

# Hawking Radiation in the Lab

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## Abstract

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Jeff Steinhauer, a physicist at the Israel Institute of Technology, has published a paper in the journal *Nature Physics* describing experiments in which he attempted to create a virtual black hole in the lab in order to prove that Stephen Hawking's theory of radiation emanating from black holes is correct —though his experiments are based on sound, rather than light. In his paper, he claims to have observed the quantum effects of Hawking radiation in his lab as part of a virtual black hole—which, if proven to be true, will be the first time it has ever been achieved.

New Research Mathematically Proves Quantum Effects Stop the Formation of Black Holes. By merging two seemingly conflicting theories, Laura Mersini-Houghton, a physics professor at UNC-Chapel Hill in the College of Arts and Sciences, has proven, mathematically, that black holes can never come into being in the first place. The works not only forces scientists to reimagining the fabric of space-time, but also rethink the origins of the universe.

Considering the positive logarithmic values as the measure of entropy and the negative logarithmic values as the measure of information we get the Information – Entropy Theory of Physics, used first as the model of the computer chess program built in the Hungarian Academy of Sciences.

Applying this model to physics we have an understanding of the perturbation theory of the QED and QCD as the Information measure of Physics. We have an insight to the current research of Quantum Information Science. The generalization of the Weak Interaction shows the arrow of time in the associate research fields of the biophysics and others. We discuss also the event horizon of the Black Holes, closing the information inside.

### **Possible way to test black hole information paradox in the lab**

A pair of researchers, one with National Taiwan University, the other with École Polytechnique in France has come up with a way to test the idea of Hawking radiation and the information paradox in a lab setting. In their paper published in the journal Physical Review Letters, Pisin Chen and Gerard Mourou describe their idea and the likely difficulties that researchers would face in trying to carry out actual experiments.

The information paradox surrounding black holes came about as researchers pondered the problem of physical information being destroyed when it is pulled into a black hole and disappearing later as the black hole dies—this would seem to violate the laws of physics. Back in the 1970s, Stephen Hawking famously postulated the idea that if a pair of entangled photons came to exist near the event horizon and one was pulled into the black hole but the other escaped, then the escaping photon would hold the information, preventing its loss, thus avoiding a paradox. Since that time, physicists have conceived thought experiments to test this idea, but of course, due to the inability to travel to and test a black hole, all remain theoretical. In this new effort, the research pair believe they may have come up with a way to test one of those thought experiments in a lab here on Earth.

The thought experiment consisted of developing a way to mimic the behavior of the photons near the black hole event horizon—perhaps by generating entangled pairs of photons and then using an accelerating mirror to mimic the impact of black hole gravity. In this scenario, one photon would be reflected (representing Hawking radiation) while the other would not—it would keep moving until the mirror finally stopped.

To carry out this experiment, Chen and Mourou suggest a laser pulse could be sent through a plasma target. As it moves, it would create a wake consisting of electrons that could serve as a moving reflecting boundary. To keep the mirror accelerating, they also note, the plasma density would have to be continually increased. The two ran simple tests of the concept, and they now claim that carrying out such an experiment would be extremely difficult, though possible. It could be done, they suggest, using a next-generation particle accelerator called a plasma Wakefield accelerator. [11]

### **Physicist claims to have observed quantum effects of Hawking radiation in the lab for the first time**

For many years, scientists believed that nothing could ever escape from a black hole. But in 1974, Stephen Hawking published a paper suggesting that something could—particles that are now called Hawking radiation. His idea was that if a particle (and its antimatter mate) appeared spontaneously at the edge of a black hole, one of the pair might be pulled into the black hole while the other escaped, taking some of the energy from the black hole with it—which would explain why black holes grow smaller and eventually disappear. Because such emissions are so feeble, no one has been able to measure Hawking radiation, so researchers have instead tried to build virtual black holes in

labs to test the theory. One type of virtual black hole was proposed back in 1981 by Bill Unruh with the University of British Columbia—he suggested that an analogue might be created using water instead of light. He imagined a phonon existing at the edge of a waterfall—as the water speeds up, it begins to move faster than the speed of sound, causing it to be trapped. But if the phonon had an entangled mate that eluded the fall by moving away before getting caught up, it could escape. In this new effort, Steinhauer has built a device based on that idea and in so doing, claims he has observed an analogue of Hawking radiation.

The experiment consisted of creating an entangled pair of phonons sitting inside a bit of liquid that had been forced (via laser) to move very fast and then observing the action as one of the pair was pulled away as the liquid began to move faster than the speed of sound, while the other escaped—the fluid was a Bose-Einstein condensate of rubidium-87 atoms. After repeating the experiment 4,600 times Steinhauer became convinced that the particles were entangled, a necessity for a Hawking radiation analogue. His findings do not prove Hawking's theory to be true, of course, but they do appear to add a degree of credence that other researchers have thus far not been able to achieve. [10]

## Quantum Effects Stop the Formation of Black Holes

For decades, black holes were thought to form when a massive star collapses under its own gravity to a single point in space – imagine the Earth being squished into a ball the size of a peanut – called a singularity. So the story went, an invisible membrane known as the event horizon surrounds the singularity and crossing this horizon means that you could never cross back. It's the point where a black hole's gravitational pull is so strong that nothing can escape it.

The reason black holes are so bizarre is that it pits two fundamental theories of the universe against each other. Einstein's theory of gravity predicts the formation of black holes but a fundamental law of quantum theory states that no information from the universe can ever disappear. Efforts to combine these two theories lead to mathematical nonsense, and became known as the information loss paradox.

In 1974, Stephen Hawking used quantum mechanics to show that black holes emit radiation. Since then, scientists have detected fingerprints in the cosmos that are consistent with this radiation, identifying an ever-increasing list of the universe's black holes.

But now Mersini-Houghton describes an entirely new scenario. She and Hawking both agree that as a star collapses under its own gravity, it produces Hawking radiation. However, in her new work, Mersini-Houghton shows that by giving off this radiation, the star also sheds mass. So much so that as it shrinks it no longer has the density to become a black hole.

Before a black hole can form, the dying star swells one last time and then explodes. A singularity never forms and neither does an event horizon. The take home message of her work is clear: there is no such thing as a black hole.

Many physicists and astronomers believe that our universe originated from a singularity that began expanding with the Big Bang. However, if singularities do not exist, then physicists have to rethink their ideas of the Big Bang and whether it ever happened.

“Physicists have been trying to merge these two theories – Einstein’s theory of gravity and quantum mechanics – for decades, but this scenario brings these two theories together, into harmony,” said Mersini-Houghton. “And that’s a big deal.” [9]

## Considering the chess game as a model of physics

In the chess game there is also the same question, if the information or the material is more important factor of the game? There is also the time factor acting as the Second Law of Thermodynamics, and the arrow of time gives a growing disorder from the starting position.

When I was student of physics at the Lorand Eotvos University of Sciences, I succeeded to earn the master degree in chess, before the master degree in physics. I used my physics knowledge to see the chess game on the basis of Information – Entropy Theory and giving a presentation in the Hungarian Academy of Sciences, proposed a research of chess programming. Accepting my idea there has built the first Hungarian Chess Program "PAPA" which is participated on the 1<sup>st</sup> World Computer Chess Championship in Stockholm 1974. [1]

The basic theory on which one chess program can be constructed is that there exists a general characteristic of the game of chess, namely the concept of entropy.

This concept has been employed in physics for a long time. In the case of a gas, it is the logarithm of the number of those microscopic states compatible with the macroscopic parameters of the gas.

What does this mean in terms of chess? A common characteristic of every piece is that it could move to certain squares, including by capture. In any given position, therefore, the pieces by the rules of the game possess certain states, only one of which will be realized on the next move. The difference of the logarithm of the numbers of such states for Black and White respectively is the "entropy of the position". The task of the computer is then to increase this value for its own benefit.

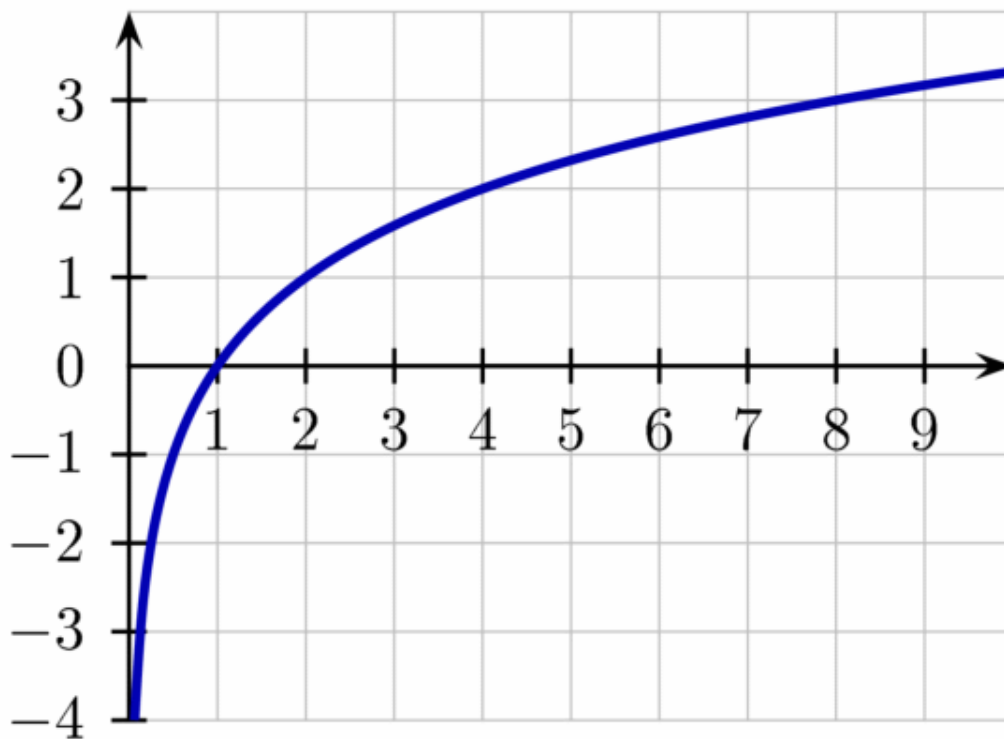
Every chess player knows that the more mobility his pieces have and the more constrained are his opponent's, the better his position. For example, checkmate is the best possible state for the attacker, and the chess program playing according to the above principle without the prior notion of checkmate will automatically attempt it if possible.

Entropy is a principle of statistical physics and therefore is only applicable in statistical contexts. The number of microstates of a confined gas is very large and therefore the statistical approach is valid. In chess, however, the number of pieces, a macroscopic parameter, is very small and therefore in this context the "value" of a position cannot be an exact function of entropy. For example, it is

possible to checkmate with a total force of a single pawn despite the fact that the opponent has many pieces and various positions available.

Examples of sacrificial combinations further demonstrate this consideration. Therefore we also need specific information about any given position. For example, entropy could be maximized by White giving check, but if the checking piece is then taken, the move was a bad one. The logarithm of the number of variations which have been examined in this way gives the amount of information. In the endgame it is rather inaccurate. Because of the small number of pieces the above noted inadequacy of the statistical principle becomes evident and we need to compute much more information to fill the gap.

We can think about the positive logarithmic values as the measure of entropy and the negative logarithmic values as the measure of information.



Shortly speaking:

- The evaluation of any position is based on the entropy + information.
- The entropy is the logarithm of the possible legal moves of the position.
- The information is simply the depth of the search, since it is the logarithm of the exponential growing number of possible positions,  $\log e^x = x$ .

E = entropy

I = information

D = depth of search

$M$  = legal moves in any position,  $M_w$  for white moves and  $M_b$  for black moves

$$E = \log M_w - \log M_b = \log M$$

And since  $\log e^x = x$ ,  $I = D$

We get information + entropy, the value  $V$  of any position in the search tree of the current chess position:

$$V(D, M) = I + E = D + \log M$$

This naturally gives better values for a deeper search with greater mobility. [2]

## Using this model in physics

Viewing the confined gas where the statistical entropy not needs the information addition is not the only physical system. There are for example quantum mechanical systems where the information is a very important qualification. The perturbation theory needs higher order calculations in QED or QCD giving more information on the system as in the chess games happens, where the entropy is not enough to describe the state of the matter. The variation calculation of chess is the same as the perturbation calculation of physics to gain information, where the numbers of particles are small for statistical entropy to describe the system. The role of the Feynman graphs are the same as the chess variations of a given position that is the depth of the variations tree, the Information is the same as the order of the Feynman graphs giving the Information of the micro system.

## Quantum Information Science

Quantum information science is an area of study based on the idea that information science depends on quantum effects in physics. It includes theoretical issues in computational models as well as more experimental topics in quantum physics including what can and cannot be done with quantum information.

## Quantum Computing Research

Quantum computing has been an intense research field since Richard Feynman in 1981 challenged the scientific community to build computers based on quantum mechanics. For decades, the pursuit remained firmly in the theoretical realm.

To understand the quantum world, researchers have developed lab-scale tools to manipulate microscopic objects without disturbing them. The 2012 Nobel Prize in Physics recognizes two of these quantum researchers: David Wineland, of the National Institute of Standards and Technology

and the University of Colorado in Boulder, and Serge Haroche, of the Collège de France and the Ecole Normale Supérieure in Paris. Two of their papers, published in 1995 and '96 in Physical Review Letters, exemplify their contributions. The one by Wineland and collaborators showed how to use atomic states to make a quantum logic gate, the first step toward a superfast quantum computer. The other, by Haroche and his colleagues, demonstrated one of the strange predictions of quantum mechanics—that measuring a quantum system can pull the measuring device into a weird quantum state which then dissipates over time.

IBM scientists believe they're on the cusp of building systems that will take computing to a whole new level. On Feb 28, 2012 the IBM team presented major advances in quantum computing device performance at the annual American Physical Society meeting. Using a variety of techniques in the IBM laboratories, scientists have established three new records for retaining the integrity of quantum mechanical properties in quantum bits, or qubits, and reducing errors in elementary computations. These breakthrough results are very close to the minimum requirements for a full-scale quantum computing system as determined by the world-wide research community. [3]

Quantum computing in neural networks is one of the most interesting research fields today. [4] The biological constructions of the brain are capable to memorize, associate and logically thinking by changing their quantum states. The machine learning of Artificial Intelligence will be one of the mainstreams of the Quantum Computing, when it will be available. Probably the main challenge will be to simulate the brain biologic capability to create new quantum states for logical reasoning, since we don't know nowadays how it is work exactly in the brain. [8]

## The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them. [5]

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater than subatomic matter structures as an electric dipole change.

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also. [6]

The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction.

## Black Holes revisited

The Black Holes are the counter example, where the matter is so highly concentrated that the entropy is very low and the information is high but closed inside the event horizon.

The problem is with the Black hole that it is not a logical physical state of the matter by the diffraction theory, because we cannot find a temperature where this kind of diffraction patterns could exist. [5]

Also the accelerating charges of the electric current say that the charge distribution maintains the accelerating force and this viewpoint of the relativity does not make possible an acceleration that can cause a Black Hole. The ever growing acceleration simply resolved in the spin. [7]

The spin is one of the most generic properties of the Universe, not only the elementary particles are spinning, but also the Sun, Earth, etc. We can say that the spin is the resolution of the constantly accelerating matter solving the problem of the relativity and the accelerating Universe. The gravity is the magnetic effect of the accelerating matter, the attracting force between the same charges; working by the electromagnetic oscillations, because of this is their universal force. Since this effect is relatively weak, there is no way for the gravitation force to compress the matter to a Black Hole.

## Conclusions

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My opinion is that information and matter are two sides of the same thing in physics, because the matter is the diffraction pattern of the electromagnetic waves, giving the temperature dependent different structures of the matter, the information about them arrives by the electromagnetic waves and also the entropy or uncertainty as the measure of disorder. [7]

The Fluctuation Theory gives a probability for Information grow and Entropy decrease seemingly proportionally with the gravitational effect of the accelerating Universe, against the arrow of time by the Second Law of Thermodynamics. The information and entropy are the negative and positive sides of the logarithmic curve, describing together the state of the matter.



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