The linear potential and the cubic phase

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The quantum mechanical propagator of a massive particle in a linear gravitational potential is well-known to contain a phase $\varphi_g$ scaling with the third power of propagation time $T$ \cite{1}. This phase has the remarkable feature of being proportional to the ratio $m_g^2/m_i$, where $m_g$ and $m_i$ denote the gravitational and the inertial mass of the particle, respectively.

We propose and analyze an experiment to observe this phase using an atom interferometer \cite{2}. As shown in Fig. 1 the atom experiences two different accelerations $a_1$ or $a_2$ depending on its internal state $|g_1\rangle$ or $|g_2\rangle$, respectively. In this way the atom accumulates two different phases $\varphi_g^{(1,2)}$ depending on its internal state and the total interferometer phase scales as $T^3$. Moreover, we compare this phase to the one accumulated by a particle moving in a time-dependent linear potential.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{time_space_diagram.png}
\caption{Space-time diagram of the $T^3$-interferometer. Four short Raman pulses effectively drive transitions between the two internal states $|g_1\rangle$ and $|g_2\rangle$ of a three-level atom.}
\end{figure}

\begin{thebibliography}{9}
\bibitem{1} E.H. Kennard, Zeitschrift für Physik 44:326 (1927)
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