This was the talk I gave to the Astronomical Society in April 2007.

One Sunday morning about 2 years ago, I was driving south west towards where I live when I saw, from the crest of one of the hills on the road, what appeared to be a firework. Now I thought: What sort of person lets off a big firework like that, on an almost horizontal trajectory, on a Sunday morning? As I watched, it split into two blazing heads, faded and disappeared. Later I discovered that what I had seen wasn't a firework at all. It was the fireball caused by a large meteor passing through the Earth's atmosphere.

Just a few months later what sounded like a sonic boom was heard over the north of Cornwall. It wasn't Concorde - she was out of service by then - and no other aircraft has been found to blame. Again it could have been a large meteor entering the Earth's atmosphere.

So what is a meteorite?

Is it just a meteor with a difference? Yes, and no.

We all know what meteors are - they're what we see when we go up to the Quantocks for our barbeque around the 12th of August each year. Well, more accurately they're what we hope to see if it's not cloudy, or raining, which of course it quite often is in August on the Quantocks. This is Britain, after all. These images are not the Perseids. This is the famous woodcut of the 1833 Leonid shower when it rained meteors, and a time lapse image of the same shower in 1966.

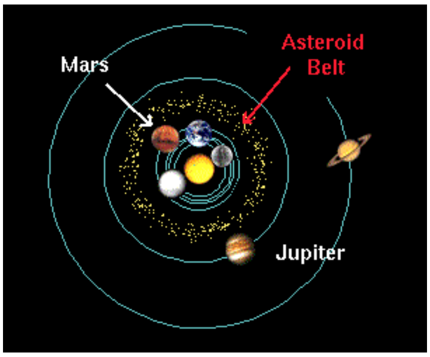
The meteors we see then are comet dust. A comet goes round the Sun and as it does so the Sun heats it. Volatile materials in the comet's nucleus turn from a solid to a gas and are ejected to form what we see as tails. But of course it's not just gas. A lot of dust and other solid material

goes too. This dust tail is the curving one we normally associate with bright, visual comets. It trails away from the comet and gets left behind. If the Earth then passes through that trail of debris, particles will collide with the Earth's atmosphere and are heated by friction. Most of them are very small and burn up. Some larger ones can take a while to burn and these leave trails which we see as meteors. Some of the exceptionally long and bright ones are referred to as fireballs.

Meteors from comets rarely hit the Earth as meteorites. Comets are rather soft and crumbly- remember the dirty snowball analogy. That's just what comets are - and the meteors we see during one of the regular meteor shower events are rarely large enough or hard enough to survive passage through the atmosphere, so, spectacular though the Orionids and Taurids were in 2005, there probably aren't any of them lying around for anyone to find.

But any bit of debris floating around in space can penetrate the atmosphere and be seen as a meteor, and there is a lot of debris out there. Some of it comes from nice, soft, squidgy comets, but some of it is made of sterner stuff. There are bits out there which have broken off asteroids, the Moon and even other planets. It needn't have broken off any time recently. Bits could be floating around for millions of years before finding something to hit.

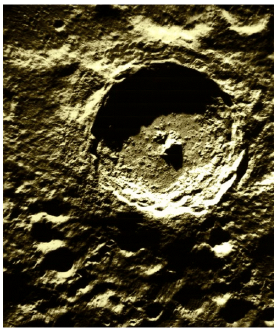
Back around the time of its formation, our solar system was a far more deadly place than it is now. The Asteroid Belt, lying between Mars and Jupiter, may well be a planet that was either smashed before it had chance to form properly, or a planet that was prevented from forming by Jupiter's massive gravitational influence. The latter theory is the more likely. Jupiter's influence would have stirred up the area and kept everything moving at high speed, so instead of coalescing into a planet the pieces stayed small and smashed into each other, destroying rather than creating, and sometimes being flung out of their orbits to collide with other bodies in the embryonic solar system.



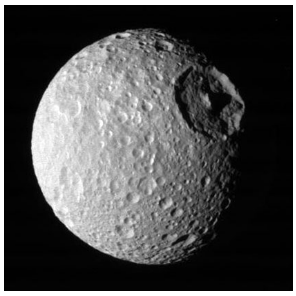
This is the asteroid Gaspra, and as you can see it's peppered by small impact craters. Gaspra in common with a lot of asteroids is irregular in shape, not spherical like the planets and their moons, and this and the lack of any large craters leads to the conclusion that Gaspra was formed comparatively recently by the breakup, due to a collision, of a much larger body, perhaps ten times the size of Gaspra.

Our Moon, it is thought, was formed much earlier, when the still semi molten Earth was struck hard enough, probably by an object the size of Mars, to knock chunks off which then coalesced to form a completely separate body. The Earth, the Moon, and other planets and their moons have all been bombarded by debris in their distant past.

We see the evidence now in craters on our Moon, the moons of other planets and also the asteroids we have been able to photograph in recent years. Saturn's moon Mimas, on the right below, shows clearly that the impact that created the Herschel Crater was a catastrophic event.



Fortunately for us, that bombardment has slowed dramatically. There are now empty gaps in the Asteroid Belt, known as Kirkwood gaps after their discoverer Daniel Kirkwood - areas where Jupiter's influence is greatest and most of the asteroids have just been cleared out.
But there are still things out there.



Most meteorites are tiny - comparatively speaking - anywhere between the size of a small pebble and a large stone. There are, however, plenty larger than that - the largest ever found has weighed in at a wopping 60 tons and was 3 metres square and a metre high. It fell in Namibia, which fortunately is not the most populated area. It's now a national monument and goes by the name of Hoba. But you wouldn't want to be hit by even a small one. Its speed, even after deceleration, has been likened to something dropped from a tall building.

It's estimated that between 30 and 80 thousand meteorites larger than 20 grams - that's about 3/4 of an ounce in weight - fall to the Earth every year. In spite of that, there is no record of anyone ever being killed by a meteorite strike, however that doesn't mean that no-one ever has been back in the mists of history. A dog is reputed to have been killed by a meteorite in Egypt in 1911. A very privileged dog - the meteorite came from Mars and there haven't been many of those found. A boy was hit in Uganda in 1992, but he wasn't seriously hurt.

There has been plenty of recorded damage to property. This meteorite ended up in the corner of someone's study after coming through the roof. The bits are what remained of the printer. However, the populated areas of our planet are smaller than we think. Places like Britain, Europe and parts of North America may be densely populated, but take a good look at a world atlas and the unpopulated areas and oceans are vast. That's where the majority of meteorites will fall.

Meteorites are termed falls or finds depending on how they are found. Very few are witnessed falling to earth - the fireball in the touched up photograph at the beginning would have been far too high up in the atmosphere for me to have followed it to the fall - so if one does and ends up through your television set or car windscreen, you may not think it at the time but you're actually very privileged. These are falls, obviously, but the vast majority are finds.

Thousands of small meteorites have been found on our planet, but probably a fairly small percentage of what is actually here. They're not that easy to find. Most have been found in deserts and particularly in Antarctica, where a meteorite might be buried by snow and ice and lie for many thousands of years before movement in the ice turns it up to the surface. Deserts and icecaps are the areas where they are relatively easy to spot. A large number fall in the oceans, but in general, unless the meteorite is actually seen to fall, one stone looks much like another. A newly fallen meteorite may still have the burnt crust from its fall through the

atmosphere in place, but it is a thin crust and once it's eroded away, only chemical analysis can categorically distinguish between a meteorite and a lump of stone. You'd be hard pushed to spot one in your garden. Even in a desert you'd think one stone would look much like another. To find one you really need the knowledge to recognise a particular stone as being different, as not fitting with what should be there. If you ever did find one in your garden, that's how you'd do it.

Meteorites fall into three main types - stony(shown on the left), iron (on the right) and iron-stony. Each of these types is further divided by chemical composition. The type and composition of a meteorite tells us where it came from. Given that asteroids are planets that were either destroyed early on in their lives or never formed, it is no surprise that the Asteroid Belt in our own solar system is between the orbits of Mars and Jupiter. Jupiter with its massive gravitational influence is quite capable of destroying anything too close to it, of capturing comets into orbit around itself and perturbing the orbits of other objects. What we now know as the Near-Earth Asteroids, the ones that pose the most danger to us, were almost certainly perturbed out of their orbits by Jupiter into a new path that brings them close to us.

Just as planets differ in their compositions, so do asteroids. Spectral analysis can infer the composition of the known asteroids, of which there are many thousands. Most of the main belt asteroids are stony and fall into type S, or silicate, or type C - carbonaceous or carbon rich. Of these, the bulk are type C. The basic composition of asteroids in the main belt depends largely on their distance from the Sun. There is a divide in the solar system between the rocky, Earth type inner planets and outer gas giants. That divide cuts through the centre of the asteroid belt, so it is not really a surprise that the asteroids closer to the Sun are silicate type S - rocky, dry and stripped of volatiles and water. Those further out are predominantly type C - rich in carbon and water.

There are other types, mostly found outside the main belt, but the other significant main belt asteroid is the type M, or metallic. The Sun's influence can't explain these, and they could be remnants of the metallic cores of their parent bodies which have been smashed by collisions over billions of years. Our friend Jupiter would have allowed only a small number of the original asteroids to grow large enough to accumulate enough heat to produce iron cores. The detailed study of surface composition and orbits has led to many of the known asteroids being grouped together into families, giving further credence to the theory that they are the remnants of a number of relatively small bodies rather than one large one.

The vast majority of meteorites found on Earth are stony and probably from type S asteroids, which is reasonable given that these are found in the inner reaches of the asteroid belt and are therefore nearer to us. Having said that, the majority found in places like here in the UK are metallic, simply because these are the ones which will stand out as being different to all the other lumps of rock and stone.

A few meteorites are pieces of the Moon, and a smaller number still originated from Mars, including the controversial ALH84001 pictured here, which may or may not contain evidence of microbial life. Whatever the outcome of that, this particular meteorite is interesting for its age. Most Martian meteorites were born of volcanic activity and are comparatively young. ALH84001 is a piece of the original Mars, about four and a half billion years old. It parted company with the planet about 18 million years ago, and eventually fell to Earth a mere 13 thousand years ago, where it lay buried in Antarctica until it was found in 1984. How do we know it came from Mars? The impact that removed the meteorite from the planet melted bits of the rock into pockets of glass, and within that glass are trapped gasses with the same composition as Mars' atmosphere.
Few asteroids would ever have been big enough for volcanic activity, so like ALH84001, meteorites from asteroids are as old as the solar system. They are the oldest rocks we can study, and therefore provide us with a means to look back in time.

But what of the larger, more destructive, meteorites?
The Earth's relatively dense atmosphere has a considerable effect on anything hitting it. Given a sufficiently shallow angle of attack, a would be meteor can glance off. Many more are small enough to burn up completely before they ever reach the ground. Some large ones just can't take it and explode like a nuclear bomb, but high enough that the effects are not felt on the ground. This could have been the source of the sonic boom I mentioned at the beginning. A stony asteroid less than 50 metres across won't make it through. A comet would have to be ten times that size, but a metallic fragment could be considerably smaller. Even then, it's likely to break up before impact and many of the small meteorites found on Earth almost certainly come from the same parent body.
If a large meteor does make it through intact, what are the consequences?

First, there's the airburst. The meteorite that exploded over the Tunguska River area of Siberia

in 1908 was too big to explode or break up in the upper atmosphere but not quite man enough to make it all the way down intact. It exploded 5 to 10 kilometres up with the force of the nuclear bomb that destroyed Hiroshima at the end of the Second World War. It flattened trees for thirty miles in all directions. Fortunately, there was nothing but trees to flatten, but people about forty miles away had their windows broken, their wooden houses were damaged and they themselves were knocked about by the strong, immensely hot wind akin to a nuclear blast.
There are theories that the Tunguska explosion wasn't a meteor at all - after all there is no crater and no fragments have ever been found - but there were witnesses who saw something like an enormous fireball at about the right time. Stony asteroid or comet - there is no way of knowing.

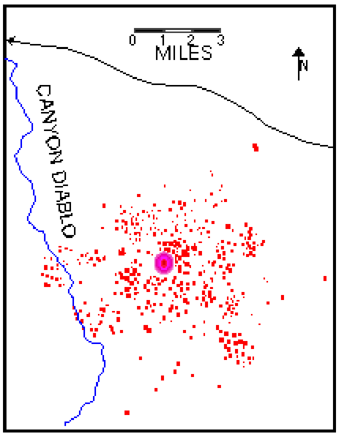
Interestingly, because of its remoteness and the later intervention of the Russian Revolution, the first expedition to study the area wasn't until 1927, nineteen years later, and the devastation to the forest remained fresh, as you can see from these images. It was only luck that brought that meteorite over an unpopulated area. If it had chosen London, or any other city, the toll in human life and property would have been very different.

And if it had not exploded in the air? If it had been big enough to make it all the way down intact?
Only about 160 impact sites remain on the Earth in any recognizable form. Unlike the Moon, the surface of the Earth is moving and evolving, eroding and depositing sediments that over a long period of time remove traces of meteorite craters. The largest found to date, the Vredefort Dome in South Africa, is 300 kilometres across and about two billion years old. Only a look at the Earth from space can reveal any trace of these huge and ancient scars.

The Manicouagan crater in Canada, on the left here, is about 100 km in diameter and about 214 million years old. As you can see, it's well eroded and would not be at all obvious for what it is from the ground.

In contrast the Wolf Creek crater (right) in Australia is still, at 300 thousand years old, a classic crater.

Arizona's Meteor Crater, Canyon Diablo Crater or Barringer Crater, is a mere 40 to 50 thousand years old. It is relatively small at about two thirds of a mile in diameter and 600 feet deep, and is thought to be the result of an iron meteorite around 80 feet in diameter and weighing somewhere in the region of 63000 tons, striking at a speed of around 9 miles per second - that's over 30,000 mph. Obviously it is difficult to estimate the size, weight, and sometimes even composition of the original meteorite responsible for these craters, and equally difficult to date exactly when it fell, so in every account I've read of the Barringer Crater the figures have been different. One thing is certain - of the original huge lump no trace has even been found. Part of it at least broke up on impact. The largest piece ever found weighed 639 kg, with a huge number of smaller ones of which the majority have been less than 10 kg, but the total known material found still weighs far short of the original 63000 tons, so where's the rest of it? Two possible answers - it either vaporised on impact, or it's still down there, buried deep where no-one has yet discovered it. One of the crater's several names is that of Daniel Barringer, who in 1903 bought mining rights to it and drilled in vain for a deep buried mass of iron. The Barringer family still own it.



This map shows the spread of meteorites found around the Barringer Crater, and it's well over three miles in every direction.

I own one of the Meteor Crater, Barringer Crater or Canyon Diablo meteorites.. One of the first things you notice about it is how dense it is - it feels heavy for its size. This is a characteristic of meteorites whether they be stony or metallic and is another possible, although far from infallible, way to tell a meteorite from a stone. It is a very small piece of an extremely large iron mass which was almost certainly an asteroid, and because it is metallic, could have been part of a large asteroid that was well on its way to becoming a planet. It is, therefore, as old as the solar system. It's highly possible that its original parent body was broken up in one or more collisions between similar bodies, the pieces orbiting in the Asteroid Belt quite happily for millions of years before one of those pieces got just that little bit too close to Jupiter and was thrown into a new orbit, an orbit that crossed that of the Earth. Who knows how long it spent there before crashing to Earth with enough force to shatter and send fragments for miles around. And the rest of it - well it was either completely vapourised or buried so deep it can't be found. My little meteorite, then, all less than 2 ounces of it, lay in the Arizona desert for tens of thousands of years before being collected in 1897.

What if something of that size struck today? Or something even bigger. What could we expect? Let's look at the consequences of a rocky meteorite 10 km across - just a little bigger than the 8 km asteroid Annefrank shown here - or something like a large comet nucleus, striking somewhere like the Gulf of Mexico.

The explosion would make the biggest nuclear blast that mankind can currently devise look pathetic. The resulting crater would be between 180 and 280 km, that's about 110 to 175 miles, across. Billions of tons of rock and debris would be blasted as a fireball into the atmosphere and even into space, possibly to fall as meteorites somewhere else.
Tsunamis a mile or more high would devastate coastal areas well up into the eastern United States.
The dust and debris remaining in the atmosphere would spread quickly around the globe, cutting out light from the Sun. The result - nuclear winter. Dark and cold, lasting for months until the dust settled back to earth. The freezing temperatures, however, could remain for decades. Any vegetation surviving months without sunlight would freeze. Life dependant on that vegetation would die, starting with the grazers and working up through the food chain.
Hot material from the initial explosion would rain back down and cause wildfires across a huge area, again destroying vegetation and life. Acid rain would devastate the oceans.
Shock waves from the initial impact would probably trigger volcanoes as far away as India.
The overall result - mass extinction on a grand scale.
This scenario has already happened - 65 million years ago a 10 km meteorite struck on the Yucatan Peninsular in the gulf of Mexico. All together half of all plant and animal species on Earth died out, amongst them the dinosaurs which had ruled the planet for 160 million years, and

we're probably overdue another Big One.

However, just as an extraterrestrial body could yet wipe out the human race, its predecessors could be responsible for life being here on Earth in the first place. Life cannot exist without water, and there's a lot of water on our planet. Earth could not have formed with its oceans in place - it would have been far too hot and any surface water would have simply vaporised. There are two possibilities. Either the water was here but beneath the surface - as there is thought to be water below the surface of Mars - and released by volcanoes, or water was carried here from the cold outer reaches of the solar system by comets and asteroids. There is also the possibility of meteorite impacts triggering volcanoes, so that water arrived from both sources. Whatever the truth, the Earth was originally formed by the impacting and coalescing of many small bodies into the one rock we know and love today, so whether it was earlier in the Earth's history or slightly later, impacts resulted in water being here and laid the foundations for life.

So if you walk outside and find a meteorite has landed on your car, just bear in mind that without it and many others like it, you wouldn't be here and neither would your car, so look kindly on it. And as for the next Doomsday Asteroid....... Well, we don't have the technology to destroy it before it destroys us...... yet.

There will be a draft UN treaty this year to determine the action to be taken on finding a large asteroid on collision course with the Earth. This document will set out global policy. It is the brainchild of the Association of Space Explorers, a professional body for astronauts and cosmonauts.

Earth can expect to be struck by something the size of the Canyon Diablo or Tunguska meteorite about once in a thousand years. We've had the Tunguska event almost exactly one hundred years ago. That doesn't mean we're safe for 900 years until the next one. NASA is monitoring 127 NEOs or Near Earth Objects which have the potential of hitting the Earth, so there is no question of 'if' our planet suffers another large meteor strike - it is 'when'.