In Ultra-Planck a 2 N Scattering, Black Hole Creation and Classicization Studied

Raj Kumar Gupta, Associate Professor

Department of Physics, Vivekananda Global University, Jaipur

Email Id- gupta.rk@vgu.ac.in

ABSTRACT: In field and string theory, we demonstrate a link between ultra-Planck a scattering amplitudes and unitarization via black hole creation in these scattering processes. We were able to identify and calculate a set of perturbative amplitudes important for black hole creation using an explicit microscopic theory in which the black hole represents a bound-state of many soft gravitons at the quantum critical point. In a kinematical regime (called the classicalization limit), these are the tree-level N-graviton scattering S-matrix elements where the two entering ultra-Planck and gravitons generate a huge number N of soft gravitons. The Kawai–Lewellen–Tye relations, as well as scattering equations and string theory methods, are used to calculate these amplitudes. This limit exposes the essential characteristics of the tiny corpuscular black hole N-portrait, according to our findings. When N approaches the quantum criticality value, the perturbative suppression factor of an N-graviton final state, calculated from the amplitude, equals the non-perturbative black hole entropy, while non-perturbative corpuscular physics suppresses or excludes final states with various values of N. As a result, we've discovered the microscopic cause for black holes' supremacy over alternative final states, such as non-black hole classical objects. The scattering equations can be solved precisely in the parameterization of the classicalization limit, enabling us to get closed formulas for the high-energy limit of the open and closed superstring tree-level scattering amplitudes for a generic number N of external legs. In various large-s and large-N regimes, we show that string theory and field theory are compatible and complementary.

KEYWORDS: Scattering, Planck, Black Hole, Dark Matter, Superstring.

1. INTRODUCTION

Understanding the nature of quantum gravity at ultra-Planck an energies requires the development of a microscopic model of black hole formation in high-energy particle scattering. This problem is particularly important in light of the notion that gravity is UV-complete in a non-Wilsonian sense, which is based on the concept of classicization. The conventional (Wilsonian) approach to UV-completion assumes that weakly coupled degrees of freedom of shorter and shorter wavelengths govern interactions at higher and higher energy. When extended to gravity, the Wilsonian image would suggest that UV-completion must be accomplished by new quantum degrees of freedom with wavelengths considerably shorter than the Planck length, R 1 s LP, at energies surpassing the Planck mass, s MP. Instead of introducing new hard quanta, the UV-completion in the classicalization approach is accomplished by collective states composed of a large number N s/M2 P of soft gravitons of wavelength R nLP that, in the mean-field approximation, recover the semi-classical behavior of macroscopic black holes. To put it another way, classicalization is the process of replacing hard quanta with a slew of soft ones that, under a mean-field (big N) approximation, take on some of the characteristics of classical objects.

The present knowledge of black hole formation in the semi-classical method is quite disturbing. On the one hand, it is generally recognized that the dispersion of very energetic particles leads in the creation of a black hole. This acceptance is based on the following argument: any source of center of mass energy s, when concentrated within its gravitational (Schwarzschild) radius R = sL2 P, must produce a black hole according to classical gravity. This argument is unaffected by the source's exact nature, and it should be relevant to elementary particle sources in particular. As a consequence, it is plausible to anticipate the creation of a solar mass black hole from a two-particle scattering with center of mass energy of the order of the solar mass with an impact parameter smaller than 3 km [1].

On the other hand, we must acknowledge that this method of thinking contradicts the traditional understanding of black holes as classical macroscopic objects, since normal macroscopic objects are anticipated to be exponentially suppressed in two-particle collisions. For example, in the preceding thought experiment of two particles colliding at solar mass energy, a sun-like entity being created in the end state instead of a black hole is exponentially improbable. Of fact, the Bekenstein– Hawking entropy is one of the characteristics that distinguish black holes. However, without a microscopic explanation of how entropy is created in two-particle collisions, invoking the entropy simply adds to the complexity of the problem. Indeed, it is a complete mystery how a two-particle state with zero entropy acquires such a large amount of entropy during the collision process.

Without a microscopic theory of the black hole and the associated microscopic mechanism of black hole creation in particle scattering processes, the following issues are difficult to address. This is why, despite the fact that the study of black hole formation in particle collisions at ultra-Planking energies was pioneered and has since been taken as far as predicting the production of micro black holes at the LHC [8], the above questions remain unanswered. The reason for this is because there is no quantum corpuscular image of black holes, making it difficult to determine how the quantum gravity amplitude translates into the creation of a black hole final state[2]. The goal of this paper is to find the missing connection between quantum gravity amplitudes and a corpuscular representation of black holes. We will show the connection between the corpuscular black hole picture and the classicalization concept for gravitational scattering amplitudes in particular. 1 We will discover some essential components underlying the microscopic genesis of black hole creation by combining the corpuscular black hole image with formulations of graviton scattering amplitudes in field and string theory[3]. To put it another way:

- We identify the black hole formation regime as the regime of multi-particle creation, in the form of 2 N graviton scattering amplitudes, with the number of soft gravitons in the final state being given by the number of black hole constituents, as suggested by classicalization, guided by non-perturbative input from the corpuscular black hole N-portrait.
- Next, we estimate the perturbative part of these N-graviton amplitudes using powerful field and string-theoretic techniques, such as scattering equations [9] and Kawai–Lewellen–Tye (KLT) relations [10].
- Finally, we provide the missing non-perturbative information by using the microscopic corpuscular picture of black holes as N-graviton self-bound states at a quantum critical point.
- By applying perturbative N-graviton amplitudes to the creation of non-black hole type classical configurations characterized by multi-particle coherent states for which semi-classical estimates must also be accurate, we offer a cross-check of perturbative N-graviton amplitudes. We next compare the two findings and find that the perturbative 2 N gravity amplitudes replicate the exponential suppression predicted by the semi-classical theory. Thus, in addition to providing independent information about the multi-graviton amplitudes, this matching also confirms that the microscopic origin of black hole dominance, as compared to other possible multi-particle final states of the same energy, lies in the black hole constituents' quantum criticality, which is absent for other classical objects.
- One of the findings of our study is that multiparticle amplitudes in gravity have significantly different large-N behavior than non-derivatively linked scalar theories.

The aforementioned framework provides a true physical picture that explains, among other things, why the creation of black holes is the dominating process while that of other macroscopic multi-particle states is exponentially repressed. The perturbative kinematics that we will identify has exactly the proper amount of suppression to be compensated by the quantum critical point degeneracy of states. In other words, in this multi-particle production kinematics, the amplitude predicts the entropy value that should be used. We also see a beautiful interaction between the amplitudes of the field and the amplitudes of string theory. We find that the amplitudes of the string and field theories coincide whenever the size of the generated object is the same. Another effort at synthesis is to sew two 2 N graviton amplitudes into a ladder loop diagram and sum across various N in an eikonal area coherently[4].

We will outline the fundamental findings and their physical significance before going on to the technical portion of the article, which will be addressed in the following sections. To do so, we'll go through the non-perturbative input from the corpuscular black hole picture, which, as a microscopic quantum theory, offers a key missing connection between perturbative N-graviton generation amplitudes and the theory's unitarization via black hole creation.

1.1. Input from a microscopic picture that is non-perturbative

Let us describe some non-perturbative input from the black hole corpuscular quantum picture to make the link clear (for additional parts of this approach, see [13], and some parallels with this idea may be found in . The concept behind this picture is that the black hole is a composite creature. Its corpuscular components are gravitons with a de Broglie wavelength determined by the black hole's classical size, R. That is, the quantum interaction of gravitons of wavelength R completely determines the interior (and near-horizon) physics of black holes. The regimes in which the black hole is considerably heavier than the Planck mass MBH MP, or equivalently, R LP, will be of interest to us[5]. The following are the two most important characteristics:

• The quantum gravitational coupling among individual corpuscles of macroscopic black holes, L2 P R2 (1.1), is very weak. • The number N of components of wavelength R is: N = M2 BH/M2 P. (1.2)

Thus, a black hole is a quantum-mechanical representation of a self-bound state of soft gravitons, with a unique interaction between quantum coupling and the number of components, N = 1. Alternatively, a black hole is a condition in which the graviton wavelengths fulfill R = NLP. This characteristic suggests that black holes have physics comparable to a graviton Bose–Einstein condensate at a quantum critical point [12]. The next two stages are separated by this crucial moment. The system is at a phase where collective graviton–graviton attraction is insufficient to produce a self-bound state, and the graviton Bose-gas is basically free for N 1.

The bound-state is created for N = 1.

Order N collective Bogoliubov modes become gapless at this critical point, resulting in an exponential degeneracy of states of order ecN, where c is a positive constant. When we deform the system and move away from the crucial point N = 1, the exponential degeneracy of states is rapidly removed. When it comes to the generically appealing Bose-gas[6]

2. DISCUSSION

The following is a breakdown of the work. In the next part, we'll go through some of the technical processes involved in calculating the gravitational scattering amplitudes for a large number of objects is the ultimate state of gravitons in a high-energy environment known as the classicalization regime. The classicalization regime will be described in Section 3 together with other high energy limitations. In Section, we will give the results of the computation of the gravitational scattering amplitude. Information to calculate the on-shell scattering amplitude and generate a vast number of results in this manner is an explicit formula for the likelihood of two particles transitioning into N 2. In the fifth section, For the situation of N-point open and closed string scattering, a similar calculation is given. Amplitudes in the classicalization high energy limit we demonstrate, in particular, how the relevant The technique of scattering equations producing the combinatorial factor may be used to determine it. The preceding section's field theory factor yielded the right answer. The findings for the scattering amplitudes in the light will be interpreted in the following sections. Considering the corpuscular representation of black holes and the concept of classicalization More specifically, we expand on the topic in Subsections 1.2 and 1.3 in Section 6 by describing how As an overlap between the perturbative and gravitational scattering amplitudes, the complete gravitational scattering amplitude is constructed. The non-perturbative projection between the N-graviton state and the black hole state, which is given by the entropy factor end, and the N-graviton amplitude, which was computed in Sections 4 and 5.In Section 7, we continue our exploration of perturbative insights into non-perturbative physics by comparing the gravitational situation to the scalar 4 theory[7].

Includes the paper's perspective, as well as a conjecture on the planar limit of gauge theories with a big number of colors NC and the limit of a large number N of gravitons, both of which are taken into consideration. in this research study2. Review of technical procedures. The main goal of this article, as stated above, is to explain some important features of classicalization and black hole generation in the context of enormous high-energy scattering amplitudes. In the ultimate state, there are N soft, elementary quanta. As previously stated, the phenomena. The related N-particle scattering amplitudes have a specific high-energy limit as a result of classicalization. In particular, we'll look at tree-level scattering in the kinematics of at the level of the trees. In the final state, s is evenly distributed across the N 2 particles. This will be referred to as the “classicalization” or eikonal Reggae limit is a specific kinematical limit. Because computing the huge N field theory amplitudes using conventional Feynman methods is time-consuming, we shall use new amplitude technology techniques known as on-shell methods in our diagrams. Have been developed in recent years.

For an overview of the topic, see and the references therein. Significant progress has been made. Furthermore, we benefit from the scattering method for obtaining tree-level amplitudes equations. To be more specific, we'll do the following calculations using the following major variables new outcomes. We utilize a variant of the KLT relations for so-called amplitudes to obtain these amplitudes.Gravon amplitudes that are maximally helicity violating (MHV). These are two-dimensional amplitudesGravons with a negative helicity and the remainder with a positive helicity. We may use the scattering equations to solve the problem. These amplitudes' combinatorial factors. We extract important information from these amplitudes.based on the prevalence of this kinematics, regarding the underlying unitarization mechanism as well as the variables that cause perturbative suppression. These disconcerting findings support a strong hypothesis [8].

Both the physics image of unitarization by black hole creation and the physics picture of unitarization by black hole formation are supported. finished until these perturbative findings are superimposed on non-perturbative data derived from graviton condensates' many-body physics• Second, for any (big) number of external legs, we will calculate the high-energy open/closed string tree level scattering amplitudes. Furthermore, the string will be compared. Amplitudes with amplitudes from field theory, and explain the classicalization regime in both instances. In particular, for sufficiently high N, the two agree for fixed s. However, depending on the situation, when the string coupling is of a certain value, intermediate domains of N are feasible.Reggeization and non-perturbative field theory black hole regimes are examples of stringy effects. And exclude specific geographic areas [9].

One general finding is that non-unitary areas are less prosperous. On-perturbative corpuscular black hole physics cuts them out in perturbative treatment. Onthe foundation of the string amplitudes' concrete shape we'll say a few words about it.N2. The circle containing the black hole's Bose–Einstein condensate nature is shown by wavy double lines. At the brink of black hole creation, some secret color kinematics duality emerges to allude to the well-known gauge–gravity duality. Figure 1discloses the Perturbative and non-perturbative regimes as variation of λ

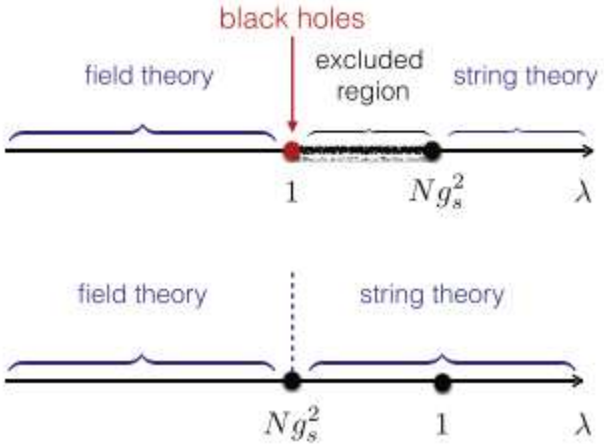

Figure 1: Perturbative and non-perturbative regimes as variation of λ

3. CONCLUSION

Finally, we looked at a specific high-energy limit of Yang–Mills and gravity scattering amplitudes, both from a field theory and a string viewpoint, in this work. We have developed new closed equations for the tree-level string scattering amplitudes at high energies that are valid for an arbitrarily large number of external particles on the technical side. Furthermore, we examined a specific high-energy limit that corresponds to classicalization through black hole generation, in which black holes are bound states of a huge number of extremely soft gravitons. As previously stated, the presence of a possibly new kind of big N gauge–gravity correspondence with N the number of external particles in eikonal Regge kinematics lends credence to this connection. As previously stated, relating this big N duality to the usual large N duality occurring in the context of holography and the AdS/CFT connection would be fascinating[10].

REFERENCE:

[1] C. Bambi, “Astrophysical Black Holes: A Compact Pedagogical Review,” *Annalen der Physik*. 2018.

[2] G. Ruppeiner, “Thermodynamic black holes,” *Entropy*, 2018.

[3] S. W. Hawking, M. J. Perry, and A. Strominger, “Superrotation charge and supertranslation hair on black holes,” *J. High Energy Phys.*, 2017.

[4] S. Leutheusser and M. Van Raamsdonk, “Tensor network models of unitary black hole evaporation,” *J. High Energy Phys.*, 2017.

[5] O. James, E. Von Tunzelmann, P. Franklin, and K. S. Thorne, “Gravitational lensing by spinning black holes in astrophysics, and in the movie Interstellar,” *Class. Quantum Gravity*, 2015.

[6] R. Carballo-Rubio, F. Di Filippo, S. Liberati, C. Pacilio, and M. Visser, “On the viability of regular black holes,” *J. High Energy Phys.*, 2018.

[7] F. Belgiorno and M. Martellini, “Black holes and the third law of thermodynamics,” *Int. J. Mod. Phys. D*, 2004.

[8] B. P. Abbott *et al.*, “Observation of gravitational waves from a binary black hole merger,” *Phys. Rev. Lett.*, 2016.

[9] P. Hayden and J. Preskill, “Black holes as mirrors: Quantum information in random subsystems,” *J. High Energy Phys.*, 2007.

[10] A. M. Sirunyan *et al.*, “Search for black holes and other new phenomena in high-multiplicity final states in proton–proton collisions at √s=13TeV,” *Phys. Lett. Sect. B Nucl. Elem. Part. High-Energy Phys.*, 2017.