Back-Action Evading Measurement

Suppose that, given an observable *A* there is no disturbance on-average, i.e. $T_A(\varrho) = \varrho$ for all $\varrho \in \mathfrak{M}(\mathcal{H})$. In such a case, $\mathcal{E}_k(\varrho)$ is proportional to the identity map for all $k \in \Omega_A$, and there is no information gain on any outcome [661] [664]. This shows that there must be some disturbance of the system being measured in order for there to be information gain.

Given a measurement that implements observable *A* and an implementation that has average mapping $T_A(\varrho)$, the measurement of *A* is a back-action evading (BAE) measurement if for all $\varrho \in \mathfrak{M}(\mathcal{H})$ and all $j \in \Omega_A$ the probability of measuring A_j is the same whether or not $T_A(\varrho)$ is previously applied. The condition for back-action evading measurement is $\mathrm{Tr}\left[A_j T_A(\varrho)\right] = \mathrm{Tr}\left[A_j \varrho\right]$ [186]. A back-action evading measurement is one for which the probability of measurement is unaffected whether or not the average mapping of *A* is implemented before the second measurement of *A*.

The condition for non-disturbing measurement can be rewritten equivalently in terms of the dual map of *A*, $T_A^*\left(A_j\right) = A_j$ and $j \in \Omega_A$ [229]. BAE measurement is also referred to in the literature as *measurement of the first kind* [229]. A Lüder’s implementation of a commutative POVM observable is also BAE (see Exercise 7.3 in the book or kindle version of theQMP). A sufficient condition for a BAE measurement is that each A_i has an eigenvalue of unity.