

Lecture 23 *Relativity* Introduction

Tuesday 4.05.2016

Relativity: Relativistic wave mechanics I. 1st-order Doppler shifts

(Unit 3 4.05.16)

Special Relativity and Quantum Mechanics regarded as *mysterious* and *lacking clarity*

Bob&Alice regard for clarity of SR: **foggy** or QM: **opaque**

Can this situation be improved at fundamental axiomatic level?

Evidence and concepts needing critical review:

QM (*Planck, 1900*) and SR (*Einstein, 1905*) are both about light (*em waves*)

Galilean relativity, how it fails for light and how it doesn't

The great light-wave speed-limit ($c=2.99792458m/s$. by *Evenson, ..., Hall 1972*)

Need better axioms (*Occam's Razors & Evenson's Lasers*): CW axioms outwit old PW axioms

Introduce "*Keyboard of the gods*" CW per-space-time (κ, ν) that rules (λ, τ) space-time

Introduce idea of quantized wavenumber- κ_n and amplitude A_n (*1st and 2nd quantization*)

Introduce **infrared (IR) 300 THz**, **green 600THz**, and **ultra-violet (UV) 1200THz** CW laser beams

Optical Doppler CW frequency shift ν_A/ν_B : A hidden key to understanding modern physics

Bob and Alice deduce Evenson's CW Axiom: *All colors march together at $c = \nu\lambda = \nu/\kappa$*

Bob, Alice, and Carla discover *rapidity* ($\rho_{AB}=\ln \nu_A/\nu_B$), a longitudinal measure of speed

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Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$



Bob: Don't worry Alice, I don't understand this relativity or the quantum theory, but I bet the professor doesn't either.

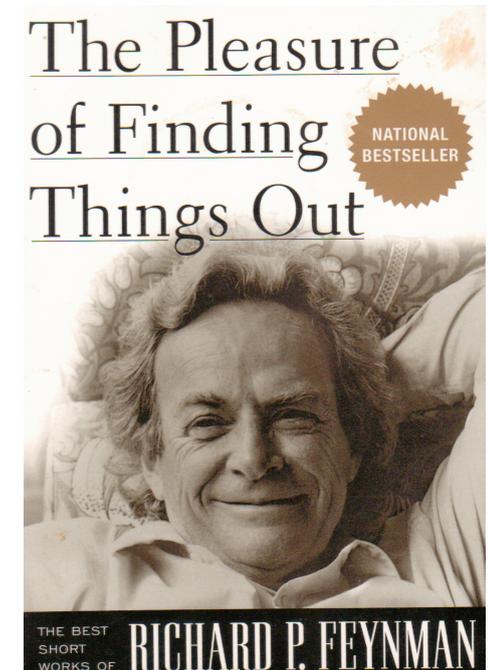
"If you think you understand quantum mechanics, you don't..."
 Quote from R. P. Feynman in "Character of Physical Law" University Lecture

The quote, exact words, "If you think you understand quantum mechanics, you don't..." in Google hits about 16,500 pages. But I can't find anywhere that actually gives a written source! What to do? Possibly, originated with [Niels Bohr](#): "Anyone who is not shocked by quantum theory has not understood it." Similar problems with checking a *much* older quote "Only 12 people understand relativity..."

My personal opinion about my first graduate advisor: I doubt he meant to attach a Catch-22 to understanding physics.

I like relativity and quantum theories
 Because I don't understand them
 and they make me feel as if space shifted about like a swan that can't settle, refusing to sit still and be measured:
 and as if the atom were an impulsive thing always changing its mind.

—D. H. LAWRENCE
 From [Jargodzki and Potter](#)
 "Mad About Physics"



Current understanding of relativity and QM at UAF



NWAT photo by David Gottschalk

Current understanding of relativity and QM at UAF (and the World)



- [1] D. F. Styer, M. S. Balkin, K. M. Becker, M. R. Bums, C. E. Dudley, S. T. Forth, J. S. Gaumer, M. A. Kramer, D. C. Oertel, L. H. Park, M. T. Rinkoski, C. T. Smith, and T. D. Wotherspoon, “**Nine Formulations of Quantum Mechanics**”, *Am. J. Phys.* **70**, 288 (2002).

Current understanding of relativity and QM at UAF (and the World)



NWAT photo by David Gottschalk



Can we clarify? ...and simplify?

Current understanding of relativity and QM at UAF_(and the World)



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Can we clarify by simplifying?

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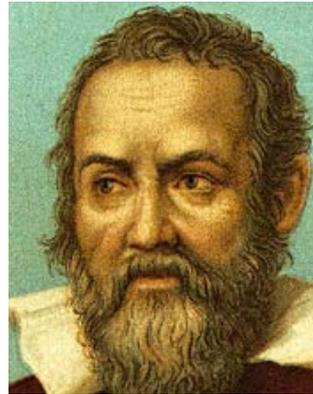
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Level 1 Secrets *(which really shouldn't be secrets at all!)*

Some have forgotten... Special relativity and quantum mechanics
are very much a story of
the geometry of light-wave motion

looks worried?



Galilei Galileo
1564-1642

Need to review...

- Where Galilean relativity fails for light waves,
...and where it doesn't.

and then see...

- How to make sense of light-wave **SPEED LIMIT** axiom(s)

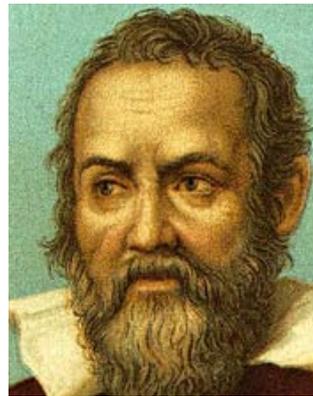
**SPEED
LIMIT**
C=
299,792,458
m/s

Good approximation:
 $c \cong 300 \text{ million m/s}$
 300 Megameter/s

(We'll use frequencies divisible by 3)

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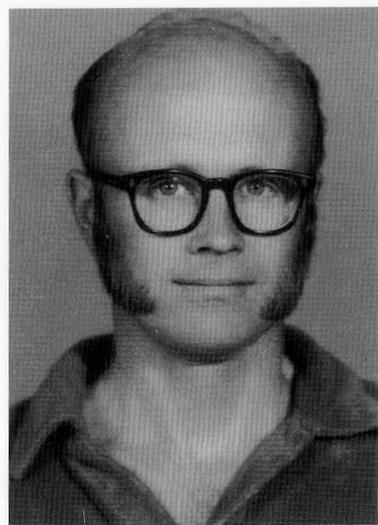
axiom(s)

by comparing *Einstein Pulse Wave (PW)* axiom
with
Evenson Continuous Wave (CW) axiom

Good approximation:
 $c \cong 300 \text{ million m/s}$
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in *space-time* and *inverse space-time*

(We'll use frequencies divisible by 3)



PAULINIA, BRASIL 1976

THE SPEED OF LIGHT IS
299,792,458 METERS PER SECOND!

Kenneth M. Evenson
1932-2002

[Link to ⇒ Speed of Light From Direct Frequency and Wavelength Measurements](#)

At Journal site ⇒ [K. M. Evenson, J.S. Wells, F.R. Peterson, B.L. Danielson, G.W. Day, R.L. Barger and J.L. Hall, Phys. Rev. Letters 29, 1346\(1972\).](#)

In 2005 the Nobel Prize in physics was awarded to Glauber, Hall, and Hensch†† for laser optics and metrology.

†† *The Nobel Prize in Physics, 2005.* <http://nobelprize.org/>

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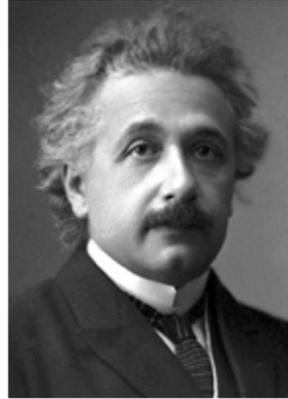
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axiom(s)?

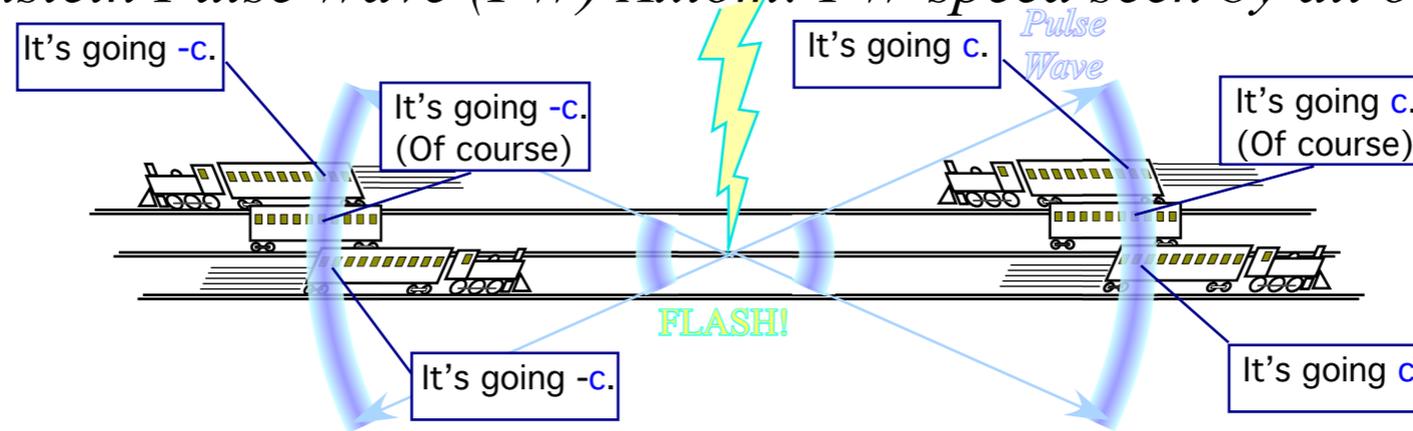
And, HE-eee-rRE'S Albert!

Albert Einstein

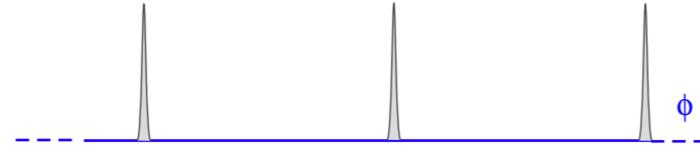


1879-1955

Einstein Pulse Wave (PW) Axiom: PW speed seen by all observers is c



Pulse wave (PW) train

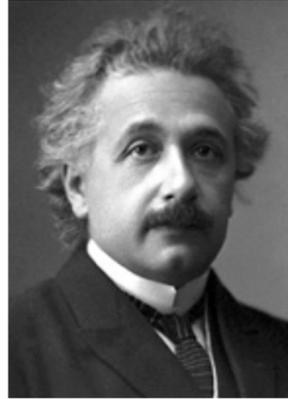


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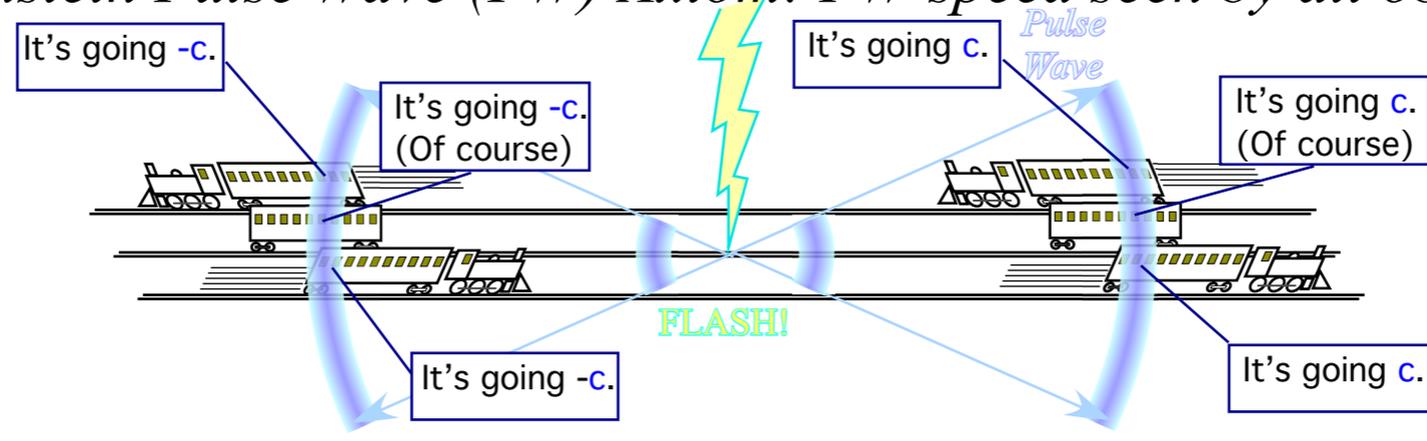


Albert Einstein

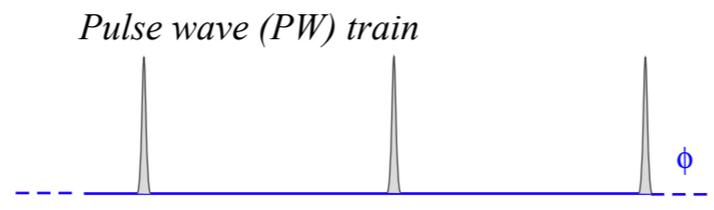
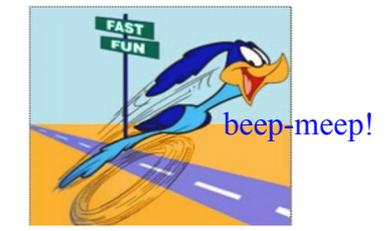


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A "road-runner" axiom is a "show-stopper"

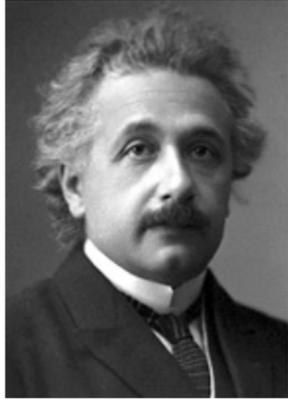


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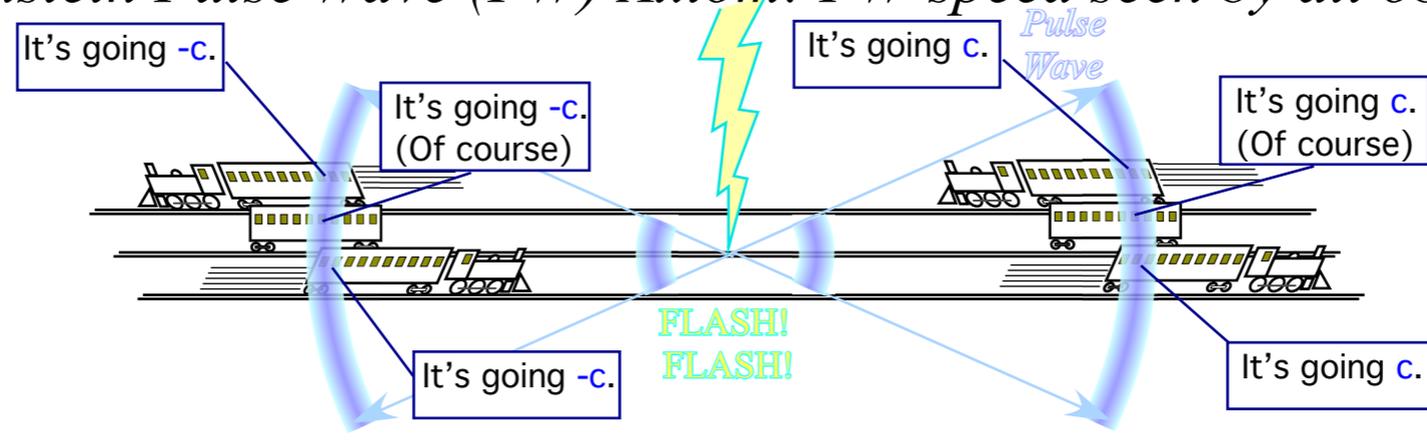


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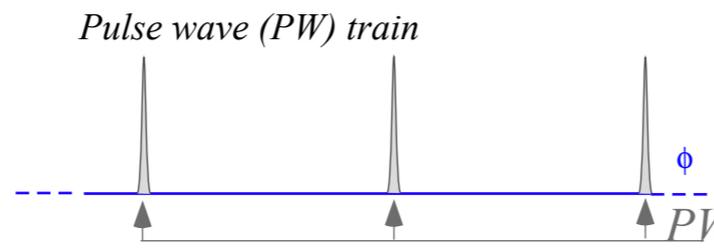
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Since when is cartoon physics a reality?!



$$A_1 \cos \omega t + A_2 \cos 2\omega t + A_3 \cos 3\omega t + A_4 \cos 4\omega t + \dots$$

..though it has a Newtonian "Place for everything & everything in place" feel.

PW Axiom is complicated

PW peaks precisely locate places where wave is.

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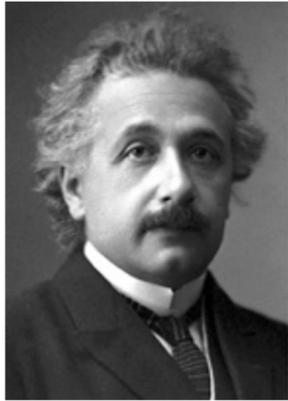
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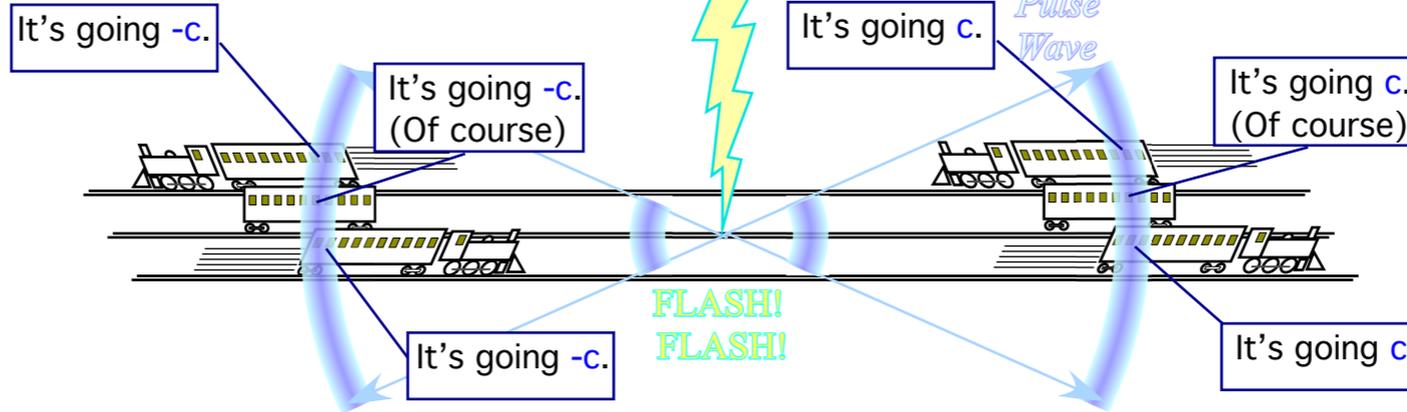


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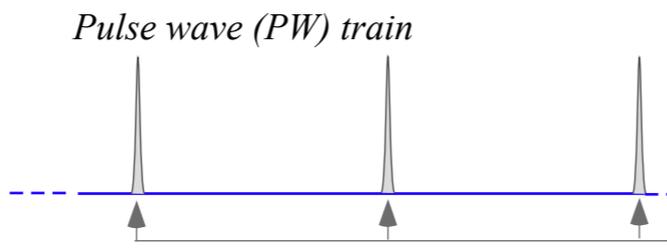
William of Ockham



1285-1349

Using Occam's Razor

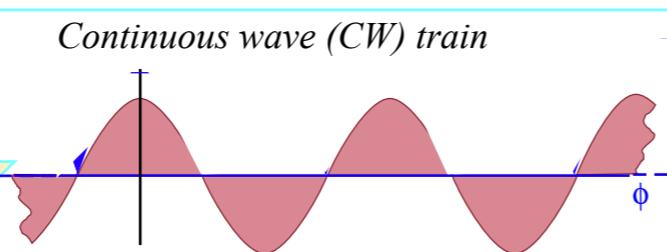
(and Evenson's lasers)



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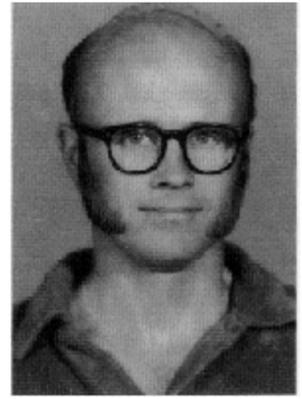
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$A \cos \omega t$

Evenson Continuous Wave (CW) axiom: CW speed for all colors is c

Kenneth Evenson



1932-2002

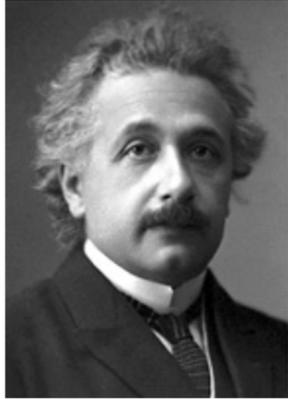
Cut a PW to just one Continuous Wave

• How do you make sense of light-wave axiom(s)?

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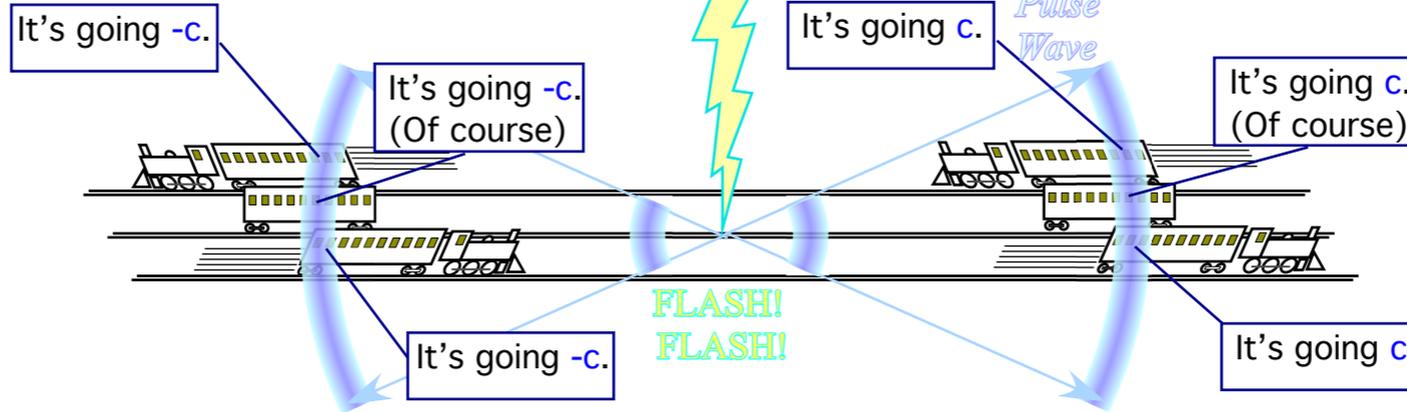


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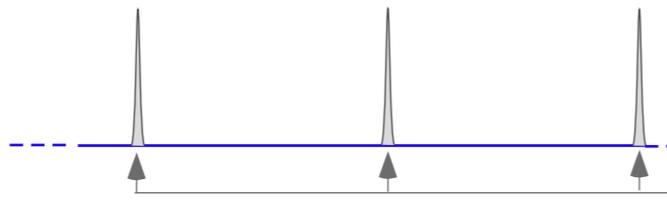


1285-1349

Using Occam's Razor

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Pulse wave (PW) train

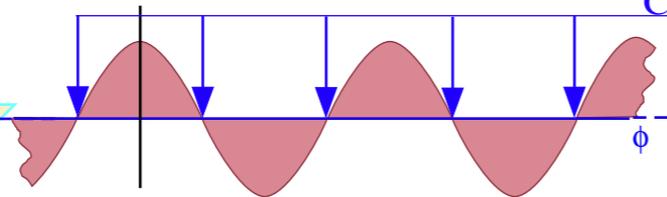


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Continuous wave (CW) train



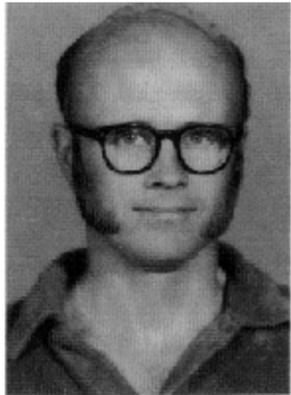
$A \cos \omega t$

Simpler 1CW coherence is more "Zen-like"

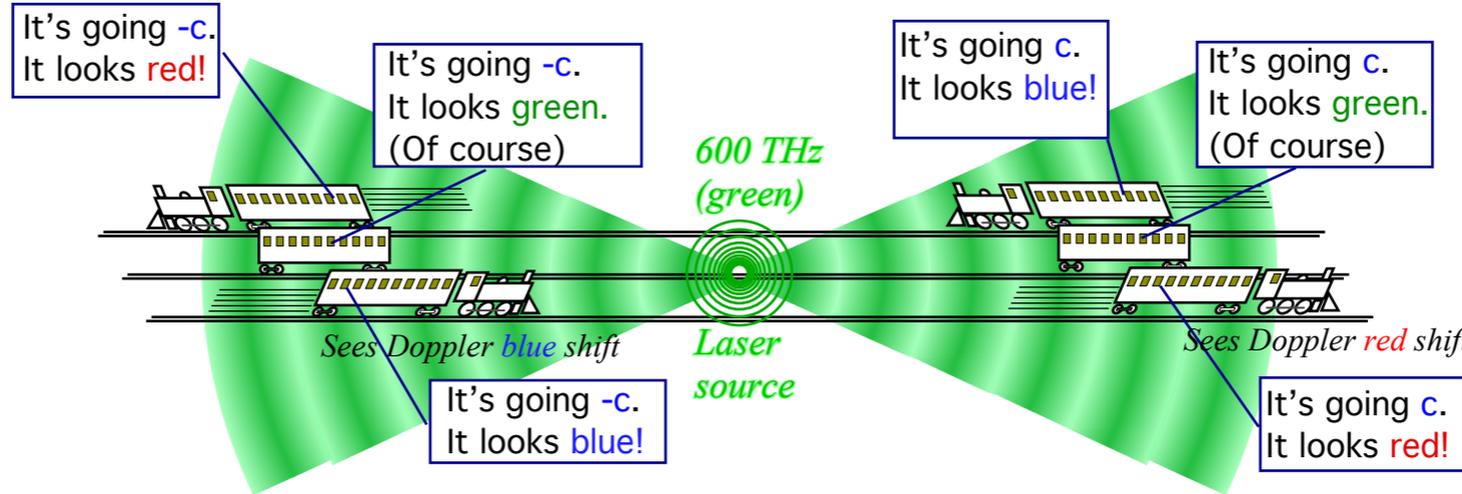
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Can be made more self-evident and productive

Kenneth Evenson



1932-2002



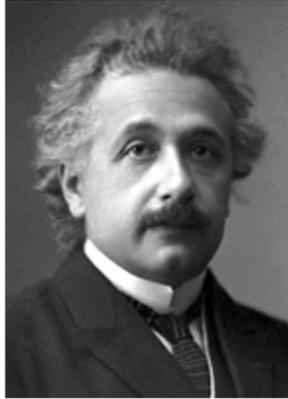
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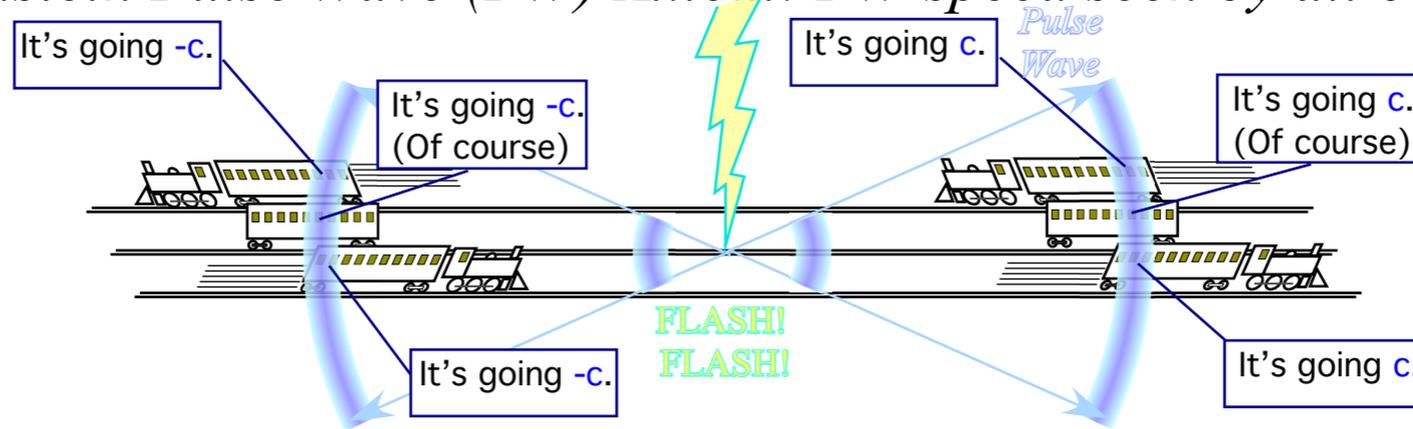


Albert Einstein



1879-1955

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Since when is cartoon physics a reality?!

First of all it's **Complicated**

William of Ockham

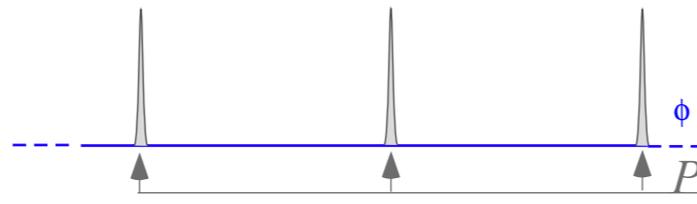


1285-1349

Using Occam's Razor

(and Evenson's lasers)

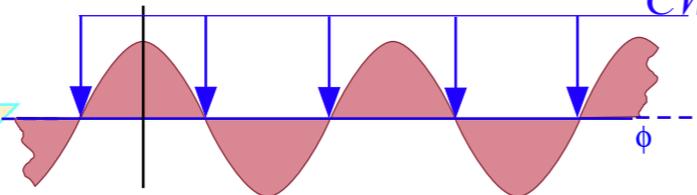
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Continuous wave (CW) train



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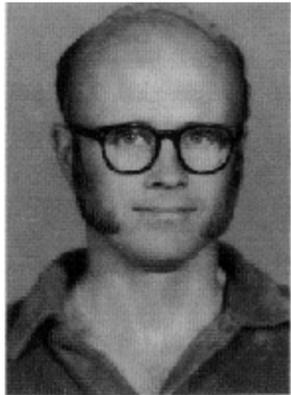
CW zeros precisely locate places where wave is not.

Simpler CW coherence It's "Zen-like"

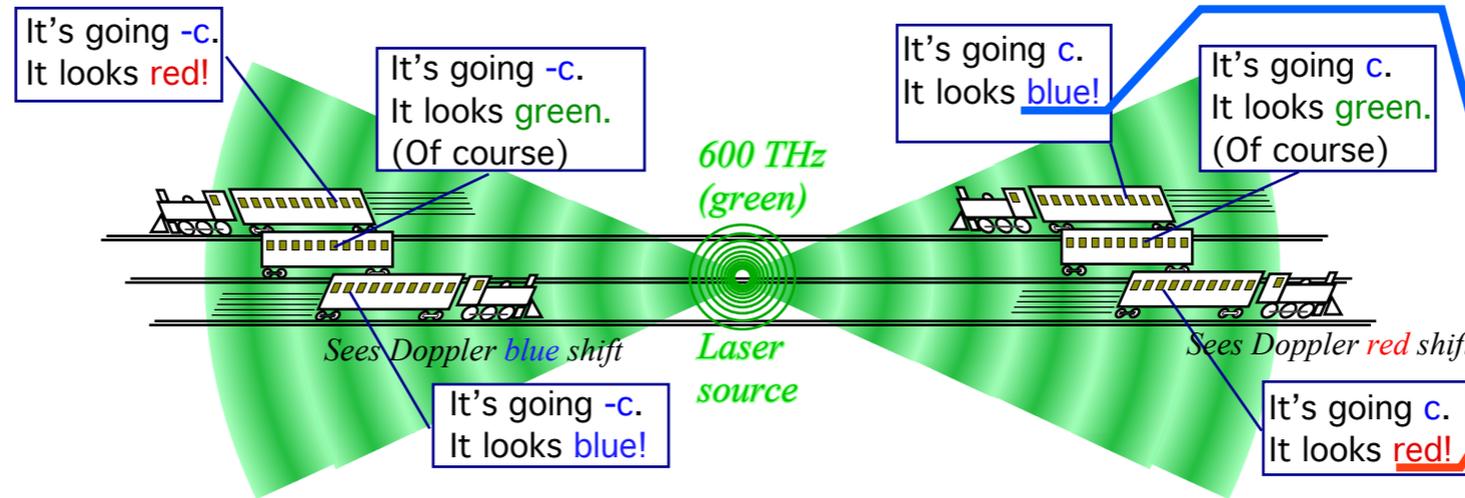
Can be made more self-evident and productive

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1932-2002



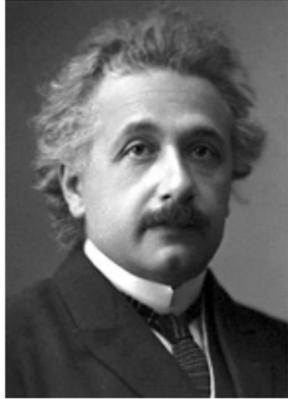
1CW is affected by 1st-order Doppler Blue shifts $b = e^{+\rho}$ and Red shifts $r = e^{-\rho}$ of frequency ν and wavenumber κ

Cut a PW to just one Continuous Wave (1CW) that changes Color if you accelerate!
 CW also stands for "Cosine Wave" or "Coherent Wave" or "Colored Wave" (all helpful things!)

• How do you make sense of light-wave **SPEED LIMIT** axiom(s)?

SPEED LIMIT
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Albert Einstein



1879-1955

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A major objection to relativity/QM theory:
 It's the only major theoretical development that starts with 2nd-order (and quite mysterious!) (and very very very tiny!) effects.

William of Ockham

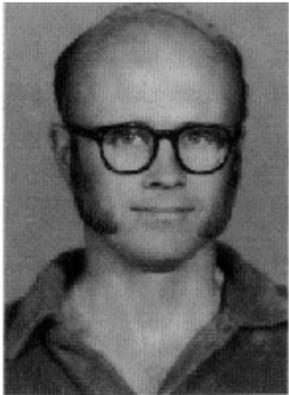


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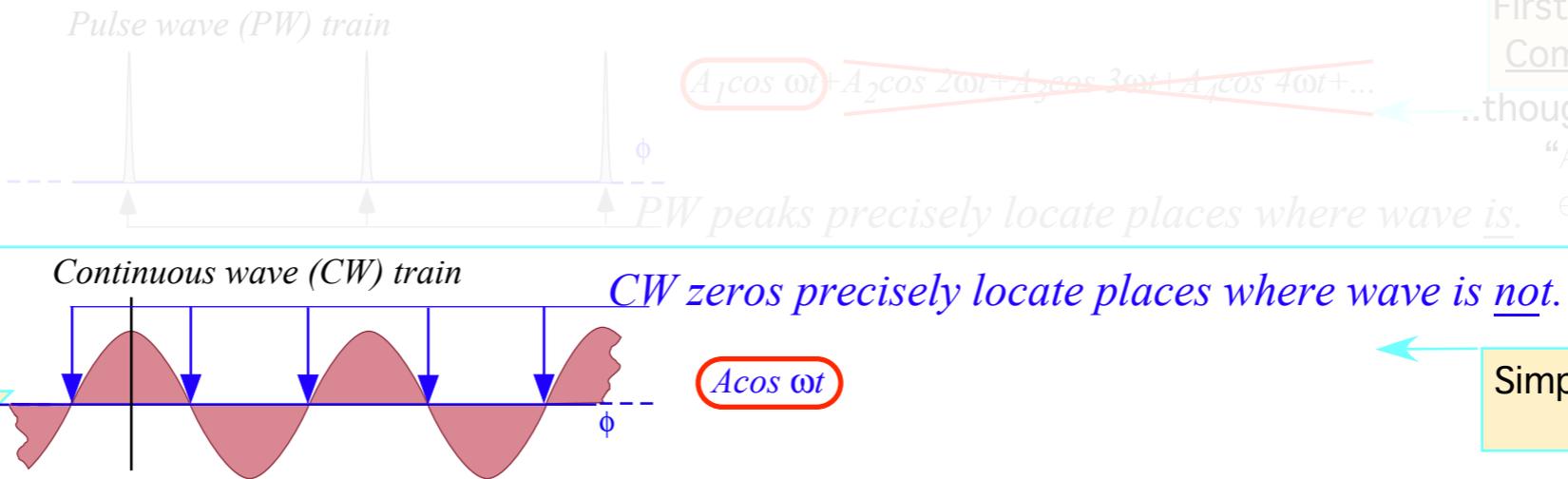
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Kenneth Evenson



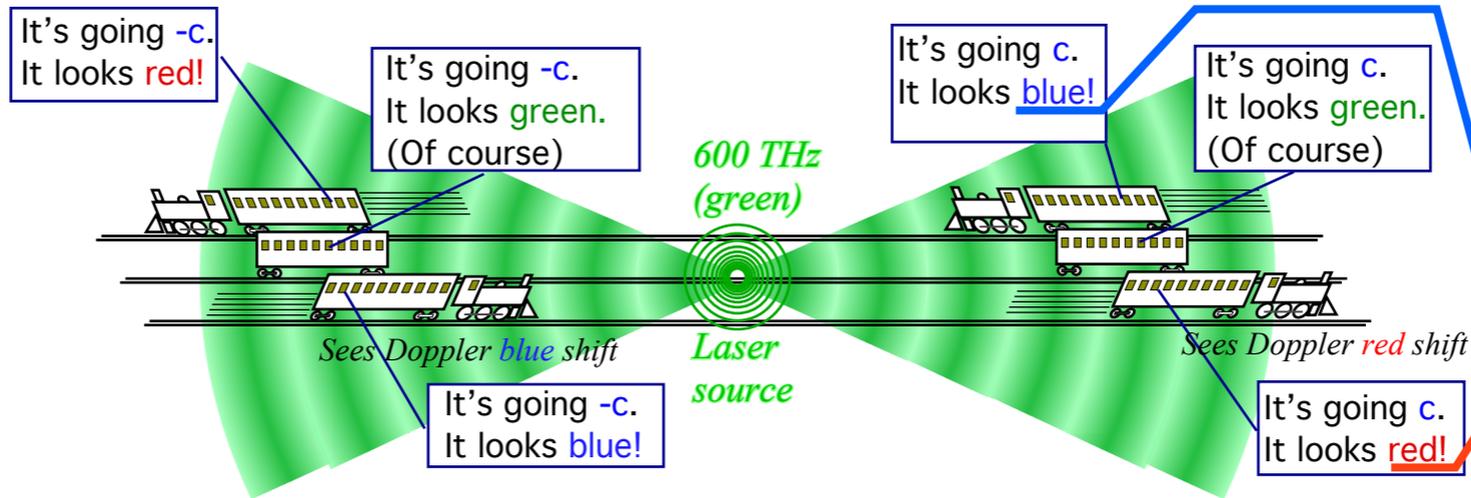
1932-2002

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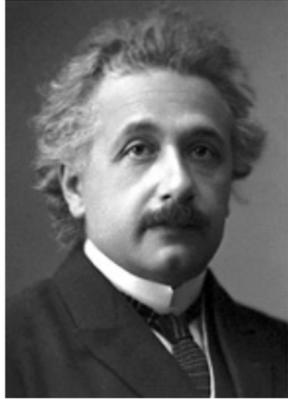
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1879-1955

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So lets try doing first-things first!

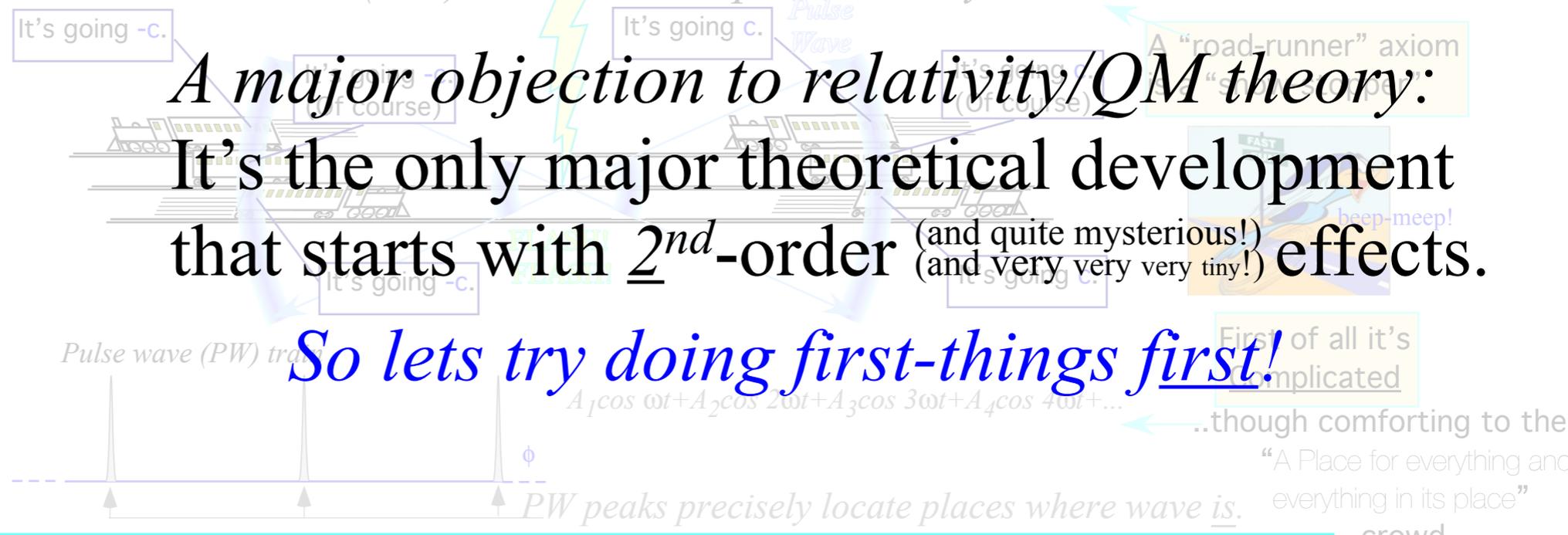
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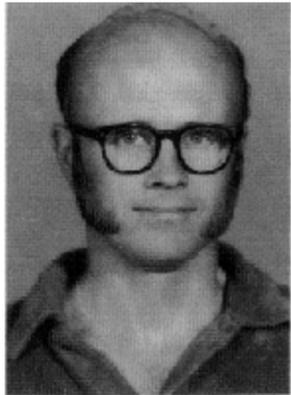
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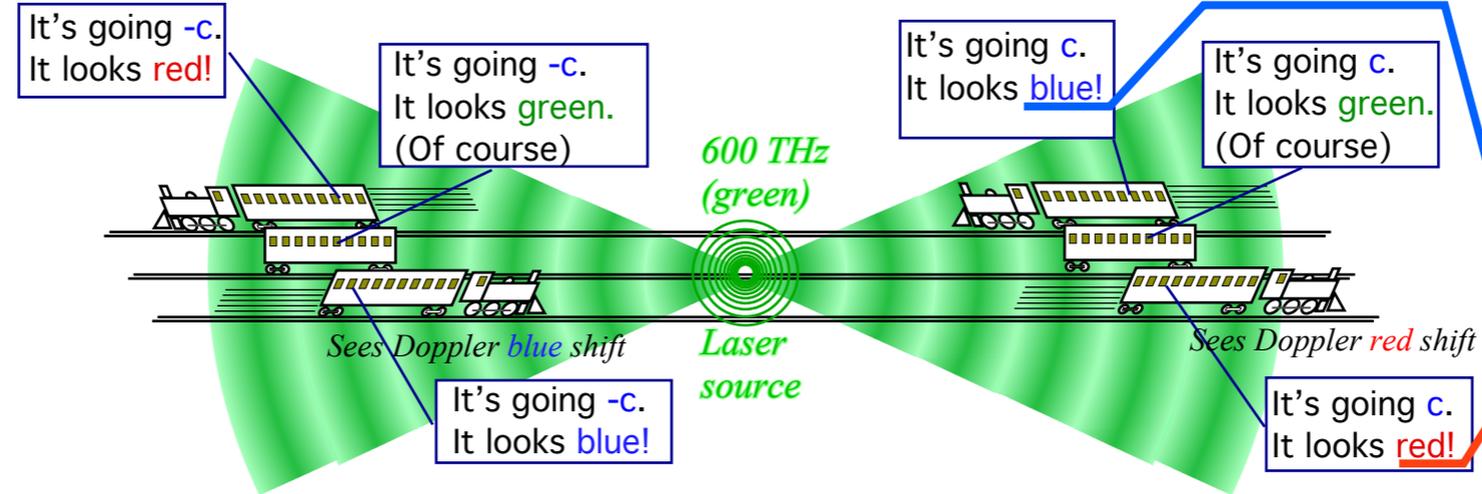
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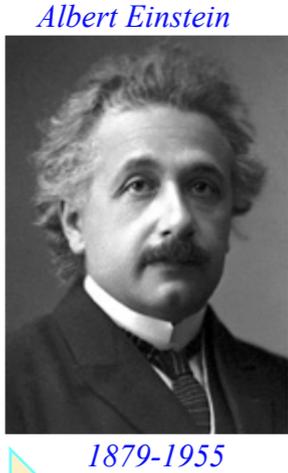
Can be made more self-evident and productive

1CW is affected by 1st-order Doppler
 Blue shifts $b = e^{+\rho}$
 and
 Red shifts $r = e^{-\rho}$
 of frequency ν
 and wavenumber κ

Cut a PW to just one Continuous Wave (1CW) that changes Color if you accelerate!
 CW also stands for "Cosine Wave" or "Coherent Wave" or "Colored Wave" (all helpful things!)

• How do you make sense of light-wave axiom(s)?

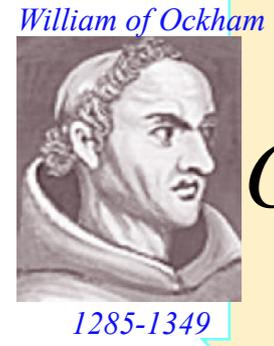
SPEED LIMIT
 $c = 299,792,458$
 m/s



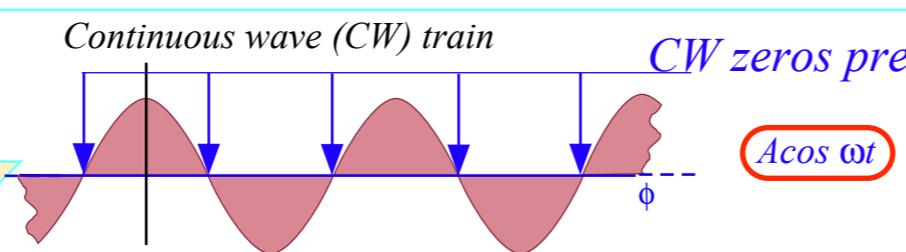
Einstein Pulse Wave (PW) Axiom: PW speed seen by all observers is c

A major objection to relativity/QM theory:
 It's the only major theoretical development
 that starts with 2nd-order (and quite mysterious!) (and very very very tiny!) effects.

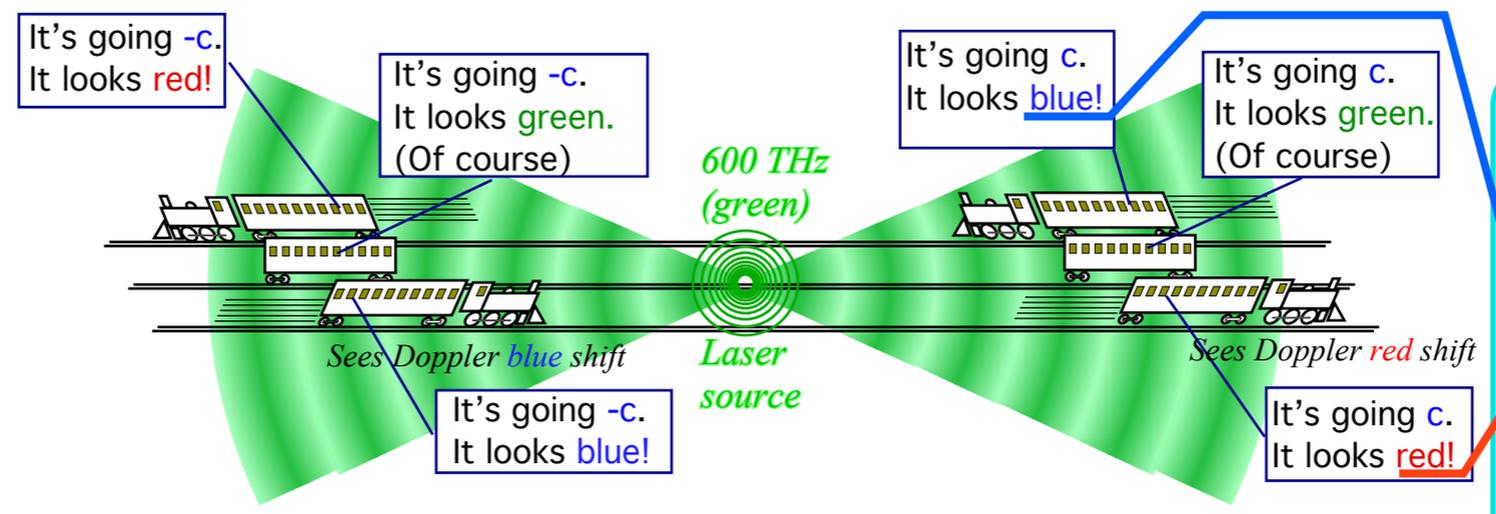
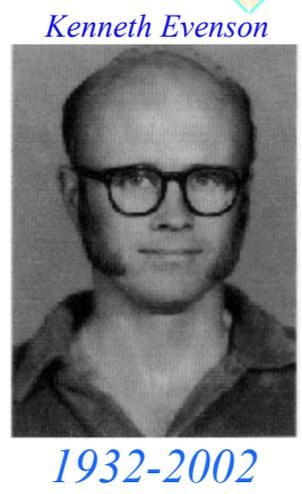
So lets try doing first-things first!
 ...and start off by dealing with this enigma...



Using Occam's Razor
 (and Evenson's lasers)



Evenson Continuous Wave (CW) axiom: CW speed for all colors is c



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➔ Introduce "*Keyboard of the gods*" ➔ CW per-space-time (κ, ν) that rules (λ, τ) space-time ←

Introduce idea of quantized wavenumber- κ_n and amplitude A_n (*1st and 2nd quantization*)

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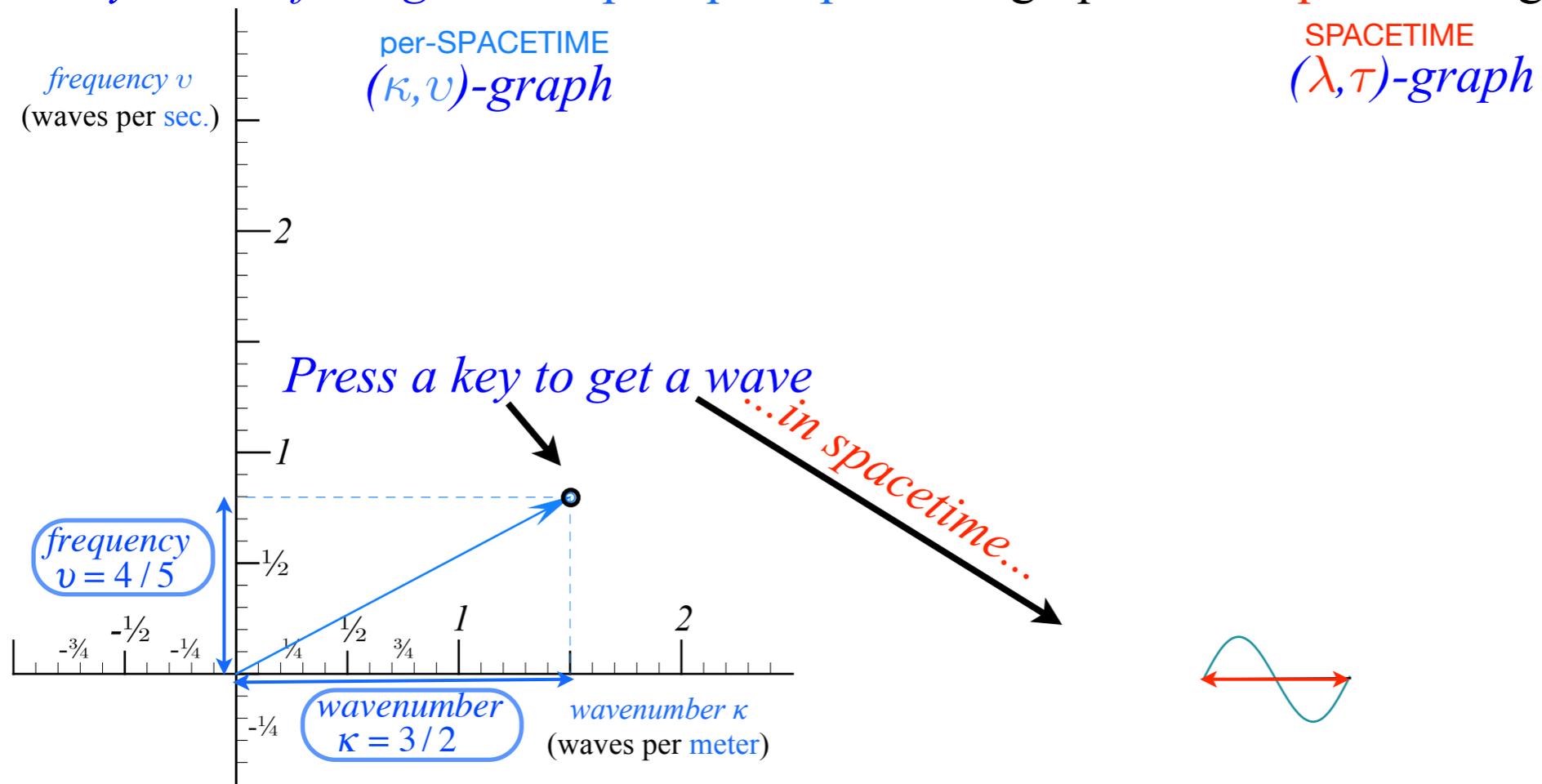
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The “Keyboard of the gods” or per-space-per-time graphs versus space-time graphs



“Keyboard of the gods” is known as “Fourier-space”

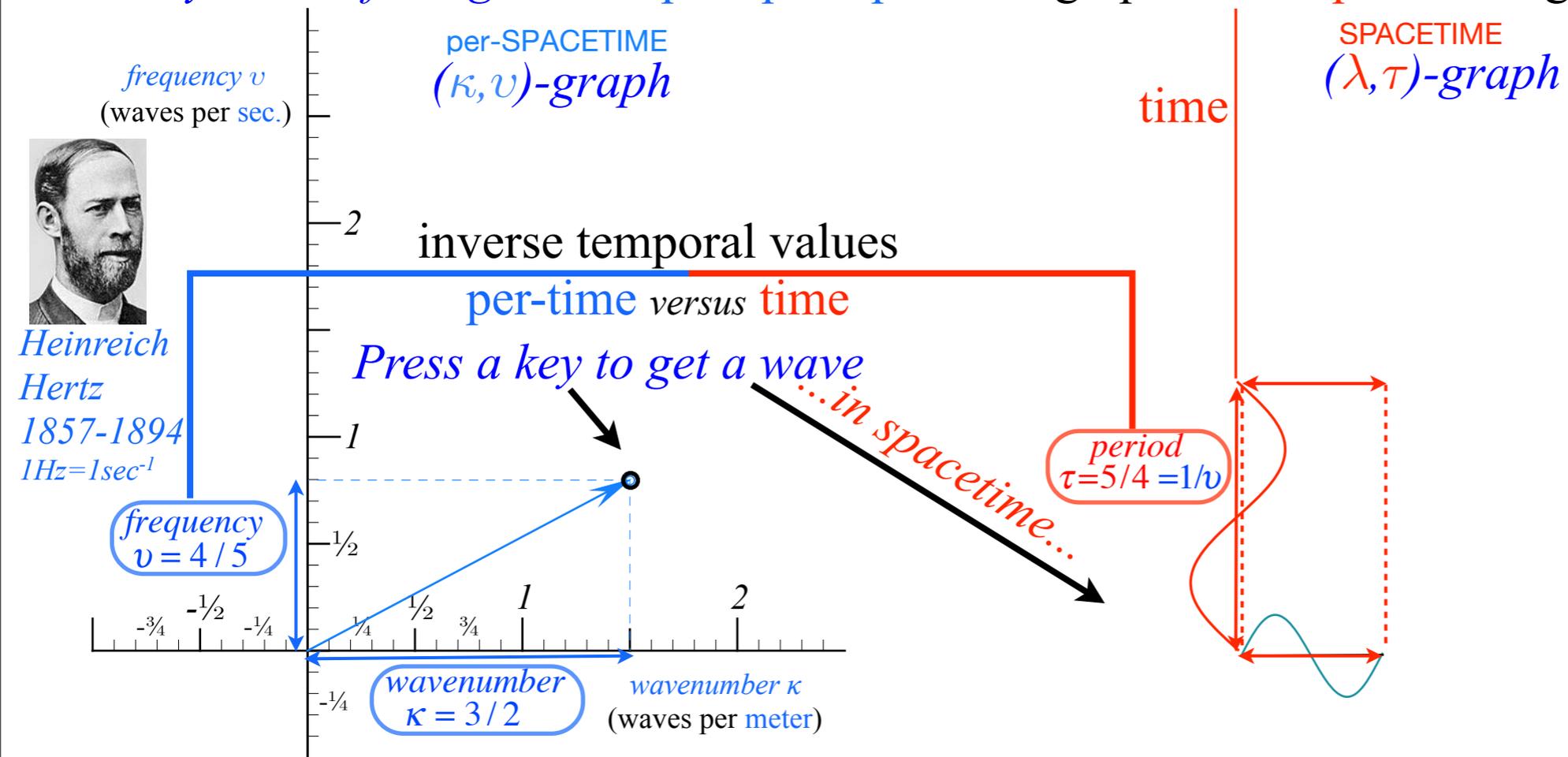


Jean-Baptiste
Joseph Fourier
1768-1830

•How to understand waves
and
wave velocity V_{wave}

[RelaWavity Web Simulation](#)
[Keyboard of the Gods](#)
(per-Time vs per-Space)

The “Keyboard of the gods” or per-space-per-time graphs versus space-time graphs



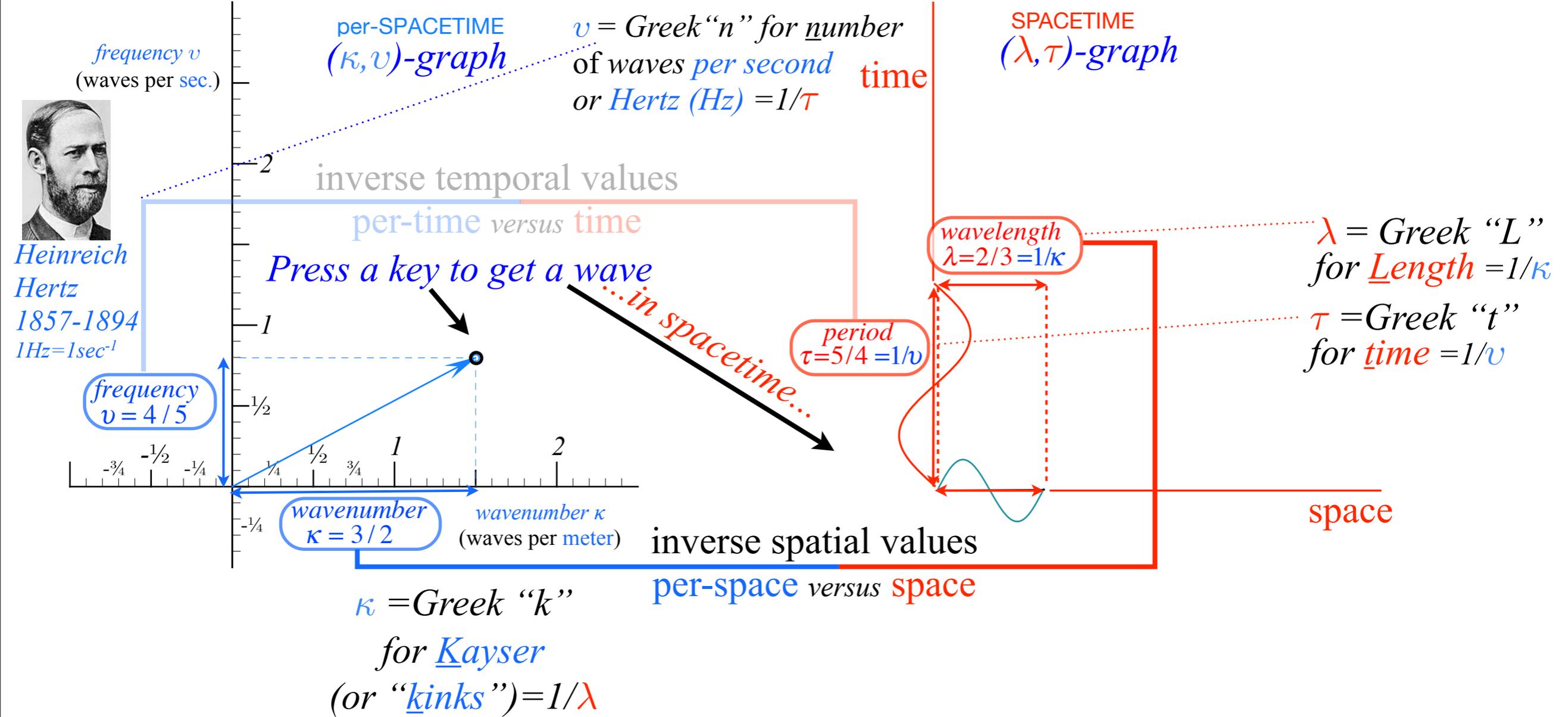
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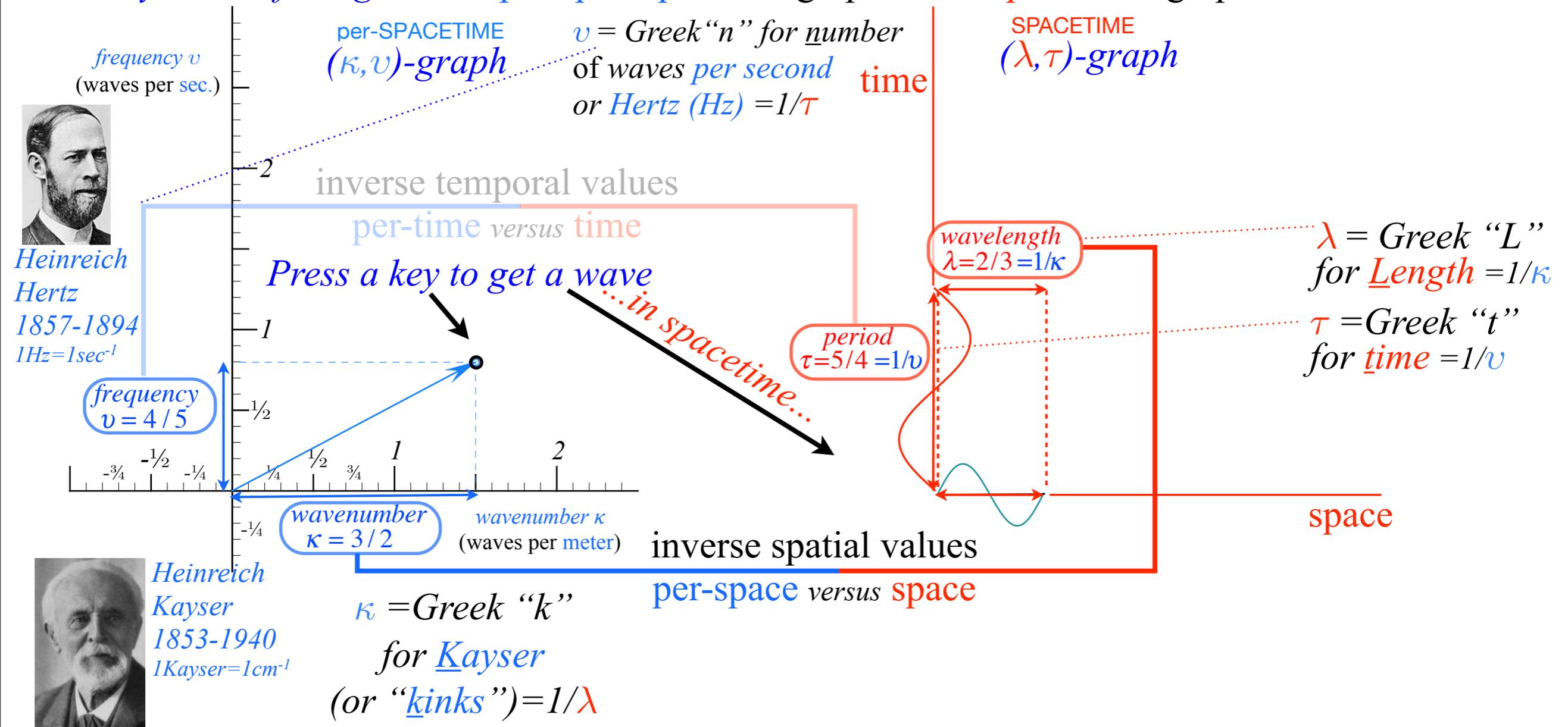


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Heinrich Hertz
1857-1894
1Hz=1sec⁻¹

Heinrich Kayser
1853-1940
1Kayser=1cm⁻¹

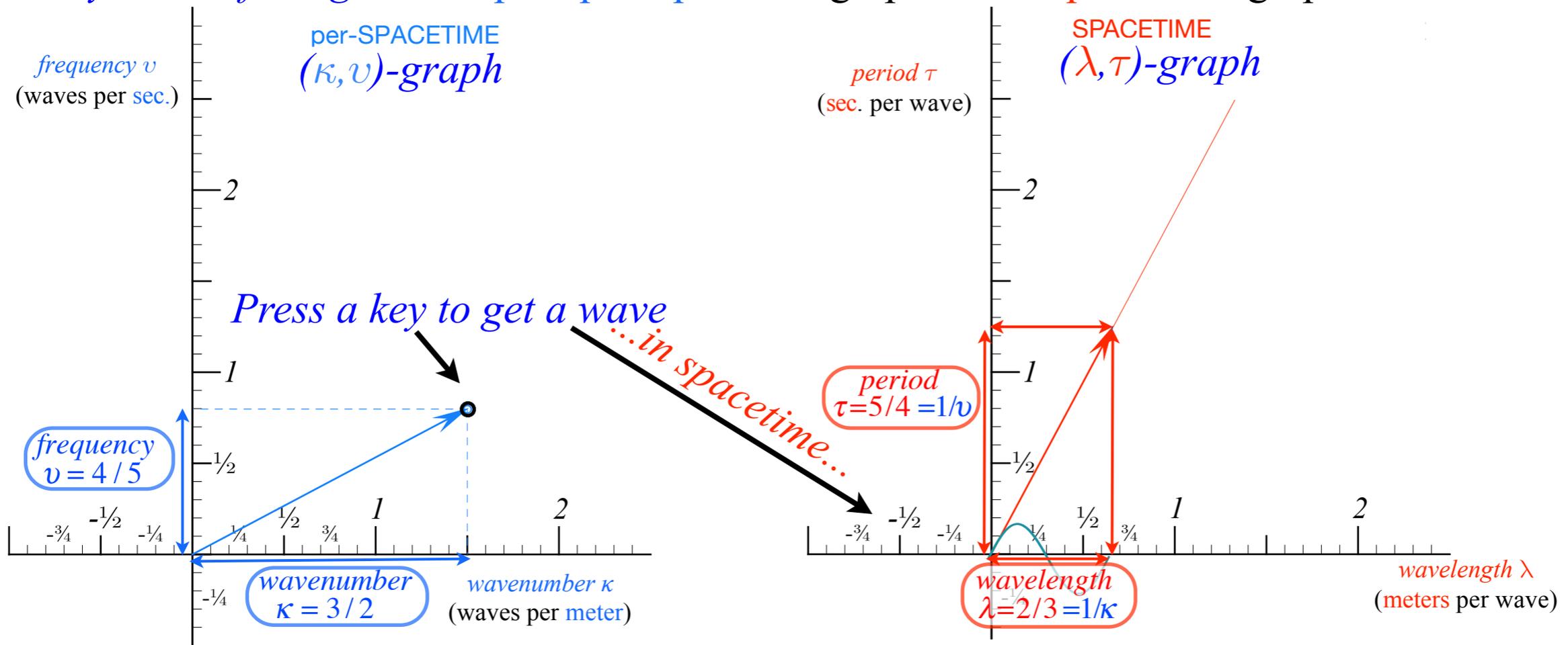
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[RelaWavity Web Simulation Keyboard of the Gods \(Dual Plot\)](#)

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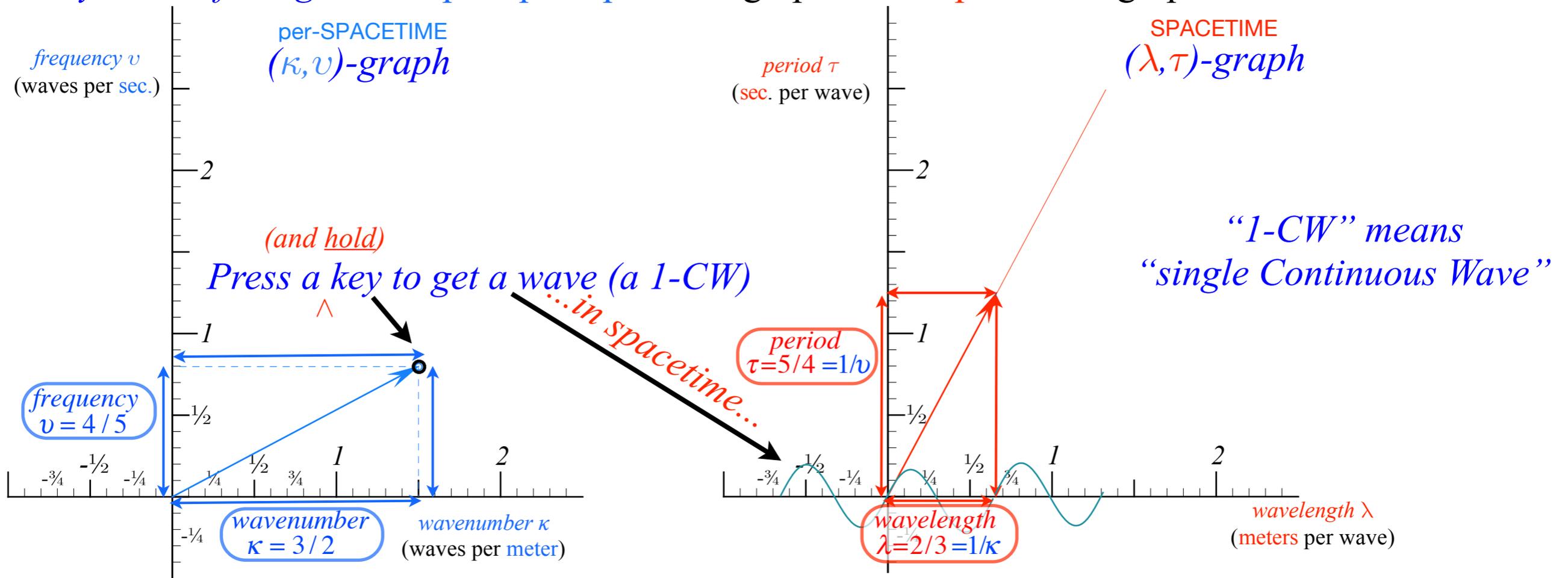
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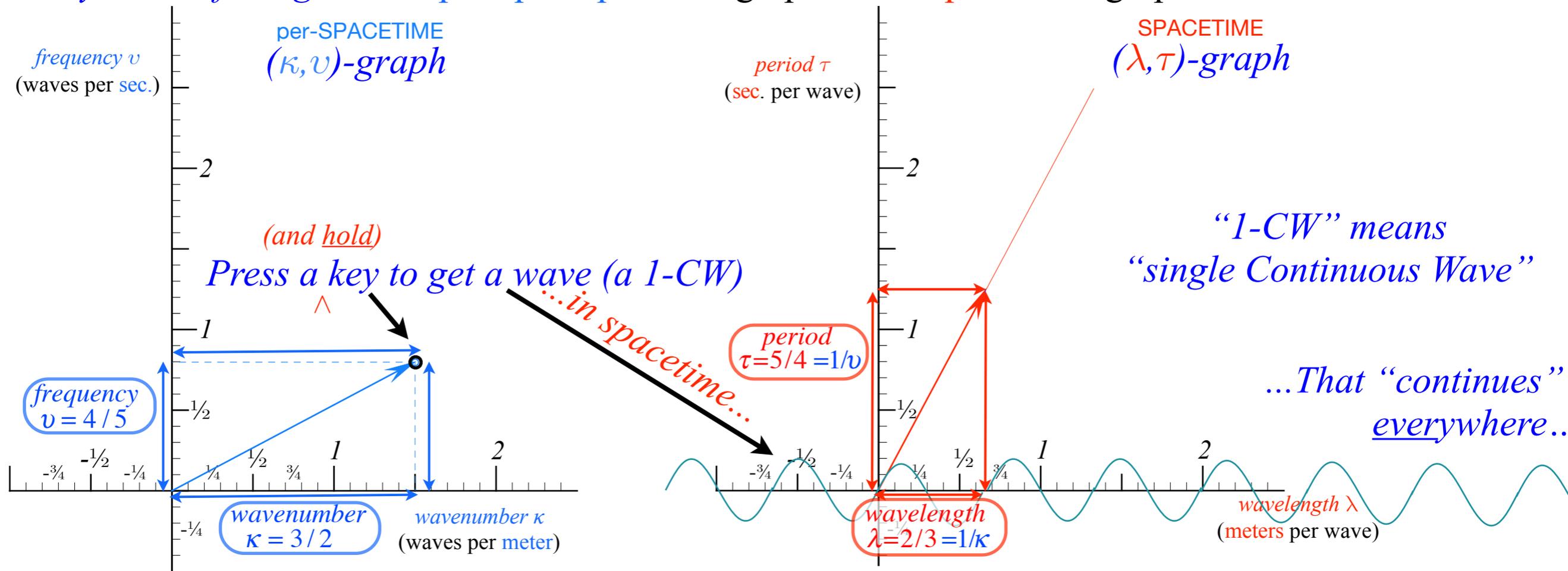


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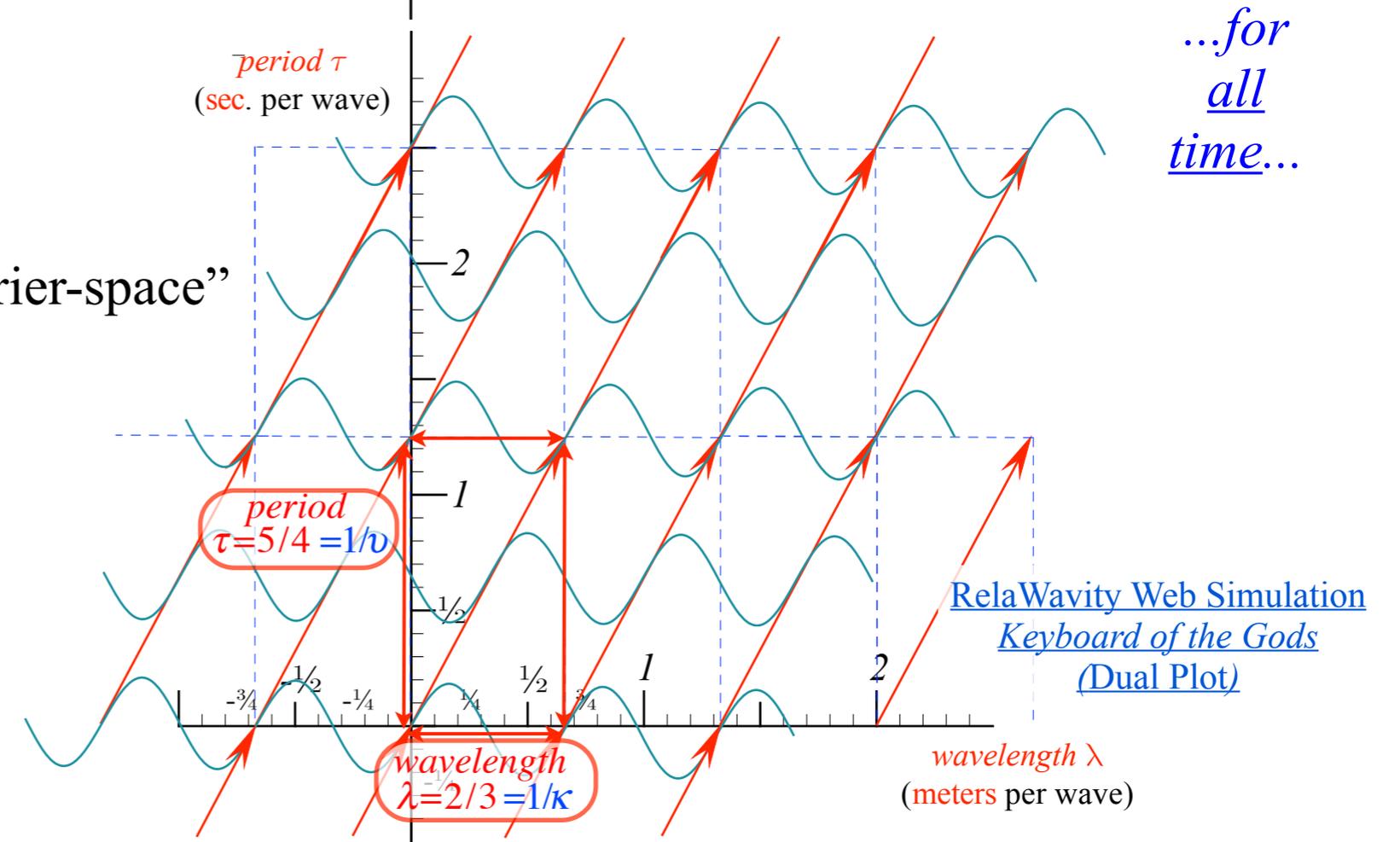
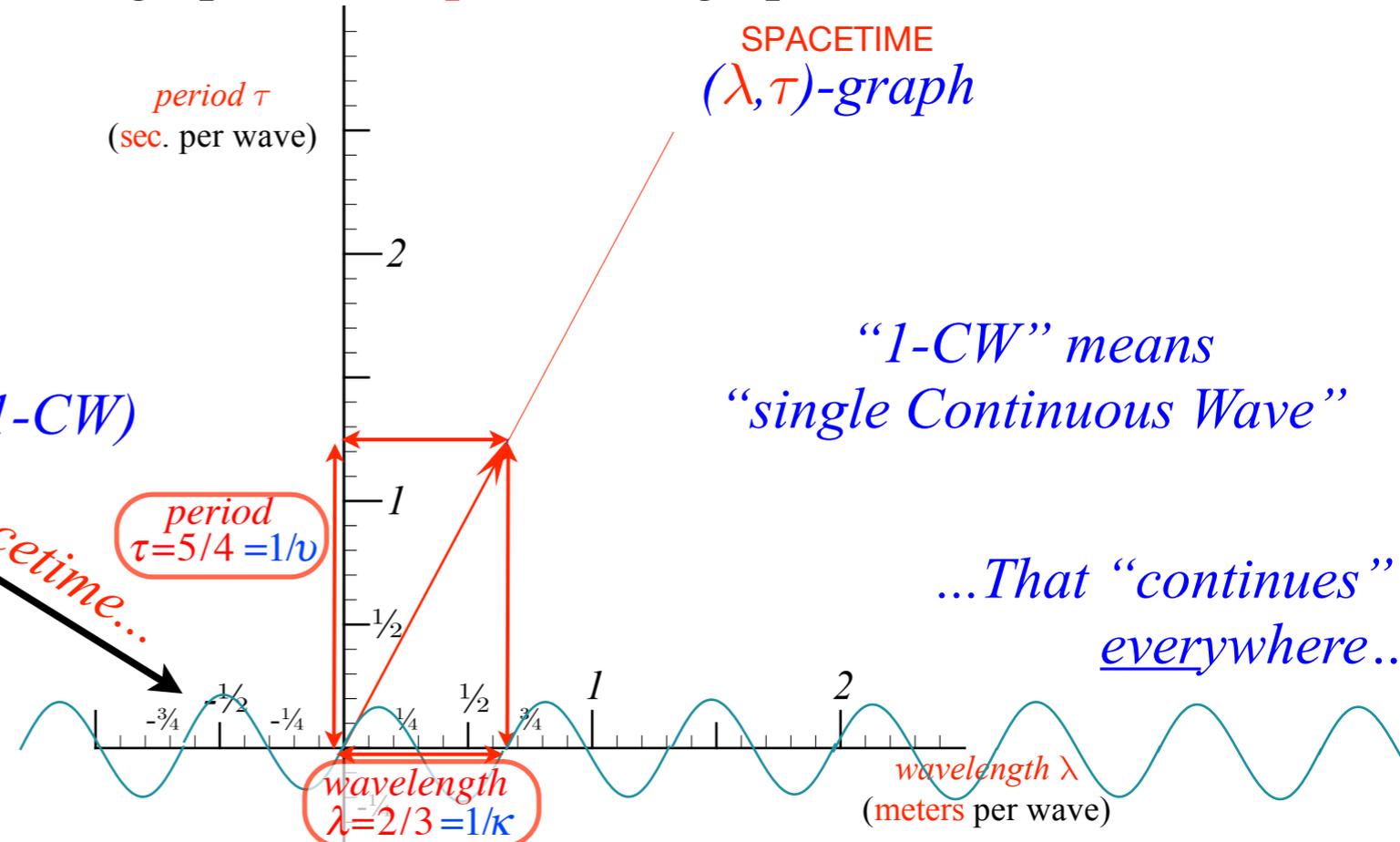
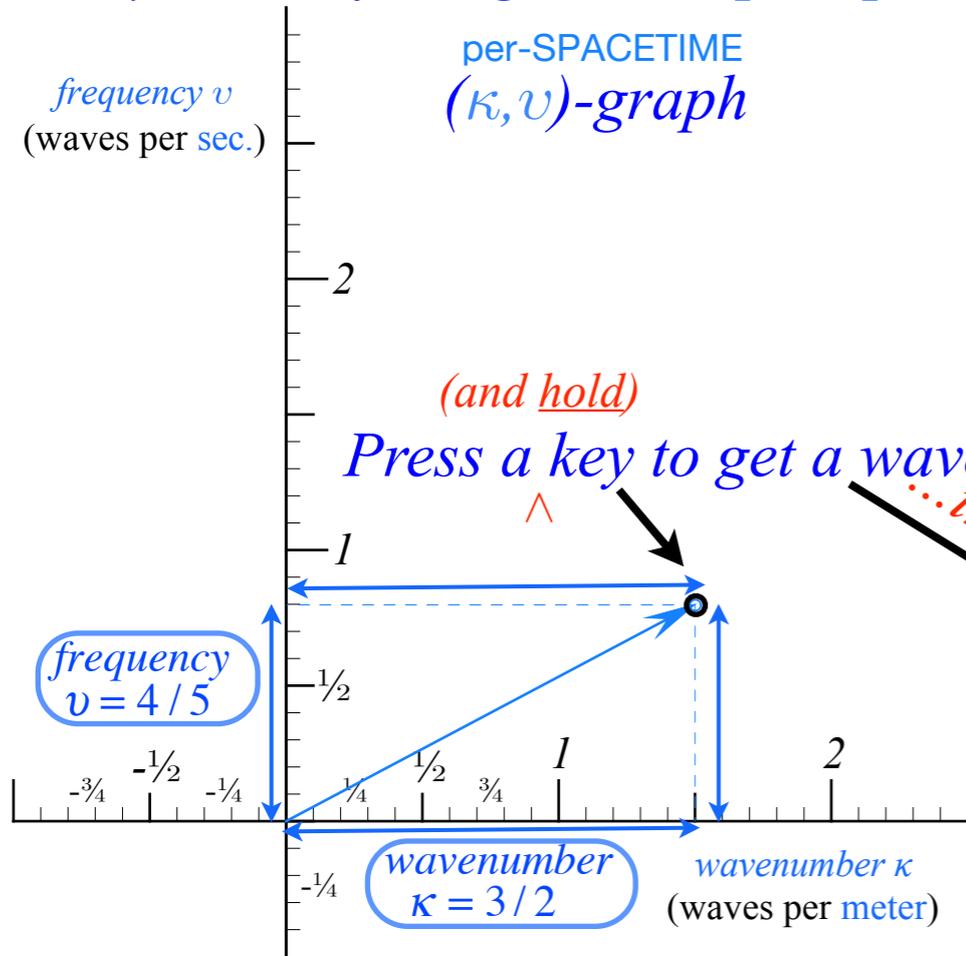


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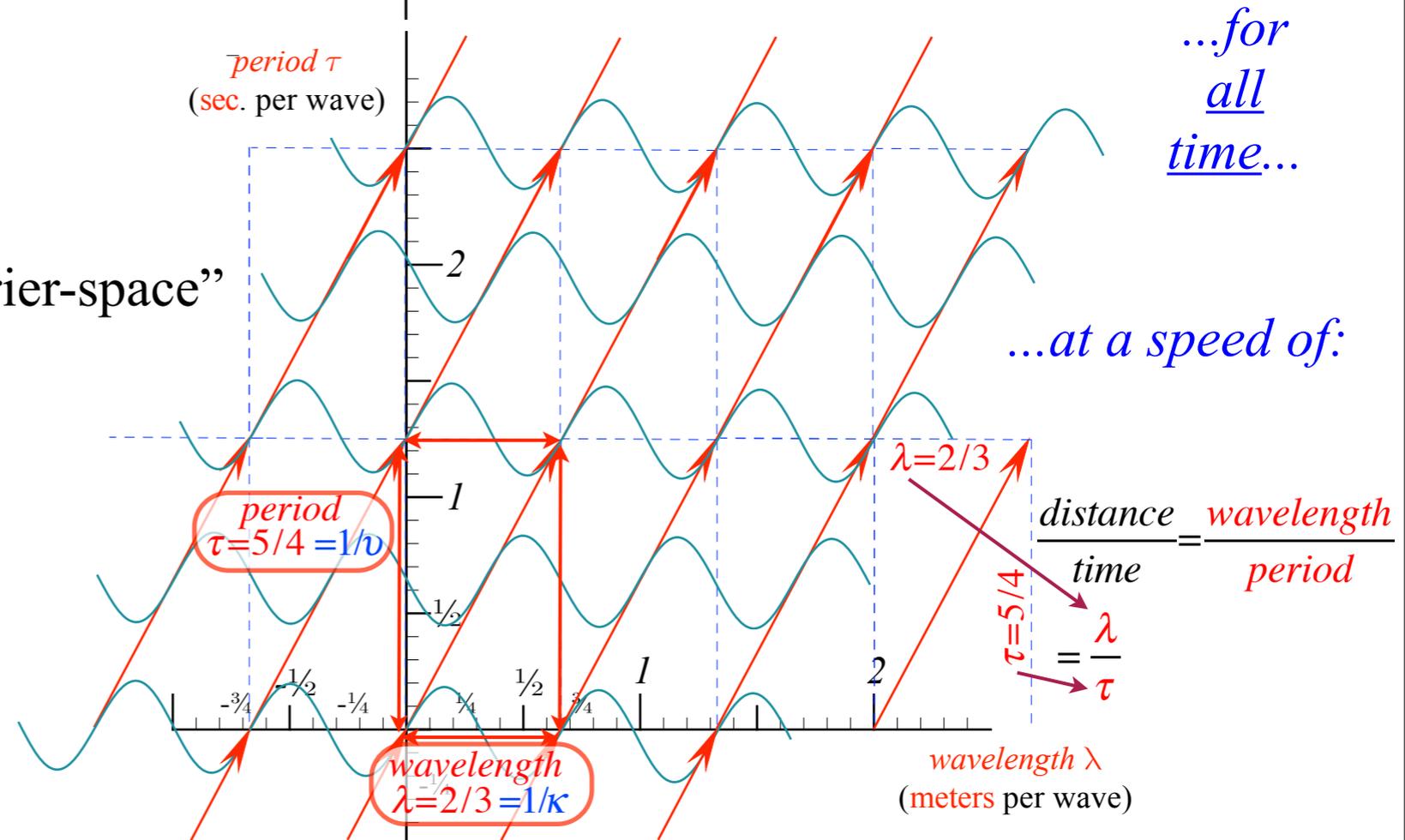
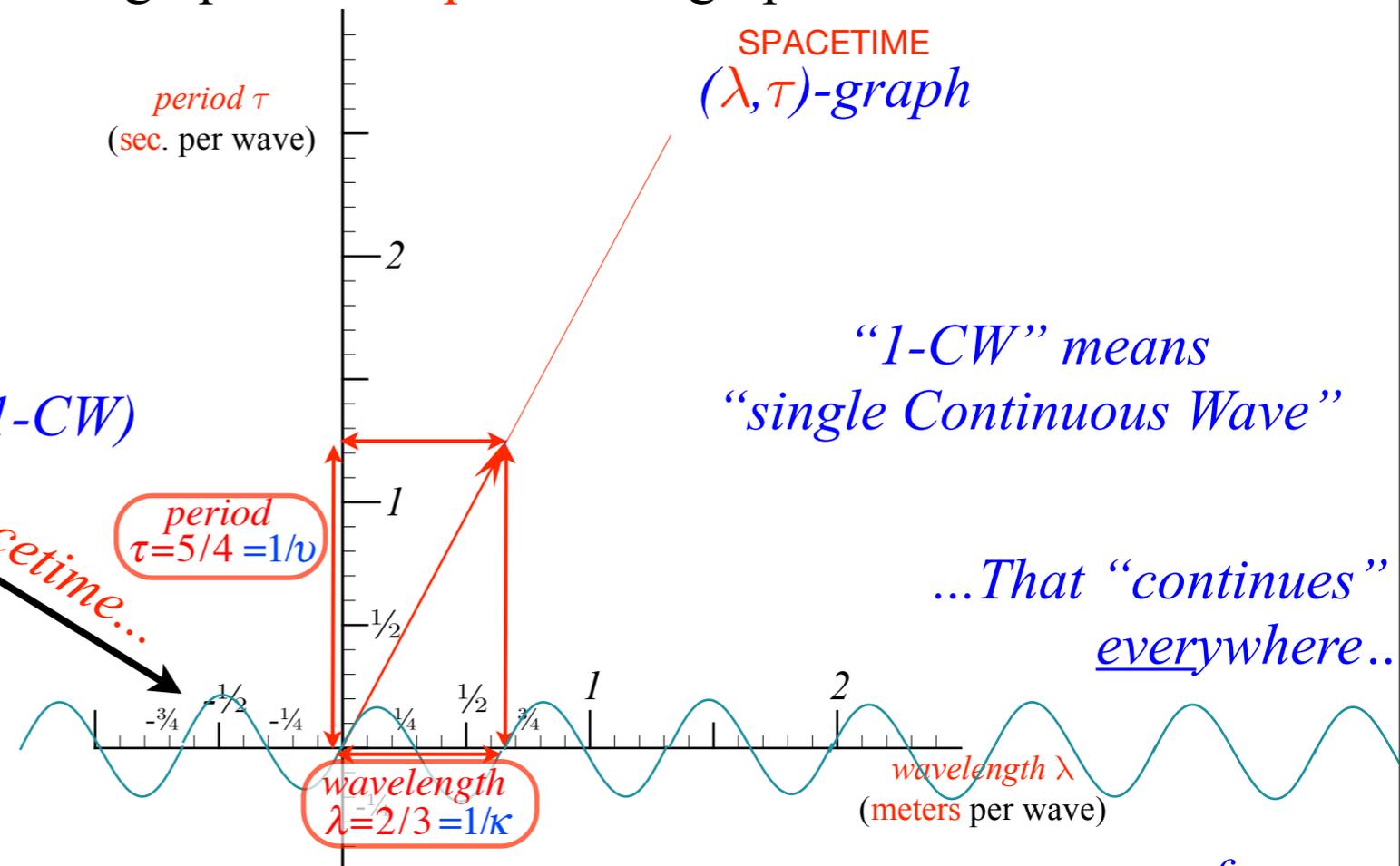
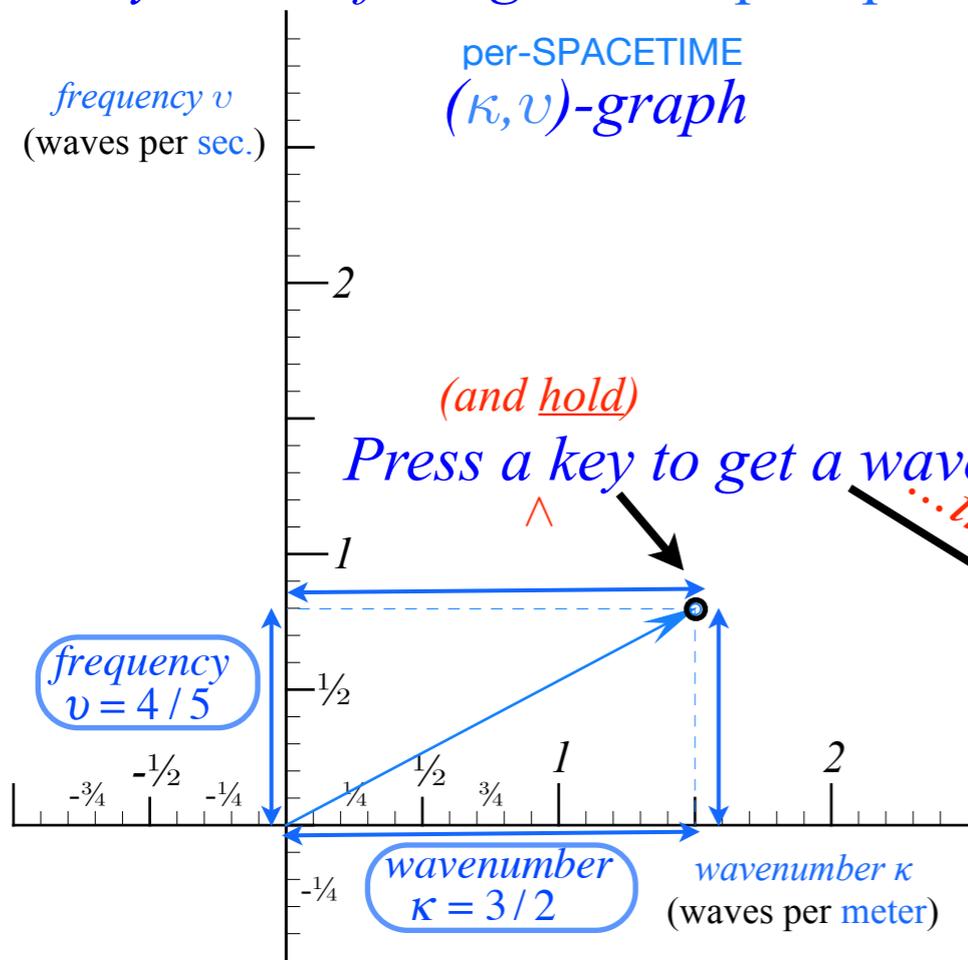


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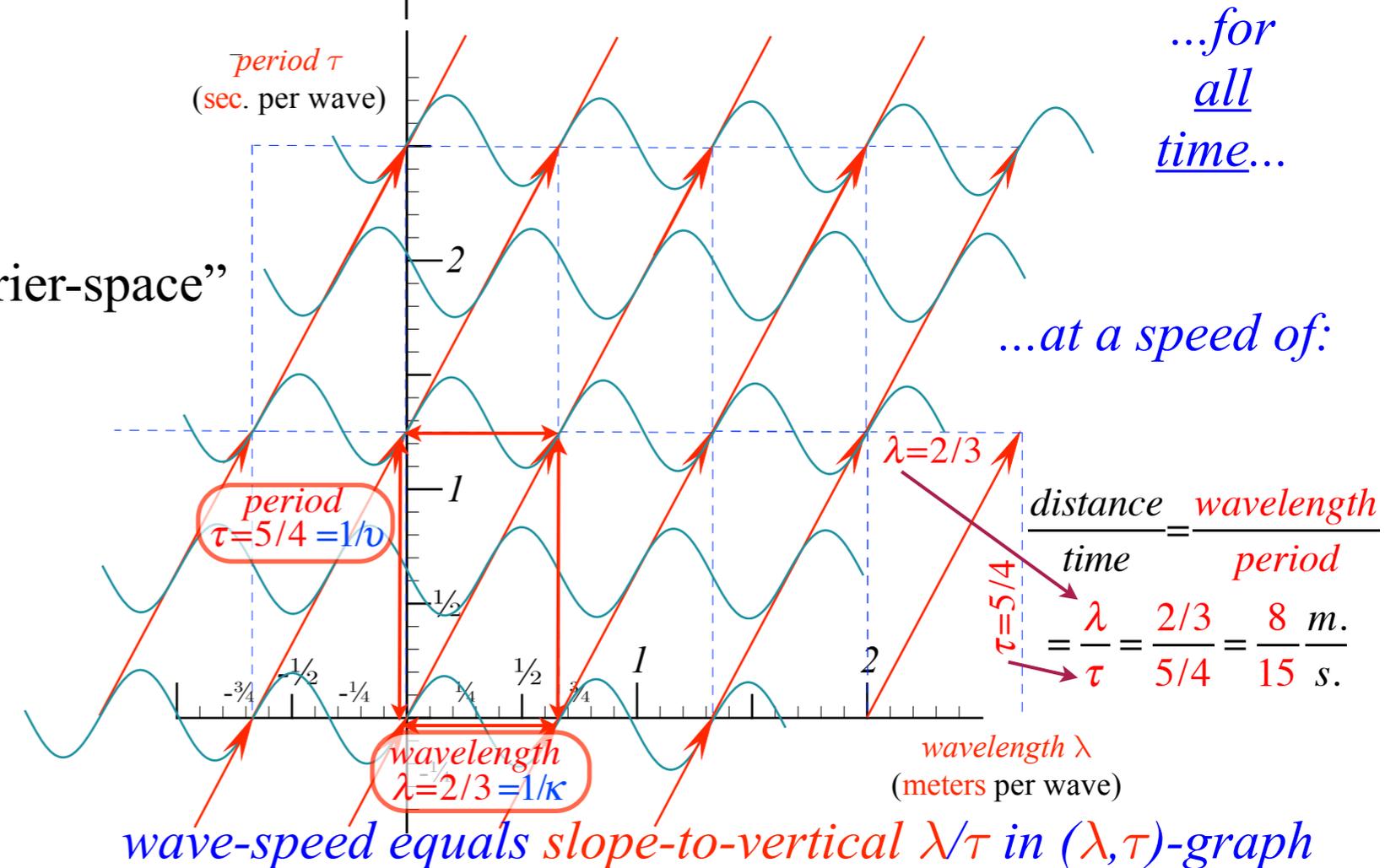
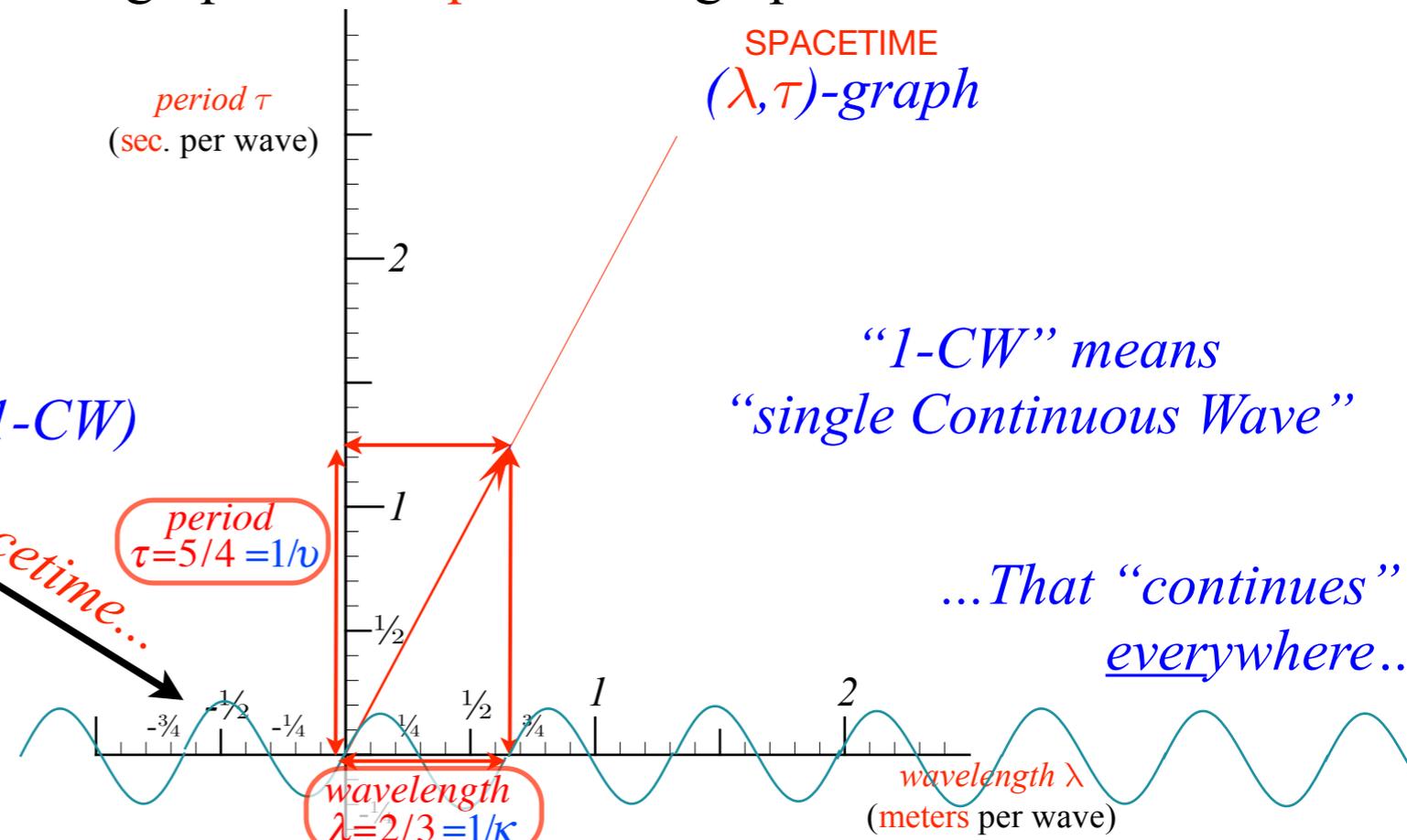
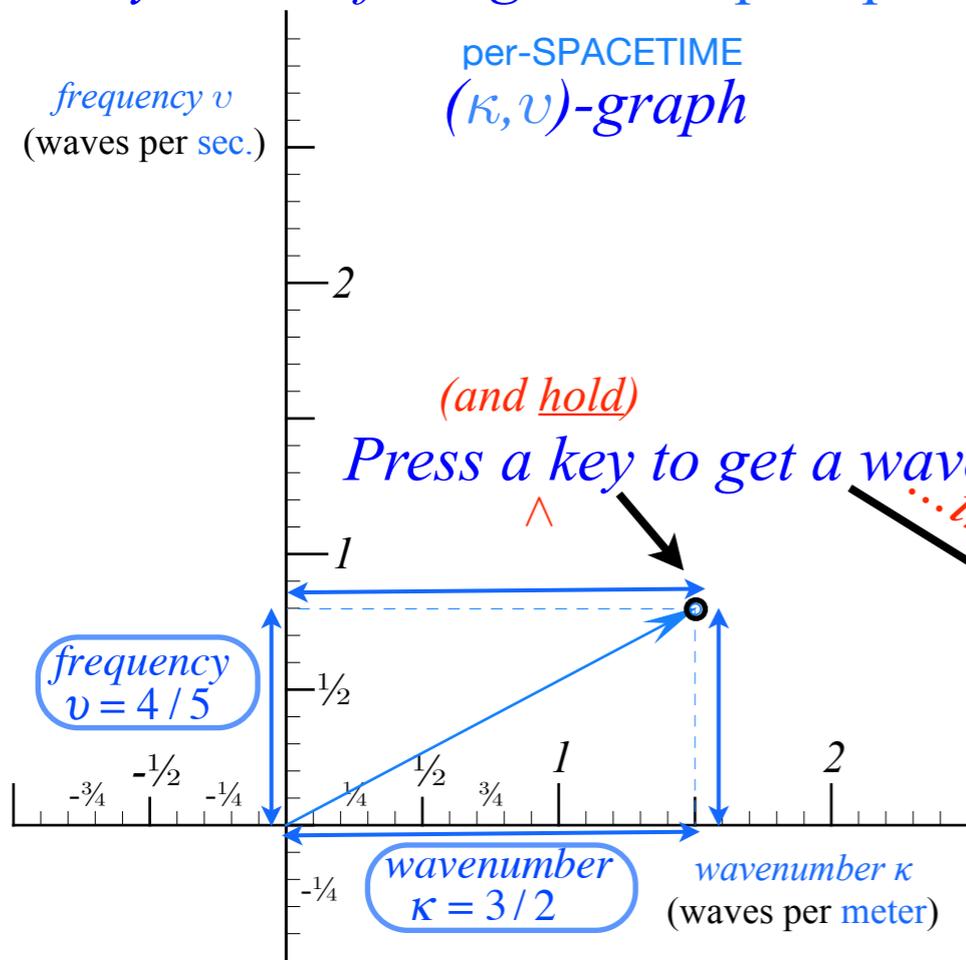
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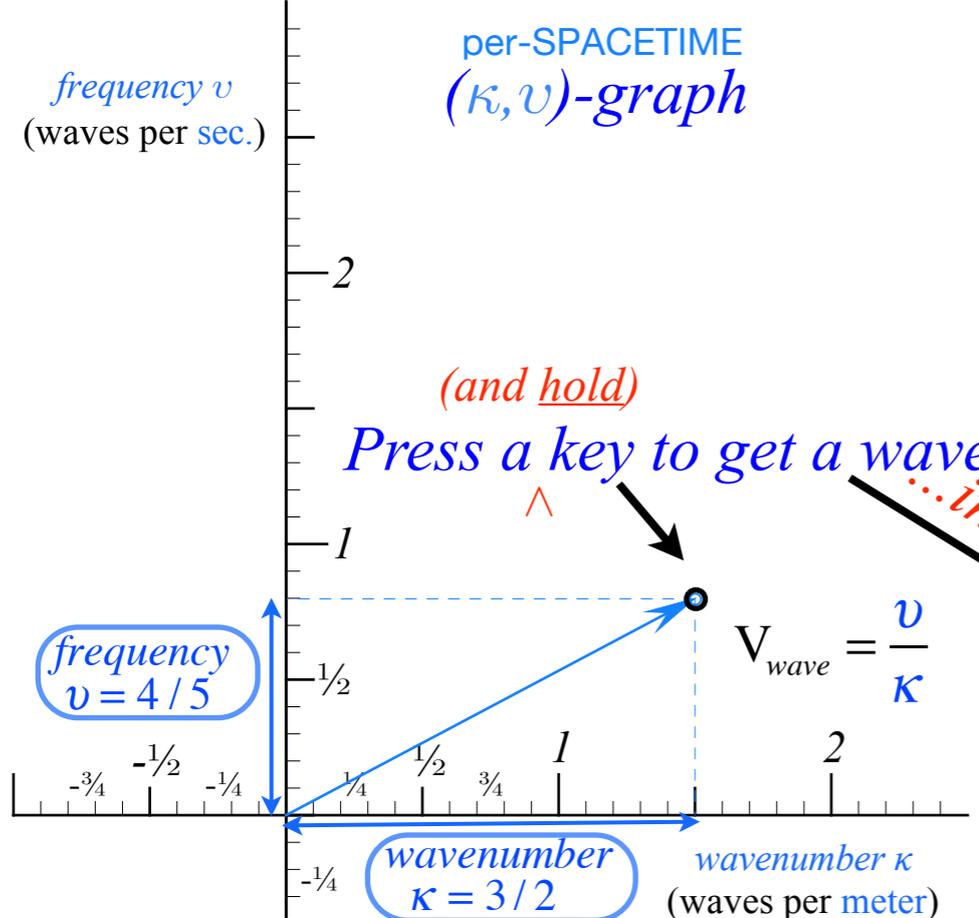


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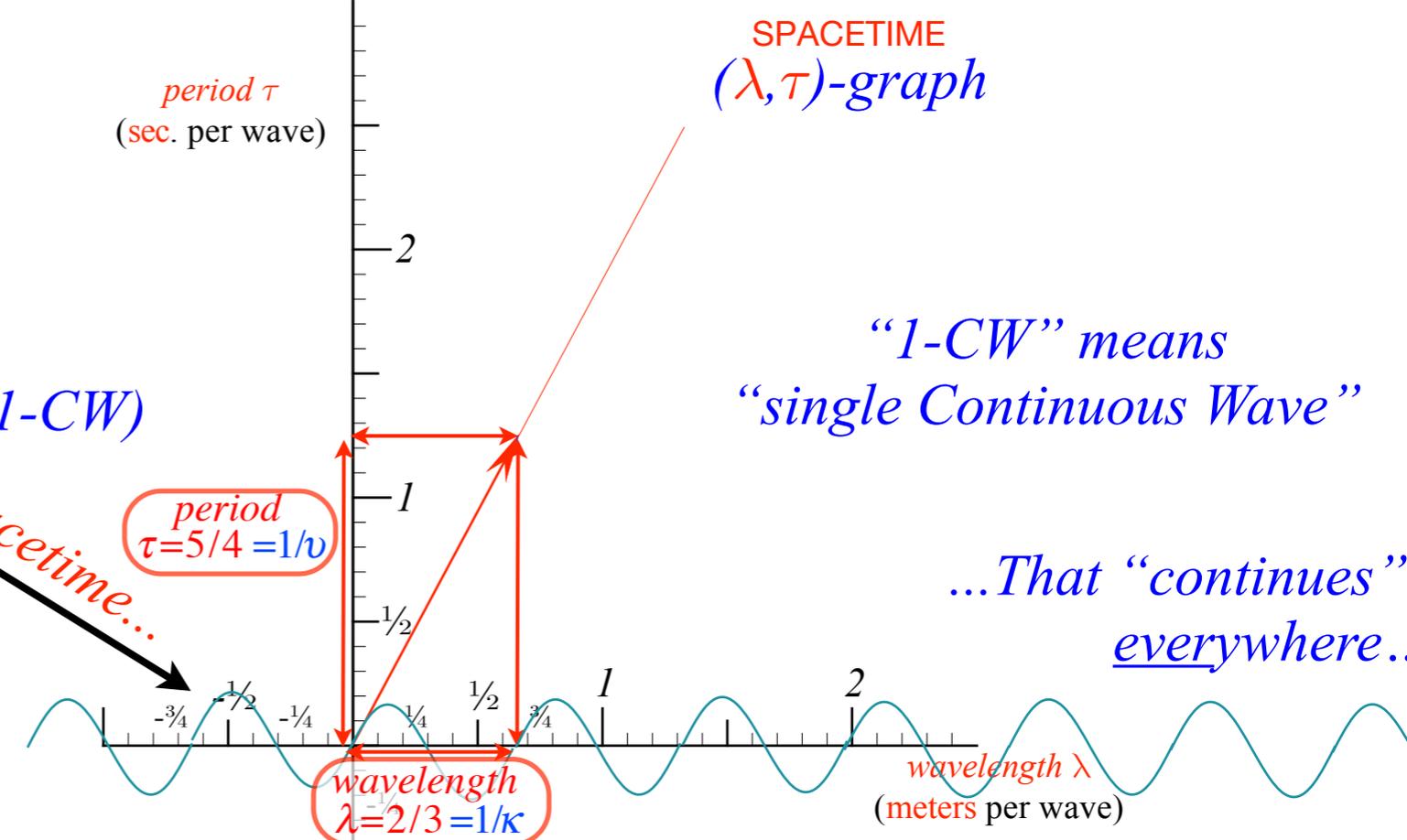
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(and hold)
Press a key to get a wave (a 1-CW)

...in spacetime...

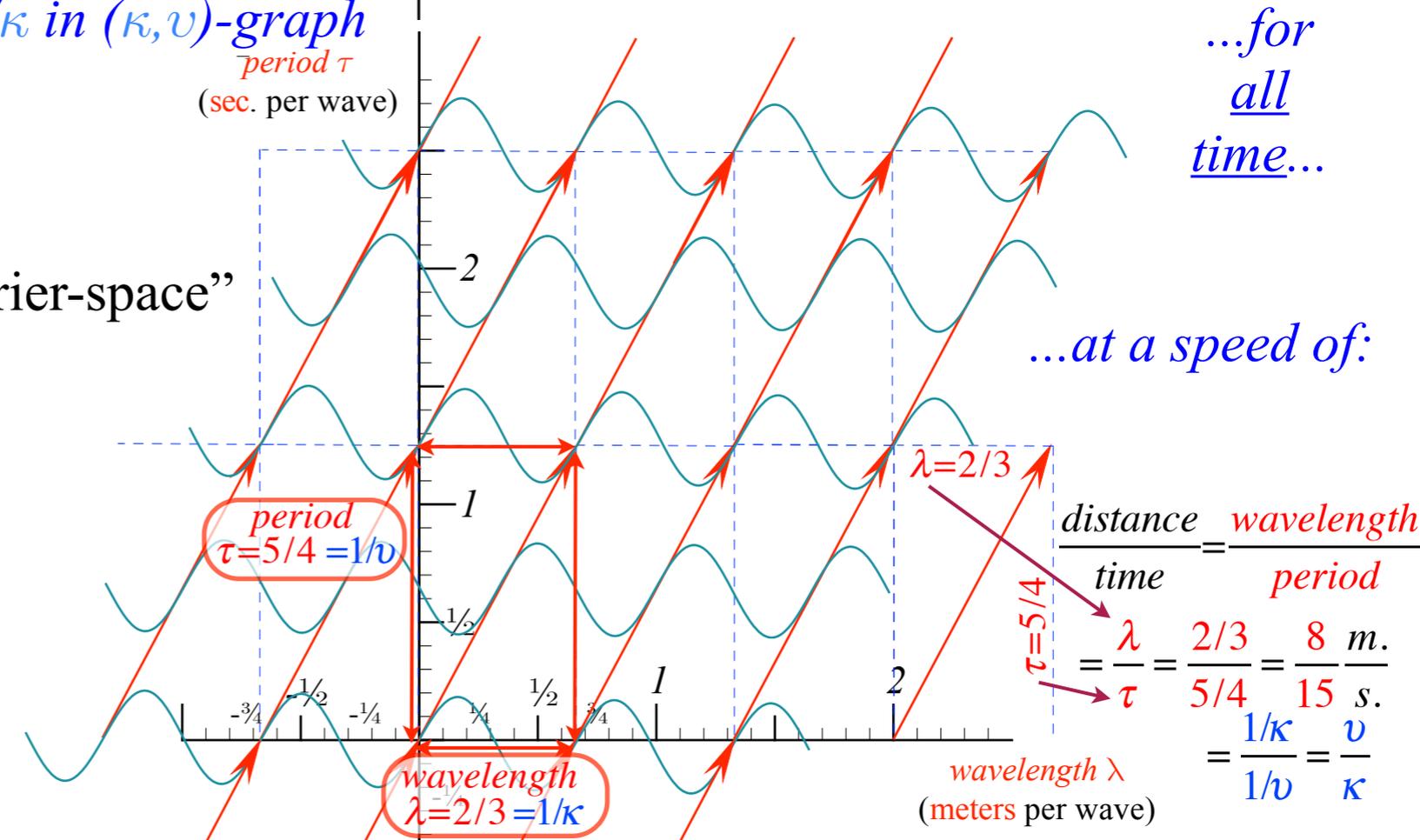


"1-CW" means
"single Continuous Wave"

...That "continues"
everywhere..

...for
all
time...

...at a speed of:



wave-speed equals slope-to-vertical λ/τ in (λ, τ) -graph

wave-speed equals slope-to-horizontal ν/κ in (κ, ν) -graph

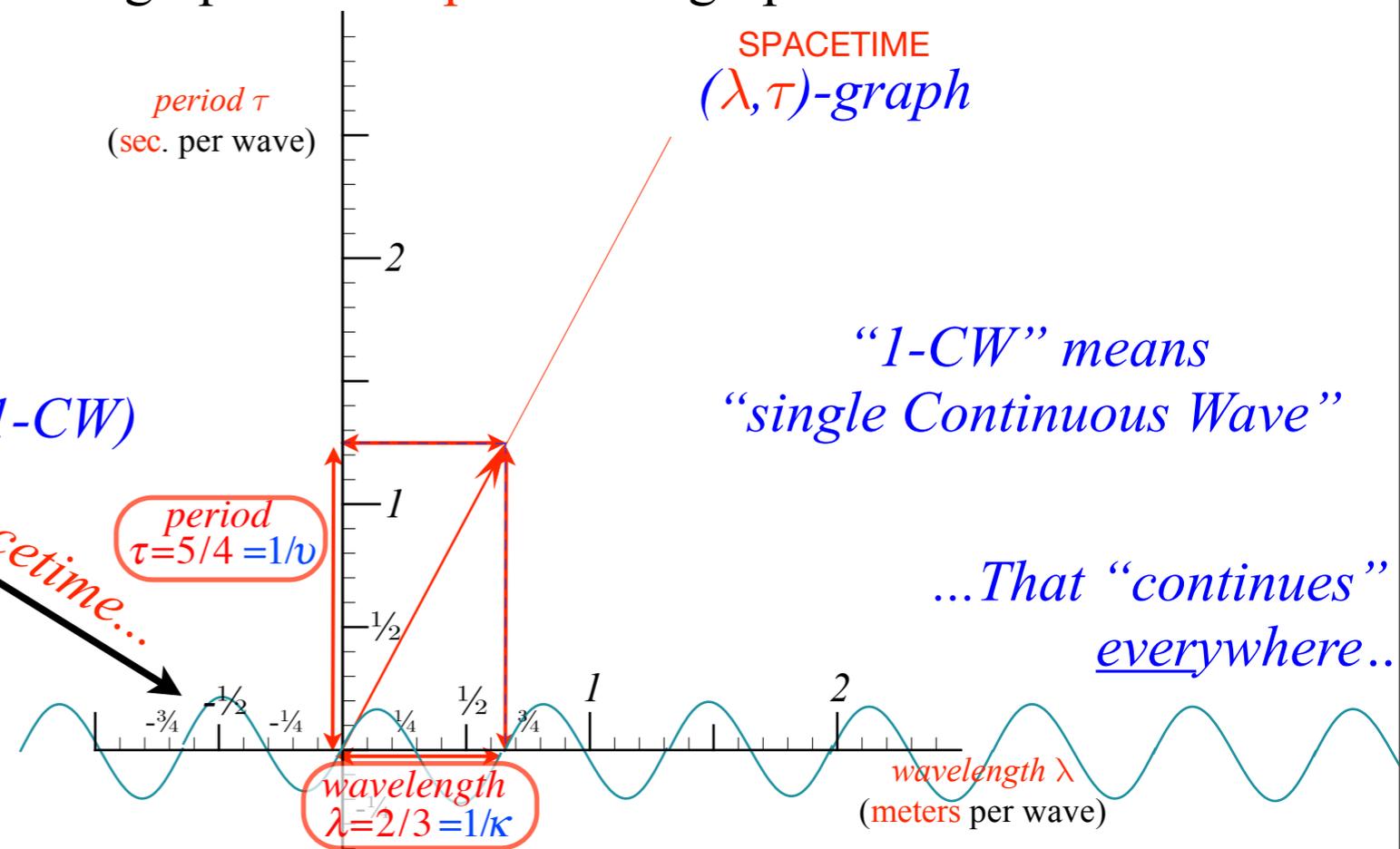
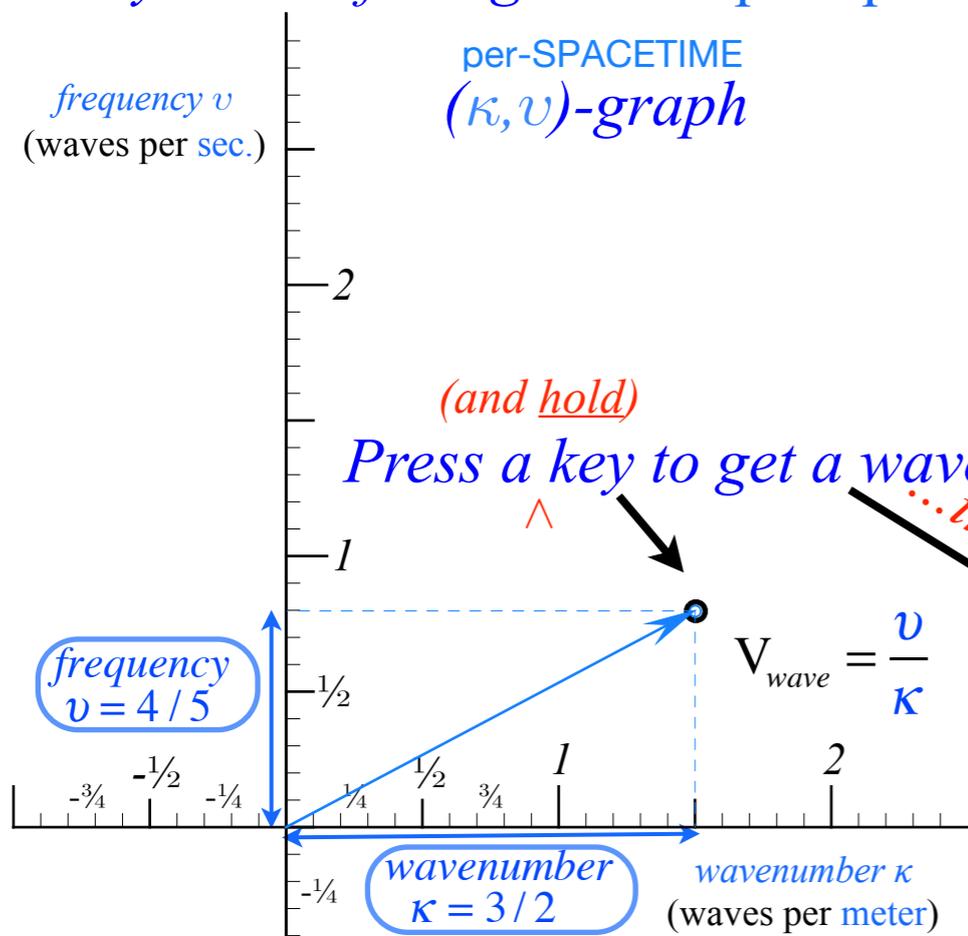
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wave-velocity formulas

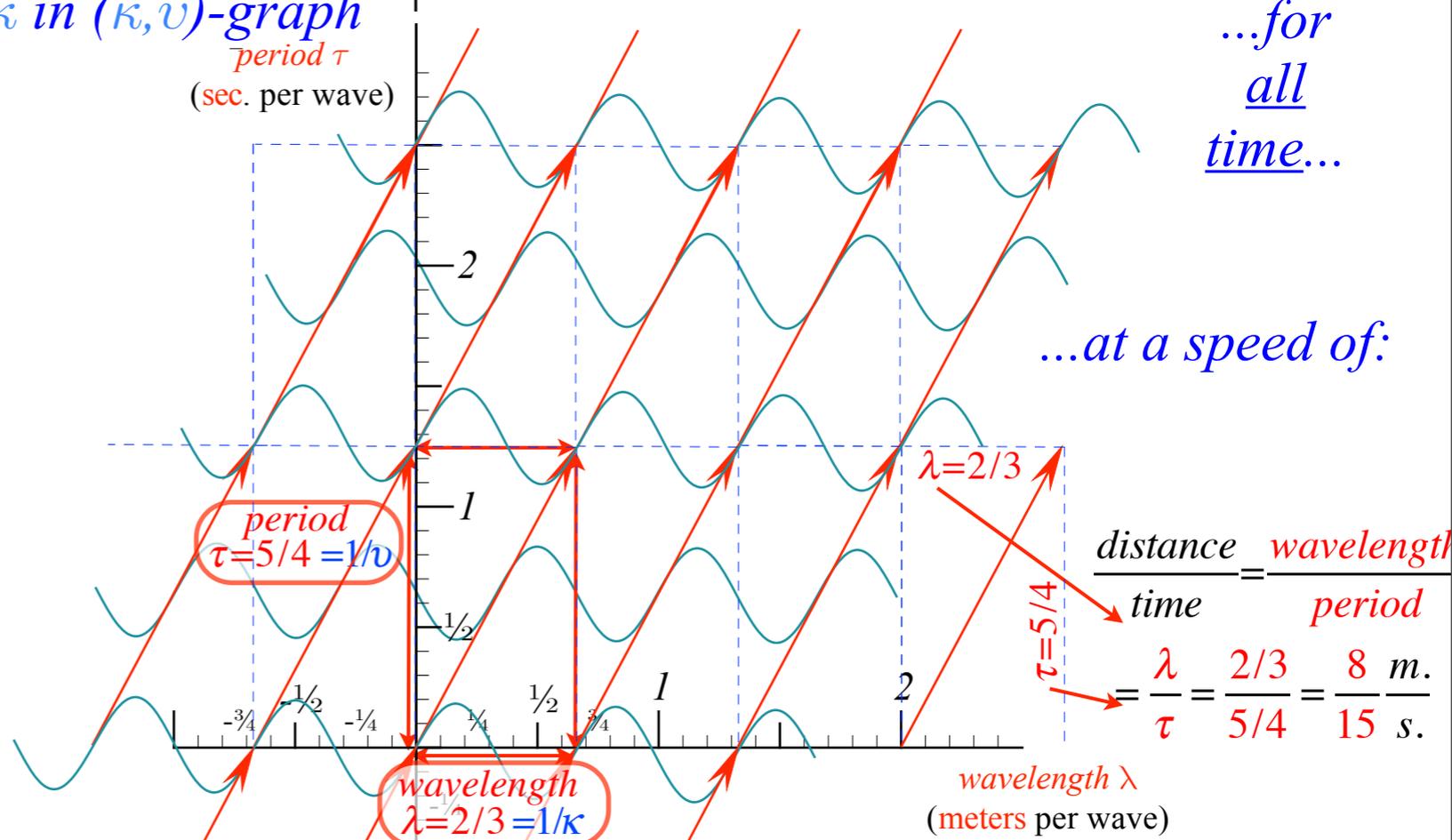
$$\frac{\text{distance}}{\text{time}} = \frac{\text{wavelength}}{\text{period}} = \frac{\text{frequency}}{\text{wavenumber}}$$

$$v_{\text{wave}} = \frac{\lambda}{\tau} = \frac{1/\kappa}{1/\nu} = \frac{\nu}{\kappa} = \frac{1/\tau}{1/\lambda}$$

$$= \frac{2/3}{5/4} = \frac{4/5}{3/2} = \frac{8 \text{ m.}}{15 \text{ s.}}$$

wave arithmetic is simpler to explain using fractions

•How to understand waves and "1st quantization"



...at a speed of:

$$\frac{\text{distance}}{\text{time}} = \frac{\text{wavelength}}{\text{period}} = \frac{\lambda}{\tau} = \frac{2/3}{5/4} = \frac{8 \text{ m.}}{15 \text{ s.}}$$

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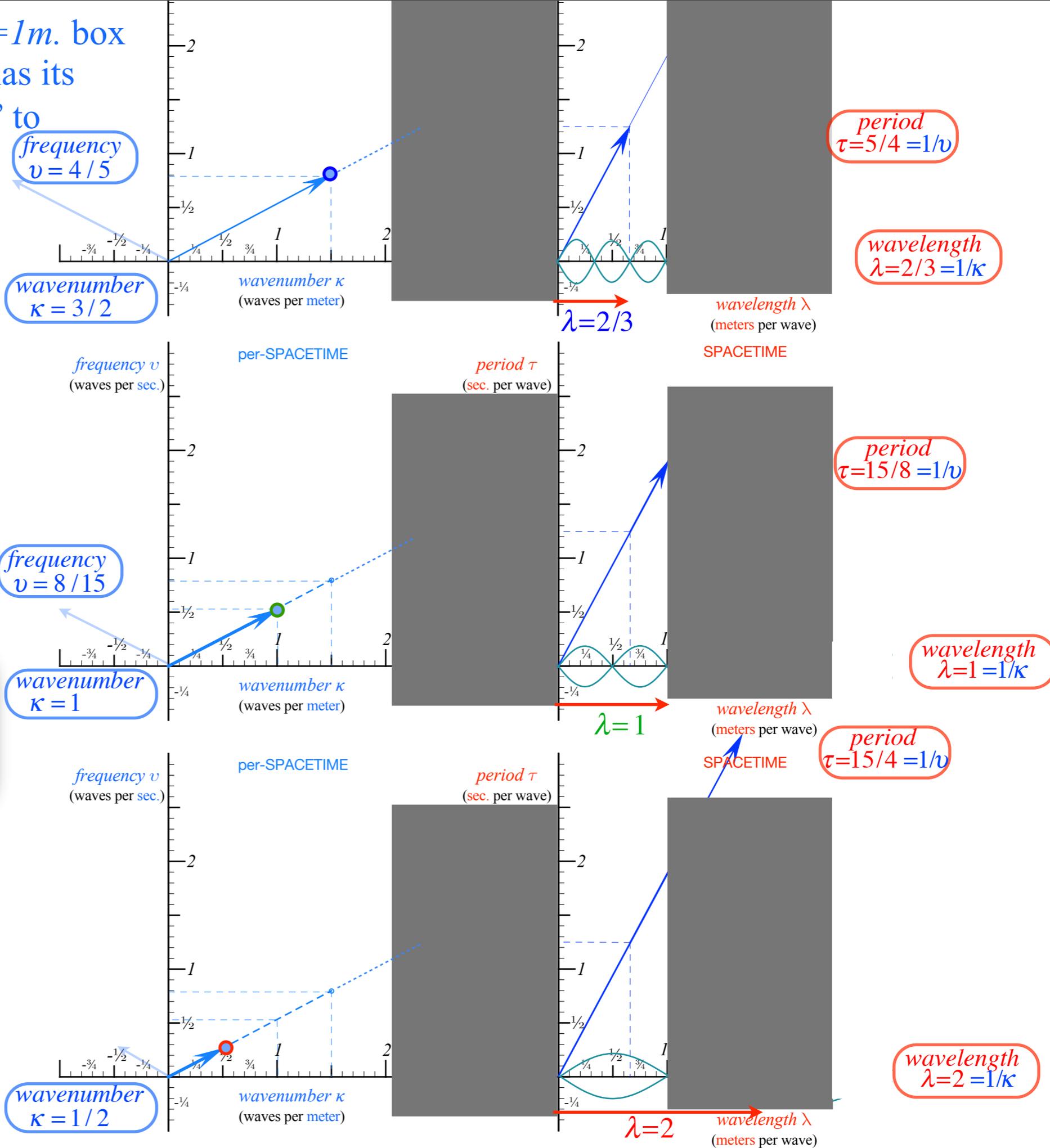
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If a wave is confined to an $L=1m.$ box
the “Keyboard of the gods” has its
wavenumber κ is “quantized” to
multiples of $1/2L=1/2.$

$$\kappa = \frac{1}{2}, \frac{2}{2}, \frac{3}{2}, \frac{4}{2}, \dots$$



•How to understand waves
and
“1st quantization”
or κ -quantization

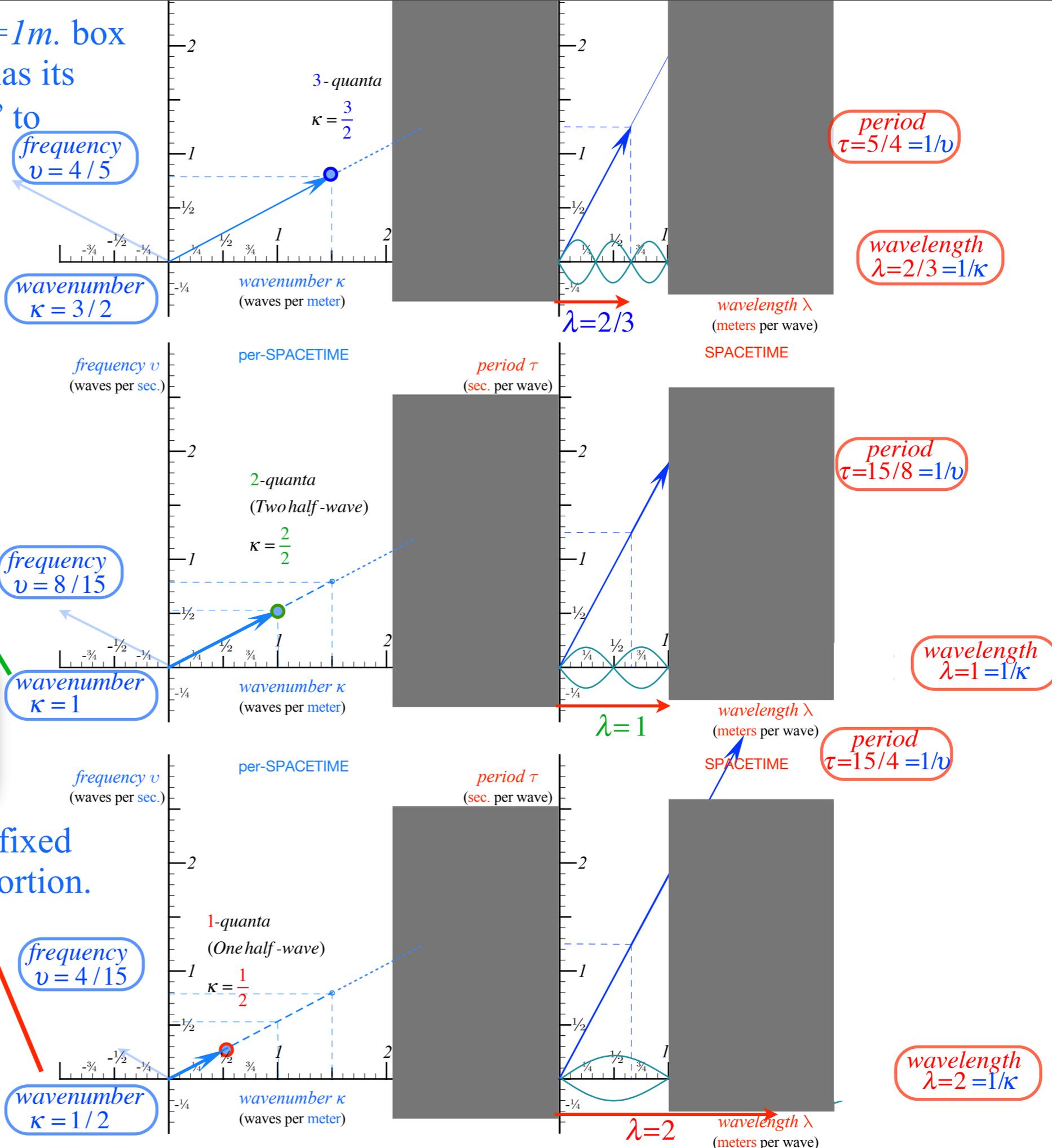
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If wave velocity $V_{wave}=8/15$ is fixed frequency is quantized in proportion.



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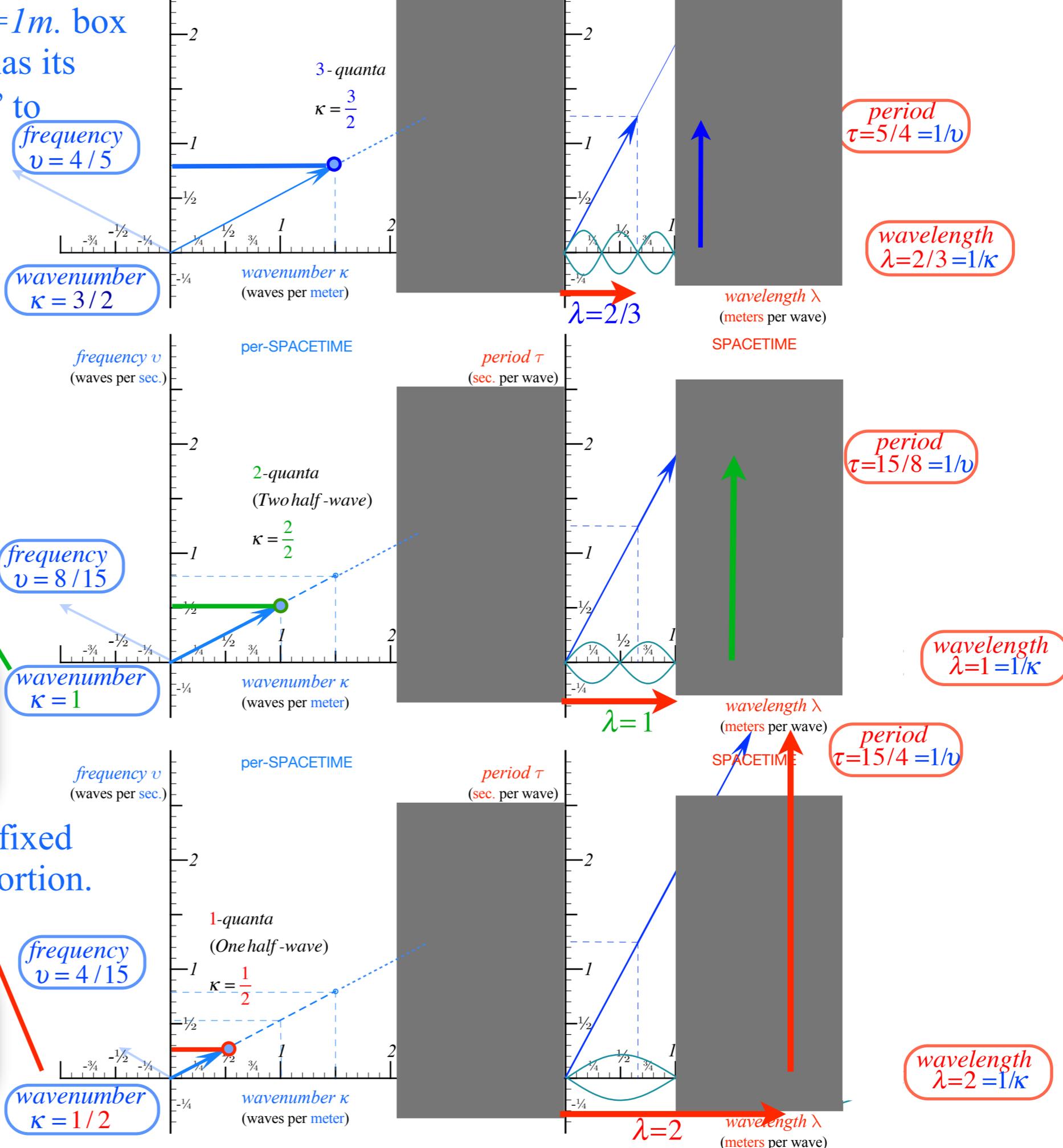
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•How to understand waves and “1st quantization” or κ -quantization

...as QUALITY (color) versus QUANTITY (Number of photons)

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frequency $\nu = 4/5$

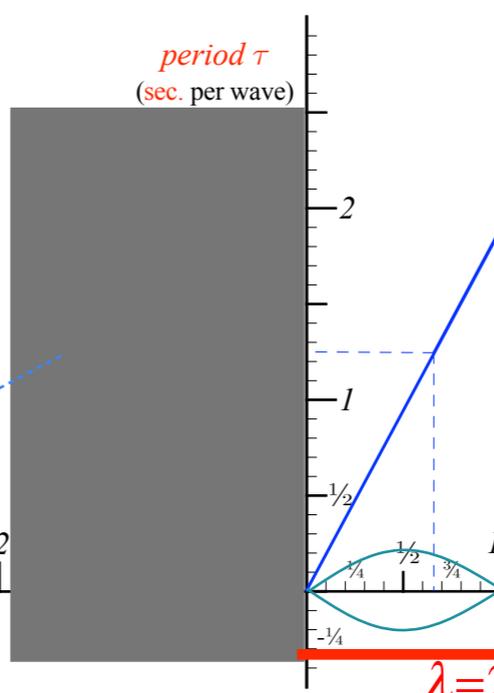
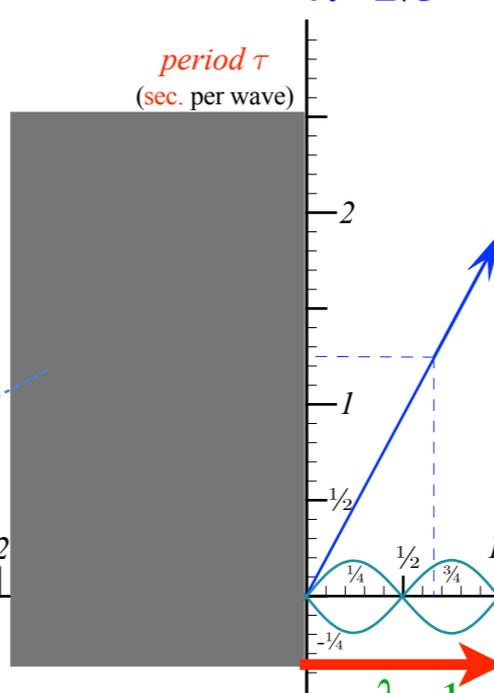
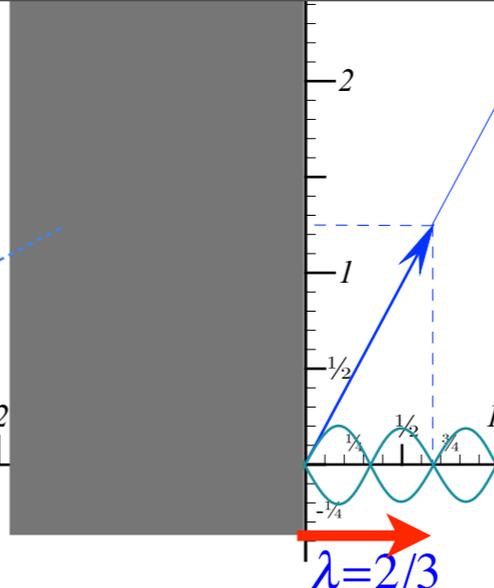
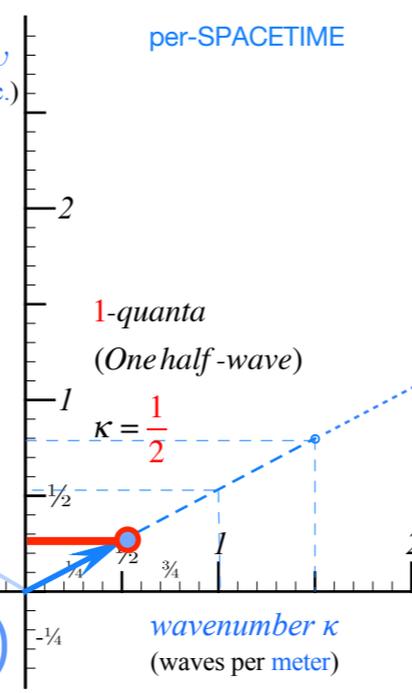
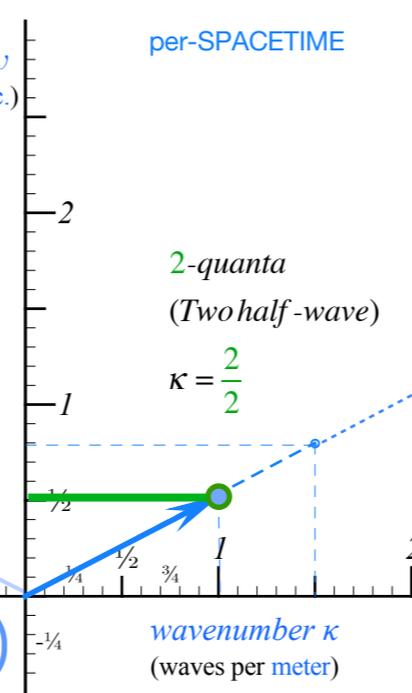
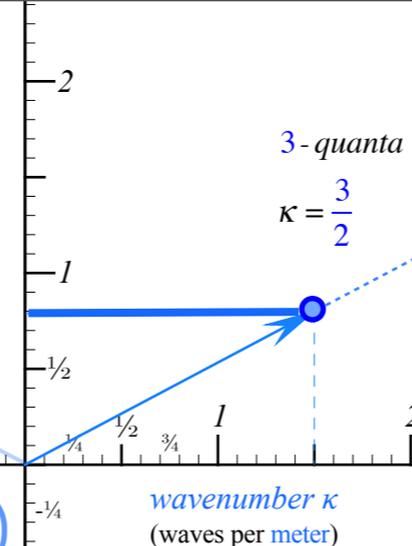
wavenumber $\kappa = 3/2$

frequency $\nu = 8/15$

wavenumber $\kappa = 1$

frequency $\nu = 4/15$

wavenumber $\kappa = 1/2$



period $\tau = 5/4 = 1/\nu$

wavelength $\lambda = 2/3 = 1/\kappa$

period $\tau = 15/8 = 1/\nu$

wavelength $\lambda = 1 = 1/\kappa$

period $\tau = 15/4 = 1/\nu$

wavelength $\lambda = 2 = 1/\kappa$

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As will be shown:

Light wave-velocity *c* is *VERY* fixed

$$V_{light} = c = \frac{\lambda}{\tau} = \frac{1/\kappa}{1/\nu} = \frac{\nu}{\kappa} = \frac{1/\tau}{1/\lambda} = 299,792,458 \frac{m.}{s.}$$

After 1982 the \pm error was dropped and $c=299,792,458m/s$ became the definition of the meter

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Then it's convenient to use:

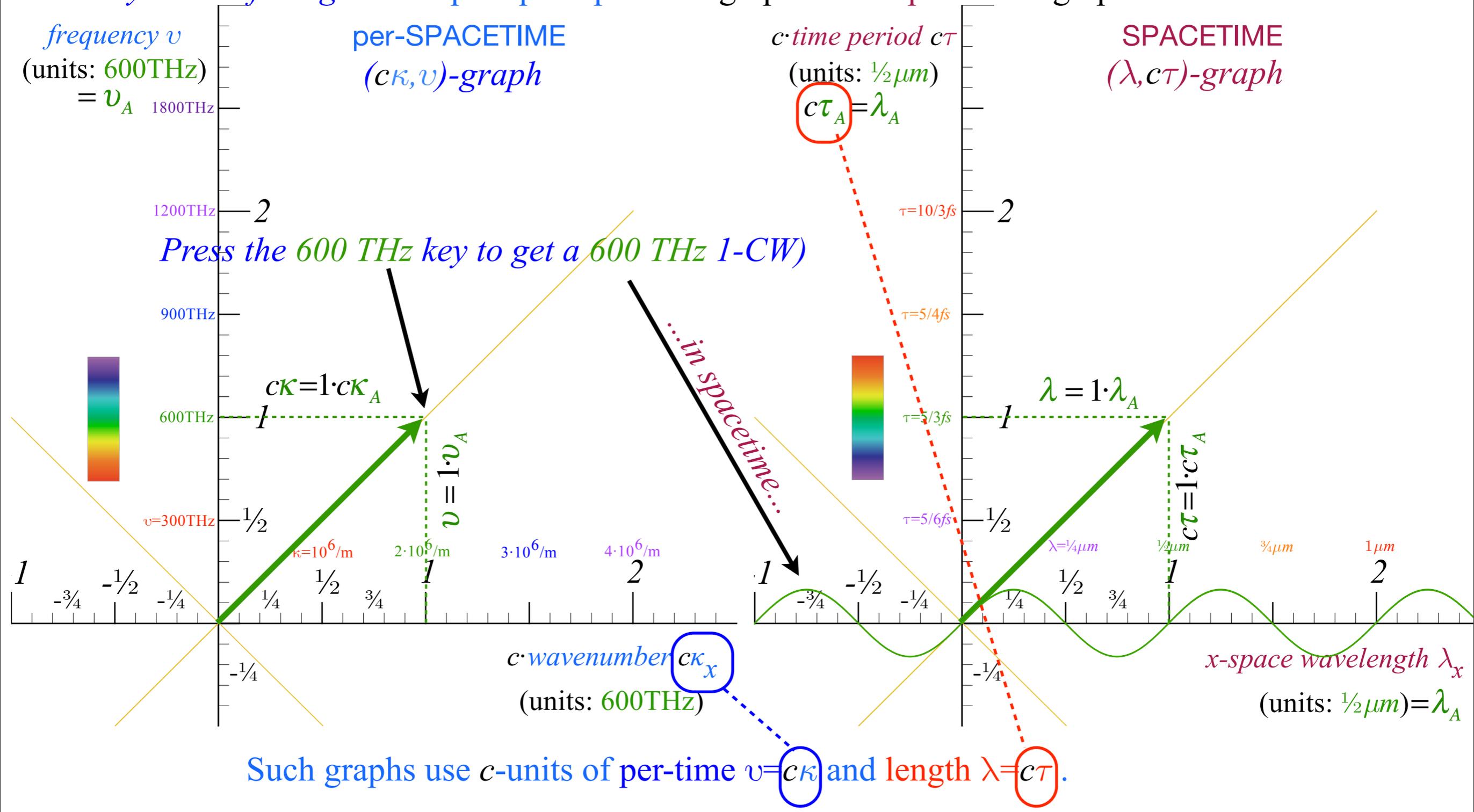
Dimensionless *Light* wave-velocity $c/c=1$

$$\frac{V_{light}}{c} = \frac{v}{c\kappa} = \frac{\lambda}{c\tau} = 1 \quad \text{instead of:} \quad \frac{v}{\kappa} = \frac{\lambda}{\tau} = c$$

Such graphs use c -units of per-time $v=c\kappa$ and length $\lambda=c\tau$.

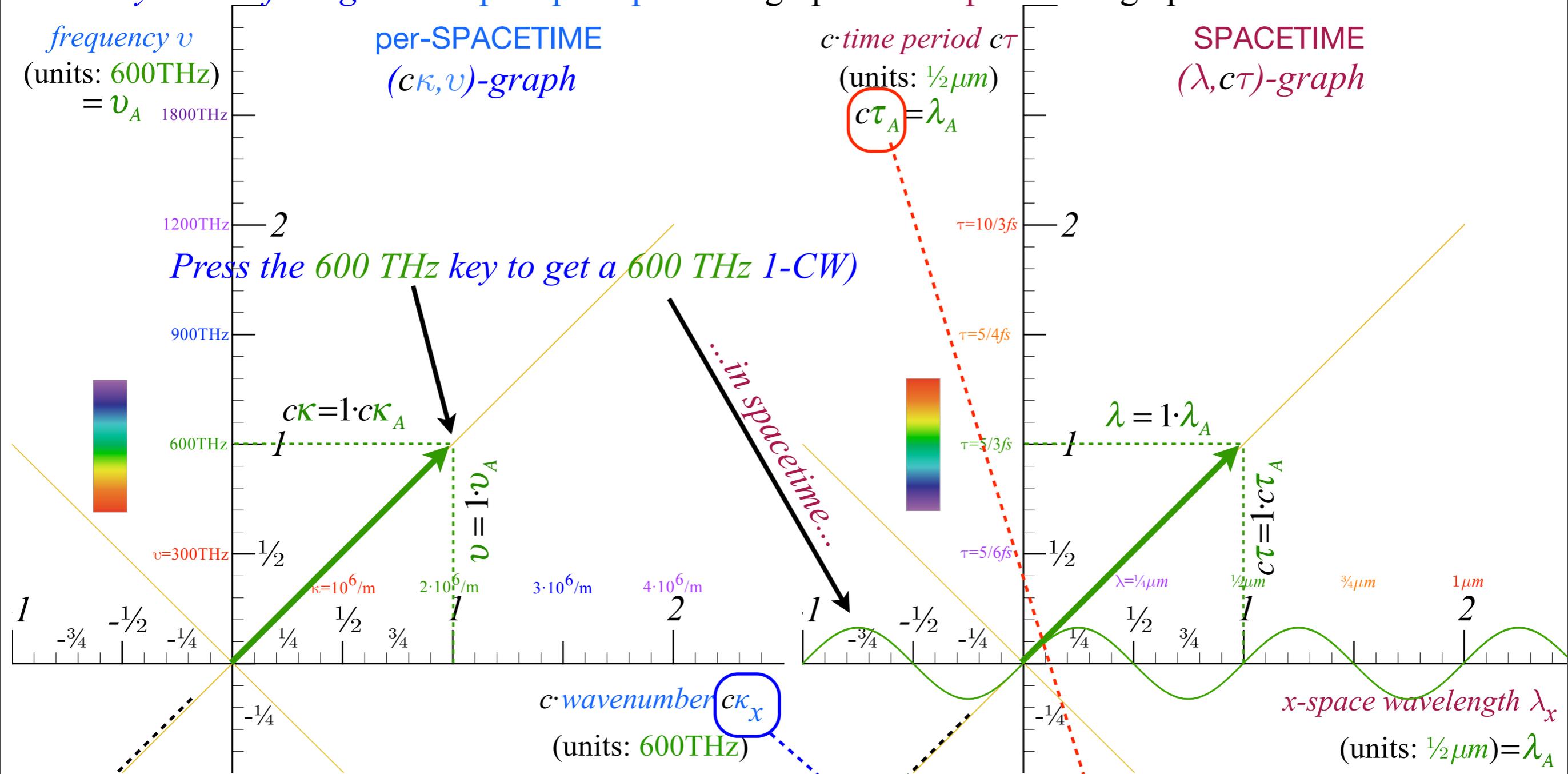
$$\frac{V_{light}}{c} = \frac{v}{c\kappa} = \frac{1/\kappa}{c/\nu} = \frac{\lambda}{c\tau} = \frac{1/\tau}{c/\lambda} = 1$$

The "Keyboard of the gods" or per-space-per-time graphs versus space-time graphs



Ways to quantify light waves (600 THz example)

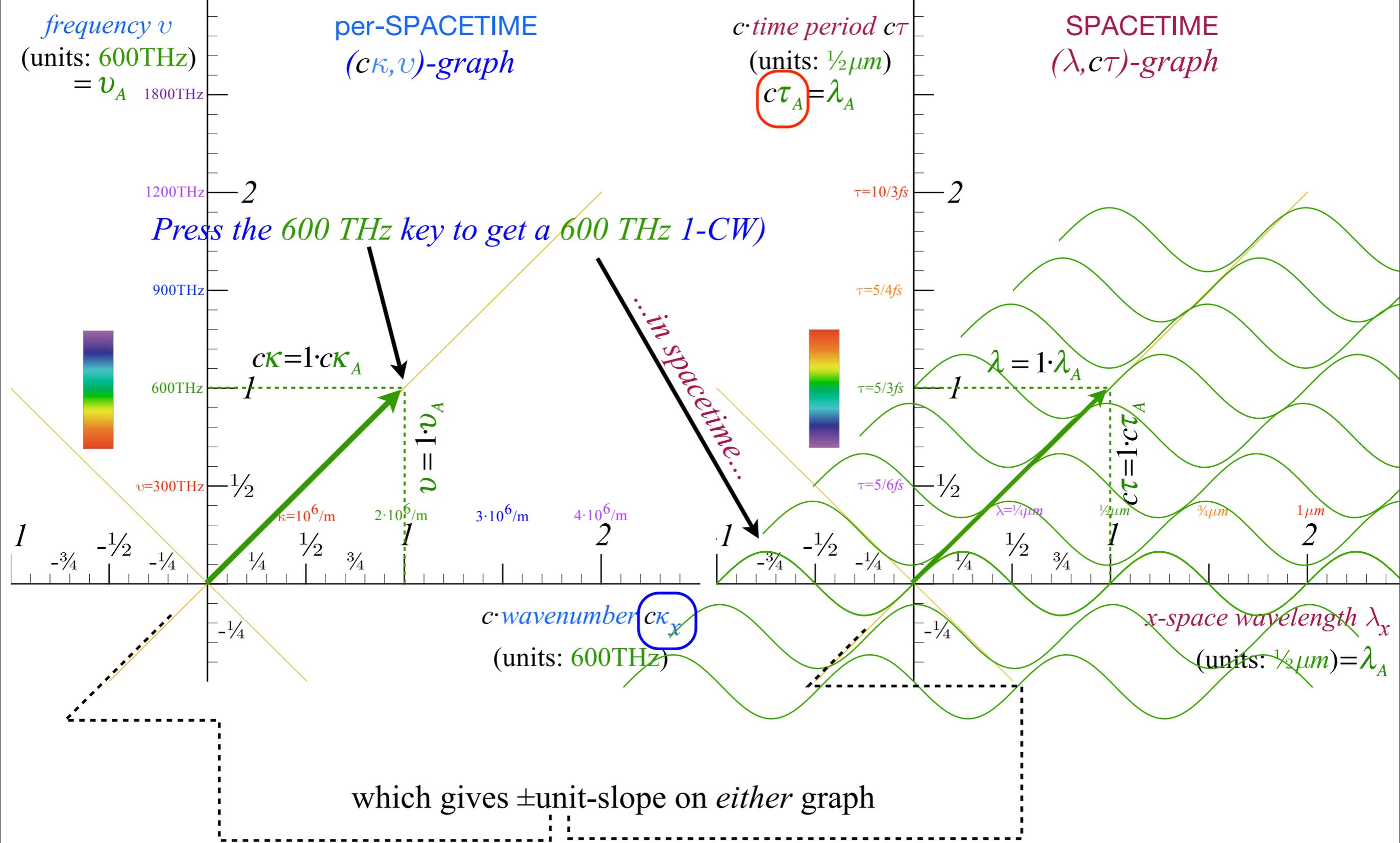
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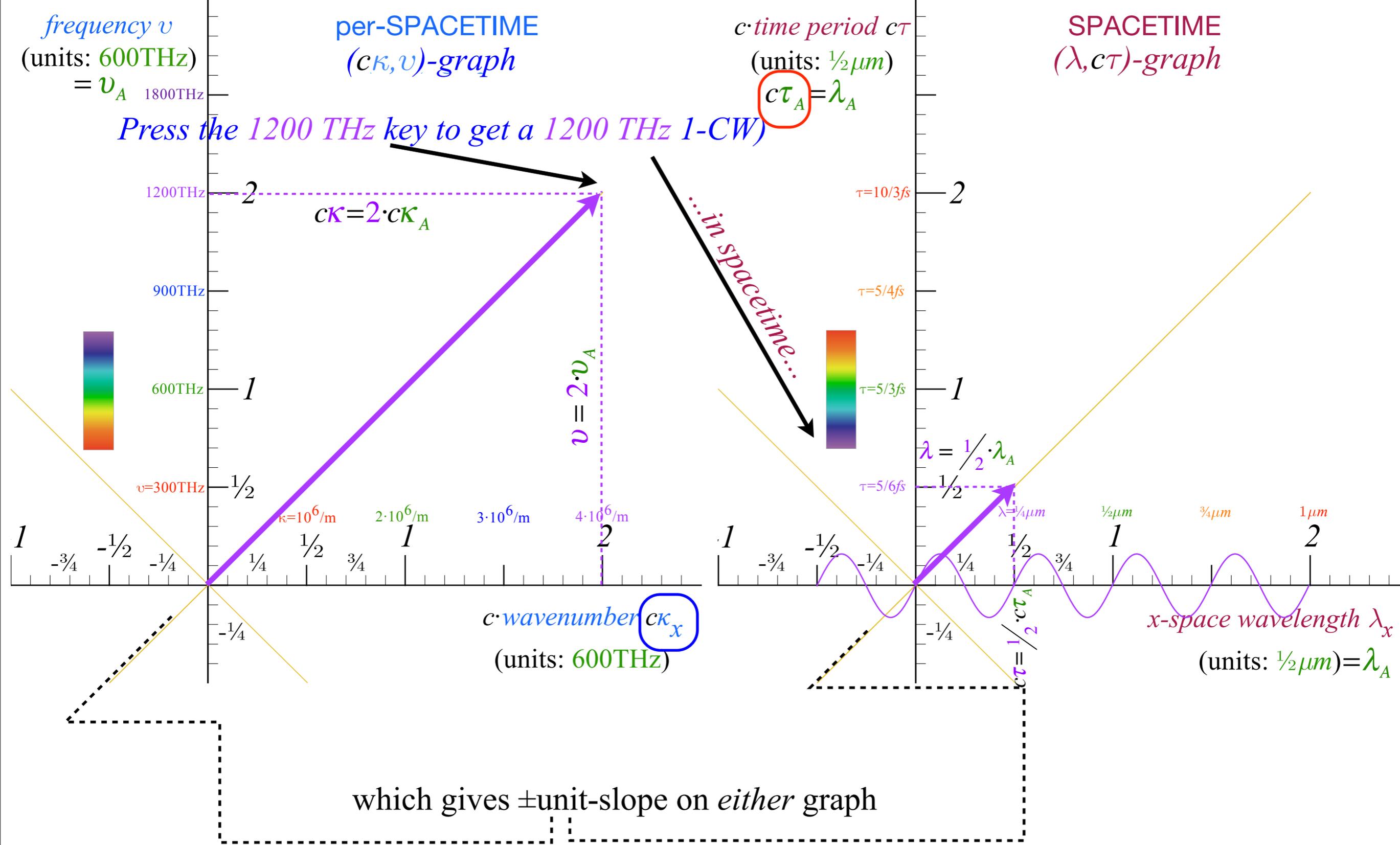
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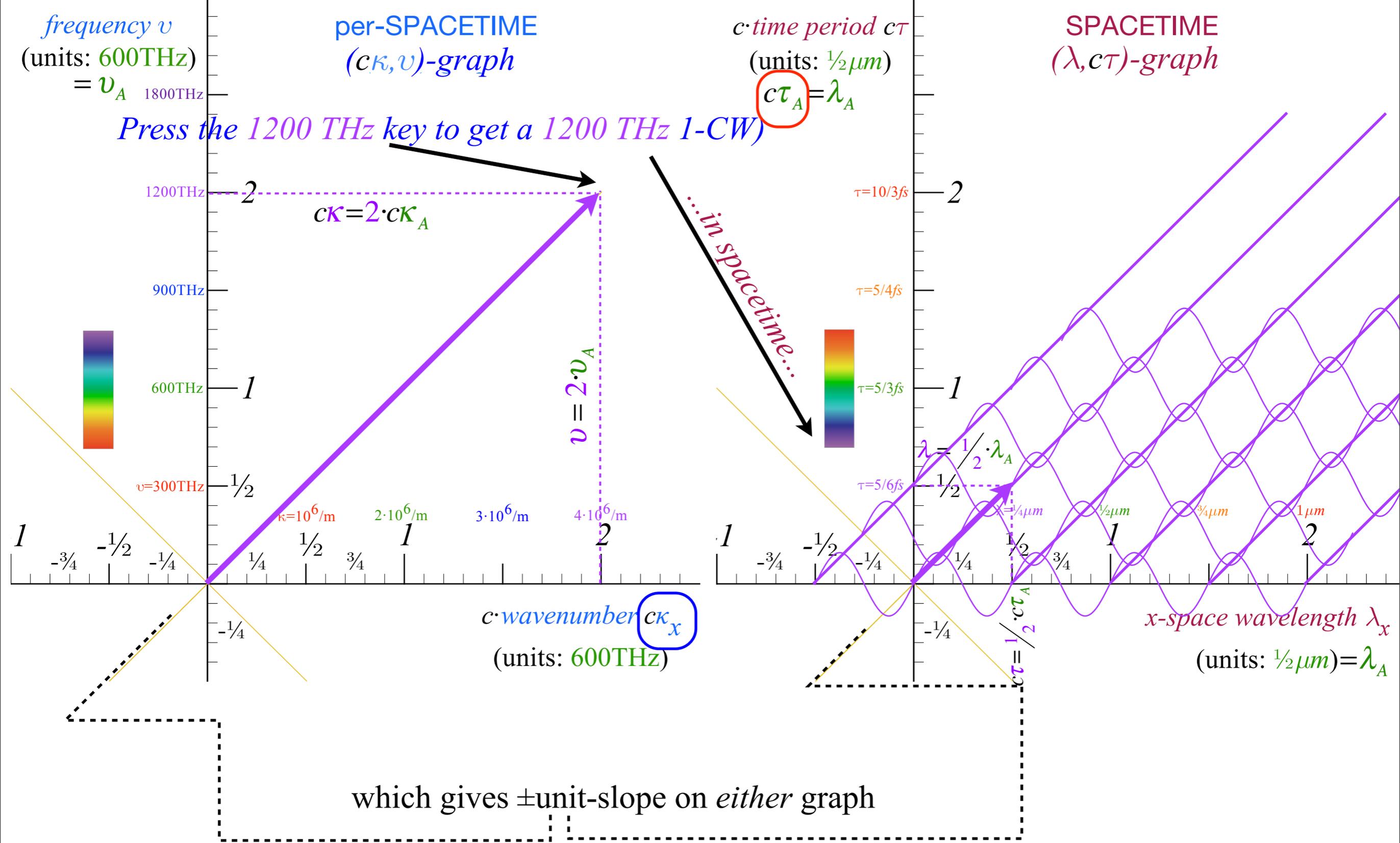
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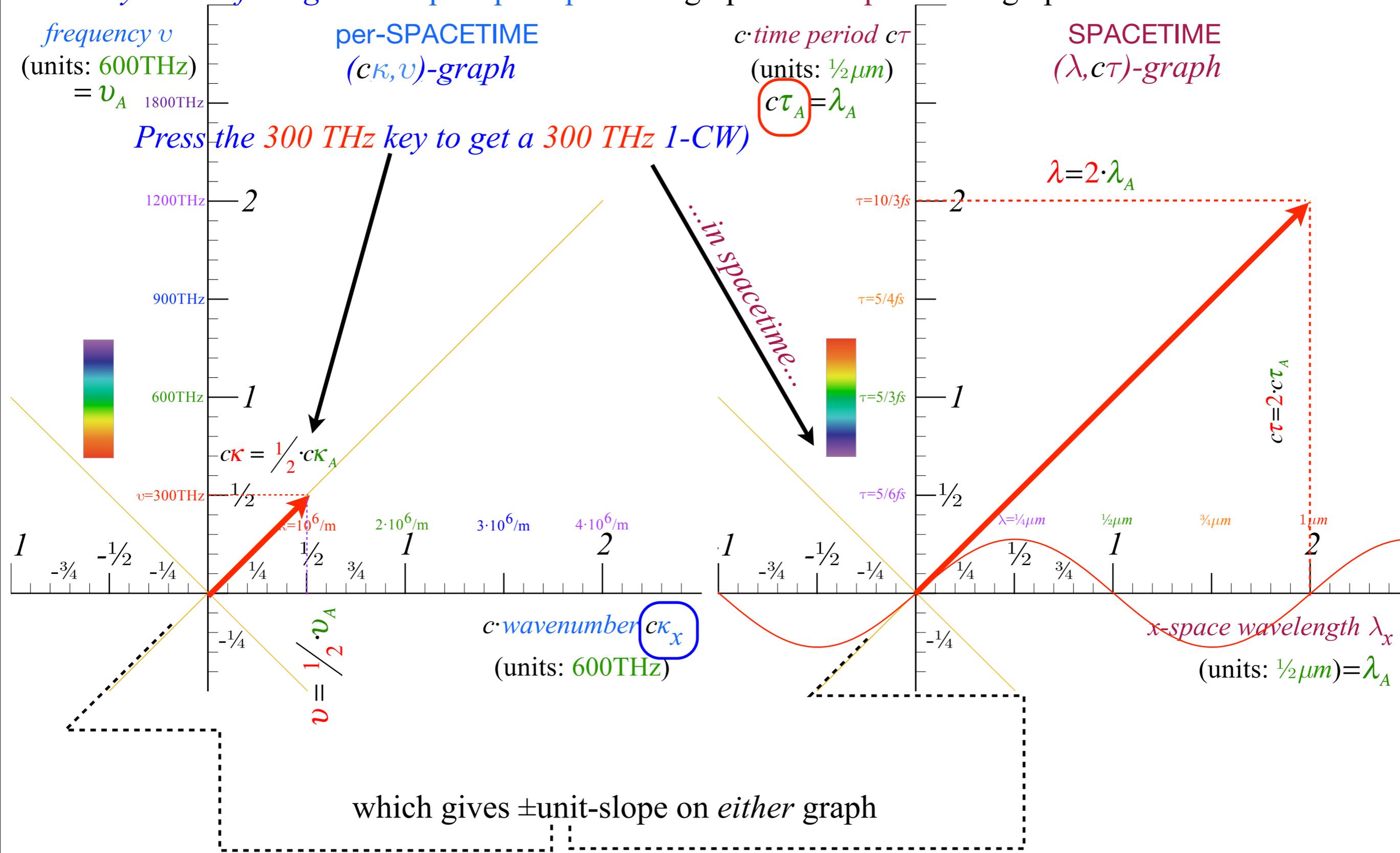
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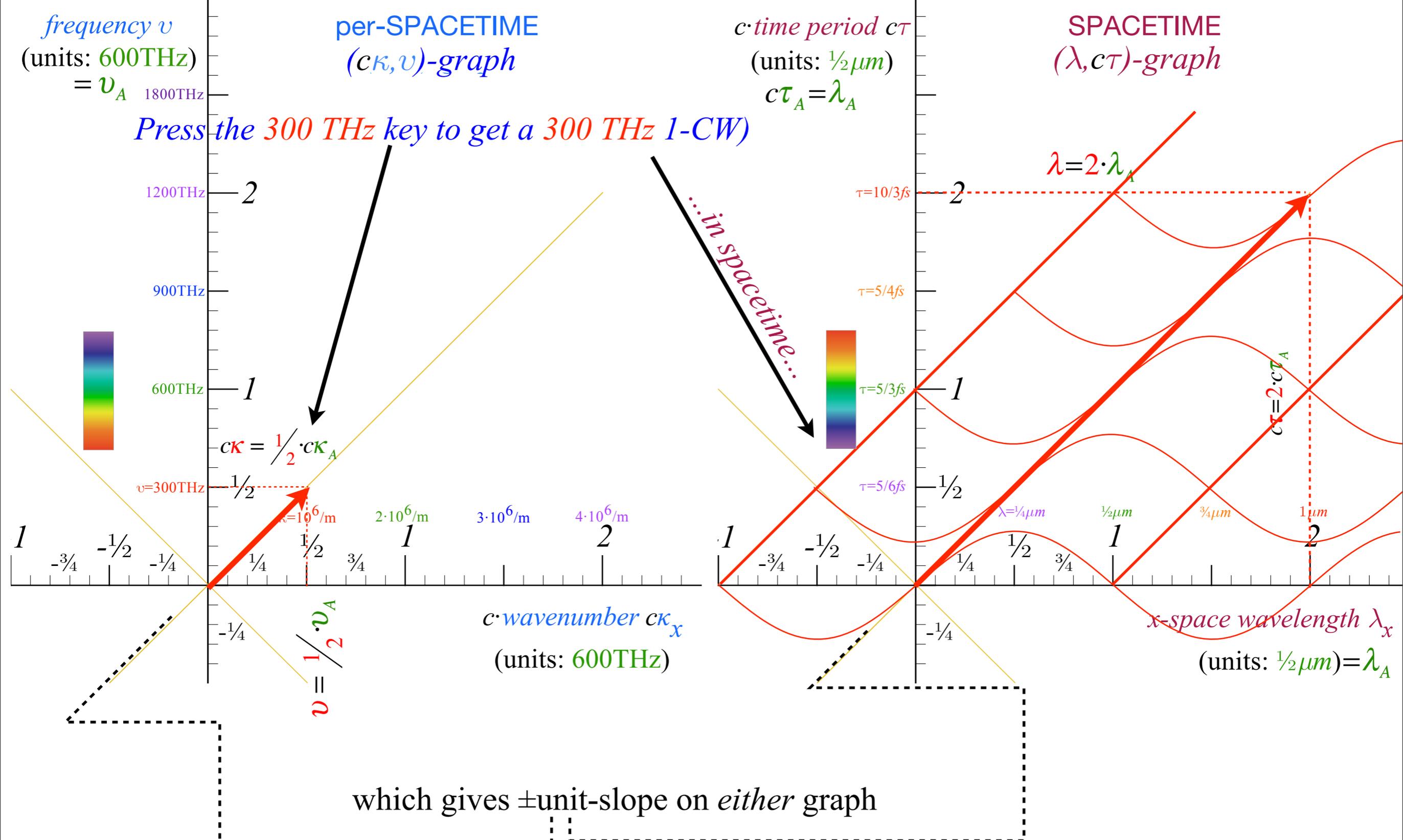
Ways to quantify **light** waves (1200 THz example)

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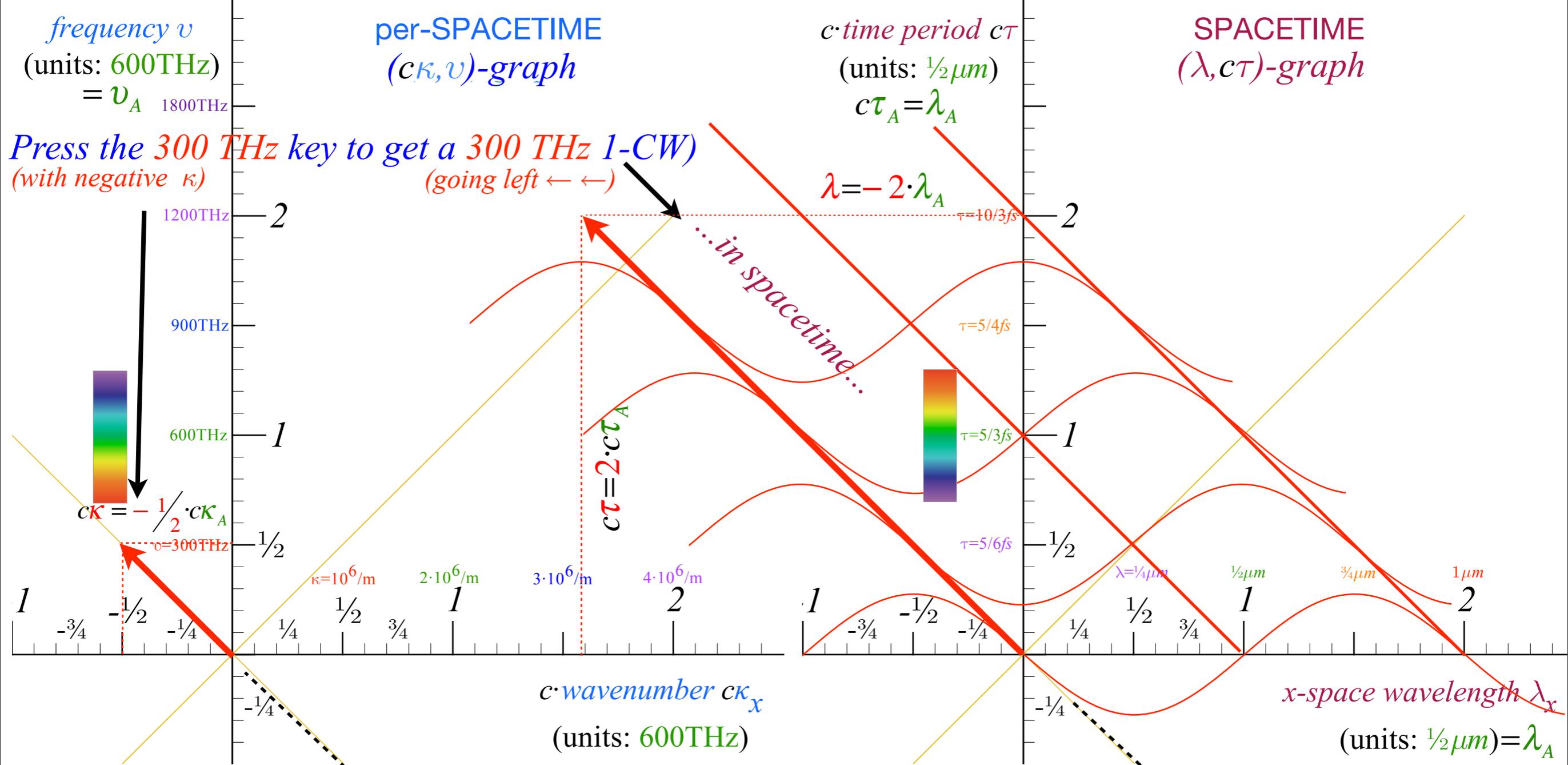
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Ways to quantify *light* waves (300 THz example)

Special Relativity and Quantum Mechanics regarded as *mysterious* and *lacking clarity*

Bob&Alice regard for clarity of SR: **foggy** or QM: **opaque**

Can this situation be improved at fundamental axiomatic level?

Evidence and concepts needing critical review:

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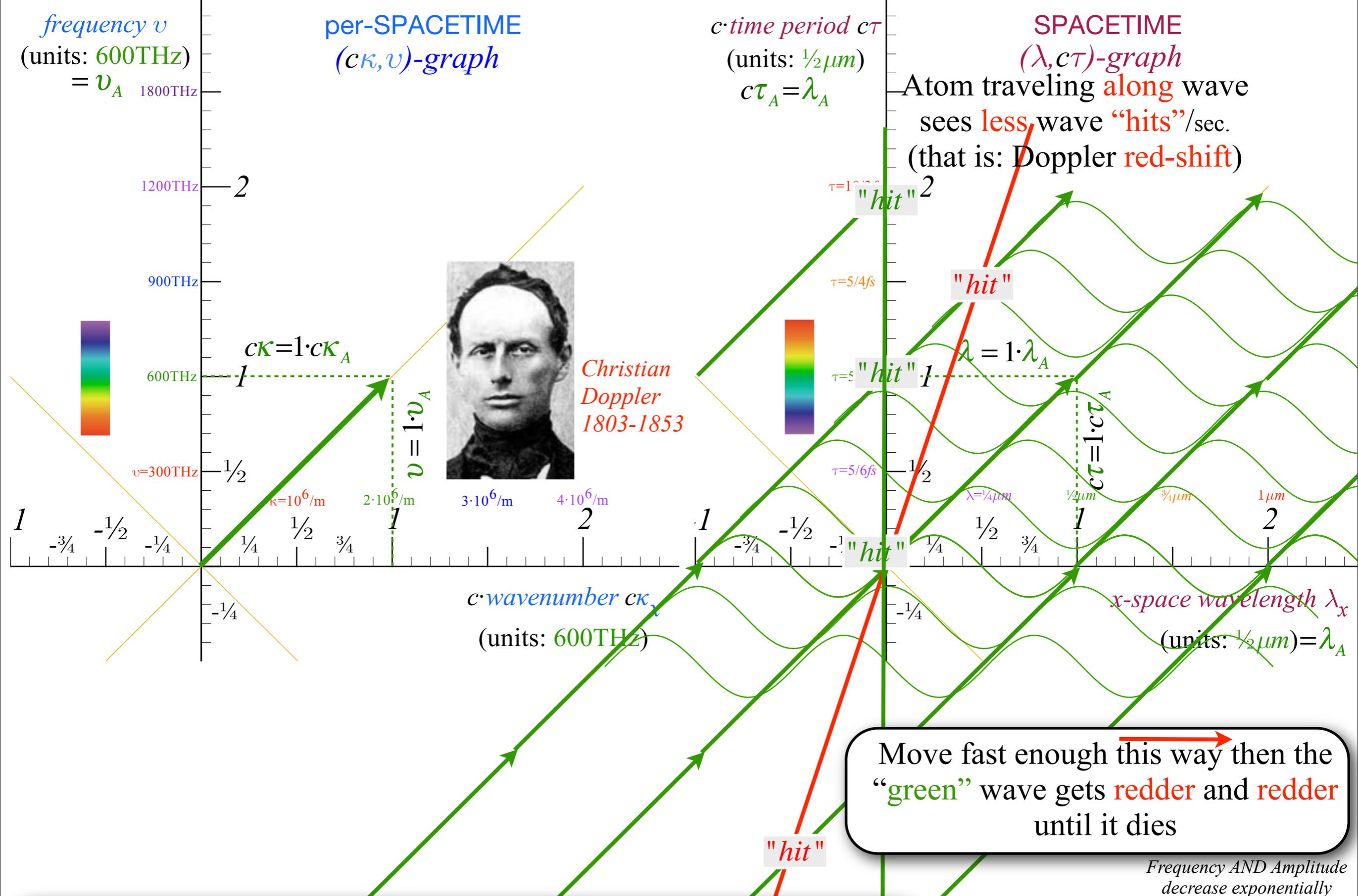
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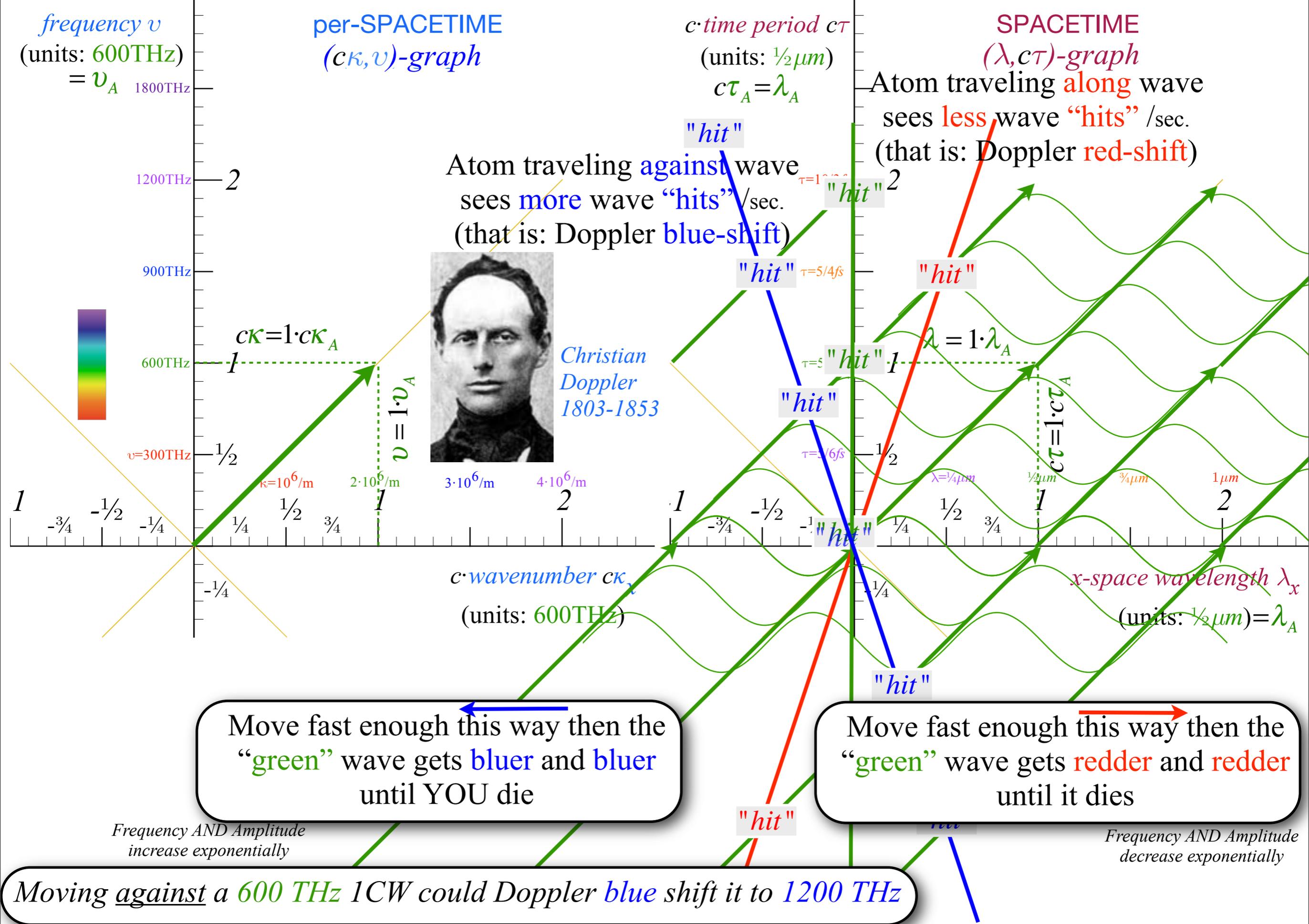
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Christian Doppler 1803-1853

Moving along a 600 THz 1CW could Doppler red shift it to 300 THz

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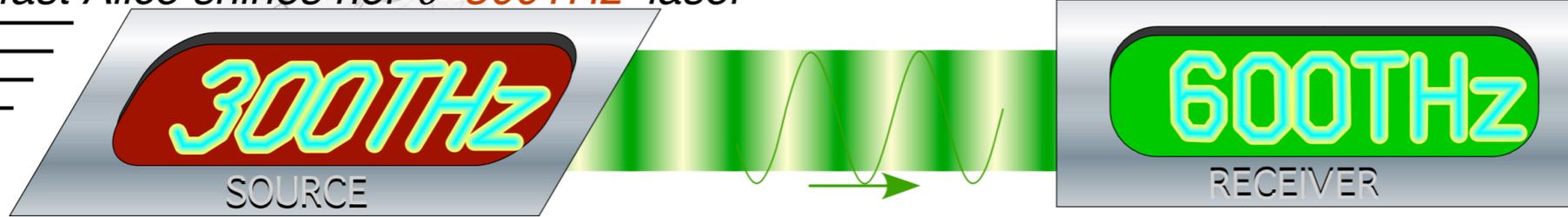


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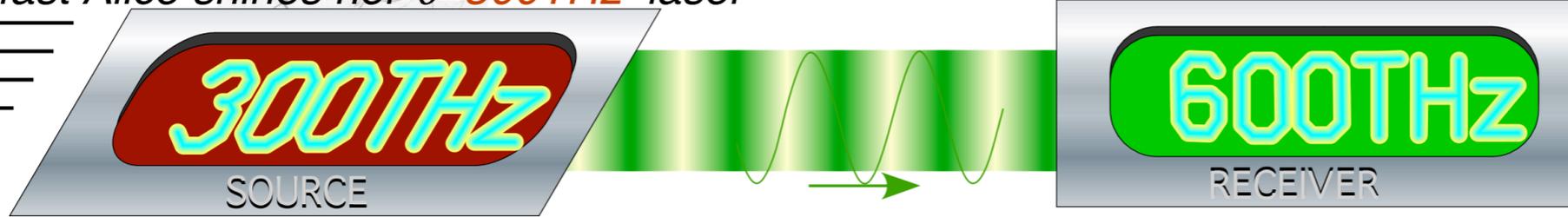


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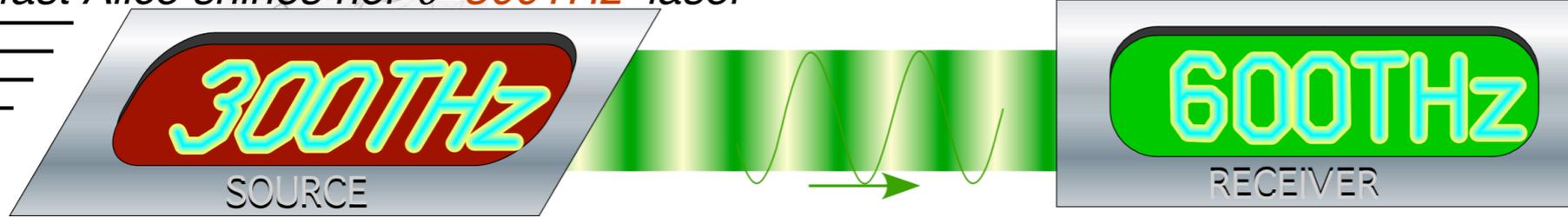


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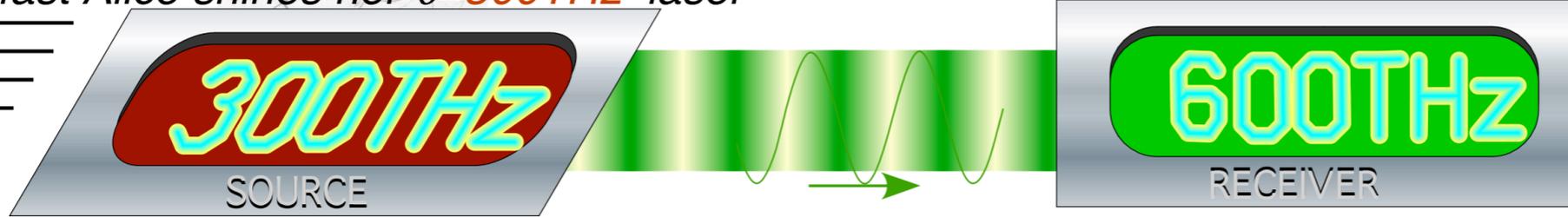
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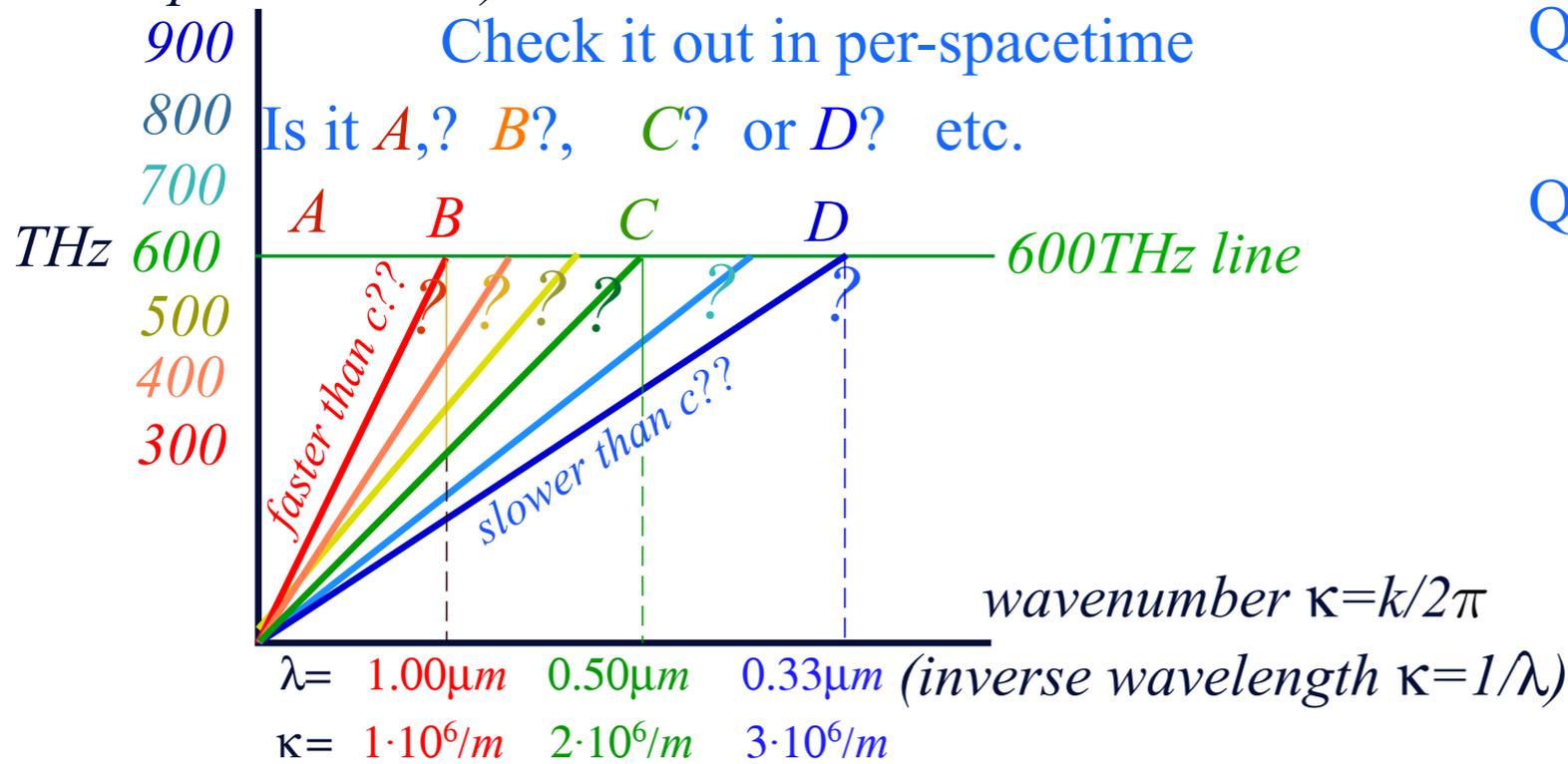


frequency $\nu=\omega/2\pi$

(Inverse period $\nu=1/\tau$)

Check it out in per-spacetime

Is it A, B, C or D? etc.



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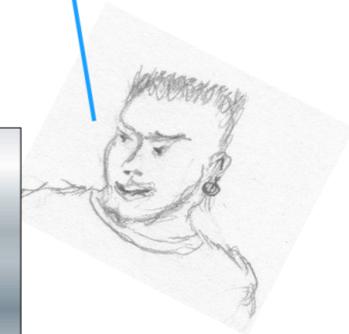
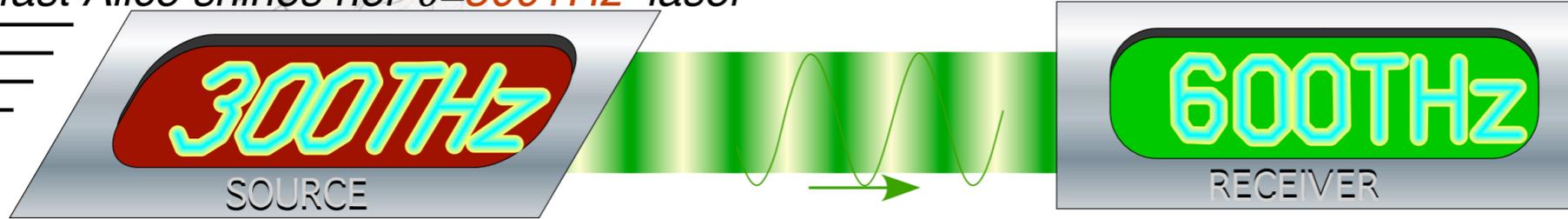
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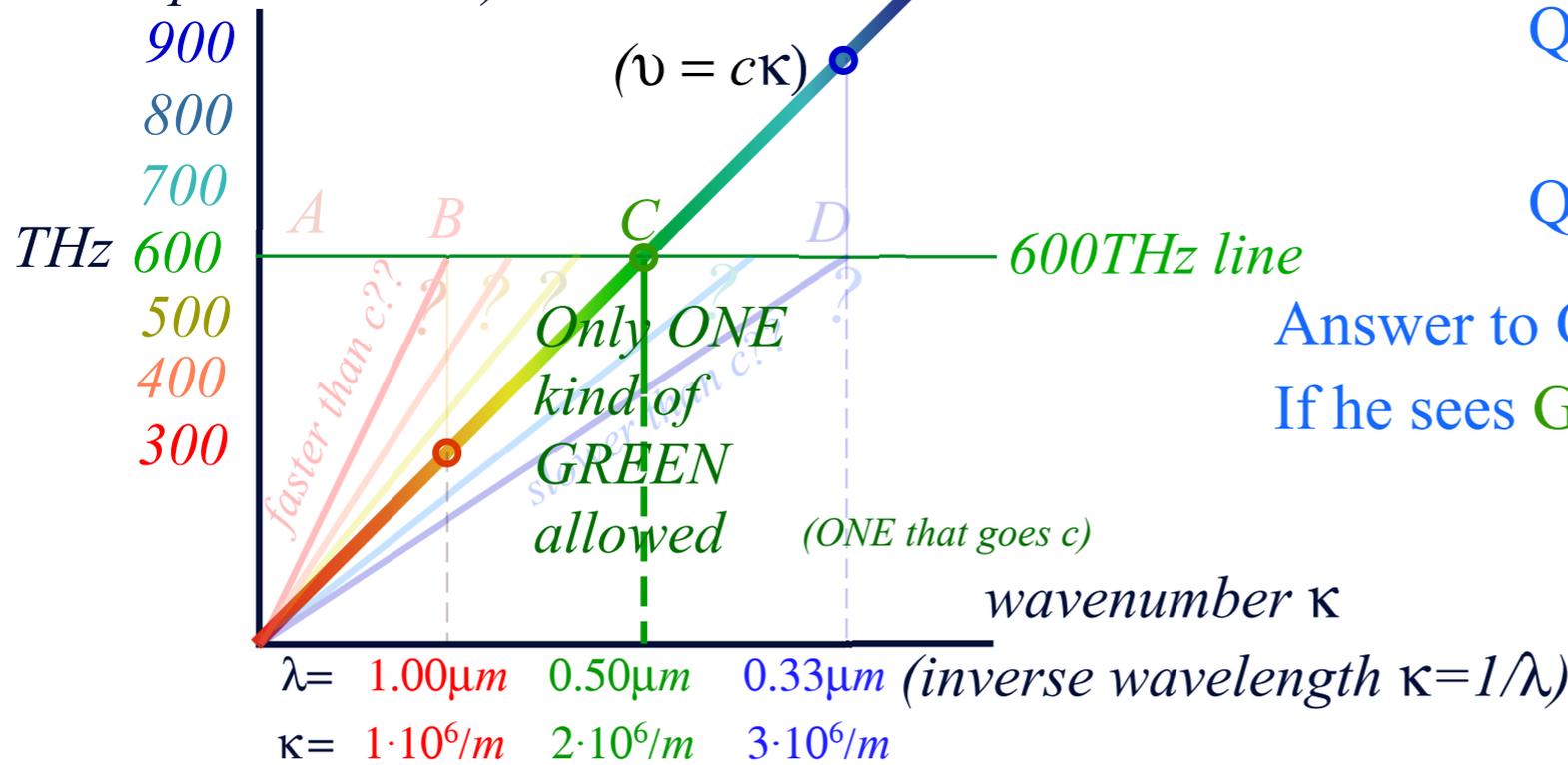
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If he sees Green 600THz then he measures $\lambda = 0.5\mu\text{m}$.

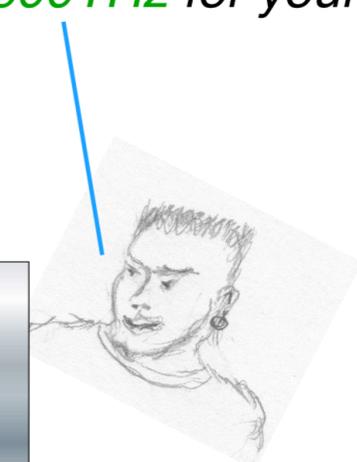
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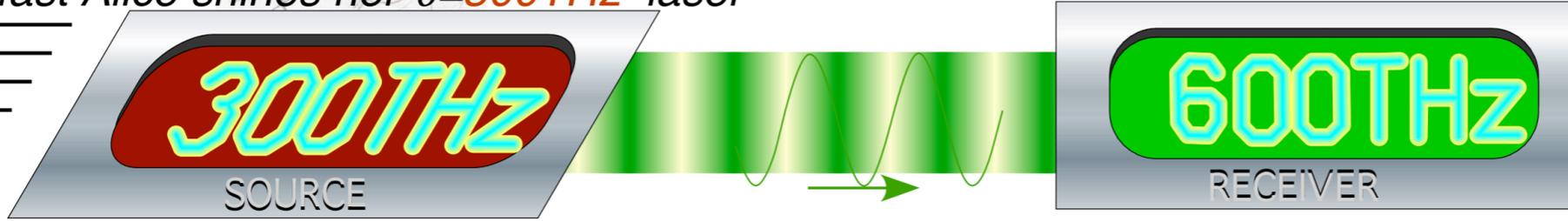


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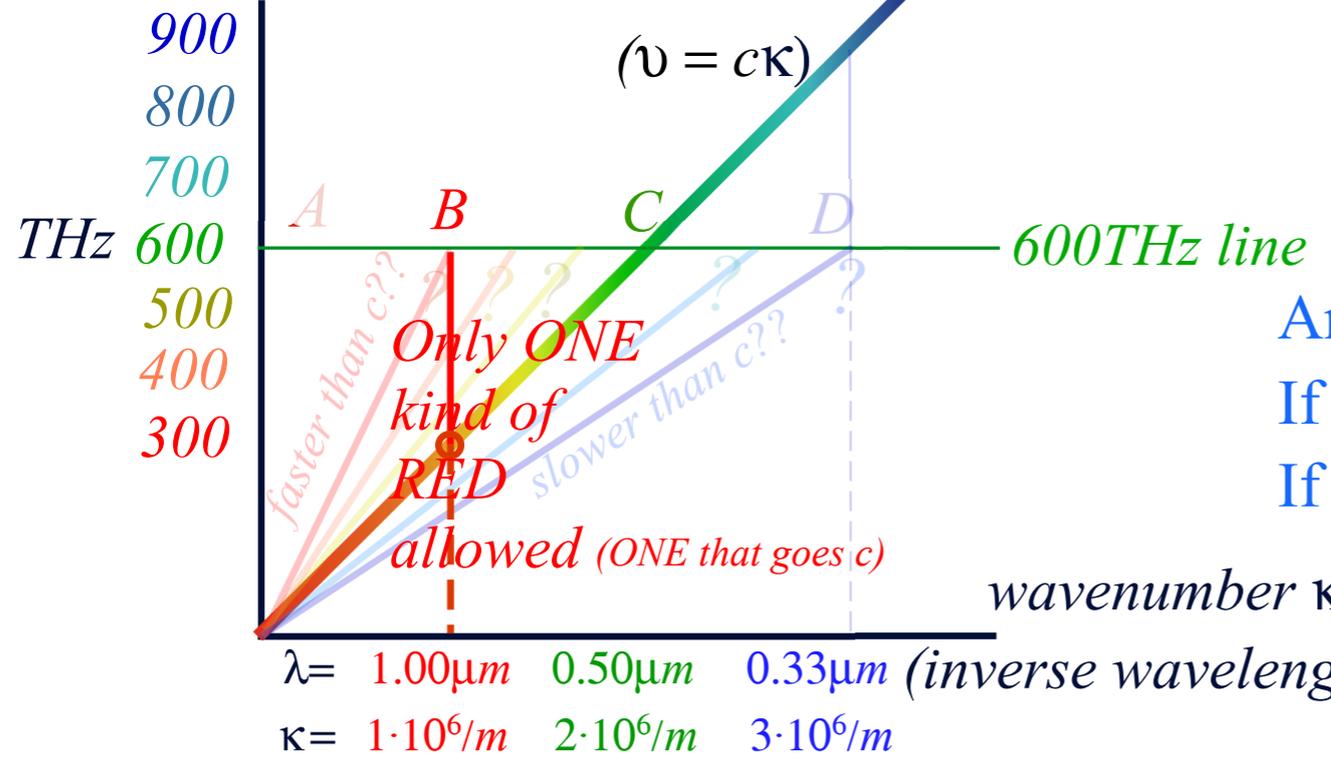
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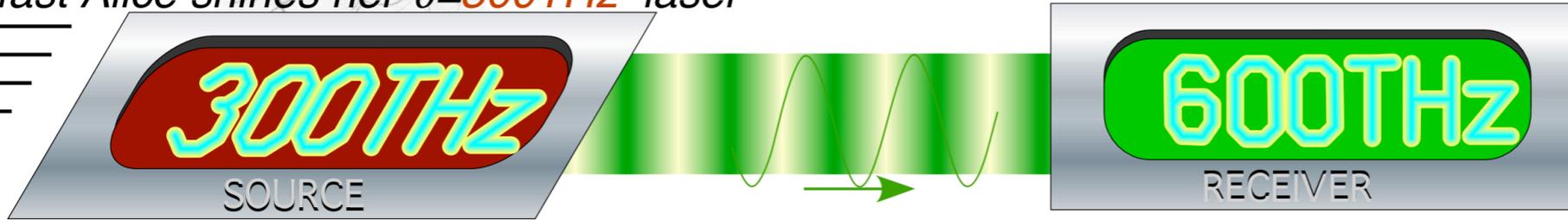


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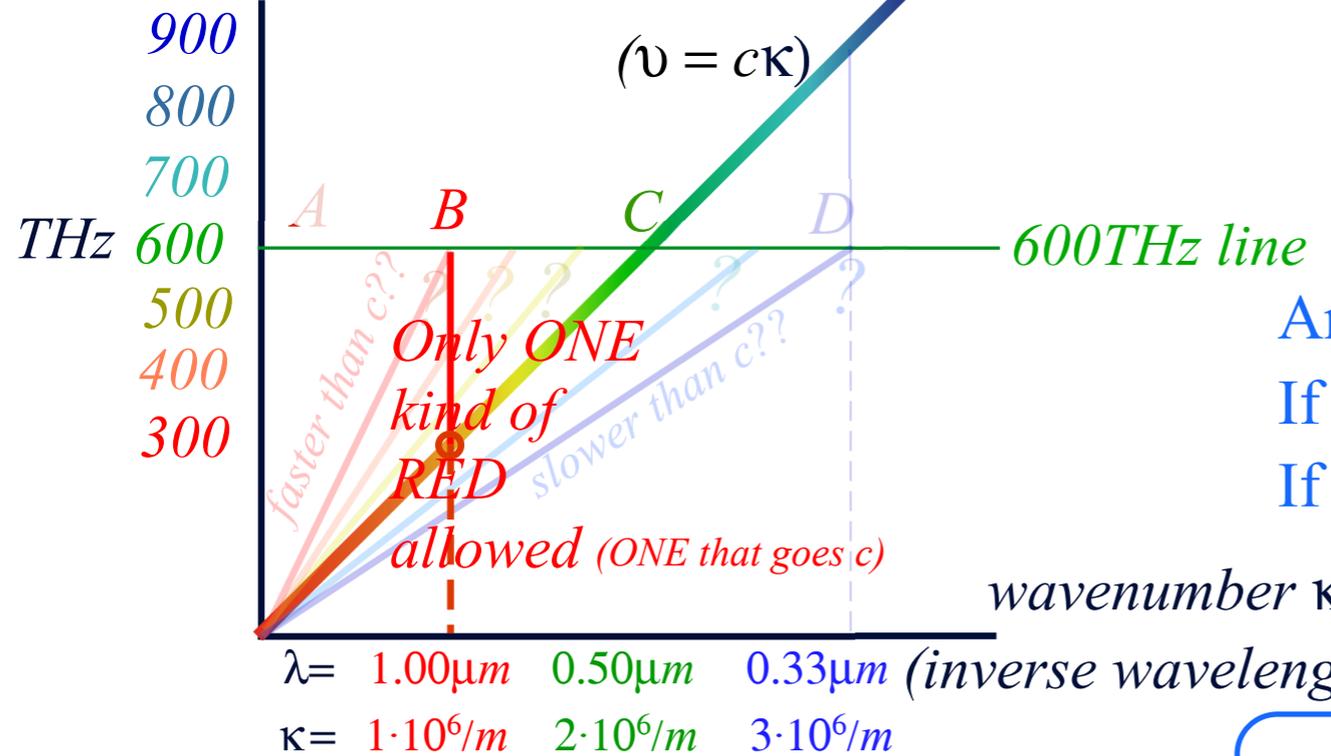
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Answer to Q1 is **NO!**
CW Light carries **no** birth-certificate!

Vacuum only makes one λ for each ν .*

"All colors go $c = \lambda\nu = \nu/\kappa$ "

Then *Evenson's axiom* holds:

*for each beam and polarization orientation

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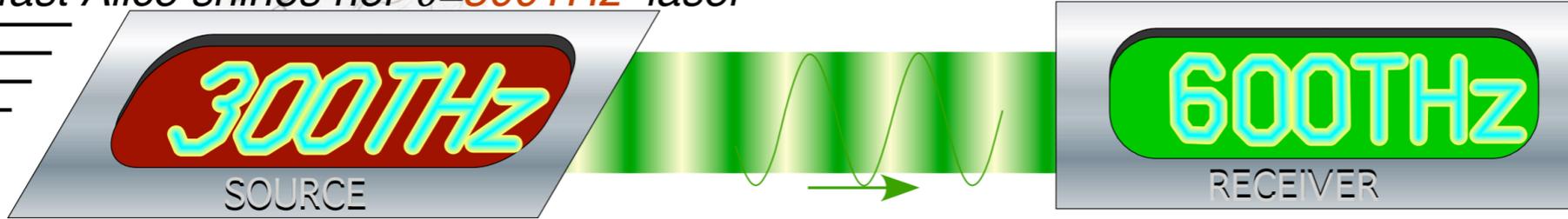
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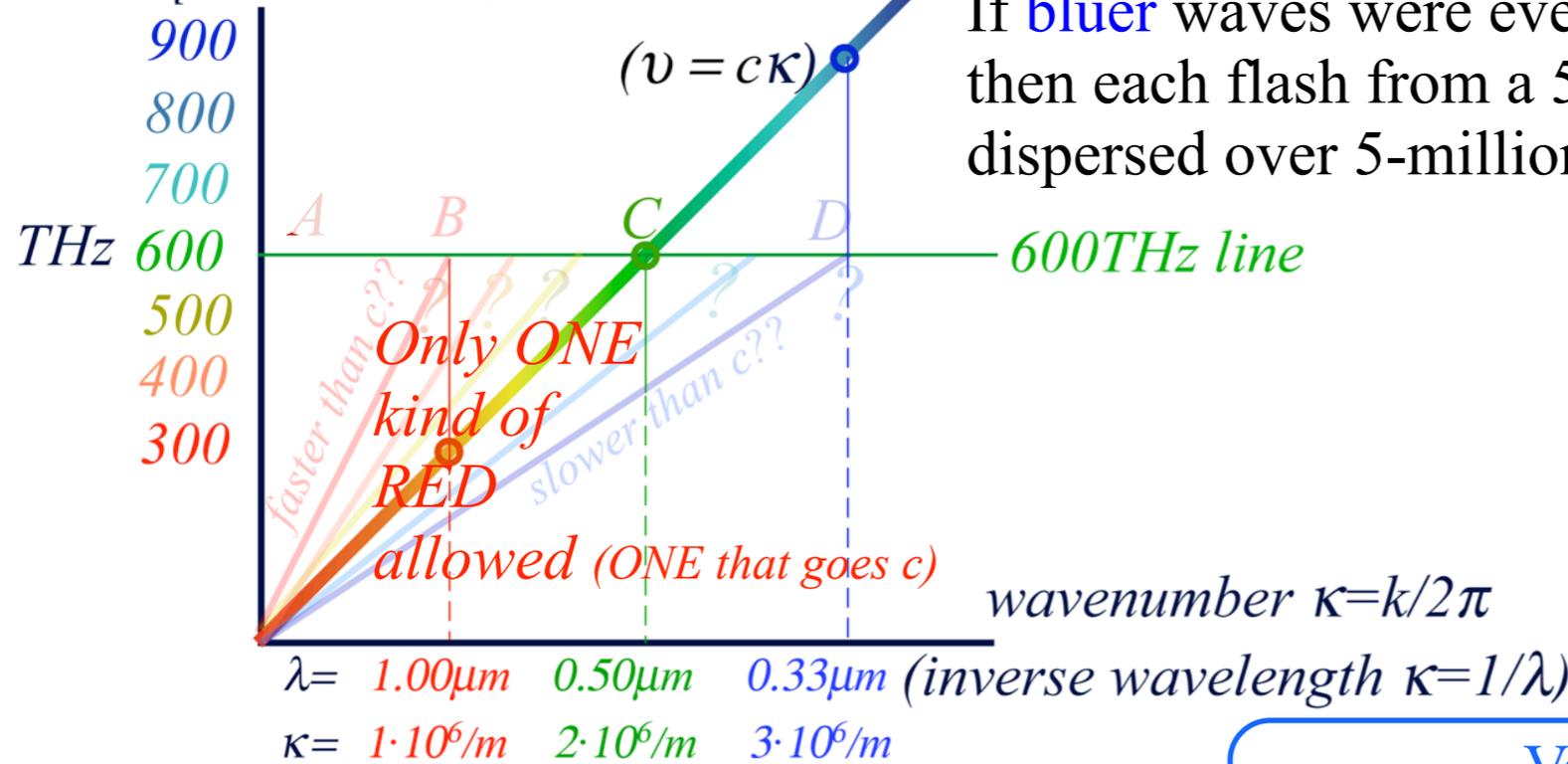
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More evidence supporting Evenson's axiom

If bluer waves were even 0.1% faster (or slower) than redder ones then each flash from a 5-billion light-year distant galaxy shows up dispersed over 5-million years. (Goodbye galactic astronomy!)

Also could be labeled :

Linear-(non)-dispersion

axiom: $\nu = c\kappa$

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Easy Doppler-shift and Rapidity calculation

ALICE'S
LASER
GAUNTLET



Alice: Hey, Bob and Carla! Read off your Doppler shift ratios $\langle B|A \rangle$ and $\langle C|A \rangle$ to my 600THz beam.

Bob: I see Doppler Blue shift to 1200THz



Carla: I see Doppler Red shift to 400THz



$v_A=600\text{THz}$



$v_A=600\text{THz}$



Doppler ratio:

$$\langle R|S \rangle = \frac{v_{RECEIVER}}{v_{SOURCE}}$$

Bob-Alice Doppler ratio:

$$\langle B|A \rangle = \frac{v_B}{v_A} = \frac{1200}{600} = \frac{2}{1}$$

Carla-Alice Doppler ratio:

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I got $\langle B|A \rangle = 2$,

Carla: I see Doppler Red shift to 400THz



I got $\langle C|A \rangle = 2/3$,



$\nu_A = 600\text{THz}$

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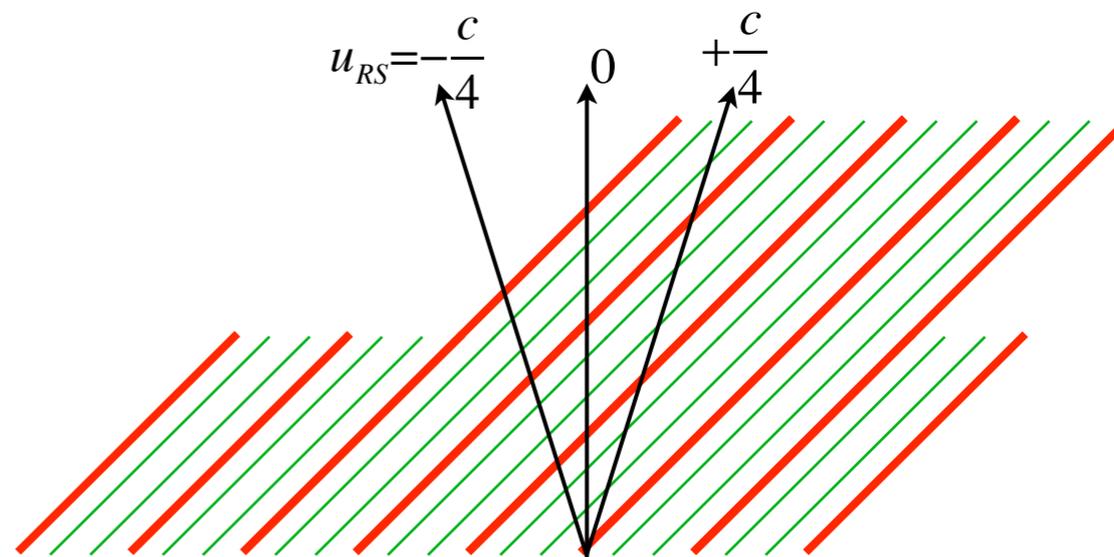
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IMPORTANT POINT:

Evenson axiom says Blue, Green, Red, etc. all march in lockstep and so *all* frequencies Doppler shift in same *geometric* proportion $\langle R|S \rangle$.



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If Alice sends $\nu_A = 600\text{THz}$

Bob sees: $\nu_B = \langle B|A \rangle \nu_A = 1200\text{THz}$

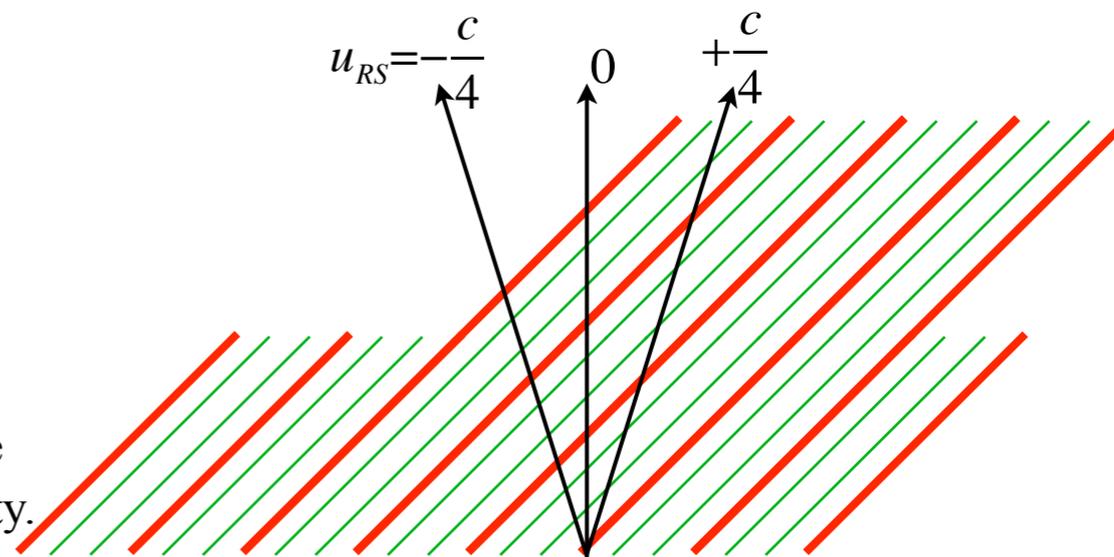
If Alice sends $\nu_A = 60\text{ THz}$

Bob sees: $\nu_B = \langle B|A \rangle \nu_A = 120\text{THz}$

If Alice sends $\nu_A = 6\text{ Hz}$

Bob sees: $\nu_B = \langle B|A \rangle \nu_A = 12\text{ Hz}$

$\langle B|A \rangle = 2$ for any frequency **Alice** and **Bob** use while they maintain their relative velocity.



Easy Doppler-shift and Rapidity calculation

ALICE'S
LASER
GAUNTLET



Alice: Hey, **Bob** and **Carla**! Read off your Doppler shift ratios $\langle B|A \rangle$ and $\langle C|A \rangle$ to my **600THz** beam.

Also, **rapidity** ρ_{BA} and ρ_{CA} relative to me.

Bob: I see Doppler **Blue shift to 1200THz**

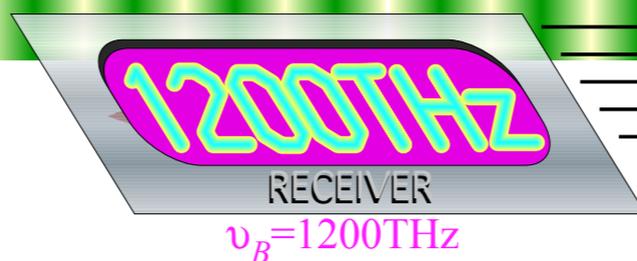


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rapidity:

$$\rho_{RS} = \log_e \langle R|S \rangle$$

Definition of Rapidity

Rapidity is most convenient!

1TeV proton has

$u = 0.999995598 \cdot c$ (Pain in the A)

or: $\langle R|S \rangle = 2131.6$ (Better)

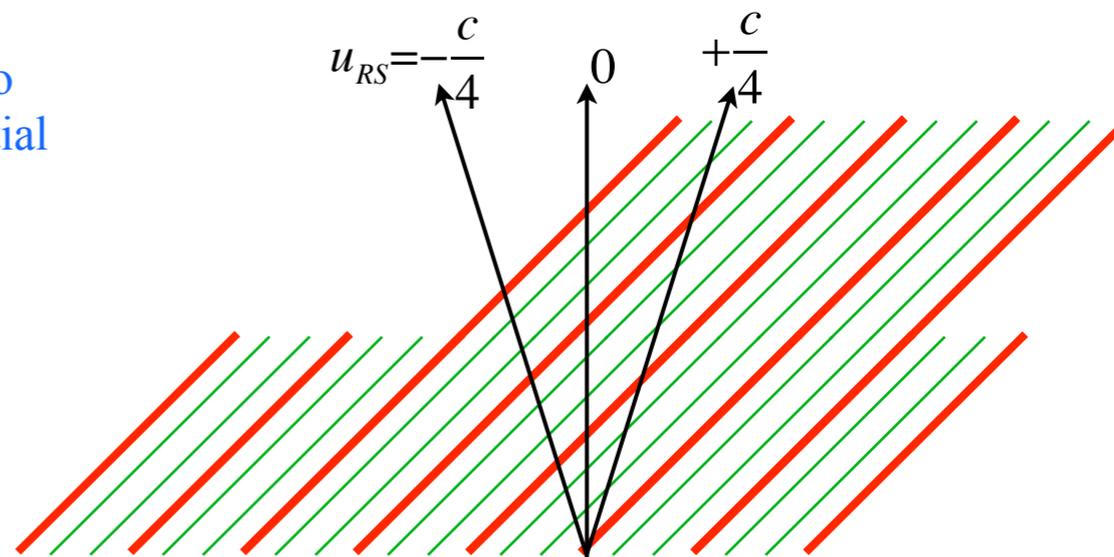
or: $\rho_{RS} = 7.6646$ (Best)

For low velocity $u \ll c$ rapidity ρ_{RS} approaches u/c

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Geometric phenomena tend to involve logarithmic/exponential functionality!



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ALICE'S
LASER
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= +0.69

Carla: I see Doppler
Red shift to 400THz



I got $\langle C|A \rangle = 2/3$,
and $\rho_{CA} = \ln(2/3)$
= -0.41



$\nu_A = 600\text{THz}$



$\nu_B = 1200\text{THz}$



$\nu_C = 400\text{THz}$

Doppler ratio:

$$\langle R|S \rangle = \frac{\nu_{RECEIVER}}{\nu_{SOURCE}}$$

Bob-Alice Doppler ratio:

$$\langle B|A \rangle = \frac{\nu_B}{\nu_A} = \frac{1200}{600} = \frac{2}{1}$$

Carla-Alice Doppler ratio:

$$\langle C|A \rangle = \frac{\nu_C}{\nu_A} = \frac{400}{600} = \frac{2}{3}$$

rapidity:

$$\rho_{RS} = \log_e \langle R|S \rangle$$

Bob-Alice rapidity:

$$\rho_{BA} = \log_e \langle B|A \rangle = \log_e \frac{2}{1}$$

(time-reversed)
 $\rho_{BA} = 0.69$ (so: $\rho_{AB} = -0.69$)

Carla-Alice rapidity:

$$\rho_{CA} = \log_e \langle C|A \rangle = \log_e \frac{2}{3}$$

$\rho_{CA} = -0.41$

Definition of Rapidity

$$\langle B|A \rangle = \frac{\nu_B}{\nu_A} = \frac{2}{1}$$

is time-reversal of:

$$\langle A|B \rangle = \frac{\nu_A}{\nu_B} = \frac{1}{2}$$

Mnemonic: You can think of rapidity ρ_{BA} as "R" for "Romance"... (+) positive on approach, (-) negative on reproach

Do the stars
hate us?

Easy Doppler-shift and Rapidity calculation

ALICE'S
LASER
GAUNTLET



Alice: Hey, Bob and Carla! Read off your Doppler shift ratios $\langle B|A \rangle$ and $\langle C|A \rangle$ to my 600THz beam.

Also, rapidity ρ_{BA} and ρ_{CA} relative to me.

Now, Carla, what's your rapidity ρ_{CB} relative to Bob?

Bob: I see Doppler Blue shift to 1200THz



I got $\langle B|A \rangle = 2$,
and $\rho_{BA} = \ln(2) = +0.69$

Carla: I see Doppler Red shift to 400THz



I got $\langle C|A \rangle = 2/3$,
and $\rho_{CA} = \ln(2/3) = -0.41$



Doppler ratio:

$$\langle R|S \rangle = \frac{v_{RECEIVER}}{v_{SOURCE}}$$

rapidity:

$$\rho_{RS} = \log_e \langle R|S \rangle$$

Definition of Rapidity

$$\langle B|A \rangle = \frac{v_B}{v_A} = \frac{2}{1}$$

is time-reversal of:

$$\langle A|B \rangle = \frac{v_A}{v_B} = \frac{1}{2}$$

Bob-Alice Doppler ratio:

$$\langle B|A \rangle = \frac{v_B}{v_A} = \frac{1200}{600} = \frac{2}{1}$$

Bob-Alice rapidity:

$$\rho_{BA} = \log_e \langle B|A \rangle = \log_e \frac{2}{1}$$

(time-reversed)

$$\rho_{BA} = 0.69 \quad (\text{so: } \rho_{AB} = -0.69)$$

Carla-Alice Doppler ratio:

$$\langle C|A \rangle = \frac{v_C}{v_A} = \frac{400}{600} = \frac{2}{3}$$

Carla-Alice rapidity:

$$\rho_{CA} = \log_e \langle C|A \rangle = \log_e \frac{2}{3}$$

$$\rho_{CA} = -0.41$$

Carla-Bob Doppler ratio:

$$\langle C|B \rangle = \frac{v_C}{v_B} = \frac{v_C}{v_A} \frac{v_A}{v_B} = \langle C|A \rangle \langle A|B \rangle$$

Mnemonic: You can think of rapidity ρ_{BA} as "R" for "Romance"... (+) positive on approach, (-) negative on reproach

More at Pirelli Challenge page: [Time Reversal Symmetry](#)

Easy Doppler-shift and Rapidity calculation

ALICE'S
LASER
GAUNTLET



Alice: Hey, Bob and Carla! Read off your Doppler shift ratios $\langle B|A \rangle$ and $\langle C|A \rangle$ to my 600THz beam.

Also, rapidity ρ_{BA} and ρ_{CA} relative to me.

Now, Carla, what's your rapidity ρ_{CB} relative to Bob?



$\nu_A = 600\text{THz}$

$\nu_A = 600\text{THz}$



RECEIVER
 $\nu_B = 1200\text{THz}$

$\nu_A = 600\text{THz}$



RECEIVER
 $\nu_C = 400\text{THz}$

Bob: I see Doppler Blue shift to 1200THz



I got $\langle B|A \rangle = 2$,
and $\rho_{BA} = \ln(2) = +0.69$

Carla: I see Doppler Red shift to 400THz



I got $\langle C|A \rangle = 2/3$,
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Doppler ratio:

$$\langle R|S \rangle = \frac{\nu_{RECEIVER}}{\nu_{SOURCE}}$$

rapidity:

$$\rho_{RS} = \log_e \langle R|S \rangle$$

so:

$$\langle R|S \rangle = e^{\rho_{RS}}$$

Definition of Rapidity

$$\langle B|A \rangle = \frac{\nu_B}{\nu_A}$$

is time-reversed

$$\langle A|B \rangle = \frac{\nu_A}{\nu_B}$$

Bob-Alice Doppler ratio:

$$\langle B|A \rangle = \frac{\nu_B}{\nu_A} = \frac{1200}{600} = \frac{2}{1}$$

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$$\rho_{BA} = \log_e \langle B|A \rangle = \log_e \frac{2}{1}$$

$$\rho_{BA} = 0.69 \quad (\text{so: } \rho_{AB} = -0.69)$$

Carla-Alice Doppler ratio:

$$\langle C|A \rangle = \frac{\nu_C}{\nu_A} = \frac{400}{600} = \frac{2}{3}$$

Carla-Alice rapidity:

$$\rho_{CA} = \log_e \langle C|A \rangle = \log_e \frac{2}{3}$$

$$\rho_{CA} = -0.41$$

Carla-Bob Doppler ratio:

$$\langle C|B \rangle = \frac{\nu_C}{\nu_B} = \frac{\nu_C}{\nu_A} \frac{\nu_A}{\nu_B} = \langle C|A \rangle \langle A|B \rangle$$

Carla-Bob rapidity:

$$e^{\rho_{CB}} = e^{\rho_{CA}} e^{\rho_{AB}}$$

Easy Doppler-shift and Rapidity calculation

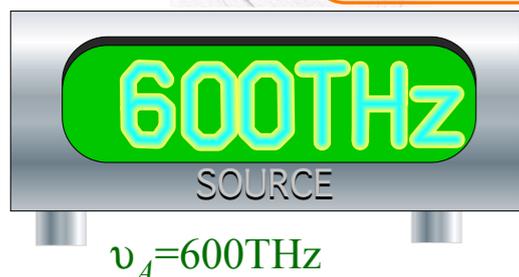
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LASER
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$v_A = 600\text{THz}$



$v_B = 1200\text{THz}$

$v_A = 600\text{THz}$



Bob: I see Doppler Blue shift to 1200THz

I got $\langle B|A \rangle = 2$,
and $\rho_{BA} = \ln(2) = +0.69$



$v_C = 400\text{THz}$

Carla: I see Doppler Red shift to 400THz

I got $\langle C|A \rangle = 2/3$,
and $\rho_{CA} = \ln(2/3) = -0.41$

I got $\langle C|B \rangle = \langle C|A \rangle \langle A|B \rangle = (2/3)(1/2) = 1/3$,
and $\rho_{CB} = \rho_{CA} + \rho_{AB} = -1.10$
We're in Splitsville!

Doppler ratio:

$$\langle R|S \rangle = \frac{v_{RECEIVER}}{v_{SOURCE}}$$

rapidity:

$$\rho_{RS} = \log_e \langle R|S \rangle$$

or:

$$\langle R|S \rangle = e^{\rho_{RS}} = e^{-\rho_{SR}}$$

Definition of Rapidity

$$\langle B|A \rangle = \frac{v_B}{v_A}$$

is time-reversed

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Bob-Alice Doppler ratio:

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Carla-Alice Doppler ratio:

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Carla-Bob rapidity:

$$e^{\rho_{CB}} = e^{\rho_{CA}} e^{\rho_{AB}} \quad \text{implies: } \rho_{CB} = \rho_{CA} + \rho_{AB} = -0.41 - 0.69 = -1.10$$

Easy Doppler-shift and Rapidity calculation

ALICE'S
LASER
GAUNTLET



Alice: Hey, Bob and Carla! Read off your Doppler shift ratios $\langle B|A \rangle$ and $\langle C|A \rangle$ to my 600THz beam.

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Carla: I see Doppler Red shift to 400THz



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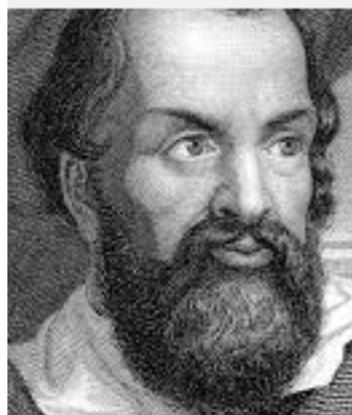
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is time-reversed

$$\langle A|B \rangle = \frac{v_A}{v_B}$$

Happy now, Galileo?



Bob-Alice Doppler ratio:

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Carla-Bob rapidity:

$$e^{\rho_{CB}} = e^{\rho_{CA}} e^{\rho_{AB}} \text{ implies:}$$

Galileo's Revenge (part 1)

Rapidity adds just like Galilean velocity

$$\rho_{CB} = \rho_{CA} + \rho_{AB}$$

$$= -0.41 - 0.69 = -1.10$$

Special Relativity and Quantum Mechanics regarded as *mysterious* and *lacking clarity*

Bob&Alice regard for clarity of SR: **foggy** or QM: **opaque**

Can this situation be improved at fundamental axiomatic level?

Evidence and concepts needing critical review:

QM (*Planck, 1900*) and SR (*Einstein, 1905*) are both about light (*em waves*)

Galilean relativity, how it fails for light and how it doesn't

The great light-wave speed-limit ($c=2.99792458m/s$. by *Evenson, ..., Hall 1972*)

Need better axioms (*Occam's Razors & Evenson's Lasers*): CW axioms outwit old PW axioms

Introduce "*Keyboard of the gods*" CW per-space-time (κ, ν) that rules (λ, τ) **space-time**

Introduce idea of quantized **wavenumber**- κ_n and **amplitude** A_n (*1st and 2nd quantization*)

Introduce **infrared (IR) 300 THz**, **green 600THz**, and **ultra-violet (UV) 1200THz** CW laser beams

Optical Doppler CW frequency shift ν_A/ν_B : A hidden key to understanding modern physics

Bob and Alice deduce Evenson's CW Axiom: *All colors march together at $c = \nu\lambda = \nu/\kappa$*

Bob, Alice, and Carla discover *rapidity* ($\rho_{AB}=\ln \nu_A/\nu_B$), a longitudinal measure of speed

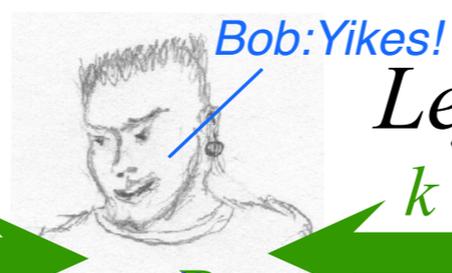
Bob, Alice, and Carla get *Galileo's Revenge Part I*: $\rho_{CB}=\rho_{CA}+\rho_{AB}$, a simple speed sum

➔ Bob, Alice, and Carla get *Galileo's Revenge Part II*: and map space-time by phase-group 2-CW ←
 $\frac{1}{2}$ -sum- $\frac{1}{2}$ -difference of phasor angular velocity determines space-time geometry

Relating rapidity ρ_{AB} and relativity parameter $\beta_{AB}=u_{AB}/c$

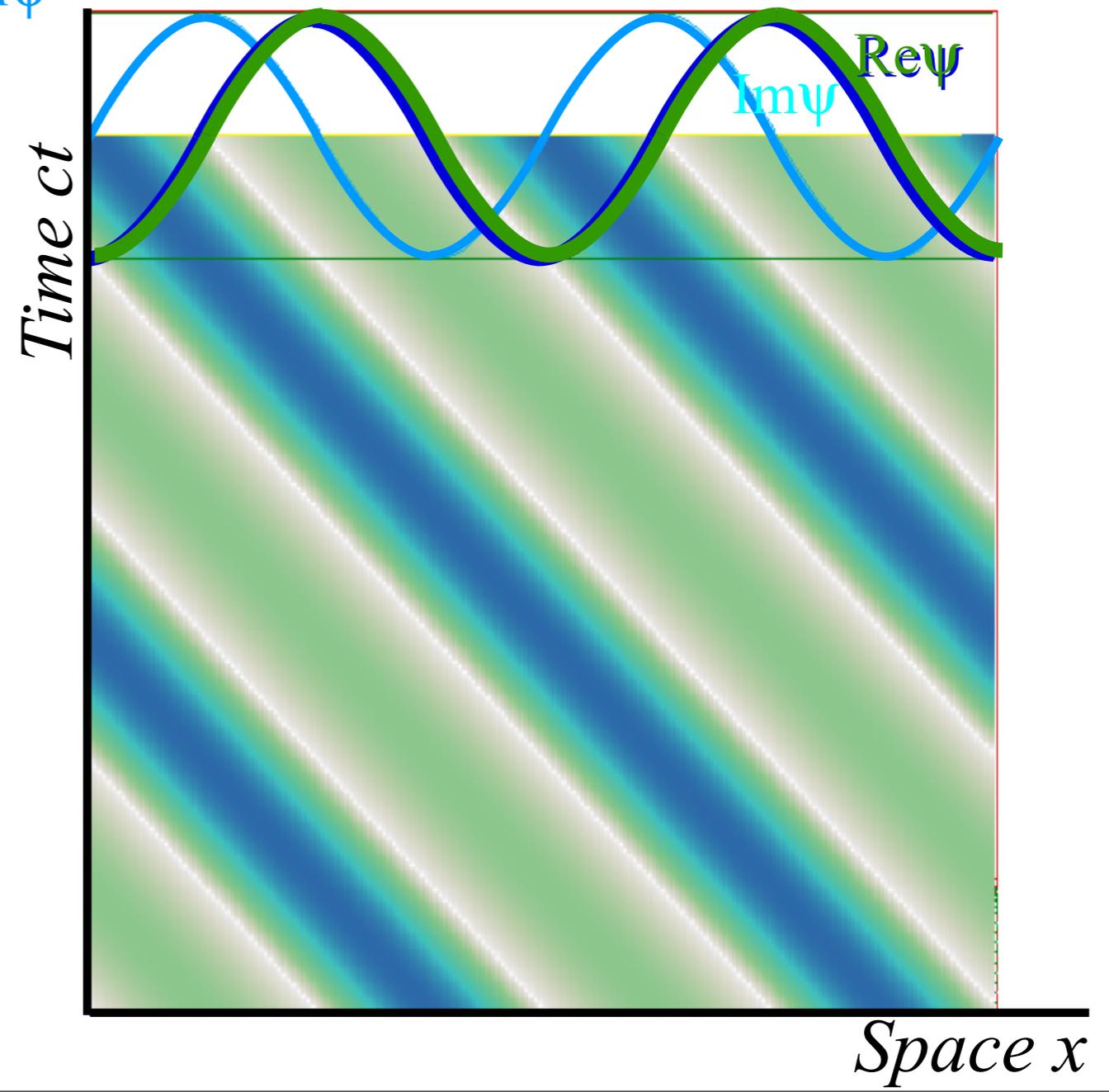
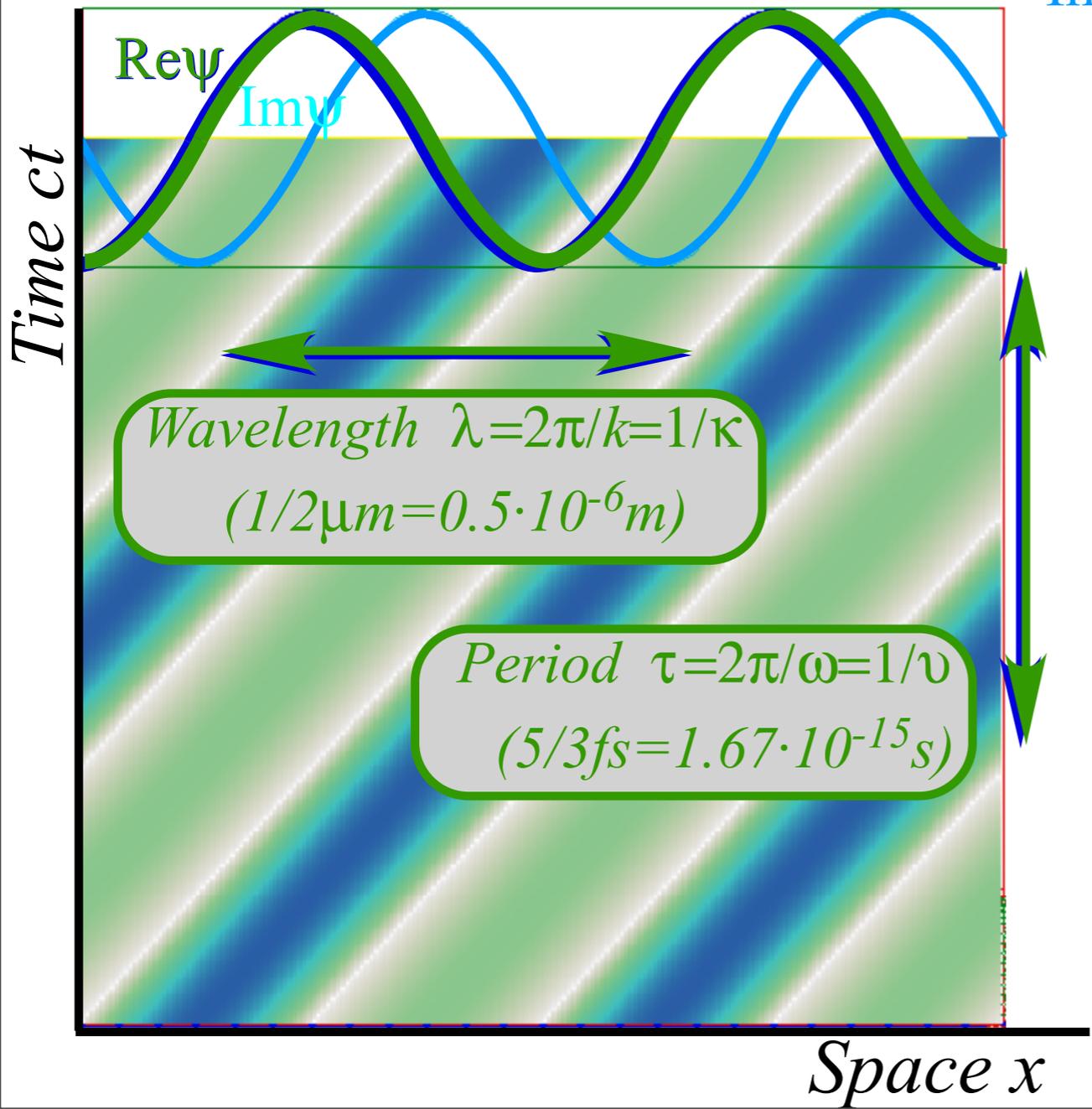
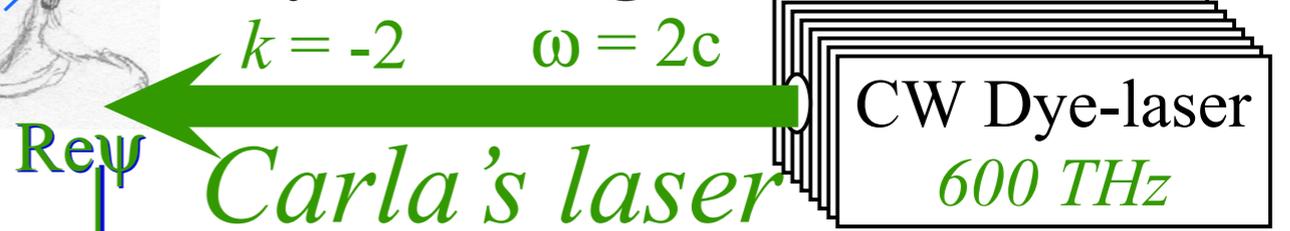
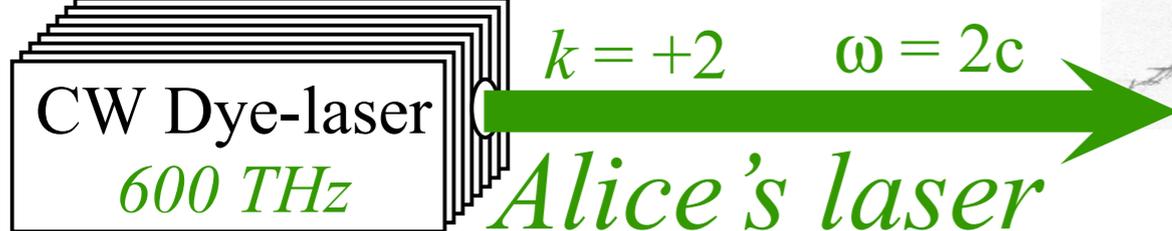
More at [Pirelli Challenge page: 'Un Grande Affare' - Light Meets Light](#)

Colliding 2CW laser beams



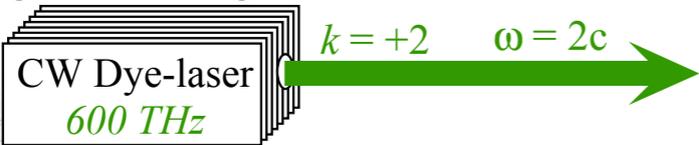
Right-moving wave $e^{i(kx-\omega t)}$

Left-moving wave $e^{i(-kx-\omega t)}$

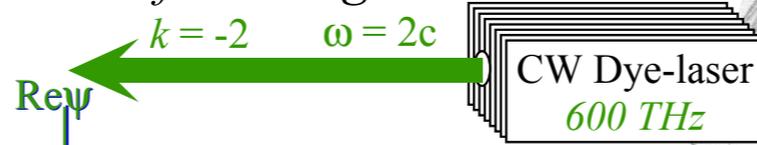




Right-moving CW $e^{i(kx-\omega t)}$



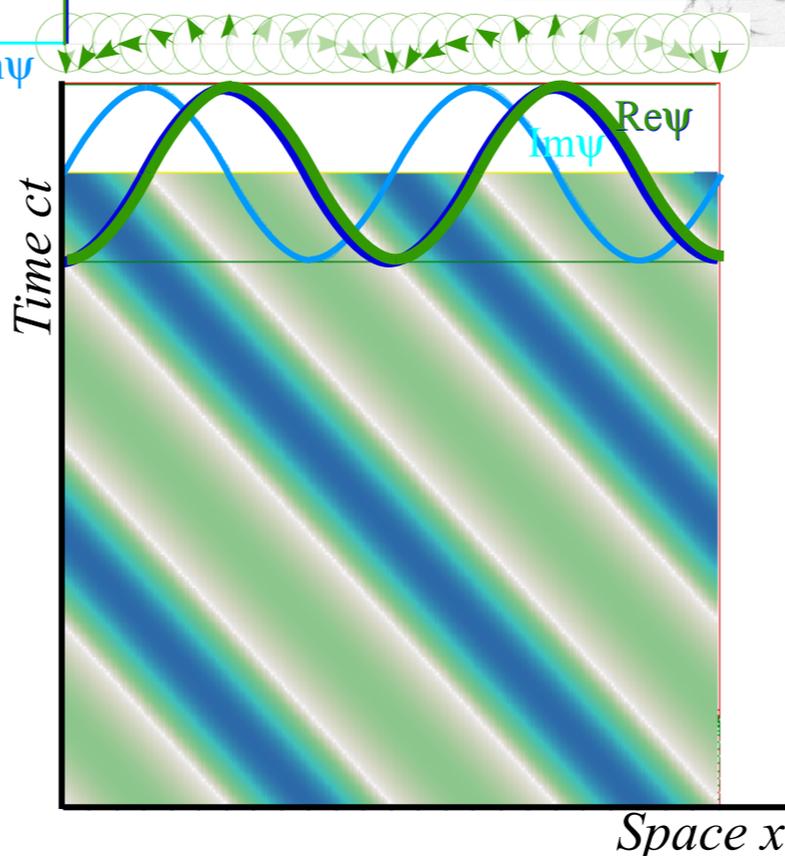
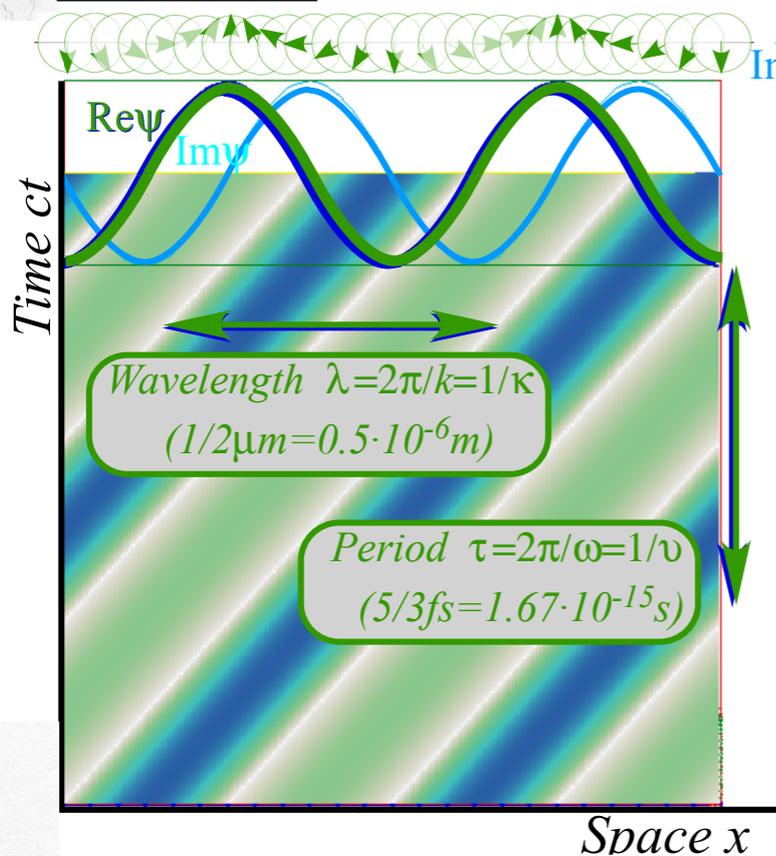
Left-moving CW $e^{i(-kx-\omega t)}$



Carla:

Easy!

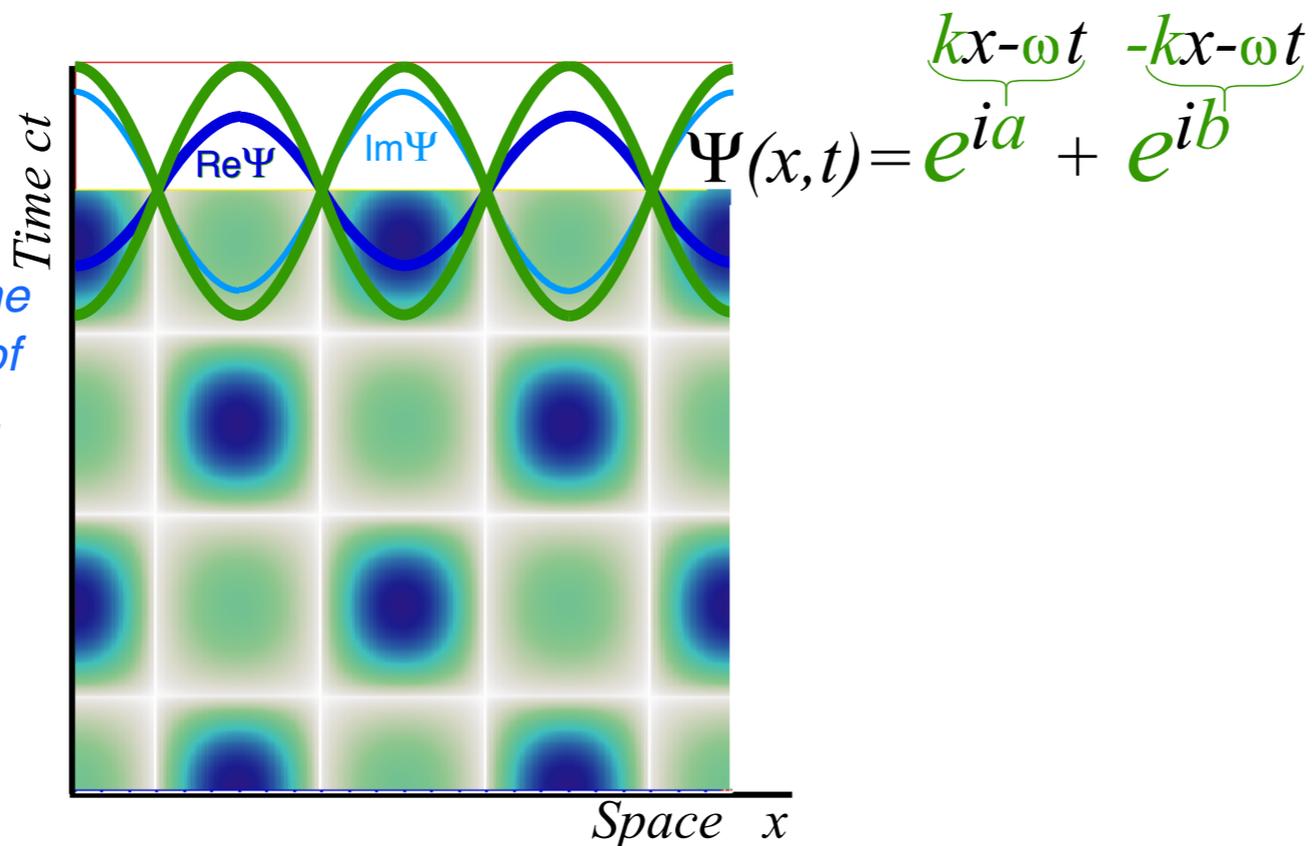
You get zeros of any wave-sum $e^{ia} + e^{ib}$ by factoring it into *phase* and *group* parts.



Bob:

Cool!
You guys made me a space-time graph out of real zeros.

How'd it do that?

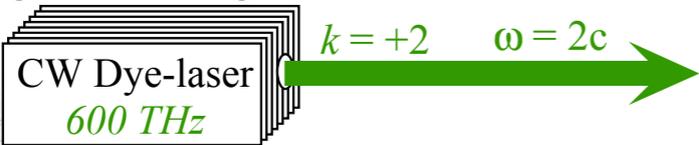


[BohrIt Web Simulation](#)
[1 CW ct vs x Plot \(ck = +1\)](#)
[Single panel with Zero Tracers](#)

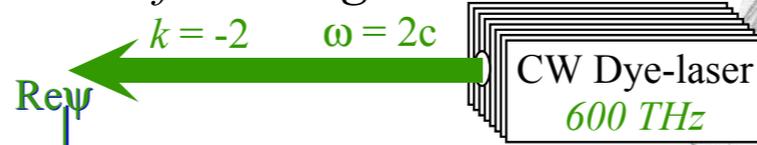
[BohrIt Web Simulation](#)
[2 CW ct vs x Plot \(ck = +/-2\)](#)
[Multi-panel with Zero Tracers](#)



Right-moving CW $e^{i(kx-\omega t)}$



Left-moving CW $e^{i(-kx-\omega t)}$



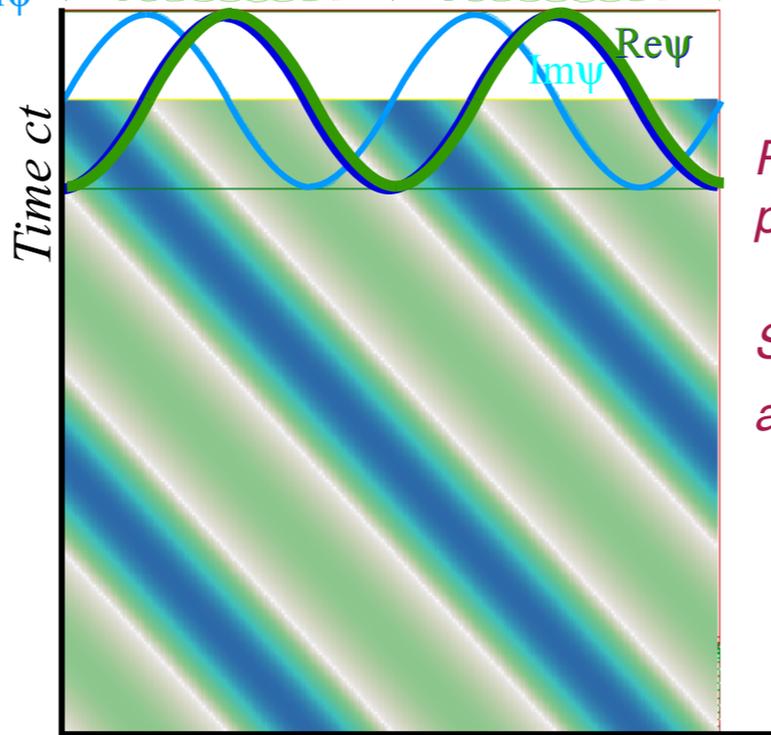
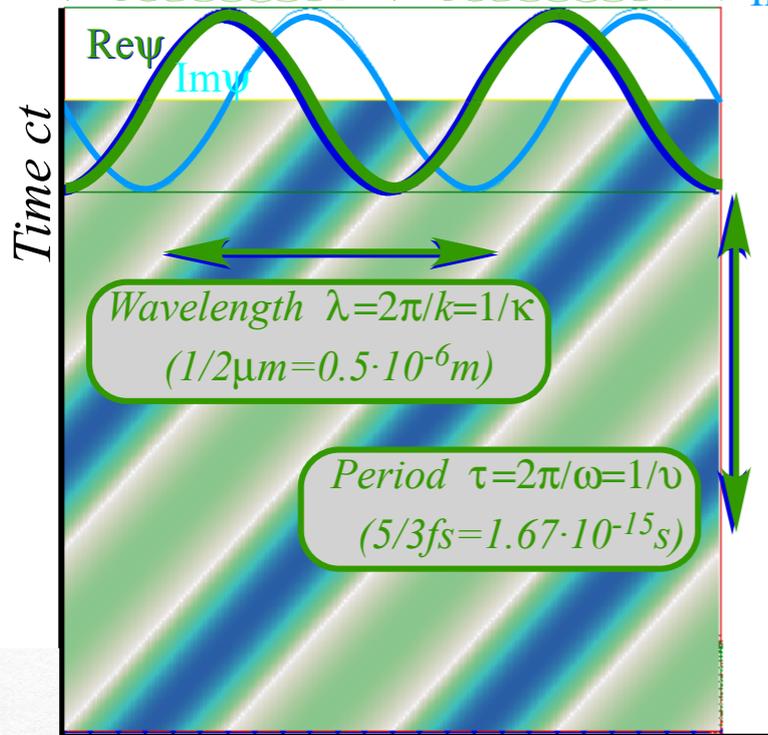
Carla:

Easy!

You get zeros of any wave-sum $e^{ia} + e^{ib}$ by factoring it into *phase* and *group* parts.

Remember your algebra? Exponents of products add.

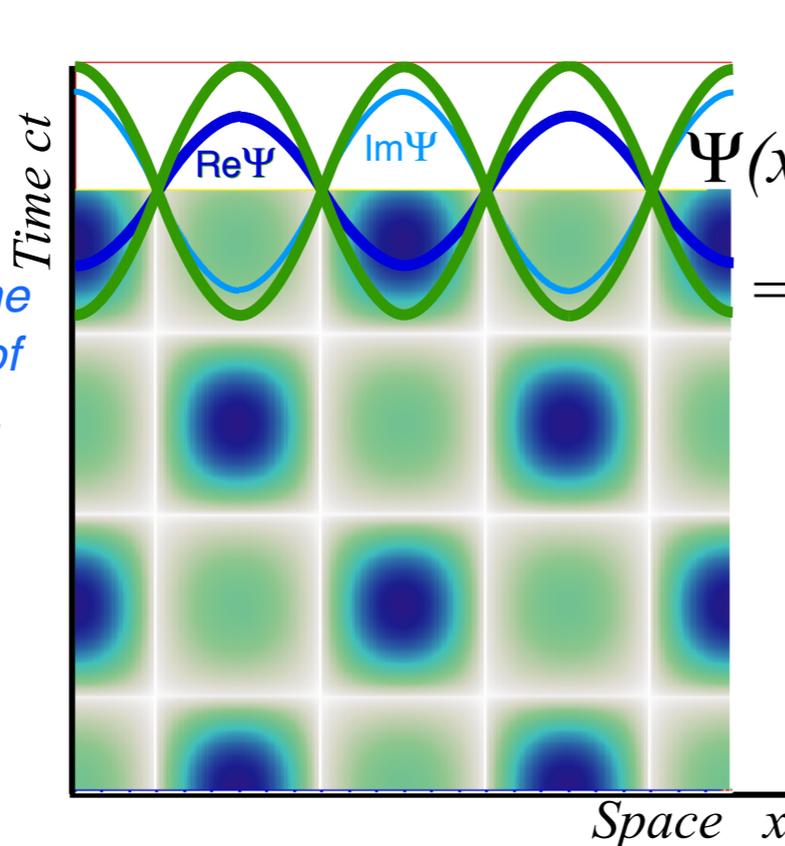
So, half-sum $\frac{a+b}{2}$ plus half-diff $\frac{a-b}{2}$ gives a , and half-sum $\frac{a+b}{2}$ minus half-diff $\frac{a-b}{2}$ gives b .



Bob:

Cool! You guys made me a space-time graph out of real zeros.

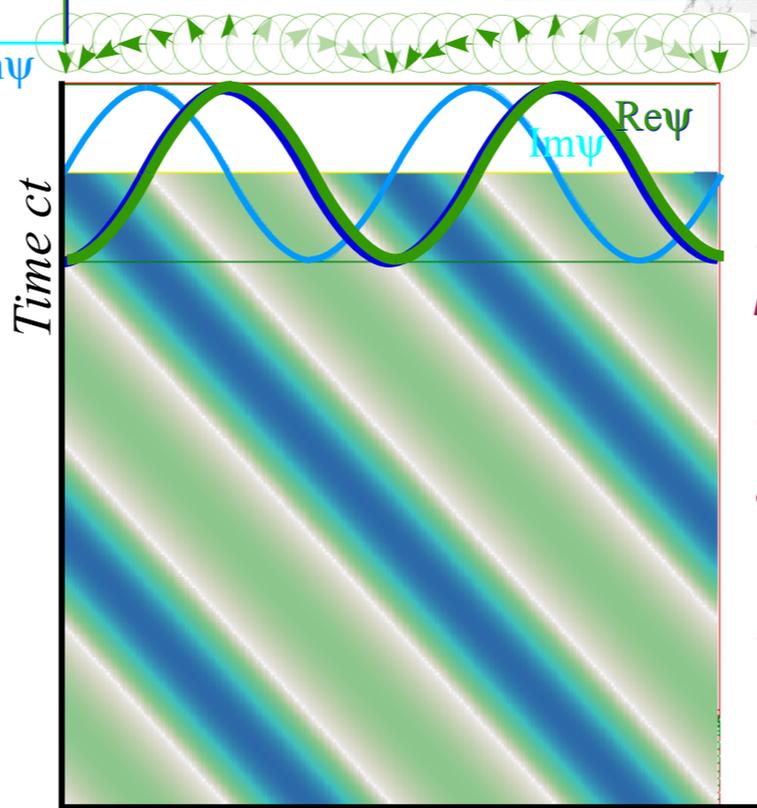
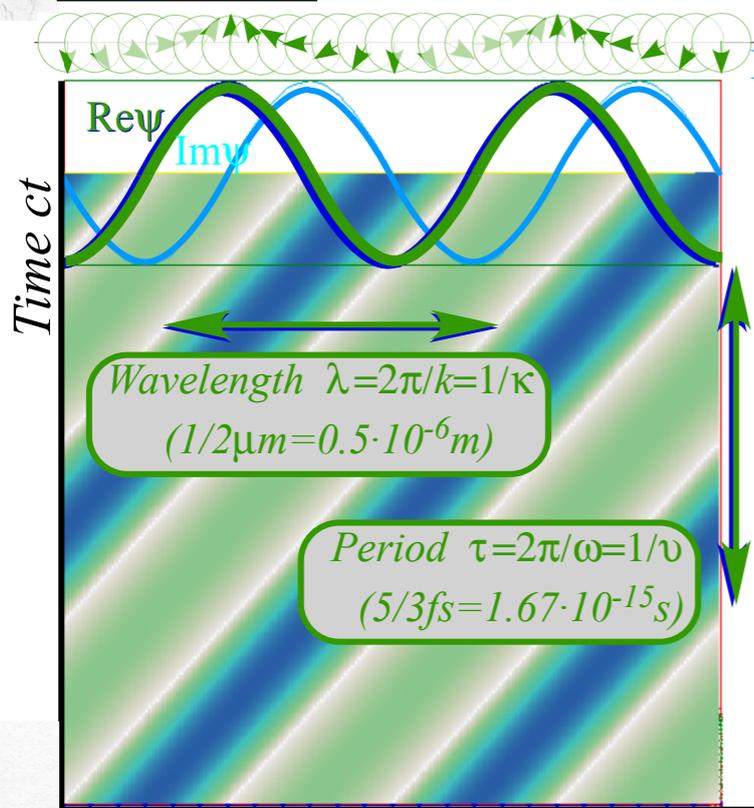
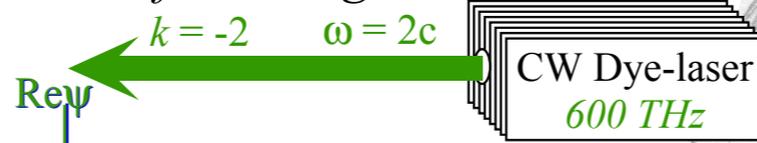
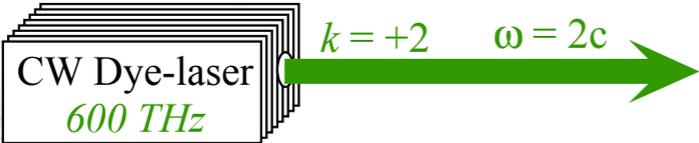
How'd it do that?



$$\Psi(x,t) = e^{i(kx-\omega t)} + e^{i(-kx-\omega t)}$$
$$= e^{i\frac{a+b}{2}} (e^{i\frac{a-b}{2}} + e^{-i\frac{a-b}{2}})$$

Right-moving CW $e^{i(kx-\omega t)}$

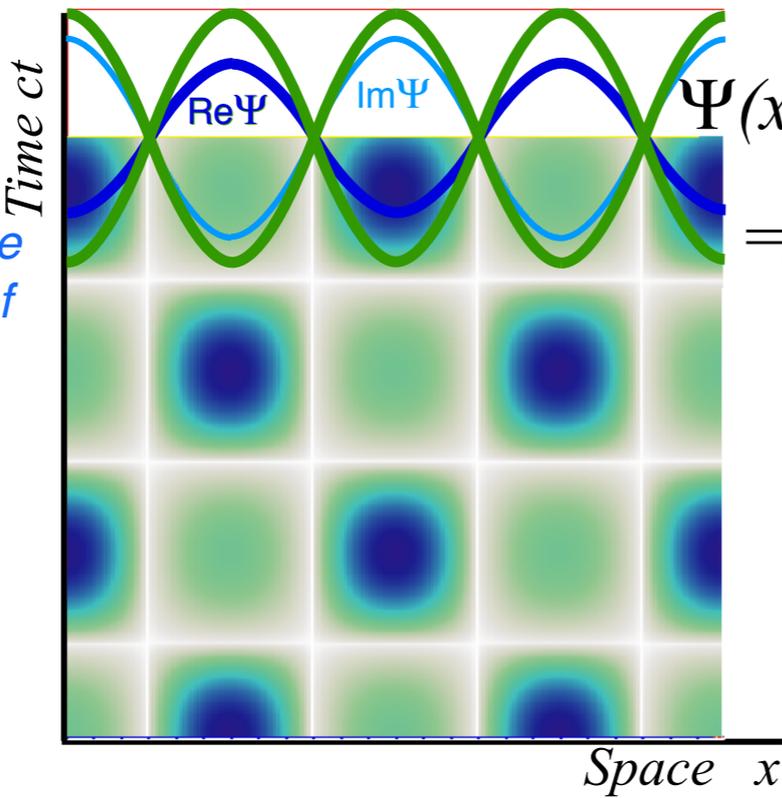
Left-moving CW $e^{i(-kx-\omega t)}$



Space x

Space x

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$$\Psi(x,t) = e^{i(kx-\omega t)} + e^{i(-kx-\omega t)}$$

$$= e^{i\frac{a+b}{2}} \left(e^{i\frac{a-b}{2}} + e^{-i\frac{a-b}{2}} \right)$$

Carla:

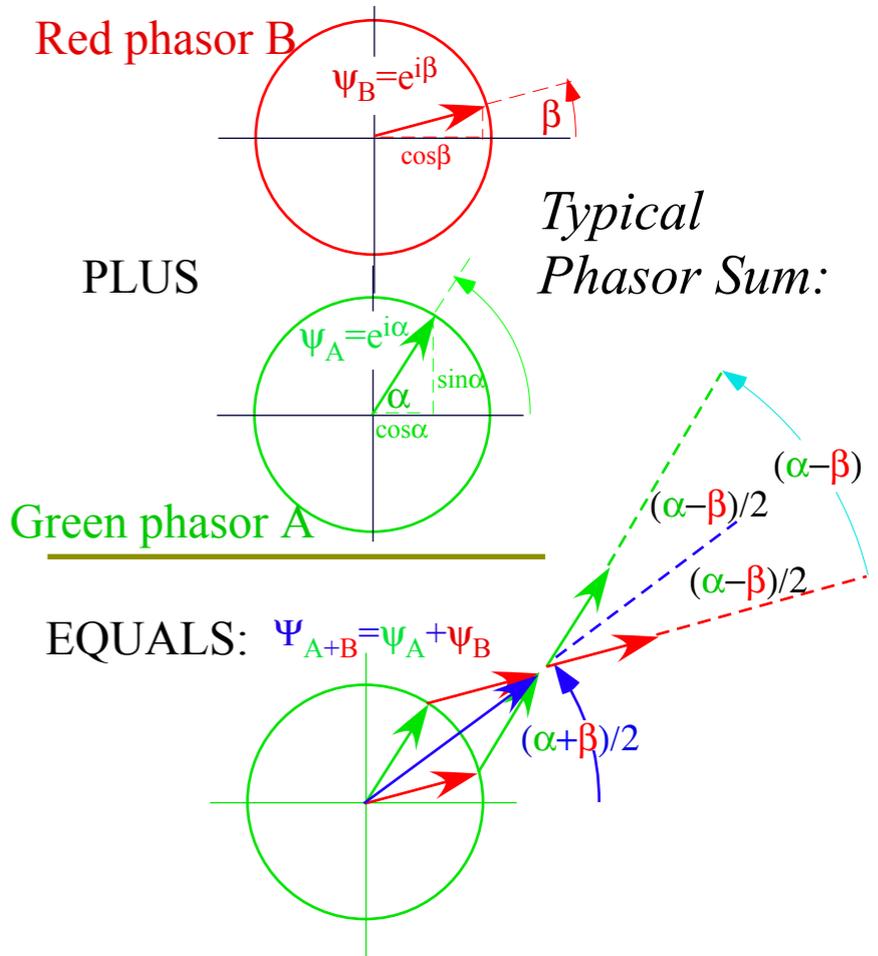
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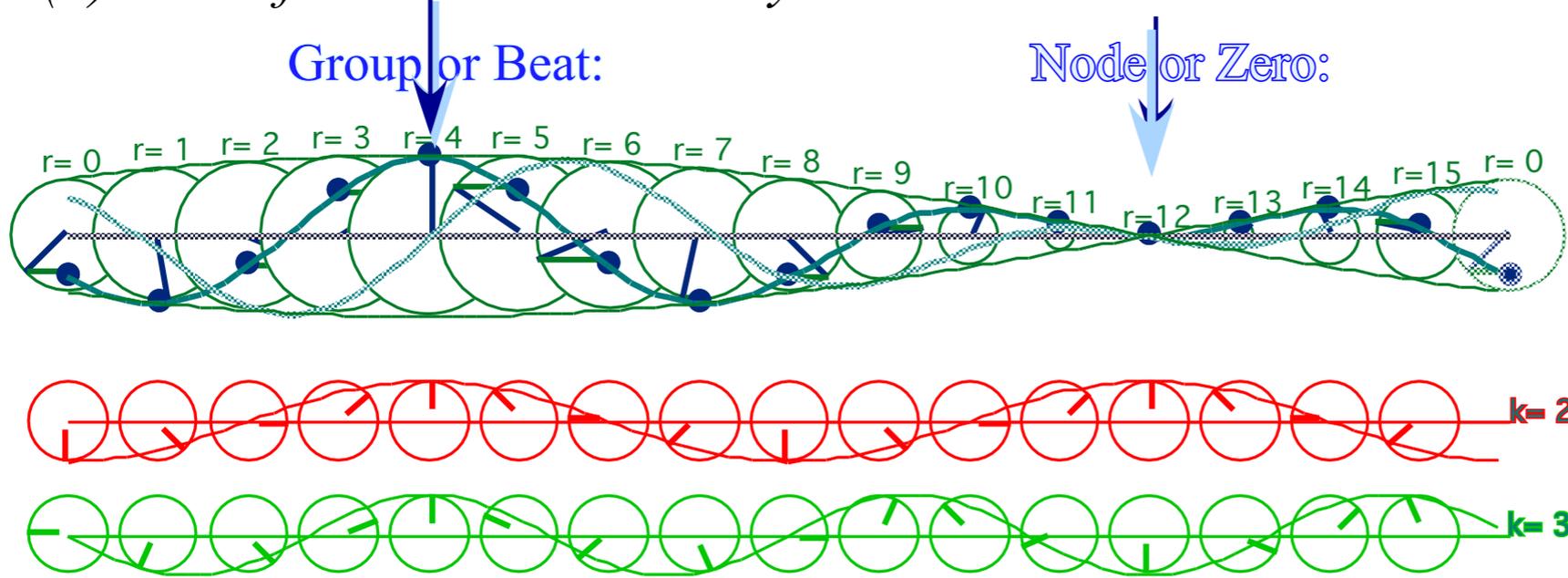
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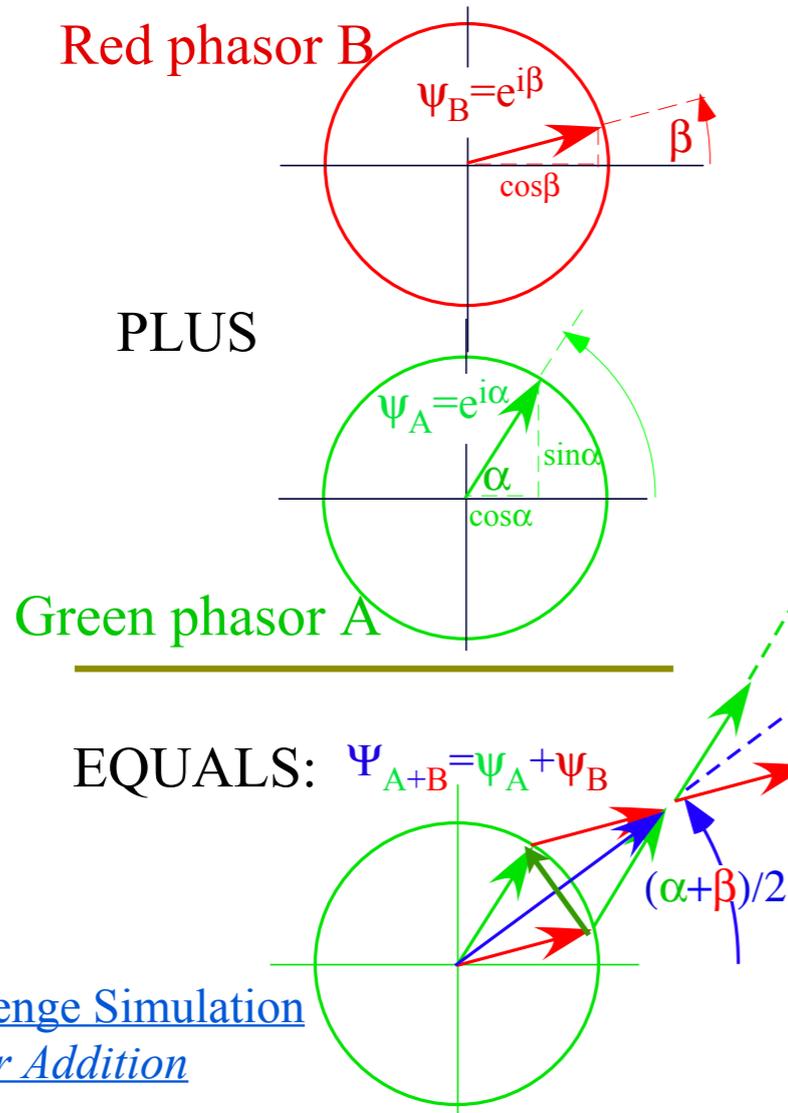
Presto!
You factor $e^{ia} + e^{ib}$ into $e^{i\frac{a+b}{2}} \left(e^{i\frac{a-b}{2}} + e^{-i\frac{a-b}{2}} \right)$



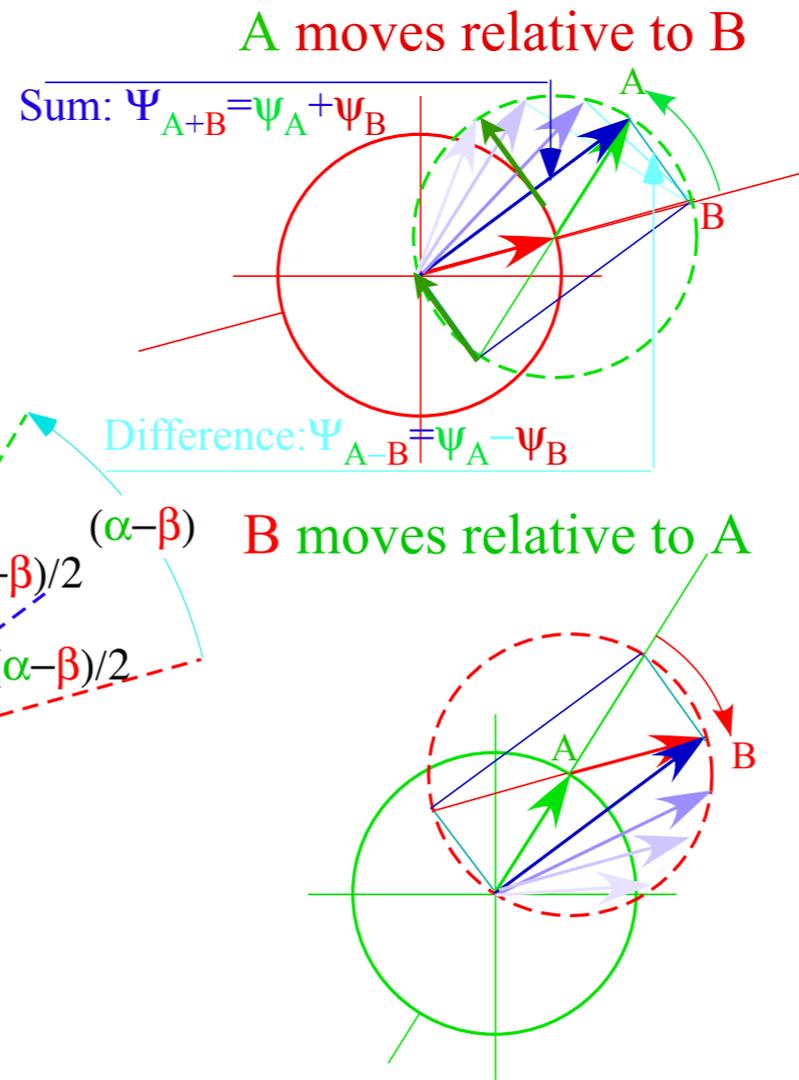
(a) Sum of Wave Phasor Array



(b) Typical Phasor Sum:

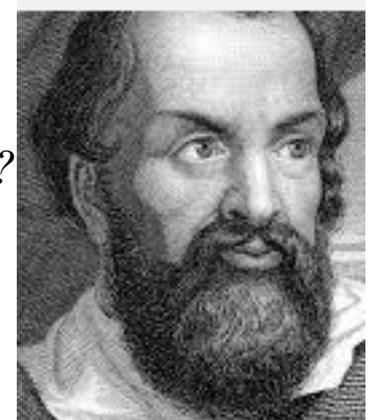


(c) Phasor-relative views

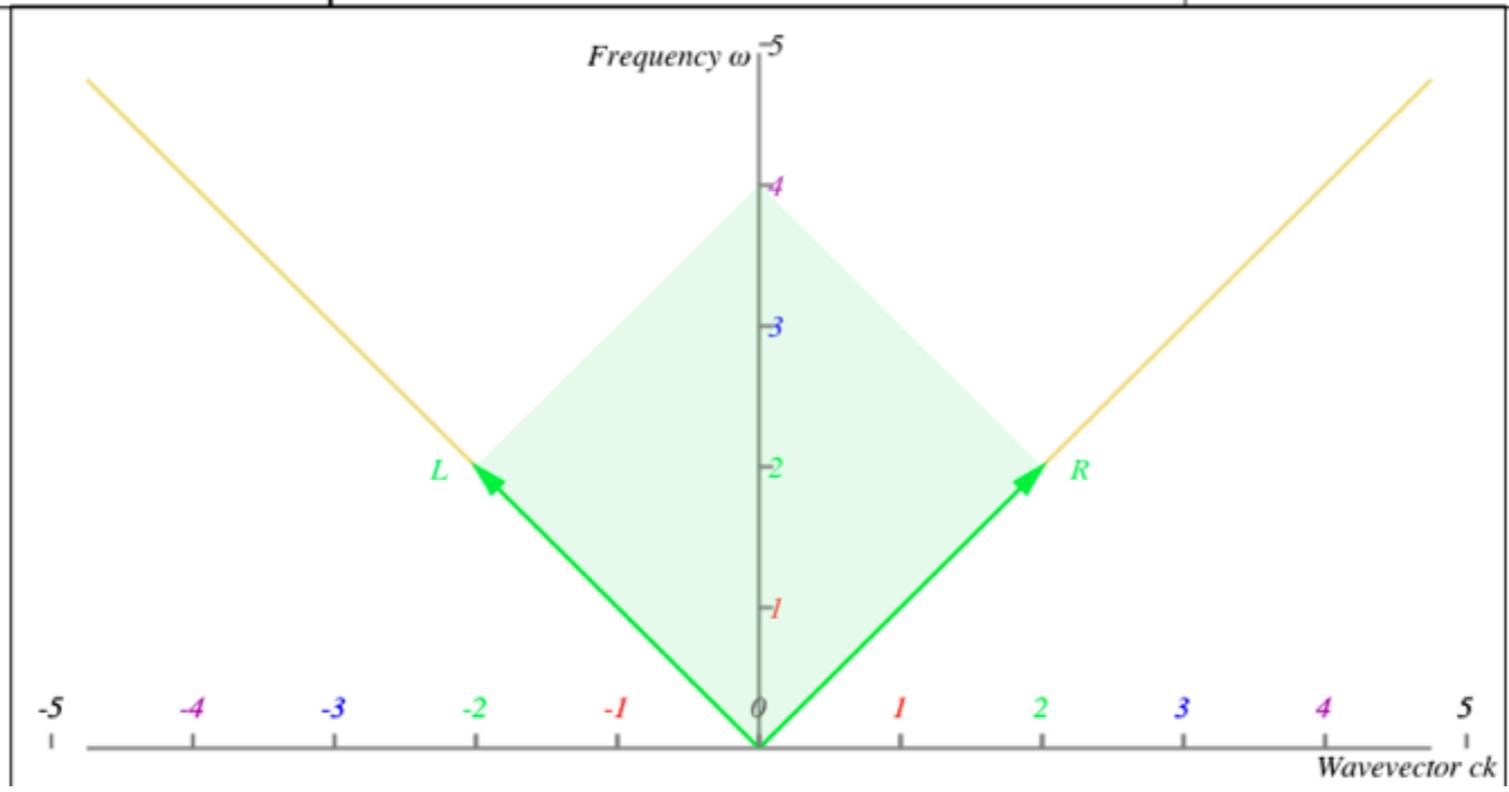
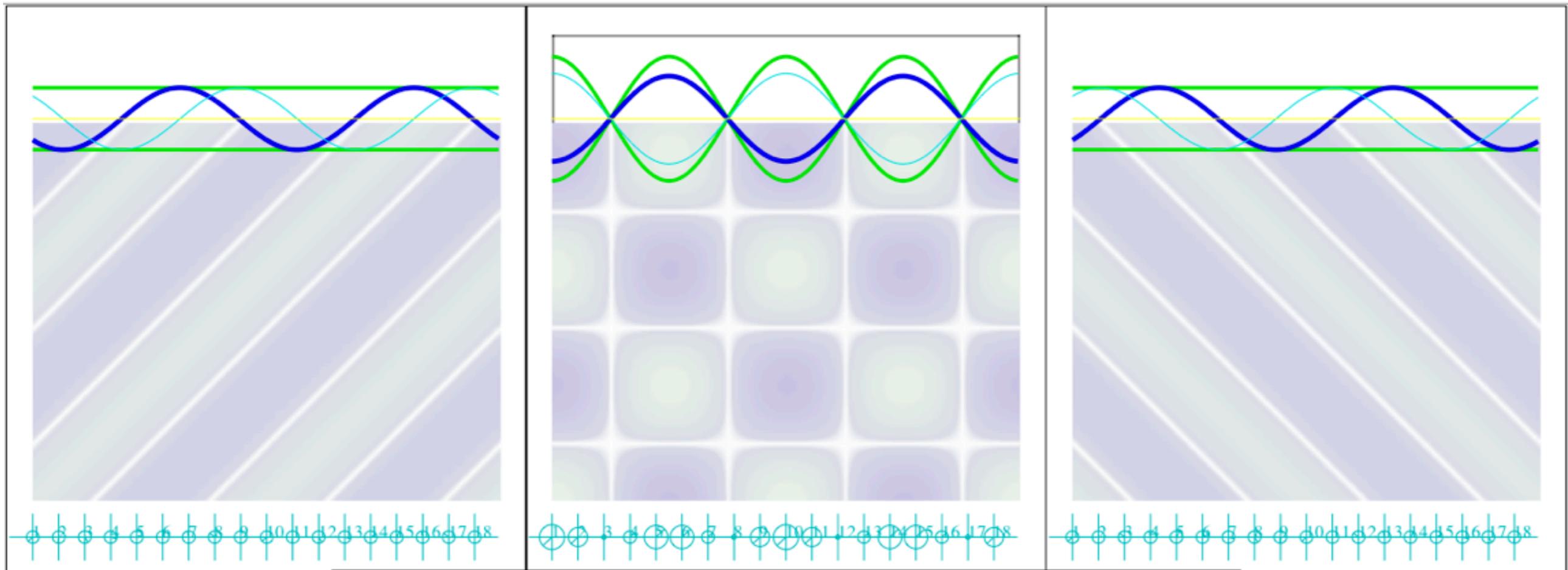


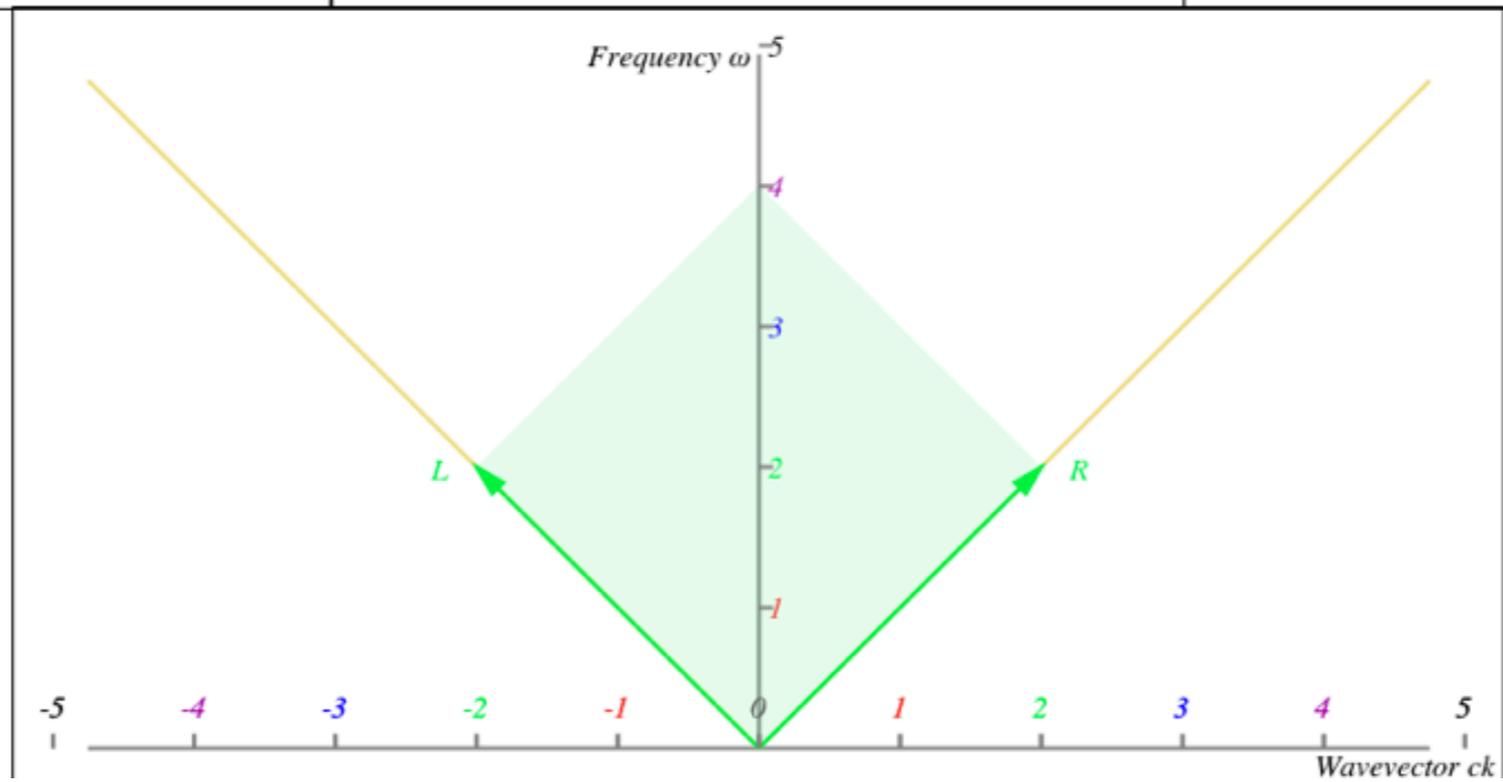
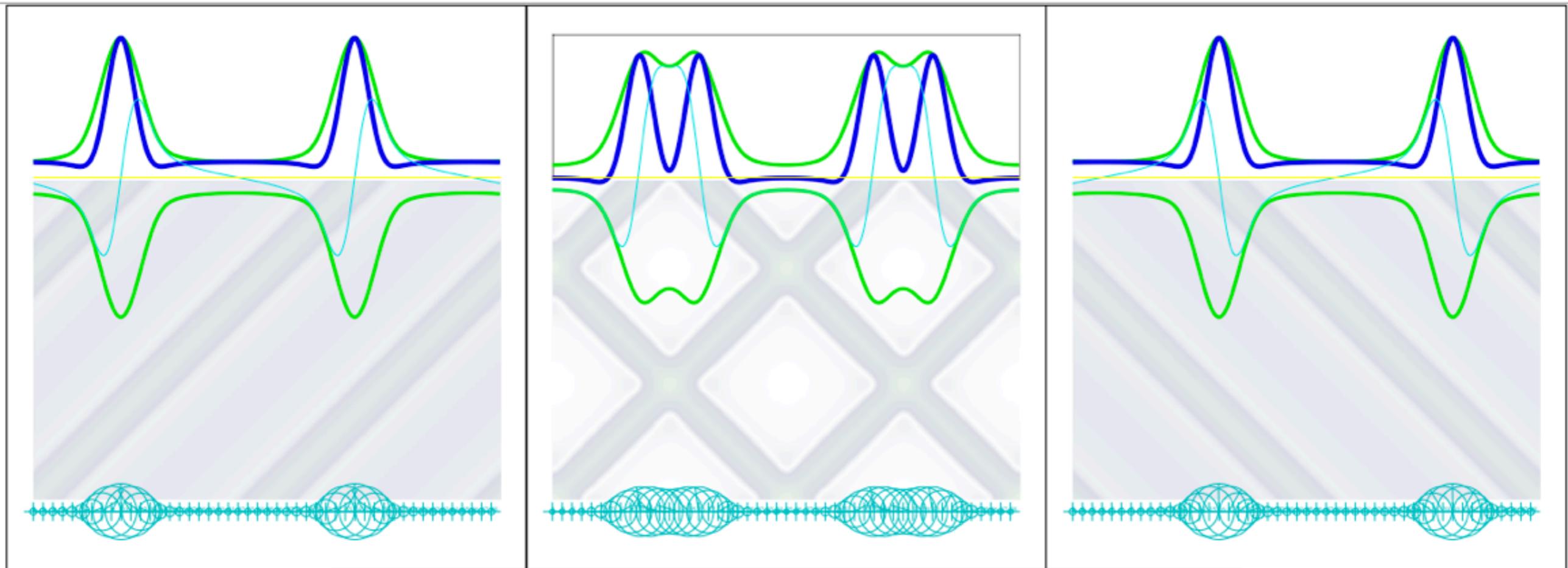
Geometry of the Half-sum Phase and Half-difference Group

Happy now?



Galileo's Revenge (part 2)
Phasor angular velocity adds just like Galilean velocity





2PW beta = 0

<http://www.uark.edu/ua/modphys/markup/BohrItWeb.html?scenario=-1119>

2PW beta = 3/5

<http://www.uark.edu/ua/modphys/markup/BohrItWeb.html?scenario=-1118>

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Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$

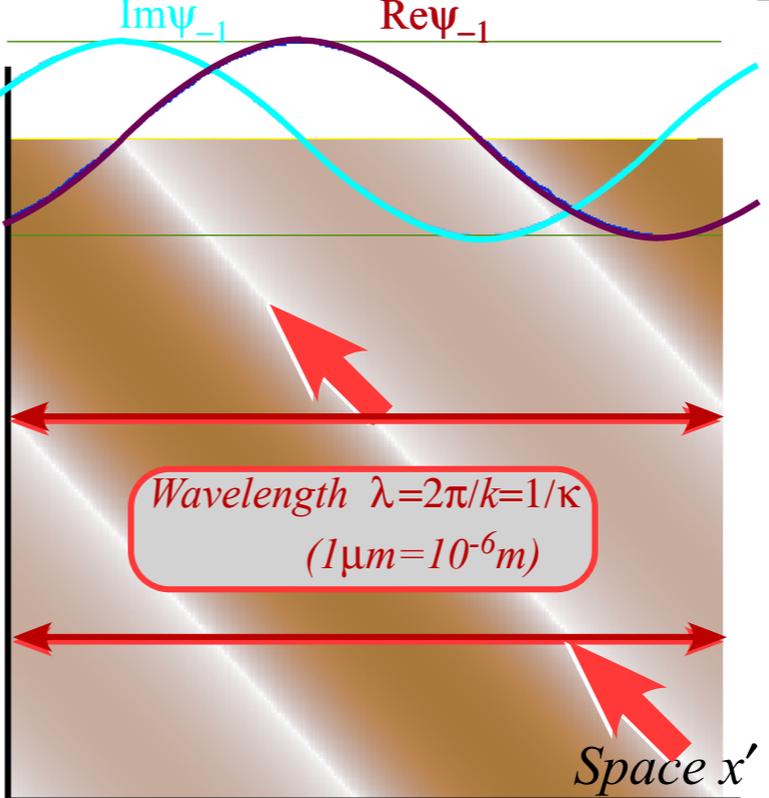
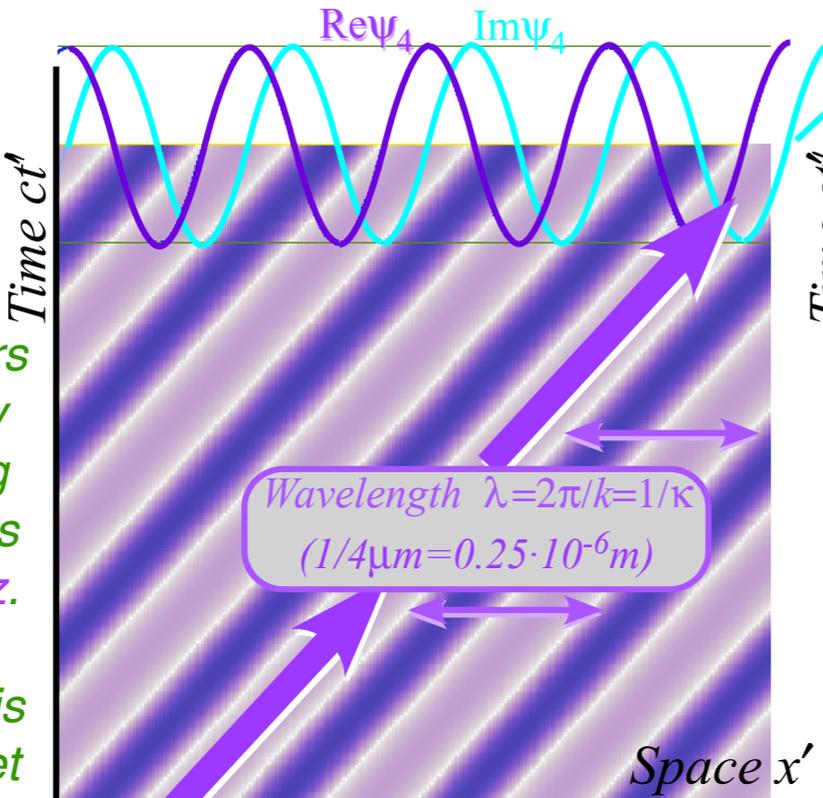
More at [Pirelli Challenge page: 'Un Grande Affare' - Light Meets Light](#)

Right-directed 1CW $e^{i(k_4x - \omega_4t)}$

CW green-laser 600 THz Doppler blue shifted to 1200THz
 $k_4 = +4$ $\omega_4 = 4c$

Left-directed 1CW $e^{i(k_{-1}x - \omega_{-1}t)}$

CW green-laser 600 THz Doppler red shifted to 300THz
 $k_{-1} = -1$ $\omega_{-1} = 1c$



$\nu = 1200\text{THZ}$ or $\lambda = 1/4 \mu\text{m}$

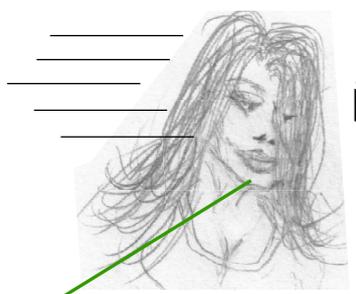
$\nu = 300\text{THZ}$ or $\lambda = 1 \mu\text{m}$

Bob: That UV burns!
 I need to put on my sunglasses.

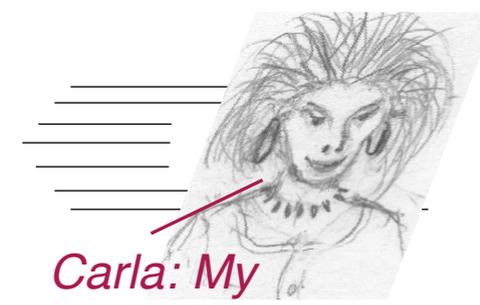
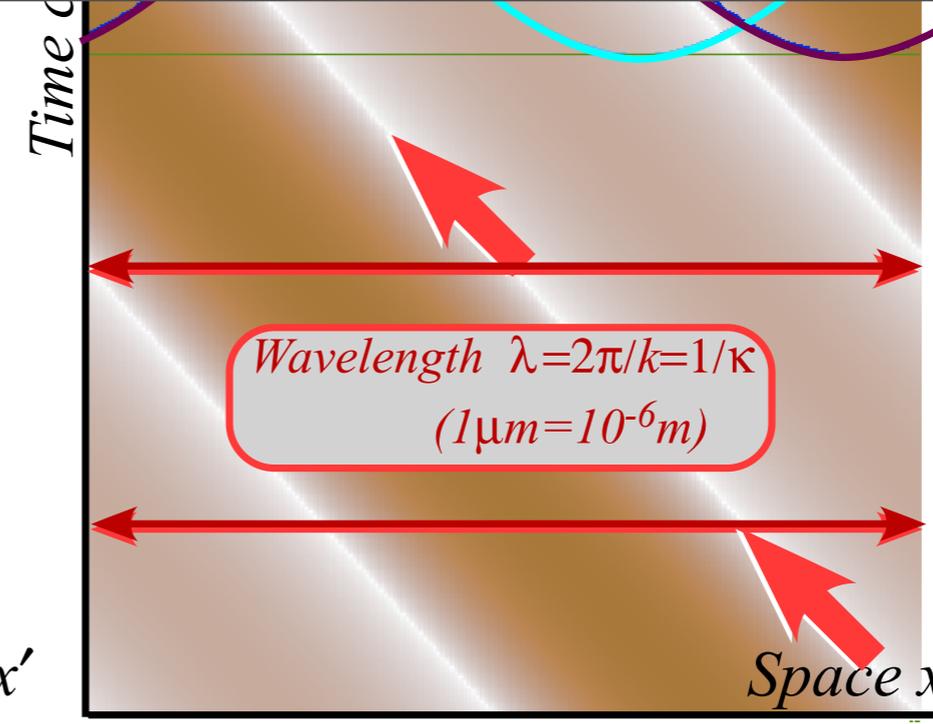
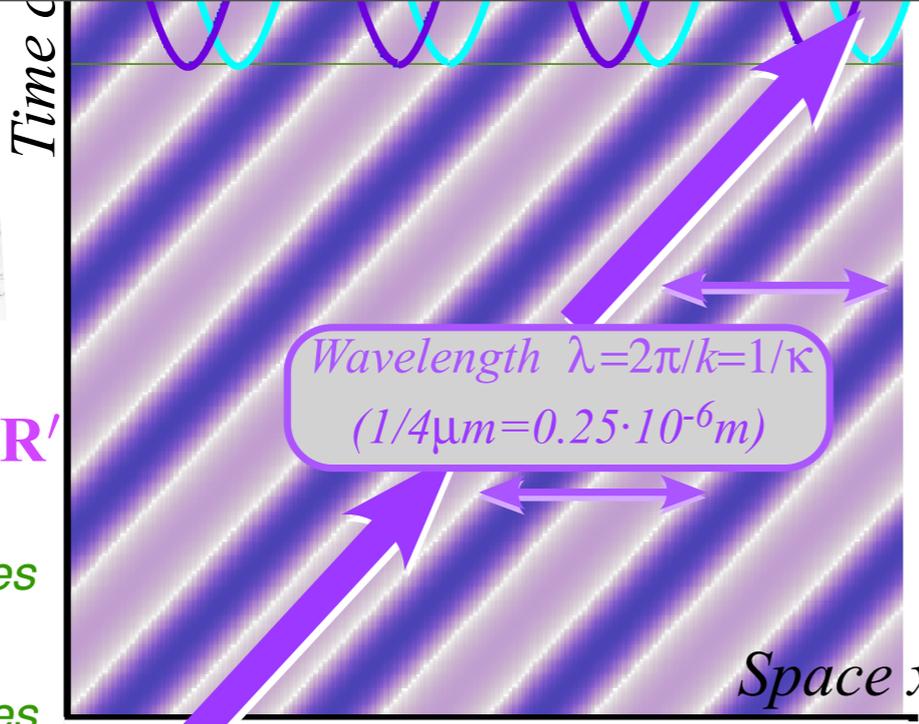
Alice:

Now our 600THz lasers move left-to-right. My 600THz laser is going so fast its beam blasts you with UV 1200THz.

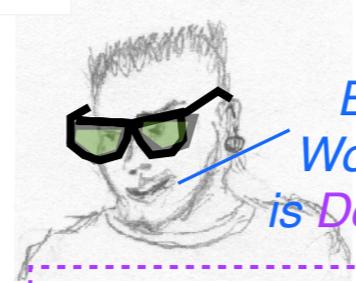
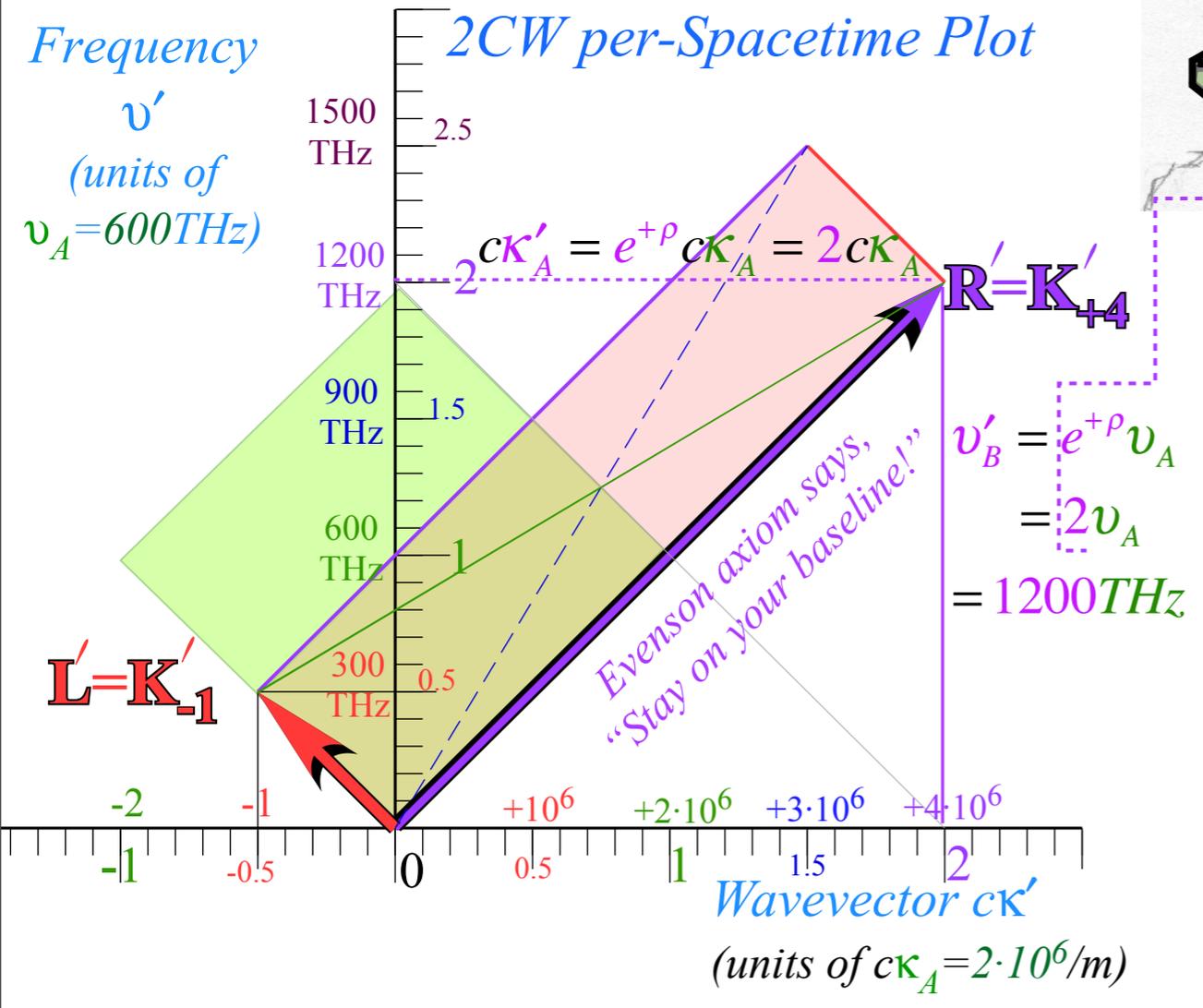
Carla's 600THz laser is going away so you get a nice infrared 300THz.



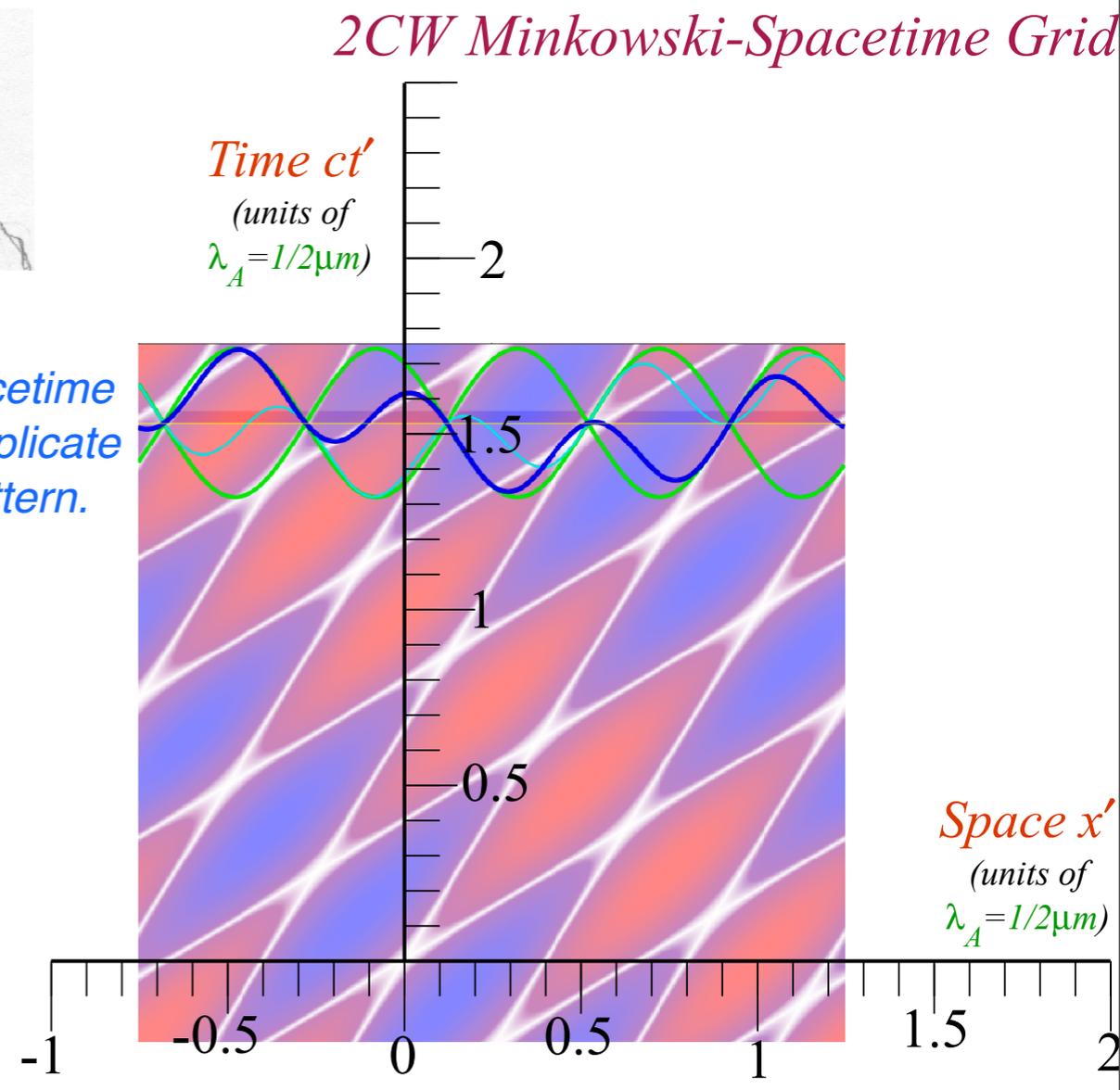
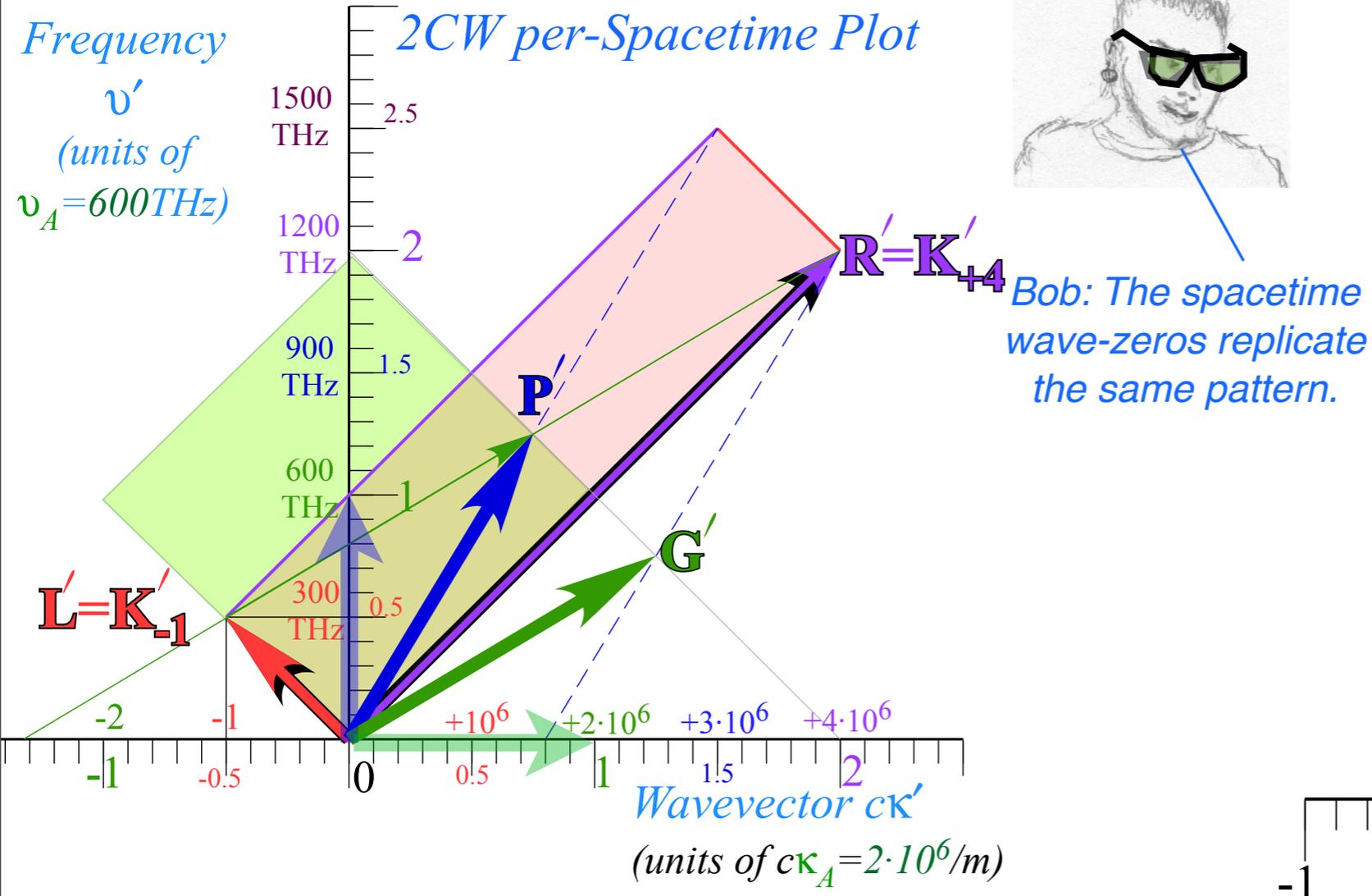
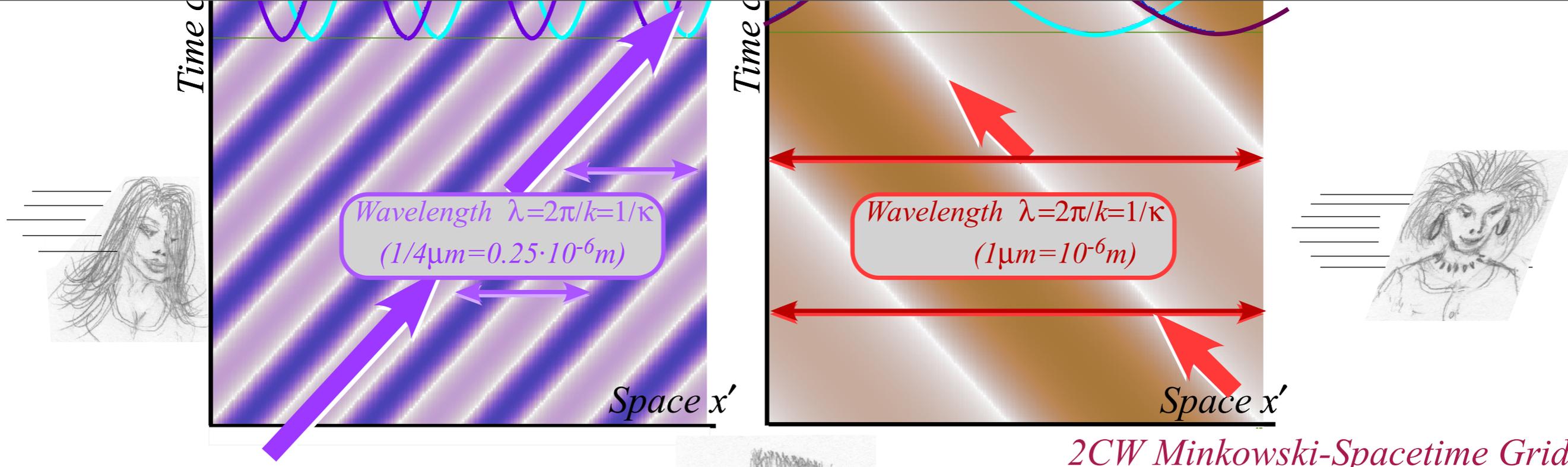
Alice: OK.
 My UV 1200THz R'
 vector is fierce!
 You'll need glasses
 to see P' and G'
 lines or coordinates.



Carla: My
 IR 300THz L'
 3rd baseline
 is a lot nicer!

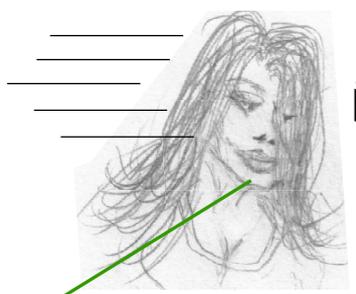


Bob: Sunglasses help.
 Wow! Your 1st baseline R'
 is Doppler blue'd up by $e^{+\rho} = 2$.

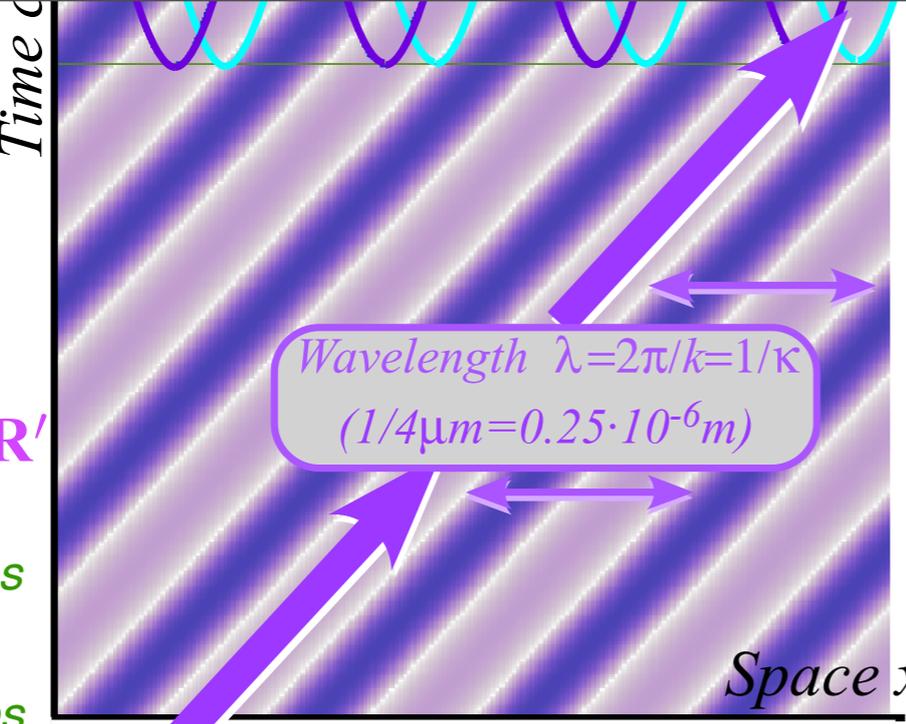


Phase vector \mathbf{P} 1/2-sum vector $\mathbf{K}'_{phase} = \mathbf{P} = \frac{\mathbf{R} + \mathbf{L}'}{2}$

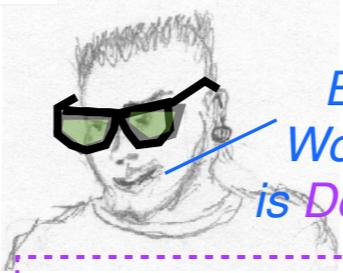
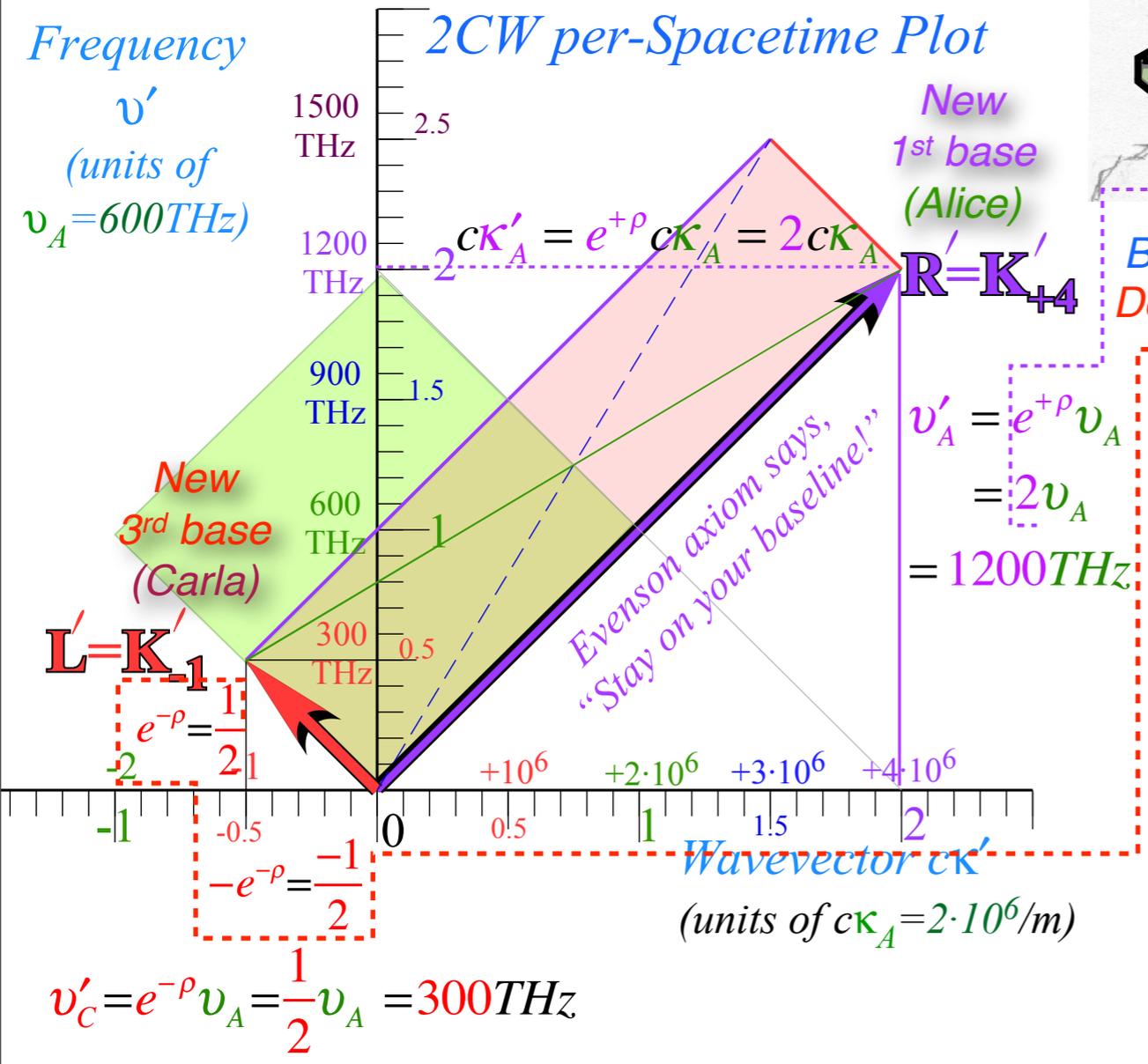
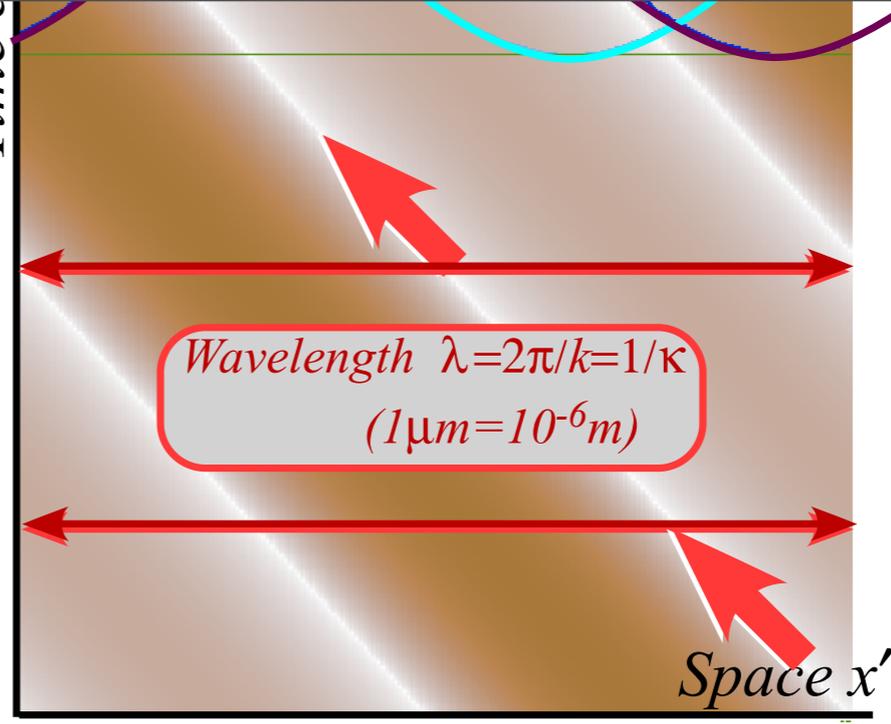
Group vector \mathbf{G} 1/2-diff vector $\mathbf{K}'_{group} = \mathbf{G} = \frac{\mathbf{R} - \mathbf{L}'}{2}$



Alice: OK.
 My UV 1200THz R'
 vector is fierce!
 You'll need glasses
 to see P' and G'
 lines or coordinates.

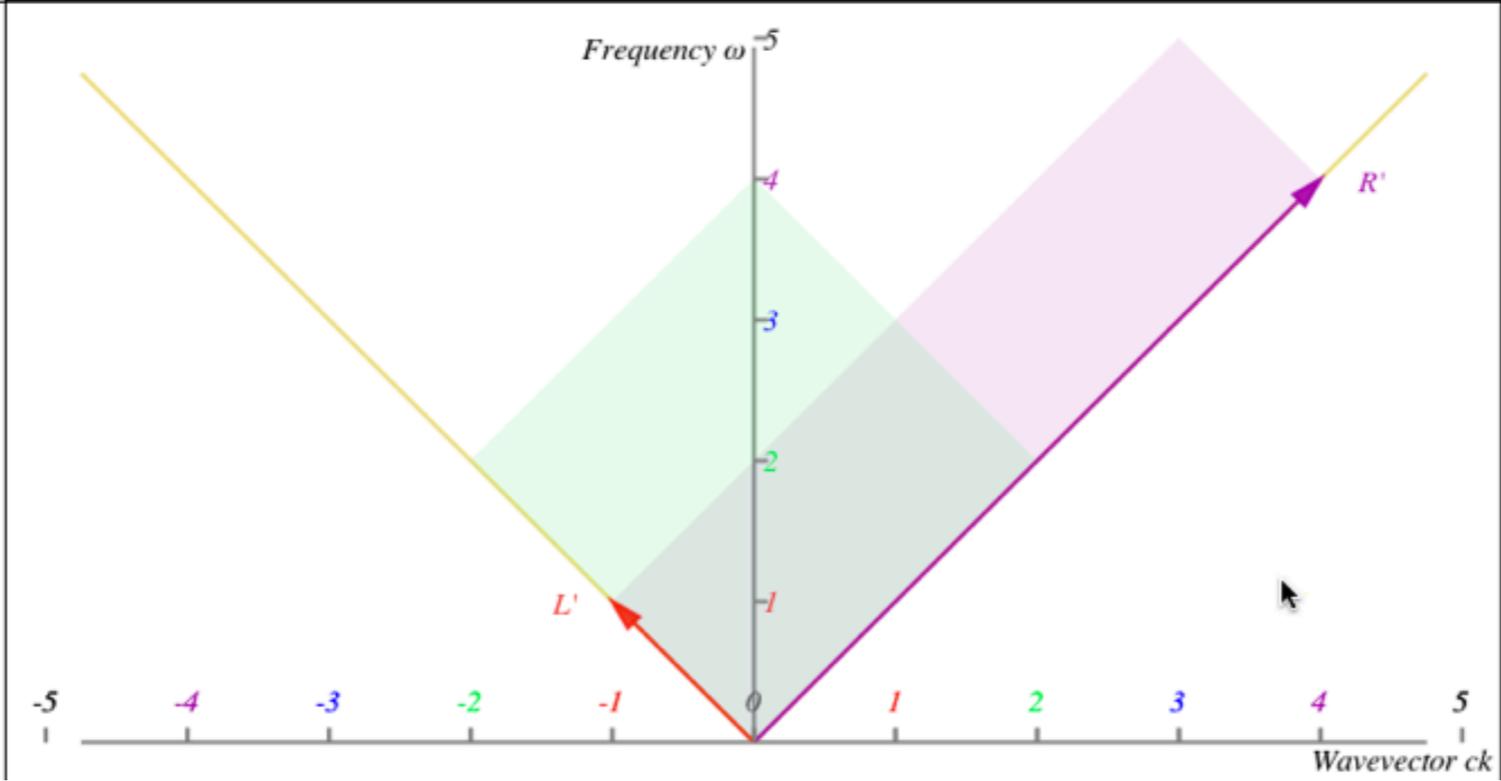
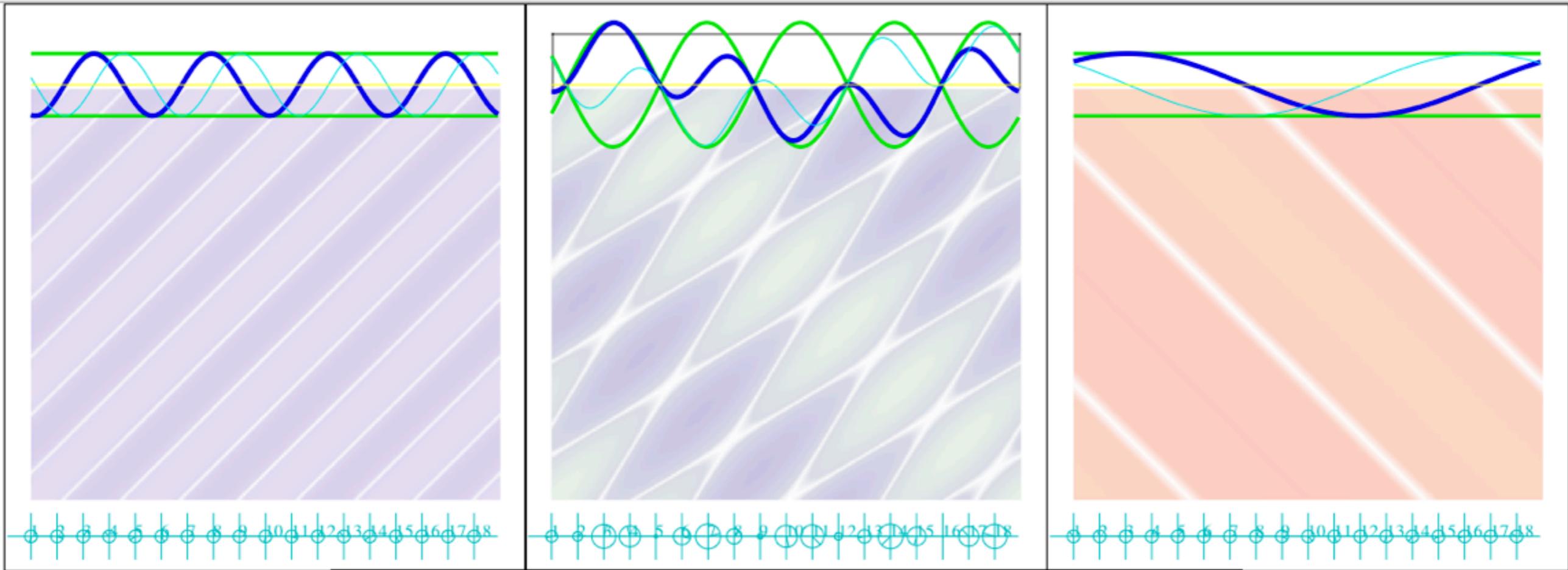


Carla: My
 UV 300THz L'
 3rd baseline
 is a lot nicer!
 (and half as long.)



Bob: Sunglasses help.
 Wow! Your 1st baseline R'
 is Doppler blue'd up by $e^{+\rho} = 2$.

But, Carla's 3rd baseline L' is
 Doppler red shifted by $e^{-\rho} = 1/2$.



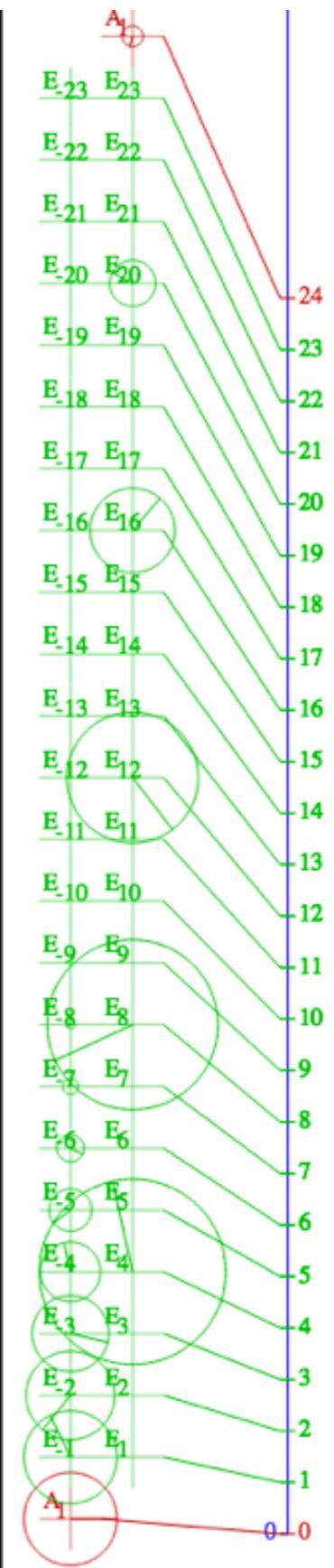
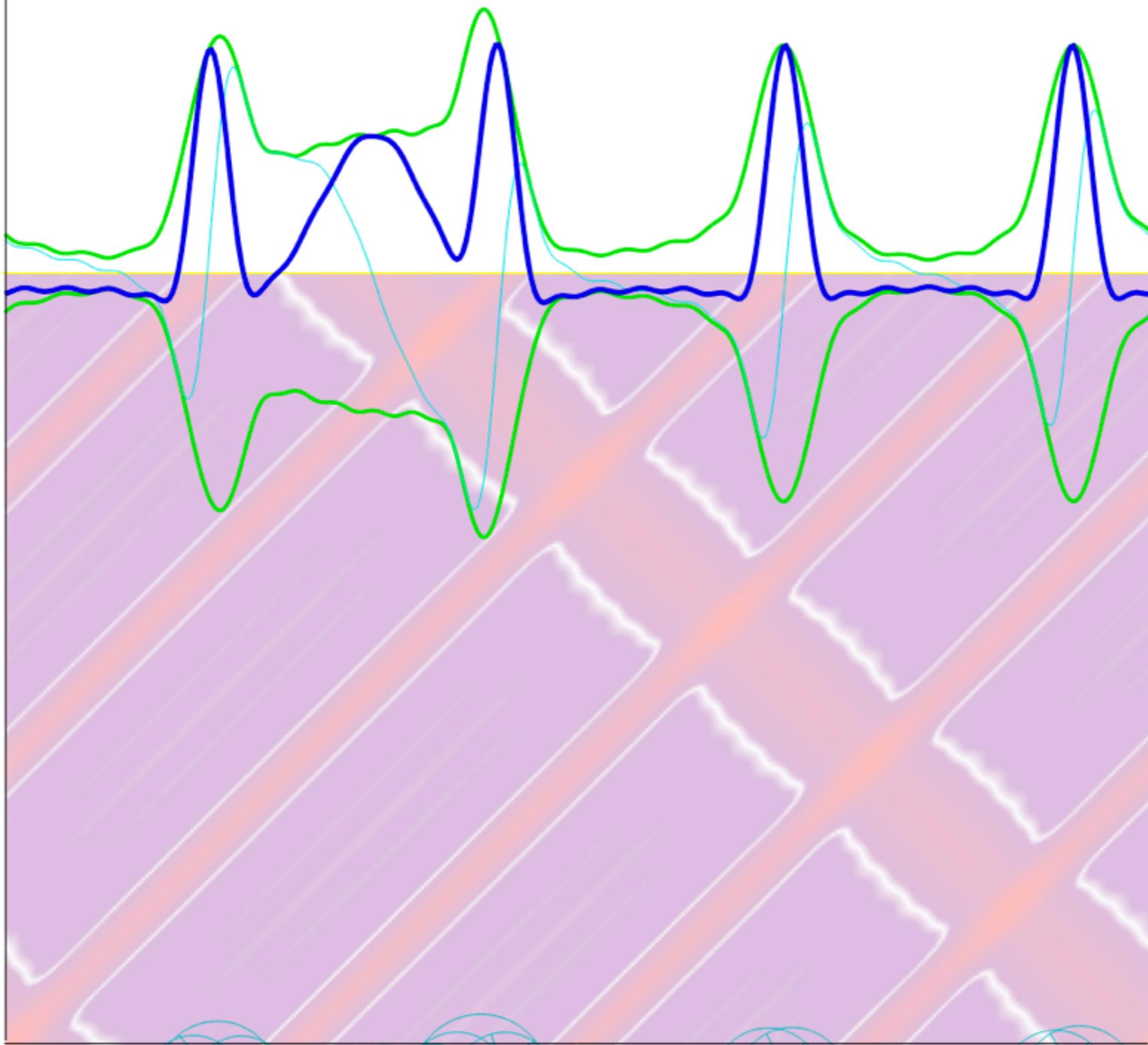
2PW beta = 0

<http://www.uark.edu/ua/modphys/markup/BohrItWeb.html?scenario=-1119>

2PW beta = 3/5

<http://www.uark.edu/ua/modphys/markup/BohrItWeb.html?scenario=-1118>

Time



2PW beta = 0

<http://www.uark.edu/ua/modphys/markup/BohrItWeb.html?scenario=-1119>

2PW beta = 3/5

<http://www.uark.edu/ua/modphys/markup/BohrItWeb.html?scenario=-1118>

Special Relativity and Quantum Mechanics regarded as *mysterious* and *lacking clarity*

Bob&Alice regard for clarity of SR: **foggy** or QM: **opaque**

Can this situation be improved at fundamental axiomatic level?

Evidence and concepts needing critical review:

QM (*Planck, 1900*) and SR (*Einstein, 1905*) are both about light (*em waves*)

Galilean relativity, how it fails for light and how it doesn't

The great light-wave speed-limit ($c=2.99792458m/s$. by *Evenson, ..., Hall 1972*)

Need better axioms (*Occam's Razors & Evenson's Lasers*): CW axioms outwit old PW axioms

Introduce "*Keyboard of the gods*" CW per-space-time (κ, ν) that rules (λ, τ) **space-time**

Introduce idea of quantized **wavenumber**- κ_n and **amplitude** A_n (*1st and 2nd quantization*)

Introduce **infrared (IR) 300 THz**, **green 600THz**, and **ultra-violet (UV) 1200THz** CW laser beams

Optical Doppler CW frequency shift ν_A/ν_B : A hidden key to understanding modern physics

Bob and Alice deduce Evenson's CW Axiom: *All colors march together at $c = \nu\lambda = \nu/\kappa$*

Bob, Alice, and Carla discover *rapidity* ($\rho_{AB}=\ln \nu_A/\nu_B$), a longitudinal measure of speed

Bob, Alice, and Carla get *Galileo's Revenge Part I*: $\rho_{CB}=\rho_{CA}+\rho_{AB}$, a simple speed sum

Bob, Alice, and Carla get *Galileo's Revenge Part II*.and map space-time by phase-group 2-CW ←

$\frac{1}{2}$ -sum- $\frac{1}{2}$ -difference of phasor angular velocity determines space-time geometry

➔ Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$

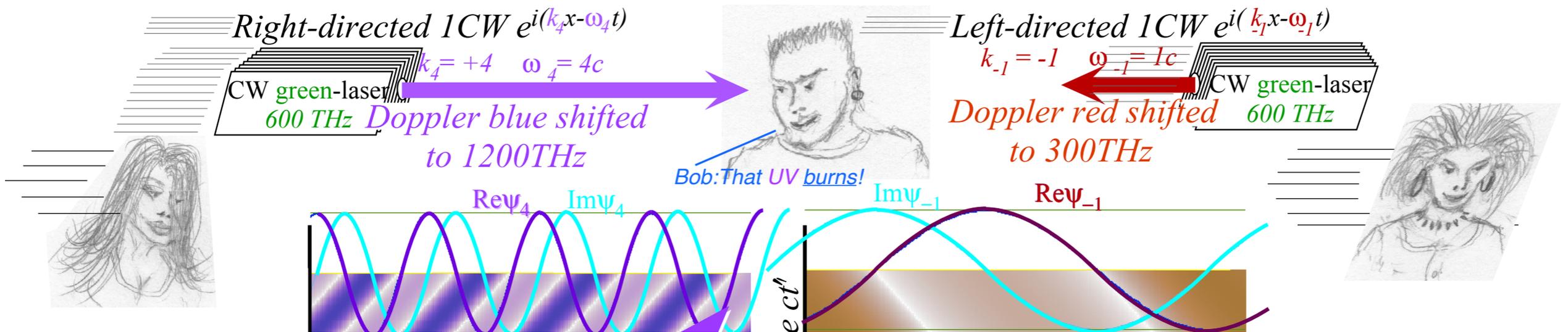
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Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$

Imagine that Bob detects counter-propagating laser beams of frequency

$\omega_R=\omega_A$ going left-to-right (Alice's laser) and

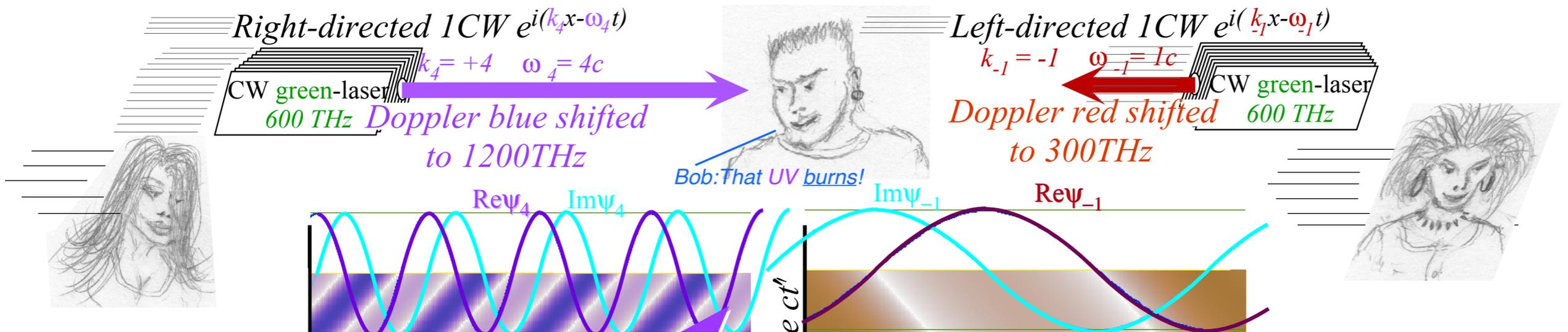
$\omega_L=\omega_C$ going right-to-left (Carla's laser).



Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$

Imagine that Bob detects counter-propagating laser beams of frequency

$\omega_R=\omega_A$ going left-to-right (Alice's laser) and $\omega_L=\omega_C$ going right-to-left (Carla's laser).



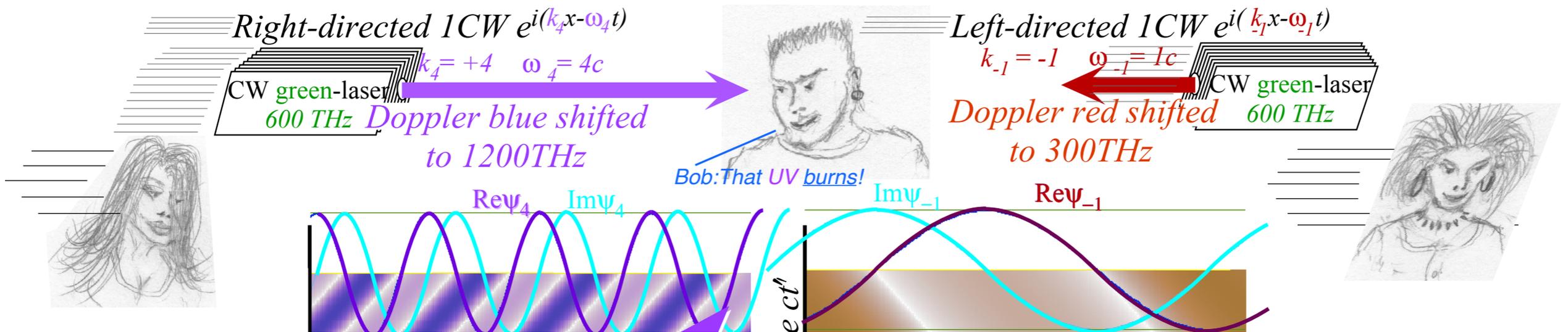
We ask two questions:

- (1.) To what velocity u_E must Bob accelerate so he sees beams with equal frequency ω_E ?
- (2.) What is that frequency ω_E ?

Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$

Imagine that Bob detects counter-propagating laser beams of frequency

$\omega_R=\omega_A$ going left-to-right (Alice's laser) and $\omega_L=\omega_C$ going right-to-left (Carla's laser).



We ask two questions:

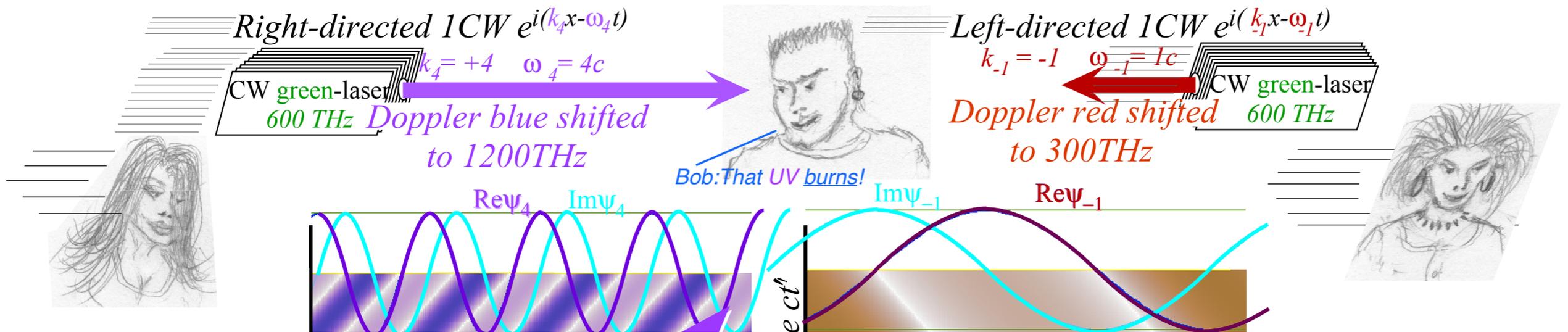
- (1.) To what velocity u_E must Bob accelerate so he sees beams with equal frequency ω_E ?
- (2.) What is that frequency ω_E ?

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

$$u_E = V_{group} = \frac{\omega_{group}}{k_{group}} = \frac{\omega_R - \omega_L}{k_R - k_L} = c \frac{\omega_R - \omega_L}{\omega_R + \omega_L}$$

Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$

Imagine that Bob detects counter-propagating laser beams of frequency $\omega_R=\omega_A$ going left-to-right (Alice's laser) and $\omega_L=\omega_C$ going right-to-left (Carla's laser).



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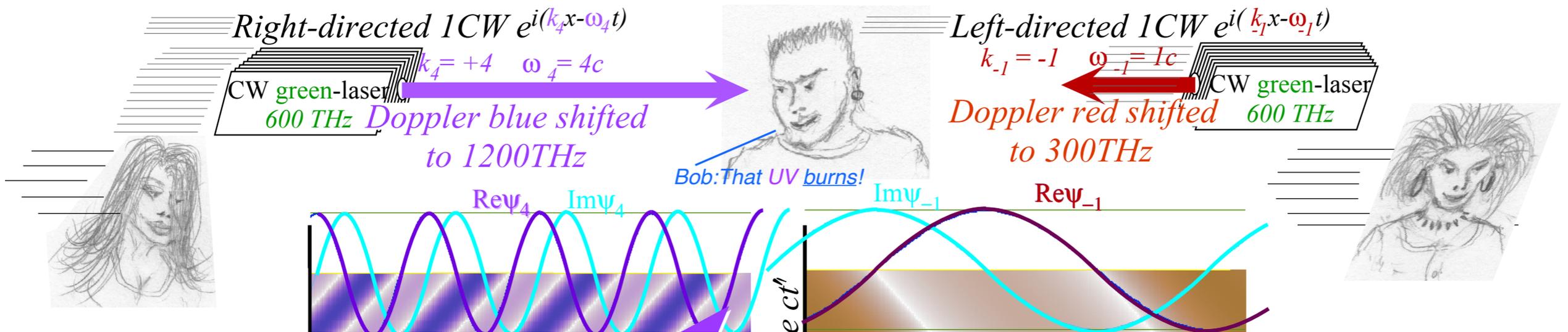
$$u_E = V_{group} = \frac{\omega_{group}}{k_{group}} = \frac{\omega_R - \omega_L}{k_R - k_L} = c \frac{\omega_R - \omega_L}{\omega_R + \omega_L} = c \frac{e^{\rho_E} - e^{-\rho_E}}{e^{\rho_E} + e^{-\rho_E}} = c \frac{\sinh \rho_E}{\cosh \rho_E} = c \tanh \rho_E$$

Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$

Imagine that Bob detects counter-propagating laser beams of frequency

$\omega_R = \omega_A$ going left-to-right (Alice's laser) and

$\omega_L = \omega_C$ going right-to-left (Carla's laser).



We ask two questions:

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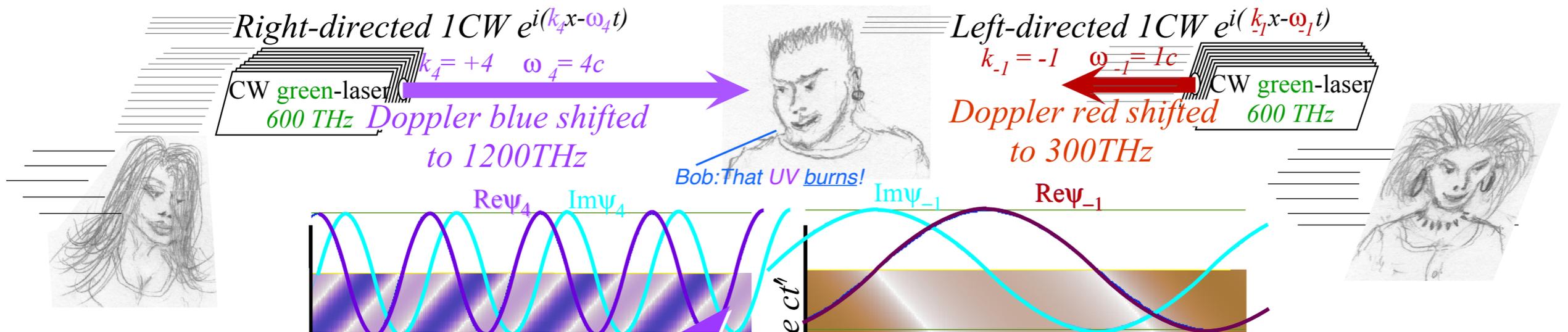
$$u_E = V_{group} = \frac{\omega_{group}}{k_{group}} = \frac{\omega_R - \omega_L}{k_R - k_L} = c \frac{\omega_R - \omega_L}{\omega_R + \omega_L} = c \frac{e^{\rho_E} - e^{-\rho_E}}{e^{\rho_E} + e^{-\rho_E}} = c \frac{\sinh \rho_E}{\cosh \rho_E} = c \tanh \rho_E$$

$$\frac{u_E}{c} = \frac{\omega_R - \omega_L}{\omega_R + \omega_L} = \frac{1200 - 300}{1200 + 300} = \frac{3}{5}$$

Relating rapidity ρ_{AB} and relativity velocity parameter $\beta_{AB}=u_{AB}/c$

Imagine that Bob detects counter-propagating laser beams of frequency

$\omega_R=\omega_A$ going left-to-right (Alice's laser) and $\omega_L=\omega_C$ going right-to-left (Carla's laser).



We ask two questions:

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$$\frac{u_E}{c} = \frac{\omega_R - \omega_L}{\omega_R + \omega_L} = \frac{1200 - 300}{1200 + 300} = \frac{3}{5}$$

Query (2.) similarly:

What ω_E is blue-shift $b\omega_L$ of ω_L and red-shift ω_R/b of ω_R ?

$$\omega_E = b\omega_L = \omega_R/b \quad \Rightarrow \quad b = \sqrt{\omega_R/\omega_L} \quad \Rightarrow \quad \omega_E = \sqrt{\omega_R \cdot \omega_L} = \sqrt{1200 \cdot 300} = 600 \text{ THz}$$

(Geometric Mean)

