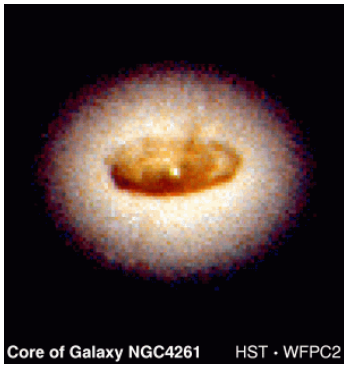
# Black Holes and Beyond
# Modeling a Black Hole




**Subject:** Science

**Grade Level:** $6^{th}$ – $8^{th}$

**Materials:** (For a class of 28 working in pairs)

| | |
|---|---|
| 14 small round balloons | 14 basic calculators |
| 14 pieces of string in 1 meter lengths | 1 roll of aluminum foil |
| 14 meter sticks | 14 balances |
| 14 push pins | |

**Lesson Duration:** 60 minutes

**National Standards**
**UCP.1, UCP.2, UCP.3, UCP.5, D.4**

**TEKS**
6.2(A), 6.2(B), 6.2(C), 6.2(D), 6.2(E), 6.3(C)

7.2(A), 7.2(B), 7.2(C), 7.2(D), 7.3(C)

8.2(A), 8.2(B). 8.2(C), 8.2(D), 8.3(C), 8.13(A), 8.13(C)

IPC 1(A), 2(A), 2(C), 2(D)

**Connections to AP**
**AP Physics**

## I. Newtonian Mechanics F. Oscillations and gravitation

### Teacher Notes

*Black Holes and Beyond* is designed to familiarize students with the concepts of volume, mass and density and then relate these concepts to stars and black holes. Prior to this activity introduce the stages of the life cycle of a star to your students, either through lecture, reading assignment or internet search. In addition, there are several words used to discuss the ideas surrounding black holes that your students may not be familiar with. Spacetime, for instance, can be explained as continuum of four dimensions (3 space and 1 time) in which any object or event can be located. In a way, spacetime is an area so large that you have to include the concept of time to understand it. For example, when you see the star Alpha Centauri in the night sky, you are seeing it as it was four years ago because it has taken four years for the light to reach Earth. Therefore when you look into space you are looking back in time, which means time and space (spacetime) are inseparable. Be sure to read the intro to the lab with your students and help them understand the text.

Depending on your students' math ability they may need some assistance with the formulas.

Watch the students to be sure that they do not crush the foil entirely after the star is popped. It is important that the balloons have four different sizes and that the students make the foil ball smaller and smaller each time.

Students may observe a very small change in mass, although theoretically there should not be one. Since the amount of foil is not changed by its crushing any mass change should be minimal at best. If there is a difference in mass it is probably due to experimental error. This is an important point to discuss with students during a post lab discussion.

### Activity

Students will model a black hole to investigate the properties and formation of a black hole.

### Possible answers to the conclusion questions and Sample Data

1. What stage of a star's life cycle is represented when you popped the "star" balloon?

- **The popping of the "star" balloon represents a supernova.**

2. What kind of stars become black holes: low mass, medium mass, or high mass? Explain your answer.

- **High mass stars become black holes because it takes a huge mass to collapse to the form the density of a black hole**

3. Describe any observed changes in the circumference of your "black hole" as you completed each trial?

- **After each trial the "black hole" decreased in size or circumference.**

4. Describe any observed changes in the mass of your "black hole" as you completed each trial?

- **The mass of the black hole remained essentially constant throughout each trial.**

5. Describe any observed changes in the density of your "black hole" as you completed each trial?

- **The density of the "black hole" increased with each trial.**

6. How do the masses of your "star" and "black hole" compare? How do the densities of your "star" and "black hole" compare?

- **The mass of the star and the black hole are relatively the same while the density of the black hole is much greater than the star.**

| **Trial** | **Circumference** | **Radius** | **Volume** | **Mass** | **Density** |
|---|---|---|---|---|---|
| **1** | **45 cm** | **7.17 cm** | **1543.2 $cm^3$** | **12 g** | **0.0078 $g/cm^3$** |
| **2** | **40 cm** | **6.37 cm** | **1082.1 $cm^3$** | **11 g** | **0.0102 $g/cm^3$** |
| **3** | **35 cm** | **5.57 cm** | **723.5 $cm^3$** | **11 g** | **0.0152 $g/cm^3$** |
| **4** | **20 cm** | **3.18 cm** | **134.6 $cm^3$** | **11 g** | **0.0817 $g/cm^3$** |

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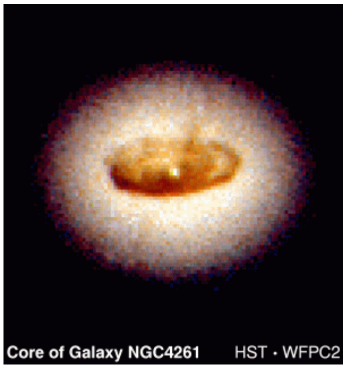



What is a black hole? A black hole is a region of spacetime from which nothing can escape, even light. But what does that mean? Well, as the matter, or the mass of a star,is crushed into a smaller and smaller volume, the gravitational attraction increases, and hence the escape velocity also increases. Things have to move faster or be propelled harder to escape this gravitational pull. Eventually a point is reached when even light, which travels at $3x10^8$ meters per second, is not traveling fast enough to escape. If light cannot get out, nothing else can either and we call it a black hole.

Einstein's general theory of relativity describes gravity as a curvature of spacetime (caused by the presence of matter. If the curvature is fairly weak, Newton's laws of gravity can explain most of what is observed. For example, the regular motions of the planets can be explained by Newton's laws. But, very massive or dense objects generate much stronger gravity. The most compact objects imaginable are predicted by general relativity to have such strong gravity that nothing, not even light, can escape their grip.

Scientists today call such an object a *black hole*. Why black? Though the history of the term is interesting, the main reason is that no light can escape from inside a black hole; it has, in effect, disappeared from the visible universe.

Do black holes actually exist? Most physicists believe they do, basing their views on a growing body of observations. In fact, present theories of how the cosmos began rest in part on Einstein's work that predicts the existence of black holes. Yet Einstein himself denied their existence, believing that black holes were a mere mathematical curiosity. He died in 1955, before the term "black hole" was coined or understood and observational evidence for black holes began to mount.

### Purpose
To simulate the formation of a black hole.

## Materials

| | |
|---|---|
| small round balloon | basic calculator |
| string | aluminum foil |
| meter stick | balance |
| push pin | |

**Safety Alert**
Be careful when using the push-pin to pop the balloon.

## Procedure

1. Inflate the balloon until the circumference is roughly 45 cm. To measure the circumference,wrap a string around the middle of the balloon. Use your finger to mark the length of the string. Measure the length of the string using a meter stick. When you have inflated your balloon to the proper circumference, tie off the end of the balloon.

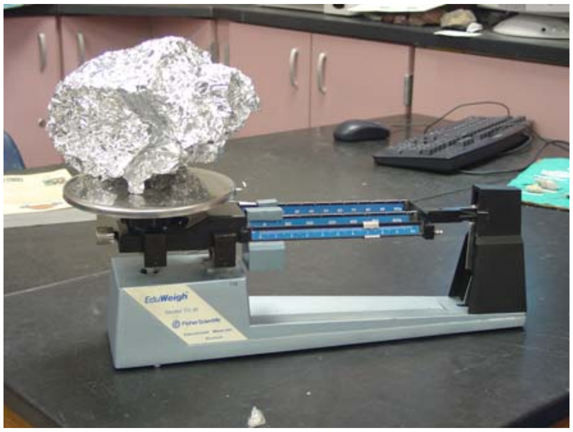
2. Carefully cover the inflated balloon with aluminum foil. Try and cover the entire surface of the balloon.

3. 

4. Using the string, measure the circumference of the "star" three times at three different angles. Take the average of the circumferences and record the average in the data table under Trial 1.

5. Place the "star" on the triple beam balance to determine the mass. Record the mass in the data table under Trial 1.

6. Using a push-pin carefully pop the "star". This represents the stage of a star becoming a supernova. DO NOT CRUSH THE FOIL. You will crush the foil in stages. Carefully crush the foil so that it is slightly smaller than its original volume.

7. 

8. Measure and record the circumference of the "star" three times at three different angles. Take the average and record this circumference in the data table under Trial 2. Be careful not to further crush the "star". Measure the mass and record it under Trial 2.

9. Measure the mass of the "star" on a balance. Record the mass under Trial 2 in the data table.

10. Crush the "star" slightly once again so that it is not quite completely crushed. Measure and record the new circumference of the "star" three times at three different angles. Take the average and record this circumference in the data table under Trial 3 in the data table.

11. Crush the "star" once again so that it is now as compact as possible. Measure and record the new circumference and mass under Trial 4 in the data table.

12.

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## Data and Observations

| Trial | Circumference | Radius | Volume | Mass | Density |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

## Analysis

13. Use the values from your data table and the formulas below to calculate the radius of the "star", the volume of the "star", and the density of the "star". Record these values in your data table.

$$\text{Circumference} = 2\pi r$$

$$\text{Volume} = \frac{4}{3}\pi r^3$$

14. $\text{Density} = \frac{m}{V}$

$$\pi = 3.14$$

## Conclusion Questions

1. What stage of a star's life cycle is represented when you popped the "star" balloon?

2. What kind of stars become black holes: low mass, medium mass, or high mass?

3. Describe any observed changes in the circumference of your “black hole” as you completed each trial?

4. Describe any observed changes in the mass of your “black hole” as you completed each trial?

5. Describe any observed changes in the density of your “black hole” as you completed each trial?

6. Compare the mass and density of your “star” to the mass and density of your “black hole”?