Are **Firewalls** really **Cataclysmic** events**?**

E. M-M, Jorma Louko
Phys. Rev. Letters 115, 031301 (2015)

EDUARDO MARTÍN-MARTÍNEZ

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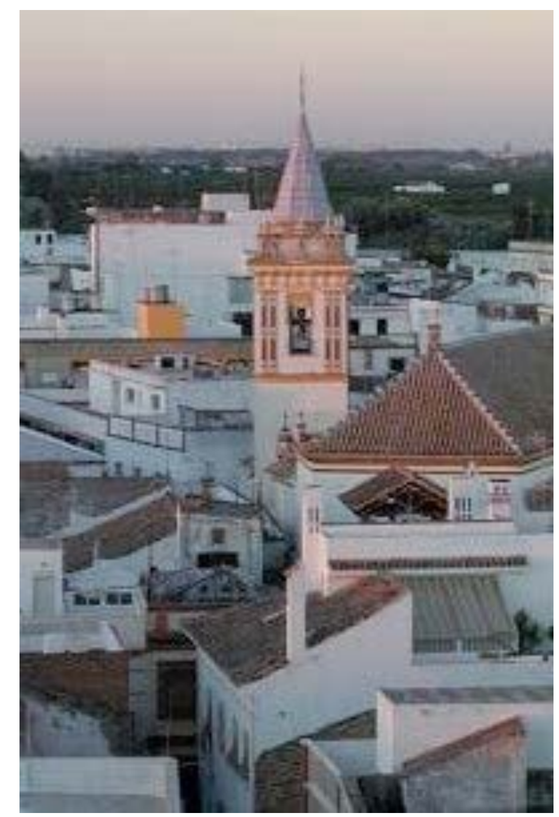
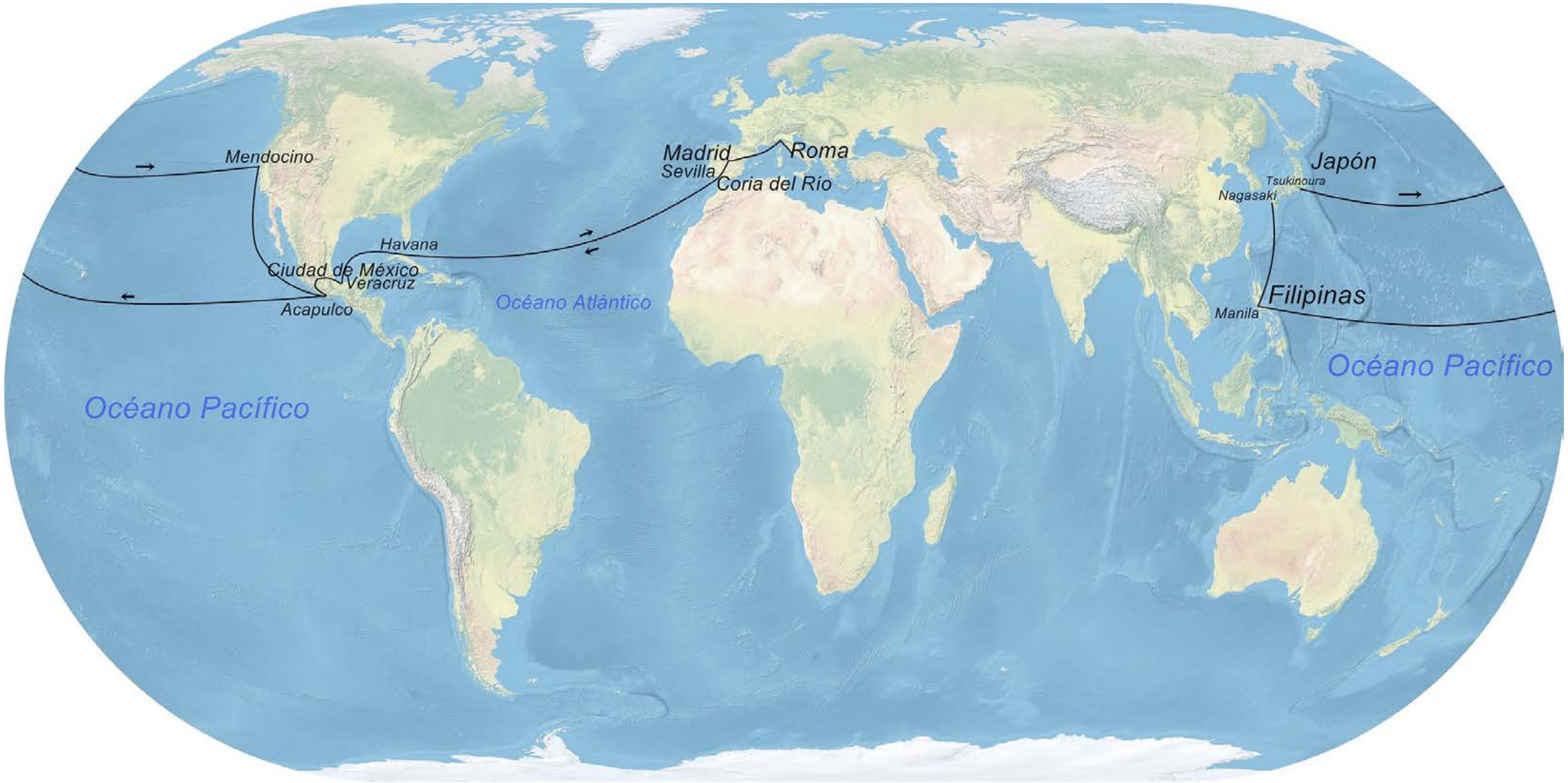
Perimeter Institute for Theoretical Physics


支倉常長
HASEKURA TSUNENAGA



CORIA DEL RIO
(SPAIN)



OCTOBER 1614
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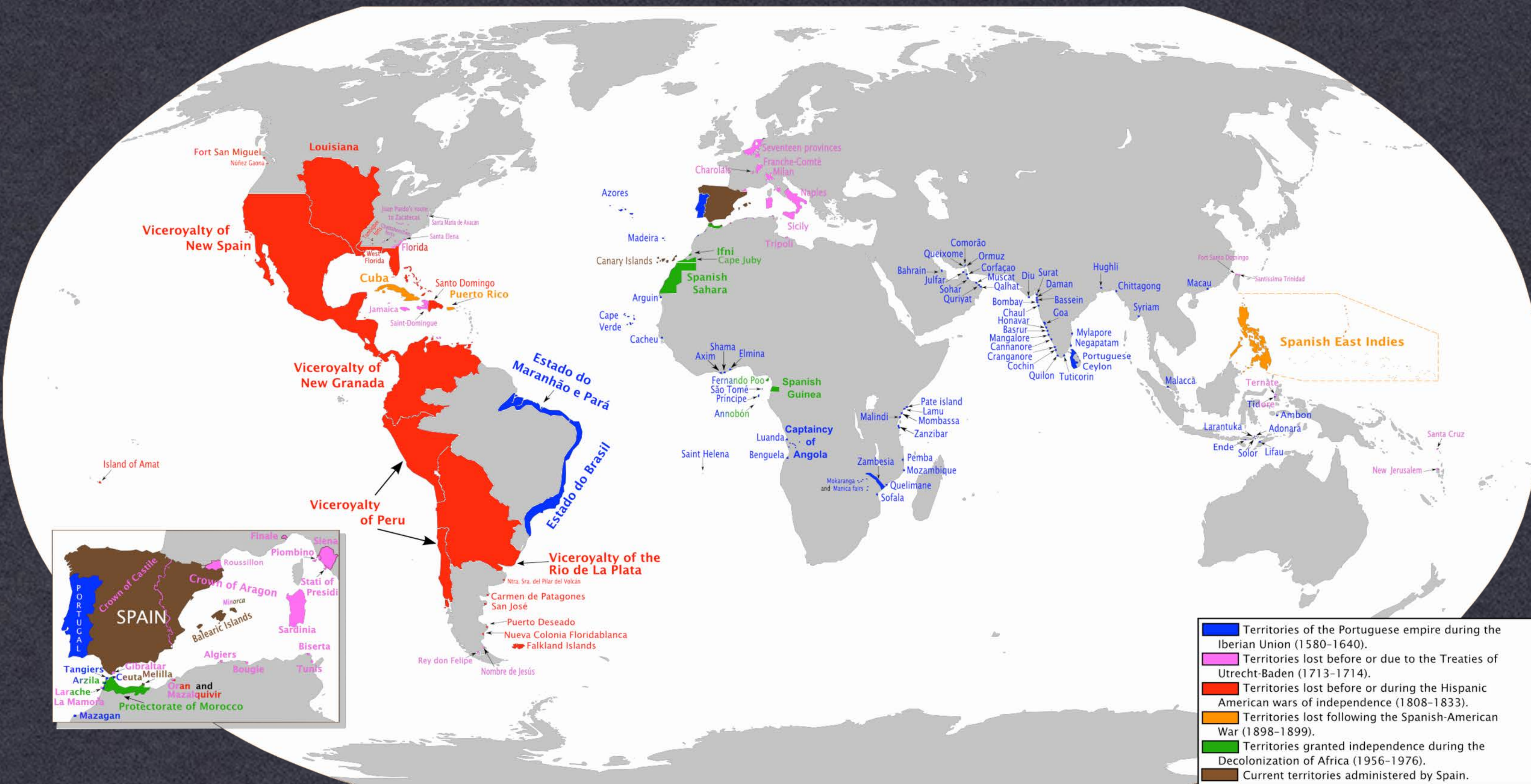
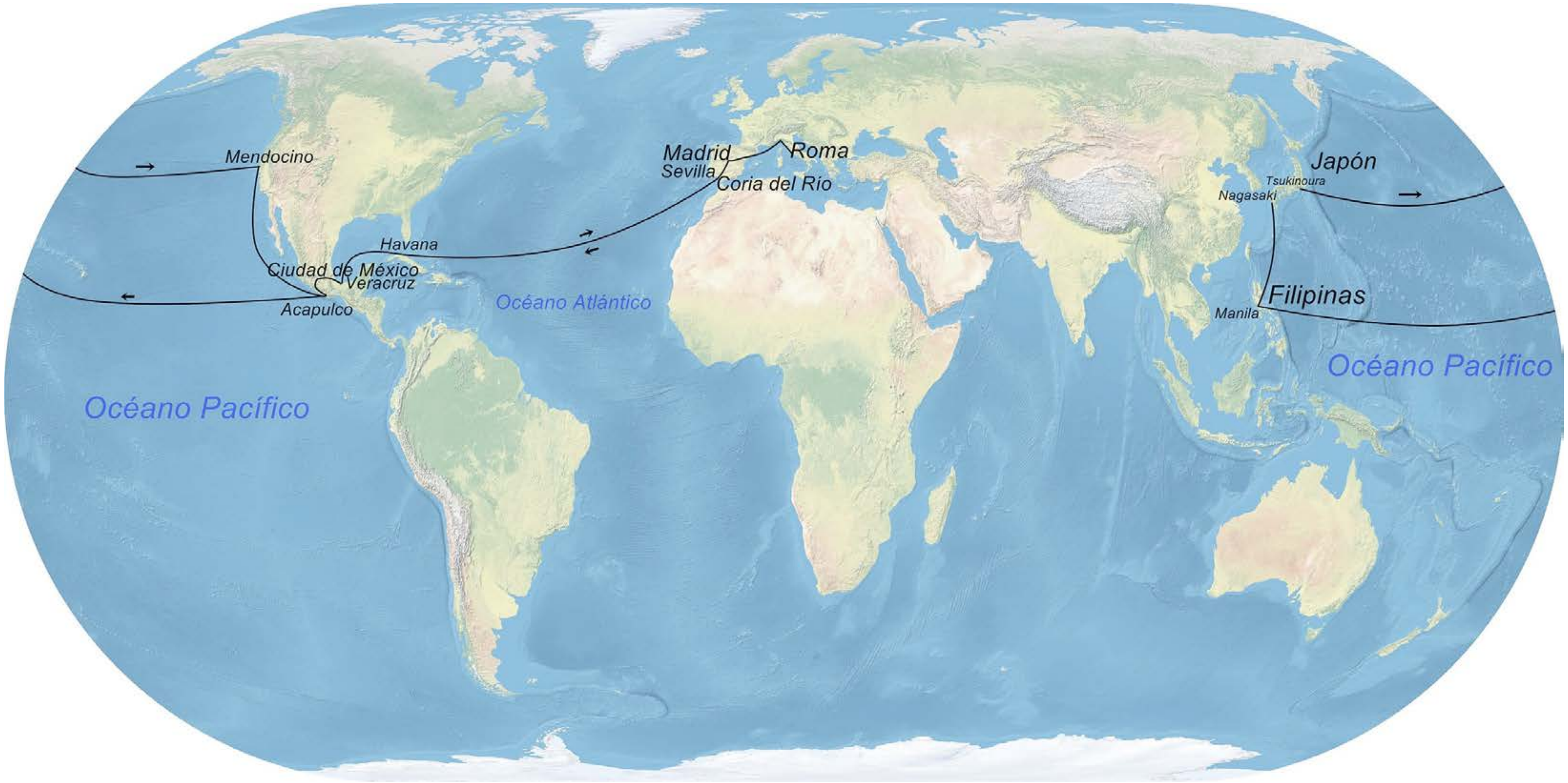
The diplomatic mission of Hasekura Tsunenaga


Louisiana
Fort San Miguel
Viceroyalty of New Spain
Florida
Cuba
Santo Domingo
Puerto Rico
Jamaica
Saint-Domingue
Viceroyalty of New Granada
Viceroyalty of Peru
Estado do Maranhão e Pará
Estado do Brasil
Viceroyalty of the Rio de La Plata
Carmen de Patagones
San José
Puerto Deseado
Nueva Colonia Floridablanca
Falkland Islands
Rey don Felipe
Nombre de Jesús
Island of Amat
Seventeen provinces
Franche-Comté
Charolais
Milan
Naples
Sicily
Tripoli
Azores
Madeira
Canary Islands
Ifni
Cape Juby
Spanish Sahara
Arguin
Cape Verde
Cacheu
Shama
Axim
Elmina
Fernando Poo
São Tomé
Príncipe
Annobón
Spanish Guinea
Luanda
Captaincy of Angola
Benguela
Saint Helena
Malindi
Pate island
Lamu
Mombassa
Zanzibar
Zambesia
Pemba
Mozambique
Quelimane
Sofala
Comorão
Queixome
Ormuz
Corfaçao
Muscat
Qalhat
Bahrain
Julfar
Sohar
Quriyat
Diu
Surat
Daman
Bassein
Bombay
Chaul
Honavar
Basrur
Mangalore
Cannanore
Cranganore
Cochin
Quilon
Goa
Tuticorin
Mylapore
Negapatam
Portuguese Ceylon
Hughli
Chittagong
Syriam
Macau
Malaccá
Spanish East Indies
Ternate
Tidore
Ambon
Larantuka
Adonara
Ende
Solor
Lifau
Santa Cruz
New Jerusalem
SPAIN
PORTUGAL
Crown of Castile
Crown of Aragon
Roussillon
Finale
Piombino
Siena
Stati of Presidi
Minorca
Balearic Islands
Sardinia
Algiers
Bizerta
Bougie
Tunis
Gibraltar
Tangiers
Ceuta
Melilla
Arzila
Larache
La Mamora
Oran and Mazalquivir
Protectorate of Morocco
Mazagan
Territories of the Portuguese empire during the Iberian Union (1580–1640).
Territories lost before or due to the Treaties of Utrecht-Baden (1713–1714).
Territories lost before or during the Hispanic American wars of independence (1808–1833).
Territories lost following the Spanish-American War (1898–1899).
Territories granted independence during the Decolonization of Africa (1956–1976).
Current territories administered by Spain.



OCTOBER 1614
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CORIA DEL RIO (SPAIN)

No other Japanese diplomatic mission to Europe until 1862


Foto Moreno

OCTOBER 1614
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CORIA DEL RIO (SPAIN)

Hasekura Rokuemon Tsunenaga (or "Francisco Felipe Faxicura")

西

West

Spain

OCTOBER 1614
支倉常長

CORIA DEL RIO
(SPAIN)

2013
2014
AÑO DUAL ESPAÑA-JAPÓN
日本スペイン交流400周年
400 AÑOS DE RELACIONES


JAPON SEVILLA, José
24-03-59 Sevilla
AUDITOR Partidos en 1ª: 71
Debut: 03-09-95 Athletic, 4-Racing, 0
1 39
X 16
2 16
TARJETAS
Amarillas 301 Media p.p. 4,23
Expulsiones 31 Media p.p. 0,4
GURUCETA Promedio en la Liga 98/99 1,17
COLEGIO ANDALUZ

What if the chicken were to cross the Firewall?

$(1+1)$D Calculation Provides Evidence that Quantum Entanglement Survives a Firewall

Eduardo Martín-Martínez and Jorma Louko
Phys. Rev. Lett. **115**, 031301 – Published 14 July 2015

Article | References | No Citing Articles | PDF | HTML | Export Citation

ABSTRACT

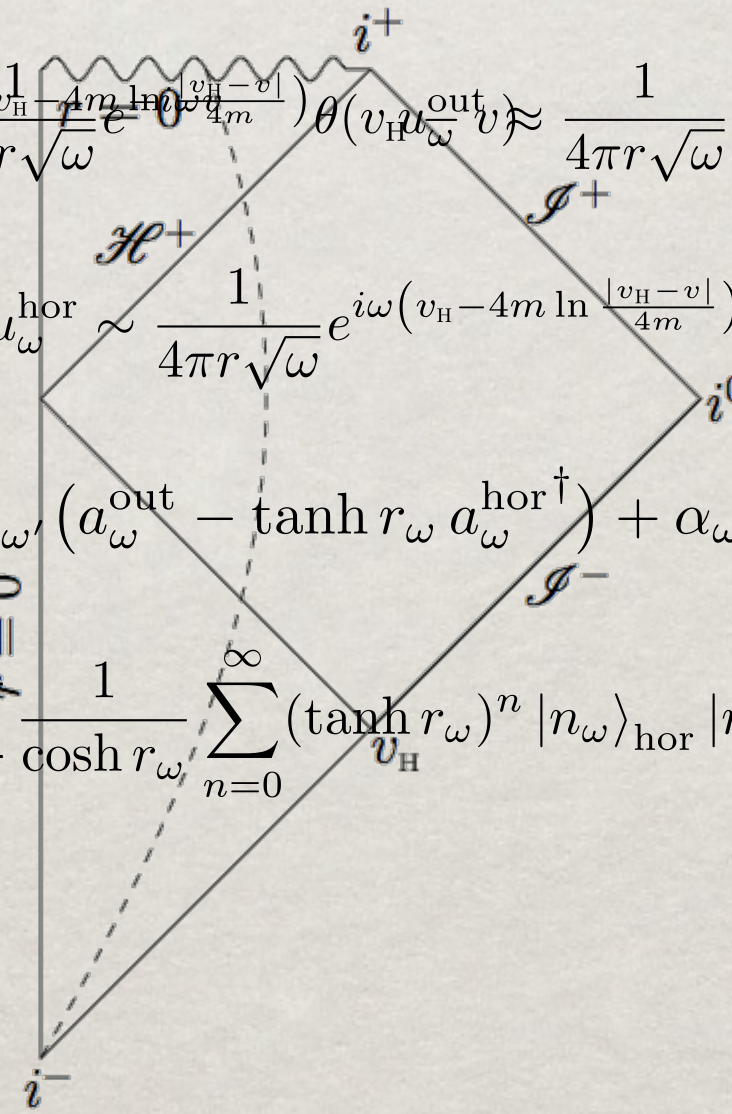
We analyze how preexisting entanglement between two Unruh-DeWitt particle detectors evolves when one of the detectors falls through a Rindler firewall in $(1+1)$-dimensional Minkowski space. The firewall effect is minor and does not wash out the detector-detector entanglement, in some regimes even preserving the entanglement better than Minkowski vacuum. The absence of cataclysmic events should continue to hold for young black hole firewalls. A firewall's prospective ability to resolve the information paradox must hence hinge on its detailed gravitational structure, presently poorly understood.

Entanglement in a Stellar Collapse

We can write the annihilation operators of field modes in the asymptotic past in terms of the corresponding creation and annihilation operators defined in terms of modes in the future:

u_ω^{hor}

$$u_\omega^{\text{out}} \approx \frac{1}{4\pi r\sqrt{\omega}} e^{-i\omega\left(v_{\text{H}} - 4m \ln \frac{|v_{\text{H}} - v|}{4m}\right)} \theta(v_{\text{H}} - v)$$



$$u_\omega^{\text{hor}} \sim \frac{1}{4\pi r\sqrt{\omega}} e^{i\omega\left(v_{\text{H}} - 4m \ln \frac{|v_{\text{H}} - v|}{4m}\right)} \theta(v - v_{\text{H}})$$

$$a_{\omega'}^{\text{in}} = \int d\omega \left[\alpha_{\omega\omega'}^{*} \left(a_\omega^{\text{out}} - \tanh r_\omega \, a_\omega^{\text{hor}\,\dagger}\right) + \alpha_{\omega\omega'} e^{i\varphi} \left(a_\omega^{\text{hor}} - \tanh r_\omega \, a_\omega^{\text{out}\,\dagger}\right)\right]$$

$$u_\omega^{\text{in}} \sim \frac{1}{4\pi r\sqrt{\omega}} e^{-i\omega v}$$

$$|0\rangle_{\text{in}} = \prod_\omega \frac{1}{\cosh r_\omega} \sum_{n=0}^{\infty} (\tanh r_\omega)^n \, |n_\omega\rangle_{\text{hor}} \, |n_\omega\rangle_{\text{out}}$$

$$\text{Tr}_{\text{hor}} \rightarrow \text{Hawking radiation}$$

Black holes Information loss problem

$$|0\rangle_{\text{in}} = \prod_{\omega} \frac{1}{\cosh r_\omega} \sum_{n=0}^{\infty} (\tanh r_\omega)^n \, |n_\omega\rangle_{\text{hor}} \, |n_\omega\rangle_{\text{out}}$$

$$\text{Tr}_{\text{hor}} \left(|0\rangle \langle 0| \right) = \bigotimes_{\omega} \frac{1}{\cosh^2 r} \sum \tanh^{2n} r_\omega \, |n_\omega\rangle_{\text{out}} \, \langle n_\omega|_{\text{out}}$$

$$\text{Tr} \left(N_\omega \rho_{\text{out}} \right) = \frac{1}{e^{\hbar\omega / K_{\text{B}} T_{\text{H}}} - 1}$$

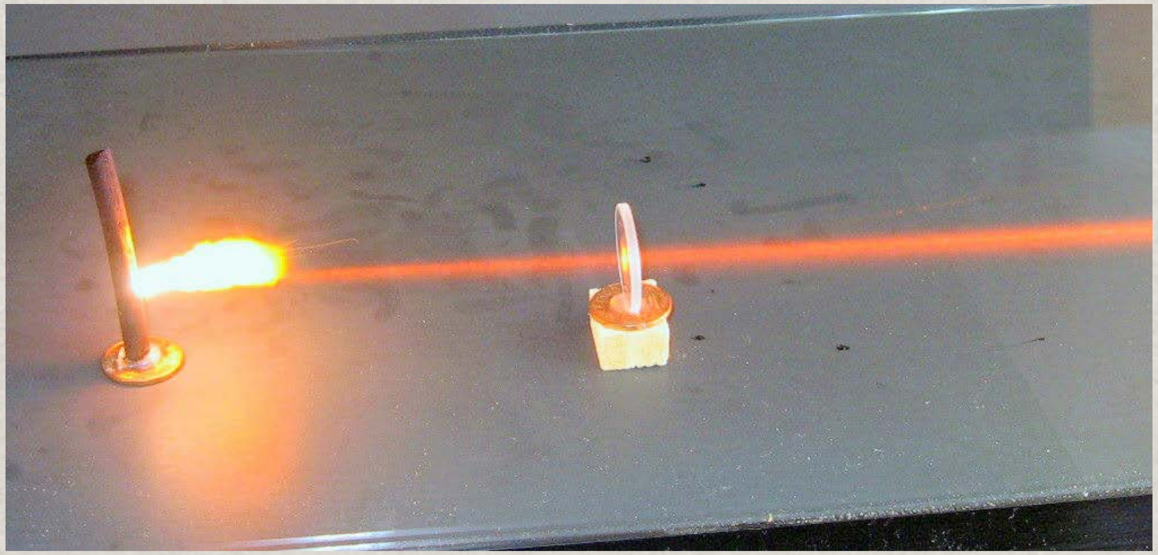
$$T_{\text{H}} = \frac{1}{8\pi G} \frac{\hbar c^3}{m K_{\text{B}}}$$

Black hole Information loss problem

If we believe in quantum theory, information cannot be lost…

After corrections, the outflow may not be entirely thermal…

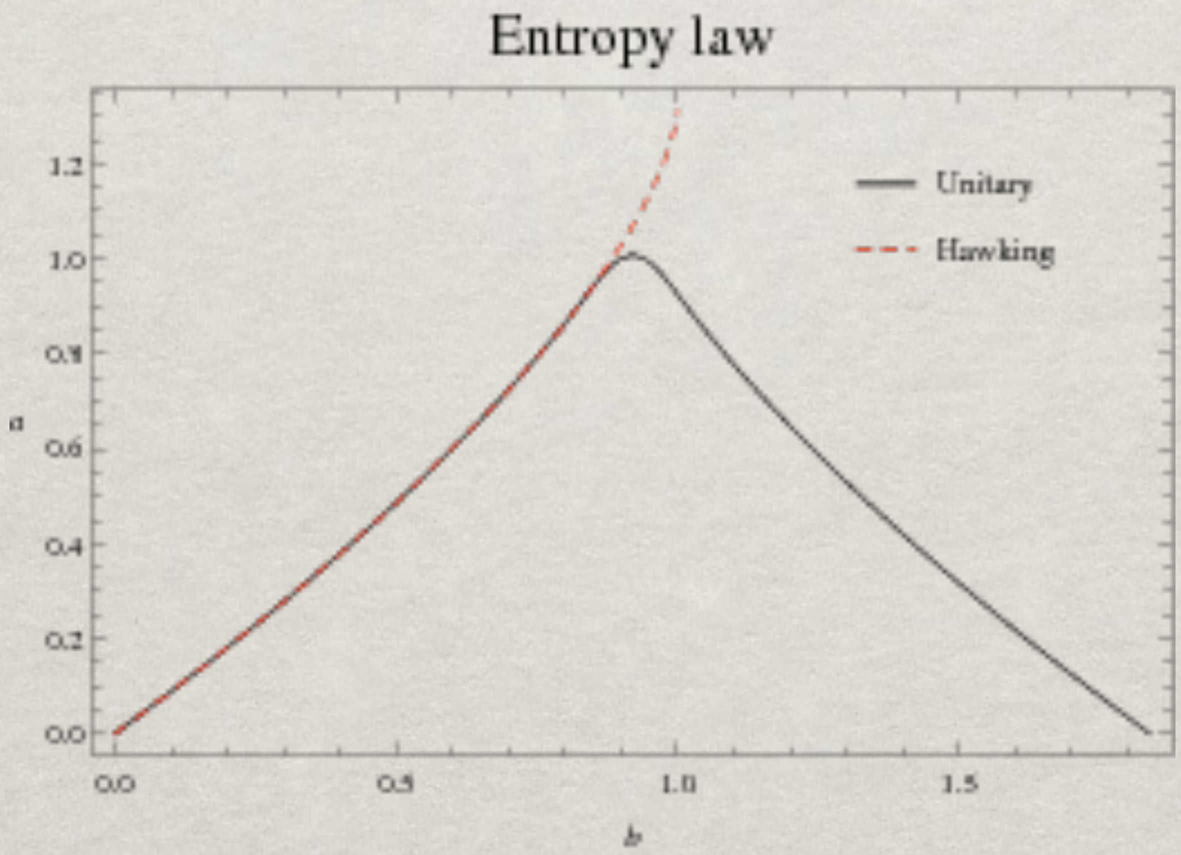
Like when a piece of charcoal burns



Black holes Information loss problem

Page Hypothesis:

Entanglement between radiation emitted at different times in the black hole life!



Page time

Black holes Information loss problem

So… The outflow is not entirely thermal…

Hold on!! that's potentially even worse!!

Black holes Information loss problem

The New York Times.

NEW YORK, SATURDAY, MAY 4, 1935. P TWO CENTS

EINSTEIN ATTACKS QUANTUM THEORY

Scientist and Two Colleagues Find It Is Not 'Complete' Even Though 'Correct.'

SEE FULLER ONE POSSIBLE

Believe a Whole Description of 'the Physical Reality' Can Be Provided Eventually.

Black hole Information Paradox

A: Radiation emitted after Page Time

B: Infalling Radiation

C: Radiation emitted before Page Time

Black hole Information Paradox

A: Radiation emitted after Page Time

B: Infalling Radiation

C: Radiation emitted before Page Time

Entropy subadditivity:

$$S(\rho_{\mathrm{ABC}}) + S(\rho_{\mathrm{A}}) \leq S(\rho_{\mathrm{AB}}) + S(\rho_{\mathrm{AC}})$$

Black hole Information Paradox

A: Radiation emitted after Page Time

B: Infalling Radiation

C: Radiation emitted before Page Time

Entropy subadditivity:

$$S(\rho_{\mathrm{ABC}}) + S(\rho_{\mathrm{A}}) \leq S(\rho_{\mathrm{AB}}) + S(\rho_{\mathrm{AC}})$$

Entanglement subadditivity:

$$\mathcal{E}(A, B) + \mathcal{E}(A, C) \leq \mathcal{E}(A, BC)$$

Black hole Information Paradox

Possible Solution: Firewalls!

Almheiri, Ahmed; Marolf, Donald; Polchinski, Joseph; Sully, James. Journal of High Energy Physics 2013 (2).

Black hole Information Paradox (Firewalls)

What-if scenario:

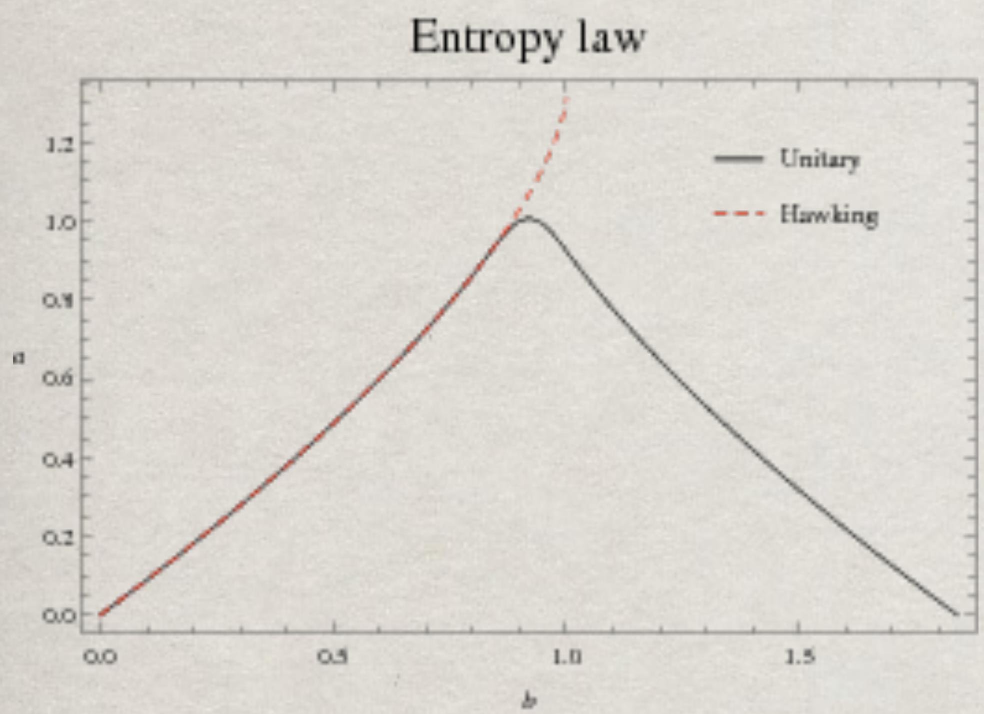
Somehow dynamics is such that it destroys the correlations between "in" and "out" regions

Entanglement subadditivity:

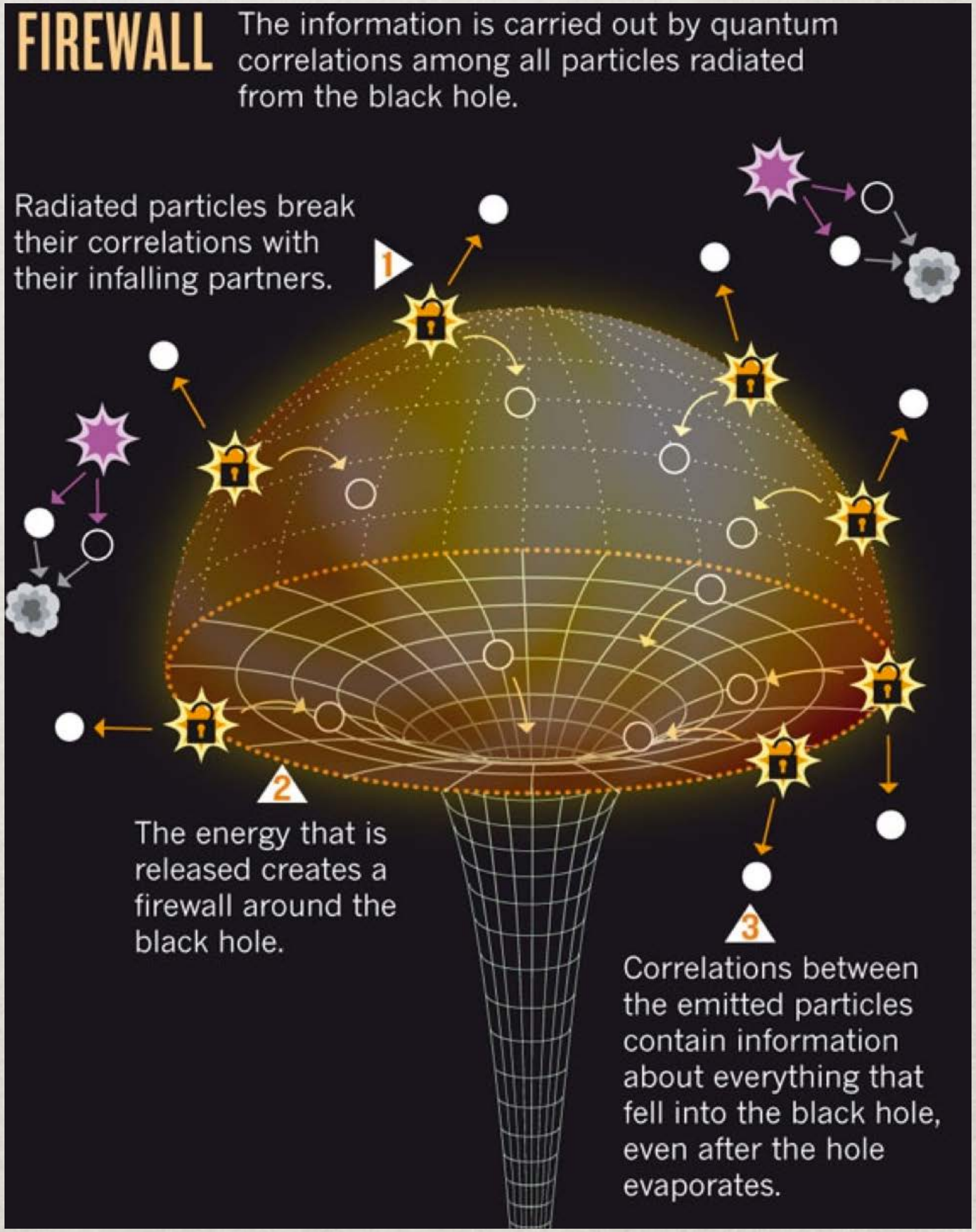
$$\mathcal{E}(A,B) + \mathcal{E}(A,C) \leq \mathcal{E}(A,BC)$$

Make this zero

Black hole Information Paradox (Firewalls)

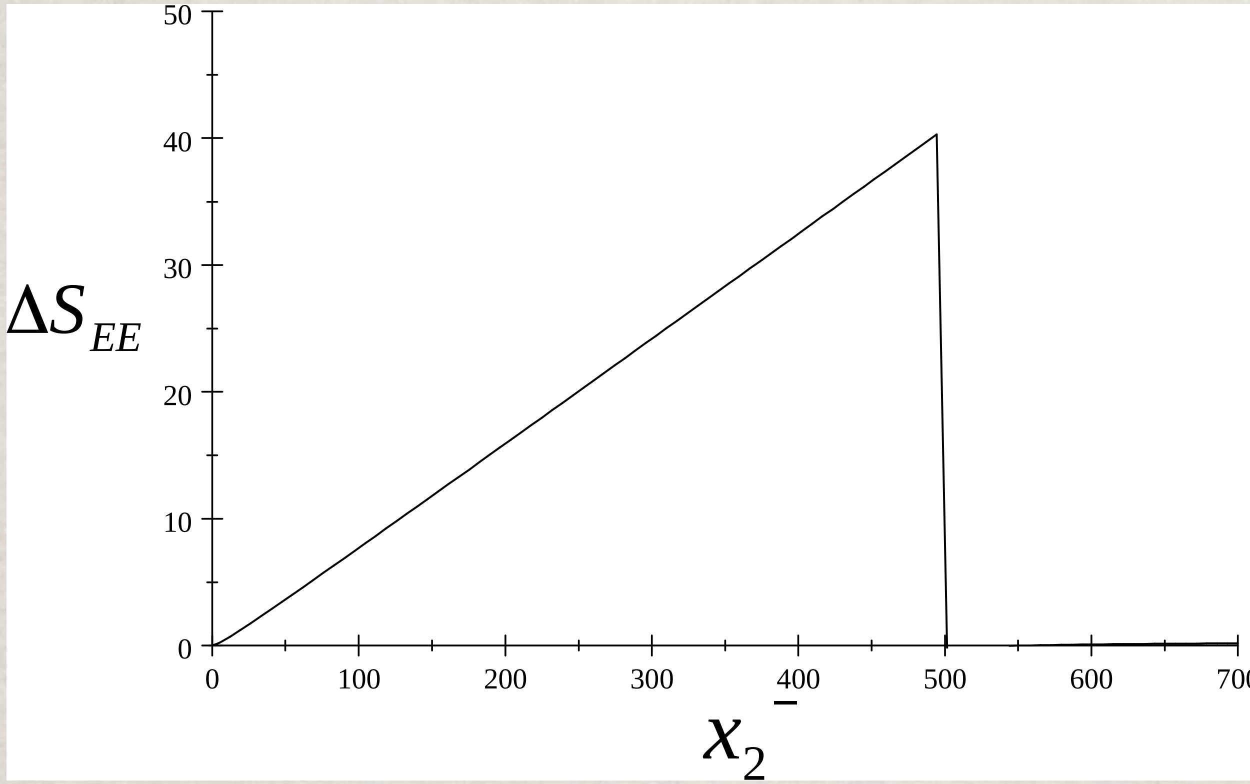


“Charcoalization” of the BH



Black hole Information Paradox (Firewalls)

Perhaps Information is released in vacuum fluctuations in a last burst



The Fall of Black Hole Firewall: Natural Nonmaximal Entanglement for Page Curve

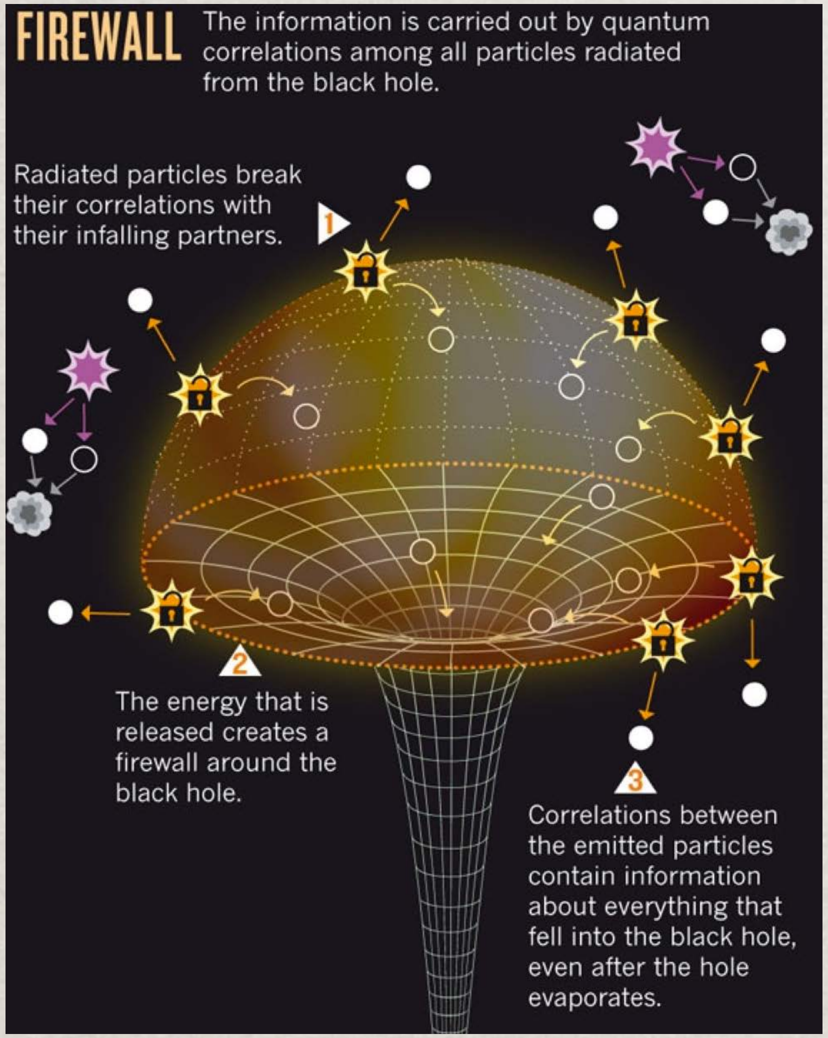
Masahiro Hotta, Ayumu Sugita

(Submitted on 20 May 2015 (v1), last revised 6 Jun 2015 (this version, v2))

The black hole ?rewall conjecture is based on Page curve hypothesis, which claims that entanglement between black hole and Hawking radiation is almost maximum. The hypothesis is inspired by Lubkin-Lloyd-Pagels-Page theorem for degenerate systems with zero Hamiltonian. Adopting canonical typicality for nondegenerate systems with nonvanishing Hamiltonians, the entanglement becomes nonmaximal,and energetic singularities (?rewalls) do not emerge for general systems. For static thermal pure states of black hole and Hawking radiation, entanglement entropy equals thermal entropy of the smaller system.

Comments: 28 pages, 16 figures, some comments and figures are added
Subjects: **General Relativity and Quantum Cosmology (gr-qc)**; High Energy Physics - Theory (hep-th); Quantum Physics (quant-ph)
Cite as: arXiv:1505.05870 **[gr-qc]**
(or arXiv:1505.05870v2 **[gr-qc]** for this version)

Firewalls are '*Monsters*'



Divergences in the stress-energy tensor: Violence at the horizon

Measuring the field

Monsters might exist, but how can you tell if you don't look under your bed?

Measuring the field

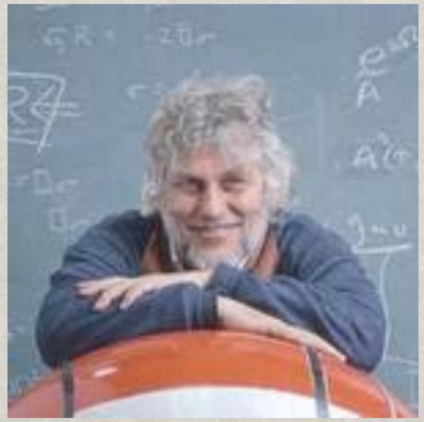
How do we measure quantum fields?

Particle detectors: Non-relativistic quantum systems coupling 'locally' to the field

Measuring the field

How do we measure quantum fields?

Particle detectors: Non-relativistic quantum systems coupling 'locally' to the field

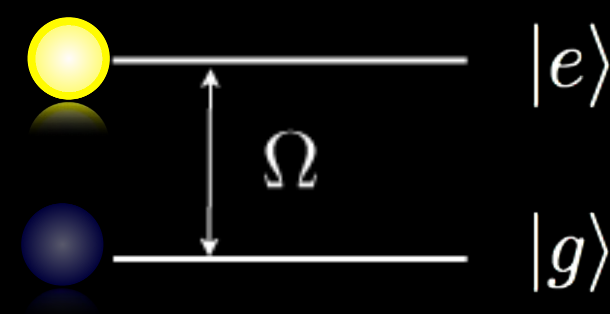


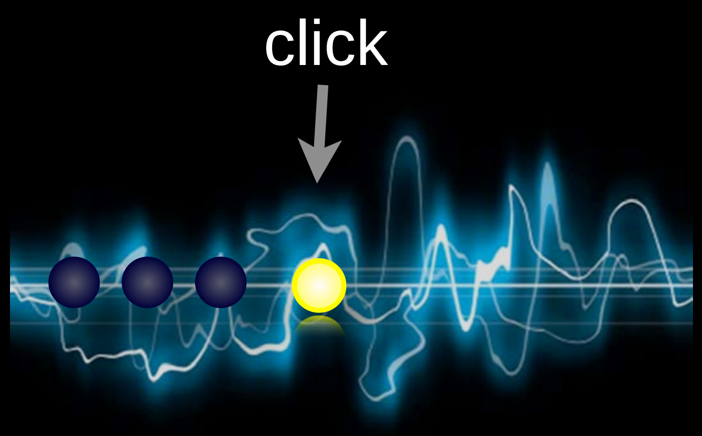
Particles are what particle detectors detect

ALICE & BOB's **DETECTOR** MODEL

Unruh-DeWitt DETECTOR

-Two-level system





-Interaction Hamiltonian (interaction picture):

$$H_{I,\nu} = \lambda_\nu \chi_\nu(t) \mu_\nu(t) \Phi[\vec{x}_\nu, \eta(t)]$$

-Detectors: $\nu = \{A, B\}$

DETECTOR-FIELD

INTERACTION HAMILTONIAN

$$H_{I,\nu} = \lambda_\nu \chi_\nu(t) \mu_\nu(t) \Phi[\vec{x}_\nu, \eta(t)]$$

DETECTOR-FIELD
INTERACTION HAMILTONIAN

Monopole moment

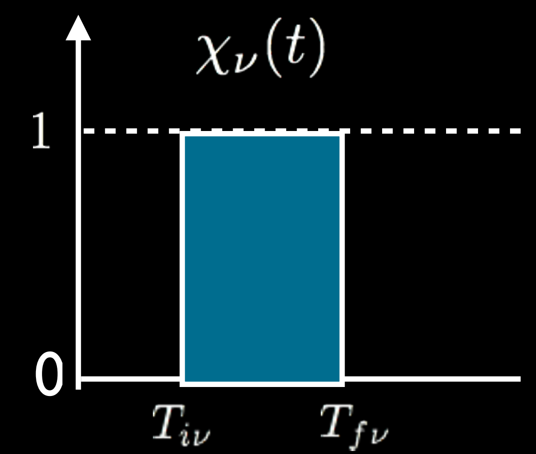
$$\mu_\nu(t) = |e_\nu\rangle\langle g_\nu| e^{i\Omega_\nu t} + |g_\nu\rangle\langle e_\nu| e^{-i\Omega_\nu t}$$

$$H_{I,\nu} = \lambda_\nu \chi_\nu(t) \mu_\nu(t) \Phi[\vec{x}_\nu, \eta(t)]$$

Coupling strength

Detector's world-line

Switching function



DETECTOR-FIELD
INTERACTION HAMILTONIAN

Monopole moment

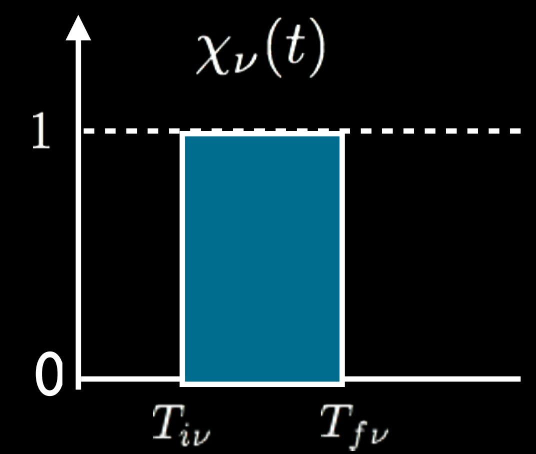
$$\mu_\nu(t) = |e_\nu\rangle\langle g_\nu| e^{i\Omega_\nu t} + |g_\nu\rangle\langle e_\nu| e^{-i\Omega_\nu t}$$

$$H_{I,\nu} = \lambda_\nu \chi_\nu(t) \mu_\nu(t) \Phi[\vec{x}_\nu, \eta(t)]$$

Coupling strength

Detector's world-line

Switching function



Total Interaction Hamiltonian: $H_I = H_{I,A} + H_{I,B}$

Sees the Unurh effect (in fact thermalizes)

$\rho_0 = |0_d\rangle\langle 0_d| \otimes |0\rangle\langle 0|$ Pointlike H.O. detector with acceleration “a”

What does time evolution do to the state?

The UDW detector experiences:

-Detector Squeezing
-Multimode squeezing detector-field $\Rightarrow$ Squeezed thermal state
-Phase rotations

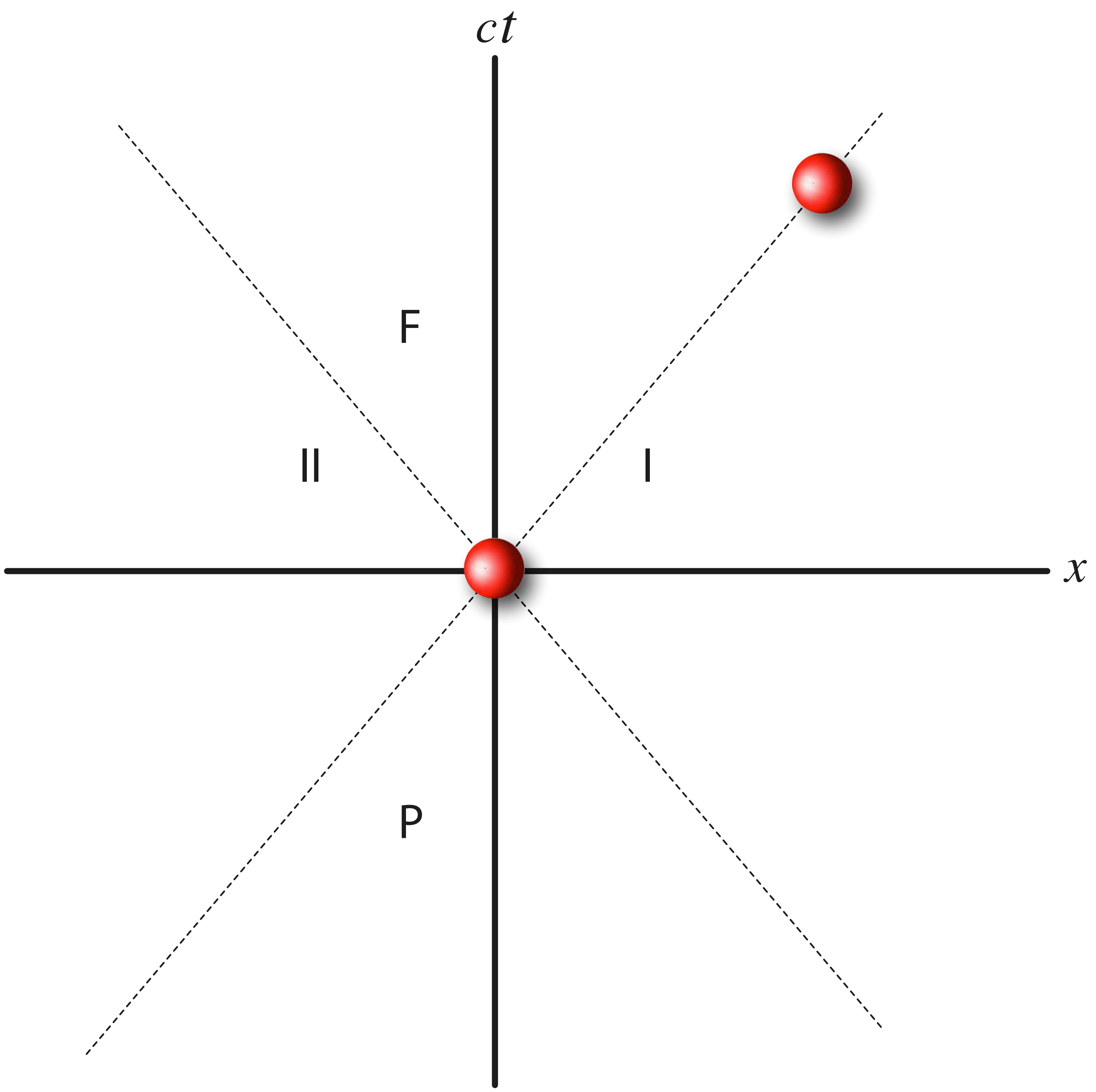
How much squeezed?/ How much thermal?

-(Relative) Entropy

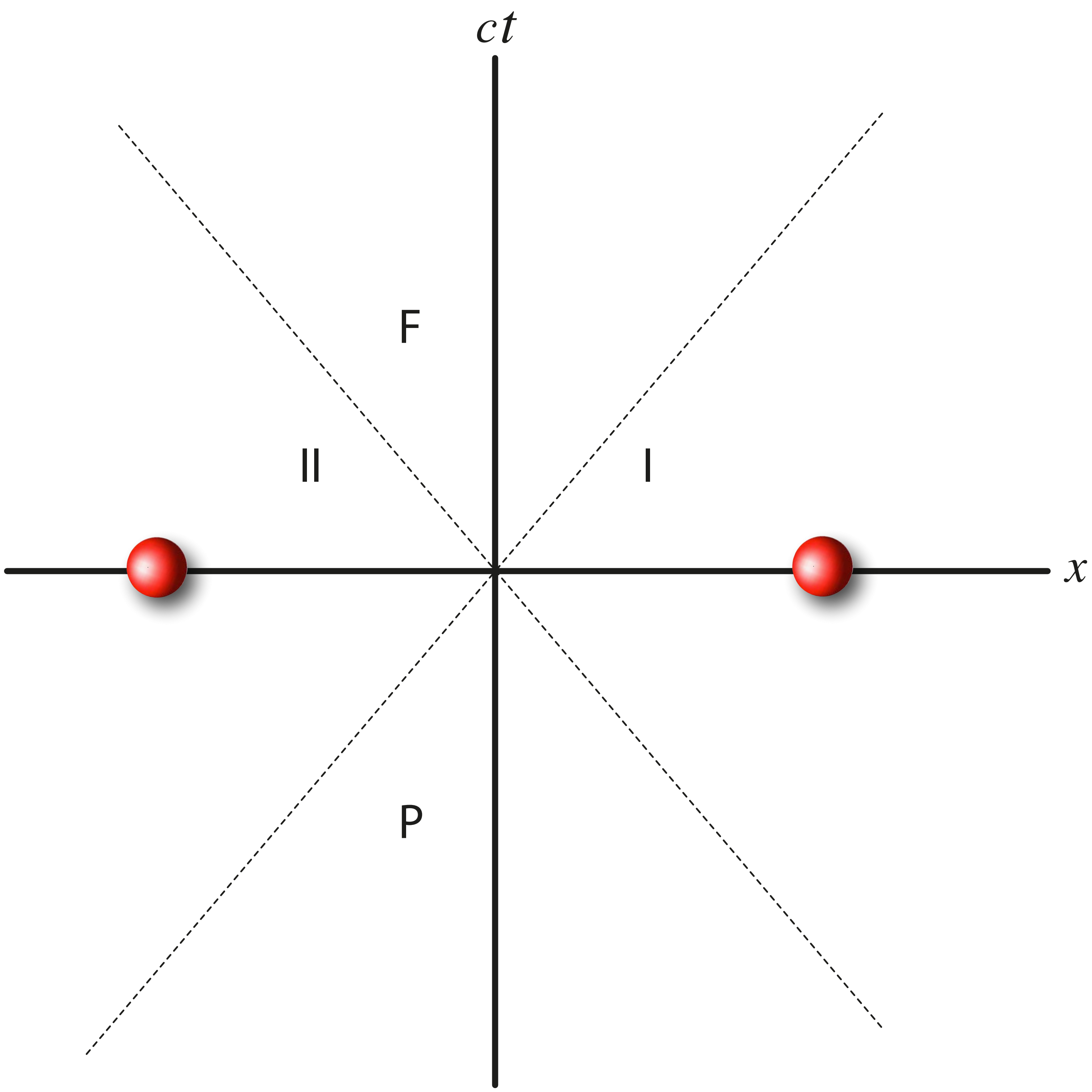
-Ratio of the energy contribution from squeezing and thermality

W. G. Brenna, E. G. Brown, R. B. Mann, E. M-M, PRD 87, 084062 (2013)

Entanglement Harvesting

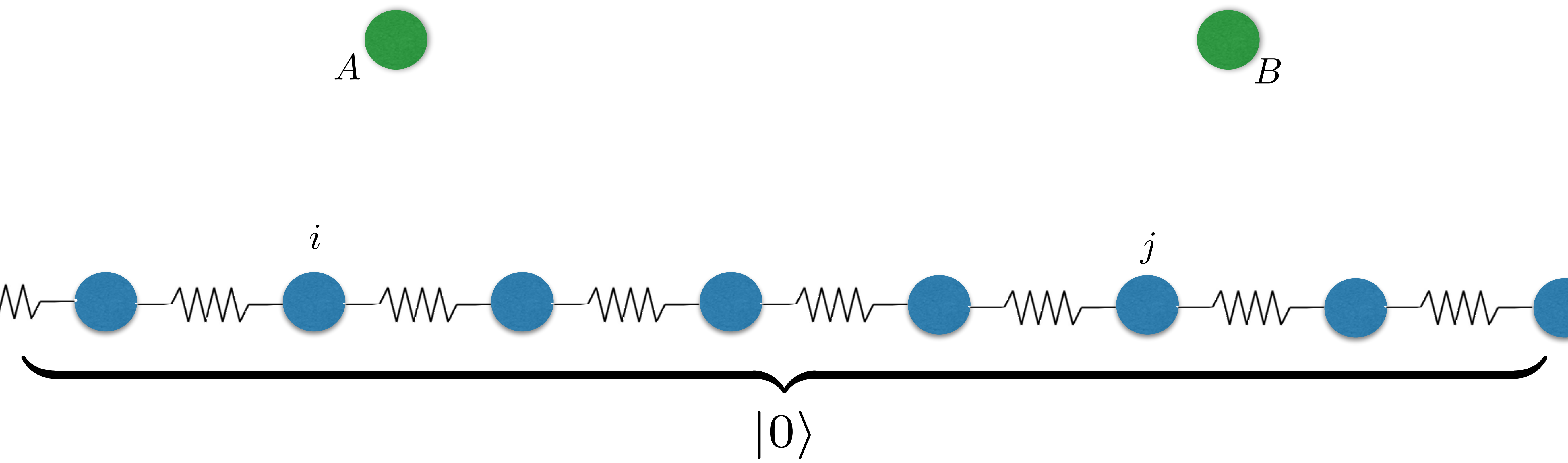


(Spacelike) Entanglement Harvesting



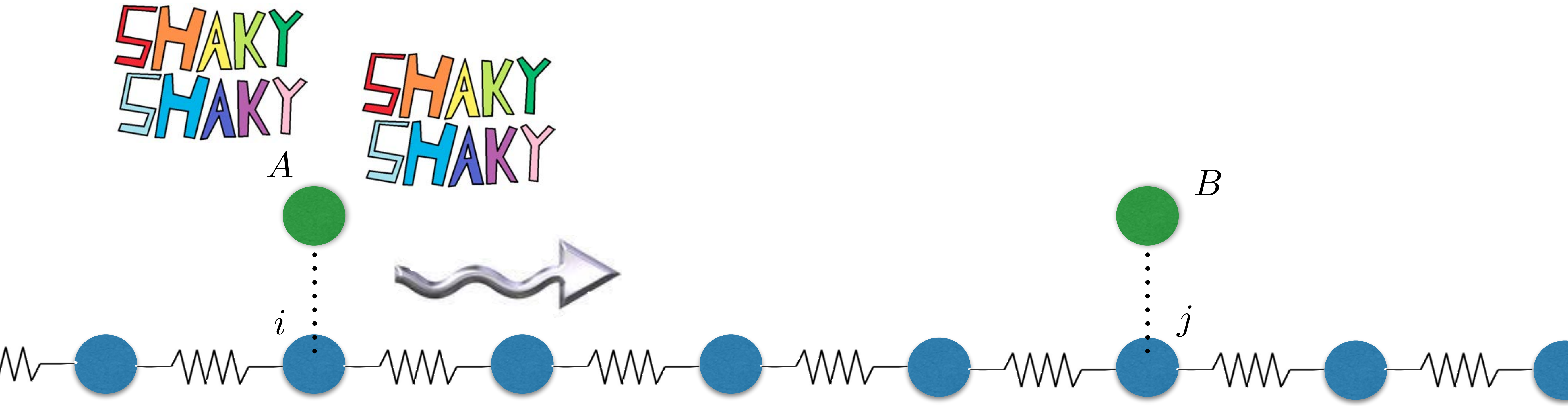
1-D Harmonic lattice in the Ground state

How do we get two systems entangled by means of local interactions with a lattice in the ground state?



Two possible mechanisms.

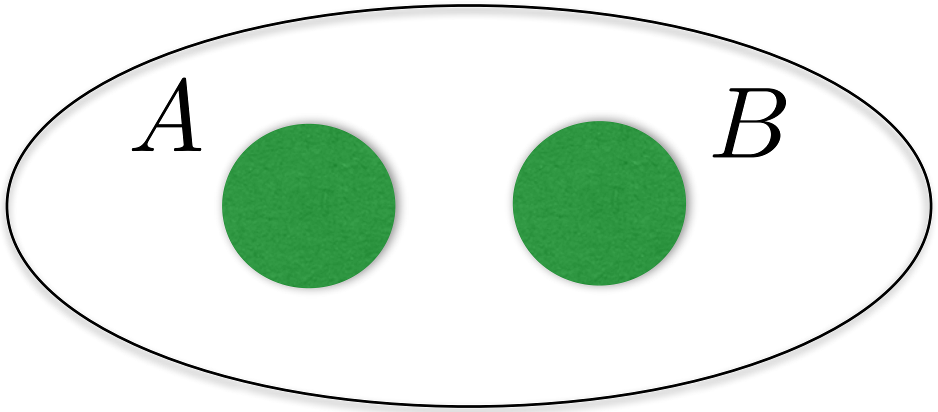
1-D Harmonic lattice in the Ground state



1) Communication via phonons

1-D Harmonic lattice in the Ground state

1) Communication via phonons



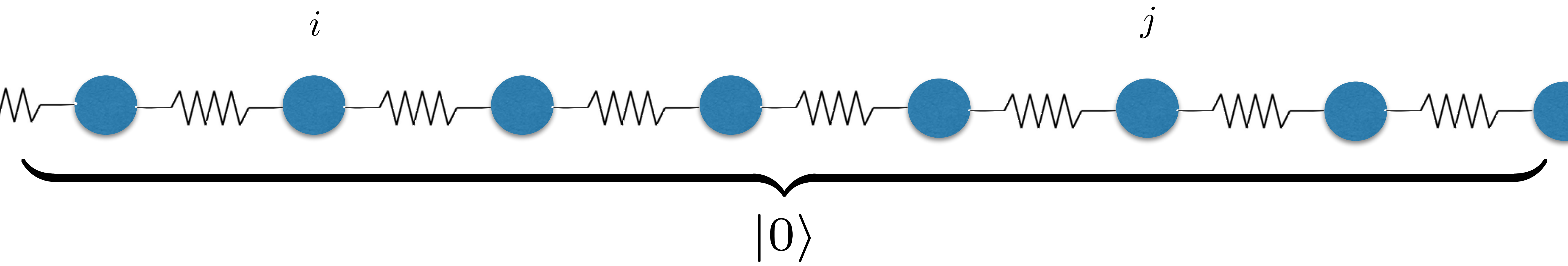
$$\rho_{AB} \neq \sum_i p_i \rho_A \otimes \rho_B$$

Limited by the speed of 'sound'

1-D Harmonic lattice in the Ground state

There's another possibility:

Take advantage of pre-existent entanglement

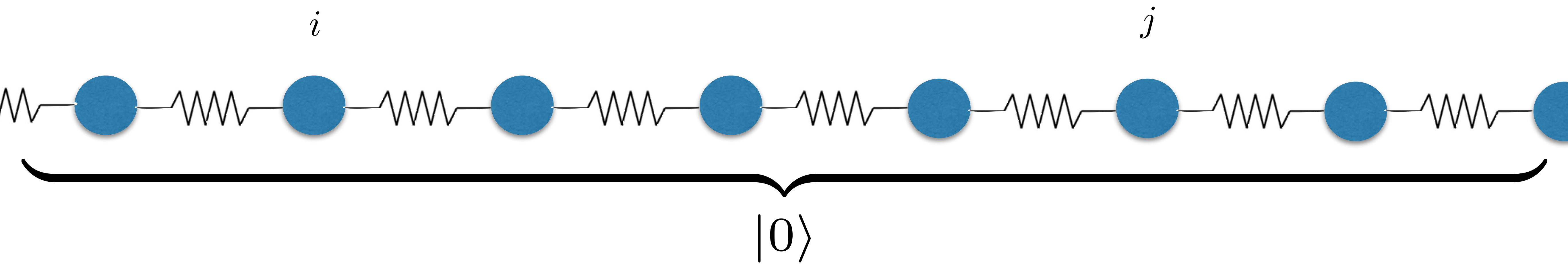


1-D Harmonic lattice in the Ground state

'Non-local' basis: Normal modes $|0\rangle\,, |1\rangle\,, |2\rangle\,, \ldots$

'Local' basis: individual number states $\{|n_1, \ldots, n_i, \ldots, n_j, \ldots\rangle\}$

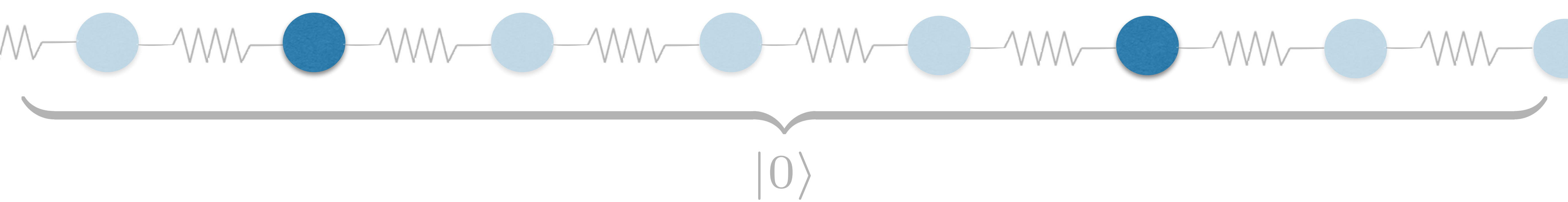
$$|0\rangle \neq \bigotimes_n |0_n\rangle$$



1-D Harmonic lattice

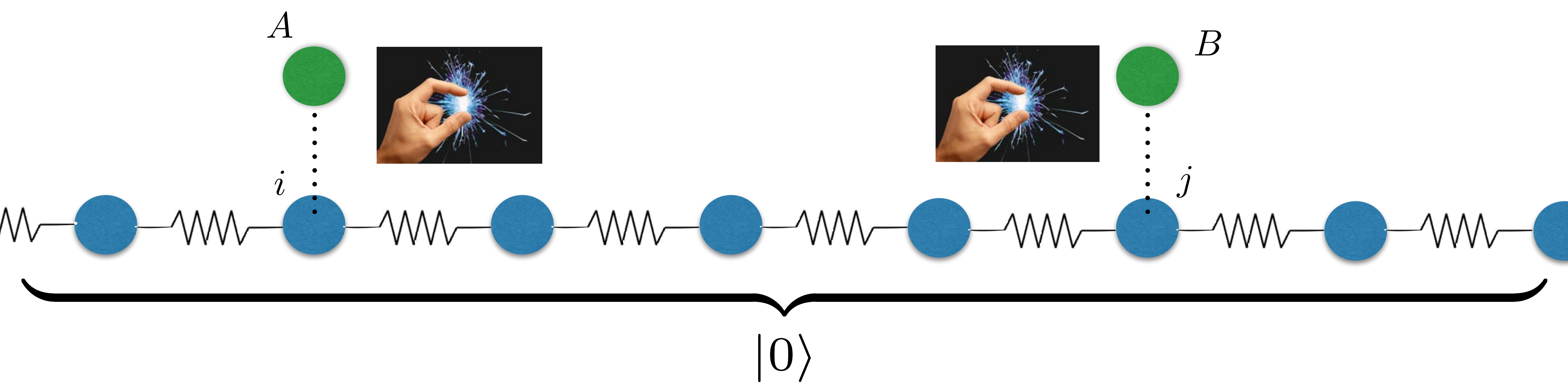
$$|0\rangle \neq \bigotimes_n |0_n\rangle$$

$$\rho_{ij} = \mathrm{tr}_{n\neq i,j}\, |0\rangle\langle 0| \neq \sum_k p_k \rho_i \otimes \rho_j$$



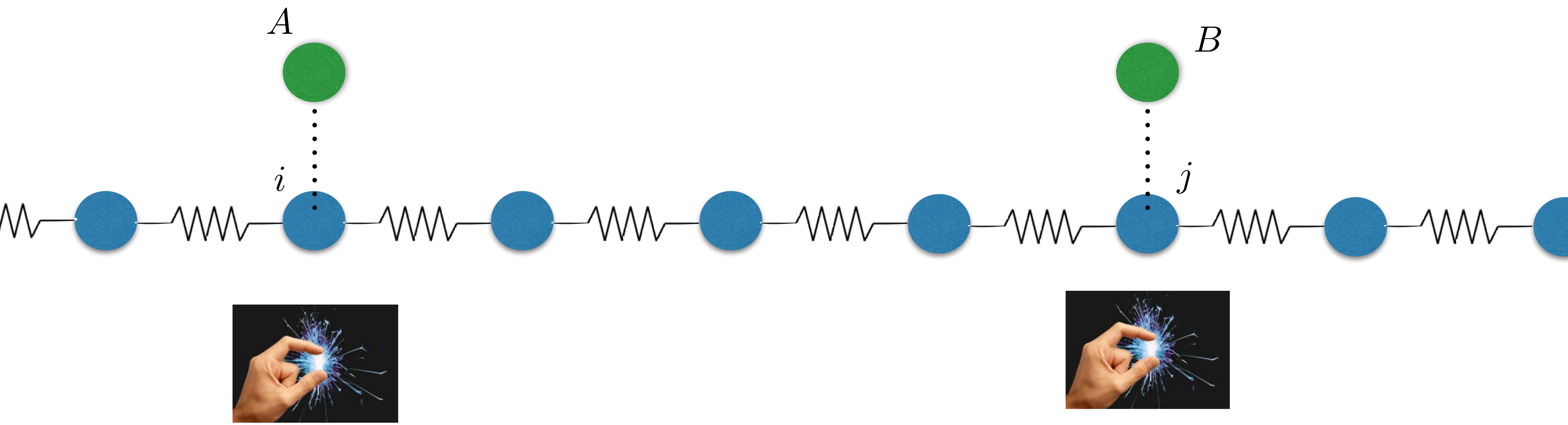
1-D Harmonic lattice in the Ground state

2) Swapping ground state entanglement



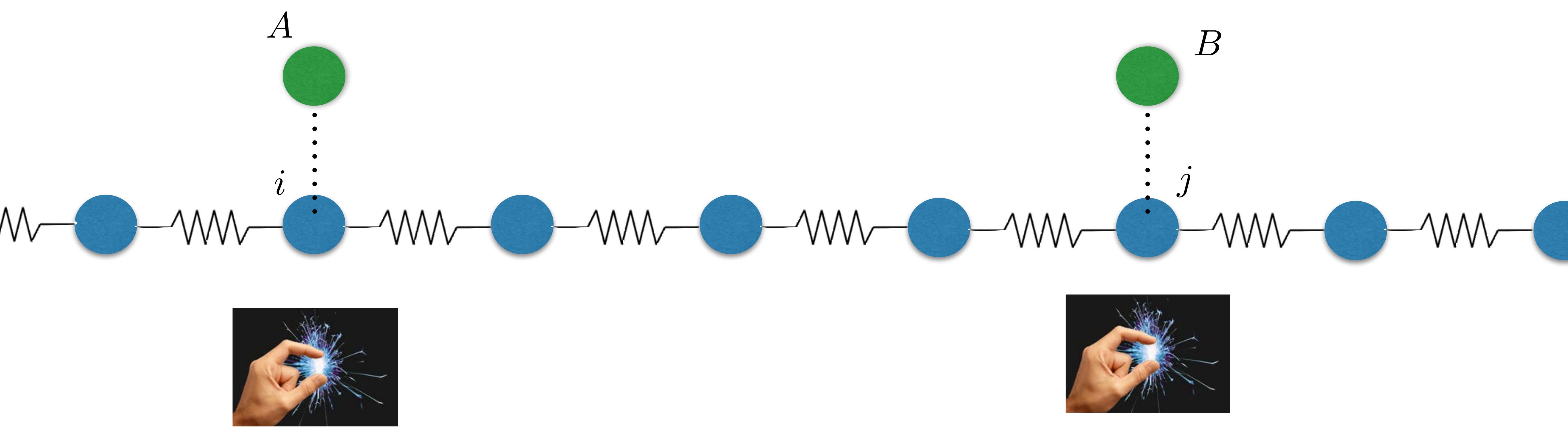
1-D Harmonic lattice in the Ground state

2) Swapping ground state entanglement



1-D Harmonic lattice in the Ground state

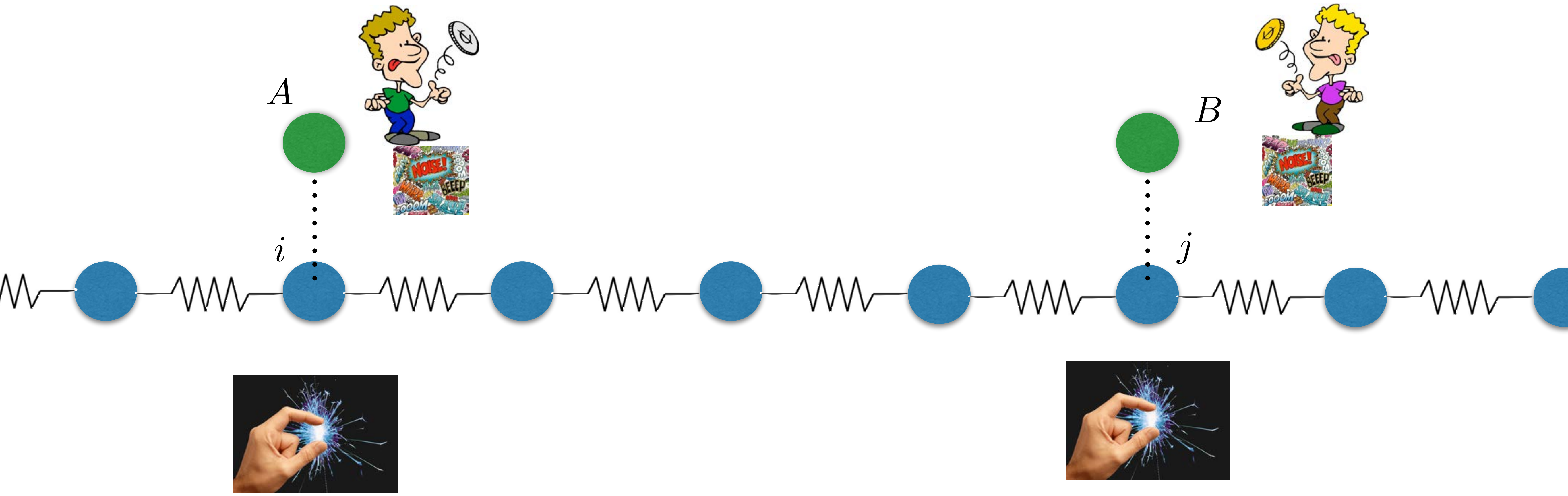
Local coupling to the vacuum: Observed fluctuations are correlated



2) Swapping ground state entanglement

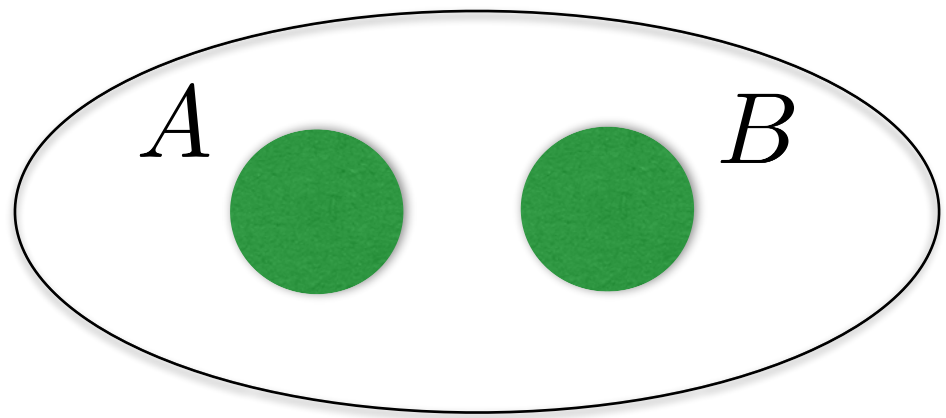
1-D Harmonic lattice in the Ground state

2) Swapping ground state entanglement



1-D Harmonic lattice in the Ground state

2) Swapping ground state entanglement

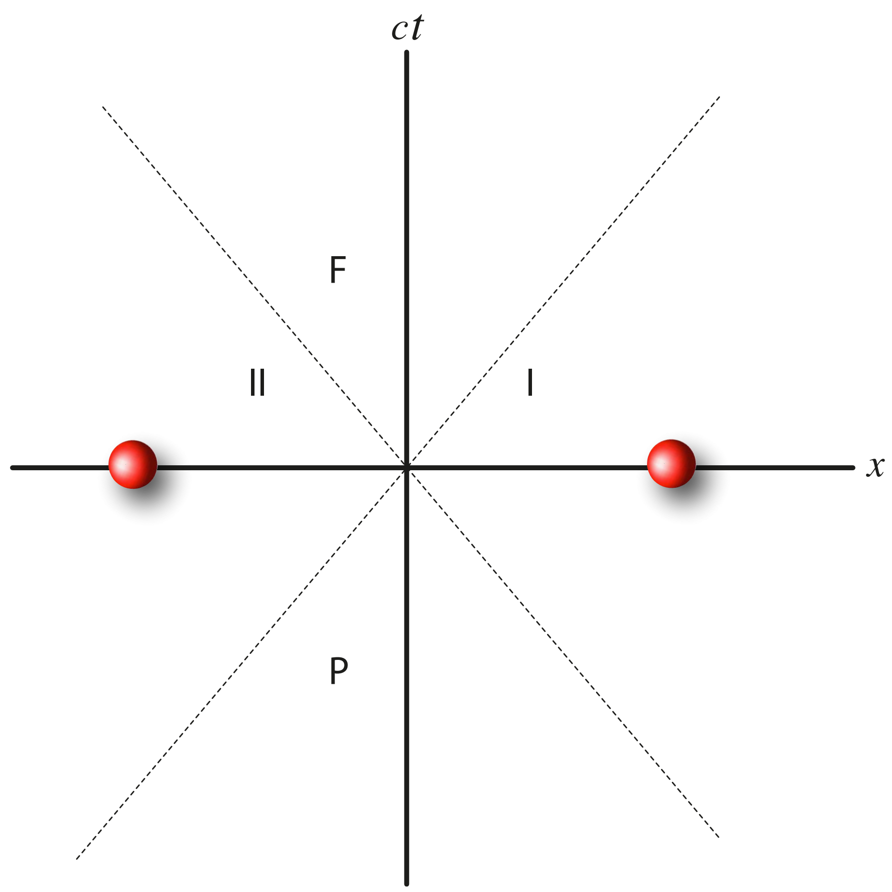


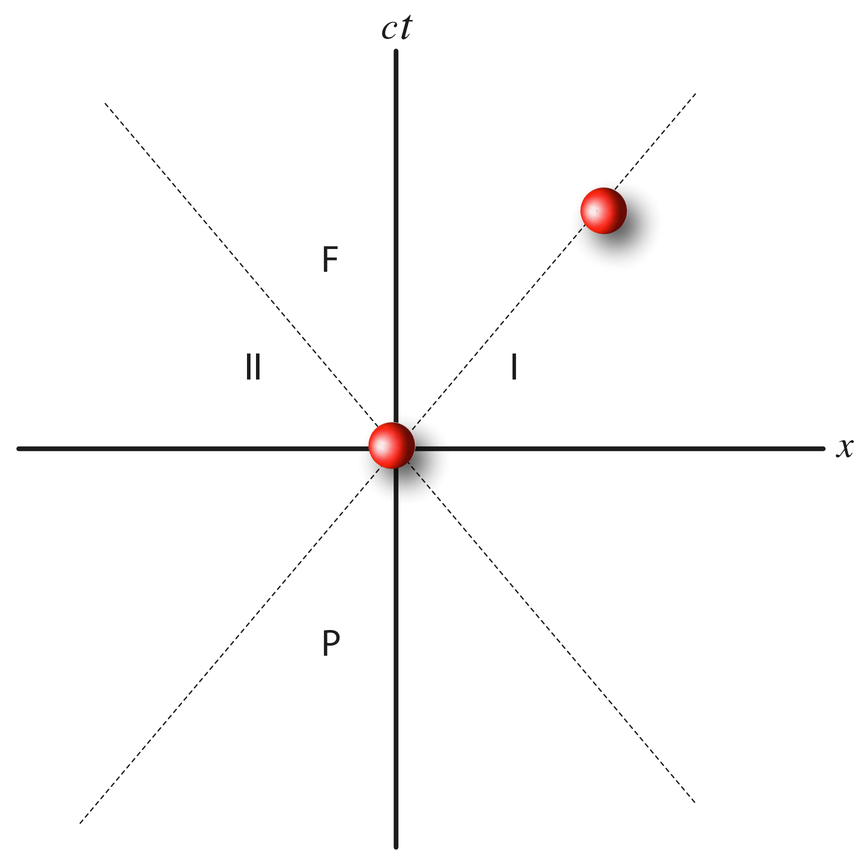
$$\rho_{AB} \neq \sum_i p_i \rho_A \otimes \rho_B$$

NOT Limited by the speed of 'sound'

Quantum Fields

A 1D quantum field can be thought as the ‘continuum limit’ of such a lattice





Two mechanisms to get ‘atoms’ entangled via interaction with quantum fields:

1) Via exchange of real field quanta

2) Swapping vacuum entanglement

Can we extract vacuum entanglement?

Entanglement from the Vacuum

Benni Reznik[1]

Received December 3, 2002

We explore the entanglement of the vacuum of a relativistic field by letting a pair of causally disconnected probes interact with the field. We find that, even when the probes are initially non-entangled, they can wind up to a final entangled state. This shows that entanglement persists between disconnected regions in the vacuum. However the probe entanglement, unlike correlations, vanishes once the regions become sufficiently separated. The relation between entropy, correlations and entanglement is discussed.

KEY WORDS: entanglement; entropy; vacuum state; entanglement probes.

Can we extract vacuum entanglement?

Volume 153, number 6,7 PHYSICS LETTERS A 11 March 1991

Non-local correlations in quantum electrodynamics

Antony Valentini [1]
Institute for Theoretical Physics, Technical University Vienna, Karlsplatz 13, A-1040 Vienna, Austria

Received 18 June 1990; accepted for publication 16 January 1991
Communicated by J.P. Vigier

It is shown that a pair of initially uncorrelated bare atoms, separated by a distance R, develop non-local statistical correlations in a time $t<R/c$. The effects arise from the non-locality of the Feynman photon propagator, and from interference between the two indistinguishable ways of jointly emitting a pair of photons. For physical dressed atoms, the latter effect leads to a non-locally correlated probability for joint spontaneous emission. The effects may also be understood in terms of non-locally-correlated vacuum-field fluctuations.

Can we extract vacuum entanglement?

PHYSICAL REVIEW A **71**, 042104 (2005)

Violating Bell's inequalities in vacuum

Benni Reznik, Alex Retzker, and Jonathan Silman

PRL **106,** 110404 (2011) PHYSICAL REVIEW LETTERS week ending 18 MARCH 2011

Entanglement between the Future and the Past in the Quantum Vacuum

S. Jay Olson* and Timothy C. Ralph

PRL **109,** 033602 (2012) PHYSICAL REVIEW LETTERS week ending 20 JULY 2012

Extracting Past-Future Vacuum Correlations Using Circuit QED

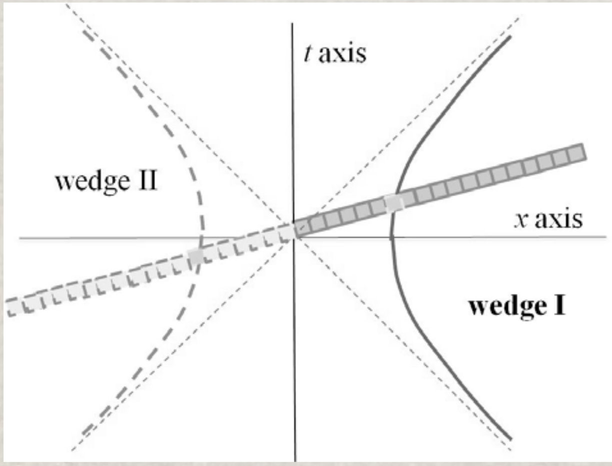
Carlos Sabín,[1] Borja Peropadre,[1] Marco del Rey,[1] and Eduardo Martín-Martínez[1,2]

The Rindler Firewall:

Break the correlations between the two Rindler wedges:

$$\rho = \rho_L \otimes \rho_R$$

$$\rho_R = \mathrm{Tr}_L |0\rangle\langle 0| \qquad \rho_L = \mathrm{Tr}_R |0\rangle\langle 0|$$



J. Louko, Journal of High Energy Physics **2014**, 142

The Rindler Firewall:

Examples of Dynamical generation:

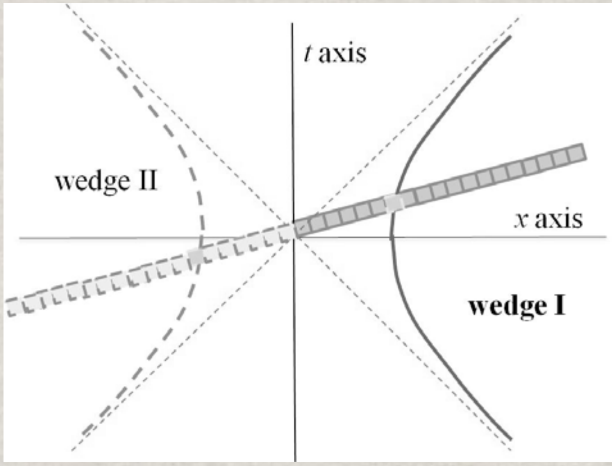
'Smooth and sharp creation of a Dirichlet wall in 1+1 quantum field theory: how singular is the sharp creation limit?

Eric Brown, Jorma Louko, JHEP 1508 (2015) 061

Mimics the severing of correlations that supposedly develop dynamically during evaporation as discussed in AMPS

$$\rho_R = \mathrm{Tr}_L |0\rangle\langle 0|$$

$$\rho_L = \mathrm{Tr}_R |0\rangle\langle 0|$$



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The Rindler Firewall:

Break the correlations between the two Rindler wedges:

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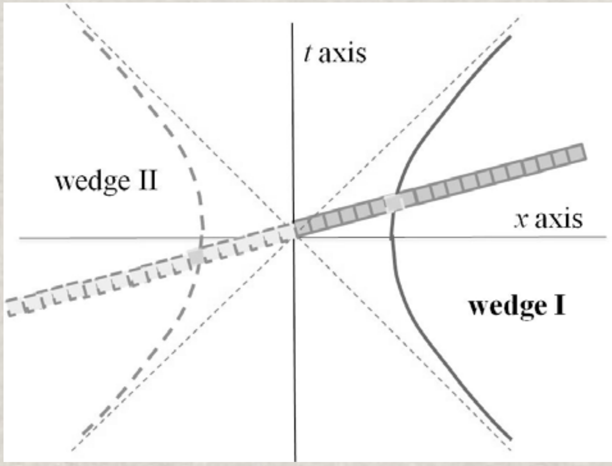
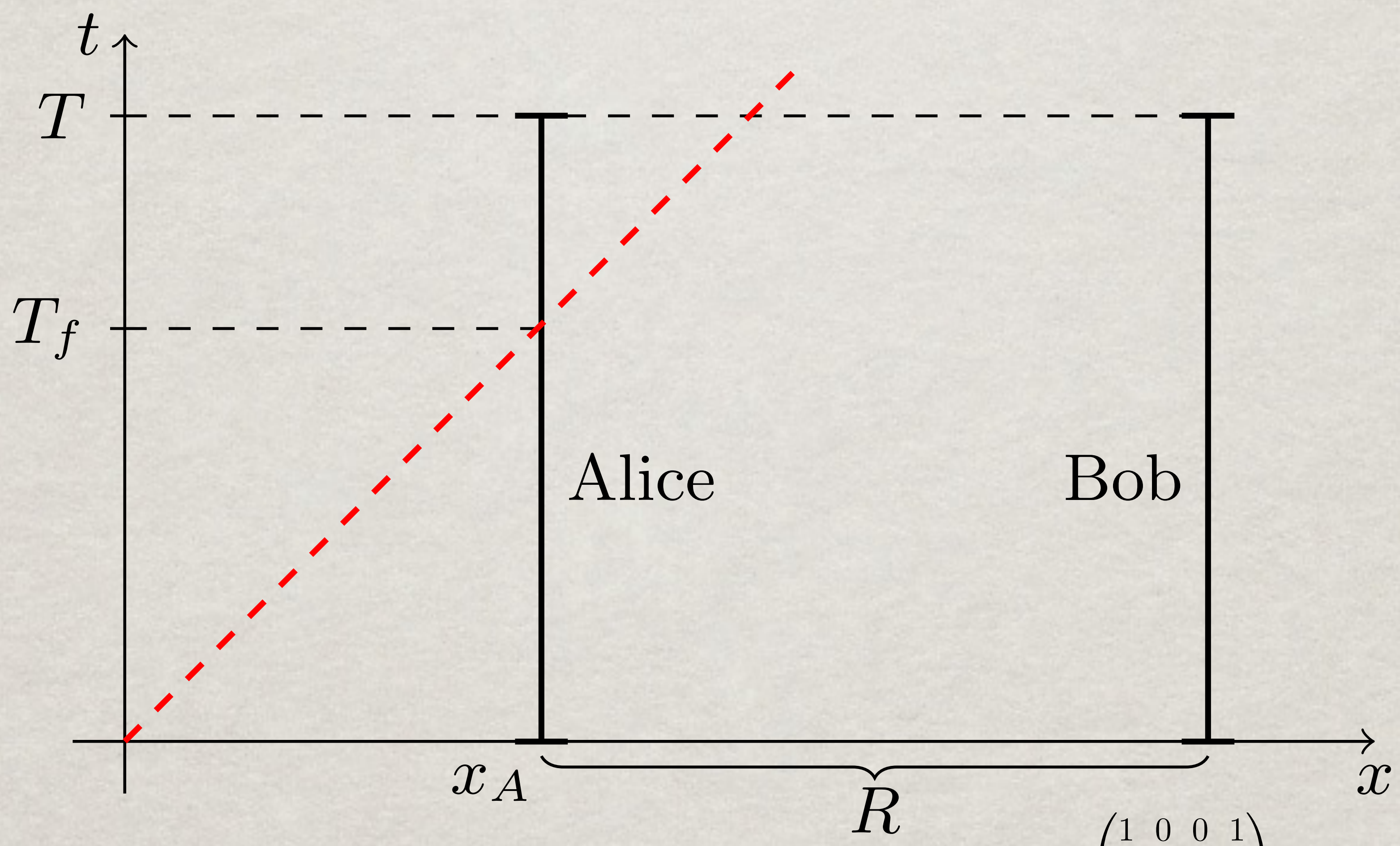


Young black hole firewall.

Modeling a Firewall

Two Unruh-DeWitt detectors



$$|\psi_{\max}\rangle = \frac{1}{\sqrt{2}}\big(|gg\rangle + |ee\rangle\big)$$

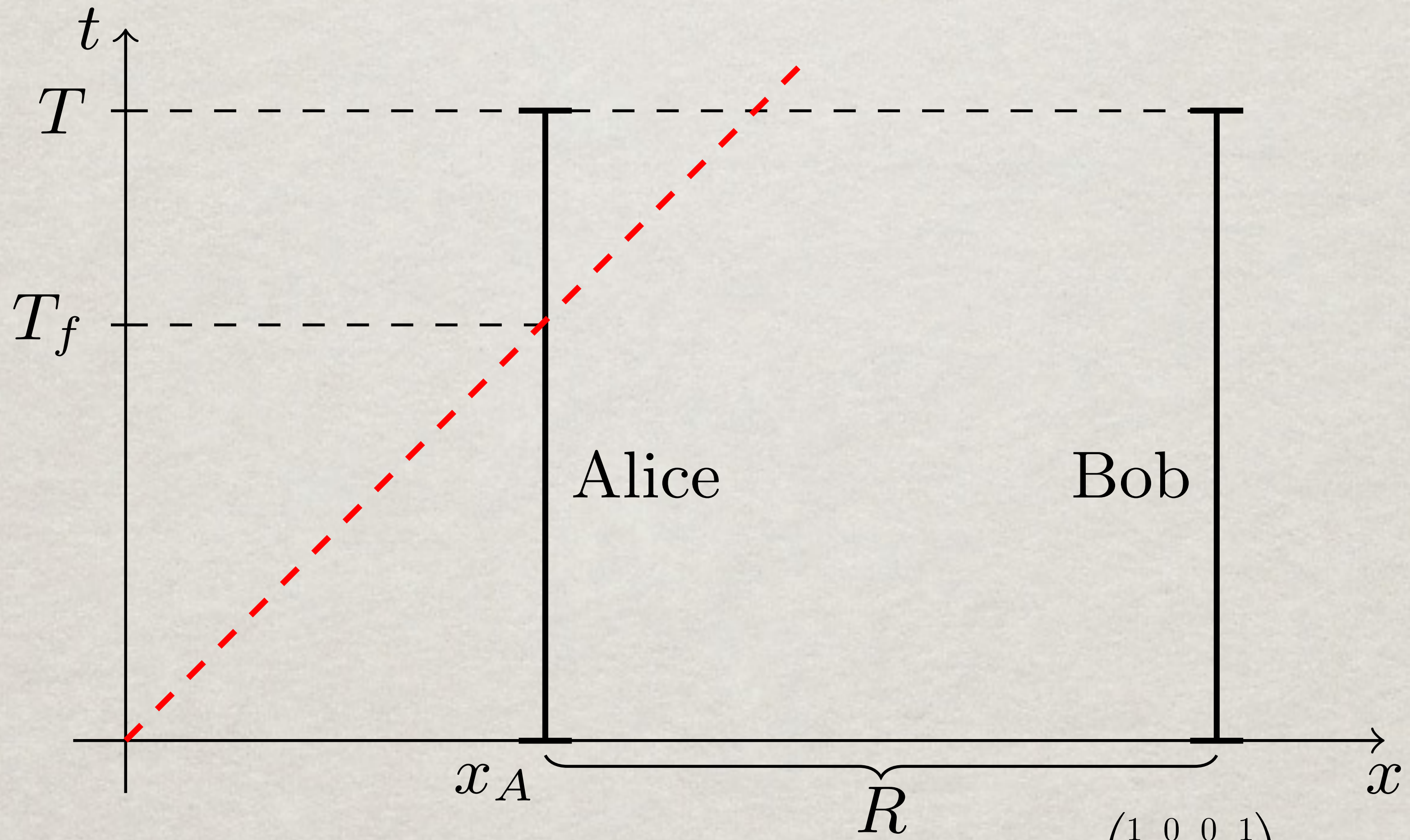
$$\rho_{\mathrm{d},0} = |\psi_{\max}\rangle\langle\psi_{\max}| = \frac{1}{2}\begin{pmatrix}1&0&0&1\\0&0&0&0\\0&0&0&0\\1&0&0&1\end{pmatrix}.$$

More demanding than computing transition rates…

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

Modeling a Firewall

Two Unruh-DeWitt detectors



$|\psi_{\text{max}}\rangle = \frac{1}{\sqrt{2}}\big(|gg\rangle + |ee\rangle\big)$

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$$\rho_T^{(1)} = U^{(1)}\rho_0 + \rho_0 {U^{(1)}}^\dagger ,$$

$$\rho_T^{(2)} = U^{(1)}\rho_0 {U^{(1)}}^\dagger + U^{(2)}\rho_0 + \rho_0 {U^{(2)}}^\dagger .$$

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

Two max. entangled Unruh-DeWitt detectors

$$\rho_{\mathrm{d},T} = \mathrm{Tr}_\phi(\rho_T) = \rho_{\mathrm{d},0} + \rho^{(2)}_{\mathrm{d},T} + \mathcal{O}(\lambda^3) \ ,$$

$$\rho^{(2)}_{\mathrm{d},T} = \lambda_A^2 \rho_{AA} + \lambda_B^2 \rho_{BB} + \lambda_A \lambda_B \rho_{AB}$$

$$\rho_{AA} = \frac{1}{2}\begin{pmatrix} -2\,\mathrm{Re}(J^{AA}_{-+}) & 0 & 0 & -J^{AA}_{-+} - J^{AA*}_{+-} \\ 0 & I^{AA}_{+-} & I^{AA}_{++} & 0 \\ 0 & I^{AA}_{--} & I^{AA}_{-+} & 0 \\ -J^{AA}_{+-} - J^{AA*}_{-+} & 0 & 0 & -2\,\mathrm{Re}(J^{AA}_{+-}) \end{pmatrix}, \ \rho_{BB} = \frac{1}{2}\begin{pmatrix} -2\,\mathrm{Re}(J^{BB}_{-+}) & 0 & 0 & -J^{BB}_{-+} - J^{BB*}_{+-} \\ 0 & I^{BB}_{-+} & I^{BB}_{--} & 0 \\ 0 & I^{BB}_{++} & I^{BB}_{+-} & 0 \\ -J^{BB}_{+-} - J^{BB*}_{-+} & 0 & 0 & -2\,\mathrm{Re}(J^{BB}_{+-}) \end{pmatrix}$$

$$\rho_{AB} = \frac{1}{2}\begin{pmatrix} -2\,\mathrm{Re}(J^{AB}_{--} + J^{BA}_{--}) & 0 & 0 & -J^{AB}_{--} - J^{BA}_{--} - J^{AB*}_{++} - J^{BA*}_{++} \\ 0 & I^{AB}_{++} + I^{BA}_{--} & I^{AB}_{+-} + I^{BA}_{-+} & 0 \\ 0 & I^{AB}_{-+} + I^{BA}_{+-} & I^{AB}_{--} + I^{BA}_{++} & 0 \\ -J^{AB}_{++} - J^{BA}_{++} - J^{AB*}_{--} - J^{BA*}_{--} & 0 & 0 & -2\,\mathrm{Re}(J^{AB}_{++} + J^{BA}_{++}) \end{pmatrix},$$

$$I^{\nu,\eta}_{\epsilon,\delta} = \int_{-\infty}^{\infty}\mathrm{d}\tau \int_{-\infty}^{\infty}\mathrm{d}\tau' \chi_\nu(\tau')\chi_\eta(\tau)\, e^{\mathrm{i}(\epsilon\Omega_\nu\tau' + \delta\Omega_\eta\tau)} W[\mathsf{x}_\eta(\tau), \mathsf{x}_\nu(\tau')],$$

$$J^{\nu,\eta}_{\epsilon,\delta} = \int_{-\infty}^{\infty}\mathrm{d}\tau \int_{-\infty}^{\tau}\mathrm{d}\tau' \chi_\nu(\tau)\chi_\eta(\tau')\, e^{\mathrm{i}(\epsilon\Omega_\nu\tau + \delta\Omega_\eta\tau')} W[\mathsf{x}_\nu(\tau), \mathsf{x}_\eta(\tau')]$$

$$W[\mathsf{x}_\nu(\tau), \mathsf{x}_\eta(\tau')] = \mathrm{Tr}_\phi\big(\phi\big(\mathsf{x}_\nu(\tau)\big)\phi\big(\mathsf{x}_\eta(\tau')\big)\rho_{\phi,0}\big)$$

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

Modeling a Firewall

We can explicitly compute the Wightman function for the Rindler firewall

$$W[\mathsf{x}_\nu(\tau), \mathsf{x}_\eta(\tau')] = \mathrm{Tr}_\phi\big(\phi\big(\mathsf{x}_\nu(\tau)\big)\phi\big(\mathsf{x}_\eta(\tau')\big)\rho_{\phi,0}\big)$$

$$\Delta W(\mathsf{x}, \mathsf{x}') = \frac{1}{4\pi}\Big[\Theta(u)\theta(-u') + \theta(-u)\theta(u')\Big] \times \Big(\log(\Lambda\,|u - u'|) + \mathrm{i}\frac{\pi}{2}\,\mathrm{sgn}(u - u')\Big)$$

J. Louko, Journal of High Energy Physics **2014**, 142

The firewall ‘drama’s’ impact on the Wightman function: non-continuity

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

Modeling a Firewall

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J. Louko, Journal of High Energy Physics **2014**, 142

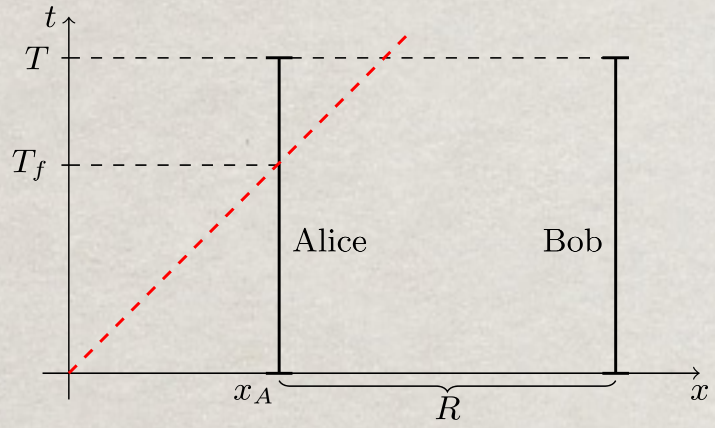
The firewall 'drama's' impact on the Wightman function: non-continuity

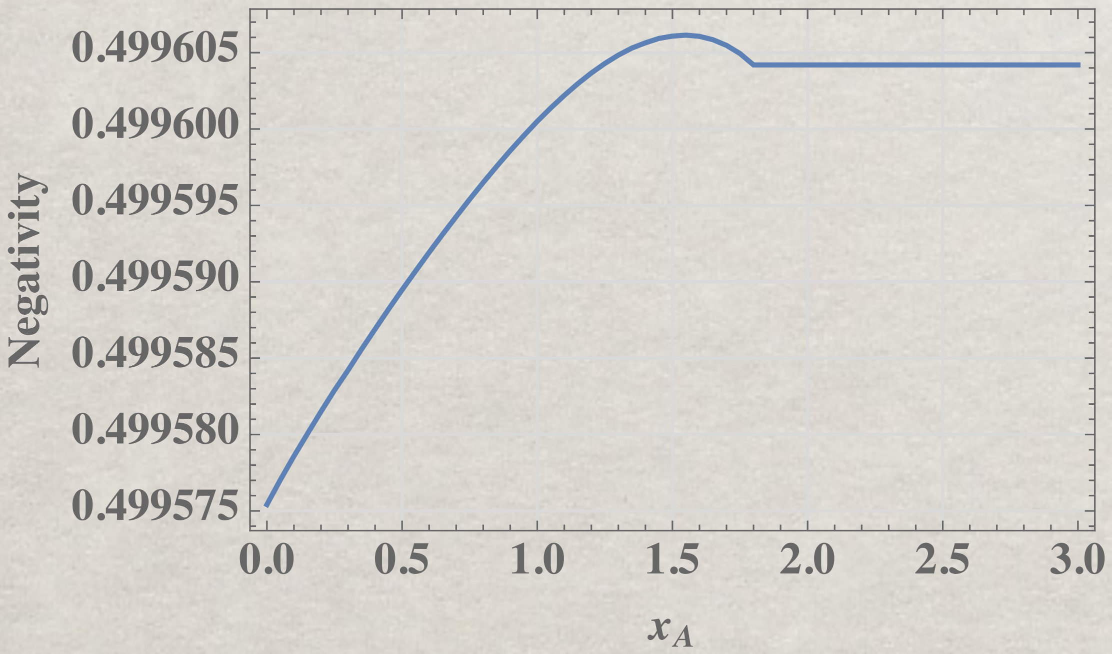
Does this violence impact the information content of an in-falling detector?

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

Modeling a Firewall

Two max. entangled Unruh-DeWitt detectors

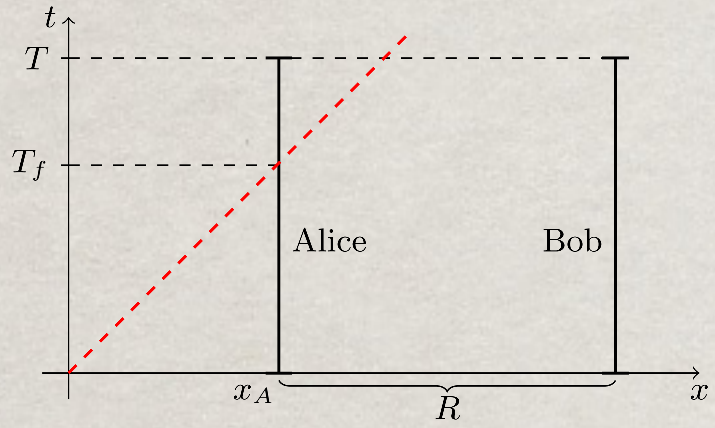




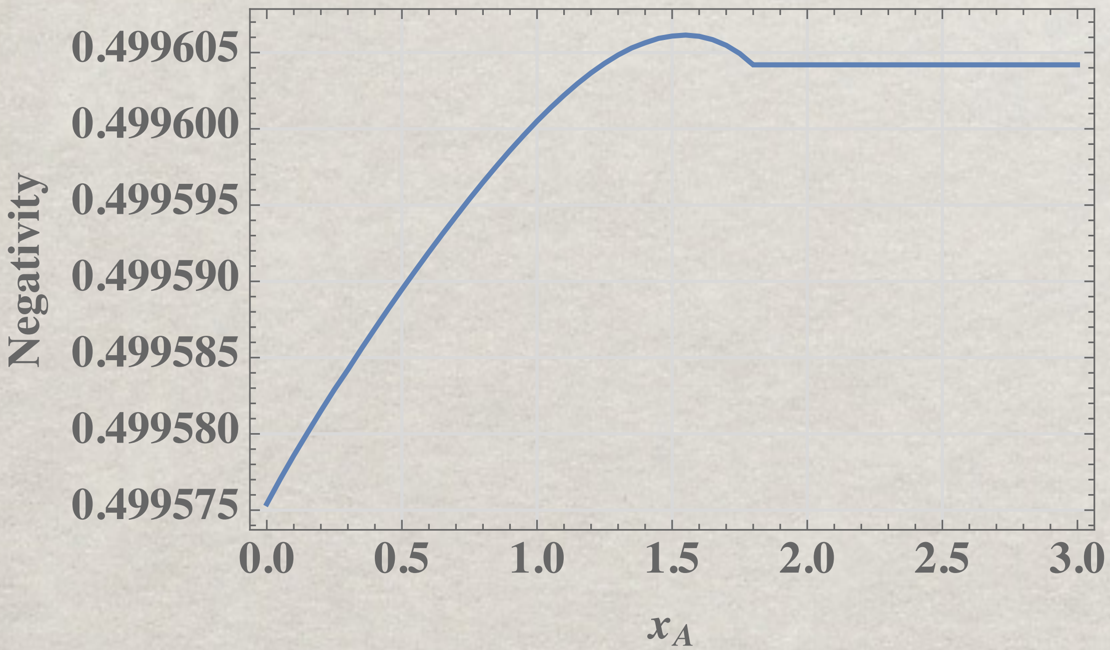
Sudden Switching

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

Two max. entangled Unruh-DeWitt detectors



1-Entanglement almost not changed! Mild degradation



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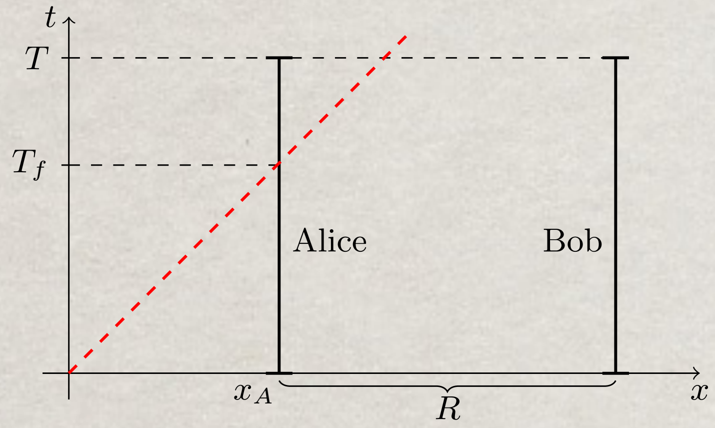
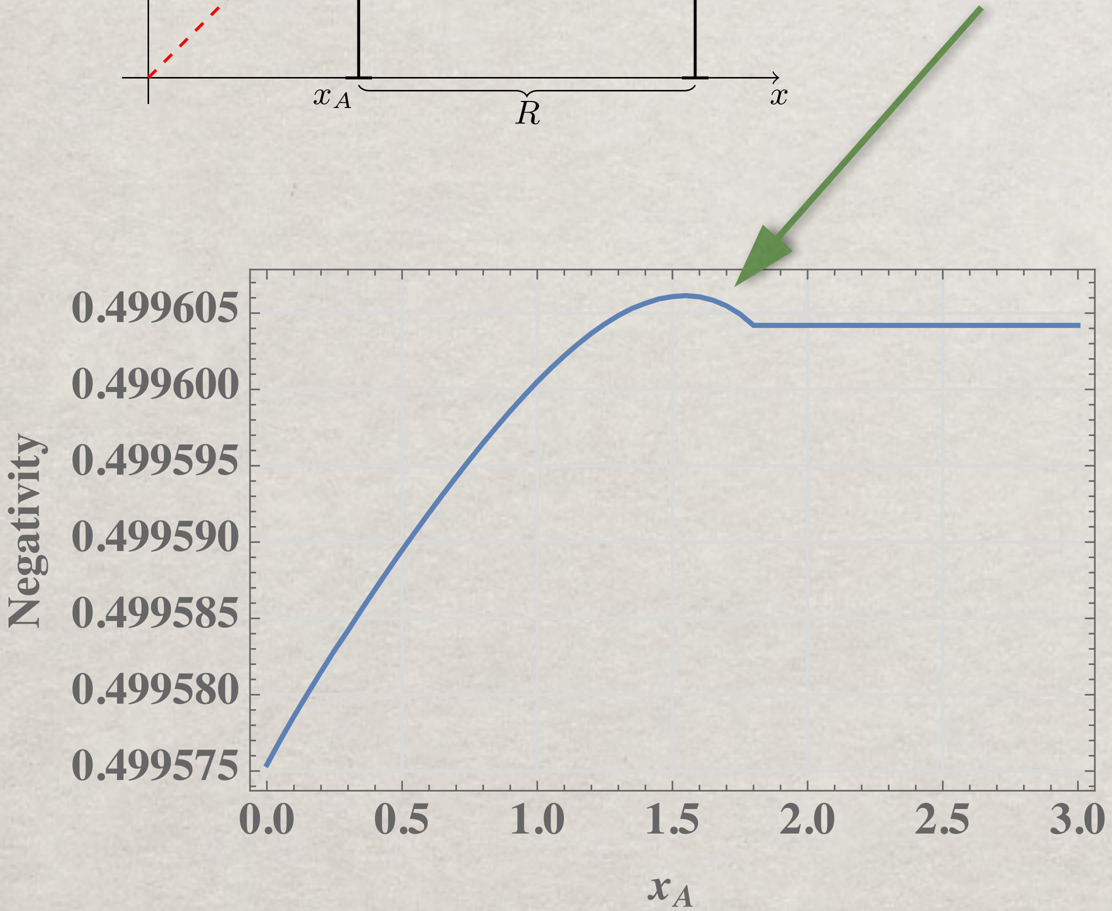


1-Entanglement almost not changed! Mild degradation

2-Regimes where entanglement less degraded than with only plain vacuum int.



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Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

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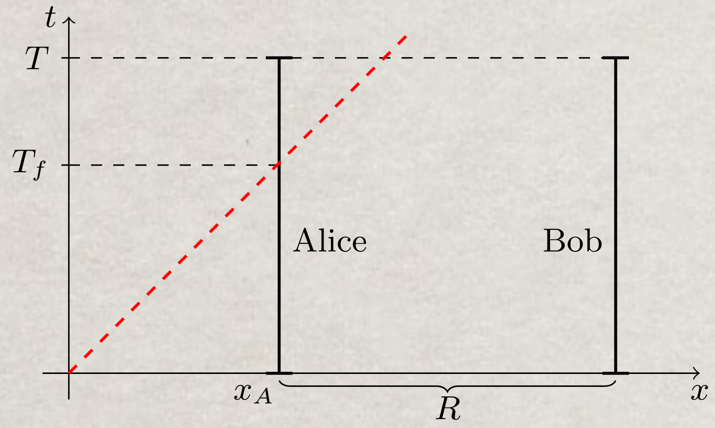

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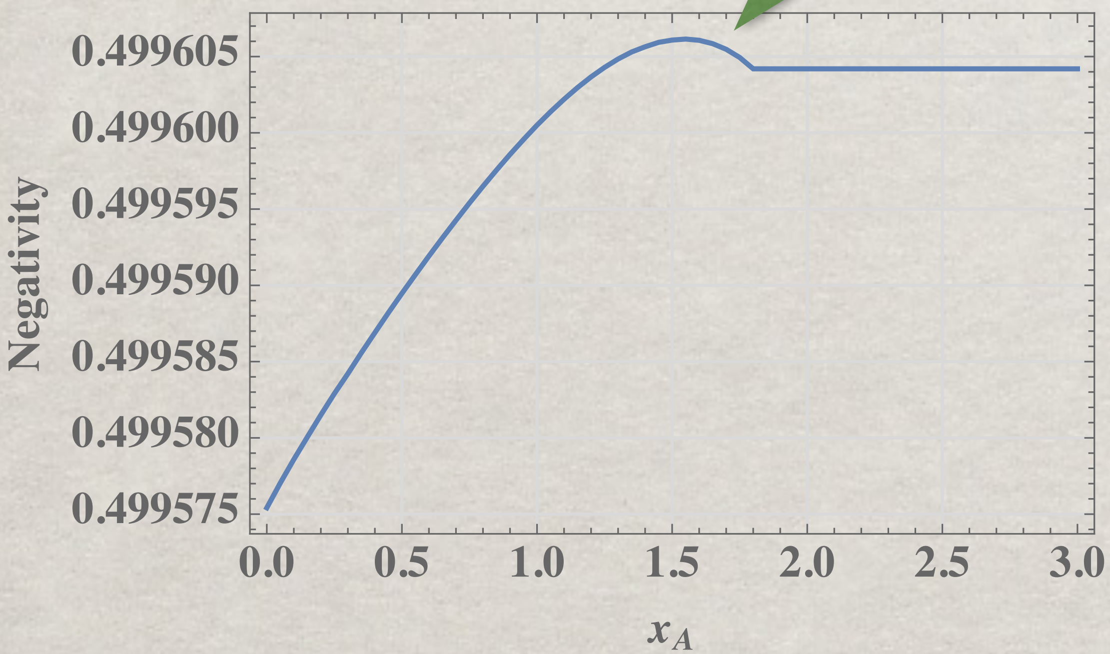
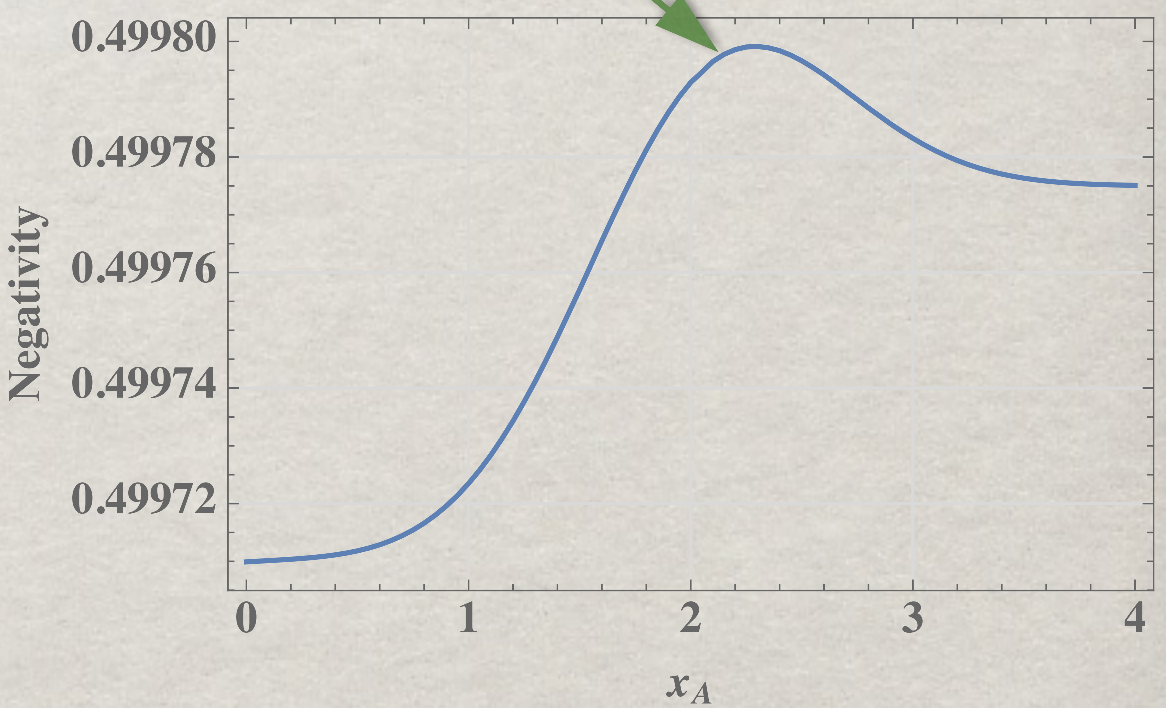


Sudden Switching



Gaussian Switching

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

Two max. entangled Unruh-DeWitt detectors

Conclusions.— Our main conclusion runs contrary to the vision of a firewall as a violently singular surface [3]: the Rindler firewall has only a modest effect on the entanglement between two inertial Unruh-DeWitt detectors when one of the detectors crosses the firewall. There is even a parameter range in which the firewall slows down the entanglement degradation, compared with the degradation that takes place in Minkowski vacuum.

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

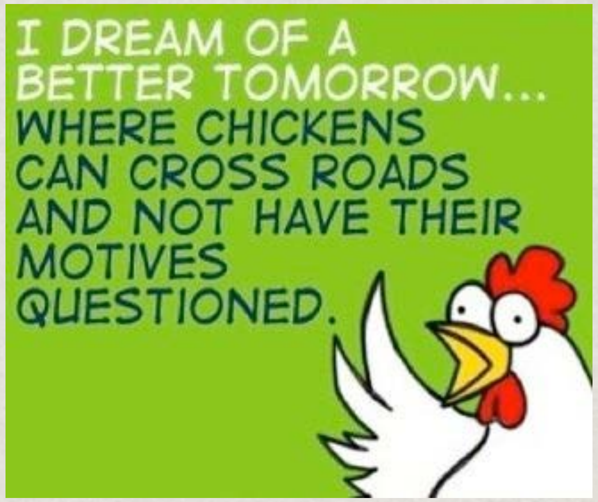
Modeling a Firewall

Two max. entangled Unruh-DeWitt detectors

We cannot think of a firewall as a surface of cataclysmic events that erases all information about matter that crosses the firewall. If the matter is correlated with the outside world, these correlations will not be significantly altered by the crossing.

Eduardo Martin-Martinez, Jorma Louko. Phys. Rev. Lett. 115, 031301 (2015)

Firewalls do not work as advertised!



Why did the chicken cross the firewall?

We do not know… but it did get to the other side, with most of its memories intact.

Thanks!!

Eduardo Martin-Martinez, Jorma Louko.

Phys. Rev. Lett. 115, 031301 (2015)

More to come: signalling across firewalls.