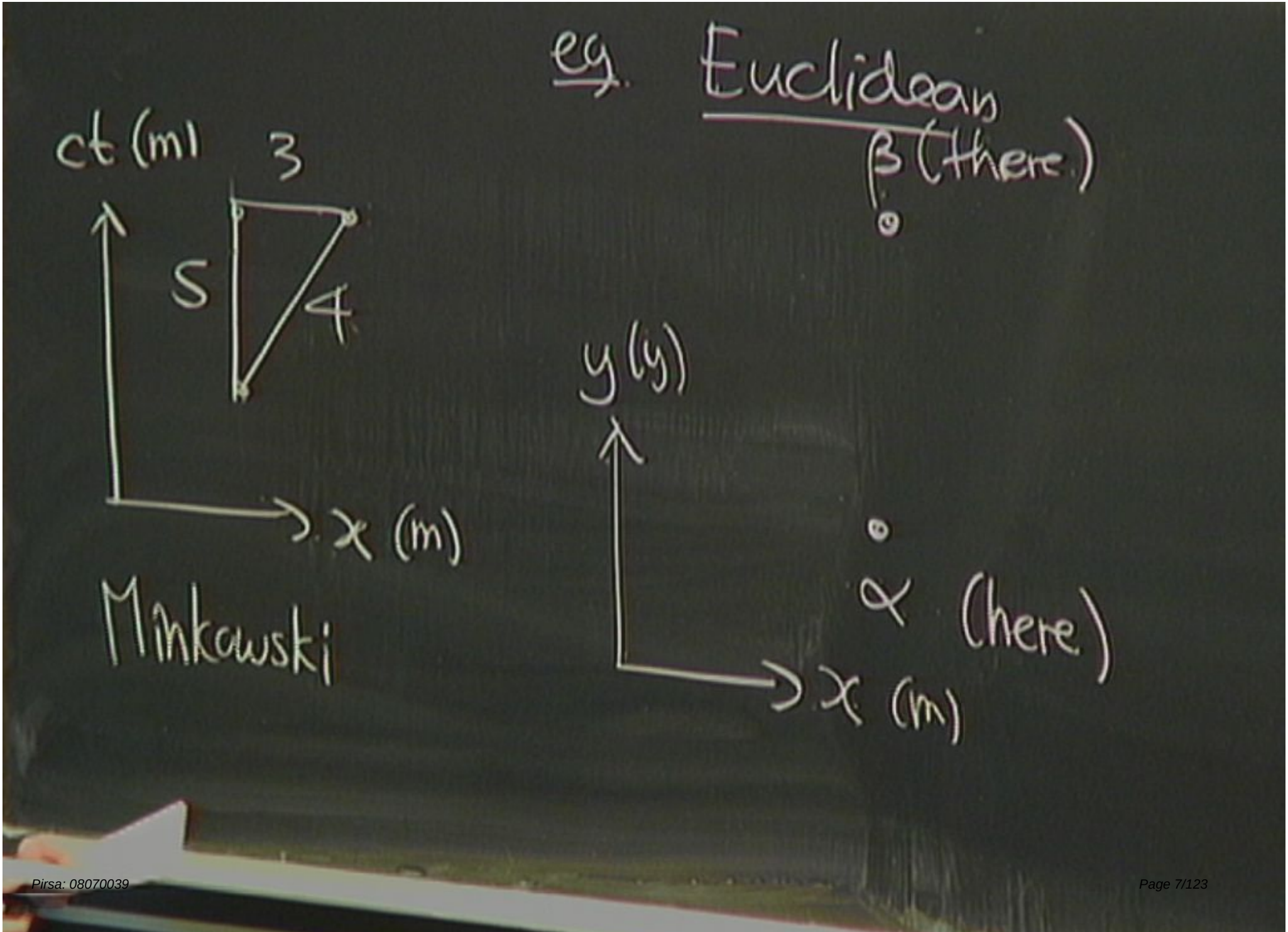

ct
x

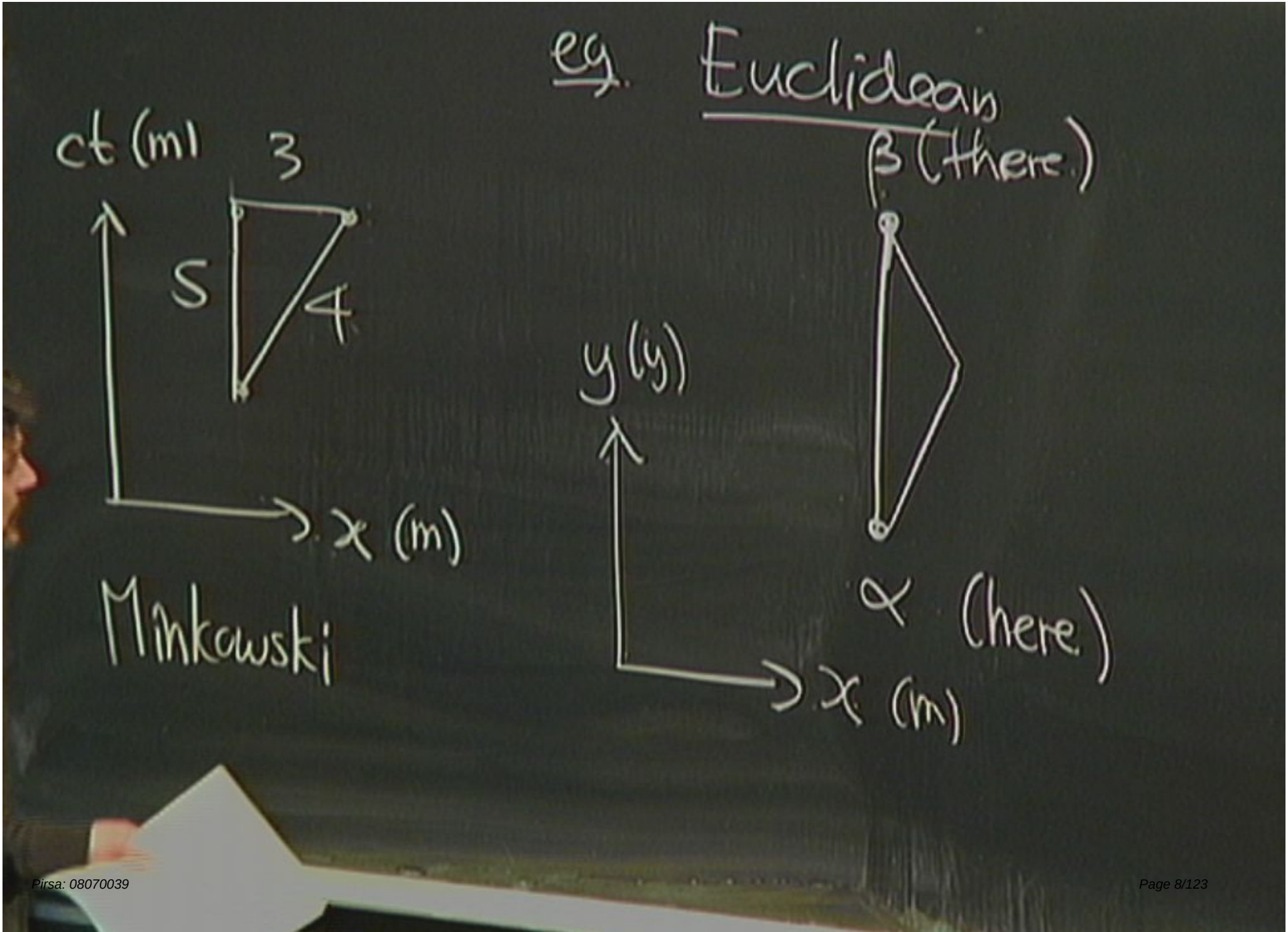

ct
x


ct
x

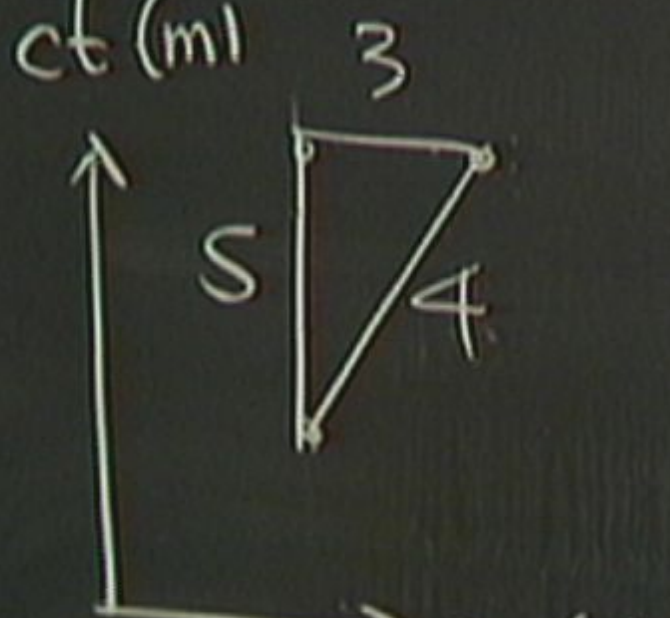

ct (m)
3
5
4
x (m)
Minkowski


eg. Euclidean
ct (m)
3
5
4
x (m)
Minkowski
y (y)
x (m)

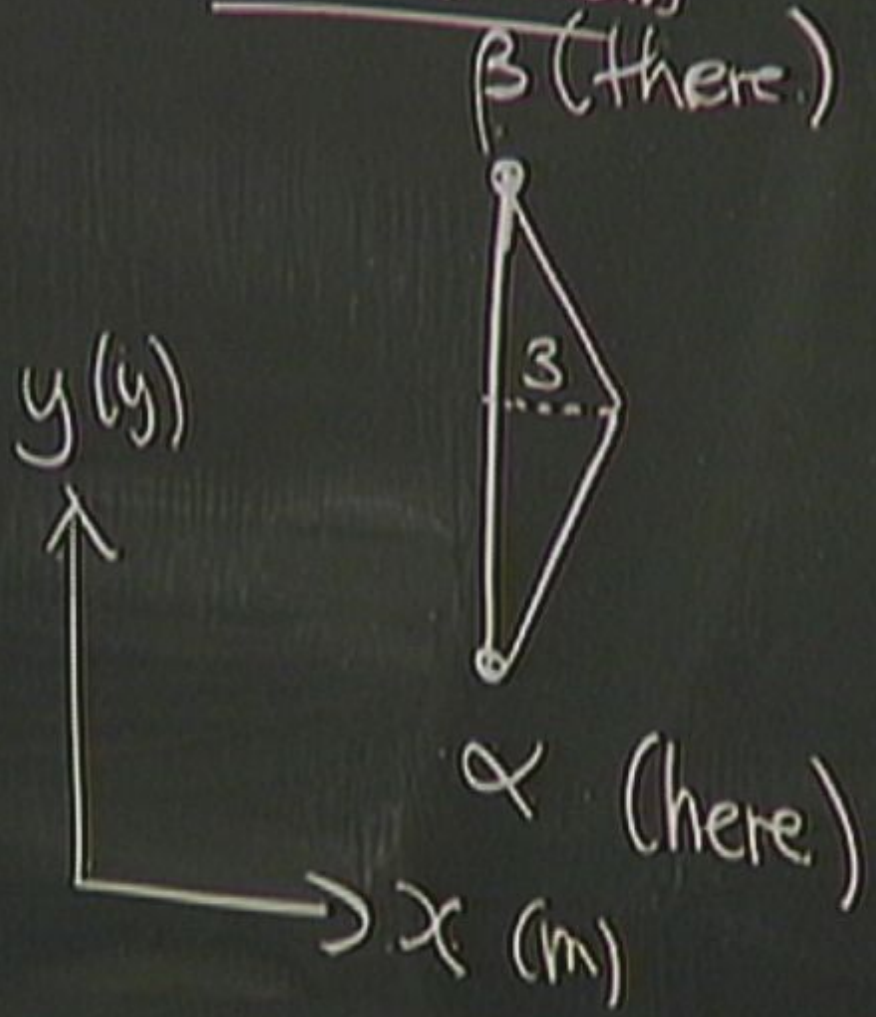

eg. Euclidean
β (there)
ct (m)
3
5
4
x (m)
Minkowski
y (y)
α (here)
x (m)

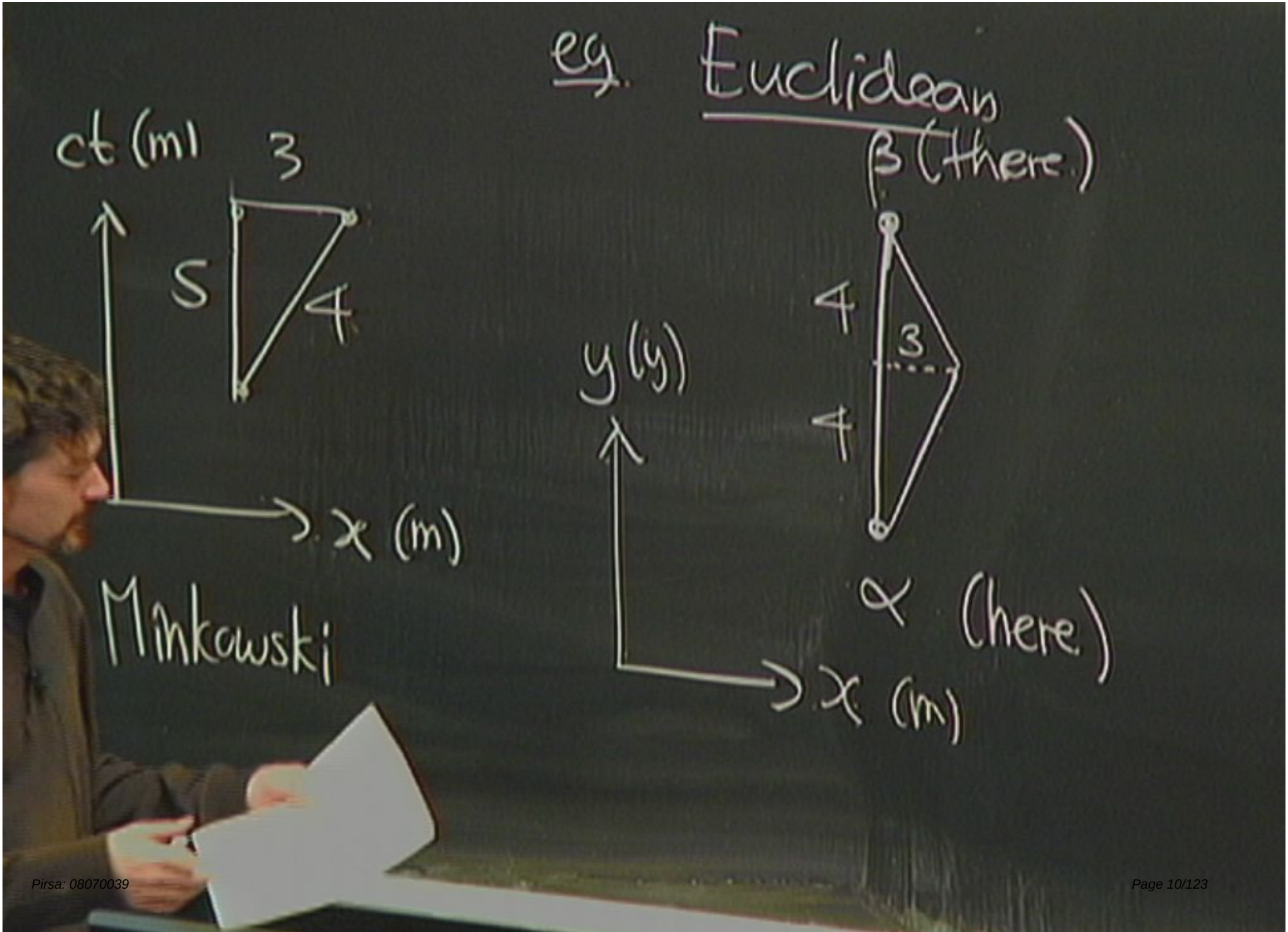

eg. Euclidean
ct (m)
3
5
4
x (m)
Minkowski
y (y)
β (there)
α (here)
x (m)

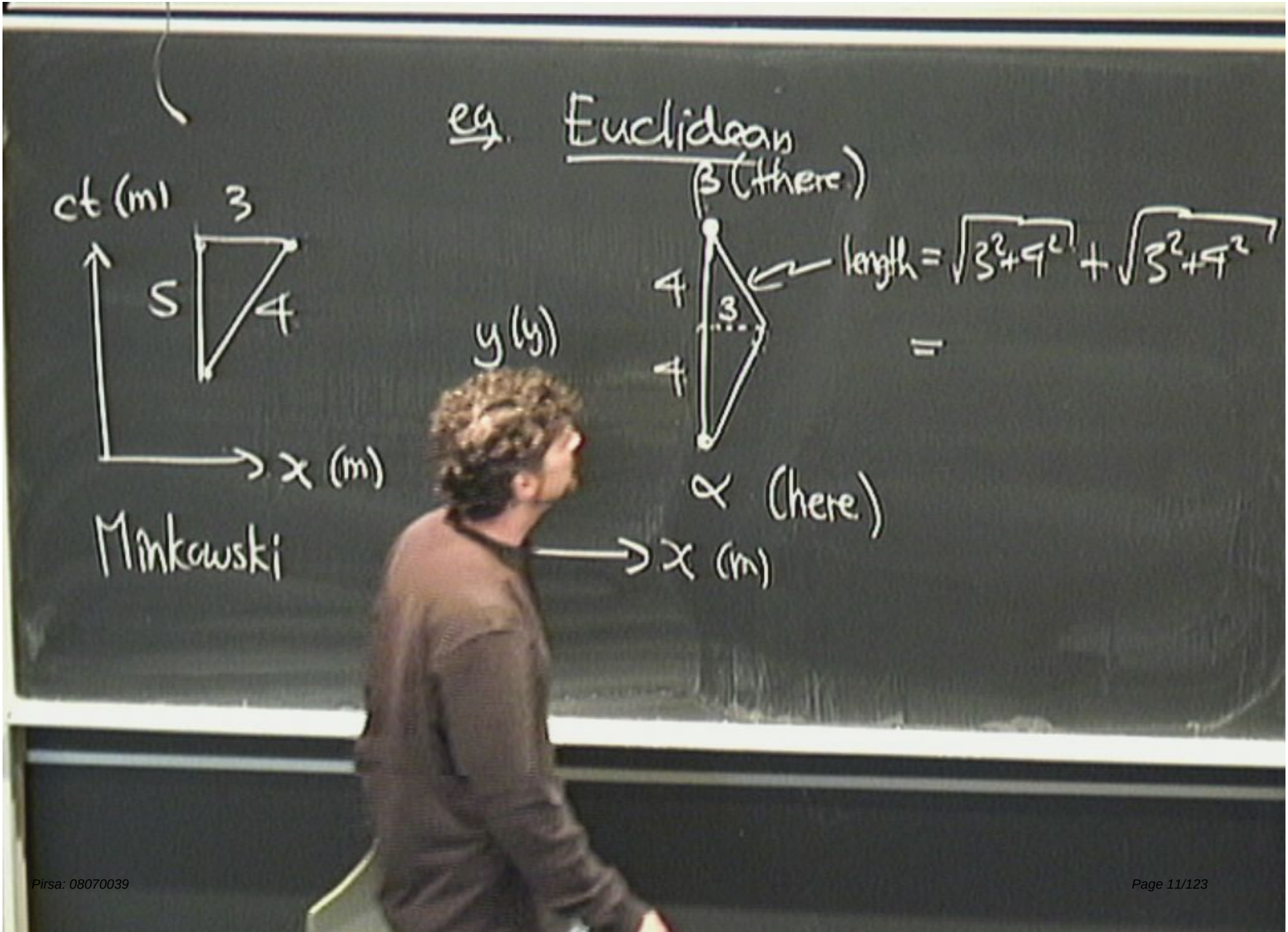
eg. Euclidean



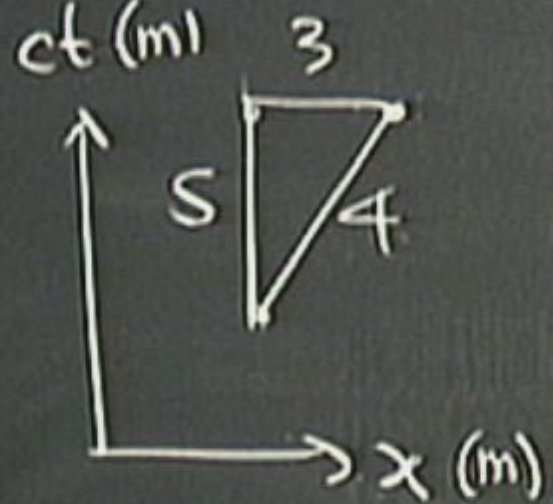
Minkowski



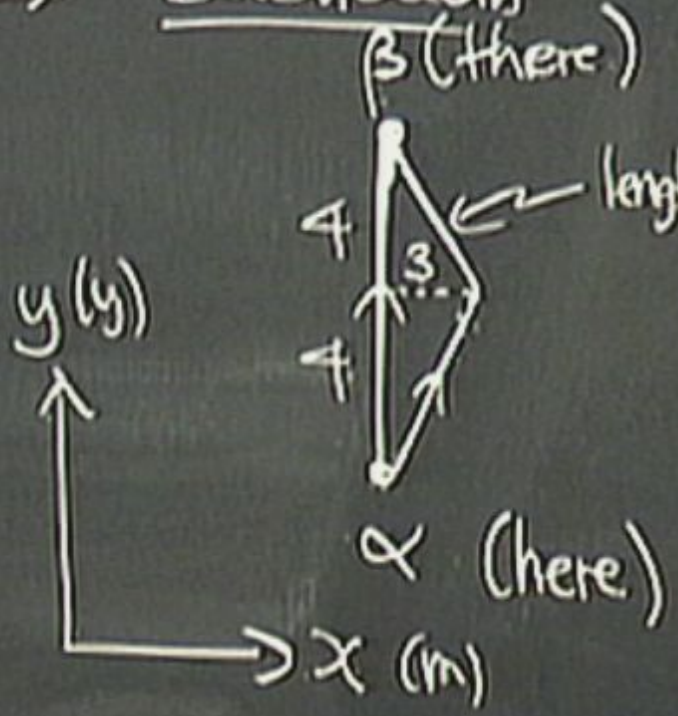

eg. Euclidean
ct (m)
3
5
4
x (m)
Minkowski
β (there)
4
3
4
y (y)
α (here)
x (m)


eg. Euclidean
ct (m)
3
5
4
x (m)
Minkowski
y (y)
β (there)
length = $\sqrt{3^2+4^2} + \sqrt{3^2+4^2}$
4
3
4
=
α (here)
x (m)

eg. Euclidean



Minkowski

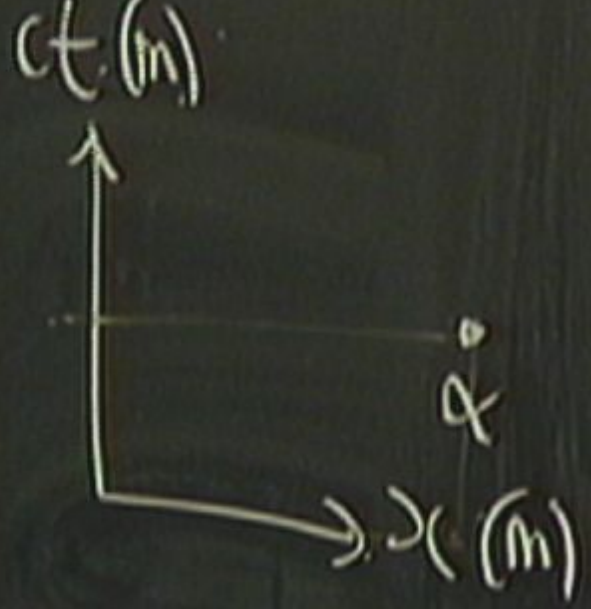


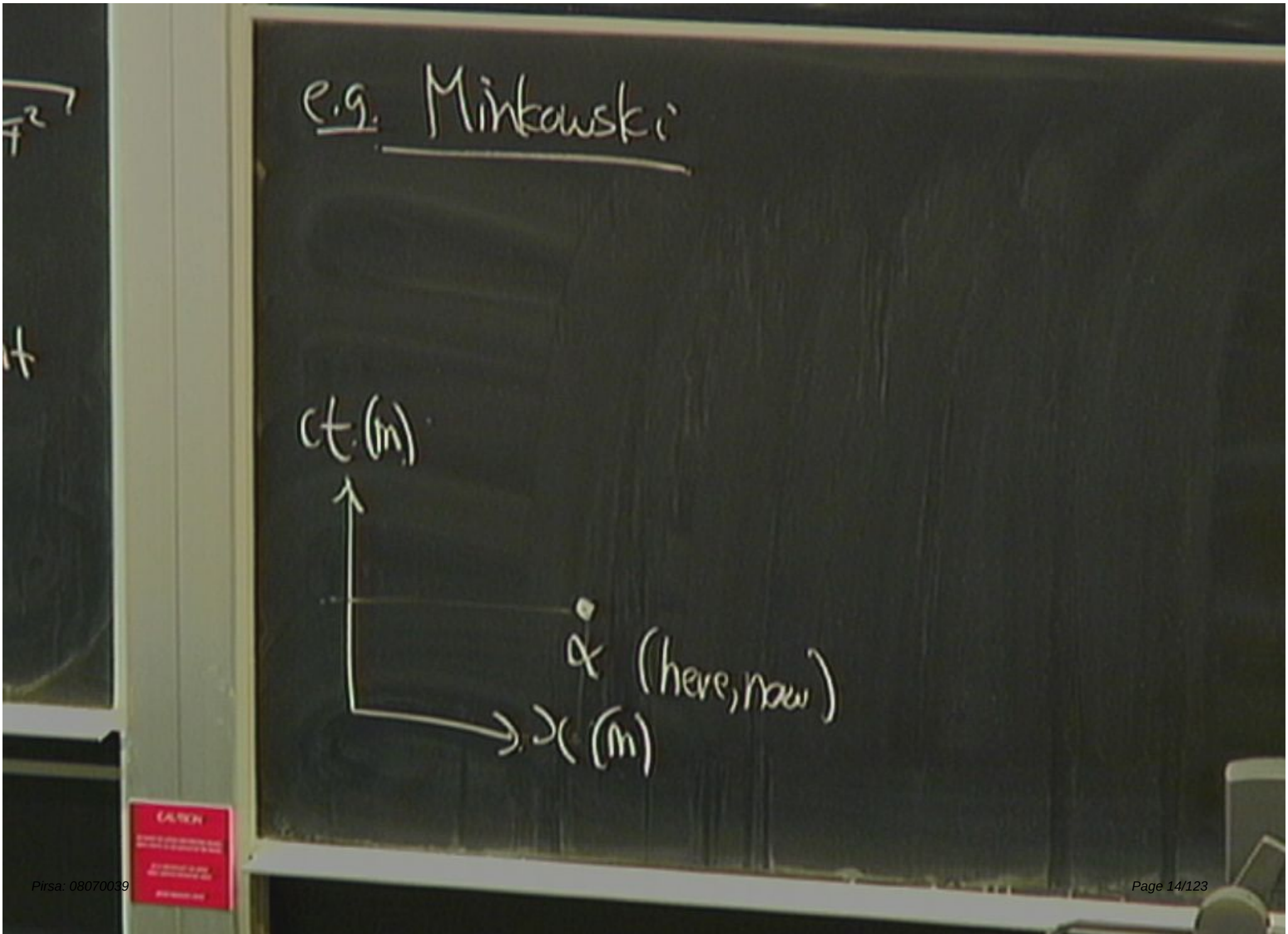
length $= \sqrt{3^2+4^2} + \sqrt{3^2+4^2}$

$= 10 > 8$

longer than straight

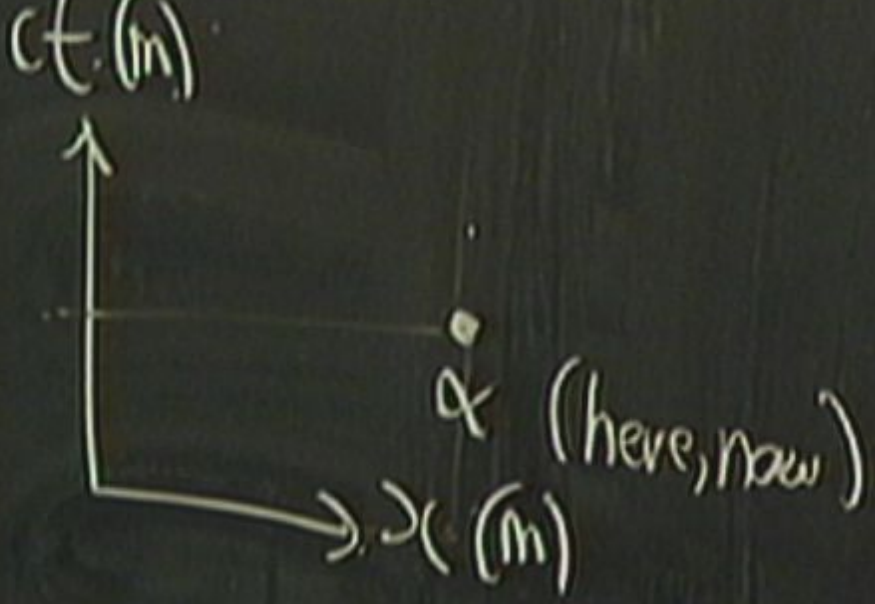
e.g. Minkowski:



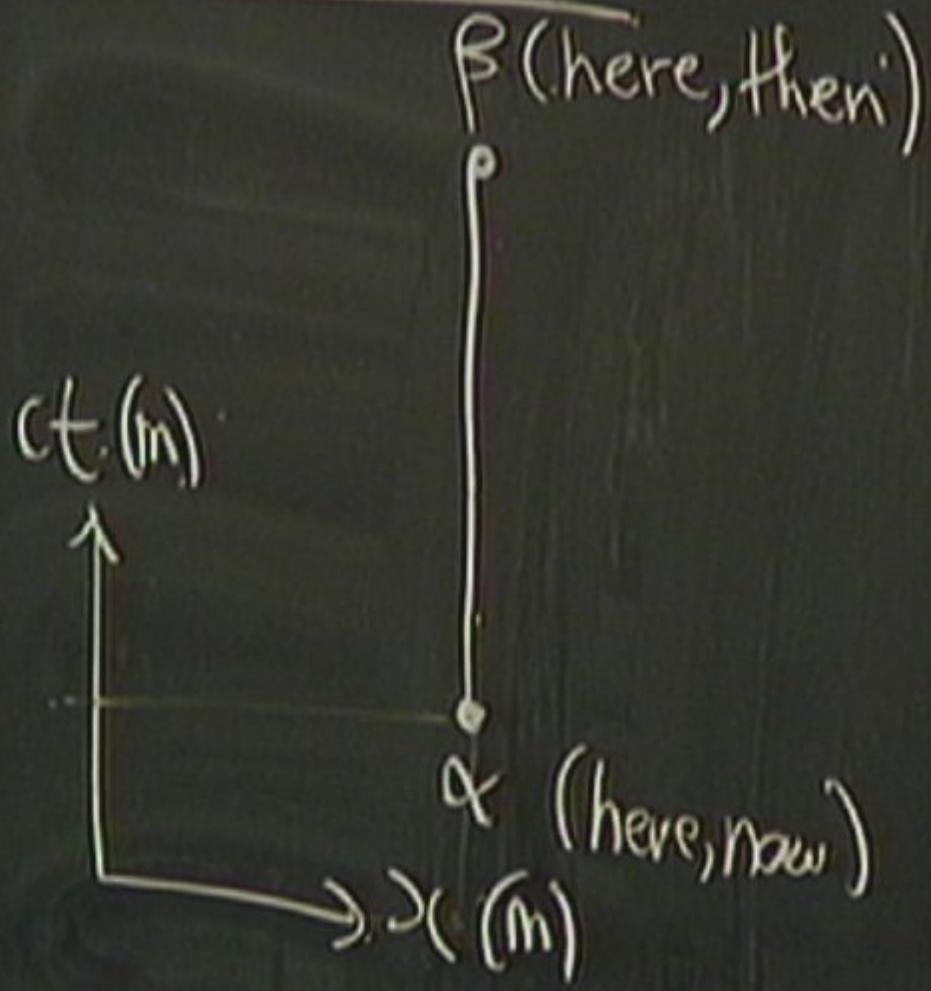

e.g. Minkowski
ct (m)
x (m)
(here, now)

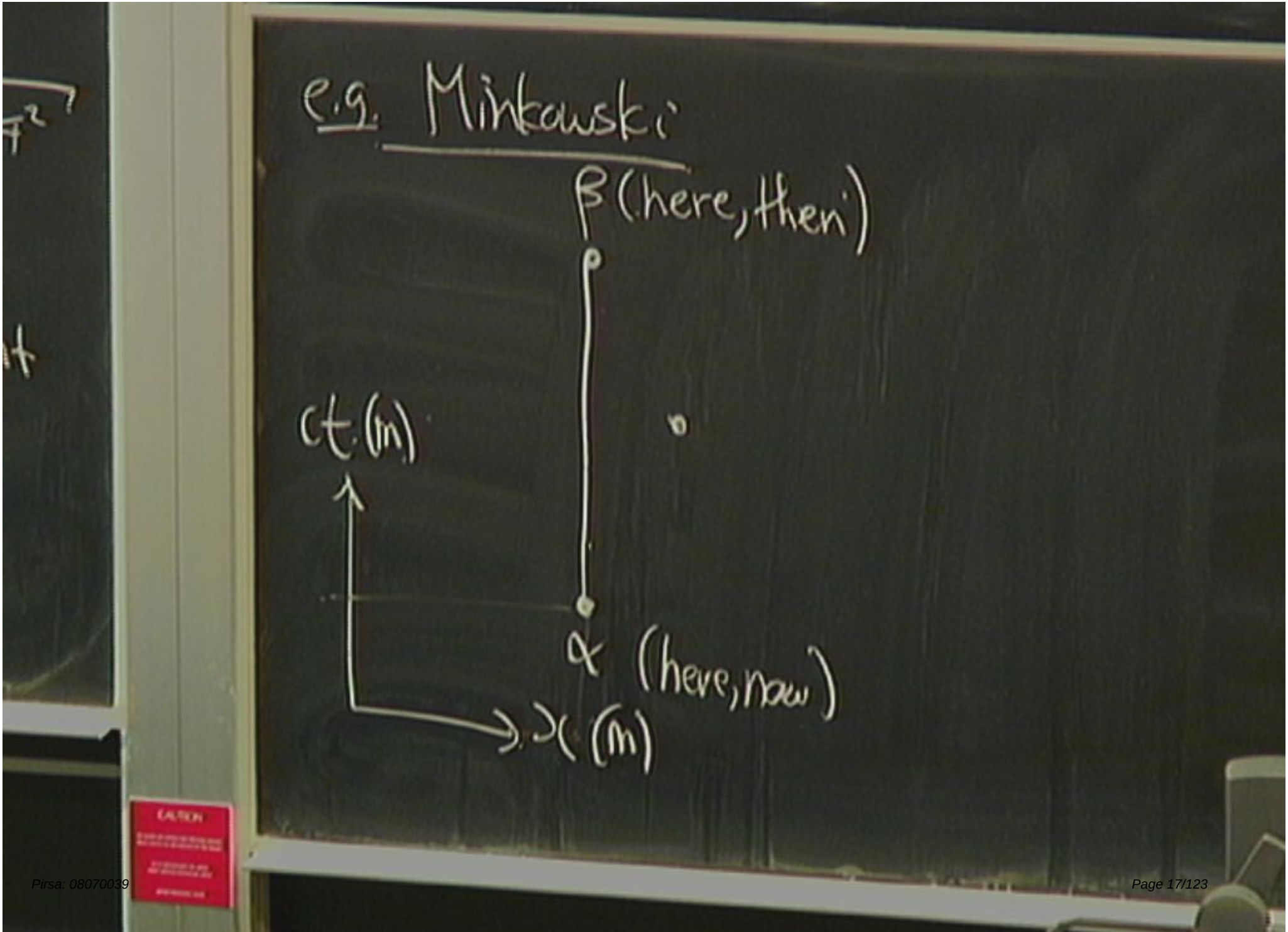
e.g. Minkowski:

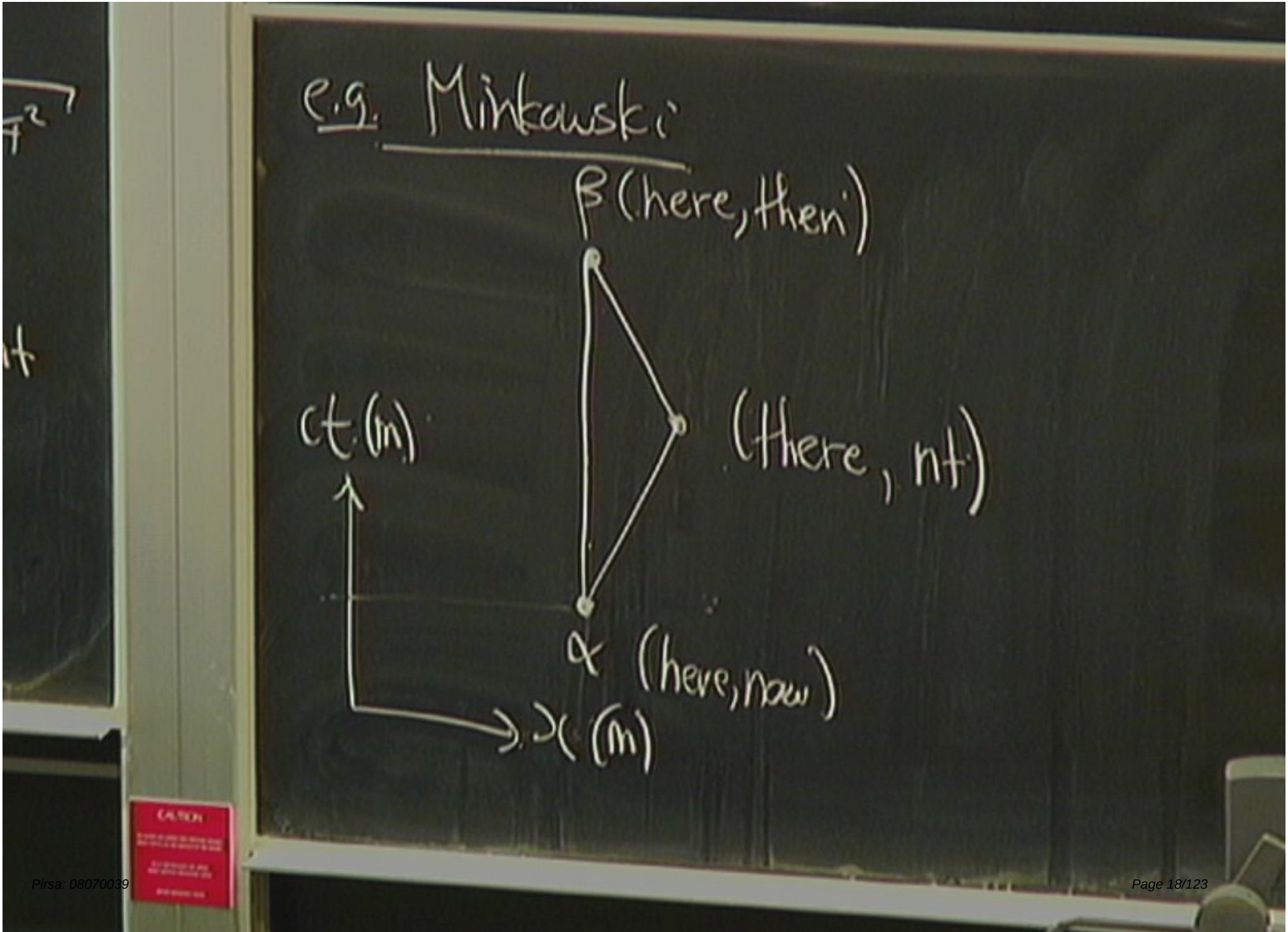
P (here, then)

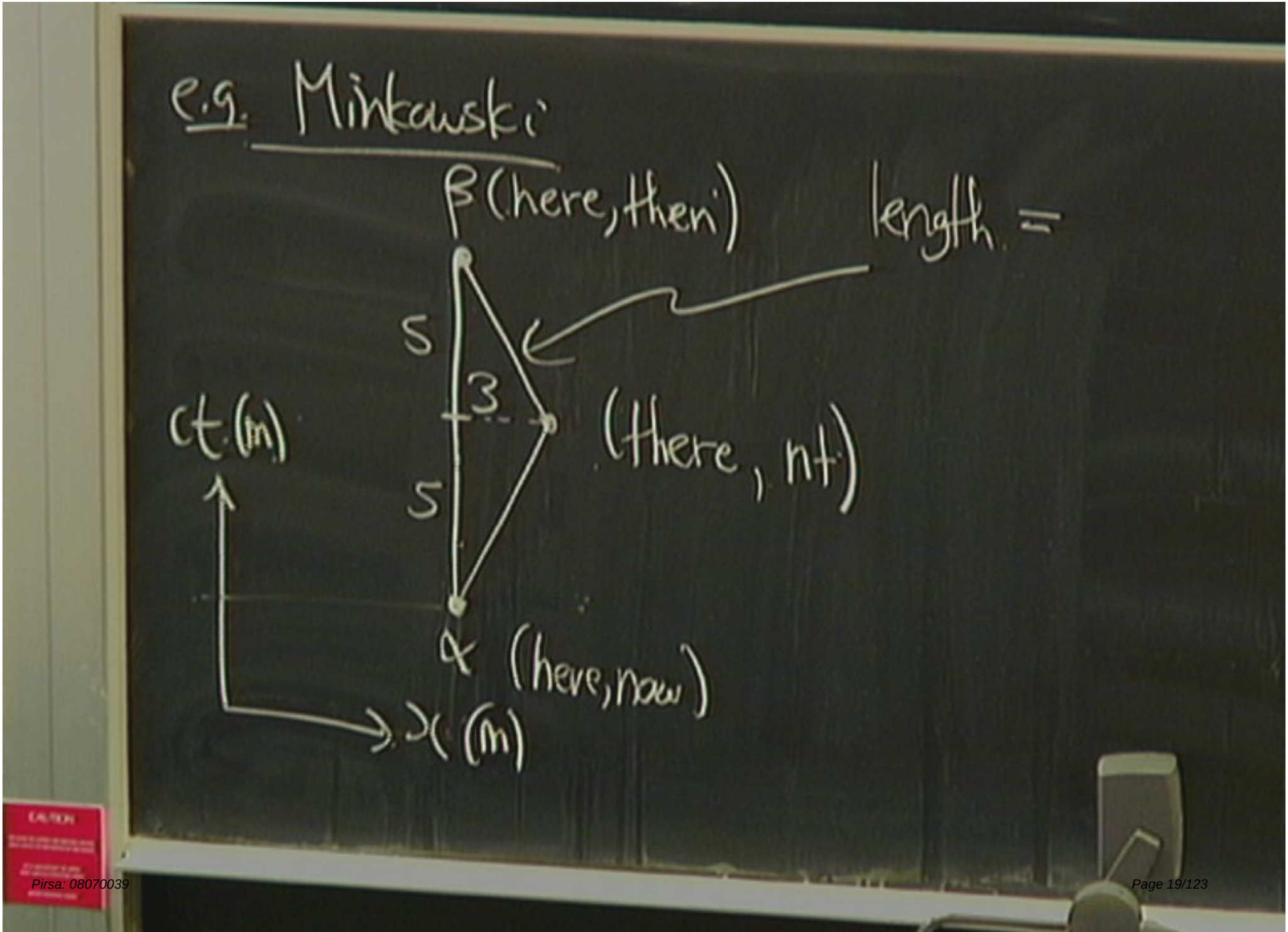


e.g. Minkowski:




e.g. Minkowski:
p (here, then)
ct (m)
q (here, now)
x (m)

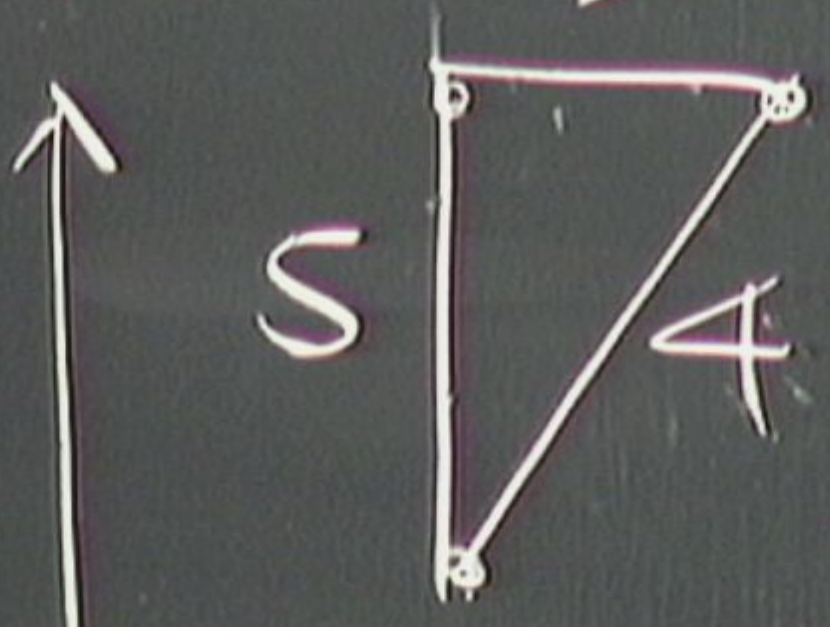

e.g. Minkowski:
β (here, then)
ct (m)
(there, nt)
α (here, now)
x (m)


e.g. Minkowski
β (here, then)
length =
5
3
5
(there, nt)
ct (m)
α (here, now)
x (m)

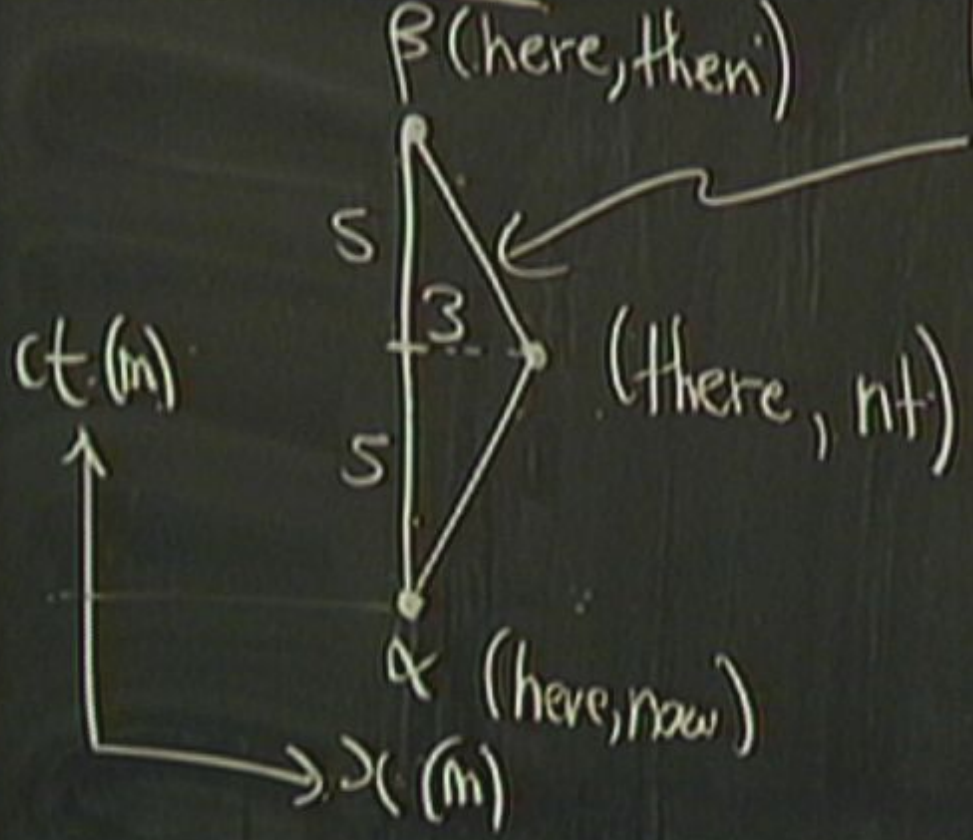
$4^2 = 5^2 - 3^2$

eg.

ct (m)



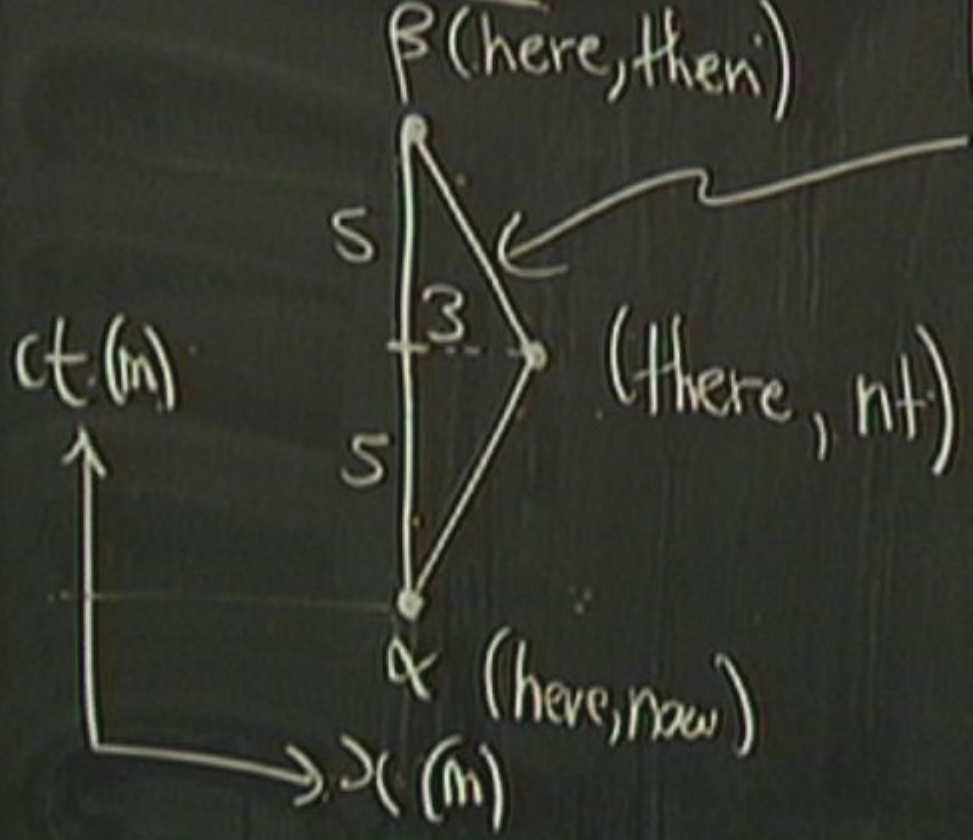
e.g. Minkowski:



length $= \sqrt{5^2-3^2} + \sqrt{5^2-3^2}$

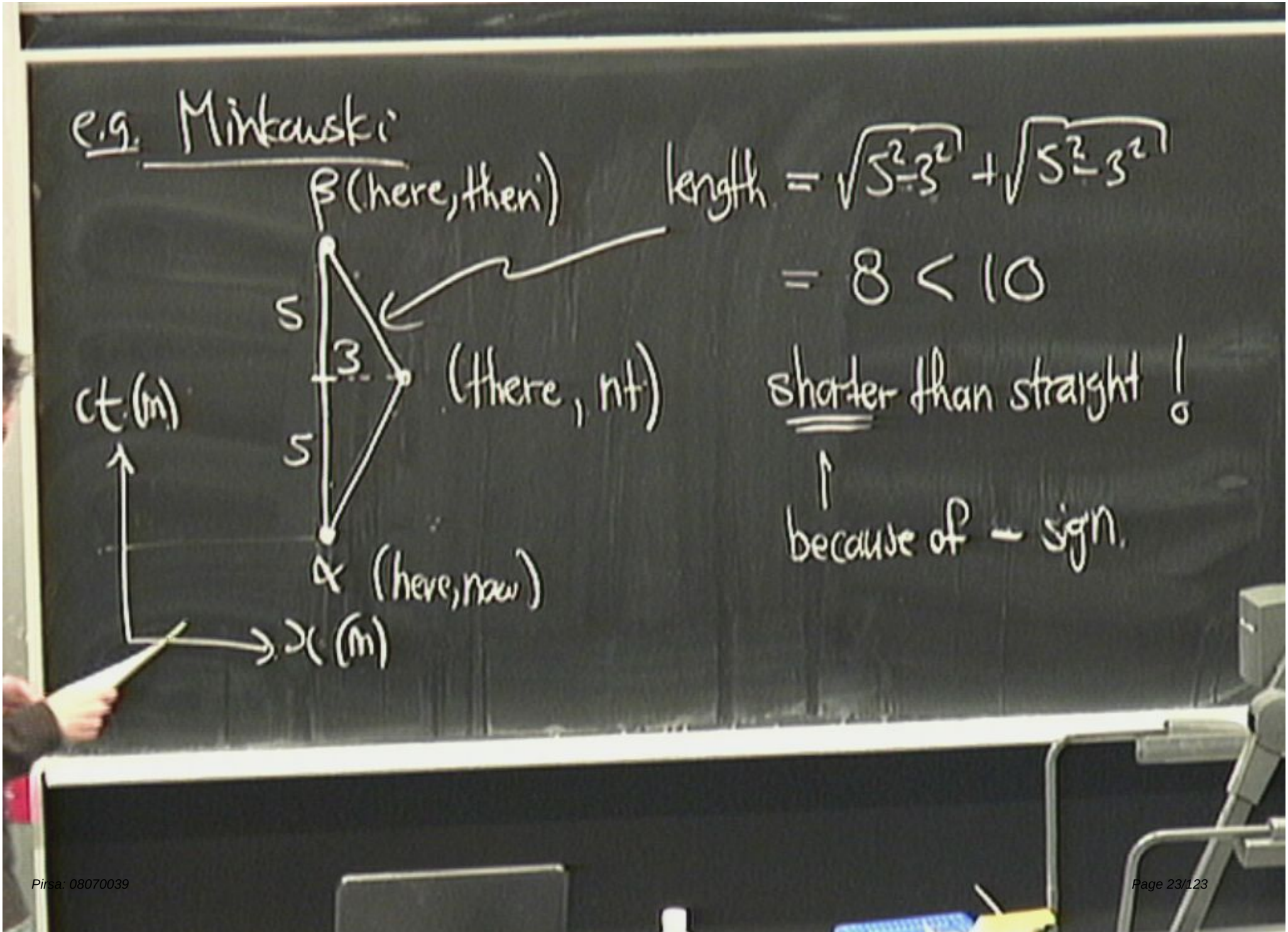
$= 8$

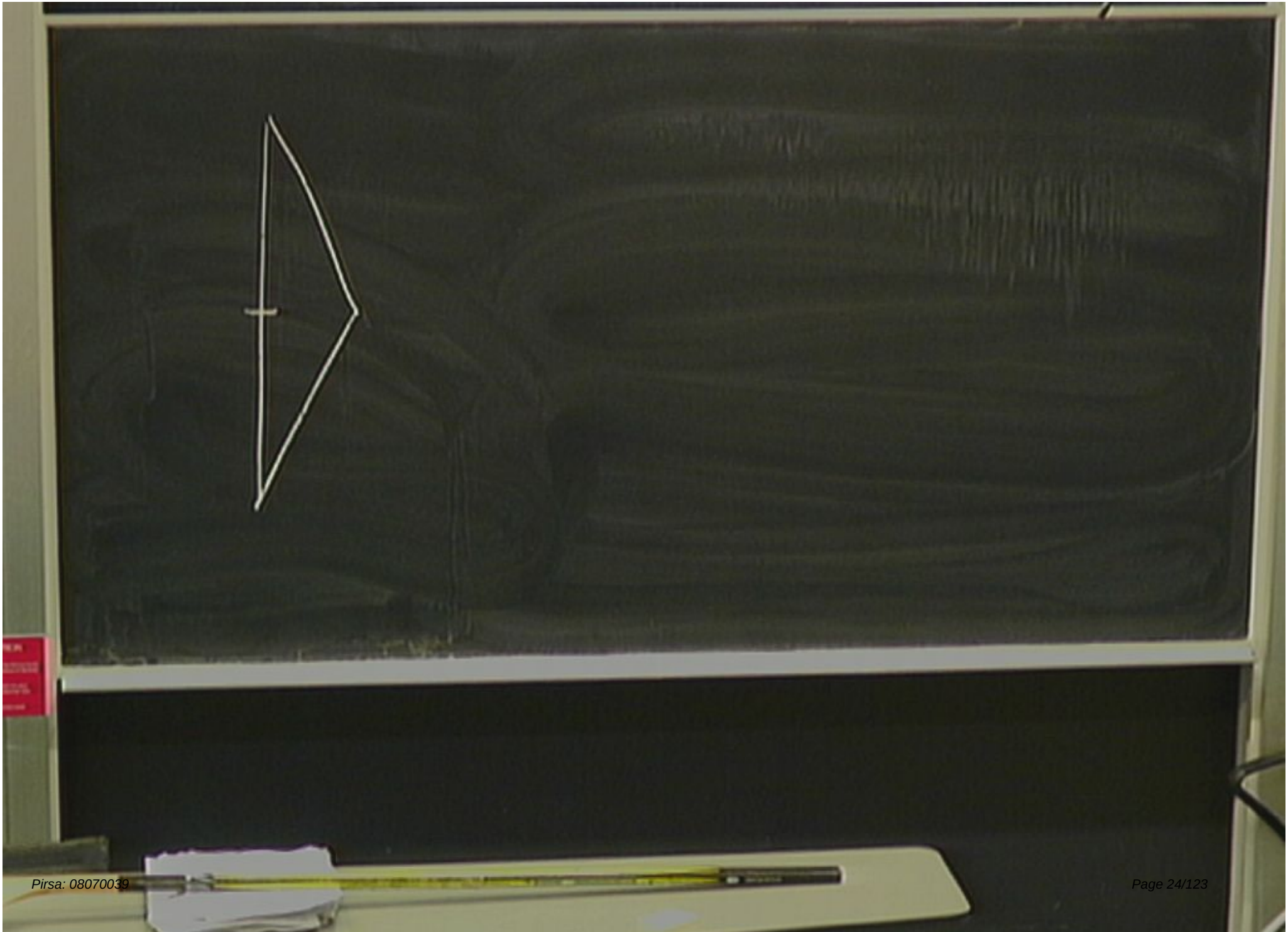
e.g. Minkowski:

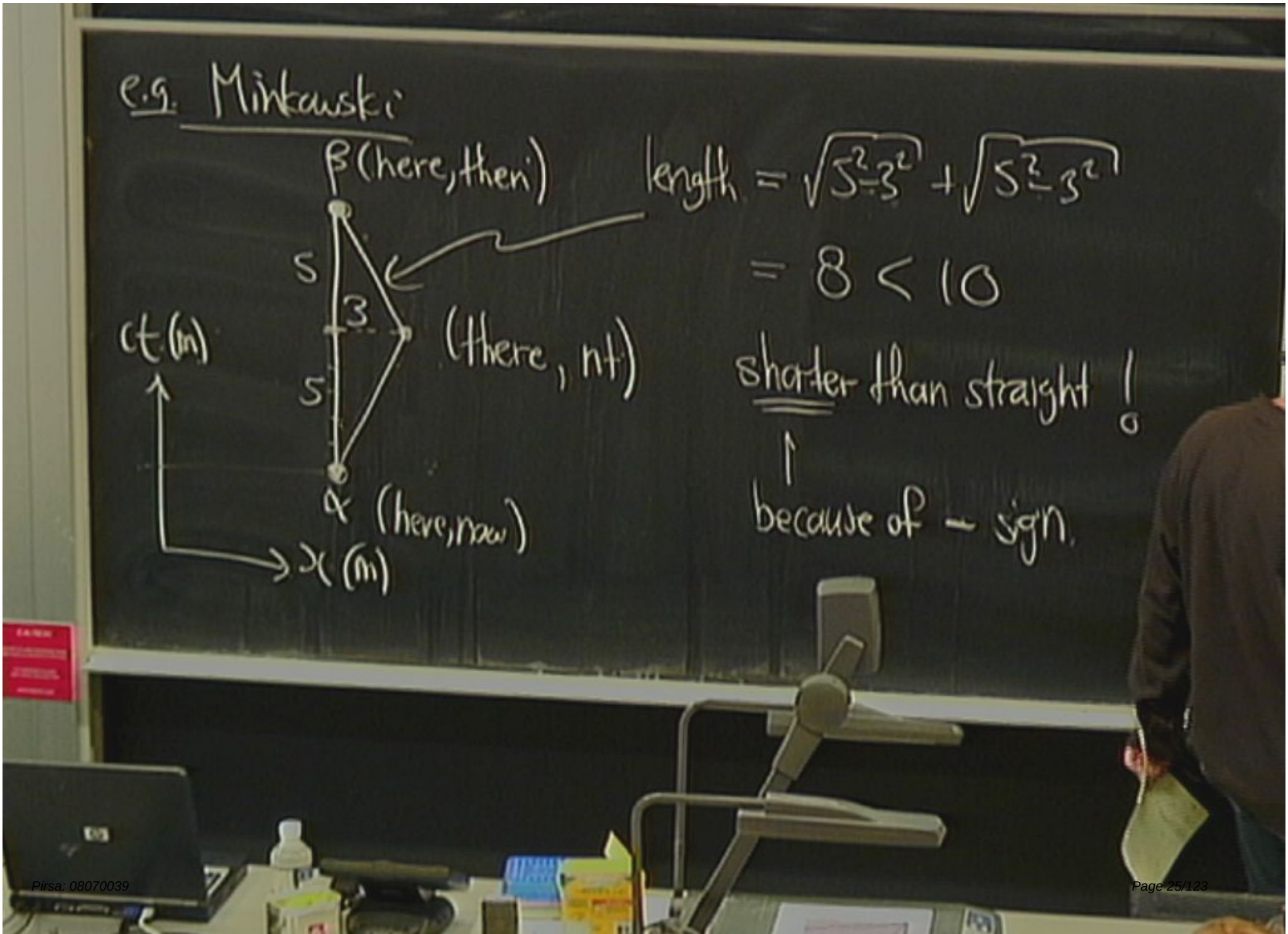


length $= \sqrt{5^2 - 3^2} + \sqrt{5^2 - 3^2}$

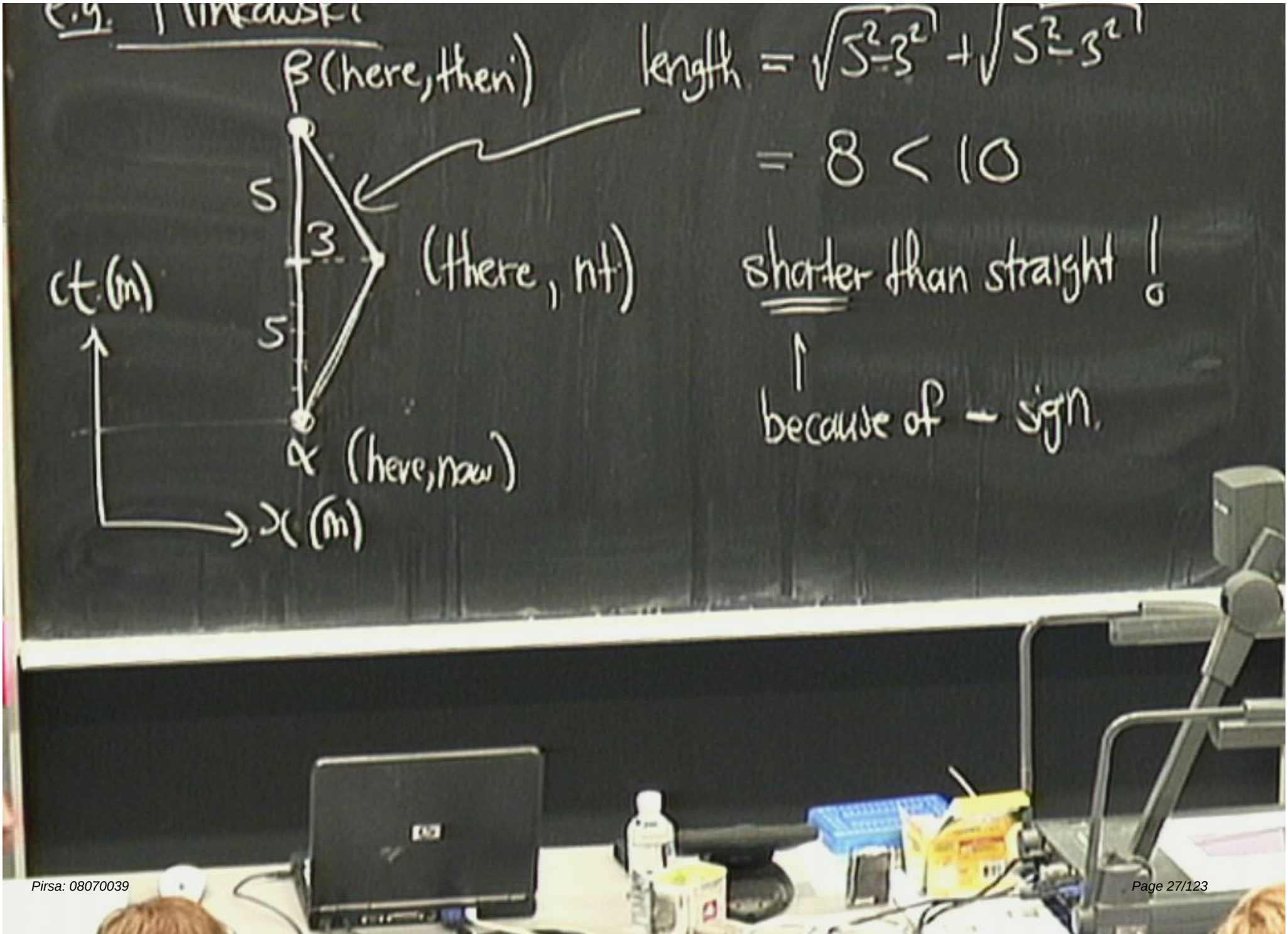
$= 8 < 10$


e.g. Minkowski
B (here, then)
length = $\sqrt{5^2-3^2} + \sqrt{5^2-3^2}$
= 8 < 10
5
3
5
(there, now)
shorter than straight !
because of − sign.
ct (m)
x (m)
A (here, now)

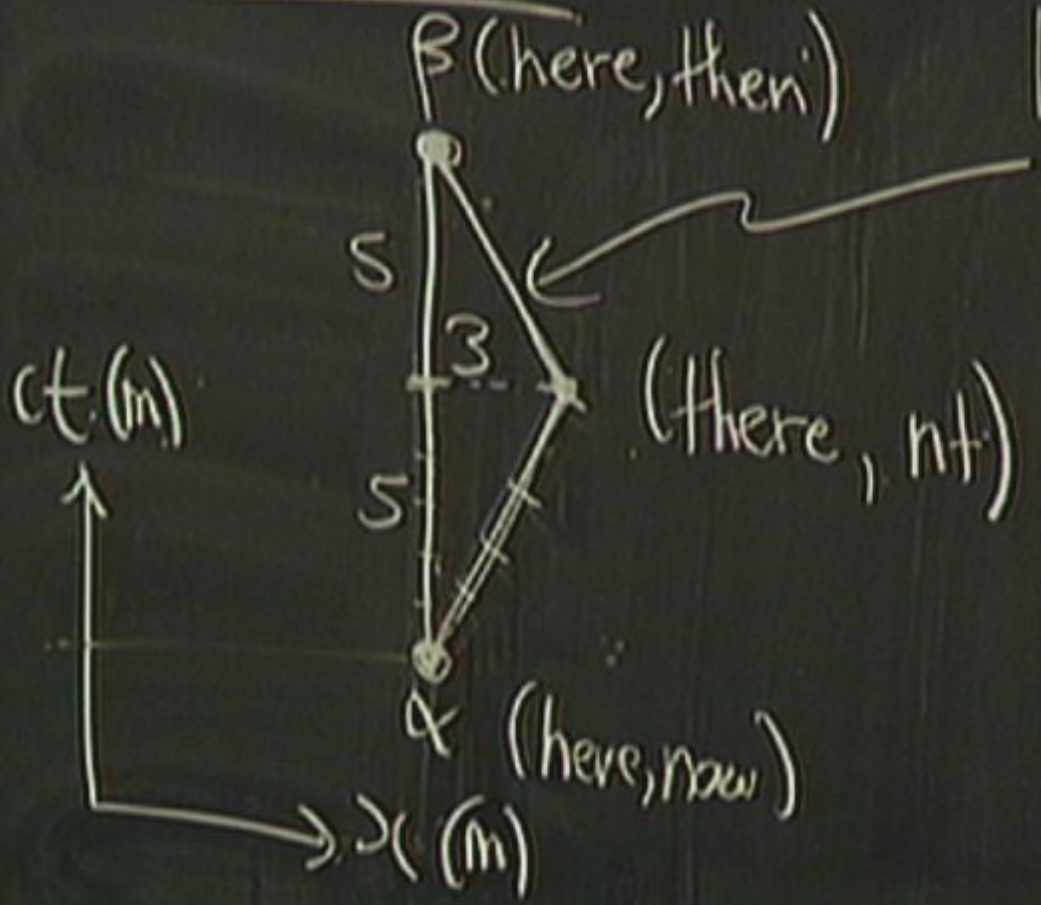



e.g. Minkowski
B (here, then)
length = $\sqrt{5^2-3^2} + \sqrt{5^2-3^2}$
= 8 < 10
5
3
5
ct (m)
(there, now)
A (here, now)
x (m)
shorter than straight !
because of − sign.

10
5
0


B (here, then)
length = $\sqrt{5^2-3^2} + \sqrt{5^2-3^2}$
= 8 < 10
5
3
5
(there, now)
shorter than straight !
because of − sign.
ct (m)
x (m)
A (here, now)

e.g. Minkowski:



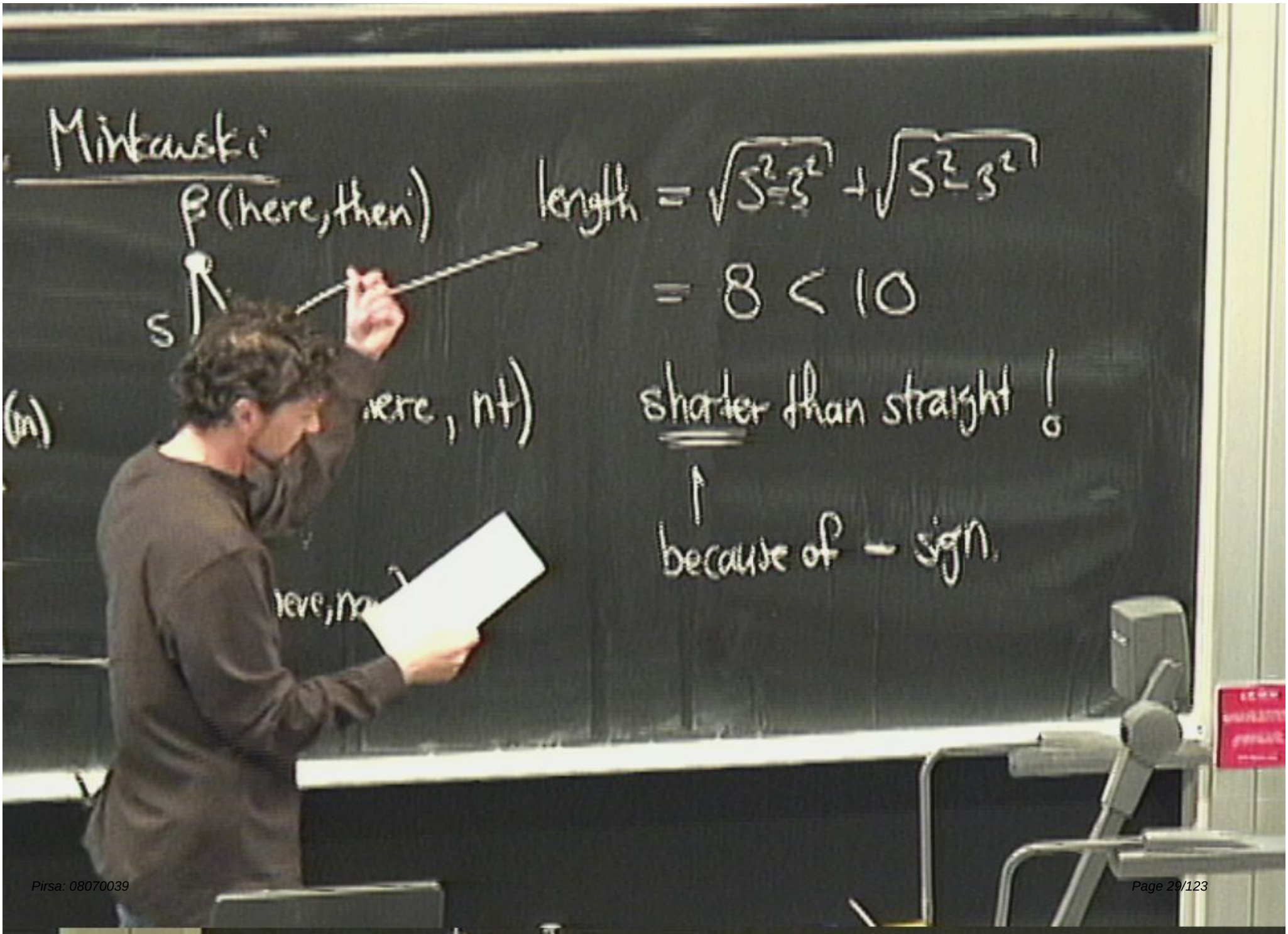
length = $\sqrt{5^2-3^2} + \sqrt{5}$

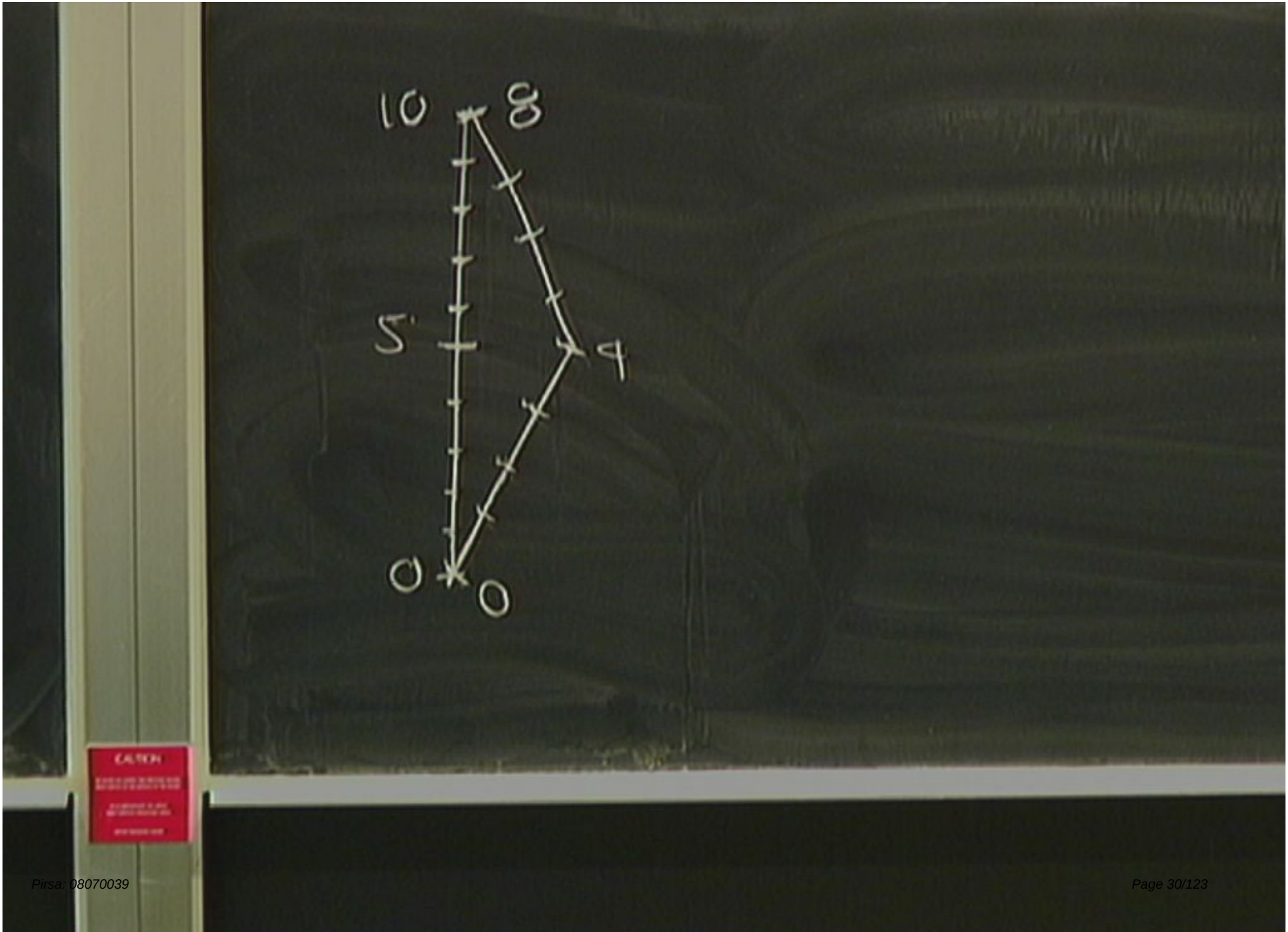
$= 8 < 10$

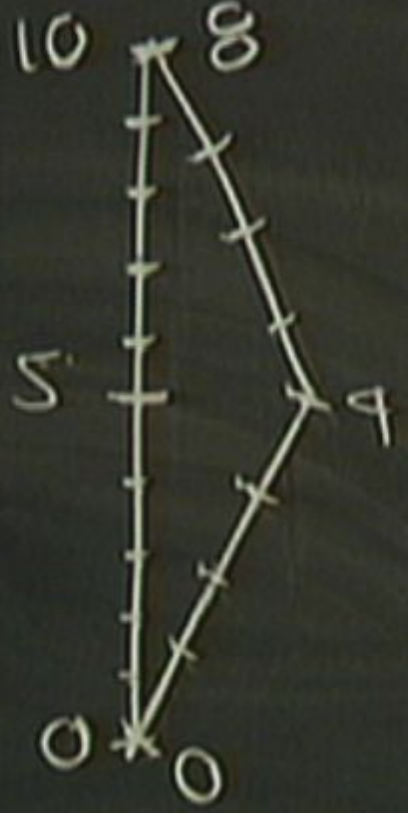
shorter than str

↑

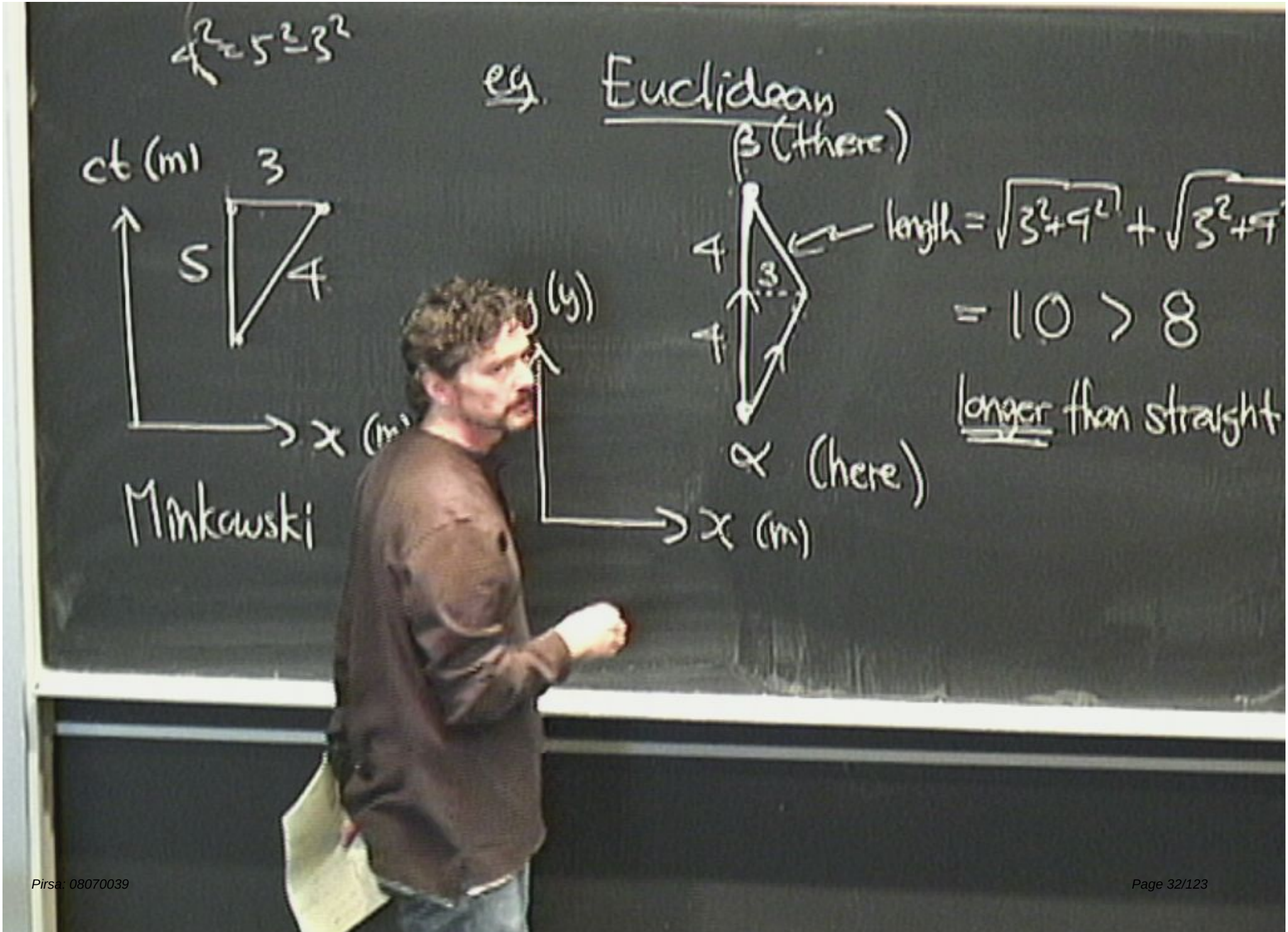
because of –

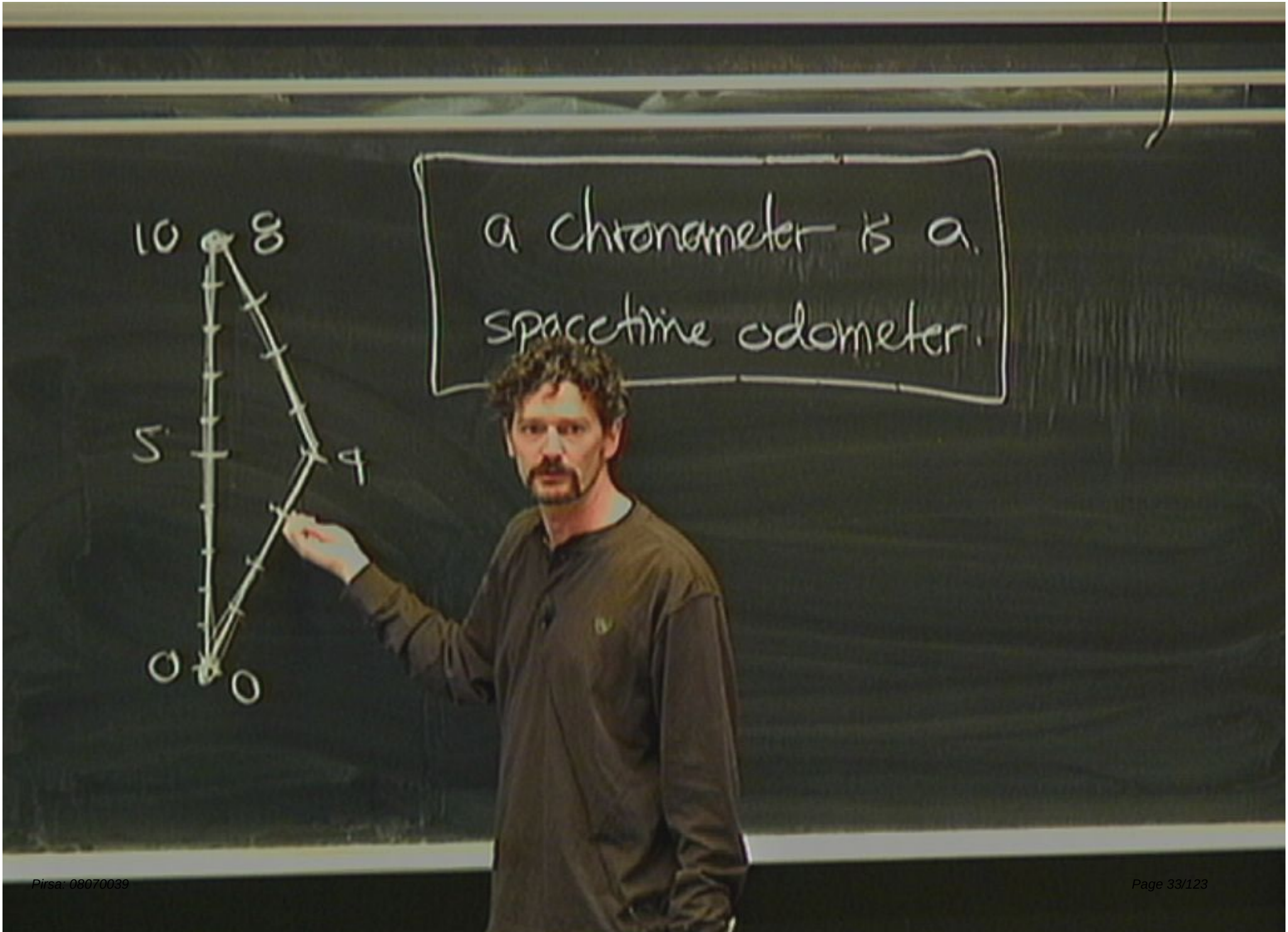

Minkowski
P(here, then)
length = $\sqrt{s^2-3^2}$ + $\sqrt{s^2-3^2}$
= 8 < 10
shorter than straight !
because of − sign.

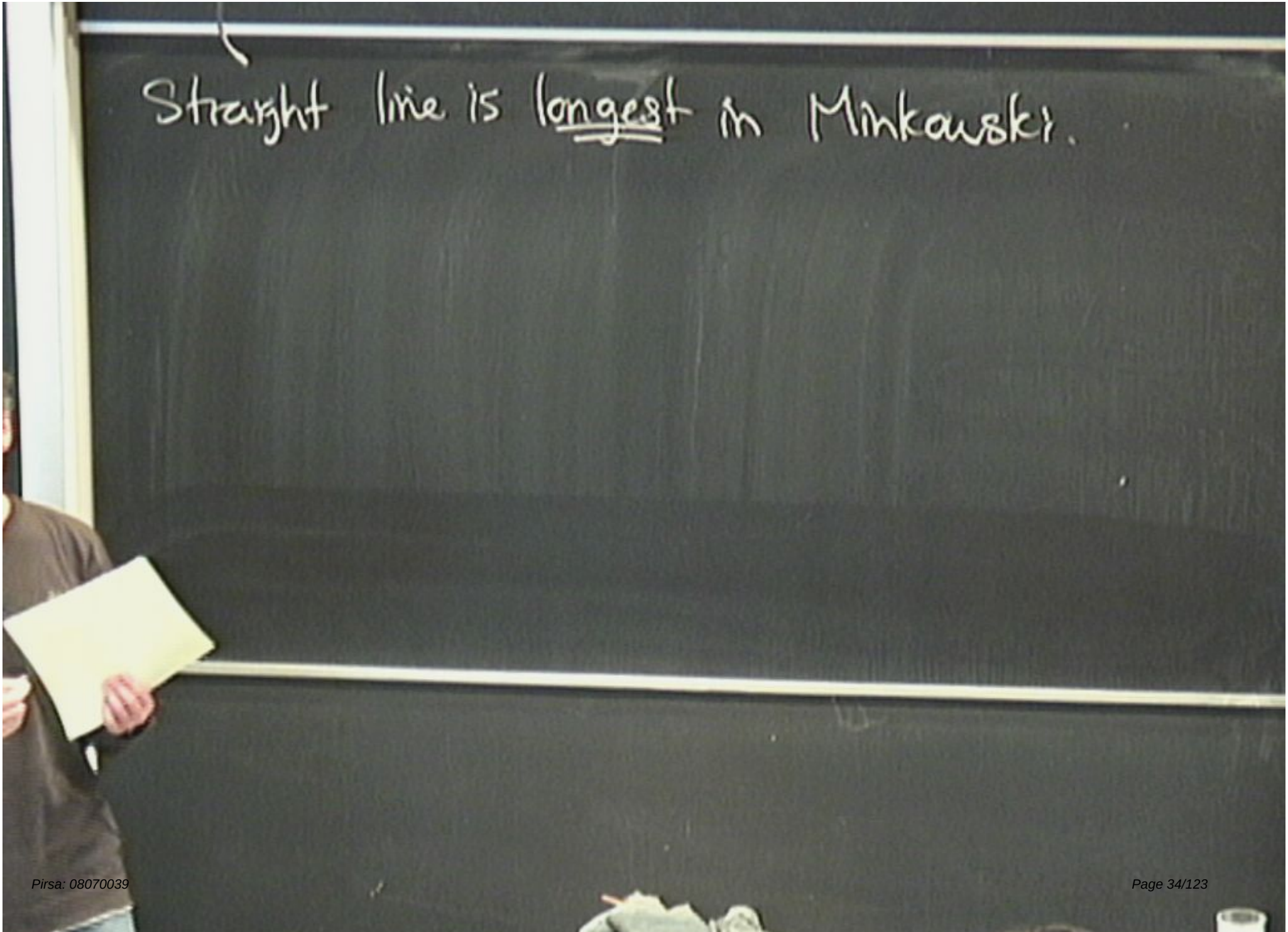

10
8
5
4
0
0

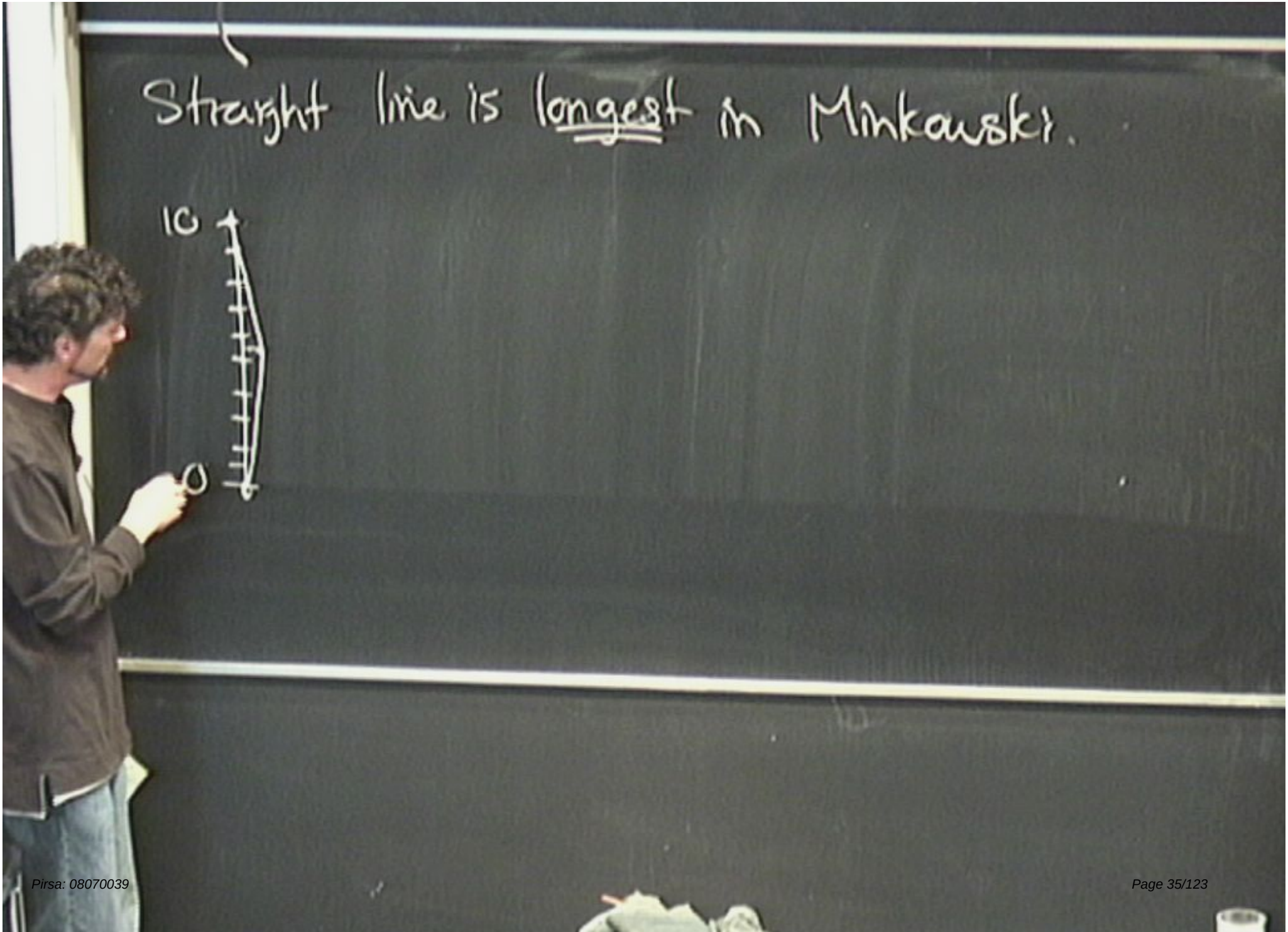


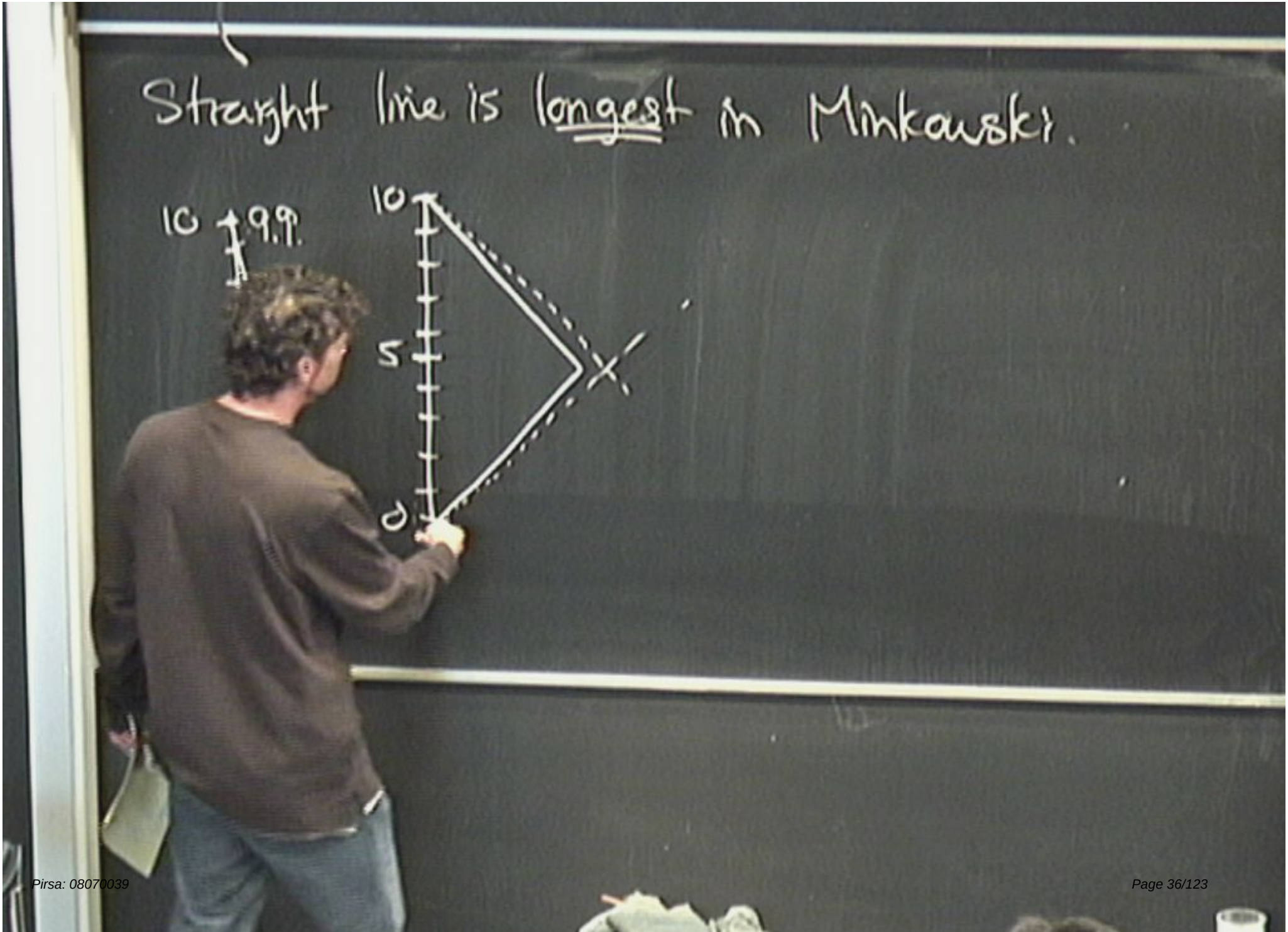
a chronometer is a spacetime odometer.

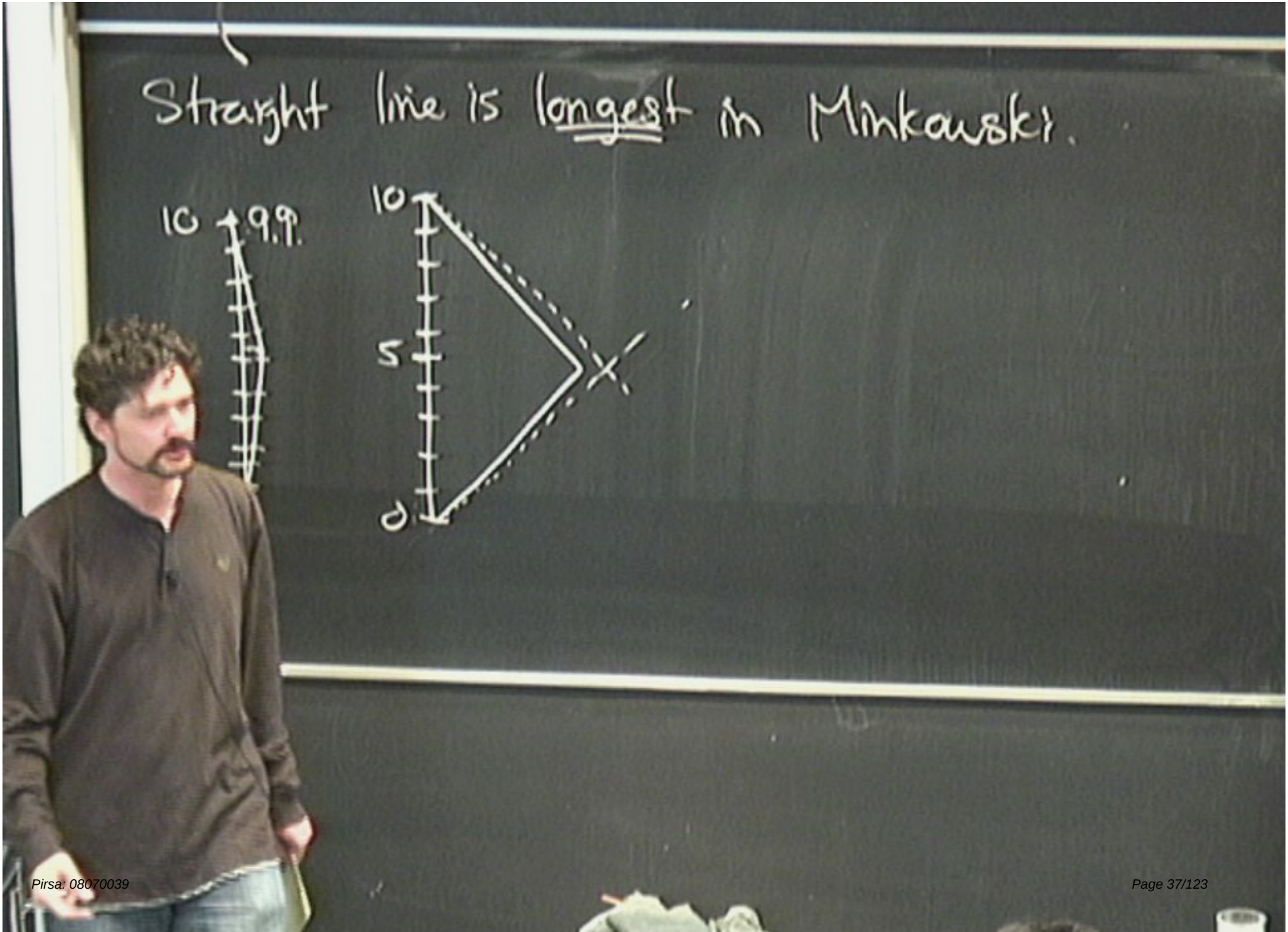

$4^2 = 5^2 - 3^2$
eg. Euclidean
ct (m)
3
5
4
x (m)
Minkowski
(y)
x (m)
β (there)
length = $\sqrt{3^2+4^2} + \sqrt{3^2+4^2}$
4
3
4
= 10 > 8
longer than straight
α (here)

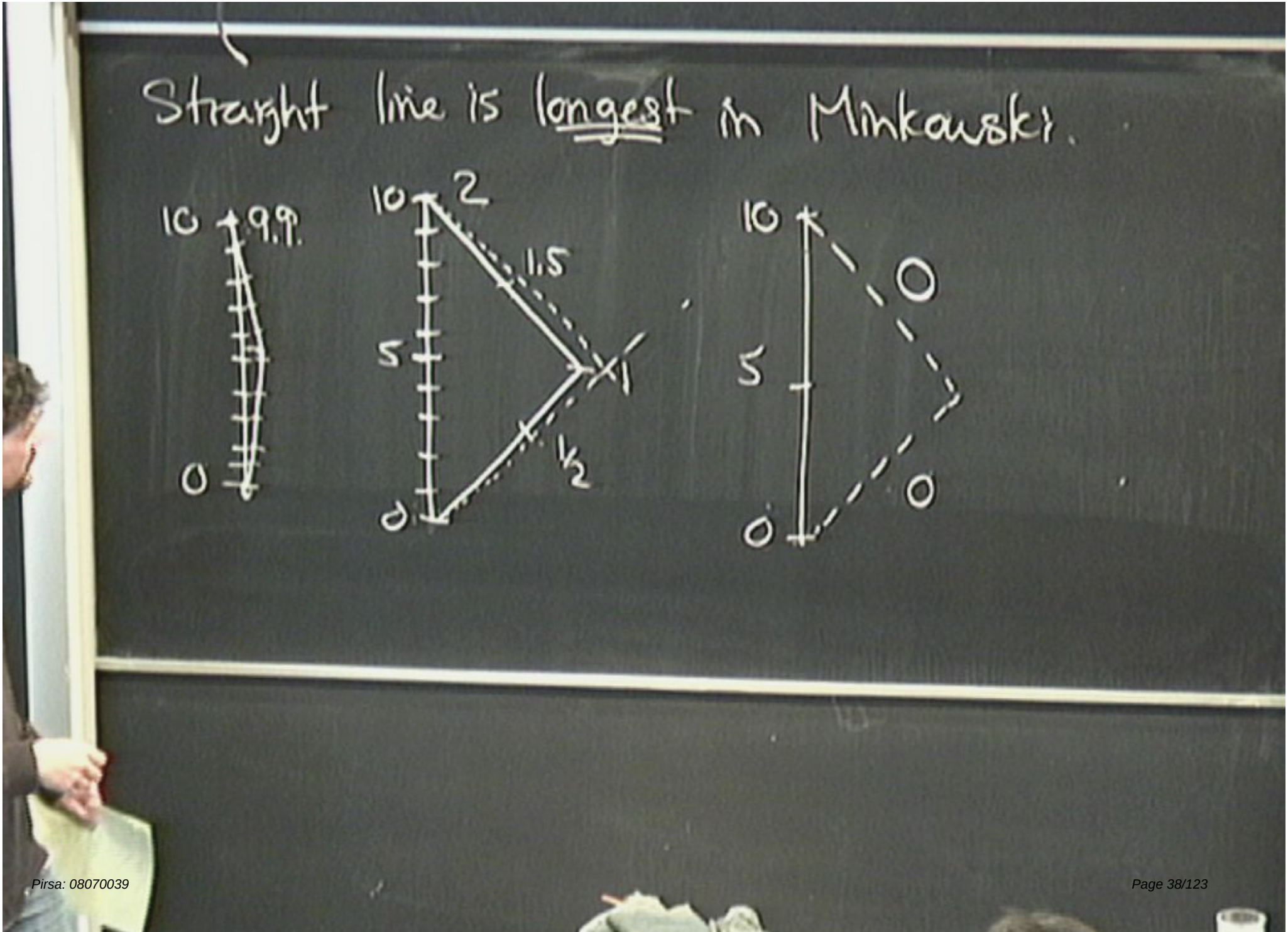

a chronometer is a spacetime odometer.
10
8
5
0
0

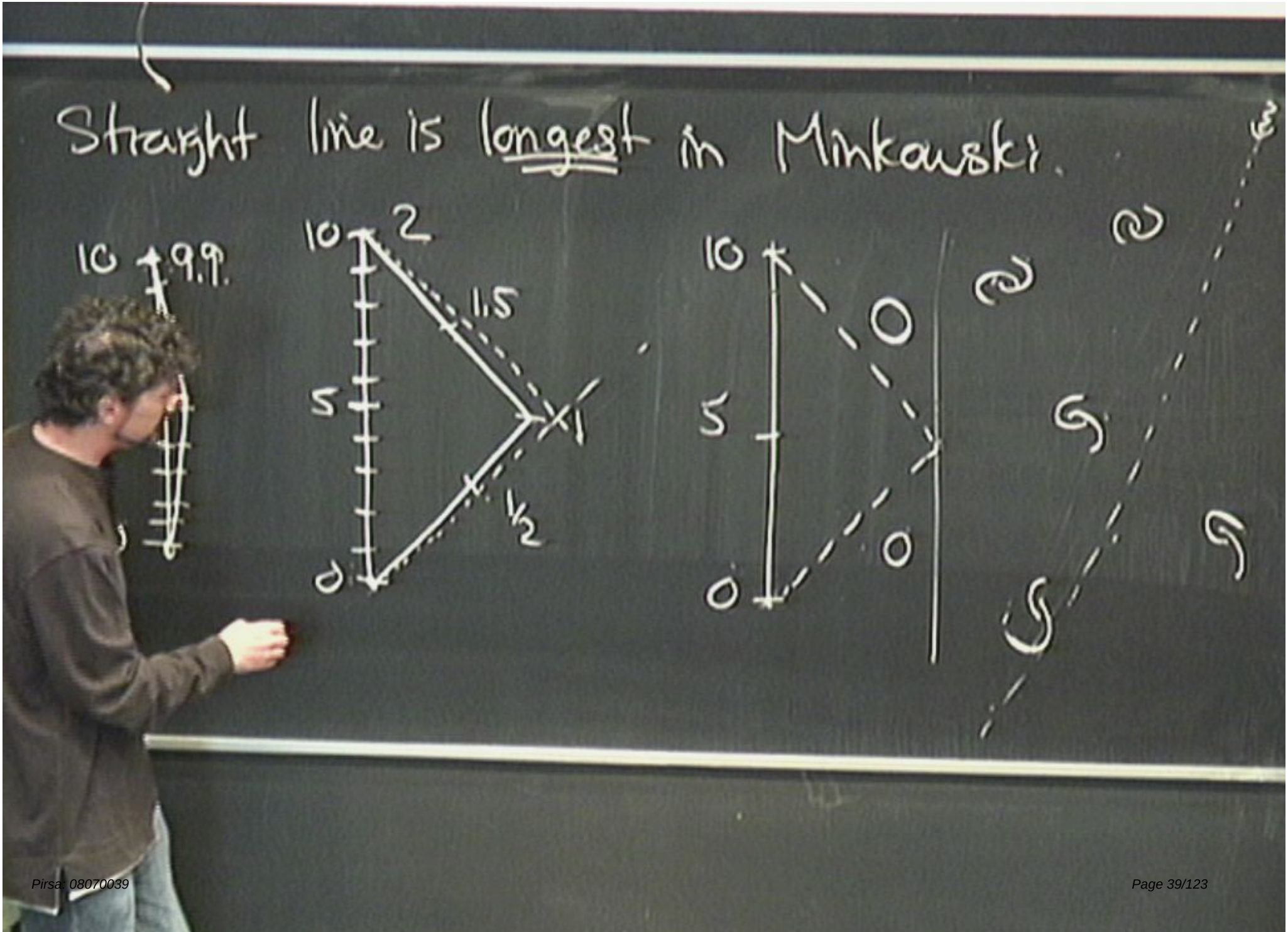

Straight line is longest in Minkowski.

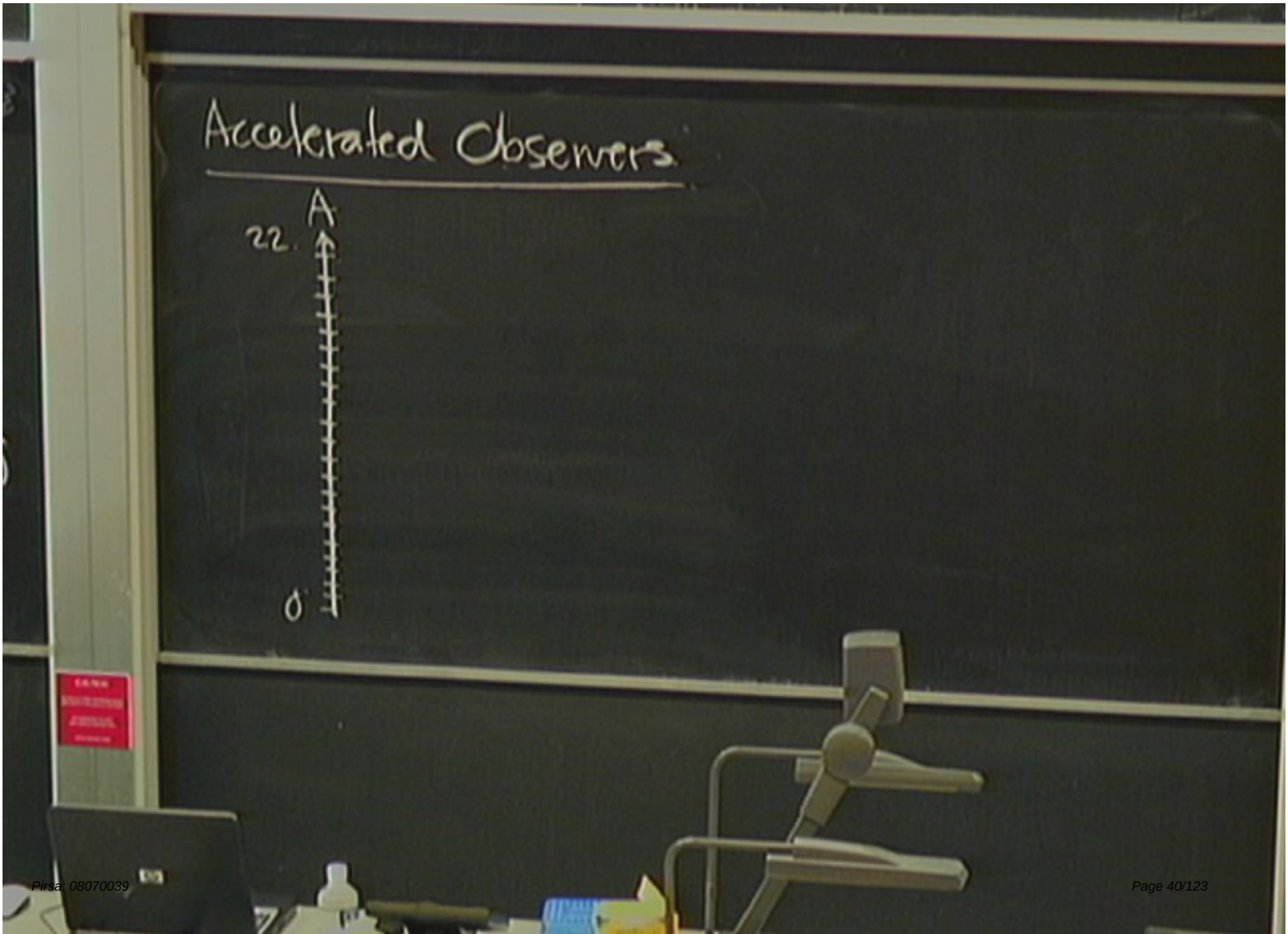

Straight line is longest in Minkowski.
10
0

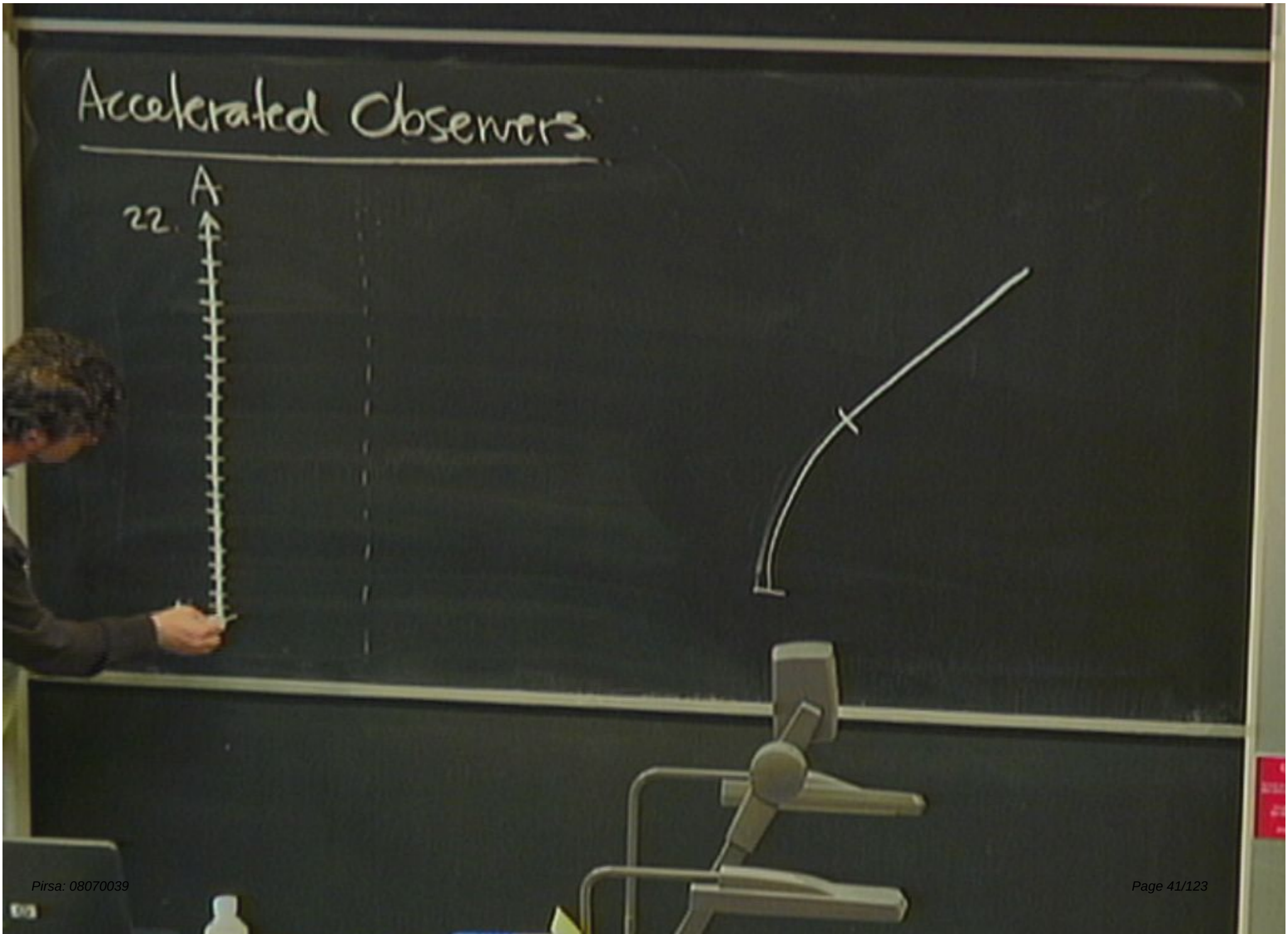

Straight line is longest in Minkowski.
10
9.9
10
5
0

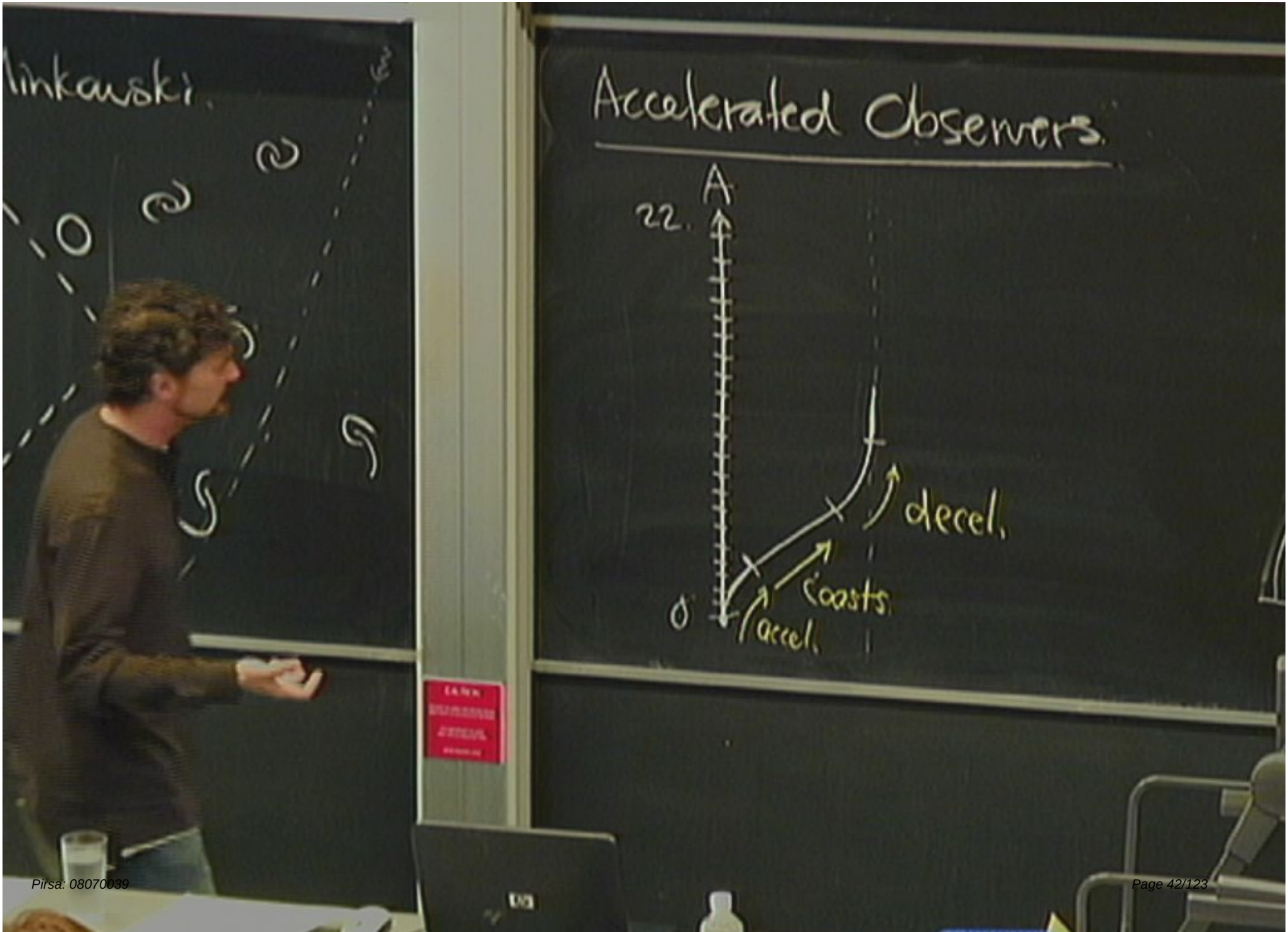

Straight line is longest in Minkowski.
10
9.9
10
5
0

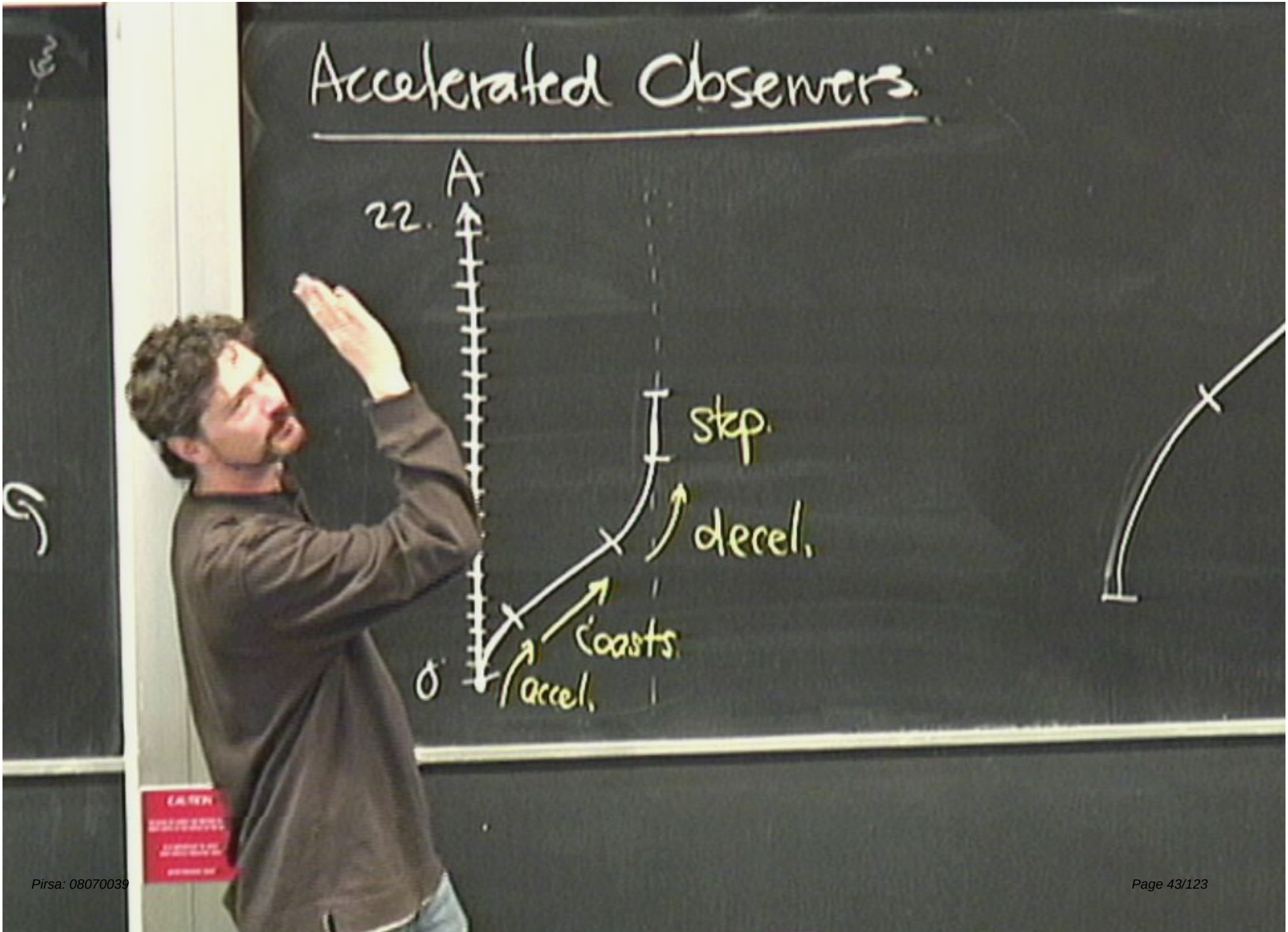

Straight line is longest in Minkowski.
10
9.9
0
10
2
1.5
5
1
½
0
10
0
5
0
0

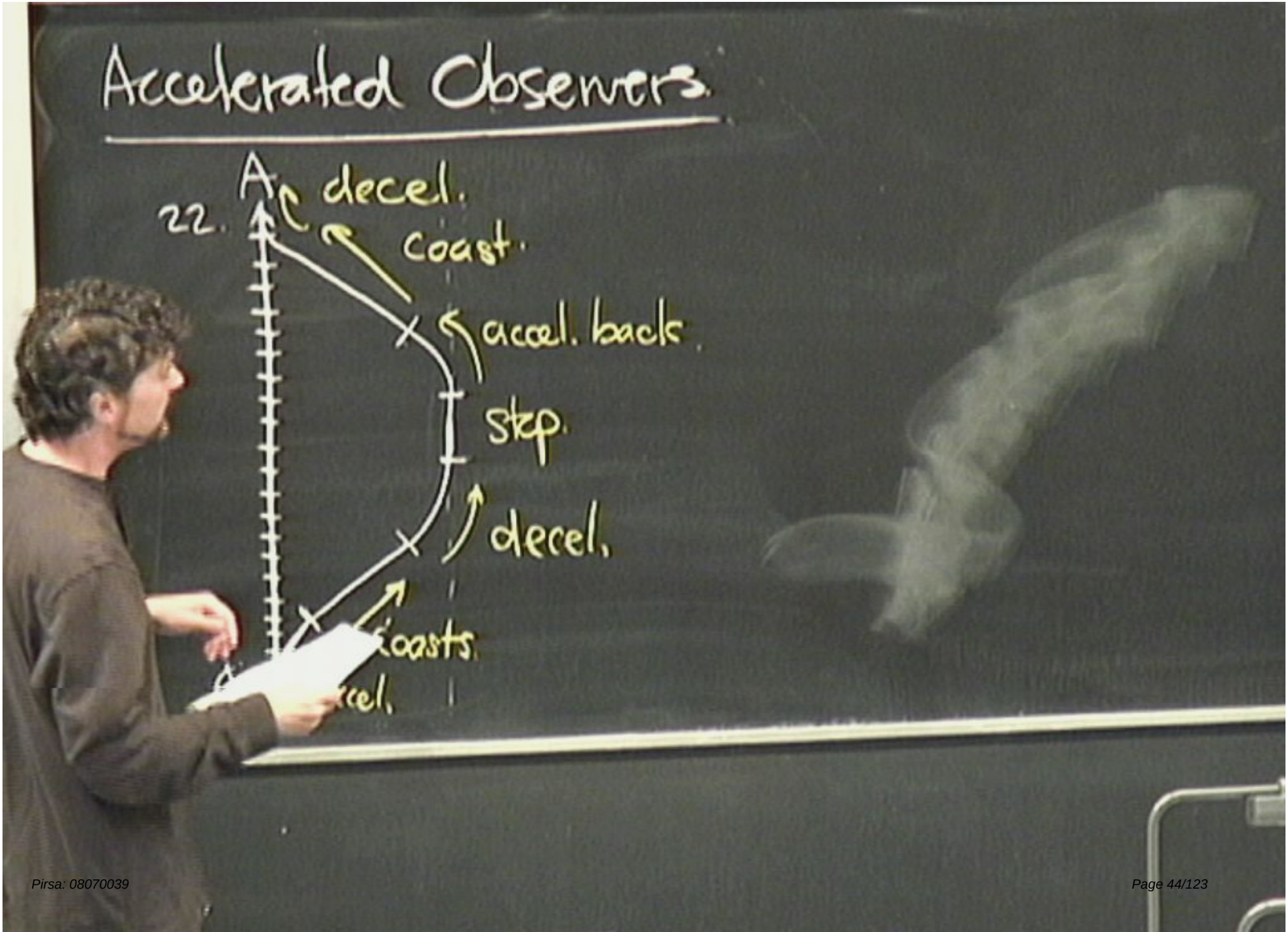

Straight line is longest in Minkowski.
10
9.9
10
2
1.5
1
½
5
0
10
5
0


Accelerated Observers
A
22
0

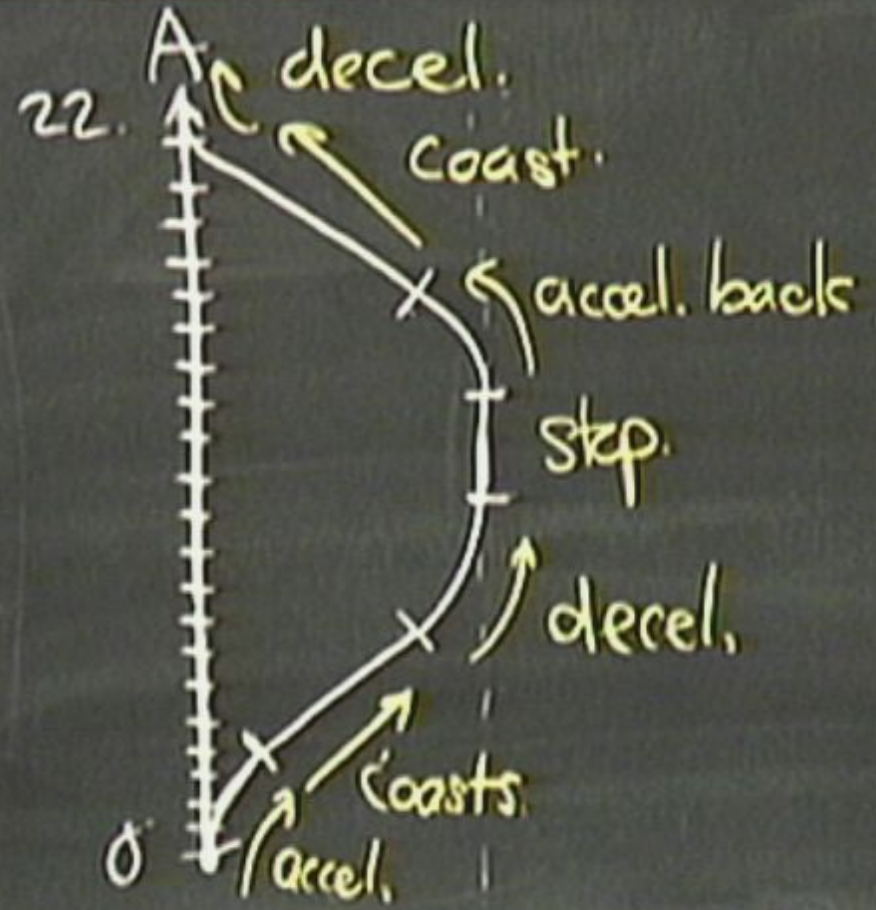

Accelerated Observers
A
22.

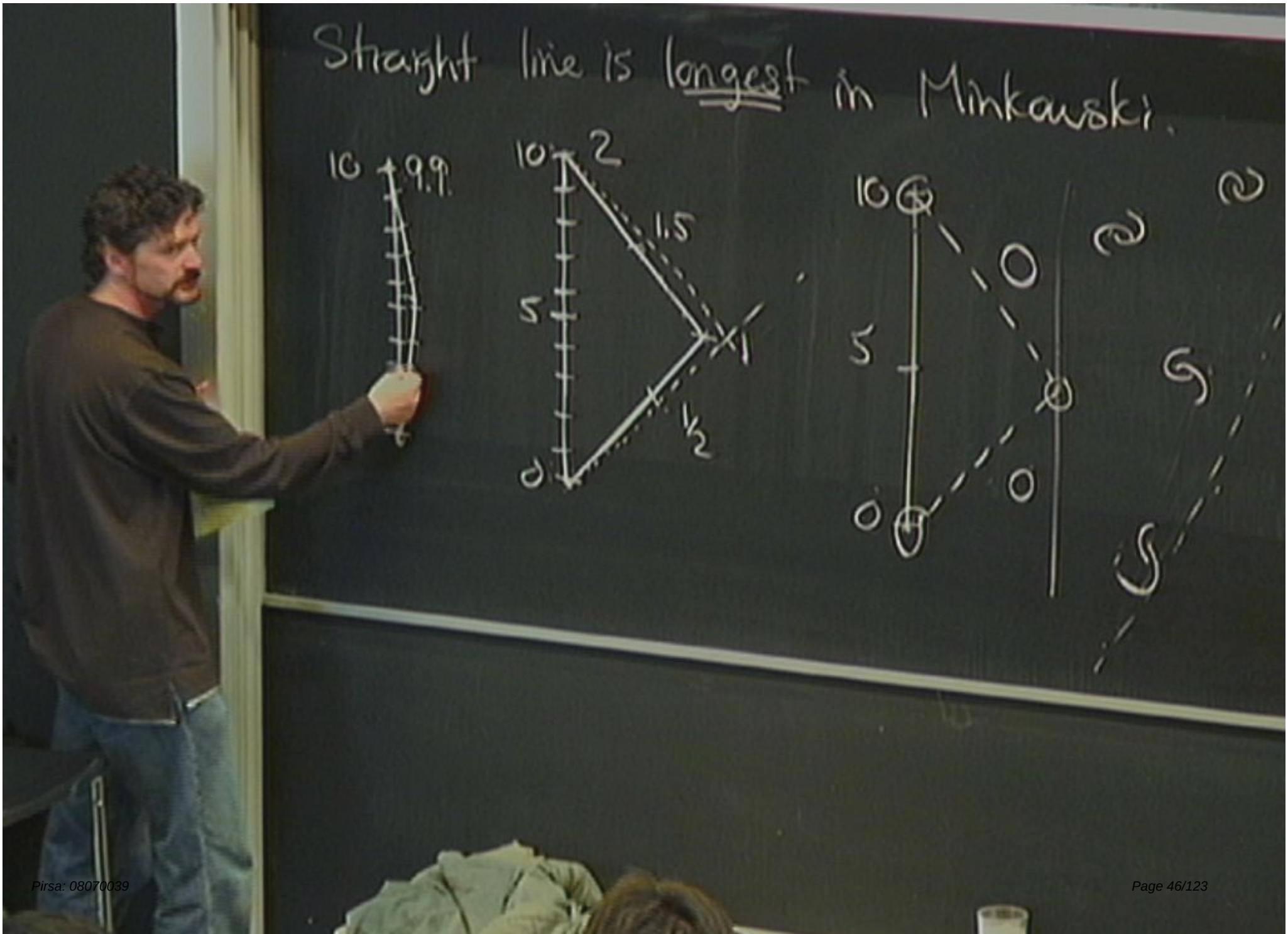

linkowski
Accelerated Observers
A
22.
decel.
coasts
accel.
O

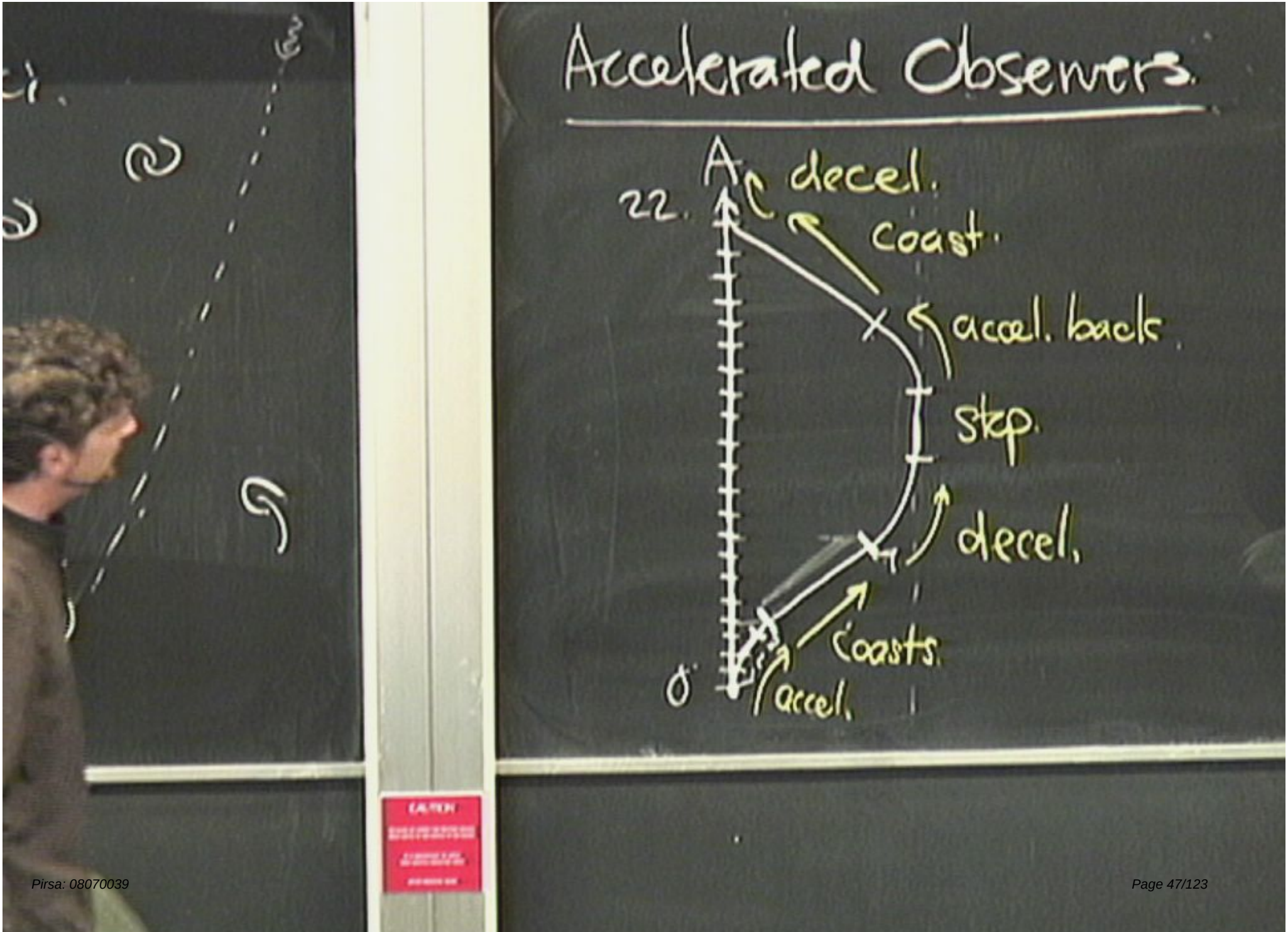

Accelerated Observers
A
22.
stop.
decel.
coasts.
accel.
0

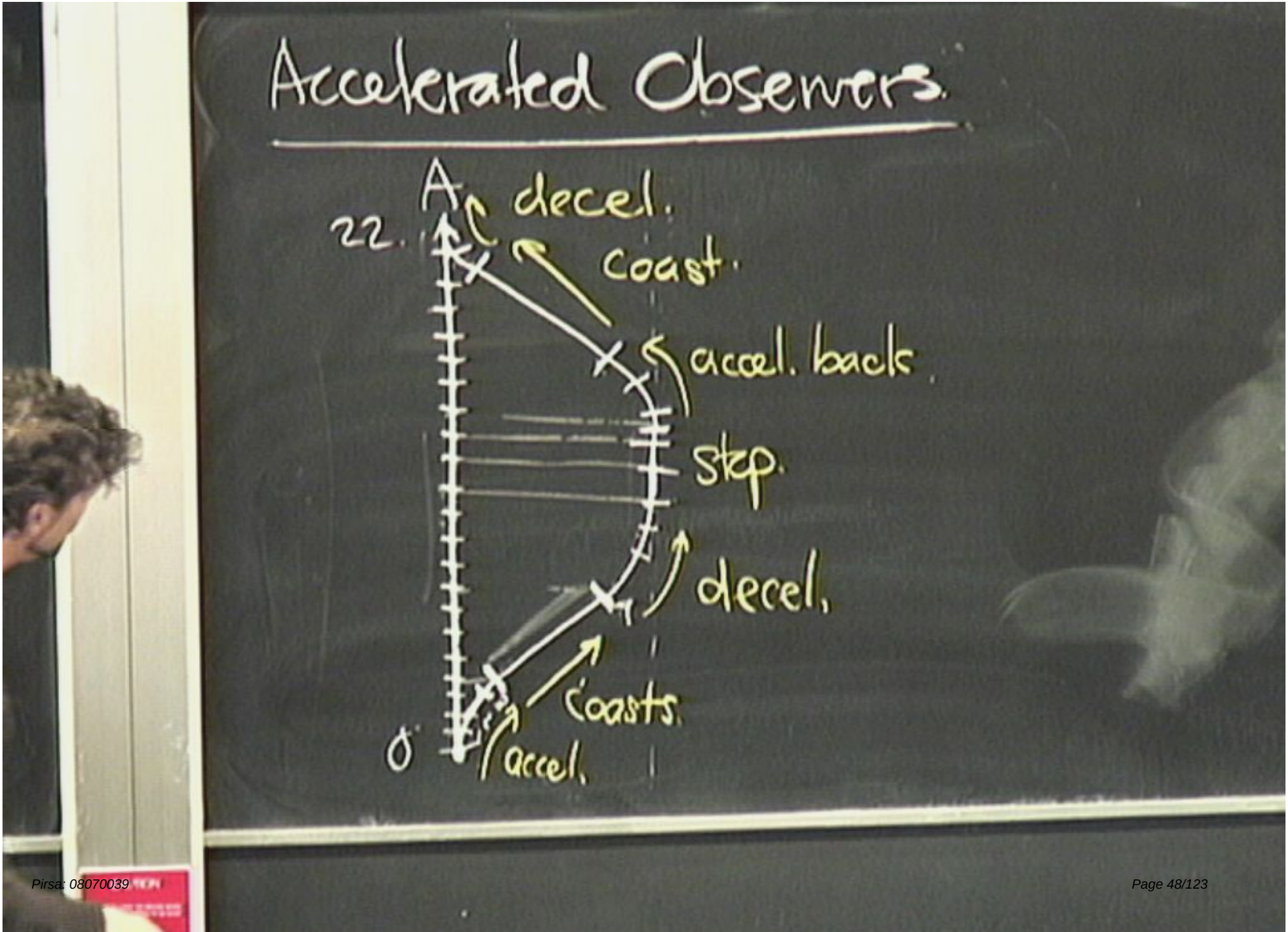

Accelerated Observers
A
22.
decel.
coast.
accel. back
step.
decel.
coasts.

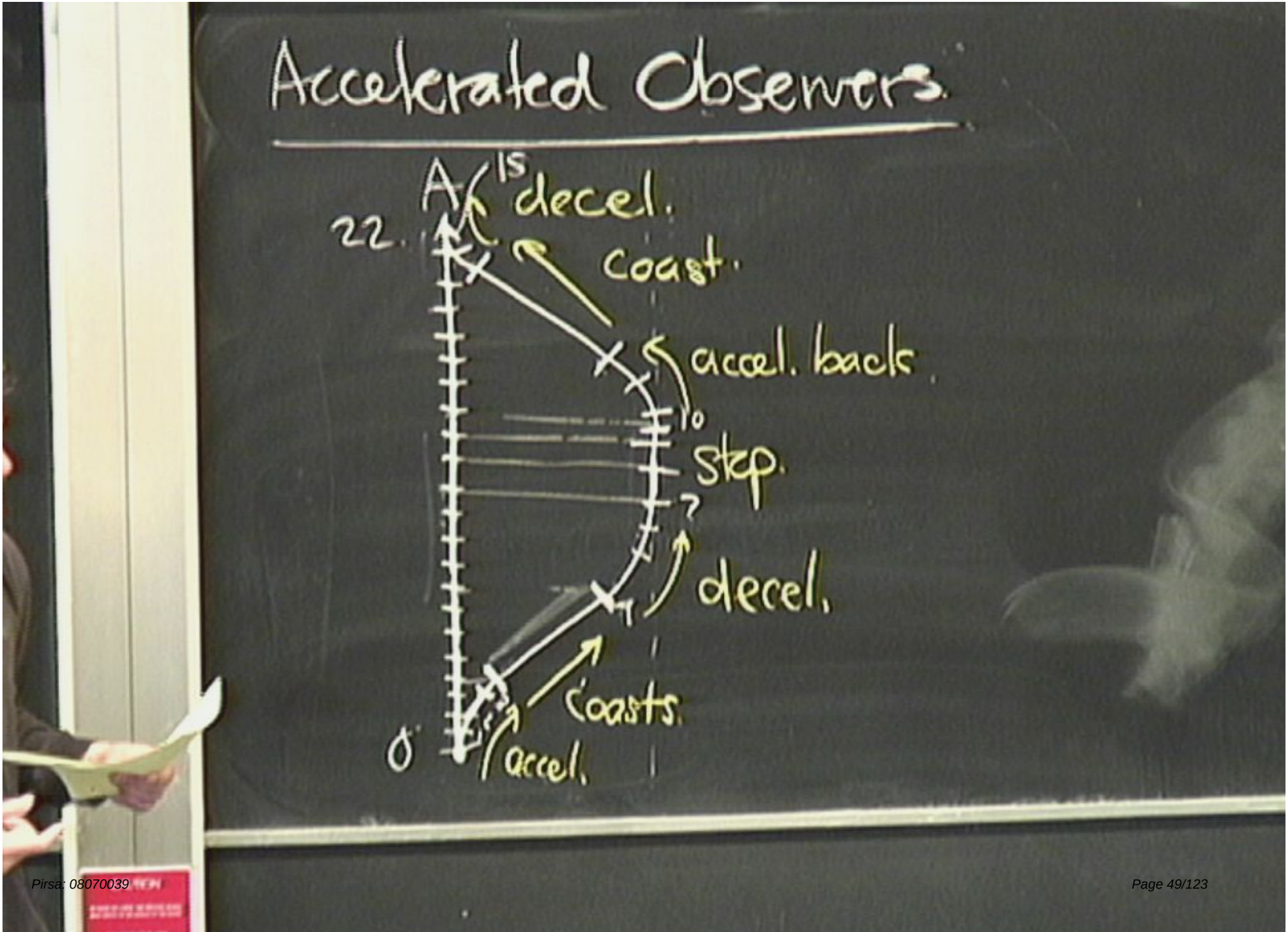
Accelerated Observers

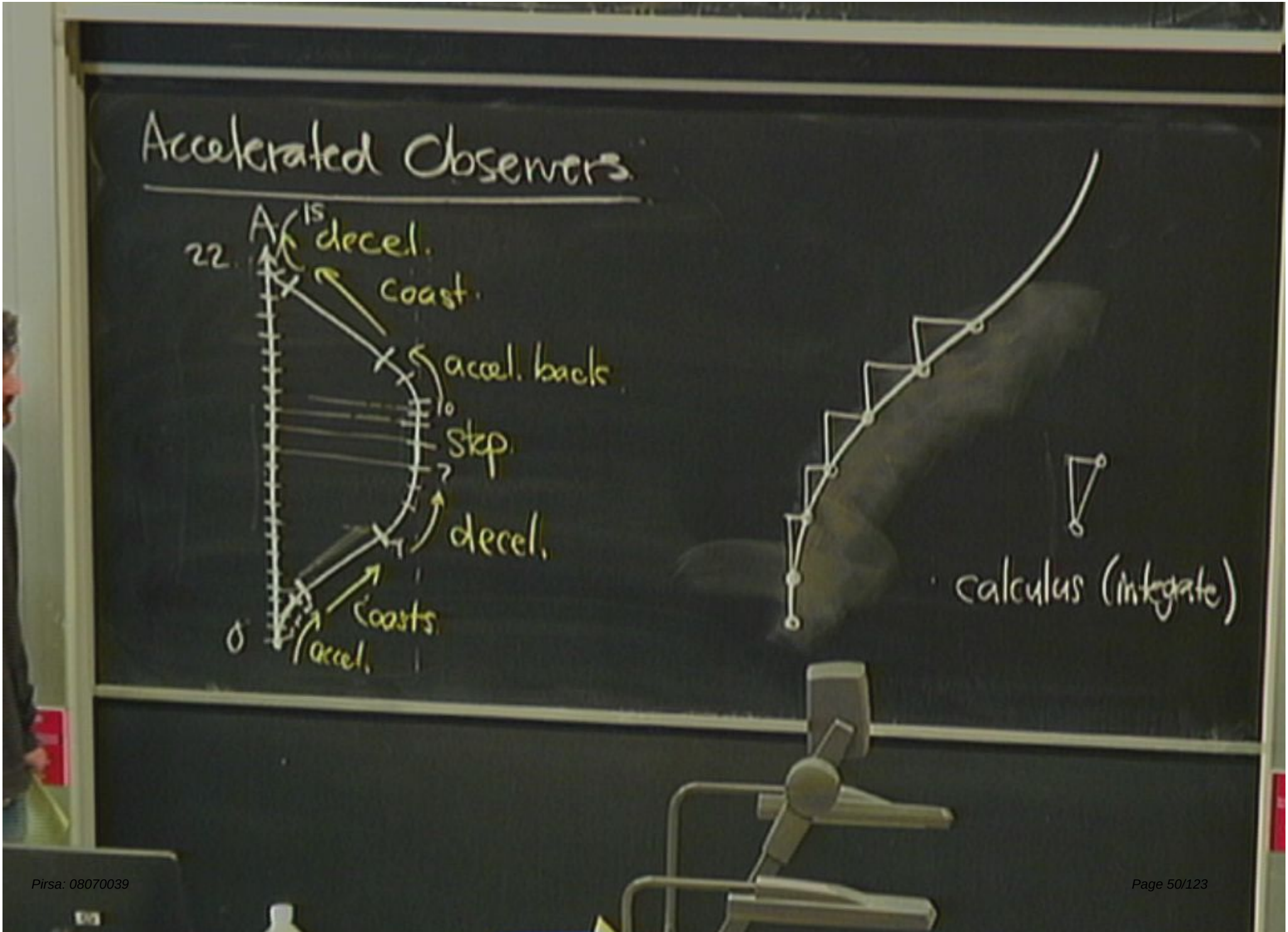


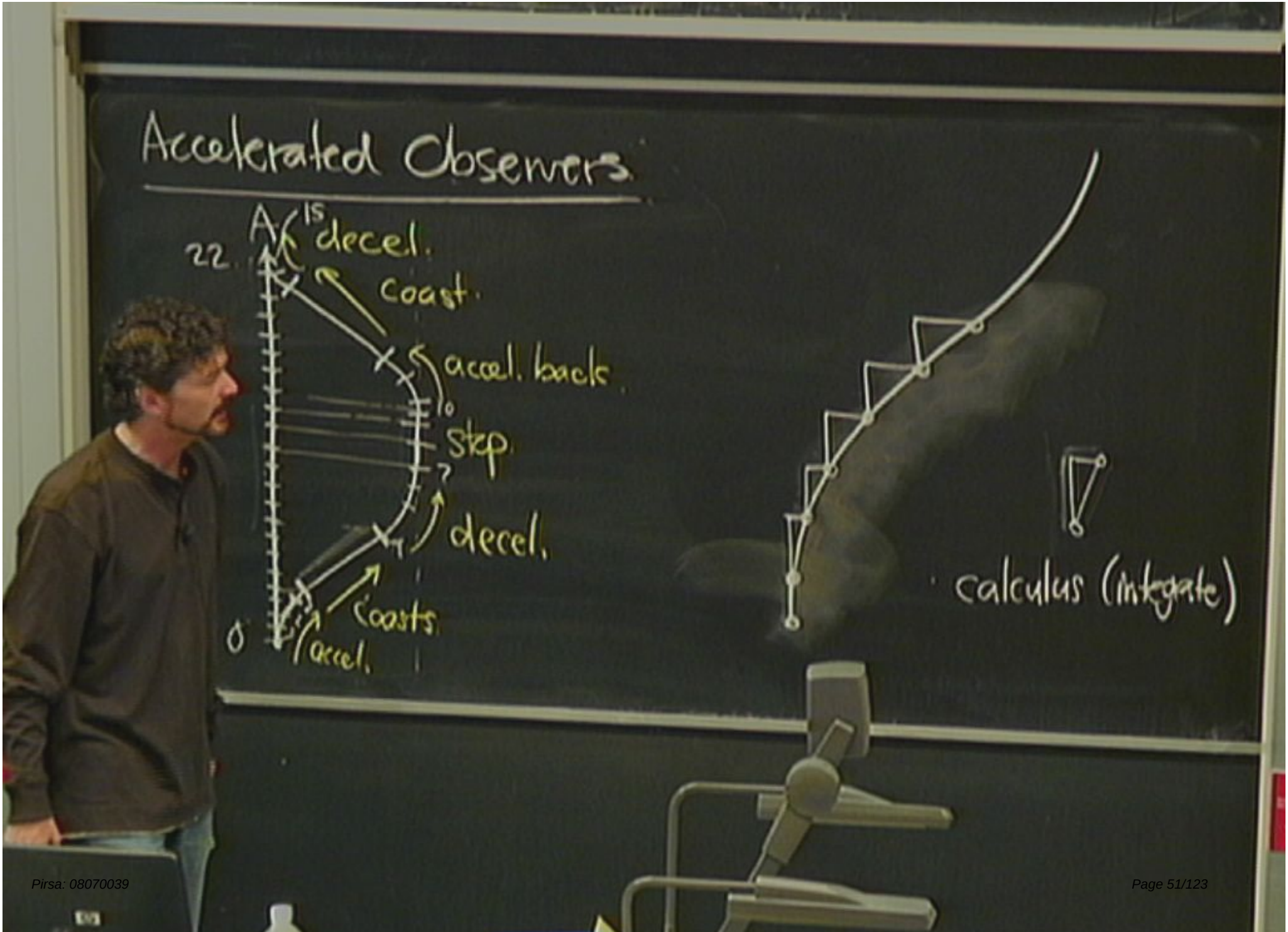

Straight line is longest in Minkowski.
10
9.9
10
2
1.5
5
1
½
0
10
5
0

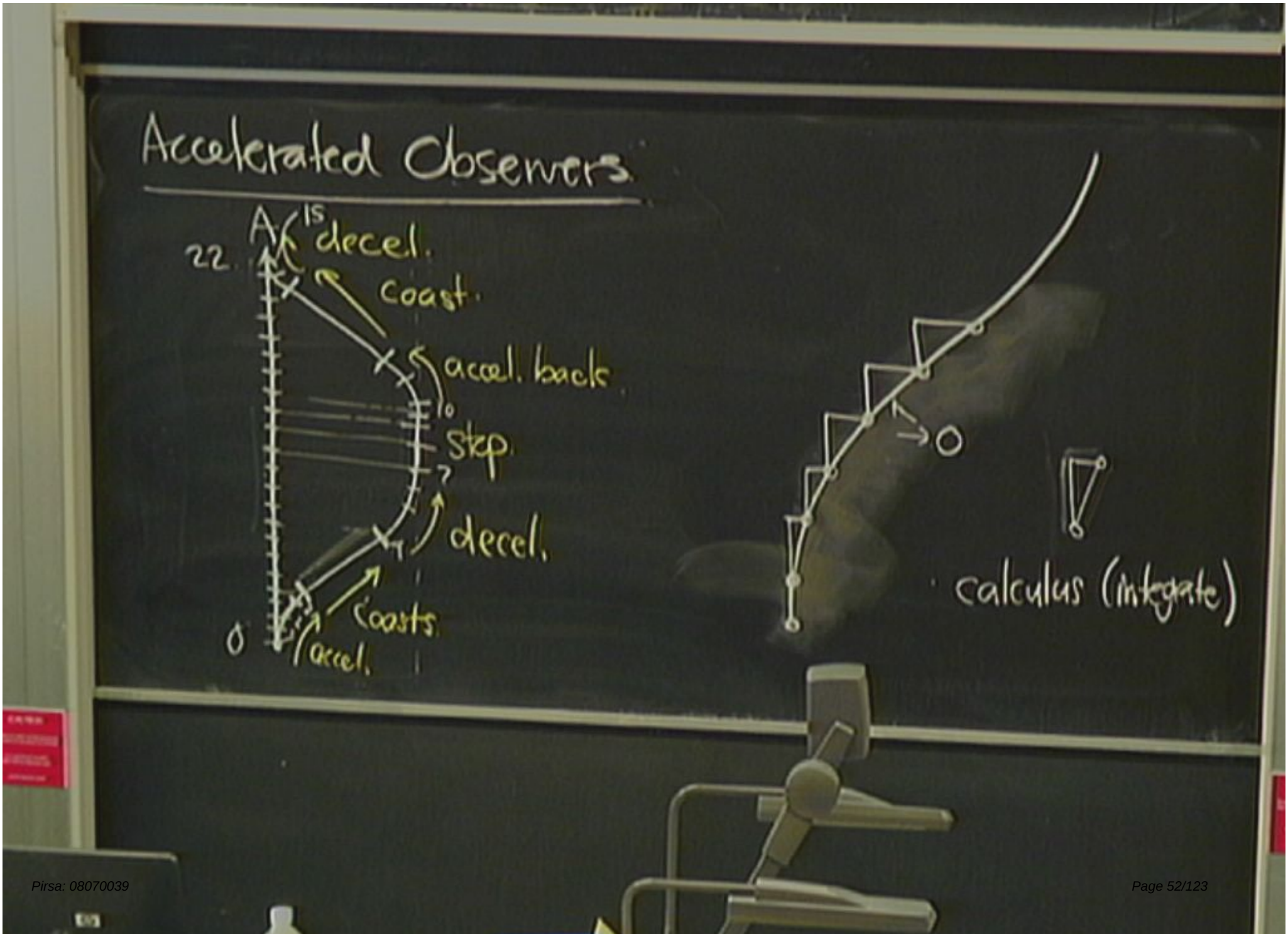

Accelerated Observers.
A
22.
decel.
coast.
accel. back
stop.
decel.
coasts.
accel.
0.


Accelerated Observers.
A
22.
decel.
Coast.
accel. back
stop.
decel.
Coasts.
accel.
O

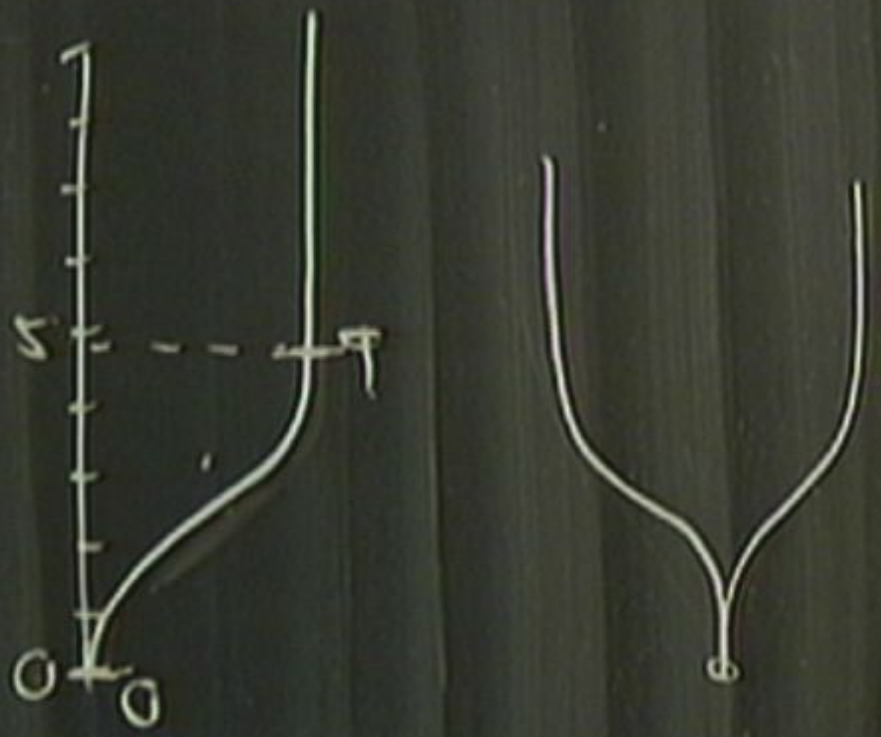

Accelerated Observers
A
15
decel.
22
coast.
accel. back
10
stop.
7
decel.
coasts
0
accel.


Accelerated Observers
A
15
22
decel.
coast.
accel. back
stop
decel.
coasts
0
accel.
calculus (integrate)

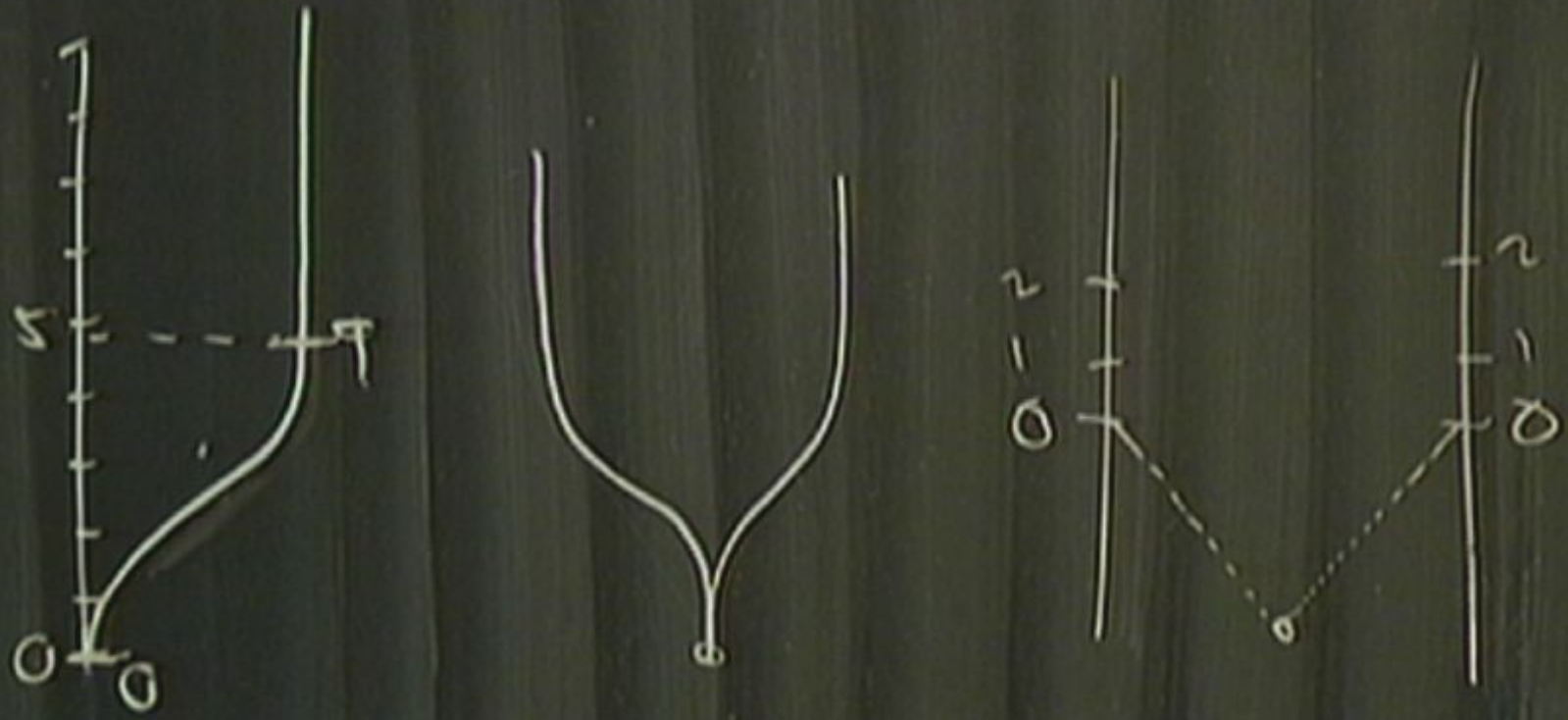

Accelerated Observers
A
22
decel.
coast
accel. back
stop
decel.
coasts
accel.
0
calculus (integrate)


Accelerated Observers
A
15
22
decel.
coast.
accel. back
stop
decel.
coasts
0
accel.
0
calculus (integrate)

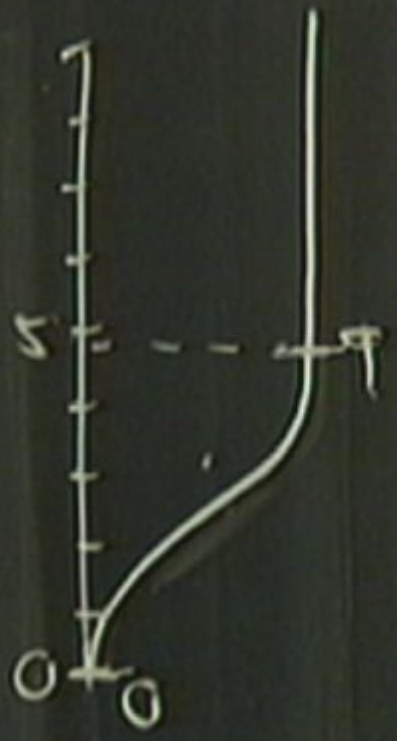
Synchronizing Clocks

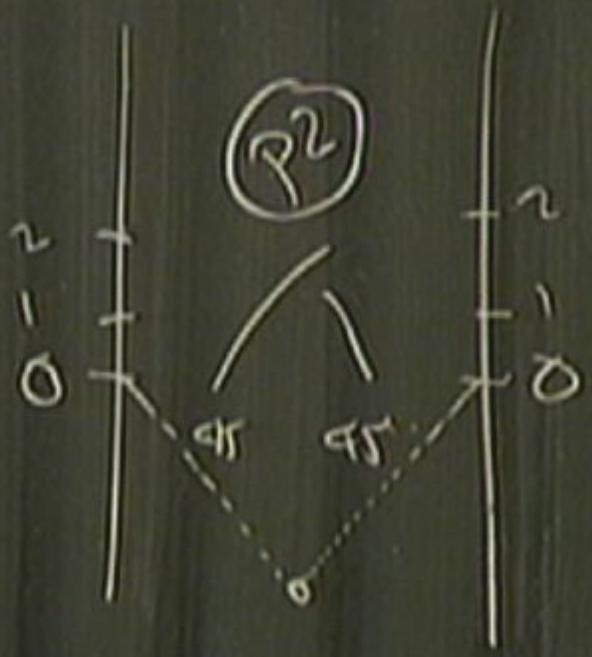


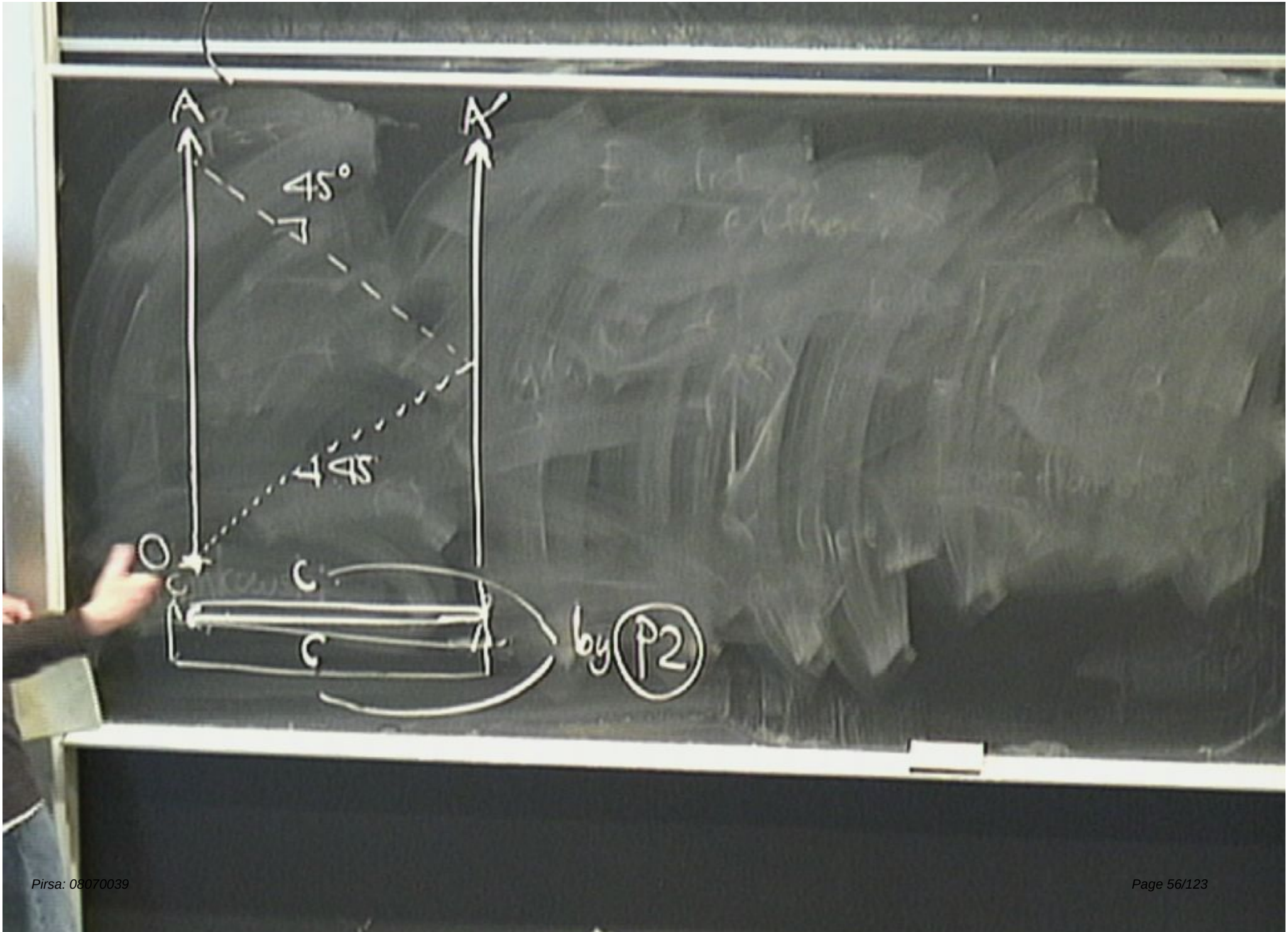
Synchronizing Clocks

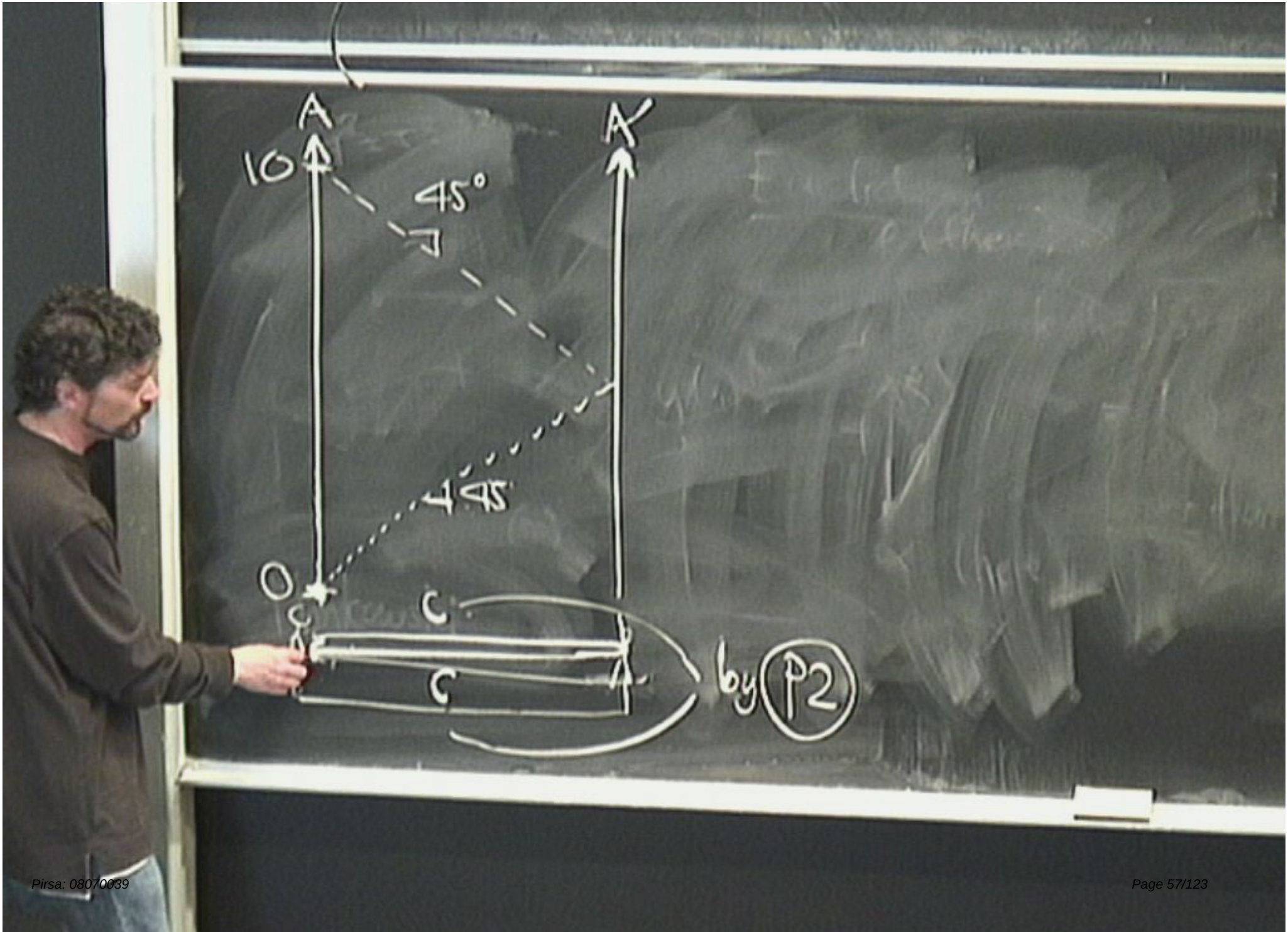


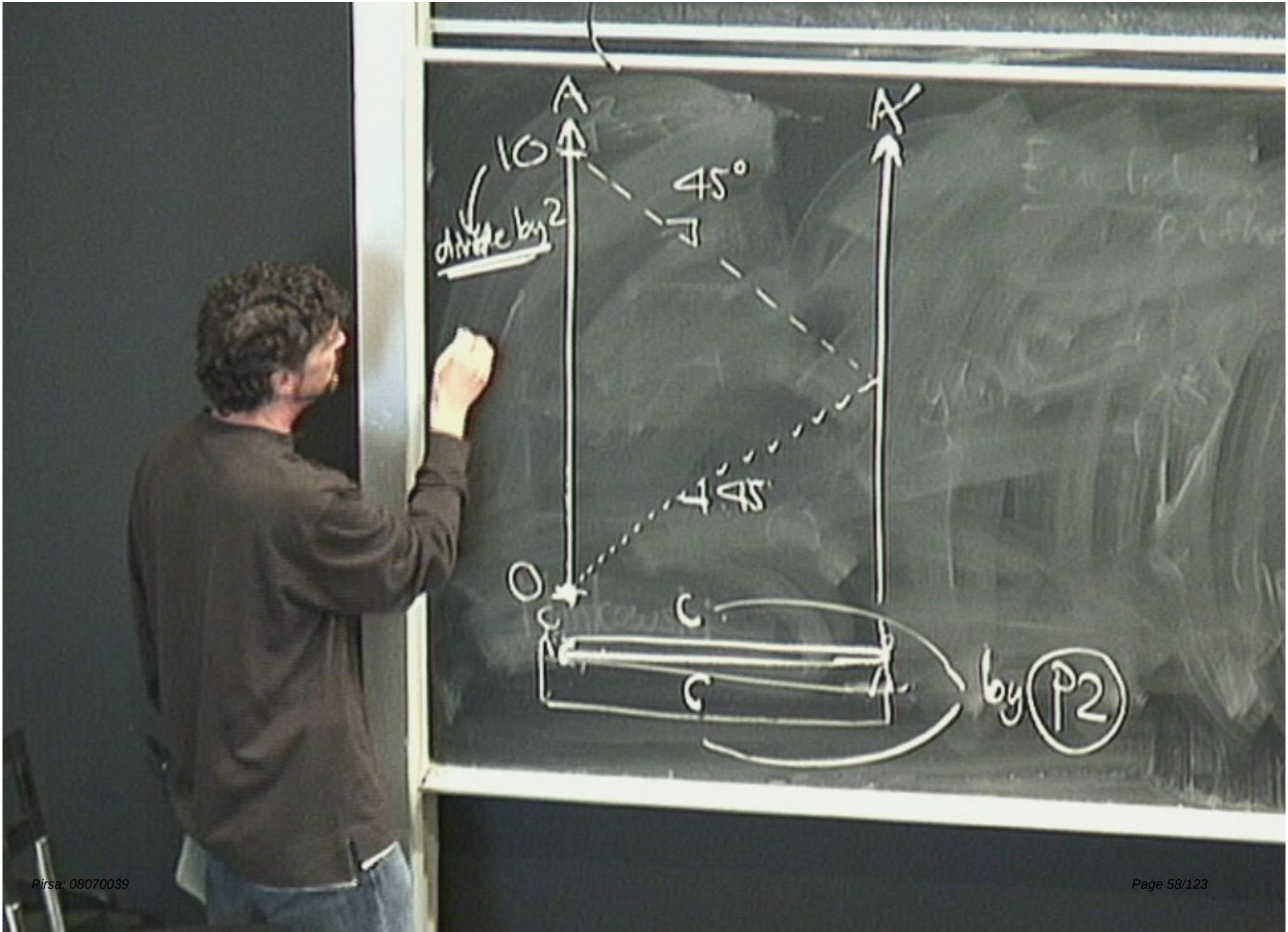
Synchronizing Clocks

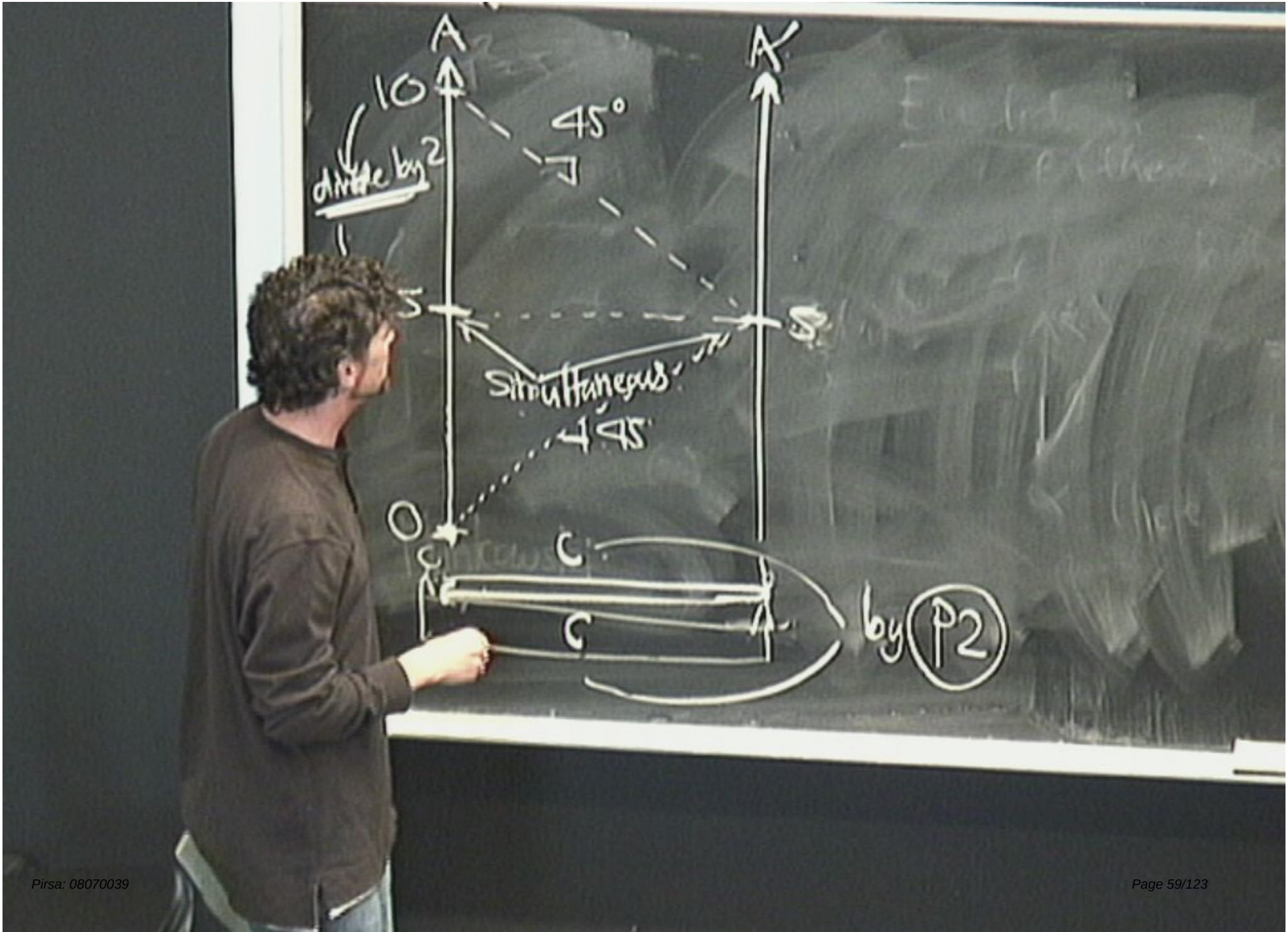


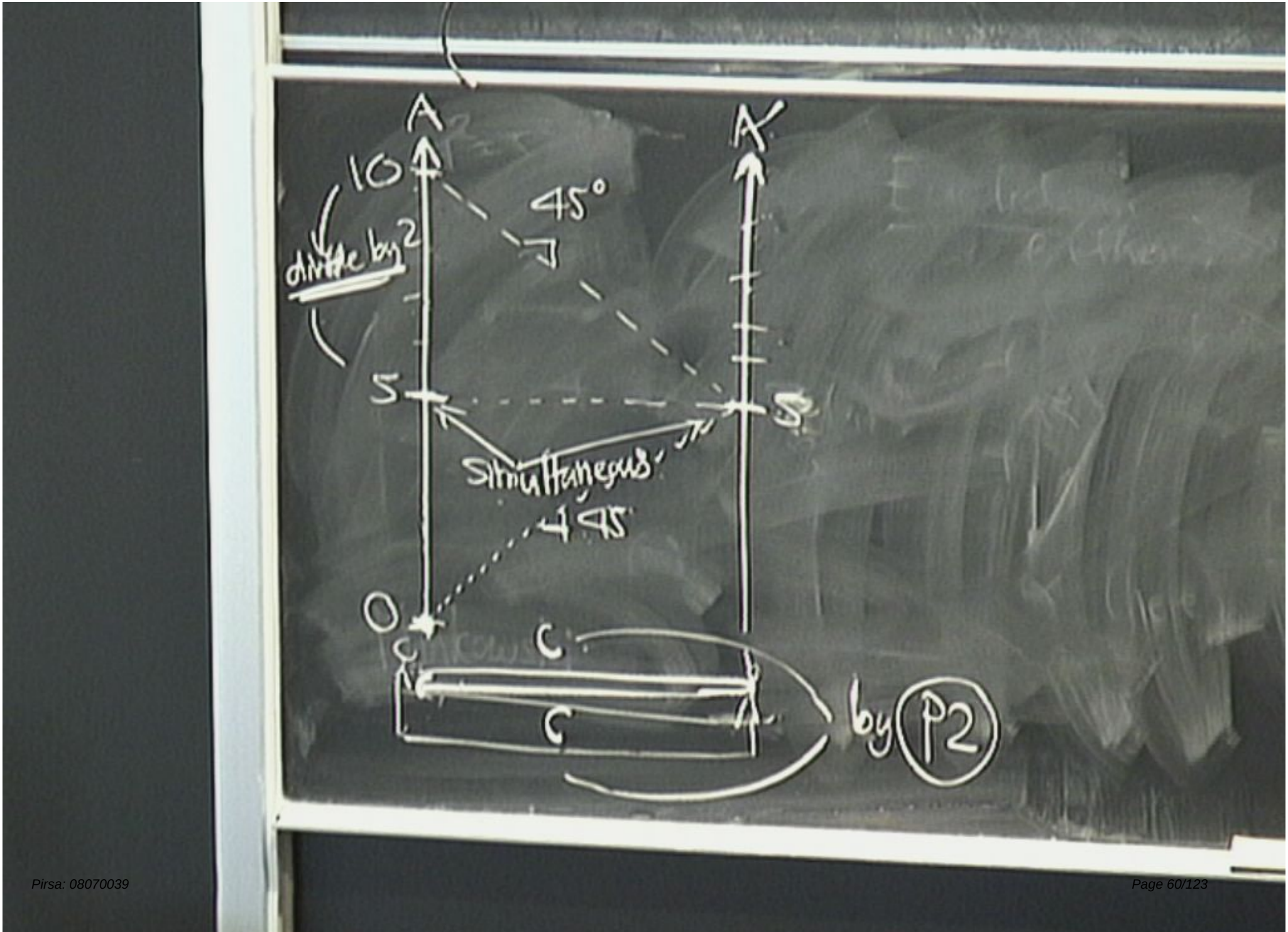


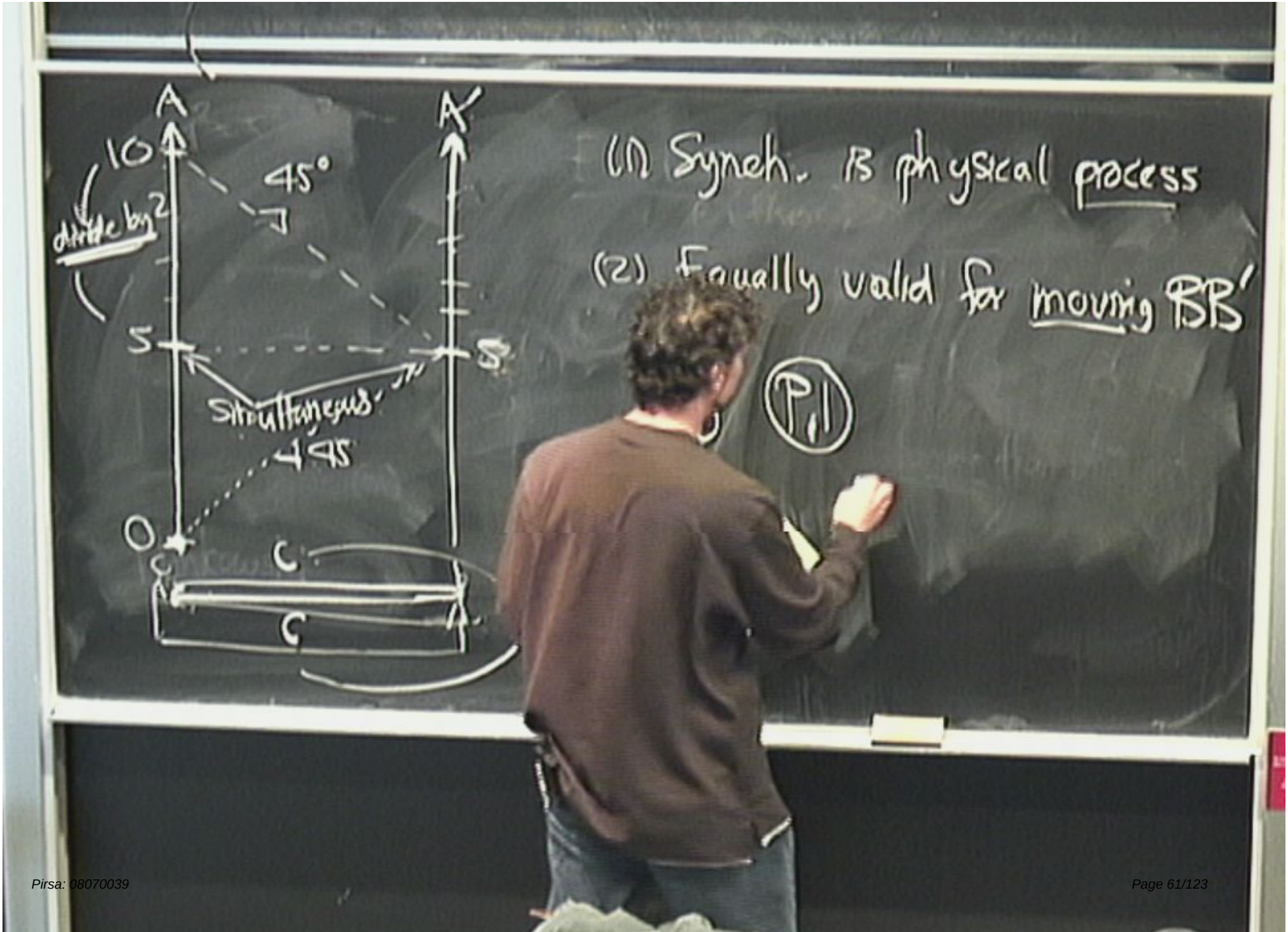

A
A'
45°
45
O
C
C
C
by P2

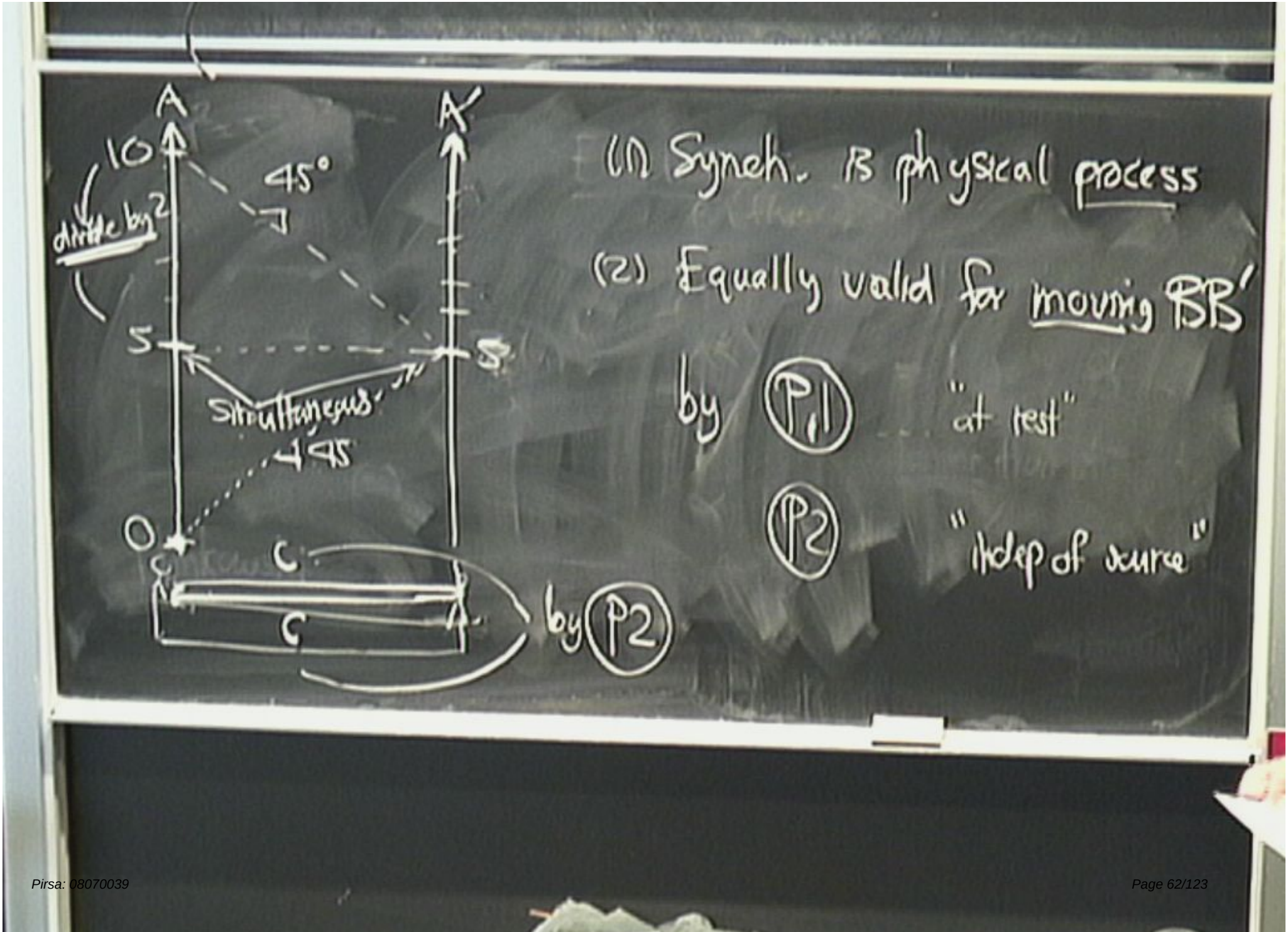

A
A'
10
45°
45°
O
C
C
by P2

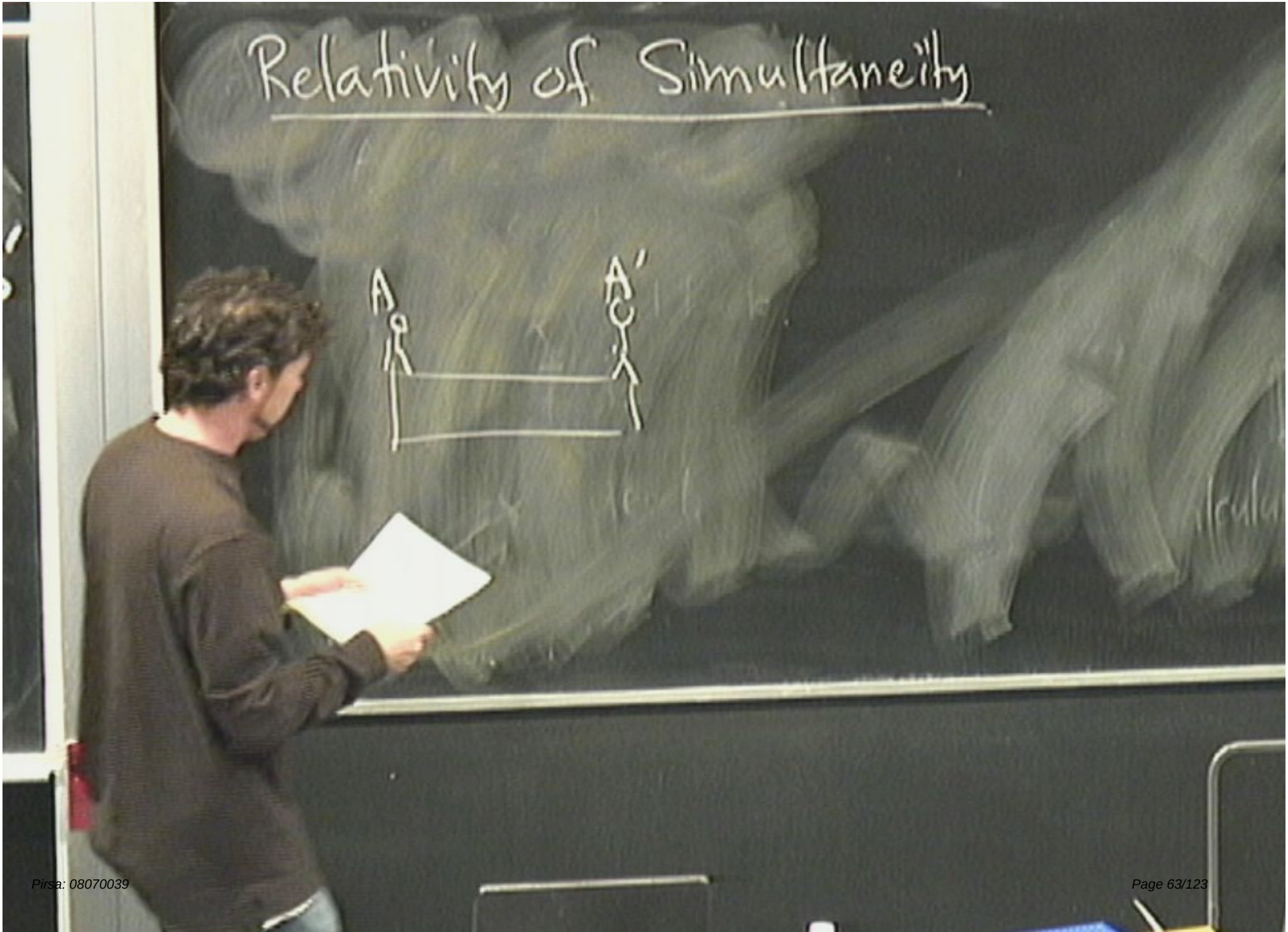

A
A'
10
divide by 2
45°
45°
O
C
C
by P2

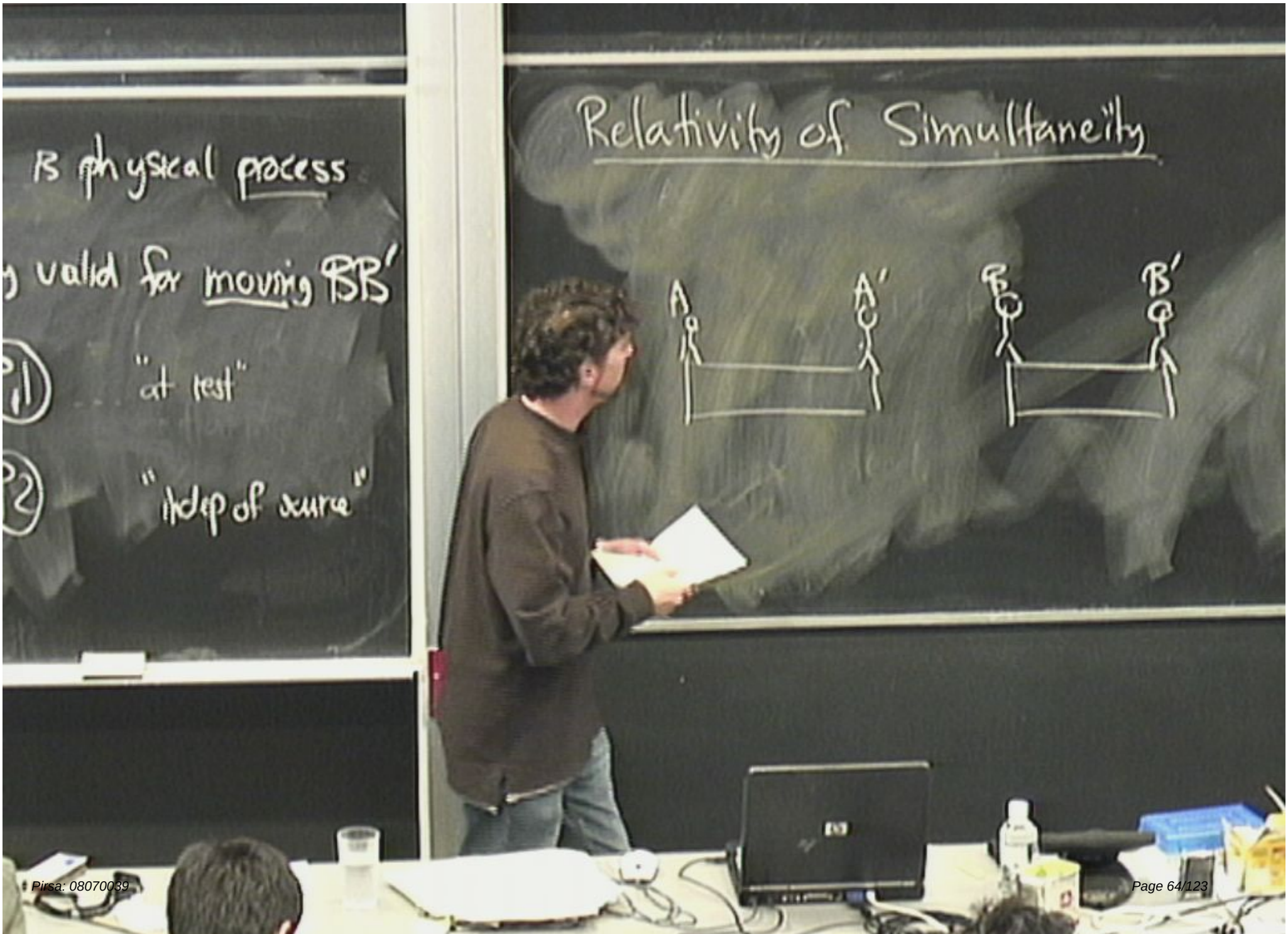

A
A'
10
divide by 2
45°
S
S'
Simultaneous
45°
O
C
C
C
by P2

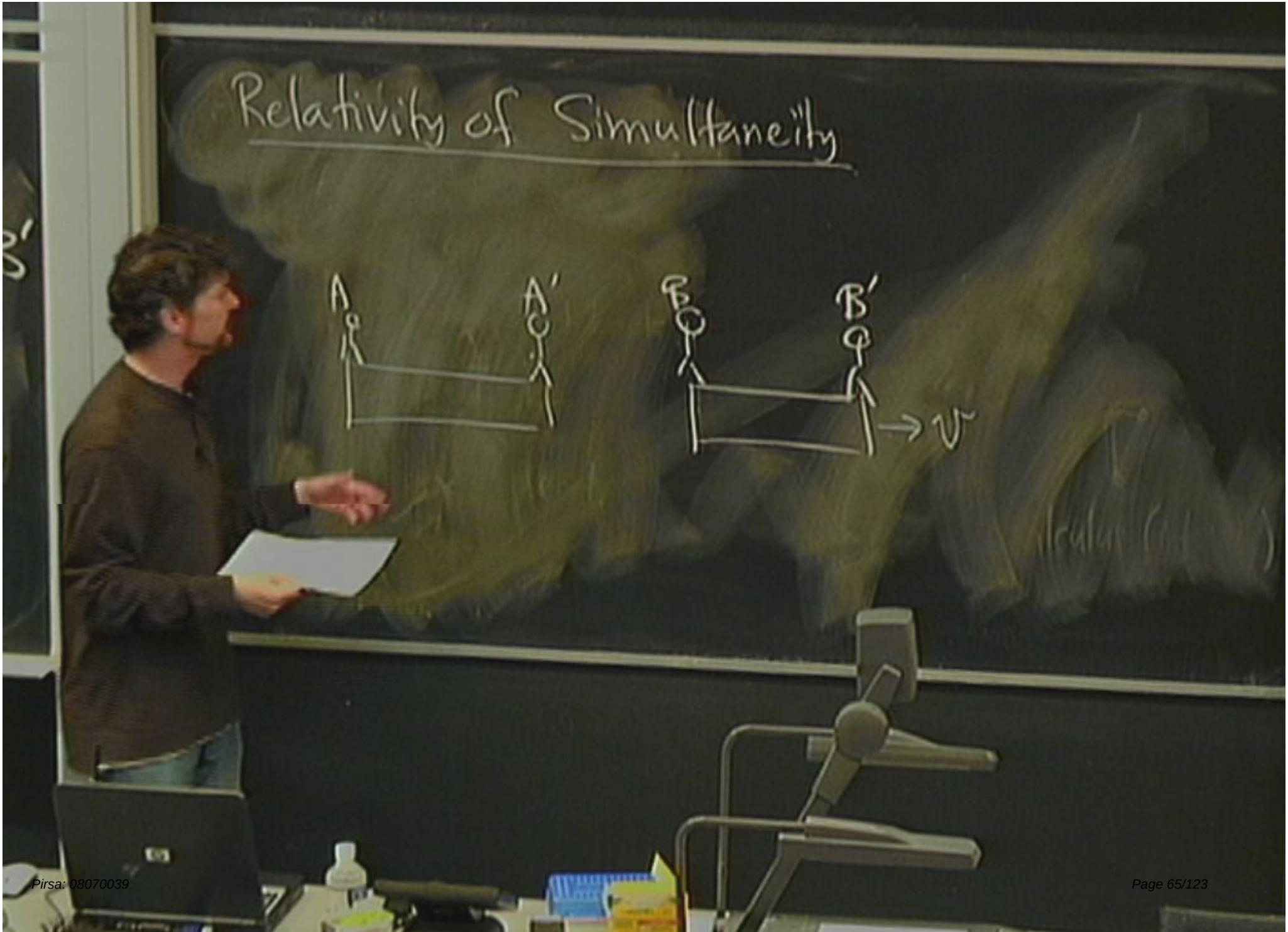

A
A'
10
divide by 2
45°
S
S'
simultaneous
45
O
C
C
C
by P2

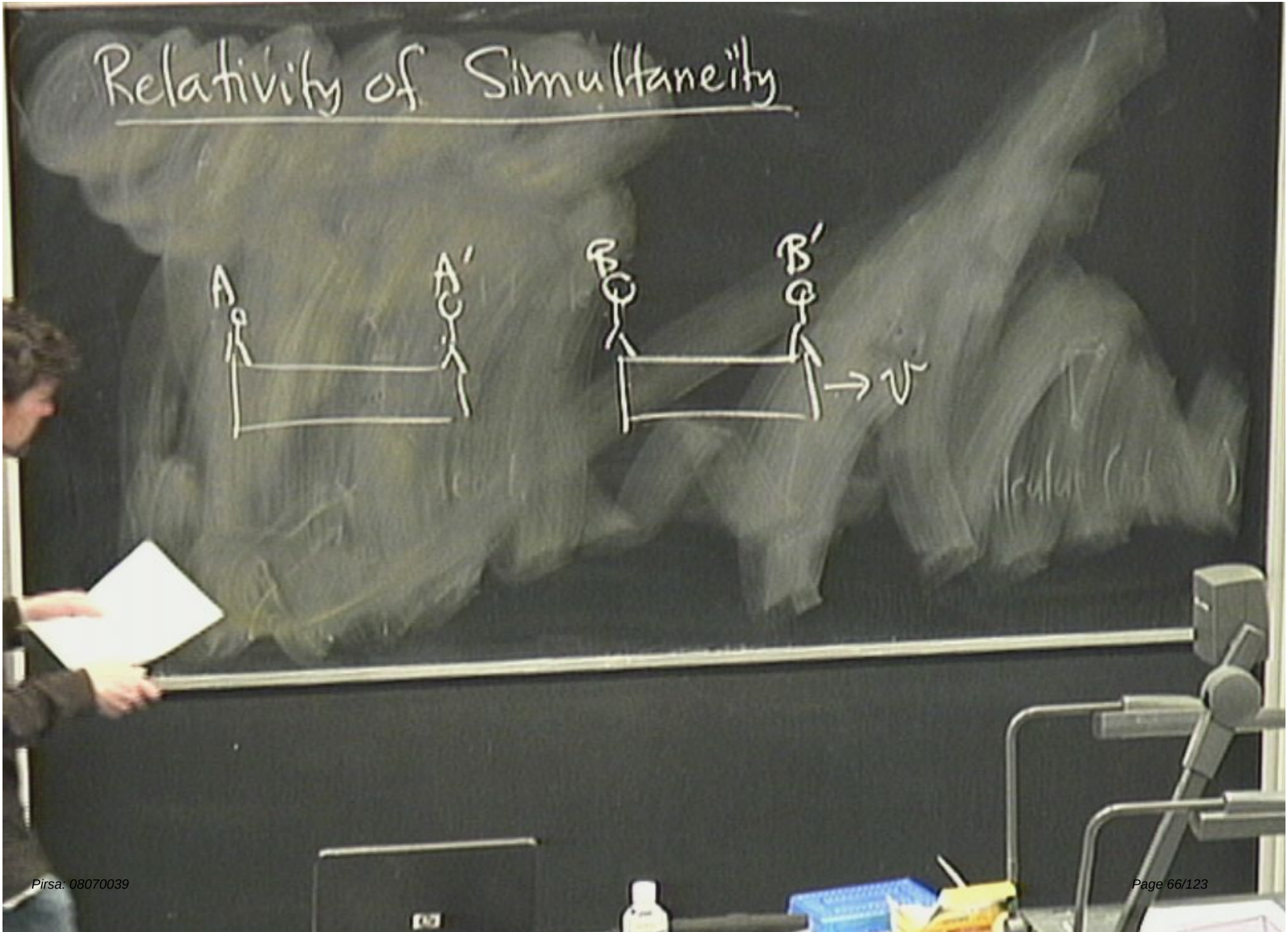

A
A'
10
divide by 2
45°
S
S'
simultaneous
45
O
C
C
C
(1) Synch. is physical process
(2) Equally valid for moving RR'
P1

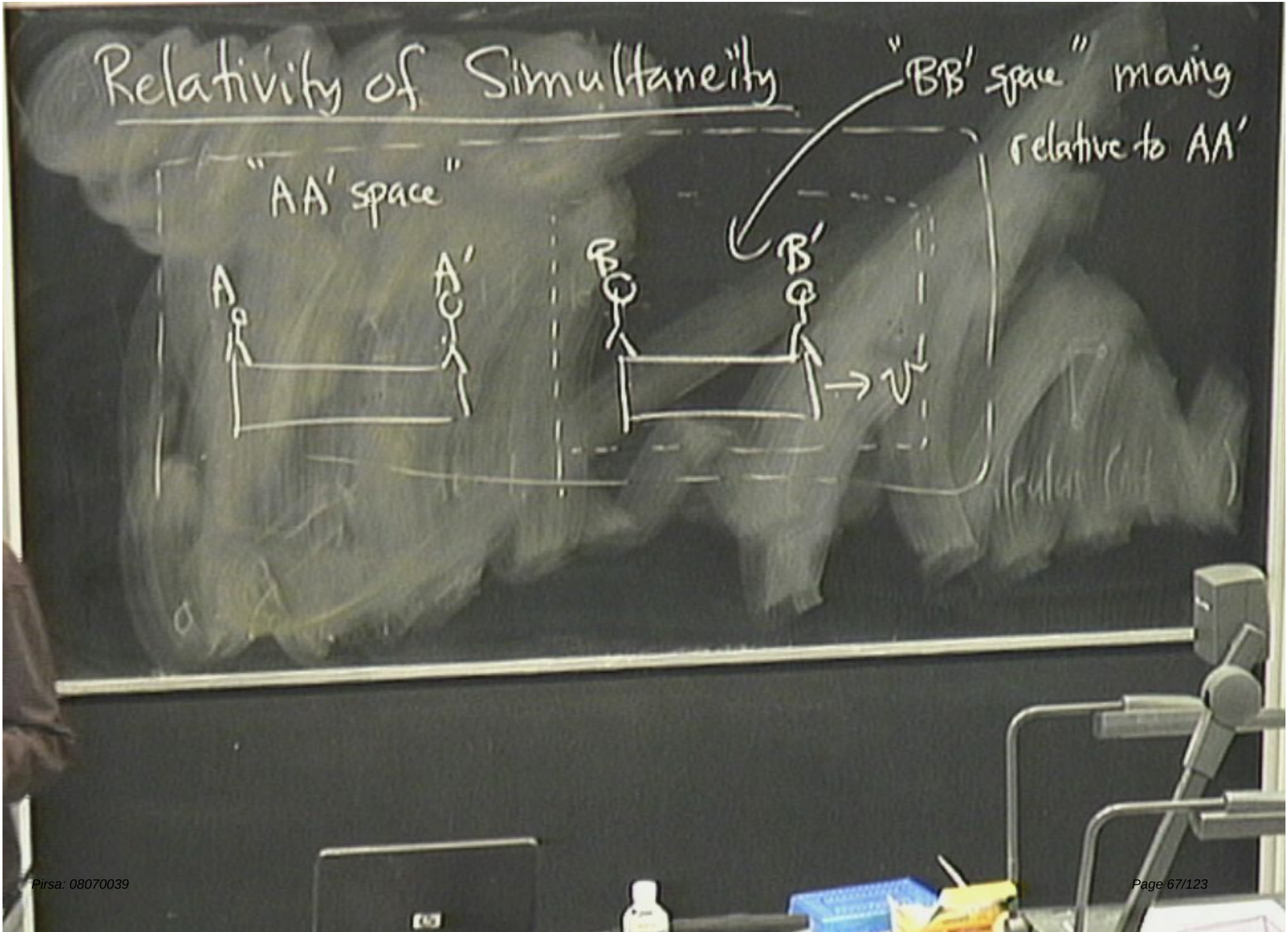

A
A'
10
divide by 2
45°
S
S'
simultaneous
45
O
C
C
C
by P2
(1) Synch. IS physical process
(2) Equally valid for moving IS'
by P1 "at rest"
P2 "Indep of source"

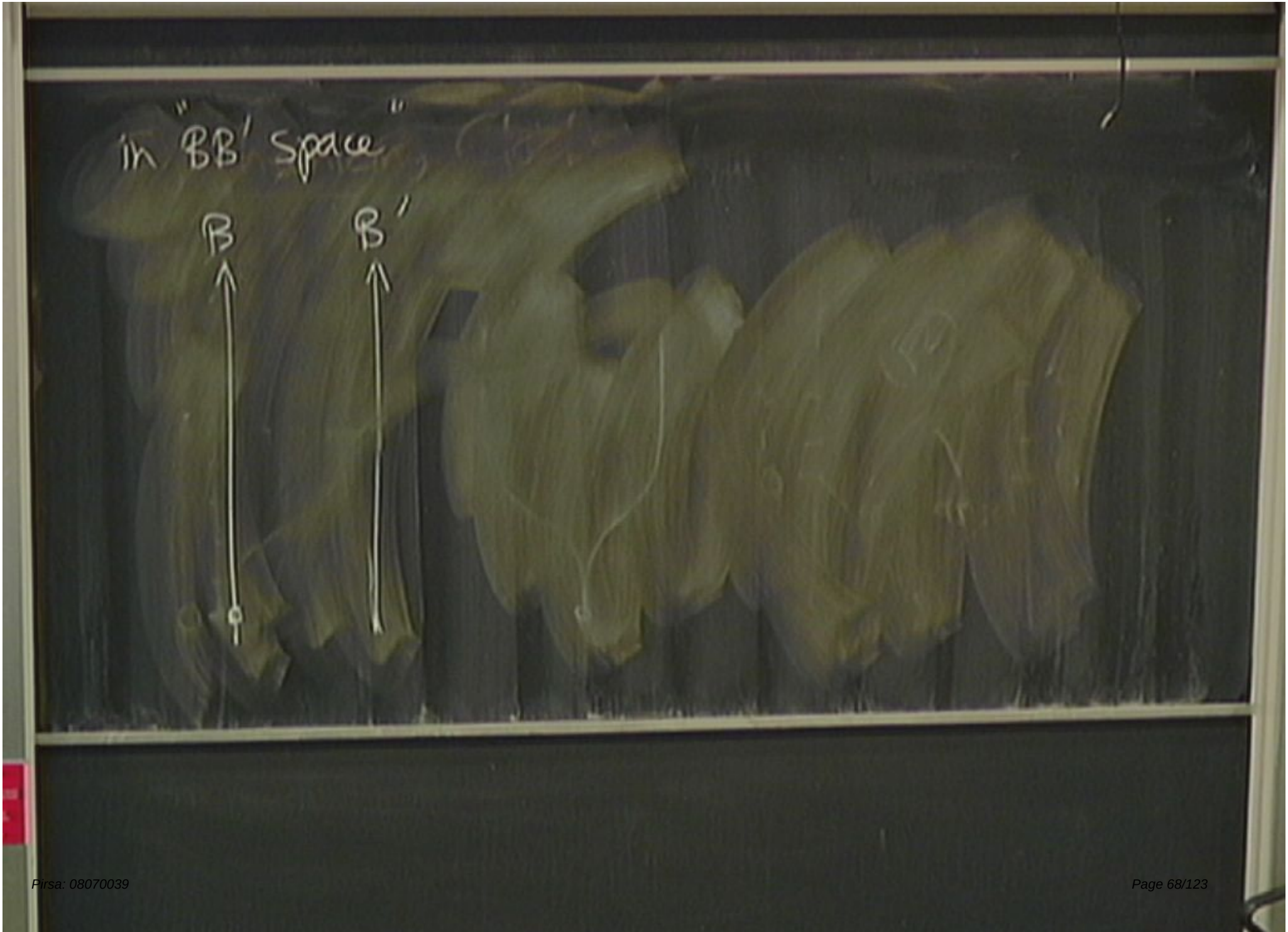

Relativity of Simultaneity
A
A'

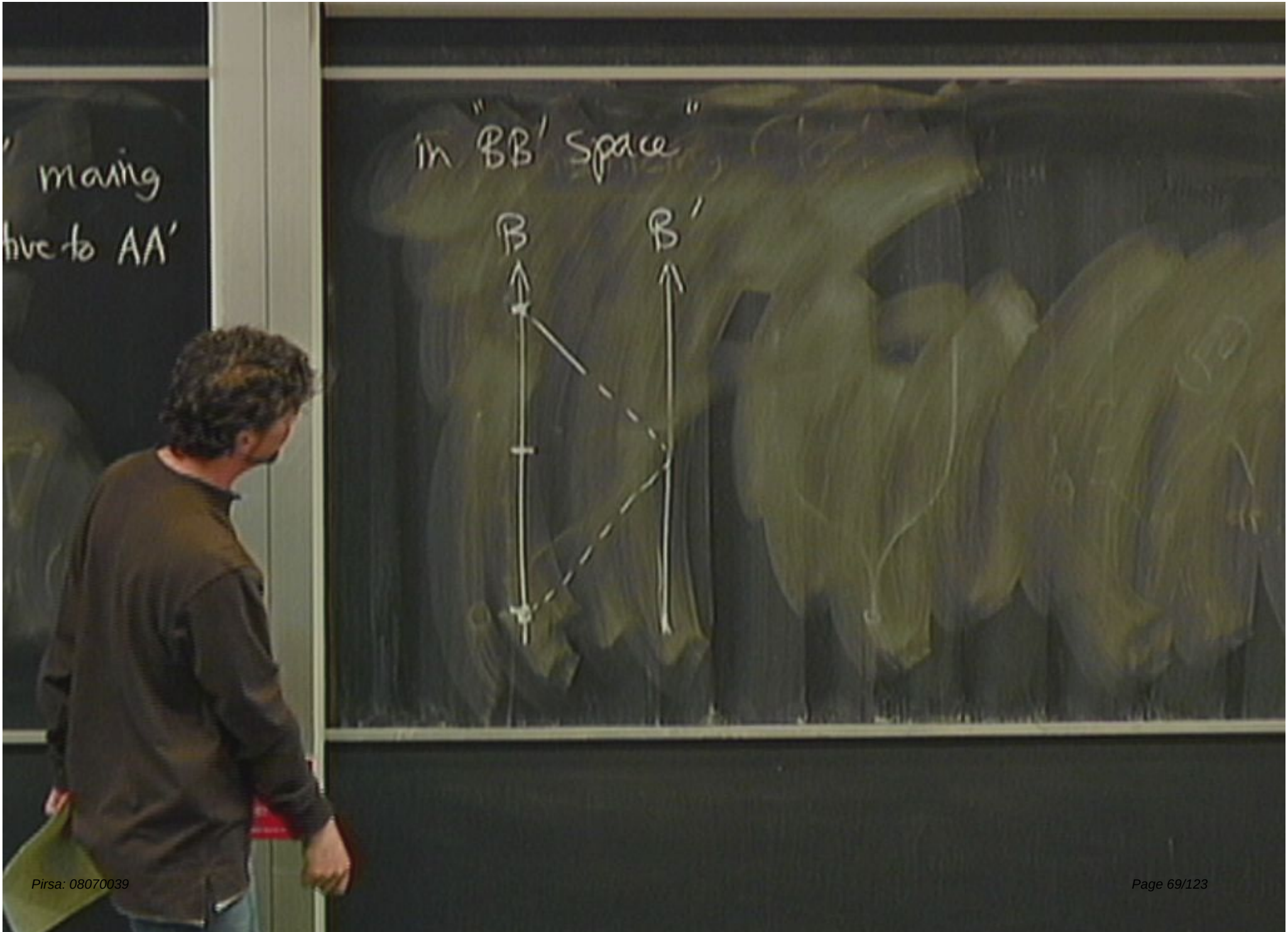

B physical process
y valid for moving BB'
P1) "at rest"
P2) "indep of source"
Relativity of Simultaneity
A
A'
B
B'

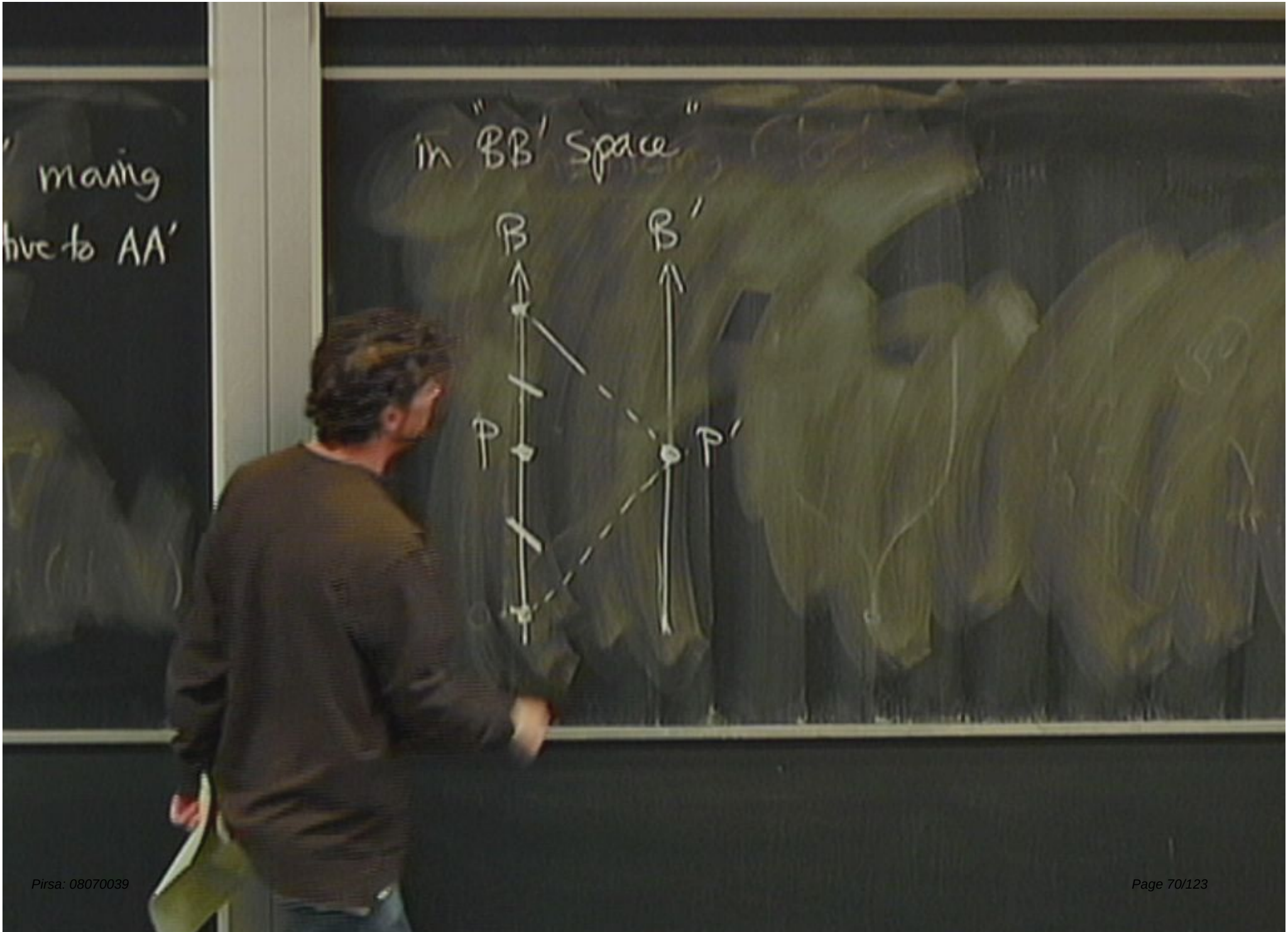

Relativity of Simultaneity
A
A'
B
B'
v

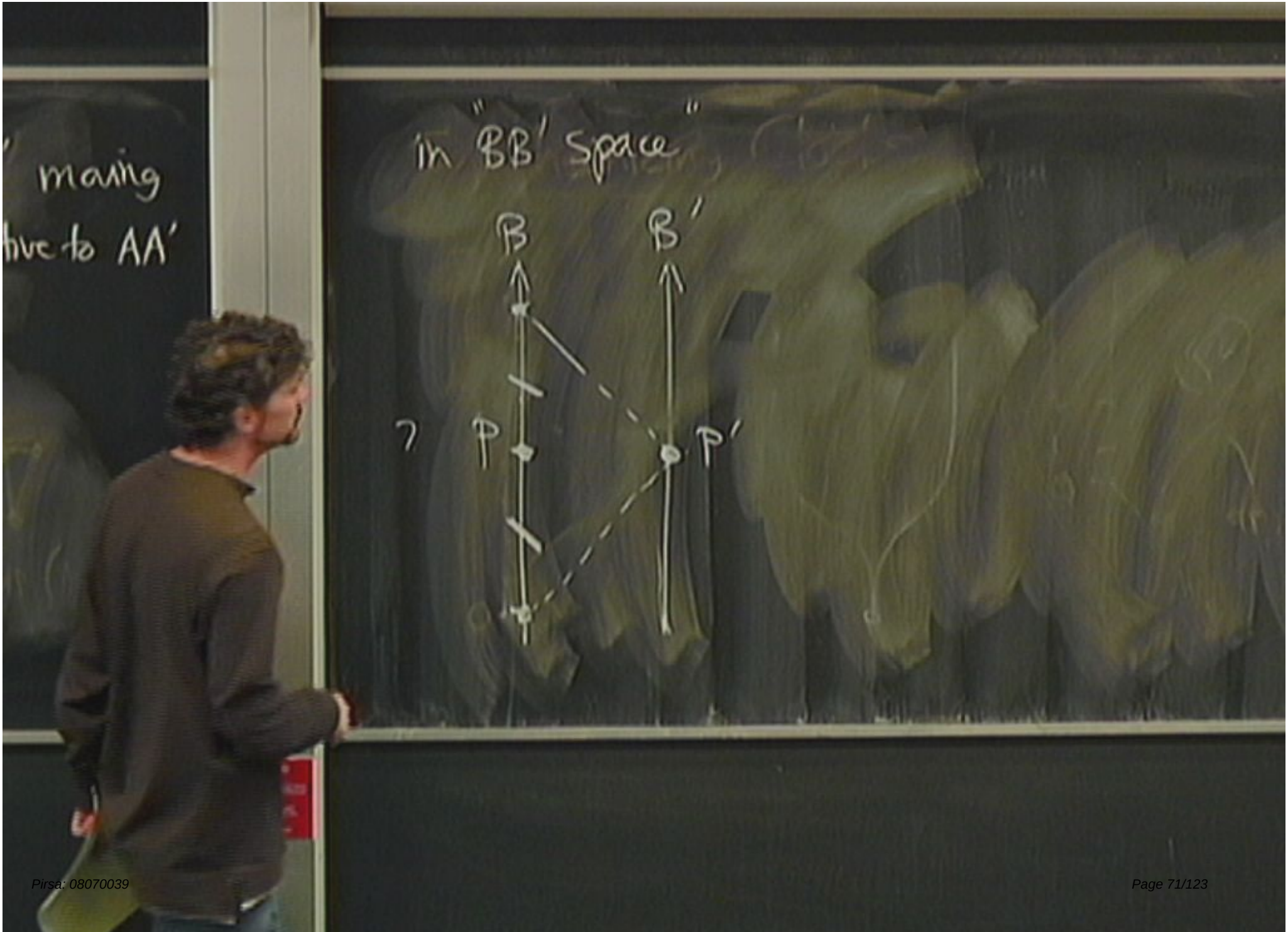

Relativity of Simultaneity
A
A'
B
B'
v

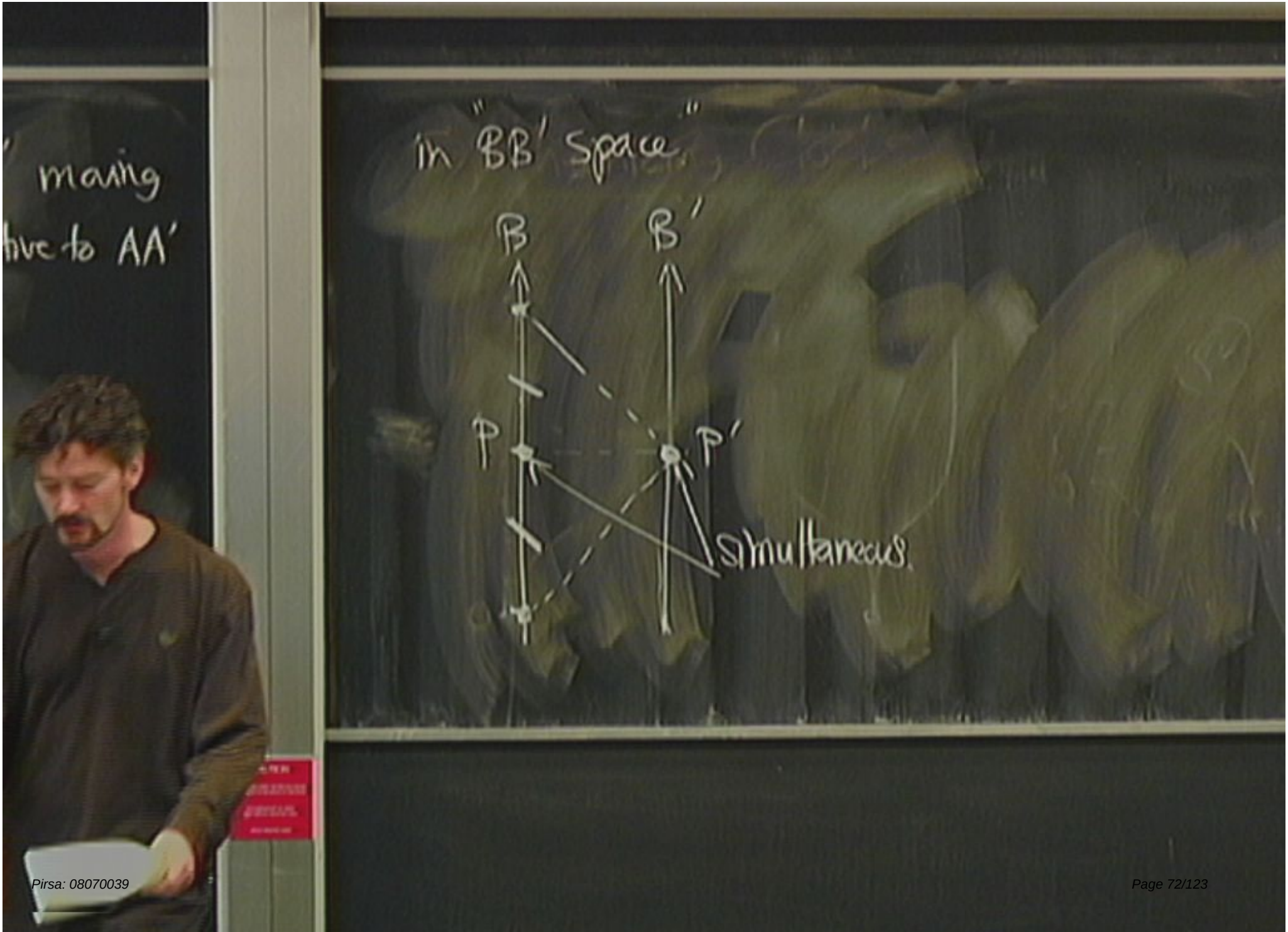

Relativity of Simultaneity
"AA' space"
A
A'
"BB' space" moving relative to AA'
B
B'
v

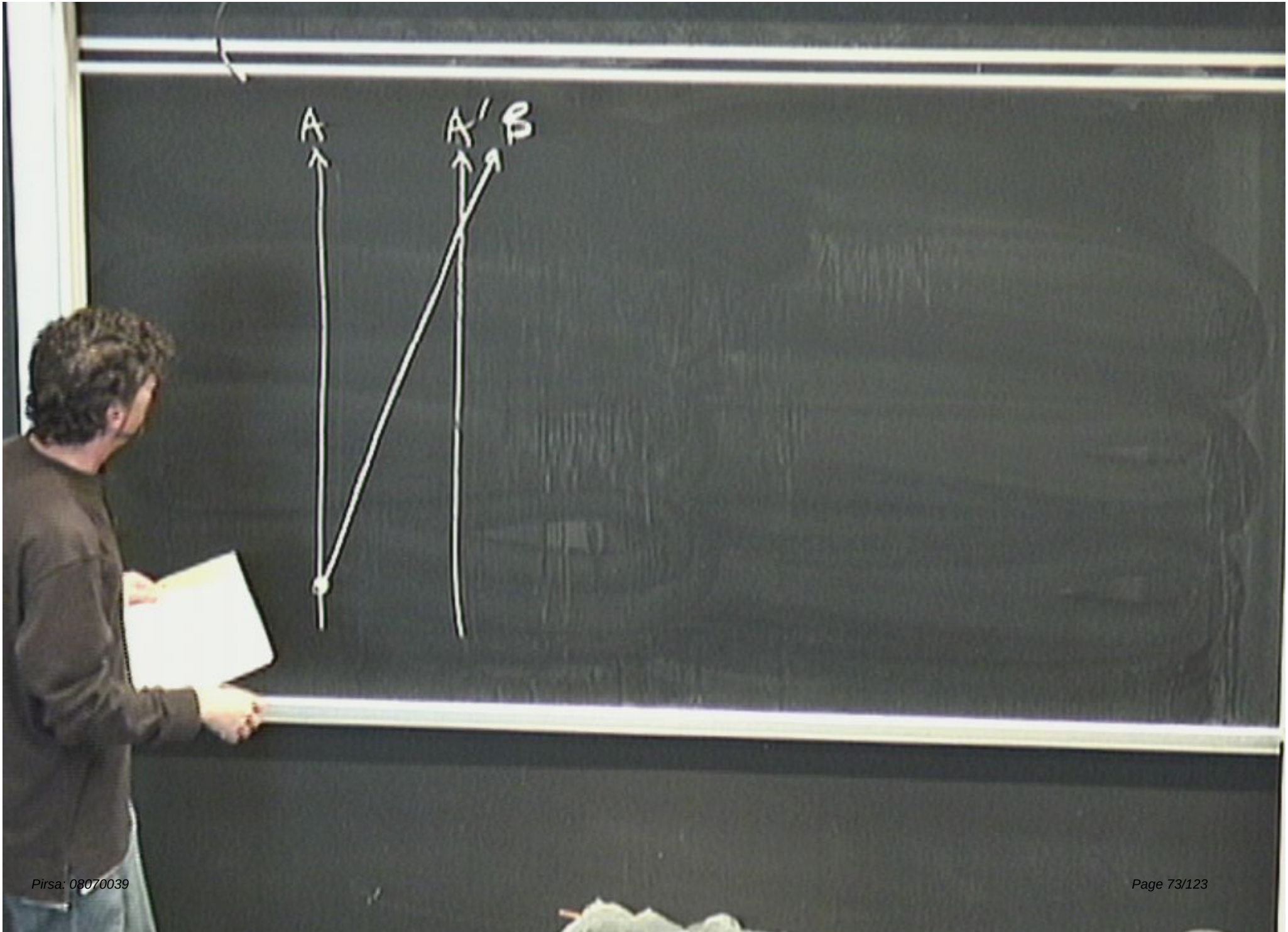

"BB' Space"
B
B'

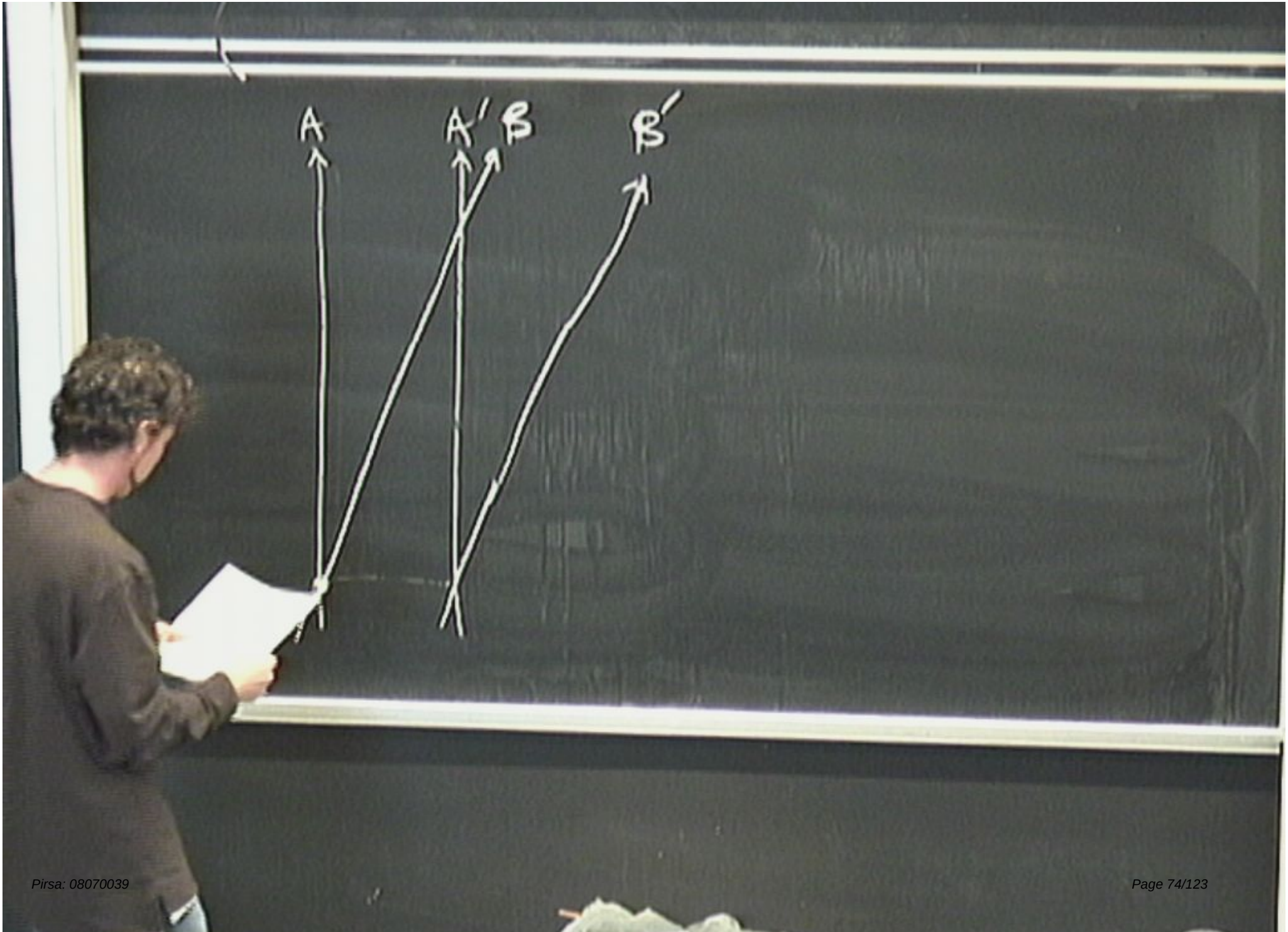

mating
tive to AA'
"in BB' space"
B
B'

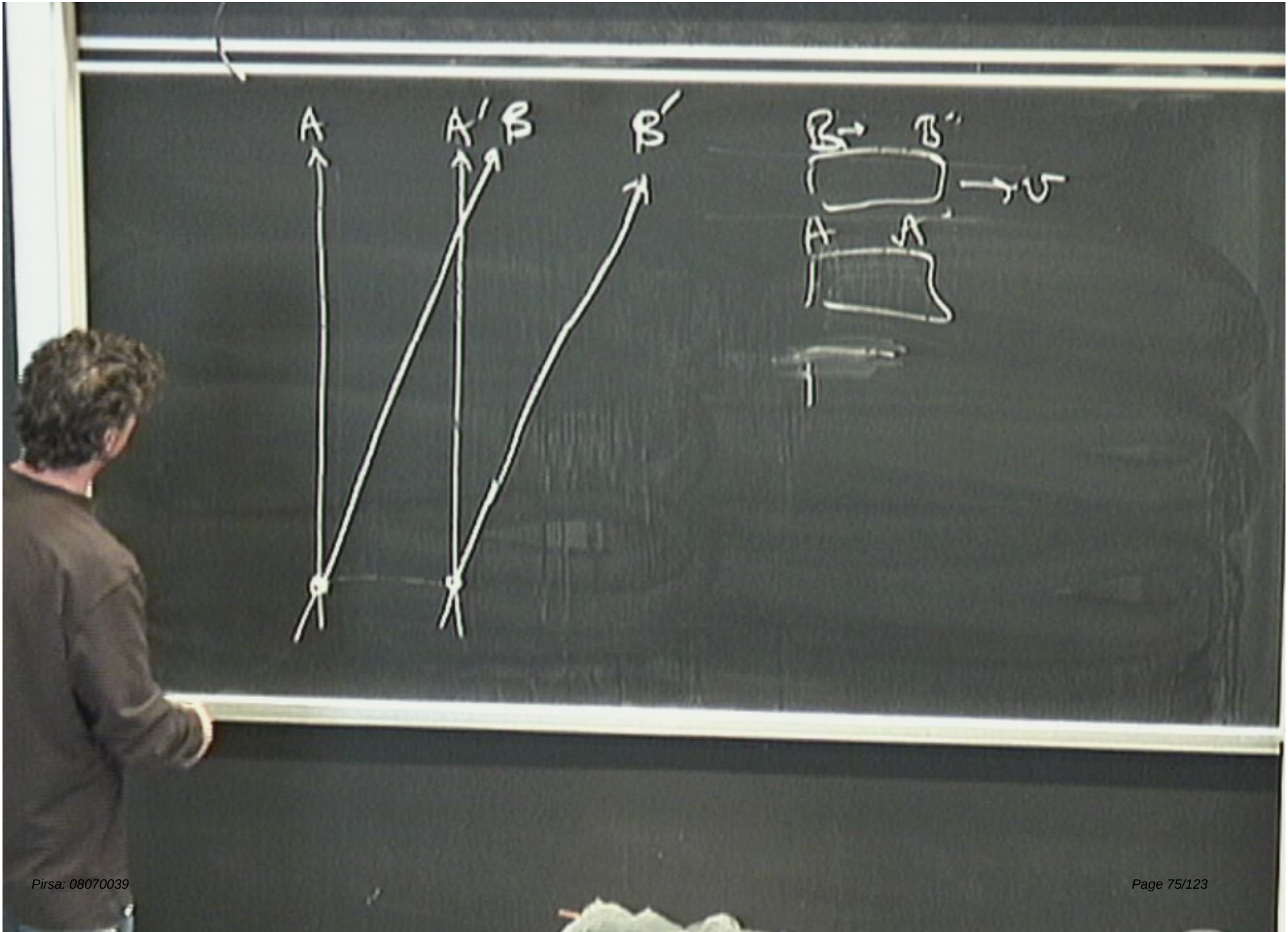

mating
tive to AA'
"in BB' Space"
B
B'
P
P'

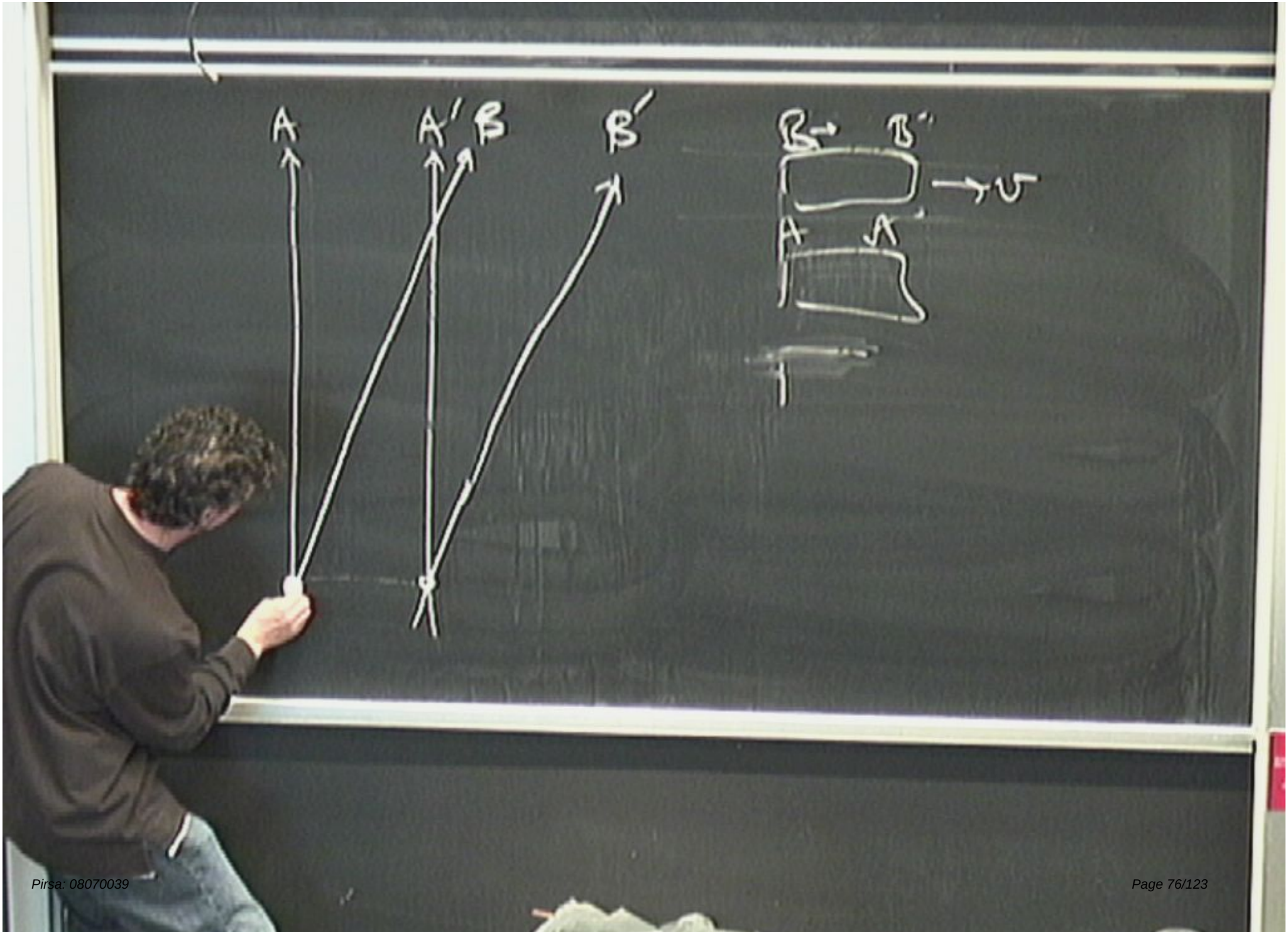

mating
tive to AA'
"in BB' Space"
B
B'
?
P
P'

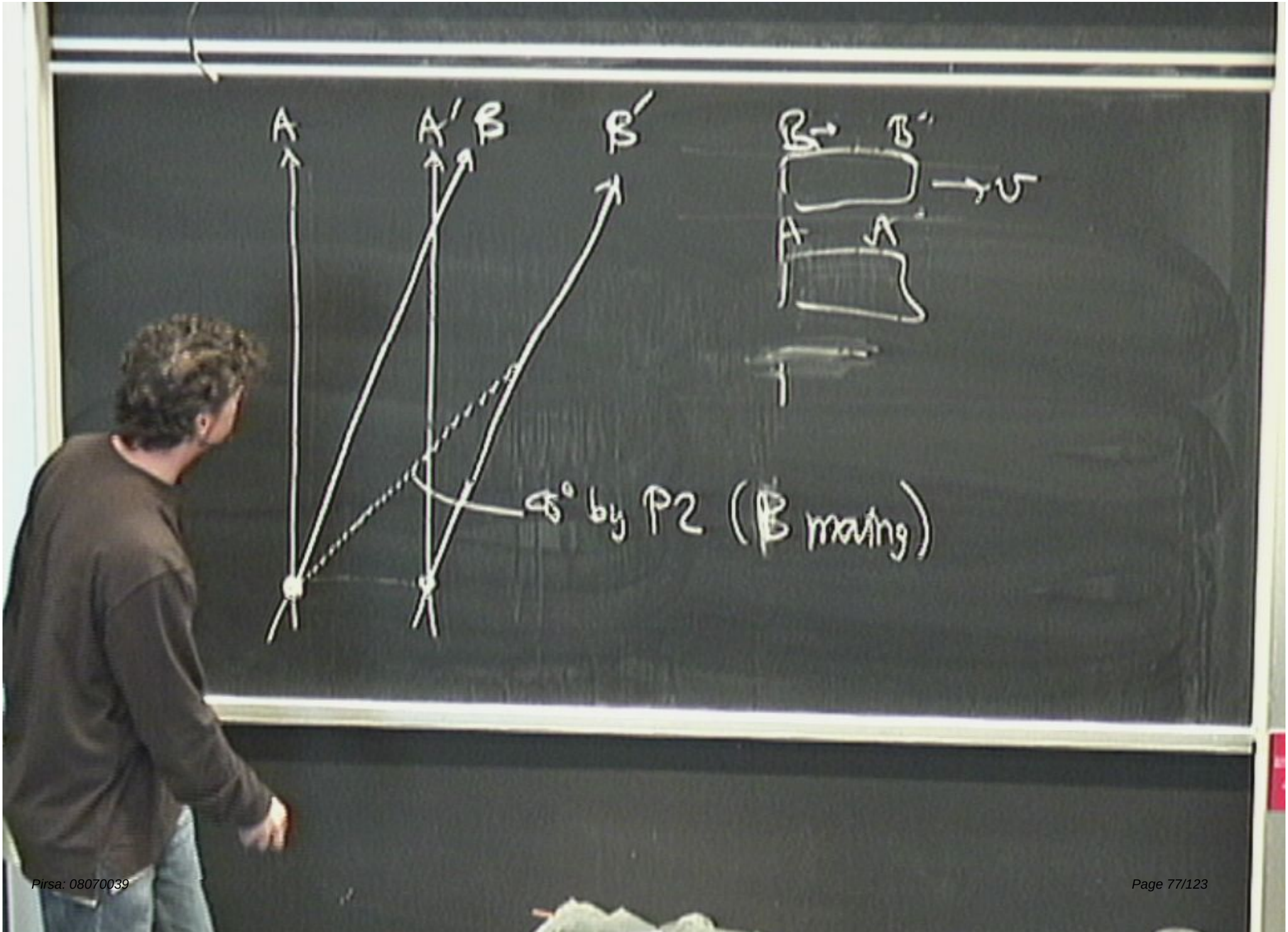

moving
tive to AA'
in "BB' Space"
B
B'
P
P'
simultaneous

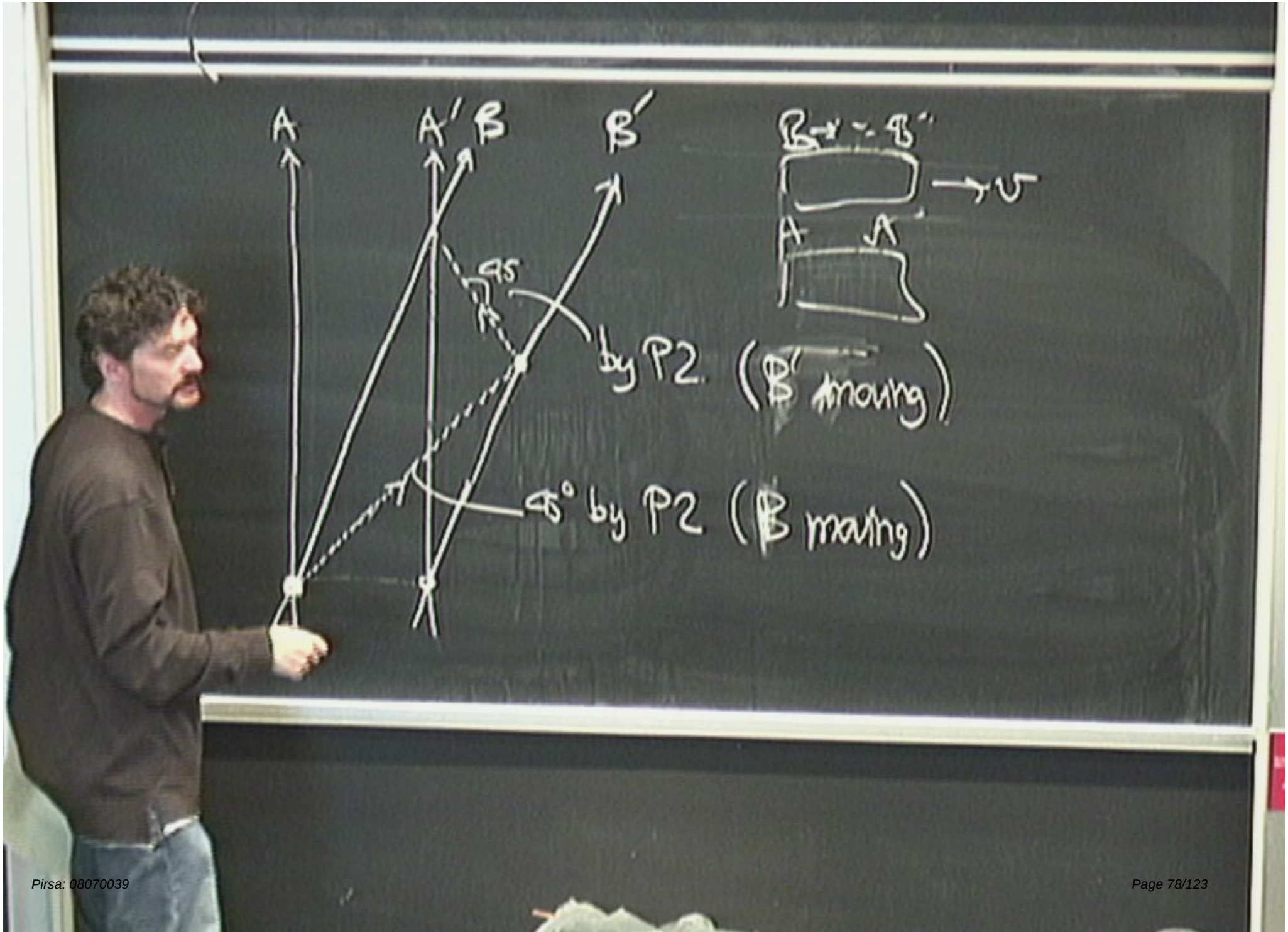

A
A'
B

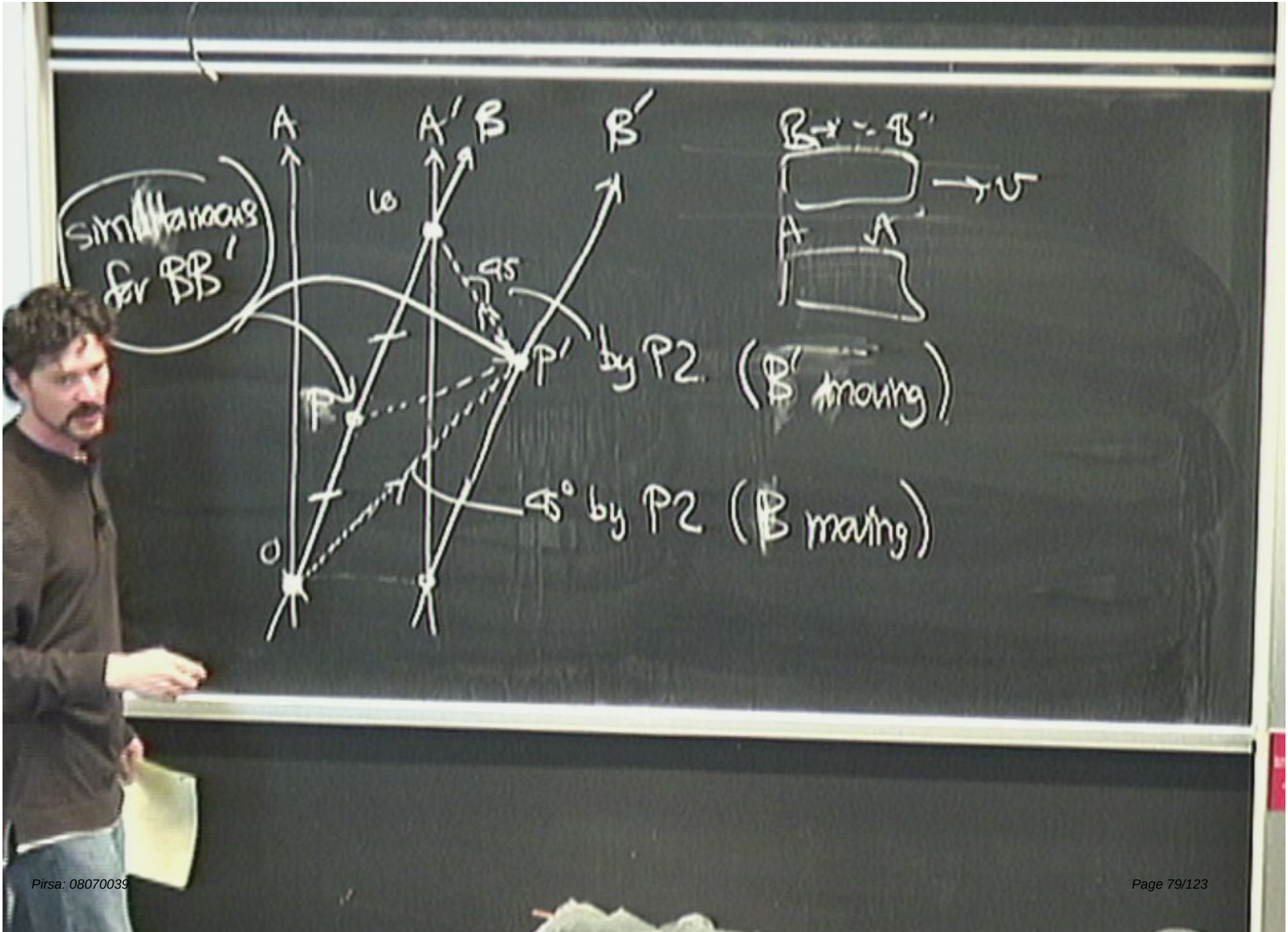

A
A'
B
B'

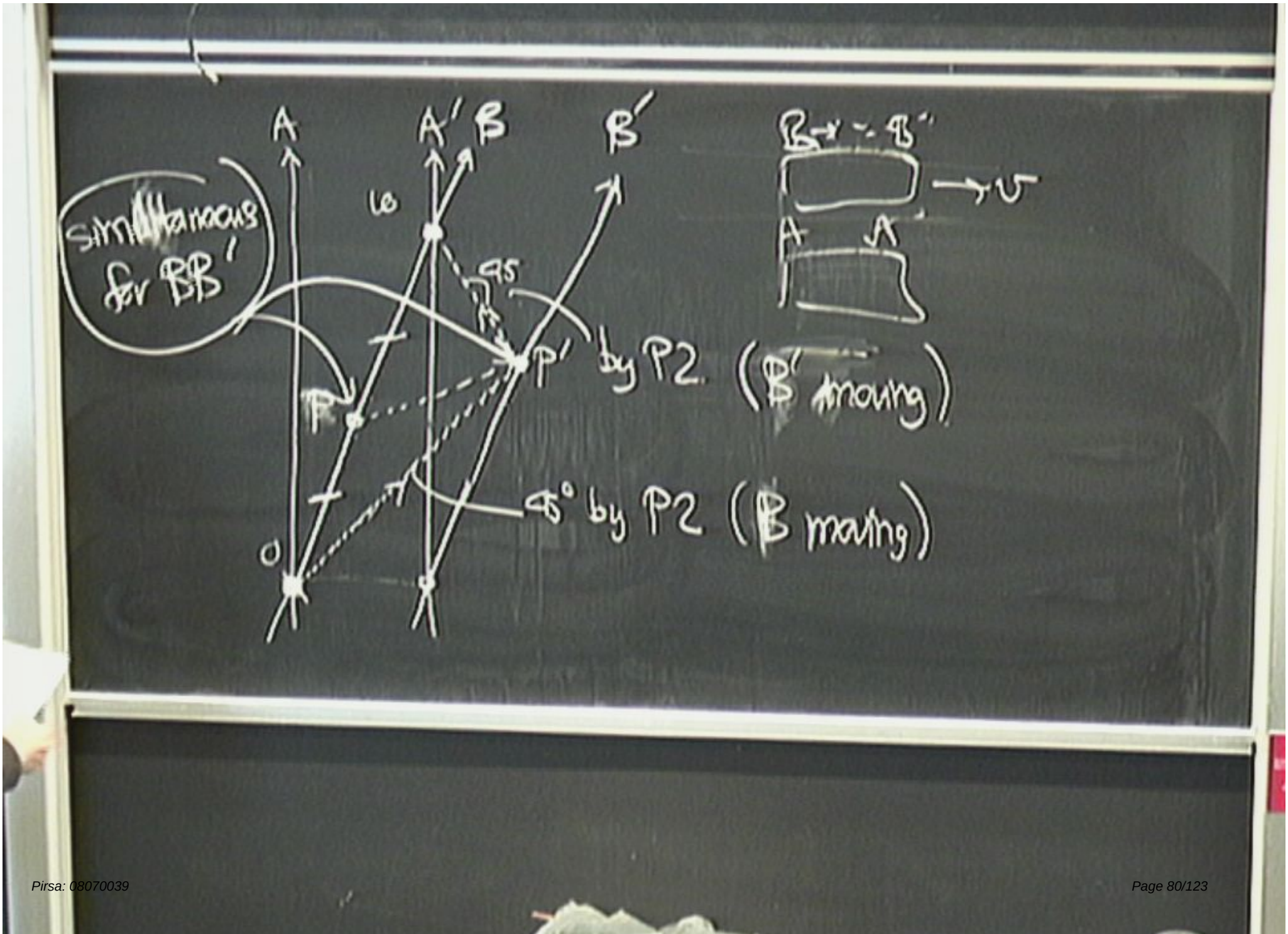

A
A'
B
B'
B
B'
v
A
A'

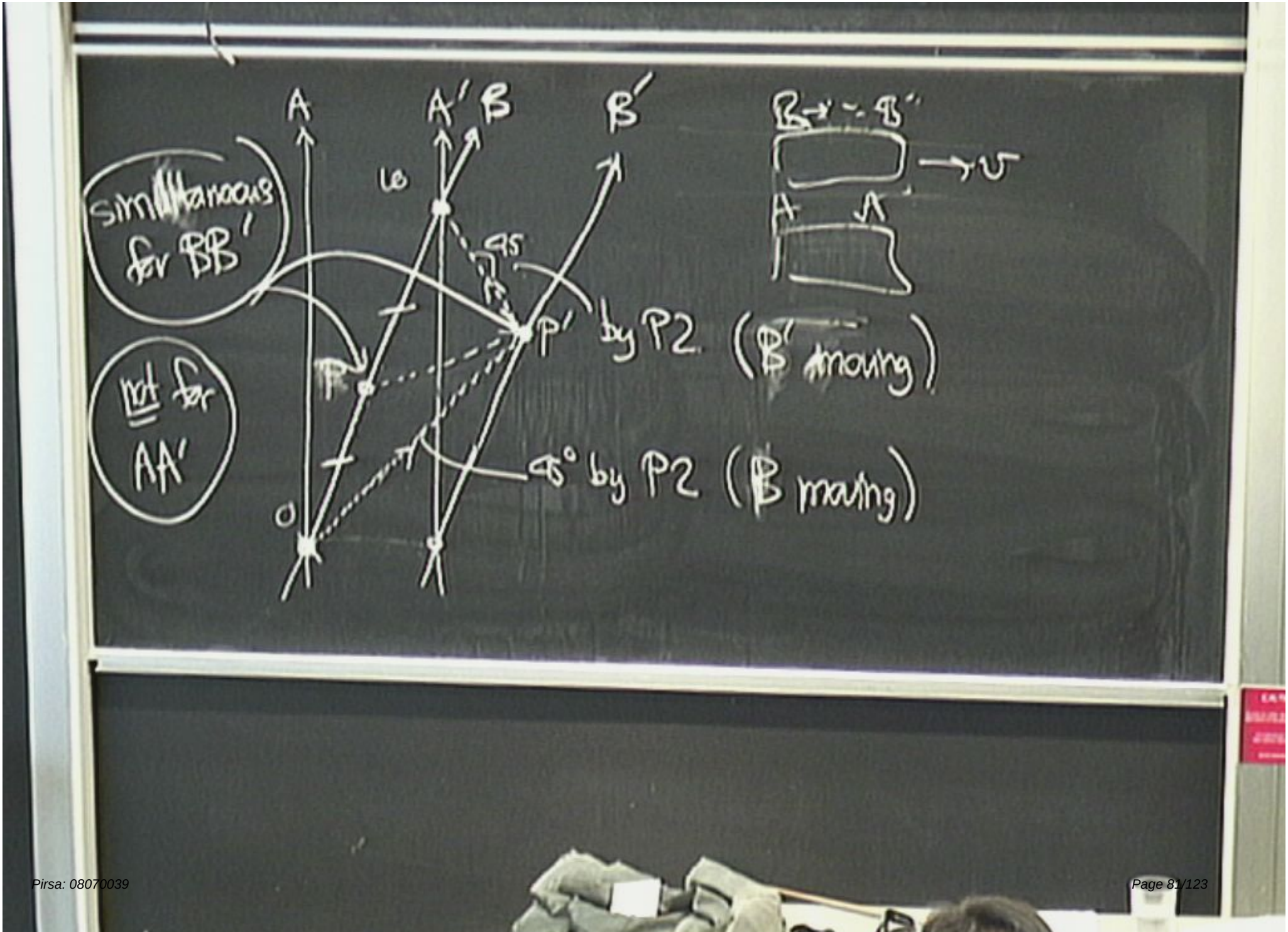

A
A'
B
B'
B
B'
v
A
A'

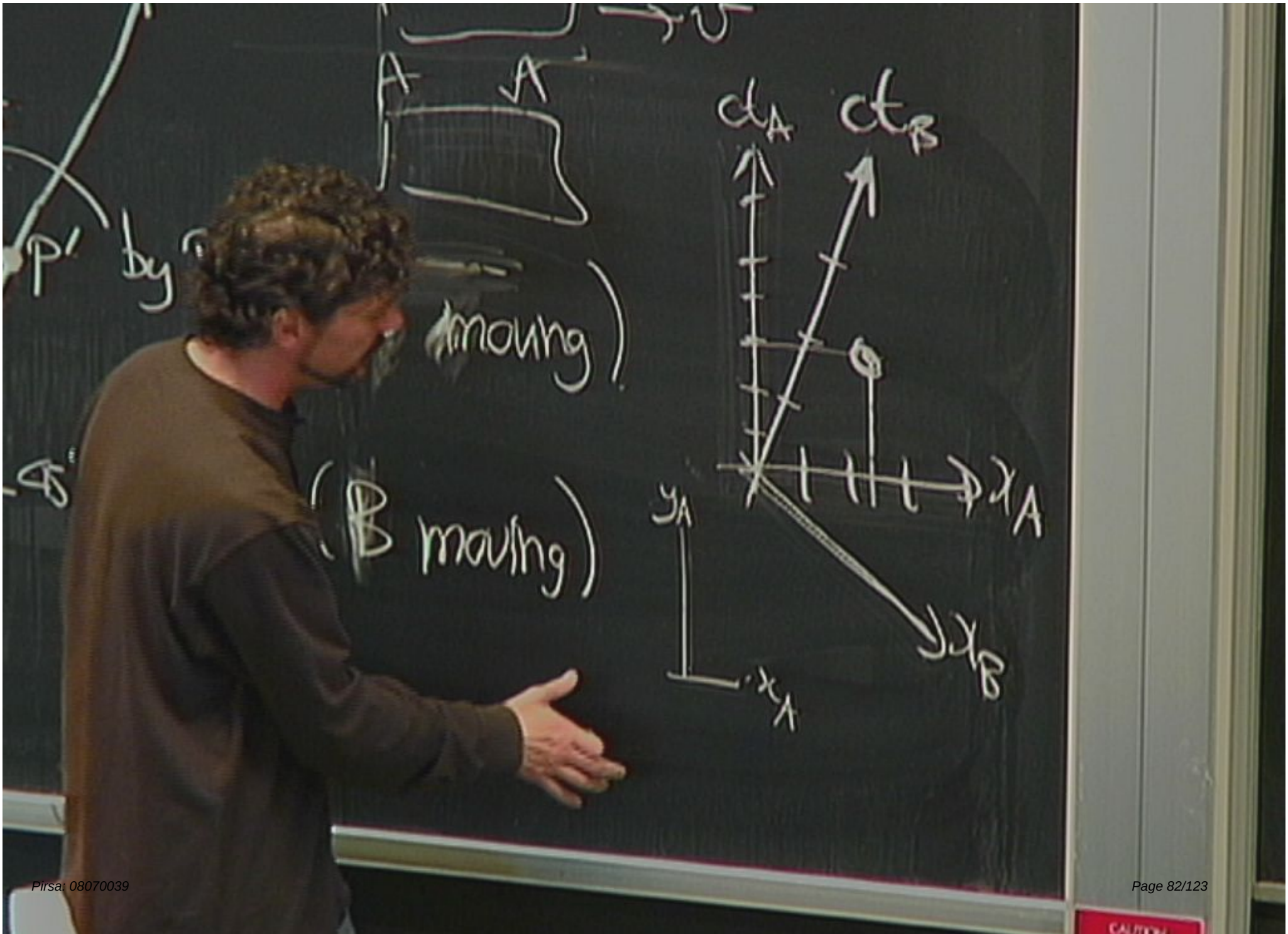

A
A'
B
B'
B
B'
v
A
A'
δ° by P2 (B mating)

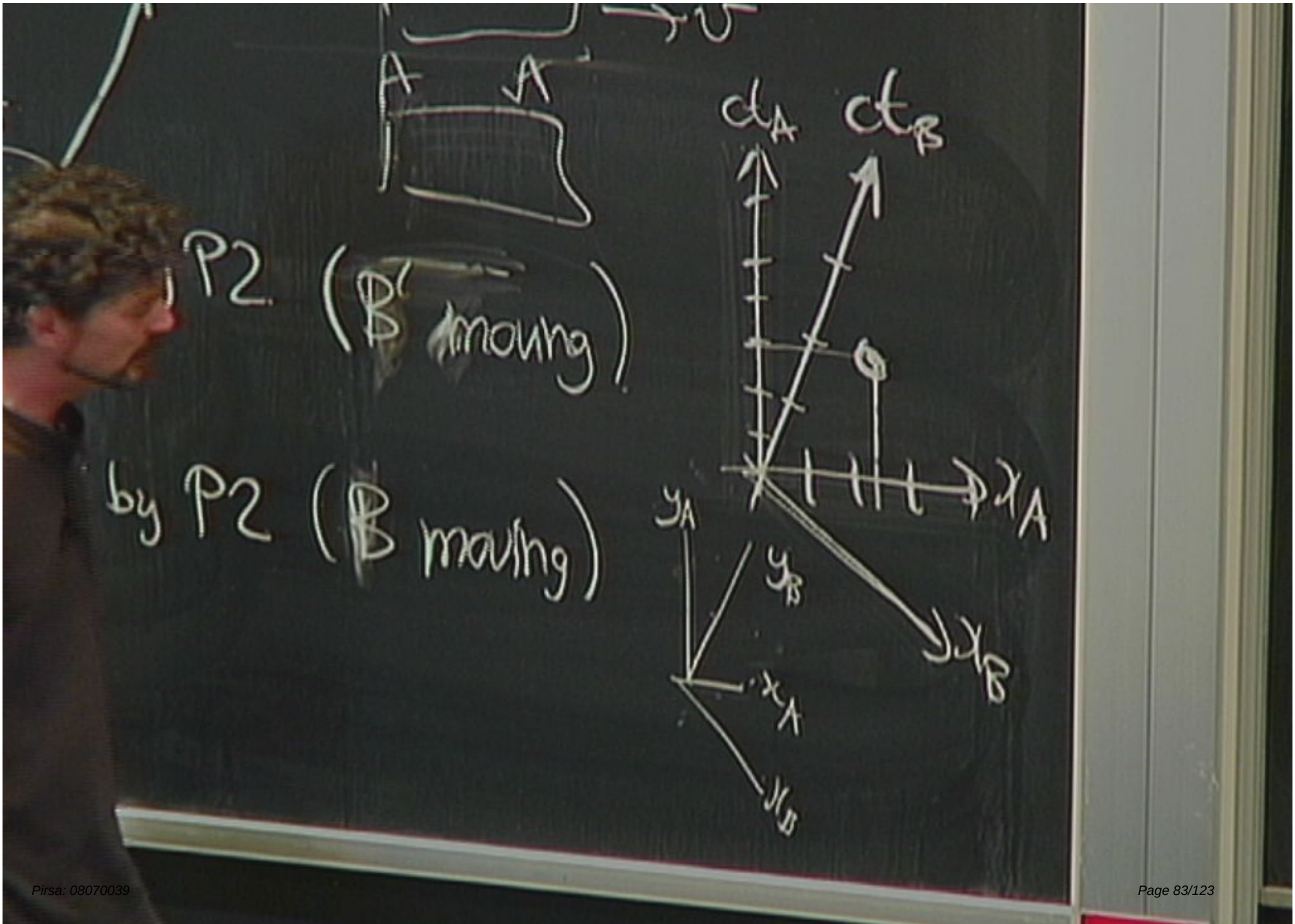

A
A′ B
B′
B → ~ B′
→ v
A A′
45
by P2 (B′ moving)
45° by P2 (B moving)

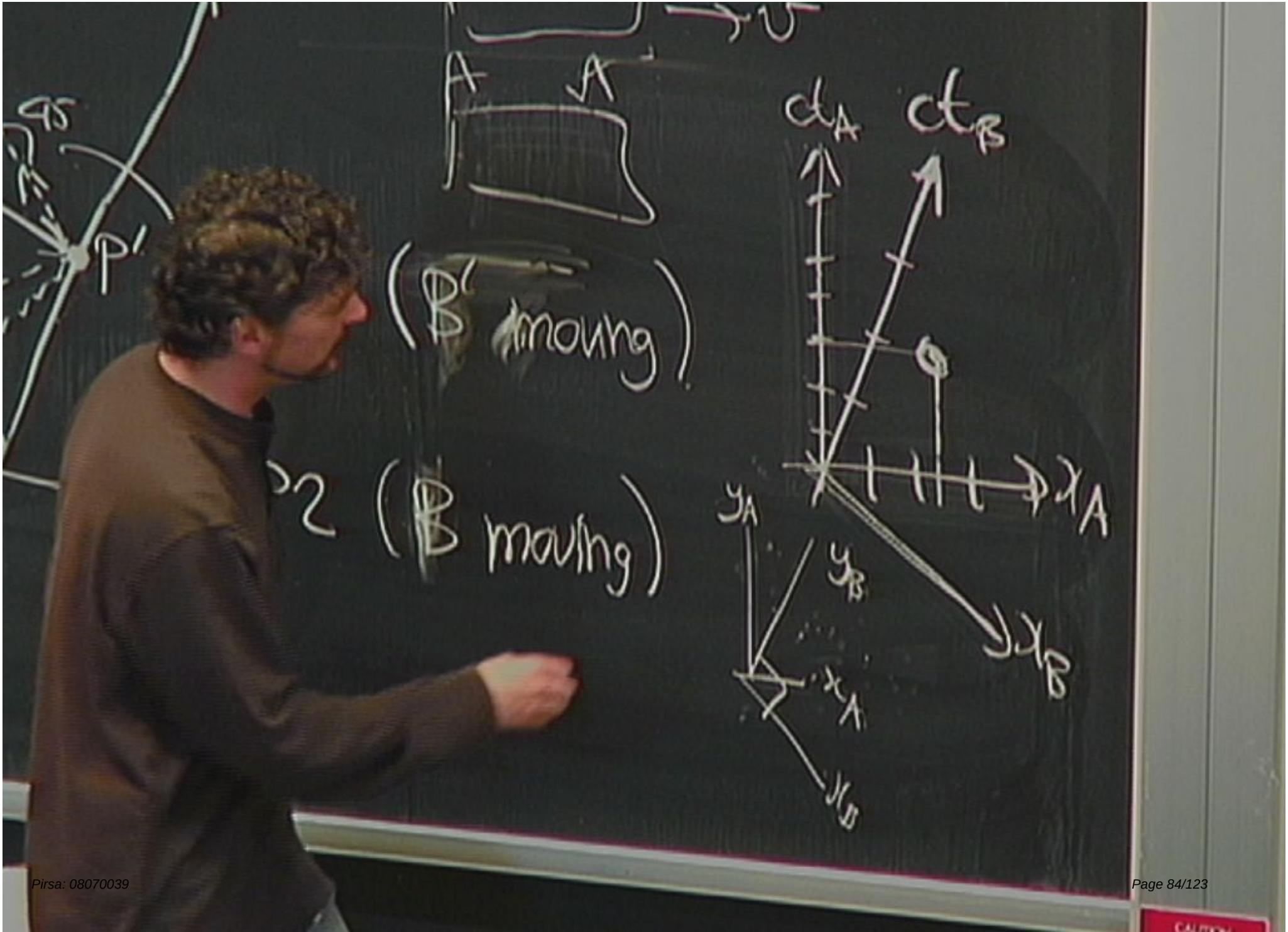

A
A'
B
B'
simultaneous for BB'
P
P'
by P2 (B' moving)
45° by P2 (B moving)
0
v

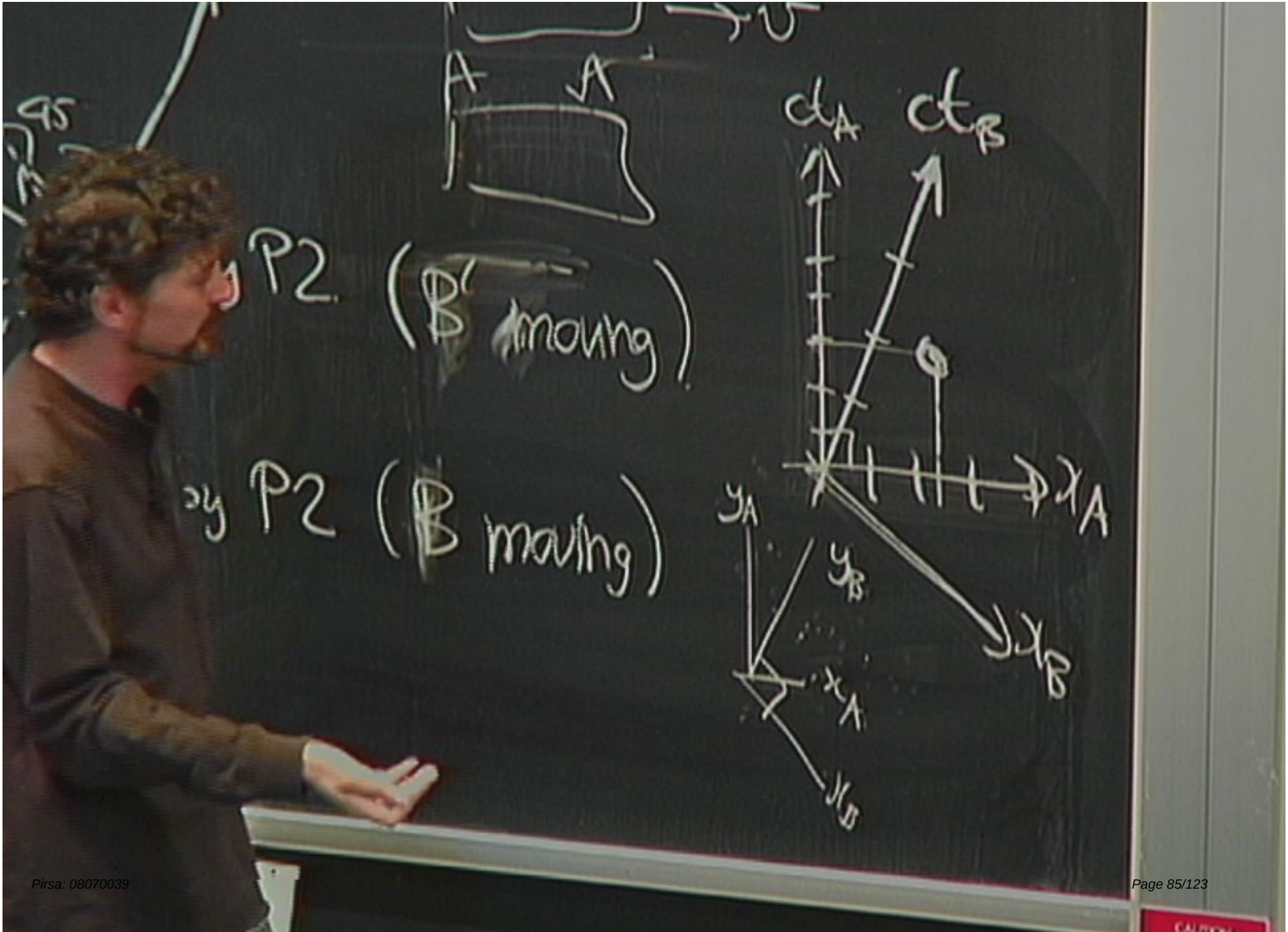

A
A'
B
B'
simultaneous for BB'
P
P'
by P2 (B' moving)
45° by P2 (B moving)
0
v

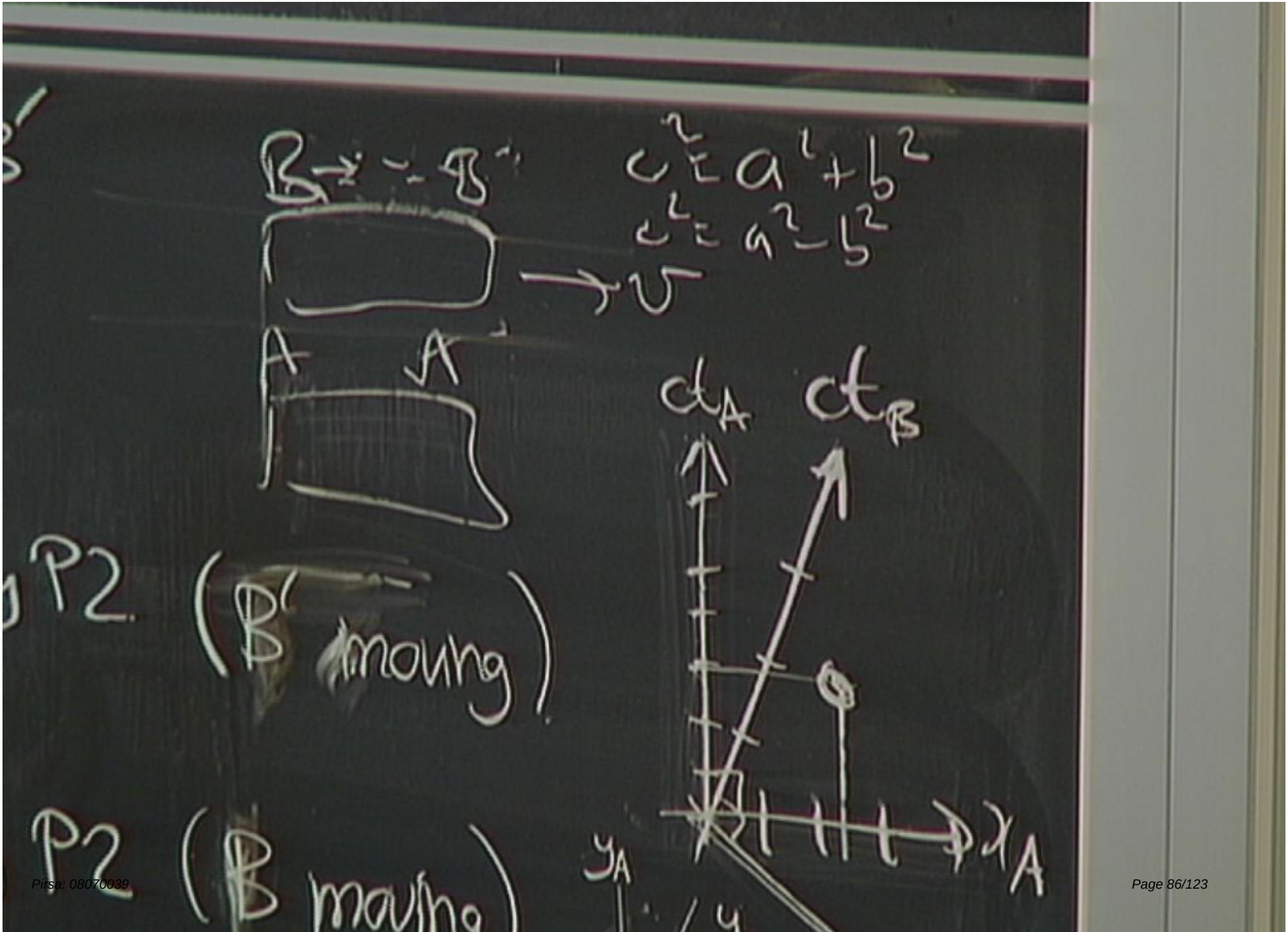

A
A' B
B'
simultaneous for BB'
not for AA'
P
P'
by P2 (B' moving)
by P2 (B moving)
0
v

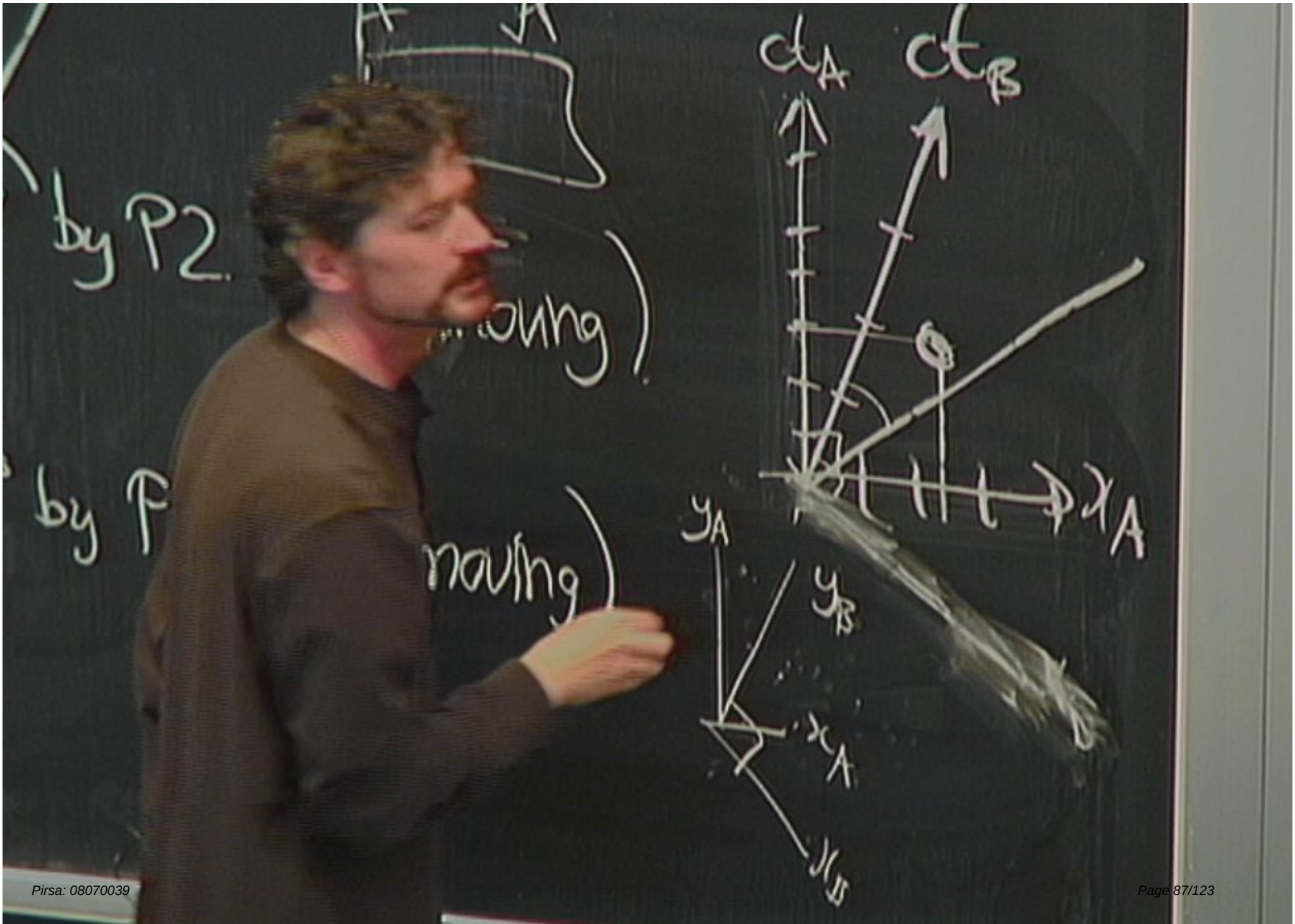

A
A
P' by
moving)
(B moving)
ct_A
ct_B
x_A
y_A
x_A
x_B

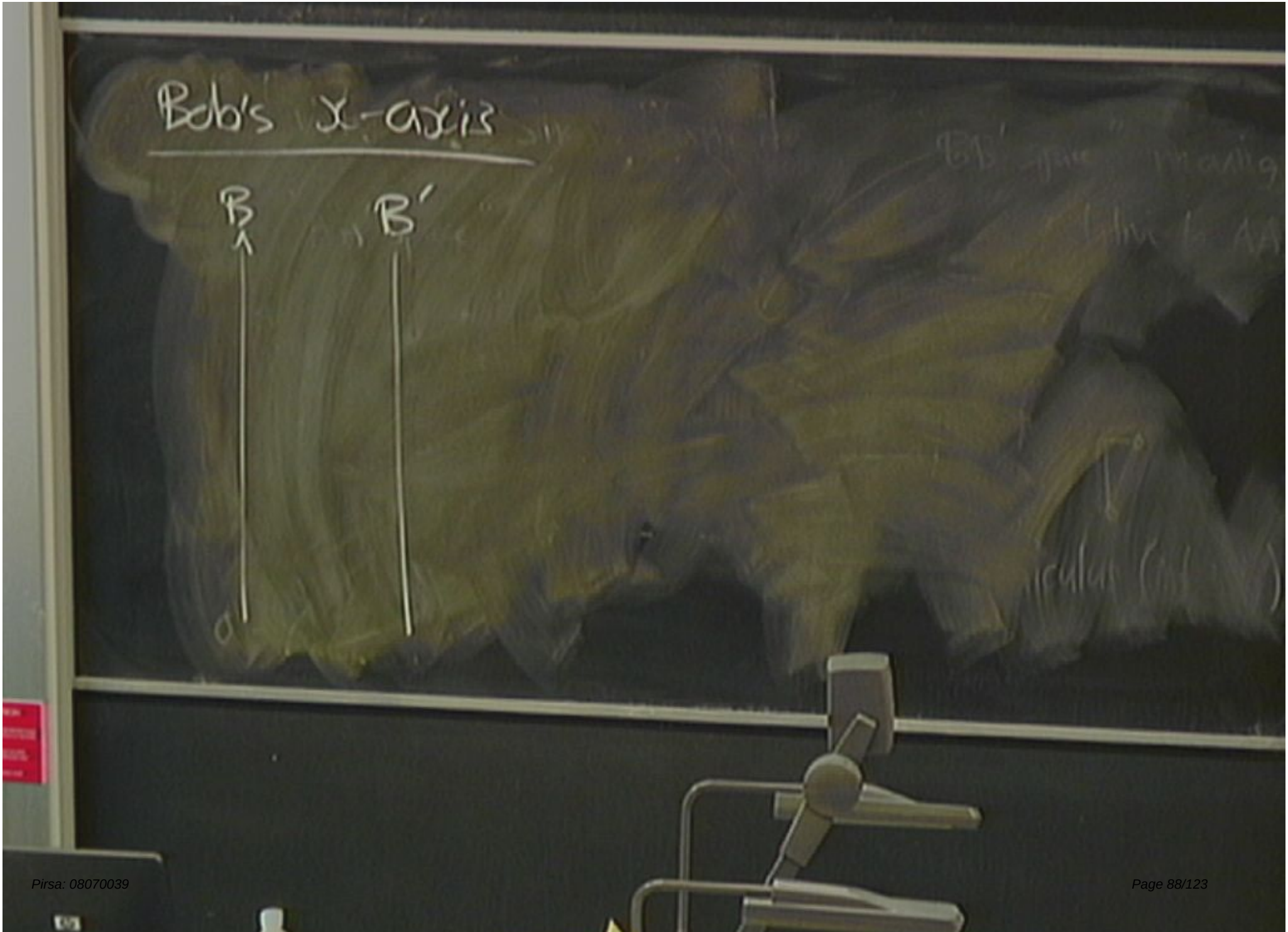

A A
P2 (B' moving)
by P2 (B moving)
ct_A
ct_B
x_A
y_A
y_B
x_B
x_A
y_B

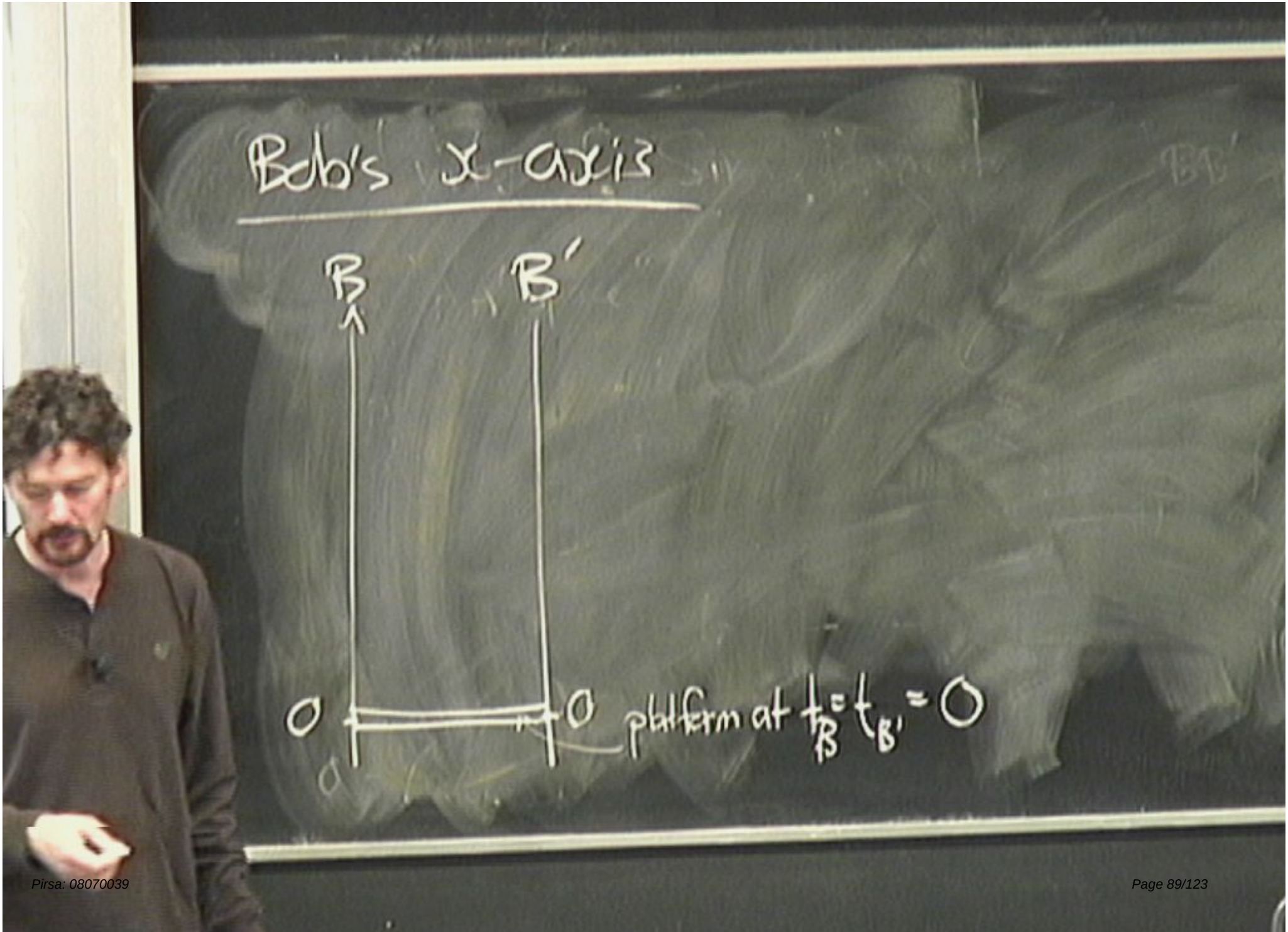

A
A
P'
(B' moving)
2 (B moving)
ct_A
ct_B
x_A
y_A
y_B
x_B
x_A
x_B

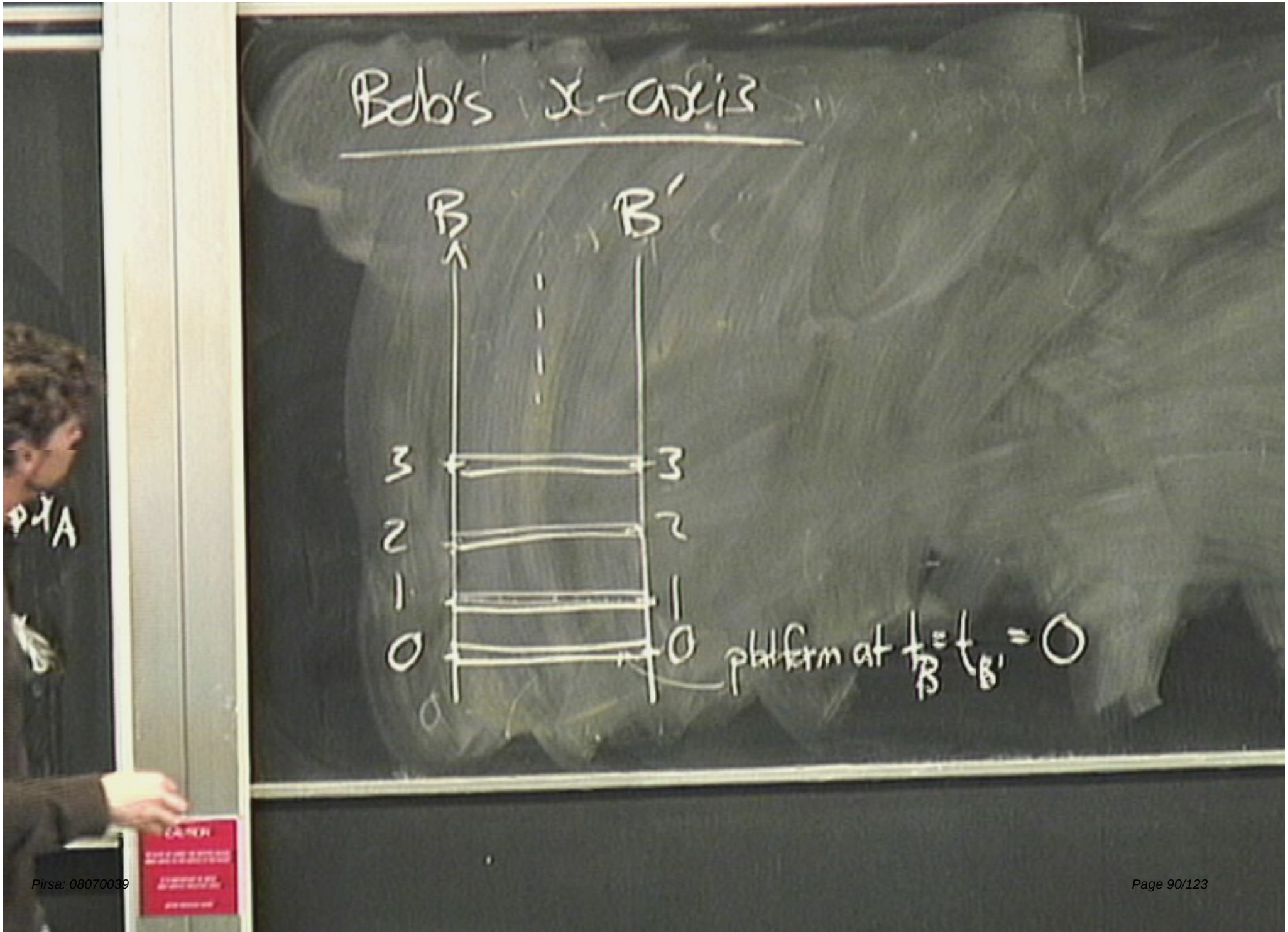

A
A
P2 (B' moving)
P2 (B moving)
ct_A
ct_B
x_A
y_A
y_B
x_B
x_A
x_B

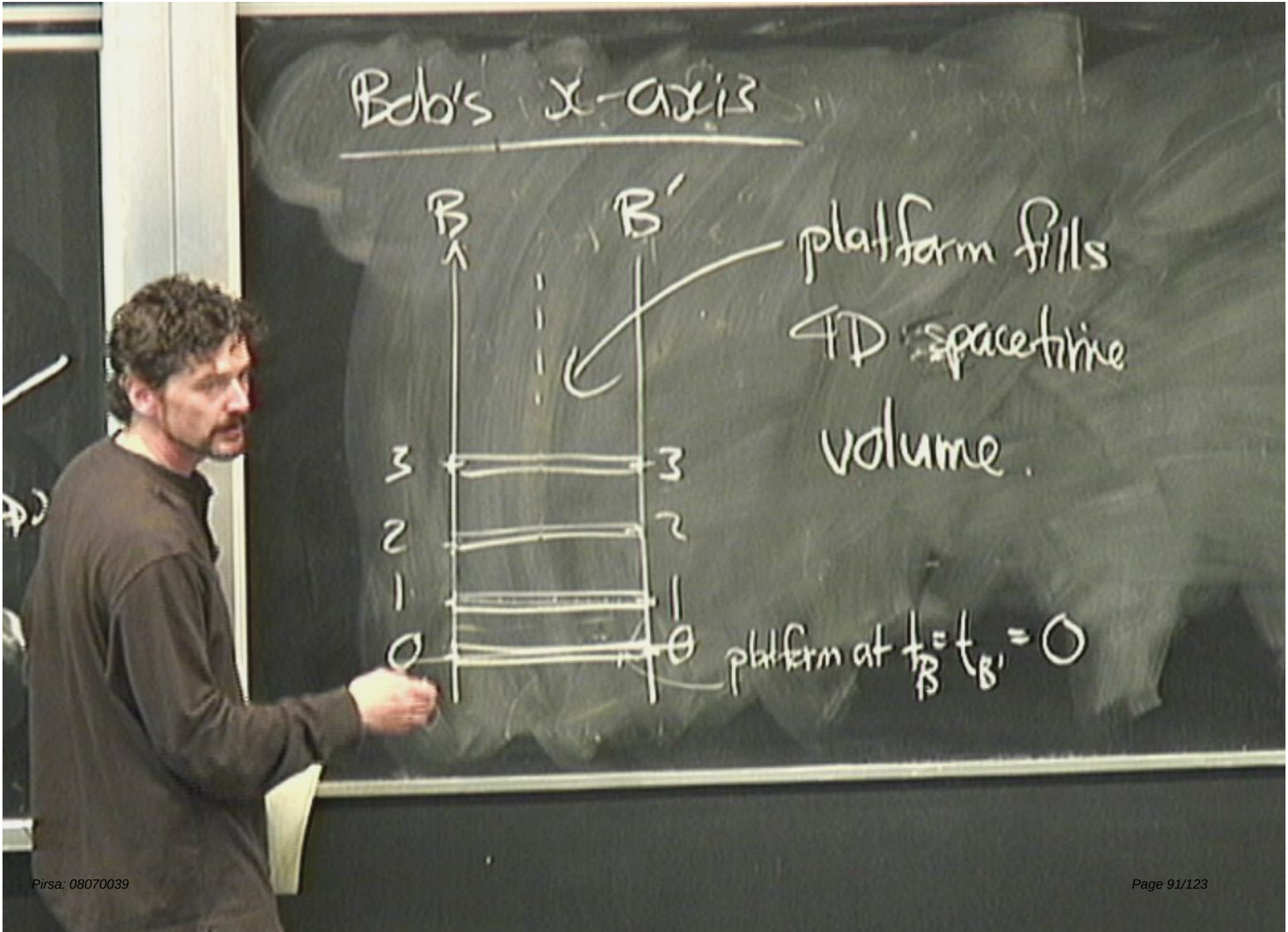

B → B'
c² = a² + b²
c² = a² − b²
v
A A'
ct_A ct_B
P2 (B' moving)
P2 (B moving)
x_A
y_A


by P2.
by P
ct_A
ct_B
x_A
y_A
y_B
x_A

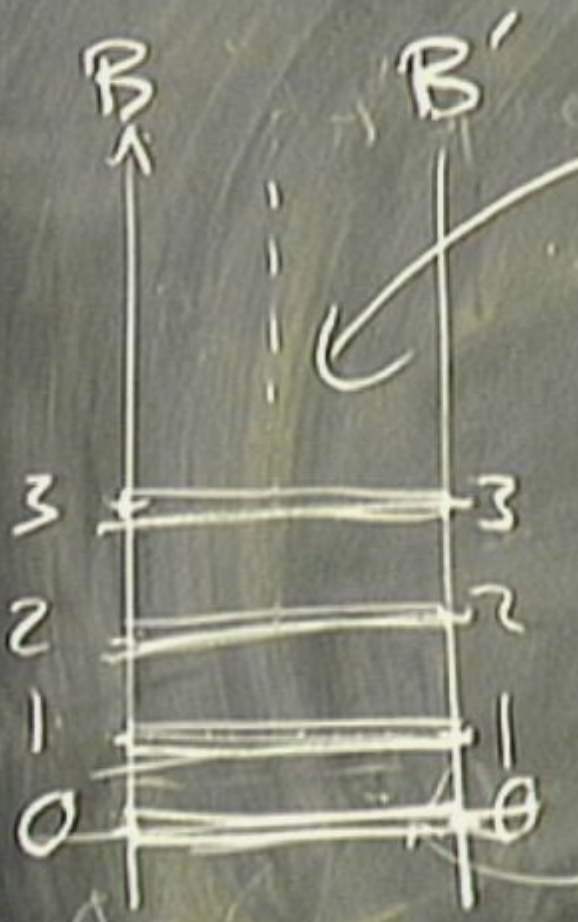

Bob's x-axis
B
B'
O


Bob's x-axis
B
B'
platform at $t_B = t_{B'} = 0$


Bob's x-axis
B
B'
3
2
1
0
platform at $t_B = t_{B'} = 0$

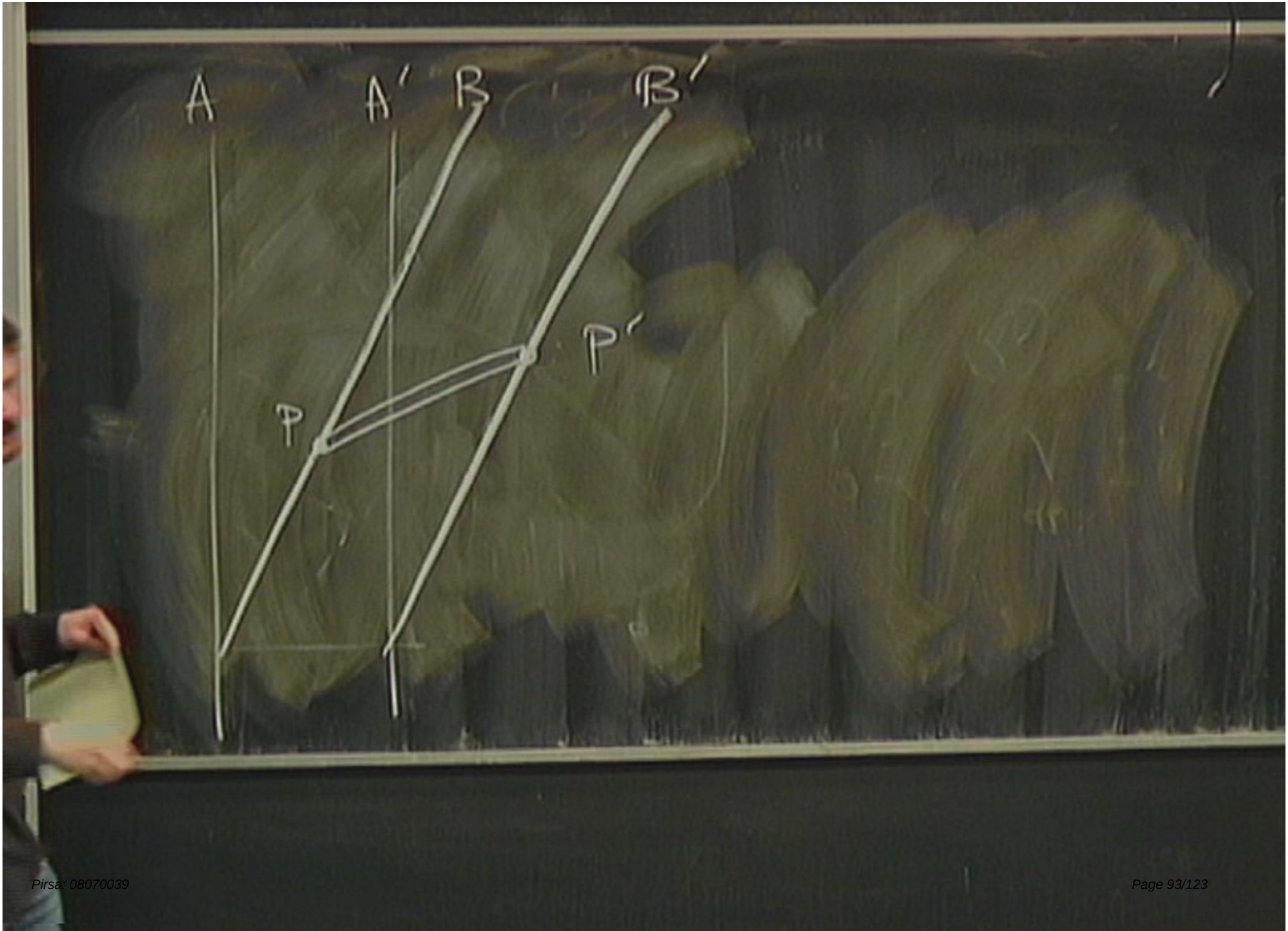

Bob's x-axis
B
B'
platform fills
4D spacetime
volume
3
2
1
0
platform at $t_B = t_{B'} = 0$

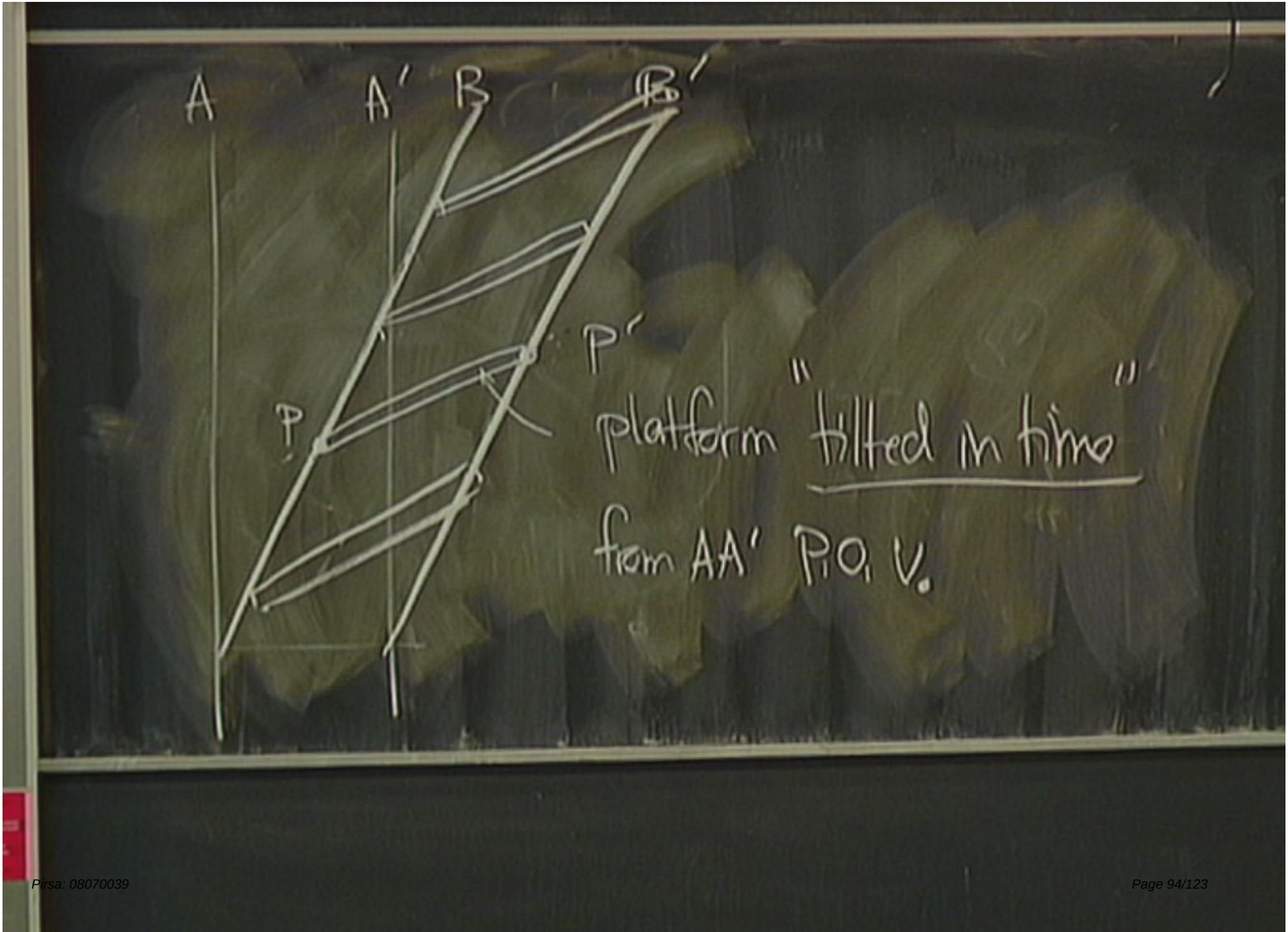
Bob's x-axis

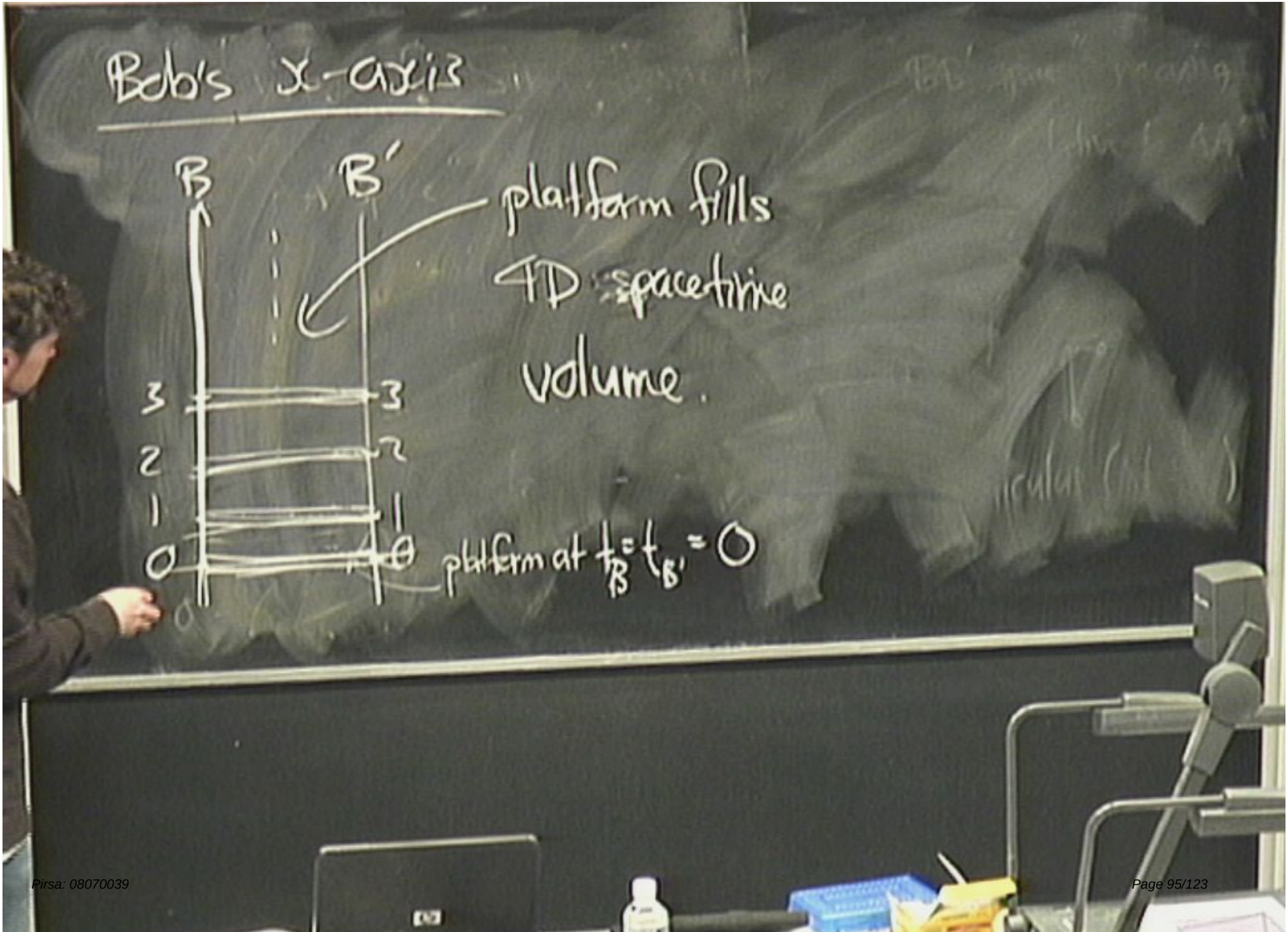


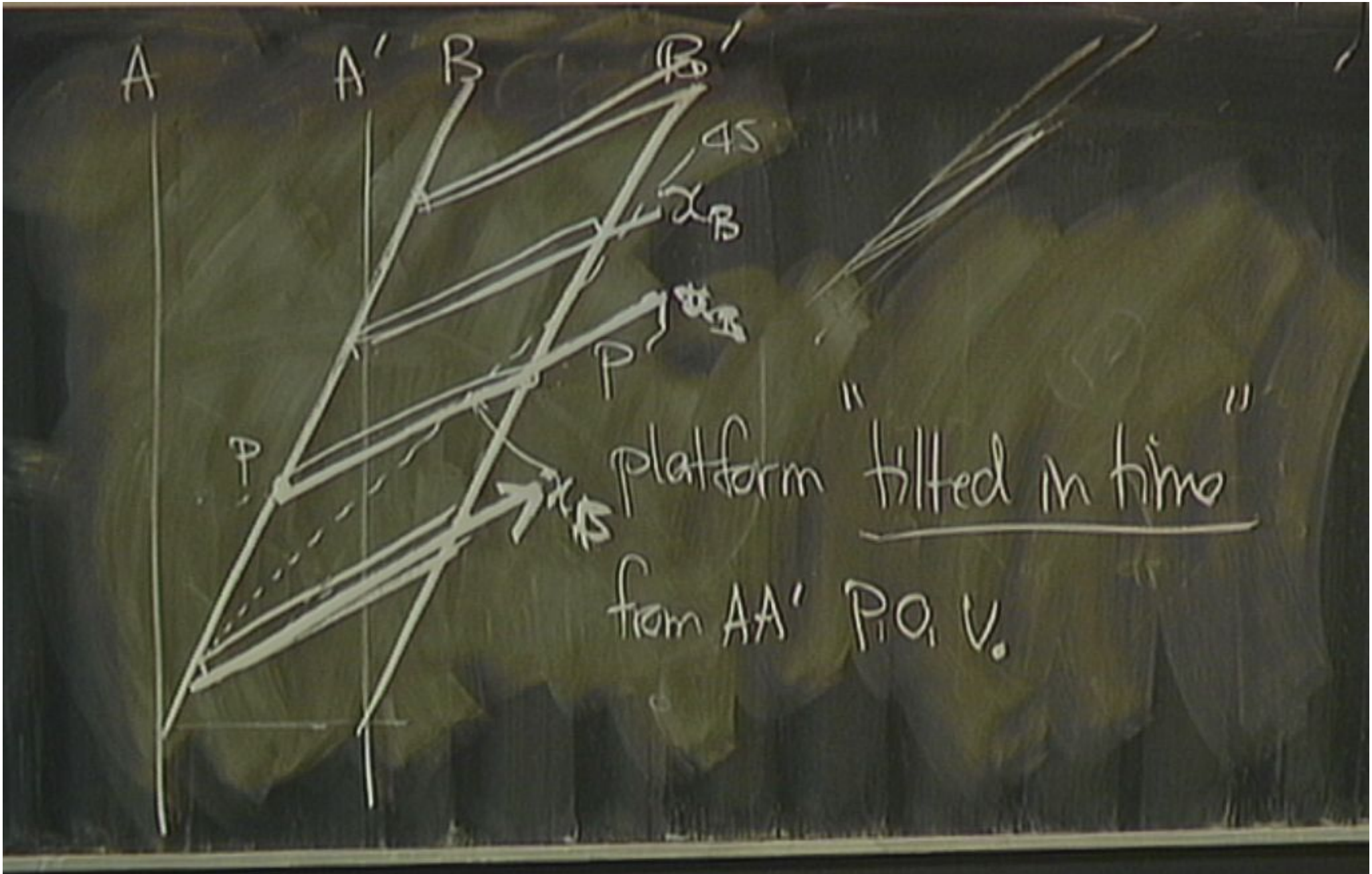
platform fills 4D spacetime volume.

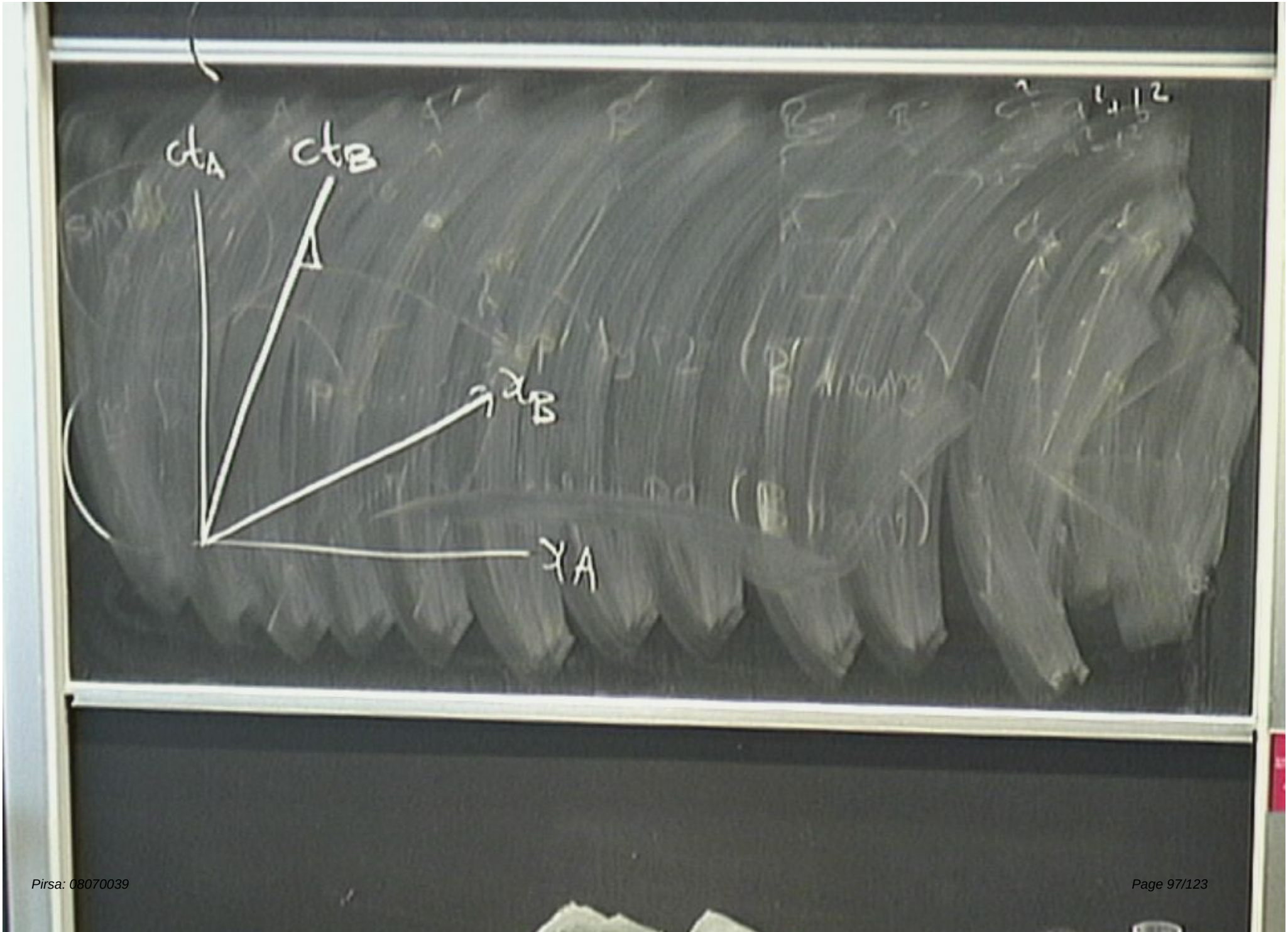
platform at $t_B = t_{B'} = 0$

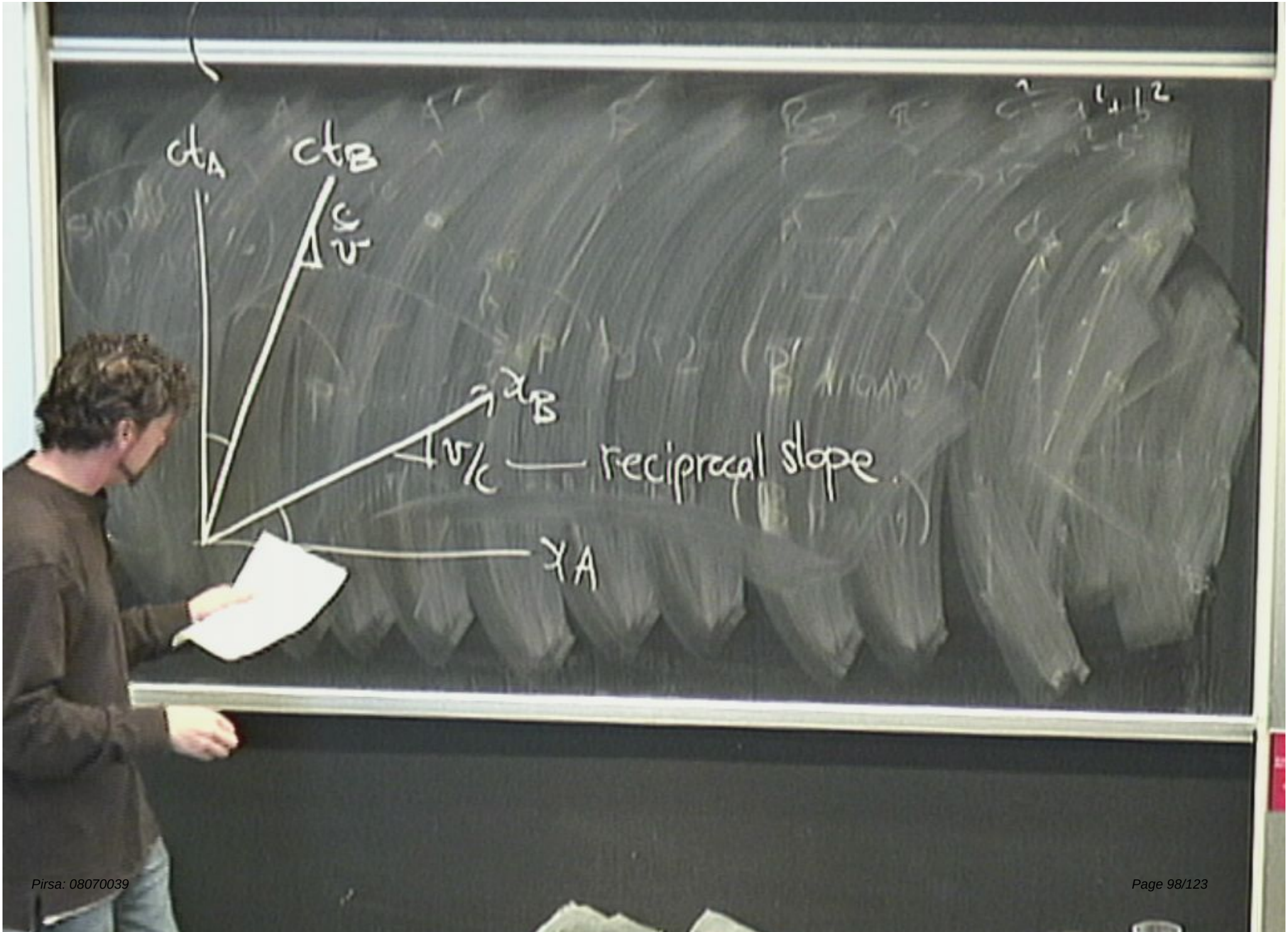

A
A'
B
B'
P
P'

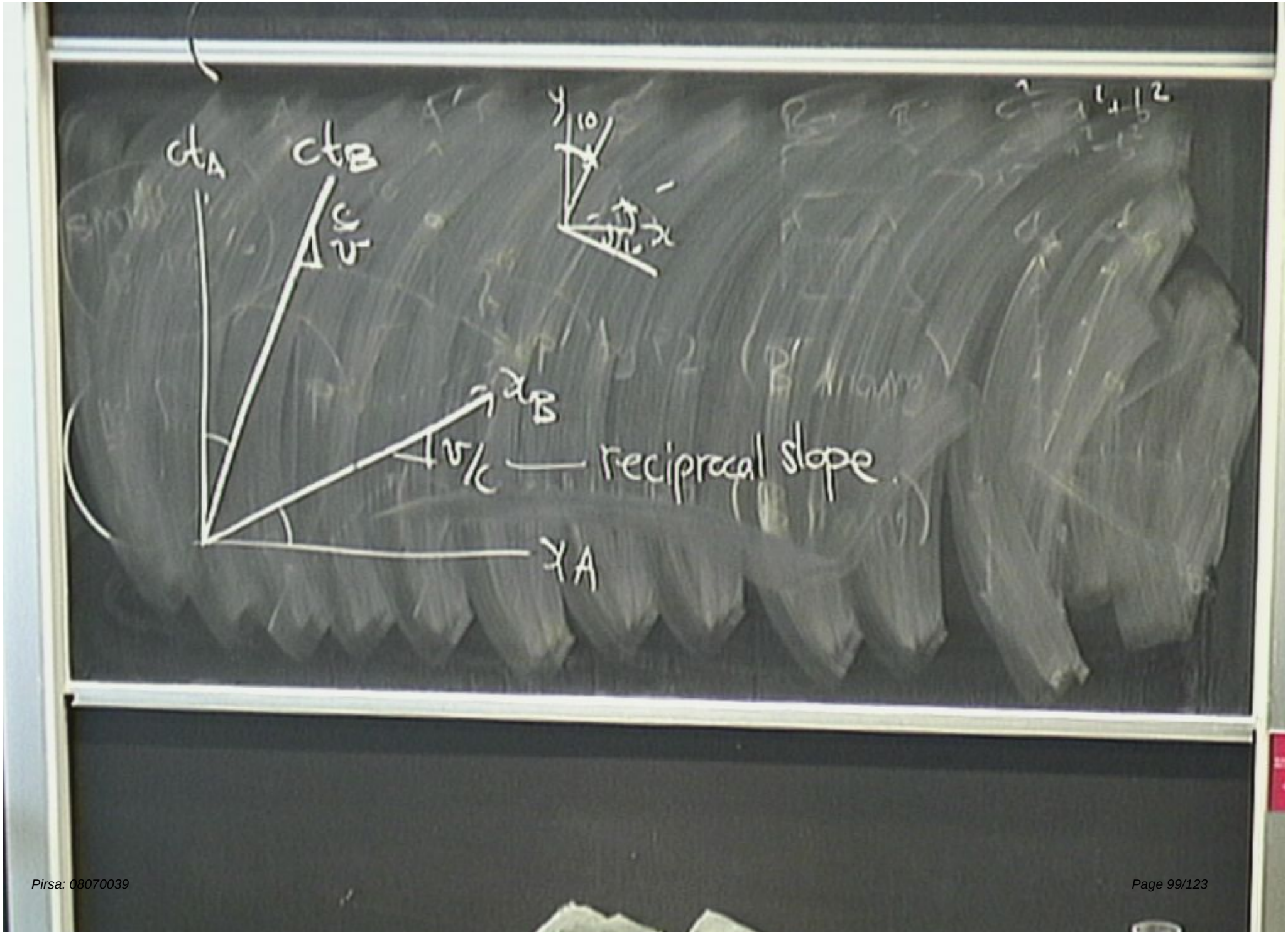

A
A'
B
B'
P
P'
platform "tilted in time"
from AA' P.O.V.

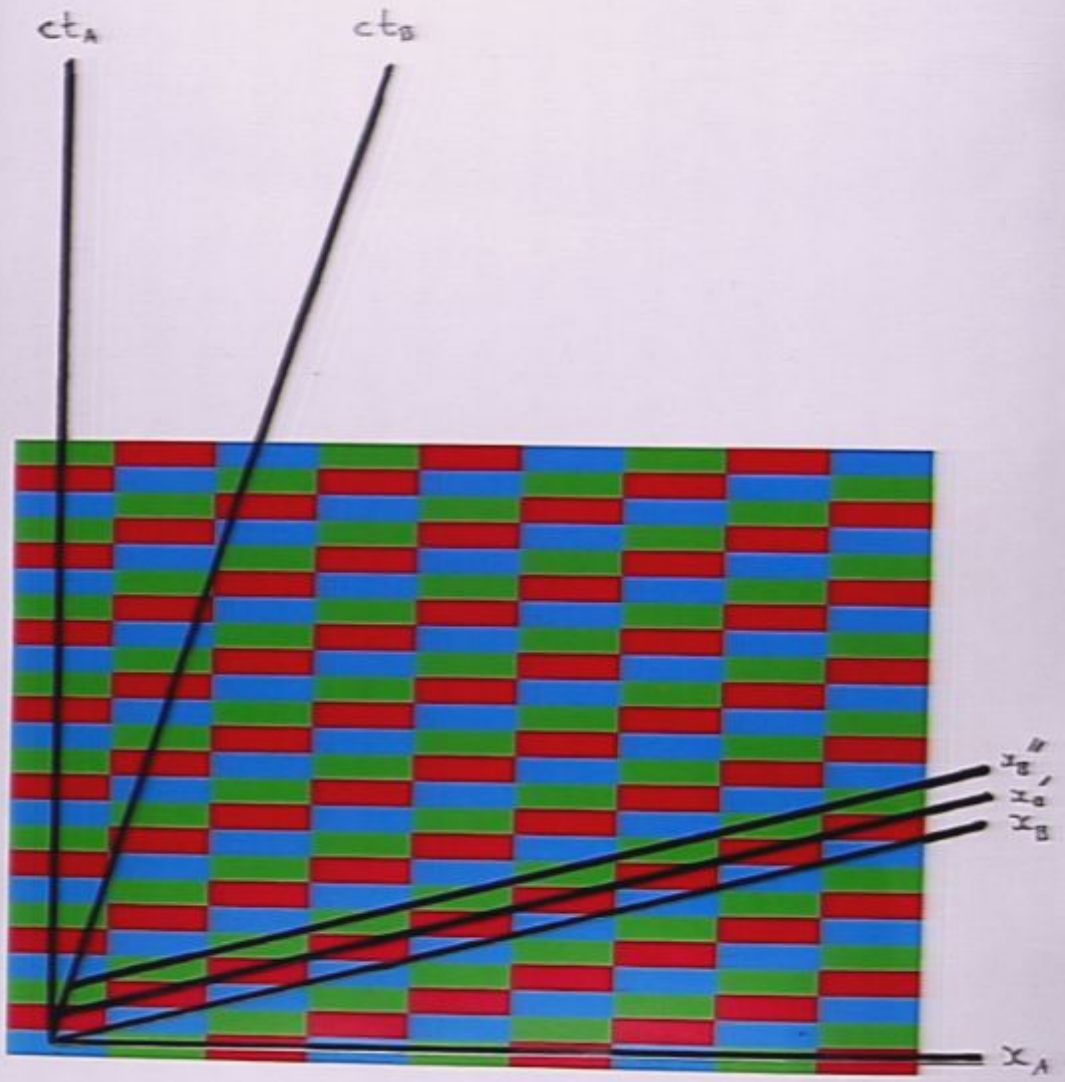

Bob's x-axis
B
B'
platform fills
4D spacetime
volume.
3
2
1
0
platform at $t_B = t_{B'} = 0$

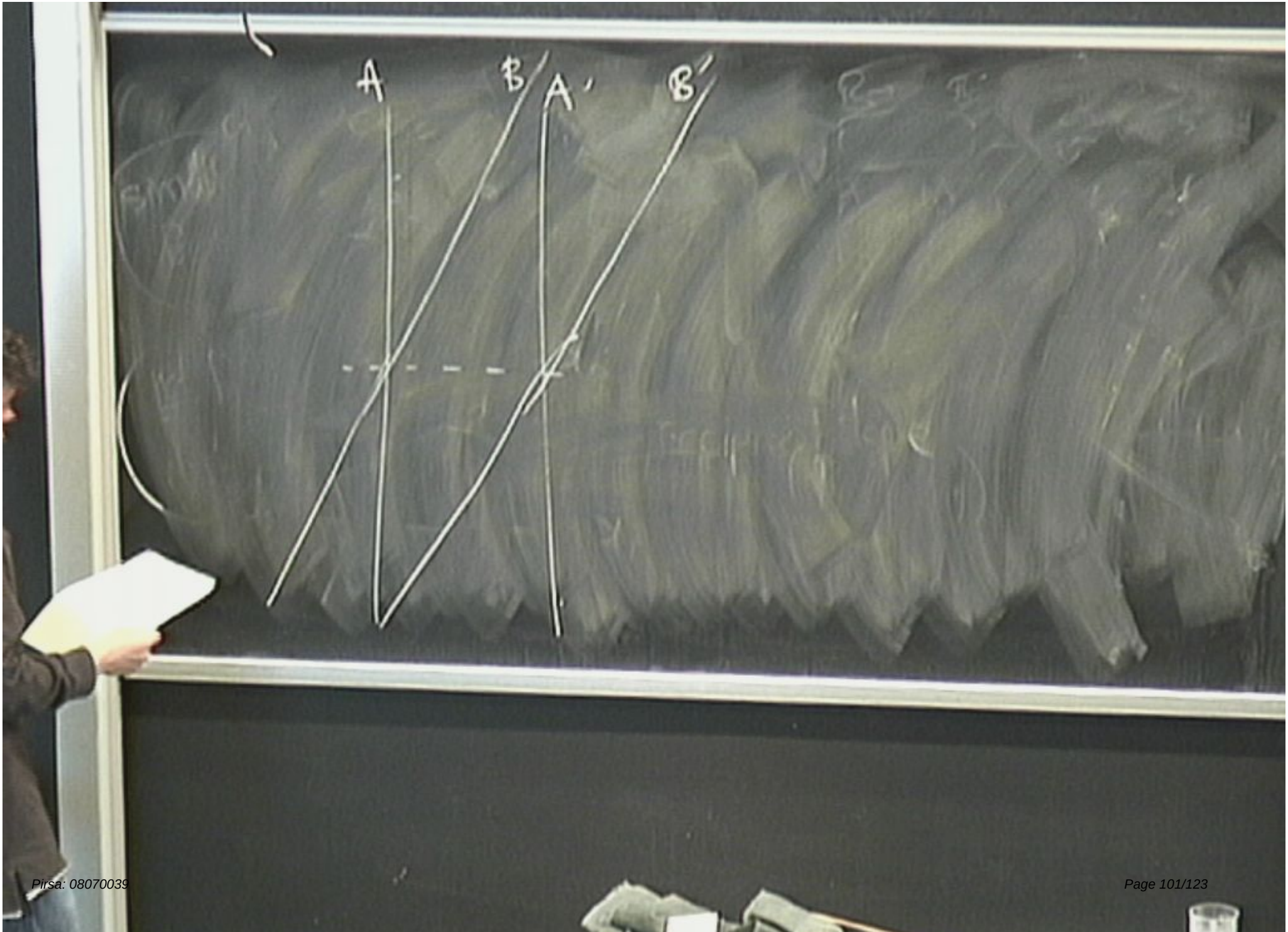

A
A'
B
B'
45
α_B
P'
P
α_{45}
platform "tilted in time"
from AA' P.O.V.

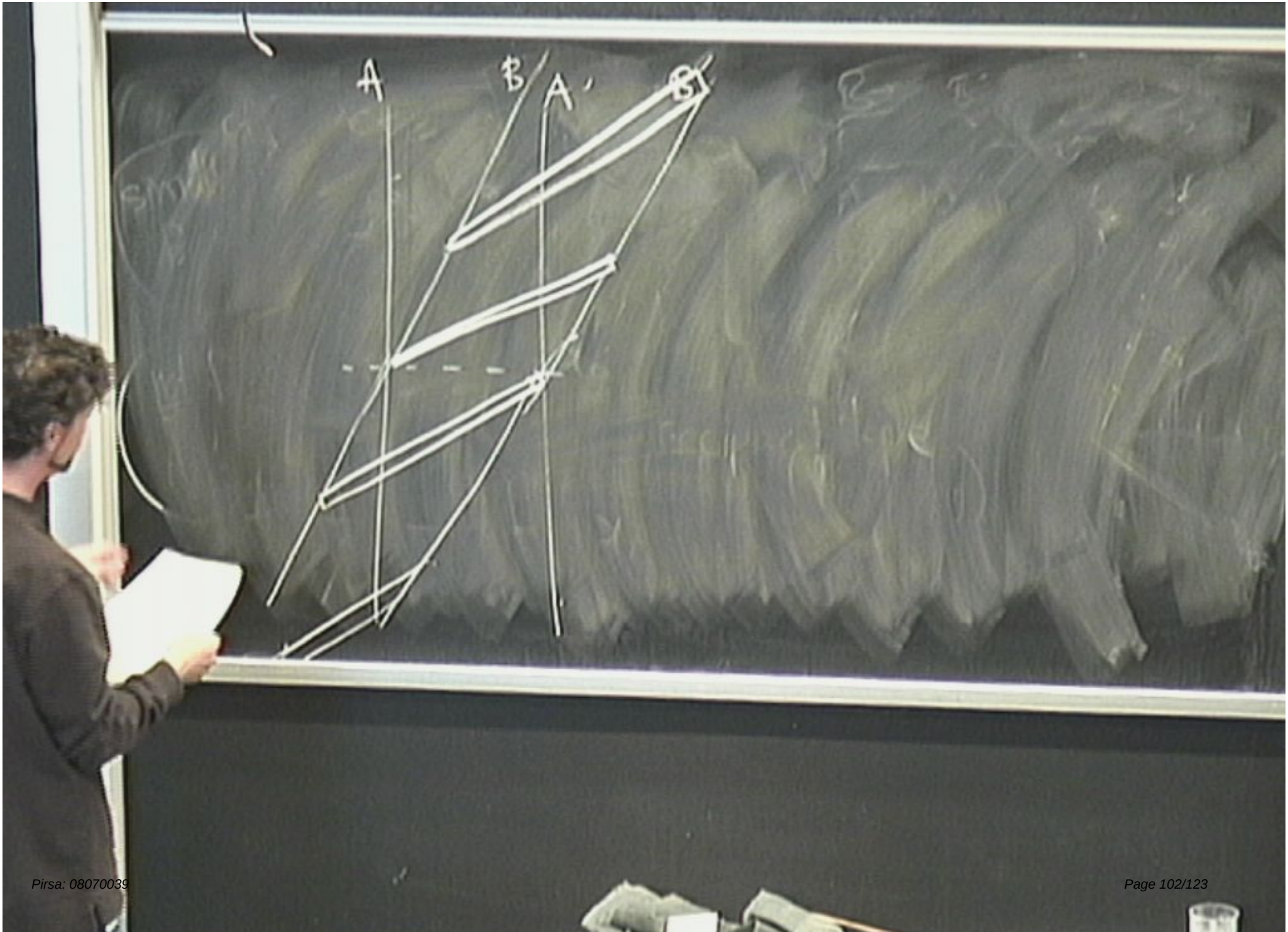

α_A
α_B
χ_B
χ_A

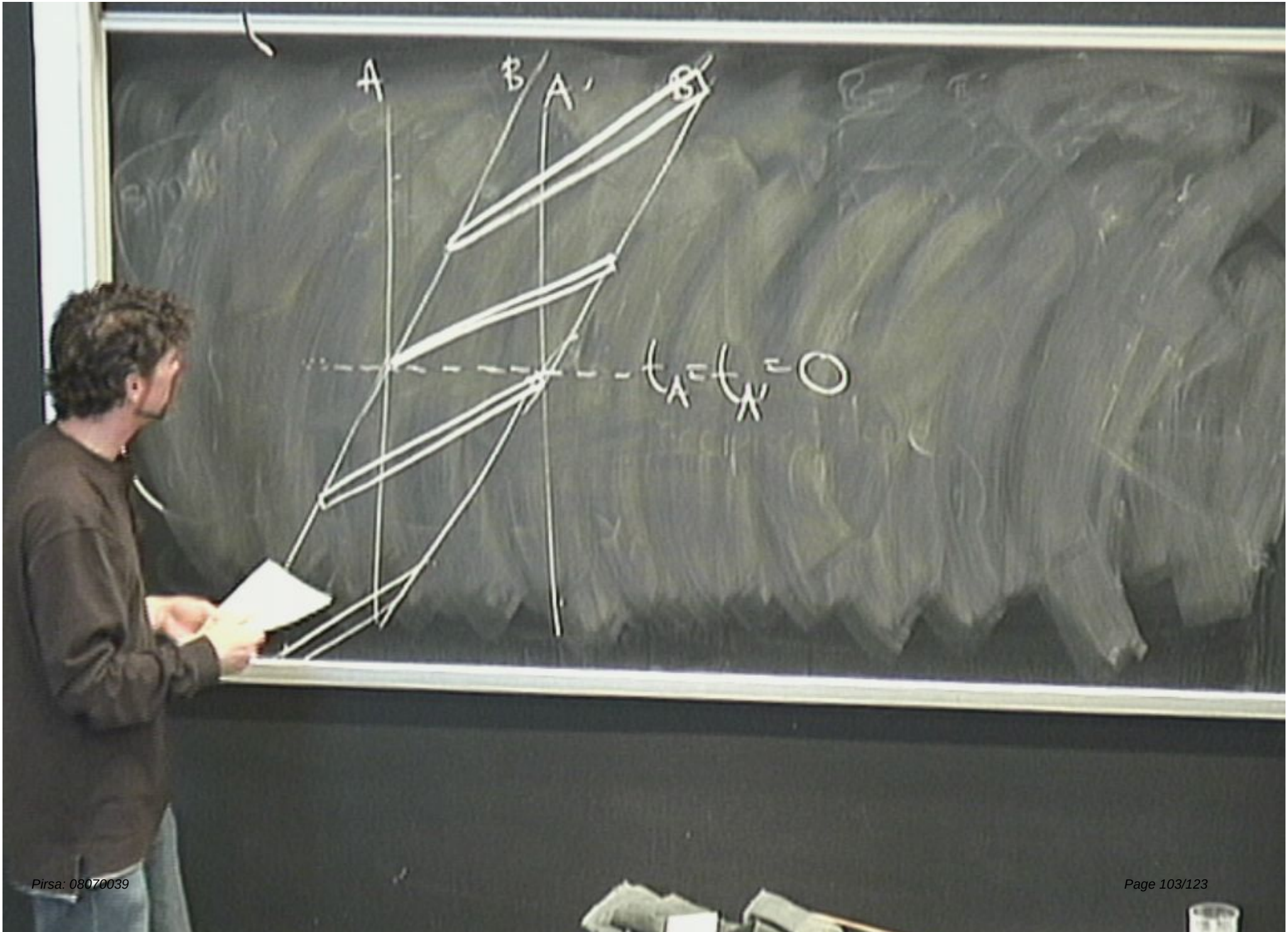

α_A
α_B
α_B
$1/c$ — reciprocal slope
x_A

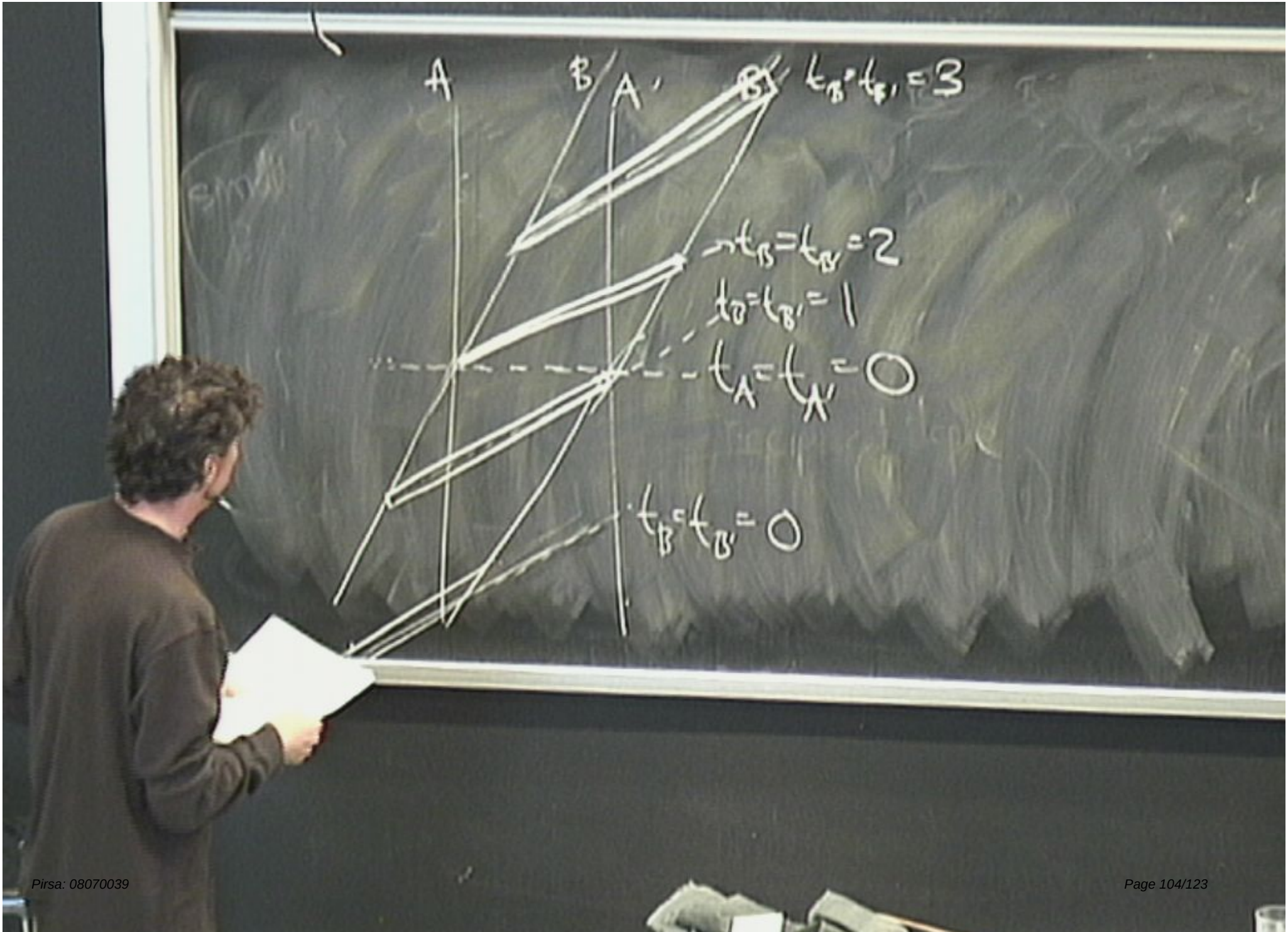

ct_A
ct_B
v/c
x_B
v/c — reciprocal slope
x_A
y
10

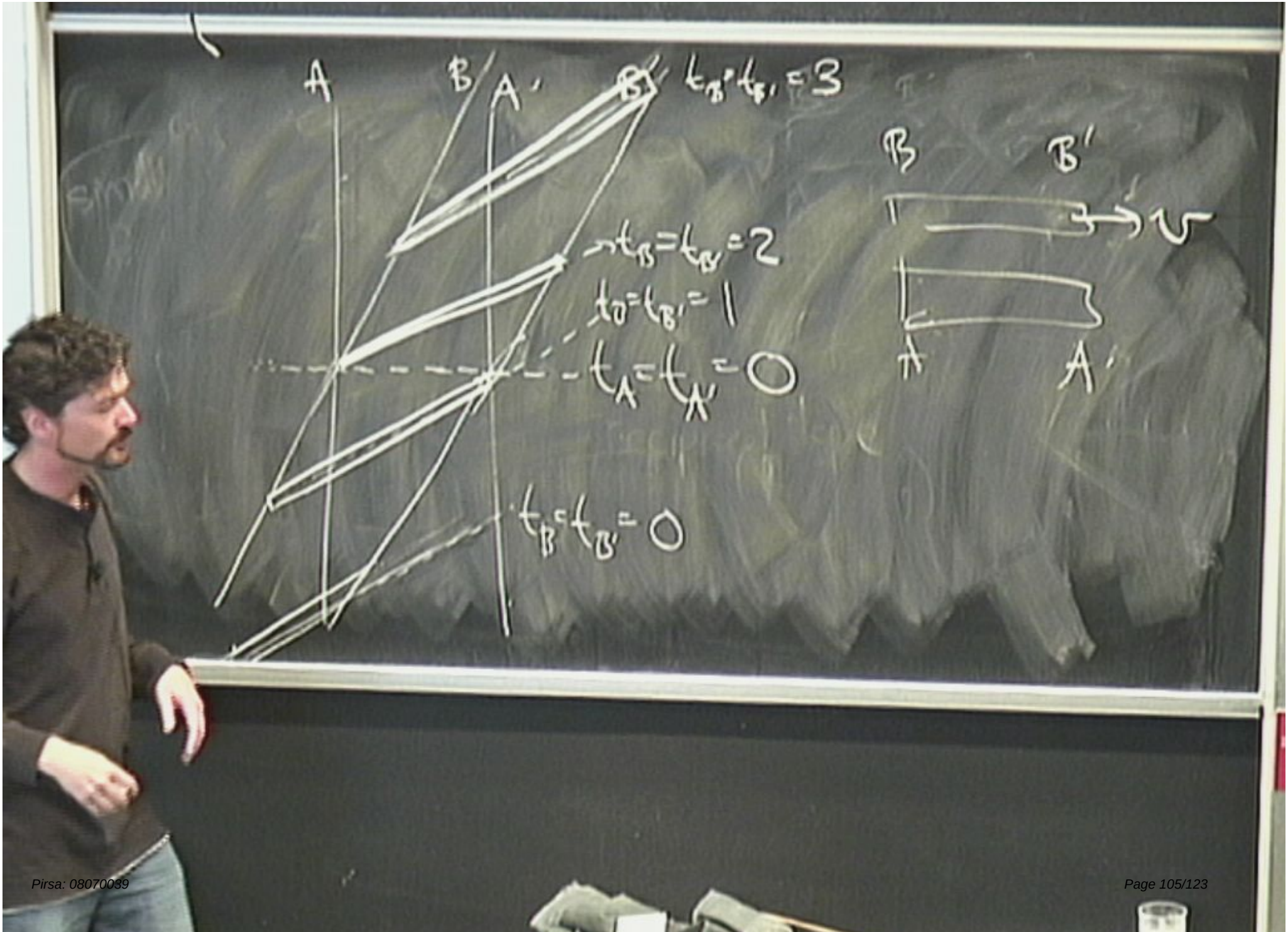

ct_A
ct_B
x_B''
x_B'
x_B
x_A

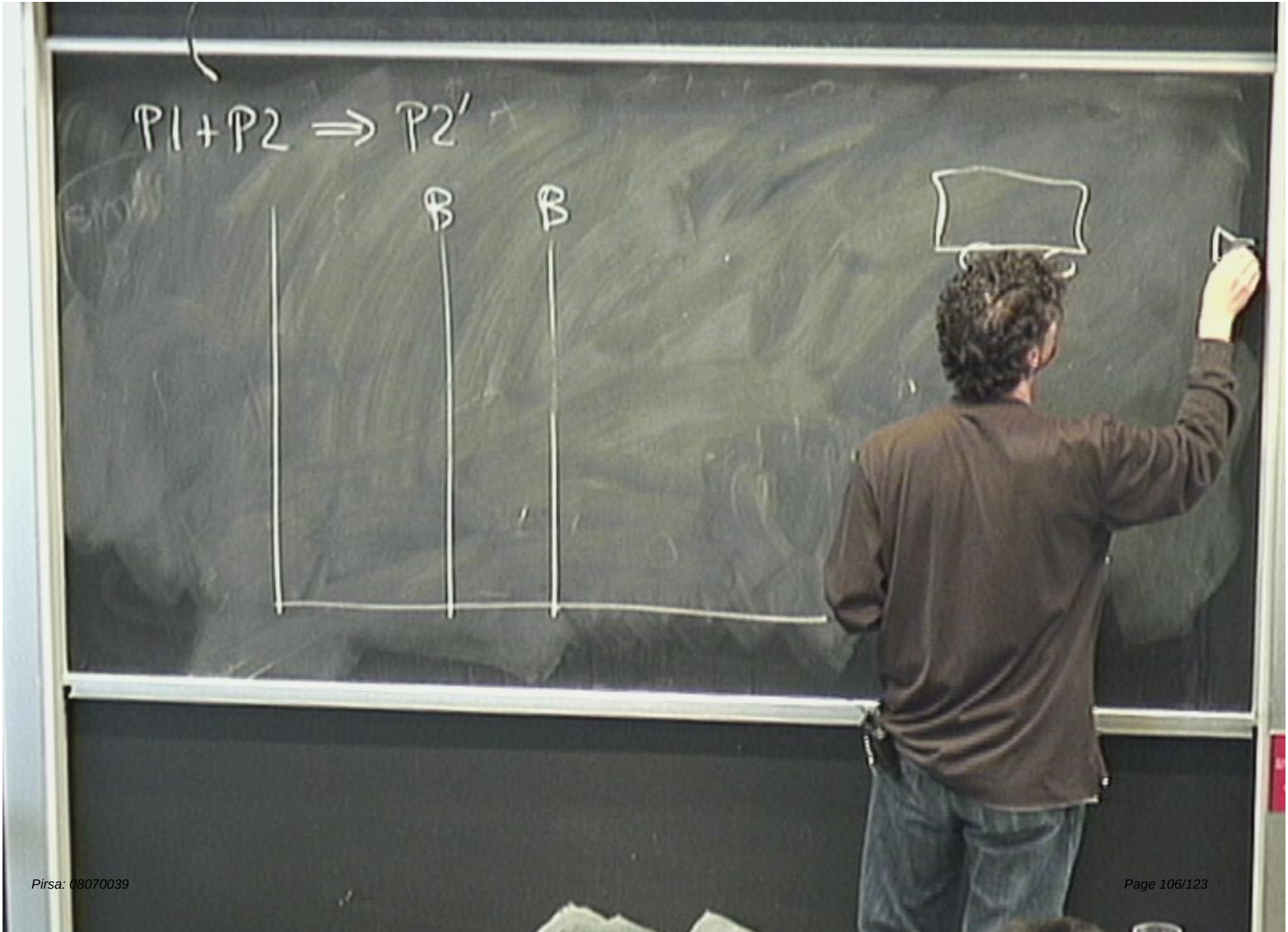

A
B
A'
B'

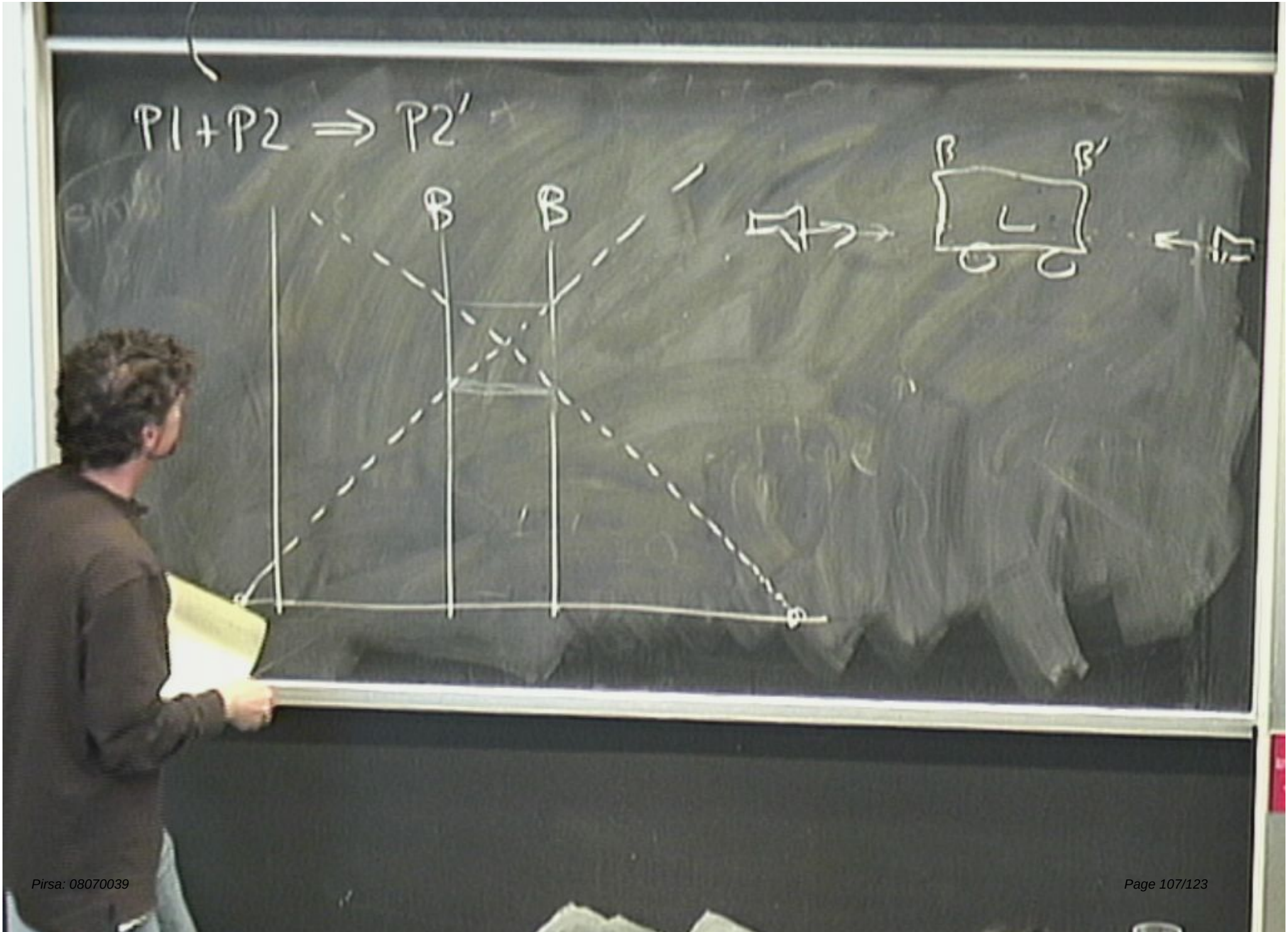

A
B
A'
B'

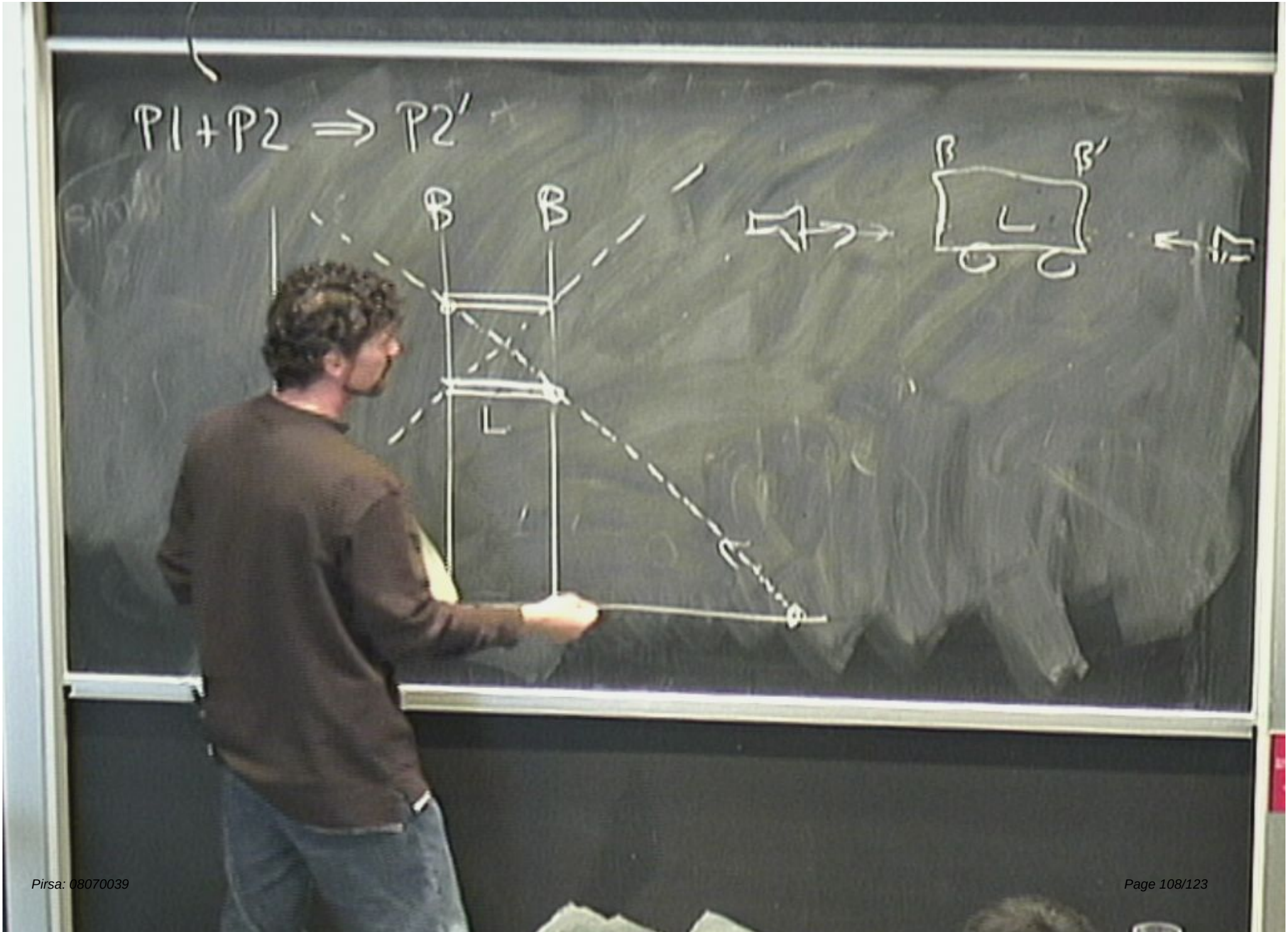

A
B
A'
B'
$t_A - t_{A'} = 0$

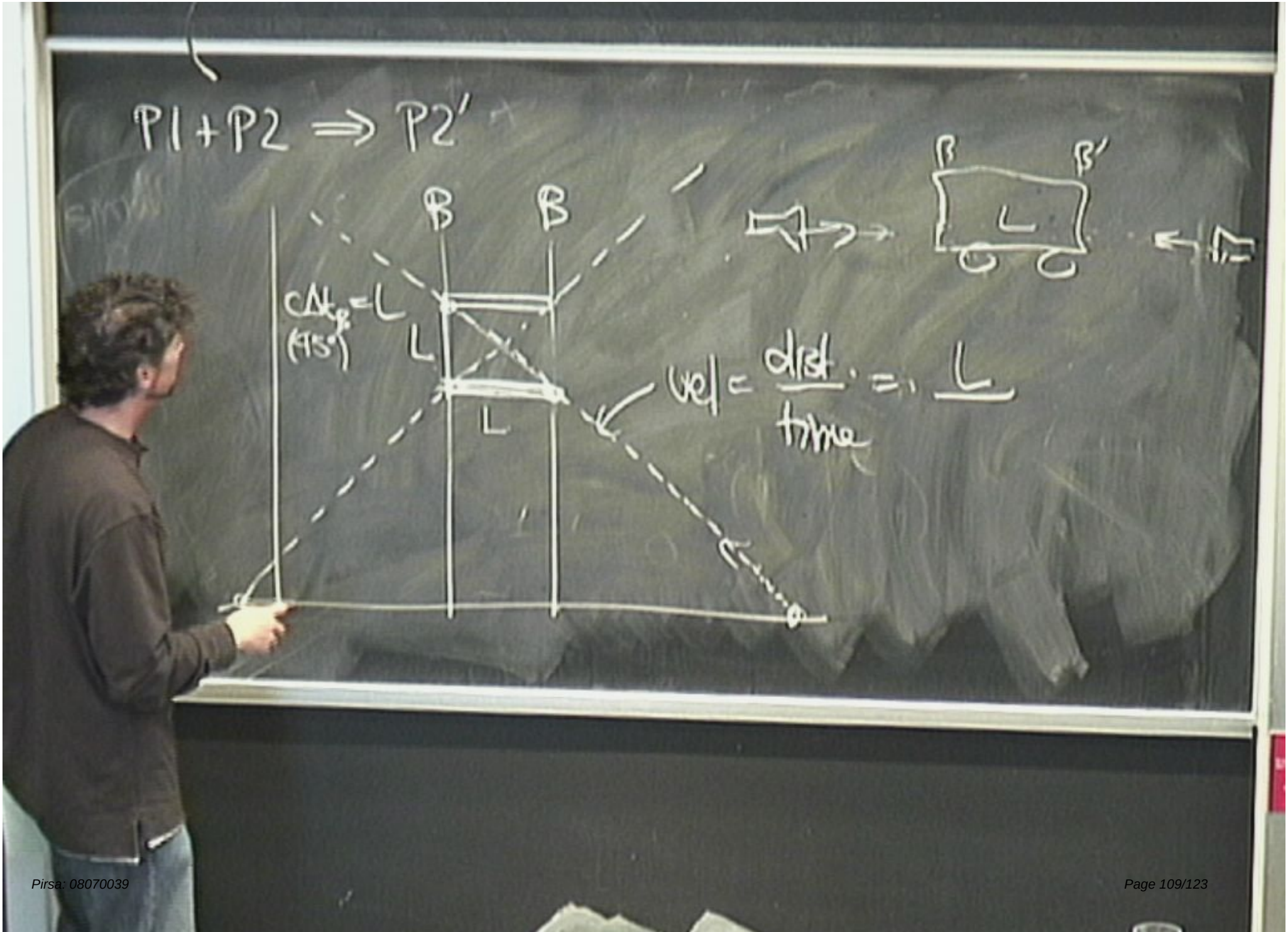

A
B
A'
B'
$t_{B'} - t_B = 3$
$t_B = t_{B'} = 2$
$t_0 = t_{B'} = 1$
$t_A = t_{A'} = 0$
$t_B = t_{B'} = 0$

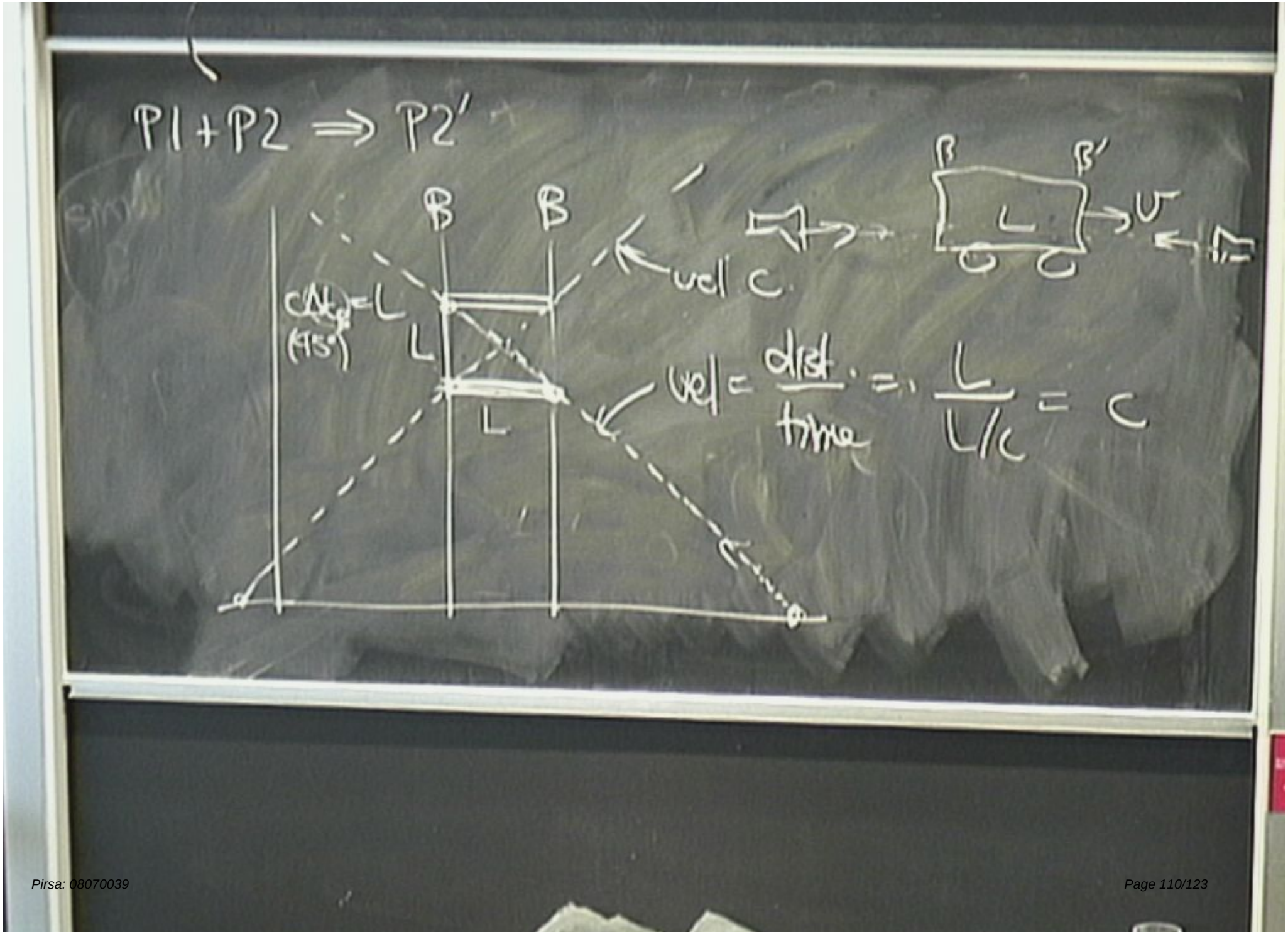

A
B
A'
B'
$t_{B'} - t_B = 3$
$t_B = t_{B'} = 2$
$t_0 = t_{B'} = 1$
$t_A = t_{A'} = 0$
$t_B = t_{B'} = 0$
B
B'
v
A
A'

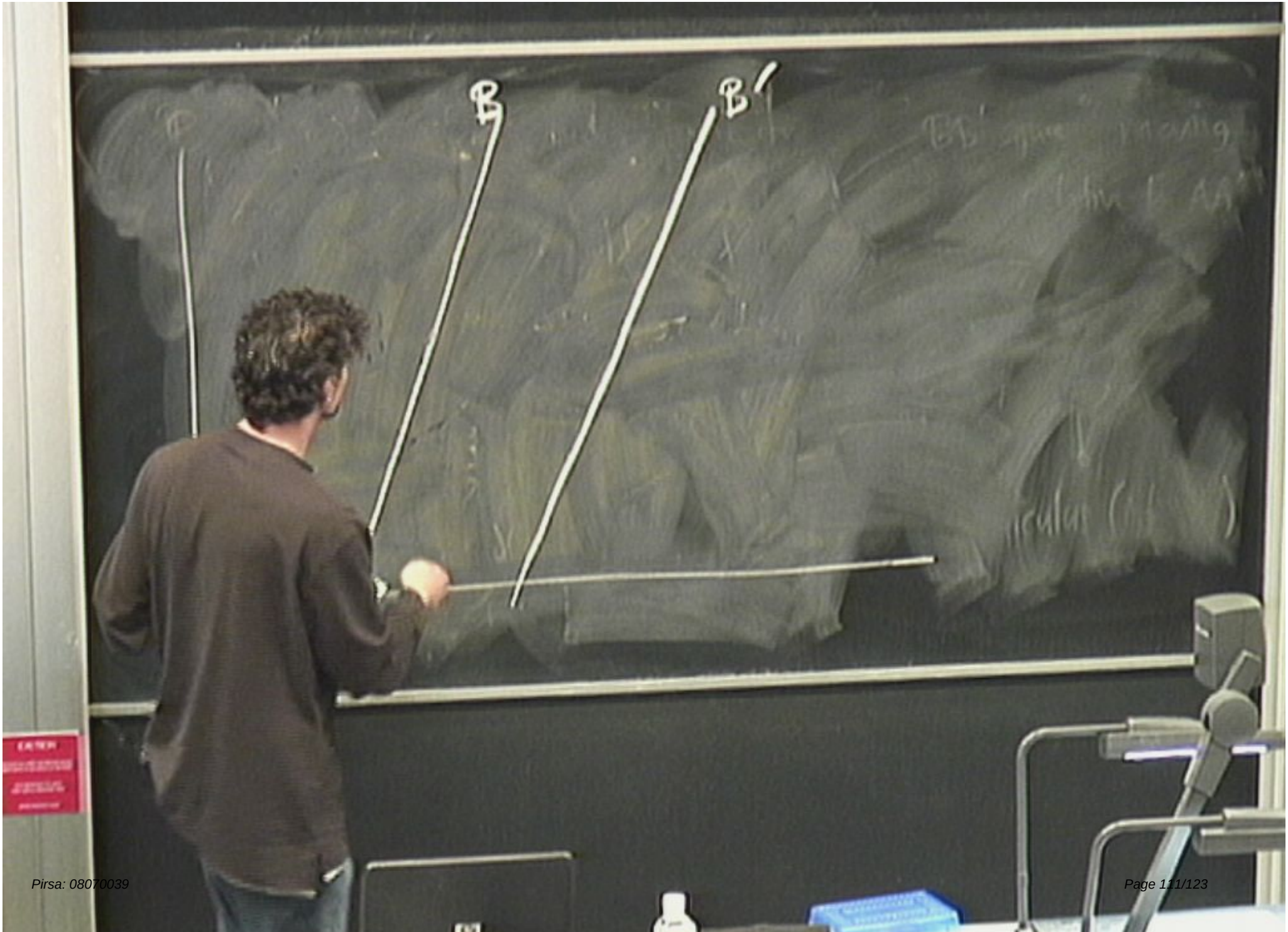

P1+P2 ⇒ P2'
B
B

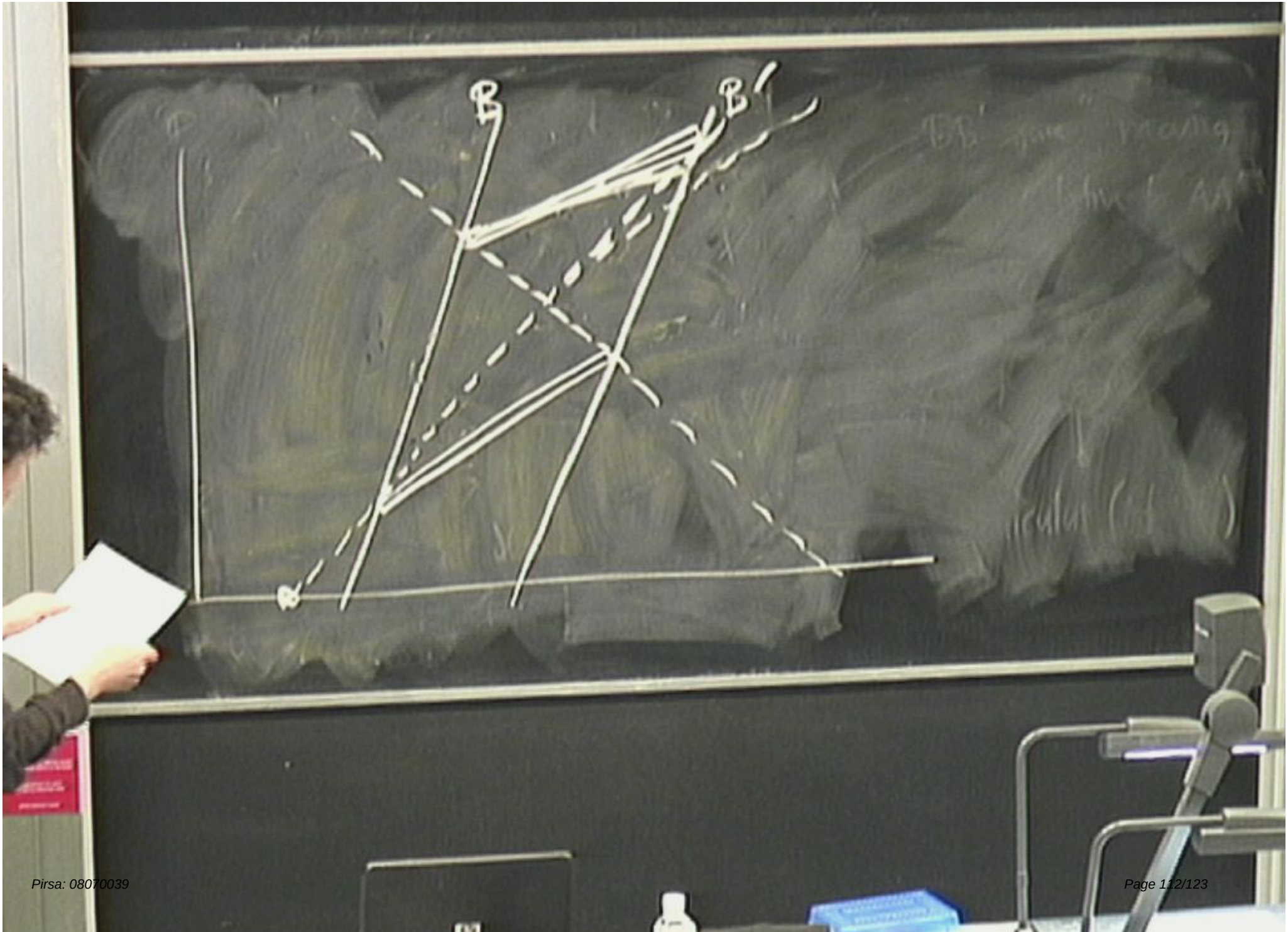

P1+P2 ⇒ P2'
B
B
B
B'

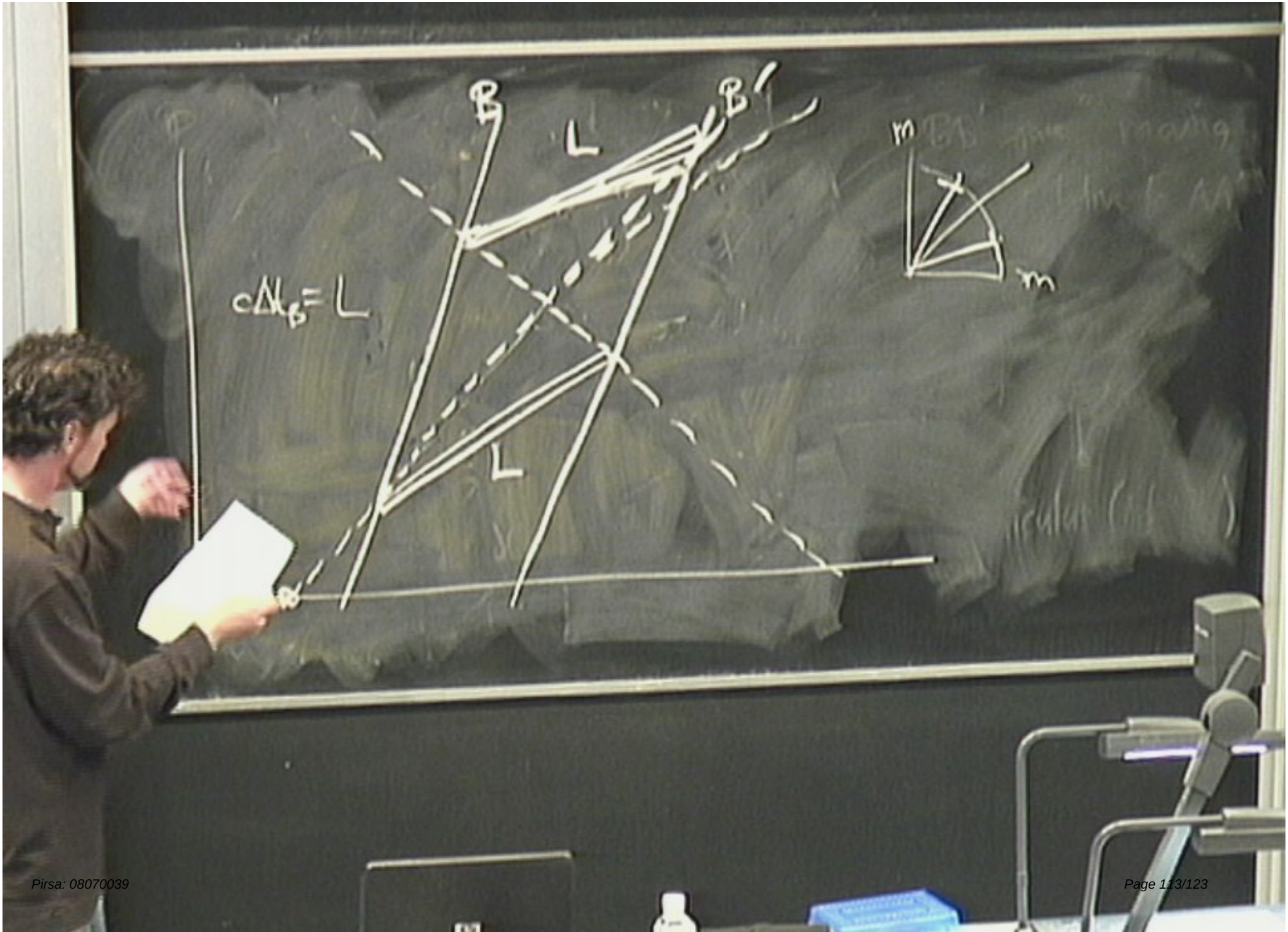

P1+P2 ⇒ P2'
B
B
L
B
B'
L

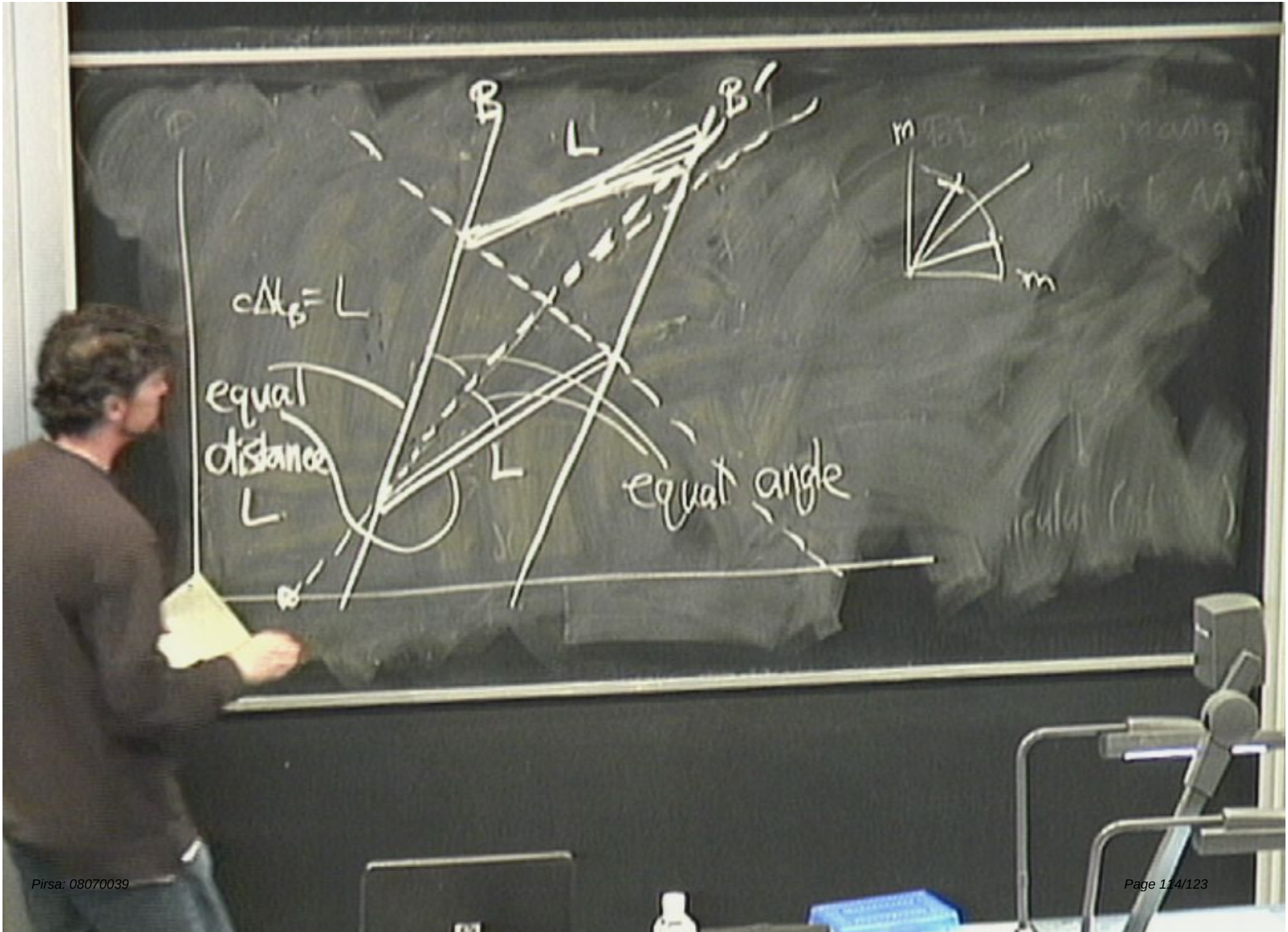

P1 + P2 ⇒ P2'
B
B
L
L
vel = dist / time = L
B
B'
L

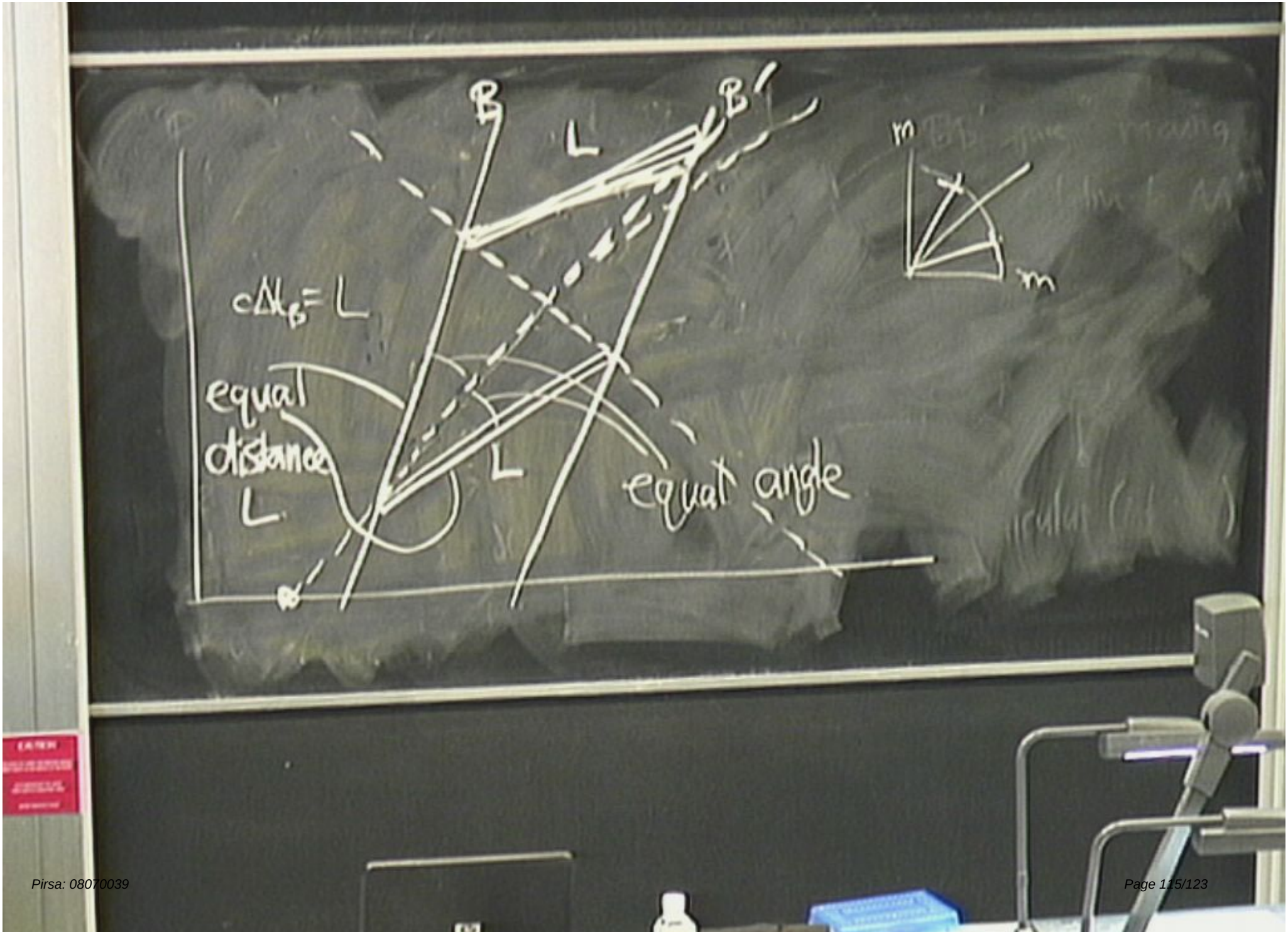

P1 + P2 ⇒ P2'
B
B
vel c
L
L
vel = dist / time = L / (L/c) = c
B
B'
L
v

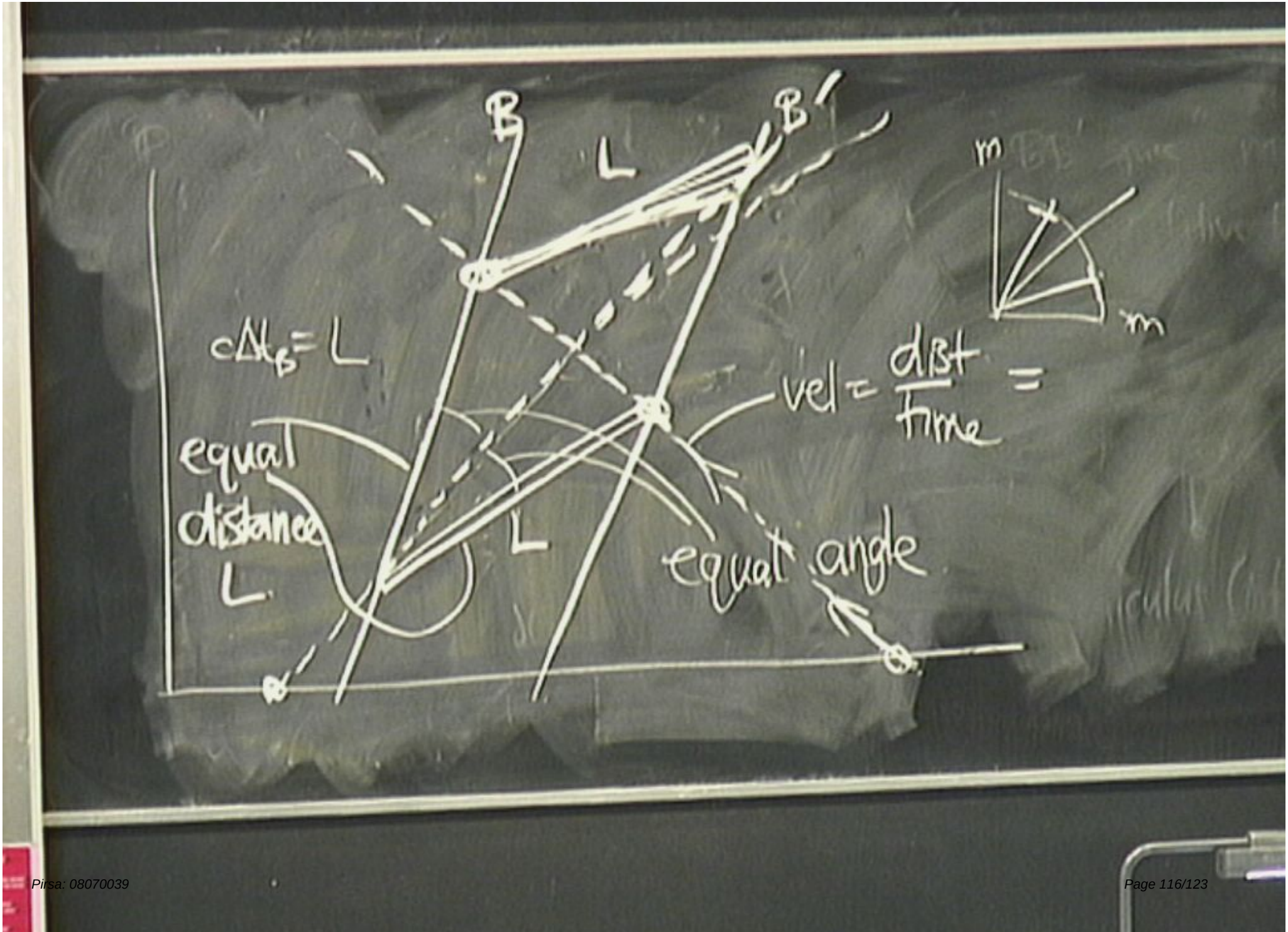

B
B'

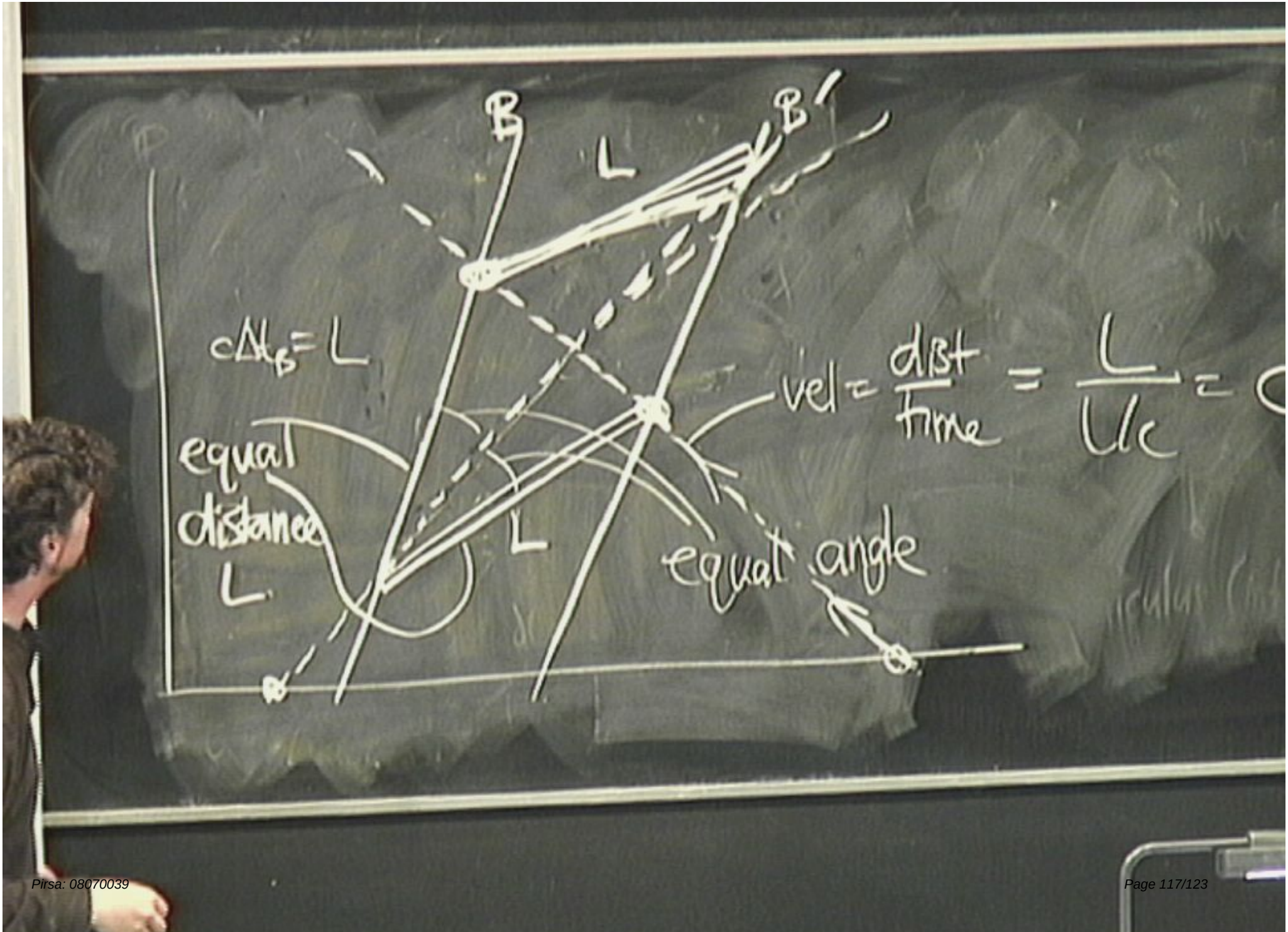

B
B'

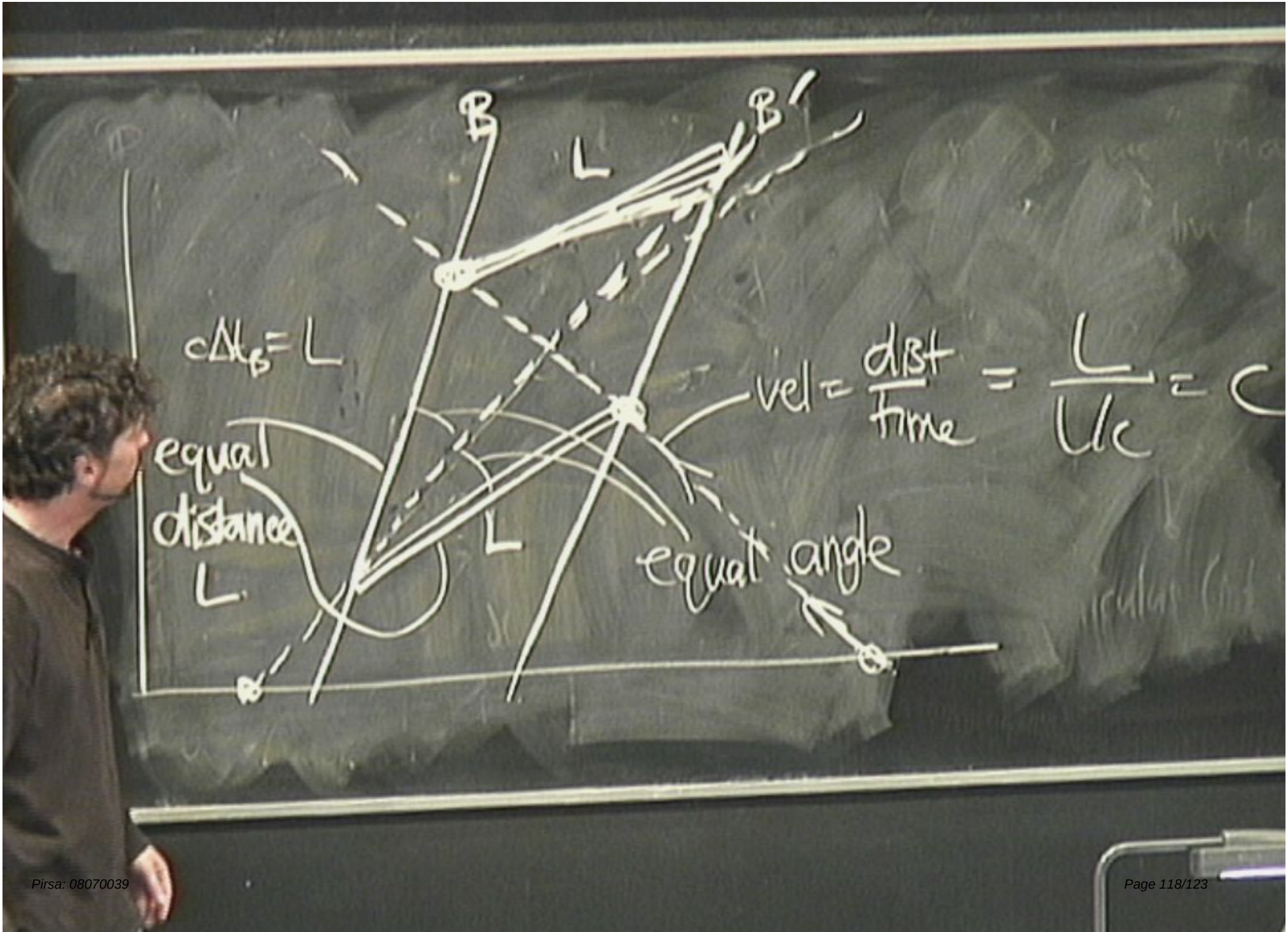

B
L
B'
m
m
$c\Delta t_B = L$
L

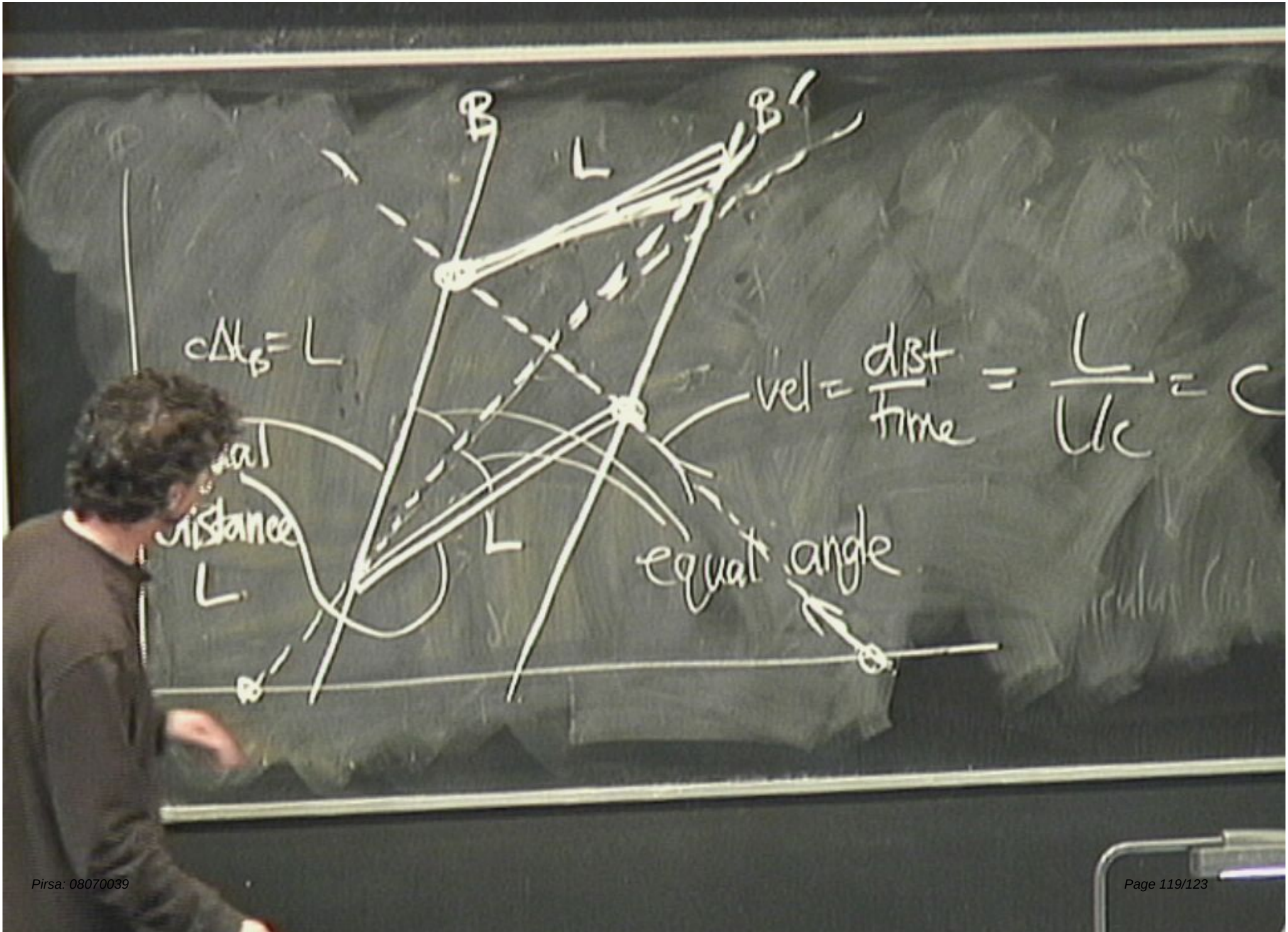

B
L
B'
m
m
$c\Delta t_B = L$
equal
distance
L
L
equal angle

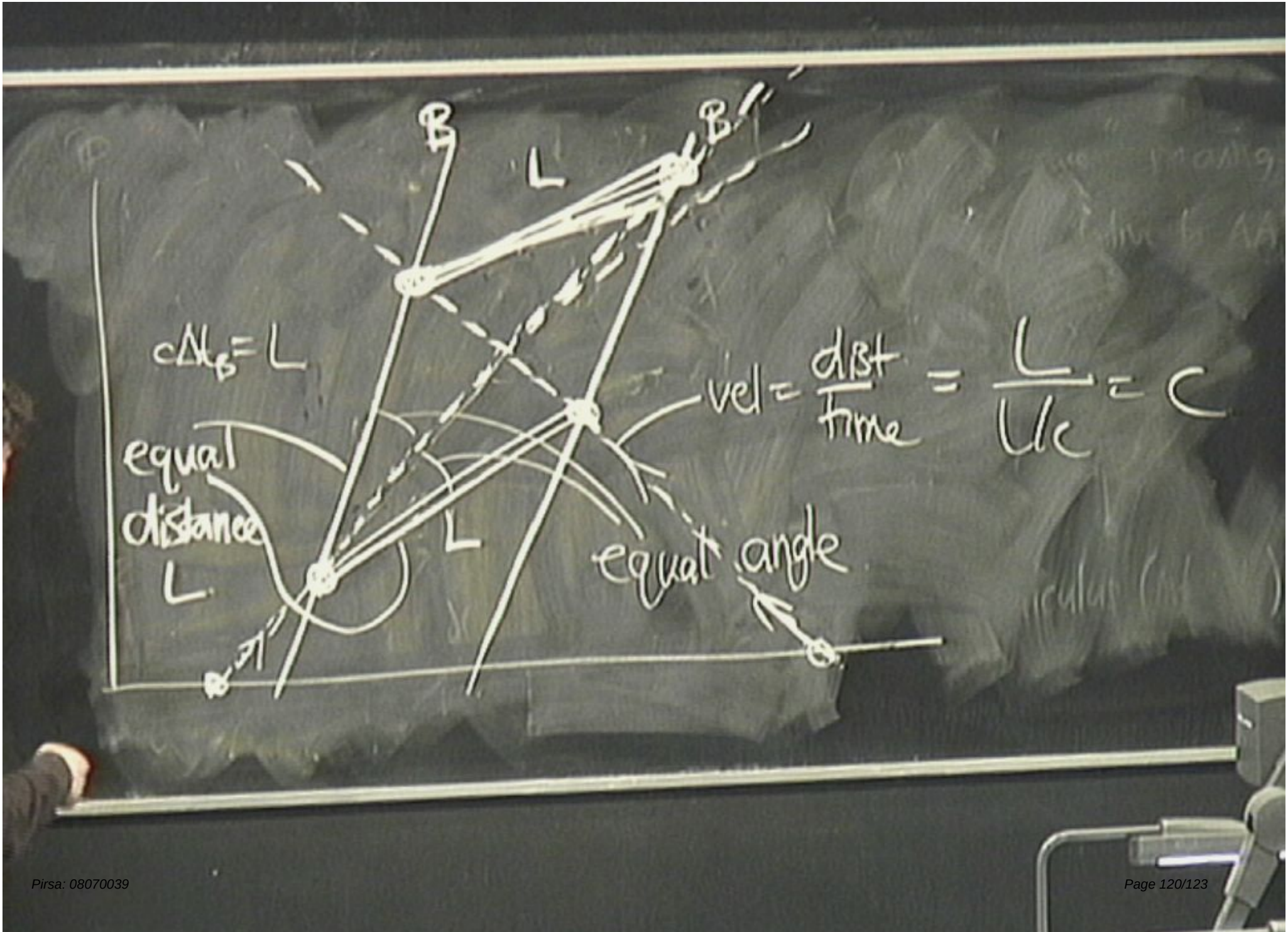

B
L
B'
m
m
$c\Delta t_B = L$
equal
distance
L
L
equal angle

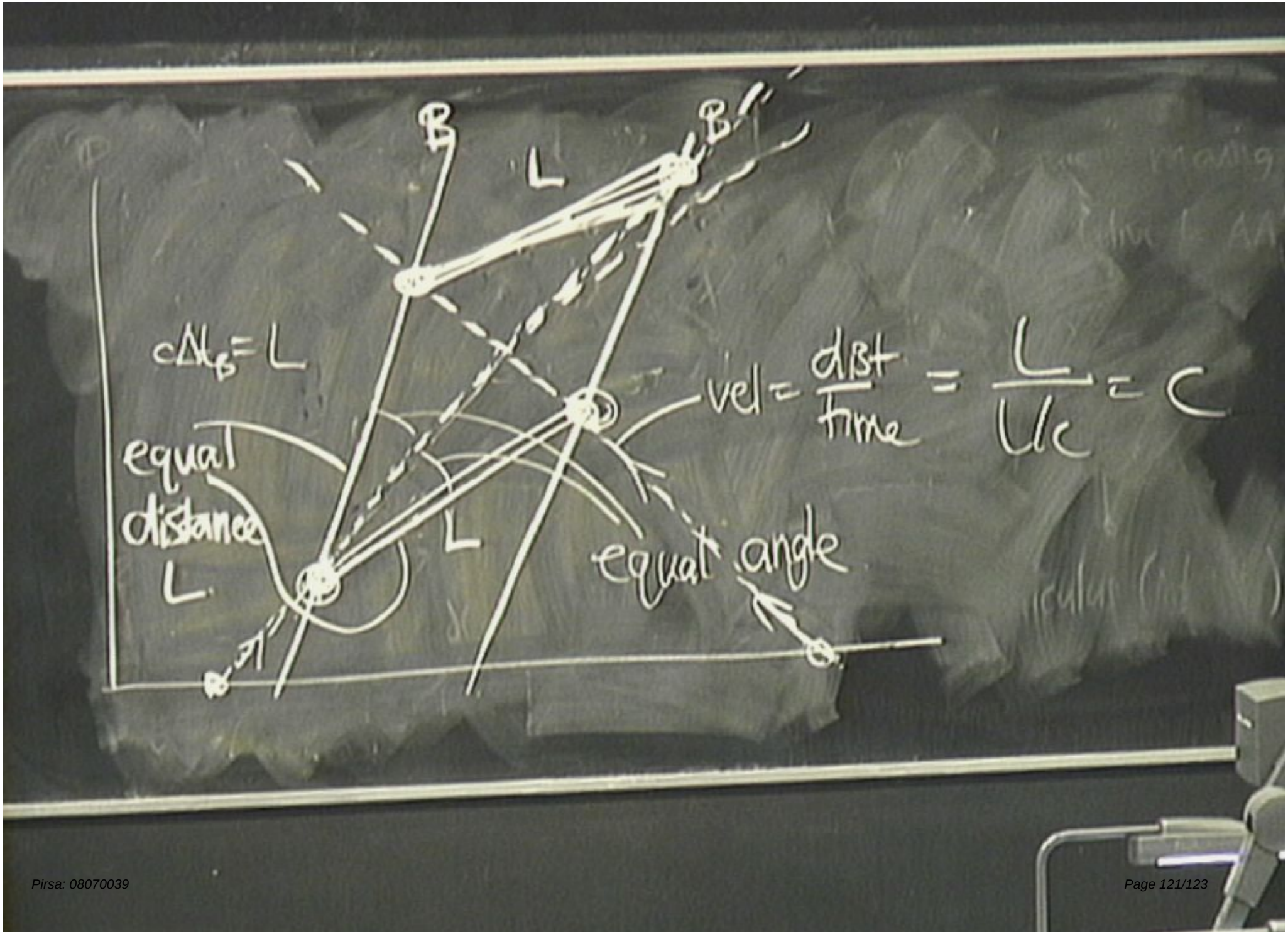

B
B'
L
m
m
$c\Delta t_B = L$
vel = $\frac{\text{dist}}{\text{time}}$ =
equal distance L
L
equal angle


B
B'
L
$c\Delta t_B = L$
equal distance L
L
$vel = \frac{dist}{time} = \frac{L}{Uc} = c$
equal angle

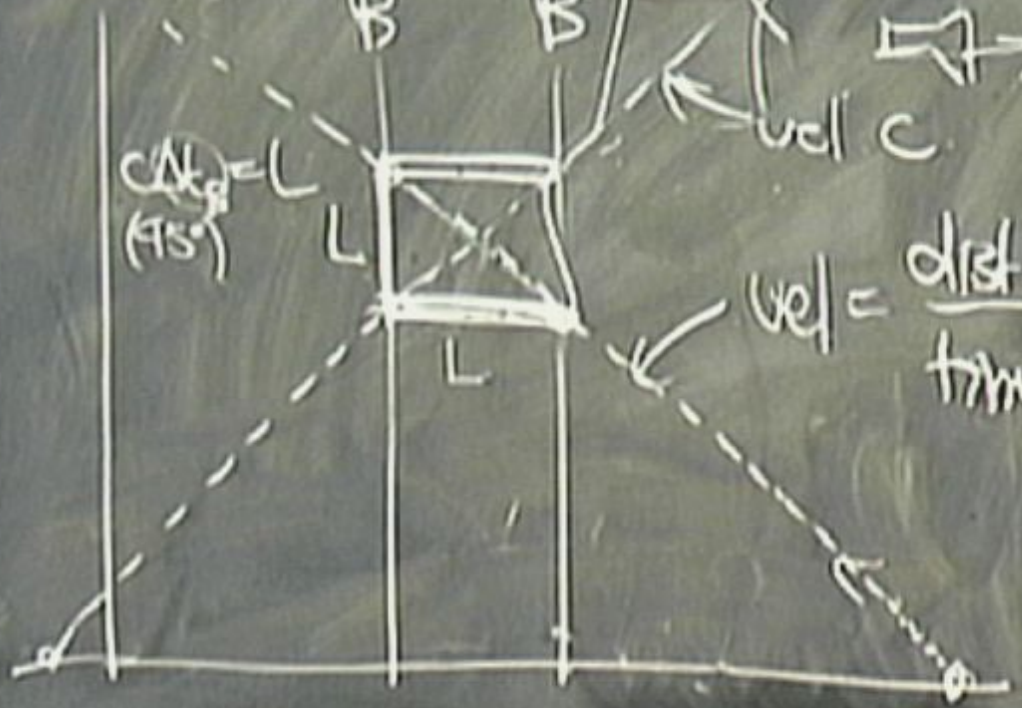

B
L
B'
$c\Delta t_B = L$
$vel = \frac{dist}{time} = \frac{L}{Uc} = c$
equal distance L
L
equal angle

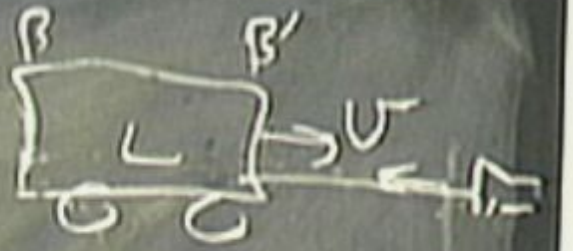

B
L
B'
$c\Delta t_B = L$
vel = dist / time = L / Lc = c
distance
L
L
equal angle


B
B
L
$c\Delta t_B = L$
equal distance L
L
equal angle
vel = dist / time = L / (L/c) = c

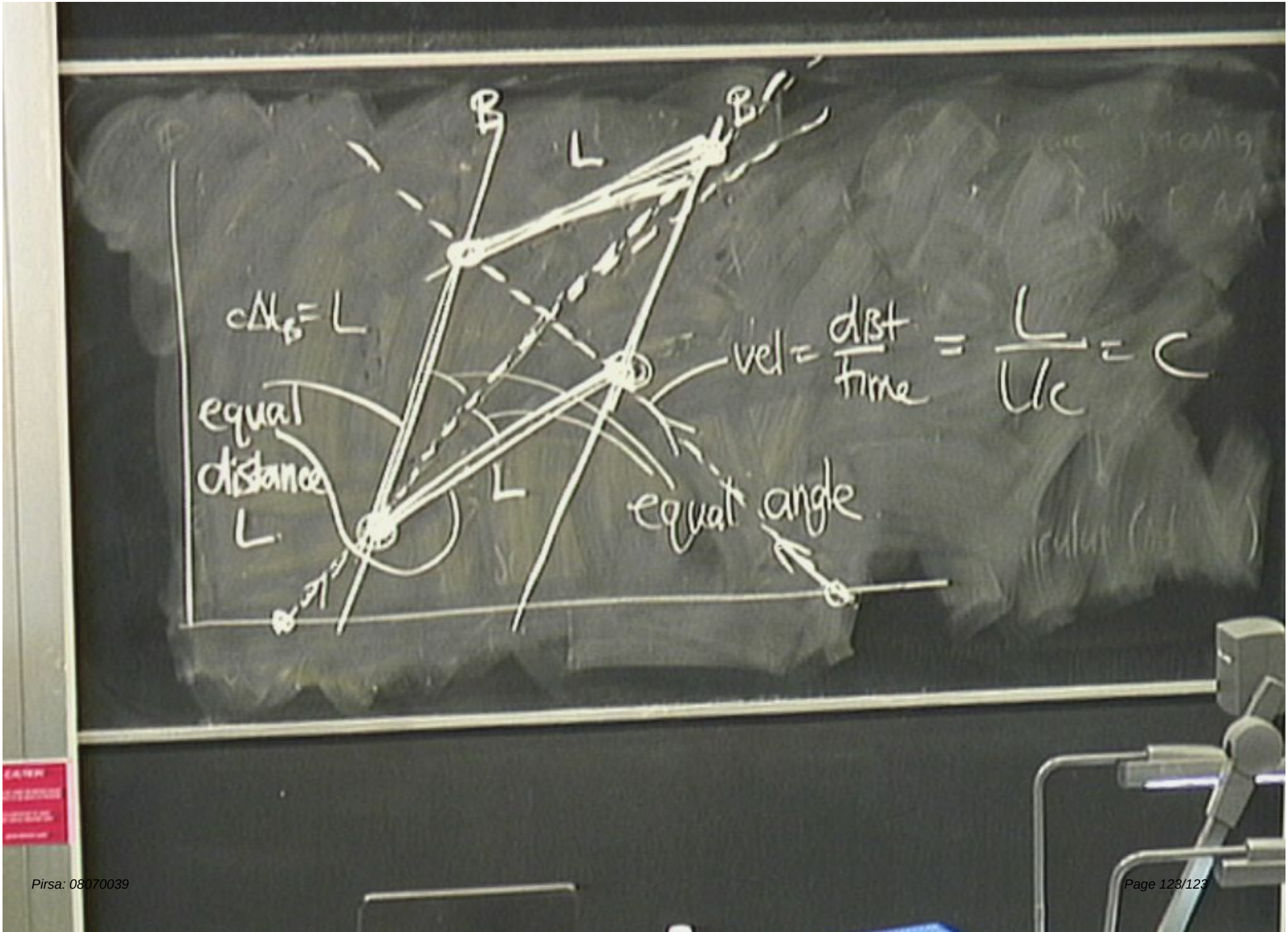

B
B
L
$c\Delta t_B = L$
equal distance L
L
equal angle
vel = dist / time = L / L/c = c

P1 + P2 ⇒ P2′





$$\text{vel} = \frac{\text{dist}}{\text{time}} \Rightarrow \frac{L}{L/c} = c$$


B
B
L
$c\Delta t_B = L$
equal distance L
L
vel = dist / time = L / (L/c) = c
equal angle