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BINOCULAR VISION
Page 16

Brilliant Beacons

Supernovae probe universe's past, predict its future

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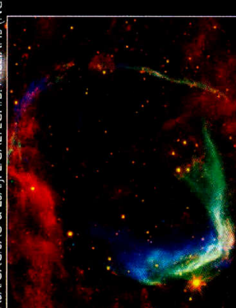
Features

Departments



NASA/CXC/SAO & ESA/JPL-CALTECH/B. WILLIAMS (NCSU)

On The Cover
A composite infrared and X-ray image shows RCW 86, the expanding remains of a tiny star that exploded in AD 185 as seen from Earth. Blue and green are from interstellar gas that is heated by the shockwave from the explosion, while yellow and red depict cold dust clouds. RCW 86, which is 8,000 light-years away, is a type of star that astronomers use to measure intergalactic distances and the expansion of the universe. See more on page 4.

This Page
The view of galaxy Hercules A combines optical light from Hubble Space Telescope (the elliptical galaxy at center) with a radio view from the Very Large Array (red). The giant radio lobes extend 1.5 million light years from end to end, dwarfing the visible galaxy. The lobes are powered by jets from the vicinity of a supermassive black hole at the galaxy's heart.

Coming Up
In May/June, StarDate *will bring your our recommendations for your summer reading from new books in astronomy and space exploration. We'll also bring you the latest astronomy news, summer skywatching tips, and Merlin's answers to your questions.*

NASA/ESA/S. BAUM AND C. O'DEA (RIT)/R. PERLEY AND W. COTTON (NRAO/AUI/NSF)/HUBBLE HERITAGE TEAM (STScI/NASA)

MERLIN

Dear Merlin,

I recently saw that there's a shift in the alignment of Earth's poles, causing, among other phenomena, the alternate wetting and drying of the Sahara desert region of Africa. What is this cycle and how rapidly do the climate changes occur?

Ed Rice
Charleston

Tiny wiggles and wobbles in Earth's orbit and its orientation in space appear to drive several long-term climate cycles. Scientists still debate the significance of these changes, though, so their full effect is unclear.

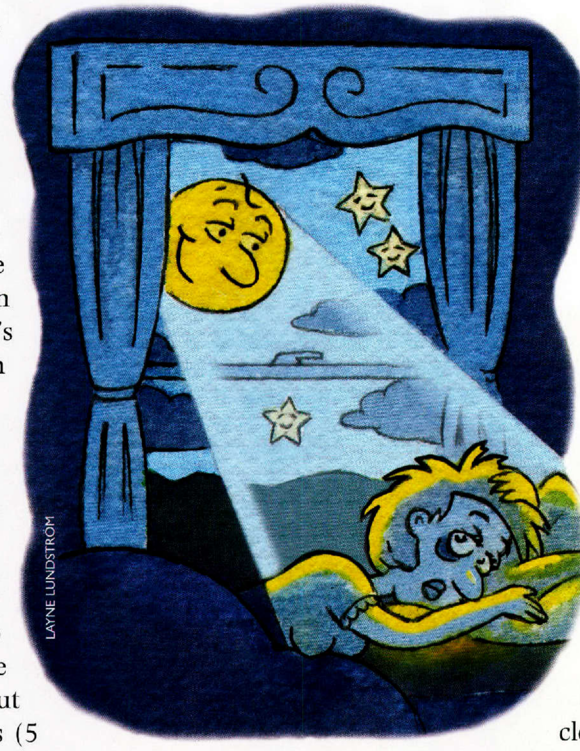
The wiggles and wobbles are caused by the gravitational pull of the Sun, Moon, and the other planets, particularly Jupiter and Saturn. They create possible cycles, named for Serbian scientist Milutin Milankovitch, who posited their existence and calculated their effects in the early 20th century.

One cycle, known as precession, causes Earth to wobble like a spinning gyroscope that's starting to run down. As Earth wobbles, its axis draws a wide circle on the sky, so different stars serve as the Pole Star. It takes about 23,000 years to complete a full turn with respect to the Sun.

A second cycle changes Earth's tilt on its axis. Today, the planet is tilted at 23.5 degrees, but over a period of about 41,000 years the angle varies from 22 to 24.5 degrees. When the angle is steeper, summers and winters are more extreme; when it's shallower, there's less variation from season to season.

The third cycle changes Earth's eccentricity, which is the "roundness" of its orbit. Today, the orbit is slightly stretched out, so the distance to the Sun varies by about three million miles (5 million km), with Earth closest to the Sun in early January and farthest in July. Over a 100,000-year period, though, the eccentricity can vary from almost zero to about twice today's value. When the eccentricity is greatest, the changing Earth-Sun distance causes greater seasonal variations.

These cycles (and others that appear to be less significant) may work together to create major climate shifts, such as ice ages. The changes appear to take place slowly, however, with significant warming or cooling (such as that seen in the Sahara) generally requiring centuries or millennia.



Dear Merlin,

I was surprised to see the Moon rising in the southwest tonight [October 18]. I could swear I typically notice the Moon rising in the east and, by 3 a.m., wreaking havoc on my sleep by shining through my west window. Could you explain why we see the Moon rising in different positions and at different times each day?

Julianne Cull
Glendora, California

In today's world, many people notice the Moon only when it's depriving them of sleep or illuminating a romantic stroll along the beach, so they expect to find it at the same location in the sky at the same hour every day. When they realize that the Moon isn't where they expect it to be, they get a little confused. Merlin will try to clear up that confusion for you.

First, the timing. On average, the Moon rises about 48 minutes later each day (or night), so the Moon actually spends as much time in the daytime sky as in the nighttime sky. The timing varies, however, for several reasons. One is that, while Earth rotates at a steady pace, the Moon's orbital speed changes because its orbit is slightly elongated. The Moon moves faster when it is close to Earth, and slower when its farther away.

Second, the location. The Moon stays close to the ecliptic, which is the Sun's path across the sky. During the year, as Earth's angle relative to the Sun changes (the north pole dips sunward at the summer solstice, the south pole at the winter solstice), the angle of the ecliptic in the sky changes as well. So where the Moon rises along the horizon depends on the time of year and the Moon's location along the ecliptic.

Although it always rises in the east, depending on your latitude its exact rising point can vary by quite a bit, from roughly southeast to northeast. (It can't rise in the southwest, though; Merlin suspects you saw it as it was setting, not rising.) The angle of the ecliptic also plays a role in the timing of moonrise and moonset.

So like a baby in a cradle, the rising and setting Moon rocks back and forth along the horizon during its month-long cycle of phases.

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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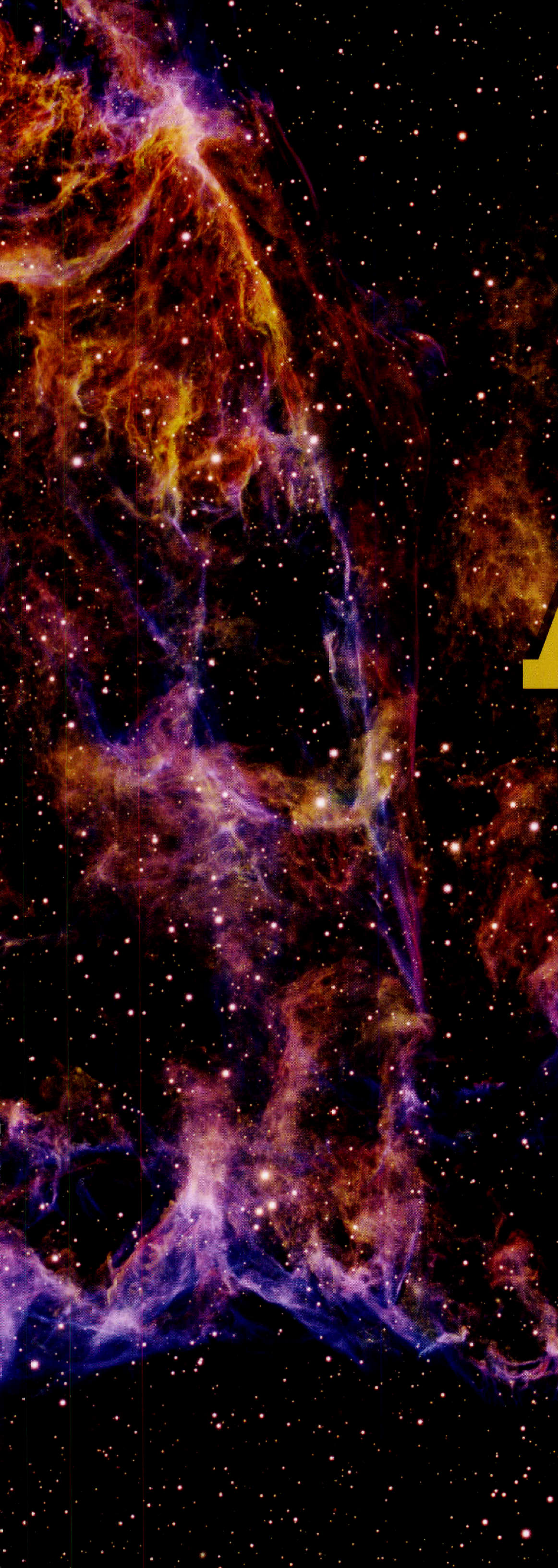
Cosmic Fireworks

Exploding stars light up the heavens, and help us probe the universe's evolution from beginning to end. But do we understand them well enough to trust our findings?

By Rebecca Johnson

An exploding star 5,000 to 8,000 years ago created the Cygnus Loop supernova remnant. One part of the giant remnant, known as IC 1340, is seen here. Oxygen gas is shown in blue, sulfur in green, and hydrogen in orange. As seen from Earth, the still-expanding Cygnus Loop spans three times the width of the full Moon.

T.A. RECTOR (UNIV. OF ALASKA ANCHORAGE) AND H. SCHWEIKER (WIYN/NOAO/AURA/NSF)



A star explodes — a brilliant beacon outshining its home galaxy, visible far across the cosmos. It gives off huge quantities of radiation across all wavelengths. Heavy chemical elements forged in its core are thrown into the open, to become part of future generations of more complex stars. The blast's shockwave can help trigger the birth of the next generation. And yet these are not the most crucial facts about supernovae. Understanding how and why stars explode, and parsing all the variations on that theme, could change our understanding of the universe's past and its fate.

In trying to understand these cosmic fireworks, astronomers look at a supernova's light output in a couple of different ways. They study its spectrum — breaking the light into its component wavelengths to detect which chemical elements are present. They also track how a supernova brightens and then fades over time (a function scientists call its lightcurve). Both measurements provide clues to the type of star that exploded as a supernova, known as the supernova's progenitor.

Rudolph Minkowski was the first to classify exploding stars into different categories. Starting in the early 1940s, he looked at their spectra and realized that some contain hydrogen and some don't. He called those without hydrogen Type I, and those with hydrogen Type II. Since then, astronomers have identified several sub-types of each.

Type I supernovae come in three flavors. The most famous is Type Ia. Found in all varieties of galaxies, Type Ia are the brightest supernovae of all and behave the most consistently. When a Type Ia explodes, it brightens continually for three weeks until it reaches its peak luminosity. It then starts to dim, and fades for six months. These characteristics make Ias useful as "standard candles" for measuring distances to far-away galaxies. Type Ia supernovae are thought to come from the interaction between two stars in a binary pair, but there is some disagreement over the types of stars in the pair and how they interact with each other to lead to an explosion.

Type Ib and Ic are similar to each other but much different from Type Ia. Not only are they dimmer, but both are thought to result from the collapse of a lone massive star that has burned through the nuclear fuel in its core and can no longer maintain outward pressure against its own weight, leading to a collapse followed by an explosion.

These "core-collapse" supernovae represent the demises of stars that are at least eight times as massive as the Sun. They have short lives compared to less-massive stars, which burn their nuclear fuel more slowly. They are found only in star-forming regions of spiral galaxies. (Elliptical galaxies, in general, have no gas for making new stars.) Type Ib and Ic supernovae are similar in that both show strong evidence of oxygen, magnesium, and calcium. Type Ib contains helium, while Ic does not.

Type II supernovae also are the result of core collapse in a single, massive star. They, too, are found only in spiral galaxies. There are several sub-types of Type II, characterized by how their brightness changes over time and the chemical elements they contain.

The pace of discovery of new types of supernovae in recent years has been especially frenetic. The proliferation of large, automated surveys to find supernovae has raked them in by the hundreds, and has found some strange ones.

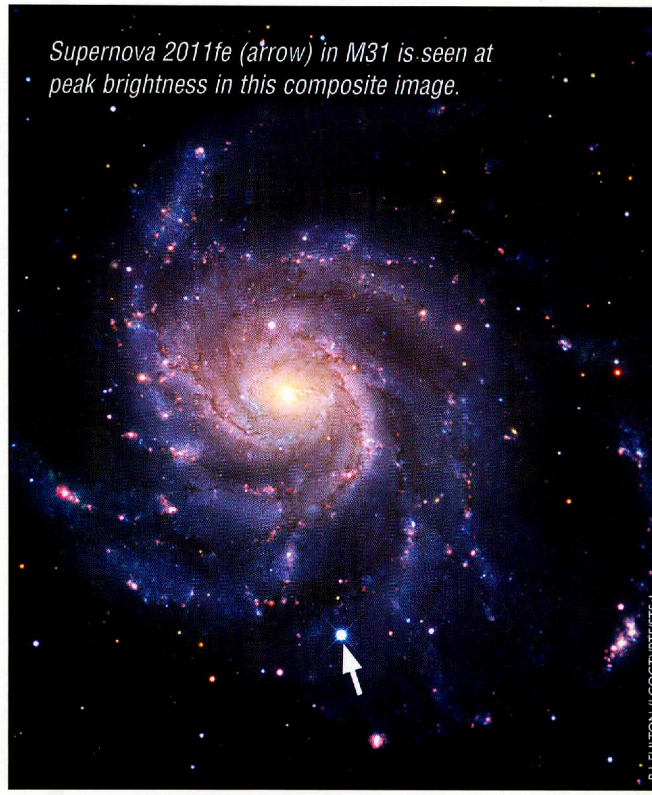
"The research field of supernovae is exploding right now, if you'll pardon the pun," says Alex Filippenko of The University of California, Berkeley. "Many supernovae with peculiar properties have been found, pointing to a greater richness in the physical mechanisms by which nature chooses to explode stars."

Of all the variations, Type Ia are the most important for astronomers to understand, because they are used to study the universe's past and predict its future. Their extreme brightness means they can be detected in distant galaxies, and their predictable behavior means the distances to those galaxies can be accurately measured.

Astronomers know how intrinsically bright a Type Ia supernova is. When they identify one at an unknown distance, they can compare how bright it appears to its absolute brightness. Because the intensity of light decreases with the square of the distance from the source, the comparison provides the distances to the supernova (and by association, its host galaxy).

More than a decade ago, the use of Type Ia supernovae as standard candles to measure the distances of far-flung galaxies was key to the discovery that the universe is expanding faster as it ages — a phenomenon attributed to an unknown force called dark energy. The discovery of dark energy forever changed how we see the universe, and scientists around the globe are working to decipher what dark energy is and how it works.

Some studies of Type Ia supernovae in the past few years, however, are showing that perhaps these standard candles aren't so standard after all. It seems likely that there are different kinds of Type Ia supernovae. The implications for cosmology are unknown.


Supernova 2011fe (arrow) in M31 is seen at peak brightness in this composite image.

B.J. FULTON (LCOGT)/PTF/STScI

"Supernovae are being used to make statements about the fate of the universe and our theory of gravity," says Richard Scalzo of the Australian National University. "If our understanding of supernovae changes, it could significantly impact our theories and predictions."

For more than four decades, the leading theory has said that a Type Ia supernova was born in a binary star system made up of a dead star called a white dwarf and a "normal star" — one that is still burning nuclear fuel in its core. The two stars formed together, but one evolved faster than the other, shedding its outer layers and leaving behind only its dense core — the white dwarf. The theory says that the white dwarf's gravity tugs on the normal star, pulling gas away from its outer layers and onto the white dwarf. Over time, so much gas builds up on the white dwarf that its structure cannot hold it, and the white dwarf explodes. The tipping point at which a white dwarf becomes unstable is when its mass exceeds 1.4 times that of the Sun, a value called the Chandrasekhar limit.

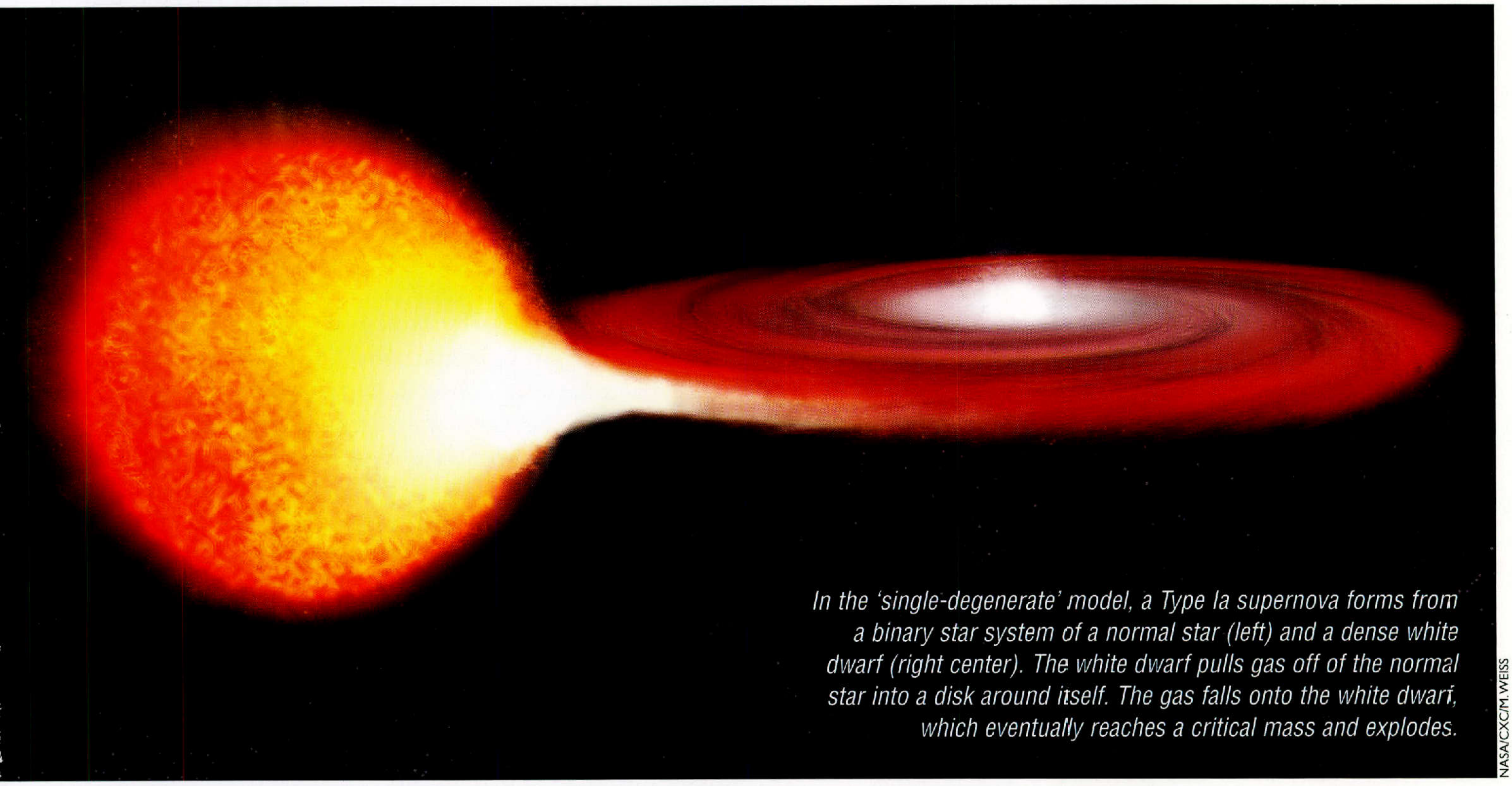
degeneracy pressure, keeps the white dwarf from collapsing further. However, once a white dwarf's mass exceeds the Chandrasekhar limit, gravity overwhelms this pressure and the white dwarf explodes.

For this reason, the progenitor model for a Type Ia supernova that involves one white dwarf and one normal star is called the single-degenerate model, and the model involving two

would evolve into a Type Ia explosion.

These studies have turned up good evidence for both the single-degenerate and double-degenerate models.

Recent evidence for the single-degenerate model includes a survey from the Carnegie Observatories, as well as deeper looks into a couple of individual supernova cases, one a famous historical supernova and the other detected only recently.



In the 'single-degenerate' model, a Type Ia supernova forms from a binary star system of a normal star (left) and a dense white dwarf (right center). The white dwarf pulls gas off of the normal star into a disk around itself. The gas falls onto the white dwarf, which eventually reaches a critical mass and explodes.

NASA/CXC/M. WEISS

In recent years, astronomers have found that there is at least one other way to create a Type Ia supernova. It involves two white dwarf stars in a binary pair. In this case, the two dead stars spiral together over time and ultimately collide, creating a catastrophic explosion.

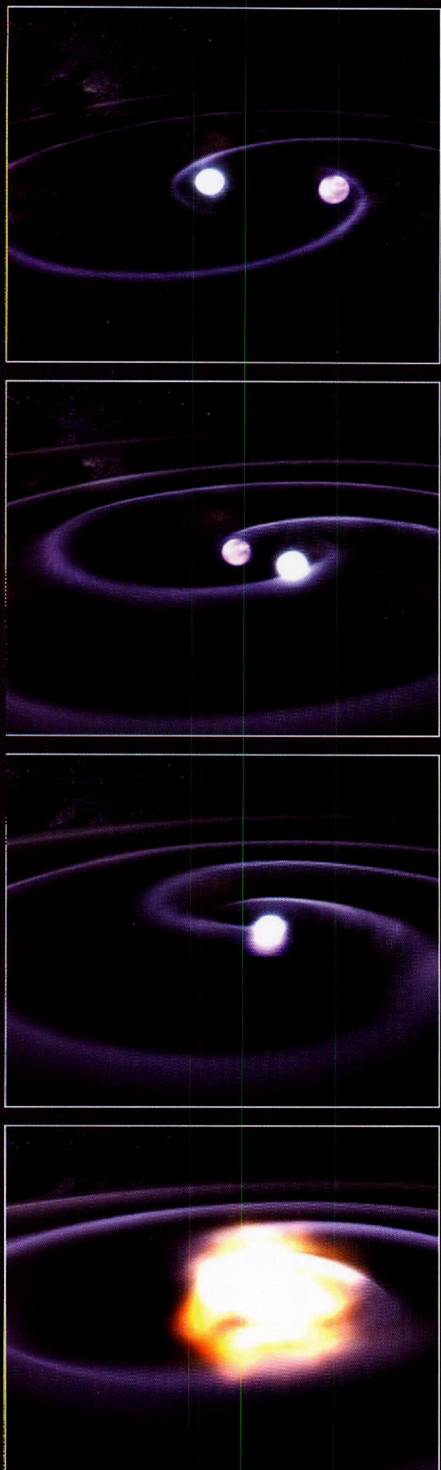
The names for the two progenitor models for Type Ia supernovae are based on an alternate name for a white dwarf: a degenerate star. Because white dwarfs are the collapsed cores of Sunlike stars, they are extremely dense. Individual atoms have broken apart into free-floating electrons that are pressed tightly together. Pressure exerted by the electrons, known as

white dwarfs is known as the double-degenerate model.

Supernova researchers are trying to determine the identities of Ia progenitors. Some make in-depth studies of the few gaseous supernova remnants in our own and nearby galaxies. Others study large numbers of supernovae in survey projects, measuring the frequency of characteristics that would match one progenitor type or another. And some work in the opposite direction: Instead of starting with the results of an explosion and working backwards to its beginning, they use supercomputers to build models of interacting binary star systems, trying different types of stars in the pair and setting them in motion to see if they

The Carnegie team studied 41 Type Ia supernovae and found signs that most of their progenitor systems had expelled cool gas prior to exploding. This means that at least one of the stars in the system was not a white dwarf, the scientists said.

The case of the historical supernova involves the remains of an exploded star discovered in 1572 by Tycho Brahe, one of the greatest astronomers of the pre-telescope age. Fangjun Lu of the Chinese Academy of Sciences led a team that made a deep study of Tycho's supernova remnant — an expanding cloud of debris from the explosion — with Chandra X-ray Observatory. The team found an arc of X-ray emission,



GSFC/D. BERRY

In the 'double-degenerate' model, two white dwarf stars orbiting in a binary pair move closer together over time as they lose gravitational energy, which is radiated away as gravitational waves (shown). When the two dwarfs merge, they will explode as a supernova. Both dwarfs are completely destroyed.

which the scientists believe was made by material blown off of the companion star when the white dwarf exploded. Had the supernova been caused by the collision of two white dwarfs, there would be no companion star left behind to create the arc, Lu said.

The recently discovered supernova is SN 2011fe. Discovered on August 24, 2011, by the Palomar Transient Factory, the supernova lies 21 million light-years away in M101, the Pinwheel galaxy. The nearest Type Ia in the past 25 years, SN 2011fe gave astronomers an opportunity to study a Type Ia in great detail. The explosion was caught early on, allowing astronomers to track how it brightened and faded beginning only hours after it exploded, and to pin down the explosion time to within 20 minutes.

The Pinwheel is a well-studied galaxy. Many pre-supernova images of the galaxy existed, including a deep Hubble Space Telescope image. A group of astronomers including Weidong Li and Joshua Bloom of The University of California, Berkeley, studied the image in depth to try to identify a companion star that would have been left behind when the white dwarf exploded.

They did not find a companion, which is significant. It means that if a companion exists, it must be dim enough to be undetectable by Hubble Space Telescope. This rules out the types of giant stars that are possible partners to the white dwarf in a single-degenerate system.

Additionally, the supernova's discoverers, including Peter Nugent of Lawrence Berkeley National Laboratory, worked on computer models of the explosion. Because the supernova had been caught so early, they were able to figure out both the upper limit of the diameter of the star that exploded and the diameter of the binary star system. Their findings confirmed that the exploding star was a white dwarf, and at the same time ruled out a second white dwarf as its companion star.

Taken together, the findings of Li and Nugent confirm that SN 2011fe formed from a single-degenerate binary system, made up of a white dwarf and a star that is similar to the Sun.

Li's team plans to search for the companion star when better technology becomes available, perhaps using James Webb Space Telescope, which is scheduled for launch late in the decade.

"What caused [Type Ia] explosions has divided the astronomical community deeply," says Caltech's Shri Kulkarni, principal investigator for the Palomar Transient Factory. "SN 2011fe is like the Rosetta Stone of Type Ia supernovae."

Not everyone is convinced that the question is settled, though. There is plenty of evidence that double-degenerate systems can create Type Ia supernovae, too.

Early last year, astronomers from Louisiana State University announced they had found proof of a Type Ia supernova created in a double-degenerate system. Bradley Schaeffer and Ashley Pagnotta studied the supernova remnant SNR 0509-67.5 in the Large Magellanic Cloud, a companion galaxy to the Milky Way. They studied an archival Hubble Space Telescope image and found that there was no companion star left behind in the remnant. They say this means that the progenitor was a merger of two white dwarfs in which both stars were completely destroyed.

A pair of larger studies lends support to this single case. First, early last year a group of astronomers set out to find if there are enough double-degenerate binary stars to account for all cases of Type Ia supernovae. The team included Dan Maoz of Tel Aviv University and Carles Badeness of the University of Pittsburgh. The team used data from the Sloan Digital Sky Survey, which has mapped a large swath of the northern sky, to look for white dwarf-white dwarf binaries within 1,000 light-years of Earth.

"We found 15 double white dwarfs in the local neighborhood and then used computer simulations to calculate the rate at which double white dwarfs would merge," Badeness says. "We then compared the number of merging white dwarfs here to the number of Type Ia supernovae seen in distant galaxies that resemble the Milky Way."

The team found that, on average, one double white dwarf merger occurs in the Milky Way each century.

"That is remarkably close to the rate of Type Ia supernovae we observe in galaxies like our own," Badeness says. "This suggests that the merger of a double white dwarf system is a plausible explanation for Type Ia supernovae."

A 2011 study of Ias in the distant universe also points toward the double-degenerate model, according to a research team that included Dovi Poznanski of Lawrence Berkeley National Laboratory. The researchers used the Subaru Telescope in Hawaii to stare at a patch of sky about the size of the full Moon for four days. The resulting image, dubbed the Subaru Deep Field, contains 150,000 galaxies that are so far away that we seem them as they looked 10 billion years ago, when the universe was less than four billion years old.

Among these early galaxies, the team found 150 Type Ia supernovae. They said this shows that Type Ias were five times more frequent in the young universe than today. They argue that because the early universe contained more young stars rapidly evolving into white dwarfs, the higher instance of Type Ias at early times supports the double-degenerate progenitor theory.

"There are not good answers yet," Poznanski says, "and it could be that we are seeing a mix of the two types of explosions. The subtle differences between single- and double-degenerate models could introduce a systematic error that we'll need to account for" when Type Ias are used for cosmology studies.

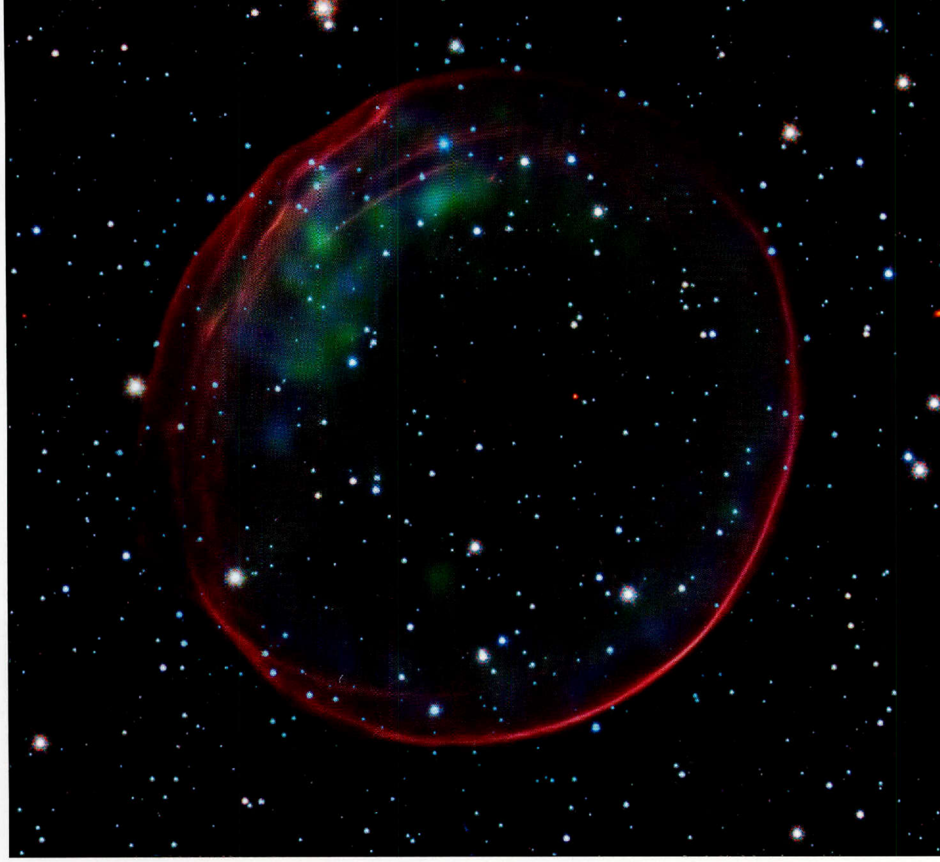
To put it another way, says Ryan Foley of the Smithsonian Astrophysical Observatory, "It's like measuring the universe with a mix of yardsticks and meter sticks. You'll get about the same answer, but not quite. To get an accurate answer, you need to separate the yardsticks from the meter sticks."

Foley may have found a way to do so. He studied 23 Type Ia supernovae with the X-ray camera on the orbiting Swift telescope, looking for signatures of X-ray gas around the explosions. Gas should appear only in single-degenerate systems.

The study found that the more powerful supernovae did show signs of the X-ray gas, and the less powerful did not. Foley suggests that these less-powerful Type Ia supernovae are the result of double-degenerate systems.

It seems clear that there are at least two ways to make a Type Ia supernova, and that astronomers will need to plan how to account for the differences in using them as standard candles for cosmology studies. Although some dark energy projects will use other methods to probe this mysterious force, the proposed Joint Dark Energy Mission between NASA and the Department of Energy plans to use a dedicated space telescope to find hundreds of Type Ias at the earliest cosmic times to probe how dark energy changes over time.

Rebecca Johnson is editor of StarDate *magazine.*



NASA/ESA/CXC/SAO/HUBBLE HERITAGE TEAM (STScI/AURA)/J. HUGHES (RUTGERS UNIV.)

Astronomers searched supernova remnant 0509-67.5 in vain for a left-behind companion star to the destroyed white dwarf. They argue the progenitor was a double-degenerate system in which two white dwarfs merged and were destroyed. Seen in optical light (pink) by Hubble Space Telescope and X-rays (green and blue) by Chandra X-ray Observatory, the 23-light-year wide shell of gas is expanding faster than 11 million miles per hour.

Resources

Internet

StarDate Astro Guide: Stars
stardate.org/astro-guide/btss/stars

Discovery of Dark Energy
nobelprize.org/nobel_prizes/physics/laureates/2011

Supernova Cosmology Project
supernova.lbl.gov

High Z Supernova Search
www.cfa.harvard.edu/supernova/HighZ.html

Palomar Transient Factory
astro.caltech.edu/ptf

Hobby-Eberly Telescope Dark Energy Experiment
hetdex.org

Article

"Stirring Up a Supernova," by Damond Benningfield, *StarDate*, November/December 2006

SKY CALENDAR

by Alan MacRobert

As the flower buds open, winter's constellations give way to those of spring. The Big Dipper wheels around to dump April showers, and the lion stalks westward. Jupiter blazes overhead in the evenings, with Saturn putting on a lesser show.

MARCH 1 - 15

Look around as the glow of daylight dwindles, and the first "star" of the evening you're likely to see is Jupiter, high in the southwest. The next is likely to be Sirius, not quite so high in the south. They are the brightest planet and brightest star of this season.

Jupiter and Sirius bracket the brightest constellation, Orion. Look for Orion midway between them as night comes on. Orion is now starting to tip southwestward on the way to its annual springtime departure. In its middle, Orion's Belt of three stars points more or less toward Jupiter to the right and Sirius to the left.

This whole big alignment turns to lie lower and more horizontal as night advances.

Jupiter and Sirius each come with a bright sidekick. Look five degrees to Jupiter's lower left (about the width of three fingers held at arm's length) for orange Aldebaran. It's a first-magnitude star, but Jupiter far outshines it.

Look five degrees to the lower right of Sirius for Mirzam, which is fairly bright at second magnitude.

Procyon is high above Sirius and perhaps a bit to its left. Sirius and Procyon are the Dog Star and the "little dog star," the highlights of Canis Major and Canis Minor. And they share another trait: Both are close neighbors of our solar system. Sirius is 8.6 light-years away; Procyon, 11. That still makes them 540,000 and 720,000 times farther from Earth than the Sun.

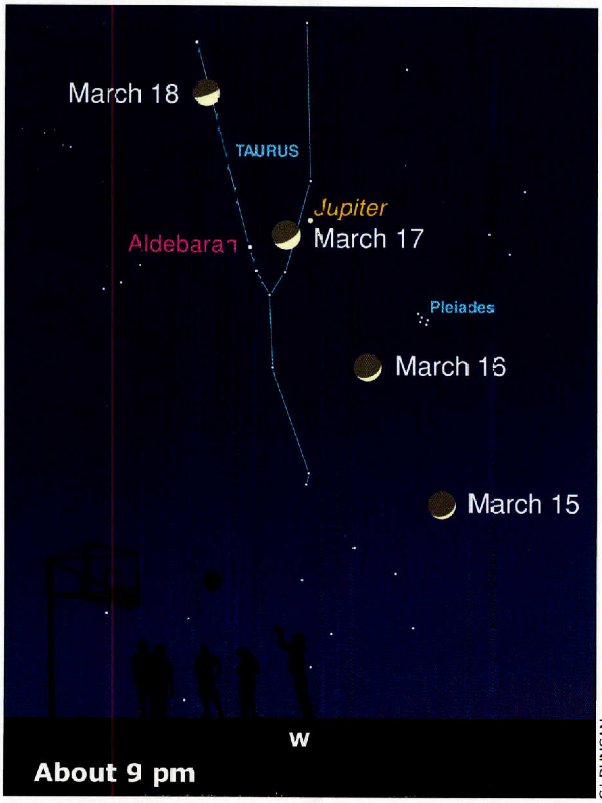
Bright orange Betelgeuse represents Orion's left shoulder. Procyon, Sirius, and Betelgeuse form the equilateral Winter Triangle.

Now imagine that you could take hold of the Winter Triangle, pin Sirius and Procyon in place, and flip it over so Betelgeuse shined on their opposite side. From that spot, move to the left by one or two fist-widths at arm's length to find lonely, Betelgeuse-colored Alphard. (Its name means "the solitary one.") Alphard is not at all hard to spot, just qualifying as a first-magnitude star. It represents the heart of dim, sprawling Hydra, the sea serpent.

Look above Alphard by about a fist and a half for the thumb-sized clump of dim stars forming Hydra's head — an evening harbinger of spring's approach.

MARCH 16 - 31

Jupiter drops a little lower in the west each week now. And the big parade of Orion and Sirius stretching to its left is becoming more horizontal — more so the farther south you live.



Aldebaran still shines to the lower left of Jupiter. Look just below them for the faint V pattern of the big, loose Hyades star cluster. The V stands upright at this time of year. Aldebaran forms its left top point, and Jupiter forms an extension of its right top point.

Look farther to the lower right of Jupiter for the fingertip-size Pleiades star cluster.

Make a note that on Sunday evening, March 17, the waxing crescent Moon passes through the midst of this arrangement, posing between Jupiter and Aldebaran.

With spring arriving, Sirius is a little past due south as night comes on. There's still time to trace out the rest of the constellation Canis Major before it trots offstage.

Under typical city or suburban light pollution, only five stars of Canis Major show through, forming more of a meat-cleaver shape than a dog. Sirius is a bright glint on the top corner of the cleaver. To Sirius' lower right, Mirzam marks the front corner of the cutting edge. Three stars farther to the lower left form the narrower back of the cleaver and its stubby handle.

These last three are named, from right to left, Adhara, Wezen, and Aludra. They're about as high right now as they ever get, which isn't very high as seen from the latitudes of the northern United States.

In a dark sky, more stars come out, and with only a little imagination (and a good constellation guide) you can spot the Big Dog's dim, triangular head above Sirius (which he wears proudly on his chest like a dog tag). Adhara is his hind leg, Wezen is his rump, and Aludra is his tail.

Aside from Jupiter, Saturn is the only other bright planet visible these nights. Wait up until 10 or 11 (depending on where you live in your time zone) to see Saturn rising in the east-southeast. Don't confuse it with brighter Arcturus, high to Saturn's upper left, or Spica, closer to Saturn's upper right. Mercury, Venus, and Mars are hidden in the glare of the Sun.

APRIL 1 - 15

With the start of April, Arcturus is already twinkling low in the east-northeast as twilight fades. Look well to its right for Spica, which is not quite as bright. If you live as far south as Miami, you'll find Arcturus and Spica shining equally high in the evening. Farther north of there, your eastern horizon is tilted differently with respect to the stars, so Arcturus stands higher.

Keep watch to the lower left of Spica for Saturn. It comes up around 9 or 10 p.m., depending on whether you live near the eastern or western side of your time zone, respectively. The big triangle of Arcturus, Spica, and Saturn swings higher through the night.

High to the upper left of Arcturus, in the northeast, the Big Dipper stands on its handle, turning over to dump out April showers. The dipper's curving handle arcs back toward Arcturus.

The handle also can guide you to a lesser-known sight. If you picture the handle and that side of the bowl as a segment of a circle, then near the circle's center is the modestly bright star Cor Caroli — a grand yellow-and-violet double star in a telescope. It's in the dim constellation Canes Venatici, the hunting dogs.

Meteor Watch

The Shower

Lyrids

Named for the constellation Lyra, the harp, which is notable for its brightest star, Vega, the third-brightest star visible from most of North America.

Peak

Night of April 21

Notes

The Lyrids are a modest shower, with perhaps a dozen or two meteors per hour at best. The Moon is in its waxing gibbous phase, so it fills the sky with light for most of the night. It sets a couple of hours before sunrise, though, providing a brief viewing window before morning twilight erases the fireworks.

An even more famous double star, of course, is Mizar, at the bend in the Big Dipper's handle. With good vision (or binoculars) you can see its little companion star Alcor tucked just to its lower left. A small telescope magnifying 25 times or more splits Mizar and Alcor widely, and also reveals a second level of duplicity, with Mizar itself becoming two closely paired white suns.

Look far to the dipper's right, due east, for the spring constellation Leo, the lion, with blue-white Regulus on its right side.

Meanwhile, Jupiter, Aldebaran, and the Hyades and Pleiades star clusters are sinking rapidly in the west at dusk during April. The crescent Moon joins them on April 13 and 14.

APRIL 16 - 30

The big, long triangle of Arcturus, Spica, and Saturn rising in the eastern sky is changing shape. It's becoming narrower, as Saturn creeps toward Spica week by week. Saturn will continue to approach Spica all spring, though at an ever slower pace, until it gives up the effort in late June and starts to pull back.

Meanwhile the Big Dipper is assuming its highest position after dark, floating almost straight overhead when you face north (from most U.S. latitudes). It's upside down, as if dumping toward the northern horizon.

Look below the Big Dipper for the much dimmer Little Dipper. It's highlighted only by Polaris, at its handle-end on the left, and the two stars forming the end of its bowl on the right. These stars, Kochab and Pherkad, wheel around Polaris as the sky rotates, earning their title "Guardians of the Pole."

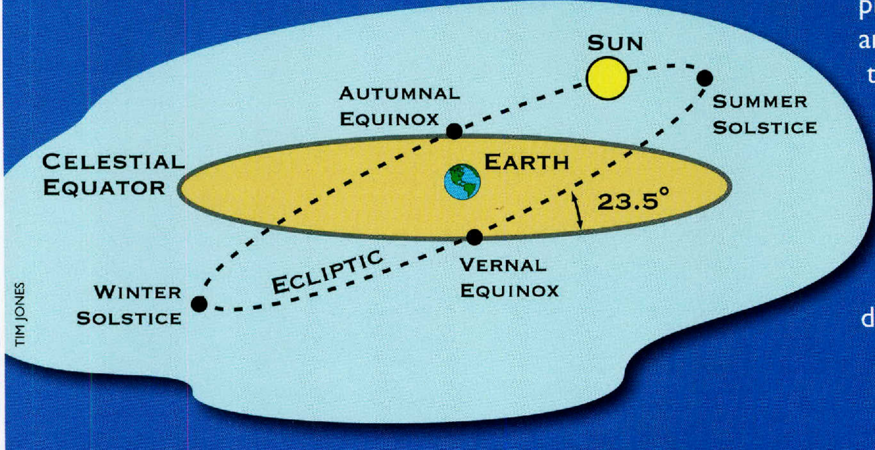
If you have an open horizon to the north, look low on the other side of Polaris from the Big Dipper for the dipper's eternal opposite: W-shaped Cassiopeia, usually considered a constellation of fall and winter. Cassiopeia and the Big Dipper forever circle the pole on opposite sides of Polaris, their ascendancies and declines marking the turning of the seasons.

Turn around; Leo is high in the south these nights. We see the lion in profile, stalking westward, with its tail star Denebola on the left and the Sickle pattern forming the lion's head, mane, and forequarters on the right.

Leo always announces spring. Now that spring is here, he's already walking westward, preparing to leave the sky come summer.

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

March 20:
VERNAL EQUINOX



TIM JONES

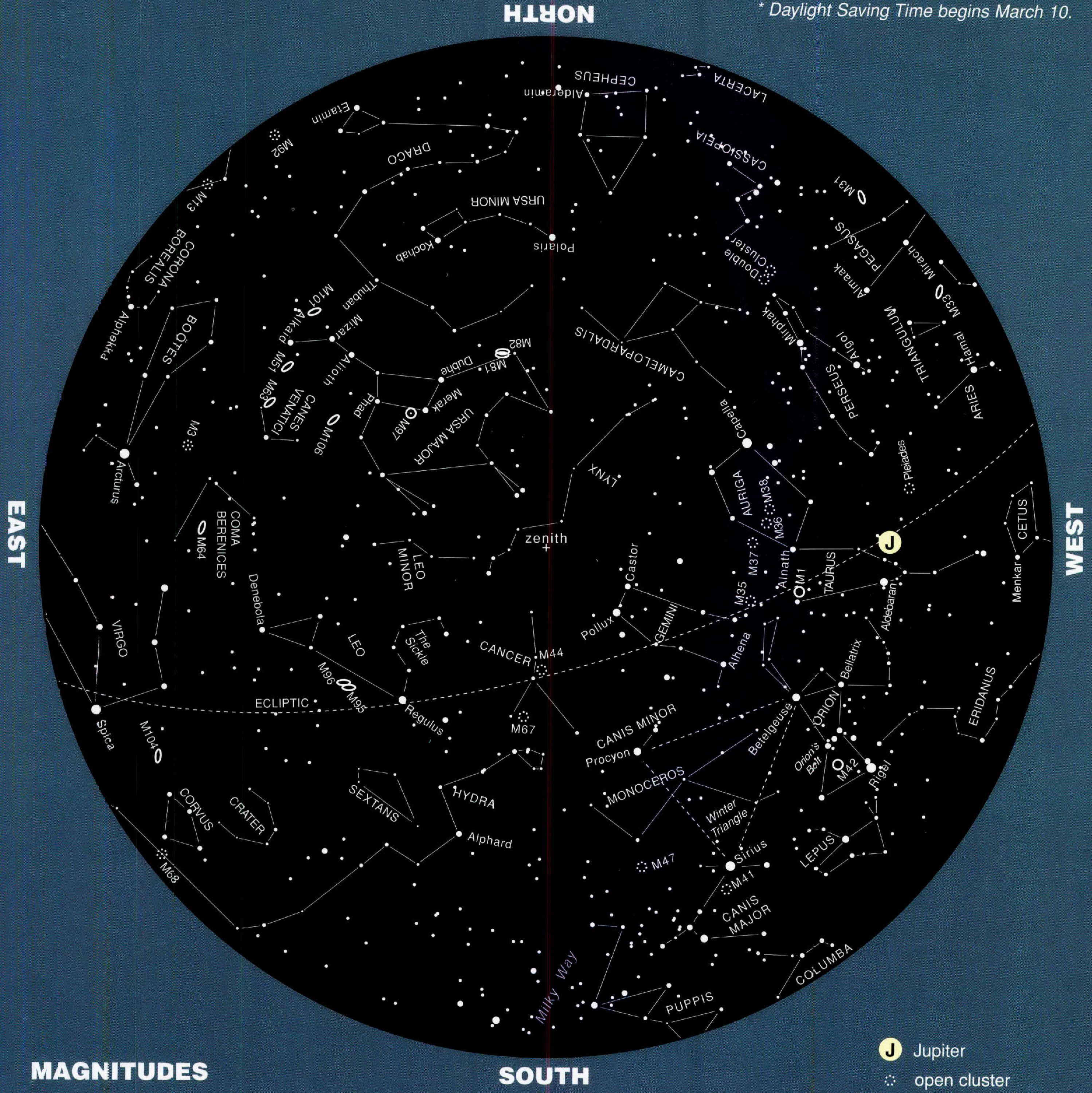
As seen from Earth (left), the Sun's apparent path through the stars, over the course of one year, forms a circle called the ecliptic. Twice each year, the Sun's path crosses the celestial equator (Earth's equator projected onto the sky). At these times, night and day are of equal length. These dates are called equinoxes — the Latin word for "equal night." This year's spring, or vernal, equinox is coming up on March 20. The fall, or autumnal, equinox, will occur on September 22. Soltices — Latin for "standing Sun" — occur when the Sun is at its highest point above the celestial equator (summer solstice, the longest day of the year) and lowest point below it (winter solstice, the shortest day of the year).

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	**10 p.m.***

** Daylight Saving Time begins March 10.*



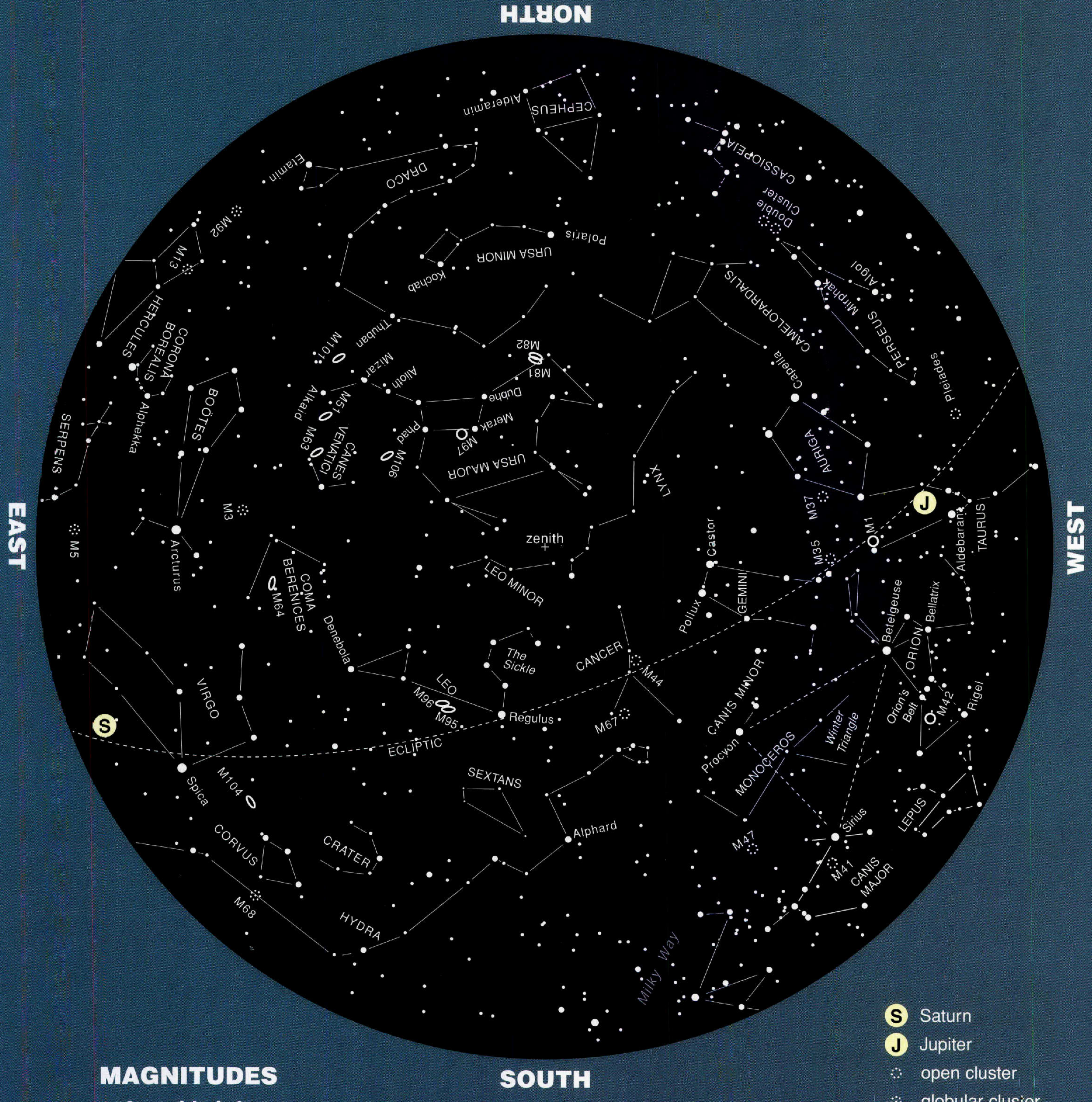
MAGNITUDES
- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

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

Charts produced with Voyager II software.

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
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- 4 and fainter

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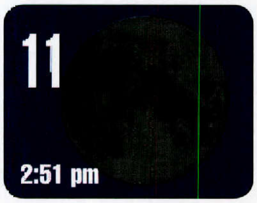
- globular cluster
- nebula
- planetary nebula
- galaxy

Charts produced with Voyager II software.

Sky Highlights

by Damond Benningfield

MARCH



Moon phase times are for the Central Time Zone.

1 Spica, the brightest star of Virgo, is close to the right of the Moon at first light.

2 The planet Saturn, which looks like a bright golden star, stands just above the Moon at dawn.

4 Antares, the bright orange heart of Scorpius, huddles below the Moon in the pre-dawn sky.

9 Comet C/2011 L4 (PANSTARRS) is expected to shine at its brightest, although it will be quite low in the western sky at sunset. (See details, page 18.)

10 Daylight Saving Time begins in the United States at 2 a.m.

17 Dazzling Jupiter is close to the upper right of the Moon at nightfall, with the orange star Aldebaran, the eye of Taurus, a little farther to the lower left of the Moon.

20 Spring arrives in the northern hemisphere with the vernal equinox at 6:02 a.m. CDT, as the Sun crosses the equator from south to north.

23/24 The Moon swings by Regulus, the heart of Leo. Regulus is to the lower left of the Moon as darkness falls on the 23rd, and about the same distance above the Moon on the 24th.

27 The bright star Spica rises almost directly below the Moon in late evening, and is quite close to the upper left of the Moon at first light on the 28th.

28 Spica is to the upper right of the Moon, with the planet Saturn about the same distance to the lower left of the Moon late this evening. They are high in the sky at first light on the 29th, with Saturn to the upper left of the Moon and Spica farther to the right.

30 Saturn stands above the Moon as they climb skyward in the wee hours of the morning.

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

APRIL

13 Aldebaran, the orange eye of Taurus, the bull, is to the upper left of the Moon this evening, with brilliant Jupiter well above them.

14 Jupiter, the largest planet in the solar system, stands close to the lower right of the Moon this evening.

19/20 Regulus, the leading light of Leo, the celestial lion, is the Moon's companion for a couple of nights. The bright white star is well to the left of the Moon at nightfall on the 19th, and much closer to the upper left of the Moon on the 20th.

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

21 The Lyrid meteor shower should be at its best tonight (see page 11).

24 Spica, the brightest star of Virgo, stands just above the Moon at nightfall, with the bright planet Saturn to their lower left.

25 Golden Saturn poses to the upper left of the Moon early this evening. They remain close together as they sail across the sky during the night.

28 Antares, the luminary of Scorpius, is the bright orange star below the Moon at first light.

28 Saturn, the second-largest planet in the solar system, is at its best for the year. It rises around sunset and shines all night in Virgo, with the constellation's brightest star, Spica, to the right of Saturn. Saturn looks like a bright golden star.

AstroMiscellany



NASA (3)

Participants in the 2012 race

Dashing Through the Moondust

Moonbuggies will kick up some (simulated) lunar dust as teams of students from around the world compete in NASA's 20th Great Moonbuggy Race April 26-27 at the U.S. Space and Rocket Center in Huntsville, Alabama. High school and college teams will race their rovers across a half-mile course that simulates conditions on the Moon. Racers from Erie (Kansas) High School hold the course record of 3 minutes, 17 seconds, set in 2008. The event is open to the public.

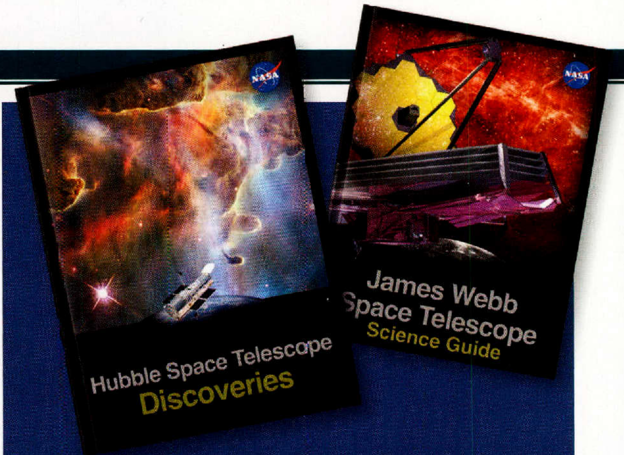
www.nasa.gov/moonbuggy

Experience the Webb Telescope at SXSW

NASA and Northrop Grumman are bringing a full-size model of the James Webb Space Telescope (seen here in front of the Maryland Science Center) to the South by Southwest Interactive Festival in Austin March 8-10. Festival passes will not be necessary to visit the tennis-court-sized model, which will also be the site of talks by scientists from NASA, The University of Texas at Austin, MIT, and others. University of Texas astronomers will host free public star parties in conjunction with the exhibit each of the three nights.

NASA/ED CAMPION

go.nasa.gov/JWSTsxsw



Free E-Books Feature Space Telescopes

NASA is offering free e-books about two of its workhorse space telescopes, one current and one future.

Hubble Space Telescope: Discoveries covers Hubble's findings over more than 20 years in space, along with many of Hubble's iconic images. The book also details the telescope's technology.

James Webb Space Telescope: Science Guide is about the long-awaited successor to Hubble that should launch later this decade. It includes a tour of the telescope and explains its scientific goals.

Both books are available in iBook and PDF versions. The iBook versions include interactive video; the PDF versions do not.

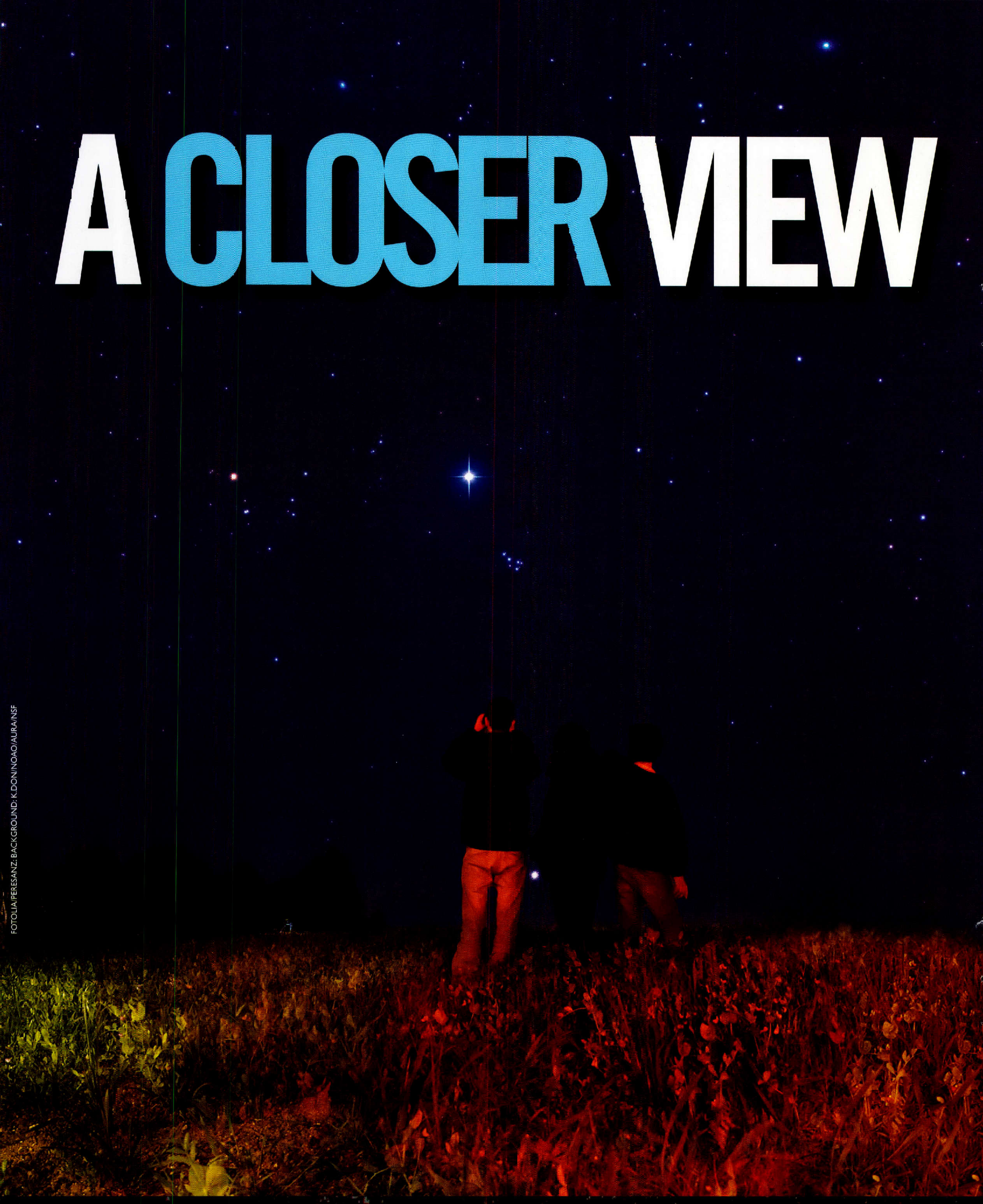
www.nasa.gov/topics/nasalife/features/e-books.html

Stellar Musicology

If you've ever wondered if anyone has written a love song to a black hole, an online article by astronomer Andrew Fraknoi has the answer. "Music Inspired by Astronomy" offers notes on more than 130 musical pieces arranged by astronomical theme, from comets to quasars. The listings cover centuries of music (all of which is currently available on CD), from Vivaldi and Handel to Jethro Tull, Barenaked Ladies, and XTC. And yes, there is a love song to a black hole: "Places Named After Numbers," by Frank Black.

aer.aas.org/resource/1/aerscz/v11/i1/p010303_s1?view=fulltext

A CLOSER VIEW



FOTOLIA/PERESANZ; BACKGROUND: K.DON/NOAO/AURA/NSF

Lightweight and easy to use, binoculars allow you to see deeper into the universe without digging too deeply into your pocketbook

The human eye is a pretty good astronomical instrument. It can detect tiny differences in brightness and color, see features on the lunar surface, and even sense the faint glow of remote star clusters and galaxies. Indeed, the eye alone is a near-perfect instrument for an evening of casual stargazing.

Eventually, though, many skywatchers yearn to see more. They want to gaze deeper into the universe, to see more stars and planets and moons, to experience the thrill of watching a faint comet as it slides against the background of stars from night to night.

And that's when many of them foul things up. They buy a telescope, plop it on the deck, and expect to see Hubble-like views of the universe. But when the telescope proves to be more difficult to use than expected, or the views aren't magazine-cover quality, they chuck the thing in the garage with the unused treadmill and give up.

Fortunately, there's an intermediate solution between the unaided eye and the telescope that can sharpen the view of the night sky quickly, easily, and inexpensively: binoculars.

The performance of a pair of binoculars is indicated by two numbers, expressed as "7x35" or "10x50." The first number is magnification, which tells you how much closer an object will look, while the second is the diameter, in millimeters, of the glass lenses at the front of the twin tubes. Larger lenses let in more light, so they provide a brighter view of the sky, although they also make the binoculars heavier.

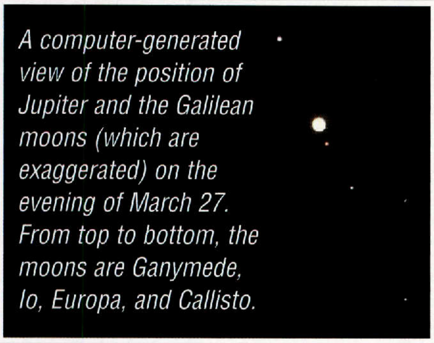
Most experts recommend 7x50 or 10x50 binoculars for skywatching because they provide a good blend of light-gathering power, light weight, and a wide field of view, which allows you to take in entire star clusters at a single glance. Most binoculars in this class run less than $200, with some coming in at less than $100. You might also want to invest in a tripod, which steadies the view and keeps your arm muscles from turning to jelly during an evening of stargazing.

Depending on the pair you choose, the binoculars should allow you to see objects that are two or three magnitudes fainter than you can see with the unaided eye — a factor of roughly 10 or so. With that boost in your light-gathering power, the hazy band of the Milky Way becomes a speckled field of individual stars, and some star clusters transform from fuzzy blobs to dense balls of twinkling lights.

This guide offers some suggestions for popular targets, but you don't need a lot of help to let your binoculars open new vistas on the universe — just step outside, take aim, and gaze deeply into the universe.

Moons of Jupiter

Jupiter's four largest moons are among the most interesting worlds in the solar system. Giant volcanoes cover one of them, while an ocean of liquid water may lie beneath the icy crust of another. And these moons — known collectively as the Galilean moons because they were discovered by Galileo — are excellent binocular targets. (Incidentally, your binoculars will gather much more light than Galileo's early telescope, which was roughly the equivalent of 14x26 binoculars.) They look like tiny stars lining up on either side of the brilliant planet.


A computer-generated view of the position of Jupiter and the Galilean moons (which are exaggerated) on the evening of March 27. From top to bottom, the moons are Ganymede, Io, Europa, and Callisto.

They orbit so rapidly that the configuration changes from night to night, so over time you might see two moons on one side of Jupiter and two on the other, or all four on one side. Sometimes, Jupiter covers one or more of the moons (or hides them in its shadow), so you won't always see four of them. The changing configuration makes the Jovian system a popular target for repeated viewing. Jupiter shines in the western evening sky in March and April, so it is well positioned for binocular viewing.

Jovian Moon Tracking Tool
www.skyandtelescope.com/observing/objects/javascript/3307071.html

Comets

March may offer a great target for those new binoculars. Comet C/2011 L4 (PANSTARRS) will lurk low in the west beginning early in the month, then climb slightly higher into the sky as the month progresses. As of late January, astronomers were expecting the comet to grow bright enough to see with the unaided eye at its peak brightness, around March 10-12, when it passes just 28 million miles (45 million km) from the Sun. The comet will be so low in the sky, however, that it will be immersed in the glow of fading twilight. Binoculars will enhance the view, allowing you to see the comet's tail, which will extend upward from the horizon. The comet should remain a good binocular target through March and into April. An even brighter comet is expected to adorn the night sky in November, and binoculars will allow you to track it as it approaches the inner solar system.

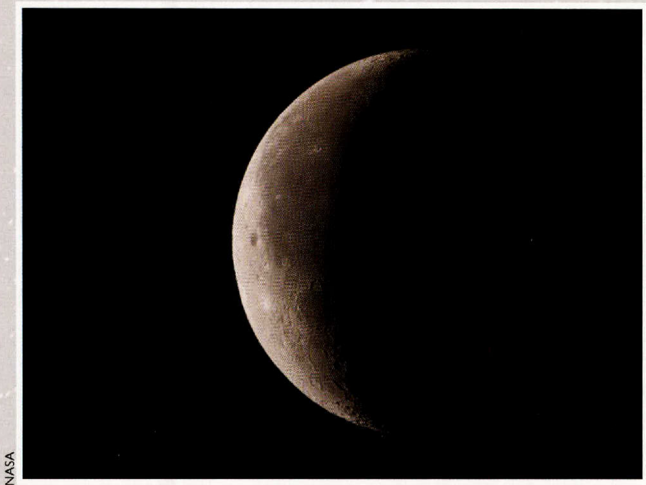

March 13, About 30 minutes after sunset

The Moon

Before Galileo Galilei turned his crude early telescope toward the Moon, our satellite world generally was considered to be perfectly smooth. Yet Galileo saw long shadows across the lunar sphere, indicating that it was marred by mountains, canyons, and giant craters. While binoculars don't show as much detail as a telescope, they allow you to see the Moon's imperfections, especially when the Moon is in its crescent phase. If you scan the terminator, which is the line that divides night and day, you will see shadows slicing across the edge of the sunlit crescent.

Slide your view over to the dark portion of a crescent Moon and you'll see the lunar features outlined like phantoms in the faint glow of earthshine, which is sunlight reflected from Earth.

And when the Moon is more fully illuminated — between first quarter and last quarter — binoculars reveal many impressive features that are invisible (or nearly so) to the unaided eye, including small volcanic plains and craters surrounded by bright rays, which consist of material blasted out by the crater-forming impacts.


NASA

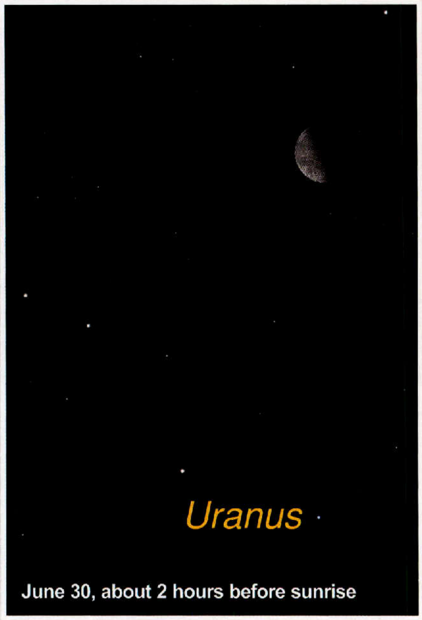
Double Stars

Many stars that look single to the eye alone become double when viewed with optical aid. Some are true binaries, so they are gravitationally bound to each other, while others simply line up along the same line of sight. The most famous example is the pairing of **Mizar** and **Alcor**, which mark the middle of the Big Dipper's handle. Most people can resolve the two stars with the eye alone, but binoculars really sharpen the view. Mizar and Alcor may form a true binary, although there are uncertainties in the distances to the two stars. Another example, which the eye sees as a single star, is **Rho Cancri**, which is close to M44 in the constellation Cancer. Its two stars are known as 53 and 55 Cancri. What makes the system particularly interesting is that 55 Cancri has at least five planets (none of which is visible through binoculars or even powerful telescopes), so it more closely resembles our own solar system than any other planetary system yet found.

Other Planets

Good, steady binoculars will show that Venus reveals phases, just as the Moon does. **Venus** is too close to the Sun to see in March and April, but will return to view as the "evening star" in May. In fact, at the end of the month Venus, Jupiter, and Mercury will huddle close together quite low in the west shortly after sunset, providing a wonderful opportunity to put your binoculars to work (make sure you have a clear horizon, with no buildings or trees blocking the planetary trio). **Mercury** is the faintest of the three. As the closest planet to the Sun it never strays far from the Sun in our sky, appearing for a little while before sunrise or after sunset. It is usually immersed in the twilight, so binoculars can really help you pick it out.

Uranus, the seventh planet from the Sun, is so remote that, at best, it barely shines bright enough to see with the unaided eye — but only under especially dark sky conditions. Binoculars easily reveal it, however, and may even show a hint of the planet's blue-green color. Like Venus, it is too close to the Sun to observe during March and April. It returns to view in the morning sky in June, and stages a good pairing with the Moon on June 30. Simply find the Moon then tip your binoculars downward until you come to the first moderately bright star-like point of light.



June 30, about 2 hours before sunrise

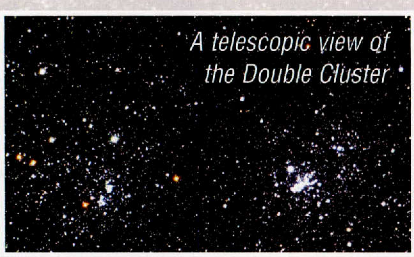
Star Clusters

Stars are born in giant agglomerations known as clusters. Over time, most clusters dissolve, but a few stick together, either because they're still young or because their stars are tightly bound. To the eye alone, several clusters are visible as small, fuzzy patches of light. Binoculars, however, resolve anywhere from a handful to a couple of dozen stars. Some good choices for this time of year include **M35**, **M44**, and the **Double Cluster**, all of which are marked on our monthly starcharts on pages 12 and 13.

M35 lies at the feet of Gemini, well below the constellation's brightest stars, Castor and Pollux. Depending on the darkness of your sky and the quality of the binoculars, you might see a half-dozen or more of its stars.

M44, also known as the Beehive, is at the center of faint Cancer, the crab. It's one of the best binocular clusters, showing about 15 or so stars under average conditions, and more under good conditions.

The Double Cluster, NGC 884 and 869, is in Perseus, which stands above the sideways



A telescopic view of the Double Cluster

N.A.SHARP/NOAO/AURA/NSF

W or M of Cassiopeia on March and April evenings and is a great binocular target.

One of the finest examples of another class of star cluster, globulars, climbs into view by around midnight in mid-March, but by 10 p.m. in mid-April: **M13**, the Hercules Cluster. It lies along one side of the lopsided square of stars, the Keystone, that outlines Hercules' body. It is faintly visible to the unaided eye, but binoculars see it as a bright, dense knot of stars. It is actually a family of several hundred thousand very old stars — a relic from the birth of the Milky Way galaxy. It is about 22,000 light-years away, so when you gaze upon the cluster, you're seeing its stars as they looked 22,000 years ago.

Resources

Binocular Manufacturers

Meade
www.meade.com

Orion
www.telescope.com

Celestron
www.celestron.com

Books

Binocular Astronomy, by Craig Crossen and Wil Tirion, 2008
www.willbell.com/handbook/hand2.htm

Binocular Stargazing, by Mike Reynolds, 2005

Binocular Highlights: 99 Celestial Sights for Binocular Users, by Gary Seronik, 2007
www.garyseronik.com/?q=node/20

Exploring the Night Sky with Binoculars, by Patrick Moore, 2000

Internet

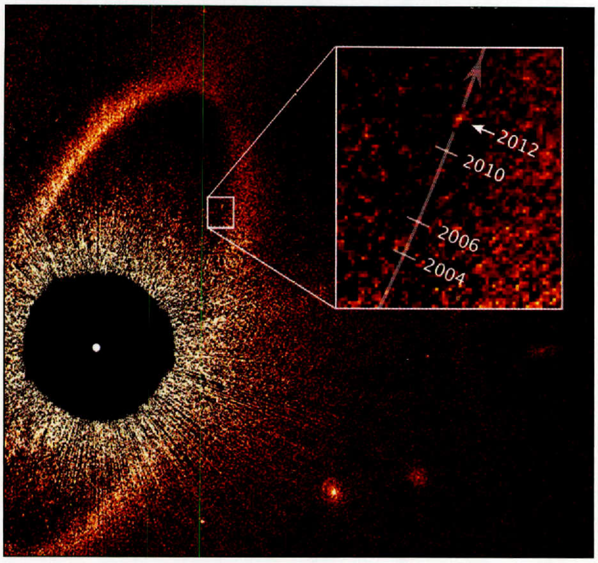
StarDate Beginner's Guide
stardate.org/nightsky/bguide

Binoculars for Astronomy
www.skyandtelescope.com/howto/howtoequipment/3389576.html

A Guide to Binoculars
www.nightskyinfo.com/binoculars/

Binoculars for Astronomy
www.universetoday.com/13665/binoculars-for-astronomy

by Rebecca Johnson and Damond Benningfield



NASA/JPL; LEFT: NASA/ESA/P.KALAS (UNIV. CALIFORNIA, BERKELEY)

LEFT: Astronomers combined Hubble Space Telescope images of Fomalhaut b shot over almost a decade to show its path around the star. The background image shows the disk of material around Fomalhaut, with the star blacked out. RIGHT: An artist's concept shows rocky asteroids being pulverized as they spiral close to a white dwarf. The debris will fall onto the star, 'polluting' its spectrum.

Beyond the Numbers

Astronomers add up the evidence to learn more about exoplanets

Storms many times bigger than Earth may swirl through the atmospheres of giant planets that are locked in tight orbits around their parent stars. Comet-like bodies, which are the building blocks of planets, are swirling around young stars. The possible remains of rocky planets appear to be falling onto the surfaces of several dead stars, known as white dwarfs. And one or more planets may reside in a wide gap between an outer band of comets and a recently discovered inner band of asteroids around the bright star Vega.

These recent findings show that the study of exoplanets — worlds that orbit stars other than the Sun — is entering a new phase. Individual planet discoveries generate little buzz, largely because the number of known planets is growing rapidly. By early January, it was close to 900, with another 2,600 candidates in observations by the planet-hunting Kepler spacecraft and hundreds more in ground-based observations.

With so many worlds to compare and contrast, astronomers now can turn to the business of understanding more about how planets form, how planetary systems evolve, and how many of them are possible homes for life.

Not that the numbers don't matter. At the January meeting of the American Astronomical Society, for example, one group of astronomers reported that, based on a statistical study, the Milky Way galaxy may contain one planet for every star (100 billion total according to the group's numbers, although some estimates put the number of stars in the Milky Way at up to 400 billion). Another group said that one in six stars should have a roughly Earth-size planet in a close orbit.

Even in systems where no planets have been discovered, there is evidence of the planet-building process, or of the demise of a former planetary system. One study, for example, has found evidence of icy comets around 11 young stars. An abundance of comets around a star suggests that planets are taking shape there. Other studies have found evidence of disintegrating asteroids around 30 white dwarf stars, which are the final stage of life for stars like the Sun. The material in the asteroids roughly matches the composition of Earth, suggesting that the residue of rocky planets is falling onto these dead stars.

So far, only a handful of planets have been detected in their stars' habitable zones, which are the regions where temperatures are right for liquid water. One candidate is in the star system Tau Ceti, a star quite similar to the Sun just 12 light-years away. An international team reported the discovery of five planets around the star, with one planet, about five times the mass of Earth, at about Earth's distance from Tau Ceti.

Several teams are searching for planets in the habitable zones of red dwarfs, which are the smallest and most feeble stars. Although their habitable zones would be small, it should be easier to detect planets around these stars than around larger stars like the Sun.

All of these discoveries and ongoing projects show that exoplanets are one of the hottest topics in present-day astronomy, and are likely to remain at the forefront as many more planets are discovered in the years ahead. **DB**

Fool Me Once...

Supernova 'impostor' finally blasts itself apart

A giant star that twice teased astronomers into thinking it had exploded finally blasted itself to bits last year, offering new insights into the final days of some of the most massive stars in the universe.

The star is in the spiral galaxy NGC 7259, which is 67 million light-years away. After it staged a mammoth eruption in 2009, astronomers designated the star as Supernova 2009ip. Within days, though, they had second thoughts, because the explosion faded too quickly and the material it expelled was moving slower than that from a typical supernova. The star staged a similar outburst one year later. Neither eruption was a true supernova, but "a supernova impostor," said Jon Mauerhan of the University of Arizona during a January press conference.

A third outburst, on July 24, 2012, finally matched the specifications of a true supernova. The outburst remained bright for weeks, and the ejected material was traveling at about three percent of the speed of light. The supernova grew even brighter in September as this high-speed material rammed into the gas expelled in the earlier, smaller outbursts.

Pictures of the star from several years before the explosion revealed that it was a luminous blue variable. The star was 50-80 times as massive as the Sun, one million times brighter, and it underwent rapid changes in brightness. Supernova 2009ip is the first confirmed instance of such a star exploding as a supernova, and suggests that a similar star just a few thousand light-years from Earth, Eta Carinae, could explode at any time.

Astronomers are not sure what caused the earlier outbursts from 2009ip. "The star was undergoing instabilities, temper tantrums in its core," says Mauerhan. "We don't know why." One possibility is a reduction in the radiation pressure in its core, which keeps the star from collapsing, while another is the ignition of nuclear fusion in successively heavier elements in the core. Either process could mimic a true supernova, in which the star's core collapses and its outer layers blast into space. **DB**

ETTORE CARRETTI (CSIRO)/S-PASS SURVEY TEAM/AXEL MELLINGER (CENTRAL MICHIGAN UNIVERSITY)

Letting Off Some Steam

Geysers of hot gas erupt from the center of the Milky Way galaxy in this composite radio and optical view. Observations with the Parkes radio telescope in Australia suggest the gas comes from generations of exploding stars. The explosions create giant bubbles that rise out of the Milky Way's dense core. As they rise, they help compress clouds of gas and dust that give birth to new stars, the most massive of which soon explode as well, adding to the outflow. The bubbles of hot gas merge to form a nearly continuous geyser that's blowing away from the core at speeds of more than 2 million miles per hour (3.6 million kph). In this image, the outflows span about 50,000 light-years from top to bottom. The outflows were detected by earlier telescopes, but the Parkes observations provide by far the sharpest view to date.

Sleeping Away the Martian Day

There's no evidence of life on Mars, but a recent laboratory experiment shows that some types of extreme life could survive on the planet. Researchers from Villanova University sealed *E. coli* bacteria and tiny creatures known as tardigrades inside a vacuum chamber under Mars-like conditions of temperature, pressure, and atmospheric composition.

When exposed to harsh conditions, tardigrades enter a hibernation-like state; when conditions improve, they re-animate. The tardigrades never entered their hibernation state during the first Villanova test runs, but did go to sleep and successfully revive during subsequent tests. The bacteria survived as well. In upcoming tests, the researchers plan to subject the tardigrades to even colder temperatures and harsher radiation, and to add *bacillus* bacteria to the test runs.

ALMA (ESO/NAOJ/NRAO)/M. KORNMESSER (ESO)/N. RISINGER

ESO/C. MALIN

The Large and Small Magellanic Clouds shine over ALMA. Inset: Artist's concept of gas crossing a gap in the planet-forming disk to fall onto a young star.

ALMA Comes of Age in Chile's High Desert Plains

One of the world's largest ground-based observatories is set to be dedicated March 13 in the Chilean desert. The Atacama Large Millimeter/Submillimeter Array (ALMA) is an international partnership between North America, Europe, and Asia. The U.S. partner is the National Science Foundation.

ALMA is the first telescope to probe the millimeter-wavelength universe in great depth. It should uncover new details about the birth of the first stars and galaxies, and probe the early stages of planet formation around other stars.

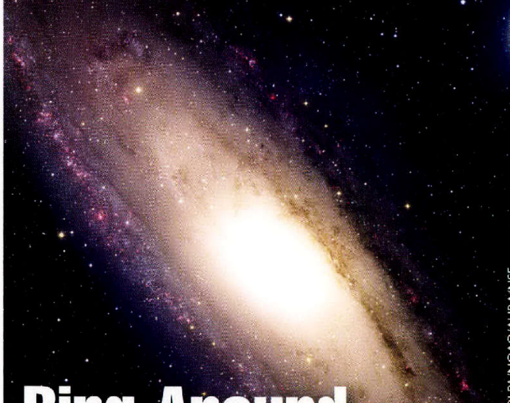
The array is scheduled for completion later this year. But with more than 50 of its planned 66 millimeter-wave antennas operational, ALMA has already produced some intriguing scientific results. In one recent study, a team led by Simon Casassus of the University of Chile found that still-forming planets can help their parent star to continue growing.

Planets form inside a disk of material orbiting a star. As the planets grow by attracting gas and dust, they clear out gaps in the disk. Previous studies had shown that the star continues to increase in mass simultaneously, puzzling astronomers. How could material cross the gap to reach the star?

Casassus' team found that the gap is not empty; it contains carbon monoxide gas. The team discovered streamers of dense gas passing through the gap, from the outer disk into the inner. The researchers suggest that protoplanets near the star are pulling the streamers, and some of the gas overshoots the planets and falls onto the star.

Another team, led by Luca Ricci of Caltech, found that it may be possible for rocky planets to form around brown dwarfs, which are failed stars. A brown dwarf forms like a star, but is not massive enough to ignite nuclear fusion in its core.

Using ALMA, Ricci's team found that a disk around a small brown dwarf contains millimeter-sized dust particles, the kind scientists think are large enough to stick together to form the core of a protoplanet. They also found that the disk contains carbon monoxide gas. These findings mean that the disks around failed stars are more like disks around young true stars than astronomers realized. **RJ**



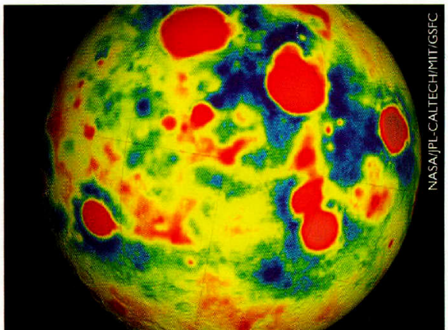
Ring Around the Galaxy

An international team of astronomers has found that more than half of the satellite galaxies of our largest neighbor galaxy, Andromeda or M31, orbit it in a flat disk more than one million light-years across.

Roderigo Ibata of France's Observatoire de Strasbourg led a team that carried out the Pan-Andromeda Archeological Survey (PANDAS) with the Canada-France-Hawaii Telescope and confirmed its findings through follow-up with the giant Keck telescopes.

Historically, scientists thought that each satellite, or dwarf, galaxy behaved independently of the others orbiting a larger galaxy. The PANDAS study could force astronomers to re-think how galaxies form, as dwarf galaxies are the most numerous in the universe and are thought to be the building blocks of giant galaxies like our own.

"We don't know yet where this is pointing us," Ibata said. "It flies in the face of our ideas about galaxy formation, but it surely is very exciting." **RJ**



NASA/JPL-CALTECH/MIT/GSFC

GRAIL Moon Map

The twin GRAIL spacecraft have completed their gravity map of the Moon. In this view of the lunar nearside, red circles indicate mass concentrations below the surface caused by variations in the thickness of the Moon's crust or the density of its mantle. The craft were crashed into the Moon in December.

SPRING BREAK UNDER THE STARS

McDonald Observatory has expanded its schedule of tours and star parties in March, so you can spend your spring break with us! Daytime tours include large research telescopes and 100-mile vistas in a beautiful mountain setting. After hours, enjoy one of our famous star parties under the darkest night skies of any professional observatory in the continental United States. To guarantee your spot, make your reservations online at mcdonaldobservatory.org/visitors.

GUIDED TOURS

March 9-16

10:30 a.m, 11:15 a.m.*, Noon, 12:45 p.m.*,
1:30 p.m., 2:15 p.m., 3 p.m., 3:45 p.m.*

March 11-13, 15-16

All of the above, plus 4:30 p.m.

* These tours not held March 10 or March 16

TWILIGHT PROGRAM & STAR PARTIES

March 9

Twilight program at 4:45 p.m. and 6:05 p.m.
Star party starts at 7:30 p.m.

March 11-13, 15-16

Twilight programs at 6 and 7:20 p.m.
Star parties start at 8:45 p.m.

FOR MORE INFORMATION

MCDONALDOBSERVATORY.ORG/VISITORS | TOLL FREE 877-984-7827

Hubble Space Telescope captured this image of planetary nebula NGC 5189. Actually the remains of a dying star, a planetary nebula forms when the bloated star puffs off its outer layers of gas into space. The gas forms wispy tendrils around the star's remaining core, a cooling cinder called a white dwarf.

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