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Page 16

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SHIFTING SANDS

Dunes reveal secrets of diverse worlds

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

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NASA/JPL/UNIVERSITY OF ARIZONA

On The Cover

Sand dunes and ripples on the Red Planet, seen by Mars Reconnaissance Orbiter. For more on what dunes can tell us about the history of Mars and other worlds, see page 4.

This Page

This Chandra view is the deepest X-ray image ever. It shows the highest concentration of black holes yet seen: about 5,000 over an area the size of the full Moon. Astronomers will use it to study the growth of black holes over billions of years.

Coming Up

Our Summer Reading Issue is up next. We'll bring you excerpts from new books in astronomy and space science. Additionally, we'll have summer skywatching tips and charts, plus the latest astronomy news.

MERLIN

Dear Merlin,

We see the Milky Way and we see stars in the same area. Are these stars all part of our galaxy but closer to us than the background?

Ed Dennis
Laurel, Maryland

Indeed.

Every individual star that's visible to the unaided eye is a member of the Milky Way galaxy. Some of those stars line up in the direction of the faintly glowing band known as the Milky Way, which outlines the galaxy's disk, but most are scattered around the rest of the sky.

That's because Earth and the Sun also belong to the Milky Way, so they are surrounded by other galactic residents. Looking out into a starry night sky, then, is like standing just inside a forest. You see a lot of big trees scattered all around you (the individual stars), but as you look toward the bulk of the forest, all you see is a sea of green (the starry canopy of the Milky Way).

Dear Merlin,

What keeps a globular star cluster from collapsing from the mutual gravitational attraction of its components? To look at that many discrete bodies of mass that close together, it appears to the layman (me) that they would have to collapse from the gravity of all of the component stars.

Philip A. Anderson
Pocatello, Idaho

Think "kitchen blender."

For readers who are unfamiliar with globular clusters, a little background. A globular is a collection of hundreds of thousands or even millions of stars packed into a dense ball that's usually no more than a few dozen light-years across. Globulars were born when the universe was quite young, so they contain the oldest stars in the entire Milky Way galaxy. That's provided a lot of time for gravitational interactions to pull the stars together.

Gravitational interactions among the stars don't just pull inward, however: they can also sling outward. So as stars approach each other, their mutual gravity gives each star a big kick, which stirs things up. Some stars are pushed deeper into the core, but others are pushed away from the core (and, in some instances, completely out of the cluster). This blender effect helps keep the stars from smashing together.

Even so, some stars in globular clusters do settle in the core, where they move closer and closer to each other. Some of the stars may merge to form black holes. In fact, some globular clusters may contain rare intermediate-mass black holes, which are hundreds or thousands of times the mass of the Sun.

So a globular can wind up with a lot of dense, heavy stars in the core, less-massive stars beyond that, and the lightest stars at the edge.

Dear Merlin,

Which concerns you most, the Sun expanding to become a red giant and engulfing Earth, or a merger of the Milky Way and Andromeda galaxies?

Wayne C. Parker
Henrico, Virginia

As an all-powerful wizard, Merlin isn't especially worried about either event. For the mortals of planet Earth, however, the expanding Sun probably is a bigger concern.

The Sun will consume the hydrogen fuel in its core in about five billion years. That will cause the Sun to get much bigger and brighter, which will fry what's left of planet Earth.

Notice Merlin's phrasing: "what's left" of Earth. By the time the Sun enters its red-giant phase of life, Earth will long since have become uninhabitable. That's because as the Sun ages, it has less hydrogen in its core to power its nuclear reactions. As a result, it has to work harder to fuse the remaining hydrogen, which makes the Sun brighter. So within the next billion years or so, that extra energy will boil away Earth's atmosphere and oceans, leaving only a burned-out hulk.

Andromeda and the Milky Way most likely will merge in a few billion years — perhaps before the Sun becomes a red giant. There's almost no chance of a collision with another star, but it's possible that the solar system could be hurled out into interstellar space. On the other hand, it's also possible that the solar system could be incorporated into the body of the merged galaxy, settling in beside its new neighbors. (Merlin, of course, knows the answer, but isn't allowed to tell.)

Merlin is unable to send personal replies. Answers to many astronomy questions are available through our web site:

stardate.org/astro-guide

SEND QUESTIONS TO
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BLOWIN' IN THE WIND

NASA/JPL/UNIVERSITY OF ARIZONA

Sand dunes dominate this view of Noctis Layrinthus, located in the Valles Marineris canyon system, from Mars Reconnaissance Orbiter. Bedrock is visible through the sand.

Scientists investigate sand dunes on Earth, Mars, and Titan

In the early nineteenth century, poet William Blake speculated that one can "see a World in a Grain of Sand." Today, science tells us that piles of grains can reveal a lot about a world — both ours and others. Planetary scientists are finding familiar-looking sand dunes across the solar system, sometimes in unexpected places. The dunes are revealing secrets about the past and present environments of their home worlds and about an ephemeral yet world-shaping agent: the wind.

These discoveries have spurred scientists to create computer models, conduct wind-tunnel experiments, and employ other techniques to investigate how the dunes are created. Scientists want to know, for example, why sand accumulates in characteristic wave-like shapes instead of blanketing an area evenly, and they are striving to understand what individual dunes can reveal about local conditions.

"Dunes record the direction, and, to some extent, the wind strength, at the time of their formation," says Lori Fenton, a senior research scientist at the SETI Institute in Mountain View, California. Conditions must be just right for dunes to form. "When you see wind-blown dunes on a planetary surface, there must have been, first, enough sand-size particles lying around, perhaps recently exposed by erosion, erupted by a volcano, or broken down from rocks by a river or glacier," Fenton says. In addition, the wind must have been strong enough to send the grains scooting along the surface, and there should be nothing to stop their trek, such as vegetation, ice, or damp soil.

BY LEILA BELKORA

Geologists investigate dunes through field studies on Earth, remotely controlled samplings and observations on Mars, and remote observations of other worlds. They look into all the factors that go into dune formation, such as what minerals formed the sand grains and what weathering processes might have produced the grains. On Earth, investigators usually have ample information about the climate and weather conditions. On other worlds, though, such knowledge may be sparse. However, simply discovering dunes and studying their orientation can tell scientist some things about winds on that world.

"Dunes are important on planetary surfaces, where there are no instruments to make any wind measurements," Fenton says. "They serve as geologic wind vanes. Sometimes they're seen in the rock record, and then you can reconstruct wind patterns that existed in ages past, which may be very different from those that occur today."

Scientists have known about dunes on some planets for decades. In 1972, Mariner 9 revealed dunes inside a large crater on Mars. Magellan detected dune-like features in its radar observations of Venus in the early 1990s.

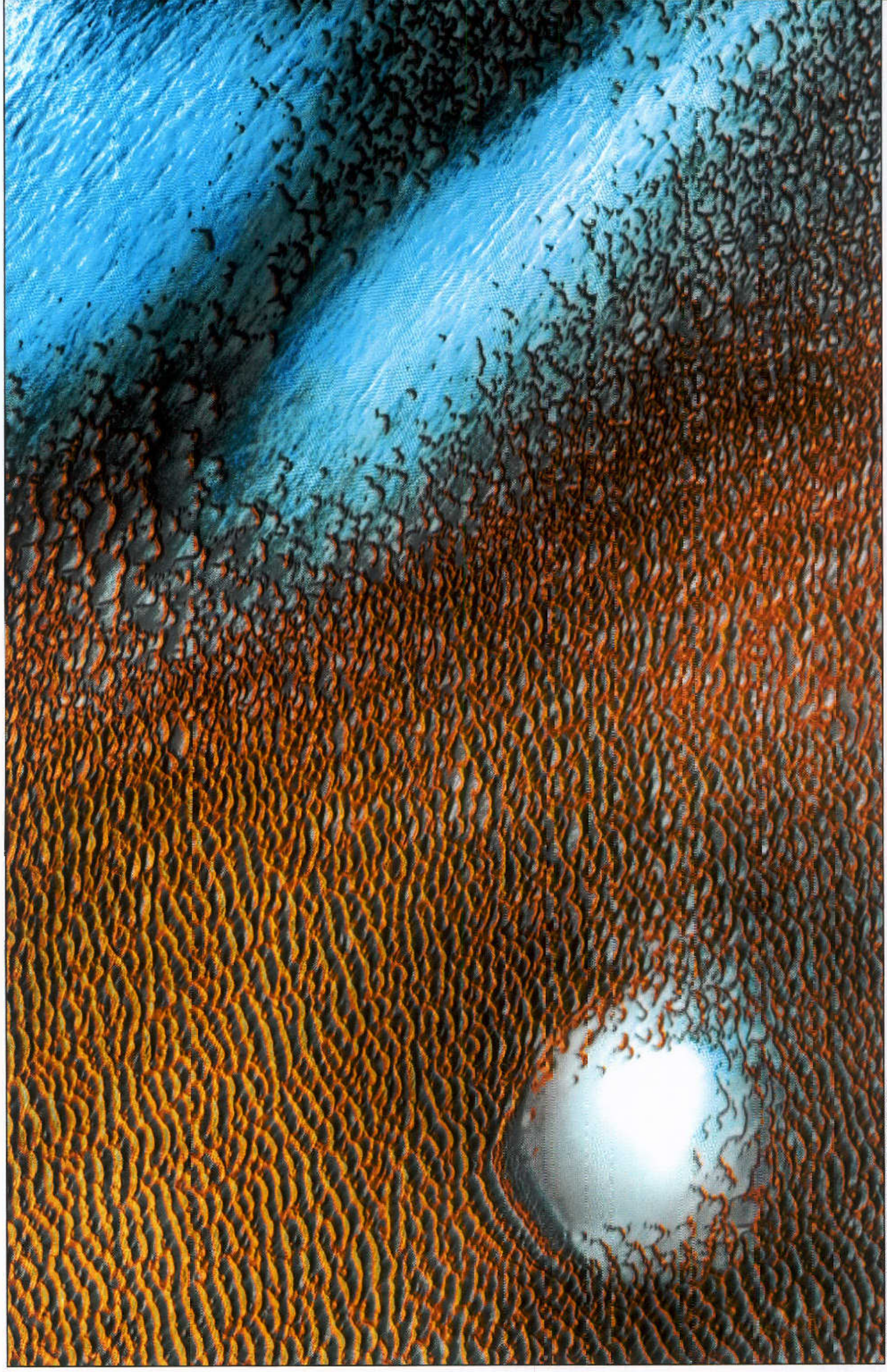
More recently, scientists have found dunes made of a dark substance on Saturn's giant moon Titan. Long ridges of regularly spaced dunes arc across large swaths of Titan's equatorial regions, and other parts of the moon have smaller areas of thinner ridges.

Dune-like ripples even appear in the loose grains on Comet 67P/Churyumov-Gerasimenko, presumably formed not by wind, but by jets of gas that propel dust grains onto the comet's surface.

It's possible that dunes may await discovery on Jupiter's moon Europa and Saturn's moon Enceladus, where ancient dunes may be locked under ice or hidden at the bottom of global oceans.

Finding dunes in so many different places means the processes that create them are widespread and fundamental, as planetary scientists Ralph Lorenz and James Zimbelman note in the introduction to their book *Dune Worlds: How Wind-Blown Sand Shapes Planetary Landscapes*. "This universality is perhaps nowhere better highlighted than by the vast sand seas of Titan," they write, "where, despite sands made of organic muck, in frigid air four times denser than ours, on a world with gravity only one-seventh our own, the landscape is covered in dunes of exactly the same shape, height and width of the Earth's largest sand seas. Thus Titan is almost as exotic a world as one can imagine, and yet standing on its surface are landforms almost indistinguishable from those on Earth."

There are several basic types of dunes, including long and narrow ridges (often regularly spaced across a sand sea), and crescent-shaped dunes called barchans (pronounced "bar-cans").



NASA/JPL-CALTECH/ARIZONA STATE UNIVERSITY

Dunes surround an ice- or frost-covered hill (bottom right) in Mars' north polar sand sea. The hill is about 300 feet (100 meters) tall. Wind has blown from the upper right of the image, diverting around the hill and breaking up the line of dunes into barchans.

The formation of a barchan illustrates the basic principles for all dunes. The wind, blowing consistently from one direction, briefly lifts particles of sand a few inches above the ground. This action is called saltation, a word derived from the Latin *salire*, to leap forward. Saltating grains move a short distance in the direction the wind blows them and then hit other grains on the ground, causing them to move, too, in a chain reaction.

This movement can lead to the growth of dunes. "Dunes grow because of an instability — that is, one part of the dune loses sand while another part of the dune gains sand," Fenton explains.

A pile of sand or other small obstacle to the wind can get the process started. When the wind moves up the windward side of a pile of sand it speeds up, peaking in strength shortly before it reaches the crest. But the place where the sand is most moved and eroded is not where the wind is strongest; the sand takes a little time to respond to the wind.

If the pile of sand is wide enough — about 65 feet (20 meters), Fenton says — then the point of peak erosion comes before the crest. "This means there's more sand being removed from the windward side, and it is being piled up at the crest," Fenton says. "This is what makes dunes grow upwards into distinct, large landforms."

The leeward face of the dune gets steeper as sand accumulates at the crest. When the slope of the leeward (downwind) side reaches a certain angle — 32 to 34 degrees for dry sand — gravity causes an isolated "avalanche" or even large-scale slumping of material.

Active dunes gradually move forward (in the direction the wind is pushing them) as material piles up on the crest and then slips or slumps down the leeward side. The barchan dunes form their characteristic "horns" or arms in the downwind direction because of the way the streams of wind flow sideways around the dune, as well as over the top. Typically, a barchan dune 10 feet high on Earth travels quite fast, up to about 200 feet per year, while one that is 50 feet high travels about 33 feet per year.

Mars dunes can be as tall or perhaps taller than big dunes on Earth, some of which loom as high as an urban skyscraper, about 1,000 feet (300 meters) from the base of the leeward side to the crest. The tallest Mars dune measured so far, in Russell Crater, is up to twice that tall, depending on assumptions made about the base level.

Mariner 9 first revealed many of Mars' geological features. It found transverse dunes — that is, dunes that lie at right angles to the wind — in Proctor Crater, in the planet's southern highlands near the giant Hellas impact basin. Successive missions have allowed planetary geologists to monitor these dunes for more than four decades. These longer-term and increasingly detailed studies have revealed some surprises.

"In the 1990s, when Mars Global Surveyor arrived at Mars and took images

What are dunes made of?

The simple answer might seem to be, simply, sand. But technically, "sand" refers not to the composition, but to the size of a grain. Sand is larger than a particle of silt or dust, and smaller than a piece of gravel.

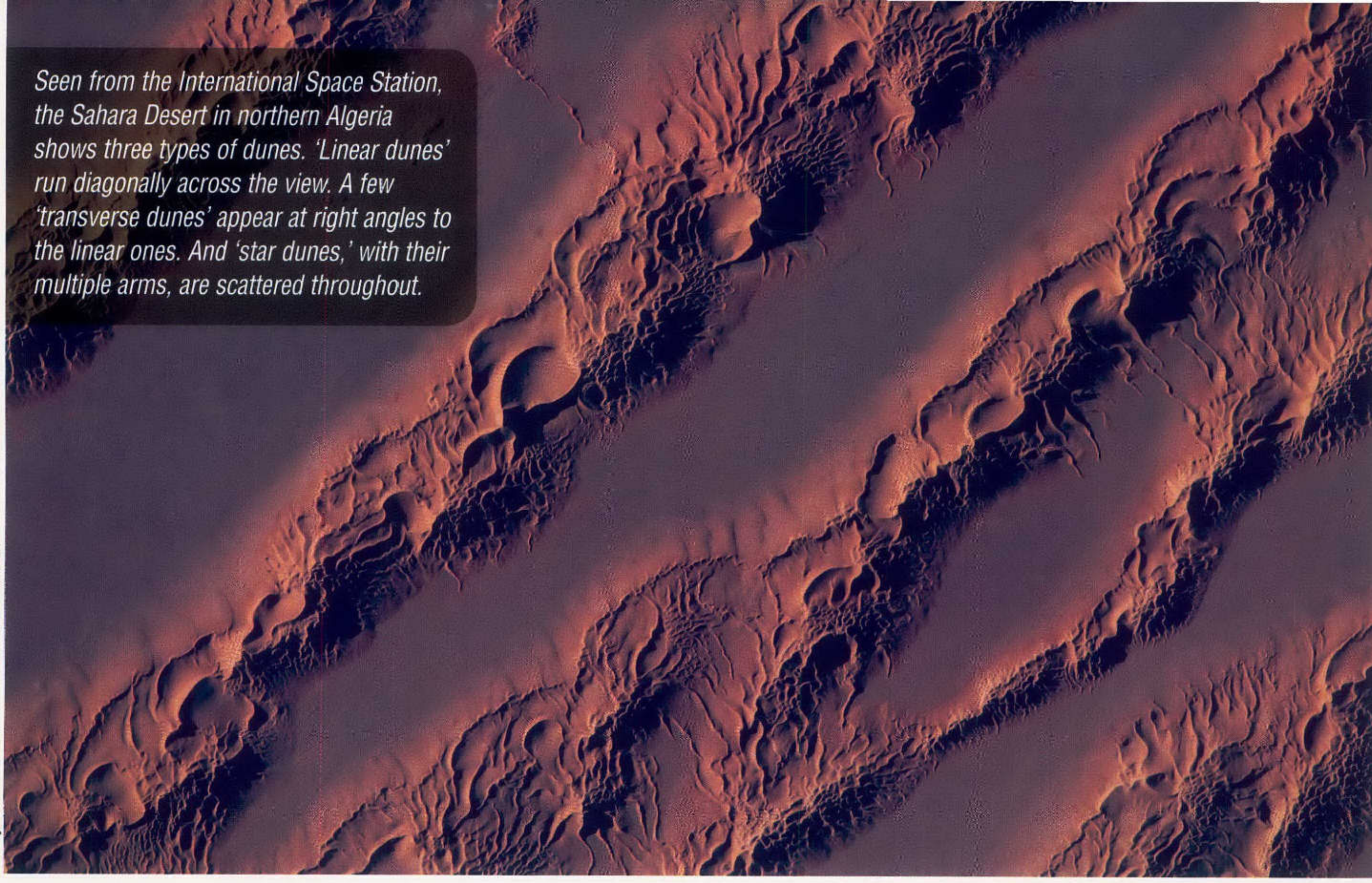
On Earth, wind-blown sand grains commonly consist of quartz (a crystalline form of silica or silicon dioxide) or feldspars (a group of minerals consisting of various elements abundant in Earth's crust, such as aluminum silicates). On Venus and Mars, most sand grains consist of iron-rich basalt, which is a volcanic material.

White Sands National Monument in New Mexico showcases unusual dunes made of crystals of gypsum (a calcium salt), which were left behind by the evaporation of an ice-age lake. Oregon's Christmas Valley dunes are composed mostly of volcanic ash and pumice. Pacific island beach dunes, such as those in Hawaii, contain bits of shells from sea creatures. In the Bodélé Depression in Chad, winds blowing over an ancient lakebed sweep fragments of diatomite, the fossilized remains of algae, into dunes, along with Sahara quartz sand. In Antarctica, dunes form from dry snow.

Perhaps the most unusual dune-forming material in the solar system, at least discovered so far, is on Titan. The dark grains are thought to consist of large carbon-containing molecules created from methane in Titan's hazy atmosphere. **LB**

SIM SEPP

Sand from various Earth environments, including glass, quartz, volcanic basalt, coral, and others.



Seen from the International Space Station, the Sahara Desert in northern Algeria shows three types of dunes. 'Linear dunes' run diagonally across the view. A few 'transverse dunes' appear at right angles to the linear ones. And 'star dunes,' with their multiple arms, are scattered throughout.

Dune Shapes

Geologists recognize several forms of sand dune. Among the more common, found on both Earth and Mars, are barchans (crescent-shaped dunes), as well as transverse, longitudinal, and star-shaped dunes.

Transverse dunes lie at right angles to the wind. They form in areas with an abundant supply of sand, and where the sand-moving winds almost always blow from roughly the same direction. The windward side of the transverse dune has a gentler slope than the leeward side.

Barchan dunes are transverse dunes that form where sand is too sparse to cover the ground.

Linear dunes can be curvy or straight, and often have a symmetrical cross-section. They form where strong winds alternate from directions more than 90 degrees apart, or where a surface-stabilizing agent (like a salt crust) or a limited sand supply act to keep the dunes aligned roughly parallel to the wind. They can be hundreds of miles long.

Star dunes form where the wind blows from at least three different directions because of topography, seasonal changes, or both. They have three or more arms. LB

in the same areas where Mariner 9 and the Viking orbiters did, people looked at overlapping images of dunes and found little change," Fenton says. "They assumed from this that the dunes weren't active in the present climate state. It turns out that the dunes are indeed active" — currently evolving in response to wind — "but we needed to look more closely, with better resolution. Careful looking in the mid-2000s showed that some of the dunes were changing, and [Mars Reconnaissance Orbiter] has really helped us begin to map out where dunes are active and where they're not."

Sand tends to get trapped inside impact craters on Mars, and dunes populate many craters besides Proctor. Observers have catalogued more than 900 dune fields that cover more than a square kilometer (one-third square mile). These fields exhibit a variety of dune forms. The largest extent of dunes is in a "sand sea" in a ring around the Red Planet's north polar ice cap. This region is about the same size as the Rub al Khali desert in the Arabian Peninsula, the largest sand desert on Earth.

All of these dunes are potential sources of information about local winds. Scientists use computer models that take into account much of what is known about the atmosphere on Mars, including seasonal winds, the planet's location within its orbit, and modifications to normal weather patterns caused by global dust storms, ice clouds, seasonal polar caps, and many others.

Over the past decade, planetary scientists, including Fenton, have used these models to understand the weather patterns that form the dunes. They have also looked at how the dunes might validate the model. "The shapes and organization of the dunes can be used to understand prevailing weather patterns," Fenton says, "checking to see how accurate the atmospheric models are."

Saturn's largest moon, Titan, is shrouded in a thick atmosphere that's topped by an orange organic haze, so, until recently, astronomers could only guess about the nature of Titan's surface. The moon's density is too low for it to be made of a lot of silicates like the abundant quartz and feldspar on Earth. Instead, the "bedrock" on Titan may be water ice, so cold and hard that it behaves like rock.

Most of what we know about Titan's surface comes from the long-duration Cassini mission to study the Saturn system (which will end later this year) and its short-lived but productive companion, the Huygens probe, which Cassini dropped into Titan's atmosphere in January 2005.

Prior to the Cassini mission, Lorenz and other planetary scientists were skeptical about finding dunes on Titan. "The post-Voyager view of Titan, with its thick, superficially bland appearance, assumed conditions were rather uniform, failing to imagine the wide variation of surface conditions with latitude," Lorenz says. "This view also considered Titan to be rather wet — with methane. Indeed, one idea was that the entire surface was covered with liquid. On a damp world, sand would not be mobile, and overall winds were expected to be weak. So dunes seemed unlikely."

All of that changed when Cassini transmitted the first images of Titan made with its radar, which peers through the obscuring haze. "There were many dramatic features we called 'cat scratches,' not being quite sure what they were," Lorenz says. "Although dunes were recognized as a possibility, we couldn't be sure they weren't some sort of 'seep' related to liquid, or just streaks of material." A radar pass in October 2005 resolved the ambiguity. "We saw much more extensive features, and we saw them broadside-on, where the textural shading in the radar image revealed them to be ridges 100 meters [330 feet] or more high. That made it clear they were dunes, and we matched them up against the largest terrestrial dunes with similar shape, in the Namib and Arabian deserts."

One aspect of the dunes initially didn't make sense. "A big puzzle was that the dune arrangement with respect to mountain obstacles suggested predominant sand transport to the east, but models of atmospheric circulation predict equatorial surface flow to the west," he says. To understand what was happening, scientists began creating atmospheric models. They proposed that the dunes reflect infrequent but strong springtime storms, rather than average conditions in which the winds are not strong enough to change dune patterns.

Questions about dunes on Earth and other worlds continue to engage planetary scientists, including geologists, chemists, atmospheric scientists, and computer modelers.

The mystery of the composition of Titan's dunes remains. The dunes are dark as seen in optical light, and also appear dark on radar scans. These facts are consistent with their sand grains coming from carbon-bearing particles in Titan's atmosphere, but details are still lacking. It may take a future mission to analyze the composition of the sand to unravel the story.

Fenton notes that there are many features of Mars' surface yet to be fully understood. One example is the ripples of 6.5 to 13 feet (2-4 meters) in length that are "superposed on nearly every sandy surface on Mars." Much smaller ripples, 2 to 4 inches (5-10 centimeters) in length, are seen on dunes on both Mars and Earth. The larger ripples, however, have no counterpart on Earth, except on dunes that form underwater.

"Why conditions may be right to form them in Martian air is still not known," Fenton says. If enough such ripples could be found preserved in Martian sandstones created in different epochs, scientists hope, they could be used to reconstruct how the density of the planet's atmosphere has evolved over millions or billions of years.

Resources

Book

Dune Worlds: How Windblown Sand Shapes Planetary Landscapes, by Ralph D. Lorentz and James R. Zimbelman, 2014

Internet

Mars Geology
mars.nasa.gov/programmissions/science/goal3

Titan
nasa.gov/subject/3163/titan

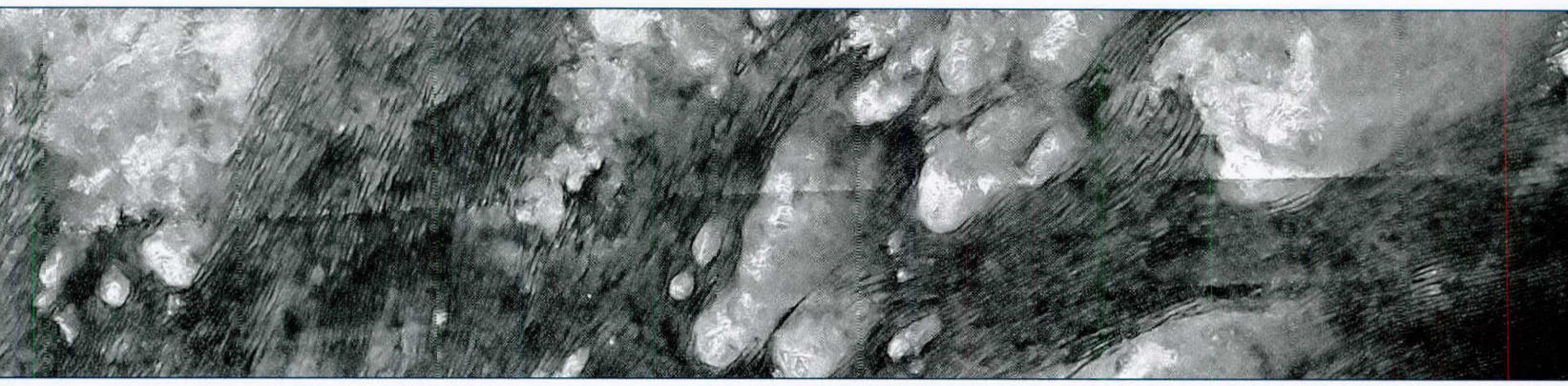
Sand Dunes
nationalgeographic.org/encyclopedia/dune

Dune Types
nps.gov/grsa/learn/nature/dune-types.htm

Planetary Science
usgs.gov/science/science-explorer/Planetary+Science

Throughout the solar system, it seems, there is plenty more work for planetary geologists. In the coming years, they will continue to delve into these mysteries, learning more from each new mission. And perhaps, someday, probes to planets around other stars will help us understand if their geology is like that of our nearby worlds', too.

Science writer and solar physicist Leila Belkora is a frequent contributor to StarDate.



Hundreds of sand dunes snake across the surface of Saturn's moon Titan in this July 25 Cassini radar image of its Shangri-La Sand Sea. The dunes swirl around mountains, which show up here as bright areas.

by Alan MacRobert

Spring has sprung, and the evening twilights of March bring views of Venus, Mercury, and Mars. In April evenings, Venus is lost but Jupiter appears. The spring constellations Virgo, Boötes, and Leo also light up the night.

MARCH 1 - 15

Even after all these many months, bright Venus and little Mars both remain poised in the evening twilight. But not for long.

Venus has dominated the western dusk since last November. Distant Mars has been floating around to Venus' upper left all the while, moving nearer and farther from it as the months passed. But now Venus drops lower quickly. It begins March high in the west in mid-twilight, sinks to half that height or less by mid-month, and a week later it's at the horizon.

What's happening? Venus is catching up to Earth in its faster orbit around the Sun. It's racing toward *inferior conjunction* with the Sun on March 25. That's when Venus passes closest to our line of sight from Earth to Sun, which means from our viewpoint, it will be practically out of sight in the Sun's glare.

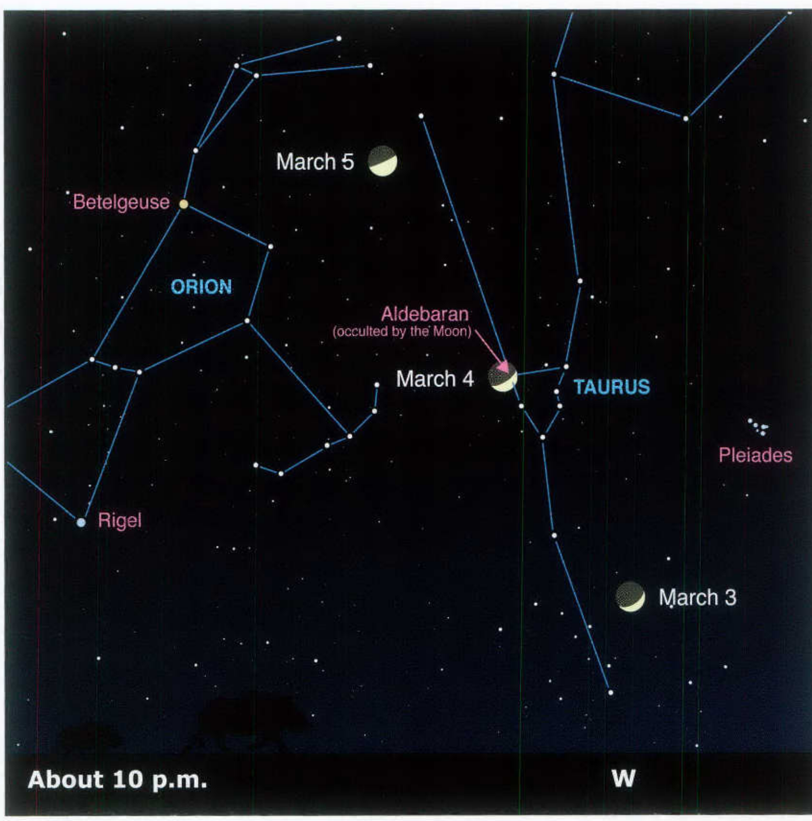
Rare is the inferior conjunction when Venus actually crosses the Sun's face; the next transit of Venus doesn't happen until 2117. Venus almost always passes somewhat north or south of the Sun as seen in our sky. But this year is special. Venus misses the Sun by a whopping 8 degrees, just about the maximum possible. And luckily for us northern hemisphere dwellers, Venus' wide miss happens this time on the Sun's north side.

That means two special things for Venus-watchers.

The first is that, with a telescope, you'll have an especially good view of Venus thinning to a fine crescent this month. The smallest telescope, or even high-quality binoculars firmly braced, will show Venus as a tiny, dazzlingly white crescent-moon shape as it descends the western sky from one evening to the next. You'll be able to watch the crescent grow thinner, while the planet's apparent size gets bigger, as Venus swings closer to the Sun.

The second special effect happens in March's second half. See below.

By the way, if this conjunction is so cool, why is it called an *inferior* conjunction? The term dates back to Earth-centered astronomy. If you thought Earth was the center of the universe and the celestial bodies moved high above it, then when Venus passed between Earth and Sun, Venus was *lower* than the Sun. That is, inferior to it.



MARCH 16 - 31

The Venus excitement builds. For just a few days around March 22, you have a chance to see Venus in both the evening *and* morning sky on the same day, or at the beginning and end of the same night.

It won't be easy. You'll want binoculars. Scan carefully just above the western horizon 5 or 10 minutes or so after sunset (don't confuse Venus with Mercury, to its left or upper left), and just above the eastern horizon 5 or 10 minutes before sunrise.

Few people in the world have ever managed such a double Venus sighting, because the right circumstances are rare and planning is required, with good views of the western and eastern horizons. But now you know when and how to look.

As Venus sinks lower day by day, Mercury climbs rapidly out of the sunset glow. They appear equally high around March 19, depending on your latitude, with fainter Mercury 9 degrees to Venus' left (nearly a fist-width at arm's length.)

Thereafter, Mercury keeps rising, becoming easier to see, through the end of March.

Don't forget orange Mars to their upper left, becoming obvious in late twilight.

Scan from Mars upward and perhaps a touch to the left, and you'll land on the lovely Pleiades. Look to the upper left of the Pleiades for Aldebaran, Mars-like in color and just a little brighter.

Continue the line from the Pleiades through Aldebaran and you pass through upper Orion. The topmost bright star of Orion now is Mars-colored Betelgeuse, brighter still.

APRIL 1 - 15

Venus is gone; Mars and Mercury remain in the west at dusk. In the first week of April, look for fast-fading Mercury 15 or 20 degrees to the lower left of Mars. Meanwhile, Aldebaran and the Pleiades are closing in toward Mars from the upper left.

And let's not forget Jupiter on the opposite side of the sky! It glares low in the east in late twilight and rises higher all evening. It's the brightest point in the sky now that Venus is out of sight.

Jupiter comes to opposition on April 7, opposite the Sun as seen from Earth. So from mid-March through April, Jupiter is at its closest, biggest, and brightest for the year. Telescopes will show its cloud features most sharply when it's highest, shining in the south in the middle of the night.

Jupiter resides in Virgo this year. Look below it during evening (by about 7 degrees) for Spica, Virgo's brightest star, tinted a pale blue-white. The full Moon joins Jupiter and Spica on the night of April 10.

Arcturus is the second-brightest point of light on the eastern side of the sky. It's the yellowish star about three fists at arm's length to Jupiter's left or upper left. Arcturus is the lead star of the constellation Boötes, the herdsman. Its other main stars lie to the left of Arcturus in a shape like a long, bent kite lying on its side, about two fists from end to end. Arcturus is the point where the tail would be tied on.

Look very high to the upper left of Arcturus for the Big Dipper. It's tipped to dump spring showers now, with its handle to the lower right and its upside-down bowl to the upper left. The Big Dipper isn't truly a springtime pattern; it can be seen all night throughout the year, at least from the latitudes of the northern U.S. But the warm-weather months are when it's highest and most obvious.

APRIL 16 - 30

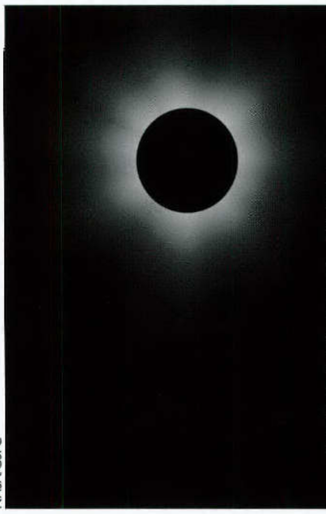
Now Mercury, too, is gone from the western twilight pageant. Of the planets, only Mars remains. Aldebaran and the Pleiades, in the background, move down toward it and past it. On April 26, Mars crosses the line from the Pleiades to Aldebaran. The scene is best viewed in late twilight, an hour or more after sundown.

Meteor Watch

The Shower
Lyrids

Peak
Night of April 21

Notes
The Lyrids are modest, with around one or two dozen meteors per hour at best. The Moon is a waning crescent at the shower's peak, so it won't rise until the wee hours of the morning and should not present a big problem for meteor watchers.



NASA/GSFC

Time's Almost Up!

If you haven't made your plans to watch the August 21 solar eclipse in person, don't dawdle! Hotels in many cities in and along the path of totality, which stretches from Oregon to South Carolina, are already booked up, and the ones that are open are filling fast. We'll debut our own eclipse web site in the spring, so keep an eye open for future announcements.

Orion, to their left, is far into his springtime descent. He tilts to the right as he lumbers downward at this time of year, and as a result, his three-star belt appears horizontal. As ever, Orion's Belt points more or less toward Aldebaran in one direction, currently the right, and brilliant Sirius in the other direction, currently left.

This whole horizontal lineup is characteristic of nightfalls in April. How horizontal it appears will depend on your latitude. The farther south you are, the higher its Sirius-bright left hand end will be.

Look high above Orion for the stars Pollux and Castor, the heads of Gemini, the twins. Pollux is a little brighter than Castor, and shows a detectable orange tint, while Castor is pure white.

Pollux and Castor form the top of the enormous Arch of Spring. Procyon, shining to their lower left, is one end of the Arch. Its other end consists of Menkalinan and then bright Capella, farther to the lower right of Pollux and Castor. The Arch of Spring is the last departing portion of the even bigger Winter Hexagon.

Leo, the springtime lion, is already standing high in the south at nightfall. His forefoot is Regulus, the brightest star in the area. Leo's mane and head are marked by the Sickle of Leo, a backward question-mark shape that extends up from Regulus. Well to the left of this is a long triangle: Leo's hindquarters and long tail.

When Leo stands highest in the south, the Big Dipper is approaching its highest stance in the north.

This means the Dipper's pointer stars now point down. These are the two stars forming the end of the Dipper's bowl. All night and all year, whatever their orientation, they point to Polaris, the North Star. It stands essentially motionless through all the starry changes as Earth turns. That's because Earth's rotation axis points almost straight at it. Think about it; *of course* that's why Polaris never seems to move.

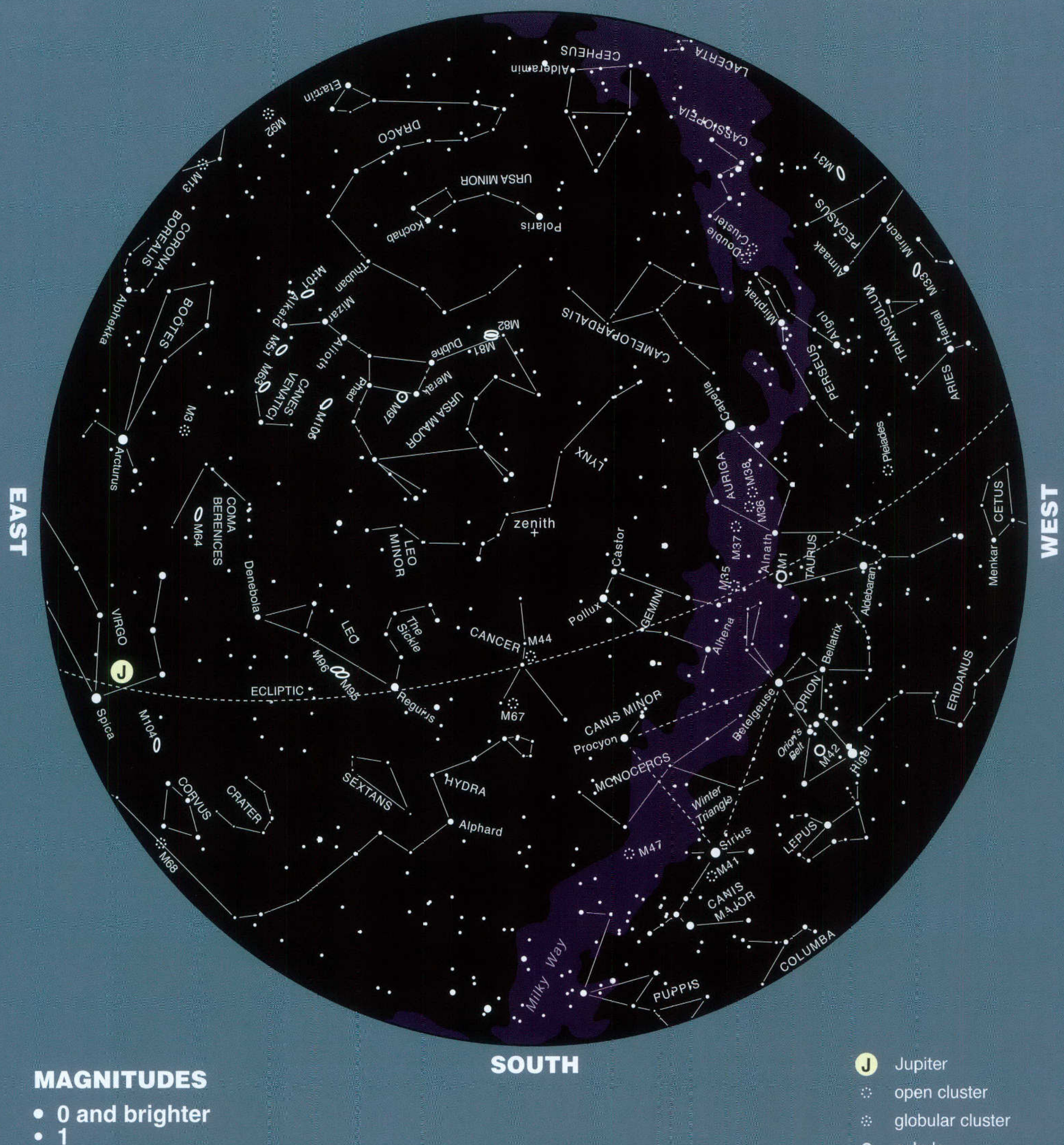
Alan MacRobert is a senior editor of Sky & Telescope *magazine.*

MARCH

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

February 20	**11 p.m.**
March 5	**10 p.m.**
March 20	**8 p.m.***

** Daylight Saving Time begins March 12.*



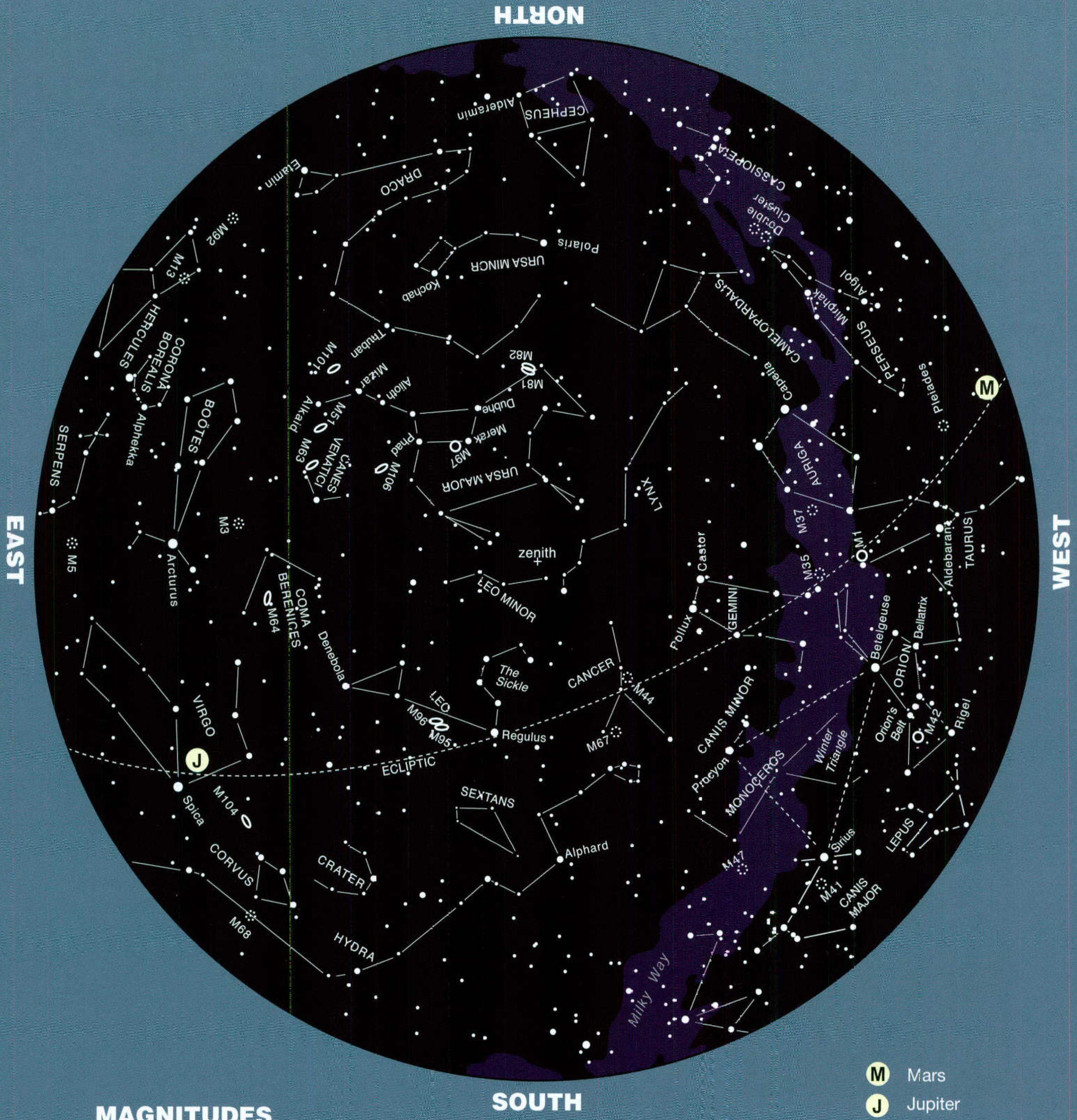
MAGNITUDES
- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

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

APRIL

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

March 20 — **11 p.m.**
April 5 — **10 p.m.**
April 20 — **9 p.m.**



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

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

Many Ways to Picture Space

When Nicole Stott had some spare time aboard the International Space Station during a 2009 mission, she did something no astronaut had ever done in space before: She painted. Using a small set of watercolors provided by another artist, Stott painted "The Wave," a small depiction of the coast of Venezula based on a photo she snapped through a station window.

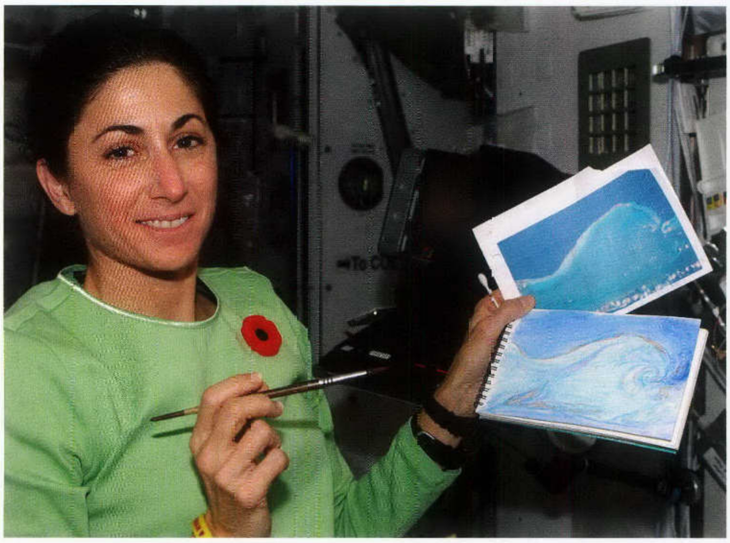
"Watercolors in microgravity actually turned out to be a lot easier to manage than I had thought it might be," Stott wrote on the AstroArts blog, a site managed by Astronomers Without Borders.

Stott, who left the astronaut corps in 2015 to devote full time to her painting, is among the scores of painters, poets, filmmakers, and other artists featured on the AstroArts site. The site includes artist profiles, poetry, crafts, and other *bon mots.*

In addition to Stott, for example, the site includes a lengthy section on the work of directors Alexander Ryneus and Per Bifrost, who have spent months following leaders in the search for extraterrestrial intelligence and related fields for a documentary, "Earthling's Quest," which is scheduled to debut in 2019.

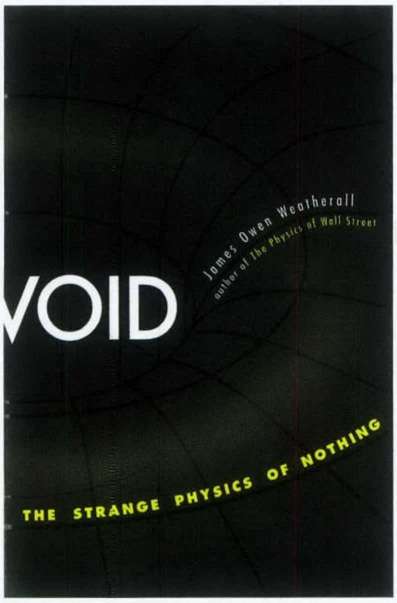
The poetry section features hundreds of works, with titles such as *Pointillist Starscape, Butterfly Dream, Equinox Thoughts,* and *Galactic Rose.* And readers can learn how to make a Jupiter-and-moons mobile or a cereal-box spectroscope in the crafts section.

All of the sections are well illustrated with works by the artists themselves, as well as pictures from Hubble Space Telescope, which are pieces of art in their own right.



Nicole Stott holds a photo of the Venezuelan coast (top) and the painting it inspired, "The Wave," aboard the space station.

astronomerswithoutborders.org



Void
The Strange Physics of Nothing
Yale University Press
$26, Hardcover

Much Ado About Nothing

The television show "Seinfeld" was famously about nothing. But a new book by the author of the 2013 bestseller *The Physics of Wall Street* elevates "nothingness" to an even higher level. It takes on science's concept of the cosmic void — the supposed emptiness between stars and galaxies. And it demonstrates that "nothing" can be as complicated as the best Seinfeld script.

In *Void: The Strange Physics of Nothing,* James Owen Weatherall, a professor of logic and philosophy of science at the University of California, Irvine, describes how concepts of a cosmic void have changed over the centuries.

Before Isaac Newton, many scientists thought that space was filled with an ill-defined "aether" — a medium that transmitted light from the stars. Newton, however, described it as literally nothing — no matter, energy, or structure at all. Later still, Albert Einstein's theories of relativity gave substance to the vacuum, uniting space and time into the fabric of the universe itself, with its own physical properties. And quantum physics provides a void in which particles can pop into and out of existence, and energy from space itself can cause the universe to expand faster as it ages.

Despite the complexity of the topic, Weatherall breezes through it in just 136 pages of text, providing solid analogies and intriguing tidbits about the scientists who spent their lives studying nothing.

by Damond Benningfield and Rebecca Johnson

NASA Space Place Gazette

The Space Place is NASA's home online for space information, images, crafts, and other activities geared for elementary-school students. The free monthly e-mail newsletter, the Space Place Gazette, brings parents and teachers the latest space news, games, and more from the site. Additionally, the newsletter sends out special bulletins ahead of skywatching events like eclipses and meteor showers, and NASA-related happenings like planetary fly-bys.

spaceplace.nasa.gov/subscribe

Astronomy on Tap

Fun and irreverent astronomy events for adults are springing up across the country in the form of Astronomy on Tap. Thousands have attended the free monthly events, generally organized by professional astronomers and graduate students, that are held in bars.

A typical Astronomy on Tap night includes three 10-to-15-minute talks on topics at the cutting edge of astronomy and space science. Audience members can ask questions of the presenters, and the talks are interspersed with music and games.

Logo of the Austin chapter of Astronomy on Tap.

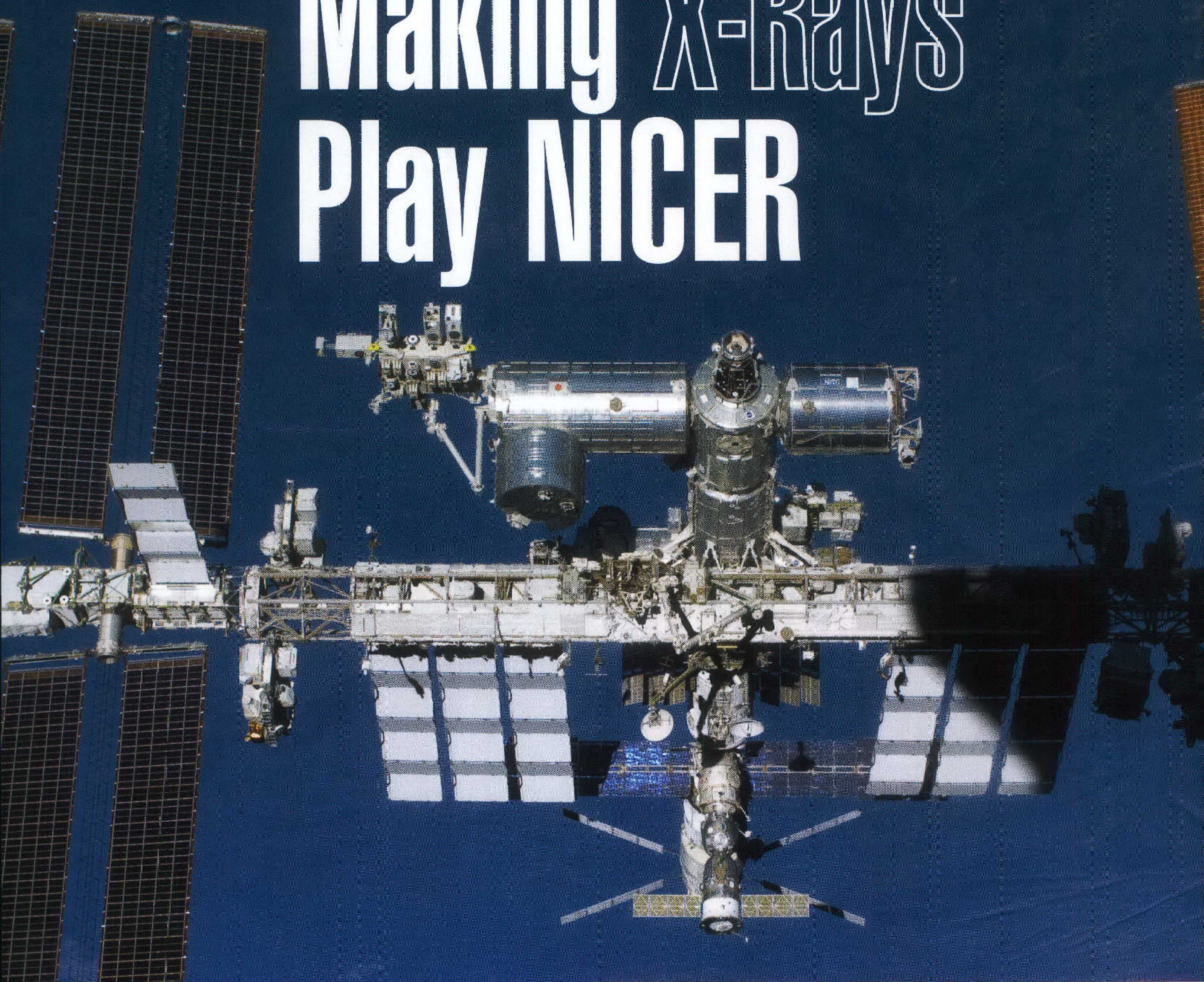
Groups typically give out prizes for correct answers to trivia questions.

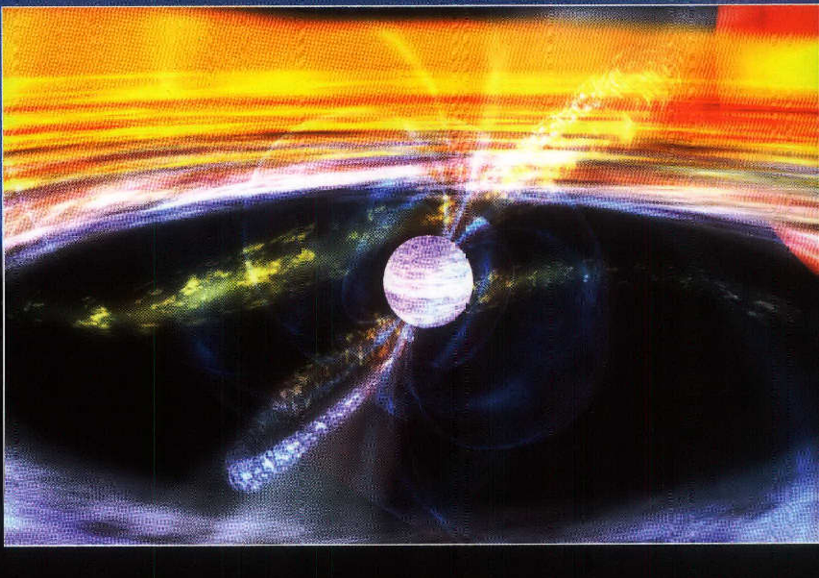
Astronomer Meg Schwamb started Astronomy on Tap in New York City in 2013. Since then, satellite groups have sprung up in Ann Arbor and Lansing, Michigan; Austin; Chicago; Palo Alto, Pasadena, and Santa Barbara, California; Seattle; New Haven, Connecticut; Tucson; Washington, D.C.; and Urbana, Illinios. Still more locations have held one-time events.

The organization's website has links to all of the satellite groups, as well as a schedule of events and contact information.

astronomyontap.org

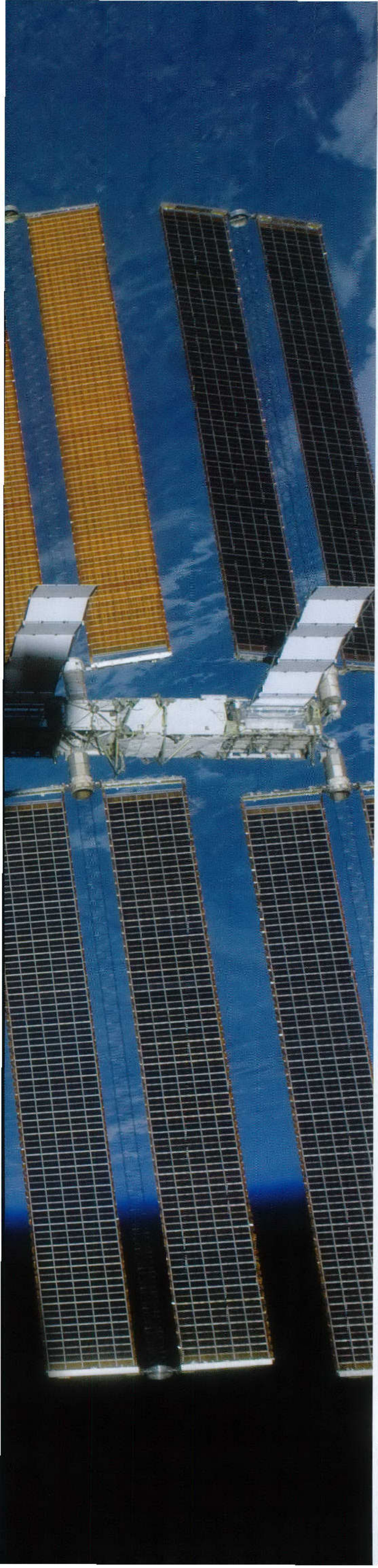
Making X-Rays Play NICER





The NICER X-ray telescope will study pulsars, rotating neutron stars like the one seen in this artists' concept, from its perch attached to the International Space Station.

NASA (2)



A new X-ray telescope destined for the International Space Station will study neutron stars and test technologies for exploring space beyond our solar system

On April 9, a new X-ray telescope is scheduled to be launched into space and attached to the outside of the International Space Station. The Neutron star Interior Composition Explorer (NICER) has a dual purpose: to study the physics of neutron stars, and to demonstrate a pair of technologies useful for exploration of the outer solar system and beyond — pulsar navigation and X-ray communication.

A NASA Explorer-class mission, NICER is set to be launched from Cape Canaveral aboard a SpaceX Falcon 9 commercial rocket. It will be affixed to the space station's ExPRESS Logistics Carrier 2, a platform for science experiments that take place in the vacuum of space, away from where the station's astronaut crew normally operates.

The telescope will study the X-ray universe in a different way from other space-based X-ray telescopes. Chandra X-ray Observatory is optimized for taking images, and the more recently launched NuSTAR mission observes a different part of the spectrum from NICER. (NuSTAR studies the highest-energy X-rays, often called hard X-rays, while NICER studies lower-energy soft X-rays.)

NICER is a timing instrument, which means that it will measure the variation in X-ray brightness over time from a type of neutron star called a pulsar. It's a follow-up mission to the free-flying Rossi X-ray Timing Explorer (RXTE), which operated from 1995 to 2012.

According to NICER Principal Investigator Keith Gendreau of Goddard Space Flight Center, technology advancements since RXTE was built mean that NICER has an "order of magnitude better timing resolution, energy resolution, and sensitivity."

"So NICER really is unique," Gendreau says. "It complements other missions like NuSTAR and Chandra ... but NICER really brings to bear the state-of-the-art X-ray timing capability to understand the transient universe."

One of the chief benefits of this mission, says science team leader Zaven Arzoumanian, "is that you can do the science and the technology with very much the same, or at least an overlapping set, of targets. We can look at the same neutron stars with NICER, and our science team and our technology team — our navigation team — can use the same data for their own purposes. So there's that efficiency that's really appealing, where we can accomplish the two objectives almost simultaneously."

By Rebecca Johnson

On the science side, NICER's main goal is to investigate the strange physics of neutron stars. When a star at least 10 times as massive as the Sun consumes all of the nuclear fuel in its core, the core can no longer produce energy through nuclear reactions. Without the radiation from those reactions to counteract the pull of gravity, the core collapses. The star's outer layers fall inward then rebound, blasting into space as a supernova.

The leftover core is known as a neutron star — an object so dense that it packs the mass of two Suns into a ball the size of a mid-sized city. On Earth, a single teaspoon of this ultra-dense material would weigh a billion tons.

NICER will study a specific kind of neutron star called a pulsar — a rapidly rotating neutron star that emits a narrow beam of radiation as it spins, like a lighthouse. If the beam sweeps across Earth, we see the neutron star pulse on and off — hence the name "pulsar." Some pulsars can spin hundreds of times per second, and their pulses are extremely regular, like the ticks of a cosmic clock. These are called millisecond pulsars.

NICER is specially designed to record these pulses. And though pulsars emit radiation at many different energies, from radio waves through gamma rays, NICER is designed to time them at X-ray wavelengths because they provide the most information about what's going on in the star's interior.

"Science is really buried in the shape of those pulses, as a function of energy and phase," Gendreau says. "And there are multiple techniques that we have to measure things that are of scientific interest out of the shape of those pulses." Mission scientists will tease apart the recorded pulses to better understand neutron stars' extreme gravity, density, and magnetic fields.

NICER's main science mission should be completed in 18 months. It's expected that the telescope will still be operating at peak performance, Gendreau says, and that NASA then will open up use of NICER to other astronomers who would compete for time on the telescope for all manner of astrophysics research.

In particular, Arzoumanian says, "there is really a lot of excitement, especially in the community of X-ray astrophysicists who study black holes of all sizes, stellar-mass black holes all the way up to those at the centers of galaxies that are tens or hundreds of millions of solar masses."

NICER's first technology demo, pulsar navigation, will take place at the same time as its science observations.

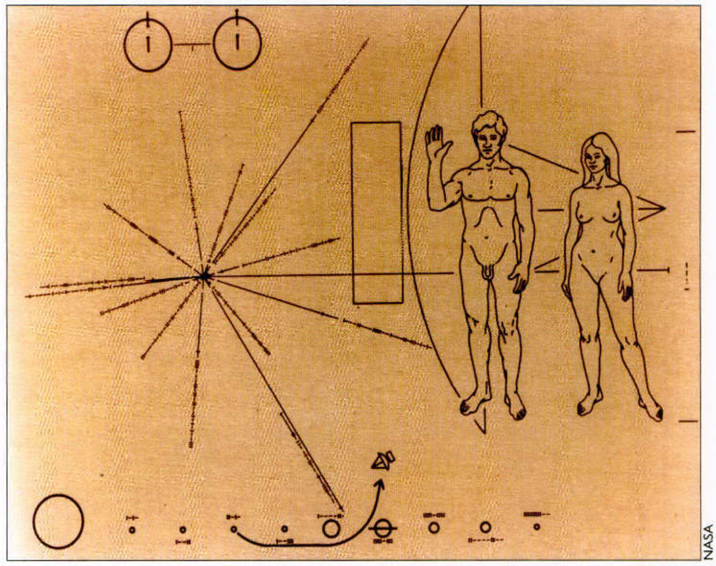
The idea for pulsar navigation has been around for decades. Soon after pulsars were discovered, in 1967, scientists recognized their possible use as beacons.

"Around the time of the discovery," Gendreau says, "NASA was getting ready to launch the Pioneer spacecraft" to fly by the outer planets. An informational plaque was affixed to both the Pioneer 10 and Pioneer 11 spacecraft, for the benefit of any intelligent life that might encounter the craft.

"The Pioneer plaque has got a star-pattern feature to the left," Gendreau explains. "That's actually a pulsar map of where the solar system is, based on where pulsars are. So right from the beginning, it was thought that pulsars could be used for navigation, or figuring out where you are in the universe."

More than a decade ago, the Defense Department's research arm, DARPA, began a project called XNAV to build a pulsar navigation instrument. Gendreau was a NASA representative on the XNAV team. Though ultimately XNAV did not get built, Gendreau says it led him and others to propose the NICER mission.

"Pulsar navigation relies on the steady stream of pulses that come from a pulsar," Gendreau says, "and checking whether or not a pulse arrives a little early or a little late, compared to when you expect it to arrive. And that essentially gives you information that allows you to correct a navigation error — a



NASA

This plaque, on the Pioneer 10 and 11 spacecraft, included a diagram showing the location of Earth in relation to multiple pulsars (left).

position model of where you are."

"The ones that are really useful for navigation purposes are the ones that are called millisecond pulsars, or sometimes they're called 'recycled' pulsars," says Arzoumanian. "They're the extremely old ones. They have weak magnetic fields, and they've been spun up to very, very high rates — hundreds of rotations per second. They've been spun up by accreting matter from a companion in a binary system, usually. And those stars, whether they're in binaries today or not, are the ones that are extremely stable. They maintain predictable pulse arrival times at the level of a part in ten to the fifteenth. So a part in … a thousand trillion," he says.

"There isn't a huge number of these beacons available for navigation, but one of NICER's objectives is to find more of them."

Today, space mission teams use the Deep Space Network, a system of giant radio antennas spaced around the globe, to communicate with spacecraft and help them navigate the solar system. But as spacecraft get farther from home, traditional navigation methods become less reliable, Gendreau says. "As you go farther and farther away from the Earth, those techniques break down, the accuracy gets worse," he explains. "What pulsar navigation does [is] it allows us to do solutions that could be as good as a kilometer or so in three-dimensional space, anywhere in the solar system — and beyond."

NICER will use pulsar data to find the precise location of the International Space Station. NICER's on-board computers will calculate a solution autonomously, with no help from the mission team on the ground. Since the space station's precise location is already known to high accuracy at all times, the NICER team can compare the pulsar solution to that provided by conventional tracking techniques to test for accuracy.

If this new method can be proven, Gendreau says, "pulsar navigation will be used in conjunction with the traditional Deep Space Network ranging technique, to reduce the load on those heavily used facilities by NASA."

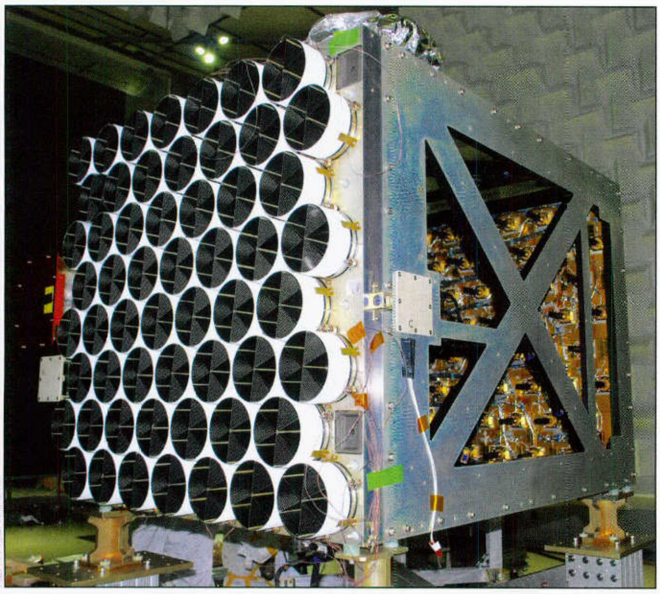
"There's only a few really big dishes that are used for the Deep Space Network and there are more and more spacecraft going to the outer planets," he says. "So we're looking at providing alternate ways to enable deep-space navigation, to allow us to explore more."

NICER also will test technology for X-ray communication. While most spacecraft use radio antennas to communicate with Earth, a few have tested laser navigation, which has proved to be more efficient. It's possible that X-rays would improve on both of these, especially for reaching the edge of the solar system or beyond.

Gendreau explains that, at their higher energies, X-ray beams stay more tightly focused over long distances, so the message does not spread out across all of the solar system as it heads back toward Earth. Longer-wavelength radio beams spread out a lot, he says, citing the Voyager missions as an example. The Voyager spacecraft are at the edge of the solar system, headed into interstellar space. Most of the power from their messages gets diluted, making the message extremely weak by the time it reaches Earth. "If you want to go to the outer planets and beyond," Gendreau says, "your interest is to come up with a way that, when you have [a spacecraft] very far out, Pluto and beyond, that the meager amount of power you have to power your transmitter is being used to send photons containing the information you care out about mostly at the Earth, as opposed to all over the place."

Another way that X-ray communication might be useful is in staying in contact with vehicles re-entering Earth's atmosphere. Astronauts in the Apollo capsules returning from the Moon, for instance, were not able to communicate with controllers on the ground while the capsule was hurtling into the atmosphere, surrounded by plasma — gases ionized by the heat of the craft's reentry. The plasma created a barrier that radio waves could not cross. X-rays, on the other hand, would be able to penetrate the burning plasma and allow communications between astronauts and ground controllers.

Arzoumanian says that NICER's X-ray communications demonstration will take place in a year or two. NICER will act as the receiver for an X-ray message sent by a transmitter on a spacecraft approaching the space station, from dozens of miles away.



KEITH GENDREAU

A pre-launch view of NICER without its protective blanketing shows its 56 sunshades (black and white cylinders, left) that protect its X-ray optics. Some of the 56 X-ray detector enclosures, to which incoming X-rays will be focused, can be seen inside (gold-colored plate, right).

Resources

Internet

NICER mission
nasa.gov/nicer

ISS Research and Technology
nasa.gov/mission_pages/station/research

Articles

What Are Pulsars?
space.com/32661-pulsars.html

How to Navigate Deep Space by Pulsar
newatlas.com/pulsars-gps-space-navigation

The NICER team hopes its small mission will make a big difference in the way researchers think about astronomy, and even science as a whole, on the space station.

"There's been a great desire within NASA, and Congress even, for the space station to be a laboratory. It is considered a national laboratory," Arzoumanian says. "And there have been many, many successful experiments run on space station. But the vast majority of them have been one-off kinds of experiments, where you take up some hardware, you do the experiment, and the hardware may come back down. … And the experiment may generate one or two or a handful of papers from the group that's done that experiment. And that's great.

"But what NICER offers, which I think has been rare so far, is ... it will become a facility that will be open to many different users with many different ideas for many different astrophysics experiments," he adds. "So this one effort could generate, and we expect it will generate, a whole slew of publications of scientific results. That's just a different model from what's been done in the past on space station. We're putting out a capability that's new … and we're hopeful that it will be a great success for the space station program, as well as for astrophysics."

Rebecca Johnson is editor of StarDate *magazine.*

by Damond Benningfield and Rebecca Johnson

Water Above, Water Below

Ice coats Pluto's surface, with perhaps a deep ocean beneath

Water, water everywhere,
Nor any drop to drink.

Like Samuel Taylor Coleridge's ancient mariner, the New Horizons spacecraft saw water everywhere, but none of it was fit to drink. Instead, the water on Pluto was frozen harder than granite, with some perhaps locked in a deep ocean mixed with enough ammonia to make it an unpalatable concoction the consistency of syrup.

New Horizons flew past Pluto in July 2015 and transmitted the last of its observations to Earth last October. A detailed analysis reveals that most of the dwarf planet's surface is coated with water ice. It's so hard that it forms Pluto's bedrock, which is dusted with frosts of methane, nitrogen, and carbon dioxide. The ice even forms mountains that tower above the surrounding ice plains.

New Horizons detected almost no water ice, however, in Pluto's most prominent feature, the white, heart-shaped Tombaugh Regio basin, which is filled with other ices. One lobe of the basin, Sputnik Planitia, aligns on the opposite side of Pluto from its largest moon, Charon, which always remains above the same hemisphere of the little world. That provides clues to the region's formation and evolution, although mission scientists have different interpretations of those clues.

One group says Sputnik Planitia was created when an asteroid 125 miles (200 km) wide slammed into Pluto more than four billion years ago. Liquid water then pushed up close to the bottom of the basin. Since liquid water is denser than ice, it provided a massive pocket that acted as a counterweight to Charon, causing Pluto's crust to reorient itself with Sputnik Planitia opposite the moon.

Another group, however, says the basin wasn't carved by an impact. Instead, it formed as ice built up at the north pole of the newly born Pluto. The ice compressed the surface layers below it, forming a dense pocket. As with the other scenario, the gravitational influence of Charon then changed Pluto's orientation so the basin aligned on the opposite hemisphere.

There's evidence than an ocean of liquid water lies beneath Sputnik Planitia. It could be up to 600 miles (1,000 km) wide and 50 miles (80 km) deep, with the decay of radioactive elements in Pluto's core providing the heat to keep the ocean liquid or slushy.

A high concentration of ammonia could also prevent the water from freezing, giving it the consistency of syrup at temperatures as low as minus-145 degrees Fahrenheit (minus-100 C), which is hundreds of degrees warmer than Pluto's surface, according to William McKinnon, a professor of earth and planetary sciences at Washington University in St. Louis.

"What I think is down there in the ocean is rather noxious, very cold, salty, and very ammonia-rich — almost a syrup," McKinnon said in a press release. "It's no place for germs, much less fish or squid, or any life as we know it. But ... it raises the question of whether some truly novel life forms could exist in these exotic, cold liquids." **DB**

A slushy or syrupy ocean of liquid water could lie beneath Sputnik Planitia, the white, heart-shaped feature at the lower right of this color-enhanced image.

NASA/JHUAPL/SwRI

Mapping a Star's Spotty Surface

Tracking a Neptune-sized planet as it repeatedly crossed in front of its star has allowed astronomers to map the dark magnetic storms, which are like sunspots, on another star. They found that the starspots appear at the same latitudes as sunspots.

HAT-P-11, which is about 125 light-years away, is a bit smaller, cooler, and redder than the Sun, and two billion years older.

A network of small telescopes discovered the planet, known as HAT-P-11 b, by watching it transit the star every few days, blocking some of the star's light. Observations by telescopes on the ground and in space revealed that the amount of starlight blocked by the planet varies from transit to transit. That's because the planet sometimes passes in front of the dark starspots, which don't add much to the star's overall brightness.

By tracking the planet through 200 crossings, the astronomers mapped hundreds of starspots. They found that the star has more spots than the Sun, and that many of them are bigger than typical sunspots. But they appear at the same latitudes as the spots on the Sun, giving HAT-P-11 some dark bands on either side of its equator.

The changing frequency of the starspots indicates that HAT-P-11 undergoes a magnetic cycle that's longer than the Sun's 11-year cycle.

T-Minus Five Years and Counting

Cygnus is already one of the most prominent constellations of summer and fall, with its brightest stars forming the easy-to-spot outline of a swan or a crucifix. In five years, though, it could become even easier to see as a "new" star appears within its borders.

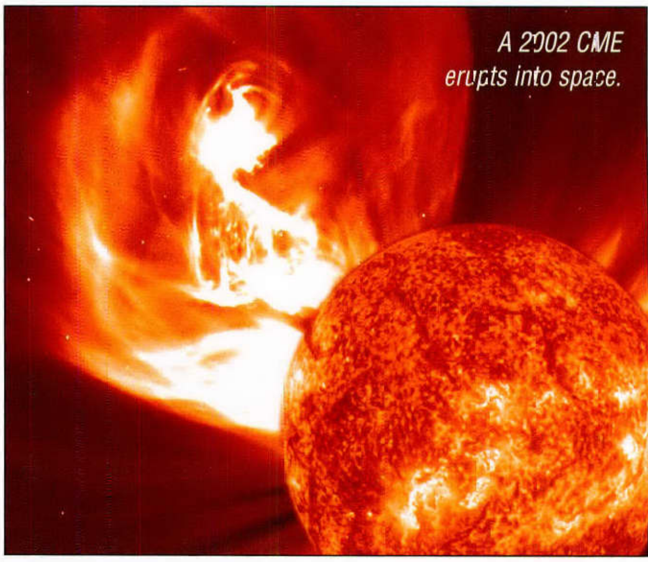
A team led by Lawrence Molnar, an astronomer at Calvin College in Michigan, has predicted that a pair of stars in Cygnus will merge in 2022 (give or take a year), creating an explosion known as a nova. For a few months, the system will shine 10,000 times brighter than its current luminosity, making it as bright as Polaris, the Pole Star.

In a sense, the binary system, known as KIC 9832227, has already merged. The centers of the two stars are so close that they form a contact binary, with the gravity of each star pulling gas off the surface of the other. As a result, the two stars share their outer layers of gas. In profile, that would make the system resemble a peanut or an elongated bowling pin.

Molnar and his colleagues have monitored the system for several years, and reviewed observations by other astronomers that date back 15 years. They found that the two stars are spiraling closer together, changing the system's overall brightness. The way it is changing matches that of V1309 Scorpii, a contact binary that was seen to explode in 2009, when its two stars merged.

From KIC 9832227's distance of about 1,800 light-years, the system shines at 12th magnitude, which is far too faint to see with the eye alone but an easy target for amateur telescopes. If it merges, though, Molnar says it should grow brighter over several months, peaking at second magnitude, making it one of the brightest stars in the night sky. It should also shine with a reddish hue, making it even easier to pick out.

The two stars are expected to survive the merger and outburst, eventually settling back into obscurity.



A 2002 CME erupts into space.

ESA/NASA/SOHO

Solar Punches Could K-O American Economy

Powerful solar storms that trigger massive blackouts could cost the American economy tens of billions of dollars per day, according to a recent study by the American Geophysical Union.

Known as coronal mass ejections (CMEs), the storms consist of billions of tons of electrically charged particles blasted into space at several million miles per hour. When such an outburst hits Earth, our planet's magnetic field funnels some of the particles toward the surface, where they can overload power grids, triggering blackouts. The most damaging storm yet recorded, in 1989, blacked out Quebec for nine hours.

Engineers are concerned that even more powerful CMEs could cause more extensive damage, not only disrupting power grids but destroying transformers and other equipment that would take months to replace. That could black out a large portion of the United States for up to several months.

The new study examined the economic effects of blackouts triggered by CMEs impacting different latitudes of the United States. The least severe impact, accompanying a blackout from New England westward to Washington, could cause \$7 billion in losses per day. The greatest impact, affecting 41 states, could cause \$48.5 billion in daily losses.

The study says that only about half of that impact is through direct causes, such as loss of manufacturing. The rest comes from a ripple effect that impacts vendors, customers, and others. "[F]ailure in the power sector can cascade to other critical interdependent infrastructure systems," the report said, "disrupting business activities and inducing a range of other economic and social consequences that can affect the global economy."

Power systems that automatically shut down when they detect dangerously high voltages could minimize the damage, the report notes, allowing power grids to return to service in hours. **DB**

Gem-like Clouds Swirl Around Giant Planet

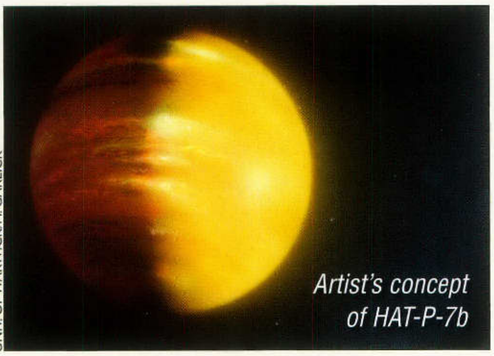
Astronomers have detected weather patterns on a planet 1,000 light-years away using the orbiting Kepler telescope. The planet, called HAT-P-7b, is 40 percent larger than Jupiter and was discovered in 2008.

David Armstrong of the UK's Warwick University studied the light reflected by the planet's atmosphere, and found that a bright point in the atmosphere changes position over time. He concluded that a jet located at the planet's equator is pushing clouds across the planet with variable wind speeds, likely leading to massive storms.

"HAT-P-7b is a tidally locked planet, with the same side always facing its star," Armstrong said. "We expect clouds to form on the cold night side of the planet, but they would evaporate quickly on the hot dayside.

"These results show that strong winds circle the planet, transporting clouds from the night side to the dayside. The winds change speed dramatically, leading to huge cloud formations building up and then dying away. This is the first detection of weather on a gas-giant planet outside the solar system," he said.

The clouds themselves probably are made of corundum, the mineral that makes up rubies and sapphires. They would be visually stunning, Armstrong's team said. **RJ**



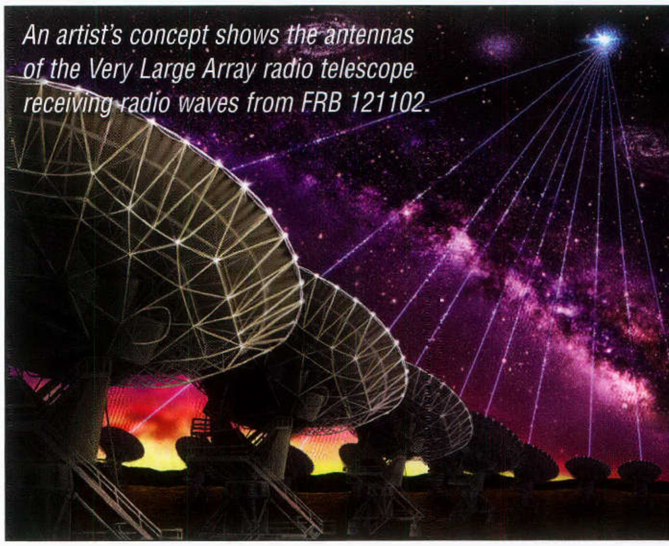
UNIV. OF WARWICK/M. GARLICK

Artist's concept of HAT-P-7b

Astronomers Pinpoint Mysterious Radio Bursts

A mysterious source of short but loud bursts of radio waves sits at the center of a small galaxy that is three billion light-years away, according to recent observations, suggesting that the bursts are powered by a magnetic stellar corpse or a disk of gas around a giant black hole.

The object, known as Fast Radio Burst (FRB) 121102 (for the date it was discovered), is the first FRB seen to produce more than one outburst. Over the last decade, astronomers have found about 20 FRBs, which emit powerful bursts of radio waves that last for only a few thousandths of a second. They have remained mysterious, though, because follow-up observations with other telescopes have revealed nothing that could produce such outbursts.



An artist's concept shows the antennas of the Very Large Array radio telescope receiving radio waves from FRB 121102.

Astronomers used three radio telescopes and an optical telescope to pinpoint the location of FRB 121102, which erupted nine times during a series of observations last August. The coordinated observations showed that the object lies at the heart of a dwarf galaxy, which is just one-thousandth the mass of our home galaxy, the Milky Way. The astronomers also found a continuous radio glow from the galaxy's center, which probably is produced by the same or a related source.

Because the FRB repeats, it can't be caused by a supernova or similar event, because the explosion would destroy the star, leaving nothing to "burst" again. Instead, astronomers say there are a couple of likely origins.

One theory says a burst occurs when a bubble of hot gas erupts from a disk around a supermassive black hole. A jet of charged particles directed into space by magnetic fields then zaps the bubble, which produces a short but bright burst of radio waves as it vaporizes.

The other idea says a burst is powered by a magnetar, the ultra-compact and highly magnetized corpse of a star that exploded as a supernova. The magnetar spins hundreds of times per second, emitting jets of energy that strike pockets of matter ejected into space during the supernova explosion.

Hubble Space Telescope is scheduled to take a look at the galaxy, which may help astronomers resolve the mystery of FRBs. **DB**

Habitable, Uninhabitable, Habitable, Uninhabitable...

Simulations show range of outcomes for neighbor world

Proxima Centauri b, the closest planet beyond our solar system, lies inside its star's habitable zone, which is the distance from the star where temperatures are just right for liquid water. That doesn't mean the planet is actually habitable, though. A lot depends on what happened when it was young. And recent simulations show many possible outcomes for the planet.

The star, Proxima Centauri, is our closest stellar neighbor, at a distance of just 4.2 light-years. It is so small, cool, and faint, however, that it is invisible to the eye alone. When the star was born, though, it probably was much hotter and brighter than it is now, so a lot could have happened to the young planet.

A team led by Victoria Meadows of the University of Washington looked at many possible early conditions for the planet, which is 1.3 times the mass of Earth and orbits the star at roughly one-tenth the Earth-Sun distance.

If the planet formed at its current position, it would have been too hot for habitability until the star was 160 million years old, so any atmosphere or oceans would have vaporized, leaving the planet dry and airless, the researchers concluded. If it formed farther from the star and later moved inward, however, it could have retained its water and atmosphere, producing relatively Earth-like conditions.

We won't know what Proxima Centauri b is really like until future telescopes provide a direct look at this neighbor world.

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NGC 6357 is a jumble of three star clusters 5,000 light-years distant. In it, hundreds of young, massive, hot stars are giving off X-rays (purple, seen here by the Chandra and ROSAT telescopes), and blowing strong winds that hollow out cavities around themselves. The composite image also shows the gas surrounding these stars, in both visible light (blue, from the UKIRT telescope) and infrared (orange, from Spitzer Space Telescope).