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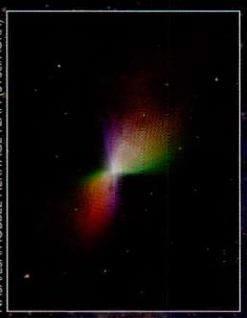
Departments



NASA/ESA/HUBBLE HERITAGE TEAM (STScI/AURA)

On The Cover

Gas blows away from a dying star, forming the Boomerang Nebula, in this false-color Hubble Space Telescope image. The nebula contains the coldest spot ever measured in space. For more astronomical superlatives, see page 16.

This Page

The starbirthing nebula NGC 346, seen here by Hubble Space Telescope, is home to many infant stars that have yet to start burning hydrogen in their cores. Some of these stars have only half the mass of the Sun.

Coming Up

In our September/October issue, we'll bring you up to date on the mysterious class of black holes that are heavier than an exploded star but lighter than a galactic heart. We'll also introduce you to a group of amateur astronomers that hunts for lost satellites, sometimes helping space agencies re-establish contact with them.

NASA/ESA/A. NOTA(STScI)

MERLIN

Dear Merlin,

Could you please help me out a little by telling me about Orion? How wide is Orion's Belt, for example? If all the stars were the same distance from Earth, how wide would the Belt be — two light-years, three?

Terry J. Weidner
Port Trevorton, Pennsylvania

Orion is Merlin's favorite constellation, so he is glad to help you out. Not only is the constellation big, bright, and beautiful, it contains some of the most impressive stars in the Milky Way galaxy. And many of those stars are fated to explode as supernovae, including its two brightest stars, orange Betelgeuse and blue-white Rigel.

The stars of Orion's Belt are just as impressive. They look fainter only because they are farther away. Just how far is the subject of continued debate among astronomers. Estimates for each star vary by hundreds of light-years, making it tough to pin down their details.

From east to west (left to right, as observed from the northern hemisphere), the stars of the Belt are Alnitak, Alnilam, and Mintaka.

Alnitak is a system of at least three stars. The primary star is class O, which encompasses the hottest and brightest of all stars. In fact, it's the brightest O star visible from Earth, shining at second magnitude. At visible wavelengths, it's more than 20,000 times brighter than the Sun. When you incorporate its ultraviolet light, though, it shines perhaps a quarter of a million times brighter than the Sun.

Alnilam consists of a single known star, which could be the most impressive member of the Belt. Estimates of its distance, however, vary by about 600 light-years. One recent study says it's 2,000 light-years away. If so, it's more than 40 times as massive as the Sun, and more than 500,000 times brighter.

Mintaka, like Alnitak, is at least a triple system, and recent estimates place it at roughly the same distance — about 1,200 light-years. Its main star is also far bigger, heavier, and brighter than the Sun. And like the other stars of the Belt, it is only a few million years old. Yet the primary star of each system is nearing the end of its life. Within a few million years more, each star probably will explode as a supernova, leaving behind only a neutron star or a black hole.

Since the distances to the stars are so uncertain, it's tough to calculate how far apart they are. However, if they all lined up at a distance of 1,200 light-years, Orion's Belt would span about 60 light-years.

Orion will be lost in the Sun's glare for much of July, but will be low in the east in early twilight by month's end. It will climb into better view throughout August.

Dear Merlin,

I have a follow-up to a question printed in the September/October StarDate. *During a magnetic field reversal, would a coronal mass ejection, or perhaps a series of them, lead to a mass extinction event?*

Jack Mathis
Mountainside, New Jersey

Not likely. There's no evidence of a solar influence on any of the mass extinction events discovered so far.

A weakened magnetic field would let more solar and cosmic radiation enter the atmosphere, but the atmosphere would absorb most of it. The radiation that hit the surface could lead to more instances of cancer and other effects, perhaps including the demise of especially sensitive or endangered species. But the Sun would have to be much more active than is shown in the geologic record (or that we observe today), and sustain that activity for a long time, to threaten mass extinctions.

Dear Merlin,

With the upcoming close approach of Mars, the usual hoax, of Mars having the same angular diameter as the Moon, is making its "orbit" through the Internet again. If such a thing were possible, how far would Mars have to be from Earth to have the same angular diameter as the Moon, and what would be the gravitational consequences?

Fred Zimmerman
Canoga Park, California

Since Mars is almost twice the diameter of the Moon, it would have to zoom in to about twice the Earth-Moon distance to appear as big as the Moon, or about 480,000 miles. (Compare that to Mars' closest approach to Earth, in late July, at about 36 million miles.)

Among the consequences if Mars orbited Earth at that distance, the Moon would be kicked into a different orbit (if not into Earth or out into space), the angle of Earth's axis might change, and there would be much higher tides.

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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SEEDS of LIFE

Scientists investigate whether meteorite impacts delivered life to Earth or elsewhere

By Leila Belkora

KATERYNA_KON/FOTOLIA

Queenie Chan, a post-doctoral researcher at the Open University in the United Kingdom, writes about some far-out-sounding things. A recent research paper by Chan and others discusses a meteorite named Zag, studded with tiny blue crystals; a phenomenon called the YORP effect; and state-of-the-art laboratory techniques like "quadrupole time-of-flight hybrid mass spectrometry." By the time you get to the end, you might not be surprised to see a reference to Santraginus V, a fictional planet in Douglas Adams' 1979 novel *The Hitchhiker's Guide to the Galaxy*.

Yet Chan's research, published in January, is a serious investigation on a topic that excites both science fiction writers *and* scientists: What clues do meteorites hold about distant worlds that may harbor life, or even conditions favorable to the emergence of life?

Even though Zag — named after the mountain it hit in Morocco in 1998 — carried no life, scientists know that meteorites that bombarded early Earth contributed significantly to its complex chemistry. Those meteor-delivered substances, in turn, may have boosted the emergence of life.

The idea that life on our planet could be tied to extraterrestrial matter goes back a long way. In an 1871 lecture to the British Association for the Advancement of Science, William Thomson (later given the title Lord Kelvin, namesake of the Kelvin temperature scale), astonished his audience by arguing for such a connection. He took it for granted that plant and animal life was widespread in the cosmos, and had existed "from time immemorial."

Thomson said it was probable that there were "countless seed-bearing meteoric stones moving about through space," and that a meteorite landing on a newly formed Earth could lead to the planet being covered with vegetation. Indeed, Thomson noted, if Earth were to collide with another planetary body, fragments of our planet — containing its plant and animal seeds — would be similarly dispersed through space.

Many of Thomson's peers took his remarks to be, in the words of one biographer, "a huge scientific joke." The public learned of his startling idea through spirited reactions in newspapers and magazines. The popular satirical weekly *Punch* ran humorous poems about the meteoric hypothesis for a few weeks after. Some scientists pointed out that Thomson's hypothesis did nothing to clarify the question of the origin of life on Earth, but simply moved it to distant worlds, making it impossible to investigate scientifically. Others doubted that living organisms could survive a long journey through space.

Yet an interesting and valid question remained about meteorites' importance. While most are small, Earth is constantly pelted by them. Over eons, meteorites have contributed significantly to the planet's mass and composition (currently, they add 20,000 tons per year).

In the 1830s, Swedish chemist Jacob Berzelius showed that some meteorites carry carbon-rich compounds to Earth. Are they carrying anything significant to the development of life?

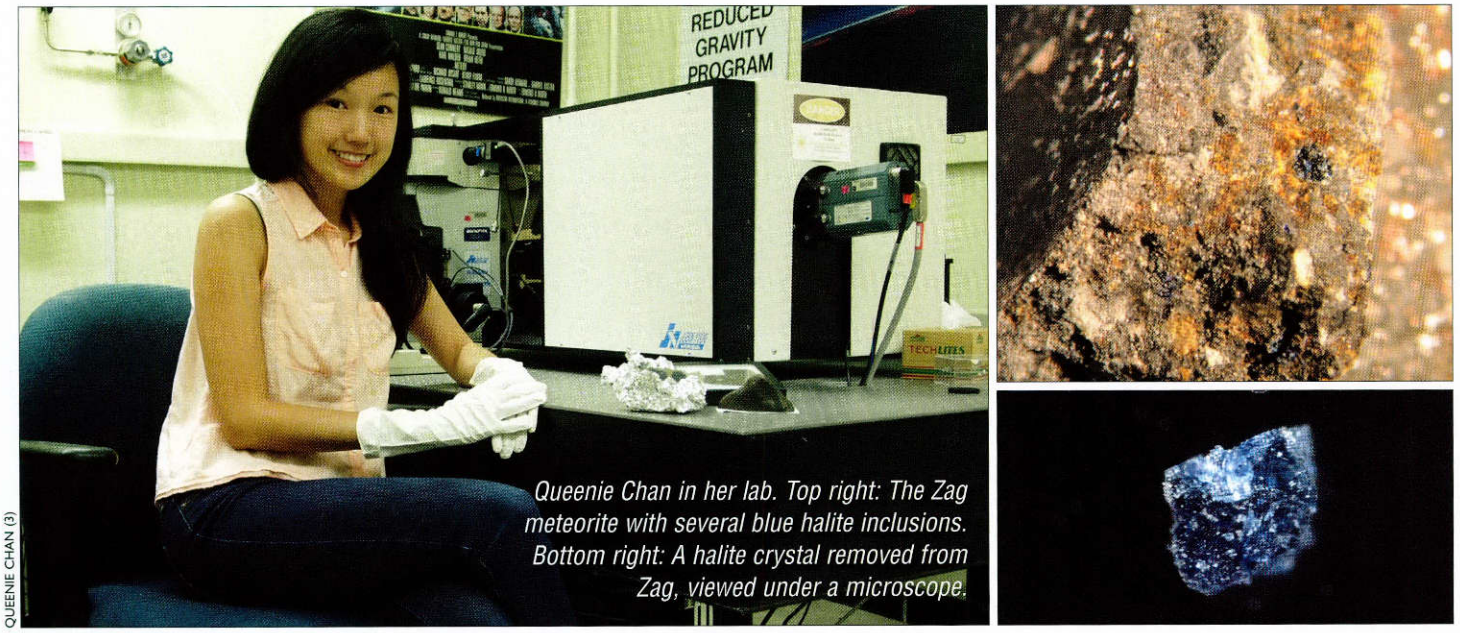
In the early 20th century, Nobel Prize-winning chemist Svante Arrhenius answered some of Kelvin's critics. He suggested a way that "germs of organic life" could survive a trip between Earth and other solar system bodies, calculating that something the size of a single bacterial spore could be carried along by small dust particles propelled by the solar wind. In this way, the tiny organic messengers would move much more quickly than larger meteoroids.

With this reduced travel time, Arrhenius thought the spores might survive. In popular books and in a 1907 article he contributed to *Scientific American*, the idea of seeds of life spreading through the cosmos became known as the theory of panspermy, or panspermia.

As the decades passed, researchers interested in the question of how life began on Earth — and potentially elsewhere — took their investigations in different directions. Biochemists explored the question of how to rec-

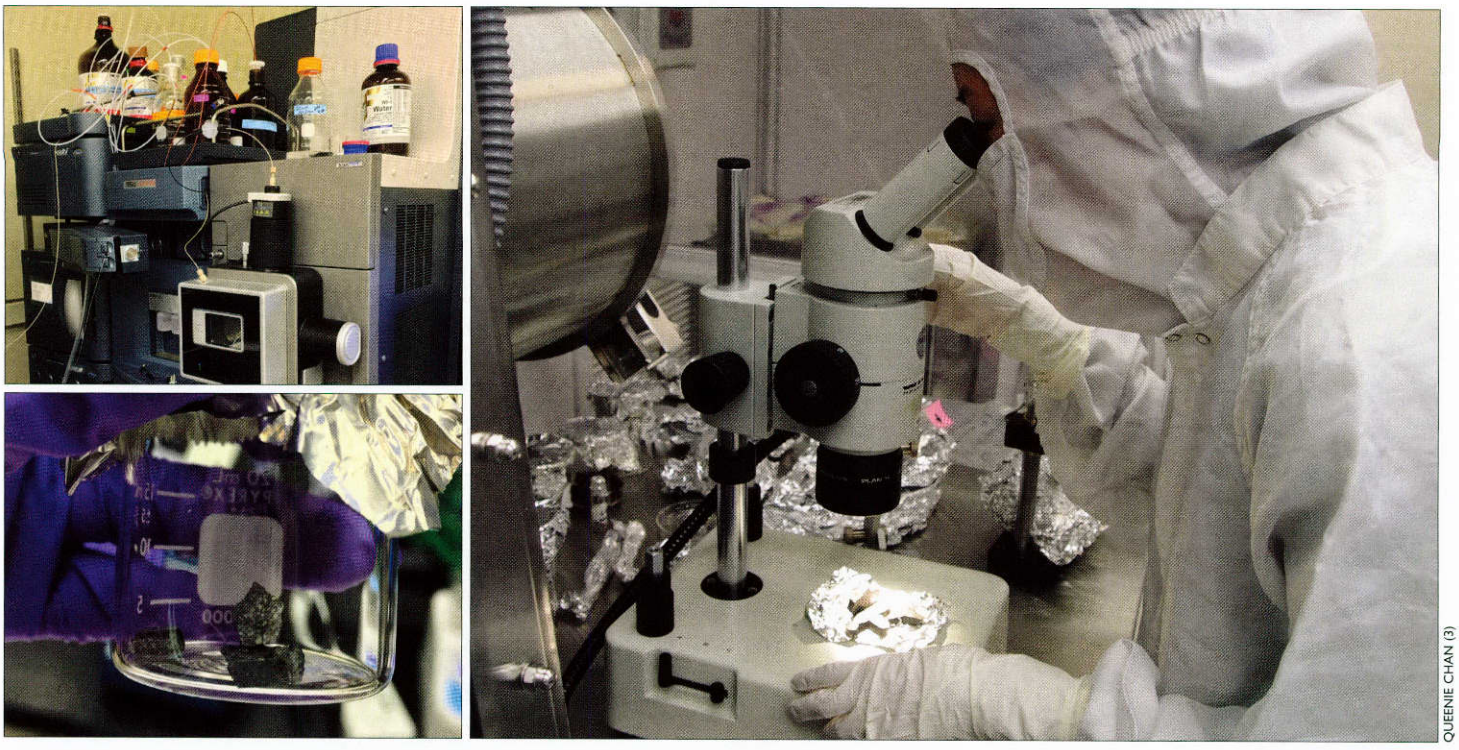
What is Life?

The gap between complex but totally lifeless molecules on one hand, and the simplest living things (probably single-celled organisms), is a huge and mysterious one. Much astrobiology research is devoted to exploring the naturally occurring chemical reactions that might help explain how we got from one to the other. Some scientists believe there may be gradations of living-ness rather than a clear dichotomy between life and non-life. Astrobiologists Carol Cleland and Christopher Chyba point out that the difficulties we face today in trying to define "life" may be similar to those faced by 18th-century scientists trying to define water before anyone knew about molecules. "The controversy over life's definition is inescapable as long as we lack a general theory of the nature of living systems and their emergence from the physical world," they wrote. In the meantime, many scientists rely on a working definition of life as "a self-sustained chemical system capable of undergoing Darwinian evolution." **LB**



Queenie Chan in her lab. Top right: The Zag meteorite with several blue halite inclusions. Bottom right: A halite crystal removed from Zag, viewed under a microscope.

QUEENIE CHAN (3)



QUEENIE CHAN (3)

Above: Chan studies meteorites in a class-10 cleanroom to avoid contamination; Top left: an instrument used to analyze the amino acid content of meteorites. Bottom left: small chips from the Zag meteorite.

ognize primitive life at tiny scales. Some crystals, for example, might be mistaken for living organisms, because under the right conditions they move on their own in a fluid, merge, and break apart again. Other researchers experimented with different recipes for "primordial soup," a watery mix of compounds thought to have existed on the young Earth, to see if molecules associated with living organisms might arise there naturally. Other biologists tested the ability of viruses, bacteria, and fungal spores to survive conditions in space, including temperature extremes, cosmic radiation, and low gravity. Astrobiology developed as a new field, with conferences organized around topics like "What is Life?" and discussions of how to detect life on other planets.

In the 1950s, biochemists Stanley Miller and Harold Urey made a breakthrough. They tried to re-create primitive Earth conditions in a laboratory, zapping lightning-like electric pulses through a mixture of water, methane, ammonia, and hydrogen.

The result was astonishing: Amino acids (the building blocks of proteins) formed, along with other building blocks of cells, like carbohydrates and cell membranes. The result seemed "magical" at the time, astrobiologist Robert Hazen said. The experiment suggested that laboratory scientists might be able to investigate the chemical development of life itself.

As it turned out, though, Miller and Urey's recipe for "primordial soup" — their version of primitive Earth — did not match conditions we now know existed four billion years ago, just prior to the emergence of simple cells. That means their experiment has little bearing on understanding that time period.

However, they were the first to discover that making complex organic compounds, and even molecules forming the basis of DNA, isn't as hard as was thought. Since then, experiments have shown that a wide range of complex molecules containing carbon, hydrogen, oxygen, nitrogen, and phosphorus — key ingredients in biochemistry — naturally come together in space and on planetary bodies. Indeed, complex organic molecules must have formed in interstellar space billions of years before Earth existed.

The Monahans meteorite fell to Earth in 1998, not far from a group of children playing basketball in the small West Texas town of Monahans (about 130 miles northeast of McDonald Observatory). This meteorite and Zag were analyzed at the same time. Perhaps not surprisingly, given how widespread organic compounds are in space, both meteorites were found to contain a large number of different types of organic molecules.

What is amazing is how much scientists can learn from these meteorites. Even 19th-century advocates of panspermia theory like Lord Kelvin might be consoled to know that while modern researchers are not finding seeds or eggs in meteorites, they are finding molecules that are the building blocks of living systems, as well as indications of conditions on distant worlds favorable to life.

Queenie Chan and her team analyzed the Zag and Monahans meteorites and their blue crystals extensively, using advanced tools and techniques from NASA's Johnson Space Center, the Carnegie Institution of Washington, the Lawrence Berkeley National Laboratory, and, in Japan, the High Energy Accelerator Research Organization and the Japan Agency for Marine-Earth Science and Technology. They learned that Zag is a fragment of a body that was itself an amalgam of two different asteroids or planetesimals.

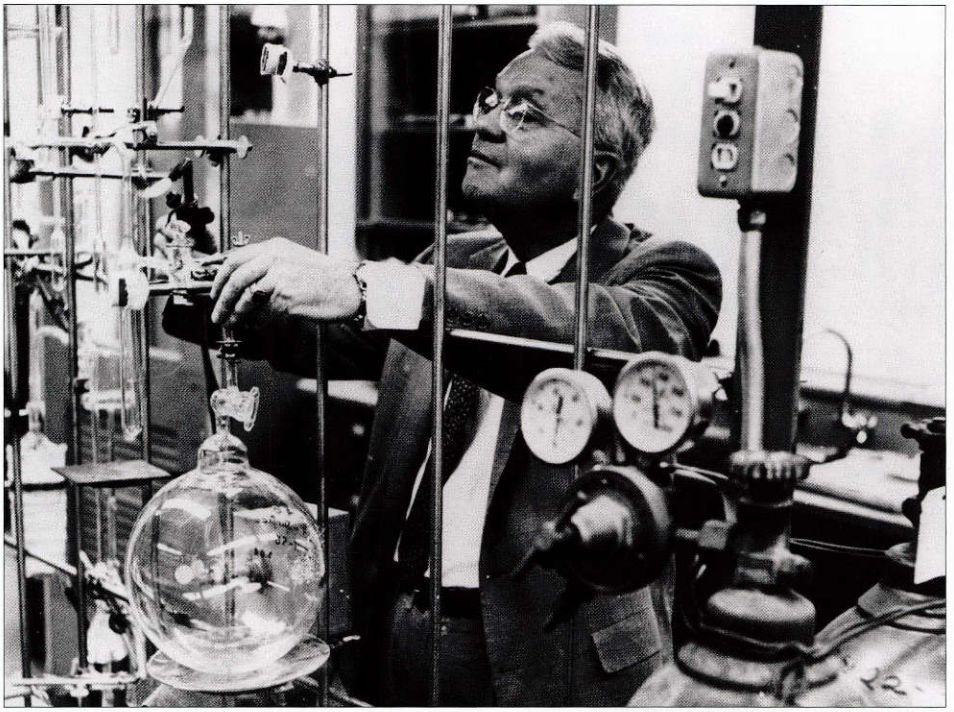
Cool Contents

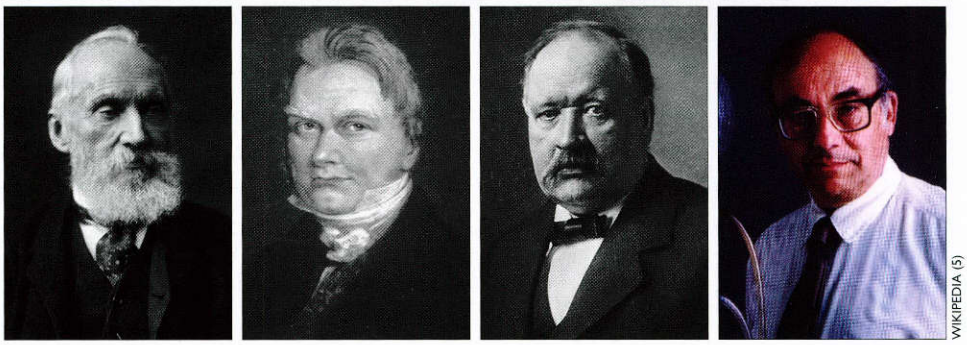
Modern techniques can uncover chemical compounds even if they occur in minute amounts — for instance, a couple of molecules of one particular type amid a billion others. When scientists inventory the contents of meteorites using such sensitive means, they find an astonishing variety of compounds. A 2010 study of the famous Murchison meteorite that landed in Australia in 1969 found that it contains, according to its authors, "tens of thousands of different molecular compositions and likely millions of diverse structures."

The list of organic (carbon-containing) compounds that have been found in meteorites includes not only the building blocks of proteins and DNA, but also hydrocarbons (like oil), alcohols, aldehydes, ketones (like nail-polish remover), carboxylic acids (like vinegar), amines (used in medicines like decongestants), and many more. No sure indications of living organisms have been found yet, but interstellar and interplanetary space has proven to be an impressive chemical laboratory. **LB**

WIKIPEDIA

A piece of the Murchison meteorite, seen in the National Museum of Natural History in Washington, D.C.





WIKIPEDIA (5)

Several scientists made strides that led to today's breakthroughs in the study of how life might spread through space. Some of these were (bottom, from left): in the Victorian era, British chemist William Thomson (Lord Kelvin) and Swedish chemist Jacob Berzelius; in the early 20th century, Swedish chemist Svante Arrhenius; and in the 1950s, American biochemists Harold Urey and Stanley Miller (top).

The bulk of Zag, which is classified as an "ordinary chondrite" meteorite, is similar to the asteroid Hebe. Hebe is thought to be the parent body of many stony meteorites found on Earth. It is a relatively large and dense asteroid orbiting the Sun within the main asteroid belt, between Mars and Jupiter.

The Hebe-like component of Zag — the "matrix" in which the crystals are embedded — contains minerals and compounds typical of its class of ordinary chondrites. It also contains a range of amino acids. It shows signs of having experienced physical shock and temperatures above the melting point of metals like magnesium and aluminum.

The second component of Zag — the component with the blue crystals — is quite different in composition. The crystals, which are just a millimeter or two in diameter, are mostly rock salt: potassium chloride or sodium chloride. Amino acids also are present in the crystals, as is argon gas. A previously published study of the argon in the Monahans meteorite's similar blue crystals indicated that they formed by the evaporation of water about 4.5 billion years ago, early in the formation of the solar system.

The crystals themselves hold microscopic surprises. They contain even smaller inclusions of brine — liquid water containing minerals. The brine droplets are on the scale of 1 to 10 microns, about the size of a red blood cell.

The crystals are delicate in the sense that they easily dissolve in humid conditions. Indeed, they are preserved

only in samples of Zag and Monahans that were stored under dry nitrogen gas soon after they were collected. The crystals had to have been formed and continuously maintained at temperatures between about 75 and 120 degrees Farrenheit (25-50 C). This is far less than the at least 1,100 degrees Fahrenheit (600 C) experienced at one time by the Hebe-like component of Zag. From this, the researchers deduce that the microscopic blue crystals landed on the Hebe-like material and became incorporated with it *after* the Hebe-like material had changed.

Where did these crystals come from? Chan and her colleagues were thrilled to find, from a detailed study of the minerals and organic solids in the brine droplets, that the brine inclusions are "almost identical" to those of the surface of Ceres, the largest object in the asteroid belt. Scientists know a lot about Ceres thanks to the Dawn mission, which entered orbit around Ceres in 2015 and is still there. Dawn has found suggestive evidence of past oceans and recent geological activity. "These halite crystals are the only available direct samples" from Ceres or a similar asteroid, Chan wrote.

Chan and her team's paper describes a possible sequence of events leading to the formation of Zag and its intriguing blue crystals: A parent body, probably Ceres, experienced hydrovolcanism — volcanic eruptions resulting from molten rock interacting violently with water. Various kinds of organic matter formed on the parent body from formaldehyde and ammonia acted upon by water. At the end of the major episodes of volcanic activity, about 4.5 billion years ago, surface water evaporated, leaving behind the rock salt crystals and their incorporated brines.

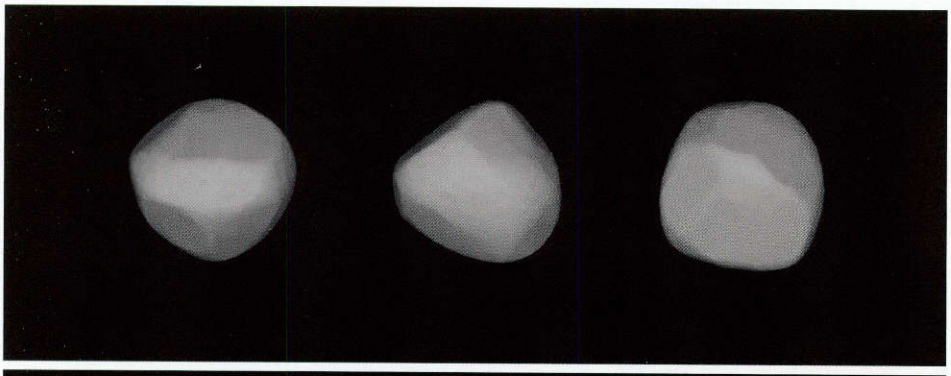
Later, further hydrovolcanism spewed inorganic stones and their surface layers of salts into space. Radiation from the young Sun acted on the salt crystals, leading to further chemical changes and the development of the bluish color.

Next, these salt-covered stones landed on a different asteroid, possibly Hebe, which had already been modified by high temperatures. The salt-covered stones became incorporated into their new asteroid home.

Sometime later a fragment broke off from the new home, possibly through a relatively gentle process called the YORP effect (named for the astrophysicists who studied how asteroids can start to fly apart as their spin changes).

Finally, one August day in 1998, someone in the vicinity of Zag, Morocco, saw a meteorite fall to Earth.

Panspermia is still just a dream, but studying the contents of meteorites is nevertheless amply satisfying to Chan and her fellow astrobiologists. "Panspermia discusses the delivery of life itself to Earth, while we discuss the delivery of organic components, but not life, in our paper," she says. "However, via studying the chemistry of the meteoritic organics, we can postulate that the asteroidal body where the salt crystals come from was — or still is — a water-rich world with abundant organic precursors for complex chemistry to occur."



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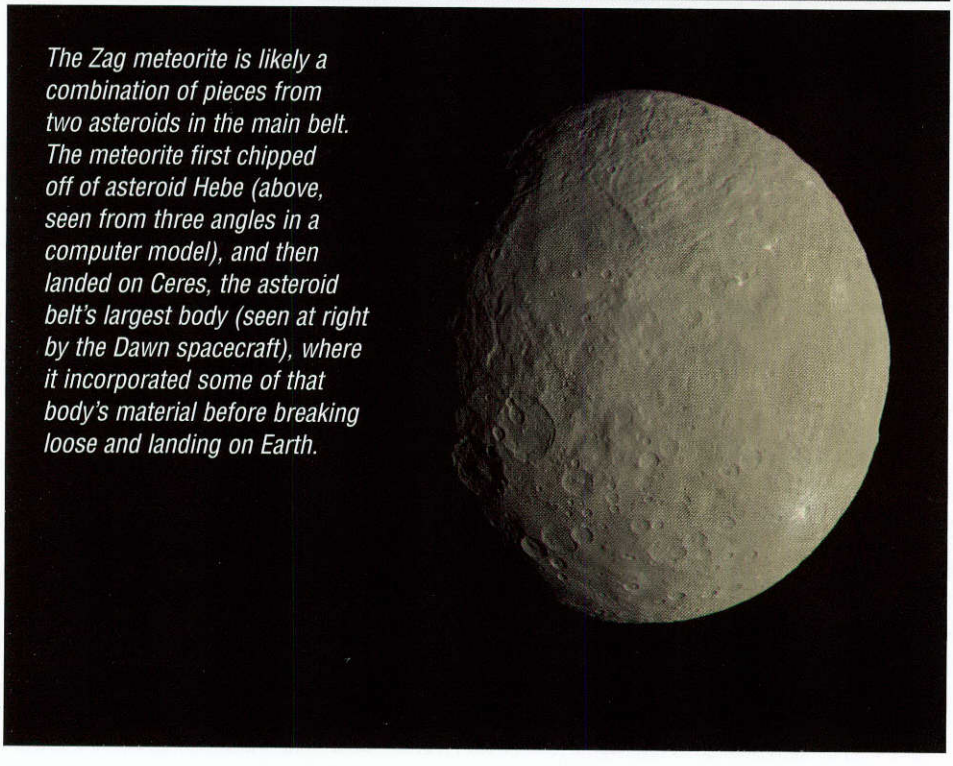


NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

The Zag meteorite is likely a combination of pieces from two asteroids in the main belt. The meteorite first chipped off of asteroid Hebe (above, seen from three angles in a computer model), and then landed on Ceres, the asteroid belt's largest body (seen at right by the Dawn spacecraft), where it incorporated some of that body's material before breaking loose and landing on Earth.

Leila Belkora is an astronomer and science writer in California and a frequent contributor to StarDate.

Resources

Books

Biological Cosmology, Astrobiology, Extraterrestrial Life, by Rudolf Schild and Richard Hoover, 2013

Biological Big Bang: Panspermia and the Origins of Life, edited by Chandra Wickramasinghe, 2010

Genesis: The Scientific Quest for Life's Origin, by Robert Hazen, 2005

Internet

Astrobiology at NASA
astrobiology.nasa.gov

Meteorites, Asteroids, & Comets
astrobiology.com/meteorites-asteroids-comets

SKY CALENDAR

by Alan MacRobert

In July and August, the long summer days mean shorts nights of skywatching. Luckily, there are some great sights in early evening. In July, Venus shines brightly as the Evening Star, and little Mercury makes an appearance, too. As summer advances into August, Venus, Jupiter, and Mars all light up the night. The Red Planet puts in its best appearance in 15 years.

JULY 1 - 15

Venus and Mercury, the solar system's hottest, most Sun-baked planets, emerge into view as our hot, Sun-baked July days give way to evening.

Venus is the first to appear after sunset. Look for it due west, one or two fist-widths at arm's length above the horizon. In fact, you may be able to detect it *before* sunset if the sky is an especially clear, deep blue. Keep looking; your eye will probably take a while to land precisely on this tiny white pinpoint.

Under more ordinary sky conditions, binoculars may still enable you to pick up Venus before sunset. Just don't look directly at the dangerously dazzling Sun!

When twilight deepens enough for Venus to be easy and obvious, it's time to start trying for Mercury. During the first half of July, Mercury remains about 16 degrees to Venus' lower right — about a fist and a half at arm's length. It, too, becomes easier as the sky darkens further, but it soon sets. In addition, Mercury is fading day by day. It loses half of its brightness from July 1 to 15.

There's more here, too. Bright Regulus glimmers about one fist to Venus' upper left as July opens. On July 9, it passes close by the dazzling planet (just 1 degree to Venus' lower left). After that, it heads to the lower right, toward fading Mercury.

A thin crescent Moon hangs above Mercury on the 14th, then pairs beautifully with Venus on the 15th.

Jupiter, usually the second brightest planet after Venus, shines higher in the south-southwest as night comes on. Binoculars show at least two or three of Jupiter's four largest moons, close to the planet.

Do you see that wide double star in the same binocular field, to Jupiter's left? That's Alpha Librae, also known as Zubenelgenubi. Its two components, white-hot stars 35 and 4 times as luminous as the Sun, are 75 light-years away.

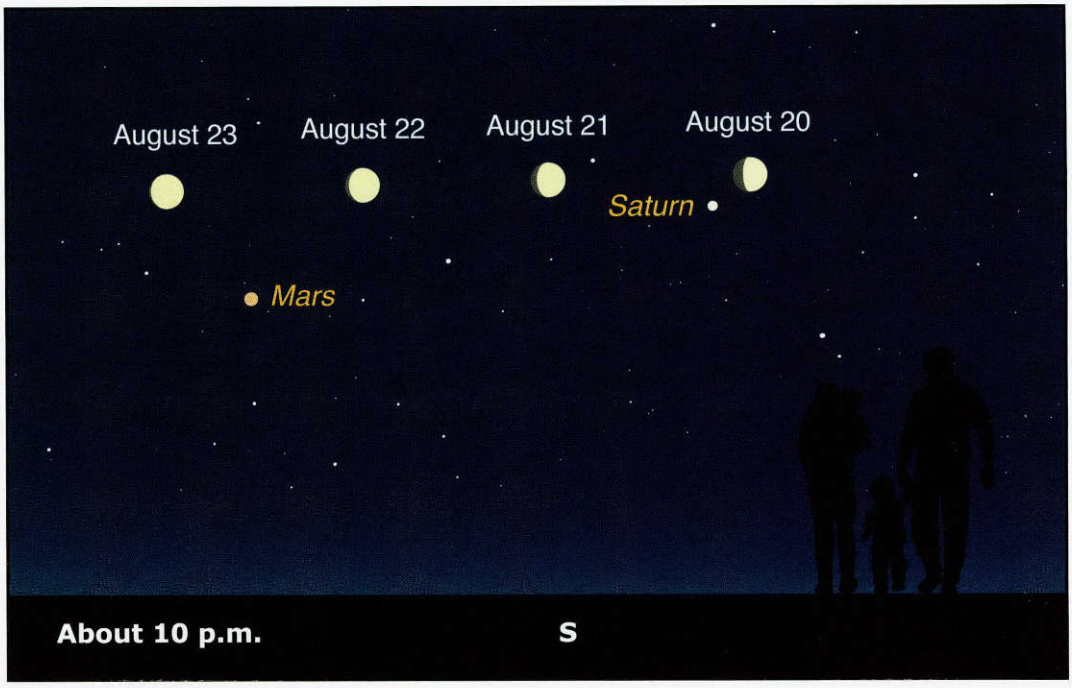
Jupiter glares between Spica, two fists to its right or lower right, and Antares, farther to Jupiter's left or lower left. Antares is the orange-red supergiant heart of Scorpius. Around it and to its right are the other, bluer stars of upper Scorpius. The whole group forms a distinctive pattern to the naked eye, and this area is particularly interesting to explore with a chart, guidebook, and binoculars or a telescope.

Look two or three fists to the left of Antares for Saturn, somewhat brighter. It glows above the dimmer, fist-sized Sagittarius teapot, which currently sits almost level.

Keep watch low in the southeast! As evening grows late, Mars will be rising into view there, to the lower left of Saturn by three fists at arm's length. Once the Red Planet climbs above the horizon murk, it shines even a little brighter than Jupiter! On July 1, Mars is already closer to Earth than it has been since 2003. Mars is highest in the south, in sharpest telescopic view, from about 2 a.m. until the first light of dawn. And the best is yet to come — in the second half of July.

Other bright points? Arcturus looks down from high in the southwest at dusk. Vega, its equal in brightness, watches from high in the east. Vega is the top star of the big Summer Triangle, formed with Deneb a couple fists to Vega's lower left and Altair farther to Vega's lower right.

And the Big Dipper hangs by its handle high in the northwest. It starts to curl around through the evening to scoop its bowl toward the right.



JULY 16 - 31

Venus continues to shine in the western twilight. Jupi-

ter illuminates the southwest. Saturn remains over the Sagittarius teapot in the south-southeast after dark. But all eyes will be on Mars.

Every 2.1 years, Earth passes Mars in their race around the Sun, so Mars passes through opposition as seen in our sky. But Mars' oppositions differ a lot from year to year. They run from distant, to close, to back to distant in a 15-year cycle. And this summer we're at the cycle's peak. Throughout July and August, Mars is the closest and brightest we've seen it in 15 years.

You'll find it shining like a campfire spark stuck on the sky low in the southeast as twilight fades into night. It appears to brighten as it rises above the low thick air, and its telescopic image sharpens up, too. Its best time for telescopic viewing now runs from about midnight to 3 a.m. Mars peaks in brightness in July's last week, easily outshining Jupiter. Opposition night is July 26, and its closest approach to Earth is July 30. But Mars appears essentially the same for a couple of weeks running.

The full Moon shines near Mars on July 26 and 27 to make striking night scenes. (For more on the Mars opposition, see page 14.)

Meanwhile, Arcturus has been losing a little height in the west-southwest, while Vega approaches the zenith from the east. The Big Dipper is turning more into its scooping stance, and the dim Little Dipper, curving up from Polaris, is tipping to the left.

And although summer is not yet half over, the W of Cassiopeia is an easy catch toward the north-northeast these nights — though for skywatchers in the latitudes of the southern U.S., it's still low.

AUGUST 1 - 15

Venus remains the signature "star" of this summer's western twilight, but it's a little lower every week. Jupiter, far to its upper left, dominates the southwest. Look midway between them for Spica, and a similar distance to the left of Jupiter for Antares. Saturn is similarly far to the left of Antares. The next step to the left (and lower) is brilliant Mars.

Keep checking in on Mars with your 'scope every clear night, and sooner or later you'll catch a spell of unusually steady atmospheric seeing when the detail improves. Mars is just beginning its long, slow shrink after opposition and closest approach. On the other hand, every week now it reaches a peak altitude 38 minutes earlier.

One side of Mars shows more dark markings than the other. The thing is, though, Mars rotates once every 24 hours and 39 minutes, so if you come back to look at the same time from one night to the next, you'll see nearly the same side again. Keep at it though, and Mars will appear to make a complete rotation for you in about five weeks. That's another reason to keep looking! Maybe you've just been seeing Mars' duller side.

Don't let Mars steal the show from the other bright planets. Saturn is a tiny, stark wonder in amateur telescopes. And currently, just a finger-width at arm's length to its lower right, is the big Lagoon Nebula, M8, in Sagittarius. In a really dark sky, M8 is a naked-eye patch of glow amid the much wider grandeur of the Sagittarius-Scutum-Aquila Milky Way. Saturn and M8 easily fit together in the field of view of even high-power binoculars. In fact, the whole Sagittarius region is my favorite for picking through with binoculars, sky atlas, and guidebook.

AUGUST 15 - 31

From August 15 through the 23rd, the waxing Moon marches eastward above the giant, ragged line of (counting right to left) Venus low in the west, Spica, Jupiter, Antares, and Saturn, to Mars in the south-southeast.

Since Mars is *past* opposition now, when the Moon shines with it on August 22 and 23 the Moon is *before* its own opposition (full phase).

The reason? The Moon circles Earth from west to east as seen in our sky, moving *toward* the opposition point — the point opposite the Sun for us — as it waxes in the evening. But the whole background celestial sphere of stars and planets is turning in the opposite direction, carrying objects westward *away* from the opposition point from evening to evening. Sounds confusing, but once you picture the setup correctly, everything suddenly pops into place.

Turning around to the northeast after dark, we see a stark warning of fall's approach. Cold-weather Cassiopeia has climbed almost shockingly high for summer, and its right-hand side is tipping upward toward its fall orientation.

And in the east is fall's Great Square of Pegasus, well clear of the horizon now and standing on one corner. It's a little bigger than a fist at arm's length. Come December, it will pose boxy and upright after nightfall almost overhead.

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

Meteor Watch

The Shower
Perseids

Peak
Night of August 12

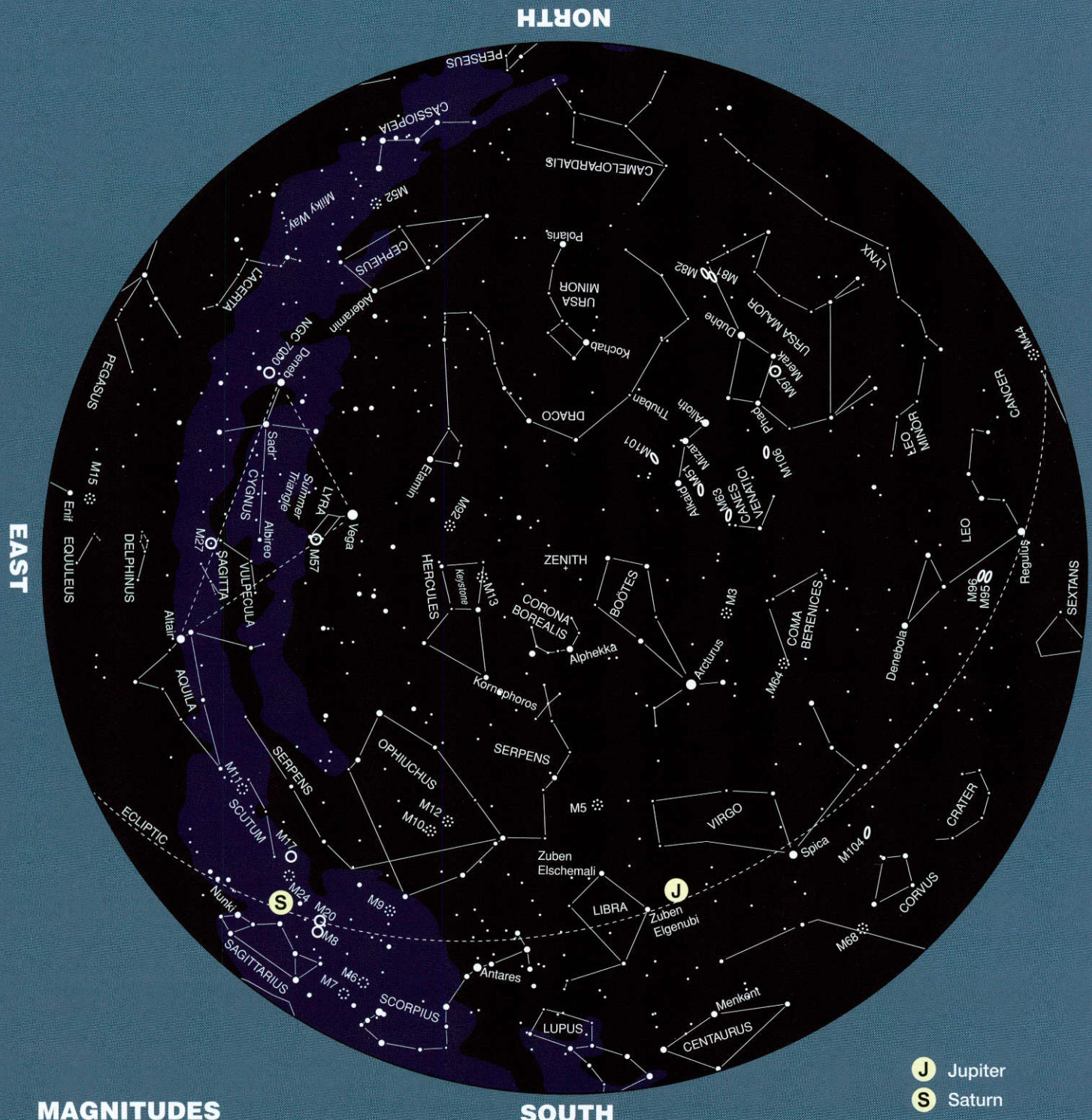
Notes
The thin crescent Moon sets not long after the Sun, so it won't interfere at all with the fireworks.

JULY

How to use these charts:

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

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



MAGNITUDES

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

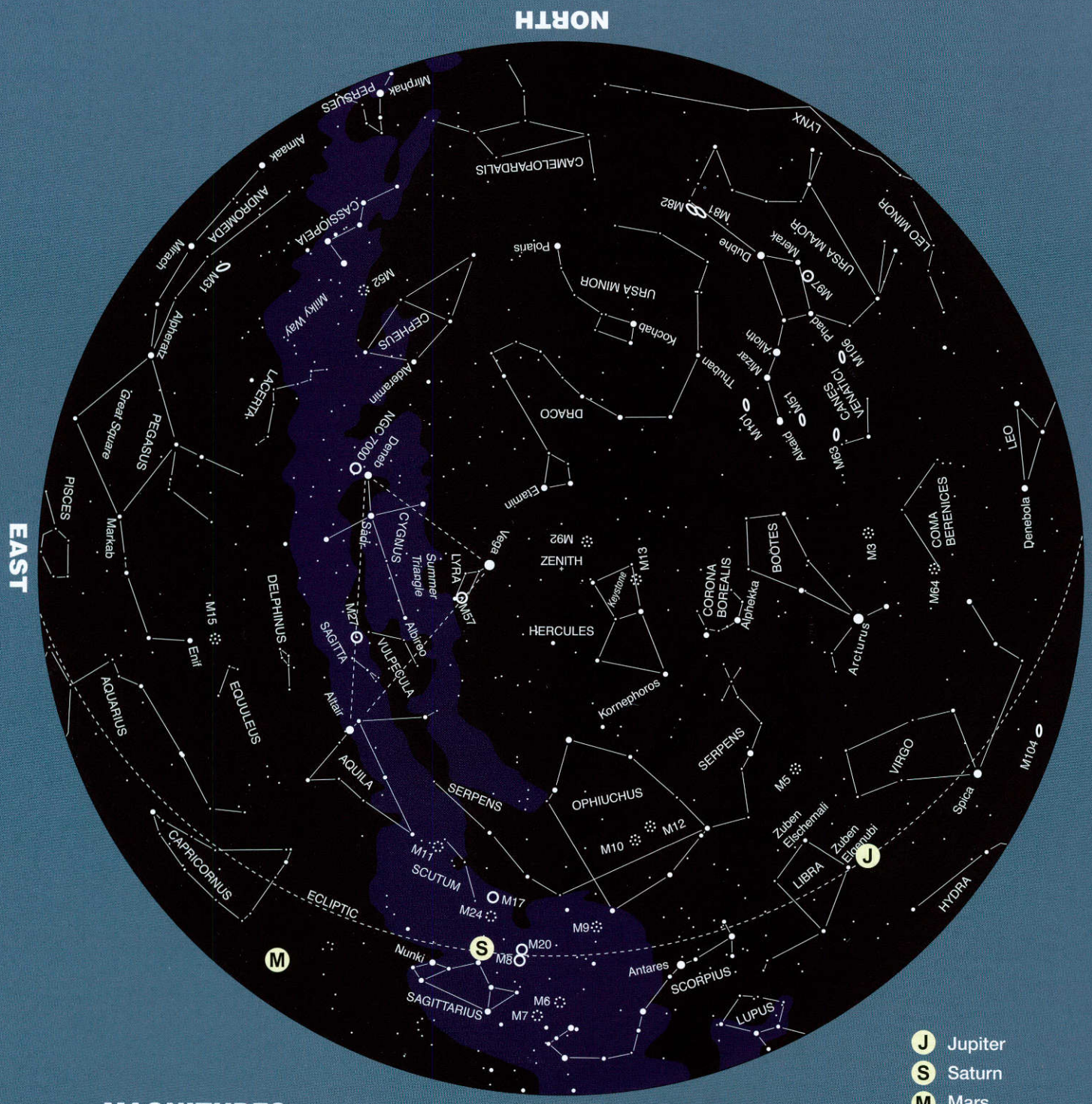
- J Jupiter
- S Saturn
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

AUGUST

How to use these charts:

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

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



MAGNITUDES

- 0 and brighter
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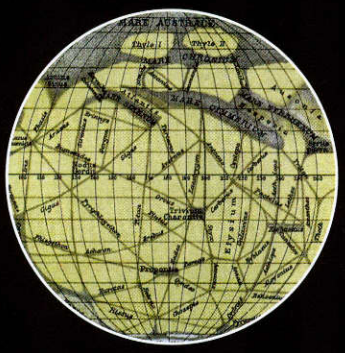
- J Jupiter
- S Saturn
- M Mars
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

A Bigger, Brighter Mars

Mars stages its best appearance since 2003 on July 27, when it lines up opposite the Sun, a point called opposition. It will rise at sunset and remain in view all night, and will outshine everything else in the night sky except the Moon and the planet Venus. Mars will pass closest to Earth four days later.

Since Mars is a bigger target at opposition than at any other time, astronomers have taken advantage of these appearances to study the planet in detail. They've made some important discoveries during oppositions — some of which were real.



1877: MOONS AND CHANNELS

During a good opposition, astronomer Asaph Hall of the U.S. Naval Observatory in Washington, D.C., discovered the two small Martian moons, now known as Phobos and Deimos. At the same time, Italian astronomer Giovanni Schiaparelli compiled the most detailed map of Mars to date, and assigned feature names that are still used today. The map includes a network of "canali" — long, straight lines that Schiaparelli originally interpreted as natural channels.

1879: SNOW

Schiaparelli discovers a "small whitish patch" on Mars, which he names Nix Olympica — the snows of Olympus. Today, it's known as Olympus Mons (Mount Olympus), the largest mountain in the solar system.

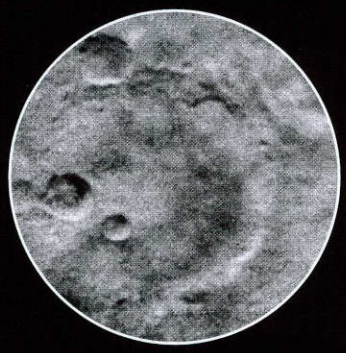
1892: CANALS

French astronomer Camille Flammarion interprets Schiaparelli's channels as a network of artificial canals created by a dying Martian civilization.

1894: MORE CANALS

Percival Lowell, working at his new observatory, in Flagstaff, Arizona, sees twice as many canals as previous maps, convincing him of their artificial nature. His work spurs the creation of a science-fiction genre, with H.G. Wells and Edgar Rice Burroughs writing about the dying Red Planet.

by Damond Benningfield



1909: NO MORE CANALS

Most astronomers conclude that the canals seen by Lowell and many others are simply optical illusions.

1965: SETTING SAIL

NASA takes advantage of the closeness of opposition to launch the first successful mission to the Red Planet, Mariner 4. It flies close to Mars in July, returning pictures of a dead, crater-filled landscape.

AUGUST 2003: REALLY CLOSE

Mars passes just 34.6 million miles (55.7 million km) from Earth, its closest approach in almost 60,000 years (though only by a tiny amount). It spawns a myth that pops up every summer, which says that Mars will look as big as the full Moon. It won't.

JULY 2018: BY THE NUMBERS

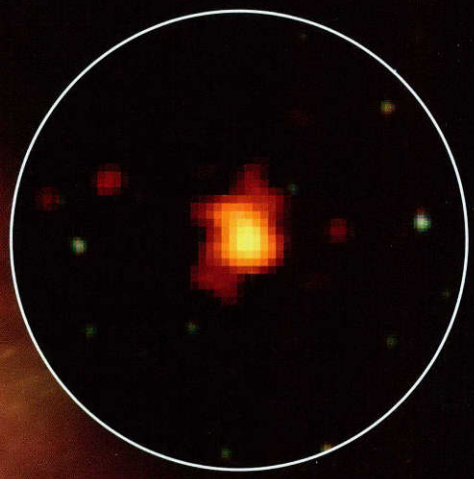
Mars and Earth will pass about 35.8 million miles (57.3 million km) apart. Such a close passage is possible because Mars' distance from the Sun varies by more than 25 million miles (162 million km). When Earth passes by Mars during the summer, the planet is near its closest point to the Sun, so it looks big and bright. When it passes at other times of year, Mars is farther from the Sun, so the Earth-Mars distance can stretch to as much as 63 million miles (101.4 million km).

NASA; INSETS, FROM LEFT: WIKIPEDIA (4), NASA (2), LIBRARY OF CONGRESS

Cosmic Superlatives

Exploring a universe of extreme curiosities: the farthest, largest, brightest, darkest, hottest, coldest, fastest, and loudest phenomena in the cosmos

By Alastair Gunn



Artist's concept of a gamma-ray burst; inset: X-ray view of GRB 080916c

ESO/A. ROQUETTE; NASA/SWIFT/STEFAN IMMLER

The universe is filled with beautiful, fascinating, and often weird objects and phenomena. It's also filled with staggering extremes of distance, size, heat, and speed. These mind-blowing cosmic superlatives don't just test the limits of our imagination; they test our current theories of everything from nuclear physics to General Relativity. So, where and what are these astonishing astronomical record-holders?

FARTHEST

It's not certain whether the universe has a limited volume or whether it extends forever. Some distant parts of the universe may simply be too far away for light to have travelled to us on Earth. This defines what astronomers call the observable universe — the parts of the universe we can actually see. We can never discover anything about the universe beyond this limit. But there's no reason to suspect this limit is an actual boundary to the universe, or that what lies beyond has a boundary at all.

The farthest phenomenon that astronomers can actually see is the cosmic microwave background (CMB). It is the background radiation left over from the Big Bang — a snapshot of the oldest light in the universe, imprinted on the sky when the universe was only about 380,000 years old. It covers the entire sky.

But the CMB isn't really an object. The record for the most distant *object* known to astronomers is currently held by a galaxy called GN-z11. It was discovered in 2016 using observations from Hubble Space Telescope. With the highest redshift yet discovered (a measure of how fast an object is moving away from us as a result of the expanding universe), its distance is estimated at 13.4 billion light-years. That means we see GN-z11 as it looked only 400 million years after the Big Bang. Since the universe has expanded significantly since the galaxy emitted the light we see today, if GN-z11 still exists, it now lies about 32 billion light-years from Earth.

LARGEST

The largest known structure within the universe is the Hercules-Corona Borealis Great Wall, discovered in November 2013. It is a vast cluster of galaxies bound together by gravity. It appears to be up to 10 billion light-years across, more than double the size of the previous record holder.

The largest known elliptical galaxy probably is IC1101, which spans more than 200,000 light-years, while the largest known spiral galaxy is Malin 1; its disk spans an estimated 650,000 light-years, which is about six times the diameter of the Milky Way.

There are so many stars in the universe that astronomers cannot be sure which are the biggest or most massive. The largest known star by size generally is accepted as UY Scuti, a red hypergiant star about 9,500 light years from Earth. It probably is more than 1,700 times the Sun's diameter — a whopping 1.5 billion miles (2.6 billion km). The most *massive* star (rather than the largest) probably is R136a1, a hot star about 165,000 light-years away in one of the Milky Way's companion galaxies. Astronomers estimate that it is more than 250 times the mass of the Sun.

BRIGHTEST AND DARKEST

Gamma-ray bursts (GRBs) are extremely energetic flashes of radiation apparently caused by the collapse of massive stars to form neutron stars or black holes. They are the most energetic events in the universe but are rare and short-lived.

The current record for the most energetic burst yet discovered belongs to GRB 080916C, which was seen on September 16, 2008. It appears to have occurred in a small galaxy in the constellation Leo, about 12.2 billion light-years away. At its peak, it was shining more than one sextillion times brighter than the Sun — a one followed by 21 zeroes. To put that another way, in a blast that lasted less than half an hour, GRB 080916C produced 10 million times more energy than the Sun will emit in its 10 billion-year lifetime. If such a blast had occurred nearby, in our own arm of the Milky Way, it could have damaged life on Earth.

The brightest steadily emitting objects in the universe are quasars. They are the cores of distant galaxies in which a massive black hole feeds on a copious supply of stars and gas. As this doomed material spirals inward, it becomes white hot, forming a brilliant disk. In addition, magnetic fields create jets of particles that race away from the poles of the black hole at almost the speed of light. The combination of disk and jets can make a quasar shine with the light of trillions of Suns.

The most luminous known quasar is 3C454.3. This object is also classified as a blazar, a type of quasar in which a jet points directly at Earth. Its estimated luminosity is roughly 300 trillion times that of the Sun, or several thousand times the luminosity of the entire Milky Way galaxy.

Some stars can burn brighter than the average quasar during the cataclysmic explosions known as supernovae. The brightest recorded supernova was ASASSN-15lh, detected in 2015. It appeared in a dim galaxy 3.8 billion light-years distant and shone with the equivalent of about 570 billion Suns.

Since the brightness (or, in fact, "luminosity," which is jargon for an

object's intrinsic brightness) of a normal star generally increases with its mass, it is no surprise to find that R136a1 is not only the most massive star known to science, but the brightest, too, shining 8.7 million times as bright as the Sun.

The darkest stuff in the universe is, as you might expect, dark matter, a mysterious and elusive material needed to balance the universe's gravitational budget. It's so dark that astronomers haven't found it yet, but they know it's out there somewhere!

HOTTEST AND COLDEST

Surprisingly, both the hottest and coldest known places in the universe have occurred right here on planet Earth!

The highest temperature known, of about 5.5 trillion degrees, occurred when physicists at the Large Hadron Collider smashed lead ions together. And in a laboratory in Finland, in 2000, scientists created a temperature only 100 trillionths of a degree above absolute zero. The highest temperature probably occurred just moments after the Big Bang, at perhaps 100 million trillion trillion degrees.

For naturally occurring objects, generally the brightest also are the hottest. So temperatures generated in the cataclysmic interactions that create GRBs are likely to be in the region of a trillion degrees.

The coldest naturally occurring temperature in the universe was discovered inside the Boomerang Nebula in 1995. This cloud of gas and dust, in the constellation Centaurus, was thrown off by a star nearing the end of its life. Its temperature, a result of the slow expansion of the gas cloud, is only one degree above absolute zero.

FASTEST

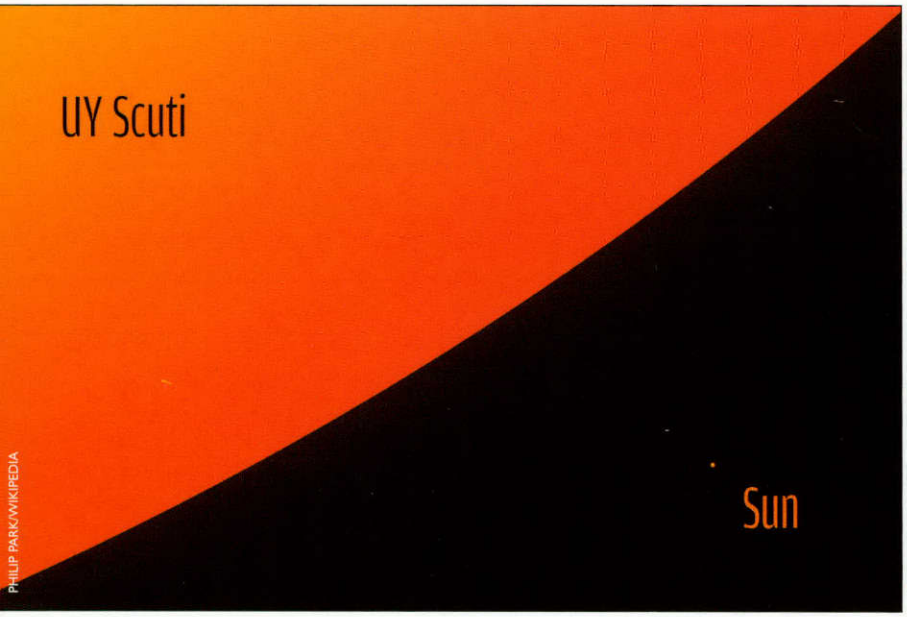
The fastest objects on record are cosmic rays. These aren't "rays" at all. Instead, they are subatomic particles created in the most powerful events in the universe, such as galaxy mergers and especially brilliant supernovae. The fastest cosmic ray yet detected was traveling so close to the speed of light that it had the same amount of energy as a medium-paced baseball, even though it was a fraction of the size of a single atom.

For large chunks of matter (as opposed to subatomic particles), the speed record is held by the jets seen in blazars. Black holes at the hearts of these galaxies release huge amounts of energy. Magnetic fields funnel subatomic particles into jets. The jets in some blazars have been observed to move at about 99.9 percent the speed of light!

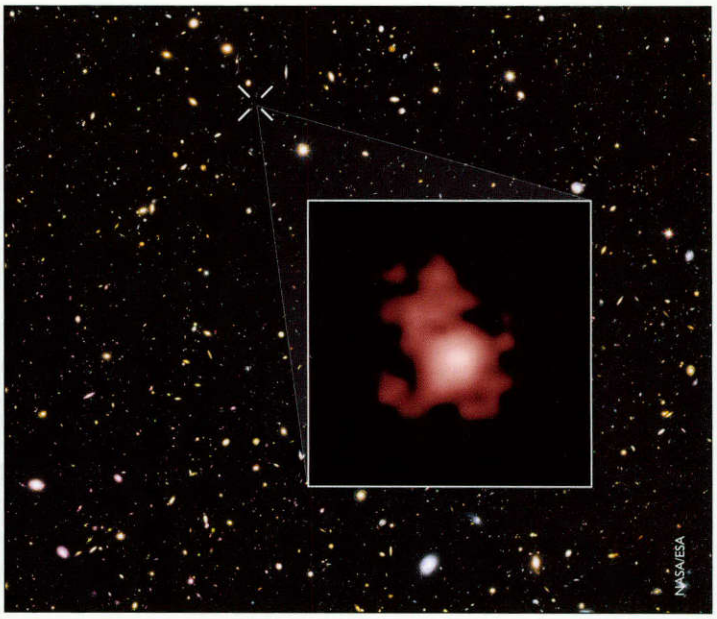
To date, the fastest known star is called US 708. It is one of a class of objects called hyper-velocity stars (HVSs), which move so rapidly that they will one day escape from the Milky Way galaxy. Most HVSs are thought to be formed by the close encounters of stars with the Milky Way's central black hole, which slingshots them out of the galaxy. However, the trajectory of US 708 shows that this cannot be the case for this star. Instead, US 708 probably was a member of a binary system. Its companion — the dead core of a once-normal star, known as a white dwarf — stripped gas from the surface of US 708 as it neared the end of its own life and swelled to giant proportions. The white dwarf then exploded as a supernova and ejected its companion at about 2.7 million miles per hour (1,200 km/s).

Stars also spin, of course. At present, the fastest-spinning star known to astronomers is VFTS 102. This is a hot blue star, 25 times the mass of the Sun, residing within the Tarantula Nebula, a vast stellar nursery in a companion galaxy. At its surface, VFTS 102 is rotating at more than one million miles per hour (600 km/s) — so fast that it is almost, but not quite, flinging itself apart.

Although VFTS 102 is the fastest-



PHILIP PARK/WIKIPEDIA


NASA/ESA

rotating "normal" star, pulsars actually spin much quicker. Pulsars are the collapsed cores of stars that exploded as supernovae. The fastest-spinning pulsar yet discovered is Ter5AD. It rotates 716 times every second. That means the rotation speed at its equator is about 80 million mph (36,000 km/s), or about 12 percent of the speed of light!

LOUDEST

Sound is the movement of a pressure wave through matter. Since space is almost (but not quite) a complete vacuum, sound does not propagate easily through space. So, as a famous movie tells us, in space no one can hear you scream! However, where matter is denser, such as in the atmospheres of planets, within stars, in gas clouds, or in the environments surrounding black holes, sound waves are common.

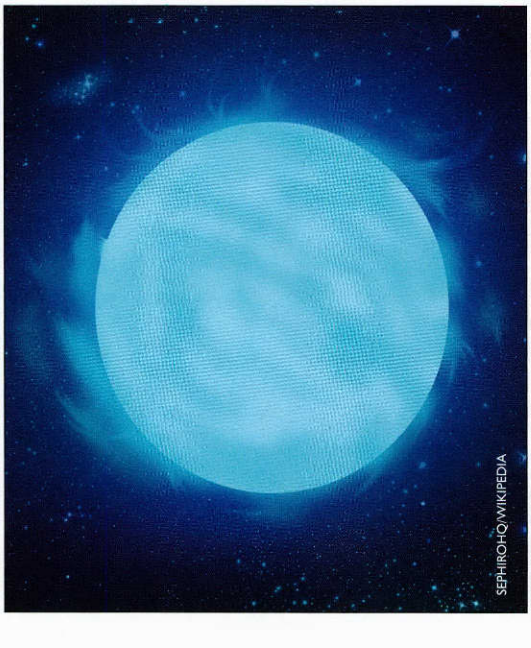
Although there were no humans around to hear it, the Big Bang did in fact create sound. We can deduce the scale of these sound waves by observing tiny temperature variations in the cosmic microwave background. Their wavelength is measured in hundreds of thousands of light-years, so the "notes" are far too low to be heard by humans. The details are rather complicated, but, as a rough estimate, we can calculate the loudness of these waves to be between 100 and 120 decibels (dB).

Although this is near the human ear's pain threshold (similar to standing next to a chainsaw or about 100 yards from a jet engine), it is by no means the loudest thing you could experience. The loudest sounds we know of have actually occurred here on Earth. It's thought that the eruption of Krakatoa in 1883 produced sound waves at about 180 dB, while blue whales "talk" (or "shout") at up to 188 dB. It is estimated that the loudest event on Earth probably was the explosion of the Tunguska meteor, in 1908, at about 300 dB.

Record holders are always superseded, of course. As astronomers refine and develop their techniques of observing the skies, pushing our knowledge to even greater extremes, these astonishing cosmic superlatives undoubtedly will be toppled by new discoveries. And these undiscovered curiosities likely will be more beautiful, more fascinating, and even more weird than we are yet able to imagine.

Alastair Gunn is a writer and professional astrophysicist based in the UK. His fiction includes a collection of supernatural stories called Ballymoon *and his debut novel,* The Bergamese Sect.

From left to right: UY Scuti, which may be the largest known star, compared to the Sun; GN-z11, the most distant object yet observed; the Boomerang Nebula, site of the coldest measured spot in space; artist's concept of R136a1; Malin 1, the largest known spiral galaxy



RESOURCES

ONLINE

Cosmic Microwave Background
www.bbc.co.uk/science/space/universe/sights/cosmic_microwave_background_radiation

NASA Press Release on GN-z11
www.nasa.gov/feature/goddard/2016/hubble-team-breaks-cosmic-distance-record

Gamma-Ray Bursts
imagine.gsfc.nasa.gov/science/objects/bursts1.html

Introduction to Cosmic Rays
www.i2u2.org/elab/cosmic/content/CosmicExtremes.pdf

by Damond Benningfield and Rebecca Johnson

Probe to Set Sail for the Sun

In mythology, Icarus and his father tried to fly away from the island of Crete with wings made of wax and feathers. The father warned Icarus not to fly too close to the Sun, but Icarus ignored the advice and soared high into the sky. The Sun's heat melted his wings, so he plunged into the sea and drowned.

NASA is about to launch a mission that will venture far closer to the Sun than any other spacecraft to date. Unlike Icarus, though, it's carrying protection: a shield that will keep its instruments as cool as a spring day.

Parker Solar Probe (PSP) is scheduled for launch on July 31. The craft will orbit the Sun 24 times, eventually dropping to within four million miles (six million km) of the surface. Temperatures on the leading edge of the probe's heat shield, which is made of a reinforced carbon composite, will reach 2,500 degrees Fahrenheit (1,375 C). Behind the shield, though, engineers say the probe's instruments will remain near room temperature.

PSP will fly through the region where the solar wind is generated to learn how it's created and how it's accelerated to millions of miles per hour. The craft also will study the Sun's outer atmosphere, the corona.

The corona is millions of degrees hotter than the Sun's surface, but scientists don't fully understand why. It may be heated by small, continuous outbursts on the surface of the Sun, or by waves traveling through the Sun's magnetic field. By zipping through the region where the corona is heated, PSP should help scientists choose between those two possibilities.

PSP will make its first close pass by the Sun on November 1, at a distance of about 15.4 million miles (24.7 million km). That will break the record for closest solar approach, 27 million miles (43.4 million km), set by the Helios B spacecraft in 1976. During its seven-year mission, PSP will fly past Venus seven times, using the planet's gravity to steer it closer to the Sun with each pass. It will make the first of three especially close approaches in December 2024.

The probe is named for Eugene Parker, a professor at the University of Chicago. It is the first NASA spacecraft named for a living person. In the 1950s, Parker proposed that a complex interplay of hot gas and magnetic fields on the Sun produces a "wind" of charged particles. Interplanetary spacecraft discovered the solar wind in the 1960s.

PSP will carry a plaque honoring Parker, along with photographs and a copy of his 1958 paper on the solar wind, on a small memory card. The device also includes the names of more than 1.1 million people who signed up to send their names to the Sun. **DB**

Artist's concept of Parker Solar Probe flying close to the Sun

NASA/JHUAPL

Planet Hunter Gets to Work

A new planet-hunting observatory is scanning the heavens for worlds around nearby bright stars after attaining its final science orbit and checking out its four wide-angle cameras.

TESS (Transiting Exoplanet Survey Satellite) will closely monitor 200,000 bright stars and make less-frequent observations of millions more. If a planet passes in front of one of the stars (a transit), the star will get slightly fainter. The intensity of the dip in the star's light will reveal the planet's size, while repeated transits will reveal the planet's orbital period.

The Kepler space telescope has used the same technique to discover thousands of planets in other star systems. During its primary mission, Kepler monitored relatively faint, distant stars in a single patch of sky. TESS, however, will look at brighter stars, which generally are no more than a few hundred light-years from Earth, across almost the entire sky. The proximity of the stars will make it easier to conduct follow-up studies of their planets. Scientists expect TESS to discover at least 1,500 planets around its target stars, plus thousands more around the other stars in the craft's field of view.

TESS was launched on April 18. It passed about 5,000 miles (8,000 km) from the Moon on May 17, using lunar gravity to refine its orbit. A thruster firing two weeks later was scheduled to place the craft in its final science orbit, which ranges from 67,000 to 233,000 miles (108,000-375,000 km) above Earth. **DB**

NASA/MIT/TESS

The first test image from TESS shows about 200,000 stars in Centaurus, including the constellation's second-brightest star, Beta Centauri, at bottom center.

Solving the Mystery of the Puzzling Galactic Gas

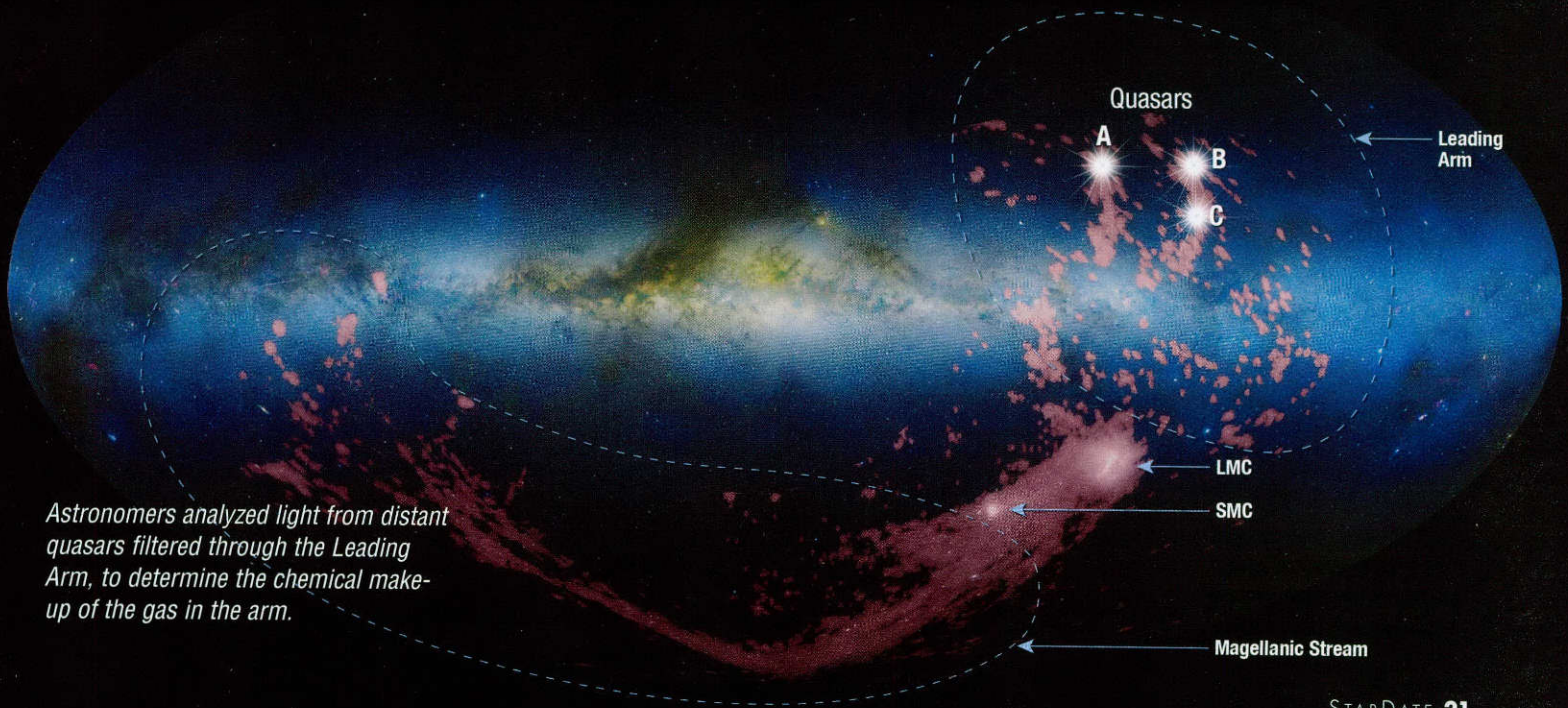
The best known of the Milky Way's cadre of satellite galaxies are the Large and Small Magellanic Clouds, visible in the night sky from the southern hemisphere. These two tagalongs are forever orbiting our galaxy, while locked in a gravitational dance with each other. As they go, a trail of gas called the Magellanic Stream fans out behind them, winding around our galaxy.

An even more mysterious cloud of gas fans out ahead of the two satellite galaxies, stretching for 300,000 light-years. It's called the Leading Arm of the Magellanic Stream, and it's pumping gas into the Milky Way, which our galaxy is using to make new stars.

For years, the origin of the Leading Arm has baffled astronomers. They knew that the gas came from the continuous interaction of the Magellanic Clouds. One was clearly pulling the gas from the other. But who was draining whom?

A group of astronomers led by Andrew Fox of the Space Telescope Science Institute used both Hubble Space Telescope and the Green Bank Telescope to analyze the chemical make-up of the Leading Arm. They determined it matches the chemistry of the Small Magellanic Cloud, indicating that its larger sibling is winning the gravitational tug-of-war.

This work, published in *The Astrophysical Journal*, should help refine models of the orbits of the two satellite galaxies. It also forms an important case study of how galaxies take on gas from outside and incorporate it into new stars — a process that goes on in all galaxies but is hard to see outside the Milky Way because other galaxies are too distant and too faint. **RJ**



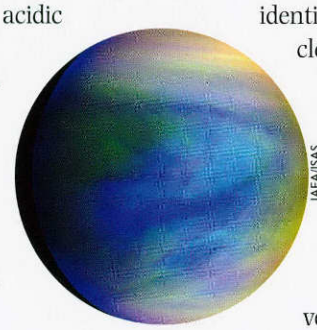
D. NIDEVER ET AL/NRAO/AUI/NSF/A. MELLINGER/LAB SURVEY/PARKES OBS/WESTERBORK OBS/ARECIBO OBS/A. FIELD/NASA/ESA/A. FOX/STScI

Astronomers analyzed light from distant quasars filtered through the Leading Arm, to determine the chemical make-up of the gas in the arm.

Could There be Life in Venus' Clouds?

Astronomers working with Japan's Akatsuki probe, currently in orbit around Venus, are reviving an idea first posited decades ago: that life might exist in the planet's dense, acidic clouds.

Sanjay Limaye of the University of Wisconsin, Madison, and his team proposed in an article in the journal *Astrobiology* that microbial life could exist as dark patches in the planet's atmosphere.



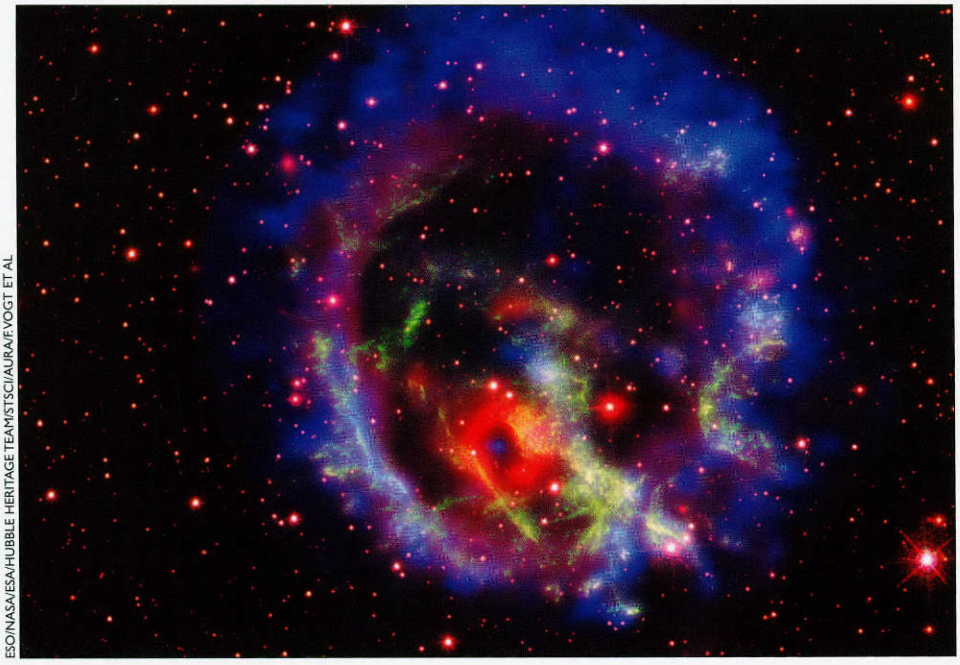
JAEA/ISAS

View of Venus from Japan's Akatsuki probe.

Limaye worked with Grzegorz Slowik of Poland's University of Zielona Gora. Slowik told Limaye about bacteria on Earth with light-absorbing properties similar to unidentified components of dark patches in Venus' clouds. Akatsuki studied these regions in ultraviolet light, and determined that they are made of sulfuric acid and other unidentified light-absorbing particles.

The idea of cloud-borne life is not unprecedented. Balloon experiments have identified live bacteria in Earth's clouds as high as 25 miles (41 km). And Venus' clouds' harsh chemical make-up is not necessarily a deterrent to life, either. On Earth, hardy microbes called extremophiles thrive in harsh environments like thermal vents at Yellowstone National Park.

Space probes that visited Venus in the 1960s and 1970s measured the temperature and pressure in the planet's lower and middle atmosphere and determined the conditions don't rule out microbial life. (The surface conditions, however, do.) **RJ**



ESO/NASA/ESA/HUBBLE HERITAGE TEAM/STSCI/AURA/F.VOGT ET AL

Pinpointing the Blast

A horde of telescopes on the ground and in space cooperated to make this image of the remnants of an exploded star, and to pinpoint the first neutron star identified outside of the Milky Way galaxy (blue dot, below center, surrounded by red doughnut). The neutron star is the leftover core of a massive star that exploded in the Small Magellanic Cloud, a satellite galaxy of our own. The various rings and strings of gas it has emitted are seen by Hubble Space Telescope (red diffuse background), the Very Large Telescope in Chile (red doughnut), and Chandra X-Ray Observatory (blue, purple).

NASA/ESA/P.VAN DOKKUM (YALE)

A faint blue glow is all we see of NGC 1052-DF2; the galaxy is so thin that background galaxies shine through it.

No Dark Matter for Odd Galaxy

Physics can be weird. The discovery of a galaxy with little or no dark matter, for example, is considered good evidence that dark matter exists.

A team led by Pieter van Dokkum of Yale University studied NGC 1052-DF2 with one of the Keck telescopes in Hawaii and with Hubble Space Telescope. It is a diffuse galaxy, which means its stars and gas are so thinly spread that we can see through it.

By plotting the motions of 10 of the galaxy's giant star clusters, the scientists calculated that NGC 1052-DF2 is about 0.5 percent as massive as the Milky Way. They also calculated that it has almost no dark matter, which produces no detectable energy but accounts for most of the mass of every other galaxy yet measured, including the Milky Way.

The team can't yet explain how a galaxy can form without dark matter, since it is the cosmic "glue" that holds galaxies together. In fact, the gravity of dark matter may pull in normal matter, helping galaxies form.

The leading idea says that dark matter consists of some type of heavy subatomic particle, although multiple searches have turned up no evidence of such particles.

Alternative theories discount the possibility of dark matter. Some, for example, suggest that our understanding of gravity is wrong. In such theories, though, the observed effects would be the same in every galaxy. So the discovery of a galaxy with no apparent dark matter actually supports the idea that dark matter is real.

Join Us This Summer for Planet Fest 2018!

DAMOND BENNINGFIELD

A plethora of planets will light up the sky in late July and August. Jupiter, Saturn, and Mars will put on quite a show, and we've got a great way for you to experience it at McDonald Observatory.

Come enjoy Planet Fest 2018 on our 36-inch telescope. Situated near the summit of Mount Locke, this large telescope's long focus allows for awesome views. This comprehensive viewing program is guided by skywatching experts from our Frank N. Bash Visitors Center, and lasts approximately three hours. Check availability and make your reservations online early, as programs are likely to sell out.

$75 per person

Reservations and information
mcdonaldobservatory.org/visitors/programs/36-viewing-night

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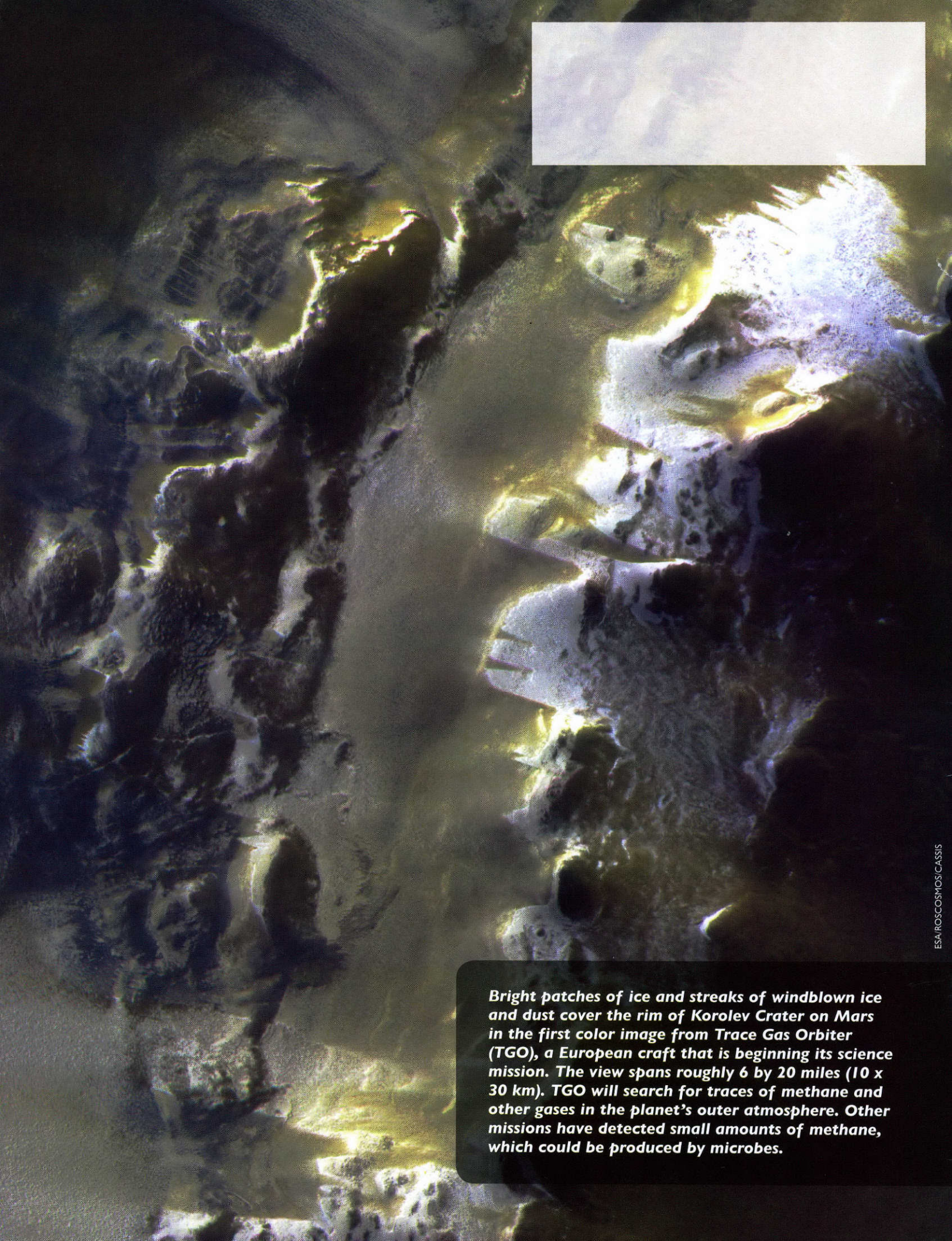
Our thanks to Charlotte A. Smith, who sponsored our June 18 program.



ESA/ROSCOSMOS/CASSIS

Bright patches of ice and streaks of windblown ice and dust cover the rim of Korolev Crater on Mars in the first color image from Trace Gas Orbiter (TGO), a European craft that is beginning its science mission. The view spans roughly 6 by 20 miles (10 x 30 km). TGO will search for traces of methane and other gases in the planet's outer atmosphere. Other missions have detected small amounts of methane, which could be produced by microbes.