Most scientists think that the Universe began with a huge explosion called the Big Bang. A ball of matter smaller than an atom but at an incredibly high density and temperature exploded, producing a fireball of matter and space.

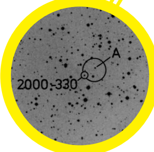
It is thought that the Big Bang happened around 14 billion (thousand million) years ago. If you imagine that time reduced to just one year, a human lifetime would amount to less than one fifth of a second! Ever since the Big Bang, the matter that was created has been moving apart at great speeds, a fact discovered by the American astronomer Edwin Hubble in the 1920s.

When he looked at the light emitted by distant galaxies for the spectral lines characteristic of particular chemical elements, Hubble found that each line had moved towards the red end of the spectrum, where the light has longer wavelengths. This implied that the light waves had been stretched during their journey. Not only that, but the further away the galaxy, the greater the movement of the lines – or 'red shift', as the phenomenon is called. It was clear to Hubble that this effect could only happen if the galaxies were moving away from us at great speed.

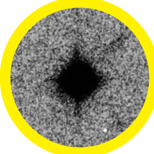
The General Relativity Theory of the great physicist Albert Einstein suggests that it is not the galaxies themselves that are moving but the space in between them – the space–time continuum – that is expanding. Hard as it may be to imagine, the galaxies are being forced apart rather as currants in a cake mixture are moved apart as it rises. This gives us a way of understanding what happened at the beginning of the Universe. It is not that all matter started squashed together at one point in space and then moved outwards to fill up the rest of space. Instead, all matter was created squashed up because all of space was squashed up – there was no other space outside. At the moment of the Big Bang, time began and space started to expand. As it did so, it carried all matter with it.

what was the BIG Bang?

Quasar PKS 2000-330
In 1982, the most distant known object in the Universe



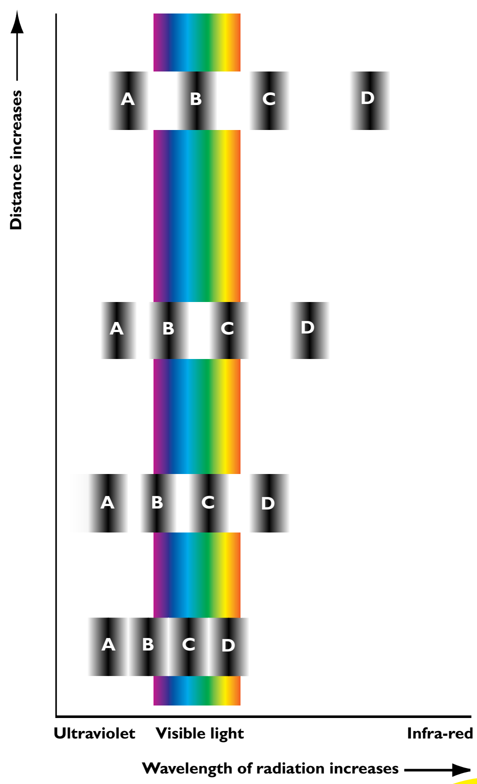
Quasar 3C273
Three billion light years away



Pleiades Cluster
400 light years away

The Sun
Eight light minutes away

Redshift



Edwin Hubble
1889–1953

The spectrum of radiation from distant galaxies shows peaks at wavelengths which are characteristic of various elements, especially hydrogen. If a galaxy is moving away from us, these characteristic peaks occur at longer wavelengths – in other words they are shifted towards the red end of the spectrum. This is the 'red shift' – an example of the Doppler Effect. The faster the galaxy is moving, the greater the red shift. In the diagram, A, B, C and D represent four peaks seen in the spectrum of stars and galaxies.

Albert Einstein
1879–1955

The General Relativity Theory suggests that it is not the galaxies themselves that are moving but the space in between them – the space–time continuum – that is expanding

more

Further Information

If you would like to know more about the Big Bang theory and cosmology, the following resources may help.

World Wide Web sites

BBC Science
www.bbc.co.uk/science/space/origins/bigbang/index.html

Cosmology links
http://www.damtp.cam.ac.uk/cosmos/Public/index.html

DAMTP
www.damtp.cam.ac.uk/user/gr/public/bb_home.html

MAP
map.gsfc.nasa.gov/m_uni.html

Books

Russell Stannard
Our Universe – A Guide to What's Out There
Kingfisher 1996

Stuart Clark
The Encyclopedia of Stars and Atoms
Andromeda Oxford 1994

Robert Snedden
Science Horizons – Space
Belitha Press 1995

PPARC also publishes information on a variety of topics related to physics and astronomy, to help increase public awareness of the UK's achievements in science and technology. Find out more by visiting the PPARC World Wide Web site: **www.pparc.ac.uk**

Particle Physics and Astronomy Research Council

The Particle Physics and Astronomy Research Council (PPARC) is the UK Government-funded body that exists to support research in basic science:

- **Particle Physics**
- **Astronomy**
- **Space Science**

This support is provided by funding UK researchers and by ensuring that they have access to world-class facilities in the UK and overseas. The Council pays the UK's subscription to the science programmes of the European Laboratory for Particle Physics (CERN) and the European Space Agency (ESA).

PPARC recognises the importance of its science in assisting wealth creation; in post-graduate training; and in motivating young people towards an interest and career in science generally.

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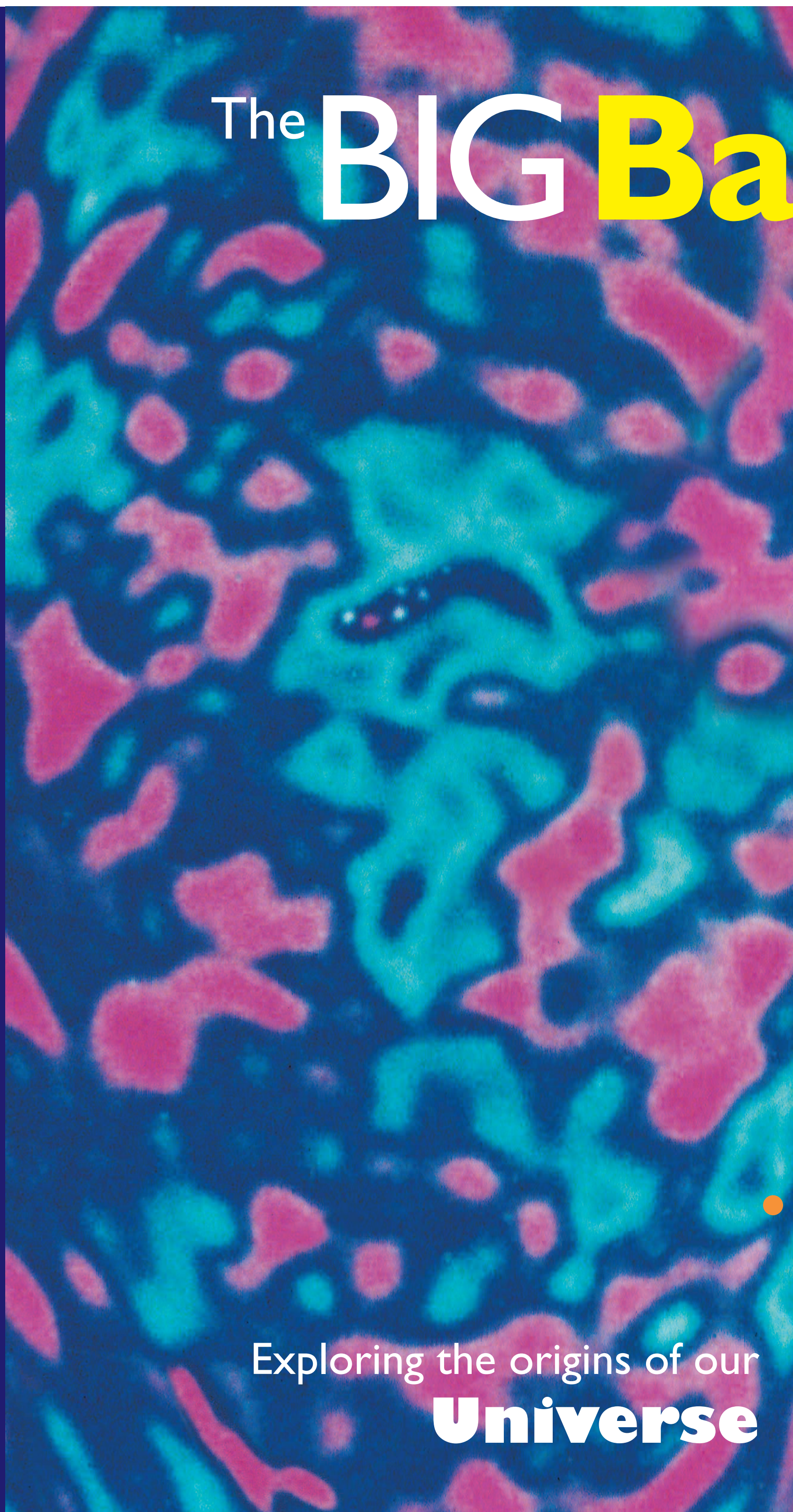
The BIG Bang



Exploring the origins of our **Universe**

BIG Bang OR STEADY STATE?

radio astronomy

Support for Big Bang Theory was discovered in 1964, while using a horn radio antenna in Holmdel, N.J. to isolate, identify and measure sources of noise in the atmosphere, Bell Labs scientists Arno Penzias (right) and Robert Wilson discover faint cosmic radiation from the farthest reaches of known space.

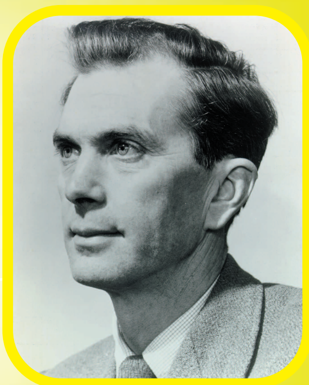
COBE (Cosmic Background Explorer) Satellite revealed tiny temperature differences that reflect early variations in the density of matter, the seeds of galaxies.

Boomerang is a balloon-bourne millimetre-wave robotic telescope, built to observe structure in the Cosmic Microwave Background radiation. It takes advantage of the wind pattern that circulates around the Antarctic continent to run a long duration flight, arriving close to its launch site.

A new development is the Very Small Array, designed to help build up a more-detailed microwave picture of the early Universe. It will consist of 15 small horns and reflectors, each connected to an extremely sensitive receiver, and will be constructed among the conventional telescopes already operating at the Teide Observatory, in Tenerife.

Big Bang Supporters

George Gamow
1904–1968



Martin Ryle
1918–1984

Arno Penzias
b 1933
Robert Wilson
b 1936

Fred Hoyle
1915–2001

Hubble's discoveries of an expanding Universe led a Russian-born scientist, George Gamow, to argue in the late 1940s that there must have been a point when the Universe started to expand. Soon after Gamow published his idea, the English astronomer Fred Hoyle gave a radio talk in which he dismissed the theory as 'some sort of big bang'. Although Hoyle had meant the phrase to be insulting, it stuck, and from then on, as far as most people were concerned, Gamow's idea was called the Big Bang theory of the beginning of the Universe.

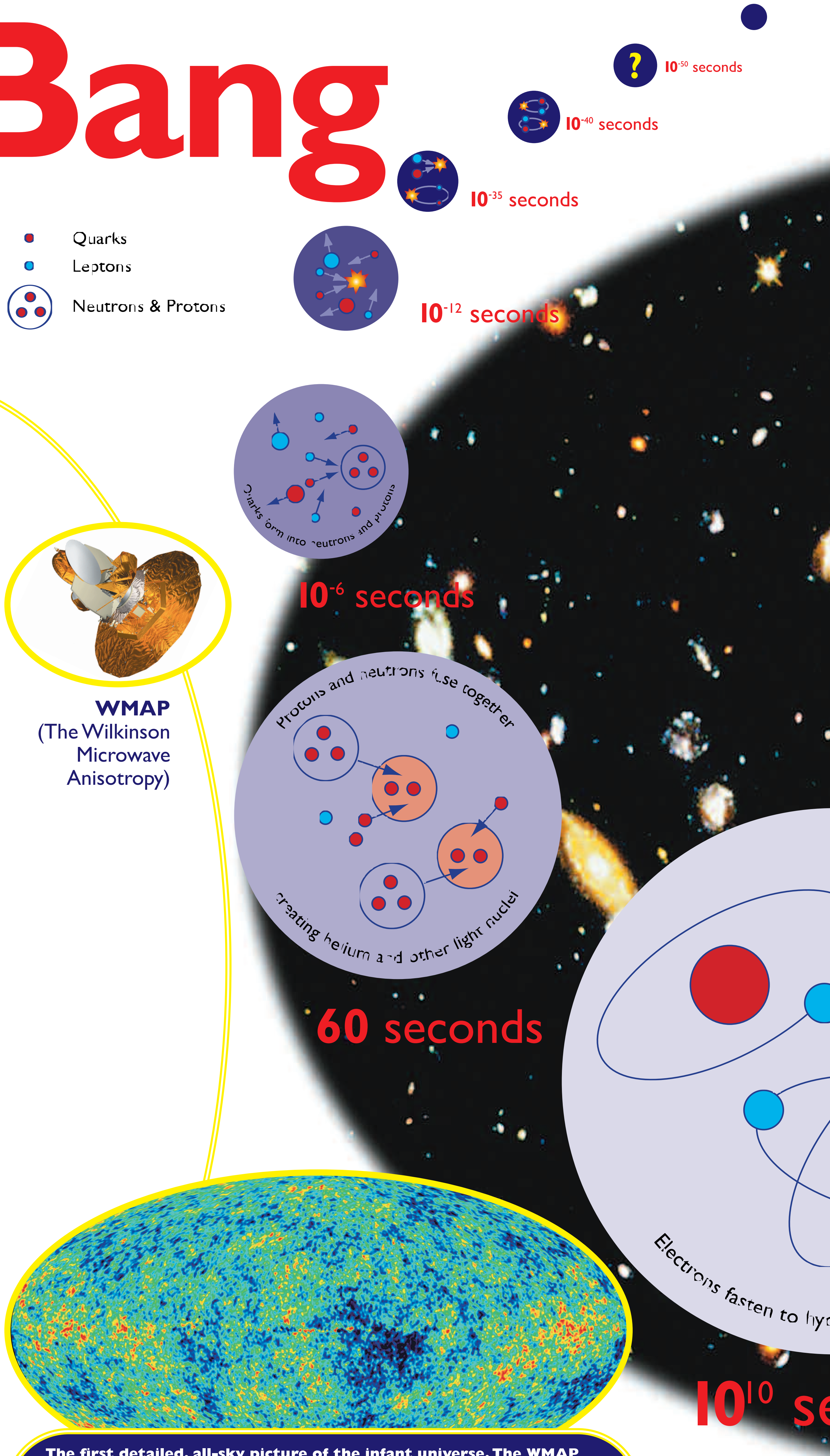
For almost 20 years, arguments raged between the believers in the Big Bang theory and Hoyle's supporters, who believed in the rival 'steady-state' theory, in which the Universe has always existed in much the same way as we see it now, with no beginning. Strong evidence for the Big Bang, and a tough challenge to the steady-state theory, came from the new branch of science called radio astronomy.

It was discovered in the 1930s that galaxies emitted radio waves, but the first map of the sky's radio sources was made in the 1950s by Martin Ryle, the Cambridge radio astronomer. If Hoyle's steady-state theory was correct, Ryle should have found an even distribution of galaxies through space. But he didn't. The further Ryle looked into space with his receiver, the more sources of radio waves he found. Since both the light and the radio waves from distant galaxies have taken billions of years to reach us, we see them as they were in the distant past. Ryle was detecting galaxies that were closer in time to the Big Bang. The fact that there were more of them suggested that the Universe had been much denser then than it is now. This was tremendous support for the Big Bang theory.

Then, in 1964, two American scientists, Arno Penzias and Robert Wilson, made a discovery that finally tipped the balance in favour of the Big Bang theory. They were using a radio antenna to look for interference to satellite broadcasts when they accidentally picked up microwave radiation coming from all areas of the sky. This is the same form of energy that we use (at a much greater strength) to cook with in microwave ovens. The radiation had a temperature equivalent to 2.7 degrees Kelvin – less than three degrees above absolute zero, the coldest temperature possible. One of their colleagues, Robert Dicke, guessed very quickly that they had found the remains of the vast amount of heat energy released at the time of the Big Bang – the lingering afterglow of creation. This would make it quite clear to the reader what the modern view of cosmology is.

more

evidence for the BIG Bang



WMAP
(The Wilkinson Microwave Anisotropy)

The first detailed, all-sky picture of the infant universe. The WMAP image reveals 13 billion+ years old temperature fluctuations (shown as colour differences) that correspond to the seeds that grew to become the galaxies. Encoded in the patterns are the answers to many age-old questions, such as the age and geometry of the Universe.

Time elapsed (in seconds) from Big Bang to now

We can't say anything about the conditions in the Universe before about 10^{-43} seconds, but by 10^{-35} seconds the lightest particles, quarks and leptons, had appeared. Particles were constantly being created and annihilated at 10^{-12} seconds and it was only at 10^{-6} seconds that quarks formed into neutrons and protons. Some of those particles were annihilated, but the remainder gradually joined up to form the atoms we find now in our Universe.

10^{20}

Early observations with the COBE satellite, launched in 1989, showed conclusively how uniform the background radiation was, but more detailed data seemed to show for the first time small variations in this cosmic radiation. The results indicated that 'ripples' had formed in the substance of the Universe within 300,000 years of the Big Bang. These findings appear to back up physicist Alan Guth's 'inflationary model' of how the Universe formed. According to Guth's idea, during the rapid expansion, or inflation, of the Universe that followed the Big Bang, 'imperfections' might have spread through space as matter began to appear, where previously there had been only energy. Each of these imperfections might have been a focal point around which stars and galaxies formed, condensing together under the force of their own gravity.

The COsmic Background Explorer (COBE) satellite looked for radiation from the very edge of space for clues to the origin of the Universe.

More evidence that the Big Bang happened comes from a closer look at the elements that astronomers have detected in the regions of space where new stars are forming. The first stages of the Big Bang took place in a small fraction of a second, when the Universe was only a million billion billion billionth of a centimetre across. Within a billion billionth of a second it had swelled to many times the size of a star and consisted of an incredibly dense sea of particles called quarks and leptons. By the time it was a hundred millionth of a second old, the single unified force that was present at the birth of the Universe had already branched into the four forces familiar to scientists: strong, electro-magnetic, weak, and gravitational.

The End of the Universe?

Until recently, astronomers believed that gravity was slowing the expansion of the Universe. What would then happen to the Universe would depend on the amount of matter in the Universe. If there turned out to be enough matter, then its current expansion would slow down and stop. In that case, we would be living in a Universe destined to collapse in the far distant future. This scenario is known as the "Big Crunch" - in which galaxies and stars would eventually be compressed into a hot dense gas at a temperature of over a billion degrees. The alternative would be that the Universe is destined to expand forever - leading to a cold, dark Universe filled with dead stars.

Then in 1998, astronomers announced that observations of remote supernovae seemed to show that the expansion of the universe is actually speeding up. If that is so, there must be some form of unknown dark energy in the Universe powering this acceleration. Since 1988, observations of the cosmic microwave background and more accurate estimates of the total amount of matter in the Universe have strongly supported the idea that we live in an accelerating Universe with far too little matter to cause a big crunch. However, we are far from understanding what the mysterious dark energy actually is.