Study reports a transition from spontaneous to stimulated Hawking radiation in a sonic black hole

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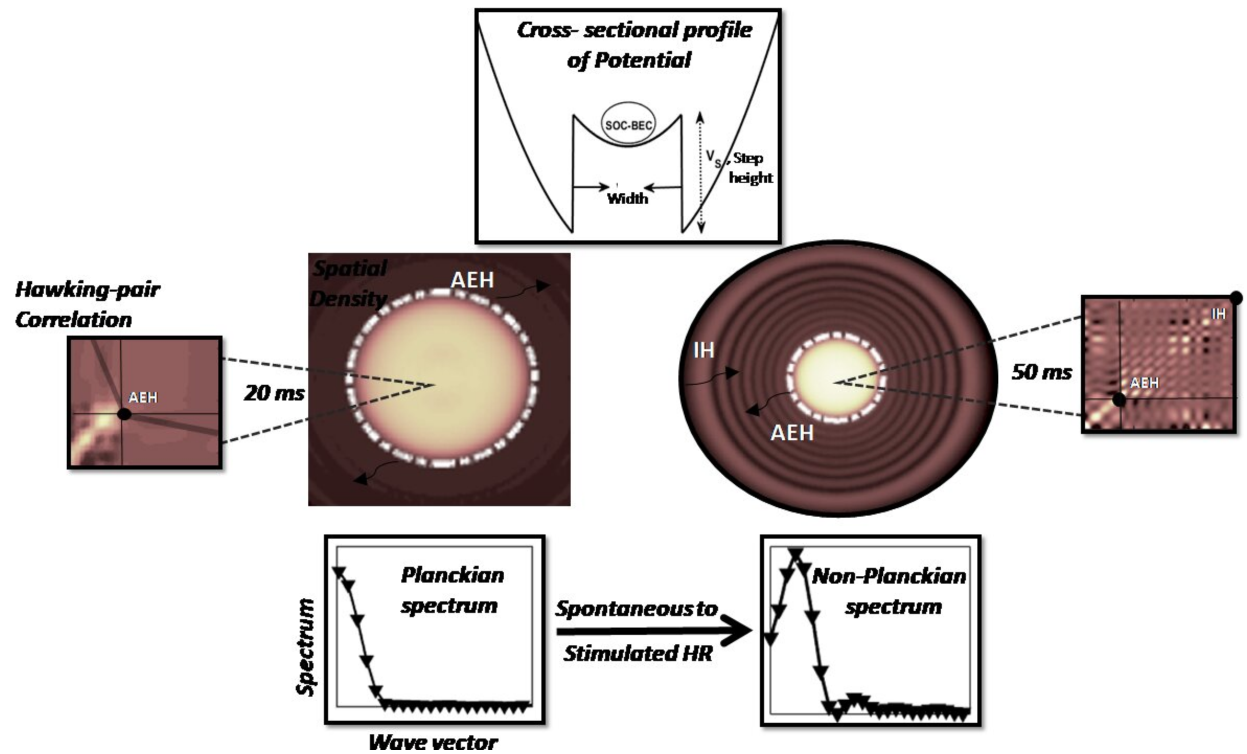

Fig: proposed set up, density and correlation at 20 and 50 ms, HR spectrum at 20 and 50 ms showing clear transition from spontaneous to stimuated emission. (Fig. parts taken from the Fig.1, Fig.2 Fig 7 and Fig 11 of the manuscript) Credit: All figures are provided by the authors

In 2014 and 2016, Jeff Steinhauer of Technion, Israel, successfully conducted two significant experiments. The first one demonstrated stimulated Hawking radiation in a sonic black hole laser (SBHL). The next one showed spontaneous Hawking radiation from a sonic black hole (SBH). Both experiments were performed in an ultra-cold Bose-Einstein condensate (BEC) of rubidium atoms at nano-Kelvin temperature, an extreme form of quantum fluid almost at absolute zero temperature.

To give you some background, a sonic analog of a black hole (SBH) traps sound within a single acoustic event horizon (AEH), and, emits spontaneous sonic Hawking radiation (HR), an analogy first suggested by Bill Unruh to show a possible way to test the ground breaking idea of Stephen Hawking.

To form a SBHL, the sound wave quanta phonon needs to go back and forth between two such event horizons (inner and outer) with the creation of more phonons, resulting in a stimulated Hawking radiation. This idea was first suggested by Jacobson and Corley more than a decade after Unruh's suggestion. It indicates that to realize an SBHL, spontaneous radiation from a sonic event horizon should take place at some earlier time. Naturally, you would like to see a transition from one to another in the same system.

A two-dimensional sonic black hole and its Hawking radiation:

To test this possibility, we analyzed and simulated a quasi two-dimensional spin-orbit-coupled BEC of the same rubidium atoms by accelerating it through a ring-shaped laser-induced potential. We made two major changes. Firstly, our system is two-dimensional as compared to Steinhauer's quasi-one-dimensional system. Unruh's original theory rigorously started working only in two spatial dimensions and beyond. Secondly, it has synthetic spin-orbit coupling. This property allows it to move non-uniformly along various directions in a plane with slight rotation.

We found that at the initial stage, the system forms a single sonic horizon showing spontaneous Hawking radiation. This is the regime where the fluctuation in the density of the moving condensate is relatively weaker and behaves in the same way as waves in the water. It is this regime where the mathematical analogy that was proposed by Unruh is valid. The spectrum of the Hawking radiation in this regime is a featureless thermal distribution as envisaged by Hawking. Spin-orbit coupling enhances this spectrum, and moreover, it makes it relatively more pronounced in a certain direction.

The breakdown of gravitational analogy:

Further in time, the density changes in the condensate gets wilder, and, the analogy suggested by Unruh breaks down. Nevertheless, the system now started forming a second horizon with a strong spatially oscillating, and temporally growing density pattern in between the two horizons, indicating the formation of a sonic black hole laser with stimulated Hawking radiation. The radiation spectrum deviates from the featureless thermality and forms a distinct peak.

Observation of the thermal nature of the Hawking radiation is a key to understanding the fundamental issue of information paradox. Such a clear transition from spontaneous to stimulated Hawking transition in a given atomic fluid over a period of time, eventual breakdown of the gravitational analogy and the thermality condition provides important insights to the possible use of such an analog model to study these fundamental issues.

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More information: Jeff Steinhauer. Observation of quantum Hawking radiation and its entanglement in an analog black hole, *Nature Physics* (2016). DOI: 10.1038/nphys3863

Steven Corley et al. Black hole lasers, *Physical Review D* (2002). DOI: 10.1103/PhysRevD.59.124011

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Bio:

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