**Modeling Black Hole Formation**

**Introduction:** This activity will model the collapse of a star into a black hole. Unlike other modeling activities, this lab allows the students to visualize the gravitational field before and after the collapse of the star. Students may model a star, one of the celestial bodies listed in the table or any other they choose with an available mass and radius. For simplicity, the model represents a star and a stellar black hole. Another option is for the students to measure the circumference of their balloon star, calculate the diameter then radius and conduct the calculations of field and Schwarschild radius of this star. In the model, the string represents the gravitational field of the star, the balloon represents the star and the bead represents the singularity. If desired, glitter may be added to the glue so that when the balloon is popped, the glitter dispersing will represent the super nova. After popping the balloon and replacing it with the bead, representing the collapse of the star, the students will be able to see that the density and the volume changed (the balloon to the bead), but the mass did not change (balloon and bead are the same mass) and the gravitational field strength to a given distance did not change. Students should then be able to explain why, if our sun were to turn into a black hole, the Earth would not get “sucked” into it. First, there is no sucking in space. Also, the field strength, as measured from the center of the black hole to the earth is the same, as the mass did not change.

An extension of this activity is for the students to model the “no drama” and “ring of fire” scenarios of black holes as have been discussed by Stephen Hawking and recently re-examined. This is done by wrapping the string around a funnel or similar shape and using different color strings to represent the different regions of the event horizon or apparent horizon. Articles on the issue are available on a variety of levels and also serve as a method for discussing original sources, reviews and popular summaries.

Field strength before collapse = field strength after collapse g = G m/r2

Star of mass m Black hole of mass m

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**Phyllis J. Friello, M.S.**

**Unit:** Universal Gravitation

**Topic:** Black holes

**Time Needed for Activity:** Two 45 minute periods. One for the build, and one to follow up.

**Target Grade Level:** High school. For lower grades use to define density, volume and mass.

**Standards**

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| **HS-PS2-4.** | **Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.** |

CLG 5.1.1: Use analytical techniques appropriate to the study of physics

CLG 5.1.4: Analyze the behavior of forces.

CLG 5.7.2: The student will recognize the important role that mathematics serves when solving problems in physics.

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| --- | --- |
| HS-PS2-4. | Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects. |

**Board Quote:**

“Black holes humming b-flat, heard only by street cats, astronauts in orbit and singers in the bars.” Jimmy Buffet

**Lesson Objectives:**

HS: Students will model star collapse, singularity formation and gravitational fields.

Lower grades: Investigate the difference between volume, density and mass.

**Opening Activity/Drill Review previous day’s closing problem.**

1. What equation do you use to find the gravitational field? à Fg = G m/d2
2. Calculate the gravitational field on earth’s surface. à g = 9 .80 m/s2

*Modifications:* Extra processing time and additional teacher assistance will be provided.

**Engagement**

HS: Event Horizon Telescope image. Discussion of Interstellar. What topics in physics were represented? Were they accurate? What is a black hole? The lowest tone ever detected in our universe was found using NASA’s Chandra x-ray observatory. It is 57 octaves below middle C and from a supermassive black hole in the Perseus cluster of galaxies located 250 million light years from Earth.

Lower grades: Discuss the differences between volume, density and mass. Measure the mass and volume of a single piece of bread. Squash the piece into a tiny ball and again measure the mass and volume.

Ask the students what changed (volume, but mot mass). Discuss the concept of density.

*Modifications:* Extra processing time and additional teacher assistance will be provided.

**Exploration**

<https://www.nasa.gov/mission_pages/chandra/news/black-hole-image-makes-history>

Andrea Ghez: Hunt for the Supermassive Black Hole (Ted Talk). http://science.nasa.gov/science-news/science-at-nasa/2003/09sep\_blackholesounds/Activities:

Black Hole lab – see attached lab.

*Modifications:* Students will be paired and instructions will be read.

**Explanation**

Gravity: a force generated by anything with mass and acts on anything with mass.

Lower grades: The volume, the amount of space on object takes up may change if the object is compressed (like the squashed bread) or expanded (like blowing up a balloon). The mass, or the amount of material in the object did not change, but its matter or stuff it is made of, became closer and more tightly packed. The amount of matter or stuff per given area is the density.

HS. If needed review section A and B from previous day. If not, skip to C.

* 1. Universal Gravitation: 
		1. It gives the force of gravity between any mass A (mA) and any mass B (mB)
		2. ß G is called the gravitational constant
		3. The closer the masses, the greater the force
	2. Derivation of g = 9.80



**C.** Field strength before collapse = field strength after collapse g = G m/r2

Star of mass m Black hole of mass m

 *Modifications:* Formulas are on the formula board. The notes are given out as requested.

**Extension:** Students will be given recent articles of various levels from National Geographic, Scientific American and other sources on black holes.

**Evaluation/Assessment:** Assessment is based on conduct of the activity and the report.

 *Modifications:* Check responses, notes provided.

**Closure and next questions:** If you were in a spaceship and could escape the gravitational field of a star, could you escape the field at the same location after it turned into a black hole? How do we observe black holes?

**Home Assignment:** complete activity report

**Next Lesson:** Event Horizons. The students will start with the poem, Fire and Ice by Robert Frost. Students will be offered recent popular and journal articles on the structure of event horizons discussing the no drama and ring of fire scenarios. Students will then construct an event horizon choosing and justifying their chosen structure.

**Resources:**

Black Hole Math <https://www.nasa.gov/pdf/377674main_Black_Hole_Math.pdf>

<https://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Black_Hole_Math.html>

**Nature | News** Stephen Hawking: 'There are no black holes'[Zeeya Merali](http://www.nature.com/news/stephen-hawking-there-are-no-black-holes-1.14583#auth-1) 24 January 2014

**Notion of an 'event horizon', from which nothing can escape, is incompatible with quantum theory, physicist claims.**

**Stephen Hawking: "There Are No Black Holes"**

<http://www.scientificamerican.com/article/stephen-hawking-there-are-no-black-holes/>

**Stephen Hawking’s new research: ‘There are no black holes’**

By [Sebastian Anthony](http://www.extremetech.com/author/santhony) on January 27, 2014

 http://www.extremetech.com/extreme/175414-stephen-hawking-research-there-are-no-black-holes

# Information Preservation and Weather Forecasting for Black Holes

Authors: [S. W. Hawking](http://arxiv.org/find/hep-th/1/au%3A%2BHawking_S/0/1/0/all/0/1) (Submitted on 22 Jan 2014)

[arXiv:1401.5761](http://arxiv.org/abs/1401.5761) [hep-th] <http://arxiv.org/abs/1401.5761>

First photo of a black hole JPL

[How Scientists Captured the First Image of a Black Hole - Teachable Moments | NASA/JPL Edu](https://www.jpl.nasa.gov/edu/news/2019/4/19/how-scientists-captured-the-first-image-of-a-black-hole/)

**Modeling Black Hole Formation Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Introduction:** This activity will investigate the collapse of a star into a black hole. You will be able to model the gravitational field, the star and the singularity of a collapsing star. Useful constants, formulas and values for the mass and radius of various celestial bodies are provided.

**Materials**

Glue, Water, Embroidery floss or yarn. Balloon, Bead (approximately the same mass as the balloon), Clear monofilament or fishing line

**Methods**

1. Take the mass of the uninflated balloon.
2. Inflate balloon to a spherical shape and tie off. Do not over-inflate.
3. Take the mass of the inflated balloon
4. Using 5-6 feet of floss, dip lengths in a mixture of glue and water and drape around the balloon. Be sure to cover the balloon like a cage.
5. Tie a piece of string or fishing line to your balloon and hang from a class hook.
6. Let the balloon dry overnight.
7. Pop the balloon, gently remove.
8. Tie the bead (with the same mass as the balloon) with fishing line securing it in the middle of the sphere.

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| **Gravitational Field** **Strength** | G.f.s | g = G m/r2 | Calculate the Rs and Gfs for all bodies below. **Show all your work on a separate piece of paper and provide the answers in the spaces below.** |
| **Universal Gravitation** | FG | FG = Gm1m2/d2 |
| **Schwarschild Radius** | Rs | Rs = 2Gm/C2 |
| **Constant** | **Symbol** | **Value** |
| Speed of light | C | 3.00 x 108 m/s |
| Gravitational Constant | G | 6.67 x 10-11 Nm2/kg2 |
| Acceleration of Earth’sGravity | G | 9.81 m/s2 |
| **Body** | **Mass** | **radius** | **Rs**  | **Gfs** |
| Earth | 5.98 x 1024kg | 6.37 x 106 m |  |  |
| Sun | 2.0 x 1030kg | 6.96 x108m |  |  |
| Moon | 7.3 x 1022kg | 1.74 x 106m |  |  |
| Jupiter | 1.9 x 1027kg | 71.5 x 106m |  |  |
| Neutron star | 2.8 x 1030kg | * 1. x 104m
 |  |  |
| BSA | 50,000kg | 100m |  |  |

Modeling Questions Name\_\_\_\_\_\_\_\_\_\_\_

1. What **chemicals and process** fuel a star?
2. What are the two primary forces that control the size of a star?
3. How does a black hole form? Do they form from all stars or bodies?

1. Give a description of an event horizon.
2. After the star collapses, has the density changed? Why or why not?
3. Has the strength of the original gravitational field of the star changed (from its original distance from the center of the star)? Why or why not?
4. If our sun collapsed into a black hole, would the Earth fall in? **Explain.**
5. How was the first picture of a black hole obtained?