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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ MAY 23, 2009

SPECIAL ASTRONOMY ISSUE

Time travel at the speed of a 1935 Speedster?

The 1930s brought unprecedented innovation in machine-age technology and materials. Industrial designers from the auto industry translated the principles of aerodynamics and streamlining into everyday objects like radios and toasters. It was also a decade when an unequaled variety of watch cases and movements came into being. In lieu of hands to tell time, one such complication, called a jumping mechanism, utilized numerals on a disc viewed through a window. With its striking resemblance to the dashboard gauges and radio dials of the decade, the jump hour watch was indeed "in tune" with the times!

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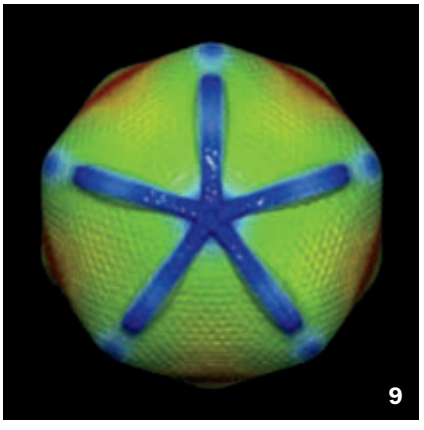

ScienceNews

In The News

Special Section

YEAR OF ASTRONOMY

Departments

COVER A 1925 issue of *Le Petit Inventeur* shows youths exploring the night sky. *Original photograph: Stefano Bianchetti/Corbis; Photo illustration:* Science News

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FROM THE EDITOR

Celebrating astronomy's illumination of the mind

Astronomy is a special science.

As the French mathematician Henri Poincaré observed more than a century ago, it was astronomy that inspired the origins of science in general. In ancient times, people observing the night sky saw that its "multitude of luminous points is not a confused crowd wandering at random, but a disciplined army," he noted. Such observations provided a clue that nature's chaos concealed order that humans could discern. It was astronomy, in other words, that taught humankind that the world obeys natural laws that people are capable of discovering.

"Under heavens always overcast and starless, the Earth itself would have been for us eternally unintelligible," Poincaré wrote in *The Value of Science*. "The stars send us not only that visible and gross light which strikes our bodily eyes, but from them also comes to us a light far more subtle, which illuminates our minds," he observed. "Astronomy ... has given us a soul capable of comprehending nature."

That lesson is sometimes lost in the glare of hoopla surrounding the dramatic revelations of telescopes small and large, from Galileo's handheld tube to the orbiting observatory named for Edwin Hubble. Still, the 400th anniversary of Galileo's telescope fully warrants this year's International Year of Astronomy celebrations. Galileo's work, as the award-winning science writer Dava Sobel articulates so clearly (Page 16), opened science's eyes to the vast diversity of wondrous phenomena that telescopes can reveal. In that tradition, astronomers today contemplate truly cosmic questions about the universe's origin, its contents, its future, and the prospects for life beyond Galileo's home planet, as Ron Cowen describes (Page 22). Solutions to some of those mysteries may come from the future successors to Galileo's original technology, surveyed by Janet Raloff (Page 30).

All this attention to astronomy stems from its attachment to the curiosity infused in the human spirit, not from practical uses like those expected from other sciences. Not that astronomy is useless — historically, it has been fertile with applications, from aiding the earliest calendar makers to navigation guides for ships in the dark. But mostly astronomy's usefulness is not its applications, but its inspiration. "Astronomy is useful," Poincaré wrote, "because it raises us above ourselves."

—Tom Siegfried, Editor in Chief

Statistical Patterns Reveal the World's Laws

How likely is it that a poll is correct? Which hospital has the best outcome for a given procedure? When is it a good idea to buy a product's extended warranty? In today's data-driven society, it's more important than ever to understand statistics. Now you can with **Meaning from Data: Statistics Made Clear**. A uniquely accessible introduction to the principles and methods of statistics, this entertaining course will both intrigue and delight you.

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Scientific Observations

We've created a "perfect storm" for viruses. And we'll continue to see — as we have in the past few years — a whole range of new animal diseases as outbreaks in human populations. But we have to stop being surprised by them. Right now, global public health is like cardiology in the '50s — just waiting for the heart attack, without understanding … the many ways to monitor for them, detect them early and ultimately prevent them. Swine flu is not an anomaly. We know that swine flu — like the vast majority of new outbreaks — comes from animals. We should be monitoring those animals and the humans that come into contact with them, so we can catch these viruses early, before they infect major cities and spread throughout the world.

— NATHAN WOLFE, STANFORD UNIVERSITY BIOLOGIST AND DIRECTOR OF THE GLOBAL VIRAL FORECASTING INITIATIVE, IN AN INTERVIEW AT BLOG.TED.COM

Science Past | FROM THE ISSUE OF MAY 23, 1959

NUCLEAR-POWERED BLIMP — America's first nuclear-powered aircraft could very well be a huge blimp, about three times the size of those now being used by the U.S. Navy for submarine and plane spotting.... The blimp's length would be 540 feet, making it possible to locate the atomic reactor far enough away from the craft's control car to permit personnel to work in an environment comparable to that of an atomic plant.... Security requirements, the officials said, prevent disclosure of the airship's detail and the extent of its shielding.

Science Future

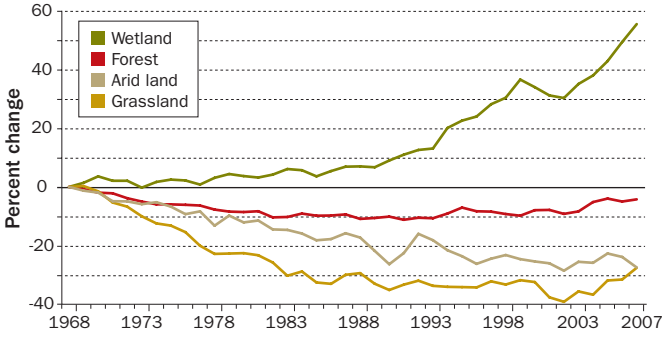
June 4–6
Organization for the Study of Sex Differences annual meeting in Toronto. See www.ossdweb.org

June 6
The annual Galaxy Ball held in Arlington, Va. See www.foge.org

July 22
Get to eastern Asia to watch the total solar eclipse. Visit eclipse.gsfc.nasa.gov

Science Stat | STATUS OF U.S. BIRDS

PERCENT CHANGE IN U.S. BIRD POPULATIONS BASED ON TRENDS FOR SOME SPECIES IN FOUR MAJOR HABITATS, 1968–2007



SOURCE AND GRAPH: THE STATE OF THE BIRDS REPORT 2009, WWW.STATEOFTHEBIRDS.ORG

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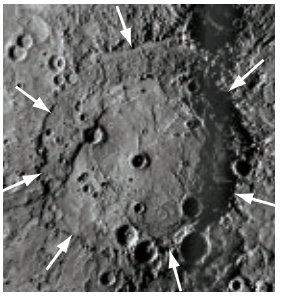
ATOM & COSMOS

The MESSENGER spacecraft sleuthed more clues about Mercury, including views of its second-largest known crater (below) and details of the planet's magnetic interactions with the sun. Read "MESSENGER's second pass."



LIFE

Scientists recovered what they believe to be collagen, bone cells and other soft tissue from the remarkably well-preserved fossil of an 80-million-year-old hadrosaur. Read "Soft tissue from a dino fossil."

For Daily Use

Chewing sugarless gum throughout the afternoon can curb consumption and craving of sweets and make people feel more energetic and alert through the p.m. doldrums, scientists reported April 19 at the Experimental Biology meeting in New Orleans. The new study was funded, natch, by the Wrigley Science Institute, a research arm of the chewing gum company. Participants were asked to periodically chew sugarfree gum during a three-hour stretch after lunch one day. Researchers found that, on average, chewers ate some 60 fewer calories of sweets in the mid-afternoon, when compared with a gum-free day. Chewers also reported feeling steadier energy levels during the afternoon, versus flagging levels on the day without gum.

CLOCKWISE FROM TOP LEFT: TED/ASA MATHAT; T. WATTERS *ET AL./SCIENCE*/AAAS; PHOTO ILLUSTRATION BY J. KORENBLAT, SOURCE: BELKNAP/ISTOCKPHOTO

“Gliese 581 is a truly fascinating exoplanet system.... It is like a gift that keeps on giving.” —SARA SEAGER, PAGE 11

In the News

STORY ONE

Males, females swap sex-role stereotypes

Analysis finds that mating strategies are not universal

By Bruce Bower

A new cross-cultural study finds that men and women in monogamous societies, such as Pitcairn Islanders (left), and some polygynous societies, including the Aka in the Central African Republic (right), have overlapping ranges of number of offspring.

LUIS MARDEN/*NATIONAL GEOGRAPHIC*/GETTY; BARRY HEWLETT

Chuck that nonsense about “men are from Mars, women are from Venus.” Here on Earth, the sexes play the mating game with a flexible set of rules. A new study suggests that scientists should abandon the idea that males evolved to be promiscuous and females to be selective.

Combined data from 18 modern and traditional societies show greater overall variation in reproductive success for men than for women—with some men producing lots of children with multiple partners and other men conceiving few or no children, say psychologist Gillian Brown of the University of St. Andrews in Fife, Scotland, and her colleagues. Women tend to have a handful of children.

In the past, researchers have treated this pattern as a sign of universal mating tendencies, with women limiting how many children they bear and men conceiving as many children as possible.

Yet the same pattern of distinctive male and female sex roles doesn’t appear when many of these same 18 societies are examined individually, Brown’s group reports in the June *Trends in Ecology & Evolution*. In monogamous societies and even in some polygynous ones, where men can have more than one wife or mate, men and women can have similar variation in the number of children they produce, the scientists find.

Monogamous societies in the new study included Pitcairn Islanders in the South Pacific, Dobe !Kung hunter-gatherers in southern Africa and 19th century Swedes. Polygynous societies displaying comparable or only slightly unequal patterns of reproductive success for men and women included Aka hunter-gatherers in central Africa, Hadza hunter-gatherers in southern Africa and nomadic Yomut Turkmen in Iran.

Looking at the data all together, patterns of reproductive success were skewed by data from a few polygynous societies in which small numbers of men conceived the bulk of the offspring, the researchers contend. Examples of this pattern came from the Dogon and Kipsigis, both in Africa.

“Half of the populations we studied had similar variations in male and female reproductive success, which is inconsistent with universal stereotypes of passive, discriminating females and promiscuous males,” Brown says.

These scientific generalizations originated with fruit fly studies conducted by English geneticist Angus Bateman in 1948. He reported that male flies exhibited greater variation than females in numbers of sexual partners and offspring. Females mating with several males showed less of an increase in the number of offspring than males mating with many females.

Bateman concluded that it was more costly for females to produce a single egg than for males to produce a single sperm, leading to “discriminating passivity” among female flies and “undiscriminating eagerness” among male flies.

But in the past decade or so, studies of fruit flies and other animals have documented considerable variation in numbers of sexual partners and offspring for both sexes. Situational factors shape animals’ mating decisions, Brown asserts. Investigations suggest that females

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often get choosy when outnumbered by males or required to raise offspring alone. Males become picky when outnumbered by females or when required to help raise offspring. In small, spread out populations with roughly equal numbers of males and females, both sexes tend to mate indiscriminately.

Brown and her colleagues provide initial evidence that the "astonishing flexibility" of mating strategies also applies to people, remarks behavioral ecologist Stephen Emlen of Cornell University.

"A lot of nonhuman animals that are thought of as innately controlled robots actually perform sophisticated cost-benefit analyses of different choices and adjust their behavior based on flexible rules of thumb," asserts Emlen, who studies mating decisions in birds. Emlen says it would be surprising if people didn't have even more variable mating strategies than other animals.

Anthropologist Lee Cronk of Rutgers University in New Brunswick, N.J., says that he hopes the study "will have a major impact on future evolutionary work on human mating patterns."

Cronk still thinks that universal mating strategies exist for men and women and were genetically ingrained during the Stone Age. But these strategies can play out in a variety of ways depending on the cultural, social and demographic features of modern societies.

Brown sees the situation differently. Disparities in learned mating strategies and cultural beliefs that have developed among groups over the past 50,000 years or so have also led to genetic differences among those populations, not to universal mating tendencies, she suspects.

Brown's group analyzed information on reproduction and mating in hunter-gatherer, farming and industrialized societies from already published studies. Although these studies depended on women's reports of who fathered their children, Brown regards the reliability of such evidence as comparable between monogamous and polygynous societies.

Scientists must now try to estimate and compare numbers of sexual partners, as well as offspring, for individuals in different societies, she says. Doing so will be challenging, since attempts to establish the numbers of sexual partners for men and women have relied on self-reports that are unreliable, Brown asserts.

She and her colleagues remain cautious about assuming that men always have more sexual partners than women in polygynous societies. In about half of polygynous societies, most men still take no more than one wife, they note. In others, women as well as men conceive children with two or more partners.

Thorough cross-cultural studies would likely reveal a great variety of mating strategies that respond to local conditions, predicts behavioral ecologist Mhairi Gibson of the University of Bristol in England. "Unfortunately, few anthropologists continue to collect such quantitative data on human behavior," she says. ■

Mating strategies take many forms

New data from a variety of societies question assumptions that sex roles are universal

Country	Population/ ethnic group	Ratio of variability in reproductive success, men to women*	Mating system
Iran	Yomut Turkmen	1.14	Polygyny/monandry
Sweden	1825–1896 genealogies	1.18	Monogamy
U.S.	General social survey	1.27	Monogamy
Central African Republic	Aka	1.66	Polygyny/monandry
Botswana	Dobe !Kung	1.77	Serial monogamy
Paraguay	Ache	4.22	Serial monogamy
Mali	Dogon	4.75	Polygyny/serial monandry

*Higher numbers indicate more variability among men than women within a group

Back Story | LET'S TALK ABOUT SEX ROLES, IN THEORY

1871
Charles Darwin proposes his theory of sexual selection, arguing that members of each sex within a species compete for resources and display traits most valued by mate-seeking members of the opposite sex. The evolution of the male peacock tail is a classic example.

1948
Geneticist Angus Bateman reports that male fruit flies that mate with more partners conceive more offspring, while female fruit flies show lesser gains when they mate with more partners. He concludes that sexual selection should favor promiscuous males and discriminating females.

1972
Evolutionary biologist Robert Trivers, now of Rutgers University, elaborates on Bateman's idea by predicting that members of the sex that make the largest investment in parenthood, usually female, become a relatively scarce quantity on the mating scene. Thus males usually compete for females.

1981
Anthropologist Sarah Blaffer Hrdy challenges Trivers' perspective by arguing that females of some species, including the langurs she studied, benefit from mating with many males. This strategy increases uncertainty about who fathered whom and reduces the likelihood of infanticide by males, as well as boosting the probability of getting pregnant.

TABLE ADAPTED FROM BROWN *ET AL.*; IMAGES FROM LEFT TO RIGHT: BKINDLER/ISTOCKPHOTO; REPRODUCED WITH PERMISSION FROM JOHN VAN WYHE, ED., THE COMPLETE WORK OF CHARLES DARWIN ONLINE (DARWIN-ONLINE.ORG.UK); JANEFF/ISTOCKPHOTO; JOHN INNES ARCHIVES, COURTESY OF THE JOHN INNES FOUNDATION; AJPHOTO/ISTOCKPHOTO; NICK ROMANENKO/COURTESY RUTGERS UNIV.; SERENGETI130/ISTOCKPHOTO

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Life

For videos of Snowball bopping to the Backstreet Boys, visit **www.sciencenews.org/life/birds-bust-a-move**

Birds bust a move to musical beats

Studies suggest vocal mimics have a flair for moving in time

By Bruce Bower

Don't begrudge Snowball his hankering for boy bands. The sulfur-crested cockatoo with a spiky haircut bobs his head, sways his body and stomps his feet in time to the beat of pop songs such as the Backstreet Boys' "Everybody."

Two new studies, published online April 30 and slated to appear in *Current Biology*, indicate that he and other parrots can synchronize rhythmic movements to musical beats. Until now, most researchers thought that only people align physical movements to timed sounds, a phenomenon known as entrainment.

"This is the first evidence that there could be an animal model of rhythm perception in music," says neuroscientist Aniruddh Patel of the Neurosciences Institute in San Diego, who directed one of the new investigations.

Patel proposes that brain circuitry for vocal learning gets co-opted to support musical-beat perception and synchronized movements to music: Animals that can imitate sounds can also move in time to a beat, but animals that can't imitate sounds can't keep the beat.

Music's origins remain a mystery. Some regard music as a pleasurable by-product of other mental skills, such as language. Others suspect music arose as an evolutionary adaptation to Stone Age life, perhaps to promote social cohesion.

"Even if entrainment emerged as a by-product of vocal mimicry, other parts of music perception and cognition may easily be adaptive," says Harvard University's Adena Schachner, a psychology graduate student who directed the other new study.

Evidence of what amounts to a kind of dancing to music by at least some parrot species "comes as a big surprise," remarks W. Tecumseh Fitch of the University of St. Andrews in Fife, Scotland.

In experiments conducted by Patel and his team, Snowball listened to "Everybody." As the music sped up or slowed down across a range of tempos on different trials, Snowball frequently adjusted his dancing to stay synchronized to the beat, Patel says.

Schachner's group played familiar and unfamiliar musical pieces to Snowball, to an African gray parrot named Alex (before his death in 2007) and to 50 human volunteers. The birds synchronized their movements about as well as volunteers tapped a button. The researchers then analyzed thousands of YouTube videos showing hundreds of animal species moving to music. Signs of entrainment to a beat appeared only in vocal mimics, represented by 14 parrot species and Asian elephants that moved their trunks or legs in time with music.

Patel suspects that, as with people, some parrots have rhythm to spare and others can't pick up a beat with a forklift. Snowball's dancing, it seems, has more in common with boy band *NSYNC.

Oops, botanists missed that tree

Newly found acacia common in Ethiopia's Ogaden region

By Susan Milius

Botanists couldn't see the forest or the trees. An acacia in eastern Africa that grows up to 6 meters tall and dominates the landscape across an area almost three times the size of Rhode Island is new to science.

"It's astounding," says David Mabberley of the Royal Botanic Gardens in Kew, England. He summarizes the findings in the April 24 *Science*, though the tree was officially named *Acacia fumosa* in the *Nordic Journal of Botany* in September 2008.

Finding a new species in itself isn't such a surprise. Scientists describe and give Latin names to some 10,000 new organisms a year. About 2,350 of these are flowering plants, with a new one from Africa appearing on average every weekday. What is surprising is that no specimens or botanical mentions of the new acacia existed even though it's so widespread, says Mats Thulin of Uppsala University in Sweden, who named the plant.

Thulin says few botanists have explored the acacia's home in Ethiopia's Somali National Regional State, or Ogaden. The sparse population of the region is mostly ethnic Somali, he says. The Ogaden National Liberation Front is fighting for independence and has made traveling to the region perilous. Thulin, who spent 18 years as editor of *Flora of Somalia*, made a trip to the area for the first time in 2006.

A recently discovered tree now named *Acacia fumosa* (shown) dominates thousands of square kilometers of the limestone hills in eastern Africa.

M. THULIN

Almost immediately, Thulin says, he recognized the acacia as an unknown species. It has unusual smooth, gray bark and bursts into pink, sweet-smelling blooms during the dry season.

With a bit of travel and some help from Google Earth, Thulin realized how widespread the acacia is in its arid habitat. The tree provides vegetation in a landscape too dry for perennial grasses.

Genes & Cells

For longer versions of these and other Genes & Cells stories, visit **www.sciencenews.org**

Yeast bred to bear artificial vanilla

Scientists co-opt fungi to produce flavor more efficiently

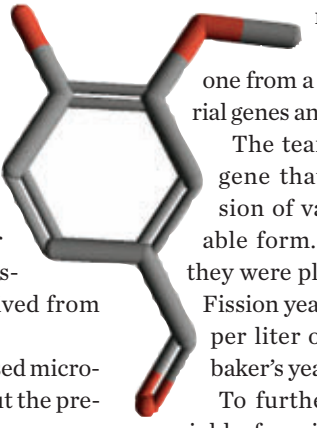
By Rachel Ehrenberg

A jug of wine, a loaf of bread and now, vanilla.

Yeast has long been pressed into service for making food and drink, and now scientists have recruited the fungus for a loftier flavor: vanillin, vanilla's dominant compound. Scientists report in the May *Applied and Environmental Microbiology* that they have engineered two strains of yeast to produce vanillin from glucose, a greener and cheaper route than previous methods.

"This is absolutely beautiful work," says John Rosazza, a medicinal and natural products chemist at the University of Iowa in Iowa City. There is a huge market for vanillin, Rosazza says.

Vanillin is the dominant compound of the hundreds that are found in vanilla—an extract from the seed-bearing pods, called beans, of orchids in the genus *Vanilla*. But real vanilla beans are precious, rare and costly. Today, less than 1 percent of the vanillin sold each year is derived from the orchids. The majority is synthesized in chemistry labs, and typically made from lignin, a constituent of wood left over from the paper-making industry, or guaiacol, which is derived from wood creosote.



Two species of yeast have been engineered to make vanillin (right), the dominant flavor compound in vanilla.

Scientists previously have used microorganisms to make vanillin, but the precursors are expensive and the process involves environmentally unfriendly chemicals, says Jørgen Hansen of Evolva Biotech's Copenhagen office. Also, vanillin itself is toxic to many microbes.

Now Hansen, Birger Lindberg Møller of the University of Copenhagen and colleagues have created a chemistry lab within two different species of yeast growing in flasks: *Schizosaccharomyces pombe*, also known as fission yeast, and *Saccharomyces cerevisiae*, baker's or brewer's yeast. Instead of using the typical, expensive starting material, the team turned to glucose, a cheap and available sugar. To make the yeast convert the glucose to vanillin, the team added genes that encode for specific enzymes that spur the biochemical reactions. These genes included versions of one from a dung mold, two bacterial genes and a human gene.

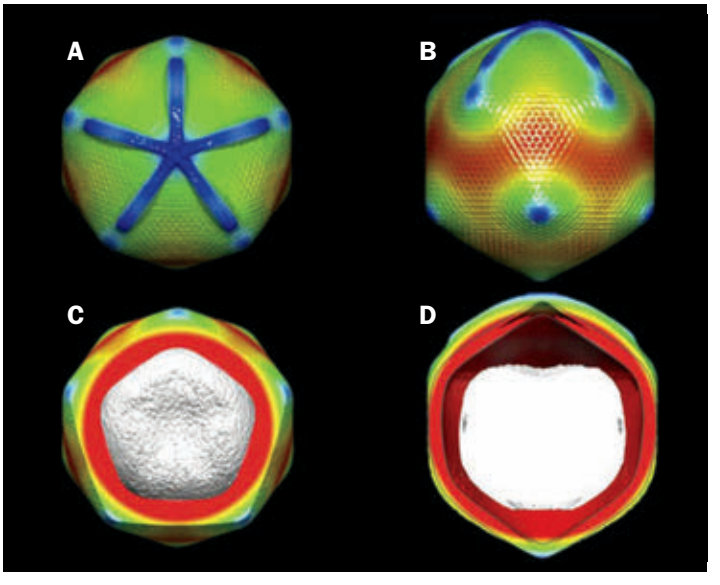
The team also knocked out a gene that directs the conversion of vanillin to an undesirable form. The researchers say they were pleased with the yields: Fission yeast made 65 milligrams per liter of liquid in the flasks, baker's yeast 45 mg/l.

To further increase the yeast yield of vanillin, the researchers added an additional gene that encodes for an enzyme that converts the straight vanillin into a form with a sugar attached, vanillin beta-D-glucoside. This form isn't toxic, says Møller, allowing the yeast to hold more of the compound. Both the straight and sugar-laden vanillin could be used in foods and perfumes.

While synthetic vanillin doesn't offer the rich flavors of true vanilla, the artificial form has its place, says Daphna Havkin-Frenkel, director of research and development at Bakto Flavors in Rutgers, N.J.

A good look at mimi

Scientists have zoomed in on mimivirus, the enormous virus with the delicate name that has perplexed researchers since its discovery in 1992. Its size (its diameter is more than 10 times that of the virus that causes the common cold) and its hodgepodge of genetic and structural traits blur the line of what is alive, says Michael Rossmann of Purdue University in West Lafayette, Ind. Rossmann and an international team report the results of their reconnaissance online April 28 in *PLoS Biology*. Cryo-electron microscopy images reveal the details of a starfish-shaped structure (A, B) that covers an opening in the virus coat through which DNA might be expelled when the virus infects a host. The DNA is enveloped in a membrane, seen in gray in reconstructed renderings (C, D). The new work may help scientists understand if and how the virus could cause disease. —*Rachel Ehrenberg*



BOTTOM: XIAO *ET AL.*/*PLOS BIOLOGY* 2009

Humans

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DNA comparison of Africa's ethnic groups quantifies genetic diversity

Differences could reveal details of modern human origins

By Solmaz Barazesh

The largest genetic study of African populations reveals a greater diversity among the continent's cultural groups than previously known, scientists say. The study also offers insight into the origins of modern humans and the ancestry of African-Americans, researchers said in an April 29 teleconference and in a paper posted online April 30 in *Science*.

Until now, most genetic surveys of this type have used data from just a few African groups assumed to reflect Africa's genetic diversity. But the new research shows that "no single African population is representative of the diversity of the continent," says study coauthor Sarah Tishkoff of the University of Pennsylvania in Philadelphia.

Tishkoff and her colleagues analyzed particular DNA sequences — series of the chemical letters that encode genetic information — from more than 3,000 people from 121 different populations scattered throughout Africa. Researchers divided the participants based on self-identified ethnic groups.

To reach remote groups, such as the Pygmies of Cameroon and the hunter-gatherers of Tanzania, researchers drove off-road and set up makeshift labs with equipment powered by their car battery.

"This is by far the most in-depth analysis in terms of the number of populations analyzed," comments evolutionary geneticist Mark Stoneking of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany.

The researchers found that the genetic sequences were highly diverse from one population to the next. "We knew that African populations were diverse in culture, art, religious ideas," says Roy King of Stanford University School of Medicine. "Now we see that genetic diversity goes along these same lines."

Because modern humans originated in Africa, there has been more time for changes to accumulate in the African DNA sequences than there has been in sequences from people in other parts of the world, Tishkoff says.

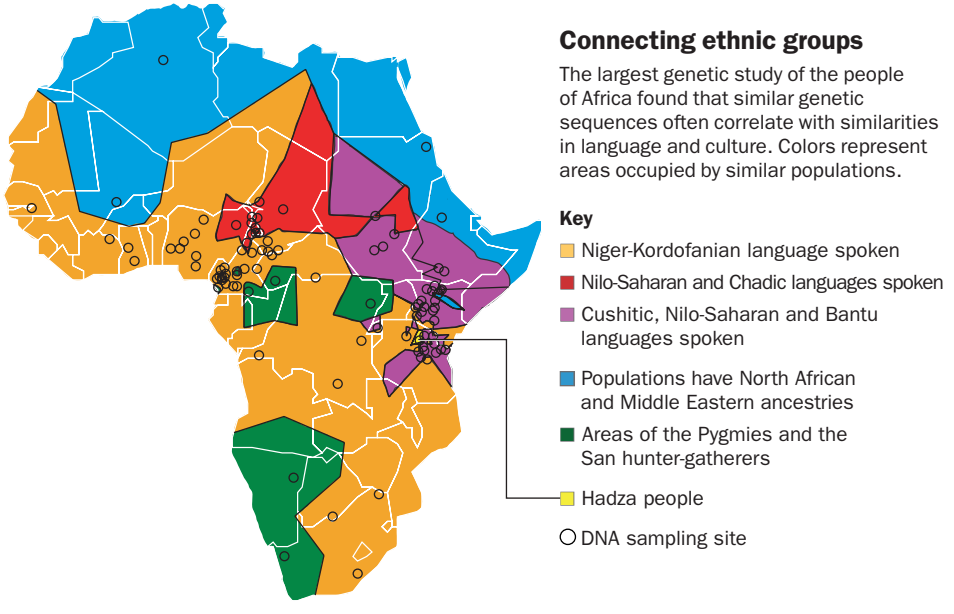
It turns out that the San bushmen of southern Africa have the most distinct, and therefore oldest, genetic sequences, the team reports. Researchers theorize that the San homeland could be the spot where modern humans began their exodus from Africa to the rest of the world. This location, near the coastal border of Namibia and Angola in southwestern Africa, fits with previously proposed sites of the out-of-Africa migration. But the scientists note the area could just be where the San settled most recently.

Tishkoff and her colleagues also found that some sequences were relatively similar across various populations, often correlating with similarities in culture and language. These patterns serve as "genetic footprints" revealing the past migration of different groups around the continent. Somewhat similar groups — such as three hunter-gatherer groups now living in different parts of Africa, but who all speak languages that incorporate click sounds — probably shared common ancestors, the scientists say.

Genetic information from African-Americans living in three U.S. cities and an additional state was also collected and analyzed. On average, African-Americans inherited 71 percent of their DNA from western Africa, 8 percent from other locations in Africa and 13 percent from Europe, the team says. Most of the African-Americans in the study had mixed ancestry from different regions of western Africa, which made tracing ancestry to particular ethnic groups difficult, Tishkoff says.

The researchers are quick to point out that the data set is incomplete. "We analyzed 121 populations out of a possible 2,000," Tishkoff says. Details of the analysis are sure to change as more information becomes available, but the study is a good starting point, the researchers say.

"We're hoping to provide a framework for others to build on," Tishkoff says. ■



Connecting ethnic groups

The largest genetic study of the people of Africa found that similar genetic sequences often correlate with similarities in language and culture. Colors represent areas occupied by similar populations.

Key

- Niger-Kordofanian language spoken
- Nilo-Saharan and Chadic languages spoken
- Cushitic, Nilo-Saharan and Bantu languages spoken
- Populations have North African and Middle Eastern ancestries
- Areas of the Pygmies and the San hunter-gatherers
- Hadza people
- DNA sampling site

FLOYD A. REED, TISHKOFF *ET AL.*/*SCIENCE*/AAAS

Atom & Cosmos

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Exoplanets keep getting smaller

Object orbiting red dwarf may be as light as 2 Earths

By Ron Cowen

Inching ever closer to the goal of discovering a planet just like home, astronomers have found the smallest extrasolar planet ever detected. A mere 20.5 light-years away, the object could be as tiny as 1.9 Earth masses and is unlikely to exceed four Earths.

Because the planet lies so close to its parent star, a red dwarf called Gliese 581, it's hot enough to boil away any surface water and could not support life similar to that on Earth. But detecting a planet not much heavier than Earth shows that astronomers "are on the right track" for finding an Earthlike planet that orbits another star's "habitable zone," where water could exist as a liquid, says Stéphane Udry of the University of Geneva's observatory in Sauverny, Switzerland.

Veteran planet hunter Michel Mayor, also of the Geneva observatory, described his team's findings on April 21 at the European Joint National Astronomy Meeting at the University of Hertfordshire in Hatfield, England.

The smallest exoplanet yet found (foreground, in this illustration) and another planet (blue), in the habitable zone, orbit the nearby star Gliese 581.

Another already discovered planet in the same system, though not as close in size to Earth, is now the only known low-mass exoplanet that lies in a habitable zone, the team also reported.

"Gliese 581 is a truly fascinating exoplanet system," says Sara Seager of MIT. "It is like a gift that keeps on giving."

According to the leading model of planet formation, an orb as small as the newly found planet, 581e, would almost certainly be rocky like Earth, rather than icy or gaseous. Mayor and colleagues, including Udry, detected Gliese 581e indirectly by the gentle pull the planet exerts on its parent star. It is the innermost planet in the system.

Gliese 581d, with a minimum mass of seven Earths, is the outermost. Measurements by Mayor's team place this planet closer to the star than previously thought, and unequivocally in the habitable zone, Udry says. It's even possible, he says, that Gliese 581d could have a deep ocean.

Researchers have found more than 340 extrasolar planets to date.

Monster blob on a feeding frenzy

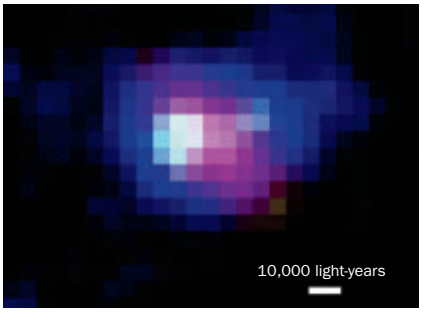
Body may be early galaxy caught in the act of forming

By Ron Cowen

Quick, Marge, call the *Cosmic Enquirer*! Astronomers have discovered a monster blob lurking at the universe's edge. The blob may be the earliest known galaxy to be caught in the act of a feeding frenzy.

The giant parcel of gas and stars stretches for 55,000 light-years, a little more than half the diameter of the Milky Way's disk today. Yet this newfound object hails from a time when the universe was only 6 percent of its current age.

Masami Ouchi of the Carnegie Observatories in Pasadena, Calif., and his colleagues first recorded light from the blob with the infrared Subaru Telescope on Hawaii's Mauna Kea. Spectra taken at the Keck Observatory on Mauna Kea and at the Magellan Telescope near La Serena, Chile, confirmed that the blob resides 12.9 billion light-years from Earth, making it the fifth most distant object known in the cosmos.



This blob of gas and stars (false color image) is 55,000 light-years across and 12.9 billion light-years from Earth.

The body's distance reveals that it dates from just 800 million years after the Big Bang.

This kind of body, dubbed a Lyman-alpha blob, has never before been seen so early in the universe. Infrared observations reveal that the blob contains a stellar mass equivalent of about 35 billion suns, Ouchi and colleagues report online (arxiv.org/abs/0807.4174) and May 10 in *The Astrophysical Journal*.

Simulations have shown that massive galaxies early in the universe grow bigger by snaring streams of cold intergalactic gas. In an article posted online, Avi Loeb and Mark Dijkstra of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., show that these streams are likely to appear as Lyman-alpha blobs, just like the one Ouchi's team found (arxiv.org/abs/0902.2999).

"In our model, such a detection implies the formation of a massive galaxy" early in the cosmos's history, Loeb says.

FROM TOP: EUROPEAN SOUTHERN OBSERVATORY; M. OUCHI *ET AL./ASTROPHYSICAL JOURNAL*

Body & Brain

For longer versions of these and other Body & Brain stories, visit **www.sciencenews.org**

New weapon helps fight hepatitis C

Experimental drug on its way to joining standard medications

By Nathan Seppa

A new drug works with a standard hepatitis C drug combination to clear the virus from patients' blood substantially better than the existing treatment alone, new studies suggest.

"As far as these patients are concerned, they're pretty much cured," says John McHutchison, a gastroenterologist at Duke University in Durham, N.C. "We don't need to see them anymore."

Ten years ago, McHutchison wouldn't have used the word "cure" when discussing hepatitis C with his patients. But the results seen from drugs since cleared for use — and the new drug, telaprevir, now in the final stages of testing — are changing that, he says.

Two studies, one coauthored by McHutchison, look at patients receiving their first course of drugs for the disease and appear in two papers in the April 30 *New England Journal of Medicine*. Both studies show gains with telaprevir and also suggest that the typically lengthy hepatitis C treatment time could be halved with telaprevir's addition.

"Telaprevir appears to be a material advance in the therapy of hepatitis C, beginning a new era of treatment," says physician Jay Hoofnagle of the National Institute of Diabetes and Digestive and Kidney Diseases in Bethesda, Md., writing in an editorial in the same *NEJM* issue. Telaprevir inhibits viral replication in a way similar to other drugs that have shown success in treating HIV.

A third study finds that about half of people who hadn't responded to initial treatment for hepatitis C or had relapsed were able to clear the virus after getting a second round of drugs that included telaprevir. Those data were presented April 25 in Copenhagen at a meeting of the European Association for the Study of the Liver.

In general, patients are considered cured if they don't have detectable hepatitis C virus for six months after drug treatment. More than 99 percent of such patients remain free of the virus for the next five years, says Jean-Michel Pawlotsky, a hepatologist at the Henri Mondor Hospital in Créteil, France, and coauthor of the other study in *NEJM*.

The researchers agree that the drug can cure many of those patients who have received treatment but are still fighting a losing battle with hepatitis C.

"We had to tell them we had nothing to

NEWS BRIEFS

Contraceptives and muscle gains

NEW ORLEANS — Some female athletes may pay a price for using oral contraception: lower strength gains from resistance exercises, which include lifting weights or working against tension bands and bars.

Personal trainers have long noted that all women don't garner the same benefits from such exercise, and Chang Woock Lee of Texas A&M University in College Station and his colleagues wanted to know why.

After 10 weeks of intense resistance training, women taking oral contraceptives gained an average of 2.1 percent muscle mass — compared with 3.5 percent in women not on the pill, Lee reported April 21 at the Experimental Biology 2009 meeting. And before and after the trial, women on the pill had dramatically lower blood levels of natural muscle-building hormones and substantially higher concentrations of cortisol, a hormone associated with the breakdown of muscle, than did recruits not on the pill. — *Janet Raloff*

Signals of impending violence

Swift swings in symptom intensity may peg psychiatric patients on the verge of threatening or hurting others.

Employing a statistical technique, new work shows that among psychiatric patients with documented histories of committing violent acts, those whose symptoms of emotional distress rapidly and repeatedly fluctuated from mild to severe during a 26-week period were particularly apt to assault others or to threaten them with a weapon, say Candice Odgers of the University of California, Irvine and her colleagues.

In cases of rapid symptom fluctuation, patients went from peaks to valleys of emotional health about every two to four weeks, the team reports in a paper published online April 15 and in the May *American Journal of Psychiatry*. — *Bruce Bower*

New neurons don't heal

Rubbernecking neurons don't do an injured brain any good. Newborn neurons rush to the scene of brain damage but don't pitch in to help heal the wound, a new study shows.

Scientists have had hopes that new neurons produced in the brain after a stroke or other insult could migrate to the wounded area and replace damaged cells, and previous research has shown that the newborns are attracted to injury sites.

But Zhengang Yang of Fudan University in Shanghai and colleagues report in the April 22 *Journal of Neuroscience* that neurons don't form replacements for the majority of cells. In the study, neurons that moved to the striatum, a part of the brain involved in movement, didn't form medium-sized spiny neurons, the type most common in the striatum. The results indicate that simply boosting neuron production may not be enough to help heal the brain. — *Tina Hesman Saey*

180 million Estimated number of people worldwide with hepatitis C

offer," Pawlotsky says. "Now there might be something to offer."

McHutchison and his colleagues randomly assigned 250 hepatitis C patients to get the standard drugs ribavirin and peginterferon alfa-2a, with or without telaprevir. The team found that up to 67 percent of those getting telaprevir were cured, compared with 41 percent of those not getting it.

The drug can cure many patients who have received treatment but are still fighting a losing battle.

Pawlotsky and his team looked at 334 patients in Europe. The cure rates were up to 69 percent with telaprevir compared with 46 percent with ribavirin and peginterferon alfa-2a alone, Pawlotsky says.

Both studies in *NEJM* found that taking telaprevir for three months and the standard drugs for five and a half months worked as well as taking the standard drugs for the usual 11-month course.

In the study reported at the Copenhagen meeting, 453 patients who had failed to respond to earlier treatment or had relapsed afterward were similarly assigned to get telaprevir or not as part of a combination.

Hepatologist Michael Manns of the Hannover Medical School in Germany and his colleagues reported that slightly more than half of those getting telaprevir were cured, compared with only 14 percent of those getting just the standard drugs.

The studies were funded by Vertex Pharmaceuticals of Cambridge, Mass., which makes telaprevir. Schering-Plough makes a similar drug, called boceprevir, which tested well against first-time–treated hepatitis C patients, according to data presented at the Copenhagen meeting.

About 3.2 million people in the United States have hepatitis C. It infects about 180 million people worldwide. Hepatitis C can cause fatigue, fever, jaundice and abdominal pain. Patients who fail to improve during treatment or who relapse afterward risk developing cirrhosis of the liver and liver cancer. The virus comes in four varieties. In these studies, all patients had genotype 1, the most common and difficult-to-treat kind in Europe and North America.

Both telaprevir and boceprevir are now in large-scale trials. McHutchison says he expects both to get approved, possibly as early as 2011.

Earth

For longer versions of these and other Earth stories, visit **www.sciencenews.org**

Aerosols may have boosted carbon uptake

Plant productivity could drop as skies continue to clear

By Sid Perkins

The world's vegetation soaked up carbon dioxide more efficiently under the polluted skies of recent decades than it would have under a pristine atmosphere, an analysis in the April 23 *Nature* suggests. The trend hints that relying on forests and other vegetation to sequester carbon may not be effective if skies continue to clear, researchers say.

Major volcanic eruptions throw large quantities of aerosols, such as bits of fractured rock and droplets of sulfuric acid, high into the atmosphere. Those particles scatter incoming solar radiation, preventing some of it from reaching Earth's surface and thereby cooling climate temporarily (*SN: 11/5/05, p. 294*).

That scattering also, however, boosts the amount of carbon that vegetation takes in, says Lina M. Mercado, an ecosystem modeler at the Centre for Ecology & Hydrology in Wallingford, England. Although aerosols, including air pollution, decrease the overall amount of light falling onto a tree, the particles diffuse the radiation so that it actually illuminates more leaves, including those below the tree's outer canopy.

To estimate how aerosols affect the rate at which the world's plants take up carbon, Mercado and her colleagues adjusted an ecosystem model to include the effects of diffuse radiation on vegetation. Then the team plugged in meteorological data gathered worldwide since 1901.

From the 1950s through the 1980s, many regions received less solar radiation overall — a phenomenon called global dimming and attributed in part to aerosols (*SN: 9/24/05, p. 196*) — and received a larger proportion of diffuse radiation. Since the 1980s, however, skies have brightened in many areas — especially some industrialized parts of the Northern Hemisphere, where control measures have been instituted to decrease aerosol levels because of their role in acid rain.

Those atmospheric changes show up in the Earth's carbon balance, the team's model suggests. From 1960 through 1980, the researchers estimate, Earth's land plants stored about 440 million metric tons of carbon each year on average, but from 1980 to 1999 vegetation stored only 300 million metric tons annually.

"Surprisingly, the effects of atmospheric pollution seem to have enhanced global plant productivity by as much as 25 percent from 1960 to 1999," Mercado notes. Short-term variations in atmospheric aerosols, such as those following the 1991 eruption of Mount Pinatubo in the Philippines, had the same effect.

If pollution control measures continue to increase atmospheric clarity, the boost in natural carbon sequestration provided by diffuse radiation will abate to near zero by the year 2100, the researchers note.

"I'm quite impressed that they've improved their [ecosystem] model to include the effect of diffuse radiation," says Dennis Baldocchi of the University of California, Berkeley.

Michael Roderick of the Australian National University in Canberra notes that researchers could use the revised model to assess the costs and benefits of geoengineering — for example, artificially adding large quantities of aerosols to the atmosphere to ameliorate the effects of global warming.

Walking seal had otterlike body

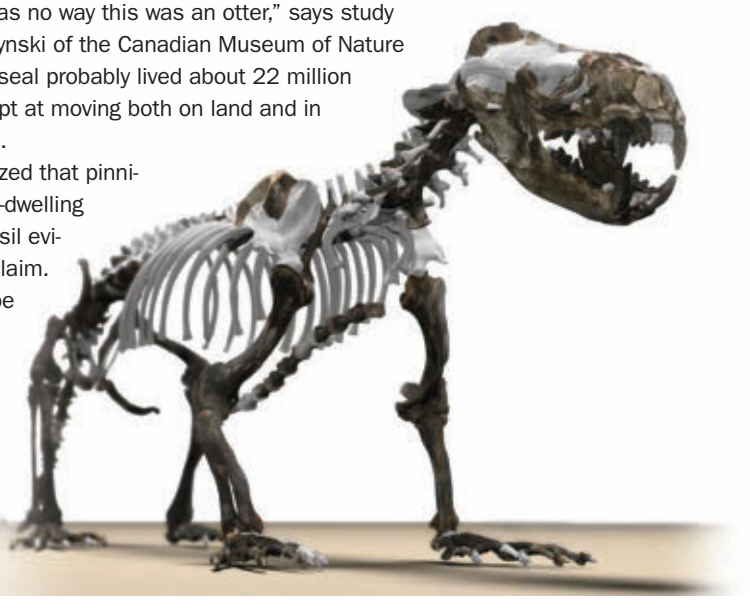
A fossilized skeleton of what researchers are calling a walking seal has been uncovered in the Canadian Arctic. The remains of this previously unknown mammal (fossil reconstruction shown) could shed light on the evolution of pinnipeds, the group that includes seals, sea lions and walruses, researchers report in the April 23 *Nature*.

The animal, named *Puijila darwini*, had a long tail and an otterlike body with webbed feet and legs like a terrestrial animal, the researchers say. But *P. darwini* also had a pinniped-like skull and was more than a meter from head to end.

"We realized there was no way this was an otter," says study coauthor Natalia Rybczynski of the Canadian Museum of Nature in Ottawa. The walking seal probably lived about 22 million years ago and was adept at moving both on land and in water, the team reports.

Scientists had theorized that pinnipeds evolved from land-dwelling ancestors, but little fossil evidence supported that claim. The new finding could be the missing link in pinniped evolution, the researchers note.

"This is a fantastic discovery," comments evolutionary biologist Annalisa Berta of San Diego State University. — *Solmaz Barazesh*



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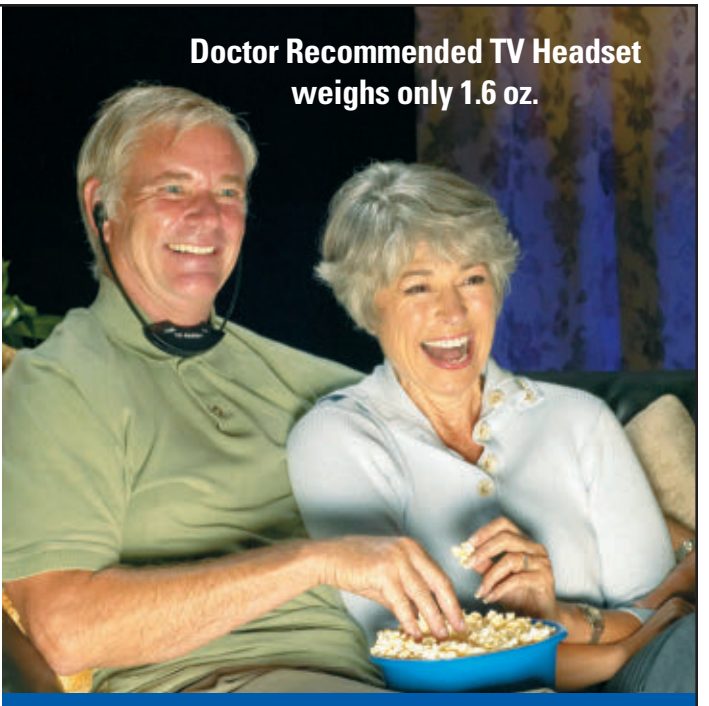

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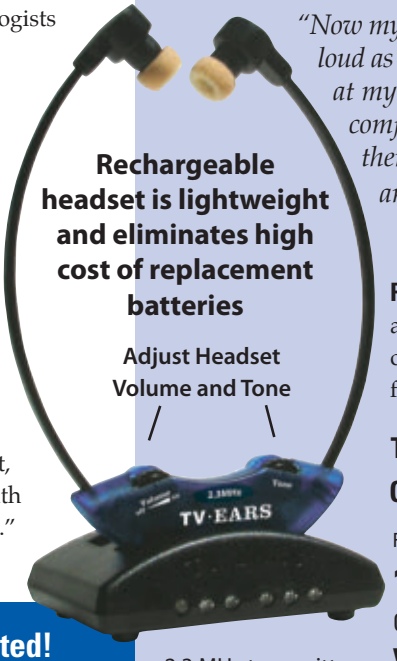

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Gazing deeper s

Four hundred years ago, Galileo and his telescope brought the heavens into focus, setting the stage for modern astronomy

By Dava Sobel

Such a small thing, really — two pieces of glass and a tube no longer than the span of a man's arm. The first telescope that Galileo built (and I don't mean he was the first to build one, for surely he wasn't) played tricks with distance and size. The device transported faraway objects into the viewer's presence, and magnified them there. As Galileo demonstrated to the Doge of Venice in 1609, even an entity invisible to the naked eye, such as an enemy ship on the horizon, would loom large within the purview of his spyglass.

Later, alone in the dark, after he'd learned how to grind better lenses, Galileo pointed his instruments skyward to reveal uncomfortable truths about the universe:

1. The supposedly smooth, silvery orb of the moon mimicked the Earth with chains

PHOTOGRAPH: ALFREDO DAGLI ORTI/THE ART ARCHIVE/CORBIS

A fresco in a museum in Florence, Italy, depicts Galileo (center) showing the Doge and Senators of Venice a telescope.

still

Galileo insisted that inquiring minds could fathom the universe, while the never unravel itself to puny human reasoning.

of mountains and depths of valleys. **2.** The familiar constellations contained more stars than anyone had counted, while the mysterious Milky Way consisted of nothing but stars, too densely packed for unaided eyes to discern. **3.** The planet Jupiter commanded a retinue of four attendant bodies — "never seen since the beginning of time," as Galileo pointed out — whose positions changed from hour to hour. **4.** Venus, when followed through the telescope, waxed and waned like the moon. **5.** And the large pair of companions on either side of Saturn occasionally disappeared!

This year, four centuries after those early nights of wonder, the International Year of Astronomy salutes Galileo for ushering in a new worldview. 2009 also commemorates the 400th anniversary of the publication of *Astronomia Nova*, by Johannes Kepler, who propounded laws of planetary motion as stunning as Galileo's observations.

Today giant telescopes dominate mountaintops around the world, fly through space, even orbit other planets. Yet it is still possible to feel awe looking through a simple tube at the things Galileo saw. Perhaps 10 million children and adults will get that chance for themselves as they look up through IYA "Galileoscopes" and other inexpensive telescopes distributed through schools and science centers in scores of countries this year. Given the number of astronomers who recall their first glimpse of Saturn's rings as a transformative moment, I'm betting the IYA may produce a large crop of lifelong stargazers.

Unfortunately, one of the sights that most delighted Galileo — the live view of the Milky Way — is already all but lost for most people, drowned out by the glare of urban skyglow. Understandably, therefore, an important focus of IYA activities is raising "dark skies awareness" among the 3-billion–plus city dwellers of planet Earth.

As one might expect in a multicentennial celebration year, Galileo himself is not only lionized, but also under attack as undeserving of all the attention directed at him. In England, for example, Thomas Harriot boosters are claiming that their countryman sketched the moon through a rudimentary telescope several months before Galileo did. This is true, and I hope more people will come to know and admire Harriot — not to mention the innovative Islamic astronomers of the Middle Ages and many other unsung heroes — as part of the IYA spin-off. Still, Harriot's drawings of the moon are dimensionless renderings, whereas Galileo's explore the play of light on a textured surface. By combining his artistic training in perspective with his mathematical skills, Galileo gauged the heights of the lunar mountains from his backyard in Padua.

Galileo's explanations of his astounding discoveries won him admiring followers and princely rewards, but also attracted jealous enemies and zealous defenders of the faith. Even now, religious and philosophical questions that he raised reverberate — and make him the one astronomer that so many people recognize, remember something about, react to on an emotional level.

Galileo never set out to be an astronomer. Had the telescope not distracted him from his other scientific pursuits, we would remember him today "only" as the father of experimental physics. But from the moment in his mid-40s when he first heard rumors of the instrument's existence, he became enchanted by its possibilities. Then the sky was his oyster. In one memorable phrase from his published writings, he acknowledged his debt to God, "for being so kind as to make me alone the first observer of marvels kept hidden in obscurity for all previous centuries."

Galileo's discoveries convinced him that Copernicus had been right to rearrange the cosmos with the sun, instead of the Earth, at the center. He marveled at how Copernicus had come to his convictions without benefit of the telescope, and praised him publicly. As a result, Galileo took all the heat for Copernicus — who had died in 1543, as soon as his book, *On the Revolutions*, appeared in print. That book — a technical tome, written in Latin and dense with geometric diagrams — had not ignited the outrage of any religious censors before Galileo began touting it. But now it suddenly seemed suspect, and was listed on the Index of Prohibited Books in 1616.

Galileo's own book on the subject, his *Dialogue Concerning the Two Chief Systems of the World*, came out in 1632. He wrote it in Italian rather than Latin, so that people without benefit of a university education could read about the new developments in science. You might say he was the Carl Sagan of his day. Yet the book brought him to trial before the Inquisition, and won its own place on the Index, which it occupied for nearly two centuries.

The long-standing misunderstanding between Galileo and the church led, in 1979, to a request by Pope John Paul II that the case be reopened with an eye toward reconciliation. The papal commission reviewing the Galileo affair encountered numerous difficulties, however, and the pope's official concluding statement in 1992 fell far short of his original goal. Although it is widely held that John Paul "pardoned" Galileo, he simply regretted the "tragic mutual incomprehension" that had persisted between science and faith.

Galileo, a Catholic, accepted the Bible as the true word of God, but saw it as a book about how to go to Heaven, not how the heavens go. In other words, passages referring to the sun moving in the sky, or the Earth remaining fixed on its foundations, were never intended to teach astronomy. For that,

pope believed the universe would

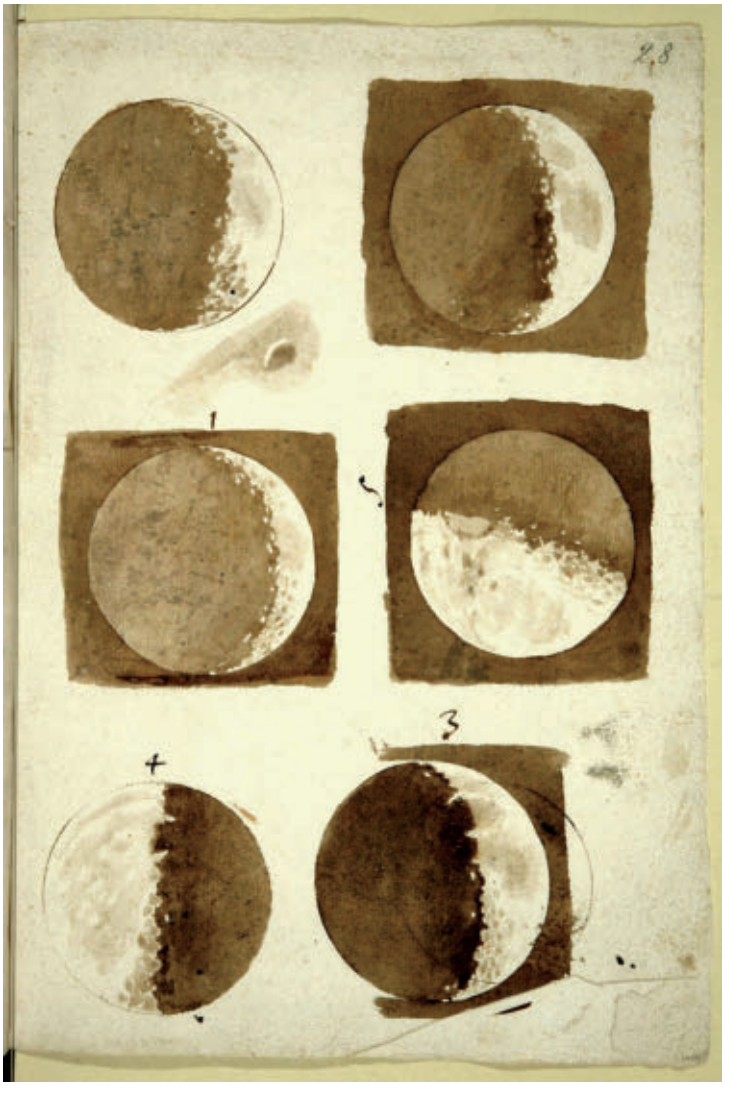
one had to consult God's other book — the book of Nature, which Galileo said was "written in the language of mathematics." Galileo's fight with the pope of his time, Urban VIII, balanced on their different attitudes toward science: Galileo insisted that inquiring minds could fathom the universe, while Urban believed the universe would never unravel itself to puny human reasoning.

Church authorities have recently been asked to weigh in on a new Galileo matter, namely the opening of his tomb in the Basilica of Santa Croce, in Florence. So far, they have denied permission to exhume, while the director of the city's museum of the history of science persists in his request. Examining Galileo's remains might establish the cause of his blindness, as well as confirm the identity, by DNA testing, of the female body buried with him, presumed to be the eldest of his three children.

When I first learned the terrible irony of Galileo's blindness, I thought he had perhaps blinded himself by staring at the sun to draw its spots. But of course he was too clever to risk his eyesight that way. Instead, he had let the sunlight fall through the telescope tube onto a sheet of paper, where he safely traced the dark splotches that blemished "the very face of the sun." The month's worth of sunspots he drew in June and July 1612 led him to the discovery of the sun's monthly rotation.

Galileo had complained of visual problems from an early age. No one knows whether his adolescent eye infections and miscellaneous later impairments led to the eventual loss of his sight, or whether he suffered the usual age-related insults of cataracts and glaucoma. (He was close to 80 when he died.) One of the most interesting difficulties he reported was the shimmer of colored halos around bright lights. Some historians question how his impairments may have shaped his perceptions — whether they prevented him, for example, from identifying the odd bulges at Saturn as the tips of the planet's rings. But none of Galileo's keenest-sighted contemporaries or immediate followers could parse that anomaly either. (The rings kept their secret another five decades before yielding to the insights and superior telescopes of Christiaan Huygens.)

Galileo, who had always been quick to announce and defend his own achievements, railed at the new darkness that enveloped him. "This universe," he despaired in writing to a friend, "which I with my astonishing observations and clear demonstrations had enlarged a hundred, nay, a thousandfold beyond the limits commonly seen by wise men of all centuries past, is now for me so diminished and reduced, it has shrunk to the meager confines of my body."



Galileo's 1609 sepia wash drawings highlighted the moon's visible imperfections, which his telescope revealed as mountains and valleys.

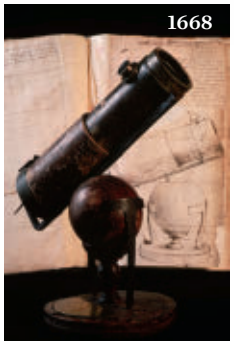
ISTITUTO E MUSEO DI STORIA DELLA SCIENZA

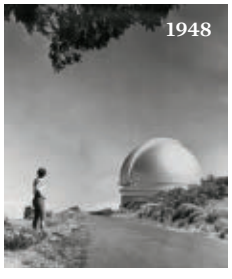
In his final self-assessment, Galileo appreciated that he stood at the beginning of a long process of inquiry into "recesses still deeper" that awaited "minds more piercing than my own." Today's astronomers find themselves standing right beside him in those sentiments, despite the progress of 400 years and a vastly extended view of our expanding universe. Information gathered by the greatest telescopes in current use suggests that all the galaxies we can see, full of bright stars and black holes, perch like mere fluff on the dominant cosmic components of dark matter and dark energy, the nature of which remains unknown. ■

Dava Sobel is a science writer and the author of Galileo's Daughter, Longitude *and* The Planets.

Seeing better

In 400 years, telescopes advance from rooftops to mountains to orbit





1608
Invention of the telescope. Claimed by Dutch lensmaker Hans Lippershey, although others (including Jacob Metius and Zacharias Janssen) are also sometimes credited.

1609
Galileo improves the telescope and begins using it for astronomy, starting with lunar observations.

1611
German astronomer Johannes Kepler designs a new telescope using convex lenses.

1616
A concave reflecting telescope is built by Niccolo Zucchi, an Italian Jesuit and physicist.

1655
Dutch scientist Christiaan Huygens discovers Saturn's rings and its moon Titan using a Keplerian telescope with an 11-foot focal length.

1663
James Gregory, a Scottish mathematician, describes a new type of reflecting telescope.

1668
Isaac Newton invents a small but powerful reflecting telescope using mirrors.

1672
Laurent Cassegrain, a French priest, invents a reflecting telescope based on Gregory's principles.

1675
King Charles II commissions the Royal Greenwich Observatory in England.

1781
Astronomer William Herschel uses a reflecting telescope to discover the planet Uranus; he later builds more powerful telescopes with which he discovers several moons of Uranus. Herschel's largest telescope has a focal length of 40 feet.

1839
Harvard College Observatory is established in Cambridge, Mass.

1845
In Ireland, William Parsons builds the Leviathan, a reflecting telescope with a mirror that is 6 feet in diameter. He uses it to discover the spiral structure of the nebula M51.

1908
The Hale reflecting telescope is constructed atop Mount Wilson in California. At that time, it was the world's largest telescope.

1917
The 100-inch Hooker reflecting telescope is completed at Mount Wilson. It ranks as the world's largest telescope for the next 30 years.

1937
Grote Reber, an American radio engineer, builds the first telescope designed to observe the radio region of the electromagnetic spectrum.

1946
British astronomer Martin Ryle builds an interferometer for making radio observations of space.

1948
The 200-inch Hale reflecting telescope is built at the Mount Palomar observatory in California.

1957
A 250-foot radio telescope is completed in England at the Jodrell Bank Observatory, which was established by Bernard Lovell in 1945.

1959
Optical telescopes are launched into space on the Vanguard II satellite.

1967
Construction begins on an observatory complex atop Mauna Kea on the Big Island of Hawaii.

1968
The 10-meter Whipple telescope is built at Mount Hopkins in Arizona to study gamma rays.

1980
The Very Large Array of radio telescopes is completed near Soccoro, N.M., by the National Radio Astronomy Observatory.

1989
COBE—the Cosmic Background Explorer—is launched, designed to measure the cosmic microwave background radiation.

1990
The Hubble Space Telescope launches from the space shuttle Discovery. The first of NASA's four Great Observatory telescopes, it is designed to collect information throughout the entire electromagnetic spectrum.

1991
NASA launches the Compton Gamma Ray Observatory, the second in the Great Observatory series.

1993
The first of the twin 10-meter Keck telescopes on Mauna Kea—the largest optical and infrared telescopes—is completed.

1996
The second of the Keck twins is completed.

1997
The Hobby-Eberly Telescope is built at the McDonald Observatory in Texas, testing a new cost-effective instrument design.

1999
The Chandra X-ray Observatory, the third Great Observatory, is launched from the shuttle Columbia.

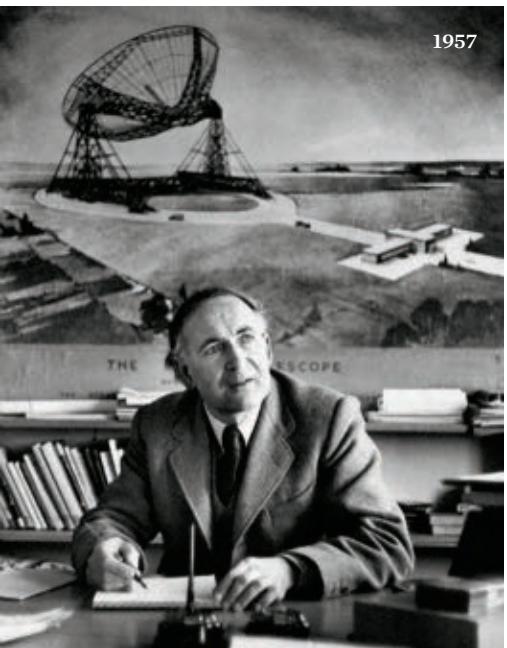
2001
NASA launches the Wilkinson Microwave Anisotropy Probe to map background radiation. Data it collects help revise the universe's age to 13.7 billion years.

2003
The Spitzer Space Telescope, the last Great Observatory, launches via a Delta rocket. It measures the thermal infrared portion of the electromagnetic spectrum.

2009
The Planck telescope, set to launch in mid-May, will measure radiation left over from the Big Bang with high precision (*SN: 4/11/09, p. 16*).

View a timeline of astronomy history at sciencenews.org/astronomy_timeline

1996



1957

1991

Beyond Galileo's

Astronomers grapple with cosmic puzzles both dark and light

By Ron Cowen

Four hundred years ago, astronomy embraced all that was visible. For Galileo, looking through his primitive telescope, the vistas included jewel-like stars, mountains on the moon, moons orbiting Jupiter and the glow of comet tails.

Today astronomy is often about what cannot be seen. Astronomers have known for decades that stars and galaxies are mere baubles floating on a vast sea of dark matter. More recently, astronomy's roster of Darth Vaders has expanded to include an even more mysterious force: dark energy, an entity that drives the universe to accelerate its expansion just when gravity's tug ought to be slowing it down.

On the brighter side, astronomers are beginning to learn more about the complicated processes that formed stars and galaxies, giving the universe its light. The Planck mission (*SN: 4/11/09, p. 16*) will test the idea

ADOLF SCHALLER, STSCI

The first stars that lit up the cosmos (white areas in this artist's illustration) coalesced inside halos of dark matter (purple), according to the leading model of star formation.


Universe

that the Big Bang was accompanied by a brief burst of rapid expansion called inflation, which is thought to have created the seeds of matter from which stars and galaxies arose.

On smaller scales, explorations within the solar system, along with the discovery of more than 345 extrasolar planets, pose questions about the possible existence of life beyond Earth. The Kepler mission, launched in March, will provide a head count of Earthlike planets in the nearest reaches of the galaxy. Other new telescopes will examine the composition of these orbs and their potential for life.

Galileo's successors have pieced together an impressive outline of cosmic history, from the inflationary beginnings of spacetime to the arrival of planets and people. But many details remain to be filled in, and strange new features may be added as astronomers push the limits of current theory and knowledge. New forms of matter, new twists in spacetime and even entire extra universes may emerge from the ongoing efforts to explain and understand the workings of the heavens.

From light to darkness

To understand the points of light that decorate the sky, it has become necessary to embrace the darkness. The brilliant but irascible astronomer Fritz Zwicky first realized that truth more than 75 years ago, when he found that all the visible matter in the Coma galaxy cluster wasn't nearly enough to keep the cluster intact. And individual galaxies, like our rapidly rotating Milky Way, would fly apart if the only gravitational glue came from visible matter. Something else, something unseen, must be providing the extra gravitational pull, Zwicky and others reasoned.

Over the past few decades, astronomers have come to the conclusion that only about 15 percent of all the matter in the universe is visible. Researchers have deduced that vast halos of dark matter envelop and extend thousands of light-years beyond a galaxy's visible outlines.

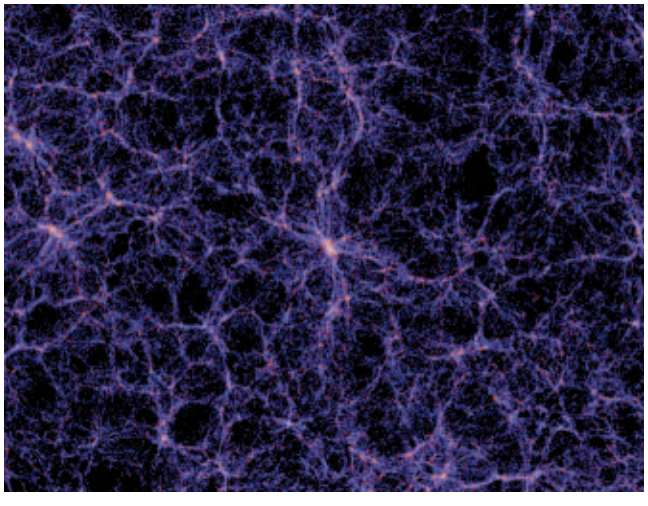
While most astronomers agree that dark matter exists, nobody knows for sure what it is. But last year, several teams of researchers reported finding hints for the existence of one of the leading candidates for dark matter, known as WIMPs, for weakly interacting massive particles. WIMPs respond only to gravity and the weak nuclear force.

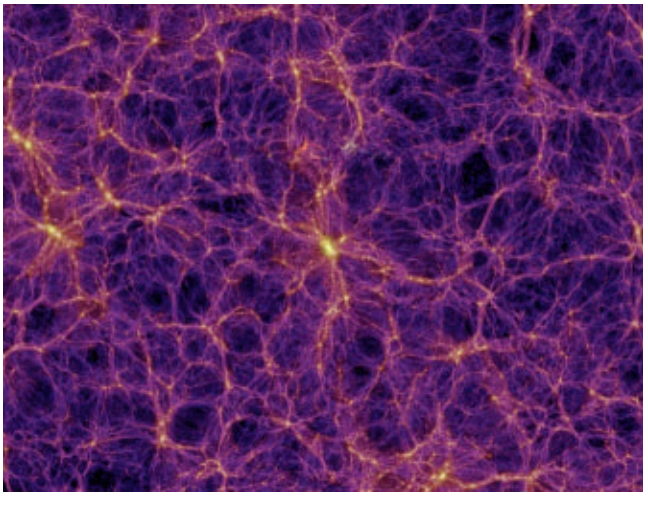
Theory predicts that WIMPs would have been forged by the Big Bang. Moreover, their calculated density in the present-day universe would be just right to account for the observations that require the presence of dark matter. Researchers call this cosmic coincidence "the WIMP miracle."

Like any proposed dark matter particle, WIMPs can't be seen. But some WIMPs have an odd property: Whenever two collide, they annihilate each other, producing a spray of ordinary, visible elementary particles such as positrons, electrons and neutrinos, along with gamma rays. Two recent experiments found a greater than expected abundance of positrons and electrons in the Milky Way. Scientists say the surplus particles may have been produced by WIMP annihilations (*SN: 9/27/08, p. 8; 2/28/09, p. 16*).

Other experiments have now joined the WIMP search. NASA's orbiting Fermi Gamma-ray Space Telescope is looking for an excess of gamma rays, a possible product of WIMP annihilation. IceCube, a telescope at the South Pole, is searching for an excess of neutrinos that might indicate WIMPs' existence. Some experiments are seeking to directly detect these dark matter particles through the energy they would deposit in underground detectors. Finally, studies at the Large Hadron Collider, the world's most powerful accelerator (scheduled to reopen this fall), could provide new clues about the identity of dark matter (*SN: 7/19/08, p. 16*).

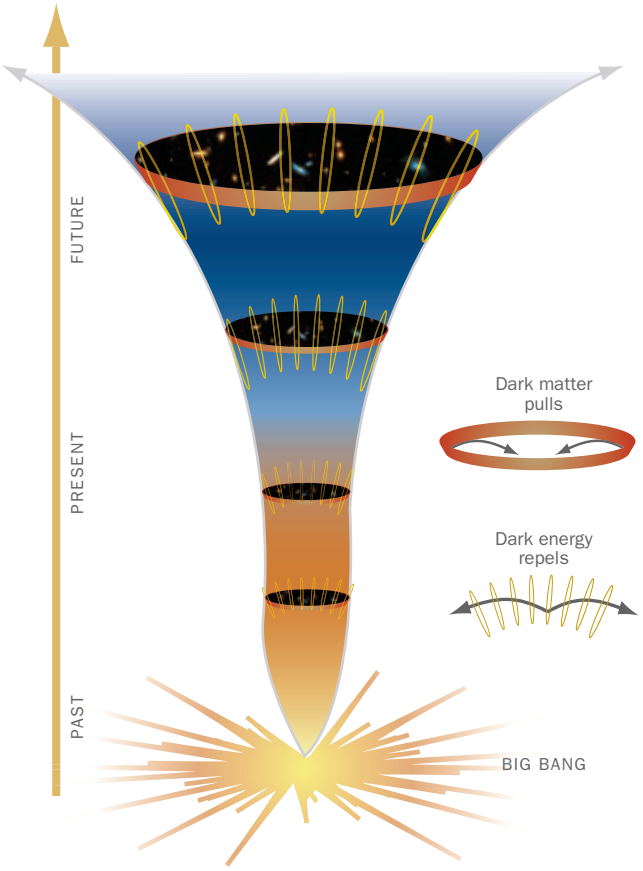
"There's a very good chance in the next two to three years





An international supercomputing effort to model the evolution of the early universe created this pair of images. The simulations depict how the distribution of the visible galaxies and galaxy clusters (left) mirrors the distribution of dark matter (right). Dark matter, scientists believe, provides the gravitational scaffolding that allows visible particles to coalesce into galaxies.

Cosmic Tug-of-War
Early in the universe, the cosmos was compact and the density of dark matter so high that it slowed down the expansion that began with the Big Bang. At such early times, by comparison, dark energy's push was almost inconsequential. But as the universe grew bigger, and the density of dark matter diminished, dark energy's outward push grew stronger than dark matter's inward pull. Dark energy began to dominate about 5 billion years ago. Ever since, the universe has expanded at an accelerating rate.



we might find out what dark matter is," says theorist Carlos Frenk of the University of Durham in England.

Energy of darkness

But even if researchers soon unmask dark matter, a gloomier mystery remains. In 1998, astronomers were astonished to find that the expansion of the universe has been speeding up. Cosmologists call whatever is behind this accelerated expansion dark energy.

At a recent seminar at the Space Telescope Science Institute in Baltimore, Mario Livio did something perfectly ordinary. He threw his car keys up in the air. As expected, the keys rose, slowed down and then fell, landing back in his hand.

Now, said Livio, a theorist at the institute, imagine if the car keys kept accelerating skyward instead of returning to his hand. "That's how shocking dark energy is," he exclaimed.

In fact, Einstein's theory of relativity does allow gravity to exert a cosmic push as well as the more familiar pull. According to relativity, gravity has two sources: the pressure exerted by a substance as well as its mass. Ordinary pressure contributes to gravitational attraction, but dark energy exerts negative pressure, which pushes space apart. If the push is strong enough, the needle on the gravity meter swings from attraction to repulsion.

Dark energy seems to resemble the cosmological constant, a space-filling energy represented by a term that Einstein inserted into his equations to keep the universe balanced between expansion and collapse. The most likely source of this constant would be the energy associated with the vacuum of space.

On the subatomic scale, the vacuum seethes with pairs of particles and antiparticles popping in and out of existence. But calculations of the expected vacuum energy predict an amount of dark energy 10^{120} times larger than observations allow, notes Robert Caldwell of Dartmouth College. So despite thousands of papers written

FACING PAGE: V. SPRINGEL *ET AL.*/MILLENNIUM SIMULATION (BOTH); THIS PAGE: GRAPHIC: NASA, ADAPTED BY J. KORENBLAT; GALAXIES IMAGE: NASA, ESA, J. BLAKESLEE/JOHNS HOPKINS, M. POSTMAN/STSCI, P. ROSATI/ESO

Arp 274 is a trio of galaxies, the two largest of which appear about to merge in this image, with the third much smaller galaxy on the far left. Scientists want to figure out how galaxies and large groups of galaxies, called clusters, evolve.

about dark energy, there's no convincing explanation of what it actually is.

It may even turn out that dark energy isn't real. Some physicists suggest that the observed cosmic acceleration might be a sign that Einstein's beloved relativity theory needs revision.

New ways to chart the expansion of the universe may help determine whether dark energy is real and whether it's truly constant over time. And that will give astronomers new insight into the fate of the universe — whether cosmic expansion will slow down, continue to accelerate at its current rate or speed up even more, ultimately ripping apart the universe and every galaxy within it.

Enlightening puzzles

When it comes to understanding star and galaxy formation, astronomers must straddle the boundary between darkness and light. On the one hand, without dark matter, there would be no stars, galaxies, planets or people, says theorist Avi Loeb of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. On the other hand, once stars and galaxies begin to coalesce within halos of dark matter, the messy "gastrophysics" involving visible matter such as stellar winds and gas particles become just as important in shaping galaxies and their pattern on the sky.

Dark matter, unlike visible matter, can't be pushed around by photons, so it was able to collapse earlier than the visible material. Clumps of dark matter eventually pulled in the visible matter. Because it doesn't interact with photons, the dark matter retained the memory of the original cosmic blueprint — the lumps laid down and amplified during the first tiny fraction of a second after the birth of the universe.

According to the dark matter theory, the first stars to coalesce and ignite within dark matter halos were about 100 times heftier than the sun and appeared about 30 million years after the Big Bang. Large collections of those stars became the universe's first galaxies about 200 million years after the Big Bang, the theory holds.

With dark matter's role firmly in place, "we were told by theorists that we had a pretty good picture of galaxy formation," says Richard Ellis of the California Institute of Technology in Pasadena. According to the model, small galaxies would form first and grow larger. Only later, as small dark matter halos coalesced to form bigger halos, would bigger galaxies emerge.

But beginning in the mid-1990s, as telescopes became more powerful, astronomers stumbled upon a puzzle: They discovered massive galaxies that existed when the universe was only half its current age, about 7 billion years after the Big Bang. Soon a slew of new observations revealed that massive galaxies finished forming their stars early, while smaller galaxies began making stars later, seemingly the opposite of what dark matter theory dictated. Even more surprising, astronomers found "big, well-fed galaxies when the universe was just a billion years old," Ellis notes. "There hasn't been enough time in the universe for them to have got there by merging," as the theory had predicted, he says (*SN: 4/25/09, p. 5*).

Finding young, big galaxies forced astronomers to the realization that although dark matter plays a critical role in galaxy formation, other factors also come into play. For instance, supermassive black holes that develop at the centers of galaxies may generate jets and winds that push gas away or heat it so that it cannot coalesce and form stars. Because smaller galaxies have less gravity, these jets and winds may be more effective in temporarily halting or delaying the onset of star formation in smaller systems.

It's also possible, says Ellis, that dark matter theory needs some revision, although not a major overhaul. For instance, if massive dark matter halos grow faster than theorists have calculated, it could explain the production of massive galaxies early in the universe.

The discovery of these massive galaxies has spurred researchers to search for starlit bodies even farther back in time. A new infrared spectrograph scheduled to be installed at the Keck Observatory on Hawaii's Mauna Kea next year, along with a powerful new infrared camera that astronauts are set to install on the Hubble Space Telescope, "will enable

TOP: NASA, ESA, M. LIVIO AND THE HUBBLE HERITAGE TEAM (STSCI/AURA); FACING PAGE: DAVID A. AGUILAR/HARVARD-SMITHSONIAN CFA

us to systematically start charting the universe" when it was less than 800 million years old, Ellis says.

Astronomers have begun to pinpoint the era when spiral galaxies like the Milky Way began taking on their distinctive appearance. Observers have caught glimpses of some of the first galaxies with rotating disks — the earmark of a spiral galaxy — that began taking shape when the cosmos was between 2 billion and 3 billion years old.

Using bigger telescopes to study such galaxies in detail "would allow us to start to really understand what state young galaxies are in and how we can link them to galaxies today," says Ellis.

C'est la vie

Where there are galaxies, there are planets — some perhaps with life. For seekers of life beyond Earth, the solar system harbors an abundance of possibilities. There's Saturn's largest moon, Titan, a frigid world shrouded in an organic haze with pools of liquid methane on its surface. In 2005, astronomers discovered that a much tinier Saturnian moon, Enceladus, spews geysers of water vapor from its south pole and have since found hints that the moon's interior may contain a reservoir of salty water. The fractured surface of Jupiter's icy moon Europa suggests that it may have an underground ocean that occasionally wells up, heated by the internal flexing that the gravitational tug-of-war between the moon's siblings and Jupiter generates. And then of course, there's Mars, the desiccated reddish world crisscrossed by channels that might once, at least briefly, have carried water.

"Mars clearly has got to be the top place" to look for life, "and that's exactly what NASA is [focusing] on," says Alan Boss of the Carnegie Institution for Science in Washington, D.C. One new wrinkle, he notes, is the seasonal detection of methane on the planet (*SN: 2/14/09, p. 10*).

Although plenty of nonbiological processes produce methane, the gas could be a signature of the decay of biological material. "NASA's mantra should not be just 'follow the water' but 'follow the water and follow the methane,'" says Boss. "We would really like to find the locations of the methane; it really focuses the search."

But Phil Christensen, a Mars researcher at Arizona State University in Tempe, says it isn't clear that the Red Planet was ever warm and wet long enough for life to gain a foothold. Some evidence suggests that the era of flowing water lasted for only hundreds to thousands of years — and was confined to a few specific places on Mars. Finding out whether that era lasted long enough to support life could speak volumes about the conditions required to support life elsewhere, says Christensen.

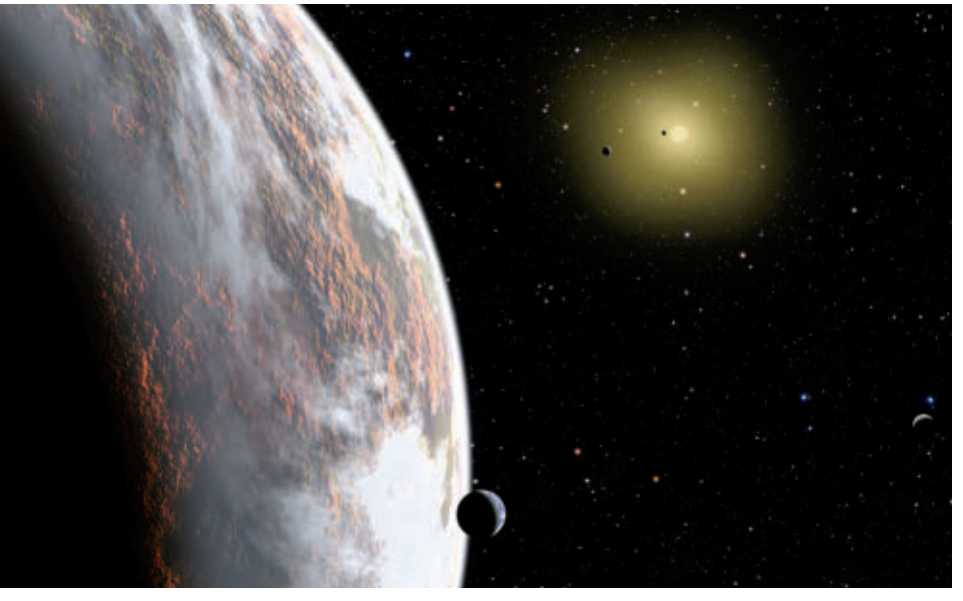
Another planetary scientist, Jonathan Lunine of the University of Arizona in Tucson, thinks that Saturn's moon Titan may offer a more promising venue for life. Pools of liquid methane on Titan, Lunine says, may play the same role that liquid water does on Earth.

"If I have to identify a place where one might find, right on the surface, a self-organizing chemical system, even if it's not life as we know it, I would say go and look at the hydrocarbon seas of Titan," says Lunine. "The most dangerous thing we can do is to define life so narrowly that the only place we're going to find it is Earth."

Beyond the solar system, researchers have now found more than 345 planets. While most of these extrasolar orbs are blisteringly hot, hugging their parent stars tightly, some lie in the habitable zone, where water would be cool enough to be liquid. NASA's Kepler mission will soon begin its hunt for Earth-sized planets around 100,000 sunlike stars.

"I'm a wild-eyed optimist that the Kepler mission is going to find hundreds and hundreds of Earths," says Boss. The mission, however, can reveal only the size of the planet and how far away it lies from its star, not its mass, chemical composition or whether life exists there.

To measure the mass of such a planet will require a space-based mission that can monitor stars for telltale wobbles induced by the planet's tiny gravitational tug. Such space technology is already available, and a mission could be launched in only a few years, if funding were available. Then, another space mission could examine the starlight filtering through the atmosphere of some of these Earthlike planets to look for pos-



In the next decade, the search for Earthlike exoplanets, and thus the search for life, will get a boost from new missions. A superEarth like the one in this artist's conception can be twice the size of Earth, with five to 10 times its mass.

sible signatures of biological activity, such as carbon dioxide and ozone, or oxygen in combination with methane. Though not a biomarker in itself, water would also be required for a planet to support life — as least as it is known on Earth, notes Lisa Kaltenegger of Harvard-Smithsonian.

A mission capable of detecting these chemical fingerprints in a planet's atmosphere wouldn't be ready for launch for another decade. Such a mission might also manage to take a blurry picture of an Earthlike planet by using advanced techniques to blot out the blinding light from the parent star.

An exoplanet task force that included Boss and Lunine recently noted, however, that there could be a shortcut to looking for habitable exoplanets. Instead of looking for Earth-mass planets orbiting sunlike stars, scientists could focus on superEarths — planets five to 10 times as massive as Earth — orbiting lightweight, cooler stars called M dwarfs. Because M dwarfs aren't as hot as sunlike stars, the habitable zone lies relatively closer to these low-mass stars. That makes a habitable planet easier to detect. And it's more likely that such a close-in planet will pass in front of its star as seen from Earth, allowing the starlight to filter through the distant planet's atmosphere and reveal whether the composition might be compatible with life. The James Webb Space Telescope, scheduled for launch in 2013, could examine superEarths, determining which might be the best candidates for the search for extraterrestrial life.

Seeking strangeness

The universe has no dearth of oddball objects. But the JWST and a slew of other powerful telescopes now in the planning stages are likely to reveal even more exotic beasts that the cosmos has kept under wraps.

Astronomers have long known about neutron stars, the ultracompact cinders left behind by supernovas. These cinders are so dense that they squeeze electrons and protons into giant balls of neutrons. And for more than two centuries researchers have theorized about black holes, which capture all matter and light that enter them.

But even stranger stuff may exist. For instance, particularly massive neutron stars may squeeze neutrons so tightly that they break down into quarks. By measuring the size and radius of neutron stars, researchers are attempting to find evidence for such "strange stars" or "quark stars."

Another novel space oddity would be a wormhole — a black hole's distant cousin. In 1935, Einstein and Nathan Rosen realized that general relativity allows such tunnels, which would directly connect two vastly distant regions of spacetime, or even locales in different universes.

Theorists once believed that these proposed portals could exist only for a fraction of a second. But calculations suggest that "exotic matter" — material endowed with a special property called negative energy — could prop a wormhole open much longer.

"There are mathematical solutions, but whether or not they correspond to something in reality remains to be seen," says cosmologist Michael Turner of the University of Chicago.

Perhaps the strangest notion about the cosmos is that the observed universe is only one among many other universes, each residing in a pocket disconnected from the others.

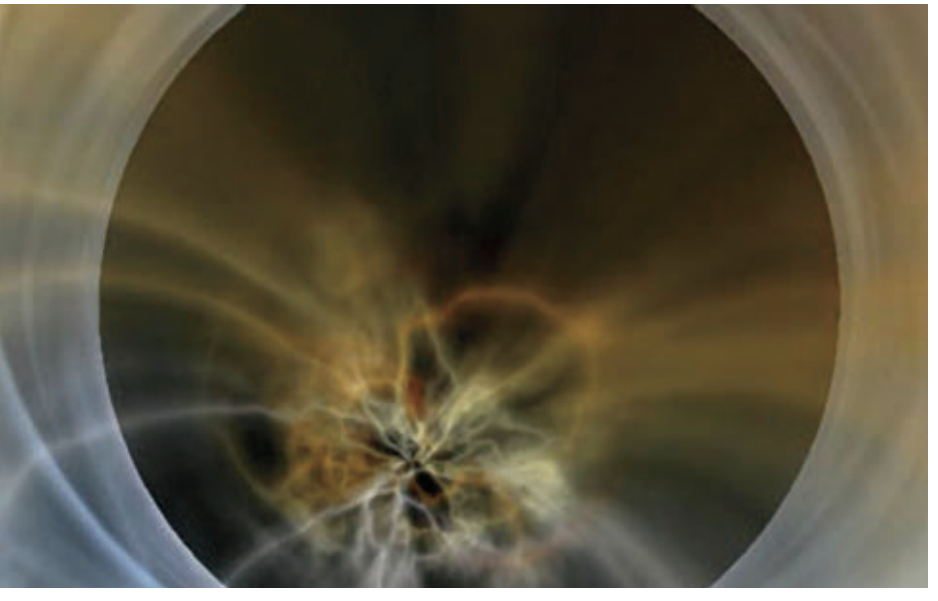
Inflation — the early epoch of rapid expansion — could allow for an infinity of separate bubble universes. And string theory, which envisions each elementary particle as a string rather than a point, also suggests the existence of a vast ensemble of different universes, each with its own physical laws.

The notion of such a multiverse is the ultimate in the revolution begun by Copernicus nearly five centuries ago, Turner says. Not only is Earth not the center of the solar system or the galaxy, but our universe may be just one of many.

Four hundred years from now, says Turner, inflation may be remembered as the theory that drastically changed people's view of the cosmos. "It may be infinitely bigger than we imagined," he says. Much bigger than Galileo could have realized when he first peered at the sky through a crude set of magnifying lenses in 1609. ■

Explore more

- For several papers highlighting recent progress and enduring riddles in astrophysics, cosmology and planetary science, see: www7.nationalacademies.org/bpa/Astro2010_SWP_byTitle.html



A wormhole, as depicted by an artist in this illustration, would form a portal into a remote region of space or perhaps even into another universe.

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Finally a poster on one of the most famous and fascinating fossil sites on our planet, the Burgess Shale. This poster features a history of the Burgess Shale, depiction through photos of the various fossils, and an extinction and geologic age time line. One section features 28 fossil creatures which are graphically depicted together in an environmental scene. This is a colorful and informative poster on one of the most interesting fossil sites in the world. Size: 26.5" X 38" Laminated, Copyright 2009; Published by Jensan Scientifics, LLC Photos with permission from the Royal Ontario Museum, Canada **Order #JPT-14881, Cost: $23.95**

Bioterrorism and World Epidemics

A fabulous poster describing, in words and pictures, 40 subjects include: Anthrax, Smallpox, West Nile Virus, Botulism, Cholera, Dengue Fever, SARS, Avian Flu, Aflatoxin, Dysentery (Shigella), Ebola, E. coli, Enchephalitis, Hantavirus, HIV, Influenza, Legionaire's, Lyme Disease, "Mad Cow" Disease, Melioidosis / Glanders, Plague, Pneumonia, Salmonella, Staph, Tuberculosis, Tularemia, Q Fever, Brucellosis, CJD, T-2 Mycotoxin, Stachybotrys (toxic molds), Ricin, Chemical agents, and Nuclear Explosion. Size: 38.5 x 26 inch, Laminated. Comes with folded 11" X 17" information sheet. **Order #JPT-7604, Cost: $19.95; #JPT-7608 - 2 for $38**

The Periodic Table in Minerals - This study collection demonstrates a new way to actually experience the elements of the Periodic Table as colorful mineral samples that contain the individual elements! 20 samples are presented in a 5 inch by 7.5 inch snap-close plastic display case, and each set includes a detailed information sheet. **Order #JPT-2008, Cost: $21.95**

The Surface of the Moon - This set uses the research done on the actual Moon rocks to identify the closest Earth rock analogues available from around the world. 7 specimens are presented that allow a "hands-on" approach to teach the fact that the Moon and the Earth are very closely related, and made of much the same materials. Samples are presented in a 5 x 7.5 inch snap-close plastic display case, detailed information sheet, copyright 2009; **Order #JPT-137, Cost: $19.95**

New Acquisitions on Our Website:

- K/T Boundary Spherules, Colorado; other locales available
- Coal from Antarctica - A seam that Shackleton passed in his journeys
- Antarctica Petrified Wood - Glossopteris, Permian
- Hematite Extremophiles; White and Black Chimney Smokers
- Shattercones; Rare Minerals

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Diamond Shaped 14K Gold
Allende meteorite is one of the most research and most sought after meteorites. 14K Gold with matching 20" chain. Comes with authenticity, attractive crushed velvet black jewelry box and information.
Size: 1 1/4" W X 1 1/4"L X 1/16"D
Meteorite size: 5/8" Diameter; Weight: 4.9 grams; **Order #JPT-4216, Cost: $385**

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Ancient Reproduction - Earliest Known Prescription Written in Cuneiform - This piece is a reproduction of a Sumerian medical tablet. It is the earliest known prescription. It is written in cuneiform. Along with the tablet you will receive a booklet which gives you the translation and history of the tablet. The original was found at Nippur. (c. 2100 B.C.) It comes with a walnut stand and detailed information sheet
size: 6"H X 3"W by 1" D
Order #JPT-sumer, Cost: $69.95
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Ideal gifts for lawyers, doctors, students, teachers, writers

Jewelry with a Story
Libyan Desert Glass 14K Gold Pendant

Libyan Glass is thought to have been made by the action of a comet or asteroid hitting the sand in the Libyan desert and causing it to vaporize into these beautiful droplets of glass. This pendant has all the attractive features a Libyan Desert glass pendant should have. The rich yellow- colored glass was cut and polished and placed as a cabachon in this beautiful 14k gold sunburst pendant.

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Other pendant styles and individual Libyan Glass specimens are available on our website!

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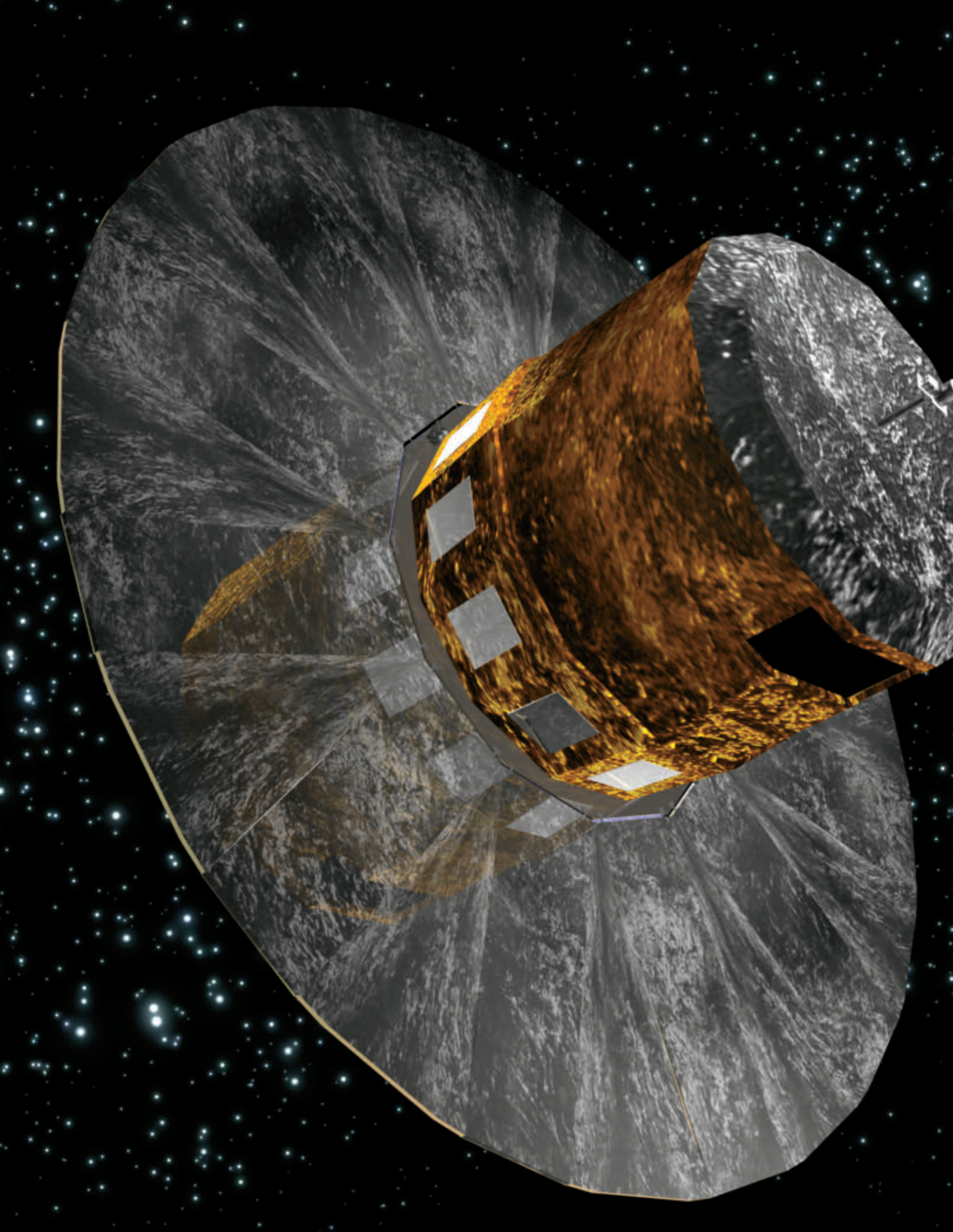


The next constellation of telescopes will dramatically extend and sharpen scientists' view of the universe *By Janet Raloff*

New eyes on the cosmos

When Galileo began pointing spyglasses toward the heavens — scanning methodically, classifying what he observed — he started a trend. Four centuries later, telescopes from the huge to the massive peer at the skies with an array of technologies. They look up from all over the Earth — and from far above it. But the heavens still conceal many secrets. So over the next decade or so, Galileo's successors plan to deploy new, super-high–definition spyglasses to view the most distant objects in the cosmos, map the Milky Way and catalog newfound solar systems. Others would survey the heavens for breaking news: stellar explosions, passing comets or the appearance of potential "killer" asteroids.

These new instruments will be far more sophisticated — and colossal — than Galileo's original. And they'll carry astronomical price tags.

Some ground-based telescopes will run $1 billion or more to build, with yearly outlays of $30 million or more throughout the decades they operate. "The scale of these facilities is such now that no single institution can finance them by themselves — not even a single country can," notes Wendy Freedman, director of the Carnegie Observatories in Pasadena, Calif. At least 10 new telescopes or networks of instruments are now in production or in the late stages of design. Until construction is well under way, of course, most astronomers would acknowledge that their pet instruments may encounter delays, or get shelved.

One astronomer who is among the most confident that his instrument is a go: Markus Kissler-Patig, project scientist in Garching, Germany, for the European Extremely Large Telescope. This ground-based colossus, currently slated to begin operation in 2018, will have a primary mirror 42 meters wide (almost half as long as a U.S. football field) and made from nearly 1,000 hexagonal segments, each about 1.5 meters in diameter. Roughly 100 million euros has already been spent on the E-ELT's design, Kissler-Patig says, and all but about a third of its projected construction cost of 1 billion euros is banked or already committed by partnering agencies.

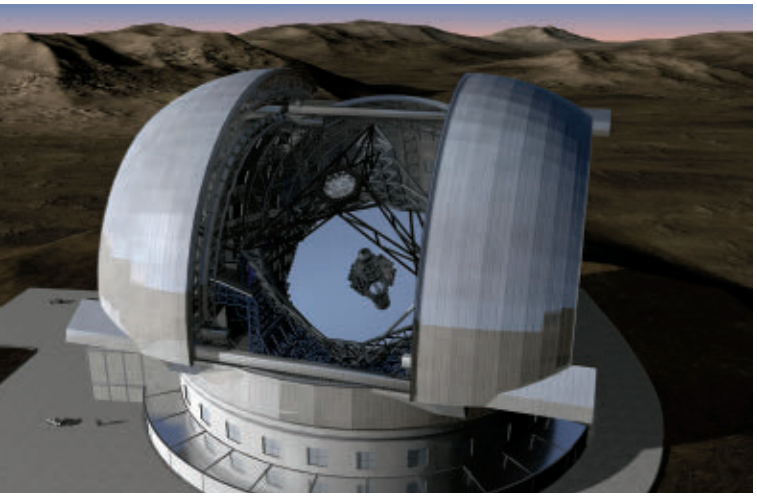
Every 10 years, the U.S. National Academies gathers leading astronomers to assess priorities for new facilities. Results of the current survey are due out in 2010. Waiting to learn how much the astronomy

The European Space Agency's Gaia craft, scheduled to launch in 2011 and illustrated here, will spin as its two optical telescopes map the Milky Way in 3-D.

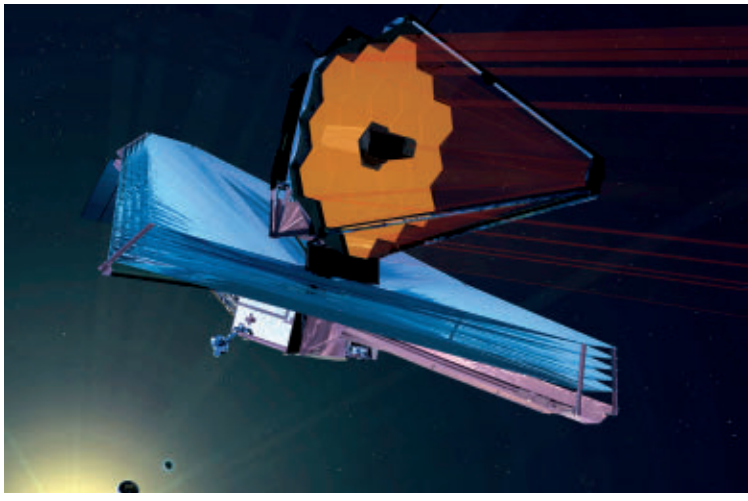
C. CARREAU/ESA

Three eyes on the sky

For a longer list of telescopes set to see first light in the coming decades, visit www.sciencenews.org/



E-ELT
FULL NAME The European Extremely Large Telescope
MIRROR SIZE 42 meters (diameter) **PROJECTED COST** €1 billion
TIMELINE Projected to open in 2018
MISSION Largest ground-based optical/near-infrared telescope
LOCATION Possible sites in Chile, Argentina, Canary Islands, Morocco
WEBSITE www.eso.org/public/astronomy/projects/e-elt.html



JWST
FULL NAME The James Webb Space Telescope
MIRROR SIZE 6.5 m **PROJECTED COST** $3.5 billion (could change as fiscal year 2010 budget is finalized) **TIMELINE** Launch set for 2013
MISSION Use infrared wavelengths to image oldest, most distant objects
LOCATION The space-based telescope will orbit the sun
WEBSITE www.jwst.nasa.gov

community prizes their proposals has created more than a little rivalry among Pasadena astronomers. Those at the Carnegie Observatories are among scientists planning the 24.5-meter Giant Magellan Telescope, or GMT. Caltech is a lead partner in the international consortium developing the Thirty Meter Telescope, or TMT.

Design on the Giant Magellan Telescope is moving right along, but Carnegie astronomer Alan Dressler notes that "until two or three years ago, I would have bet against seeing two of these big telescopes" — or against U.S.-led consortia building both. "But lately I've begun to believe that GMT has at least a fifty-fifty chance."

Hoping to boost the chances for their instrument of choice, astronomers are pointing to the new science that this coming generation of behemoth spyglasses would kick-start.

View from the ground

In orbit since 1990, the Hubble Space Telescope was the first optical telescope to operate in space. Once its flawed mirror was corrected with prescription optics in 1993, the orbiting observatory began sending back to Earth images of breathtaking clarity. But even with the approaching retirement of Hubble — and with its successor, the James Webb Space Telescope, not designed to send back photos in near-true color — astronomers aren't panicking. Several telescopes now on the drawing board should deliver images with a resolution Hubble engineers could only dream of.

The E-ELT, for instance, will see individual objects with unprecedented detail, delivering images that are at least 15 times crisper than Hubble's — and of much fainter objects.

E-ELT's immense light-gathering capacity will capture "twice as many photons as the TMT could and three times as many photons as the GMT," Kissler-Patig says. But to resolve details from these images, which would ordinarily be heavily blurred by turbulence in Earth's atmosphere, all of the new large telescopes must employ adaptive optics. One of each telescope's resolving mirrors will, in real-time, undergo micro-sized deformations to precisely counter fluctuations in light's path as it moves through the atmosphere.

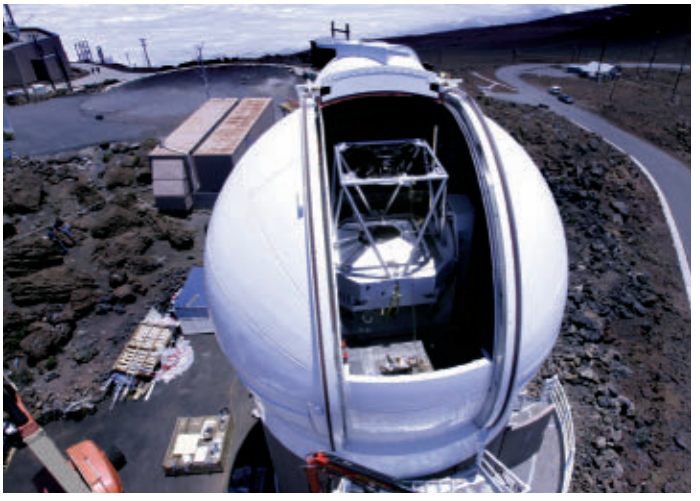
In the past decade, some ground-based telescopes have been retrofitted with adaptive optics. The next generation will be the first to have the optics built-in and available from day one. The superior resolution this technology enables means that, for the first time, "big ground-based telescopes will deliver better images than we're getting in space," says TMT adviser Richard Ellis of Caltech.

Moreover, argues Freedman, "this jump in both sensitivity and resolution is a killer application. It opens up new windows."

For instance, she notes, "we're very interested in peering back into the early universe. Today we can see faint smudges with Hubble and current ground-based telescopes where we know galaxies are forming." Some of these regions date to just a few hundred million or so years after the Big Bang — prehistoric within the universe's 13.7 billion years.

The massive ground-based facilities will finally "let us peer into what astronomers have started calling the 'dark ages,'" Freedman says, "where we currently know just noth-

FROM LEFT: ESO; NASA; BRETT SIMISON (OPPOSITE PAGE)



PAN-STARRS
FULL NAME Panoramic Survey Telescope & Rapid Response System
MIRRORS 1.8 m each **PROJECTED COST** $100 million
TIMELINE One (above) of four planned systems is built
MISSION 1.4 gigapixel cameras to image sky, find "killer" asteroids
LOCATION Pan-STARRS 1 sits atop Haleakala on Maui in Hawaii
WEBSITE pan-starrs.ifa.hawaii.edu/public

ing. We've had ideas about what happened back then." At last, she says, "we'll get to witness this directly."

Stellar census

Big telescopes peer deeply into space but can see only a tiny portion of the heavens at once. While an instrument gazes intently at a speck of sky, spectral fireworks may be breaking out elsewhere. To spot such drama, a new class of survey telescopes is rolling out.

The first to debut is Pan-STARRS, the Panoramic Survey Telescope & Rapid Response System, with a modest 1.8-meter telescope. This facility atop Haleakala on the Hawaiian island of Maui should enter full-scale operation this spring, notes Nick Kaiser, a principal scientist with the project.

Pixels, the discrete elements that make up an image, are a measure of resolution, and Pan-STARRS will capture pixels in abundance. The field of view will be vast — 7 square degrees for each mirror in its four planned telescopes. Each will have a 1.4-gigapixel camera, so even this wide view will encompass a high resolution. The telescope will train its eye on a patch of sky for about 30 seconds and then move to another. By photographing 1,000 segments nightly, "we'll image the entire sky once a week," Kaiser predicts.

One high priority "is being able to detect 90 percent of all killer asteroids, near-Earth asteroids bigger than 300 meters," he says. "That should take us about 10 years," which is the projected duration of the mission.

Right now, Pan-STARRS relies on a single telescope. If funds hold out, it should get three clones. Each of the four telescopes would simultaneously view the same patch of sky. Sometimes a digital detector registers a false positive, perhaps from a stray cosmic ray, Kaiser says. With four images of the same spot, he says, three will veto any false report.

The far more ambitious Large Synoptic Survey Telescope is scheduled to see first light in 2014 from a Chilean mountaintop. Its 8.4-meter mirror is in production, and the completed system would use the world's largest digital camera to get a resolution of 3.2 gigapixels. By 2016, LSST is expected to be scanning not only for asteroids and supernovas but also for details of dark matter — the majority of the universe's mass, now unseen — and the dark energy serving as a mysterious, accelerating force (*SN: 2/2/08, p. 74*).

Compared with the recently completed set of data from the ongoing Sloan Digital Sky Survey, even the smaller Pan-STARRS will offer "a lot more pixels," Kaiser observes. "So we'll see a lot fainter objects."

Galactic archaeology

Other new missions will put communities of stars in perspective — literally.

"At the moment we don't know the distances to most stars in the Milky Way," observes Ellis, "so we don't have a three-dimensional map of even the galaxy that we inhabit." But Gaia, a European Space Agency project due to launch in 2011, will correct that, he predicts.

The mission will carry two telescopes into orbit, each focused at a different angle to provide the equivalent of binocular vision. And the spacecraft itself will spin slowly to scan the entire celestial sphere. Over several years, its precision measurements — its accuracy is expected to be the equivalent of measuring the diameter of a human hair at a distance of 1,000 kilometers — should provide a 3-D map of all the stars within 30,000 light-years of the sun.

During its five-year mission, Gaia should map about a billion stars and other objects roughly 70 times — each time charting their position, distance and brightness, with unprecedented precision, to track changes over time.

Another mission will offer a historical perspective on stars, what's being called "galactic archaeology," notes Mike Irwin of the University of Cambridge in England. Its data will be the chemical fingerprints of stars as read by a new Wide-Field Multi-Object Spectrograph, or WF-MOS. This instrument is being designed for use, perhaps by 2014, with Japan's refurbished 8.2-meter Subaru telescope atop Hawaii's Mauna Kea.

Star trajectories can become jostled, as passing galaxies kidnap stars or as maturing stars take up relationships with strangers. But wherever it goes, a star carries the chemical fingerprint unique to its nursery environment, Irwin explains. By analyzing a star's spectral, or chemical, fingerprint, he says, astronomers hope to identify which stars in a throng are related, and which trace back to other regions of the galaxy. Similarly, he says, "as our galaxy cannibalizes

a neighboring one, we can look for traces of the disrupted satellite galaxy by fingerprinting its stars in the great trail of debris left behind."

WF-MOS will simultaneously measure the spectra of up to 2,400 objects at once, the most ever. "So we can rapidly build a very large database" that points to the history — and, in some ways, the genealogy — of residents across a wide swath of the Milky Way, Irwin predicts.

New synergies

Because Earth's atmosphere screens out some wavelengths of electromagnetic radiation, WF-MOS can't collect a full fingerprint of distant stars. Only space-based telescopes have access to full spectra. And NASA will be launching a powerful successor to Hubble around 2013 that will not only chemically fingerprint stars but also collect images of them.

The James Webb Space Telescope will have seven times Hubble's light-collecting area and 15 times its field of view. And whereas Hubble collects radiation in multiple wavelengths, including visible, its successor is being optimized to pick up the infrared radiation associated with the oldest, most distant objects. This spectral specificity means, however, that the JWST won't be able to cover for the Chandra X-ray Observatory, which has completed 10 of its 15 projected years (Chandra scientists say it could last even longer).

The new space telescope will orbit the sun with Earth — but not circle Earth. Because Hubble did orbit Earth, astronauts could service its instruments. At 1.5 million kilometers from Earth, roughly four times as far as the moon, the JWST will not be accessible for repairs or upgrades. And carrying fuel for only about 10 years, the mission will likely be far shorter than that of Hubble, which is now 19 years old.

Like Hubble, the JWST will serve as a scout. But unlike Hubble, this scout will leave the rest of the work to the next generation of ground-based telescopes that have the capacity to produce high-resolution, super-crisp images. This crispness means that individual objects will be easier to discern, as will each object's spectral fingerprint.

Those big ground-based observatories will also be turning to spacecraft such as Gaia as well as NASA's recently launched Kepler mission to find planets beyond the solar system. Relatively small ground-based telescopes will also be recruited for detailed observations of distant solar systems. "Looking for planets has become big business in astronomy," Ellis says.

More than 345 extrasolar planets have been logged. "But we can only easily spot planets today that are Jupiter-sized," Ellis says. What everyone wants to find are rocky, Earth-sized planets that have atmospheres. And that, he says, is about to become possible.

Even GMT, the smallest of the three next-generation big-bruiser telescopes, "can essentially mask out the light from a parent star so that we can directly image its planet and study the spectra of the planet's atmosphere," Freedman says.

This is "exciting and very inspirational," says her colleague Dressler. Cosmologists are starting to investigate not only how to uncover Earthlike planets in the sun's region of the Milky Way, "but also whether such planets might have the elements of life. Even whether their atmospheres show evidence of seasons, or signatures of likely vegetation."

Although the new generation of telescopes will likely make inroads into understanding extrasolar planets, Dressler suspects astronomers will probably need far bigger space telescopes to "break the field open." But the growing trend in astronomy, he says, is that instead of focusing primarily on "the broad scope of things over vast distances and eons of time, we're starting to examine how all of those grand but simple processes in the universe have led to great complexity." Like life on Earth. ■

Explore more

■ The National Academies Board on Physics and Astronomy website: www7.nationalacademies.org/bpa

The Day We Found the Universe

Marcia Bartusiak

Until January 1, 1925, the Milky Way might have been alone. That day, astronomers learned that the universe extends at least a million light-years and the faint lights observed by the world's largest telescope at the time twinkled from distant galaxies. Essentially, the date marked the universe's discovery, Bartusiak argues in this history of early 20th century astronomy.

"Our celestial home was suddenly humbled, becoming just one of a multitude of galaxies residing in the vast gulfs of space," she writes.

But this tale is not about breakthroughs. It focuses on the dramatic insights, sidesteps and missed opportunities, persistence, pride and bits of luck that accompany the scientific process. Edwin Hubble wrote the paper describing the telltale blinks in distant nebula, but he was busy observing and let a colleague read the historic paper. Quite fitting, considering he was not alone in his endeavor.

Details regarding countless other personalities, the interplay between them and the times in which they worked make this story satisfying. Bartusiak, for example, delves into archival material to describe Hubble's sometimes tense relationship with Harlow Shapley—the two worked together at California's Mount Wilson Observatory. "Hubble's affection for wearing jodhpurs, leather puttees, and a beret while observing or going around and saying 'Bah Jove' was simply too much for Shapley to bear," she writes.

Bartusiak's account never gets boring and never feels anticlimactic. Instead, moments of drama and intimacy make the reader forget, somewhere along the way, the final outcome: The Milky Way is merely one of many stellar collections in a vast universe. —*Elizabeth Quill*

Pantheon Books, 2009, 337 p., $27.95.

Astronomical Spectrographs and their History

John Hearnshaw

Astronomers have used these instruments to explore the heavens since the 19th century. *Cambridge Univ., 2009, 240 p., $140.*

The Crowded Universe: The Search for Living Planets

Alan Boss

A renowned astronomer details, by day, the history of planet hunting, and argues that alien life is common and will soon be found. *Basic Books, 2009, 227 p., $26.*

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David H. DeVorkin

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Enjoy the indelible experience of emulating Galileo

I was tickled when Rick Fienberg, then editor of *Sky & Telescope* magazine, stood up at a special session at the August 2006 meeting of the International Astronomical Union in Prague, grabbed the microphone and proclaimed that every person on Earth should look at the night sky through a telescope in 2009, as Galileo did 400 years earlier. Audacious? Yes! Appropriate? Absolutely! Practical? Well ... of course not! But Rick's enthusiasm soon caught on, and it made good sense. Better sense, I thought, than the mess astronomers got themselves into over the "demotion" of Pluto a few days later.

As a reader of *Science News*, you don't have to be told to go outside some night and look through a telescope at Mars, Saturn or the moon. You probably already have had the pleasure to do so and therefore accept that there is no better way to enhance science awareness than to engage in the direct observation of nature and all the wonderfully wild things in it.

Casual observation is, of course, only a first step, and Fienberg's goal just the foot in the door. But looking through a telescope can be a memorable experience, especially if the person peering into the eyepiece is properly instructed on how to see all that the telescope can reveal and is prompted to realize that the photons striking his or her retina have been traveling through space for seconds, or centuries, or longer. And all those photons, now collected by the telescope and concentrated into their eye, are in fact theirs and theirs alone to savor, as long as the memory lives.

Beyond the obvious romance of standing in the dark and viewing infinity, there are other benefits that the casual observer can accrue. In the spirit of Robert Hooke, disciplined seeing and communicating the experience are the next two steps along the path. When I have a chance to guide visitors to look through a telescope at the U.S. Naval Observatory, or on occasion from the terrace of the National Air and Space Museum, I ask people to report to the rest of us what they are seeing. Descriptions from visitors, especially kids, can be delightful and insightful, alerting those down the line what to expect, firing their imaginations, and stimulating discussion and friendly banter. Does everyone agree on what they see and how to describe it? No. Viewing through the eyepiece is a solitary act. But the shared experience is social and indelible.

There is no better way to enhance science awareness than to engage in the direct observation of nature.

The International Year of Astronomy 2009 — fostered by the IAU and its 137 (and counting!) adhering countries, by the U.N. and UNESCO — is indeed a social phenomenon. Just look at the website www.astronomy2009.us and click on "Projects." Dozens pop up, from everywhere, by a wide range of enthusiasts, all inviting you to participate and enjoy. By the time you read this, *400 Years of the Telescope*, sponsored by the National Science Foundation, will have premiered on PBS stations across the nation. Soon thousands of surprisingly inexpensive Galileoscopes will be introducing millions of people to views of the moon, planets and stars far clearer but still reminiscent of Galileo's. And there's a way to leverage this experience: You can purchase a telescope from www.galileoscope.org, and you can also donate one, at reduced cost, to those unable to afford the $15 price.

IYA 2009 activities have already started at the Smithsonian's National Air and Space Museum. The Exploring Space Lecture Series, presented monthly from March through June, will be directed to both the popularity of astronomy and the present state of play, contrasting them with Galileo's time. Our popular Saturday Family Days in April and October are devoted to IYA 2009 themes. By July 1, we hope to open the first public observatory on the National Mall, on a street-level terrace of the museum. With funding from the NSF, we've borrowed a 1960s-era Boller & Chivens 16-inch reflector from Harvard and are now placing it in a 22-foot dome visible from Independence Avenue. It will welcome visitors at least four hours a day, 364 days a year (weather permitting). We will be doing our part to heed Rick Fienberg's call.

Outreach is nothing new to the museum life, but it's enhanced by the community spirit of IYA 2009. In February, we locally debuted *400 Years of the Telescope* as a warm-up for this year's John Bahcall Lecture. Invited by NASA and the Space Telescope Science Institute, astronomer Sandra Faber carried more than 400 listeners in the audience to the limits of imagination, from quantum fluctuations to supermassive black holes, to the point where one breathless woman rushed up after the Q&A to ask, as if her life depended upon it, what the difference was between a star and a galaxy. She had to know. So let's all do our part this year to invite her, and the millions she represents, to see both for herself through a telescope. ■

David H. DeVorkin is senior curator for astronomy and the space sciences at the National Air and Space Museum.

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I just threw my watch in the trash. I got it as a gift a while back—and it was something else. It had four different digital displays, about a dozen buttons, was waterproof to about a thousand feet, and I think it could even tell me the weather. I'll never know, though, because, like I said, it's in the trash. Turns out it couldn't do the one thing I want a watch to do … tell me the correct time. It always ran a little slow, which was bad enough, but there were so many displays and they were so small that I couldn't tell the time even if it was accurate. When I tried to reset it, I pushed the wrong button and set it on military time, and I couldn't figure out how to switch it back. That was the last straw. Now, I've got a great watch. It's super-accurate, easy-to-read, and it will even tell … yes tell … me the time. Best of all, I'll never have to set it! This is the watch I've been waiting for.

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