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Impact Earth

GCSE key words

Asteroid
Comet
Risk

Astronomers say that, one day, a giant rock from space will collide with the Earth and cause mass devastation. This could lead to the extinction of many species, including humans. Is there anything we can do to prepare for such an impact?

On 18 March 2004, asteroid 2004 FH passed between the Earth and the Moon. At its closest, it was within 43 000 km of the Earth (that's just 3.4 Earth diameters). The asteroid was 30 m across, big enough to do serious damage if it reached the Earth's surface. However, that was unlikely, for two reasons:

- Its orbit did not bring it close enough for the Earth's gravity to pull it down.
- Friction with the atmosphere would have caused it to burn up before it reached the ground.

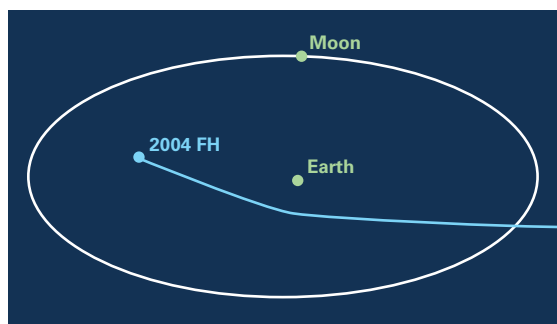
Small asteroids come as close as this every year or two. The unusual thing about the fly-past of 2004 FH was that astronomers saw it coming and could observe it as it went by (Figure 1).

Rocks from space

Astronomers keep an eye out for any object in space whose orbit may bring it within 50 million km of the Earth's orbit. Such space rocks are known as **near-Earth objects (NEOs)**. There are two types:

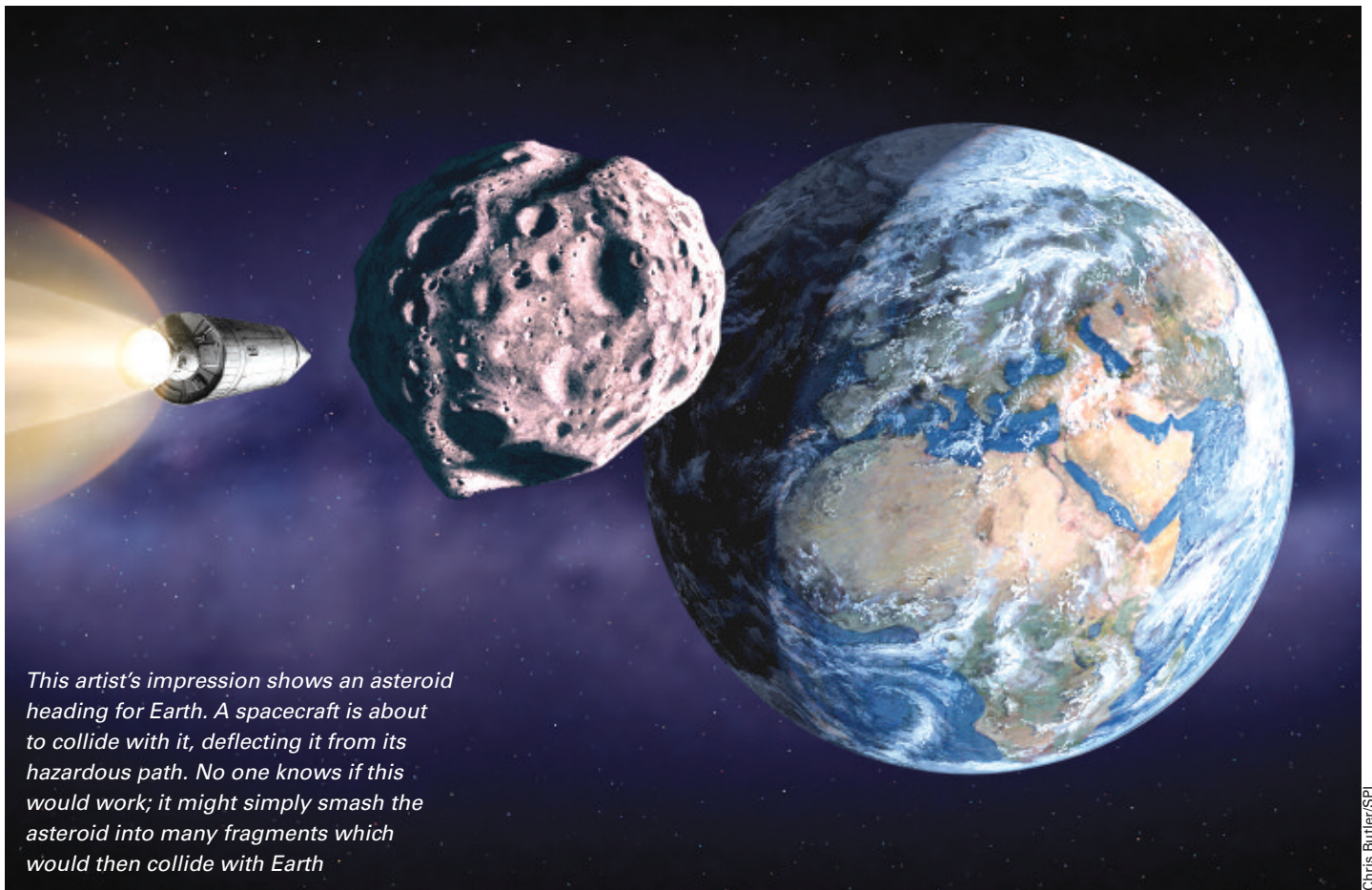
- **Asteroids:** rocky lumps, mostly in orbit between Mars and Jupiter.
- **Comets:** frozen balls of dust and ice which approach the Sun from orbits far out in the solar system.

The way in which the solar system formed explains why these two types of object exist. A swirling cloud of dust and gas collapsed under the pull of its own



The total mass of all the asteroids is only about 3% of the mass of the Moon. The two largest (Ceres and Vesta) account for half of the total mass.

Figure 1 Orbit of 2004 FH



This artist's impression shows an asteroid heading for Earth. A spacecraft is about to collide with it, deflecting it from its hazardous path. No one knows if this would work; it might simply smash the asteroid into many fragments which would then collide with Earth

Chris Butler/SPL

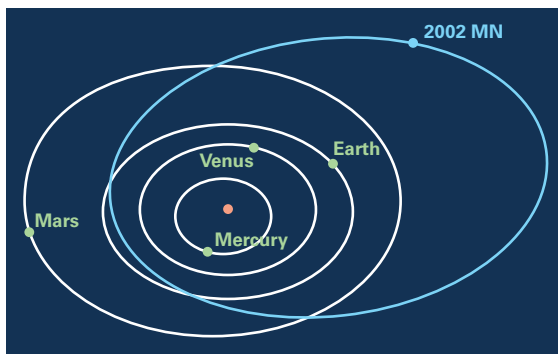
- Visit <http://neo.jpl.nasa.gov/neo> to download a multimedia presentation on NEOs.

gravity. The Sun (mainly hydrogen) formed at the centre. The planets formed from dust and gas circulating round the Sun. The closest planets (Mercury, Venus, Earth and Mars) are rocky, because their temperatures are too high for gases to condense. The outer 'gas giant' planets, particularly Jupiter and Saturn, are made of frozen gases.

Another rocky planet tried to form between Mars and Jupiter. However, the gravitational pull of massive Jupiter prevented it from becoming a planet, and so the asteroid belt was created. Comets formed further out in the icy depths of space.

Occasionally, asteroids jostle one another, and one may be pushed out of the belt so that it plunges further in towards the Sun. If its orbit crosses that of the Earth, it may become an NEO (Figure 2).

Figure 2 NEO orbit for 2002 MN



- You can download a movie showing orbits of known NEOs at http://szyzyg.arm.ac.uk/~spm/neo_map.html

It has happened before

The Earth has been hit by NEOs before (see Box 1). We know this because impact craters can be seen in a number of places. Among the most famous is Meteor Crater in Arizona. Over 1 km wide and hundreds of metres deep, it has been dated to 49 000 years ago. It is estimated that the cause of this crater was a lump of iron and nickel about 40 m across, moving at about 25 km/s. That's a lot of kinetic energy, equivalent to 20 million tonnes of TNT!

Such craters on Earth are rare. However, the Moon's surface is covered in craters. The difference is that here on Earth, craters are eroded by wind and water. In addition, the movement of tectonic plates has resurfaced the Earth over millions of years, hiding the evidence of ancient impacts. But the Earth's stronger gravity means that it must have been hit with a greater frequency than the Moon.

NEO scares

The effect of an NEO impact depends on its size (see Table 1). It is only within the last two decades that astronomers have established programmes to track NEOs. You may have heard about potential hazards in the media. The usual pattern is something like this:

- Astronomers announce that they have spotted an NEO whose track might bring it into collision with the Earth.

Box 1 Did a comet kill off the dinosaurs?

In 1980, Luis and Walter Alvarez published a paper suggesting that the extinction of the dinosaurs could be traced back to an asteroid impact 65 million years ago. Palaeontologists had established that dinosaurs and many other species became extinct at that time, but the cause was unknown. The father-and-son team examined rocks at the boundary between two geological zones, the Cretaceous and Tertiary. They found a thin layer, called the K/T boundary, containing two elements – iridium and osmium – which are rare on Earth but common in asteroids. They deduced that an asteroid about 10 km across had collided with the Earth; it evaporated, so that its material was spread around the Earth.

The impact must have produced a mass of dust which darkened the skies, causing freezing temperatures for several years, and this resulted in mass extinction. Fortunately for us, some mammal species survived.

Ten years after the Alvarez paper, a giant crater on Mexico's Yucatán peninsula was identified from observations by a space shuttle. Most scientists now accept this theory of dinosaur extinction, although some believe that other factors, including volcanic activity, may have been involved.

Table 1 The effect of NEO impacts

Diameter of NEO	Effect of impact
< 50 m	Disintegrates in atmosphere
< 500 m	Local damage around impact site
> 1 km	Worldwide effects
> 10 km	Mass extinctions

- After a few weeks, the NEO's orbit has been determined more accurately; astronomers announce that it is very unlikely to strike Earth.
- The media declare that this was a scare story put about by astronomers, perhaps to justify their research programmes.

Such media criticism is a bit unfair. Like all observations of moving objects, first measurements have a large degree of uncertainty. As an NEO moves across the sky, its track can be determined with greater precision. Should astronomers keep quiet when they first become aware of a possible impact?

The hazard associated with an NEO is represented by its position on the Torino scale (see Box 2).

Deflecting NEOs

Dr Alan Harris is a UK scientist based at the German Aerospace Centre in Berlin. He is chairman of a project called NEOMAP (NEO Mission Advisory

Box 2 The Torino scale

The Torino scale runs from 0 (minimal chance of impact) up to 10 (global catastrophe likely).

Figure 3 shows how the rating of an NEO depends on its energy and its probability of colliding with Earth. Kinetic energy is given in megatonnes of TNT equivalent (1 MT = 4×10^{15} J approximately).

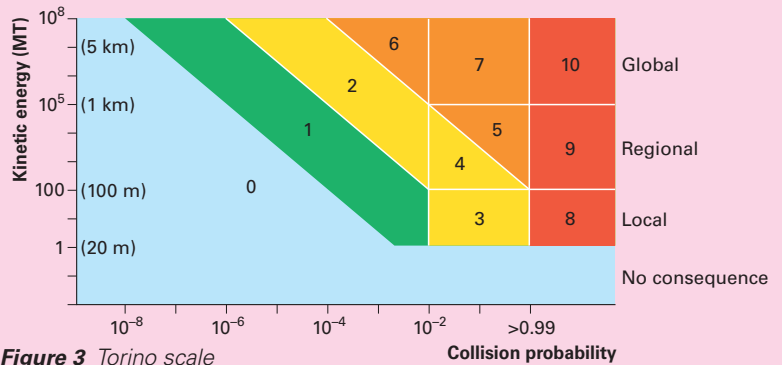


Figure 3 Torino scale

Box 3 Taking chances

You are more likely to die as a result of a near-Earth object impact than in an air crash – true or false? It's probably true. Air crashes are rare events, and cause only 1 in 30 000 deaths. (Road accidents cause about 1 in 100 deaths.) NEO impacts are even rarer, but the death toll could be vast, so scientists estimate that the chance of an individual dying is about 1 in 10 000.

A near-Earth object which strikes the Earth is more likely to land in the sea than on solid ground, simply because 70% of the Earth's surface is ocean.

Panel), which has been looking at what we might do if we detect an NEO heading our way. He describes the problem we face:

If you think about the chain of events between detecting a hazardous object and doing something about it, there is one area in which we have no experience at all and that is in directly interacting with an asteroid, trying to alter its orbit.

Various methods of deflecting an asteroid have been proposed, but we do not know enough about asteroids to decide what would be best. The Don Quijote mission has been proposed to the European Space Agency (ESA) to rendezvous with an asteroid and find out more. Dr Harris thinks this is important:

Don Quijote has the potential to teach us a great deal, not only about the internal structure of an NEO, but also about how to mechanically interact with it. Don Quijote could provide a vital missing link in the chain from threat identification to threat mitigation.

Don Quijote will consist of two spacecraft. The first will make preliminary observations of the target asteroid; the second will impact with it, so that the first can measure the effect on the asteroid's orbit. ESA will make a final decision on the target asteroid in 2007.

David Sang writes textbooks and is an editor of CATALYST.

- Spaceguard UK is the British arm of a worldwide network of astronomers concerned with the hazards posed by NEOs. Go to www.spaceguarduk.com/sguk.htm to find out more.