QTNS2018

Abstract (Oral)

November 7-10, 2018

Program

Wednesday 7		Thursday 8		Friday 9		Saturday 10	
		9:00-9:30	Kishine, Junichiro	9:00-9:30	Nakata, Yosuke	10:00-10:30	Discussion session
Invited talks		9:30-9:50	Kato, Takeo	9:30-9:50	Aono, Tomosuke	10:30-11:00	Coffee
		9:50-10:30	Coffee	9:50-10:30	Coffee	11:00-12:00	Discussion session
		10:30-11:30	Entin-Wohlman, Ora	10:30-11:00	Otsuka, Tomohiro		
11:30-12:50	Registration	11:30–12:00	Yamamoto, Kaoru	11:00-11:30	Shevchenko, Sergey		
12:50-13:00	Opening	12:00-13:00	Hatano, Naomichi	11:30-11:50	Nakagawa, Masaya		
13:00-14:00	Moskalet, Michael	13:00-14:00	Lunch	11:50-12:50	Kwek, Leong-Chuan		
14:00-15:00	Aharony, Ammon	14:00-15:00	Sagawa, Takahiro	12:50-14:00	Lunch		
15:00-15:30	Coffee	15:00-15:20	Shirai, Tatsuhiko	14:00-15:00	Vacchini,Bassano		
15:30-16:30	Tokura, Yasuhiro	15:20-15:40	Mori, Takashi	15:00-15:30	Bastidas, Victor Manuel		
16:30-17:30	Katsumoto, Shingo	15:40-16:10	Coffee	15:30-16:00	Hashimoto, Kazunari		
17:30-19:00	Welcome reception	16:10-16:30	Kato, Akihito	16:00-16:15	Coffee		
		16:30-16:50	Phuc, Nguyen Thanh	16:15-17:15	Esposito, Massimiliano		
		16:50-18:00	Poster	17:15-17:45	Uchiyama Chikako		
				17:45-18:00	Summary (Aharony, A)		
				18:00-20:00	Banquet		

Wednesday, 7th

Invited talk

A few-electron system surfing in the Fermi sea

Moskalets M.

In this talk I will give a brief introduction into the Floquet scattering matrix approach and will apply it to describe properties of single electrons injected on-demand into the Fermi sea.

When an electron is injected into a conductor, it meets another electrons. Actually, it meets the whole Fermi sea of electrons, whose state becomes imprinted in the state of the injected electron (if the process of injection is gentle enough). At zero temperature, the Fermi sea is quiet, its quantum state is a pure state. The state of the injected electron is also a pure state that is orthogonal to the state of the Fermi sea. In contrast, at nonzero temperatures, the state of the Fermi sea becomes a mixed state, each component of which is responsible for the appearance of the state of the injected electron orthogonal to it. All together, these states form a mixed state of an injected particle.

The pure-to-mixed state conversion results in a bizarre temperature dependence of quantities like shot noise, which are sensitive to multi-particle events. The single-particle shot noise decreases with temperature, which is explained as if a single-particle mixed state would demonstrate some degree of second-order coherence. In the case of injection of N-electron excitations, the shot noise is not additive and less prone to temperature, which is due to HBT-like correlations between injected electrons developed at nonzero temperatures. Moreover, in the macroscopic limit, $N \to \infty$, the shot noise becomes additive and completely insensitive to temperature. Another manifestation of mixedness is the fusion phenomenon, where the system of N electrons behaves as one particle of the total charge Ne. The reason for this is that with increase of a temperature-induced mixedness, the difference between the states of N electrons is diminished.

Invited talk

Spin Orbit interactions, time reversal symmetry and spin filtering

Amnon Aharony
Ben Gurion and Tel Aviv Universities, Israel

Quantum computing requires the ability to write and read quantum information on the spinors of electrons. Here we discuss writing information on *mobile* electrons, which move through mesoscopic (or molecular) quantum wire networks. When such a network is connected to one source and one drain then time-reversal symmetry and unitarity imply no spin polarization. Tunable spin filtering can be achieved by adding an Aharonov-Bohm flux [1], which breaks time-reversal symmetry, or by leakage, which breaks unitarity [2]. Alternatively, filtering is also achieved with more than one drain [3].

Filtering can also be achieved for **a single** one-dimensional wire which has both spin-orbit interactions and a Zeeman field [4].

1. A. Aharony, Y. Tokura, G. Z. Cohen, O. Entin-Wohlman, and S. Katsumoto, *Filtering and analyzing mobile qubit information via Rashba-Dresselhaus-Aharonov-Bohm interferometers*, Phys. Rev. B **84**, 035323 (2011); (arXiv:1103.2232)
2. S. Matityahu, A. Aharony, O. Entin-Wohlman, and S. Katsumoto, *Robustness of spin filtering against current leakage in a Rashba-Dresselhaus-Aharonov-Bohm interferometer*, Phys. Rev. B **87**, 205438 (2013); (arXiv:1302.6772)
3. S. Matityahu, A. Aharony, O. Entin-Wohlman, and C. A. Balseiro, *Spin filtering in all-electrical three-terminal interferometers*, Phys. Rev. B **95**, 085411 (2017); (arXiv:1611.01832)
4. A. Aharony, O. Entin-Wohlman, M. Jonson, R. I. Shekhter, *Electric and Magnetic Gating of Rashba-Active Weak Links*, Phys. Rev. B **97**, 220404(R) 2017; (arXiv:1804.09936)

Invited talk

Adiabatic and diabatic dynamics in quantum systems

Yasuhiro Tokura (University of Tsukuba)

For open quantum systems described by the quantum master equation (QME), we investigated quantum adiabatic pumping using the full counting statistics formalism [1,2]. The adiabatic pump is given by a line integral in the control parameter space and its integrand is called the Berry–Sinitsyn–Nemenman (BSN) vector. We showed that this approach is equivalent to the adiabatic response formalism as far as the average values are concerned [2] and investigate the gauge freedom in this formalism [3]. We apply this formalism to the excess entropy production under quasistatic operations between nonequilibrium steady states [4]. The average entropy production is composed of the time integral of the instantaneous steady entropy production rate and the excess entropy production. In the weakly nonequilibrium regime, we derived the BSN vector which is described with the density operator of the instantaneous steady state of the QME and the density operator given by the QME with reversing the sign of the Lamb shift term. We will also refer to other types of quantum pumping [5].

References:

[1] M. Esposito, et al., Rev. Mod. Phys. 81, 1665 (2009) [2] S. Nakajima, M. Taguchi, T. Kubo, and Y. Tokura, Phys. Rev. B 92, 195420 (2015).
[3] T. Pluecker, et al., Phys. Rev. B 95, 155431 (2017).
[4] S. Nakajima and Y. Tokura, J. Stat. Phys. 169, 902 (2017).
[5] M. Taguchi, S. Nakajima, T. Kubo and Y. Tokura, J. Phys. Soc. Jpn. 85, 084704 (2016).

Invited talk

“Zitterbewegung” appeared as fluctuation in transport between quantum point contacts

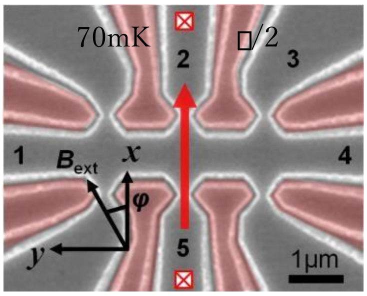
Shingo Katsumoto, Yu Iwasaki, Yoshiaki Hashimoto and Taketomo Nakamura

Institute for Solid State Physics, University of Tokyo, Kashiwa, Chiba 277-8581, Japan

For a particle which obeys the Dirac equation, velocity is not a well-defined quantity in that the kinetic motion in real space mixes with the spin freedom. Such a quantum mechanical state can be described as a superposition of states with zigzag motion (trembling motion), which is called “Zitterbewegung” (ZB) in Germany[1]. A trivial analog in electrons in solids is oscillation in velocity of classical electrons due to periodic lattice potential. A bit non-trivial phenomenon closer to the ZB of electrons in vacuum is a zigzag motion of electrons due to the spin-orbit mixing of the two (electron and hole) freedoms. This is also called ZB and expected to be observable in experiments though no clear observation has been reported.

For the observation, we need to prepare spin-polarized electrons through some non-adiabatic process. We have experimentally confirmed that a quantum point contact (QPC) in a system with strong Rashba-type spinorbit interaction (RSOI) can work as an efficient spin polarizer on plateaus of a half and of a one conductance quantum ($2e^2/h$) [2]. Hence a system of QPCs with RSOI can provide an ideal test-bed of ZB in solids. Figure 1(a) shows a schematic view of the present system with two sets of three parallel QPCs made from InAs 2DEG. The two are placed face-to-face. The two-terminal conductance through a confronting QPC pair as a function of magnetic field for various field directions is shown in Fig.1 (b). Reproducible fluctuations reminiscent of universal conductance fluctuation (UCF) appear in the magneto-conductance. Surprisingly the amplitude nor the characteristic frequency does not change with the field angle. In combination with transport measurement *not through* QPCs, the fluctuation can provide evidence that the Zitterbewegung really occurs in our sample [3].

References
[1] W. Zawadzki and T. M. Rusin, J. Phys.: Condensed Matter **23**, 143201 (2011).
[2] S. W. Kim, Y. Hashimoto, T. Nakamura, S. Katsumoto, Phys. Rev. B **94**, 125307 (2016). 0 [3] Y. Iwasaki, Y. Hashimoto, T. Nakamura, S. Katsumoto, Scientific reports **7**, 7909 (2017).



(a)

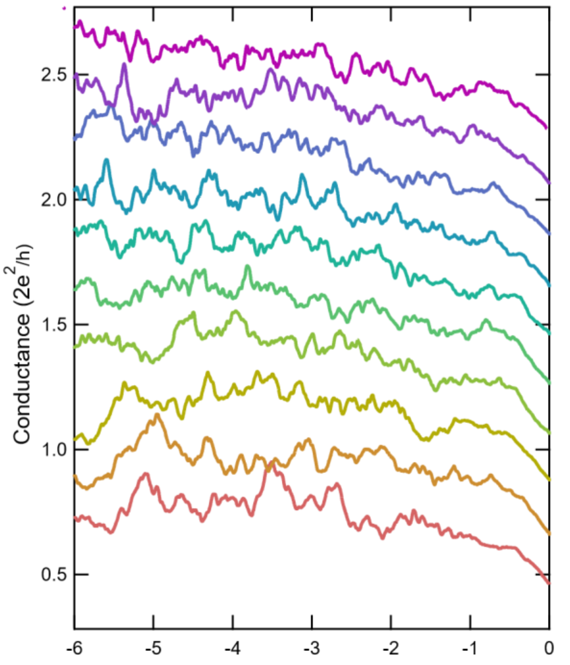


Fig. 1. (a) QPC positioning in the sample. (b) Conductance fluctuation (through QPC 2 to 5) versus magnetic field. The field is rotated from 0
(parallel to the plane) to □/2 (perpendicular).

(b)

Thursday, 8th

Invited talk

Soliton transport in chiral helimagnet

Jun-ichiro Kishine
The Open University of Japan, Chiba261-8586, Japan

In chiral magnetic materials, the intrinsic spin-orbit coupling may appear on a macroscopic level in the form of the asymmetric Dzyaloshinskii-Moryia interaction (DMI) that can stabilize topologically nontrivial magnetic phases. In a monoaxial chiral helimagnet, the ground state continuously transforms into a periodic array of the commensurate (C) domains partitioned by incommensurate (IC) chiral twists. This discommensurate state, a main subject of this review article, has several names, i.e., chiral soliton lattice (CSL), helicoid, or magnetic kink crystal. The CSL was first predicted by Dzyaloshinskii[1] in 1960s but finally overbed in 2012[2]. Refs.[3] and [4] are review articles on this topics.

As the magnetic field strength increases, the spatial period of the CSL increases and finally goes to infinity at the critical field strength, as depicted in Fig. 1. The Hamiltonian density in the continuum limit, which describe the CSL, is given by

$$\tilde{\mathcal{H}} = \frac{J_z S^2 a_0^2}{2}\left(\partial_z \boldsymbol{n}\right)^2 - a_0 S^2 \boldsymbol{D}_z \cdot \boldsymbol{n} \times \partial_z \boldsymbol{n} + S\tilde{\boldsymbol{H}} \cdot \boldsymbol{n}$$

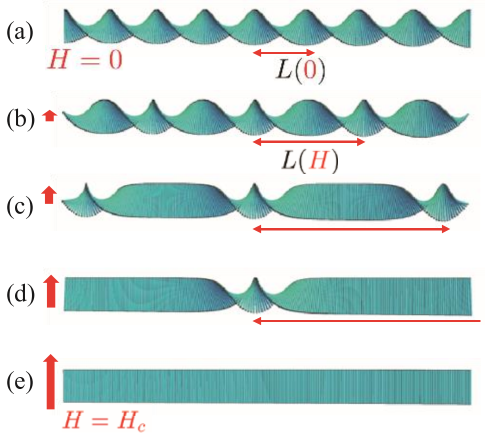


Figure 1: Formation of chiral soliton , (1) lattice in mono-axial chiral helimagnet.

where a_0 is the lattice constant, $\mathrm{S} = S\mathrm{n}$ is the local spin moment, $J_z > 0$ is the nearest-neighbor ferromagnetic exchange interaction, $\mathrm{D}_z = D_z\hat{\mathrm{e}}_z$ is the mono-axial Dzyaloshinskii-Moriya (DM) interaction along a certain crystallographic helical axis (z-axis). We take z-axis as the mono-axis and apply a static magnetic field $\tilde{\mathrm{H}} = \tilde{H}_0^x \hat{e}_x = g\mu_B H_0^x \hat{e}_x$ to stabilize the CSL state. Apparently, the Hamiltonian (1) is quite simple, but it contains quite rich dynamics [2,4,5] including

1. **Zero mode and elementary excitations**
2. **Collective sliding dynamics of the whole CSL**
3. **Isolated chiral soliton surfing over the CSL**
4. **Confined dynamics of the CSL**
5. **Strong non-linear response in the dilute soliton regime**

In this presentation, I will show how to describe and use these soliton dynamics.

This work has been done under close collaboration with Alexander Ovchinnikov, Igor Proskurin and Yoshi Togawa.

References

[1] I. E. Dzyaloshinskii, Sov. Phys. JETP19, 960 (1964), JETP 20, 223 (1965), JETP 20, 665 (1965). [2] Y Togawa, T Koyama, K Takayanagi, S Mori, Y Kousaka, J Akimitsu, S Nishihara, K Inoue, AS Ovchinnikov, J-i Kishine, Phys. Rev. Lett.108 (10), 107202 (2012).

[3] Y. Togawa, Y. Kouska, K. Inoue and J. Kishine, J. Phys. Soc. Jpn., J. Phys. Soc. Jpn. 85, 112001 (2016).

[4] J. Kishine and A.S.Ovchinnikov, Solid State Physics Vol.66, Chapter 1 (Elsevier, Academic Press, 2015).

[5] F. J. T. Goncalves, T. Sogo, Y. Shimamoto, I. Proskurin, Vl. E. Sinitsyn, Y. Kousaka, I. G. Bostrem, J. Kishine, A. S. Ovchinnikov, and Y. Togawa, Phys. Rev. B98, 144407 (2018).

Spin-current noise in magnetic bilayer systems

Takeo Kato
Institute for Solid State Physics, The University of Tokyo

In the research field of mesoscopic physics, current noise measurement is an important tool to obtain useful information on electronic transport such as determination of the effective charge, evaluation of electron entanglement, and even spin accumulation. In the research field of spintronics, the pure spin current induced by, e.g., spin pumping and spin Seebeck effect (see the left pictures of Fig. 1) is a central research subject. Recently, the noise of this pure spin current has measured by using the inverse spin Hall effect [1]. Although the noise of the pure spin current is expected to have useful information, its theoretical study has, however, been overlooked for a long time, and has just started recently in a few papers [2, 3].

In this presentation, we consider a normal metal(NM)/ferromagnetic insulator(FI) bilayer system, which is an important platform of spintronics [4]. Starting with a microscopic spin-exchange model, and using the secondorder perturbation with respect to the NM-FI interface coupling [5], we derive expressions of the spin-current noise in terms of the propagators of electrons and magnons. We discuss how temperature dependences of the spin-current noise contain useful information on the microscopic mechanism of the spin-current generation (see the right graph of Fig. 1). We conclude that measurement of the spin-current noise indeed provides a powerful tool in research of spintronics.

This study is a joint research with M. Matsuo (Kavli Institute for Theoretical Physics China), Y. Ohnuma (Kavli Institute for Theoretical Physics China), and S. Maekawa (RIKEN).

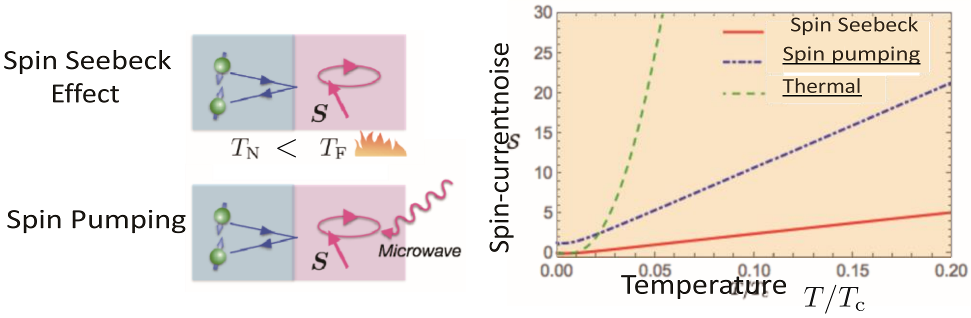


Figure 1: (Left) Schematics of spin-current generation by spin Seebeck effect and spin pumping. (Right) Temperature dependence of the spin-current noise. The temperature is normalized by the Curie temperature of the ferromagnetic insulator. Temperature dependence of thermal spin-current noise is also shown.

References

[1] A. Kamra, F. P. Witek, S. Meyer, H. Huebl, S. Geprags, R. Gross, G. E. W. Bauer, and S. T. B. Goennenwein,¨ *Phys. Rev. B* 90 (2014) 214419.

[2] A. Kamra and W. Belzig, *Phys. Rev. Lett.* 116 (2016) 146601.

[3] S. Takei and M. Mohseni, *Phys. Rev. B* 97 (2018) 014427.

[4] M. Matsuo, Y. Ohnuma, T. Kato, and S. Maekawa, *Phys. Rev. Lett.* 120 (2018) 037201.

[5] Y. Ohnuma, M. Matsuo, and S. Maekawa, *Phys. Rev. B* 96 (2017) 134412.

Invited talk

Enhanced performance of three-terminal thermoelectric devices

Ora Entin-Wohlman
Tel Aviv University and Ben Gurion University, Israel

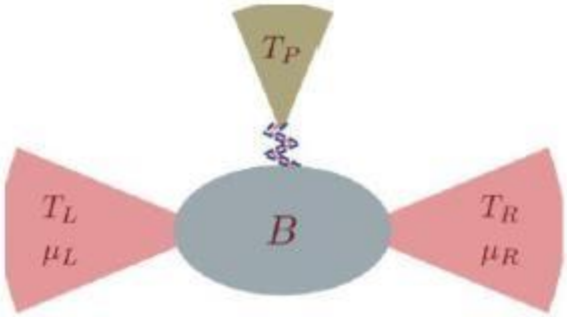
A three-terminal device, comprising two electronic terminals and a thermal one (see figure below), is discussed. In the first part, we investigate the coefficient of performance for the joint operation of cooling one of the electronic terminals and producing electric power. Surprisingly enough, the coefficient of performance can be enhanced as compared to the case where that electronic terminal is cooled by investing thermal power (from the thermal bath) and electric power (from voltage applied across the electronic junction). We next examine the efficiency of an effective two-terminal thermoelectric device under a broken time-reversal symmetry which is derived from the three-terminal thermoelectric device. We find that breaking time-reversal symmetry can enhance the figure of merit for delivering electric power by supplying heat from a phonon bath beyond the one for producing the electric power by investing thermal power from the electronic baths. We also show that such a device cannot reach the Carnot efficiency, contrary to a recent claim.

[1] O. Entin-Wohlman and A. Aharony, *Three-terminal thermoelectric transport under broken time-reversal symmetry*, Phys. Rev. B **85**, 085401 (2012).

[2] O. Entin-Wohlman, Y. Imry, and A. Aharony, *Enhanced performance of joint cooling and energy production*, Phys. Rev. B **91**, 054302 (2015).

[3] Kaoru Yamamoto, Ora Entin-Wohlman, Amnon Aharony, and Naomichi Hatano, *Efficiency bounds on thermoelectric transport in magnetic fields: the role of inelastic processes*, Phys. Rev. B **94**, 121402(R) (2016).

[4]



Invited talk

Efficiency bounds on thermoelectric transport in magnetic fields: the role of inelastic processes with a three-terminal junction

Kaoru Yamamoto
Research Center for Magnetic and Spintronic Materials, National Institute for Materials Science (NIMS), 1-2-1 Sengen, Tsukuba 305-0047, Japan
Ora Entin-Wohlman, Amnon Aharony
Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv 69978, Israel
Physics Department, Ben Gurion University, Beer Sheva 84105, Israel
Naomichi Hatano
Institute of Industrial Science, The University of Tokyo, Kashiwanoha 5-1-5, Kashiwa, Chiba 277-8574, Japan

It has been argued that breaking time-reversal symmetry can enhance thermoelectric efficiency. Benenti *et al*. recently claimed [1] that in this case one can achieve the Carnot efficiency with a finite power, which appears to contradict the second law of thermodynamics. This idea has attracted much interest recently; see refs. [2, 3] for example.

In order to investigate this claim and to seek high efficiency, we consider a mesoscopic thermoelectric device made of an Aharonov-Bohm ring threaded by a magnetic flux, incorporating electron-phonon scattering [4]. The model has a quantum dot and three reservoirs: two electronic reservoirs and a bosonic one; see Figure 1. Electrons are inelastically scattered by bosons at the quantum dot. This three-terminal model can be reduced to an effective two-terminal one, that complies with the requirements of Benenti *et al*.

With this model, we find the following two results [5]: First, we find that, contrary to Benenti's claim [1], such a device cannot reach the Carnot efficiency under a magnetic field because of the non-negativity condition on the entropy production of the original model with three reservoirs. Second, we find that breaking time-reversal symmetry and including the electron-phonon interaction can enhance the thermoelectric efficiency significantly beyond the one without the interaction.

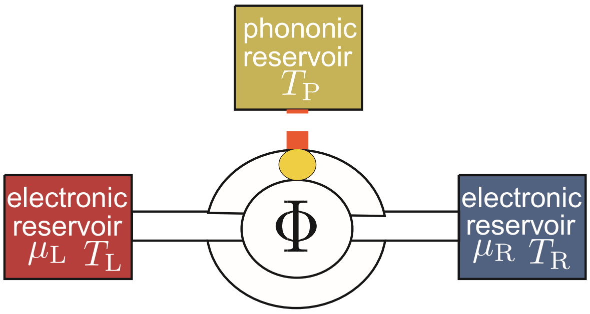


Figure 1: Model of a thermoelectric device, comprising two electronic terminals (held at chemical potentials μ_L and μ_R, and at temperatures T_L and T_R) and a thermal terminal held at a temperature T_P, with which the electrons exchange energy. The nanostructure is modeled by an Aharonov-Bohm ring threaded by a magnetic flux Φ. The electrons exchange energy with vibrational modes on a dot placed on the upper arm..

References

[1] G. Benenti, K. Saito, and G. Casati, *Phys. Rev. Lett.* 106 (2011), 230602 .
[2] N. Shiraishi, K. Saito, and H. Tasaki, *Phys. Rev. Lett.* 117 (2016), 190601 .
[3] N. Shiraishi and H. Tajima, *Phys. Rev. E* 96 (2017), 022138 .
[4] O. Entin-Wohlman and A. Aharony, *Phys. Rev. B* 85 (2012), 085401 .
[5] K. Yamamoto, O. Entin-Wohlman, A. Aharony, and N. Hatano, *Phys. Rev. B* 94 (2016), 121402(R) .

Hatano Naomichi

Invited talk

Second law and eigenstate thermalization in isolated quantum many-body systems

Takahiro Sagawa

The origin of macroscopic irreversibility under microscopic reversible dynamics is a fundamental problem ever since the seminal thought by Boltzmann. In recent years, this problem has attracted renewed attentions, in light of quantum statistical mechanics and experimental progress in ultracold atoms. In particular, it has been recognized that the eigenstate thermalization hypothesis (ETH) plays a crucial role in understanding the mechanism of thermalization in isolated quantum systems, which states that even a single energy eigenstate is thermal.

In this talk, I will present our recent result on the second law and the fluctuation theorem for pure quantum states [1]. In our setup, the entire system obeys unitary dynamics, where the initial state of the heat bath is not the Gibbs ensemble but a single energy eigenstate. Our proof is mathematically rigorous, where the Lieb-Robinson bound plays a crucial role. Our result would reveal a scenario that the second law emerges from quantum mechanics. In addition, I will also talk about numerical large deviation analysis of the ETH [2], which directly evaluates the number of athermal energy eigenstates and validates the ETH for non-integrable systems.

[1] E. Iyoda, K. Kaneko, and T. Sagawa, PRL 119, 100601 (2017). [2] T. Yoshizawa, E. Iyoda, and T. Sagawa, Phys. Rev. Lett. 120, 200604 (2018).

Emergence of the Gibbs state in weakly dissipative quantum systems based on the eigenstate thermalization hypothesis

Tatsuhiko Shirai
Institute for Solid State Physics, University of Tokyo
Takashi Mori
RIKEN Center for Emergent Matter Science (CEMS)

We investigate steady states of macroscopic open quantum systems weakly coupled to out-of-equilibrium environment. Coupled to a large environment, the system is relaxed to a steady state due to dissipation. When the environment is in thermal equilibrium, the system is universally relaxed to a Gibbs state by virtue of the detailed balance condition. In contrast, when the environment is out-of-equilibrium, the detailed balance condition is violated, and there is no simple form to describe the steady state. It is a challenge in statistical physics to predict steady states in such non-equilibrium situations. The study of steady state under dissipation not obeying the detailed balance is also motivated by recent experimental progress in cold atoms and trapped ions. In these systems, it becomes possible to introduce a controlled dissipation so that the steady state possesses a desired property, e.g. long-range order or topological order [1].

In this work, we suggest a connection between the steady states in the non-equilibrium situation and eigenstate thermalization hypothesis (ETH) [For ETH, see [2, 3]]. We found that the Gibbs state at a certain effective temperature is a good description of the steady states of some open quantum systems despite the violation of the detailed balance condition [4]. We theoretically argue that there are two ingredients in emergence of the Gibbs state: the validity of the perturbation theory in the weak system-environment coupling and the ETH.

Our main discussion for the emergence of the Gibbs state is on the validity of the weak-coupling perturbation theory. It was discussed in [5] that the convergence radius of the perturbative series quickly shrinks to zero as the system size increases for generic open quantum systems. Nonetheless, our numerical results for spin systems suggest that the perturbative expansion is an asymptotic expansion in the thermodynamic limit and the leading order of the perturbative series well describes the steady state if there is no stationary current of a conserved quantity. By combining this finding with the ETH, we can conclude that the steady state is given by the Gibbs state, although the exact density matrix of the steady state is different from the Gibbs one. We finally demonstrate that our theory is not applicable to transport phenomena, in which there is a stationary current in the bulk, due to the failure of the perturbation theory.

References

[1] S. Diehl, A. Micheli, A. Kantian, B. Kraus, H. Buchler, P. Zoller,¨ *Nat. Phys.* 4 (2008) 878.
[2] M. Rigol, V. Dunjko, M. Olshanii, *Nature* 452 (2008) 854.
[3] T. Mori, T. N. Ikeda, E. Kaminishi, M. Ueda, *J. Phys. B: At. Mol. Opt. Phys.* 51 (2018) 112001.
[4] T. Shirai, T. Mori, in preparation.
[5] H. C. Lemos, T. Prosen, *Phys. Rev. E* 95 (2017) 042137.

Mori, Takashi

Non-Markovian charge separation and system-reservoir correlation effect in heat transport

Akihito Kato
Institute for Molecular Science

Interaction of quantum systems with their surrounding environment causes dissipation, relaxation, and the loss of quantum coherences. Early studies on the dynamics of these open quantum systems are mostly focused on the weak system–environment coupling regime, where the Markovian master equation has been often employed for its description. Recent experimental studies, however, observed the quantum coherent signature of the excitation energy transfer in photosynthetic light-harvesting complexes, and motivate us to develop the quantum dynamical theory beyond the weak coupling regime. These studies pointed out that the interplay between the quantum coherent dynamics and the environmental noise optimizes the rate and/or the efficiency of the transfer. In these intermediate and strong coupling regimes, the open quantum dynamics can be non-Markovian and strong systemenvironment correlation can give rise to. These unexplored properties may provide the novel phenomena and functions to be the design principles for the artificial quantum devices. Here, I will give two examples for such cases: Non-Markovian effect for the electron–hole separation in organic photovoltaic systems [1] and the system– reservoir correlation effect in a model quantum heat engine [2].

Organic photovoltaic systems consist of the blend of donor–acceptor molecules and proceeds as follows: Absorbed photon generates the exciton in the donor domain, which dissociate into the donor–acceptor interface. Then, an electron transfer to the acceptor domain and the interfacial bound electron–hole state forms. Finally, they separate into free careers and are extracted as photocurrent. Due to the strong electron–hole binding energy, which is typically one order of magnitude larger than the thermal energy in room temperature, the interfacial bound state seem to be stable. Therefore, elucidating the physical mechanism of the electron–hole separation is the fascinating problem from the quantum dynamical point of view. We focused on the small polaron formation consists of the charge and its surrounding phonons and revealed that the finite timescale, i.e. non-Markovianity, of the polaron formation enabled the combination of the fast forward charge separation via quantum delocalization and subsequent backward slow charge recombination by the incoherent hopping. The resulting dynamics maintains, especially for the slower formation case, the long-range charge separated states for a long time.

Quantum heat engine is the paradigmatic model to investigate thermodynamic effects in small quantum systems. Because we cannot take the thermodynamic limit in these systems, the system–reservoir couplings can be strong, and therefore, theoretical description and computational methods for thermodynamic quantities in a thermodynamically consistent manner beyond the conventional ones are required. By assuming that the first and second laws hold in the same form with the macroscopic thermodynamic laws, we derive the general reduced description of the heat current, which is valid for strong coupling regime and non-Markovian conditions, and develop the numerical method to evaluate the derived expression. We apply this method to three-level heat engine model and give the role played by the system–environmental correlation for the performance of the quantum heat engine.

References

[1] A. Kato and A. Ishizaki, *Phys. Rev. Lett.* 121 (2018) 026001.

[2] A. Kato and Y. Tanimura, *J. Chem. Phys.* 145 (2016) 224105.

Control of quantum dynamics of electronic excitation transfer in condensed-phase molecular systems under strong decoherence

Nguyen Thanh Phuc
Institute for Molecular Science

Manipulationof quantum systems is the basis for many promisingquantum technologies. However, how quantum mechanical principles can be used to manipulate the dynamics of quantum dissipative systems remains unanswered because of strong decoherence effects arising from interaction with the surrounding environment. In this talk, I will show that the electronic excitation transfer (EET), one of the most important processes in chemical and biological molecular systems, can be manipulated by using the Floquet engineering, in which the Franck-Condon transition energy is temporally modulated in a periodic manner. In particular, despite strong dephasing, the EET rate is found to be significantly enhanced [1], and the EET dynamics spontaneously breaks the chiral symmetry of a molecular loop structure in a controllable fashion, followed by the generation of a steady-state electronic excitation current [2].

References

[1] Nguyen Thanh Phuc, Akihito Ishizaki Journal of Physical Chemistry Letters 9 (2018) 1243.

[2] Nguyen Thanh Phuc, Akihito Ishizaki arXiv:1809.10362.

Friday, 9th

Invited talk

Heterodyne micro-focused Brillouin light scattering spectroscopy towards observation of topological modes in magnonic crystals

Y. Nakata, S. Baba, R. Hisatomi, A. Gloppe, R. Shindou, Y. Nakamura, and K. Usami

Artificial crystals for spin waves are called magnonic crystals, and they are one of essential components for spin-wave controls [1].
Recently, the concept of topology was introduced to band structures of magnonic crystals, and the chiraledge-mode formation at the boundary of a topological magnonic crystal is predicted [2-3].
However, nobody has experimentally observed such an exotic topological propagation in a magnonic crystal yet, as far as we know.
The challenges are in the developments of a characterization method and a practical design of a topological magnonic crystal.

To resolve the first problem, we propose a comprehensive heterodyne imaging method for magnons. By utilizing the developed system, we experimentally realize phase-sensitive magnon imaging in onedimensional dipolar magnonic crystals defined by metallic strips on a YIG film. To tackle the second issue, we provide a feasible design of a topological magnonic crystal.
For this purpose, we formulate a magnonic tight-binding model composed of confined Damon-Eshbach modes in a YIG film with metallic structures.
Referring to Su-Schrieffer-Heeger (SSH) model, we introduce staggered hopping to it.
We show that a topological number is defined for such a magnonic system, and numerically demonstrate the topological-edge-mode formation at the interface between two regions with different topological numbers.

[1] A. V. Chumak et al., J. Phys. D. Appl. Phys. 50, 244001 (2017).
[2] R. Shindou et al., Phys. Rev. B 87, 174427 (2013).
[3] Y.-M. Li, J. Xiao, and K. Chang, Nano Lett. 18, 3032 (2018).

Nuclear spin polarization in a quantum point contact

Tomosuke Aono1, Peter Stano2,3, Minoru Kawamura2
1 *Faculty of Engineering, Ibaraki University, 4-12-1 Nakanarusawa, Hitachi 316-8511, Japan*
2 *RIKEN Center for Emergent Matter Science, Wako 351-0198, Japan*
3 *Institute of Physics, Slovak Academy of Sciences, 84511 Bratislava, Slovakia*

In a quantum point contact (QPC) system, the electron-electron interaction induces spin correlations of conduction electrons. The correlations change the nuclear spin distribution near the QPC center. Recently the magnetization of conduction electron is measured by the resistively detected NMR (RDNMR) [1]. In this work, we discuss the dynamical nuclear spin polarization (DNP) due to the current through QPCs.

When an external magnetic field B_{ex} is applied, the QPC potential is spin-dependent, described by an S-matrix through the QPC. The hyperfine interaction between conduction electrons and nuclei induces the spin flip-flop processes. The spin-flip rate is calculated by the S-matrix via the Fermi's golden rule. The value of the DNP, I_z, is determined by the rate equation for the nuclear spin [2,3].

Figure 1(a) shows the distribution of I_z for the conductance $G = e^2/h$ as a function of the coordinate x, where the center of the QPC is located at $x = 0$. The black arrow indicates the direction of the current through the QPC. The DNP distribution changes its sign at the QPC center; $I_z < 0$ for the upstream side of the QPC while $I_z > 0$ for the downstream side. This DNP reverses its orientation when the direction of the current is reversed. The DNP distribution comes from the scattering processes for conduction electrons and nuclear spins as shown in Fig. 1(b). When $G = e^2/h$, only up spin electrons can pass through the QPC. When an electron with the down spin that flips to the up spin before the transmission, it induces the down DNP, while the electron flips its spin after the transmission, it induces the up DNP [3].

We discuss electron transport under the DNP structure in Fig. 1(a). The effective magnetic field $B = B_{\mathrm{ex}}+B_{\mathrm{N}}$ is $B > B_{\mathrm{ex}}$ for $I_z < 0$ and $B < B_{\mathrm{ex}}$ for $I_z > 0$, since the Overhauser field $B_{\mathrm{N}} < 0$ for $I_z > 0$. The conductance under the DNP is calculated with and without the NMR, denoted by $G(\mathrm{NMR})$, and $G(\mathrm{w/oNMR})$, respectively. It is shown that $\Delta G = G(\mathrm{NMR}) - G(\mathrm{w/o\ NMR})$ is proportional to the shot noise and $G > 0$ for weak Coulomb interactions. When the Coulomb interaction is strong, ΔG can change its sign [3]. We also discuss the RDNMR signal at a finite bias voltage, and find that the dipole-like DNP leads to a "dispersive" lineshape, where the signal changes its sign as a function of the NMR frequency [3].

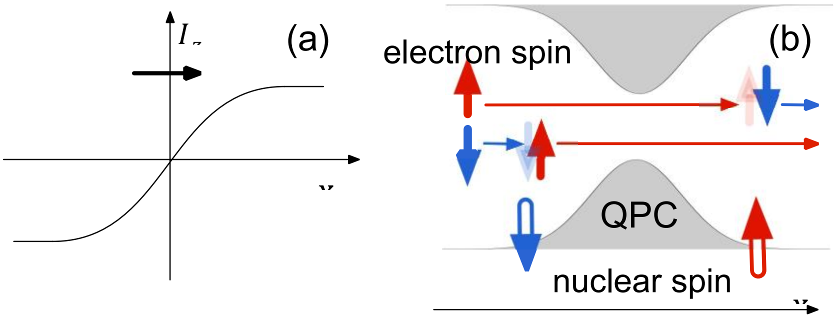


Figure 1: (a) Dipole-like DNP distribution; (b) Spin exchange between electrons and nuclear spins in (a)

References

[1] M. Kawamura, K. Ono, P. Stano, K. Kono, and T. Aono, Phys. Rev. Lett. 115, 036601 (2015).

[2] A. Singha, M. H. Fauzi, Y. Hirayama, and B. Muralidharan, Phys. Rev. B 95, 115416 (2017).

[3] P. Stano, T. Aono, and M. Kawamura, Phys. Rev. B 97, 075440 (2018).

Invited talk

Charge and Spin Dynamics in a Quantum Dot-Lead Hybrid System

T. Otsuka,1,2,3 T. Nakajima,2,3 M. R. Delbecq,2,3 P. Stano,2,4 S. Amaha,2 J. Yoneda,2,3 K. Takeda,2 G. Allison,2 S. Li,2 A. Noiri,2,3 T. Ito,2,3 D. Loss,2,5 A. Ludwig,6 A. D. Wieck,6 and S. Tarucha2,3
1Research Institute of Electrical Communication, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
2Center for Emergent Matter Science, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
3Department of Applied Physics, University of Tokyo, Bunkyo, Tokyo 113-8656, Japan
4Institute of Physics, Slovak Academy of Sciences, 845 11 Bratislava, Slovakia
5Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland 6Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany
tomohiro.otsuka@riec.tohoku.ac.jp

The dynamics in open quantum systems attracts interest in basic science and applications for quantum devices. To explore the physics of open quantum systems, semiconductor quantum dots (QDs) offer good experimental platforms because important parameters including the coupling to the environment can be tuned electrically. Also, high-speed detection of charge and spin states in the QDs have been developed and established in the research field of spin quantum bits for quantum information processing [1]. Here, we apply the technique to a hybrid system that consists of a single quantum dot and an open electric reservoir. We explore the charge and spin dynamics in the hybrid system.

The measured device is a GaAs/AlGaAs gate-defined double QD. A target QD is coupled to an open electric reservoir through a tunneling barrier, and the charge state is monitored by a nearby QD charge sensor. The QD charge sensor is embedded in a high-frequency resonator for the high-speed measurement technique called RF reflectometry [2]. Another ancillary QD is used to detect the target spin state by utilizing Pauli spin blockade. We initialize the charge and spin states by utilizing singlet formation in the ancillary QD and transfer the initialized electron into the target QD. Then, we monitor the change of the charge state in the target QD by the fast charge sensor and the spin state by the following spin blockade measurement.

We first measure the change of the charge and spin states around the charge transition, where the energy level of the QD is close to the Fermi level of the reservoir. The charge and spin relaxations are observed and their timescales are the same. From the detailed analysis of the charge state transition, the mechanizm is revealed as a result of the first order tunneling process, in which the electron escapes and the charge and spin states are changed. When we increase the coupling between the target QD and the reservoir, we observe spin relaxation signals even in a deep Coulomb blockade region, which is much faster than the intrinsic spin relaxation time in a QD. The observed dynamics properties are different for the charge state signal, indicating the second order process through intermediate states, in which only the spin state is modified [3]. These results will be important in the exploration of further dynamics in quantum dot-lead coupled systems and utilized for spin manipulations.

References

[1] R. Hanson, et al., Rev. Mod. Phys. **79**, 1217 (2007).
[2] D. J. Reilly et al., Appl. Phys. Lett. **91**, 162101 (2007). [3] T. Otsuka et al., Sci. Rep. **7**, 12201 (2017).

Invited talk

Quantum interferometry with a quantum dot

S. N. Shevchenko (1,2,3), K. Ono (4,5), T. Mori (6), S. Moriyama (7), Franco Nori (1,8)
(1) Theoretical Quantum Physics Laboratory, Cluster for Pioneering Research, RIKEN, Wako-shi, Saitama 351-0198, Japan
(2) B. Verkin Institute for Low Temperature Physics and Engineering, Kharkov 61103, Ukraine
(3) V. N. Karazin Kharkov National University, Kharkov 61022, Ukraine
(4) Advanced device laboratory, RIKEN, Wako-shi, Saitama 351-0198, Japan
(5) CEMS, RIKEN, Wako-shi, Saitama 351-0198, Japan
(6) Nanoelectronics Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8568, Japan
(7) International Center for Materials Nanoarchitectonics, National Institute for Materials Science (NIMS), Tsukuba, Ibaraki 305-0044, Japan and
(8) Department of Physics, The University of Michigan, Ann Arbor, MI 48109-1040, USA

Sensitive measurement techniques are based on the interference of waves. The most striking illustration is the recent use of interferometry for the detection of gravitational waves. If in place of classical electromagnetic waves one can use the wave functions of quantum objects, such techniques can be called quantum interferometry. We consider this interference applied to the example of a double-quantum dot driven and modulated by microwaves and probed by a transport current [1]. Importantly, such a system can be useful as a high-temperature spin qubit [2]. Theoretically, such driven quantum system can be described in terms of consecutive transitions between energy levels, known as Landau-Zener-Stuckelberg-Majorana interferometry [3]. In this talk, I will tell how the work of those four prominent physicists is important nowadays for both quantum dynamics and quantum control of modern few-level systems.

[1] K. Ono, S. N. Shevchenko, T. Mori, S. Moriyama, and F. Nori, Quantum interferometry of a hightemperature single-spin qubit, arXiv:1809.02326.
[2] K. Ono, T. Mori, and S. Moriyama, High temperature operation of silicon qubit, arXiv:1804.03364.
[3] S.N. Shevchenko, S. Ashhab, and F. Nori, Landau-Zener-Stueckelberg interferometry, Physics Reports 492, 1-30 (2010)

Topological pumping in strongly interacting systems

Masaya Nakagawa
RIKEN Center for Emergent Matter Science (CEMS)

Topological pumping is adiabatic quantum transport which pumps a quantized amount of charge reflecting the topology of the ground-state wavefunctions over the time evolution. This phenomenon was discovered in seminal work in 1983 by Thouless [1], who showed that an adiabatic cycle of one-dimensional band insulators induces such quantized charge pumping and pointed out its close connection to the quantum Hall effect. Despite its significance, topological Thouless pumping had not been observed experimentally until recently. However, after almost 30 years from the original prediction by Thouless, the topological pumping was finally observed by using ultracold atoms in optical lattices [2, 3]. Since the interactions between ultracold atoms are highly controllable, correlation effects on topological pumping can be significant in those systems, and even enable us to realize interaction-induced pumping. In this presentation, I will address the following two fundamental questions on topological pumping in strongly interacting systems:

(i) Is topological pumping robust in strongly interacting systems?
(ii) Can interactions induce new topological pumping that cannot be realized in non-interacting systems?

For (i), we show that a key to understanding of the stability of topological pumping against interactions is a crossover of topological phases from fermionic to bosonic ones [4]. We demonstrate that the topological pumping in Rice-Mele model with repulsive interactions breaks down in a strongly correlated regime, whereas it is quite robust against attractive interactions. We explain the qualitative difference between the repulsive and attractive cases using symmetry protection of the topological phases. For (ii), we show that a quasi-one-dimensional limit of various quantum Hall states gives a systematic construction of interaction-induced topological pumping that cannot be realized in free fermion systems. Examples include fractional charge pumping and intriguing “off-diagonal” topological pumping [5], which correspond to the fractional quantum Hall effect and the bosonic integer quantum Hall effect, respectively. Furthermore, we show that the fractional Thouless pumping realizes a discrete time crystal as a non-equilibrium phase of matter, which offers robust charge transport even in nonadiabatic regimes
[6].

References

[1] D. J. Thouless, *Phys. Rev. B* 27, 6083 (1983).

[2] S. Nakajima *et al.*, *Nat. Phys.* 12, 296 (2016).

[3] M. Lohse *et al.*, *Nat. Phys.* 12, 350 (2016).

[4] M. Nakagawa, T. Yoshida, R. Peters, and N. Kawakami, *Phys. Rev. B* 98, 115147 (2018).

[5] M. Nakagawa and S. Furukawa, *Phys. Rev. B* 95, 165116 (2017).

[6] K. Mizuta, K. Takasan, M. Nakagawa, and N. Kawakami, *Phys. Rev. Lett.* 121, 093001 (2018).

Invited talk

Exploring Mesocopic Physics with Atomtronics

Leong-Chuan Kwek
Center for Quantum Technologies,
National University of Singapore

Atomtronics is an emerging field in quantum technology that promises to realize ‘atomic circuit’ architectures exploiting ultra-cold atoms manipulated in versatile micro-optical circuits generated by laser fields of different shapes and intensities or micro-magnetic circuits known as atom chips. Although devising new applications for computation and information transfer is a defining goal of the

field, atomtronics wants to enlarge the scope of quantum simulators and to access new physical regimes with novel fundamental science. In this talk, we survey the state of the art of atomtronics-enabled quantum technology. We also extend the scope of the existing atom-based quantum devices and to devise platforms for new routes to quantum technology.

LC Kwek is a Principal Investigator at the Center for Quantum Technologies, National University of Singapore since its inception. He is also the Co-Director of the Quantum Engineering Program of National Research Foundation in Singapore. He works on quantum information science and atomtronics and he has published more than 200 refereed papers on the subject. He is an elected Fellow of the American Association for the Advancement of Science (AAAS), the Institute of Physics (UK) and the Institute of Physics (Singapore). He currently serves as a council member of the Tan Kah Kee Foundation (Singapore) and IUPAP WG5 (Women in Physics). He is also an editorial member of the Association of Asia Pacific Physical Societies Bulletin Board. LC Kwek was a co-recipient of the Singapore National Science Award (Team) in 2006, the IPS Premier Research award (2006) and the IPS President Medal (2016). He is also very active in the local secondary school education system.

Invited talk

Characterization and modelling of quantum dynamics with memory effects

Bassano Vacchini
Dipartimento di Fisica, Universita degli Studi di Milano, Via Celoria 16, I-20133 Milan, Italy`
INFN, Sezione di Milano, Via Celoria 16, I-20133 Milan, Italy

The study of open quantum systems has led to identify notions of quantum non-Markovian dynamics, which have recently been the object of quite intense research. Such dynamics should naturally provide a description of memory effects in the quantum domain. We will provide a characterization of quantum non-Markovianity making reference to mathematical properties of the time evolution map describing the reduced dynamics of the open system [1, 2]. We will further discuss the general structure of evolution equations that can describe a non-Markovian dynamics, thus going beyond the Lindblad result [3]. Applications and modelling of non-Markovian dynamics will be considered, making reference in particular to collision models [4, 5].

References

[1] H.-P. Breuer, E.-M. Laine, J. Piilo and B. Vacchini, Colloquium: Non-Markovian dynamics in open quantum systems, *Rev. Mod. Phys.* 88, 2016 (021002)

[2] H.-P. Breuer, G. Amato and B. Vacchini, Mixing-induced quantum non-Markovianity and information flow, *New J. Phys.* 20, 2018 (043007)

[3] B. Vacchini, Generalized master equations leading to completely positive dynamics, *Phys. Rev. Lett.* 117, 2016 (230401)

[4] G. Guarnieri, C. Uchiyama and B. Vacchini, Energy backflow and non-Markovian dynamics, *Phys. Rev. A* 93, 2016 (012118)

[5] S. Campbell, F. Ciccarello, G. M. Palma and B. Vacchini, System-environment correlations and Markovian embedding of quantum non-Markovian dynamics *Phys. Rev. A* 98, 2018 (012142)

Invited talk

Floquet Stroboboscopic divisibility in Non-Markovian Dynamics

V. M. Bastidas
NTT Basic Research Laboratories & Research Center for Theoretical Quantum Physics, 3-1 Morinosato-Wakamiya, Atsugi, Kanagawa, 243-0198, Japan

One of the fundamental concepts in statistical mechanics is the notion of ergodicity, which is closely related to the lack of memory of a system. In quantum mechanics, it is observed that the interactions redistribute the available energy and enable thermalization [1]. Under some conditions, however, an external drive can inhibit ergodicity [3, 4, 5]. In this case, the system looses the ability to explore all the available states [6, 7, 8, 9, 10] and keeps memory of the initial state. In this talk, I will discuss a model where ergodic behavior is broken due to integrability. The reduced dynamics of such as system is given by a time-local master equation with time-periodic rates. Due to the time-periodicity of the master equation, the dynamical map is divisible at discrete times, which is referred to as Floquet stroboscopic divisibility [11]. I will illustrate general theory by studying an oscillator coupled to both non-Markovian and Markovian baths. In this example, if one prepares the system in a cat state, the environment induces stroboscopic revivals of the cat after its death. Our theory may have profound implications in entropy production in non-equilibrium systems.

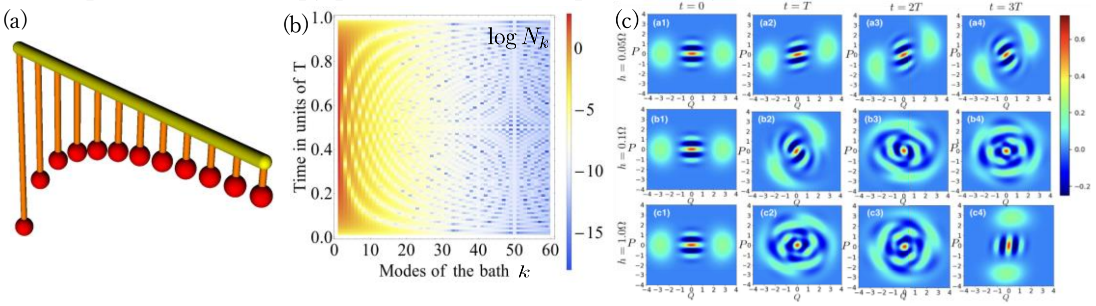


Figure 1: Floquet Stroboscopic divisivility. (a) A mechanical analogue of the non-Markovian bath. (b) Reversible dynamics of the non-Markovian bath and (c) evolution of the Wigner function of a Schrodinger cat[11].¨

References

[1] M. Srednicki, Phys. Rev. E 50, 888 (1994).

[2] A. Lazarides, A. Das, and R. Moessner, Phys. Rev. Lett. 115, 030402 (2015).

[3] S. Restrepo, J. Cerrillo, V. M. Bastidas, D. G. Angelakis, and T. Brandes, Phys. Rev. Lett. 117, 250401 (2016).

[4] A. Eckardt, Rev. Mod. Phys. 89, 011004 (2017).

[5] V. M. Bastidas, B. Renoust, Kae Nemoto, W. J. Munro, arXiv:1807.00080 (2018).

[6] D. Basko, I. Aleiner, B. Altshuler, Ann. Phys. 321, 1126 (2006).

[7] R. Nandkishore, D. A. Huse, Annu. Rev. Condens. Matter Phys. 6, 15 (2015).

[8] E. Altman, R. Vosk, Annu. Rev. Condens. Matter Phys. 6, 383 (2015).

[9] M. Schreiber, S. S. Hodgman, P. Bordia, H. P. Lschen, M. H. Fischer, R. Vosk, E. Altman, U. Schneider, I. Bloch, Science 349, 842 (2015).

[10] P. Roushan, C. Neill, J. Tangpanitanon, V. M. Bastidas, A. Megrant, R. Barends, Y. Chen, Z. Chen, B. Chiaro, A. Dunsworth, A. Fowler, B. Foxen, M. Giustina, E. Jeffrey, J. Kelly, E. Lucero, J. Mutus,1 M. Neeley, C. Quintana, D. Sank, A. Vainsencher, J. Wenner, T. White, H. Neven, D. G. Angelakis, J. Martinis, Science 358, 1175 (2017).

[11] V. M. Bastidas, T. H. Kyaw, J. Tangpanitanon, G. Romero, L.-C. Kwek, D. G. Angelakis, New J. Phys. 20, 093004 (2018).

Lower bounds for the mean dissipated heat in the spin-boson model

Kazunari Hashimoto, Chikako Uchiyama
University of Yamanashi
Bassano Vacchini
Universita degli Studi di Milano`

In 1961, Rolf Landauer linked information theory and thermodynamics by showing that erasing of classical bits of memory must be accompanied by an inevitable heat dissipation [1]. According to Landauer's principle, the dissipated heat is bounded from below by heat proportional to the corresponding reduction of information.

In recent years, the principle has been reviewed from the quantum statistical point of view, and two different types of quantum mechanical Landauer's principle have been derived. The first one is referred to as the 'entropic bound' derived by Reeb and Wolf by introducing an environment-aided quantum information erasure protocol equipping a relevant system (memory) attached to an environment [2]. It states that the mean value of the heat dissipates to the environment is bounded from below by corresponding reduction of von Neumann entropy of the relevant system:

$$\beta\langle\Delta Q\rangle \geq \Delta S. \tag{1}$$

The second one is referred to as the 'thermodynamic bound' derived by Goold by applying the Jensen inequality to the exponentiated dissipated heat [3]:

$$\beta\langle\Delta Q\rangle \geq -\ln\langle e^{-\beta\Delta Q}\rangle. \tag{2}$$

Since these two bounds have different origins, their tightness against the mean dissipated heat have been studied by several authors [3, 4]. So far, however, these comparative studies of the two bounds have been performed with finite environment consists of one or few spins. In this talk, we will report our resent results of the comparative study of tightness of the two bounds performed in a spin-boson model consisting of a single spin (relevant system) attached to a large bosonic environment.

References

[1] R. Landauer, IBM. J. Res. Dev. 5, 183(1961).

[2] D. Reeb and M. M. Wolf, New J. Phys. 16, 103011(2014).

[3] J. Goold, M. Paternostro, and K. Modi, Phys. Rev. Lett. 114, 060602(2015).

[4] S. Campbell, G. Guarnieri, M. Paternostro, and B. Vacchini, Phys. Rev. A 96, 042109(2017).

Invited talk

Quantum and Information Thermodynamics, with and without factorized initial conditions

Massimiliano Esposito
University of Luxembourg

The nature of dissipation in open quantum system and its information-theoretic interpretation will be discussed. I will first present an exact second law-like identity for an externally driven quantum systems interacting with a finite ”reservoir”, i.e. another quantum system that is initially at equilibrium [1]. I will then consider various specific scenarios where the system dynamics can be described by a closed quantum master equation and formulate its corresponding second-law [2, 3, 4]. All these schemes rely on the assumption of a factorized initial condition between system and reservoir. I will briefly discuss possible ways to formulate Quantum Thermodynamics beyond this assumption [5, 6].

References

[1] M. Esposito, K. Lindenberg and C. Van den Broeck, ”Entropy production as correlation between system and reservoir”, New J. Phys. 12, 013013 (2010).

[2] G. Bulnes Cuetara, M. Esposito and G. Schaller, ”Quantum Thermodynamics with Degenerate Eigenstate Coherences”, Entropy 18, 447 (2016).

[3] F. Barra and M. Esposito, ”Dissipation in small systems: A Landau-Zener approach”, Phys. Rev. E 93, 062118 (2016).

[4] P. Strasberg, G. Schaller, T. Brandes, M. Esposito, ”Quantum and Information Thermodynamics: A Unifying Framework based on Repeated Interactions”, Phys. Rev. X 7, 021003 (2017).

[5] P. Strasberg and M. Esposito, ”Stochastic thermodynamics in the strong coupling regime: An unambiguous approach based on coarse-graining”, Phys. Rev. E 95, 062101 (2017).

[6] P. Strasberg and M. Esposito, ”Non-Markovianity and negative entropy production rates”, arxiv:1806.09101.

Quantum energy transport under environmental engineering

Chikako Uchiyama

In this talk, I will present a possibility to control quantum energy transport with environmental engineering.

Recently, energy transport in the light harvesting molecules of photosynthetic bacteria has attracted much attention because of its high efficiency[1,2]. To describe the efficiency, importance of the role of environmental noise has been recognized to assist quantum transport[3], which is in contrast to the conventional thinking on the noise as an obstacle for transport.

While the research trend has been proceeding to mimic the biological system, my colleagues and myself considered to propose a way to control quantum energy transport with applying noise[4]. Such change of viewpoint enables us to enlarge the choice of the feature of noise: we considered to apply noise with spatial-temporal correlation on the sites. We found that the anti-spatial correlation and optimal temporal correlation can greatly assist the energy transport.

In addition to the above topics, I would like to talk about a survey of the theoretical treatment on the open quantum system for the quantum transport.

[1] R. E. Blankenship, *Molecular Mechanisms of Photosynthesis*, (Blackwell Science: Oxford/Malden, 2002).
[2] T. Brixner et. al., “Two-dimensional spectroscopy of electronic couplings in photosynthesis”, Nature vol.434, 625 (2005).
[3] P. Rebentrost, M. Mohseni, I. Kassal, S.Lloyd, and A. Aspuru-Guzik, “Environment-assisted quantum transport”,
New J. Phys. Vol.11, 033003 (2009).
[4] C. Uchiyama, W. J. Munro, and K. Nemoto, “Environmental engineering for quantum energy transport”, npj Quantum Information vol.4, 33 (2018)