StarDate™

SEPTEMBER/OCTOBER 2011 $5

BUBBLES FROM BEYOND
Page 16

Busy Hub

Young stars, big clouds, and a giant black hole at the heart of the galaxy

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

StarDate™

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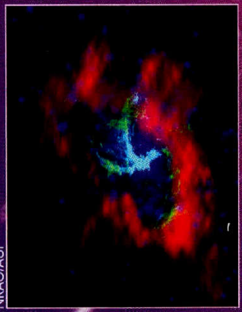


NRAO/AUI

On The Cover

Streamers of stars and gas swirl around the supermassive black hole at the heart of the Milky Way in this combined infrared and radio image. Red indicates cold gas, green is warm gas, and blue is stars. For more on the galaxy's turbulent center, see Page 4.

This Page

This 350-million-year-old cosmic pile-up of four galaxy clusters is collectively known as Pandora's Cluster. The galaxies, seen by Hubble Space Telescope and the Very Large Telescope, make up only 5 percent of the total mass. Hot gas (pink, in X-rays from Chandra X-ray Observatory) accounts for about 20 percent, and dark matter (blue, a computer simulation), 75 percent.

Coming Up

In the November/December issue of StarDate, *we'll celebrate the 100th anniversary of the birth of Grote Reber, one of the pioneers of radio astronomy. We'll also bring you fall skywatching information and the latest astronomy news.*

NASA/ESA/ESO/CXC & D. COE (STScI)/J. MERTEN (HEIDELBERG/BOLOGNA)

MERLIN

Dear Merlin,

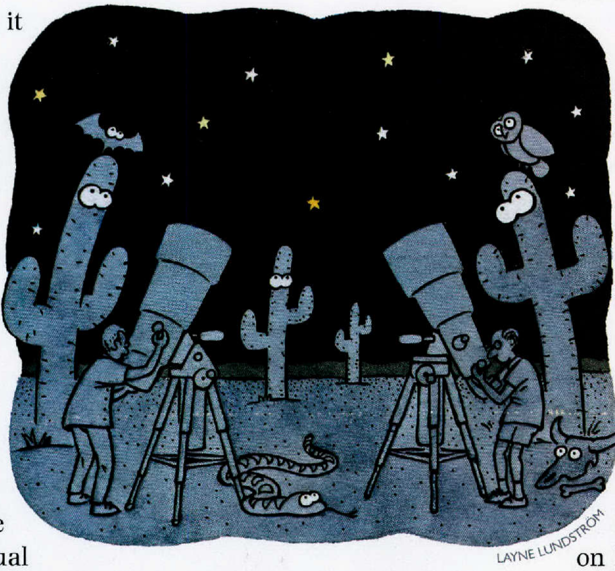
Is it possible that the properties of dark matter are such that it can influence both matter and antimatter throughout the universe?

Lawrence Konn
Rolling Meadows, Illinois

Not just possible, it does.

Dark matter is something that produces no detectable energy of any kind (hence the name "dark" matter), but that makes its presence known by exerting a gravitational pull on the visible galaxies. By measuring the motions of galaxies in clusters, and the stars in the outskirts of individual galaxies, astronomers calculate that dark matter makes up more than 80 percent of all the matter in the universe. It probably consists of massive particles that were forged in the Big Bang.

In terms of how they react to gravity, there's absolutely no difference between "normal" matter and antimatter, so dark matter's influence on them is identical.



Dear Merlin,

Where is the best place in the United States to see stars from horizon to horizon? Is it true that the best time is when the Moon is not visible in the night sky?

Joyce Tatum
Chattanooga, Tennessee

Alas, though beautiful, the Moon is a skywatching pest. Its light scatters through the atmosphere, creating a sort of luminous curtain that makes it more difficult to see the stars beyond. The greater the Moon's illumination (the "fatter") it is, the more light it casts into the sky. So yes, it's always best to watch the stars under a dark sky, with neither Moon nor artificial light sources to spoil the view.

As for where to go, try the deserts of the southwest or the flat, empty spaces of the Great Plains. Desert skies tend to be clearer than those of other regions, and they host fewer towns and cities to fill the sky with light. The plains also offer wide-open views, providing that horizon-to-horizon panorama you seek.

Even if you don't live in these regions, though, many state and national parks offer beautiful starry vistas as well. Search the Internet for nearby parks that offer special skywatching events, or for local astronomy clubs that host star parties at their own dark-sky sites.

Dear Merlin,

Since the Moon causes ocean tides, can it also cause tides in underground aquifers?

Fred Donecker
Canyon Lake, Texas

'Fraid not.

The Moon's gravitational pull causes the oceans to "bulge" toward it. As Earth turns on its axis, this bulge of water follows the Moon across the sky, creating the tides. (There's a second bulge on the opposite side of Earth, which is why there are two daily high and low tides.)

This effect works for the open oceans because the bulges can move freely around the planet. It does not work for small, self-contained bodies of water, such as lakes (although, to call on Mr. Parentheses again, there are small tidal effects in large lakes, such as Lake Michigan).

Aquifers are hemmed in, just as lakes are, so there is no way to raise a tide that will oscillate back and forth as the Moon moves across the sky. And to complicate matters, the water in most aquifers moves through cracks and pores in the rocks or through loosely packed sand or gravel, and does not form big pools as oceans or lakes do.

Dear Merlin,

A recent "Believe It or Not!" feature said that two asteroids flew closer to Earth than the Moon is in September 2010, but that the asteroids were discovered less than a week before that. I didn't hear anything about it, so they must have been very small.

John Gonzalez
San Antonio

Good deduction! In fact, their small size is why they weren't discovered until just three days before passing Earth. One flew less than 50,000 miles (80,000 km) from Earth, but it was only about the size of a house, so it was too faint to be detected earlier. The other was slightly larger but missed Earth by a wider margin.

Astronomers are finding that such encounters are common. On June 27, for example, another house-sized asteroid — also recently discovered — passed just 7,500 miles (12,000 km) above the surface. And that close call came less than a month after a similar-sized asteroid missed Earth by 200,000 miles.

Fortunately, all of those objects are so small that even if they were to hit Earth, they most likely would inflict little or no damage.

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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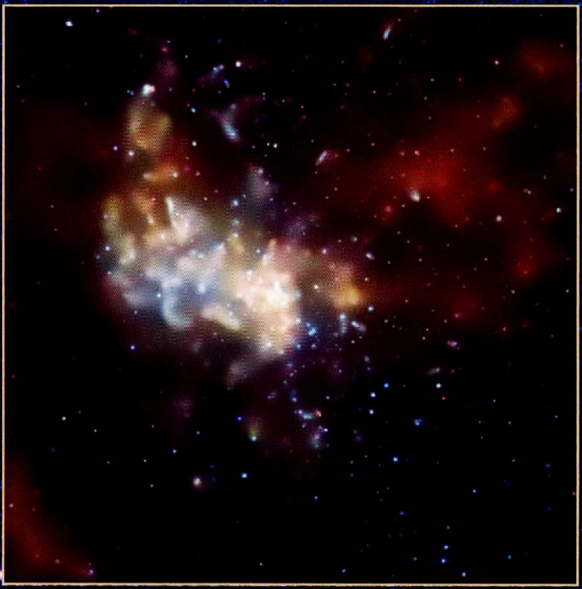


The star cluster at the center of the galaxy looks like a brilliant rose at the upper left of this infrared image from Spitzer Space Telescope. Other clusters, plus glowing clouds of gas and dust, form a kaleidoscopic pattern around the galaxy's center. The supermassive black hole is buried deep within the central star cluster. Inset: Glowing clouds of gas at upper right and lower left, shown in X-rays from Chandra X-Ray Observatory, may have been produced by powerful eruptions around the central black hole over the last few thousand years.

NASA/JPL; NASA/CXC/MIT/F.K. BAGANOFF ET AL.

URBAN JUNGLE

The stars at night (and during the day) are big and bright around the black hole deep in the Milky Way's busy 'downtown'

By Damond Benningfield

From a planet at the center of the Milky Way galaxy, stars would blaze across the heavens like the lights of a sky-spanning Broadway marquee — a million times more stars than we see from Earth, with many shining as brightly as the Moon. Their configurations would change from year to year as they raced around the galactic center. And amid the stellar chaos, a tiny blue dot would glow faintly, almost invisibly: a thin cloud of gas around a supermassive black hole — the galaxy's dark heart.

The black hole itself is invisible to us. Like all black holes, it emits no energy of any kind, so it's completely dark. And it is so small and far away that not even the most powerful telescopes can see its silhouette against the background of more-distant stars — yet.

Astronomers know quite a bit about the black hole, though. It's about four million times the mass of the Sun. It's surrounded by a cluster of young stars, some of which plunge to within a few billion miles of the black hole. And although it's quiet today, a century ago it gorged on a clump of matter that passed too close, creating a pyrotechnic display that lit up the Milky Way's heart.

"This is the best case we have for a supermassive black hole anywhere in our universe," says Andrea Ghez, a professor of physics and astronomy at UCLA and one of the leading experts on the Milky Way's center. "What's happening in other galaxies made us ask the question in the first place, but in fact we have the best evidence for the existence of these incredibly exotic objects from the center of the galaxy."

Much of that evidence has been amassed by two teams, one led by Ghez and the other by Reinhard Genzel, director of the Max Planck Institute for Extraterrestrial Physics in Germany. Using giant telescopes in Hawaii and Chile and cutting-edge observational techniques, they have probed closer to the black hole than ever before. That has allowed them to plot the orbits of giant stars that pass hair-raisingly close to the black hole, providing the best measurement of the black hole's mass. And it has revealed that some of the stars around the black hole are far younger than expected.

"There's been a myriad of surprises, which is the fun of doing research," says Ghez. "You go in expecting to answer one thing and you come out the other end with more questions than you started with."

The central question that Ghez, Genzel, and others hoped to answer was whether a supermassive black hole inhabits the center of the Milky Way.

As early as 1980, radio observations revealed that gas was swirling around a dark, massive object at the center of the galaxy. That object, which glowed steadily at radio wavelengths, was designated Sagittarius A* ("A-star") for its location in the constellation Sagittarius. And by the early '90s, observations of the motions of stars and gas clouds suggested the dark object was more than two million times as massive as the Sun.

But that region of the galaxy is about 27,000 light-years away, so it looks tiny in even the largest telescopes, and it is hidden behind thick clouds of dust in the galaxy's disk. No telescope had been able to probe deeply enough into the heart to determine just how tightly the mass was packed, leaving a lot of wiggle room for interpretation. The large mass could have been concentrated in a single black hole, but it just as easily could have been spread out in a cluster of smaller black holes, neutron stars, or other dense, faint objects.

Narrowing the list of possibilities required sharper pictures. With enough detail, astronomers could see many individual stars orbiting the concentrated mass at the galaxy's center. Plotting the orbits of the stars, then applying the laws of orbital motion, would allow them to calculate the mass of the central object and narrow the estimates of its size. Those measurements, in turn, would whittle the list of possible explanations.

How Far to Downtown?

If you want to hire a taxi to take you to the Milky Way's busy downtown, don't expect the cabbie to know the fare. That's because astronomers are uncertain of the distance to the galactic center. In recent years, they have published several estimates, ranging from about 23,500 to 30,000 light-years, for an average of about 27,000 light-years. The difference is more than just a curiosity. It affects estimates of the sizes and ages of stars that orbit the central black hole, for example, which affects the estimates of the black hole's mass.

Genzel began obtaining those measurements with a large telescope in Chile, while Ghez soon followed with the 10-meter (33-foot) Keck telescope in Hawaii. Both telescopes are above most of the water vapor in Earth's atmosphere, allowing them to view the universe at infrared wavelengths, which penetrate the galaxy's dust clouds.

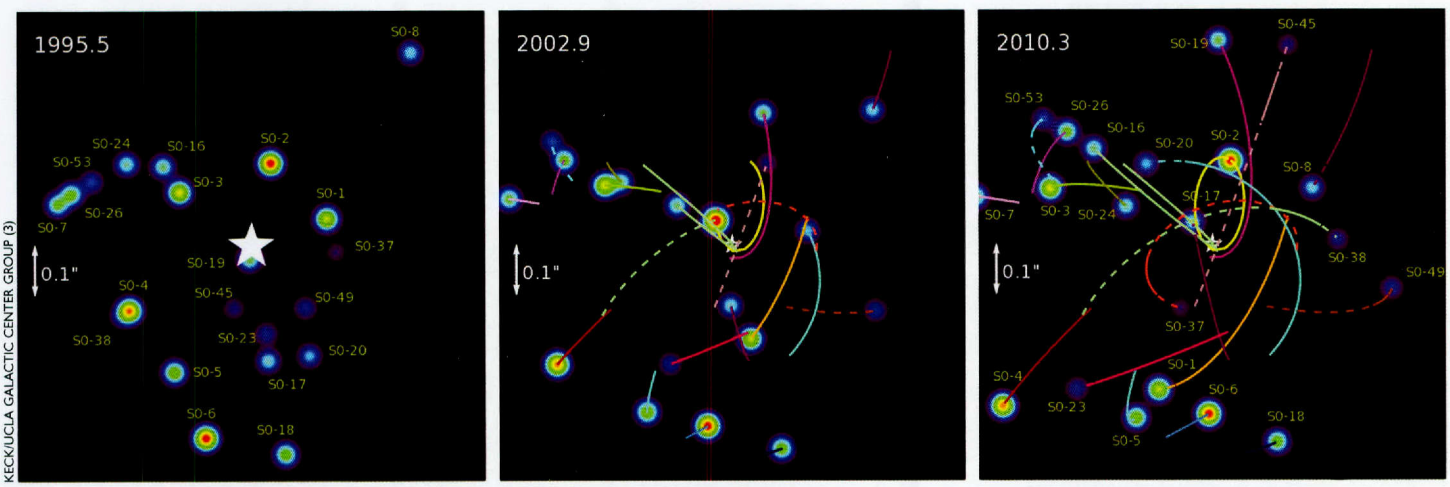
In addition, they could apply a new technique, called speckle imaging, that compensates for Earth's atmosphere by taking thousands of short-exposure images and stacking them together. Each frame "freezes" the atmosphere in place, eliminating the blurring caused when starlight passes through atmospheric layers of different density. Instead of a fuzzy blob, a star looks like a crisp pinpoint — a necessity for plotting precise orbits of stars in the crowded "downtown" of the Milky Way's center.

So the two teams began probing about two dozen stars that are within a few light-weeks of Sagittarius A*. (The orbit of Neptune, the most distant planet from the Sun, spans about two-thirds of a light-day, which is the distance that light travels in one day.) The stars are much bigger and brighter than the Sun, so they are relatively easy to pick out.

Over the following decade, the teams plotted the positions of their target stars several times a year, primarily in summer in the northern hemisphere, when the center of the galaxy is in best view.

As the orbits began taking shape, another technological advancement sharpened the view even more.

Called adaptive optics, it was developed by the military to track orbiting satellites and space junk. Both the Keck system and the one used by the Very Large Telescope in Chile, a group of four eight-meter telescopes which Genzel has used over the last decade, beam a laser into the upper atmosphere, where it strikes sodium atoms, causing them to glow. The telescope keeps this pinpoint of light in sharp focus by altering the shape



KECK/UCLA GALACTIC CENTER GROUP (3)

A sequence of images tracks the orbits of stars around the black hole from 1995 to 2010.

of a small secondary mirror to compensate for the blurring motions of the atmosphere. If this laser-generated "guide star" is in good focus, so are the stars that appear near it in the sky.

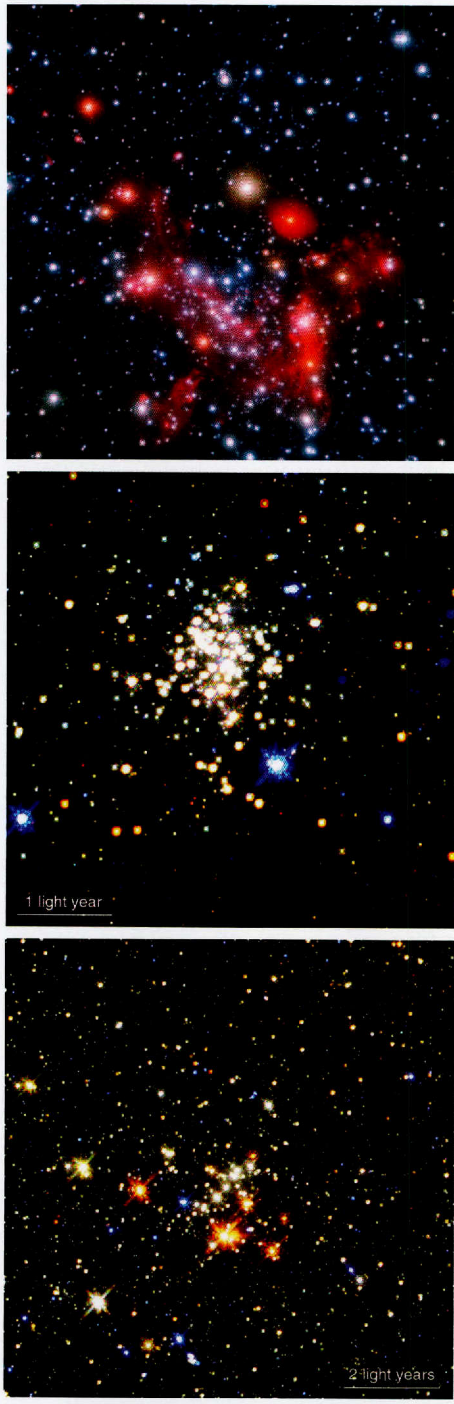
The combination of techniques allowed the teams to plot detailed orbits for each of the stars in their studies. One of the stars, a bright blue sizzler designated S2 or SO-2, has already made a full turn around Sagittarius A*, passing less than one light-day from it, but most of the others still haven't completed the circuit. Even so, the astronomers have plotted the orbits with enough accuracy to greatly refine the measurements of the size and mass of the object they are orbiting.

In addition, continued observations with radio telescopes show that the central object remains fixed in place relative to the stars around it like the hub of a merry-go-round. "This source is motionless, which is perfectly consistent with it being very massive, because the more massive you are the less you move," says Milos Milosavljevic, an astronomer at The University of Texas at Austin who studies Sagittarius A* and other supermassive black holes. "We see the stars but do not see anything terribly interesting at the location of the common center, the place where a large amount of mass has to be located to explain the motion of the stars."

The conclusion, says Ghez, was as inescapable as a black hole's gravity.

"[We went] from knowing there's four million times the mass of the Sun confined in a region where you see lots of other stuff that could easily explain the mass that you're seeing, down to a region that's the size of our solar system," she says. "And at that point, there are no other alternatives to explain this mass concentration. You really are left with a supermassive black hole."

The new observing technologies allowed astronomers to probe not just the black hole but the conditions around it.



ESO/S. GILLESSEN ET AL.; NASA/STScI/DON FIGER (2)

From top: The cluster of stars around the black hole at the center of the galaxy; Arches Cluster; Quintuplet Cluster

"The Milky Way center is one of the most important laboratories we have to study, in very great detail, what's happening in the centers of galaxies, in much more detail than we can ever hope to do in all other galaxies," Genzel said in 2009.

Genzel and others found that, like a cartoon guru sitting atop a mountain, Sagittarius A* is surrounded by followers — a tightly packed cluster of stars. Most of the stars are small, faint, and old. But the teams found almost 200 stars that are only about six million years old orbiting within half a light-year of Sagittarius A*.

"That introduces some tremendous challenges," says Mark Morris, a professor of physics and astronomy at UCLA and one of Ghez's collaborators. "We expected that the tidal forces from the black hole would prevent star formation from taking place near the black hole, and so it was a growing surprise as we realized that there is a young cluster of stars there."

"You don't expect to see young stars near a black hole because a black hole is not a nice neighbor to a stellar nursery," says Ghez. "Black holes tend to shred things apart. To get stars to form you need a gentle environment that allows big, fragile clouds of gas and dust to collapse under their own self gravity. If you have a black hole right next to you and it shreds the cloud apart, it's very hard to imagine how to get stars to form."

Two other giant clusters, the Arches and the Quintuplet, lurk near the black hole, each with its own population of young stars.

"Stars are forming out of those clouds [around the black hole], but not in the same way they do out in the disk or in the suburban neighborhood where we live," says Morris, who has been studying the center of the galaxy since the 1970s. "The stars that form in the galactic center, at first sight, seem to form in these incredibly rich clusters that form all at once, in one fell swoop, 10,000 stars — bang! — in very compact, massive clusters."

"It's an interesting problem — the paradox of youth," says Ghez. "How in the world do you get these young stars in a region where you just don't expect them? There's been a huge industry of theoretical ideas trying to overcome this conundrum."

One idea says the stars aren't really young at all, but instead have been altered by mergers or other events that make them look young.

A second idea says the cluster's stars

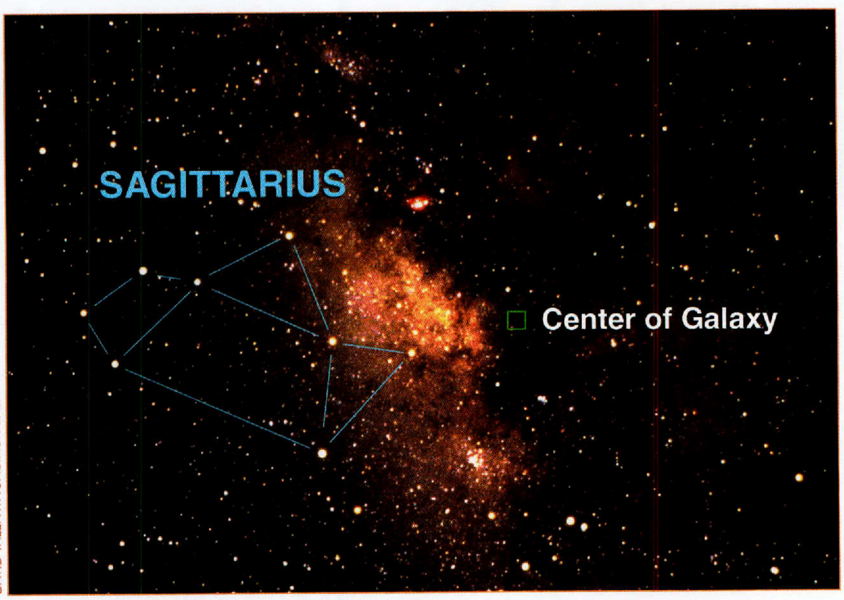
are young, but they formed farther from the black hole and were quickly funneled inward, perhaps by gravitational encounters with medium-sized black holes. Yet astronomers know of no way for that many stars to be pushed such a great distance in so short a time, and there's no evidence of another good-sized black hole in the vicinity of Sagittarius A*.

A third idea says the stars actually formed where we see them today, in a disk encircling the black hole — an idea supported by the orbits of many of the young stars, which follow a similar orbital plane. (In fact, there may be two groups of the young stars, each following its own orbital path.)

Yet like the other two, that scenario presents some serious questions, Ghez says. "If you think star formation happened at the center of the galaxy, where did all that gas come from? How do you funnel it in? Is it a cloud that just happened to pass by in the right kind of orbit that got captured in this region? Is it the collision of clouds that allows the material to stream into the center? Or is it a recent merger? We don't know. We have no idea. This is one of the $64,000 questions."

Another question is why the black hole itself is so anemic. The supermassive black holes in the centers of many other galaxies are surrounded by large, turbulent disks of infalling material, known as accretion disks. As the gas, dust, and demolished stars spiral toward the black hole's "surface," the event horizon, they are heated to millions or billions of degrees. That produces enormous amounts of energy, particularly X-rays.

Magnetic fields in the disk funnel some of the material from the innermost region of the accretion disk into thin jets that shoot into space at nearly the speed of light. The jets produce lots of radio energy, which radio telescopes on Earth detect as active galactic nuclei. In fact, it was the discovery of these objects that motivated the earliest searches for a supermassive black hole at the center of the Milky Way.



The center of the galaxy is about 27,000 light-years away in the constellation Sagittarius, the archer, whose brightest stars form a teapot. The center itself is hidden behind thick clouds of dust in the galaxy's disk, which form a dark lane to the right of the glowing band of the Milky Way in this image. During September, Sagittarius is in the south as night falls, and sets in late evening.

Yet the Milky Way's black hole is an *in*-active galactic nucleus. It does have a small accretion disk, which produces a faint glow in radio, infrared, and visible wavelengths. But the total amount of material in the disk probably equals the mass of a pulverized asteroid or two, not a star.

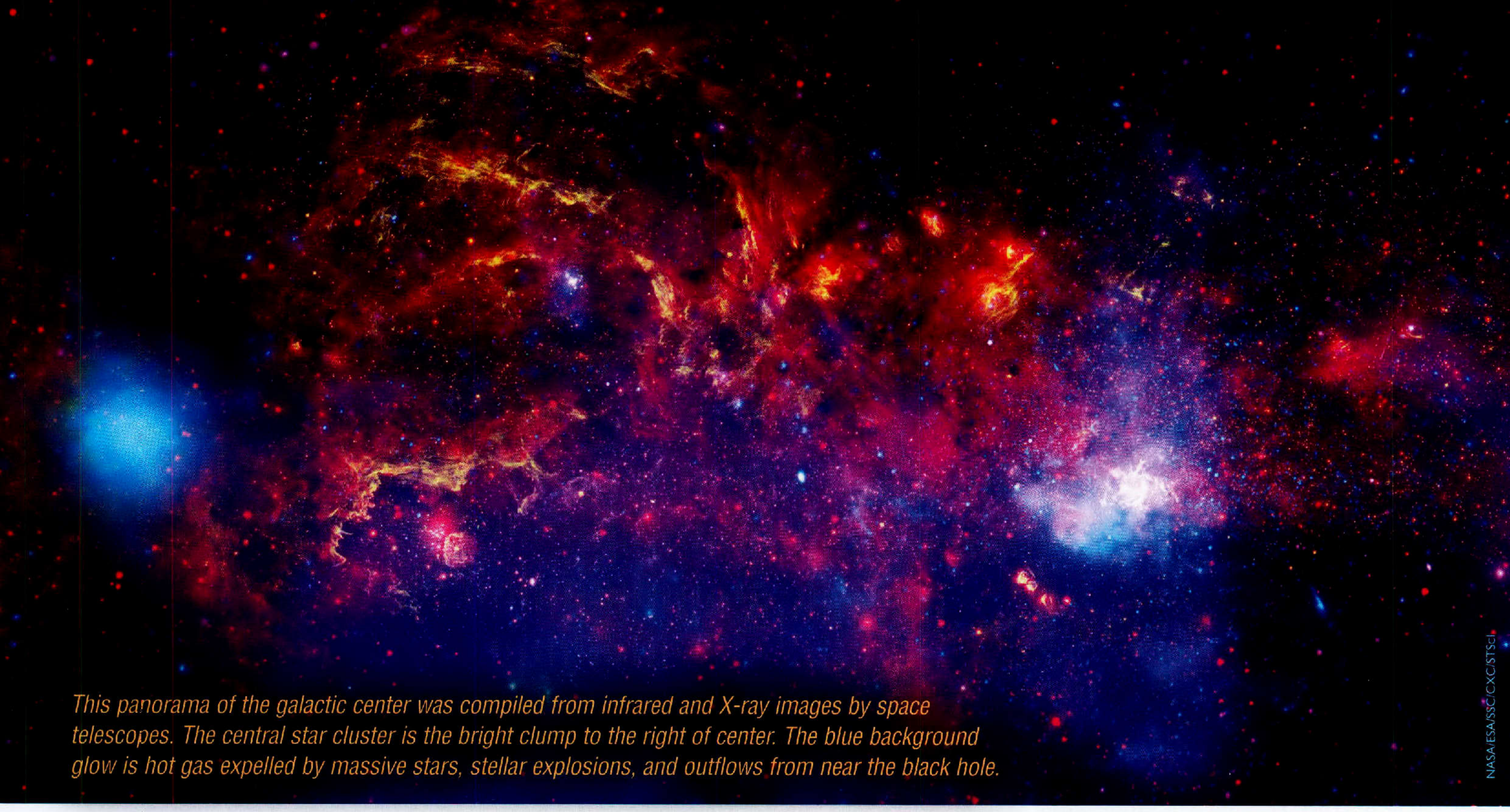
"We have these young stars in this region losing mass" through strong stellar winds, says Ghez. "The mass should fall into the black hole, and this is one of the reasons why it's odd that the black hole today is so quiet."

One reason for the puny showing is that the gas around the black hole is hot, so it moves quickly and is difficult to squeeze into a small space, says Milosavljevic. "It's tough squeezing the gas into that relatively small black hole. The event horizon is something like a tenth of the distance between the Sun and Earth. You have to compress that gas by a large factor to help it get close to the black hole. You can only do that to a small fraction of the gas."

The black hole probably hasn't always been so quiet, though. A century ago or longer, it seems to have gorged itself on something, such as a large amount of gas. Space-based X-ray telescopes have seen evidence of the feast as "light echoes" — the sudden brightening of large gas clouds near the galactic center as they are illuminated by an older source of energy.

"We're seeing evidence that there was a tremendous flash of X-rays, one or a few hundred years ago, at or near the center of the galaxy," Morris says. "We can't really pinpoint exactly where, but it could easily have been the central supermassive black hole eating a star."

Other flashes also light up the galactic center: The explosions of the heaviest stars as supernovae. These blasts stir up the gas clouds and magnetic fields that permeate the galactic center. They also leave behind small, dense remnants — either neutron stars or black holes a few times the mass of the Sun.



This panorama of the galactic center was compiled from infrared and X-ray images by space telescopes. The central star cluster is the bright clump to the right of center. The blue background glow is hot gas expelled by massive stars, stellar explosions, and outflows from near the black hole.

NASA/ESA/SSC/CXC/STScI

"We think that the net result of this process happening throughout the lifetime of the galaxy is that the one big supermassive black hole is surrounded by an entourage of tens of thousands of small black holes," says Morris. "They are there to stay. The only place they can go is to merge with the central supermassive black hole, which is probably the ultimate fate of most of them. But for the most part, they're doomed to quietly and darkly stay in the immediate vicinity of the one big black hole.

"We'd really like to know whether they're there, because those 10- or 20,000 black holes would wreak havoc with the orbits of stars that we can see. We won't understand the dynamics of the galactic center unless we know whether this elephant in the room is really sitting there or not."

Nor, despite their conclusion that the central object really is a black hole, will they be able to stamp the subject "case closed" until they actually see the black hole itself — something that could happen within the next few years, Milosavljevic says.

"The good thing about the gas that's flowing into the black hole is that it's transparent, so that you can see it approaching the event horizon," he says. "The bigger the radio telescope that's being used to observe this gas, the closer we get to the actual event horizon. We are on the verge of observing the gas as it plunges across the event horizon. Once that's been done, we will know for sure" that a supermassive black hole inhabits the Milky Way's busy heart.

The process will take years or decades of additional work, which will be enhanced by new telescopes, new observational techniques, and new ideas.

"One of the fascinating things about this study, that's unlike any other that I've done in my lifetime, is that it's a study that *lasts* a lifetime," says Morris. "Most of the things I do, I work on them for one or two years, get a result, publish it, and then move on. We started this in 1995 and I don't see any end, and I don't see any end of the richness of results that we're getting, either. Each time we get a new capability or a longer time base for studying some of these things, we learn a lot more than we knew before."

Damond Benningfield is executive editor of StarDate *and writer/producer of the StarDate radio program and the* StarDate Black Holes Encyclopedia *web site.*

RESOURCES

VIDEO

An introductory video about black holes will be posted on the Texas Cosmology Center website by September 1.
www.tcc.utexas.edu

RADIO

StarDate will air a series of programs on the center of the Milky Way September 26-30
stardate.org/radio

INTERNET

StarDate Black Holes Encyclopedia
Details on individual black holes, research profiles, black holes in popular culture, and much more
blackholes.stardate.org

UCLA Galactic Center Group
astro.ucla.edu/~ghezgroup/gc

Black Holes: Gravity's Relentless Pull
hubblesite.org/explore_astronomy/black_holes

ARTICLES

"The Galactic Center Massive Black Hole and Nuclear Star Cluster," by Reinhard Genzel, et. al.
arxiv.org/ftp/arxiv/papers/1006/1006.0064.pdf

BOOKS

The black hole at the center of our galaxy, by Fulvio Melia, 2003

by Alan MacRobert

This fall, be on the lookout for the bright planets Saturn, Jupiter, and Mars. Fomalhaut, the lonely "Autumn Star," shines in the south. In late October, Venus returns to view from behind the Sun.

SEPTEMBER 1 - 15

Saturn and Jupiter, the two largest planets, display themselves on opposite sides of the sky as the school year begins.

Saturn is the trickier one. Look for it low in the west as twilight fades, the earlier in the month the better. It's far below brighter Arcturus, the brightest star in the western sky at dusk. Binoculars can help you locate Saturn. To its left, by roughly a fist-width at arm's length, try to pick up twinkling Spica, too.

Jupiter is something else. It doesn't rise until well after dark. Once it does, it's a bright, steady light shining low in the sky, just to the left of due east. As the night proceeds, Jupiter rises above whatever horizon obstructions you may have and dominates first the eastern sky, then the higher southeast after midnight. Jupiter shines at its highest in the south before dawn, when it is likely to appear sharpest in a telescope.

Mars also is well up by dawn, shining in the east near Pollux and Castor in Gemini. As dawn brightens, look for little Mercury low in the east-northeast where the Sun will rise. Binoculars will help show Mercury passing just 0.8 degree from fainter, twinkly Regulus on the morning of September 9.

Venus, the last of the bright planets, remains out of sight near the Sun.

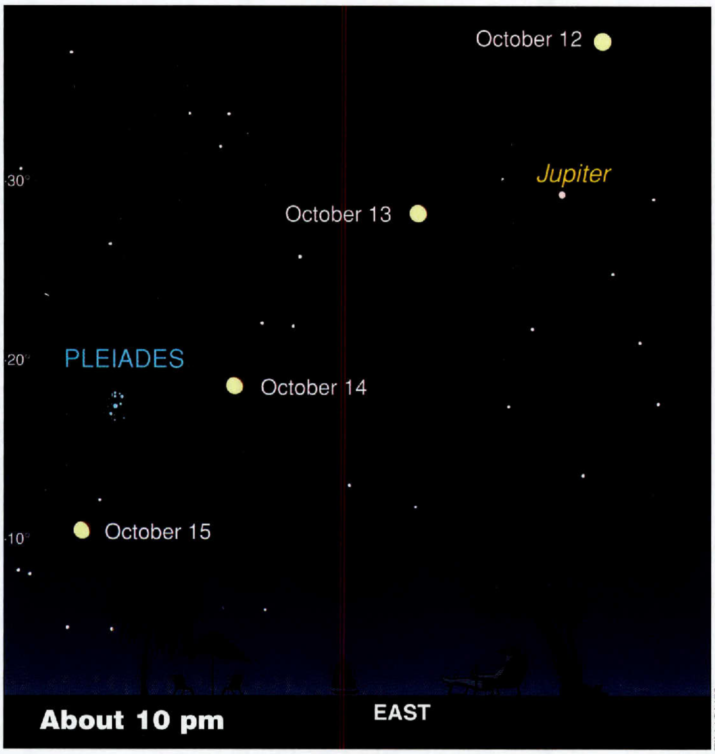
Let's turn back to the evening sky. Look high in the west after nightfall to pick up bright, landmark Arcturus again. This is an aging, yellow-orange giant of a star, 113 times brighter than the Sun. Its pale ginger-ale color is quite evident if you look carefully, especially when contrasted against a deep-blue twilight background.

Look way off to its right for the Big Dipper in the northwest. The Dipper's bowl lies to the right and its handle curves to the left, pointing back in the general direction of Arcturus.

Keep turning around to the right; the next important sky landmark is Polaris, the North Star, due north and rather dim. Use the Big Dipper to find it: The two stars forming the front of the Dipper's bowl point upper right almost to Polaris, about three fist-widths at arm's length away.

Brilliant Vega, the "Summer Star," is almost straight overhead. Vega matches Arcturus in brightness but is tinted very pale blue-white. It's 36 times as bright as the Sun.

Look south-southwest as soon as darkness falls to catch another summertime landmark, orange-red Antares. This is a true red supergiant, glaring at us from a great distance (about 600 light-years), shining about 10,000 times brighter than the Sun.



TIM JONES

SEPTEMBER 16 - 30

Jupiter is now rising in the east almost as soon as twilight ends, but Saturn has sunk away into the sunset.

This year Jupiter inhabits the constellation Aries. Look above the bright planet, by almost a fist and a half at arm's length, for the two or three brightest stars of Aries' little pattern. They're roughly horizontal.

Once Jupiter climbs higher, look a similar distance below it for modestly bright (3rd-magnitude) Menkar, or Alpha Ceti. Menkar is the brightest star in the head of Cetus, the whale. The rest of Cetus' head is a lopsided pentagon of dimmer stars between Menkar and Jupiter.

The bright Moon shines above Jupiter on the evening of September 15 and to its left on the 16th.

Turn northeast and look high for the fall landmark constellation Cassiopeia. Its five brightest stars form a flattened W that's currently tilted up toward the left.

Meanwhile, Arcturus continues to decline in the west as the season turns. You can't miss it — nothing else in that area is so bright. But look early in the evening before it gets too low.

Arcturus is the brightest star of Boötes, the herdsman. The other leading stars of Boötes look more like a narrow kite than a person. Arcturus forms the kite's bottom point, and the kite's upper part is tilted to the right. It appears about as tall as the width of your fully outstretched hand at arm's length, from thumbtip to little fingertip.

OCTOBER 1 - 15

Jupiter season really is coming on now! The bright planet is already rising above the east-northeast horizon in late twilight, and rises higher and shines brighter after dark. It far outclasses even bright Capella, which is now shining fairly well up in the northeast by 9 p.m.

Meteor Watch

The Shower
Draconids

Named for the constellation Draco, the dragon, a long line of stars that wraps halfway around the Little Dipper and the North Star.

Peak

Night of October 8

Notes

The nearly full Moon will wash out many meteors; lucky viewers may catch some of the 200 per hour expected this year. This shower's output varies wildly, most years producing only a few meteors per hour, with a few spectacular meteor storms per century.

The Shower
Orionids

Named for the constellation Orion, the hunter, which is notable for a short line of three fairly bright stars known as Orion's Belt, and for the Orion Nebula, which is visible below the belt as a hazy smudge of light.

Peak

Night of October 21

Notes

The gibbous Moon rises after midnight. Its bright glare will overpower most of the meteors in the shower, allowing only a few of the brightest to shine through.

Look far to the lower left of Jupiter, and far to the right of Capella, for the little Pleiades star cluster, on its way up carrying its message of cold weather and early darkness to come.

The Moon shines to the upper right of Jupiter on October 12 and left of it on the 13th.

Vega, meanwhile, has moved off the zenith to shine high in the west, starting a long descent down the western evening sky that will continue into the start of winter.

Look to Vega's left or lower left, by about three fist-widths at arm's length, for bright Altair. These two stars once represented two birds of prey staring down from the sky. Altair still marks the bright eye of Aquila, the eagle. Vega was once part of a celestial vulture, but at some point in the ancient world the vulture became its present constellation, Lyra, the harp.

Altair has a little marker star just to its upper right that helps identify it: 3rd-magnitude Tarazed.

Far below Altair, tilting down in the south-southwest right after dark, is the Teapot pattern of the constellation Sagittarius, departing with the cooling season. Look just after nightfall or you'll be too late.

Meanwhile, bright Fomalhaut, the "Autumn Star," is rising in the south-southeast. The only notable star of Piscis Austrinus, the southern fish, Fomalhaut shines alone in its dim section of the heavens, climbing higher and shifting to the south as evening grows late. Physically, Fomalhaut is much like Vega but slightly less hot and luminous. They're even at the same distance from us, 25 light-years — so their difference in brightness shows us the true difference in their intrinsic luminosities.

OCTOBER 16 - 31

Jupiter has been reigning as king of the night, and now it upholds its title more than ever. Jupiter comes to opposition on October 28, when it's opposite the Sun in our sky and (nearly) closest and brightest for the year. Look for it rising higher in the east and southeast as night grows late.

However, a challenger to Jupiter's brilliant rule is now appearing on the horizon. Venus, the brightest planet of all, is rounding toward Earth from behind the Sun.

If you have an open view of the west-southwest horizon, look there for Venus about 20 minutes after sunset if the air is nice and clear. If you see a lone skypoint there (that's not an airplane!), you have picked up Venus earlier in its just-begun apparition than the majority of humanity. Venus is slowly on its way up for a grand, high showing as the brilliant "Evening Star" this winter and spring — where it will attract the eyes of people all over the world if they happen to look westward on clear evenings.

Use binoculars to help pick up Venus in less-than-excellent sky conditions — and also to find little Mercury below or to the lower right of Venus in the last half of October and into November.

Our friend Arcturus is sinking low into the twilight now as autumn deepens. Look for it twinkling far to the right of Venus and, for most of North America, somewhat higher.

With Halloween approaching, Arcturus is taking on its role as "the ghost of summer Suns." Every year for several days around October 29, Arcturus occupies a special place above your local landscape. It closely marks the spot where the Sun stood at the exact same time of day (by the clock) during warm June and July — in broad daylight, of course. So in the last days of October every year, you can think of Arcturus as the chilly Halloween ghost of the departed summer Sun.

Alan MacRobert is a senior editor of Sky & Telescope *magazine (skyandtelescope.com).*

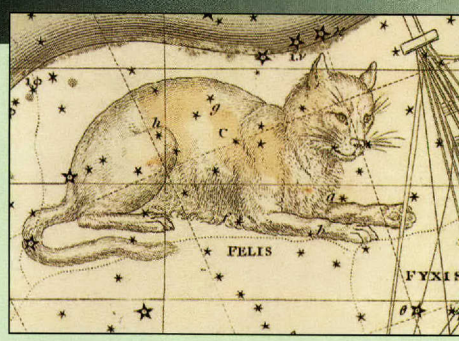
Inconstant Constellations

For millennia, world cultures traced star patterns on the sky that varied from civilization to civilization. A few centuries ago, constellations became important to the science of astronomy as a way for astronomers to communicate to each other the position of stars, galaxies, and other objects on the sky.

By 1930, astronomers decided they need an official system of constellations. The International Astronomical Union divided the celestial sphere into the 88 constellations we know today.

Some previously accepted constellations did not make the list. Ian Ridpath lists two dozen on his "Star Tales" website (www.ianridpath.com/startales). For instance, Antinous was a constellation made up of six stars now part of Aquila, the eagle. A real person, Antinous was a favorite of the Roman emperor Hadrian and died around 1000 AD. Cat lovers will be saddened to know that the constellation Felis, the cat, created by French astronomer Joseph Lalande in 1799, did not make the cut either.

Some defunct constellations have remained with us by lending their names to astronomical phenomena. For in-



stance, the Quadrantid meteor shower which returns each January is named for Quadrans Muralis, an old constellation representing a scientific instrument called a quadrant. RJ

SEPTEMBER

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

August 20	**11 p.m.**
September 5	**10 p.m.**
September 20	**9 p.m.**

NORTH

EAST

WEST

SOUTH

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

- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

Charts produced with Voyager II software.

OCTOBER

How to use these charts:
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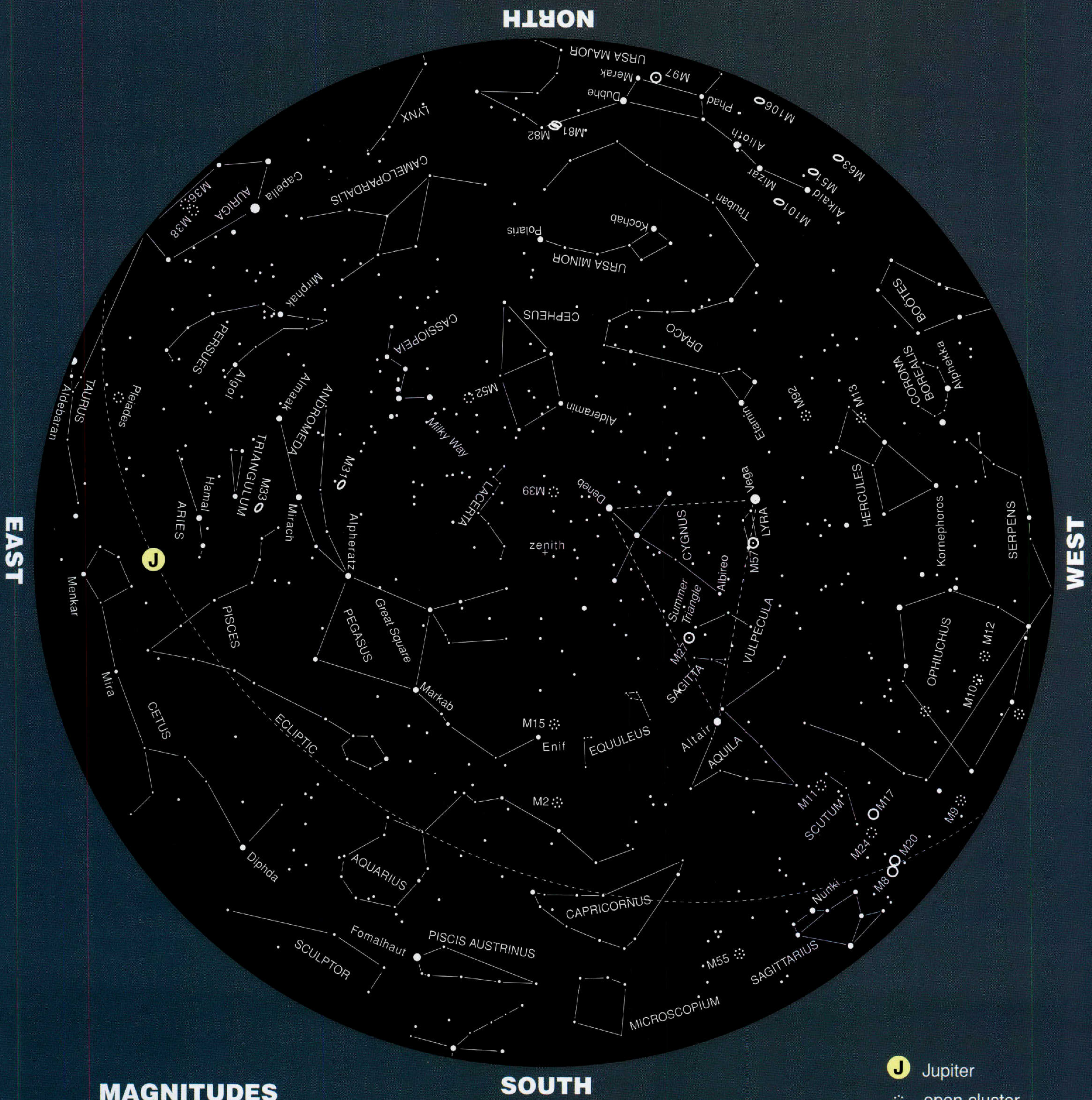
September 20	11 p.m.
October 5	10 p.m.
October 20	9 p.m.



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- 0 and brighter
- 1
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- J Jupiter
- open cluster
- globular cluster
- nebula
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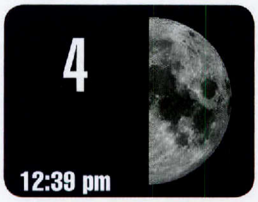
- galaxy

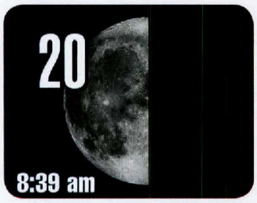
Charts produced with Voyager II software.

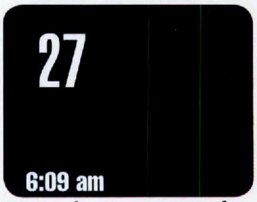
SKY HIGHLIGHTS

by Damond Benningfield

SEPTEMBER







Moon phase times are for the Central Time Zone.

2 Mercury puts in one of its best appearances of the year. It is low in the east about 45 minutes before sunrise and looks like a fairly bright star.

3/4 Antares, the brightest star of Scorpius, is to the left of the Moon on the evening of the 3rd, and to the lower right on the 4th.

9 Mercury and Regulus stand side by side low in the east 30 to 45 minutes before sunrise. Mercury is brighter, with Regulus just to its right.

11 The Moon is full tonight. As the full Moon closest to the autumnal equinox, it is the Harvest Moon.

15/16 The Moon passes Jupiter. The brilliant planet is to the lower left of the Moon as they rise late in the evening of the 15th, and closer to the right of the Moon on the 16th. They are high in the southwest at first light.

19 Orange Aldebaran, the brightest star of Taurus, the bull, keeps company with the Moon this morning.

23 Mars stands close to the upper left of the Moon in the wee hours of the morning. It looks like a moderately bright orange star.

Su	M	T	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

23 The autumnal equinox is at 4:05 a.m. CDT, marking the beginning of autumn in the northern hemisphere.

25 Uranus is at opposition. The seventh planet from the Sun rises at sunset and is above the horizon all night. It is brightest for the year, too, yet even though it is the solar system's third-largest planet, you need binoculars to see it, in the southern part of Pisces.

25 Regulus, the brightest star of Leo, is to the upper left of the Moon at first light.

OCTOBER

1 Antares is the bright orange star just below the Moon at nightfall.

12/13 The brilliant planet Jupiter stands to the lower left of the Moon as they rise on the evening of the 12th, and closer to the right of the Moon on the 13th.

13 Saturn is in conjunction, passing behind the Sun as seen from Earth.

21 Orange Mars lines up to the left of the Moon at first light.

22 Regulus is close to the left of the Moon at first light, with Mars well above them.

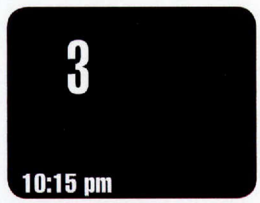
Su	M	T	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

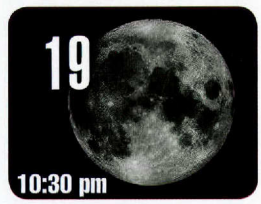
28 The Moon is a thin crescent low in the southwest as darkness begins to fall. The star Antares is close to its left, with the brilliant planet Venus farther to its lower right. Mercury is directly below Venus, although you will need binoculars to pluck it from the twilight.

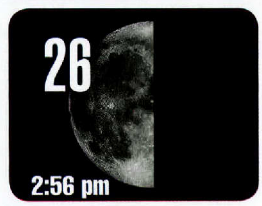
28 Jupiter puts in its best showing of the year. It rises at sunset and remains in the sky all night. It is brightest for the year, blazing brighter than any other object in the night sky except the Moon and Venus.

31 Saturn and Spica team up quite low in the east as dawn twilight brightens. They are about equal brightness, with Spica to the lower right of Saturn.

31 Halloween! It is one of four cross-quarter days, which fall roughly halfway between a solstice and an equinox. In other cultures, these days mark the beginning of a new season, not its midpoint.



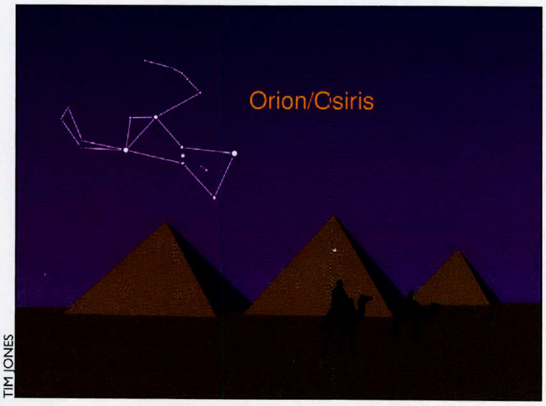




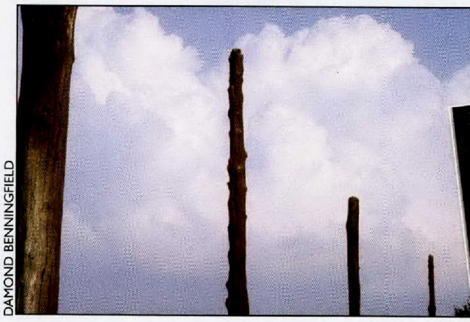
Empowering the Stars

Legend says that in the year 840, a Chinese emperor died of fright during a solar eclipse, perhaps fearful that a dog was devouring the bright orb. True or not, it shows the power of the sky over daily affairs and the human imagination, which is the theme of Thomas Hockey's new book, *How We See The Sky*. In part, it's a guide to what's in the sky (day and night) and how to observe those objects. It describes everything from basic sky terminology to what causes the phases of the Moon, and offers tips on how to view the night sky (avoid artificial lights and give your eyes a half-hour to adapt to the darkness). But the book also shows how cultures have used the sky (night and day) as a guide to daily life. The Great Pyramid of Khufu, for example, was aligned to the Pole Star (at the time a star in Draco, the dragon) and Orion's Belt, while the largest pyramid of Teotihuacan apparently was aligned to the rising of the Pleiades. It's a quick and easy look at the beauty and power of the sky.

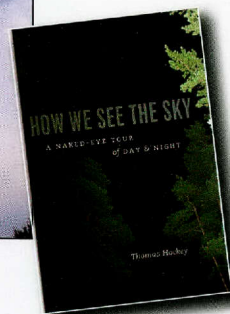
How We See The Sky: A Naked-Eye Tour of Day & Night
By Thomas Hockey; $60 hardback, $20 paperback; to be published in October



TIM JONES


DAMOND BENNINGFIELD

The Great Pyramid of Khufu was aligned with Orion's Belt, which represented the god Osiris. Lower left: A structure known as Woodhenge, near St. Louis, had several astronomical alignments.



Join the Hunt for Icy Dwarfs

The folks at Zooniverse have created another online game in which astronomy enthusiasts can help out the pros. In IceHunters, users try to identify icy worlds in the outer solar system in photos taken by some of the world's largest telescopes. The object is to find Kuiper Belt objects that the New Horizons spacecraft can visit after it completes its mission to Pluto.

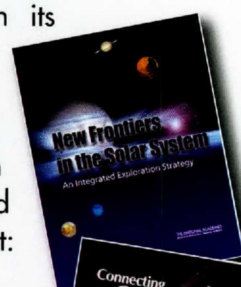
The site includes a running tally of the number of images that have been viewed by users, and how many have been followed up by astronomers. It also provides users with a tutorial, FAQs, and information on the New Horizons mission and its science goals.

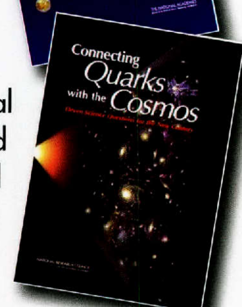
Currently en route to Pluto, New Horizons will fly past the dwarf planet in 2015. It will move on to study other Kuiper Belt objects beginning the following year.

To get started, visit ***www.icehunters.org.***

NASA, National Academies Offer Free Books

NASA has long produced books on its history and made them available to the public. Scores of these volumes can now be downloaded free of charge, and the agency is converting some of them into e-book format for Kindle, Nook, and other e-readers. They are available at: ***history.nasa.gov/series95.html#ebooks***.





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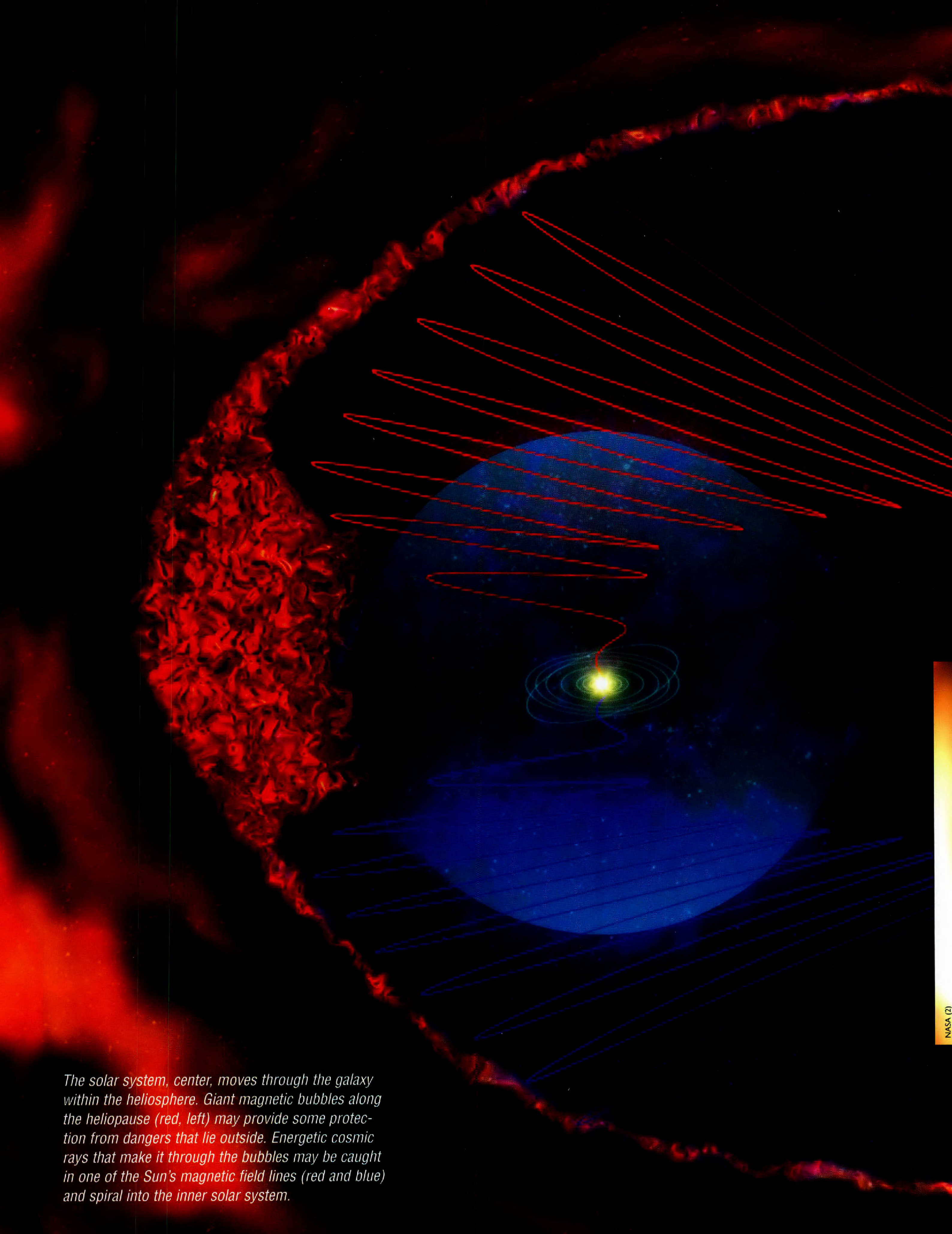


The solar system, center, moves through the galaxy within the heliosphere. Giant magnetic bubbles along the heliopause (red, left) may provide some protection from dangers that lie outside. Energetic cosmic rays that make it through the bubbles may be caught in one of the Sun's magnetic field lines (red and blue) and spiral into the inner solar system.

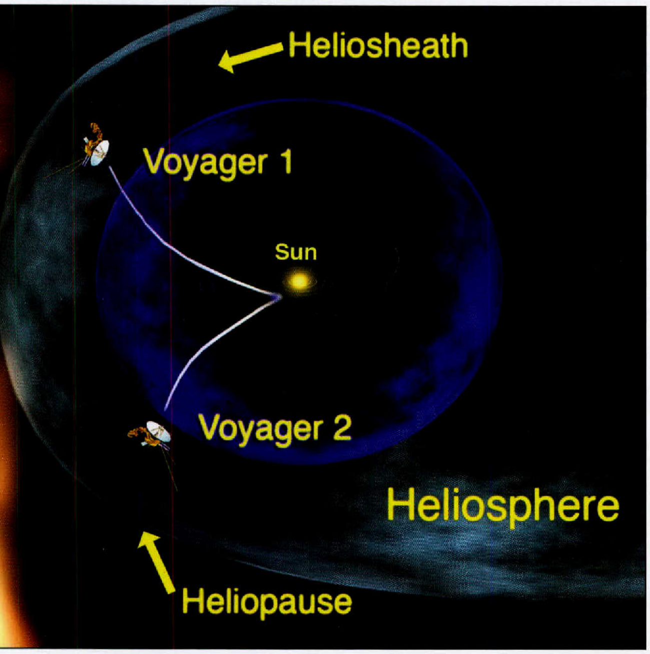
NASA (2)

Sausages in Space

Scientists are making new discoveries about the outer solar system as the Voyager spacecraft launched in the 1970s keep chugging along

By Harvey Leifert

You may have read about the restaurant at the end of the universe in *The Hitchhiker's Guide to the Galaxy*, but do you know about the sausage factory at the end of the solar system? Although author Douglas Adams' cosmic eatery is pure fiction, leading scientists see evidence that the sausages are out there. Their latest discovery, based on computer models using recent observations from the twin Voyager spacecraft, will change how astronomers think about our solar system's interaction with its surroundings, says Arik Posner of NASA's Division of Heliophysics, which runs the Voyager program. The discovery "has consequences that reach down to Earth," he says.



After more than 30 years of travel, the twin Voyager spacecraft are exploring the boundary between the solar system and what lies outside.

Known to the ancient Greeks as *helios*, the Sun blows a steady stream of charged particles into space that envelopes the solar system. Called the heliosphere, it surrounds the planets and extends far beyond their orbits. As the Sun makes its way through the galaxy, the heliosphere plows head-on into gas clouds and winds from other stars.

That motion blows the heliosphere into a comet-like shape, with the leading side rounded like the head of a comet and the trailing side pushed into a long tail. "Think of the heliosphere as the Sun's 'sphere of influence,' not an actual sphere," says Voyager project scientist Edward Stone of the Jet Propulsion Laboratory (JPL) in Pasadena, California.

The boundary between the heliosphere and the rest of the galaxy — where the solar wind meets the interstellar wind — is called the heliopause. About three times as far from the Sun as the orbit of the outermost planet, Voyager 1 and 2 are now approaching this boundary. They are currently in the heliosheath, the region just inside the heliopause.

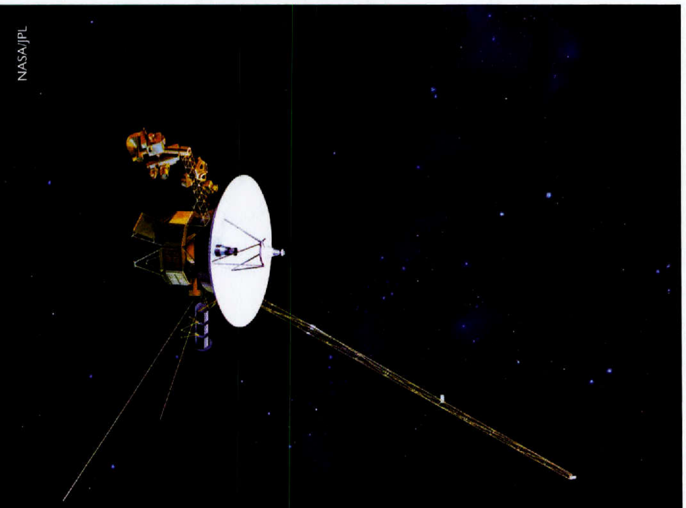
Whereas scientists had expected the transition from the solar system to interstellar space to be smooth, Boston University's Merav Opher says her team's new computer simulations indicate that the transitional space is like a porous membrane, with fingers and indentations poking in and out.

Opher's simulations have led her to conclude that the two spacecraft are plowing through a sea of previously unknown enormous magnetic bubbles in the heliosheath. She and several colleagues made that case in a paper published in *The Astrophysical Journal* in June.

Opher's team has dubbed the bubbles "sausages." Each one is roughly as long as the distance from the Sun to Saturn (one billion miles). They are as wide as the distance from Earth to the Sun (nearly 100 million miles). Thousands and thousands of them lie end to end and side by side.

According to Opher's co-author James Drake of the University of Maryland, the sausages formed from the Sun's twisting magnetic field lines.

The Sun's magnetic field stretches all the way into the outer solar system, past the planets and out to the heliopause. Until now, scientists thought these lines were simple, graceful arcs that began at one of the Sun's poles, extended far into space, and then looped back and reconnected with the Sun at the opposite pole.


NASA/JPL
An artist's concept of a Voyager spacecraft

For much of volume of the solar system, this description holds true. But a major factor complicates this beautiful simplicity: The Sun rotates. As it does, its magnetic fields twist into a spiral and are carried outward by the solar wind, Drake says. Far from the Sun, near the heliopause, the lines twist and break and reorganize in what Drake calls "a remarkable transformation." The result? A sea of magnetic bubbles, or sausages.

It appears that the majority of the magnetic field lines enter the magnetic bubbles and remain in them for some time, not directly connected to the Sun, Opher says.

The size of the bubble-filled region varies with the Sun's 11-year magnetic cycle, Opher says. At solar minimum, when the Sun is least magnetically active and shows few sunspots and flares, the bubble-filled region extends only 10 degrees north and south of its center line, an imaginary line where the plane of the solar system, projected far out into space, bisects the heliosphere. At solar maximum, however, when the Sun is most active and displays multiple groups of sunspots and large solar flares, the bubble-filled region may extend to 30 degrees north and south of the center line. Voyager 2 has apparently flown into and out of the sea of bubbles several times.

The bubble hypothesis is forcing scientists to rethink various phenomena, in particular the effect of galactic cosmic rays that enter the solar system. These charged particles, mainly protons, are created as giant stars explode in supernovae within our Milky Way galaxy. The cosmic rays accelerate almost to the speed of light, and some punch through the heliopause into our solar system.

"In this new scenario, it's more like a membrane — it's permeable to the galactic cosmic rays," Opher says. "We expect the galactic cosmic rays to enter and slowly wander through the sea of magnetic bubbles, almost like a pinball, until they can access field lines that connect back to the Sun and quickly escape."

Drake adds that scientists do not yet have a "quantitative understanding" of that scenario. "Depending on how the particles wander through the bubbles," he says, "that can impact our understanding of how intense the galactic cosmic ray radiation is just outside the heliopause. It's still an open question, and we really need to pin this down."

Opher says that scientists will have to rethink their current ideas about radiation throughout the solar system, but she emphasizes that our planet is protected. "On Earth, we don't have to worry about that. We are shielded by a thick atmosphere that protects us from most of the galactic cosmic-ray radiation. But, if you're an astronaut and you're headed to Mars, you really have to care about the radiation environment in the heliosphere."

Eugene Parker, who posited the existence of the solar wind in 1958 (before its discovery), notes that the new discovery "changes our understanding of how [cosmic rays] get into the heliosphere from outside. It really impacts attempts to estimate the cosmic rays outside the solar system."

Cosmic rays are more intense outside the solar system, says Parker, an emeritus professor at the University of Chicago, because once inside, the solar wind sweeps them back and reduces their intensity. "The information we have about the magnetic bubbles means we have to modify our estimates of how much sweeping back there is taking place." Opher agrees that the number of galactic cosmic rays outside the heliopause is probably higher than previously thought.

The Voyagers launched 16 days apart in 1977. They accomplished their primary mission of exploring Jupiter and Saturn and their moons and rings. Thanks to a fortuitous lineup of the solar system's outer planets at the time, Voyager 2 went on to fly by Uranus and Neptune, the only spacecraft to do so. By 1990, the two craft had completed their Grand Tour of the solar system and continued into their extended "interstellar mission." As of April 2011, Voyager 1 was almost 11 billion miles from Earth, and Voyager 2, traveling at a slower speed, was almost 9 billion miles away.

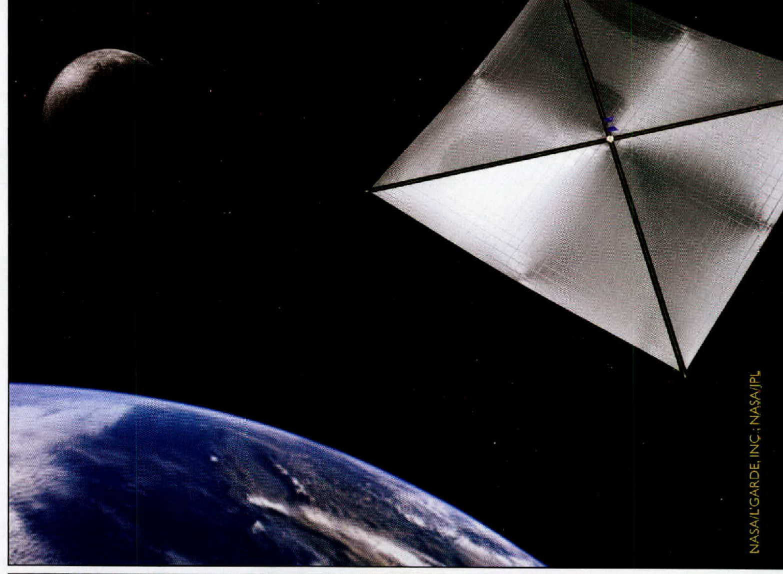
Radio signals sent from the spacecraft at the speed of light require more than 16 and 13 hours, respectively, to reach us. Their signals are extremely weak (about one billionth of a watt) by the time they are picked up by NASA's Deep Space Network (DSN), Opher says. With giant parabolic antennas in California, Spain, and Australia, at least one station remains in contact with the Voyagers at all times as Earth rotates. DSN's receivers amplify and clean up the signals, and transmit the data to JPL.

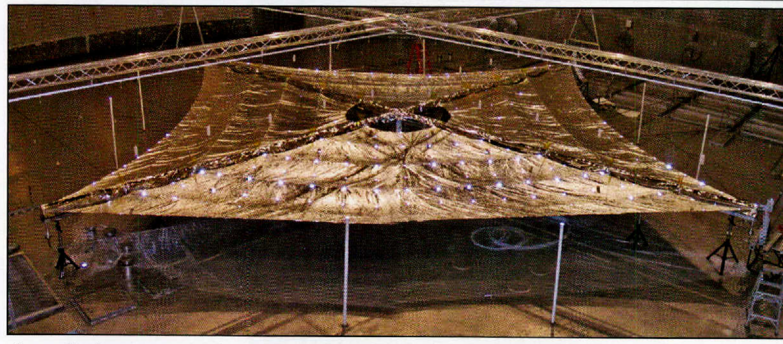
Then, Opher says, the hard part begins: trying to make sense of the huge mass of data. She became interested in the heliosheath's magnetic field in 2005, but had no way to process all of the data the spacecraft were returning to Earth. Starting in 2008, the Voyagers started sending back unusual readings from their on-board particle detectors as they approached the heliopause.

The following year, Opher's work made a huge leap forward when she began using the Pleiades supercomputer at the Ames Research Center in Mountain View, California. She worked with scientists from the University of Michigan who were developing a code to run her simulations. "It was all coming together," she says. "I have the powerful computers, and I have the code."

Opher had been working with Drake, an expert on magnetic reconnection, since 2007, and from early 2010 they concentrated on the simulations that led to their recently published paper.

It was Drake who had first detected the sausage-like bubbles as rapidly alternating positive and negative fields. "This was a very unexpected result," Opher says. She and Drake think the bubbles are relics of twisted, broken, and reconnected magnetic field lines. In her words, they are "isolated structures" — magnetic structures not connected directly to the Sun.





An artist's concept of a solar sail in flight (top); a real solar sail undergoes tests at a NASA facility in Sandusky, Ohio.

Scientists who have studied the sausage bubble hypothesis agree that it is a plausible explanation of the available data, but as Voyager project scientist Edward Stone puts it, "there isn't any direct evidence yet that these bubbles are formed, when I look at the data. Whether they form or not depends on details that we don't know."

Stone has devoted his entire career to the Voyager mission. When asked if she might also find herself in that position, Opher said she has been "completely hooked" by space physics since 2001, when she was introduced to it as a postdoctoral researcher. She will stick with analyzing Voyager data from the heliosheath for a long time, she says. "This is an incredible dataset; you can smell, you can touch the data. You can really take a sample of the heliosheath."

Stone thinks the Voyagers are close to the heliopause. One or the other spacecraft could leave the solar system in as soon as a few days or as long as a few years, he says; we won't know where the heliopause is until a Voyager crosses it. Opher says she is pushing as hard as she can for a fast mission to follow the Voyagers, noting that the available technology now is way beyond that of the 1960s, when the Voyagers were conceived. Several suggestions are on the table, she says. She says she hopes for a new interstellar mission using solar sails (that use the solar wind to propel spacecraft) or another technology to get a spacecraft to the heliosheath and send data back.

It may take another decade, Opher concedes, but she says NASA is well aware that some of the most "revolutionary" new science recently has come from the outer heliosphere — not just from the Voyagers, but also the Interstellar Boundary Explorer and other spacecraft. She thinks this means the agency will assign it a high priority. In the meantime, she has years' worth of existing data to study and analyze, a prospect that clearly delights her.

Harvey Leifert is a freelance writer in Bethesda, Maryland.

Resources

Internet

A Big Surprise from the Edge of the Solar System
www.nasa.gov/mission_pages/voyager/heliosphere-surprise.html

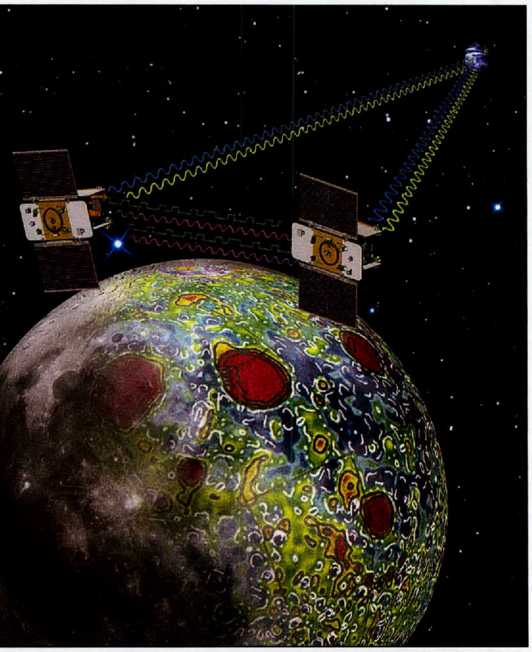
Voyager
voyager.jpl.nasa.gov/mission/

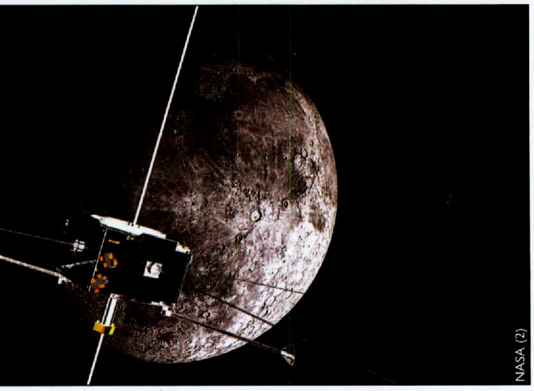
Deep Space Network
deepspace.jpl.nasa.gov/dsn/

IBEX
www.nasa.gov/mission_pages/ibex/

Solar Sails
www.nasa.gov/vision/universe/roboticexplorers/solar_sails.html

by Rebecca Johnson and Damond Benningfield





NASA (2)

Artists' concepts depict GRAIL (top) mapping the Moon's variable gravitational field, and ARTEMIS.

Dynamic Duos

Twin spacecraft link up for lunar adventures

Like chopsticks, Pop Tarts, or animals lining up for a trip on Noah's Ark, new spacecraft are arriving at the Moon two by two. One pair arrived this summer, while another is scheduled to head toward the Moon in September.

September's duo is GRAIL, which will map the Moon's gravitational field in unprecedented detail.

Earlier missions revealed areas known as mascons (mass concentrations), where the rock beneath the surface is much denser than average. The denser rock exerts a stronger gravitational pull than the surrounding rock, causing orbiting spacecraft to wander off course. Despite decades of study, though, many details about the mascons remain unknown.

GRAIL should fill in some of the gaps. Its two spacecraft, which are scheduled for launch September 8 and arrival at the Moon on December 31 and January 1, will follow an identical orbital path. Their instruments will track the relative positions of the two craft to within a few millionths of an inch. As they pass over the mascons, their position will shift by a tiny amount. From that, scientists can reconstruct the Moon's gravity field in minute detail, providing a better understanding of mascons as well as the size and shape of the Moon's core and the giant basins that were gouged by ancient impacts.

The GRAIL spacecraft won't head directly for the Moon, though. Instead, they first will head toward a point in space where the gravity of Earth, Sun, and Moon are in balance. That path requires less fuel than a more direct approach to the Moon and gives flight controllers extra time to precisely align the approach to lunar orbit.

The other lunar pair, ARTEMIS, followed a similar path to the Moon.

The two craft began life as part of THEMIS, a five-spacecraft Earth-orbiting mission that studied the solar wind and its interaction with Earth's teardrop-shaped magnetic field. Flight controllers nudged two of the spacecraft out of Earth orbit and toward another gravitational balance point in 2010, then on to the Moon this year. One entered lunar orbit on June 27, with the other following July 17.

Mission scientists say the ARTEMIS craft could operate for another decade, studying the solar wind and its interaction with the lunar surface, measuring the Moon's magnetic wake, and probing the lunar interior. **DB**

Break Out the Swim Trunks?

Apollo 17 astronauts Jack Schmitt and Gene Cernan got a little excited when they stumbled on a patch of orange soil while hopping across the lunar surface in December of 1972. It was the only splotch of color in the otherwise gray landscape.

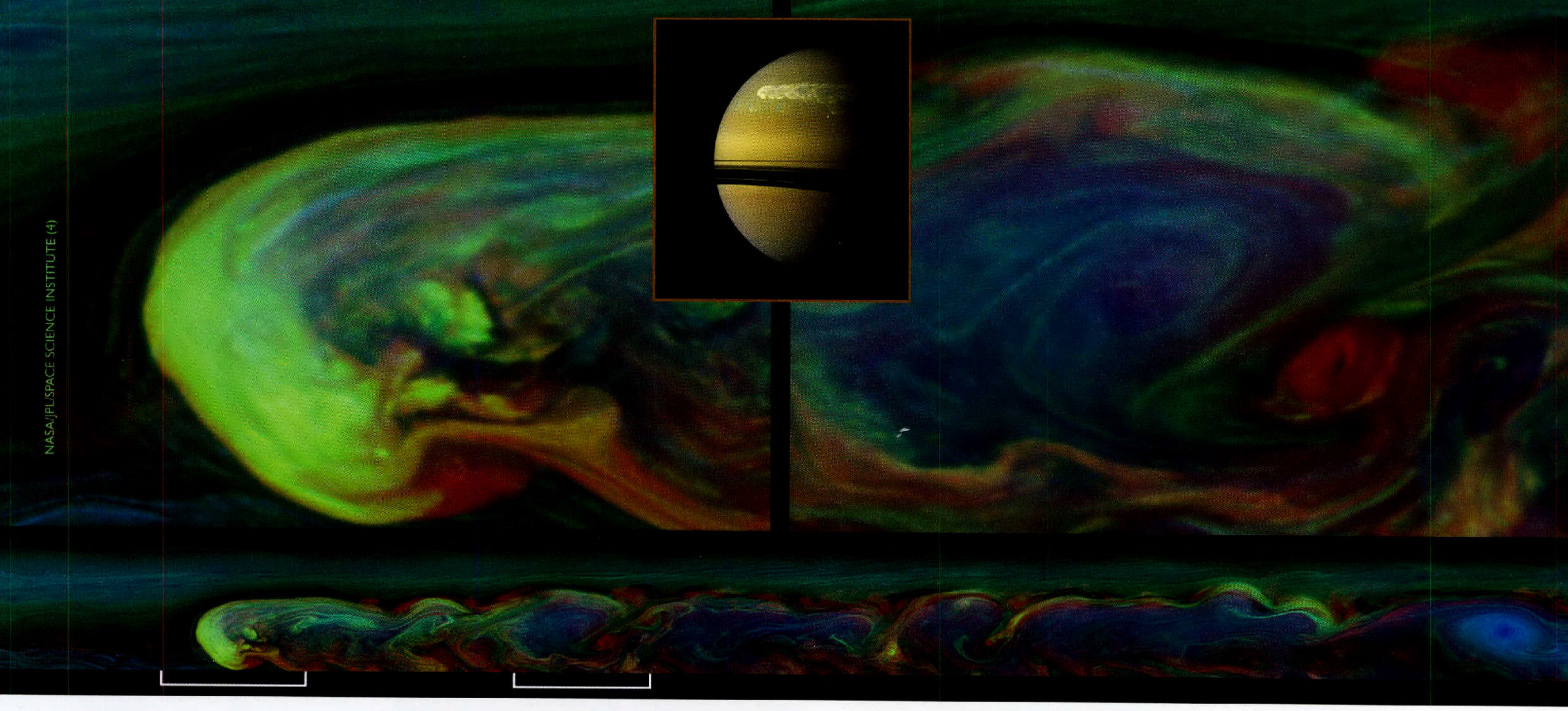
And now, that same soil has planetary scientists a little excited, too. A recent microscopic analysis of volcanic beads in the sample found that the soil contains a lot of water. The study was conducted by scientists from the Carnegie Institution and Brown and Case Western Reserve universities. Combined with observations by robotic spacecraft, the finding shows that the Moon is much wetter than anyone had expected even a few years ago.

That's an exciting prospect for future lunar explorers because water is a precious resource, but a scary prospect for lunar scientists because it makes it tougher to explain how the Moon was born.

The leading theory says the Moon coalesced from the debris from a powerful collision between Earth and another planet. That scenario should have left the Moon dry. The Moon could have picked up some water from impacts by comets and asteroids, but not as much as the soil study suggests. The theory of the giant impact isn't dead, but it will need some tweaking.

The orange soil with a few astronaut footprints around it.

NASA



NASA/JPL/SPACE SCIENCE INSTITUTE (4)

Stormy Skies Streak Across Saturn

One of the largest storms ever observed on the planet Saturn is calming down a bit. It began last December and has been raging ever since.

The storm began as a violent thunderstorm that pushed water and ammonia from hundreds of miles below the planet's visible cloudtops. As the plume hit the upper atmosphere, powerful winds sheared off the top, pushing the clouds all the way around the giant planet's northern hemisphere (inset photo). At its peak, the storm was almost 200,000 miles long and covered an area equal to eight times the total surface area of Earth.

Big storms aren't unusual on Saturn. Beginning in 1876, a new one has been seen about every 30 years, which is the length of the planet's orbit around the Sun. Until now, all of the storms started during early summer in the northern hemisphere. But this storm came well ahead of schedule, developing in early northern spring. It would be as if a Category 5 hurricane hit the American coastline in April instead of during the warmer months of summer or early fall.

These images of the storm, snapped by the Cassini spacecraft, are coded to show the heights of the clouds. Yellow and white clouds are high and thick, green are in the middle layers of the atmosphere, and red and brown are many miles below. The top two images show close-ups of small areas of the storm, while the strip at bottom shows the entire storm; the bars show the locations of the close-ups. **DB**

The Seven Percent Solution

Spin direction of spiral galaxies offers clues about the Big Bang

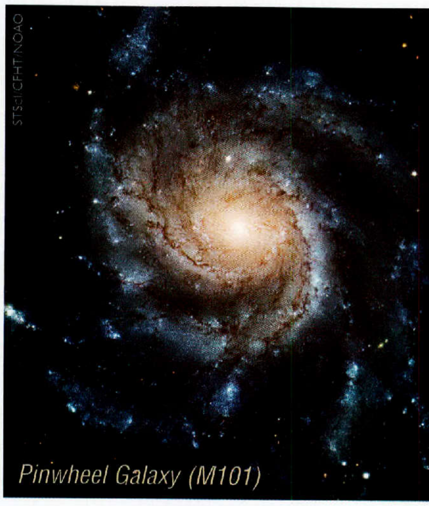
A basic tenet of cosmology is that, on the largest scales, the universe looks the same in all directions. But new research from University of Michigan astronomers is calling that belief into question.

Michael Longo and students studied thousands of images of spiral galaxies made by the Sloan Digital Sky Survey. They found that more spirals rotate counterclockwise than clockwise. Seven percent more, to be exact.

"The chance that it could be a cosmic accident is something like one in a million," Longo said.

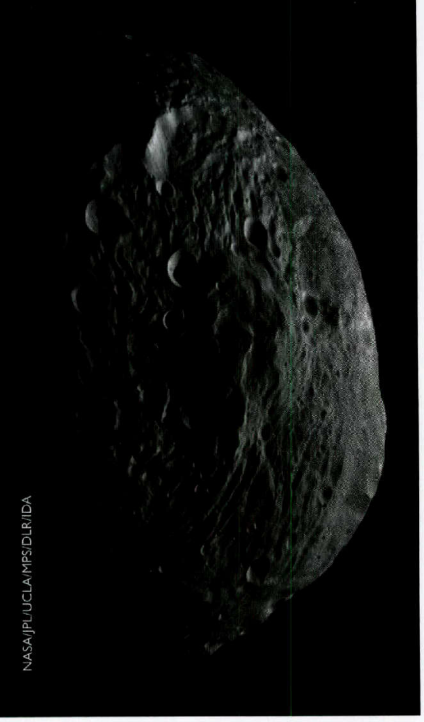
The excess could mean that the Big Bang was not a symmetrical expansion but a rotating one. If the universe was born rotating, like a spinning basketball, it would have a preferred axis and galaxies would have retained that initial motion, Longo said.

There is one critical test astronomers can do to check the result. The Sloan Survey galaxies were all viewed from the northern hemisphere. If Longo's result is right, his experiment would be repeatable by checking thousands of galaxies seen in southern skies. There should be a 7 percent difference in these, too — with the greater number rotating clockwise. **RJ**



STSCI/CFHT/NOAO

Pinwheel Galaxy (M101)



NASA/JPL/UCLA/MPS/DLR/IDA

New Exploration Era Dawns

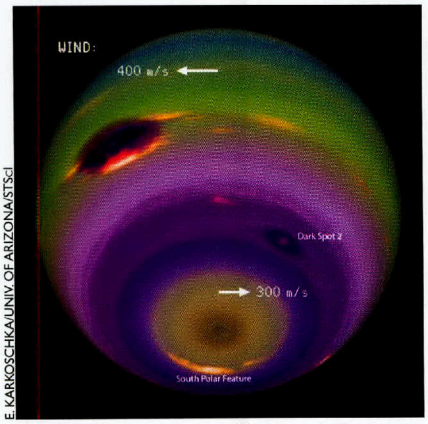
A spacecraft that will explore the dawn of the solar system slipped quietly into orbit around Vesta (above, from a range of about 9,500 miles/15,000 km) on the night of July 15, beginning a year-long reconnaissance of the giant asteroid. The Dawn probe will map Vesta's surface features and composition. Since Vesta probably is a leftover from the birth of the planets, Dawn's measurements will tell scientists more about conditions at the time when Earth and the other planets were taking shape. Dawn eased into orbit using the gentle thrust of its electrically powered ion engines instead of a large chemical rocket. It will use those same thrusters to leave Vesta next July and head toward the largest asteroid, Ceres, which Dawn will orbit beginning in 2015, making it the first craft ever to orbit two bodies other than Earth.

Neptune Finishes First Orbit as Astronomer Measures its Day

A University of Arizona astronomer says he nailed down the length of Neptune's day just as the giant planet completed its first trip around the Sun since its discovery.

The rotations of the giant planets Jupiter, Saturn, Uranus, and Neptune are difficult to study because they present only their thick atmospheres to the world. Cloud layers that rotate at different speeds hide the rotation of their comparatively small rocky cores.

One way to try to get a handle on such a planet's rotation is to identify stable features in its atmosphere, just as Giovanni Cassini did 350 years ago when he became the first to study Jupiter's Great Red Spot.



E. KARKOSCHKA/UNIV OF ARIZONA/STScI

False color enhances Neptune's features.

Following Cassini's lead, Arizona's Erich Karkoschka slogged through 500 archival Hubble Space Telescope images of Neptune. He tracked the movements of features on the planet as they appeared and disappeared over time, finally identifying two stable features called the South Polar Feature and the South Polar Wave. They are probably vortices swirling in the planet's atmosphere — just like Jupiter's Great Red Spot.

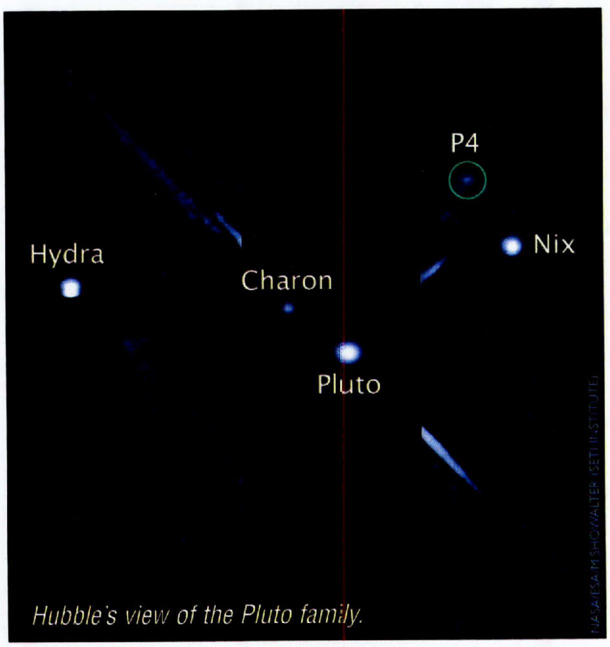
Karkoschka followed the motions of these features through 20 years of Hubble observations of the planet, and determined that a day on Neptune lasts 15 hours, 57 minutes, and 59 seconds.

A Neptunian year, on the other hand, lasts about 165 Earth years. And that's just how long ago the planet was identified. Based on a prediction by French astronomer Urbain Le Verrier, Berlin Observatory's Johann Galle discovered Neptune on September 23, 1846.

Hubble Space Telescope took new images of Neptune in late June to commemorate the anniversary of its discovery. These images show that the numbers of Neptune's high-altitude clouds of methane crystals have increased over the past several years. The clouds also seem to be moving from the southern hemisphere, now experiencing early summer, to the wintry north.

The planet's 29-degree tilt on its axis causes it to experience seasons like Earth, whose axis is tilted a similar 23 degrees. But instead of three months, each season on Neptune lasts about 40 Earth years. **RJ**

Yet Another (Tiny) Moon for Pluto



NASA/ESA/M. SHOWALTER (SETI INSTITUTE)

Hubble's view of the Pluto family.

Pluto has suffered humiliation in recent years as it's been downgraded to dwarf-planet status, but its entourage continues to grow. Astronomers using Hubble Space Telescope recently found a fourth moon orbiting the diminutive iceball. The newly discovered moon is just eight to 21 miles (13 to 34 km) wide. Pluto's other known moons include comparatively large Charon. Discovered in 1978, this moon is so large (650 miles or 1,000 km wide) that many considered Pluto and Charon a double-planet system. In 2005, Hubble astronomers discovered the moons Nix and Hydra. They are each 20 to 70 miles (30 to 110 km) wide. The newest moon, called P4 until it gets an official name, orbits Pluto between Nix and Hydra.

In the heart of the Milky Way, gas and dust swirl through the Omega Nebula (Messier 17) as it forms hot young stars. The nebula lies 5,500 light-years away in Sagittarius. This view is from the new VLT Survey Telescope at Chile's Paranal Observatory.

ESO/INAF-VST/OMEGACAM