*Project:*

**Project Working Title:** Differential Scattering Cross-section of Neutrinos about a Massive Object

**Project End Date**: 7 May 2021 (The end of week 6 of spring term)

*Student:*

**Name**: Thomas Knudson

**Affiliation:** Department of Physics, Oregon State University

*Statement*: I will work regularly and diligently on this project throughout the year and initiate meetings with my advisor to seek feedback and guidance on the research. I understand that a significant portion of the research should be completed by the end of winter term to enable me focus on the writing process in the PH403 class.

Student Signature: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*Advisor:*

**Name** Dr. Kathryn Hadley

**Affiliation** Department of Physics, Oregon State University

I have read this thesis proposal. I agree that the scope is reasonable for completion by May 7, 2021 and that sufficient progress can be made by early winter term 2021 to allow significant revision of the thesis during the winter and spring terms of 2021.

Advisor Signature*:* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Project Summary**

Using various models of spacetime, we will endeavor to determine the minimum stable orbit for a collection of neutrinos above the event horizon of a series of increasingly complicated black holes. By solving the geodesic equations for each spacetime, we can discuss the trajectories of the neutrinos and whether or not they correspond to a stable and circular orbit. There already exists the notion that light can establish a stable circular orbit just above the event horizon, where each wave/photon will remain until the black hole expands/contracts and alters the trajectory of the trapped light. In an equilibrium situation, this light will be trapped for eternity and form a complete spherical shell that an observer could only grasp a flash of as they descend into the black hole. This will be analyzed by plotting the impact parameter versus the angle of incidence to discover valid geodesics for neutrinos.

**Project Description**

*Introduction*

The consequences of General Relativity can be easily observed in the modern day when viewing distant stars or galaxies. The most prominent visual indicator of these counter-intuitive relativistic effects is through gravitational lensing, wherein the light emitted behind a star or galaxy is bent and distorted, allowing us to observe sources that we otherwise shouldn’t be able to.

Albert Einstein is notorious to the greater public for upending what is now considered Classical Physics and providing a more complete description of gravity and our universe. Initially unintuitive, light actually offers the simplest view in which to examine the geometry and consequences of curved spacetime. Alongside the effects of time dilation and length contraction, the most extreme examples of the consequences of this curved geometry are Black Holes.

Exploring the possible trajectories and the outcomes using the geodesic[[1]](#footnote-1) for light is rather easy due to the universe’s unspoken rule that light must always move at . These null geodesics offer a simplified view of how physics acts in the context of extremely curved spacetime. The important distinction of geodesics for massive[[2]](#footnote-2) particles, is that mathematically, they describe the trajectories similar to null geodesics, but these particles aren’t told by the universe to always move at , which opens up interesting possible outcomes for how low-mass particles might be scattered in the presence of a Black Hole.

In classical mechanics, this type of analysis is called differential scattering, and we use this method to determine the aftereffects from particles colliding with each other or some other object. An excellent example of this is Rutherford’s experiment regarding the scattering of alpha particles from gold atomic nuclei. In the general case, the equation which describes this motion is given by,

(1)

A picture containing text

Description automatically generated

Through the language of geodesics, the answer seems straightforward and is given as a homework problem in undergraduate General Relativity courses and as end of Chapter exercises in other textbooks. The geodesic equation for describing circular orbits don’t assume properties about the massive objects but they also allow for invalid trajectories if one is not careful with the parameters.

*Plan of work*

We seek to investigate the resulting trajectories of neutrinos by analyzing the scattering angle as a function of the impact parameter. Neutrinos are chosen as the vehicle of interest as they are lowest massive particle and weakly interact with each other. By analyzing the results, we should observe the effects of introducing mass to particles traveling this curved spacetime and any possible counter intuitive effects that are not immediately apparent from merely studying simplified geodesic equations.

*Timeline*

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| --- | --- | --- |
| **Stage 1: Background Research** | Spring 2020 – Fall 2021, Week 3 | Perform background research on General Relativity and differential scattering. Document sources used along the way. |
| **Stage 2: Prototype and Test Model** | Fall 2021: Week 3 – Week 5 | Solve scattering eqn and test results with light wave impact parameters. Consult with advisor on results and interpretation. Ensure Thesis Proposal is complete and describes discussed project. |
| **Stage 3: Use Model** | Fall 2021: Week 5 – Week 9 | Use model with parameters for neutrinos. Begin scaffolding thesis through a lab report template. Verify method of data analysis and continue to discuss with Advisor. |
| **Stage 4: Draft and Refine** | Winter 2022: Week 1 – Week 6 | Expand lab report into thesis format. Utilize peers and connections to gather feedback on clarity of explanations and verify tone of audience is correct. |
| **Stage 5: Finalize and Prepare Presentation** | Winter 2022: Week 7 – Spring 2022: Week 5 | Iterate revisions and finalize for submission. Create PowerPoint Presentation and utilize feedback of mock presentations for possible revisions. |

*Data management*

Local copies of files will be saved on personal computer and back-ups created at regular intervals. A GitHub repository will also serve as an informal back-up but its main purpose will be for version control capabilities. Data retention for this project will include and drafts of the Thesis, notes/supplemental documents discussing equations and how to utilize them, and files/code used to generate plots .

*Facilities, Equipment and Other Resources*

* Computer
* Plotting Software
  + Mathematica (<https://www.wolfram.com/mathematica/>)
    - Requires license but can perform Computer Aided Algebra and provides an easier to read code file for interpretation of steps.
  + Python 3 (<https://www.python.org/>) with MatplotLib (<https://matplotlib.org/>) and NumPy (<https://numpy.org/>)
    - Open source but equations and variables must be encoded using programming syntax (effects ease of readability).
* Atom (<https://atom.io/>) / Text Editor
  + Most files will most likely be created as markdown documents. Emphasis on quick construction and words onto a page. Formatting and beautification can occur later. Also supports LaTeX rendering for easy to read mathematical expressions.
* pandoc (<https://pandoc.org/>)
  + Facilitates quick porting from one document type to another: e.g. markdown to LaTeX
* GitHub (<https://github.com/>)
  + Version control software to serve as an external off-site backup and to facilitate copies of documents at/before major milestones.

**References Cited**

[1] E.F Taylor and J. A. Wheeler, "Exploring Black Holes: Introduction to General Relativity”.

**Format**

Text must be in single column format with 1-inch margins. Use 1.5 or double spacing between lines of text (this helps the peer review process). Use 10-point to 12-point Arial, Times, Times New Roman or Cambria fonts. Do not exceed 8 pages excluding the coversheet and curriculum vitae (see below). Number each page. Remove anything in red in this template.

Curriculum Vitae  
Your name, Department of Physics Oregon State University

Education: B.S. Physics, Oregon State University (expected 2021)

Employment: (could be paid or volunteer)

Honors: (fellowships, scholarships, awards, recognition)

Professional affiliations: (SPS, APS, AAPT, other science/engineering or student societies …)

Relevant experience or skills: (research, courses, programming, database, management ...)

Outreach activities:

Publications or presentations:

Do not include names of references, personal information such as gender, citizenship, marital status *etc*.

**Format:** 2-page maximum, but otherwise organize and format as you prefer.

1. Treat “geodesic” as a synonym for “the path an object takes”. “Null geodesic” is a special subset of these paths in that only light waves/photons can take them. [↑](#footnote-ref-1)
2. Convention is to refer to particles that have non-zero mass as “massive”. [↑](#footnote-ref-2)