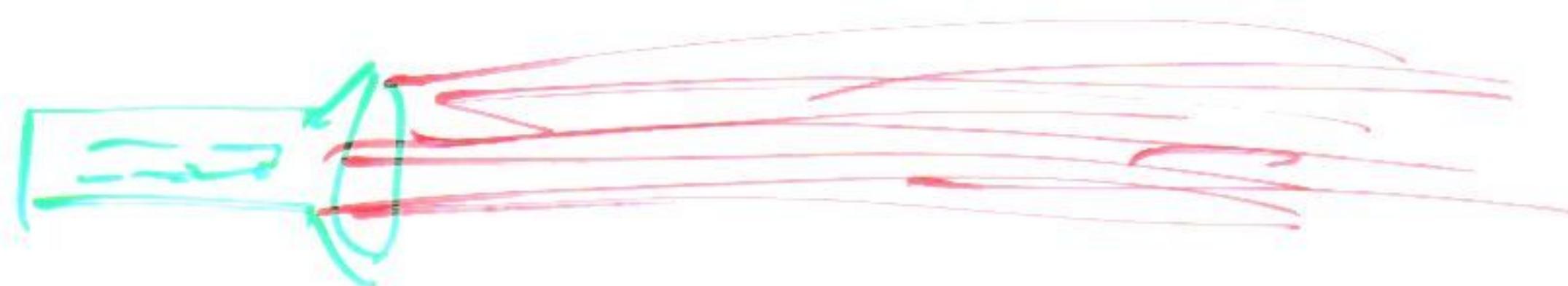
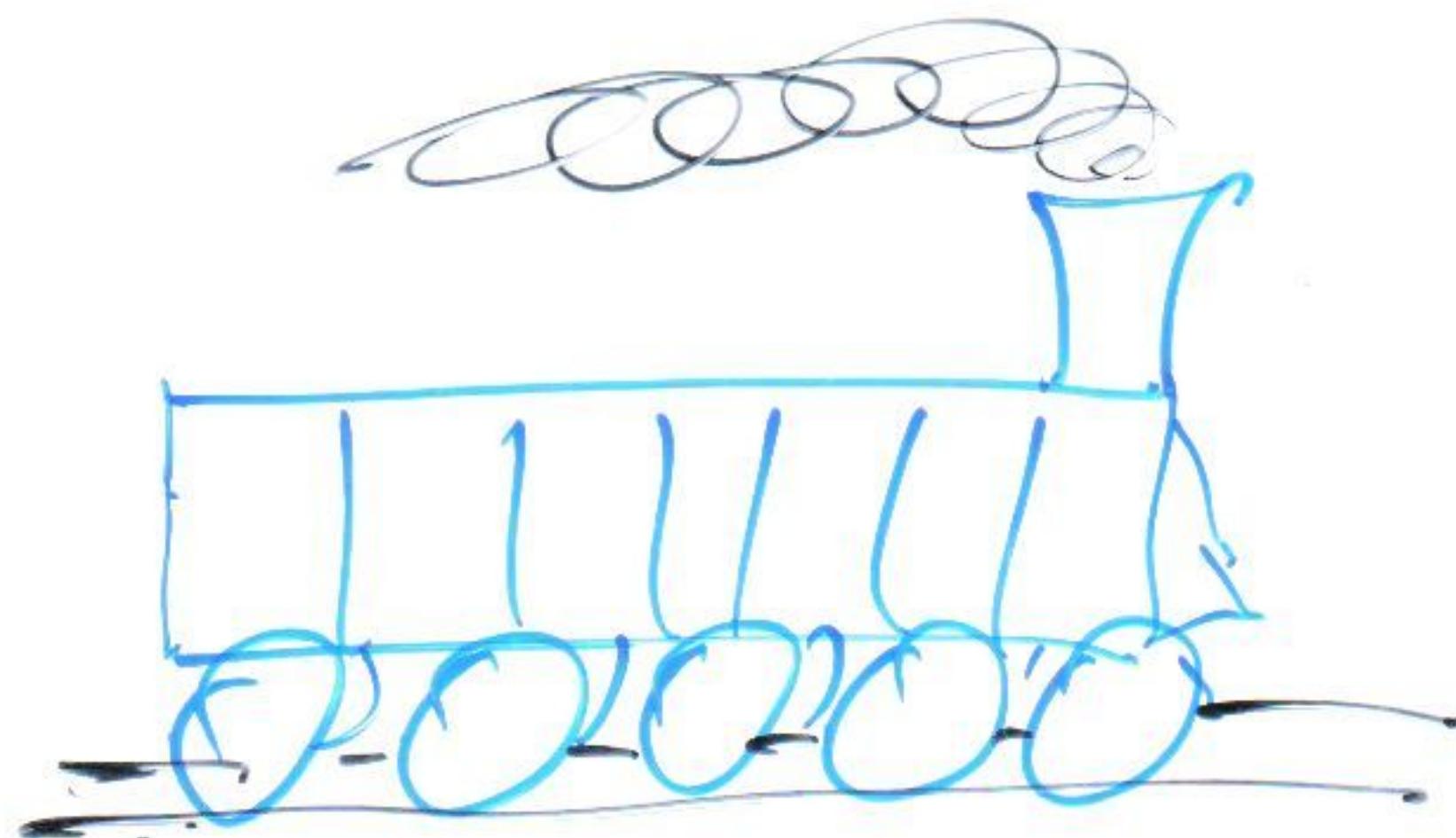


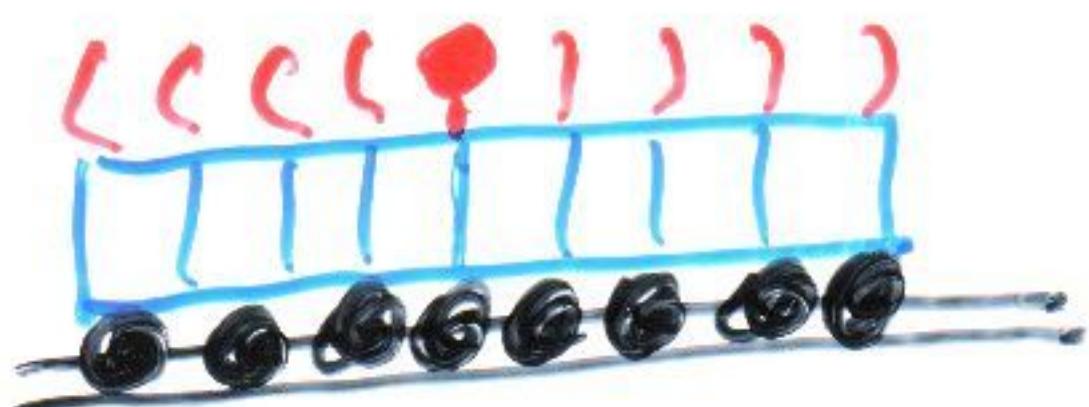
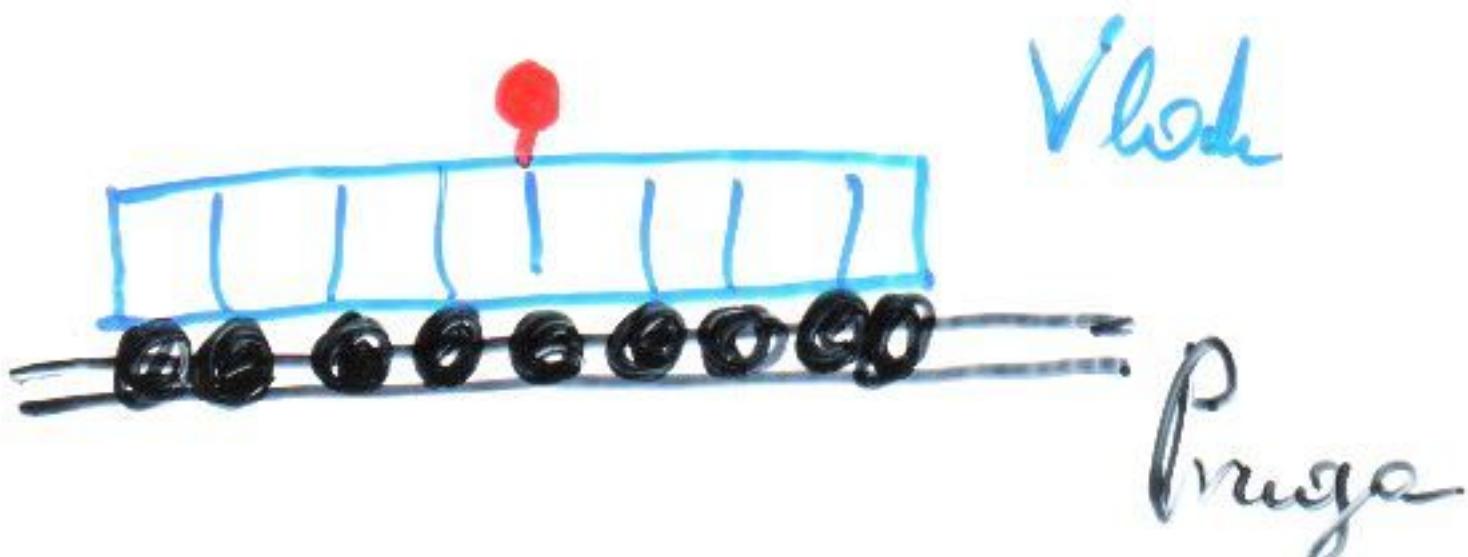
- (1) FIZIKA RELATIVNOSTI 1-2d (6 str.)
- (2) EPSTENOVU DIJAGRAMU 3-10 (10 str.)
- (3) BONDIJEV h-PRISTUP DIJAG. NINK. 11-19e (12 str.)
- (4) EPSTEIN M. NINKOWSKI 20-28 (9 str.)
- (5)* NINKOWSKI BRZ h-PRISTUPA 29-31 (3 str.)
- (6) NASA ENERGIJA 32-37 (6 str.)

BRZINA SVJETLOSTI JE
BRZINA SVEGA VIT.



(AKO JE BRZ. SVJETL. ABSOLUTNA)

"U VLAKU":



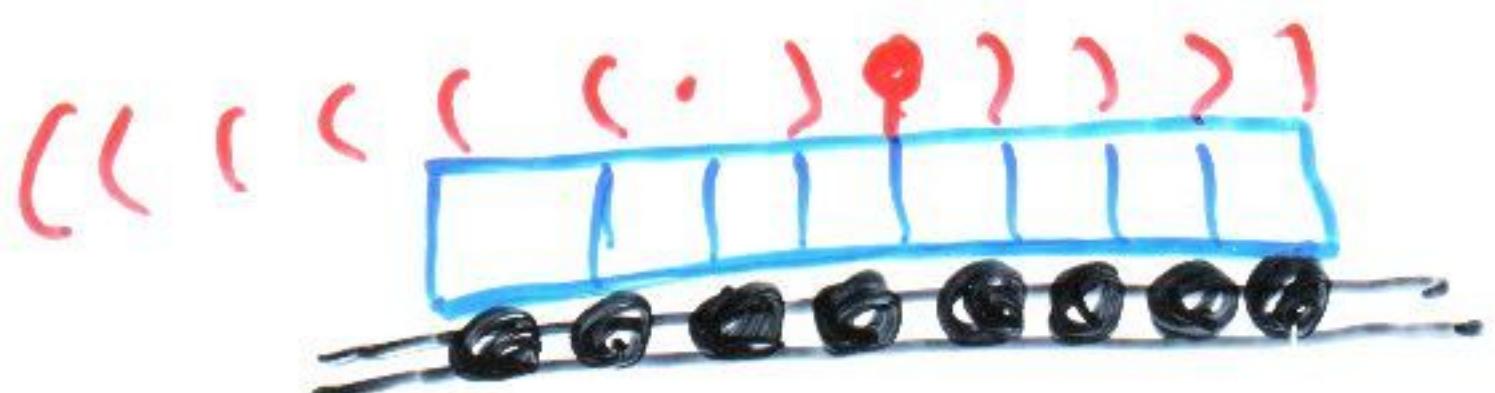
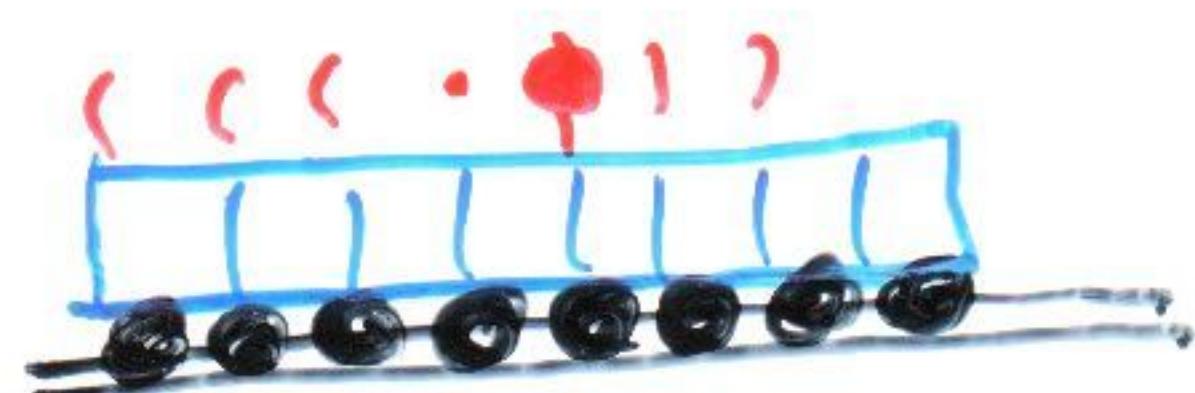
PRIJEM SIGNALA NA
"PROVI", "KRII" SIMULTAN

- Kognitivo je da je brzina signala ista u obja sustavu
- Analiza je (za sada) kvalitativna

SVAKI SUSTAVIMA SVOJU SIMULTANOST

[SVAKI SUSTAVIMA SVOJE VRIJEME]

"NA PROVI":



PRIJEM SIGNALA NA "KRII"
JE PRUE ONOGA NA "PROVI"

NAPORENA O JEDINICA :

$$C = 3 \cdot 10^8 \text{ m/s} = \frac{3 \cdot 10^8 \text{ m}}{1 \text{ s}} = \frac{1 \text{ A}}{1 \text{ n}}$$

$$C = 1 \text{ A}/\text{n}$$

$$C = 1 \text{ A}$$

$$C = 3 \cdot 10^8 \text{ m/s} = \frac{3/10 \text{ m}}{10^{-9} \text{ s}} = \frac{1 \text{ nt}}{1 \text{ nn}}$$

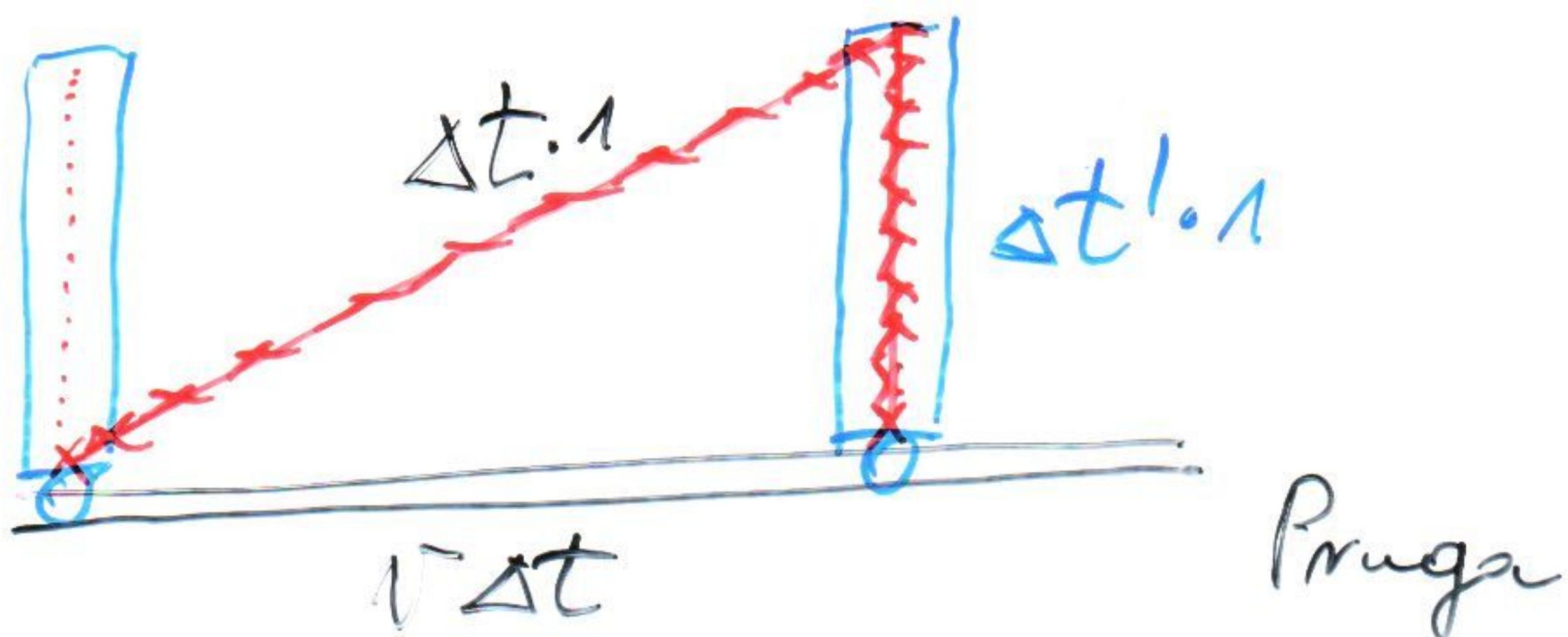
$$C = 1 \text{ nt/ms}$$

TO NISLIMO KAO A KAZENO $C=1$

KONTRAKCIJA VREMEÑA U SUST.

KOJI SE GIBA?

Vlak
= sat



$$\sqrt{\Delta t^2 + \Delta t'^2} = \Delta t'$$

$$\Delta t' = \Delta t \sqrt{1 - v^2}$$

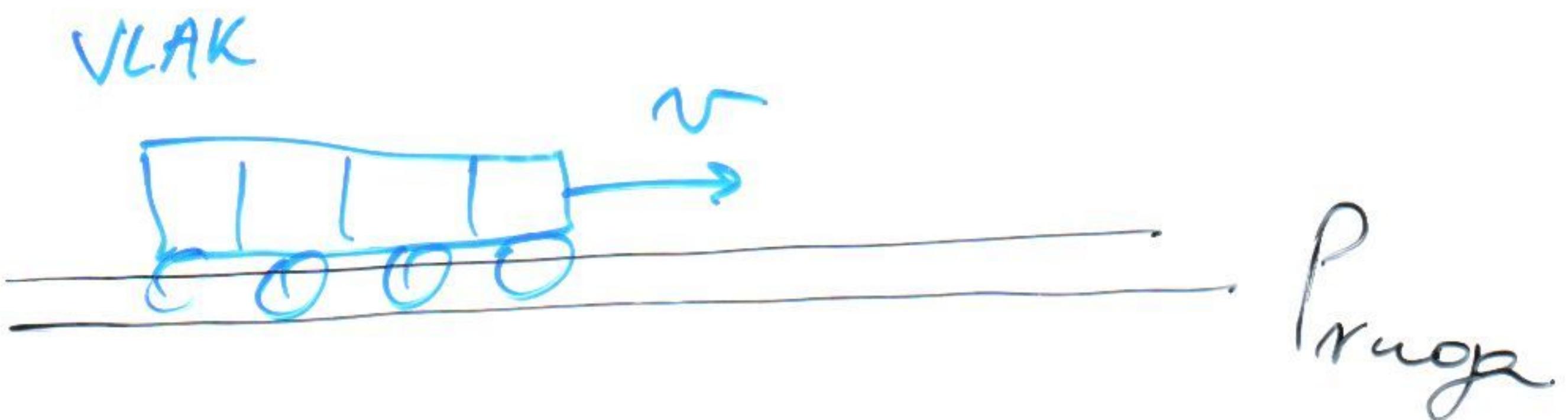
VRIJEME
U GIBAJU-
ĆEN SUS-
TAVU

VRIJEME
U NERUJEN
SUSTAVU

F2a

KONTRAKCIJA PROSTORA U SUSTAVU

KOJI SE GIBA?



$$\frac{\Delta x}{\Delta t} = v = \frac{\Delta x'}{\Delta t'} \quad (\text{BROJ. PRUGE U SUSTAVU VELAKA})$$

(APSOLUTNI IZNOSI!)

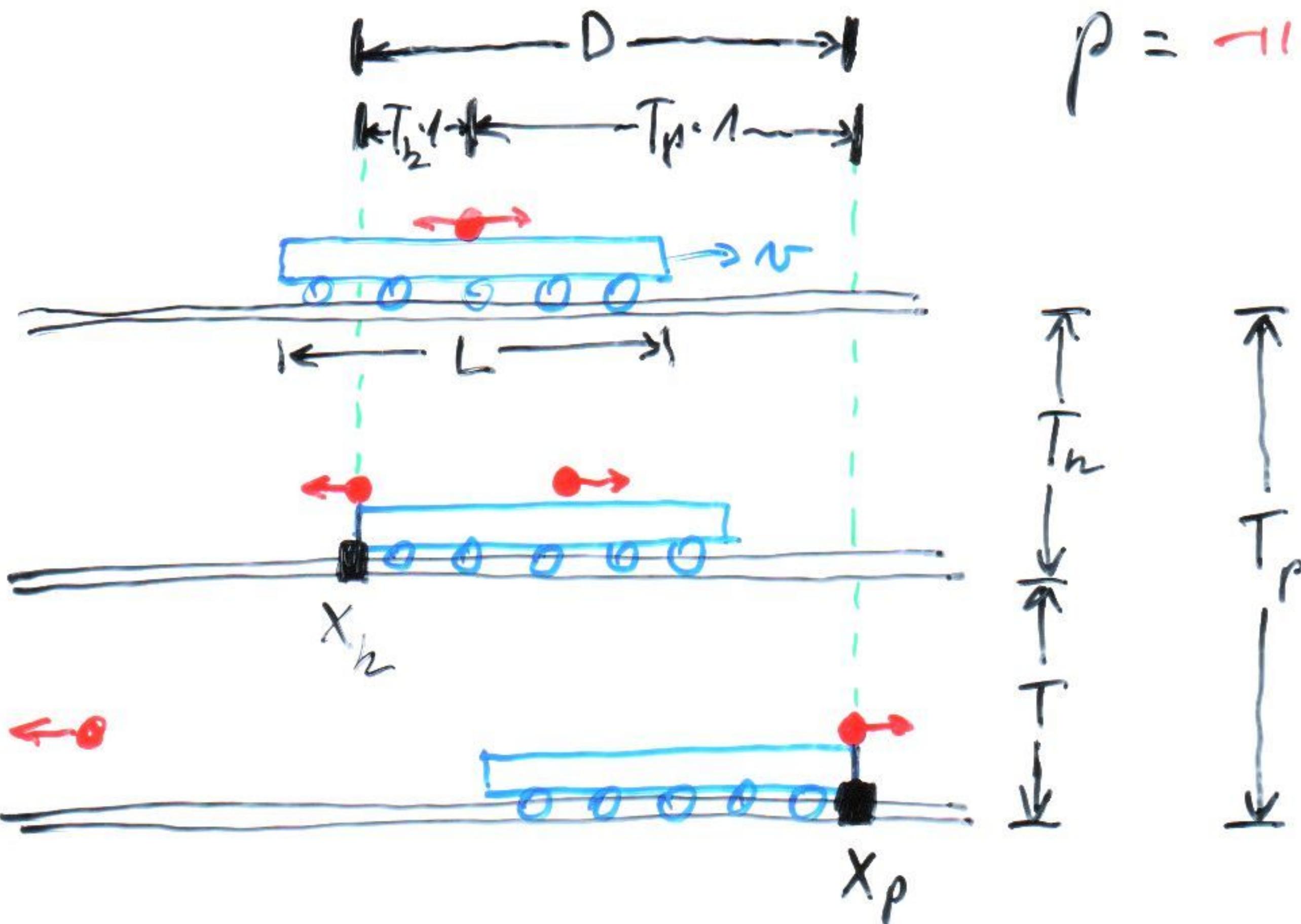
$$\Delta x' = \frac{\Delta x}{\Delta t} \Delta t' = \Delta x \sqrt{1 - v^2} \quad (\text{PRETH. STR.})$$

$$\boxed{\Delta x' = \Delta x \sqrt{1 - v^2}}$$

↑
UDALJENOST
U SUSTAVU
KOJI SE GIBA

↑
UPAYEGOST
U SUSTAVU
KOJI NERUJE

DESINKRONIZACIJA



$b = \text{SVJETLO U KRNI}$
 $p = \text{--II--II--PROVI}$

$$\left. \begin{array}{l} T_h \cdot 1 = L/2 - T_h \cdot v \\ T_p \cdot 1 = L/2 + T_p \cdot v \end{array} \right\} \quad T = (T_p + T_h) \cdot v$$

$$v = \frac{T}{D}$$

$$T = D \cdot v$$

$$T \cdot c = D \cdot \frac{v}{c}$$

AKO SU POGAĐAJI PIK H SIMULTANI U NEKOM SUSTAVU, ONDA SE U SUSTAVU KOSTI SE BRZINA OD GIBA OD PREMA L, IZ DOGADA ZA $T = D \cdot v$ PRIMJE P, GOJE JE D PROSTORNA UDALJENOST OD PIK H U DRUGOM SUSTAVU.

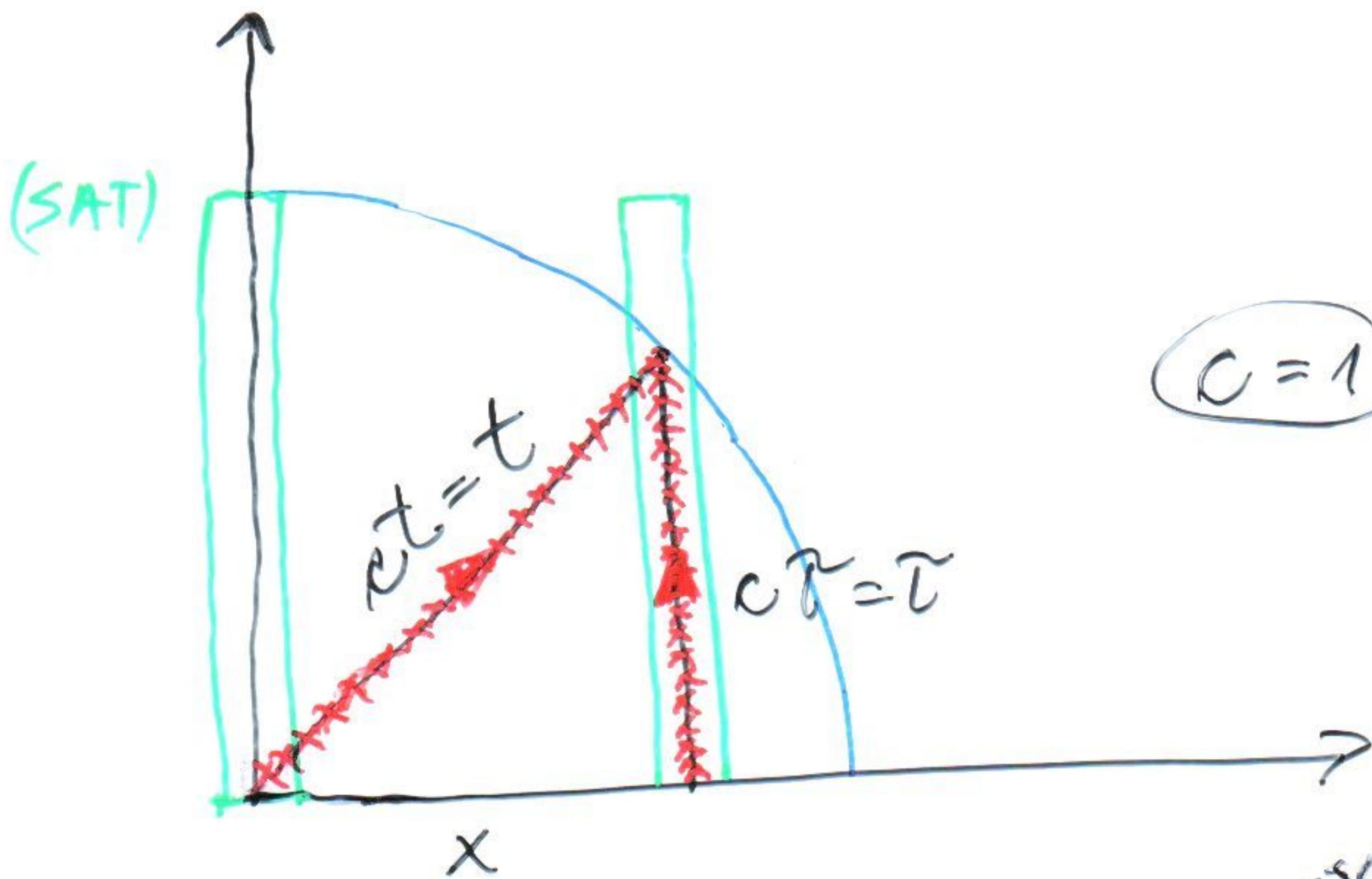
(2c)

AKO SU DVA DOGAJAJA U VLAKU
ISTOVRENNA ONDA JE NIHOV
VRENSKI OPRAK NA PRUZI U NANO-
SEKUNDARA JEDNAK PROSTORNOJ VODA-
GENOSTI TIH DOGAJASA U STOPANA
PORNOŽENOS S BRZINOM VLAKA V.

$$T = D \cdot v$$

AKO SU DVA DOGAJAJA U VLAKU
ISTOVJEŠNA ONDA JE NIHOV
PROSTORNI OPRAK NA PRUZI U
STOPANA JEDNAK VRENSKOJ UD-
AHENOSTI TIH DOGAJAJA U NANOSEK-
UNDARA PORNOŽENOS S BRZINOM VLAKA V.

$$D = T \cdot v$$



$$c=1$$

(SKLICK
GIBAHA)
SATA

$$x^2 + \tilde{t}^2 = t^2$$

$$(\tilde{t}=t')$$

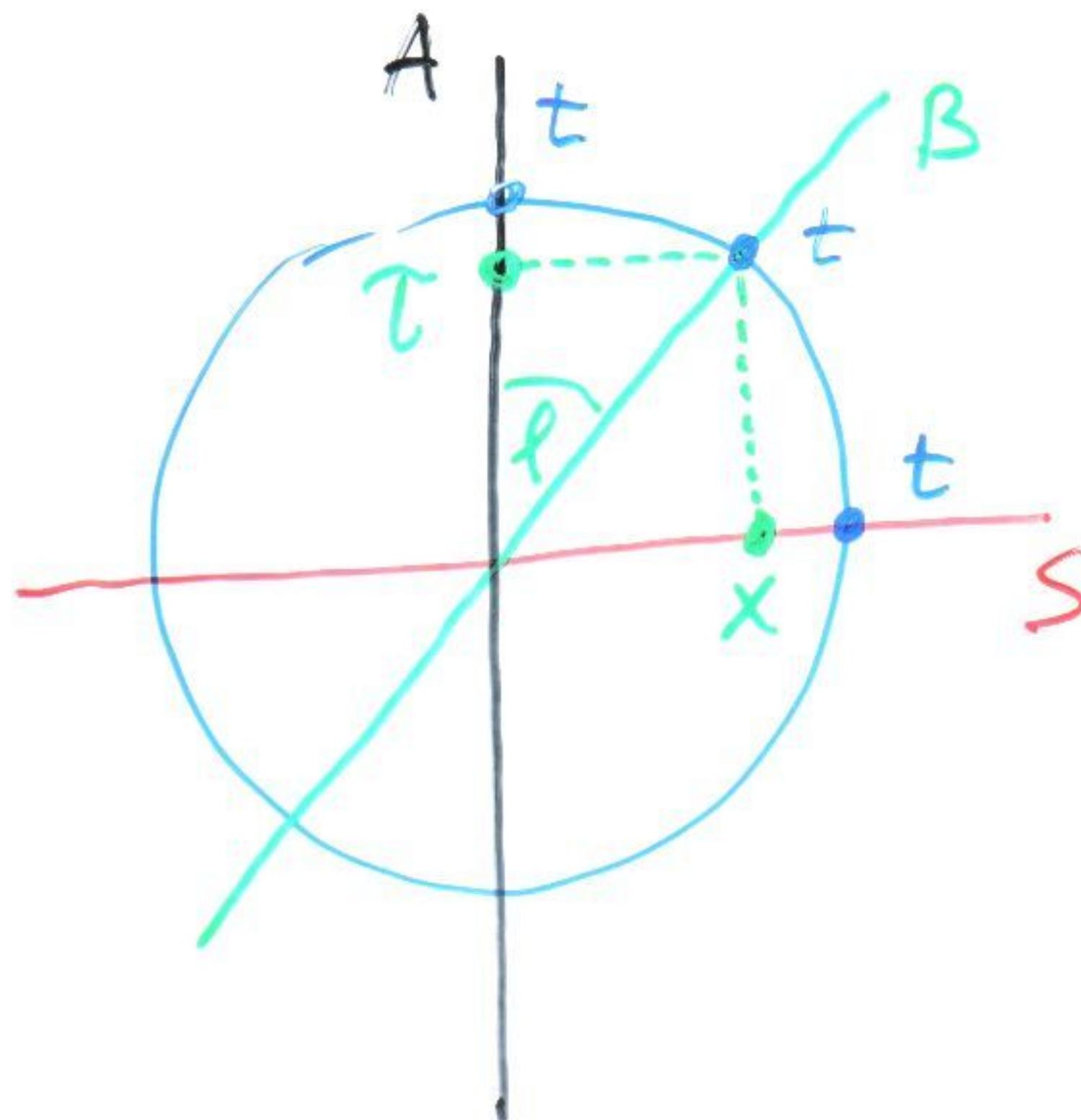
$$\left(\frac{x}{t} \right)^2 + \left(\frac{\tilde{t}}{t} \right)^2 = 1$$

$\frac{x}{t} = \dot{x}$ = BRZINA GIBAMA V PROSTORU

$\frac{\tilde{t}}{t} = \dot{\tilde{t}}$ = BRZINA GIBAMA V VREMIENU

EPSTEINOV DIJAGRAM

(Nije dijagram Minkovskog)



$$\frac{x}{t} = \sin \varphi$$

$$v = \sin \varphi$$

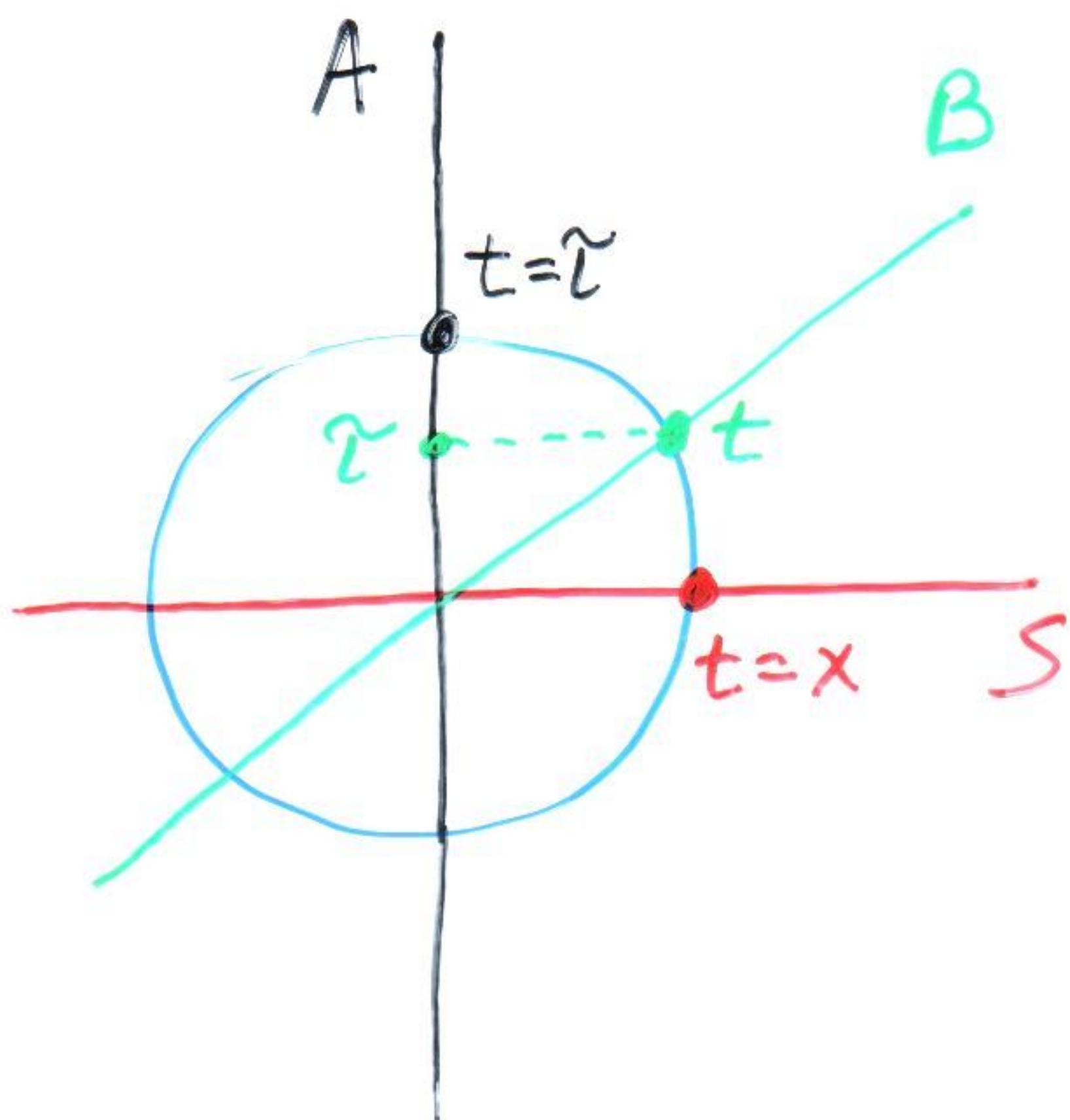
$$\sqrt{1-v^2} = \cos \varphi$$

A miruje u A $x=0$ $t=\tilde{t}$

B ne giba u A $x=vt$ $\tilde{t}=t\sqrt{1-v^2}$

S ne max. giba u A $x=t$ $\tilde{t}=0$

EPSTEINOV DIJAGRAM



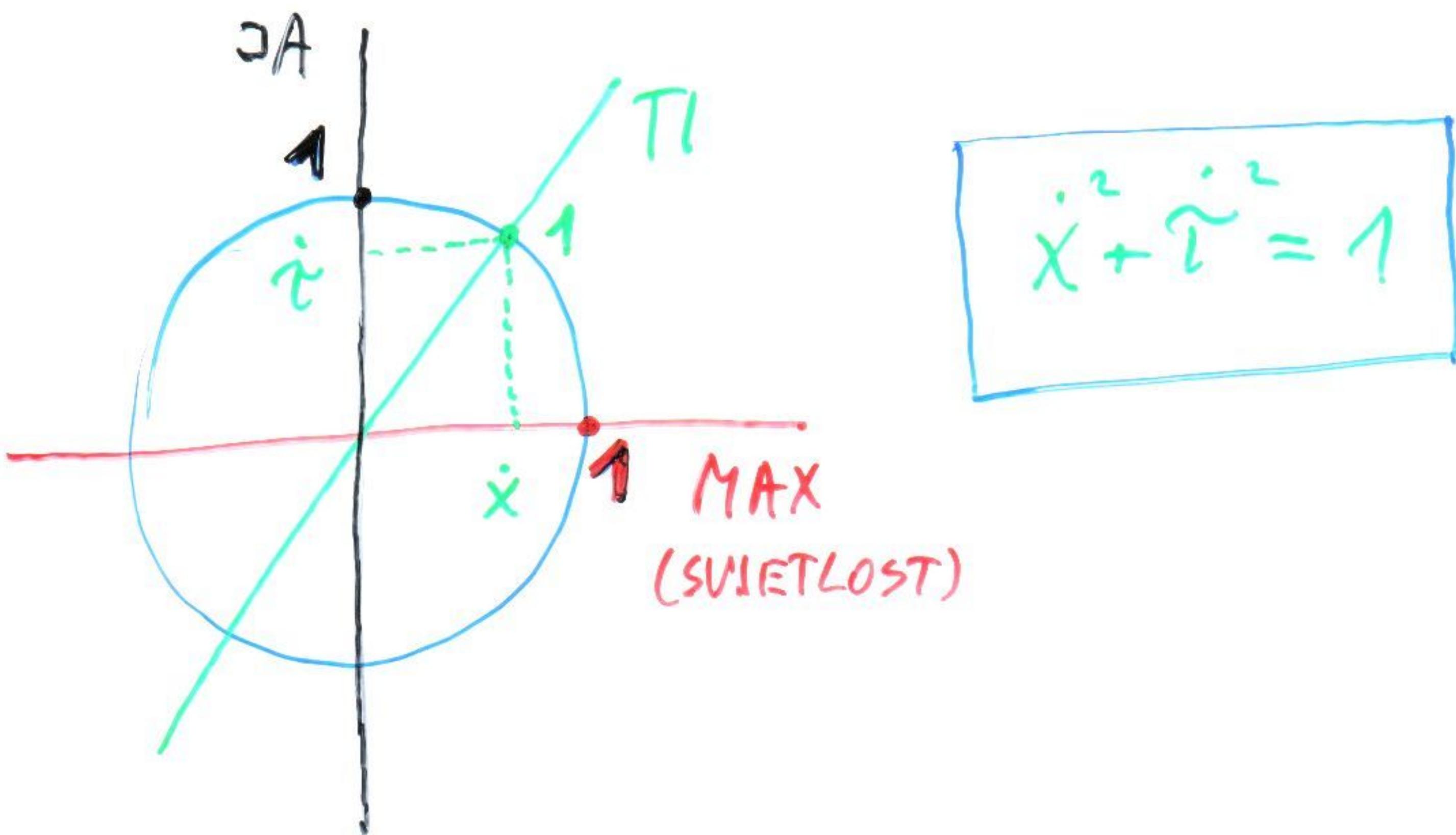
$$\frac{x}{t} = v$$

$$\frac{t}{x} = \sqrt{1-v^2}$$

A NIKRUIJE U ODNOŠU NA A $x=0 \quad t=\tilde{t}$

B SE GIBA U ODNOŠU NA A $x=vt \quad \tilde{t}=\sqrt{1-v^2}t$

S SE MAKSIZR. GIBA U ODNOŠU NA A $x=t \quad \tilde{t}=0$



$$\dot{x}^2 + \dot{i}^2 = 1$$

JA NIRUJEM NAJBREŽE STARIN:

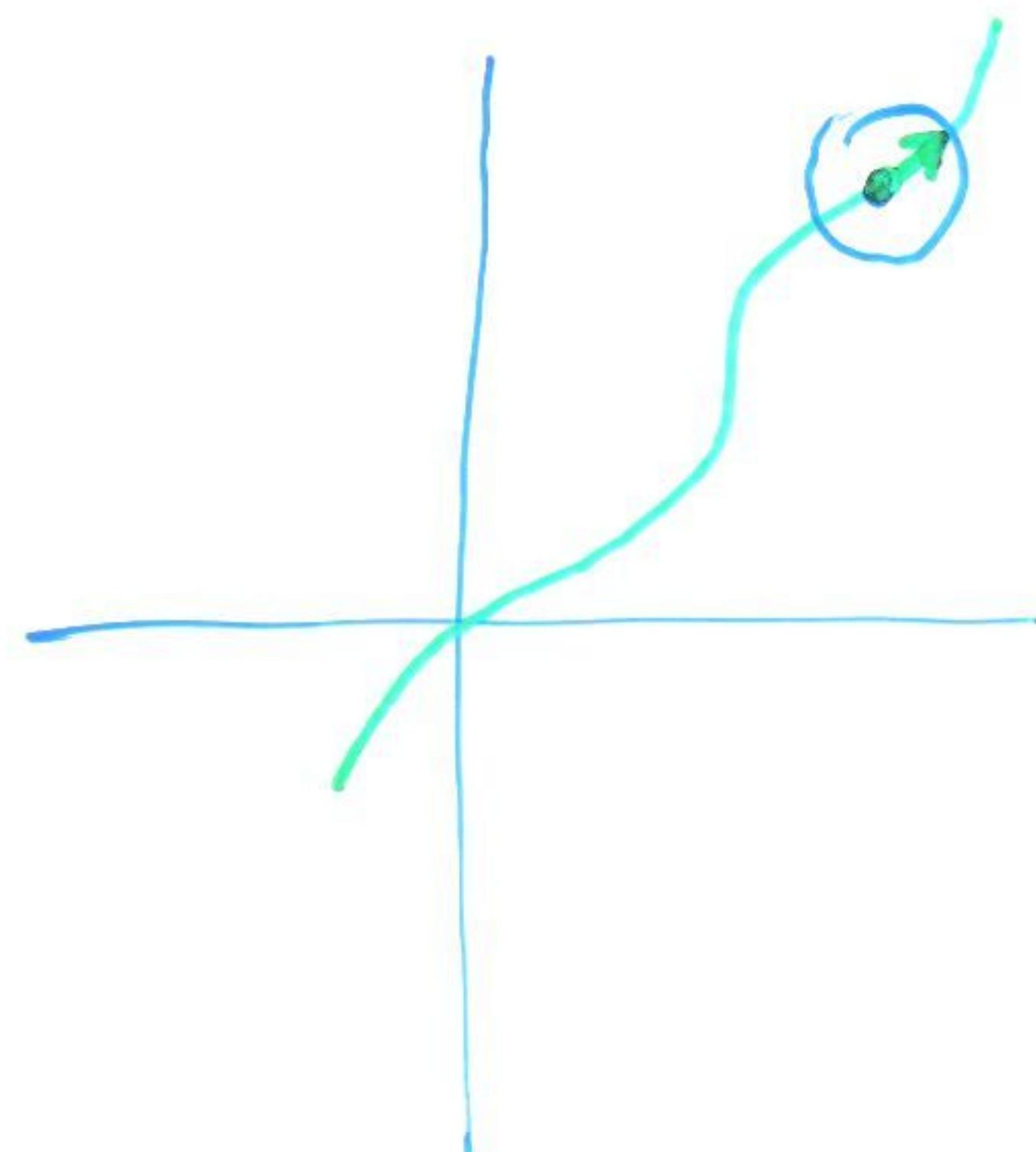
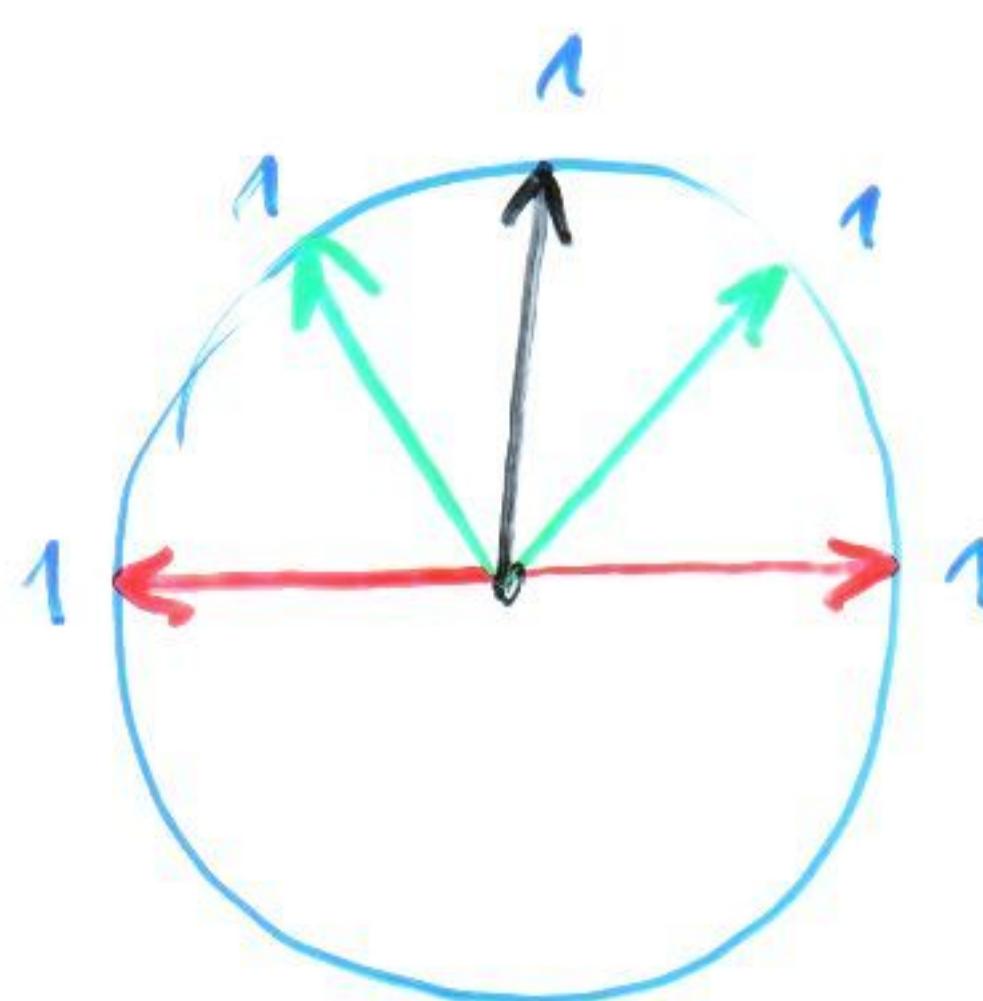
$$\dot{x}=0 \quad \dot{i}=1$$

TI SE GIBAŠ I SPORIJE STARIS:

$$\dot{x} \neq 0, 1 \quad \dot{i} = \sqrt{1 - \dot{x}^2}$$

MAX JE NAJBREŽI I UOPĆE NE STARI:

$$\dot{x}=1 \quad \dot{i}=0$$



U PROSTOR - VREMENU BRZINA
SVEGA JE 1!!

BRZINA SVIJETLOSTI JE
BRZINA SVEGA !!!

$$x^2 + \tilde{t}^2 = t^2$$

DVA VREZNA!

t = KOORDINATNO VRNIJENJE
(V. V SUSTAVU KOJI NARUJE)

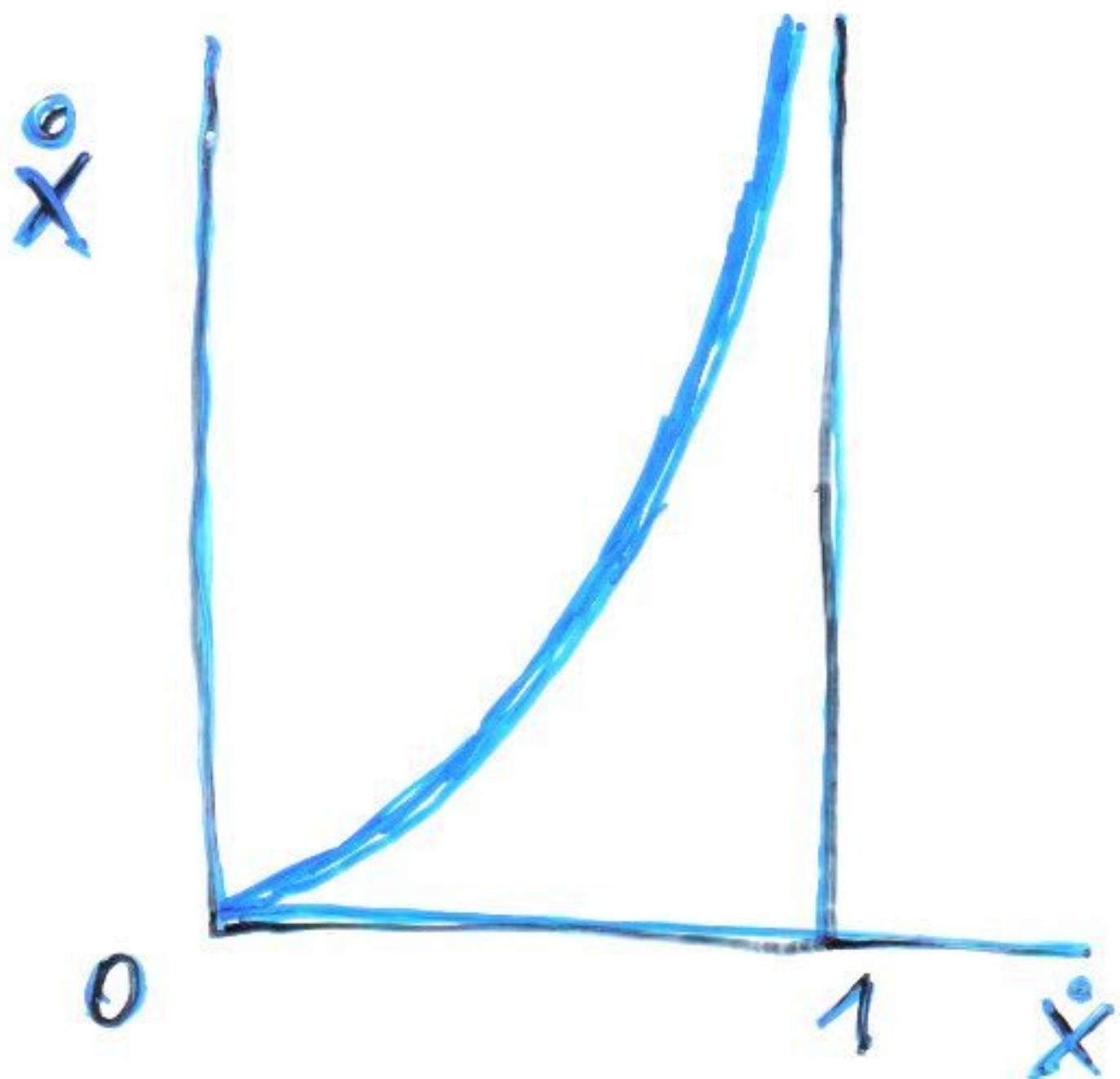
\tilde{t} = VLASTITO (PRAVO) VRNIJENJE
(V. V SUSTAVU KOJI SE GIBA)

$$\text{BRZINA} = \dot{x} := \frac{x}{t}$$

$$\text{VL. BRZINA} = \dot{\tilde{x}} := \frac{x}{\tilde{t}}$$

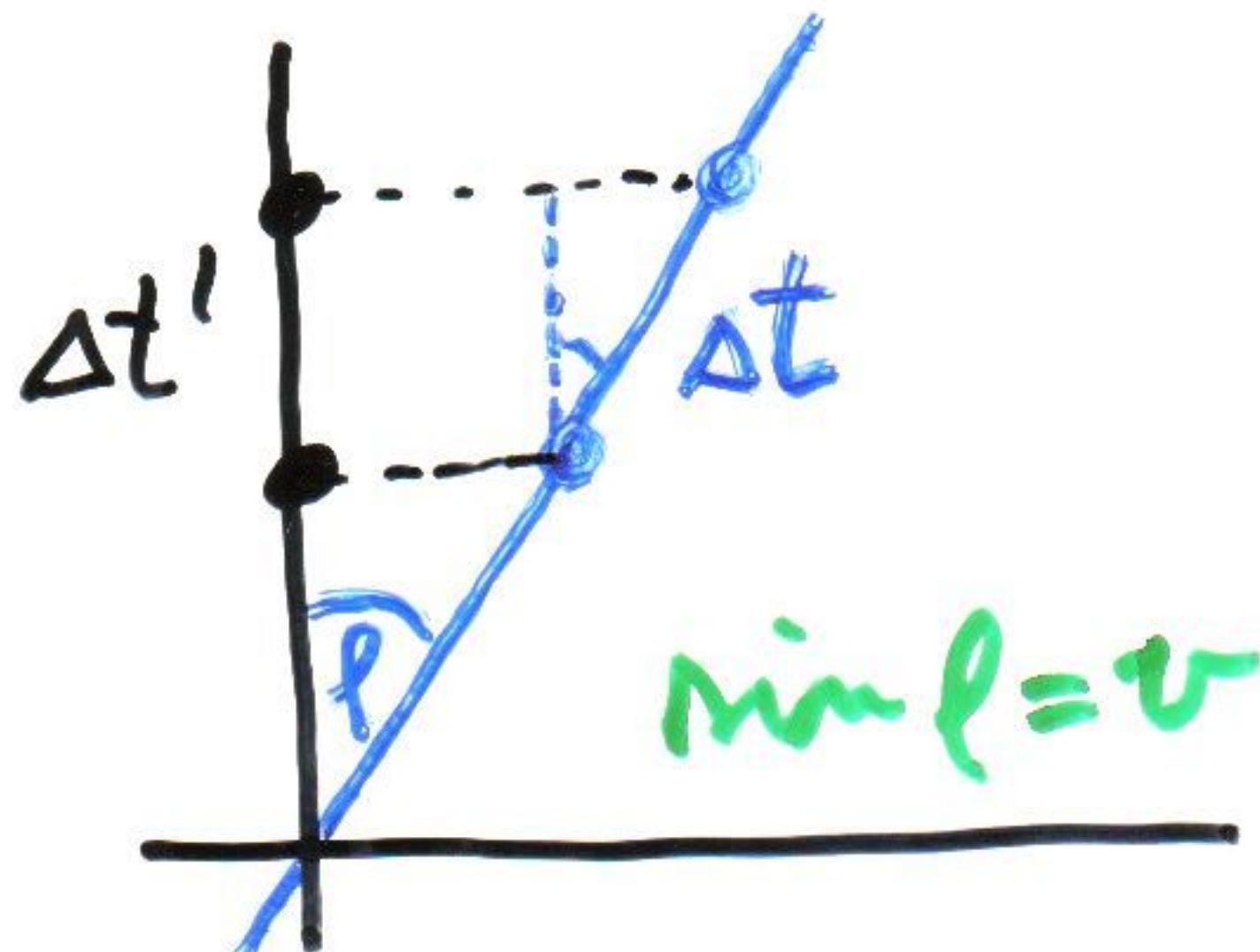
$$\left(\frac{x}{\tilde{t}}\right)^2 + 1 = \left(\frac{t}{\tilde{t}}\right)^2 = \frac{1}{\tilde{t}^2} = \frac{1}{1 - \dot{x}^2} \Rightarrow$$

$$\overset{\circ}{x}^2 = \frac{1}{1 - \dot{x}^2} - 1 = \frac{\dot{x}^2}{1 - \dot{x}^2}$$



$$\overset{\circ}{x} = \frac{\dot{x}}{\sqrt{1 - \dot{x}^2}}$$

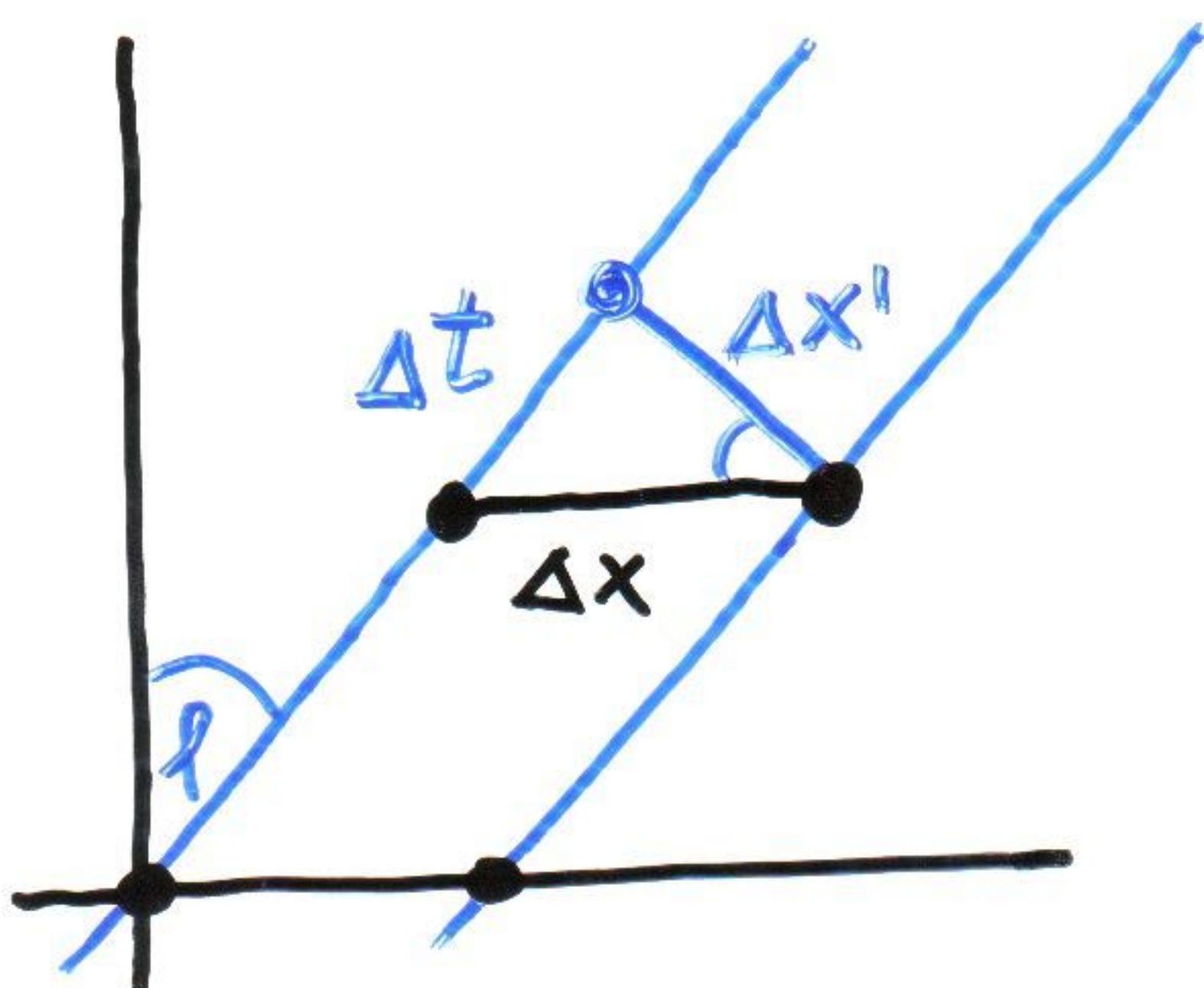
KONTRAKCIJA VREMENA:



$$\Delta t' = \Delta t \cdot \cos \phi$$

$$\boxed{\Delta t' = \Delta t \sqrt{1 - v^2}}$$

KONTRAKCIJA PROSTORA I DESINKRONIZACIJA:



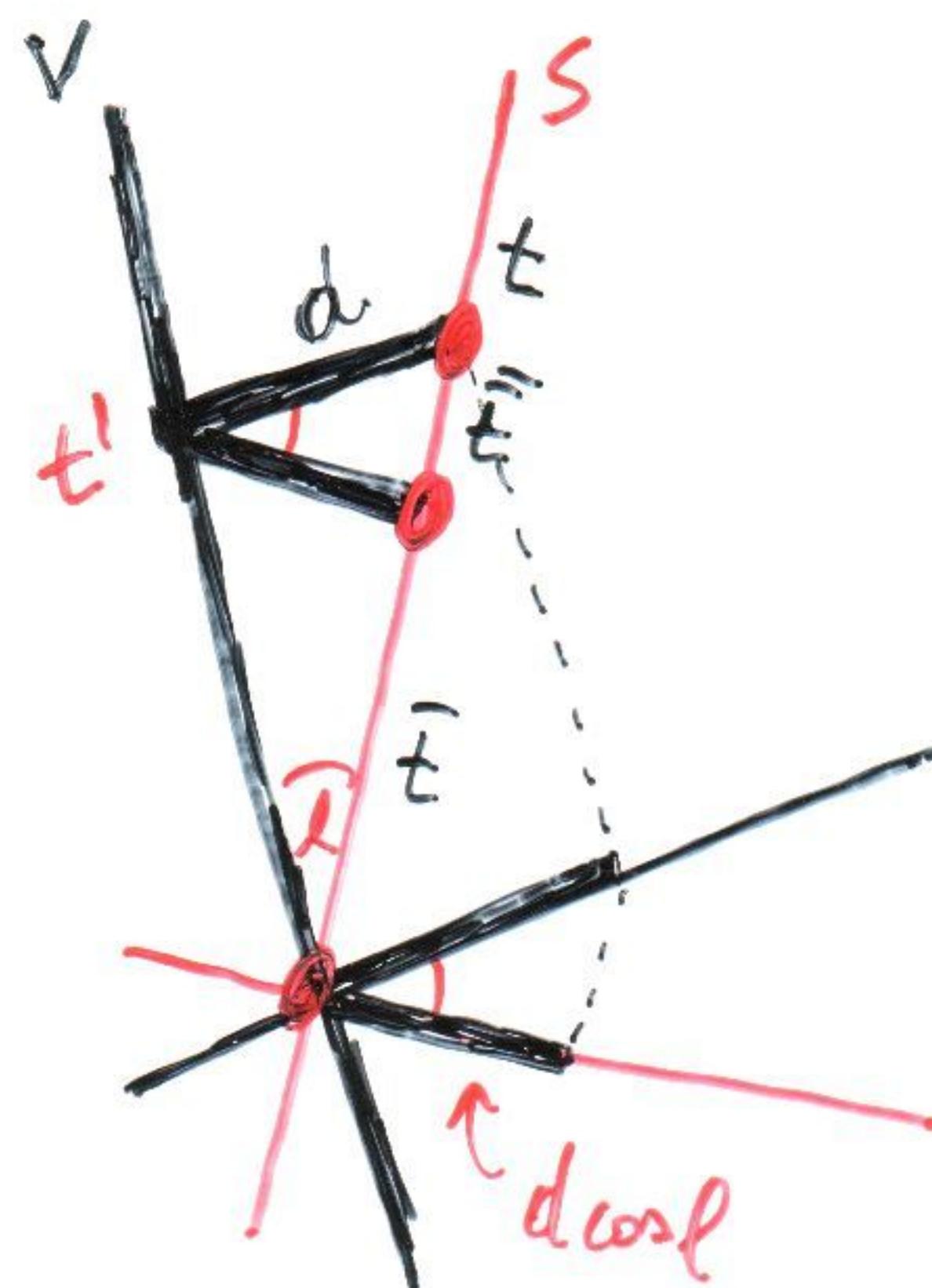
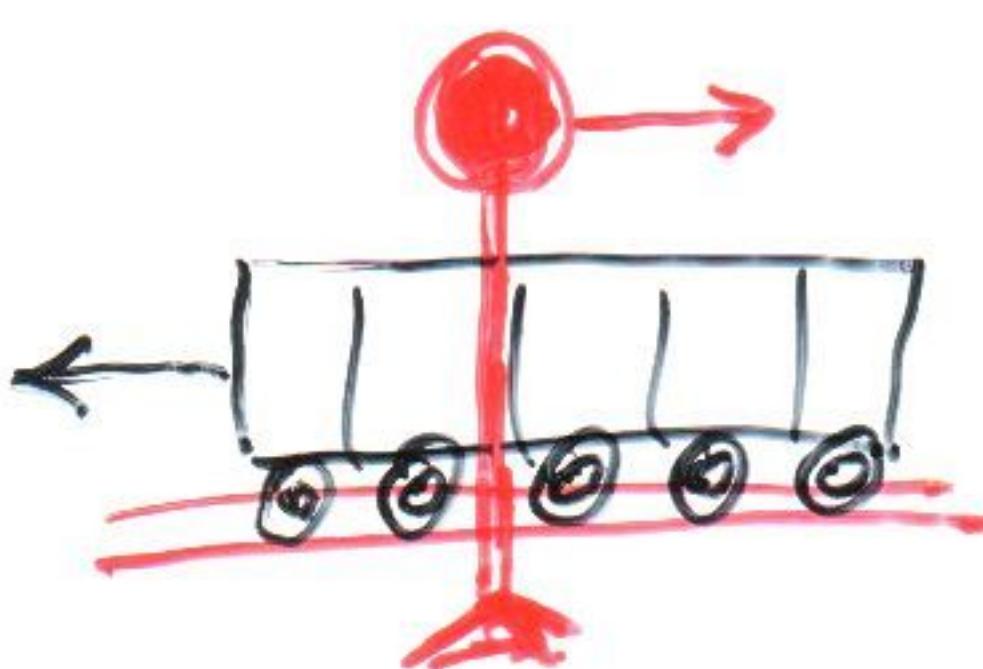
$$\Delta x' = \Delta x \cdot \cos \phi$$

$$\boxed{\Delta x' = \Delta x \sqrt{1 - v^2}}$$

$$\Delta t = \Delta x \cdot \sin \phi$$

$$\boxed{\Delta t = \Delta x \cdot v}$$

VLAK POKRAJ SERAFORA:



U SUSTAVU VLAKA:

VLAK NIRUJE I STARI, SERAFOR SE GIBA I SPORIJE STAR!

$$\text{DUŽINA VLAKA} = \text{PUT SERAFORA} = d$$

$$?? \text{ VRIJENE PUTA SERAFORA} = t = d/v = d/\text{min}$$

$$!! \text{ U SUSTAVU SERAFORA DOTLE PROARE} t' = t \cos \varphi = t \sqrt{1 - v^2}$$

U SUSTAVU SERAFORA (I PRUGE):

SERAFOR NIRUJE I STARI, VLAK SE GIBA I SPORIJE STAR!

$$\text{DUŽINA VLAKA} = d \cos \varphi = d \sqrt{1 - v^2}$$

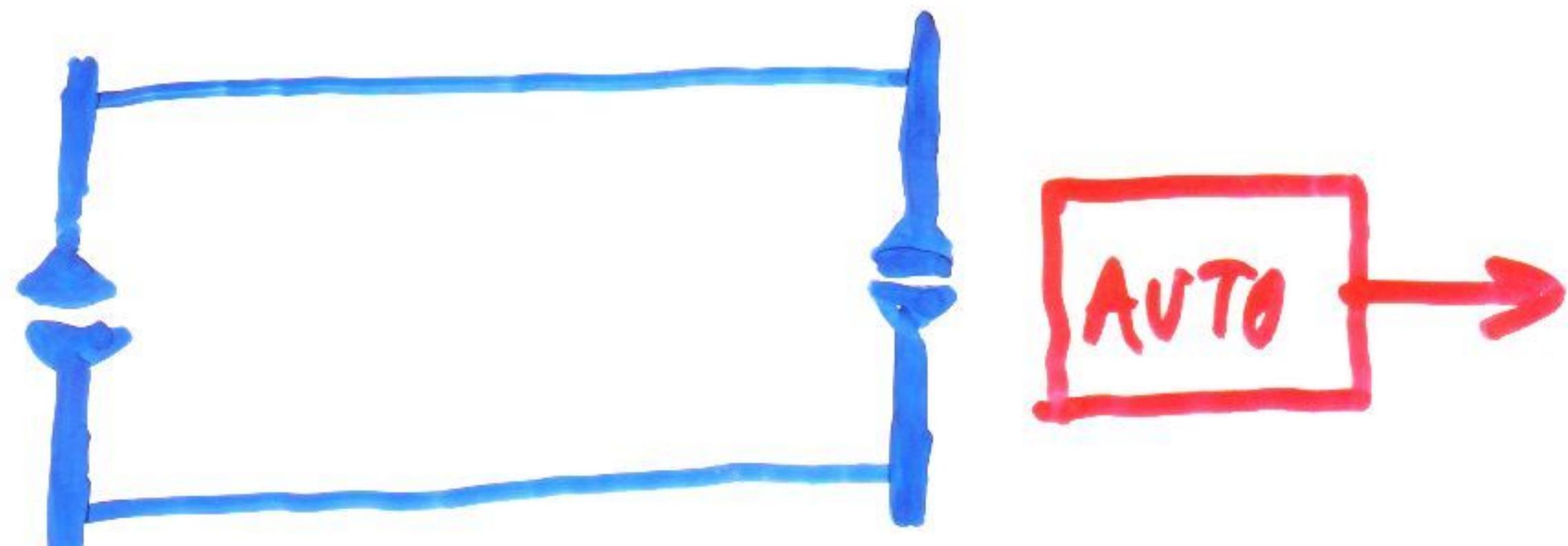
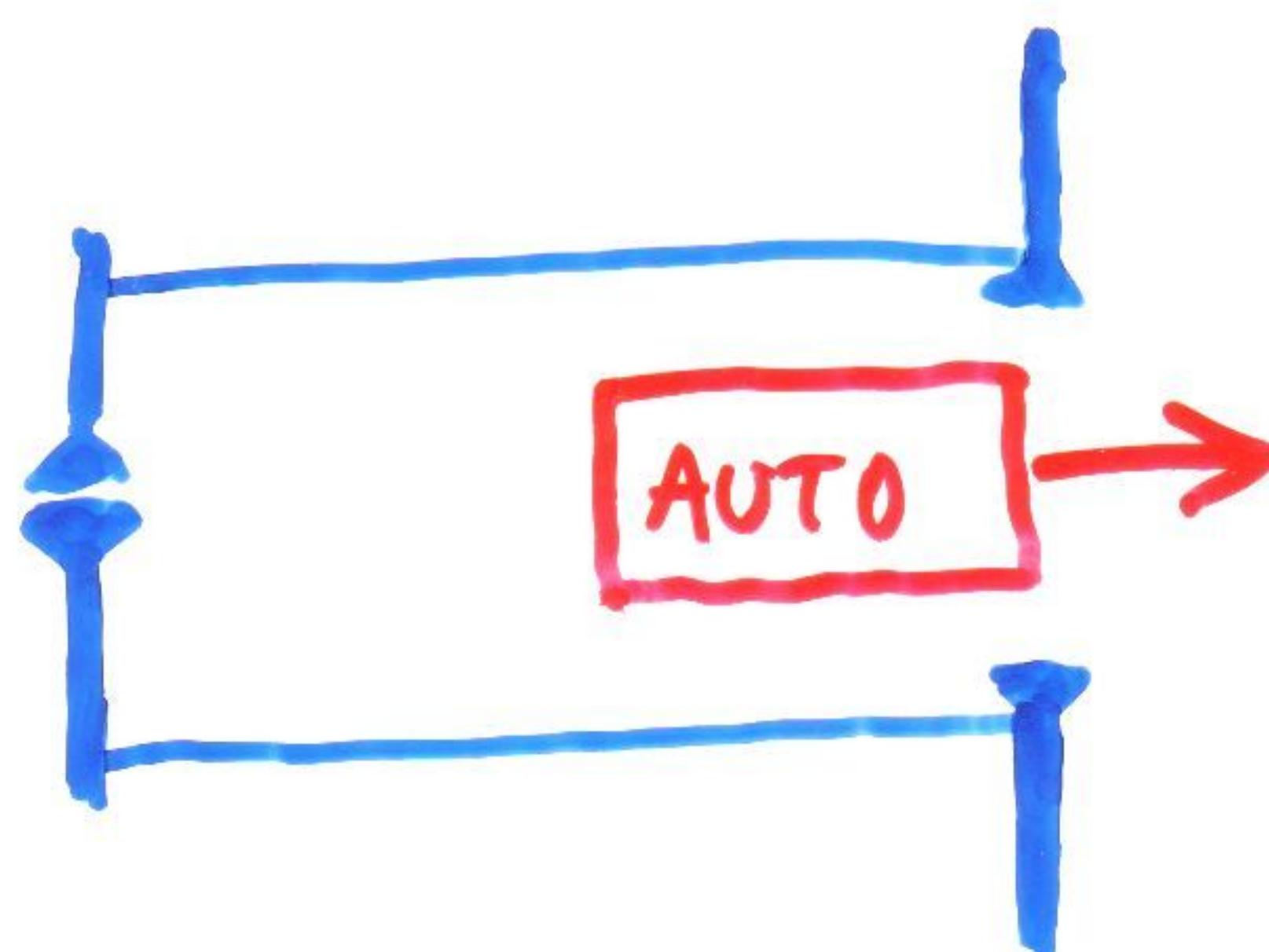
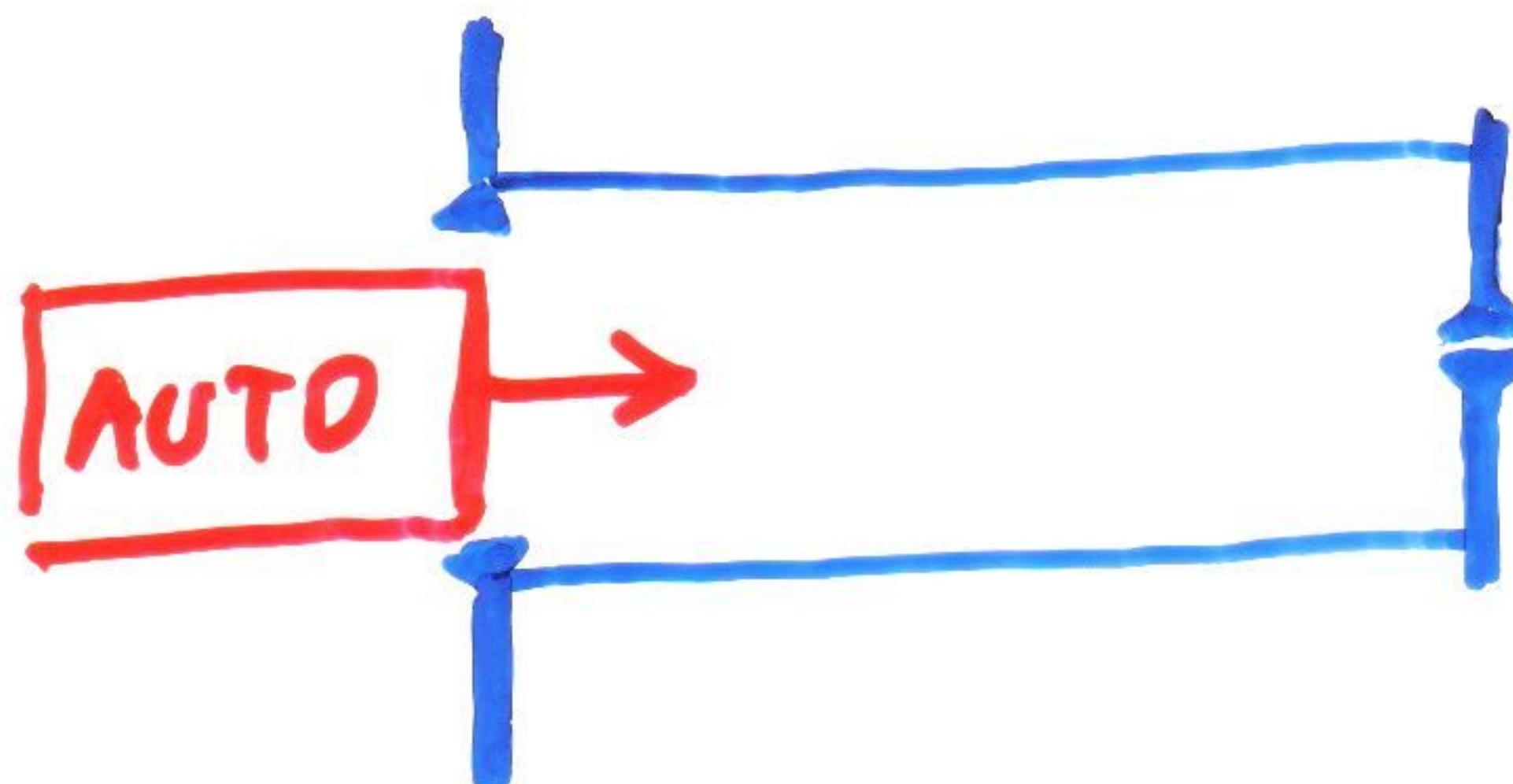
$$!! \text{ VRIJENE PROCLASKA V. KRAJ S.} = t' = t \cos \varphi = t \sqrt{1 - v^2}$$

$$?? \text{ U SUST. VLAKA DOTLE PROARE} \bar{t} = t' \cos \varphi = t \cos^2 \varphi = t(1 - v^2)$$

$\bar{t} \neq t$ RADI DESINAKA. $\bar{t} = d \cdot \min(v) = d \cdot v$, NAINE

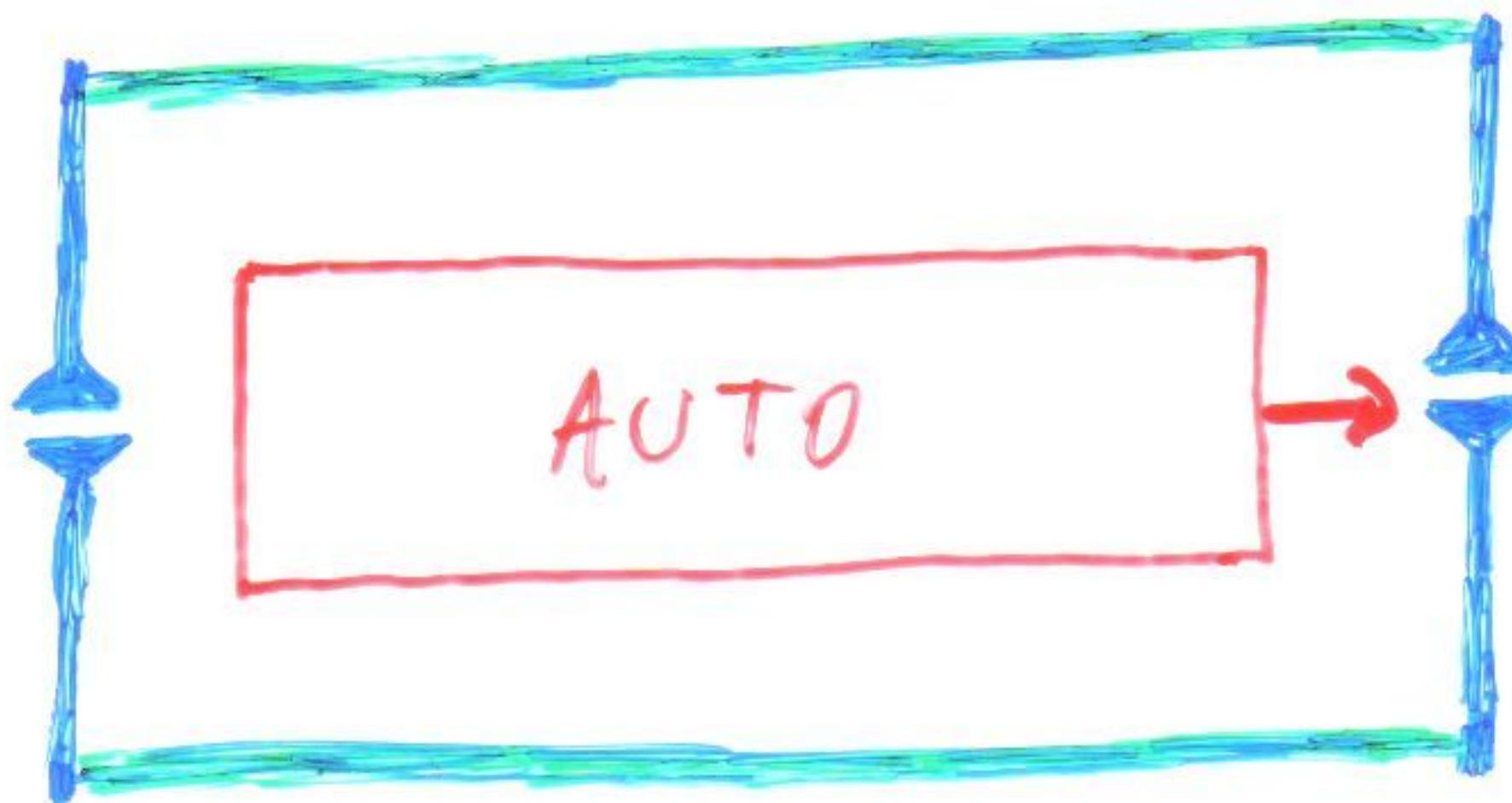
$$\bar{t} + \bar{t} = t(1 - v^2) + dv = t(1 - v^2) + v \cdot v = t$$

AUTO U PRAONICI :

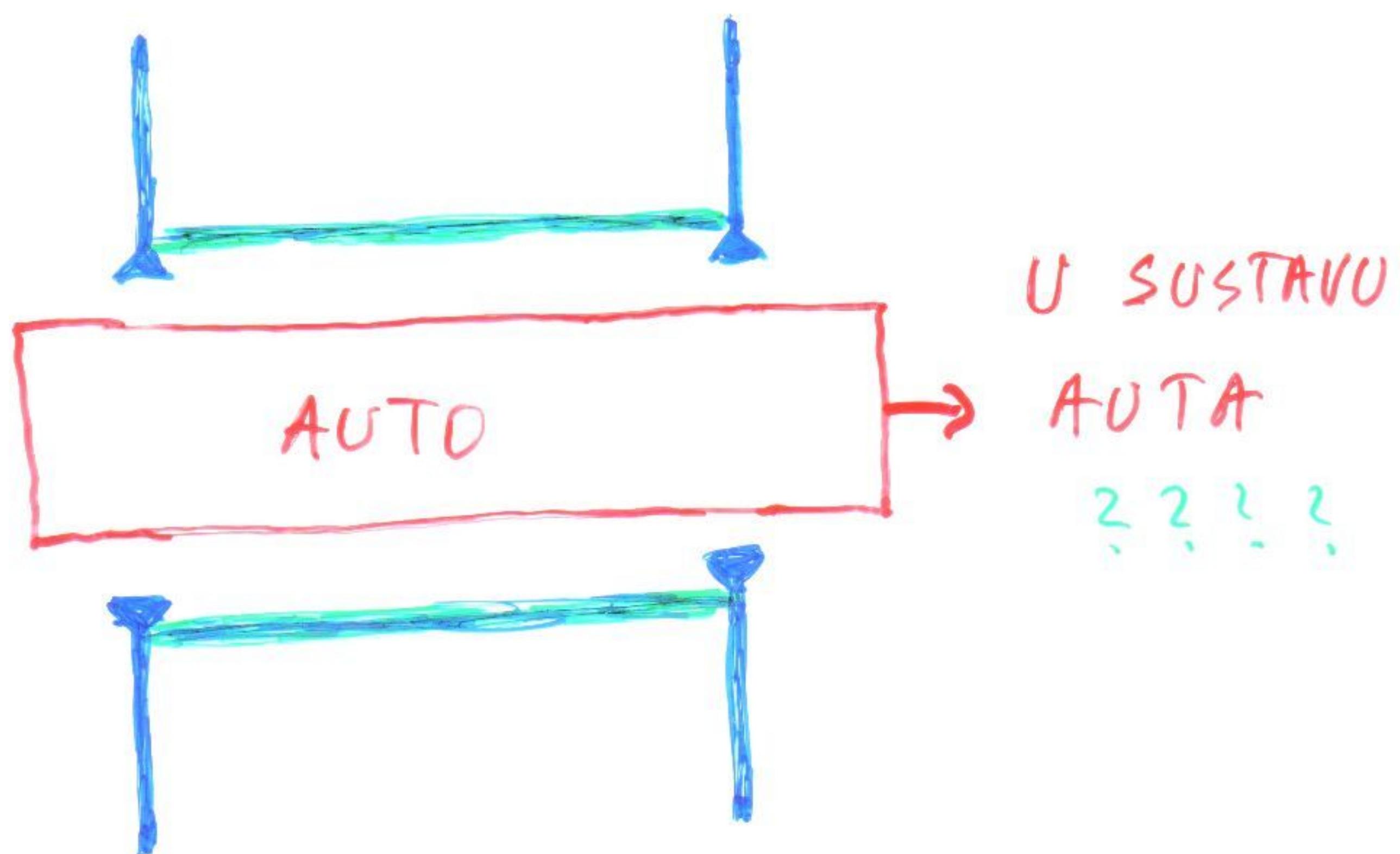


(8a)

AUTO U PRAONICI :



U SUSTAVU
PRAONICE
???



U SUSTAVU
AUTA
???

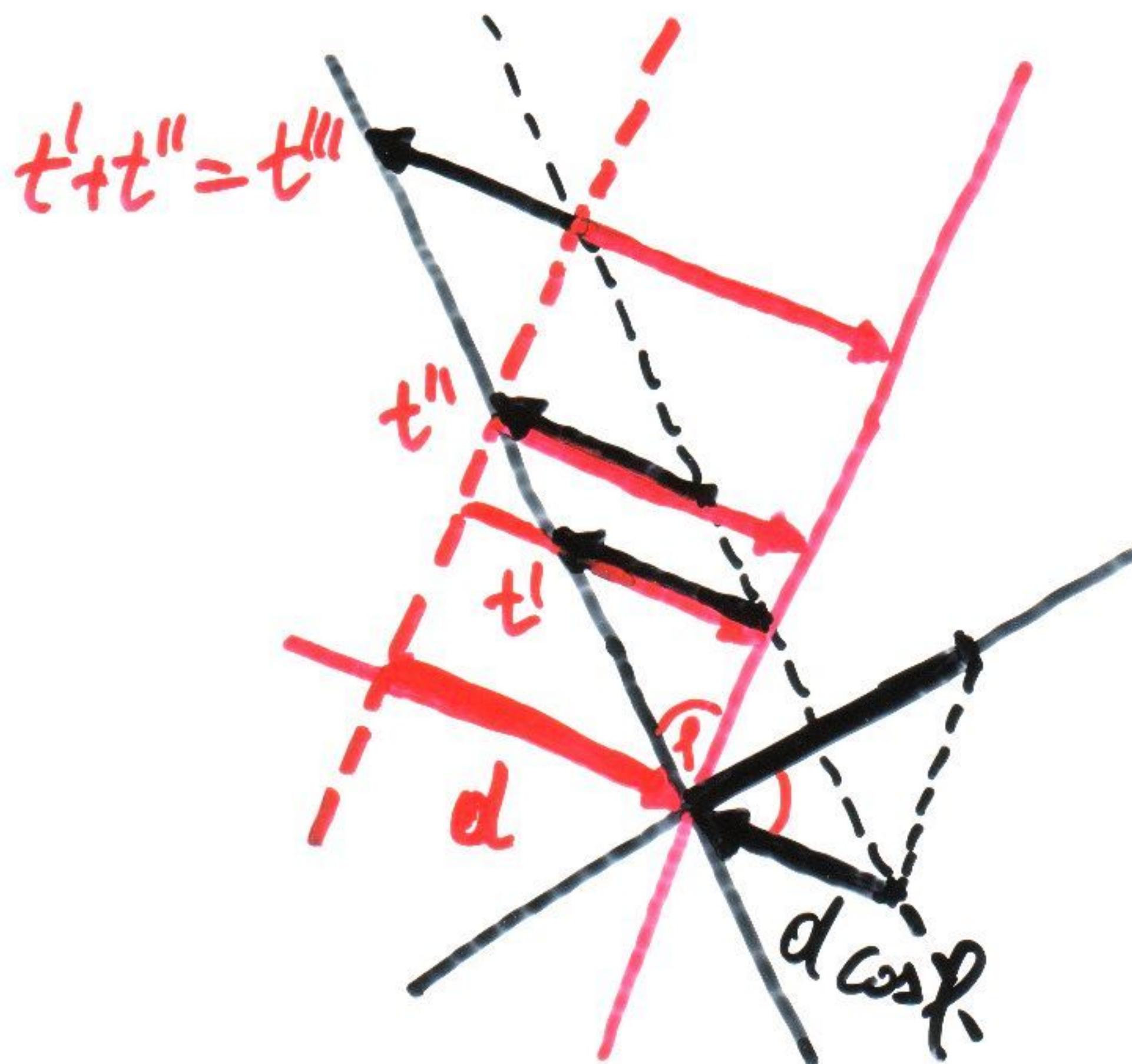
1. VRATA SE OTV.

1. VRATA SE ZATV.
2. VRATA SE OTV.
2. VRATA SE ZATV.

1. VRATA SE OTV.

2. VRATA SE OTV.
1. VRATA SE ZAT.
2. VRATA SE ZAT.

AUTO U PRAONICI :



PRAONICA JE CRVENA:

$t=0$ 1.VRATA SE OTV.

$t=t'$ 1.VRATA SE ZAT.

$t=t''$ 2.VRATA SE OTV.

$t=t'''$ 2.VRATA SE ZAT.

AUTO JE CRVENO:

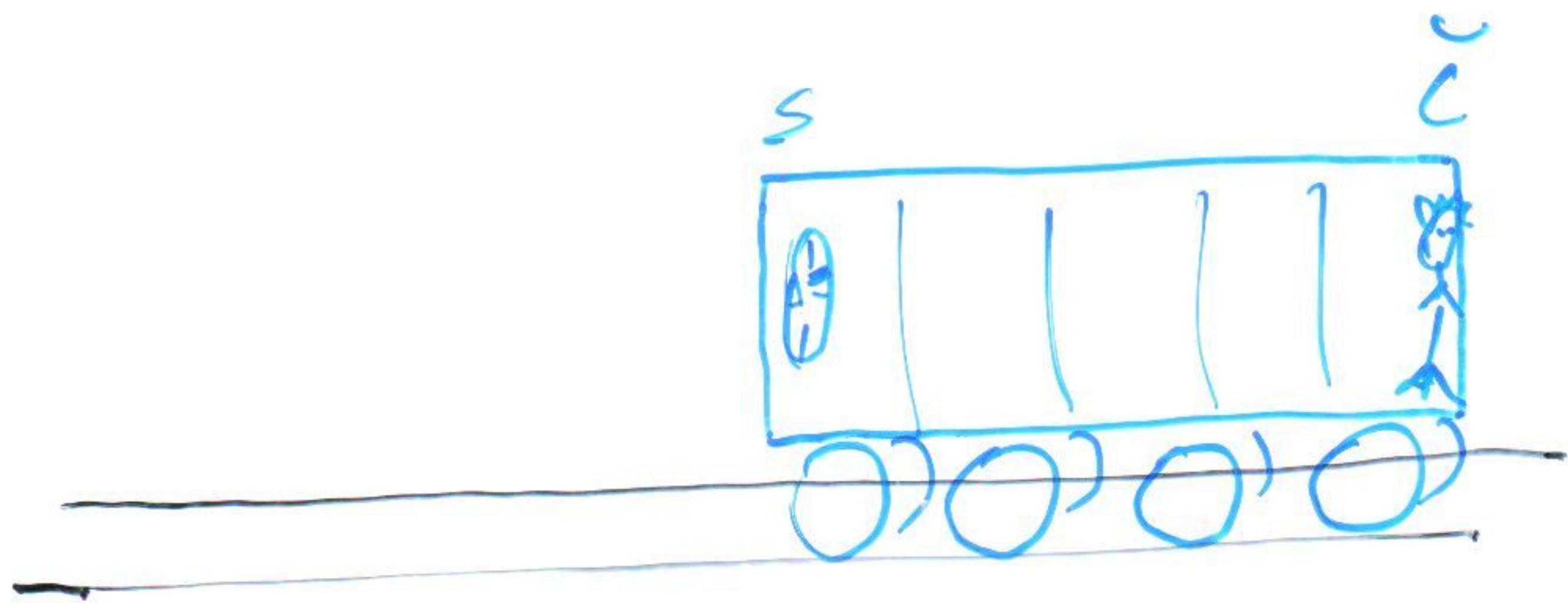
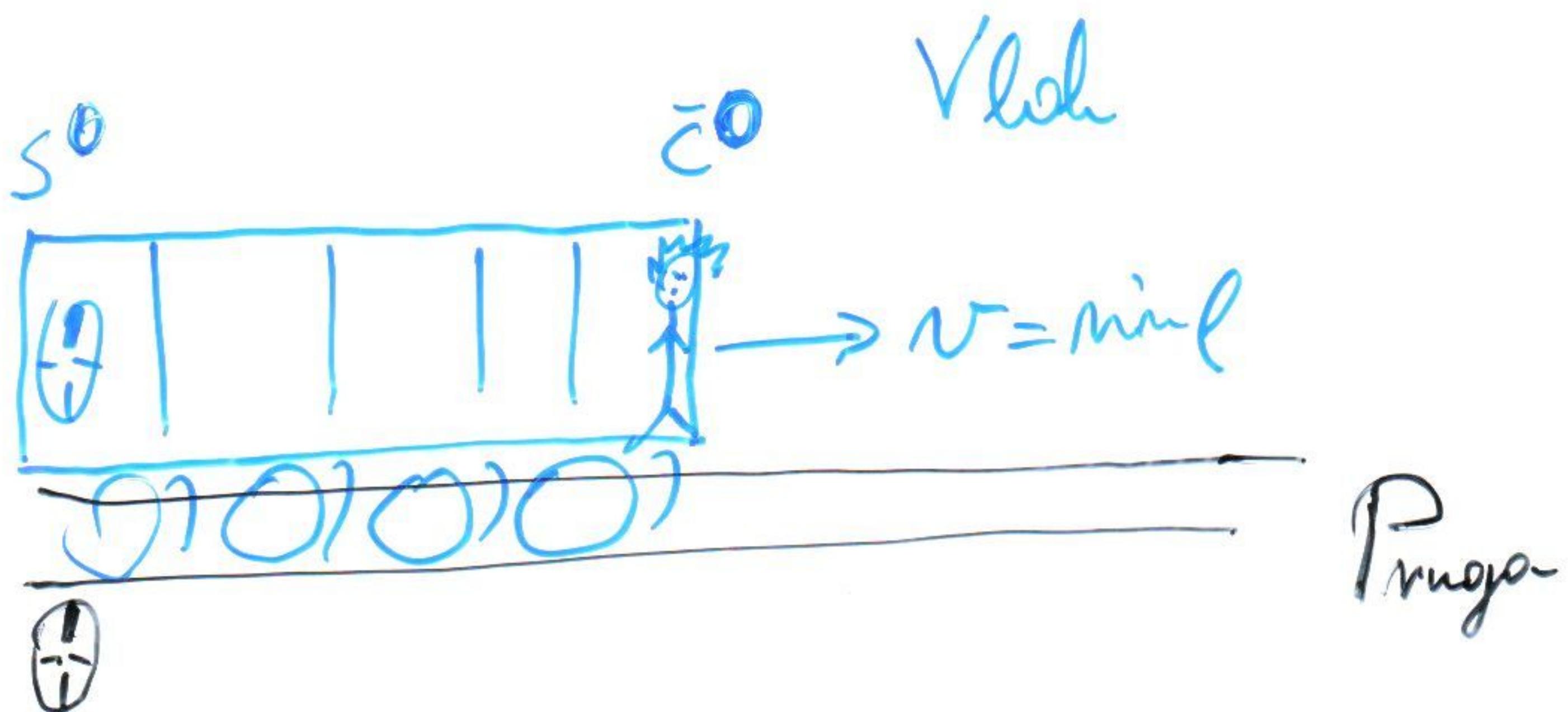
$t=0$ 1.VRATA SE OTV.

$t=t'$ 2.VRATA SE OTV.

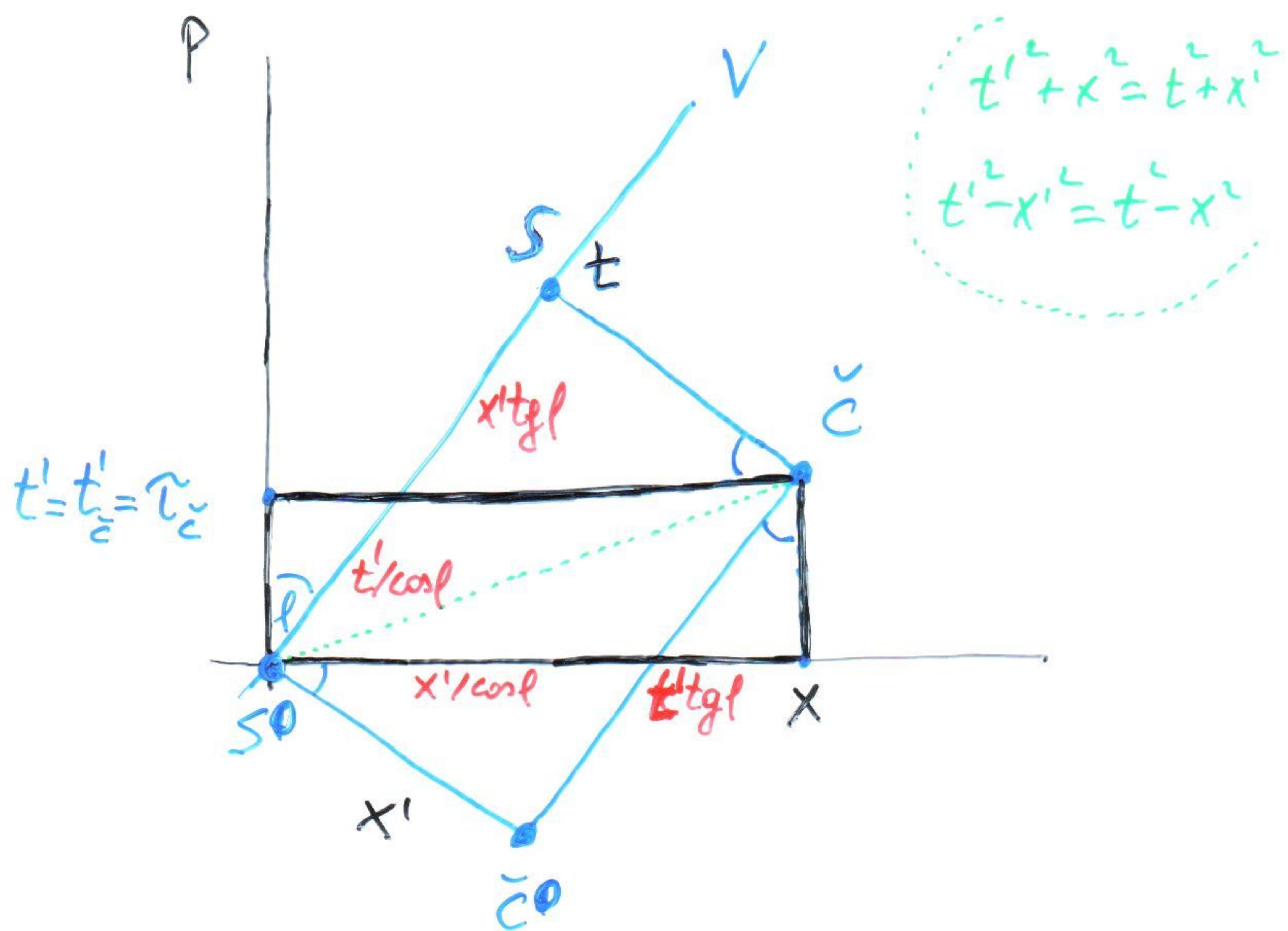
$t=t''$ 1.VRATA SE ZAT.

$t=t'''$ 2.VRATA SE ZAT.

ČOVJEK U VLAKU :



Lorentzove transformacije



$$x = x'/\cos\phi + t'\tan\phi \quad t = t'/\cos\phi + x'\tan\phi$$

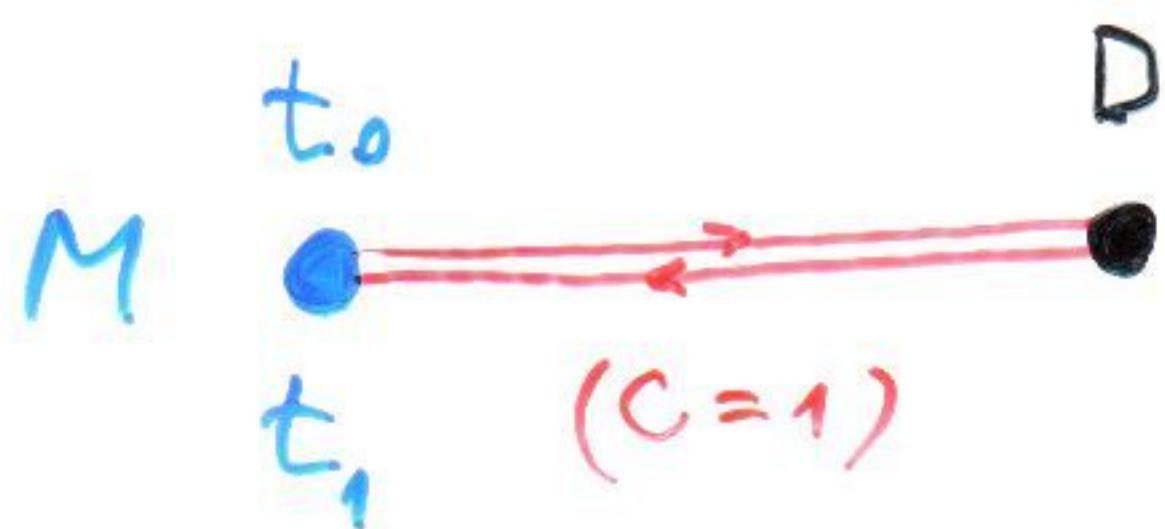
$$x = \frac{x'}{\sqrt{1-v^2}} + t' \frac{v}{\sqrt{1-v^2}} \quad t = \frac{t'}{\sqrt{1-v^2}} + x' \frac{v}{\sqrt{1-v^2}}$$

$$x = \frac{x' + t'v}{\sqrt{1-v^2}} \quad t = \frac{t' + x'v}{\sqrt{1-v^2}}$$

LORENTZOVE TRANSFORMACIJE

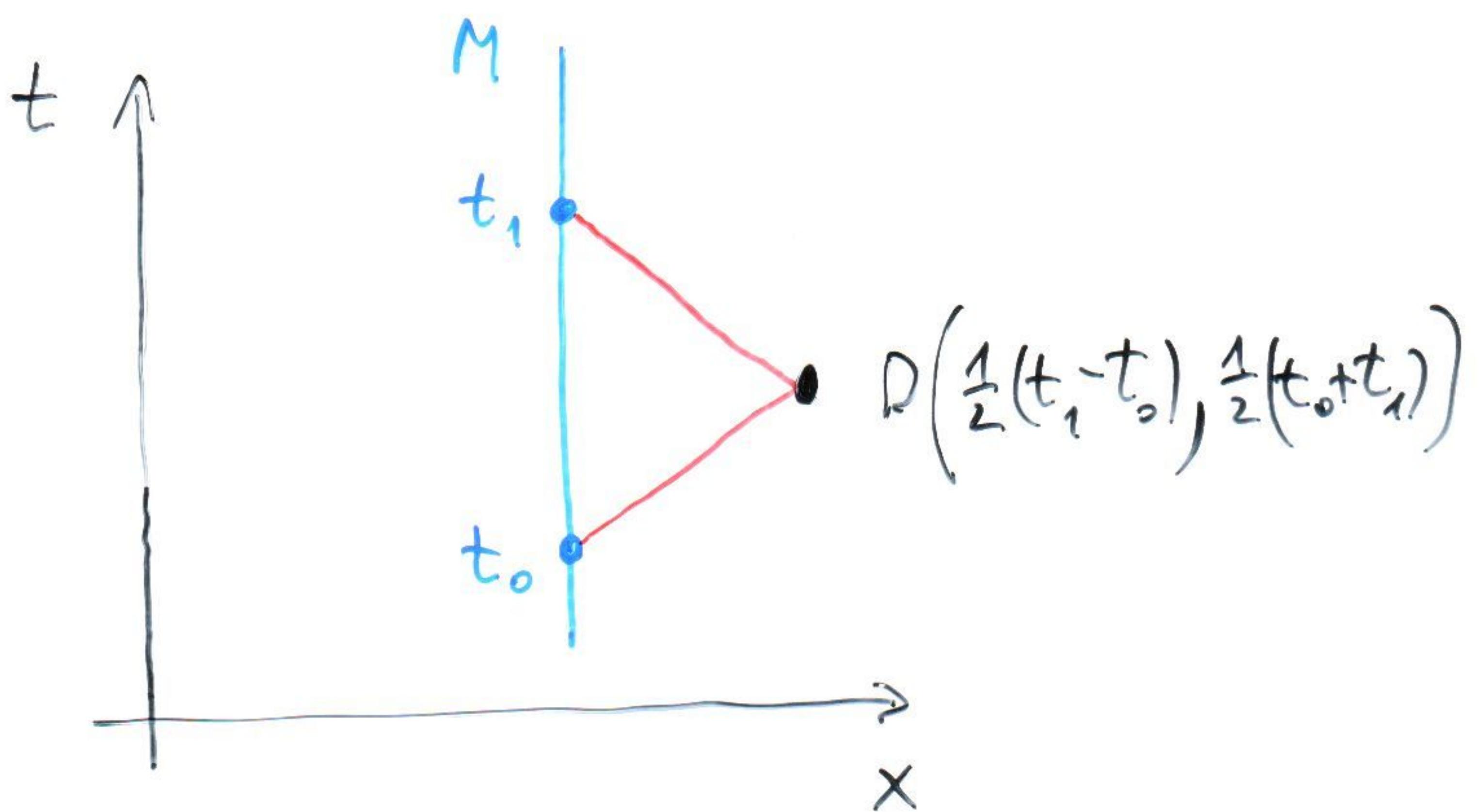
$$x' = \frac{x - vt}{\sqrt{1-v^2}} \quad t' = \frac{t + xv}{\sqrt{1-v^2}}$$

MJERENJE POLOŽAJA X I VREMENAT DOGAĐAJA D U MOJEN SUSTAVU M_g



$$x = \frac{1}{2}(t_1 - t_0)$$

$$t = \frac{1}{2}(t_0 + t_1)$$



x, t JE DIJAGRAM RINKOWSKOG !

x, \tilde{t} JE EPSTEINOV DIJAGRAM !

(NIRUJE)

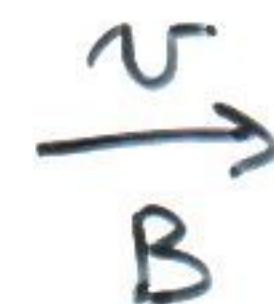
A



Δt

FLEŠEVI

SVJETLA



$k\Delta t$

FLEŠEVI

SVJETLA

(NIRUJE)

C

Δt

FLEŠEVI

SVJETLA

KAKO JE OVISI O v ?

(HERMAN BONDI)

NEWTONOVSKI ODGOVOR:

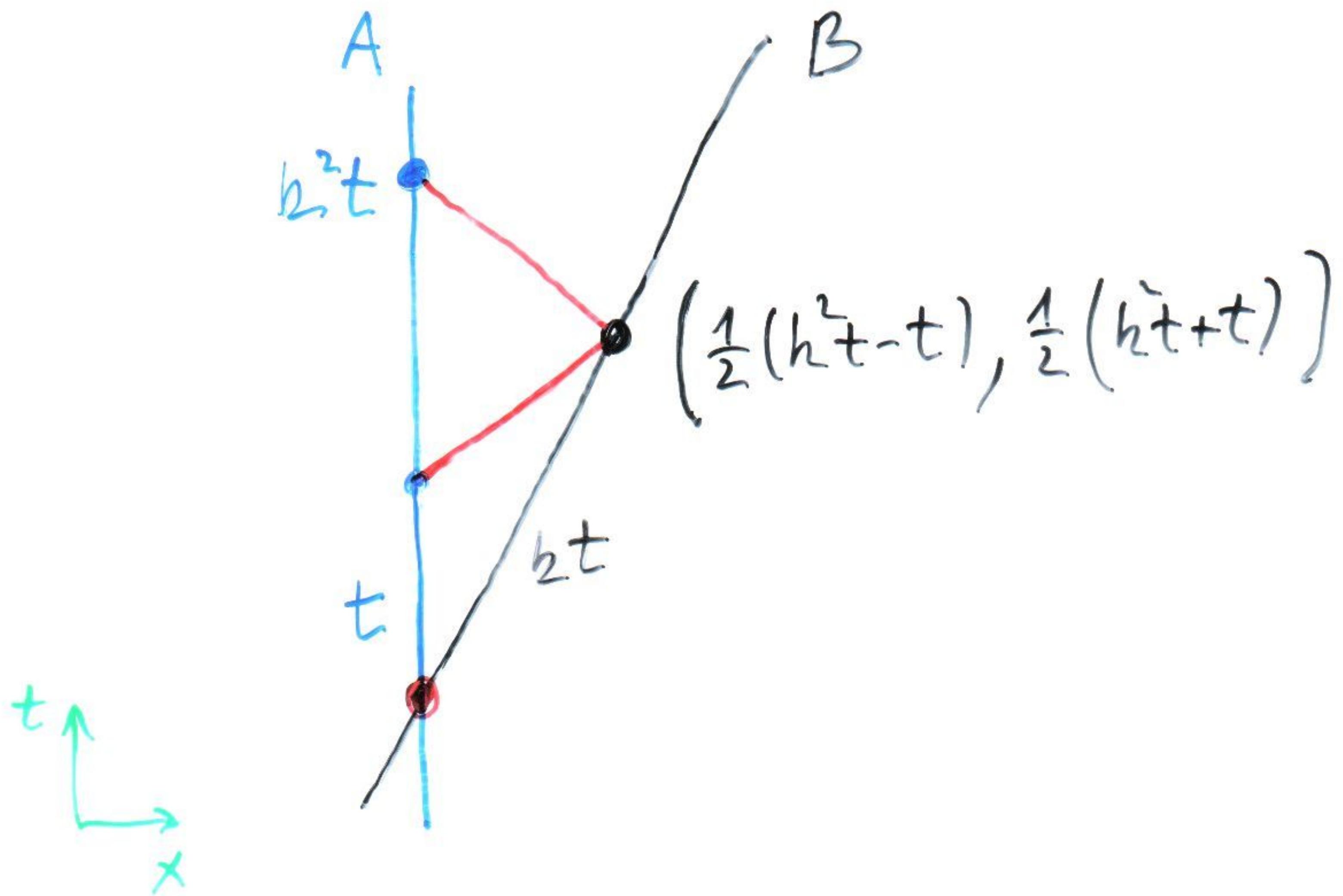
$$(1-v) \cdot k \Delta t = 1 \cdot \Delta t$$

<u>BRZINA</u>	<u>TRAJANJE</u>	<u>BRZ.</u>	<u>TRAJ.</u>
SVJETLA	FLEŠA U B	SVJ.	FLEŠA
UB		U A i C	U A i C



$$k = \frac{1}{1-v}$$

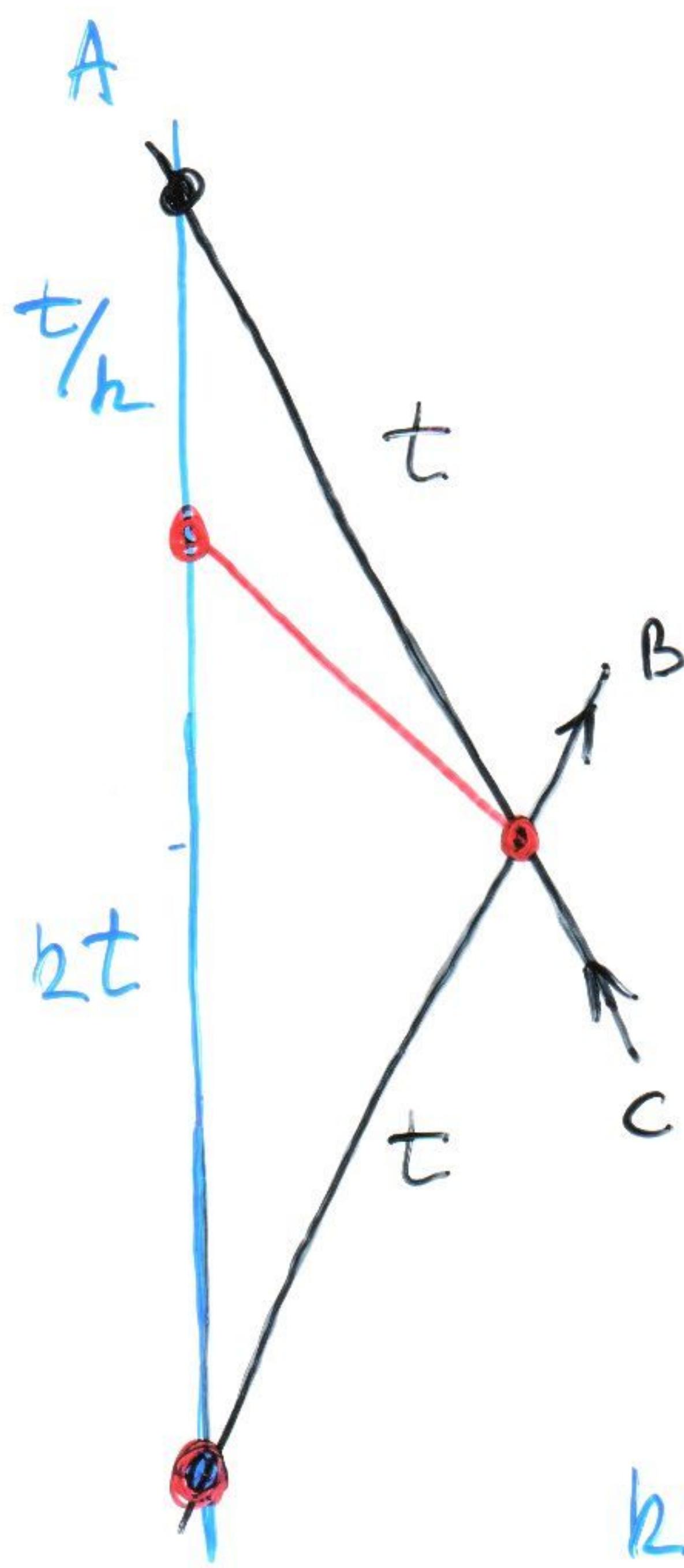
EINSTEINSKI ODGOVOR :



$$v = \frac{\frac{1}{2}(b^2 t - t)}{\frac{1}{2}(b^2 t + t)} = \frac{b^2 - 1}{b^2 + 1}$$

$$\Rightarrow h = \sqrt{\frac{1+v}{1-v}}$$

"PARADOOKS" BLÍŽANÁCT



B SE UDÁVÁ VÁ ODA
("S FAKT." t/h)

C SE PRIBlíEKA
("S FAKT." t/h)

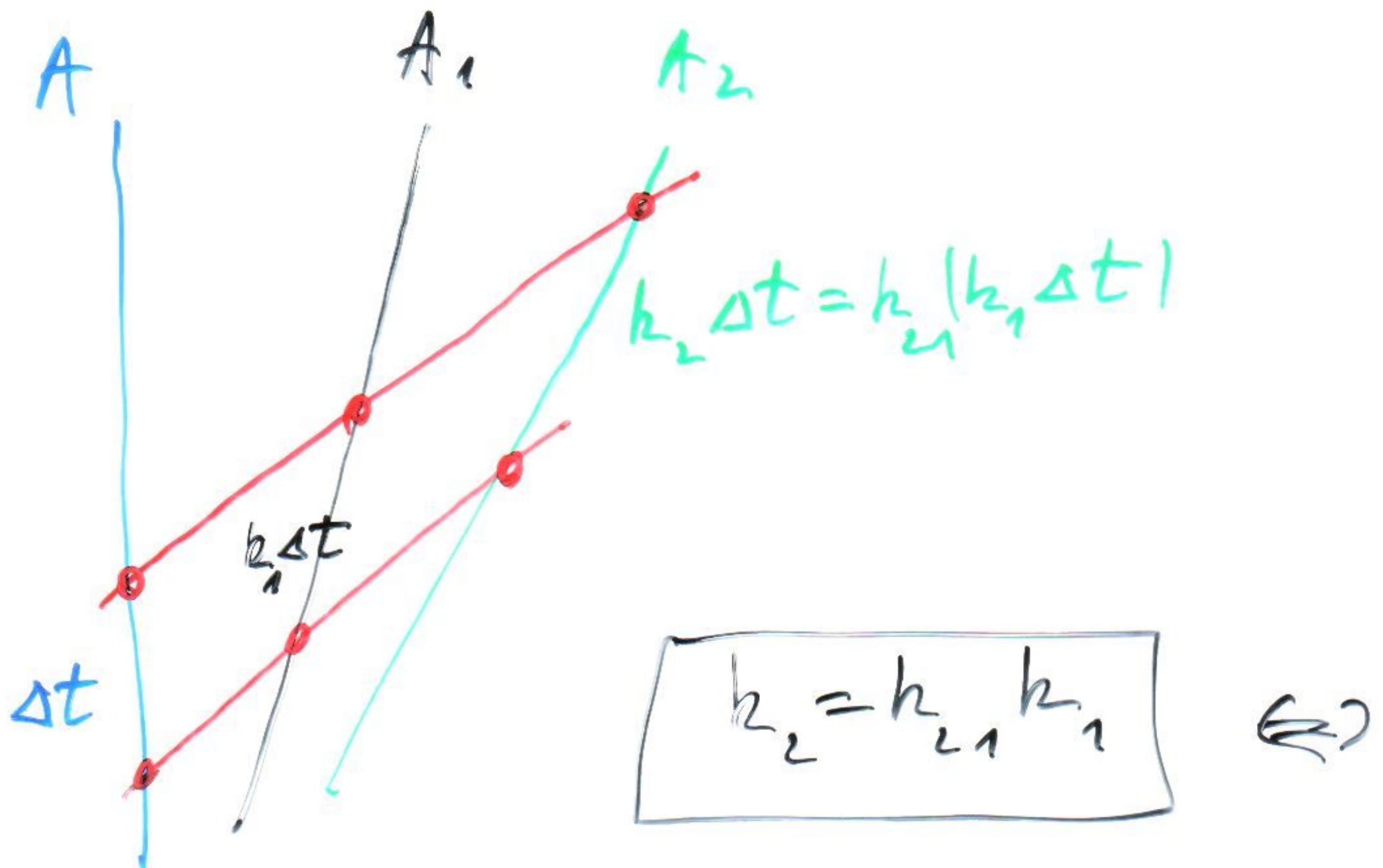
$$ht + \frac{t}{h} \neq 2t$$

VRII. PNT.
U A-SUST.

VRII. PNT.
U B+C - SUST.
?

$$h + \frac{1}{h} \neq 2$$

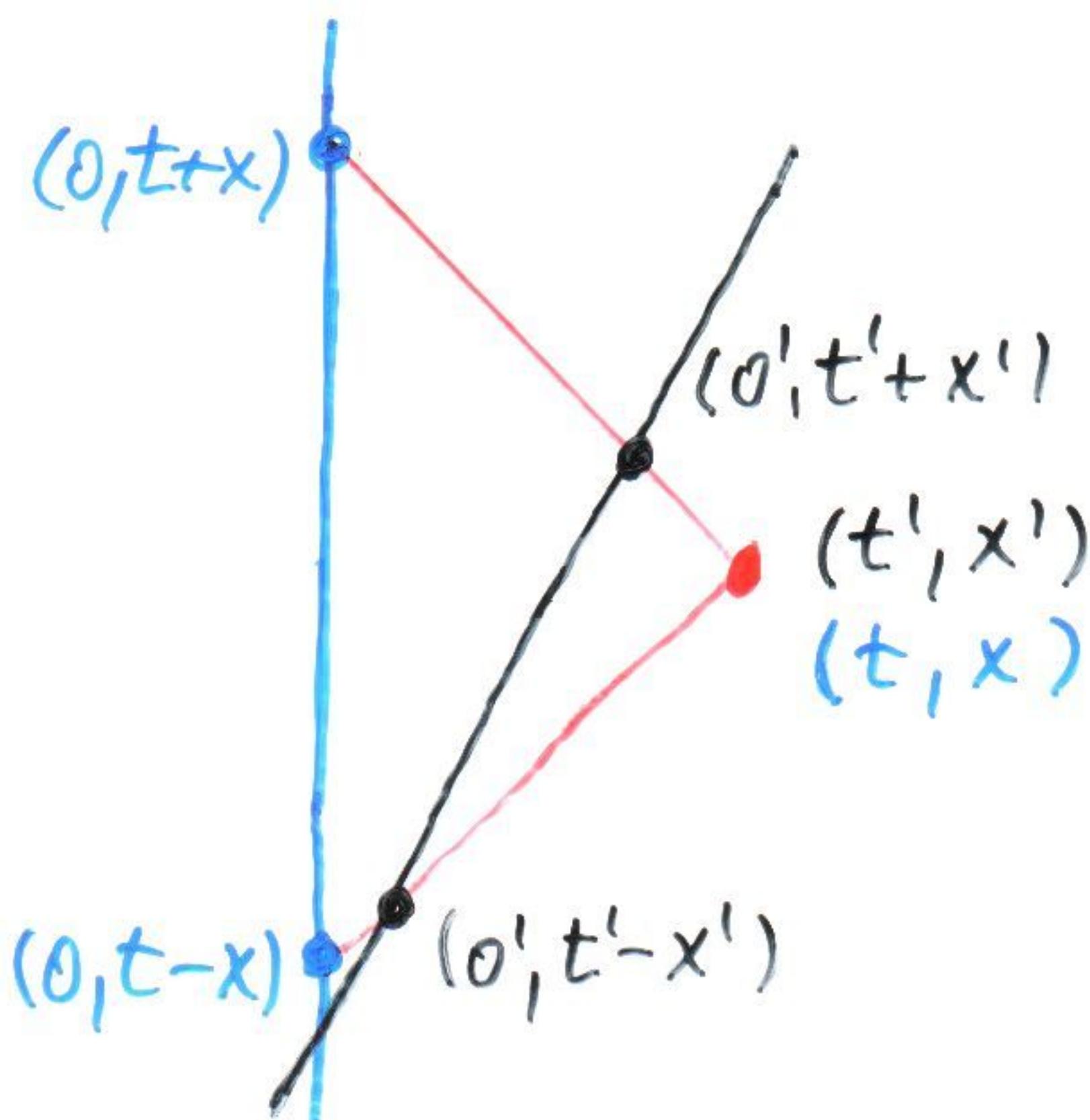
"ZBRAJAME" BRZINA



$$\frac{1 + v_2}{1 - v_2} = \frac{1 + v_{21}}{1 - v_{21}} \cdot \frac{1 + v_1}{1 - v_1} \quad \Leftrightarrow$$

$$v_2 = \frac{v_1 + v_{21}}{1 + v_1 v_{21}}$$

Lorentz Transformation k-Rechnung



$$\boxed{t' - x' = k(t - x)}$$

$$t + x = k(t' + x')$$

$$\boxed{t - x = t' - x'}$$

USPUT

$$\Rightarrow 2t' = k(t - x) + \frac{1}{k}(t + x)$$

$$2x' = \frac{1}{k}(t + x) - k(t - x)$$

$$\Rightarrow t' = \frac{k+1}{2k}t - \frac{k-1}{2k}x$$

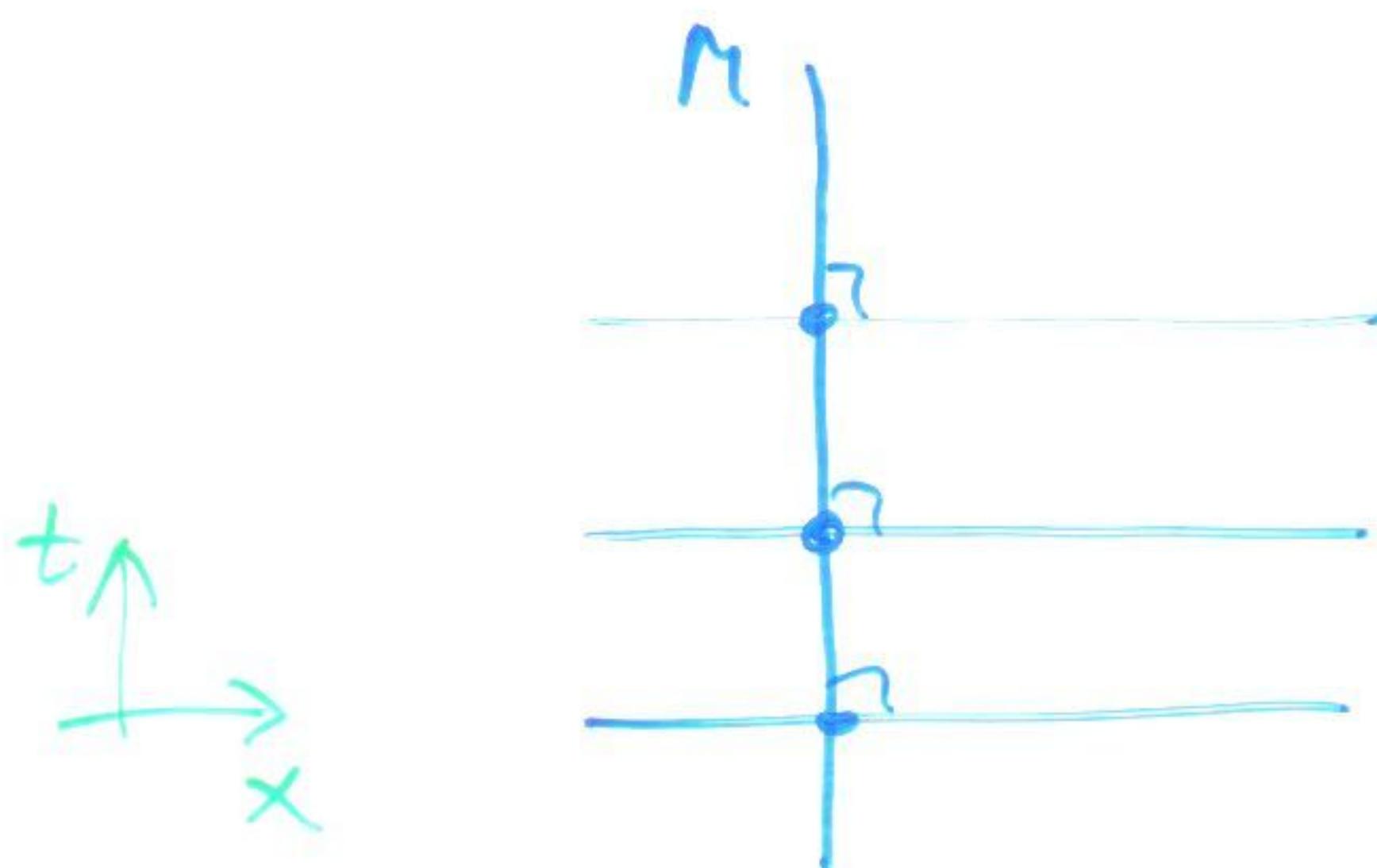
$$x' = \frac{k+1}{2k}x - \frac{k-1}{2k}t$$

$$k = \sqrt{\frac{1+v}{1-v}}$$

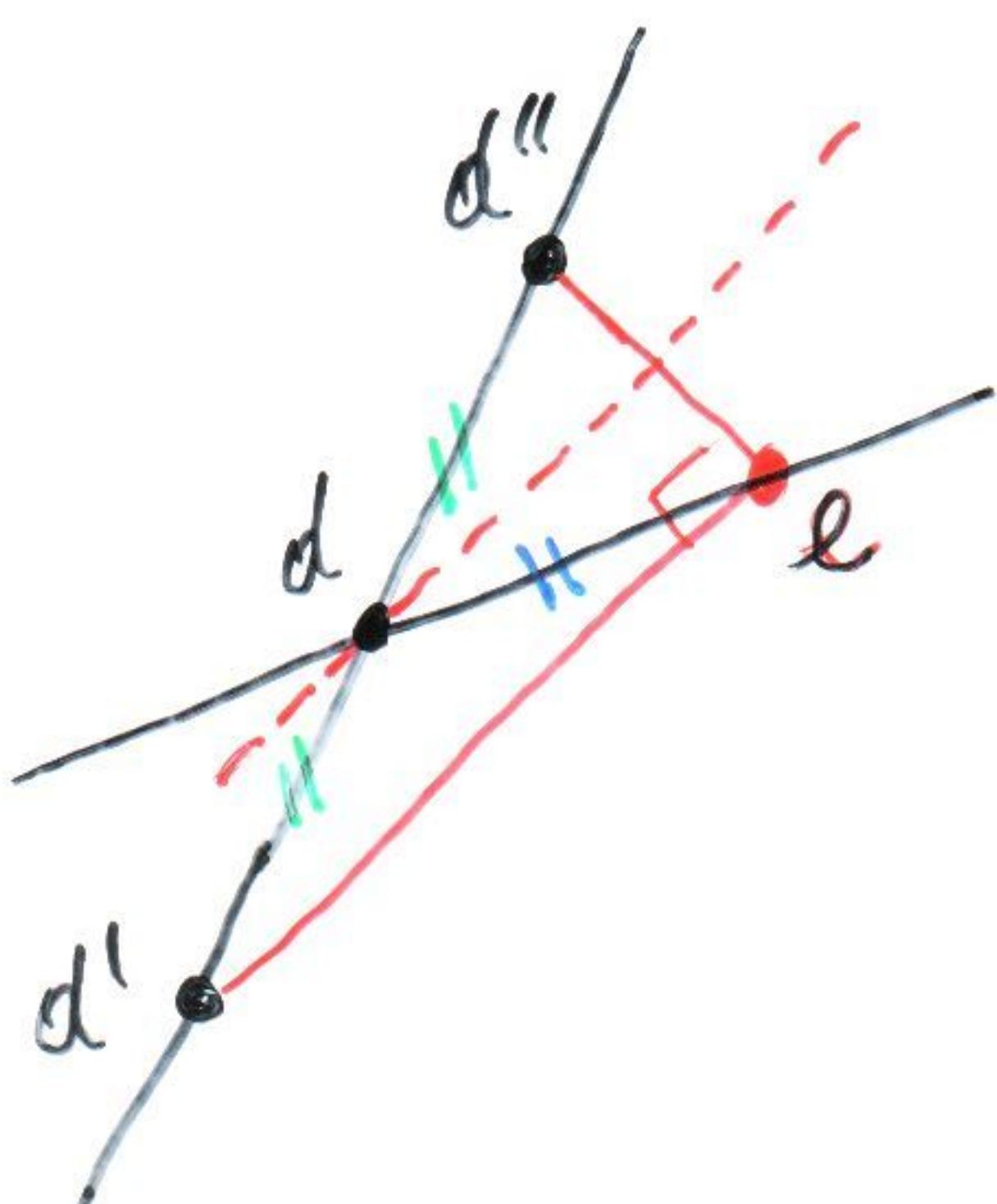
$$\Rightarrow \boxed{t' = \frac{t - vx}{\sqrt{1 - v^2}}}$$

$$\boxed{x' = \frac{x - vt}{\sqrt{1 - v^2}}}$$

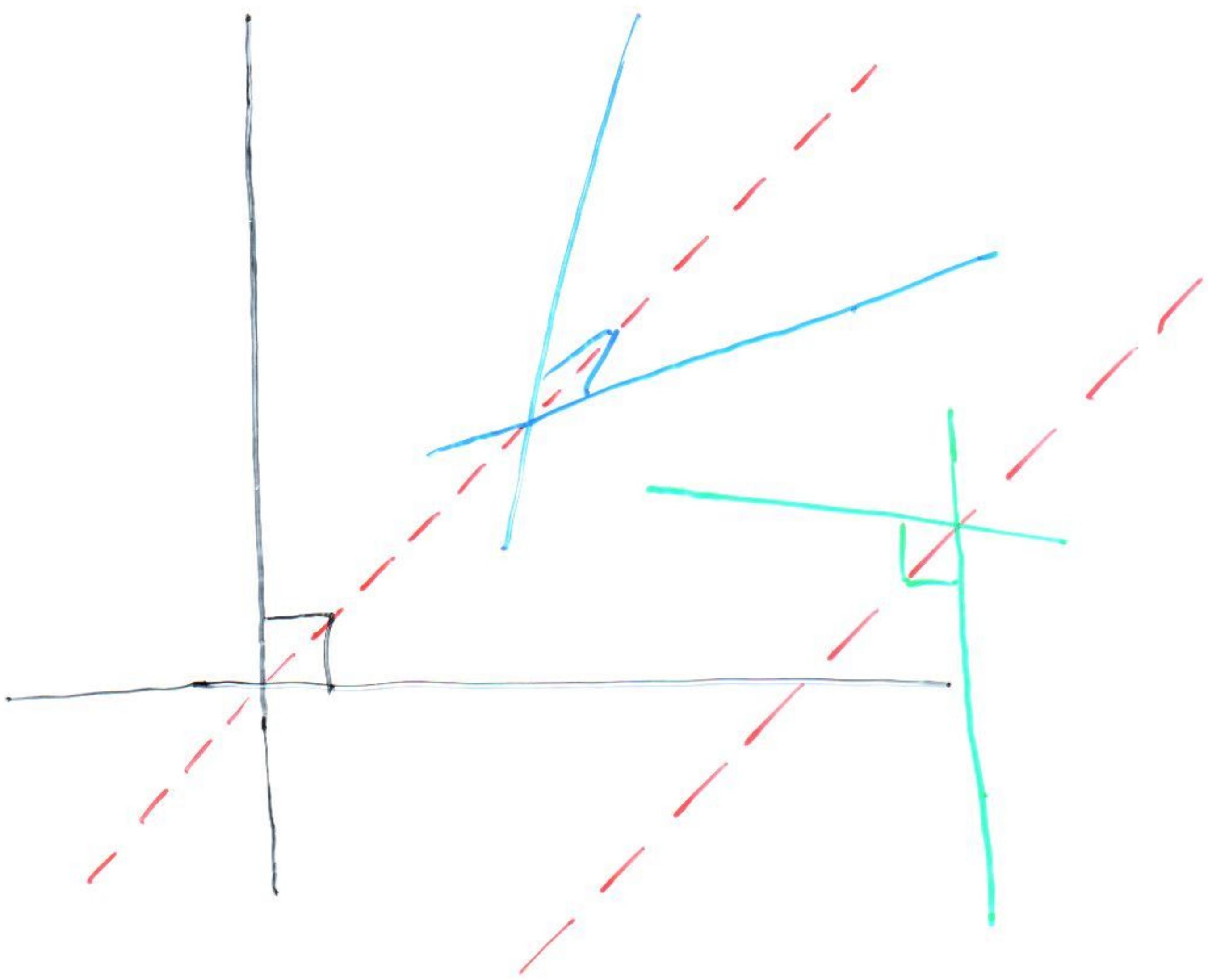
PROSTOR SIMULTANIH DOGAĐAJA ZA
MENE KOJI MIRUJEM JE OKONIT NA
MOJU VREMENSKU OS:



ŠTO JE PROSTOR SIMULTANIH DOGAĐAJA
ZA TEBE KOJI SE GIBAŠ (PREMA m):



AKO SVIETLOST IZ d' STIJE
U L, PA SE VRAĆA U d'',
ONDA JE ^{KOJI JE} L ISTOVREMEN
SA d'' POSRED INTERVALA
 $d' - d''$.
DAKLE, iz d'' i dle su
SIMETRIČNI u odnosu na
ENISIJU SVIETLA iz d
JER JE $\| = \| = \|$



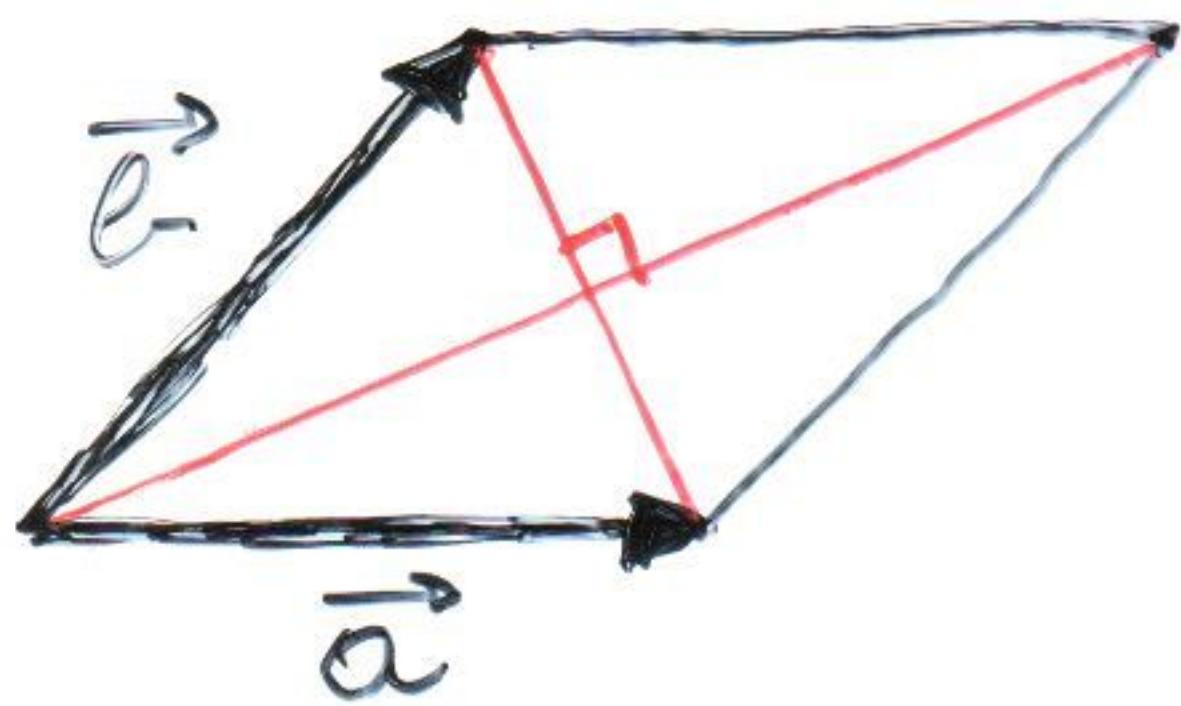
ORTOGONALNOST DETERMINIRATA
METRIKU (GEOMETRIJU) !!!
(INARAVNO OBROTNO)

"ORTOGONALNOST & GEOMETRIJA
PROSTOR - VRELJAVNA"

DR-STUDIJS KRAJEM 80-tih

17a

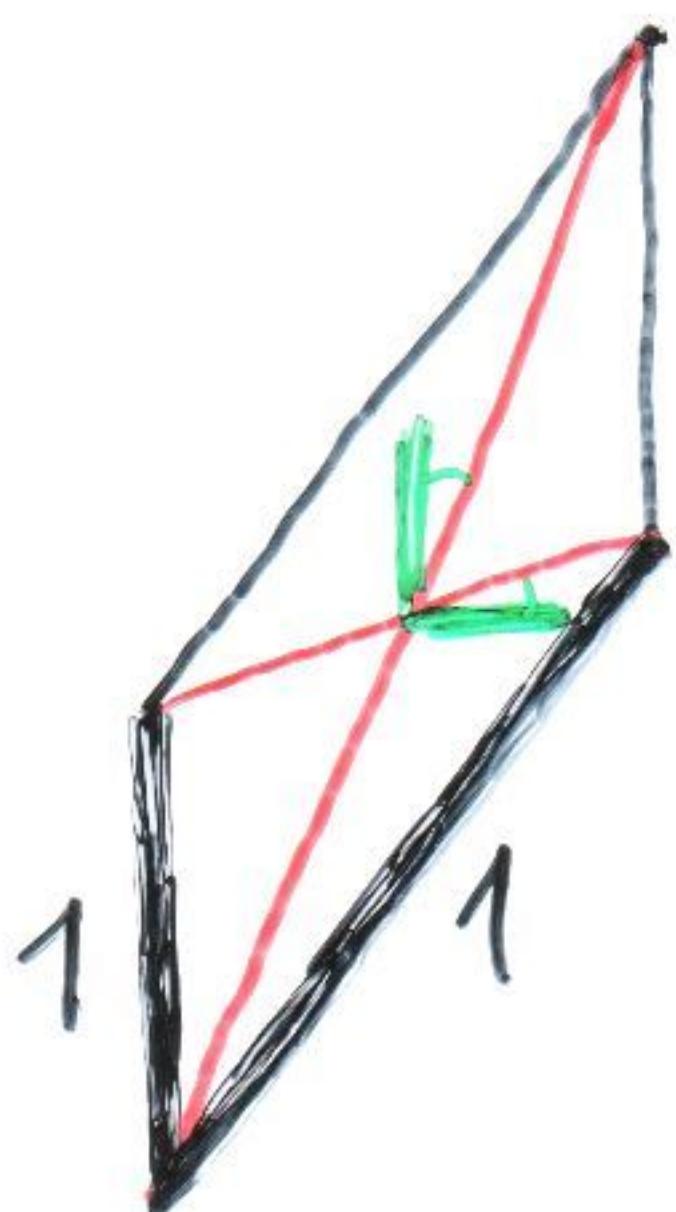
OKOMITOST & METRIKA:



$$|\vec{a}| = |\vec{b}| \iff$$

$$(\vec{a} + \vec{b}) \perp (\vec{a} - \vec{b})$$

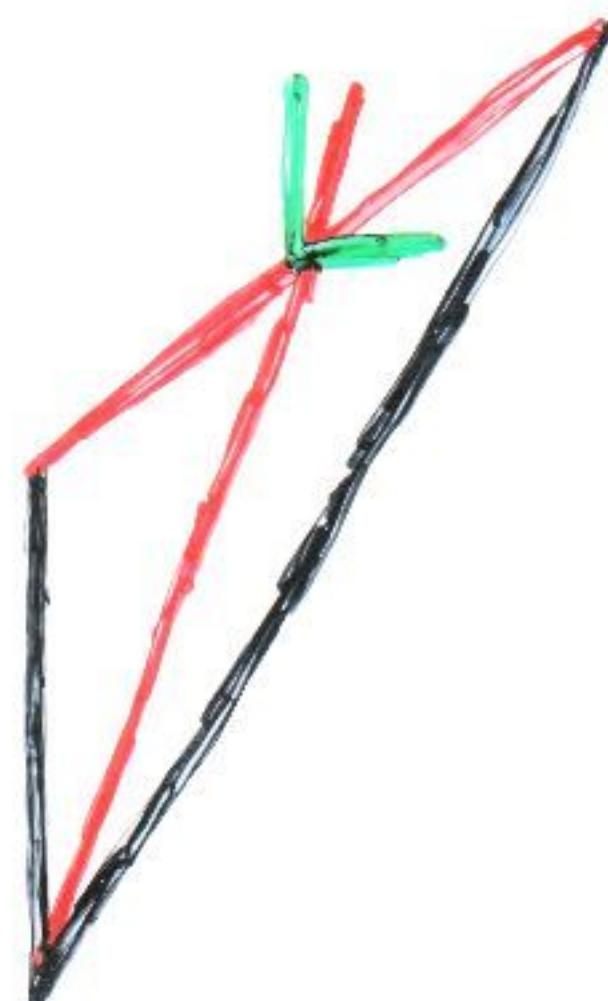
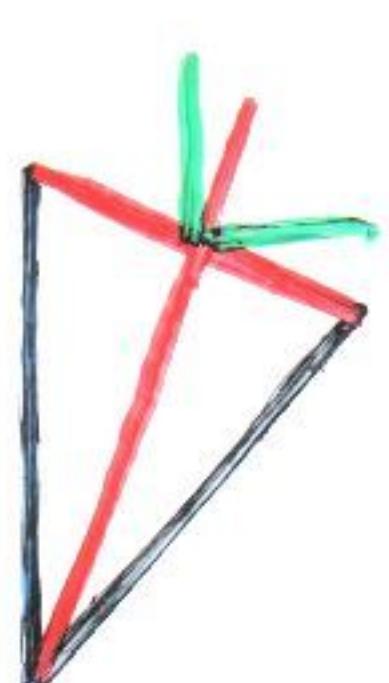
U LORENTZOVU RAVNINU



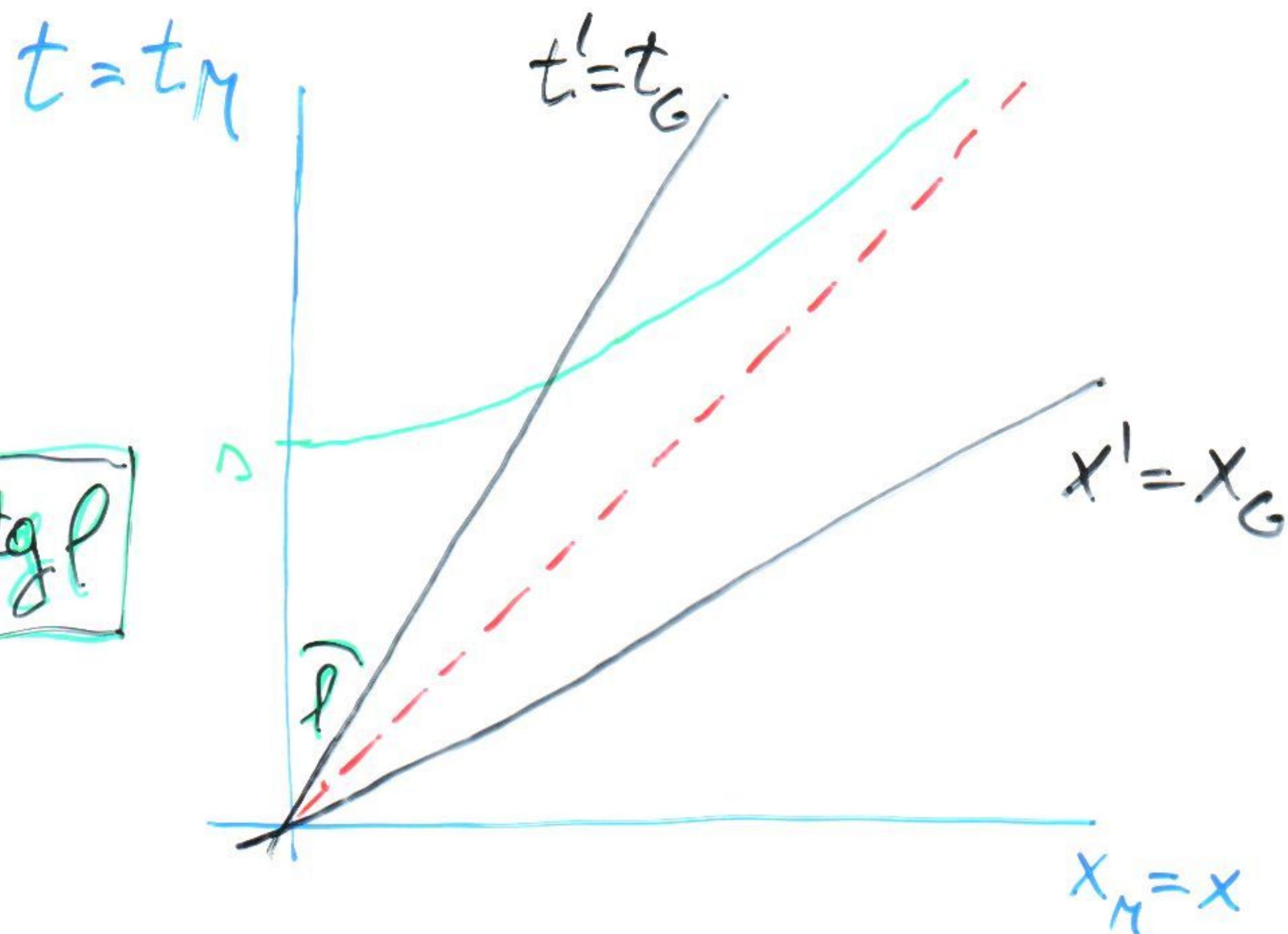
CRNI SU ISTE DUGINE \iff

CRVENI SU OKONITI \iff

CRVENO I ZELENO KUTOVI ISTI



DIJAGRAM RINKOKOSKOG:



ZA SVAKI SUSTAV G ZNANO PRIKAZATI
MEGOVU OS "ISTORIJESNOSTI" t_G I MEGOVU
OS (PROSTOR) "ISTOVREDEFENOSTI" x_G

ŠTO JE \wedge SEKUNDI NA $t_G = t'$?

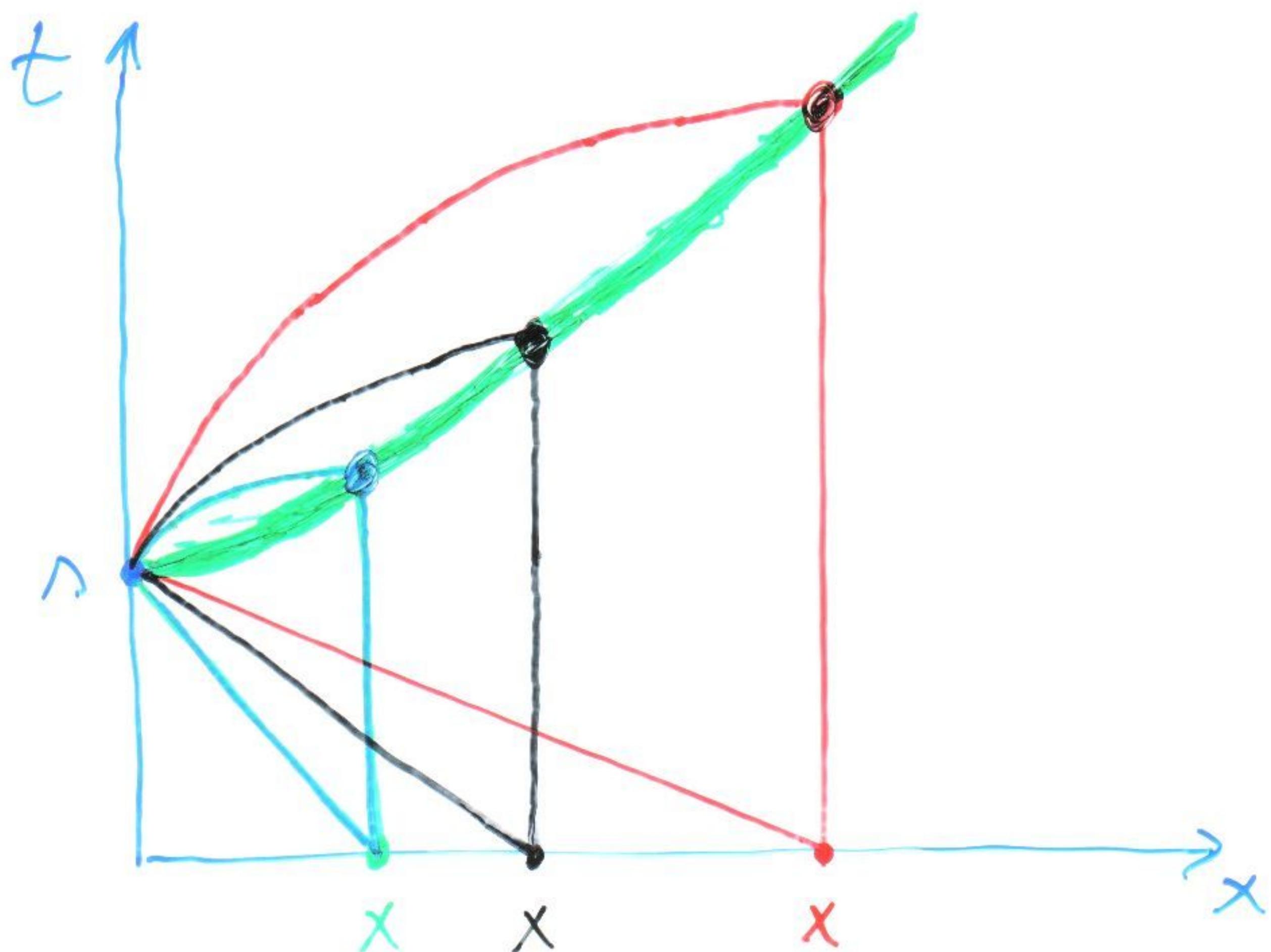
$$t'^2 + x^2 = t^2 \quad (\text{tj. } \tau^2 + x^2 = t^2)$$

$$t' = \Delta$$

$$t^2 - x^2 = \Delta^2$$

HIPERBOLA !!

KONSTRUKCIA HIPERBOLE $t^2 - x^2 = \Delta^2$

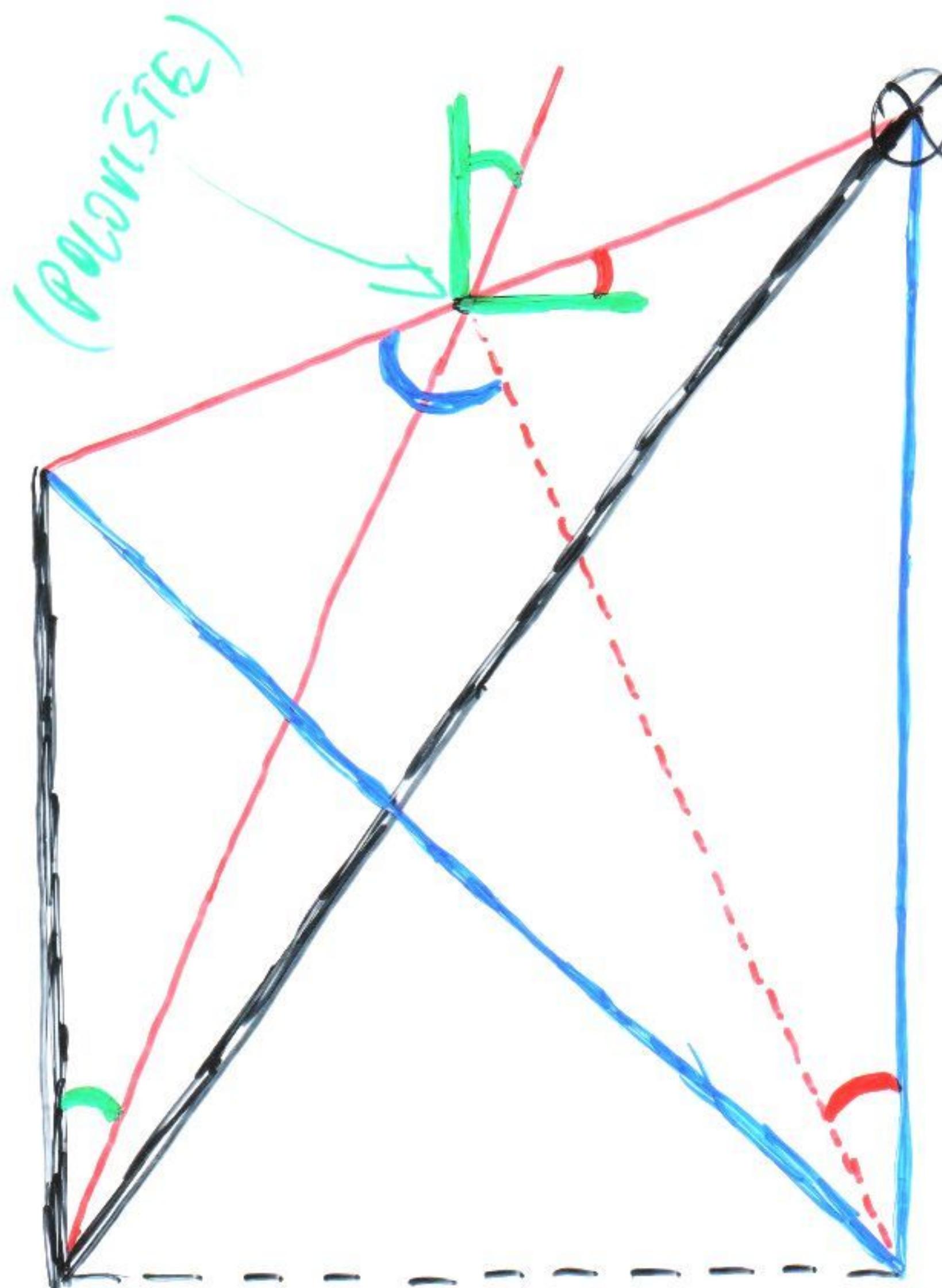


$$x^2 + \Delta^2 = t^2$$



$$t^2 - x^2 = \Delta^2$$

PREKO LORENTZOVE + DO HIPERBOLE?



CRNE DUGINE JEDNAKE \Leftrightarrow

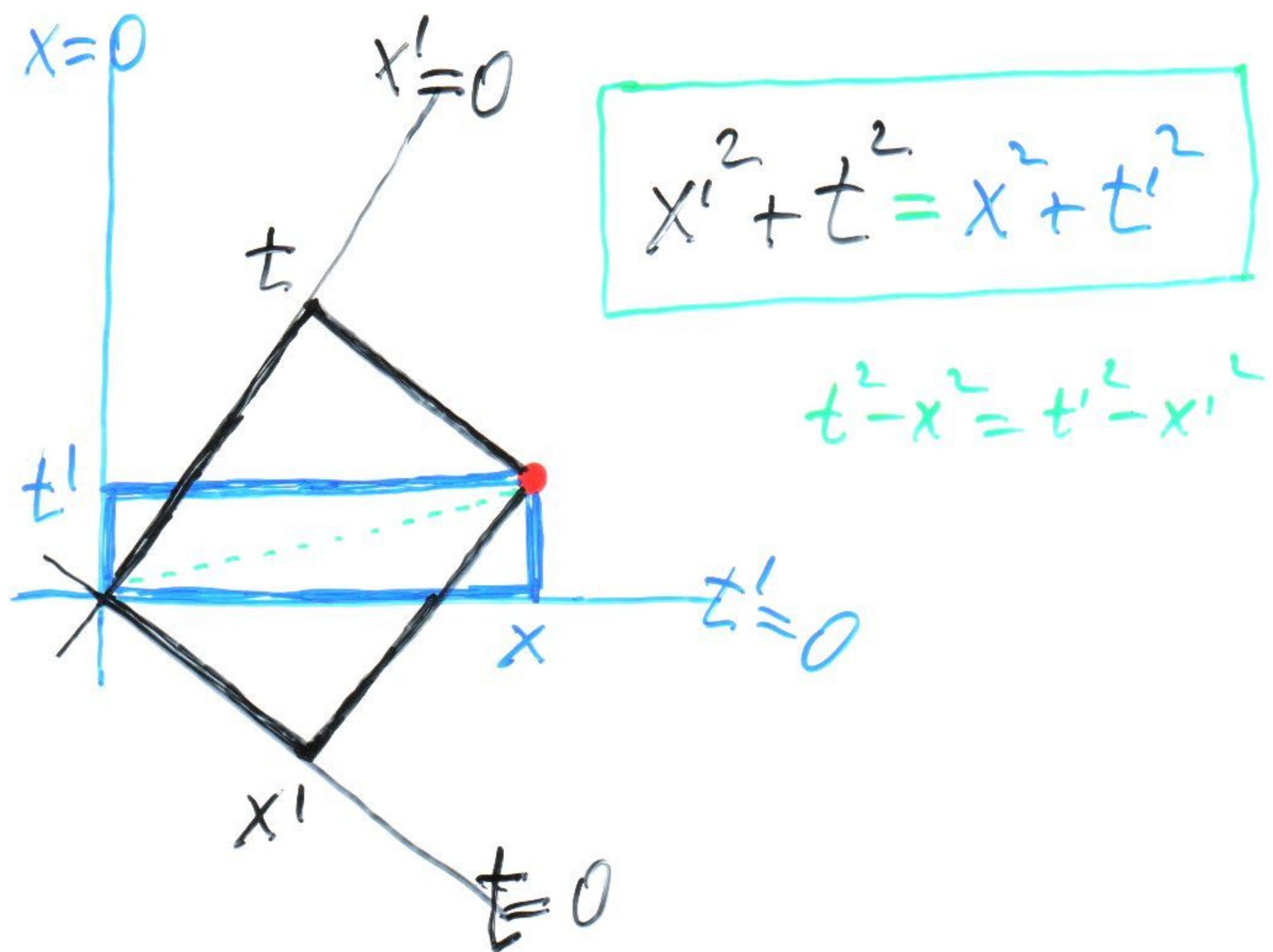
C. KUT = Z. KUT \Leftrightarrow

($\angle \alpha = \angle \beta$) PLAVI KUT = 90° \Leftrightarrow

PLAVE DUGINE JEDNAKE \Leftrightarrow

\otimes LEŽI NA HIPERBOLI

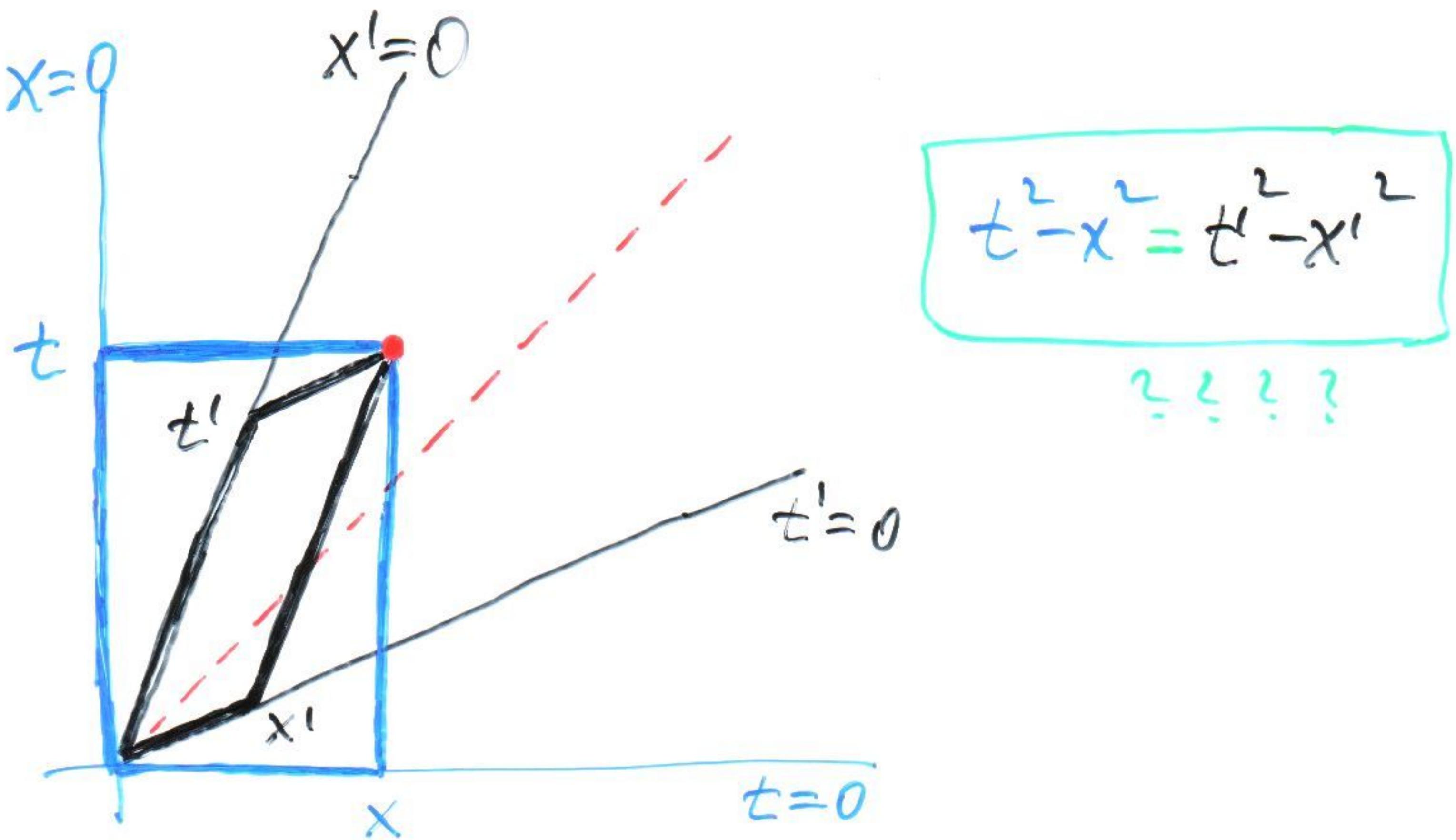
EPSTEIN D. M. RINKOWSKI D.



NA $x'=0$ OCITAVAMO t
NA $t'=0$ OCITAVAMO x
NA $x=0$ OCITAVAMO t'
NA $t=0$ OCITAVAMO x'

} EPSTEIN !

MJERE SU EUKLINSKE !!!



NA $x=0$ OCITAVANO t

NA $t=0$ OCITAVANO x

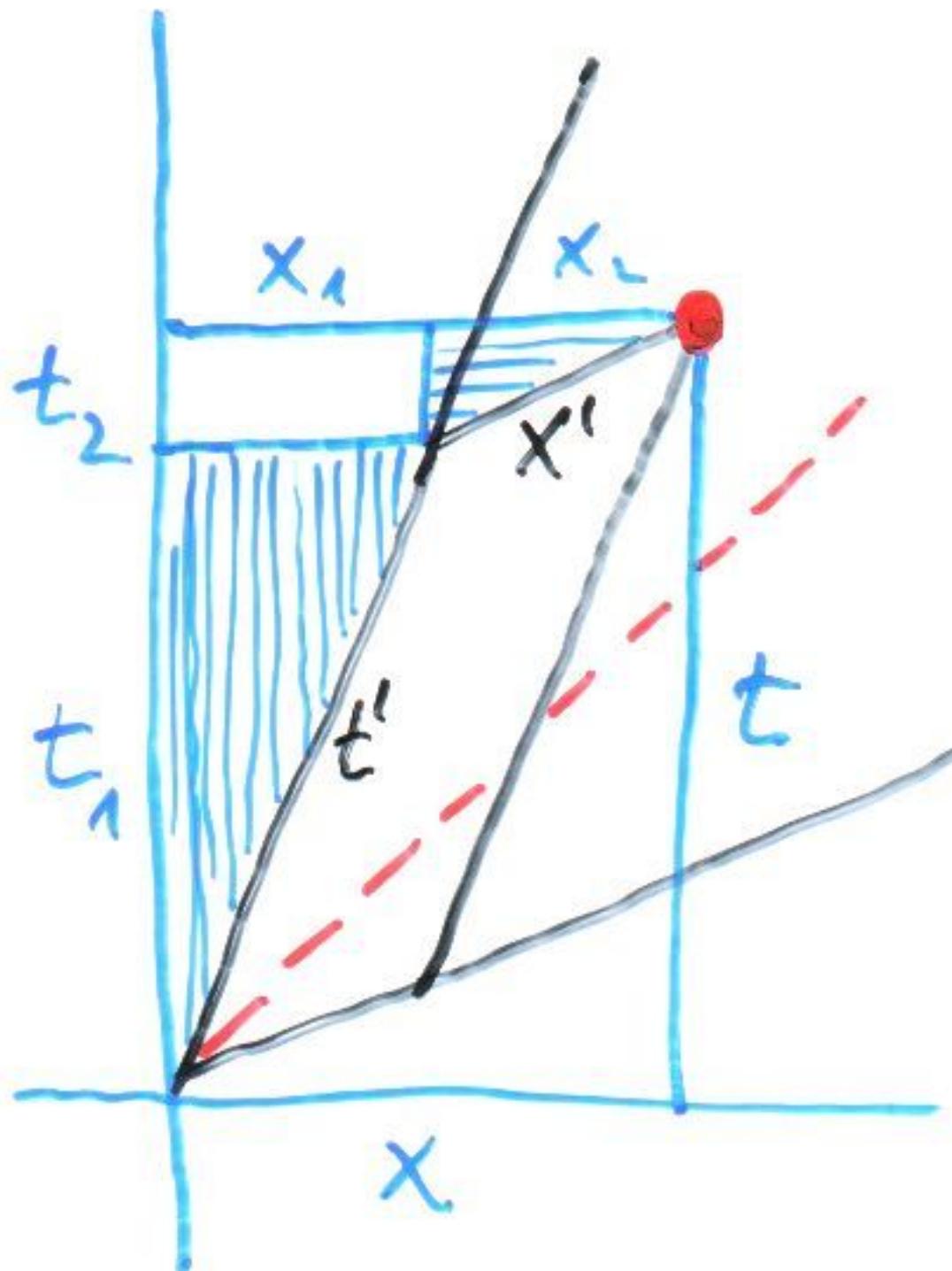
NA $x'=0$ OCITAVANO t'

NA $t'=0$ OCITAVANO x'

MINKOWSKI

?????

MJERE NISU EUKLIDSKE !!!



NE EUKLIDSKI !!! :

$$t'^2 = t_1^2 - x_1^2$$

$$x'^2 = x_2^2 - t_2^2$$

$$(t^2 = t^2 - x^2)$$

DUAL

$$t'^2 - x'^2 = (t_1^2 + t_2^2) - (x_1^2 + x_2^2)$$

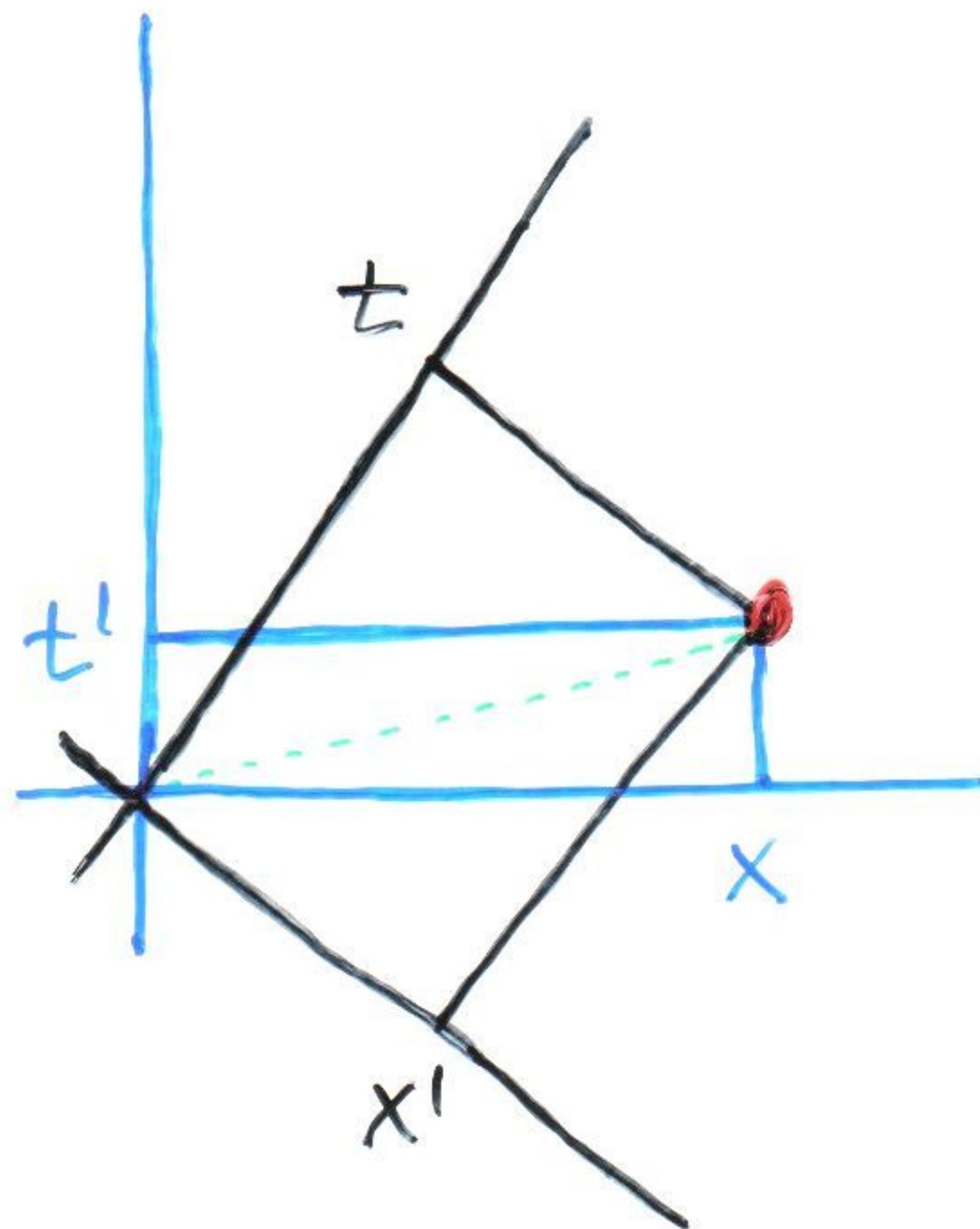
$$\equiv (t_1^2 + t_2^2 + 2t_1 t_2) - (x_1^2 + x_2^2 + 2x_1 x_2)$$

$$= (t_1 + t_2)^2 - (x_1 + x_2)^2 = t^2 - x^2$$

* IZ PLAVIH SUČINIH TROKUTA:

$$\frac{x_1}{t_1} = \frac{t_2}{x_2} \quad \text{d}\cdot \quad x_1 x_2 = t_1 t_2$$

OD EPSTEINA DO MINKOWSKOG :



$$x'^2 + t'^2 = x^2 + t^2$$

(TRIVIJALNO !!)

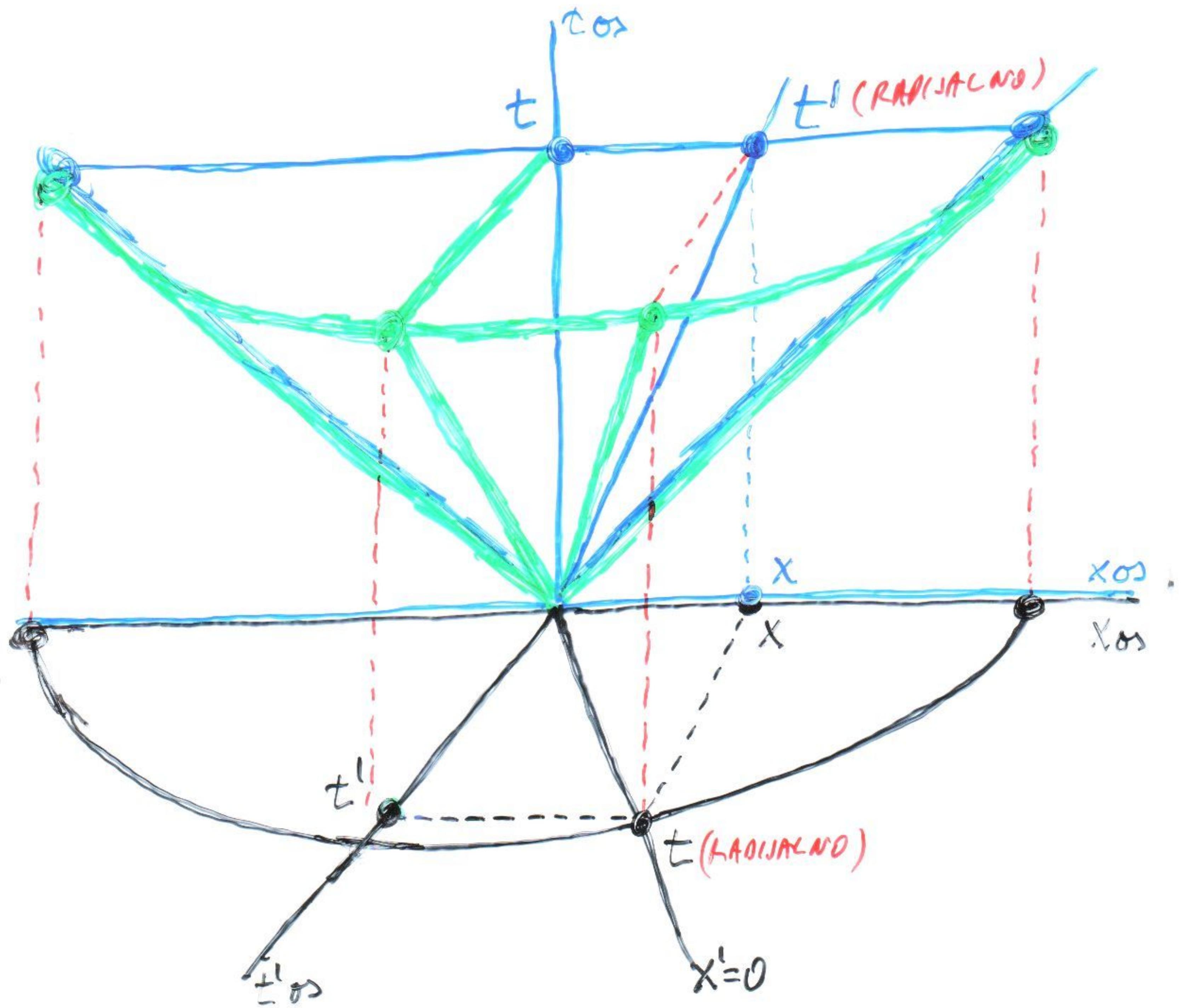
$x'^2 + t'^2 = x^2 + t^2$ JE PLOHA U 4-DIM
PROSTORU (x', t', x, t) .

EPSTEINOV I MINKOWSKI OBIJAGRANI SU
(NA RAKNIJE NAČINE) REDUCIRANI PRI-
KAZI TE 4-DIM PLOHE U 2 DIM-
ENZIJE.

(STALNO SE BAVRIO S GIBANJOM
U 1 DIREKTICI)

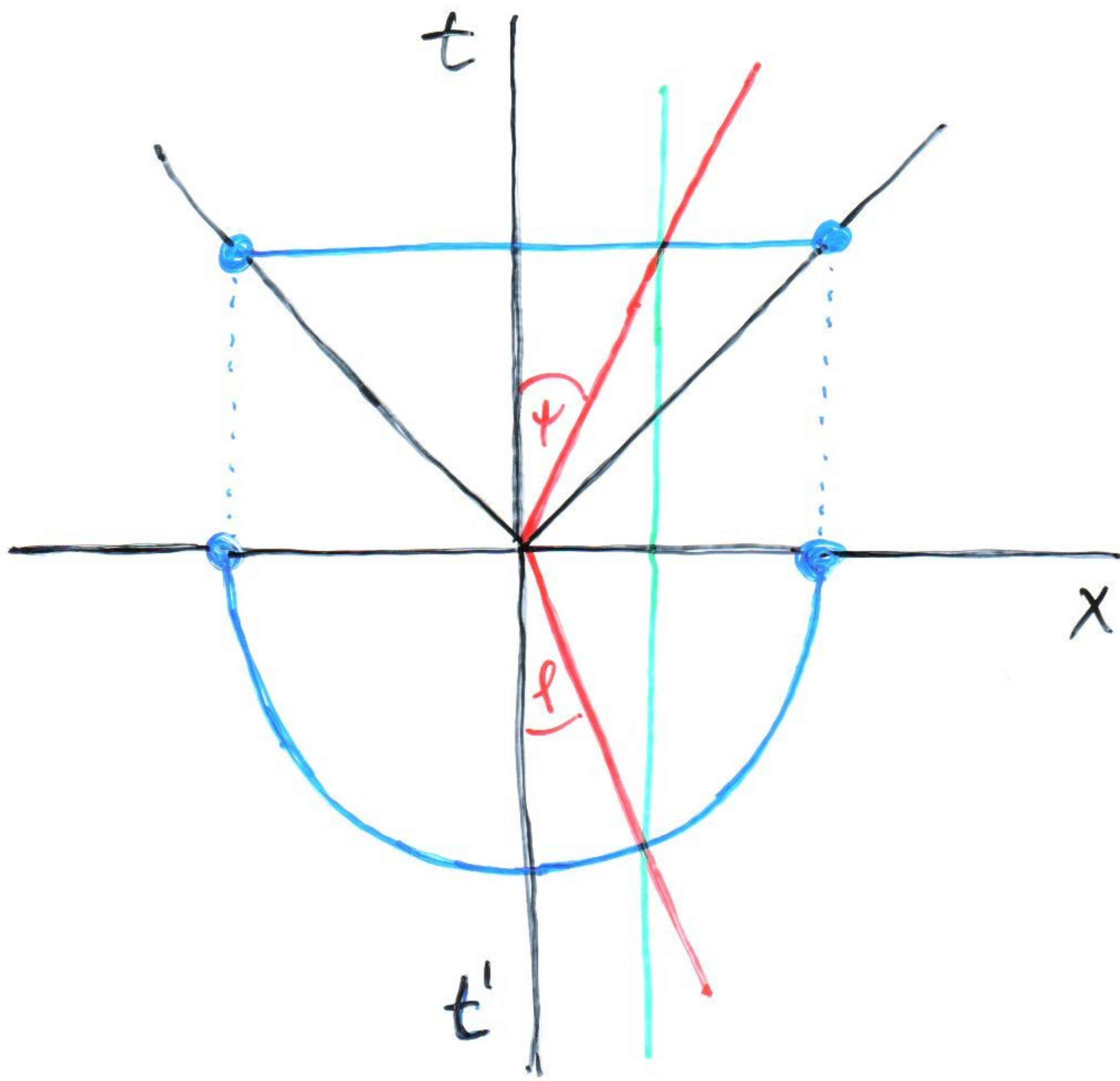
$$x^1 = 0$$

$$t^2 = x^2 + t'^2$$



x, t' - EPSTEINOV DIJAGRAM PRESLIKAVA SE
PREKO KONUSA $t^2 = x^2 + t'^2$ U

x, t - DIJAGRAM RINKOWSKOG



$t = \text{const.}$

$x = \text{const.}$

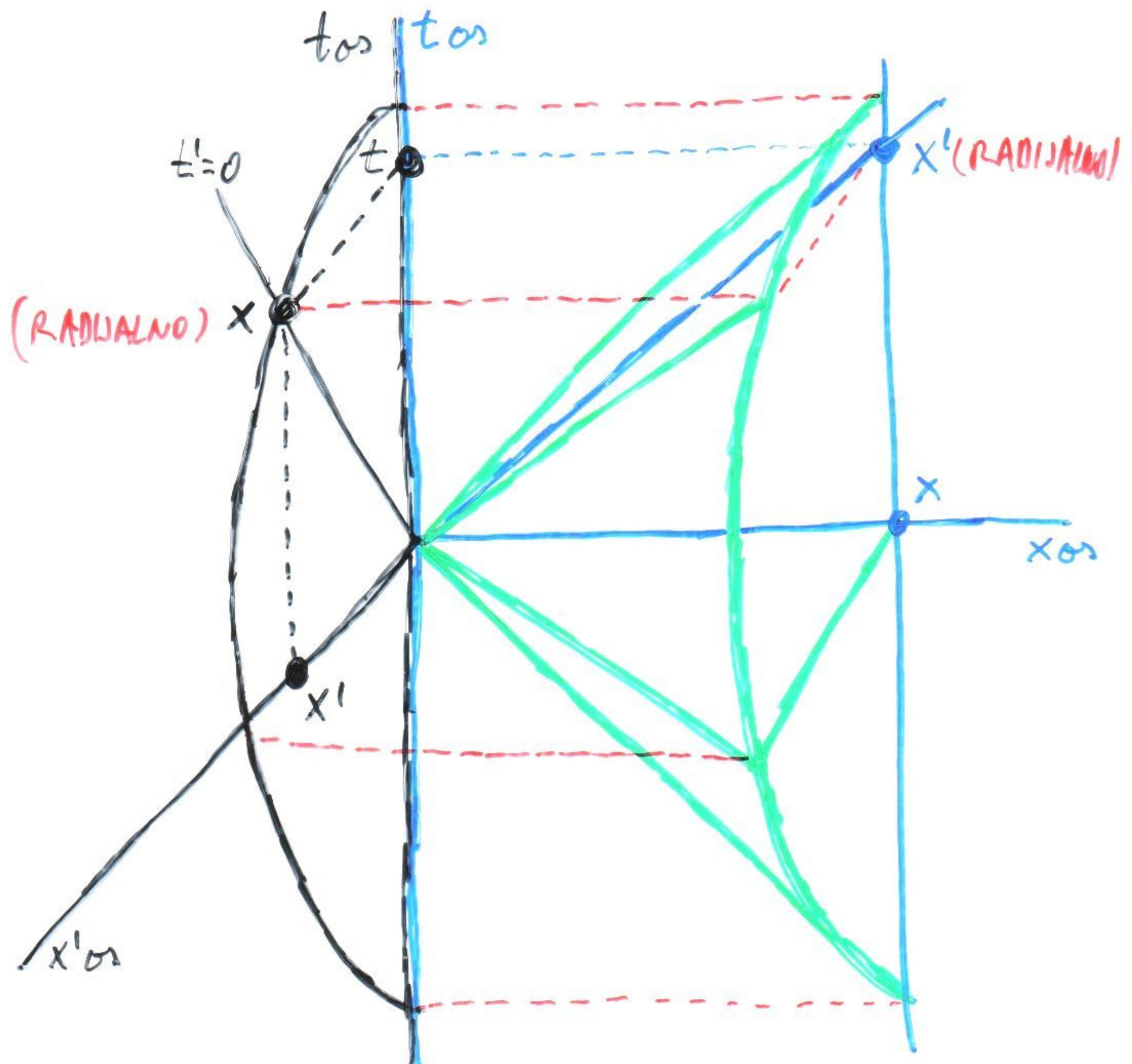
$v = \text{const.}$

$$= \sin \ell$$

$$= t \tan \varphi$$

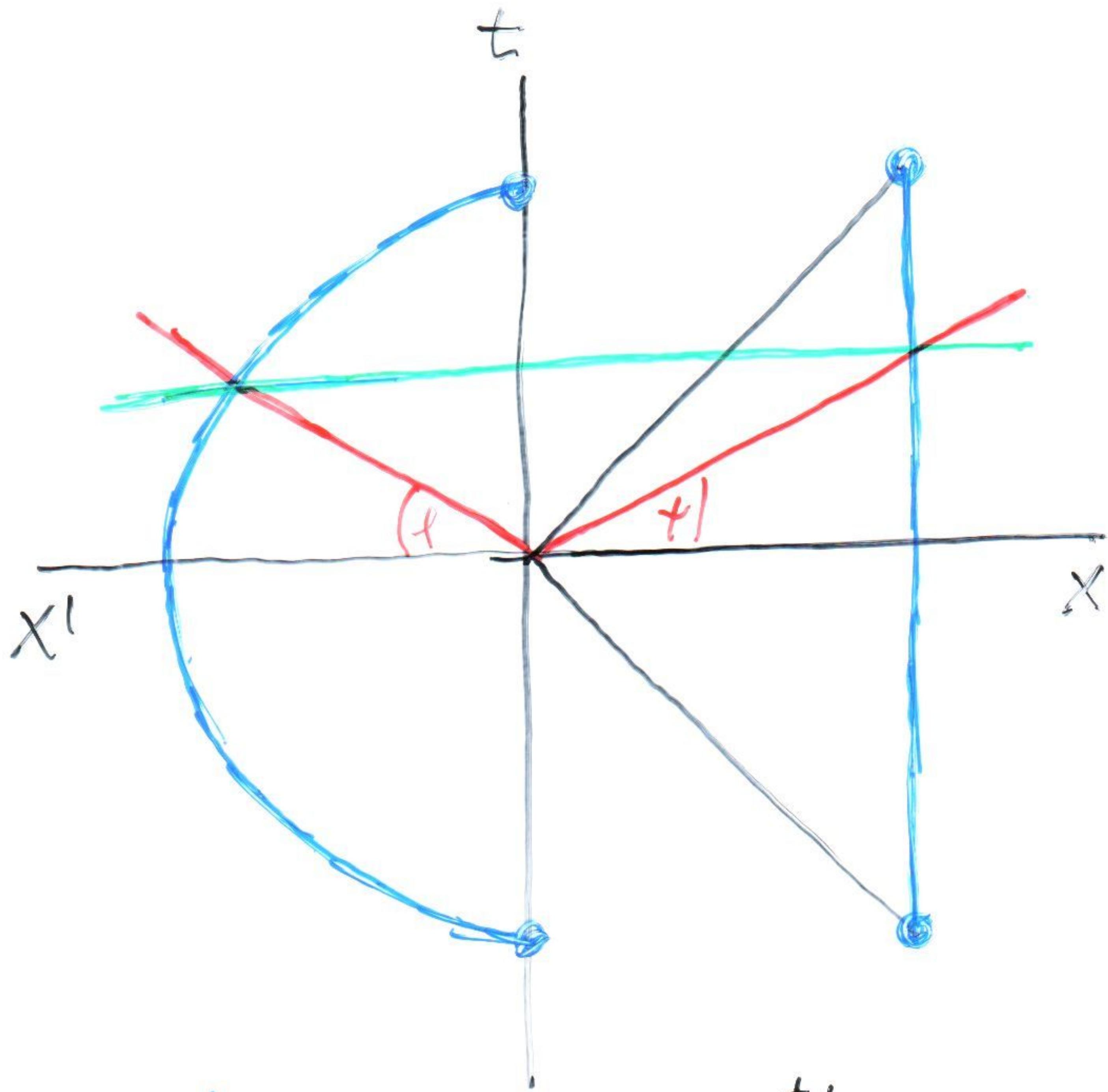
$$t'=0 \rightarrow$$

$$x^2 = x'^2 + t^2$$



x', t - EPSTEIN. DIJAGRAM PRESLIKAVA SE
PREKO KONUSA $x^2 = x'^2 + t^2$ U

x, t - DIJAGRAM RINKOWSKOG



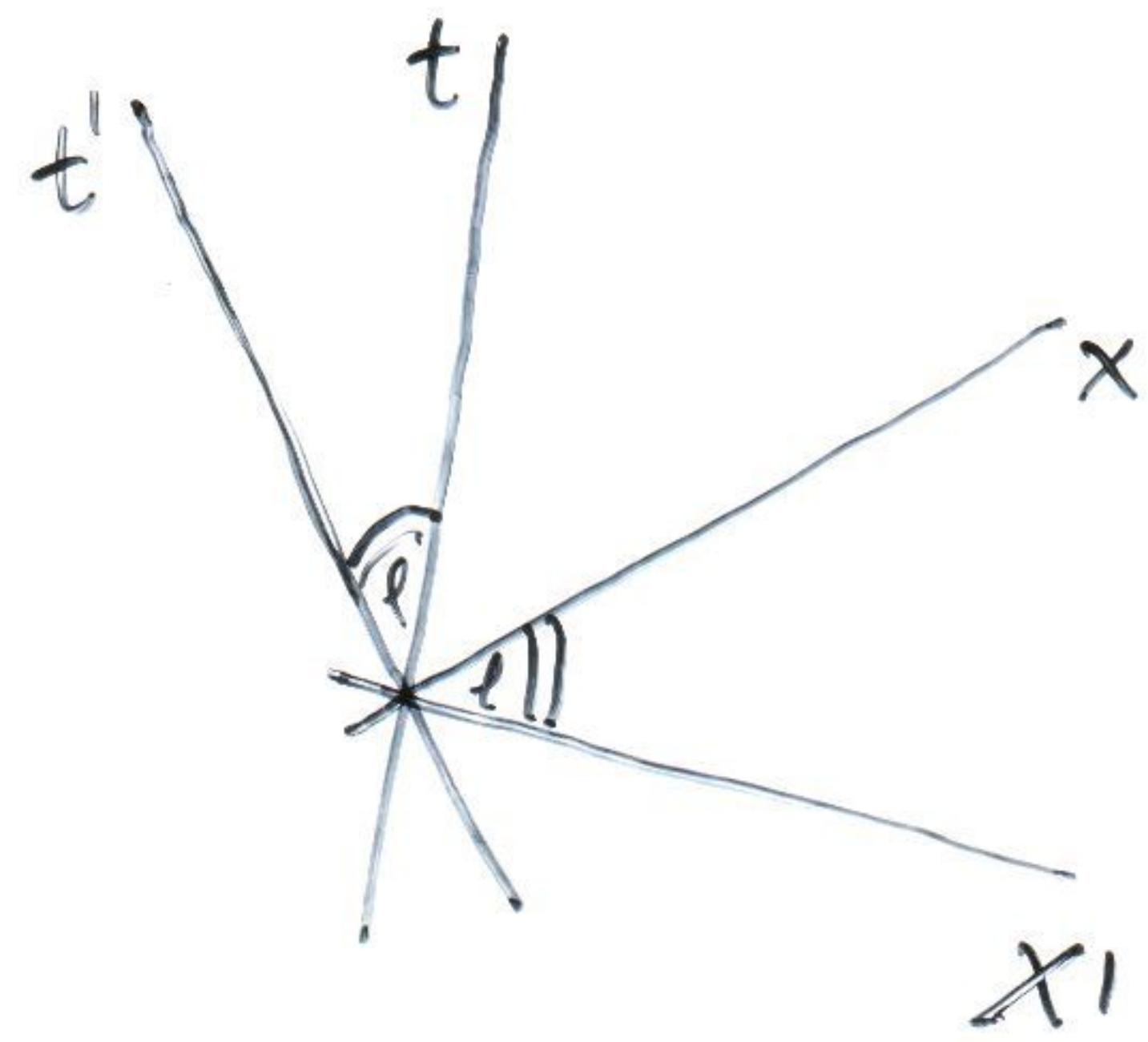
$x = \text{const.}$

$t = \text{const}$

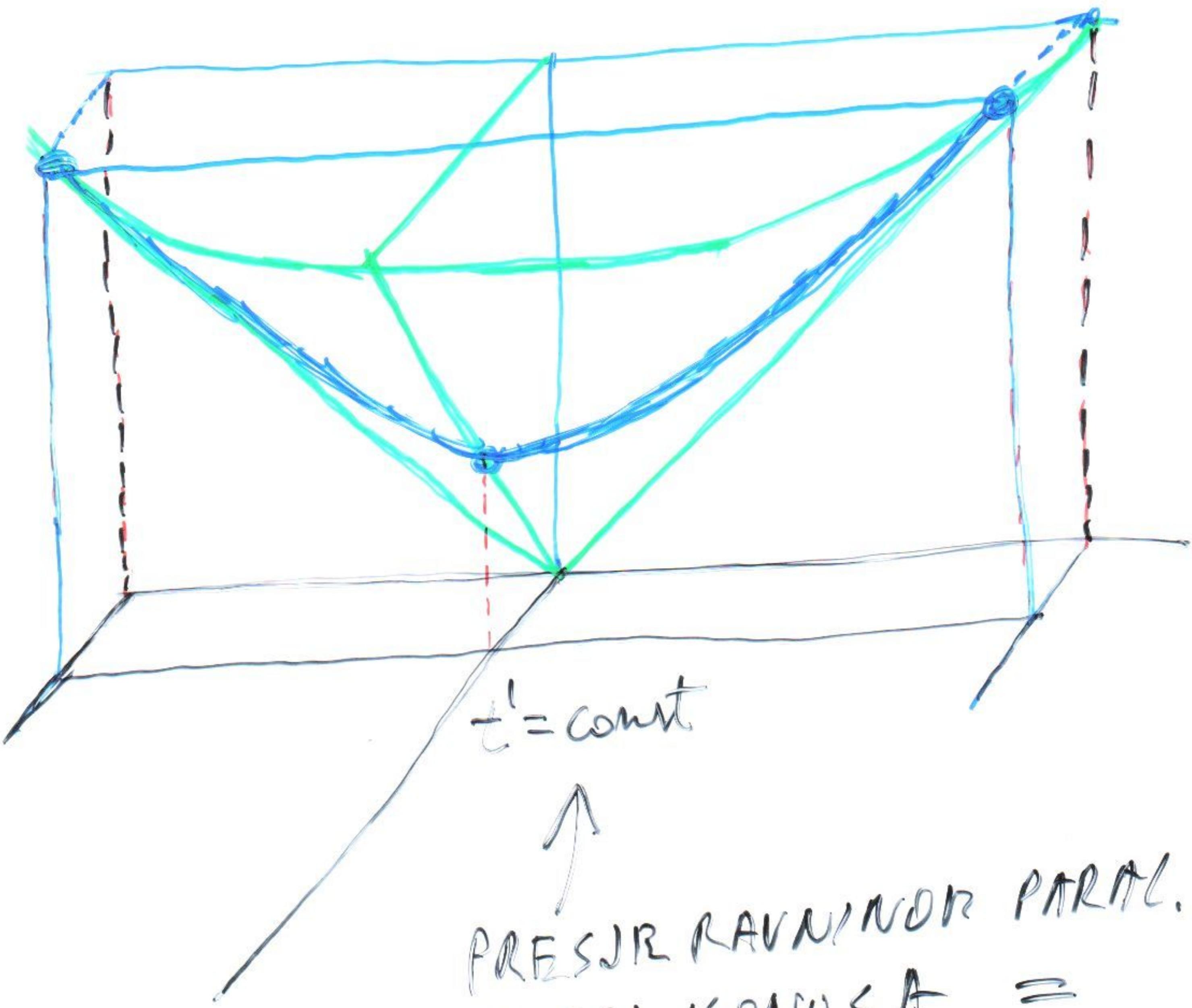
$r = \text{const}$

$= \min f$

$= \operatorname{tg} t$



"RADIJALNA METRIKA"



PREJSJEV RAVNINOR PARAL.
S OSI KONUSA =

HIPERBOLA

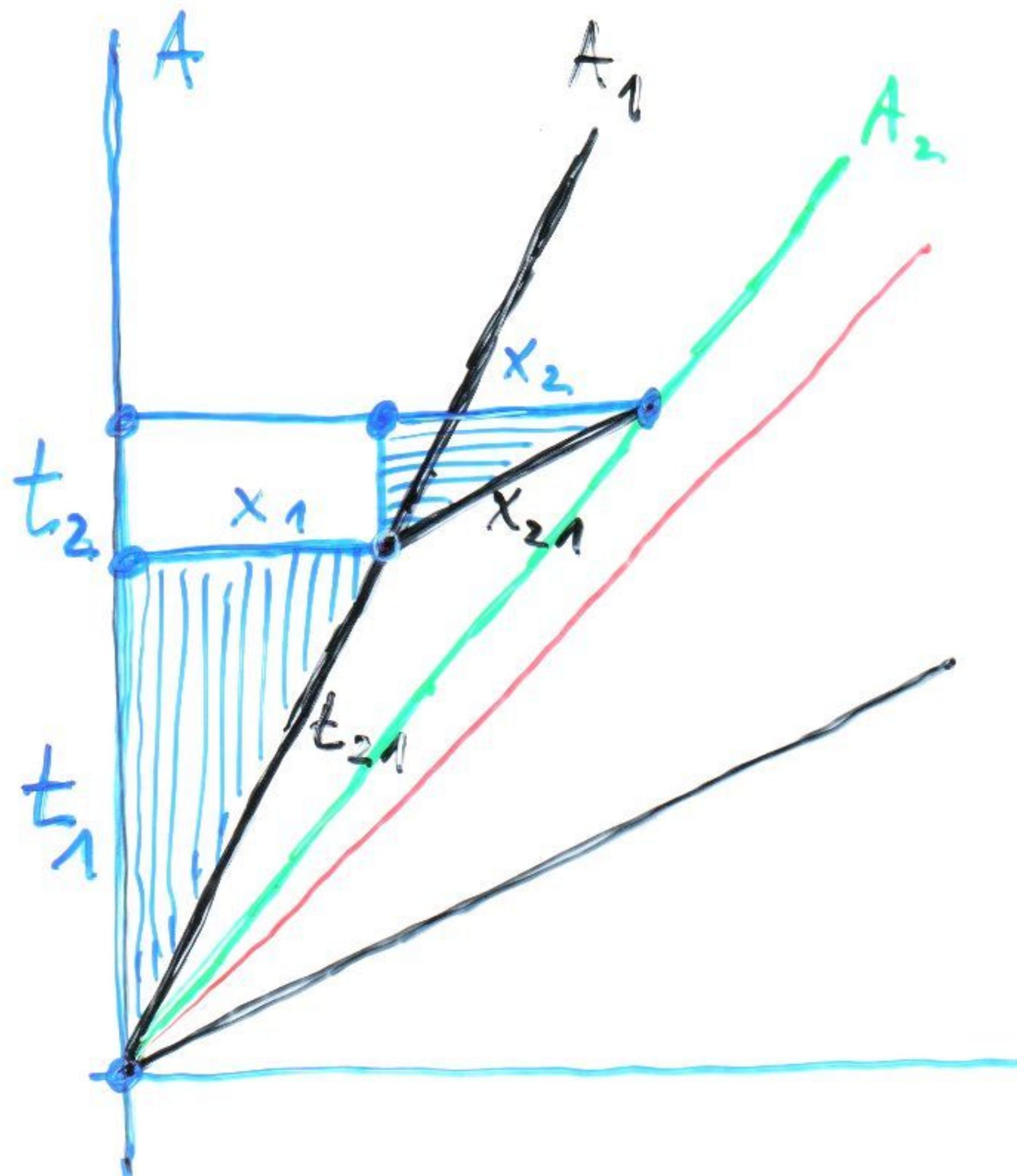
(SA STR. 18, 19)

$$\text{cons} = t^2 - x^2$$

ANALOGNO:

$$x'^2 = \text{cons}^2 = x^2 - t^2$$

"ZBR" BRZINA JE DÍL. RINK (BEZ h)



$$\frac{x_1}{t_1} = v_1$$

$$\frac{x_{21}}{t_{21}} = v_{21}$$

$$\frac{x_1 + x_2}{t_1 + t_2} = v_2$$

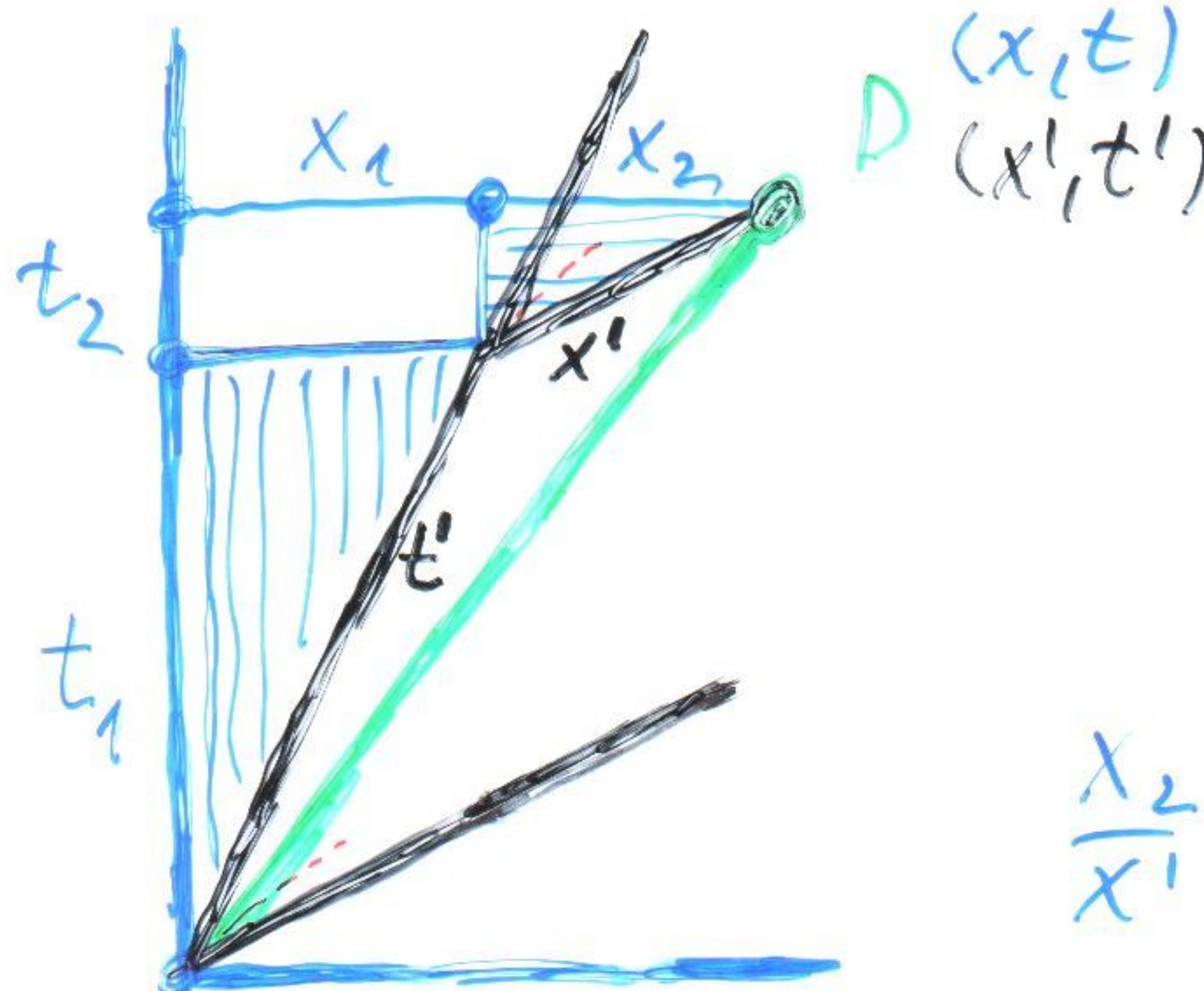
$$\frac{x_2}{t_1} = \frac{t_2}{x_1} = \frac{x_{21}}{t_{21}} = v_{21} \Rightarrow x_2 = v_{21} t_1$$

$$t_2 = v_{21} x_1 = v_{21} v_1 t_1$$

$$\Rightarrow v_2 = \frac{x_1 + x_2}{t_1 + t_2} = \frac{v_1 t_1 + v_{21} t_1}{t_1 + v_{21} v_1 t_1}$$

$$v_2 = \frac{v_1 + v_{21}}{1 + v_1 v_{21}}$$

Lorentzove transf. (Beta < 1)



$$x = x_1 + x_2$$

$$t = t_1 + t_2$$

$$\frac{x_1}{t_1} = v$$

$$\frac{x_2}{x'} = \frac{t_1}{t'} \quad \frac{t_2}{x'} = \frac{x_1}{t'}$$

$$x_1 = vt_1 \quad x_2 = x' \frac{t_1}{t'} \quad t_2 = x' \frac{x_1}{t'} = x' \frac{vt_1}{t'}$$

$$t' = t_1 \sqrt{1-v^2}$$

$$x_1 = \frac{vt'}{\sqrt{1-v^2}} \quad x_2 = \frac{x'}{\sqrt{1-v^2}}$$

$$t_1 = \frac{t'}{\sqrt{1-v^2}} \quad t_2 = \frac{x'v}{\sqrt{1-v^2}}$$

$$x = \frac{x' + vt'}{\sqrt{1-v^2}}$$

$$t = \frac{t' + x'v}{\sqrt{1-v^2}}$$

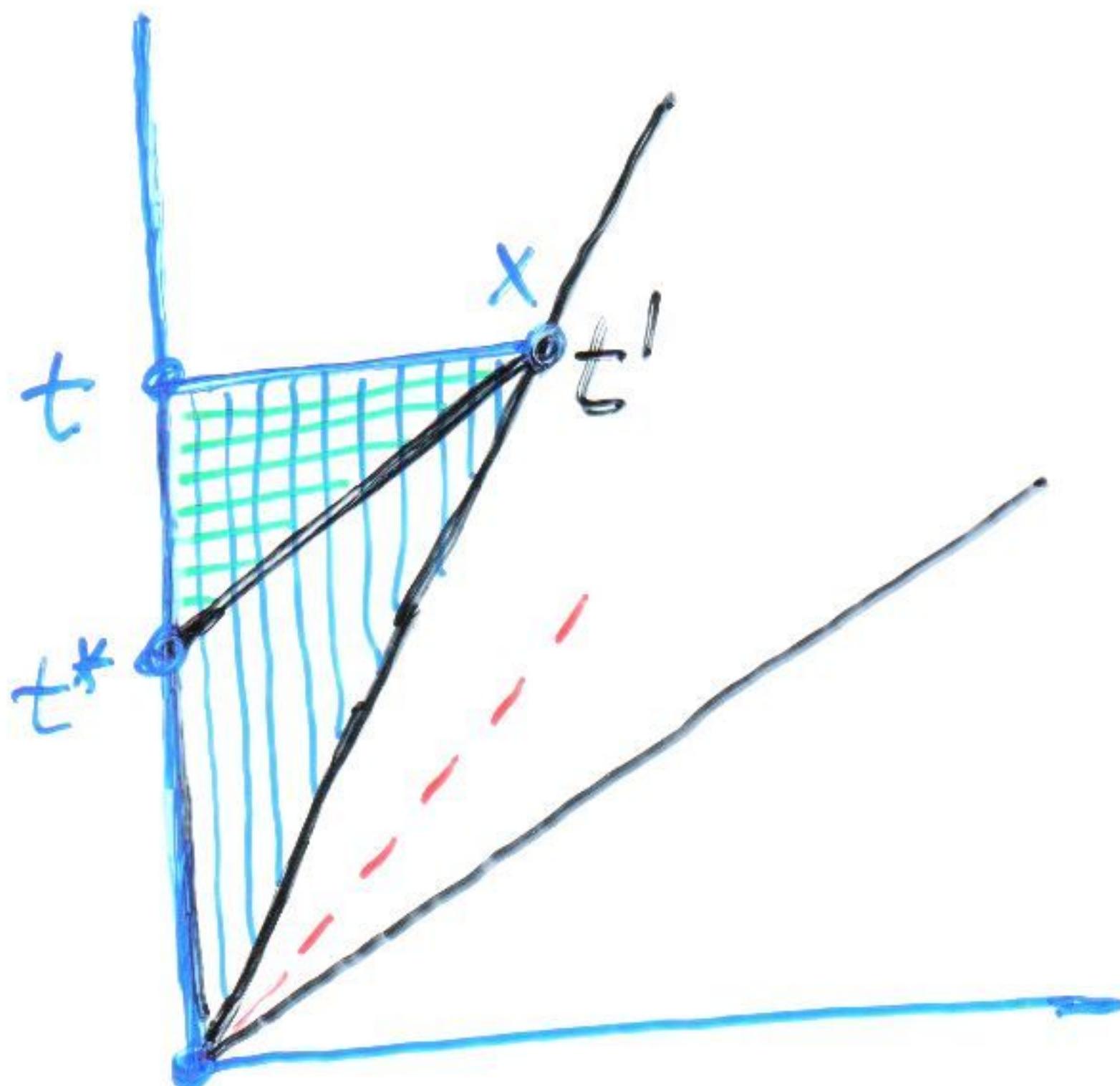
KAKO U R.P.
NAČI FAKTOR
RAZTEZAMA
VREDNINA JE
VIOLOD.

FAKTOR RASTETAJA VREMIENA γ (Iz A.A.)

$$\gamma t^* = t' \quad \& \quad \gamma t = t \Rightarrow t = \gamma^2 t^*$$

(IZA ORTINA ISTI γ)

$(t > t^* \rightarrow \gamma > 1)$
 $\rightarrow t > t'$ USPRK. SL.



$$\frac{x}{t} = v \quad \text{tj. } x = tv$$

I^t SLIČNOST III ≡

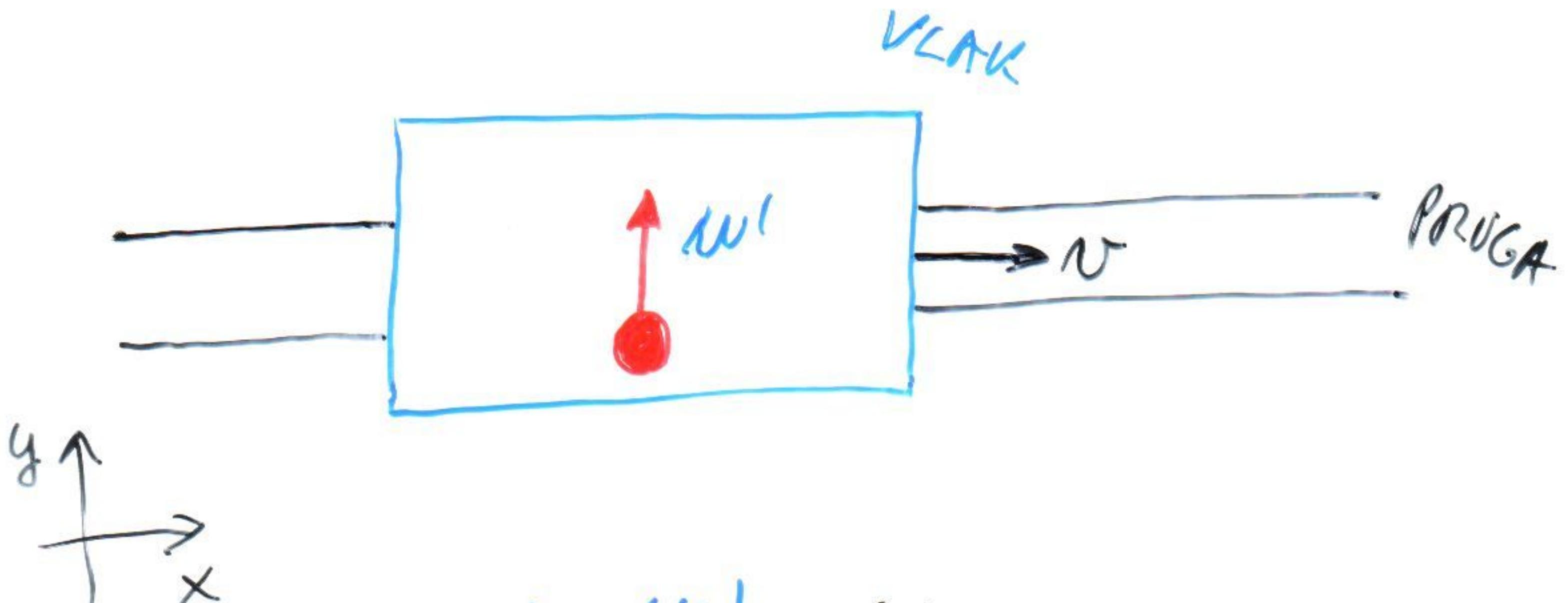
$$\frac{x}{t} = \frac{t - t^*}{x}$$

$$\Rightarrow v = \frac{t - t^*}{tv} \Rightarrow t = \frac{t^*}{1 - \gamma^2}$$

$$\Rightarrow \gamma = \frac{1}{\sqrt{1 - v^2}} \quad \text{DAKLE } \circ$$

$$t' = t \sqrt{1 - v^2}$$

TRANSVERZALNA BRZINA



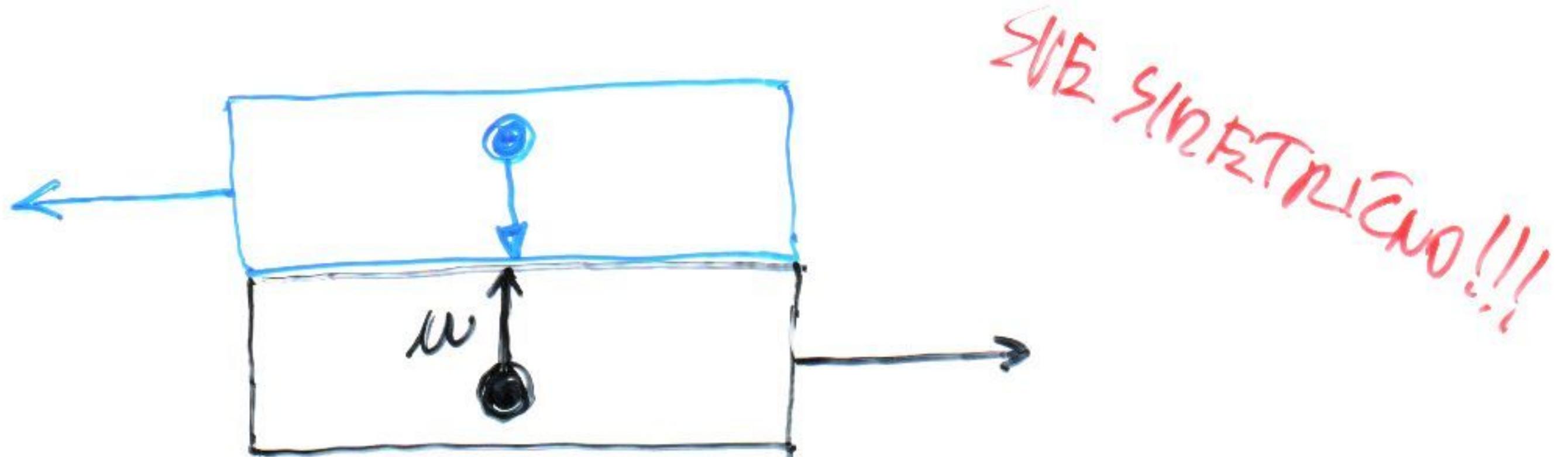
$$w' = \frac{\Delta y'}{\Delta t'} = \frac{\Delta y}{\Delta t \sqrt{1-v^2}} = \frac{w}{\sqrt{1-v^2}}$$

$$w = w' \sqrt{1-v^2}$$

CRNI RJEZI NAMO TRANSVERZALNU BRZINU !!

ZA CRNOG SU TRANSVERZALNA KRETANJA USPORENA S FAKTOROM $\sqrt{1-v^2}$!!!

RELATIVISTIČKA MASA



CRNI MOJ UDAR (IMPETUS) MASA JE
ZA FAKTOR $1/\sqrt{1-v^2}$ JAĆI OD UP-
ARA PLAVOG

(ALI NIJE !!! JER JE SVE SIMETRIČNO I ISTI)
ARGUMENT INA I PLAVI !!!

NAKON SRAŽA VIDIM DA NIJE !!
PLAVI OČITO INA MASU UVREĆANO
ZA FAKTOR $1/\sqrt{1-v^2}$!!

$$m_v = m_0 / \sqrt{1-v^2}$$

$$m = m_0 / \sqrt{1-v^2}$$

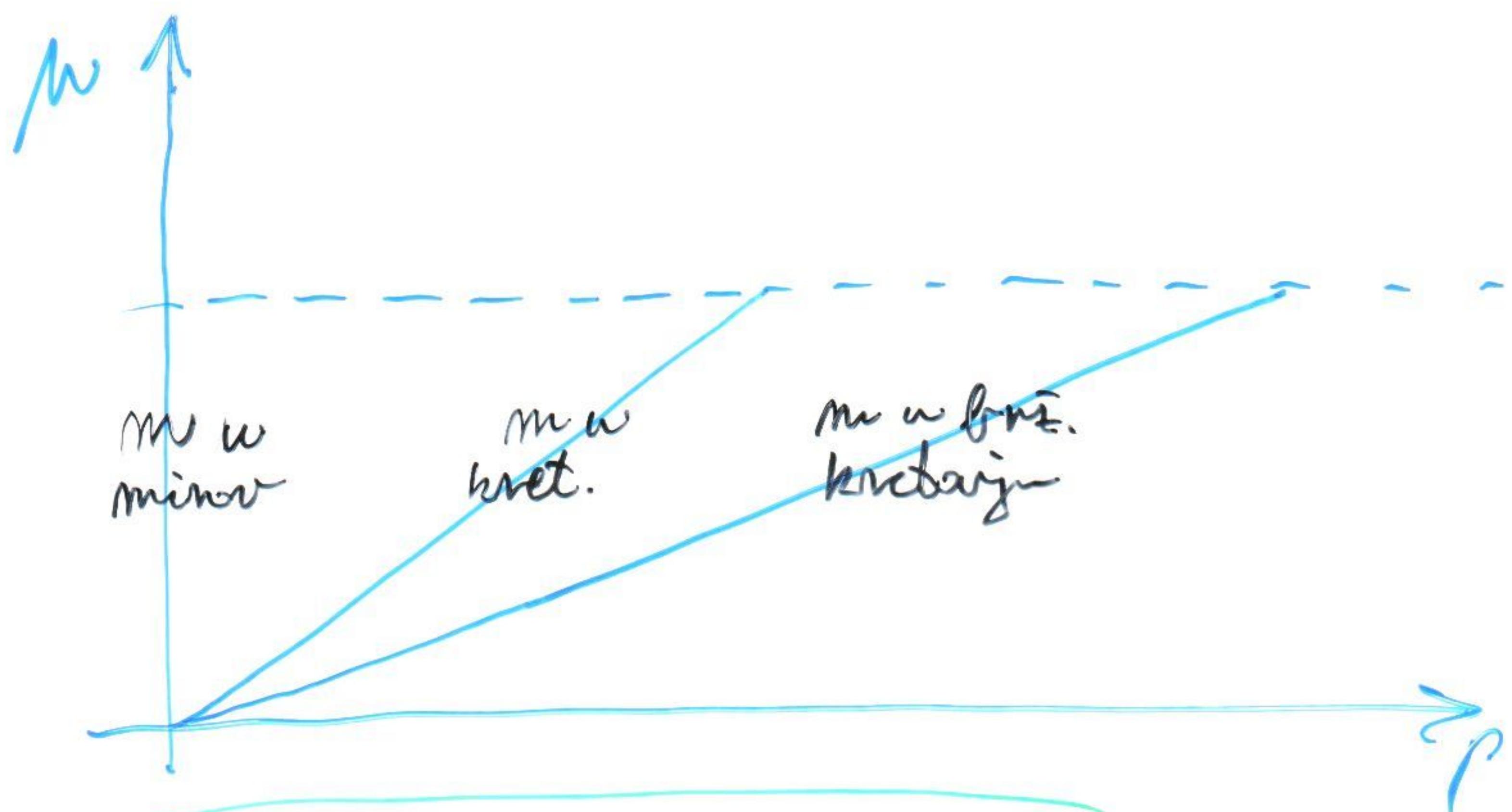
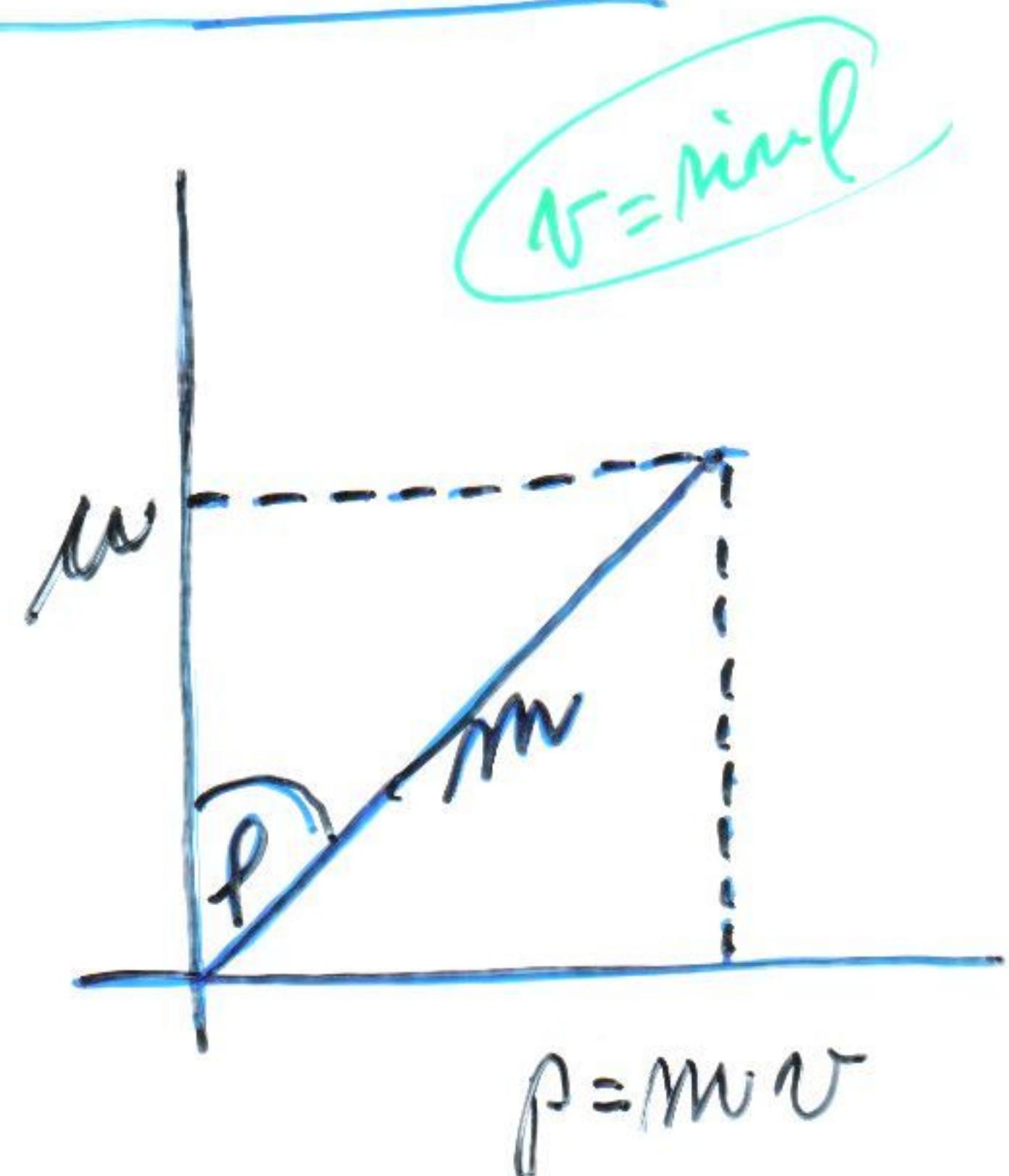
EPSTEINOV DIAGRAM ZA RASE

$$\mu = m \sqrt{1 - r^2}$$

$$\mu = m \cos \varphi$$

$$P = m \sin \varphi$$

$$P = m v$$

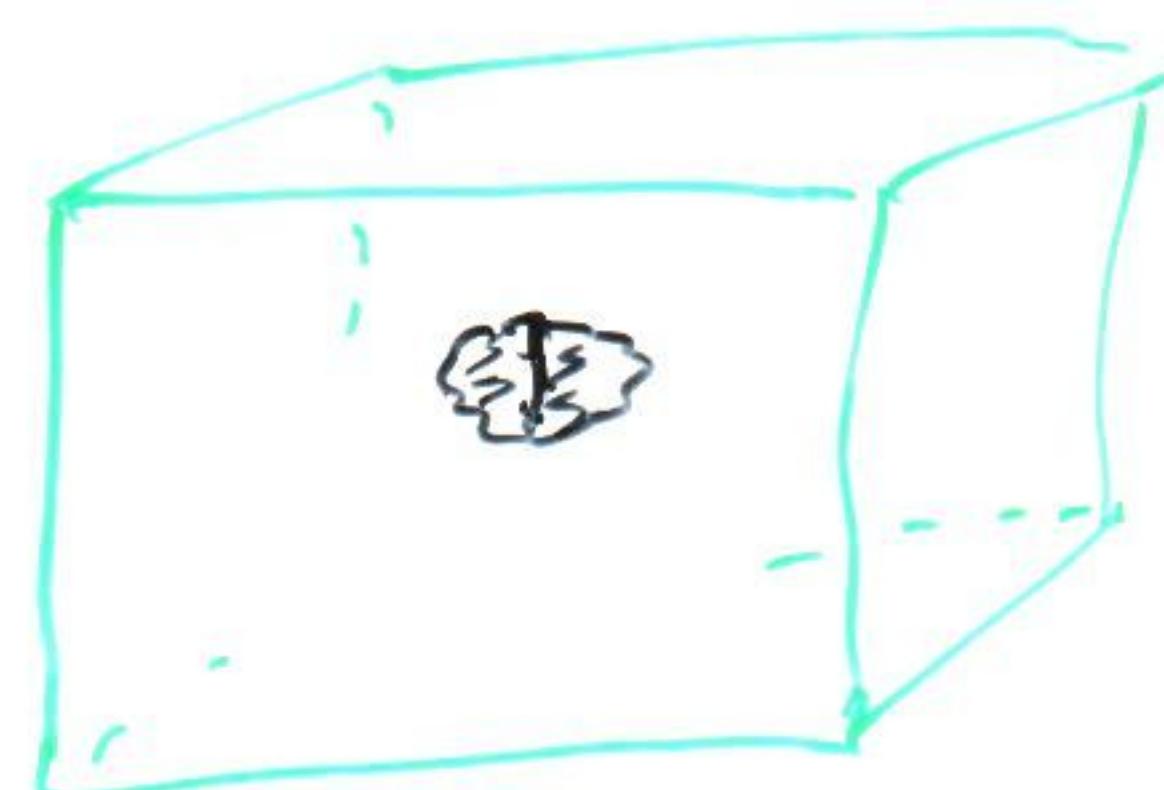
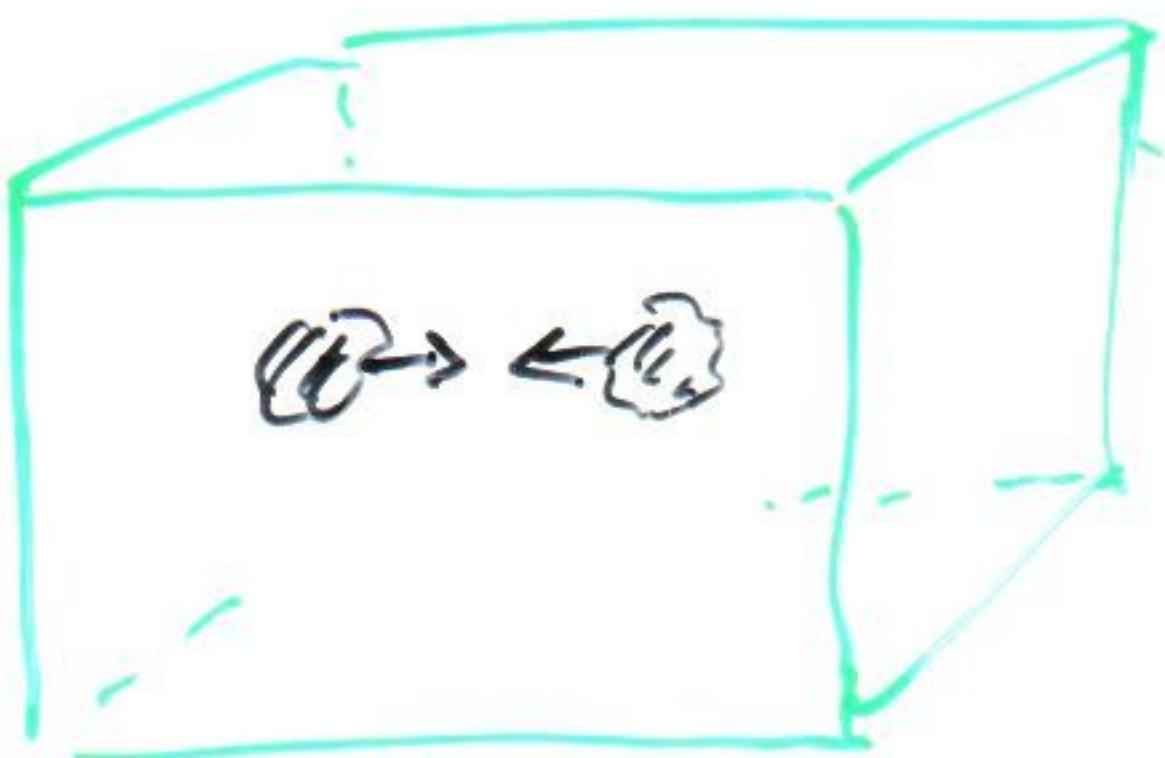


$$N = \min \varphi \rightarrow 1 \Rightarrow m \rightarrow \infty$$

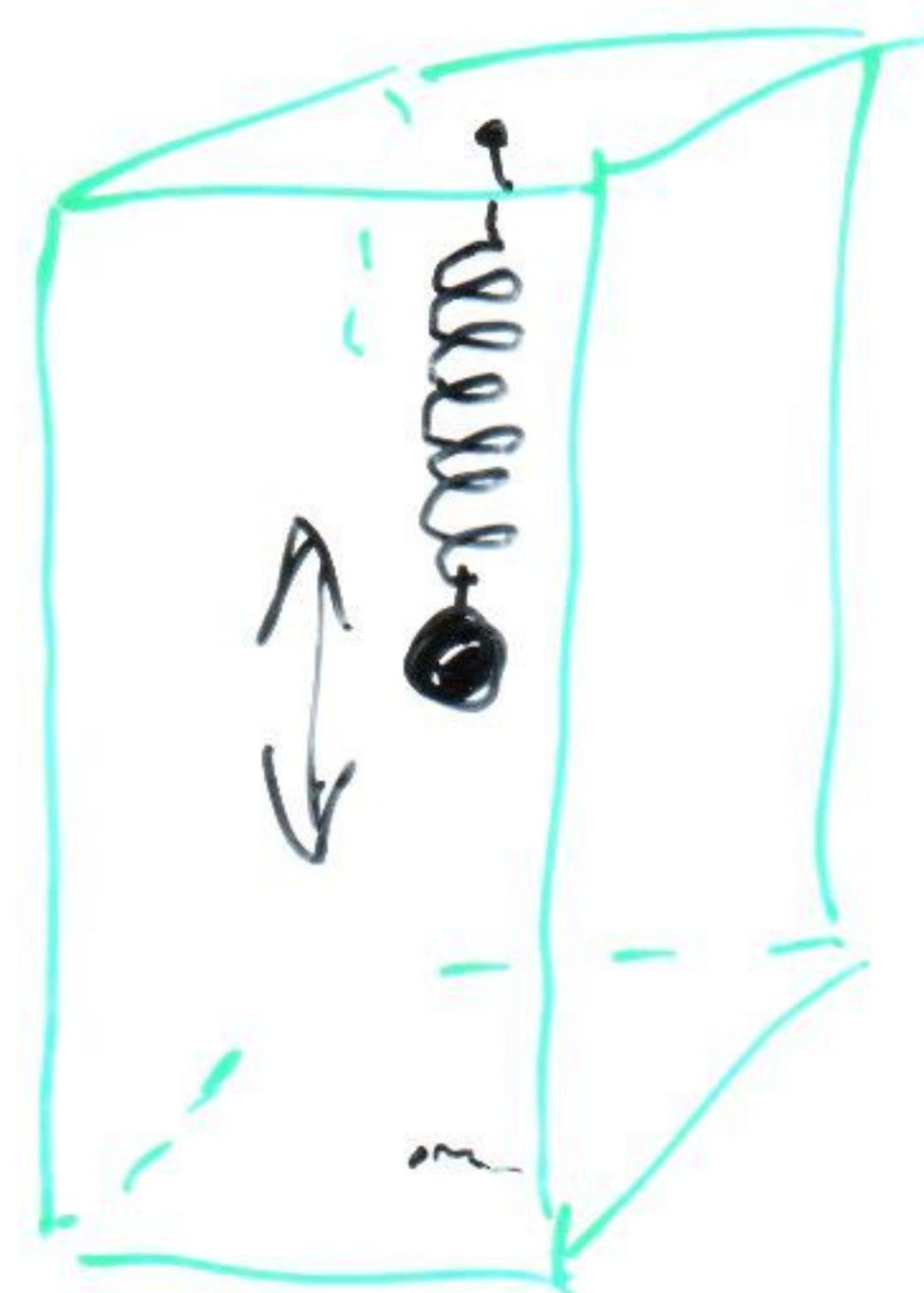
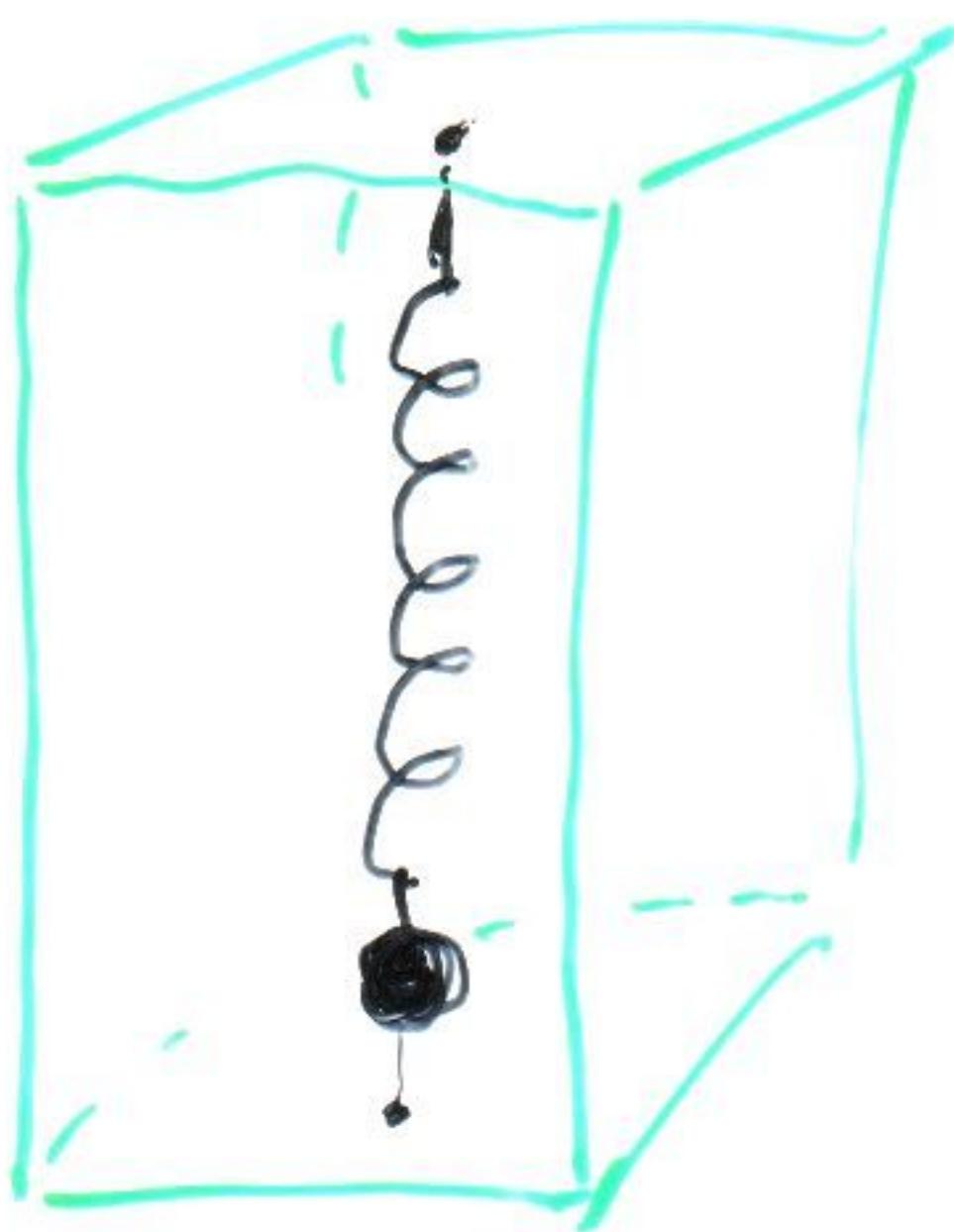
ZATO JE $c=1$ GRANICA!! (???)
gravitacija [34]

ENERGIJA = MASA

KVALITATI VNO:



GDJE JE NESTALA V-MASA?
U TOPLINSKOJ ENERGIJI!



OTKUD JE DOŠLA V-MASA?

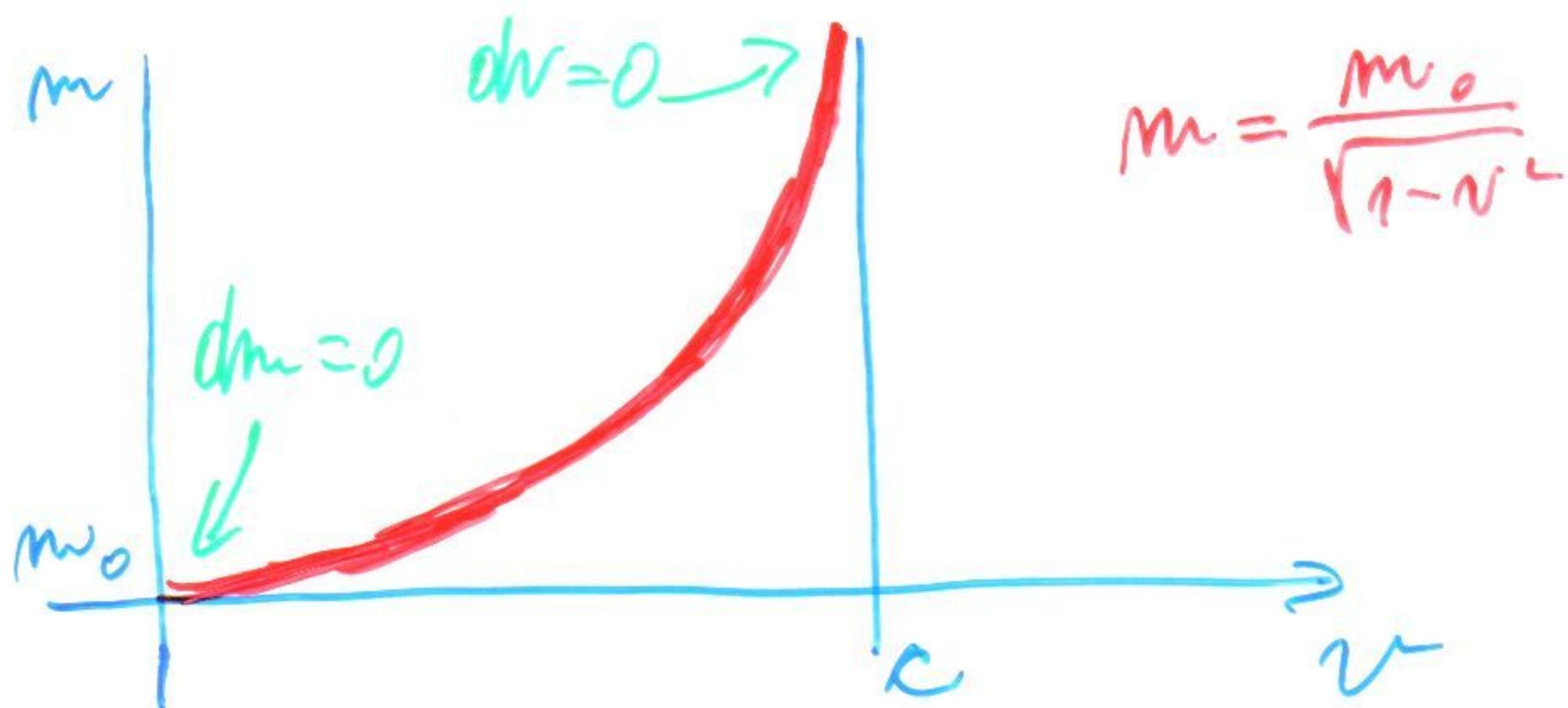
IZ POTEKCIJALNE ENERGIJE!

ENERGIJA = MASSA

KVANTITATIVNO:

$$F dt = d(mv) = m dv + v dm \quad | \cdot v$$

$$F dt \frac{ds}{dt} = dE = mv dv + v^2 dm$$



$$\left. \begin{array}{l} m = m_0 \\ dm = 0 \end{array} \right\} \boxed{\Delta E = \int_0^{\Delta v} dE = \int_0^{\Delta v} m_0 v dv = \frac{1}{2} m_0 \Delta v^2}$$

$$\left. \begin{array}{l} v = c \\ dv = 0 \end{array} \right\} \boxed{\Delta E = \int_0^{\Delta m} dE = \int_0^{\Delta m} c^2 dm = c^2 \Delta m}$$

VEŽA ENERGIJE I MASE U SVAKOJ JE SITUACIJI I STA!

DAKLE, UVREJK JE $\Delta E = \Delta m c^2$!

EINSTEIN: ČAK I ZA $0 \leq \Delta m \leq m_0$ tj. $E_0 = m_0 c^2$

$\Rightarrow E = mc^2$ (TO NE PROVL. (Z STR) $\sqrt{36}$)

MOZE I TEZEEG

$$dE = F dx = F dt \frac{dx}{dt} = d(mv) v$$

$$dE = \frac{d(mv)}{dv} v dv \quad \left(m = \text{const. } dE = mv dv \right)$$

$$\Rightarrow E = \epsilon_0 m v^2$$

$$\frac{d(mv)}{dv} = d\left(\frac{m_0 v}{\sqrt{1-v^2/c^2}}\right)/dv = \dots = m_0 \left(1-\frac{v^2}{c^2}\right)^{-\frac{3}{2}}$$

$$dE = m_0 \left(1-\frac{v^2}{c^2}\right)^{-\frac{3}{2}} v dv \quad / \int_0^v$$

$$\Delta E = m_0 \int_0^v \left(1-\frac{v^2}{c^2}\right)^{-\frac{3}{2}} v dv = \left[\frac{v}{c} = 1 - \frac{v^2}{c^2} \right]$$

$$dv = -\frac{2}{c^2} v dv$$

$$= -\frac{m_0 c^2}{2} \int_0^v u^{-\frac{3}{2}} du = m_0 c^2 \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} \Big|_0^v$$

$$= \frac{m_0 c^2}{\sqrt{1-v^2/c^2}} - m_0 c^2 = (m - m_0) c^2 = \Delta m c^2$$

$$\boxed{\Delta E = \Delta m c^2}$$

