Abstract

Quantum Zeno Effect for continuous measurement

Stanisław M. Sołtan

Slowing down of a quantum system time evolution due to repeated measurements that check, if the system is in its initial state is called the quantum Zeno effect. Conversely, the speed up of the evolution under such procedure is called Anti-Zeno effect. When the time between (projective) measurements approaches zero, a paradoxical theoretical result is obtained, that the time evolution of the observed system is stopped. It is universally accepted that to solve this problem one has to take detector into account in detection model, that is, apply the generalised measurement theory when the times between measurements are very short.

In this dissertation the quantum system is modelled by a single state (taken as initial one) coupled to a continuum of states. Calculations and numerical analysis are greatly simplified by taking Lorentzian form factor as describing this coupling. This is due to the so-called method of pseudomodes. The PhD thesis contains the analysis of aforementioned effects for a continuous measurement (that is, the limit of zero time intervals has been taken) in which the observed system interacts weakly with a different probe at any instance of time, independent of other probes. It could be assumed, that the system interacts with a stationary flow of particles (probes). The outcome of such measurement is a continuous variable assigned to every moment of time. Correlations of these values taken at different moments are expressed by correlations of observables. Here the observable is taken as a projection onto the initial state. These correlations can be calculated with the help of a Lindblad equation for the observed system.

Due to these circumstances, criteria for Zeno or Anti-Zeno effects to occur are defined with the use of the expectation values and the two-point time correlations of the measurement outcomes. This is in contrast with a standard approach of analysing the probability of a chain of positive results. Therefore, criteria are firstly tested in the case of repeated projective measurements and are found to reproduce a qualitatively the same form of results as standard ones. However, the transition to the regime of sparse measurements and damped oscillations of the probability of the initial state (a case where the investigated effects are undefined) is smooth as compared to the case of standard criteria (this was investigated for the Lorentzian form factor). Additionally the Anti-Zeno effect occurs for smaller range of controlled parameters. Furthermore, a weak measurement using exactly two probes (with no limit of short times) allows to obtain the so-called weak value of the observable. A condition for this quantity reproduce standard criteria provided the coupling of initial state to the continuum is small.

I consider these results justify the proposed criteria. Thus, I apply them to the case of continuous measurements. For long duration time of the experiment and weak coupling with a continuum, the corrections due to the measurement take the form of modified Fermi Golden Rule. Corrections for short times are also obtained. Exact calculations and numerical analysis were performed for the case of the Lorentzian form factor. In principle, a possible effect was identified of a resonance between a detector and a measured system, but the influence of this resonance on outcomes are negligible.

In the last chapter I also point out the difficulties in defining a chain of positive results of the continuous measurement. This problem is worth further investigations.