BY JAMES RESTON, JR.

ORION

Where Stars Are Born

A scattering of stars in the heart of the Orion nebula illuminates an unfolding cloud of gas and dust reaching across six light-years of space (35 trillion miles). Unprecedented views of the nebula's center reveal the birth pangs of stars, and perhaps the creation of planetary systems like our own.

DAVID MALIN, ANGLO-AUSTRALIAN OBSERVATORY

IN A SPECTACULAR space shuttle mission two years ago, astronauts repaired the blurred vision of the Hubble Space Telescope, and at last a new epoch of astronomy began. The Hubble telescope is the modern equivalent of the one Galileo used to prove that the earth revolves around the sun—a brilliant new device that allows us to peer far more deeply into the heavens.

On December 29, 1993, the instrument was turned on the great Orion nebula. As the brightest, the youngest, the closest, and perhaps the most romantic nebula in the northern winter sky, Orion made an appealing target. The nebula (the word means "mist" or "cloud" in Latin) spreads its gas and dust across an unimaginable 35 trillion miles of sky and is bursting with young stars.

For C. Robert O'Dell, an astronomer at Rice University in Houston, Texas, and the lead scientist for these Hubble observations, the fresh look at the Orion nebula promised to solve a tantalizing riddle. With Hubble's previously suspect vision, he had found an unexpected set of splotches he couldn't identify. The dots, irregular in shape and random in placement, might be "artifacts" introduced into the picture by the imperfect optics of the telescope, just as surely as air bubbles in the lens of Galileo's telescope could have appeared to be moons around Jupiter. If the dots were real, why were they so luminous? What could they be?

He suspected that they might be planetary systems coalescing out of the gas and dust around young stars. If so, their discovery would increase the probability of detecting life elsewhere in the universe. Only planets have the right density of material for DNA to grow and multiply, and only planets are likely to have a suitable temperature range to sustain life as we know it.

While Robert O'Dell was working with data from the Space Telescope Science Institute in Baltimore, Maryland, I was repairing

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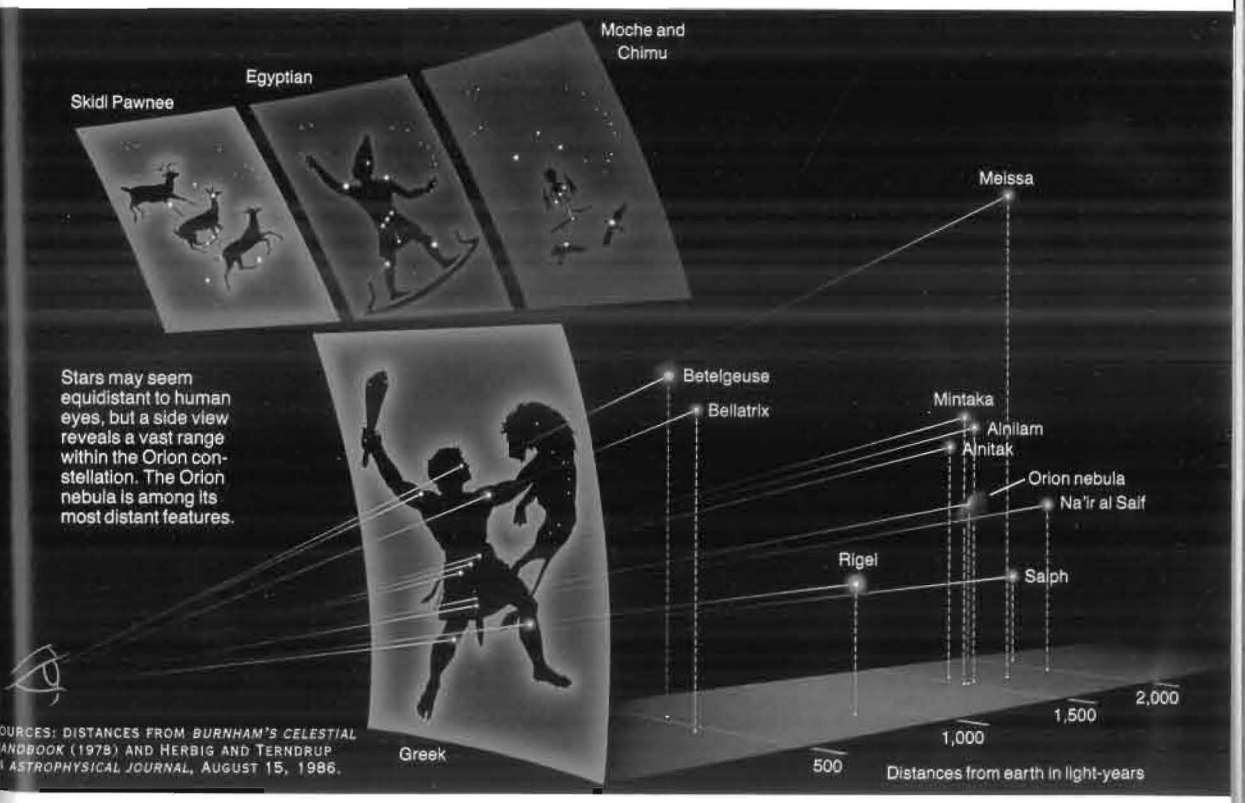

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Its namesake nebula glowing red in this time exposure, the giant constellation Orion commands the winter sky (left). The Greeks saw a hunter (above), Pawnee imagined deer, Egyptians the god Osiris, and South America's Moche and Chimu a thief thrown to buzzards.

ROGER RESSMEYER (LEFT); PAINTING BY JOE TUCCIARONE

HARVARD COLLEGE OBSERVATORY (TOP); NEW YORK ACADEMY OF SCIENCES

First photograph of the Orion nebula was taken in 1880 by American astronomer Henry Draper. He mounted a bulky glass-plate camera on a telescope and followed Orion with a tracking mechanism for 51 minutes to produce this inverted view.

to Pigeon's Perch, a hill near our family farm in Virginia, to look at the Orion constellation with Devin, my 15-year-old son. Combining science with folklore, Orion's blazing stars and sheets of gas and dust would allow me to tell Devin about the entire night sky.

WE PAD THE WAGON of the lawn tractor with pillows, carefully place the eight-inch reflecting telescope I have borrowed from a Johns Hopkins astronomer on its bed, and putter off. By the time we set up at 9 p.m., Orion is already low in the sky. It is spring, and the constellation is about to go into hiding behind the sun for a few months. When it reemerges in July, it will deliver a message written by the Greek poet Hesiod and heeded by farmers for almost three millennia: "Forget not, when Orion first appears, / To make your servants thresh the sacred ears."

"Tell me the story of Orion," Devin asks. I explain that Orion and the other constellations, so romantic in their conception and yet so useful, are simply an invention of the human mind, a way of ordering chaos. They place us in the heavens.

Around 2000 B.C., stargazers joined dots in the sky and conjured up a figure that the Greeks came to know as Orion the Hunter. Artemis, the goddess of the hunt, fell in love with Orion, but her twin brother, Apollo, was jealous and sent a scorpion to kill him.

"I like that," Devin says, thinking of his older sister and her annoying boyfriends.

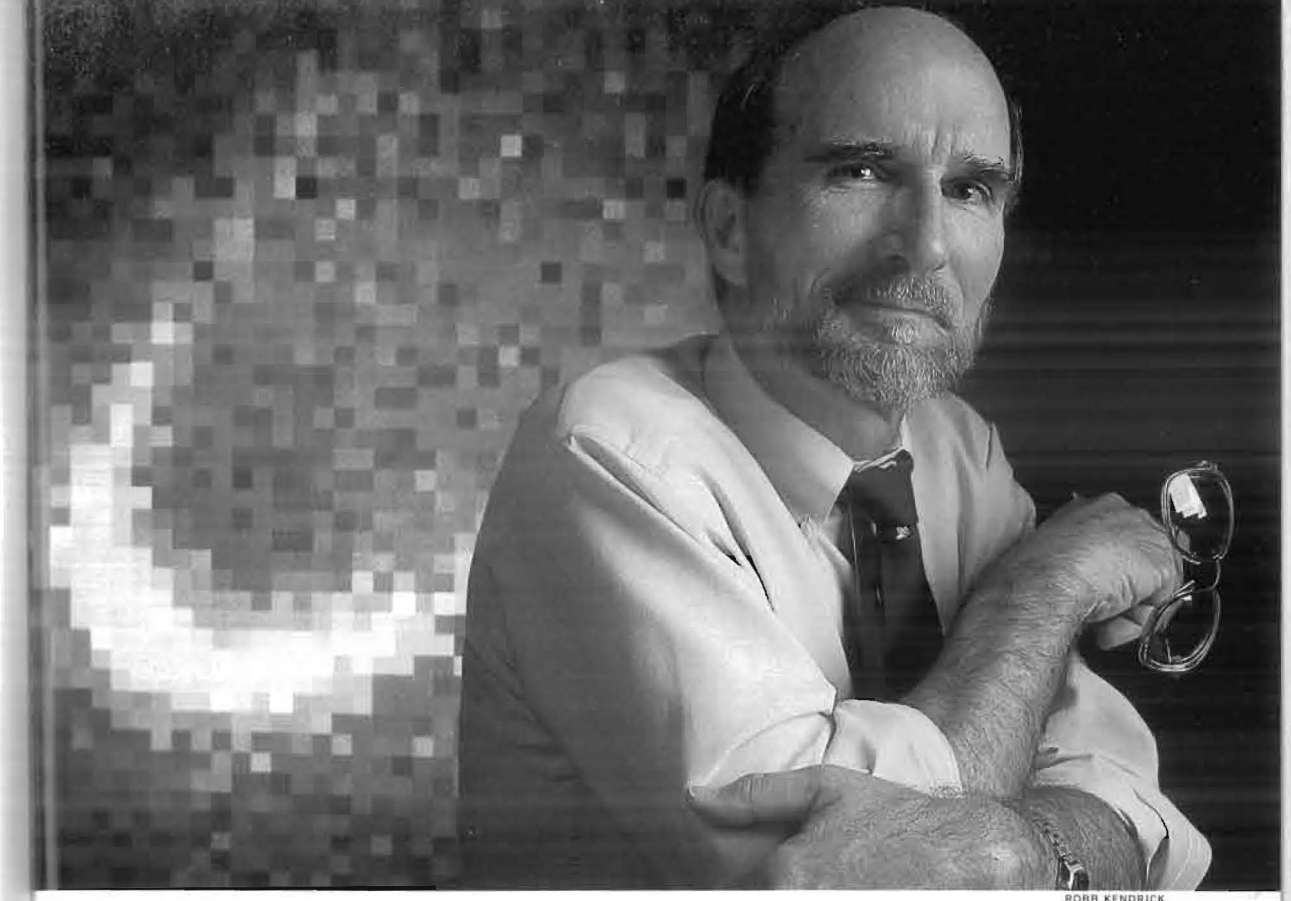
The hunter faces us. His belt is formed by three almost perfectly aligned, perfectly spaced stars that are among the most luminous anywhere in the Milky Way galaxy. The Orion nebula can be seen below the belt as the second of the three points of light that form the hunter's scabbard. His right armpit looms as Betelgeuse, an enormous pulsating red star 20 times as massive as our sun. North of Betelgeuse six smaller stars outline the giant's club. Rigel, a brighter, more distant star, is his left knee. Saiph marks his right knee, and Bellatrix, the Amazon star, his left shoulder. A semicircle of stars extends out from his left arm.

By the end of our celestial tour it is nearly midnight. Orion has ducked behind the hulk of Mount Marshall, and Scorpius, the scorpion constellation, is emerging from the glow of metropolitan Washington. For father and son, with the passage of the hunter, the sky has become a collection of interwoven bedtime stories.

Meanwhile Robert O'Dell had confirmed that the Hubble's latest look at the Orion nebula was free of artifacts and any confusing clutter. "We're seeing Orion as it really is," he said, "and we're seeing the unexpected."

The first clear-sighted observation, a portion of the nebula's center, revealed 110 stars—and a surprise. Fifty-six stars were surrounded by pancake-shaped clouds, the puzzling splotches O'Dell had noticed in the earlier, flawed images. He surmised that there were more: Some, less brightly lit by nearby stars, would have escaped even the telescope's keen eye.

Whatever explains the clouds, the stars inside them—and all other stars—are the



ROBB KENDRICK

source of all matter, from the gas molecules in the Orion nebula to the planets in our solar system and the trees in your backyard.

Like us, stars are born, mature, reach old age, and die. Exactly what triggers a new star is still a mystery, but gravity must play an important part. If, for some reason, a knot of gas in a nebula becomes more dense than the material around it, the knot will start to collapse because its own gravitational force is greater than that of the surrounding material. As the clump continues to contract through self-gravitation, it becomes even more dense and its core heats up.

When the center reaches a certain density and temperature, nuclear fusion begins. A star is born—a nuclear furnace of hydrogen and helium enveloped in a spinning cloud of gas and dust. O'Dell and other astronomers have long believed that this rotating cocoon is the raw material of planets. Eventually the cloud is blasted away to reveal the luminous mass within.

A star's color depends on its temperature. Betelgeuse, a reddish star, is cool—only 3000°C at the surface. Our sun is an average yellowish star with a temperature of 5500°C.

"It has it all," says C. Robert O'Dell, who has studied the Orion nebula for 30 years. "It's the brightest nebula, the closest, the youngest." His Hubble Space Telescope mosaic of Orion (following pages and supplement) used millions of optical pixels.

Massive, hot stars like Rigel are blue-white and glow at 10,000°C. Such stars rapidly consume themselves as their hydrogen converts to helium.

In its old age a massive star converts helium to carbon and carbon to iron. It becomes a red supergiant, like old, bloated Betelgeuse, and when the nuclear furnace shuts off, gravity causes the star to collapse. The energy from this sudden contraction is released in a huge explosion, or supernova—a fate that no doubt will befall Betelgeuse.

If the explosion occurs near a cloud of gas and dust, the shock waves may compress part of it. The gas becomes more dense, and the star cycle begins anew.

Of all the stellar nurseries scattered throughout the spiral arms of our galaxy, none is more *(Continued on page 100)*

vibrantly dynamic than the Orion nebula. Although it is 1,500 light-years away (one light-year equals about six trillion miles), you can see it clearly in the winter sky.

When Galileo pointed his telescope at the Orion constellation from his window in Padua in 1610, he somehow missed the nebula. It was first observed, in the same year, by Nicolas-Claude Fabri de Peiresc, a French lawyer and amateur astronomer, using a telescope given to him by Galileo. Through a telescope, the nebula looks pearly gray. Our eyes isolate only its brightest parts, which appear essentially colorless. We cannot see the red outer edges, painted by nitrogen and hydrogen emissions.

The nebula is actually a hot spot of glowing gases—mainly hydrogen but also helium, carbon, nitrogen, and oxygen—on a much larger dark cloud of gas and dust called the Orion molecular cloud. The presence of dozens of different kinds of molecules, including water and carbon monoxide, suggests the cloud is laden with the material from which stars are made.

The topography of the illuminated nebula is highly irregular. Ultraviolet radiation from its hottest stars enlarges the nebula, expanding it most in places where the molecular cloud is thinnest, much as a brush fire on a prairie rushes through the thin grass and slows down where the brush and trees are thicker. The most striking feature is its brow, a long, visible streak known as the Bright Bar, which is actually an upturned edge of the nebula's concave form.

"When we look at Orion," says O'Dell, "we're seeing a star factory and what our solar system looked like in its infancy." Most of the stars in the nebula are between 300,000 and one million years old—mere toddlers, given that our sun is 4.5 billion years old. The smallest ones are usually reddish and low in mass.

Four massive hot stars, visible as a kite-like box, form the Trapezium, the throbbing heart of the star factory. Theta 1 C, the largest, is 20 times as massive as the sun and 100,000 times as luminous. It alone can light up the entire nebula. Ultraviolet radiation from the stars of the Trapezium, which are probably no more than a million years old, causes the nebulous material near them to glow brightly in all the hues of the rainbow.

The area around the Trapezium is packed with a thousand lesser stars. Indeed, because of the abundance of soupy material in the nebula, this is one of the most densely congested star clusters of any known region in our galaxy.

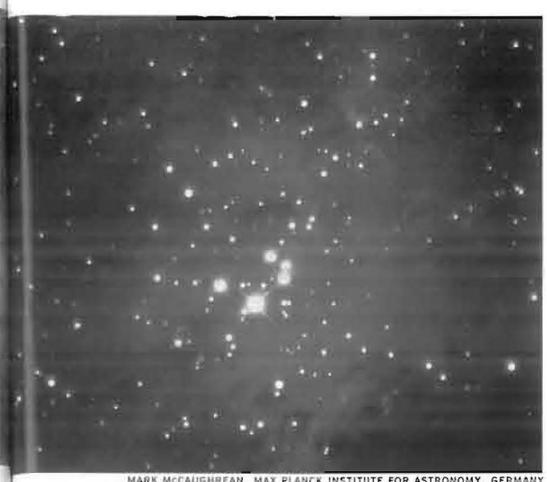
JOHN BALLY

A teardrop 40 billion miles across, a cloud elongated by stellar wind envelops a young star in Orion's Trapezium cluster. Silhouetted at upper right is a star surrounded by a disk of dust—possibly the beginnings of planet development. Such protoplanetary systems have been seen around most of the nebula's dust-clad stars.

BY THE SPRING OF 1995 the space telescope had revisited the Orion nebula four more times, capturing 15 different areas of its varied topography. It took O'Dell several laborious weeks at his computer to align the stars in the overlapping edges of each Hubble image, but in the end he had a single, coherent picture of the heart of Orion's stellar nursery.

"It's a violent, stirred-up place, where material is moving at supersonic velocities," he explains, taking me on a guided tour of the richly textured image, with its knots of starlit gas and arcing shock fronts.

Shock fronts remain one of the Orion nebula's last mysteries. Whatever their cause, they are worthy of Jackson Pollock: inspired bravura strokes across the background of swirling gas. The most dramatic shock front spouts off the Bright Bar, and O'Dell affectionately refers to it as his diplodocus, the head and neck of the great Jurassic dinosaur.



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Pearls in the mist, a cluster of stars emerges when the Orion nebula is viewed in infrared wavelength. Cool stars, like most of those in the nebula, glow primarily in the infrared range. Some 700 stars are visible, about 63.5 stars per cubic light-year—a density 20,000 times as great as our stellar neighborhood.

Astronomers believe shock fronts define the forward edges of gas jets streaming from an infant star. They are thought to be formed by the magnetic field present in the star's original gas cloud. As gravity shrinks the cloud, the magnetic field is compressed with it—but only to a certain limit. "A magnetic field cannot be squeezed too tightly," O'Dell says. When it reaches that limit, magnetic energy escapes from the spinning mass, accelerating the particles of gas along its path to very high speeds. "The easiest place for the magnetic energy to spew out is at the poles. So the jets probably mark the magnetic poles of nascent stars."

If shock fronts suggest the forces at work in newborn stars, the saucers of gas and dust around young stars—protoplanetary disks—provide the strongest evidence yet for the birth of planets.

"We use the word 'protoplanetary,' " says O'Dell, "because we are seeing the necessary ingredients for the formation of planets. The disks are the missing link in our understanding of how planets like those in our solar system form."

Protoplanetary disks seem to substantiate Immanuel Kant's 1755 hypothesis that planets form out of spinning clouds of gas, where material collapses into a dense center, spawning a star. The leftovers spin off as planets.

Most of the protoplanetary disks O'Dell has identified are flat rather than spherical—evidence, he says, that an active, evolutionary process is at work. (If a cloud is to spawn planets, it must be rotating, and as it rotates, the spinning motion flattens it into a disk.) Some appear circular, in part because an object's shape varies with its angle of view. Others are tear shaped. This is apparently because their material is being blown out by the powerful stellar winds of the Trapezium stars.

When O'Dell measured the disks, he found that some are much larger than our solar system. The blackness of one disk made it easy to measure precisely: seven and a half times the diameter of the solar system. At its center glows a faint red star with a mass one-third that of our sun.

IT IS LIKELY that many of the stars in the disks will form their own planets, and it is possible that some of those planets will support life. "The universe is a very big place," says O'Dell. "I have always believed there is life out there somewhere. I believe it more strongly now."

Parallel studies strengthen the case for planets elsewhere in our galaxy. It had been thought that stars formed by the thousands in huge clusters, but astronomers at the Kitt Peak National Observatory in Arizona who turned new infrared equipment on a cloud south of the Orion nebula saw stars forming in clusters of only 10 to 50. This could be the way most stars in the Milky Way are born. Nearly all the stars observed were encased in disks of gas and dust. As these stars drift away from their birthplace, they may come to resemble our sun.

Speculation aside, Robert O'Dell is excited enough by the hard science of his discoveries. Gazing with a hint of pride at the Hubble image of the Orion nebula, he says, "In the future there will be bigger and better space telescopes, and there will be another giant step forward like this one. But it will take a long time. I feel fortunate to have been around at this moment." □