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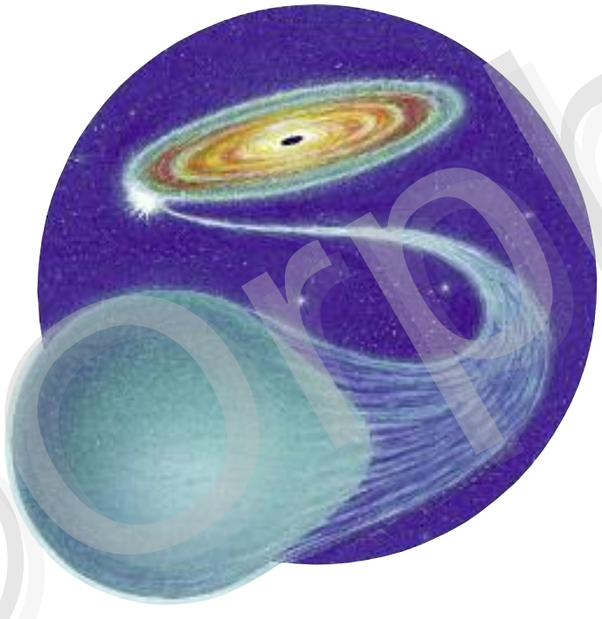
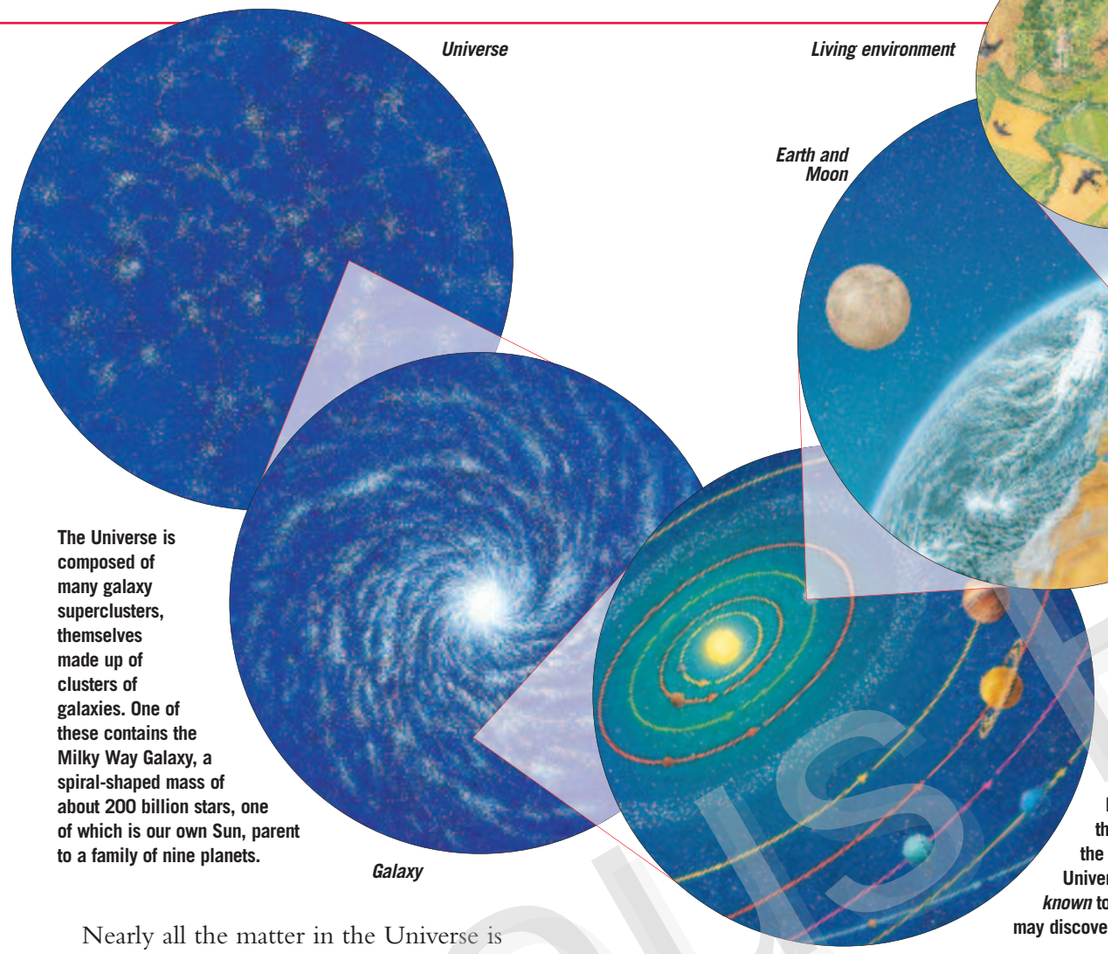


Contents

UNIVERSE

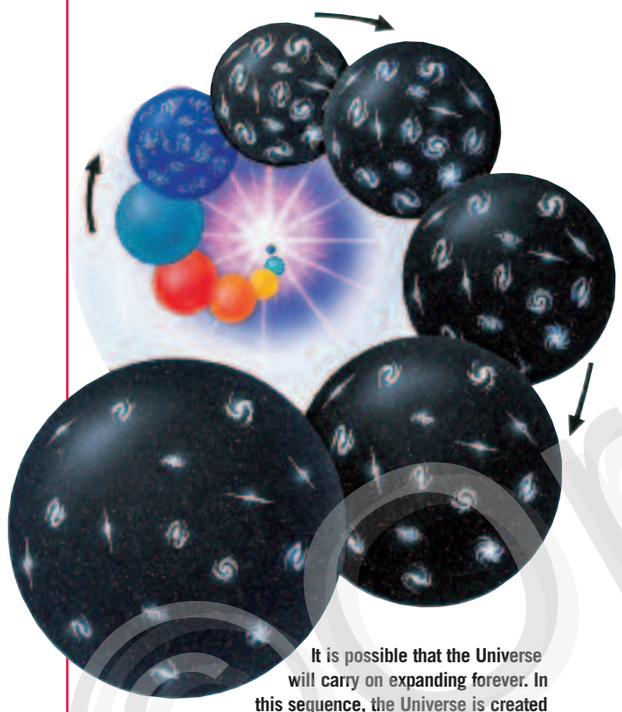
EVERYTHING that we can think of—and everything else that exists—all belong to the Universe. From grains of sand to tall buildings, from particles of dust to giant stars and planets, from microscopic bacteria to people—all are part of the Universe. It even includes empty space.

The Universe is unimaginably vast: billions upon billions of kilometres wide. Distances in the Universe are so great that we have to use a special measure to record them. This is a light year, or the distance that light, which moves at a speed of about 300,000 kilometres per second, travels in one year: about 9,460,528,405,000 kilometres. The nearest star to Earth (after the Sun), Proxima Centauri, is 4.2 light years away. The most distant objects we know in the Universe are more than 13 billion light years away from Earth.



The Universe is composed of many galaxy superclusters, themselves made up of clusters of galaxies. One of these contains the Milky Way Galaxy, a spiral-shaped mass of about 200 billion stars, one of which is our own Sun, parent to a family of nine planets.

The third planet from the Sun is Earth, orbited by the Moon. Earth is the only world in the Universe where life is *known* to exist, but we may discover others one day.



It is possible that the Universe will carry on expanding forever. In this sequence, the Universe is created in an immense explosion called the Big Bang. It expands rapidly, with all the galaxies moving away from one another as the Universe inflates like a balloon.

Nearly all the matter in the Universe is contained in **galaxies,** enormous masses of stars, gas and dust *(see page 6)*. There may be about about 100 billion galaxies, each containing hundreds of billions of stars. Galaxies are grouped into giant "clouds" of galaxies, called superclusters. These are spread round the Universe like a net, made up of strings and knots. In between there are gigantic empty spaces.

The superclusters are, themselves, made up of smaller clusters of galaxies. One of these, a cluster of 30 galaxies or so, is called the Local Group. It contains the Milky Way Galaxy, the vast spiral of stars to which our own local star, the Sun, belongs.

Astronomers have discovered that all galaxies are rushing away from one another. This means that, a long time ago, they were once all close together. So the Universe had a definite beginning—and may have an end.

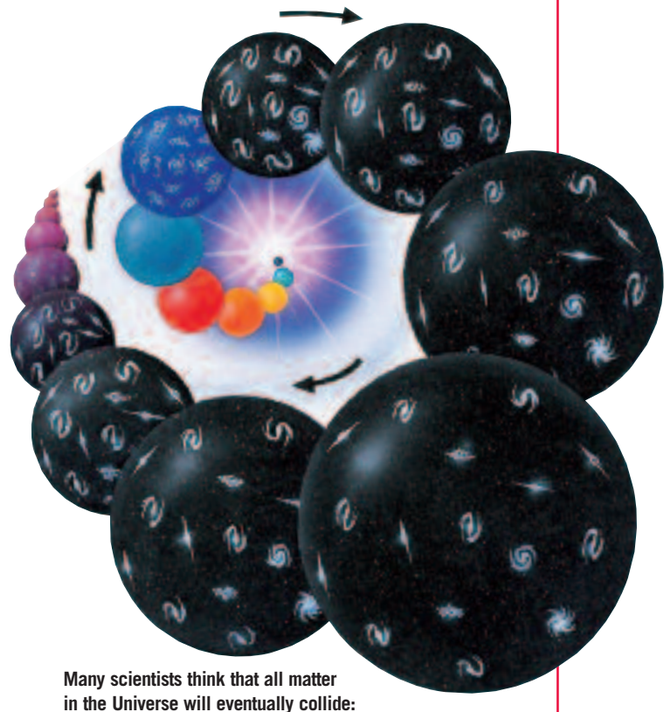
BIG BANG

Many astronomers believe that the Universe began life in a single momentous event. This was an incredibly hot, dense explosion called the Big Bang, which took place about 15 billion years ago. During this explosion, all matter, energy, space—and time itself—were created.

In the first few millionths of a second, the particles that make up atoms, the building blocks of all matter, were formed. It took about 100,000 years for the first atoms, those of the gases hydrogen and helium, to come together. By this time, the searing heat of the Big Bang had cooled, space had expanded and the gases began to spread out. Gradually, however, gravity drew the gases together, leaving vast regions of empty space in between.

About a billion years after the Big Bang, the clouds of gas started to form into galaxies. Matter inside the galaxies went on clumping together until stars were created *(see page 7)*. Our own Sun was born in this way about 5 billion years ago. Its family of planets, including our Earth, was formed from the debris spinning round the infant Sun *(see page 17)*. With billions and billions of stars and planets forming in the same way across the Universe, it seems almost certain that life will have also evolved elsewhere. Will we on Earth one day make contact with these alien life-forms?

The expansion of the Universe is slowing down. Some astronomers think that gravity may eventually bring the expansion to a halt, then collapse all matter once more to a single point in a "Big Crunch". Others believe that there is not enough material in the Universe to do this and that the Universe will carry on expanding forever.



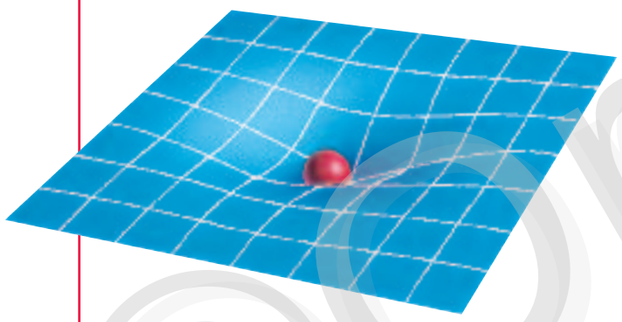
Many scientists think that all matter in the Universe will eventually collide: the "Big Crunch". Vast amounts of invisible "dark matter" in the Universe may exert sufficient gravity to halt its expansion and cause the galaxies to compress together.

Black Holes

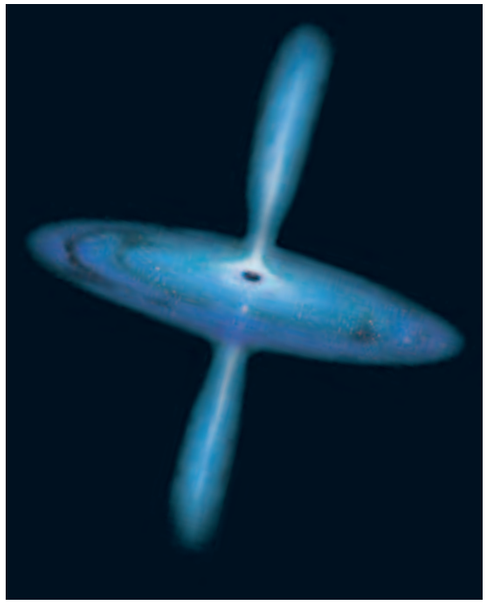
BLACK HOLES are the strangest objects in the Universe. No-one has ever seen one, but most astronomers are convinced that they exist. They are tiny regions of space surrounded by a force of gravity so strong that nothing, not even light, can escape from them.

All bodies in space exert a force of gravity, the force which attracts other things towards them. The greater an object, the stronger its gravitational pull, and the harder it is to escape from it. A rocket launched from Earth must go faster than 40,000 kilometres per hour (its "escape velocity") to escape Earth's gravitational pull. The Sun is many thousands of times more massive than Earth, so a rocket would have to travel much faster: more than 2 million kilometres per hour. If there was an object much bigger or denser than the Sun, an escape velocity equal to that of the speed of light may be needed to escape from it.

Where might an object of such high density be found? Stars more than 10 times as heavy as the Sun burn up their fuel in a much shorter time—a few million years, compared to the Sun's 10 billion years. They swell into massive supergiants before blasting apart in supernovas *(see page 7)*. A supernova's core compresses in seconds to a tiny, super-dense body called a neutron star.



Imagine a star in space as ball on a rubber sheet. A massive object like a star will "bend" space and anything close to it will fall in towards it. If the ball were so heavy that the sheet stretched into a long, deep tube, the result would be a black hole.



Billions of light years away, a huge, disc of gas and dust swirls around a giant black hole at the core of a quasar. The incredible energy blasts two jets of particles—the component parts of atoms—out into space.

If it weighs more than the three Suns, it squeezes further. An escape velocity of the speed of light would be needed to travel away from it. Any light rays would be pulled back in, so the object is invisible: a black hole.

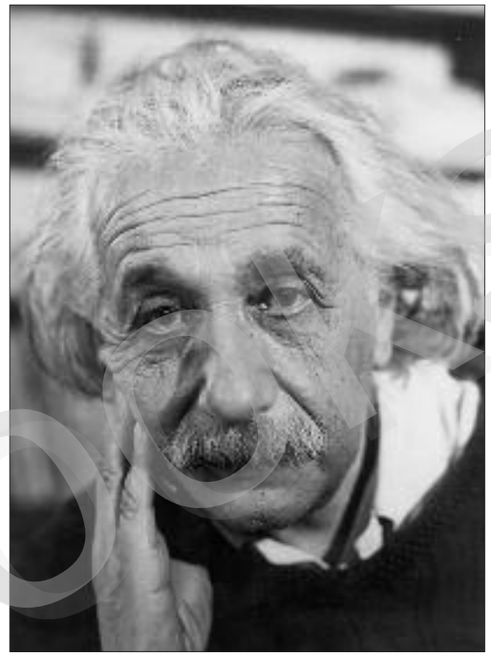
Einstein's General Theory

The great German physicist Albert Einstein (1879-1955) found another way to explain how space, light and matter would behave close to a black hole. In his General Theory of Relativity of 1915, Einstein proposed that the gravitational pull of an object would result in the "curving" of space, in the same way that a person can curve a trampoline. A massive object creates a large "dent" in space into which light and matter would fall. The denser the object, the greater the dent. So the Sun would make only a shallow dent, whereas a neutron star would create a very deep dent. A black hole, the densest object of all, creates a dent so deep that nothing can escape from it.

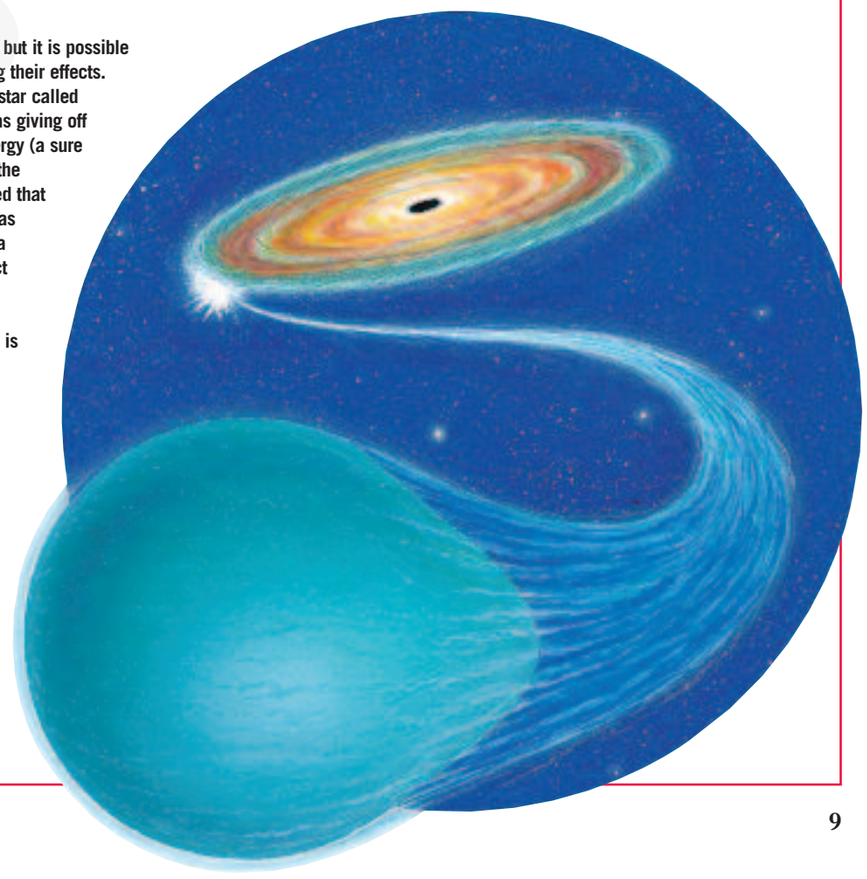
Quasars

Incredibly powerful, massive black holes may, astronomers think, be found lurking at the centres of galaxies. There could even be one at the centre of our own Milky Way Galaxy. Astronomers have detected a ring of fast-moving, hot gas swirling around the centre. The ring of gas is probably in the grip of a powerful gravitational pull—most likely, astronomers suspect, to be the work of a black hole.

The activity at the centre of our Galaxy is as nothing compared to that of quasars. These objects look like stars, but they lie at incredible distances from us: the farthest quasars are 13 billion light years away. To be visible at that distance means they must be giving off immense amounts of energy. Quasars are the centres of extremely violent galaxies containing supermassive black holes, weighing up to 100 billion Suns. The brilliant light comes from the disc of hot gas and dust spiralling into the black hole.



To Albert Einstein, gravity was a property of space and not a force between objects.



Black holes are invisible, but it is possible to detect them by studying their effects. Astronomers observing a star called Cygnus X-1 saw that it was giving off enormous amounts of energy (a sure sign of violent activity in the Universe). They discovered that this huge, hot blue star was being dragged around in a circle by an unseen object with a huge gravitational pull. That unseen object, astronomers now believe, is a black hole, which is tearing gas from the star. The gas forms a whirling disc before plummeting into the black hole. As it falls, it travels faster and faster until it moves almost at the speed of light itself. Close to the hole, the gas becomes so hot it emits massive amounts of energy.