

Explanation for the Increase in the Expansion of the Universe through Gravitational Waves

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Abstract : This thesis explains the expansion rate of the universe and establishes the relationship between the expansion rate and the number of black holes in the universe and Inspiralling binary neutron stars, white dwarfs and binary systems of black holes, black hole merges and supernovae, hyper novae and all other catastrophic explosions taking place in the universe and which in turn establishes the relation between the expansion rate of the universe and the age of the universe.

I. INTRODUCTION

This thesis explains the reasons behind the rapid increase in the expansion rate of the universe with increase in the age of the universe. There are of several theories to explain this staggering problem. This thesis explains the major cause for the rapid expansion of the universe with the help of the established laws of physics and explains Hubble's graph for the expansion of the universe satisfactorily. This thesis primarily establishes the relation between the number of black holes in the universe and Inspiralling binary neutron stars, white dwarfs and binary systems of black holes, black hole merges and supernovae, hyper novae and all other catastrophic explosions taking place in the universe and its expansion rate and uses this concept to deduce the relation between the expansion rate of the universe and the age of the universe.

Known Facts:

- **From Hawking Radiation :**

A black hole of one solar mass has a temperature of only 60 nanokelvin (60 billionths of a Kelvin); in fact, such a black hole would absorb far more cosmic microwave background radiation than it emits. A black hole of 4.5×10^{22} kg (about the mass of the Moon) would be in equilibrium at 2.7 Kelvin, absorbing as much radiation as it emits. Yet smaller primordial black holes would emit more than they absorb, and thereby lose mass.

- **The gravitational waves**

In Einstein's theory of general relativity, gravity is treated as a phenomenon resulting from the curvature of space-time. This curvature is caused by the presence of mass. Generally, the more mass that is contained within a given volume of space, the greater the curvature of space-time will be at the boundary of this volume. As objects with mass move around in space-time, the curvature changes to reflect the changed locations of those objects. In certain circumstances, accelerating objects generate changes in this curvature, which propagate outwards at the speed of light in a wave-like manner. These propagating phenomena are known as gravitational waves.

In general, any acceleration that is not spherically or cylindrically symmetric will produce a gravitational wave. Consider a star that goes supernova. This explosion will produce gravitational waves if the mass is not ejected in a spherically symmetric way, although the center of mass may be in the same position before and after the explosion. Another example is a spinning star. A perfectly spherical star will not produce a gravitational wave, but a lumpy star will.

EXPLANATION OF THE INCREASE IN EXPANSION RATE OF THE UNIVERSE

- The black holes have very strong gravitational field so they pull stars towards them. The massive stars revolve around the black hole at a very high speed and are in an accelerated motion due to elliptical orbits. So this produces intense gravitational waves. Moreover, if a star approaches too close to a black hole it gets sucked up in the black hole. When this happens the matter from the stars is highly accelerated and again gravitational waves are produced. As the number of black holes increases, these phenomena also increase and so does the gravitational waves.
- Inspiralling binary neutron stars and binary systems of black holes and also the number of black hole merges. In spirals are very important sources of gravitational waves. Any time two compact objects (white

dwarfs, neutron stars, or black holes) are in close orbits, they send out intense gravitational waves. As they spiral closer to each other, these waves become more intense.

1.1 Interference Of Waves:

- The gravitational waves are a type of waves so they undergo interference like all other waves.
- They can undergo constructive as well as destructive interference.
- Due to the constructive interference of several gravitational waves the amplitude of the resultant gravitational wave increases .This increase in amplitude of the gravitational wave means that the amplitude of the crest of the resulting wave also increases.
- Now, when his crest of increased amplitude passes through a region of less intensity of gravitational field which can be represented by a shallow curvature in the space-time, then it can easily nullify this curvature in space time caused by the resultant gravitational field of two galaxies placed far apart from each other on astronomical scales.
- Now, if the amplitude of the resultant gravitational wave is greater than the depth of the shallow space time curvature then the amplitude of the resultant wave reduces but is not nullified.
- This resultant wave of reduced amplitude now continues to propagate and imparts some (though small) momentum to the galaxies after nullifying their mutual gravitational forces of attraction.
- If this is continued continuously for a significant amount of time then it can cause the galaxies to drift apart.

1.2. Important relation:

- Now we arrive at an important result from the discussion in section 1.1.
- The expansion rate of the universe (E_{universe}) is proportional to the amplitude and frequency of the resultant gravitational wave and also to the time period of exposure of the galaxies to the resultant gravitational wave produced due to constructive interference .
- $E_{\text{universe}} \propto A * v * t \dots\dots\dots(1)$
- Where A=amplitude of the resultant gravitational wave produced due to constructive interference of the gravitational waves.
- t= time period of exposure of the galaxies to the resultant gravitational wave produced due to constructive interference.
- v= frequency of the resultant gravitational wave produced due to constructive interference of the gravitational waves.

1.2 The deduction of the relation between the number of black holes and the expansion rate of the universe

- Now we have $E_{\text{universe}} \propto A * v * t$
- $A * v \propto C$
- Where C= number of constructive interference of gravitational waves
- $C \propto N_b$
- N_b =number of black holes in the universe and Inspiralling binary neutron stars, white dwarfs and binary systems of black holes and black hole merges and supernovae, hyper novae and all other catastrophic explosions taking place in the universe
- $E_{\text{universe}} \propto N_b * t \dots\dots\dots(2)$
- Now as the age of the universe increases the number of black holes also increases as more and more of the super massive stars collapse or die out with increase in the age of the universe and so the number of black holes in the universe also increases. Again most of the black holes formed are massive having masses several times that of the sun. So instead of evaporating on account of hawking radiation, they absorb more amount of electromagnetic radiation and so its mass keeps on increasing. As the rate of destruction of black holes is much slower and almost negligible as most of them are super massive and have almost no possibility of evaporating so on the whole the number of black holes in the universe is increasing with time, that is, with the age of the universe.

Also the probability of finding inspiralling binary neutron stars and binary systems of black holes ,black hole merges, white dwarfs and also the number of supernovae, hyper novae and all other catastrophic explosions taking place in the universe (after big bang) increases with the age of the universe .

- $N_b \propto T_{\text{universe}} \dots\dots\dots(3)$
- Where $T_{\text{universe}} = \text{Age of the universe.}$
- So we can say that

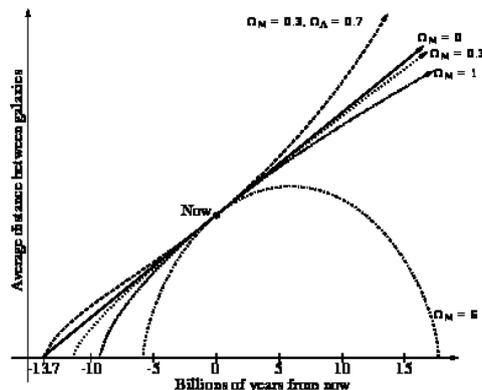
- $E_{\text{universe}} \propto T_{\text{universe}} * t \dots\dots\dots(4)$
- **Now again we have $t \propto T_{\text{universe}} \dots\dots\dots(5)$**
- **This is because as the age of the universe increases naturally the time period of exposure of the galaxies to the resultant gravitational wave produced due to constructive interference should also increase.**
- $E_{\text{universe}} \propto T_{\text{universe}} * T_{\text{universe}}$
- **This implies $E_{\text{universe}} \propto (T_{\text{universe}})^2$**
- **This implies $E_{\text{universe}} = K_{td} * (T_{\text{universe}})^2 \dots\dots\dots(6)$**
- **Where K_{td} is a constant of proportionality**

II. Conclusion:

- From the result derived above : $E_{\text{universe}} = K_{td} * (T_{\text{universe}})^2$
The following can be derived:

E_{universe} is a measure of the change in distance between the galaxies

- $D_2 - D_1 = K_{td} * (T_{\text{universe}})^2$
- **This implies $(D_2 - D_1) / (T_{\text{universe}}) = K_{td} * T_{\text{universe}}$**
- **This implies $V = K_{td} * T_{\text{universe}}$**
- **This implies $V / T_{\text{universe}} = K_{td}$**
- **This implies $A_{\text{universe}} = K_{td}$**
- **Where $V = (D_2 - D_1) / (T_{\text{universe}})$ and V is the velocity of separation / drifting of the galaxies.**
- **$A_{\text{universe}} = \text{acceleration of the galaxies away from each other.}$**
- From this we can conclude that the expansion of the universe which in turn is a measure of the change in the average distance between the galaxies is changing with the square of the age of the universe, i.e., the galaxies are accelerating away from each other as derived above.
- But there is another important result associated with it.
This relation is not valid for the primordial universe as in that era the expansion rate was far greater than present day as soon after the big bang, which was a colossal explosion, was solely responsible for this expansion. But as the energy from the big bang dissipated initially the expansion rate of the universe slowed down but with increase in the age of the universe the expansion rate is increasing which is a direct consequence of the increase in the number of black holes and Inspiralling binary neutron stars and binary systems of black holes ,black hole merges and also the number of supernovae, hyper novae and all other catastrophic explosions taking place in the universe (after big bang).
- The graph of the expansion of the universe vs. Age of the universe is expected to be a parabolic curve not passing through the origin .
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This is the graph plotted by Edwin Hubble for the increase in the distance between the galaxies with the age of the universe from his theory and observations.

This graph can be precisely explained in terms of the above mentioned theory.

The portion of the curve from the -13.7billion years to 0(present) shows a decline in the expansion of the universe. This is because the expansion rate was far greater than present day as soon after the big bang, which was a colossal explosion, was solely responsible for this expansion. But as

the energy from the big bang dissipated initially the expansion rate of the universe slowed down till (Now).

After this, the curve is parabolic which is in accordance with $E_{\text{universe}} = K_{\text{td}} * (T_{\text{universe}})^2$

Hence it can be concluded that the expansion of the universe will accelerate with the age of the universe.

References: