Lecture 31.

Relativity of interfering and galloping waves: SWR and SWQ III.

(Ch. 4-6 of Unit 2 4.15.12)

Review of Lecture 30

1st Quantization: Quantizing phase variables ω and k

Understanding how quantum transitions require "mixed-up" states

Closed cavity vs Ring cavity

2nd Quantization: Quantizing amplitudes ("photons", "vibrons", and "what-ever-ons")

Introducing coherent states (What lasers use)

Analogy with (ω,k) wave packets

Wave coordinates need coherence

Field Energy $=|\mathsf{E}|^2\varepsilon_0$ $\quad 1/4\pi\varepsilon_0 = 9\cdot 10^9$

Relativistic effects on charge, current, and Maxwell Fields

Current density changes by Lorentz asynchrony

Magnetic B-field is relativistic effect

Lecture 31 ended here

Review of Lecture 30

1st Quantization: Quantizing phase variables ω and k

Understanding how quantum transitions require “mixed-up” states

Closed cavity vs Ring cavity

Quantized ω and *k* *Counting wave kink numbers*

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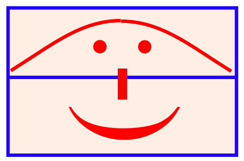
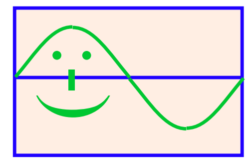
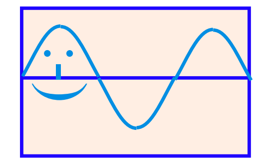
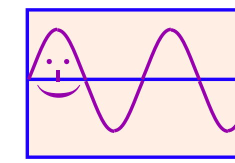
(+ integers only)

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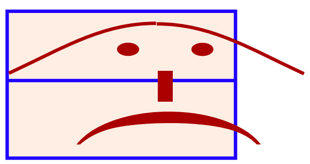
too fat!



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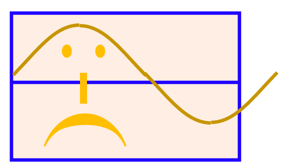

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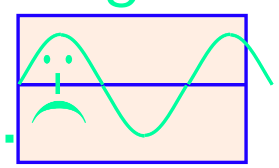
misfits...



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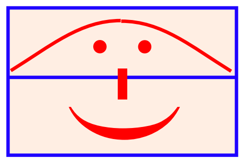
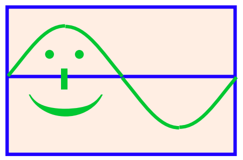
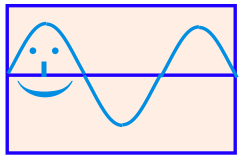
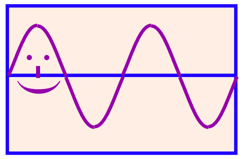

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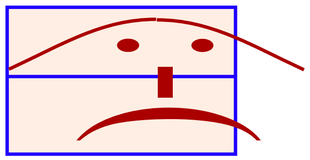

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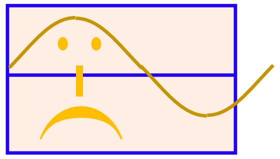

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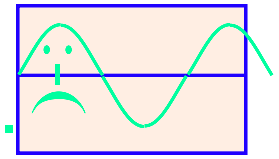

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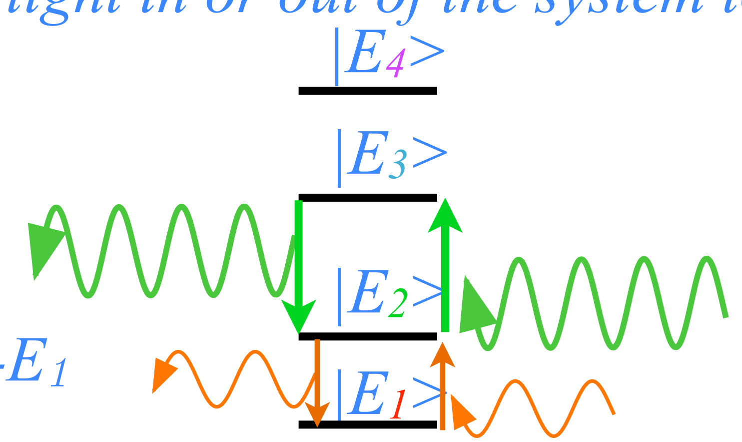
That's the only way you get any light in or out of the system to "see" it.

frequency $\hbar\omega_{32} = E_3 - E_2$

frequency $\hbar\omega_{21} = E_2 - E_1$



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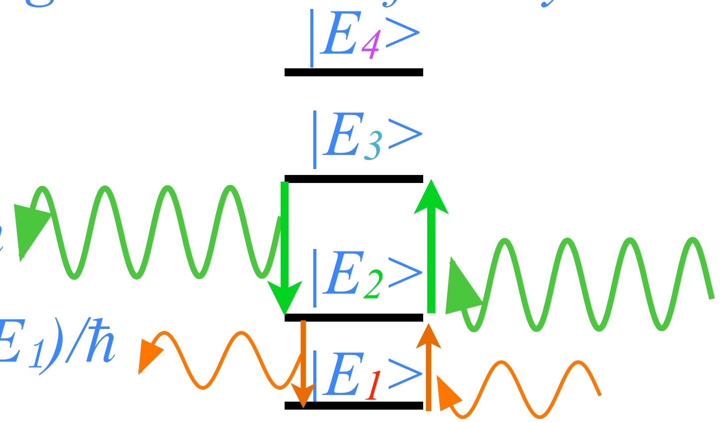
frequency $\omega_{32} = (E_3 - E_2)/\hbar$

frequency $\omega_{21} = (E_2 - E_1)/\hbar$



These eigenstates are the only ways the system can "play dead"... ... " sleep with the fishes"...

Quantized ω and *k* *Counting wave kink numbers*

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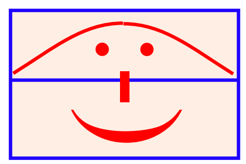
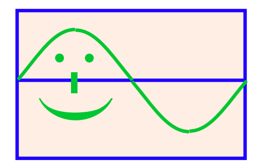
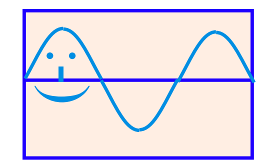
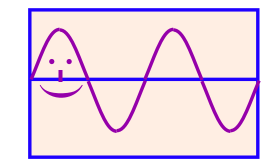

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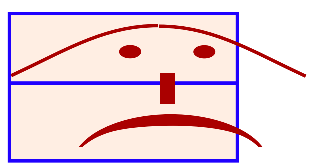

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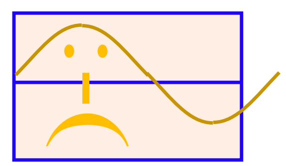

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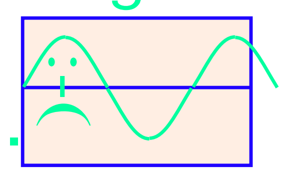

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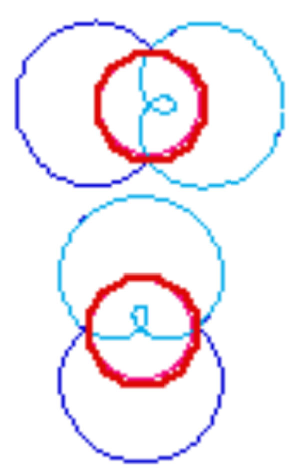
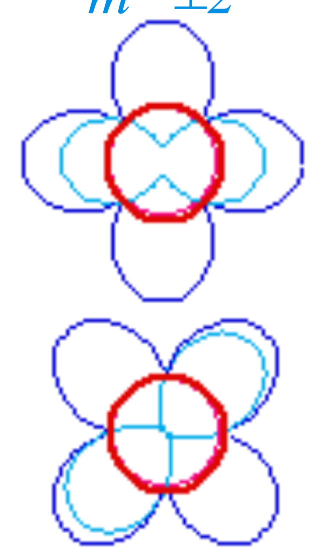
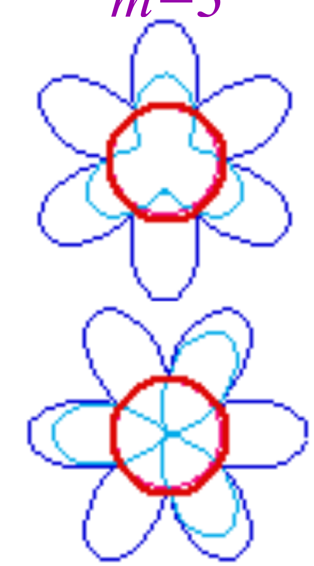
Rings tolerate a *zero* (kinkless) quantum wave but require ±*integral wave number.*

OK ring quantum numbers: $m=0$ $m=\pm 1$ $m=\pm 2$ $m=3$

(± integral number of wavelengths)


Bohr's models of *atomic spectra (1913-1923)* are beginnings of *quantum wave mechanics* built on *Planck-Einstein (1900-1905)* relation $E=h\upsilon$. *DeBroglie* relation $p=h/\lambda$ comes around *1923*.

2nd Quantization: Quantizing amplitudes ("photons","vibrons", and "what-ever-ons")

Introducing coherent states (What lasers use)

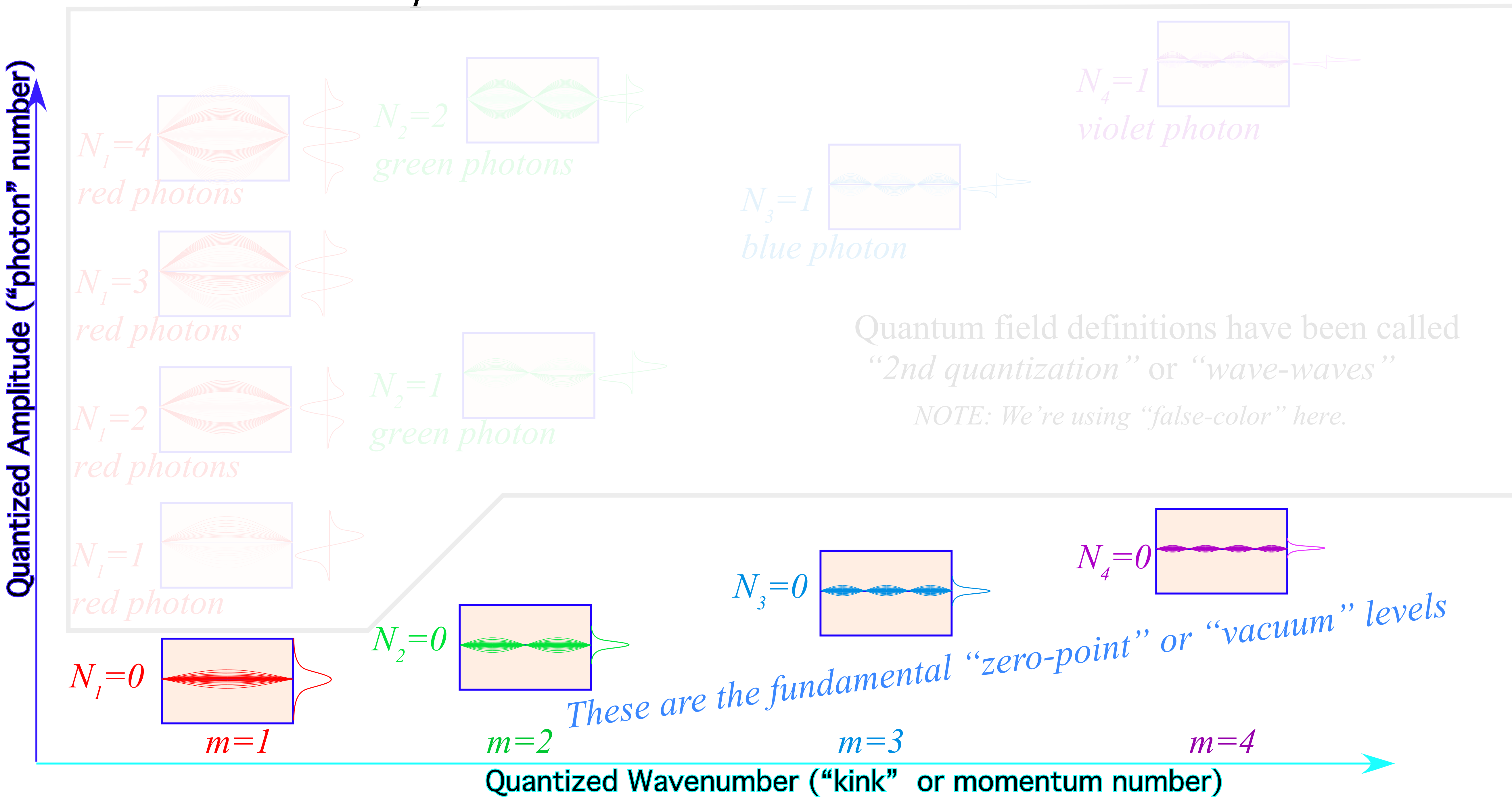
Analogy with (ω,k) wave packets

Wave coordinates need coherence

Quantized *Amplitude* *Counting "photon" number*

Planck's relation $E=Nh\upsilon$ began as a tenative axiom to explain low-T light. Then he tried to disavow it! Einstein picked it up in his 1905 paper. Since then its use has grown enormously and continues to amaze, amuse (or bewilder) all who study it.

A current view is that it represents the *quantization* of optical field *amplitude*. We picture this below as *N-photon* wave states for each box-mode of *m* wave kinks.



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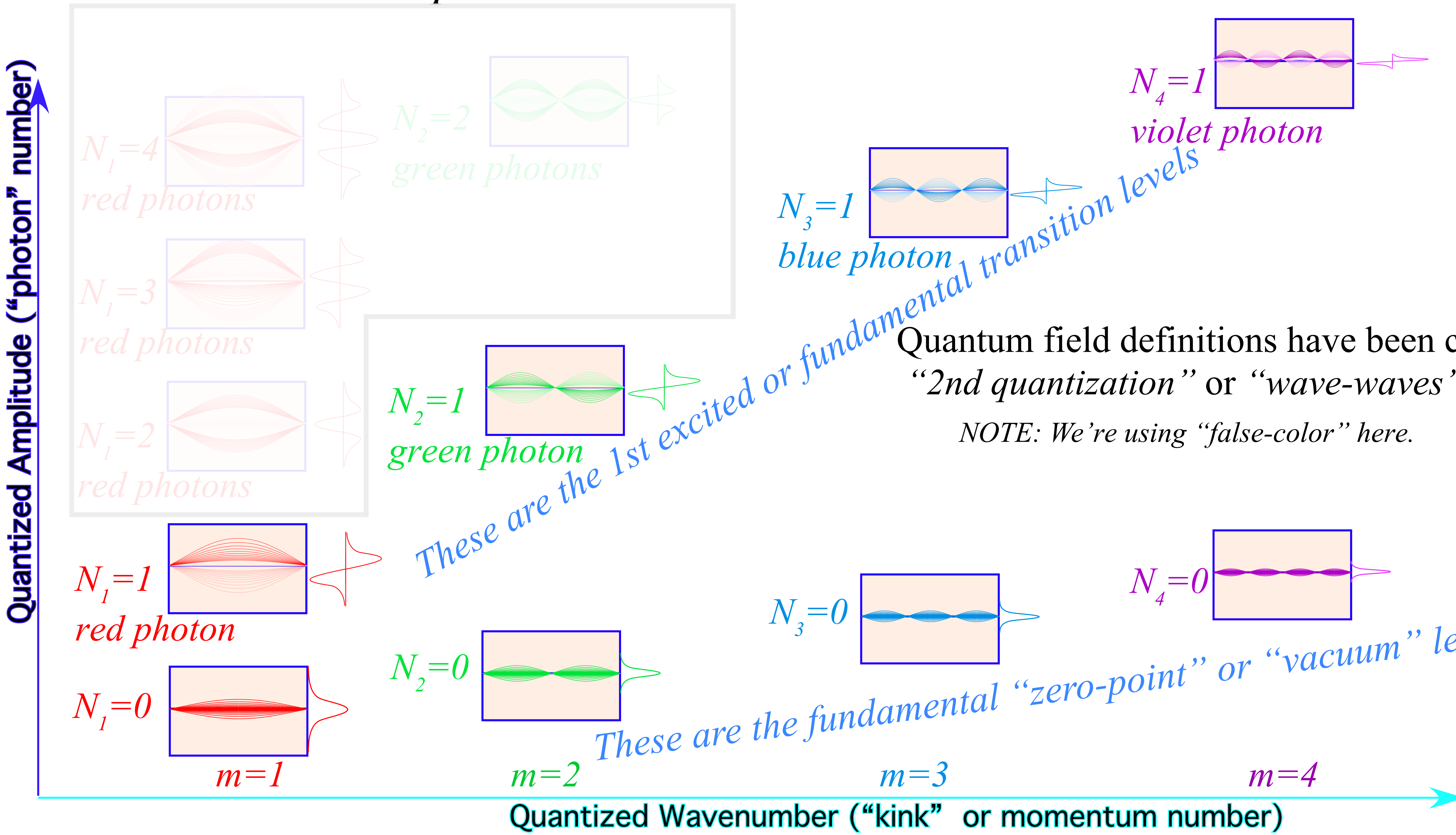

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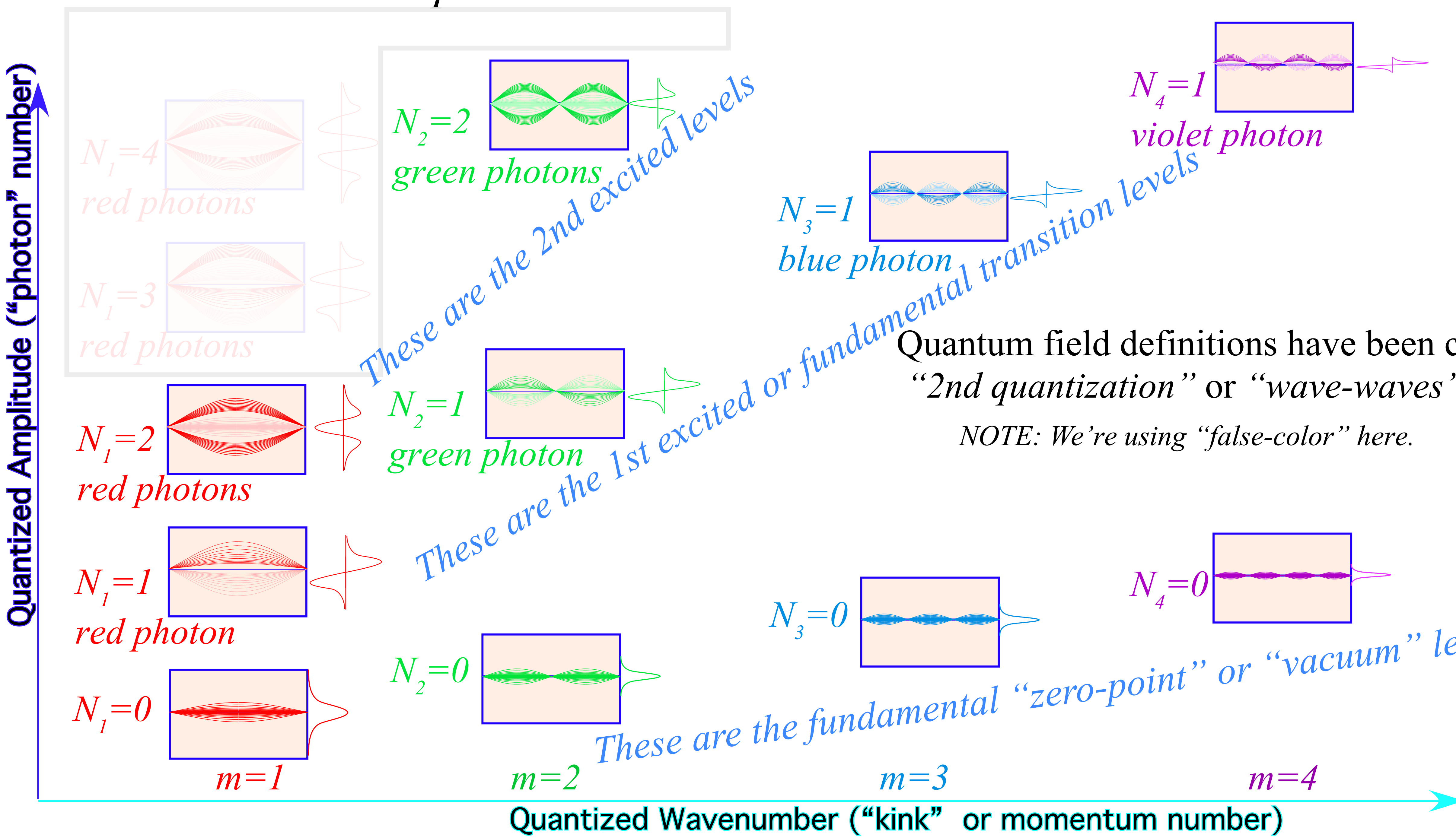

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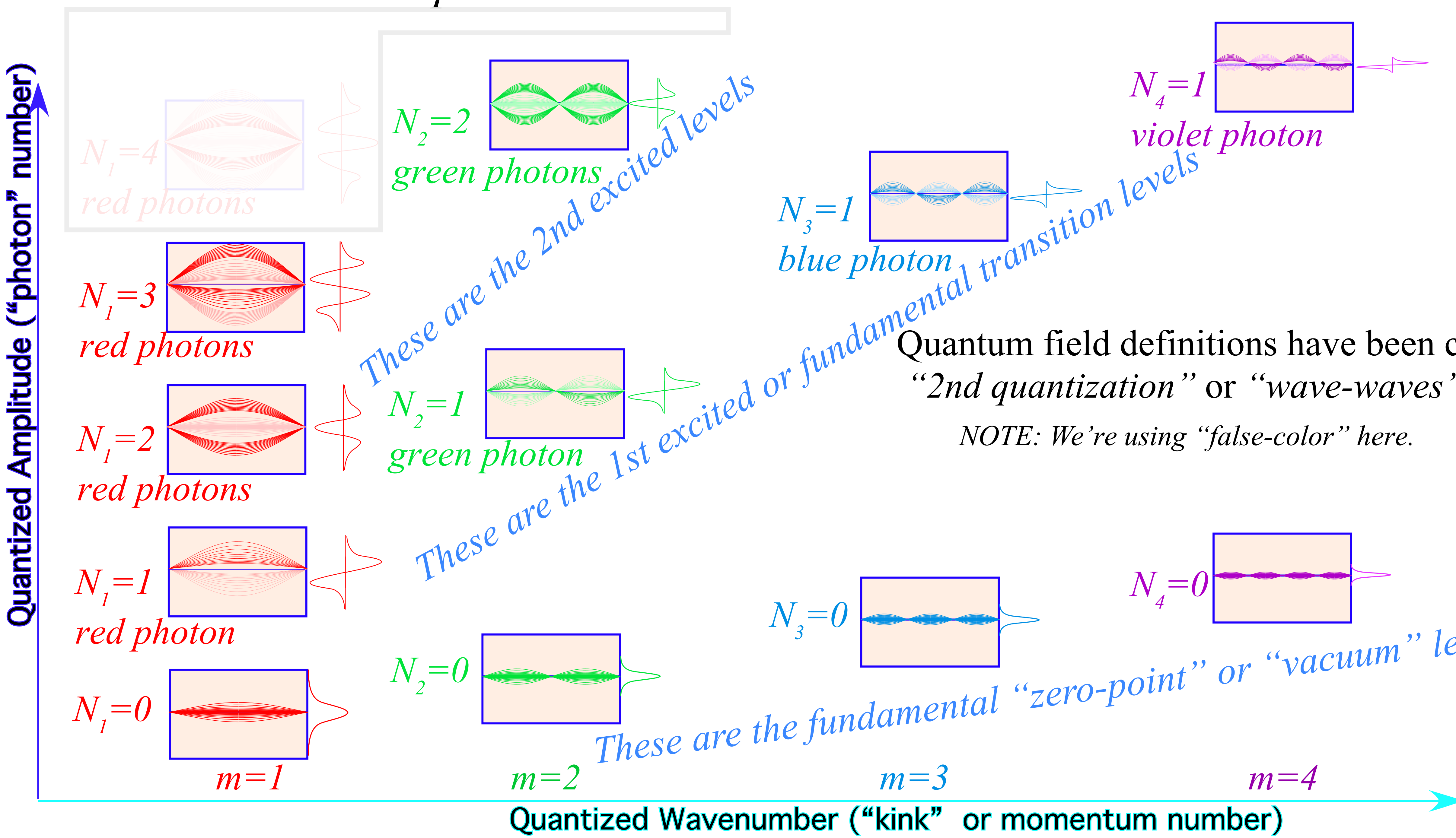

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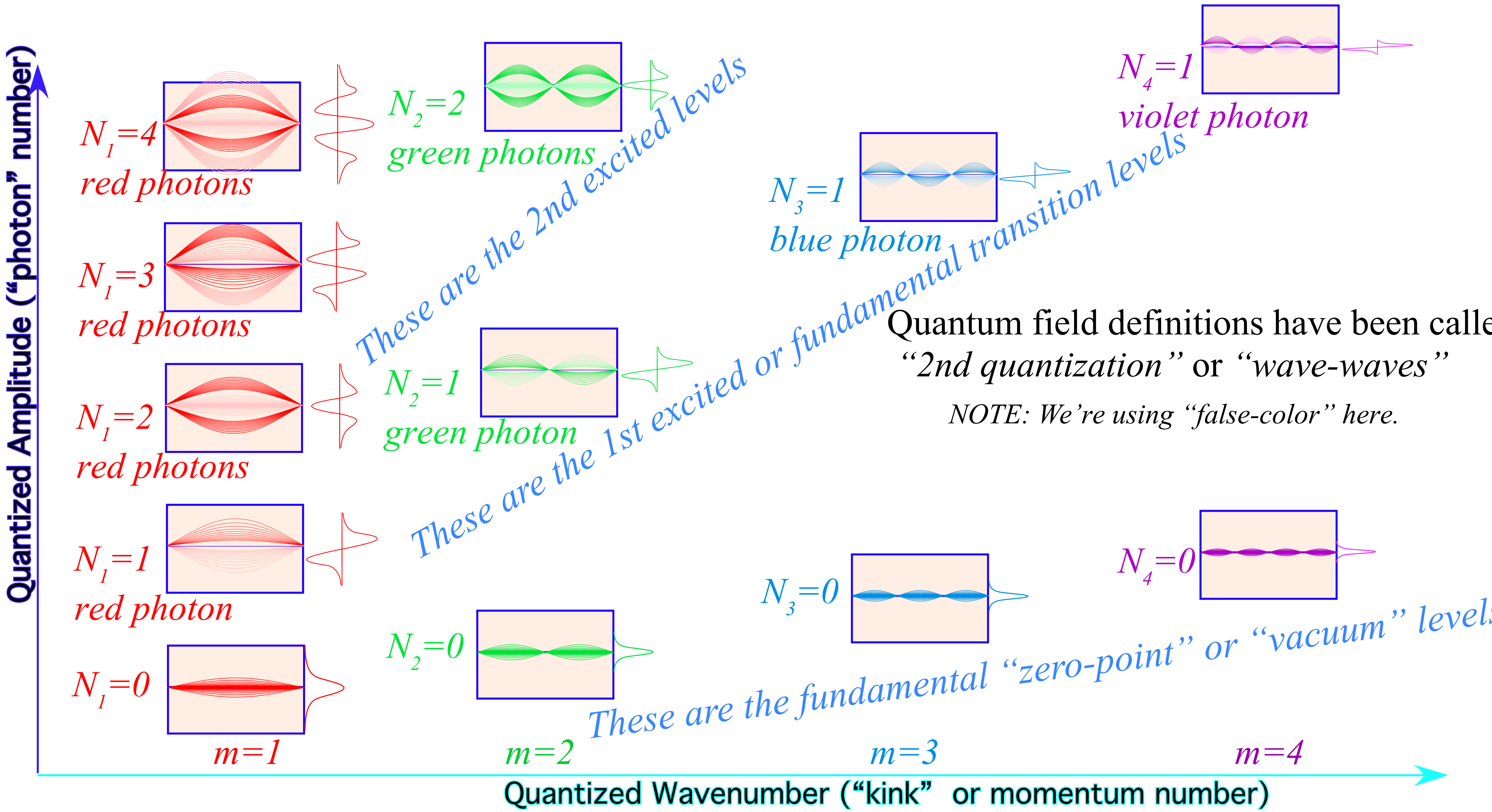
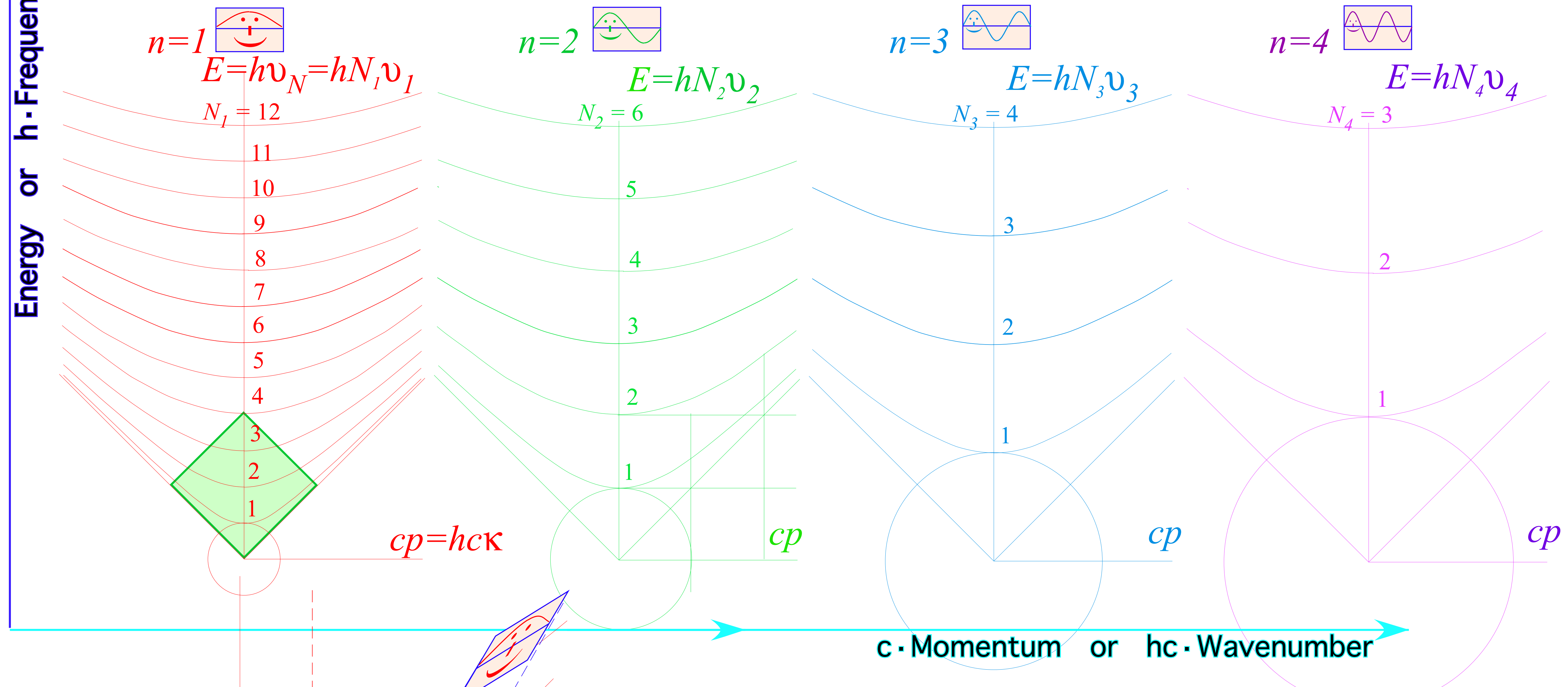
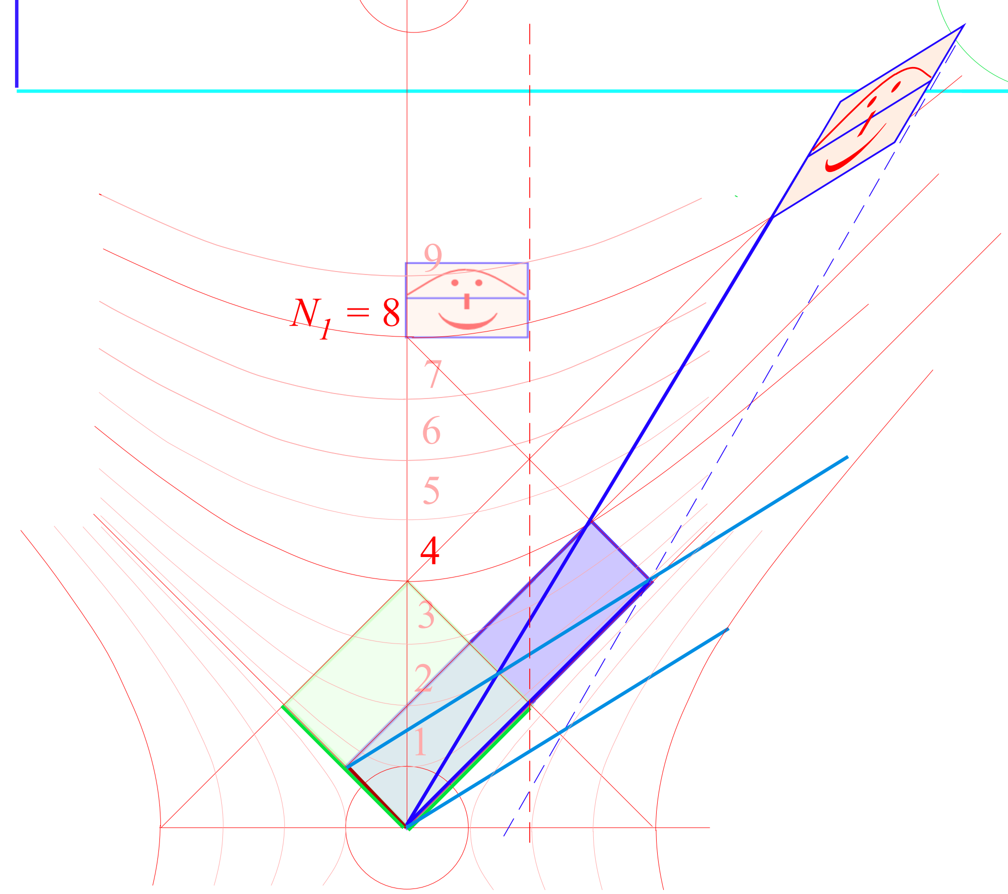


Quantum numbers N of field or n, m,.. of modes are *invariants* and *not* changed by boosting velocity.
Each mode fundamental frequency $\upsilon_n = n\upsilon_1$ and its N-photon multiples belong to invariant hyperbolas.





Boosted observers see distorted frequencies and lengths, but will agree on the *numbers n* and N of mode *nodes* and *photons*.

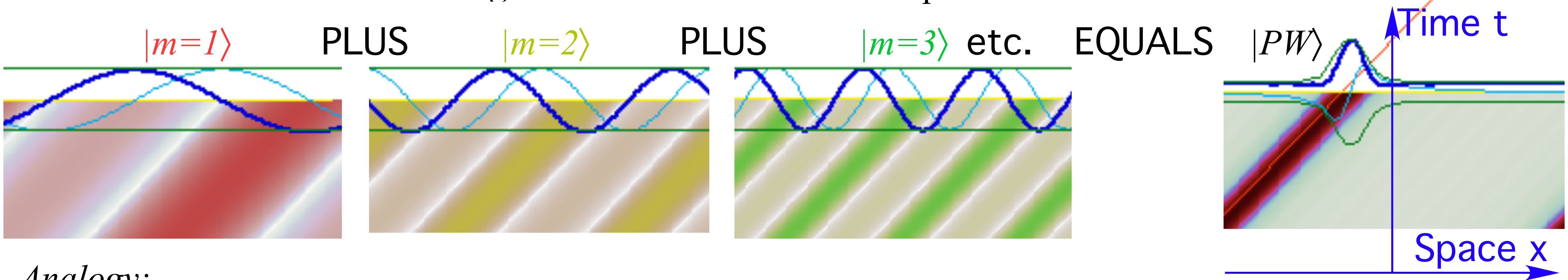
This is how light waves can "fake" some of the properties of classical "things" such as *invariance* or *object permanence*.

It takes at least *TWO CW*'s to achieve such invariance. One CW is not enough and cannot have non-zero invariant N . Invariance is an *interference* effect that needs at least *two-to-tango!*

www.uark.edu/ua/pirelli/php/quantized_2.php

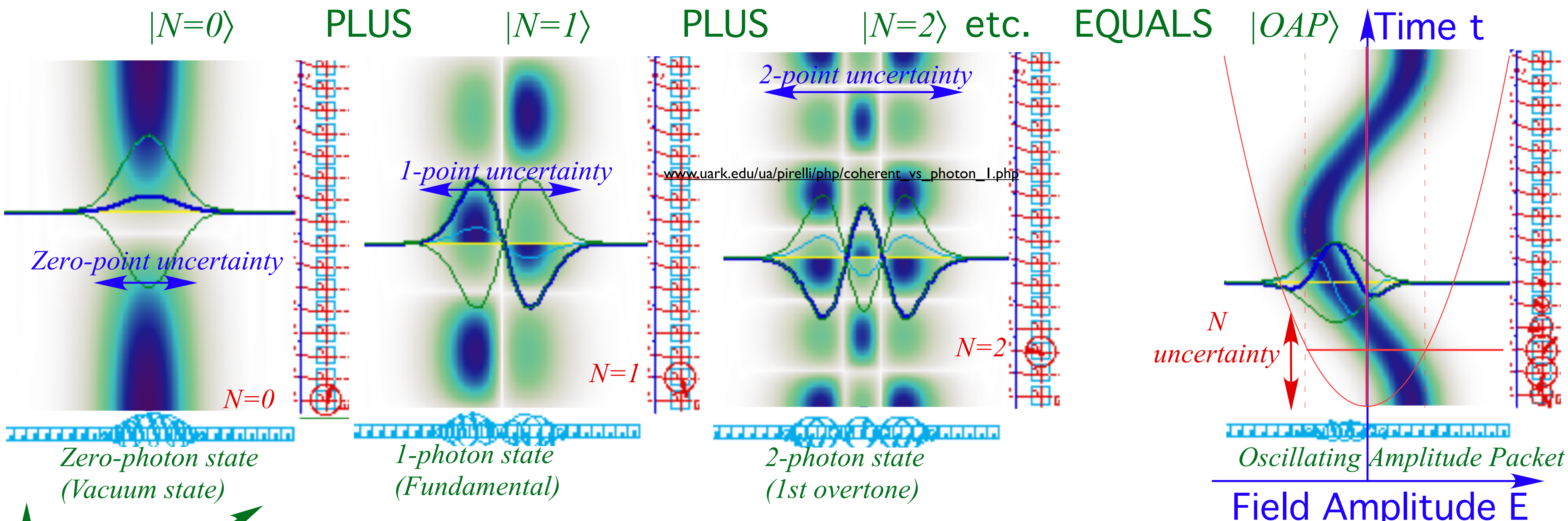
Coherent States: Oscillator Amplitude Packets *analogous to* *Wave Packets*

We saw how adding *CW*'s *(Continuous Waves m=1,2,3...)* can make *PW (Pulse Wave)* or *WP (Wave Packet)* that is more like a classical *"thing"* with more *localization* in space *x* and time *t*.



Analogy:

Adding *photons (Quantized amplitude N=0,1,2...)* can make a *CS (Coherent State)* or *OAP (Oscillator Amplitude Packet)* that is more like a *classical wave oscillation* with more *localization* in field amplitude.

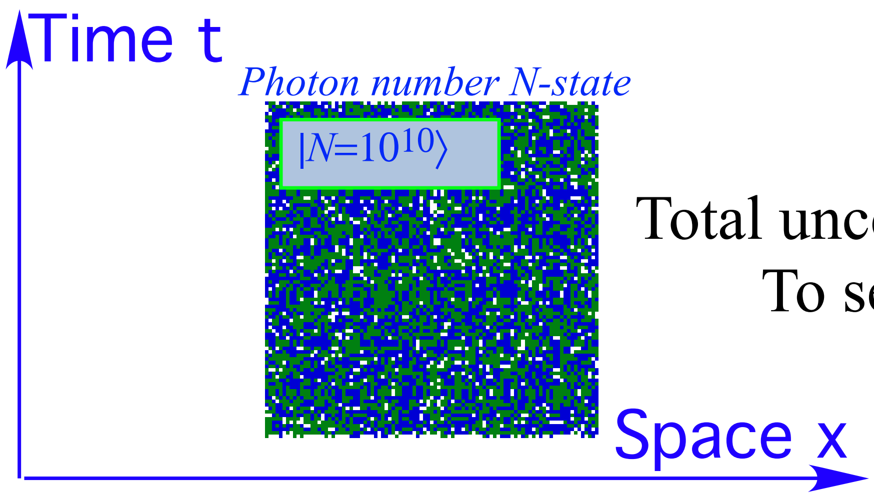


Pure photon states have localized (certain) *N* but *de*localized (*un*certain) amplitude and phase.

OAP states have *de*localized (*un*certain) *N* but more localized (certain) amplitude and phase.

Coherent States(contd.) *Spacetime wave grid is impossible without coherent states*

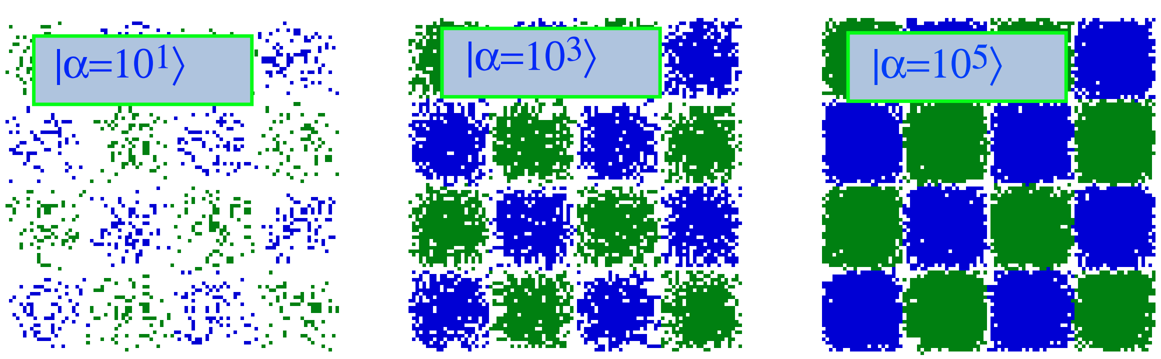
Pure photon number N-states would make useless spacetime coordinates



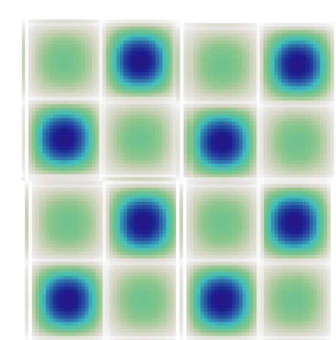
Total uncertainty of amplitude and phase makes the count pattern a wash.
To see grids *some N-uncertainty is necessary!*

Coherent-α-states are defined by continuous amplitude-packet parameter α whose square is average photon number $\bar{N}=|\alpha|^2$. Coherent-states make better spacetime coordinates for larger $\bar{N}=|\alpha|^2$.

Quantum field coherent α-states



Classical limit



$\bar{N}=100$ $\Delta N=10$ | $\bar{N}=10^6$ $\Delta N=10^3$ | $\bar{N}=10^{10}$ $\Delta N=10^5$

Coherent-state uncertainty in photon number (and mass) varies with amplitude parameter $\Delta N \sim \alpha \sim \sqrt{N}$ so a coherent state with $\bar{N}=|\alpha|^2=10^6$ only has a 1-in-1000 uncertainty $\Delta N \sim \alpha \sim \sqrt{N}=1000$.

Relativistic effects on charge, current, and Maxwell Fields

➡ *Current density changes by Lorentz asynchrony*

Magnetic B-field is relativistic effect

Relativistic effects on charge, current, and Maxwell Fields

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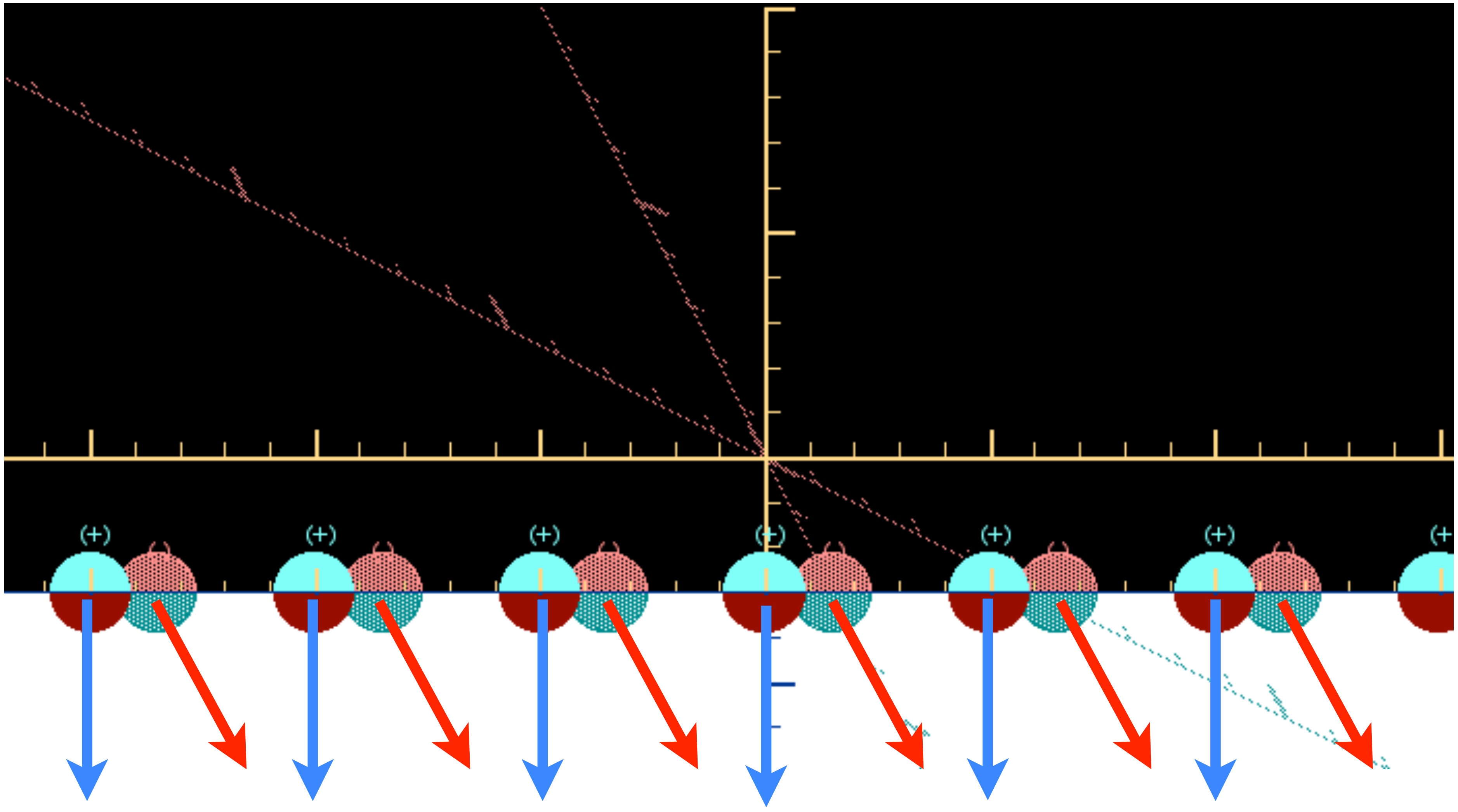
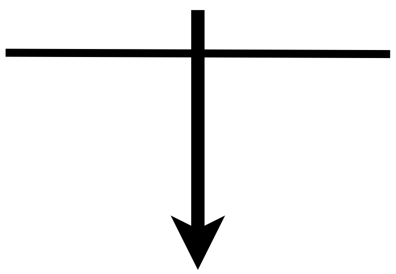


Observer velocity is zero relative to (+) line of charge



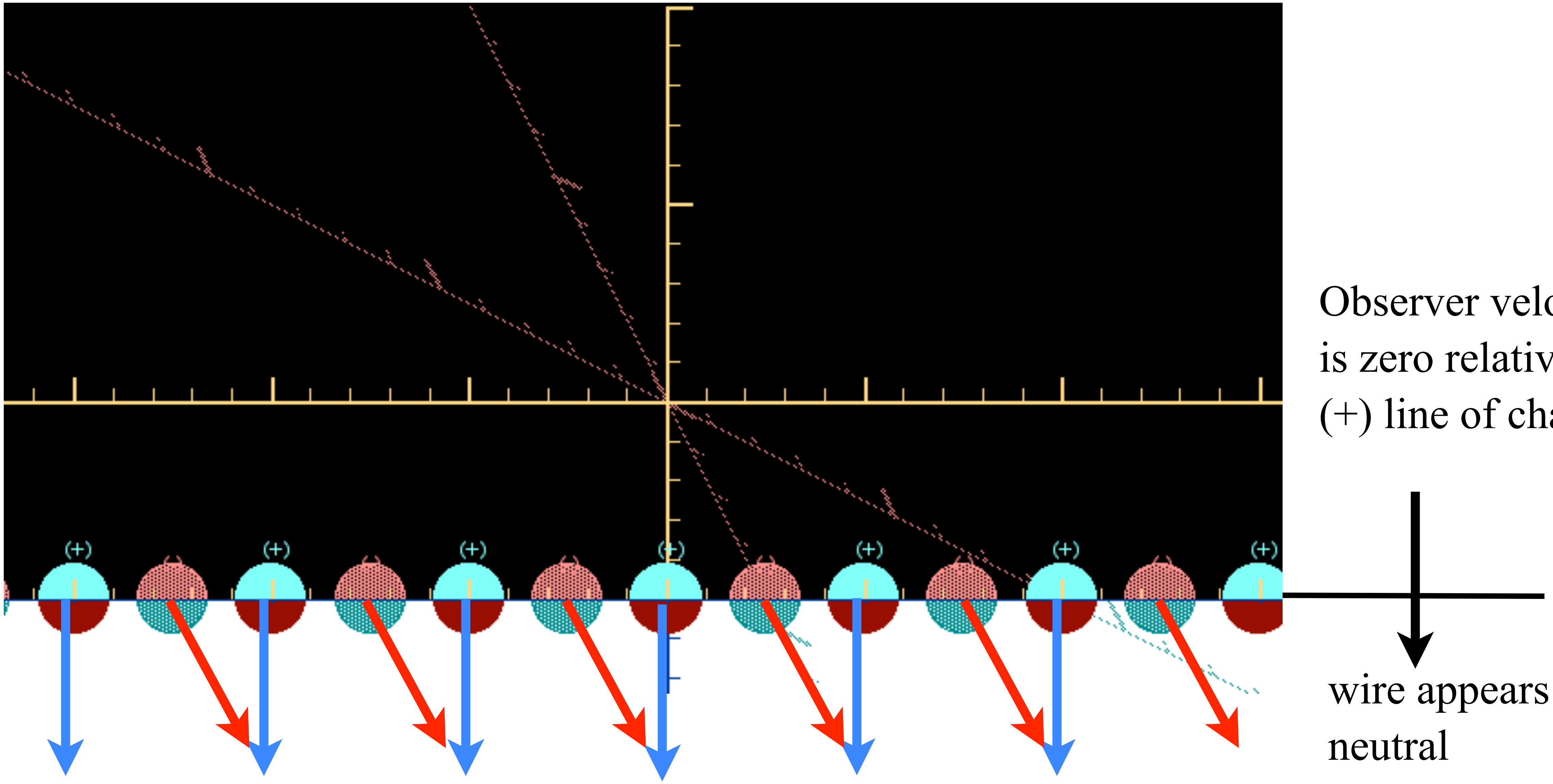
wire appears neutral

(+) Charge fixed (-) Charge moving to left (*Negative current density)*

(+) Charge density is Equal to the (-) Charge density

Relativistic effects on charge, current, and Maxwell Fields

Current density changes by Lorentz asynchrony



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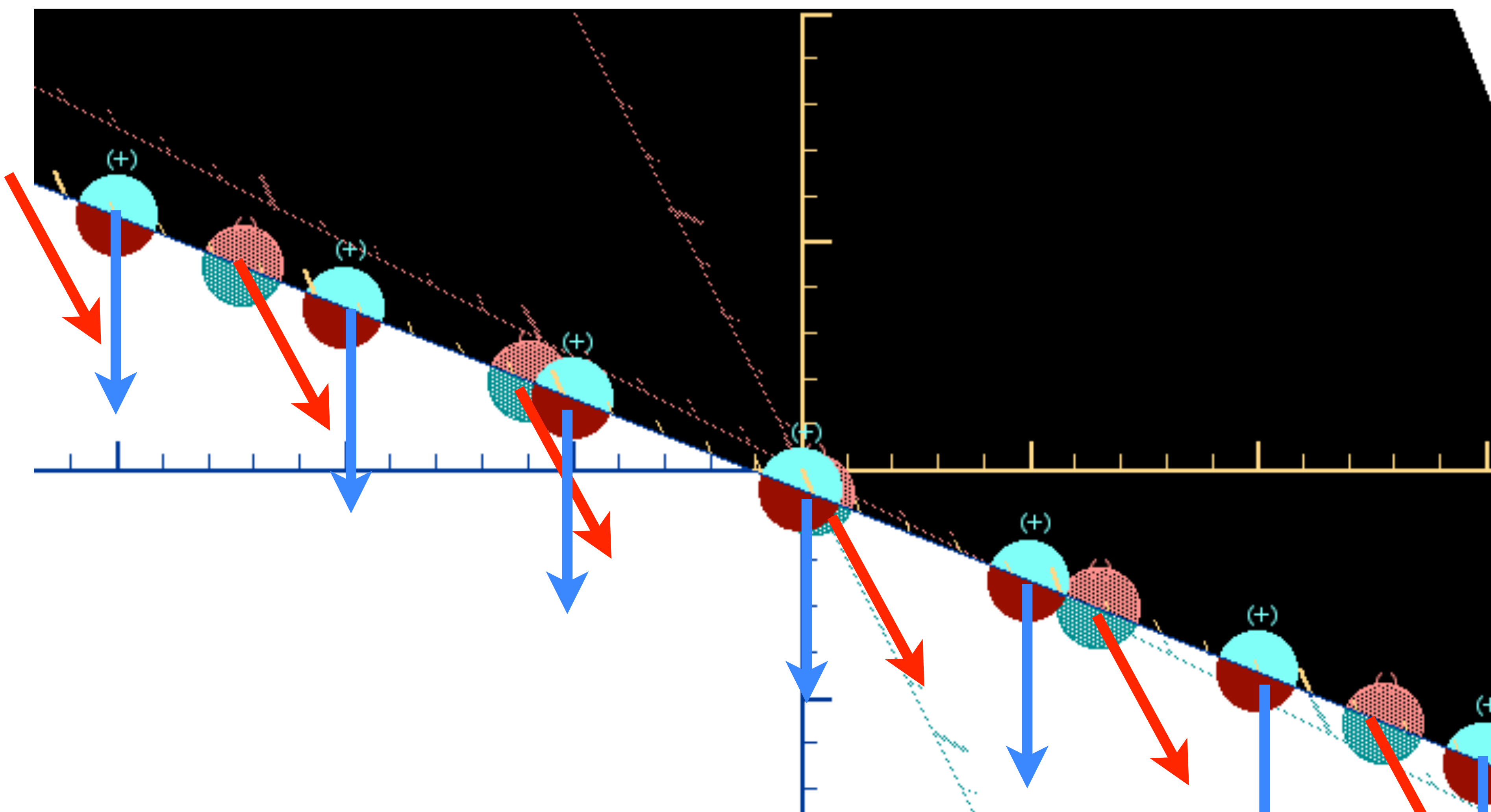

Observer velocit
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(+) line of charge

(+) Charge fixed (-) Charge moving to right (*Negative current density*)

(+) Charge density is *Greater* than (-) Charge density

wire appears
postive (+)
(repulsive to +)

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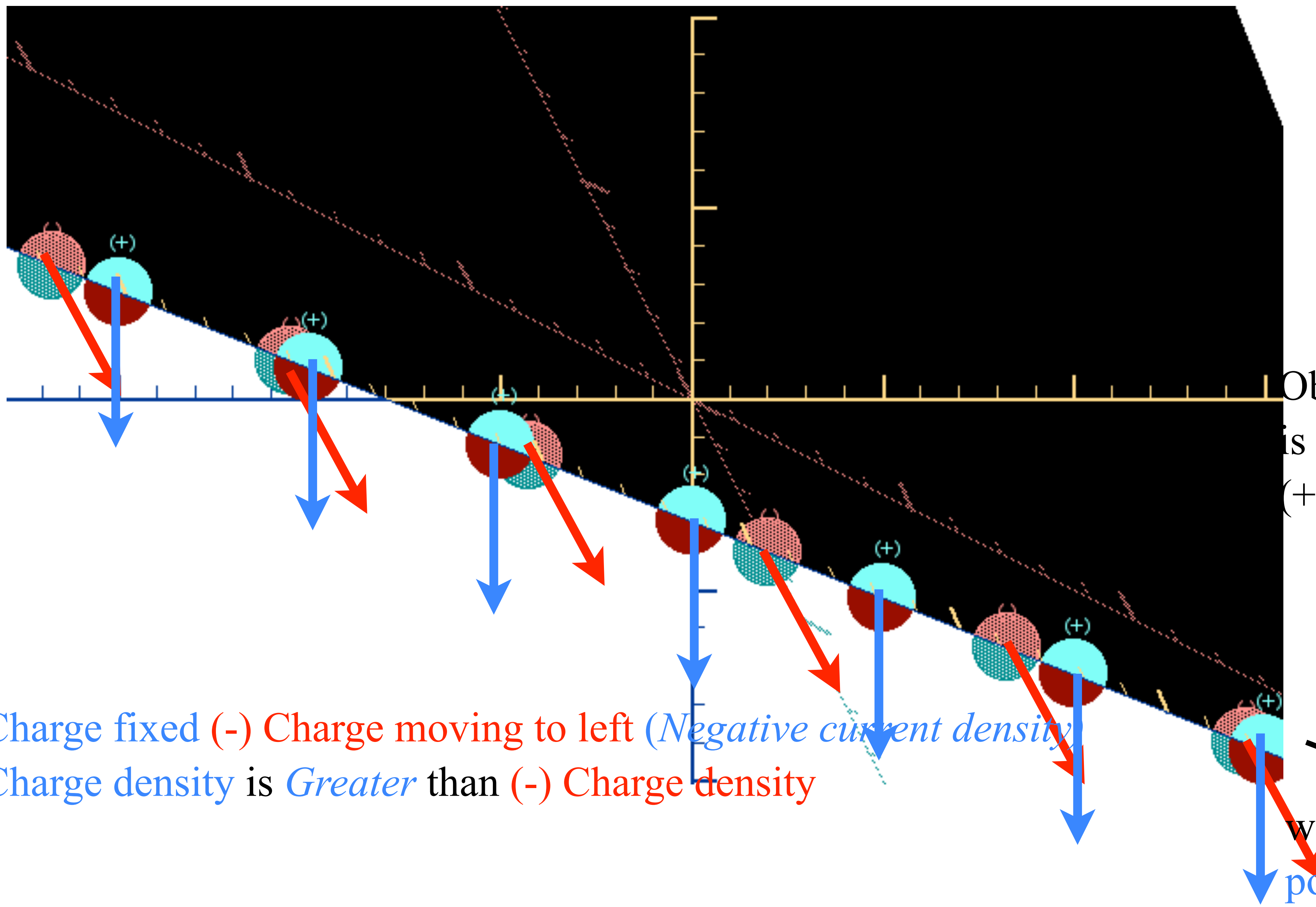

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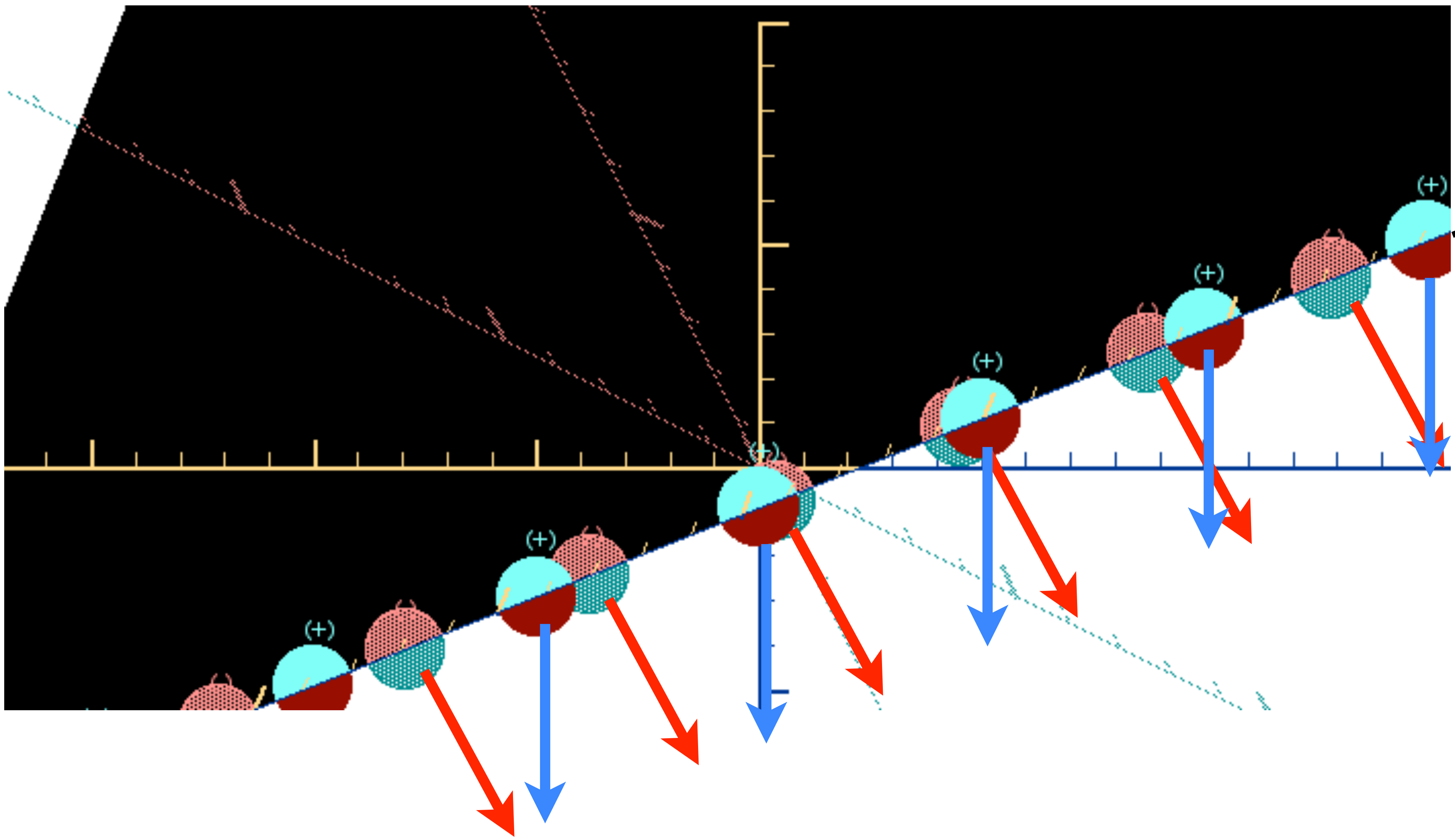


Observer velocity is (-) relative to (+) line of charge

wire appears negative (-) (attractive to +)

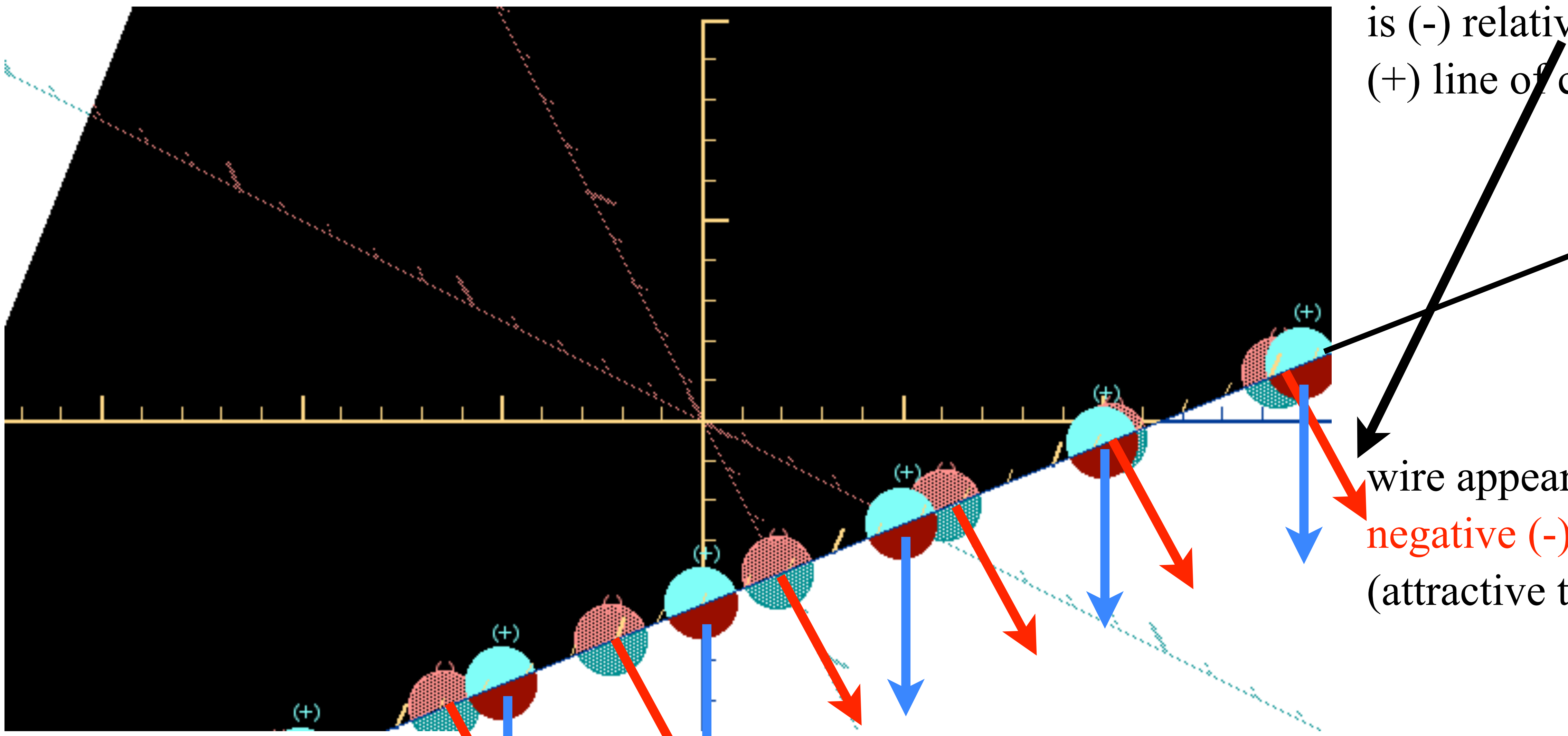
(+) Charge fixed (-) Charge moving to left (*Negative current density)*

(+) Charge density is *Less* than (-) Charge density

Relativistic effects on charge, current, and Maxwell Fields

Current density changes by Lorentz asynchrony

Observer velocity is (-) relative to (+) line of charge



wire appears negative (-) (attractive to +)

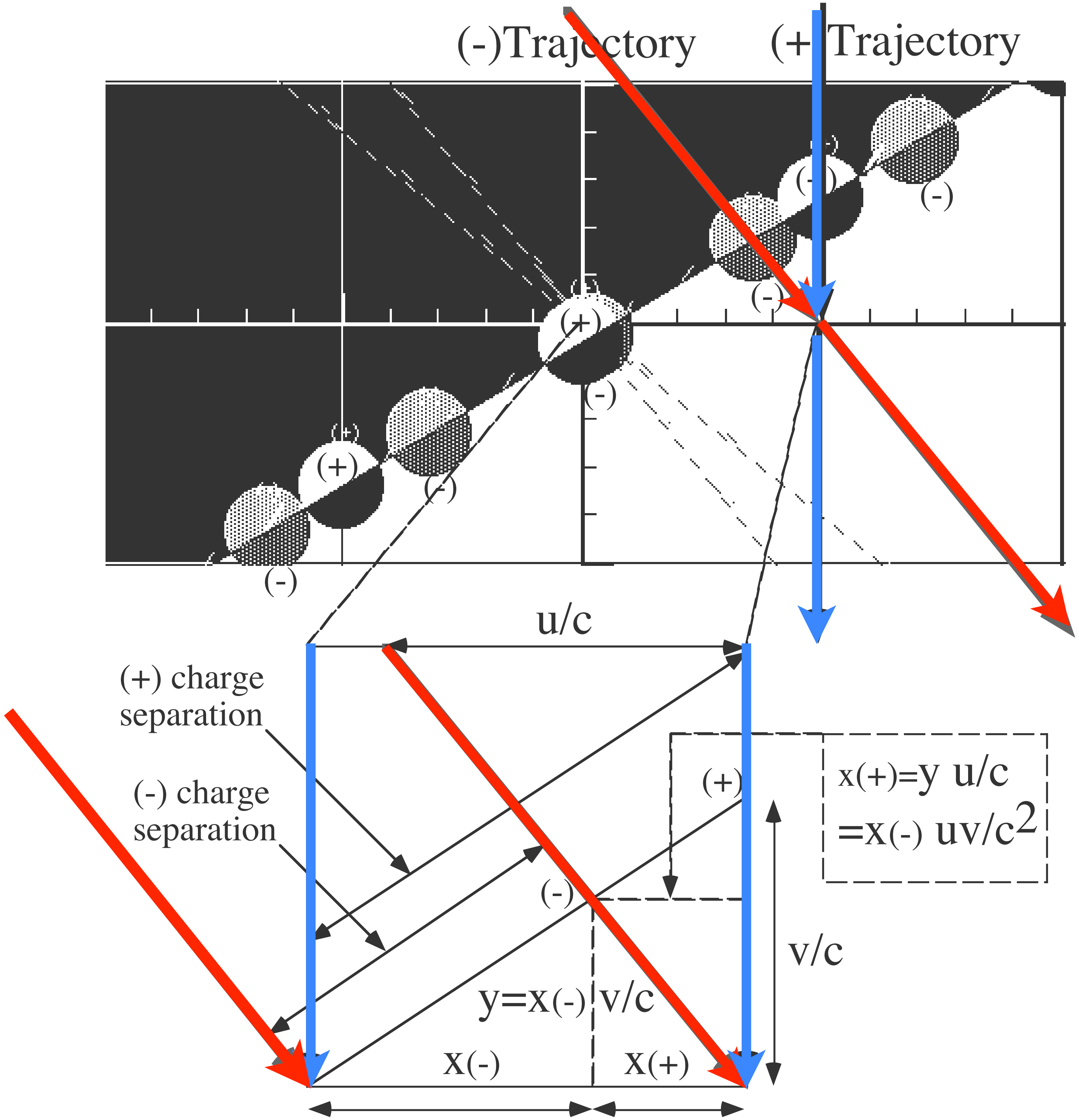
(+) Charge fixed (-) Charge moving to left *(Negative current density)*

(+) Charge density is *Less* than (-) Charge density

Relativistic effects on charge, current, and Maxwell Fields

Current density changes by Lorentz asynchrony

➔ *Magnetic B-field is relativistic effect*



$$\frac{\rho(-)}{\rho(+)} = \frac{(+)\text{ charge separation}}{(-)\text{ charge separation}} = \frac{x(+)+x(-)}{x(-)}$$

$$\frac{\rho(-)}{\rho(+)} = \frac{x(+)}{x(-)} + 1 = \frac{uv}{c^2} + 1$$

$$\rho(+) - \rho(-) = \rho(+)\left(1 - \frac{\rho(-)}{\rho(+)}\right) = -\frac{uv}{c^2}\rho(+)$$

Unit square: (u/c) /1 = x(+)/y

(v/c) /1 = y/x(-)

Magnetic B-field is relativistic effect!

The electric force field **E** of a charged line varies inversely with radius. The Gauss formula for force in mks units :

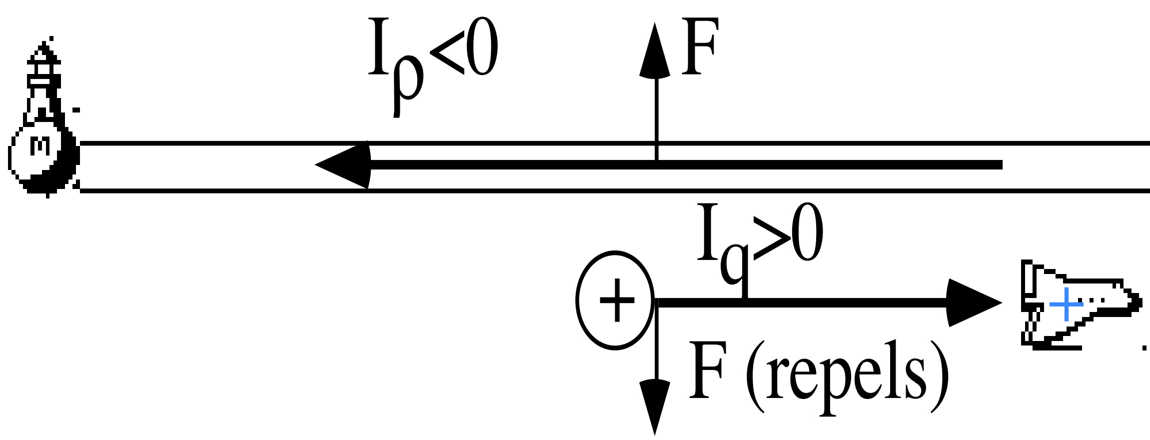
$$F = qE = q\left[\frac{1}{4\pi\varepsilon_0}\frac{2\rho}{r}\right] \quad , \quad \text{where: } \quad \frac{1}{4\pi\varepsilon_0} = 9\times 10^9 \frac{N\cdot m^2}{Coul.}$$

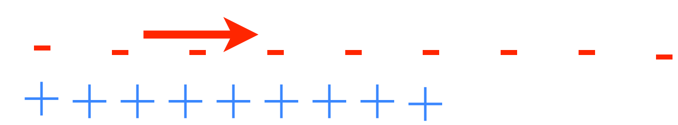
$$F = qE = q\left[\frac{1}{4\pi\varepsilon_0}\frac{2}{r}\left(-\frac{uv}{c^2}\rho(+)\right)\right] = -\frac{2\,qv\,\rho(+)u}{4\pi\varepsilon_0 c^2\, r} = -2\times 10^{-7}\frac{I_q\, I_\rho}{r}$$

$1/4\pi\varepsilon_0 = 9\cdot 10^9$

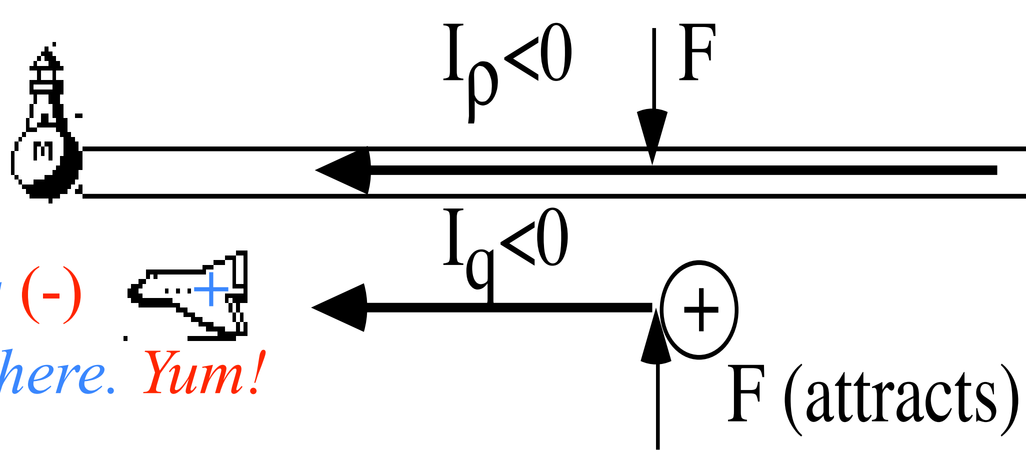
$c^2 = 9\cdot 10^{-16}$

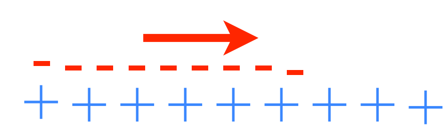
$1/(4\pi\varepsilon_0 c^2) = 10^{-7}$





I see excess (+) charge up there. Yuk!





I see excess (-) charge up there. Yum!

Magnetic B-field is relativistic effect!

The electric force field **E** of a charged line varies inversely with radius. The Gauss formula for force in mks units :

$$F = qE = q\left[\frac{1}{4\pi\varepsilon_0}\frac{2\rho}{r}\right] \quad , \quad \text{where:} \quad \frac{1}{4\pi\varepsilon_0} = 9\times10^{9}\,\frac{N\cdot m^2}{Coul.}$$

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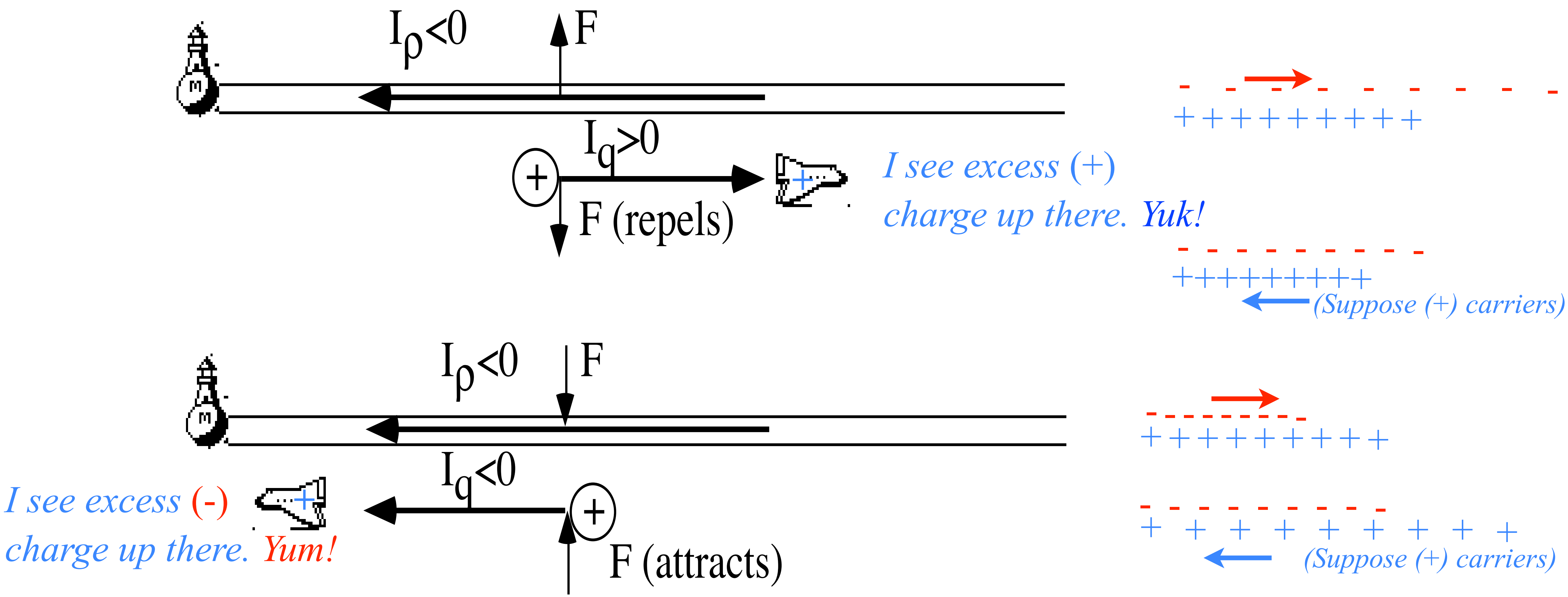

➔ *Relating photons to Maxwell energy density and Poynting flux*

Relativistic variation and invariance of frequency (ω,k) and amplitudes

How probability ψ-waves and flux ψ-waves evolved

*Properties of amplitude ψ*ψ-squares*

More on unmatched amplitudes AND unmatched frequencies AND unmatched quanta