Fun facts about gravity

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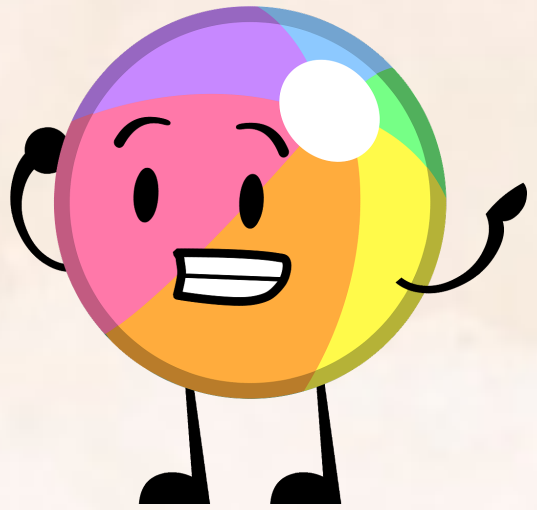
A tale of scales

When is a quantum world and when we need gravity?



Compton wavelength

$$\lambda_C = \frac{\hbar}{m}$$

Schwarzschild Radius

$$R_s = \frac{2Gm}{c^2}$$

Compared to what?

$$\lambda_C = \frac{\hbar}{E_{CM}}$$

$$R_s = \frac{2GE_{CM}}{c^2}$$

Strongly coupled gravity

$$L_p \sim \frac{1}{M_{Pl}}$$

New d.o.f.

$$L_*$$

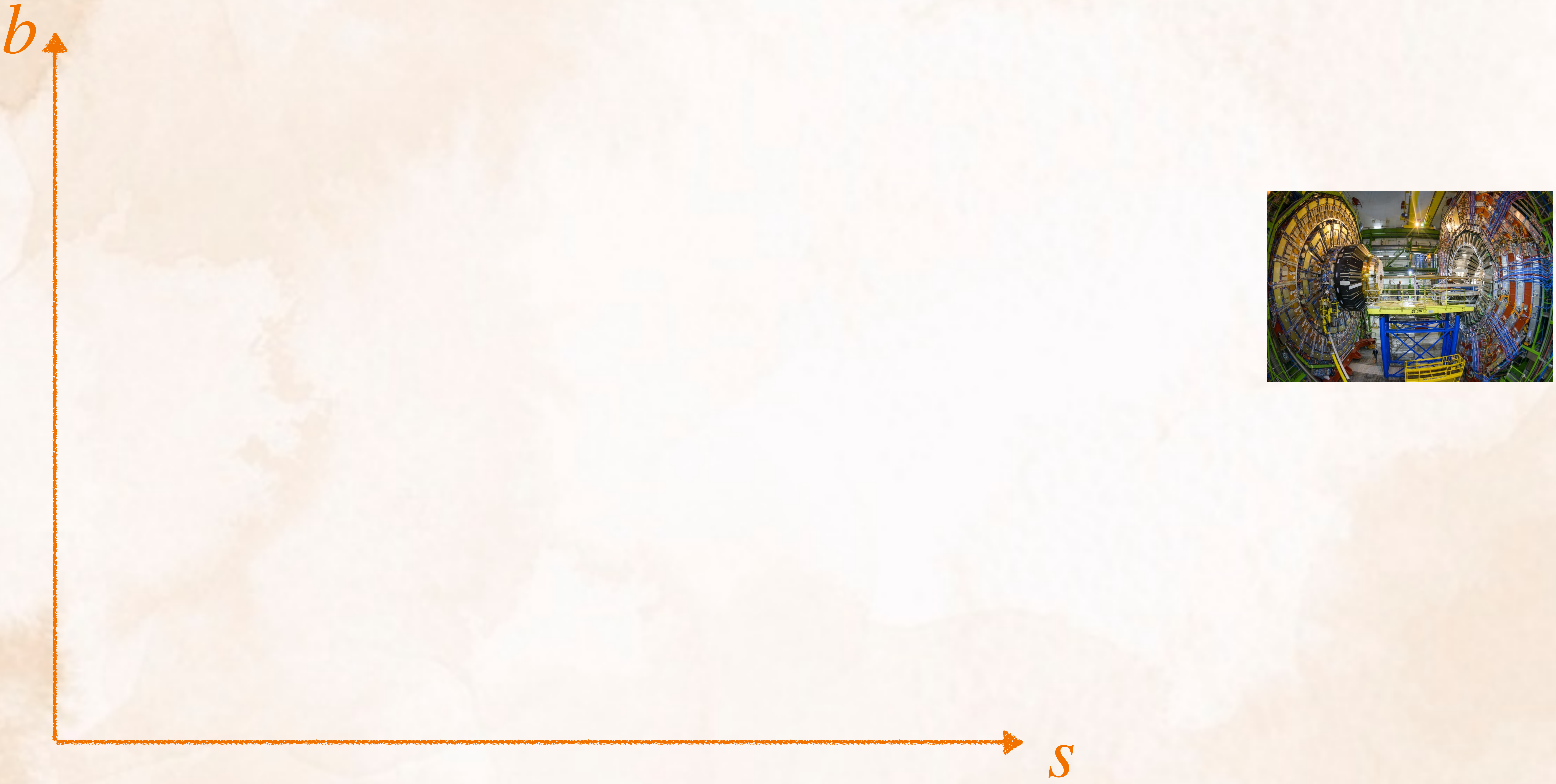
Mandelstam: $s \; t \; u, \quad s + t + u = 4m^2$

$$s = E_{CM}^2$$

$t \leftrightarrow b$ Impact parameter

Validity of gravitational amplitudes

Validity of gravitational amplitudes



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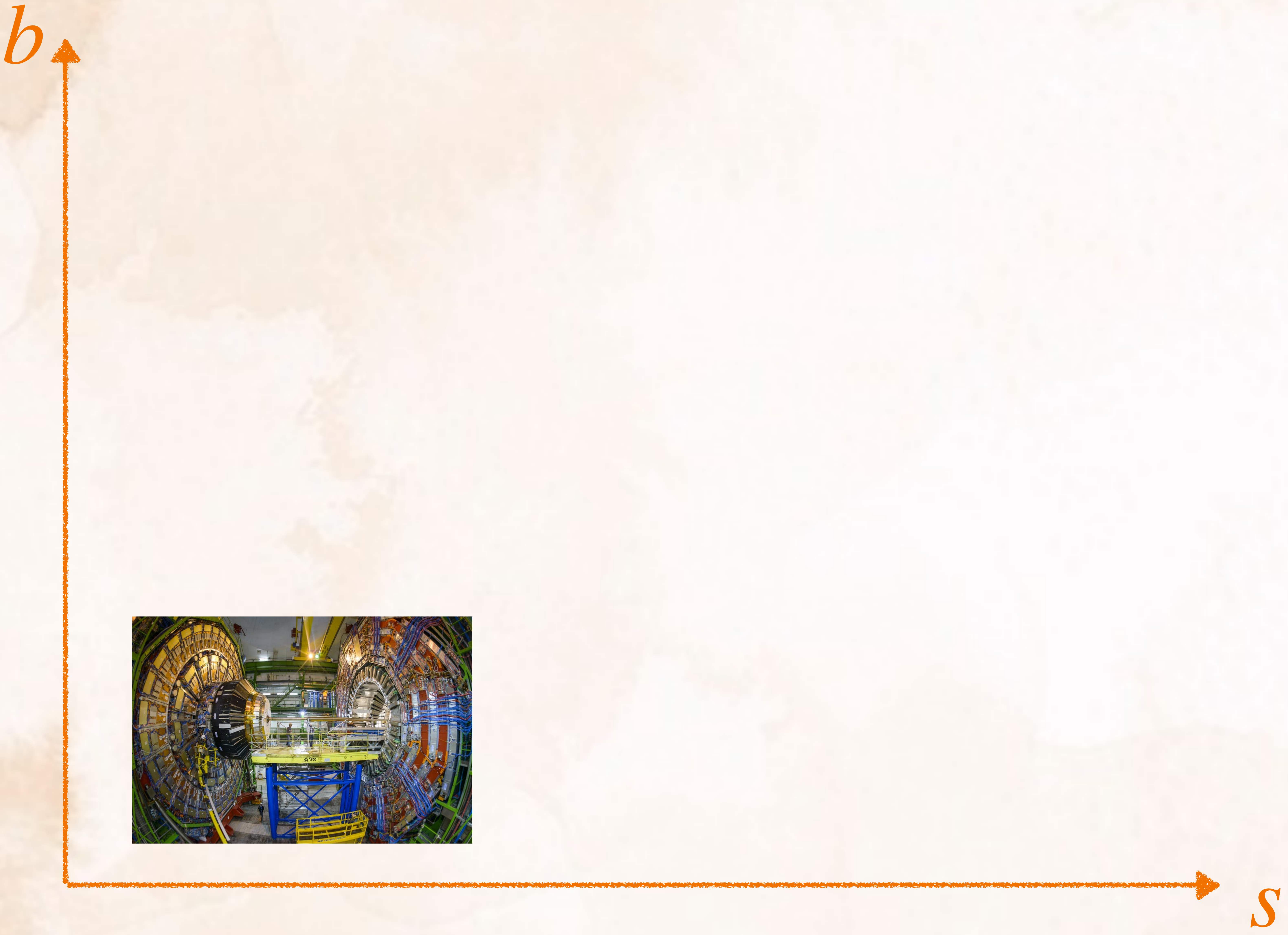

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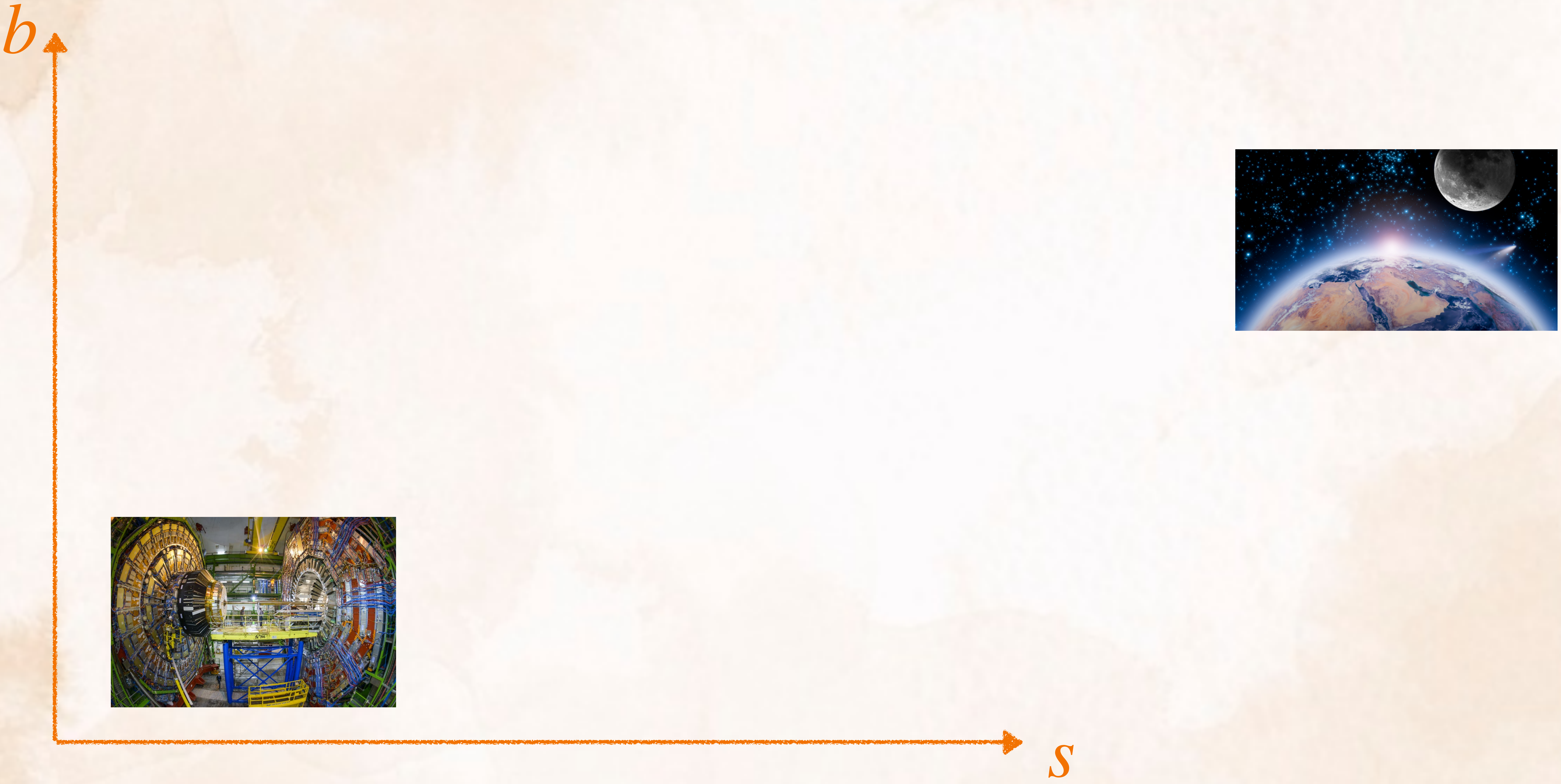

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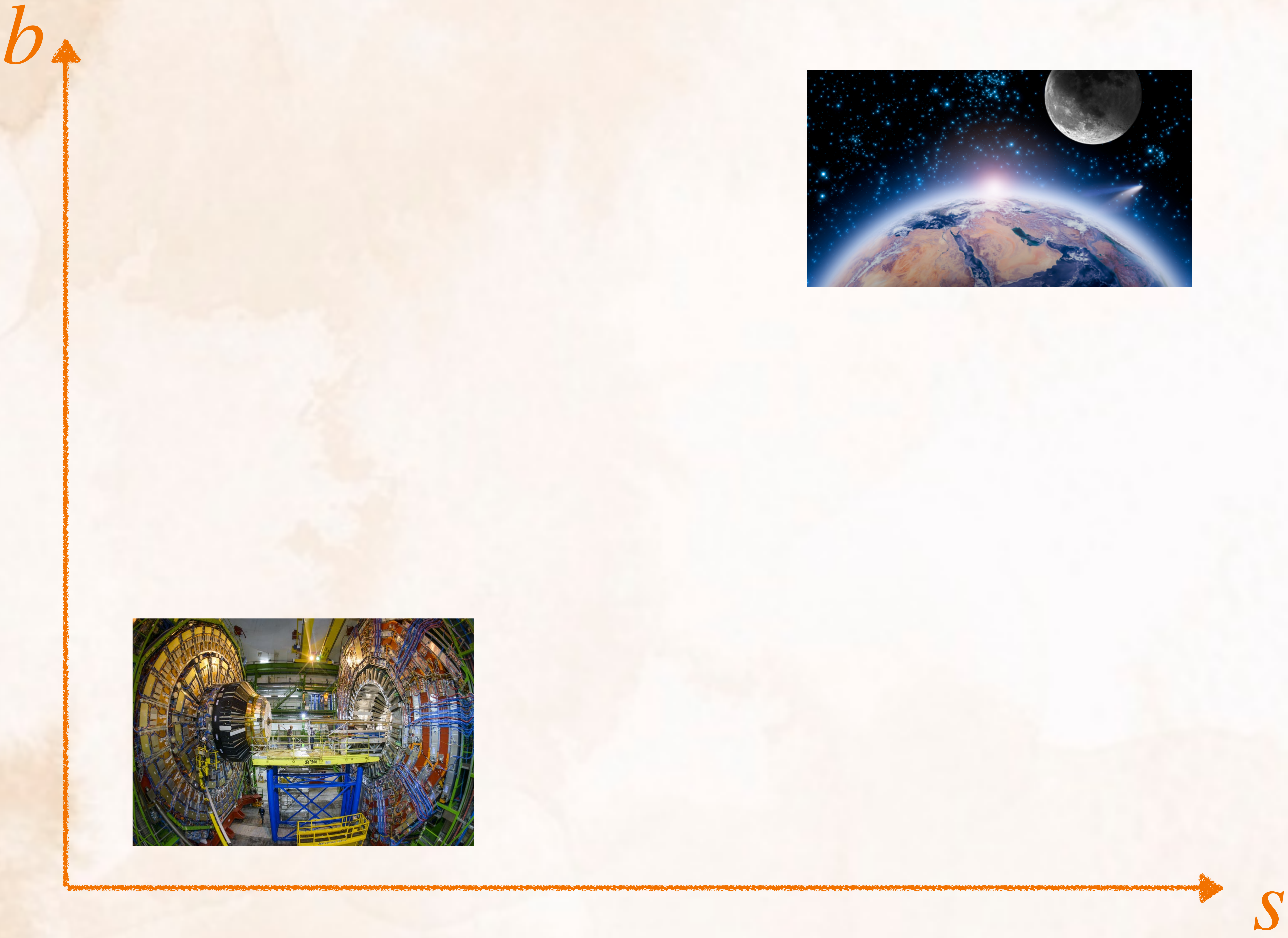


A QFT approach to gravity

From GR to Feynman rules

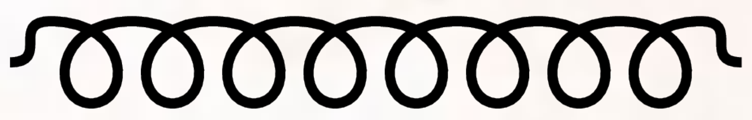
$$S = \frac{M_{pl}^2}{2}\int d^4x\sqrt{-g}(R + \mathscr{L}_m)$$

$$g_{\mu\nu} = \eta_{\mu\nu} + \boxed{h_{\mu\nu},} \qquad |h| \ll 1$$

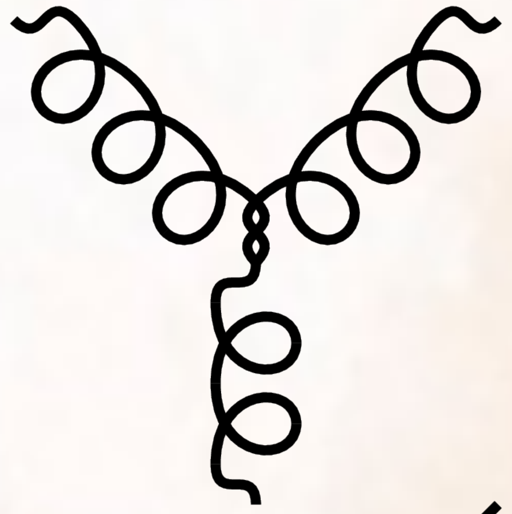
I'm a graviton!

From R :

1. $\mathcal{O}(h^2)$ Kinetic term : $-\frac{1}{2}\partial_\alpha h_{\mu\nu}\partial^\alpha h^{\mu\nu} + \dots$



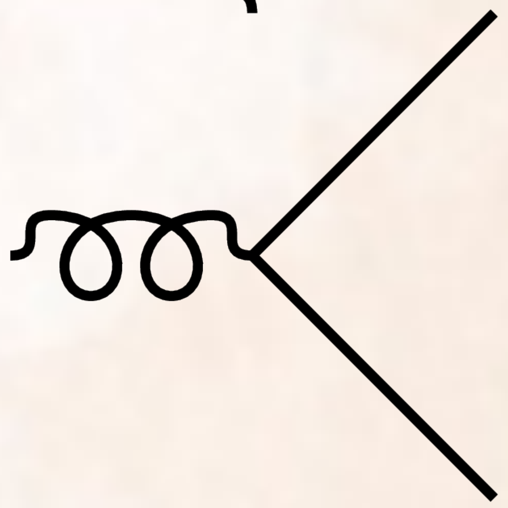
2. $\mathcal{O}(h^3)$ Couplings : $-\frac{1}{2}\partial_\alpha h_{\mu\nu}\partial^\alpha h^{\mu\nu} h + \dots$



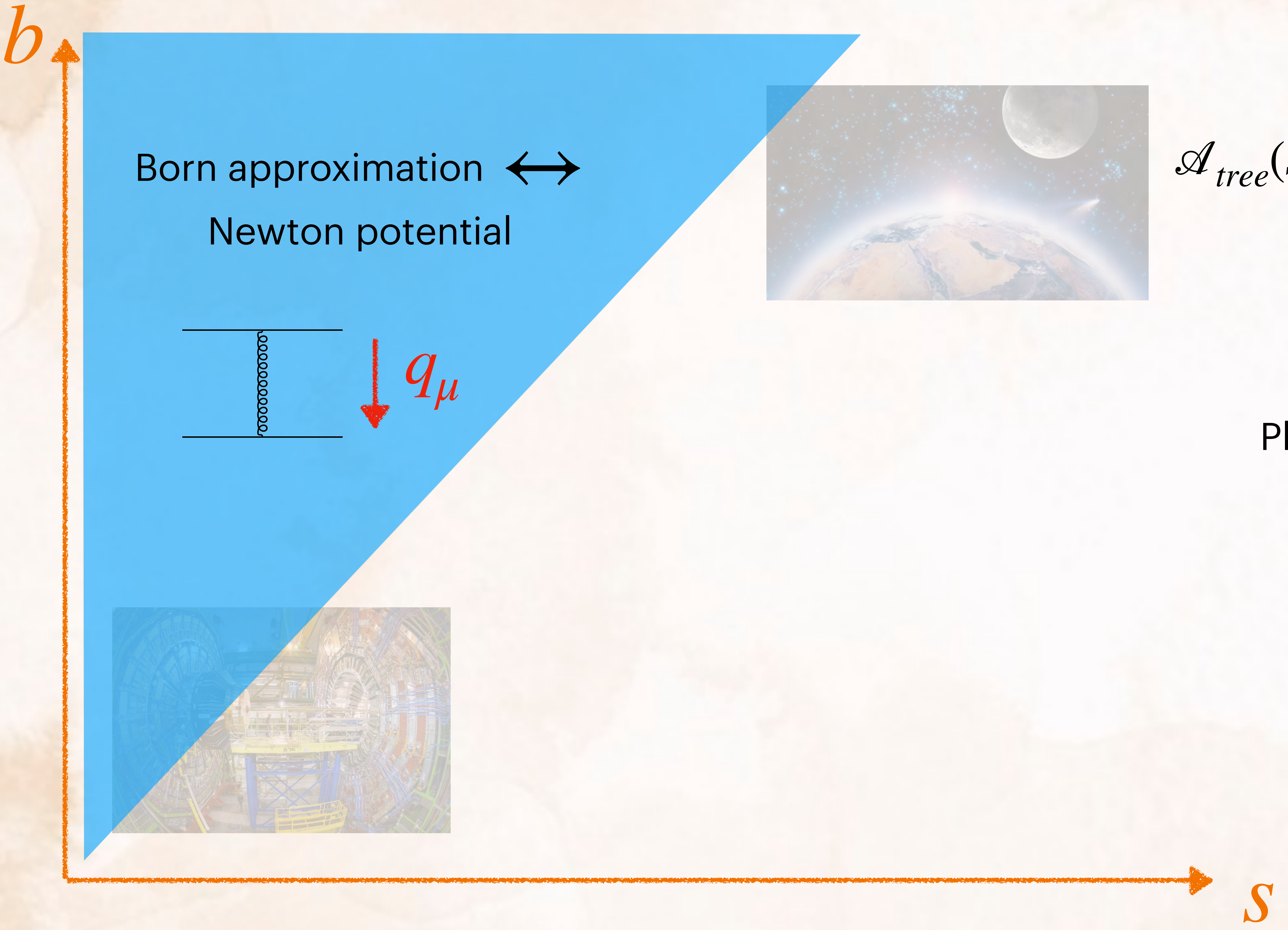
From matter :

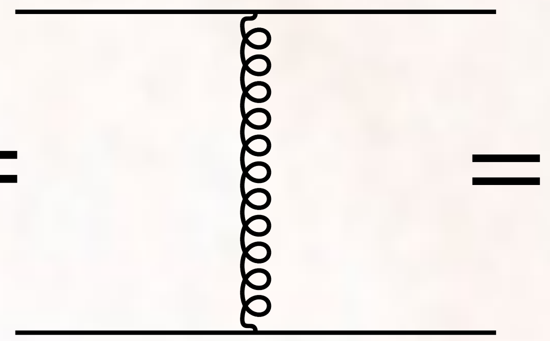
$$g_{\mu\nu}\partial^\mu\phi\partial^\nu\phi = \partial^\mu\phi\partial_\mu\phi + \boxed{h_{\mu\nu}\partial^\mu\phi\partial^\nu\phi}$$

Gravitational interaction



Validity of gravitational amplitudes



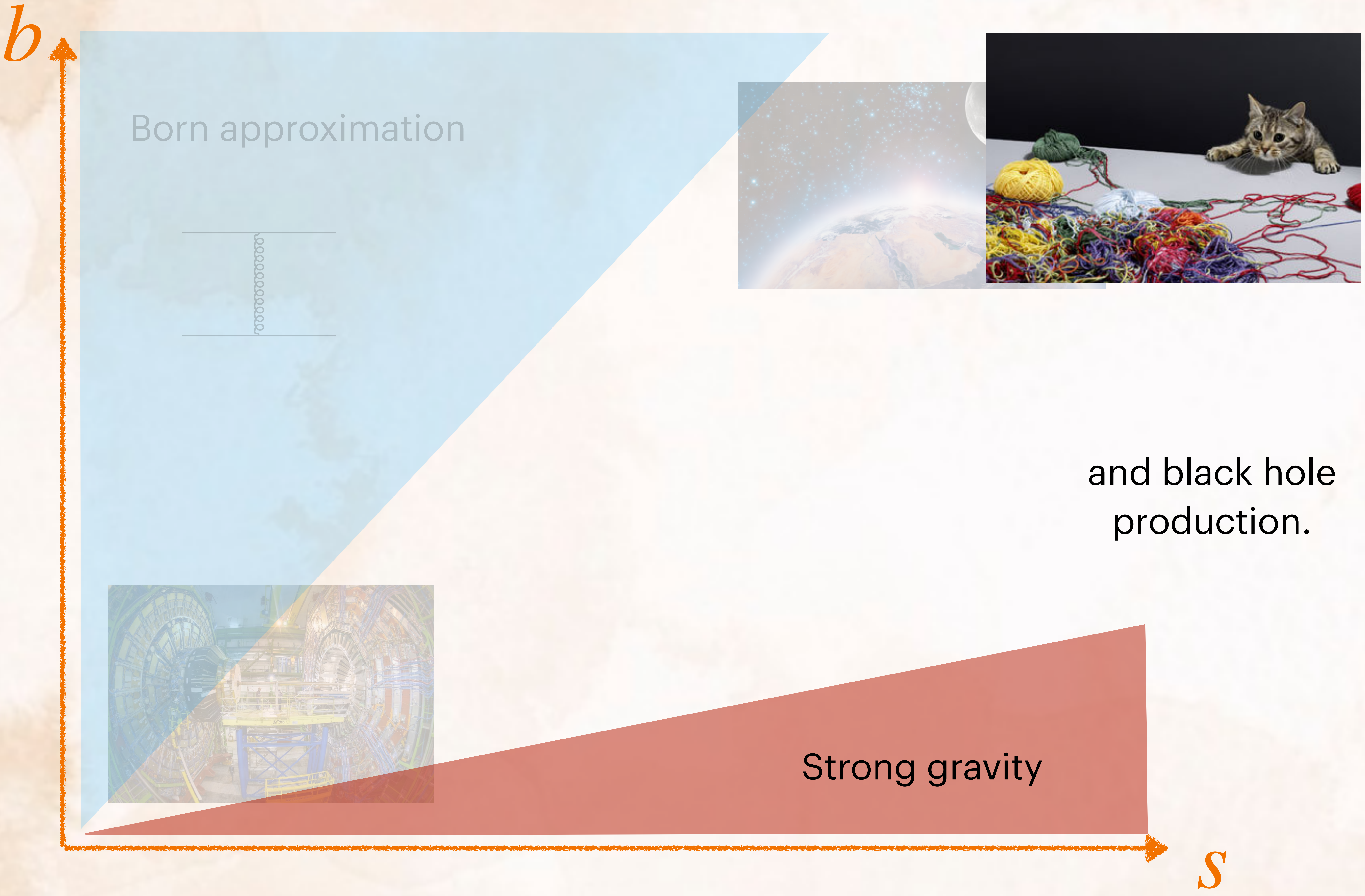
$$\mathcal{A}_{tree}(s,t) = $$  $$ = \int \delta_0(s,b) e^{-i\vec{b}\cdot\vec{q}} d^2b$$

$$= F[\delta_0(s,b)]$$

Phase shift:

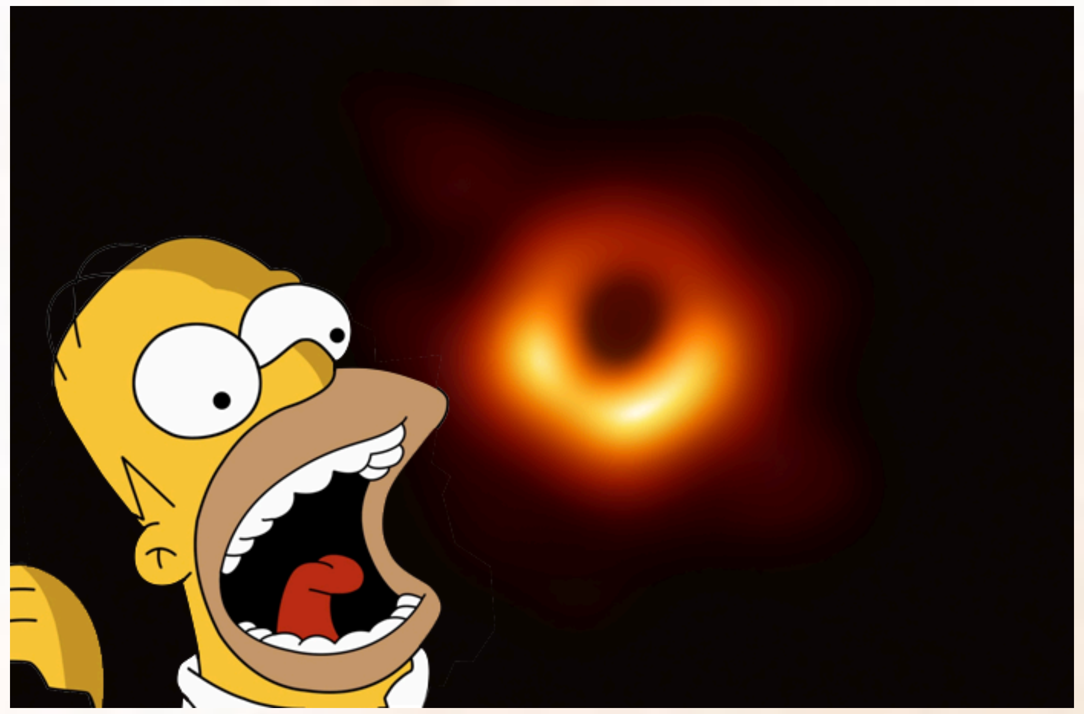
$$\delta_0(s,b) = \int \mathcal{A}_{tree}(q^2,t) e^{i\vec{b}\cdot\vec{q}} d^2q$$

Validity of gravitational amplitudes

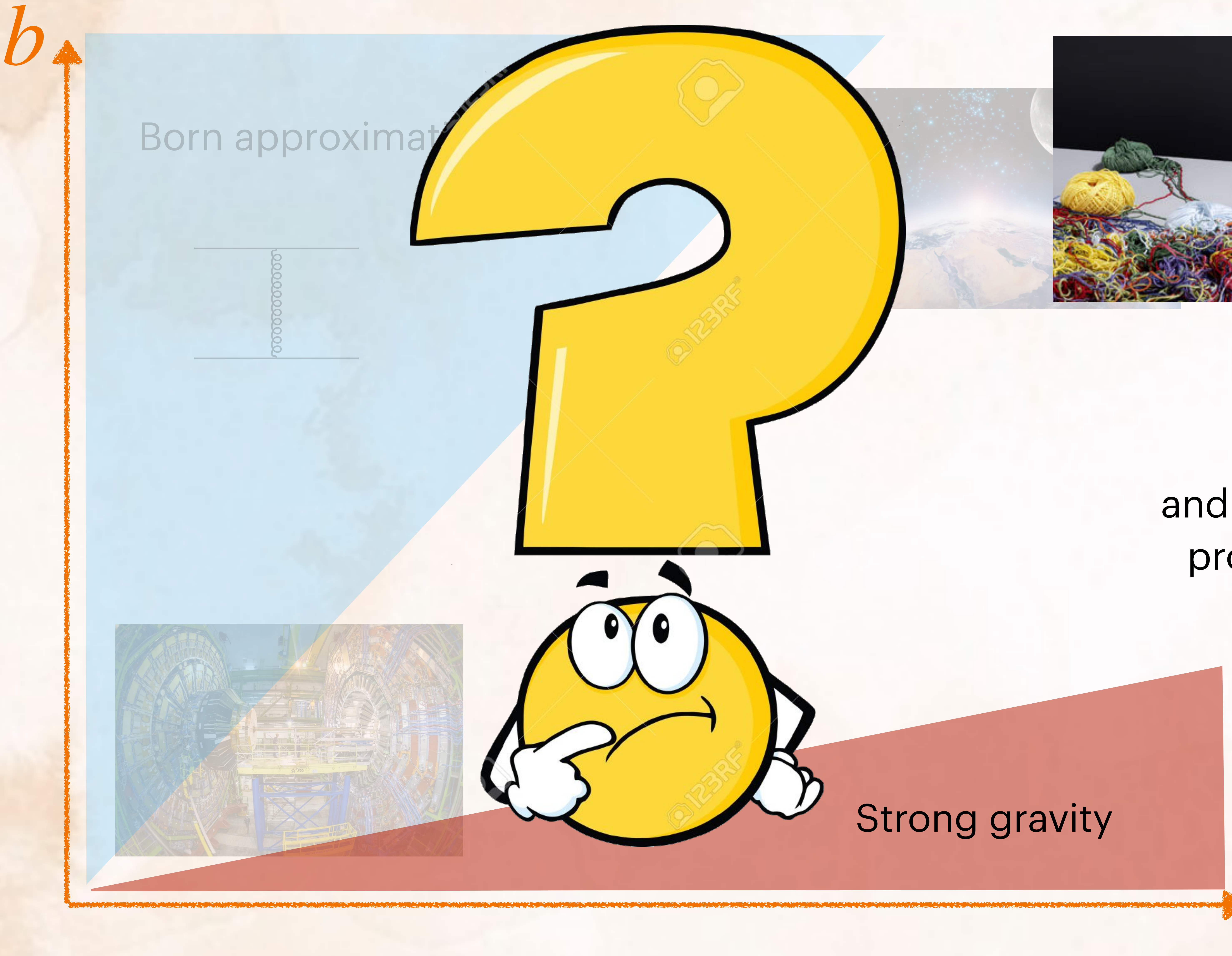


New degrees of freedom
(string theory, ...)

and black hole
production.



Validity of gravitational amplitudes



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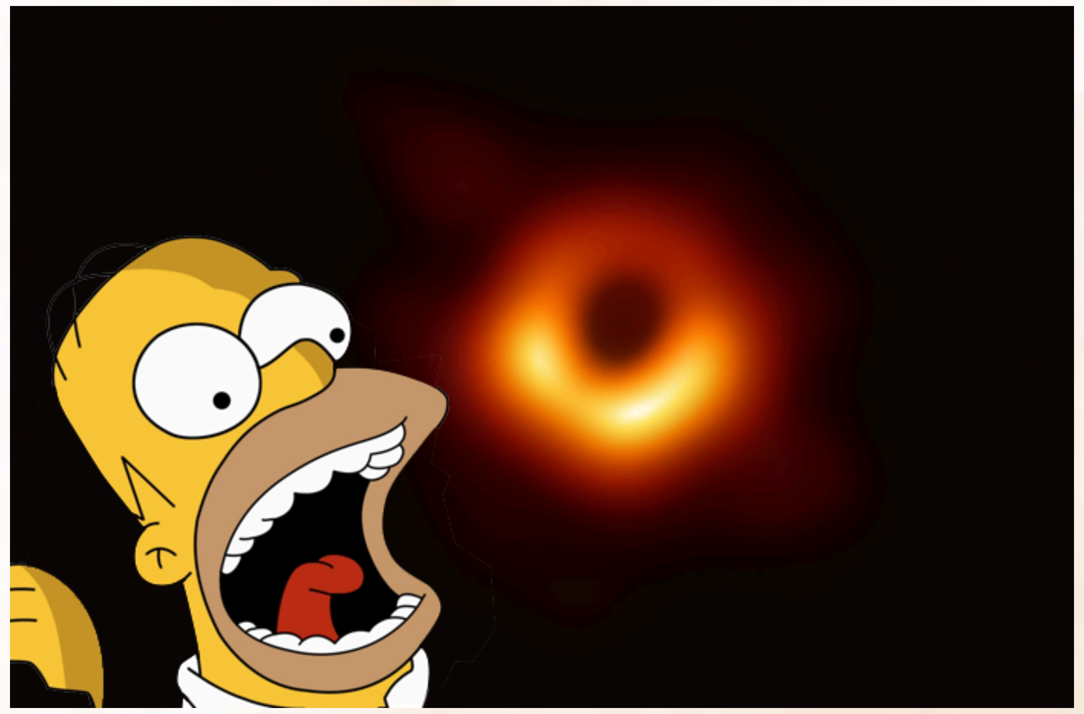
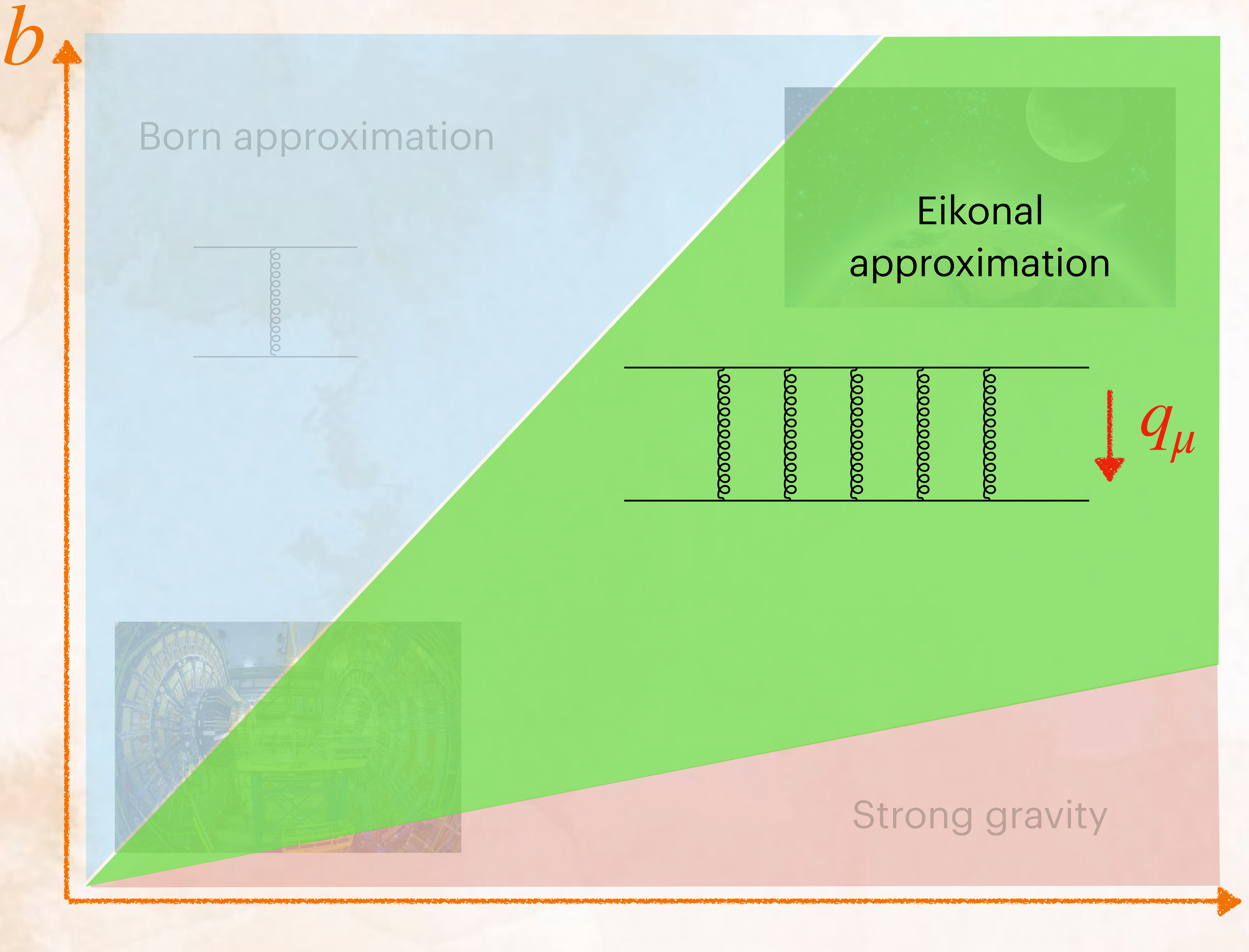
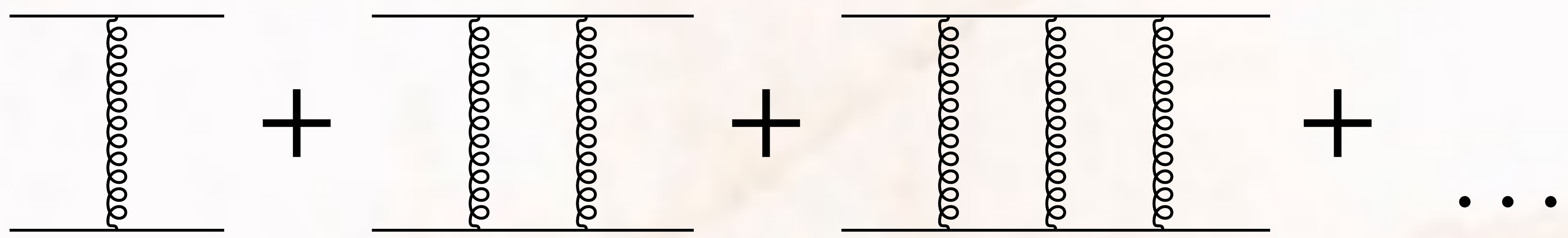


Validity of gravitational amplitudes



$t \ll s$

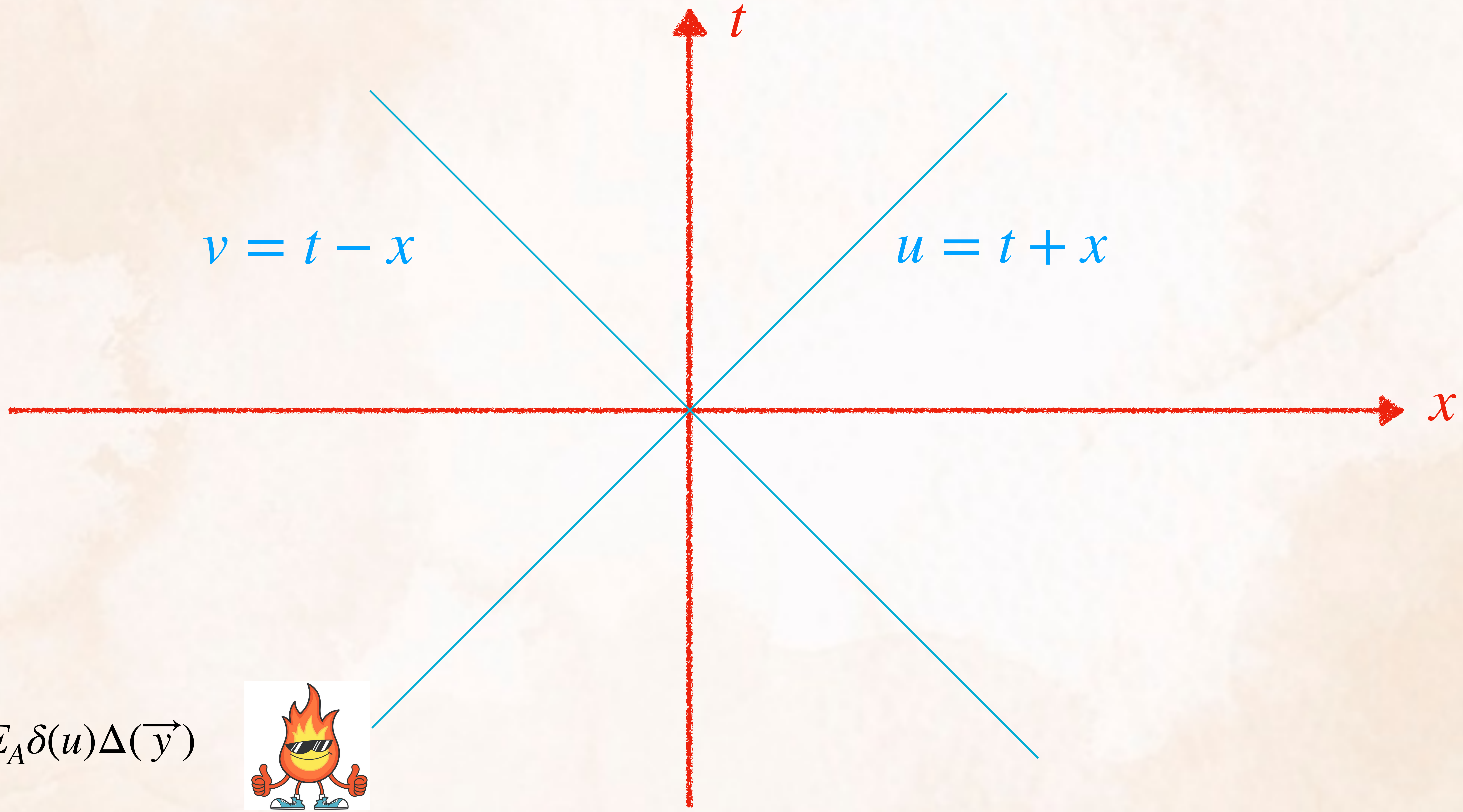
$\mathscr{A}_{eik}(s,t) =$



$$= F\left[i\delta_0(s,b) + \frac{(i\delta_0(s,b))^2}{2!} + \frac{(i\delta_0(s,b))^3}{3!} + \ldots\right]$$

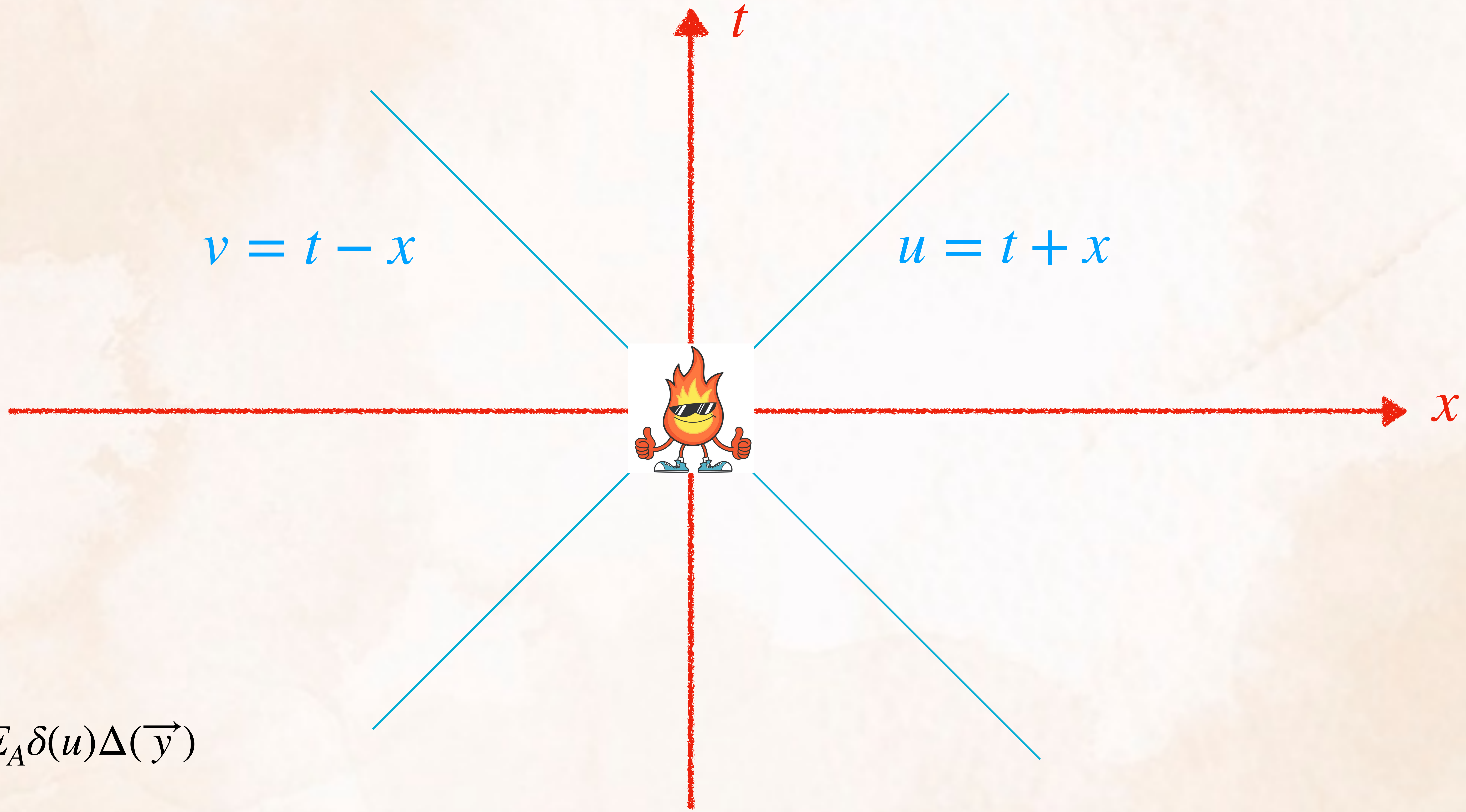
$$= \int \left[e^{i\delta_0(s,b)} - 1\right] e^{-i\vec{b}\cdot\vec{q}} d^2b$$

Physical meaning of the phase-shift



$T_{\mu\nu} = E_A \delta(u) \Delta(\overrightarrow{y})$

Physical meaning of the phase-shift



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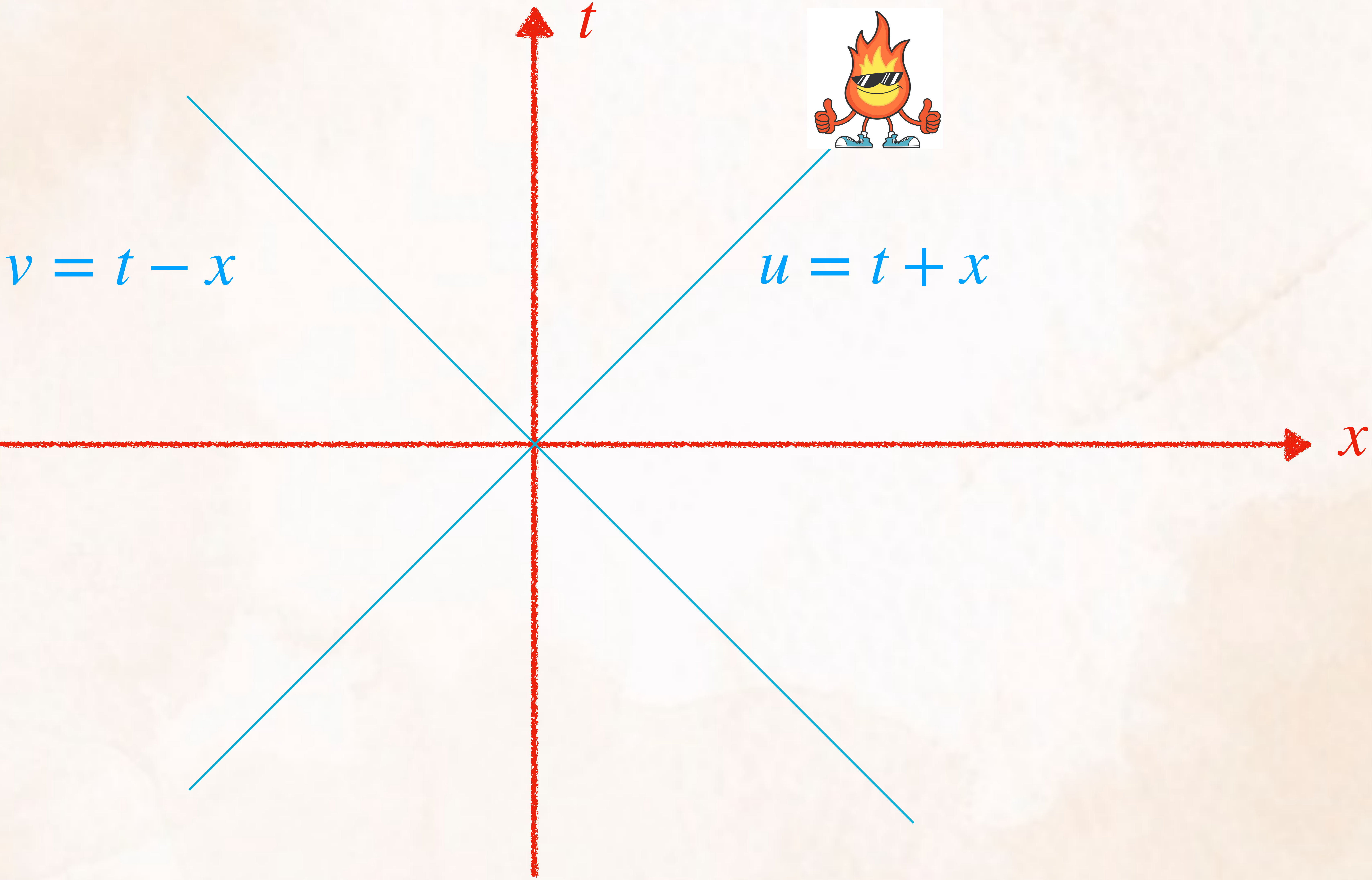

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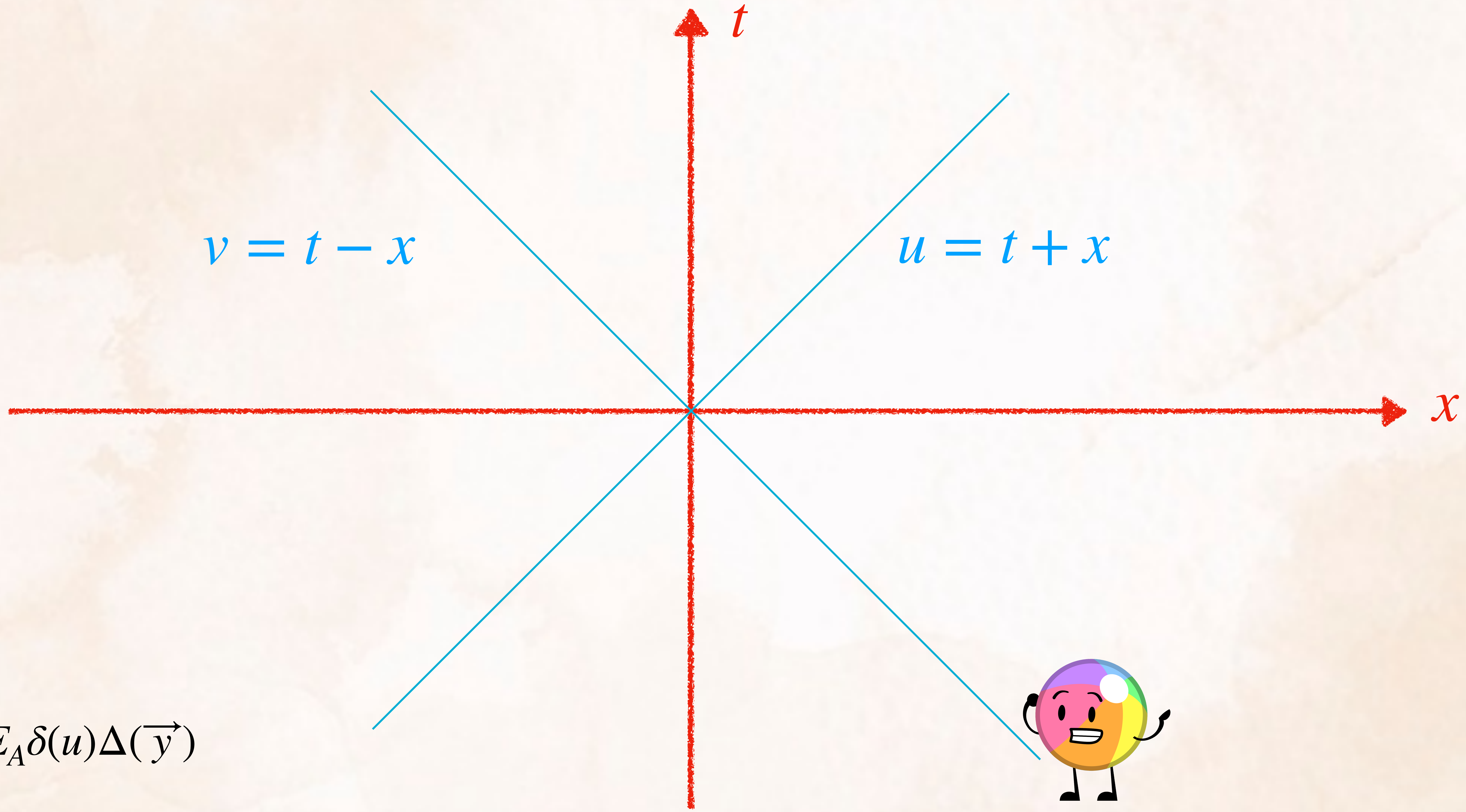

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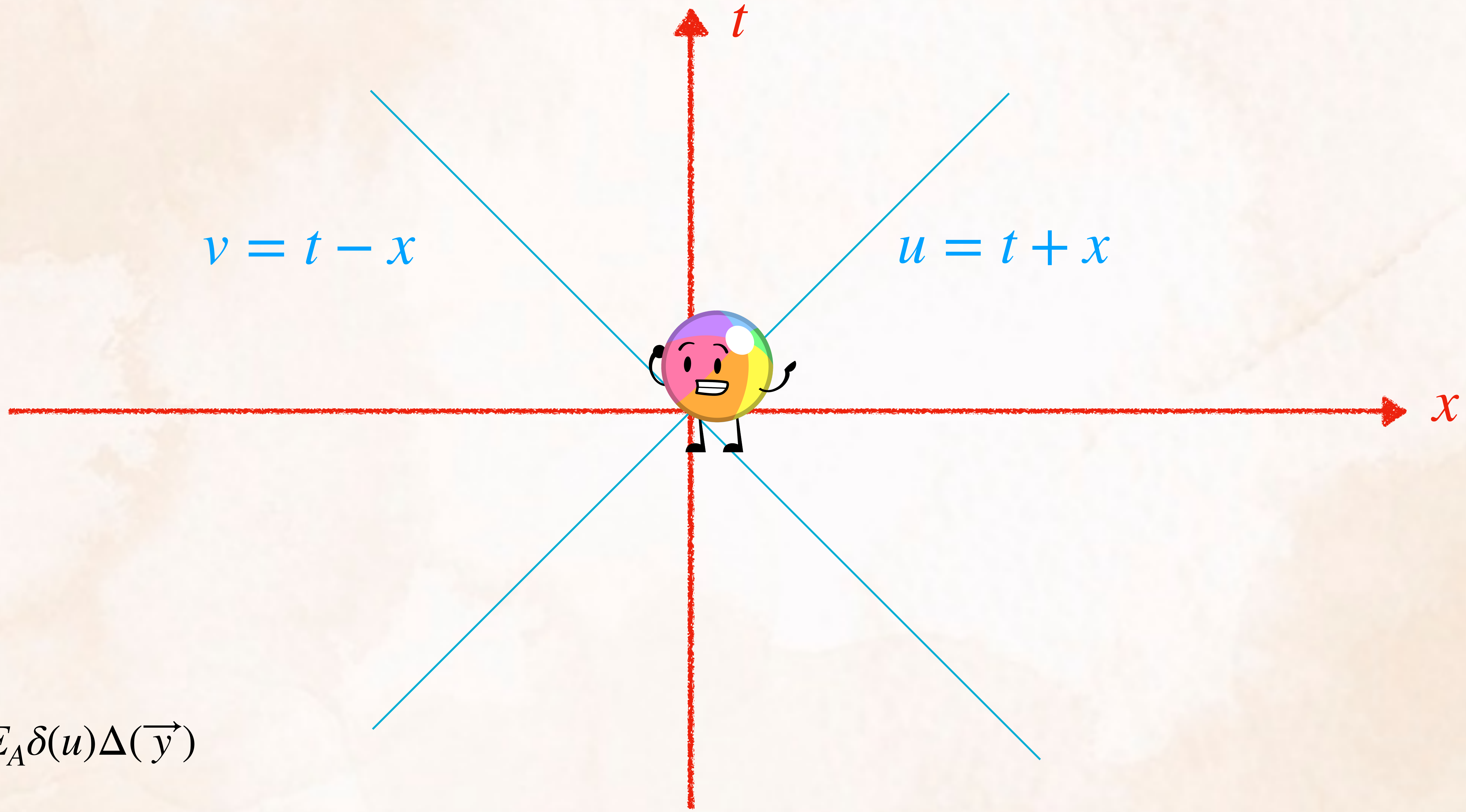

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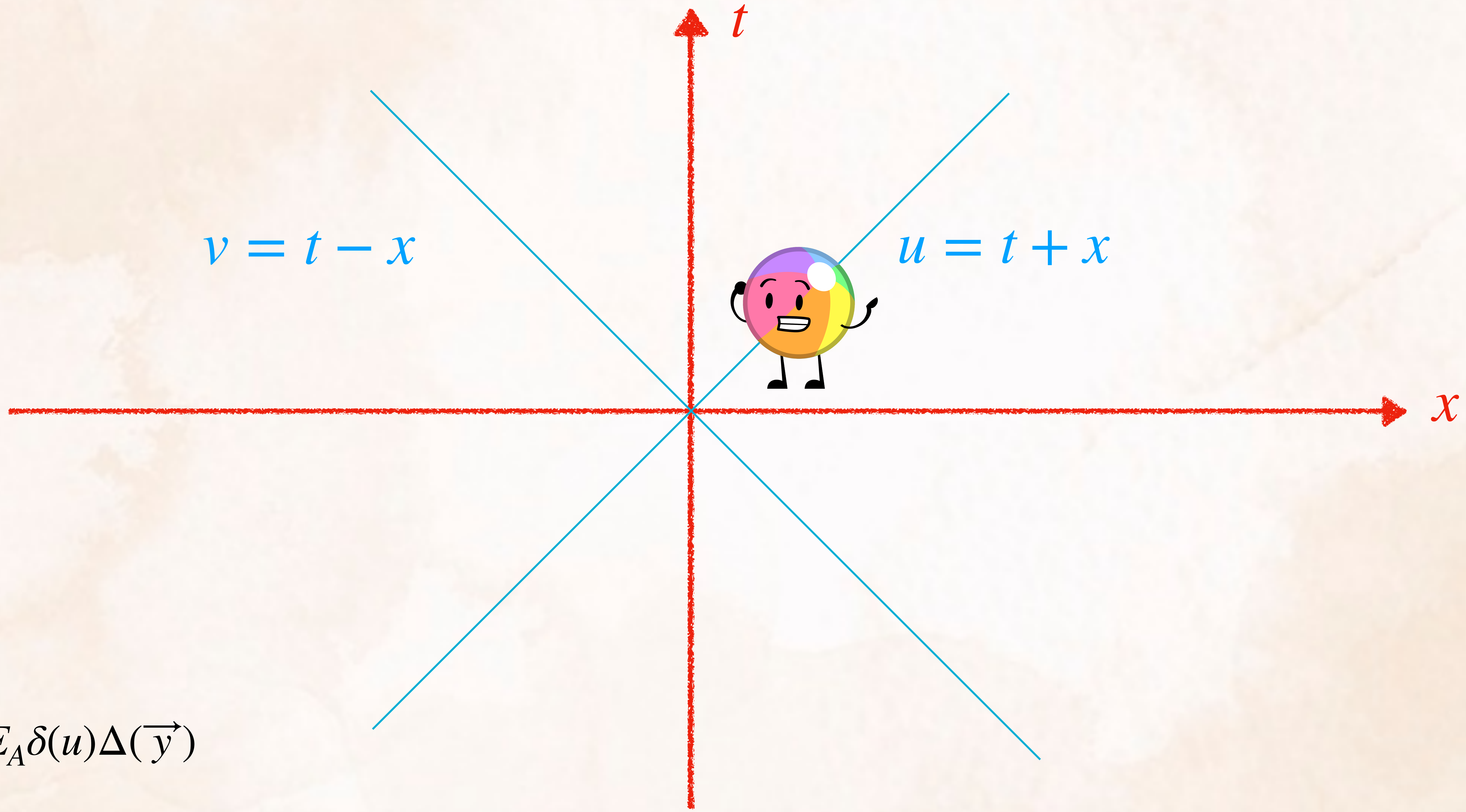

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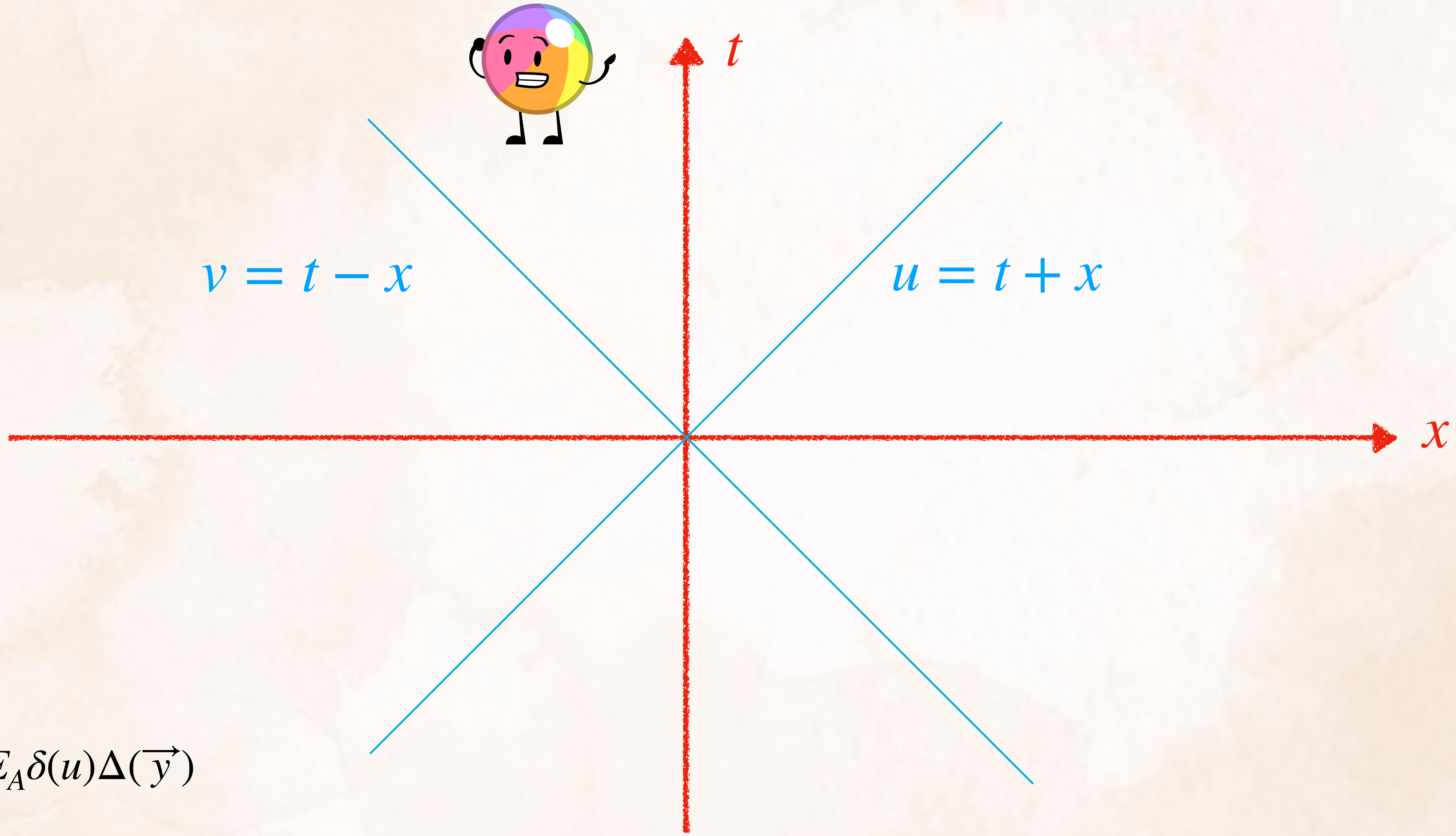

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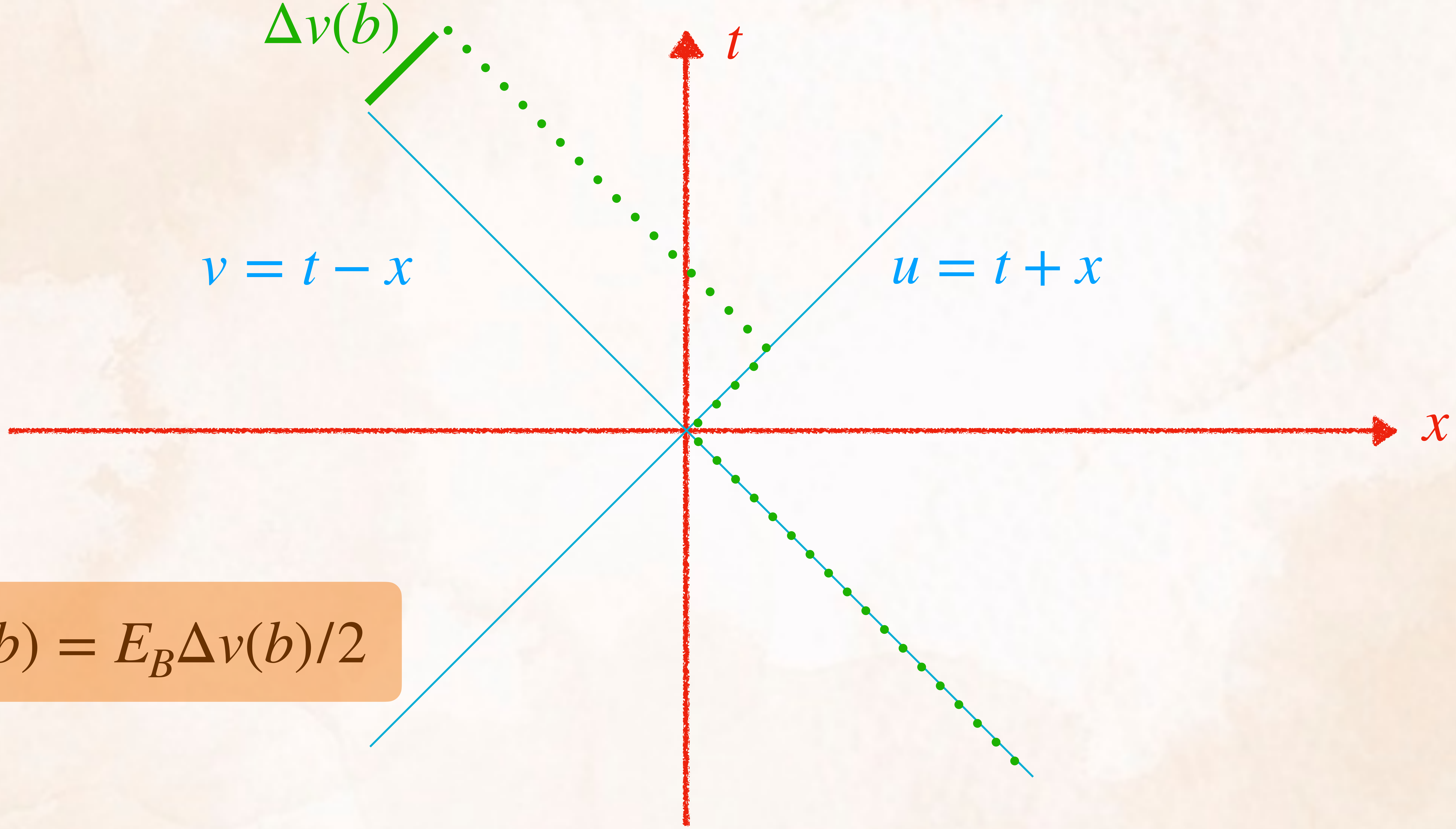
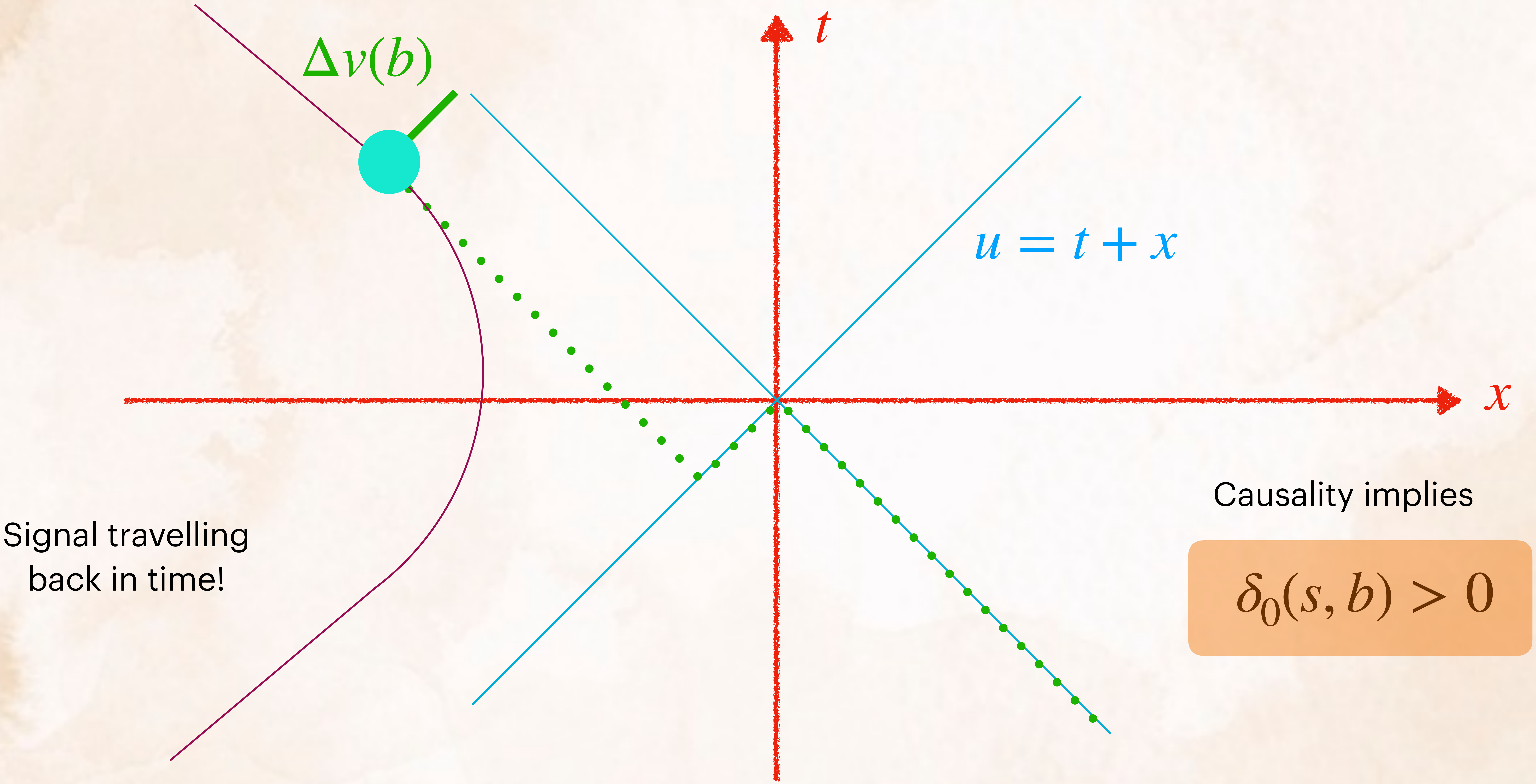


$\delta_0(s, b) = E_B \Delta v(b)/2$

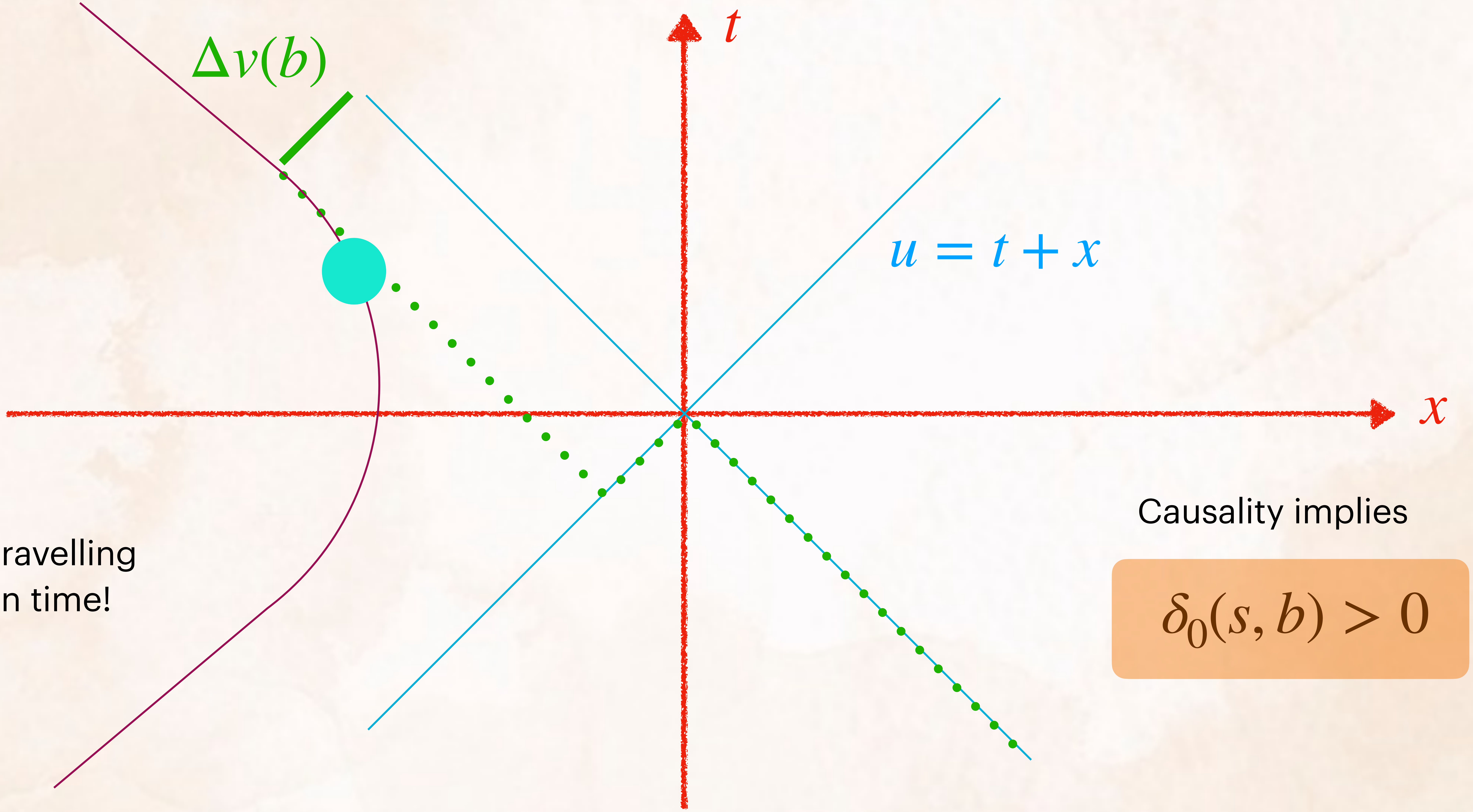
Physical meaning of the phase-shift



Causality implies

$$\delta_0(s, b) > 0$$

Physical meaning of the phase-shift

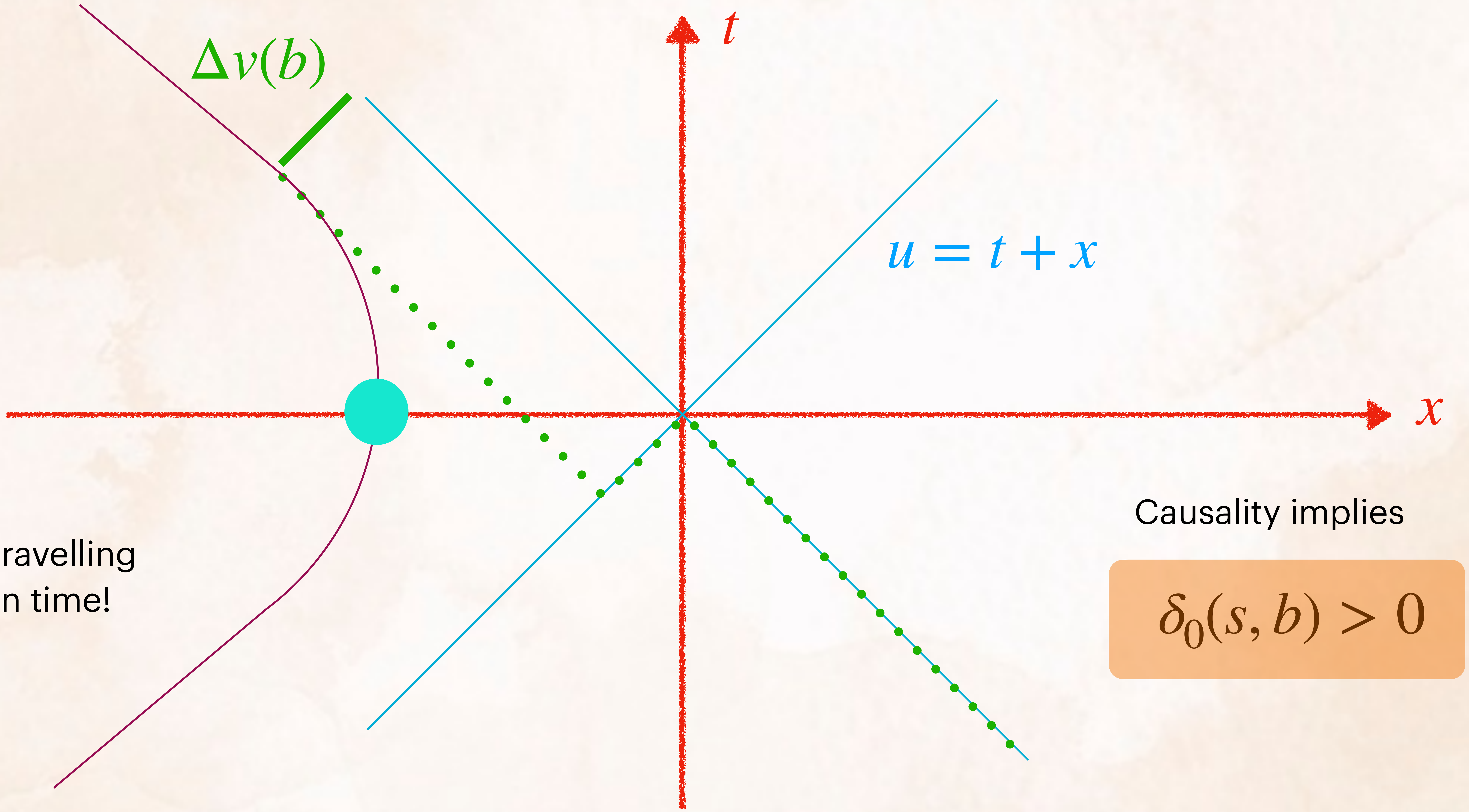


Signal travelling
back in time!

Causality implies

$$\delta_0(s,b) > 0$$

Physical meaning of the phase-shift



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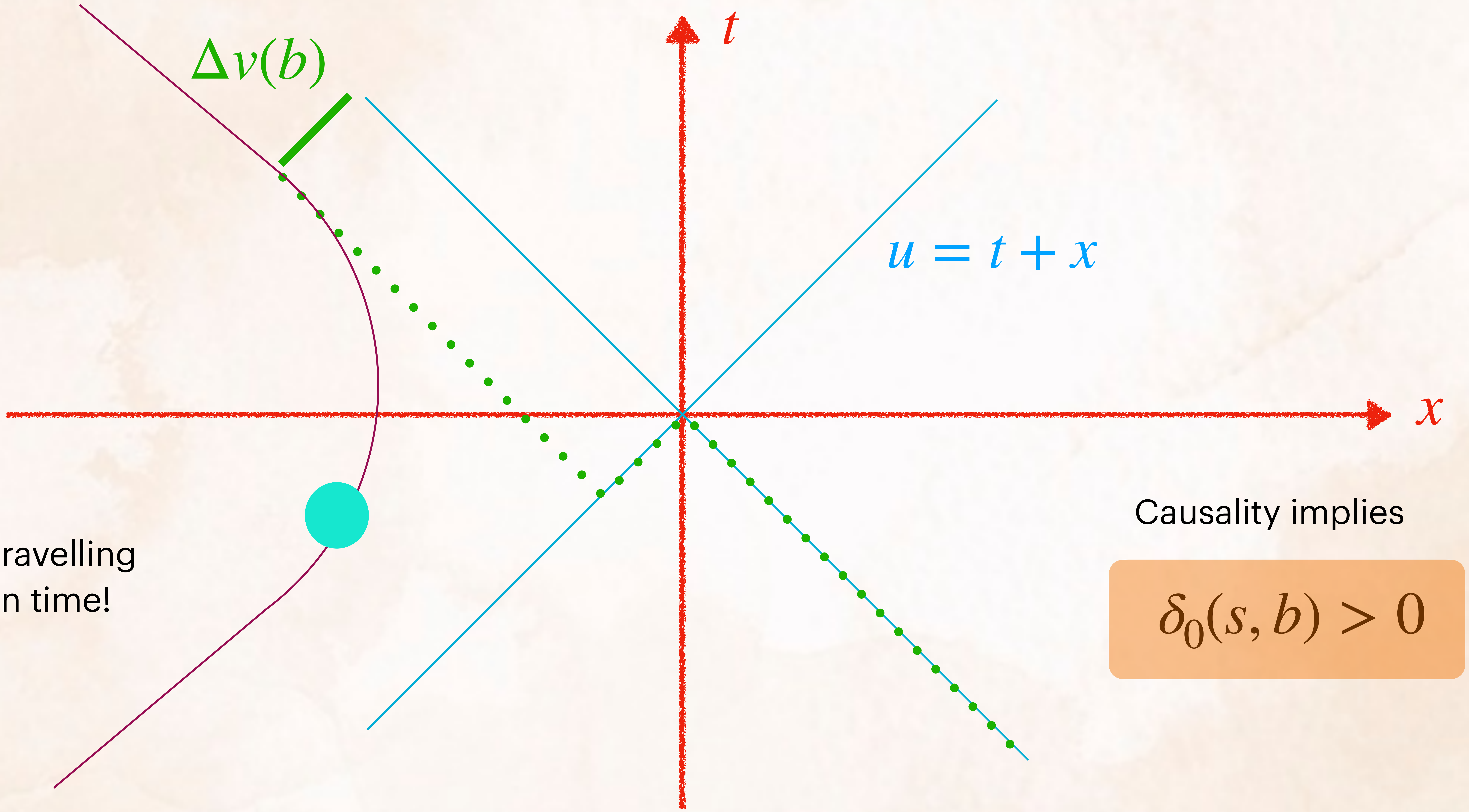

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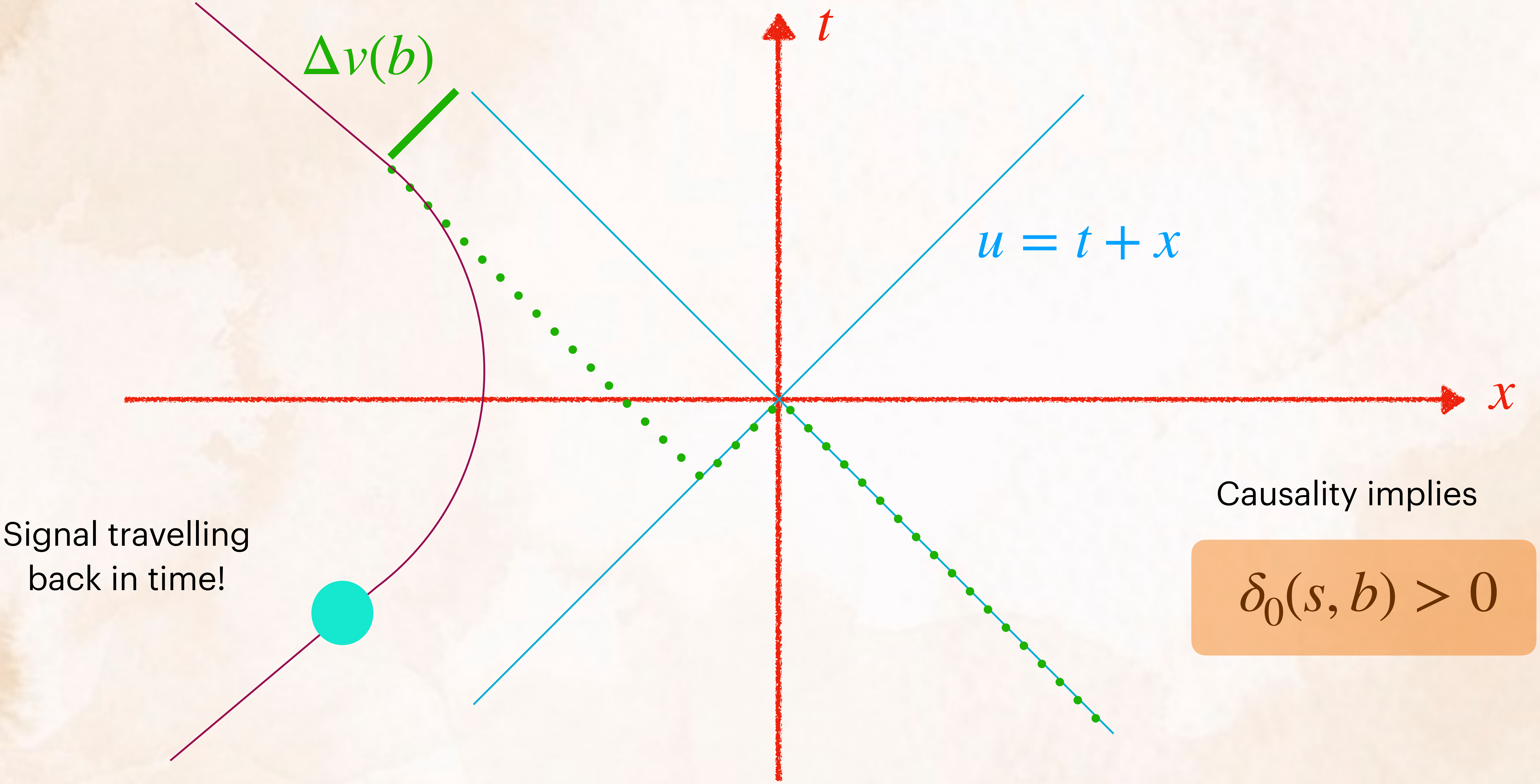

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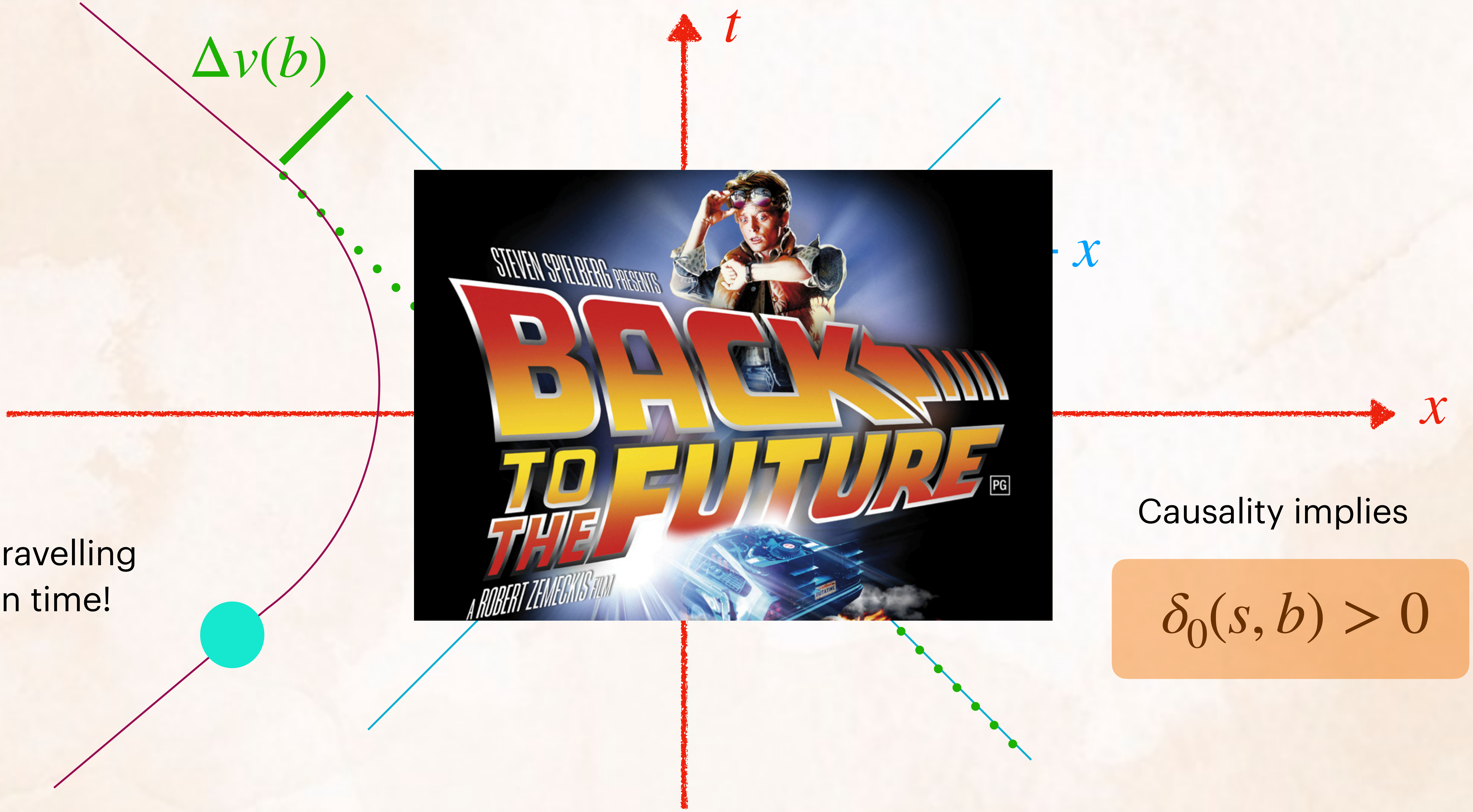

Signal travelling back in time!

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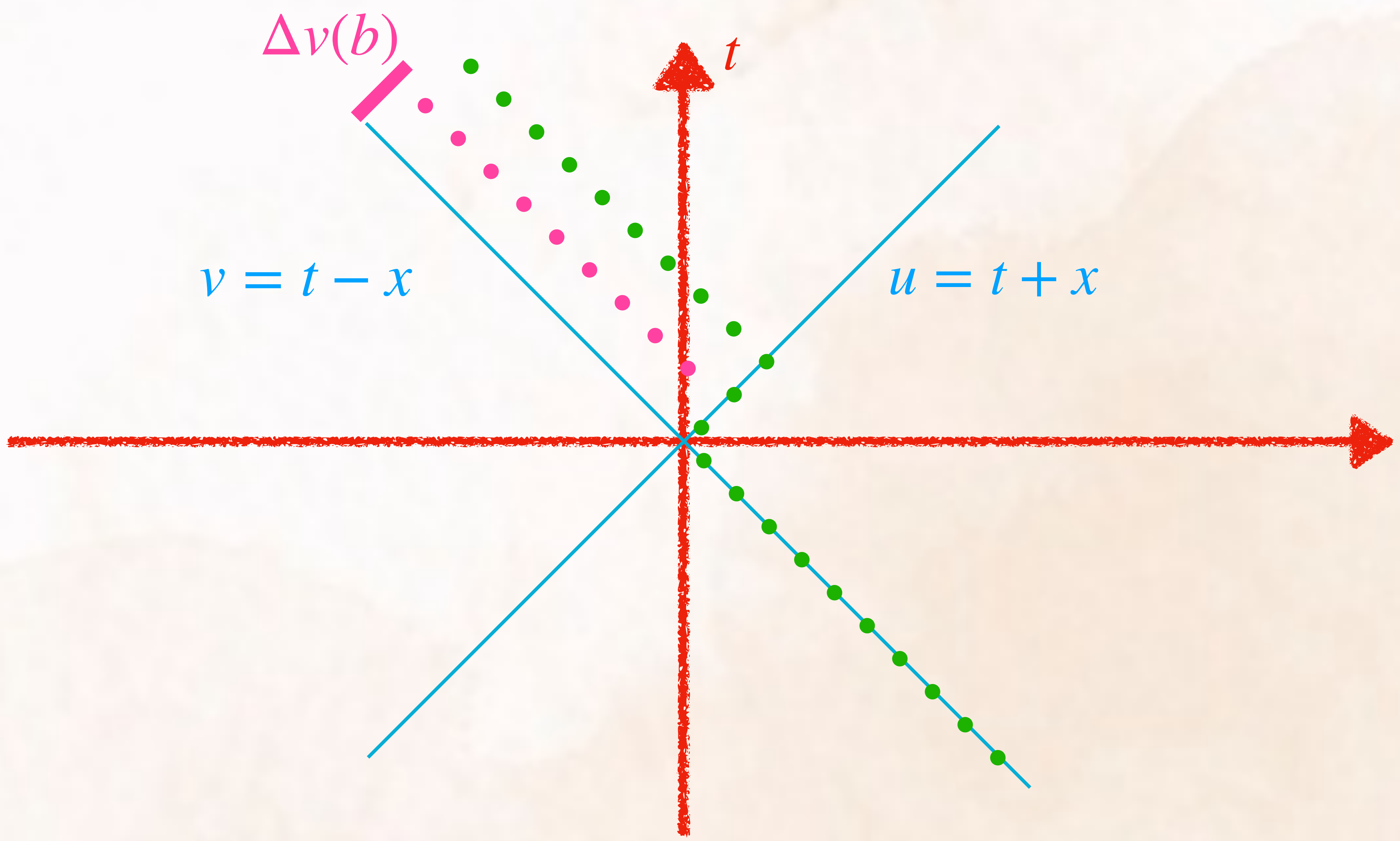
Effect of higher order terms

Following the EFT philosophy

$$S = \frac{M_{pl}^2}{2}\int d^4x\sqrt{-g}\left(R + \mathscr{L}_m + \alpha\, R_{\mu\nu\alpha\beta}R^{\mu\nu\sigma\rho}R^{\alpha\beta}_{\sigma\rho} + ..\right)$$

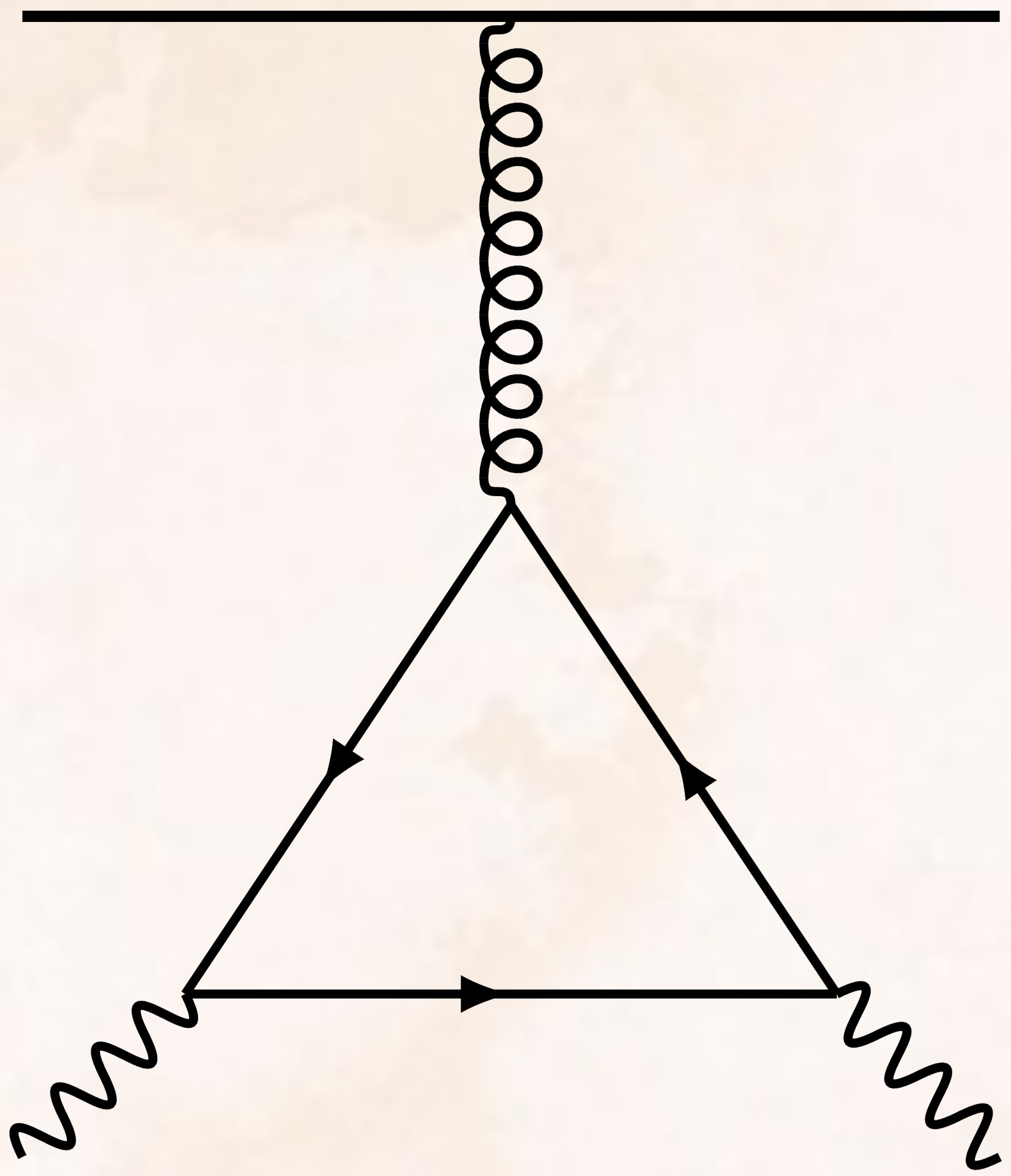
$$\delta(s,b) = \delta_0(s,b) + \alpha\, \delta_{R^3}(s,b) > 0$$



We can constraint the Wilson coefficients
and learn something about quantum gravity!

What I'm working on

Electron loop



$$\delta_{new}(s, b)$$

Hopefully learn something !

$$\frac{1}{b_{min}} \sim \Lambda < m e^{1/\alpha}$$

Thank you !