

Curriculum Vitae

Name : *Shubhashis Rana.*
Father's Name: Subrata Rana.
Date of Birth: 22nd January 1986.
Gender: Male.
Marital status: Unmarried
Nationality: Indian
email: shubho@iopb.res.in.
Phone: +91-9583657275.

Present Address : Room no.103,
New Hostel,
Institute of Physics,
Sachvalaya Marg,
Bhubaneswar,
Orissa. India,
Pin-751005.

Permanent Address: Hatishala Ghat,
Baidyabati,
dist-Hooghly,
West Bengal, India,
Pin-712222.

Academic Qualification:

Degree	Year of qualification	Institute / University
Secondary	2001	West Bengal Board of Secondary Education
Higher Secondary (Science)	2003	West Bengal Council of Higher Secondary Education
B. Sc. (hons. in Physics + Chemistry + Mathematics)	2006	Barrackpore Rastraguru Surendranath College, Calcutta University
M. Sc. (Physics)	2009	Presidency College, Calcutta University
Pre-Doctoral	2010	Institute of Physics, Bhubaneswar

Present Status:

Designation: Research Scholar, since 2010 August.
Name of the Supervisor : Prof. A M Jayannavar.
Institution: Institute of Physics, Bhubaneswar

Research Interest:

Non-equilibrium statistical mechanics:

Stochastic thermodynamics, Classical and quantum Fluctuation Theorems, Information theory and statistical mechanics, stochastic resonance, Heat engines/ refrigerators at nanoscale.

Academic Fellowship: 2009-2011 Junior Research Fellowship
2011- Senior Research Fellowship

Language Known: Bengali(Native), English, Hindi.

Hobby: Paintings, Trekking, Photography

Computer Skills: Software Packages: Mathematica
Simulation Techniques: Brownian Dynamics, Monte-Carlo simulation

Research Experience:

Classical thermodynamics holds for macroscopic system and is built around the concept of equilibrium states. If we shift our focus away from the equilibrium states we came across rich diverse field of non-equilibrium processes which is a subject of intensive ongoing current studies. As the system size become microscopic or smaller, fluctuations start playing dominating role. All the thermodynamic quantities such as work, heat, entropy etc. now depend on the particular phase space evolution or the trajectory. To this end new field of stochastic thermodynamics has emerged which has proved successful in our understanding of the micro and the nano world.

When the system are driven far away from equilibrium, fluctuations in physical quantities satisfy a number of strong relations so called fluctuation theorem. These theorems are valid even beyond the linear response regime and replace inequalities of thermodynamics into equalities. From these theorems one can obtain linear and non linear response coefficients, and moreover second law of thermodynamics can be obtained as the corollary. These theorems also constrain the performance characteristics of engines/molecular motor at nano-scales. With the improvement of technology one can monitor micron/nano sized objects. This gives us an opportunity to verify these fluctuation theorems and calculate the equilibrium free energy from out of equilibrium measurements. In the following I mention briefly our research contribution to this field :

A. Fluctuation theorems in presence of information gain and feedback:

We have generalized the fluctuation theorems in presence of feedback and measurements. Intermediate measurements on the system leads to information gain that can be used to extract more work from the system by driving it using appropriate feedback, the system being in contact with a single heat bath. This seems to be in contradiction with second law if we do not take into account information and feedback. Our treatment extends several classical theorems in the presence of information and feedback. Some of these include the Jarzynski Equality, total entropy production and Hatano-Sasa identity for transition between non-equilibrium steady states. We have derived in the presence of information the extended quantum fluctuation theorems in open systems composed of coupled subsystem and bath. No assumption is made on the nature of environment and the strength of system-bath coupling. However, it is assumed that measurement process involve classical errors.

B. Quantum Jarzynski Equality with multiple measurement and feedback for isolated system:

In this work, we have derived the Jarzynski equality (JE) for an isolated quantum system in three different cases: (i) the full evolution is unitary with no intermediate measurements, (ii) with intermediate measurements of arbitrary observables being performed, and (iii) with intermediate measurements whose outcomes are used to modify the external protocol (feedback). Our treatment is based on path probability in state space for each realization. This is in contrast to the formal approach based on projection operator and density matrices. We have found that the JE remains unaffected in the second case, but gets modified in the third case where the mutual information between the measured values with the actual eigenvalues must be incorporated into the relation.

C. Generalized entropy production fluctuation theorems for quantum systems:

Based on trajectory dependent path probability formalism in state space, we have derived generalized entropy production fluctuation relations for a quantum system in the presence of measurement and feedback. We have obtained these results for three different cases: (i) the system is evolving in isolation from its surroundings; (ii) the system being weakly coupled to a heat bath; and (iii) system in contact with reservoir using quantum Crooks fluctuation theorem. In case (iii), we have built on the treatment carried out in [H. T. Quan and H. Dong, arxiv/cond-mat: 0812.4955], where a quantum trajectory has been defined as a sequence of alternating work and heat steps. The obtained entropy production fluctuation theorems retain the same form as in the classical case. The inequality of second law of thermodynamics gets modified in the presence of information. These fluctuation theorems are robust against intermediate measurements of any observable performed with respect to von Neumann projective measurements as well as weak or positive operator valued measurements.

D. Fluctuation relations for heat engines in time-periodic steady states:

A fluctuation relation for heat engines (FRHE) has been derived recently. In the beginning, the system is in contact with the cooler bath. The system is then coupled to the hotter bath and external parameters are changed cyclically, eventually bringing the system back to its initial state, once the coupling with the hot bath is switched off. In this work, we lift the condition of initial thermal equilibrium and derive a new fluctuation relation for the central system (heat engine) being in a time-periodic steady state (TPSS). Carnot's inequality for classical thermodynamics follows as a direct consequence of this fluctuation theorem even in TPSS. For the special case of the absence of hot bath we obtain the integral fluctuation theorem for total entropy and for no extraction of work we get the generalized exchange fluctuation theorem. Recently micro-sized heat engines have been realized experimentally in the TPSS. We numerically simulate the same model and verify our proposed theorems.

E. Stochastic thermodynamics of small Scale heat engines/ Anomalous Brownian refrigerator:

Small scale heat engines have been realized experimentally. They operate in presence of highly fluctuating input and output energy fluxes and are therefore much better characterized by fluctuating efficiencies. Finite time stochastic thermodynamics provides us with a consistent framework for small scale systems operating arbitrary far from equilibrium. Using this framework we have carried out an extensive analysis of single particle heat engines by manipulating a Brownian particle in a time dependent harmonic potential with time-dependent coupling to two heat baths. Different cyclic protocols with and without inertia are considered. Thermodynamic quantities such as work, heat and stochastic efficiency exhibit strong fluctuations in time periodic steady states. The fluctuations of stochastic efficiency dominates over the mean value even in the quasi-static regime. The phase diagrams for system operations are qualitatively different for inertial and over-damped regimes. This is supported by our analytical results in the quasi-static regime. In time periodic steady state there are several realizations where the system does not work as a heat engine. Such transient Second law violating realizations decrease as we increase cycle time. Hence for larger cycle times our system work more reliably as an engine. Some of our results differ qualitatively from earlier claims in the literature. We have also verified fluctuation relations for heat engines in time periodic steady state.

we have studied Carnot-type refrigerator (same protocol as in the engine, however in the reverse direction) operating between two thermal baths. Both the underdamped as well as the overdamped limits are investigated. Besides working as a stochastic refrigerator, it is shown analytically that in the quasistatic regime the system can also act as stochastic heater, depending on the bath temperatures. Interestingly, in non-quasistatic regime, our system can even work as a stochastic heat engine for certain range of cycle time and bath temperatures. We show that the operation of this engine is not reliable. The fluctuations of stochastic efficiency/coefficient of performance (COP) dominate their mean values. Their distributions show power law tails, however the exponents are not universal. Our study reveals that microscopic machines are not the microscopic equivalent of the macroscopic machines that we come across in our daily life. We find that there is no one to one correspondence between the performance of our system under engine protocol and its reverse.

F. Extracting work from single heat bath in presence of feedback:

In equilibrium it is impossible to extract work from a single heat bath. In non-equilibrium process this is possible for few trajectories and these trajectories are termed as transient second law violating trajectories. However, Second law is obeyed on average. Now, if measurement is done and applied a proper feedback, then one can extract energy even on average from single heat bath utilising the acquired information. As an example we studied a Brownian particle confined in a two dimensional harmonic trap in presence of magnetic field, whose position co-ordinates are measured with finite precision. Two separate cases are investigated in this study - (A) moving the center of the potential and (B) varying the stiffness of the potential. Optimal protocols which extremise the work in a finite time process are explicitly calculated for these two cases. For Case-A, we show that even though the optimal protocols depend on magnetic field, surprisingly, extracted work is independent of the field. For Case-B, both the optimal protocol and the extracted work depend on the magnetic field. However, the presence of magnetic field always reduces the extraction of work.

G. Fluctuation theorems in inhomogeneous media under coarse graining:

We compare the fluctuation relations for work and entropy in underdamped and overdamped systems, when the friction coefficient of the medium is space-dependent. We find that these relations remain unaffected in both cases. However, for the overdamped system, the analysis is more involved, and a blind application of normal rules of calculus would lead to inconsistent results.

H. The effect of confinement on stochastic resonance in continuous bistable systems:

Stochastic resonance (SR) is a phenomenon in which a feeble input signal applied to a bistable potential gets magnified at a particular noise strength. In this phenomenon noise plays a constructive role as opposed to its being looked upon as unwanted. It has previously been shown that the average injected energy to the system is the best quantifier of SR. Using this quantifier, we have observed bistability is a necessary but not a sufficient condition for observing SR. It is observed in superharmonic (hard) potentials, but is not observed in subharmonic (soft) potentials, even though potential is bistable. However, in both soft and hard potentials, we have observed resonance phenomenon as a function of driving frequency. Some subtleties in the dynamics of particle in the two different types of potentials are analyzed through the probability distributions of work done on the system over a period.

Publications:

- The role of soft versus hard bistable systems on stochastic resonance using average cycle energy as a quantifier.
S. Rana, S. Lahiri and AM Jayannavar.
The European Physical Journal B **84**, 323 (2011).
- Fluctuation theorems in presence of information gain and feedback.
S. Lahiri, **S. Rana** and A. M. Jayannavar.
J. Phys. A: Math. Theor. **45**, 065002 (2012) .
- Quantum Jarzynski equality with multiple measurement and feedback for isolated system.
S. Rana, S. Lahiri and A. M. Jayannavar.
Pramana **79**, 233 (2012).
- Fluctuation relations for heat engines in time-periodic steady states.
S. Lahiri, **S. Rana** and A. M. Jayannavar.
J. of Phys. A: Math. and Theor. **45**, 465001 (2012).
- Generalized entropy production fluctuation theorems for quantum systems.
S. Rana, S Lahiri and A. M. Jayannavar.
Pramana **80**, 207 (2013).
- Fluctuation theorems in inhomogenous media under coarse graining.
S. Lahiri, **S. Rana** and A. M. Jayannavar.
Physics Letters A **378**, 979 (2014).
- Extracting work from a single heat bath - A case study on Brownian particle under external magnetic field in presence of information .
P. S. Pal, **S. Rana**, A. Saha and A. M. Jayannavar.
Phys. Rev. E **90**, 022143 (2014).
- Single Particle Stochastic Heat Engine.
S. Rana, P. S. Pal, A. Saha and A. M. Jayannavar.
Phys. Rev. E **90**, 042146 (2014).
- Anomalous Brownian Refrigerator .
S. Rana, P. S. Pal, A. Saha and A. M. Jayannavar.
ArXiv: 1503.02559

Conference-presentation/ School Attended :

- Attended in ' 2nd RRI school on Statistical Physics' held at Raman Research Institute, Bangalore, India during 7-19 March, 2011.
- Delivered a talk with title 'Stochastic thermodynamics of small scale heat engines' at 'CMDAYS 14' held at Centre for Research in Nanoscience and Nanotechnology (CRNN), Technology Campus, University of Calcutta, Kolkata, West Bengal, India during 27-29 August, 2014.
- Presented a Poster with title 'Single particle stochastic heat engine' at STATPHYS-KOLKATA held at S.N Bose National Center of Basic Sciences, Kolkata, India, during 1-5 December, 2014
- Delivered a talk with title 'Stochastic thermodynamics of small scale heat engines/ Strange Refrigerators' in the Workshop on recent Developments In Non-Equilibrium Physics "Luxembourg out of Equilibrium" held at University of Luxembourg, Luxembourg during 12-15 January, 2015.

Reference:

Prof. Arun M. Jayannavar
Sr. Professor
Institute of Physics
Sachivalaya Marg
Bhubaneswar – 751005, India
e-mail : jayan@iopb.res.in
ph : 0091 674 230 6424