Cosmic questions, answers pending

Throughout human history, great missions of exploration have been inspired by curiosity, the desire to find out about unknown realms. Such missions have taken explorers across wide oceans and far below their surfaces, deep into jungles, high onto mountain peaks and over vast stretches of ice to the Earth's polar extremities.

Today's greatest exploratory mission is no longer Earthbound. It's the scientific quest to explain the cosmos, to answer the grandest questions about the universe as a whole.

What is the identity, for example, of the "dark" ingredients in the cosmic recipe, composing 95 percent of the universe's content? And just what, if anything, occurred more than 13.7 billion years ago, when the universe accessible to astronomical observation was born? Will physicists ever succeed in devising a theory to encompass all the forces and particles of nature in one neat mathematical package (and in so doing, perhaps, help answer some of these other questions)? Will that package include the supposedly basic notions of space and time, or will such presumed preexisting elements of reality turn out to be mere illusions emerging from ur-material of impenetrable obscurity? And finally (fittingly), what about cosmic finality? Will the universe end in a bang, a whimper or the cosmic equivalent of a Bruce Willis movie (everything getting blown apart)?

In the pages that follow, *Science News* writers assess the state of the evidence on these momentous issues. In none of these arenas are the results yet firm. But as string theorist Brian Greene wrote in his book *The Elegant Universe*, "sometimes attaining the deepest familiarity with a question is our best substitute for actually having the answer."

—Tom Siegfried, Editor in Chief

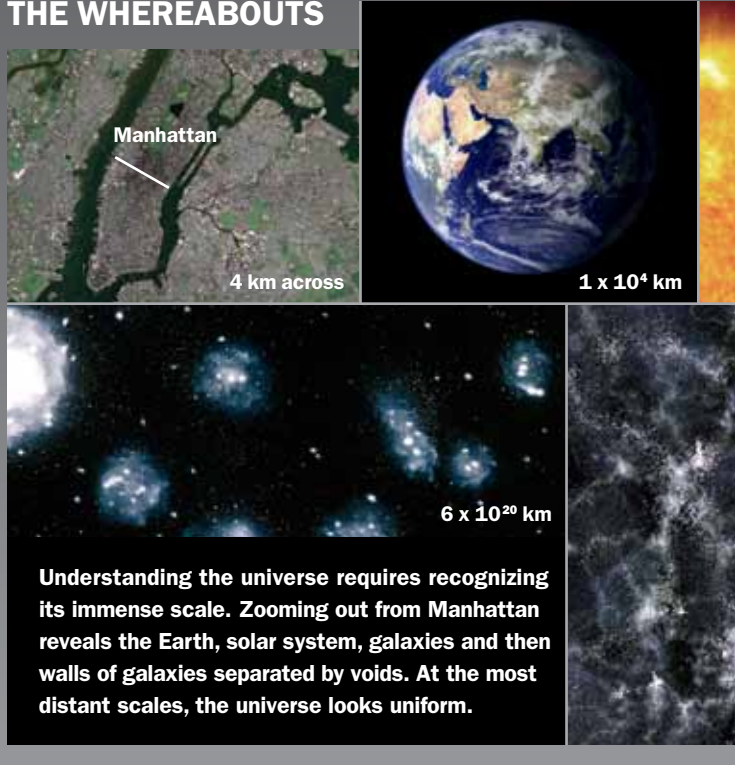
MISSION: REVEAL THE SECRETS OF THE UNIVERSE

THE OBJECTIVE

For millennia, people have turned to the heavens in search of clues to nature's mysteries. Truth seekers from ages past to the present day have found that the Earth is not the center of the universe, that countless galaxies dot the abyss of space, that an unknown form of matter and dark forces are at work in shaping the cosmos. Yet despite these heroic efforts, big cosmological questions remain unresolved:

Find tools for the mission on Page 32. For pdfs of this section, and more resources, visit www.sciencenews.org/cosmicquestions

THE WHEREABOUTS



Understanding the universe requires recognizing its immense scale. Zooming out from Manhattan reveals the Earth, solar system, galaxies and then walls of galaxies separated by voids. At the most distant scales, the universe looks uniform.

THE VITAL STATISTICS

13.75 billion years (uncertainty +/–0.11): Time since the Big Bang, the creation of the universe.

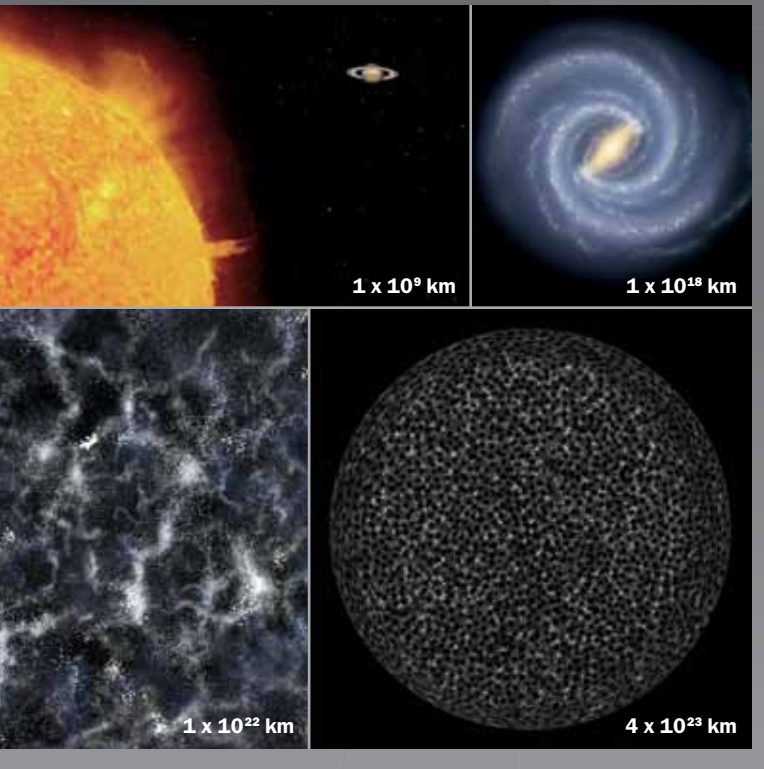
377,730 years (+3,205/–3,200): Time after the Big Bang when photons stopped interacting with charged matter and produced the relic radiation known as the cosmic microwave background.

70.4 kilometers/second/megaparsec (+1.3/–1.4): Expansion rate of the universe assuming its spacetime geometry is flat. Also known as the Hubble constant.

90 billion light-years: Rough diameter of the known universe.

–0.980 (+/–0.053): Equation of state, a measure of the (negative) pressure exerted by dark energy divided by its density. An unvarying value of –1 suggests that dark energy is Einstein's cosmological constant.

1.0023 (+0.0056/–0.0054): Value of omega, the total mass-energy density relative to the critical mass-energy density. Omega equal to 1 signifies a universe with flat spatial geometry.



PAST MISSION FINDINGS

1543 Nicolaus Copernicus publishes a mathematical description of planetary motion, assuming that the sun is the center of the solar system. Later work by Johannes Kepler, Galileo Galilei and Isaac Newton provides further evidence.

1666 Isaac Newton formulates the law of gravity and laws of motion, published in 1687.

1900 Max Planck formulates the first description of quantum theory, which will eventually explain the nature of matter and energy on the subatomic scale.

1917 Albert Einstein applies general relativity to the universe. Later work by Willem de Sitter and independently by Aleksandr Friedmann implies the possibility that the universe is expanding.

1924 Edwin Hubble announces that the "spiral nebulae" sit beyond the Milky Way and later that the Milky Way is just one of many galaxies.

1929 Hubble finds that the universe is expanding, after analyzing the redshifts of distant galaxies.

1933 Fritz Zwicky examines galaxies in the Coma cluster and determines that there is unseen mass, what scientists call "dark matter."

1960s Steven Weinberg, Abdus Salam and Sheldon Glashow independently propose a theory to unify electromagnetism and the weak nuclear force.

1964 Arno Penzias and Robert Wilson discover the cosmic microwave background radiation; in 1990 NASA's COBE mission confirms that the radiation's properties verify the universe's birth in a Big Bang.

1986 Astronomers Margaret Geller, John Huchra and Valérie de Lapparent map a section of the observable universe, revealing a structure that encompasses large walls and giant voids.

1998 Researchers discover that the universe is expanding at an accelerating rate, suggesting a mysterious force dubbed "dark energy" might be at work.

TOP, FROM LEFT: USGS, NASA EARTH OBSERVATORY; RETO STÖCKLI AND ROBERT SIMMON, MODIS/GSFC/NASA, USGS, DMSP; JPL-CALTECH/NASA, T. PYLE/SSC; ADAPTED BY T. DUBÉ; R. HURT/SSC, JPL-CALTECH/NASA; BOTTOM, FROM LEFT: DAVID PARKER/PHOTO RESEARCHERS; NICOLLE RAGER FULLER; NICOLLE RAGER FULLER; TABLET: VIKTOR GMYRIA/SHUTTERSTOCK.COM