

THE COMPLETE COSMOS

Chapter 18: Impact!

The threat of comets and asteroids. What would happen if the spacerock which slew the dinosaurs hit New York today.

Outline

The asteroid belt - and the ways that asteroids can be knocked into planet-crossing orbits. Two major impacts on planet Earth. In the most recent, some 65 million years ago, a mountain-sized rock is ejected from the asteroid belt and strikes Earth – slaying the dinosaurs. In the earlier, about four-and-a-half billion years ago, Earth is hit by a planetesimal the size of Mars. Debris splashes into space, some of which forms our Moon. The Moon's airless, cratered surface is testament to billions of years worth of impacts.

Comet Shoemaker-Levy 9's collision with Jupiter in 1994. Without Jupiter's powerful gravity, more comets would threaten Earth. In 1972, a spacerock skips off Earth's atmosphere and back into space. In 1992, a fireball breaks up over America's East Coast. In 1908, a cosmic missile explodes over Siberia with the destructive power of a huge nuclear bomb.

Space missions to assess the threat. The NEAR probe investigates Eros, an Earth-approaching asteroid 40 kilometers across. Rosetta, to be launched in 2003, will fly by two asteroids and a comet. Methods for protecting Earth from incoming dangers – a mirror that concentrates sunlight on to asteroids, solar sails which tug away intruders. As a last resort, the nuclear option - attaching a warhead to a rocket and firing it at an approaching asteroid.

The nightmare scenario - a comet from the Oort Cloud surprises us. A 100-million megaton blast vaporizes New York City opening up a crater 200 kilometers wide. As cosmic winter descends, the final curtain falls on humanity.

Sub-chapters

Cosmic Collisions

- Between Mars and Jupiter lies the asteroid belt. Two asteroids collide, an ejected fragment is drawn towards the Sun. A nudge from Mars' gravity knocks it Earthwards. This ten-kilometer projectile impacts Earth. Doomsday for the dinosaurs.
- Four-and-a-half billion years ago, a Mars-sized planetesimal strikes Earth. The debris falls back to Earth or gathers to form the Moon. Over eons, the Moon slows Earth's spin and accelerates the evolution of life.

Impacts on Moon and Jupiter

- The Moon's surface, pockmarked by 30,000 craters. With no wind or water, every impact is preserved. Earth's surface would look the same, if stripped of atmosphere, oceans, vegetation and geological movement.
- Comet Shoemaker-Levy 9's impacts with Jupiter in 1994. Discovered in 1992, after the comet is drawn close to Jupiter and is torn apart by the planet's gravity. Without Jupiter's pulling power, more comets would threaten Earth.

Target Earth

- In 1972, a spacerock, 80 meters wide, traveling at ten kilometers a second, crosses the sky. It could have destroyed a city, but skips off the upper atmosphere and returns to space.
- A fireball fragments over America's East Coast in 1992. Fragments drop to the Earth as meteorites, the name for any cosmic debris reaching the ground.
- Tunguska, Siberia, 1908. A fragment of a comet or asteroid, 60 meters across, explodes in the atmosphere like a nuclear bomb. More than 2000 square kilometers of uninhabited forest is flattened.

Asteroid Hazard

- More than 100,000 asteroids are in Earth-crossing orbits - at least 2000 are large enough to pose a threat.
- The NEAR craft that investigates the 40-kilometre asteroid Eros in 1999. An asteroid less than a quarter its size would threaten life on Earth.
- In July 1999, the Deep Space 1 probe intercepts asteroid 1992 KD, sending pictures back to Earth. Currently in a Mars-crossing orbit, gravitational perturbations could send it Earthwards.
- Rosetta, to be launched in 2003, will pass two asteroids and fly with comet Wirtanen for two years. A lander will touchdown on the surface of its nucleus.

Fighting Back

- For every asteroid and comet known to travel in near-Earth space, 20 more are yet to be discovered. Various ideas for fighting incoming threats have been proposed.
- A parabolic mirror could be towed into space. Concentrating sunlight onto a threatening asteroid, it could scorch it off course.
- Huge mylar sails could be attached to the asteroid, to catch the solar wind, and tug the rock into a new orbit.
- Another solution - a mass-driver is attached to an asteroid to shunt it away from Earth.
- The nuclear option is our only quick response we have to an imminent impact - attaching a warhead to a rocket and firing it at the asteroid. But launching rockets with a nuclear cargo carries inherent dangers.

Checking for Intruders

- Currently, 90% of our skies go unchecked. Suppose a comet, dislodged from the Oort Cloud by a gravitational disturbance, took us by surprise.
- At ten kilometers wide, the comet would increase speed as it approached the Sun. Upon striking Earth, it would be traveling at 20 kilometers per second.
- Accompanying the 100 million megaton blast and 200 kilometer wide crater, massive earthquakes and tsunami would sweep the globe.
- Cosmic winter would probably finish those of us who survived the initial destruction.

Background

The Tunguska Event

Siberia, June 30, 1908, 7:17 am local time. In the Podkamennaya Tunguska region, a fireball screeched across the sky. Eyewitnesses said the ball of fire touched the horizon and a "tongue of fire" rose into the air. An explosion was followed by tremors and massive bangs, heard over 800 kilometers away. Closer in, hot winds blew with hurricane ferocity.

The cause of this catastrophe was an asteroid or cometary fragment exploding in the atmosphere. The subsequent air-blast wave was recorded by meteorological barographs thousands of kilometers away in England. Seismograph stations detected a magnitude-five earthquake. In the days that followed, abnormally bright nights were recorded, outshining all but the most luminous stars, across Europe.

The turmoil of World War One and the Russian Revolution meant that an expedition to the remote, uninhabited site did not occur until 1927. Led by Leonid Alekseevich Kulik, a meteorite expert at the Mineralogical Museum in St. Petersburg, the team discovered a vast area of destruction, approximately 2,200 kilometers square. Within the central 15 kilometers, many forest trees stood stripped of branches. Farther out, trees were snapped, or were felled in a radial pattern up to distances of 40 kilometers from the end point of the fireball's trajectory. Thermal radiation caused the spontaneous combustion of large numbers of trees in this region. No fragments of an impacting body or impact crater were ever found. The theory is that the incoming fragment of a comet or asteroid was 50-100 meters in diameter, exploding in a terminal burst about eight to nine kilometers above the ground, with an energy equivalent to 15-20 megatons of TNT.

Near-Earth Asteroids.

Near-Earth asteroids (NEAs) are sub-divided into three categories, Apollo, Amor and Aten asteroids, depending on the precise characteristics of their orbits. Near-Earth asteroids all have perihelion distances less than 1.3 AU. Members of the Amor group cross the orbit of Mars - often called 'Mars crossers' - but do not quite reach Earth's orbit, and are occasionally referred to as "Earth-approaching asteroids".

Apollo and Aten asteroids do cross Earth's orbit. They are known as "Earth-crossing asteroids". The three groups are not entirely separate from one another. Planetary perturbations can shift an asteroid's orbit from one group to another. The NEAs are mainly small objects, ten kilometers or less in size. Compositionally, the NEAs span all common asteroid types. They originate from main-belt asteroids, through a mixture of collisional fragmentation and chaotic orbital dynamics.

The number of known NEAs is constantly increasing. The total number of NEAs with diameters over 100 meters is estimated at more than 100,000. Only a few hundred currently known. Most Earth-crossing asteroids will eventually leave the Solar System, due to planetary perturbations. Almost all the rest will collide with one of the terrestrial planets. One-third are calculated to collide with the Earth.

Asteroids and Comets in Close-Up

The Near-Earth Asteroid Rendezvous (NEAR) mission is the first spacecraft to orbit an asteroid and make comprehensive measurements of its composition and structure. Crucial questions about the nature and origin of near-Earth asteroids will be answered.

Launched on February 16, 1996, NEAR encountered the main belt asteroid 253 Mathilde on June 27 1997, and met the Earth-approaching asteroid Eros in 1999. Eros was spotted in 1898, the first Mars-crossing asteroid to be discovered. It is currently a member of the Amor group. In relation to other NEAs, Eros is a colossus. With dimensions of 36 x 15 x 13 kilometers, it is almost four times larger than the asteroid thought to have hastened the extinction of the dinosaurs 65 million years ago.

In 1931, Eros came within 0.15 AU (23 million km) of Earth, an astronomical close shave. The most recent close encounter was in 1975. The perihelion distance of Eros is currently 1.13 AU, its aphelion distance 1.78 AU. Eros has a rotation period of 5.27 hours. Instruments aboard NEAR are recording the size, shape, volume, mass gravity field and spin of Eros, plus its elemental and compositional make-up, geology, topography, mass distribution and magnetic field.

The Rosetta mission, to be launched in 2003 or 2004, will observe the short-period comet Wirtanen over a long period of time. Observations of its behavior in relation to its distance from the Sun will be carried out. The plotted route for Rosetta will be once past Mars and twice past Earth, negotiating two asteroids en route. Rosetta will rendezvous with comet Wirtanen in 2011, when it is at a distance of 5 AU from the Sun, remaining with the comet from then on. Two probes will be deployed on to the comet's nucleus in 2012, with the comet passing perihelion in August 2013. Instruments on the spacecraft will monitor surface processes on the nucleus and investigate the composition of the cometary dust, gas and ices, along with the plasma environment around the comet. Instruments on the probes will analyze the surface material of the icy nucleus.

Studying this primitive cometary matter may aid understanding of the most basic composition of the Sun and planetary system. The significance of the mission has been likened to that of inscriptions on the Rosetta Stone, from which ancient hieroglyphic writing was deciphered - hence the choice of name for the mission.

Links for Further Information

The Spacewatch page. Good site, with information on Near-Earth-asteroids, including a complete list of discoveries. Very good image section, including images of comets and asteroids with accompanying text.

<http://xlr8.lpl.arizona.edu/spacewatch/>

Catastrophism. An incredibly detailed page concerning the threat of impacts and how comets and asteroids have helped to shape the Solar System and planets. Includes extensive links and images.

<http://pibweb.it.nwu.edu/~pib/catastro.htm>

Comet Shoemaker-Levy 9 home page. Comprehensive site featuring the discovery of SL9, its impacts with Jupiter, plus a good gallery of images.

<http://manbow.ori.u-tokyo.ac.jp/tamaki-html/sl9/sl9.html>

Rosetta Home Page, including mission objectives, key facts, spacecraft information, and image gallery.

<http://sli.esa.int/rosetta>

The Near-Earth Object home page.

<http://cfa-www.harvard.edu/cfa/psNEO/TheNEOpage.html>

The Probability of Collision with Earth. No images, but informative text on previous Earth impacts, and the possibility of collisions in the future.

<http://bang.lanl.gov/solarsys/comet/appendc.htm>

Questions and Activities for the Curious:

1. Describe the location of the asteroid belt. Explain how some asteroids end up in Earth-crossing orbits.
2. Research the theory that the extinction of the dinosaurs was caused by a major cosmic impact 65 million years ago.
3. Show how the Moon may have been formed by a major impact of a Mars-sized object with Earth.
4. Is there evidence that the Earth has been hit by asteroids or comets in the past?
5. What is thought to have caused the flattening of pine trees over a huge area of Siberia in June 1908?
6. Assuming an asteroid was discovered on a collision course with Earth, what could be done to tackle the problem.
7. Explain why it is possible for a comet approaching us from the edge of the Solar System to be on a collision course with Earth and yet remain undetected until it is too late.
8. Predict what would happen if a ten-kilometer diameter asteroid or comet was to hit Earth.