StarDate™

DANGEROUS MATTERS
Page 20

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StarDate

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Features

Departments

Coming Up
We'll celebrate the 25th anniversary of Magellan's arrival at Venus with a look back at its finds and a look forward to future Venus science. And we'll shed light on innovations that enable ground-based research telescopes to do more than ever.

BEN BROMLEY/UNIV. OF UTAH

On The Cover
Astronomer Ben Bromley depicts a double sunset on a possible Earthlike exoplanet. Bromley's recent simulations predict Earthlike planets could form around binary stars, though only gas giant planets have been found in such systems to date.

This Page
CG4 is a nebula 1,300 light-years away in the southern-hemisphere constellation Puppis, the stern. It belongs to class of objects called 'cometary globules,' a title related to appearance rather than origin. Winds from a nearby supernova are blowing out a comet-like tail (not shown) that stretches for eight light-years behind the head (shown) that spans 1.5 light-years.

ESO

MERLIN

Dear Merlin,

Instead of dark energy, is it possible that the accelerated expansion of the universe is due to less gravitational pull as matter occupies more space? If so, will this expansion continue ad infinitum*?*

Curran Rode
Schulenburg, Texas

It's a good thought, but it doesn't quite work.

You are correct that as the universe expands, the same amount of matter is spread across a larger volume of space. As a result, each galaxy "feels" a slightly weaker gravitational pull from all the other galaxies in the universe. Before the discovery of dark energy, in fact, one of the big astronomical questions was whether that weakening pull would allow the universe to expand forever, or whether there was enough mass to halt the expansion and cause the universe to collapse, perhaps ending with a Big Crunch — the opposite of the Big Bang.

Dark energy appears to render that question moot. Instead of an ever-slowing expansion rate, the universe appears to be expanding faster as it ages. That suggests that something is "pushing" the univere outward.

For now, that "something" is identified as dark energy, although its exact nature isn't known. Several experiments are studying the expansion of the universe at different points in its history to try to narrow down the range of possibilities. (One of those projects, the Hobby-Eberly Telescope Dark Energy Experiment, is scheduled to get under way in the next few months at McDonald Observatory.)

Dear Merlin,

Imagine that we launch an object from Earth and suspend it beyond our gravitational field in space. Then we leave it. When Earth circles the Sun and returns to the vicinity of the object, should it still be there? Would it then be drawn into our gravitational field, back to Earth? Does the answer differ depending on the size of the object (tennis ball, car, bus)?

Mick Scott
Winston-Salem, North Carolina

Unfortunately, you can't just drop stuff off and pick it up later. Anything that is launched from Earth begins with the same motion around the Sun as the planet itself. If its booster rocket provides enough "kick," then it will escape Earth's gravity and assume its own orbit around the Sun. If it doesn't get enough boost to escape Earth's gravity, it either enters orbit around Earth or falls back to the ground, which can ruin the day for everyone involved.

That scenario applies to anything that gets launched into space, from the smallest microsatellites to the giant pieces of the International Space Station.

Dear Merlin,

Since the gas giants in our solar system have no surface, what gives them their spherical shape?

Karen Calloway
Glenville, North Carolina

The same thing that makes Earth and the other solid planets spherical: gravity. When it's molding a world, gravity doesn't discriminate between solids and gases — it exerts an equal pull on both.

In some ways, in fact, it's easier for gravity to mold the gas- and ice-giant worlds (Jupiter, Saturn, Uranus, and Neptune) than the smaller, solid rocky inner planets like Earth. That's because as an object's mass increases, so does its gravitational pull.

And although a planet is big, gravity pulls everything toward its center. As a result, anything at a given distance from the center "feels" the same pull, whether it's a molecule of a heavy element, such as iron or lead, or a lighter element, such as hydrogen and helium, which make up the bulk of the outer planets. That molds planets, stars, and any other objects with enough mass (such as large asteroids) into tightly packed balls.

There is one caveat. The rotation of a planet or star pushes material outward at the equator, giving the object a bulge around the middle. The giant planets not only have gaseous outer layers, but they rotate faster than the rocky planets, so they are shaped like slightly flattened beachballs instead of spheres. Saturn, in fact, is about a tenth wider through the equator than through the poles.

Merlin is unable to send personal replies. Answers to many astronomy questions are available through our web site:
stardate.org/astro-guide

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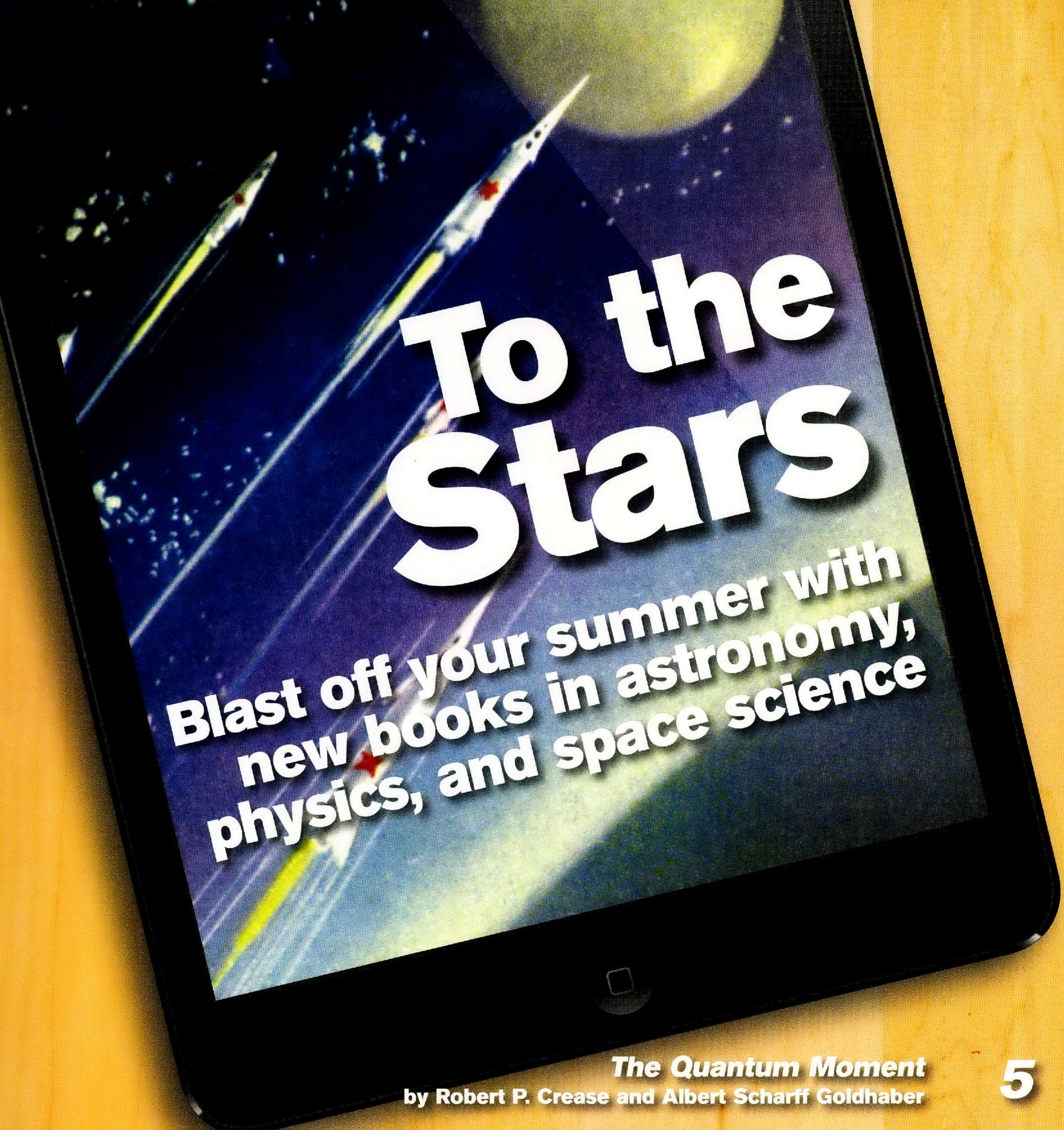
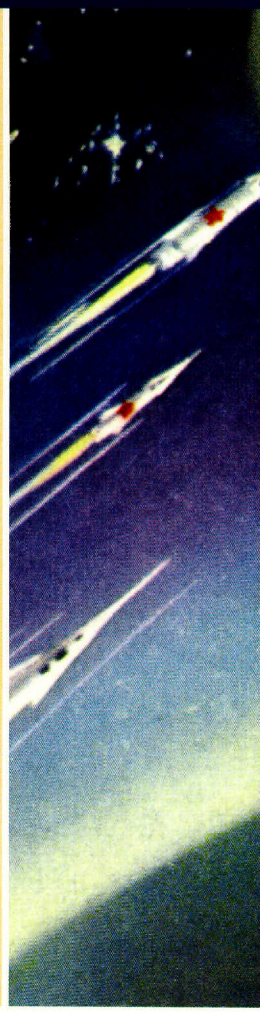


To the Stars

Blast off your summer with new books in astronomy, physics, and space science

LIVING IN A WORLD OF UNCERTAINTY

Two scientists see different meanings in the discovery of a fundamental limit on what we can know



SETUP

In *The Quantum Moment*, Robert B. Crease and Alfred Scharff Goldhaber explain how the development of quantum mechanics — the study of the universe on the smallest scales, inside the atom — was not only a scientific revolution, but a thought revolution. In this excerpt, they focus on German physicist Werner Heisenberg and his famous uncertainty principle, published in 1927. Two conflicting implications for mankind of this fundamental uncertainty were announced almost immediately by the most famous astronomer of the day and an American physicist who would later win a Nobel Prize.

EXCERPT

Why the uncertainty principle became so widely discussed so shortly after its discovery had to do with a lucky turn of events involving the British astronomer Arthur Eddington. A prominent and articulate astronomer, Eddington was the leading communicator of physics and astronomy in Britain between the world wars. Of Quaker background, he was a conciliator, and often sought to reconcile warring factions. After the First World War, for instance, he championed the cause of German scientists, including Einstein, who were being openly spurned by English scientists. In 1926, Eddington was invited to deliver the Gifford Lectures, the most prominent lecture series worldwide on religion, science, and philosophy, held in Edinburgh, the following year. He decided to address "the philosophical outcome of the great changes of scientific thought that have recently come about."

Eddington began writing his lectures in mide-1926, a year after Heisenberg developed matrix mechanics and while Schrodinger was publishing papers on wave mechanics. He delivered the first lecture, "The Failure of Classical Physics," on January 21, 1927. Our entire conception of the physical world has been shaken to the core by quantum mechanics, he told those who packed the Natural History classroom of Edinburgh University. Shortly after Eddington delivered his final lecture in March, Heisenberg installed the capstone on the quantum revolution by announcing the uncertainty principle. Eddington spent the remainder of 1927 revising the lectures for publication, which now included the first clear explanation of the uncertainty principle for outsiders. The lectures—enthusiastically received by the public—were published in 1928 as *The Nature of the Physical World*.

Here's the gist of the uncertainty principle, Eddington wrote: "a particle may have position or it may have velocity but it cannot in any exact sense have both." He described in detail how measuring one property meant that the other becomes imprecise. The problem is no fluke, but "a cunningly arranged plot—a plot to prevent you from seeing something that does not exist, viz., the locality of the electron within the atom. … an association of exact position with exact momentum can never be discovered by us *because there is no such thing in Nature*." The uncertainty principle means we need a "new epistemology." "It reminds us once again that the world of physics is a world contemplated from within surveyed by appliances which are part of it and subject to its laws. What the world might be deemed like if probed in some supernatural manner by appliances not furnished by itself we do not profess to know." The quantum teaches us that science has been aiming at a "false ideal of a complete description of the world."

This has two remarkable philosophical implications, Eddington said. The first has to do with free will. The Newtonian world had settled the conflict, from the scientific perspective at least, in favor of determinism: human beings are simply machines, like little clocks, whose operations were as fully determined by forces and motions as anything else in the universe. But the discovery of uncertainty shattered this, opening the door to more traditional religious ideas. A narrow-minded, rational person, Eddington said, might even conclude that "religion first became possible for a reasonable scientific man about the year 1927."

The second implication was that the scientific world is only part of THE world: "We recognize a spiritual world alongside the physical world." As a result, "the physicist now regards his own external world in a way which I can only describe as more mystical, though not less exact and practical, than that which prevailed some years ago." By setting limits on what science could know, Eddington said, quantum mechanics implied the validity of other kinds of knowledge, including mysticism. He saw quantum mechanics as giving birth to a kind of cultural commune, a human rainbow coalition where everyday humans, religious believers, and quantum physicists could stand arm in arm in a common spiritual quest.

BRIDGMAN

Some scientists agreed with Eddington's thoughts, while others disagreed. Most scientists in the latter category politely ignored him, viewing him once again as playing the conciliator, using the prestigious pulpit of the Gifford Lectures to propose the possibility of a deep harmony between science and religion.

The Harvard physicist Percy Bridgman [1882-1961] could not ignore Eddington. Several years later he wrote, "I still cannot think of his book *The Nature of the Physical World* ... without bridling at the sheer bunk of a good deal of it. I regard Eddington as the supreme example of a crystal clear expositor of ideas as murky as mud." For a few months after Eddington's book appeared, the future Nobel laureate fulminated. Then, just before Thanksgiving 1928, Bridgman did something rash. He put down his instruments, brushed aside his scientific literature, and set out to enter the vulgar world of writing a magazine article. He sent a letter to *Harper's*, a magazine that occasionally ran articles about recent scientific developments. ...

"Dear editors," he wrote to *Harper's*, "I am enclosing a manuscript dealing with some general and evolutionary implications of the recent discoveries in physics." He outlined his expertise. Then he continued, "I would particularly like to get this before the popular audience of *Harper's* because I believe that the consequences of the new discoveries are so important for everyone that all of us, sooner or later, will have to make considerable readjustments to meet the situation." In the manuscript, Bridgman wrote that quantum theory would soon exert a cultural impact greater than evolution and relativity, greater even than Newton and his work. Thanks to the uncertainty principle, discovered only a few months previously, quantum theory appeared to put a limit on what could be known—which, Bridgman predicted, would "let loose a veritable intellectual spree of licentious and debauched thinking." He continued:

> The imagined beyond, which the scientist has proved he cannot penetrate, will become the playground of the imagination of every mystic and dreamer. The existence of such a domain will be made the basis of an orgy of rationalizing. It will be made the substance of the soul; the spirits of the dead will populate it; God will lurk in its shadows; the principle of vital processes will have its seat here; and it will be the medium of telepathic communication. One group will find in the failure of the physical law of cause and effect the solution of the age-long problem of the freedom of the will; and on the other hand the atheist will find the justification of his contention that chance rules the universe.

Bridgman wrote to the editor, "I hope I am not irretrievably wrecking the Magazine." But he really didn't care; he wanted to set things straight. Those who promoted nonsense about the quantum did not know what they were talking about. The implications of the new physics were far more bizarre and unsettling than anything he'd heard so far.

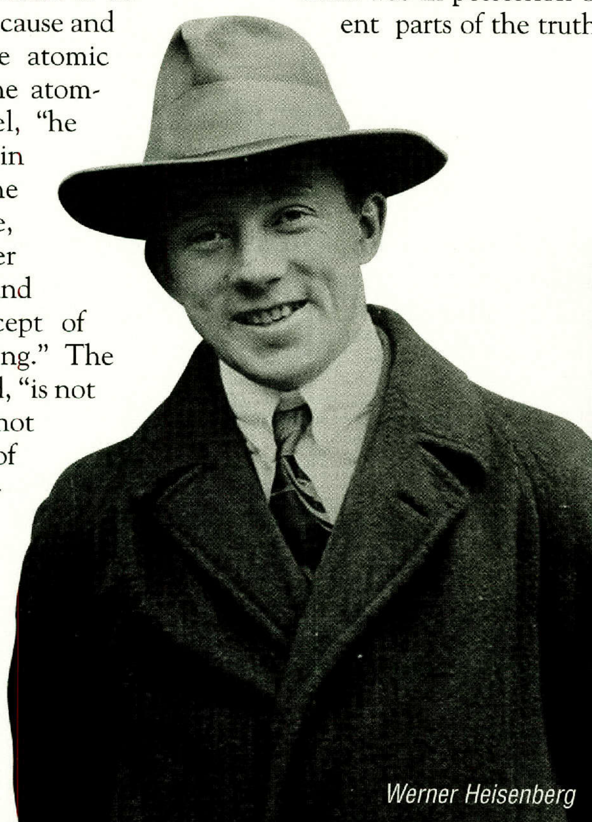
An associate editor at *Harper's* returned his letter, and accepted Bridgman's article. *Harper's* published "The New Vision of Science" in March 1929.

"The thesis of this article," Bridgman wrote in his introduction, "is that the age of Newton is now coming to a close, and that recent scientific discoveries have in store an even greater revolution in our entire outlook than the revolution effected by the discovery of universal gravitation by Newton." These discoveries, in the field of quantum physics, show that we were mistaken to think that nature is fundamentally understandable and law-governed. The uncertainty principle, Bridgman wrote, was as "fraught with the possibility of greater change in mental outlook than was ever packed into an equal number of words." He explained that the impossibility of measuring exactly both the position and momentum of an electron means that electrons do not have position and momentum; in accord with his operationalist philosophy, he wrote that "no meaning at all can be attached to a physical concept which cannot ultimately be described in terms of some sort of measurement." More pointedly:

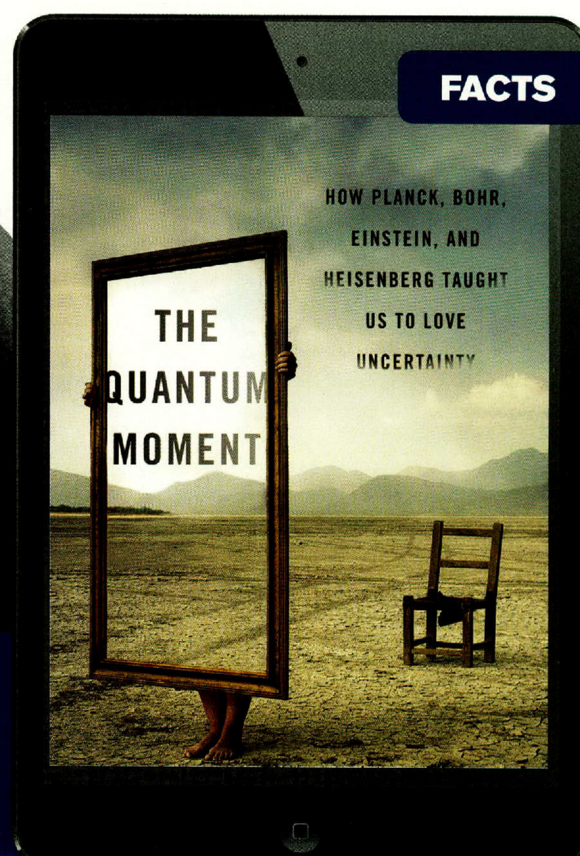
> To carry the paradox one step farther, by choosing whether I shall measure the position or velocity of the electron I thereby determine whether the electron has position or velocity. The physical properties of the electron are not absolutely inherent in it, but involve also the choice of the observer.

This principle, Bridgman went on, "probably governs every known type of action between different parts of our physical universe." This is "enormously upsetting" because it undermines our ideas of cause and effect. Wherever the atomic physicist looks on the atomic or electronic level, "he finds things acting in a way for which he can assign no cause, for which he never can assign a cause, and for which the concept of cause has no meaning." The reason, Bridgman said, "is not that the future is not determined in terms of a complete description of the present, but that in the nature of things the present cannot be completely described." Some German physicists have concluded that the world is governed by chance, but that is incorrect; quantum mechanics gives a definiteness and inevitableness to the subatomic world, but not the conventional kind. …

Eddington and Bridgman saw the implications of quantum mechanics in dramatically different ways. Eddington was the conciliator, willing to acknowledge the truth in everything, Bridgman was more careful, unwilling to venture beyond what he knew. Eddington saw quantum mechanics as pointing to a broader sense of reality than the traditional one, Bridgman to a narrower sense. Eddington found the implications of quantum mechanics comforting, Bridgman disturbing. Each was in possession of different parts of the truth.


Werner Heisenberg

FACTS



THE QUANTUM MOMENT

How Planck, Bohr, Einstein, and Heisenberg taught us to love uncertainty

By Robert P. Crease and Alfred Scharff Goldhaber

$29.95 hardcover

KABOOM! MASSIVE STARS MAKE 'GOLDEN' EXITS

SETUP

Stars are giant chemical factories. In their cores, where temperatures reach millions of degrees, they fuse together atoms of lighter-weight elements to make heavier ones. Stars begin by converting their original hydrogen, the lightest chemical element, to the next-lightest, helium. Stars like the Sun then fuse the helium to make carbon and oxygen. Heavier stars, however, don't stop there. In this excerpt from *How to Build a Universe*, author Ben Gilliland, who describes everything from the Big Bang to the fate of the universe in an accessible and entertaining style, explains what happens in these massive stars.

EXCERPT

A nucleus of iron-56 is the pinnacle of nuclear stability—no other element is as stable. Normally we think of stability as a good thing—we all want a stable relationship, or a stable bridge to walk across—but, for a star, iron's stability spells its doom. Because it is so stable, iron-56 doesn't have the same appetite for alpha particles as its predecessors—so the only way to get an iron-56 nucleus to bond with an alpha particle to make a heavier element is to put more energy into the process than could ever be released from the reaction. So fusion shuts down once more in the core, but this time it won't start up again. The star has run out of options and its fate is sealed.

Even the most massive stars will perish at this point—first collapsing and then exploding in a violent supernova explosion. But only truly massive stars have enough gravitational clout to squeeze the core to this stage: stars of lesser stature will have shuffled off their mortal coils long before now. The Sun, for example, has only enough mass to see it through to the end of helium fusion. Stars of this size end helium fusion by throwing off their gaseous outer layers and spending the rest of eternity as a slowly cooling ball of carbon, about the size of Earth, called a white dwarf … .

But even in death, a giant star can contribute to the elemental richness of the Universe—in fact, it is only in the explosive death throes of giant stars that elements heavier than iron, such as gold, lead, mercury, titanium, and uranium, can be produced.

When fusion closes down with the production of iron, the core can no longer support itself, and it collapses so violently that the rest of the star's material is caught by surprise and is left hanging above the void like Warner Bros' eponymous animated antihero, Wile E Coyote. Of course, just as it does for the Road Runner's nemesis, gravity eventually catches up with reality, and the stellar material falls down towards the core.

At the same moment, the core releases a huge blast wave of gravitational energy that collides with the in-falling material. Where the two fronts smash together, material is compressed and super-heated—forming a shockwave, where the conditions are so extreme that some nuclei are torn apart and others are bombarded with the resulting barrage of high-energy neutrons. The neutrons are forced to fuse with heavy nuclei, creating elements heavier than iron, most of which are unstable radioactive elements such as uranium (the heaviest naturally produced element), which will decay to become elements like gold.

As the shockwave spreads through the remaining stellar material, the whole kit-and-caboodle is blasted out into space—creating vast clouds of hydrogen, helium, carbon, oxygen, iron, gold (and everything else cooked up during the star's lifetime) around the leftover core. These clouds of enriched star stuff are called supernova remnants, or planetary nebulae (a misleading name coined before astronomers understood that they had nothing to do with planet formation). Eventually, these clouds will collapse to form the next generation of stars.

WHEN CORES COLLIDE

Until recently, it was thought that

was where the story ended—it seemed to be the only available mechanism for heavy element production. But observations made in 2013 by the mighty Hubble Space Telescope of a burst of energy seen radiating from a galaxy 3.9 billion light years from Earth may have revealed a second possible mechanism for the creation of the heaviest elements: colliding neutron stars.

A neutron star is what is left over when the iron core of a massive star undergoes its final supernova-triggering implosion. In its last seconds, the iron core, which has the mass of between one-and-a-half and three Suns, collapses into a sphere just 7-12 mi in diameter … .

When atoms are that closely packed, all the empty space between the nucleus and its orbiting electrons is squeezed out, and the electrons are forced into the protons—converting them into neutrons. Within a matter of seconds, the ball of iron becomes a solid ball of neutrons—it has become a neutron star. As an anecdotal aside, if you were to gather up every one of the 7 billion humans alive today, pack them into an atom-squashing machine (the author isn't aware of such a device but, if it exists, it's probably manufactured by the Acme corporation), and then squeeze them down to neutron star density, all of humanity would fit in a box the size of a sugar cube.

If this stellar remnant (the neutron star, not the human cube) meets another neutron star, their combined gravitational pull means that they feel an irresistible mutual attraction, which—like the affairs of all great star-crossed lovers—can only end in tears.

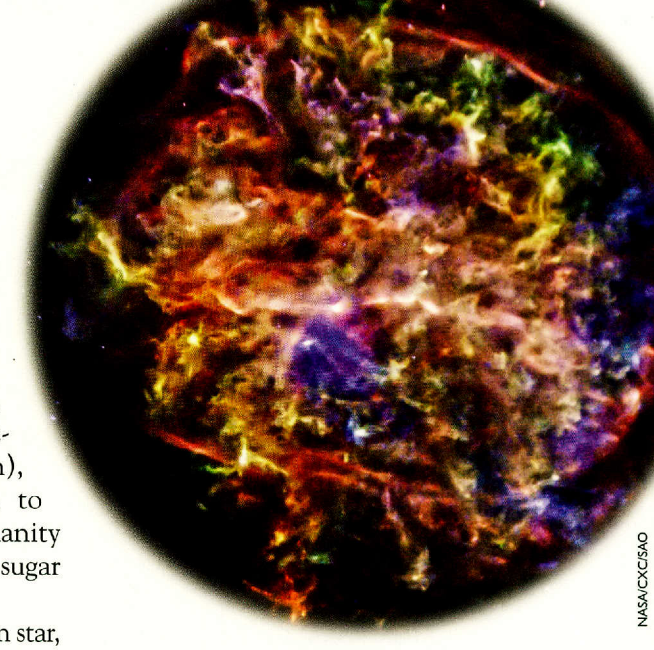
As they orbit each other, they are drawn closer and closer together, and the speed of their orbit increases thanks to conservation of momentum (just as an ice skater's spin speeds up as they pull their arms into their body) until, traveling at a combined speed of more than 130 million miles per hour, they smash together so violently that billions of tons of high-energy neutrons are hurled into space. These crash into particles in the surrounding environment—super-heating it and fusing to create heavy elements.

Another by-product of the neutron star collision and the union of all that mass is the creation of a black hole and a blinding flash of radiation, which is called a gamma-ray burst.

Thanks to a clever piece of capitalist-instinct-exploiting PR spin, Hubble's discovery made global news after revealing that as much as 10 lunar masses' worth of gold might be produced from such an event. …

Obviously a single observation does not make a scientific consensus, but, if it turns out that heavy elements are indeed manufactured in such vast quantities by neutron star collisions, it could solve a problem that has been bugging astrophysicists for decades. Because, although the stellar fusion (nucleosynthesis) theory for heavy-element production up to and including iron is pretty, well, iron-clad, when they estimate the amount of heavy elements that could be created in supernova explosions alone, the results invariably fall short of the amounts we see in the Universe today.

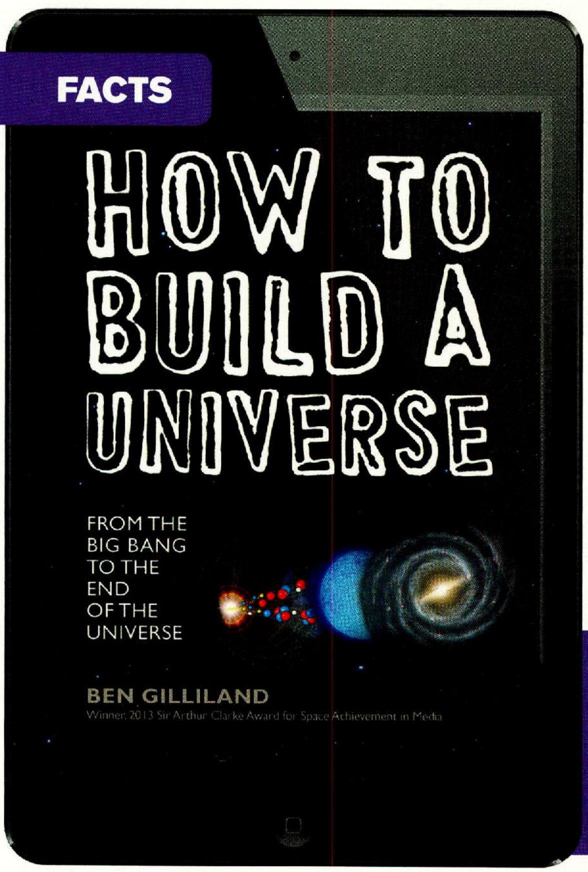
Anyway, whether created solely in the explosive death throes of stellar giants or in the collision of neutron stars, or a bit of both, the result is the same: all the elements heavier than lithium are made by stars and are distributed throughout the cosmos by colossal cosmic kabooms.



NASA/CXC/SAO

An X-ray image from a space telescope shows tendrils of different elements in the debris from a supernova explosion. Oxygen glows yellow and orange, magnesium green, and silicon and sulfur blue.

FACTS



How to Build a Universe
From the Big Bang to the End of the Universe
By Ben Gilliland
$24.95 hardcover

SKY CALENDAR

by Alan MacRobert

Venus and Jupiter pass various bright stars throughout May and June as they move toward an impressive conjunction. In June, Saturn bursts onto the twilight scene. By June 21, the summer solstice will usher in 2015's longest days and shortest nights.

MAY 1 - 15

The first "stars" to come out in the evening this spring are the two brightest planets. Watch as they continue to draw toward each other week by week.

Venus is the brightest, shining in the west during and after twilight. As the light fades, spot Capella far off to Venus' right and Betelgeuse a similar distance to Venus' lower left.

Jupiter is the other bright planet, shining much higher, to the upper left of Venus. Jupiter never manages to outdo Venus for brightness, though. Jupiter's enormous size can't quite make up for its greater distance from both Earth and the Sun.

Roughly midway between Jupiter and Venus, look for the stars Pollux and Castor, the heads of Gemini, the twins. They are assuming their horizontal alignment. Exactly how horizontal they'll be depends on your latitude and the time of evening.

The "little dog star," Procyon, shines straighter below Jupiter. Look much farther down below Procyon while twilight is fading and you can still pick up Sirius, the Dog Star, twinkling brightly on its way to setting.

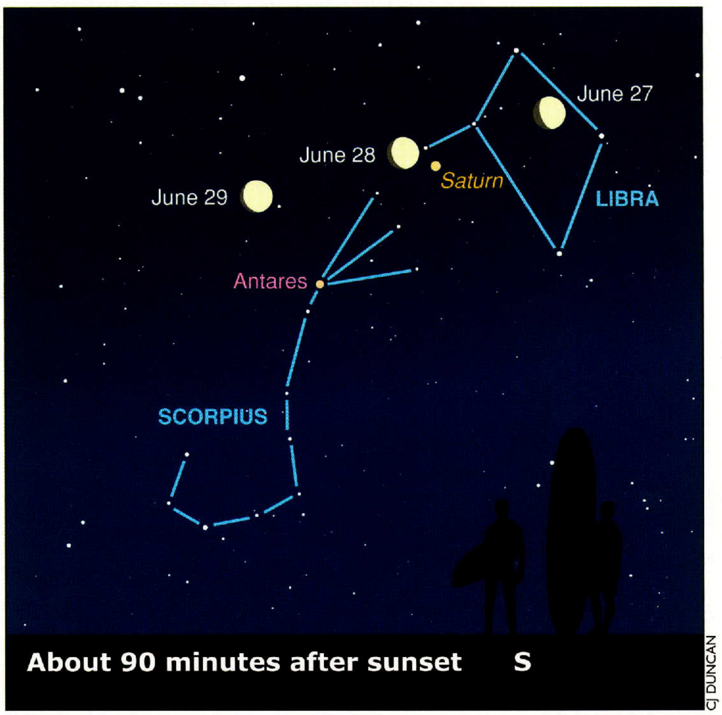
Venus and Jupiter begin May a huge 57 degrees apart, but watch them close in on each other! They narrow their separation by about one degree per day; they'll be only 36 degrees apart by May 15, and 21 degrees apart by month's end. (By comparison, your fist at arm's length is about 10 degrees wide.) They're on their way to a very close conjunction low in the sunset at the end of June.

In the first half of May, follow the line from Jupiter through Venus down to the lower right while the sky is still fairly light. There, near the horizon, you'll find Mercury glimmering through.

On the other side of the sky, Saturn rises in the east a few hours after sunset. Antares twinkles about a fist at arm's length below it. Much nearer to Saturn's lower right, look for fainter Beta Scorpii, the top of the diagonal star-row marking the head of Scorpius. The waning Moon adds itself to this scene on May 4 and 5.

MAY 16 - 31

Venus shines lower now in the west-southwest at dusk. But Jupiter to its upper left, and the stars behind them, are sinking faster as the season advances. So Venus is now crossing central Gemini, with Pollux and Castor above it or to its upper right. Look to its left for Procyon. Then look farther to Venus' right for Capella. These four stars form the "Arch of Spring" every year, but this year the arch has the distinction of Venus passing through it.



The waxing crescent Moon also passes through this scene from May 20 to 24. It poses to the lower left of Venus on the 21st and then to the lower left of Jupiter on the 23rd. On the night of the 24th, the Moon shines quite close to Regulus.

The three brightest *stars* in the sky now are Capella in the northwest; Arcturus, the "spring star," high in the southeast; and Vega, the "summer star," lower in the northeast. All are magnitude 0, one step brighter than 1st magnitude on the astronomical brightness scale.

How carefully do you look for colors in the stars and planets? The colors are weak, but definitely there. Capella is a pale yellowish white, the same color as the Sun (and, like the Sun, is a G-type star). Arcturus is a deeper yellow. It's technically an "orange giant" (stellar type K), but the tint is subdued enough that most people would not call it orange at first look. Pale golden yellow, maybe.

Vega, by distinct contrast, is icy white with just a trace of blue.

Colors are harder to see in fainter stars — Pollux and Castor, for instance. Pollux, the one on the left, is slightly brighter and also golden like Arcturus, while Castor is pure white.

Among even fainter stars, most people see little or no color at all. But that's just a limitation of the eye. Binoculars or a telescope reveal that stars of all brightnesses come in pretty much the same range of tints as the sky's leading lights.

How faint a star can you see color in with the unaided eye? Make your best judgment, then raise your binoculars and check.

JUNE 1 - 15

Mark your calendar to look west at dusk on June 1. You'll find brilliant Venus there, perfectly lined up with Pollux and Castor to its right. Is Jupiter, looking down from their upper left, jealous of this lovely display? Not for long! Venus quickly leaves Pollux and Castor behind and turns its attention toward Jupiter, edging closer toward it every day. By June 15, they're only nine degrees apart.

Turn around and look to the other side of the sky. Now that we're into June, Saturn and the distinctive top parts of Scorpius are well up in the south-southeast as the stars come out. They're highest due south soon after dark.

Saturn is a yellowish planet — that's fairly obvious, if you stop to notice. In fact, Saturn is the most strongly colored planet in the solar system after Mars, which is currently out of sight in the glare of the Sun.

Look below Saturn at nightfall for Antares, a first-magnitude "red" supergiant. Astronomers have a different idea of red than most people do; I'd call Antares fiery yellow-orange. But it's as red as any bright star gets; Betelgeuse in wintry Orion is its only competition.

A few fainter stars, visible only through telescopes, qualify as truly red. These are the rare "carbon stars" — also called type C stars. They are giants whose atmospheres are loaded with carbon vapor ,which acts as a red filter above the star's glowing surface. Carbon stars have been compared to flecks of garnets or tiny drops of blood.

JUNE 16 - 30

Every skywatcher's eyes will turn west in the twilights of the second half of June, where Venus is pulling up alongside Jupiter. The crescent Moon shines below them on June 19, and to the left of them on the 20th: Plan for photo opportunities. And don't overlook fainter Regulus to the two planets' upper left. The Sickle of Leo, attached to Regulus, can be seen overarching Venus and Jupiter once the sky grows dark enough.

Day by day, Venus pulls closer alongside Jupiter. But they're also both sinking lower and lower into the sunset glow. You'll increasingly need a skywatching spot with a good view of the western horizon.

By June 25, they're less than three degrees apart. Their conjunction finally arrives on June 30, when they're only one-third degree apart: less than the width of a pencil held at arm's length. Binoculars give a great view.

And if you have a telescope, turn it on the Venus-Jupiter pair as early in twilight as you can locate them. Don't expect to see sharp detail when looking so low through Earth's thick, shimmery atmosphere, but Venus is now a thin crescent compared to Jupiter's slightly oblate ball. And see how different their surface brightnesses are. Both are covered with clouds that actually have nearly the same reflectivity, but Jupiter is about seven times farther from the Sun, so it is lit by sunlight only about 1/49th as bright. So its surface brightness, as seen in your telescope, is about 1/49th that of Venus. Rarely do we get such a good opportunity to make this comparison in the same telescopic field of view.

Spring turns to summer at the June solstice, which this year comes on June 21 at 11:38 a.m. CDT. This is when the Sun reaches its northernmost position in Earth's sky for the year. Consequently, this time of year brings the longest days and shortest nights for the northern hemisphere.

So if you want a dark sky now, you have to stay up late. How late depends on your location, especially your latitude. At Miami (latitude 26 degrees north), the last twilight is gone from the sky by 9:45 p.m. during the second half of June; but at New York (41 degrees), there's still a little light in the sky as late as 10:30 p.m. At Seattle (48 degrees), it's truly dark only from 12:15 a.m. to 1:05 a.m. around the June solstice. In Winnipeg (50 degrees), a little twilight lasts right through the night; and north of the Arctic Circle (66.5 degrees), the Sun doesn't set.

In the southern hemisphere, meanwhile, things are the opposite. This is the dead of winter and the days are the year's shortest.

What can you see as the stars come out now? Arcturus is at its highest overhead (or a little south of overhead). Bright Vega dominates the east. Look for Deneb, the tail of Cygnus, the swan, as the brightest star to Vega's lower left. Altair, the eye of Aquila, the eagle, is the brightest star farther to Vega's lower right. And the Big Dipper hangs bowl-down high in the northwest, its handle arcing toward Arcturus, as always.

Alan MacRobert is a senior editor of Sky & Telescope *magazine.*

Meteor Watch

The Shower

Eta Aquarids

Named for a star in the constellation Aquarius, which rises a few hours before dawn

Peak

Morning of May 6

Notes

The Eta Aquarids are a modest shower for skywatchers in the northern hemisphere, with maximum rates of about a dozen meteors per hour. Unfortunately, the Moon will be almost full this year, so it will wipe out all but the brightest meteors.

Colors of Bright Summer Stars

COLOR	TYPE	EXAMPLE	TEMPERATURE (°C)
	B	SPICA	11,000–28,000
	A	VEGA	7,500–11,000
	G	SUN	5,000–6,000
	K	ARCTURUS	3,600–5,000
	M	ANTARES	2,000–3,600

Moon phase times are for the Central Time Zone.

MAY

How to use these charts:
1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

April 20	11 p.m.
May 5	10 p.m.
May 20	9 p.m.

MAGNITUDES

- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

- V Venus
- S Saturn
- J Jupiter
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

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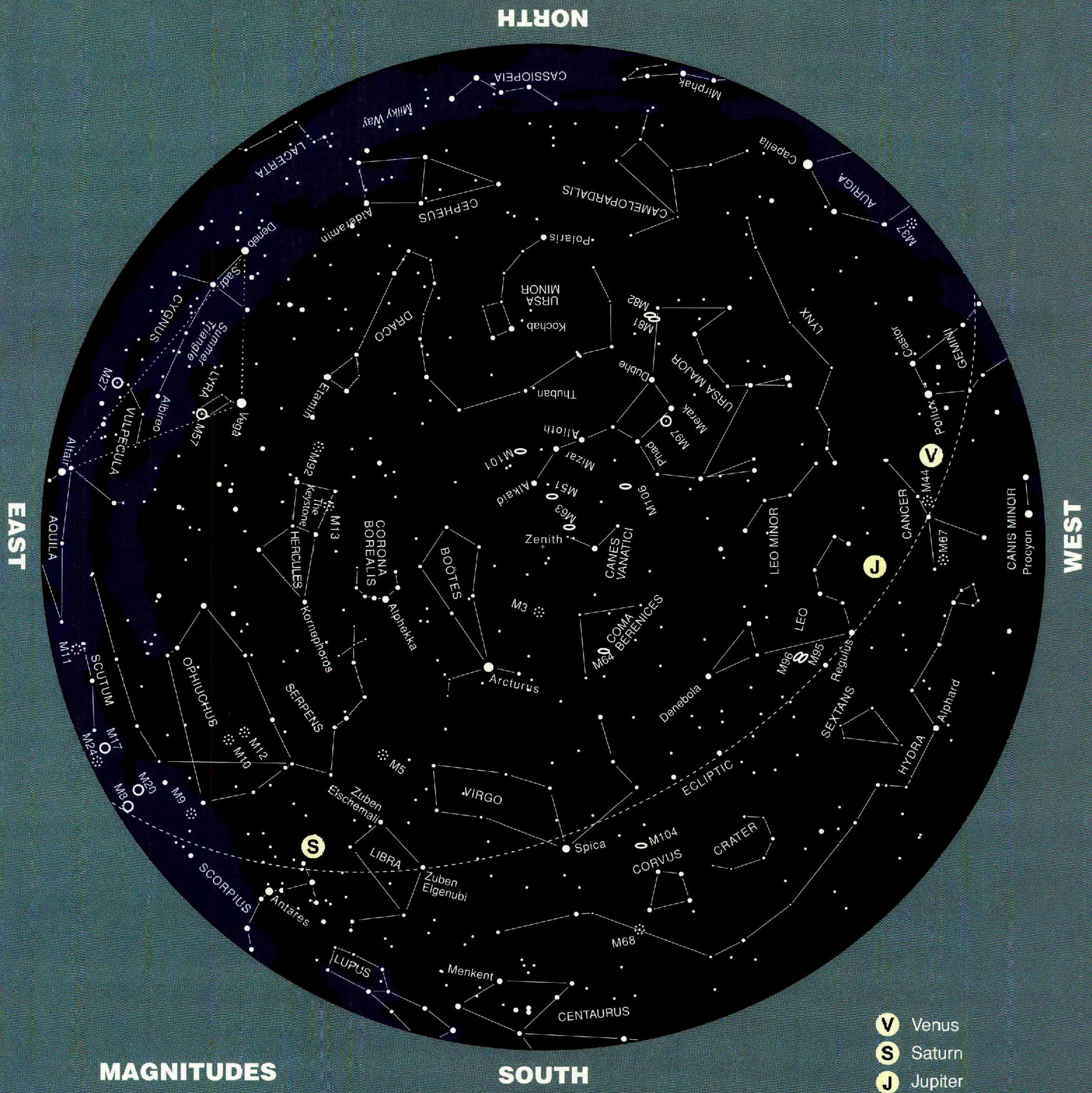

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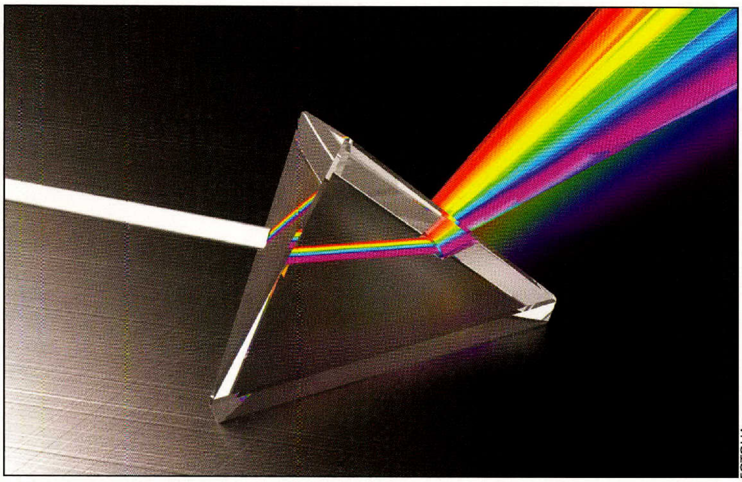
Look into the Light

Light is an astronomer's currency. Through the study of photons from stars, galaxies, gas clouds and more, scientists deduce an object's distance, motion, composition, and even history. The United Nations has declared 2015 the International Year of Light. In celebration, an exhibit called *Light: Beyond the Bulb* will be on view around the world. The exhibit focuses on how light is used in scientific investigations. Here are some places to view these exhibits in the US. More information at **www.light2015.org**.


FOTOLIA

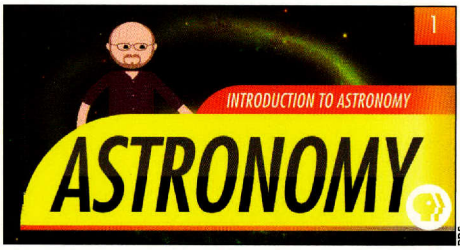
CITY	LOCATION	DATES
Las Vegas	Science and Engineering Festival	April 24-May 2
Ferndale, WA	Ferndale Public Library	May 4-15
Bellingham, WA	Squalicum High School	May 18-29
Washington, DC	National Mall	June 19
West Hartford, CT	The New Children's Museum	July
Honolulu	International Astronomical Union Meeting	August 3-14
Atlanta	Fernbank Science Center	August
Atlanta	Agnes Scott Observatory	August
San Diego	The Central Library	September
Framingham, MA	Christa Corrigan McAuliffe Center	October

PBS Launches Pair of Online Space Shows

Two new online video series from PBS Digital Studios are putting astronomy lessons at the click of a mouse.

Crash Course: Astronomy is designed as an AP-level series with 10- to 12-minute episodes. Host Phil Plait, better known as The Bad Astronomer, formerly hosted *Bad Universe* on the Discovery Channel and blogs for *Slate* magazine. About half a dozen episodes of *Crash Course: Astronomy* are currently available, on topics from naked-eye skywatching to telescopes, Moon phases, and more.

Episodes of the other new series, *Space Time*, are a bit shorter, at six to eight minutes. Astrophysicist Gabe Perez-Giz tackles serious science topics from a pop-culture angle. The currently available episodes include "What Planet is Super Mario World?," which uses lessons about gravity, exoplanets, and physiology to pick a planet on which the character Mario could jump as high as he does in the video game, and "Is it Irrational to Believe in Aliens?"



PBS

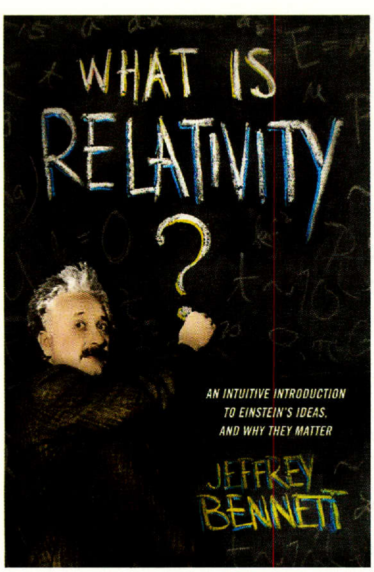
youtube.com/user/pbsdigitalstudios

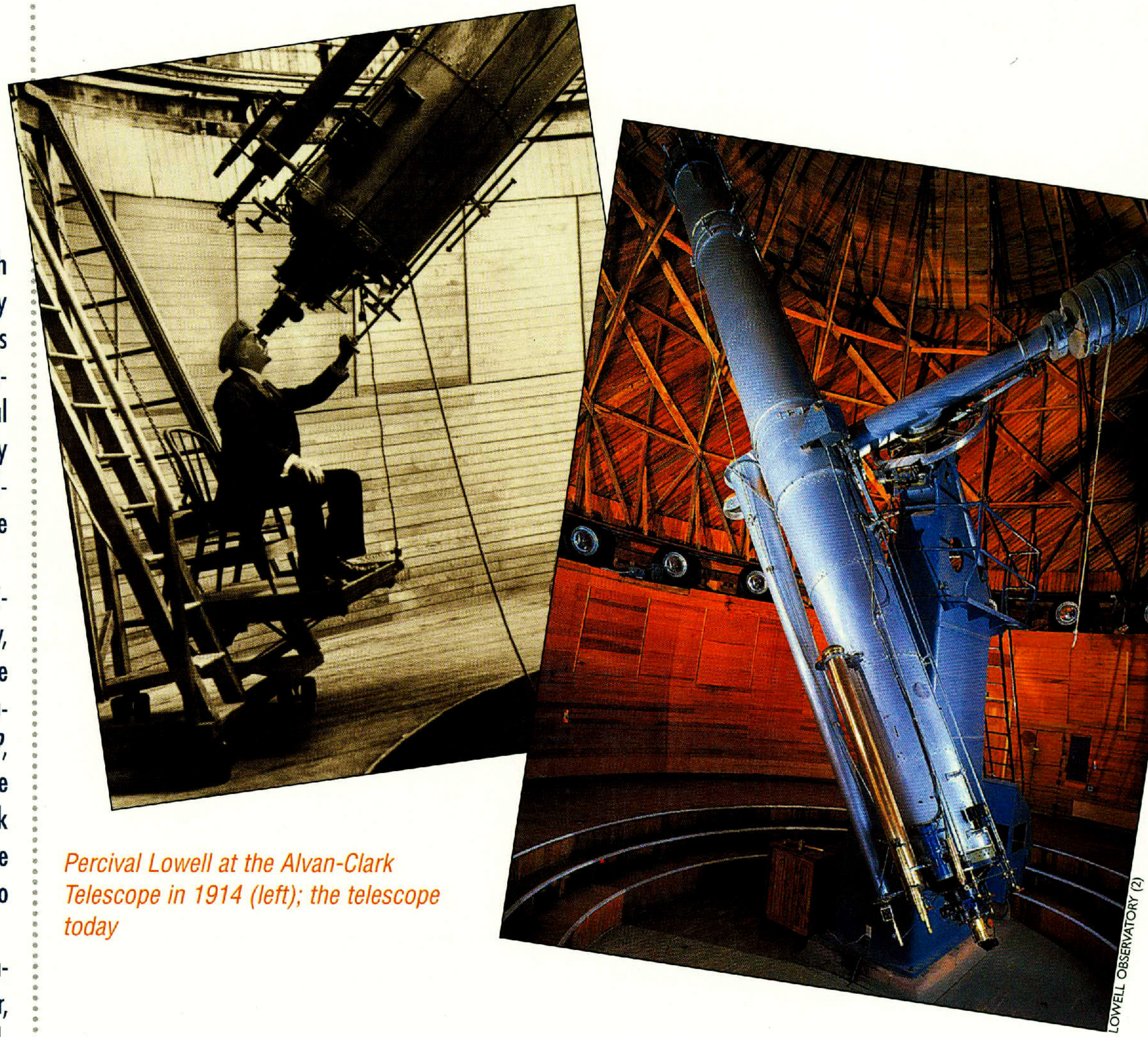
Tracking Einstein

Without Albert Einstein, Apple Watch couldn't track you on your daily jog and you'd still be using paper maps to navigate. That's because without Einstein's theories of relativity, the Global Positioning System wouldn't accurately account for the motion of the GPS satellites and the pull of Earth's gravity, so the system would fail within hours.

November marks the 100th anniversary of Einstein's theory of gravity, general relativity. To commemorate the event, astronomer Jeffrey Bennett, author of last year's *What Is Relativity?*, is staging a nationwide lecture tour. The events provide an overview of black holes, time dilation, $E=mc^2$, and the applications of Einstein's equations to everyday life.

The current schedule includes presentations in Silicon Valley, May 6; Denver, August 27; and Tucson, November 16, although additional dates and venues will be added. Check the current schedule at www.bigkidscience.com/relativity-tour.





Percival Lowell at the Alvan-Clark Telescope in 1914 (left); the telescope today

LOWELL OBSERVATORY (2)

Historic Telescope Goes Back to Work

The telescope that Percival Lowell used to map the "canals" of Mars is returning to service in May. The 24-inch instrument, built by famed telescope makers Alvan Clark & Sons, entered service in 1896. In addition to Lowell's Mars observations, it was used to measure the motions of galaxies, which was instrumental in determining that the universe is expanding. Astronomers also used to it map the Moon for the Apollo missions.

The telescope has been a centerpiece of Lowell Observatory's public programs since the 1980s, and the observatory says that more than one million visitors have looked through it. Over the past year, it has been disassembled and cleaned, and some balky parts were replaced. Its dome and electrical system were upgraded as well.

The telescope will be rededicated on May 12, with public viewing resuming the following weekend.

lowell.edu/outreach

UNIVERSE IN A TEACUP

Physicists probe the structure of the cosmos by smashing its tiniest structures to get a peek inside

SETUP

Jon Butterworth of University College London is one of the lead scientists in the ATLAS collaboration. This group, and a competing one called CMS, used the Large Hadron Collider at CERN, the European particle physics laboratory outside Geneva, to find the Higgs boson — the long-sought particle predicted to give mass to all objects in the universe. In *Most Wanted Particle*, Butterworth describes the hunt for the Higgs by both groups. Here, he explains the excitement leading up to the announcement that later led to a Nobel prize for Peter Higgs and Francois Englert.

EXCERPT

In December, with our hints and the CMS hints, I had started to think the odds were better than evens that the Higgs existed. Quite a step, for a confirmed Higgs sceptic. Now, when I saw the first 2012 mass distribution, I knew in my guts that we had it. The data needed checking, and were not really significant enough to be sure, but there was a small bump in the same place as the December results. This felt real. I could not actually, scientifically, be sure. But my stomach was having none of that.

This is a very dangerous phase for a scientist.

The next update on the ongoing Higgs hunt was planned for 4 July. Data were still coming in, cross-checks were still being made. We lapsed into a strange kind of state, desperate to know the answer but desperate to avoid any spoilers, any credible rumours from CMS. The rumour mill had been running for a while, of course. There was even a hashtag higgsrumors (US spelling!) that trended briefly on Twitter. All very entertaining for the neutrals, and it was pleasing that we were not the only ones interested in and excited by our experiment.

But … when it came to CMS data, I really did not want to know.

Part of the point of having two independent experiments is that they cross-check each other — independently. We do that most effectively when we are blind to the other experiment's data, right up to the last minute. In fact, up to a point we even try to blind ourselves to our own data. As much as possible of the analysis should be optimised and decided in advance, before looking at the key data. This prevents even the possibility of subconscious bias entering the studies. If you are biased, the truth will probably still out in the end, but in the meantime your statistical estimations of confidence and significance will all be wrong. When your guts think they have the answer, you have to be even more careful. Guts can be wrong.

So hearing gossip from CMS would be at best distracting, a babble of inaccurate noise. At worst, it would be accurate and would bias our analysis. Likewise, as well as betraying confidences and damaging trust within the collaboration, leaking our own ATLAS data could bias CMS. …

The CERN seminar was to be at the start of the International Conference on High Energy Physics (ICHEP). There is one of these every two years. In 2008 in Philadelphia, the LHC had been about to turn on for the first time and the Tevatron [the U.S. particle collider located at Fermilab, outside of Chicago] had just ruled out their first mass point for the Higgs. Two years later, in Paris 2010, first LHC data were shown and Higgsteria was intense. This time, in Melbourne, would not be the last. But we all knew it would be another big step, one way or another.

We would be surprised at how big a step it would turn out to be.

THE ANNOUNCEMENT

It was 3 July 2012 and I was in Salle

Curie, one of the conference rooms below Building 40 at CERN. There are four of these rooms (Andersson, Bohr, Curie, Dirac), and the weekly meetings of the Standard Model group were usually held in Salle Curie. However, this morning Fabiola Gianotti, the spokesperson (meaning boss) of ATLAS, would be rehearsing the talk she would give the following morning. The talk was entitled, with studied neutrality, 'Status of Standard Model Higgs Searches in ATLAS'. It would be given on the morning of the following day, with a webcast around the world and especially to ICHEP, which was just opening in Melbourne.

It had become increasingly clear, initially to us and gradually to the media, that this was likely to be the big one. Peter Higgs had been sighted in town (having lunch with Edinburgh colleagues involved in the search) and Francois Englert would be in the audience on Wednesday too. There was a definite tension in the air as Fabiola prepared to speak. Very few of us had seen all the ATLAS results collected together. Some of them were only hours old. We all knew we had something special, but how would it stack up? And would Fabiola stick with Comic Sans?

That question was answered immediately. ATLAS and CERN are not very corporate, and no one is going to tell Fabiola how to make slides. Comic Sans it was. The content was more important, of course, though presentation makes a difference and as Patrick Kingsley pointed out in the *Guardian*:

> Comic Sans may be overused, it may look silly, and it may have been designed in a hurry. But it's also very legible, and tests have shown that it makes complex information easier to understand. There's a reason it's used by dyslexia coaches: it facilitates reading.

So, perhaps not a bad choice for communicating tricky new results in as friendly and accessible a way as possible.

The question of how the data would stack up was answered over the next hour. The 2012 run had, up until two weeks earlier, delivered 6.6 inverse femtobarns of data. The recorded data equated to something like 5km [3 miles] of CDs stacked on top of each other, and more than 90 per cent of it had already been analysed and would be included in these results, along with the data from previous years. Several important Standard Model processes had been measured quite precisely, showing that both the detector and the physics were pretty well understood in these collisions.

The key results would be the search for a bump in the two-photon mass distribution and in the four-lepton mass distribution, and Fabiola spent some time discussing the details of the photon identification before showing the result. From the 2011 data alone, we had a 3.5 sigma significance. From the new data alone we had 3.4. The combined data set was 4.5 sigma. Very strong evidence, but not, on its own, up to the conventional 5 sigma threshold to call it a discovery.

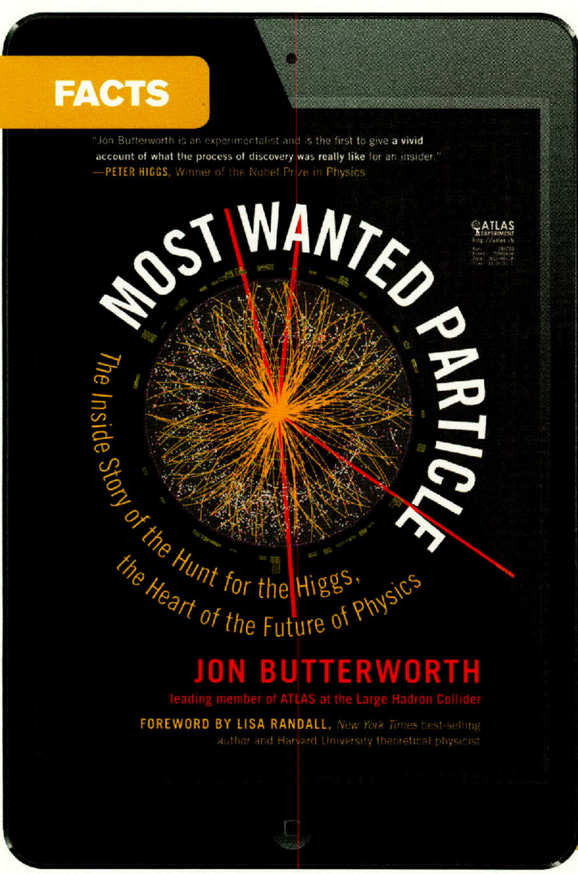
But there was more. Fabiola then gave a brief discussion of electron and muon reconstruction, and showed the four-lepton distribution. Another bump. In 2011 it had a significance of 2.3 sigma. In the new data alone, 2.7. Combined, 3.4 sigma. More strong evidence, still not 5 sigma. But put these together, also with the WW and other decay channels from the 2011 data (the 2012 update for those was not yet ready) and the magic number came up. Five sigma.

An arbitrary threshold, just a convention. But one we had set ourselves in advance — we couldn't move the goalposts even if we wanted to be more cautious. We didn't have to beat about the bush. We had a discovery.

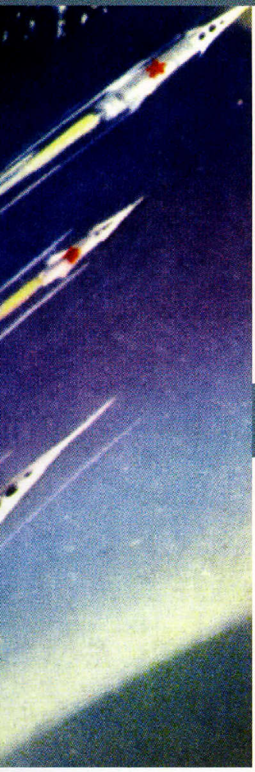
This was a very powerful experience. The moment when Fabiola showed our data, and our conclusions, hit me hard. I had seen some of the slides already, and the documentation and the analyses behind them. These were the work of hundreds of colleagues, many of them more directly involved than me in this particular analysis. And years and years of work for us all lay behind the results. But even knowing what was coming, seeing Fabiola declare to all of us what we had done was surprisingly emotional.

At the end of the talk, we decided to stop calling it an 'excess of events' and call it a new boson.

FACTS



Most Wanted Particle
The Inside Story of the Hunt for Higgs, the Heart of the Future of Physics
By Jon Butterworth; $27.95 hardcover



DÉJÀ VU ALL OVER AGAIN

This summer's encounter with Pluto recalls a meeting with another icy world 25 years ago

SETUP

The Voyager missions provided the first detailed look at the solar system's outer planets and moons, in the 1970s and '80s, and more recently at interstellar space beyond. In *The Interstellar Age*, Jim Bell – a planetary scientist who worked on Voyager and Mars rover missions – recalls the final world that Voyager visited, and tells us that we may see its cousin this summer.

EXCERPT

If the moons of Neptune were to be the last planetary hurrah for Voyager, it would head for the stars with fanfare. After swinging just 3,000 miles above the cloud tops of Neptune (closer than to any planet that the spacecraft visited since leaving Earth), Voyager 2's trajectory would take it past one final, glorious, unknown destination: Triton. ... The spacecraft would fly within 25,000 miles of Triton, taking pictures of surface features as small as 5 to 10 miles across, and no one really knew what to expect. Because it is so bright and so far from the sun, Triton's is among the coldest natural surfaces in the solar system, with an average temperature only about 38 degrees above absolute zero (or an incomprehensible –391°F). Triton's brightness suggested that there would be relatively clean ice on the surface, perhaps even including exotic, low-temperature ices other than water ice. And its strange backward orbit suggested that it may have been through some sort of planetary-scale trauma, such as being captured by Neptune, or had its course changed by some sort of giant impact. It was a great way to end the surface-imaging phase of a great mission—with an encounter that would be surprising no matter what was revealed.

About five hours after closest approach to Neptune, Voyager 2 flew past Triton. Several days later, I remember being in the JPL workroom with imaging team member Larry Soderblom, looking over the first high-resolution images of Triton that had come in. Larry is a friendly, outgoing, sometimes mischievous, and highly respected member of the planetary science community who works at the US Geological Survey's Astrogeology Science Center in Flagstaff, Arizona. Larry was one of the Voyager imaging team members who would occasionally give me a nod and a wink and beckon me away from some dark, out-of-the-way corner to come sit at the big table and look at some images. How could I resist?

Luckily, I didn't feel too stupid, because what bizarre images they were! Larry was as mystified as I was. Instead of a surface covered with classic impact craters, cracks and ridges, or other typical features like those that had been seen on many icy moons before, Triton was determined to be different. The part of Triton's southern hemisphere that was sunlit during Voyager's flyby was split into two very weird kinds of terrains: a darker one consisting of pits and dimples and ridges reminiscent of the skin of a cantaloupe, and a brighter one consisting of smoother plains materials interspersed with terraced depressions that looked like frozen lakes. A translucent, reddish layer of nitrogen ice in some places, and nitrogen snow or frost in others, appeared to drape much of the terrain. That, and the relative lack of impact craters, suggested that the surface was geologically very young. It was as strange and unexpected a place as Voyager had ever revealed, and I remember Larry laughing to himself more than once. "Isn't that just beautiful?" he would ask rhetorically.

To top it off, Voyager's ultraviolet spectrometer team had recently discovered a surprise—Triton has a very thin atmosphere (less than 0.001 percent of Earth's pressure) made mostly of nitrogen and methane. Larry was looking for some evidence of the interaction of that thin atmosphere with the surface. He and others had already noticed dark wind streaks near the south pole—places where that thin atmosphere appeared to be moving sediments across the surface. ... Larry was making short time-lapse movies of Triton's surface as Voyager sped past, looking for evidence of any changes that the wind might be actively making. That's when they noticed something remarkable: dark plumes, rising up more than 5 miles above the brighter surface of Triton and then spreading out more than 60 miles downwind. Four of them had been caught in the act of erupting as Voyager 2 flew past, and photographing them at different angles during the flyby is what allowed Larry and colleagues to view them in stereo and determine their heights.

"I was analyzing newly received Triton images with longtime USGS Flagstaff friend and colleague Tammy Becker," Larry recalls, thinking back to that wonderful moment of discovery. "We were building a new map of Triton's surface, pasting the overlapping Voyager images together into a mosaic. Because the flyby images were all taken from different angles as we flew past, we had to try to paste the images onto a spherical model of Triton's surface so they could be aligned into a global map. But some dark and bright streaks seen in two particular overlapping images just would not line up. We puzzled a bit and the reason soon became clear—the streaks were not on the surface but were above it! We put those two images together into a stereo viewer, grabbed our red-blue glasses, and Triton's plumes popped out of the surface and into full view!"

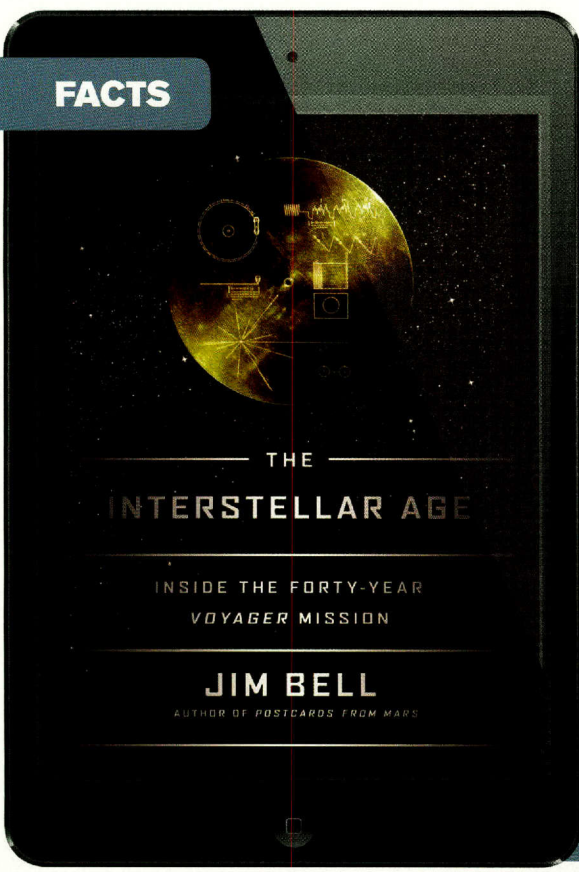
Active geysers on Triton! Larry and the team came up with a model to explain what they were seeing: sunlight warms the bottom of a relatively transparent 3-to-5-foot-thick layer of seasonal surface nitrogen ice, causing it to sublime (evaporation of ice directly from a solid to a gas) and collect under pressure under the ice. When the ice cracks somewhere, the nitrogen gas is explosively released, carrying dark dust and mineral grains along with it up to high altitudes under the low gravity and atmospheric pressure. ...

We haven't been back to Triton since Voyager 2 zipped past, but we have made some progress in trying to figure out where Triton may have come from. The discovery of Pluto, in 1930, was among the earliest pieces of evidence that astronomers used to argue for the existence of a large disk of similar small bodies extending well beyond Neptune's orbit. Among these visionaries was one of the fathers of modern planetary science, the Dutch-born American astronomer Gerard P. Kuiper. In the early 1990s, planetary astronomers began discovering the first members of that population beyond Pluto... . Today, taking advantage of substantial improvements in telescopes and camera detectors over the past few decades, more than 1,200 of these Kuiper Belt Objects, or KBOs, as they are now known, have been discovered. Many of them, like Pluto, are in an orbital resonance dance with Neptune that always keeps them far away from that giant planet's gravity... . Over the 4.6-billion-year history of the solar system, it is hypothesized that some fraction of KBOs that were in unfortunate orbits bringing them too close to Neptune either crashed into the planet or were slingshot out of the solar system or even into the sun. But, just possibly, one of them—Triton—survived that close encounter and was captured by Neptune's gravity.

Voyager's flyby of Triton, then, may have been humanity's first encounter with a Kuiper Belt Object... . To illustrate how rare and precious the Triton flyby was, we would have to wait twenty-six years for our second encounter with a KBO, when the NASA New Horizons spacecraft flies by Pluto in July of 2015. After more than nine years of traveling through space as the fastest mission ever launched, New Horizons will have to do all its best science, and take all its best images, within about a thirty-minute period around closest approach to Pluto (no pressure on that team, eh?).

There's a lot of speculation that Pluto will resemble Triton. The two are comparable in size, and Pluto is already known to have a thin atmosphere like Triton's, as well as a surface dominated by nitrogen ice. But there are also significant differences. For example, though smaller than our own moon, Pluto has five moons of its own, including a relatively large one (half the size of Pluto itself) called Charon, which has a surface dominated by water ice instead of nitrogen. While Pluto itself may end up showing some similarities with its possible cousin Triton, my bet is that the Pluto system overall will turn out to be just as new, strange, and alien as every other place that we've encountered in our travels out into the solar system.

FACTS



The Instellar Age
Inside the Forty-Year Voyager Mission
By Jim Bell; $27.95 hardcover

by Rebecca Johnson and Damond Benningfield

Dark Danger

Passages through the Milky Way's disk could mean trouble for Earth

As our solar system orbits the center of the Milky Way galaxy, it bobs up and down like a pony on a merry-go-round. It's not all a joyride, though, because each passage through the plane of the galaxy's disk may trigger destruction here on Earth.

Some researchers have found evidence that nasty things happen to our planet roughly every 30 million to 35 million years, including bombardment by comets and huge volcanic eruptions, which can trigger mass extinctions. That cycle corresponds to the gap between the solar system's passages through the densest part of the galaxy's disk. To some, that suggests there could be a relationship between these passages and the cycles of destruction.

A recent study says that one source of destruction could be dark matter, which produces no detectable energy but exerts a gravitational pull on the visible matter around it. It probably consists of some form of subatomic particle, and accounts for roughly 80 to 90 percent of the mass of the Milky Way galaxy. There could be more dark matter concentrated in the plane of the galaxy's disk, so it would exert a stronger influence when the solar system passes through that plane.

The study, by Michael Rampino of New York University, suggests the dark matter could harm Earth in two ways. First, it could nudge giant iceballs far from the Sun into the inner solar system, where they could hit Earth. An impact by a comet or asteroid roughly 65 million years ago probably contributed to the extinction of the dinosaurs, for example.

And second, the dark matter could accumulate in the center of Earth itself. Dark matter particles rarely interact (if at all) with the normal matter that makes up planets and stars. Yet some theories of dark matter say that if two particles of dark matter contact each other, they would annihilate, producing energy.

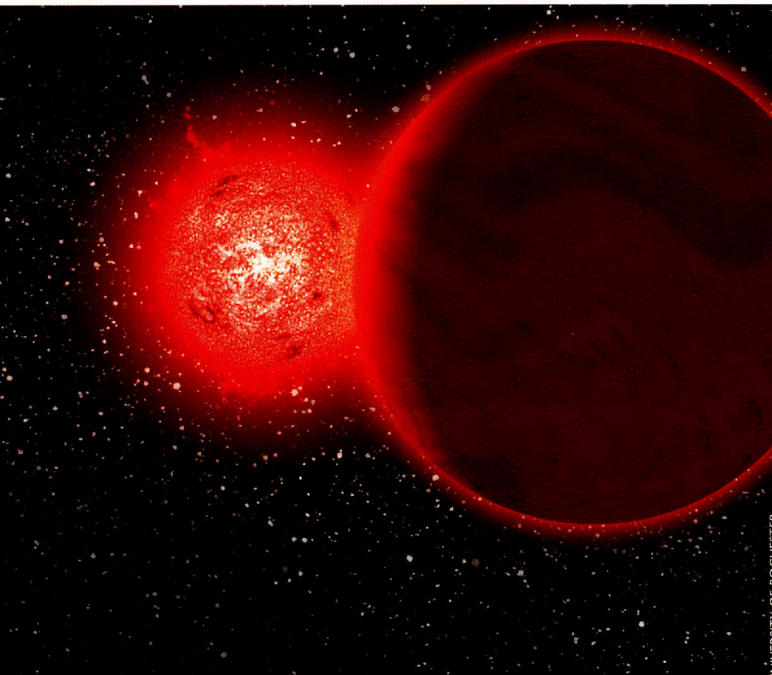
Rampino suggests that as the solar system bobs through the densest part of the galactic plane, some of the relatively slow-moving dark matter particles, which usually zip through Earth without stopping, could accumulate in the planet's core. If there are enough particles, they could stage enough interactions to heat Earth's core and mantle, potentially triggering massive volcanic outbursts — one possible hazard in our merry-go-round ride around the center of the galaxy. **DB**

Getting to Know a Former Neighbor

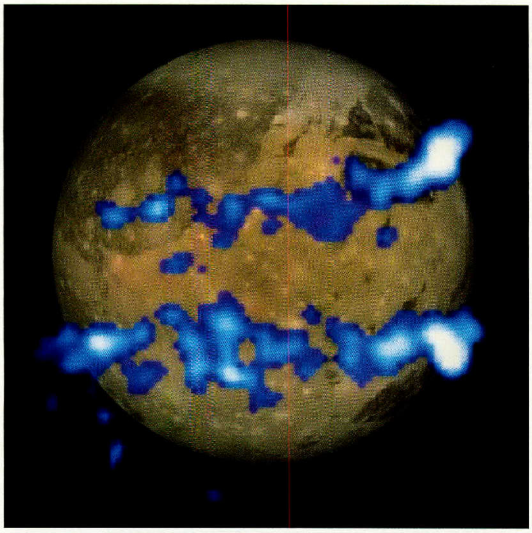
A star system that was discovered in 2013 is one of our closest neighbors, at a distance of just 20 light-years. Not long ago, however, it was the closest neighbor of all.

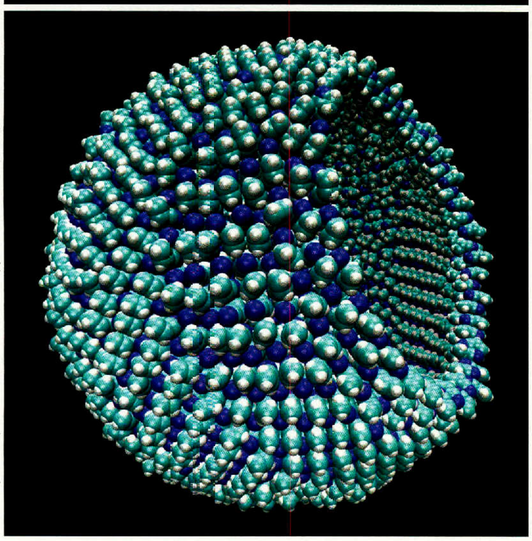
The system, known as Scholz's Star for its discoverer, consists of a tiny, faint star known as a red dwarf, plus a failed star known as a brown dwarf. A team led by Eric Mamajek of Rochester University plotted the motions of the system and found that 70,000 years ago it passed just 0.8 light-years from the solar system, which is less than one-fifth the distance to today's nearest star system.

The system probably passed through the edge of the Oort Cloud, a vast shell of comets around the Sun. The researchers, however, say it probably had little effect on the comets, so it did not send any of them plunging toward the inner solar system.



An artist's concept shows the red dwarf and brown dwarf (foreground) that make up Scholz's Star passing close to the Sun (bright star at left).





ASA/ESA/J. SAUR (UNIVERSITY OF COLOGNE)/JPL/GALILEO PROJECT; JAMES STEVENSON

Life on Distant Moons

Scientists continue to pursue the possibility of life on two of the solar system's largest moons: Ganymede and Titan.

Recent observations of Ganymede, Jupiter's largest moon, point to a saltwater ocean underneath the icy crust. Ultraviolet observations of the moon's auroras with Hubble Space Telescope indicate there is more water on Ganymede than in all of Earth's oceans combined.

Ganymede's auroras are caused by its magnetic field. The giant moon orbits inside Jupiter's enormous magnetic field, too. Changes in Jupiter's magnetic field cause Ganymede's auroras to rock back and forth.

Since the 1970s, scientific models of Ganymede have suggested it might have an ocean. If the ocean existed, Jupiter's magnetic field would create a secondary magnetic field in Ganymede's ocean that would hold back the rocking of the moon's auroras. And that's what seems to be happening: the auroras are rocking only 2 degrees rather than the expected 6 degrees.

The researchers, led by Joachim Saur of Germany's University of Cologne, estimate the ocean is buried under 95 miles (150 km) of ice crust, and is 60 miles (100 km) deep.

While evidence of a water ocean on Ganymede increases the chances that it might harbor life, scientists at Cornell are modeling strange life that could live on Saturn's giant moon Titan.

Titan is covered in lakes and seas of methane. The Cornell group posits that it could harbor life forms that do not use oxygen, and are based on methane. These cells could live in liquid methane at minus-292 degrees Fahrenheit.

"We're not biologists and we're not astronomers," said molecular chemist Paulette Clancy, "but we had the right tools. Perhaps it helped, because we didn't come in with any preconceptions . . . . We just worked with the compounds that we knew were there and asked, 'If this was in your palette, what can you make out of that?'"

Clancy's group said the next step is to demonstrate how their theorized cells would behave in a methane environment, particularly finding analogs to reproduction and metabolism. **RJ**

Top: Galileo image of Ganymede overlaid with Hubble ultraviolet view of its aurorae. Left: Partial cutaway view of an azotosome, the hypothetical methane-based, oxygen-free cells that could live on Titan. An azotosome is about the same size as a virus.

Filling an Ancient Martian Ocean

Oceanside property is tough to come by on modern-day Mars, but it might have been common when the planet was younger. Recent research suggests that an ocean as big as Earth's Arctic Ocean once covered about half of the planet's northern hemisphere.

Although present-day Mars is cold, dry, and barren, scientists have found copious evidence that it was warmer and wetter in the distant past. The evidence includes a possible ancient shoreline ringing much of the northern hemisphere.

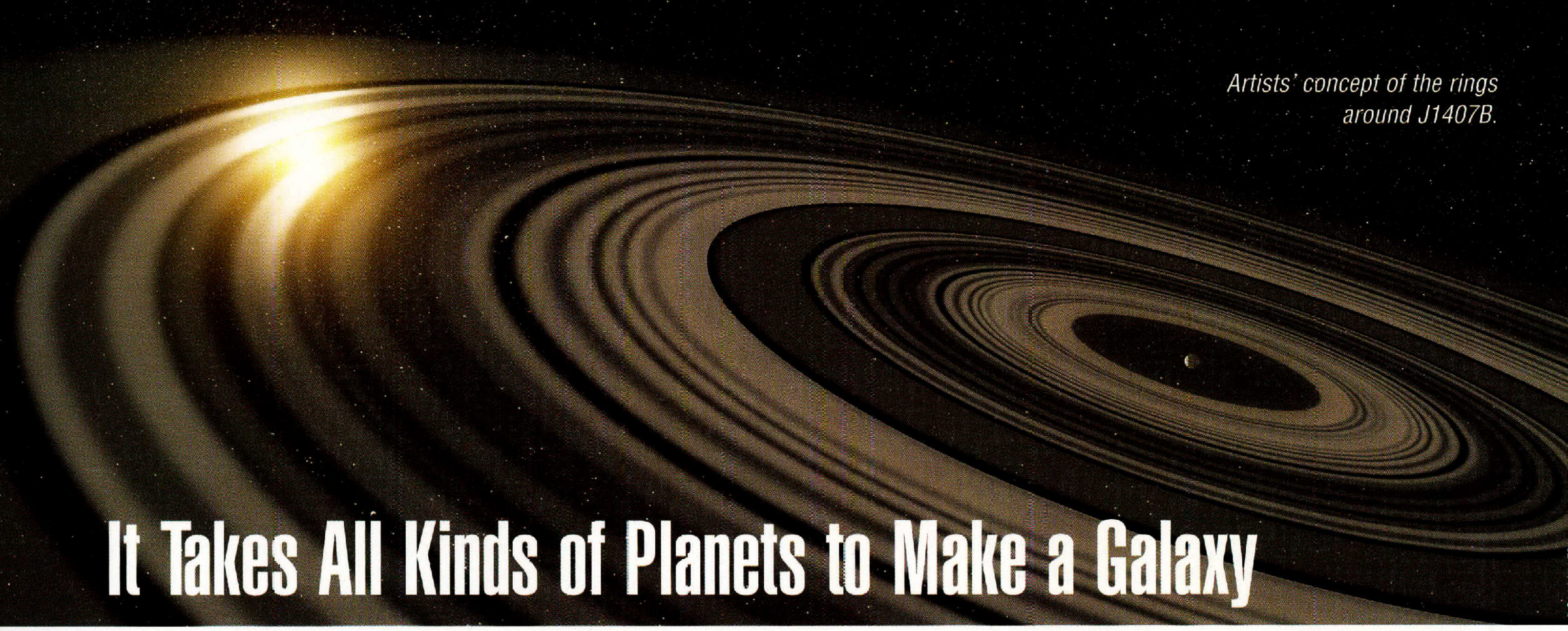
A study published earlier this year suggested that roughly four billion years ago, the ocean basin was filled with about eight million cubic miles (20 million cubic km) of water, which is the equivalent of Earth's Arctic Ocean.

Over a period of six years, a team led by scientists at NASA's Goddard Space Flight Center used three large ground-based telescopes to measure the ratio of two different forms of water in the present-day Martian atmosphere, and compared those results to the ratio found in a 4.5-billion-year-old Martian meteorite. The comparison revealed how much water Mars has lost in the intervening eons. Some of the water is frozen in the planet's polar ice caps or in layers of permafrost, but much of it was lost to space.

Based on the volume of liquid water and the contours, the study's authors calculated that the ancient ocean covered roughly one-fifth of the planet's surface, with depths of up to one mile (1.6 km). **DB**

NASA/GSFC

Artist's concept depicts an ancient Martian ocean



Artists' concept of the rings around J1407B.

It Takes All Kinds of Planets to Make a Galaxy

The types of planets and planetary systems found in the Milky Way continue to grow. Recent discoveries from two teams expand their age range and characteristics.

The Kepler spacecraft has uncovered an ancient solar system with five planets between the sizes of Mercury and Venus. All orbit Kepler-444 in fewer than 10 days, much closer in than Mercury is to the Sun.

The system is about 11 billion years old, and formed when the universe was less than 20 percent of its current age of 13.8 billion years.

"The discovery of this ancient planetary system shows that even the very old stars in our galaxy were accompanied by rich planetary systems," said team member William Cochran of The University of Texas at Austin. "This tells us that there are nearby planets that are far, far older than the planets in our own solar system."

Observations from orbit revealed the planets' presence as they passed in front of the star — an event called a transit — as well as their orbits and sizes. Ground-based observations from McDonald Observatory revealed the star's (and thus the planets') composition and age.

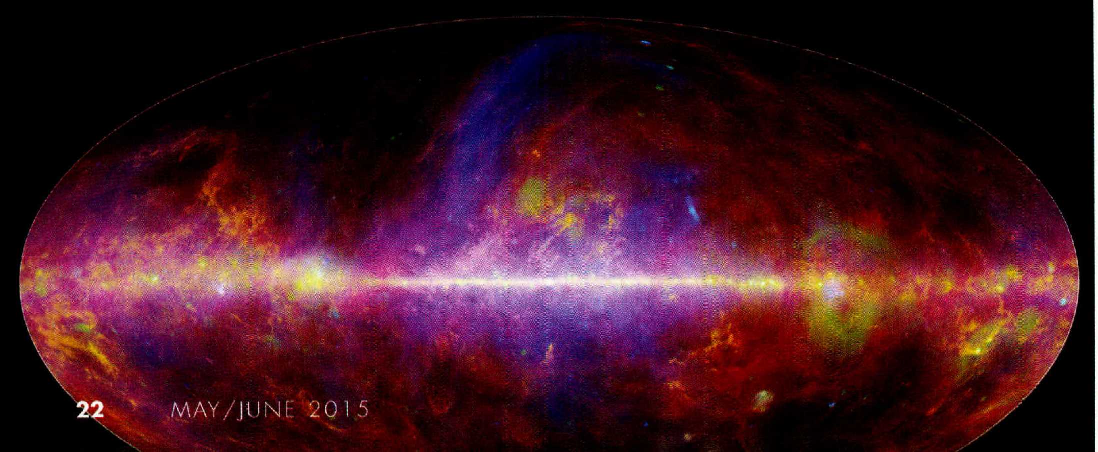
In other planet-finding news, a team led by Matthew Kenworthy of The Netherlands' Leiden University found that a planet detected by the WASP project in 2012 is likely surrounded by a ring system 200 times larger than Saturn's. The more than 30 rings around J1407b contain as much mass as Earth.

Astronomers studied the detailed changes in the light from the star as the planet crossed in front of it. "The details we see ... are incredible," Kenworthy said. "The eclipse [or transit] lasted for several weeks, but you see rapid changes on time scales of tens of minutes as a result of fine structures in the rings.

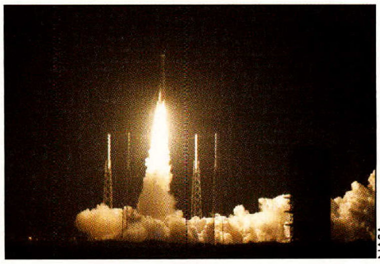
"The star is much too far away to observe the rings directly," he said, "but we could make a model based on the rapid brightness variations in the starlight passing through the ring system. If we could replace Saturn's rings with the rings around J1407b, they would easily be visible at night and be many times larger than the full Moon." **RJ**

Mining the Skies with Planck

The European Planck mission recently released four years' worth of data. Planck studies the sky in microwave and millimeter wavelengths to probe cosmology — the formation and fate of the cosmos on the largest scales. In this colorful all-sky image, the Milky Way's most abundant type of dust glows in red as it gives off heat. The carbon monoxide in the dense clouds of gas and dust making new stars follows the plane of the galaxy. Fast-moving electrons flowing out of exploding stars and other energetic phenomena, called synchrotron radiation, show up in blue. And the green light comes from 'free-free' radiation — electrons and protons near massive stars that are slowing down to come close to crashing into each other, but don't.



ESA NASA JPL-CALTECH



NASA

MMS Quartet Aloft

The four identical spacecraft of the Magnetospheric MultiScale (MMS) mission were launched aboard an Atlas V rocket March 12 from Cape Canaveral. MMS will study how Earth's magnetic fields give off energy as they disconnect and reconnect. Scientists plan to use what they learn about magnetic reconnection at Earth to better understand the same process around stars, black holes, and at the boundary between our solar system and interstellar space.

Debris from a stellar explosion races into space in this multi-wavelength view. Known as GK Persei, the explosion is classified as a nova, which occurs when gas from a companion star piles up on the surface of a stellar corpse known as a white dwarf. When enough gas accumulates, it triggers a brilliant thermonuclear explosion. This nova was observed to explode in 1901. X-ray observations (blue) from Chandra X-Ray Observatory show gas that has been heated to millions of degrees; radio waves (red) from the Very Large Array show electrons that have been energized by a shockwave; and optical (yellow) from Hubble Space Telescope show clumps of material that were hurled into space by the explosion.

X-RAY: NASA/CXC/RIKEN/D.TAKEI ET AL; OPTICAL: NASA/STScI; RADIO: NRAO/VLA