Journal Club: Observation of thermal Hawking radiation and its entanglement in an analogue black hole

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Observation of thermal Hawking radiation and its entanglement in an analogue black hole

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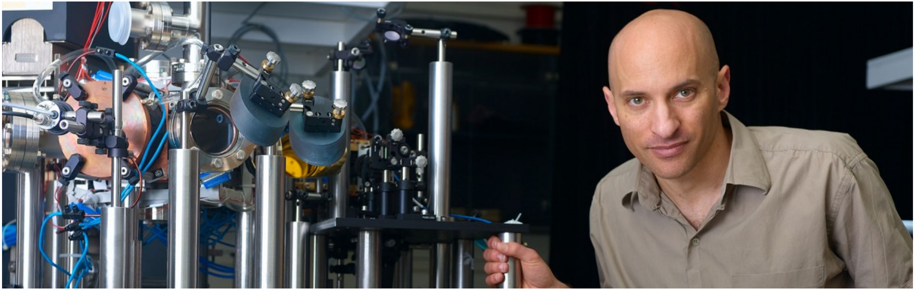
We observe a thermal distribution of Hawking radiation, stimulated by quantum vacuum fluctuations, emanating from an analogue black hole. This confirms Hawking's prediction regarding black hole thermodynamics. The thermal distribution is accompanied by correlations between the Hawking particles outside the black hole and the partner particles inside. We find that the high energy pairs of Hawking and partner particles are entangled, while the low energy pairs are not. This has implications for the problem of information loss in a black hole. The observation of Hawking radiation reported here verifies Hawking's semiclassical calculation, which is viewed as a milestone in the quest for quantum gravity.

Prof. Jeff Steinhauer

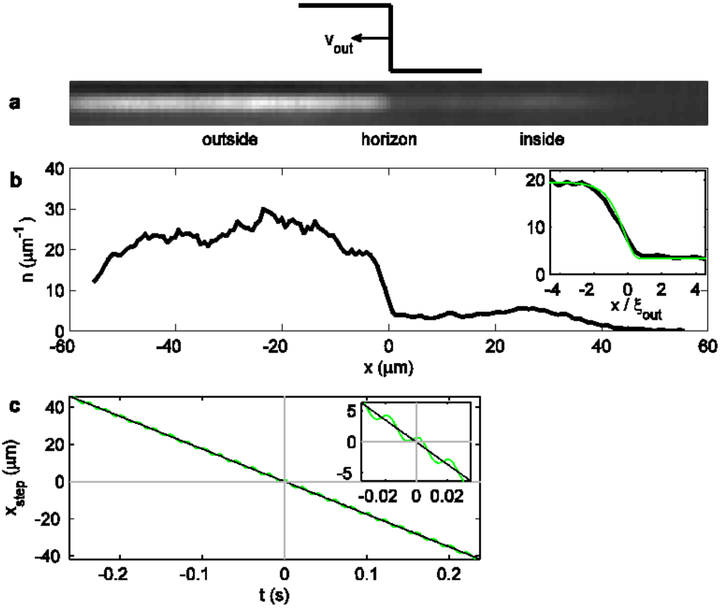


Measurement of Stimulated Hawking Emission in an Analogue System

S. Weinfurtner, E. W. Tedford, M. C. J. Penrice, W. G. Unruh, and G. A. Lawrence, Phys. Rev. Lett. **106**, 021302 (2011).

Video: `https://youtu.be/qPzEyj1zoQk`

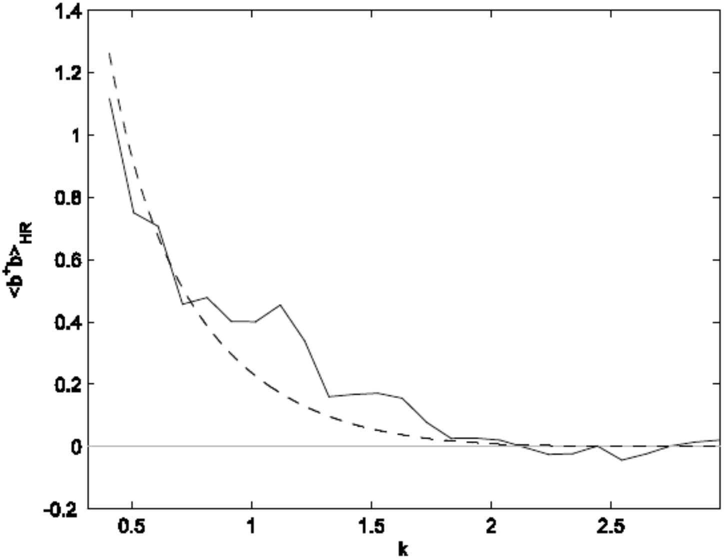
The analogue black hole



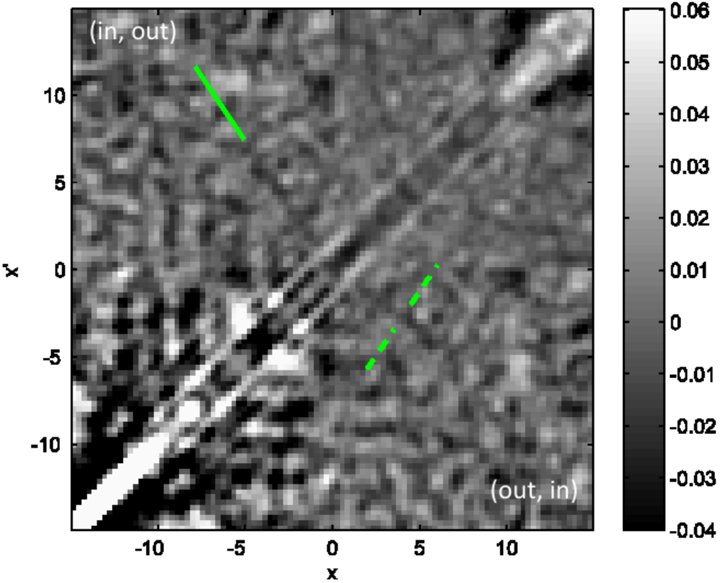
Parameters

- Wavelength of trapping laser $812\,\mathrm{nm}$
- Sharp potential step is created by laser with $\lambda = 442\,\mathrm{nm}$
- The step potential is swept along the condensate at a constant speed of $v_{\mathrm{out}} = 0.18\,\mathrm{mm/s}$

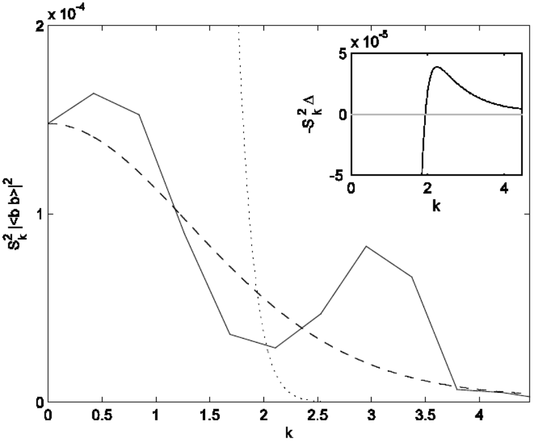
Power spectrum of phonons outside



Two-body correlation function



Entanglement of phonons



$$\Delta = \langle \hat{b}^{\dagger}_{k_{\mathrm{HR}}} \hat{b}_{k_{\mathrm{HR}}} \rangle \langle \hat{b}^{\dagger}_{k_{\mathrm{P}}} \hat{b}_{k_{\mathrm{P}}} \rangle - |\langle \hat{b}_{k_{\mathrm{HR}}} \hat{b}_{k_{\mathrm{P}}} \rangle|^2$$

Summary

In conclusion, thermal Hawking radiation stimulated by quantum vacuum fluctuations has been observed in a quantum simulator of a black hole. This confirms the prediction of Hawking regarding spontaneous pair production in the presence of a horizon. This has implications beyond the physics of black holes, as it confirms the semiclassical step toward the understanding of quantum gravity. The Hawking spectrum is observed, as are the correlations between the Hawking radiation exiting the black hole and the partner particles inside the black hole. These correlations are surprisingly narrow in position space, which implies that the high frequency tail of the distribution of Hawking pairs are entangled. On the other hand, the overall weakness of the correlations in position space implies that the low frequencies are not entangled. The entanglement confirms that there is an issue of information loss within the semiclassical approximation.

Thank you for your attention!