"...our mistake is not that we take our theories too seriously, but that we do not take them seriously enough. It is always hard to realize that these numbers and equations we play with at our desks have something to do with the real world..."

S. Weinberg, "The first three minutes"

Inflation and CMB

V. Mukhanov
LMU, München

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– *Gravity waves*

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Which concrete scenario was realized ???

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Can quantum fluctuations be amplified up to "needed" value 10^{-5} in expandng Universe???

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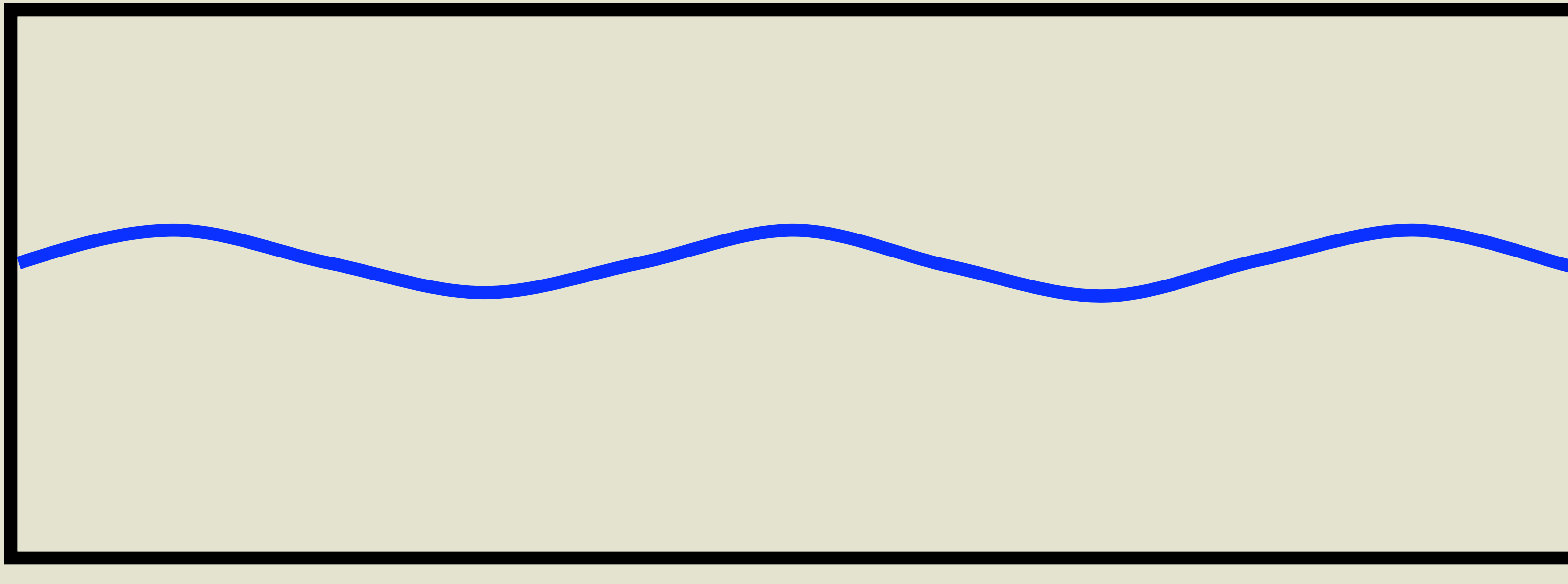
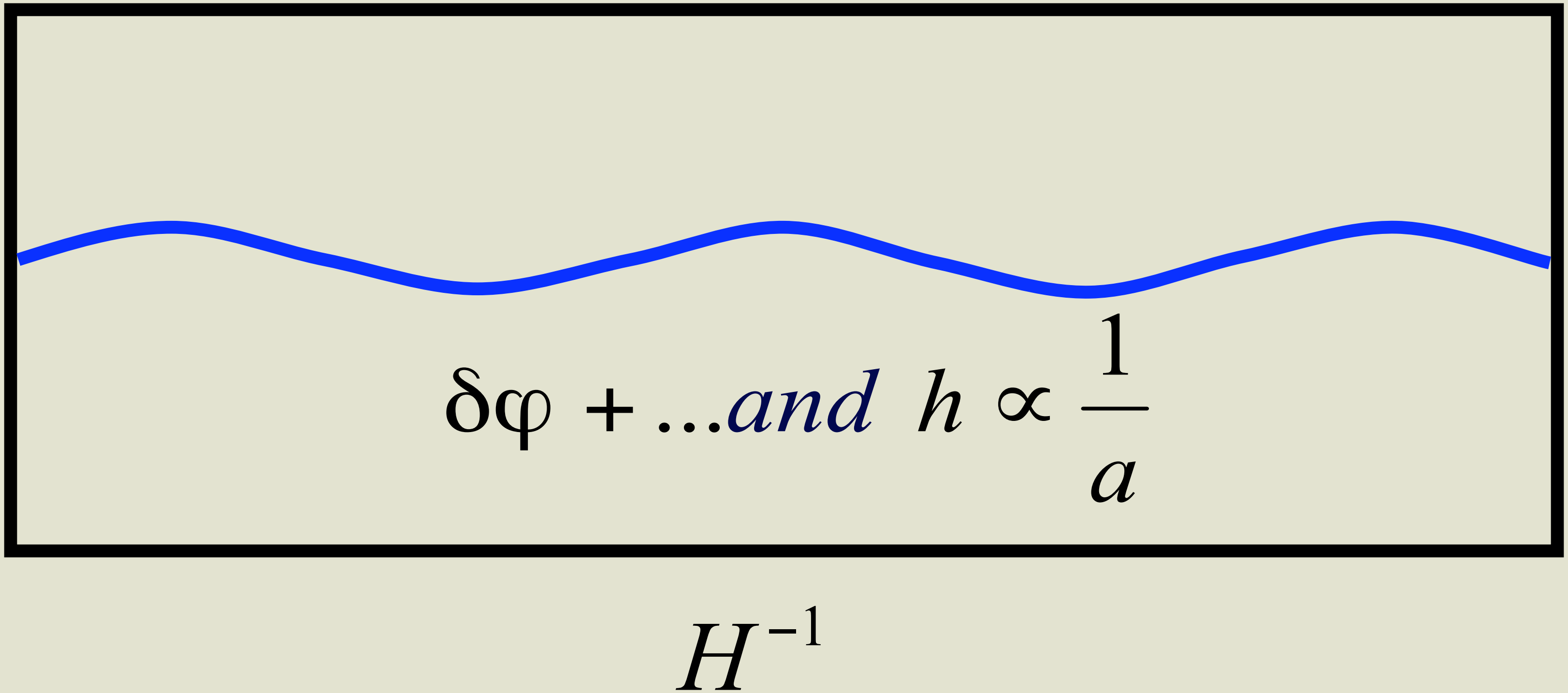
For given k_{com}, $\lambda_{ph}(cm) \propto a / k_{com} \propto a(t)$ and the change of the amplitude with time depends on how big is λ_{phys} compared to the curvature scale (size of Einstein lift) $H^{-1} = a / \dot{a}$

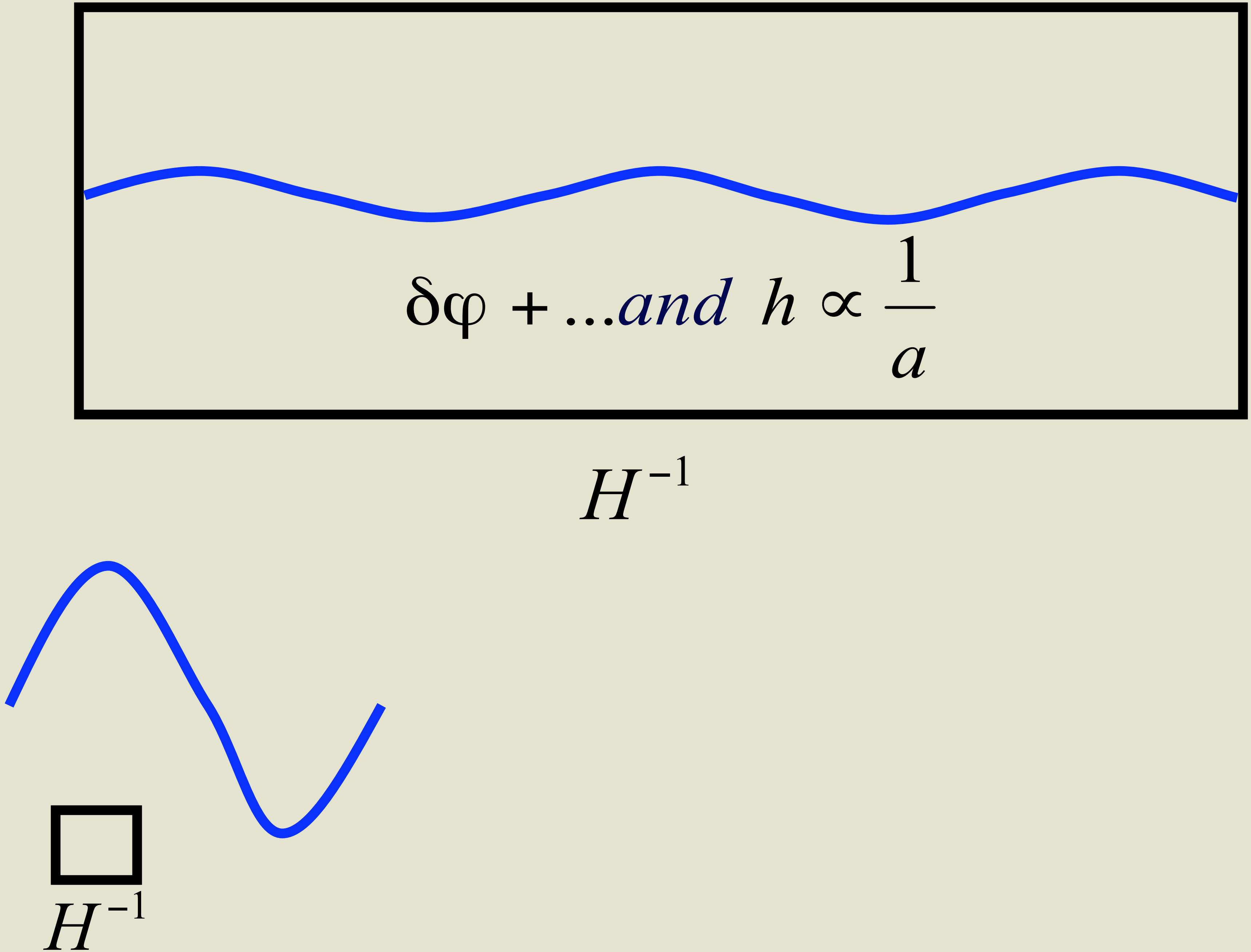
$$H^{-1}$$

H^{-1}



H^{-1}


$\delta\varphi + \ldots$ *and* $h \propto \frac{1}{a}$
H^{-1}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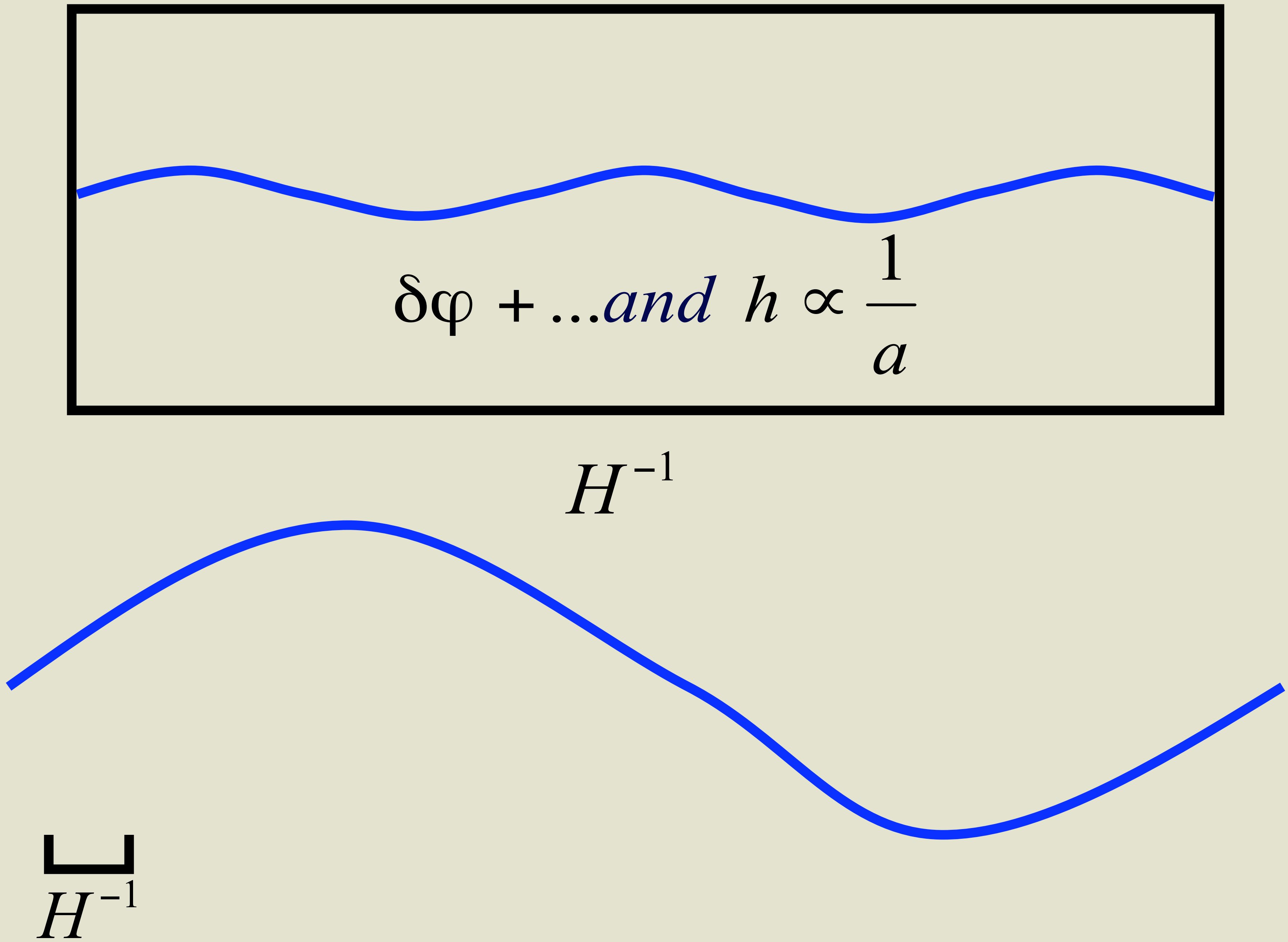
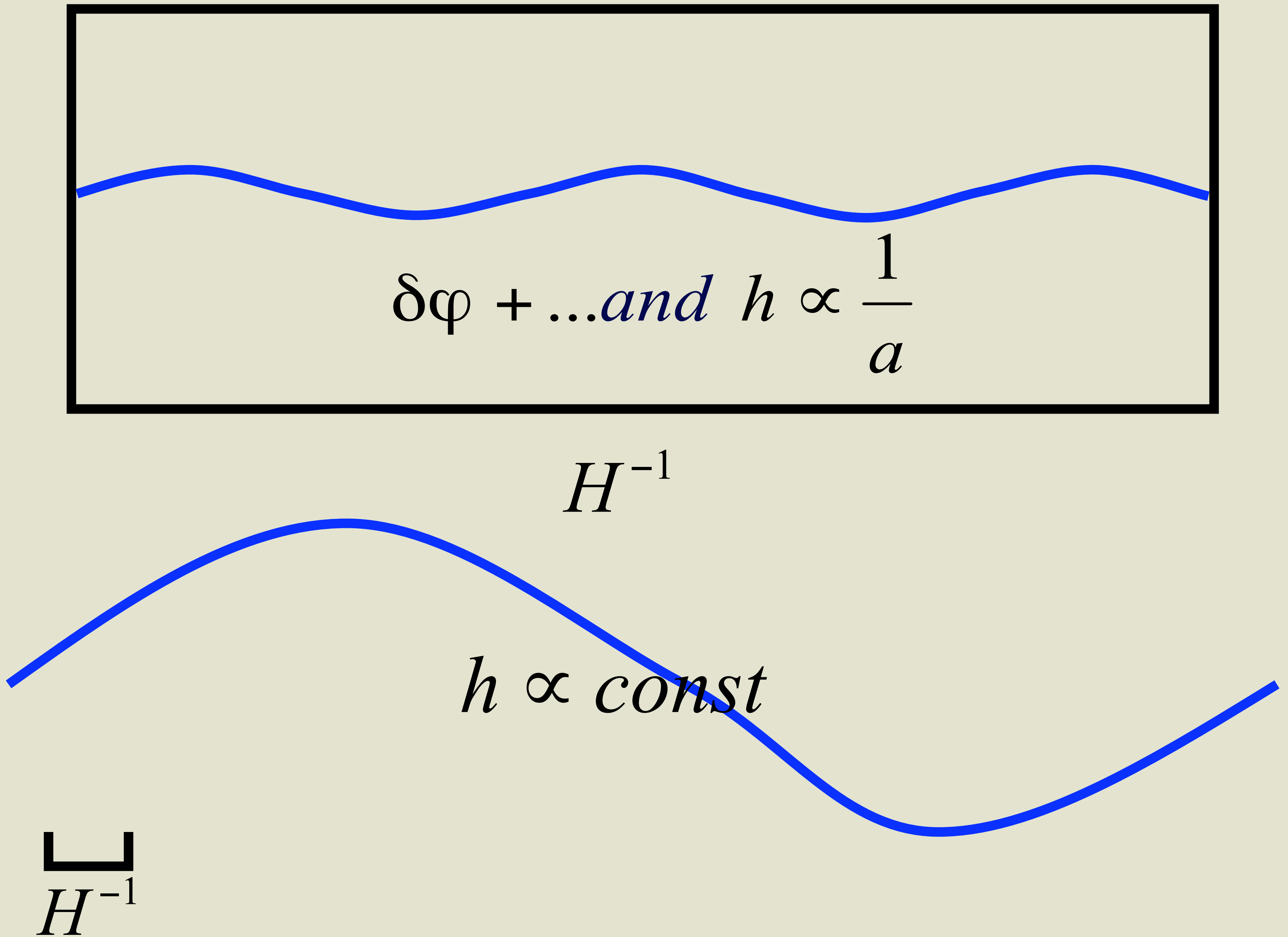


δφ + ...and h ∝ 1/a
H^{-1}
H^{-1}



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H^{-1}
$h \propto const$
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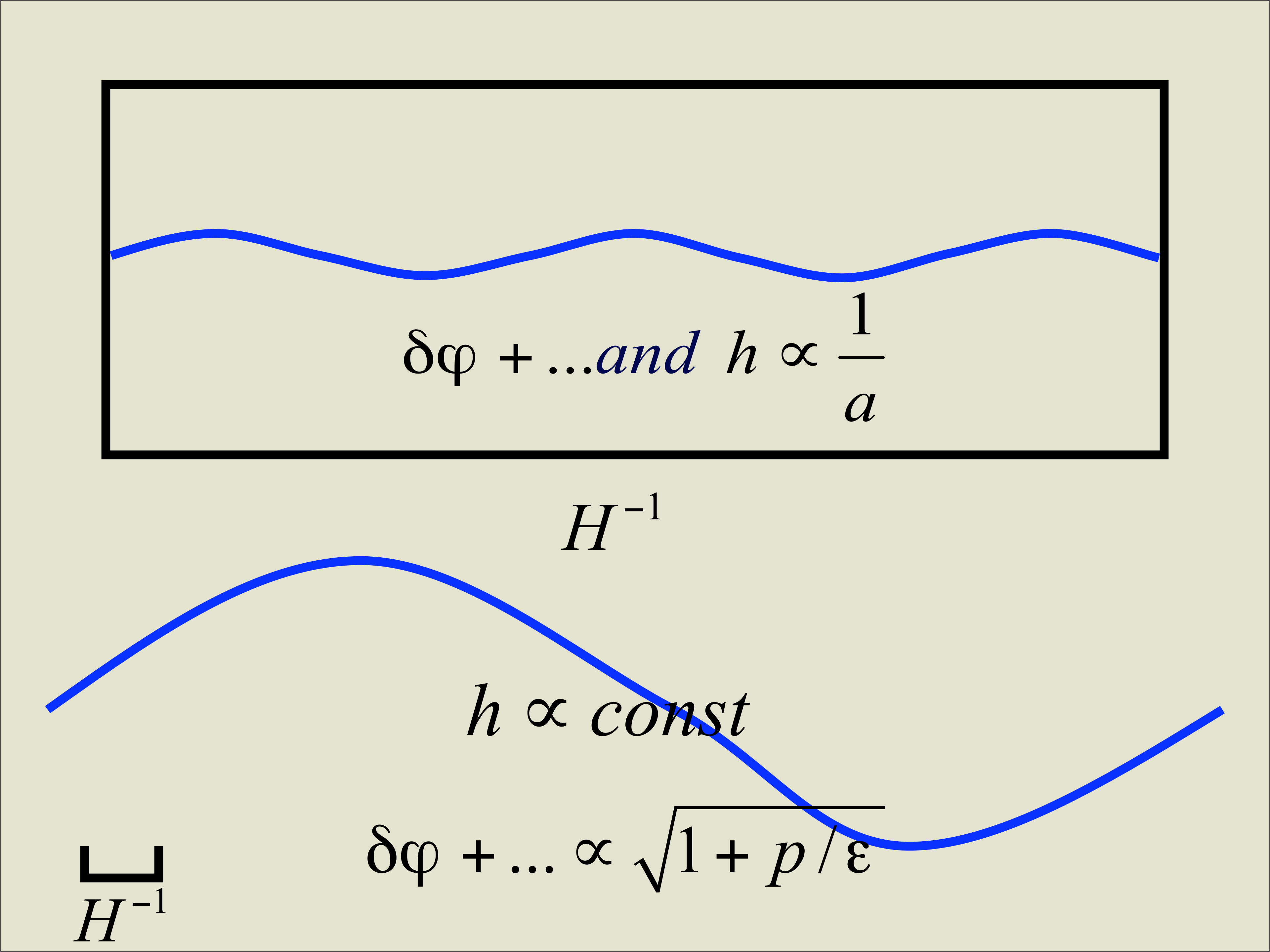

$\delta\varphi + \ldots$ *and* $h \propto \frac{1}{a}$
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$\delta\varphi + \ldots \propto \sqrt{1 + p/\varepsilon}$
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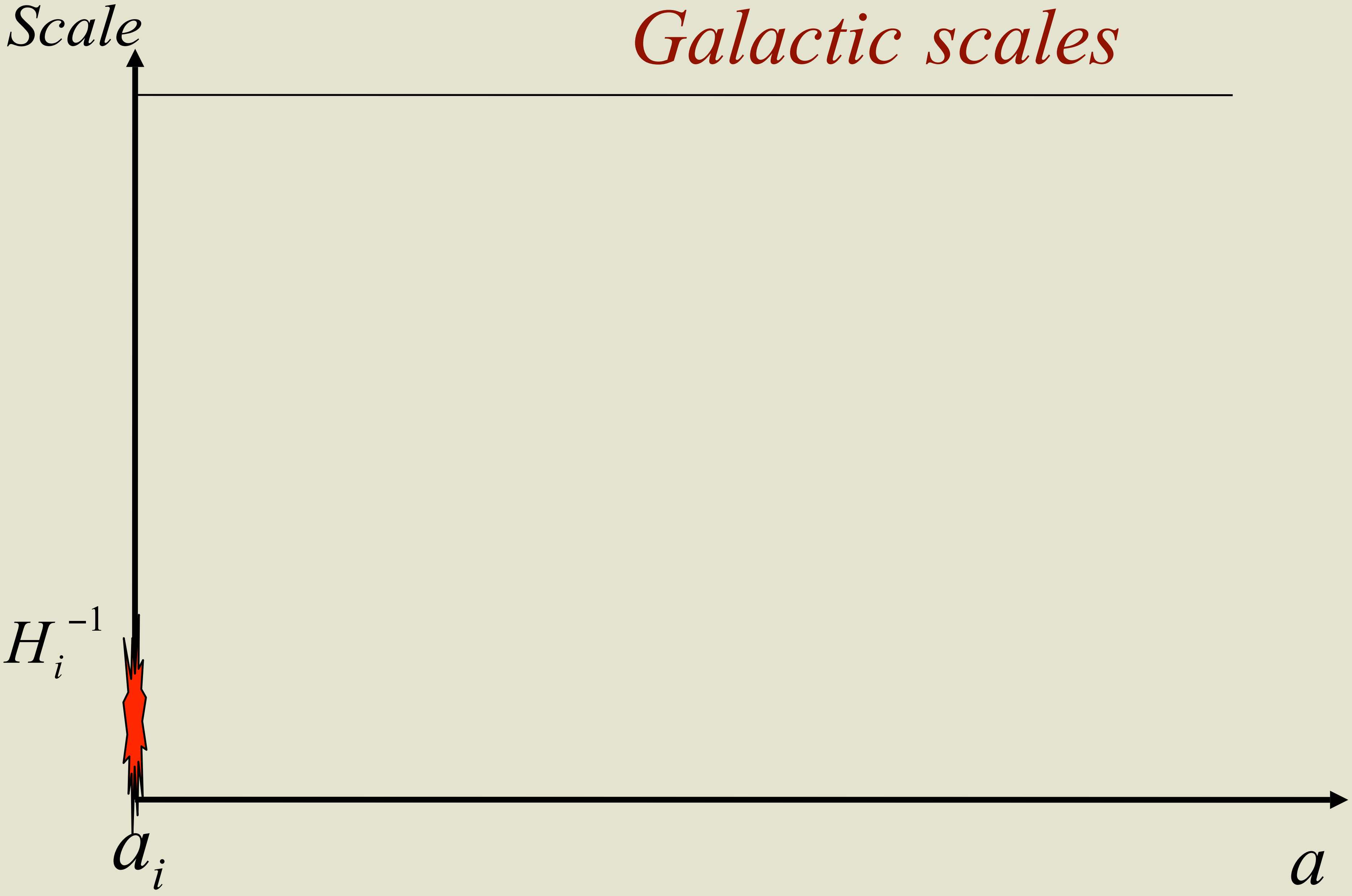
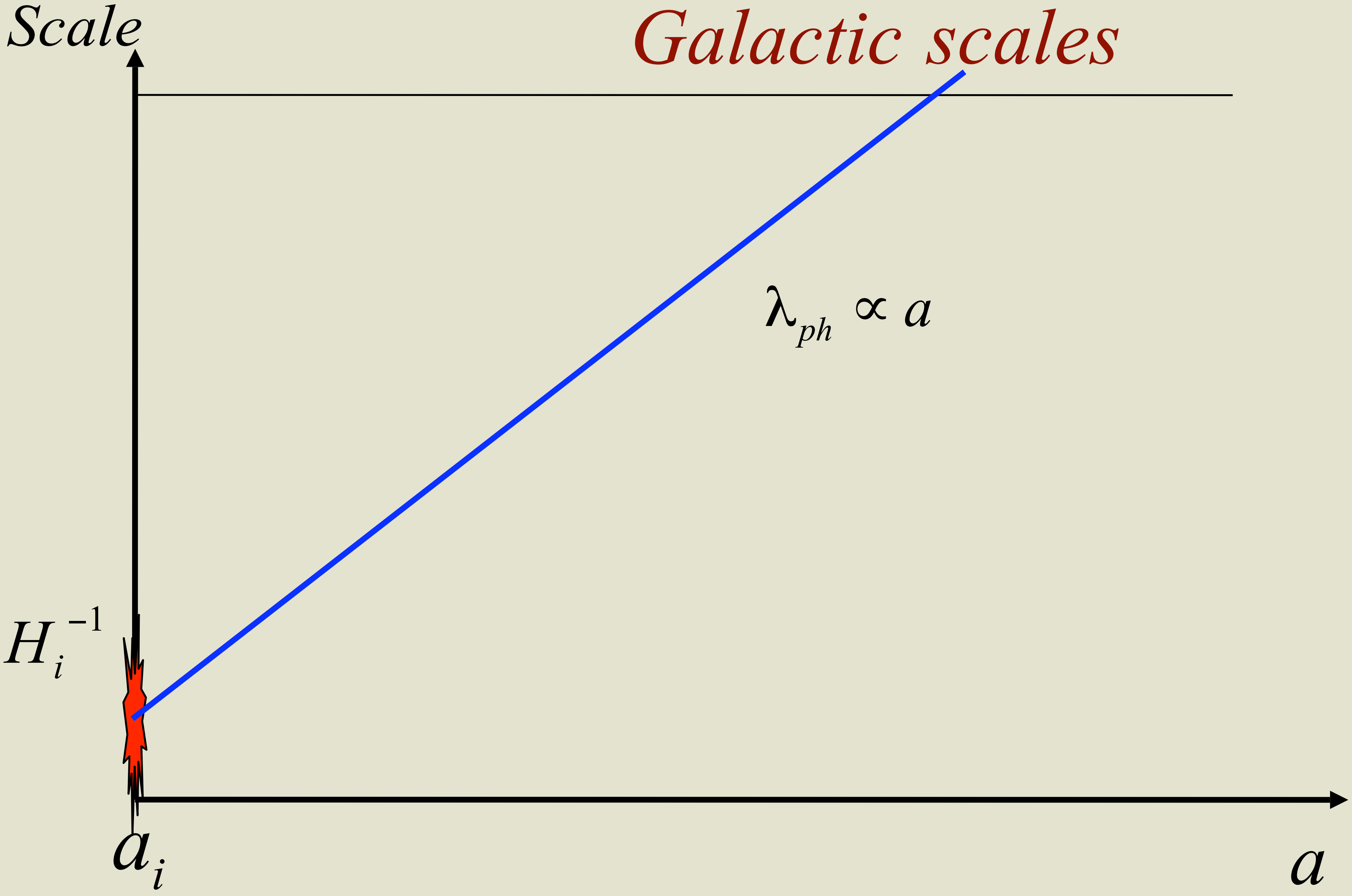
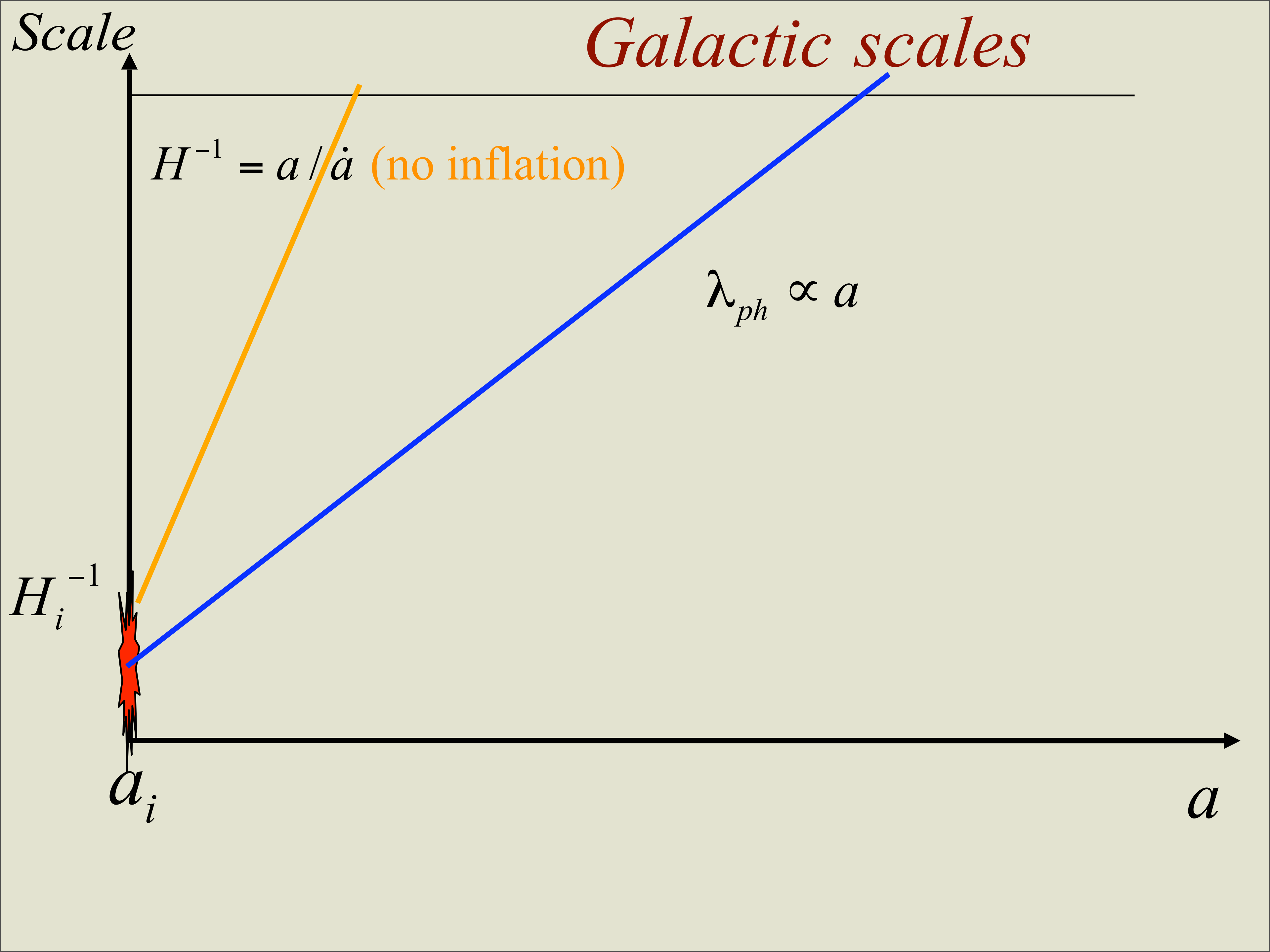
Galactic scales




Scale
Galactic scales
$\lambda_{ph} \propto a$
H_i^{-1}
a_i
a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$H^{-1} = a/\dot{a}$ (no inflation)
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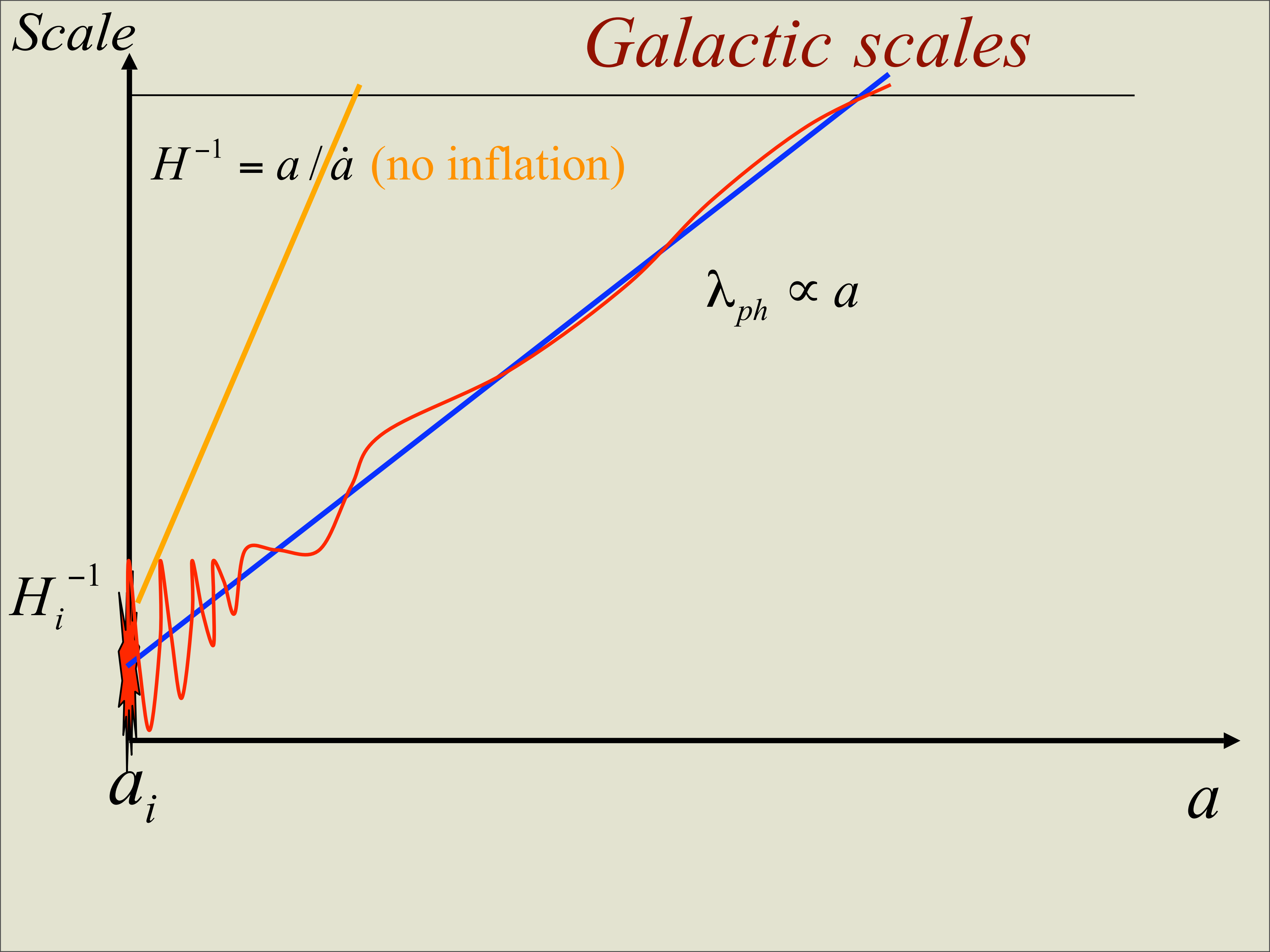
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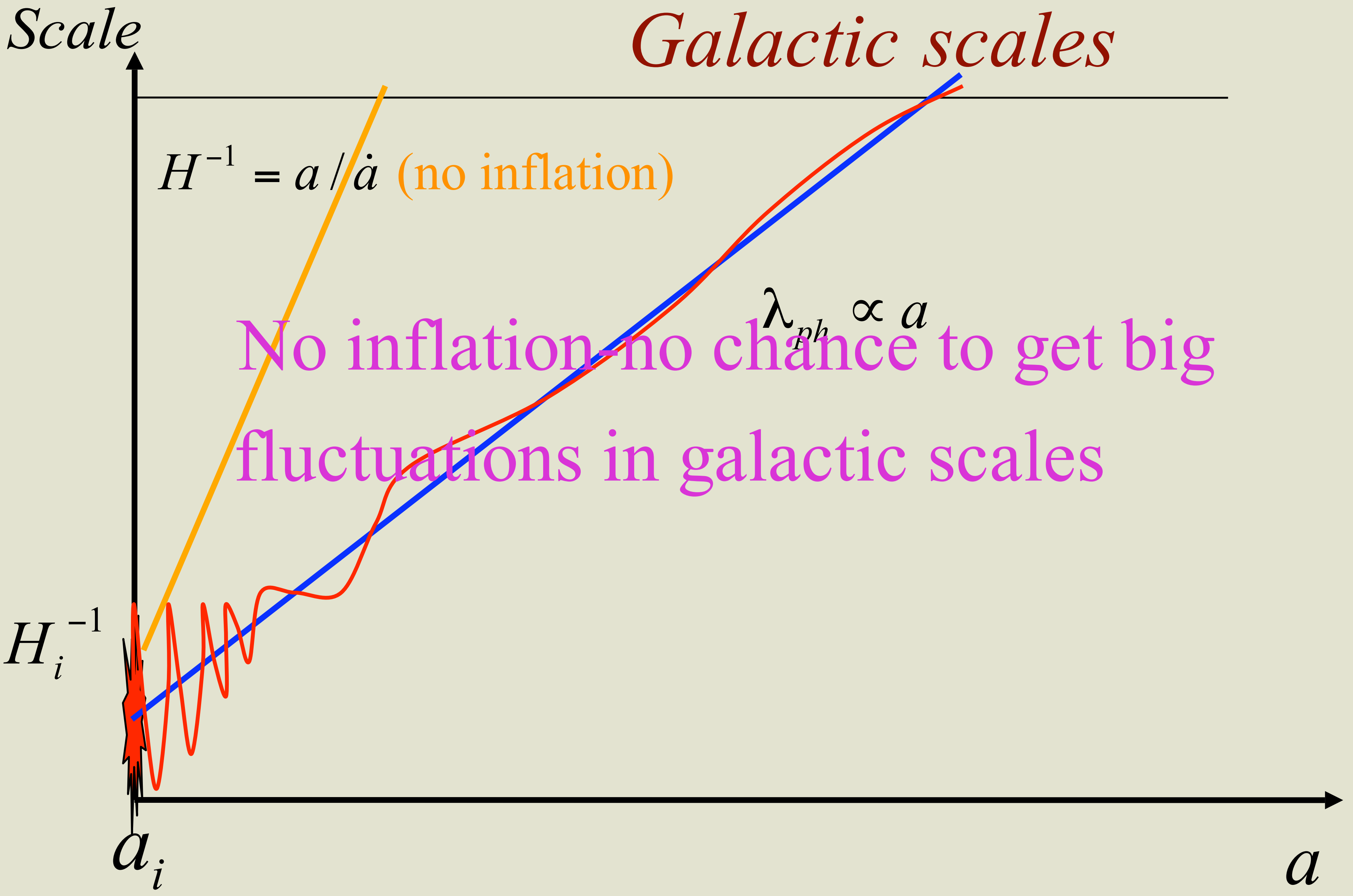
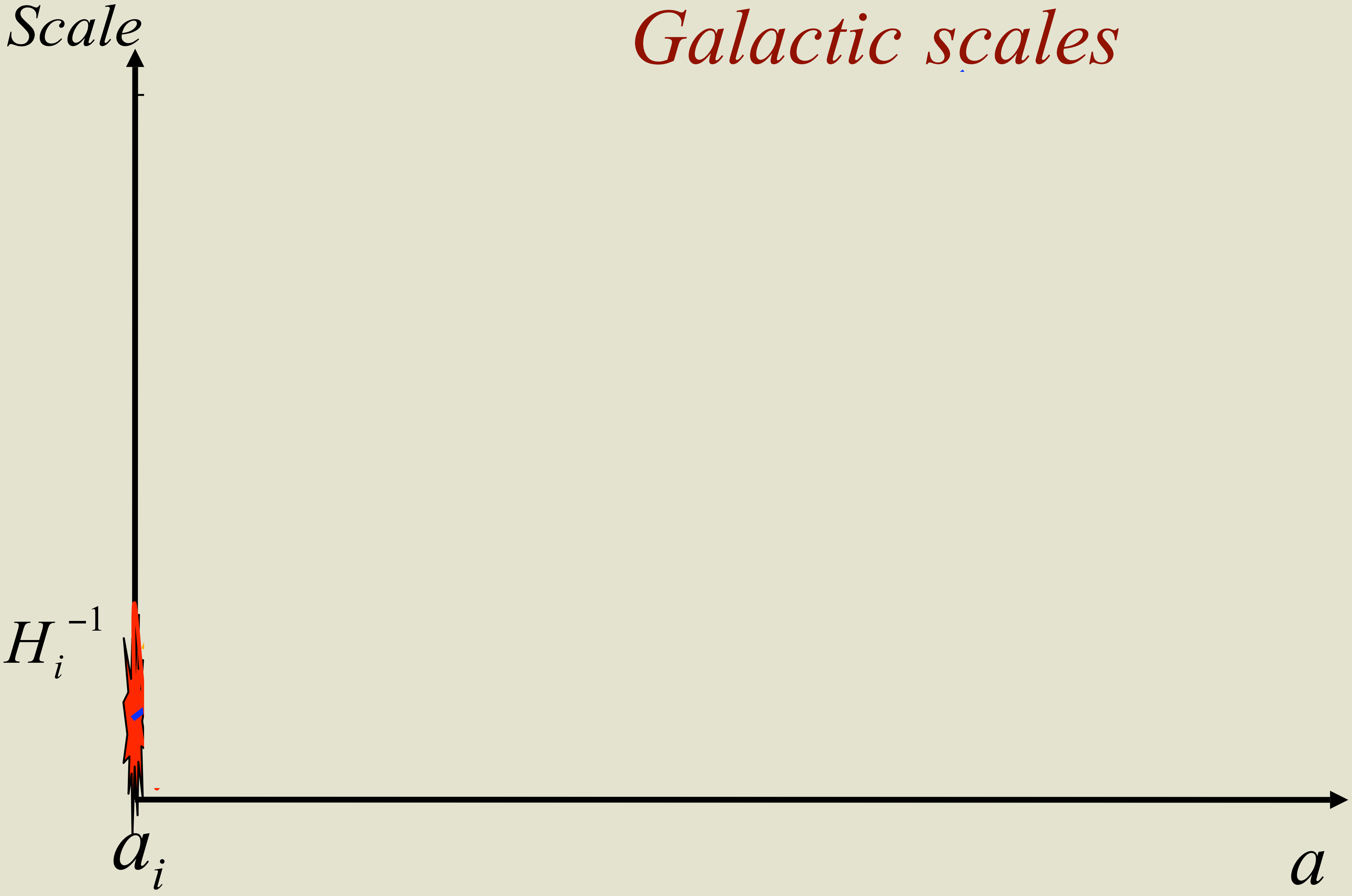
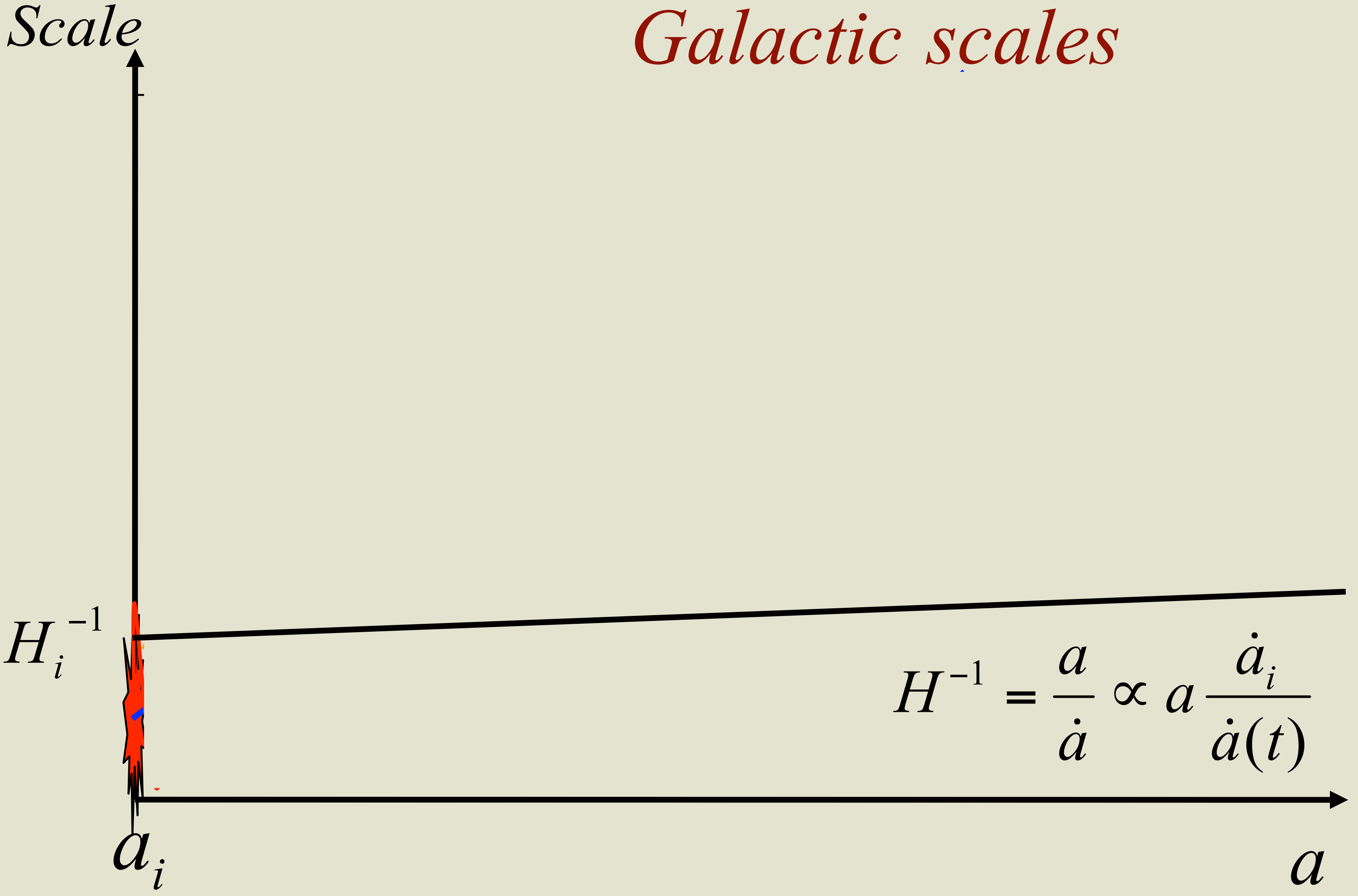


Scale
Galactic scales
$H^{-1} = a/\dot{a}$ (no inflation)
$\lambda_{ph} \propto a$
No inflation-no chance to get big fluctuations in galactic scales
H_i^{-1}
a_i
a

Galactic scales



Galactic scales



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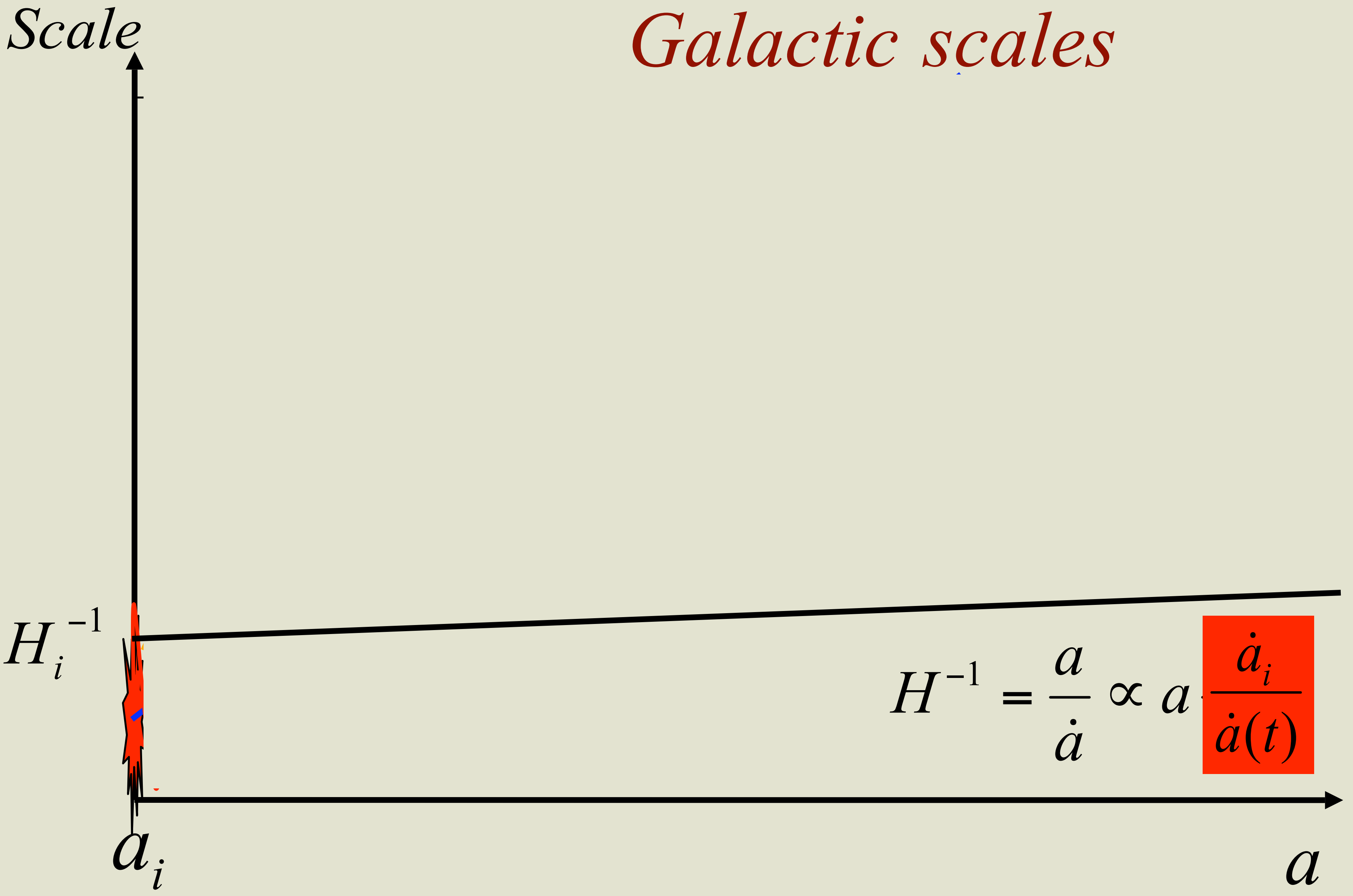

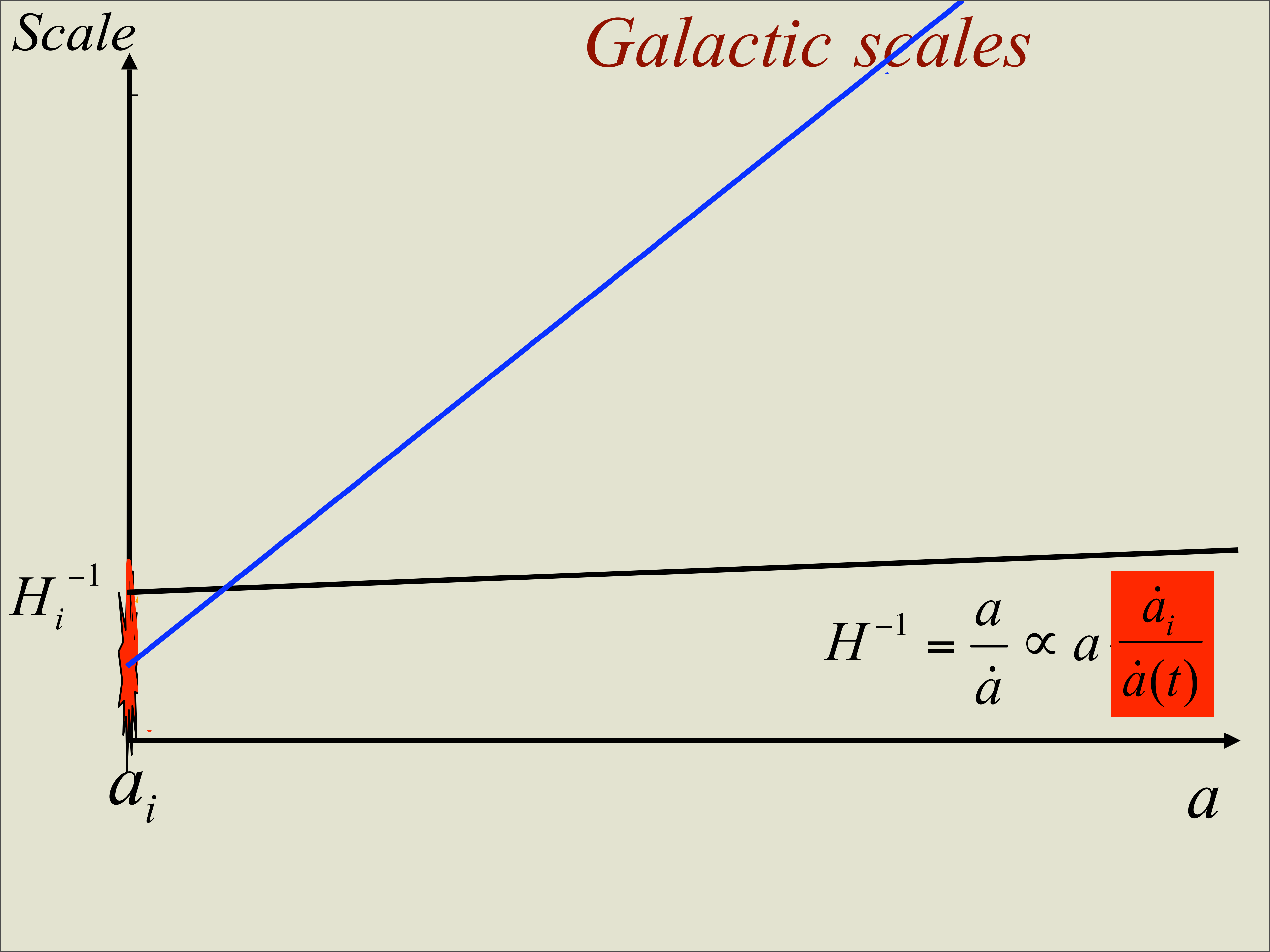

Scale
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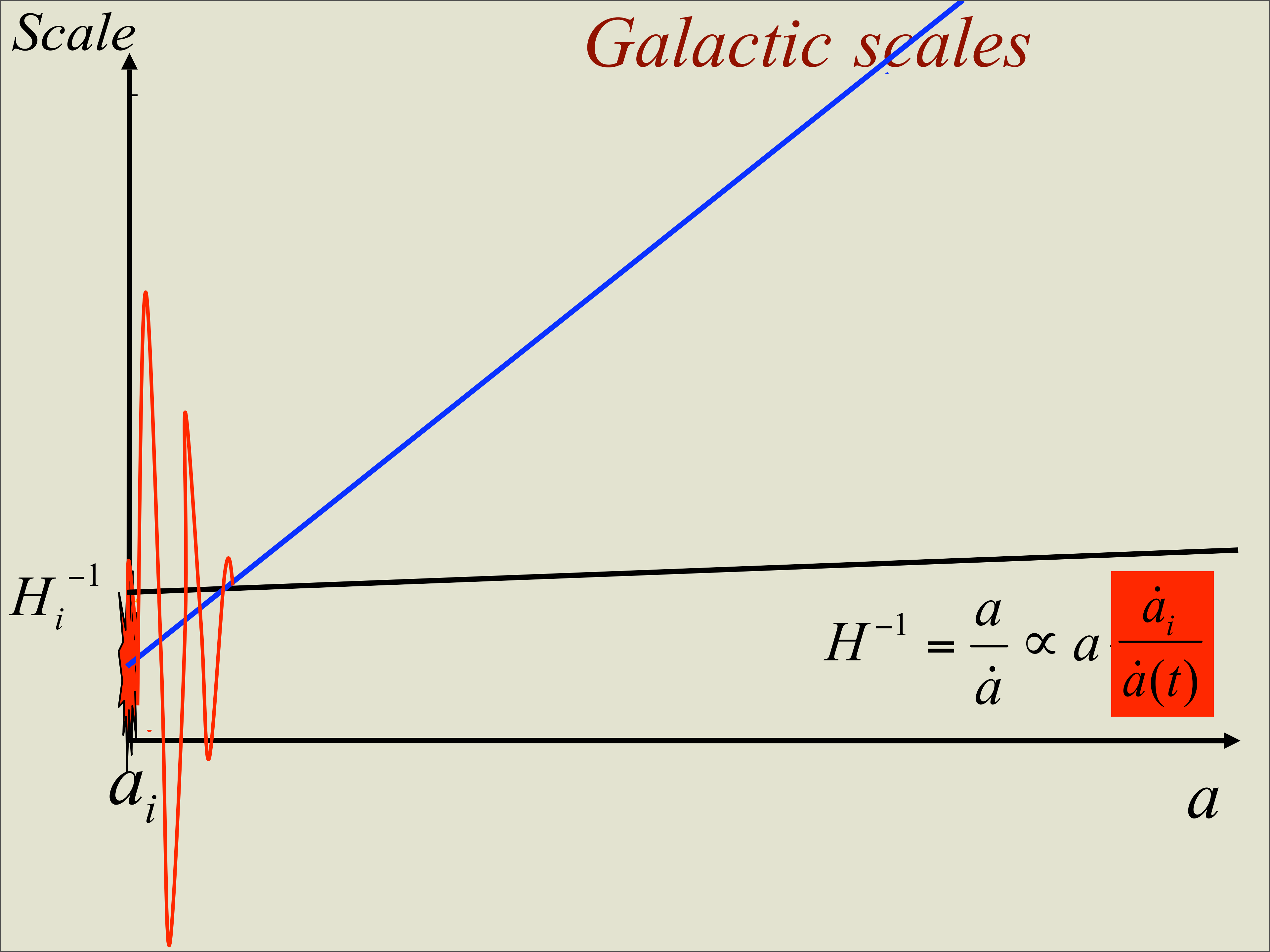
a_i
a



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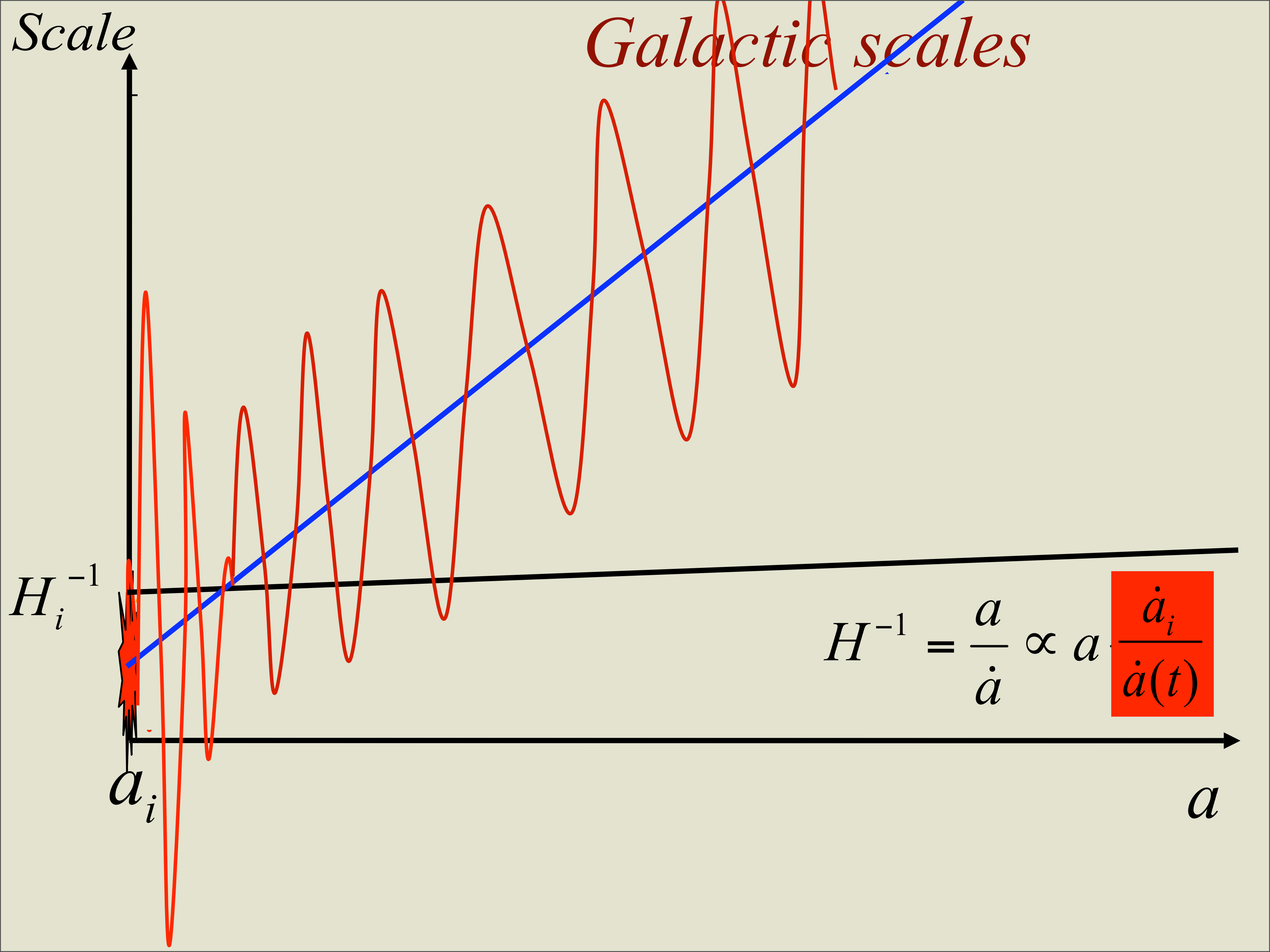

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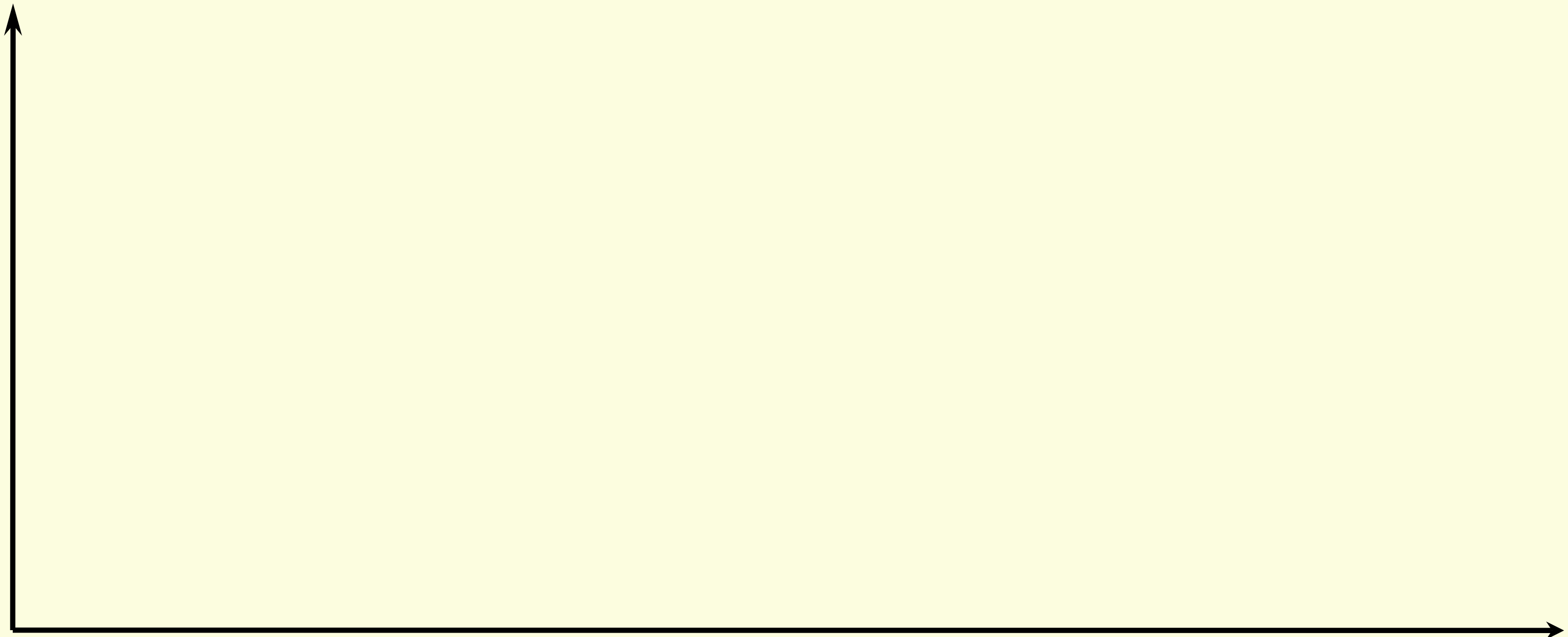
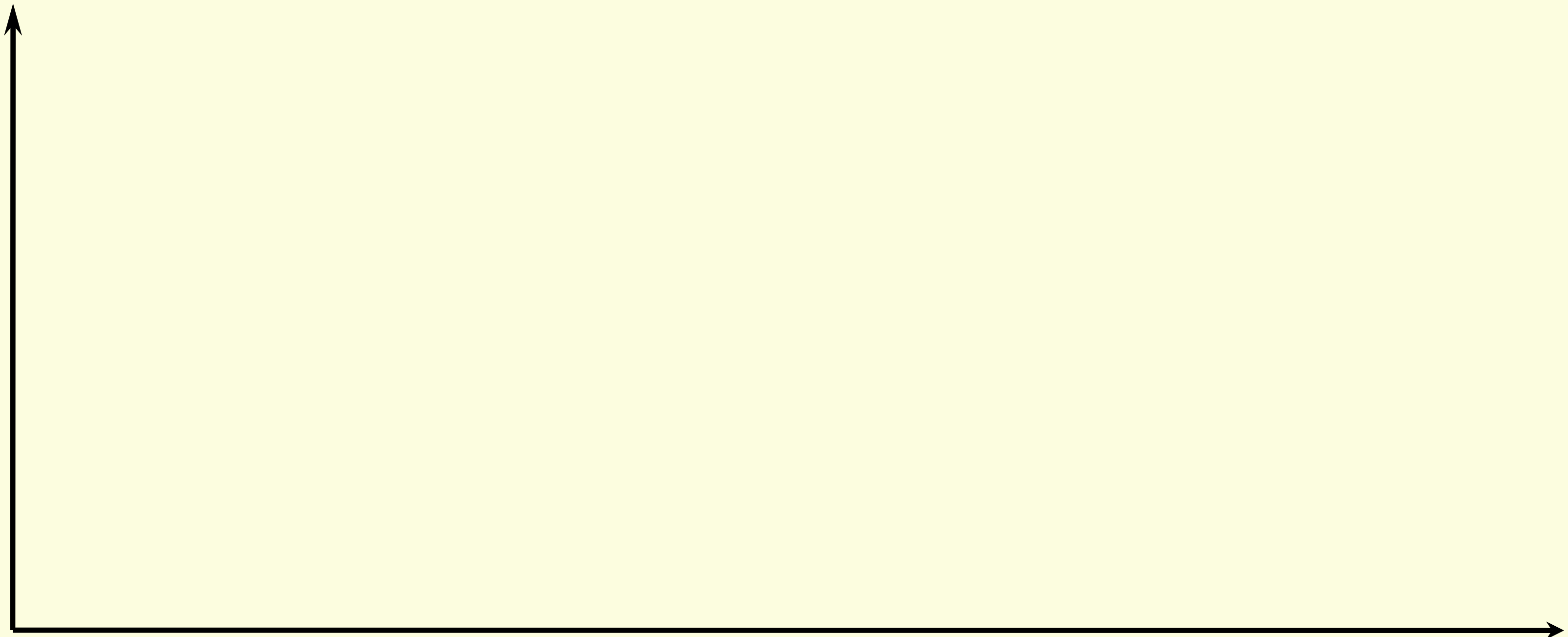
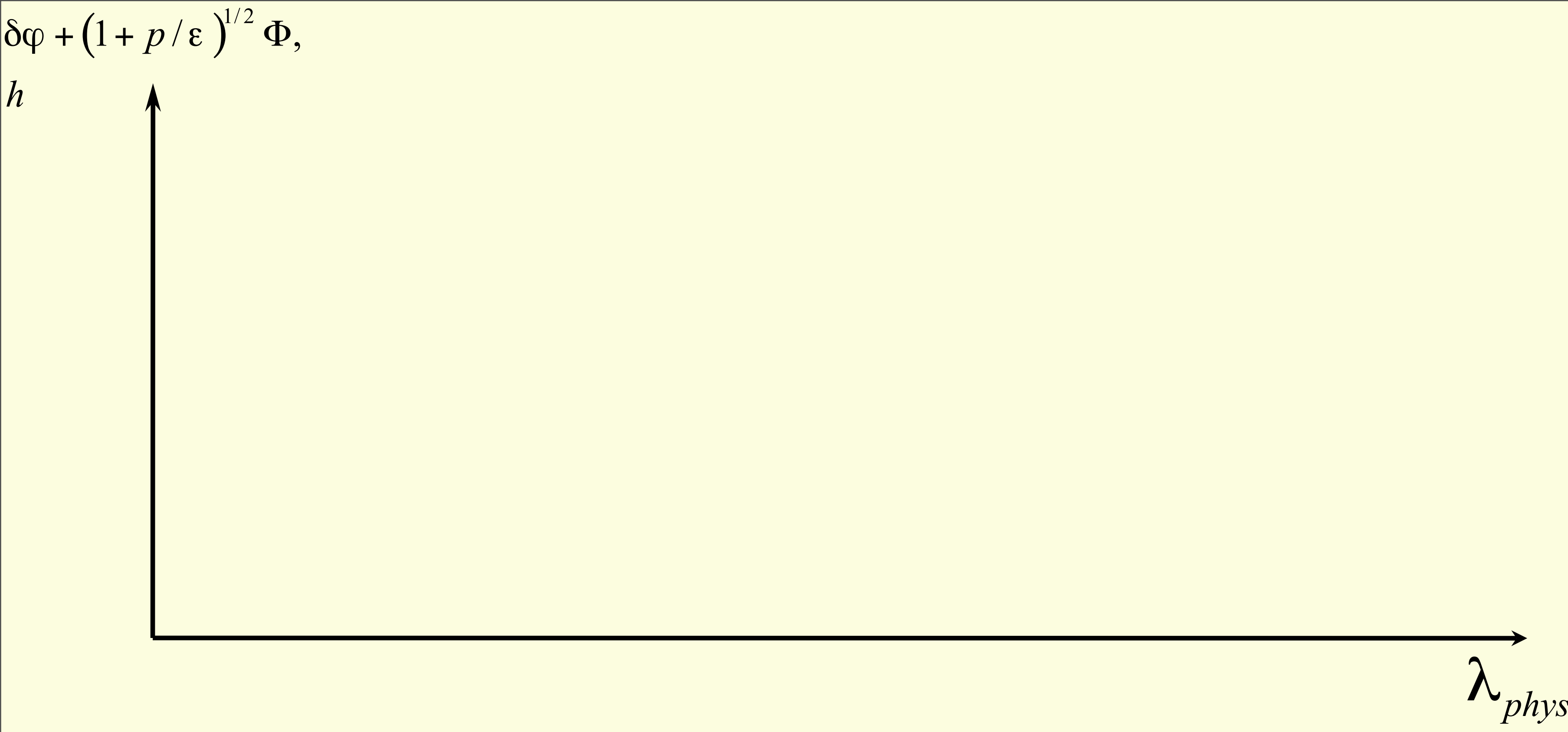


$\delta\varphi + \left(1 + p/\varepsilon\right)^{1/2} \Phi,$

h





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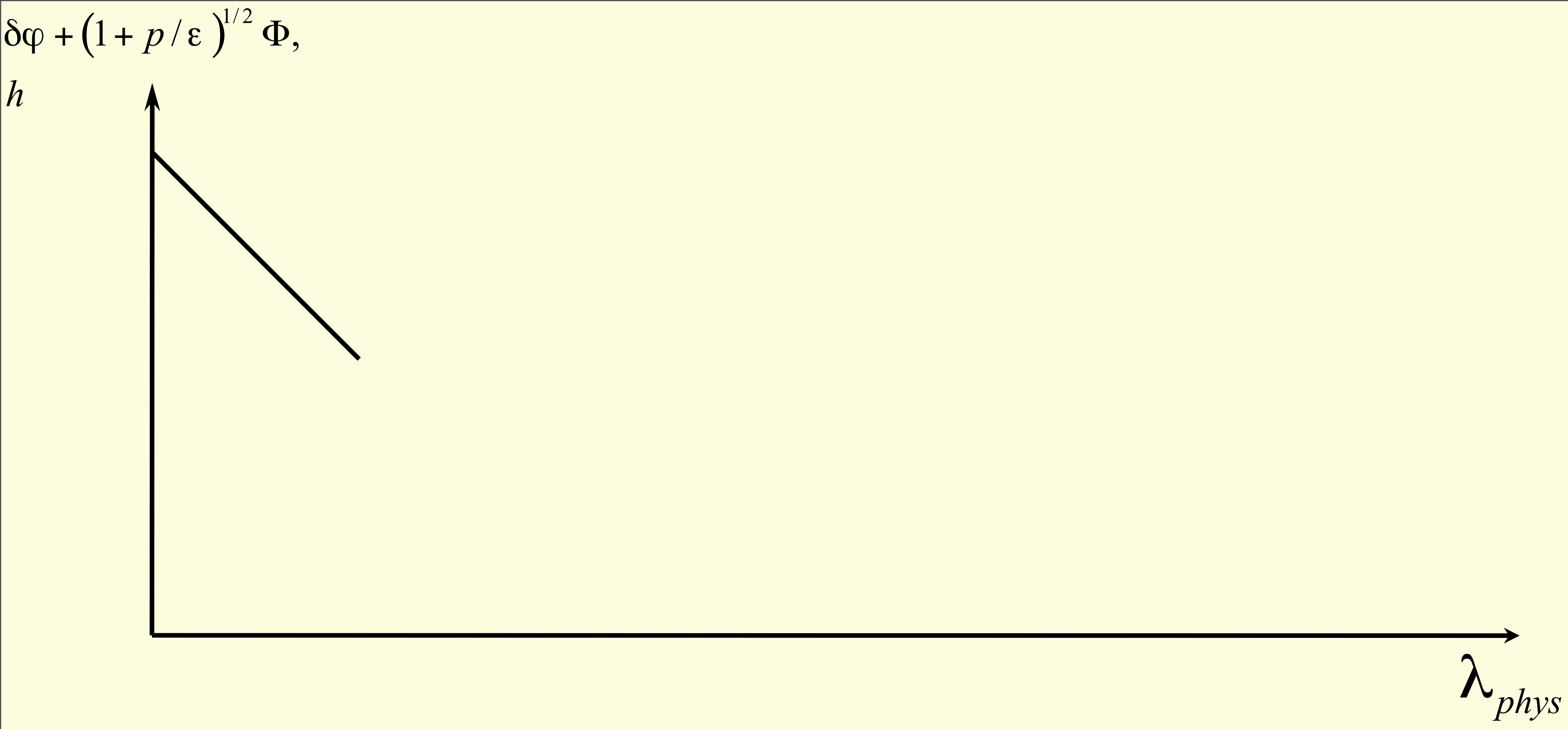
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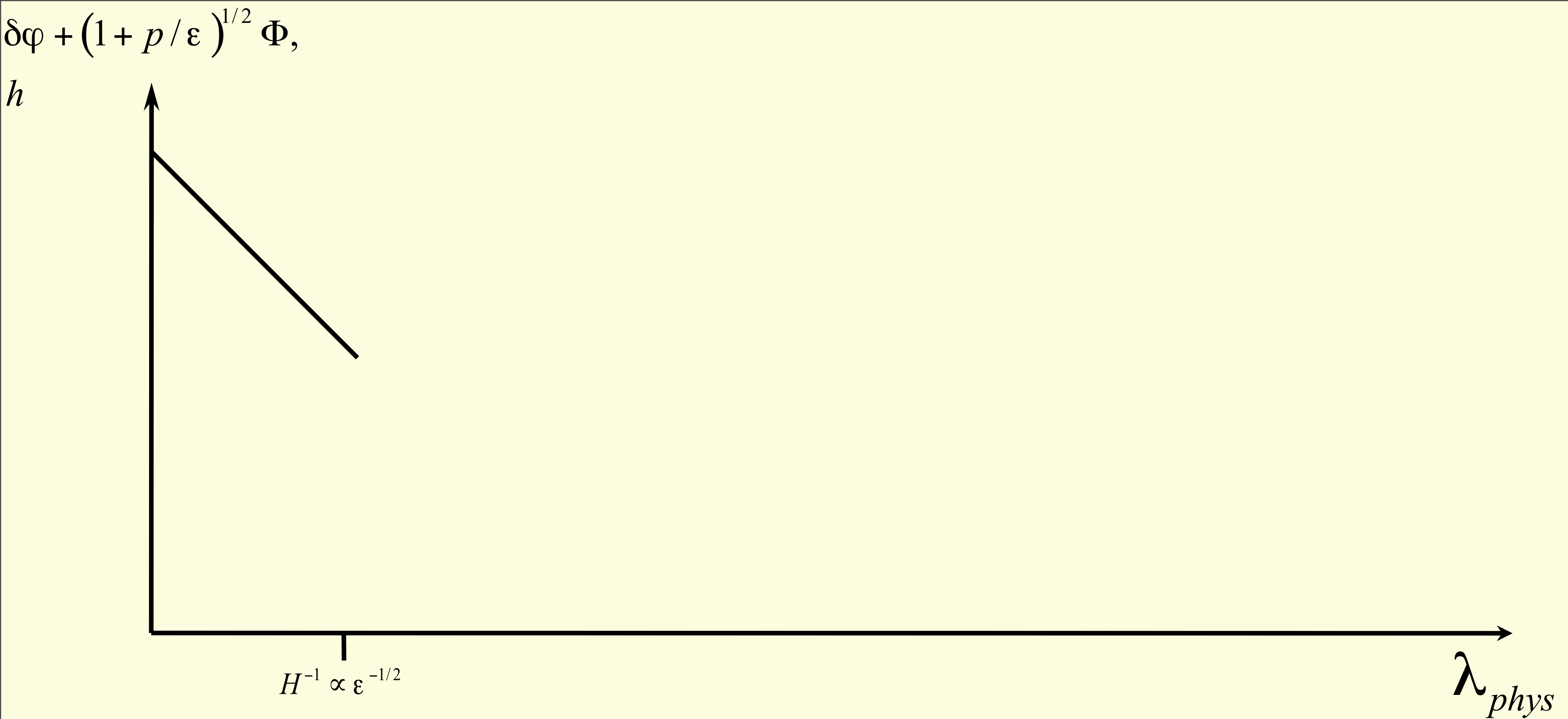

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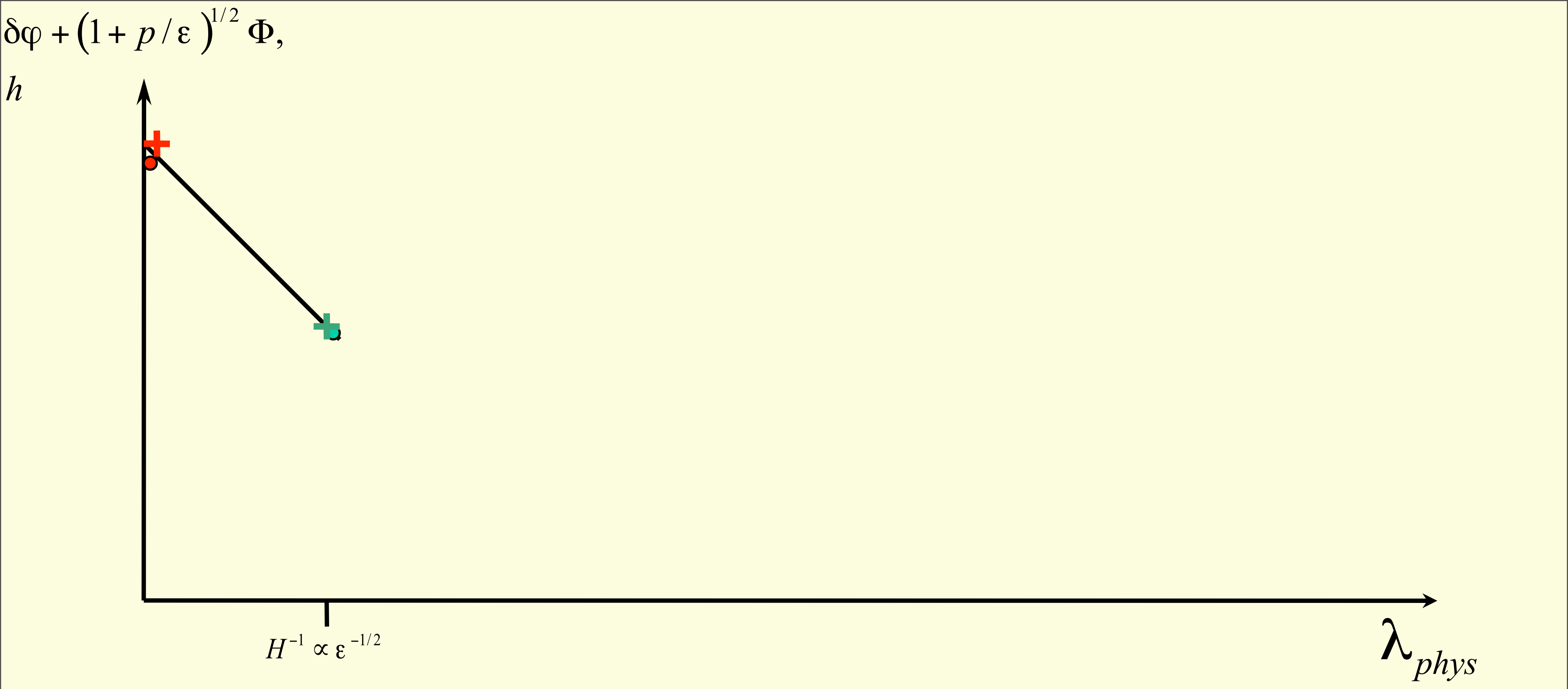

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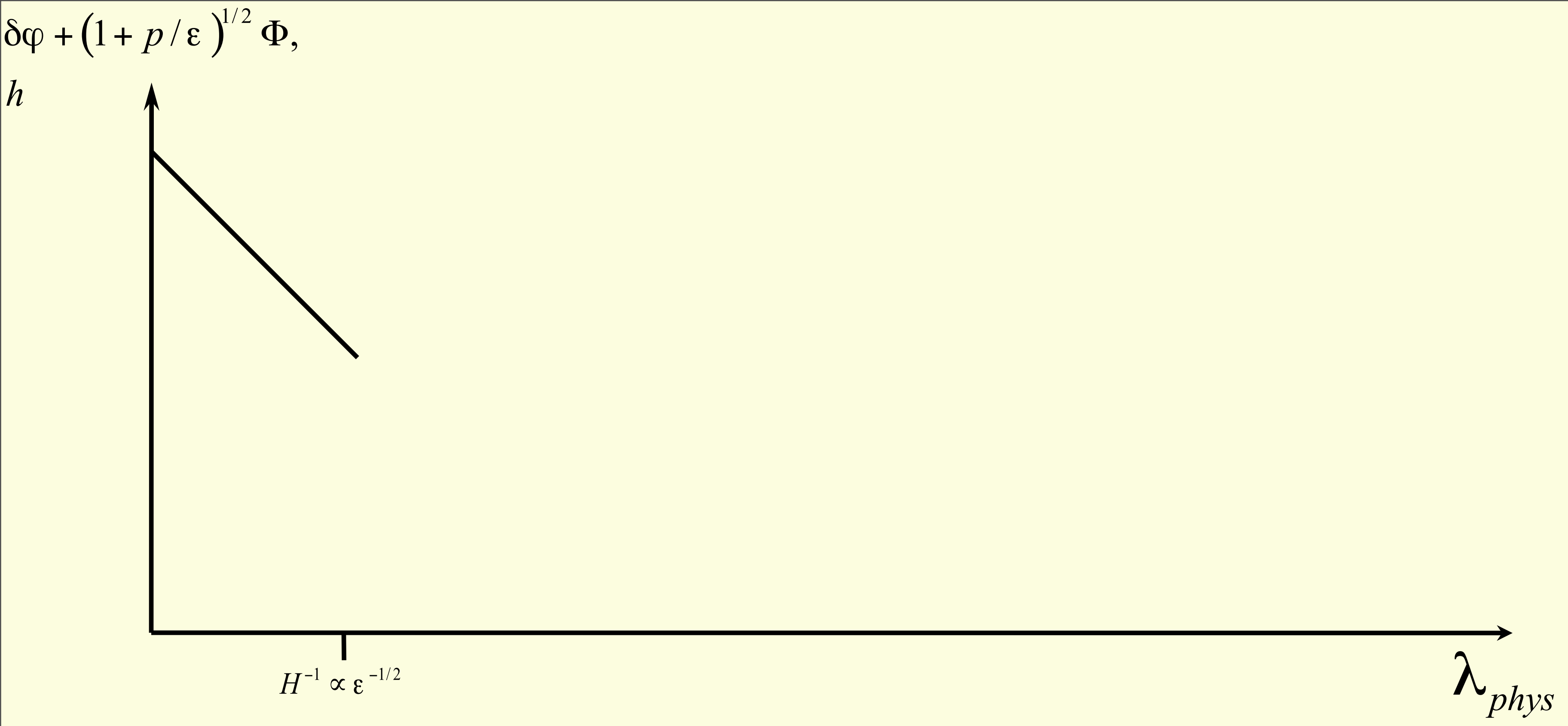

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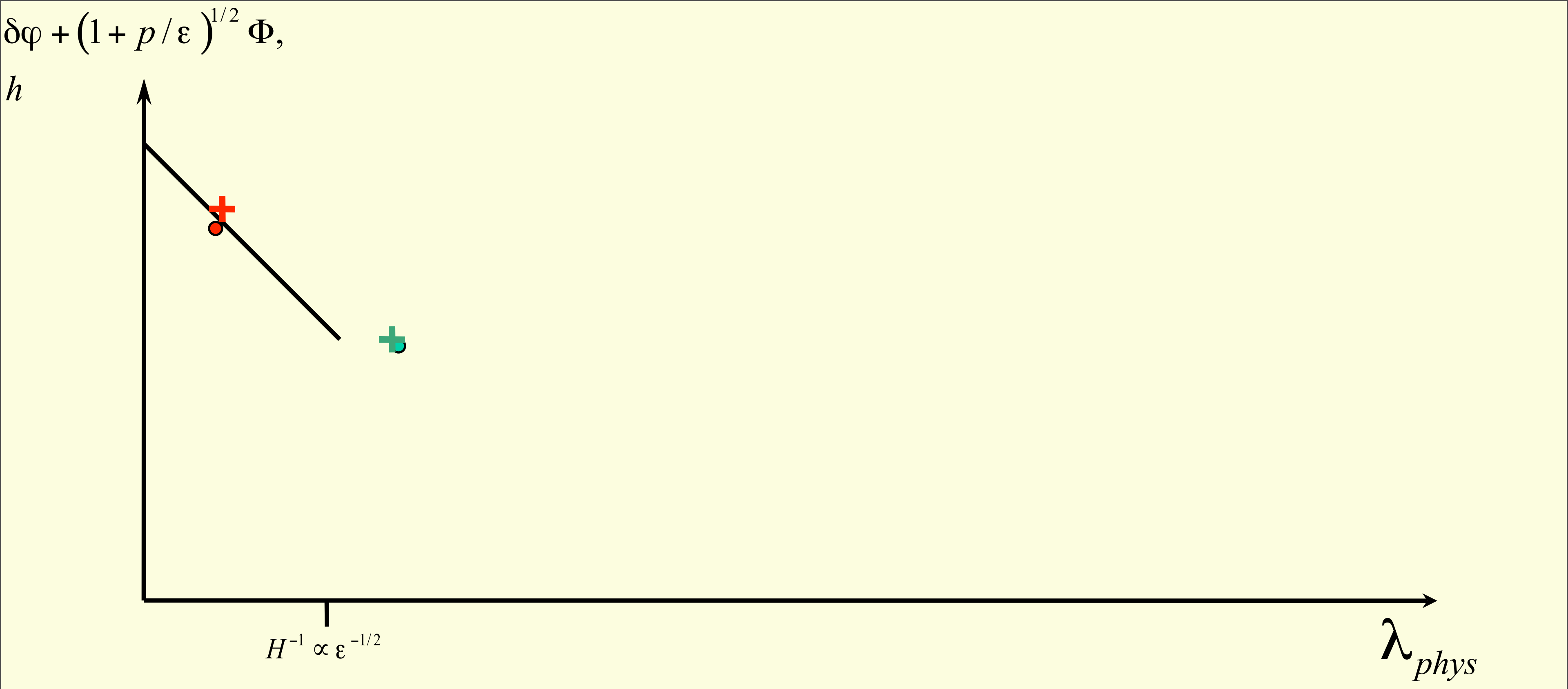

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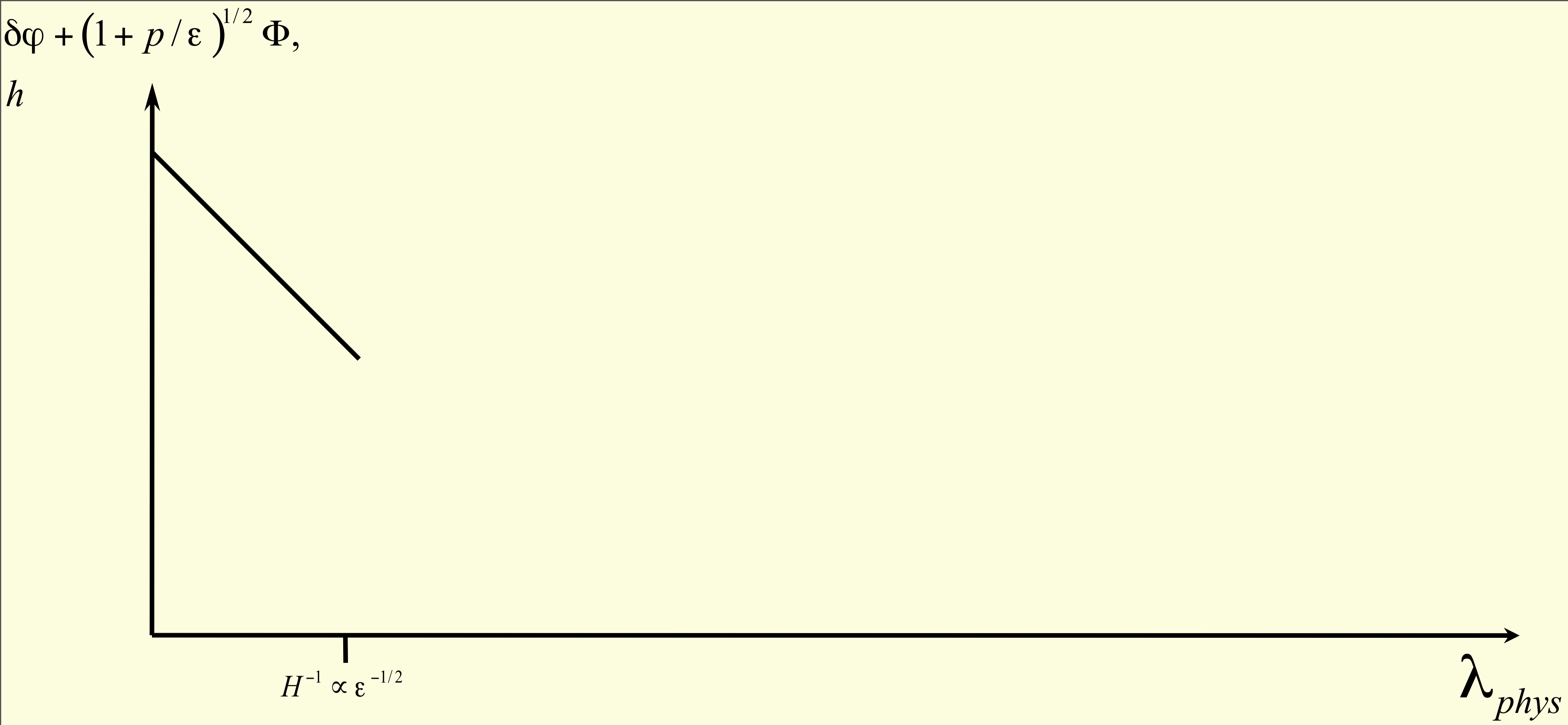
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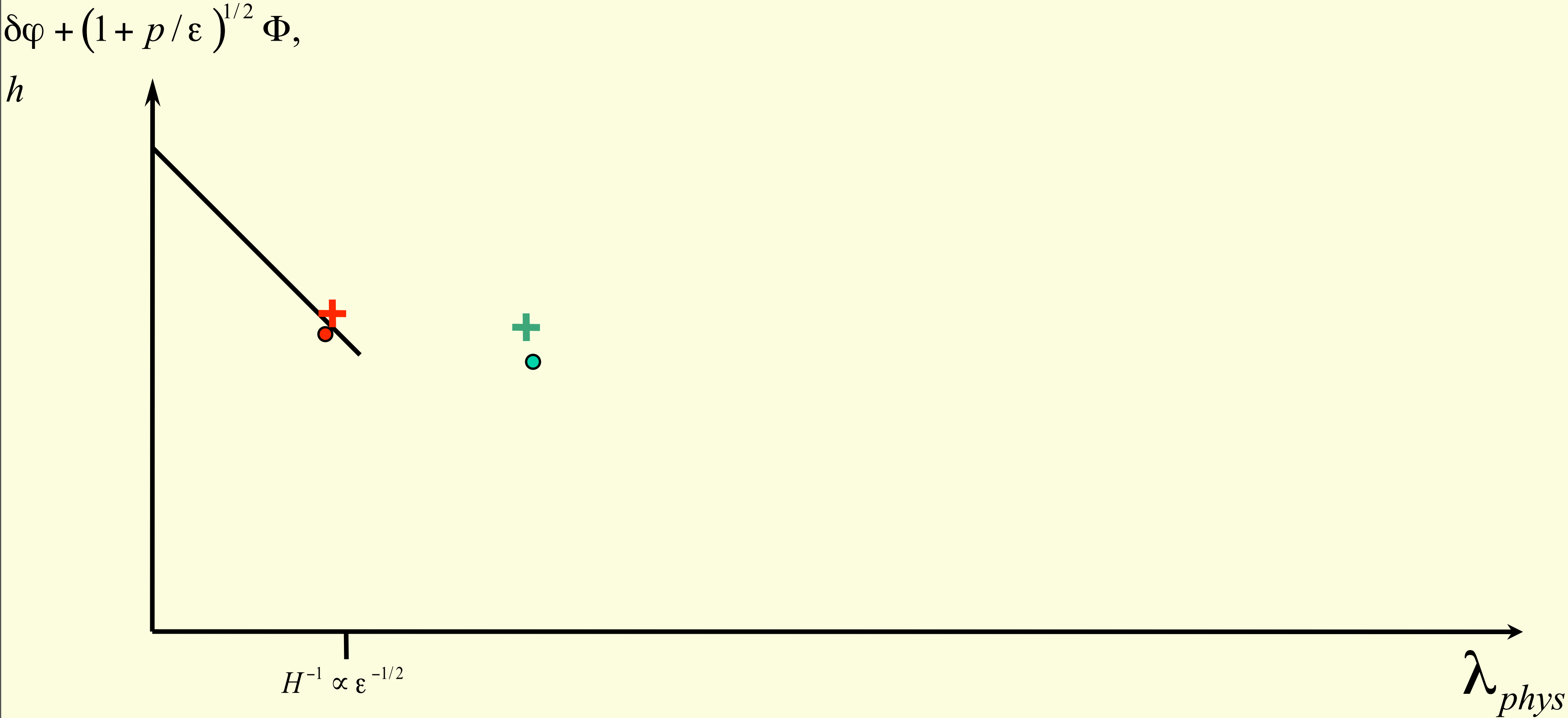

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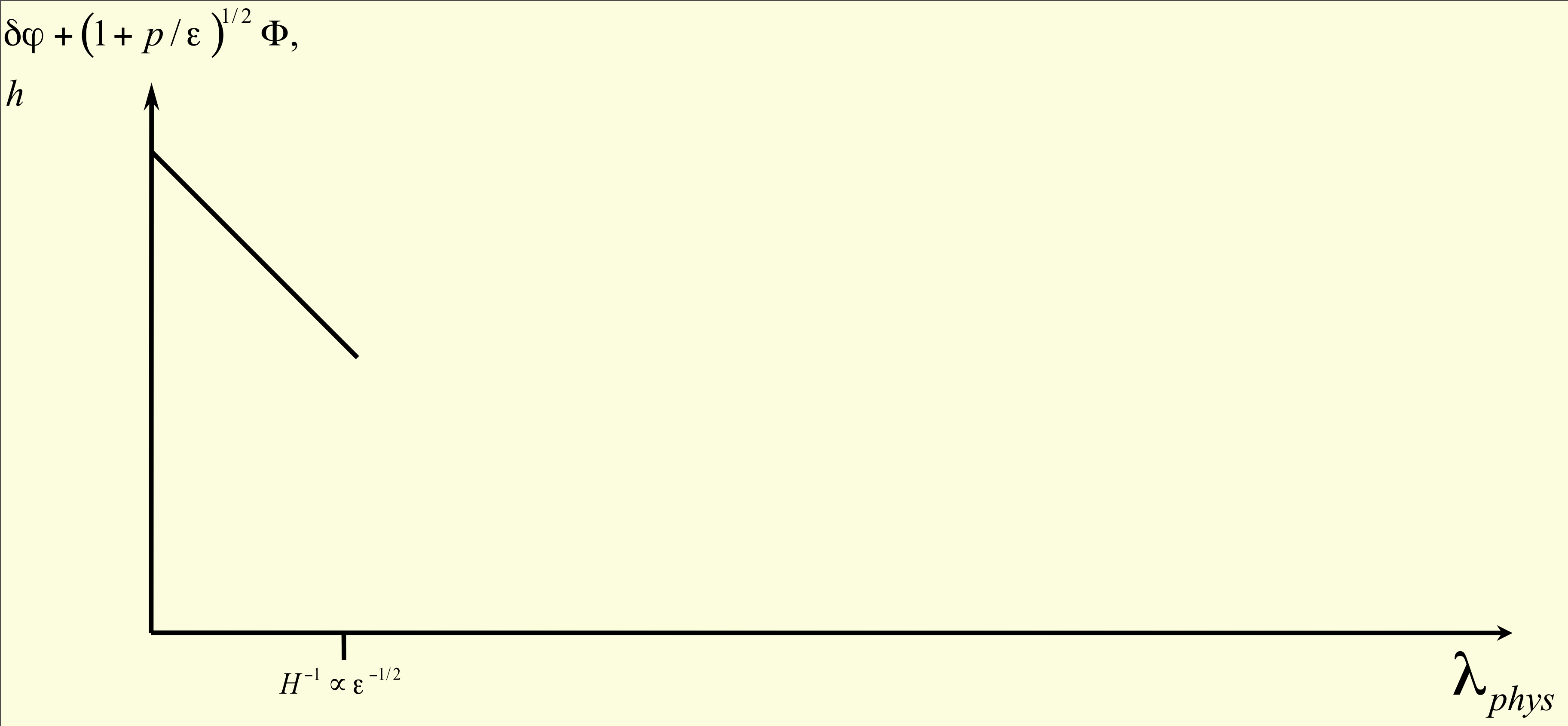

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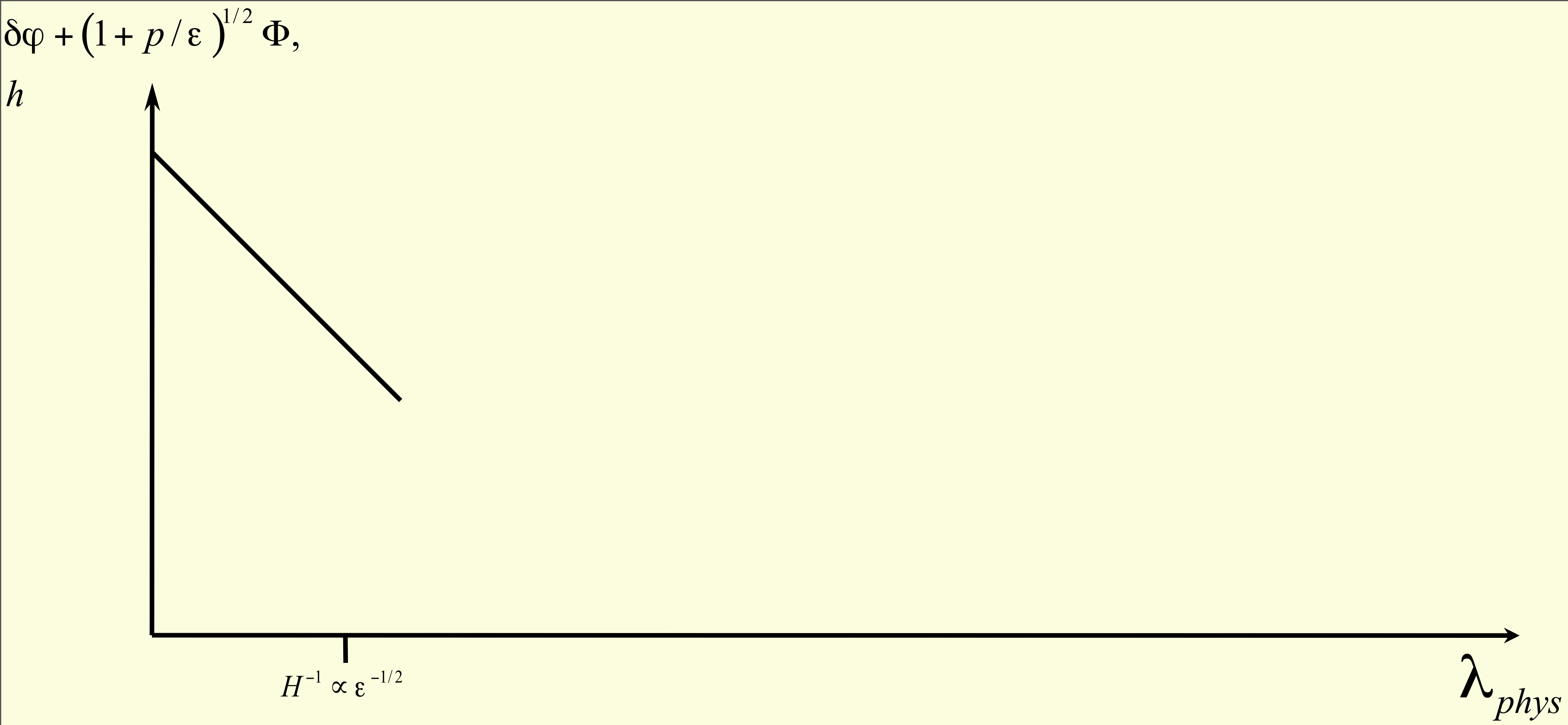
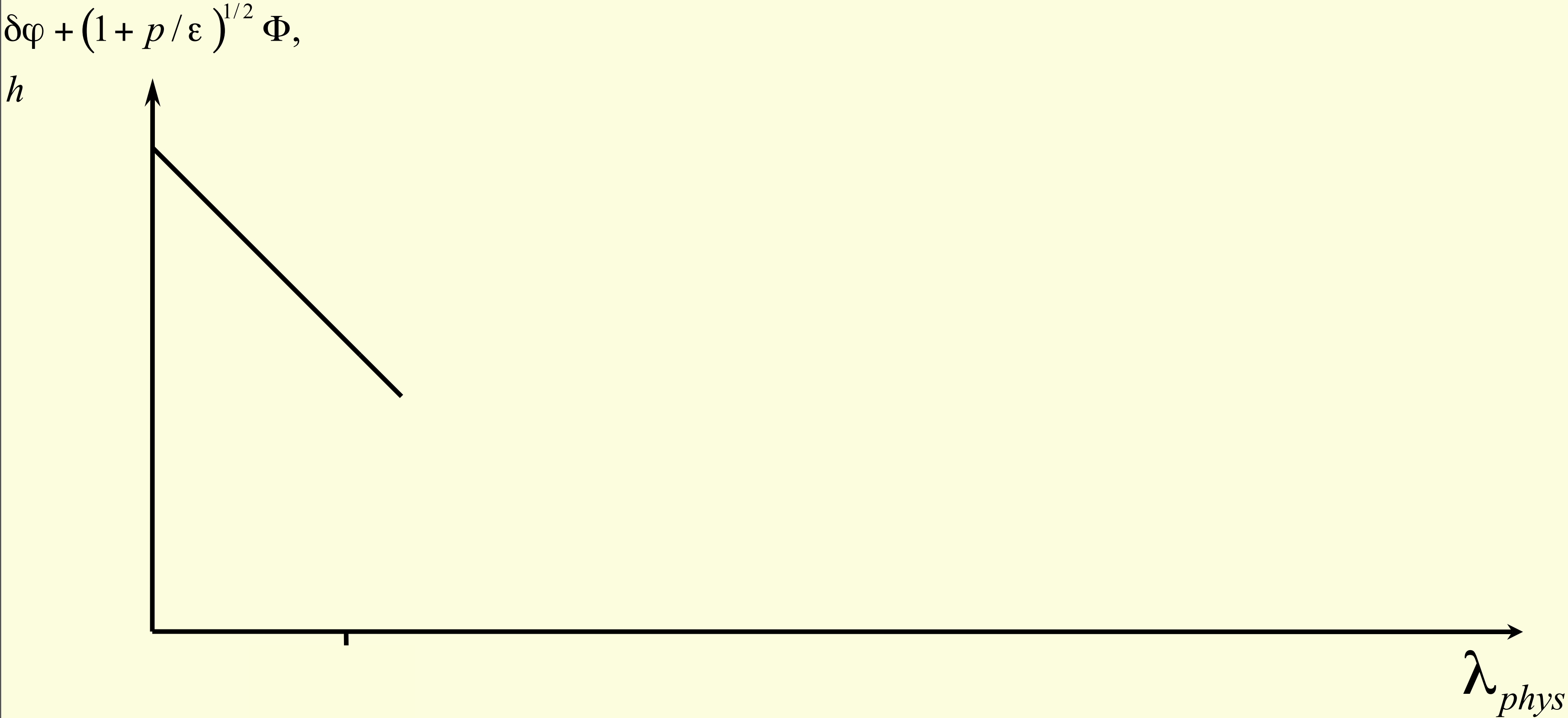
$H^{-1} \propto \varepsilon^{-1/2}$
λ_{phys}


$\delta\varphi + \left(1 + p/\varepsilon\right)^{1/2}\Phi,$
h
$H^{-1} \propto \varepsilon^{-1/2}$
λ_{phys}



$\delta\varphi + (1 + p/\varepsilon)^{1/2}\,\Phi,$
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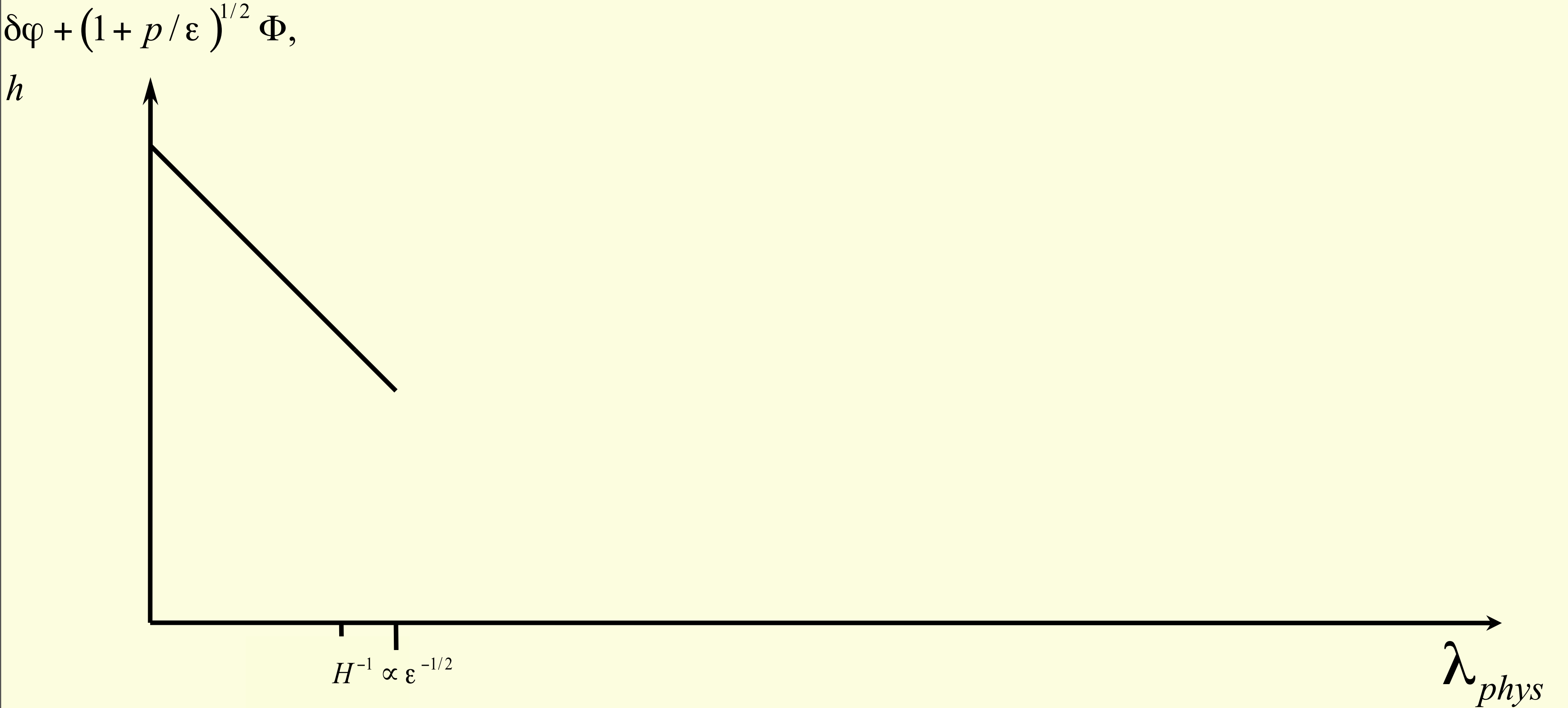

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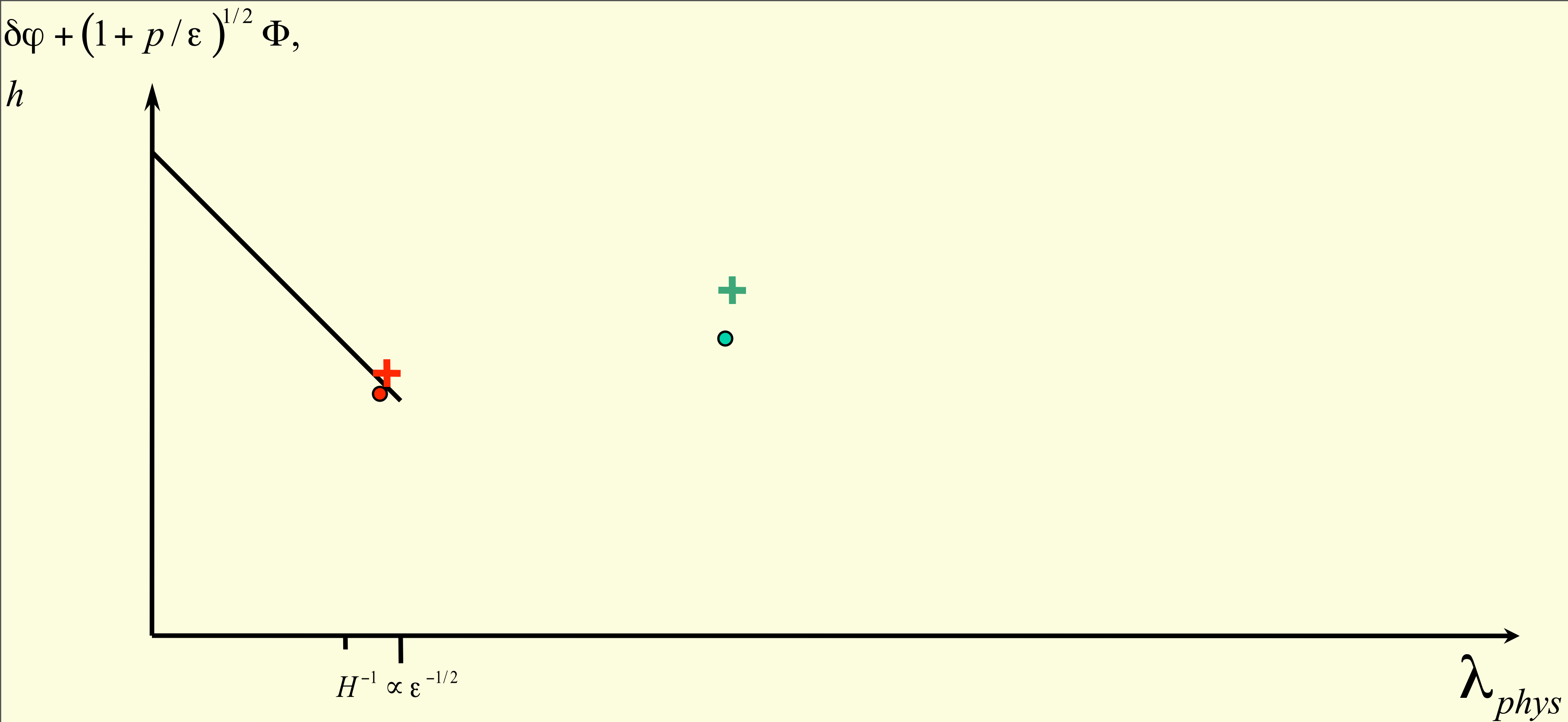

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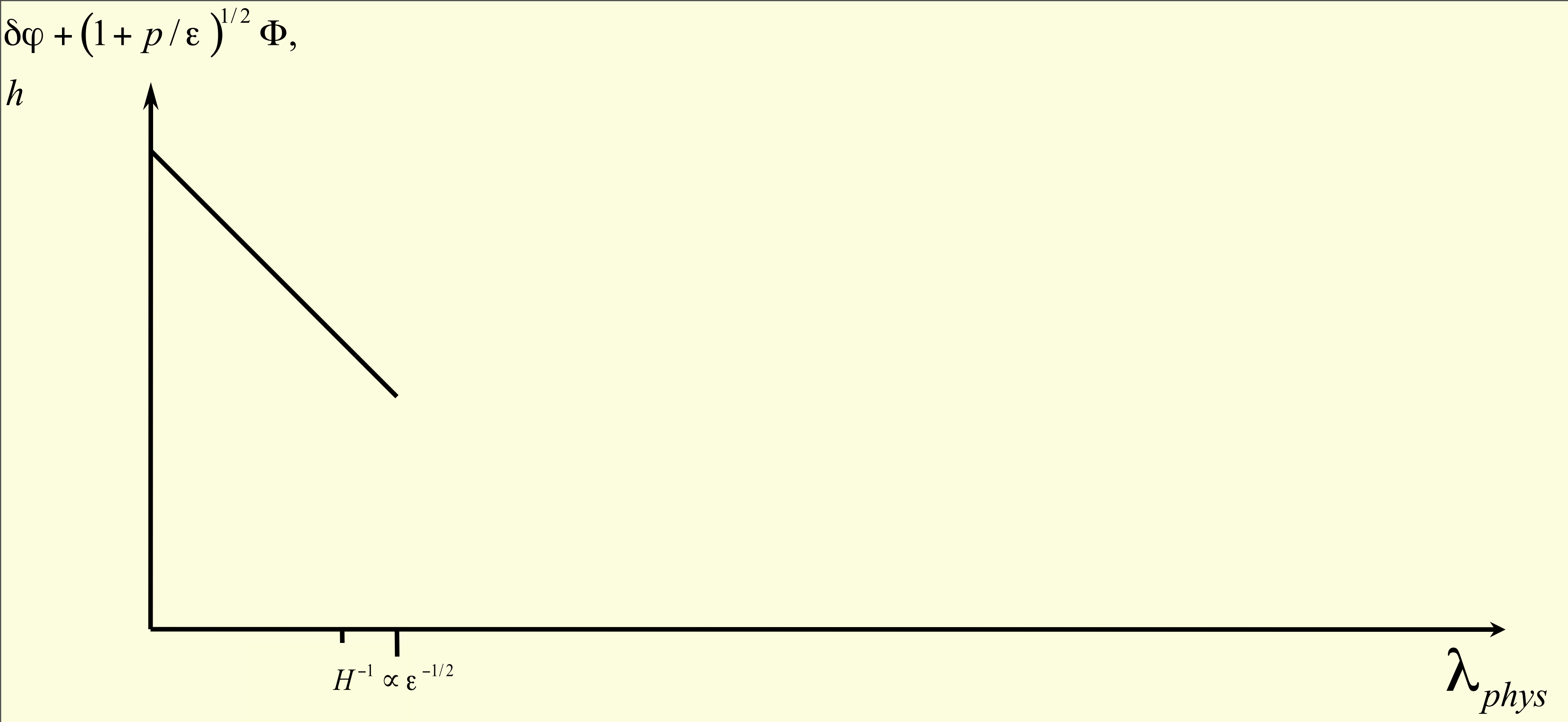
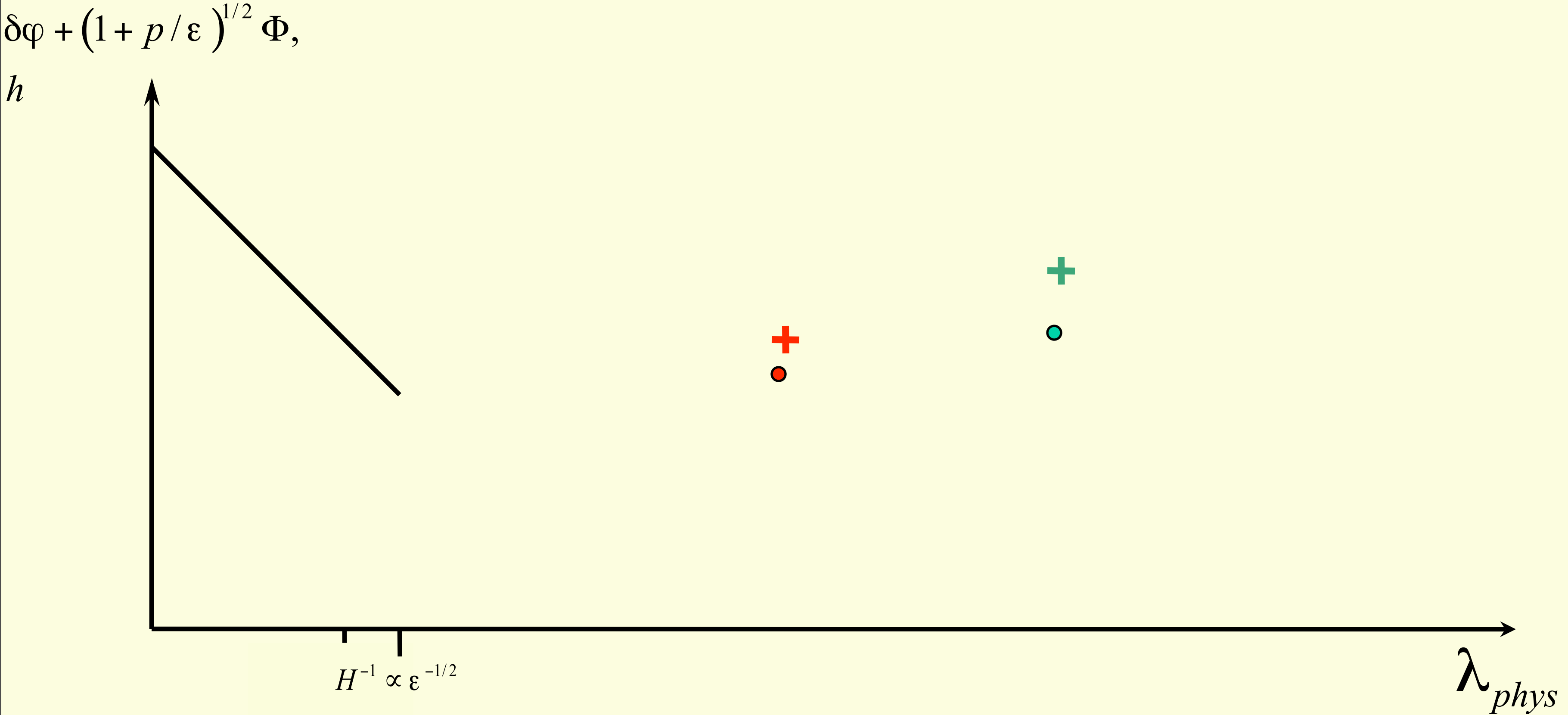


$\delta\varphi + (1 + p/\varepsilon)^{1/2}\,\Phi,$
h
$H^{-1} \propto \varepsilon^{-1/2}$
λ_{phys}



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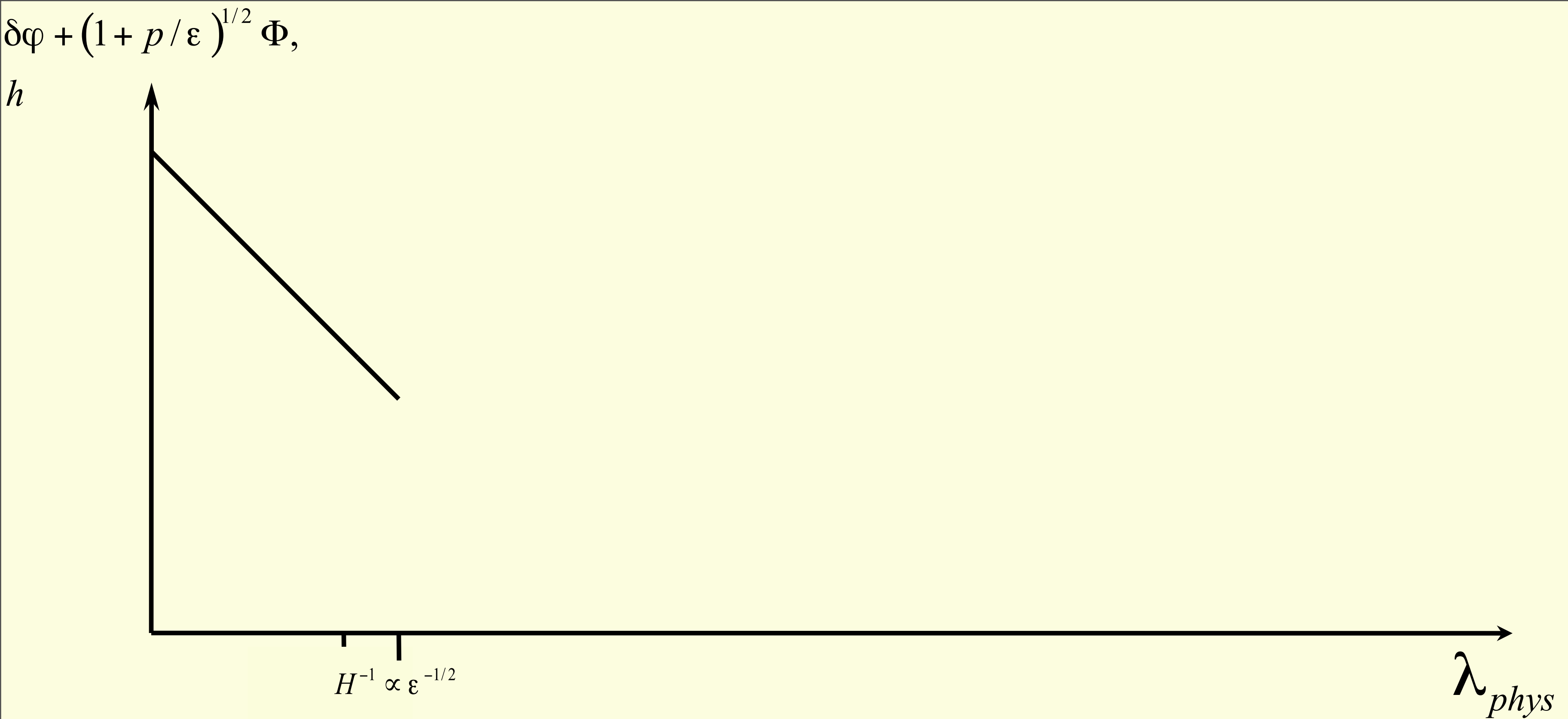
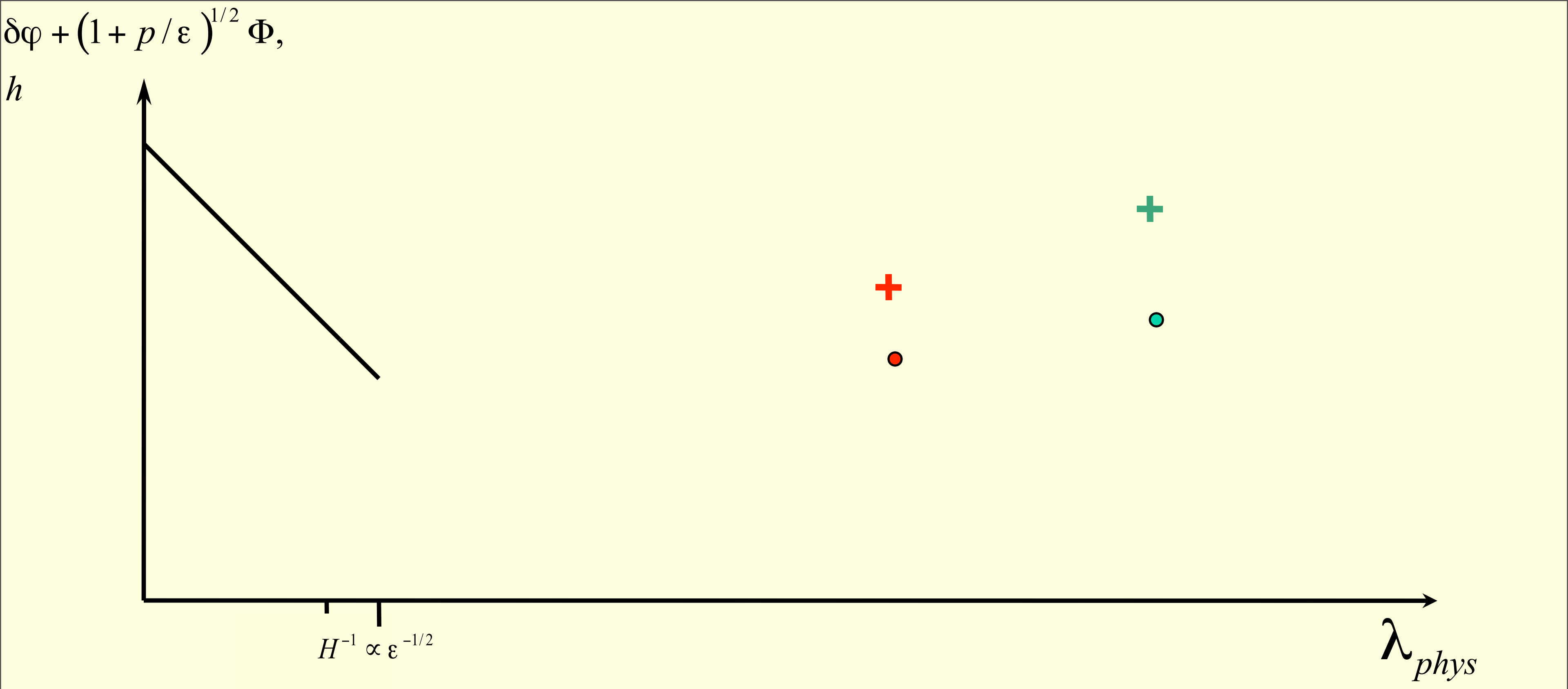
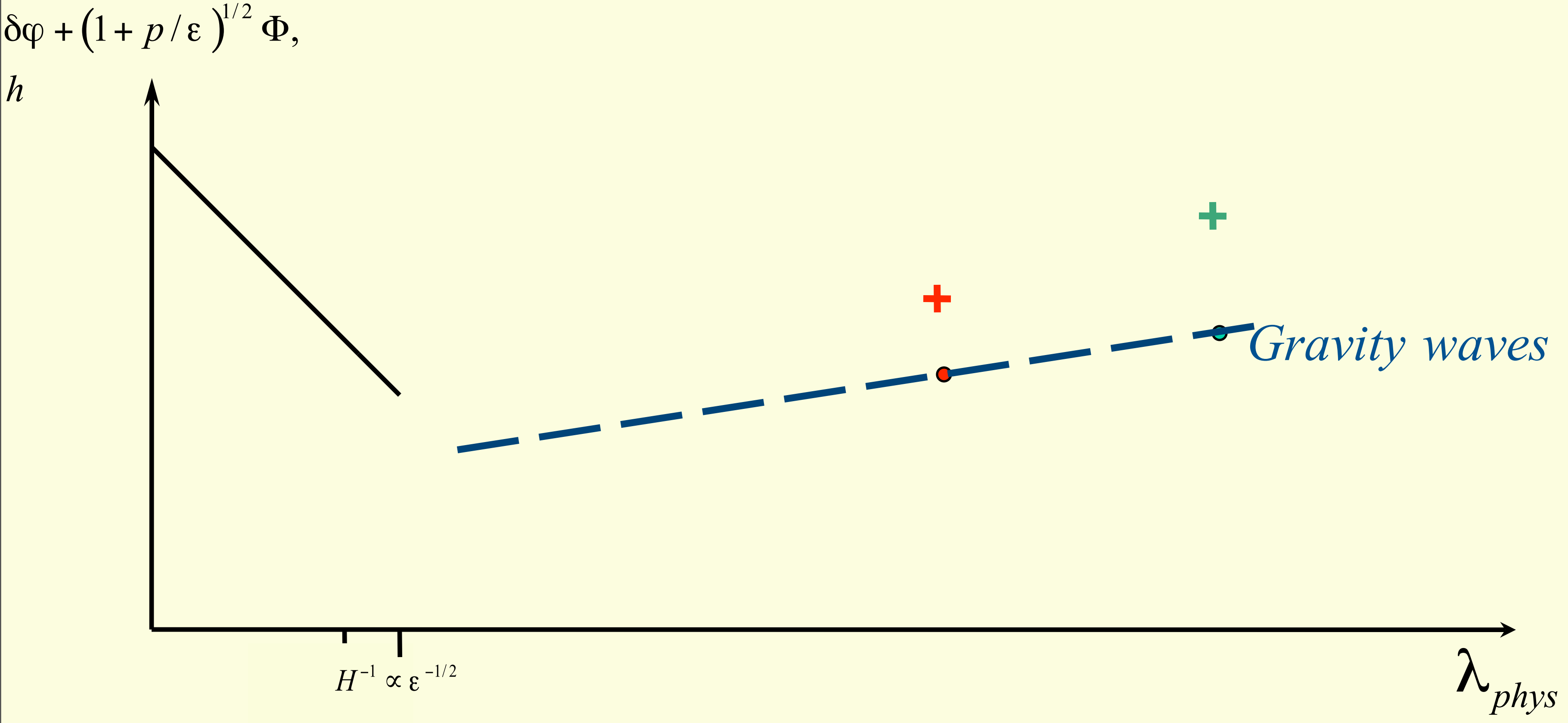
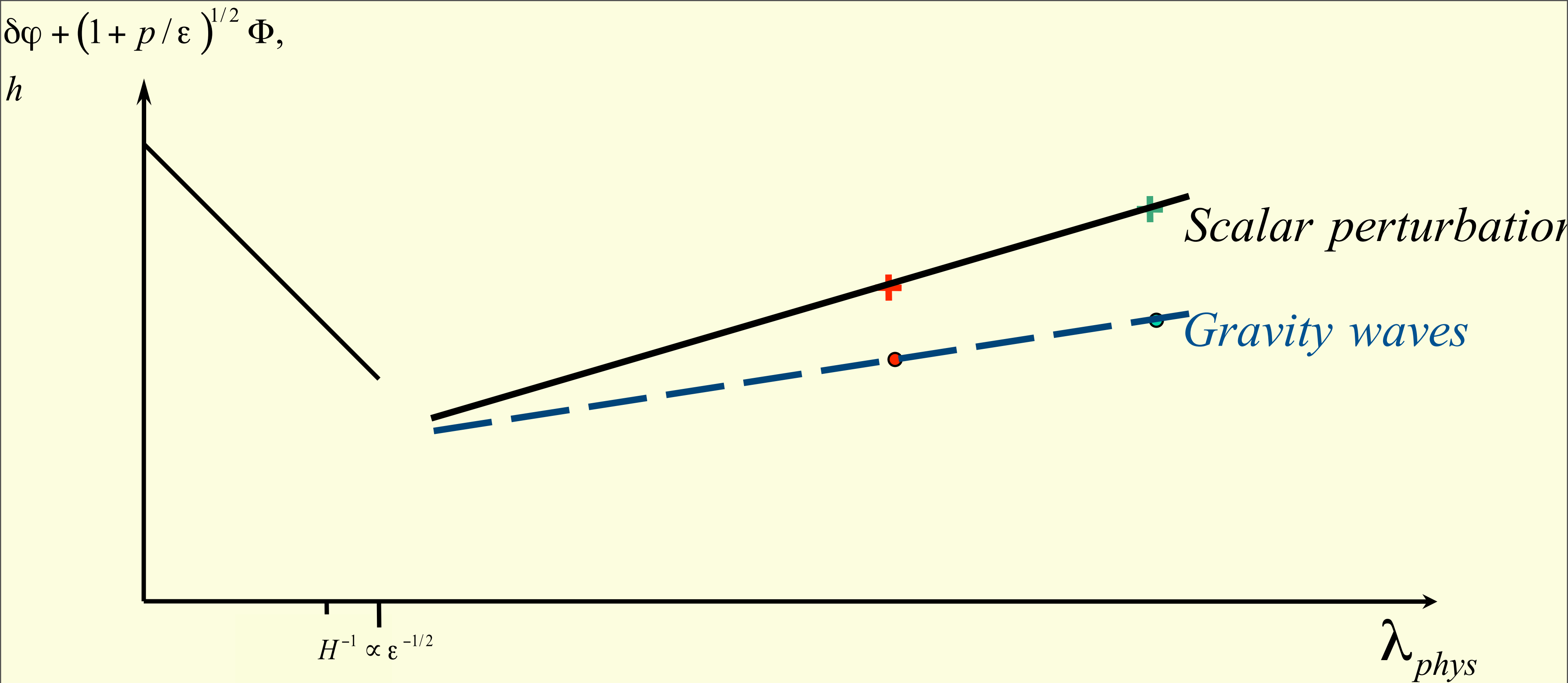

$\delta\varphi + (1 + p/\varepsilon)^{1/2}\,\Phi,$
h
$H^{-1} \propto \varepsilon^{-1/2}$
λ_{phys}

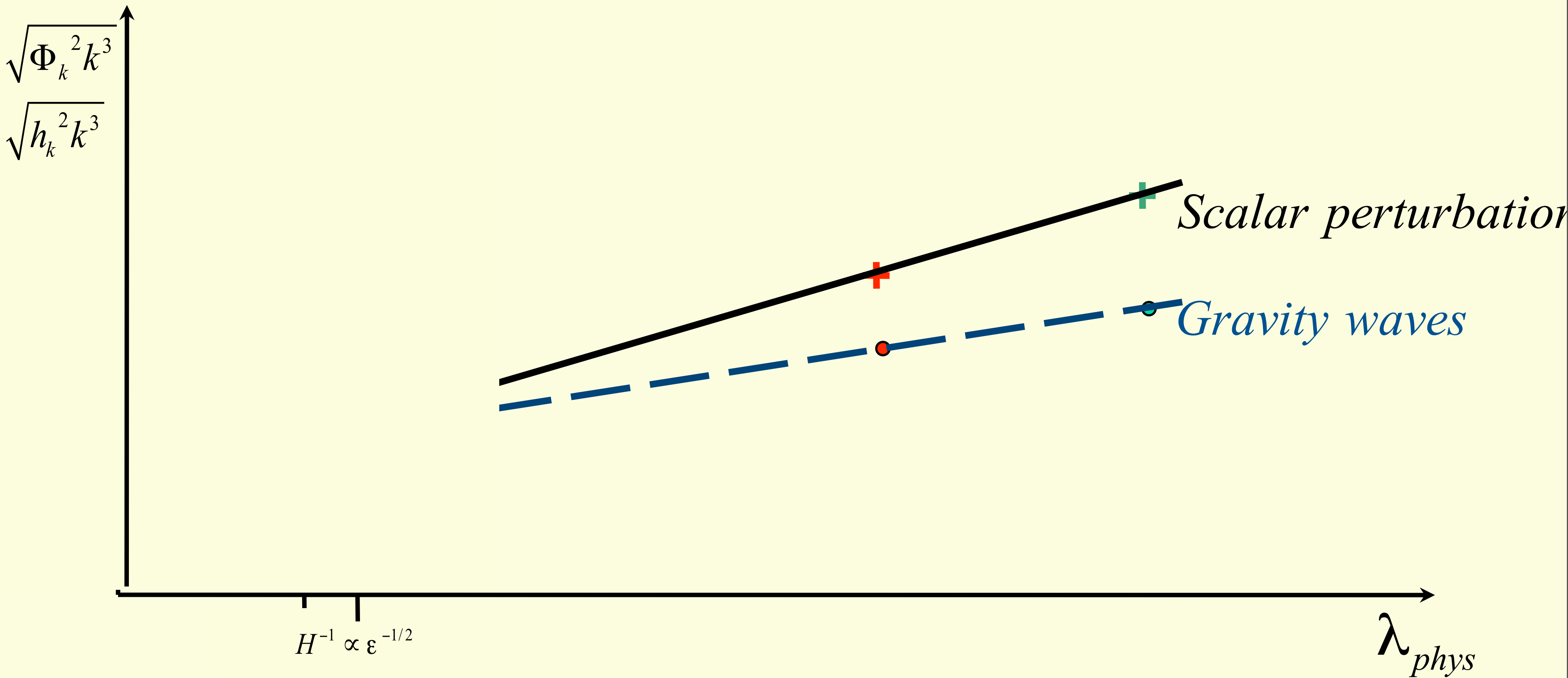

$\delta\varphi + (1 + p/\varepsilon)^{1/2}\,\Phi,$
h
$H^{-1} \propto \varepsilon^{-1/2}$
λ_{phys}



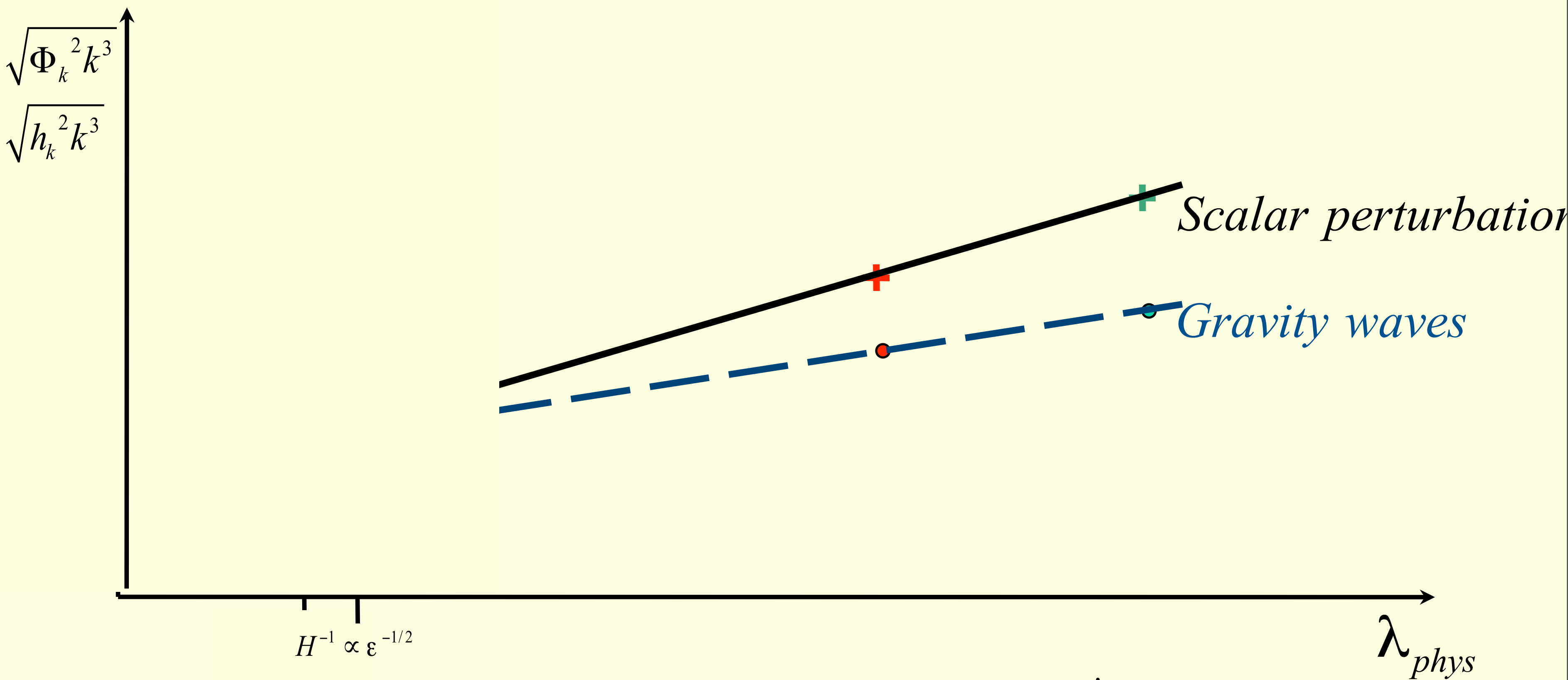
$\delta\varphi + (1 + p/\varepsilon)^{1/2}\Phi$,
h
Gravity waves
$H^{-1} \propto \varepsilon^{-1/2}$
λ_{phys}



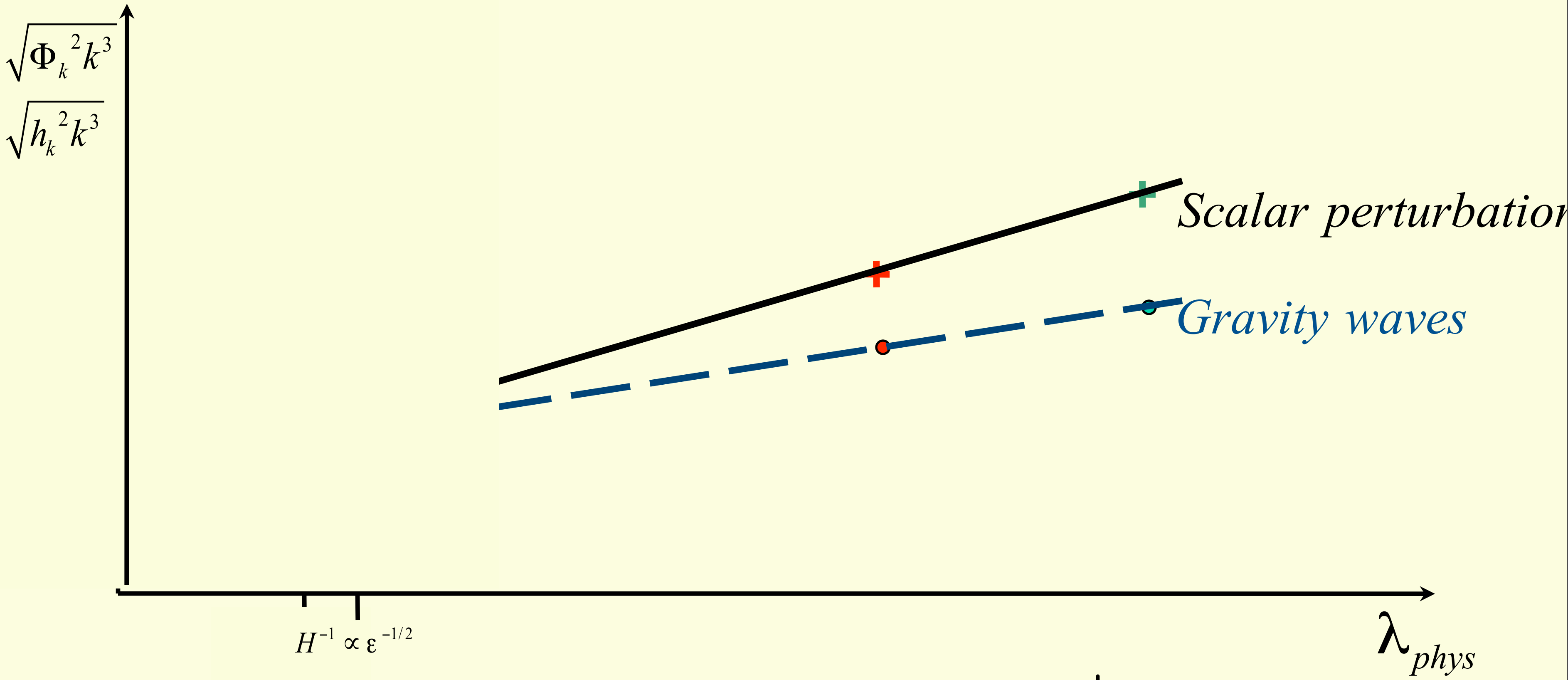
δφ + (1 + p / ε)^1/2 Φ,
h
Scalar perturbation
Gravity waves
H^−1 ∝ ε^−1/2
λ_phys



$\sqrt{\Phi_k^{\ 2} k^3}$
$\sqrt{h_k^{\ 2} k^3}$
Scalar perturbation
Gravity waves
$H^{-1} \propto \varepsilon^{-1/2}$
λ_{phys}

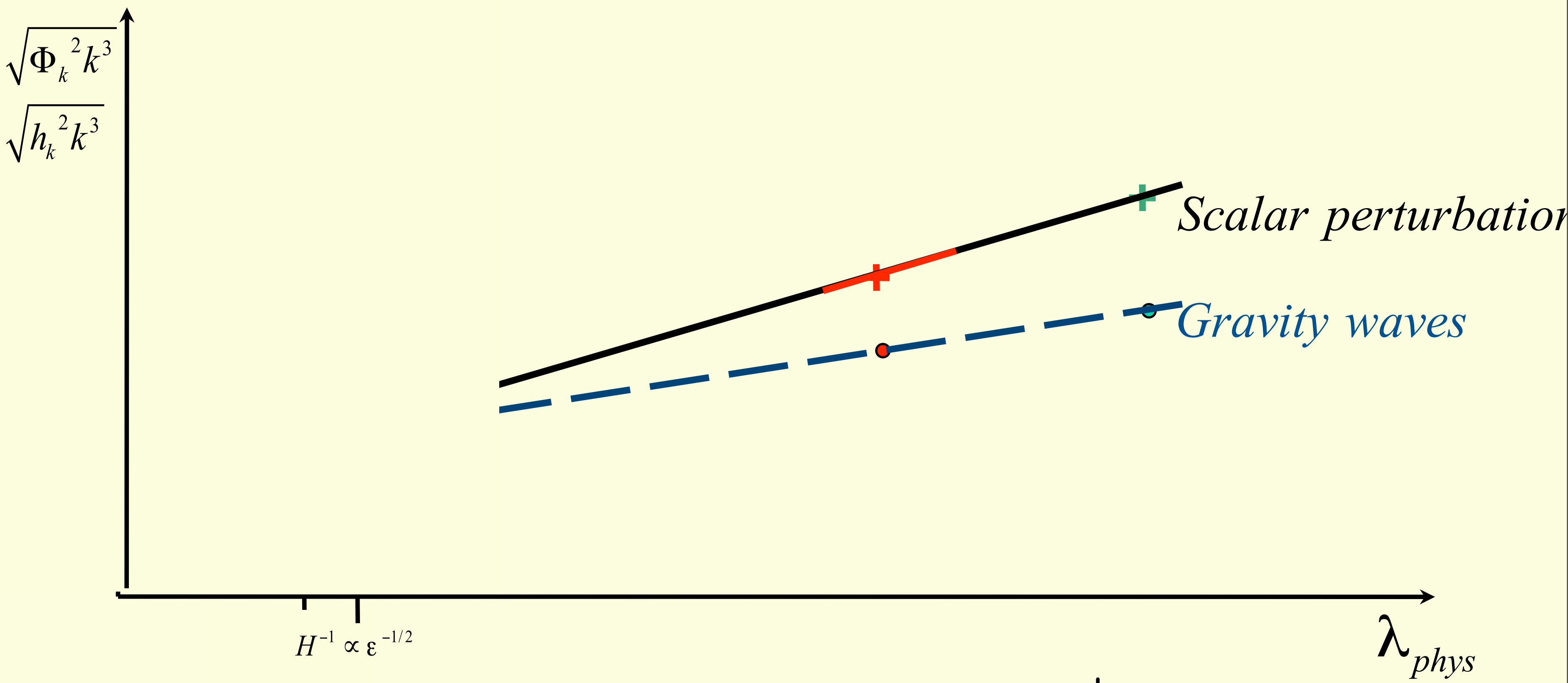


$$\Phi_k^2 k^3 = O(1) \frac{1}{1 + p/\varepsilon} \left(\frac{\varepsilon}{\varepsilon_{Pl}} \right) \Bigg|_{k \approx Ha}$$



$$\Phi_k^{\;2} k^3 = O(1)\frac{1}{1+p/\varepsilon}\left(\frac{\varepsilon}{\varepsilon_{Pl}}\right)\Bigg|_{k\approx Ha}$$

$$h_k^{\;2} k^3 = O(1)\frac{\varepsilon}{\varepsilon_{Pl}}\Bigg|_{k\approx Ha}$$



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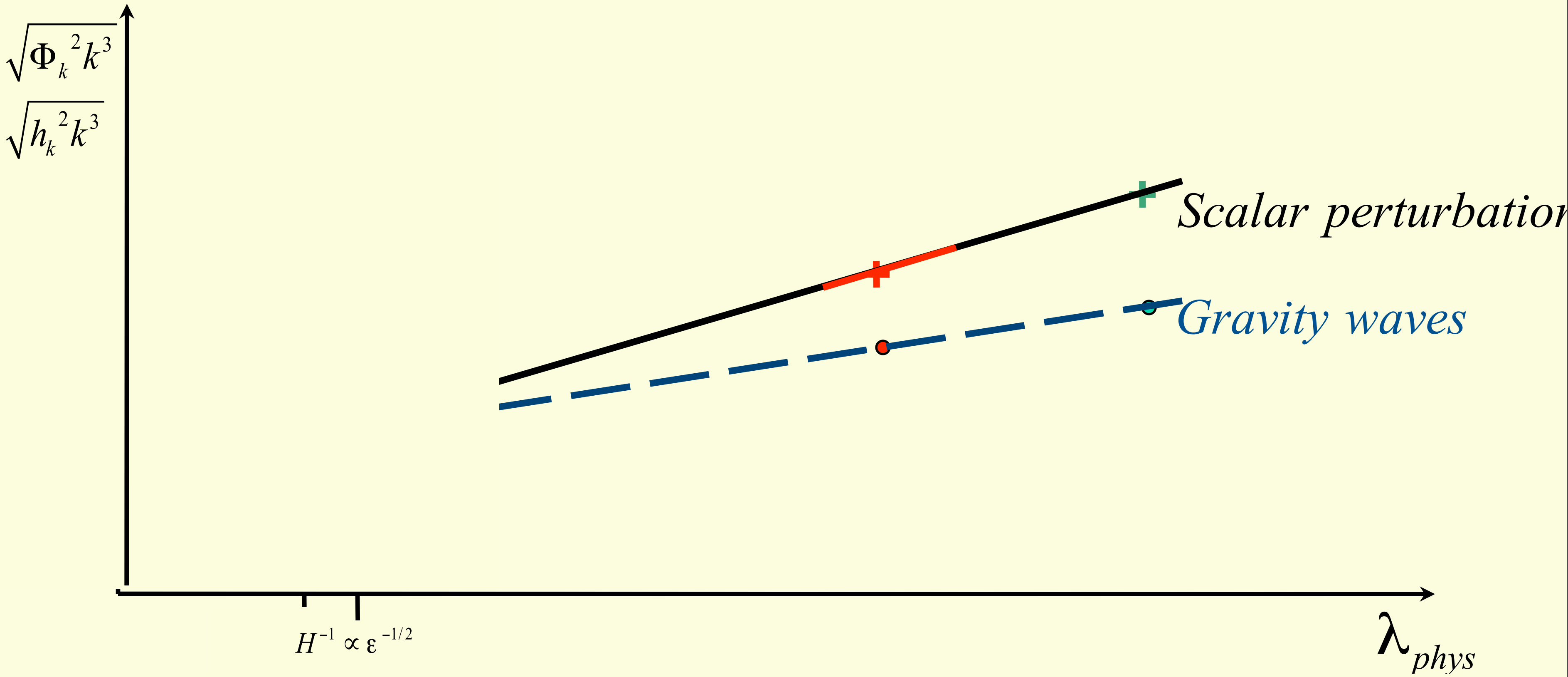
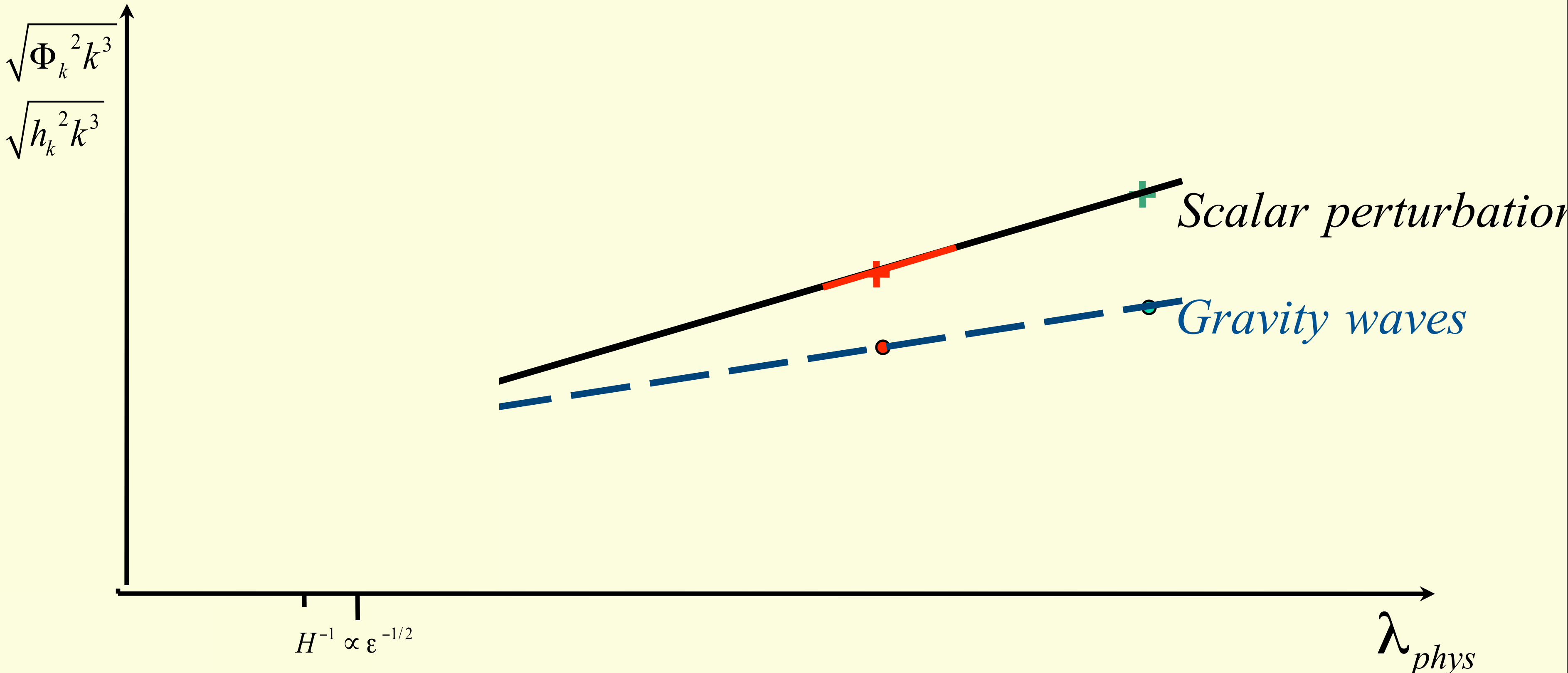


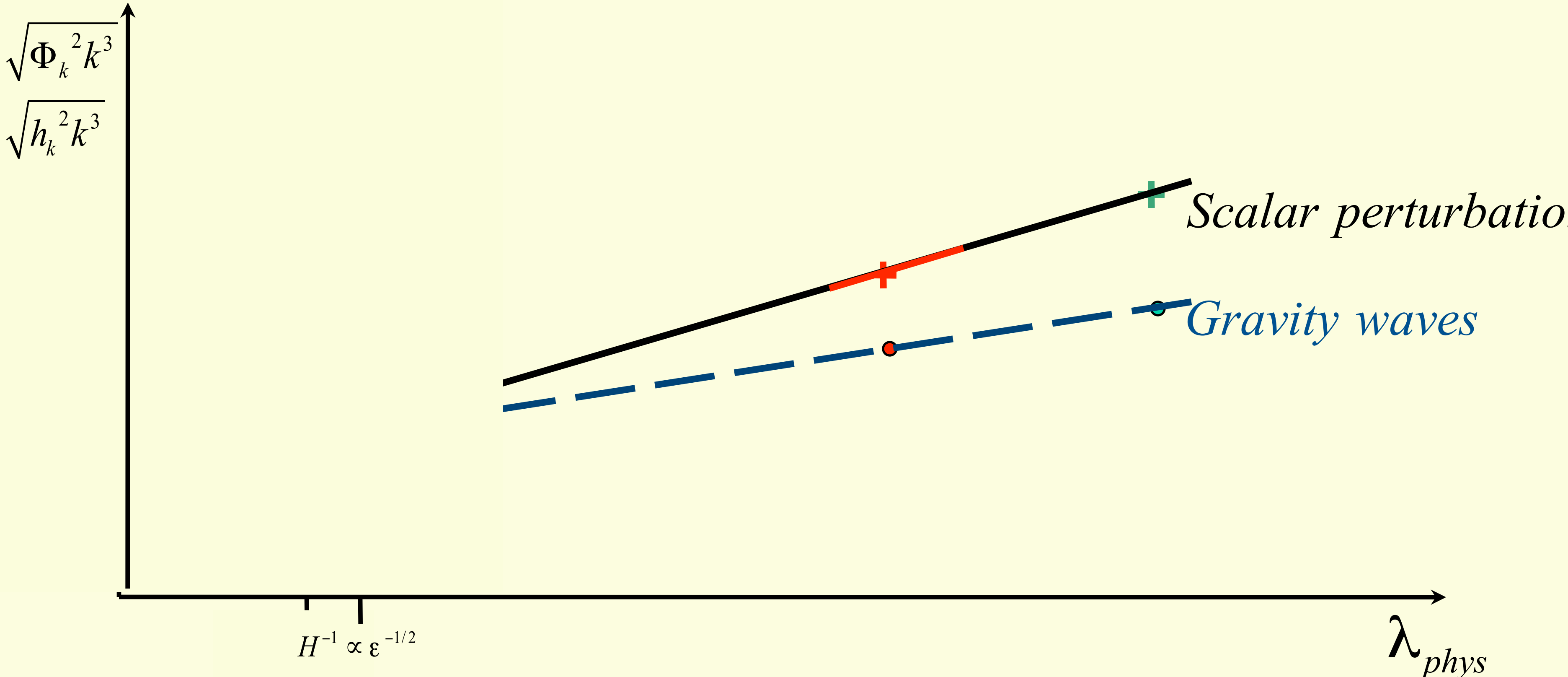
$$n_S - 1 = -3\left(1+\frac{p}{\varepsilon}\right)_{k\approx Ha} + 3\frac{d}{d\ln\varepsilon}\left(1+\frac{p}{\varepsilon}\right)_{k\approx Ha}$$

$$h_k^2 k^3 = O(1)\frac{\varepsilon}{\varepsilon_{Pl}}\bigg|_{k\approx Ha}$$



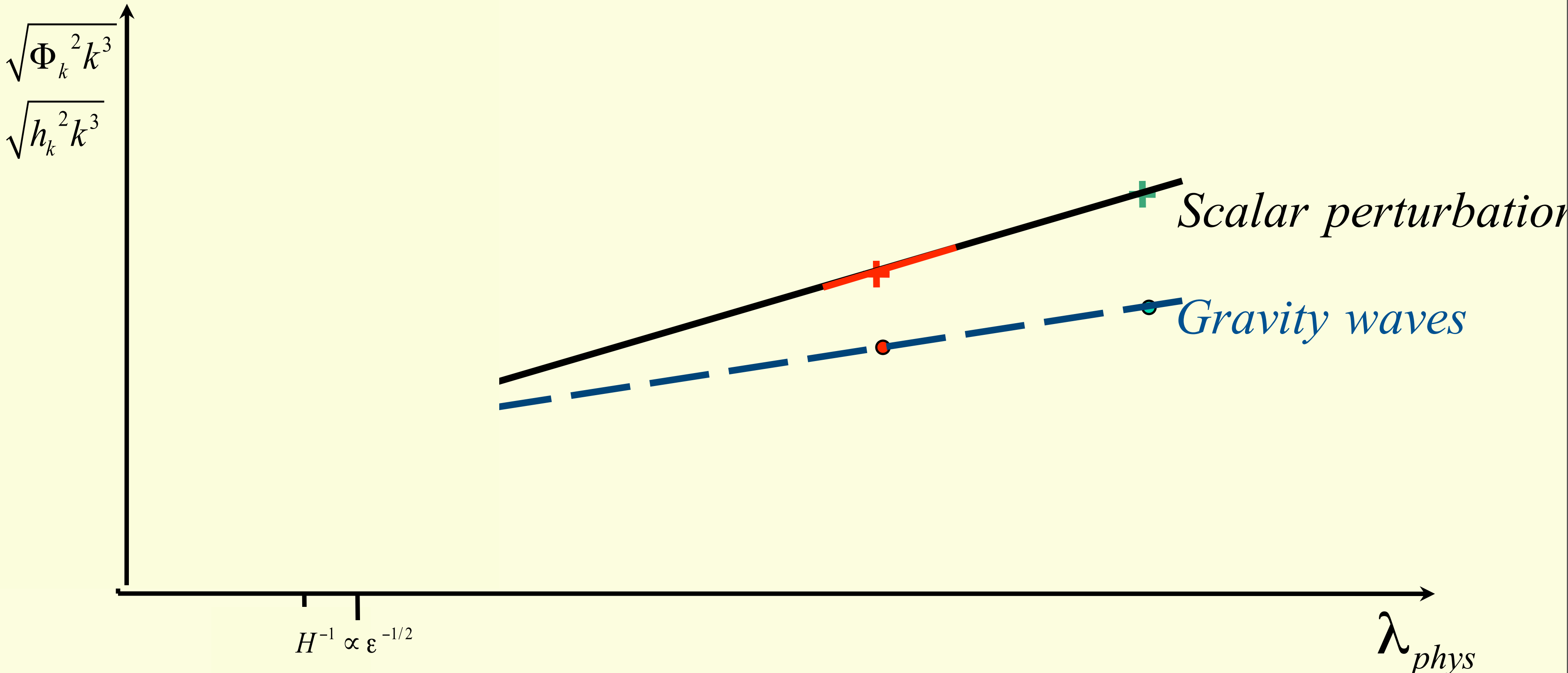
$$n_S - 1 = < 0 + 3 \frac{d}{d \ln \varepsilon} \left(1 + \frac{p}{\varepsilon} \right)_{k \approx Ha}$$

$$h_k^{\,2} k^3 = O(1) \frac{\varepsilon}{\varepsilon_{Pl}} \Bigg|_{k \approx Ha}$$



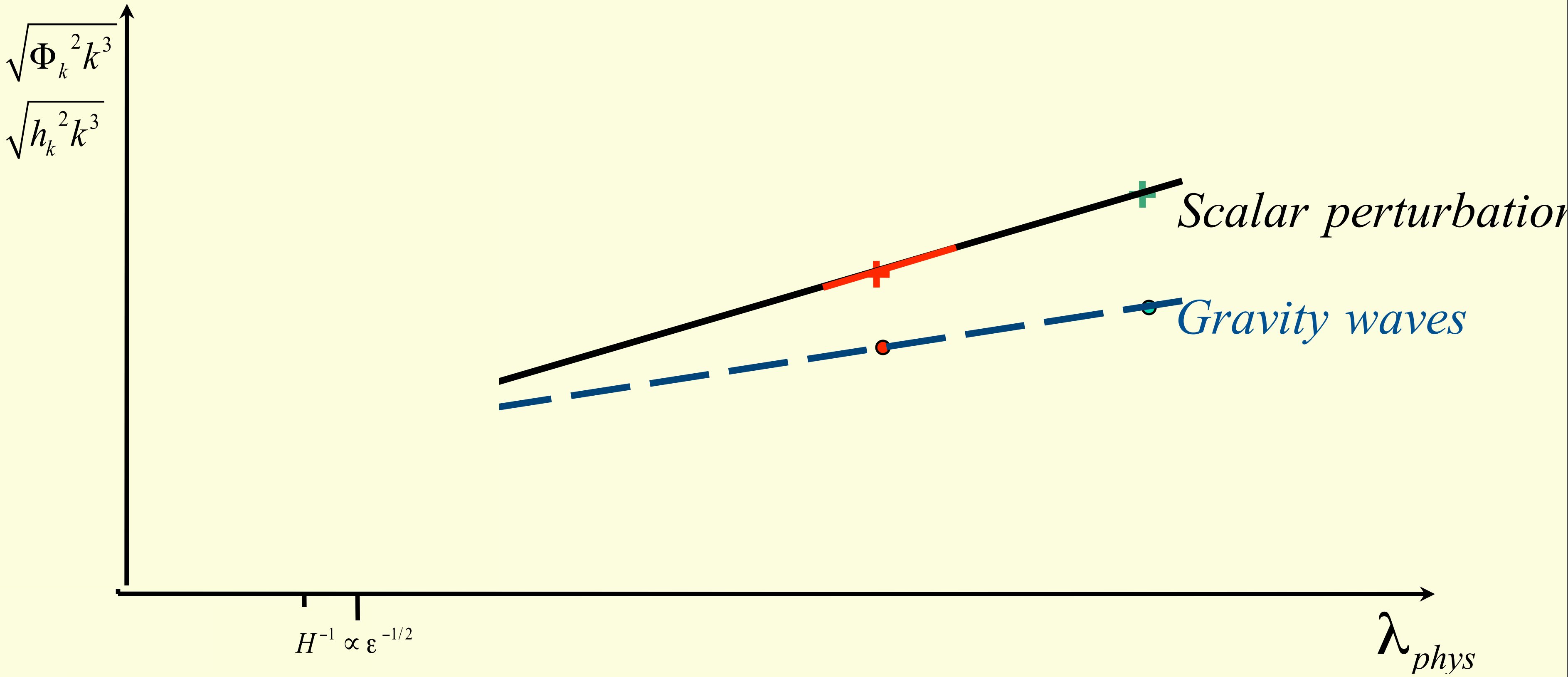
$n_S - 1 =$ < 0 < 0

$$h_k^2 k^3 = O(1) \left.\frac{\varepsilon}{\varepsilon_{Pl}}\right|_{k \approx Ha}$$



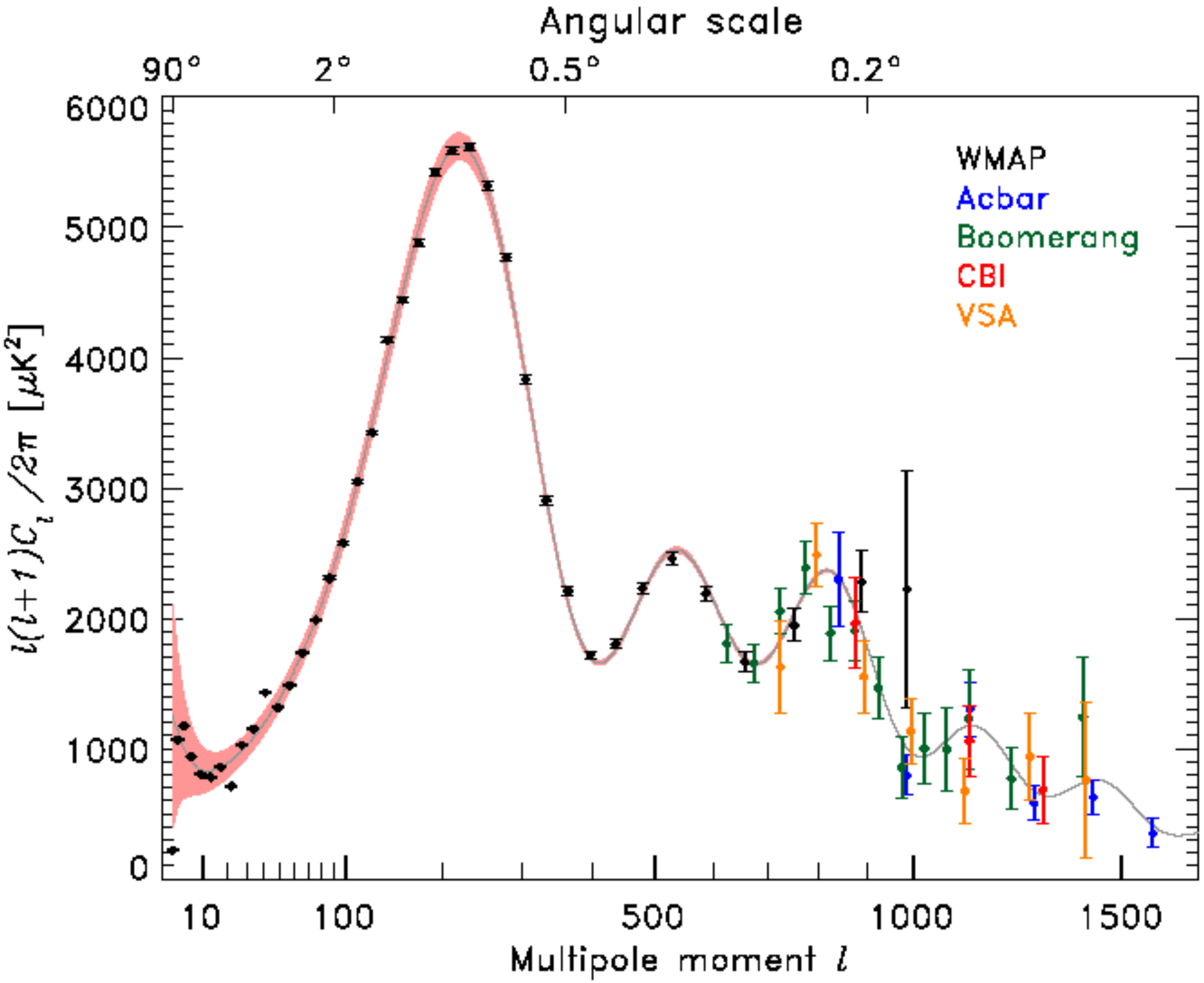
$$0.92 < n_S < 0.97$$

$$h_k^2 k^3 = O(1) \frac{\varepsilon}{\varepsilon_{Pl}} \Big|_{k \approx Ha}$$



$$0.92 < n_S < 0.97$$

$$h_k^2 k^3 = O(1)\left.\frac{\varepsilon}{\varepsilon_{Pl}}\right|_{k\approx Ha} \qquad \frac{T}{S} = O(1)\left(1+\frac{p}{\varepsilon}\right)^{1/2}_{k\approx Ha}$$


Angular scale
90°
2°
0.5°
0.2°
6000
5000
4000
3000
2000
1000
0
WMAP
Acbar
Boomerang
CBI
VSA
l(l+1)C_l /2π [μK²]
10
100
500
1000
1500
Multipole moment l

"A finite duration of the de Sitter stage does not by itself rule out the possibility that this stage may exist as an intermediate stage in the evolution of the universe. An interesting question arises here: Might not perturbations of the metric , which would be sufficient for the formation of galaxies and galactic clusters, arise in this stage?..........

$$Q(k) \approx 3lM\left(1+\frac{1}{2}\ln\frac{H}{k}\right)$$

The fluctuation spectrum is... nearly flat...."

(Mukhanov, Chibiov,1981)

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"In models with the initial superdense de Sitter state ... such a large amount of relic gravitational waves is generated
...that ... the very existence of this state can be experimentally"
verified in the near future.
(Starobinsky, 1980)

"What really interests me is whether God had any choice when he created the World"

A. Einstein

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Inflation was inevitable!!! (it is unique opportunity to create World starting from generic initial conditions with minimal efforts)

What was before inflation?

God creates new worlds constantly (Zohar)

In the beginning was the Word, and the Word was with God,and the Word was God (The Holy Gospel St.John)

Big Brain Theory: Have cosmologists lost theirs?
(NYT, Jan. 15, 2008)