

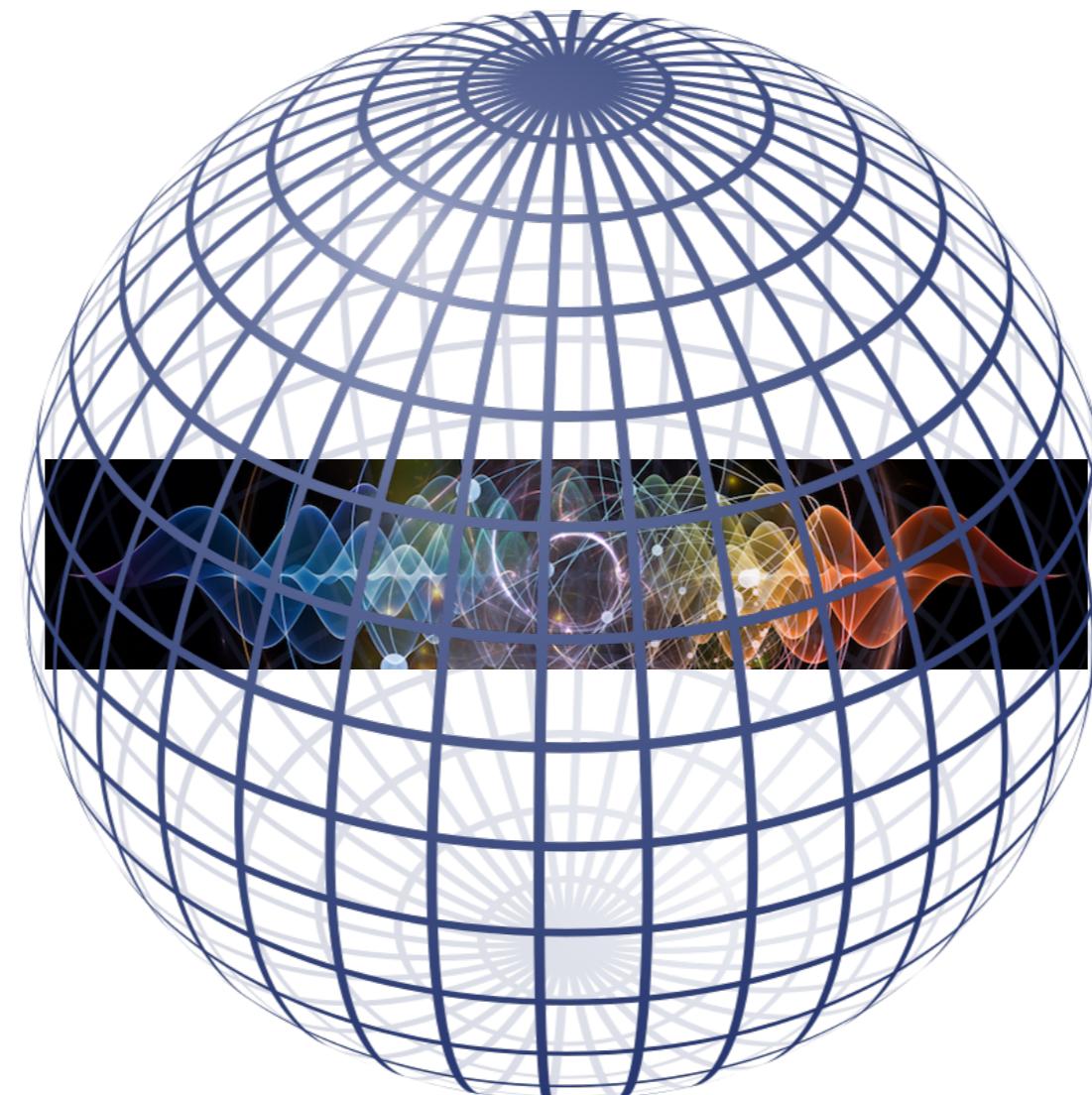
Cosmology

A combination of Mathematics, Physics, and Philosophy

$$a^2 + b^2 + c^2 = d^2$$

$$E = mc^2$$

$$e^{i\theta} = \cos(\theta) + i \sin(\theta)$$



Hosted by Dr. Pierros Ntelis

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*

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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 $f(x) : \mathbb{R} \rightarrow \mathbb{R}^+$

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

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

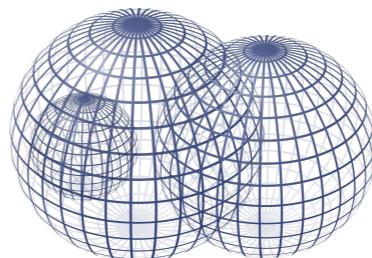
Derivatives

$$\dots = \dots$$

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

$$(a \pm b)^2 = a^2 \pm 2ab + b^2$$

Geometry



Sets

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 2nd Law of motion

$$F = ma$$

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

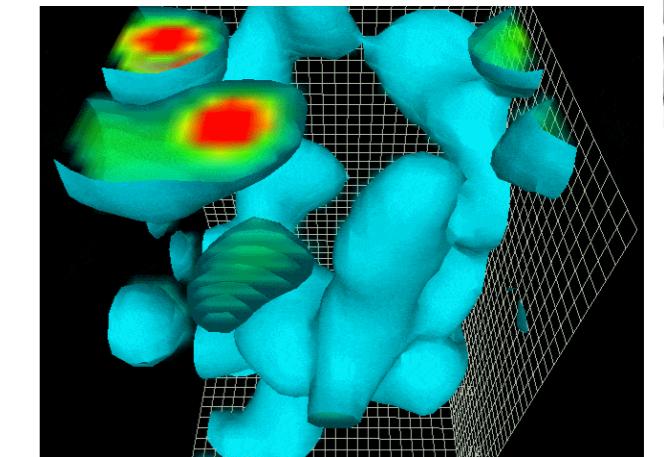


Cosmology is the study of the smallest to largest objects



Electric force

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



Quantum mechanics (Special Relativity)

Energy is a manifestation of **matter**

$$E = mc^2$$

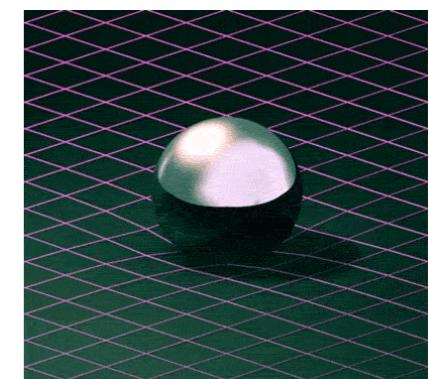
Small world

Gravity (General Relativity)

Geometry is a manifestation of **Energy**

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

Large world



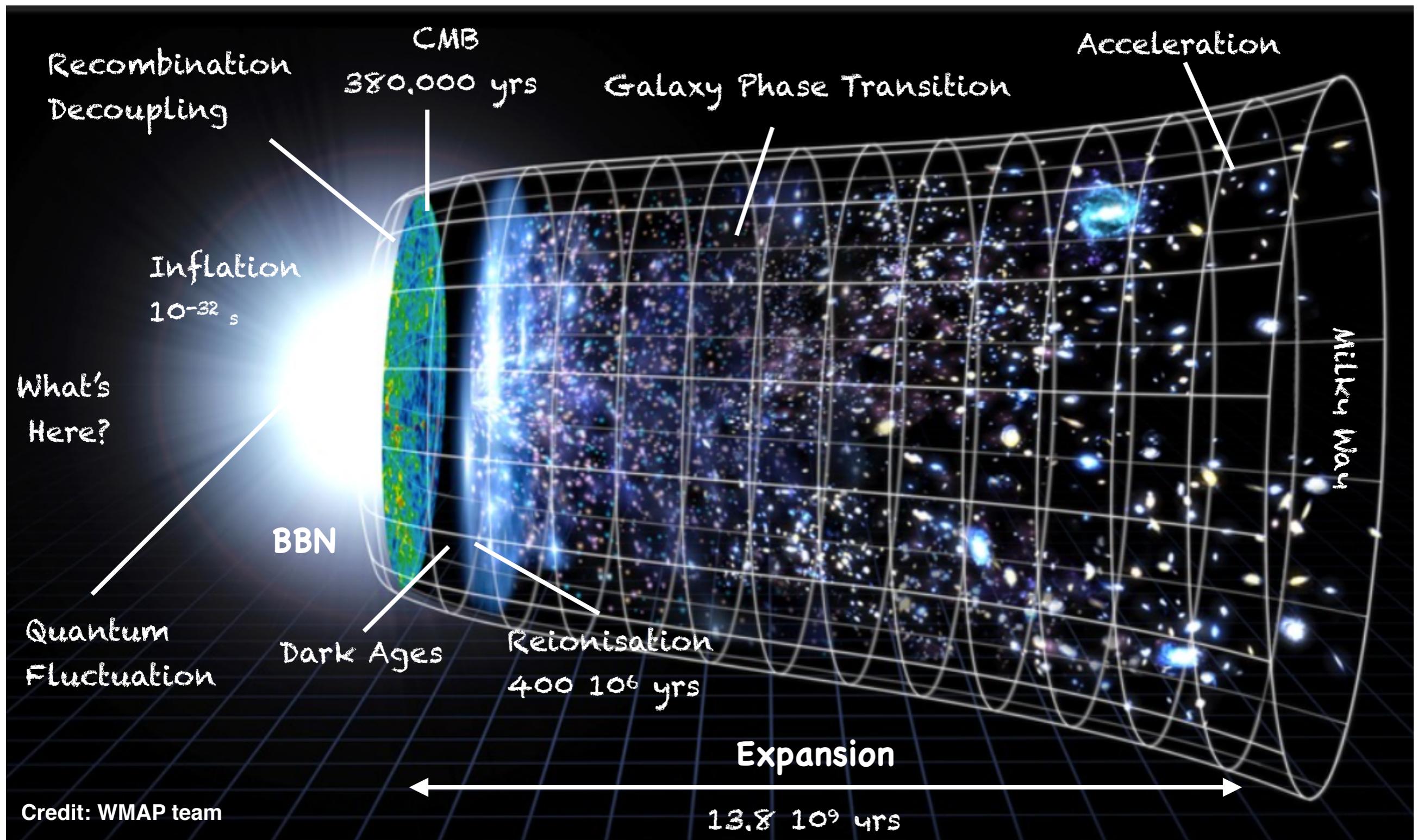
To describe/explain positioning, timing, motions and properties of the whole universe, we use experimental and theoretical physics, which results to the study of cosmology

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_{out} : b, l, γ 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

~7x10⁸ yr after Big Bang (Cold BAO) first galaxies appears along with quasars

~13x 10⁹ 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)

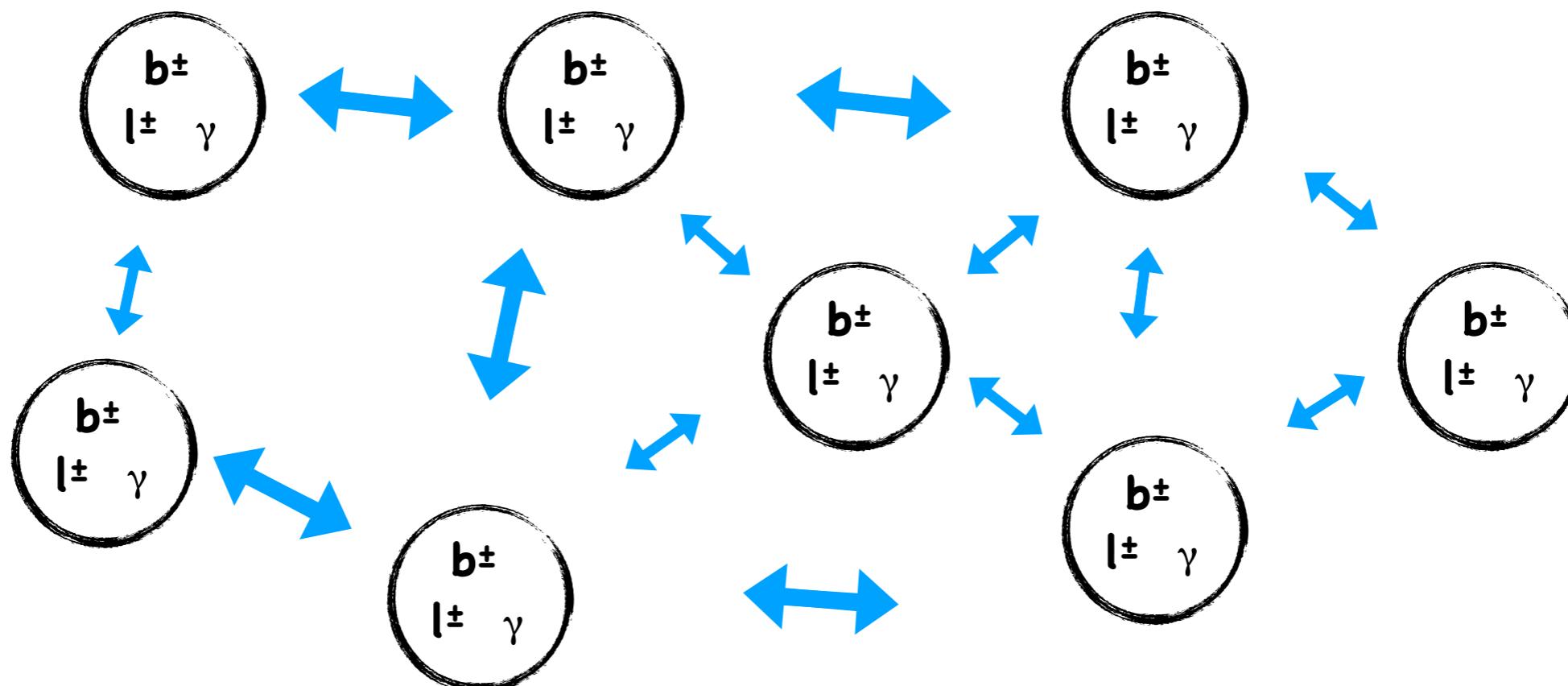
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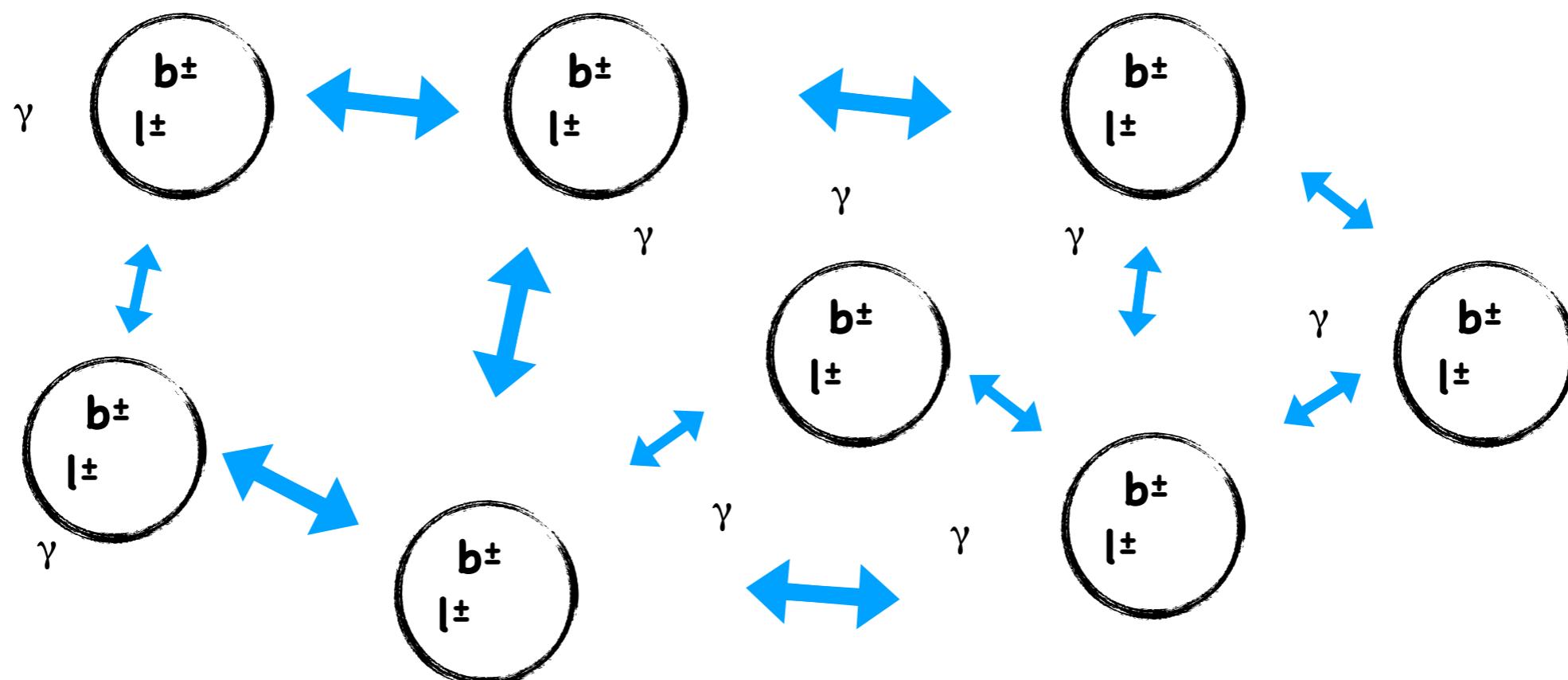
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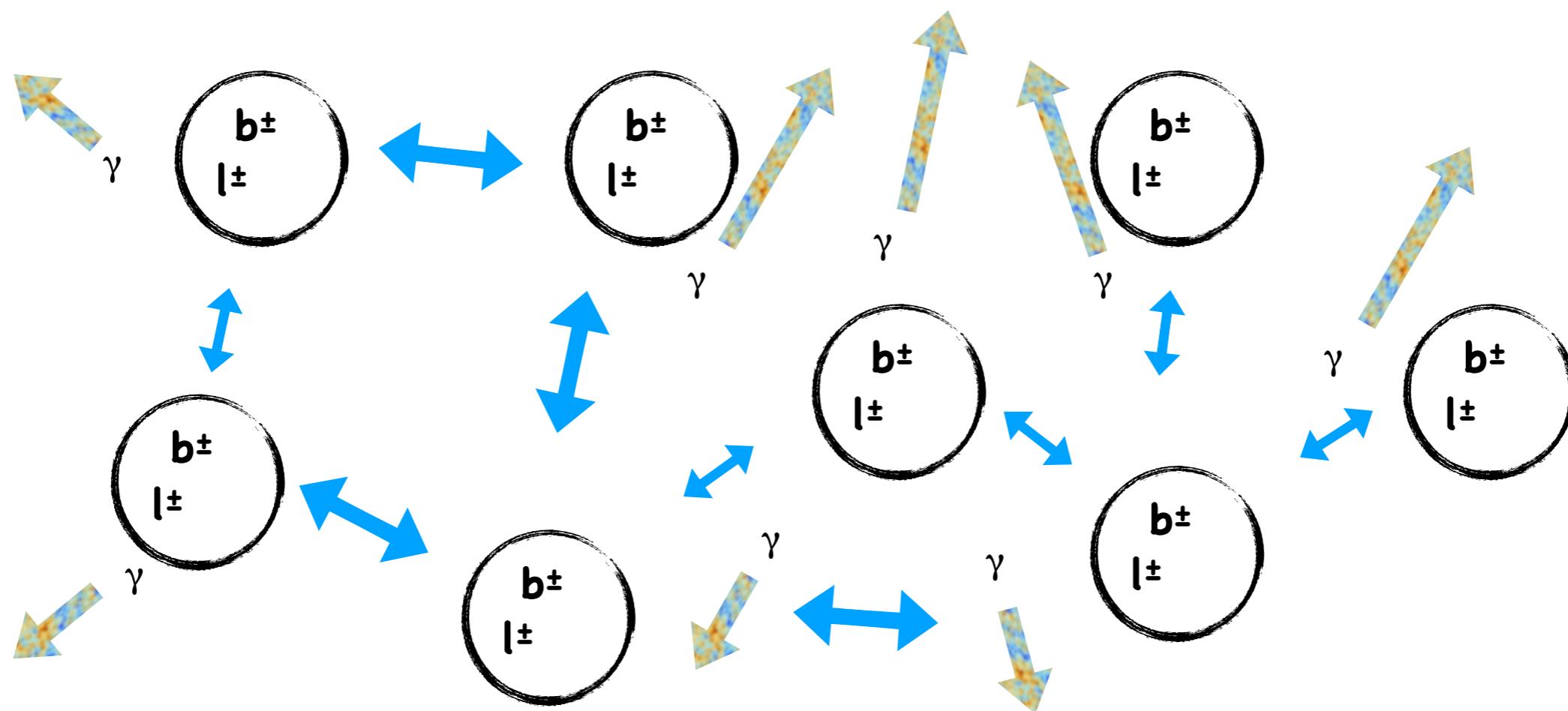


Baryon Acoustic Oscillations (Briefly)

~380,000yr after Big Bang (Decoupling)

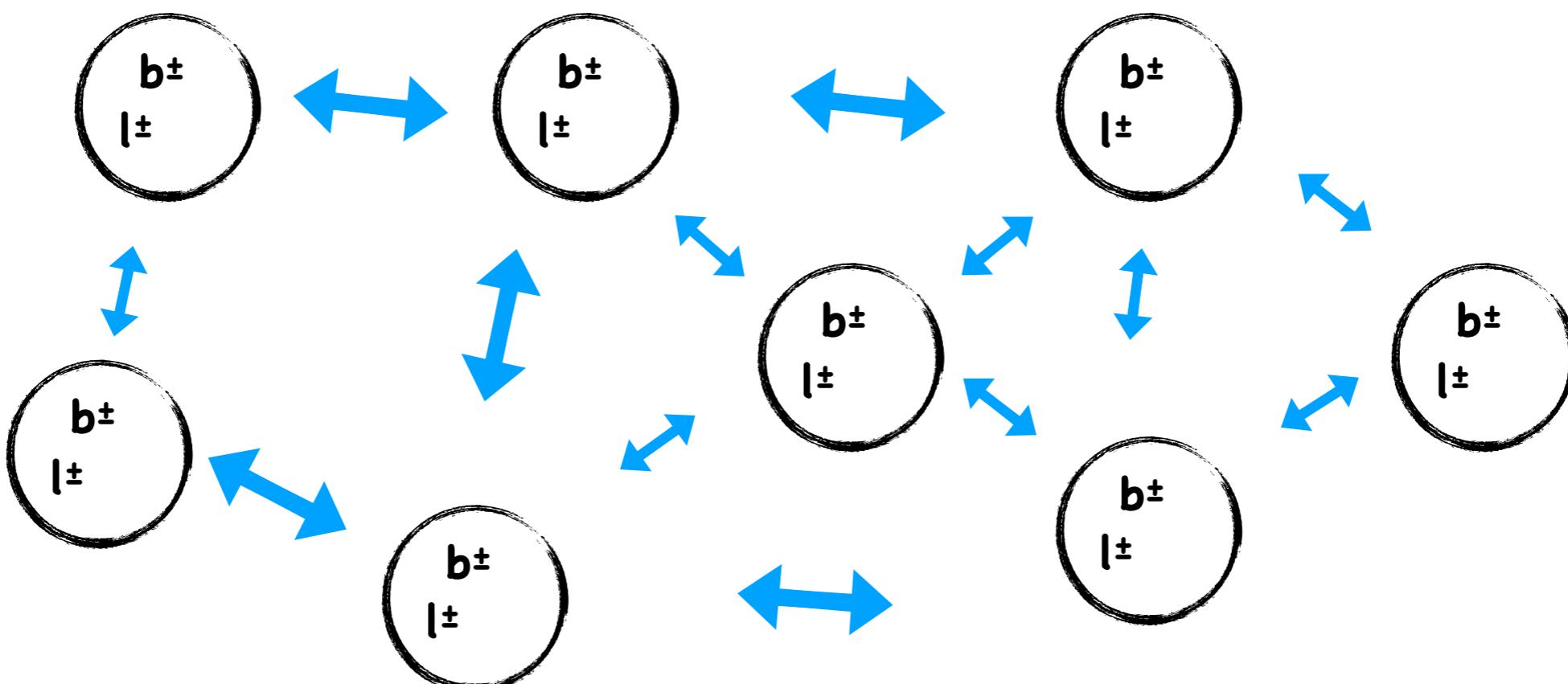
The photons cannot interact anymore with atoms => free stream as CMB

Frozen BAO start evolve with time



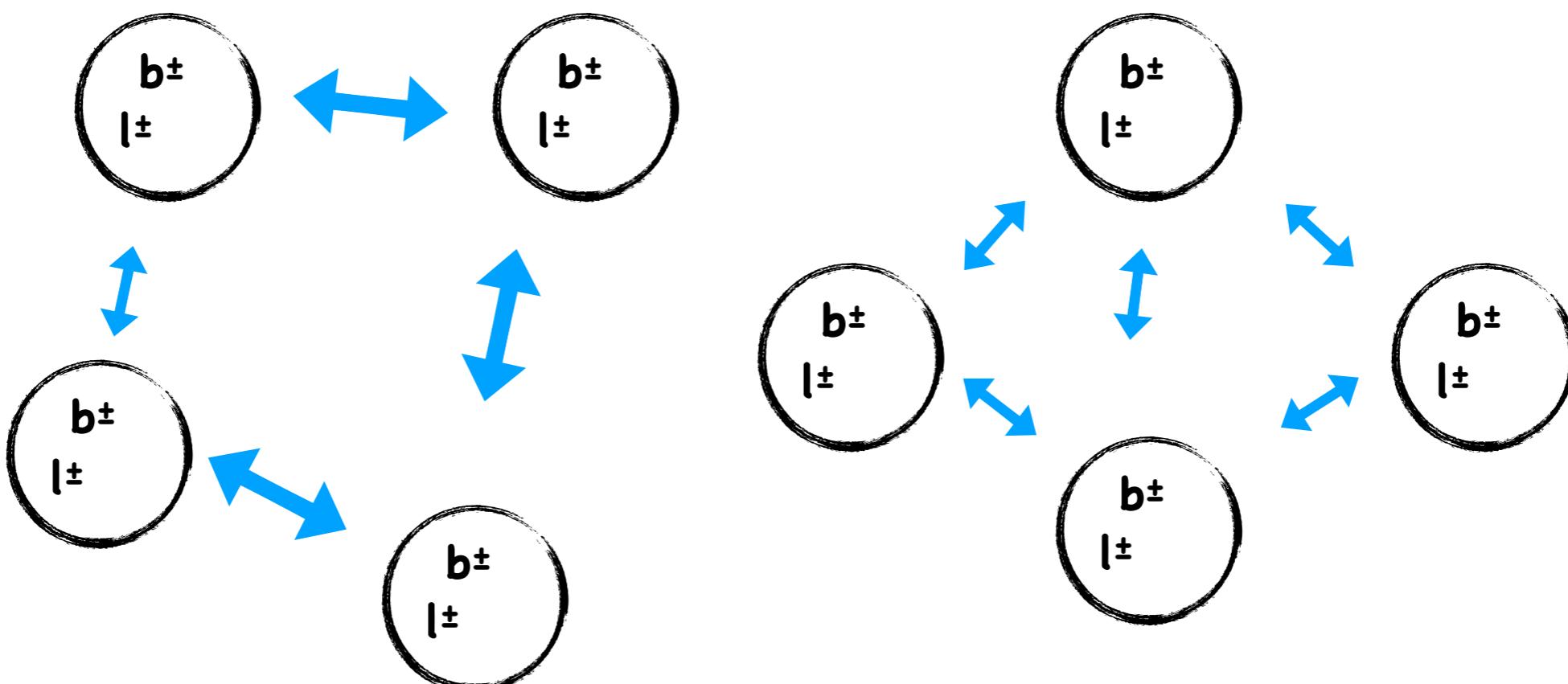
Baryon Acoustic Oscillations (Briefly)

~ 7×10^8 yr after Big Bang (Cold BAO), first galaxies appears along with quasars



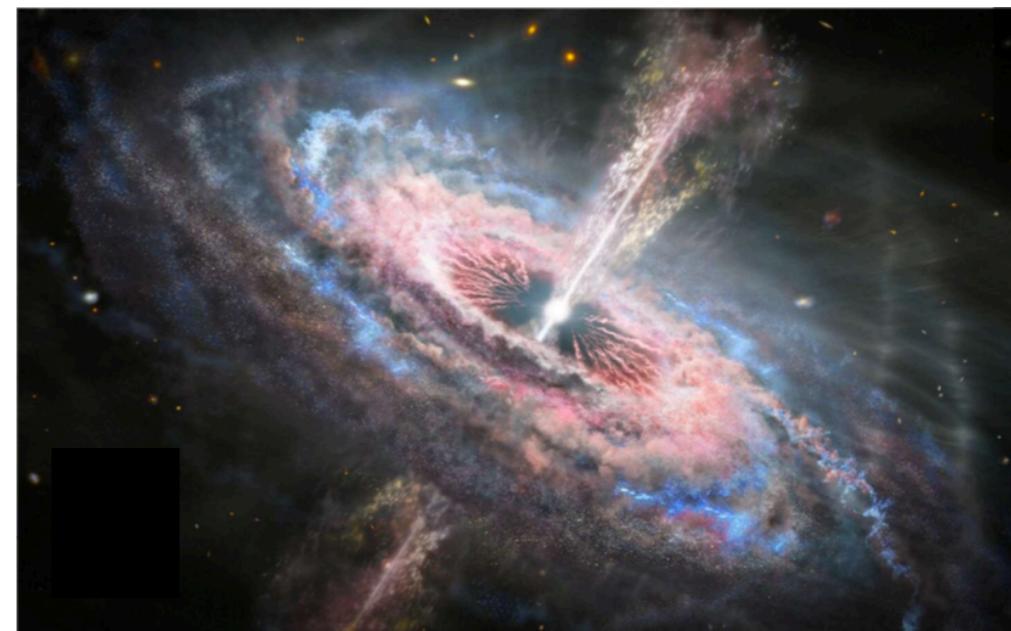
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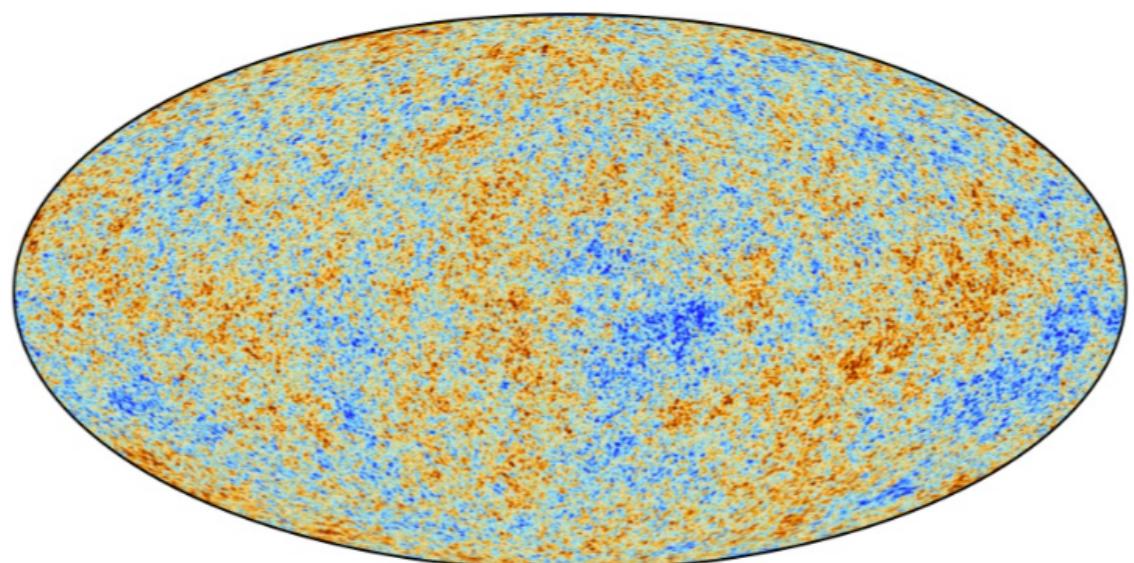
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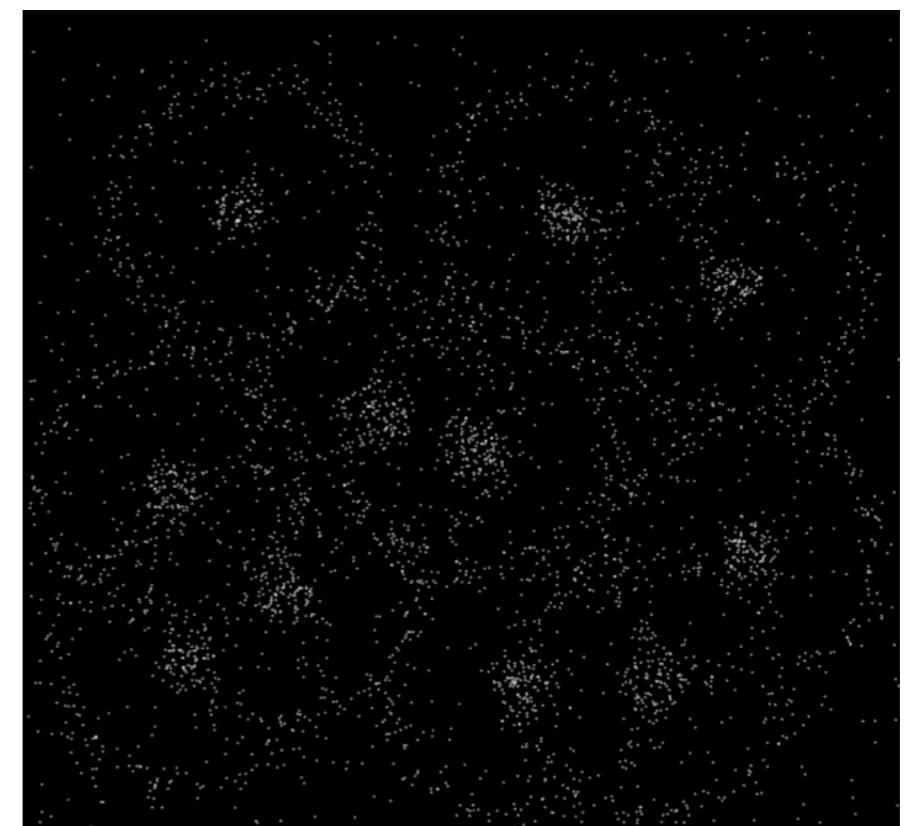
Baryon Acoustic Oscillations (Briefly)

~ 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

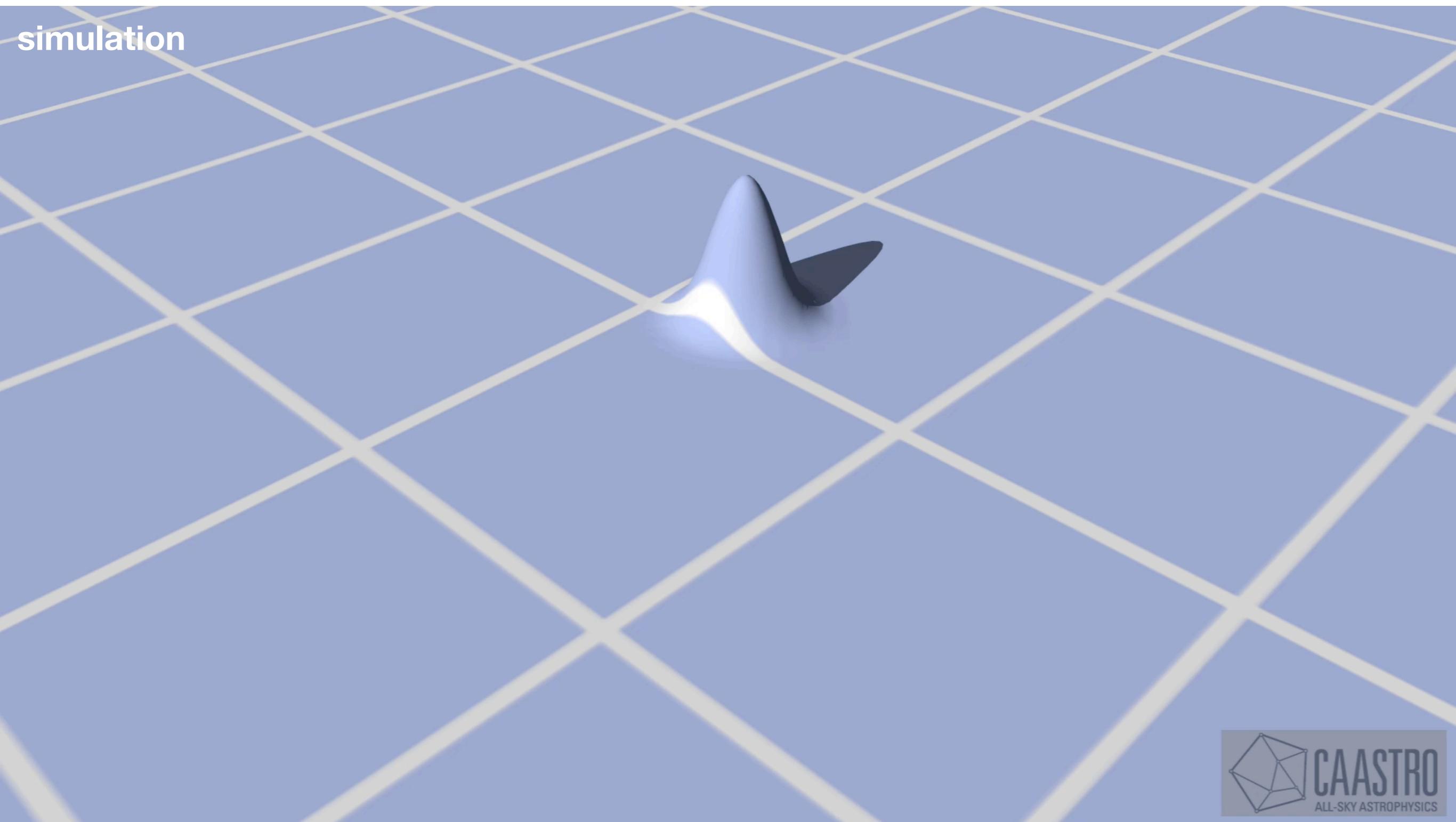
→

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

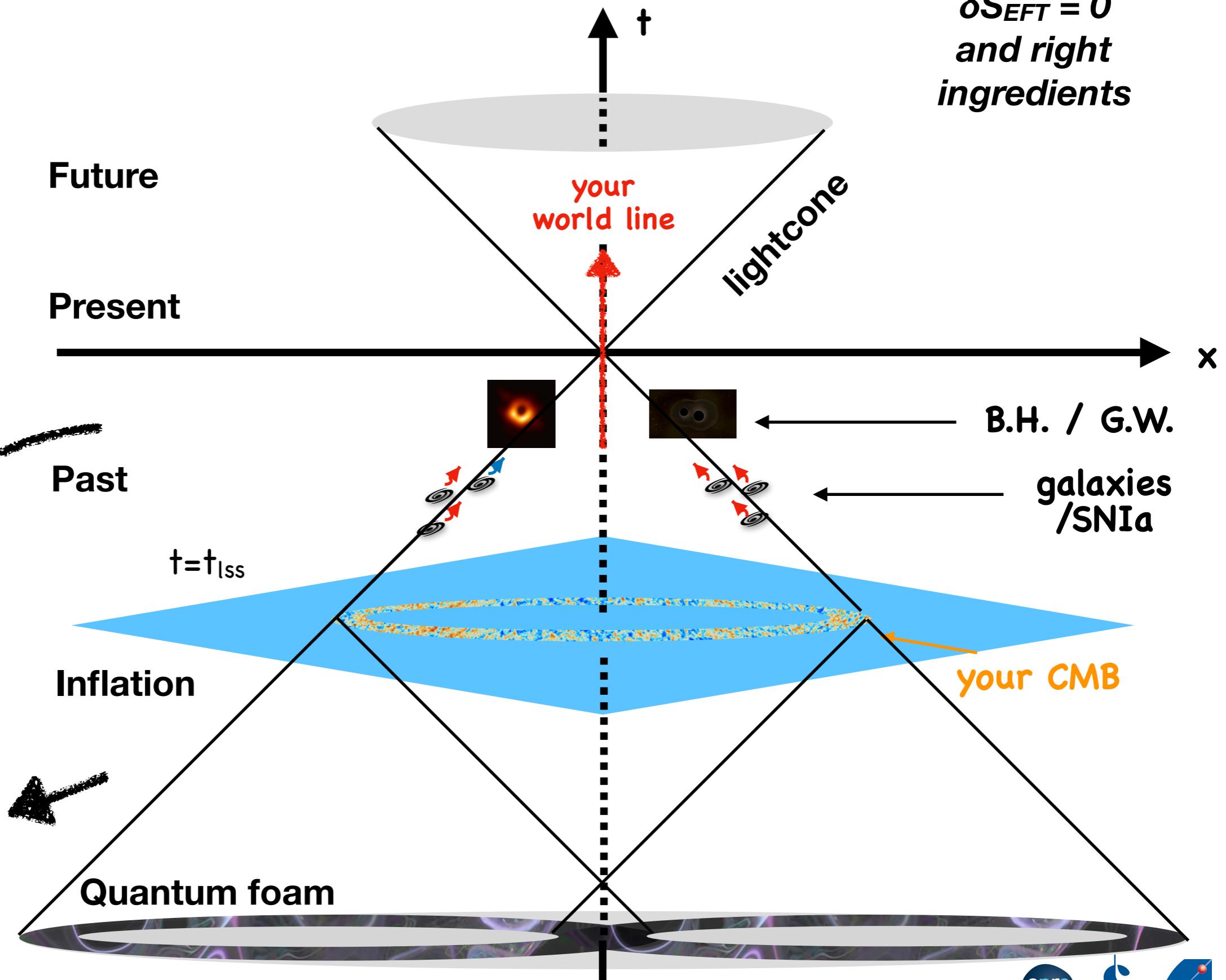
Future

Present

Past

Inflation

Quantum foam



Theoretical Framework

