Comet — A Physical Model

Dark Skies — Bright Kids
University of Virginia, Department of Astronomy
Charlottesville, VA 22904
darkskiesbrightkids@gmail.com

Goals

- To teach students what comets are made of and how they evolve over time.
- To see the physical effects of sublimation and different phase change temperatures.
- To emphasize that comets are largely made of the same types of materials found on Earth—both the similarities and differences are instructive.

Description

The students (individually or in small groups) build a physical analog of a comet, including carbon dioxide (CO_2) and water ices, dirt (for silicates), household cleaner (for ammonia), and corn syrup (for complex organic materials). As the CO_2 sublimates, students can observe the processes of outgassing and jets that lead to comet tails. For younger students or limited time/space, the instructor can build a single comet to show everyone else.

Materials Needed

- 2 heavy-duty garbage bags
- Rubber mallet (preferable) or a hammer
- Paper towels
- Large bowl or tub
- Gloves (ideally a pair for each student, but they can be shared. Alternatively, old rags or towels can be used.)
- Gallon-sized baggies with secure zip tops (one for each student, plus a couple of extras)
- Windex (or household cleaner containing ammonia)
- Cooler or ice chest for storage
- Dark corn syrup or cola ($\sim$1 T per student)
- Dry ice ($\sim\frac{3}{4}$ cup per student)
- Dirt and/or sand ($\sim\frac{3}{4}$–1 cup per student, preferably without roots and large chunks of plant material.)
- Charcoal briquettes ($\frac{1}{2}$ per student, optional)
- Pebbles or small rocks (just a couple per student)
- Water ($\sim\frac{1}{3}$–$\frac{1}{2}$ cup per student)

Instructions

1. Before the activity begins, there is some prep work to do.
   (a) Put on the protective gloves, double-bag the dry ice with the garbage bags, and use the mallet (or similar) to crush it. The goal is to have most of the ice become a fine powder–larger chunks won't mix well with the other ingredients—though a few fingertip-sized chunks will lead to more visible outgassing.
   (b) Place the briquettes in one of the extra baggies and crush to a fine powder.
   (c) Fill the large bowl with water.
   (d) Divide the comet "ingredients" (dirt, sand, charcoal, pebbles, corn syrup) in whatever manner suits the group's size and abilities. Some options are to set up stations where each individual student comes by to get a teacher-measured amount of each ingredient, or to split the students into groups of 3–5 and provide each group with enough of each component for the members.
2. Give each student a plastic baggie (and gloves, if available). Explain the components they will be using and what each represents, on an appropriate level.
3. Distribute the comet components (dirt, sand, charcoal, pebbles, corn syrup) and instruct the students to add them to their baggies and mix together. An instructor can circulate among the students with the ammonia cleaner and add a few sprays to each baggie.
4. Add $\sim\frac{3}{4}$ cup of dry ice powder and $\sim\frac{1}{3}$ cup of water to each baggie, and instruct the student to mush the baggie quickly to mix the ingredients, and then form the mixture into a ball and put pressure on it until it freezes. **The bags will be dangerously cold at this point**–only someone wearing gloves should touch the bag for any length of time.

   - It may be necessary to add more dry ice, if the mixture isn't freezing enough or if the student takes too long getting pressure on it.

5. After a hard ball forms, the instructor or student (wearing gloves) can pull it out of the baggie and examine in—look for jets of escaping CO_2 and the "craters" they leave behind. Students can move the comet through the air, watching the jets swept back in a sort of tail, or use a hair dryer on LO to simulate the comet's motion through the solar system. Point out how dark and "dirty" the actual nucleus is, in stark contrast to the bright coma or tails we see in the sky!

Post-Activity Discussion

- *What parts of a real comet are represented by each of the model's ingredients?* The idea is to get the students connecting the ingredients in front of them to the things that make up a real comet, and thinking about the fact that these mysterious, beautiful things in the sky are made up of materials that they see (or could see) every day on Earth. (All ingredients are roughly equivalent to those found in real comets, with the exception of the household cleaner [cometary ammonia is in solid ice form] and corn syrup [representing the complex organic molecules found mixed in comets].)

- *What stages of the comet's evolution that we see in the sky are mimicked in the model?* While the comet model is outgassing, it resembles a comet as it approaches the sun and its surface warms. After the gas ejection has ceased, the dirt-ball looks like a comet far from the sun, more similar in appearance to an asteroid, with no bright coma or tail to reflect sunlight. Emphasize that comets are *not* static, unchanging objects—their appearance and properties depend strongly on their distance from the sun, which is constantly changing!

- *Why are there jets escaping from the ball, and what are they?* Depending on the ages of the students, this activity can be used to demonstrate the process of sublimation and the concepts of phase change and phase change temperatures. CO_2 freezes at a much lower temperature than water, so dry ice is much colder than ice, which is what causes the water to freeze when placed in contact with dry ice. Dry ice also sublimates (compare to melting and evaporation) at a lower temperature than water ice, so it becomes gaseous (and expansive) while the water ice remains solid.