UNIVERSITÀ DEGLI STUDI DI MILANO
DIPARTIMENTO DI FISICA

BELL
Fundamental Problems in Quantum Physics

Dipartimento di Fisica
Università degli Studi di Milano

INFN
Sezione di Milano

Consiglio Sezione INFN

Milano, Luglio 2023

Outline

- General infos on BELL
- Quantum thermodynamics
- Collaborations and publications

BELL

- Involved units:

  Trieste (Angelo Bassi)

  Genova

  Parma

  Pavia

  Milano

  Trento

BELL

UNIVERSITÀ
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DI MILANO

Mathematics Department (field theory and general relativity)

Livio Pizzocchero

POLITECNICO
MILANO 1863

Mathematics Department (quantum measurement)

Alberto Barchielli

Alessandro Toigo

Davide Fermi

BELL

- Members of Milan unit:

Physics Department (open quantum systems)

Bassano Vacchini

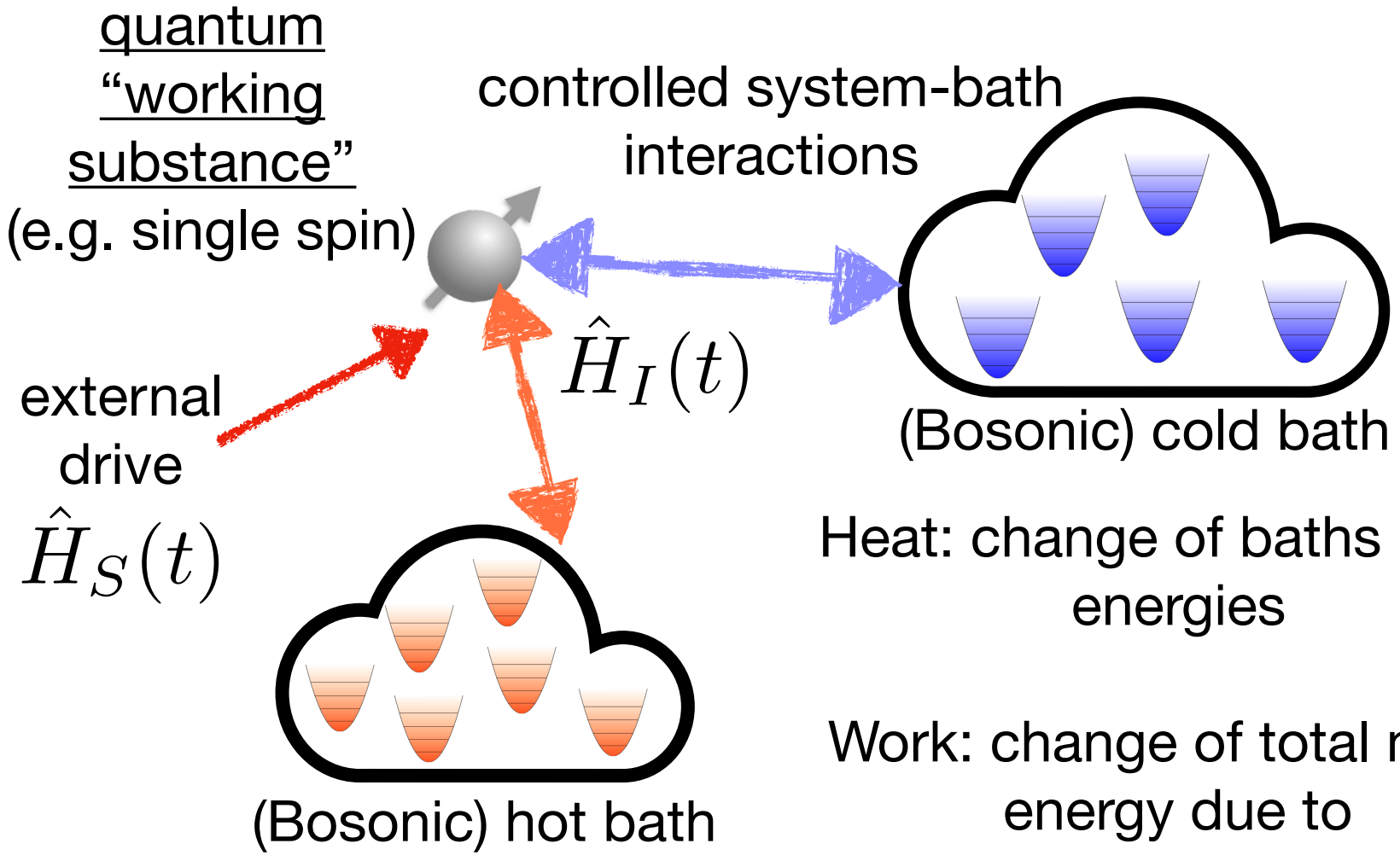
Andrea Smirne

Francesco Albarelli

Outline

- General infos on BELL
- **Quantum thermodynamics**
- Collaborations and publications

Quantum thermal machines



Heat: change of baths mean energies

Work: change of total mean energy due to external time-dependence

Quantum thermal machines

- Many challenges to study QTM going beyond standard idealised scenarios:
  - Strong system-bath coupling: non-Markovian dynamics & nonperturbative simulation techniques
  - Finite-time evolution (non-adiabaticity)

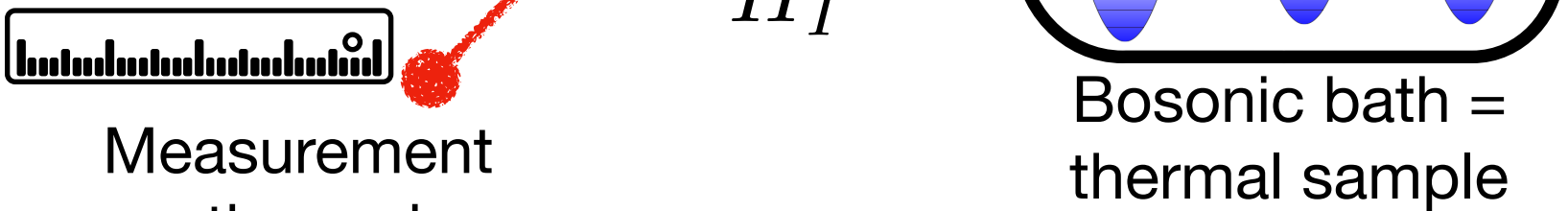
Invasiveness of quantum thermometry

$$\rho_B(0) = \mathcal{Z}^{-1} e^{-H_E/kT}$$

quantum **probe** (e.g. single spin)

probe-sample interaction

$\hat{H}_I$



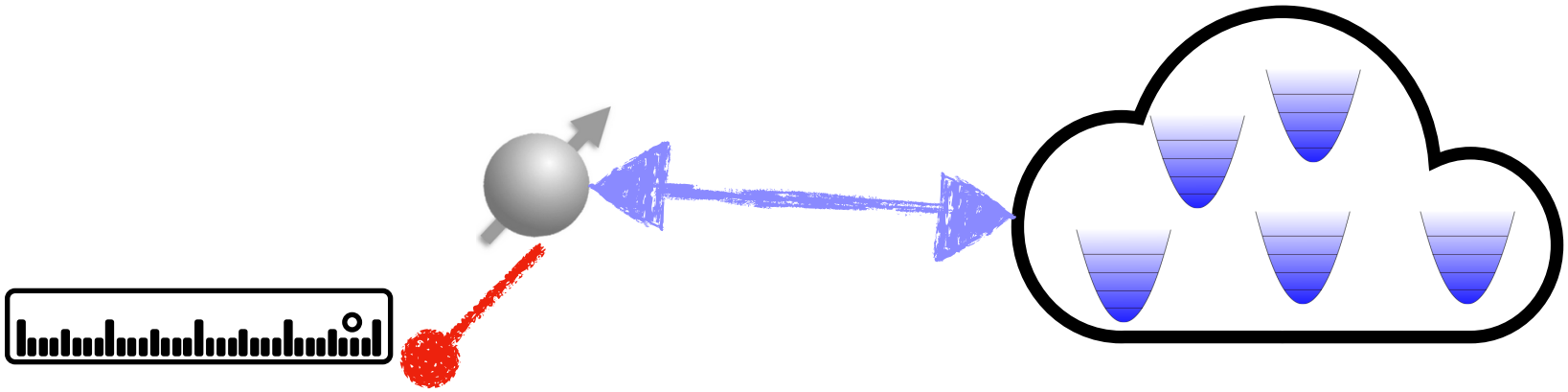
Measurement on the probe

Bosonic bath = thermal sample

outcomes statistics ⇨ estimate of T

The probing is invasive!
Bosonic bath increases mean energy: absorbed heat

Case study: pure-dephasing thermometry

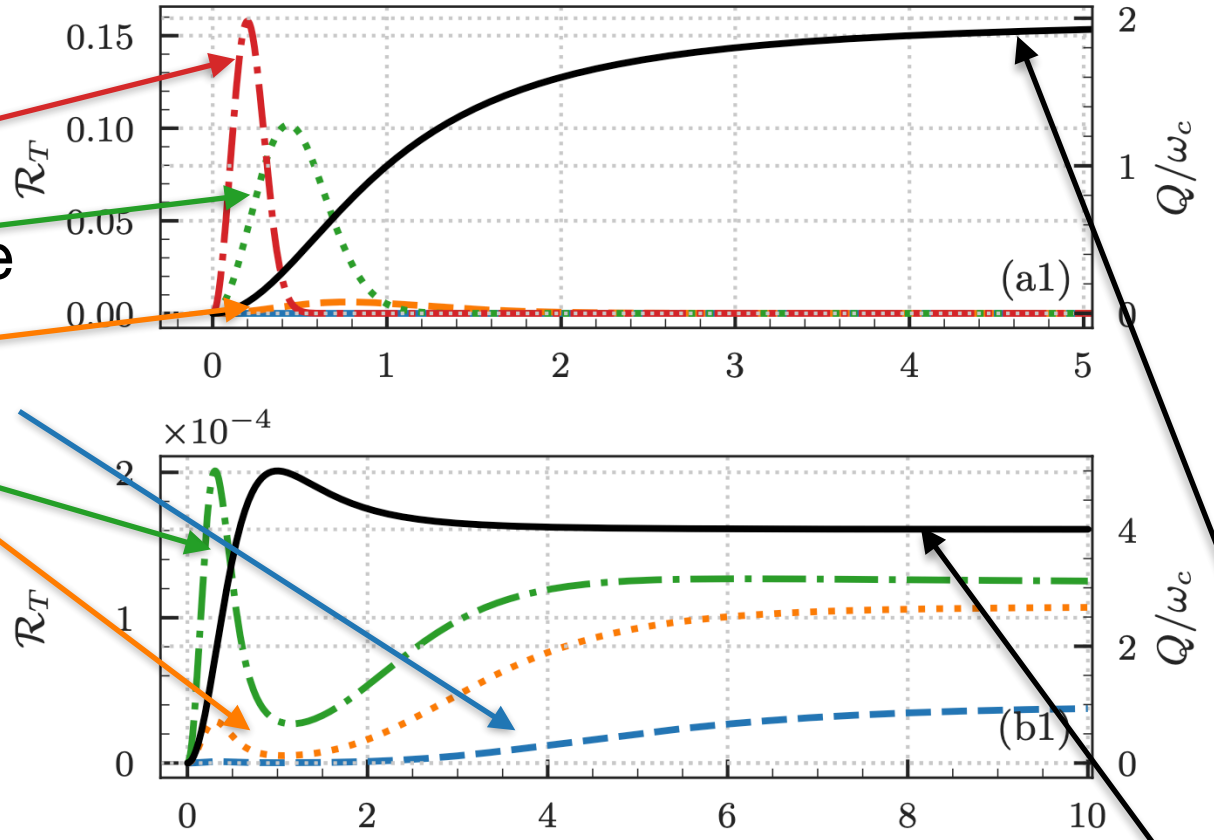


- Interaction preserves energy of the probe, but not of the sample
- Dissipated heat = external work to couple and decouple probe and sample

Dynamics of relevant figures of merit

Albarelli, Paris, Vacchini, Smirne, arXiv:230503436

accuracy of temperature estimation (for various T)

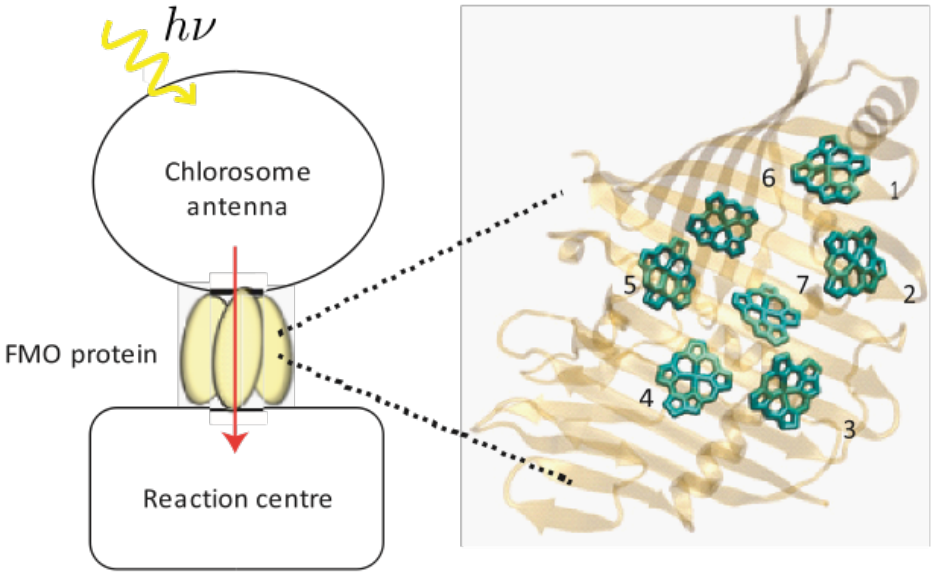


Inevitable tradeoff at short times

-> study of optimal schemes

absorbed heat (indep of T)

Complex and structured environments

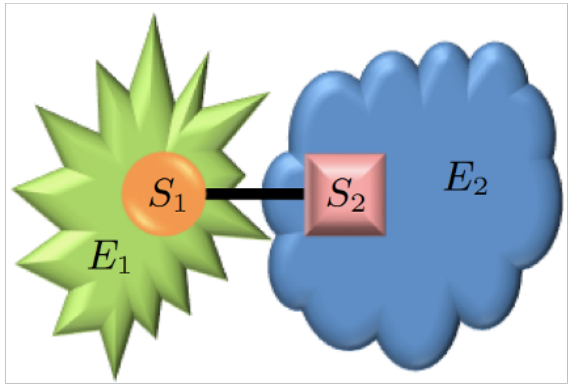


Thermal machines, Quantum biological systems, Solid-state systems (eg NV centers), ….

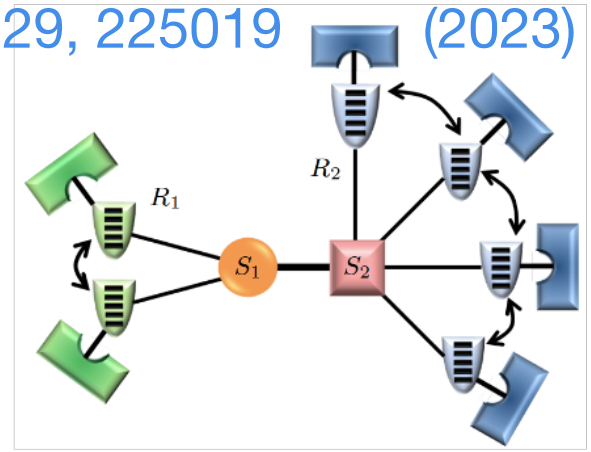
- Memory effects: **non-Markovian** dynamics
- Strong coupling: **nonperturbative** approaches are needed

Exact mapping to an auxiliary configuration

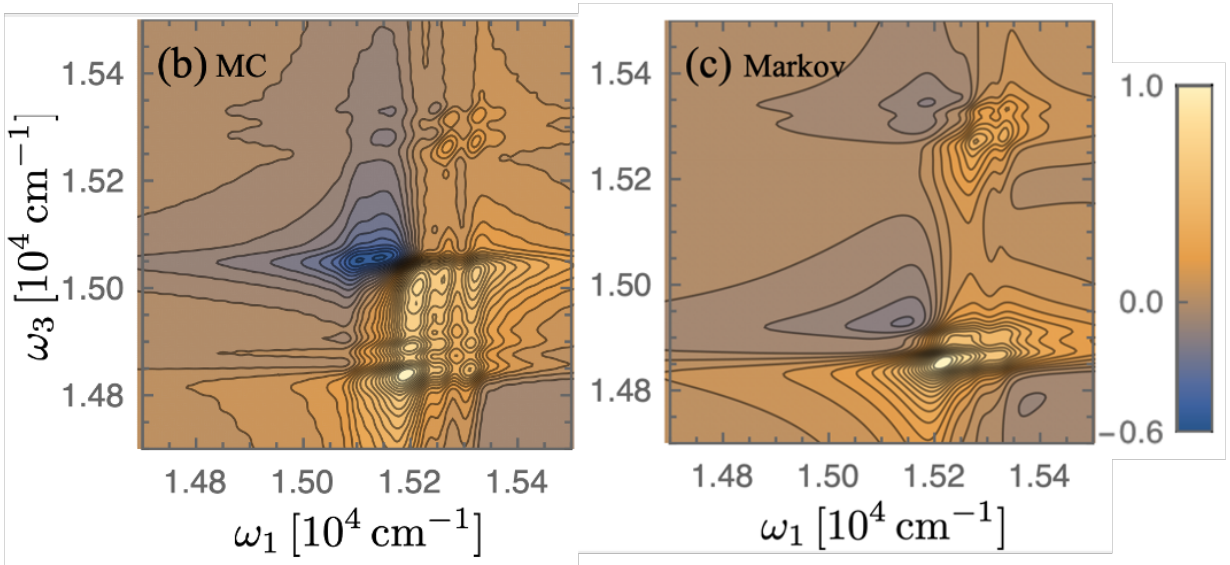
Smirne, Tamascelli, Lim, Plenio, Huelga OSID 29, 225019 (2023)



Equivalence theorem: match C(t)/J(ω)



2D electronic spectrum of a dimeric complex



- Non-Markovian features detected
- **Linear** (instead of quadratic) **scaling of CPU time** vs simulation time

Collaborations

 H.-P. Breuer - Uni Freiburg - Germany

 M. Paternostro - Uni Belfast - United Kingdom

 S. Campbell - University College Dublin - Ireland

 F. Ciccarello, S. Lorenzo, G. Palma - Uni Palermo

 J. Piilo, K. Luoma - Uni Turku - Finland

 D. Chruscinski - Uni Torun - Poland

 S. Huelga -Uni Ulm - Germany

Publications (2020-2023)

	Autori	Titolo	Rivista	Anno
1	Fermi, D; Pizzocchero, L	On the Casimir Effect with delta-Like Potentials, and a Recent Paper	ANN HENRI POINCARE	2023
2	Gherardini, S; Smirne, A; Huelga, SF; Caruso, F	Transfer-tensor description of memory effects in open-system dyna	QUANTUM SCI TECHNOL	2022
3	Smirne, A; Cialdi, S; Cipriani, D; Carmeli, C; Toigo, A; Vacc	Experimentally determining the incompatibility of two qubit measu	QUANTUM SCI TECHNOL	2022
4	Carmeli, C; Heinosaari, T; Toigo, A	Quantum guessing games with posterior information	REP PROG PHYS	2022
5	Megier, N; Smirne, A; Campbell, S; Vacchini, B	Correlations, Information Backflow, and Objectivity in a Class of Pur	ENTROPY-SWITZ	2022
6	Smirne, A; Megier, N; Vacchini, B	Holevo skew divergence for the characterization of information back	PHYS REV A	2022
7	Barchielli, A; Santamato, A	Eight-port homodyne detector: The effect of imperfections on quant	PHYS REV A	2022
8	Settimo, F; Breuer, HP; Vacchini, B	Entropic and trace-distance-based measures of non-Markovianity	PHYS REV A	2022
9	Smirne, A; Megier, N; Vacchini, B	On the Use of Total State Decompositions for the Study of Reduced	OPEN SYST INF DYN	2022
10	Dann, R; Megier, N; Kosloff, R	Non-Markovian dynamics under time-translation symmetry	PHYS REV RES	2022
11	Chruscinski, D; Luoma, K; Piilo, J; Smirne, A	How to design quantum-jump trajectories via distinct master equati	QUANTUM-AUSTRIA	2022
12	Smirne, A; Tamascelli, D; Lim, J; Plenio, MB; Huelga, SF	Non-Perturbative Treatment of Open-System Multi-Time Expectatio	OPEN SYST INF DYN	2022
13	Pizzocchero, L	On the global stability of smooth solutions of the Navier-Stokes equ	APPL MATH LETT	2021
14	Smirne, A; Megier, N; Vacchini, B	On the connection between microscopic description and memory ef	QUANTUM-AUSTRIA	2021
15	Barchielli, A; Gregoratti, M	Quantum optomechanical system in a Mach-Zehnder interferomete	PHYS REV A	2021
16	Megier, N; Smirne, A; Vacchini, B	Entropic Bounds on Information Backflow	PHYS REV LETT	2021
17	Megier, N; Ponzi, M; Smirne, A; Vacchini, B	Memory Effects in Quantum Dynamics Modelled by Quantum Renev	ENTROPY-SWITZ	2021
18	Cakmak, B; Mustecaplioglu, OE; Paternostro, M; Vacchini	Quantum Darwinism in a Composite System: Objectivity versus Clas	ENTROPY-SWITZ	2021
19	Trevisan, A; Smirne, A; Megier, N; Vacchini, B	Adapted projection operator technique for the treatment of initial c	PHYS REV A	2021
20	Campbell, S; Vacchini, B	Collision models in open system dynamics: A versatile tool for deep	EPL-EUROPHYS LETT	2021
21	O'Connor, E; Vacchini, B; Campbell, S	Stochastic Collisional Quantum Thermometry	ENTROPY-SWITZ	2021
22	Pizzocchero, L; Tassi, E	On approximate solutions of the equations of incompressible magne	NONLINEAR ANAL-THEOR	2020
23	Smirne, A; Caiaffa, M; Piilo, J	Rate Operator Unraveling for Open Quantum System Dynamics	PHYS REV LETT	2020
24	Hashimoto, K; Vacchini, B; Uchiyama, C	Lower bounds for the mean dissipated heat in an open quantum sys	PHYS REV A	2020
25	Barchielli, A; Gregoratti, M	Entropic measurement uncertainty relations for all the infinite comp	J PHYS COMMUN	2020
26	Puebla, R; Smirne, A; Huelga, SF; Plenio, MB	Universal Anti-Kibble-Zurek Scaling in Fully Connected Systems	PHYS REV LETT	2020
27	Carmeli, C; Heinosaari, T; Toigo, A	Quantum random access codes and incompatibility of measuremen	EPL-EUROPHYS LETT	2020
28	Fermi, D; Gengo, M; Pizzocchero, L	Integrable scalar cosmologies with matter and curvature	NUCL PHYS B	2020
29	Megier, N; Smirne, A; Vacchini, B	Evolution Equations for Quantum Semi-Markov Dynamics	ENTROPY-SWITZ	2020
30	Vacchini, B	Quantum renewal processes	SCI REP-UK	2020
31	Megier, N; Smirne, A; Vacchini, B	The interplay between local and non-local master equations: exact a	NEW J PHYS	2020
32	Smirne, A; Nitsche, T; Egloff, D; Barkhofen, S; De, S; Dhar	Experimental control of the degree of non-classicality via quantum c	QUANTUM SCI TECHNOL	2020