Thesis Abstract and Proposal

PHYS 480 – Fall 2018

Over the next few weeks, you will be developing your thesis proposal by discussing it with your advisor, doing literature searches, and understanding how your work will fit into the greater picture. Two important things you will need to do is develop an **abstract (*aka* executive summary)** of your proposal, as well as a full **thesis proposal.** The former is a short and concise description of your project, what you intend to do, and how it is relevant. Generally, this is no more than a paragraph in length. The latter is a more comprehensive summary of your project, including a discussion of existing work that you intend to build on, a description of how you will carry out your research, and a summary of its impacts.

The proposal should contain the following items that were indicated on the Thesis Checklist handed out last class:

- **Introduction**: what are you doing?
- **Goals:** what do you plan to do?
- **Methodology:** How will you do it?
- **Significance:** Why is it important?
- **References:** On which giants' shoulders did you stand?

The significance portion can be sub-divided into two categories, defined by the NSF as follows:

Intellectual Merit:
This is a statement about why your project is important, and (especially in the case of grant applications!) why others should have confidence that your work will lead to something important. The NSF defines intellectual merit as "encompassing the potential to advance knowledge" in your field (and beyond).

Broader Impacts:
It is also important for you to consider how your work might be important beyond its immediate applications, and in particular how it might benefit society as a whole. These could include implications for teaching or education (both academic and general public), enhancing research or educational infrastructure, and overall benefits to society.

The following sample proposal shows what your final thesis proposal should look and sound like. Your language and writing should ideally be scientific in nature, not "book report" style or colloquial.

Sample Executive Summary (Abstract) and Proposal

Deciphering quantum effects from classical black holes

Abstract

This project will study the characteristics of "black hole shadows" - regions surrounding black holes from which no light escapes - in alternative and quantum-improved theories of gravity. The investigation will expand on the phenomenological and observational aspects of these models, in particular constrained by the state of the art in observational relativity: the Event Horizon Telescope. Specifically, this will entail calculations of the near horizon characteristics of two putative supermassive black holes (Sagittarius A* and M87) in a large class of quantum-corrected frameworks. These include non-commutative geometry inspired gravity, generalized uncertainty principles, quantum-N portrait descriptions, and other non-local metric fluctuations. A second but parallel analysis will clarify the theoretical theoretical issues in the field of gravity information (holographic considerations and AdS/CFT) beyond the semiclassical gravity limit. The intellectual merits of this project lie in the identification of testable, model-independent predictions that can be resolved by future experiments. It will also strengthen the PI's international collaborations, and will help advance the study of quantum gravity by building a new bridge between theoretical and observational researchers.

Project Proposal

Black hole physics is entering a golden age. A century after Einstein proposed his celebrated theory of General Relativity, two key experiments are providing new data that promise to revolutionize the field: the Laser Interferometer Gravitational Wave Observatory (LIGO) [1], and the Event Horizon Telescope (EHT) [2]. LIGO has already ushered in the era of gravitational wave astronomy, allowing us for the first time to probe the Universe beyond the electromagnetic spectrum. Through this window, we will be able to test black hole mergers, coalescence, and ringdowns with high precision. Conversely, the EHT is expected to reveal such novel characteristics as "black hole shadows" - i.e. regions surrounding black holes from which no light escapes - which will provide unprecedented tests of gravitational physics at the event horizon.

Direct imaging of a black hole may be a reality in the coming years. The advent of the EHT and similar experiments has opened a novel new avenue for testing General Relativity (GR), by means of improved imaging of Saggitarius (Sgr) A*, the putative supermassive black hole at the centre of our galaxy [3], as well as that at the center of M87 [4]. Identifying the experimentally-observable characteristics of a supermassive black hole shadow will allow for precision measurement of the object’s mass, but can also be used to probe the curvature, and thus the underlying gravitational theory. This will provide a new way to test gravity on an astrophysical scale, and place strong constraints on a variety of competing models.

There is growing evidence, however, that quantum gravity phenomena may manifest themselves at macroscopic distances from the horizon [5,6,7]. This is a timely proposal, since it implies that for supermassive black holes in the range of a billion solar masses, quantum gravity effects could start to modify GR on measurable scales within the sensitivity of Earth-based telescopes. This portion of the sabbatical project will expand upon the phenomenology of such new physics, and the resulting measurable quantities that can be detected by present and future experiments.

The aim of the project is to explore the extent to which quantum effects will be traceable in observational data from classical black holes. This investigation will expand on the phenomenological and observational aspects of these models, in particular constrained by the state of the art in observational relativity. Specifically, this will entail calculations of the near horizon characteristics of the aforementioned supermassive black holes in a large class of quantum-corrected frameworks. These include non-commutative geometry inspired gravity [8], generalized uncertainty principle black holes [9-11], quantum-N portrait descriptions [12], and other non-local metric fluctuations. The PI has extensive experience with such models [13-15]. Calculation of such characteristics are a standard application of GR, and incorporation of the quantum gravity extensions will modify these calculations in a model-dependent fashion. Identifying the size of the deviations will provide information on the likelihood that they can be observed by the EHT and similar experiments.

While this research is of a theoretical nature, connecting with the observational component will play a crucial role in informing the method and assessing the results. The PI is currently collaborating with observational astronomers at the Max Planck Institute for Radio Astronomy in Bonn, Germany, and is planning a sabbatical visit in March 2018 to develop the experimental aspects of the project. Several other extended research visits abroad will be undertaken through this funding, through which new collaborations will be established with observational astrophysicists, particularly those associated with the EHT consortium. These site visits will also allow the PI to have local meetings with other nearby European collaborators, with the aim of broadening the scope of the project.

Intellectual Merit

The underlying framework for this proposal is a growing line of research in high energy theory, astrophysics, and quantum gravity that contributes to the literature of quantum-corrected models of gravity. These approaches can facilitate the resolution of numerous outstanding problems in fundamental physics, particularly as the Planck scale is approached. This project represents a confluence between gravitational theory and observations studied by the PIs in separate contexts. The tools developed will be made publicly available for the benefit of a wide physics community.

A significant benefit of this proposal lies in the identification of testable, model-independent predictions that can be realized in high-precision present and future observations. Taking advantage of the state of the art in both fields, we aim to build a world-leading team that will bring collaboration between quantum gravity theory and astrophysical observation to a new level of efficiency.

Broader Impacts

The broader impacts aim to deepen the scientific relations between Germany and the US. The DFG-NSF partnership offers a new opportunity for like-minded researchers in the two countries, a chance to enhance their current collaborations, as well as forge new ones. We believe this is a crucial feature that is particularly important for the young generation to promote free science, circulation of new ideas, competitive educational programs and avoid scientific isolation. Pursuant to the goal of promotion of science in the young generations, we will bring this frontier research into the classroom, train highly qualified personnel, and plan outreach activities designed to sustain scientific literacy in the society.

References

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