Abstract

In an experimental setup, by making measurements on quantum states one ends up with a family of probability distributions- quantum statistics (also called ``boxes"). For some specific type of measurements and states, these statistics can exhibit interesting properties, for example violating Bell inequalities (i.e. exhibiting so called Bell nonlocality) or contextuality inequalities. Apart from their fundamental interest, these features are important from quantum information processing point of view. To better understand such behaviours of quantum mechanical boxes one usually considers boxes which do not necessarily come from measurements done on quantum states, but satisfy some very basic properties, such as no-signalling or, more generally, some consistency. In the present thesis, we study some aspects of nonsignalling boxes as well as broader notion that of contextuality.

This thesis is mainly divided into two parts. In the first part, we study Bell nonlocality in a quantum setting as well as in nonsignalling scenario. It consists of two opposite direction approaches to Bell nonlocality. The first one tests how much quantum box is limited to achieve algebraic violation for Bell inequalities due to determinism in it. The developed approach is new. We provide a quantitative result and give a universal upper bound on violation of Bell inequalities in the considered quantum setting. The other approach investigates how Bell nonlocality limits nonsignalling thoery (which includes quantum theory) to perform even simple tasks compared to classical theory. This is shown by proving a version of the no-broadcasting theorem where we limit the allowed class of operations to the locality preserving operations. In specific, we consider 2 inputs and 2 outputs boxes and, the proof heavily relies on the geometry of convex polytope of these class of boxes and twirling operations. Similar technique is also developed to prove some of the results in the second part of the thesis where contextuality is the main topic of investigation. A monotone is

introduced which is used in analogous manner as in entanglement theory approach.

In the second part of the thesis, we explore contextuality and take a quantitative approach to it. This further includes two sub-parts. The first of which explores additivity property of a contextuality measure for a family of boxes. The proof involves exploiting convex structure of a broader class of boxes known as consistent boxes and twirling maps. These are similar techniques which are developed in the first part of the thesis for no-broadcasting case. Next, considering contextuality as a resource, we study an important property of this resource: distillability. We have presented a distillation protocol for a class of contextual XOR boxes. In particular, a 2-copy of a weaker contextual box is distilled to a better resource using operations that preserve non-contextuality.