Estimating how often Mass Extinctions due to Impacts Occur on the Earth

Grades 8-12

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Abstract

This hands-on, inquiry based activity has been taught at JPL's summer workshop "Teachers Touch the Sky" for the past two decades. Students act as mini-investigators as they gather and analyze data to estimate how often an impact large enough to cause a mass extinction occurs on the Earth. Large craters are counted on the Moon, and this number is extrapolated to the size of the Earth. Given the age of the Solar System, the students can then estimate how often large impacts occur on the Earth. This activity is based on an idea by Dr. David Morrison, NASA Ames Research Center.

Introduction

In addition to its 8 major planets, the Solar System contains millions of small bodies, including asteroids, comets, and dwarf planets. Most asteroids are rocky fragments that orbit in the space between Mars and Jupiter. Small asteroids are sometimes called meteoroids. Comets are dirty snowballs that show beautiful tails of gas and dust as they approach the sun. Dwarf planets include Pluto and large asteroids that are just not big enough to be considered full-blown planets. Images of the asteroids visited by spacecraft are shown in Figure 1.

Asteroids and sometimes comets are moved out of their orbits and approach the Earth or even impact it. If the asteroid is large enough – about 100 meters in diameter – it can case a large crater and disrupt life on Earth. The largest impacts can cause mass extinctions of life, wiping out a large fraction of living species. The dinosaurs and many other life forms became extinct 65 million years ago following such an impact by an asteroid or comet.

How often do impacts large enough to cause mass extinctions occur on the Earth? We can estimate this number by looking at the Earth's Moon. The Moon has also been hit by asteroids throughout its history at about the same rate as the Earth. We still see the scars of these impacts in the form of craters on the Moon. On the Earth, these craters are eroded away by water, wind, and geologic processes such as plate tectonics. It is incorrect to think that the Earth's atmosphere burns up meteoroids that are large enough to cause large impact craters. The atmosphere only burns up very small meteoroids, those smaller than about 10 meters.

Because it has very little erosion, the Moon keeps a record on its surface of most of the impacts that ever occurred on it. If we count large impacts on the Moon, and then account for the larger size of the Earth, we can estimate how many large impacts have occurred on the Earth throughout its history. Scientists know how old the Earth is, so we can figure out how often a massive impact large enough to cause mass extinctions happens.

Activity

Step 1: Scientists estimate that a crater large enough to cause a mass extinction is about the size of the circle in Figure 2 or larger. This size corresponds to a crater of about 100 km in diameter. Count the number of craters at least this size on the Moon. There is no "right' answer, with most students seeing between 5 and 30 craters. A 100 km crater on the Moon is just large enough to be seen through a pair of binoculars at night (if conditions are right,

during the day as well). If you have a pair of binoculars and it's clear and near full Moon, go outside and count craters! All the craters visible are large enough to cause a mass extinction. Just before or after full moon is the best time to spot craters, because near full moon there aren't enough shadows to make the craters visible.

Number of large craters on the Moon = _____

Step 2: The next step is to account for the larger size of the Earth. Think about throwing a ball at a target. As the target gets bigger it will get hit more often. The relative sizes of the Earth and Moon tell how much more often the Earth will get hit. Even though the Earth and the Moon are both round, their targets in space appear as circles. Remember that the area of a circle is πR^2, where R is the radius. Thus, the relative size of the Earth and Moon as targets is:

Relative size = Area of Earth/Area of Moon = πR^2 (Earth)/ πR^2 (Moon) = _____

(The radius of the Earth is 6371 km and the radius of the Moon is 1737 km). The number of expected large impact craters on Earth – big enough to cause mass extinctions – is this relative size times the number of large craters on the Moon.

Expected large impacts on Earth = Relative size X Number of craters on the Moon = _____

Step 3: The final calculation is to find out how often during the history of the Earth large impacts occurred. We can estimate this number by dividing the age of the Earth by the expected number of large craters on Earth:

Frequency of large impacts = Age of Earth/Number of expected large impacts on Earth = _____

Scientists currently estimate the age of the Earth and the Solar System as a whole to be 4.54 billion years (4.54 X 10^9 years). Step 3 yields the final calculation giving an estimate of the average time interval between large impact events on the Earth. The last great extinction believed to have been caused by an impact was the one that occurred about 65 million years ago, when the dinosaurs went extinct. Are we due for another impact?

Discussion

Many students will realize that the numbers of craters should be multiplied by 2, since we are observing only half of the Moon. Other students might get confused by this concept, or they may argue that only one side of the Moon "sweeps up" craters. In fact, the side of the Moon we do not see (the "far side") is most heavily cratered, so a more "correct" activity would be to count craters on the entire moon. Other students might claim that the Earth has more gravity, so it will attract more objects. This idea is correct, but the effect is slight, because the Earth and Moon act as a single unit for objects coming from deep space.

Other students will know that the number of impacts has been getting less, as the planets swept up most of the debris (asteroids and meteoroids) early in the Solar System's history. Our estimate is thus larger than the current number of large impacts that occur on the Earth.

This lesson works well with other traditional hands-on classroom activities, such as cratering processes (see http://deepimpact.umd.edu/educ/mod_DesigningCraters/5compare/tg_cratering_class_lab_SS.pdf for an example of craters in the classroom put together by the Deep Impact Science Team), and phases of the moon (http://www.jpl.nasa.gov/education/index.cfm?page=123).
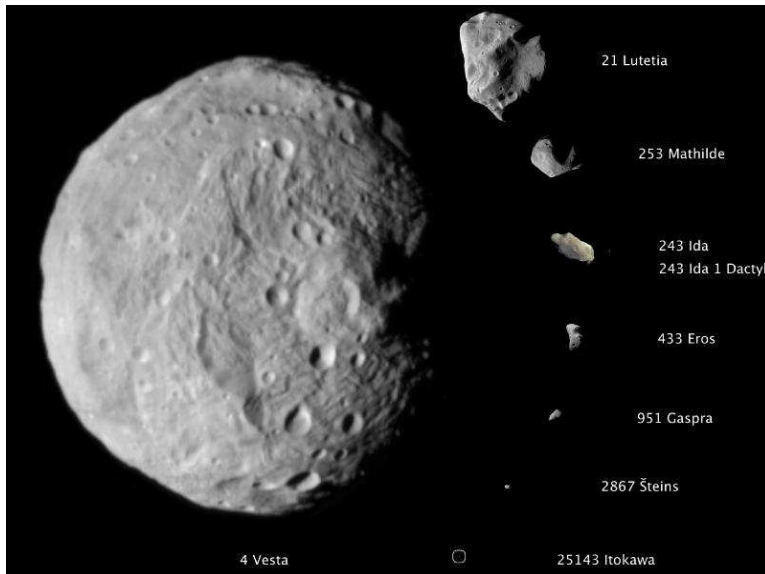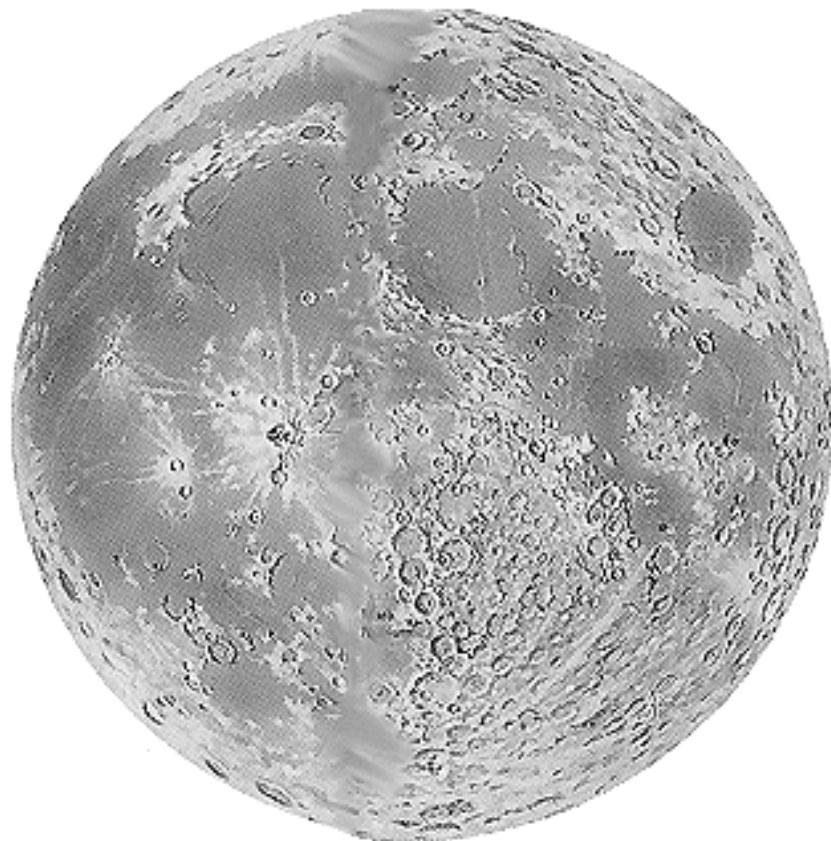
Acknowledgements

Figure 1 – Images of asteroid visited by NASA's spacecraft, to scale. The largest, Vesta, has a diameter of 525 km. Image courtesy of JPL/Caltech

HOW MANY LARGE CRATERS ARE THERE ON THE MOON (LARGER THAN O)?

Figure 2. This drawing of the surface of the Moon can be used to count large craters. Alternatively the moon can be observed through binoculars, for which any crater visible is large enough to cause a mass extinction. Image from NASA Goddard Space Flight Center.
(http://starchild.gsfc.nasa.gov/docs/StarChild/solar_system_level1/moon.html)