We consider the quasinormal modes for a class of black hole spacetimes that, informally speaking, contain a closely “squeezed” pair of horizons. (This scenario, where the relevant observer is presumed to be “trapped” between the horizons, is operationally distinct from near-extremal black holes with an external observer.) It is shown, by analytical means, that the spacing of the quasinormal frequencies equals the surface gravity at the squeezed horizons. Moreover, we can calculate the real part of these frequencies provided that the horizons are sufficiently close together (but not necessarily degenerate or even “nearly degenerate”). The novelty of our analysis (which extends a model-specific treatment by Cardoso and Lemos) is that we consider “dirty” black holes; that is, the observable portion of the (static and spherically symmetric) spacetime is allowed to contain an arbitrary distribution of matter.

Dated: 20 October 2003; -ed

Introduction

The perturbations of the spacetime outside of a black hole horizon are expected to be radiated away, at late times, with a discrete set of complex-valued frequencies; the so-called quasinormal mode frequencies of a black hole $P_{r,XX3,Rev}$. Knowledge of these modes should have particular importance in gravitational-wave astronomy and, in a more speculative scenario, may even provide insight into the very essence of black hole entropy (which still lacks a convincing statistical explanation).

With regard to the latter motivation, an interesting proposal has been put forth by Hod Hod. On the basis of Bohr’s correspondence principle, Hod has suggested that, in the asymptotic limit of a “highly damped” black hole, By highly damped, it is meant that the imaginary portion of the mode frequency has become very large. This connection follows from the imaginary part being a measure of the inverse relaxation time of a radiating black hole. The real part of the quasinormal frequency should represent a characteristic (transition) frequency for the black hole itself. Moreover, it was then argued that the value of this special frequency could be used as a means for uniquely fixing the level spacing of the black hole area spectrum. (The concept of a uniformly spaced area spectrum for black holes was first advocated by Bekenstein Bek.)

To help flesh out these somewhat esoteric statements, let us consider the asymptotic behavior of the quasinormal modes for a Schwarzschild black hole. In the case of scalar or gravitational perturbations, these asymptotic frequencies are known to take the following form $\text{Nol,And: equation } k_{qnm}(n) = \frac{1}{4m} \left[ i \left( n + \frac{1}{2} \right) + \frac{\ln 2}{2\pi} \right] + \mathcal{O}[n^{-1/2}] \quad \text{as } n \to \infty$, 0.