Collision of Domain Walls in asymptotically Anti de Sitter spacetime

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COSMO 05

Standard cosmology scenario

Big bang theory

Reheating

Energy transition from inflaton to matter

Inflation

Inflaton??

Braneworld scenario

More natural cosmology?

- **Brane inflation scenario**

  (Dvali, Tye, Quevedo)

- **Ekpyrotic or Cyclic scenario**

  (Khoury, Steinhardt 2002)

Two branes collide and evolve into a hot big bang!

Alternative to Inflation

Ekpyrotic or Cyclic scenario (Khoury, Steinhardt 2002)

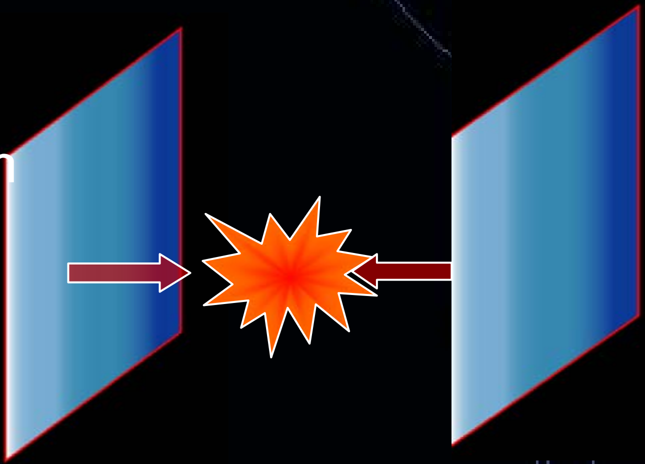
Previous works

- Spectrum : not scale invariant

- Martin, Felder, Frolov, Peloso, Kofman (PRD 69 084017)

  Brane approximated as δ function

- Reheating mechanism is not investigated well : consistent collision process should be considered



Purpose of our work

◆ *Construction of consistent brane collision model and considering its reheating mechanism*

◆ Correct spectrum index?

Our work

1. Analysis of Reheating mechanism in Minkowski

(Y. T, K. Maeda PRD 70 123514)

Motivation

- ◆How a spacetime affects the above results ?
- ◆Change of scale factor → helpful to spectrum index

2. Analysis of Reheating mechanism in Asymptotically AdS spacetime

(Y. T, K. Maeda in preparation)

1. Collision of Domain walls and Reheating mechanism in Minkowski spacetime

(Y. T , K. Maeda PRD 70 123514)

Abstract

Modeling of brane : Domain wall constructed by 5-D scalar field (Φ)

Following dynamics of domain wall numerically

Reheating mechanism : Estimate particle production of 5-D scalar field (Ψ) confined on wall coupled with Φ

Result

◆**Typical produced energy scale**

$$\omega \approx 1/d$$

Thickness of wall

◆**Temperature**

$$T_{\rm R} \propto g N_b^{1/4}$$

Coupling constant

Number of bounces

$$L_{\rm int} \approx g^2 \Phi^2 \Psi^2$$

2. Collision of Domain walls in Asymptotically AdS

Model

5-D spacetime + 5-D scalar field Φ

$$ds^2 = -a(t,y)^2 dt^2 + b(t,y)^2 \delta_{ij} dx^i dx^j + c(t,y)^2 dy^2 + 2d(t,y) dy dt$$

2D conformal gauge $a = c\ ,\ d = 0$

$$ds^2 = e^{2B(\tau,z)} \delta_{ij} dx^i dx^j + e^{2A(\tau,z)} (-d\tau^2 + dz^2)$$

⇒ 3 variables A, B, Φ

Invariant

Lorentz boost

$$z = \gamma(z' - v\,\tau')$$

$$\tau = \gamma(\tau' - v\,z')$$

$$ds^2 = e^{2A\left(z=\gamma(z'-v\tau')\right)}(-d\tau'^2 + dz'^2)$$

Place of the wall ⇔ $z' = v\,\tau'$ ⇒ Helpful to studying collision of walls

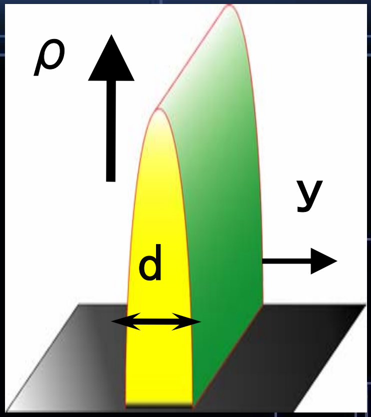
$z = 0$

Static solution

Moving solution with constant speed

Flow chart

Modeling of brane



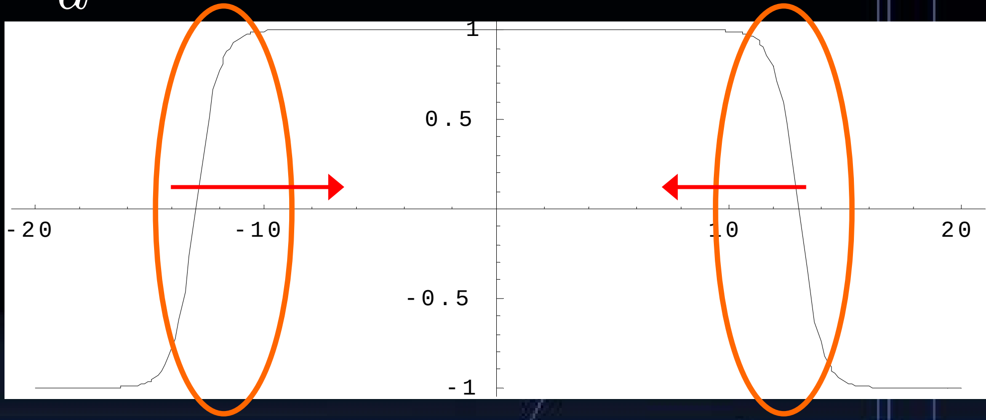
- ***Static solution*** : Finding domain wall solution for the equation without time derivative terms

$$\Phi(y) = \tanh[\frac{y}{d}]$$

- ***Moving solution*** : obtained by Lorentz boost

$$\Phi_{\mathrm{M}}(y) = \tanh[\frac{\gamma(y - vt)}{d}]$$

- ***For initial data***, we provide two moving solutions



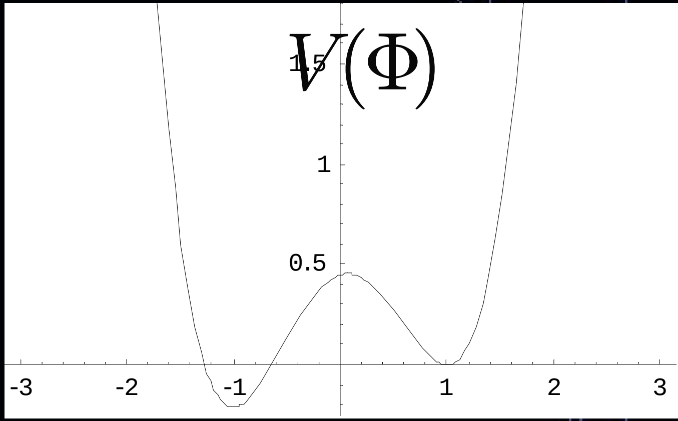
- ***Dynamics:*** Following dynamical equation mixed with 3 variables (A, B, Φ) numerically

Static wall solution

Exact solution M. Eto, N. Sakai (**PRD68 125001**)

Scalar field : $\Phi = \tanh[y/d]$

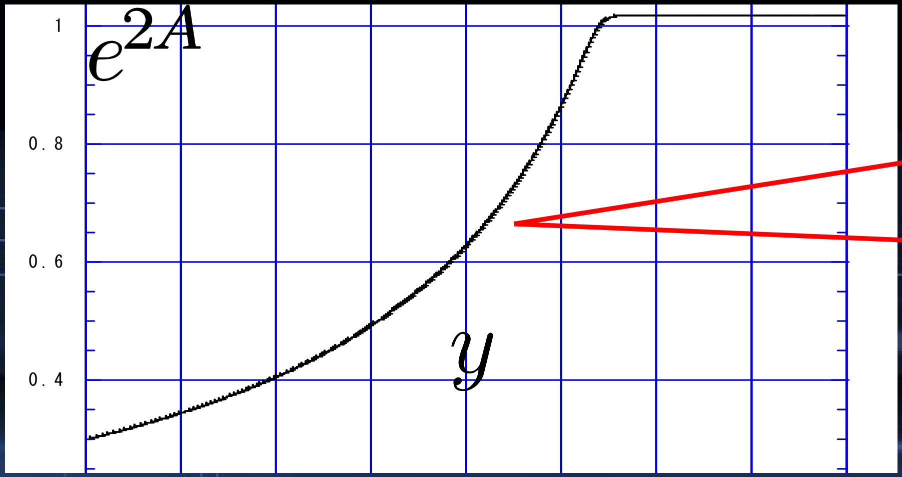
Thickness of wall



Metric : 5-D

$$ds^2 = e^{2A(y)}\eta_{\mu\nu}dx^\mu dx^\nu + dy^2$$

A=B at t=0



Asymptotically AdS

$$e^{-2k|y|}$$

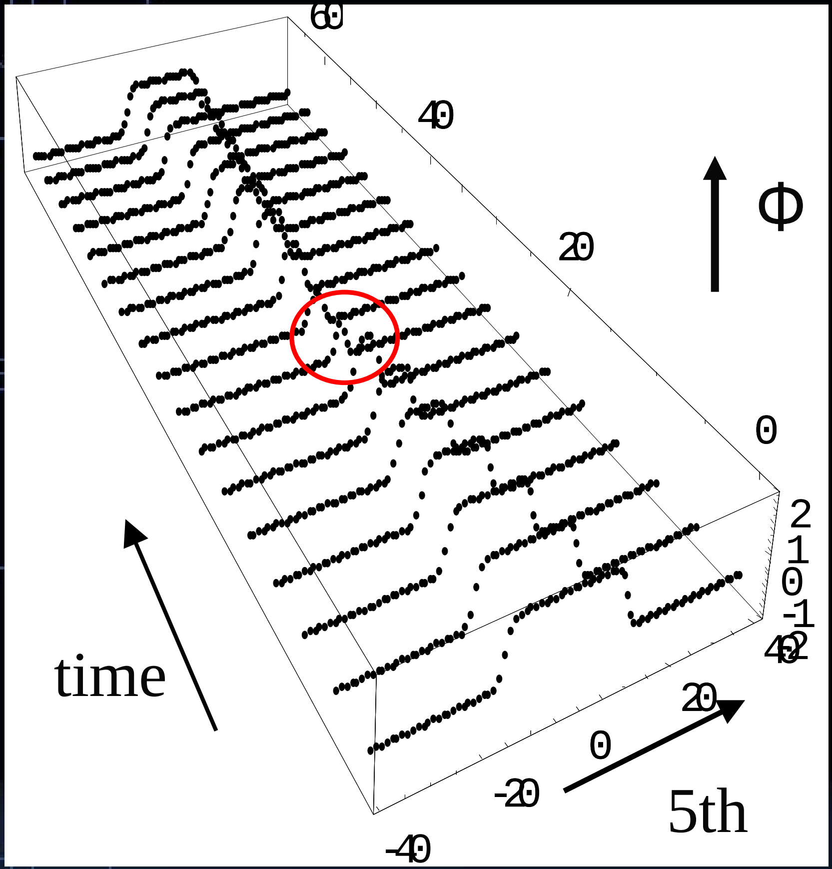
where $k = 8\kappa_5^2/9d$

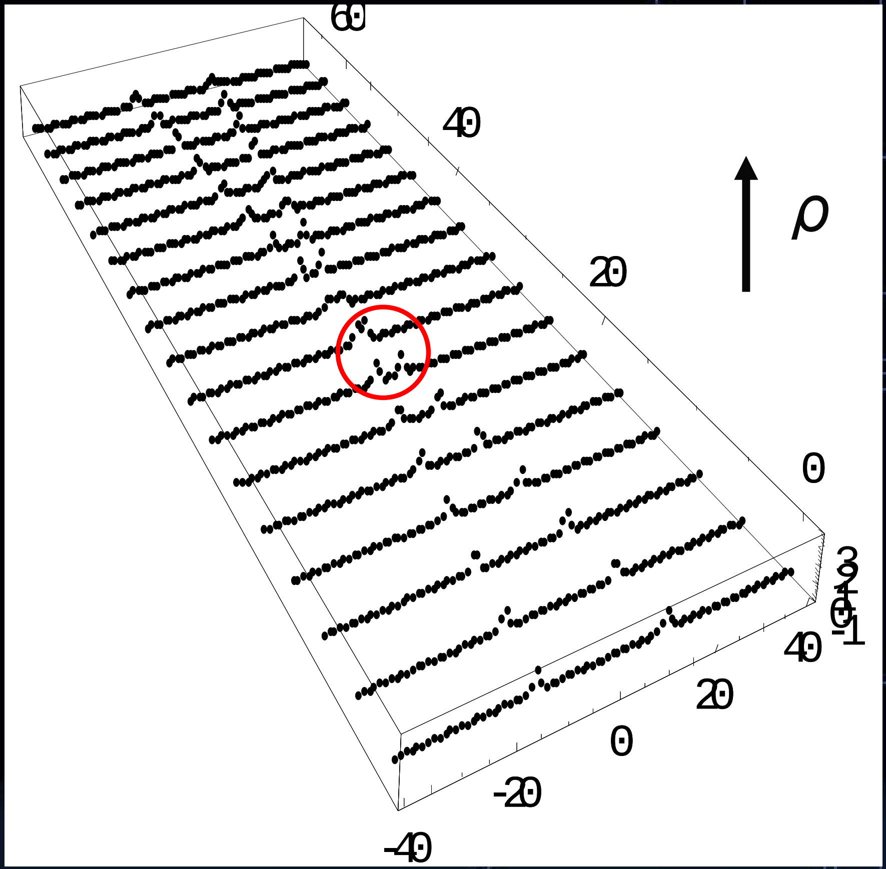
κ_5 : ***Parameter denoting spacetime effect***

Results (Collision process)

Numerical simulation

$v = 0.4, \ \kappa_5 = 0.01$



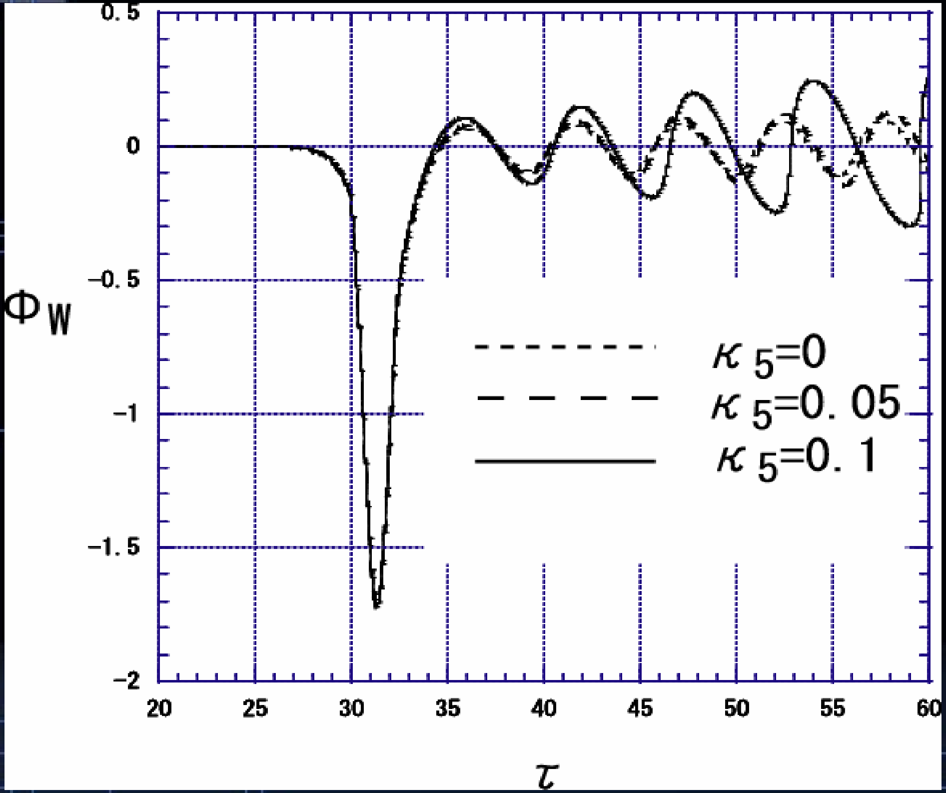


ρ is maximum = position of brane ($y = y_W(t)$)

Estimate $\quad \Phi(\tau) = \Phi(t, y_W(t))$

Time evolution of Scalar field on the wall

For small value of κ_5



Estimate the value on the wall

$$\Phi_W(\tau) = \Phi(t, y_W(t))$$

After bounce, we find Oscillation phase

This was shown stable oscillation using perturbation analysis in Minkowski.

Effect of spacetime (κ_5)

Period : longer as κ_5 increases

Amplitude : bigger as κ_5 increases

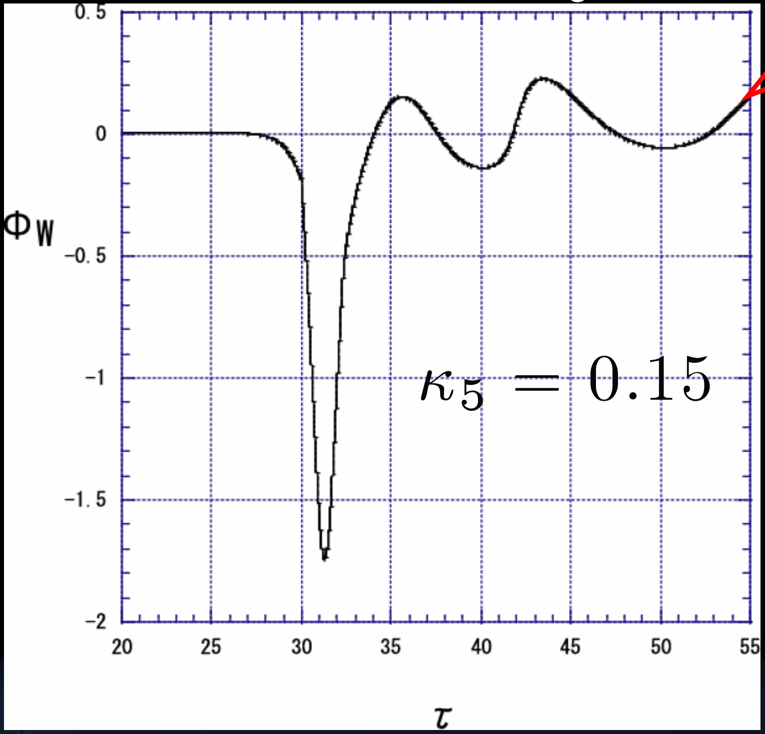
- But, except the oscillation phase, the result for collision process is the almost same as the Minkowski case

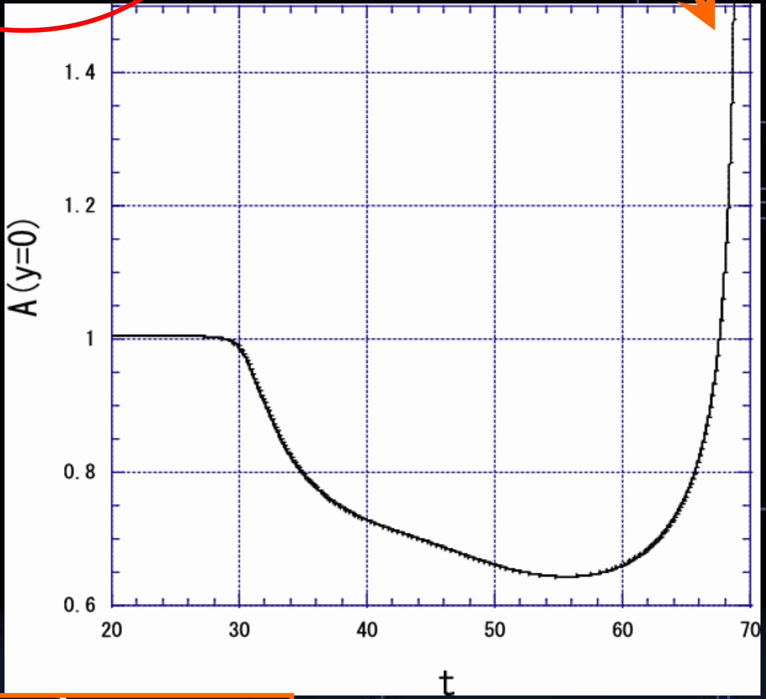
Time evolution of Scalar field on the wall

As κ_5 increases $\kappa_5 > 0.1$

Numerical simulation stops !

Because of the divergence of the metric





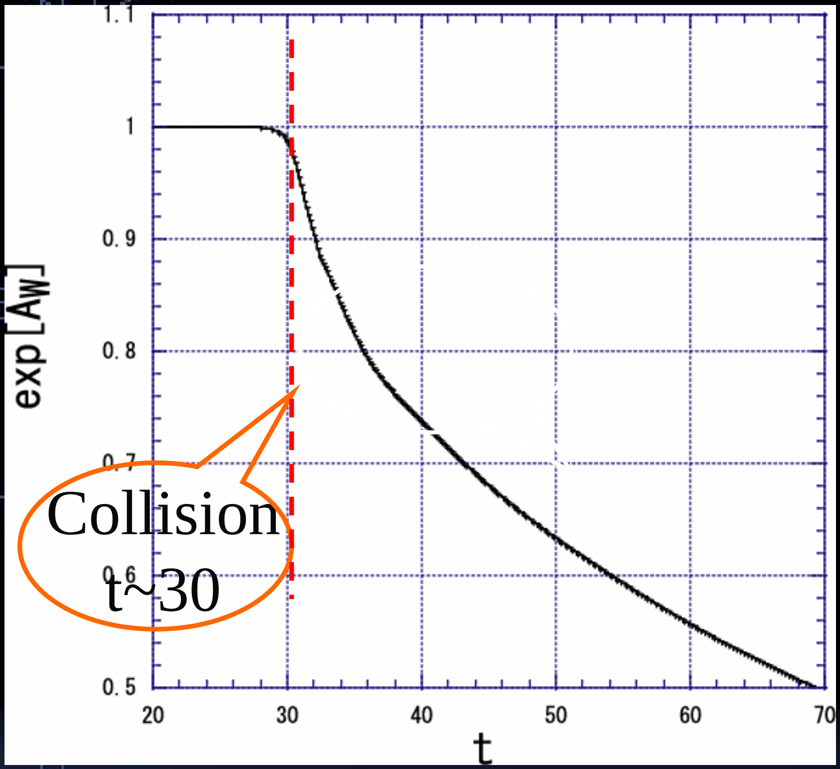
This divergence is not a numerical error.

- Kretschmann scalar also diverges !
- Singularity of spacetime forms !

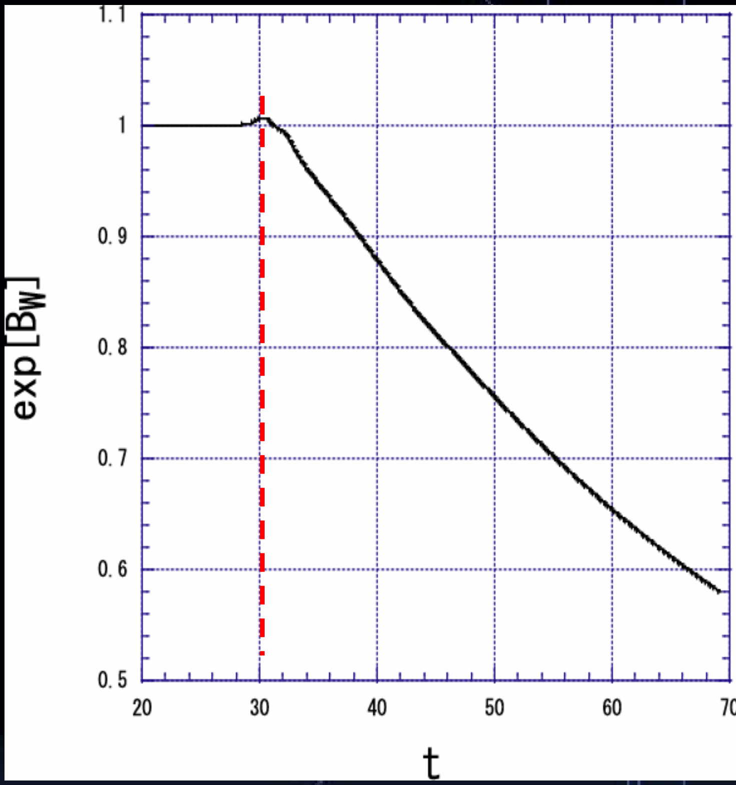
Time evolution of Metric (A, B) on the wall

Estimate the value on the wall

$$e^{A_W(t)} = e^{A(\tau, y_W(\tau))}$$



Divergence of metric after that



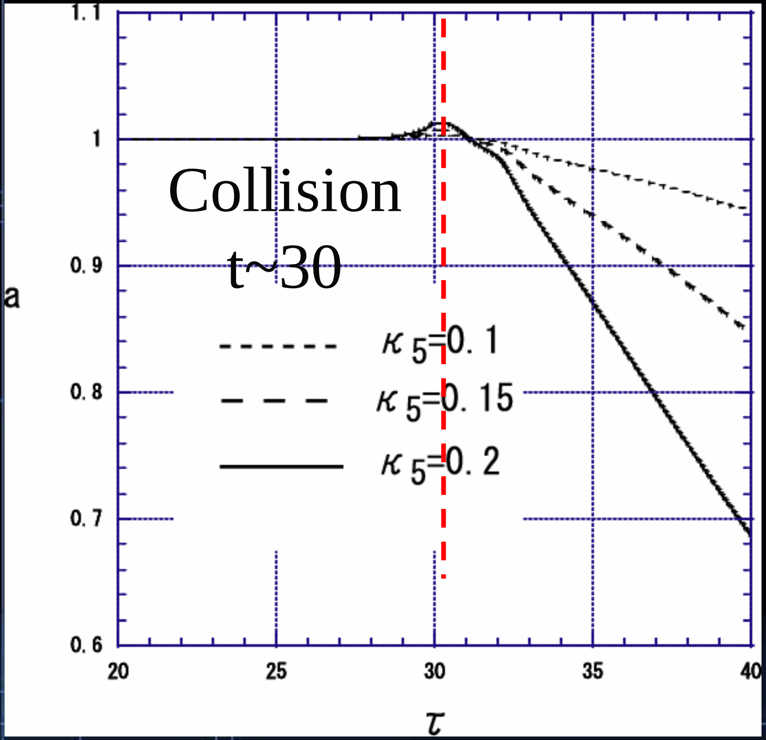
◆ Both of two quantities decreases with time except $e^{B_W(t)}$ increases slightly through the bounce

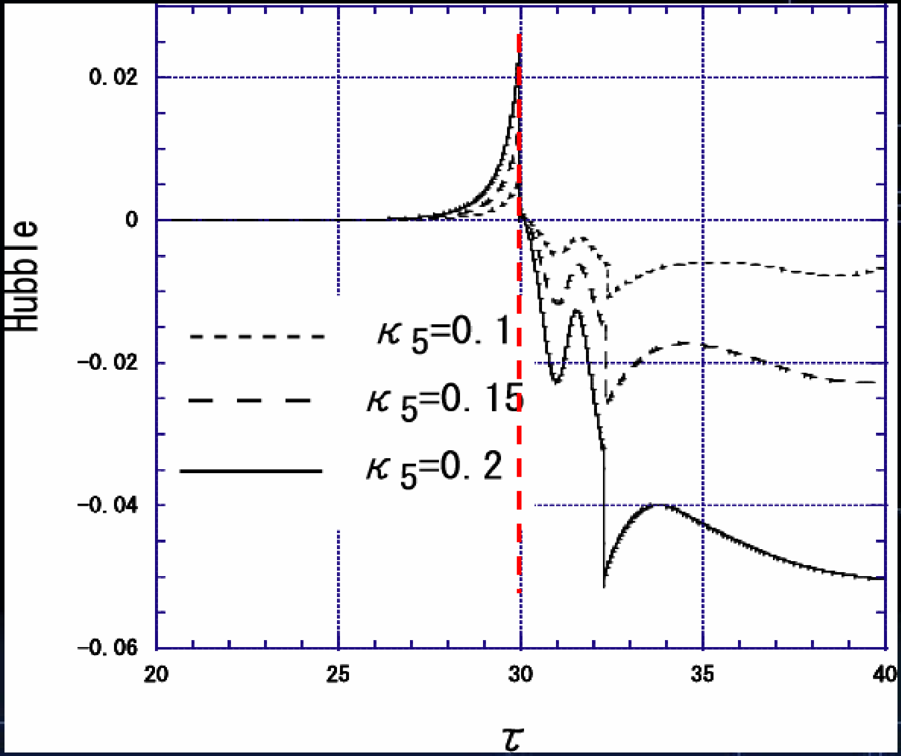
Time evolution of Scale factor and Hubble parameter

Proper time on the wall : $\tau = \int e^{A_W} dt$

Scale factor $a = e^{B_W(\tau)}$

Hubble $H = \frac{1}{a}\frac{da}{d\tau} = e^{-A_W}\frac{dB_W}{dt}$





- Expanding : before collision ⟶ Contracting : after
- Speed of expanding and contracting is larger as κ_5 increases

Summary

- In Minkowski spacetime case, we analyze the collision of domain walls and estimate its reheating mechanism.
- Moreover we study how the effects of spacetime (Asym. AdS) modify the above results.
- For small value of warp factor, we obtain the almost same results as the Minkowski case.
- For some large value of warp factor, we find the formation of singularity of spacetime.
- Our universe expands before collision and then contracts after collision in this model. Negative result !

Future work

- We would like to analyze this results for the collision and investigate its reheating mechanism.