# Emergence of the Geometric Phase from Quantum Measurement Back-action

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**Abstract**
The state vector representing a quantum system acquires a phase factor following an adiabatic evolution along a closed trajectory in phase space [1, 2]. This is the traditional example of a geometric phase, or Pancharatnam–Berry phase, a concept that has now been generalized beyond cyclic adiabatic evolutions to include generalized quantum measurements [3]. However, a clear description of the relationship between the emergence of a geometric phase and the effects of a series of generalized quantum measurements on a quantum system has not yet been provided. Here we report that a sequence of weak measurements with continuously variable measurement strengths in a quantum optics experiment conclusively reveals that the quantum measurement back-action is the source of the geometric phase [4].

**Results**
The initial state $|\psi\rangle$, the final projection, and the first measurement are fixed, respectively, at $\boldsymbol{\psi} = \boldsymbol{\varphi} = \{0, 1, 0\}$ and $\boldsymbol{a} = \{0, 0, 1\}$. The second measurement is varied with $\boldsymbol{b} = -\{\sin 4\theta_B, 0, \cos 4\theta_B\}$ such that the geometric phase $\Phi_G$ is accumulated by increasing the angle $\theta_B$, see Figure 1. When the measurement strength $\gamma$ goes to zero, no geometric phase is observed because there are no changes to the quantum state due to the measurements (i.e., no measurement back-action). Note that, at $\gamma = 1$, a sudden phase jump is observed. This singular behavior can be understood by the geodesic hypothesis or by the fact that no phase can be defined as the visibility $V = 0$ at this point.

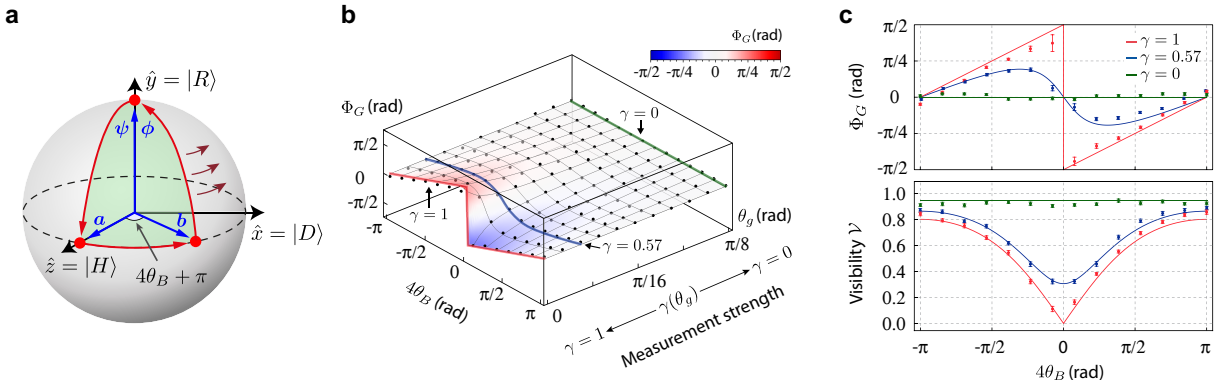


Figure 1. **a**, The quantum state trajectory based on the geodesic hypothesis due to sequential projective quantum measurements. **b**, The measurement-induced geometric phase $\Phi_G$ as a function of the measurement direction $\theta_B$ and the measurement strength $\gamma(\theta_G)$. **c**, The data show that the geometric phase is indeed due to quantum measurement back-action; that is, the stronger the measurements, the larger the accumulated geometric phase.

**References**
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