PARTING THE COSMIC VEIL

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Cover illustration: The Orion Nebula, or M17, is a hotbed of newly born stars residing 5,500 light-years away in the constellation Sagittarius. The wavelike patterns of cold hydrogen gas clouds have been sculpted and illuminated by intense ultraviolet radiation from young massive stars, which lie outside the picture to the upper left. The warmed surfaces glow orange and red in this photograph. The green represents an even hotter gas that masks background structures. Various gases represented with color are: sulfur, represented in red; hydrogen, green; and oxygen blue. (Image from the *Hubble Space Telescope*, abbreviated *HST*, courtesy of NASA.)

Title page illustration: A spinning neutron star, or pulsar, at the center of the Crab Nebula is accelerating particles up to the speed of light, and flinging them out into interstellar space. This X-ray image, taken from the *Chandra X-ray Observatory,* shows tilted rings or waves of high-energy particles that appear to have been flung outward from the central pulsar, as well as high-energy jets of particles in a direction perpendicular to the rings. The inner ring is about one light-year across. (Courtesy of NASA/CXO/SAO.)

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Dedicated to my children,
David, Julia, and Marina,
and
my wife Marcella

Preface

Parting the Cosmic Veil describes our gradual awareness of a much vaster and concealed Universe, more exciting than anyone imagined. It is a story of expanding horizons and the discovery of invisible worlds, made possible with new technology and novel telescopes that have broadened our range of perception and sharpened our vision. They have begun to part the Cosmic Veil, providing a partial glimpse of the Universe in its entirety.

Our account presents those discoveries that have significantly transformed our understanding of the Cosmos. They include the origin of the elements; sending the first humans to the Moon and inquisitive spacecraft throughout the Solar System; observations of planets around other stars; discoveries of the enormous extent and expansion of the Universe; observations of the invisible radio and X-ray Universe, with the discoveries of pulsars, black holes and quasars; the realization that cosmic violence is everywhere, from exploding stars to gamma-ray bursts and the Big Bang itself; and observations of dark invisible matter that fills the spaces between planets or stars and envelops galaxies.

Scientists have one method of perceiving the world, and artists, musicians, poets and writers have other unique points of view. They have all shown us that our awareness is limited by what we are able to see, and, to some extent, by what we expect to see. Some interpret the Universe with line, form, music or words, often illuminating the emotional or mystical perspectives. And just as astronomers use powerful telescopes to transport us into distant realms, beyond our hectic, everyday lives, modern artists also remove us from our immediate surroundings, drawing us into the Cosmos beyond. We therefore broaden our account by including the perceptions of artists, poets and writers, each example chosen for the insight it offers, thereby increasing the appeal and scope of our narrative, but at a modest level that enhances the scientific content of the book and does not interfere with it.

We present this voyage of discovery within universal themes, which provide the book's foundation and explain the chapter titles. They are brave new worlds; motion, content and form; the explosive Universe; the fullness of space; and origins and destinies. There are always unseen worlds that remain to be discovered, with new content and form. Everything is moving, and nothing is at rest. Pervasive outbursts rule the Cosmos, and emptiness is an illusion. All that we can see is evolving, in a perpetual

state of impermanence, creation and reorganization. And even though we are pushing the boundaries of knowledge closer to an understanding of the origins and destinies, of either the Universe or Life, the ultimate answers to these grand questions still lie hidden behind the Cosmic Veil.

Although this book is largely an account of our growing realization of the scope and immensity of the Cosmos, it is also a story about people. The fabric of our narrative is therefore bound together with topics that concern us all, from the interests of everyday life to larger questions of our origin, fate and place. Invisibility, motion, content, form, impermanence, explosive outbursts and emptiness, beginnings and ends – these are vehicles for interpreting both the human condition and the Cosmos. Each chapter of this book therefore begins with the human aspects of a theme, helping us to take the Universe personally, followed by the relevant cosmic discoveries.

It indeed seems as if our perception of the Cosmos has been inextricably linked to an evolving understanding of our local personal world. As our ancestors explored the Earth, discovering new continents and seas, astronomers embarked on a similar voyage into uncharted regions of space. It is no accident that cosmic explosions were first understood at about the same time that humans unleashed the forces of the atomic bomb. Theories of human evolution were developed when astronomers were discovering the evolution of the stars and galaxies. Even our current, hurried pace of living seems to coincide with the realization that the galaxies are running away from us at ever increasing speeds, accelerated by a mysterious dark energy. And perhaps our cosmic science owes more than a little to a modern spiritual hunger, a craving for something beyond our familiar, material world.

Parting the Cosmic Veil is written in a concise, light and friendly style that will be appreciated by all, without being unnecessarily weighted down with incomprehensible specialized material. It is broad in scope, but comfortably accessible, a thorough, serious and readable report filled with interesting and informative ideas. There are no obtuse mathematical equations or complex scientific jargon. Throughout this book, scientific concepts have been translated into a common language with apt, down-to-Earth metaphors and analogies, making them accessible to the general reader and adding enjoyment to the material. The text is humanized by interspersing it with personal anecdotes and recollections, and spiced with lively quotations, impressions and reminisces. Vignettes containing historical, literary and artistic material make this book unusual and interesting, augmenting our description of the Cosmos without distracting from the scientific perspective. All of these diverse elements truly set this book apart for the general educated audience, as well as make the material less intimidating.

Numerous images from telescopes on the ground and in space, as well as artists' paintings, are introduced at just the right place within our narrative, providing the mortar that cements our newfound knowledge together. They can crystallize a new concept with a visual excitement that adds a new dimension to our understanding. Many important scientific insights are also compacted within line drawings, with clear labels and thorough captions, which give the reader a concise, forceful message.

Set aside *focus boxes* enhance and amplify the discussion with interesting details, fundamental scientific concepts, and important related topics. They will be read by the especially curious person or serious student, but do not interfere with the general flow

of the text and can be bypassed by the general educated reader who wants to follow the main ideas. Equations are kept to a bare minimum, and when employed are placed within the set-aside *focus* elements.

Within each chapter, our story is told in an unfolding chronological narrative, tracing out the growing awareness of a given theme and providing a sense of destination and flow in our gradual parting of the Cosmic Veil. This provides historical authority, and resurrects names and events that have fallen out of time. Our approach emphasizes the ongoing process of astronomy, in which scientists extrapolate from past discoveries in their relentless search for new clues to the mystery of the unknown. And our text does not avoid mention of false assumptions, corrections to missteps in the search, such as the Earth's displacement from its position at the center of the Universe and the discovery of the motions of the fixed stars and fleeing galaxies.

A brief discussion of cosmic vision is presented in the opening chapter, providing an opportunity to introduce our ongoing exploration of the unknown, as well as the artistic perspectives that are lightly peppered throughout the remaining text. This first chapter continues with a discussion of new technologies and novel instruments that have opened new vistas on the Cosmos, many of them a byproduct of military endeavors.

The interdependence of astronomy, technology and the military has now continued for nearly four centuries. It was strengthened during World War II (1939–1945), when the development of the atomic bomb became closely linked to our discoveries of how stars shine and the realization that most of the chemical elements were forged inside stars, during their long evolution and explosive death. And the interdependence continued during the Cold War between the Soviet Union and the United States, when the Americans won the race to put a man on the Moon and space science was begun.

Rockets initially designed to hurl bombs across continents and oceans are now routinely used to loft astronomical telescopes into space, including the *Hubble Space Telescope* that is essentially a spy telescope turned up at the heavens instead of down at the ground. Other aspects of modern astronomy have also benefited enormously from military technology. Detectors of infrared heat radiation are an example, as is the Charge-Coupled Device, or CCD.

Powerful computers and the Internet, originally designed by or for the military, have powerful, far-reaching implications for our celestial science and the rest of the public sector. They have resulted in a new way of doing astronomy, in which multi-million-dollar robotic telescopes, on the ground or in space, are using sensitive electronic detectors and giant computers to create digitized images of the sky.

Our voyage of discovery continues in the second chapter with our familiar *terrra firma* and the discovery that our home planet Earth is a glistening blue and turquoise ball suspended all alone in the chill of outer space. It continues with an account of spacecraft that have carried men to the Moon, and transported cameras and small telescopes throughout the Solar System, obtaining close-up views that have changed the moons and planets from moving points of light to fascinating real worlds that are stranger and more diverse than anyone supposed.

This second chapter concludes with an account of Jupiter-sized and Neptune-sized planets found orbiting nearby stars. This fantastic discovery involved everything that

modern technology has to offer, including digital electronic detectors, sophisticated computer software and hardware, optical fibers and improved high-resolution spectrometers to disperse starlight into its separate colors.

Only a century ago, the known Cosmos extended no further than the starry night sky, encompassing all of existence. The Earth was at the bottom of the Universe, and the stars defined its top. Then astronomers built larger optical telescopes to collect more light and see further into space, beyond the stars. In fact, most of the stars in the Milky Way are invisible without the use of a telescope, as are the billions of remote galaxies rushing away from us at speeds that can approach the velocity of light, each with billions of stars wheeling around their massive central hub. They are all spinning, darting and flowing through the Universe, while great concentrations of mass pull the galaxies here and there, distorting the uniform expansion. As far as we can see, the galaxies are also lumped together into vast chains and walls, marking the edges of gigantic seemingly empty voids.

These discoveries, of stars and galaxies with their collective shapes and motions, are described in Chapter 3. Like the discovery of planets around nearby stars, the full distribution of galaxies could not be seen without the aid of electronic detectors, optical fibers, supercomputers, and other marvels of new technology.

Astronomers have now learned to see all over again, using radio waves and X-rays that lie beyond the range of visual perception. They reveal a violent Universe, from exploding stars to the Big Bang, which is presented in the fourth chapter. Here we discover that a massive, bankrupt giant star explodes when it has run out of fuel, while also imploding at its center to form a neutron star and radio pulsar. Precise timing of one radio pulsar indicates that a pair of neutron stars are approaching each other, headed on a collision course and moving together at the rate expected by radiating gravity waves, providing the first evidence for these ripples in the fabric of space-time.

Matter rushing into a stellar black hole, from a nearby visible star in tight orbit around it, emits rapid, irregular bursts of X-rays. Further out in the Cosmos, supermassive black holes power the double jets and lobes of radio galaxies, quasars, and most likely the gamma-ray bursts, all of them radiating an astonishing power never imagined before. Radio astronomers have additionally discovered the relic radiation of the Big Bang, which set the expanding Universe in motion, and used its rippling temperature fluctuations to measure the geometry of the Universe and inventory the dominant kinds of mass it contains.

Our journey continues in Chapter 5, with the discovery that the emptiness of space is an illusion. The space between the planets, which was once thought to be a cold, tranquil and empty void, is filled with hot, charged pieces of the Sun, forming a perpetual solar wind. The Sun also curves and deforms the space around it, twisting Mercury's orbital motion along a winding path and deflecting visible light rays and radio waves that pass near it.

Chapter 5 continues with a description of invisible matter in the unseen places between and beyond the stars. Although most of the interstellar medium is too cold to shine in visible light, it is illuminated by radio waves emitted from abundant hydrogen atoms, as well as a host of molecules, from water and ammonia to formaldehyde and ethyl alcohol.

Cosmic motions have been used to infer the presence of unseen matter on a much grander scale. As also described in the fifth chapter, the outermost stars and gas in some galaxies, including our own, are moving so fast that they have to be held together by substantial amounts of dark matter. The gravitational force of dark, invisible material must also rein in the rapid motions of individual galaxies in clusters. Physicists have additionally speculated that substantial amounts of dark matter have been around since the beginning, to help form galaxies in the early Universe, whose expansion tends to pull the newborn galaxies apart; but nobody has ever found the hypothetical particles.

Seemingly empty space may even be endowed with a capacity beyond the imaginations of many people. Some scientists have speculated that all of the mass and energy in the observable Universe could have originated from the nothingness of space, during a rapid growth spurt, or inflation, soon after the Big Bang, or by a host of microscopic, oscillating strings at earlier times closer to the beginning. These invisible loops of energy are supposed to endlessly and randomly twist and vibrate in a cosmic dance, so perfectly choreographed that they explain everything that exists. Such fascinating speculations are also presented in Chapter 5.

Most recently, the urgency of the "missing" dark matter has diminished, with the discovery that dark energy might take its place. After all, mass is equivalent to energy. As discussed in greater detail in Chapter 5, the dark energy is just as elusive; representing an invisible something that fills the nooks and crannies of supposedly empty space. But no one knows where the stuff came from, or why it might be filling up space.

Chapter 5 concludes with an overview that highlights all the significant things we have learned as astronomers begin to part the Cosmic Veil.

In the closing Chapter 6, and Epilogue, the reader is reminded that everything on the Earth and in the Cosmos is changing from one form to another, and that eventually the Sun and all the other stars will fade away into darkness. This brings us to the mystery of creation, of both the Universe and humans.

Up until recently, science was thought to deal with questions that have answers. Art, poetry and religion were supposed to be about unanswerable questions, and it is the lack of answers to these fundamental questions that gives them power. But now there is overlap between these domains in cosmological investigations of the origin and destiny of the Universe.

A vocal minority of modern cosmologists has proposed highly speculative theories, which might never be verified by observation. They imagine, for example, innumerable Universes so completely disconnected from us, and each other, that we will never ever see them, communicate with them, or know with certainty that they exist. Such theories are comparable to ancient myths, but expressed in the language of mathematics that only the cosmologists can understand.

Although modern astronomy has traced the history of the Universe back to the Big Bang, and thereby explained the origin of the elements, what happened before this beginning is completely unknown, as far as verifiable science is concerned, and may not be understood by science alone.

Scientists can also specify the physical ingredients of living things, and speculate on the conditions for life's beginning and survival. And they are actively searching for

life outside the Earth. But no one knows how life originated, or how inanimate, non-biological molecules might have coalesced into a living thing. As with the origin of the Universe, it is possible that an understanding of the origin of life may also lie beyond the capabilities of science alone.

Other speculative topics that may lie outside the domain of pure science include both your fate and the destiny of the entire Universe. Our final sixth chapter also discusses these questions, which now remain beautiful mysteries.

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Kenneth R. Lang
Tufts University *and* Anguilla, B.W.I.
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Chapter One

Cosmic Vision, War and Technology

1.1 NO ONE SEES IT ALL

The Cosmic Veil

Our perception is always limited to just a small part of the much larger world that we are immersed in. We each have our own individual reality, molded by the unique way that we view the external world, and to some extent, we all live in a world that others do not see. So nobody is ever completely aware.

Astronomers observe, measure and quantify the known constituents of the Universe, often looking at them in new ways. Their ultimate goal is to reveal the entire Cosmos. As the American astronomer Cecilia Payne-Gaposchkin asserted, it's all "a search for the Unseen."[1] And in a sense, we only see the shadows on the wall, like people in Plato's cave. Or as William Blake, the English poet and visionary, wrote, "man has closed himself up, til he sees all things thro' chinks of his cavern."[2]

The unseen Cosmos is something like the Japanese rock garden, Ryoan-ji, in Kyoto. It consists of 15 rocks set on raked sand, but only 14 are visible at a time. One rock is always "hidden," and which one it is depends on the viewer's perspective. So the garden has different appearances that change according to the angle of view, or the way of looking. There is always something that remains unseen, something to know more about, but it is either hidden, or viewed dimly from restricted angles or at a distance.

Even our most eminent scientists knew that despite all of their marvelous discoveries they had opened just a small window on a much vaster, concealed Universe. The great English physicist Isaac Newton compared himself to a boy playing on the seashore and diverting himself in "now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."[3] And the German physicist Albert Einstein remarked, "all our science, measured against reality, is primitive and childlike."[4]

Einstein knew that there are underlying patterns in the Universe that exist independent of humans, and that we stand before them, awaiting discovery and understanding of a great hidden mystery. To him, anyone who cannot experience that mystery can no longer wonder or feel amazement. Such a person "is as good as dead, a snuffed-out candle."[5]

It is as if the complete essence, the sum total of all things, lies shrouded behind some Cosmic Veil, so the Universe in its entirety, the complete picture show, always escapes our perception. And every method of describing it, including the scientific one, is missing something; all methods of perceiving the world are incomplete.

Ways of Seeing

Everything we see is molded, shaped and constrained by our education, background, and past experience. They determine our individual perception, with which we analyze, interpret and view the world. And it isn't all heredity. Genes count, but differently in different environments, and there is no gene for the human spirit.

Some people are more alert to their surroundings than others, seeing beyond the immediate world around them. Children are a wonderful example. They can have an amazing clarity of vision, with a clean and innocent face that is filled with intelligence. After all, a child looks and recognizes before it can speak, establishing its place in the world.

Young children can be entirely open and receptive, vividly aware of their external surroundings. They can perceive all kinds of fabulous events in a seemingly dull and lifeless landscape. A child might look under the surface of a stream, for example, or notice the sky reflected in a rain puddle. The British poet William Wordsworth remembered such an early childhood experience with:

> There was a time when meadow, grove and stream,
> The earth and every common sight,
> To me did seem
> Appareled in celestial light,
> The glory and the freshness of a dream.[6]

You can detect compassion, intelligence, wonder and all manner of things hidden within a person's eyes. They might be the bright eyes of a child seeing a butterfly for the first time, or the clear, longing eyes of someone in love. Even a person's lively spirit can be mirrored in their sparkling eyes.

And we all have another eye – the mind's eye. We can use it to mentally cast ourselves out of our body, watching it move about in its daily pattern of life. It takes just another leap of the imagination to use your mind's eye to look down on the spherical, rotating Earth, a suspended, spinning ball, or to imagine the Sun hurtling through space and whirling about the distant hub of our Galaxy.

Artists and writers see details that others miss, using their work to show us their perceptions of the world. Paintings, poems, or especially apt metaphors all convey a particular view, often with emotion and feeling. Poets distill a wisdom that comes from the depths of their souls. Artists recreate the world so others might see it anew. And musicians convey other states of awareness or enlightenment. Scientists also create a unique vision of the world, developing a detached perception, an ability to see beyond the apparent. Art, writing, thinking, music, religion, science, and travel – they all help us interpret and understand the world in different ways.

Waking Up, Being Aware

Every so often, the dull mask of daily life shatters like ice, and we become aware of something deeper and truer. It is as if we live within a facade that conceals the underly-

ing fabric of reality from us. But suddenly we wake up and become aware. The English poet and critic Matthew Arnold wrote of this buried life, a hidden self, which occasionally rises up from our internal depths, as from an infinitely distant land. Then:

> A bolt is shot back somewhere in our breast,
> And a lost pulse of feeling stirs again.
> The eye sinks inward, and the heart lies plain,
> And what we mean, we say, and what we would, we know.
> A man becomes aware of his life's flow,
> And hears its winding murmur; and he sees
> The meadows where it glides, the Sun, the breeze.[7]

Most of the time we have a narrower way of seeing and feeling, with blurred vision and cloudy mind, viewing the world through the filter of our selfish interests and the blinkers of everyday habit. There are computers, televisions, and the random perturbations of life that might dull our minds and keep us from thinking. They can tarnish the gleam of the world and dull the sparkle in our eyes, as we look out to see the same old thing, with puffed-up faces that have become marked by the harsher aspects of the world.

But we all wake up from time to time, catching a fleeting glimpse of the beauty that surrounds us. The silence is broken, like the first step on the crust of un-trodden snow, and a pure note that rises out of the confusing noise. Or it might instead be silence, filled with restful potential, like a pause in music that temporarily breaks the melody, or the pregnant quiet between lightning and a thunderclap.

Cosmic Perspectives

Painters use sunlight to illuminate their work, in its direct glare or with slanting shadows. That light can be alive, warm, and life-sustaining, akin to fires that dance in the face of darkness. Or a painting might depict the elusive, varying qualities of the Sun's hot glow, the source of light and color. In religious art, the light often comes from above, representing spiritual power and dividing the celestial from the terrestrial, the heavens from Earth.

The Dutch artist Vincent Van Gogh used thick brush strokes of blazing, brilliant pigment, as dense as honey, portraying another light, a powerful, yellow Sun that blazes forth with an almost supernatural radiance. And for him, the colors did not die at night. To Van Gogh, it often seemed "that the night is more alive and richly colored than the day."[8] Look up at the night sky, and you will also notice that the stars gleam with blue, green, yellow and red colors.

So Van Gogh, the painter of the Sun by day, portrayed the brilliant stars at night, describing their sparkling colors as emeralds, lapis lazuli, rubies, and sapphires. His first *Starry Night* painting, for example, contrasts the blue-green night sky and the huge, sparkling stars of the Big Dipper with the "rough gold" of the lights below (Fig. 1.1). Vincent described the painting in a letter to his brother, declaring "I have a terrible lucidity at moments, these days when nature is so beautiful, I am not conscious of myself any more, and the picture comes to me as in a dream."[9]

Painters are seeking new patterns in the world, using novel perspectives to look beyond the obvious and beneath the surface into the otherwise invisible. The Dutch

FIG. 1.1 Starry night, Arles The Dutch artist Vincent Van Gogh (1853–1890) created this painting, also known as the *Starry Night Over the Rhône,* in September 1888, describing it in a letter to his brother Theo with "The sky is greenish-blue, the water royal blue, the ground mauve. The town is blue and violet, the gas is yellow and the reflections are russet gold down to greenish-bronze. On the blue-green expanse of the sky, the Great Bear [the Big Dipper] sparkles green and pink, its discrete pallor contrasts with the harsh gold of the gas. Two colorful little figures of lovers [are] in the foreground."[a] The painting, can be compared with Van Gogh's more visionary *Starry Night* composed the following year at Saint-Rémy (see Fig. 3.12). Oil on Canvas, 0.724 × 0.92 m (Private Collection, Courtesy of Musées Nationaux, Paris).

graphic artist, Maurits Cornelis Escher, or M. C. Escher for short, was representative, with his skill at portraying spatial perspectives (Fig. 1.2).

Artists can also cultivate a sense of detachment, as if trying to look at everything from a distance to get a larger, more complete vision. You might say that they just want to retain *perspective,* from the Latin for "to look through." And that perspective has changed as astronomers have transformed our understanding of the Cosmos. Art and astronomy have together taken us beyond the curtained heavens of medieval times, into vast, open cosmic space, a world without end, culminating in our modern realization that man is no longer the center of the Universe or the measure of all things.

A poet's vision can also sweep us into the boundless celestial realms, keeping the world forever young; as in this passage, which describes what the Chilean poet Pablo Neruda felt when he wrote his first line of poetry:

[a] Vincent Van Gogh (1853–1890), *The Complete Letters of Vincent Van Gogh.* New York Graphic Society, Geenwich, Connecticut 1958, Volume 3, page 56.

FIG. 1.2 Three worlds The Dutch graphic artist Maurits Cornelius Escher (1898–1972) was a master at depicting various perspectives. In this print, a forest pond is shown with three distinct components. Fallen autumn leaves suggest the surface of the water, which recedes and blends into the sky at an invisible horizon. The reflection of the trees in the distance provides a second component. In the foreground, a fish seems to stare out at us from a third location, below the water surface. 1955 Lithograph 0.362 × 0.247 m. (© 2003 Cordon Art B.V.–Baarn–Holland. All rights reserved.)

> And I, tiny being,
> drunk with the great starry
> void,
> likeness, image of
> mystery,
> felt myself a pure part of the abyss.
> I wheeled with the stars,
> my heart broke lose on the wind.[10]

Like the poet, astronomers provide us with a sense of something larger than us, which lies beyond our individual daily concerns. And it's at just the right time, when our close, intimate natural world is becoming a dream of the past. Nobody sits in front

of their house anymore, to take in the breezes of the afternoon. And practically no one listens to you, or looks you in the eye.

Although we used to look up, to see the stars wheeling slowly across the black lagoon of a clear night sky, tall buildings now block out the celestial heavens and city lights drown out their beacons. Modern astronomy helps fill this vacuum, with remote telescopes that have carried us out through the darkness and shadows, even beyond the known stellar worlds (Fig. 1.3). They have drilled a hole through the heavens, transporting us into captivating realms that lie far beyond our busy little planet with its hectic pace and material concerns.

Modern artists have also been separating themselves from their immediate environment, placing nature at a distance to obtain a cosmic perspective. The Russian painter Wassily Kandinsky was one of the first to become completely detached from his everyday surroundings, stating that "this art creates alongside the real world a new world, which has nothing to do *externally* with reality. It is subordinate *internally* to cosmic laws."[11]

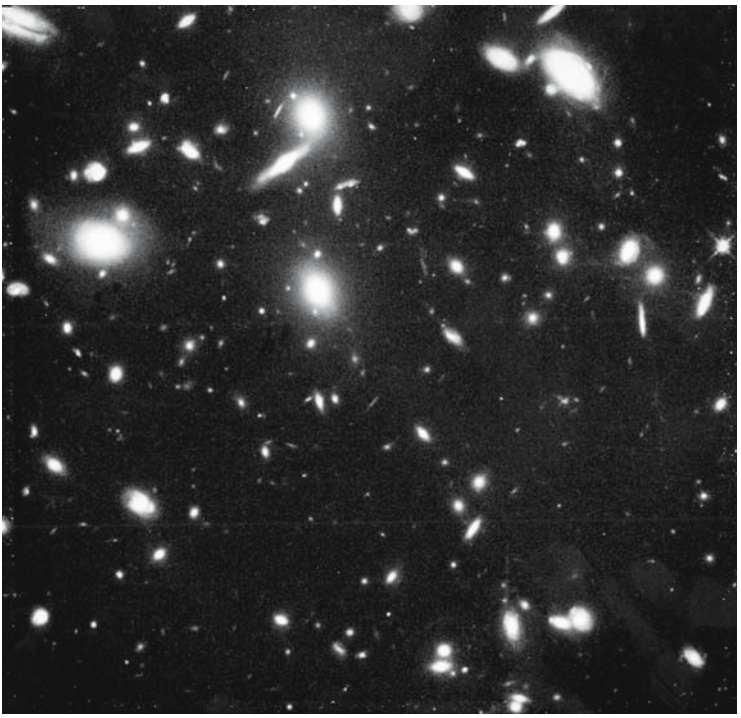

FIG. 1.3 Endless galaxies A remote cluster of galaxies, designated CL 0939 + 4713 for its coordinates on the sky, as it looked about 10 billion years ago when the light we see was emitted and the Universe was two-thirds of its present age. Many of the galaxies have distorted forms, suggesting that mergers and other interactions have disrupted them. This image was taken from the *Hubble Space Telescope* in January 1994. (Courtesy NASA, STScI, and Alan Dressler, Carnegie Institution.)

The painter omitted all resemblance to the immediate physical world in his work, obtaining depth and perception from cosmic space that could continue beyond the borders of his canvas. In some of his paintings, Kandinsky used multiple centers of interest, such as circles of varying size and color, that tend to cancel each other and draw the viewer's eyes in and out, thus creating a fourth dimension in a single throbbing whole (Fig. 1.4). They were used as a cosmic metaphor, especially when painted against a dark background, suggesting planets or stars in the night sky.

So it's perhaps not surprising that astronomy was a source of Kandinsky's inspiration. In fact, he held a lifelong interest in the celestial science. He had an astronomer

FIG. 1.4 Several circles This cosmic image, painted in 1926 by the Russian artist Wassily Kandinsky (1866–1944), draws us into space, reminding us of unseen worlds that seem to pulsate with energy and vitality. The large blue circle with white edges suggests a cloudy sky, while the deep black circle reminds us of the dark night sky. The transparent intersections of different circles lead the eye into the distance, but without any specification of the depth. It is hard to determine which circles are closer and which are more remote, as the eye focuses on different parts of the painting. Oil on canvas, 1.40 × 1.41 m. (Courtesy of the Solomon R. Guggenheim Museum, New York City, New York.)

come to give regular lectures to his family, when they would take turns looking through a telescope at the Moon, Saturn and the Pleiades star cluster. Kandinsky even once planned to construct a small private observatory in his home in Moscow.[12]

The Spanish painter, Joan Miró, created otherworldly gouaches, known as the "Constellations," which also remove us from our immediate surroundings and draw us into the Cosmos beyond. When Miró created these paintings, between 21 January 1940 and 12 September 1941, the Spanish Civil War (1936 – 1939) had recently ended, the world was falling apart in an enormously destructive World War II (1939 – 1945), and humans were subject to horrible experiences, inner agonies and a loss of identity. So Miró was probably responding to the plight of people at this tragic moment in history. Like many other people at the time, he wanted to flee from the devastating world around him, writing: "I felt a deep desire to escape. I closed myself within myself purposely. The night, music and the stars began to play a major role in suggesting my paintings."[13]

In Miró's work, intersecting circles and lines connect points and mythological signs to the stars, crescent moons and orbiting worlds (Fig. 1.5). The result is a complex web of interrelationships that join human beings, denoted by eyes, to the Cosmos. So he mimicked the stellar constellations, replacing them with his own imaginative vision, and was thus inspired by the celestial heavens.

Einstein agreed with this need to withdraw into a better world, stating "One of the strongest motives that leads men to art and science is to escape from the rawness and monotony of everyday life and take refuge in a world crowded with the images of our own creation."[14]

Open Minds, Serendipity and New Technology

The new discovery, the previously unseen wonder, is everywhere, remaining to be revealed by parting the Cosmic Veil. It might be just a simple thing – a phosphorescent, blue bird or a red dragonfly moving across a lake, or perhaps a veined yellow leaf drifting in the wind. Or it could happen when an astronomer is looking at something else, with an open mind ready to notice the unexpected.

Like creation in other areas, astronomical insight is something like taking a trip to a distant country that you have never seen before. The disorientation turns the ordinary into the unusual and strange. And when alert, you can suddenly notice things that have always been there, sharpening your focus to look at the Cosmos in a new way. Louis Pasteur, the French scientist who developed the germ theory of disease and the technique of pasteurization, expressed it succinctly with "in the field of observation, chance favors only the prepared mind."[15]

But it wasn't scientific brilliance or conceptual foresight that resulted in the major changes in our understanding of the Universe. Most of the significant astronomical discoveries have been accidental, unanticipated and completely serendipitous. And no one predicted that these fascinating discoveries would occur! They are mainly a consequence of new technology and the development of novel telescopes.

These instruments of discovery have extended our vision, enabling us to see the invisible and enlarging our perspective of the unknown. Like an imaginative story, they have taken us to unintended places, each time revealing a new previously hidden aspect of the Universe.

FIG. 1.5 Ciphers and constellations in love with a woman In his *Constellation* series, executed between 21 January 1940 and 12 September 1941, the Spanish painter Joan Miró (1893–1983) sought refuge in the stars, which gave him hope for new life. This painting, created in 1941, includes a close network of symbols and intersecting and overlapping lines, set on a nebulous and transparent background. Its parts are interconnected, as if they were all orbiting around one another or joined like the stars in a constellation seem to be. Gouache and turpentine paint on paper 0.46 × 0.38 m (Courtesy of the Art Institute of Chicago, Chicago, Illinois.)

1.2 THE SKY ABOVE AND THE ENEMY BELOW

Telescopes That Detect the Unseen

The instrument-driven voyage of astronomical discovery began with the invention of telescopes that gather in the colored light seen with our eyes. We sometimes call them optical telescopes, since the science of optics describes their component lenses or mirrors. They are also known as visible-light telescopes, to distinguish them from radio or X-ray telescopes that detect invisible radiation.