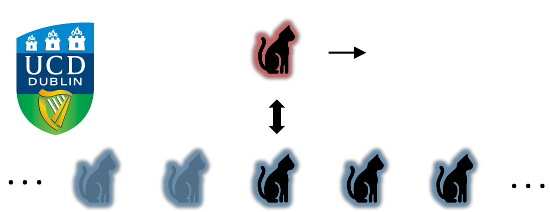
Centre for Quantum Engineering, Science, and Technology

Quantum Darwinism and classical objectivity: A collision model viewpoint

Steve Campbell

EPL 133, 60001 (2021)
PRA 99, 042103 (2019)
arXiv to appear very soon



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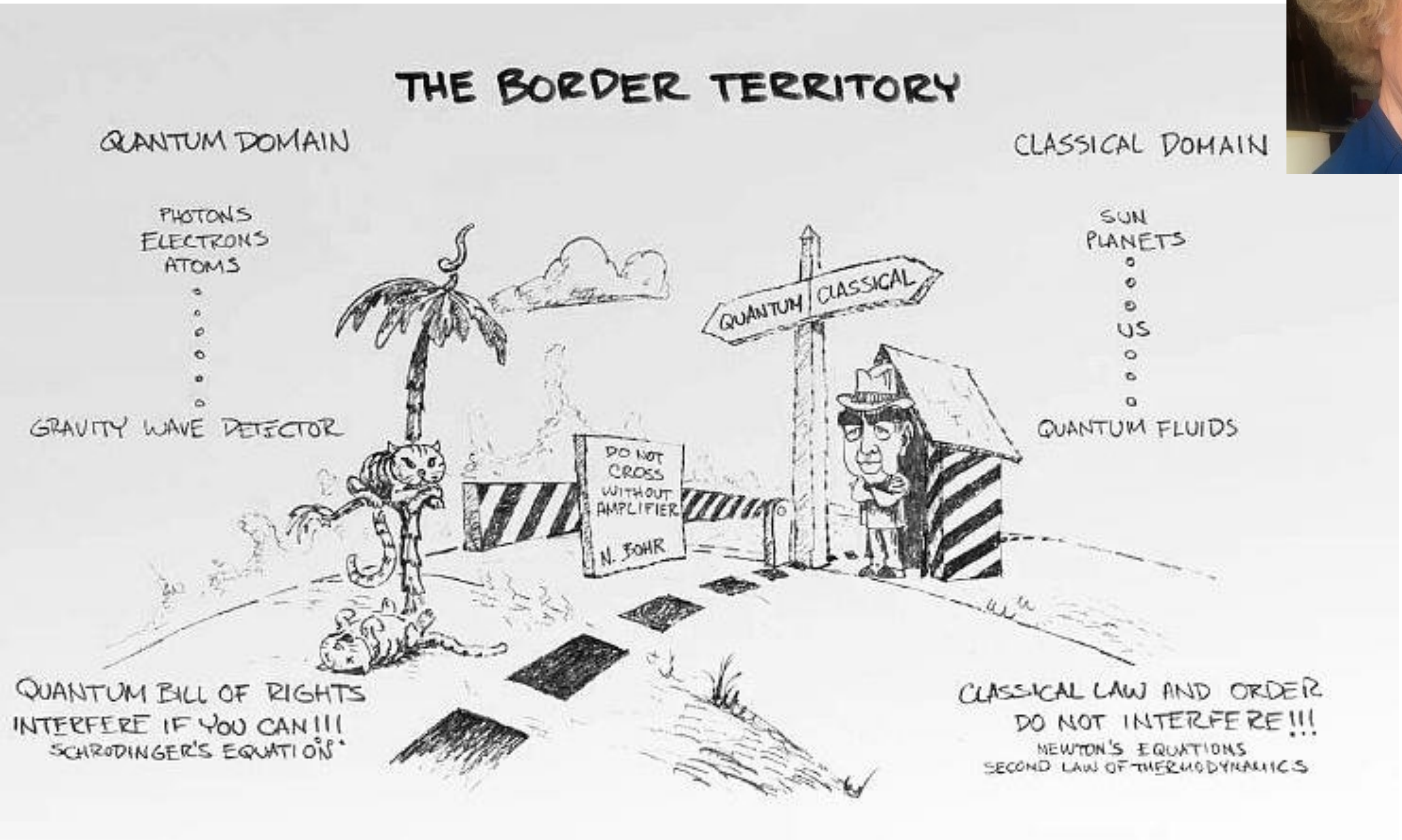
Quantum Darwinism

How does a classically objective reality emerge from an underlying quantum dynamics



Decoherence theory (pointer states etc.) tell us what sort of classical states we'll see…but not why we see them

Quantum Darwinism

nature physics

PROGRESS ARTICLE

PUBLISHED ONLINE: 2 MARCH 2009 | DOI: 10.1038/NPHYS1202

Quantum Darwinism

Wojciech Hubert Zurek*

Quantum Darwinism describes the proliferation, in the environment, of multiple records of selected states of a quantum system. It explains how the quantum fragility of a state of a single quantum system can lead to the classical robustness of states in their correlated multitude; shows how effective 'wave-packet collapse' arises as a result of the proliferation throughout the environment of imprints of the state of the system; and provides a framework for the derivation of Born's rule, which relates the probabilities of detecting states to their amplitudes. Taken together, these three advances mark considerable progress towards settling the quantum measurement problem.

Quantum Darwinism

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Environment as witness

Monitoring by the environment means that information about $\mathcal{S}$ is deposited in $\mathcal{E}$. What role does it have, and what is its fate? Decoherence theory ignores it. The environment is 'traced out'. The information it contains is treated as inaccessible and irrelevant: $\mathcal{E}$ is a place to hide the data that might endanger classicality.

Quantum Darwinism recognizes that 'tracing out' is not what we do, instead observers eavesdrop on the environment. Most of our data come from fragments of $\mathcal{E}$. The environment is a witness to the state of the system.

For example, at this very moment, you are intercepting a fraction of the photon environment emitted by a screen or scattered by a page. We never access all of $\mathcal{E}$. Tiny fractions suffice to reveal the state of various 'systems of interest'.

This insight captures the essence of quantum Darwinism: only states that produce multiple informational offspring —multiple imprints in the environment—can be found out from small fragments of $\mathcal{E}$. The origin of the emergent classicality is then not just survival of the fittest states (the idea already captured by einselection), but their ability to 'procreate', to deposit multiple records—copies of themselves—throughout $\mathcal{E}$.

The proliferation of records enables information about $\mathcal{S}$ to be extracted from many fragments of $\mathcal{E}$ (in the example above, photon $\mathcal{E}$). Thus, $\mathcal{E}$ acquires redundant records of $\mathcal{S}$. Now, many observers can find out the state of $\mathcal{S}$ independently, and without perturbing it. This is how preferred states of $\mathcal{S}$ become objective. Objective existence—a hallmark of classicality—emerges from the quantum substrate as a consequence of redundancy.

Decoherence theory was focused on the system. Its aim was to determine what states survive information leaks to $\mathcal{E}$. Now we ask: what information about the system can be found out from fragments of $\mathcal{E}$? This change of focus calls for a more realistic model of the environment (Fig. 1). Instead of a monolithic $\mathcal{E}$, we recognize that environments consist of subsystems that comprise fragments independently accessible to observers.

Quantum Darwinism

nature physics
PROGRESS ARTICLE
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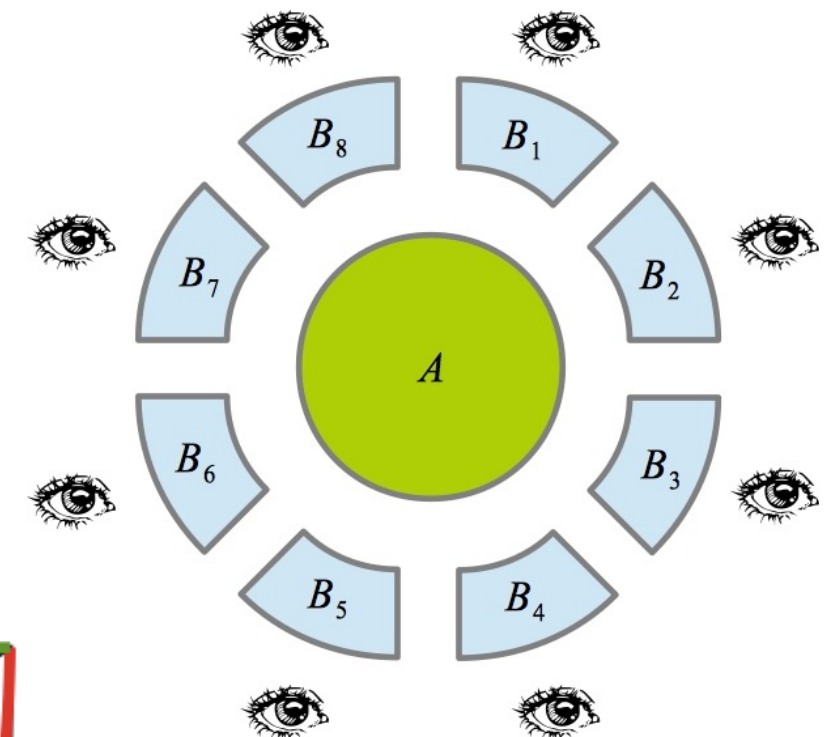
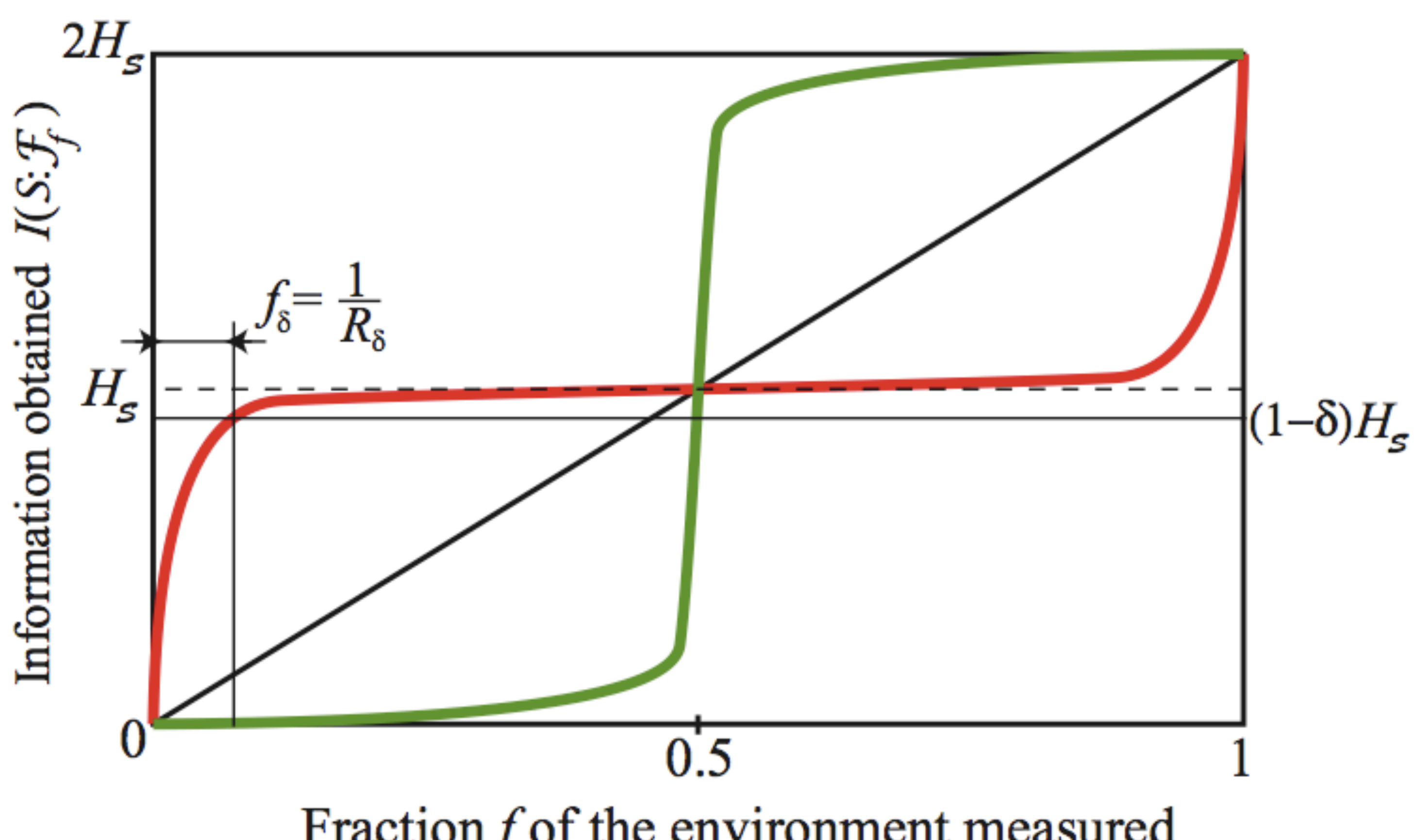
Brandão et al, Nature Communications 6, Article number: 7908 (2015)





Basics of collision models

VOLUME 88, NUMBER 9 PHYSICAL REVIEW LETTERS 4 MARCH 2002

Thermalizing Quantum Machines: Dissipation and Entanglement

Valerio Scarani,[1] Mário Ziman,[2] Peter Štelmachovič,[2] Nicolas Gisin,[1] and Vladimír Bužek[2,3]
[1]*Group of Applied Physics, University of Geneva, 20, rue de l'Ecole-de-Médecine, CH-1211 Geneva 4, Switzerland*
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[3]*Faculty of Informatics, Masaryk University, Botanická 68a, 602 00 Brno, Czech Republic*
(Received 16 October 2001; published 19 February 2002)

PHYSICAL REVIEW A, VOLUME 65, 042105

Diluting quantum information: An analysis of information transfer in system-reservoir interactions

M. Ziman,[1] P. Štelmachovič,[1] V. Bužek,[1,2] M. Hillery,[1,3] V. Scarani,[4] and N. Gisin[4]
[1]*Research Center for Quantum Information, Slovak Academy of Sciences, Dúbravská cesta 9, 842 28 Bratislava, Slovakia*
[2]*Faculty of Informatics, Masaryk University, Botanická 68a, 602 00 Brno, Czech Republic*
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[4]*Groupe de Physique Appliquée, Université de Genève, 20 rue de l'Ecole de Médecine, 1211 Genève 4, Switzerland*
(Received 23 October 2001; published 18 March 2002)

PHYSICAL REVIEW A **72**, 022110 (2005)

All (qubit) decoherences: Complete characterization and physical implementation

Mário Ziman[1,2] and Vladimír Bužek[1,3]
[1]*Research Center für Quantum Information, Slovak Academy of Sciences, Dúbravská cesta 9, 845 11 Bratislava, Slovakia*
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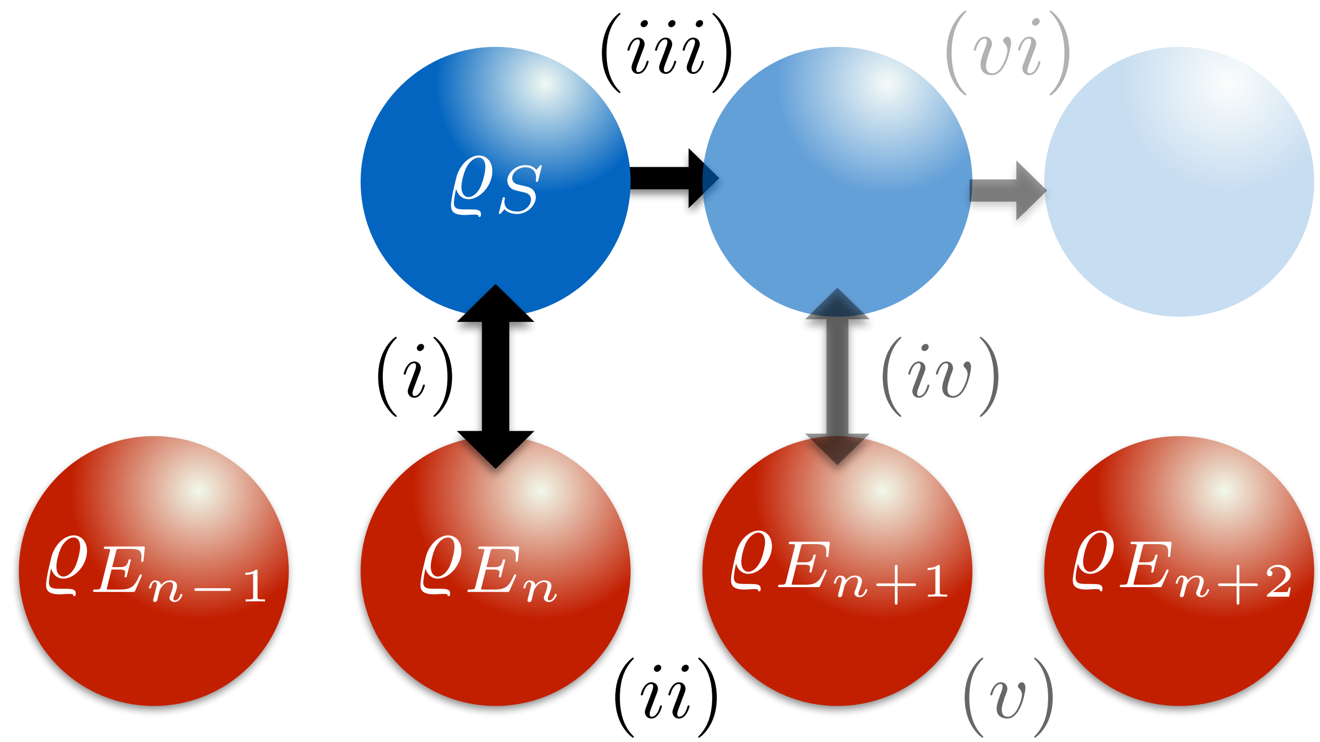
(Received 6 May 2005; published 19 August 2005)

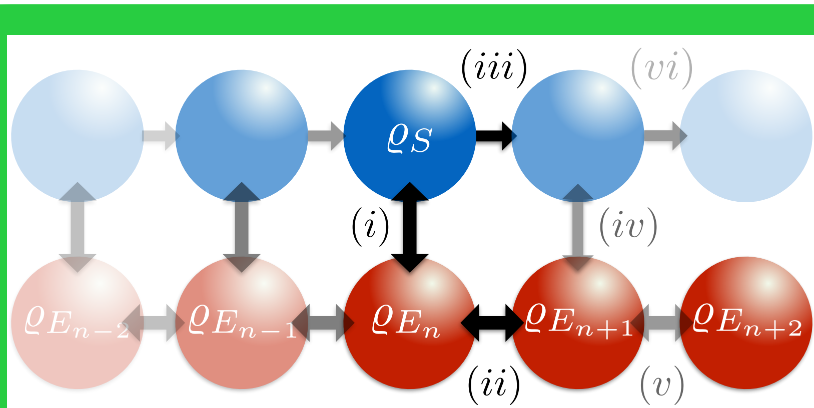


with the initial condition

$$\rho(0) = \varrho_S(0) \bigotimes_{i=1}^{N} \varrho_{E_i}$$

$$\hat{\Phi}_{S,j}[\rho] = \hat{\mathcal{U}}_{S,j}(\gamma)\,\rho\,\hat{\mathcal{U}}^{\dagger}_{S,j}(\gamma),$$

$$\hat{\Psi}_{j,j+1}[\rho] = \hat{\mathcal{E}}_{j,j+1}(\delta)\,\rho\,\hat{\mathcal{E}}^{\dagger}_{j,j+1}(\delta).$$



PHYSICAL REVIEW A **89**, 052120 (2014)

Non-Markovianity and system-environment correlations in a microscopic collision model

Ruari McCloskey and Mauro Paternostro
Centre for Theoretical Atomic, Molecular and Optical Physics, School of Mathematics and Physics, Queen's University, Belfast BT7 1NN, United Kingdom
(Received 26 February 2014; published 19 May 2014)

Basics of collision models

VOLUME 88, NUMBER 9 PHYSICAL REVIEW LETTERS

Thermalizing Quantum Machines: ...

Valerio Scarani,[1] ...
[1]Group of Ap...

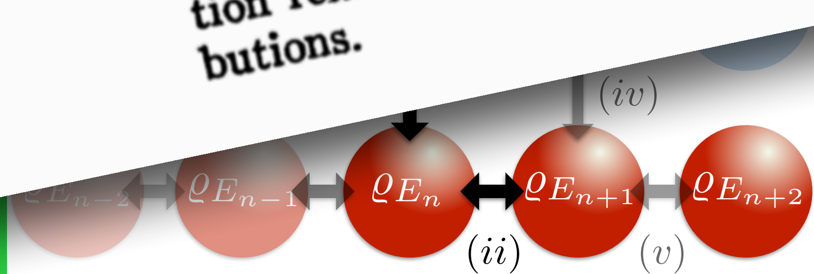
...YSICAL REVIEW VOLUME 129, NUMBER 4 15 FEBRUARY 1963

Relaxation Phenomena in Spin and Harmonic Oscillator Systems

JAYASEETHA RAU*†
Department of Physics, Brandeis University, Waltham, Massachusetts
(Received 2 August 1962)

A method is developed for generating relaxation by introducing a fundamental interval τ and a stirring hypothesis. The application to spin and harmonic oscillator systems is discussed in some detail. All the results are obtained by exact calculations without applying perturbation theory as the systems considered are simple and completely soluble. Equations similar to phenomenological Bloch equations are derived in the case of spin systems. The relaxation times obtained by the application of the theory are not only proportional to the strength of interaction, but also to the fundamental interval τ which plays an important role in the theory. It is shown that in the case of a harmonic oscillator system, an initial Boltzmann distribution relaxes to a final equilibrium Boltzman distribution through a sequence of transient Boltzman distributions.

$$\ldots = \hat{\mathcal{E}}_{j,j+1}(\delta)\, \rho\, \hat{\mathcal{E}}^{\dagger}_{j,j+1}(\delta).$$



PHYSICAL REVIEW A **89**, 052120 (2014)

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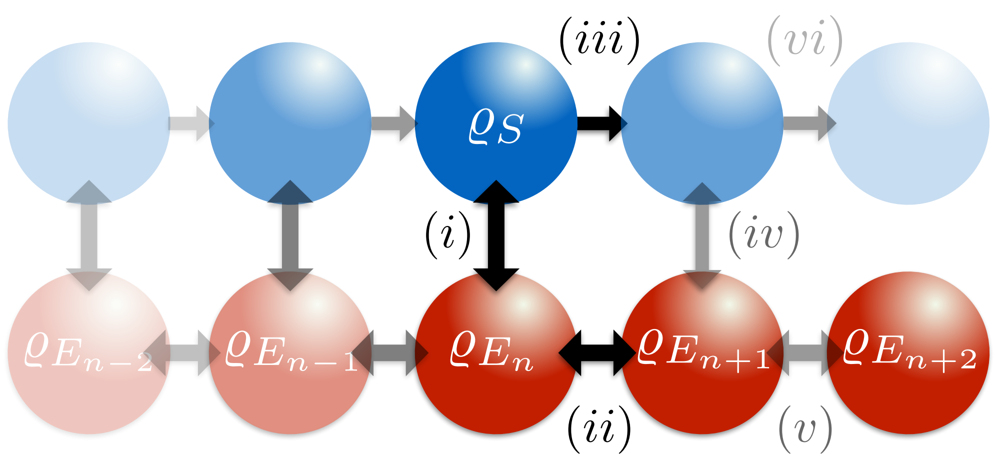
A versatile tool



PHYSICAL REVIEW A **99**, 012319 (2019)

Robust multipartite entanglement generation via a collision model

Barış Çakmak,[1,2] Steve Campbell,[3] Bassano Vacchini,[4,3] Özgür E. Müstecaplıoğlu,[1] and Mauro Paternostro[5]
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[2]*College of Engineering and Natural Sciences, Bahçeşehir University, Beşiktaş, Istanbul 34353, Turkey*
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[4]*Dipartimento di Fisica "Aldo Pontremoli", Università degli Studi di Milano, via Celoria 16, 20133 Milan, Italy*
[5]*Centre for Theoretical Atomic, Molecular and Optical Physics, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, United Kingdom*

(Received 13 July 2018; published 14 January 2019)

Effective scheme for generating entanglement between disjoint registers

PHYSICAL REVIEW A **98**, 012142 (2018)

System-environment correlations and Markovian embedding of quantum non-Markovian dynamics

Steve Campbell,[1] Francesco Ciccarello,[2,3] G. Massimo Palma,[2,3] and Bassano Vacchini[4,1]
[1]*Istituto Nazionale di Fisica Nucleare, Sezione di Milano, via Celoria 16, 20133 Milan, Italy*
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IOP Institute of Physics
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PAPER

Precursors of non-Markovianity

Steve Campbell[1,2], Maria Popovic[2], Dario Tamascelli[3,4] and Bassano Vacchini[1,3]
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Keywords: open quantum systems, non-Markovian quantum dynamics, collision models, system-environment correlations

Natural to introduce a notion of "memory depth" that *may* be related to other frameworks

PHYSICAL REVIEW A **99**, 042103 (2019)

Collisional unfolding of quantum Darwinism

Steve Campbell,[1,2] Barış Çakmak,[3,4] Özgür E. Müstecaplıoğlu,[3] Mauro Paternostro,[5] and Bassano Vacchini[6,1]
[1]*Istituto Nazionale di Fisica Nucleare, Sezione di Milano, via Celoria 16, 20133 Milan, Italy*
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[4]*College of Engineering and Natural Sciences, Bahçeşehir University, Beşiktaş, Istanbul 34353, Turkey*
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(Received 30 December 2018; published 3 April 2019)

Most correlations are not important for the dynamical characterisation

Same correlations are vital for a thermodynamic description

Non-equilibrium steady-states of memoryless quantum collision models

Giacomo Guarnieri,[1,*] Daniele Morrone,[2] Barış Çakmak,[3] Francesco Plastina,[2,4] and Steve Campbell[5]
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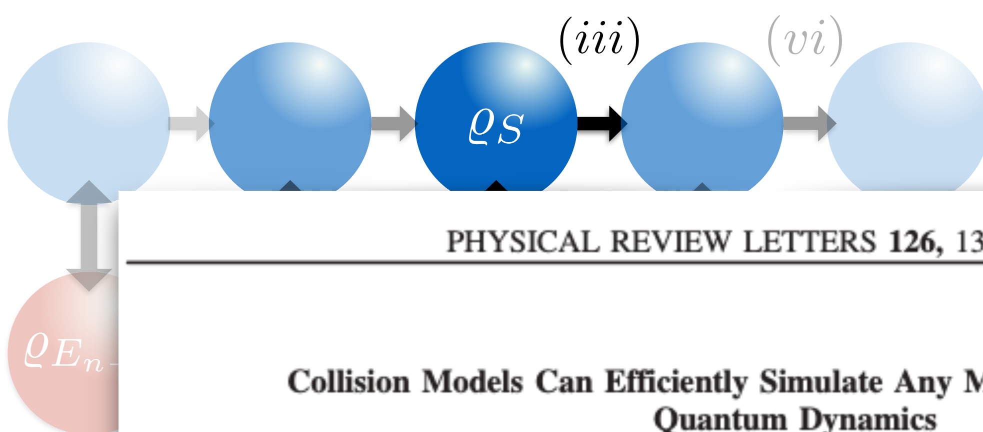
[4]*INFN-Gruppo Collegato di Cosenza, 87036, Cosenza, Italy*
[5]*School of Physics, University College Dublin, Belfield, Dublin 4, Ireland*
(Dated: February 7, 2020)

Freedom to explore the steady states available from a generic collision model dynamics

Natural setting to explore/test Darwinism

Requirement for sufficient "mutual dephasing" to occur -> large correlations established

A versatile tool



PHYSICAL REVIEW LETTERS **126**, 130403 (2021)

Collision Models Can Efficiently Simulate Any Multipartite Markovian Quantum Dynamics

Marco Cattaneo,[1,2,3,*] Gabriele De Chiara,[4] Sabrina Maniscalco,[3,2,5] Roberta Zambrini,[1] and Gian Luca Giorgi

PHYSICAL REVIEW A **99**, 012319 (2019)

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PHYSICAL REVIEW A 9

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(Received 28 May 2018; publi

arXiv.org > quant-ph > arXiv:2012.10236

Quantum Physics

[Submitted on 18 Dec 2020 (v1), last revised 16 Apr 2021 (this version, v2)]

Periodically refreshed baths to simulate open quantum many-body dynamics

Archak Purkayastha, Giacomo Guarnieri, Steve Campbell, Javier Prior, John Goold

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(Received 30 December 2018; published 3 April 2019)

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(Dated: February 7, 2020)

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Collisions EVERYWHERE!

New J. Phys. 20 (2018) 113024 https://doi.org/10.1088/1367-2630/aaecee

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PAPER

Reconciliation of quantum local master equations with thermodynamics

Gabriele De Chiara[1,2,7], Gabriel Landi[3], Adam Hewgill[1], Brendan Reid[1], Alessandro Ferraro[1], Augusto J Roncaglia[4] and Mauro Antezza[2,5,6]

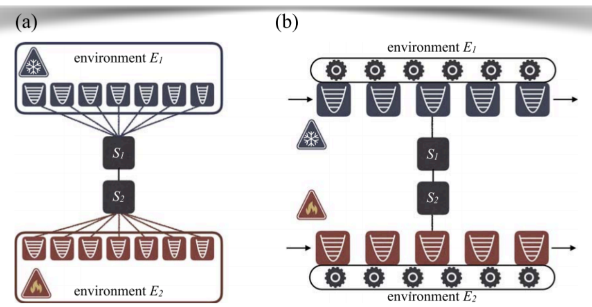

Figure 1. We consider in this paper a system S composed of several sub-systems $S_1, \ldots, S_N$ (in the figure $N = 2$). Each subsystem S_i is connected to a local environment E_i prepared in a different temperature T_i. (a) The standard bosonic heat bath model: the environment is assumed to consist of an ensemble of independent quantum harmonic oscillators with different frequencies in thermal equilibrium and coupled permanently to the system. (b) In this paper we focus instead on the framework of the repeated interactions method: the environment E_i is divided into a series of ancillas (in this case represented by individual bosonic modes with identical frequencies) which interact with S_i sequentially. This type of method leads to local master equations (LMEs), irrespective of the internal interactions between S_i and S_j.

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ARTICLE OPEN

IBM Q Experience as a versatile experimental testbed for simulating open quantum systems

Guillermo García-Pérez[1,2,4*], Matteo A. C. Rossi[1,4] and Sabrina Maniscalco[1,3]

SCIENTIFIC REPORTS

OPEN

All-optical implementation of collision-based evolutions of open quantum systems

Received: 18 September 2018
Accepted: 25 January 2019

Álvaro Cuevas[1], Andrea Geraldi[1], Carlo Liorni[1,2], Luís Diego Bonavena[1], Antonella De Pasquale[3,4], Fabio Sciarrino[1], Vittorio Giovannetti[5] & Paolo Mataloni[1]

PRL 115, 120403 (2015) PHYSICAL REVIEW LETTERS

Landauer's Principle in Multipartite Open Quantum System Dynamics

S. Lorenzo,[1,2,3] R. McCloskey,[4] F. Ciccarello,[5] M. Paternostro,[4] and G. M. Palma[5]
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[5]*NEST, Istituto*

(Received 10 Ap

PHYSICAL REVIEW A 94, 012106 (2016)

Collision model for non-Markovian quantum dynamics

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Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden, Germany
(Received 9 March 2016; published 8 July 2016)

PHYSICAL REVIEW A 98, 032308 (2018)

Quantum Zeno effect in correlated qubits

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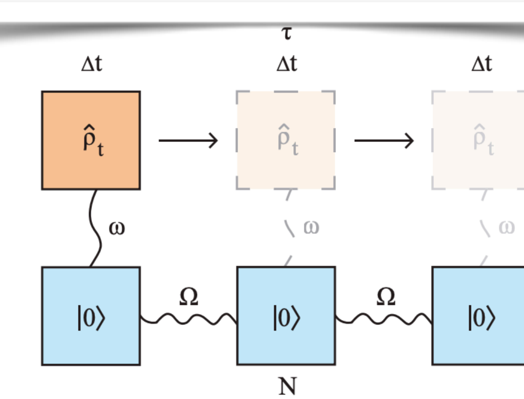
[2]*Department of Physics, University of Maryland Baltimore County, Baltimore, Maryland 21250, USA*

(Received 22 May 2018; published 10 September 2018)



PHYSICAL REVIEW LETTERS 126, 130403 (2021)

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Marco Cattaneo,[1,2,3,*] Gabriele De Chiara,[4] Sabrina Maniscalco,[3,2,5] Roberta Zambrini,[1] and Gian Luca Giorgi

arXiv.org > quant-ph > arXiv:2012.10236

Quantum Physics

[Submitted on 18 Dec 2020 (v1), last revised 16 Apr 2021 (this version, v2)]

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Archak Purkayastha, Giacomo Guarnieri, Steve Campbell, Javier Prior, John Goold

PHYSICAL REVIEW E 99, 042103 (2019)

Nonequilibrium dynamics with finite-time repeated interactions

Stella Seah,[1] Stefan Nimmrichter,[2] and Valerio Scarani[1,2]
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(Received 18 September 2018; published 2 April 2019)

Implications of non-Markovian dynamics on information-driven engine

Obinna Abah[1,*] and Mauro Paternostro[1,†]
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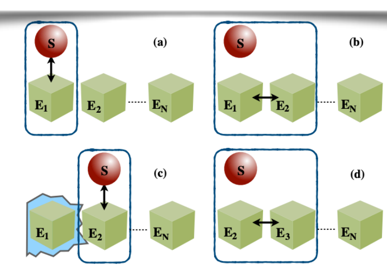

FIG. 2. Schematic of non-Markovian dynamics via collision model for nearest sub-environment collisions. The system and the sub-environment particles are initially uncorrelated. In the first step (a), the system S interacts with E_1. The next step, (b) E_1 interacts with E_2 and thereby correlating the system and particles E_1 and E_2. Then step (c), E_1 is traced away. After which the system interacts with E_2 before isolating the system for measurement and feedback processes in strategy 1. For the strategy 2, the system and sub-environment particles collisional iterations are performed up to E_3, (a) - (d), before the measurement and feedback.

PHYSICAL REVIEW X 7, 021003 (2017)

Quantum and Information Thermodynamics: A Unifying Framework Based on Repeated Interactions

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Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany

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(Received 9 October 2016; revised manuscript received 17 January 2017; published 7 April 2017)

PHYSICAL REVIEW APPLIED 14, 054005 (2020)

Exponential Improvement for Quantum Cooling through Finite-Memory Effects

Philip Taranto,[*] Faraj Bakhshinezhad,[†] Philipp Schüttelkopf, Fabien Clivaz,[‡] and Marcus Huber[§]
Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, Vienna 1090, Austria

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Collisions EVERYWHERE!

epl A LETTERS JOURNAL EXPLORING THE FRONTIERS OF PHYSICS

PERSPECTIVE • OPEN ACCESS

Collision models in open system dynamics: A versatile tool for deeper insights?

Steve Campbell[1,2] and Bassano Vacchini[3,4]

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EPL (Europhysics Letters), Volume 133, Number 6

Perspective

Citation Steve Campbell and Bassano Vacchini 2021 *EPL* **133** 60001

Article PDF

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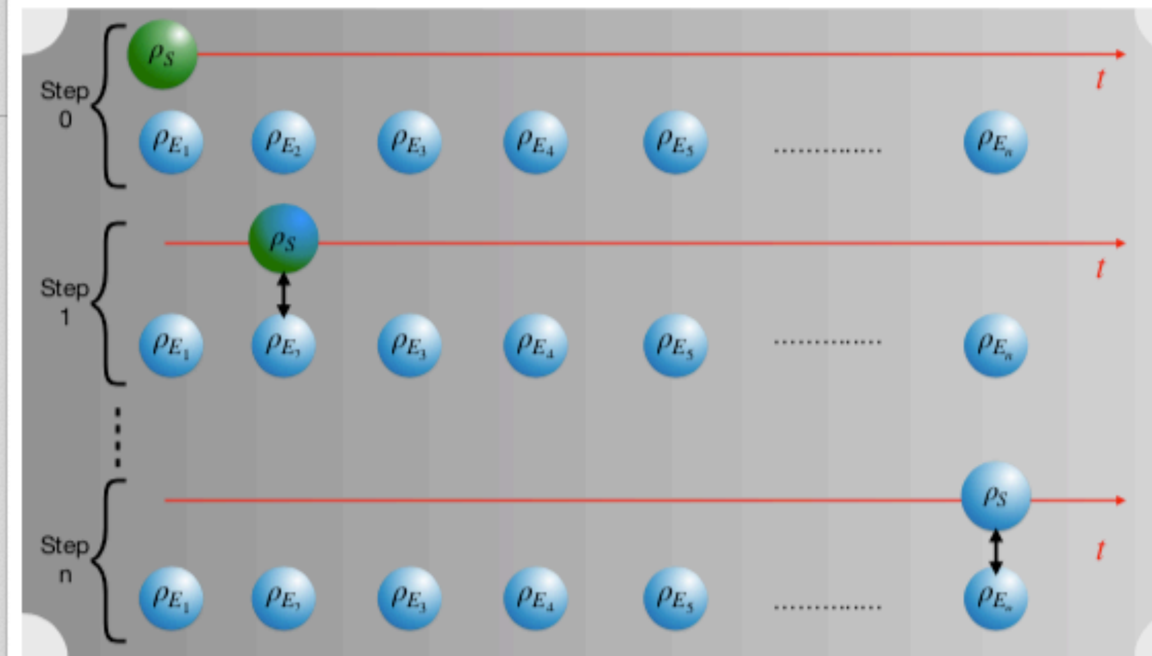

Fig. 1: CM schematics for the basic setting in which the system thermalises, with growing number of interactions, in a Markovian manner with the environment. The arrows denote time as described by number of collisions.

Ciccarello, Lorenzo, Giovannetti, Palma,
Quantum collision models: Open system dynamics from repeated interactions
To Appear 2021

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Quantum Darwinism in a collision model

Spin-star set up — CM allows to explore the role of the interaction

PHYSICAL REVIEW A 99, 042103 (2019)

Collisional unfolding of quantum Darwinism

Steve Campbell,[1,2] Barış Çakmak,[3,4] Özgür E. Müstecaplıoğlu,[3] Mauro Paternostro,[5] and Bassano Vacchini[6,1]
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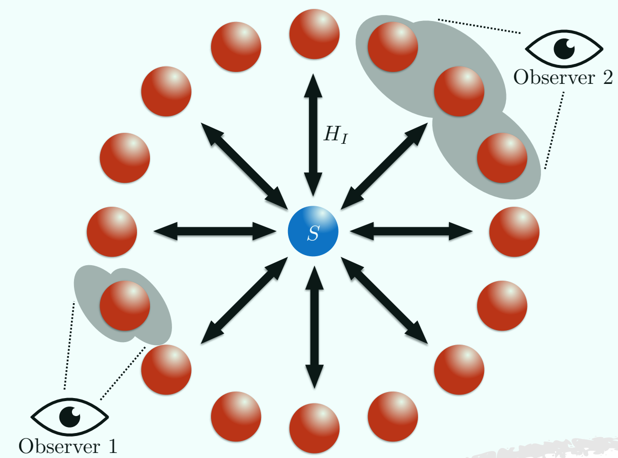
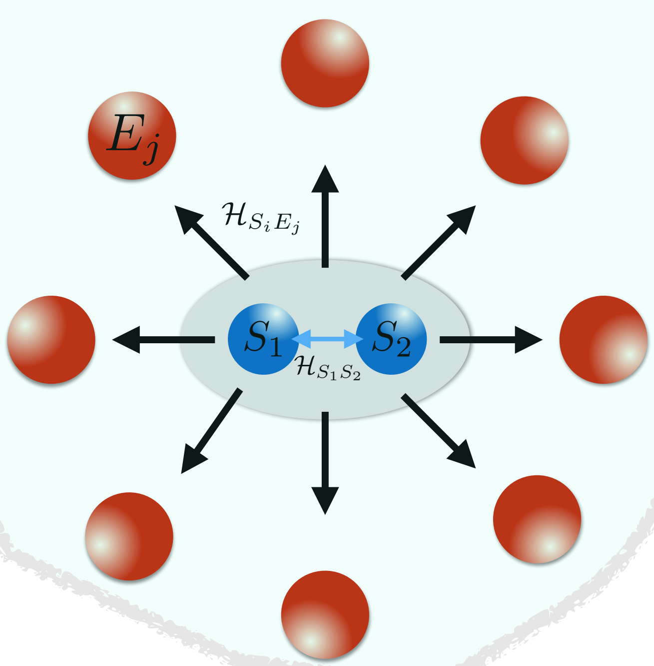


$$|\psi_0\rangle = |\phi_S\rangle \bigotimes_{k=1}^{N} |\Phi_k\rangle$$

$$H_{SE_k} = \sum_{j=x,y,z} J_j \left(\sigma_S^j \otimes \sigma_{E_k}^j\right)$$

Quantum Darwinism in a composite system: Objectivity versus classicality

Barış Çakmak,[1] Özgür E. Müstecaplıoğlu,[2] Mauro Paternostro,[3] Bassano Vacchini,[4,5] and Steve Campbell[6,7]



arXiv:2011.13385

Quantum Darwinism in a structured spin environment

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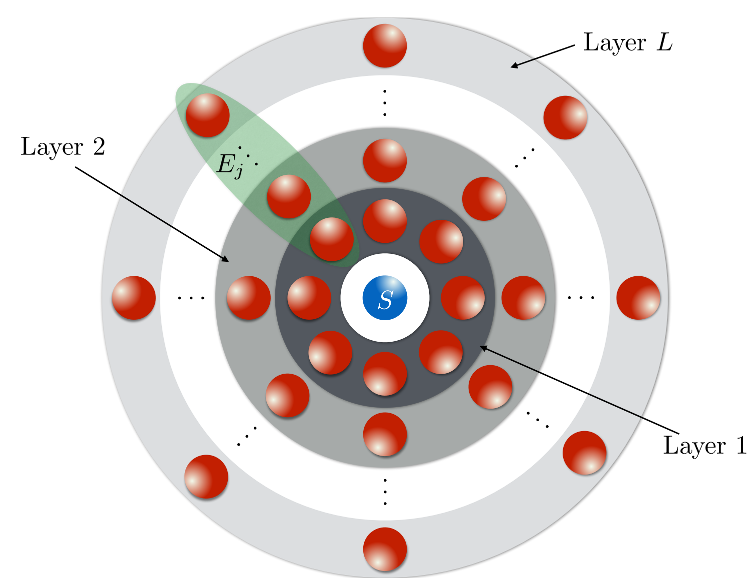
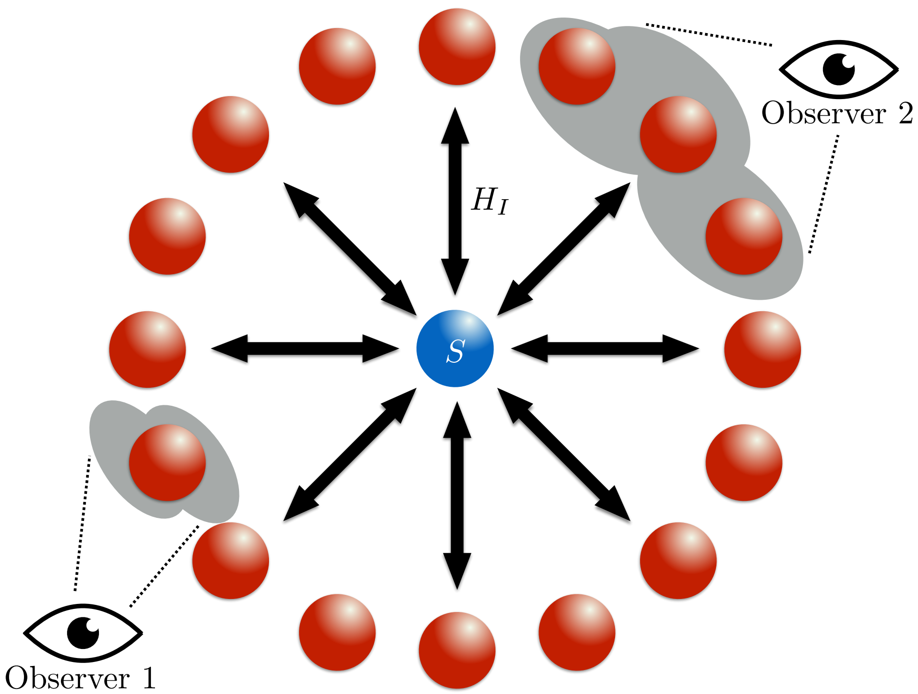
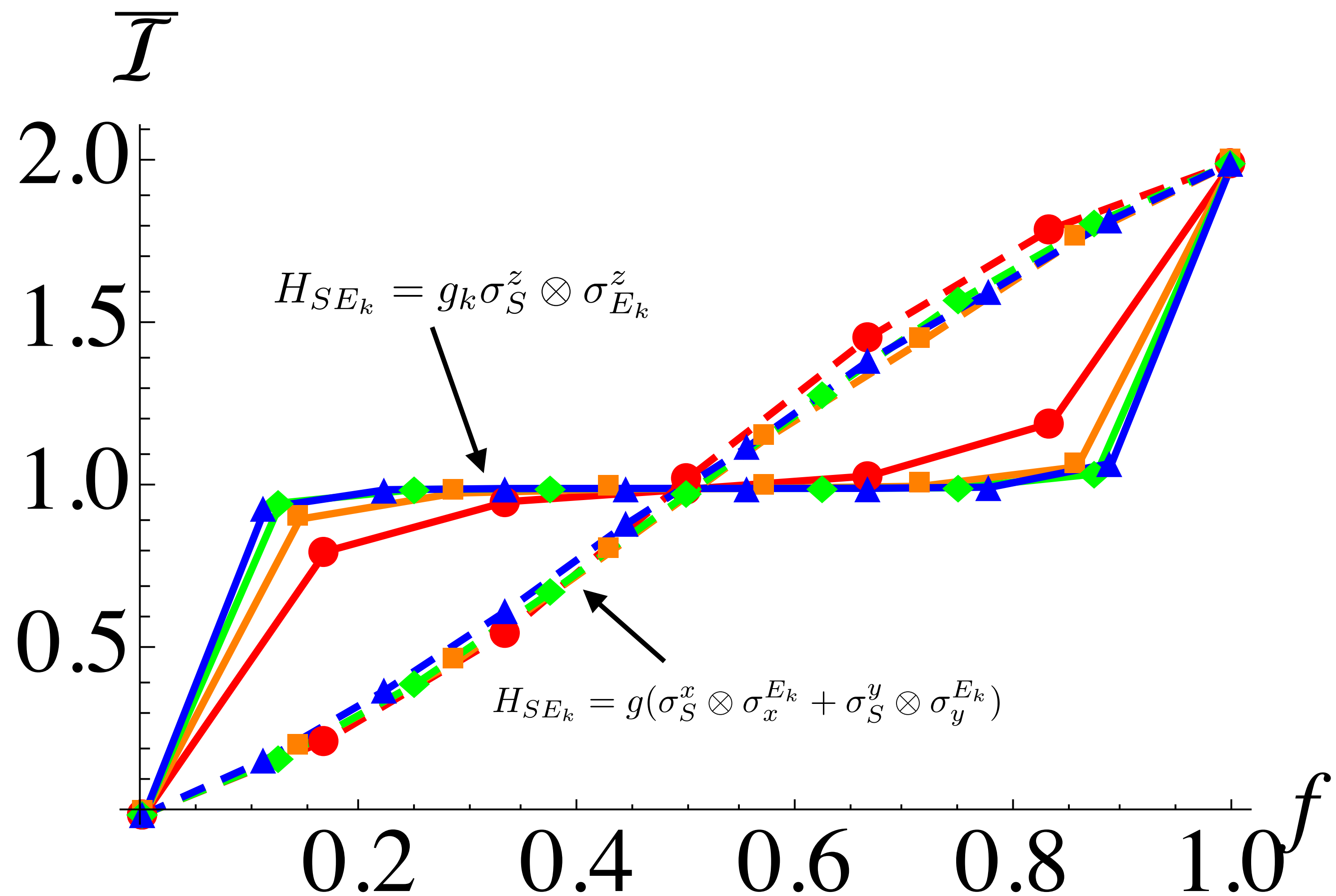
[1]*Centre for Theoretical Atomic, Molecular, and Optical Physics, School of Mathematics and Physics, Queen's University, Belfast BT7 1NN, United Kingdom*
[2]*School of Physics, University College Dublin, Belfield, Dublin 4, Ireland*



Quantum Darwinism in a collision model





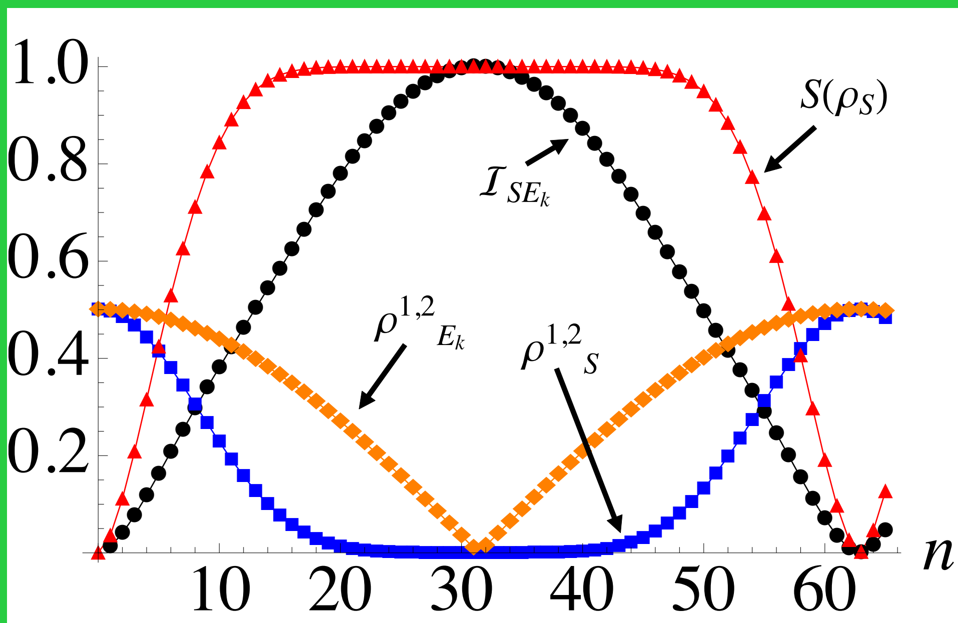
$$H_{SE_k} = g_k \sigma_S^z \otimes \sigma_{E_k}^z \quad \Longrightarrow \quad |\psi\rangle = \alpha|\uparrow\rangle_S \bigotimes_{k=1}^{N} |\Phi_{+k}\rangle + \beta|\downarrow_S\rangle \bigotimes_{k=1}^{N} |\Phi_{-k}\rangle$$

$$|\Phi_{\pm k}\rangle = e^{\mp i \sum_j g_{j,k}} \left(|\uparrow_k\rangle + e^{\pm 2i \sum_j g_{j,k}} |\downarrow_k\rangle \right) / \sqrt{2}$$

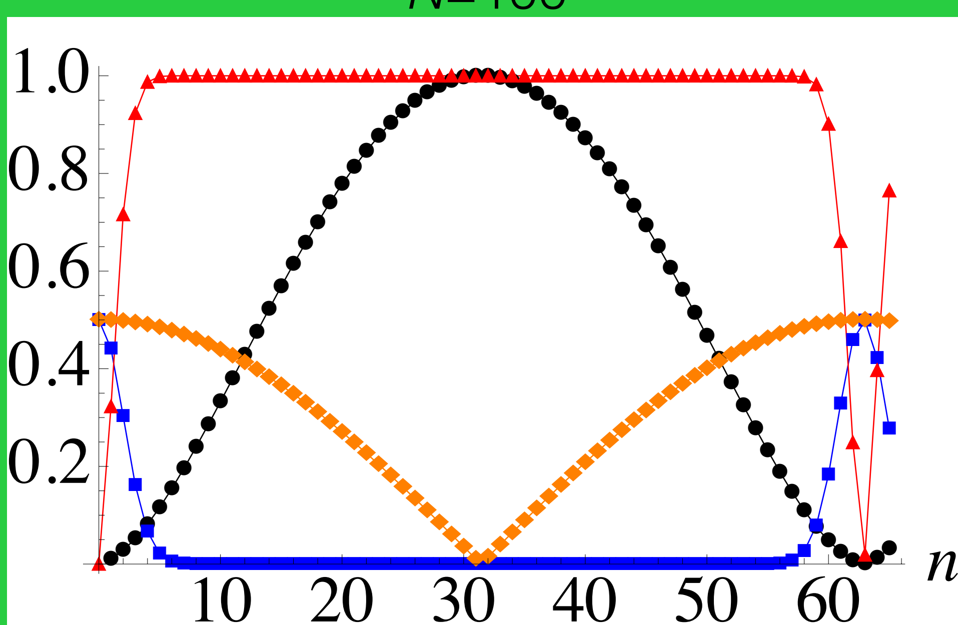
Dephasing builds up the "right" correlations needed for redundancy

Quantum Darwinism in a collision model

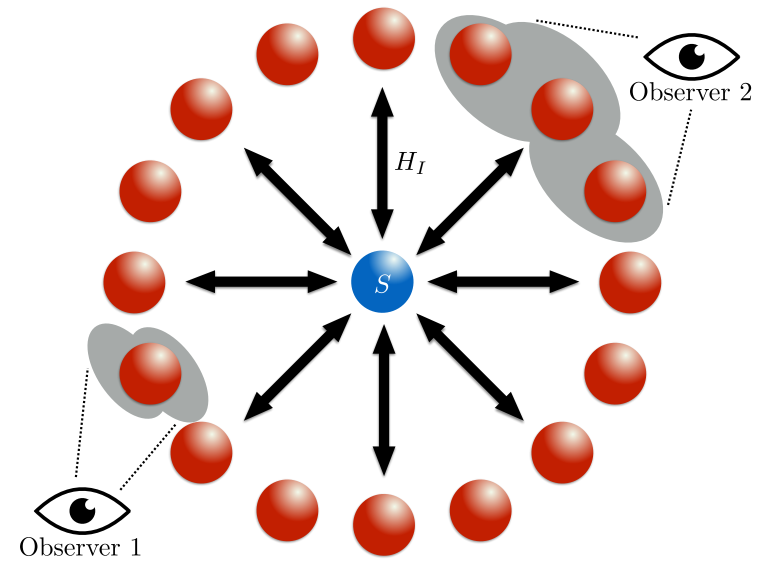
Small environment N=6



N=100

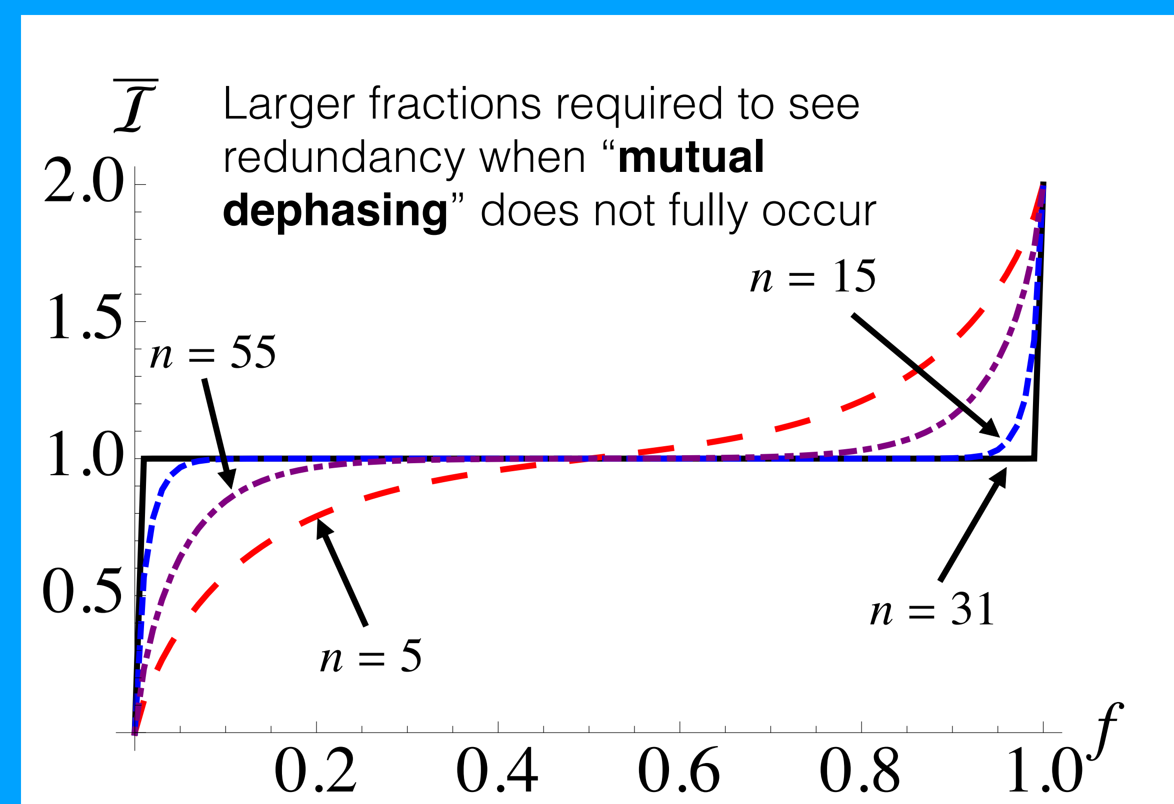


Full decoherence of the system is not enough — we require a mutual dephasing before perfect redundant encoding is achieved.



$$H_{SE} = \sigma_z^S \otimes \sigma_z^{E_i}$$

$$|\Psi_0\rangle = |\psi_S\rangle \bigotimes_{E_i} |+\rangle$$

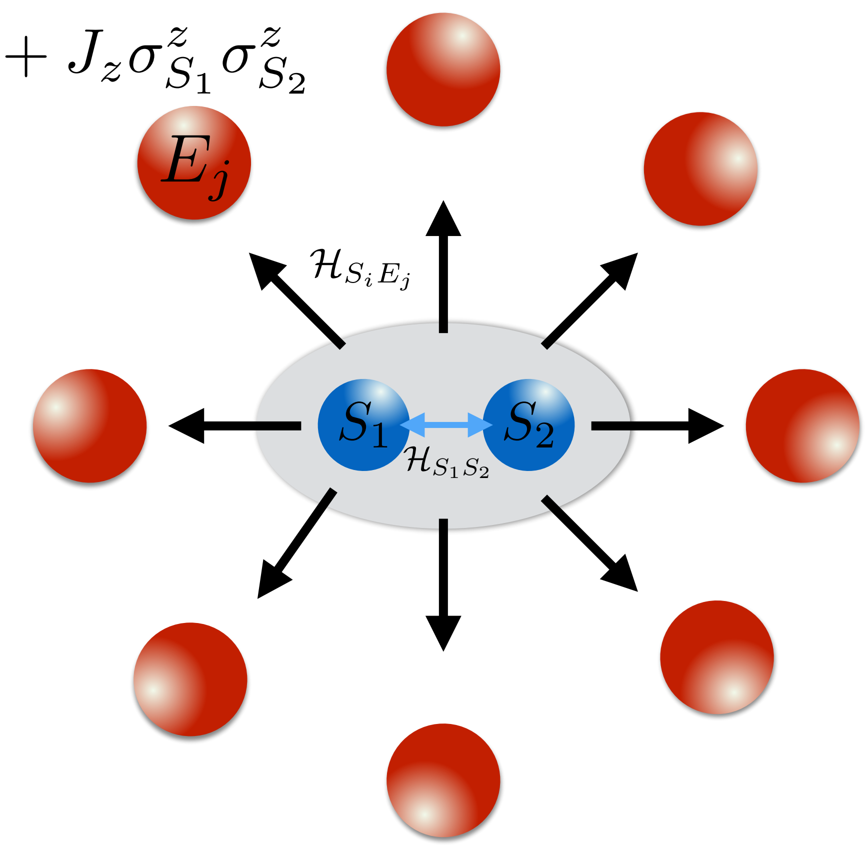


Complementarity of quantum discord and classically accessible information, M. Zwolak & W. H. Zurek Sci Rep 3, 1729 (2013)
Decoherence without entanglement and quantum Darwinism, García-Pérez et al Phys. Rev. Research 2 012061(R) (2020)

Quantum Darwinism for a composite system

$$H_{S_1S_2} = J(\sigma^x_{S_1}\sigma^x_{S_2} + \sigma^y_{S_1}\sigma^y_{S_2}) + J_z\sigma^z_{S_1}\sigma^z_{S_2}$$

$$H_{S_iE_k} = J_{SE}\sigma^z_{S_i}\sigma^z_{E_k}$$



$$|\Phi_k\rangle = \frac{1}{\sqrt{2}}(|0_k\rangle + |1_k\rangle)$$

$$|\Psi_0\rangle = |\phi_{S_1}\rangle \otimes |\phi_{S_2}\rangle \bigotimes_{k=1}^{N} |\Phi_k\rangle$$

$$|\Psi\rangle = e^{-iNtJ_z}\alpha|00\rangle \bigotimes_{k=1}^{N}\frac{1}{\sqrt{2}}\left(e^{-i2tJ_{SE}}|0_k\rangle + e^{i2tJ_{SE}}|1_k\rangle\right)$$

$$+ e^{iNtJ_z}(\beta\cos(tJ) - i\gamma\sin(tJ))\,|01\rangle \bigotimes_{k=1}^{N}\frac{1}{\sqrt{2}}(|0_k\rangle + |1_k\rangle)$$

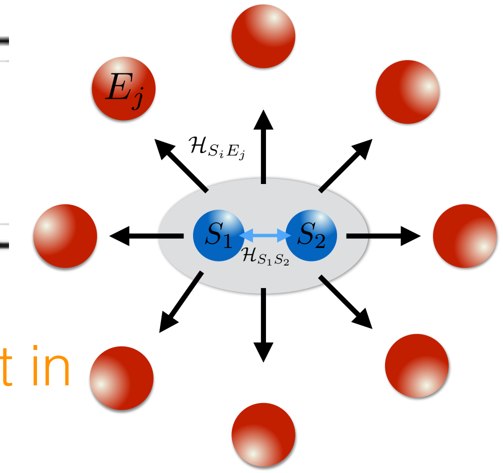
$$+ e^{iNtJ_z}(\gamma\cos(tJ) - i\beta\sin(tJ))\,|10\rangle \bigotimes_{k=1}^{N}\frac{1}{\sqrt{2}}(|0_k\rangle + |1_k\rangle)$$

$$+ e^{-iNtJ_z}\delta|11\rangle \bigotimes_{k=1}^{N}\frac{1}{\sqrt{2}}\left(e^{i2tJ_{SE}}|0_k\rangle + e^{-i2tJ_{SE}}|1_k\rangle\right)$$

Tell tale Darwinistic features

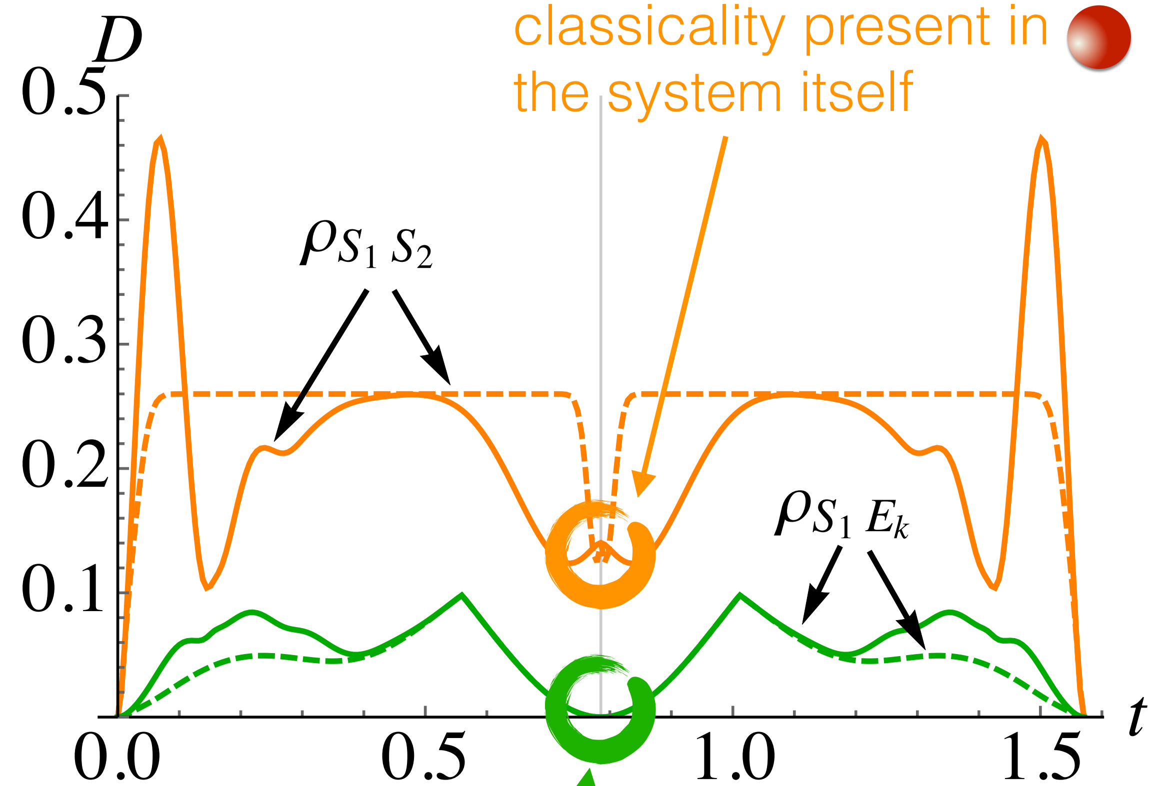
Decoherence free subspace

Quantum Darwinism in a collision model



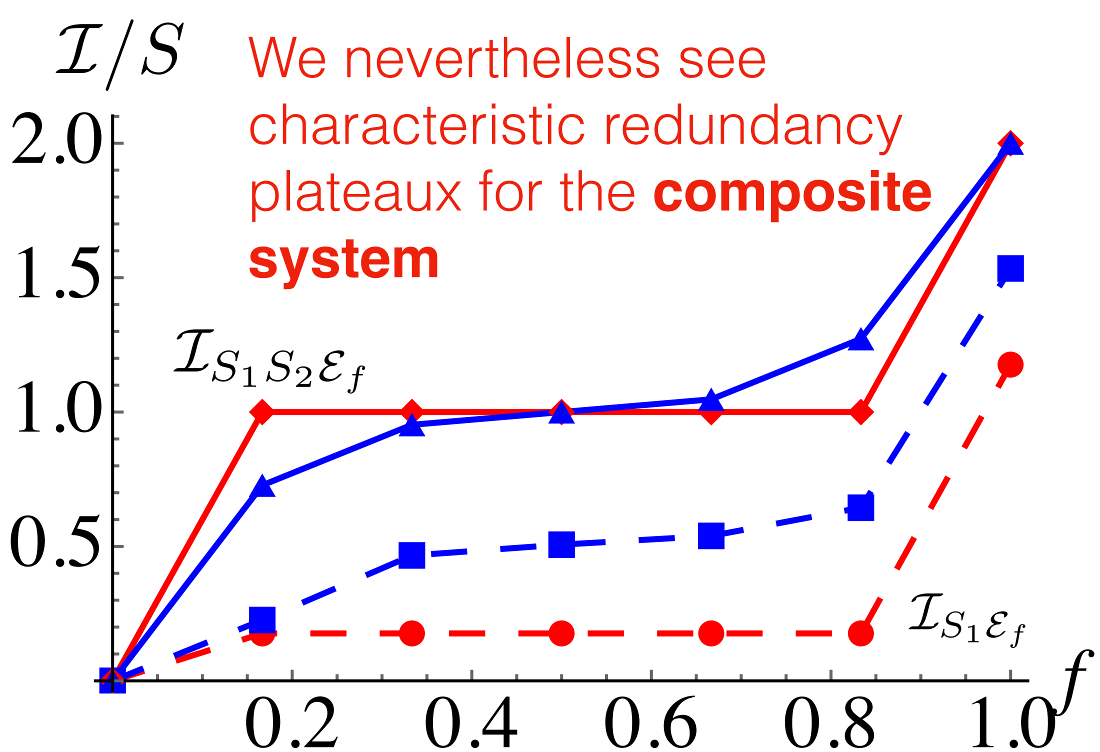
$$\rho_{S_1 S_2} = \begin{pmatrix} \alpha^2 & 0 & 0 & \alpha\delta \\ 0 & \beta^2 & \beta\gamma & 0 \\ 0 & \beta\gamma & \gamma^2 & 0 \\ \alpha\delta & 0 & 0 & \delta^2 \end{pmatrix}$$

Significant non-classicality present in the system itself

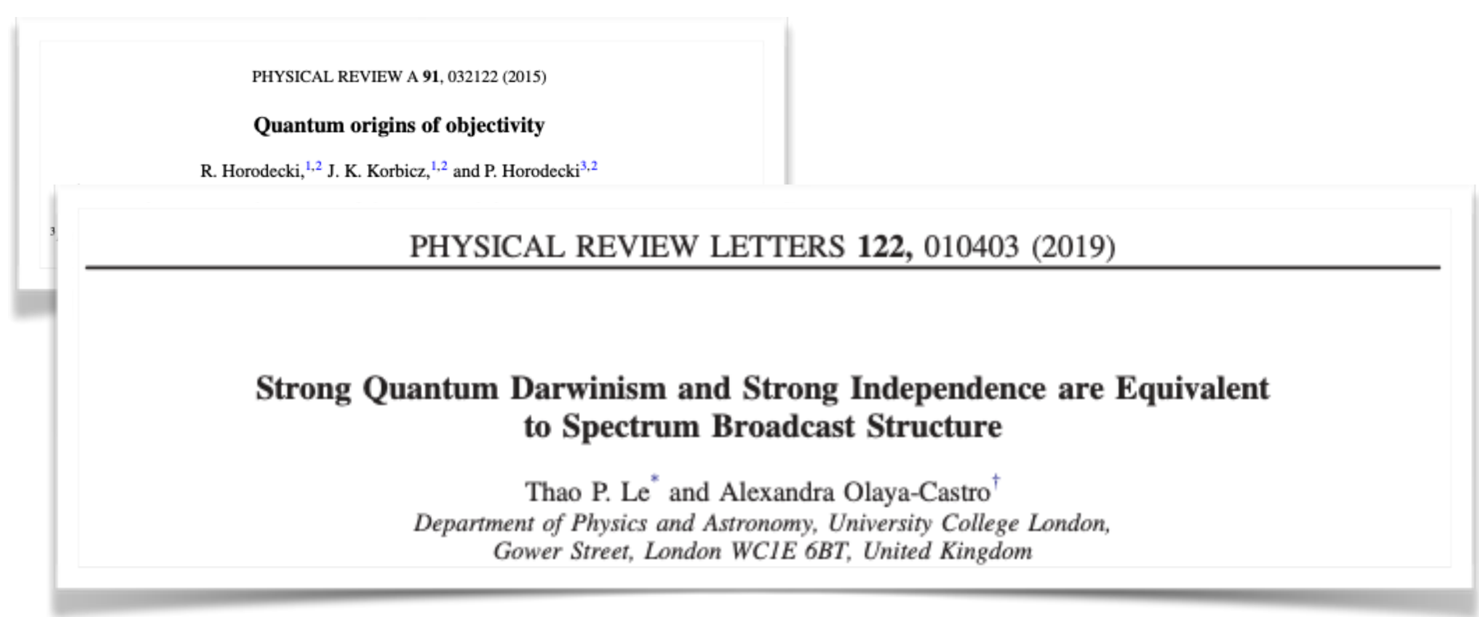


Vanishing discord shared between **one** of the system constituents and the environment

We nevertheless see characteristic redundancy plateaux for the **composite system**



Reduced single system shows redundancy but **not** all the relevant system information is shared with the environment



PHYSICAL REVIEW A **91**, 032122 (2015)

Quantum origins of objectivity

R. Horodecki,[1,2] J. K. Korbicz,[1,2] and P. Horodecki[3,2]

PHYSICAL REVIEW LETTERS **122,** 010403 (2019)

Strong Quantum Darwinism and Strong Independence are Equivalent to Spectrum Broadcast Structure

Thao P. Le[*] and Alexandra Olaya-Castro[†]

Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom

Objectivity vs. Classicality

Quantum discord is an asymmetric quantity therefore who should we be performing measurements on?

PHYSICAL REVIEW LETTERS **122**, 010403 (2019)

Strong Quantum Darwinism and Strong Independence are Equivalent to Spectrum Broadcast Structure

Thao P. Le[*] and Alexandra Olaya-Castro[†]
Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom

arXiv.org > quant-ph > arXiv:2007.04276

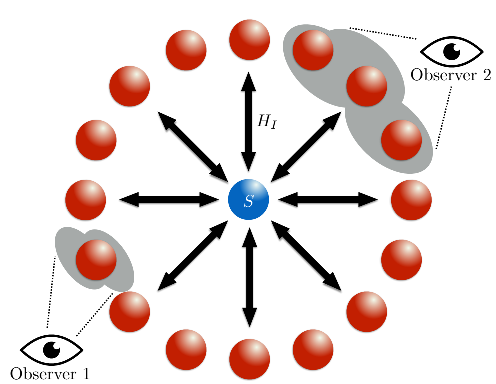
Quantum Physics

[Submitted on 8 Jul 2020]

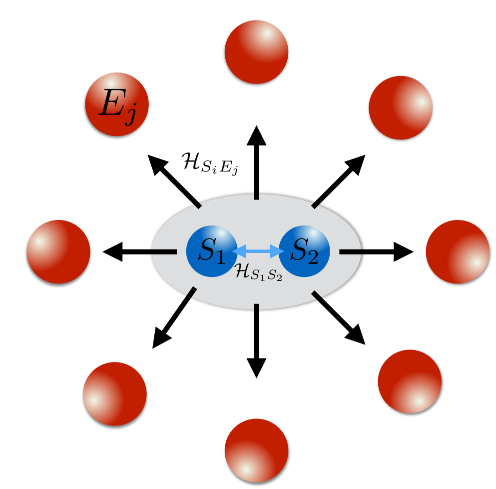
Roads to objectivity: Quantum Darwinism, Spectrum Broadcast Structures, and Strong quantum Darwinism

J. K. Korbicz

The problem of objectivity, i.e. how to explain on quantum grounds the objective character of the macroscopic world, is one of the aspects of the celebrated quantum-to-classical transition. Initiated by W. H. Zurek and collaborators, this problem gained some attention recently with several approaches being developed. The aim of this paper is to compare three of them: quantum Darwinism, Spectrum Broadcast Structures, and strong quantum Darwinism. I will concentrate solely on foundations, analyzing how the three approaches realize the idea of objectivity and how they are related to each other. I will also briefly comment on the recent quantum Darwinism experiments.



Arguably we should focus on what type of correlations are available when only the environment fragments are measured

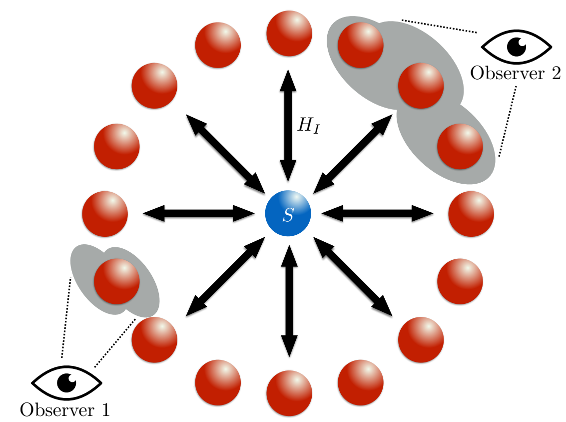


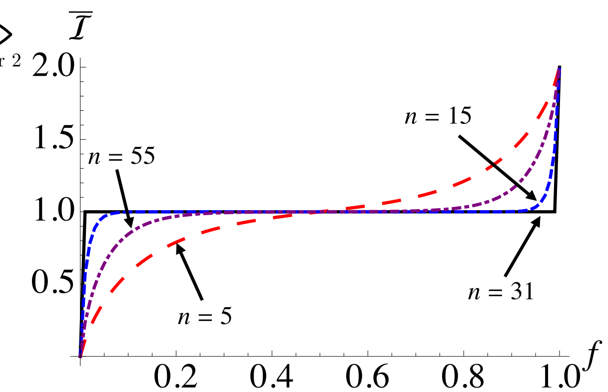
Overall **Quantum-Classical** State!
Environment's perspective = objective and fully classical
System's perspective = non-classical but (maybe??) objective

A. Touil, B. Yan, D. Girolami, S. Deffner, and W. Zurek, To appear 2021

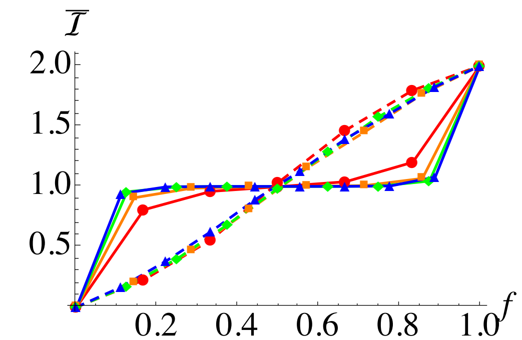
Take away message(s)

Mutual dephasing needed associated with the build up of the “right” correlations for redundant proliferation

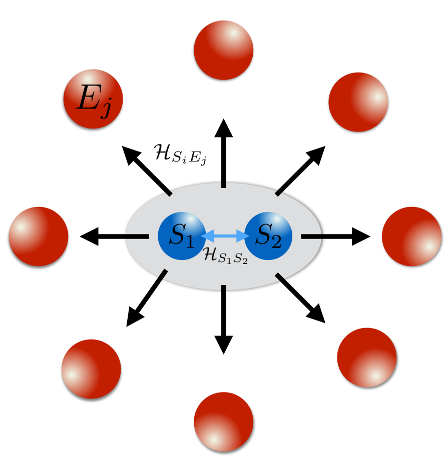




But delicately dependent on nature of the interaction, uniformity etc.

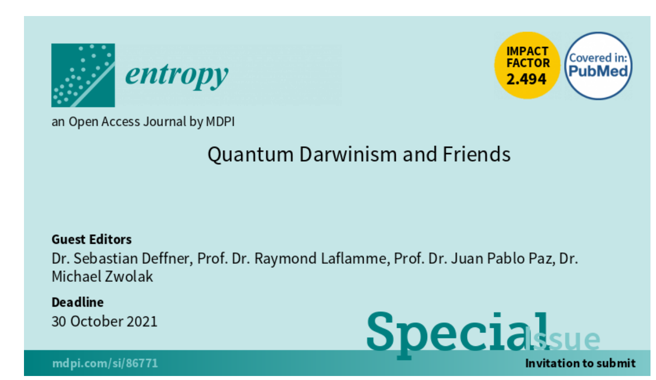


SC et al, PRA 99, 042103 (2019)



Composite systems throw up additional questions regarding classicality vs. objectivity

Barış Çakmak et al, To Appear 2021



Collision models are great craic
SC & BV EPL 133, 60001 (2021)