Hawking radiation and Backreaction

A. Fabbri (Centro Fermi)

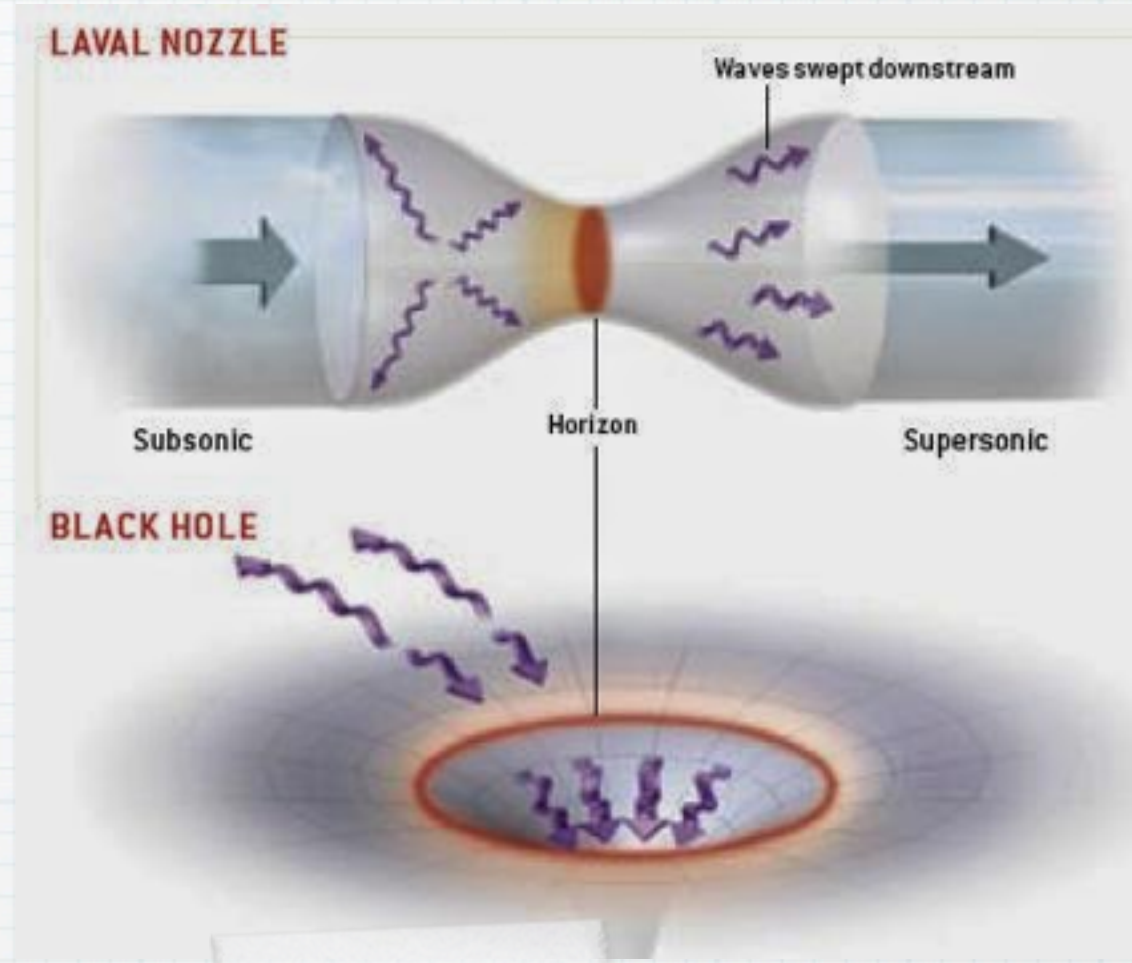
Funzioni di correlazione per lo studio della radiazione di Hawking nei condensati di Bose-Einstein
(Univ. Bologna / Univ. Paris-Sud)
Responsabile Scientifico R. Balbinot (Univ. Bologna)

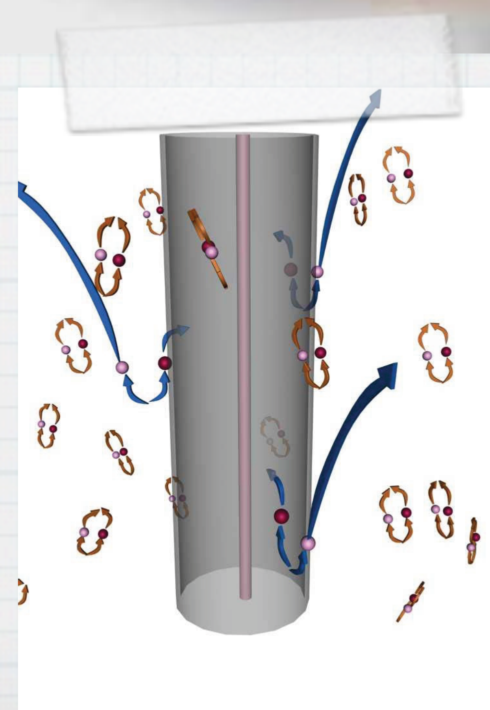
8 Marzo 2018

Reproducing a black hole in the lab

Unruh, 1981

- An analog black hole can be realized with a transonic flow
- Both systems - bh and analog bh - have a (event or acoustic) **horizon**
- **Hawking radiation**, quantum particle creation by the horizon, can be tested in the lab!



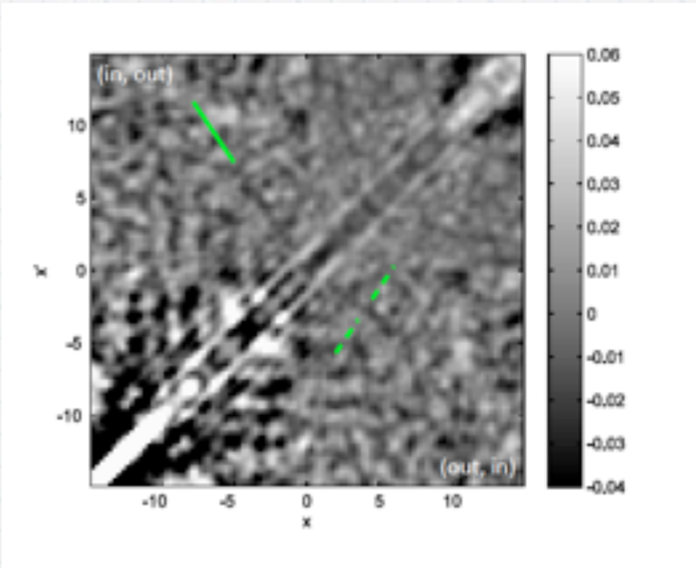


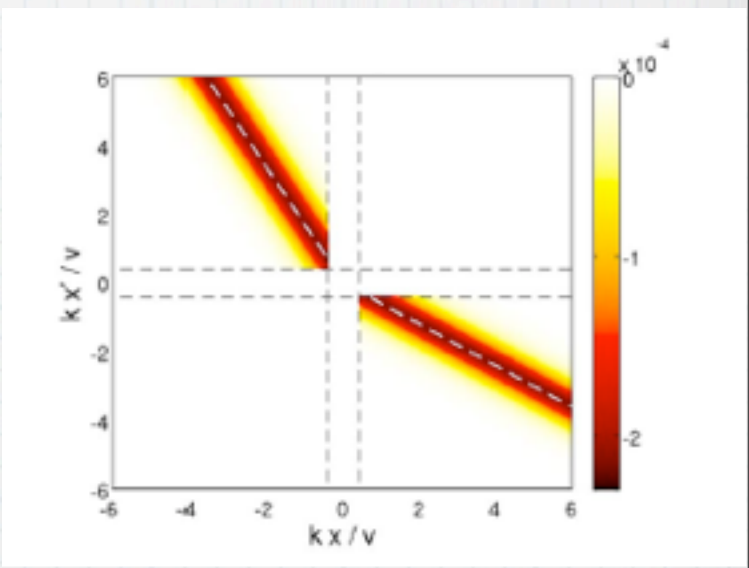
Hawking, 1974

Hawking radiation in Bose-Einstein condensates

Steinhauer, Nat. Phys. 2016

- An acoustic bh in a BEC was created with a (moving) step potential
- He measured the Hawking quanta- partner peak in the **density correlator**

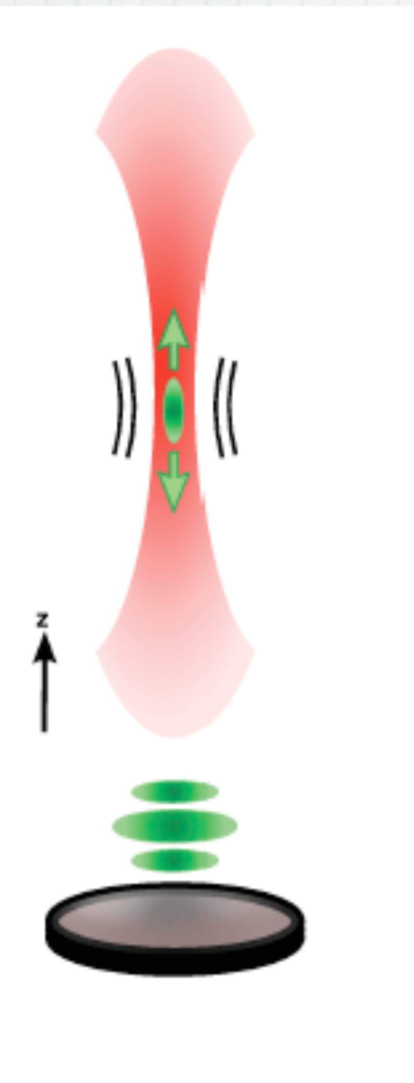




Balbinot, F., Fagnocchi, Recati, Carusotto, PRA 2008

Momentum correlators: motivation

Westbrook et al., PRL 2012



* The confining potential of the BEC was varied in time
* Particles were collected after opening of the trap with the TOF (time of flight) technique

typically 10^5 atoms
time of flight ~ 300 ms
width of TOF ~ 10 ms
We record *x,y,t* for every detected atom.

Get velocity distribution and correlation function.

By 'phonon evaporation' excitations are converted into particles with

$$v = \hbar k/m$$

Momentum correlators: theoretical results

A.F., N. Pavloff, arXiv:1712.07842

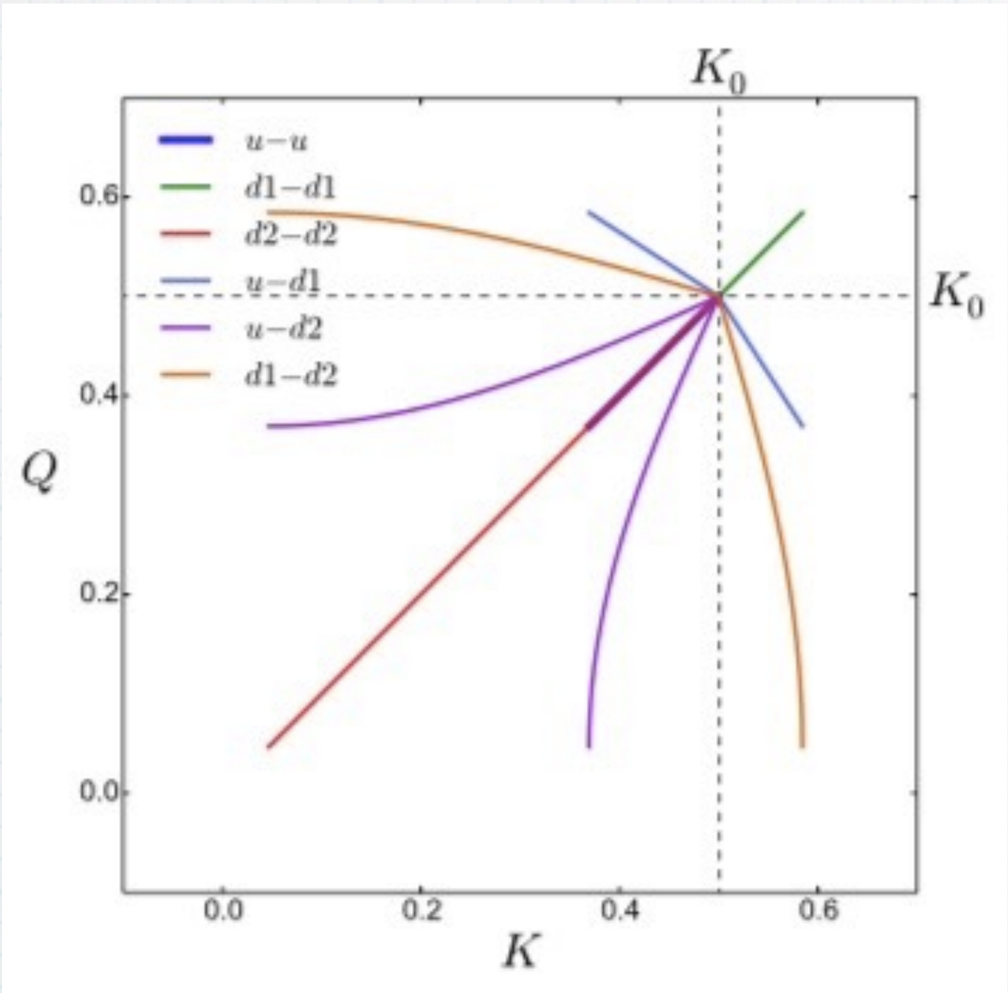
$$g_2(p,q) = \frac{\langle :\hat{n}(p)\hat{n}(q): \rangle}{\langle \hat{n}(p)\rangle\langle \hat{n}(q)\rangle}$$

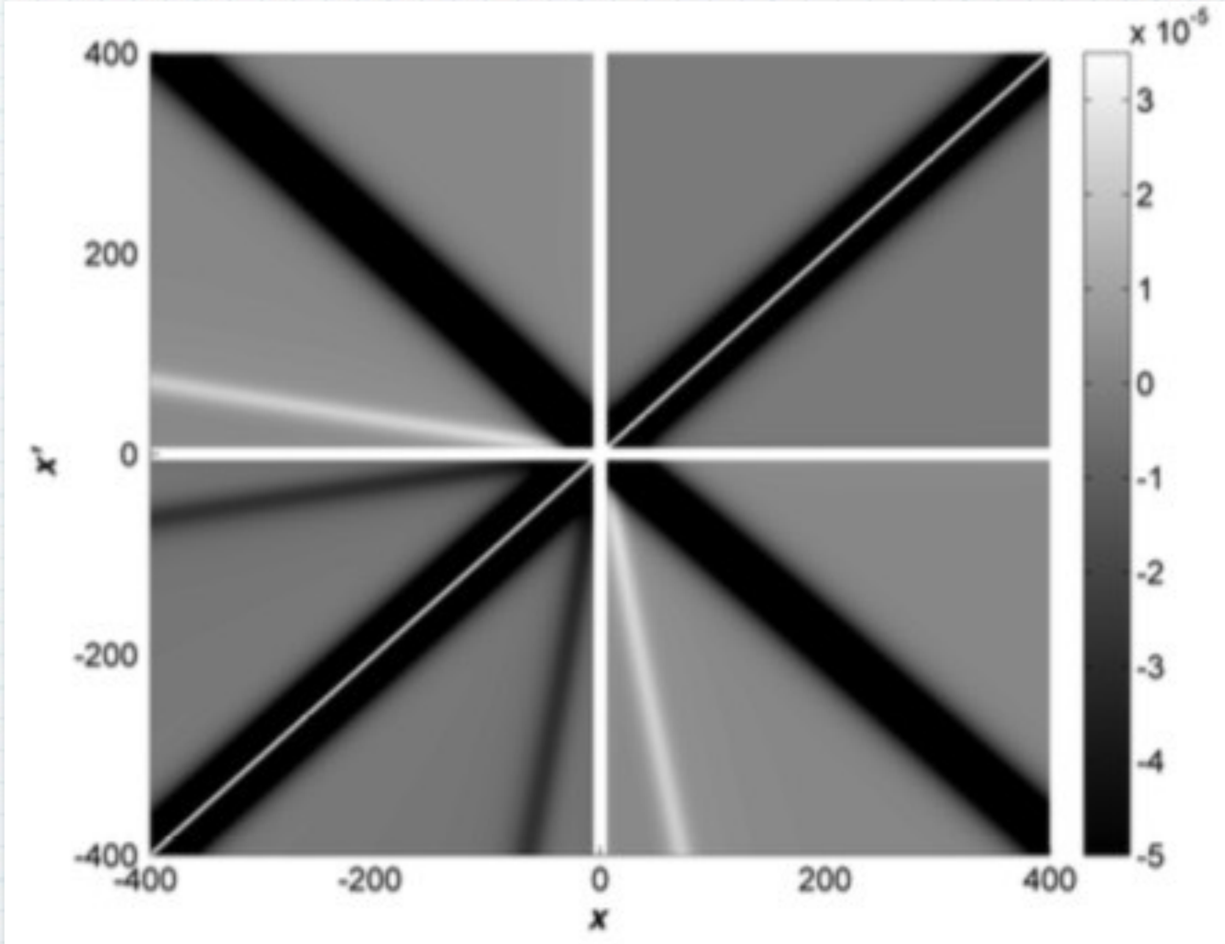
vs

$$G^{(2)}(t;x,x') = \langle \hat{n}(x)\hat{n}(x')\rangle$$

nontrivial features

density correlator



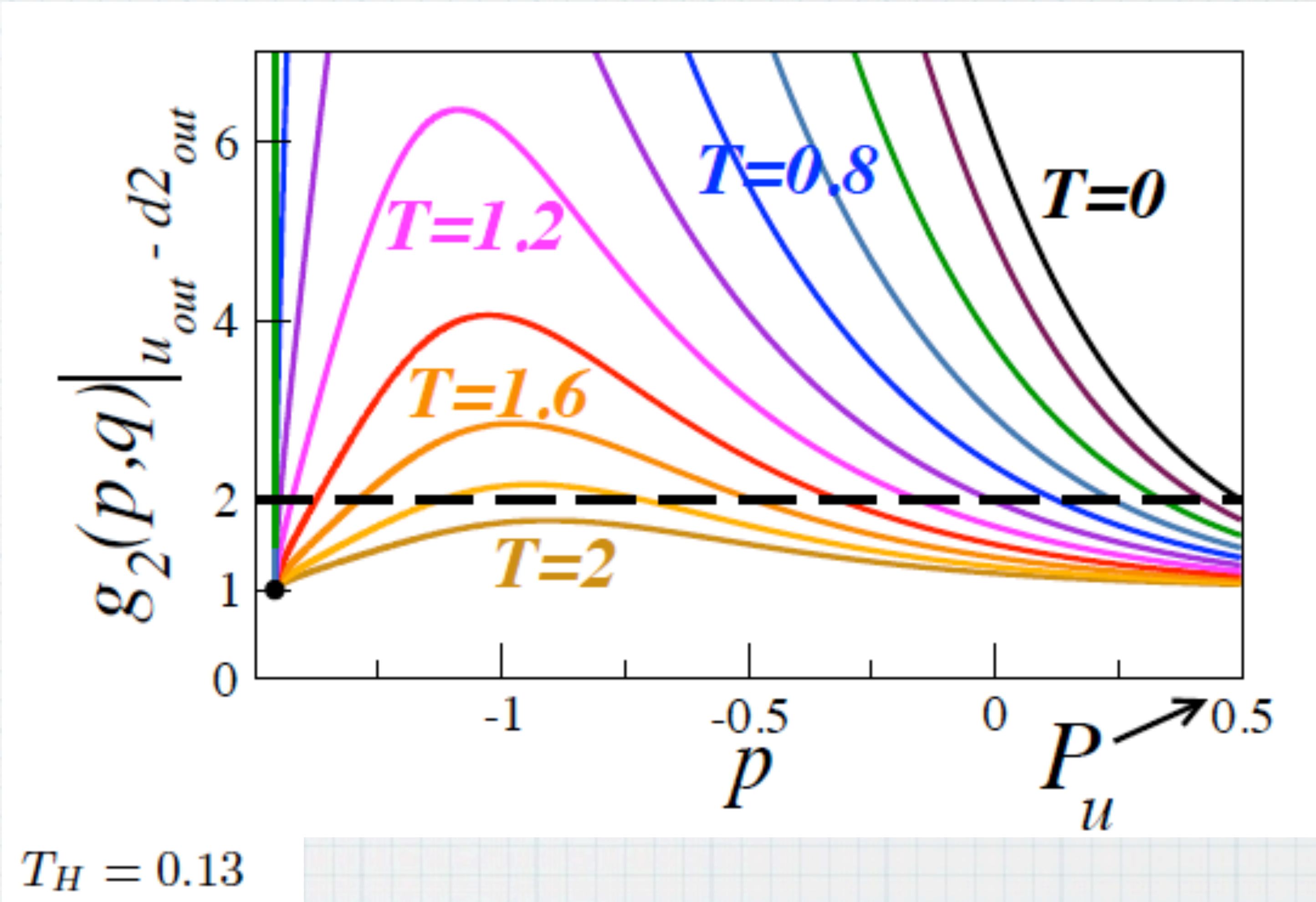


Anderson, Balbinot, F., Parentani, PRD 2013

Entanglement of the Hawking pairs

* the quantum signature in analog HR can be found in **momentum space correlators** (Bell-like inequality $g_2 > 2$)

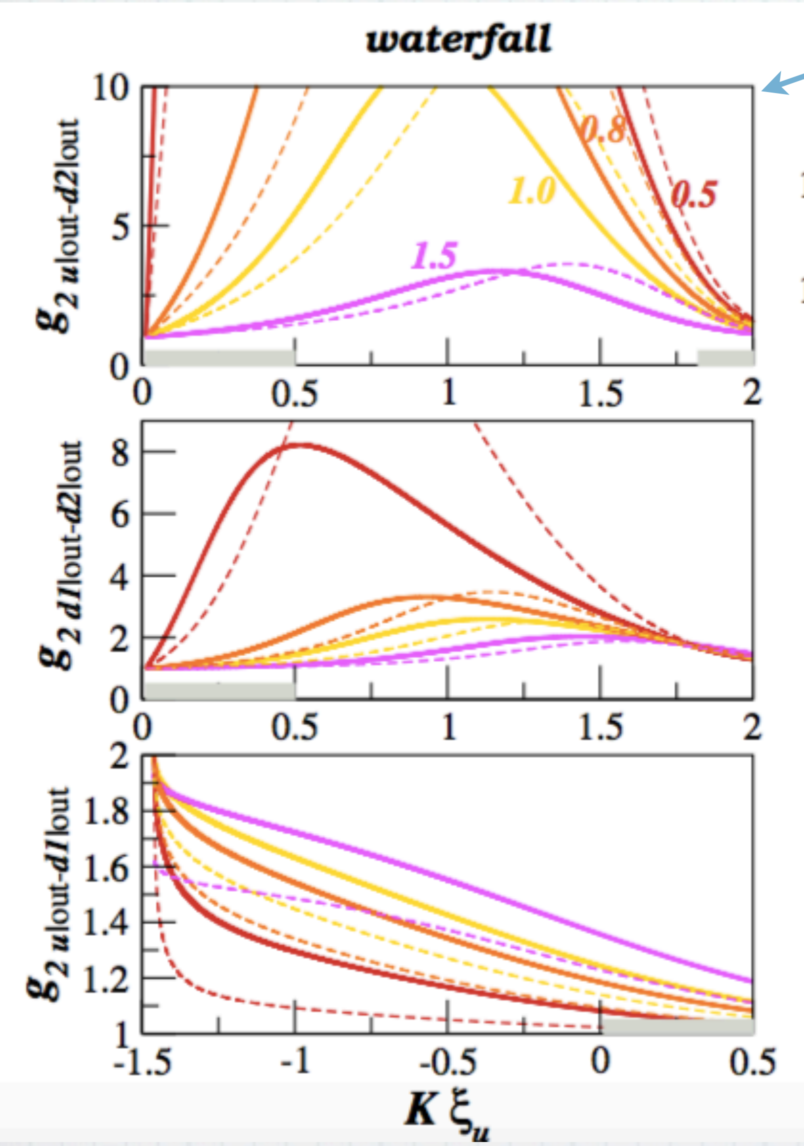
* this allows to establish the presence of spontaneous HR

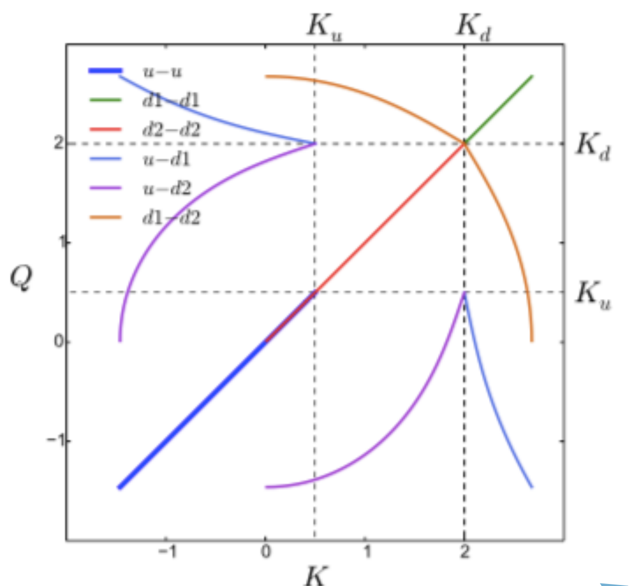


D. Boiron, A.F., P.E. Larré,N. Pavloff, C. Westbrook, P.Zin, PRL 2015 (Editor's suggestion)

Best signal/model to detect entanglement

The Hawking quanta-partner (u-d2) signal is the most appropriate signal to detect entanglement





SciPost Physics Submission

Momentum correlations as signature of sonic Hawking radiation in Bose-Einstein condensates

A. Fabbri[1], N. Pavloff[2]

1 Centro Studi e Ricerche E. Fermi, Piazza del Viminale 1, 00184 Roma, Italy
Dipartimento di Fisica dell'Università di Bologna and INFN Sezione di Bologna, Via Irnerio 46, 40126 Bologna, Italy
Departamento de Física Teórica and IFIC, Universidad de Valencia-CSIC, C. Dr. Moliner 50, 46100 Burjassot, Spain
Laboratoire de Physique Théorique, CNRS UMR 8627, Bât. 210, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay Cedex, France
2 LPTMS, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay, France

Abstract

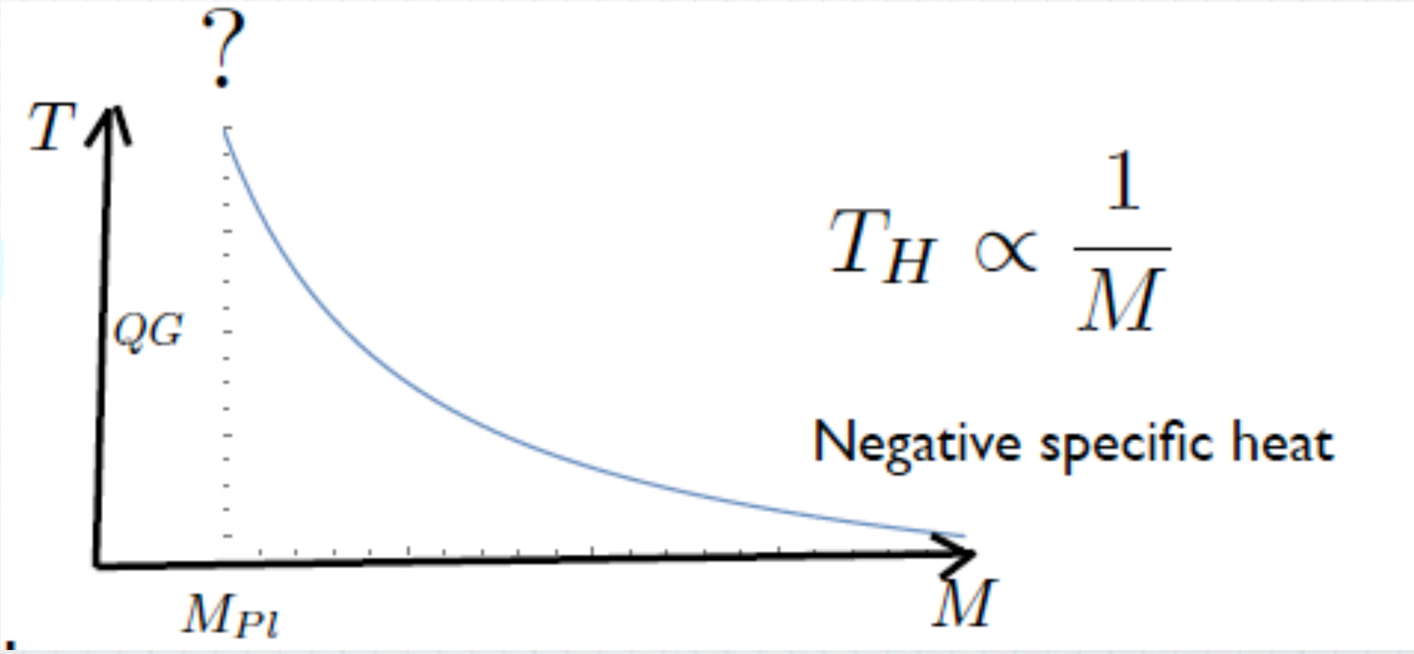
We study the two-body momentum correlation signal in a quasi one dimensional Bose-Einstein condensate in the presence of a sonic horizon. We identify the relevant correlation lines in momentum space and compute the intensity of the corresponding signal. We consider a set of different experimental procedures and identify the specific issues of each measuring process. We show that some inter-channel correlations, in particular the Hawking quantum/partner one, are particularly well adapted for witnessing quantum non-separability, being resilient to the effects of temperature and/or quantum quenches.

The best model is the one used by Steinhauer ('waterfall' Pavloff et al., 2012) and the same results are valid also 'in situ'

Quantum backreation

* Black holes evaporation gives rise to the information loss paradox Hawking `76

* Physical consequences can be understood by solving the backreaction equations



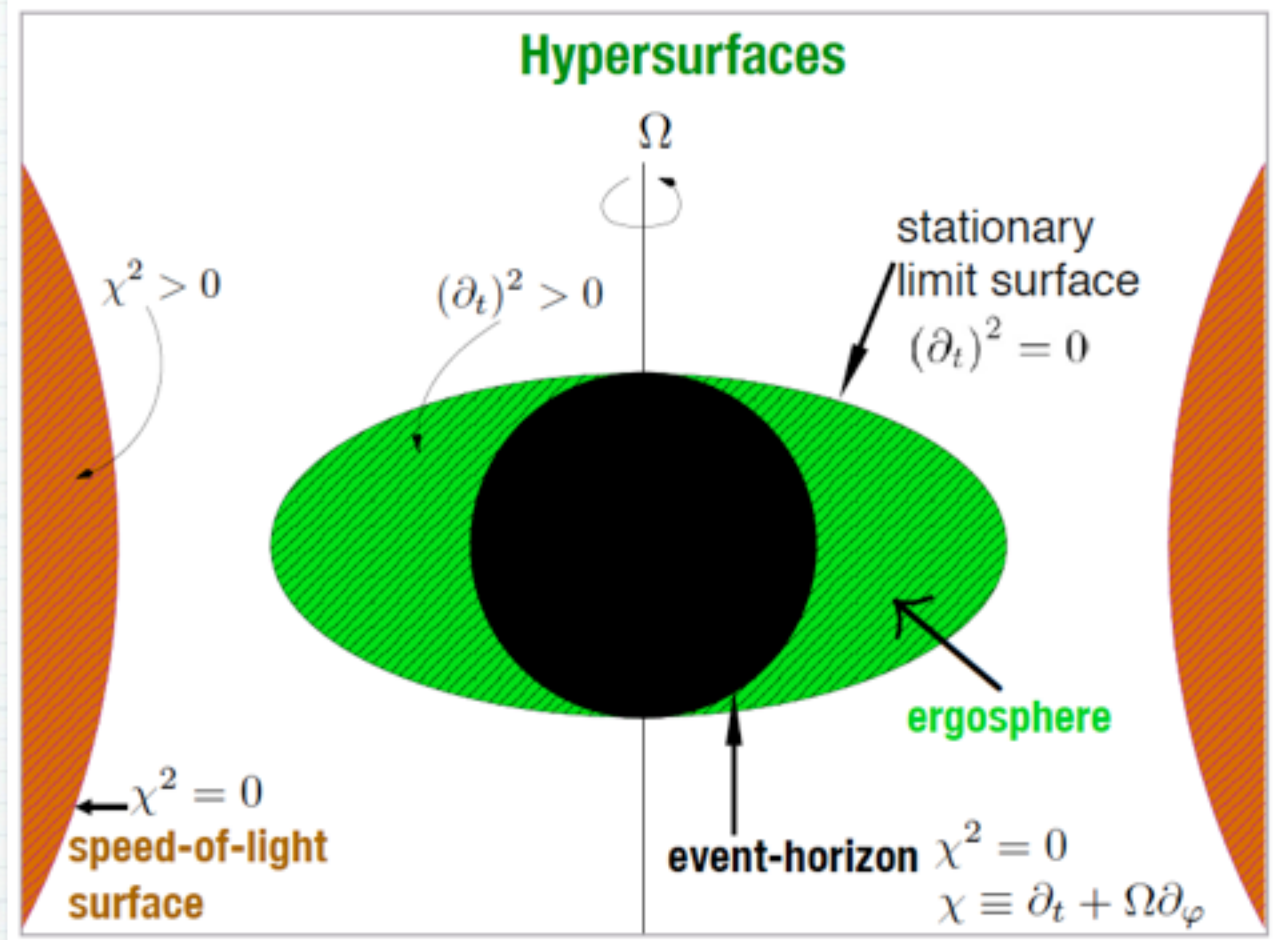
$$G_{\mu\nu} = 8\pi \langle T_{\mu\nu} \rangle$$

Rotating black holes

* In 2+1D, backreaction eqs. are solved **analytically**
* BHs grow and their angular velocity slows down
* A (small) horizon is created around naked singularities

M. Casals, A.F., C. Martinez, J. Zanelli, PRL 2017

Featured in: APS Physics, New Scientist, Media INAF, International Business Times, AIP Inside Science



PRL 118, 131102 (2017) PHYSICAL REVIEW LETTERS week ending 31 MARCH 2017

Quantum Backreaction on Three-Dimensional Black Holes and Naked Singularities

Marc Casals*

Centro Brasileiro de Pesquisas Físicas (CBPF), Rio de Janeiro, CEP 22290-180, Brazil, and School of Mathematical Sciences and Complex & Adaptive Systems Laboratory, University College Dublin, Belfield, Dublin 4, Ireland

Alessandro Fabbri†

Centro Fermi - Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Piazza del Viminale 1, 00184 Roma, Italy, Dipartimento di Fisica dell'Università di Bologna and INFN sezione di Bologna, Via Irnerio 46, 40126 Bologna, Italy, Laboratoire de Physique Théorique, CNRS UMR 8627, Bât. 210, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay Cedex, France, and Departamento de Física Teórica and IFIC, Universidad de Valencia-CSIC, C. Dr. Moliner 50, 46100 Burjassot, Spain

Cristián Martínez‡ and Jorge Zanelli§

Centro de Estudios Científicos (CECs), Av. Arturo Prat 514, Valdivia 5110466, Chile

(Received 9 September 2016; revised manuscript received 10 November 2016; published 30 March 2017)

We analytically investigate backreaction by a quantum scalar field on two rotating Bañados-Teitelboim-Zanelli (BTZ) geometries: that of a black hole and that of a naked singularity. In the former case, we explore the quantum effects on various regions of relevance for a rotating black hole space-time. We find that the quantum effects lead to a growth of both the event horizon and the radius of the ergosphere, and to a reduction of the angular velocity, compared to the unperturbed values. Furthermore, they give rise to the formation of a curvature singularity at the Cauchy horizon and show no evidence of the appearance of a superradiant instability. In the case of a naked singularity, we find that quantum effects lead to the formation of a horizon that shields it, thus supporting evidence for the rôle of quantum mechanics as a cosmic censor in nature.

DOI: 10.1103/PhysRevLett.118.131102

Recent Publications

A.F., N. Pavloff, arXiv:1712.07842 (submitted to SciPost Physics)

M. Casals, A.F., C. Martinez, J. Zanelli, Proceedings of the Amazonian Symposium of Physics (2018)

M. Casals, A. F., C. Martinez, J. Zanelli, Phys. Rev. Lett. 118 (2017) 13, 131102

M. Casals, A. F., C. Martinez, J. Zanelli, Phys. Lett. B760 (2016), 244

A. F., P. Anderson, R. Balbinot, Phys. Rev. D93 (2016) 6, 064046

G. Clement, A. F., Nucl. Part. Phys. Proc. 273-275 (2016), 1499

S. Mauro, R. Balbinot, A. F., I. Shapiro, Eur. Phys. J. Plus 130 (2015), 135

P. Anderson, A. F., R. Balbinot, Phys. Rev. D91 (2015) 6, 064061

D. Boiron, A. F., P. Larré, N. Pavloff, C. Westbrook, P. Zin, Phys. Rev. Lett. 115 (2015) 2, 025301

G. Clement, A.F., Class. Quant. Grav. 32 (2015) 9, 095009

A. F., J. Phys. Conf. Ser. 600 (2015) 1, 012008