How Dense is a Black Hole?

Introduction

How and when does a black hole form in the life of a star or quasar galaxy? What happens to the density of a black hole that it becomes so dense that not even light can escape it? What happens to the mass, volume and density of a star that ends its life as a black hole?

Background Information

Black holes are fascinating astronomical objects that capture our imagination. Most of the information that we have learned about them was discovered in the last few decades. We know that black holes come in different sizes. The smallest – stellar or star size black holes – form at the end of the life cycle of a very massive star. As the star runs out of hydrogen the core begins to shrink due to gravity. A supernova explosion occurs and the gravitational collapse continues until a black hole forms. The largest – supermassive black holes – exist in the center of old, distant galaxies called quasars (quasi-stellar radio object). In both types, a great deal of mass is compacted into a very tiny space with a tremendous amount of density. The high density and the strong gravitational force pull in everything, even light. Since nothing is faster than the speed of light, nothing will escape the black hole.

Materials

Round, latex balloons (preferably black or dark colored)
Aluminum foil squares
1000ml beakers
Water
Paper towels
Electronic Balance

Procedure

Working in groups of 2 or 3, review the concept and formula for density (density = mass/volume).

1. Blow up the balloon to the size of your fist and tie it closed. Cover the entire balloon with the aluminum foil (be sure the entire balloon is covered at least twice). This is your massive star.
2. Using the electronic balance, measure and record the mass of your star.
3. Using water displacement, determine the volume of your star. To do this, fill the beaker with 100ml of water. Gently place your star into the beaker of water and record how much the water level rises. The difference is your star's volume. When you are finished dry your star with paper towels.
4. Now you are going to cause your supernova explosion by squeezing the balloon – or you can pop it with a pen or pencil. Using your hands as the gravitational force, squeeze the aluminum foil back into the shape of a sphere.
5. Once again, similar to steps 2 and 3, measure and record the mass and volume of your star.
6. Squeeze the star again making it as small as you can. Remember to retain the spherical shape.
7. One last time, measure and record the mass and volume of your star.
8. Calculate the density of your star at each of the three stages.

Conclusion

Students should understand that the black hole was a result of the death of a massive star, following its supernova explosion. By completing this activity, students should realize that 1) the mass of the star remained the same at each stage; 2) the volume of the star decreased at each stage; and 3) the density of the star increased, especially at the final, black hole stage. Finally, they should be able to relate the increasing density of the black hole to the realization that it could prevent light from escaping.

Extension

Advanced students can measure the circumference of the star/black hole at each of the stages. This would require them to take at least 3 measurements, at 3 different paths around the star, and then average the circumference. To calculate volume, use the formula $(4/3)\ \pi r^3$. To calculate the radius needed for this equation, divide the circumference by 2π.

Student Name: ___________________________ Period/Subject: __________________________

How Dense is a Black Hole - Student Worksheet

Data Table

Stage of Star	Mass	Volume	Density
1			
2			
3			

Conclusions and Questions

1. What happened to the mass of the star/black hole during the 3 stages?

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2. What happened to the volume of the star/black hole during the 3 stages?

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3. What happened to the density of the star/black hole during the 3 stages?

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4. What was your object considered at Stage 1?

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5. What force caused your star to collapse and become a black hole?

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6. If a black hole is extremely dense, as we believe, what happens to light that comes into contact with it?

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