Introduction

Progenitors of Short Gamma-Ray Bursts (SGRBs) are yet unknown. One of the many proposed models is the encounter and collision between black holes and compact stars such as neutron stars within dense stellar clusters. A recent Newtonian study supports this SGRB mechanism.\(^1\) With the motivation that accuracy will increase when General Relativity (GR) is considered, the study presented here will perform GR simulations using parameters similar to the Newtonian study, compare results, and assess the validity of the proposed SGRB mechanism.

- **Short Gamma-Rays Bursts (SGRB)** – Flash of high energy electromagnetic waves which last an average of one second
- **Neutron Star** – Star of nuclear density created after a massive star supernova explosion
- **General Relativity (GR)** – A theory of gravitation, space, and time for extremely dense objects
- **Newtonian Gravitation** – A limiting case of GR for moderately dense objects

![Fig. 1. – An artist’s rendition of an encounter between a black hole and a neutron star. Notice the neutron star forms a disk and a tail around the black hole in image (c). These formations are crucial to the Short Gamma-Ray Burst mechanism. A Gamma-Ray Burst jet is illustrated in image (d). Pictures courtesy of NASA.](http://www.nasa.gov/mission_pages/swift/bursts/short_burst_oct5.html)

Methods and Procedure

Black Hole – Neutron Star collisions were modeled on high-performance computers. Initial parameters necessary for collision were estimated and used as input for simulations. Certain quantities which may indicate the validity of this mechanism such as the mass of the neutron star, gravitational and thermal radiation, and time duration of the collision are computed throughout a simulation.

![Simulation Tools](http://www.cactuscode.org/)

- **Einstein Toolkit**
  - Relativistic astrophysics software
  - Open - source
- **Cactus\(^2\)**
  - Scientific software framework
  - Open - source
- **Queen Bee**
  - LONI core supercomputer
  - 50+ T flop peak performance
  - 669 node cluster
- **LONI**
  - Louisiana Optical Network Initiative
  - Network of supercomputers in Louisiana/Mississippi Region
  - LONI core supercomputer

![Initial Configuration](http://vish.origo.ethz.ch/)

<table>
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<tr>
<th>Neutron Star</th>
<th>Mass (M⊙)</th>
<th>1.4</th>
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<tr>
<td>Velocity (km/s)</td>
<td>7.6 x 10^4</td>
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<tr>
<td>Position (km)</td>
<td>x,y,z</td>
<td>[7.16, 9.8]</td>
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</table>

<table>
<thead>
<tr>
<th>Black Hole</th>
<th>Mass (M⊙)</th>
<th>4.51</th>
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<td>Position (km)</td>
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</table>

![Fig. 2. – Simulation input configuration. Velocities were estimated by assuming parabolic orbits and distance of closest approach (periastron), 20.1 km.](http://vish.origo.ethz.ch/)

Future Work

- Consider a longer time evolution of the latest simulation to observe complete accretion of the disk.
- Explore larger sets of parameters such as various neutron star and black hole masses.
- Improve the data initialization method currently employed by Einstein Toolkit to increase model accuracy.
- Perform a rigorous comparison with Newtonian models.
- Analyze neutron star oscillations and thermodynamics to build correlations with changes in system energy.

Acknowledgments

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References