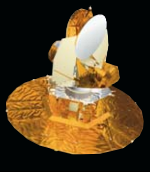


MICROWAVE ANISOTROPY PROBE

MAP

What Questions Does MAP Seek to Answer?

A century of astronomical observation has unveiled a rich structure of galaxies in our present day universe. Recently, NASA's Cosmic Background Explorer (COBE) satellite discovered subtle features in the remarkably uniform early universe that provided clues about the origin of this structure. In spite of this, there are many questions that remain unanswered:

Will the universe expand forever, or will it eventually collapse?
Is the universe dominated by exotic dark matter?
What is the shape of the universe?
How and when did the first galaxies form?
Is the expansion of the universe accelerating?

The Microwave Anisotropy Probe (MAP) satellite produces a much more detailed picture of the early universe than COBE did. This information, which is recorded in the cosmic background radiation, will allow astronomers to address these key cosmological questions.

Mission Overview

Vehicle: Delta II 7425-10
Launch: June 30, 2001, 3:46 pm EDT
Orbit: Lissajous orbit about L2 Sun-Earth Lagrange point, 1.5 million km (1 million miles) from Earth
Lifetime: 27 months (3 months transit, 24 months observing)
Mass/Power: 840 kg/419 W

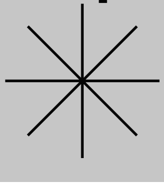
MAP Launch

Instrument Overview

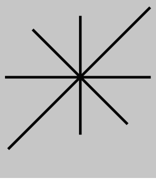
Radiometer: Differential pseudo-correlation with polarization
Optics: Dual Gregorian, 1.4 x 1.6 m primary reflectors
Thermal: Passive radiative cooling to 95 kelvins
Frequencies (GHz): 22, 30, 40, 60, 90

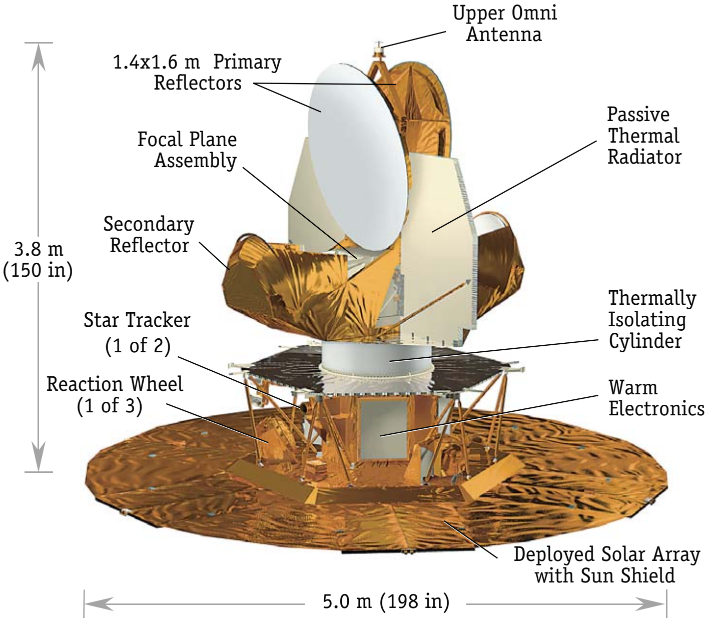
anisotropy (an-I-**sah**-tropy) noun - exhibiting properties with different values when measured in different directions. MAP will observe the anisotropy of the cosmic background radiation: differences in its temperature in different directions in the sky.

isotropic



anisotropic





What is the Cosmic Background Radiation?

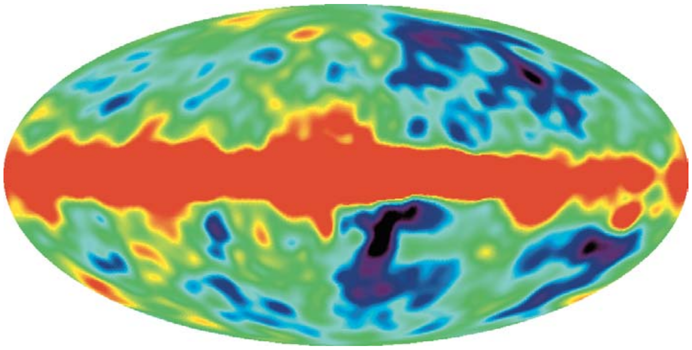
The Big Bang theory is based on Albert Einstein's general theory of relativity and the 1929 discovery that the universe is expanding. This expansion implies the universe was denser and hotter in the distant past, thus it was able to produce the lightest chemical elements such as hydrogen and helium. The Big Bang theory correctly predicts the relative amounts of these light elements. It also predicts that the universe should be bathed in a faint afterglow radiation. This "cosmic background" radiation was discovered as excess microwave static at the Bell Telephone Laboratory in 1965. The cosmic background radiation appears as a glow that is remarkably uniform in all directions in the sky ("isotropic"), though COBE discovered very faint non-uniformities ("anisotropy") in this glow in 1992.

The early universe was very hot. When the average density of matter in the universe was comparable to air at sea level, its temperature was 2.73 billion degrees! (The average density today is about one proton per cubic meter.) At these temperatures protons and electrons could not bind together to form neutral atoms. The free electrons scattered the cosmic background radiation much as water drops scatter visible light in clouds, so the early universe would appear as a dense fog. As the universe expanded, it cooled. Roughly 400,000 years after the Big Bang, it was cool enough for protons and electrons to combine into neutral hydrogen. Neutral hydrogen is transparent, so the cosmic background radiation has traveled freely through the universe since that time. On a cloudy day, we can look through the air to see the surface of the clouds. Similarly, we can see through the universe out to where it was filled with free electrons and see the "dense fog" that filled the early universe. The reason we can "see" the early universe is that we see objects as they were in the past due to the time it takes light to travel across space. For example, we see the Sun as it existed 8 minutes earlier. We see the "cloud surface" from which the cosmic background radiation was emitted as it was about 13 billion years ago - a view back to 400,000 years after the Big Bang.

What Will the MAP Results Look Like?

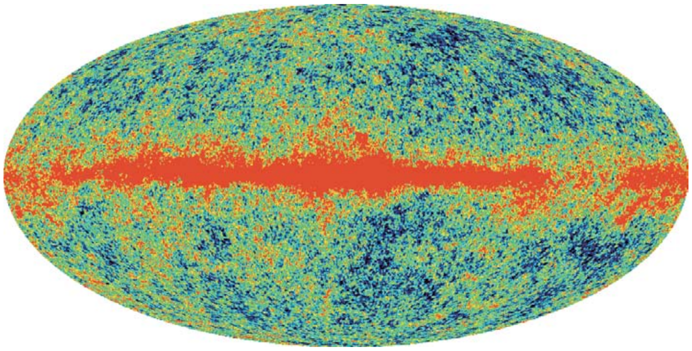
In 1992 NASA's COBE mission detected tiny variations ("anisotropy") in the intensity, or temperature, of the cosmic background radiation. These temperature variations trace the beginnings of the large-scale pattern of galaxies we see today.

COBE Sky Map



The above picture is a projection of the cosmic background radiation temperature over the full sky. The average temperature is 2.725 kelvins (degrees above absolute zero temperature; equivalent to about -270 C or -455 F), and the temperature is remarkably uniform across the sky. The variations seen are tiny: the red regions are 0.0002 degrees warmer than the black regions. These temperature variations are so small that they are like height variations of only 4.65 inches on a mile-high plateau. In addition to the cosmic radiation, emission from our Milky Way galaxy is seen as the red horizontal band across the middle of the map, corresponding to the plate-like disk of our galaxy seen edge on.

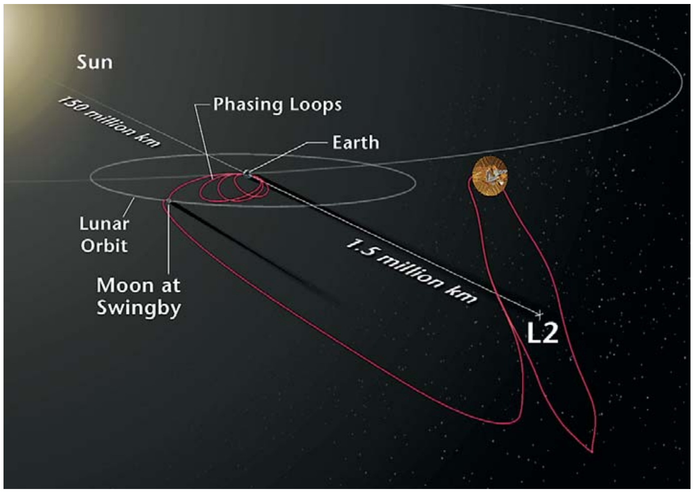
Simulated MAP Sky Map



As illustrated above, MAP measures fluctuations in the cosmic background radiation temperature with much better focus than the COBE satellite. The additional information in this highly detailed image will shed light on major scientific questions about the origin, content, and fate of the universe.

Orbit

MAP observes from an orbit about the L2 Sun-Earth Lagrange point 1.5 million km from Earth. The trajectory to the L2 orbit used 3 "phasing loops" that positioned MAP for a lunar swingby and a cruise to L2. The journey required 3 months.



Control of Measurement Errors

The sensitivity of the cosmic background radiation map will be better than 20 microkelvins (0.000020 kelvins) per 0.3 degree square pixel. To realize the full value of these measurements, sources of error must be controlled to an extraordinary level. This was the most important factor driving the MAP design, and led to the following design choices.

Differential: MAP measures temperature differences on the sky using symmetric microwave receivers coupled to back-to-back telescopes. By measuring temperature differences, rather than absolute temperatures, most spurious signals will cancel. This is analogous to measuring the relative height of bumps on a high plateau rather than each bump's elevation above sea level.

Sky scan pattern: MAP spins and precesses like a top. This allows an observing pattern that covers a large fraction of the sky (approx 30%) during each one hour precession.

Multifrequency: Five frequency bands from 22 GHz to 90 GHz allows emission from the Galaxy and environmental disturbances to be modeled and removed based on their frequency dependence.

Stability: The L2 Lagrange point offers an exceptionally stable environment and an unobstructed view of deep space, with the Sun, Earth, and Moon always behind MAP's protective shield. MAP's large distance from Earth protects it from near-Earth emission and other disturbances. At L2, MAP maintains a fixed orientation with respect to the Sun for thermal and power stability.

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The flight hardware and software were produced in a partnership between the Goddard Space Flight Center and Princeton University, under the scientific supervision of a team whose institutions also include UCLA, U. Chicago, UBC, and Brown. The Principal Investigator is Dr. Charles L. Bennett of the Goddard Space Flight Center.

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