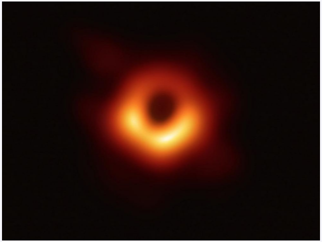
From gravitational black holes to analogue gravity: Hawking radiation in quantum fluids

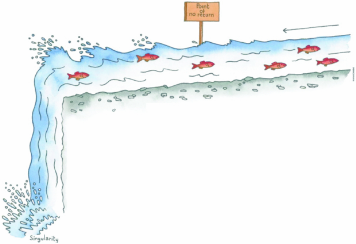
Friday, 29 November 2019

Rencontres des Jeunes Physiciens 2019, Collège de France

Mathieu Isoard & Nicolas Pavloff

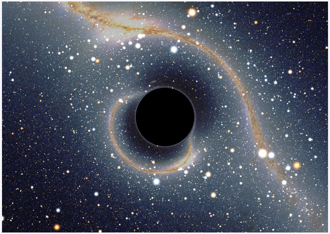
LPTMS, Université Paris-Sud





Hawking radiation

Nature, 1974; Commun. math. Phys, 1975



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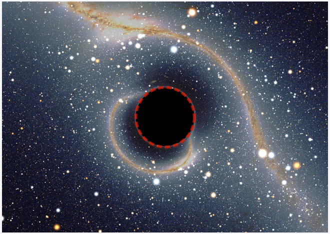

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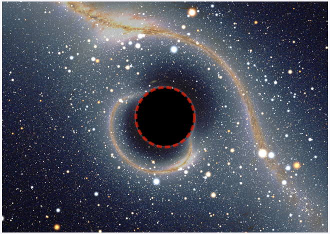

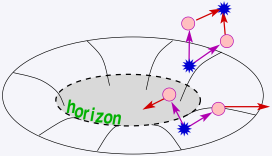

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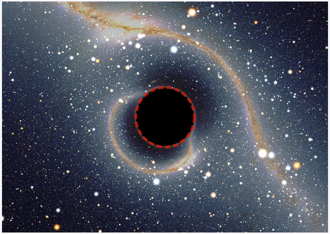

Particle Creation by Black Holes

S. W. Hawking

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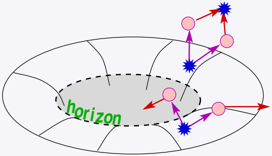
Received April 12, 1975



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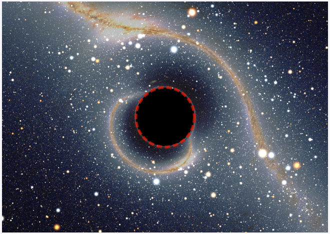

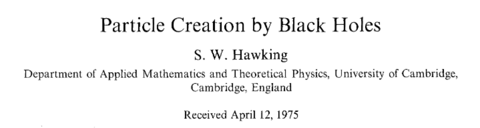

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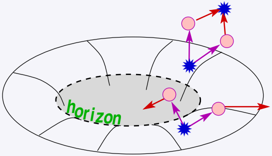

$$\hookrightarrow \; T_H = 10^{-6} \left(\frac{M_\odot}{M}\right) \text{ K.}$$

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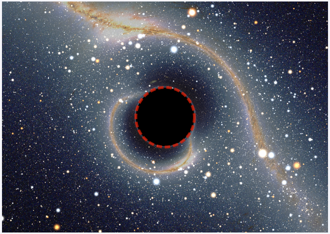

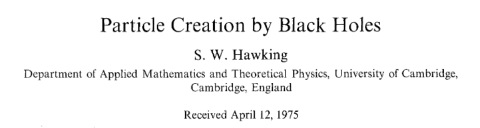

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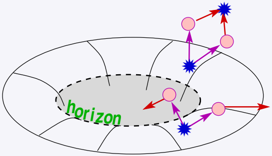

$\hookrightarrow$ $T_H = 10^{-6} \left(\frac{M_\circ}{M}\right)$ K.

$\hookrightarrow$ M87: M = 6.5 billions of solar masses

$\rightarrow T_H \simeq 10^{-14} K$.

The birth of analogue gravity

W.G. Unruh, PRL, 1981

VOLUME 46 25 MAY 1981 NUMBER 21

Experimental Black-Hole Evaporation?

W. G. Unruh

Department of Physics, University of British Columbia, Vancouver, British Columbia V6T 2A6, Canada

(Received 8 December 1980)

It is shown that the same arguments which lead to black-hole evaporation also predict that a thermal spectrum of sound waves should be given out from the sonic horizon in transsonic fluid flow.

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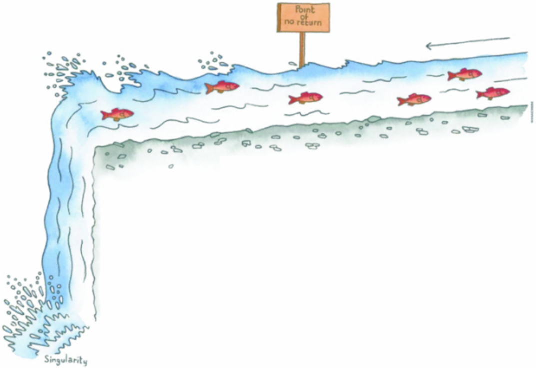

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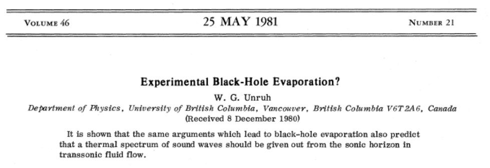

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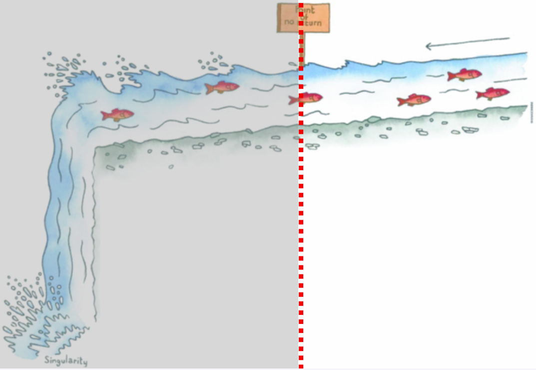

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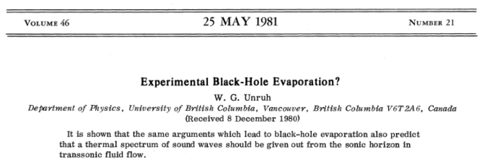

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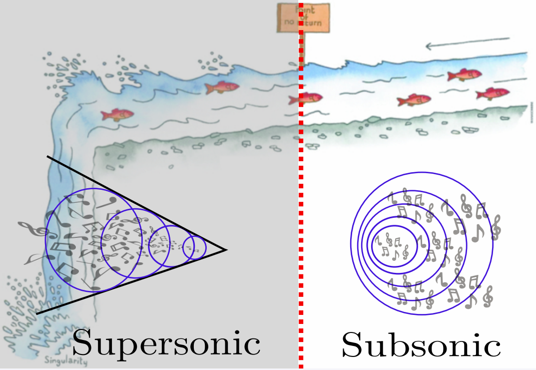

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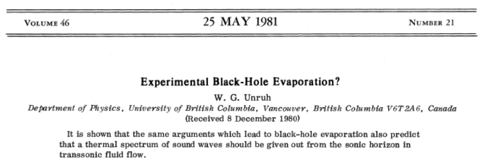
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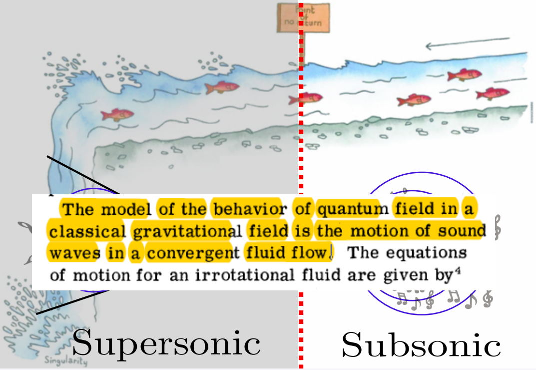
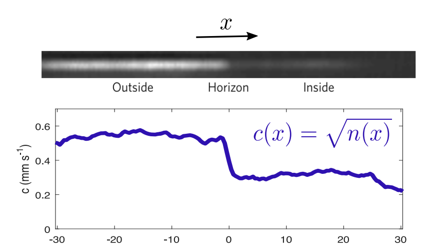
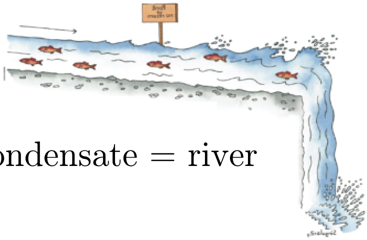


Acoustic black holes in Bose-Einstein condensates



[J. Steinhauer, Nature, 2016]



condensate = river

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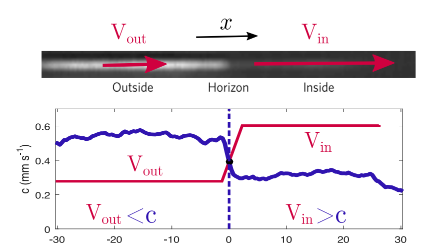

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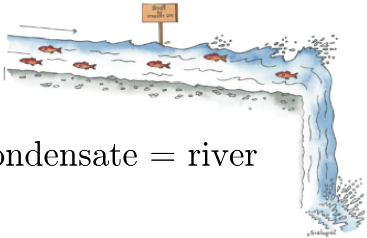

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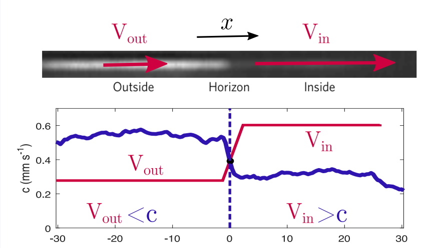

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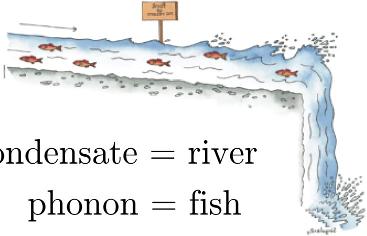

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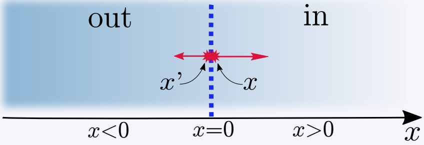

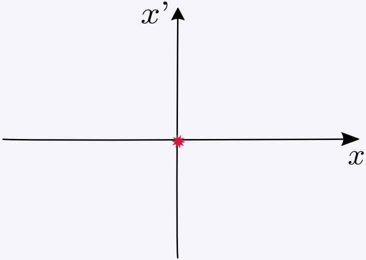

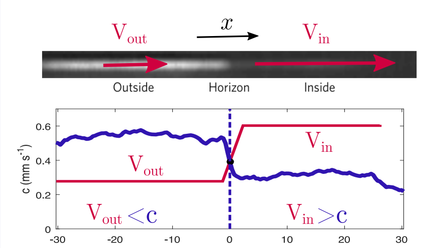

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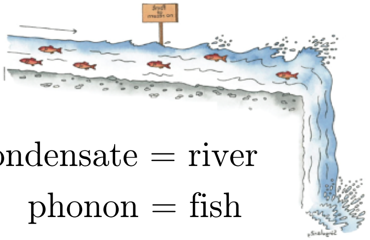

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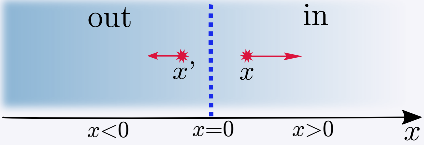

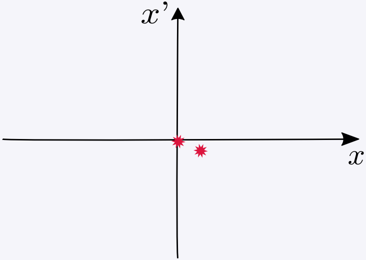

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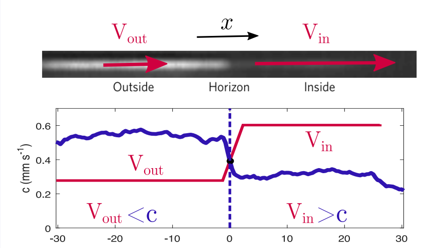

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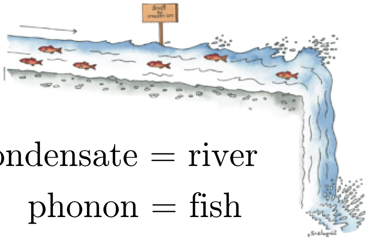

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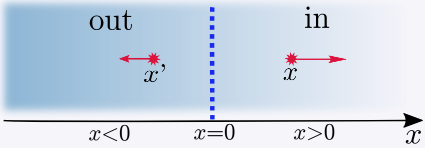

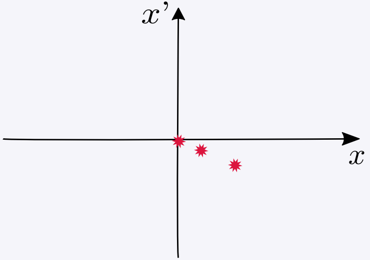

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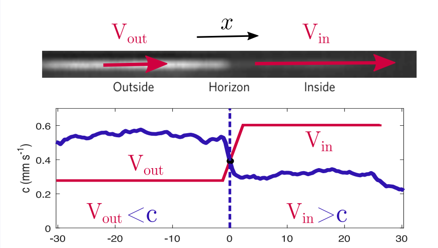

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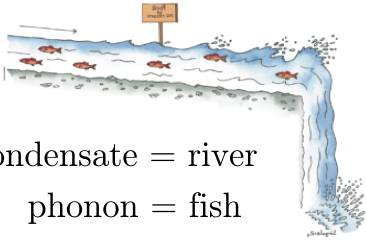

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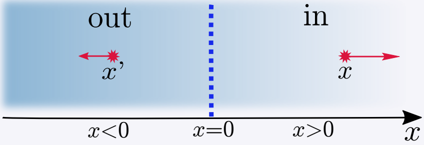

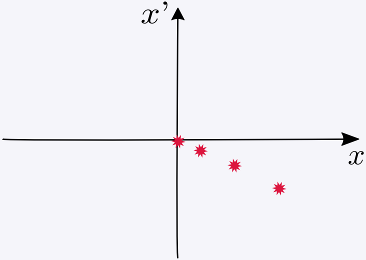

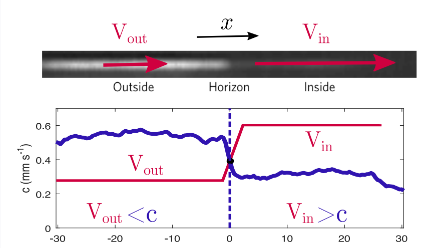

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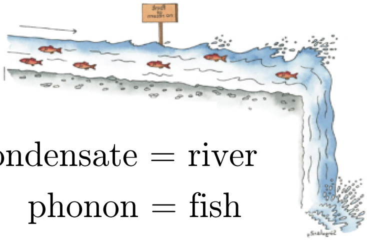

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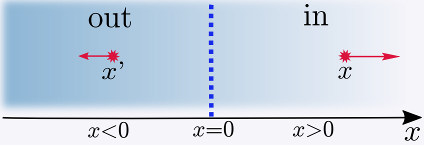

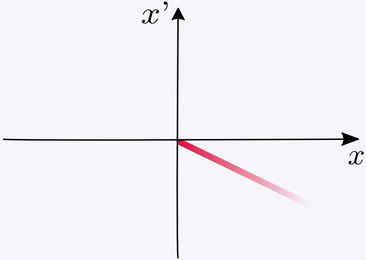

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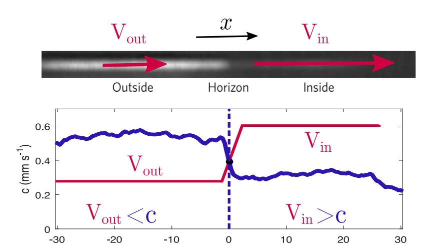

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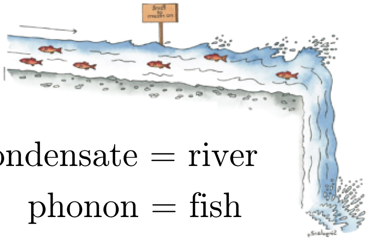

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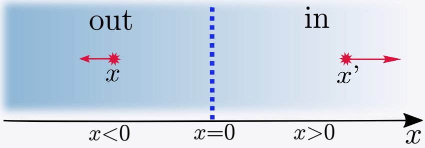

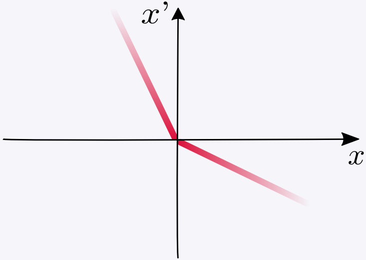

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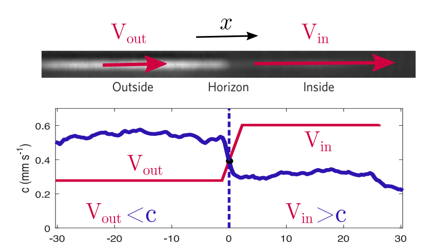

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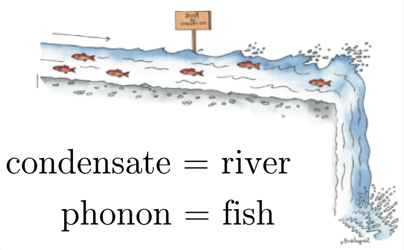
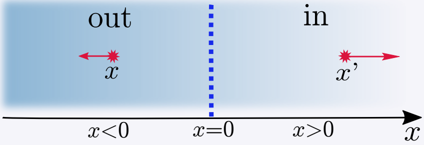
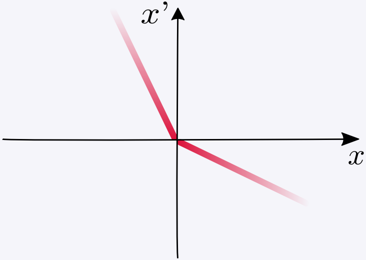
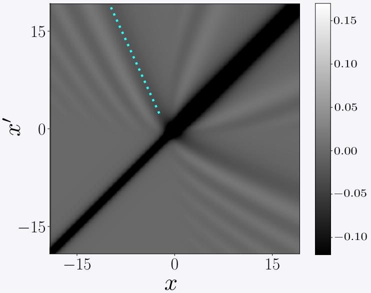


Both phonons are correlated $\Rightarrow$ Density correlations $\equiv \langle \delta n(x)\, \delta n(x') \rangle$.





Experimental detection of the Hawking effect...



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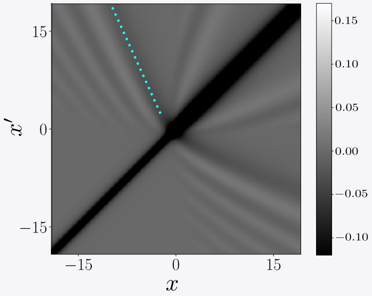

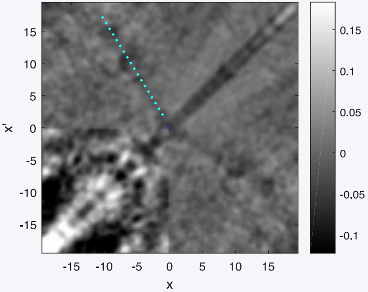

[J. Steinhauer, Nature, 2019]

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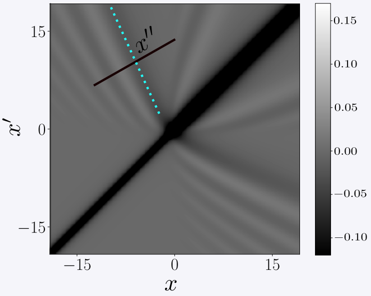

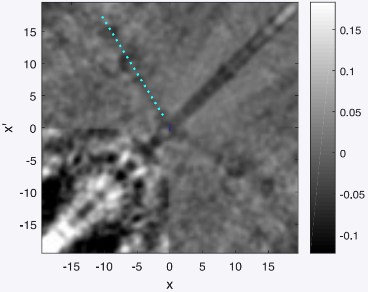

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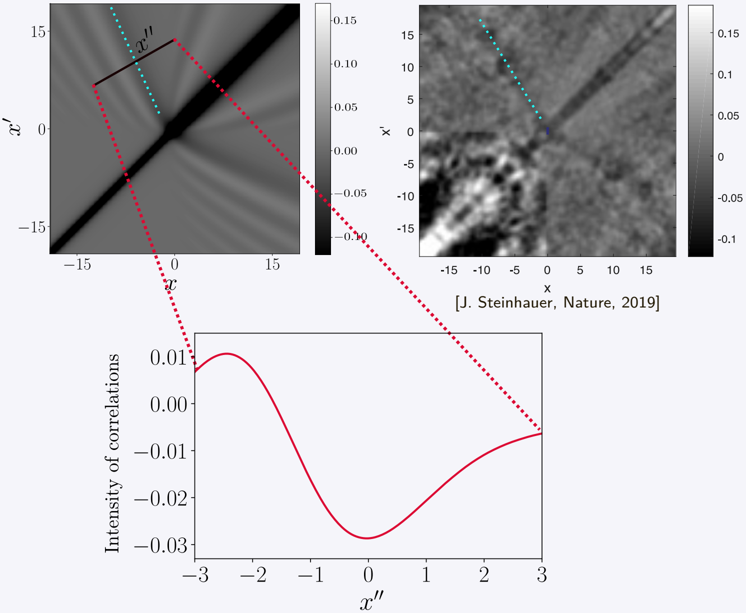

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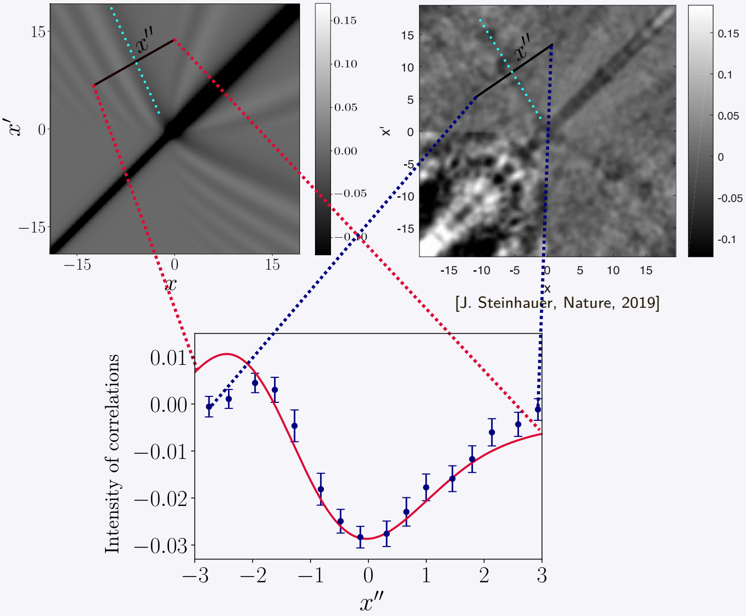

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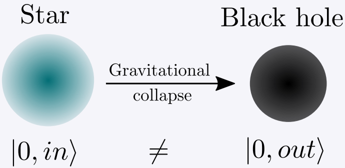
... but it's not the end!

$\hookrightarrow$ The same process everywhere



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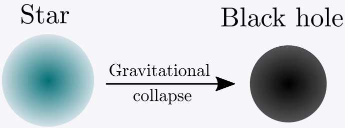

$|0, in\rangle \neq |0, out\rangle$

$$|0, in\rangle = \hat{S}_{\mathrm{sq}}(r)\, |0, out\rangle$$

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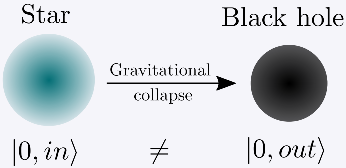

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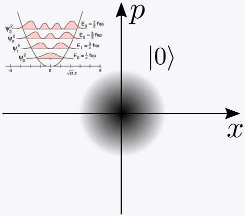
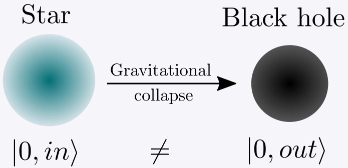


↪ The same process everywhere



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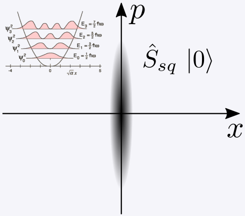

... but it's not the end!

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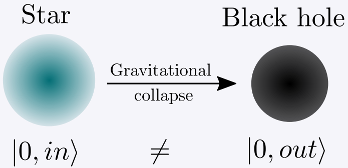

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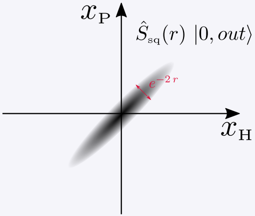

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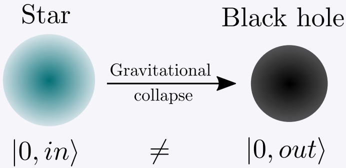

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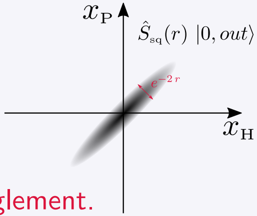

Squeezed states have a high degree of entanglement.

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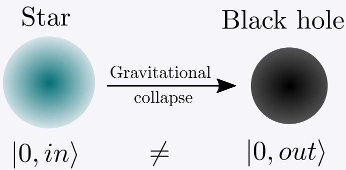

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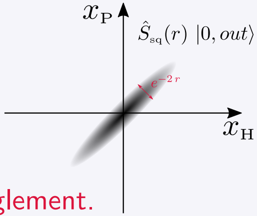

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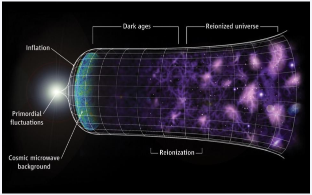

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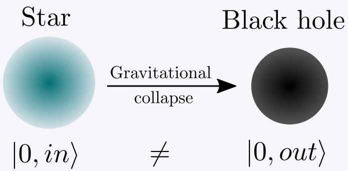

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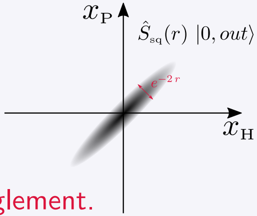

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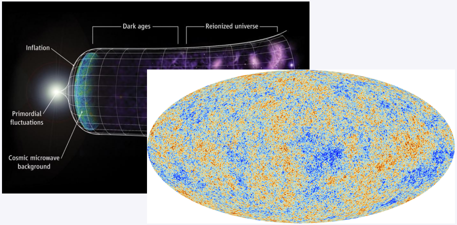

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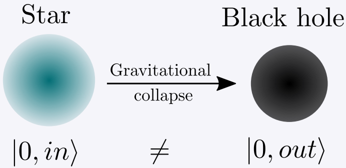

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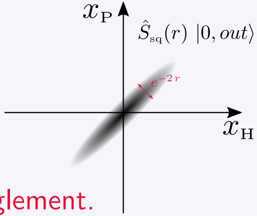

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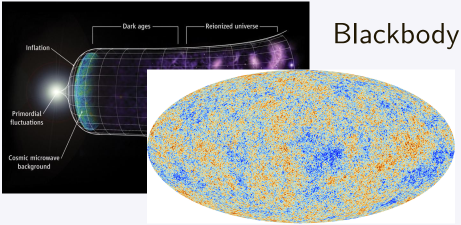

Blackbody radiation & squeezed state!

With $r = 120$!!

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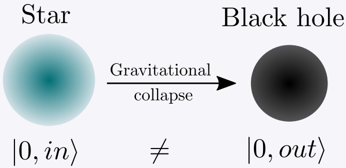

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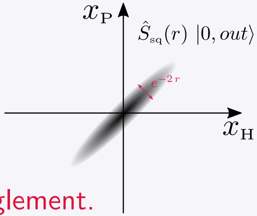

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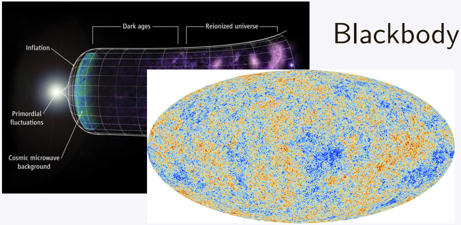

Blackbody radiation & squeezed state!

With $r = 120$!!

Hawking radiation: $r \sim 1$

The beginning!

story of Hawking radiation

- $\hookrightarrow$ Hawking's prediction, 1974
- $\hookrightarrow$ Unruh's suggestion, 1981
- $\hookrightarrow$ First detection of spontaneous Hawking radiation in an analogue system, 2016 & 2019
- $\hookrightarrow$ **Theoretical confirmation, 2019**

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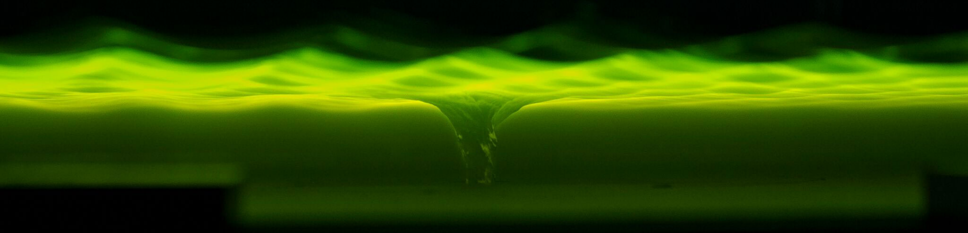
New challenges for analogue gravity

A bridge between

Condensed Matter and General Relativity



24-28 August 2020

UNIVERSITÉ DE RENNES 1

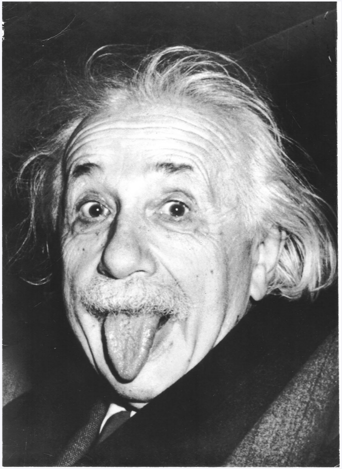
IPR PHYSIQUE

JMC, Rennes

cnrs advancing the frontiers

Société Française de Physique

image: © University of Nottingham.



Thank you!