THE 10 Most Important Days IN THE History of THE Universe (ACCORDING TO AN ASTRONOMER)

By Lawrence M. Krauss

1 July 4, 1054: The Day the Sky Got Brighter

JULY 4TH WAS A SIGNIFICANT DAY LONG BEFORE America started celebrating it. It also marks the first time on record that a new object appeared in the constellation Taurus—an object so bright it could be seen in the daytime sky. Not surprisingly, people around the world couldn't help but take notice. Chinese astronomers labeled it a "guest star" and noted that, at night, it shone almost four times brighter than Venus. They soon began speculating that its appearance heralded the Emperor at the time, Jen Tsung. Meanwhile, on the other side of the globe, the Anasazi Indians of western North America may also have noticed the star. Archeologists believe images carved into Arizona rocks from that era depict the same mysterious phenomenon. But one group of people left no record of having witnessed the "guest star"—the Europeans. It's speculated they considered it heretical to suggest that anything in the night sky was not eternal.

The Chinese astronomers were right about the object being a star. More specifically, however, it was a star in the process of exploding, otherwise known as a supernova. When stars burst, they are momentarily as bright as a billion stars, so even though the phenomenon had occurred so far away from Earth, its brightness was still immense. Now known as the Crab Nebula, this supernova remnant is hardly a distant memory. Today, it consists of an expanding shell of gas that's 10 light years across and is moving outward at about 700 miles per second. At its center is a dense remnant called a neutron star, which is about the size of Manhattan in radius and rotates roughly 30 times per second. As a result, the Crab Nebula sends out pulses of radiation that reach the Earth at that same rate. Scientists wondered about the source of this mysterious pulsing when it was first detected in 1968, but they quickly pinned it on the ancient Crab and not, say, alien civilizations trying to contact us.

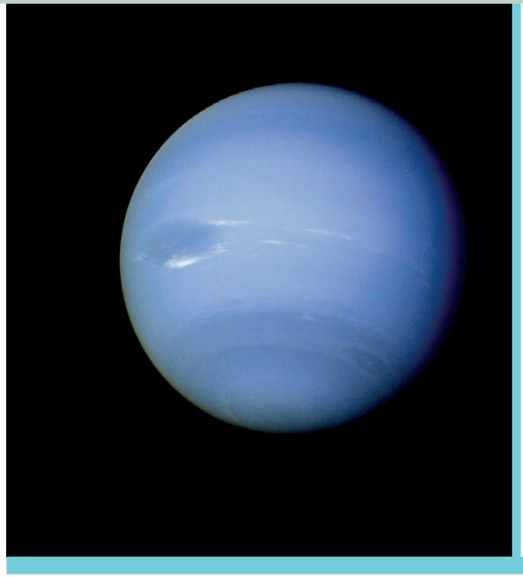
2 Nov 11, 1572: The Day that Launched Tycho Brahe's Career

IT'S SAFE TO SAY THAT DANISH NOBLEMAN and amateur astronomer Tycho Brahe was familiar with the night sky. So it's no small deal that, on this date, he noticed "a new and unusual star, surpassing the other stars in brilliancy … shining almost directly above [his] head." What Brahe was observing was a supernova in the constellation Cassiopeia, about 10,000 light years from Earth. Brahe's discovery catapulted him to astronomy fame. King Frederick II of Denmark was so impressed that he donated the entire island of Hven to Brahe, in order for Brahe to build an observatory. There, using carefully calibrated instruments (telescopes had yet to be invented), Brahe spent years observing the positions of the planets in the sky. Eventually, however, Brahe lost his privileged position on Hven and had to move to Prague when a new king took the throne. (Brahe spent so much time with his head in the skies that he ended up being a crummy feudal lord, and his peasants were vocally unhappy.) His legacy hasn't suffered, though. Brahe's data provided the groundwork for the research of his assistant, Johannes Kepler, who used it to formulate his famous three laws of planetary motion—which, in turn, allowed Isaac Newton to derive his Universal Law of Gravity. We should consider ourselves lucky for that new arrival in the sky on November 11, 1572. If it hadn't shown up, Brahe might have gotten bored and switched hobbies.

4 September 23, 1846: The Day Neptune Was Discovered (for the Second Time)

GERMAN ASTRONOMER JOHANN GALLE first observed the planet Neptune on this September evening. That might not sound too remarkable, but it was the first time an object in the solar system had been discovered using the law of gravity. Years earlier, astronomers noticed that Uranus had an irregular orbit and hypothesized that a new planet was causing Uranus to veer off its otherwise expected path. Using predictions from other astronomers regarding where the orbit would hit its "roadblock," and thus where the planet was positioned, British astronomer James Challis beat Galle to the punch, discovering Neptune in August of 1846. The problem? Challis' sky charts were so shoddy that he didn't realize what he was looking at. So when Galle began his search a month later (using a better star chart), he found Neptune within one degree of its predicted position. By the next evening, the object had moved, confirming that it was indeed a planet, not a star.

It was fortunate that both Challis and Galle observed the planet when they did, because within 30 years, Neptune was far away from where the original calculations had placed it. Of course, today we can accurately predict where Neptune will be. Five years from now, on August 10, 2011, the planet will have finally returned to the position at which it was first discovered, having made a complete revolution around the Sun.



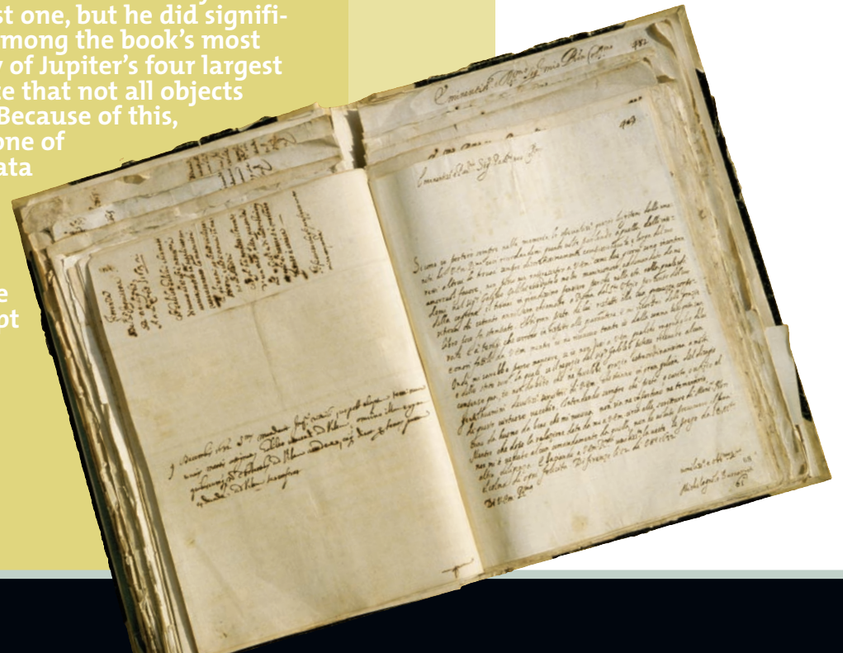
5 October 27, 1859: The Day We Discovered We Were Just Like Everything Else

EVER SINCE ISAAC NEWTON FIRST USED A PRISM to separate sunlight into its various colors, scientists have studied the nature of the solar spectrum. In 1814, for example, German optician Josef von Fraunhofer observed mysterious dark lines interrupting the otherwise continuous spectrum of light from the Sun. A few decades later, German physicist Gustav Kirchoff and chemist Robert Bunsen (of Bunsen burner fame) demonstrated that metals heated up in the laboratory produce their own unique light spectra when burned, meaning that the lines von Fraunhofer had observed were evidence of the same Earthy substances burning up in the Sun. In other words, the Earth is made up of the same stuff as the rest of the universe.

Kirchoff and Bunsen announced their revolutionary findings on October 27, 1859. Soon after, in 1868, Sir Norman Lockyer added fuel to the fire when he observed strong yellow lines in the solar spectrum that hadn't been seen before and attributed them to a new element called "helium." Thus, a study of the stars not only demonstrated that the elements that make up the Earth and the stars are the same, but it led to the discovery of elements that would later be discovered to exist on Earth.

3 March 12, 1610: The Day Galileo Revealed All His Secrets

March 12, 1610, marks the date that Galileo Galilei published his famous book, *The Starry Messenger*, in which he recounted the discoveries he'd made with his newly built telescope. (He hadn't built the first one, but he did significantly improve on the original.) Among the book's most notable revelations: The discovery of Jupiter's four largest satellites, which provided evidence that not all objects in the heavens orbited the Earth. Because of this, Galileo's book later proved to be one of Newton's best friends. Galileo's data allowed Newton to confirm that Kepler's laws of planetary motion also applied to the moons orbiting Jupiter, thus demonstrating that the force that produced these orbits was the same force that kept the planets orbiting the Sun and the Moon orbiting the Earth. In other words, it put Newton's Universal Law of Gravity on firm empirical footing.

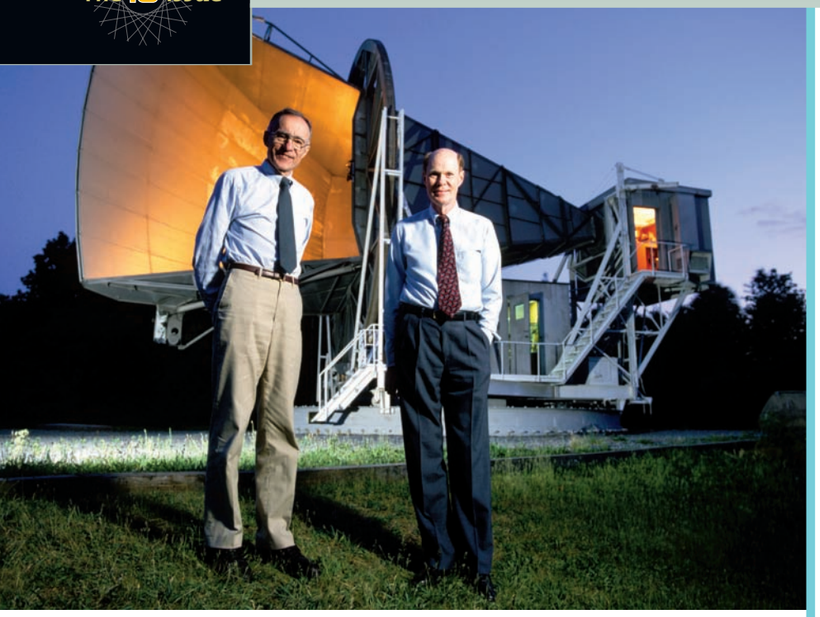


6 December 30, 1924: The Day We Expanded Our Universe

WHEN THE HOOKER TELESCOPE was installed at the Mt. Wilson Observatory in California's San Gabriel Mountains in 1917, it set the stage for astronomer Edwin Hubble to make two monumental discoveries. The first, put technically, related to his measurements of two Cepheids in a distant nebula. More simply, Cepheids are a type of star that were used to calculate the distances between objects in space (based on how bright the star was and how its brightness varied over time). So when Hubble discovered two Cepheids in one particular far-away nebula, he was able to measure the nebula's placement as being outside the Milky Way (in what we now know as the Andromeda galaxy). Up to that point, astronomers only knew about one galaxy in the universe—our own. Thanks to Hubble, we now know that there are more than 100 billion galaxies in the observable universe.

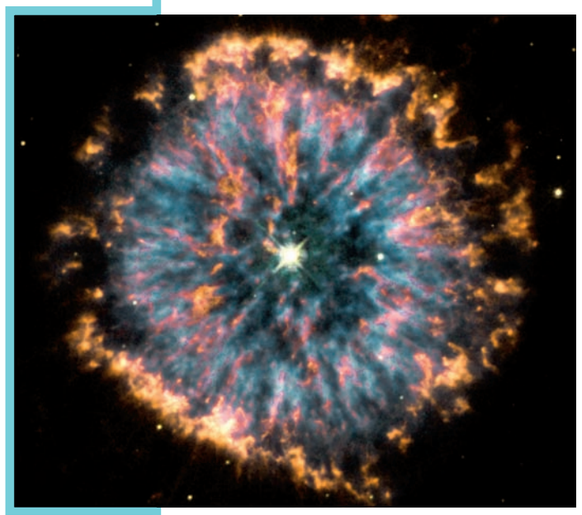
After announcing his discovery at the end of 1924, Hubble kept observing Cepheids in other galaxies, and five years later, they yielded a second stunning discovery: Galaxies are, on average, moving away from us. What's more, their speed is proportional to their distance. In short, Hubble had discovered that the universe is expanding, a fact that verified earlier theories that the universe started with a Big Bang.

Since Hubble's discovery more than 80 years ago, both the expansion of the universe and the existence of a Big Bang have become well-established facets of observational cosmology. Scientists have tweaked Hubble's observations a bit, though. For instance, he got the universe's expansion rate wrong by almost a factor of 10. His initial results suggested the universe was less than 2 billion years old; we now know it's about 14 billion years old.



7 May 13, 1965: The Day We "Heard" The Big Bang

By the second half of the 20th century, the Big Bang concept was alive and well, but it got a considerable boost in 1965, when two young radio astronomers stumbled across its afterglow. In that year, Arno Penzias and Robert Wilson, of Bell Laboratories, discovered a source of irremovable static in a sensitive microwave antenna in Holmdel, New Jersey. Try as they might to get rid of possible sources of the noise—and going so far as to scrape off the droppings from a nearby set of roosting pigeons—it persisted from season to season. Meanwhile, Robert Dicke and David Wilkinson at nearby Princeton University were haplessly trying to build an antenna to detect this very noise. Finally, the four minds met, and Dicke and his group told an astonished Penzias and Wilson what the noise was: the microwave background of radiation that exists as a remnant of the Big Bang. On May 13, Penzias and Wilson submitted their findings to the *Astrophysical Journal* and, though they didn't speculate much about the source of the noise in their paper, they were awarded the Nobel Prize for the discovery 13 years later. Since then, the Cosmic Microwave Background, as it has become known, has been measured with great precision. In fact, you've probably observed it—albeit unwittingly. The static "snow" that used to show up on TV screens after stations went off the air in the pre-cable era was made up of microwave background photons, some of which had their origin in the Big Bang.



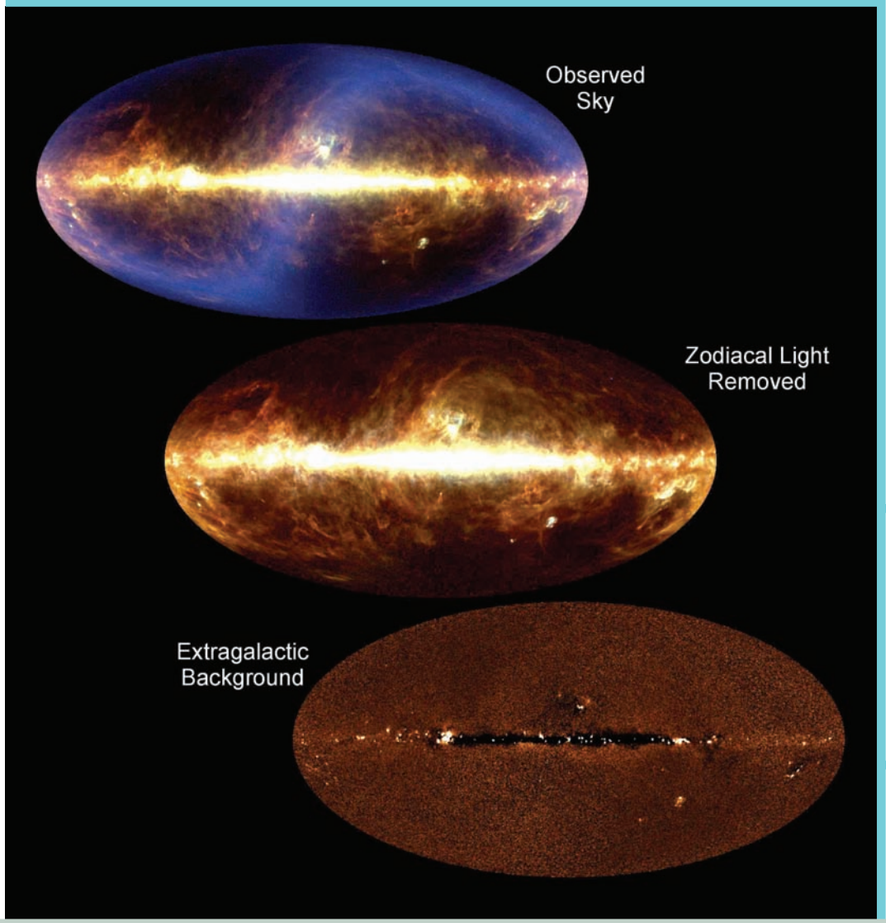
9 February 23, 1987: The Day We Gave Radiation a Second Glance

ON THE EARLY MORNING OF FEBRUARY 24, 1987, astronomer Ian Shelton was tooling about at the Las Campanas observatory in Chile when he noticed something strange in an image he'd taken of the Large Magellanic Cloud. He went outside and looked up, and there it was—the brightest observable supernova since the one Kepler had witnessed in 1604. This alone would not have made the date especially significant. However, later that week, two large underground particle detectors analyzed data from the sky and discovered that on February 23, there were 19 different spikes of energy, all within the same 10-second interval. This meant that the particles in the detector had been bombarded with other, more ephemeral particles called neutrinos, which had zoomed through the detector after being spat out by the supernova. It had long been predicted that when a star exploded, the vast majority of its radiation was emitted in the form of neutrinos, instead of light. But Shelton's discovery alerted scientists to look for this signal in their data. As a result, astronomers began to study neutrinos more closely, learning a tremendous amount about astrophysical systems such as supernovae and our own Sun, as well as studying the properties of neutrinos themselves.

9 April 23, 1992: The Day the History of the Universe Was Revealed

AFTER THE DISCOVERY OF THE COSMIC MICROWAVE BACKGROUND (CMB) in 1965 [see entry No. 7], astronomers set about trying to map it. The hope was to find out more about the nature of the universe at the time the radiation was emitted, which was just 300,000 years after the Big Bang. Enter the Cosmic Background Explorer (COBE) satellite, which launched in 1989. By 1992, the COBE collaboration announced it had discovered small, odd variations in the temperature of the CMB, which averages just a few degrees above absolute zero. The early universe, it turned out, was lumpy. Its highest-density areas eventually collapsed to form the universe's large-scale structures, such as galaxies and clusters of galaxies.

Since the COBE's discoveries, many other experiments have observed these fluctuations in finer detail, and the results have been remarkable. From these observations, **we now know that the universe is flat, that more than 90 percent of matter in the universe is "dark" (it's not visible to telescopes because it doesn't emit light),** and that—apparently—those temperature differences in density go back a long, long way. In fact, they were probably produced by quantum mechanical effects when the universe was less than one millionth of one billionth of a second old.



10 January 8, 1998: The Day the Facts of the Matter Were Turned Upside Down

HAVING DISCOVERED DECADES EARLIER that the universe was expanding, the next question for astronomers became: how fast? Two groups of astronomers—one from the United States and one from Australia—looked to a certain type of supernova for the answer. The first group announced their findings on January 8, 1998, revealing that the universe was expanding at an increasingly fast pace. That wasn't the answer scientists were expecting. Most astronomers had assumed the dominant source of energy in the universe was either matter or radiation, meaning the universe's expansion rate would have been decreasing, not increasing. The only explanation for the pedal-to-the-metal state of affairs these two teams uncovered in 1998 seems to be that the dominant energy source in the universe resided somewhere else—namely, in empty space. This "dark energy," as it has become known, is the reason the universe has enough energy today to be flat, and that's just about everything scientists know about it. We therefore find ourselves living in a universe where the dominant source of matter is invisible to telescopes and the dominant source of energy is thus far totally unexplained—a universe stranger than we ever imagined.

The latest book by Lawrence M. Krauss, entitled *Hiding in the Mirror: The Mysterious Allure of Extra Dimensions, from Plato to String Theory and Beyond* (Viking, 2005), is available in bookstores nationwide.