Special Relativity Introduction for General Relativity 2
Monday 01.30.2017

Review: Relawavity ρ functions Two famous ones Extremes and plot vs. ρ
Doppler jeopardy Geometric mean and Relativistic hyperbolas
Animation of $e^{\rho}=2$ spacetime and per-spacetime plots

Rapidity ρ related to *stellar aberration angle* σ and L. C. Epstein's approach to relativity
- Longitudinal hyperbolic ρ-geometry connects to transverse circular σ-geometry
  - "Occams Sword" and summary of 16 parameter functions of ρ and σ
    - Applications to optical waveguide, spherical waves, and accelerator radiation

Derivation of relativistic quantum mechanics
- What's the matter with mass? Shining some light on the Elephant in the room
- Relativistic action and Lagrangian-Hamiltonian relations
  - Poincare' and Hamilton-Jacobi equations

Relativistic optical transitions and Compton recoil formulae
- Feynman diagram geometry
  - Compton recoil related to rocket velocity formula
  - Comparing 2^{nd}-quantization "photon" number N and 1^{st}-quantization wavenumber κ

Relawavity in accelerated frames
- Laser up-tuning by Alice and down-tuning by Carla makes g-acceleration grid
  - Analysis of constant-g grid compared to zero-g Minkowsi grid
  - Animation of mechanics and metrology of constant-g grid

Lecture 31
Thur. 12.08.2016

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Learning about sin *and* cos *and...*

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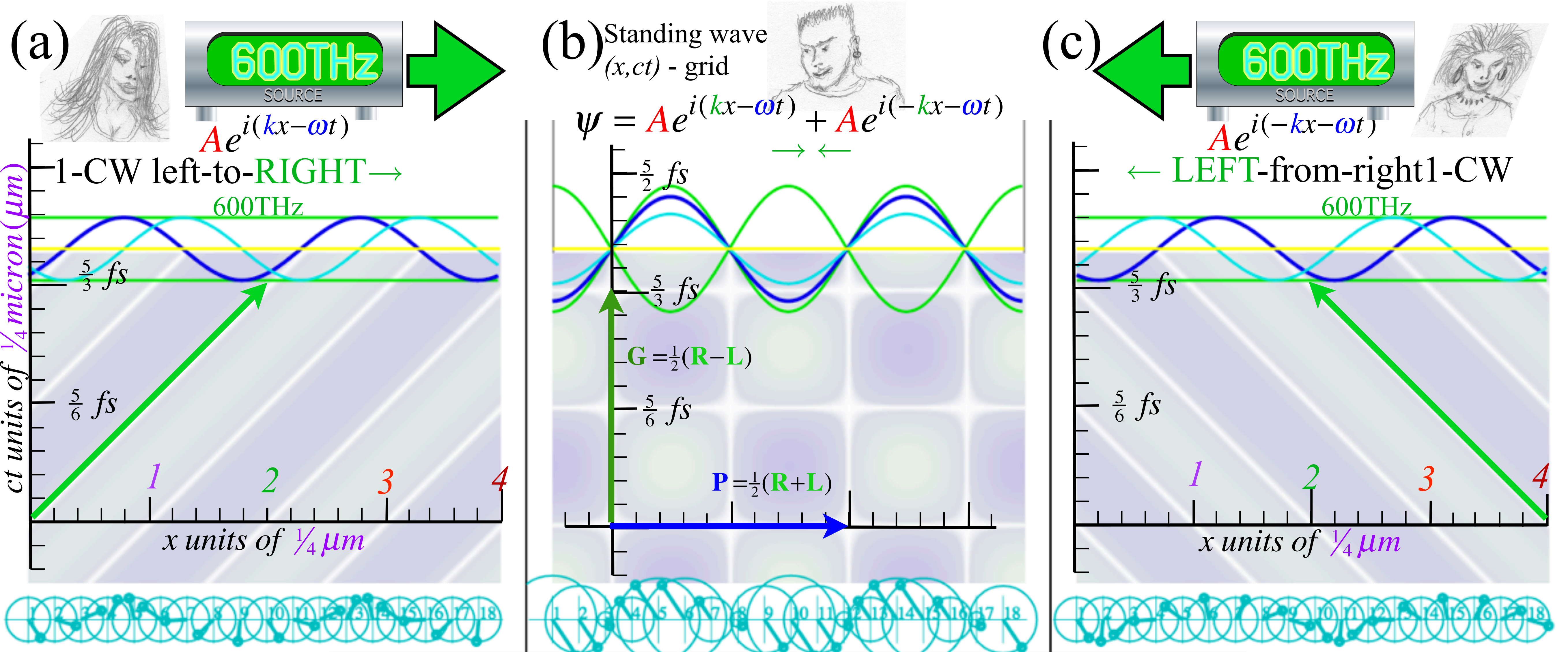
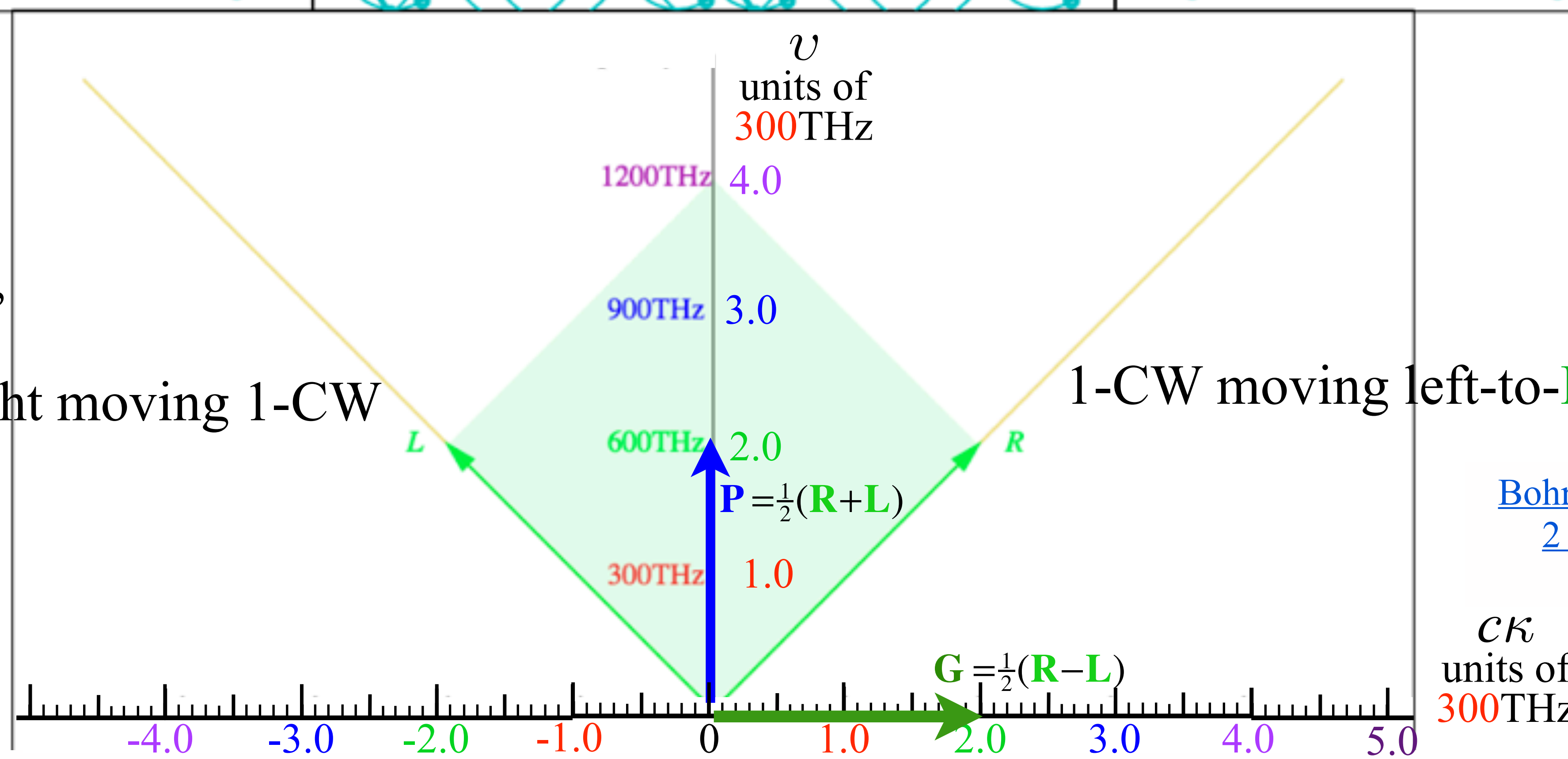
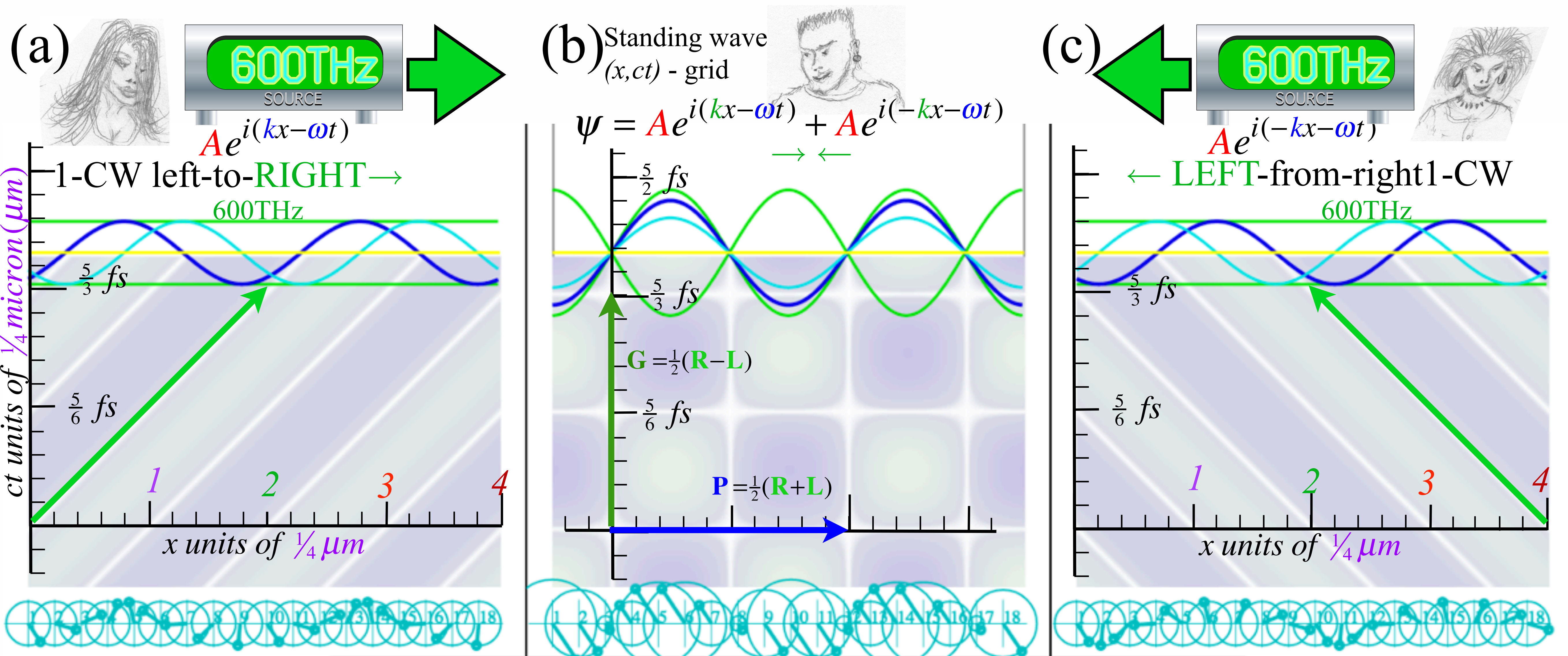


Introducing optical space-time grids and per-space-time "baseball-diamonds"



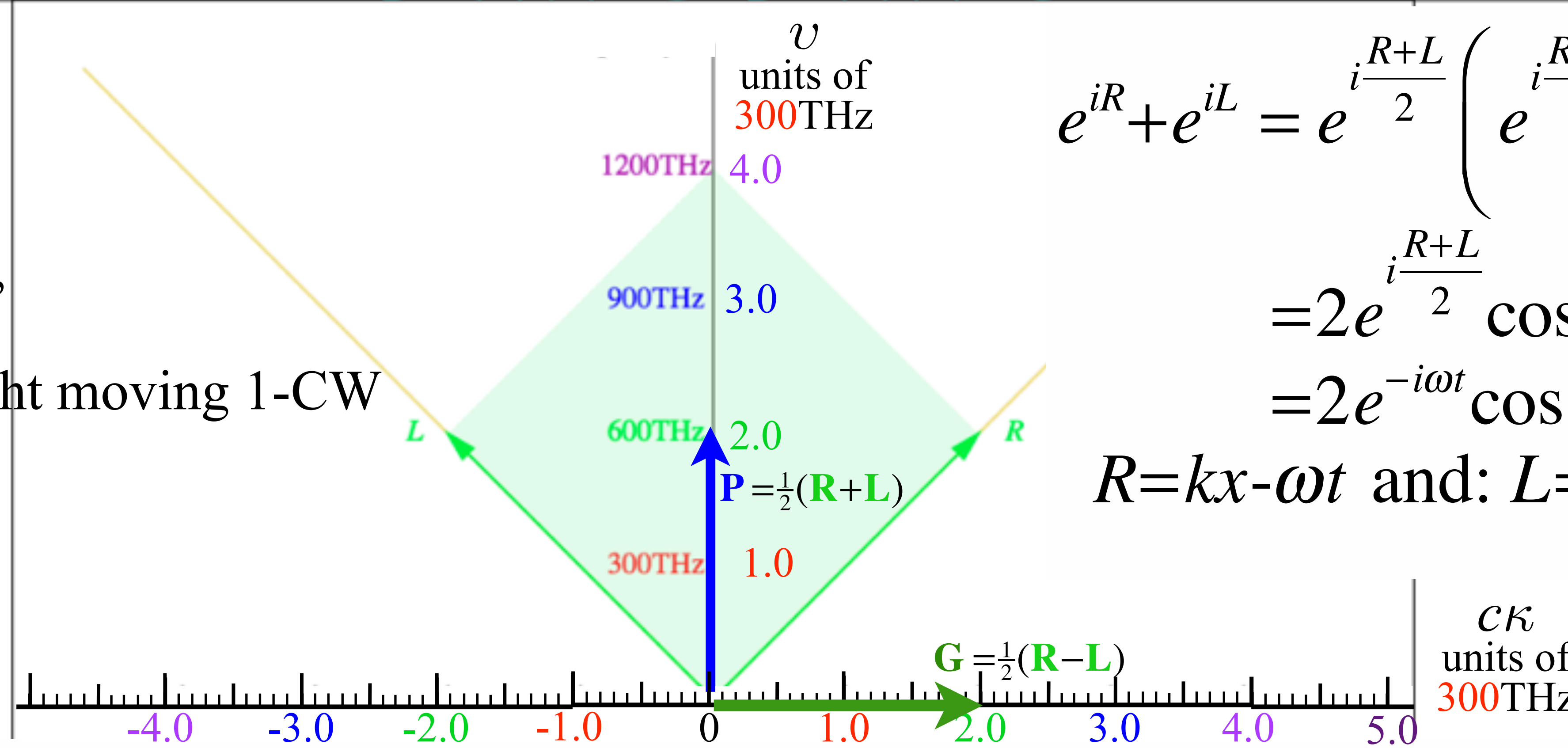
BohrIt Web Simulation
2 CW *ct vs x* Plot
(ck = ±2)



(d)

Introducing optical space-time grids and per-space-time "baseball-diamonds"

← LEFT-from-right moving 1-CW



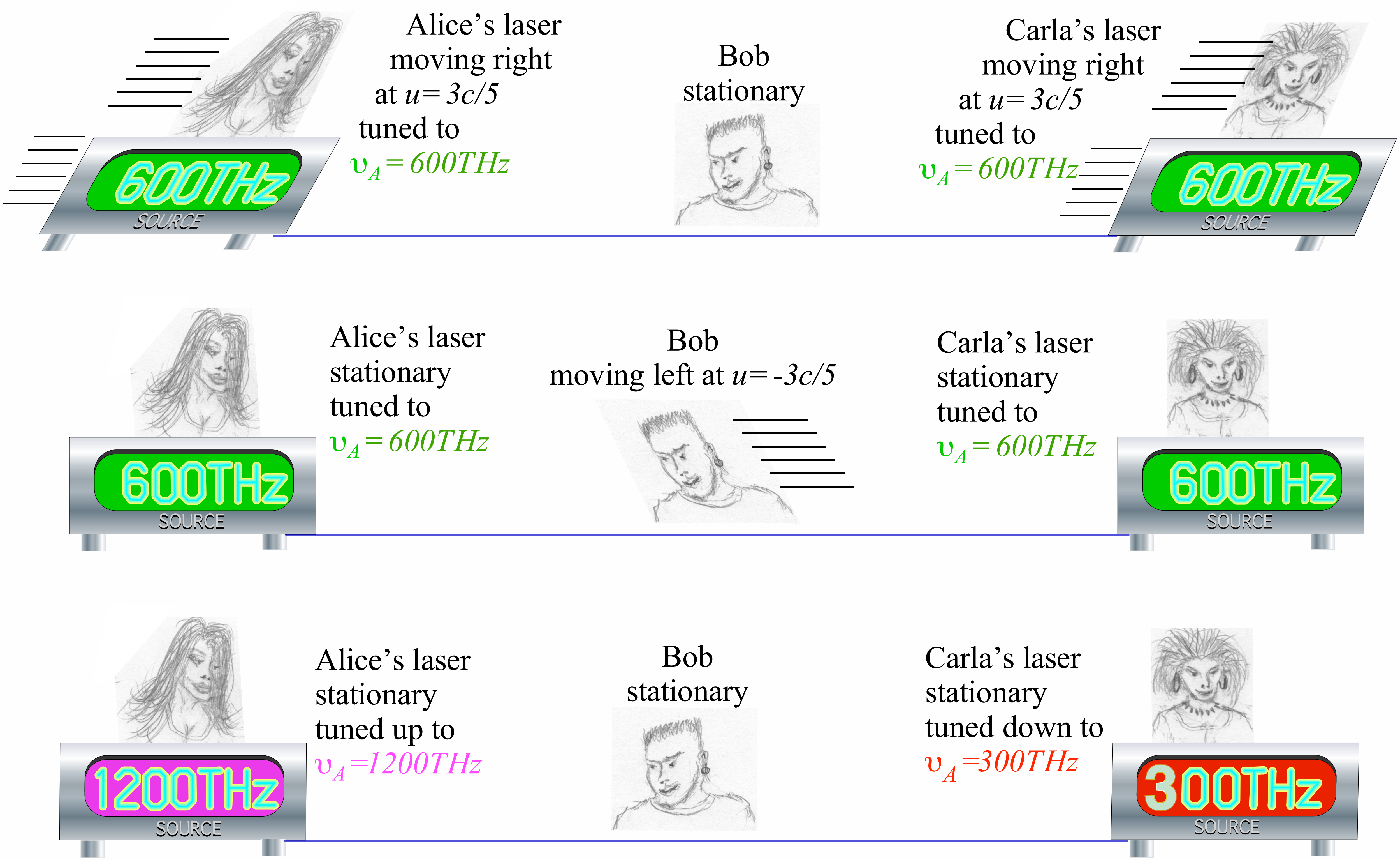
$$e^{iR}+e^{iL} = e^{i\frac{R+L}{2}}\left(e^{i\frac{R-L}{2}}+e^{-i\frac{R-L}{2}}\right)$$

$$=2e^{i\frac{R+L}{2}}\cos\frac{R-L}{2}$$

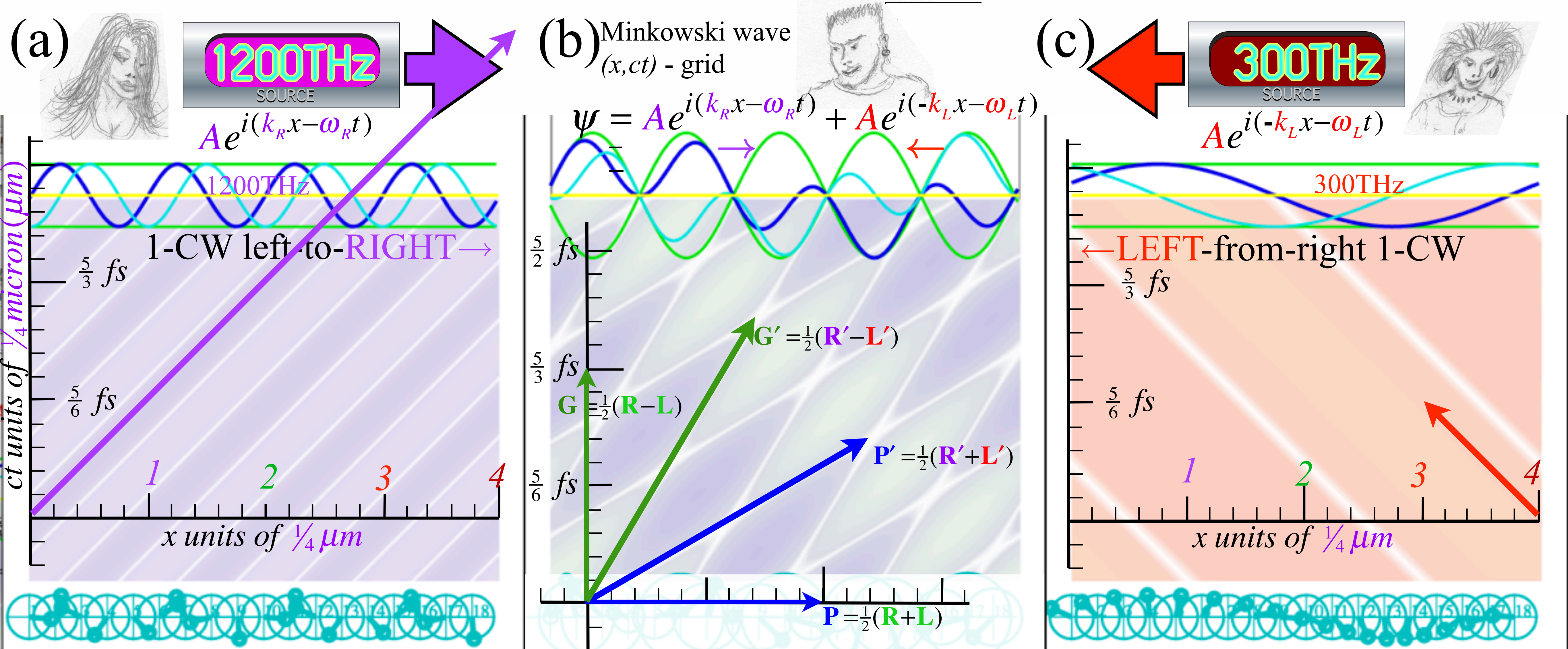
$$=2e^{-i\omega t}\cos kx$$

$R=kx-\omega t$ and: $L=-kx-\omega t$

Three scenarios that look the same to Bob



Much cheaper to do this one!$!



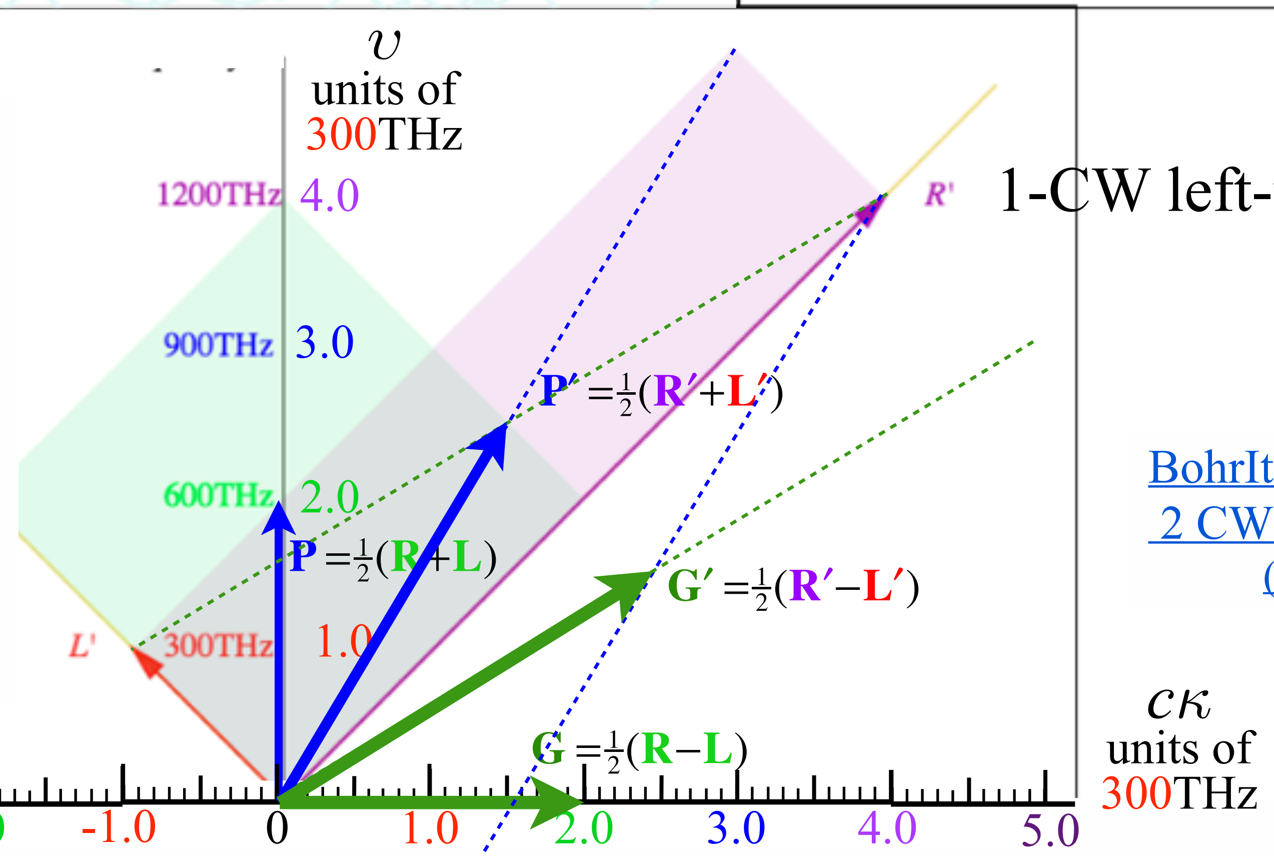
(d)

$$e^{iR'}+e^{iL'}=e^{i\frac{R'+L'}{2}}\left(e^{i\frac{R'-L'}{2}}+e^{-i\frac{R'-L'}{2}}\right)$$

$$=e^{i\frac{R'+L'}{2}}\,2\cos\frac{R'-L'}{2}$$

$$=\psi'_{phase}\psi'_{group}$$

$R'=k_R x\text{-}\omega_R t$ and: $L'=\text{-}k_L x\text{-}\omega_L t$



BohrIt Web Simulation
2 CW *Minkowski* Plot
(ck = -1, +4)

Fig. 10 in text
Relawavity...

The 16 dimensions of 2CW interference

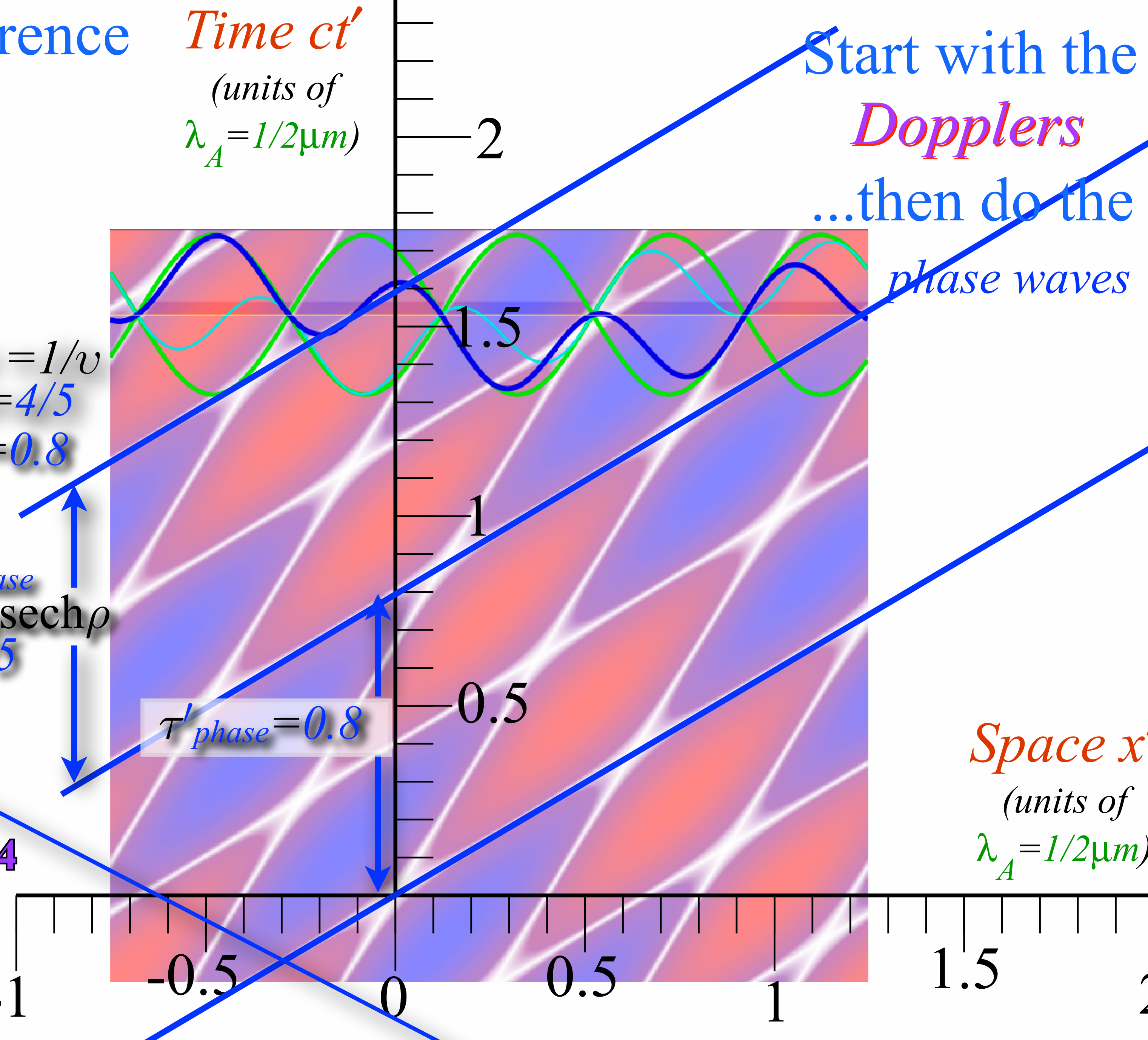
Start with the *Dopplers* ...then do the *phase waves*

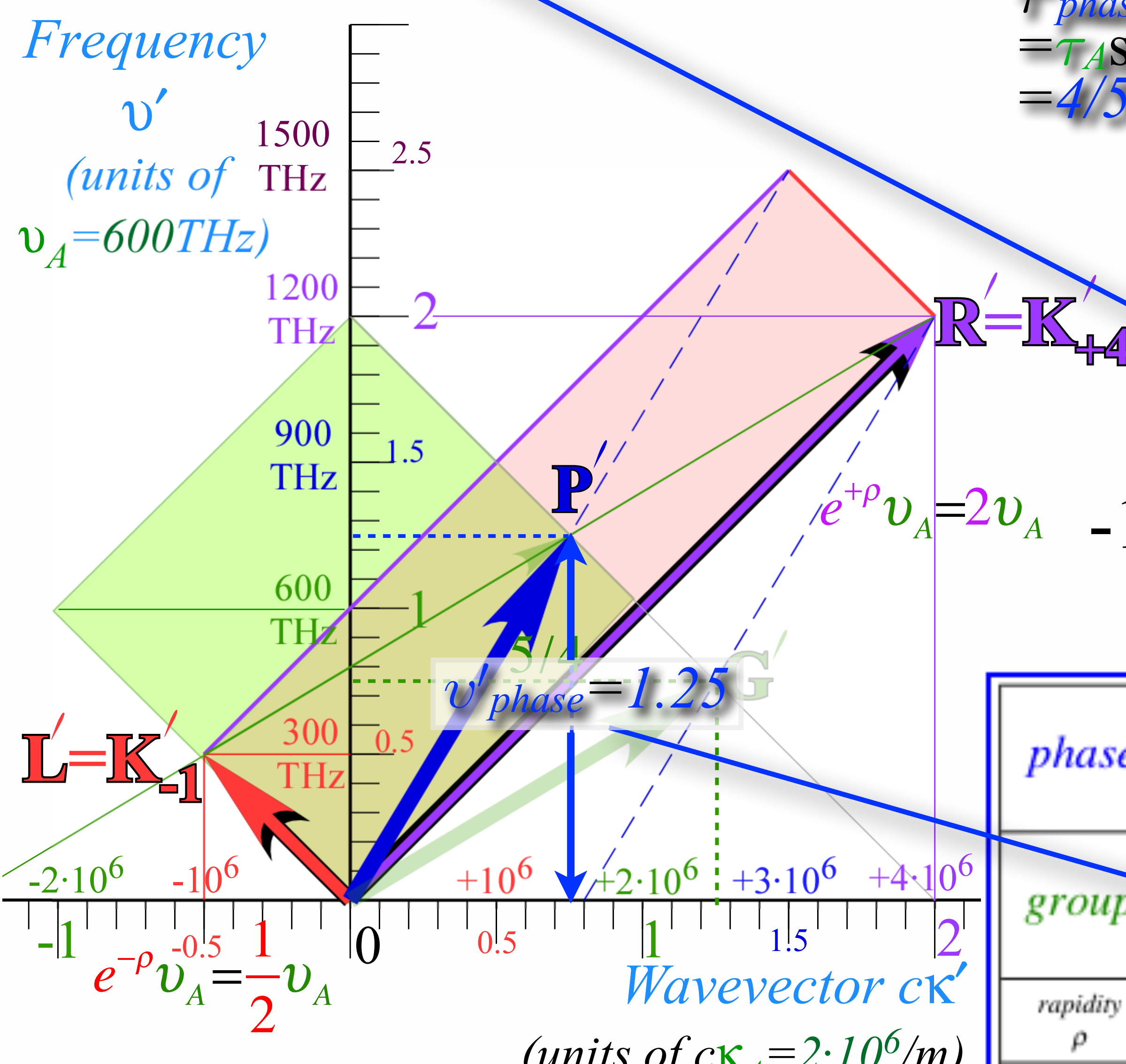
$$\mathbf{P'} = \begin{pmatrix} c\kappa'_{phase} \\ \upsilon'_{phase} \end{pmatrix} = \upsilon_A \begin{pmatrix} \sinh\rho \\ \cosh\rho \end{pmatrix} = \upsilon_A \begin{pmatrix} 3/4 \\ 5/4 \end{pmatrix}$$

Phase frequency $\upsilon'_{phase} = \upsilon_A \cosh\rho = 5/4 = 1.25$

flips to

Phase period $\tau = 1/\upsilon$ $\tau'_{phase} = \tau_A \operatorname{sech}\rho = 4/5 = 0.8$





phase	$b^{Doppler}_{RED}$	$\frac{c}{V_{phase}}$	$\frac{\kappa_{phase}}{\kappa_A}$	$\frac{\tau_{phase}}{\tau_A}$	$\frac{\upsilon_{phase}}{\upsilon_A}$	$\frac{\lambda_{phase}}{\lambda_A}$	$\frac{V_{phase}}{c}$	$b^{Doppler}_{BLUE}$
group	$\frac{1}{b^{Doppler}_{BLUE}}$	$\frac{V_{group}}{c}$	$\frac{\upsilon_{group}}{\upsilon_A}$	$\frac{\lambda_{group}}{\lambda_A}$	$\frac{\kappa_{group}}{\kappa_A}$	$\frac{\tau_{group}}{\tau_A}$	$\frac{c}{V_{group}}$	$\frac{1}{b^{Doppler}_{RED}}$
rapidity ρ	$e^{-\rho}$	$\tanh\rho$	$\sinh\rho$	$\operatorname{sech}\rho$	$\cosh\rho$	$\operatorname{csch}\rho$	$\coth\rho$	$e^{+\rho}$
value for $\beta=3/5$	$\frac{1}{2}=0.5$	$\frac{3}{5}=0.6$	$\frac{3}{4}=0.75$	$\frac{4}{5}=0.80$	$\frac{5}{4}=1.25$	$\frac{4}{3}=1.33$	$\frac{5}{3}=1.67$	$\frac{2}{1}=2.0$

The 16 dimensions of 2CW interference

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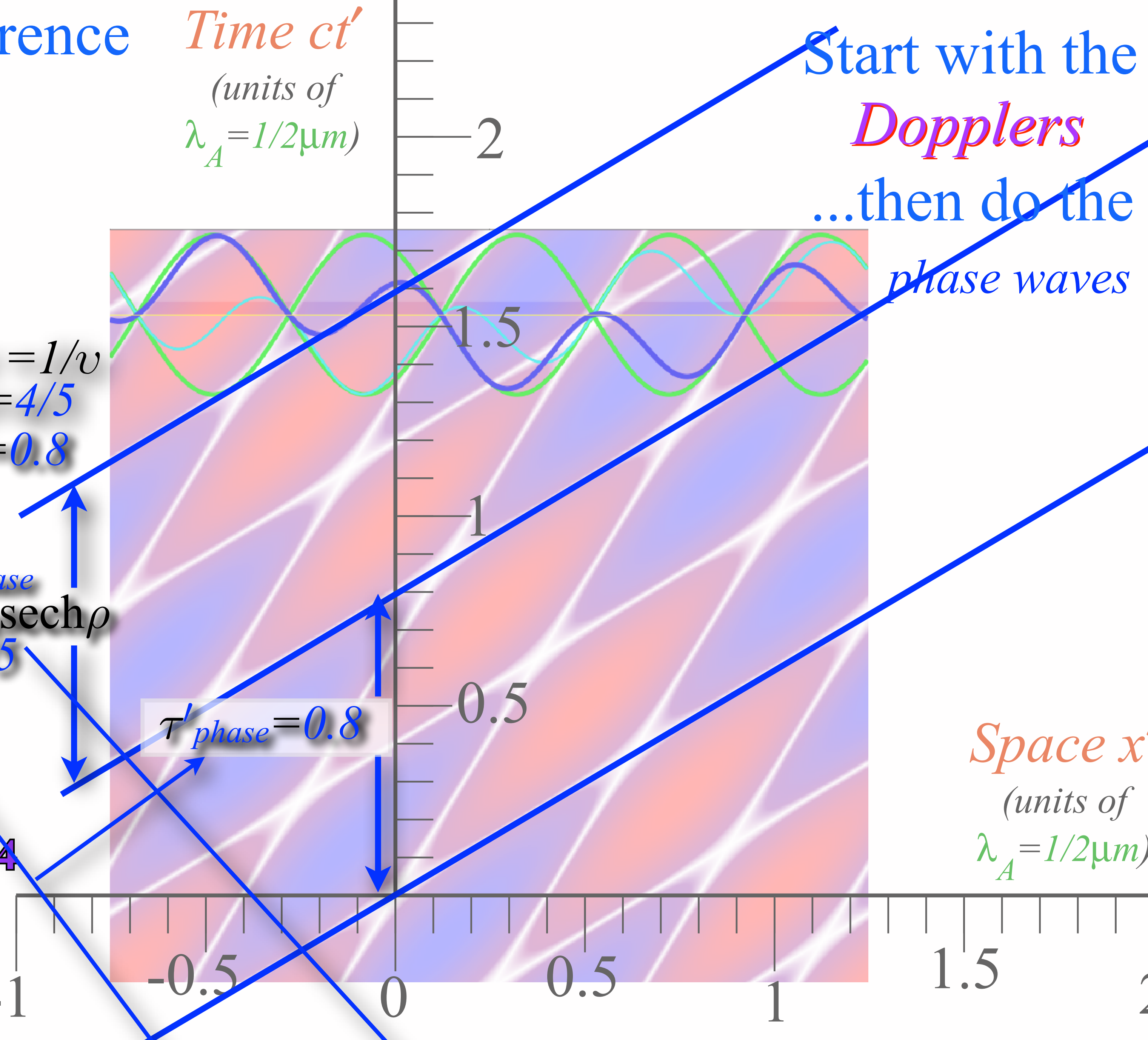

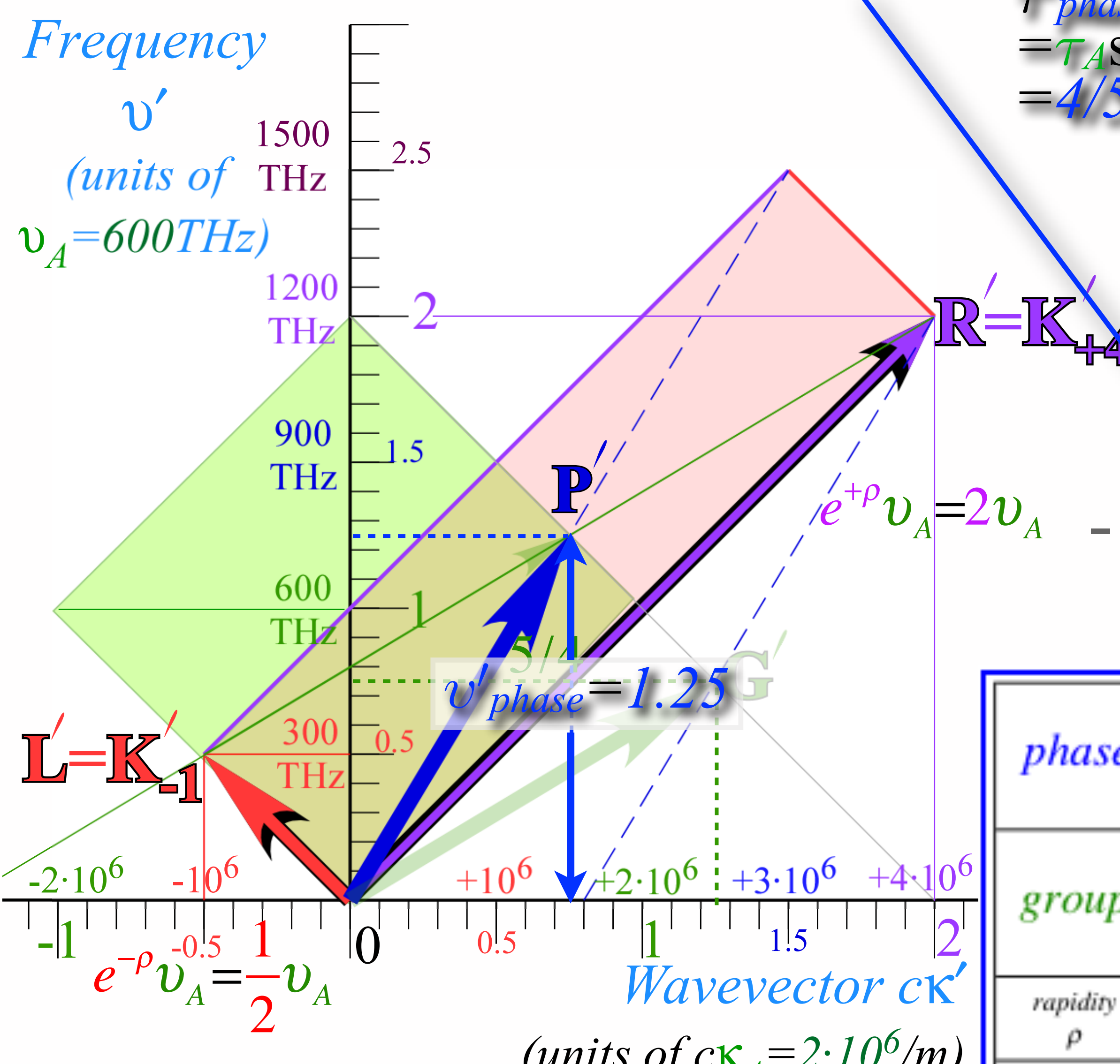

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Phase wavenumber flips to *Phase wavelength* $\lambda = 1/\kappa$

$\kappa'_{phase} = \kappa_A \sinh\rho = 3/4$ to $\lambda'_{phase} = \lambda_A \operatorname{csch}\rho = 4/3$

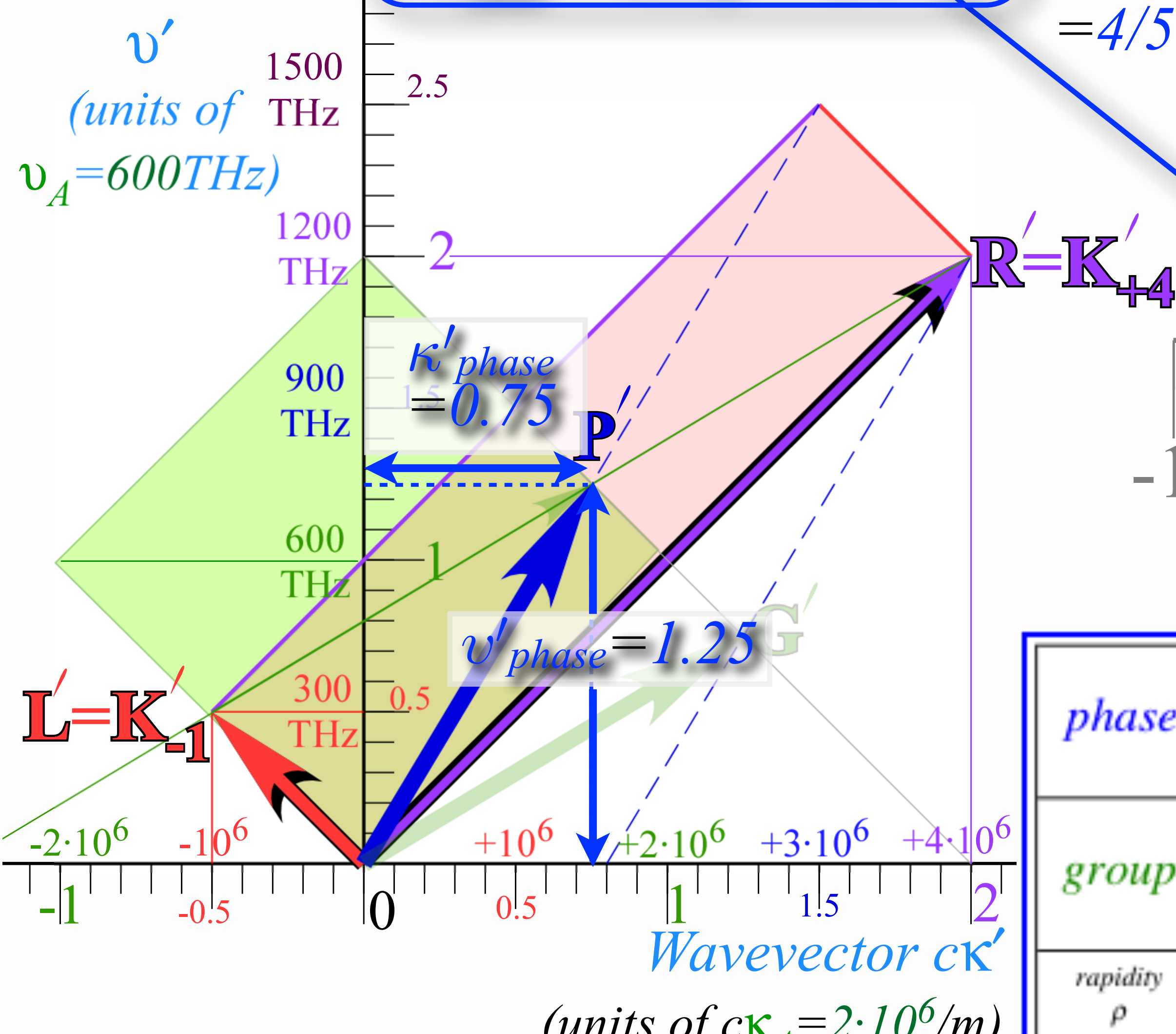
$$\mathbf{P}' = \begin{pmatrix} c\kappa'_{phase} \\ \upsilon'_{phase} \end{pmatrix} = \upsilon_A \begin{pmatrix} \sinh\rho \\ \cosh\rho \end{pmatrix} = \upsilon_A \begin{pmatrix} 3/4 \\ 5/4 \end{pmatrix}$$

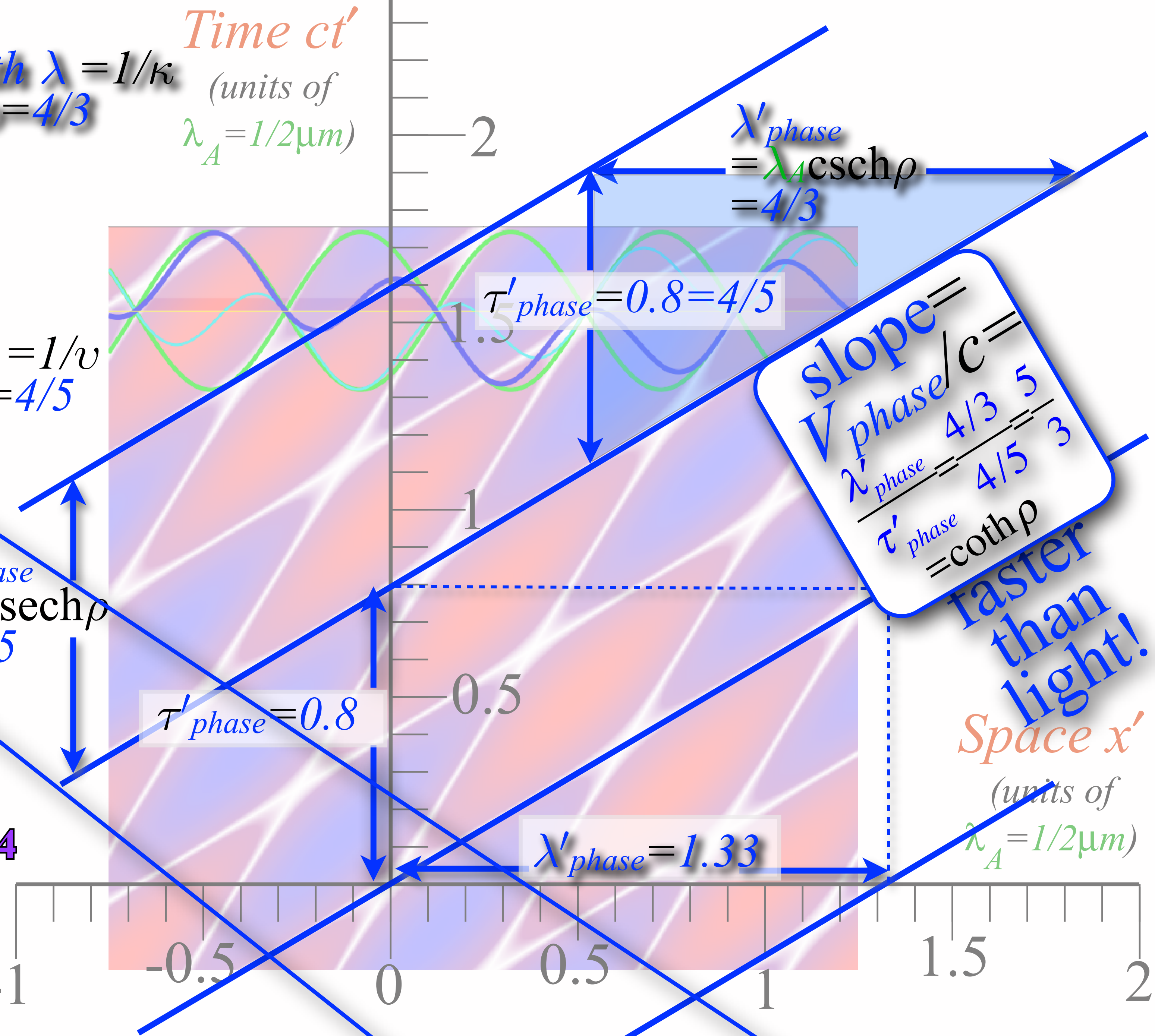
Phase frequency flips to *Phase period* $\tau = 1/\upsilon$

$\upsilon'_{phase} = \upsilon_A \cosh\rho = 5/4$ to $\tau'_{phase} = \tau_A \operatorname{sech}\rho = 4/5$

P-slope $= V_{phase}/c$

$$= \frac{\upsilon'_{phase}}{\kappa'_{phase}} = \frac{\cosh\rho}{\sinh\rho} = \frac{5/4}{3/4} = \frac{5}{3}$$





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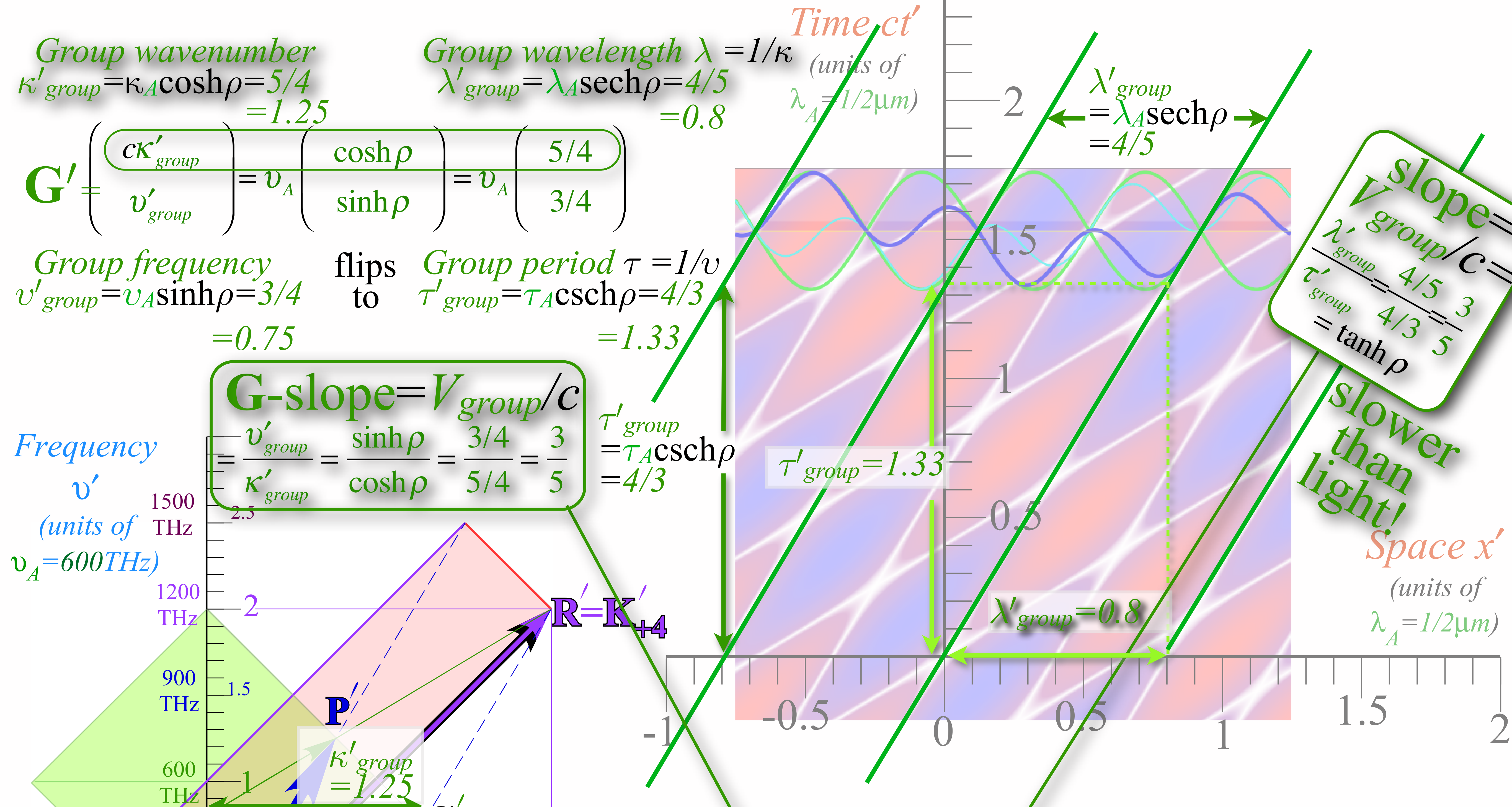

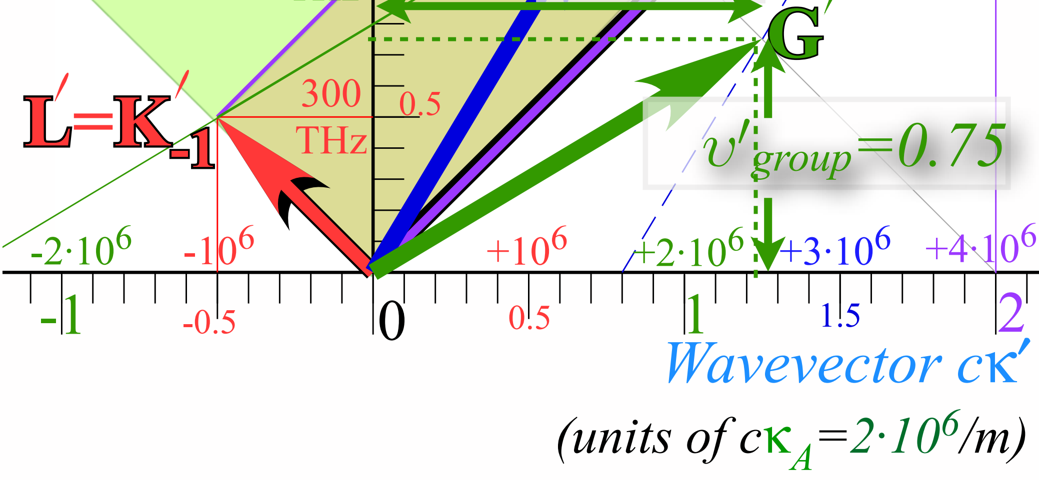

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Lorentz transformations...

write $\mathbf{G}'$ *and* $\mathbf{P}'$ *in terms of* $\mathbf{G}$ *and* $\mathbf{P}$ *using* $\cosh\rho$ *and* $\sinh\rho$

$$\mathbf{G}' = \begin{pmatrix} c\kappa'_{group} \\ \upsilon'_{group} \end{pmatrix} = \upsilon_A \begin{pmatrix} \cosh\rho \\ \sinh\rho \end{pmatrix} = \upsilon_A \begin{pmatrix} 5/4 \\ 3/4 \end{pmatrix}$$

$$= \upsilon_A \begin{pmatrix} 1 \\ 0 \end{pmatrix} \cosh\rho + \upsilon_A \begin{pmatrix} 0 \\ 1 \end{pmatrix} \sinh\rho$$

$$\mathbf{G}' = \mathbf{G} \cosh\rho + \mathbf{P} \sinh\rho$$

$$\mathbf{P}' = \begin{pmatrix} c\kappa'_{phase} \\ \upsilon'_{phase} \end{pmatrix} = \upsilon_A \begin{pmatrix} \sinh\rho \\ \cosh\rho \end{pmatrix} = \upsilon_A \begin{pmatrix} 3/4 \\ 5/4 \end{pmatrix}$$

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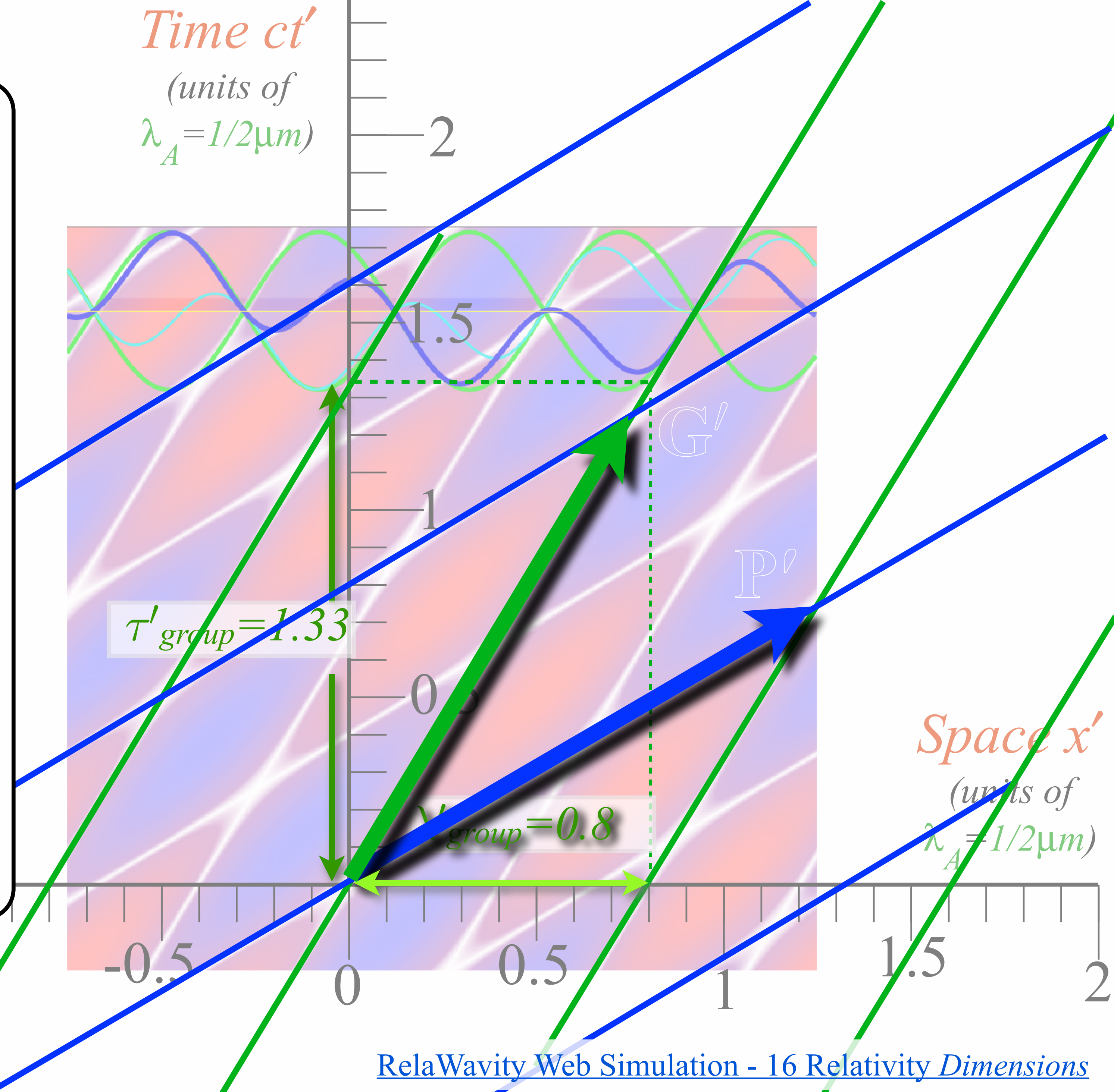

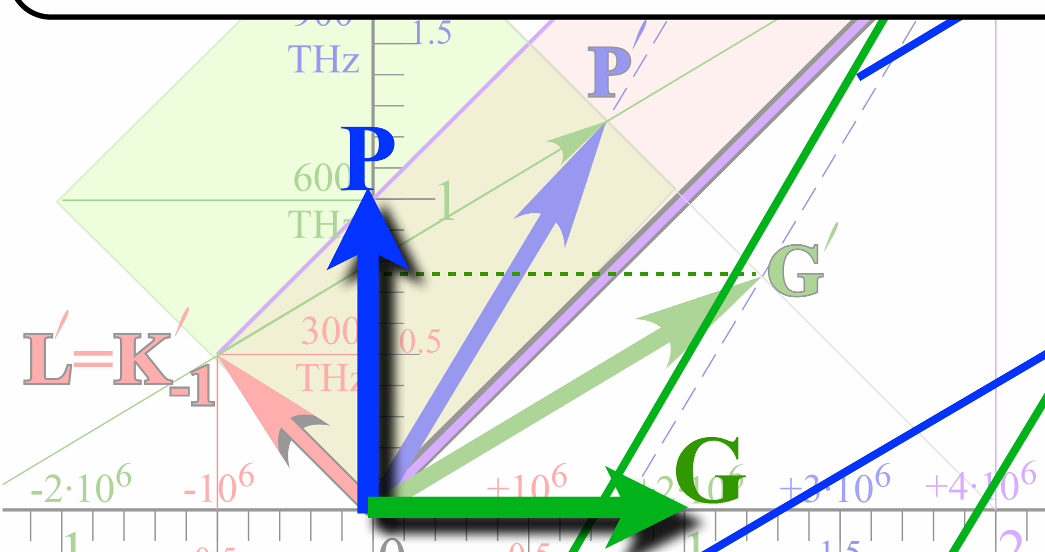

$$\begin{pmatrix} \cosh\rho & \sinh\rho \\ \sinh\rho & \cosh\rho \end{pmatrix}$$ Lorentz transform matrix

RelaWavity Web Simulation - 16 Relativity *Dimensions*

phase	$b_{RED}^{Doppler}$	$\frac{c}{V_{phase}}$	$\frac{\kappa_{phase}}{\kappa_A}$	$\frac{\tau_{phase}}{\tau_A}$	$\frac{\upsilon_{phase}}{\upsilon_A}$	$\frac{\lambda_{phase}}{\lambda_A}$	$\frac{V_{phase}}{c}$	$b_{BLUE}^{Doppler}$
group	$\frac{1}{b_{BLUE}^{Doppler}}$	$\frac{V_{group}}{c}$	$\frac{\upsilon_{group}}{\upsilon_A}$	$\frac{\lambda_{group}}{\lambda_A}$	$\frac{\kappa_{group}}{\kappa_A}$	$\frac{\tau_{group}}{\tau_A}$	$\frac{c}{V_{group}}$	$\frac{1}{b_{RED}^{Doppler}}$
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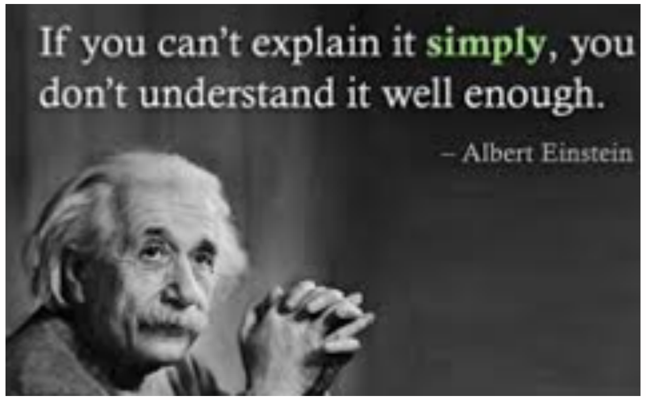
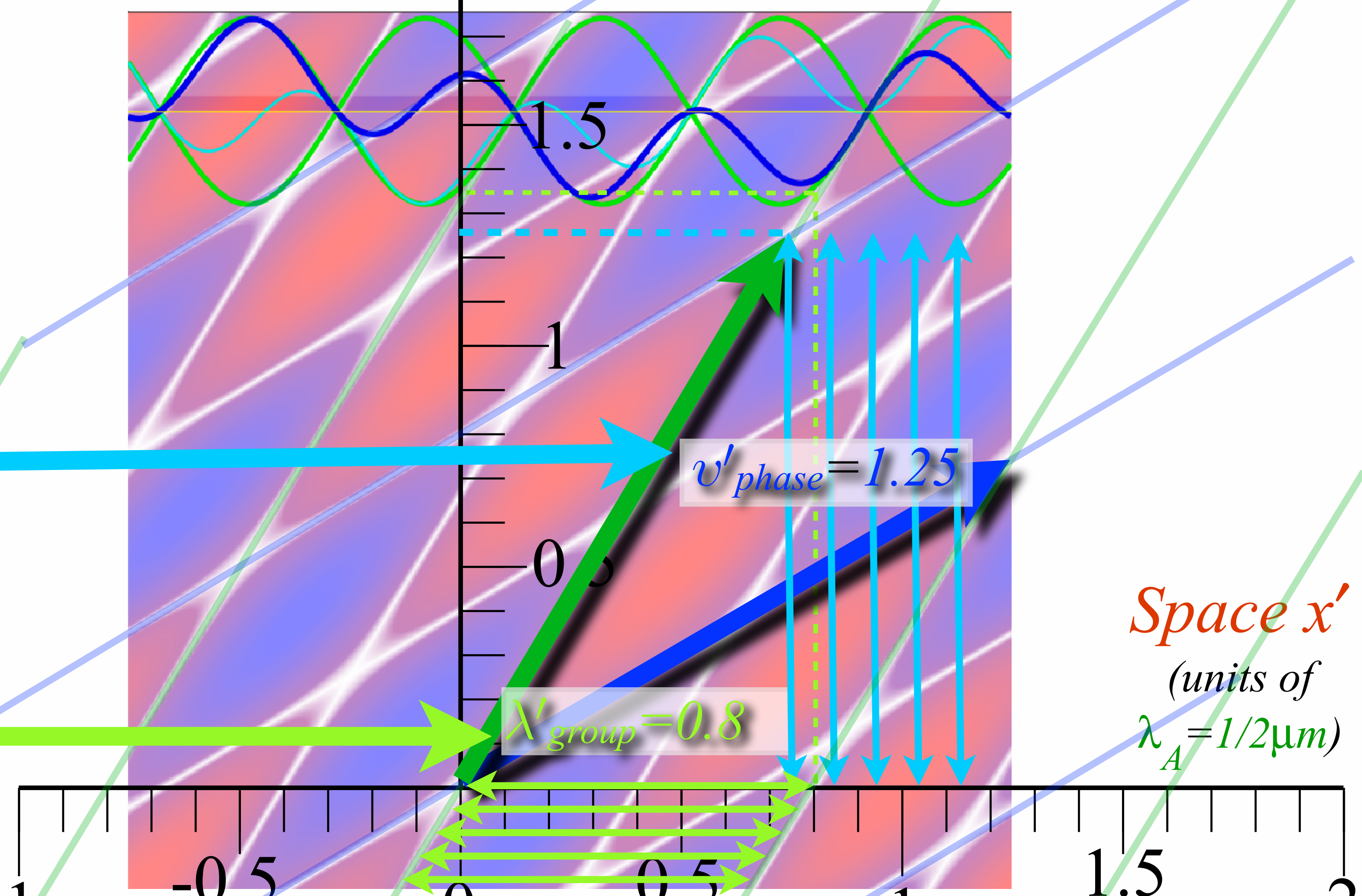
Two Famous-Name Coefficients

Review of Lect. 30 p.106

Albert Einstein 1859-1955

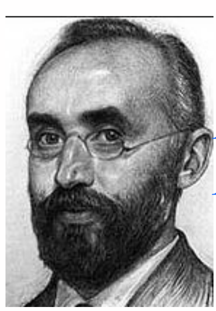


Herman Minkowski 1864-1909



This number is called an: ***Einstein time-dilation*** *(dilated by 25% here)*

This number is called a: ***Lorentz length-contraction*** *(contracted by 20% here)*



Hendrik A. Lorentz 1853-1928

Old-Fashioned Notation

phase	$b_{RED}^{Doppler}$	$\frac{c}{V_{phase}}$	$\frac{\kappa_{phase}}{\kappa_A}$	$\frac{\tau_{phase}}{\tau_A}$	$\frac{\upsilon_{phase}}{\upsilon_A}$	$\frac{\lambda_{phase}}{\lambda_A}$	$\frac{V_{phase}}{c}$	$b_{BLUE}^{Doppler}$
group	$\frac{1}{b_{BLUE}^{Doppler}}$	$\frac{V_{group}}{c}$	$\frac{\upsilon_{group}}{\upsilon_A}$	$\frac{\lambda_{group}}{\lambda_A}$	$\frac{\kappa_{group}}{\kappa_A}$	$\frac{\tau_{group}}{\tau_A}$	$\frac{c}{V_{group}}$	$\frac{1}{b_{RED}^{Doppler}}$
rapidity ρ	$e^{-\rho}$	$\tanh\rho$	$\sinh\rho$	$\text{sech}\,\rho$	$\cosh\rho$	$\text{csch}\rho$	$\coth\rho$	$e^{+\rho}$
$\beta\equiv\frac{u}{c}$	$\sqrt{\frac{1-\beta}{1+\beta}}$	$\frac{\beta}{1}$	$\frac{1}{\sqrt{\beta^{-2}-1}}$	$\frac{\sqrt{1-\beta^2}}{1}$	$\frac{1}{\sqrt{1-\beta^2}}$	$\frac{\sqrt{\beta^{-2}-1}}{1}$	$\frac{1}{\beta}$	$\sqrt{\frac{1+\beta}{1-\beta}}$
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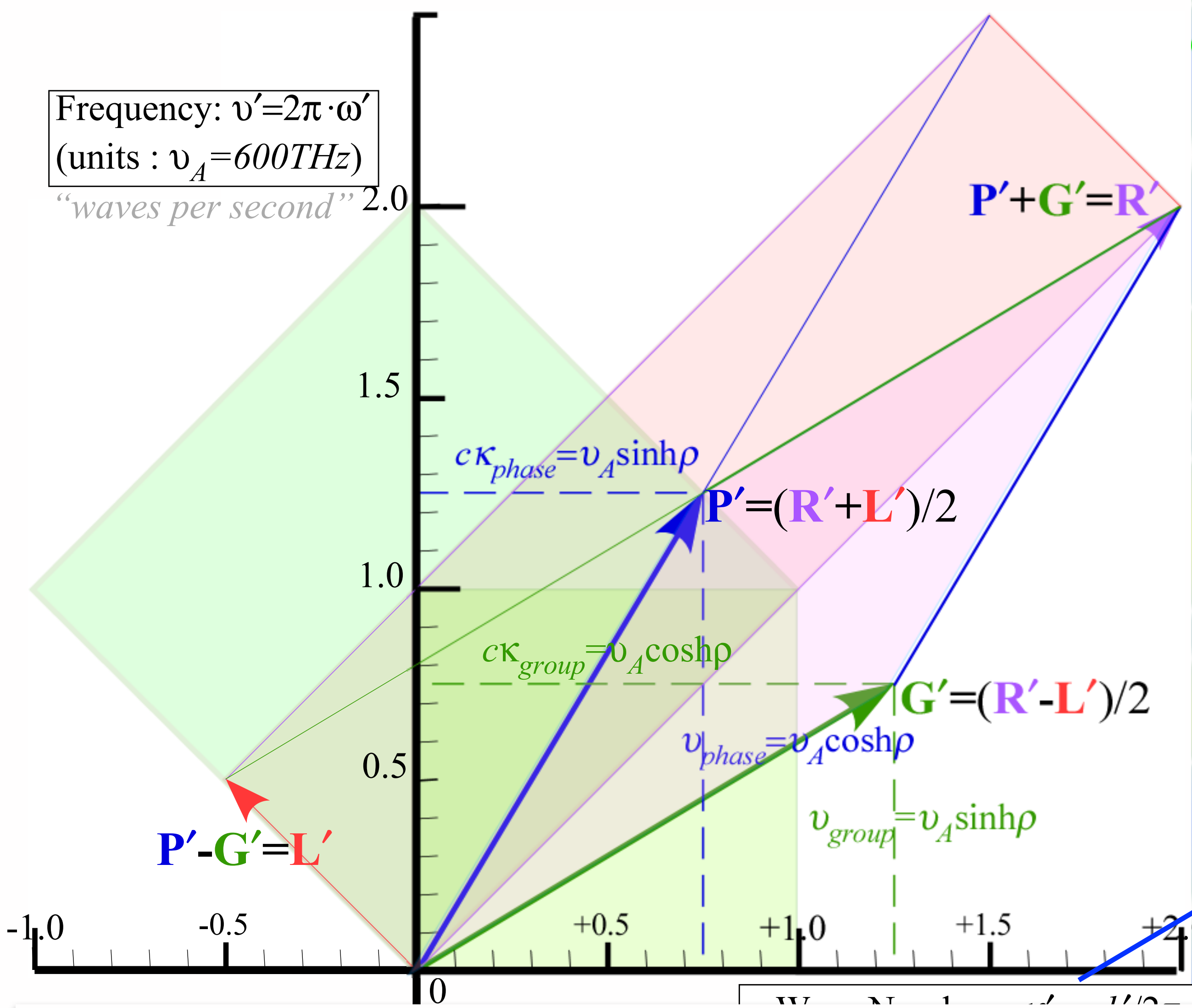
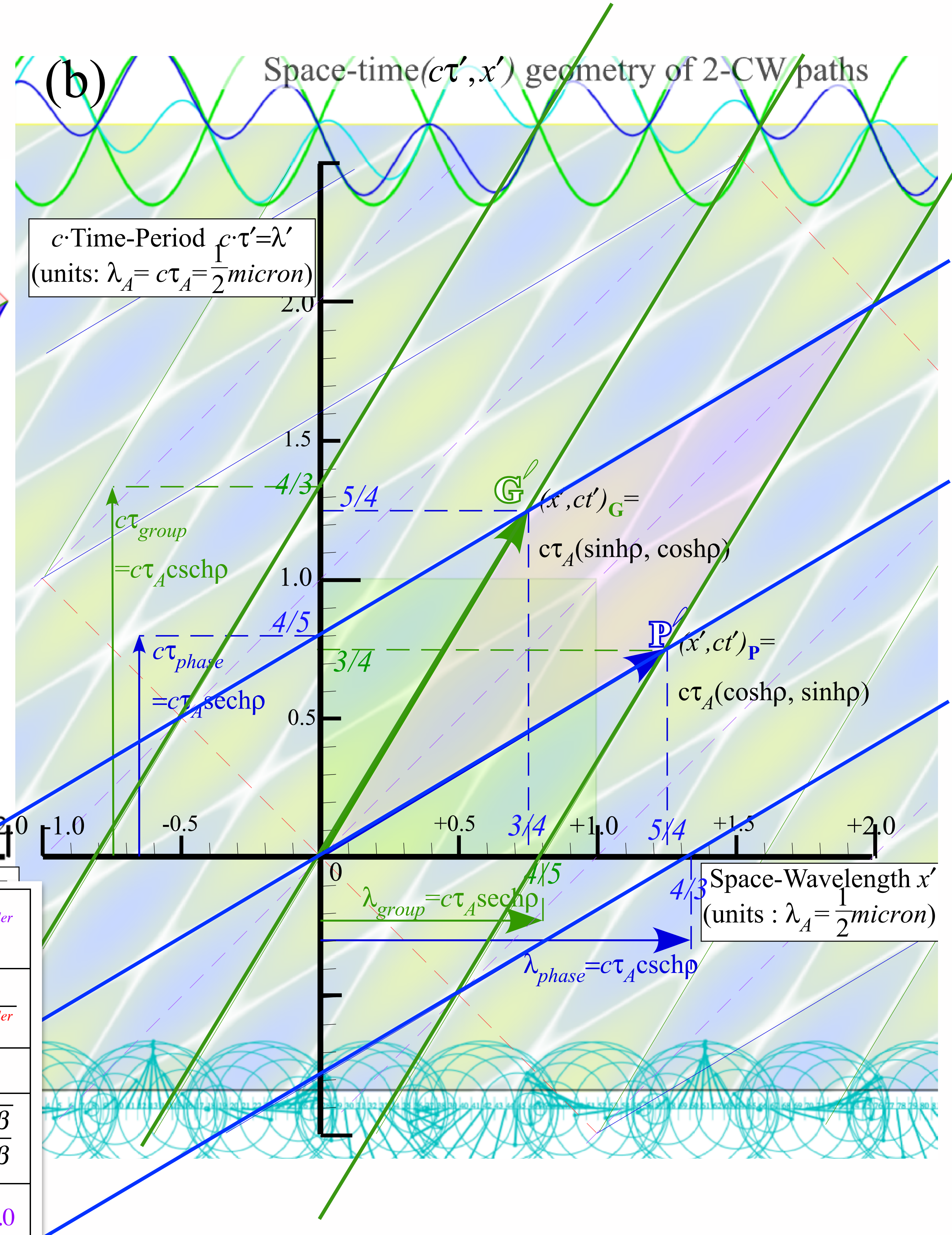
[RelaWavity Web Simulation - Relativistic *Terms* (Expanded Table)]

Fig. 11 in text *Relawavity...*

(a) Per-space-time $(\upsilon', c\kappa')$ geometry of 2-CW vectors



(b) Space-time $(c\tau', x')$ geometry of 2-CW paths



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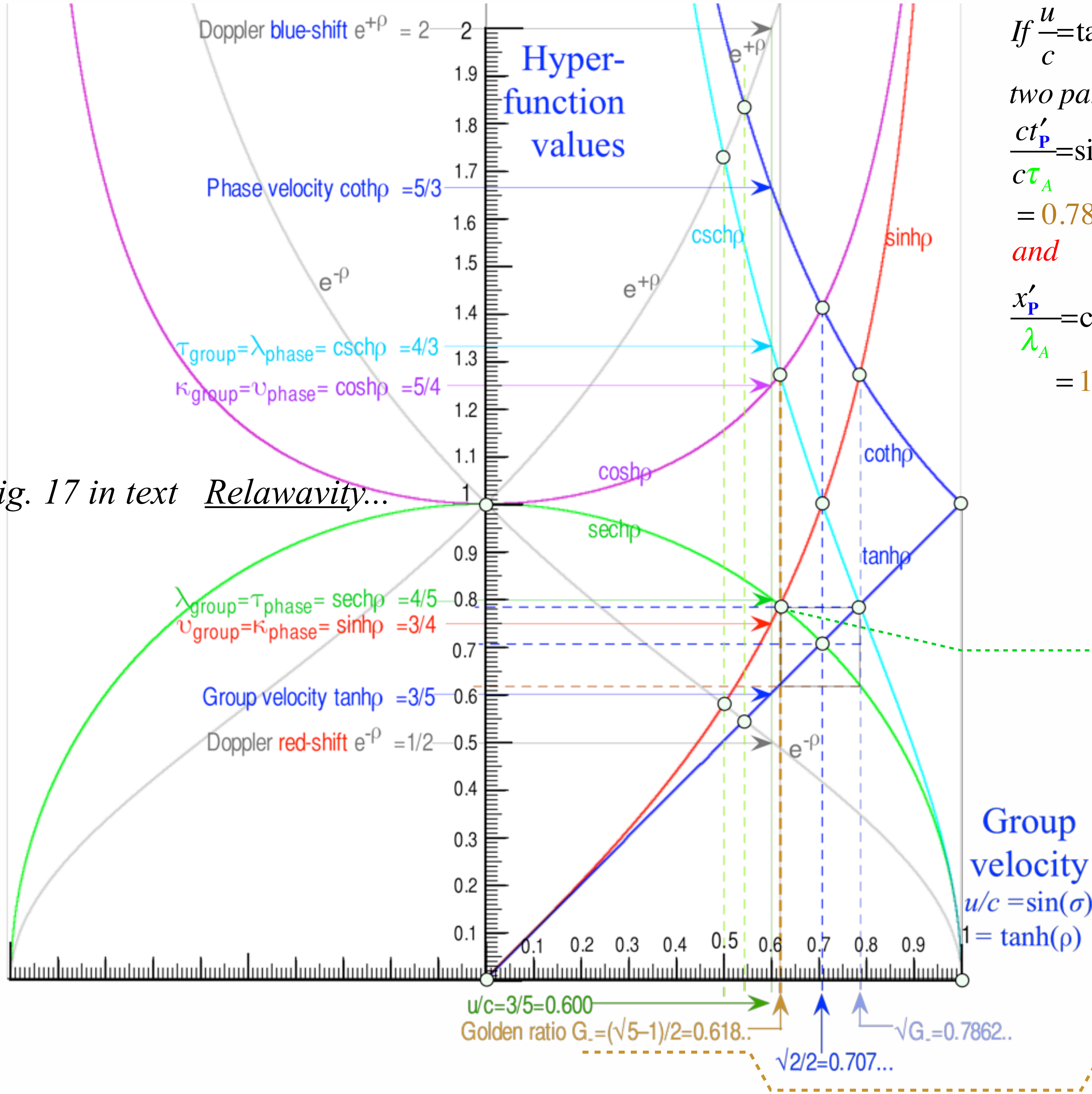

Fig. 17 in text Relawavity...

If $\frac{u}{c}=\tanh\rho=0.618...(\textit{Golden-Mean}\, G_-)$

two parameters become exactly equal:

$$\frac{ct'_{P}}{c\tau_A}=\sinh\rho=\frac{\lambda_{group}}{\lambda_A}=\frac{\tau_{phase}}{\tau_A}=\operatorname{sech}\rho$$

$$=0.786..=\sqrt{G_-} \qquad =0.786..$$

and

$$\frac{x'_{P}}{\lambda_A}=\cosh\rho=\frac{\lambda_{phase}}{\lambda_A}=\frac{\tau_{group}}{\tau_A}=\operatorname{csch}\rho$$

$$=1.272..=1/\sqrt{G_-} \qquad =1.272..$$

Solve:

$\operatorname{sech}\rho=\sinh\rho$

or:

$\sinh\rho\cosh\rho=1$

or:

$\sinh 2\rho=2$

$\rho=\frac{1}{2}\sinh^{-1}2=0.7218...$

$\tanh\rho=0.618...=\frac{\sqrt{5}-1}{2}$

Lecture 31
Thur. 12.08.2016

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Doppler Jeopardy

(1.) To what velocity u_E must Bob accelerate so he sees beams with equal frequency υ_E?

(2.) What is that frequency υ_E ?

Doppler Jeopardy

(1.) To what velocity u_E must Bob accelerate so he sees beams with equal frequency υ_E?

(2.) What is that frequency υ_E?

Query (1.) has a Jeopardy-style answer-by-question: What is beam group velocity?

$$u_E = V_{group} = \frac{\upsilon_{group}}{\kappa_{group}} = \frac{\upsilon_R - \upsilon_L}{\kappa_R - \kappa_L} = c\,\frac{\upsilon_R - \upsilon_L}{\upsilon_R + \upsilon_L}$$

Doppler Jeopardy

$\omega_R = 2\pi \upsilon_R$ $\upsilon_R = 600\text{THz}$

$\upsilon_L = 300\text{THz}$ $\omega_L = 2\pi \upsilon_L$

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Query (2.) similarly: What υ_E is blue-shift $b\upsilon_L$ of υ_L *and* red-shift υ_R/b of υ_R?

$$\upsilon_E = b\,\upsilon_L = \upsilon_R/b \quad \Rightarrow \quad b = \sqrt{\upsilon_R/\upsilon_L} \quad \Rightarrow \quad \upsilon_E = \sqrt{\upsilon_R \cdot \upsilon_L}$$

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Geometric mean

Doppler Jeopardy

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$$V_{group} = c\frac{\omega_R - \omega_L}{\omega_R + \omega_L} = c\frac{600 - 300}{600 + 300} = \frac{1}{3}c$$

Query (2.) similarly: What υ_E is blue-shift $b\upsilon_L$ of υ_L *and* red-shift υ_R/b of υ_R?

$$\upsilon_E = b\upsilon_L = \upsilon_R/b \quad \Rightarrow \quad b = \sqrt{\upsilon_R/\upsilon_L} \quad \Rightarrow \quad \upsilon_E = \sqrt{\upsilon_R \cdot \upsilon_L}$$

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$$\upsilon_E = \sqrt{\upsilon_R \cdot \upsilon_L} = \sqrt{180000} = 424$$

Geometric mean

Doppler Jeopardy

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$$\upsilon_E = \sqrt{\upsilon_R \cdot \upsilon_L} = \sqrt{180000} = 424$$

V_{group}/c is ratio of difference mean $\upsilon_{group} = \frac{\upsilon_R - \upsilon_L}{2}$ to arithmetic mean $\upsilon_{phase} = \frac{\upsilon_R + \upsilon_L}{2}$. Frequency $\upsilon_E = B$ is the geometric mean $\sqrt{\upsilon_R \cdot \upsilon_L}$ of left and right-moving frequencies defining the geometry

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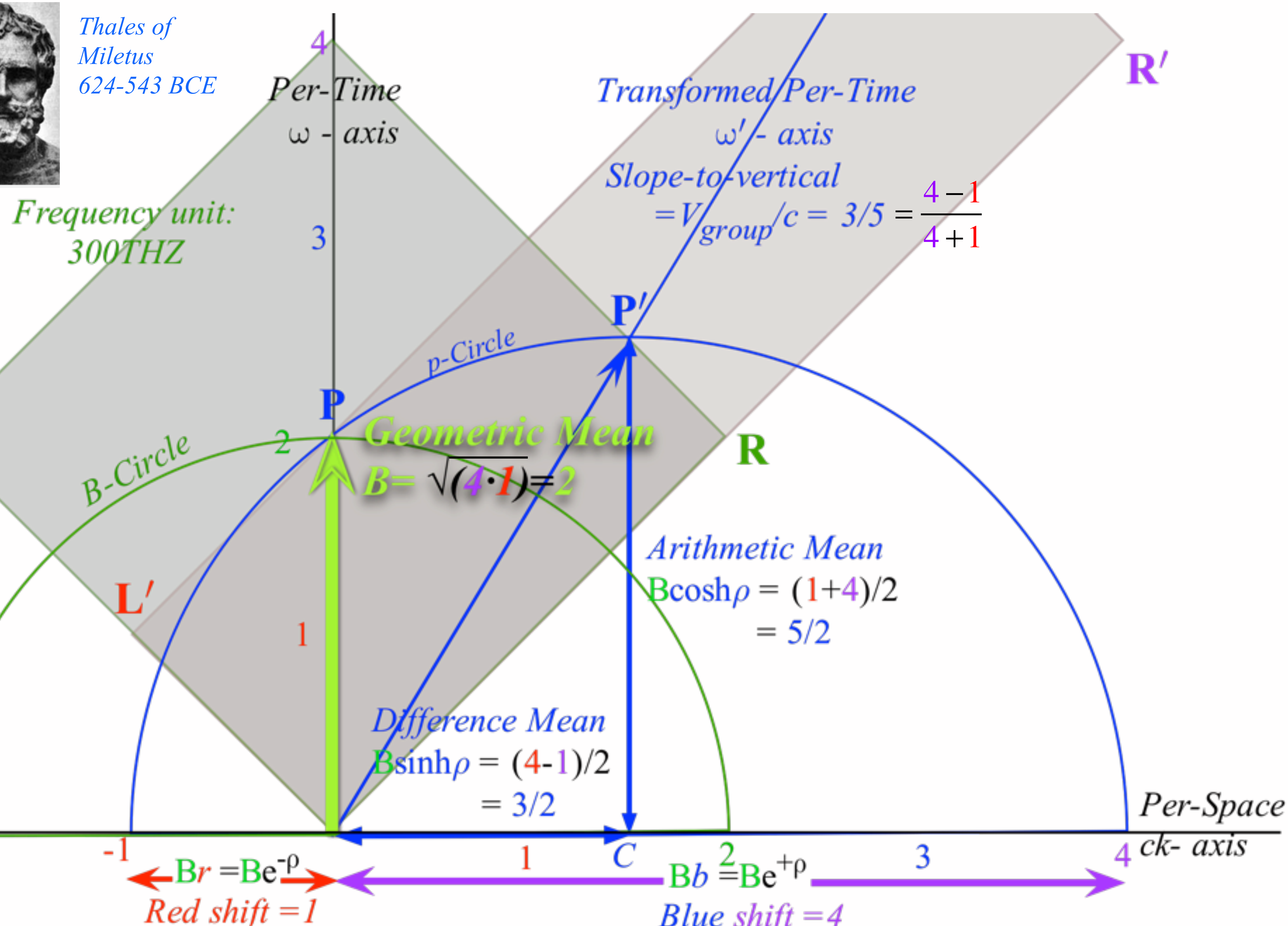
Thales Mean Geometry (600BCE)

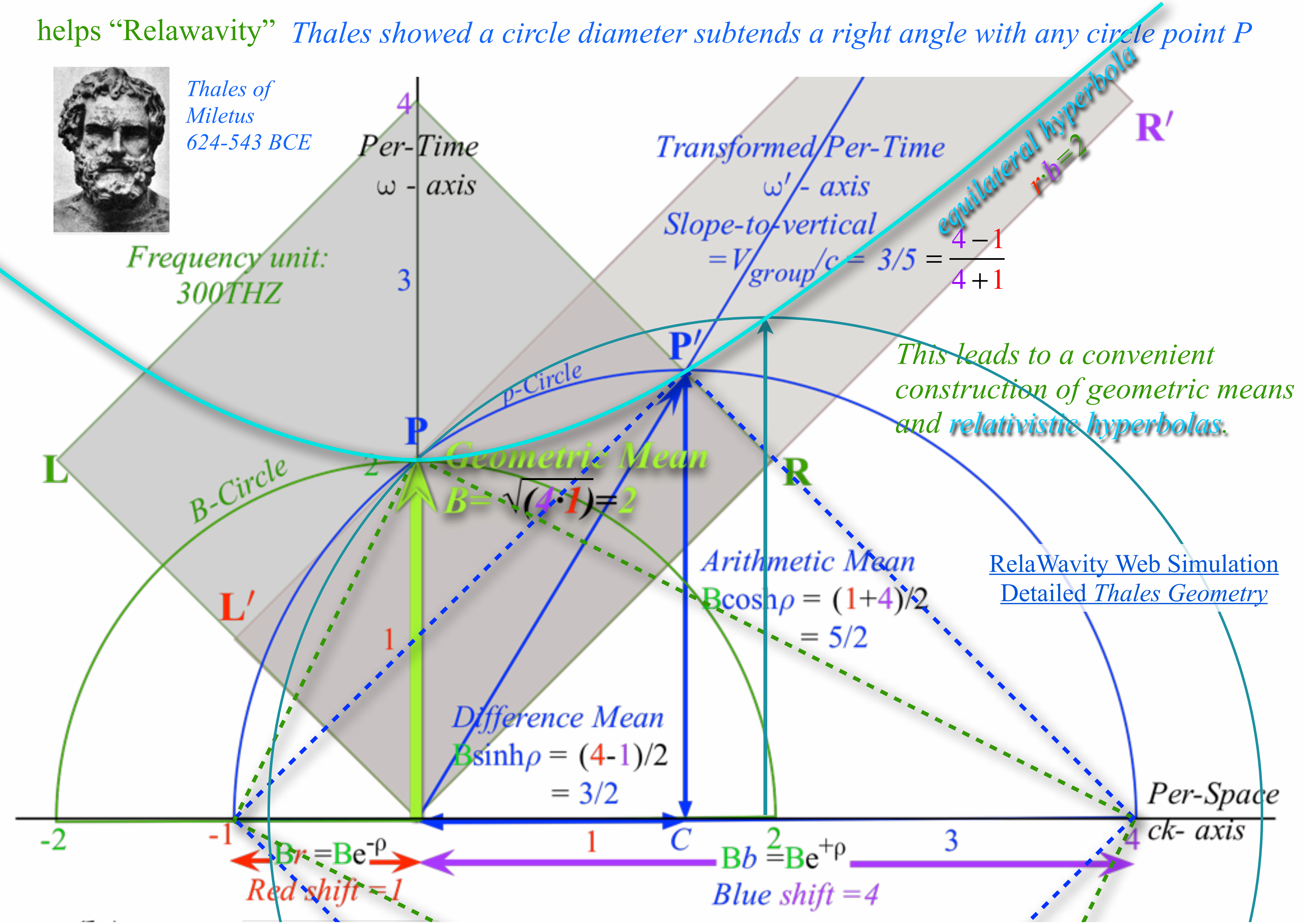
helps "Relawavity"

Thales of Miletus 624-543 BCE



Thales Mean Geometry (600BCE)

helps "Relawavity" *Thales showed a circle diameter subtends a right angle with any circle point P*

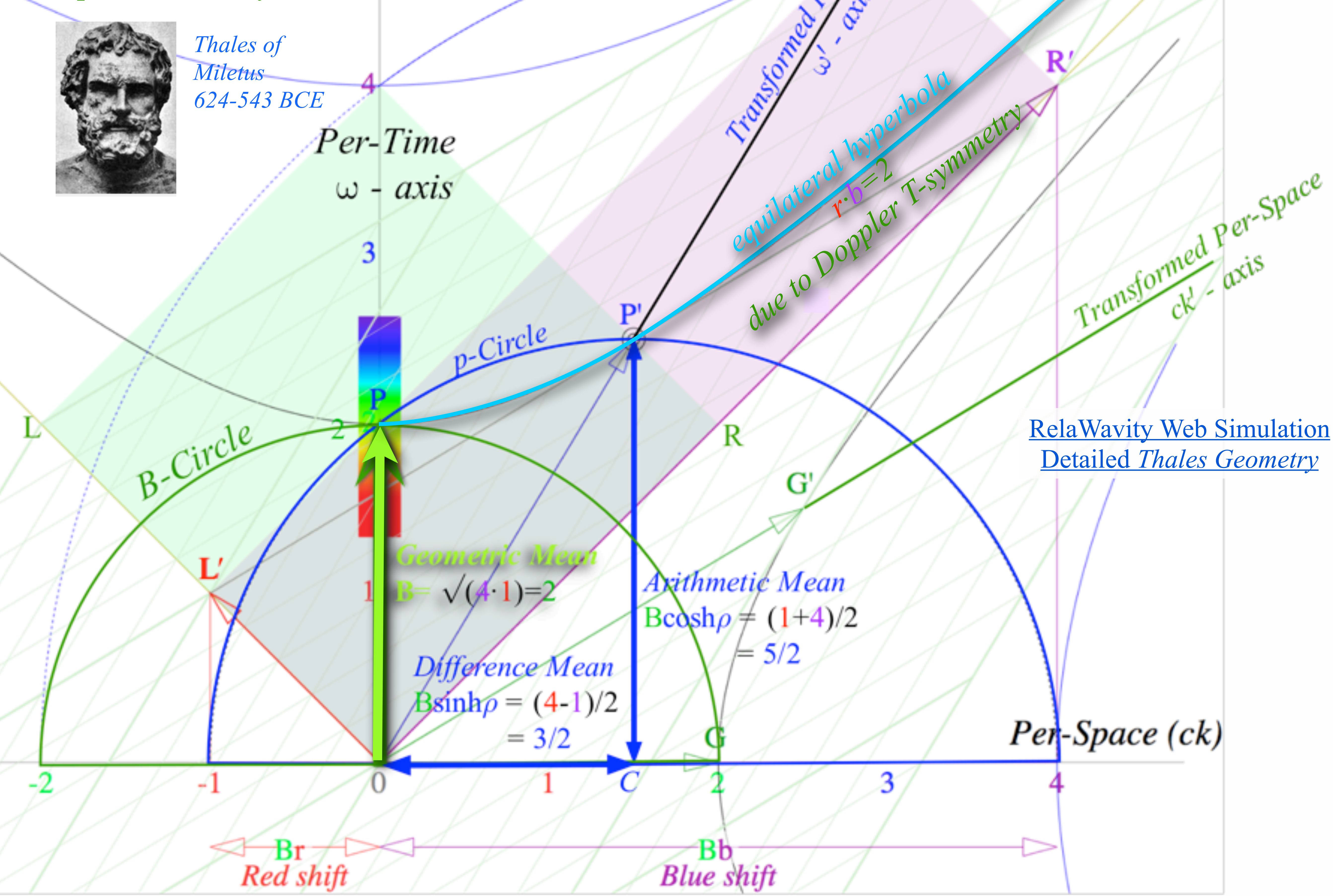


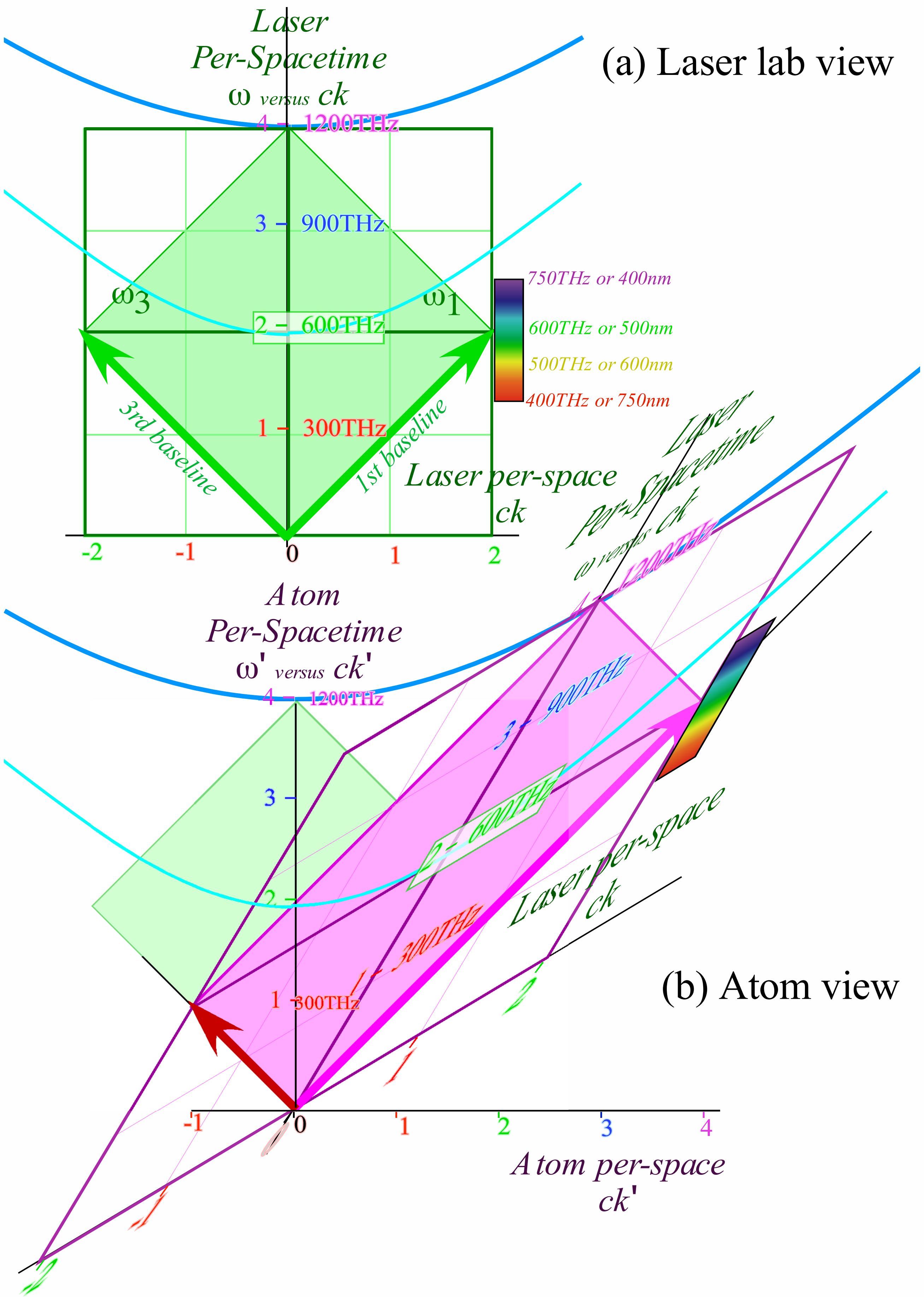
This leads to a convenient construction of geometric means and relativistic hyperbolas.

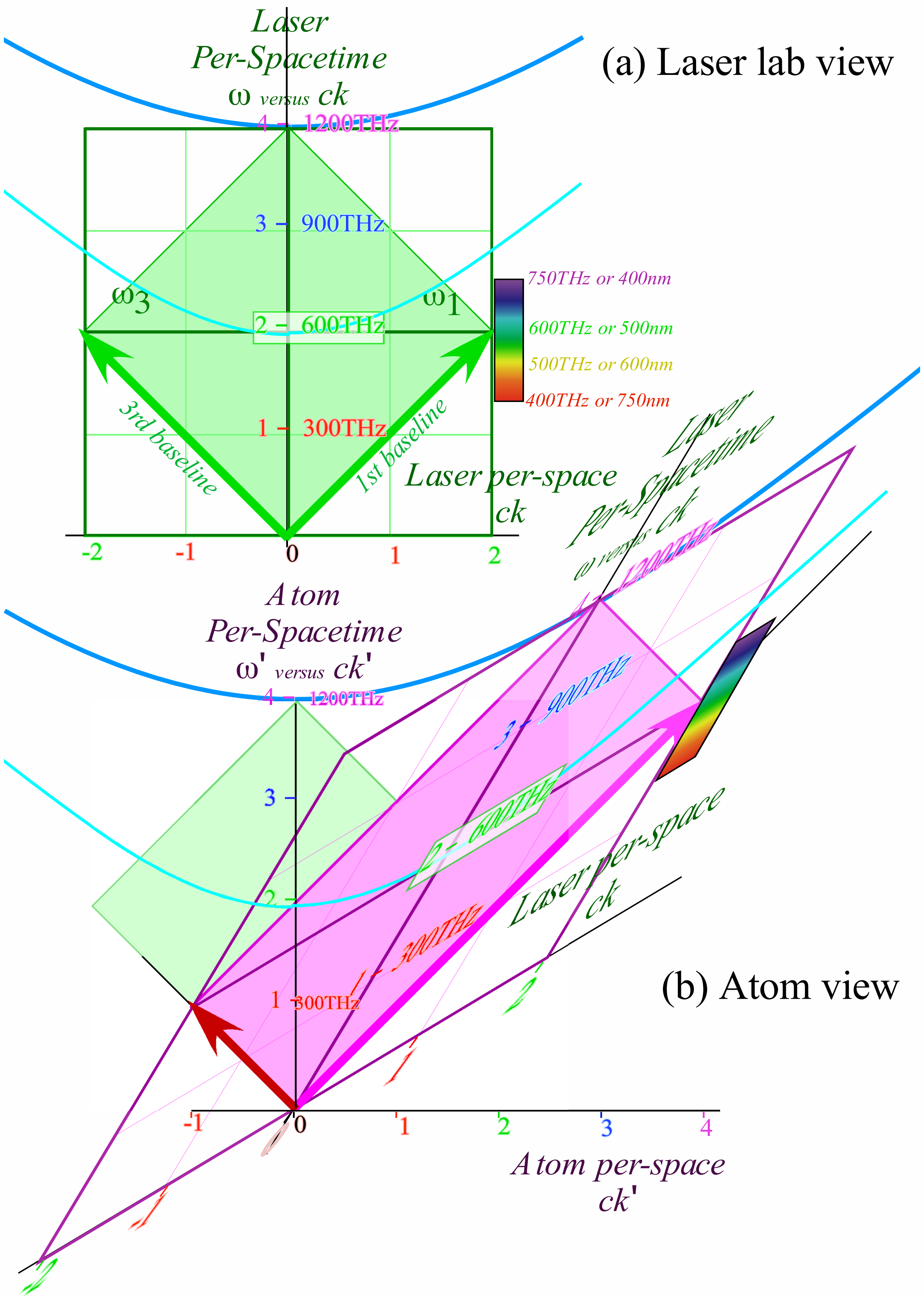
[RelaWavity Web Simulation](#)
[Detailed *Thales Geometry*](#)

Thales Mean Geometry (600BCE)

helps "Relawavity"




Laser
Per-Spacetime
ω versus ck
(a) Laser lab view
4 – 1200THz
3 – 900THz
2 – 600THz
1 – 300THz
ω3
ω1
750THz or 400nm
600THz or 500nm
500THz or 600nm
400THz or 750nm
3rd baseline
1st baseline
Laser per-space
ck
-2
-1
0
1
2
Atom
Per-Spacetime
ω' versus ck'
4 – 1200THz
3
2
1 300THz
Laser
Per-Spacetime
ω versus ck
4 – 1200THz
3 – 900THz
2 – 600THz
1 – 300THz
Laser per-space
ck
(b) Atom view
-1
0
1
2
3
4
Atom per-space
ck'


Laser
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(a) Laser lab view
4 – 1200THz
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ω3
ω1
750THz or 400nm
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500THz or 600nm
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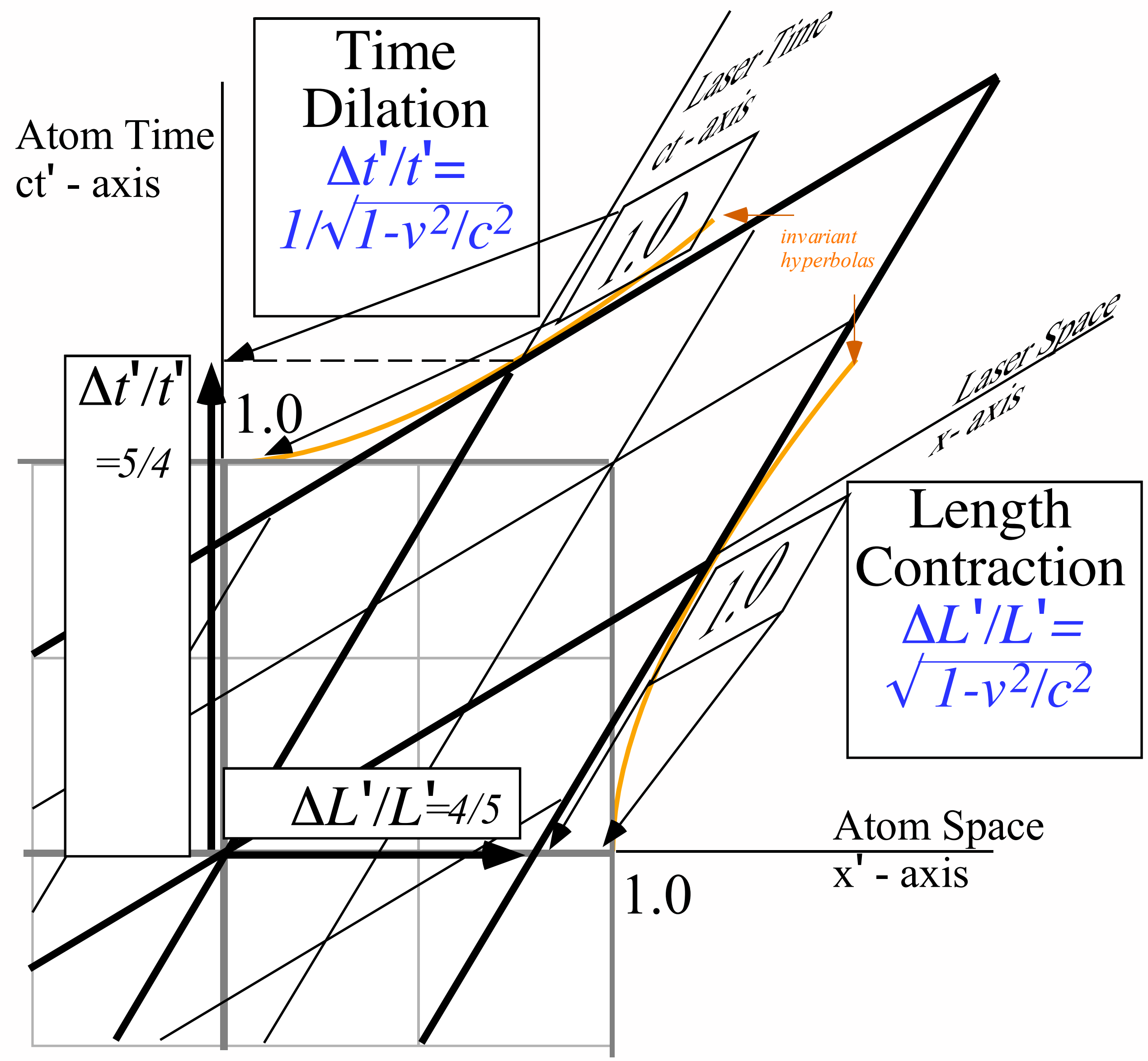
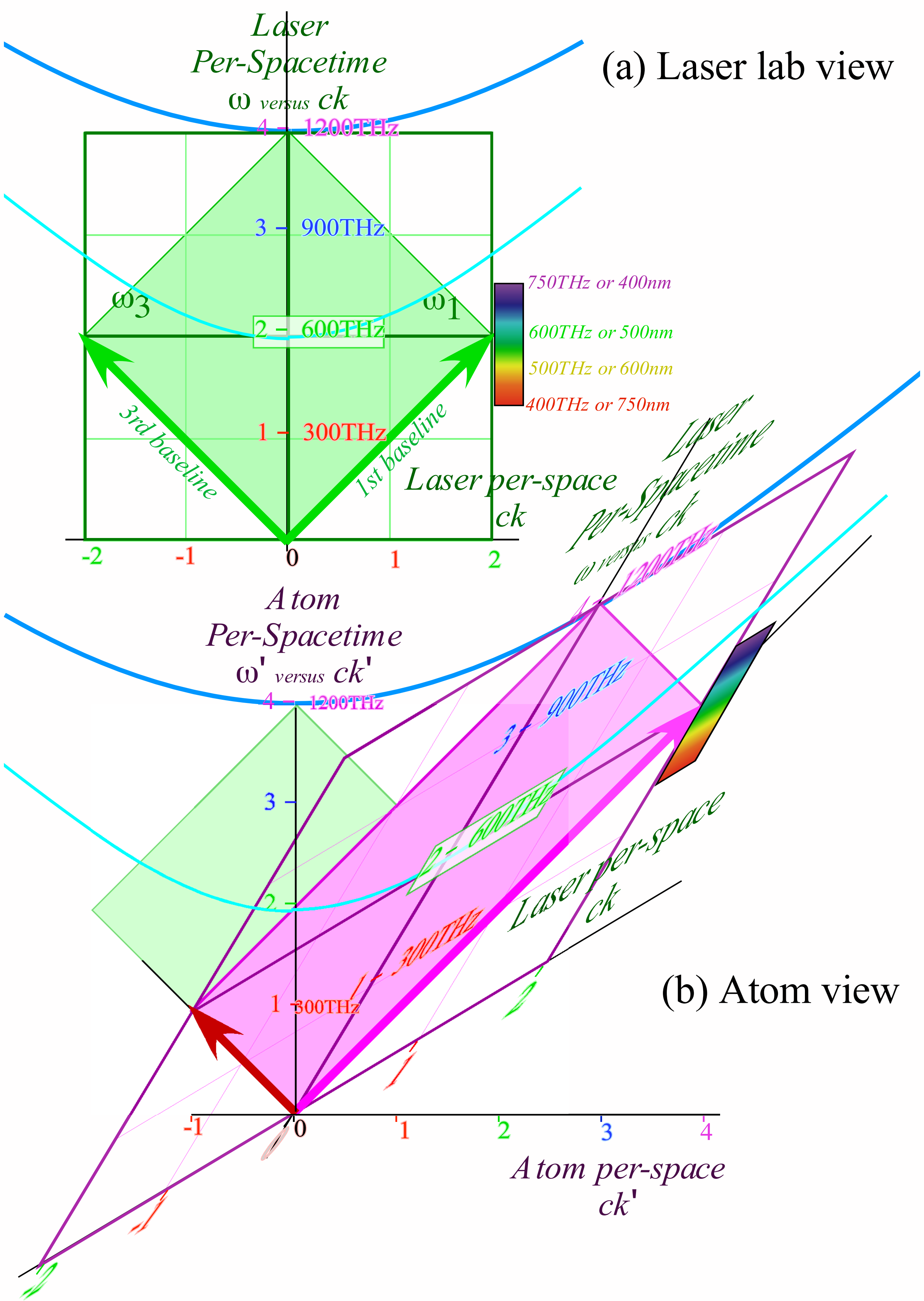
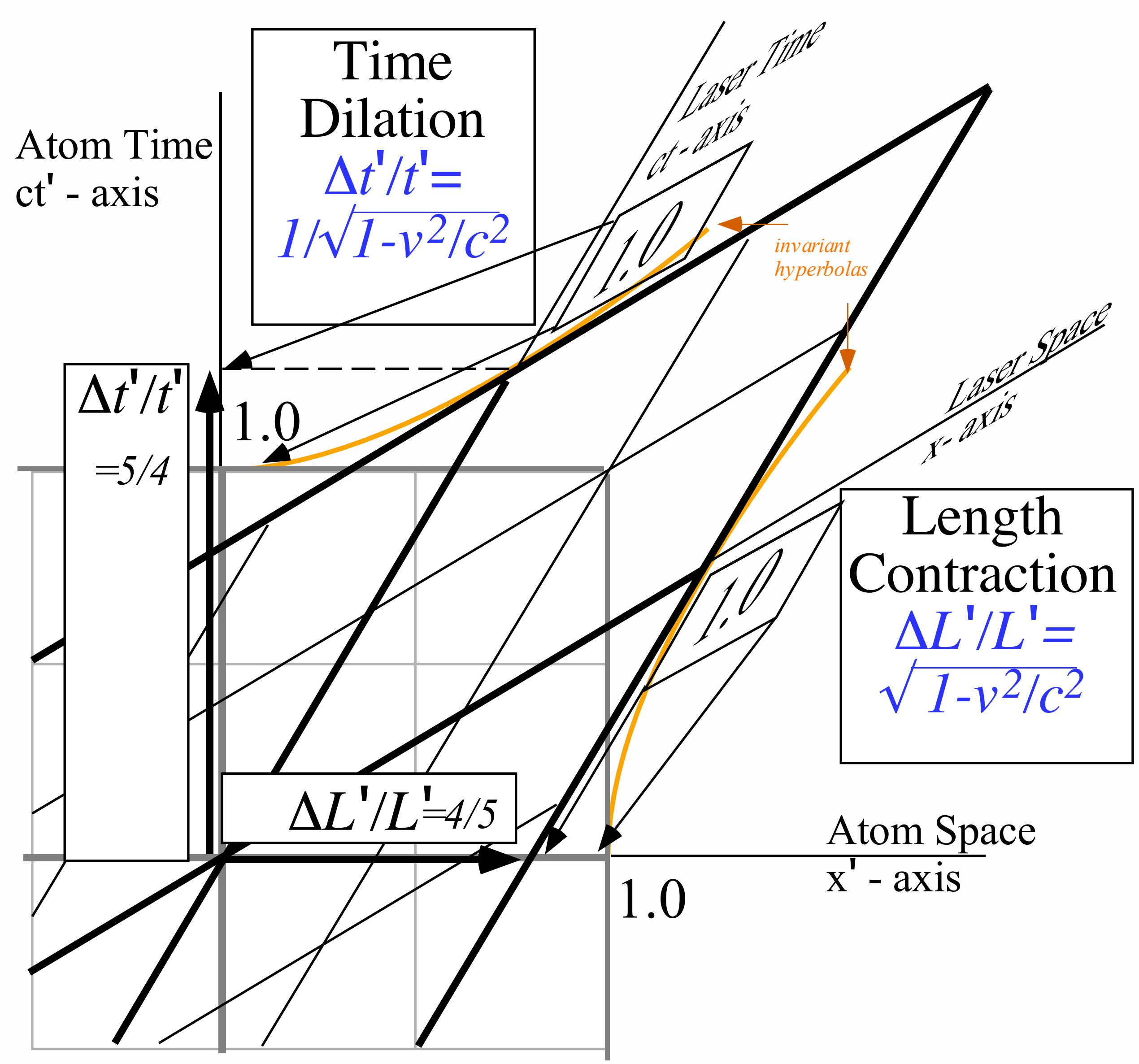
3rd baseline
1st baseline
Laser per-space
ck
-2
-1
0
1
2
Atom
Per-Spacetime
ω' versus ck'
4 – 1200THz
3
2
1 300THz
Laser
Per-Spacetime
ω versus ck
3 – 900THz
2 – 600THz
1 – 300THz
Laser per-space
ck
(b) Atom view
-1
0
1
2
3
4
Atom per-space
ck'


Time
Dilation
$\Delta t'/t' = 1/\sqrt{1-v^2/c^2}$
Atom Time
ct' - axis
Laser Time
ct - axis
1.0
invariant
hyperbolas
$\Delta t'/t'$
=5/4
1.0
Laser Space
x - axis
1.0
Length
Contraction
$\Delta L'/L' = \sqrt{1-v^2/c^2}$
$\Delta L'/L'$=4/5
Atom Space
x' - axis
1.0



OK! But...
What about "Time Contraction"?
or
"Length dilation"?



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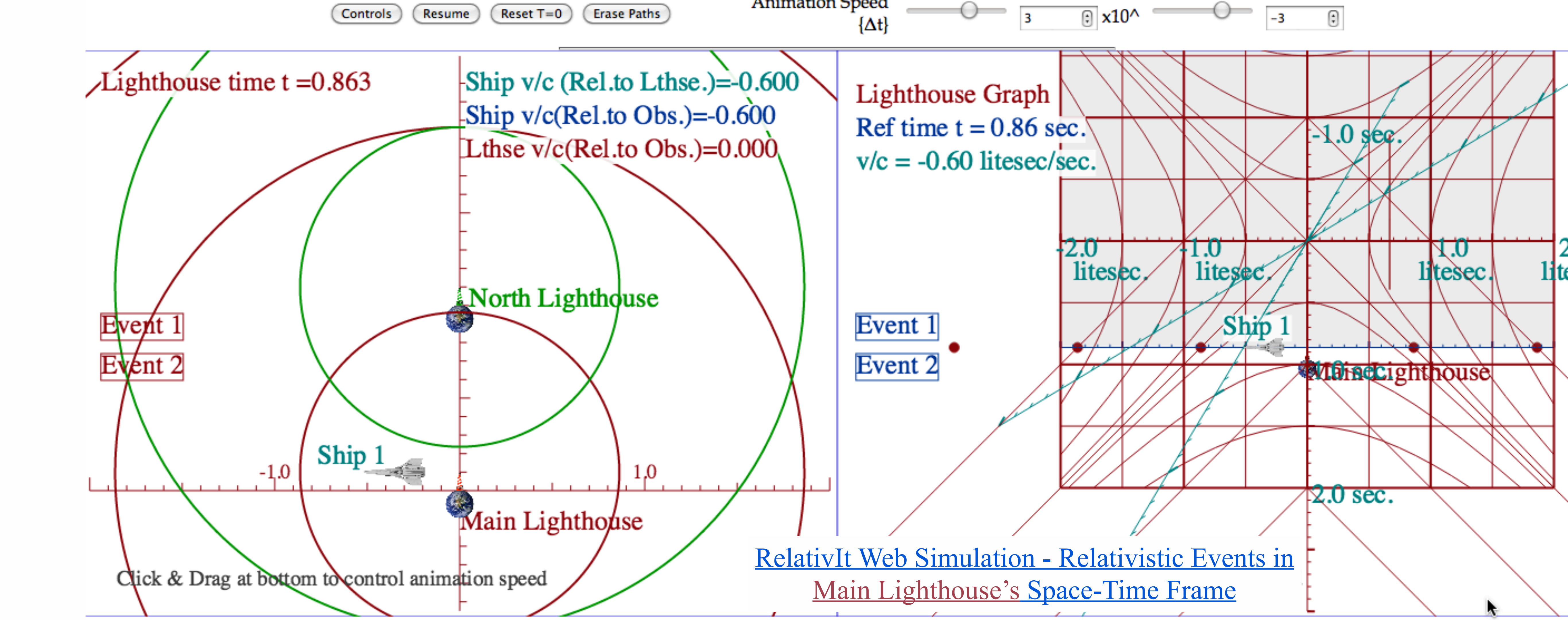
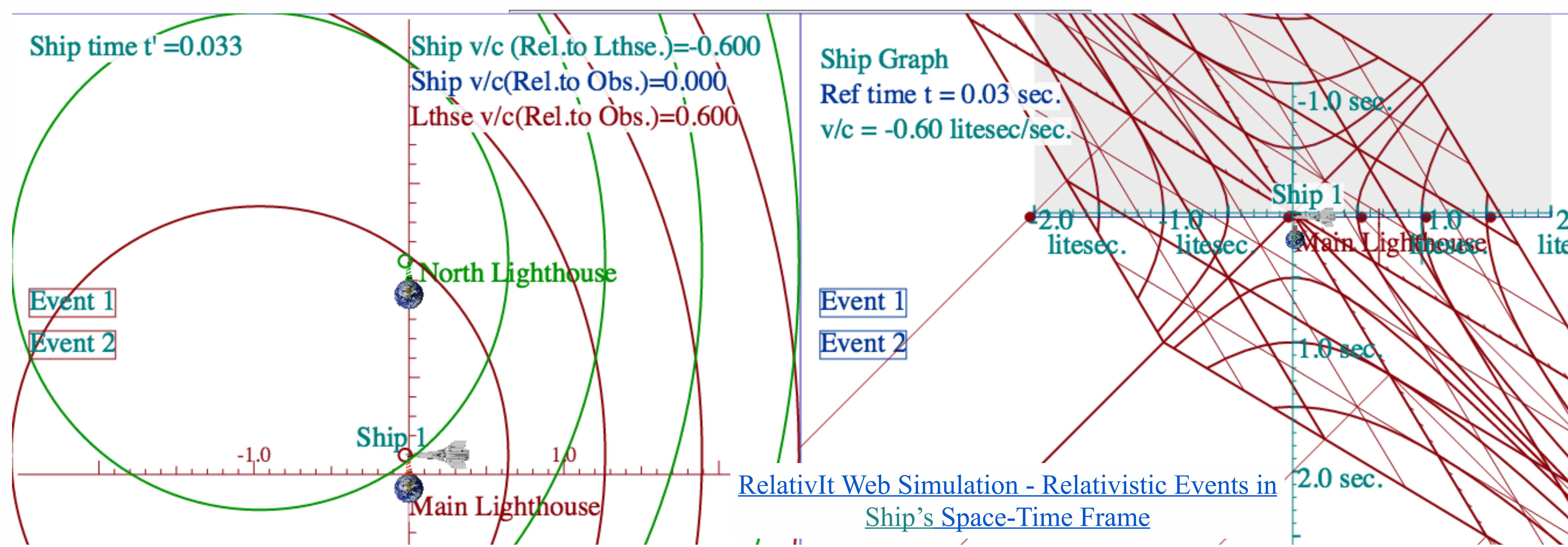


Controls
Resume
Reset T=0
Erase Paths
Animation Speed
{Δt}
3
x10^
-3
Lighthouse time t =0.863
Ship v/c (Rel.to Lthse.)=-0.600
Ship v/c(Rel.to Obs.)=-0.600
Lthse v/c(Rel.to Obs.)=0.000
North Lighthouse
Event 1
Event 2
Ship 1
-1.0
1.0
Main Lighthouse
Click & Drag at bottom to control animation speed
Lighthouse Graph
Ref time t = 0.86 sec.
v/c = -0.60 litesec/sec.
-1.0 sec.
-2.0 litesec.
-1.0 litesec.
1.0 litesec.
2.0 sec.
RelativIt Web Simulation - Relativistic Events in Main Lighthouse's Space-Time Frame



Ship time t' =0.033
Ship v/c (Rel.to Lthse.)=-0.600
Ship v/c(Rel.to Obs.)=0.000
Lthse v/c(Rel.to Obs.)=0.600
North Lighthouse
Event 1
Event 2
Ship 1
-1.0
1.0
Main Lighthouse
Ship Graph
Ref time t = 0.03 sec.
v/c = -0.60 litesec/sec.
-1.0 sec.
-2.0 litesec.
-1.0 litesec.
1.0 litesec.
1.0 sec.
2.0 sec.
RelativIt Web Simulation - Relativistic Events in Ship's Space-Time Frame

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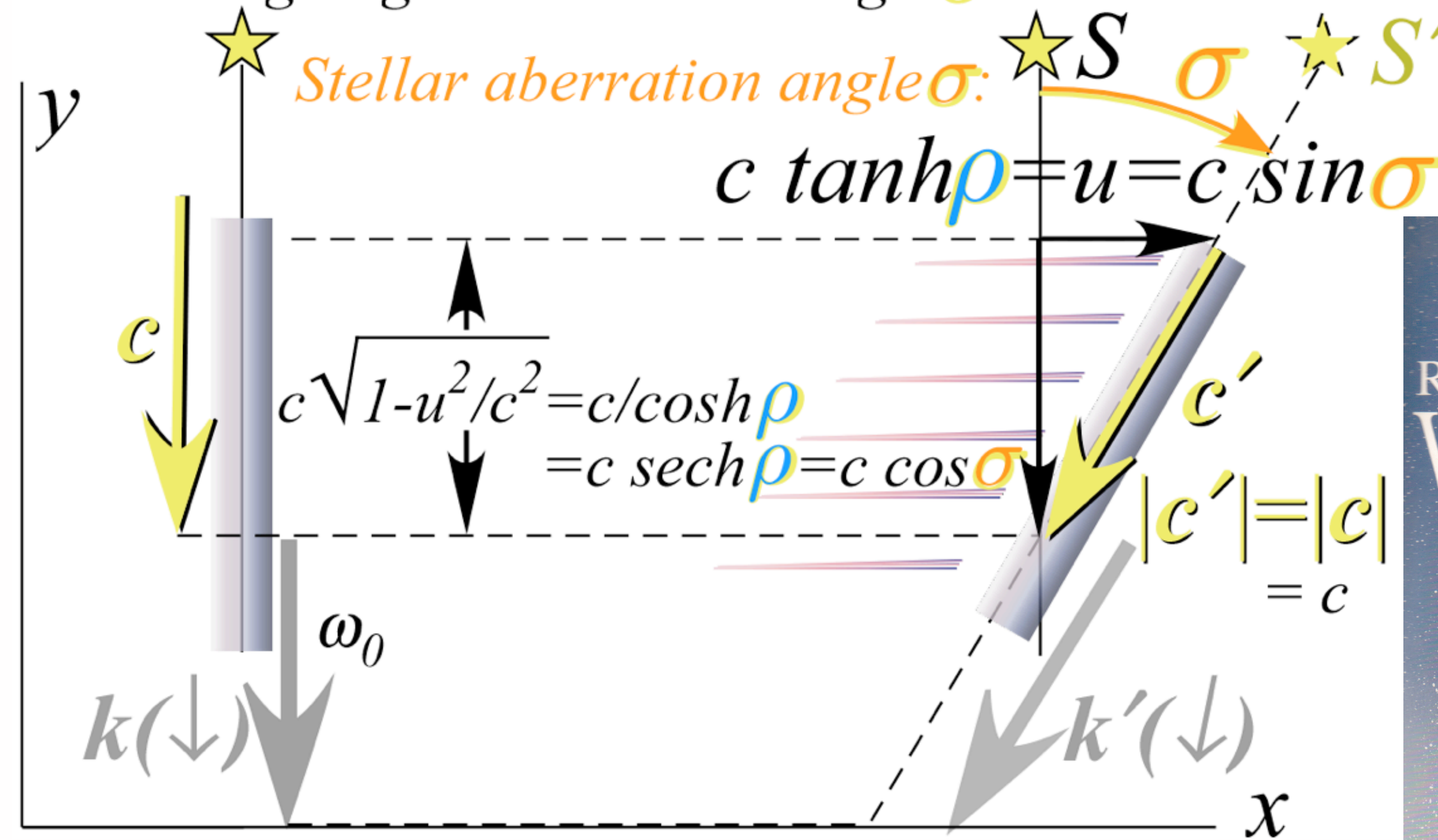
Comparing <u>Longitudinal</u> relativity parameter: Rapidity ρ = $\log_e$(Doppler Shift)

to a <u>Transverse</u>*relativity parameter: Stellar aberration angle σ

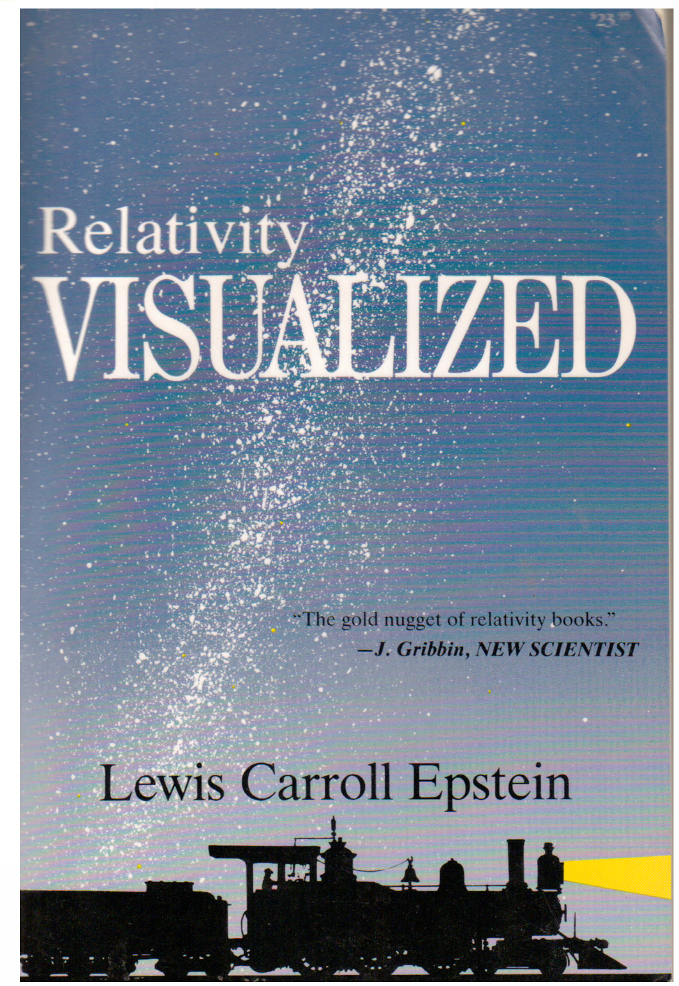
*Lewis Carroll Epstein, ***Relativitätstheorie***, Birkhäuser, (2004) Earlier English version (1985)-

Observer fixed below star sees it directly overhead.

*Observer going **u** sees star at angle σ in **u** direction.*



We used notion σ for stellar-ab-angle, (a "flipped-out" ρ). Epstein not interested in ρ analysis or in relation of σ and ρ.



Purchase at: AllBookstores.com amazon

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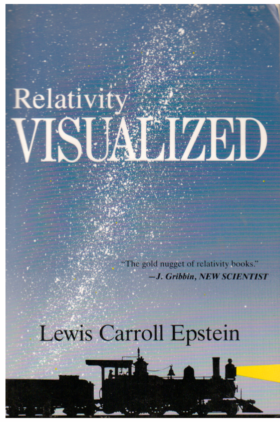
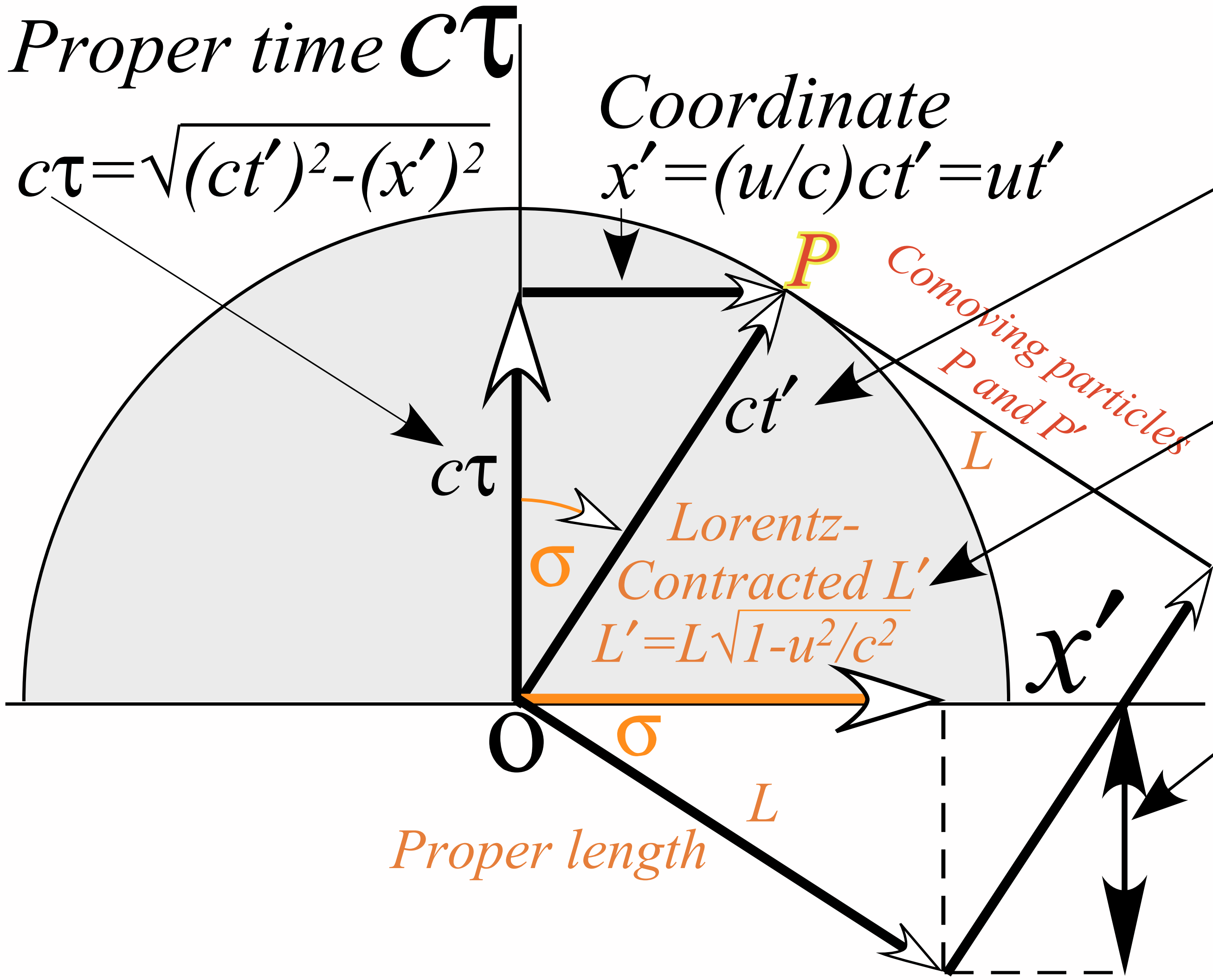


Proper time cτ vs. coordinate space x - (L. C. Epstein's "Cosmic Speedometer")

Particles P and P′ have speed u in (x′,ct′) and speed c in (x, cτ)



Einstein time dilation:

$$ct'=c\tau\sec\sigma=c\tau\cosh\rho = c\tau/\sqrt{1-u^2/c^2}$$

Lorentz length contraction:

$$L'= L\,\mathrm{sech}\rho = L\cos\sigma = L\cdot\sqrt{1-u^2/c^2}$$

Proper Time asimultaneity:

$$c\,\Delta\tau = L'\sinh\rho = L\cos\sigma\sinh\rho$$
$$= L\cos\sigma\tan\sigma$$
$$= L\sin\sigma \quad = L/\sqrt{c^2/u^2-1} \sim L\,u/c$$

Epstein's trick is to turn a hyperbolic form $c\tau=\sqrt{(ct')^2-(x')^2}$ into a circular form: $\sqrt{(c\tau)^2+(x')^2}=(ct')$

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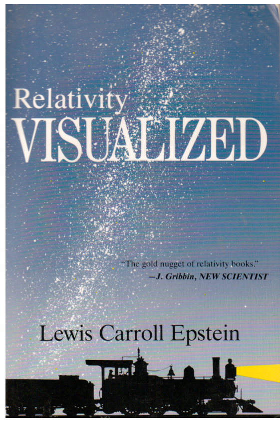

Proper time $c\tau$ *vs. coordinate space x - (L. C. Epstein's "Cosmic Speedometer")*

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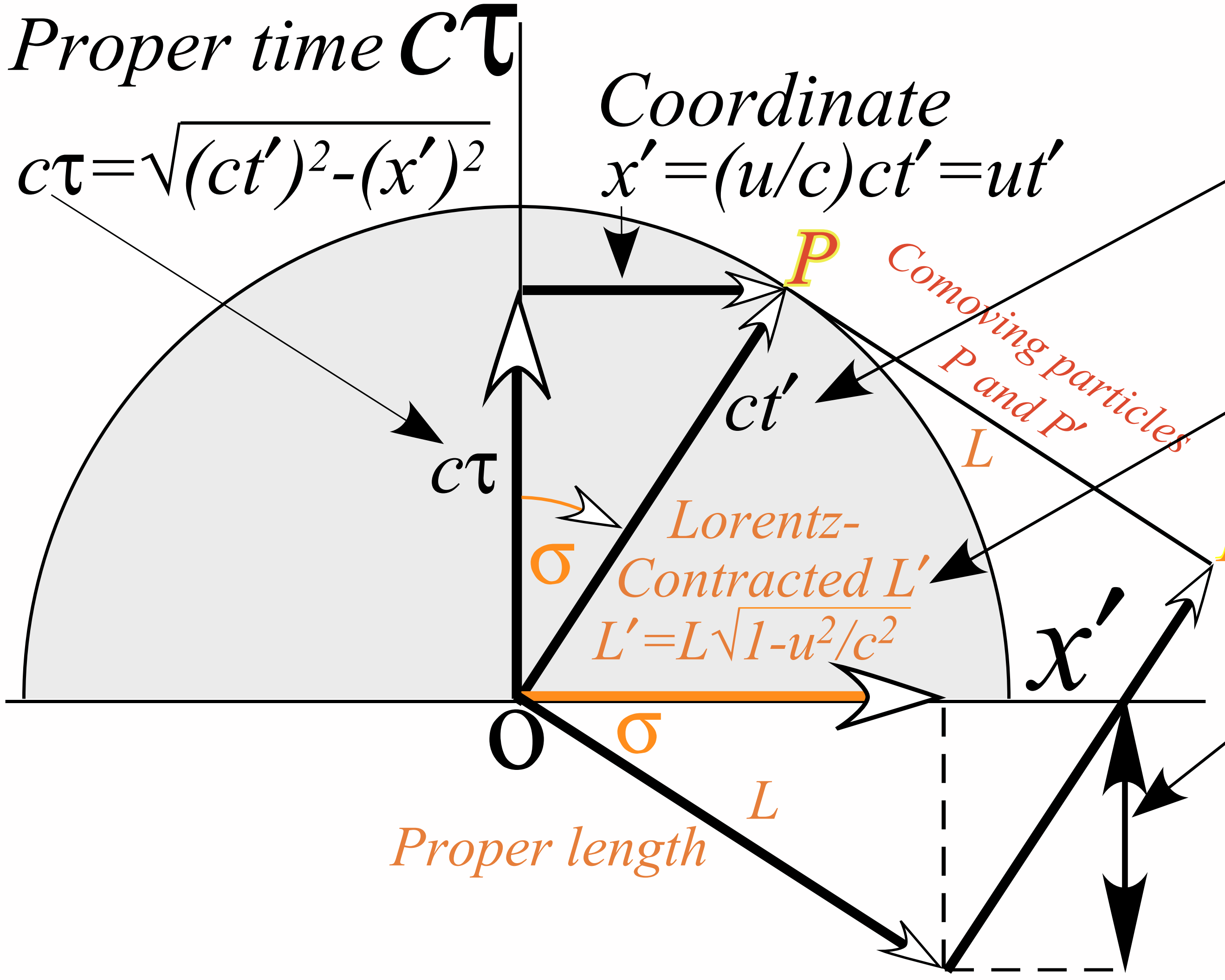

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$$ct' = c\tau \sec\sigma = c\tau \cosh\rho = c\tau/\sqrt{1-u^2/c^2}$$

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$$L' = L\,\text{sech}\rho = L\cos\sigma = L\cdot\sqrt{1-u^2/c^2}$$

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$$c\,\Delta\tau = L'\sinh\rho = L\cos\sigma\sinh\rho$$
$$= L\cos\sigma\tan\sigma$$
$$= L\sin\sigma \quad = L/\sqrt{c^2/u^2-1} \sim L\,u/c$$

Epstein's trick is to turn a hyperbolic form $c\tau = \sqrt{(ct')^2-(x')^2}$ into a circular form: $\sqrt{(c\tau)^2+(x')^2} = (ct')$

Then everything (and everybody) always goes speed c through $(x', c\tau)$ space!

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This map has circle sector arc-area $\sigma = 0.6435$ set to angle $\angle\sigma = 36.87° = 0.6435\,radian$

Also it is set to hyperbola sector arc-area $\rho = 0.6931$ angle $\angle\rho = \nu = 30.96°$

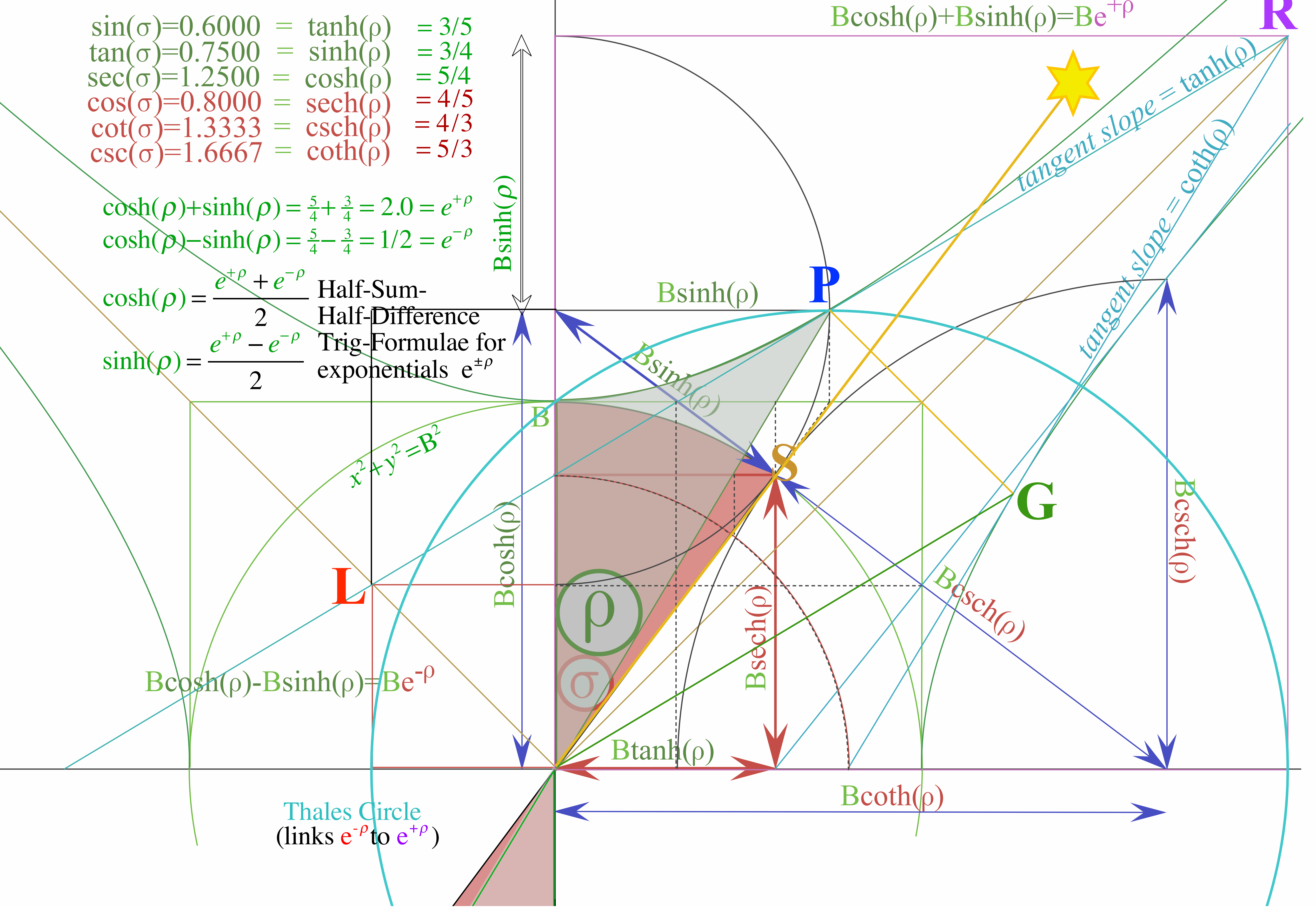
sin(σ)=0.6000 = tanh(ρ) = 3/5
tan(σ)=0.7500 = sinh(ρ) = 3/4
sec(σ)=1.2500 = cosh(ρ) = 5/4
cos(σ)=0.8000 = sech(ρ) = 4/5
cot(σ)=1.3333 = csch(ρ) = 4/3
csc(σ)=1.6667 = coth(ρ) = 5/3

$\cosh(\rho)+\sinh(\rho) = \frac{5}{4}+\frac{3}{4} = 2.0 = e^{+\rho}$

$\cosh(\rho)-\sinh(\rho) = \frac{5}{4}-\frac{3}{4} = 1/2 = e^{-\rho}$

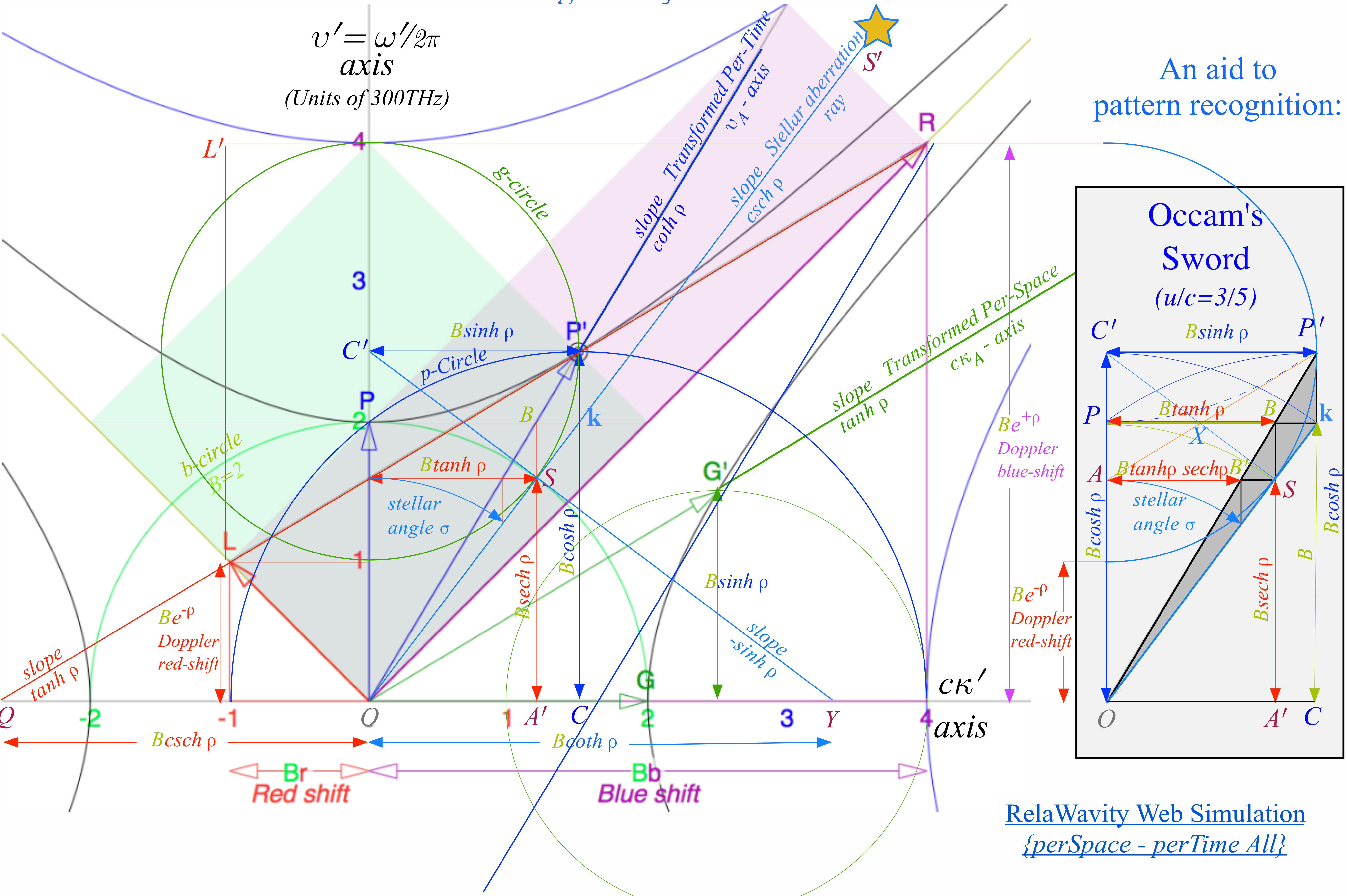
$\cosh(\rho) = \frac{e^{+\rho}+e^{-\rho}}{2}$ Half-Sum-

$\sinh(\rho) = \frac{e^{+\rho}-e^{-\rho}}{2}$ Half-Difference Trig-Formulae for exponentials $e^{\pm\rho}$

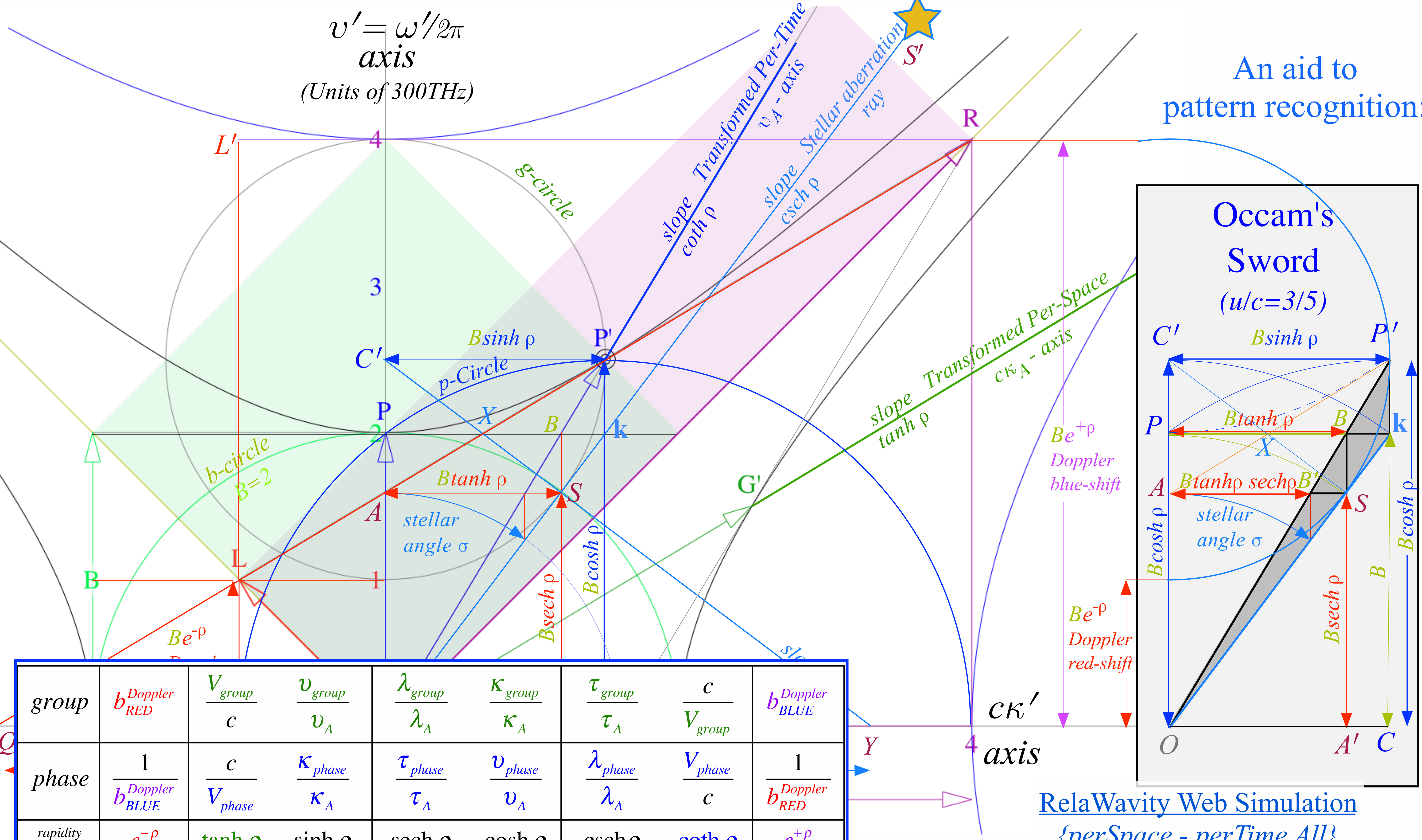


Summary of optical wave parameters for relativity and QM

...and their geometry



[RelaWavity Web Simulation {perSpace - perTime All}]



An aid to pattern recognition:

group	$b^{Doppler}_{RED}$	$\frac{V_{group}}{c}$	$\frac{\upsilon_{group}}{\upsilon_A}$	$\frac{\lambda_{group}}{\lambda_A}$	$\frac{\kappa_{group}}{\kappa_A}$	$\frac{\tau_{group}}{\tau_A}$	$\frac{c}{V_{group}}$	$b^{Doppler}_{BLUE}$
phase	$\frac{1}{b^{Doppler}_{BLUE}}$	$\frac{c}{V_{phase}}$	$\frac{\kappa_{phase}}{\kappa_A}$	$\frac{\tau_{phase}}{\tau_A}$	$\frac{\upsilon_{phase}}{\upsilon_A}$	$\frac{\lambda_{phase}}{\lambda_A}$	$\frac{V_{phase}}{c}$	$\frac{1}{b^{Doppler}_{RED}}$
rapidity ρ	$e^{-\rho}$	$\tanh\rho$	$\sinh\rho$	$\text{sech}\,\rho$	$\cosh\rho$	$\text{csch}\,\rho$	$\coth\rho$	$e^{+\rho}$
stellar ∀ angle σ	$1/e^{+\rho}$	$\sin\sigma$	$\tan\sigma$	$\cos\sigma$	$\sec\sigma$	$\cot\sigma$	$\csc\sigma$	$1/e^{-\rho}$
$\beta\equiv\frac{u}{c}$	$\sqrt{\frac{1-\beta}{1+\beta}}$	$\frac{\beta}{1}$	$\frac{1}{\sqrt{\beta^{-2}-1}}$	$\frac{\sqrt{1-\beta^2}}{1}$	$\frac{1}{\sqrt{1-\beta^2}}$	$\frac{\sqrt{\beta^{-2}-1}}{1}$	$\frac{1}{\beta}$	$\sqrt{\frac{1+\beta}{1-\beta}}$
value for β=3/5	$\frac{1}{2}=0.5$	$\frac{3}{5}=0.6$	$\frac{3}{4}=0.75$	$\frac{4}{5}=0.80$	$\frac{5}{4}=1.25$	$\frac{4}{3}=1.33$	$\frac{5}{3}=1.67$	$\frac{2}{1}=2.0$

RelaWavity Web Simulation
{perSpace - perTime All}

Table of 12 wave parameters (includes inverses) for relativity

...and values for *u/c=3/5*

RelaWavity Web Simulation
Expanded *Table of Relativistic* Relations

Lecture 31
Thur. 12.10.2015

Review: Relawavity ρ functions Two famous ones Extremes and plot vs. ρ
Doppler jeopardy Geometric mean and Relativistic hyperbolas
Animation of $e^{\rho}=2$ spacetime and per-spacetime plots

Rapidity ρ related to *stellar aberration angle* σ and L. C. Epstein's approach to relativity
Longitudinal hyperbolic ρ-geometry connects to transverse circular σ-geometry
"Occams Sword" and summary of 16 parameter functions of ρ and σ
➔ Applications to optical waveguide, spherical waves, and accelerator radiation

Derivation of relativistic quantum mechanics
What's the matter with mass? Shining some light on the Elephant in the room
Relativistic action and Lagrangian-Hamiltonian relations
Poincare' and Hamilton-Jacobi equations

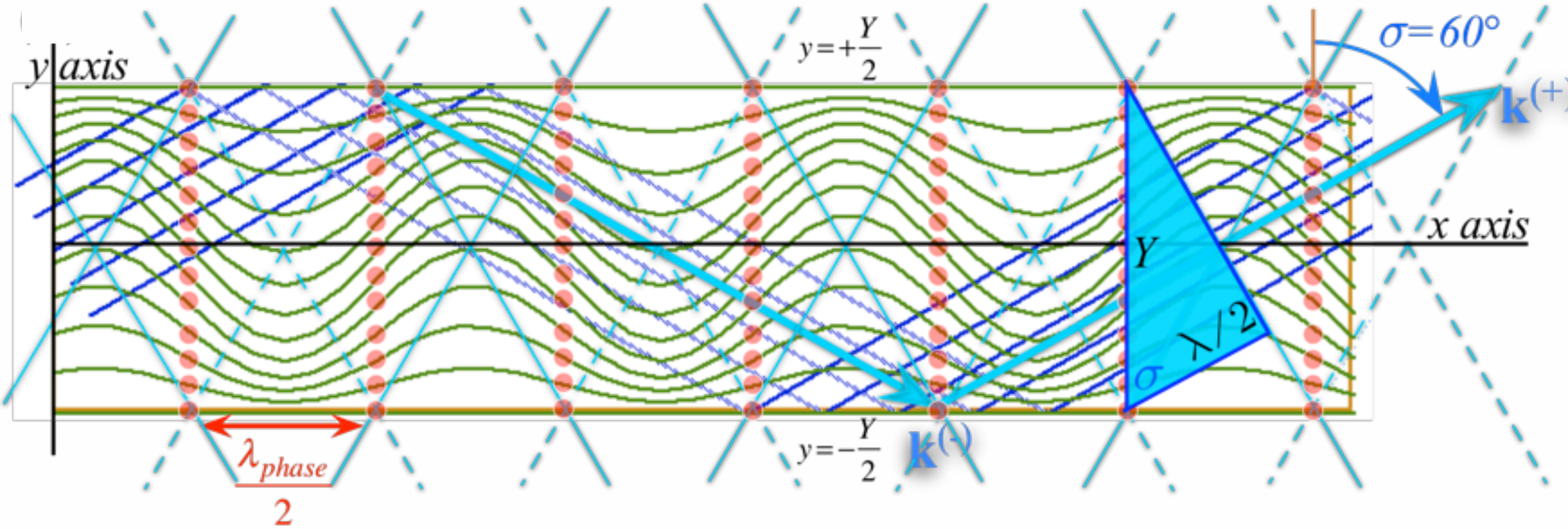
Relativistic optical transitions and Compton recoil formulae
Feynman diagram geometry
Compton recoil related to rocket velocity formula
Comparing 2^{nd}-quantization "photon" number N and 1^{st}-quantization wavenumber κ

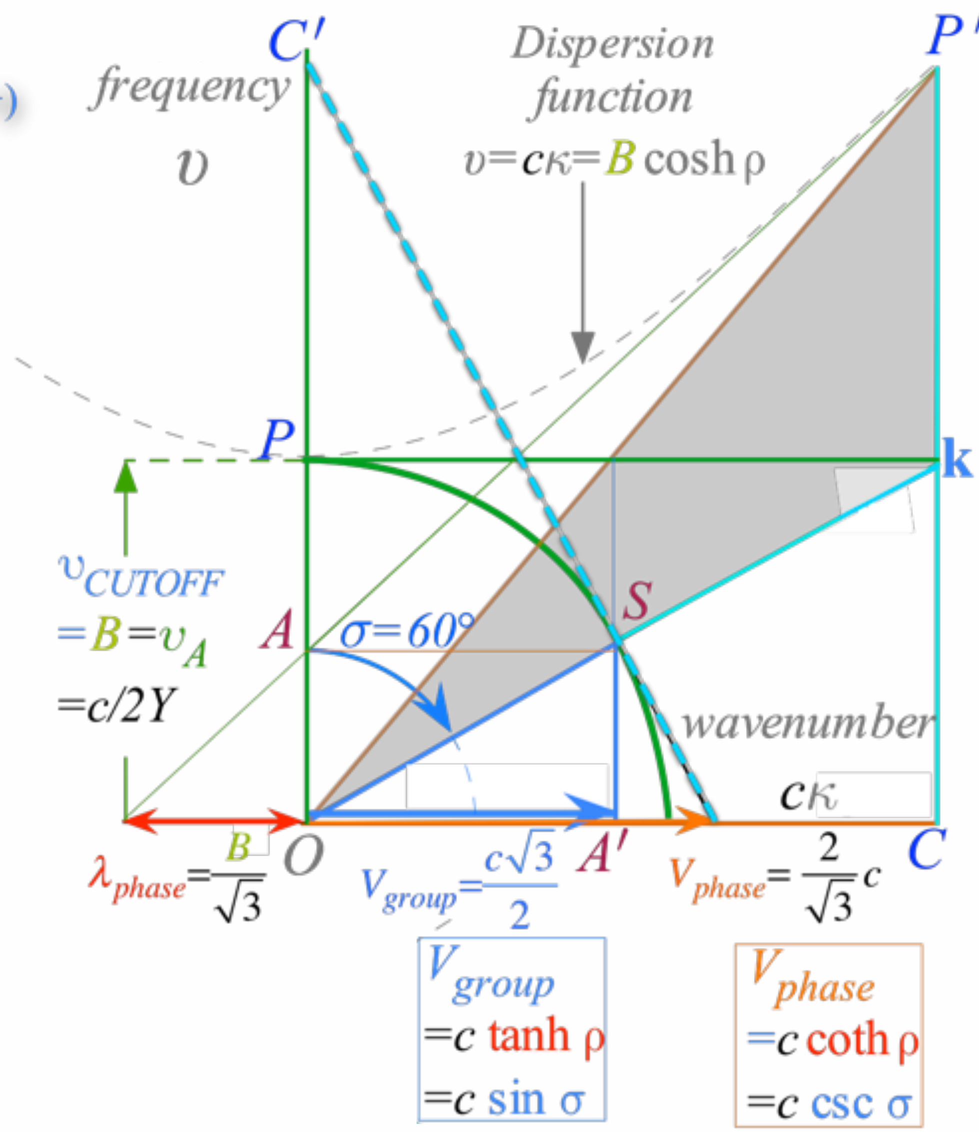
Relawavity in accelerated frames
Laser up-tuning by Alice and down-tuning by Carla makes *g*-acceleration grid
Analysis of constant-*g* grid compared to zero-*g* Minkowsi grid
Animation of mechanics and metrology of constant-g grid

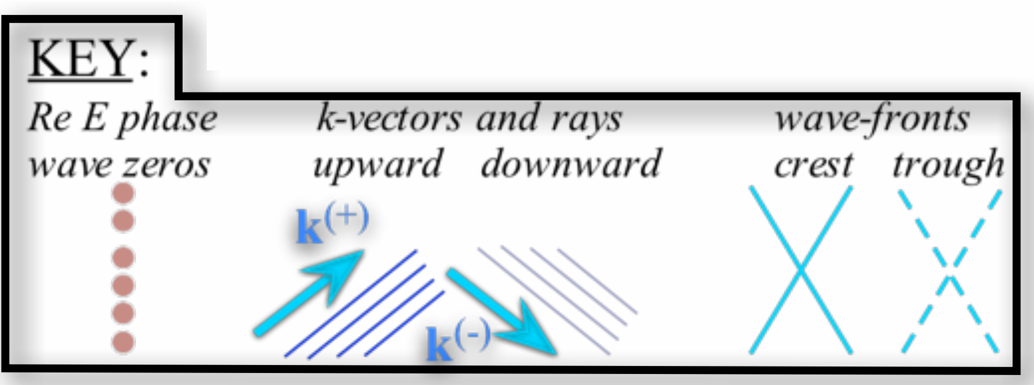
Optical wave guide relativistic geometry aided by Occam's Sword

geometry applies to (x,y) space-space
to (k_x,k_y)per-space-per-space
to (x,ct) space-time

Relativistic mode with near-c $V_{group}=c/2$ and $V_{phase}=2c$. (Low dispersion.)







Optical wave guide relativistic geometry aided by Occam's Sword

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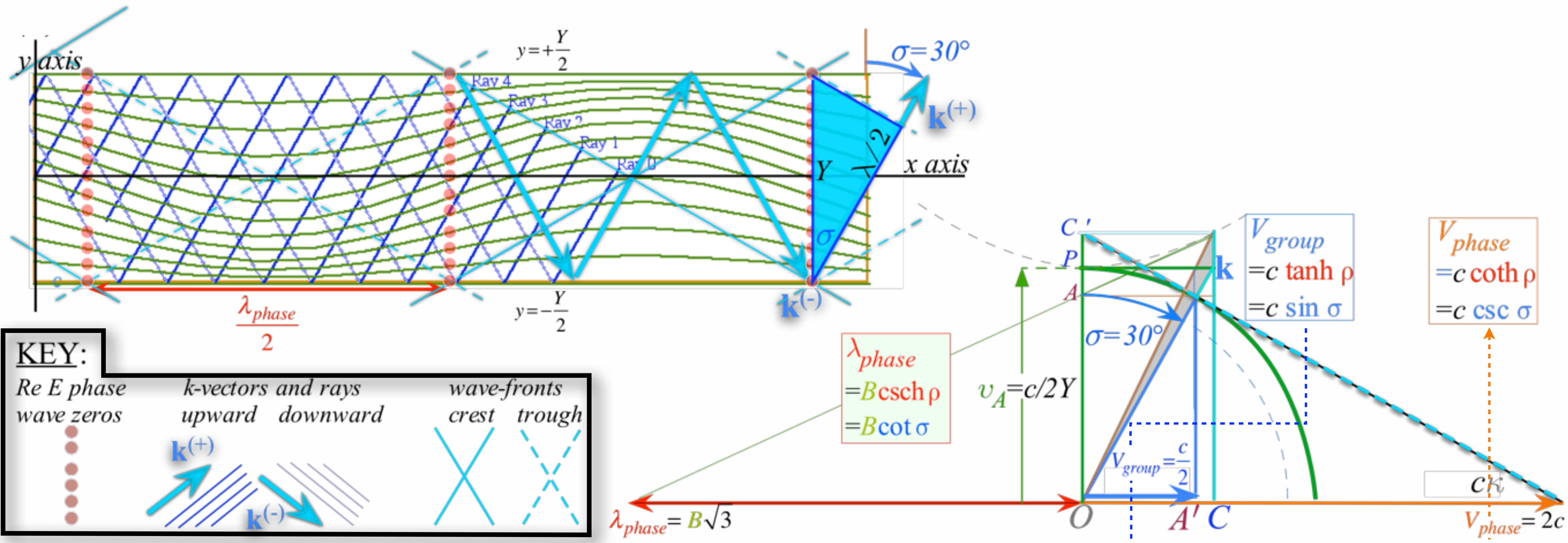
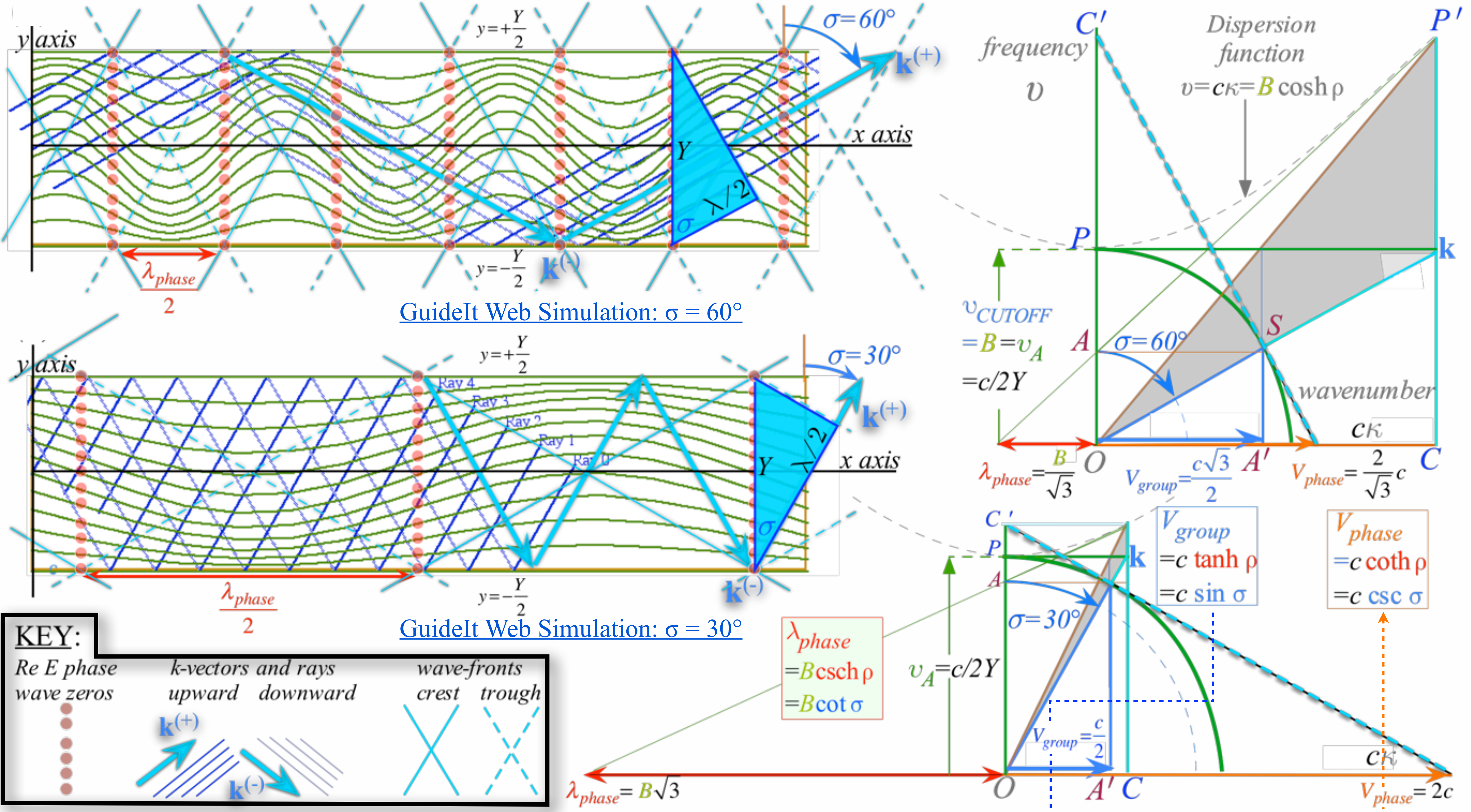


Example of near-cut-off mode with low $V_{group}=c/2$ and high $V_{phase}=2c$. (High dispersion.)

Optical wave guide relativistic geometry aided by Occam's Sword

geometry applies to (x,y) space-space
to (k_x,k_y)per-space-per-space
to (x,ct) space-time

Relativistic mode with near-c $V_{group}=c/2$ and $V_{phase}=2c$. (Low dispersion.)



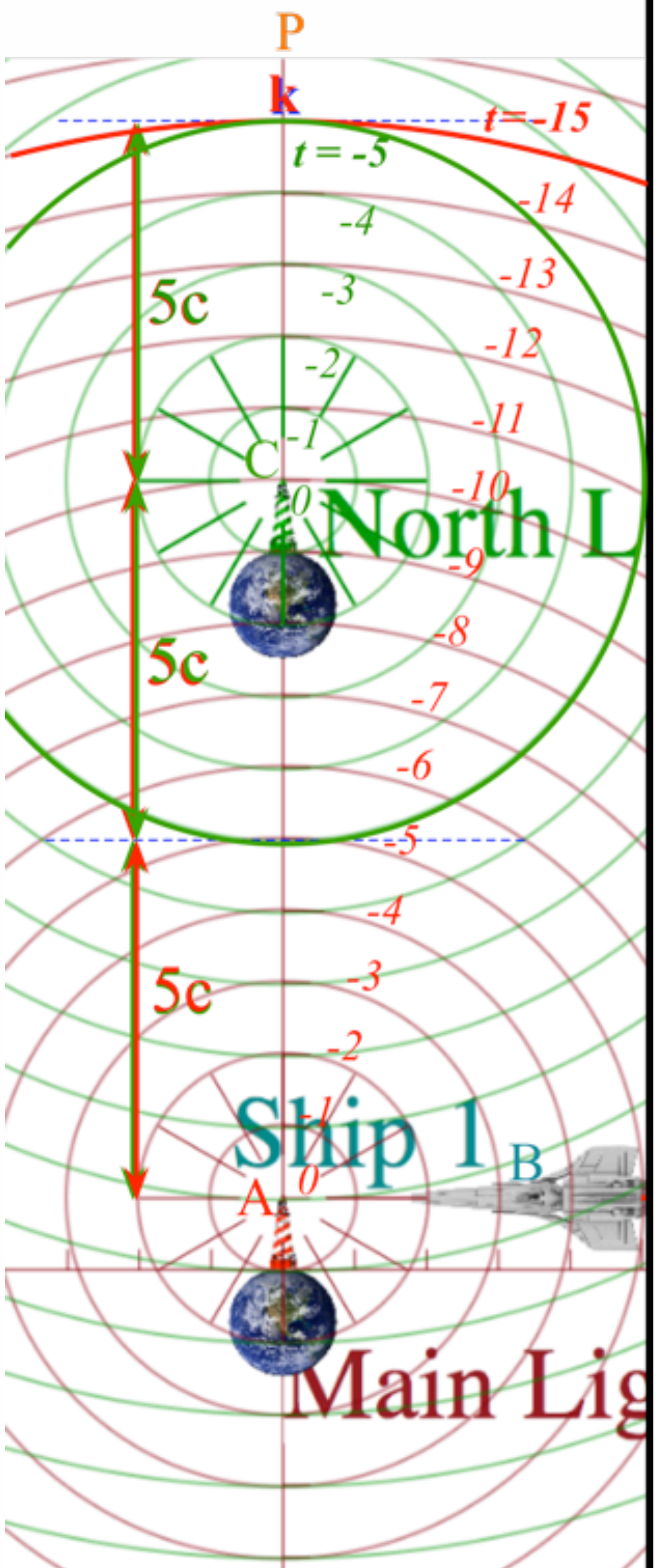
Example of near-cut-off mode with low $V_{group}=c/2$ and high $V_{phase}=2c$. (High dispersion.)

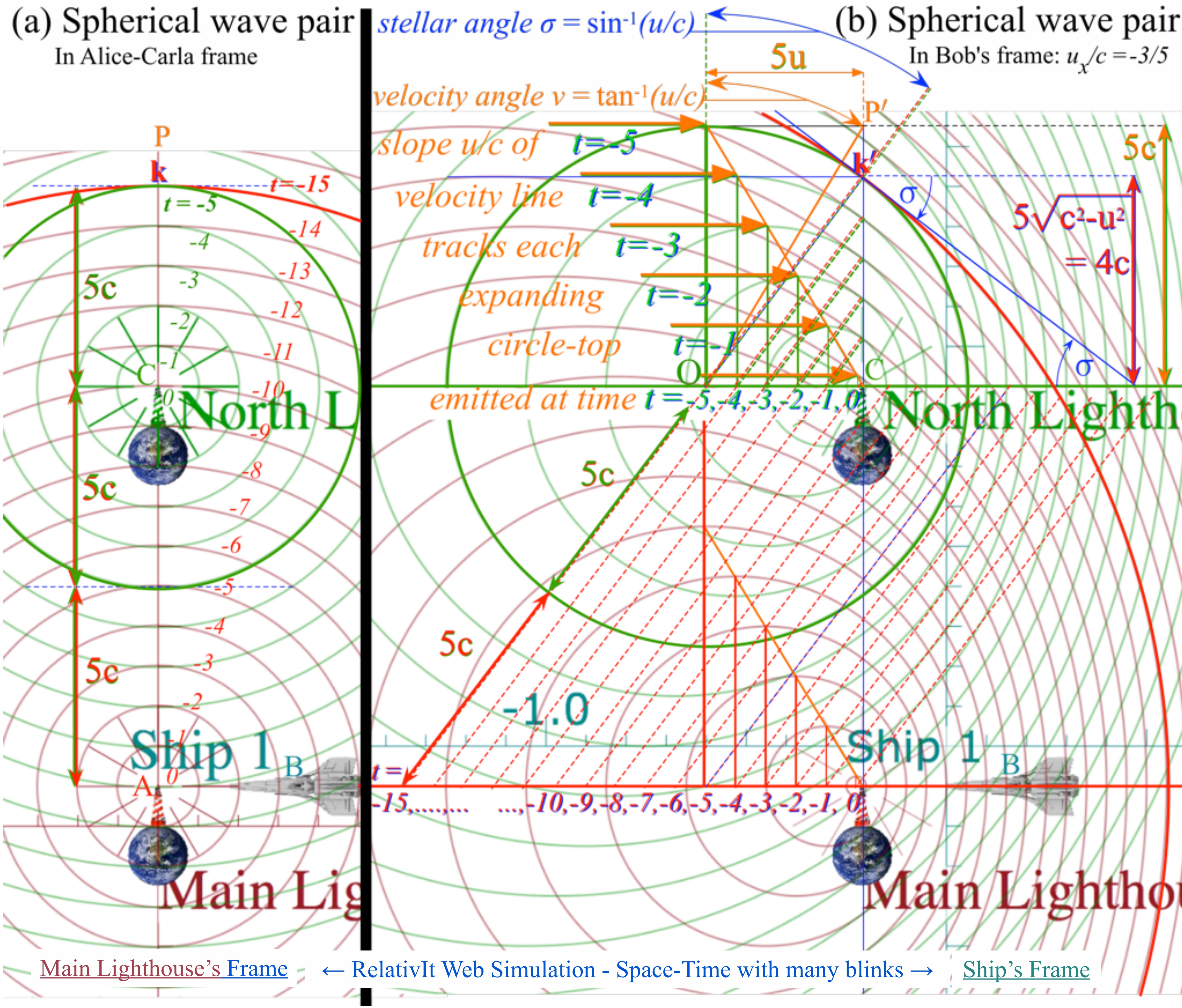
Spherical wave relativistic geometry

Also, aided by Occam's Sword

(a) Spherical wave pair

In Alice-Carla frame

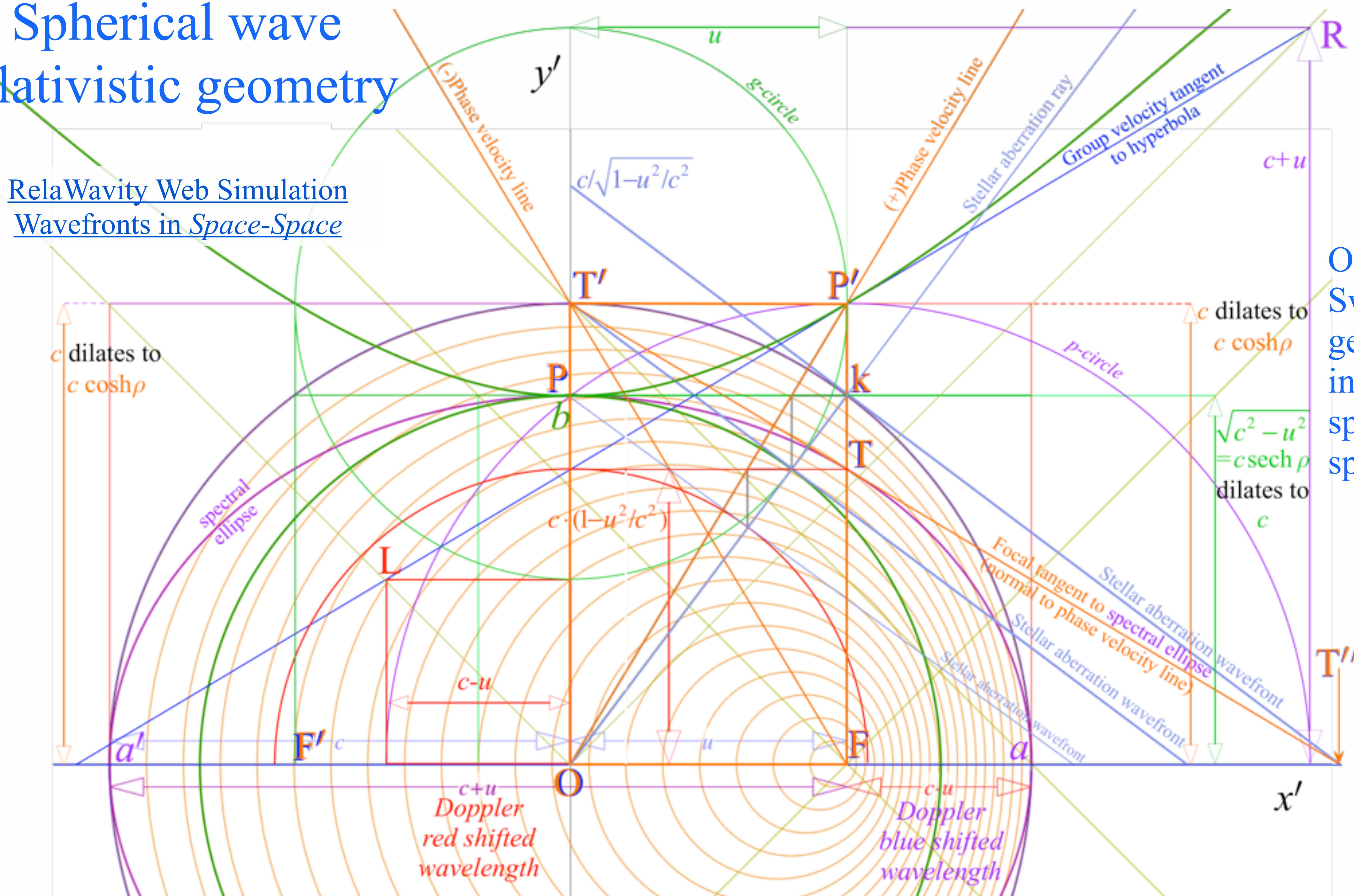




Occam Sword geometry in (x,y) space-space

Spherical wave relativistic geometry

[RelaWavity Web Simulation Wavefronts in *Space-Space*]



Occam Sword geometry in (x,y) space-space

Doppler Red λ=c+u

dilates to: $(c+u)\cosh\rho = c\sqrt{\frac{c+u}{c-u}} = ce^{+\rho}$

ellipse major radius a=**OF**a=c

dilates to: $c\cosh\rho = c/\sqrt{1-u^2/c^2}$

Applications of Einstein dilation factor:

$\gamma = \cosh\rho = 1/\sqrt{1-u^2/c^2}$

ellipse focal length **FO**= $u = c\tanh\rho$

dilates to: $u\cosh\rho = c\sinh\rho$

ellipse latus radius **FT**=$c(1-u^2/c^2)$

dilates to: $c(1-u^2/c^2)\cosh\rho$

$= c\sqrt{1-u^2/c^2} = c\ \mathrm{sech}\rho$

Doppler Blue λ=$c-u$

dilates to: $(c-u)\cosh\rho = c\sqrt{\frac{c-u}{c+u}} = ce^{-\rho}$

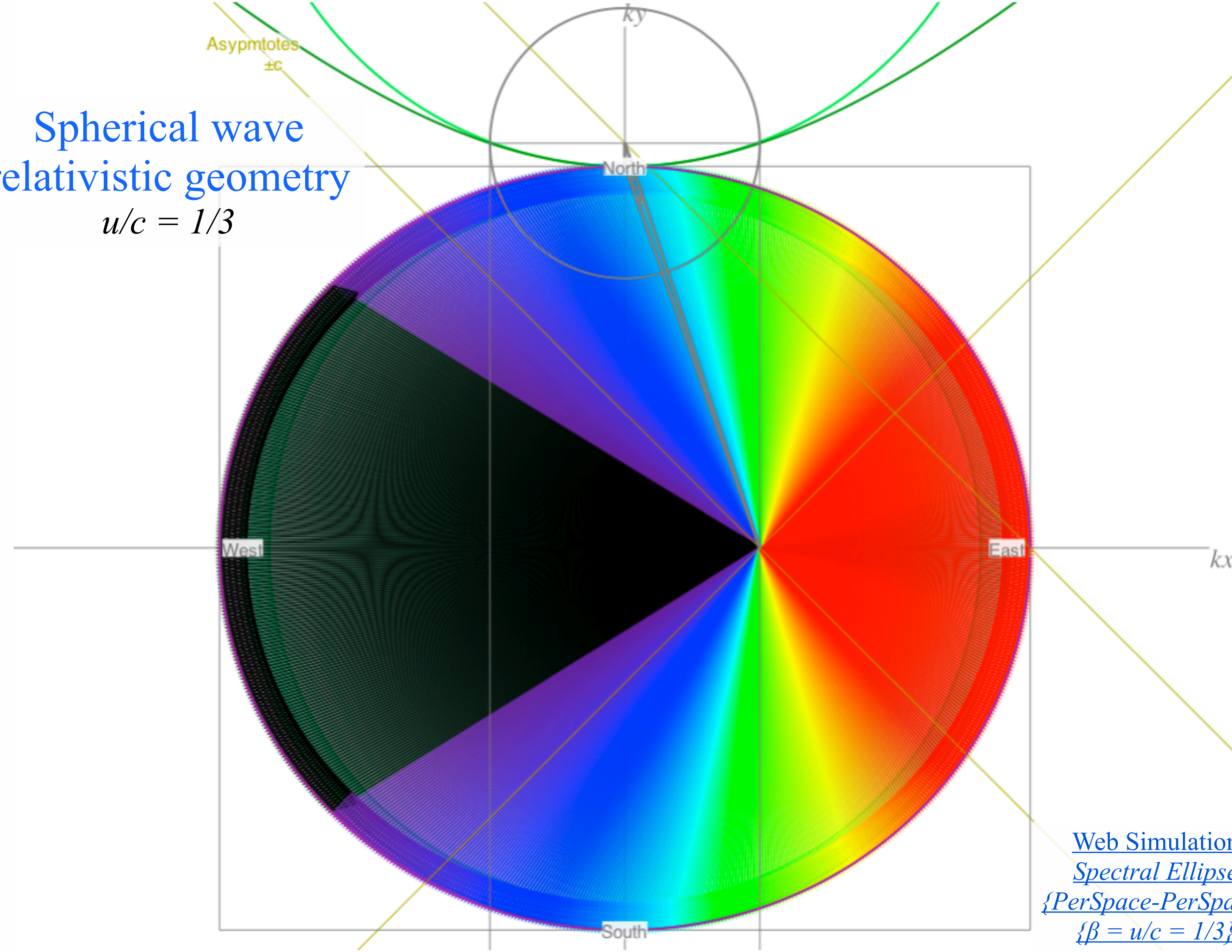
Base height **FTk**=$\sqrt{c^2-u^2}$

dilates to: $\sqrt{c^2-u^2}\cosh\rho = c$

(equal to ellipse minor radius b)

Spherical wave relativistic geometry

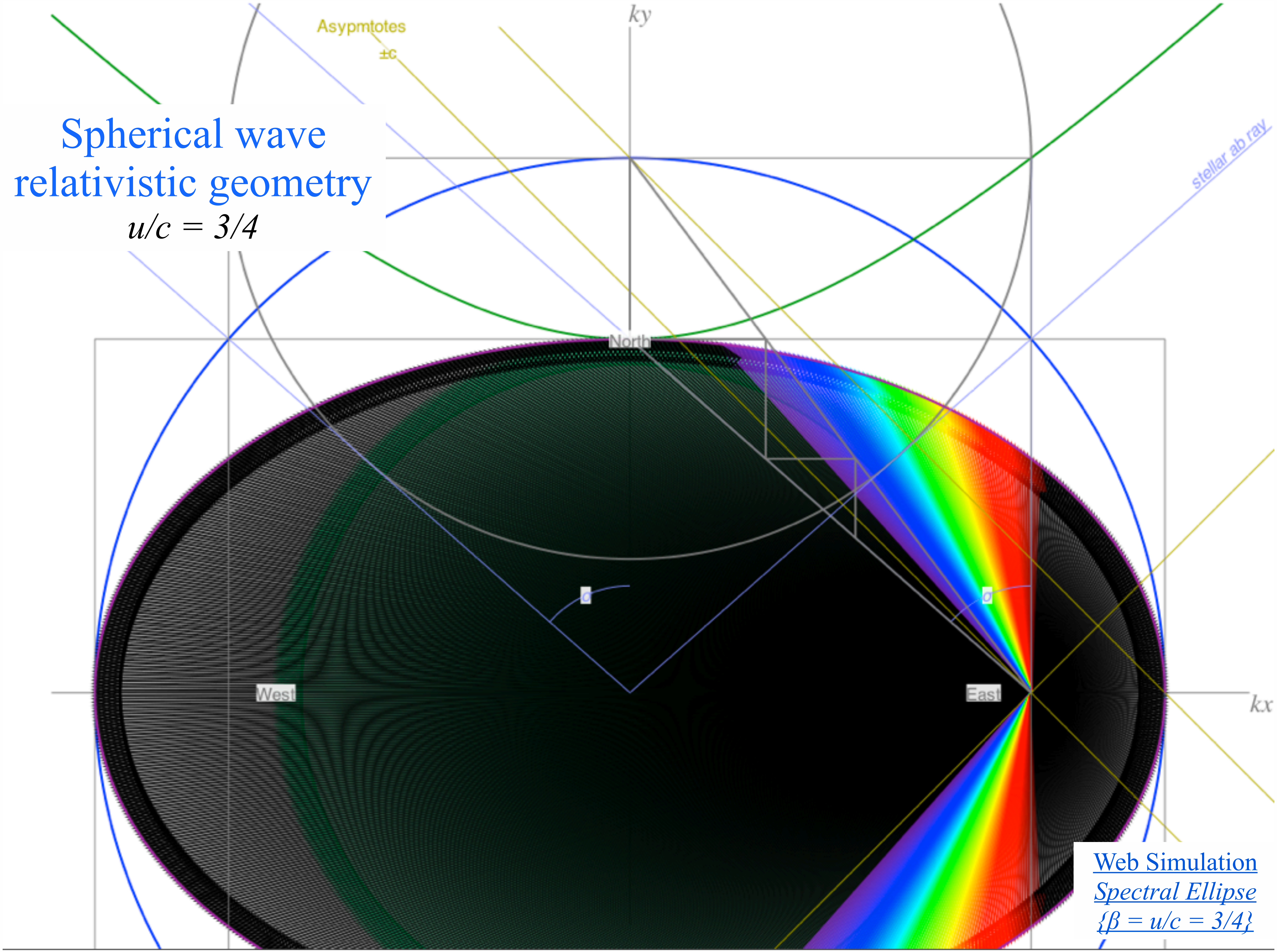
u/c = 1/3



[Web Simulation](#)
[*Spectral Ellipse*](#)
[*{PerSpace-PerSpace}*](#)
[*{β = u/c = 1/3}*](#)

Spherical wave relativistic geometry

u/c = 3/4



Web Simulation
Spectral Ellipse
{β = u/c = 3/4}