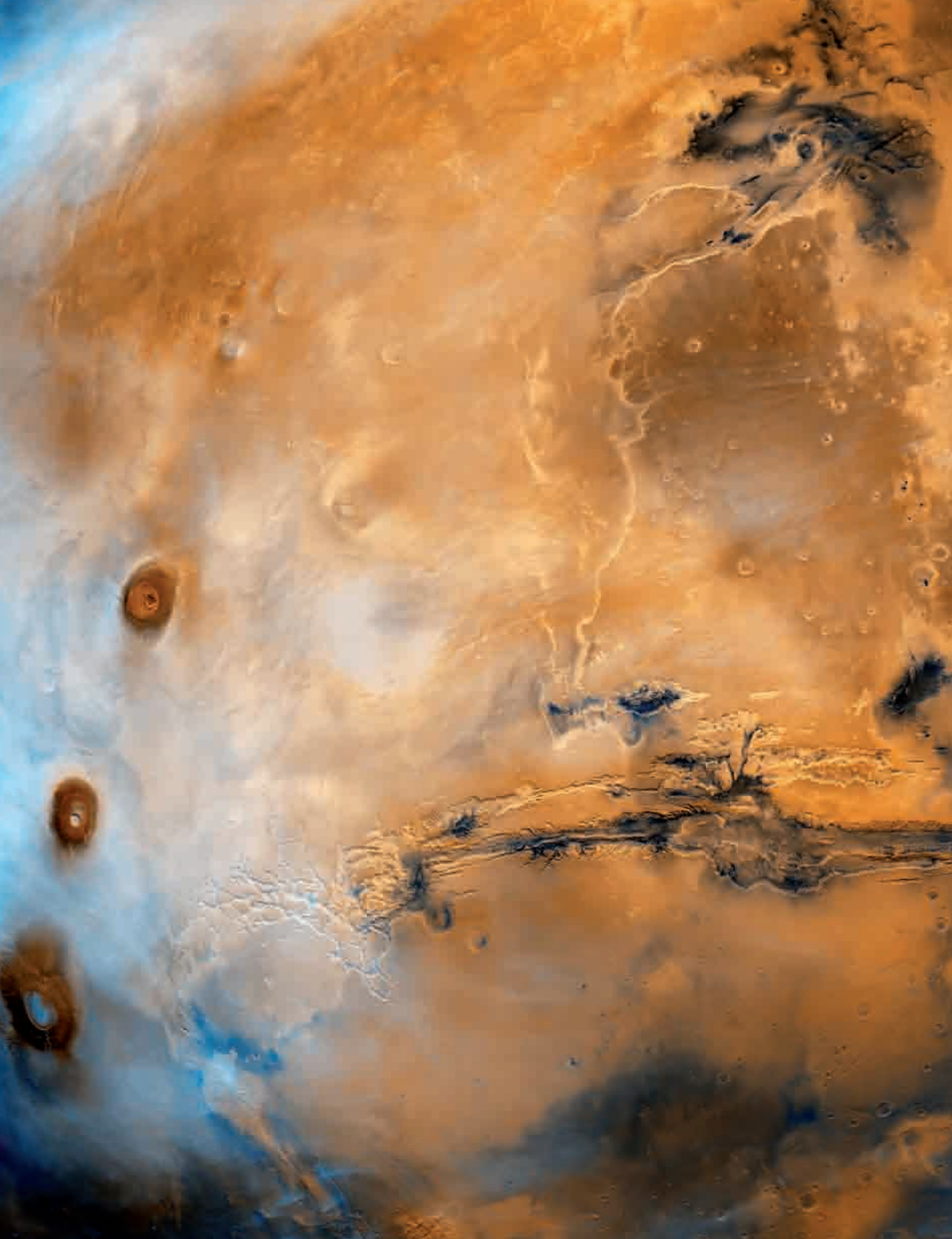
A S T R O N O M I C A



ASTRONOMICA

foreword by
Sir PATRICK MOORE

chief consultant
Professor FRED WATSON

GALAXIES • PLANETS • STARS
CONSTELLATION CHARTS • SPACE EXPLORATION

h.f.ullmann

C o n t




e n t s




The Sun

FACT FILE

Average Distance from Earth
1 AU/92,955,820 miles/
149,597,870 km

Age
4.6 billion years

Length of day
25.38 Earth days

Equatorial radius
432,200 miles/695,500 km
(109 times that of Earth)

Mass
4.385 x 10^{30} lbs/
1.98892 x 10^{30} kg
(332,900 times that of Earth)

Average Temperature
10,000°F/5,500°C

Composition by mass
74 percent hydrogen,
25 percent helium

Notable features
The Sun is a G2 star. Energy generated in the Sun's core takes a million years to reach its surface.

It holds the planets in their orbits, it provides life-giving energy, and it dominates our sky. The Sun truly is the center of our local universe.

The Sun is located at the center of the Solar System. All the planets, minor planets (asteroids), Kuiper Belt Objects, and most comets are gravitationally bound to it in orbits. To the ancient Greeks it was Helios; to the Romans, Sol; to the Egyptians it was associated with one of their leading gods, Ra.

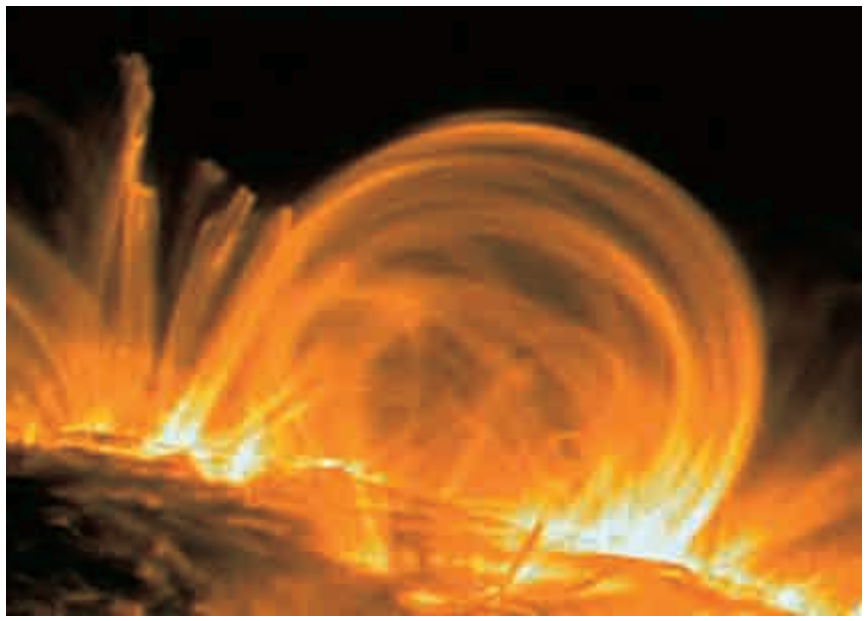
The Sun contains 99.8 percent of all the mass in the Solar System, with the eight planets, the dwarf planets, asteroids, comets, and meteoroids make up the remaining two-tenths of a percent. It dominates everything in its region of space.

The Sun is a massive 865 million miles (1,392 million km) in diameter; by comparison, Earth measures only 7,920 miles (12,746 km) wide. In fact, the Sun is so massive that you could fit Earth 1.3 million times inside, and it has about 330,000 times more mass than Earth!

Because the Sun is not a solid body, like a rocky planet is, but rather is a huge globe of intensely hot gas, it does not rotate as a solid mass. It rotates faster at the equator—around 25 days for a full rotation—than it does at its polar regions where it takes a much longer 35 days. The Sun, along with its retinue of planets and other bodies, orbits around the center of the Galaxy, taking around 220–260 million years to complete one circuit at a speed through space of around 135 miles (217 km) per second. It, and everything else in the Solar System, is made from the material ejected during the explosive destruction of earlier generations of stars. In fact, scientists think our star probably belongs to the third generation of stars born after the Big Bang. Although it looks big and bright in our daytime skies, the Sun is, in fact, a fairly ordinary star as stars go. Its surface temperature is a white-hot 9,932°F (5,500°C), though to our eyes it looks yellow, as part of its blue light is scattered in the atmosphere of Earth.

The Sun is what is known as a main sequence star, which means that it is in its middle age—roughly 4.6 billion years old. Scientists estimate it has probably another five billion years of life before it peters out and becomes a white dwarf star—a dying stellar ember.

Above right An ancient Roman carving, from Tyre, of the Sun god, Helios. Helios was imagined as a handsome god, crowned with the shining aureole of the Sun, who drove a chariot across the sky.



Right Digital impression of solar flares swirling off the surface of the Sun. This region is where the solar wind originates.

GREAT BALLS OF FIRE

The Sun is composed mainly of hydrogen (74 percent by mass) and helium (25 percent), with small amounts of some other elements. Its internal structure is broken into three zones: The core, the radiation zone, and the convection zone. In the core, the pressure is so great that hydrogen atoms get squashed together (fused) to form helium, releasing prodigious amounts of energy in the process. The temperature

Opposite Amazing snapshot of the solar corona taken by SOHO (Solar and Heliospheric Observatory). The corona is a plasma and can reach temperatures greater than 1 million°K. The North and South poles clearly show up as "cooler" regions.

***c.* 4.567 Billion BCE**
The Sun, a star, is born (give or take a few millennia).

5000-3500 BCE
The first device for indicating the time of day is built. It consists of a vertical stick casting a shadow by the Sun. The length of the shadow gives an indication of the time of day. (The first sundial.)

3000 BCE
Known as "the cave of the sun," Newgrange, Ireland, is built. On winter solstice, the sunlight perfectly aligns with an opening in the structure to illuminate the inner chamber.

***c.* 2700 BCE**
Stonehenge, in England, is built. It is a giant circle of huge stones that are aligned to the position of the Sun.

1223 BCE
The oldest eclipse is recorded on a clay tablet uncovered in the ancient city of Ugarit, (in what is now Syria).

***c.* 200 BCE**
Aristarchus of Samos, a Greek mathematician and astronomer, announces a theory of a Sun-centered universe. He also attempts to mathematically calculate the sizes and distances of the Sun and Moon.

965-1039 CE
Muslim scholar, Abu Ali Al-Hasan, invents the camera obscura and becomes the first known person to use a device to observe the Sun.

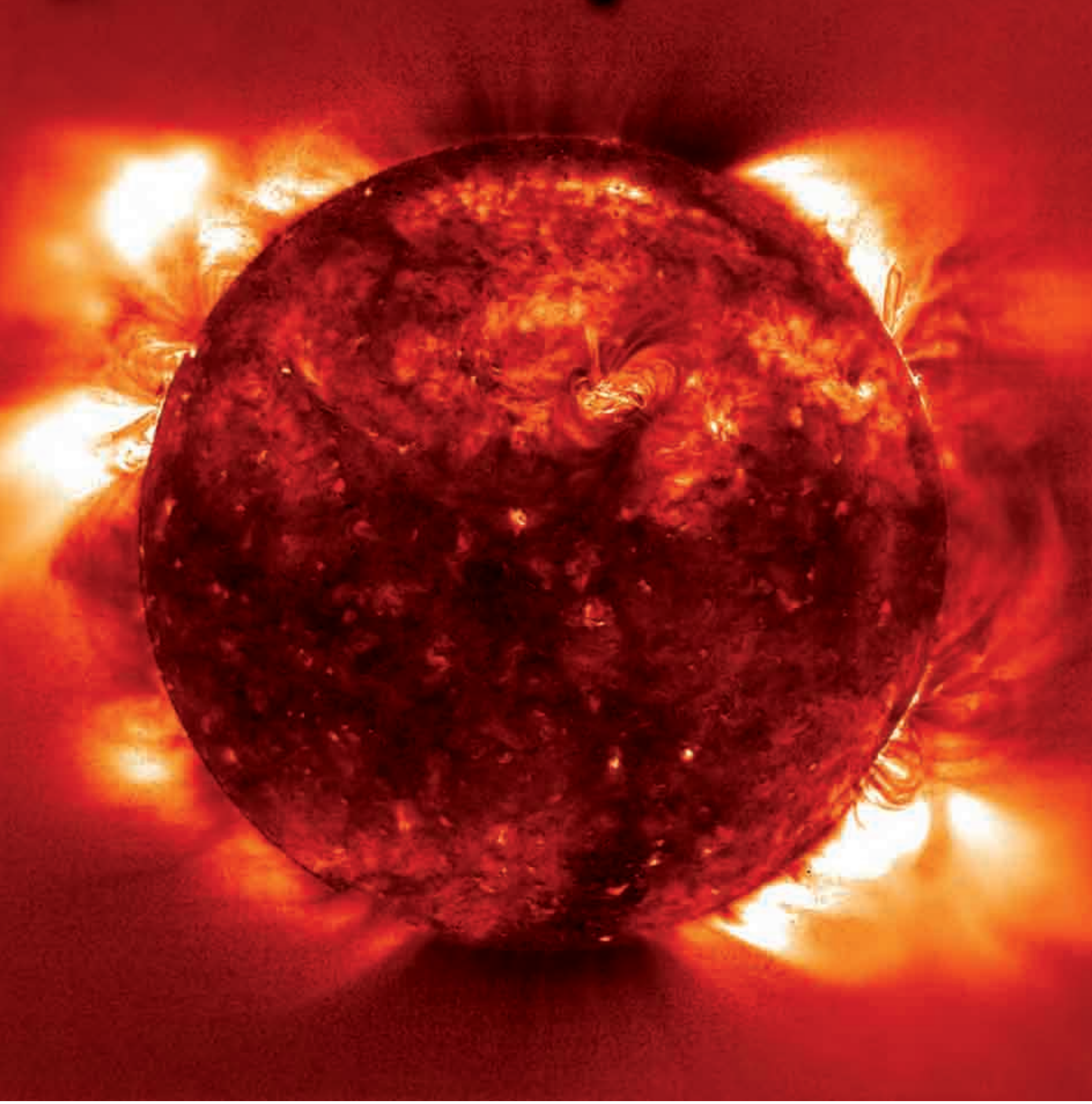
1543
Copernicus publishes his theory that Earth travels around the Sun. This contradicts the Church teachings.

1610
Galileo Galilei describes spots on the Sun that he views with his early telescope.

***c.* 1660**
Isaac Newton shows that sunlight can be divided into separate chromatic components via refraction through a glass prism.

1687
Sir Isaac Newton publishes his finding, *Principia Mathematica*, establishing the theory of gravitation and laws of motion. This allows astronomers to understand the interacting forces among the Sun, the planets, and their moons.

1800
William Herschel extends Newton's experiment by demonstrating that invisible "rays" exist beyond the red end of the solar spectrum.



1814
Joseph von Fraunhofer builds the first accurate spectrometer, and uses it to study the spectrum of the Sun's light.

1843
German amateur astronomer, Heinrich Schwabe, who has studied the Sun for 17 years, announces his discovery that the number and positions of sunspots vary over an 11-year period.

1845
First solar photograph is made on April 2.

1860
The total solar eclipse of July 18, 1860, is probably the most thoroughly observed eclipse up to this time.

1868
During an eclipse, astronomers observe a new bright emission line in the spectrum of the Sun's atmosphere. As a result of observations, British astronomer, Norman Lockyer, identifies and names helium.

1908
American astronomer, George Ellery Hale, shows that sunspots contain magnetic fields that are thousands of times stronger than Earth's magnetic field.

1938
German physicist Hans A. Bethe and American Charles L. Critchfield show how a sequence of nuclear reactions called the proton-proton chain make the Sun shine.

1982
Helios 1, a joint German and US deep space mission, sends back the last of its data indicating the presence of fifteen times more micrometeorites close to the Sun than near Earth.

1990
Ulysses, an interplanetary spacecraft, is launched with the mission to measure the solar wind and magnetic field over the Sun's poles during periods of both high and low solar activity.

1991
Launch of the YOHKOH spacecraft, to photograph the Sun in X-ray emission over a full solar cycle, (11 years).

1995
The Solar and Heliospheric Observatory (SOHO), reaches a point where the Sun's gravitational pull balances Earth's. The satellite orbits the Sun with Earth studying the Sun from its core to the outer corona, and the solar wind.

2006
NASA's two Solar TErrestrial RElations Observatory (STEREO) satellites take the first three-dimensional images of the Sun.

COMET MISSIONS

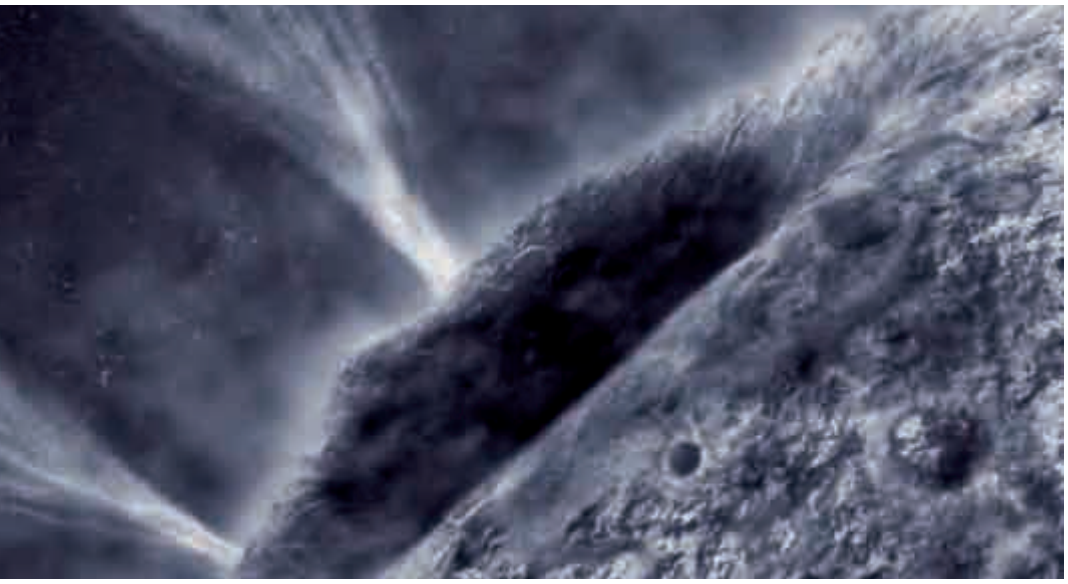
The same sort of compositions and conditions have now been seen on other comets, following spacecraft rendezvous with several comets during the last decade.

Deep Space 1 was a US spacecraft that made a close flyby of Comet Borrelly in September 2001. It found the comet to be even darker than Comet Halley.

Another US spacecraft, *Stardust*, had an ambitious mission to bring pieces of a comet back to Earth. Launched in February 1999, *Stardust* flew close to Comet Wild 2 at the beginning of 2004, collected samples of the coma as it went by, and delivered them back to Earth in a sealed capsule in January 2006. It also took high-resolution images of the Wild 2's nucleus, showing it to be a potato-shaped object with craters and gouges in its surface.

Another ambitious mission was *Deep Impact,* which intercepted Comet Tempel 1 and launched an impactor into the nucleus. The impactor buried itself under the surface and caused a huge explosion of the ices and other particles there. The *Deep Impact* mothercraft observed the explosion and took readings of the types of ices thrown out from under the surface. The impact was also witnessed by another spacecraft, *Rosetta*, which is itself on track for a comet rendezvous in the year 2014.

Below Artist's impression depicting a view of Comet Wild 2 as seen from NASA's *Stardust* spacecraft during its flyby of the comet on January 2, 2004. During the hazardous traverse, the comet caught samples of comet particles.



In addition to seeking an understanding of the origin of comets and, through them, the wider Solar System, scientists are keen to study them because of the danger they pose to Earth. Just as asteroids can collide with a planet like Earth, so too, can comets. It's wise, therefore, to learn as much as we can about them, and space missions are the best way of gaining insight into the sizes, shapes, compositions, and so on.

DISCOVERIES

In times past, comet discoveries were largely the domain of amateur astronomers. Several leading amateurs in different countries hold substantial records for the numbers of comets discovered. In the modern age, comets can be found via the Internet! For instance, the Solar and Heliospheric Observatory (SOHO) spacecraft, which monitors the Sun, often captures small comets flaring up and becoming bright as they get very close to the Sun.

These sorts of comets are not normally found in the traditional way. So, by frequent visits to the SOHO web page and keeping an eye on the images received from the spacecraft, amateur astronomers have been able to discover comets without ever having to outside and look at the night sky!

Below Artist's impression of *Deep Impact*'s encounter with Comet Tempel 1, on July 4, 2005. This digital image gives us a look at the moment of impact. The large black hole is a large crater on the surface of the comet.

Above Blue-light observation of Comet C/2002 T7 (LINEAR) made by spacecraft *Rosetta*, shows the nucleus from a distance of about 58 million miles (95 million km).

TO CATCH A COMET

Although there have been a number of spacecraft encounters with comets since 1985, with recent missions sending back good pictures of the surfaces of these bodies, so far no spacecraft has successfully landed on one. Hopefully that will change in November 2014 when the European Space Agency's *Rosetta* mission catches up with Comet 67P/Churyumov-Gerasimenko and goes into orbit around it.

Launched on March 2, 2004, the spacecraft's trajectory has already seen it do one flyby of Mars and one of Earth to pick up speed, with two more Earth flybys to go. Along the way to its destination, *Rosetta* will also zip past two asteroids.

Reaching the comet, *Rosetta* will go into a slow orbit and detach a lander, called *Philae*, which will carefully descend to the surface. Using two harpoons, it will secure itself to the comet and begin studies of the icy body's chemistry, and other characteristics as it clings on. The lander's power supply is designed to keep it going for at least one week, although a much longer life is hoped for.

Below Digital impression of *Rosetta* approaching the comet. The spacecraft will be inserted into a parking orbit before deploying its lander. It will obtain data about the comet before being sent on toward the outer Solar System.

Illuminating the Universe

They are the building blocks of the cosmos, stretching in countless numbers as far as our telescopes can see. They have inspired singers and scientists alike. Stars are our starting point for knowing the universe.

Below Star cluster Pismis 24 in the emission nebula NGC 6357, in the constellation Scorpius. Closer images show the central star to be two stars, halving the solar mass.

If you've ever been fortunate enough to have had the chance to look at the night sky from a really dark location, you'll have been amazed no doubt by the starry splendor overhead. There seem to be countless numbers of stars twinkling away quietly. How many do you think you can see? A thousand? A million? More? The answer often disappoints.

STELLAR FURNACES

Theoretically, over the entire sky there are fewer than 6,000 stars bright enough to be seen with the naked eye, under ideal conditions, away from city lights. But we can see only half of the sky at any one time, of course, and dust and other pollutants, including lights, reduce the number further. So, despite the impression we sometimes get that there are millions of stars above us, we can really only see between 1,000 and 2,500 at any time. Those who live in big light-polluted cities might be lucky if they see a hundred at one time.

But there are many more stars out there in space, of course. It's just that they are so far away that they are too dim to be seen by the unaided eye from the surface of Earth. A telescope is needed to reveal them. Those stars we see in our night sky all seem to be of different brightnesses. It would be logical to assume that the bright ones are simply brighter than the others, but appearances can be deceiving. Yes, some are brighter than others, but some are closer than others. A very bright star a long way away can look a lot fainter than a dim one located much closer.

All those stars are at different stages of their lives. Some are hot and huge, burning their nuclear fuel at a furious rate and probably destined to die young. Others are the tortoises of the heavens, small and cool, but long lived, pacing themselves. These are, no doubt, destined to outlast several generations of the hot flashy upstarts.

The stars are the basic building blocks of the universe. Gathered into giant cities we call galaxies, they are also the celestial bodies around which the planets form—planets like Earth and its many companions in the Solar System.

Our Galaxy, the Milky Way, is alone estimated to contain somewhere between 100 billion and 400 billion stars. And there is at least that number of galaxies in the observable universe. That's a lot of stars. In fact, it has been said that there are more stars in the cosmos than there are grains of sand on all the beaches in the world.

Stars produce the light and heat that illuminate and power the universe. During their lives they produce the wide variety of chemical elements—including, importantly, the heavy elements—that have made life on Earth possible. All the things we take for granted—the metals in our machines, the iron in our blood, the gold in our jewellery—were all forged in stellar furnaces. For a long time, the only star mankind could study in great detail was the one that is closest to us—the Sun. And with the Sun we are largely limited to understanding it as it is now—a snapshot of its

five billion-year-long life, so far. But with advances in theory, observation techniques, and telescope technology over the last century, we have made huge advances in our ability to study and understand all kinds of stars, and examine them at different stages in their lives. From this work, scientists have developed a sophisticated understanding of how stars came to be in the first place, and of their importance to comprehending the progress of cosmic evolution.

In this chapter we'll examine in detail the fascinating life-cycle of the stars—beginning with their birth in dark gas clouds, through their bright and glorious middle years, and then on into old age, and importantly, the process of star death and rebirth. Along the way we'll learn about the many exotic variations in star types, and then examine the strange and violent ways in which some stars end their lives —as black holes, supernovae, white dwarfs, and more. And we'll also consider the age old question of whether some of those stars we see in the night sky have planets where, right now, intelligent creatures like us could be raising their eyes to the heavens and wondering if anyone else is out there.

Above This Hubble Space Telescope image shows N90, one of the star-forming regions in the Small Magellanic Cloud. The high energy radiation blazing out from the hot young stars is eroding the outer portions of the nebula from the inside.

The Space Race Begins—Mercury and Vostok

Having put the first satellites into orbit, manned spaceflight was the next goal. With animal astronauts paving the way to ensure that living things could survive and function in the microgravity of space, both the USA and the USSR began to plan manned spaceflight programs that would put the first space travelers into orbit.

Right First person in space, Yuri Gagarin, appeared on the cover of the April 21, 1961, edition of *TIME* magazine. The young Soviet cosmonaut captured the imaginations of people both East and West.

VOSTOK

The Vostok (Russian for "east") program, was the USSR's first-ever manned space program, inaugurated in 1959 in response to NASA's announcement of Project Mercury. In early 1960, twenty military pilots were selected to become the nucleus of the Soviet cosmonaut corps. While the Mercury astronauts were accorded public adulation before their flights, the Soviet cosmonauts trained in strict secrecy and were unknown to the public until they made their spaceflights. Cosmonaut training took place under Soviet space program "Chief Designer," Sergei Korolev, who was also responsible for the development of the Vostok spacecraft (derived from the design of the Zenit spy satellite) and its identically named launch vehicle—a derivative of Korolev's R-7 ICBM. Five test flights, under the name Korabl-Sputnik, were made between May 1960 and March 1961, carrying dogs and test dummies fitted with instruments.

Above In 1963, the Soviets claimed another "first" in the Space Race—the first woman to fly in space. Valentina Tereshkova, a former textile worker, was selected for her parachuting experience. Vostok cosmonauts parachuted from their spacecraft before it landed.

Then, on April 12, 1961, 27-year-old Yuri Gagarin became the first person in space, riding the *Vostok 1* spacecraft into history for a single-orbit flight of 108 minutes. His lift-off shout of "*Poyekhali!*" ("Let's go!") heralded another huge propaganda coup for the USSR. There were six flights in the Vostok program, which tested basic spacecraft systems such as heat shields and life support, and demonstrated that humans could survive launch and re-entry into Earth's atmosphere, and could withstand weightlessness for several days. Successively, the Vostok program achieved a day-length flight (*Vostok 2*); a "joint" flight, with *Vostok 3* and *Vostok 4* launched only a day apart into similar orbits; and a five-day mission (*Vostok 5*) that was longer than the total duration of the US Mercury flights. The USSR sought to prove its claims to equality in its citizens by flying the first woman in space, Valentina Tereshkova, on the final Vostok mission (*Vostok 6*) in June 1963.

PROJECT MERCURY

Initiated in 1958, Project Mercury, which was named for the Roman messenger of the gods, was the first manned US space program. By orbiting a manned spacecraft around Earth, investigating human ability to function in microgravity, and recovering both astronaut and spacecraft safely, it aimed to discover whether humans would be able to survive in space.

Seven Mercury astronauts were announced in April 1959, but only six would eventually fly in the program. ("Deke" Slayton was grounded for many years with a heart condition.) The Mercury spacecraft, designed by the prolific engineer Max Faget and NASA's Space Task Group, was much smaller than Vostok but more versatile, with more advanced instrumentation and electronics than its Soviet counterpart. Several precursor flights, some carrying primates (including the cosmonaut chimp, Ham), tested the spacecraft and launch systems. However, considerable difficulties were experienced with the Atlas booster required for orbital missions. Consequently, the first two US spaceflights were sub-orbital, using a modified Redstone missile as the launch vehicle.

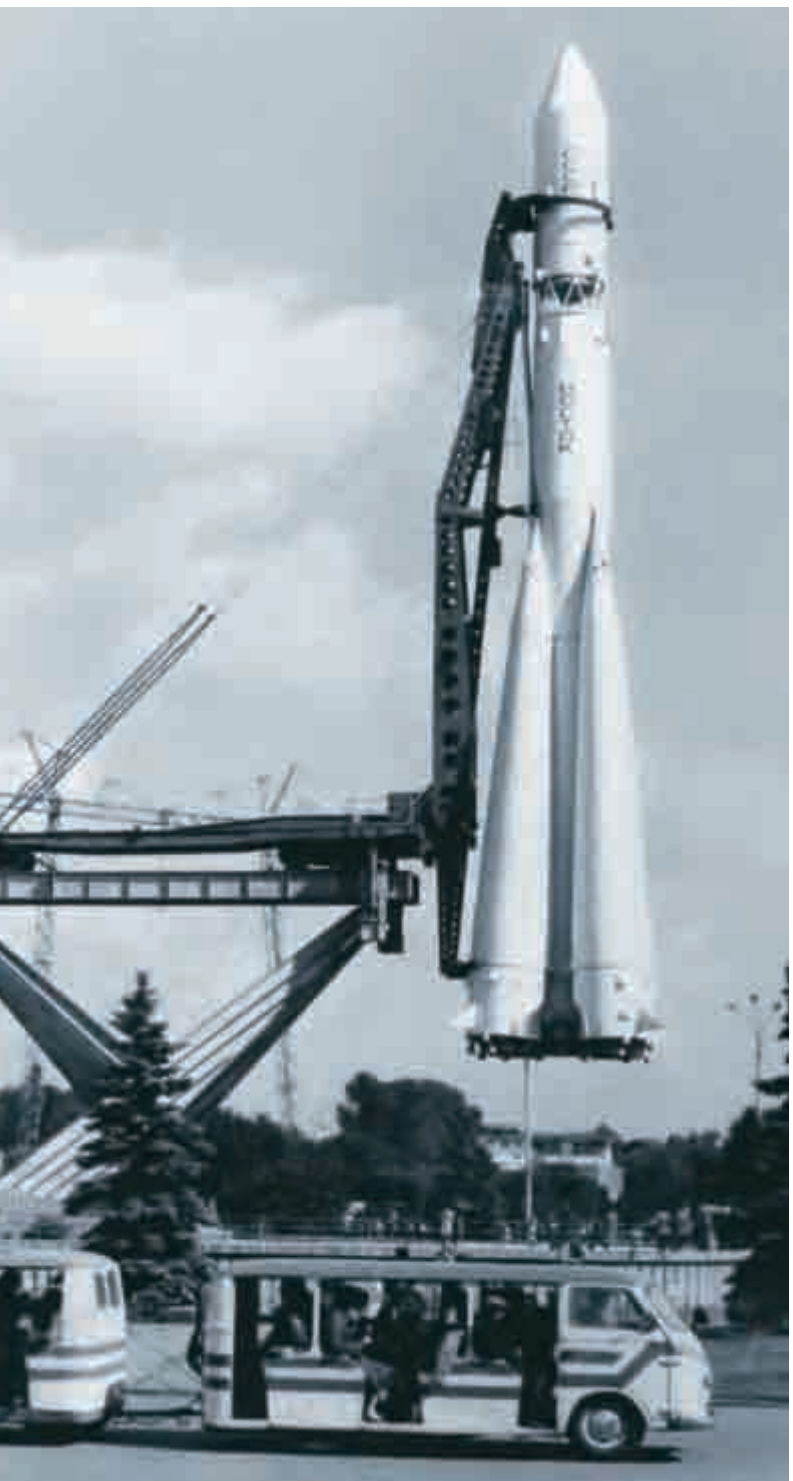
The US approach, both more public and more cautious than that of the USSR, enabled *Vostok 1* to be launched before the first US astronaut, Alan Shepard, who made the first US spaceflight (MR-3)—a 15-minute sub-orbital lob in *Freedom 7*—just 23 days later, on May 5, 1961. A second sub-orbital mission (MR-4) was marred by the loss of the spacecraft, *Liberty Bell 7*, after splashdown. The first US orbital flight finally occurred on February 20, 1962, when John Glenn orbited Earth for just over five hours in *Friendship 7* (MA-6). Glenn's mission was the first to utilize the ICBM-derived Atlas launch vehicle. The next two Mercury flights in 1962, MA-7 and MA-8, extended the duration of each mission and the complexity of the experiments undertaken. The final Mercury flight, MA-9, took place in May 1963, when Gordon Cooper, in *Faith 7*, spent a full day in space.

"WE CHOOSE TO GO TO THE MOON"

To counter the apparent Soviet lead in the Space Race, especially after Gagarin's history-making flight, US President John F. Kennedy wanted a spectacular space feat that would outweigh the USSR's space achievements. Several options were considered, and on May 25, 1961, barely three weeks after Shepard's flight, Kennedy inaugurated the Apollo lunar program in a speech to the US Congress in which he declared that the United States would "land a man on the Moon and return him safely to the Earth" before the end of the decade. The race to the Moon was on.

Right Mercury spacecraft *Freedom 7* lifts off from Cape Canaveral, Florida, at 9:34 A.M. EST on May 5, 1961. On board is Alan Shepard, the first American to fly into space.

Below A full-scale replica of *Vostok 1* supported by a giant gantry in Moscow's All-Russia Exhibition Center. The Soviet Union announced the historic flight to the world while Yuri Gagarin was still in orbit.



Left The Project Mercury astronauts were: Front row, left to right, Walter M. Schirra, Jr., Donald K. "Deke" Slayton, John H. Glenn, Jr., and Scott Carpenter; back row, Alan B. Shepard, Jr., Virgil I. "Gus" Grissom, and L. Gordon Cooper.

Andromeda

Andromeda is one of the best known constellations, more so because of the nearby galaxy it contains than the prominence of its stars.

PRINCESS IN CHAINS

Andromeda is just one player in a mythological story with many of its characters represented in the sky.

Andromeda was the daughter of Cepheus and Cassiopeia, rulers of ancient Ethiopia. Both can be found just to her north in the sky, with Cassiopeia the more obvious as a W-shaped pattern of bright stars. Cassiopeia angered the sea god Nereus by boasting that Andromeda was more beautiful than his daughters, the fifty sea nymphs known as the Nereids. Nereus's response was to dispatch Cetus to ravage Ethiopia. Cetus, variously identified as a sea monster or a whale, can be found a little to the south of Andromeda in the sky.

Seeking a way to appease the angry god, the royal couple sought advice from an oracle. The only way to save their country was to sacrifice their daughter to Cetus. Andromeda was chained to a rock near the sea, but was saved by the hero Perseus who arrived on the winged horse Pegasus. Perseus saved Andromeda by turning Cetus to stone using the hideous head of Medusa. The stars of Perseus lie just to the east of Andromeda. Pegasus, prominently marked by the stars of the Great Square of Pegasus, is found to her southwest.

THE STARS OF ANDROMEDA

The major stars of the Andromeda constellation form a long V-shape, with the southernmost leg containing the brighter stars. The vertex of the V is Alpha (α) Andromedae, which, although in Andromeda, acts as a corner star of the Great Square of Pegasus.

OBJECTS OF INTEREST

M31 (NGC 224), the **Andromeda Galaxy**, is the closest major galaxy to the Milky Way, lying 2.5 million light-years away. Along with the Milky Way, it dominates the Local Group of galaxies. M31 has the distinction of being the most distant object visible to the unaided eye. However, a dark sky is needed in order to see it well, since being so close, its light is spread over a patch of sky more than five times the size of the full moon. As a result, the view of the galaxy is often more impressive through a large pair of binoculars rather than a telescope.

M32 (NGC 221) and **M110 (NGC 205)** are small elliptical satellite galaxies to M31. Both are visible in a 4-inch (10 cm) telescope, with M32 being smaller and more compact, and therefore easier to see.

Another galaxy found within the borders of Andromeda is **NGC 891**. This is a spiral galaxy seen edge-on, but requiring the use of at least a 6-inch (15 cm) telescope in order to track it down.

Among the stars of this constellation is **Gamma (γ) Andromedae**, often regarded as one of the best double stars in the sky for a small telescope. There is an attractive contrast in color between the magnitude 2.3 golden-yellow primary and the magnitude 5.1 greenish-blue companion lying 10 arc-seconds away.

NGC 7662 is a planetary nebula that is visible through a 6-inch (15 cm) telescope as a glowing blue spot of light 30 arc-seconds across. The **Blue Snowball Nebula**—as it is sometimes known—looks more like an eye in images from the Hubble Space Telescope, peering at us across 5,600 light-years.

Left With its readily visible formation, records of the Andromeda Galaxy date back over the centuries. This nearest neighbor to our own galaxy is a member of the Local Group of galaxies and a major feature within the constellation of Andromeda.

FACT FILE

Andromeda
The Chained Princess
an-DROH-me-duh

Genitive
Andromedae

Abbreviation
And

Right Ascension
1 hour

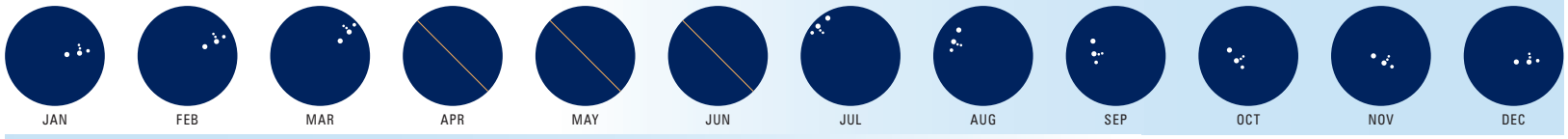
Declination
+40°

Visibility
90°N to 36°S

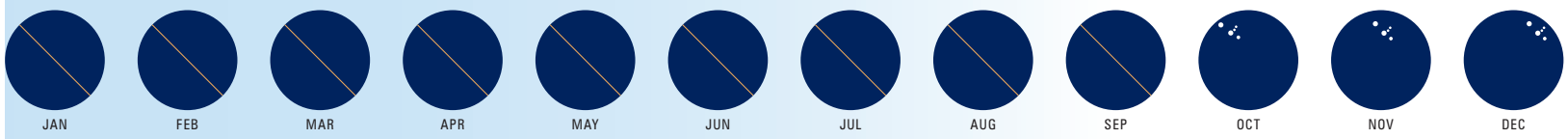
Notable Features
IC 239
M31 (Andromeda Galaxy)
M32
M110
NGC 404
NGC 891
NGC 7640
NGC 7662
NGC 7686

Named Stars
Alpheratz (Alpha [α] Andromedae)
Mirach (Beta [β] Andromedae)
Alamak (Gamma [γ] Andromedae)
Adhil (Xi [ξ] Andromedae)

NORTHERN HEMISPHERE—as viewed from New York, USA, at 10 PM on the 15th of each month



SOUTHERN HEMISPHERE—as viewed from Sydney, Australia, at 10 PM on the 15th of each month



Book block ca. 34 mm (1 3/8 inch)
1,250 illustrations and photographs
Four-color throughout
Hardcover with dust jacket

DEUTSCH

978-3-8331-4368-7

ESPAÑOL

978-3-8331-4370-0