StarDate®

FIRST STEPS IN SPACE
PAGE 20

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Cosmic Visions

From galaxies to gemstones, the universe provides many beautiful sights

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

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Features

Departments

NASA/ESA/HUBBLE SM4 ERO TEAM

On The Cover

The galaxies of Stephan's Quintet show some of the variety found in these 'island universes,' which frequently interact with each other, forcing the birth of many new stars and deforming the shapes of the individual galaxies. See page 4 for more examples, and page 16 for some other cosmic jewels.

This Page

Jets of hot gas stream into space from a young star that's about 10,000 light-years from Earth. The system is known by a catalog number, MHO 2147. The jets will disappear when the star completes its birth process and settles into maturity. While most stellar jets are relatively straight, these are twisted, perhaps by the gravitational influence of companion stars. Their parent star is hidden behind thick, dark clouds of gas at the center of the image.

In Our Next Issue

We'll tell you about some exciting research taking place at McDonald Observatory, and about efforts to study mysterious cosmic rays through the decades.

MERLIN

Dear Merlin,

I often hear about all the trash that is floating in space. I know much of it is from the International Space Station. Will it eventually just disintegrate, or will something have to be sent to space to collect it?

Carol Brown
Gatesville, Texas

Someday, perhaps visitors to Earth orbit will see work crews wearing reflective vests atop their spacesuits collecting trash from the orbital highways and byways. And maybe they'll have signs similar to those that adorn many terrestrial highways: *The next 5,000 miles kept litter-free by the Spacely Sprockets Company.*

Until then, unfortunately, space trash (or space junk, as it's more often called) is a growing problem. The world is launching thousands of new satellites into space every year, clogging the spaceways with a lot of traffic. Debris from their booster rockets sometimes accompanies them, and sometimes pieces of the satellites themselves break away. Although such pieces can be tiny—as little as a fleck of paint—a collision with one could damage or even destroy a spacecraft.

Today, some satellite operators intentionally command old or dying craft to reenter the atmosphere, with many of them aimed at a "spacecraft graveyard" in a wide, uninhabited region of the Pacific Ocean. Most satellites, though, will remain in space until their orbits naturally decay and they plunge into the atmosphere.

Space agencies are pondering plans for capturing and de-orbiting dead spacecraft and snagging bits of debris, but nothing has been approved.

Incidentally, the International Space Station (ISS) generates little space junk. Any debris that hits the station could endanger the lives of its astronauts, so most of its trash is placed in reentry vehicles that burn up in the atmosphere. NASA and the other agencies that operate the station keep a close eye on any space junk that might approach ISS. In November 2021, for example, they delayed a planned spacewalk after Russia destroyed a satellite, scattering hundreds of pieces of debris across low-Earth orbit.

So for now, at least, there's not much anyone can do to clear the space lanes of the increasing mounds of trash.

Dear Merlin,

It looks to me like most celestial systems are organized roughly into one plane. Our moon revolves around Earth in one plane, the revolutions of the planets in our solar system are roughly in one plane, and spiral galaxies are roughly one plane. Is this observation accurate? If so, why?

Stephen Harty
Irvington, New York

It's the law. The laws of gravity and angular momentum squeeze and flatten the clouds of gas and dust that give birth to star systems and spiral galaxies, creating disks that rotate in a single plane (roughly).

In the case of a star system (including the solar system), it starts as a big, widely spread blob. The cloud isn't evenly spread out, though, so as it starts to collapse (perhaps thanks to the gravitational nudge of a passing star or the shockwave from a supernova), it initially falls inward more in one direction than in the others. That pulls material into a relatively flat disk, which spins faster as it contracts, like an ice skater twirling faster as it pulls in its arms. The spin helps keep material from moving away from the disk.

Most of the gas and dust settles in the center, forming the star. Material in the disk around the star fragments, with some of the material coalescing to form chunks of ice, rock, and metal, which in turn merge to make planets.

Over time, though, the plane can grow "bumpy." Friction with material in the leftover disk, gravitational interactions among the planets, and other effects can tilt the orbits of the planets. In extreme cases, in fact, planets may be pushed into orbits that are far outside the plane, and even perpendicular to it—an effect seen in several other planetary systems.

Spiral galaxies work in a similar way. They appear to form from the mergers of smaller galaxies, which have irregular shapes. The gravity of the merging galaxies causes them to collapse, rotate, and flatten out, forming a spiral galaxy.

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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Cosmic Snowflakes

Galaxies—'island universes' of millions or billions of stars—assume many beautiful shapes, made all the more impressive by close encounters

Galaxies are like snowflakes: Every one is beautiful, and no two are alike. Some galaxies are delicate spirals, spinning through the universe like cosmic whirlpools. Others look like hazy footballs and are home to a trillion stars or more. Still others have no distinct shape at all; blobs, streamers, and filaments of stars and gas can resemble puffs of cotton candy blowing in the wind or giant spiders catching insects in messy webs.

Although millions of light-years separate most galaxies from each other, the galaxies themselves are so large that they frequently caress, sideswipe, or plow into each other, with spectacular results, as shown in the following pages. They can resemble pairs of dragons locked in mortal combat, tadpoles swimming upstream, spears ramming into fluffy targets, waves rippling across a cosmic pond, or many other fantastic shapes.

As galaxies interact, their gravity can pull out streamers of stars that can stretch for hundreds of thousands of light-years. Clouds of gas and dust can ram together, squeezing them and causing them to give birth to thousands or even millions of new stars. Some of the stars are massive, so they shine especially hot and bright. They burn out quickly, though, and explode as supernovas, which can briefly outshine the entire galaxy.

Giant galaxies frequently consume smaller ones. In fact, all the large galaxies in the modern universe probably reached their present proportions through mergers with smaller galaxies. That includes our home galaxy, the Milky Way, which has pulled in many galaxies during its lifetime, and is digesting one or more today.

Mergers between larger galaxies create galactic monsters. The largest elliptical galaxies, for example, are the result of mergers between two or more large spirals. And the Milky Way appears destined to join that list. It is on track to collide with a galactic neighbor, the Andromeda Galaxy (M31)—the closest giant galaxy to our own—in several billion years. Another nearby galaxy, M33, may join the action. For billions of years, as the galaxies settle in to their nondescript elliptical form, they may sculpt shapes that resemble those of many other interacting galaxies. They won't look exactly like any of them, however. After all, like snowflakes, no two galaxies are just alike.

By Kristen Pope

PINWHEEL, M101

GRAND DESIGN SPIRAL

Encounters between galaxies don't need to be traumatic to produce beautiful results. Consider the Pinwheel Galaxy (Messier 101). It is perhaps the best example of a Grand Design spiral galaxy, with well-defined spiral arms wrapping around its core like the blades on a toy pinwheel. Those arms probably were shaped by the gravitational influence of several small nearby galaxies.

The Pinwheel is a galactic giant—perhaps half-again as wide as the Milky Way and containing more than a trillion stars, which is hundreds of billions more than our home galaxy. It is festooned with young stars that are hot, bright, and blue, as well as large star clusters and gas clouds, which outline its spiral arms. Many of those brilliant stars will explode as supernovas, adding to the grandeur of this grand galaxy.

NASA/ESA

ESA-HUBBLE/NASA/P. SELL

A CONTORTED SPIRAL

Located 120 million light-years away, NGC 2276 is a spiral galaxy, but it's not the standard, textbook version of one. Described as "strangely lopsided" and "unusually contorted," it looks like a cartoon octopus spinning happily through space, its arms wrapping around its body. That shape probably is being sculpted by two different interactions with its environment.

One interaction is with the gas and dust between galaxies. As NGC 2276 moves through hot clouds of this material, the clouds within the galaxy itself are squeezed. The clouds fragment into smaller clumps, which collapse to form new stars, including many that are massive and hot. The stars are born in giant nurseries, which glow bright pink in the spiral arms at the galaxy's rim.

On NGC 2276's opposite side, a gravitational interaction with another galaxy—NGC 2300, a smaller elliptical galaxy with only older yellow and white stars—is causing an unusual distortion. It tugs on the outer edges of the galaxy, pulling NGC 2276's leading spiral arms in toward its core and giving it a distorted appearance.

LENTICULAR GALAXY

Staring into space like a milky eye with a heavy brow, NGC 6861 is a galactic hybrid: neither spiral nor elliptical, but lenticular. Seen from the side, such galaxies look lens shaped. In fact, they have slightly oval shapes, similar to ellipticals.

NGC 6861 was discovered in 1826 by Scottish astronomer James Dunlop. It is the second-brightest galaxy in the Telescopium Group, which is located in the southern constellation Telescopium, the telescope, and is about 95 million light-years from Earth.

Like a spiral galaxy, NGC 6861 has long lanes of dark dust clouds that encircle its core. In spirals, those lanes are where new stars are born. Yet little starbirth is going on inside NGC 6861 because it appears to have exhausted its supply of gas, like an elliptical.

That hybrid appearance suggests that NGC 6861 was once a spiral galaxy, but it has used up its star-marking material, leaving it incapable of giving birth to more stars. On the other hand, it could be the result of the merger of two galaxies—a plausible explanation given its location in a galaxy cluster.

GREAT BARRED SPIRAL

The spiral arms of many galaxies spin off the ends of a long "bar" at the center, and one of the most dramatic examples is NGC 1365, the Great Barred Spiral Galaxy. It's about 60 million light-years away, in the southern constellation Fornax, the furnace.

Bars function as superhighways for gas and dust, funneling the material from a galaxy's outer regions toward its center, where it forms many new stars. Some of the gas is directed all the way to the supermassive black hole at the galaxy's heart. It enters a super-heated disk around the black hole, which creates strong "winds" that blow some of the material back into the surrounding galaxy. (NGC 1365's central black hole is a bit puny, though—just half the mass of the black hole at the heart of the Milky Way, which itself is small compared to the black holes in many other galaxies.)

Astronomers are debating the origin of galactic bars, although mergers and gravitational encounters may play a role.

Although barred spirals are quite common (the Milky Way is an example), the bars might not last long. As they spin they become unstable, so they eventually fall apart, leaving a more conventional spiral.

NGC 1365 is one of the most impressive members of the barred class. It is about 200,000 light-years in diameter, and the bar is so huge that stars at its ends take about 350 million years to complete a single orbit (compared to about 230 million years for the Sun to orbit the center of the Milky Way).

ESA-HUBBLE/NASA

DARK ENERGY SURVEY/DOE/FNAL/DECAM/CTIO/NOIRLAB/NSF/AURA

STARBURST

The bright blue newly formed stars scattered throughout the arms of M61 show why it's known as a "starburst" galaxy: It's giving birth to millions of new stars. The massive young stars add luster to the galaxy's spiral arms, while dense regions of star formation decorate them with ruby red knots, like cosmic jewels.

Starbursts occur when galaxies pass near each other. Their gravitational influence causes giant clouds of gas and dust to collapse, giving birth to new stars. The rate of star formation can be thousands of times greater than in a typical galaxy, so the outburst uses up the galaxy's star-making materials in a hurry.

M61 is more than 50 million light-years away, and is similar in size to the Milky Way—approximately 100,000 light-years in diameter. It is one of the more impressive members of the Virgo Cluster, which is a collection of about 1,300 galaxies spread across Virgo and some adjoining constellations. That cluster, in turn, is a member of the larger Virgo Supercluster, which also includes the Milky Way.

M61

ESO

NGC 4676

NASA/ESA/H.FORD (JHU)/G.ILLINGWORTH (UCSC/LO)/M.CLAMPIN, G.HARTIG (STSCI)/ACS TEAM

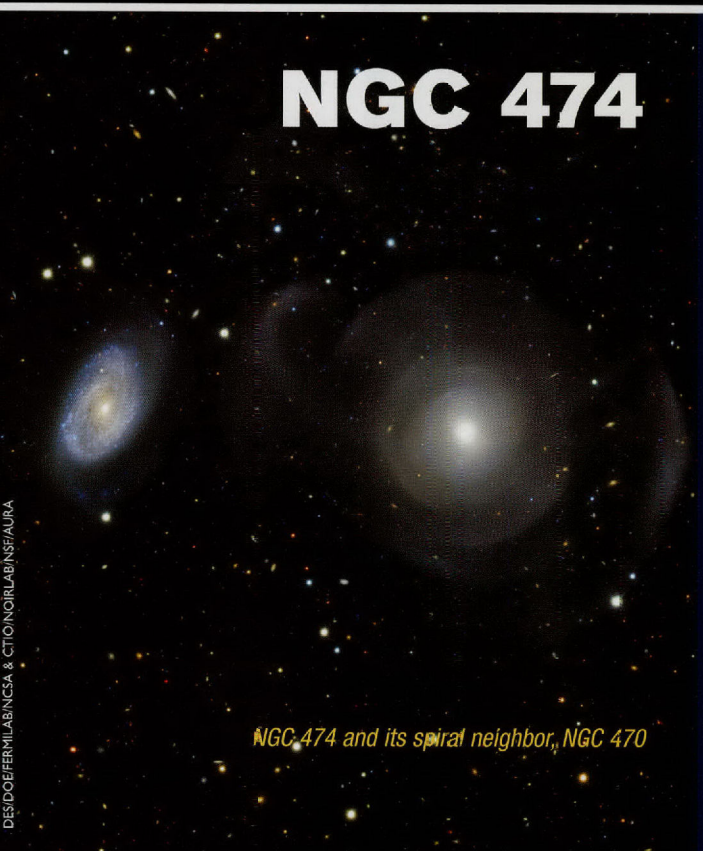
INTERACTING GALAXIES: THE MICE

A quick glance at NGC 4676 demonstrates why it is dubbed "The Mice." With moderately sized "bodies" and long rodent-like tails, this galactic pair does resemble two mice. In reality, though, they are galaxies that are tearing each other asunder.

Both galaxies are spirals, and they probably already passed through each other at least once, about 160 million years ago. The encounter pulled out massive streamers of stars and triggered the birth of many new stars (though there probably were no collisions between stars in the galaxies because of the vast distances between them). But their interactions aren't over. They will continue passing through each other until they ultimately merge into one massive galaxy—a process that will take hundreds of millions of years. Simulations show that when they do merge, they likely will create an elliptical galaxy. The Milky Way probably faces a similar fate as it joins with the Andromeda Galaxy in several billion years.

Located about 300 million light-years from Earth, NGC 4676 is in the constellation Coma Berenices.

NGC 474



DES/DOE/FERMILAB/NCSA & CTIO/NOIRLAB/NSF/AURA

NGC 474 and its spiral neighbor, NGC 470

REJUVENATED ELLIPTICAL

Elliptical galaxies are quite common, and most of them are quite dull. Although some are huge—they can span hundreds of thousands of light-years and contain a trillion stars or more—they look almost featureless. They generally have exhausted their supplies of star-forming gas and dust, so they aren't giving birth to new stars. Instead, they consist almost exclusively of older, fainter stars that give them a yellow-orange tint. Most have a long oval appearance that is bright at the center but fades toward the edges.

NGC 474 is different. This unique galaxy, which is about 100 million light-years away, in Pisces, is known for its shells and tidal tails—great arcs and streamers of stars. A study in 2020 suggested those features formed in a merger with a smaller galaxy about two billion years ago. In addition, NGC 474 appears to be stealing gas from a nearby spiral galaxy, supporting some star formation in its outer regions. As a result of these encounters, the stars in the shells are, on average, several billion years younger than those in the galaxy's inner precincts.

by Alan MacRobert

Springing a New Season: Lion, Twins, and Crow

March and April bring the transition from the brilliant stars and constellations of winter to the more sedate lights of spring. Regulus, the brightest star of Leo, springs high across the night, followed by Spica, the leading light of Virgo. The planets remain in the early morning sky, with three of them congregating in early April.

MARCH 1-15

Do you have an open sky view to the south? This matters for amateur astronomers. Most of the constellations you can see from our latitudes reach their peak heights there, showing at their best in the darkest sky.

This especially matters for telescope users. The higher you look, the less air you're looking through and the sharper the seeing.

February was Orion's month to be king of the south after dusk. Now we find him stepping westward past the meridian, and his dog Canis Major comes into its peak showing. These constellation-by-constellation replacements run all night and all year, but this one is especially notable with two such dramatic figures.

The highlight of Canis Major is, of course, Sirius, the brightest star in the night sky, which now is smack on the meridian (straight above the point due south) shortly after dark.

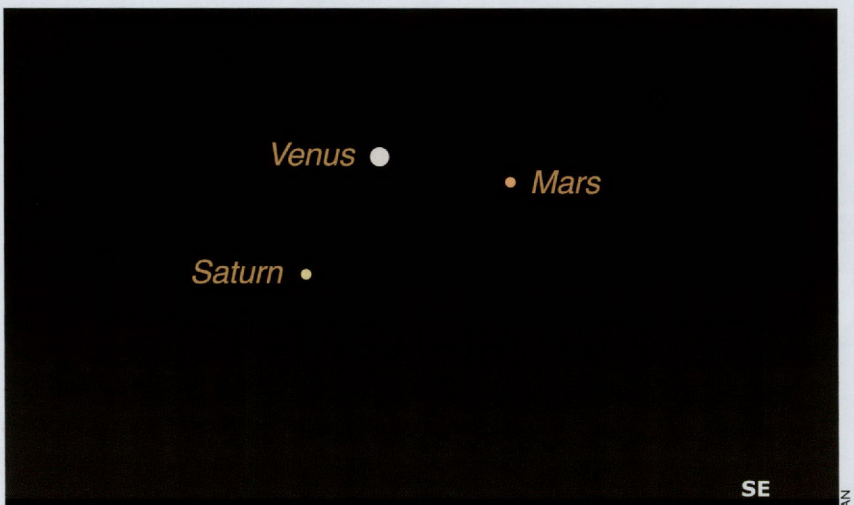
Procyon, the bright light of Canis Minor, shines to the upper left of Sirius. With orange Betelgeuse in Orion's shoulder, Sirius and Procyon form the bright equilateral Winter Triangle.

Shortly after the end of twilight—14 minutes after Sirius crosses the meridian, to be exact—the Winter Triangle balances precisely on its Sirius point (if we define balance by when the top of the triangle is perfectly level).

Watch for this to happen sometime around 8 p.m. in the first half of March, depending on your date and on how far east or west you live in your time zone. But no matter where you live, the Winter Triangle turns level every day 14 minutes after Sirius crosses due south—whether in the evening as now, at midnight around New Year's, at the break of dawn in October, or at midday in the Dog Days of summer.

As for bright planets, they are nowhere to be found these evenings. But look toward the east in early dawn! Venus blazes low in the east-southeast as the brilliant Morning Star. Faint little Mars, less than a hundredth as bright, glimmers to its lower right by about three finger-widths at arm's length. Binoculars help with Mars if the sky is growing bright.

Far to their lower left, Mercury and Saturn come up even as the sky grows brighter. On the morning of March 2, try catching Mercury and Saturn in conjunction just 0.7 degrees apart. Mercury is the brighter one; look for Saturn just to its upper left. You'll definitely need binoculars by the time they're in good view.



March 24, about 45 minutes before sunrise

CJ DUNCAN

MARCH 16-31

As winter turns to spring (the equinox comes on March 20 this year), evening darkness finds Orion walking down toward the southwest with his three-star belt more or less horizontal.

Back when fall turned to winter, Orion's Belt was vertical in the southeast. The great line of celestial landmarks that Orion's Belt points to has rotated accordingly. Sirius now sears the night to the left of Orion's Belt; orange Aldebaran shines farther to Orion's right, and the Pleiades cluster is to the right of Aldebaran (and a bit lower).

High above Orion, the starry stick figures of the Gemini twins—they're holding hands—are finally turning to stand vertical. Their heads, Pollux and slightly fainter Castor, look down from near the zenith. Canis Major, wearing Sirius on his chest like a dog-tag, still trots upward. Later in the night and later in the season, the dog turns more horizontal as he sinks toward the southwestern horizon.

All of those are traditionally "winter" constellations, at least if you watch the sky in the evening. But now, look high in the east-southeast for Leo, the springtime lion. He's walking upward, toward the right. Under heavy light pollution, all you may see of him are his first-magnitude forefoot, Regulus; his back-of-the-neck star, Algieba, a little fainter and less than a fist at arm's length to the upper left of Regulus; and his tail-tip, Denebola, two fists to their lower left.

High in the northeast, the Big Dipper still stands on its handle, but now it's starting to tilt leftward. Follow the curve of the handle way down and around to the lower right and, barring the awkwardly placed tree, building, or streetlight, there's Arcturus, the Spring Star, making its way up to shine all spring, summer, and into the fall.

In early dawn now, we're having a bunch-up of three planets: brilliant Venus low in the east-southeast, faint Mars a few degrees to its lower right or right, and Saturn moving toward them day by day from the lower left. By March's end, Saturn will be right between Venus and Mars.

APRIL 1-15

Early April finds the crescent Moon working its way up through the spring twilight in the west. On April 4, the slim waxing crescent poses cryptically with the Pleiades. It's to the upper right of Aldebaran on the 5th, between the Taurus horn-tip stars on the 6th, and it crosses Gemini on the 7th, 8th, and 9th. By then, the Moon has filled out to first quarter.

Arcturus has rapidly gained height in the east. As evening advances, look three fists to the lower right of Arcturus for Spica, which is exactly one magnitude fainter.

To the right of Spica by half that distance rests Corvus, the crow, another signature of spring. Corvus is a distinctive quadrilateral of four stars. In deep darkness you can make out fainter stars that complete a stick-figure crow-like pattern. The crow is standing in profile, eyeing sparkly Spica as if to steal it. The ancients who dreamed up most of our constellations were surely familiar with the fascination crows have for sparkly things. And why is that? My wife the animal-behavior biologist suggests it's because, in nature, sparkly often means water, sometimes a scarce commodity for creatures to seek out.

Like Spica with Corvus, Arcturus also has a small but distinctive constellation fairly close by. Once Arcturus is well up, look to its lower left by a little more than the distance separating Spica from Corvus for Corona Borealis, the semicircular northern crown. It's dimmer than Corvus, with only one moderately bright star: Alphecca or Gemma, the 2nd-magnitude crown jewel. To see the whole little tiara you need a good, dark sky.

The dawn planet dance continues: Venus is dropping a little lower, while on the mornings of April 4 and 5, Mercury and Saturn pass barely one-half degree apart. They are almost equal in brightness, but Mars is redder. Thereafter, the three separate to form a lengthening line.

APRIL 16-30

The high western twilight showcases the great Arch of Spring.

Start with Pollux and Castor, which are high in the sky, due west, and line up parallel to the horizon. They're about three finger-widths at arm's length apart. To their lower left is Procyon, the arch's left end. Farther to their lower right are second-magnitude Menkalinan and then brilliant Capella, magnitude zero, marking the arch's right end. The Arch of Spring is part of the even larger Winter Hexagon, much of which has sunk from sight.

Arcturus and Spica are climbing higher in the east and southeast, respectively. While Arcturus shines pale ginger-ale color, Spica is a pale blue-white. In fact, Spica (once it rises high into thin air) is one of the bluest stars in the sky. Binoculars show star tints better than the unaided eye, especially if you defocus a bit so stars become disks rather than tiny, overexposed points.

Sadly, though, the range of star colors is limited. Almost all stars are very pale, meaning the colors are mixed with a lot of white. On the orange and red end—the least-hot stars—the colors are strongest. An example is Betelgeuse, Orion's shoulder, still in view right after dusk. Look for it under the Arch of Spring, far below Pollux and Castor.

But no matter how hot a star becomes, it can never appear much bluer than pale Spica. That would not be the case if our vision extended into the ultraviolet, where the real action happens for the hottest stars. But limited as we are to longer wavelengths, a super-hot object stays the same pale blue-white to our eyes even if its temperature rises from more than 50,000 degrees Fahrenheit (30,000 C), which is hardly more than Spica, to 100,000 degrees or a million or more.

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

Meteor Watch

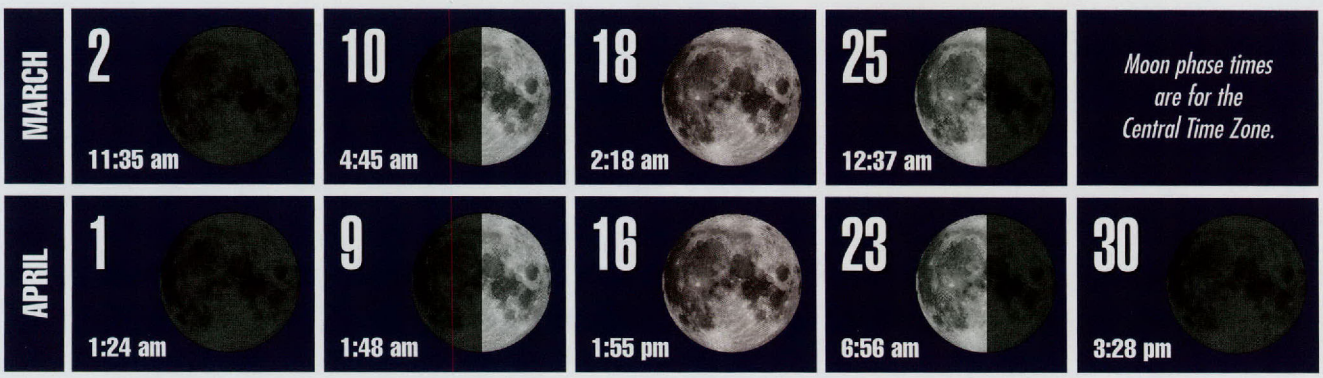
The Shower
Lyrids

Peak
Night of April 21

Notes
The Lyrids are modest, with around one or two dozen meteors per hour at best. The gibbous Moon rises about 3 a.m., so after that its light will overpower all but the brightest meteors.

AstroPrimer

Arcturus, the brightest star of Boötes, is almost 37 light-years away, and is larger, brighter, and older than the Sun. Its light was used to switch on the electricity at the 1933 Chicago World's Fair, opening the exhibition.

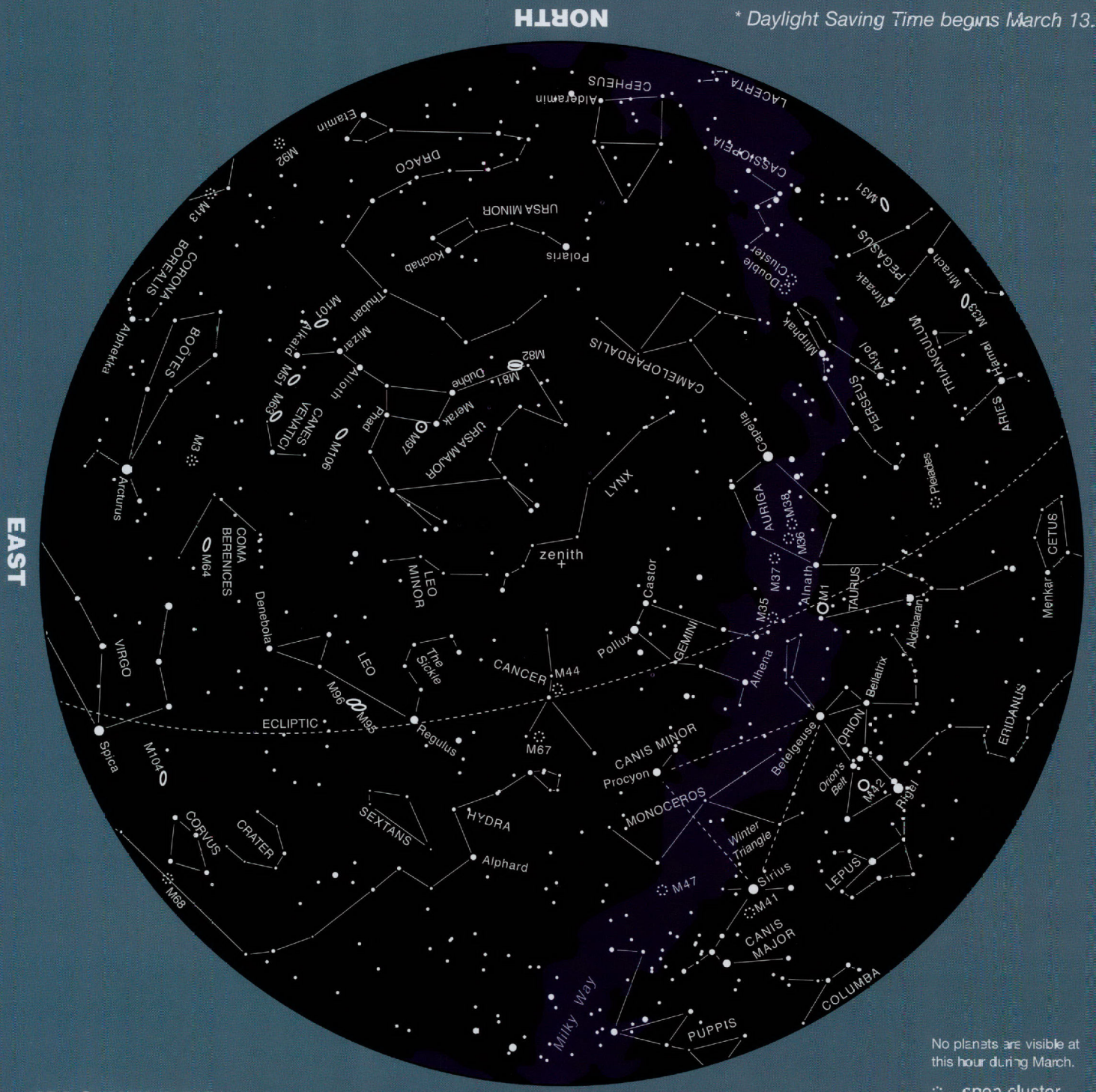


MARCH

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 13.*



MAGNITUDES

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

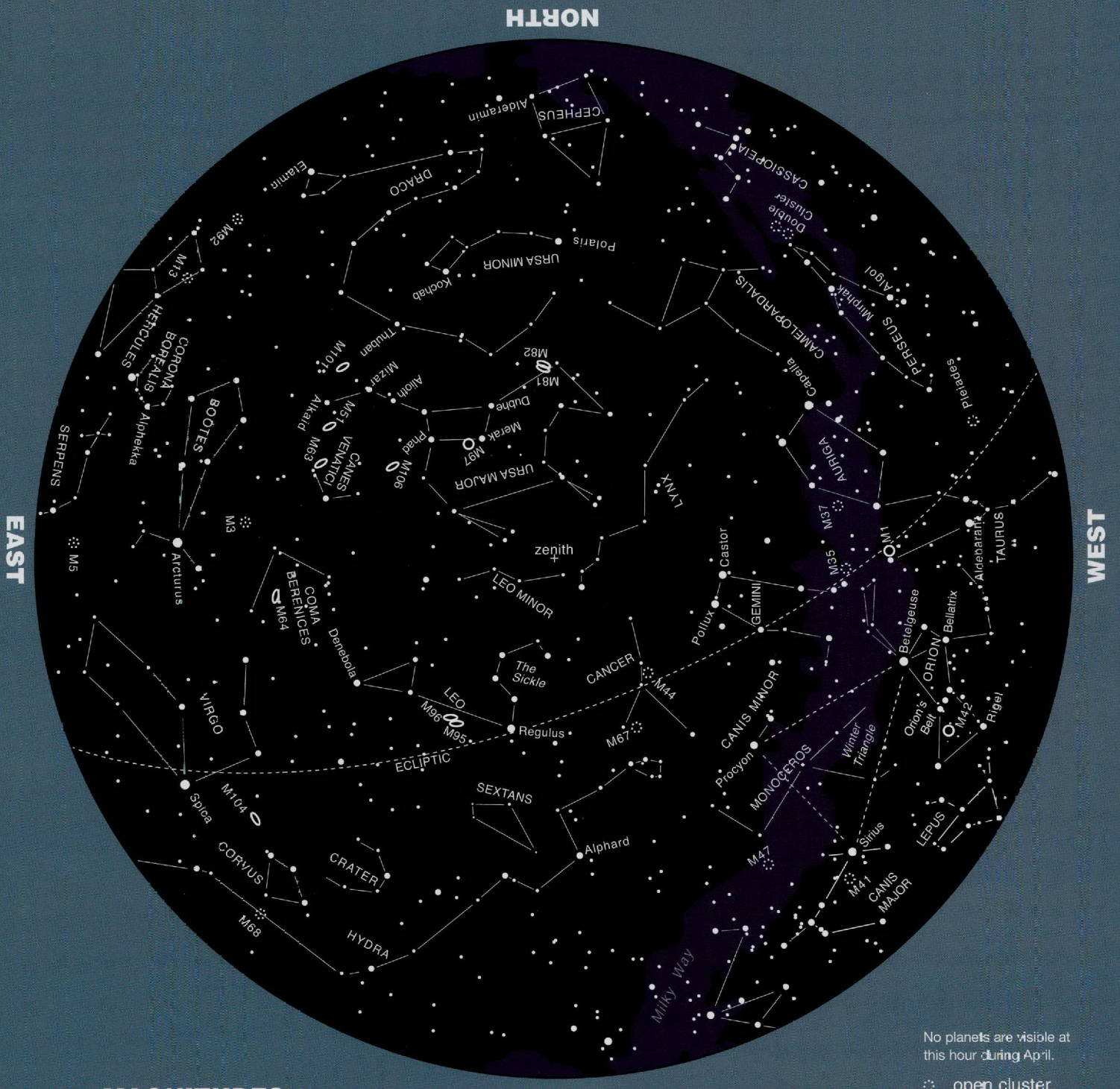
No planets are visible at this hour during March.

- 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
- 3
- 4 and fainter

No planets are visible at this hour during April.

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

Going Dark

Celebrating unhampered views of the universe

McDonald Observatory boasts some of the darkest night skies in the country, providing clear views of the heavens for astronomers and visitors alike. The Observatory will celebrate those views, while helping people learn how to make their own skies a little darker, during its inaugural Dark Skies Festival April 29-30.

The event will offer both daytime and nighttime sky-watching activities, tours of the Observatory, educational activities, guest speakers, food, live music, and more. A new exhibit on how to protect dark skies will open at the Frank N. Bash Visitors Center.

Admission to daytime programs and events is free, with a $5 per person fee for evening star parties (reservations required).

mcdonaldobservatory.org/dark-skies-festival

ETHAN TWEEDIE PHOTOGRAPHY

The Milky Way shines over a star party at McDonald Observatory.

Road Show Transports Visitors to the Moon

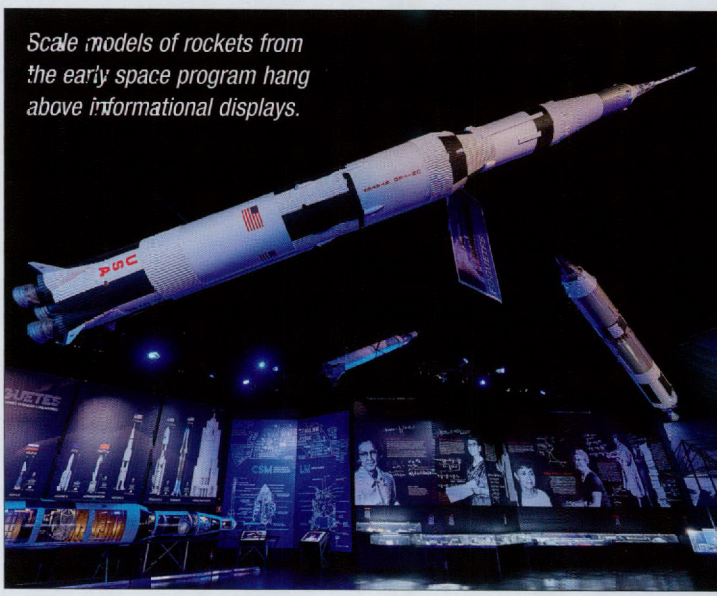
A new traveling exhibition that chronicles the early American manned space program will open in April in downtown Miami.

Space Adventure will display more than 300 artifacts from the Mercury, Gemini, and Apollo projects, which carried astronauts to Earth orbit and on to the Moon in the 1960s and early '70s. Items will include computers and consoles from the Mission Control Center in Houston, spacesuits worn by the astronauts, and equipment that was carried to the Moon, including cameras. Displays also will include mock-ups of the lunar module, which carried six pairs of astronauts to the lunar surface, and the lunar rover, which ferried three of those teams many miles across the Moon. Many of the artifacts will be displayed in special rooms, including a mock-up control room and a lunar-departure room.

Several video presentations and many high-resolution photographs will chronicle the early missions, while virtual reality and other displays are designed to augment the visitor's understanding of early space travel.

Space Adventure will tour several other American cities after the Miami run, beginning with Atlanta sometime this fall.

www.spaceadventure.us



Scale models of rockets from the early space program hang above informational displays.

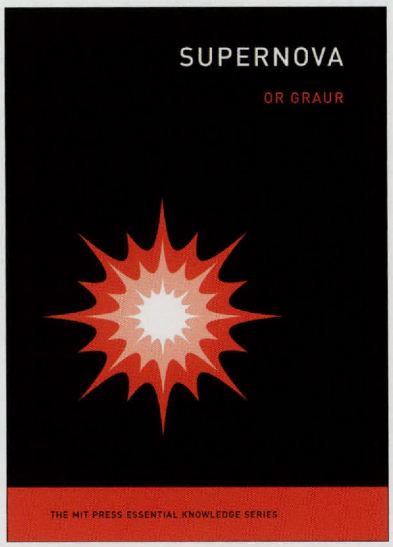
Going Bright

Destruction and creation among the stars

In *Supernova*, astrophysicist Or Graur describes the history and physics of some of the most powerful explosions in the universe.

A supernova is the destruction of a star—either a supergiant star at the end of its normal lifetime, or a stellar "corpse" that has stolen gas from a companion.

Graur, a senior lecturer at the UK's University of Portsmouth Institute of Cosmology and Gravitation, notes that supernovas that appeared in 1006, 1054, 1181, 1572, and 1604 helped dispel the notion that the universe was an immutable celestial sphere. Instead, it's constantly changing, although it takes big telescopes on the ground and in space to see most of the changes. Today, those instruments reveal new supernova explosions every night, in galaxies far beyond our own.



Supernova
By Or Graur
MIT Press; 240 pages, $16.95
mitpress.mit.edu/books/supernova

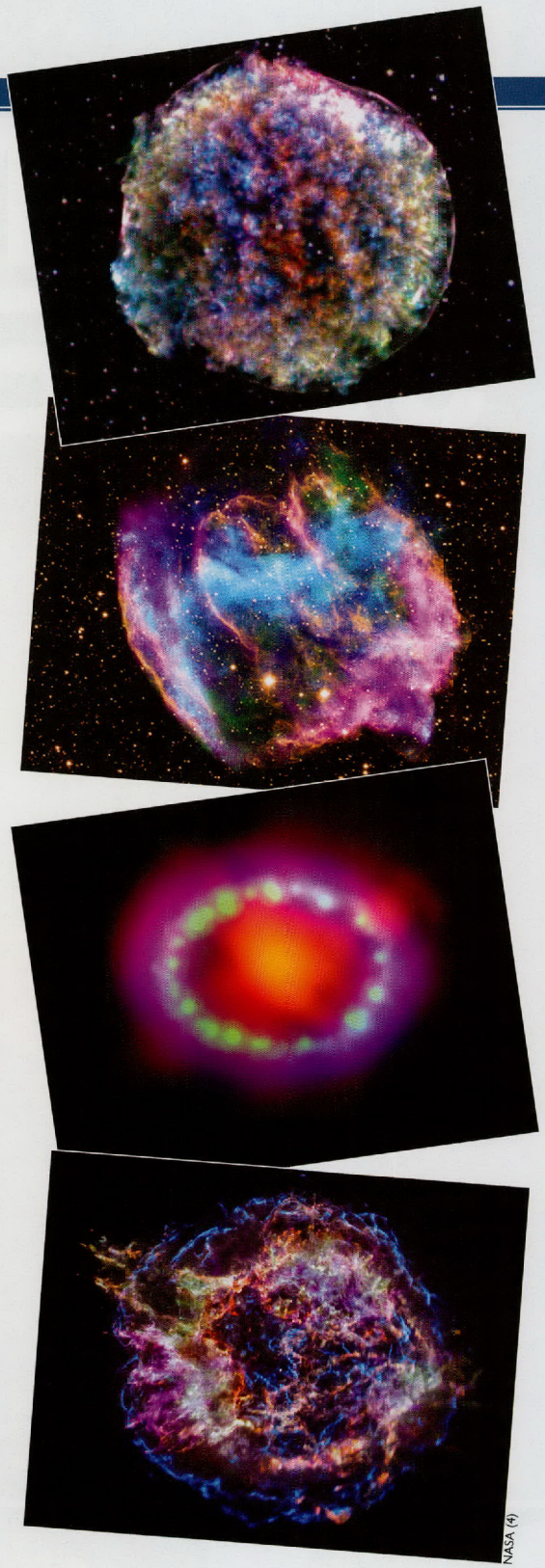
The book is sprinkled with fun facts. For example, a supernova emits more light in its first month than all of the billions of stars in its host galaxy combined. And every second, about 70 stars explode as supernovas somewhere in the universe (who knew?).

Supernovas and their progenitor stars also play key roles in the chemistry of the universe. They create many of the elements heavier than hydrogen and helium, the lightest and simplest elements, and disperse them into space, where they can be incorporated into new stars, planets, and perhaps living organisms.

The author asserts that we owe our existence to supernovae (without them, there would be no calcium for our bones or iron for our blood, for example). Yet a supernova may eventually be the death of us. One likely caused a mass extinction of marine life about 2.6 million years ago. Graur notes that we shouldn't worry too much, though, given the vastness of space, how close a supernova would have to be, and the million- to billion-year timescales of the Sun's motion and life cycles of the stars it encounters. A simulation of the Sun's future orbit and the evolution of the stars it will pass suggest we probably are safe for millions of years.

Scientists use supernovae to study other astrophysical phenomena, measure distances and the expansion of the universe, calculate its age, and to help answer other burning questions. Those answers may come more quickly with the next generation of telescopes, such as the Giant Magellan Telescope and the Rubin Observatory Legacy Survey of Space and Time (LSST). The largest astronomical survey ever attempted, LSST is expected to discover hundreds of supernovas every night—revealing many more secrets of these powerful stellar deaths.

Melissa Gaskill



NASA (4)

Supernova explosions create colorful shells that can glow for tens of thousands of years. From top: Tycho's Supernova, seen in 1572, showed that the universe can change; the center of this supernova remnant may contain a black hole; Supernova 1987a, in a companion galaxy to the Milky Way, was the brightest supernova visible from Earth in four centuries; an X-ray image of Cassiopeia A shows expanding shells of gas and dust.

COSMIC JEWELS

MANY OF THE GEMSTONES THAT ADORN THE NECKS AND FINGERS OF PEOPLE AROUND THE WORLD MAY HAVE BEEN FORGED FAR BEYOND PLANET EARTH, OR BY THE IMPACTS OF GIANT SPACE ROCKS

BY NICK D'ALTO

A small asteroid or comet explodes above Earth's surface in this artist's concept. Such explosions could create some cosmic gems. Below, from left: A moldavite; the yellow scarab in this pectoral worn by Egypt's Tutankhamun is a tektite; a magnified moissanite; carbonado diamondites (the one at top is one-half inch long and is five carats).

Some truths about the cosmos are literally gems—like the ones that sparkle in a jewelry display cabinet. That's because a host of rare and precious stones that adorn breathtaking necklaces and exquisite rings have exciting astronomical stories to tell. The stories are about Earth as a planet, its travels through the Milky Way Galaxy, and about places beyond our world. Some of the jewels that bring us these tales were carried here from outside Earth, while others were created here by objects from space.

The kinds of gems that scientists study in these pursuits may not always twinkle, like the ones from Cartier or Harry Winston. Nor are they set in gold. Yet the cosmic jewelry case is a dazzling one.

PERIDOTS: REVEALING HOW PLANETS ARE BORN

An Argentine farmer in the Patagonian village of Esquel unearthed a 1,500-pound (2,500-kg) meteorite, which bears that town's name, while digging an irrigation ditch in the 1950s. Today, a section of the meteorite on display at the American Museum of Natural History in New York reveals a kind of stained glass window of translucent green mineral, suspended in an intricate web of iron.

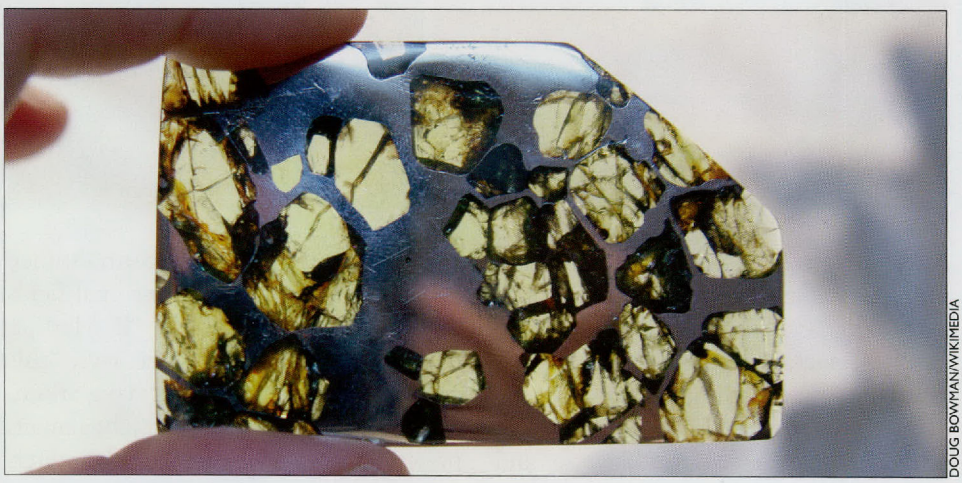
"What we have here is a small fragment of another world," says Denton Ebel, the museum's curator of meteorites. The shiny, olive-green mineral trapped within the iron is olivine, which contains magnesium and iron. The most transparent bits of it contain higher proportions of magnesium, which, to a gemologist, would make these pieces of gem quality. Such stones are known as peridots.

Peridots have been mined from naturally occurring terrestrial deposits since ancient times. Cleopatra's crown is said to have held some, and jewelry made from Earth-mined peridots remains popular today—it is the birthstone for August.

The much rarer extraterrestrial kind arrive inside meteorites known as pallasites, which are made of rock and iron. "Meteorites are broken pieces of celestial bodies," Ebel says. Iron meteorites derive from a body's metallic core, while stony ones come from the rocky mantle or crust. "Rare stony-irons show attributes of both mantle and core," Ebel says.

Those are the same layers we would see if we could slice into our own planet. Meteorites such as the Esquel date to the chaotic period when planetary bodies were still worlds in formation, massing together and breaking apart. As a result, they contain materials from different parent bodies. "What we're seeing here dates to very early in the solar system, making these meteorites, and everything inside them, clues to the histories of these early planetary bodies," says Ebel. "For example, how quickly did these planetesimals begin to [separate into layers]? And how quickly did they cool?"

On Earth, peridot occurs at a greater depth than almost any gem except diamond, reaching the surface through volcanoes or the motions of Earth's crust. Yet for alien peridots like the ones in the Esquel meteorite, the process of liberation would have been more extreme, occurring when massive collisions between newly forming planets scattered the resulting debris into space. That makes these gems glistening evidence of the frenetic ways in which planets are (or aren't) born.



DOUG BOWMAN/WIKIMEDIA

A slice of the Esquel meteorite shows peridot crystals glued together by iron and nickle.

OPALS: IS (OR WAS) THERE LIFE ON MARS?

Beside many other wonders of the cosmos on display at London's Natural History Museum in South Kensington sits a chunk of the famed Nakhla meteorite. In 1911, a small asteroid exploded in the skies above the Egyptian settlement of El Nakhla el Bahariya (hence the meteorite's name). Many fragments slammed into the ground, and, at least in legend, one of them struck and killed a dog. "That story is well-known, but may not be true," says Martin Lee of the School of Geographical and Earth Sciences at the University of Glasgow.

Lee is using this space rock to help answer an age-old question: Was there ever life on Mars?

Detailed analysis of tiny bubbles inside the meteorite fragments revealed that their gases matched the chemistry of the Martian atmosphere, suggesting the original rock came from Mars. It formed about 1.3 billion years ago, when molten rock cooled and hardened. It was blasted into space about 11 million years ago, when a larger asteroid slammed into Mars, then circled the Sun until it collided with Earth.

Nakhla contains microscopic fire opals. Earthly versions of this gem, flashing brilliant sparks of red and orange, often adorn rings (western outlaw Butch Cassidy wore one). But for extraterrestrial

life, what's most important is that opals are water gems. They were produced as dissolved sand leached through rock.

Fully formed gems still contain traces of the water that made them—up to 30 percent by weight. "It's a very thin, grainy brown film," Lee says of the deposits within the 1.7-gram sample of Nakhla his team studied with a transmission electron microscope. "In it, we could see thin spheres of silicon, oxygen, and water, which is opal"—the first such gems ever found in a visitor from space.

"On Earth, opals form around hydrothermal vents and hot springs, like the Old Faithful geyser in Yellowstone Park," says Lee. Today, such locations contain rich ecosystems of microscopic life, and similar features billions of years ago could have been where life on Earth began. In fact, terrestrial opals occasionally contain fossils and other evidence of biological activity. Might opals from another planet have done likewise, and tell this tale as well?

Nakhla's opals provide clues. "The evidence of water we see here flowed on Mars when a large impactor struck the planet and melted crustal ice, bringing water to the surface," Lee says. "Such an impact would produce enough heat to last for thousands of years. Water flowed, and opals formed. This occurred about 600 million years ago. Of course, it isn't likely there would have been life on Mars to preserve that recently." (Current estimates place the most favorable period for Martian life several billion years ago, when the planet was much warmer and liquid surface water still flowed freely.) "However, finding opals does suggest a mechanism by which earlier life could have been preserved," Lee says.

A couple of decades ago, NASA researchers conducted detailed analyses of Nakhla fragments from the British Museum and London's Natural History Museum. As with other Mars meteorites they analyzed, the scientists discovered tiny structures that resembled fossilized bacteria, along with traces of chemical elements like those produced by bacteria in terrestrial rocks. They also found amino acids, which are the chemical building blocks of life. Most scientists, however, say it's likely that the life-suggesting chemistry was contamination from Earth.

The orbiting Mars Reconnaissance Orbiter has detected ancient opal fields on the Red Planet itself. "If Martian microbes once existed," Lee says, "this could be where they might have arisen, and where fossil microbes might remain preserved." That suggests that the search for opals can guide the search for evidence of ancient life on Mars.

MOISSANITES: OLDER THAN EARTH

When Nobel laureate Henri Moissan discovered chips of an unusual rock around Arizona's Meteor Crater, in 1893, he thought he'd found diamonds. Instead, he'd discovered a new mineral, which today bears his name: moissanite. Although it's chemically different, jagged, crystalline moissanite is quite diamond-like. And it's also among the hardest substances on Earth—or off it. Chips were scattered across the landscape when their parent asteroid slammed into Arizona 50,000 years ago, gouging the almost mile-wide impact crater.

From how long ago and how far away had these gems come? A surprising answer comes from the 220-pound (100-kg) Murchison meteorite, which holds microscopic moissanites as well. At an estimated seven billion years old, they may be about 2.5 billion years older than Earth and the rest of the solar system—the oldest objects on planet Earth.

Analysis reveals an origin outside the solar system, from around carbon-rich stars that are entering their final stages of life. That origin makes moissanite a glimpse into the path that stars like our Sun eventually follow, and earning this gem the nickname "stardust."

At the end of a Sun-like star's life, its core has been converted to carbon and oxygen. As the star dies, it expels some of this material, along with other elements created during its long lifetime, into space. Atoms and molecules link together to form solid grains of dust. That can include moissanites, which consist of carbon and silicon. Strong winds from the dying star push these grains out into the surrounding galaxy, where they may someday be incorporated into new stars or planets, or the rocky debris left over from planet formation. In this case, that included the

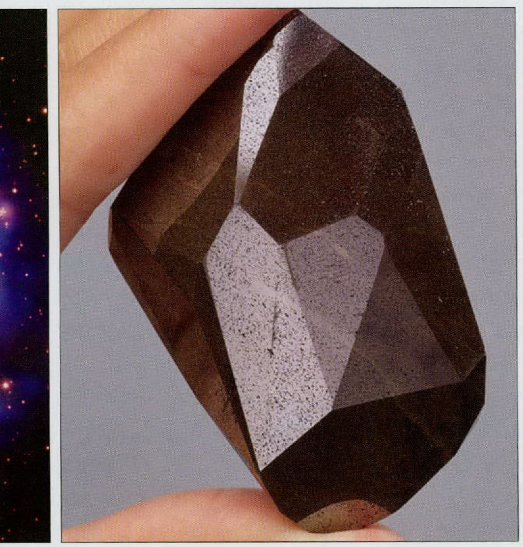
FROM LEFT: SMITHSONIAN INSTITUTION; USGS; NASA/ESO ET AL.; SOTHEBY'S

From left: A slice of the Nakhla meteorite; Meteor Crater in Arizona, where moissanites were discovered; the remnant of a supernova, an exploded star like that those that might have forged carbonados; the giant carbonado scheduled for auction in February.

asteroid that formed Meteor Crater and the smaller Murchison meteorite.

MOLDAVITES: INSTANT GEMS

Some cosmic jewels are born right here on Earth: worldly materials transformed by otherworldly events. They are pieces of glass forged when a large space rock slammed into Earth or exploded near the surface. Such an impact melts rock, dirt, and especially sand, blasting molten blobs high into the sky. As they descend, their passage through the atmosphere sculpts them into teardrops, cones, balls, or other aerodynamic shapes. As they cool and harden, they form natural glass, known



as tektites, tinted yellow, green, brown, or other colors by the minerals present in the rocks and dirt from which they formed.

Perhaps the most famous tektite is a yellow scarab adorning a pectoral worn by Egypt's young King Tutankhamun. It was carved from a piece of Libyan Desert Glass, which formed about 29 million years ago.

Most tektites are distributed across large areas, known as strewn fields. Each field contains the remnants of a single impact, and its tektites are named for the region in which they're found. Large strewnfields cover parts of Africa, North America, central Europe, and Australia and surrounding regions of Asia.

The European tektites are known as moldavites, says Research Geologist Cari Corrigan of the Smithsonian's National Museum of Natural History. About 15 million years ago, an asteroid struck today's eastern Germany, gouging the Nördlinger Ries impact crater (which served as a training site for Apollo 14 astronauts, who were headed for a similar crater on the Moon). The impact blasted molten rock up to 280 miles (450 km) away, across the modern-day Czech Republic (moldavites are named for Moldau, a Czech river where the first samples were found), as well as Germany and Austria.

Moldavites, which are olive green or brownish green, exhibit the bubbles and flow markings of glass that was churned as it cooled. Once parts of the Bavarian countryside, these amorphous chunks now seem like pieces of an alien world. "It's terrestrial rock that's been melted and reformed," Corrigan says. "In some moldavites, you can see how their shapes formed as the still-molten globs were spinning in the air. ... Moldavites are considered 'mineraloids' because they lack a mineral's crystal structure." They cooled so rapidly that they didn't have time to form the organized structure of crystals. That makes each gem a snapshot in time, recording a brief, cataclysmic Earth event.

The European strewn field yields a seemingly endless supply of these stones—at least 275 tons of them so far. Higher quality moldavites, which are more translucent than run-of-the-mill samples and display an interior pattern that looks like a fern, have been popular gemstones for centuries (early wearers considered moldavite a good-luck charm), and every piece derives from this same cosmic episode. What a difference a few seconds can make.

CARBONADOS: FROM WHERE?

In January, Sotheby's announced the pending auction in Dubai of an extraordinary stone: a black diamond weighing 555.55 carats. Expected sale price: $6.8 million. Possible source: an exploding star.

The diamond is a carbonado. The name is Portuguese for charcoal, conveyed because this gem is extremely dark. If that sounds contradictory, these chips are undiamond-like in other ways as well. For example, they are never found in the types of rocks or in the locations where traditional diamonds are mined. Harder than typical diamonds, they find common industrial uses; carbonado drill bits were used to construct the Panama Canal, for example.

It's possible that carbonados (or at least some of them) were produced as other diamonds were, under the extreme heat and pressure found deep below Earth's surface. But some scientists have suggested a cosmic origin. Carbonados could have formed in an asteroid impact. The impact heated and squeezed the rock below it, fusing carbon and other substances (forming impurities that account for the dark color).

An idea that's gained ground in recent years, however, says the diamonds came from a dying star about 3.8 billion years ago. Shockwaves from a supernova, for example, could have compressed bits of carbon created inside the star to form solid chunks of diamond. Some of the diamonds coalesced to form an asteroid, which rammed into Earth perhaps billions of years later, spewing chips across a wide area. The idea is supported by chemical and mineral analyses of the carbonados. Some contain osbornite, a mineral found only in meteorites, for example, and ratios of different types of carbon and nitrogen atoms suggest an origin off Earth as well.

One of the largest cut and faceted carbonados, the Spirit of Grisogono, measures a staggering 312 carats—about seven times the Hope Diamond. Surely a gem, no matter its origin.

Engineer and science writer Nick D'Alto is a frequent contributor to StarDate.

RESOURCES

INTERNET

Gems from Space
geology.com/gemstones/gems-from-space

Peridot
www.gia.edu/peridot

Opals on Mars
www.nhm.ac.uk/discover/news/2015/july/opals-on-mars-could-hold-record-ancient-life.html

Moldavite
www.gemsociety.org/article/moldavite-jewelry-and-gemstone-information

Carbonados
www.pbs.org/wgbh/nova/diamond/sky.html

by Damond Benningfield and Melissa Gaskill

Flipping the Switches

Engineers prepare Webb; other explorers take flight; Moon mission is nigh

With James Webb Space Telescope's (JWST) giant mirror and sunshield deployed and the spacecraft on station, engineers are beginning the tedious process of aligning its mirror segments and switching on its instruments. The process is expected to be completed about six months after JWST's Christmas Day launch, allowing the largest, most complicated, and most expensive space telescope in history to begin studying the universe.

The telescope is designed to discover how the first stars and galaxies took shape. It also will examine exoplanets, revealing details about their atmospheres and their suitability for life; probe the evolution of stars and galaxies; and study the bodies in our own solar system.

JWST reached its observing location on January 24. It is orbiting a point in space almost one million miles (1.5 million km) behind Earth as seen from the Sun. Known as L2, it will offer a wide view of the universe and help keep the telescope's infrared detectors cooled to hundreds of degrees below zero.

The 6.5-meter (21.3-foot) primary mirror consists of 18 hexagonal segments, which must be aligned with a precision of less than a millionth of an inch—a process that is expected to take weeks to complete.

ALREADY AT WORK

A much smaller space telescope began its scientific mission on January 11—a three-week look at Cassiopeia A, the remnant of an exploded star.

Imaging X-ray Polarimetry Explorer (IXPE) was launched December 9. It consists of three identical X-ray telescopes. X-rays are produced by some of the most powerful objects and phenomena in the universe. IXPE's targets include the stellar corpses known as pulsars, disks of hot gas around black holes, and the glowing remains of supernovas. It has 33 scheduled targets for its first year of operations, plus five weeks of open time to examine objects that flare into view, such as supernovas and gamma-ray bursts.

A SLIGHT HICCUP

Another explorer, Lucy, faced a slightly rockier start to its mission. Two days after its October 16 launch, engineers discovered that one of its electricity-generating solar panels did not fully deploy. It was producing less than full power, but enough to support the mission—flying past several Trojan asteroids, which share an orbit with Jupiter, the largest planet in the solar system. It will fly past Earth twice to gain gravitational boosts, and swing past an asteroid in the main belt, between Mars and Jupiter, before its first Trojan encounter, in 2027.

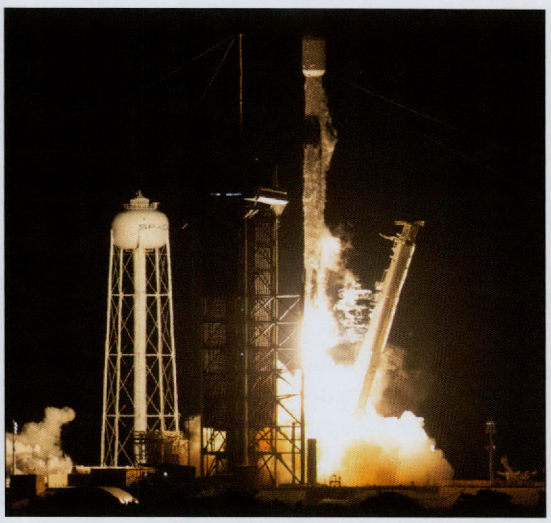
ALMOST READY

As NASA breathed a small sigh of relief over the successful launch and deployment of JWST, it began holding its breath for its next multi-billion-dollar launch: Artemis 1, the first test flight of its giant new Moon rocket and the spacecraft that will ferry astronauts to lunar orbit. A launch rehearsal was scheduled for late February, with launch to follow no earlier than late March.

Space Launch System (SLS) is the most powerful American rocket since the Saturn V, which carried Apollo astronauts to the Moon. It will be topped by the Orion spacecraft, although it won't carry a crew on this flight. During its 23-day flight it's scheduled to orbit the Moon, then return to Earth.

SLS also will carry about 10 cubesats—suitcase-sized spacecraft that will scatter through the inner solar system to study the Moon, asteroids, the Sun, and other targets. If the first Artemis flight succeeds, the second will send astronauts into lunar orbit no earlier than late 2023, while the third will land the first people on the Moon since the final Apollo mission, in 1972. **DB**

Three explorers head for space. From left: JWST, IXPE, Lucy.



NASA (3)

An artist's concept shows a 'rogue' planet floating through its stellar nursery.

NOIRLAB/NSF/AURA/J. DA SILVA

Dozens of Rogue Planets Roam Through the Milky Way

A recent survey discovered between 70 and 170 free-floating planets, which wander through space without a parent star, nearly doubling the number of known "rogue" planets. The newly discovered worlds reside in the Upper Scorpius OB association, a stellar nursery that is about 420 light-years from Earth.

The new planets are only a few million years old, so they are still hot enough to glow at infrared wavelengths. That makes them directly detectable by sensitive cameras on large telescopes. Researchers used tens of thousands of observations, along with about 20 years of archival data from observatories on the ground and in space, to measure motions, colors, and brightnesses of tens of millions of sources to identify the planets.

The discovery also sheds light on the origin of free-floating planets. They could have formed from the collapse of clouds of gas and dust that were too small to form stars, or they could have been kicked out of their original star systems by gravitational encounters with other planets. If the latter theory is correct, the researchers say there could be even more free-floating planets out there, including many the size of Earth. **MG**

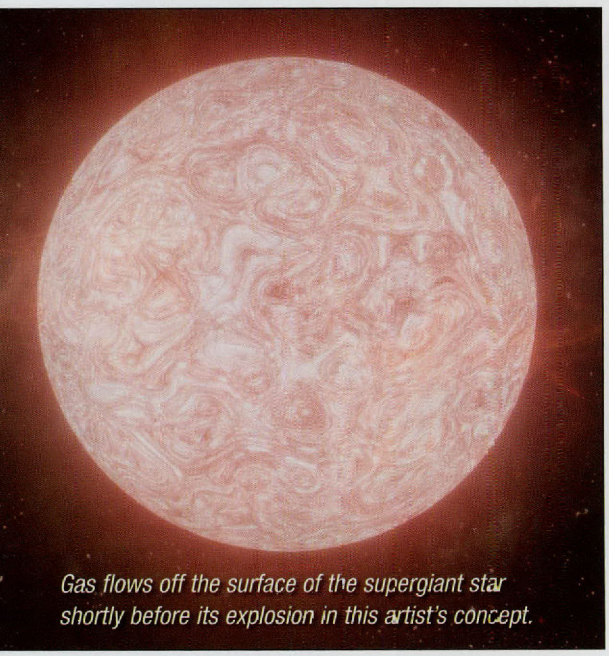
Feeling the Pull

All life on Earth experiences the tides created by the gravitational pull of the Sun and Moon, according to a study published in *Journal of Experimental Botany*.

The study, by researchers at the University of Campinas in Brazil and the University of Bristol in England, included an extensive review of the literature and an analysis of the data from previously published studies on the swimming activity of small shell-less crustaceans known as isopods, the reproductive cycles in coral, and growth modulation in sunflower seedlings. The researchers also conducted their own investigations on the latter.

Researchers found that, in the absence of other environmental influences, such as daylight or temperature, organisms arrange their cyclical behavior around local tides. For example, when crustaceans are removed from their natural habitats they continue to follow cycles that match the timing of lunar and solar tides back at their home sites.

Other studies have found that humans kept in the dark tend to establish a cyclical fluctuation lasting 24.4 to 24.8 hours, in harmony with the lunar cycle. This schedule affects sleep and wakefulness, meal times, and other metabolic functions. **MG**



Gas flows off the surface of the supergiant star shortly before its explosion in this artist's concept.

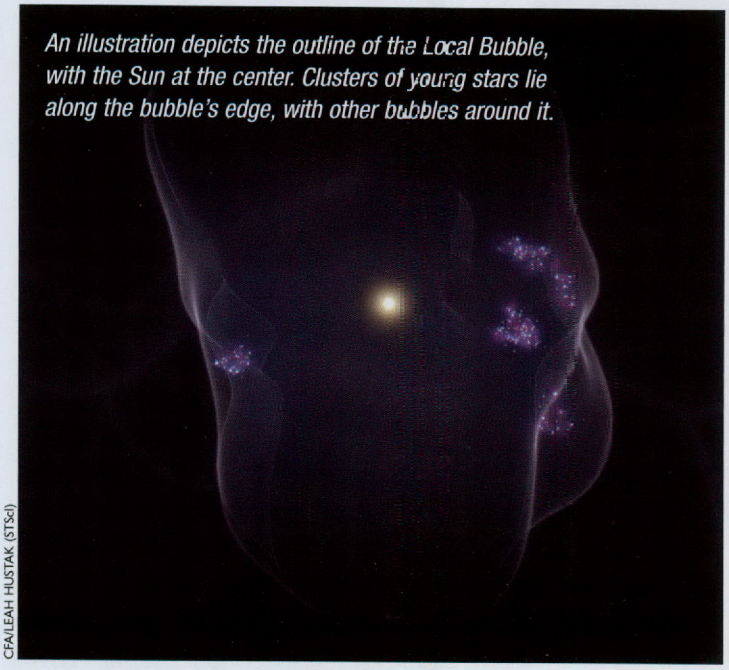
Watching the Death of a Supernova

A team of astronomers imaged in real time the last 130 days of a red supergiant star, whose life ended with a titanic explosion known as a supernova. It was the first time that astronomers had seen the build-up to a supernova blast in such detail.

Based on earlier observations, red supergiants, which are many times the size and mass of the Sun, were thought to be relatively quiet before their deaths. The radiation detected in this star's final day, however, suggests that at least some of them undergo significant internal changes that result in the ejection of gas shortly before they collapse.

The University of Hawaii Institute for Astronomy Pan-STARRS first detected the doomed star in the summer of 2020, in the galaxy NGC 3751, which is about 120 million light-years from Earth. The star exploded in the fall. The team used the W.M. Keck Observatory in Hawaii to capture the powerful flash, known as supernova 2020tlf, and continued to monitor it after the explosion. Pre-explosion observations showed that the star was surrounded by a dense cloud of gas and dust, suggesting that it expelled a great deal of material in its final months.

The star was 10 times more massive than the Sun. At the end of its life, it could no longer produce nuclear reactions in its core. The core collapsed to form a neutron star. The layers around the core fell inward, then rebounded, blasting into space and creating the supernova. **MG**



An illustration depicts the outline of the Local Bubble, with the Sun at the center. Clusters of young stars lie along the bubble's edge, with other bubbles around it.

CFA/LEAH HUSTAK (STScI)

Supernova Blasts Give Birth to Nearby Stars

A new study says that all of the young stars near the Sun share common "parents": supernovas that created a vast and expanding bubble in space. Known as the Local Bubble, it's a thousand light-years wide. The Sun is zipping through it, and currently sits right at the middle. Astronomers have known about the bubble for decades, but this is the first study to link all nearby star formation with its expansion.

Astronomers obtained precise locations of young stars within a few hundred light-years of Earth from Gaia, a space telescope that is mapping more than one billion stars in the Milky Way Galaxy. They then used data visualization software to plot the locations of the stars. "We find that, in the present day, almost every single nearby young star lies on the surface of the Local Bubble," said Catherine Zucker of the Space Telescope Science Institute during a January press conference hosted by the American Astronomical Society.

The bubble began forming about 14 million years ago, when a star exploded as a supernova. The shockwave, along with those of at least 14 more explosions, cleared out a vast cavity in the surrounding interstellar material. "As this bubble expands, it sweeps up clouds of gas and dust on its surface sort of like a snowplow can sweep up snow," Zucker said. As the material piles up, some of it collapses to form new stars, including the ones measured by Gaia.

Our solar system entered the Local Bubble about five million years ago, according to the study. That agrees with earlier studies that found a radioactive form of iron produced by supernovas in five-million-year-old ocean sediments, suggesting they fell to Earth as the solar system entered the bubble.

Today, the solar system is near the center of the bubble. It will remain inside the bubble, which is continuing to expand, for several million years longer. **DB**

Fountain of Youth for Milky Way's Heart

'Heavy metal' cuts ages of stars in galaxy's largest cluster

The heart of the Milky Way is on a youth kick. A recent study found that a giant star cluster at the center of the galaxy is only about half as old as suggested by earlier research. "We found that the center of our galaxy may be surprisingly younger than people expected," said Zhuo Chen, a member of the research team at UCLA, during a January press conference.

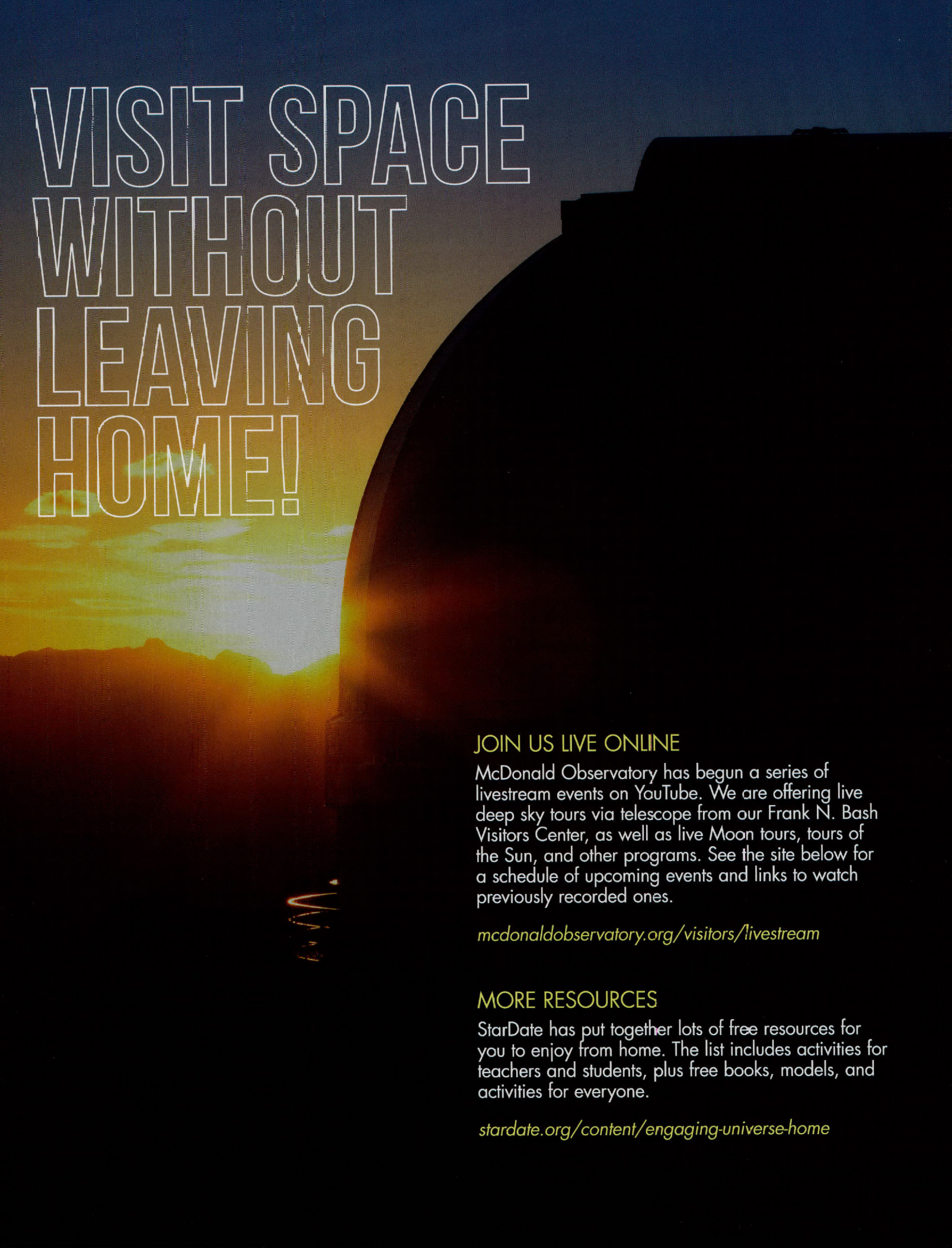
The new work measured the chemical abundances of many of the stars in the cluster, which is the largest in the entire galaxy. Astronomers found that most of the stars in the cluster contain large proportions of "metals"—anything heavier than hydrogen and helium, the lightest and simplest elements.

Metals affect a star's brightness, which is one of the factors used to calculate its age. Earlier studies assumed all the stars in the cluster had the same proportions of these elements as the Sun, which resulted in a cluster age of about 7.1 billion years. Incorporating the new measurements lowered the age to about four billion years, with some stars as young as one billion years.

The new age estimate should help astronomers better understand how the cluster's formation relates to the supermassive black hole at the center of the galaxy, and the evolution of the galactic bulge, which surrounds the cluster and black hole, Chen said. **DB**

NASA/ESA

Hubble Space Telescope view of the Milky Way's crowded heart.



JOIN US LIVE ONLINE

McDonald Observatory has begun a series of livestream events on YouTube. We are offering live deep sky tours via telescope from our Frank N. Bash Visitors Center, as well as live Moon tours, tours of the Sun, and other programs. See the site below for a schedule of upcoming events and links to watch previously recorded ones.

mcdonaldobservatory.org/visitors/livestream

MORE RESOURCES

StarDate has put together lots of free resources for you to enjoy from home. The list includes activities for teachers and students, plus free books, models, and activities for everyone.

stardate.org/content/engaging-universe-home

Ice coats part of the floor and rim of a crater on Mars in this view from ExoMars Trace Gas Orbiter, a joint European and Russian mission. The crater is about 2.5 miles (4 km) in diameter, and is in Mars's north polar region. The darker material is volcanic rock, while the redder areas are coated with powdery dust.

ESA/ROSCOSMOS/CASSIS