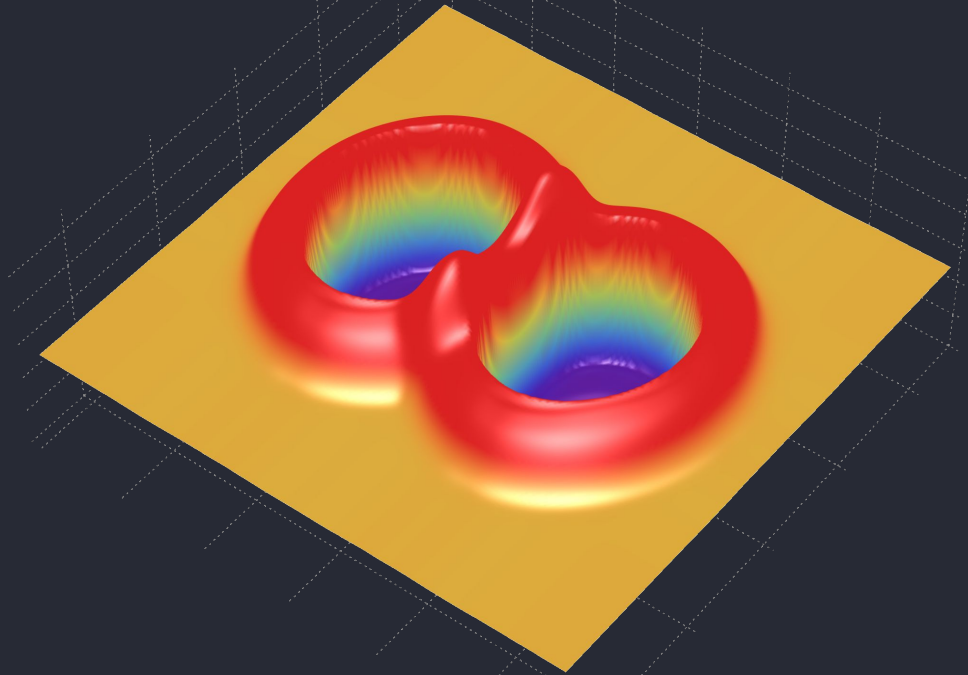
Bubble Wall Velocity From Holography

Mikel Sanchez Garitaonandia



Bea, Casalderrey-Solana, Giannakopoulos, Mateos and Zilhão

2104.05708

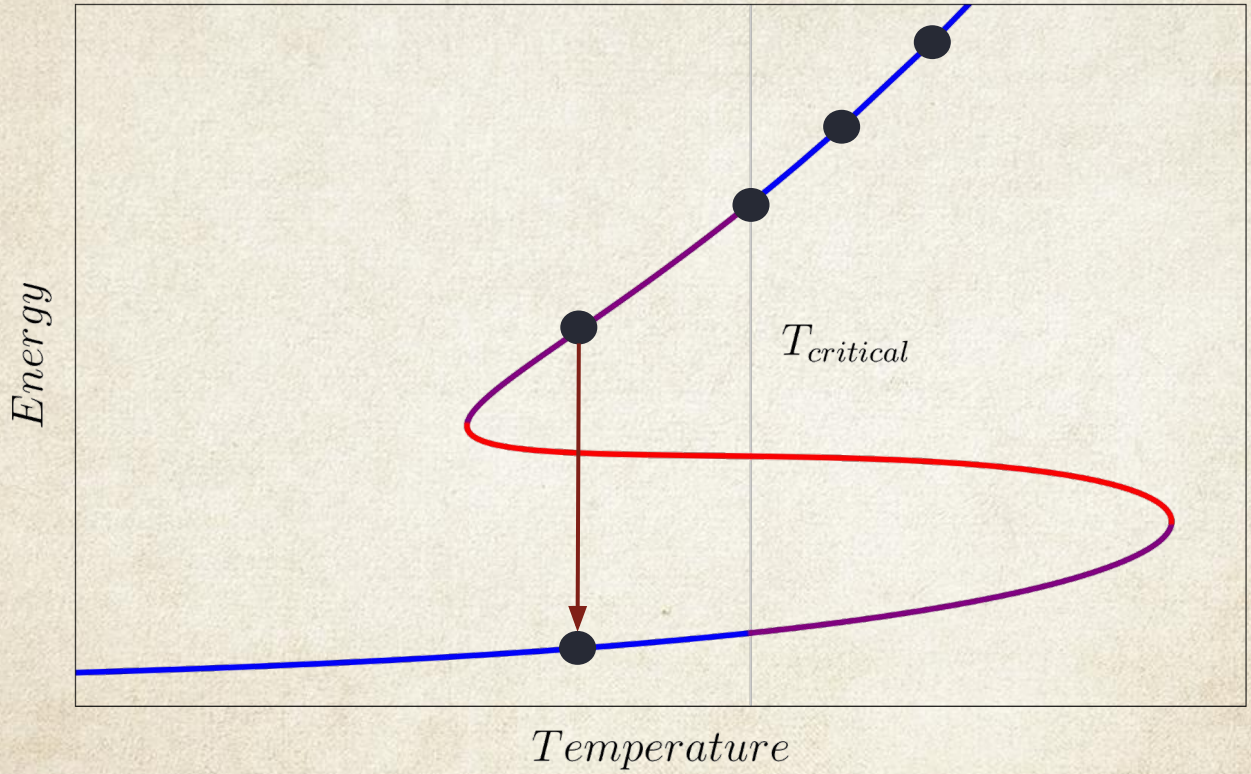
Universitat de Barcelona

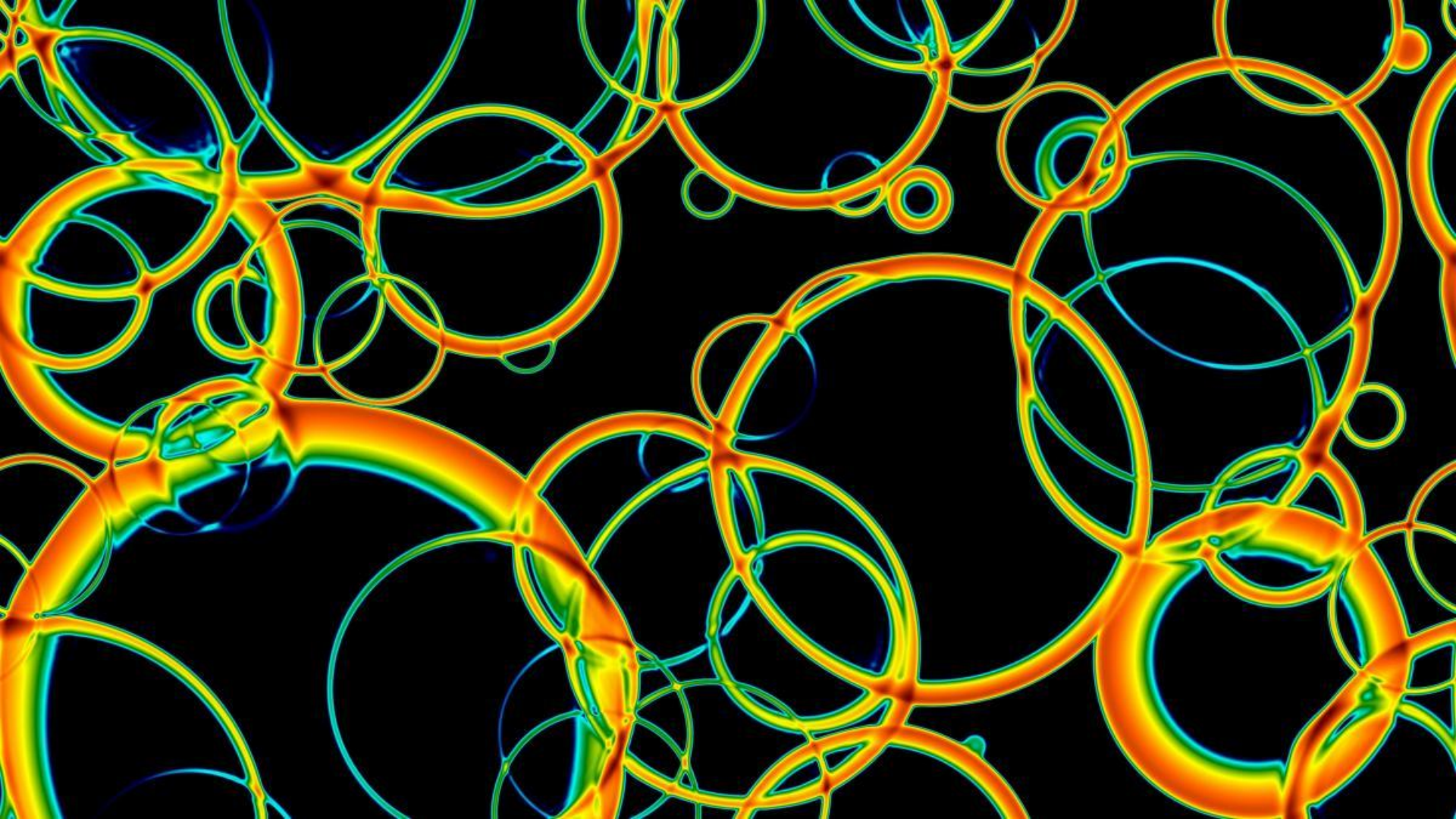
ICCUB Excelencia María de Maeztu
Institut de Ciències del Cosmos

Cosmological Phase Transitions

- First order phase transitions involve violent physics that source Gravitational Waves
- This GW could be detected by future generation interferometers: LISA
- Observe the universe before the CMB
- One of the few windows into physics beyond the Standard Model

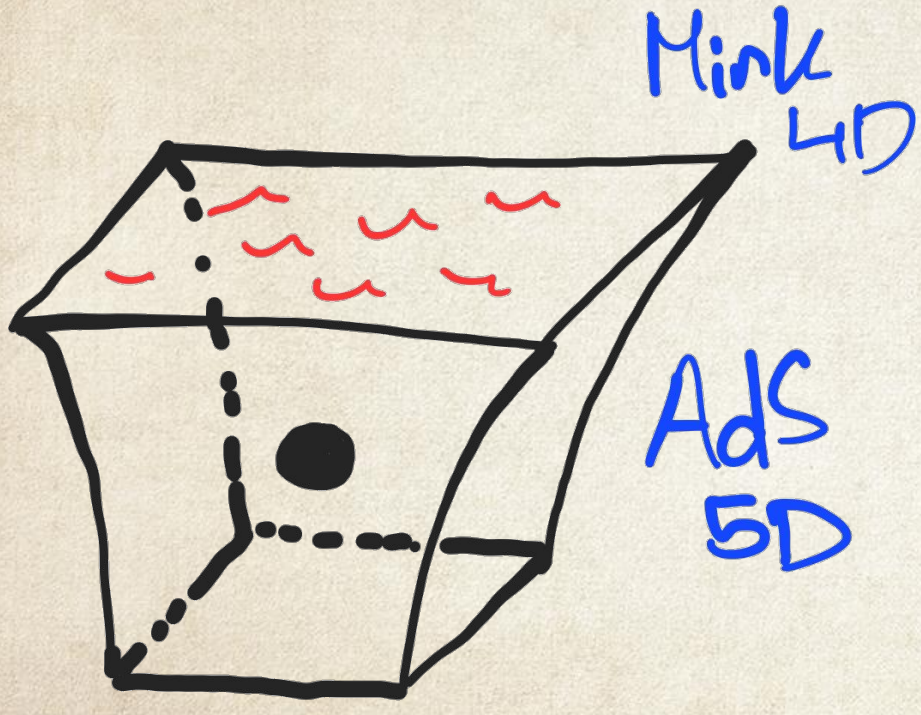
Cosmological Phase Transitions





- We have time evolution simulation based on effective descriptions
- We have formulas to estimate the the GW emission of such processes:
  - Equilibrium properties like transition strength, “easy”
  - Out of equilibrium properties: bubble wall velocity, challenging
- We use Holography to obtain this velocity from first principles in time evolution simulations.
- Holographic study of bubbles using an alternative approach [Bigazzi, Cadeo, Canneti, Cotrone ‘21]

Holography

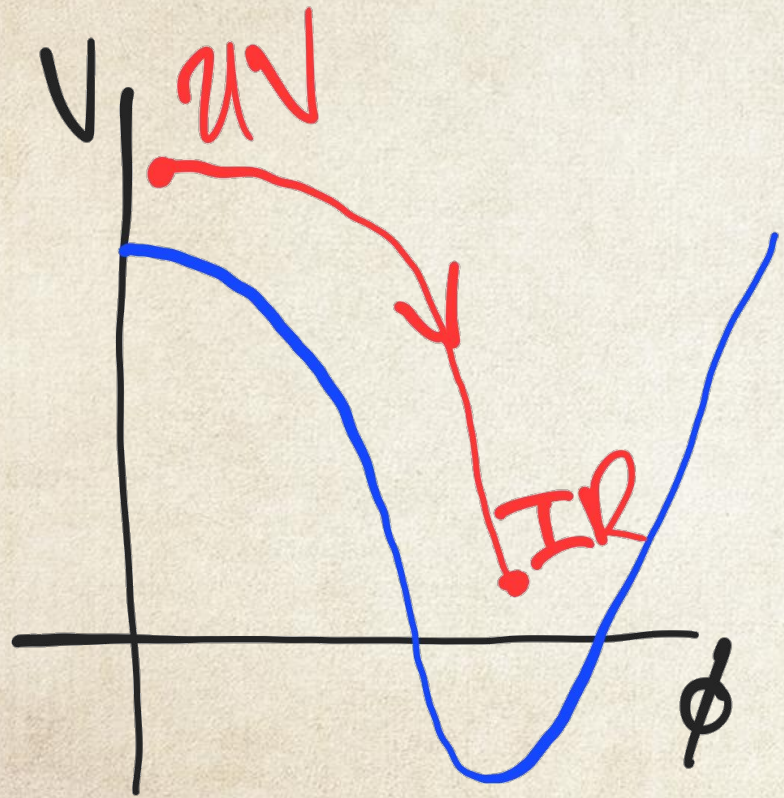


- Study strongly coupled QFT at large N_c by solving Einstein's equations
- Not QCD nor SM: we look for intuition and universalities
- Bottom-up model:

$$\mathcal{L} \sim R + \partial\phi^2 + V(\phi)$$

- Simple potential with 2 free parameters
- Gives us theories with phase transitions and unique energy scale Λ

Holography

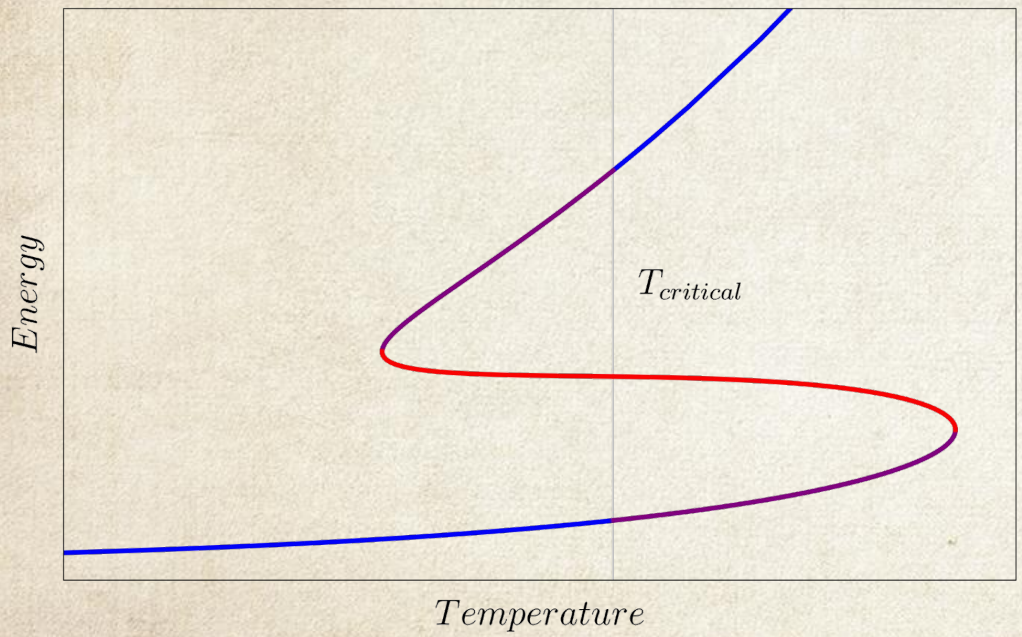


- Study strongly coupled QFT at large N_c by solving Einstein's equations
- Not QCD nor SM: we look for intuition and universalities
- Bottom-up model:

$$\mathcal{L} \sim R + \partial\phi^2 + V(\phi)$$

- Simple potential with 2 free parameters
- Gives us theories with phase transitions and unique energy scale Λ

Holography



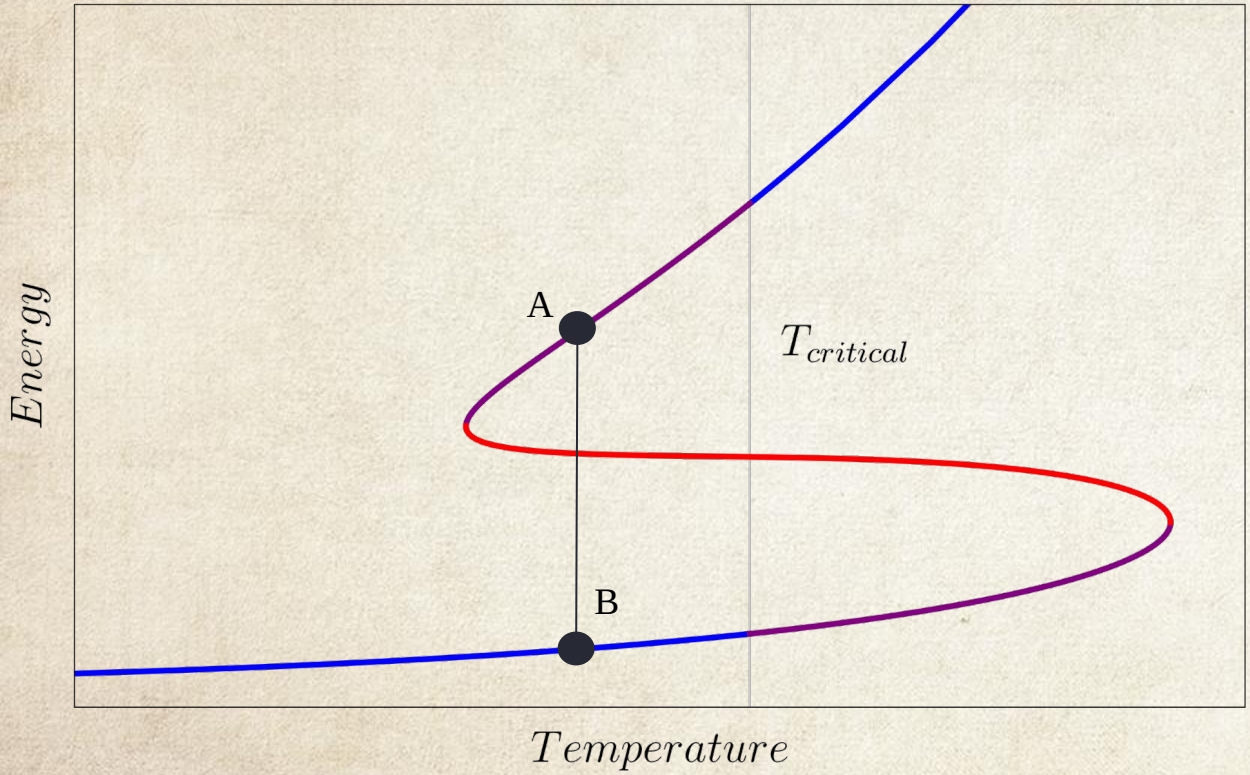
- Study strongly coupled QFT at large N_c by solving Einstein's equations
- Not QCD nor SM: we look for intuition and universalities
- Bottom-up model:

$$\mathcal{L} \sim R + \partial\phi^2 + V(\phi)$$

- Simple potential with 2 free parameters
- Gives us theories with phase transitions and unique energy scale Λ

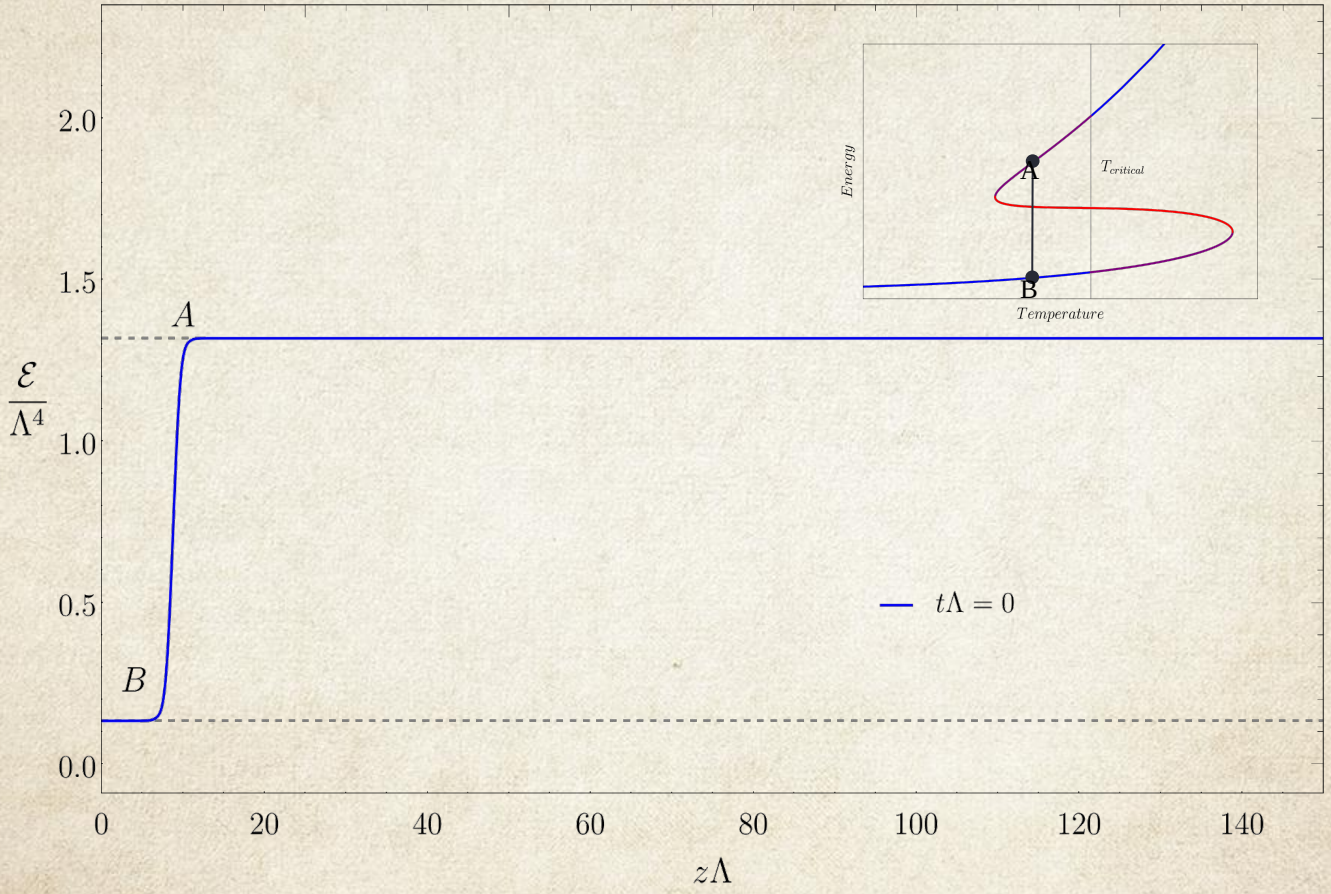
Single Expanding Bubble

Initial State

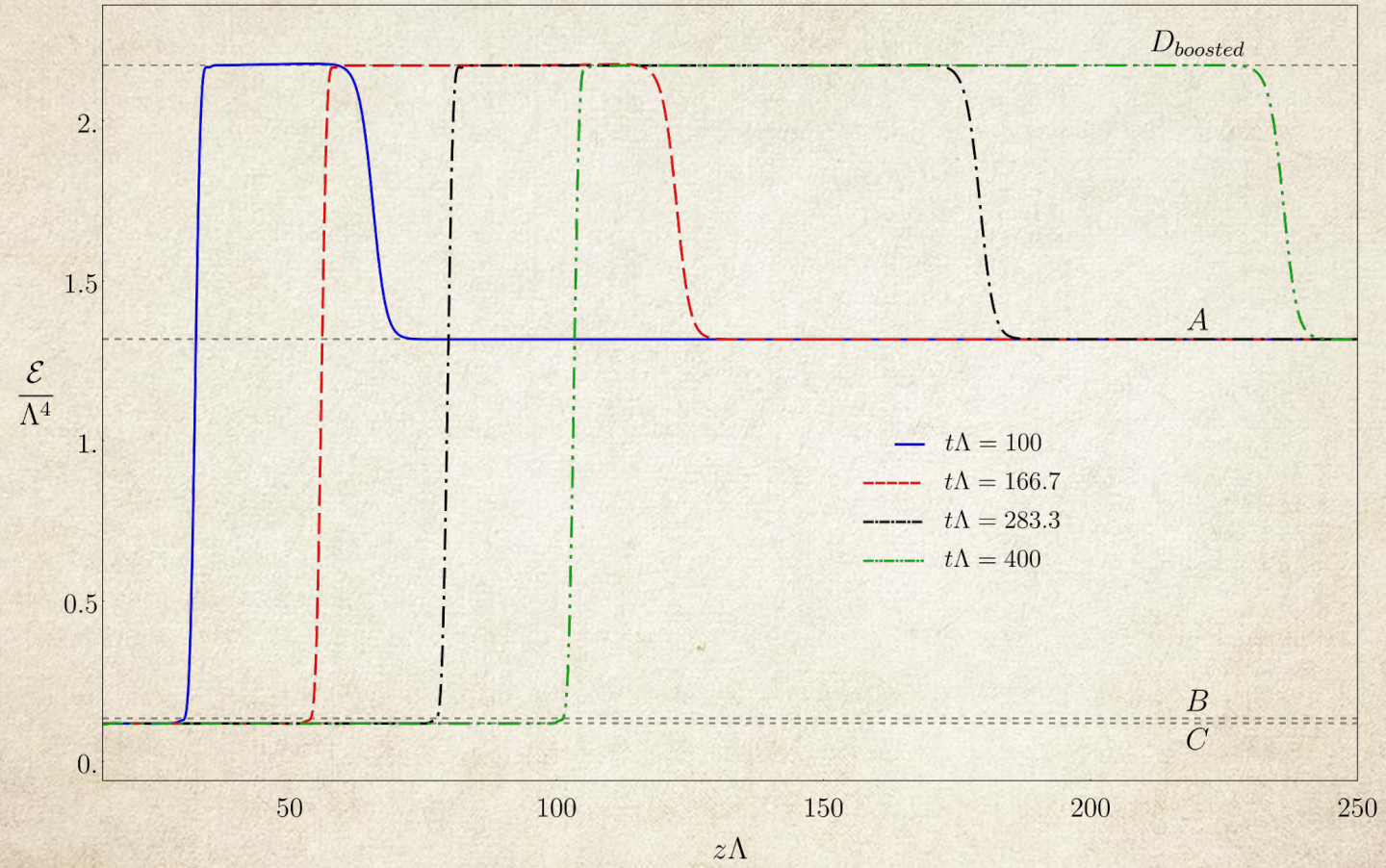


- Different B for the same A
- Different A
- Different bubble size
- Different initial wall profile
- Planar bubbles: dynamics in 1+1

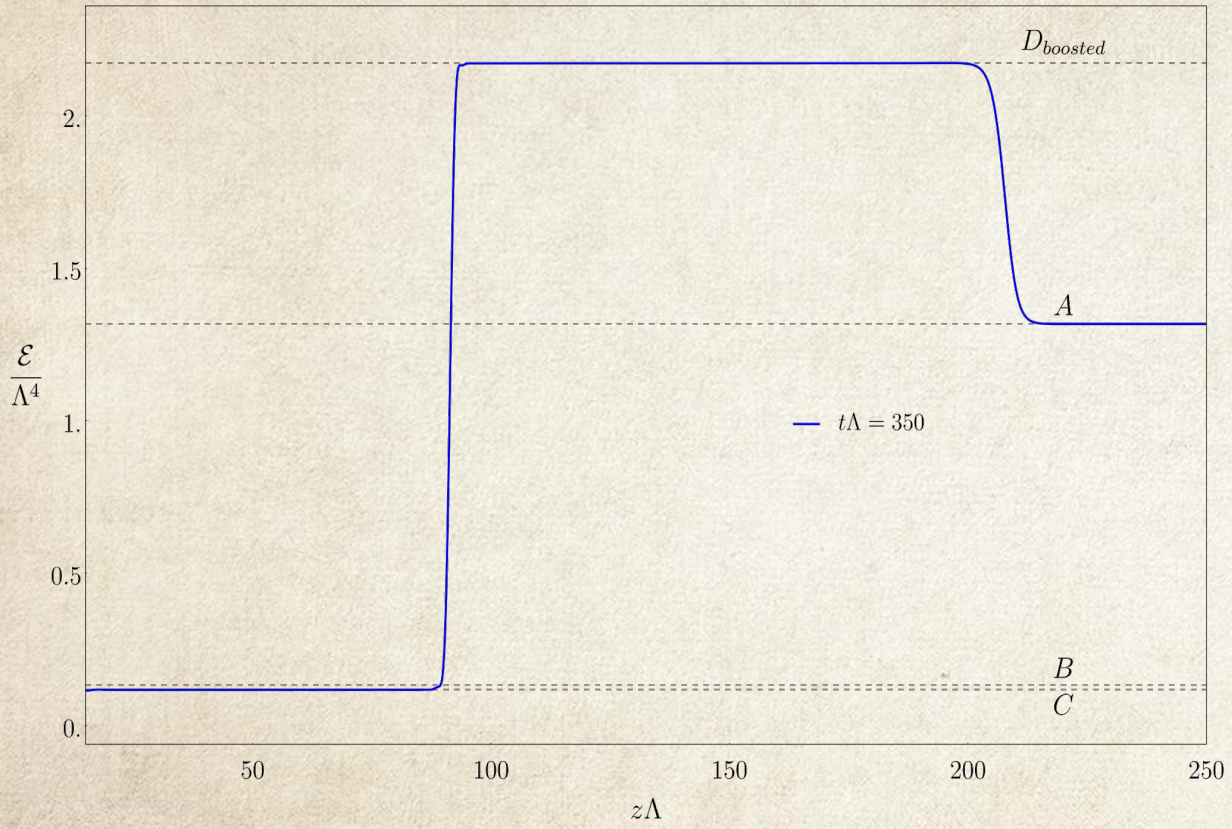
Initial State



Time Evolution

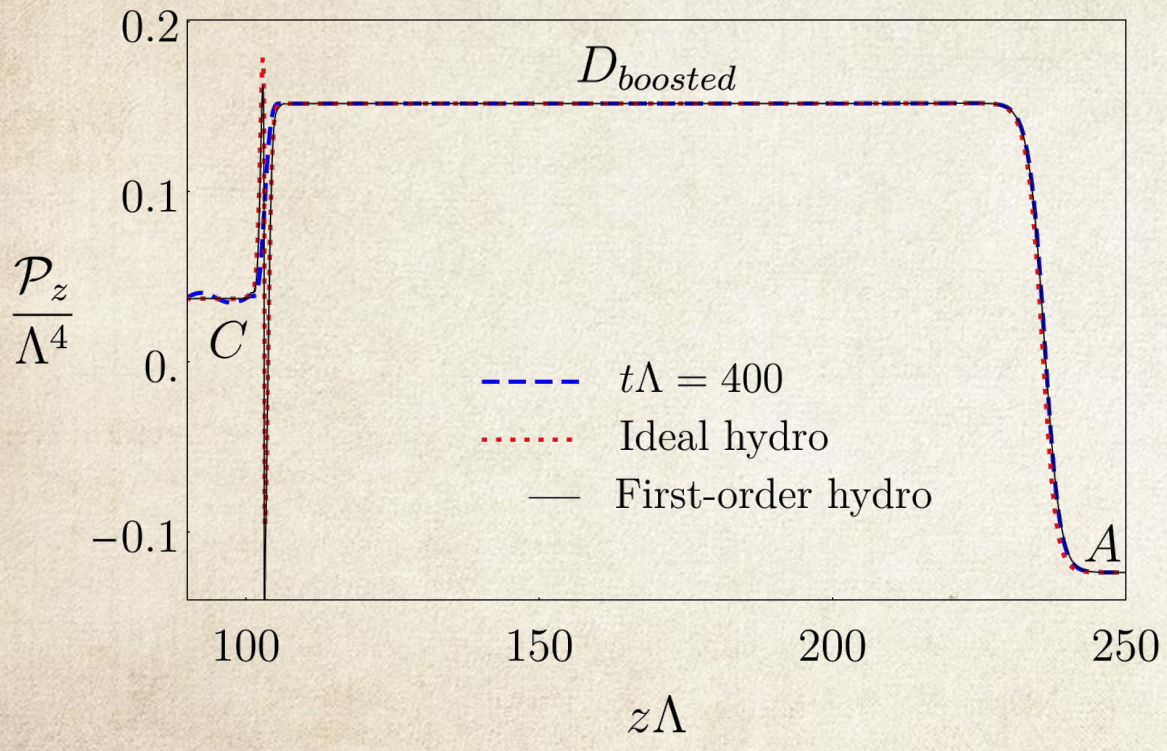


Steady State



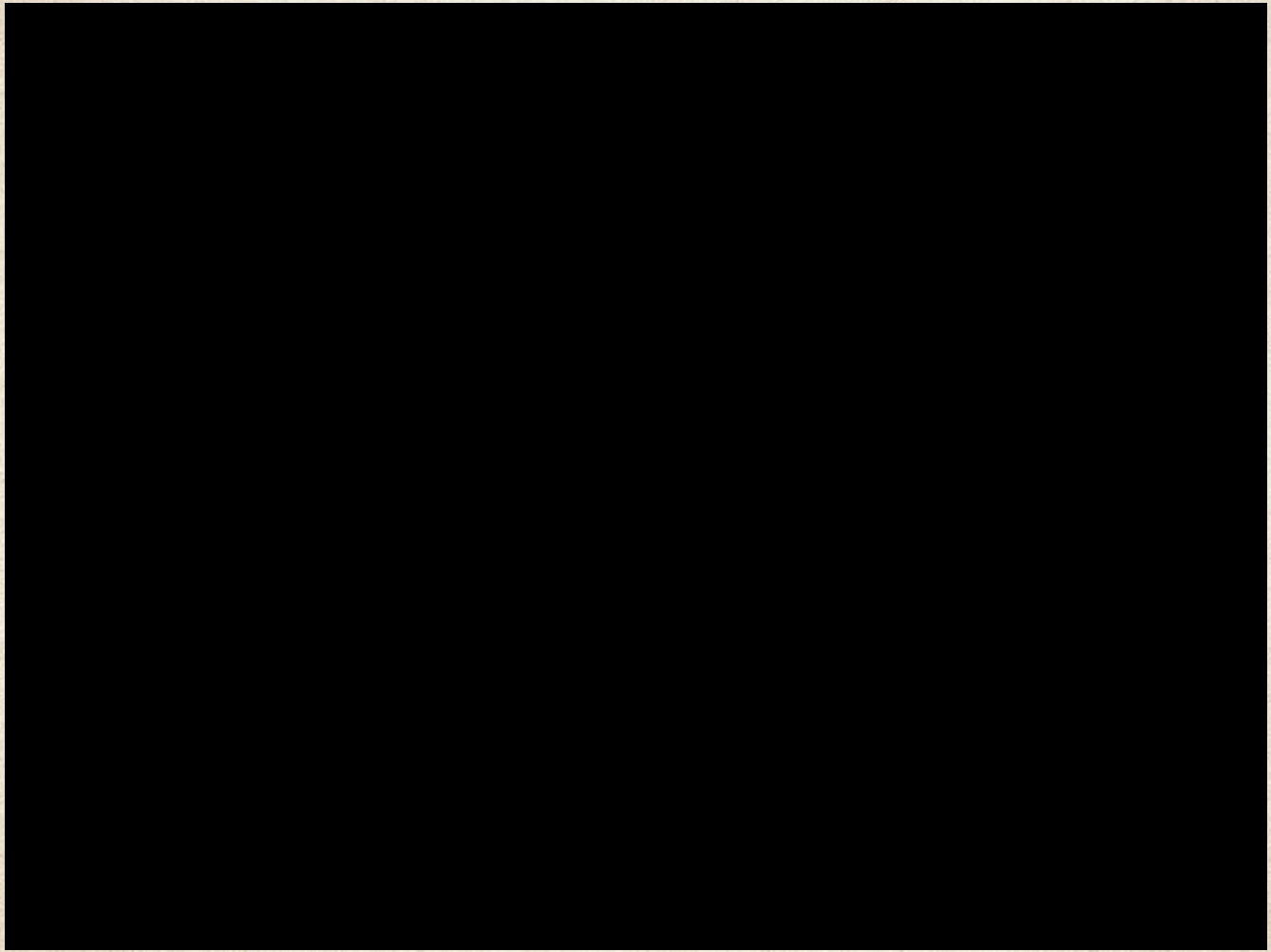
- Late time state is self similar and only depends on A (nucleation T)
- D and C regions grow in size, wall does not: thin wall
- Single profile approximates well any wall of same theory
- $V_{wall} \lesssim 0.3 < C_s$: Deflagrations

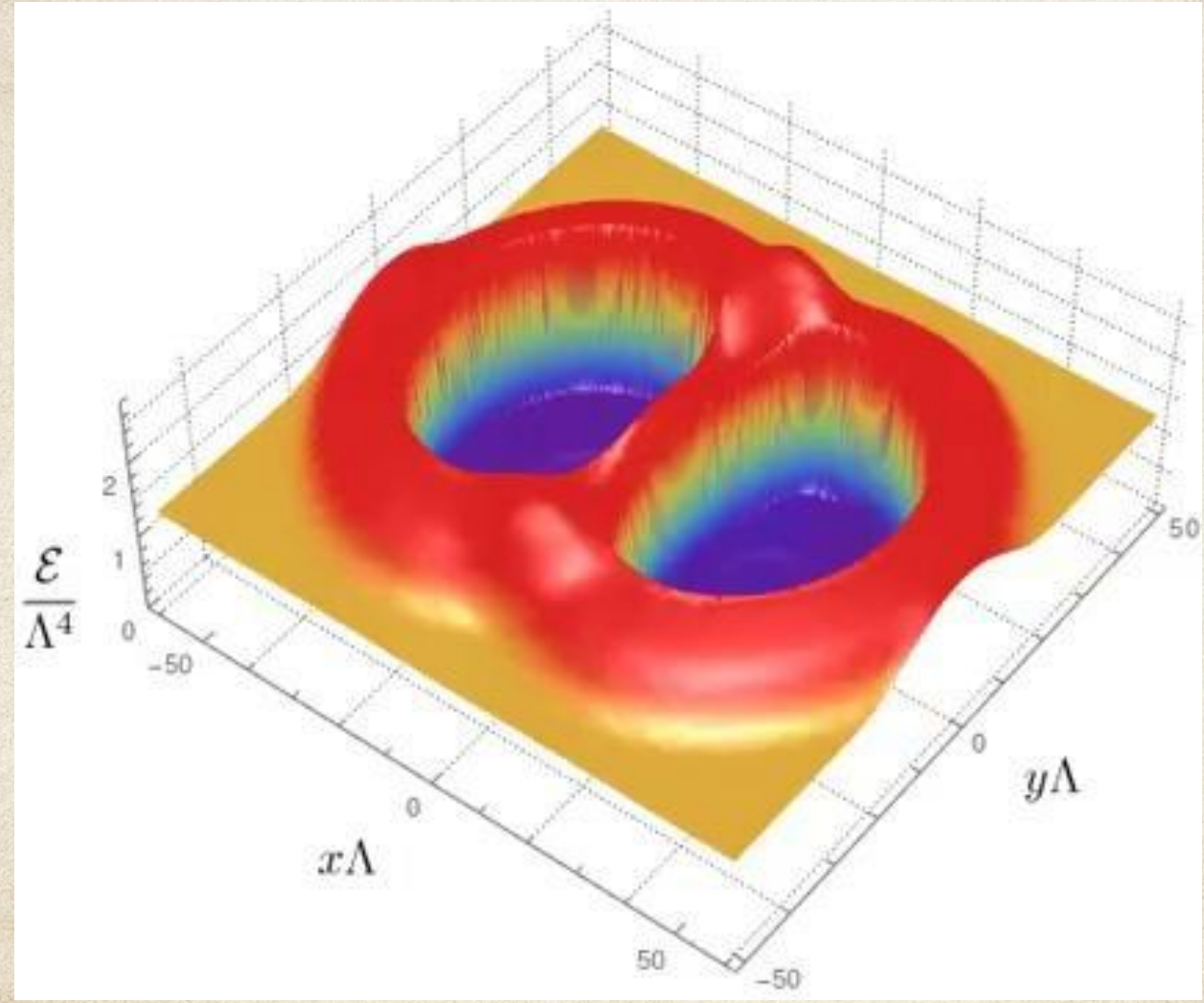
Hydrodynamics



- Both ideal and viscous hydrodynamics fail to describe the wall
- They approximate well the rest of the flow, including the region connecting D with A
- Work in progress to check the performance of 2nd order hydro

Ongoing work

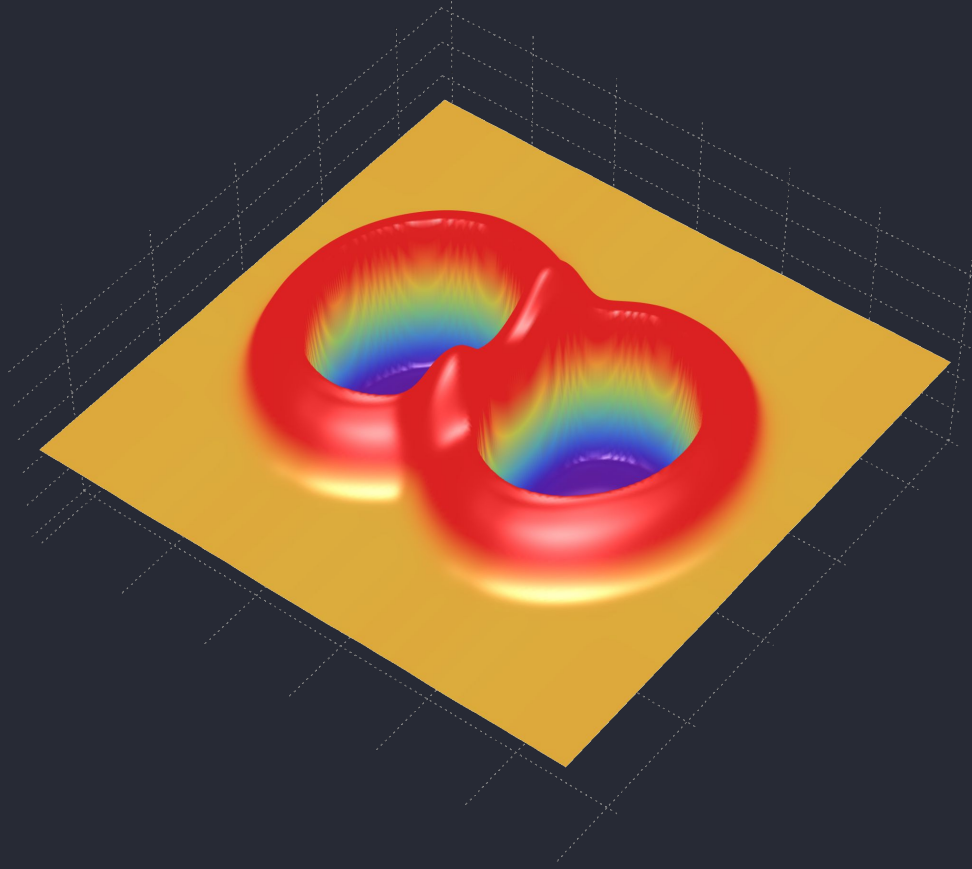



$\frac{\mathcal{E}}{\Lambda^4}$
2
1
0
-50
0
50
$x\Lambda$
50
0
-50
$y\Lambda$

Summary

- We obtained the first full dynamical evolution of an expanding bubble holographically
- We have worked with planar bubbles so far, but simulations are already being done with circular bubbles: surface tension
- Simulations of circular bubble collisions are on the way: direct computation of GW
- How far can hydrodynamics take us in the collision of bubbles?

Thank You!



UNIVERSITAT DE BARCELONA

ICCUB EXCELENCIA MARÍA DE MAEZTU
Institut de Ciències del Cosmos