Supercooling from New Strong Physics Reheating from Old One

Pietro Baratella

IFAE

Standard Model of particle physics: where do masses come from?

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From the Higgs!

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From the Higgs!

But not just, and not mainly...

(known) Matter in the Universe:

- neutrinos $\sim 3\%$
- protons $\sim 85\%$
- neutrons $\sim 12\%$
- electrons $\ll 1\%$

"Higgs-given" mass of elementary particles:

$$m_i = \left(\frac{y_i}{\sqrt{\lambda}} \right) M_H$$

Protons

non elementary: made of 3 quarks

$$m_P \sim GeV \gg (2m_u + m_d) \sim MeV$$

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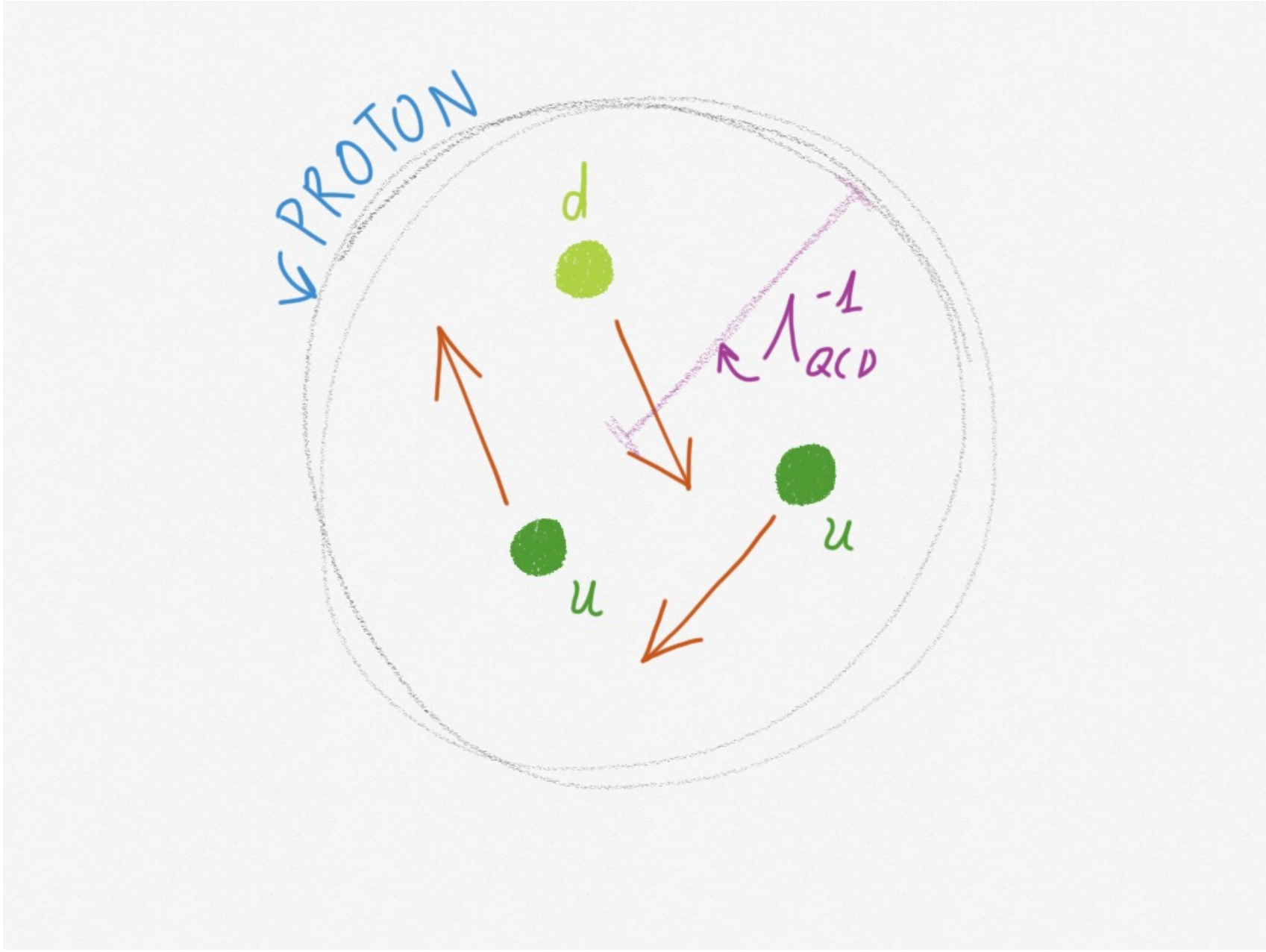
the mass of the proton is given mainly by QCD effects...

(and so the mass of the Universe we know)


PROTON
d
u
u
Λ_{QCD}^{-1}

Are there other independent physical scales?

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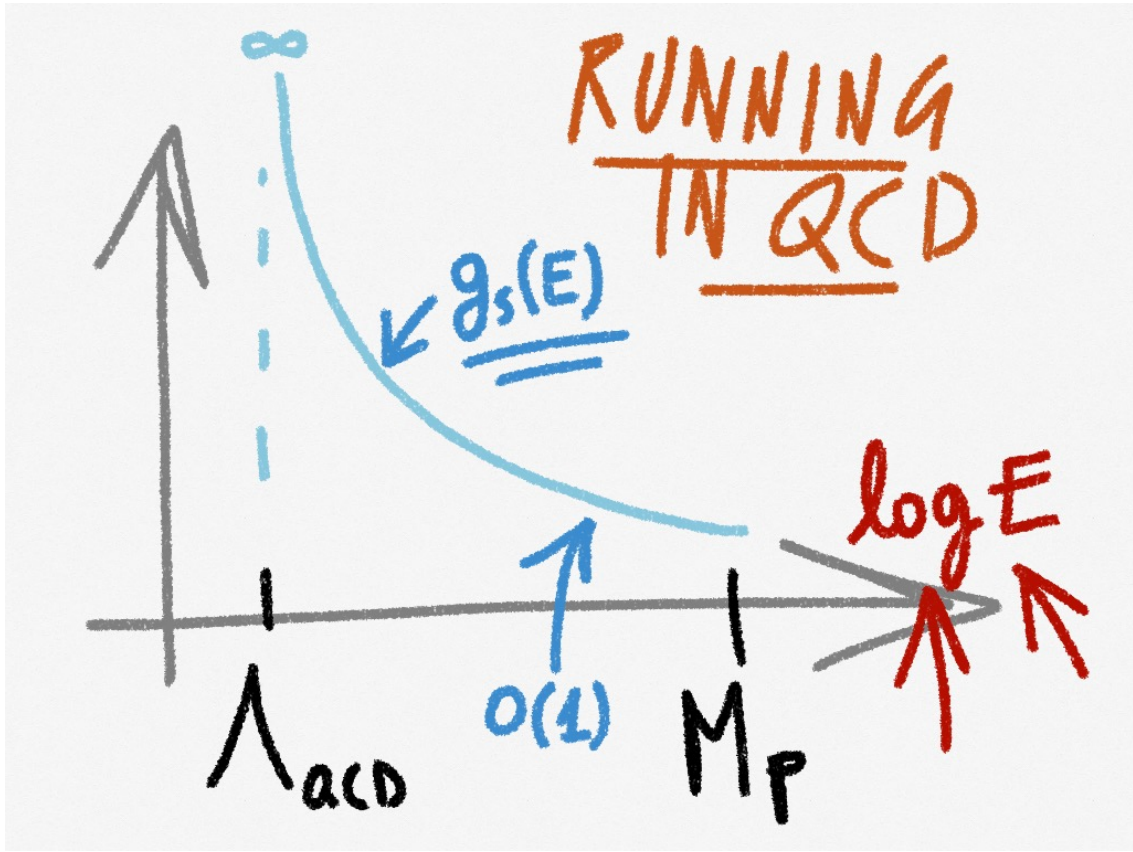
$M_P \equiv$ scale of gravity (it exists!) $\sim G^{-1/2}$

We take M_P as fundamental, and relate M_H and Λ_{QCD} to it ($M_P = 1$)

$$M_H \sim 10^{-16}$$

$$\Lambda_{QCD} \sim 10^{-19}$$

Λ_{QCD} is where strong interactions *become* strong



$$\Lambda_{QCD} = \exp\left(-4\pi/g_s^2(1)\right)$$

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easy to generate small values with $g_s(1) \lesssim 1$

do not have a similar understanding for M_H

SPECULATION: also M_H is generated when a (new) coupling becomes strong

- strong g_s is responsible for QCD resonances
- we expect more particles above $\Lambda_{EW} \equiv M_H$ $(...LHC)$

- QCD phase transition at $T \sim \Lambda_{QCD}$
- we expect a similar phenomenon for $T \sim \Lambda_{EW}$ $(...cosmology)$

Phase transitions are relevant during cosmic evolution

We expect the "EW" one to be very slow

This implies a period of *supercooling* and *inflationary* expansion

difference with respect to the standard case: naturally 1^{st} order and slow

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1. rule out the theory...

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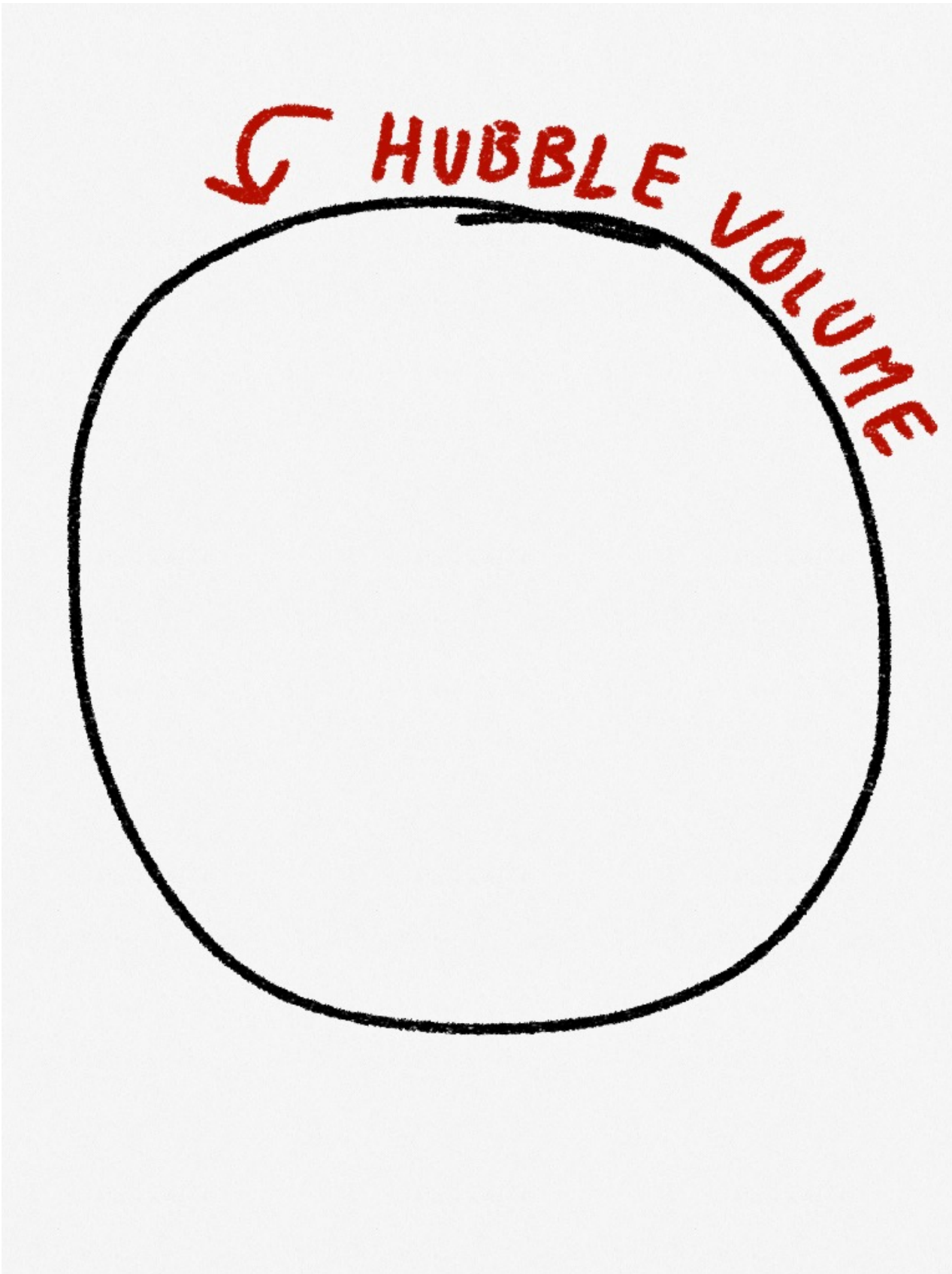
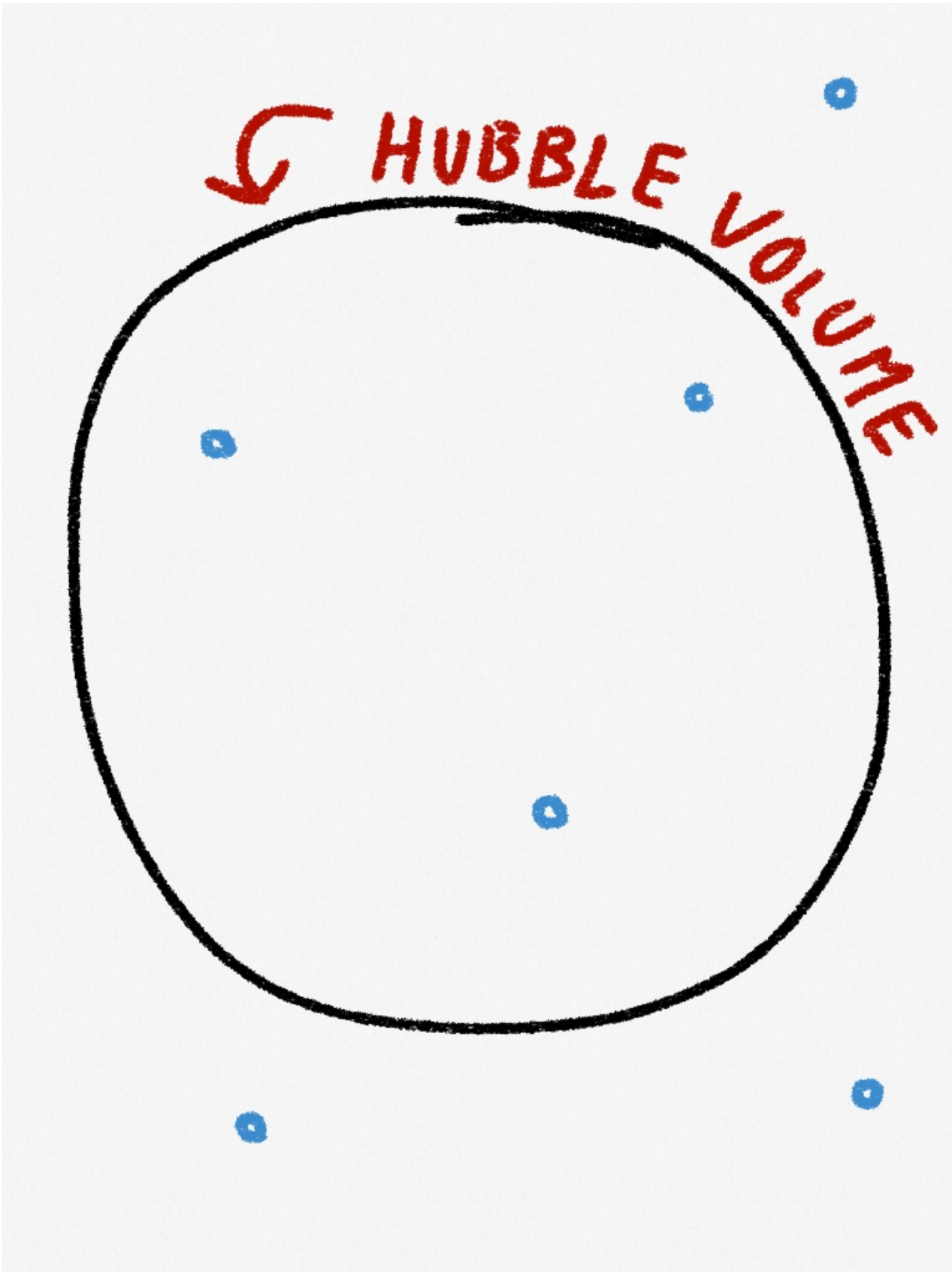
1. rule out the theory...
2. find a way out!


HUBBLE VOLUME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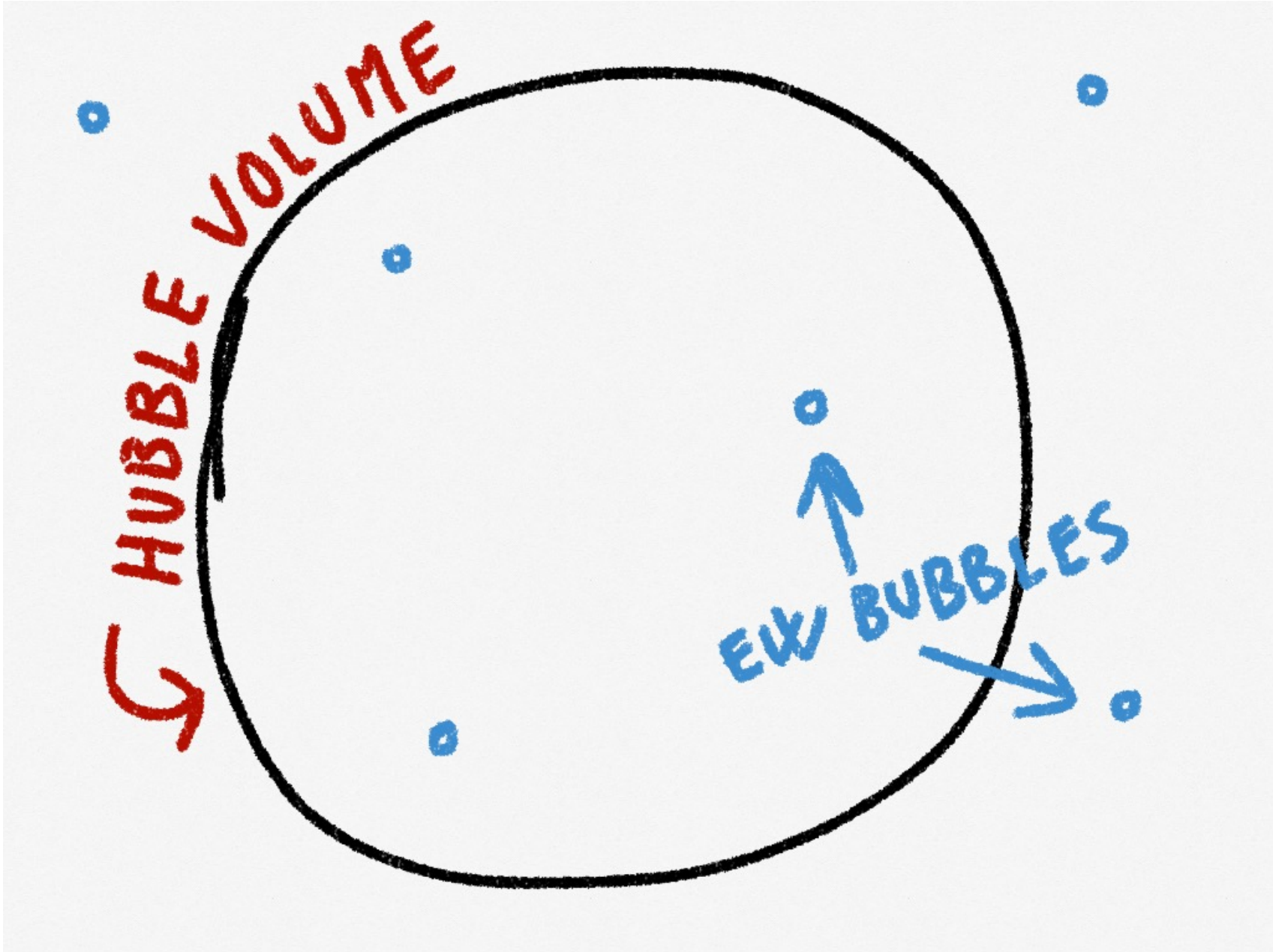
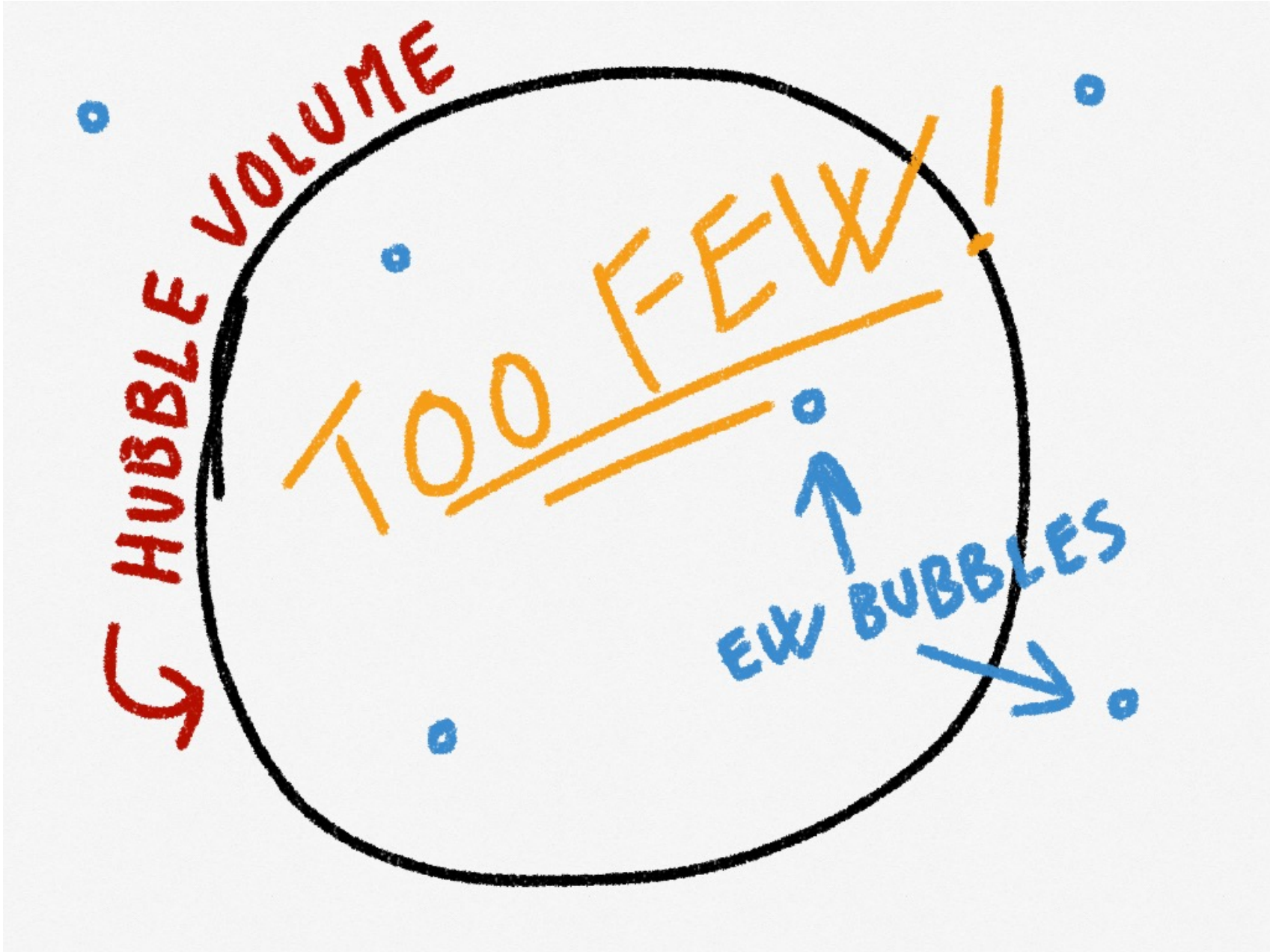
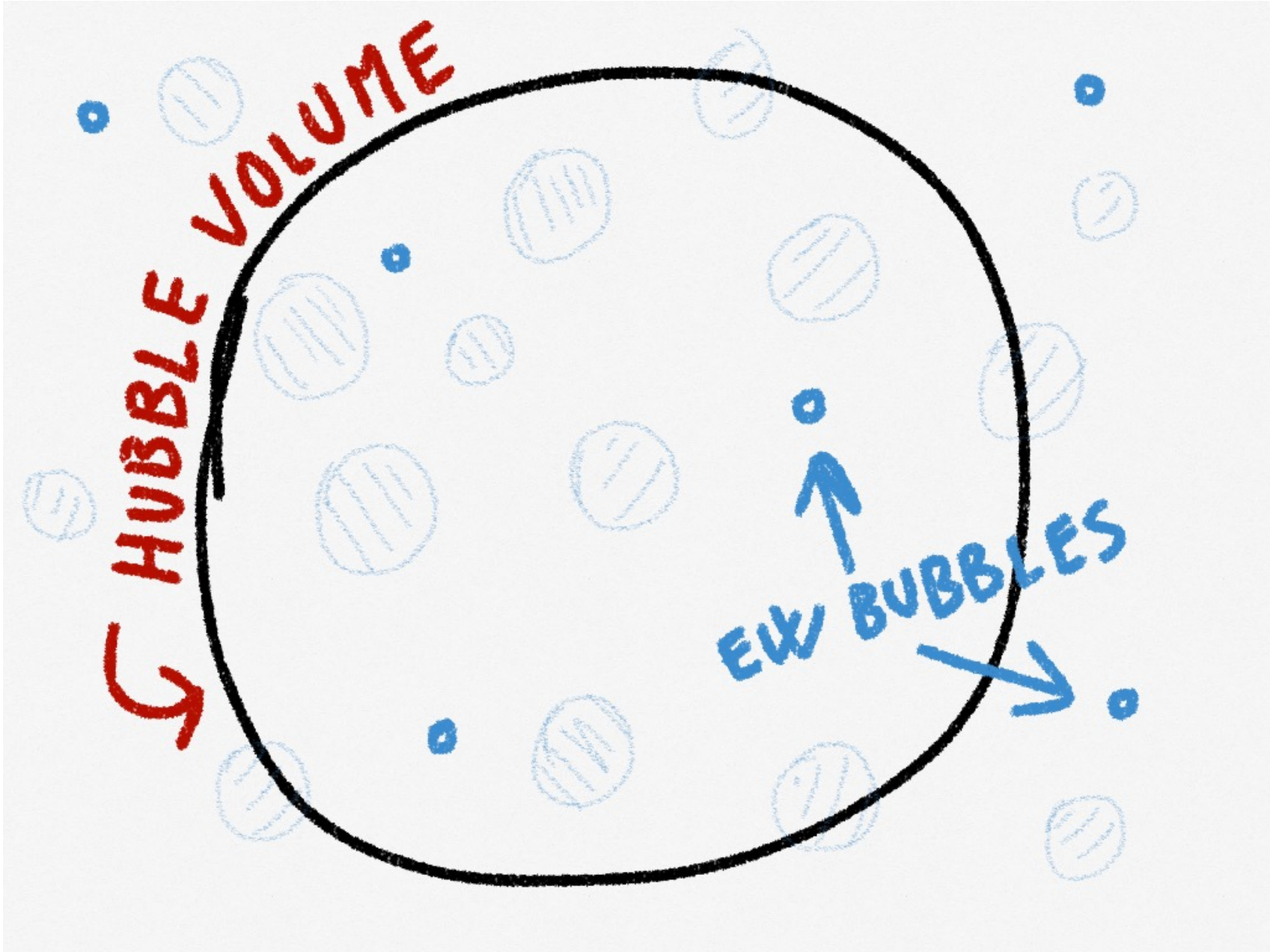
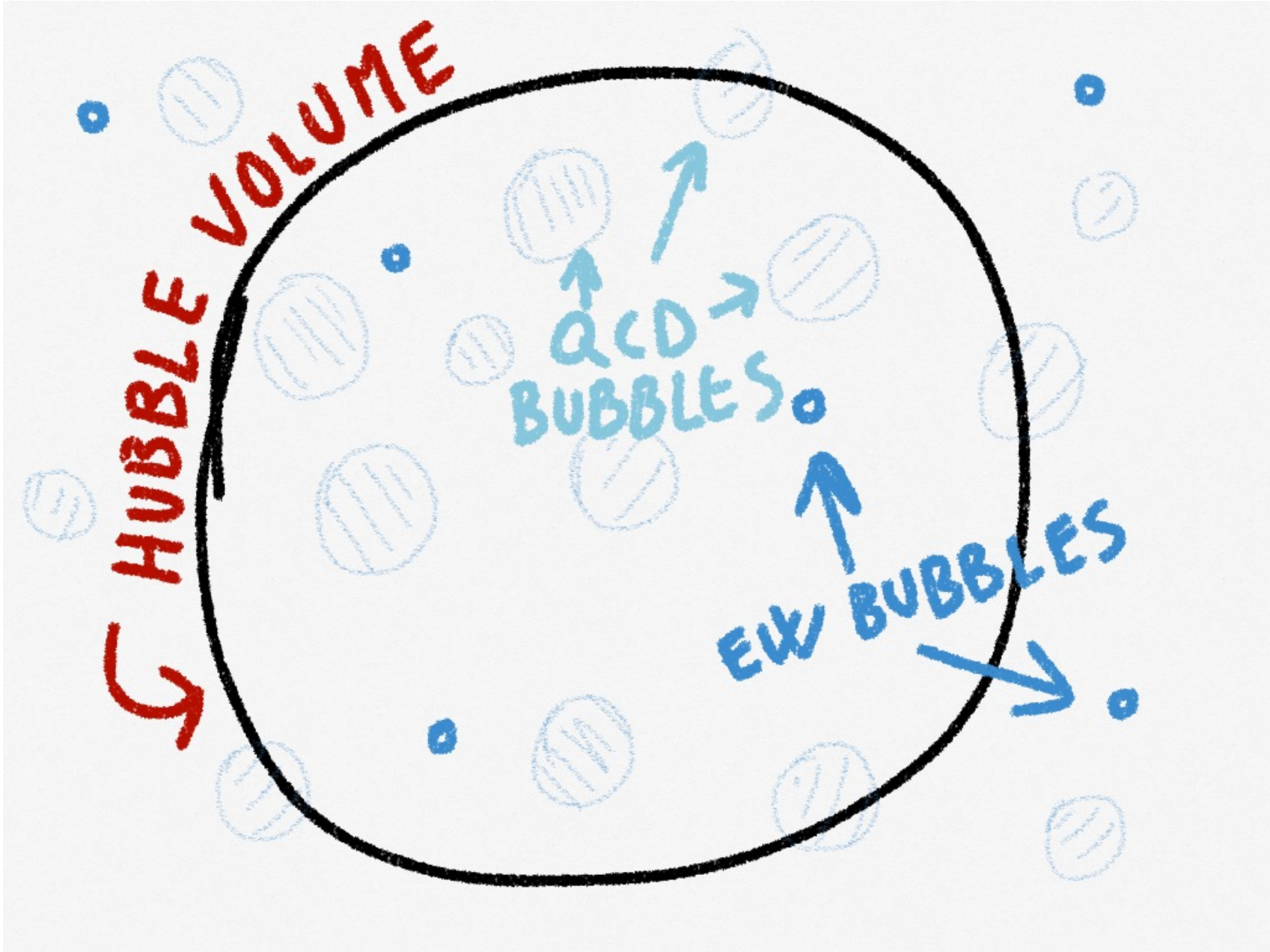
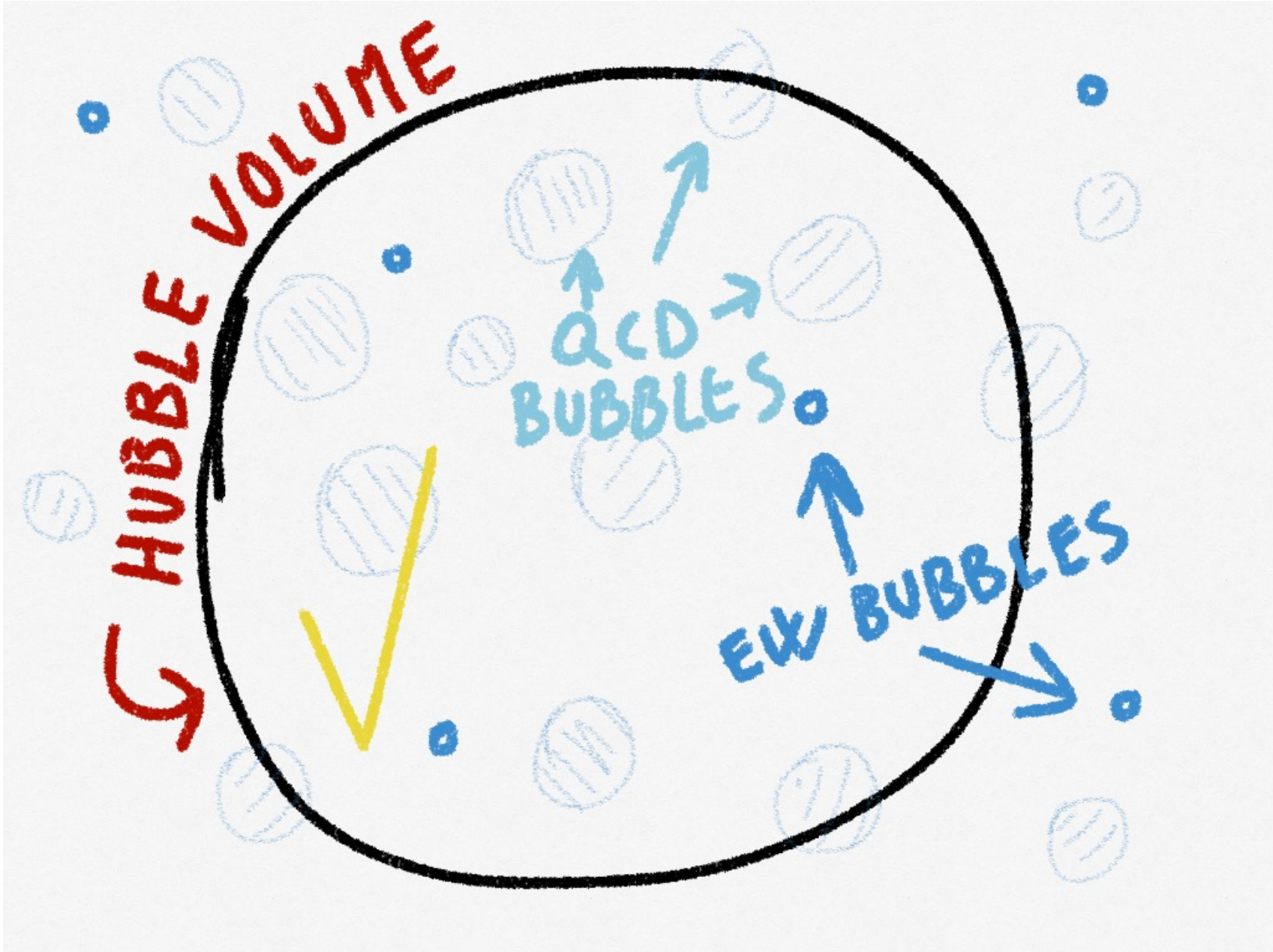

HUBBLE VOLUME
EW BUBBLES


HUBBLE VOLUME
TOO FEW!
EW BUBBLES


HUBBLE VOLUME
EW BUBBLES


HUBBLE VOLUME
QCD BUBBLES
EW BUBBLES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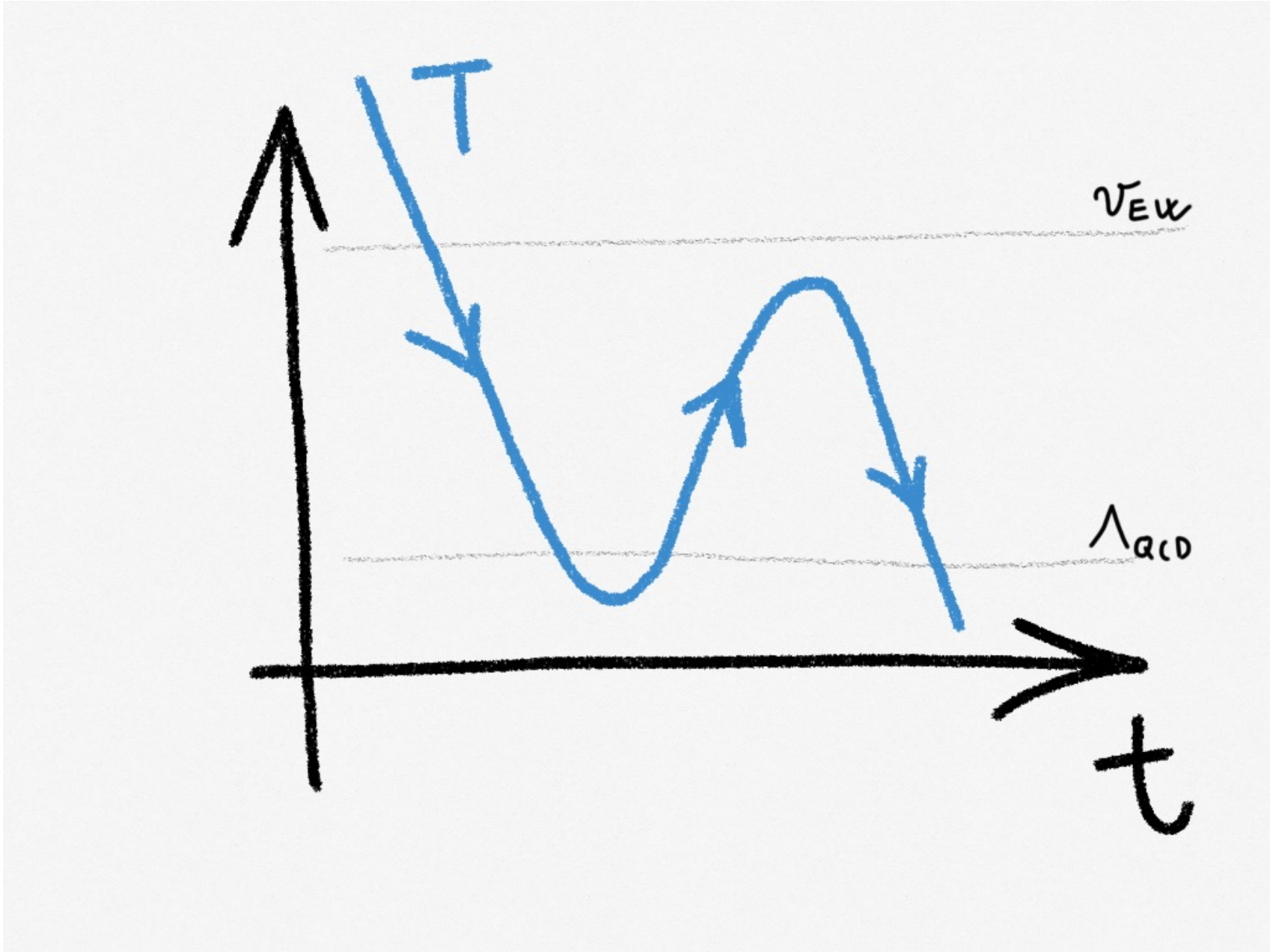
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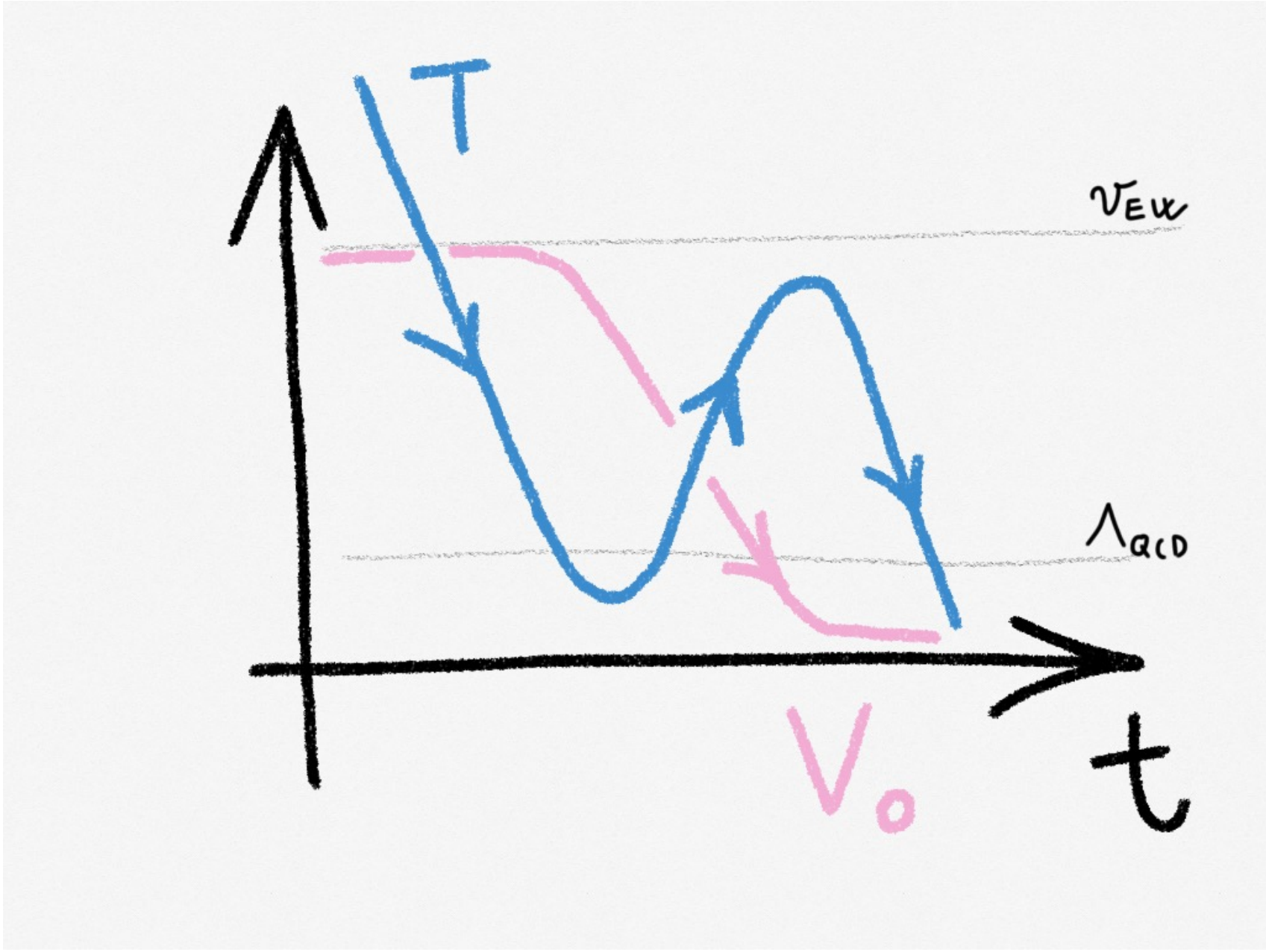
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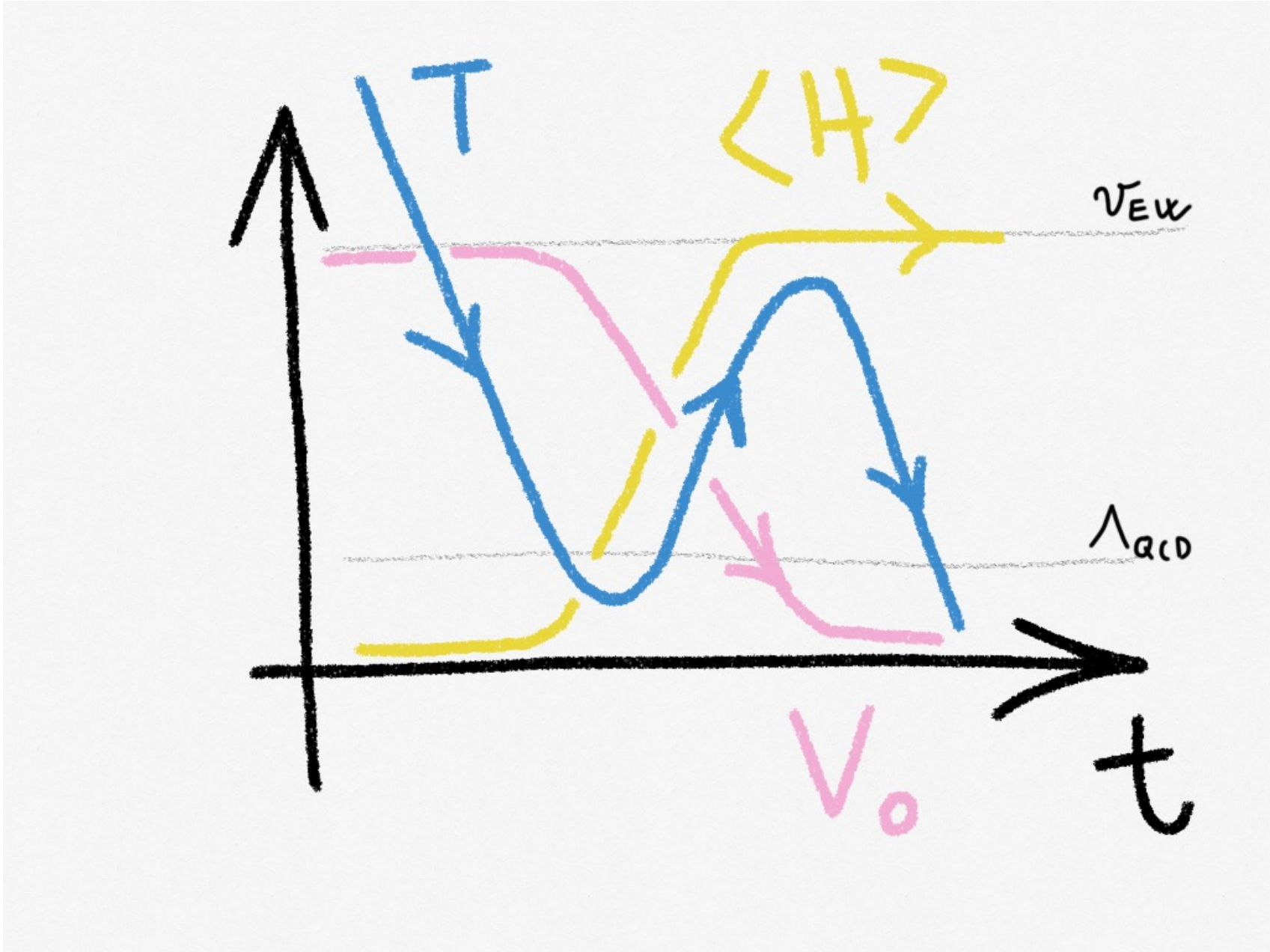
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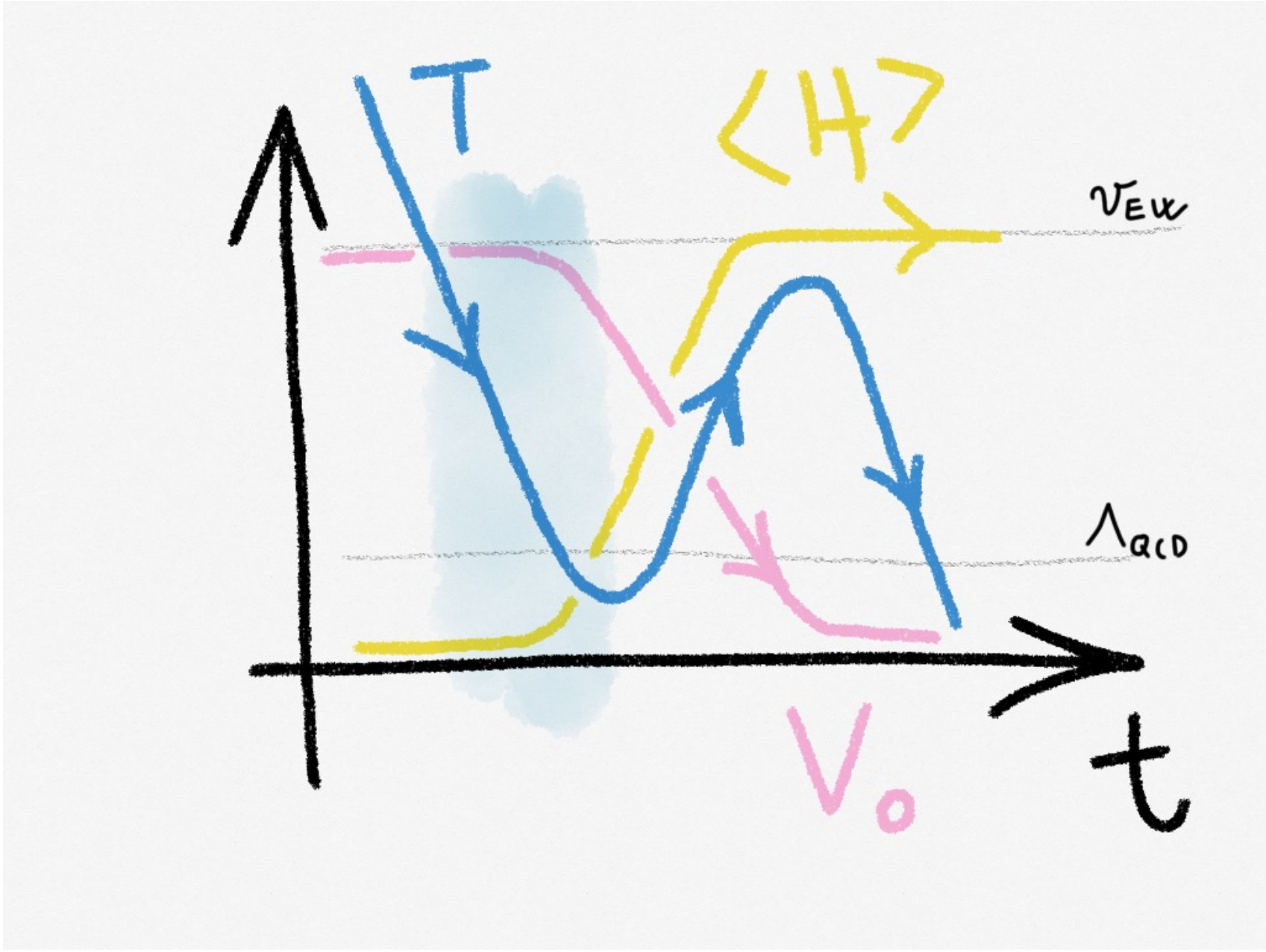
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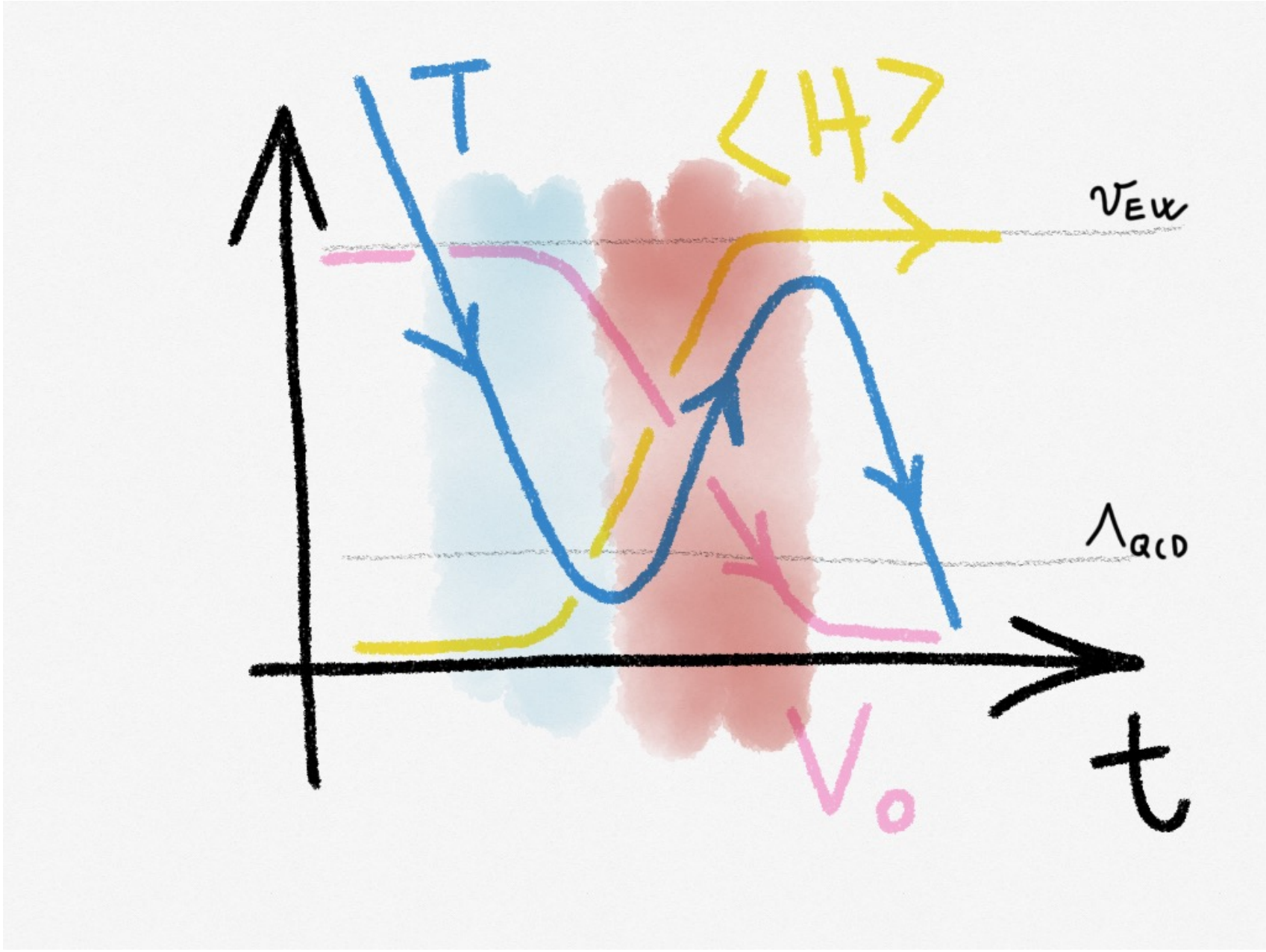
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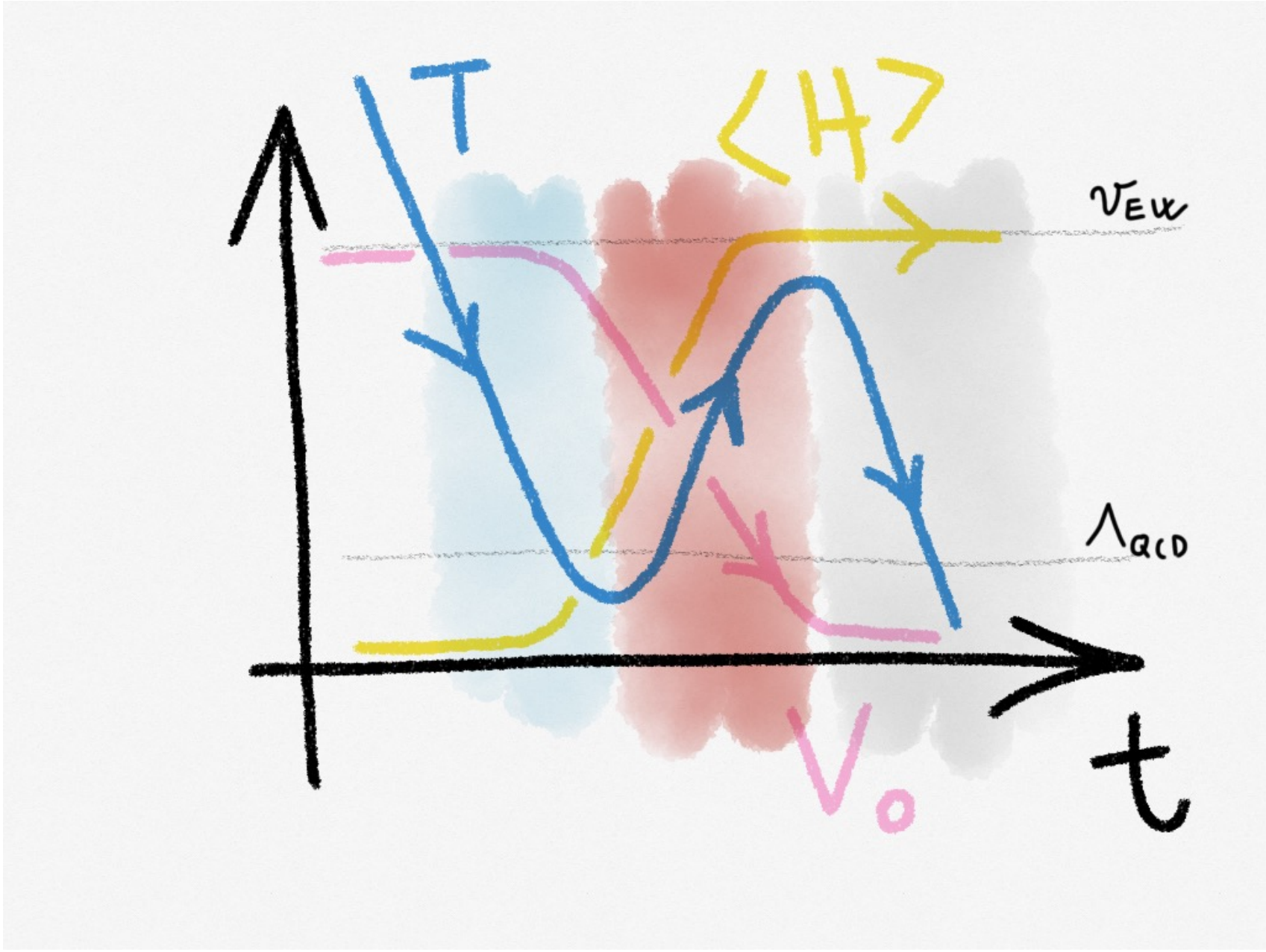
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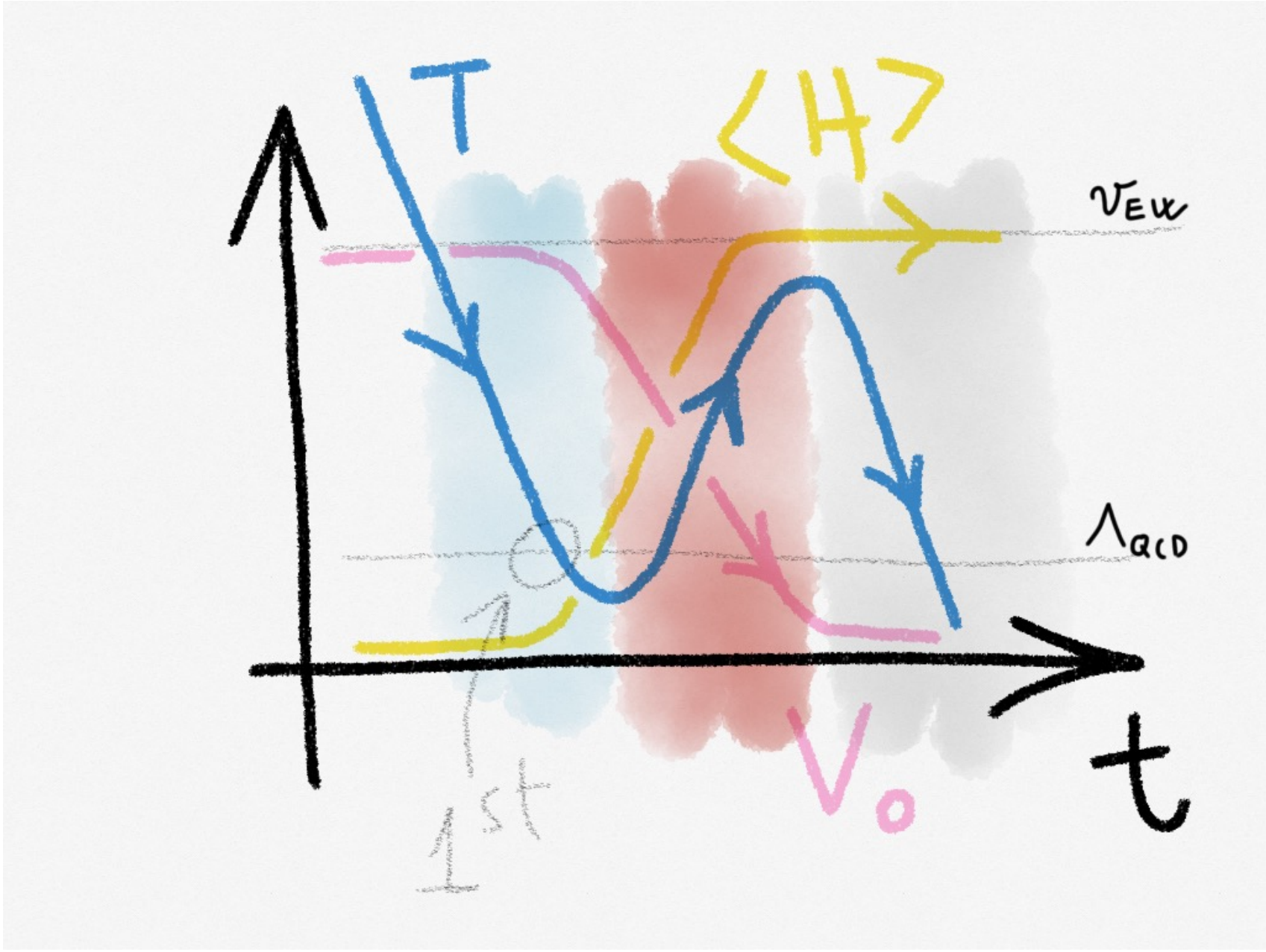
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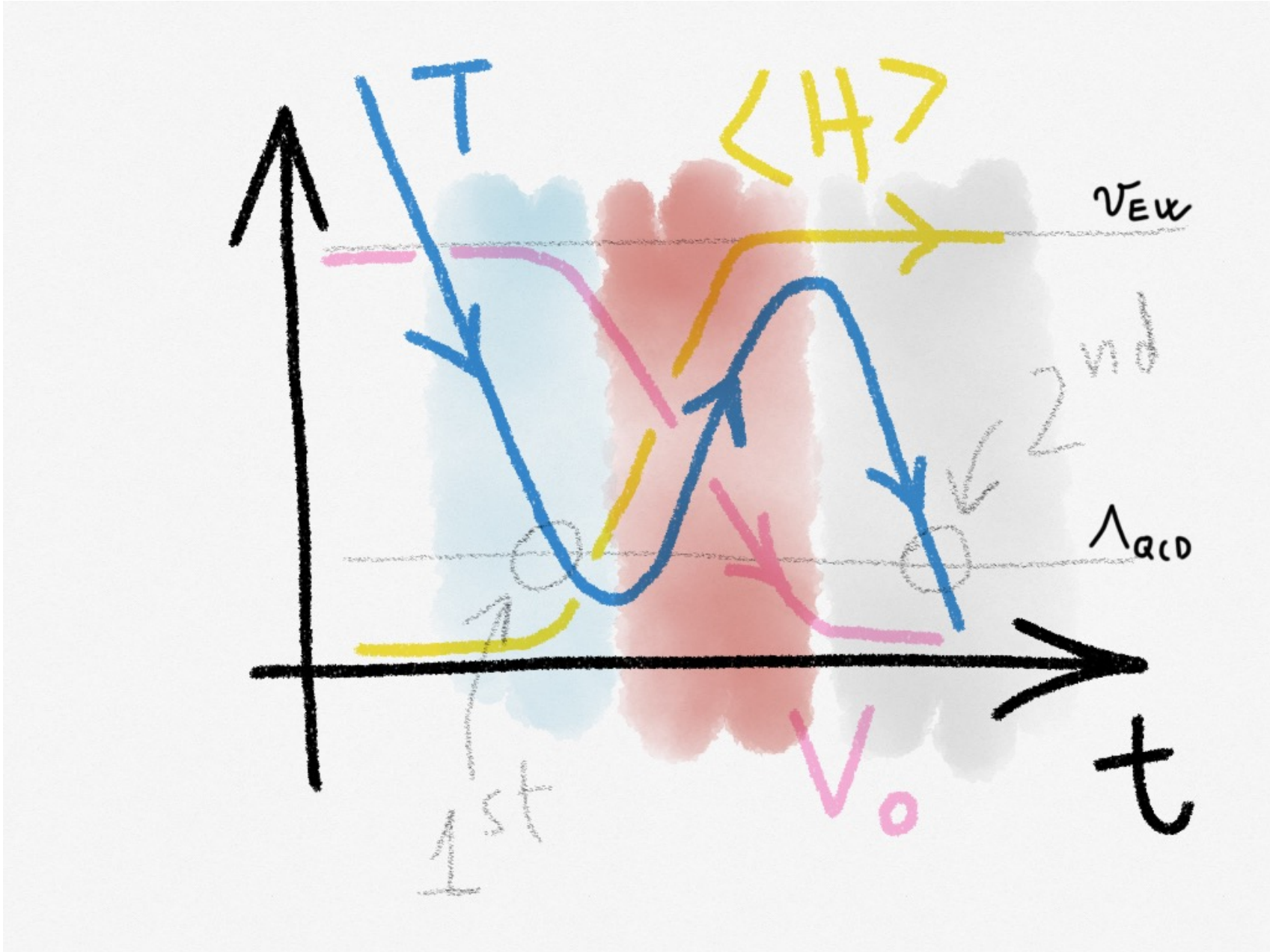
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Inflationary period: required to solve flatness and horizon problem

Usual scenario is quite different... Can we use supercooling to make inflation?

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3. adiabatic perturbations (?)

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1. de Sitter background (V)
2. enough e-folds (V)
3. adiabatic perturbations (?)
4. deviations from adiabatic (??)


TIME
FOR PIZZA