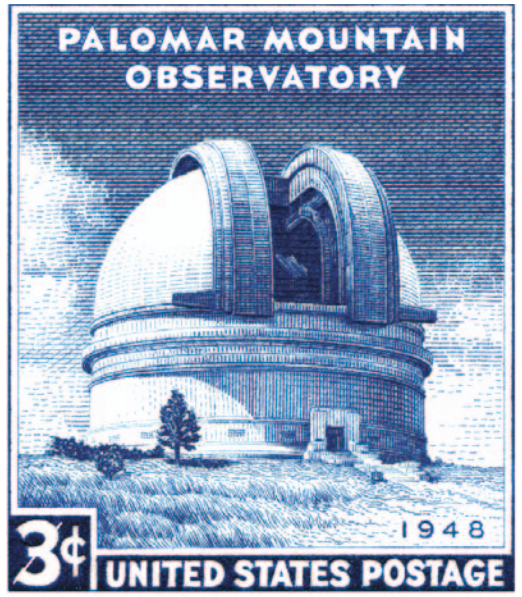
A Lifetime of Science and Skywatching



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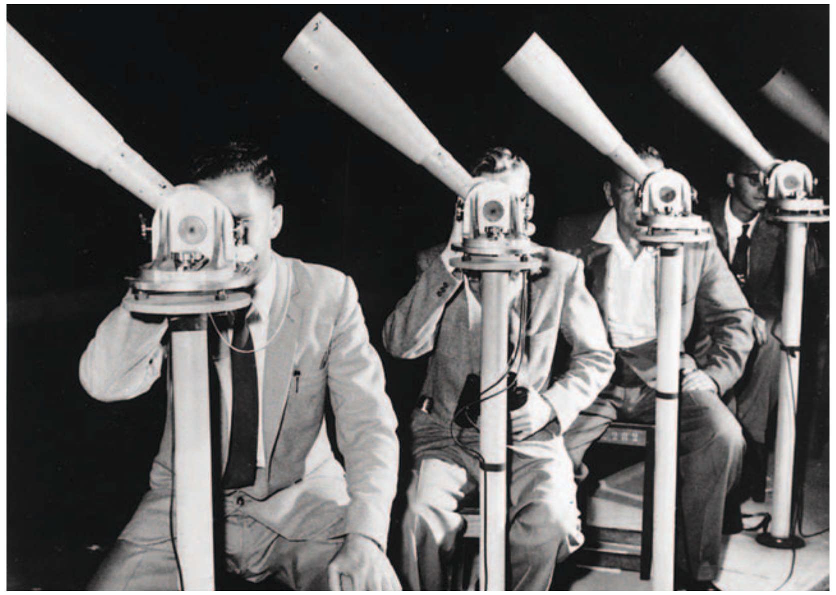


OPERATION MOONWATCH / SMITHSONIAN INSTITUTION ARCHIVES

Alan MacRobert

Astronomy grew more in the last 75 years than in all prior history. *Sky & Tel* was there at every step.

Many times a day I walk past every Sky & Telescope *ever published. They fill a bookcase of bound volumes outside my office, nearly from floor to ceiling. Occasionally I pull out one of the big blue books and open it. Always it's hard to close. Because I've just dropped into the broadest, most detailed single record of astronomy's development, culture, and events across three-quarters of a century.*

For our 75th birthday, here are some of the milestones chronicled in that bookcase. How often have you eagerly opened an issue just arrived in the mail to find revelatory new discoveries and concepts — things you immediately knew would forever change the science or the hobby? Now they rest quietly on old paper, like deep geologic layers supporting the busy and colorful, but thin, layer of the present that's accreting new material on top. We begin.

The 1940s: The 200-Inch

It is not given to us to know the fruits of what we do. So we must do them on faith, because good works occasionally pay off far beyond sight. If, in the 1930s and '40s, Charlie and Helen Federer hadn't taken one risky leap in life after another for the advancement of amateur astronomy and the popularization of science, the hobby and perhaps scientific literacy in America would not have grown as well as they did. Perhaps your own life would be less. The story of *Sky & Telescope*'s fluky, obsession-driven origin begins on page 22.

Flip open the first issue, November 1941, and on page 20 you see the hobby's embryonic backbone. Published there are Charlie's proposed founding documents for what would become the Astronomical League. Right from the start, he used the magazine to organize and grow the astronomy-club movement. And he used the resulting Astronomical League to grow the magazine. Having put the documents out for comment and input, he could then claim authority to implement them. Today the League includes 298 astronomy clubs and societies, while our entire worldwide listing (at **SkyandTelescope.com/astronomy-clubs-organizations**) has data on 2,155 clubs around the globe, many of them inspired by the League's examples.

Dipping elsewhere into the 1940s issues, we read the leading scientific thought on whether Mars is inhabited (conclusion: "we just do not know"). And we come across a report about an exciting new development: "Radar and Radio in Astronomy." To many readers, the concept of radio astronomy was new. Astronomy had always been about the narrow little bit of the spectrum spanning visible light, with slight extensions into the infrared and ultraviolet. But now, radio "noise of cosmic origin promises to become a fact-finder on Milky Way structure." In the decades to follow, readers had front-row seats on the slow opening of the entire electromagnetic spectrum to astronomy — bit by bit, here and there, from radio to the highest-energy gamma rays — something the current generation of astronomers takes for granted.

However, if you asked our readers at the end of the 1940s to pick the decade's biggest astronomical development, most would surely have named the brand-new, 200-inch (5-meter) Hale telescope on Palomar Mountain. It had twice the aperture of the world's previous largest telescope (Mount Wilson's 100-inch, dating from 1919), and it would hold the title until 1975. We had covered its construction every step of the way.

The 1950s: Dawn of the Space Age

With World War II over and America testing and improving upon captured German V2 rockets (the source of science fiction's iconic image of the finned rocket ship), a Space Age actually seemed within reach — at least to readers of literature like Willy Ley's *The Conquest of Space* (1951) and *S&T*. We reported extensively on rocketry and spaceflight planning in the 1950s.

The rest of the world suddenly awoke to the Space Age on October 4, 1957, when the Soviet Union launched the first artificial satellite, Sputnik 1. *S&T* readers were ready and waiting. Fred Whipple, just down the hall from our first office at Harvard Observatory, had already organized Operation Moonwatch worldwide. The program called for rows of observers with special wide-field telescopes to create "picket fences" of overlapping fields of view, to detect and record the paths of any orbiting

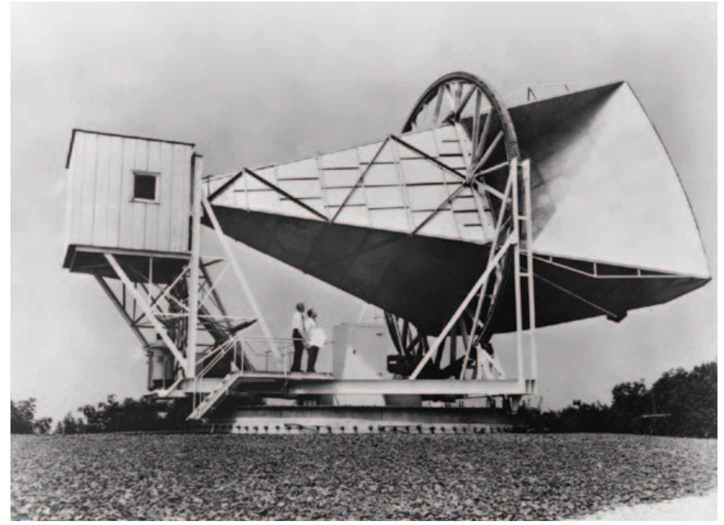
Above: When astronomers dedicated the Hale 200-inch telescope in 1948, the public was probably as excited as it was by the launch of the Hubble Space Telescope in 1990. A postage stamp honored the occasion.

In 1937 Grote Reber, an amateur astronomer and ham radio tinkerer, built the world's second radio telescope and the first that you'd recognize as such today. He hand-shaped its 31-foot paraboloidal dish and was the world's only radio astronomer for nearly a decade. Reber carried out an all-sky survey at 160 megahertz one big pixel at a time (after getting poor results at higher frequencies) and published many results in the early 1940s.

A replica of the 23-inch-wide Sputnik 1 hangs in the National Air and Space Museum. The only surviving part of the real Sputnik 1 is a small arming key, which was pulled out shortly before launch to start the satellite's radio transmitter.

A "picket fence" of satellite spotters in Pretoria, South Africa, uses Operation Moonwatch telescopes to chart the paths of any miniature new moons that might cross the sky.

NASA (2)

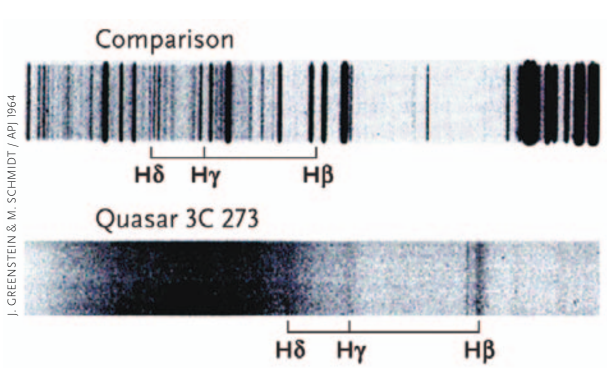


objects passing overhead. Thousands of amateur astronomers and other volunteers participated in this effort, and *S&T* covered their work in depth.

In early 1958, three months after Sputnik 1, the U.S. launched its own first satellite, Explorer 1. We reported on James Van Allen's discovery, using his detector aboard the spacecraft, of the Van Allen radiation belts surrounding Earth. They soon proved not to be the deadly blockade to space travel that some feared. Later that year the U.S. Congress established NASA.

Space and science education shot to the top of national priorities, driven by Cold War fears of the Soviet Union leaving the U.S. behind. Space was hot, astronomy was cool, planetariums opened in many cities, kids everywhere put solar-system posters over their beds, and *Sky & Telescope*'s future seemed assured.

Our readers already knew that Jan Oort was predicting a vast reservoir of distant comets orbiting the Sun in what would be called the Oort Cloud. A 1957 article set off a craze among amateur telescope makers for John Gregory's Maksutov telescope design.



J. GREENSTEIN & M. SCHMIDT / APJ 1964

The Maksutov Club quickly grew to 200 members. This is why you can buy compact Maksutovs today. Anton Kuttner submitted stunning lunar photographs that he took with an unobstructed, tilted-component 12-inch reflector, introducing *S&T*'s readers to the possibilities of tilted-component optical designs.

Large commercial telescopes were still too expensive for most people to afford. The amateur telescope making movement, led by *Scientific American* and *S&T,* democratized astronomy, drove down prices, and trained up the people who founded and staffed many of the telescope companies that we buy from today.

The 1960s: To the Moon!

The 1960s will forever be known as when America landed the first humans on another world. On July 20, 1969, as Apollo 11 astronauts Neil Armstrong and Buzz Aldrin prepared to step out of their lander, the science-fiction writer Robert A. Heinlein declared to CBS News anchorman Walter Cronkite, "This is the greatest event in all the history of the human race, up to this time. Today is New Year's Day of the Year One. If we don't change the calendar, historians will do so. This is our change . . . from infancy to adulthood of the human race."

Nope. For one thing, humans haven't again ventured beyond low Earth orbit since 1972. But it was a time when all sorts of great possibilities seemed near at hand. In 1960, Frank Drake turned centuries of speculation about civilizations among the stars into a scientific endeavor with his Drake Equation and Project Ozma, the world's

NASA / JPL

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first serious SETI experiment. *S&T* readers read Drake explaining his ideas before practically anyone else. Our readers had front-row seats on the birth of X-ray astronomy, the detection of neutrinos from the Sun's core, and the discovery that mysterious quasi-stellar radio sources, QSRS or "quasars," had redshifts that placed them at fantastic distances, meaning they had to be fantastically powerful. *S&T* readers were among the first to learn about the discovery of pulsars and had advance notice of the Leonid meteor storm of 1966.

In an even greater turning point, they learned that Arno Penzias and Robert Wilson had discovered a cosmic hiss of microwave radiation emanating from the entire celestial sphere. This was the predicted, brilliant white-light afterglow of the Big Bang itself, redshifted by a factor of 1,100 to microwave wavelengths by the subsequent expansion of space. The discovery tipped the scientific consensus into accepting that the universe truly had a Big Bang origin at a particular moment in time.

The 1970s: Black Holes

Human exploration of space dwindled in part because machines, expendable and far more economical, proved so good at it. In the 1970s and 1980s, readers followed Mariner flybys of Mars, Mariner 10 unveiling Mercury, the Soviet Union's Venera landings on Venus, and the long, epic missions of Voyagers 1 and 2 to Jupiter, Saturn, Uranus, and Neptune and their systems of moons.

The astronomical high note of the 1970s has to be the first successful Mars landers, NASA's Vikings 1 and 2, in the summer of 1976. After a lifetime of intense public yearning to know what Mars was really like, we saw the answer: barren deserts of rock and dust with no discernible trace of life, much less Martians. Once and for all the world grasped that we're alone in the solar system, and that there's no decent real estate beyond Earth. But *S&T* readers knew much earlier that this would be the case.

Every era has its particular astronomical fascination, and in the 1970s it was black holes. Physicists had only recently come around to the idea that such things could be physically real, rather than irrelevant mathematical quirks of Einstein's equations. In 1971 astronomers noted rapid X-ray variability in Cygnus X-1, a sign that extremely hot matter was cramming down onto an extremely small object. The tiny object was so massive, judging by its orbital effect on its giant companion star, that only a black hole would fit the bill. X-ray astronomers turned up more such systems that seemed to include "stellar mass" black holes. Others realized that matter accreting onto "supermassive" black holes offered the best solution to the mystery of quasars and active galactic nuclei.

A quirky visionary named John Dobson broke the rules of telescope making to popularize giant scopes on cheap, boxy altazimuth mounts: the Dobsonian reflector. He and his friends originally built them to show off the heavens to people in the sidewalks and parks of San Francisco. Dobsonians became hugely popular, and their large apertures opened up amateur deep-sky observing to a new degree. The 1970s also saw the popularization of the compact Schmidt-Cassegrain telescope, which quickly became as emblematic of the hobby as the refractor and reflector. To accompany the big new scopes, *Burnham's Celestial Handbook* to the deep sky appeared in installments and became a universal must-have.

In the winter of 1976, Comet West lit the morning sky. Readers

Top: Buzz Aldrin poses for photographer Neil Armstrong, seen reflected in Aldrin's visor. _Bottom:_ No one could make sense of quasar spectra until Maarten Schmidt realized, in 1963, that their emission lines (dark lines in this negative) were ordinary hydrogen lines extremely redshifted. Indicated above is where the lines would appear in a stationary comparison spectrum.

Arno Penzias and Robert Wilson stand under the Bell Laboratories Holmdel horn antenna (fully rotatable), with which they accidentally discovered the all-sky afterglow of the Big Bang.

No plants, no animals, no canal builders. In 1976 the Viking landers finally revealed Mars to be a bleak and barren desert. This was no surprise to planetologists and _S&T_ readers but a letdown to the many others who still held a bit of hope. Here, Viking 2 looks out on Utopia Planitia.

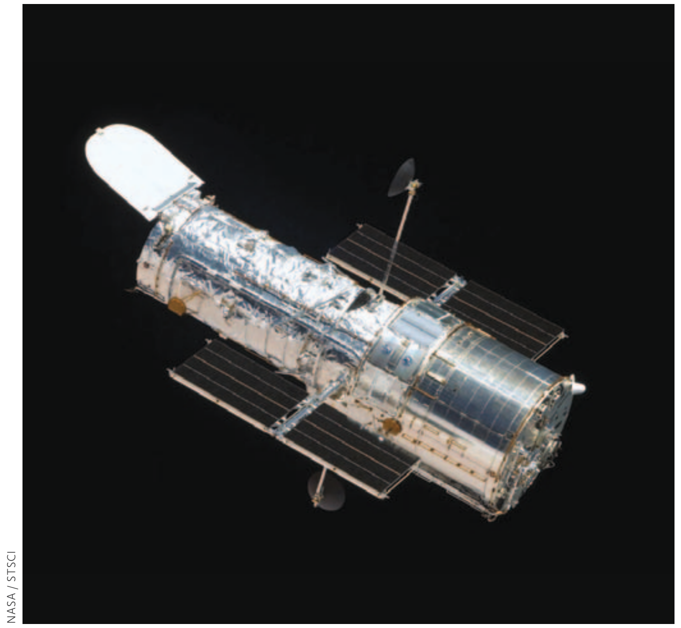
John Dobson aims a Dobsonian telescope — the 24-inch "Delphinium" of the San Francisco Sidewalk Astronomers — during a public astronomy event. Low-cost Dobsonians large and small soon became a central part of amateur astronomy.

NATIONAL ARCHIVES OF AUSTRALIA, A6135:11896739

Above: When Comet Halley was at its best in early 1986, naked-eye searchers found it only a little easier to detect than the Lagoon Nebula, M8 (the small pink patch far to the comet's right).

ESA / NASA HUBBLE

This Hubble image, taken 24 years after the explosion of Supernova 1987A, shows a faint, oblong debris remnant at center, a ring of much earlier ejecta shining under the impact of the supernova's still-expanding blast wave, and two larger, fainter rings of earlier ejecta. The three rings are part of an hourglass-shaped shell of gas blown off by the progenitor star as it neared the end of its life.



NASA / STSCI

The Hubble Space Telescope at work. Its 2.4-meter mirror was not very large by 1990s professional standards, but with no atmosphere in the way, it provided images with unprecedented resolution that wowed the world. Long before launch, we badgered its handlers to plan for and fully exploit the public's demand for the best possible astronomical imagery.

PHILIPP SALZGEBER / CC BY-SA 2.0

Comet Hale-Bopp hangs in the western twilight on March 29, 1997. To its lower right glows M31, the Andromeda Galaxy, roughly a match for Comet Halley as it appeared in 1985–86.

opened *S&T* to discover the finding of Pluto's big moon and the rings of Uranus. Cosmic gamma-ray bursts, first detected by satellites watching for nuclear weapons tests, became an intractable, but clearly important, puzzle. A binary pulsar losing orbital energy indirectly proved the existence of gravitational waves, another triumph for general relativity. The nature of the dark matter showing its influence all over the cosmos became a top problem. And in 1975, a network of clubs began the public-outreach tradition of Astronomy Day.

The 1980s: Halley

Public interest in astronomy took a permanent leap forward in 1980 with Carl Sagan's hit series *Cosmos* on public television. Less visibly, physicist Alan Guth that year had his "spectacular revelation" of how the Big Bang likely worked — whereby known physics could account for the eruption of everything from essentially nothing and explain several other "impossible" features of today's cosmos all at once. Writing about the emerging concept in my first big article after being hired at *S&T,* I came within a hair of inventing the term *multiverse* for the vastly larger ensemble of separate universes, now disconnected from ours, that the theory seemed to imply.

The first Space Shuttle, *Columbia,* launched in 1981. *Challenger* blew up in 1986. Halley's Comet, anticipated by everyone who'd had even a passing interest in astronomy since 1910, proved in 1985 and 1986 to be the distant, poorly placed dud that we had more or less predicted. At least our skilled chart-users could find it with their scopes to show to a disappointed public.

In February 1987, Supernova 1987A in the Large Magellanic Cloud erupted to magnitude 2.9; it was the closest and brightest supernova seen since before the invention of the telescope. A 13-second burst of neutrinos, detected at several places around the globe right about when the explosion should have initiated, confirmed that Type II supernovae result from the sudden collapse of a massive star's core.

The Very Large Array in New Mexico began full operation in 1980, opening today's era of high-resolution, multi-dish radio astronomy. The Dobsonian revolution continued to spread among amateurs. The price of large amateur scopes kept declining in real terms, undercutting amateur telescope making but rendering the hobby ever more accessible.

Alarmists predicted the imminent end of amateur astronomy if light pollution continued to worsen at the rate it was doing. But for the first time, night-sky enthusiasts began gaining the knowledge and organization to do more than wring their hands about it. In Tucson, Arizona, astronomers at Kitt Peak National Observatory met with startling success in getting the city to reduce its waste light beaming sideways and upward. This effort led to the founding of the International Dark-Sky Association in 1988. It's hard to remember back when the fight was hopeless, when most people ridiculed the notion of "light pollution," and when no one had heard of full-cutoff shielding for outdoor fixtures.

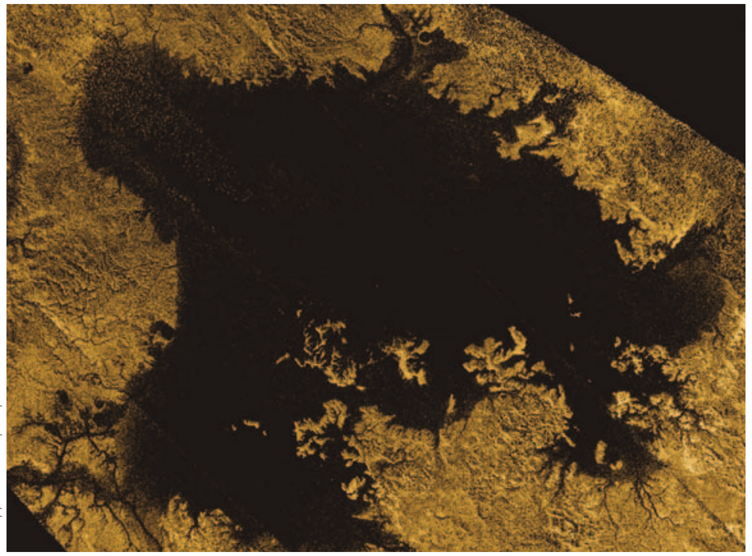
The 1990s: Hubble

The long-anticipated, long-delayed Hubble Space Telescope finally launched in 1990; *S&T* had covered the "Large Space Telescope" project since 1972. Our elation turned to horror when, once opened to the stars, its main mirror immediately proved to have been shaped to the wrong figure. The error was so gross that an amateur telescope maker could have spotted it with a homemade Foucault tester set up on a stepladder aimed at the mirror during the time it was in storage. Not for three years were astronauts able to install corrective lenses near the focal plane to allow the Hubble to see as well as designed. Today, after many other upgrades by visiting Space Shuttle crews and 23 years of spectacular productivity, the primary-mirror catastrophe is all but forgotten.

The 1993 repair mission was done just in time for Hubble to follow the fragments of Comet Shoemaker-Levy 9 as they dramatically dove into Jupiter in July 1994, one by one for several days. The impacts left such big, dark marks on Jupiter's cloudtops that you could see them with a 2.6-inch telescope, despite Jupiter's low altitude after dusk. The event dramatized the possibility of devastating impacts in today's solar system. It also revealed the power of the new World Wide Web. For the first time, many of our readers followed the news and pictures on screens rather than on paper.

We had all grown up being taught that the stars are so far away that we could never find any planets they might have. The abundance or scarcity of planets in the universe was one of the greatest unknowns of astronomy. Then in November 1995 came news that a European team had found a giant planet closely orbiting 51 Pegasi, a humdrum Sun-like star just west of the Great Square of Pegasus. They used spectroscopy to track the star's slight radial-velocity wobble induced by the orbiting planet. Teams raced to compete with this new method, and "extrasolar planets" became a new field of astronomy almost overnight. Today at least 3,493 are confirmed, and many more prospects seem likely to be real. The resulting statistics have answered the age-old question: *Most stars have planets.*

The title of "world's largest telescope" passed to the twin 10-meter Kecks atop Mauna Kea in Hawai'i, the first large telescopes with segmented mirrors. And two great comets finally made up for the disappointment of Halley. The eerie, green-headed, gas-rich Comet Hyakutake (C/1996 B2) whizzed close by Earth in the spring of 1996, with its long, straight gas tail spanning much of



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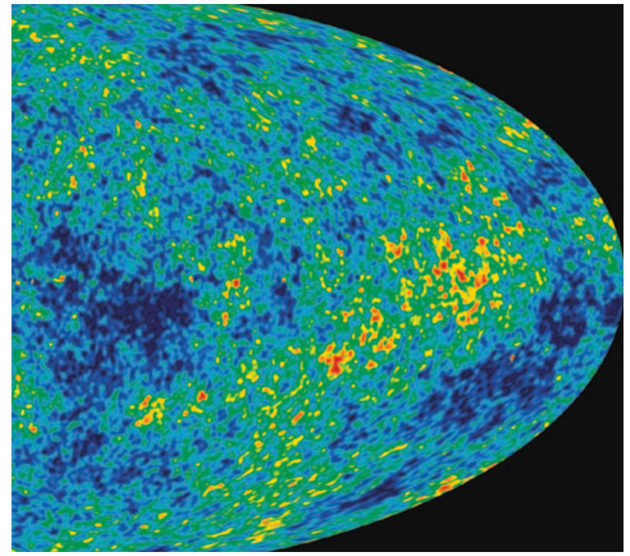

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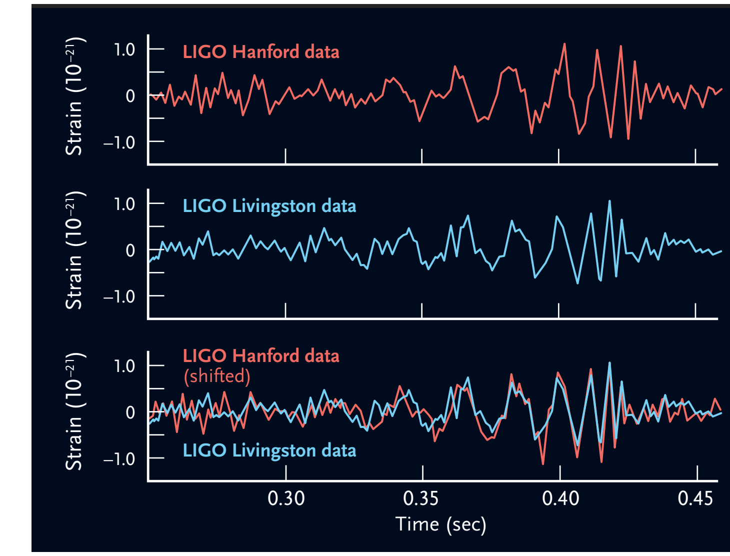


S&T: LEAH TISCIONE; SOURCE: CALTECH / MIT / LIGO LAB

the sky for a few nights. The next spring Comet Hale-Bopp shone in the west after dusk, the classic portrait of a bright comet with a curved, dust-rich tail.

The 2000s: Precision Cosmology

The exploration of the solar system continued with Mars orbiters and rovers, missions to asteroids and Comet Tempel 1, Messenger unveiling more of Mercury, and Cassini taking up orbit around Saturn. Cassini's hitchhiking Huygens lander descended through the thick hazes of Titan to find a landscape of riverbeds and methane mudflats. Among Cassini's many other revelations (which continue today), some of the most outstanding are Titan's weather cycle and great polar lakes of methane (liquified natural gas), water-powered geysers spraying out of Enceladus, and the ongoing dynamical intricacies among Saturn's rings.

Astronomers started discovering large Kuiper Belt objects, including an especially big one, Eris, that prompted the 2006 demotion of Pluto to dwarf-planethood. Regarding a supermassive black hole in the center of our own Milky Way, we declared "case closed"; no other explanation remained possible for what was going on there. In 2003, *Columbia* disintegrated with the loss of all on board. The Kepler space observatory launched in 2009, beginning the second wave of exoplanet discovery and analysis — based not on radial-velocity wobbles, but on transits of luckily aligned planets across their stars.

On the grandest scale of all, the 2000s were when "precision cosmology" came of age. NASA's Wilkinson Microwave Anisotropy Probe (WMAP) mapped the afterglow of the Big Bang well enough that cosmologists could finally pin down key cosmic parameters with high accuracy. For instance, the Big Bang happened 13.8 billion years ago. Everything about the universe — including the origin of galaxies, galaxy clusters, and the largest cosmic structures of galaxy strings and walls — proved to be an essentially perfect match for the inflation process behind the Big Bang. As most recently refined, the cosmos consists of 4.9% normal matter (stuff made of atoms and atomic particles), 26% dark matter made of something else unknown, and 69% "dark energy," the whimsical name given to a completely inexplicable property of space itself that's causing the expansion of the universe to speed up. Coincidentally, the expansion speedup had already just been discovered, totally unexpectedly, in 1998.

Add it all up and it comes to just the right total density of matter plus energy — to about 0.5% accuracy at this point — to render space flat and infinite, as predicted by the inflation theory. This, in turn, has made the issue of a multiverse, something thoroughly outlandish to many scientists, more pressing.

The 2010s: What Next?

So far, the new decade of *S&T* has seen Messenger take up orbit around Mercury, Dawn orbit the big asteroid Vesta and then move on to Ceres, the Curiosity rover crawl up the slopes of Mount Sharp on Mars, and, just this July, Juno reach Jupiter orbit. Voyager 1, at more than twice the distance of Pluto, finally left the solar system's heliosphere of solar wind and entered true interstellar space.

The European Space Agency's Planck mission, successor to WMAP, refined precision cosmology and, unexpectedly, played a key role in astronomy's biggest goof in a very long while. In March 2014 a team based at Harvard announced that their experiment at the South Pole, known as BICEP-2, had found the Holy Grail of cosmic microwave background studies. Slight patterns of polarization in the microwaves, they announced, seemed to be relics of the instant of Big Bang inflation itself — patterning the sky with fantastically magnified images of individual gravitons seen some 10^{-35} second after our Big Bang budded off from. . . what? Perhaps an eternally inflating, superdense matrix that exists *outside*, spawning multiverses. This would have been inflation's smoking-gun proof. It was our July 2014 cover story.

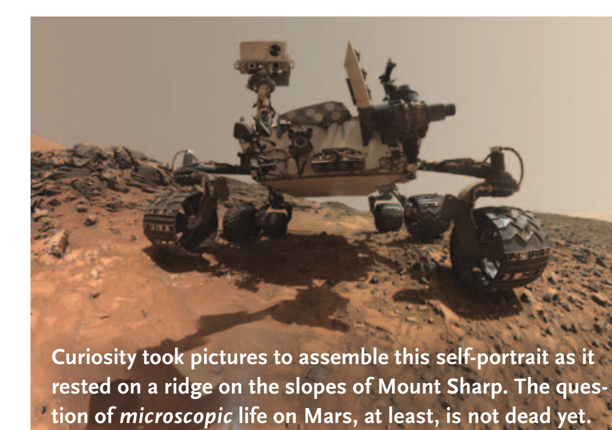
Alas, the team had relied on a map displayed at a conference by the competing Planck team, which seemed to show that the part of the sky the BICEP team was watching had no foreground dust to mimic the polarization signal. They'd misinterpreted the Planck map; dust was indeed present and could account for the entire observed signal. So it was back to square one. Deeper and better searches for the polarized inflation signal are under way.

New Horizons flew past Pluto and its bevy of moons on July 14, 2015, returning images of an inexplicably active world, with young, craterless plains of soft nitrogen ice, nitrogen glaciers, and signs of a thick atmosphere in the recent past (see page 18). Little Pluto, the non-planet, was getting the last laugh.

And in the 100th anniversary year of general relativity, LIGO caught gravitational waves from the merger of two black holes far across the universe. The new field of gravitational-wave astronomy promises a bright future.

What unexpected cosmic revelations will the rest of the decade, and the century, bring? We don't know, but we will, and we'll be telling you all about them. ✦

Alan MacRobert has worked at Sky & Telescope *for 34 of its 75 years and has been reading it for 50.*



Curiosity took pictures to assemble this self-portrait as it rested on a ridge on the slopes of Mount Sharp. The question of *microscopic* life on Mars, at least, is not dead yet.

NASA / JPL-CALTECH / MALIN SPACE SCIENCE SYSTEMS / JAMES SORENSON

Above: **Titan's Ligeia Mare is about 500 kilometers (300 miles) wide. In this composite radar image from Cassini, the rough uplands of bedrock-hard water ice are tinted yellow. The methane sea and flooded river canyons reflect no radar back to the spacecraft, except for a little from the seabottom in shallow edges.**

Part of WMAP's final (9-year) all-sky map showing temperature differences in the cosmic microwave background radiation. From red to blue, its temperature at different points on the sky differs by only a few parts per hundred thousand.

Pinpoints no more, Pluto and Charon revealed their unexpectedly youthful glories to New Horizons during its flyby in July 2015. The craft is now on its way to fly past the smaller Kuiper Belt object 2014 MU_{69} on January 1, 2019.

Top: **On September 14, 2015, the twin LIGO detectors in Hanford, Washington, and Livingston, Louisiana, detected the death-chirp of two black holes spiraling together, with waveforms that exactly matched predictions. The detections came 7 milliseconds apart — the difference in light-travel time.**