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(I) Quantum archæology: how much time does an atom spend tunneling through a beam of light, and how much time do photons spend "trapped"in atoms?

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One of the most famous tidbits of received wisdom about quantum mechanics is that "you can't ask"which path a photon took in an interferometer once it reaches the screen, or in general, that only questions about the specific things you finally measure are well-posed at all. Much work over the past decades has aimed to chip away at this blanket renunciation, and investigate "quantum retrodiction."Particularly in light of modern experiments in which we can trap and control individual quantum systems for an extended time, and quantum information protocols which rely on "postselection,"these become more and more timely issues.

All the same, the principal experiment I wish to tell you about addresses a century-old controversy: that of the tunneling time. Since the 1930s, and more heatedly since the 1980s, the question of how long a particle spends in a classically forbidden region on those occasions when quantum uncertainty permits it to appear on the far side has been a subject of debate. Using Bose-condensed Rubidium atoms cooled down below a billionth of a degree above absolute zero, we have now measured just how long they spend inside an optical beam which acts as a "tunnel barrier"for them. I will describe these ongoing experiments, as well as proposals we are now refining to study exactly how long it would take to "collapse"an atom to be in the barrier.

I will also say a few words about a more recent experiment, which looks back at the common picture that when light slows down in glass, or a cloud of atoms, it is because the photons "get virtually absorbed"before being sent back along their way. It turns out that although it is possible to measure "the average time a photon spends as an atomic excitation,"there seems to be no prior work which directly addresses this, especially in the resonant situation. We carry out an experiment that lets us distinguish between the time spent by transmitted photons and by photons which are eventually absorbed, asking the question "how much time are atoms caused to spend in the excited state by photons which are not absorbed?"

Primary author: Prof. STEINBERG, Aephraim (University of Toronto)

Presenter: Prof. STEINBERG, Aephraim (University of Toronto)

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