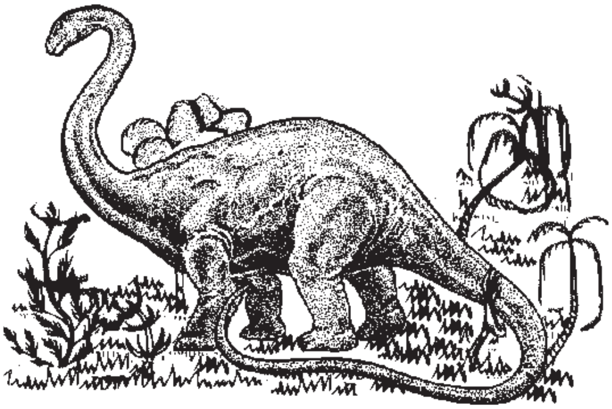
1. Beware of Large Flying Objects

We normally think of things in space as remote and not really able to affect things around us much. But there are some types of cosmic events that could really mess things up badly for us. In fossil records, there are many instances of species going extinct—apparently unable to cope with some change in environment. At certain times in Earth's history, not just one species has died off, but lots of species have died off, in *mass extinctions*.

The latest such *mass extinction* happened 65 million years ago, when the Age of Reptiles ended and the Age of Mammals began. Scientists have disagreed and squabbled for quite a while over the the question, “What caused the mass extinction at the end of the dinosaur age?” The candidates for the cause of the extinction were:

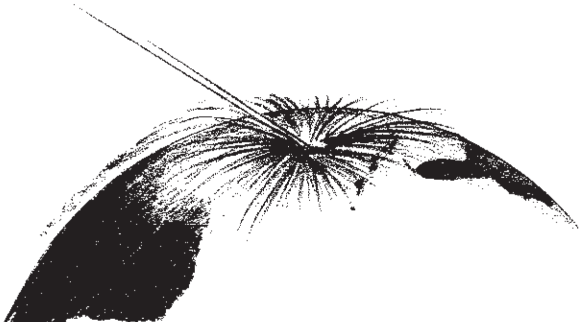


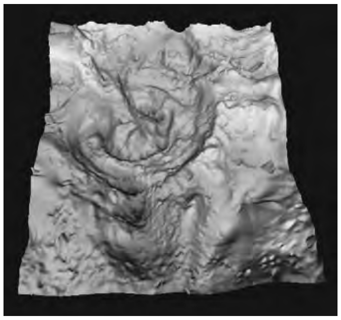
a. The theory of gradual change — mass extinctions took place over thousands or maybe millions of years, possibly due to long term climate change. Fossil evidence indicates that prior to sixty-five million years ago the dinosaurs were beginning to decline and many dinosaur species had already become extinct.

b. The volcanic eruption theory—A huge series of lava flows in India, named the Deccan Traps, which covers 10,000 square kilometers and is in some places more than 2 kilometers thick, is evidence of a period of volcanic activity that spanned about half a million years—including the period of the mass extinction at the end of the Cretaceous Period. The volcanic eruption theory is in agreement with paleontologists’ original idea that the extinction of species was gradual, or at least occurred in several steps, over hundreds of thousands of years.

The Deccan Traps *are extensive lava flows in India. Source: © Dr. Keith G. Cox, University of Oxford, Oxford, England.*

c. The impact theory — that a really huge object struck the Earth at about that time, cuasing global devastation. An underground crater found near Chixulub (pronounced *Chi’-shoo-loob*), Mexico, was found to be about 65 million years old. A clay layer contained tiny pieces of minerals (shocked quartz) and glassy rocks (tektites), which are found at nuclear test sites and large meteor impact sites, as well as soot—indicative of continent-sized forest fires. An asteroid in the 10 kilometer diameter size range could have caused the event.



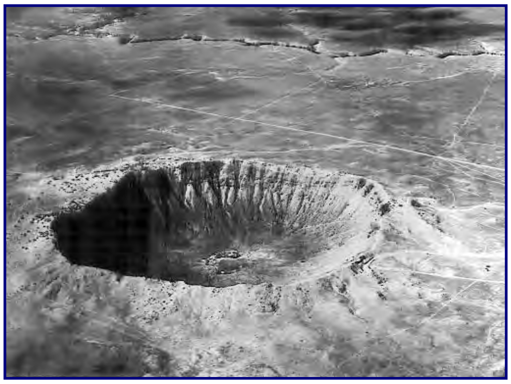


The Chixulub Crater *is buried underground, so it cannot be directly photographed. This is a 3-D graph made with equipment normally used to search for oil. It shows gravitational attraction of underground structures. Photo courtesy of Virgil L. Sharpton, Center for Advanced Space Studies, Houston, Texas, USA*

When a 10 km-sized asteroid strikes the ground, it buries itself in the Earth and coverts its tremendous energy of motion into heat in a period of only seconds. It opens a crater that reaches a diameter of 100 miles and a depth of fifteen miles. Red hot rock debris streams outward, forming a plume heading into the sky. The plume can go so high it sends hot debris into orbit that eventually rain back all over Earth. On the ground, you would feel an effect very similar to an oven on broil for about an hour. As a result of this thermal radiation, even green vegetation would dry out and begin to burst into flames spontaneously, causing global forest fires.

Which Theory is Right?

It may well be that we will never know for sure if either a large impact or massive volcanism *caused* the death of the dinosaurs.



The Barringer Meteor Crater *near Winslow, Arizona, is as deep as a 60 story building and more than a kilometer across. It was created about 30,000 years ago by a rocky object about 30 meters in diameter traveling at 40,000 miles per hour. The impact had an explosive energy equivalent to over a million tons of TNT. It is $^{1}/_{100}$ the size of the crater in Chixulub, Mexico. Source: Yerkes Observatory.*

Will Earth be Hit by a Large Asteroid?

Eventually, it is likely. But the odds of one hitting tomorrow, or next week, or in the next few thousand years are quite low. Of course tons of smaller bodies (sand grain size) enter Earth's atmosphere every day. While in space, they are called meteoroids. When they enter the atmosphere, they can heat up so much they vaporize and leave a streak of light. That's called a meteor, also known as a "shooting star" or "falling star." But the larger the body, the rarer it is to collide with Earth.

Asteroids that are made of rock and/or metal are not the only menace. Comets are bodies of ice that can go crashing into planets as dramatically seen in 1994 when the large comet Shoemaker-Levy 9 fragmented and created huge explosions when it struck the planet Jupiter at more than 20 different sites.

It would behoove us to seek advance warning of such an approaching body. An asteroid could come in quickly, but it may be technically possible to deflect an asteroid from an Earth impact course if there is enough advance warning.

Hubble space Telescope image of Comet Shoemaker-Levy 9 fragments before they collided with Jupiter.

The Search for Near Earth Asteroids (NEOs)

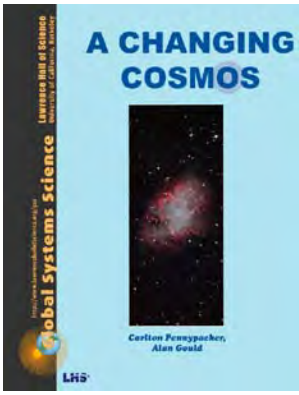
Asteroids must be discovered and their orbits tracked. At this point in time North American Aerospace Defense Command (NORAD) has a limited number of people monitoring the skies for asteroids. There is also a project called Space Guard which is an international network of telescopes and people working together to discover and track asteroids, with the idea of providing lots of advance warning if an asteroid is found to be on a collision course with Earth, so that an effort could be made to divert it. Currently, NASA carries out the "Spaceguard Survey" to find NEOs greater than 140 meters in diameter, and this program was budgeted at $4.1 million per year for FY 2006 through FY 2012.

The NASA Wide-Angle Inrared Survey Explorer (WISE) mission (launch in December 2009) is especially suited to find a multitude of asteroids —of immense value in the the overall effort to detect more NEOs.

Understanding, Helplessness, and Empowerment

It is nearly inevitable that Earth will be hit by an asteroid—only a matter of time, though we do not know if it will be today, tomorrow, or in many millions of years. But we certainly are not helpless. If we are able to detect a body that is hurtling towards Earth with enough advance warning, there are a number of strategies proposed to avert disaster. It's tempting to try blowing the thing up with nuclear weapons, a typical video game-style mentality. Unfortunately that could create a number of smaller bodies that would still continue on their trajectories and impact Earth with devastating effect. Other ideas for averting disaster are mostly different ways of nudging the asteroid to deflect it into a path that will not strike Earth.

But the key is "early warning." The sooner we find that asteroid "with our name on it," the more time we would have to plan action to prevent disaster—another mass extinction. This book is devoted to better understanding the science that relates directly or indirectly with the challenge of early detection of "near Earth asteroids."



Chapters 1 and 2 or this book are adaptations of respective chapters from A Changing Cosmos,from the Global Systems Science series

How Can We Assess the Danger?

If we've identified an asteroid in the WISE mission data, there are key questions that are of great import:

- Will it hit Earth?
- If it were to impact Earth, how bad would it be: a puff of smoke in the atmosphere or the end of civilization as we know it?
- What else can we learn from the data?

Essentially we have 4 key parameters in the data:

Position

Time

Intensity (or brightness)

Wavelength

POSITIONS and **TIME** determine the orbit which can tell us if the asteroid is likely to hit Earth. This can also give us the **DISTANCE** and **SPEED** of the asteroid at any given time.

From the **DISTANCE**, **INTENSITY**, and **WAVELENGTH** we can approximate the asteroid's

SIZE

TEMPERATURE

ROTATION RATE

ALBEDO (or reflectance: how light or dark the body is—how much it reflects light)

Position

Time

Intensity/Brightness

Wavelength/Frequency

Distance

Speed/Velocity

Size

Temperature

Rotation rate

Albedo/Reflectance

Density

Composition

Mass

Kinetic Energy

From the **ROTATION RATE**, we can also get an estimate of the **lower limit** of the asteroid's **DENSITY**, since an object held together by its own gravity (a "pile of rubble" as opposed to a giant rock), will fly apart if spins too fast.

The ALBEDO can also give an indication of the **COMPOSITION** of the asteroid. Asteroids with very low albedos ~ 0.03, that is, very dark asteroids, are called C-type and are typically rocky. Brighter asteroids with albedos between 0.1 and 0.2 are either S-type – metallic (nickel-iron) mixed with rock (silicate) – or M-type – purely metallic.

For mathematical computations needed to arrive at the asteroid attributes mentioned on this page, see Appendix B.

The COMPOSITION also gives another indication of the DENSITY of the asteroid. The densities of C, S, and M class asteroids are 1.38, 2.71, and 5.32 g/cm^3, respectively. There is a wide range of asteroid densities, but if albedo or composition is unkown, a density of 2 kg/m^3 can be assumed.

From **SIZE** of the asteroid and its **DENSITY**, the **MASS** of the asteroid can be calculated.

Which finally brings us to the KINETIC ENERGY ($E_{kinetic}$) which is

$E_{kinetic}$ = 1/2 x MASS x (SPEED)^2

It's this KINETIC ENERGY that tells us how dire our situation might be if the asteroid hits us— the answer to that question: "If it were to impact Earth, how bad would it be: a puff of smoke in the atmosphere or the end of civilization as we know it?" In SI units, the KINETIC ENERGY is in Joules (the mass is in kilograms and the velocity is in meters per second). A typical stick of dynamite contains about 2×10^6 Joules (a meteoirite might have that sort of energy. The largest nuclear bomb ever detonated was about 2×10^{17} Joules—large asteroids have many times that amount of kinetic energy.