Case Strengthened for Inflation

NASA's WMAP satellite gives a big new boost to cosmology's prevailing theory.

Since early 2003 the scientific community has waited with bated breath for new results from NASA's Wilkinson Microwave Anisotropy Probe (WMAP). It appears the wait was worth it. On March 16th the WMAP science team announced a series of findings based on two additional years of collecting data on the cosmic microwave background (CMB) — the afterglow of the Big Bang.

With improved measurements of the CMB's subtle warm and cool spots, the team refined several key cosmological parameters. And with a new, all-sky map of how CMB photons are polarized, the WMAP team found powerful new evidence to support inflation — an explosive growth spurt in perhaps the universe's earliest moments, first 10−32 second during which its volume expanded by a factor of 10^26. This resulted in a universe with a uniform temperature 13.7 billion years ago, with the first stars appearing about 400 million years later. According to the WMAP science team leader, John C. Bennett (Johns Hopkins University), the new results strongly support the notion of an inflationary period soon after the Big Bang, at a redshift of 11 or 12.

WMAP's results strengthen this prevailing cosmological paradigm and give scientists new confidence that they are closing in on some of the great mysteries pondered by scientists and philosophers for centuries. Among the new results:

- **The universe** is 13.7 billion years old with a margin of error of only 2%. This age closely agrees with WMAP's 2003 results and with numerous other astronomical studies. But the new figure has a smaller range of uncertainty.

- **Dark energy** dominates the cosmic recipe. This unknown form of energy, which is causing cosmic expansion to accelerate, represents 74% of the universe's matter-and-energy density. Dark matter constitutes 22%, and the familiar type of matter made of atoms amounts to only 4%. These values are very similar to those released in 2003 but are more accurate. They also agree nicely with other studies, such as measurements of distances to Type Ia supernovae.

- **The new WMAP data**, combined with other astronomical findings, narrow down dark energy's "equation of state" \( w \) to a value of \(-1\) with an accuracy of about 10%. The dark energy thus behaves like Einstein's "cosmological constant" — it's an inherent property of space-time itself. That is, a cubic centimeter of space contains the same amount of dark energy no matter how much space expands throughout cosmic history — unlike the number density of particles, which thin out as the universe enlarges. Previous measures of \( w \) were good to about 15% accuracy (S&T: June 2004, page 16). If \( w \) is fixed at \(-1\), it means the cosmos will never be destroyed in a runaway super-expansion ("Big Rip") or contraction ("Big Crunch").

- **Surveying the entire sky**, WMAP measured the extent to which the CMB's microwave photons were polarized during their long journey across the universe. Ground-based experiments have also detected polarization, but only across small areas of sky. The WMAP team used these measurements to gain a better handle on when the first stars in the universe began to ionize the gas from the Big Bang, a critical phase transition in cosmic history (May issue, page 30). The analysis shows that this process started about 400 million years after the Big Bang, at a redshift of 11 or 12.

- **By combining the all-sky polarization measurements** with the improved temperature measurements, the team pinned down the "scalar spectral index" to a value of 0.95 with an uncertainty of only 2%. This parameter compares the CMB temperature fluctuations seen over large scales to those seen at small scales. The simplest inflationary models predict that the scalar spectral index should be slightly less than 1, exactly as the WMAP team has found. This result rules out a number of more exotic inflation models, which require new energy fields or fine-tuning mechanisms.

Most researchers in the field were quick to hail the WMAP science team for its diligent work. "This is big news, indeed," says cosmologist Anthony Aguirre (University of California, Santa Cruz), who is not a member of the WMAP team. "I will feel more confident once a second group has analyzed the data and obtained similar results. This should not take very long. In the meantime, I am fairly confident, however, as this team has been quite careful."

"It's wonderful how the different experiments support each other and confirm each other," says Chuck Bennett (Johns Hopkins University), leader of the WMAP science team. "It gives us the warm feeling that we're on the right track. We have so much data with crosschecks and interlocks that you can pull out the results of any experiment and get the same answer."

— R. N. and Alan MacRobert

With three total years of WMAP data, scientists have produced a more detailed picture of the cosmic microwave background. In this all-sky map colors indicate warmer (red) and cooler (blue) spots. The white bars show the polarization directions. This new information helps to pinpoint when the first stars formed and provides important clues about events that transpired in the universe's first 10−32 second.