Imagine an empty room with four walls. Away from the walls and inside the space, a person has the freedom to move 3-dimensionally in any direction and is constrained to move 1-dimensionally with respect to time. However, this person is unable to view the entire room while simultaneously residing in the interior. There are photons, particle interactions, and various physical phenomenon that are unable to transmit their information to the person when these events are out of sight − that is, unless this person is at the wall. At the boundary of this room, a person sacrifices a dimension of freedom in exchange for viewing the internal dynamics of their space. This way, a person is able to survey their space and return to the interior with knowledge of the native physical interactions − fully revealing the underlying dynamics. This duality between an n-dimensional interior and an $(n-1)$-dimensional boundary is known as the *Anti-deSitter Space/Conformal Field Theory Correspondence*.

This correspondence is powerful. General Relativity asserts that space-time and gravity are fundamentally connected, while a pivotal aspect of Quantum Field Theory is the freedom for symmetries to arise and reduces the number of degrees of freedom. Maldacena[1] was the first to assert that an interior space-time, such as Anti-deSitter Space described by General Relativity, could be connected to a conformal boundary, where a Quantum Field Theory would reside, thereby linking Gravity and QFT. This *gauge/gravity duality* has a variety of applications ranging from *condensed matter experiments* to *particle physics*.

With respect to the Standard Model of Particle Physics, Quantum Field Theory asserts that fundamental particles can be described as excitations of quantum fields. These particles, such as *quarks* and *gluons*, constitute most of the visible matter in the universe, and are described by Quantum Chromodynamics through the strong force. As a strongly coupled gauge theory that lacks a fully theoretical description, the mapping provided by the gauge/gravity duality might reveal a gravitational dual to QCD, which is not only highly desirable but also **potentially feasible**.

During the previous summer, I had the opportunity to conduct research through my second NSF REU at the University of Minnesota studying the AdS/CFT conjecture as applied to non-perturbative gauge theories, specifically Quantum Chromodynamics. Under the tutelage of Dr. Joseph Kapusta, I studied the properties of the *glueball*, a particle composed of multiple gluons predicted by the Standard Model, and a dilaton, a hypothetical particle that arises from the scalar fields accompanying gravity. To incorporate the behavior and structure of these fundamental particles into this duality, one usually embarks on the bottom up approach by assuming the existence of such a dual and, thereby, models QCD as an effective five-dimensional gravitational theory. This approach, known as AdS/QCD, provides the freedom for the computation of physical quantities in QCD that can then be tested at the high energy collisions at particle accelerators.

At the REU, I developed the equations of motion from considering an action[2],[3] that connects both gravitational field and the glueball and dilaton fields. This pen and paper work derived an analytic expression for the potential and this **result** describes the behavior of these particles at the IR and UV energy ranges. Early in the universe's lifetime and in modern-day particle collisions, a hot QCD quark-gluon plasma exists for short times whose behavior poses a challenge for QCD physics. The results of our study might shed light on this plasma, while furthering a theoretical description for QCD using the AdS/CFT conjecture, thereby connecting theory and experiment. As the lead author, I have attended the DNP 2015 and APS 4C Conferences to present this work and aim to obtain my second publication.

I wish to continue applying the AdS/CFT Correspondence to QCD for my Ph.D dissertation. *With my Ph.D research, I aim the further bridge the gap between the plethora of experimental evidence and the developing theoretical considerations for QCD by incorporating additional phenomenological metrics into the AdS/QCD conjecture.*

A critical question that I wish to pursue is the construction of a model incorporating the dilaton field, glueball field, quark field, and other matter fields with finite temperature field theory. As finite temperature quantum field theory describes the expectation values of physical observables at finite temperatures in $(n-1)$-dimensions and links them to statistical classical field theories, such as gravity, in n-dimensions, the AdS/QCD conjecture seems to have a natural supplement. Since Dr. Kapusta is a leader in the field of finite temperature theory[4], joining his research group is highly desirable for the formation of this model.

Currently, I am working with Dr. Kapusta to determine the predicted glueball mass spectra from our REU analysis and ultimately compare this value against lattice QCD calculations. In fact, a recent publication[5] has argued that an experimentally detected particle, known as $f_0(1710)$, is the glueball. Therefore, improving our model to include more realistic glueball dynamics and performing a comparative analysis after determining the mass spectra of the glueball is of principle importance.

In addition to tackling fundamental science harmoniously through theoretical and experimental considerations, this project contains broader impacts. A significant result from this analysis would lend further credence to the AdS/CFT conjecture. Although the conjecture was founded on the premise of revealing a theory of quantum gravity, a more immediate application resides in condensed matter experiment where chiral magnetic fields are frequently studied with the conjecture. Also by revealing physics beyond the Standard Model, we may be able to describe or construct new matter from gluons and quarks − one such highlight is the strong evidence for the tetraquark found at CERN. This new matter might impact our searches for dark matter often hypothesized[6] as complex quark matter, additional stable elements that may assist in creating new materials, and efforts in high energy plasma physics which has immediate applications for fusion.

The purpose of the AdS/CFT conjecture is to explore and discover a unified description of the universe and the interactions within our universal boundary. Matter is the fundamental link that interacts with and connects gravity with the other forces. In the short term, developing a theoretical framework for QCD will inform and drive further experimental endeavors, while the long term promises support for a candidate conjecture that currently sees a versatility of applications. With the support from the NSF GRFP, I will have the freedom to immediately pursue this research and continue my current studies of the AdS/CFT conjecture to develop a unifying framework of quantum matter and gravity.

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