Mapping Worlds That Look Like Stars

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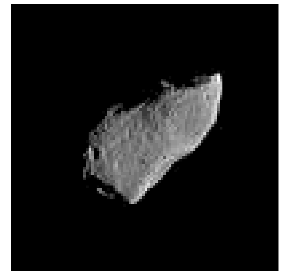

Objective

Changes to the intensity and color of light reflecting from objects too distant to show detail can be used to map the surface. These classroom examples show how an important astronomical technique, multi-color photometry, can be used to learn about distant worlds.

Keywords: reflected light, color, rotation, mapping, photometry, asteroid

Materials

- Overhead projector (or high intensity, focusing flashlight) that serves as an artificial Sun
- Peanuts: 3 or 4 for classroom demonstration (or per group of students), with different sizes and shapes (potatoes, avocados, carrots, and colored clays may also be used as alternatives) that will become asteroids.
- Black paper, cardboard, or cloth for sky background
- Colored marking pens
- Construction paper with colors matching the artificial asteroids and/or the colors of the marking pens.
- Pencils with good erasers (one per peanut asteroid) or lightweight monofilament fishing line.
- Paper clips (one per peanut asteroid)
- Large (approximately 12"x12"x18") box, one per group of students, if desired.

Discussion

Most individual objects in the universe are too distant to discern details on their outer layers, whether they are solid planets or gaseous planets or stars. With a handful of exceptions, the surface geographies of asteroids remain a mystery. Yet, astronomers have developed many techniques that yield a wide variety of information about these objects. In particular, measurements of the light intensity and color from objects can reveal parameters like rotation rate, shape, and geographic features.

To make these measurements, astronomers measure the sunlight reflected by an asteroid over the course of hours to days. In "integrated" (white) light, the strongest signal can be measured. Over the course of time, changes will be due to the rotation of the asteroid. If it is spherical, changes in the light reflected by the surface indicate differences in the reflectivity of surface materials. If the asteroid has a more complex shape, changes in reflected light can indicate both differences in surface materials and the effects of the different, illuminated cross-section presented to observers on Earth.

Astronomers will usually use filters to measure brightness in a variety of colors to better discern geographic features. The variation in color even provides hints to the composition of the surface. All such astronomical measurements rely on comparison with constant intensity background stars.

Procedure

Prepare your peanut asteroids in advance, by mounting each one in a pencil-handle: bend a paper clip around the waist of the peanut or create a cradle or clasp for the peanut, sticking one end of the paper clip into the pencil's eraser so the peanut is separated from the eraser. The pencil will be much less distracting if it is dark-colored. Alternatively, monofilament strings can be tied around the peanuts so they can be suspended. Controlling their rotation will be more difficult, however, if string is used. Set up some peanut-asteroids so that they present different cross-sections to an observer as they rotate and at least one that does not change its apparent shape as it rotates.

The background sky and comparison stars should also be prepared in advance. Use black construction paper or black cloth (black velvet is especially effective) to make the background sky, large enough for the classroom demonstration. Cut out at least four circles of various sizes, one smaller than the smallest peanut and one larger than the largest peanut, from the construction paper that comes closest to matching the peanuts' color. Attach (with tape or glue) these "stars" to the black background. It may prove convenient to also have unique numbers or letters attached near the stars so students can discuss their comparisons of the asteroid with the stars.

Set up the classroom so that the overhead projector will shine its "sun" light on the sky background that has been mounted to the wall.

Stand near the background, being careful not to obscure any stars with your body for any students around the room. Holding a sample peanut-asteroid, ask the students to make a judgment about how bright the asteroid appears in comparison with the stars. Realize that students looking from different angles around the room will record different brightnesses. Rotate the asteroid 90 degrees and ask them to note the brightness, repeating this three more times (to confirm that the results "close" on themselves). Repeat these observations with other peanut-asteroids.

Compare results around the room. The students will see that as tiny as the peanut appears from their seats, they can still tell that it is rotating and they can even get a feel for its relative dimensions. They may also note that because of the different viewing angle at the far ends of the room, there is a phase shift in when maximum/minimum apparent brightness occurs.

Variation and Extension

More stars for comparison allow more precise estimates of brightness and can generate smoother light curve (a plot of brightness vs. time [in this case, asteroid orientation with respect to the viewer]). The light curve will also be smoother if brightness measurements are made at intervals spaced more closely than 90 degrees of rotation. Actual brightness measurements may be possible with a photographic spot meter.

Obtain two small balls (or marbles). One should be uniform in color, and the other should be painted black on one hemisphere. Mount them in the same manner as the peanuts and have the students observe their light curves. The uniform sphere will have no variations. The two-faced sphere will demonstrate that reflectivity (albedo) variations can mimic the effects complex shapes.

Small groups of students can make their own observations by constructing a sky box. The box should have a viewing hole and "sun" hole in one end and a starry sky background affixed to the inside of the other end. A hole in the side or top, near the sky background, should be large enough to allow insertion of a peanut-asteroid and allow it to be rotated. Shine a flashlight through the sun hole. The illumination has to be uniform on the comparison stars and the asteroid. This may be accomplished by (1) adjusting the focus of the flashlight's reflector, (2) placing a wax paper diffuser over the flashlight (with or without adjusting the focus), or (3) shining the same portion of the beam over the asteroid and the comparison stars. Problems with illumination will illustrate experimental error.

Color some significant portions of the peanuts with the colored pens. Three possibilities can be pursued for the star background: (1) Create sets of similarly colored stars (from construction paper or white paper colored with the same pens). Your background, comparison star constellations will, of necessity, have many more stars since size-sets are needed in each color. (2) Use colored filters on the sun-analogs (overhead projector or flashlight). (3) For a sky box, filters can be interchanged at the eye-hole, in a manner similar to the way real astronomical observations are made. Colored gift wrapping film is an easily available and inexpensive source of color filter material. Have the students perform the same observations of the asteroids, but now they have to interpret the variations they see as being due to both shape and color reflectivity. Asteroids can also be constructed from clays of different colors and tested the same way.

<u>Standards</u>
A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

Level III Middle School (6-8) Science Standard 3. *Understands essential ideas about the composition and structure of the universe and the Earth's place in it.*
Knows characteristics and movement patterns of asteroids, comets, and meteors.

Level I Lower Elementary (K-2) Science Standard 12. Understands motion and the principles that explain it.
Knows that the position of an object can be described by locating it relative to another object or the background.

Level II Upper Elementary (3-5) Science Standard 12. Understands motion and the principles that explain it.
Knows that an object's motion can be described by tracing and measuring its position over time.

Level I Lower Elementary (K-2) Science Standard 15. *Understands the nature of scientific inquiry*.
Knows that learning can come from careful observations and simple experiments.

NOTE: This activity is currently posted to the Cassini web site as a field-test version. Educators who use this activity for classroom demonstration purposes are encouraged to submit comments to the Cassini Education Outreach Coordinator. We are dedicated to providing high-quality activities for classroom use and welcome your suggestions.