

# Theoretical Cosmology

## Outline:

### Observations:

- Trigonometry
- Parallax
- Optics
- Doppler
- Redshift
- Advanced methods

### Theory:

- Philosophy
- Mathematics
- Physics
- Current picture
- Components
- Baryon Acoustic Oscillations

### Stellar objects:

- Planets
- Stars
- Galaxies
- Supernovae
- Quasars
- Black holes
- Hawking radiation
- *Actionic field-particles*

Hosted by Dr. Pierros Ntelis

**Philosophy** originates from the greek word, **φιλοσοφία**  
Which is a compound word, composed by  
The word **φιλο-**, **friendly**, and word, **-σοφία**, **wisdom**.  
*Ergo, philosophy means being friends with wisdom*

**Look at :**

- **Theory Of Knowledge (TOK)**
- **Global Perspectives (GP)**

Officially, modern Philosophy is the study of general and fundamental questions:

abstraction, existence, reason, knowledge, values, mind, and language.

Such questions are often posed as problems to be studied or resolved.



# Mathematics

Mathematics (μαθηματικά) originates from the greek word, μάθημα, which means learning.

Axioms . /  $1 \in \mathbb{N}, \pi \simeq 3.14 \in \mathbb{Q}', e^\pi \in \mathbb{R}, e^{i\pi} \in \mathbb{C}$  Numbers

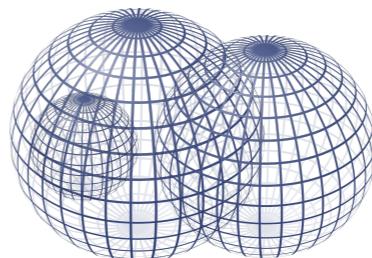
Functions  $f(x) : \mathbb{R} \rightarrow \mathbb{R}^+$   $(a \pm b)^2 = a^2 \pm 2ab + b^2$  Algebra

$f'(x) = \frac{\partial f}{\partial x}$



Geometry

$f''(x) = \frac{\partial^2 f}{\partial x^2}$



Sets

Derivatives  $\dots = \dots$

$f^{(n)}(x) = \frac{\partial^n f}{\partial x^n}$   $f'(x) = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$  Limits

Integrals  $F(x) = \int_0^x f(s)ds$   $P(x; \mu, \sigma) \propto e^{-\frac{1}{2}(\frac{x-\mu}{\sigma})^2}$  Probabilities

Statistics  $\lim_{s \rightarrow +\infty} \int_{-s}^{+s} dx P(x) = 1$   $a^2 + b^2 + c^2 = d^2$  Theorems

with proofs !

# Physics

Physics (φυσική) originates from the greek word, φύση, and it means the study of nature.

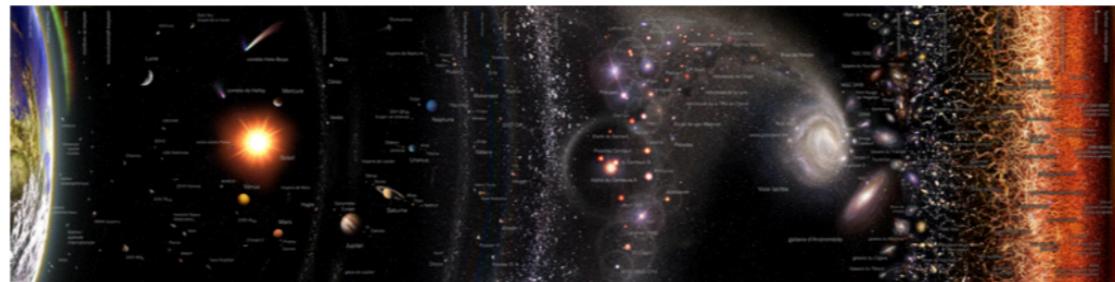
## Newton 2<sup>nd</sup> Law of motion

$$F = ma$$

$$\frac{\partial p}{\partial t} = m \frac{\partial^2 x}{\partial t^2}$$

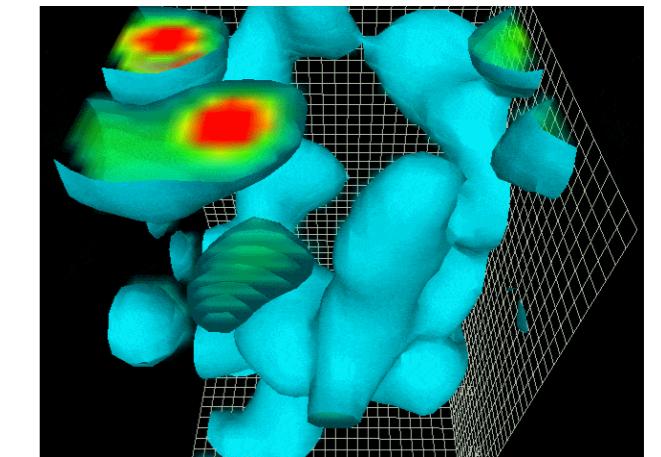


Cosmology is the study of the smallest to largest objects



## Electric force

$$F_{12} = k_e \frac{q_1 Q_2}{r_{12}^2}$$



## Quantum mechanics (Special Relativity)

**Energy is a manifestation of matter**

$$E = mc^2$$

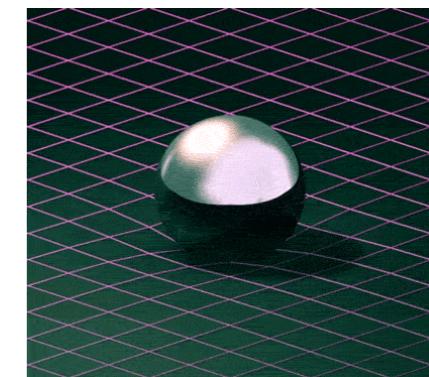
Small world

## Gravity (General Relativity)

**Geometry is a manifestation of Energy**

$$G_{\mu\nu} \simeq E_{\mu\nu}$$

Large world



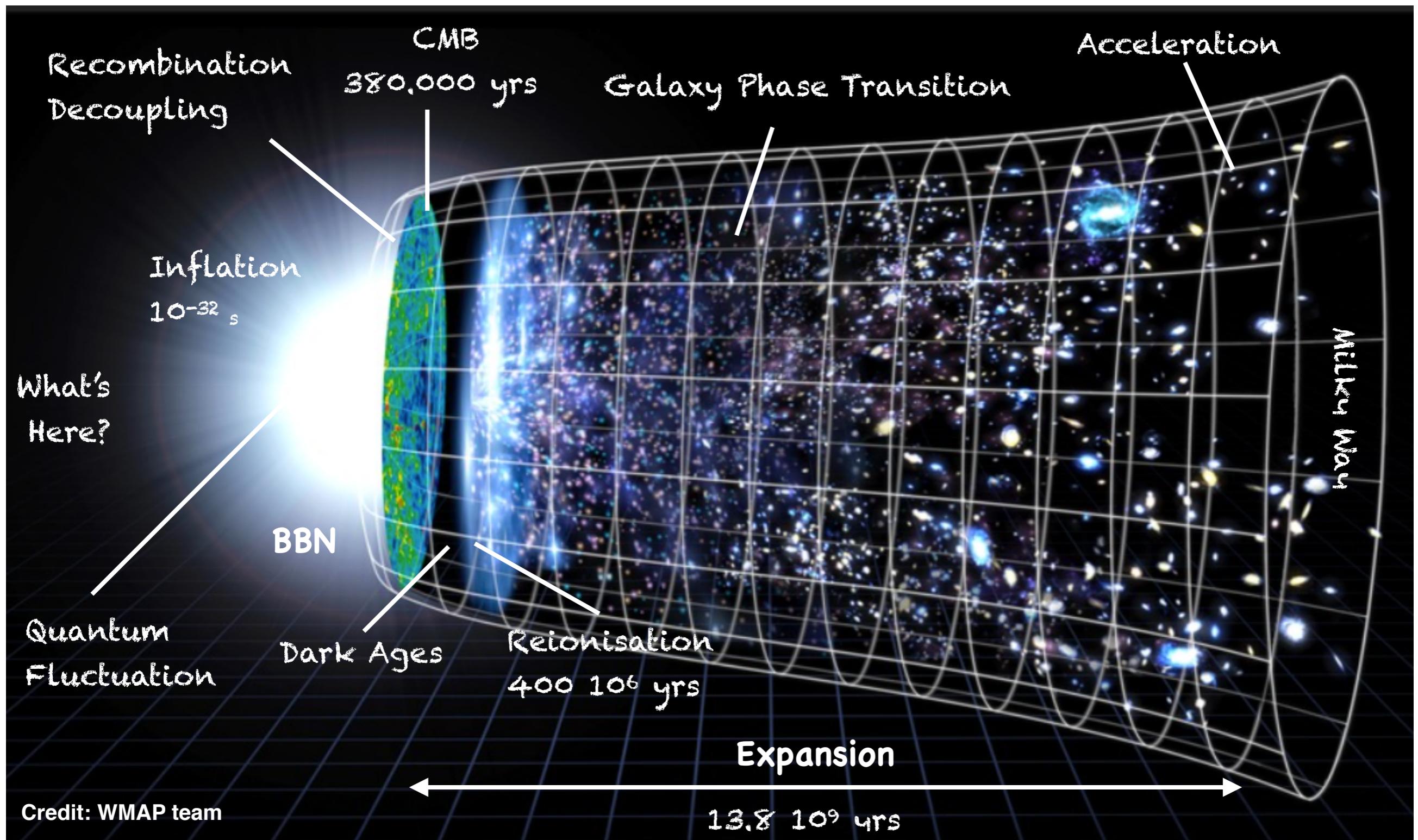
To describe/explain positioning, timing, motions and properties of the whole universe, we use experimental and theoretical physics, which results to the study of cosmology

**Where did all came from ?**

**universe !**

**but we do not know the whole universe!**

## Current Picture



# Baryon Acoustic Oscillations (BAO)

## ~300,000yr after Big Bang (Hot BAO)

The universe was hot and dense.

$F_{\text{out}}$  : b, l,  $\gamma$  interact  $\rightarrow$  high Temperature  $\rightarrow$  kinetic energy  $\rightarrow$  outward Pressure

$F_{\text{in.}}$  : Attractive gravitational potential of matter

Counteracting forces create acoustic oscillations to the structures

## ~360,000yr after Big Bang (Recombination)

The universe cools down at a point where the baryons are combined with the leptons

Acoustic oscillations "freeze" at the very large scales

## ~380,000yr after Big Bang (Decoupling)

The photons cannot interact anymore with atoms  $\Rightarrow$  free stream as CMB

Frozen BAO start evolve with time

## ~7x10<sup>8</sup> yr after Big Bang (Cold BAO) first galaxies appears along with quasars

## ~13x 10<sup>9</sup> yr after Big Bang (Today)

We observe these frozen BAO in the universe:

Either in the late universe with

density fluctuations of the

galaxy distributions

or. In the early universe with

temperature fluctuations of the total matter distributions

## Baryon Acoustic Oscillations (Briefly)

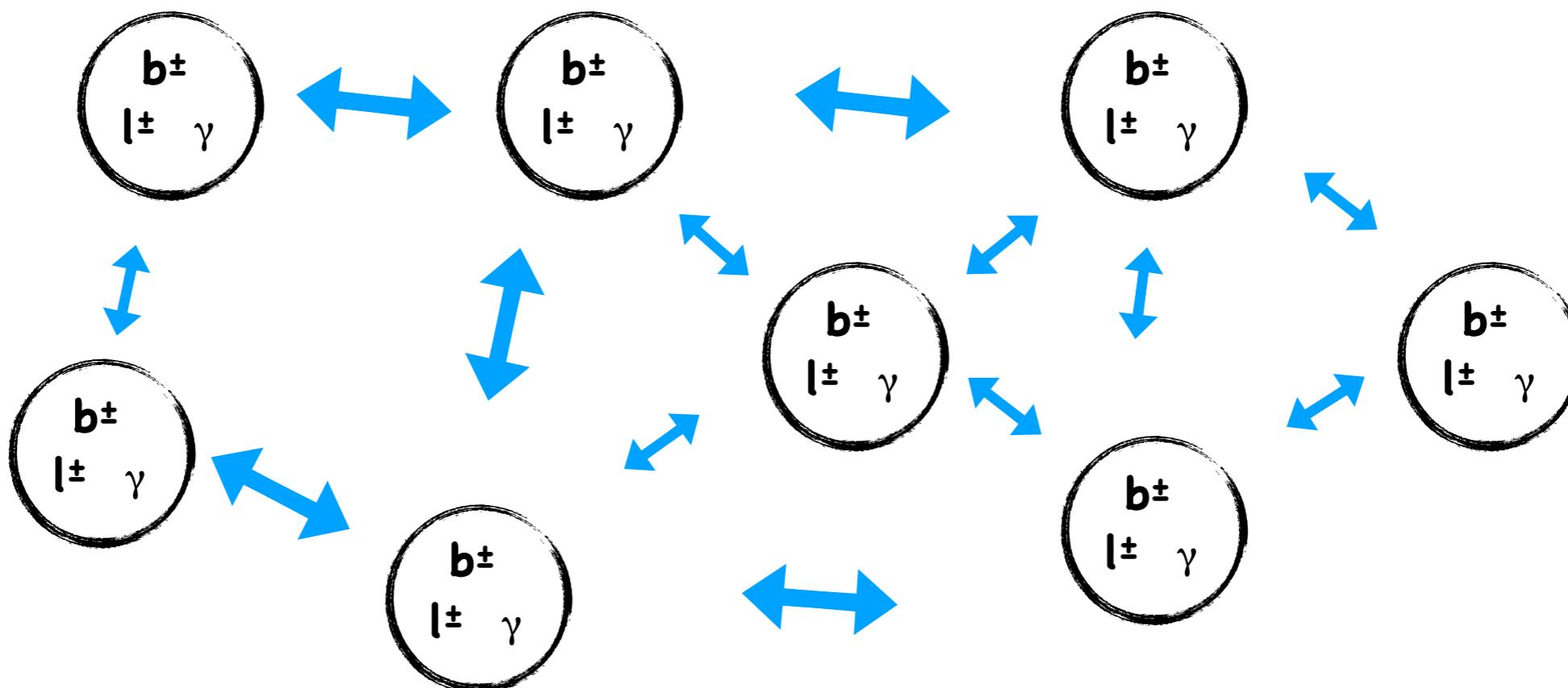
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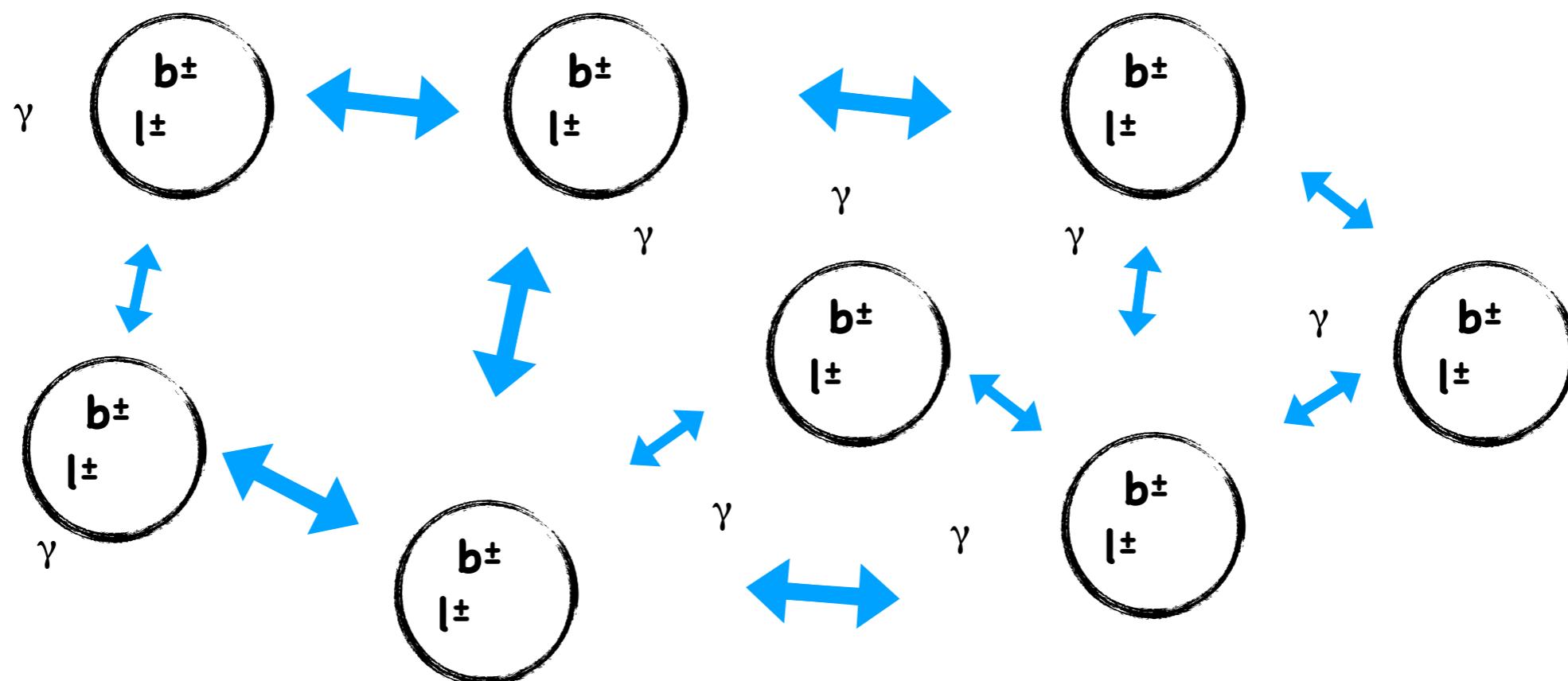
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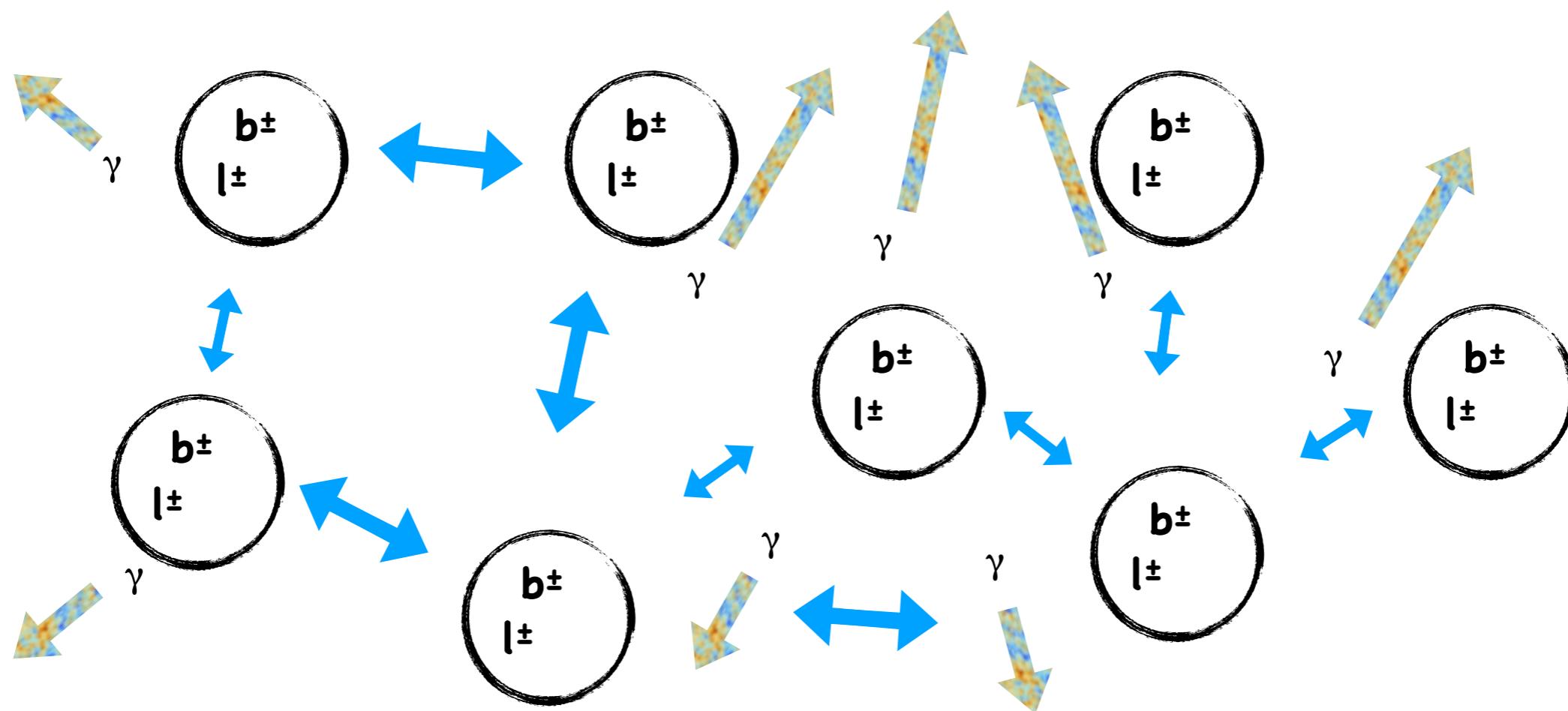


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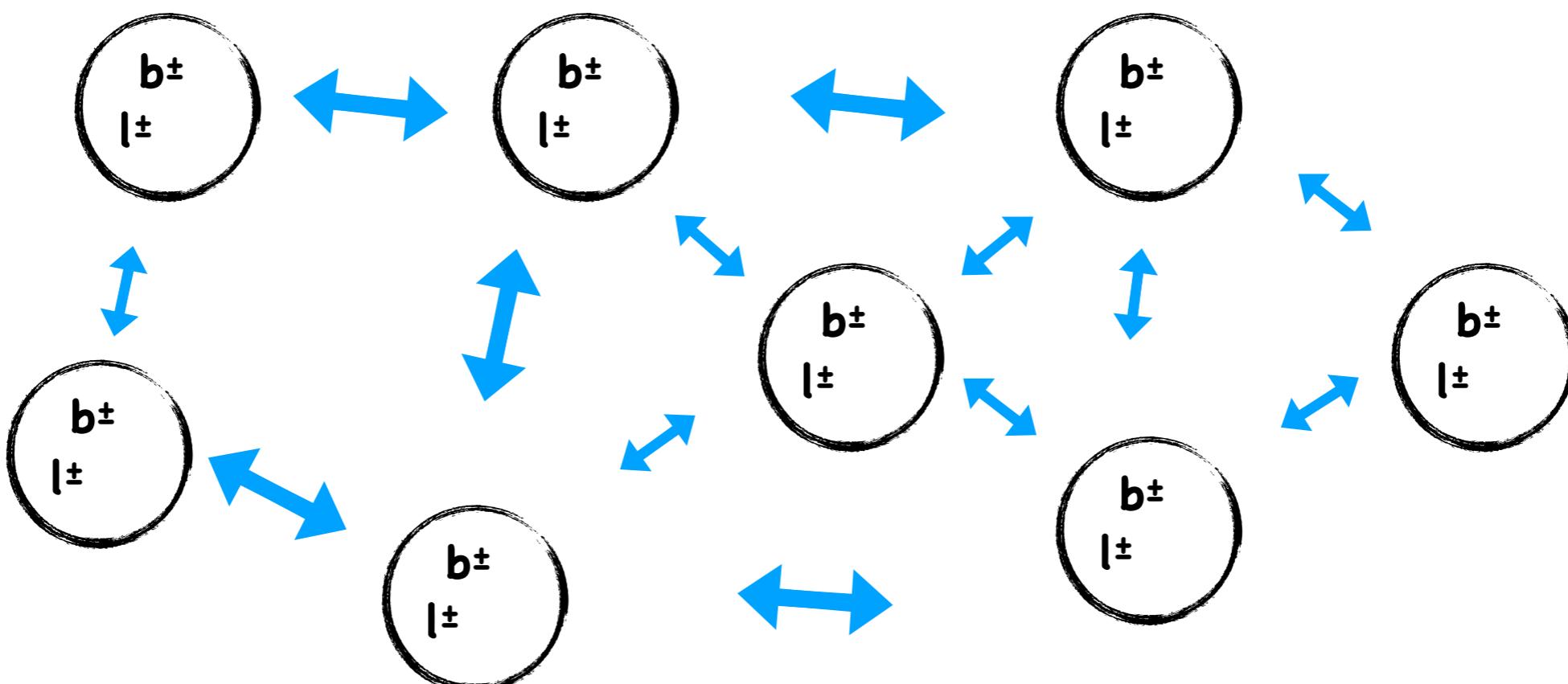
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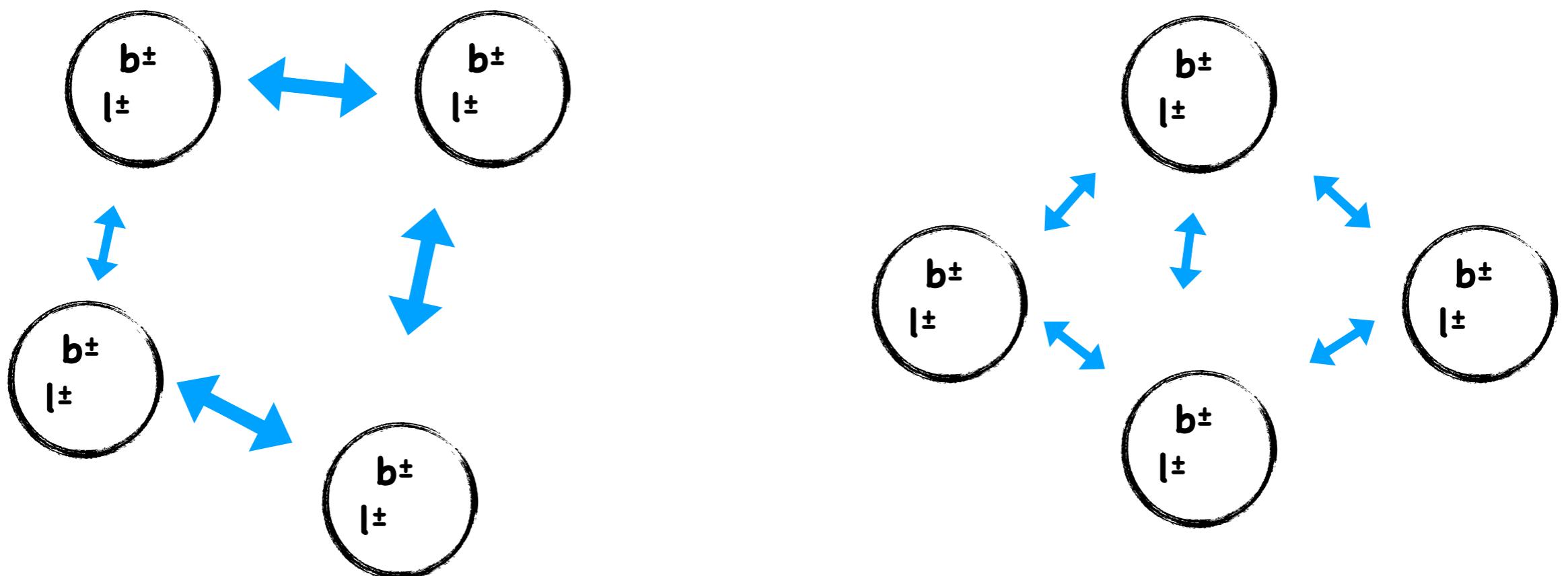
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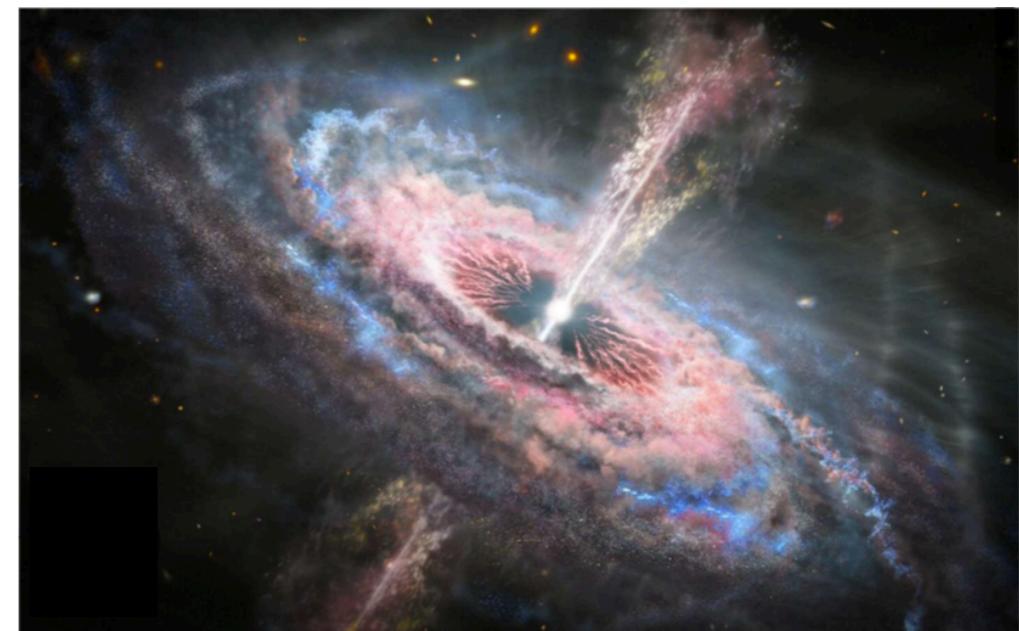
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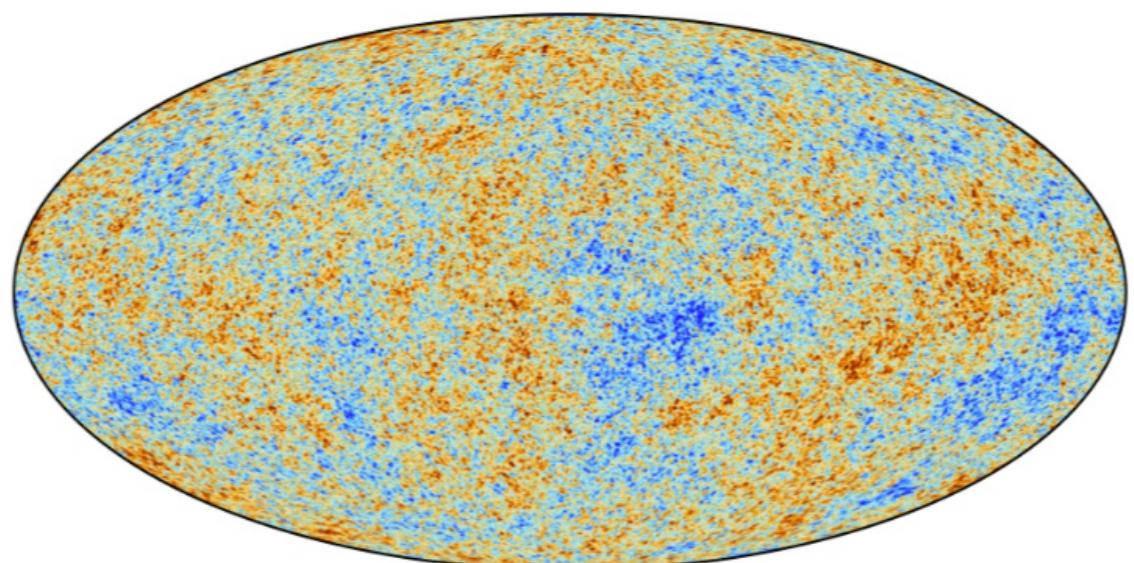
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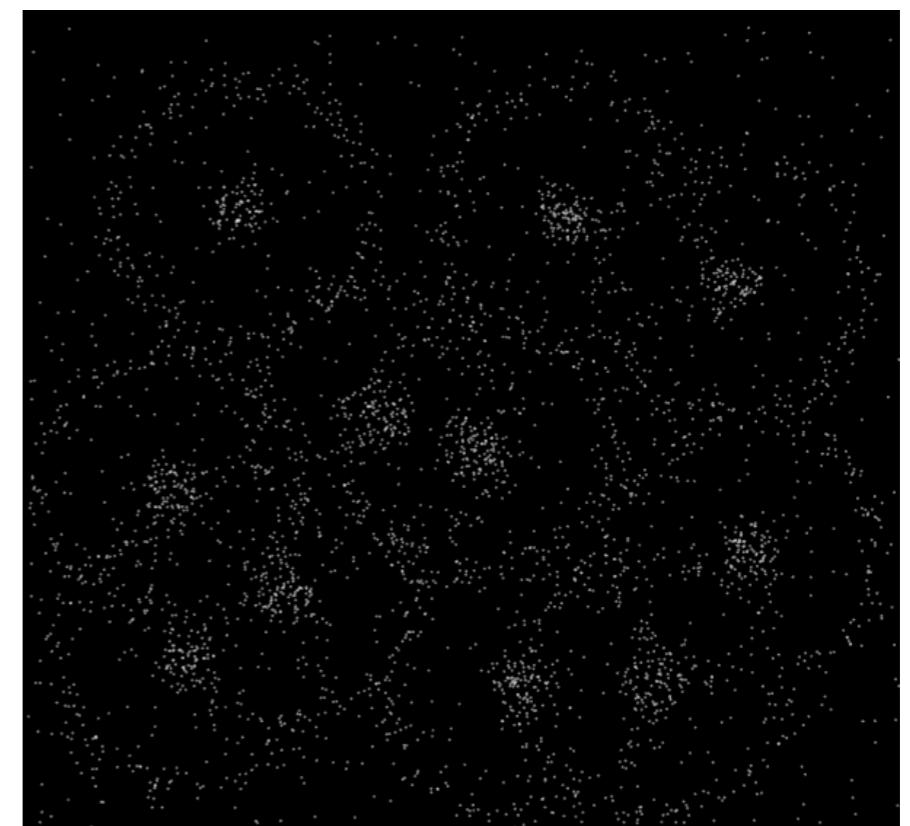
## Baryon Acoustic Oscillations (Briefly)

~ After Big Bang (Today) in the universe:

380000 yr after BB



13 Gyr after BB



↔

↔

$150 \text{ Mpc} = 10^{25} \text{ m}$

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Hot BAO

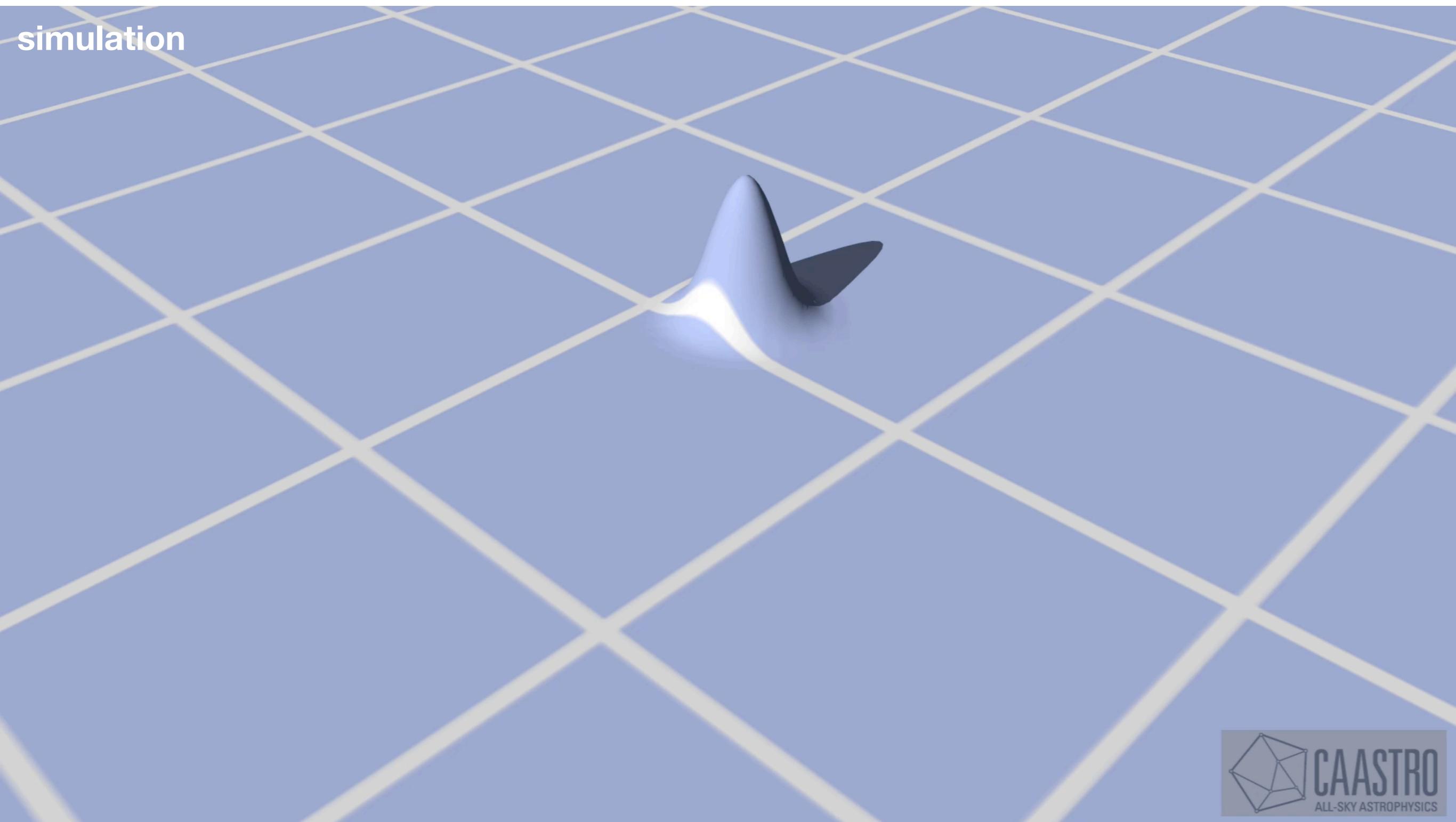


Time

frozen BAO

## Baryon Acoustic Oscillations (Briefly)

simulation



# Relativistic Universe

## Current Picture

Action Principle  
 $\delta S_{EFT} = 0$   
and right  
ingredients

DE & DM  
fills space

Inflation  
Is  
Imprinted  
In LSS

Primordial  
Features  
Signal

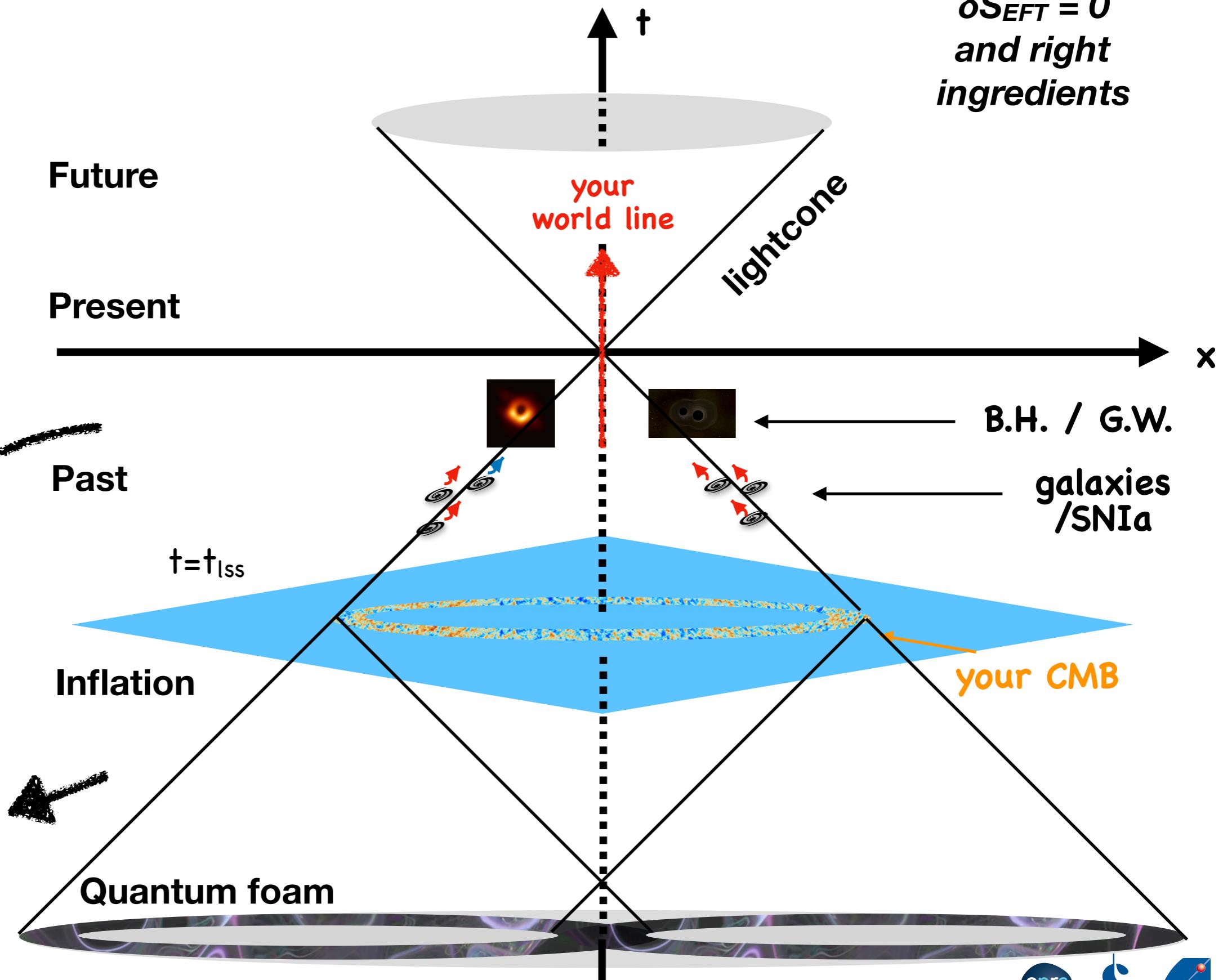
Future

Present

Past

Inflation

Quantum foam



# Theoretical Framework

