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CA2 4.9 Active Galactic Nuclei

Purpose: To model an active galactic nucleus, and understand the Unified Theory of AGN

Equipment needed: 2 sugar-type ice cream cones, a bagel, a chocolate doughnut hole, and some cake frosting (something dark, with a bit of chips in it, like chocolate chips); paper plate, plastic knife, and possibly toothpicks.

Background: This activity is derived from the *Tasty AGN* activity developed by the Sonoma State University NASA Education and Public Outreach office, and is used with permission.

Black holes come in a variety of sizes. **Stellar class black holes** are formed from individual super massive star core collapses. Multiple black holes may merge, and when they do, what you get is simply a larger black hole with more mass and a larger event horizon. Thus, multiple black holes may form **Intermediate size black holes** anywhere from a few solar masses to several thousand in size. **Super massive black holes** combine millions to billions of suns, and are typically located in the centers of galaxies. It is not clear if these super massive black holes form from multiple mergers of black holes or form in place from tremendous nebulae that collapse before radiation pressure of newly formed stars can disperse the gas. Of the super massive black holes, there are two kinds: **Quiet** and **Active galactic nucleus**. The giant black hole in the center of the Milky Way is quiet. Other galaxies have active super massive black holes, such as NGC 7502.

When these AGN form, as much as 10% of the galaxy's mass consists of the black hole in the center. Contrary to popular belief, a black hole is not some sort of ultimate cosmic vacuum cleaner. We are not all ultimately doomed to fall into one. However, an explorer finding themselves in the vicinity of such a black hole will not find the trip a comfortable one.

Any material orbiting near the black hole will have a tremendous orbital velocity due to the intense gravity. Things even slightly closer to the hole will move significantly faster; this is caused by the tidal effect of gravity, which can even stretch individual objects as their near-side parts attempt to orbit faster than their far-side parts.

Near the singularity the tide force can even rip things apart. This effect is described by astronomers as **spaghettification**. (No, I did not just make that up.)

These traumatic events, combined with the possibility that orbiting debris can collide, generates a lot of energy. Much of this energy is turned into heat, where the kinetic energy of collisions turns into heat the same way a meteor can cause a tremendous crater simply by colliding with a planet at a high rate of speed.

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The energy lights up the surrounding nebula, and makes it glow; material actively falling into the black hole as a result of collisions, giving off radiation at every wavelength, is called the **accretion disk**. Material farther out, in a calmer, more stable orbit, is cooler and can block the radiation from certain angles, is called the **torus.**

Some of the material does not quite make it to the event horizon, however. In a process apparently driven by powerful magnetic fields caused by the rapidly spinning ionized gas near the black hole, powerful magnetic fields redirect some of the accretion disk material as it falls in to the hole. This material is separated into two **jets** of material that spray out above and below the accretion disk. Oftentimes, these jets are the only visible structure near the AGN, as the accretion disk and torus are so small they cannot be seen. (The black hole itself, which cannot radiate energy, can never be seen directly.)

Many years ago (well, if you consider 20-30 years many years) astronomers had an intriguing collection of odd objects they did not completely understand. These objects are described in a table below. Now we know that each of them is an AGN, and the primary difference between them is simply the viewing angle we have from the earth.

Procedure:

To understand this idea, called the **angular unification of AGN models**, we are going to build a model of an AGN using the materials described on the first page. The task at hand is for you to build a model AGN using the materials provided, and then draw a labeled picture of it here. Remember the following points.

- The black hole cannot be seen because it is dark. The event horizon of the black hole surrounds it and forms a border between the rest of the universe and the area closest to the singularity. Once this border is crossed, objects are no longer able to be retrieved or observed.
- The torus resembles a doughnut and surrounds the black hole. The accretion disk, if it is present, tends to be very small and near the event horizon. They also tend to be flat.
- The torus surrounds the accretion disk and is dark. It may contain stars or other debris that has not been destroyed by tidal forces or collisions.
- The jets are narrow at the base and widen slightly as they move away from the black hole in both directions, and they are usually perpendicular to the accretion disk.

Leave the model assembled while your teacher inspects it. Afterwards, if you find it appetizing, you can exert your revenge on the black hole's insatiable appetite by eating it.

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Draw a picture of your assembled model here; don't forget to label the parts.

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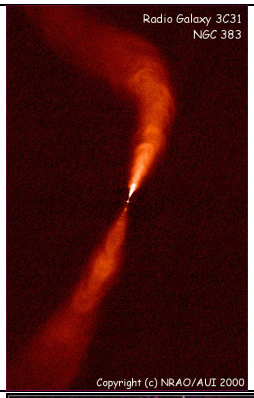
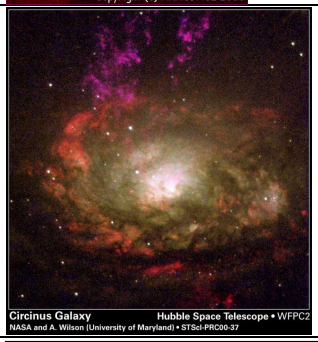
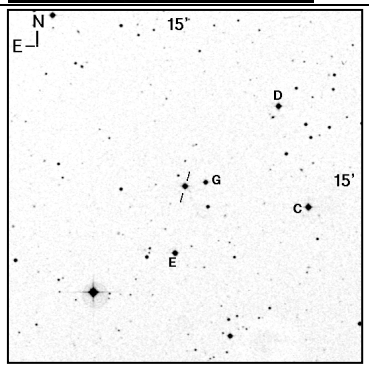
The model of the AGN can be used to explain a variety of odd phenomena observed from earth. Each of the objects described below used to exist independently of the others; that is, astronomers thought they were unrelated. The unification model proposes that all of them are AGN, seen from different angles. Call the angle with respect to the jet theta (θ). What angle of viewing would produce the effects described below? Sketch the AGN's angle with respect to the earth as well.

Description	Photo	Sketch of AGN angle	θ
Radio Galaxy Only the jets are seen in radio telescope images of distant galaxies. The torus is tiny, and the side view blocks any light from the accretion disk area.	 Image source: National Radio Astronomy Observatory. NGC 383.		
Seyfert Galaxy These are galaxies seen at angles, where the cores of the galaxies are unusually bright, allowing some of the radiation from the accretion disk to illuminate the center of the galaxy.	 Hubble image of a Seyfert galaxy, by A. Wilson.		
Quasar These are some of the most distant objects in the universe, visible only because the jet is aimed directly at earth. It is too far away to harm us, and appears only as a star; hence the name, a combination of quasi-stellar. Using the Hubble Law, the distances to quasars help us define the limits of the observable universe.	 Quasar 3C 273 is marked with two small lines. The other labeled stars are comparison stars. Credit: Landesternwarte Heidelberg-Königstuhl.		