



Teacher's Guide

ACTIVE GALAXIES

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PopUp Book Science Leader Guide

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Credits: The activities have been developed as part of the NASA Education and Public Outreach (E/PO) Program at Sonoma State University, under the direction of Professor Lynn Cominsky.

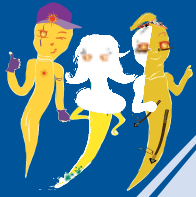
Contributors to this education unit include Dr. Philip Plait, Sarah Silva, Aurore Simonnet, and Sharon Janulaw.



The Active Galaxy pop-up book was created to introduce students to supermassive black holes, their components, and their environments. The use of a 3D pop-up model gives students a visual and conceptual understanding of how the various components fit together and, we have found, is an excellent device to engage their attention and enthusiasm.

The book, however, has many more uses than simply delivering black hole content. It can be used as an introduction to astronomical objects (including stars, galaxies, and all the different kinds of black holes), a hands-on kinesthetic exercise in geometry and perspective, and even as a cross-disciplinary language arts platform. It also captures the wonder and interest of children of all ages, and can lead to them reading more on the internet and in books.

Pop Up Standards	The book conforms to many National Education Standards for Science and English Language Arts:
Science	“Unifying Concepts and Process” (K-12): Systems, order, and organization; Evidence, models, and explanation.
Earth and Space Science	Origin and evolution of the Universe (9-12), Objects in Sky (3-4), Changes in Earth and Sky (3-4), Earth in the Solar System (5-8)
English (all K-12):	“Reading for Perspective”: Students read a wide range of print and nonprint texts to build an understanding of texts, of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classic and contemporary works.
Applying Knowledge	Students apply knowledge of language structure, language conventions (e.g., spelling and punctuation), media techniques, figurative language, and genre to create, critique, and discuss print and nonprint texts.
Evaluating Data	Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and nonprint texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.
Developing Research Skills	Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.
Participating in Society	Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.
Applying Language Skills	Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).



Pop-Up Content

The book has three main parts: the pop-up section with the black hole components and an explanatory section; “Tasty Active Galaxy”, a fun activity in which students create their own model of a black hole out of food; and a “Just So” story entitled “How the Galaxy Got Its Jets”, a whimsical fictional tale designed to engage younger students.

Different parts of the book are designed for different age groups: the pop-up section and Tasty Galaxy activity are appropriate (with minor variations in pedagogy; see the next section for specifics) for grades 7-9, and the Just So story for Grades 3-6.

A wealth of free supplemental materials are available. We have collected them in the section labeled “Resources”. These include a lithograph of the Tasty Active Galaxy activity, the “Just So” story in various formats (PowerPoint, PDF, and a printed booklet), a PDF of the content of the pop-up book, and much more.

The pop-up book itself is only distributed to educators who are trained in its use. For more information about obtaining a pop-up book for your classroom please contact Lynn Cominsky at: lynnc@universe.sonoma.edu.



Before Using the Pop-Up Book in Your Classroom

Some preparation must be done before presenting the book to your students.

Grades 3-4:

For this grade level, the best use of the book is with English Language Arts. Reading the story to the children and asking them questions about it conforms to many of the national English standards. The book can also be used in conjunction with other activities about science over a wide range of topics. At this age level, students may not be familiar with astronomical objects other than those in the solar system. Asking them questions about what they already know (or think they know) is an excellent introduction to black holes. Through movies and other sources they will probably have heard of black holes, but they will have many misconceptions. This can lead to excellent discussions about topics covered in the book.

Grades 5-6:

For students at this grade level, the book can be used as a springboard for them to create their own stories and pop-up books. A general question-and-answer session to start things off will warm them up to the concepts and lead to discussions about misconceptions they may have about black holes and galaxies. After reading the story to the students, they can create their own stories about other science topics, or they can focus on one set of characters from the black hole story. Another direction can be for them to create their own pop-up book on a different science topic such as biology or plate tectonics. In this way, the class can cover many national standards in both science and English language arts simultaneously.

Grades 7-9:

Students at this level will have a relatively easy time grasping the concepts in the book. In this case, it can be used as an engagement and introduction to the actual science of black holes and their components. After an interactive discussion about black holes, they can watch a video about active galaxies and the black holes thought to be at their cores. They can examine the pop-up book, and then create their own models of black holes from food as described in the “Tasty Active Galaxy” activity.



Overview:

The pop-up book will give students great visual cues on how the various components of a black hole in the center of a galaxy fit together. However, it's best not to jump right in with the pop-up immediately upon starting the lesson. For any grade level, it's best to start a dialog with your students on black holes in general, to get them thinking about what they know – and, perhaps more importantly, what they think they know – about black holes.

Engage them by talking about black holes in movies, on TV shows, in cartoons, and even in the news. Pictures of black holes (including artists' conceptions)

can be used here as well, punctuated with a discussion using some of the vocabulary from the book. For younger kids you'll want to introduce them to Just So stories in general, stressing that they are exaggerated fantasy stories intended to make a broad point. Then go over the black hole Just So story. For older students, you can have them do the tasty Active Galaxy activity. Once they are familiar with the concepts and the components of a black hole, show them the pop-up book.

The description of active galaxies from the pop-up book has been placed in Appendix A for your use.



“How the Galaxy Got Its Jets”

This story is written in the age-old method of a “Just So” story, a wildly fantasized story used to explain a natural phenomenon. These types of stories are fun and not meant to be taken seriously, but can also be used to teach life lessons and make children think about how things come about.

In this story, groups of various anthropomorphized astronomical objects cannot get along, and are tricked into meeting at the center of a galaxy, where a super-massive black hole lives. The black hole scrambles them up and ejects them out, telling them to come back when they learn how to behave.

Although it is appropriate for younger children, older children can use the story to learn about the various types of astronomical objects. They can also use the story as a springboard to create their own stories, or write more about one of the characters (really, astronomical objects) in the story. Based on factual information they gather about the astronomical objects, they could also write about whether or not the anthropomorphic characteristics actually suit the astronomical objects. This provides a cross-disciplinary curriculum with language arts, using an engaging scientific idea to help them learn to read and write. Please refer to the Appendix B: Separating Fact from Fiction in the “Just So” Story to guide the students in what is real and what is fable in the story.

Tasty Active Galaxy

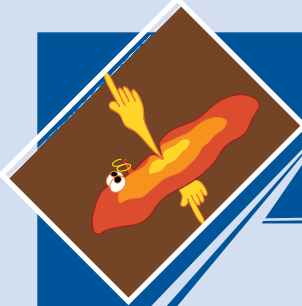
This well-tested (and well-tasted) activity has never failed to be a hit among students. It is based on an activity where they build a model of a black hole out of paper, but in this case the various black hole components are modeled with food: ice cream cones, doughnuts or bagels, and chocolate frosting (if you desire a more healthy alternative, substitutions can be made). Students really enjoy this activity for obvious reasons, but they also are able to retain the knowledge they acquire by doing it.

Pop-Up

The pop-up itself shows how the components of a black hole fit together. The black hole itself is only a tiny dot, but the matter swirling around it in an accretion disk is shown as several layers of the pop-up, indicating its much larger size. A jet – a beam of matter and energy emitted near the black hole as material plunges into the hole – is also represented. While not all black holes in the centers of galaxies have jets, many do.

The components are described in the book with a diagram to tie the explanations to the popup. There is also a description of active galaxies and their black holes, and a glossary.

For specific examples of how to use the book in the classroom, see the appropriate lesson plans below, which are divided by grade levels.



Appendix A: Active Galaxies – *This is the text from the inside of the Pop-Up book.*

Under the diagram:

In this popup, the jet can be seen coming from the black hole itself. The next layer down represents the accretion disk, glowing from its heat. The next layer down is the cooler torus of gas and dust, and the final layer represents the inner, central part of the galaxy. The book itself represents the galaxy, but on this scale, the galaxy is actually larger than your classroom, your school, and maybe even the town you live in!

Description:

A galaxy is a collection of stars, gas, and dust held together by gravity. A typical galaxy has billions of stars, and some have trillions of stars.

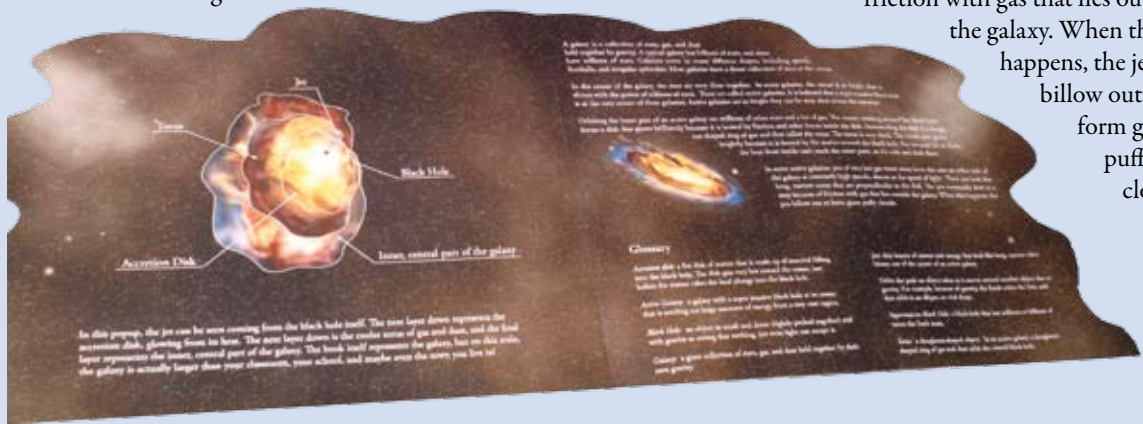
Galaxies come in many different shapes, including spirals, balls, and irregular splotches. Most galaxies have a dense collection of stars at the center.

In the center of the galaxy, the stars are very close together. In some galaxies, the center is so bright that it shines with the power of trillions of suns. These are called active galaxies. It is believed that a supermassive black hole is at the very center of these galaxies. Active galaxies are so bright they can be seen clear across the universe.

Orbiting the inner part of an active galaxy are millions of other stars and a lot of gas.

The matter swirling around the black hole forms a disk that glows brilliantly because it is heated by friction and other forces inside the disk. Surrounding the disk is a doughnut-shaped ring of gas and dust called the torus. The torus is very thick. The inside part glows brightly because it is heated by the matter around the black hole. But because it's so thick, the heat from inside can't reach the outer parts, so it's cold and dark there.

In some active galaxies, jets of very hot gas move away from the core on either side of the galaxy at extremely high speeds, almost at the speed of light. These jets look like long, narrow cones that are perpendicular to the disk. The jets eventually slow to a stop because of friction with gas that lies outside the galaxy. When this happens, the jets billow out to form giant puffy clouds.



Glossary:

Accretion disk: a flat disk of matter that is made up of material falling into the black hole. The disk gets very hot toward the center, just before the matter takes the final plunge into the black hole.

Active Galaxy: a galaxy with a super massive black hole at its center that is sending out huge amounts of energy from a tiny core region.

Black Hole: an object so small and dense (tightly packed together) and with gravity so strong that nothing, not even light can escape it.

Galaxy: a giant collection of stars, gas, and dust held together by their own gravity.

Jets: thin beams of matter and energy that look like long, narrow tubes blown out of the center of an active galaxy.

Orbit: the path an object takes as it moves around another object due to gravity. For example, because of gravity, the Earth orbits the Sun, and that orbit is an ellipse, or oval shape.

Supermassive Black Hole: a black hole that has millions or billions of times the Sun's mass.

Torus: a doughnut-shaped object. In an active galaxy, a doughnut-shaped ring of gas and dust orbit the central black hole.

Appendix B: Separating Fact from Fiction in the “Just So” Story



As in all Just So stories, “How the Galaxy Got Its Jets” has reality mixed together with fantasy. This section helps you sort out which is which. The ideas presented here are not meant to be exhaustive, but more to give you a place to start. When discussing this with your students encourage them to use their imaginations!

Fact

- All the objects in the story – hydrogen, helium, asteroids, planets, stars, comets, galaxies, and black holes – do exist.
- Asteroids do “smack into things,” causing craters.
- Some stars are hot, and some are cooler.
- Comets are icy.
- The diagram of the center of a galaxy is (within an artist’s limitation) correct.
- Black holes can and do mix together matter as it swirls around them, and can also eject matter and energy in the form of beams called “jets”.
- Black holes can draw in light.
- Scientists study the light from galaxies and jets to determine more about them.

Fiction

- Astronomical objects are not alive. They don’t bicker either.
- Objects in space don’t always hang together in groups of similar types.
- Black holes don’t “reach out” and grab objects; things only fall in if they get too close.
- Most objects in space get along just fine, even when they are close together. Comets and asteroids pass the Earth quite often with no ill effects.
- Hydrogen is not necessarily invisible. In fact, in many objects (such as gas clouds) the hydrogen emits light very strongly.

Resources

- The Pop-up book website is located at <http://glast.sonoma.edu/teachers/popup.html>. It has the Tasty Active Galaxy activity, the Just So story (in HTML, PDF, and Powerpoint formats), and the text of the book, and this teachers’ guide.
- The Black Holes Resource Area: <http://glast.sonoma.edu/teachers/blackholes/index.html> has a wealth of information and materials about black holes, including an education workshop for activities based on black holes. This includes an Educators Guide and PowerPoint presentation to introduce the activities.
- A video explaining active galaxies is on a public FTP site at: ftp://universe.sonoma.edu/pub/GLAST/SM_GLAST_1/agn_animation/Sonoma_4.mov
- An Active Galaxies Educators Guide with activities and a beautiful poster are online at: <http://glast.sonoma.edu/teachers/teachers.html>
- A Black Hole Fact Sheet outlining facts and fiction can be downloaded from the Black Holes Resource Area: <http://glast.sonoma.edu/teachers/blackholes/index.html>
- There are many web sites that cover these topics, including:
 - The GLAST website: <http://glast.sonoma.edu>
 - NASA Imagine the Universe; grades 9-12 : <http://imagine.gsfc.nasa.gov>
 - NASA Starchild grades 5-8: <http://starchild.gsfc.nasa.gov>
 - The Astronomy Picture of the Day: <http://antwrp.gsfc.nasa.gov>
 - SpacePlace: <http://spaceplace.jpl.nasa.gov>

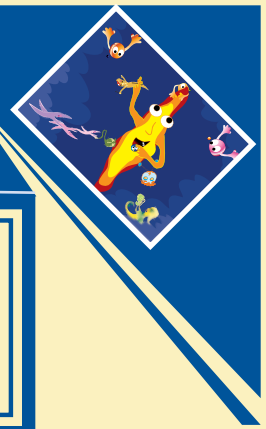


- Active galaxies pop-up book
- Just So story printout (one per student)
- Active galaxies poster

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- Diagram illustrating the structure of a black hole and its surrounding regions:
- Accretion Disk:** The large, glowing, yellowish-orange disk of gas and dust surrounding the black hole.
 - Jet:** The high-speed outflow of matter from the inner disk, shown as a narrow beam of light.
 - Inner Central part of Galaxy:** The region immediately surrounding the black hole, including the accretion disk and the innermost parts of the galaxy.
 - Torus:** The thick, donut-shaped structure of gas and dust that surrounds the inner central part of the galaxy.

Galaxy Layers Description

Basic Outline for Pop-up Book Presentation 5th and 6th grade students

**Materials needed:**

- Pop-Up book
- Active galaxies poster
- Just So story printout (one per student)
- Paper and art supplies for project

1. Open with the general question, “What do we know about galaxies?” “What is in a galaxy?” “What do you know about Black Holes?”

a. As the answers die down ask, “What is a Black Hole?”

b. Then ask “What are some of the craziest and unique things you’ve heard about Black Holes? In school? In the Movies or on TV? In books?”

2. Students may answer with “Black holes suck things in,” or “Black holes are created from exploded stars.” Get them talking about these ideas, and tell them that there are actually different kinds of black holes.

3. Say “Today we’re going to read a story about biggest black holes in the Universe: the cores of Large and Bright Galaxies.”

4. Read the “How the Galaxy Got Its Jets” story aloud. You can do this using the popup book or the power point slides downloadable from this page:

<http://glast.sonoma.edu/teachers/popup.html>

5. After the reading ask if the students have any questions. Prompt them with questions about the type of story it is: what genre is it? Is everything in the story fact or fantasy?

6. Talk about the different components of an AGN – use the poster images to help.

7. Open up the pop-up book and show them all of the components in 3D. Explain:

a. that what they’re seeing is the center most part of the galaxy

b. that the size of a galaxy with a center the size shown in the book would be a disk much larger than the town you live in (about 2000 km)!

8. Tell them that they’re going to make their own science story today. We suggest that you provide them with a list of topics on the board. Also make sure to point out that the story must also talk about real science facts so the learner can learn something too. Suggested list:

Galaxies, Stars, Planets, Asteroids, Star Systems, maybe a few Earth systems or processes, gravity, and light.

9. Ask them to get into groups of three and send only one person up to gather the materials.

10. Make sure you hand out the AGN story booklets so they have examples.

11. Once they are sitting and have all materials, allow them plenty of time to create their story. Possible time allocation or timeline could be: spend one day on the story writing, take it home to finalize the draft and the next day do the drawings with the story.

12. When everyone is finished have each group read their story to the class and make sure they also explain what science topics they’re teaching, too. This can be used as a form of assessment as well, to see how well they learned the materials about which they wrote. You can also ask them to write in their Journal about what they learned.

13. Close the activity saying that there is much we can learn from reading fun simple stories. We can learn about many disciplines and facts while simply reading.

Basic Outline for Pop-up Book Presentation 5th and 6th grade students

Materials needed:

- Pop-Up book
- Active galaxies poster
- Just So story printout (one per student)
- Materials to make a pop-up book (outlined in links below)

1. Open with the general question, “What do we know about galaxies?” “What is in a galaxy?” “What do you know about Black Holes?”

- As the answers die down ask, “What is a Black Hole?”
- Then ask “What are some of the craziest and unique things you’ve heard about Black Holes? In school? In the Movies or on TV? In books?”

2. Students may answer with “Black holes suck things in,” or “Black holes are created from exploded stars.” Get them talking about these ideas, and tell them that there are actually different kinds of black holes..

3. Say “Today we’re going to read a story about biggest black holes in the Universe: the cores of Large and Bright Galaxies.”

4. Have the students take turns reading the “How the Galaxy Got Its Jets” story aloud. You can do this using the popup book or the power point slides downloadable from this page:

<http://glast.sonoma.edu/teachers/popup.html>

5. After the reading ask if the students have any questions. Prompt them with questions about the type of story it is: what genre is it? Is everything in the story fact or fantasy?

6. Talk about the different components of an AGN – use the poster images to help.

7. Open up the pop-up book and show them all of the components in 3D. Explain

- that what they’re seeing is the center most part of the galaxy
- that the size of a galaxy with a center the size shown in the book would be a disk much larger than the town you live in (about 2000 km)!

8. Tell them that they’re going to make their own pop up book of an astronomical object. We suggest that you provide them with a list of topics on the board. Also make sure to point out that they can do a story with the book, but do not have to. Make sure they include real science facts so the reader can learn something, too. Suggested list:

- Hydrogen, Helium, Gases, Asteroids, Galaxies, Stars, Planets, and gravity.

9. Ask them to get into groups of three and send only one person up to gather materials.

10. Make sure you hand out the AGN story booklets so they have examples and display this pop up book and others around the room. Here are a few websites with information on pop up book engineering:

a. <http://www.robertsabuda.com/popmakesimple.asp>

b. <http://www.makersgallery.com/joanirvine/how-to.html>

c. <http://www.enchantedlearning.com/crafts/cards/flowerpopup/>

11. Allow them plenty of time and resources to help design their book. Possible time allocation or timeline could be to spend 1-3 days on the research, take it home to finalize the draft text for the book and then the following days do the drawings and pop up engineering. From start to finish this process usually takes about two weeks.

12. See handout below for a template to help students organize their thoughts.

13. For grading we suggest that you create a rubric or evaluation form with your students prior to doing the project so that they know and get to choose what they’re graded on.

Astronomy Pop – up Book Worksheet



Name: _____
Date: _____ Period: _____

Name of object I have chosen: _____

Why I think this object is interesting:

Three sources I consulted to find information about this object:

- 1.
- 2.
- 3.

The main scientific facts having to do with this object that I will be sure to feature in my pop up book are:

Information that I found that I might use:



Basic Outline for Pop-up Book Presentation 7-9 grade students

Before class:

Prepare bowls with two cones, a single (black) sprinkle, a doughnut hole, a bagel sliced horizontally (as if you were going to toast it), a plastic knife, and approximately 1 tbsp of frosting.

1. Open with the general question, "What do you know about Black Holes?"

- As the answers die down ask, "What is a Black Hole?"
- Then ask "What are some of the craziest and unique things you've heard about Black Holes? In school? In the Movies or on TV? In books?"

2. Students may answer with "Black holes suck things in," or "Black holes are created from exploded stars." Get them talking about these ideas, and tell them that there are actually different kinds of black holes.

3. Say "Today we're going to concentrate on the biggest black holes in the Universe: the cores of Active Galaxies."

4. Play the "Active Galaxies" movie.

5. After the movie ask if the students have any questions.

6. Talk about the different components of an AGN – use the poster images to help.

7. Open up the pop-up book and show them all of the components in 3D. Explain:

- that what they're seeing is the center most part of the galaxy
- that the size of a galaxy with a center the size shown in the book would be a disk about 2000 km in diameter.

8. Tell them that they're going to make their own active galaxy.

9. Ask them to get into pairs and send only one person up to gather the supplies.

10. Make sure you hand out the AGN litho so they have instructions.

11. Once they are sitting and have all materials, tell them to follow the directions on the back of the litho and create their active galaxy. Ask them the following:

- What do the cones represent? (they should answer jets)
- What does the bagel half represent? (Answer: torus)

Materials needed:

- Pop-Up book
- Tasty Active Galaxies litho
- Active galaxies poster
- Active galaxies movie (online)

• Per group of 2:

- 2 ice cream cones (pointed)
- ½ bagel
- 1 doughnut hole
- 1 Nonpareil sprinkle (black dot preferably)
- 2 tbsp chocolate frosting
- Plate to hold contents
- Butterknife

c. What does the frosting represent? (Answer: gas and dust in the torus)

d. What does the doughnut hole represent? (Answer: accretion disk)

e. Finally – What does that little sprinkle represent? (Answer: the black hole)

☞ The point here is that compared to the galaxy the black hole is rather small BUT VERY DENSE AND VERY MASSIVE.

f. Where does the black hole go in the model? (You get numerous answers – the answer is at the center of the doughnut hole – do not tell them that, just give them hints for example, "Where is the black hole in relation to the accretion disk?")

12. Make it clear that they CANNOT eat their AGN until you say it is ok.

13. Walk around and help the students. Explain what the components are as you walk around if needed. Ask each where the black hole should go and get them to stick it in the middle of the doughnut hole.

14. When everyone is finished go over every component with the class. Explain that the black hole is very small and not seen directly by scientists, and that the knowledge about AGNs is relatively recently acquired. At one time scientists thought these AGN were many different objects because they were looking at them from different views. Take one of the AGNs (wash your hands first!) and turn it so that the students can see it at different angles. Show it upright, on the side, and with the cone pointing at them. Get them to see how hard it is sometimes to really determine what you're seeing.

15. Close the activity by saying that there is a lot we don't know about black holes and galaxies, and that we need future scientists like them to help us find the answers.

Tasty Active Galaxy

Do you wonder what an active galaxy tastes like? You are about to find out...

We are going to make an *Active Galaxy* with black hole!

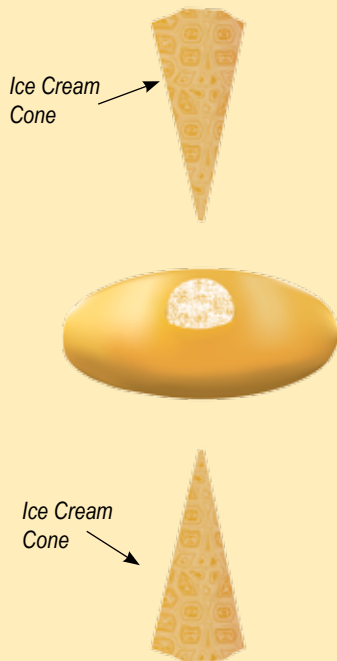
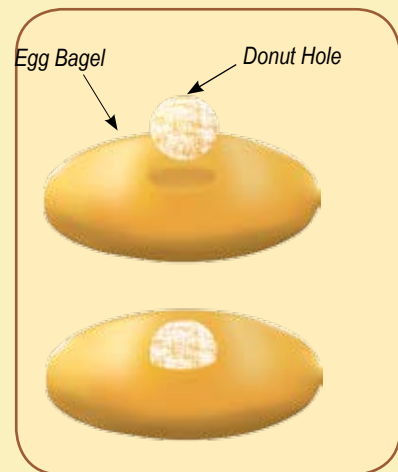
You will need:

- 2 Ice cream cones
- 1/2 Egg Bagel
- 1 Donut Hole
- 1 Nonpareil Sprinkle (black would be best)
- 1 Toothpick
- Chocolate frosting
- A butter knife

① First gather all the ingredients from the list (see “You will need”).

② Place the donut hole in the middle of the Bagel half. The Bagel represents the galaxy’s **disk** and **torus**, while the donut hole represents the **center and black hole**.

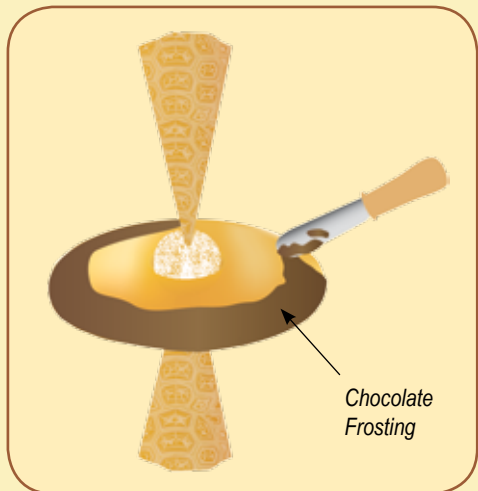
(Note: If the hole of your bagel is not large enough, cut the extra dough with the butter knife to make the donut hole fit.)



③ Using the toothpick, make a tiny hole in the middle of the doughnut hole and place your sprinkle in it. This is your **Black Hole**!



④ Gently push the ice cream cones into the middle of the doughnut hole on each side of the bagel. You have made the **jets**.



⑤ Now spread the chocolate frosting on the outside edge of the bagel to create the **torus**.

⑥ Finally, the fun part... Let’s see if you can eat your galaxy without being swallowed by the Black Hole!

