Prepared for submission to JHEP

Aspects of non-equilibrium Physics

Aditya Vijaykumar

International Centre for Theoretical Sciences, Bengaluru, India.

E-mail: aditya.vijaykumar@icts.res.in

Contents

1 Introduction and Motivation

Non-equilibrium systems can be - open, closed and quenched (changing parameters of the Hamiltonian suddenly so that the system as a whole is out of equilibrium). They arise in classical (integrable models) as well as quantum systems.

(question by Junaid on nonlinear Schrodinger equation, and a long detour about that. Manas writes the Schrodinger equation with a $|\psi|^2$ potential, and discusses a few methods of discretization of this equation. The essence of the discussion was that the nonlinear schrodinger equation can be reduced (in something called the reductive perturbation expansion) to a minimal model of the KdV equation. $u_t = -\partial_x(\alpha u^2 + \beta u_{xx})$. The solution to $\beta = 0$ case is $u(x,t) = U_0(x - u(x,t)t)$ So if we start out with lets say a Lorentzian profile, the u^2 term will cause the profile to curve to the right and steepen. But the derivative term will now convert the steepening to oscillations.)

Classical non-equilibrium systems can be classifield as :-

- Integrable Models
- Non-integrable Models
- Classical Field Theoretic systems

Quantum non-equilibrium systems :-

- **Quantum Lattice Models (Incommensurate Models)-** $H = \sum_i (a_i^\dagger a_{i+1} + \text{h.c}) \sum_i (a_i^\dagger a_i)$. Lets say one starts with $\omega_i = \lambda \cos(2\pi b i), b = 4/3$. The model basically repeats itself after every three steps in i, ie.$i \to i+3$. Under this conditions this system is called a ballistic system. But if $b = \dfrac{\sqrt{5}-1}{2}$, this model never repeats itself. Such models are called incommensurate models. For $\lambda < 1$, these systems behave ballistic, but when $\lambda > 1$, the system is localized. The current goes down. When $\lambda = 1$, it's called the critical condition. Just by a model where there are no real interactions, we see a lot of different phases with respect to the parameter λ.
- **Hybrid Quantum Systems** - Systems made of fermionic and bosonic degrees of freedom. Let's say we have a mesoscopic systems (with only a source and sink) and two quantum dots in between. Lets say one couples this fermionic system to a bosonic system. How do the bosonic degrees of freedom affect the fermionic current and vice versa.

- **Designing Quantum Hamiltonian Systems** - Open Quantum Phase Transitions, Open Quantum Spin Chains, Property of non-Hermitian systems, emergent phenomena, Quantum Devices, understanding dark states

Seni-classical non-equilibrium systems :-

- PDEs due to cold atoms, multi component gases