ON HAWKING HERTOG INFLATION

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ABSTRACT

The last joint paper of Stephen Hawking before his demise is directed at the expansion of the universe and suggests that maybe inflation is not infinite and that splitting may occur. The theory leans heavily towards the multiverse philosophy and is actually posed as a question from the question mark in the title “A Smooth Exit from Eternal Inflation?” Contrary to popular belief, the paper suggests an exit from infinite inflation and its end may be of a smooth nature. The paper itself is replete with acronyms and appears to be intentionally written in the customary prolix manner of theoretical physics. Although the subject of the paper is not particularly new it is cluttered and disjointed and somewhat grammatically challenged resulting in an obtuse presentation. It is the intention of the author of this paper to offer a clearer translation of the Hawking Hartog paper, which is undoubtedly difficult due to its reliance upon several esoteric theories.

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1. Introduction

From a prior proposal of Hartle & Hawking [i] it is suggested that there was actually no beginning to the universe and prior to the Big Bang everything existed only as a singularity, which has two properties;

a) Hartle & Hawking propose that the surface of the singularity would have a low amplitude
b) The universe is negatively curved (infinite) then the singularity would have zero surface amplitude.

This being the model upon which the entire paper is based. The subject addressed by the Hawking Hertog paper is not new the basis of this argument has actually been in existence for decades and addressed many times previously by physicists. To put it simply, the basis of the Hartle & Hawking paper is that time before the Big Bang was mathematically speaking an imaginary number and therefore it did not have a beginning but rather its position on the timeline would be a point of transition from real to imaginary time and vice versa. Considering therefore that time flows from imaginary to real numbers and in space time there is no meaning to past present or future the Big Bang is essentially any arbitrary position on the timeline. Another problem with the Hartle and Hawking theory is that it predicted the universe is closed, which appears to be contrary to current theories.

The paper suggests that in systems which are in thermodynamic equilibrium all of the properties can be expressed as a function without dimensions, a pure scalar number, whose basic elements of this function being borrowed from statistical mechanics. It is suggested that this number would vary if the system is not perfectly spherical and would be zero if the geometry was negatively curved. Here the authors are comparing the specific geometry of the universe and the curvature of space-time at an earlier point in time and its subsequent effects upon each of the current models of the universe. An understanding for this requires a description of Anti-de Sitter and Conformal field theories which can be briefly described as follows;

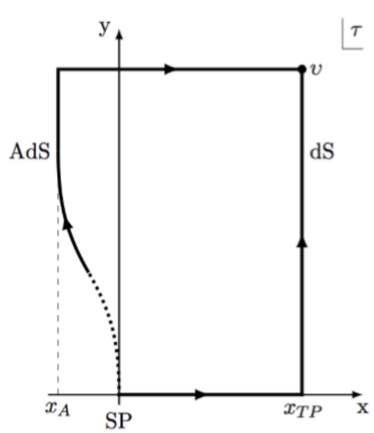
a) Anti-de Sitter space has negative curvature a two-dimensional plane is curved in a saddle shape rather than flat, and is one of the simplest geometries in which the equations of general relativity can be solved and commonly used in theories concerning quantum gravity, string theory, m-theory etc.
b) A conformal field theory is the type of field theory used in the Standard Model, which include quantum-field theory and Yang-Mills theories which describe elementary particles

The Anti-de Sitter/Conformal Field Theory (AdS/CFT) is a mathematical relationship between these two separate descriptions of the same physics. According to this theory, a string theory in a region of Anti-de Sitter space is equivalent to a conformal field theory on the boundary or the hard wall of that region. Although this field theory describes an artificially simple situation inasmuch as we appear to live in flat space rather than an Anti-de Sitter space, the mathematical correlation between these two descriptions of physics is useful on occasion to provide more straightforward calculations.

An anti-de Sitter space is somewhat similar to a de Sitter space, one of the differences being, that the sign of the curvature is changed. Lacking matter or energy in anti-de Sitter space (pre Big Bang), the curvature of space is therefore negative, corresponding to a hyperbolic geometry, which means that parallel time-like geodesics would eventually intersect. This requires that the cosmological constant is negative which of course does not match cosmological observations as space has negative energy density but positive pressure. In a de Sitter space the background expansion is smooth however random quantum fluctuations dominate the background and result in a large but irregular universe with constant density. The paper proposes that this theory may be incorrect as inflation smooths out the random quantum effects, which has not been taken into consideration. A secondary consideration made is that the observations of the Cosmic Microwave Background agree with gauge-gravity.

2. Basic Theory

As mentioned previously, the paper concentrates on the universe at an earlier point in time and when it is assumed that inflation is low and the overall density is constant throughout. In order to predict the current observations the calculations are weighted by a value represented by Σ_f which leads to a result that the universe is expanding infinitely. It is implied in the paper that the Anti-de Sitter and the de Sitter spaces are two discrete parts of one larger theory and that the imaginary time at x_A has a negative curvature when taken from the arbitrary point SP. When projecting forward on the timeline from the same arbitrary point SP to x_{TP} there should be positive curvature to agree with observation although this is not shown. In the interests of clarity the point "domain wall" represented by SP on the timeline of advancing x is nothing more than the Big Bang and represents a hard wall between the Anti-de Sitter and de Sitter domains.



The basis of the theory however has weaknesses in that point SP is necessarily an arbitrary point as in the Hartle & Hawking model upon which the paper is based. This has the effect that the curvature can be severely affected by the choice of SP and x_A in the timeline located on the x axis. The point on the timeline SP clearly represents this arbitrary point where the negative curvature of the Anti-de Sitter space is separated from the positive curvature of the de Sitter space effectively by the boundary of a hard wall. In the model suggested by Hartle & Hawking it is found that the standard wave function breaks down if projected to the current time and infinite inflation is assumed. However in gauge-gravity duality it is suggested that an alternative form of a Euclidian anti-de Sitter wave function Σ_f is used instead. This negative curvature of the Anti-de Sitter space is present in the Z_{QFT}^{-1} function as presented in the paper and the negativity will consequently be reflected in the resulting wave function;

$$\Psi_{NB}[h_{ij},\phi] = Z_{QFT}^{-1}[\tilde{h}_{ij},\tilde{\alpha}]exp(iS_{st}[h_{ij}\phi]/\hbar) \qquad (1)$$

The utility of the equation however may be in question as the presence of an exponent, which utilizes in its denominator Planck's constant, results in a significant number of solutions. As there appear to be ten solutions to the actual metric in the equation, this suggests that there are exactly "ten billion" solutions to the wave equation. As such it seems somewhat pointless to analyze any of the remaining equations in the paper.

3. Summary and Conclusions

Obviously, the foundation of the paper is based upon yet another of Hawking's unproven theories, the "no boundary proposal" in an attempt to explain the Big Bang. Current theories suggest that prior to the Big Bang, there must have been a singularity, or an infinitely dense, extremely hot point, it is questionable as to how it was dense if matter did not exist and hot when there is no space for particles to jiggle but that is another subject. At this singularity it is theorized that there is no boundary and based upon this it was imagined that the fast expanding universe, another theory, would generate more universes one of which we live in and eventually would become a multiverse. Hawking and Hertog decided to attempt to create a more coherent theory, to explain this multiverse and reduce the number of possible universes springing into existence while bridging the gap with quantum physics. The method they chose was holography yet another theory and suggested that the CMB could possibly provide proof of these alternative universes. The problem is that this all-encompassing theory, in spite of attempting to include everything from quantum mechanics to holography, presented nothing new in the way of a signature of alternative universes and is evidently not testable. Because of this, many prominent cosmologists treat it with skepticism and have simply rejected the theory, as does the author of this paper.

References

[i] *J. Hartle, S. W. Hawking and T. Hertog. The No-Boundary Measure in the Regime of Eternal Inflation. Phys. Rev. D82, 063510 (2010). 1001.0262.*