A Description of the Particle Horizon

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Outline

Types of Horizon

There are three main types of horizons that will be discussed in this talk:

1. The Particle Horizon
2. The Event Horizon
3. The Hubble Sphere * Although not Technically a horizon

Horizon Background

"The range of perception or experience"

- Comoving distance
  - A measure of distance in astronomy, based on **proper distance**
  - This measure 'factors out' the expansion of the universe

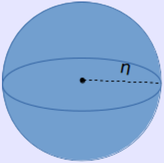
$$X = \int_{t_e}^{t} c \cdot \frac{dt'}{a(t')}$$

- Conformal time
  - A measure of time based on the **comoving distance**
  - This is the measure that will allow us to formally define the particle horizon.

$$\tau = \int_{0}^{t} \frac{dt'}{a(t')}$$

The Particle Horizon

"The present distance of an object emitting light at [a specific point in time]"



- The particle horizon at a specific time t
- Relative to an arbitrary observer ω
- is given by a sphere of radius equivalent to the comoving distance.

$$\eta = \int_{t_e}^{t} c \cdot \frac{dt'}{a(t')}$$

Mathematical Description

- Beginning with the simple fomula:

$$d = v \cdot t$$

- Measuring the distance of photons emmited towards a source we have:

$$v = c$$

- Hence photons emitted towards observer from every direction yields a sphere of radius d,

$$d = c \cdot \int_{t_e}^{t} \frac{dt'}{a(t')}$$

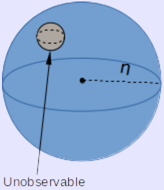
- where a(t') is a scaling factor derived beyond the confines of this course.

Physical Relevance

- The particle horizon represents a horizon of sorts.
- It is the ‘range of perception or experience’ of photons upon the observer ω.
- It is the sphere of our knowledge about the nature of the universe in this regard.
- We cannot see beyond the present particle Horizon, however it is expanding continuously in time.

The Event Horizon

"Where we can never see, as opposed to where we one day may see"



- More so related to general relativity than to special relativity as the particle horizon was
- Imagine light emitted from the center of a black hole.

Mathematical Description

- A general form is difficult if not impossible to obtain
- We can prove existence of event horizons simply, examine the following limit

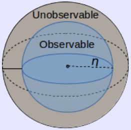
$$\exists \mathrm{EH} \implies \lim_{t\to\infty} \int_0^t \frac{c}{a(t')} dt' = K$$

$$\overline{\exists \mathrm{EH}} \implies \lim_{t\to\infty} \int_0^t \frac{c}{a(t')} dt' = \infty$$

Physical Relevance

- There exist many event horizons in our universe (Every black hole has one)
- We can never see beyond an event horizon, at any point in the future
- The event horizon of the universe is a true obstacle, we can never see beyond it.
- We may be able to hear beyond it... (Gravity Waves)

The Hubble Sphere



- Blue Represents Hubble Sphere, the universe where as $t \to \infty$ all contained within is visible
- Grey Represents beyond the Hubble Sphere, where objects receed faster than the speed of light, and will hence never be visible (E.G Black Holes)
- Some such objects which move faster than light speed are known as Tachyons.
- An Isomorphic view of the universe, which seperates Particle and Event Horizons.

Mathematic Description

- The proper length of the radius of the Hubble Sphere of our universe is given as:

$$\mathrm{H}_L = \frac{c}{H_0} \approx 1.31 \cdot 10^{26}\mathrm{metres} = 1.38 \cdot 10^{10}\mathrm{light\ years}$$

- where H_0 is known as the hubble constant
- The surface Area of the hubble sphere is then given by:

$$\mathrm{H}_A = 4 \cdot \pi \cdot (\frac{c}{H_0})^2 \approx 2.16 \cdot 10^{53}\mathrm{metres}^2 = 2.41 \cdot 10^{21}\mathrm{LY}^2$$

- The volume of the sphere is given by:

$$\mathrm{H}_V = \frac{4\pi}{3} \cdot (\frac{c}{H_0})^3 \approx 9.42 \cdot 10^{78}\mathrm{metres}^3 = 1.11 \cdot 10^{31}\mathrm{LY}^3$$

Relation to Redshift Parameter

- As we would expect the edge of the hubble sphere can be represented in terms of frequencies.
- As we measure relative velocities of objects using red shifts, velocities higher than c cannot be seen.
- Recall the formula of the redshift parameter:

$$z = \sqrt{\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}} - 1$$

- Considering $v > c$ yields an imaginary result for z.
- Hence the sphere can be described by $\{v | \{z(v)\} \in \mathbb{R}\}$

Backup Slides

Back-Up Slides

The Horizon Problem

- In 1960 Charles Misner discovered that distant regions of the universe shared temperature
- This should not be possible as information (and hence similar energies) cannot travel faster than the speed of light
- There are two proposed solutions:
    - Variable Speed of Light
    - Cosmic Inflation
- Only Cosmic Inflation will be discussed in this presentation.

Cosmic Background Radiation

- Cosmic Background Radiation (discussed in HW 3) is radiation present throughout the cosmos of which the origin is unseen.
- It is presented as evidence for the horizon problem.
- The problem arises in examining its homogeneity throughout the universe.
- It appears that at all measured locations the background radiation is nearly equivalent.
- Hence, two areas of space which were never near close enough still radiate the same amount of energy.

Cosmic Inflation as a Possible Resolution

- Imagine a balloon being inflated
- At first the balloon inflates very rapidly, its surface are grows very quickly with little volume change.
- after a little while, the surface area changes slowly with much volume change.
- When considering the expansion of the universe, applying this same ideology assists in understanding phenomena such as the cosmic background radiation.

Resources

1. *Cosmological Inflation and Large-Scale Structure*. Liddle and Lyth. **Cambridge University Press**. 2000.
2. *Evolution of the Cosmological Horizons in a Concordance Universe*. MargalefBentabol et al. **arXiv**. 17, Jun 2013.
3. *Expanding Confusion: common misconceptions of cosmological horizons and the superluminal expansion of the universe*. Davis and Lineweaver. **arXiv** 13 Nov 2003.

Thank-You

Questions?