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MARTIAN INSIGHTS
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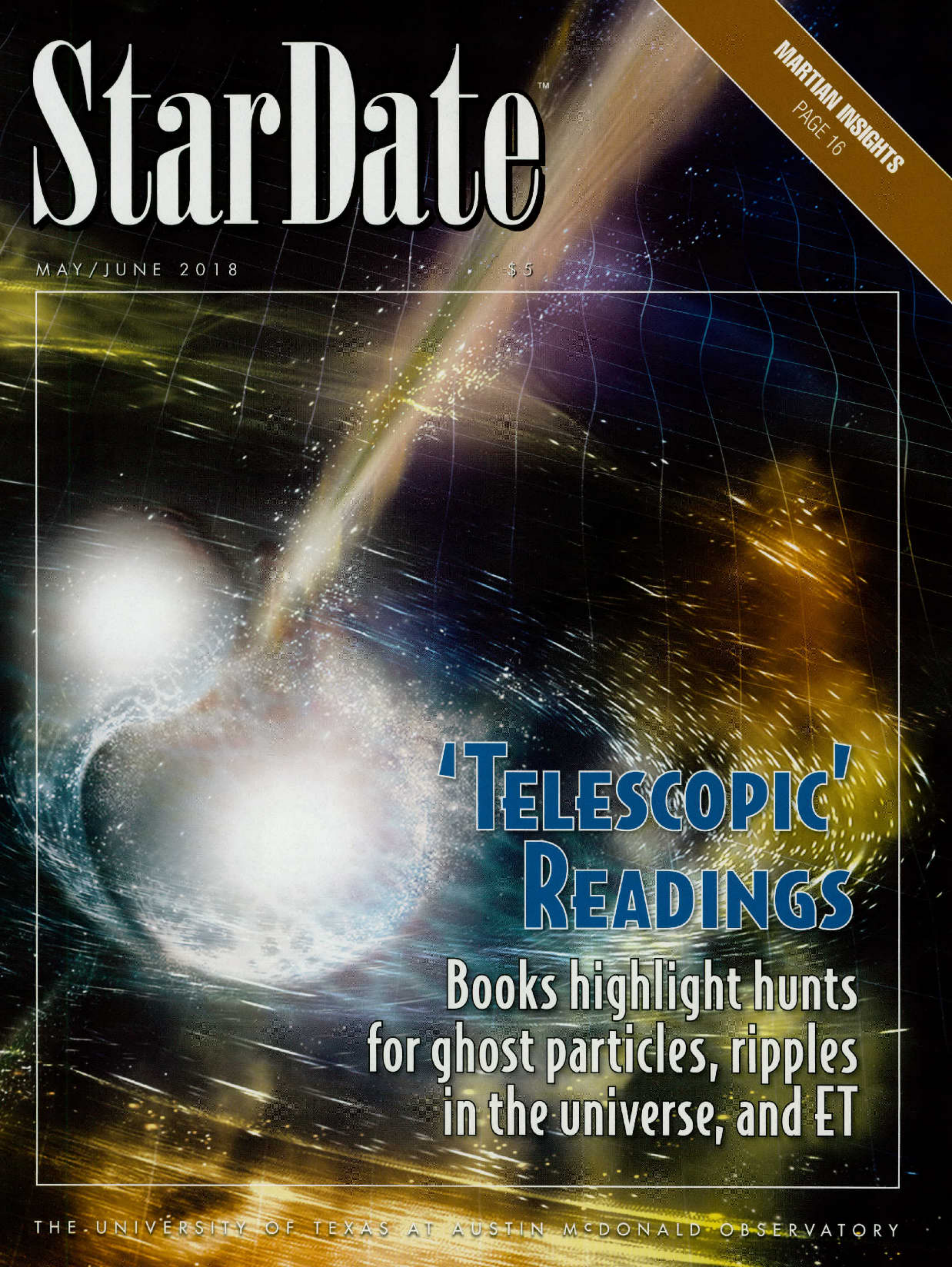

'Telescopic' Readings

Books highlight hunts for ghost particles, ripples in the universe, and ET

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Features

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On The Cover

An artist's concept shows the final moments of the merger between two neutron stars. The merger creates gravitational waves and beams of gamma rays, and ejects material from the stars into space. Such a merger was detected by LIGO, one of three unusual observatories profiled in our book excerpts.

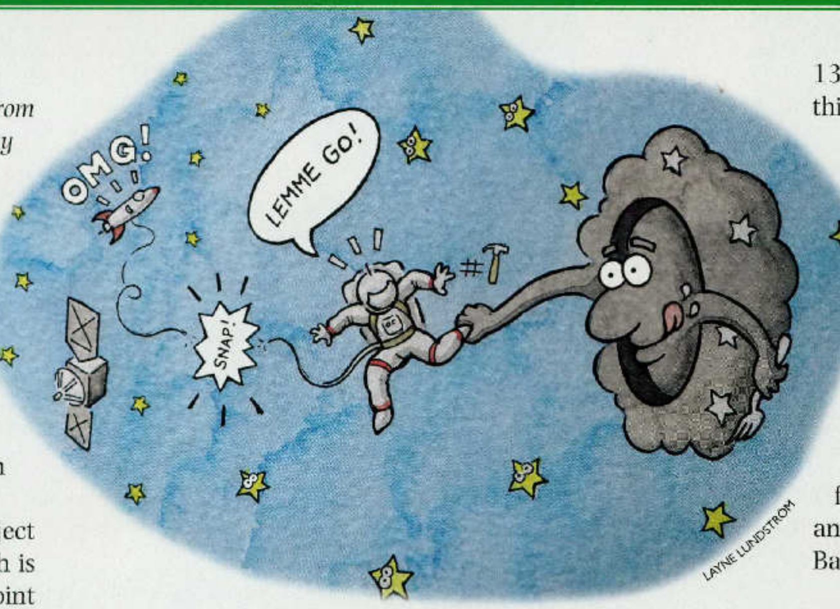
This Page

The hot, young, blue stars of the Trapezium Cluster (top right) are part of the Orion Nebula, a star-forming region about 1,350 light-years away. This composite view combines infrared light (blue) with millimeter-wave light (red).

Coming Up

In our next issue, we'll explore the idea that life on worlds like Earth may be seeded by asteroid and comet impacts. And we'll discuss cosmic superlatives — the biggest, the fastest, the oldest, and more.

MERLIN



Dear Merlin,

Say an object is observed from the early universe. Is there any possibility that the evolution of that object could be tracked through the eons?

Tom Rathz
Huntsville, Alabama

Absolutely — as long as you're willing to stick around for a few billion years to watch it.

Any astronomical object that is observed from Earth is seen as it looked at some point in the past. If it is one billion light-years away, then you see it as it looked one billion years ago. As time passes, you see it evolve, but only in real time — one day for every day that passes on Earth.

If you're asking if it's possible to speed up that process, like a video in fast forward, then the answer is also yes. As you might suspect, though, there's another catch: You would have to be racing toward the object in a starship. If you could get one light-day closer, you would see events on the distant object one day earlier than you would from Earth; at two light-days closer, you'd see them two days earlier, and so on.

There's one more trick to consider. If you could move at almost the speed of light, your clock would appear to tick slower than one outside your ship, so, from your perspective, outside events would appear to happen more quickly. That would provide a fast-forward view. (If you went all the way to another star or galaxy at that speed, you would have aged much less than those you left behind on Earth.)

If you want to watch that star or galaxy age from Earth, though, you'll have to settle for the long view — one day at a time.

Dear Merlin,

What was the status and condition of the universe, if any, before the Big Bang? Was there a universe before the present one?

Todd Fineberg
Boonsboro, Maryland

So you're asking if there was anything before there was anything? A sort of land before time? Join the crowd! Physicists are asking those questions more often these days, and they've come up with a varied lot of answers.

Most physicists agree that the universe — everything that you can see and touch — evolved from a single moment of creation, known as the Big Bang. It happened 13.8 billion years ago, and it created all matter and energy, plus all space and time.

There is no agreement, though, about what came before the Big Bang. Some say that there was nothing at all. That idea was supported by Stephen Hawking, who said that the universe wasn't *created*, it just *is*.

Others, though, have developed models in which there was something before the Big Bang. One of those says the universe began when a previous universe ended in a "big crunch." Everything in that universe smashed together into a single point of almost infinite temperature and density. That point then rebounded as the Big Bang.

Another idea says the universe had existed as a single point for a very long time — perhaps infinitely long. But 13.8 billion years ago, something caused it to begin expanding, creating the present universe. And yet another says that this universe is the offspring of a parent that could have given birth to an infinite number of others.

It's almost impossible to test these ideas. Even so, scientists hope that future tools may reveal if anything came before the Big Bang.

Dear Merlin,

I keep seeing reports about massive ejections of X-rays and other material from black holes. Is there any way to escape the grasp of a black hole?

Tom Krepel
Corpus Christi, Texas

There's a very good way to escape a black hole: don't fall in. That's what's happening with the stories about material "escaping" from a black hole.

A black hole may be encircled by a disk of superheated gas that spirals around the black hole before falling in. Such a disk can produce a powerful magnetic field, which can grab some of the disk's particles, which have an electric charge, before they fall into the black hole, then shoot them out into space from above the black hole's poles. The beams produce radio waves that can be detected from Earth.

So the particles that are snatched by the magnetic field can "escape" from the black hole before they fall in. The particles that don't get beamed back into space enter the black hole: They fall in, but they can't come back out, keeping a black hole black.

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Great Reads

New books in astronomy and space science can take you to the stars this summer

Show Me the Money

Whether you're planning to survey the cosmos or hunt for aliens, it takes a lot of money to build a world-class telescope

THE SETUP

Astronomer Jill Tarter has been hunting for aliens for decades using telescopes around the world and at the helm of the SETI Institute. In the movie Contact, Jodie Foster played a fictionalized version of Tarter. Now a new biography from Sarah Scoles tells the real story of Tarter's life and work.

This excerpt describes the hunt for Silicon Valley donors to help realize the dream of what became known as the Allen Telescope Array, the high-concept observatory visualized by Tarter and others to bring the search for extraterrestrial intelligence into the 21st century. Today, the array is operating at Hat Creek Radio Observatory in northern California, albeit scanning the skies each night with 42 antennas, rather than the planned 350.

THE EXCERPT

It is 1 A.M. on March 10, 2014, in Northern California, and Jill Tarter's face peers from the doorway of a dorm in the Hat Creek Radio Observatory residence hall.

"It's beautiful out there right now," she says, gesturing toward the window.

Tarter walks down the hallway past the observatory's library (which is filled with copies of the *Astrophysical Journal* dating back to the 1940s) and the lounge (which houses a particularly riveting issue in a burn bucket next to the fireplace). She steps out of the dormitory and onto the cold-steeped cement. The mosquitoes that normally plague the area round Hat Creek Observatory, home to the SETI Institute's Allen Telescope Array, have all gone to bed. The air feels clean, the planet quiet and emptied of creatures. Tarter looks up.

Above hangs a clear, dark sky. The stars look like the crafts kids make at school: crisp pinpricks in the blackest construction paper, a UV lamp shining behind them.

"I can't even find the North Star," says Tarter. "I'm going to get my glasses."

She has hardly reemerged with her spectacles when she rushes back inside for her iPhone.

"I think that's Mars," she says, pointing at the bright reddish dot. After her celestial chart app boots up, she hefts the screen toward the sky, scanning across a quadrant. "It says Mars, Saturn, and Pluto are all near each other," she continues. She returns to staring at the sky, turning her head a few degrees at a time to change perspectives.

Each star is a sphere of plasma whose inward-pulling gravity perfectly balances the outward-pushing pressure from nuclear fusion. This symmetry is called hydrostatic equilibrium, and it's what makes a star a star. Flaring and sun-spotted, they impose their radiation on the space around them, light-years from us. Maybe that space is home to planets, which maybe are home to biology, which perhaps evolved into beings smart enough to understand starlight.

This scene is almost too easy a mirroring of Tarter's childhood memories. Looking up from the deserted beaches of southern Florida, she was certain that an alien child was looking at the sun. Their gazes, she imagined, met in interstellar space like awkward strangers' on a subway train. She has this thought over and over. It is the kind of *Groundhog Day* observation that keeps her motivated to continue the search, despite the vastness of the universe, the brevity of human life spans, and governmental desire to spend money on missiles instead of science.

A thousand yards away, the Allen Telescope Array (ATA)—Tarter's dream observatory, or at least a version of it, made for and dedicated to SETI work—scans the sky in search of intelligent life long after she has returned to sleep.

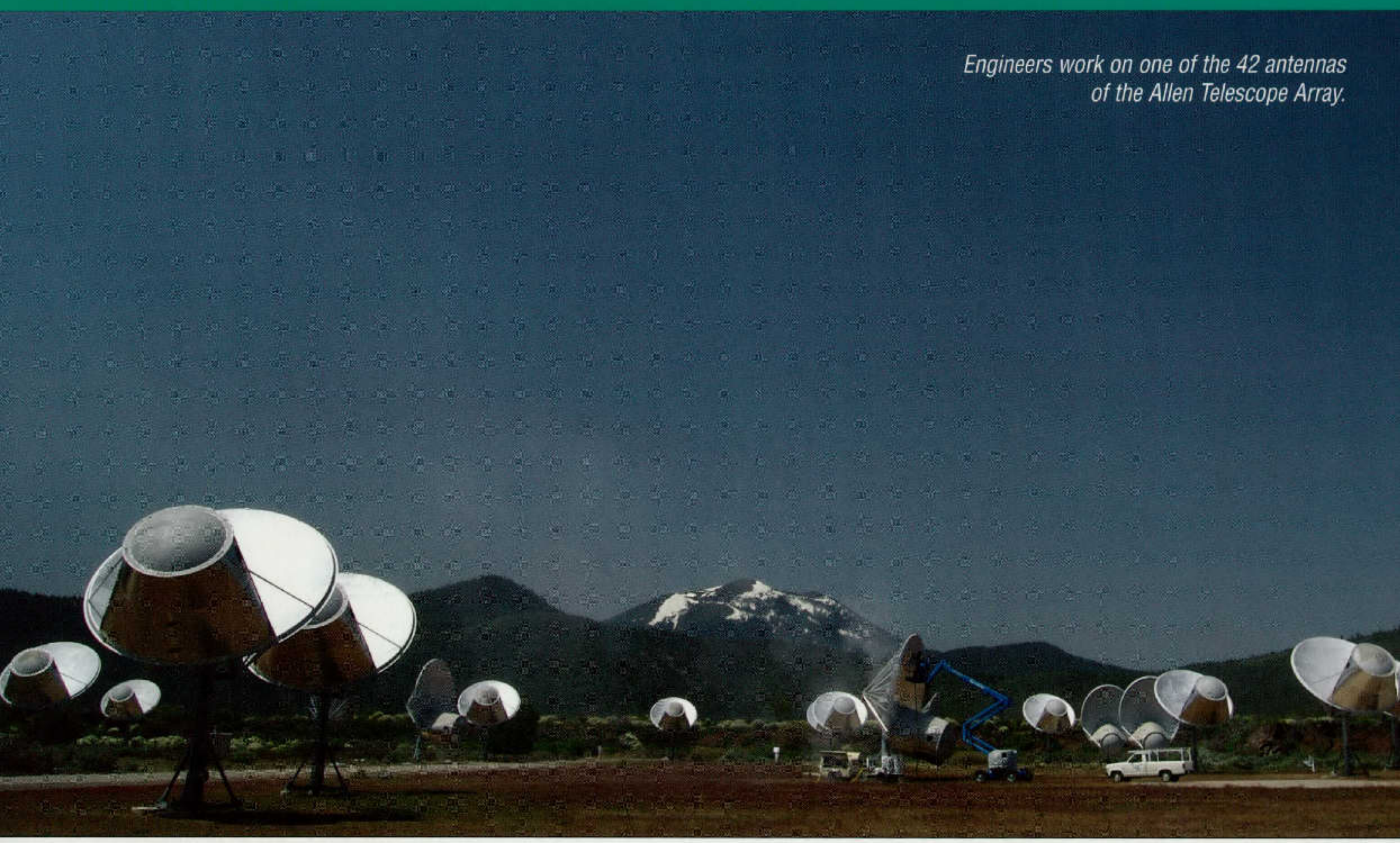
The idea for the ATA came from a series of workshops held from 1998 to 2000. These posh gatherings, collectively called SETI 2020, plotted the route of SETI research for the next 20 years. While scientists and their university salaries don't expect overly cushy conferences, Tarter and her SETI colleagues didn't want those usual invitees: They wanted Silicon Valley technologists—specifically, George Papadopoulos of Sun Microsystems, David Liddle of Interval Research Corporation, and Nathan Myhrvold of Microsoft—on board. And Silicon Valley technologists, with their dreamy entrepreneurial visions, require minibars and rooms of their own, with views.

At the conference, the attendees' main conclusion was "SETI needs its own telescope," closely followed by "And perhaps we should figure out how to build it." Though piggybacking [on other telescopes] had worked well in SETI's early decades, to gather and handle the stream of data they expected, they would need their own setup and computers hundreds of times faster than those that existed. The tech moguls, used to thinking about the big thing after the next big thing, suggest the SETI scientists "make a bet on technology," specifically on a concept called Moore's Law. This law, which is just an observation of what happens in the real world, states that computers double in power every two years. It has held true since the first gigantic Macintosh. Even if you haven't heard of this modern-day math, you know how slow your two-year-old laptop now seems compared to shiny new ones on the shelves of Best Buy. Papadopoulos and Liddle felt sure they could count on Moore's Law. The computing power does not exist today, but it will be there tomorrow, when you need it. And it will be cheap(ish).

It was a Silicon Valley idea, new to the scientists, and it felt radical back then, when everyone still had dial-up AOL and videos didn't go viral because they took too long to load.

With the future's unimaginably shiny computers in mind, Tarter and her colleagues made a plan for their SETI-specific observatory: a bunch of small antennas—350 of them—that worked together. If you point multiple antennas at the same thing at the same time, you can merge their views to make a single superior image. The telescope's combined vision will be as sharp as if it came from a single telescope 3,000 feet wide, rather than from hundreds of 20-foot telescopes spread across a 3,000-foot-wide area. It's a neat trick. After all, building a bunch of identical dollhouses and sprinkling them around a mansion-sized lot is much easier than constructing the mansion itself. "We were the pioneers of building a giant telescope out of lots of little telescopes," says Dan Werthimer, who worked on [the piggyback search] SERENDIP and the ATA and has been a leader at UC Berkeley's SETI program since its earliest days.

The team estimated the ATA's cost at $25 million. The SETI Institute just needed to find the money and a place to plop the antennas. Long-established collaboration between the Radio Astronomy Lab at Berkeley and the SETI Institute, starting with Jack Welch's 1980s offer to host the SERENDIP piggybacker, made the question of location easy: the two organizations would work on the telescope together and build it at Berkeley's Hat Creek facility. The Institute would largely build it; Berkeley would largely operate it; they would split its observation time 50/50. "The original vision for the



Engineers work on one of the 42 antennas of the Allen Telescope Array.

ATA was a world-class telescope," says Werthimer.

But the money question remained. Luckily, Tarter knew someone who had \$25 million to spare and a soft spot for SETI. Paul Allen, co-founder of Microsoft, had donated to a project called Phoenix in the 1990s. She asked him if he would again like to support and save SETI. While the team awaited Allen's response, they began building a prototype array under system scientist Douglas Bock; a collection of practice antennas on which they could test each new part, before transplanting them into the real-world antennas. The prototype lived in a horse paddock outside an empty barn in Lafayette, California, with the control center in the former tack room.

The night before the prototype's dedication ceremony, Tarter stayed up late, working and refreshing her email. She works a lot—seemingly all the time. "She puts in more time than anybody else on the project," says Gerry Harp, who took over as the director of the Center for SETI Research when Tarter retired and has gotten many late-night emails from her. "She's just an amazingly energetic woman. I remember that she would work long days and then go home and do email and write stuff all night long, and I don't know when she slept." (I'm pretty convinced she doesn't.)

She hoped Allen would respond with a yes, so they could announce his endorsement at the next day's ceremony. But the inbox disappointed, and she eventually headed to bed. Not wanting to wake [her husband] Welch, she attempted to take off her pantyhose in the dark. But instead of being stealthy, she tumbled over and shattered her elbow. Later, X-rays in hand, Tarter tried to map the many ways she'd broken her bones.

With 13 pieces of titanium and straps embedded in her arm, the newly bionic woman sat through the dedication. "I kept wanting a more heroic story to tell," she says, and sighs. "Pantyhose."

A few months later, Allen's email—a yes—came. But the yes was conditional: if the SETI Institute and Berkeley made a list of milestones—proving step by step that they could develop this telescope and its new technology without screwing up—he would support them, in installments, as they reached each goal.

"We can do that, fine," Tarter says now, imitating herself back then. "We didn't know what we were talking about."

As with any large-scale engineering project, things took longer and cost more than anticipated. Tarter was frustrated.

"Whenever we or anybody would report having completed something, Jill's first question always was, 'Well, when will you get the next thing done?'" says Harp. "Everybody felt like, 'We just did this.'"

It was frustrating to the employees to feel like their accomplishments weren't appreciated along the way. "In a way, it felt like she didn't value their contribution because it was never enough. You could never do enough," says Harp.

It became such a trope that, after a while, they just laughed it off. "But of course we had to answer the question about the next thing," he adds. They also had to fix each difficulty with the existing resources before they could ask Allen for more funds to do the next thing.

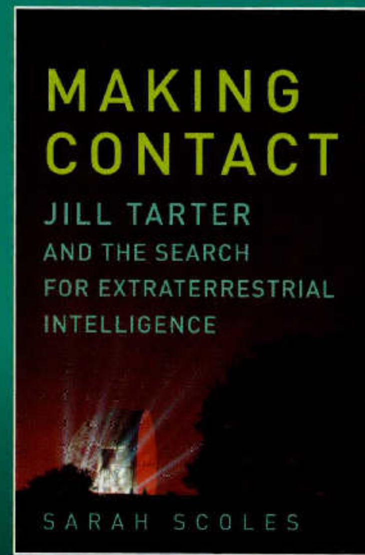
Once, Allen visited the prototype telescope to check on their progress. When he turned to the side, he found a pile of horse [manure], which had previously escaped everyone's notice, right behind him.

"Well," Tarter said to him, "at least we're not wasting your money on infrastructure."

After Tarter and the rest of the team—which included Harp; software engineer and telescope operator Jon Richards; astronomer Seth Shostak, who took over as the institute's co-director after Tarter retired; Dave DeBoer, the project manager; Werthimer and other Berkeley astronomers; an engineering team at Minex Engineering—met the milestones they'd laid out for Allen, they pitched him once again: you supported research and development; now let's make a telescope that doesn't live in a barn. But it's going to cost more than we thought. And, it being January 2003, Allen had just lost \$7 billion on Charter Communications.

He wouldn't build all 350 antennas, he said. But if the SETI Institute constructed 200 of them, at a cost of \$27.5 million, he would give \$13.5 million (the remainder of the initially promised money). As a cherry, he would donate a large amount of that sum up front so they could construct a 32-antenna demonstration array in Hat Creek so the observations could start and the astronomers could try to convince the National Science Foundation to start supporting operations. Just get other people to donate the difference, he said. He would even give some speeches to potential donors the institute lined up.

"We're pretty brash as an institute," Tarter says. "and we thought we could do it." But when they went to wealthy people and talked grandly about how the ATA could help us find our place in the universe, understand were we come from, and investigate fundamental questions of the cosmos, the response often went something like, "Well, Mr. Allen's name is already on the telescope. He's a lot richer than I am. Why doesn't he finish it?"



Making Contact

Jill Tarter and the Search for Extraterrestrial Intelligence

By Sarah Scoles

\$27.95

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Catching a Wave

The death throes of two black holes confirmed a prediction of Albert Einstein's theory of gravity

THE SETUP

It's been more than a century since Albert Einstein revealed his theory of gravity, General Relativity. It tells us that gravity isn't a force, as Isaac Newton had thought, but a curvature in space-time caused by matter. That description has been confirmed by every test physicists have devised.

The equations also predict that two objects following those curved lines of space-time — orbiting each other, as Earth orbits the Sun — should cause ripples in space-time, known as gravitational waves. And if the objects are heavy and close together, the gravitational waves should carry away enough momentum to cause them to spiral together. That prediction was confirmed, too, maintaining General Relativity's position as the leading theory of gravity on all but the tiniest of scales, as explained by astrophysicist and science writer Marcus Chown.

THE EXCERPT

Space-time's role as an actor in the cosmic drama — as a thing in its own right — gains its most remarkable expression in the phenomenon of "gravitational waves." Space-time can be jiggled by the movement of mass. And this jiggling causes waves to propagate outwards like ripples on a pond. Ripples in the very fabric of space-time.

Einstein vacillated about the existence of "gravitational waves," thinking they existed in 1916, changing his mind shortly after, and then changing it back in 1936. But on September 14, 2015, almost exactly 100 years after Einstein's prediction, gravitational waves were picked up for the first time on Earth.

Imagine being deaf since birth and suddenly, overnight, being able to hear. That is the way it was for astronomers. For all of history they have been able to "see" the Universe. Now, at last, they can "hear" it.

Our media has a tendency to over hype things. But a good case can be made that the discovery of gravitational waves is the most important development in astronomy since the invention of the telescope in 1608. They are literally the "voice of space."

The event picked up on September 14, 2015, was an extraordinary one. In a galaxy far, far away, at a time when the Earth boasted nothing more complex than a bacterium, two monster black holes were locked in a death spiral. One was 29 times the mass of the Sun and the other 36 times the mass of the Sun. Each travelling at half the speed of light, they whirled about each other one last time. As they kissed and became one, three whole solar masses were destroyed and converted into gravitational waves. A tsunami of tortured space-time surged outwards, so violent that, for a brief instant, its power output was 50 times greater than all the stars in the Universe put together.

Space-time is a billion billion billion times stiffer than steel, which is why it can be vibrated significantly only by the most violent cosmic events such as black hole mergers. But those vibrations, like ripples spreading on a lake, die away rapidly. And the gravitational waves that reached Earth on September 14, 2015, having travelled for 1.3 billion years across space, were mind-bogglingly tiny.

Enter the Laser Interferometric Gravitational wave Observatory (LIGO), in effect a couple of giant 4-kilometer rulers made of laser light — one at Livingston in Louisiana and the other at Hanford in Washington. At 5.51 a.m. Eastern Daylight Time on September 14, 2015, first the Livingston, then 6.9 milliseconds later the Hanford, rulers repeatedly expanded and contracted by 100 millionth the diameter of an atom. "The signals are infinitesimal. The sources are astronomical. The sensitivities are infinitesimal. The rewards are astronomical," writes Janna Levin of Columbia University in New York.

The LIGO physicists knew they had detected a burst of gravitational waves from space because the two detectors, separated by about 2,500 kilometers, picked up precisely the same signal, ruling out the possibility of a mundane local effect like someone slamming a car door 10 kilometers away. But the LIGO physicists were also sure they had detected gravitational waves from space because of the way in which the frequency of the waves rose to a peak then dropped off rapidly as the new-born black hole settled down. It matched precisely the prediction of Einstein's general theory of relativity.

What is so extraordinary about this is that Einstein's theory had previously been tested only in circumstances in which gravity is very weak such as the Solar System, never in the ultra-strong regime that exists in the vicinity of black holes. Yet general relativity passed this test with flying colors. The world's media were quick to declare that Einstein had been proved right. The irony is that he had been proved both right and wrong. Right for predicting gravitational waves. But wrong for not believing in another prediction of his theory of gravity: black holes.

A black hole is surrounded by an imaginary membrane which marks the point of no-return for in-falling light or matter. Just as the sound of a bell ringing is a unique signature of the bell, the sound of this "event horizon" ringing is the unique signature of a new-born black hole. Because it was heard on September 14, 2015, we now know for sure that black holes exist.

Three men, more than any others, are responsible for LIGO.

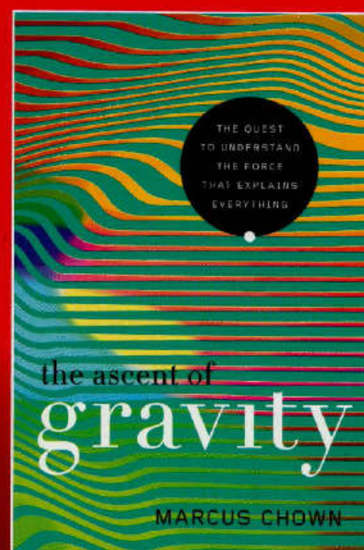
The first is Kip Thorne of the California Institute of Technology, the hippie-dressing theorist famous for his black hole wagers with Stephen Hawking, most of which he has won. The second is Rainer "Rai" Weiss, an experimentalist at the Massachusetts Institute of Technology who graduated from building hi-fi sound systems in New York in the 1940s to building sound systems for listening to the cosmos. Weiss has walked every inch of the LIGO tunnels, personally evicting wasps, rats and other intruders. But the most complex and tragic member of the LIGO "troika" is Scottish physicist Ronald Drever.

A short, dumpy man who carried his papers in supermarket carrier bags and whose overhead projector transparencies were covered with greasy fingerprints and tea stains, Drever was an experimental genius. While Thorne would get an answer to a technical question after pages of careful calculation, Drever would reach the same conclusion with a simple diagram. Unfortunately, the Scottish physicist was constitutionally incapable of sharing control of the project and, in 1997, was fired. He remained in Pasadena, close to Caltech, confused and saddened by events. An unworldly man who never married and had no real friends in the US, he finally succumbed to dementia. In *Black Hole Blues*, Levin relates the heartbreaking tale of Caltech faculty member Peter Goldreich taking the bewildered Drever to New York's JFK airport and putting him on a plane back to his brother in Glasgow. Drever now lives in a care home in Scotland.

LIGO is a technological marvel. At each site there are actually two tubes 1.2 meters in diameter, which form an L-shape down which a megawatt of laser light travels in a vacuum better than space. At each end the light bounces off 42-kilogram mirrors, suspended by glass fibres just twice the thickness of a human hair and so perfect they reflect 99.999 per cent of the light. It is the Lilliputian movement of these suspended mirrors that signals a passing gravitational wave. So sensitive is the machine that it was knocked off kilter by an earthquake in China. "It whirs with the tidal pull of the celestial bodies, the grumbling of a still settling earth, the remnants of heat in the elements, the quantum vibrations and the pressure of the laser," writes Levin.

A technological marvel LIGO may be, but not everyone thinks it is what it seems. Levin tells of a man on a flight into Baton Rouge, Louisiana, who informed the LIGO scientist in the seat beside him that the secret government facility below them was designed for time travel. "One of the arms brings you to the future," he said knowingly, "the other sends you to the past."

With the success of LIGO in 2016, we stand at the dawn of a new era in astronomy. It is as if a deaf person has gained a sense of hearing but, at present, that sense is crude and rudimentary. At the very edge of audibility they have heard a distant rumble of thunder. But they are yet to hear birdsong or a piece of music or a baby crying. As LIGO and other gravitational wave experiments around the world ramp up their abilities, who knows what wonders they will soon hear?



The Ascent of Gravity

The Quest to Understand the Force that Explains Everything

By Marcus Chown

$26.95

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SKY CALENDAR

by Alan MacRobert

As late spring turns into summer, the planets are putting on a great show. May sees Jupiter at its best for the year, while Saturn puts on its best performance in June. Venus shines throughout as the Evening Star, and Mars is climbing higher each night. Among the stars, the "arch of spring" gives way to the Summer Triangle.

MAY 1 - 15

May opens with Venus shining low in the west-northwest as the Evening Star of the eerie spring twilight. I say "eerie" because our distant ancestors regarded this May Day season, midway from the spring equinox to the summer solstice, with new life bursting out everywhere, as a time when the world was especially open to spooks and sprites of growth and creation. It was the opposite number to Halloween, on the opposite side of the year, when the same thinning of the veil exposed the world to autumn shades of death and ghostly destruction. Fertility rites were central to the May celebrations (people still dance around the maypole and bind it with ribbons, not knowing what they do), and this year Venus, goddess of fertility, looks down on such goings-on in twilight.

People who live indoors apart from nature miss so much.

Watch day by day, and you'll see that Venus is moving fast against its starry background. On May Day evening itself, you'll find orange Aldebaran, the fainter eye of Taurus, the bull, to Venus' left or lower left, twinkling from behind. Beta and Zeta Tauri, the bull's horn tips, are twice as far above Venus. Beta is the brighter one, on the right. Capella, the brighter goat star, shines farther to Venus' upper right. Fiery Betelgeuse rounds out the scene equally far to Venus' upper left.

By the second week of May, these twilight stars have descended to the point that Venus forms a much smaller, less elongated triangle with the horn tips above it. Venus passes smack between them on May 13 and 14. Our symbol-seeking ancestors, who read all kinds of things into celestial bodies they didn't understand, might have made much of that.

Higher in the sky, this scene is being watched over and sheltered by the "arch of spring." The top of the arch consists of Pollux and Castor, the Gemini head stars, now more or less horizontal. The lower-right end of the arch consists of Menkalinan and then brilliant Capella, in the northwest. Procyon is its left end, closer to Pollux' lower left.

Watch through the rest of May to see the arch of spring descend and Venus poke right up into it.

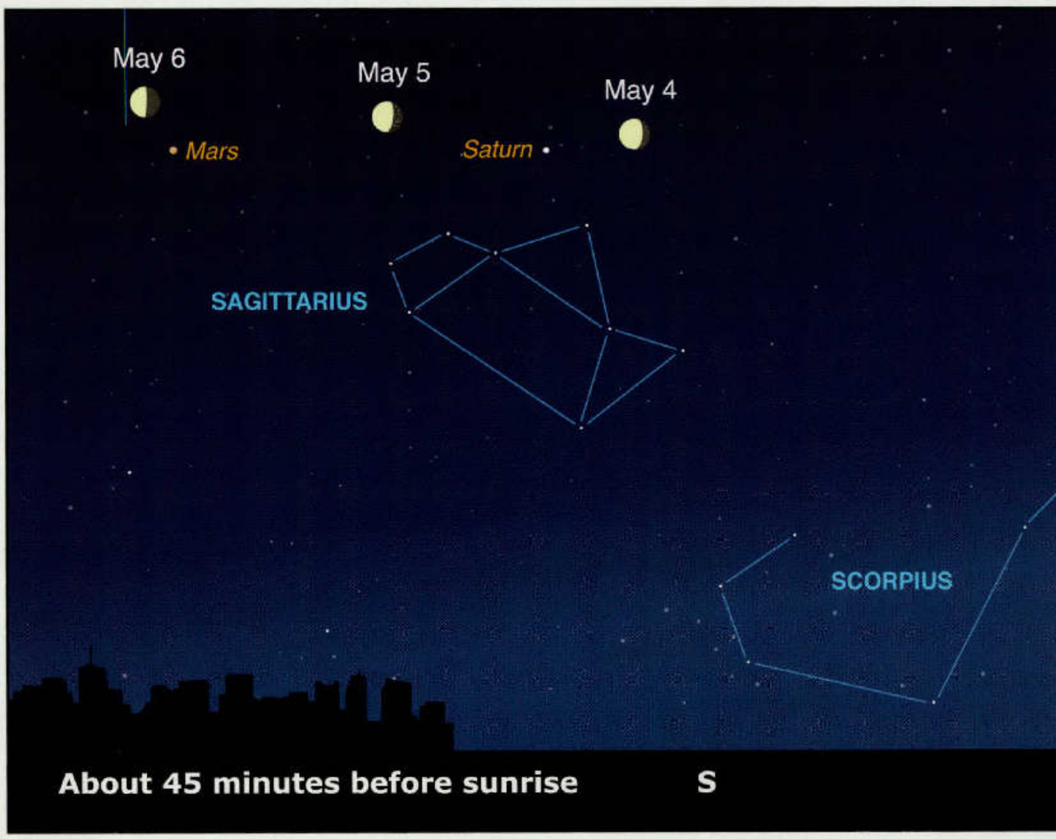
On the opposite side of the sky, Venus has competition. Jupiter blazes in the southeast as night comes on and, as Venus sets, Jupiter takes over as the brightest point in the sky. Residing in dim Libra, Jupiter comes to opposition on the night of May 8. For several weeks it's at its biggest and brightest for the year. It's highest in the south for your telescope around 1 a.m. Its Great Red Spot continues unusually vivid orange-pink this year, if you happen to catch Jupiter when its red spot side is facing Earth.

MAY 16 - 31

Venus continues to light the west-northwest during late twilight and shortly after. The arch of spring is lowering toward it as the stars continue their westward seasonal advance. On May 28, the arch finally engulfs Venus, when the planet crosses the line between Procyon, far to its left, and Capella, farther to its right.

Catch the waxing crescent Moon hanging to the left of Venus on the evening of May 17.

Elsewhere in the sky, the Big Dipper is now at its highest when the stars come out. Face north and look almost overhead. The dipper is floating upside down.



The dipper's handle arcs around to point toward Arcturus a little more than a dipper-length away, high in the southeast. Continue the arc on and around by the same distance to speed to Spica, lower in the south. Keep going around, half again as far, and you continue to Corvus, the distinctive four-star crow of springtime.

But Jupiter is trying to distract you. It's that brilliant white thing far below Arcturus. As Jupiter leaves its opposition date farther behind, it shines high earlier in the evening.

Jupiter spends late May and most of June in close company with an interesting little star: Zubenelgenubi, or Alpha Librae. The name means "the northern claw," from ancient times before the Romans broke off the scorpion's claws to be Libra, the balance. Binoculars show that Zubenelgenubi is a wide double star. Its two components, 3rd and 5th magnitude, appear roughly as far apart as Jupiter's moons usually venture from Jupiter.

The visual double star and the moon-girdled planet will remain together, easily fitting into the same binocular field of view, from mid-May through the rest of the summer.

JUNE 1 - 15

Shining valiantly in the west-northwest each clear evening, Venus continues to hold steady over your landscape while the last of the arch of spring, Pollux and Castor, descend rapidly. As June opens, look for Pollux almost straight above Venus as the stars come out. By June 11, Venus is straight in line with them to their left. From then on, the two stars move farther to the lower left of Venus and ultimately below the twilight horizon, to reappear in the east as evenings turn cold next fall.

Astronomical summer is nearly here, and already the big Summer Triangle dominates the eastern sky after dark. Its top star, and its brightest, is Vega. In fact, Vega is the brightest star on the eastern side of the sky. The brightest to the lower left of Vega is Deneb. The brightest farther to the lower right of Vega is Altair. The Summer Triangle is bigger than its winter counterpart (Sirius, Procyon, Betelgeuse), but it's not as bright nor as fetchingly symmetrical.

Jupiter dominates the south after dark, with its temporary sidekick Zubenelgenubi holding close. Arcturus shines high above Jupiter at nightfall, then high to its upper right as the night grows late.

Less far to Jupiter's lower left (by about two fist-widths at arm's length) you'll find the head and heart of Scorpius — the latter being Antares, second only to Betelgeuse as the brightest "red" supergiant in the sky. I think you'll agree that it's more campfire-orange than red. But scientists, who tend to be more concerned with wavelengths than poetry, often use "red" to mean anything on the long-wavelength end of a spectrum. Any spectrum, not just of visible light.

> ### Meteor Watch
>
> **The Shower**
> Eta Aquarids
>
> **Peak**
> Night of May 4
>
> **Notes**
> The Eta Aquarids are a modest shower for skywatchers in the northern hemisphere, with maximum rates of about a dozen meteors per hour. The gibbous Moon rises in the wee hours of the morning, though, so its light will overpower all but the brightest meteors.

The other stars of Scorpius are white or slightly blue-white. I think I see them as a little bluer than they really are because of contrast with Antares.

JUNE 16 - 30

And still the evenings open with Venus and Jupiter, low in the west and higher in the south, respectively. But now they're getting planetary company. Look low in the southeast as night comes on. Climbing up away from the horizon there is Saturn, glowing a steady pale yellow.

Later in the night you can see that Saturn is perched just above the Teapot pattern of Sagittarius. The Teapot may not be easy to see through moderate light pollution, especially if there's summer haze low in the southeast. But with binoculars you can piece it out bit by bit. The top of its lid is 3 degrees below Saturn: about the width of two fingers at arm's length. The Teapot is currently resting level, with its triangular spout to the right and its handle to the left. The whole thing is just about coverable with your fist at arm's length.

Antares shines midway between Jupiter and Saturn. It's the brightest thing between them, but for almost two decades now it's had competition. Less than a fist-width to Saturn's upper right, in the direction of Jupiter, is Delta Scorpii, a hot, blue-white star that doubled in brightness in 2000 and still remains in its new state, though with slow fluctuations from time to time.

The elephant in the room here — enormous but, sadly, unseen to many of us under light pollution — is the Milky Way. Its brightest portion is just to the right of and above the Teapot: the Large Sagittarius Star Cloud. If Sagittarius is still low, you may have better luck tracing the Milky Way diagonally up from there, past Altair and across the Summer Triangle in the east through Deneb and beyond. Shortly before you get to Deneb, you're in another bright section: the Cygnus Star Cloud. That's the richest part of the galaxy that many of us often get to see. Scan it carefully with binoculars!

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

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.**

J Jupiter
open cluster
globular cluster
nebula
planetary nebula
galaxy

MAGNITUDES

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

JUNE

How to use these charts:

1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

May 20	**11 p.m.**
June 5	**10 p.m.**
June 20	**9 p.m.**

NORTH

EAST

WEST

SOUTH

MAGNITUDES

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

- J Jupiter
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

Taking it Day by Day

There's a day for just about everything, from important topics such as children's cancer and responsible dog ownership to the more whimsical topics of sourdough bread, barbershop quartets, TV dinners, making your bed, and blaming someone else.

May and June offer several days for astronomy and space buffs. They commemorate *Star Wars*, light, towels (and author Douglas Adams), asteroids and meteor showers, and space exploration.

So check out the asteroid-belt scene from *The Empire Strikes Back*, then head outside to look at the twinkling lights and shooting stars in the night sky. And don't forget your towel.

MAY 4
Star Wars Day

Although the first Star Wars movie debuted on May 25, fans celebrate three weeks earlier, for one simple reason: May the fourth be with you. And those who prefer the dark side of the force wait until the next day: Revenge of the fifth.

www.starwars.com/may-the-4th

MAY 4
International Space Day

For those who prefer to commemorate real space accomplishments instead of make-believe ones (or who like both), some museums, planetariums, and other venues join this celebration of space exploration.

www.daysoftheyear.com/days/international-space-day

MAY 16
International Day of Light

Light is the currency of astronomers. They use it in all of its forms, from radio waves to visible light to gamma rays, to study the universe. This celebration, partly sponsored by UNESCO, strives to improve public understanding of how light and light-based technologies touch our daily lives. The International Astronomical Union is encouraging schools to have students recreate William Herschel's 1800 experiment in which he discovered infrared light using a prism and thermometers.

MAY 25
Towel Day

From the Hitchhiker's Guide to the Galaxy:

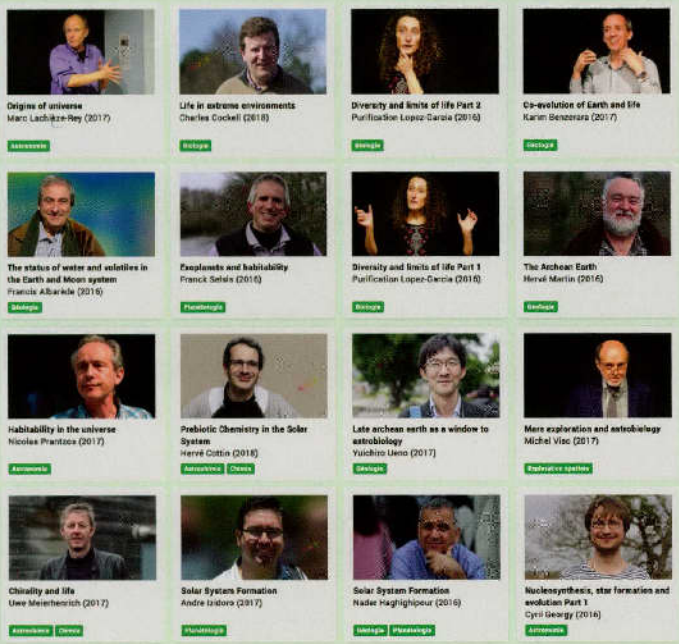
A towel ... is about the most massively useful thing an interstellar hitchhiker can have. Partly it has great practical value — you can wrap it around you for warmth as you bound across the cold moons of Jaglan Beta; you can lie on it on the brilliant marble sanded beaches of Santraginus V, inhaling the heady sea vapours; ... you can wave your towel in emergencies as a distress signal, and of course dry yourself off with it if it still seems to be clean enough.

Fans of Douglas Adams organized an impromptu celebration of his life two weeks after his death. The date caught on, and now people around the world wave their towels in honor of the creator of *Hitchhiker's Guide to the Galaxy*.

JUNE 30
Asteroid Day
Meteor Shower Day

Small space rocks are good. When they plunge into atmosphere, they create streaks of light known as meteors. Sometimes, they appear in groups, known as meteor showers, which are among the most beautiful of all skywatching events. Large space rocks, on the other hand, are bad. When they plunge into the atmosphere, they can create destruction on a local, regional, or global scale. Meteor Shower Day celebrates the little rocks, while Asteroid Day educates us about the dangers posed by the big ones, as well as their role in helping us piece together the birth of the solar system.

by Damond Benningfield and Rebecca Johnson



IAU

Learn Astrobiology Via Videos

A new website from the International Astronomical Union is full of videos from leaders in the field of astrobiology, explaining topics from astrochemistry, to biology, to astronomy, planetology, and more. Videos are available in English, French, and Spanish. There are dozens in English, with none older than 2016. Sample topics include "Life in extreme environments," "Origin and early evolution of life," and "Solar system formation." Running times vary from about 20 to 90 minutes.

astrobiovideo.com

Dancing 'Round the Maypole

For centuries, the people of the British Isles marked the beginning of summer not on the solstice, in June, but on May 1. It's a commemoration of a cross-quarter day, which comes roughly half way between a solstice and an equinox.

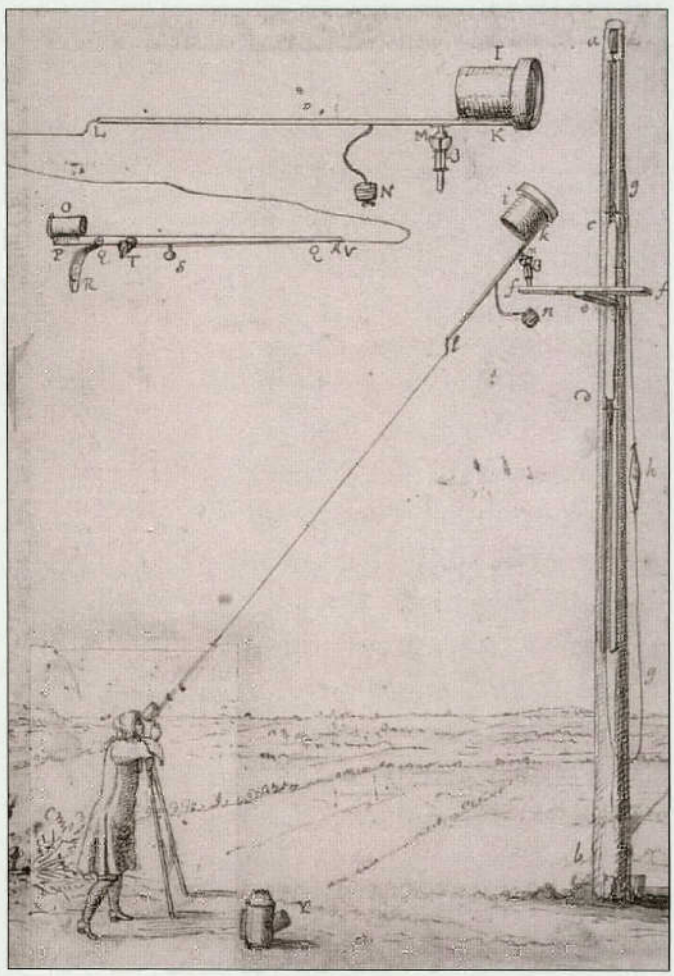
In England, the date became known as May Day, which was celebrated with village fetes and dancing around the maypole. Dancers grabbed ribbons attached to the top of the tall pole, then circled around it, getting closer with each circuit.

Especially tall maypoles were erected in an area of London known as the Strand. The last of these poles was removed 300 years ago. But it found a new life, supporting one of the world's largest telescopes.

Isaac Newton, who had formulated laws of gravity and motion, bought the pole. In April 1718, he had it moved to a park outside London for use by James Pound, a clergyman and astronomer.

The Royal Society had loaned Pound a large telescope lens forged by Christiaan and Constantine Huygens, two leading European astronomers. The telescope was created by mounting the lens on a small platform attached to the side of the maypole. The eyepiece was on the ground, linked to the lens by a long wire. When the wire was pulled taut, the lens and eyepiece aligned.

With this odd telescope, Pound measured the positions of the moons of Jupiter and Saturn. Newton used the observations to calculate the moons' orbits — measuring a celestial dance around the maypole.



An illustration depicts a similar telescope to the one built with the London maypole.

Hunting at the South Pole

Elusive particles are tracked by an unusual telescope buried deep in Antarctic ice

THE SETUP

More than half a century ago, physicist Wolfgang Pauli came up with the idea of a new, unseen particle to explain the mysterious behavior of atomic nuclei when they undergo radioactive decay. Understanding this decay process has repercussions for our knowledge of how stars live and die, including the Sun. The problem was that when they decay, atomic nuclei seem to violate the laws of conservation of energy and momentum.

Pauli suggested that if a nucleus emits an unseen particle in the decay process, then no laws are broken. This unseen particle came to be known as the neutrino. Since Pauli's time, scientists have found that the neutrino is an elusive, nearly massless starry messenger — almost impossible to detect. In his new book Telescope in the Ice, physicist and science writer Mark Bowen describes the long journey to do that, via the construction of the IceCube Observatory at the South Pole.

THE EXCERPT

In November 2013, the international collaboration that operates the IceCube Neutrino Observatory announced that they had detected high-energy neutrinos coming from outer space. This heralded the birth of a new form of astronomy, based not on the usual cosmic messenger, light, but on perhaps the strangest of the known elementary particles, the neutrino. It was also the culmination of a quest that had first fired the imagination of a small group of visionaries more than fifty years earlier and seen many heroic attempts and failures along the way.

Part of the reason this journey has taken so long is that it takes an unusual telescope to see an unusual particle. IceCube is unlike any other telescope you've ever seen or heard of, and in fact no one ever will see it, because it's buried more than a mile deep in the ice at the geographic South Pole. The collaborators couldn't even see it while they were building it. Francis Halzen, the Belgian theorist at the University of Wisconsin who dreamed up the idea, says it was like building a telescope in a darkroom.

This instrument doesn't employ lenses and mirrors in the fashion of the usual telescope. Presently, and it may grow, it consists of eighty-six kilometer-long "strings" of unadorned light detectors, housed in spherical glass pressure vessels about the size of basketballs. These "strings of pearls" have been lowered into eighty-six two-and-a-half-kilometer-deep holes that were drilled in the ice by a gargantuan hot water drill and allowed to freeze in place. Thus, the topmost pearls are one and a half kilometers— or about a mile—down. The holes have been drilled in a hexagonal grid pattern that covers a square kilometer on the surface of the ice. Hence, the more than five thousand detectors in this unique device monitor about one cubic kilometer, or a billion tons, of what the scientists were thrilled to discover to be very clear, deep Antarctic ice. It is the clearest natural substance known, clearer even than diamond.

Scientific American once called this telescope the "weirdest" of the seven wonders of modern astronomy. And perhaps the weirdest thing about it is that it doesn't look up at the southern sky from its location on the bottom of the world; it looks down into the ice. IceCube is designed to look through the planet at the northern sky. Since the neutrino is the only known particle that can pass all the way through a planet without being absorbed or deflected off course, any particle that reaches this particular cube of ice from the northern direction must be a neutrino. The instrument uses the Earth as a shield to block other types of particle, which might create a false signal.

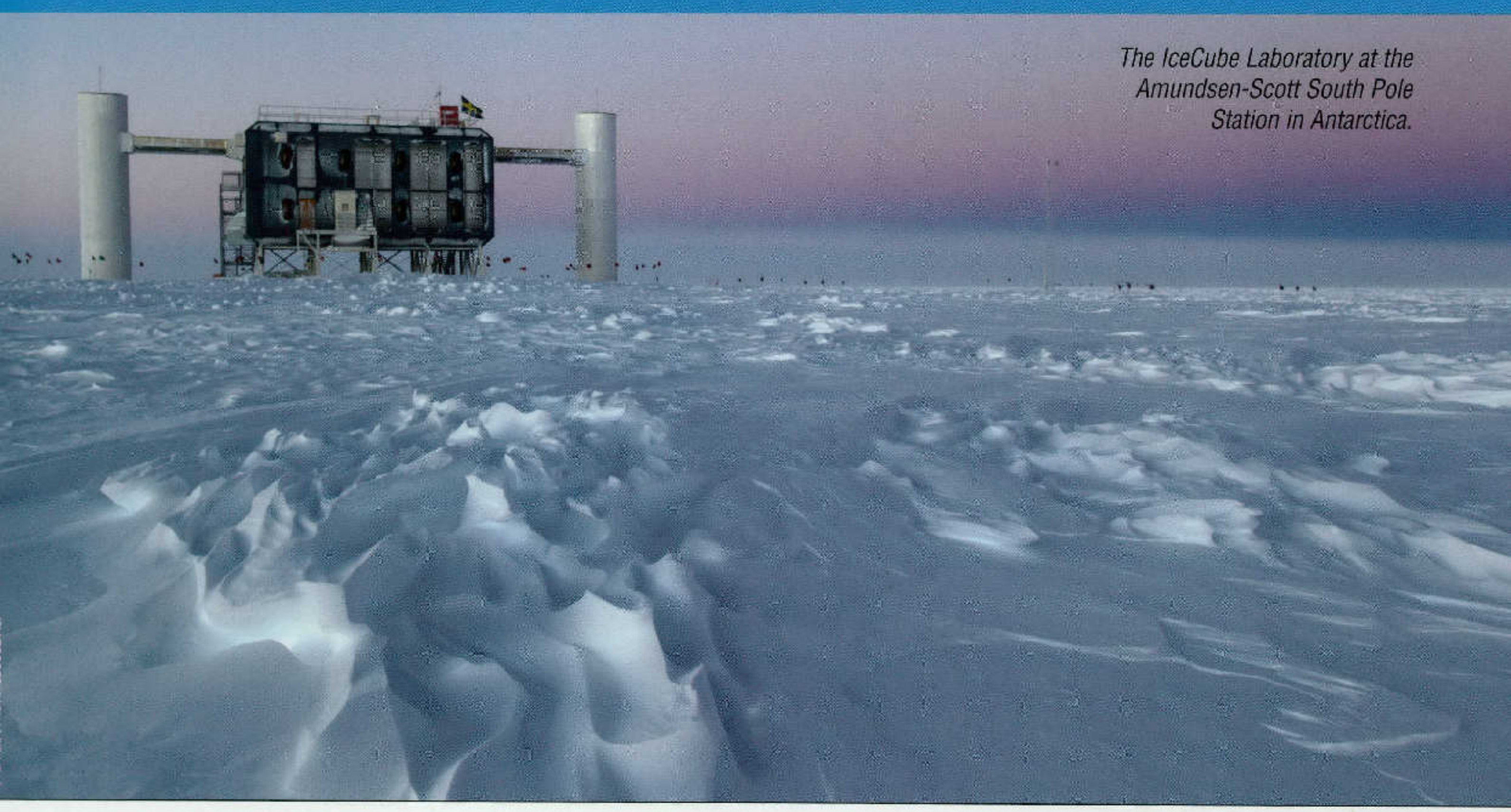
The reason the neutrino can pass so easily through a planet is that it doesn't like to show its face. It is sometimes known as the ghost particle. It may be the most plentiful particle in the universe—several hundred billion will pass through your eyeballs by the time you finish reading this sentence—but it is rarely seen, and it won't hurt your eyes, because it [rarely] interacts with any kind of matter. This makes it very hard to detect. As Nobel laureate and amateur stand-up comedian Leon Lederman once said, "A particle that reacted with nothing whatever could never be detected. It would be a fiction. The neutrino is barely a fact." Your average neutrino will pass unscathed—and therefore undetected—through a slab of lead one light year, or six trillion miles, thick. Thus it has no problem passing through the Earth, which is considerably less dense than lead and less than paper-thin in comparison to a light year, and most will pass right on through IceCube as well. Every once in a while, however, one will react with the ice in or around the detector or the bedrock below it and produce a charged particle, which will speed along in the same direction as its parent neutrino, dragging a cone of pale blue light along with it. IceCube's light sensors pick up this light, and by watching the way it passes through the three-dimensional grid of detectors, the scientists can determine the direction of the charged particle and the direction of its parent neutrino, in turn. This makes IceCube a telescope.

As it happens, the reticence that makes the little particle so hard to detect has the beneficial side effect of making it a wonderful complement to light when it comes to astronomy. Since the neutrino can pass through extremely dense media that are opaque to all wavelengths of light, it can carry information from regions of space that are inaccessible to the usual telescope, such as the interiors of stars—including the exploding ones known as supernovae—or regions of our galaxy that are obscured by interstellar dust—the black hole at our galaxy's core, for example.

One motivation for inventing this new astronomy is to see into the inner workings of the most violent events in the universe: supernovae, active galactic nuclei, supernova remnants, gamma ray bursters, colliding galaxies, and other strange beasts, some not yet imagined. The scientific possibilities also extend to cosmology and the detection of the mysterious and so far unseen cold dark matter, which constitutes most of the mass of the universe. They reach into pure particle physics as well, since all the violent creatures just named are basically huge particle accelerators, operating by the same basic principles as the manmade variety here on Earth—including the multi-billion-dollar Large Hadron Collider, which produced evidence for the Higgs boson in 2012—but on a vastly larger scale.

The neutrino itself has become a focus of particle physics in recent years, since in 1998 it produced the first and still only chink in the armor of the standard model of particle physics. This is the theoretical framework that describes the building blocks of matter, the elementary particles, and how they interact with each other through three of the four fundamental forces: the weak nuclear force, the strong nuclear force, and the electromagnetic force. The standard model, which was constructed in the 1970s, is turning out to be so successful that it's beginning to feel like a straitjacket. With the discovery of the Higgs, which was the last standard-model particle remaining to be detected, it's looking as though there's not much left to discover, and physicists don't like things to be tied so neatly with a bow. They're always looking for something new, and the surprising behavior of the neutrino suggests unknown phenomena yet to be explored. For the heart of physics, and indeed all science, is pure exploration.

This brings us to the main reason for building this unusual instrument. The



The IceCube Laboratory at the Amundsen-Scott South Pole Station in Antarctica.

newborn field of neutrino astronomy has opened a new window on the universe, and rarely in the history of astronomy has such a new window not led to a discovery that was unimaginable beforehand. Galileo is the classic example.

The first optical telescopes were developed in Flanders for merchants getting a jump on the market by taking advance inventories of the goods on ships as they approached across the English Channel. Galileo used his superior understanding of optics and math to craft a better one, which he presented to the Venetian Doge as a tool of war. A few months later, he trained another at the Moon on a clear night when Jupiter, the second brightest object in the sky, happened to be floating just above it and to the right. Thus he discovered the four "Medicean stars," now known as moons, heretically orbiting the planet, and got himself in trouble.

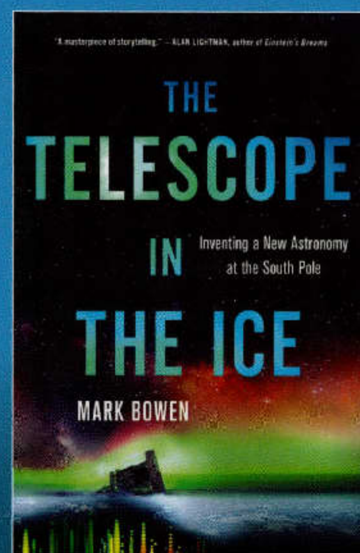
In 1965, Arno Penzias and Robert Wilson, two physicists at Bell Telephone Laboratories, made an unexpected discovery while they were designing ground-based radio antennae for communications satellites. In order to test a horn-shaped antenna they had designed to be ultra-quiet, they aimed it at what they thought was empty space and were surprised to find that it always picked up a small amount of "noise" no matter how painstaking their design. The noise turned out to be a real signal: the Cosmic Microwave Background Radiation, the afterglow of the Big Bang, the explosion out of nothingness that brought this universe into being about fourteen billion years ago. This discovery transformed the Big Bang and cosmology in general from objects of ridicule into subjects for precise study. It also illustrates another aspect of discovery: the scientist's mind needs to be prepared in order to interpret what he or she measures or "sees"—or even to be able to see it. Theories of the Big Bang and its microwave afterglow had been gestating for decades by the time Penzias and Wilson made their measurement. They won the Nobel Prize not simply for finding a signal but for interpreting it with the knowledge or "eyes" of their day. This leapfrogging between theory and experiment is what propels science forward. Sometimes theory is out in front, sometimes the accumulated weight of unexplained experimental evidence prompts new theories or even paradigm shifts. And these developments can take decades.

After the Nuclear Test Ban Treaty was signed in 1963, the U.S. Department of Defense began sending satellites into orbit in order to verify that the Soviets weren't violating the treaty by testing bombs in space, underwater, or on the Moon. The idea was to sense the gamma rays (invisible light at shorter wavelengths than X-rays) given off by the blasts. The satellites never detected any of those, but they did detect numerous "treaty violations" in deep space: brief and astoundingly intense bursts of gamma rays in the distant cosmos. The scientific community became aware of this discovery a few years later when the data was declassified, and the enigmatic sources of the bursts were given the noncommittal name "gamma ray bursters." Over the course of one to twenty seconds or so, GRBs give off about as much light as that given off by all the other stars and galaxies in the known universe. Theory holds that they should give off neutrinos, too, so they are of great interest to IceCube.

The astrophysicist Kenneth Lang observes that "our celestial science seems to be primarily instrument-driven, guided by unanticipated discoveries with unique telescopes and novel detection equipment. . . . [W]e can be certain that the observed universe is just a modest fraction of what remains to be discovered."

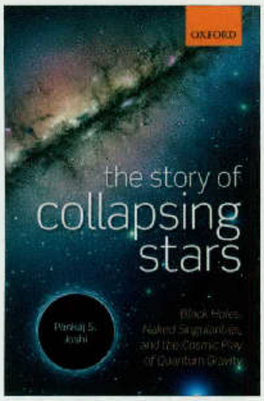
The dream of making a big discovery is one of the things that drives the working scientist; however, media coverage and prestigious awards like the Nobel give the layperson a distorted sense of its importance, I think. The clichéd emphasis on supposedly earthshattering results is especially pernicious in physics, where it would seem that a discovery that "changes our view of the universe" takes place every few months. Some such over-the-top phrase is almost inevitably employed in any newspaper or magazine article describing even the most insignificant result, and the physicists who have now taken to trumpeting their findings in press conferences before publishing them in the peer-reviewed literature share a good part of the blame. In reality, discoveries on the order of the theory of relativity or Darwinian evolution are exceedingly rare.

But there is some truth in the noise of science journalism, nevertheless. The fact is that scientists tend to enjoy their work more than most, for the main reason that what really gets them out of bed in the morning is the thrill of the chase. They come to some minor realization, solve some esoteric technical problem, or shine a light into some new dark corner of the territory they've been exploring almost every day. More than half the time they're wrong, but at least they're on track. And finding out they were wrong—going from confusion to clarity—can be just as thrilling as finding they were right.



The Telescope in the Ice
Inventing a New Astronomy at the South Pole
By Mark Bowen
$27.99

More Books



The Story of Collapsing Stars

Black Holes, Naked Singularities, and the Cosmic Play of Quantum Gravity

By Pankaj S. Joshi; $19.99

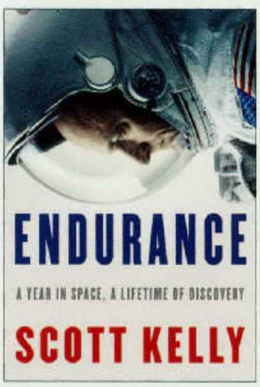
Indian astrophysicist Pankaj Joshi explains what happens to massive stars at the ends of their lives in this 240-page paperback volume. The fates of these stars are of great importance for many of the most intriguing problems in space science today, including understanding the fundamental forces of nature — gravity, on the largest scales, and at the same time, tiny forces that operate on the quantum scale. Joshi explores why some massive stars implode and collapse to become black holes, while others leave behind an even stranger beast called a naked singularity. And he explains how study of these objects provides a cosmic laboratory to examine the fundamental forces.

Rocket Men

The Daring Odyssey of Apollo 8 and the Astronauts who Made Man's First Journey to the Moon

By Robert Kurson; $28

In 1968, as the United States experienced political assassinations, riots, and the escalation of the Vietnam War, three astronauts set out on humankind's first trip to the Moon. Robert Kurson's new book *Rocket Men* celebrates the 50th anniversary of this milestone in space flight, and tells the stories of those who lived it. Commander Frank Borman was a NASA veteran on his final mission. Jim Lovell was the command module pilot, and would go on to command Apollo 13. Nuclear engineer and fighter pilot Bill Anders rounded out the crew. Kurson's book draws on interviews with them, their families, and NASA personnel to detail the real-life thriller of man's first voyage to another world.

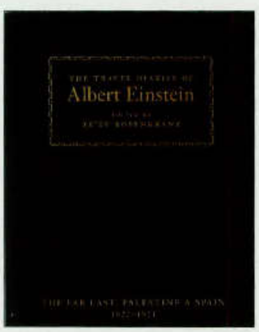


Endurance

A Year in Space, A Lifetime of Discovery

By Scott Kelly and Margaret Lazarus Dean; $29.95

The power of books to transform lives is demonstrated in this autobiography by astronaut Scott Kelly, who set an American space-endurance record by spending 340 days aboard the International Space Station. Kelly was an 18-year-old college freshman — a poor student with no ambition — when he read *The Right Stuff*, Tom Wolfe's depiction of the early space program. Kelly was so transfixed by the stories that he decided to become an astronaut. The book details his journey, alternating chapters about his early life with ones about his year in space — a time of deprivation and dreams of home. To help him get through the ordeal, Kelly turned to another book, about Ernest Shackleton, a polar explorer whose courage helped save all of his men after his ship was crushed by the Antarctic ice.



The Travel Diaries of Albert Einstein

The Far East, Palestine & Spain, 1922-1923

Edited By Ze'ev Rosenkranz; $29.95

Although several biographies depict the life of Albert Einstein, many of us still think of him strictly as the stereotypical scientist, all formulas and wild hair. A bit more of the man comes through in this diary, in which he recorded a trip to Japan, China, Palestine, and Spain. He encapsulates his scientific work and lectures, but also, like any good tourist, records the sights and sounds of the world, along with his impressions of the people he meets. He shows some grumpiness ("usual handshaking and speeches—abominable"), but also records joyous experiences ("Toledo like a fairy tale.") The editor, who oversees a collection of Einstein's papers, places the trip and diary in context. Some of Einstein's letters and speeches from the trip are included, as well as extensive notes on the people and places Einstein visited.

by Damond Benningfield and Rebecca Johnson

Headed for New 'Insights' into Martian Interior

The next Mars lander, scheduled for launch as early as May 5, will ignore the planet's canyons, volcanoes, and craters. And unlike most missions in recent decades, it's not there to sniff for evidence of Martian water. Instead, it will look deep into the planet, providing a better picture of how Mars is put together, and how it and the solar system's other rocky planets formed and evolved.

InSight (Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport) will launch from Vandenberg Air Force Base, on the California coast, and arrive at Mars on November 26.

InSight is scheduled to land on Elysium Planitia, a smooth plain just north of the equator. The location provides a safe landing spot and a steady supply of sunlight through the year to power InSight's solar batteries.

After landing, the craft will deploy a seismometer, a heat probe, a color camera, and weather instruments.

The seismometer will listen for Marsquakes — rumbles caused by volcanic activity, impacts by space rocks, or the explosions of space rocks in the atmosphere. These events create waves that bounce around inside Mars, traveling at different speeds through different materials, and reflecting off of layers deep inside the planet. Tracing these waves will help scientists determine the size and density of the planet's three layers — the crust, mantle, and core.

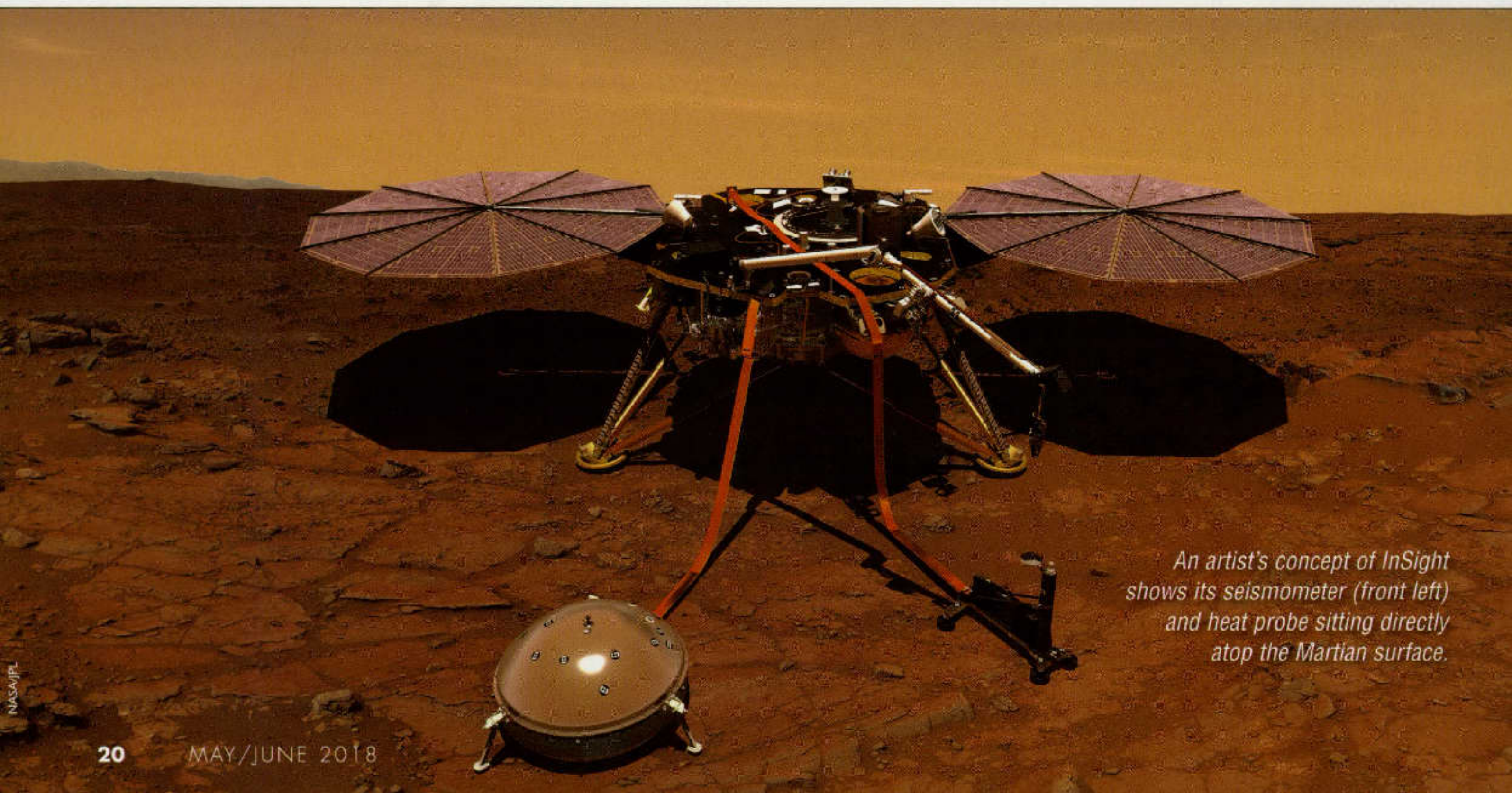
The Viking landers of the 1970s also carried seismometers. They were attached to the landers, though, so they were jiggled by the motions of cameras, robotic arms, and other equipment, limiting them to a crude picture of the Martian interior. InSight's seismometer (which had to be redesigned after failing, in 2015, causing a two-year delay in the launch) will be deployed away from the lander, though, so it will have a quieter environment, allowing it to assemble a more precise picture of the interior. And a set of weather instruments will measure how the seismometer is buffeted by winds, further refining its observations.

Precise tracking of InSight's radio signals will reveal slight "wobbles" in Mars' rotation, which are caused by the planet's structure and interior motion, providing more details on how Mars is put together.

The heat probe, which also will be deployed away from the lander, will drill about 16 feet into the powdery surface, with thermometers placed every four inches. The difference in temperatures will reveal how much heat the planet's core is producing. That will tell scientists more about the size and composition of the core.

Scientists say the observations should help them piece together how Mars was born and how it has evolved, which will help them learn more about the birth and evolution of the other rocky planets, including Earth.

A pair of briefcase-sized satellites will accompany InSight on the cruise to Mars. Known together as Mars Cube One, they will serve as communications relays for InSight during its descent through the Martian atmosphere — a phase for which scientists and engineers usually receive little or no data from the lander. The cubesats are designed to test the concept of using tiny spacecraft to explore Mars and other solar-system bodies. They will fly past Mars when their mission is done. **DB**

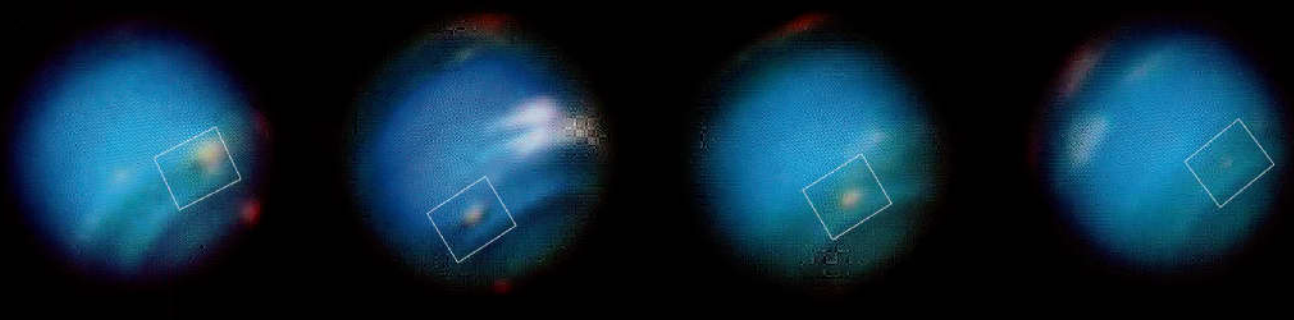


An artist's concept of InSight shows its seismometer (front left) and heat probe sitting directly atop the Martian surface.

NASA/JPL

Tracking Neptune's Incredible Shrinking Storms

Hubble Space Telescope is watching a giant storm on Neptune as it shrinks, seen in these photos taken over two years. The dark storm, which is large enough to stretch across the Atlantic Ocean from the U.S. to Europe, first appeared in 2015. It may be made of hydrogen sulfide, and thus would smell like rotten eggs. Hubble tracked two smaller Neptunian storms that appeared and then vanished in the mid-1990s. Voyager 2 discovered the first storms on the distant planet about three decades ago.



NASA/ESA/MH WONG & AI HSU (UC BERKELEY)

Surprise! Molecules Born in Black Hole Winds

Astronomers at Northwestern University may have explained the puzzling contents of energetic winds coming from black holes at the hearts of massive galaxies.

In recent years, observations from Herschel Space Telescope and the Atacama Large Millimeter Array have found molecules in the winds from black holes. These results did not make sense, as the winds are so energetic that they should break apart any molecules into individual atoms.

Even more puzzling, last year astronomers using the Very Large Telescope in Chile discovered new stars being born within these winds. This should be impossible, given the extreme conditions there.

Now the Northwestern group, led by Alexander Richinings, has posed an explanation. Richinings developed a computer code that models the chemical process in the gas given off as a supermassive black hole grows.

"When a black hole wind sweeps up gas from its host galaxy, the gas is heated to high temperatures, which destroy any existing molecules," he said. "By modeling the molecular chemistry in computer simulations of black hole winds, we found that this swept-up gas can subsequently cool and form new molecules."

The work predicts that molecules such as carbon monoxide, water, and molecular hydrogen can form in these winds.

"This is the first time that the molecule formation process has been simulated in full detail, and in our view, it is a very compelling explanation for the observation that molecules are ubiquitous in supermassive black hole winds, which has been one of the major outstanding problems in the field," said team member Claude-Andre Faucher-Giguere, also of Northwestern. **RJ**

Artist's concept of a galaxy whose central supermassive black hole is blasting out energetic winds (red).

ESA/ATG MEDIALAB

Caught in a Merry-Go-Round

Jupiter's poles are like never-ending carousels, with giant cyclones spinning around a central cyclone at each pole, according to observations by the Jupiter-orbiting Juno spacecraft. The storms neither diminished nor merged during the craft's first few months of observations, suggesting that the polar systems are stable.

Juno is the first spacecraft to orbit Jupiter from pole to pole, so it is the first to get a good look at the giant planet's polar regions. Planetary scientists had expected to see central cyclones similar to those observed at Saturn, but had not predicted the rings of storms around them.

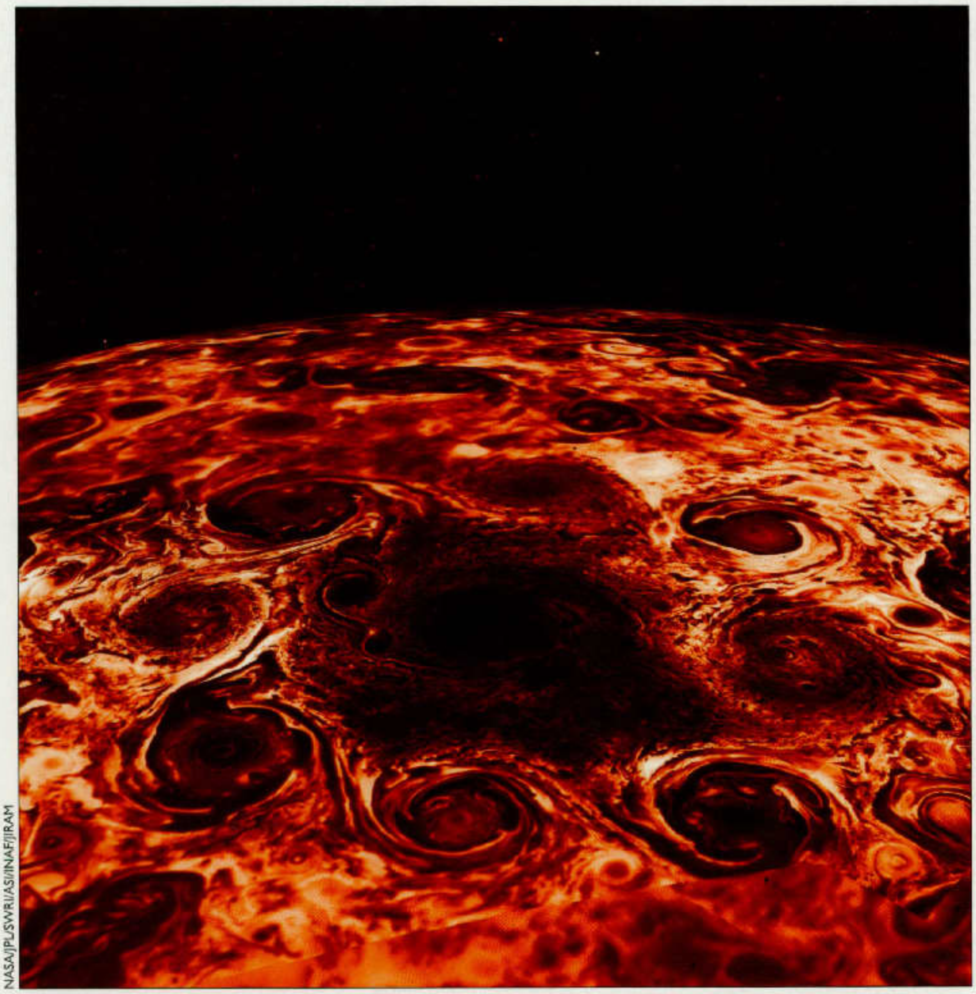
The cyclone at the north pole is about 2,500 miles (4,000 km) wide, and is encircled by eight other storms of similar size. The storms form two boxes, which are offset by 45 degrees, with one box a little smaller than the other.

The storm at the south pole is surrounded by five other cyclones, which are a bit more randomly distributed than those at the north pole. They are bigger than their northern kin, too, at up to about 4,300 miles (7,000 km) in diameter.

Each of the encircling storms shows prominent spiral cloud bands like those in terrestrial hurricanes. The storms are so close together that the spiral bands sometimes touch and interact. Winds in the cyclones reach speeds of up to 220 miles per hour (350 kph).

The polar observations were based on Juno's first few orbits around Jupiter, spanning about seven months. They showed little change in configuration from orbit to orbit, suggesting that the arrangement is stable.

Scientists aren't sure why the giant storms encircle the central cyclones, or why the rings of storms don't merge to form larger systems. Continued observations by Juno, which orbits Jupiter once every 53 days, may help them explain the dynamics of Jupiter's twin carousels. **DB**



NASA/JPL/SwRI/ASI/INAF/JIRAM

A mosaic of infrared images from Juno shows the central cyclone and eight surrounding storms at Jupiter's north pole. Darker colors depict the tops of the clouds, which are colder than the surrounding regions, which look deeper into Jupiter's atmosphere.

On Second Thought, It's a Solar 'Twin'

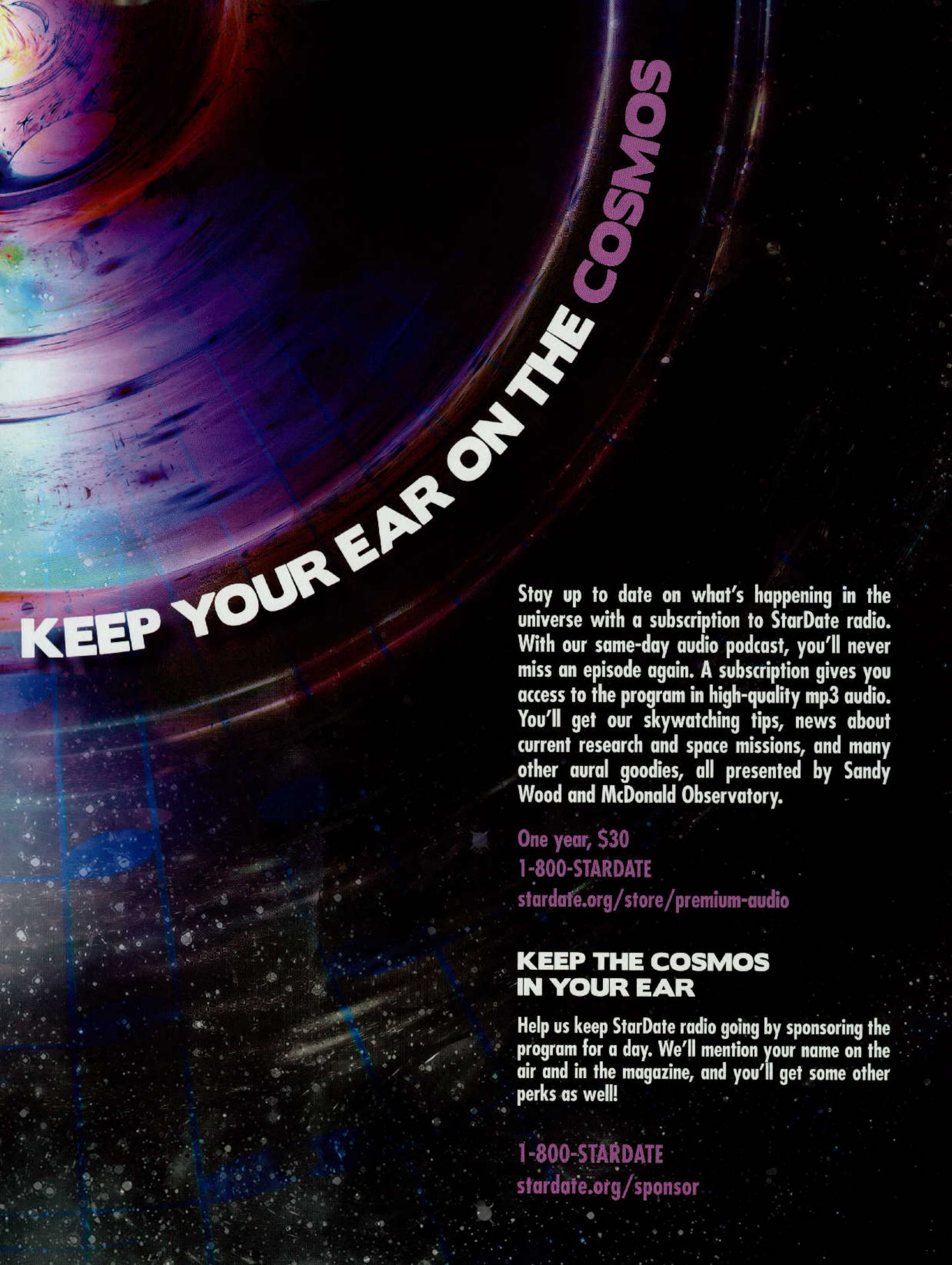
A star that astronomers first thought was an infant still in the embrace of its nursery turns out to be a near twin to the Sun, although one that's much younger.

GSC 00154-01819 appears in front of the Rosette Nebula, a beautiful gas cloud that has given birth to the stars of a young cluster. The star's location led astronomers to conclude that it was associated with the nebula and cluster. Observations with a telescope in Australia, though, revealed that it is only 715 light-years away, compared to more than 5,000 light-years for the Rosette.

The observations also revealed that the star has the same color and surface temperature as the Sun, which means it is a member of the same spectral class, G2. Although it is slightly smaller and fainter than the Sun, it is almost exactly the same mass, which is a close enough match for the astronomers who studied the star to classify it as a solar twin. (The lead author of the study, published in the May issue of *Monthly Notices of the Royal Astronomical Society*, was Jeremy Huber of Thomas More College in Kentucky.)

One major difference, though, is age. Based on the star's rotation rate (its equator turns once every 4.2 days, versus 25 days for the Sun), its spectrum, and other factors, the astronomers concluded that GSC 00154 is just 180 million years old, compared to 4.6 billion years for the Sun.

Studying solar twins at different stages of evolution helps astronomers better understand the history and future of the Sun, which in turn helps them devise better models of how all stars evolve.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These two spiral galaxies, located 350 million light-years away and collectively known as Arp 256, are in the process of merging. Their gravitational tug of war creates bursts of star formation, visible as blue knots in this view from Hubble Space Telescope.