Black hole acceleration radiation: a quantum optical perspective

Marlan Scully\textsuperscript{1,2,3}, Steve Fulling\textsuperscript{1}, David Lee\textsuperscript{1}, Don Page\textsuperscript{4}, Wolfgang Schleich\textsuperscript{1,5}, Anatoly Svidzinsky\textsuperscript{1}

\textsuperscript{1}Texas A\&M University, \textsuperscript{2}Princeton, \textsuperscript{3}Baylor, \textsuperscript{4}University of Alberta, \textsuperscript{5}Ulm University

General relativity as originally developed by Einstein is based on the union of geometry and gravity. Half a century later the union of general relativity and thermodynamics was found to yield surprising results such as Bekenstein-Hawking black hole entropy and Hawking radiation.

In their seminal works, Hawking, Unruh and others showed how quantum effects in curved space yield a blend of thermodynamics, quantum field theory and gravity which continues to intrigue and stimulate. It has been shown \cite{1} that virtual processes in which atoms jump to an excited state while emitting a photon is an alternative way to view Unruh acceleration radiation. The present work \cite{2} is an extension of that logic by considering what happens when atoms fall into a black hole (BH) as shown in Fig. 1.

Specifically, we analyze the problem of atoms outside the event horizon emitting acceleration radiation as they fall into the BH (see Fig. 1). We find that the quantum master equation technique, as developed in the quantum theory of the laser, provides a useful tool for the analysis of BH acceleration radiation and the associated entropy \cite{2}. The emitted radiation is essentially, but not precisely, thermal and has an entropy analogous to that obtained by Bekenstein and Hawking. However, the physics is very different. Here we have radiation coming from the atoms, whereas Hawking radiation requires no extra matter (e.g. atoms).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1}
\caption{(Left) Artist's concept illustrating a supermassive BH surrounded by matter flowing onto the BH in an accretion disk. Also shown is an outflowing jet of energetic particles powered by the BH's spin. (Right) BH is bombarded by a pencil-like cloud of two level atoms falling radially from infinity. The relative acceleration between the atoms and the field yields generation of acceleration radiation.}
\end{figure}

\begin{thebibliography}{9}
\bibitem{1} M.O. Scully, V.V. Kocharovsky, A. Belyanin, E. Fry, F. Capasso, Phys. Rev. Lett. \textbf{91}, 243004 (2003).
\end{thebibliography}