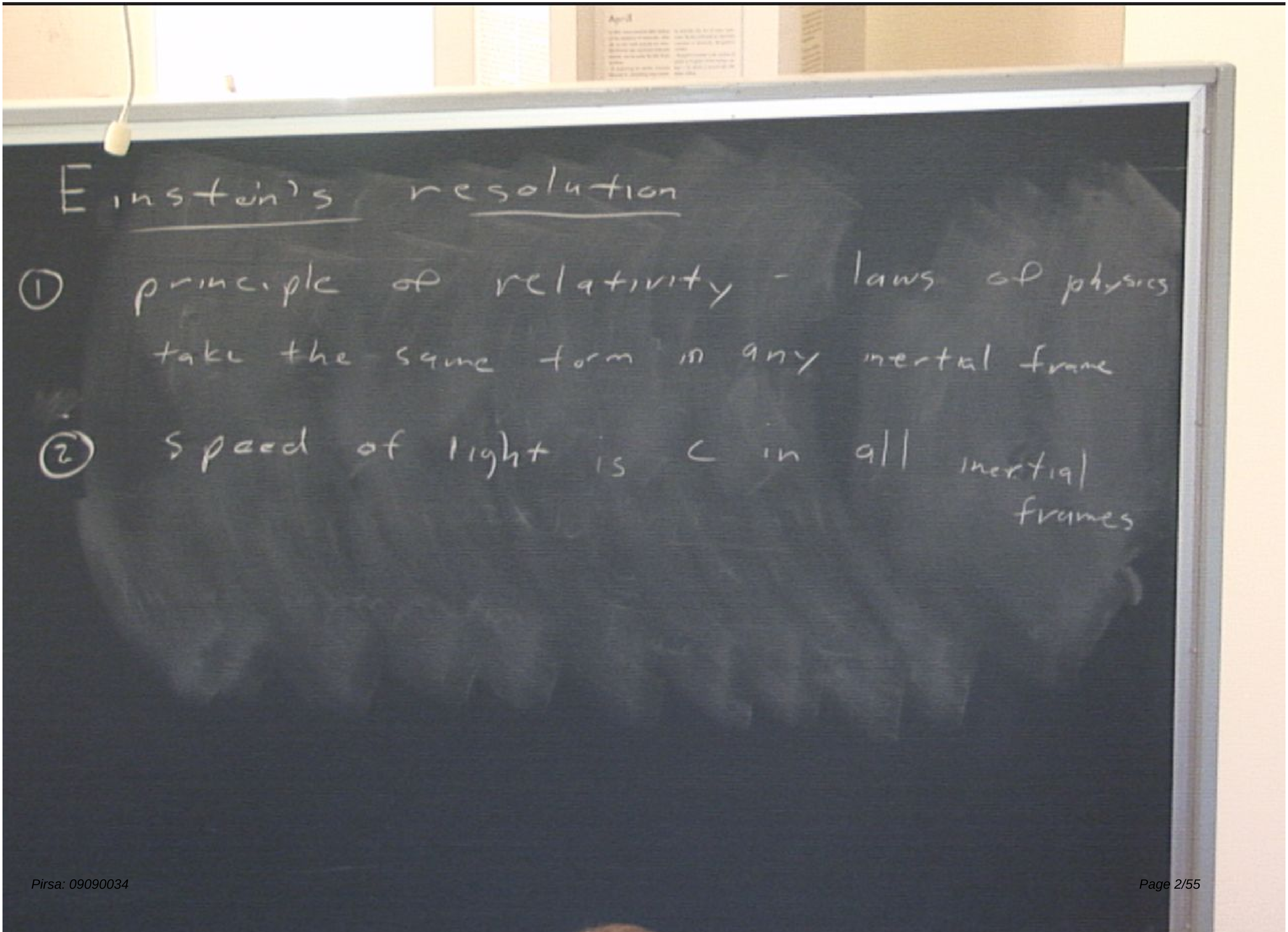
Title: Relativity - Core (PHYS 604) - Lecture 1B

Date: Sep 03, 2009 11:00 AM

URL: http://pirsa.org/09090034

Abstract:


Einstein's resolution
① principle of relativity - laws of physics take the same form in any inertial frame
② speed of light is c in all inertial frames

Einstein's resolution

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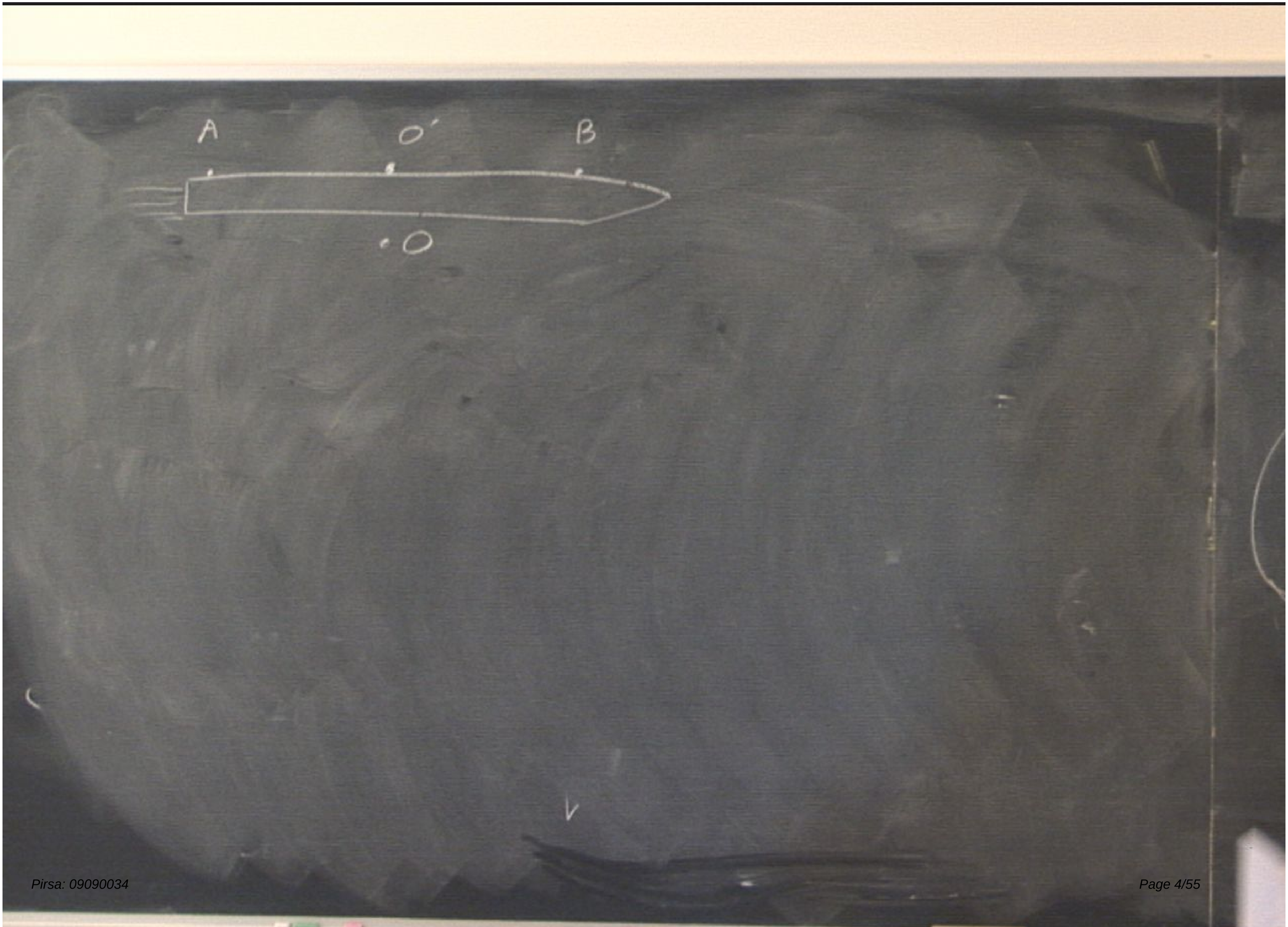
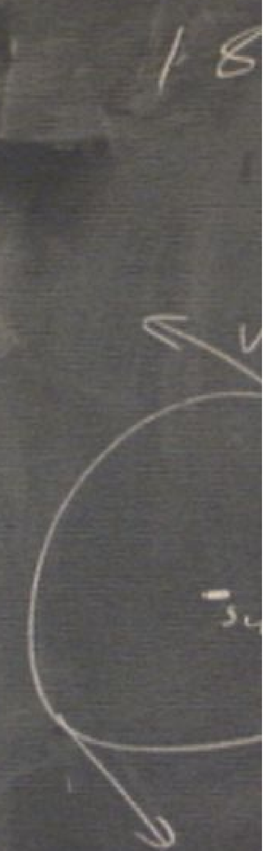
Consequences: no absolute time


A
O'
B
O
V

- If O' recieves light signals from A and B at the same time, he says that they were emmitted at precisely the same time ($\because$ same $l(O'A) = l(O$



- if O' recieves light signals from A and B at the same time, he says that they were emmitted at precisely the same time (as same $\ell(O'A) = \ell(O'B)$)

- if O sees signals being recieved at same time, can ask which was emmitted first?

A was first because his signal must travel further (because

O' moves away A and towards B)

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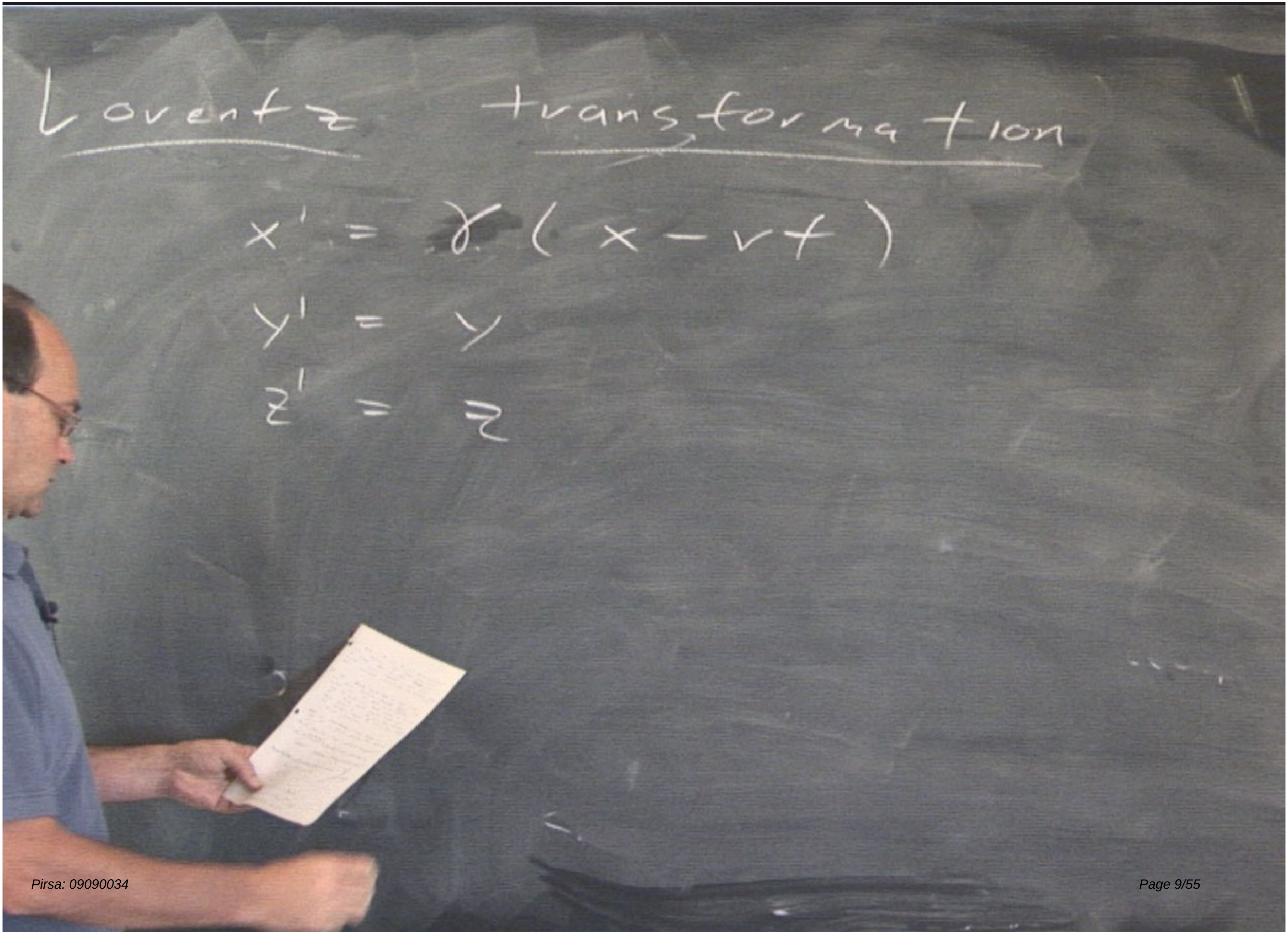
emission (by A and B) simultaneous in one frame is no longer simultaneous in another frame


Lorentz transformation
$x' = \gamma(x - vt)$
$y' = y$
$z' = z$

Lorentz transformation

$$x' = \gamma(x - vt)$$

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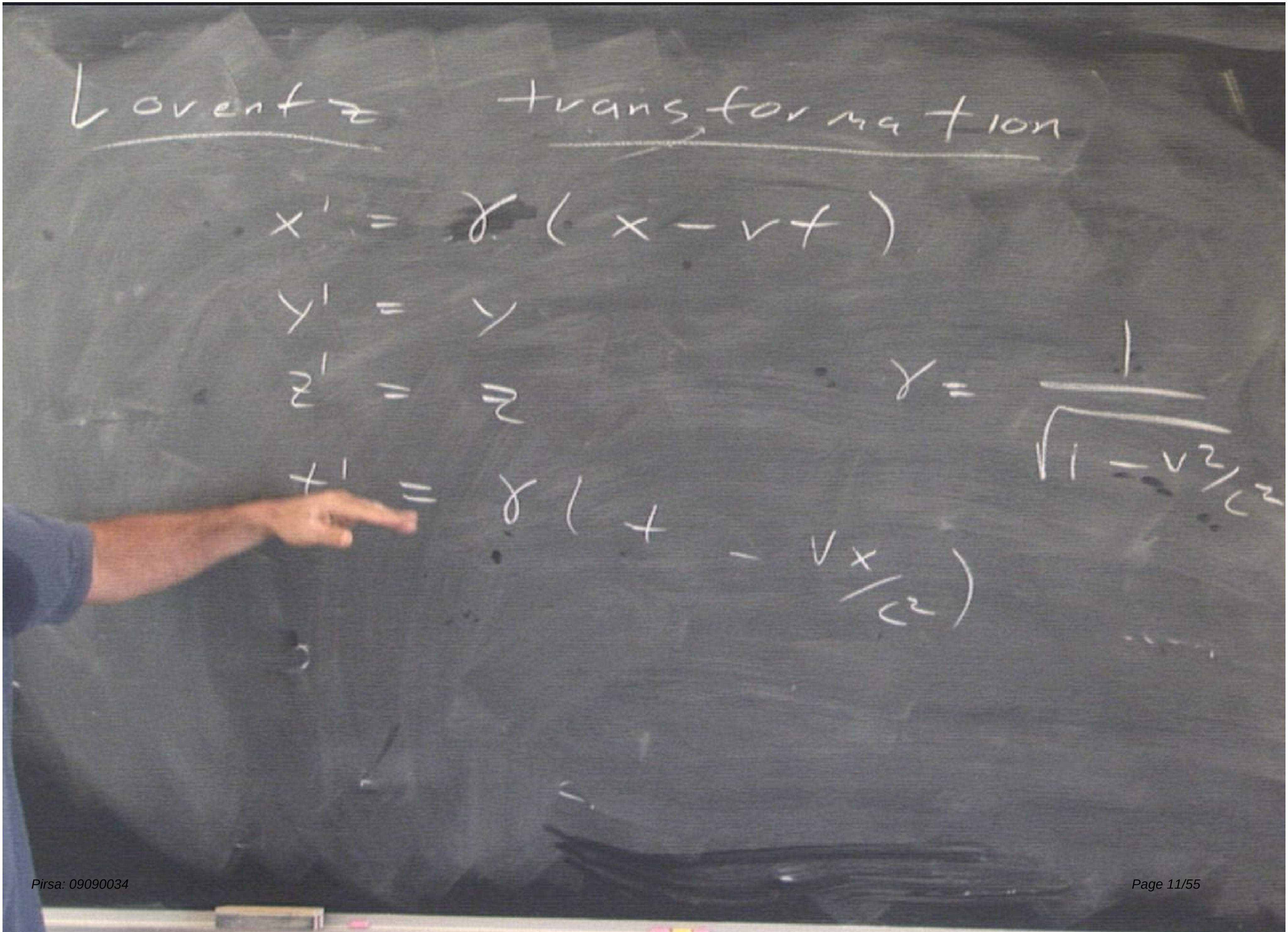
$$z' = z \qquad \gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

$$t' = \gamma\left(t - \frac{vx}{c^2}\right)$$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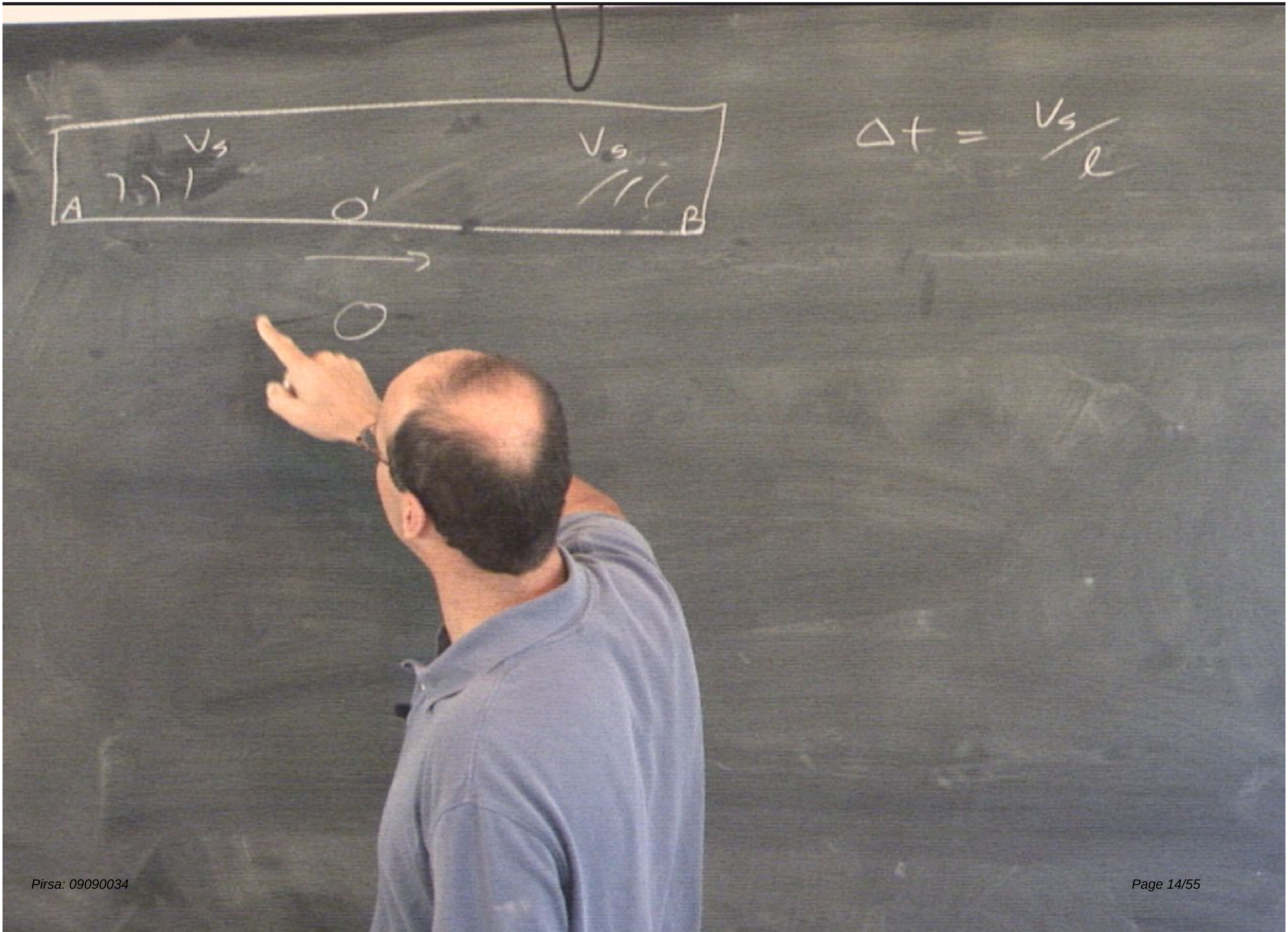
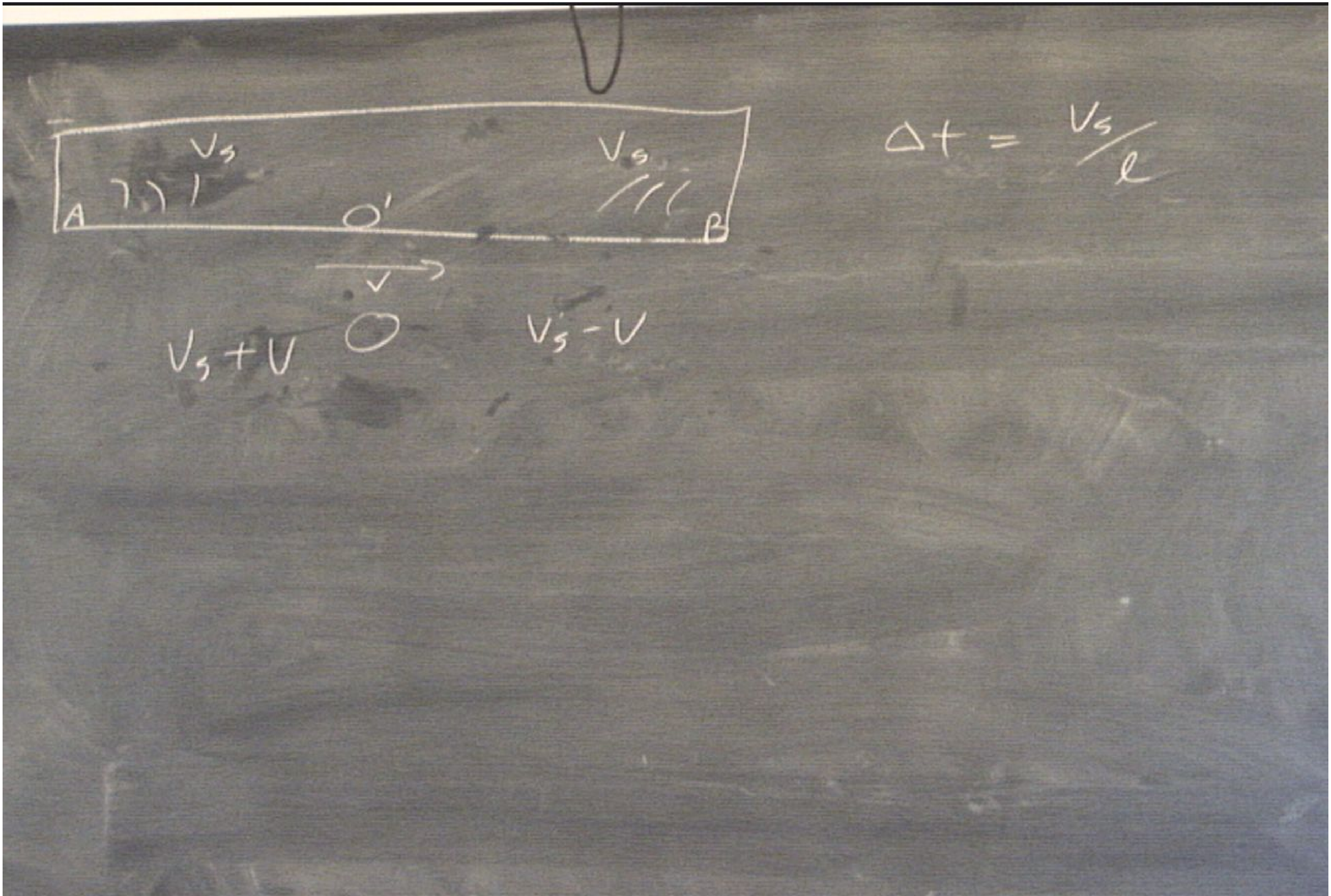
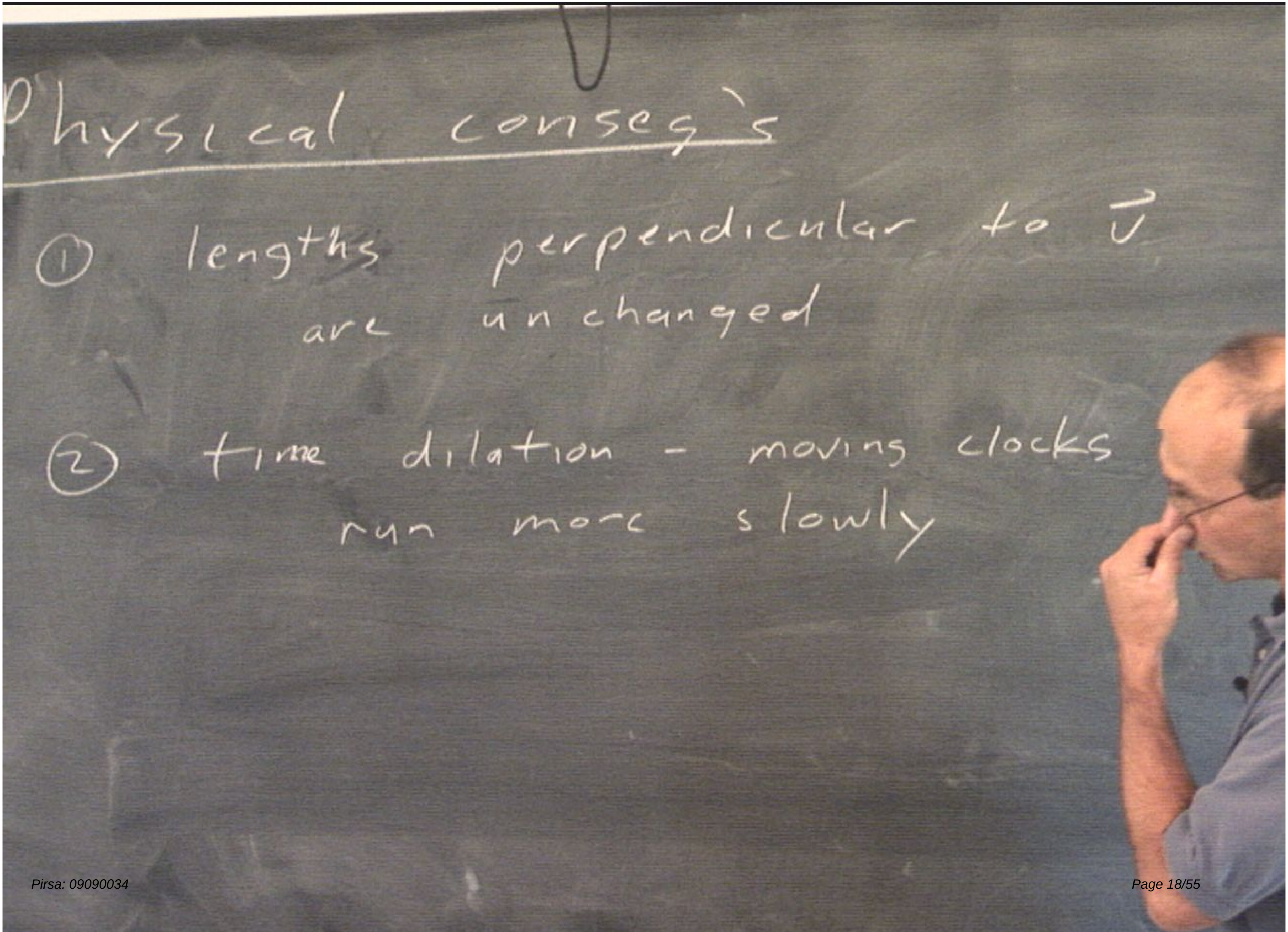

Vs
Vs
A
O'
B
O
Δt = Vs/l


V_s
V_s
$\Delta t = V_s / l$
A
O'
B
v
O
$V_s + V$
$V_s - V$

Physical conseq's

Physical conseq's

① lengths perpendicular to $\vec{v}$
are unchanged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② time dilation - moving clocks
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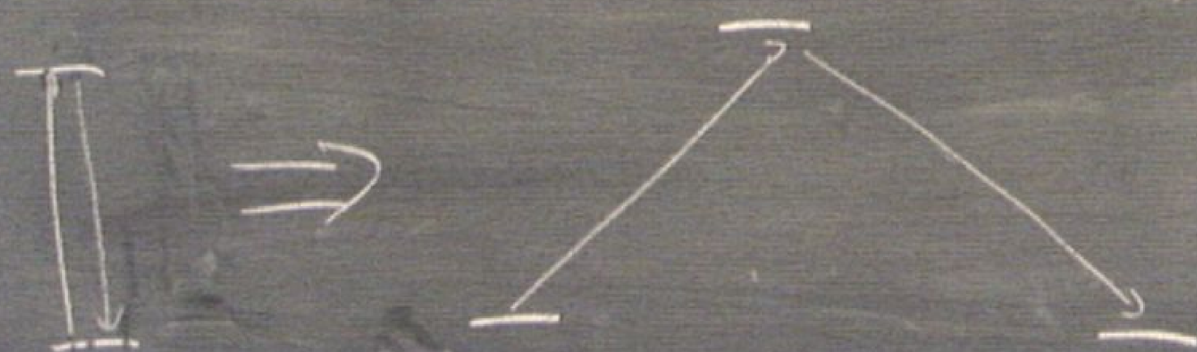
Physical conseq's

1. lengths perpendicular to $\vec{v}$ are unchanged

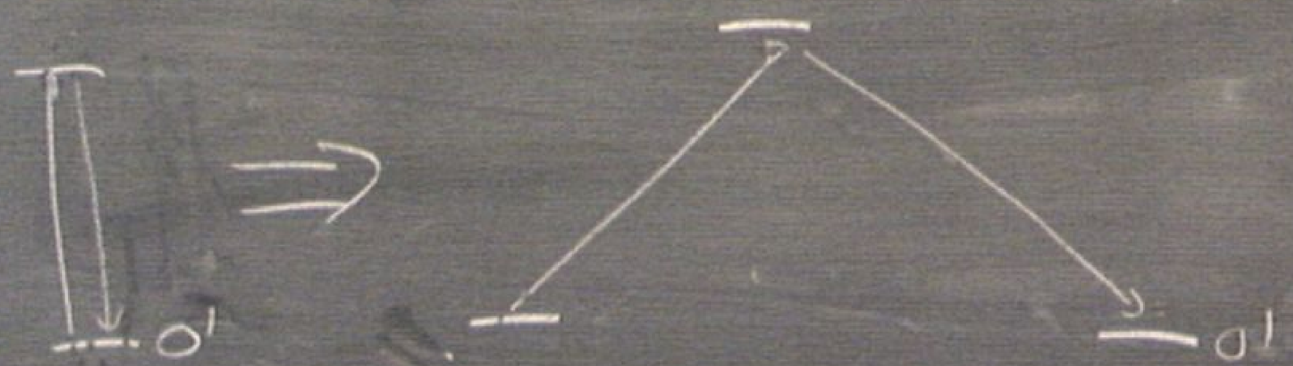
2. time dilation - moving clocks appe run more slowly



Physical conseq's

① lengths perpendicular to $\vec{v}$ are unchanged

② time dilation - moving clocks appe[ar to] run more slowly



$$\Delta t(O) > \Delta t(O')$$

– moving clocks appear to
slowly

interval on moving clocks

$$\Delta t' = \gamma\left(\Delta t - \frac{v}{c^2}\Delta x\right)$$

O'

$O) > \Delta t(O')$

...nged

– moving clocks appear to slowly

interval on moving clocks

$$\Delta t' = \gamma\left(\Delta t - \frac{v}{c^2}\Delta x\right)$$

Δt

$$= \frac{1}{\sqrt{1-v^2/c^2}}(\Delta t$$

$(O) > \Delta t(O')$

...nged

– moving clocks appear to
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interval on moving clocks.

$$\Delta t' = \gamma\left(\Delta t - \frac{v}{c^2}\Delta x\right)$$

$\Delta t'$

$$= \frac{1}{\sqrt{1 - v^2/c^2}}\left(\Delta t - \frac{v^2}{c^2}\Delta t\right)$$

$$= \sqrt{1 - v^2/c^2}\,\Delta t$$

$\Delta t(O) > \Delta t(O')$

nged

– moving clocks appear to
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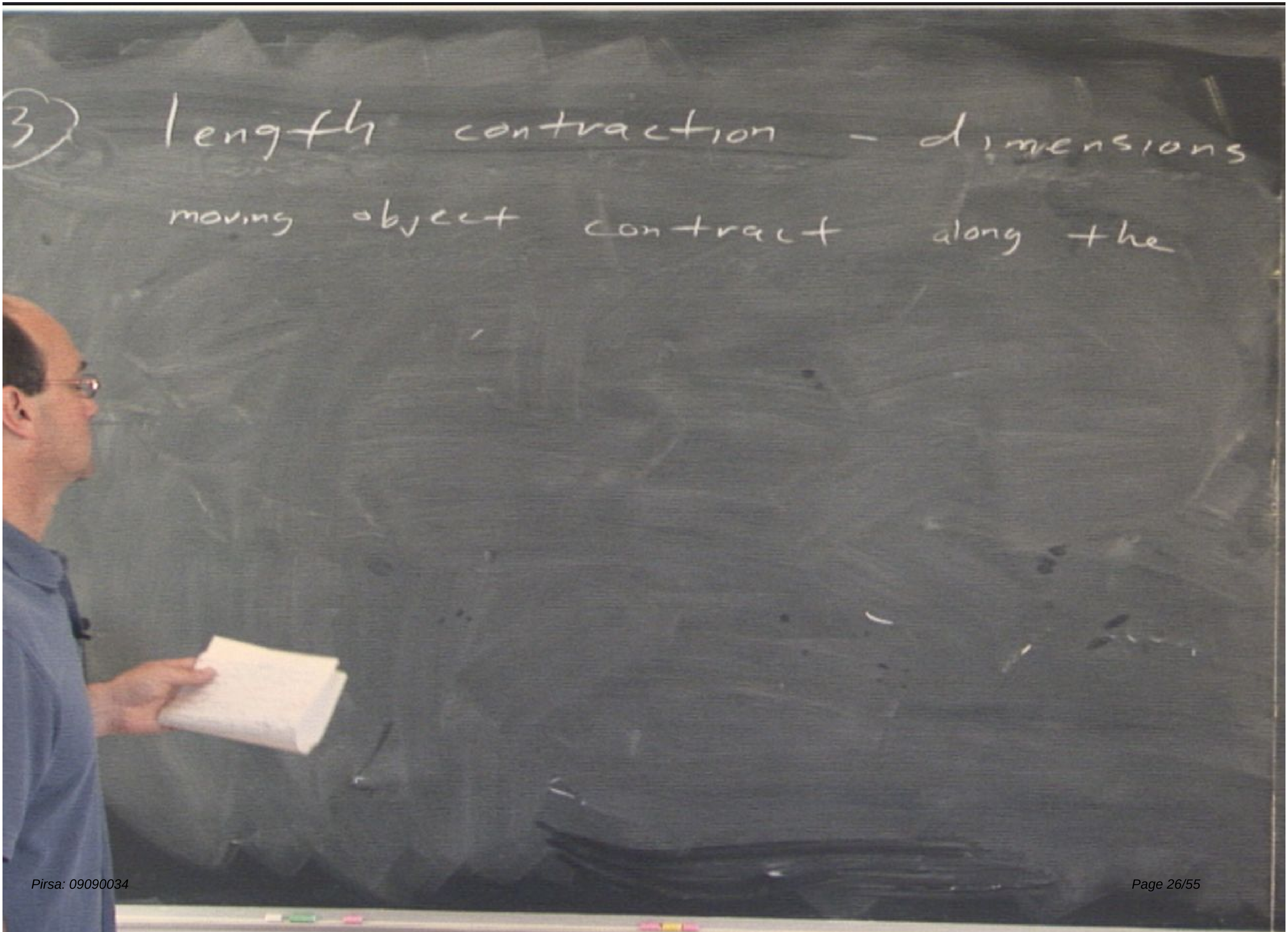
interval on moving clocks

$$\Delta t' = \gamma\left(\Delta t - \frac{v}{c^2}\Delta x\right)$$

$$= \frac{1}{\sqrt{1-v^2/c^2}}\left(\Delta t - \frac{v^2}{c^2}\Delta t\right)$$

$$= \sqrt{1-v^2/c^2}\,\Delta t < \Delta t$$

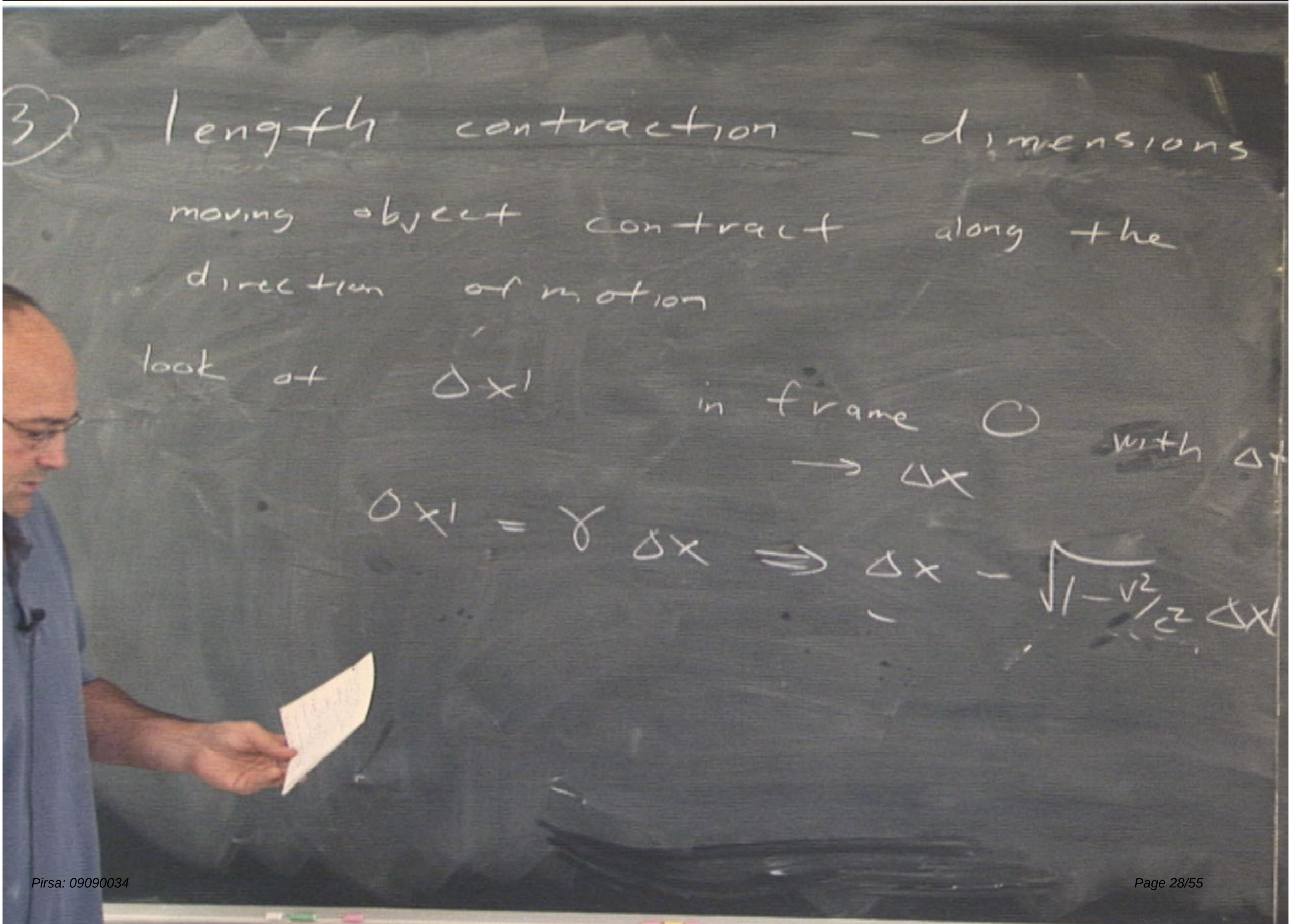
$\Delta t(O) > \Delta t(O')$

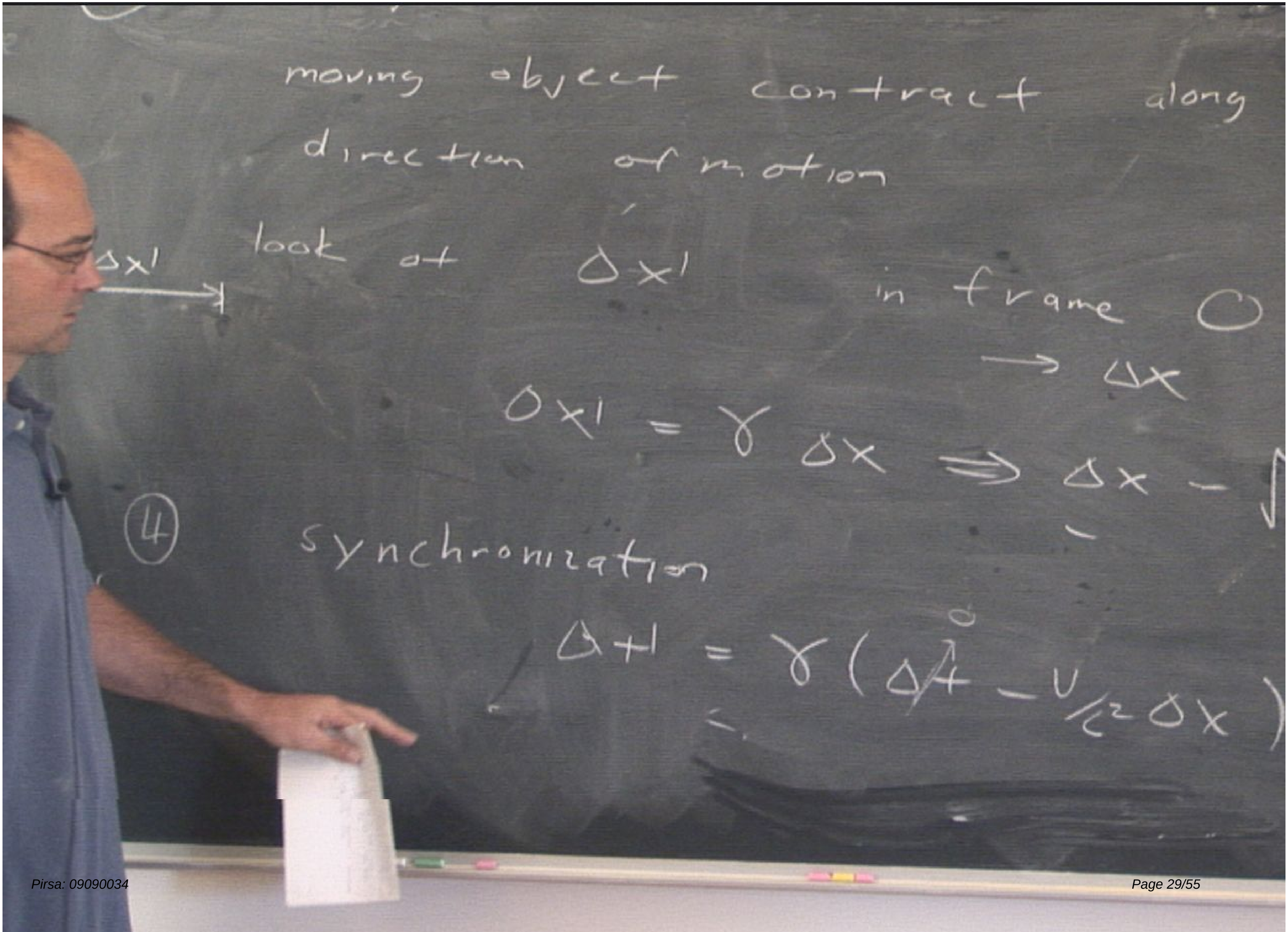

3 length contraction - dimensions
moving object contract along the

3) length contraction - dimensions

moving object contract along the direction of motion

look at $\Delta x'$ in frame O with Δ


③ length contraction - dimensions
moving object contract along the direction of motion
look at $\Delta x'$ in frame O with Δt
$\rightarrow \Delta x$
$\Delta x' = \gamma \Delta x \Rightarrow \Delta x = \sqrt{1 - v^2/c^2}\, \Delta x'$


moving object contract along
direction of motion
Δx'
look at Δx' in frame O
→ Δx
Δx' = γ Δx ⇒ Δx = √
4
synchronization
Δt' = γ (Δt − v/c² Δx)

moving object contract along direction of motion

$\Delta x'$

look at $\Delta x'$ in frame O

$\longrightarrow \Delta x$

$$\Delta x' = \gamma\, \Delta x \Rightarrow \Delta x = \ldots$$

4 synchronization

$$\Delta t' = \gamma\left(\overset{0}{\cancel{\Delta t}} - \frac{v}{c^2}\Delta x\right)$$

$$\Delta t' = -\gamma \frac{v}{c^2}\Delta x$$

addition law for velocities

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$$\vec{v} = \frac{d\vec{x}}{dt} = (v^x, v^y, v^z)$$

addition law for velocities

$$\vec{V} = \frac{d\vec{x}}{dt} = (V^x, V^y, V^z)$$

$$\vec{V}' = \frac{d\vec{x}'}{dt} = (\quad)$$

addition laws for velocities

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$$\vec{V}' = \frac{d\vec{x}'}{dt'} = (\quad)$$

$$V^{x'} = \frac{dx'}{dt'} = \gamma(dx - v\,dt)$$

addition laws for velocities

$$\vec{V} = \frac{d\vec{x}}{dt} = (V^x, V^y, V^z)$$

$$\vec{V}' = \frac{d\vec{x}'}{dt'} = (\qquad)$$

$$V^{x'} = \frac{dx'}{dt'} = \frac{\cancel{\gamma}(dx - v\,dt)}{\cancel{\gamma}(dt - v\,dx/c^2)}$$

addition laws for velocities

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ddition law for velocities

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$V^{y'} =$

$V^{z'}$

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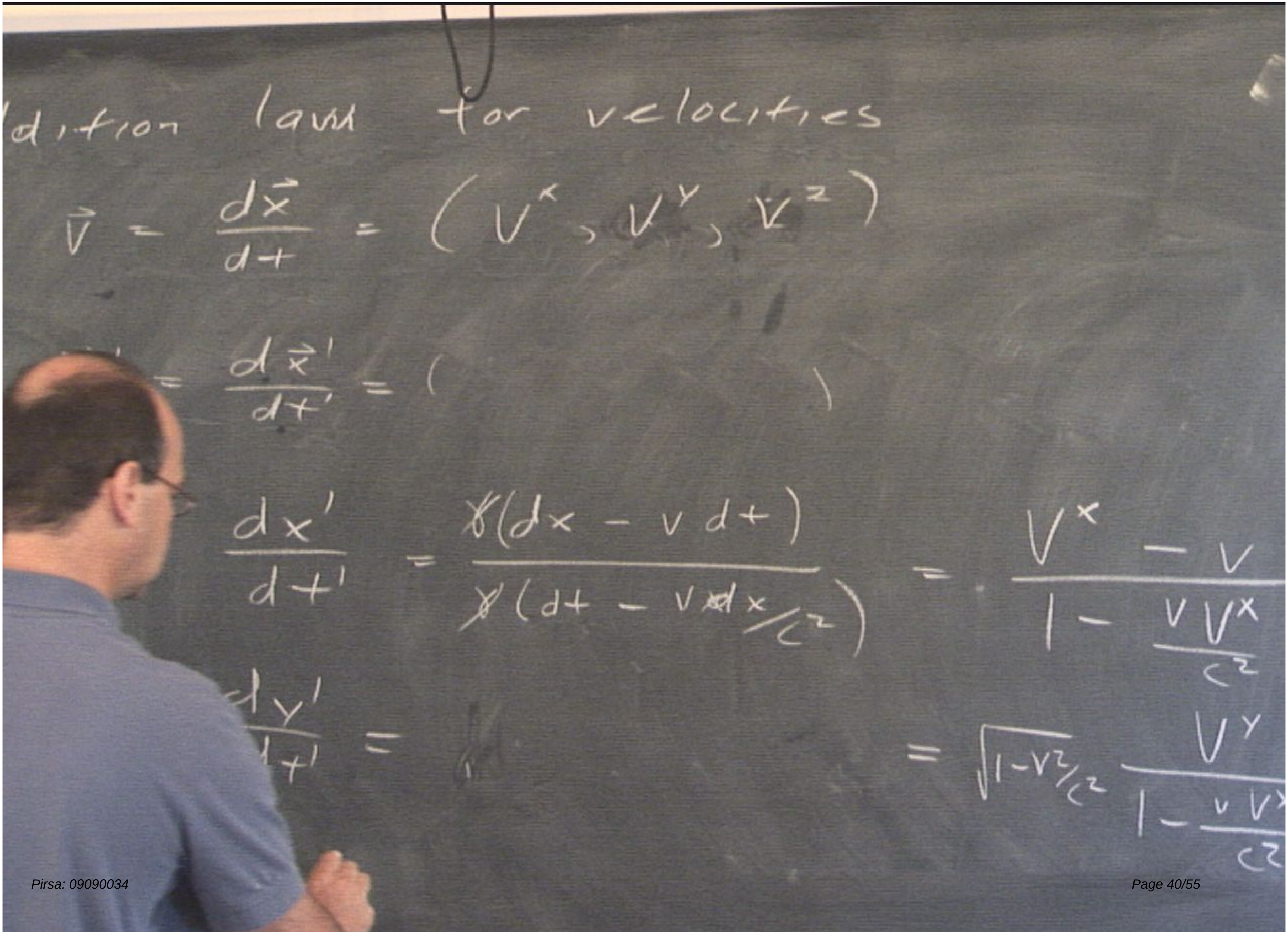
$$V^{y'} = \frac{dy'}{dt'} = \gamma \qquad = \sqrt{1 - v^2/c^2}$$

$$V^{z'}$$


dition law for velocities
$\vec{V} = \frac{d\vec{x}}{dt} = (V^x, V^y, V^z)$
$= \frac{d\vec{x}'}{dt'} = (\quad)$
$\frac{dx'}{dt'} = \frac{\gamma(dx - v\,dt)}{\gamma(dt - v\,dx/c^2)} = \frac{V^x - v}{1 - \frac{vV^x}{c^2}}$
$\frac{dy'}{dt'} = \gamma \quad = \sqrt{1-v^2/c^2}\,\frac{V^y}{1 - \frac{vV^x}{c^2}}$

ddition law for velocities

$$\vec{V} = \frac{d\vec{x}}{dt} = (V^x, V^y, V^z)$$

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$$V^{y'} = \frac{dy'}{dt'} = \sqrt{1 - v^2/c^2}\,\frac{V^y}{1 - \frac{vV^x}{c^2}}$$

$$V^{z'} = \frac{dz'}{dt'} = \quad = (y \to z)$$

- can verify if $|\vec{v}| = c$, then $|\vec{v}'| = c$

- can verify if $|\vec{v}| = c$, then $|\vec{v}'| = c$

- can also verify if $|\vec{v}| < c$

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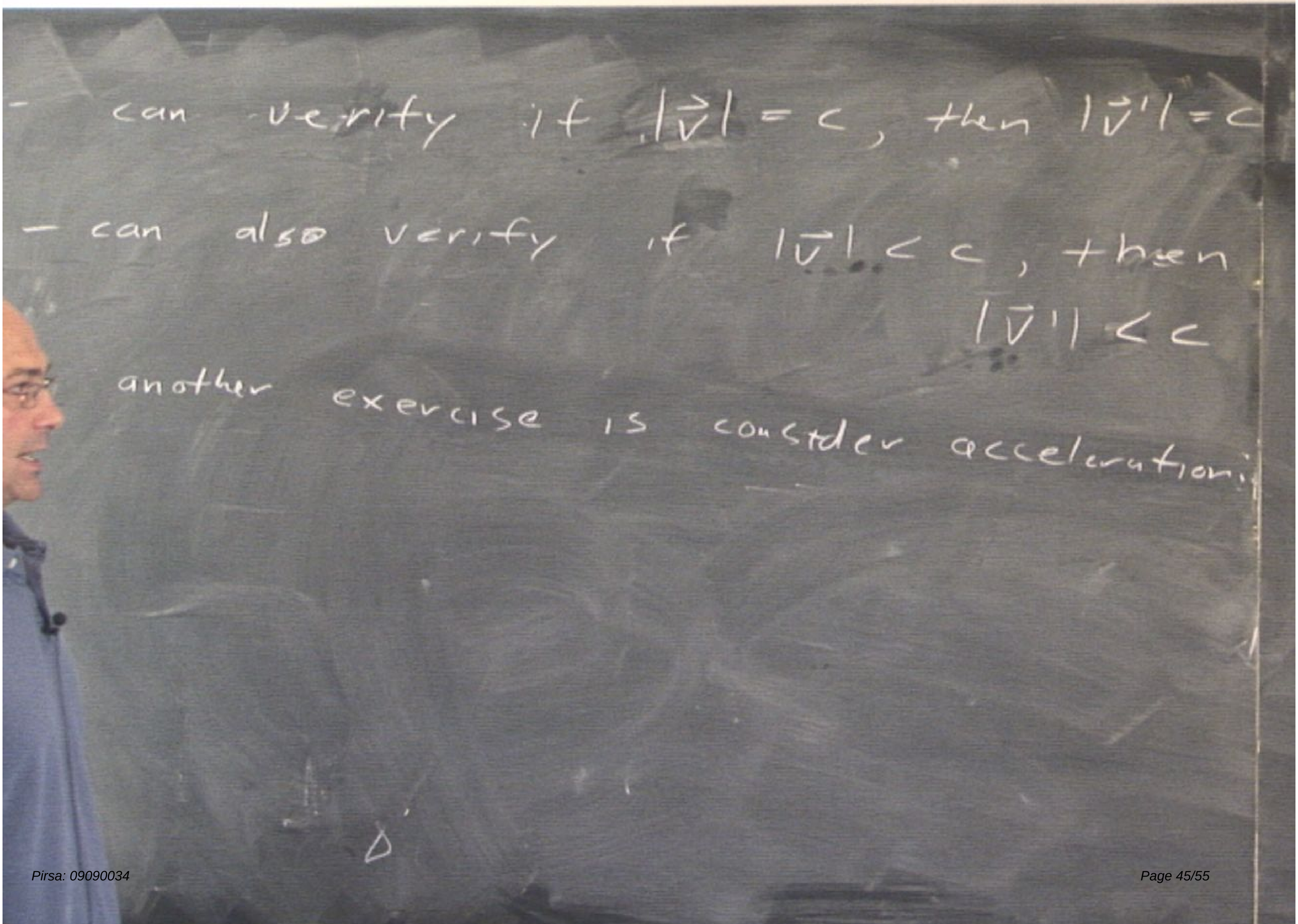
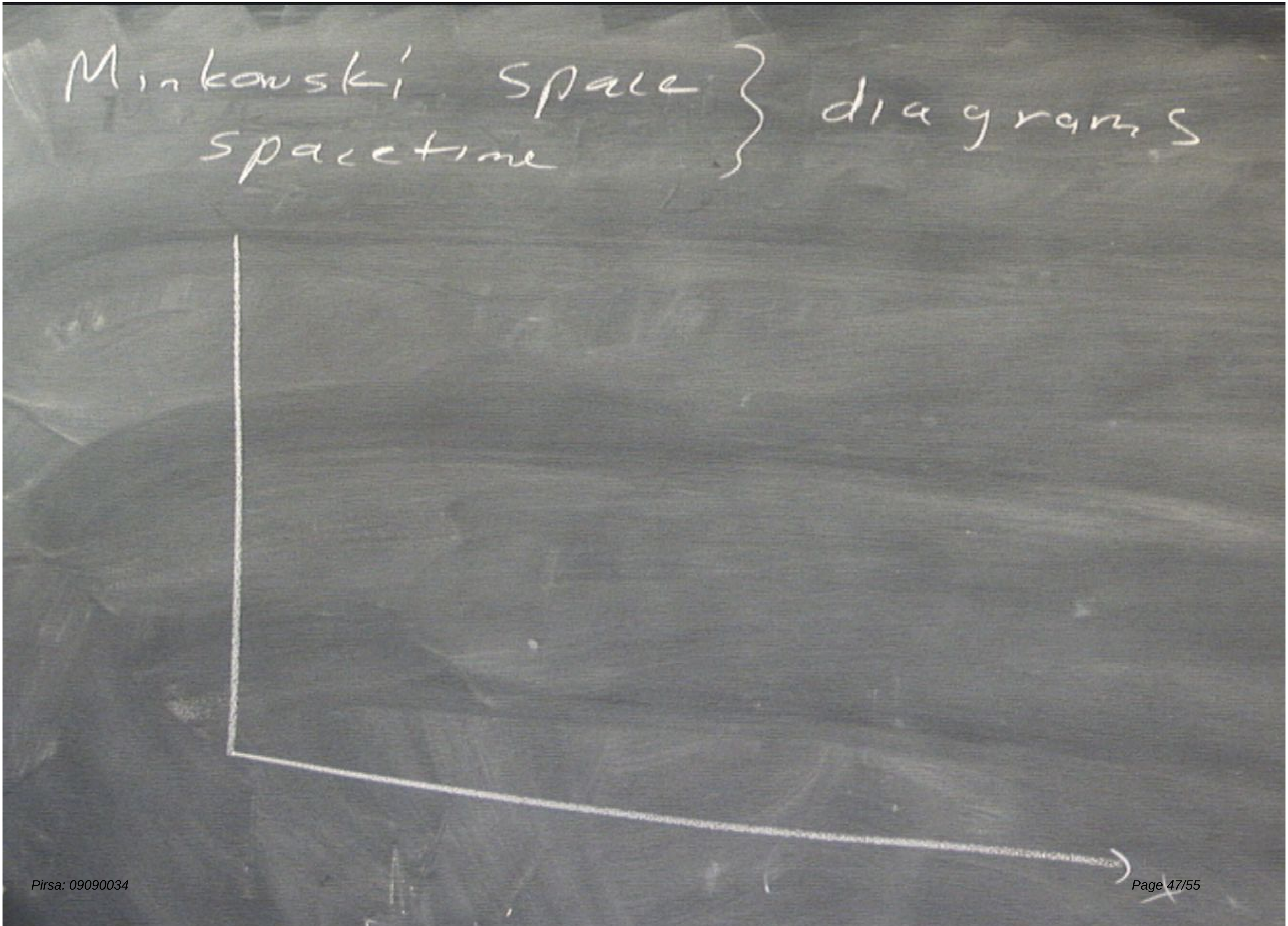
- can also verify if $|\vec{v}| < c$, then $|\vec{v}'| < c$

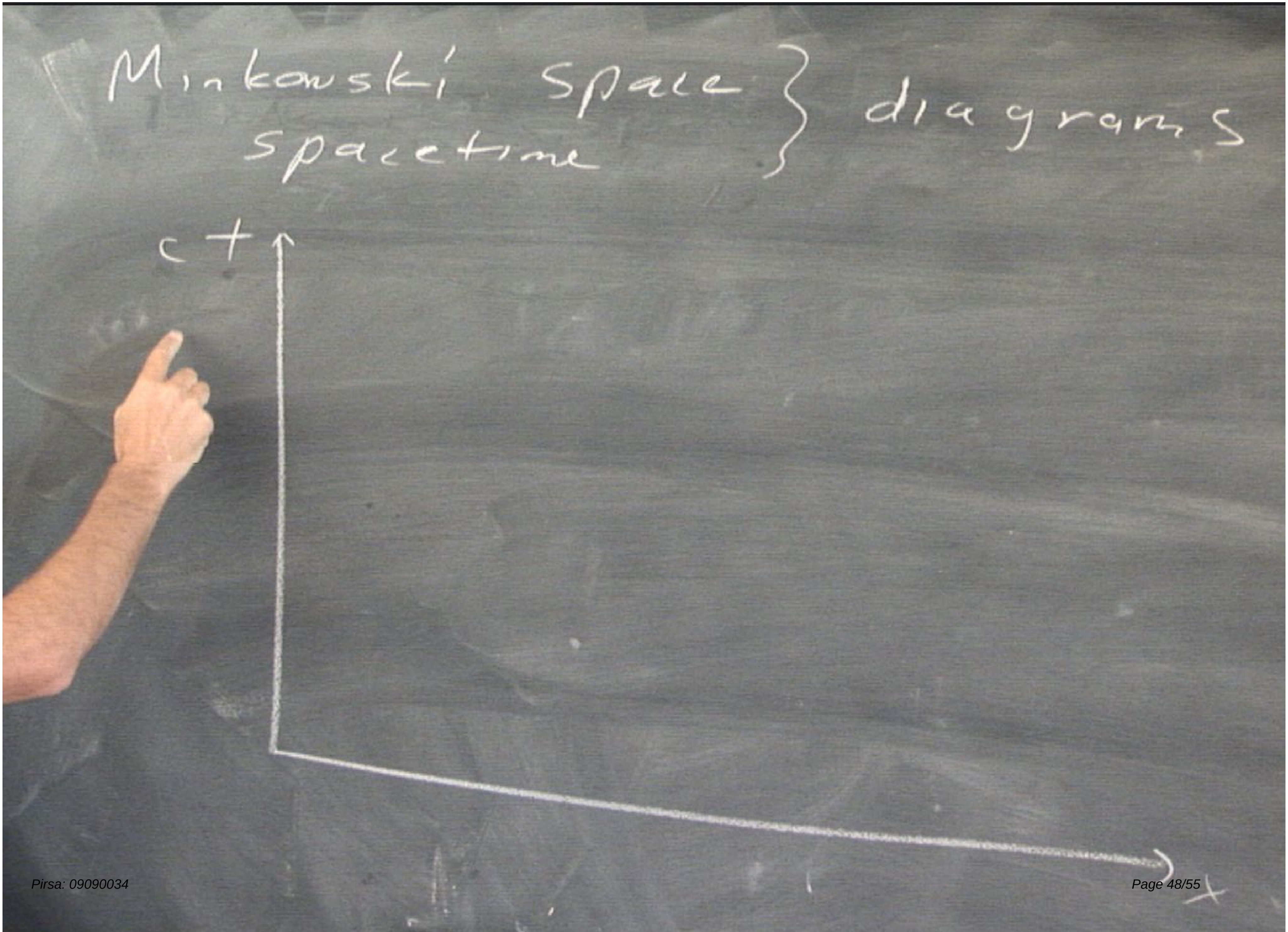

- can verify if $|\vec{v}| = c$, then $|\vec{v}'| = c$
- can also verify if $|\vec{v}| < c$, then $|\vec{v}'| < c$
another exercise is consider acceleration:

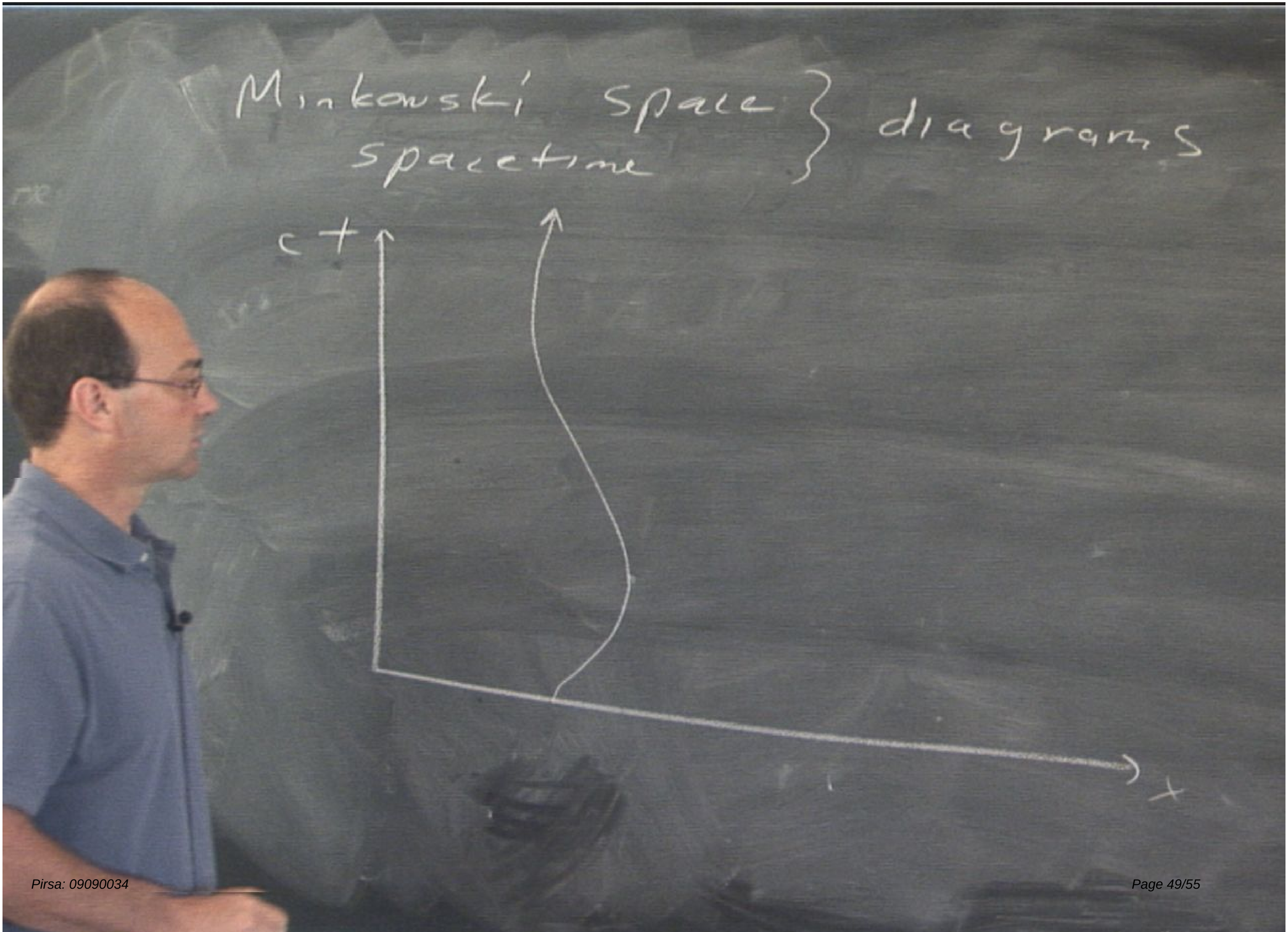
- can verify if $|\vec{v}| = c$, then $|\vec{v}'| = c$

- can also verify if $|\vec{v}| < c$, then $|\vec{v}'| < c$

- another exercise is consider acceleration:
  find that acceleration is "absolute"
  $\longrightarrow \left|\frac{d^2\vec{x}}{dt^2}\right| \neq 0$ in all inertial frames


Minkowski space
spacetime
diagrams


Minkowski space
spacetime
diagrams
ct
x


Minkowski space
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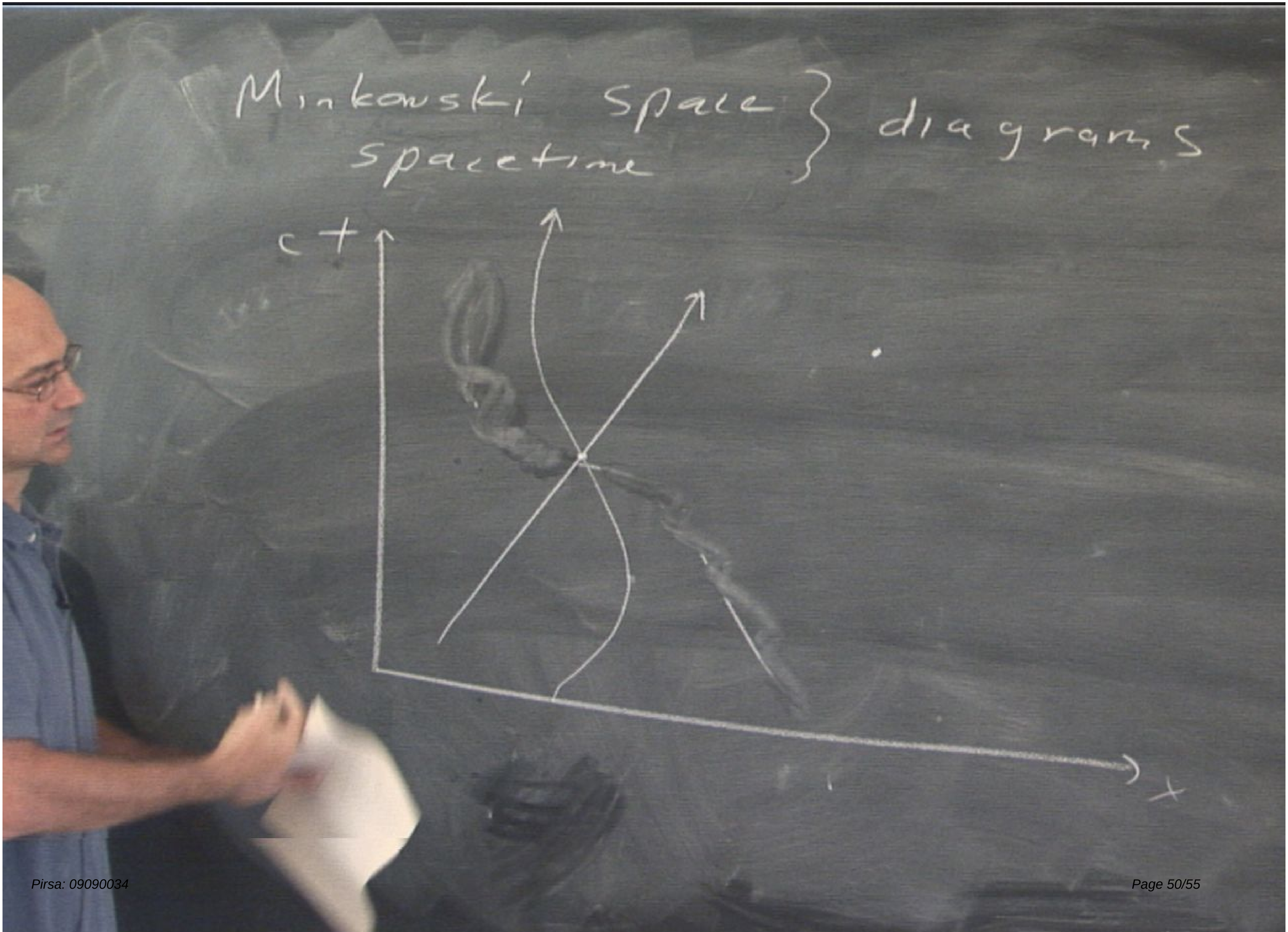
x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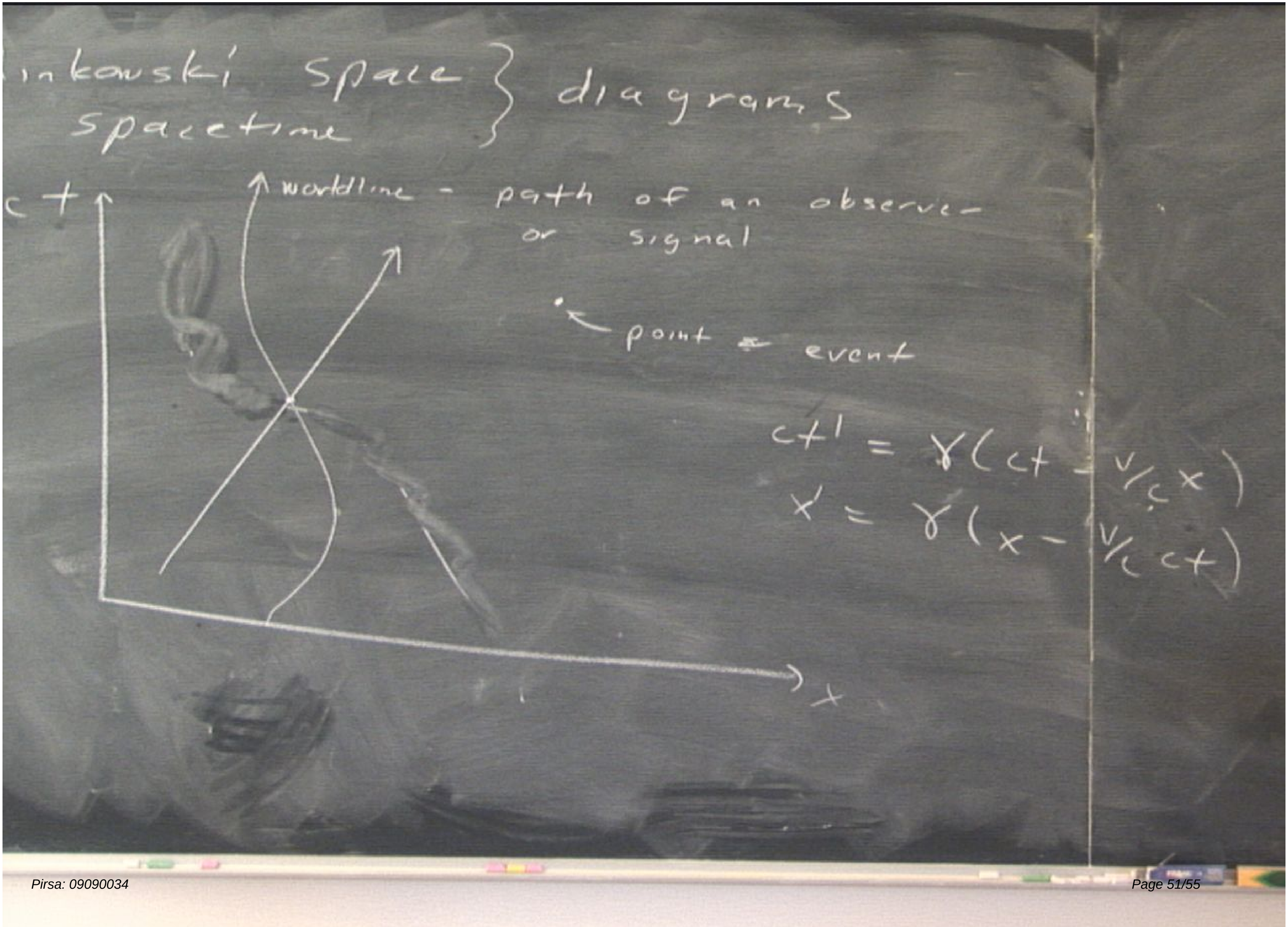
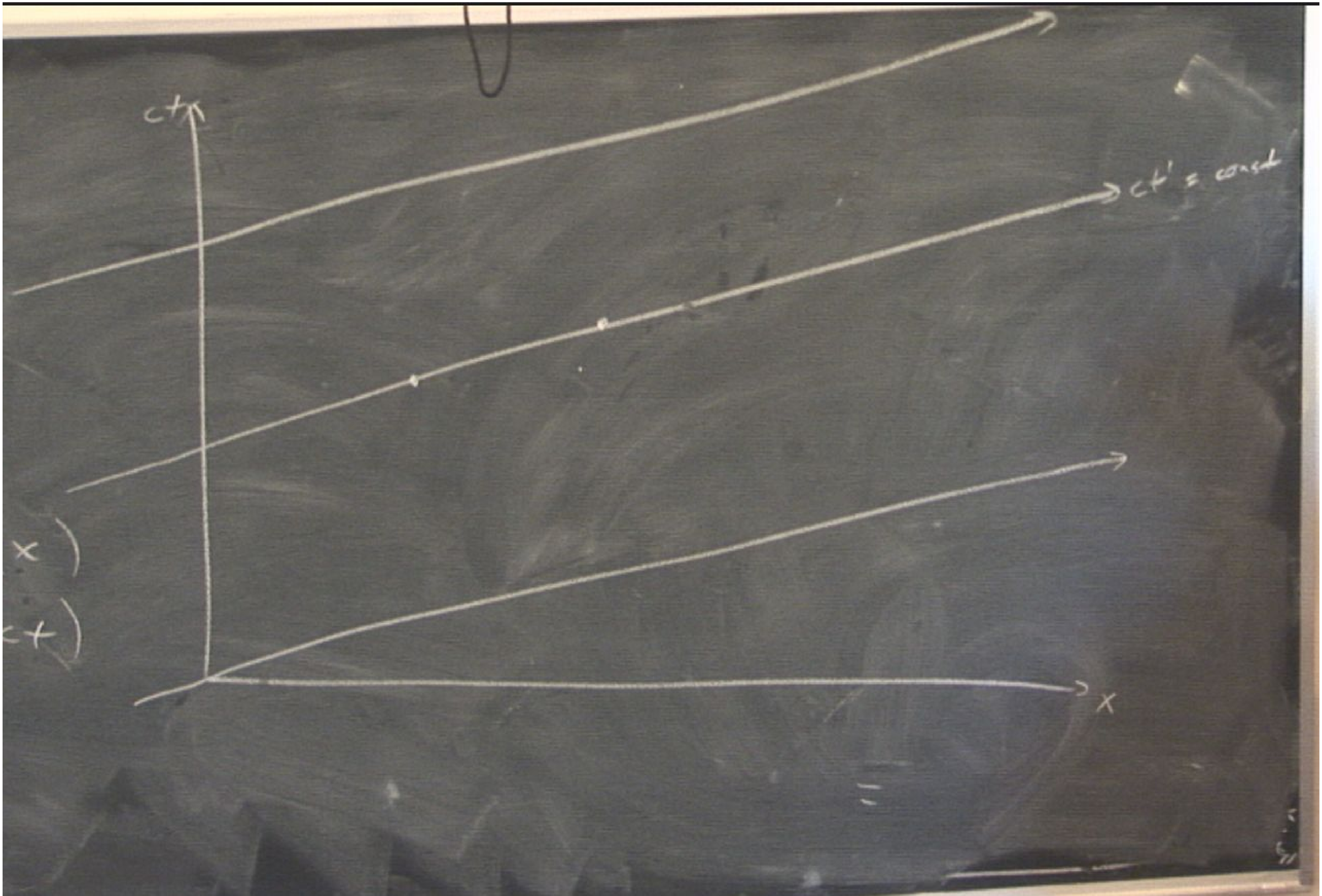
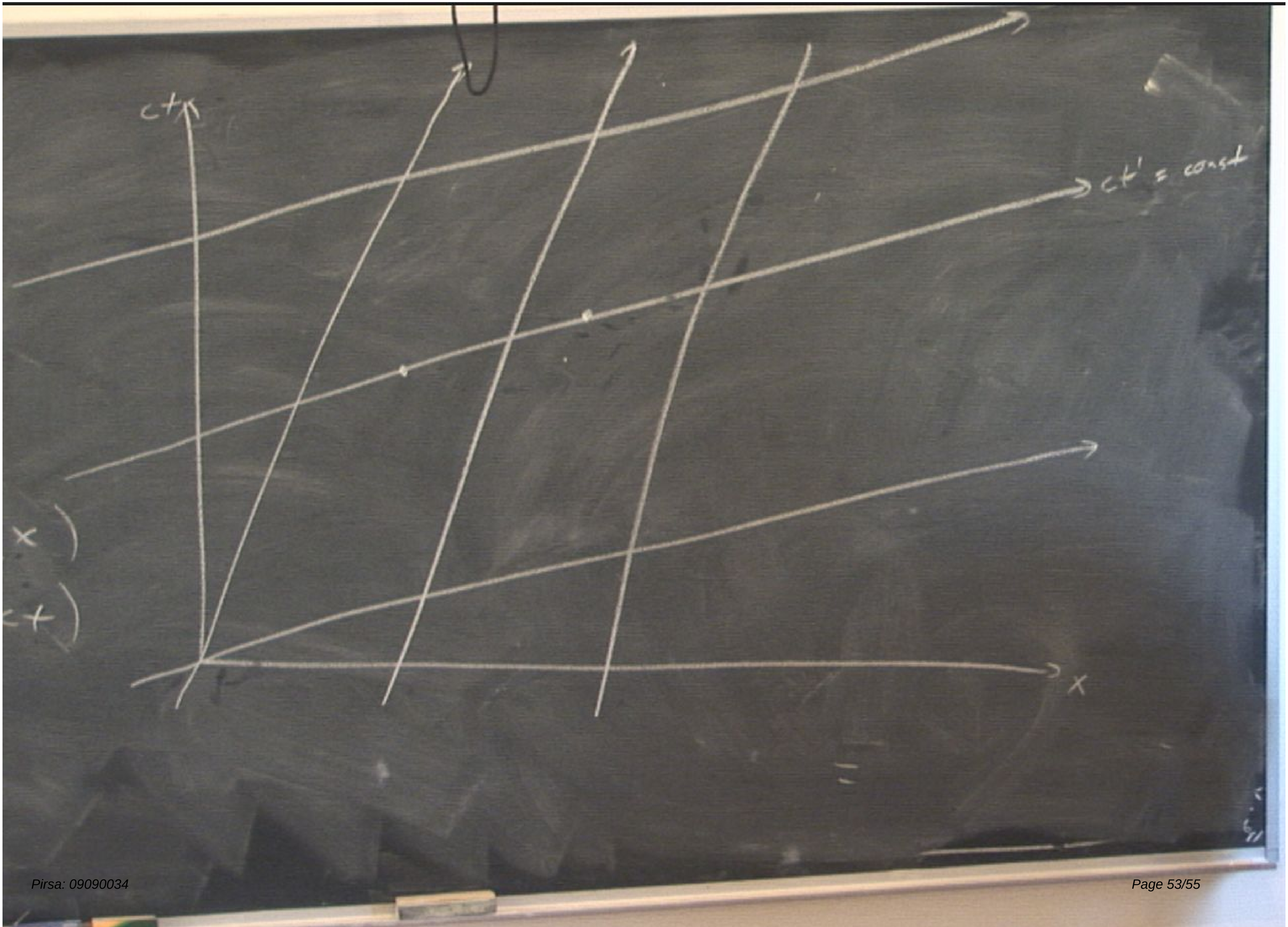

inkowski space
spacetime
diagrams
ct
worldline - path of an observer
or signal
point = event
$ct' = \gamma(ct - v/c\, x)$
$x' = \gamma(x - v/c\, ct)$
x


ct
ct' = const
x



ct
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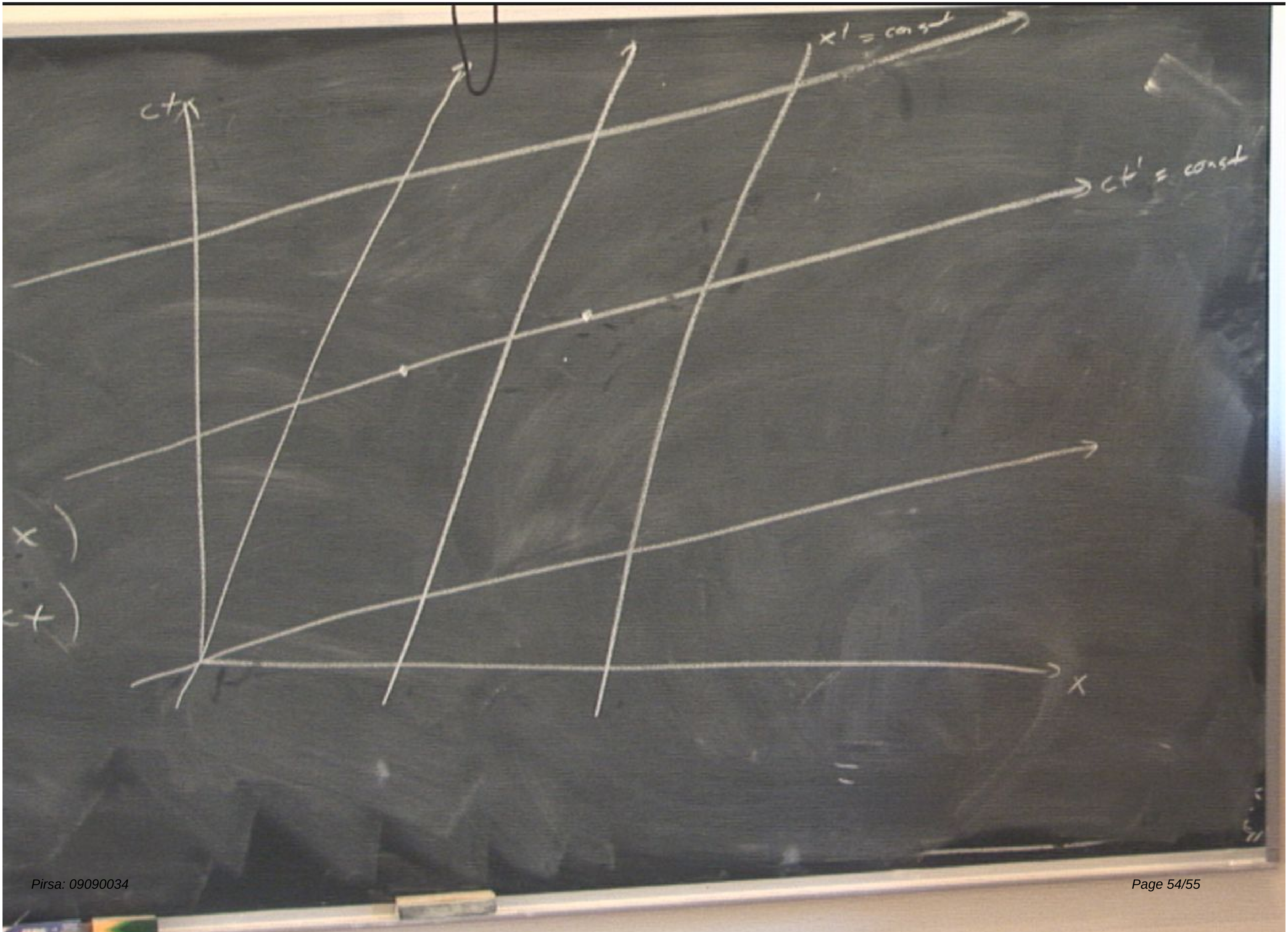
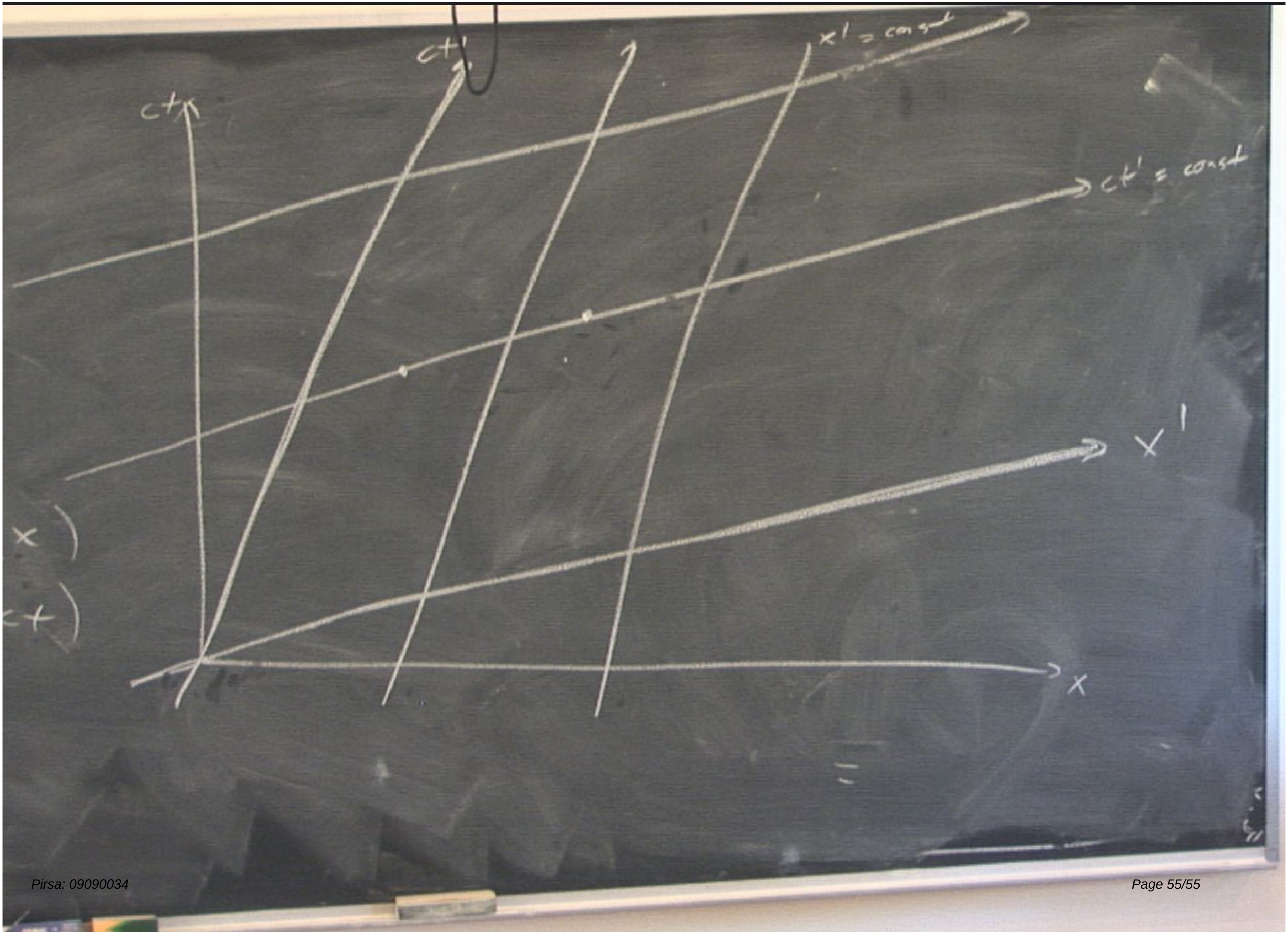
x


ct
x' = const
ct' = const
x


ct
ct'
x' = const
ct' = const
x'
x