Will the Expansion of the Universe be Ever-accelerating?

S. Sahoo[1] and M. Kumar
Department of Physics, National Institute of Technology,
Durgapur, West Bengal, India

It was suggested recently that the expansion of the Universe is accelerating. Considering the Universe as a black hole, we show that there are two future possibilities: the Universe will either contract to a point or expand to infinity.

1. Introduction

The expansion of the Universe is one of the most important discoveries. It is the basis of the Big Bang model, which describes the creation of the Universe. According to the Big Bang model, the Universe was created sometime between 10 billion and 20 billion years ago from a cosmic explosion that hurled matter and radiation in all directions [1]. The Big Bang was not an explosion in space; it was an explosion of space itself [2,3]. The formation of all the structures in the Universe, starting from atoms, molecules to galaxies, has depended on the expansion of the Universe. In 1922, Friedman had showed that the Einstein's equations imply an expanding Universe [4]. After seven years, Hubble [5] discovered that the whole Universe is expanding with distances between the galaxies increasing all the time. Further, greater is the galaxy's distance from us, greater is its speed of recession. If d is the distance of the galaxy from the earth and v is the speed with which the galaxy appears to be moving from us, then v = Hd. Here, the constant of proportionality H is known as Hubble constant. The Hubble constant quantifies how fast space is stretching – not just around us but around any observer in the Universe. Hubble's results changed the idea of steady state Universe and support the concepts of general theory of relativity, which treats space-time as a dynamical object [6]. Space can expand, shrink and curve without being embedded in a higher-dimensional space.

In 1998, Perlmutter, Schmidt and Riess discovered (through observations of distant supernovae) [7,8] that the expansion of the Universe is accelerating, which earned them the 2011 Nobel Prize in Physics [9]. It is noted that dark energy is responsible for this acceleration of the expanding Universe [7,8, 10-14]. Recently [15], the existence of rapid acceleration in the early Universe (similar to the usual inflation scenario) is proved. But here the expansion rate goes over 'smoothly' to the radiation dominated Universe when temperature becomes lower than the Planck temperature. Very recently [16], it is found that this acceleration is not uniform in all directions. The Universe's expansion seems to be accelerating faster in the direction of a small part of the northern galactic hemisphere. Various possibilities to the accelerating Universe have also been proposed [17]. In dipole like anisotropies, the Universe is accelerating faster in one direction (that of peculiar motion, where the apparent shear is positive) and in the opposite direction, the acceleration slow down by an equal amount. Although the Universe is expanding at an accelerating rate, the fate of the Universe is unknown [18]. Now question comes – Will the expansion of the Universe be ever-accelerating? In this article, we investigate this issue to some extent on theoretical grounds.

2. Expansion of the Universe

Let us assume the whole Universe as a Black Hole [19-23]. If M is mass of the Universe, then the Schwarzchild radius (R_S) of the Universe can be written as:

$$R_S = \frac{2GM}{c^2} \qquad (1)$$

Where, G is the universal gravitational constant and c is speed of light. Since the Universe is expanding the R_S will also expand. Interpreting the time derivative of the distance as the velocity of expansion of the Universe,

*sukadevsahoo@yahoo.com

$$\frac{dR_S}{dt} = \frac{2G}{c^2}\frac{dM}{dt} \qquad (2)$$

and

$$\frac{d^2R_S}{dt^2} = \frac{2G}{c^2}\frac{d^2M}{dt^2} \qquad (3)$$

At $t = 0$ i.e., at the time of Big Bang explosion,

$$\frac{dR_S}{dt} = 0 \qquad (4)$$

Let us assume that at time $t = \tau$ after the Big Bang explosion the velocity of expansion of the Universe is c.

That is, at

$$t = \tau, \quad \frac{dR_S}{dt} = c \qquad (5)$$

i.e., τ is the time interval from the Big Bang explosion to the time at which the rate of increase of Schwarzchild radius of the Universe will be the velocity of light. Hence from Eqn. (2),

$$c = \frac{2G}{c^2}\frac{dM}{dt} \qquad (6)$$

$$\frac{dM}{dt} = \frac{c^3}{2G} = \text{constant} \qquad (7)$$

Thus, at

$$t = \tau, \quad \frac{d^2M}{dt^2} = 0 \qquad (8)$$

Hence,

$$\frac{dM}{dt} \text{ is maximum or minimum at } t = \tau \qquad (9)$$

If $\frac{d^3M}{dt^3} < 0$, then $\frac{dM}{dt}$ is maximum and if $\frac{d^3M}{dt^3} >$ 0, then $\frac{dM}{dt}$ is minimum.

Case 1: If $\frac{d^3M}{dt^3} < 0$, $\frac{dM}{dt}$ is maximum and gravitational force will be so strong that the expansion of Universe will stop at $t = \tau$ and start contracting. In otherwords, the expansion of Universe will accelerate up to $t = \tau$ and after that the Universe will contract.

Case 2: If $\frac{d^3M}{dt^3} > 0$, $\frac{dM}{dt}$ is minimum at $t = \tau$ and the Universe will go on expanding. Since dM/dt is minimum at some points $d^2M/dt^2 = 0$, but since $d^3M/dt^3 > 0$, it follows that after that $d^2M/dt^2 > 0$. So in this case the Universe is accelerating.

The mass of the Universe can be written as [20]:

$$M = N\,m \qquad (10)$$

Where, M is the mass of the Universe, m is the pion mass, $N \sim 10^{80}$ is the number of elementary particles, typically pions in the Universe and N is defined as

$$R \sim l\sqrt{N} \qquad (11)$$

Where, R is the radius of the Universe ~ 10^{28} cms and l is the pion Compton wavelength.

By considering the equation for spin in the linearized general relativistic case, the spin of the Universe is found to be [20,24]:

$$S_U = N^{3/2}h \approx h_1 \qquad (12)$$

Here $h_1 \sim 10^{93}$ and we have, $R = \frac{h_1}{M\,c}$. This spin of the Universe agrees with Godel's spin value for Einstein's equations [25,26]. This also agrees with the Kerr limit of the spin of the rotating Black Hole. Further, the angular momentum of the Universe given in Eqn. (12) matches with a rotation from cosmic microwave background radiation (CMBR) anisotropy [27].

Let us consider a Kerr Black Hole. Its horizon is given by [28,24]:

$$r = \frac{GM}{c^2} + \left(\frac{G^2M^2}{c^4} - L^2\right)^{1/2} \qquad (13)$$

Where, L is the angular momentum of the rotating Black Hole and is given by

$$L = M\,Rc \qquad (14)$$

Where, R is the radius of the Black Hole. From Eqns. (13) and (14), the radius R can be given by

$$R \sim \frac{GM}{c^2} \tag{15}$$

Eqn. (15) holds good for the Universe as a whole [29,30]. Hence, the Universe can be treated as a Kerr Black Hole. But in a first approximation, we can take the Universe to be a Schwarzchild Black Hole, even if the rotation part is confirmed. So far, we do not have much knowledge beyond the CMBR anisotropy for this.

3. Conclusion

We are living in a homogeneous and isotropic Universe. Since the Big Bang, the Universe is expanding and reaches its current size. It is found that the Universe is not simply expanding but is accelerating too [7,8,10-14]. Sidharth [31] has said that the Universe would expand up to a point and then collapse. Recently, Bonasera [32] has discussed the expansion and fate of the Universe. According to him, the fate of the Universe will be determined by fluctuations: either collapse or expand forever! In this paper, we show that there are two possibilities for the expansion of the Universe in future. The Universe will either contract to a point or expand to infinity. Our result almost agrees with Perlmutter's discussion [33]. We take the Universe to be a Schwarzchild Black Hole, even if the rotation part is confirmed. But we do not have much idea beyond the CMBR anisotropy for this. Our proposed theory is not self-evident. It could be tested experimentally. We hope these ideas will open a wide horizon for new theoretical and experimental investigations.

Acknowledgments

We would like to thank Prof. B. G. Sidharth, India, and Prof. Antonio Alfonso-Faus, Spain, for helpful discussions and suggestions. We also thank P. K. Mohanty, TIFR, Mumbai; P. K. Swain, IIT, Kharagpur and J. K. Mohapatra, IIT, Mumbai for their help in the preparation of the manuscript. We thank the referees for suggesting valuable improvements of our manuscript.

References

[1] S. W. Hawking, *A Brief History of Time – From the Big Bang to Black Holes* (Bantam Press, Great Britain, 1989).

[2] C. H. Lineweaver and T. M. Davis, *Scientific American* **292**(3), 36, March (2005).

[3] T. M. Davis and C. H. Lineweaver, Publications of the Astronomical Society of Australia **21**, 97 (2004) [astro-ph/0310808].

[4] A. Friedman, Z. Phys. **10**, 377 (1922) [English translation in: Gen. Rel. Grav. **31**, 1991 (1999)].

[5] E. Hubble, Proceedings of the National Academy of Sciences of the United States of America **15**(3), 168, March 15 (1929).

[6] A. Kaya, Am. J. Phys. **79**(11), 1151 (2011) [arXiv:1107.5168 [gr-qc]].

[7] A. G. Riess et al., Astron. J. **116**, 1009 (1998).

[8] S. Perlmutter et al., Astrophys. J. **517**, 565 (1999).

[9] www.nobelprize.org

[10] G. Riess et al., Astron. J. **117**, 707 (1999).

[11] P. M. Garnavich et al., Astrophys. J. **493**, L53 (1998).

[12] A. G. Riess et al., Astron. J. **607**, 665 (2004).

[13] J. L. Tonry et al., Astrophys. J. **594**, 1 (2004).

[14] R. C. Gupta and A. Pradhan, arXiv: 1010.3826 [physics.gen-ph] (2010).

[15] C. Sivaram and K. Arun, Astrophys. Space Sci. **333**, 9 (2011) [arXiv: 1012.5608 [physics.gen-ph]].

[16] R.–G. Cai and Z.–L. Tuc, arXiv: 1109.0941 [astro-ph.CO] (2011).

[17] C. G. Tsagas, Phys. Rev. D **84**, 063503 (2011).

[18] Y. M. Butt, Physics Today **65**(2), 10, February (2012).

[19] M. S. El Naschie, Chaos, Solitons and Fractals **11**, 1149 (2000).

[20] B. G. Sidharth, Chaos, Solitons and Fractals **12**, 613 (2001).

[21] B. G. Sidharth, arXiv:physics/0003022 [physics.gen-ph] (2000).

[22] A. Alfonso-Faus, Astrophys. Space Sci. **325**, 113 (2010) [arXiv: 0912.1048 [physics.gen-ph]].

[23] M. J. F. Alfonso and A. Alfonso-Faus, Astrophys. Space Sci. **337**, 19 (2012) [arXiv: 1111.1017 [physics.gen-ph]].

[24] B. G. Sidharth, arXiv: 1004.4837 [physics.gen-ph] (2010).
[25] K. Godel, Rev. Mod. Phys. **21**, 447 (1949).
[26] S. Carneiro, Found. Phys. Lett. **11**(1), 95 (1998).
[27] A. Kogut et al., Phys. Rev. D **55**, 1901 (1997).
[28] R. Ruffini and L. Z. Zang, *Basic Concepts in Relativistic Astrophysics* (World Scientific, Singapore, 1983).
[29] B. G. Sidharth, *Thermodynamic Universe* (World Scientific, Singapore, 2008).
[30] S. Weinberg, *Gravitation and Cosmology* (John Wiley & Sons, New York, 1972).
[31] B. G. Sidharth, [arXiv: 1111.3877 [physics.gen-ph]] (2011).
[32] A. Bonasera, arXiv:1208.5385 [physics.gen-ph] (2012).
[33] S. Perlmutter, Physics Today **54**(4), 53 (2003).

Received: 21 June, 2012
Accepted: 26 October, 2012