# Unparticle may be a Remedy to the Information Loss in the Scattering of Fermion off Dilaton Black-hole

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We study s-wave scattering of fermion off dilaton black-hole. With one loop correction it was found to suffer from nonpreservation of information and that of course, went against Hawking's revised suggestion on this issue. A nonstandard approach, e.g. the probable existence of unparticle in  $(1+1)$ dimension has been adopted here that shows a remedy to get rid of the danger of information loss to bring it in agrees with the Hawking's revised suggestion.

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#### I. INTRODUCTION

There has been much interest in the physics of back-hole over the last few decades and the scattering of fermion off dilaton black hole carries special interest because the literatures related to this problem [\[1](#page-6-0)[–11\]](#page-6-1) have provided much insight into its connection to the Hawking radiation. The issue that attracted attention to a great extent was the possible information loss during the formation and the subsequent evaporation of the black-hole. A controversy in this context was generated from Hawking's initial suggestion about four decades ago [\[12\]](#page-6-2), but his revised suggestion on this issue [\[13](#page-6-3)] has brought back moderately pleasant scenario. In spite of that, it is fair to admit that the matter related to the preservation of information did not yet conclusively settl down from all corner. Therefore, investigation related to this problem still be of interest.

A general description of this process was pursued in [\[14](#page-6-4)], where it was found to be formulated through the smatrix description of the event which involved lots of inherent constructional complexity and computational difficulty. Therefore, most of the authors preferred to handle this problem with less complicated but interacting and well formulated model [\[1](#page-6-0)]; see [\[7](#page-6-5)] for review. The model took birth in the description of two dimensional noncritical string theory and the black hole solution of this was carried out in [\[15\]](#page-6-6). An extremal magnetic charged black-hole solution was considered in these studies. Eventually, it was generated from a (3+1) dimensional model involving a dilaton field. Since in the study of s-wave scattering of fermion in this black-hole, angular coordinates becomes irrelevant and an interesting  $(1+1)$  dimensional effective action takes birth. It is known from the important publication [\[1](#page-6-0)], that when the energy involved in this process is not too high, the metric and the dilaton field can be treated as external classical quantities and an amusing version of quantum electrodynamics with position dependent coupling constant emerges out.

With this framework the scattering of massless Dirac fermion was studied in [\[1](#page-6-0)]. Although the mathematical formulation did involve a general description (as permitted within this framework), the authors did not encounter the problem of information loss since one loop correction was not included there. However, with the similar framework, when this scattering phenomena was extended with the chiral fermion in [\[9\]](#page-6-7) the author had to face the danger of real information loss. The one loop correction [\[16](#page-6-8), [17](#page-6-9)] entered in this description automatically during bosonization. The present author in [\[18\]](#page-6-10), showed that there exists a remedy of this danger if the possibility of allowance of anomaly is exploited judiciously. Note that, this framework is so powerful and beautifully designed that it itself has a room for taking the anomaly into consideration. In the study of scattering of Dirac fermion [\[1\]](#page-6-0), though the author did not face the danger of information loss, the present author reported that information loss could not be avoided when one loop correction that entered during the process of bosonization was taken into account [\[10\]](#page-6-11). The result though led to an uncomfortable situation there was no known standard physical principal to avoid it as it was found in the case of chiral fermion [\[18\]](#page-6-10). It certainly diminishes the glory of this important and well formulated framework of studying the scattering problem [\[1\]](#page-6-0) since the result went against Hawking's revised suggestion [\[13\]](#page-6-3). In this work, therefore, an attempt has been made to bring it in agreement with Hawking's revised suggestion [\[13\]](#page-6-3) making it free from the danger of information loss even in the presence of one loop correction.

A failure to find the standard physical principal towards having a plausible solution of a standing unresolved problem

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does not mean that some non standard approach would not not be of worth for that. A very good instance in this direction is the introduction of unparticle to get a plausible solution of momentum distribution [\[19\]](#page-6-12) at high energy regime. After the introduction of the concept of unparticle in the seminal work [\[19\]](#page-6-12), it has been used in different important studies. The studies related to dark matter using this concept is of worth mentioning [\[20,](#page-6-13) [21\]](#page-6-14). Study of Casimir effect in presence of unparticle is another important phenomenological development [\[22](#page-6-15)]. An attempt to establish unparticle as holographic dual of gapped AdS gravity is also an interesting theoretical improvement [\[23\]](#page-6-16). Unparticle with one loop correction was studied in [\[24\]](#page-6-17) where a remarkable retrieval of gauge invariance in the usual phase space was found. In this work we are, therefore, intended to exploit the advantage of having the probable existence of unparticle in  $(1+1)$  dimension [\[25](#page-6-18)] to get a remedy of the problem of information loss that occurred in the s-wave scattering process when one loop correction got involved in [\[10\]](#page-6-11). Let us mow turn towards that end.

The Paper is organized as follows. Sec. II, is devoted with a brief discussion of Unparticle in  $(1 + 1)$  dimension to make the paper self contained. Sec. III deals with the formulation of the model related to s-wave scattering of fermion off dilaton black hole that is expected to give a plausible solation of information loss. In Sec. IV, we determine the theoretical spectrum of the model using Dirac's prescription of quantization of constrained system. Sec. V, contains a description of the plausible solution towards removal of information loss problem setting a cardinal scale and the final Sec. VI, contains the concluding remarks.

# II. A BRIEF DESCRIPTION OF UNPARTICLE IN TWO DIMENSION

To make this article self contained it would be useful to start with a brief introduction of unparticle, to be precise unparticle in  $(1 + 1)$  dimension, before going to the actual formulation of the model which is aimed to get a plausible remedy of the information loss in the Scattering of Fermion off Dilaton Black-hole.

We are habituated to see our quantum mechanical world in terms of particles. In the classical domain these a particle has definite mass and therefore carry energy and momentum in a definite relation  $E^2 = p^2c^2 + m^2c^4$ , which turns in to a dispersion relation in quantum mechanics [\[19\]](#page-6-12). The scale invariance can not be seen unless that mass reduces to zero. Therefore, a free massless particle is a very good and simple example of scale invariant stuff because the zero mass remains unaffected by resealing. The standard model though does not have the property of scale invariance but there could be a sector of the theory, which is yet unseen but it is exactly scale invariant and very weakly interacting with the rest of the standard model.

This reminds the work of Banks and Zaks [\[26](#page-7-0)] where they observed a non-trivial zero of the β function in the IR region of Yang-Mills theories with certain non-integral number of fermions that indicates the absence of a particle like interpretation. Georgi in his seminal work [\[19](#page-6-12)], termed this scale invariant stuff as unparticle and formulated an attactive frame work. The topic attracted a huge attention and a variety of fields of research, spanning astrophysics, neutrino physics, AdS/CFT duality and quantum gravity have found its application.

The exactly soluble 2D theory of a massless fermion coupled to a massive vector boson, the Sommerfield model (Thirring-Wess), is an interesting analog of a Banks-Zaks model. It is approaching to a free theory at high energies and a scale invariant theory with nontrivial anomalous dimensions at low energies. This is a toy standard interacting model where interaction of fermions with the gauge field is considered which shows a transition from unparticle behavior at low energies to free particle behavior at high energies.

The Sommerfield (Thirring-Wess) model model [\[27](#page-7-1), [28](#page-7-2)] is described by the action

<span id="page-1-0"></span>
$$
S_f = \int d^2x [i\bar{\psi}\gamma^{\mu}(\partial_{\mu} - ieA_{\mu})\psi - \frac{1}{4}F_{\mu\nu}F^{\mu\nu}]. \tag{1}
$$

Here e has one mass dimension representing the coupling constant between the vector current associated with the massless fermion field  $\psi$  and the gauge field  $A_\mu$ . The Lorentz indices  $\mu$  and  $\nu$  takes the values 0 and 1 corresponding to a  $(1+1)$  dimensional space time and  $F_{\mu\nu}$  is the electromagnetic field strength. It is the well known vector Schwinger model [\[29\]](#page-7-3) with Proca background, i.e., Schwinger model with an additional masslike term for the gauge field. Both the Schwinger model and the Sommerfield (Thirring-Wess) model are exactly solvable model where gauge field interacts vectorially with the current associated with the fermion field. The theoretical spectrum of the Schwinger model shows only a massive particle with mass  $\tilde{e}$ , where  $\tilde{e} = \frac{e}{\sqrt{\pi}}$ , however the solution of Sommerfield (Thirring-Wess) model shows the presence of a massless along with a massive field with square of the mass  $m^2 = m_0^2 + \tilde{e}^2$ . Alhough the Schwinger model does not have a scale invariant sector the Sommerfield (Thirring-Wess) model does have. A structurally identical model (in algebraic sense), the so called the Nonconfinig Schwinger model was studied by us in [\[30\]](#page-7-4) where the masslike term for gauge field although got involved in completely different perspective may certainly be useful to understand the the theoretical spectra in the present situation. In fact, that term was entered there through one loop correction in order to remove the divergence of the fermionic determinant appeared during bosonization. The contents of the

article [\[30\]](#page-7-4) is able to provide algebraically a clear exposition of the solution of Sommerfield (Thirring-Wess) model trough the determination of theoretical spectrum using constrained dynamics due to Dirac [\[31](#page-7-5)]. It can be seen just by setting  $m_0^2 = \frac{ag^2}{\pi}$  in [\[30\]](#page-7-4). It is also shown there that the gauge field propagator shows the poles at the expect positions [\[30](#page-7-4)]. To get a clear view, it would be of worth to write down the effective action that follows from [\(1\)](#page-1-0) in the manner it has been computed in [\[30\]](#page-7-4) :

$$
S_{eff} = \frac{1}{2} \int d^2x [A_{\mu}(x) M^{\mu\nu} A_{\nu}(x)], \qquad (2)
$$

where,

$$
M^{\mu\nu} = m_0^2 g^{\mu\nu} - \frac{\Box + \tilde{e}^2}{\Box} \tilde{\partial}^{\mu} \tilde{\partial}^{\nu}.
$$
 (3)

Here the standard notation

$$
\tilde{\partial}^{\mu} = \epsilon^{\mu\nu} \partial_{\nu}.
$$
\n<sup>(4)</sup>

has been used. The antisymmetric tensor is defined with the convention  $\epsilon^{01} = -1$ . From the the effective action, the gauge field propagator is found to be

$$
\Delta_{\mu\nu}(x-y) = \frac{1}{m_0^2} [g_{\mu\nu} + \frac{\Box + \tilde{e}^2}{\Box(\Box + m_0^2 + \tilde{e}^2)} \tilde{\partial}_{\mu} \tilde{\partial}_{\nu}] \delta(x-y). \tag{5}
$$

It shows the two poles at the expected positions: one at vanishing mass and the other one at  $m^2 = m_0^2 + \tilde{e}^2$  [\[30\]](#page-7-4) From the infirmations available in [\[19](#page-6-12)], it is natural to accept that physical mass  $m = \sqrt{m_0^2 + \tilde{e}^2}$  plays the role of unparticle scale  $\Lambda_m$  of this in  $(1 + 1)$  dimensional model. Here we find the presence of a free massless scale invariant sector. Georgi himself has identified this massless sector of the theory [\(1\)](#page-1-0) as unparticle [\[25](#page-6-18)] and the mass of the massive scaler was pointed out there as unparticle scale in [\[25](#page-6-18)] which agrees with his previous seminal work[\[19](#page-6-12)]. Let us now turn towards the actual formulation of the model which will serve our present purpose.

# III. FORMULATION OF THE MODEL TOWARDS GETTING A REMEDY OF THE INFORMATION LOSS

The model for studying the scattering of fermion off dilaton black hole was formulated with an interacting Dirac fermion in a dilaton back ground [\[1,](#page-6-0) [3\]](#page-6-19). The lagrangian density that describes it is contained within the action

<span id="page-2-1"></span>
$$
S_f = \int d^2x [i\bar{\psi}\gamma^{\mu}[\partial_{\mu} - ieA_{\mu}]\psi - \frac{1}{4}e^{-2\Phi(x)}F_{\mu\nu}F^{\mu\nu}].
$$
 (6)

The dilaton field Φ stands as a non dynamical back ground. This model is considered here to study the s-wave scattering of fermion off dilaton black hole. It is known that the black hole is the extrema of the following  $(3+1)$ dimensional action

$$
S_{AF} = \int d^4x \sqrt{-g} [R + 4(\nabla \phi)^2 - \frac{1}{2} F^2 + i \bar{\psi} D \psi]. \tag{7}
$$

Here g stands for the determinant of the metric  $g_{\mu\nu}$ ,  $\psi$  is the charged fermion,  $D_{\mu} = \partial_{\mu} - ieA_{\mu}$ ,  $F^2 = F_{\mu\nu}F^{\mu\nu}$  and R is the scalar curvature.

The geometry involved here consists of three region [\[1,](#page-6-0) [7\]](#page-6-5). Far from the black hole there is an asymptotically flat region. At the close vicinity the curvature begins to rise. It is essentially a mouth region. The mouth leads to an infinitely long throat. Inside the throat the metric is approximated by a flat metric on two dimensional Minkowsky space times the round metric on two sphere with radius Q. Deep into the throat the low energy physics is effectively two dimensional and it remains confined in a plane. The two dimensional effective theory can be viewed as a compactified form of four to two dimension and the standard Kaluza-Klein technique leads to the effective  $(1 + 1)$  dimensional action [\[1\]](#page-6-0)

<span id="page-2-0"></span>
$$
S_{AF} = \int d^2 \sigma \sqrt{g} [R + 4(\nabla \phi)^2 + \frac{1}{Q^2} - \frac{1}{2} F^2 + i \bar{\psi} D \psi]
$$
(8)

For sufficiently low energy incoming fermion gravitational effect can be neglected and equation [\(8\)](#page-2-0) reduces to equation [\(6\)](#page-2-1)

To bring the unparticle into action in this scattering phenomena we modify the action [\(6\)](#page-2-1) with an additional masslike term for gauge field following the line of action of Sommerfield (Thirring-Wess) model.

<span id="page-3-0"></span>
$$
S_f = \int d^2x [i\bar{\psi}\gamma^{\mu}[\partial_{\mu} - ieA_{\mu}]\psi - \frac{1}{4}e^{-2\Phi(x)}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}m_0^2A_{\mu}A^{\mu}].
$$
\n(9)

Without violating any physical principle a mass like term for the gauge field is added here which implies a shifting of the electromagnetic background from Maxwell field to Proca and a surprisingly entry of the unparticle results in. We refer the work of Georgi [\[25\]](#page-6-18) for the technical details of the probable appearance of unparticle in lower dimensional physics. In the absence of one loop correction the theoretical spectra of the above model [\(9\)](#page-3-0) shows to have a massless scalar along with a massive scalar having square of the mass mass  $m^2 = m_0^2 + e^{2\Phi(x)}e^2$ . To see how the factor  $e^{2\Phi(x)}e^2$  enters into the mass term needs detailed constraint analysis and determination of theoretical spectrum of the model [\(9\)](#page-3-0) but it can be understood from our previous work [\[10\]](#page-6-11) and the earlier work in this context reported in [\[9\]](#page-6-7). The physical mass  $m = \sqrt{m_0^2 + e^{2\Phi(x)}e^2}$  as usual plays the role of unparticle scale [\[19](#page-6-12), [25\]](#page-6-18). It sets the scale of the transition from free particle behavior at high energy to the unparticle behavior at low energy. This unparticle scale will be modified if we include the one loop correction as we did in [\[30\]](#page-7-4). The one loop correction here too enters automatically during the process of bosonization [\[30\]](#page-7-4). Here bosonization is done integrating the fermion out one by one which leads to a determinant carrying a singularity. To remove that singularity it is needed to regularize it [\[30\]](#page-7-4). After proper regularization, when the determinant is written in terms of auxiliary field the following lagrangian density results.

<span id="page-3-1"></span>
$$
\mathcal{L}_B = \int d^2x \left[\frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \tilde{e}\epsilon_{\mu\nu}\partial^\nu\phi A^\mu - \frac{1}{4}e^{-2\Phi(x)}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}\tilde{e}^2(a + \frac{m_0^2}{\tilde{e}^2})A_\mu A^\mu\right].\tag{10}
$$

The parameter a is the ambiguity parameter of regularization with which we are familiar from quite a long past [\[16,](#page-6-8) [17,](#page-6-9) [30\]](#page-7-4).

## IV. QUANTIZATION OF THE MODEL TO GET THEORETICAL SPECTRUM

To get the theoretical spectrum in the present situation, let us now proceed with the constraint analysis of the resulting theory described by the lagrangian density [\(10\)](#page-3-1). It necessities the computation of the momenta corresponding to the fields describing the Lagrangian [\(10\)](#page-3-1). The canonical momenta corresponding to the scalar field  $\phi$ , the gauge field  $A_0$  and  $A_1$  as obtained from the standard definition are

<span id="page-3-2"></span>
$$
\pi_{\phi} = \dot{\phi} + \tilde{e}A_1,\tag{11}
$$

<span id="page-3-3"></span>
$$
\pi_0 = 0,\tag{12}
$$

<span id="page-3-4"></span>
$$
\pi_1 = e^{-2\Phi(x)}(\dot{A}_1 - A'_0) \tag{13}
$$

Here  $\pi_{\phi}$ ,  $\pi_0$  and  $\pi_1$  are the momenta corresponding to the field  $\phi$ ,  $A_0$  and  $A_1$ . Using the above equations [\(11\)](#page-3-2), [\(12\)](#page-3-3) and [\(13\)](#page-3-4), it is straightforward to obtain the canonical Hamiltonian through a Legendre transformation. The canonical Hamiltonian is found out to be

$$
H_C = \int dx^1 \left[ \frac{1}{2} (\pi_\phi + \tilde{e}A_1)^2 + \frac{1}{2} e^{2\Phi} \pi_1^2 + \pi_1 A_0' + \frac{1}{2} \phi'^2 - \tilde{e}A_0 \phi' - \frac{1}{2} \tilde{e}^2 (a + \frac{m_0^2}{\tilde{e}^2}) (A_0^2 - A_1^2). \tag{14}
$$

Note that equation [\(12\)](#page-3-3) is a primary constraint of the theory. The preservation of this constraint [\(12\)](#page-3-3) leads to a secondary constraint

<span id="page-3-5"></span>
$$
\pi_1' + \tilde{e}\phi' + \tilde{e}^2(a + \frac{m_0^2}{\tilde{e}^2})A_0 \approx 0.
$$
\n(15)

The constraints standing in the equations [\(12\)](#page-3-3) and [\(15\)](#page-3-5), form a second class set. The system does not have any other constraint excepting these two. In order to get the reduced Hamiltonian (according to Dirac's terminology ) we need to impose these two constraints into the Hamiltonian which ultimately renders the following Hamiltonian in the reduced phase space.

<span id="page-4-0"></span>
$$
H_R = \int dx^1 \left[\frac{1}{2}(\pi_\phi + \tilde{e}A_1)^2 + \frac{1}{2}\frac{1}{a\tilde{e}^2 + m_0^2}(\pi_1' + \tilde{e}\phi')^2 + \frac{1}{2}e^{2\Phi(x)}\pi_1^2 + \frac{1}{2}\phi'^2 + \frac{1}{2}\tilde{e}^2(a + \frac{m_0^2}{\tilde{e}^2})A_1^2\right].
$$
\n(16)

The Dirac brackets [\[31\]](#page-7-5) between the fields describing the reduced Hamiltonian [\(16\)](#page-4-0) remain canonical and using that canonical set of Dirac brackets we get the following equations of motion.

<span id="page-4-1"></span>
$$
\dot{A}_1 = e^{2\Phi(x)}\pi_1 - \frac{1}{a\tilde{e}^2 + m_0^2}(\pi_1'' + \tilde{e}\phi''),\tag{17}
$$

<span id="page-4-2"></span>
$$
\dot{\phi} = \pi_{\phi} + \tilde{e}A_1,\tag{18}
$$

<span id="page-4-3"></span>
$$
\dot{\pi}_1 = -\tilde{e}\pi_\phi - (a\tilde{e}^2 + m_0^2)A_1.
$$
\n(19)

<span id="page-4-4"></span>
$$
\dot{\pi}_{\phi} = \frac{\tilde{e}^2(a+1) + m_0^2}{a\tilde{e}^2 + m_0^2} \phi'' + \frac{\tilde{e}}{a\tilde{e}^2 + m_0^2} \pi_1''.
$$
\n(20)

The above four equations [\(17\)](#page-4-1), [\(18\)](#page-4-2), [\(19\)](#page-4-3) and [\(20\)](#page-4-4), lead to the following two second order differential equations after a little algebra.

$$
(\Box + \tilde{e}^2 e^{2\phi} (a + \frac{m_0^2}{\tilde{e}^2} + 1)\pi_1 = 0, \tag{21}
$$

$$
\Box[\pi_1 + \tilde{e}(a + \frac{m_0^2}{\tilde{e}^2} + 1)\phi] = 0.
$$
 (22)

Here  $\pi_1$  represents a massive boson with square of the mass  $m^2 = \tilde{e}^2 e^{2\phi} (a + \frac{m_0^2}{\tilde{e}^2} + 1)$  and  $\phi$  represents a massless scalar field which was termed as unparticle in [\[25\]](#page-6-18). Note that the physical mass term  $m = \sqrt{\tilde{e}^2 e^{2\phi(x)}(a + \frac{m_0^2}{\tilde{e}^2} + 1)}$ has modified getting the effect of one loop correction which is playing the role of unparticle scale in the present situation. The model considered here has position dependent coupling constant that arose from (3+1) dimensional model involving a dilaton field and in this situation it is natural that unparticle scale (physical mass term) would be space dependent but that will not pose any problem to set the unparticle scale at at a desired value at a particular space-time point which in fact we need for our purpose. We will come to this point in detail in the next Sec. The surprising aspect of this model, i.e., the presence of the space dependent exponential factor  $e^{2\Phi}(x)$ , where  $\Phi = -x^1$ for the background generated by linear dilaton vacua in  $(1 + 1)$  dimensional gravity makes it amenable to study the s-wave scattering where information puzzle gets in. The mass of the massive boson therefore goes on increasing indefinitely towards the negative  $x^1$ . So a final contribution will be totally reflected and an observer at  $x^1 \to \infty$  will get back all the information. To be more precise mass will vanish near the mouth but increases indefinitely as one goes into the throat because of the variation of this space dependent factor  $\Phi$ . Since a massless scalar is equivalent to a massless fermion in  $(1 + 1)$  dimension, this can be thought of as a massless fermion proceeding into the blackhole it will not be able to travel an arbitrary long distance and will be reflected back with a unit probability. Thus there will be no information loss from the massive sector of the theory. But a genuine problem will arise from the massless sector because the massless boson (fermion) will remain massless irrespective of its position. So it will go on travelling through out the black hole without any hindrance. Therefore, an observer at  $x^1 \to \infty$  will never find this massless fermion with a return journey. So a real problem related to information loss appears due to the presence of the massless fermion. It is certainly an unwanted scenario and it goes against Hawking's revised Suggestion [\[13\]](#page-6-3). Unfortunately, this possibility can't be ruled out if one has to accept the said model [\[1](#page-6-0)]. The aim of this work is to find out a plausible remedy of this problem towards which we now turn

#### V. PLAUSIBLE SOLUTION TO THE REMEDY OF THE INFORMATION LOSS

To get out of this problem an attempt has been made to adopt a non standard approach because till now there is no known standard approach to achieve it. To this end we bring the unparticle into action in order to get a remedial measure. Let us see how the unparticle has been brought into service to save this particular problem from the unavoidable information information loss in presence of one loop correction. We have seen that this theory with one loop correction contains an ambiguity parameter a. We are free to exploit this ambiguity to set the unparticle scale  $\tilde{\Lambda}_m = \tilde{m} = \tilde{e} \times e^{\Phi(\tilde{x}^1)}$  at a particular space time point say for example at  $x^1 = \tilde{x}^1$  and  $x^0 = \tilde{x}^0$ , at the throat region [\[1](#page-6-0)]. The unparticle scale at  $x^1 = \tilde{x}^1$  and  $x^0 = \tilde{x}^0$ , therefore, represents the *cardinal* point of transition from unparticle behavior at low energies to pertubative behavior at high energies. This setting of scale immediately brings a drastic change into the constraint structure of the theory for all space-time points after  $x^1 = \tilde{x}^1$  and  $x^0 = \tilde{x}^0$  and that brings a miraculous change into the theoretical spectrum. In fact, the constraint [\(15\)](#page-3-5) gets modified to

<span id="page-5-0"></span>
$$
\pi_1' + \tilde{e}\phi' \approx 0,\tag{23}
$$

since that setting demands  $a + \frac{m_0^2}{e^2} = 0$ , which can be met up exploiting the regularization ambiguity. It is amazing to note that the constraints [\(12\)](#page-3-3) and [\(23\)](#page-5-0) turns into a first class set loosing their second class nature with this setting and that brings a radical change in the theoretical spectrum. To get the theoretical spectra at this stage we need two gauge fixing condition corresponding to the two first class constraints. The gauge fixing conditions are  $A_0 = 0$  and  $A'_1 = 0$  are now introduced. The canonical Hamiltonian along with the two constraints [\(12\)](#page-3-3), and [\(23\)](#page-5-0) and the above two gauge fixing conditions reduces to the following simplified form.

$$
H_R = \int dx^1 \left[\frac{1}{2}\pi^2_{\phi} + \frac{1}{2}\phi'^2 + \frac{1}{2}\tilde{e}^2 e^{2\Phi}\phi^2\right].\tag{24}
$$

The Dirac brackets [\[31\]](#page-7-5) in this situation are also found to remain canonical. These canonical Dirac brackets lead to two first order differential equation from the Hamiltonian [\(23\)](#page-5-0).

<span id="page-5-1"></span>
$$
\dot{\phi} = \pi_{\phi},\tag{25}
$$

<span id="page-5-2"></span>
$$
\dot{\pi}_{\phi} = \phi'' - \tilde{e}^2 e^{2\Phi} \phi.
$$
\n<sup>(26)</sup>

The above two first order differential equation [\(25\)](#page-5-1) and [\(26\)](#page-5-2) after a little algebra gets simplified into

<span id="page-5-3"></span>
$$
(\Box + \tilde{e}^2 e^{2\phi})\phi = 0. \tag{27}
$$

The equation [\(27\)](#page-5-3) describes the theoretical spectrum at this stage which suggests that there is only a massive boson with square of the mass  $m^2 = \tilde{e}^2 e^{2\Phi}$ . Therefore, unlike the previous situation, after the space-time point, the system does not contain any massless boson (equivalent to fermion) when the unparticle scale is set to  $\tilde{\Lambda}_m = \tilde{m} = \tilde{e} \times e^{\Phi(\tilde{x}^1)}$ at  $x^1 = \tilde{x}^1$  and  $x^0 = \tilde{x}^0$ . This setting miraculously eradicates the massless sector from the system. It was known that the source of all disastrous related to information loss was laid in the massless sector of the theory. The introduction of the concept of unparticle along with the setting of a cardinal scale of energy by exploiting the ambiguity parameter judiciously the massless sector of the theory has been found to get eradicated and that ultimately make it free from the undesired as well as uncomfortable information loss problem. This indeed agrees with Hawking's revised proposal regarding this issue. It also agrees with the more recent result reported in [\[32](#page-7-6)]. We should mention that the system does not contain any unparticle after setting that unparticle scale to  $\tilde{\Lambda}_m = \tilde{m} = \tilde{e} \times e^{\Phi(\tilde{x}^1)}$  at  $x^1 = \tilde{x}^1$  and  $x^0 = \tilde{x}^0$ . Rendering its great service it gets disappeared from the spectrum.

A question may be raised: what does actually happen here physically? The answer lies in the setting of a suitable cardinal scale of energy which is accessible from the exploitation of the ambiguity in the one loop term in suitable manner. This scale as stared earlier represents the cardinal point which indicates the starting point to transit from unparticle behavior at low energies to perturbative behavior at high energies. Therefore, from that point the combination of unparticle and the standard matter field can be considered as standard matter field only [\[25\]](#page-6-18). So the combined system effectively turns into a single one which indeed is free from the masslees excitation and that ultimately lead to a information preserving process.

## VI. CONCLUSION

The model used here is a  $(1+1)$ dimensional toy model and all the finite details of the real black-hole is not contained in it. However, the information loss issue analogous to the one as raised by Hawking is contained in it in a significant manner. The plausible remedy that is obtained from this work although has been achieved from a nonstandard approach is a novel one, and that of course, did not violate any physical principle, and above the all that agrees with the Hawking's revised suggestion on the issue of information loss [\[13\]](#page-6-3). However, we should admit that we have to be satisfied with the logical consistency keeping particular view on the crucial fact such that no physical principle gets violated since experimental detection of unparticle is a remote possibility with the hitherto developed experimental facilities in the high energy regime. Therefore, this work adds a novel way of obtaining a remedy to the information loss without violating any physical principle that ought to be faced during the s-wave scattering off dilaton black hole when it is studied with one loop correction through the model described in [\(6\)](#page-2-1). It indeed bring back the lost glory of the framework along with the results that is in good agreement with Hawking's revised suggestion. Finally, the the point on which we would like to emphasize is that the cardinal scale which represents the starting point of transition from unparticle behavior at low energies to perturbative behavior at high energies is a fixed valued energy although the unparticle scale that results from the model which has been used for studying s-wave scattering problem is space dependent.

Setting of unparticle scale to  $\tilde{\Lambda}_m = \tilde{m} = \tilde{e} \times e^{\Phi(\tilde{x}^1)}$  at  $x^1 = \tilde{x}^1$  and  $x^0 = \tilde{x}^0$  needs the requirement  $a + \frac{m_0^2}{e^2} = 0$ . careful look reveals that it has a deeper meaning. In fact, an automatic cancellation of a classical masslike term takes place by a quantum mechanically generated masslike term. It has made possible through the very exploitation of ambiguity often found in the one loop correction that appears during bosonization in order to remove the singularity in the ferneonic determinant. It can not be considered as a simple abolition of the masslike terms involved in the model. For example a naive choice  $a = 0$  and  $m_0 = 0$  may satisfy the requirement  $a + \frac{m_0^2}{e^2} = 0$ .

We are familiar with the exploitation of ambiguity from quite a long past. The ambiguity which are often found present in the one loop correction term has been found to exploit several times to obtain a fruitful and long standing suffering removal result. Quite a good number of examples are available in the literature concerning this issue [\[9,](#page-6-7) [11,](#page-6-1) [16](#page-6-8)[–18](#page-6-10), [24,](#page-6-17) [33](#page-7-7)[–35\]](#page-7-8). So it is more or less a standard approach now. The first and famous instance in this context reminds us the removal of long suffering of chiral Schwinger model from the non unitarity problem [\[16\]](#page-6-8).

#### VII. ACKNOWLEDGEMENT

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- <span id="page-6-0"></span>[1] M. Alford and A. Strominger, Phys. Rev. Lett. 69 563 1992
- [2] C. Callan, S. Giddings, J. Hervey and A. Strominger, Phys. Rev. D45 R1005 1992
- <span id="page-6-19"></span>[3] A. Peet, L. Susskind and L. Thorlacius, Phys. Rev. D46 3435 1992
- [4] D. Garfinkle, G. Horowitz and A. Strominger, Phys. Rev. D43 3140 1991
- [5] S. Giddings and A. Strominger, Phys. Rev. D46 627 1992
- [6] T. Banks, A. Dabholkar, M. Douglas and M. O'Loughlin, Phys. Rev. D45 3607 1992
- <span id="page-6-5"></span>[7] J. A. Hervey and A. Strominger [hep-th/9209055](http://arxiv.org/abs/hep-th/9209055) (based on Lecture given in 1992 Spring School on String theory and Quantam Gravity , Trieste, Italy.)
- [8] E. C. Vagenas JHEP 0307 046 2003
- <span id="page-6-7"></span>[9] A. Ghosh and P. Mitra, Phys. Rev. D50 7389 1994
- <span id="page-6-11"></span>[10] A. Rahaman, Phys. Lett. B697 260 2011
- <span id="page-6-1"></span>[11] A. Rahaman, Int. Jour. Mod. Phys. A21 1251 2006
- <span id="page-6-2"></span>[12] S. W. Hawking, Commun. Math. Phys, 43 199 1975
- <span id="page-6-3"></span>[13] S. W. Hawking, Phys. Rev D72 084013 2005
- <span id="page-6-4"></span>[14] G. 't Hooft, Nucl. Phys. B335 138 1990
- <span id="page-6-6"></span>[15] G. Mandal, A. Sengupta and S. Wadia, Mod Phys. Lett. A6 1685 1991
- <span id="page-6-8"></span>[16] R. Jackiw and R. Rajaraman, Phys. Rev. Lett. 54 1219 1985
- <span id="page-6-9"></span>[17] K. Harada, Phys. Rev. Lett. 64 139 1990
- <span id="page-6-10"></span>[18] A. Rahaman, Mod. Phys. Lett. A24 2195 2009
- <span id="page-6-12"></span>[19] H. Georgi, Phys. Rev. Lett. 98 221601 2007
- <span id="page-6-13"></span>[20] T. Kikuchi, N. Okada, Phys. Lett. B665 186 2008
- <span id="page-6-14"></span>[21] B.Bellazzini, G. Gabadadze, P. Tanedo, Phys. Rev. D88 083506 2013
- <span id="page-6-15"></span>[22] A. M. Frassino, P. Nicolini, O. Panella, Phys. Lett. B772 675 2017
- <span id="page-6-16"></span>[23] S. K. Gomokos, G. Gabadadze Phys. Rev. D92 126011 2015
- <span id="page-6-17"></span>[24] A. Rahaman, Mod. Phys. Lett. **A29** 1450072 2014
- <span id="page-6-18"></span>[25] H. Georgi and Y. Kata, Phys. Rev. Lett. 101 131603 2008
- <span id="page-7-0"></span>[26] T. Banks and A. Zaks, Nucl. Phys. B196 189 1982
- <span id="page-7-1"></span>[27] C. M. Sommerfield, Annals (N.Y.) Phys. 26 1 1963
- <span id="page-7-2"></span>[28] W. E. Thirring and J. E. Wess, Annals Phys. (N.Y.) 27 331 1964
- <span id="page-7-3"></span>[29] J. S. Schwinger, Phys. Rev. 128 2425 1962
- <span id="page-7-4"></span>[30] P. Mitra and A. Rahaman, Annals. Phys. (N.Y.) 249 34 1996
- <span id="page-7-5"></span>[31] P. A. M. Dirac, Lectures on Quantum Mechanics(Yeshiva Univ. Press New York, 1964)
- <span id="page-7-6"></span>[32] D. Singleton, E. C. Vagenas, T. Zhu JHEP 1405 074 2014
- <span id="page-7-7"></span>[33] A. Rahaman, Annals. Phys. (N.Y.) 354 511 2017
- [34] A. Rahaman, P. Mitra, Mod. Phys. Lett. A11 1996 2153
- <span id="page-7-8"></span>[35] A. Saha, A. Rahaman P. Mukherjee Mod.Phys.Lett. A23 2008 2947