Black Holes and Antimatter as the Convergence of Times

Essay written for the FQXi contest on the Nature of Time

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What is time? Is it the duration of a certain number of cesium 133 vibrational periods? Is it one dimension in our 4-dimensional reality, truly no different than the spatial dimensions? If that is so, why is it only possible to move in what we define as the forward direction of time? If time were truly no different than a spatial dimension, it should not be as easy to move backward in time as it is to retrace one's footsteps. What is it that continues to force our existence forward in time, preventing us from reversing course?

Arthur Eddington, a 20th century British astronomer, concluded that microscopic phenomena exhibit time-symmetry, appearing indistinguishable in both the forward and reversed direction of time. Macroscopic phenomena, however, exhibit time-asymmetry, a definite arrow of time that Eddington concluded was solely due to thermodynamic entropy. Entropy is (simplistically) the amount of disorder present in a given system. Mixing several pigments together, each with a unique color, would produce one muted homogeneously blended color. As the entropy (and disorder) of the final mix is higher, the Second Law of Thermodynamics dictates that the unique colors must exist in the past and the final mix must exist in the forward direction of time.

But what demands that the entropy of the universe must increase? Rather, since we know so little about the physical realities beyond our galaxy, what imposes the Second Law upon the Milky Way? I submit that it is the black hole in the center of our galaxy that is responsible for the arrow of time we observe.

Black holes, evaluated from a purely relativistic framing, are a region surrounding a spacetime singularity such that beyond a certain boundary all three spatial directions and time itself exist in exactly one direction – toward the singularity. This boundary, a sort of point of no return due to gravity even for light, is called the event horizon. The area inside the event horizon of a black hole has been shown to have the maximum entropy possible for that volume of space. Both the termination of the arrow of time derived from thermodynamics and the sole relativistic occurrence of nonreversible time exist within the event horizon of a black hole. Does one necessitate the other?

As a thought experiment, consider what the death of our galaxy might look like. Stars of sufficient mass would be collapsed into black holes at the end of their lives, absorbing everything without sufficient velocity to escape the awesome gravity concentrated in their bodies. Any matter that did escape local black holes would have to be directed out of the galaxy to avoid eventual absorption by other black holes, including the center of the galaxy. Eventually only black holes would remain in the area once occupied by our galaxy, and those black holes may combine to form larger ones depending on proximity and velocities. We know that this must occur in the future, because the arrow of time dictates that these black holes would possess localized maxima of entropy.

The scientific establishment would argue that the black holes from this thought experiment would eventually evaporate into purely thermal Hawking radiation. (1) This radiation is the result of a matter particle and antimatter particle spontaneously appearing near the event horizon of the black hole, with the antimatter particle falling into the black hole and the matter particle escaping the black hole. The particle appears to have been emitted from the black hole, while the absorbed antimatter would reduce the mass of the black hole according to Hawking. I, however, would argue that any reduction of the volume of a black hole would be a violation of the second law of thermodynamics.

Hawking's justification for exploring black hole radiation and evaporation in his 1975 paper (2) rests on the assertion that "without such emissions the Generalized Second Law [of Thermodynamics] would be violated by for example, a black hole immersed in black body radiation at a lower temperature than that of the black hole." As a thought experiment or mathematical tool Hawking's argument is justifiable, however we now know the background radiation of the universe to be constant and sufficiently high that the existence of non-radiative black holes in the universe would not violate the Generalized Second Law. Even if Hawking were correct about black hole radiation, astrophysicists have yet to find a small enough black hole that would be unable to maintain its size solely by absorbing this background radiation.

In addition to my skepticism based on entropy arguments, Hawking's work has the additional challenge of resulting in the black hole information loss paradox. Preskill has done an excellent job of summarizing both the paradox and the methods by which researchers have tried to resolve it. (3) It has been shown that information is stored in the quantum state of matter. A finite number of bits of information (yes or no questions) can be used to represent this matter. Information has an analogue to thermodynamic entropy, which Preskill elutes. When matter is absorbed by a black hole, our understanding of information mandates that somehow those bits must become encoded into the black hole itself – information cannot be destroyed. Calculations showing that black holes have the maximum entropy possible for the area within the event horizon seem to reassure that this information is preserved.

Hawking radiation resulting from the "evaporation" of black holes, however, is purely thermal and devoid of information. The complete evaporation of a black hole would therefore result in the destruction of information, which defies our understanding that information cannot be destroyed and creates the black hole information loss paradox. Hawking has attempted to further explain how information could escape the black hole through a perturbation in the event horizon or could be preserved in a parallel universe where no black holes exist (4), but physicists like Kip Thorne remain unconvinced. Thorne is one of the advocates for relativistic interpretation of black holes as true singularities, mandating only one spacetime direction inside the event horizon. (5)

Hawking's paper of 1975 did consider this, stating "instead of thinking of negative energy particles tunneling through the horizon in the positive sense of time one could regard them as positive energy particles crossing the horizon on past-directed world-lines [antimatter particles] and then being scattered onto future-directed world-lines by the gravitational field." Using Richard Feynman's framing of quantum physics, Hawking explicitly states that time reversed particles (antimatter) cannot exist beyond the event horizon of a black hole, suggesting they would transform into "normal" matter. Hawking continues stating, "... any renormalization of the energy-momentum tensor with suitable properties must give a negative energy flow down the black hole and consequent decrease in the area of the event horizon. This negative energy flow is non-observable locally." Feynman's quantum physics, however, does not allow for negative energy.

It was Feynman who put forth our first understanding of antimatter, leading to his formulation of quantum electrodynamics. In *The Theory of Positrons*, Feynman shows that a positron (antimatter electron) is nothing more than a "normal" electron traveling in a time reversed direction. (6) Though he may not have advocated its use at the time, Feynman developed his own understanding of quantum physics that allowed for the time reversibility of subatomic particles, as Alverez and Gaioli have documented. (7)

In Feynman's popular lectures on quantum electrodynamics, (8) and the book of 1985 that was subsequently published, (9) he stated "you can get rid of all the old-fashioned ideas and instead use the ideas that I am explaining in these lectures - adding arrows for all the ways an event can happen - there is no need for an uncertainty principle." Later in life, Feynman clearly felt strongly about his interpretation of quantum physics and its benefits over other methods. In his 1986 Dirac Memorial Lecture titled *The reason for antiparticles*,

(10) Feynman explained "We are going to suppose something: that all the energies are positive. If the energies were negative we know that we could solve all our energy problems by dumping particles into this pit of negative energy and running the world with the extra energy." He went on to demonstrate that any apparent negative energy must be due to antiparticles, time reversed versions of their normal particle counterparts.

Hawking depends on negative energy to overcome the logical conclusion that antimatter cannot exist inside the event horizon of a black hole. Feynman and 60 years of successful experiments proclaiming quantum electrodynamics the "crown jewel" of physics explicitly state that negative energy is not possible.

Consider another thought experiment that might help to resolve this discrepancy. If a black hole composed of matter acts to force time in one direction toward the singularity only, how would an *anti*black hole that forces time away from the singularity behave? Such a singularity would be formed by antimatter and would absorb antimatter, but otherwise would be identical to a black hole, given that antimatter particles have the same mass as their matter counterparts. In an antimatter universe such an *anti*black hole would have maximum entropy, the only difference would be an arrow of time pointing backward in time instead of forward. "Normal" matter falling into this *anti*black hole would either result in purely thermal Cuppett radiation on past-directed world-lines extending prior to the singularity in time… or not. While *anti*black hole evaporation may seem silly, things get a little more serious if you consider that my *anti*black hole could be the Big Bang singularity.

For all the matter in the universe to have come from the Big Bang, our current understanding of physics dictates that an equal amount of antimatter that also would have been created must have some how been prevented from annihilating this matter. The simplest explanation would be that the Big Bang singularity was able to absorb this antimatter but not the normal matter. Instead of absorbing the matter by scattering it onto past-directed world-lines by the gravitational field as Hawking's theory would suggest, the big bang scattered the matter away from the singularity with a force deserving of the name "Big Bang." Black holes must similarly deflect antimatter rather than absorbing it.

What would a positron deflected from a black hole look like to an observer on Earth? The antimatter likely wouldn't have far to go before encountering its matter counterpart, and the annihilation of a hydrogen atom by a positron would create an ultra high energy cosmic ray, such as the Oh-My-God particle. A short gamma ray burst would be observed if this positron encountered an electron instead of an atom. Both of these inexplicable phenomena have been observed on Earth and could be evaluated to determine if black hole deflected antimatter could be responsible for their generation.

This comparison between the Big Bang singularity and black holes raises another interesting question: why are black holes presumed to continue their existence forward in time while the Big Bang singularity is explicitly described as a singular point in both space *and* time? If the Big Bang illustrates that a singularity can exist at a fixed point in time as well as space, why don't we consider that a black hole could become fixed at a specific point in time as well. For such a time-fixed black hole, the curvature of spacetime manifested as gravity would continue to be observed a temporal distance away from the singularity. There would, however, be no electromagnetic interaction possible with this black hole except near the temporal coordinate where it exists. As the arrow of time "aged" the universe beyond the temporal radius of this black hole, observable matter would still be influenced by the seemingly rogue gravity necessitated by the spacetime curvature. Such rogue gravity has to this point been attributed to dark matter.

Allowing for time-fixed stationary black holes raises the possibility of black holes that would have motion in time different than the "aging" dictated by the arrow of time. One such black hole could exist a fixed temporal distance behind us in time, traveling at the same temporal rate that we perceive. Such a lagging black hole would provide a constant gravitational influence on our existence, while the previously described time-fixed black hole would impart a waning gravitational field that we would eventually out-age.

The possibility of so many unobservable black holes at various points in time might seem to be a theory untestable by any conventional means, but the same relativity that makes the existence of these black holes possible provides a means for detecting them. Gravitational waves, perturbations in spacetime due to the motion of objects relative to each other, would be emitted by the black holes in question. Gravitational waves would be able to propagate forward in time, and a detector such as LIGO (Laser Interferometer Gravitational-Wave Observatory) should be able to detect any such gravitational waves. In learning about LIGO, however, I realized that the detector might be compensating for the very gravitational waves it is attempting to detect.

The fact that quantum physics has an uncertainty principle is, as Feynman stated in his quantum electrodynamics lectures, dependent on the particular interpretation of quantum physics employed. The central "misunderstanding" with LIGO has been that precisely measuring the position of the very large mirrors necessary to detect gravitational waves must destroy the position data. (11) The researchers state that instead momentum should be used, for it is a quantum nondemolition observable. In the interim they are filtering out positive readings below a certain frequency threshold, attributing this signal to the quantum nature of the mirror. (12) I would argue that the motion of these large mirrors in LIGO should not be so easily dismissed, as they might point to a fundamental misunderstanding of the pervasive nature of gravitational waves. I submit that Feynman's interpretation of quantum physics justifies exploration of these positive readings, for they could reveal that the vast amount of dark matter believed to exist in our universe is all attributable to black holes located out of temporal synchronization with the arrow of time. The unpredictable disturbance that seems to result from detailed observation of subatomic particles may be found to result from a gravitational wave produced by the act of observation.

I have been careful in framing these arguments to avoid any new laws of physics. It is my firm belief that the framework we have established should be sufficient to make significant advances in our understanding of the universe, if certain currently held misconceptions are abandoned. I believe the black hole information loss paradox specifically warrants adoption of Richard Feynman's framing of quantum physics. It has proven to be successful in his development of quantum electrodynamics, and the impact on black hole theory seems to unlock the mysteries of time that have eluded physicists and other thinkers for over a century. More detailed experimental investigation of antimatter as time reversed matter will undoubtedly cast new light on the usefulness of Feynman's work, yielding revelations about the Baryon asymmetry and cosmic rays that have remained elusive. Perhaps we'll even be able to finally come out of the dark (matter) with regards to rogue gravity.

1. Hawking, S.W. 1974. "Black hole explosions?" Nature 248, 30.
2. Hawking, S.W. 1975. "Particle Creation by Black Holes," Commun. Math. Phys. 43, 199.
3. Preskill, John. 1992. "Do black holes destroy information?" hep-th/9209058. Retrieved from: http://xxx.lanl.gov/abs/hep-th/9209058 [November 20, 2008].
4. Hawking, S.W. 2005. "Information Loss in Black Holes," arxiv:hep-th/0507171. Retrieved from: http://arxiv.org/abs/hep-th/0507171 [November 20, 2008].
5. Thorne, Kip. 1999. "Spacetime Warps and the Quantum: A Glimpse of the Future." Retrieved from: http://online.itp.ucsb.edu/online/plecture/thorne/ [November 20, 2008].
6. Feynman, R.P. 1949. "The Theory of Positrons," Physical Review, Vol. 76, No. 6, 749.
7. Alvarez, Edgardo T. Garcia and Fabian H. Gaioli. 1998. "Feynman's Proper Time Approach to QED," Foundations of Physics, Vol. 28, No. 10, 1529.

8. Feynman, Richard. 1979. The Douglas Robb Memorial Lectures. Retrieved from: http://vega.org.uk/video/subseries/8 [November 20, 2008].

9. Feynman, Richard. 1985. QED: The Strange Theory of Light and Matter. Princeton University Press, Princeton, New Jersey.

10. Feynman, Richard and Steven Weinberg. 1986. Elementary Particles and the Laws of Physics: The 1986 Dirac Memorial Lectures. Cambridge University Press, Cambridge.

11. Braginsky, V.B., Yu. I. Vorontsov, and K.S. Thorne. 1980. "Quantum Nondemolition Measurements," Science, 209, 547-557.

12. Thorne, Kip. 2000. "Quantum noise and quantum nondemolition in gravitational-wave interferometers." Caltech - JPL Association for Gravitational-Wave Research Seminar. Retrieved from: http://www.ligo.caltech.edu/docs/G/G000327-00.pdf [November 30, 2008].