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New black hole simulator may shed more light on contradiction in fundamental physics

A newly proposed experiment promises to create a “tabletop” black hole that could prove whether information is truly lost when black holes evaporate. The idea that information could be lost this way has created a paradox in our current understanding of basic physics.

43 years ago, Stephen Hawking combined quantum field theory with Einstein’s theory of general relativity and discovered black hole evaporation. The debate over whether information is really lost during Hawking evaporation has persisted ever since. Almost all the contemporary leading theoretical physicists have participated in this “black hole war”. In quantum mechanics, the probability, or information, must be preserved before and after a physical process. The seeming loss of information as a result of the black hole evaporation therefore implies that general relativity and quantum mechanics, the two pillars of modern physics, may be in conflict.

SIMULATING A BLACK HOLE ON A TABLE

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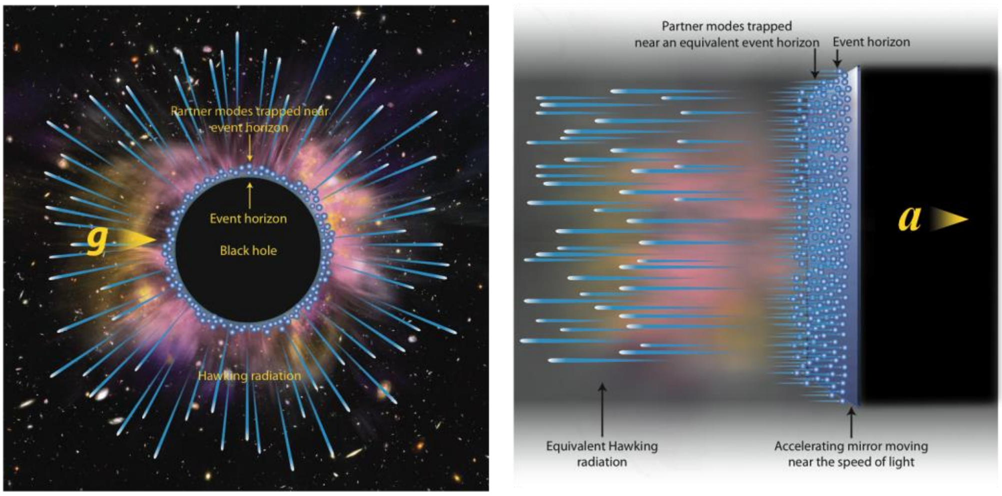


Black hole Hawking evaporation — *Accelerating mirror as an analog black hole*

Fig.1: Accelerating mirror mimics evaporating black hole. Left: Black hole Hawking evaporation and the trapping of the partner modes near the horizon. Right: An accelerating mirror also has a horizon and can also emit Hawking particles and trap their partner modes. The analogy between these two systems may be appreciated via Einstein's equivalence principle.

So far investigations of this paradox have been mostly theoretical because of the difficulty of observing black holes in their later stages, when this potential contradiction is most acute. According to theory, a solar-size black hole would take 10^{67} years to evaporate entirely, yet our universe is only about 10^{10} years old. Therefore essentially all astrophysical black holes are too young to provide useful clues on the information loss paradox even if they are observed, such as that responsible for the gravitational waves observed by LIGO in 2016.

Now, in a paper that was published in Physical Review Letters on January 23 (Phys. Rev. Lett. **118**, 045001 (2017); http://journals.aps.org/prl/issues/118/4), Pisin Chen, Professor of Physics and Director of the Leung Center for Cosmology ad Particle Astrophysics (LeCosPA), National Taiwan University, and Gerard Mourou, Professor and Director of International Center for Zeta-Exa-Watt Science and Technology (IZEST), École Polytechnique, conceived a laboratory black hole to simulate this evaporation. Using state-of-the-art laser and nanofabrication technologies, they plan to mimic black hole evolutions at their later stage, to reveal crucial details on how information may be preserved during black hole evaporation.

According to Einstein's equivalence principle, an accelerating mirror moving near the speed of light shares some common features with a true black hole. In both cases, there exist an event horizon. Interacting with quantum fluctuations in vacuum near the horizon, both will emit Hawking particles and trap their partner modes (Fig.1) until the black hole evaporates entirely or the accelerating mirror suddenly stops. By then the partner modes will be released. The purpose of this proposed experiment is to see whether and how the Hawking particles and their partners are entangled and therefore how the information would be preserved.

It is known that an intense laser traversing a plasma would push the intercepting plasma electrons to its back, which is called by experts the "plasma wakefields". Triggered by extremely intense lasers, such plasma density perturbations can be so concentrated that it can serve as a flying reflecting mirror. The authors pointed out in the paper that by properly tailoring the increase of the density of a thin-film target using nanofabrication technology, a relativistic plasma mirror would accelerate as the driving laser continues to enter higher density regions. At the time when the laser leaves the thin-film target, the plasma mirror would abruptly stop its motion, which mimics the ending of the Hawking evaporation (see Fig.2).

In addition to being published by Physical Review Letters, one of the most prestigious physics journals in the world, this paper, entitled "Accelerating Plasma Mirrors to Investigate Black Hole Information Loss Paradox", was highlighted by PRL as "Editors' Suggestion". In addition, it was featured as a "Synopsis" in American Physical Society's online magazine *Physics* (http://physics.aps.org) on January 23, 2017. On the average only a small percentage of PRL papers received such an honor.

An international collaboration has been formed, which consists of National Taiwan University, École Polytechnique, Kansai Photon Research Institute in Kyoto, and Shanghai Jiao Tong University, to carry out this experiment.

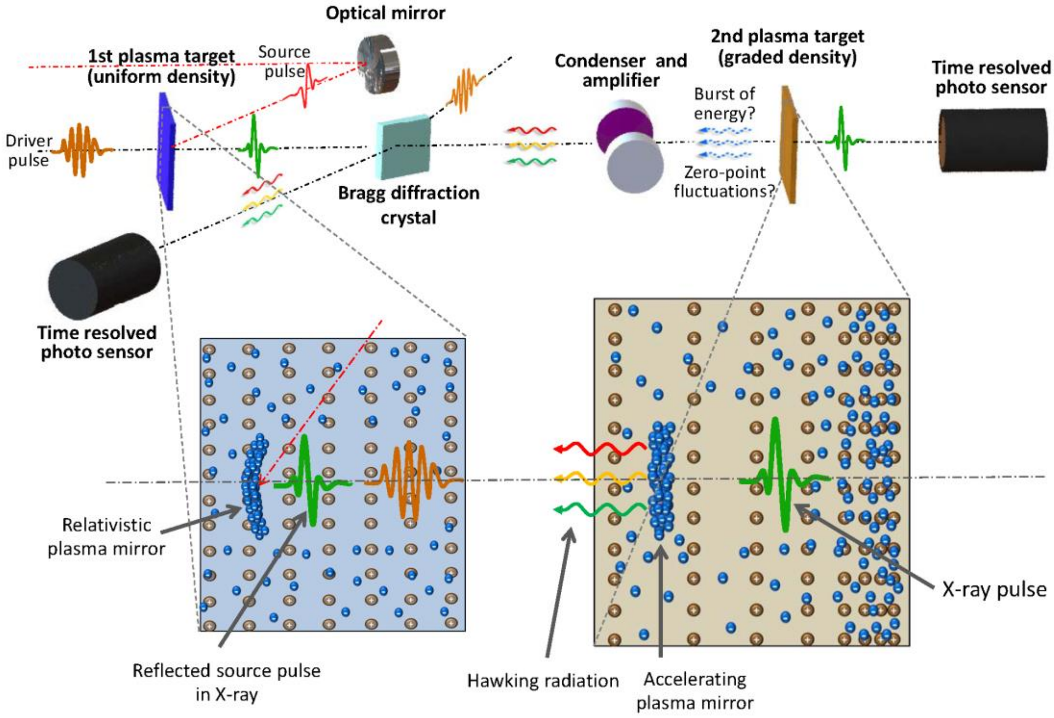
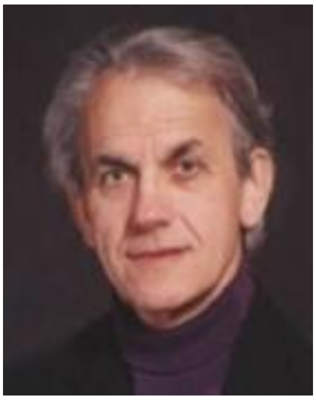


Fig.2: A schematic diagram of the proposed analog black hole experiment. The first, gaseous and uniform plasma target is used to prepare a high intensity x-ray pulse. The x-ray pulse will then induce an accelerating plasma mirror due to the increasing plasma density in the second target. As the mirror stops abruptly, it will release either a burst of energy or zero-point fluctuations. The entanglement between either of these signals and the Hawking photons emitted earlier is measured upstream.


Pisin Chen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École Polytechnique offers an exceptional education to prepare bright men and women to excel in high-level key positions and lead complex and innovative projects which meet the challenges of 21st century society, all while maintaining a keen sense of their civil and social responsibilities. With its 22 laboratories, 21 of which are joint research units with the French National Center for Scientific Research (CNRS), École Polytechnique Research Center explores the frontiers of interdisciplinary knowledge to provide major contributions to science, technology, and society. École Polytechnique is a founding member of Université Paris-Saclay.

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ABOUT NATIONAL TAIWAN UNIVERSITY / NTU's institutional predecessor was Taihoku Imperial University, founded in 1928 by the Japanese colonial administration. The first president was Shidehara Tan Tairaka Hiroshi. In 1945, the Republic of China won the war of resistance against Japan, and Taiwan was handed over to the Nationalist government of China. On November 15 of that year, Taihoku Imperial University was formally transferred to Chinese administration and renamed as National Taiwan University, with Dr. Tsung-lo Lo appointed as the first President.

After restructuring in accordance with the ROC academic system in 1945, academic departments were established and the former divisions were renamed Colleges. The Literature and Politics division was divided into the College of Liberal Arts and the College of Law. Additionally, colleges of Science, Medicine, Engineering and Agriculture were established. Initially, there were six colleges with 22 departments. In 1945, student enrollment was 585. In the following years, the departments and colleges expanded in faculty and hardware in step with growing budgets and rising social expectations. In 1960, the night school was initiated on a trial basis, and in 1967 a new night school was established. In 1987, the College of Management was established, followed by the College of Public Health in 1993 and the College of Electrical Engineering in 1997. The College of Electrical Engineering was later rechristened the College of Computer Science and Electrical Engineering; in 1999, the College of Law was renamed the College of Social Sciences, and the Night Division and the Center for Continuing Education were combined to form the School for Professional and Continuing Studies. In 2002, the College of Agriculture was renamed the College of Bio-resources and Agriculture, and in 2002 a College of Life Sciences was added. Now, the university has 11 colleges, with 54 departments and 103 graduate institutes, plus four university-level research centers: Population and Gender Studies Center, Center for Condensed Matter Sciences, Center for Biotechnology, and Bio-diversity Research Center. The total number of students, including those enrolled at the School of Professional and Continuing Studies, has grown to over 33,000, including over 17,000 undergraduate and 15,000 graduate students. Now, the number of graduate students at NTU almost equals the number of undergrads, which indicates that NTU has been successfully transformed into a research university.

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