INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

The dissipative nature of time dependent systems is well known to have an intriguing feature of superradiance like phenomena when interacting with radiation either classically or quantum mechanically. In this thesis we have considered two particular dynamical systems arising in two different realms namely, oscillating black holes (BH) in the sky and oscillating bubbles in the laboratory. In the first part of the thesis, we studied the classical scattering of massless fields from oscillating BHs and calculated the absorption cross-section. In the second part of the thesis, we have considered a laboratory system of an oscillating gas bubble, where we have proposed a framework and studied the phenomena of quantum mechanical particle production mapping the system into an analog geometric background.

The first system of the oscillating BH emerges in the merging event of binary BHs. This merging of two back holes comprises three distinct stages: inspiral, merger and ringdown. The recent detection of gravitational waves by LIGO-Virgo has been shown to describe these three phases with great detail which should be extremely useful to gain deep insight into the nature of spacetime.

We have analysed the absorption cross section of the BHs in its ringdown phase for two fundamental fields: scalar and electromagnetic field. The absorption cross section turns out to be oscillating in time reflecting the time dependent nature of the ringing BHs. Interestingly, in the appropriate parameter range (discussed in detail in the thesis) the cross section turns negative during the course of its evolution, and such change suggests that the ringing BHs is superradiant within the time scale of its oscillation.

In the second case, we have studied a special laboratory system where an air bubble submerged in the water is perturbed by an external sound wave, and the bubble undergoes rapid oscillation. Experimentally it is found that during the course of its oscillation, the bubble emits a periodic flash of light within the ranges from visible to far ultraviolet wavelength. This phenomenon is popularly known as sonoluminescence. Over the years the mechanism of such light emission has been formulated in the framework of both classical and quantum mechanics with limited success, and various potential drawbacks. Particularly, we should point out that all the proposed quantum mechanical models predict divergent photon flux. In this thesis, we have attempted to explain this phenomenon by proposing a model in the framework of quantum field theory in curved spacetime. We modelled the oscillating bubble as a time dependent analog geometric background. This background geometry is described by an acoustic metric.

We argue that the sonoluminescence is indeed a non-perturbative phenomena, and it is the parametric resonance in the oscillating background which is responsible for the photon production without any ultraviolet divergences. To this end, we should point out that due to extreme stiffness in the systems of differential equations, we could compute the spectrum up to an order of magnitude lower frequency compared to the experimentally observed values.

The universal nature of particle production in time dependent background has motivated us to propose a similar formalism for neutrino production from the oscillating air bubble in sonoluminescence phenomena. We have minimally coupled the massive fermion field to the same effective time dependent background as introduced in the case of photon production. With this coupling, we have quantified the produced number spectrum and power spectrum.