I−BALL formation with LOG potential

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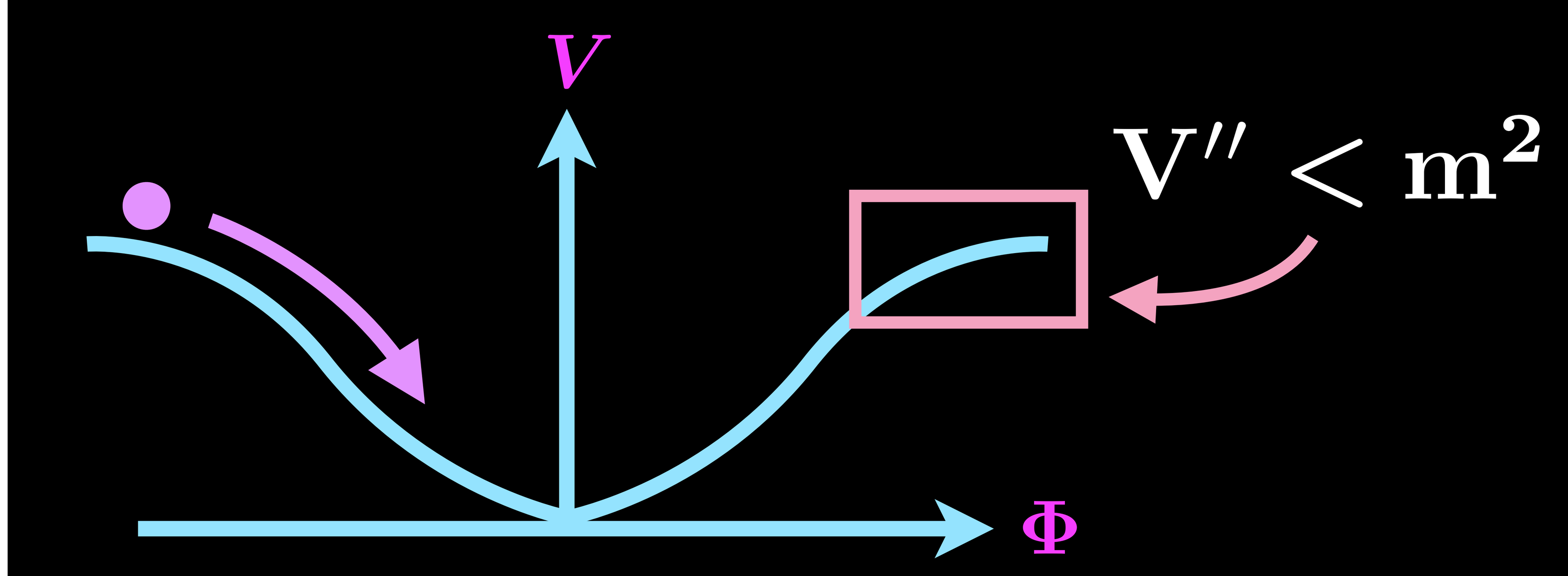
1:INTRODUCTION

In various situation, the scalar field forms the stable configuration, such as the topological defect owing the toplology or the Q-ball owing the conservation of the charge. Here, we consider the I-ball(oscillon) which is owing the adiabatic invariant. In the case that the scalar field oscillates harmonically and the frequency changes adiabatically, the enhanced fluctuations of the scalar field clump into the shperical configulation as I-ball. This I-ball is formed when the scalar field has a characteristic potential which is quadratic around the minimum and is shallower than quad. away from the min.

In the very early Universe, a scalar field(inflaton) has caused the inflation. After the end of the inflation, it decays into the radiation through some oscillations. In this epoch, the radiation gives the thermal correction to the potential of the inflaton as log. As this log potential is shallower than the quardratic potential, there is a possibility that the inflaton fragments into the I-ball. As the life time of the I-ball is remarkably large compared with the cycle of the oscillation, the decay the inflaton may delay, which would alter the scenario of the reheating. The process of the formation of the I-ball is dominated by the non-linear phenomenon of the scalar field. In this study, we explore the possibility of the formation of the I-ball with log potential executing the lattice simulation.



$$V = \frac{1}{2}m^2\phi^2 + \delta V$$

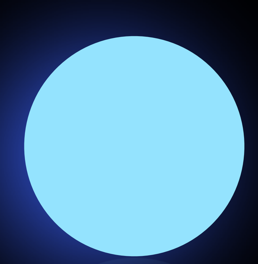
Adiabatic invariant I

$\frac{\dot\lambda}{\lambda} << T^{-1}, \ |\frac{\nabla\lambda}{\lambda}| << T^{-1}$ in region V

λ: specifying external field, T: cyclic period

⟶ $I \equiv \frac{1}{2m}\int d^3\dot\phi^2$ is conserved in V

⟶ I-ball formation



2:MODEL

potential $V = M^4 \log(1 + \frac{\Phi^2}{M^2})$

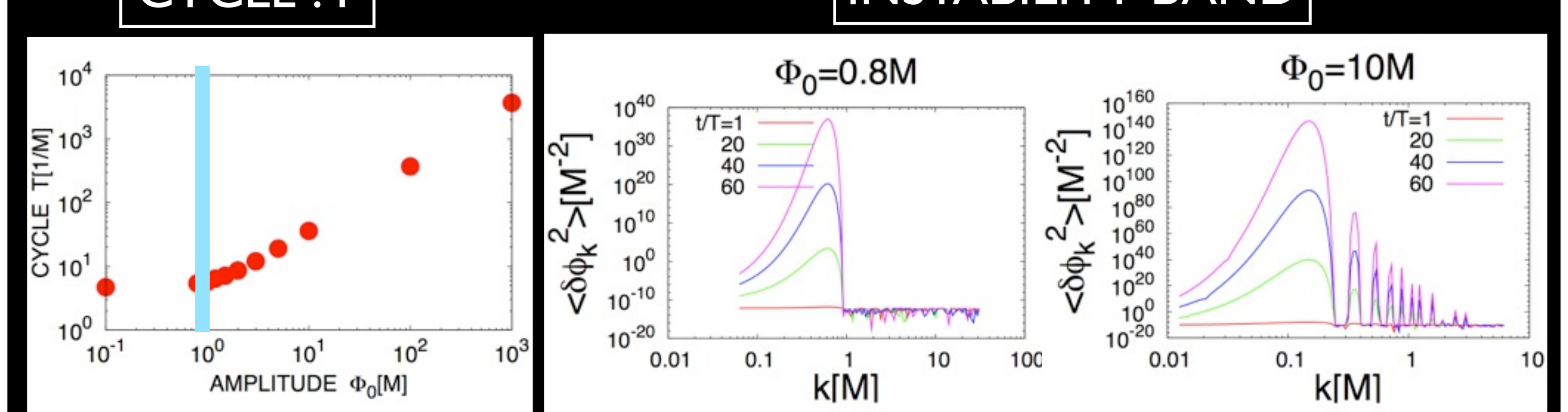
E.O.M $\ddot\phi + DH\dot\phi - \frac{\nabla^2}{a^2}\phi + V' = 0$

D: dimension of the space, H: Hubble constant

nature of the potential

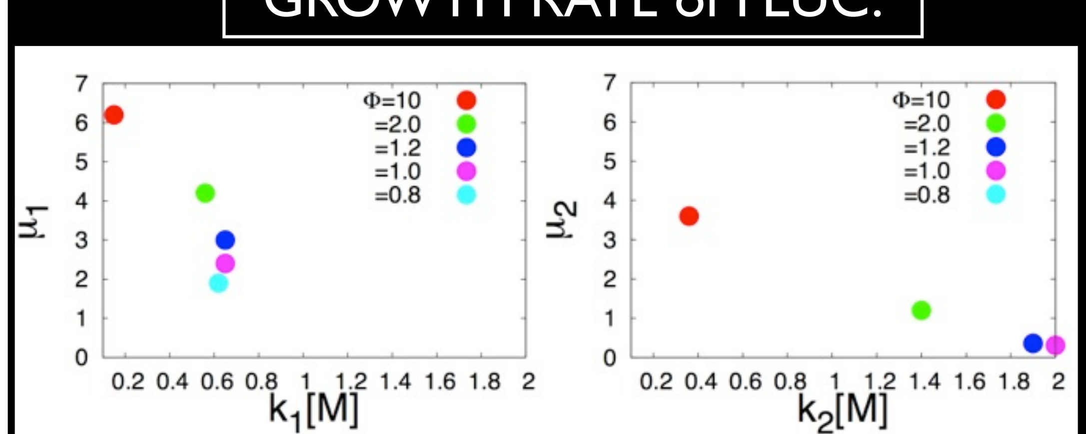
$H = 0$

CYCLE :T — INSTABILITY BAND



While the log potential is approximately quadratic around the minimum, it is dominated by the non-linear term away from min. The left panel shows this as the cycle of the oscillation. The amplitude of the turning point is 1[M]. This non-linearity affect the growth rate of the fluctuation. From the right panel, we can see that the non-linear term makes the multi instability, though, the momentum where fluc. grows most is first band for each amplitude.

GROWTH RATE of FLUC.



Left panel shows the growth rate of the fluctuation for the first and the second band.

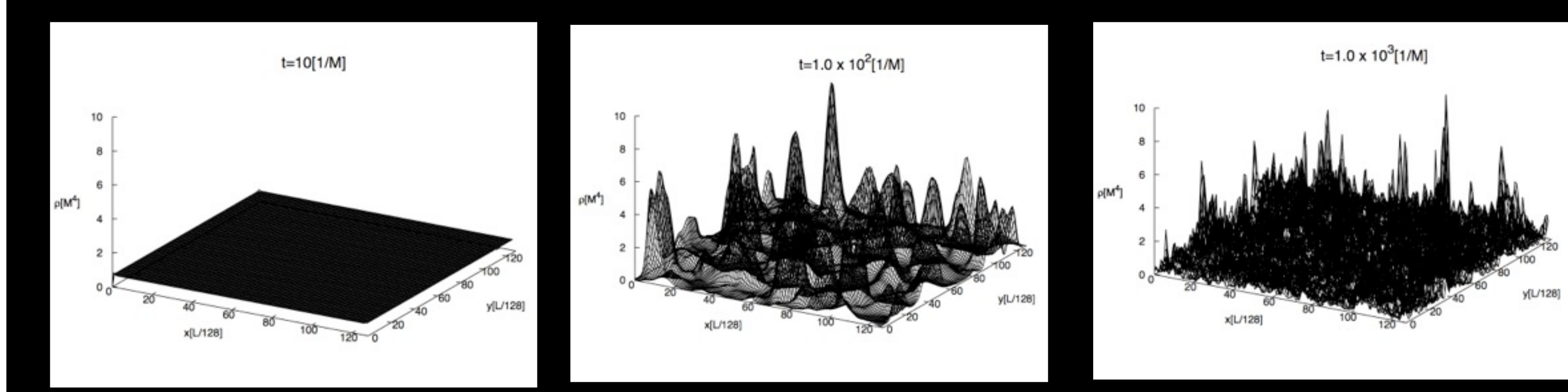
definition of the μ
$\langle\delta\phi_k^2\rangle(t) = \langle\delta\phi_{k\,\mathrm{ini}}^2\rangle \exp(\mu\frac{t}{T})$

3:RESULT

time evolution of the energy density

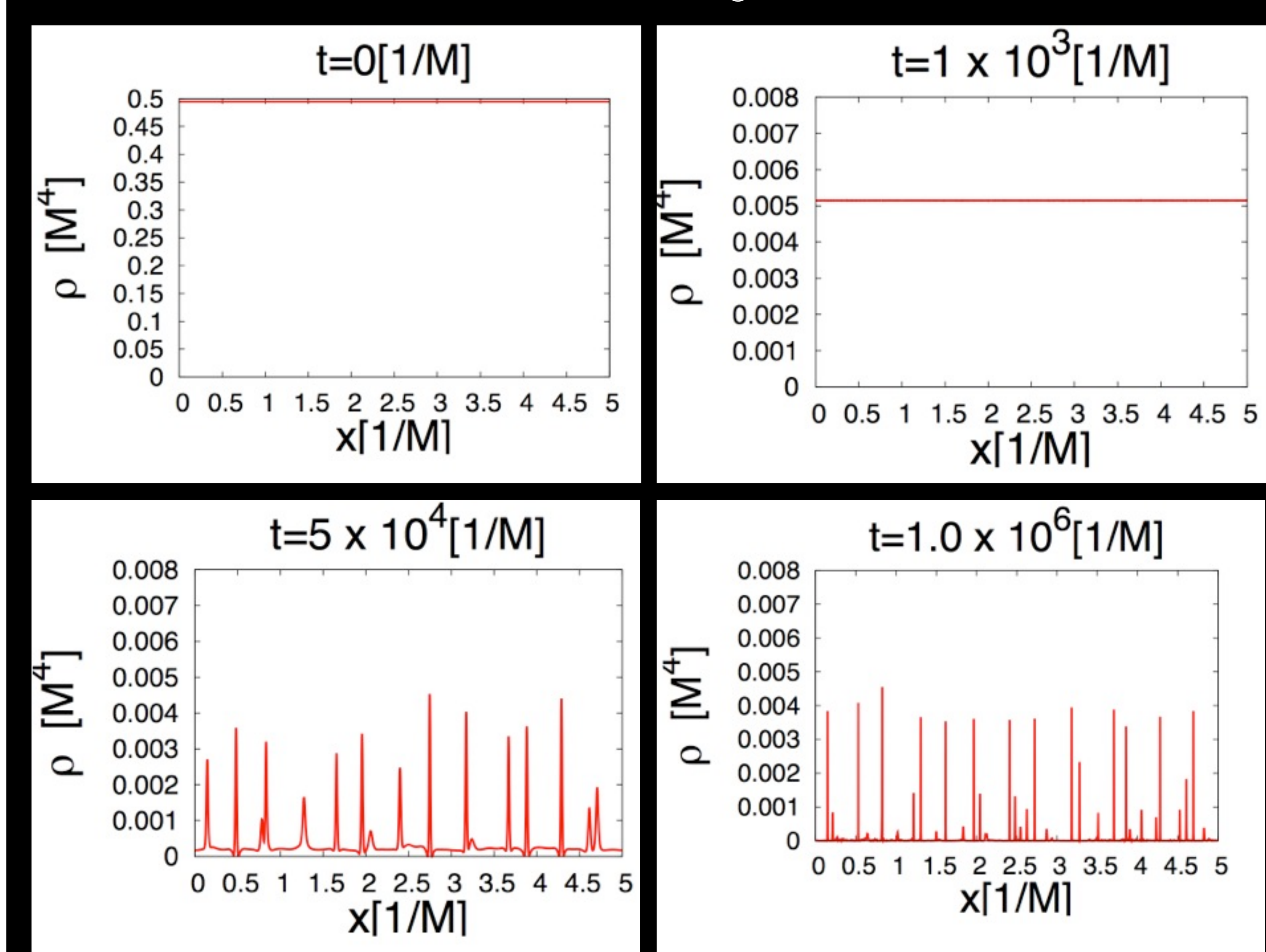
$\Phi_0 = 1[M]$

$H = 0,\ D = 2$ dimension $\quad L = 50[1/M]$



$\Phi_0[M]$	1	10	100
formation	O	O	?

$H_{\rm ini} = M(\text{matter-domi} = \frac{2}{3}t),\ D = 1$ dimension



$\Phi_0[M]$	form
0.3	O
1	O
10	?

We have followed the evolution of the scalar field for several initial conditions of the amplitude. Without Hubble expansion, after the formation of the I-ball, it collides each other and breaks becouse of the finite size of the simulation box. With Hubble expansion, the I-ball dose not breaks and its life time is remarkably large compared with the cycle of the oscillation.

4:CONCLUSION and DISCUSSION

We have executed the lattice simulations for exploring the possibility of the formation of the I-ball with log potential. In the case that the space dose not expand, the scalar field fragments into the I-ball and soon decays becoause of the finite size of the simulation box. In the case that the space expands, as the expansion prevents the collision of the I-balls, the life time of the I-ball is remarkably large compared with the cycle of the oscillation. This suggest that the inflaton dominated by the log potential may fragment into the quasi-stable state and its decay may delay.

There are still several ambiguity for I-ball with log potential, such as the initial condition of the amplitude which leads to the I-ball formation. We will clarify these ambiguity.

The I-ball is the state that the energy is lowest at fixed I(adiabatic invariant), which determine the configuration of the ball. To clarify the mechanism of the I-ball formation, we have to compare the configuration that is suggested by the conservation of the I with the result of the simulation.