Dark Energy—the Mystery that Dominates the Universe

Summary

Recently scientists sponsored by the Office of Science found that, contrary to all previous understanding, the expansion of the universe was accelerating; some force was pushing galaxies apart at ever increasing speed. The study of this force—now called "Dark Energy"—holds the promise of a new understanding of the fundamental physical laws that govern our universe.

Several years ago, a group of physicists at the DOE Office of Science's Lawrence Berkeley National Laboratory set out to measure how gravitational attraction was slowing down the expansion of the universe that started with the Big Bang. Would gravity be enough to reverse the expansion and cause the universe to end in a big crunch when everything collapsed like a deflated balloon? Or is space growing so fast that gravity can't contain it?

How is it possible to answer this huge question? The Berkeley Lab scientists showed they could use the brightness of distant exploding stars—supernovae—as natural beacons from the past. They measured the brightness of many thousands of galaxies at a time and then measured them again after waiting a few weeks so that a dozen or so new supernovae explosions would show themselves as brightening spots amidst these galaxies. They selected only one kind of supernova, which is known always to explode with the same brightness. How bright such a supernova appears to us tells how far away it must have been at the time of the explosion. And the farther away they are, the farther back in time the explosion occurred, since it takes more time for the light to reach us. In the end they were able to find supernovae that had exploded 1 billion years ago, 2 billion years ago, 3 billion years ago...as far back as 7 billion years!

While the light from the supernova is making its way to us, its wavelength expands as the universe itself expands. So measuring the wavelength of the supernova light directly reveals how much the universe has expanded since the time of the supernova explosion. After several years of supernova discoveries were collected, the scientists compared light from the more and more distant supernovae to see how much the expansion of the universe had been slowing down.

When the results were in, the answer was shocking. The universe wasn't slowing down at all, but rather speeding up, much as if the tossed ball defied gravity and picked up more and more speed as it left the earth behind. Apparently, some previously unknown energy is pushing the universe to expand faster and faster. Moreover, most of the universe—2/3 of it—is made of this mysterious "dark energy!"

Nothing of the sort had ever been seen before, but it had been imagined. Einstein's Theory of General Relativity did permit such behavior when he included a "cosmological constant" in his equations. However, Einstein eventually rejected this possibility and declared it had been a mistake from the start, "his greatest blunder." Maybe he was right the first time.

Physicists have long doubted that there is a cosmological constant because all predicttions of its size, based on everything we know today about physics, come out wildly wrong. In fact, these predictions have been called the worst predictions ever made—like guessing something weighed as much as a flea when it actually

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weighed as much as all the galaxies of all the stars and planets put together.

A hard puzzle like this is just what makes for scientific revolution. One of the greatest physicists today, Nobel Prize winner Steven Weinberg, remarks: "The problem of the dark energy is central to today's physics. Until it is solved, the problem of the dark energy will be a roadblock on our path to a comprehensive fundamental physical theory."

But with great difficulties come great opportunities. At the beginning of the last century physics was stumped by discoveries that when explained led to atomic and quantum physics, with all the incredible technological and material gains brought by understanding particles, light, and the quantum.

Jack Marburger, the President's Science Adviser, spoke about the recent discoveries: "By century's end, everything had come alive—even time and space itself. Our universe today is filled with cataclysmic change on the widest possible scales of energy and time. Its laws are deeper than we suspected, and more full of mystery than any other part of science except possibly for that which studies human consciousness. ...[I]t appears that the heavens themselves will be the laboratory in which the final pieces of the puzzle, or at least the next ones, will be found."

How do we start on this new puzzle of dark energy? By going back to the supernova explosions—but now studying them with much more precise instruments and with techniques only possible in outer space. The scientists at DOE's Berkeley Lab have embarked on a new program to design, build, and launch a new Space Telescope, called the SuperNova / Acceleration Probe (SNAP). Like the Hubble Space Telescope, SNAP would have a mirror two meters across, but its wide-field camera with a billion pixels would collect images hundreds of times larger than those of its predecessor. SNAP would examine thousands of new supernovae with a precision unattainable from the ground, and in this way map out the details of the expansion history of our universe. Measuring spurts or slowdowns in this expansion history provides the only known way to study the dark energy.

With SNAP, we have the opportunity to explore the beginning and end of the universe through this elemental, fateful dark energy. Its "antigravity" properties are unlike anything ever seen before. Today's established physics theories explain all aspects of nature, from material properties such as superconductivity to nuclear fission and fusion—but they don't explain dark energy, the dominant stuff of the universe.

The physics of a century ago similarly seemed just about complete, but the few inconsistencies at that time led to quantum physics, semiconductors, lasers, CAT scans, and nuclear power, things too strange and wonderful to have been dreamt of.

We don't know where the puzzle of dark energy will lead, but we have the tools, the knowledge, and the ability to pursue this discovery made by DOE Office of Science research, to extend our reach, and hopefully our grasp, into new realms.

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