COSMIC DISPATCHES

The New York Times

REPORTS ON ASTRONOMY AND COSMOLOGY

EDITED BY JOHN NOBLE WILFORD

"A must for every armchair cosmic voyager."
—*Science News*

Cosmic Dispatches

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The New York Times Reports on Astronomy and Cosmology

New and Expanded

John Noble Wilford, Editor

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Introduction

Informed Wonder

Each of us has struggled to recall the first memories of his or her own being. The best I can do is retrieve blurry scenes, like faded snapshots, from when I was about two or three years old and lived in a place Mark Twain described as "a pretty town perched on a handsome hill" overlooking the Mississippi River. In these memory scenes I am having no success loading wiggling puppies into my red wagon. The little girl next door, Shirley, is in the yard, and the imaginary Mr. Humbug, my alter ego and all-purpose scapegoat, is everywhere. The memories come into sharper focus at the thought of the walks I took with my grandfather.

We would go to the brink of a high bluff, and there, blind though he was in those years late in life, Granddaddy would tell me about the river below. While I saw with my eyes only the muddy currents and long barges, he told me where the waters and the boats might have come from and be going, expanding the panorama to encompass the geography of middle America. Stretching before me, as I have come to recognize, was a prospect of informed wonder, something seen with the eye but enriched with meaning and beckoning mystery by the mind's eye. A little boy standing in Kentucky could begin to imagine the world's greater dimensions.

As a species as well as individuals, we grow up straining to recall a dim past, looking out from the here and now and seeking to know something of

our place in time and in the cosmos. One response is science, an exercise of informed wonder.

By observation and constant reference to accumulated knowledge, scientists discern in an ever-flowing stream of masses and motions certain laws of nature and extend them to that which is unseen but inferred. Out of this they conceive theories of the world and the universe, present and past. Science manages in this way to catch glimpses here and there of our ultimate origins, in a remote past long before the first footsteps of hominids.

No branch of science practices informed wonder with more élan (some might say, hubris) than astronomy. The field is populated by three different but sometimes overlapping practitioners: observers, who spend their nights on chill mountaintops and all hours of night and day crunching data from instruments on the ground and in space; theorists, often called cosmologists, who leap from observations to big-picture constructs of cosmic origins and evolution; and, increasingly in recent years, particle physicists, who search for and probe the components of nature for insights into how something as grand as the universe grew out of virtually nothing.

These are among the most imaginative and provocative explorers of our time. Like the geographic explorers of earlier centuries, they venture into uncharted spaces, come upon new worlds, expand the knowable and challenge thinking about the place of humans in all things. These new explorers are the builders of spacecraft that traverse the solar system and of telescopes that can peer out to some of the most distant reaches of space and time. Those who use these instruments of discovery are writing a more comprehensive history of the universe. Their mind-flexing exploits are as fresh as today's headlines, as fascinating as an unfolding mystery story, as awesome as time travel to horizons far beyond the familiar night sky. And some of their evocative language—big bang, dark matter, black holes—has crept into the idiom of modern society.

These cosmic explorations can be a humbling experience. Time and distances expressed in light-years by the millions and billions are difficult to calibrate with our brief life spans as individuals or a species. The gravitational power of ravenous black holes and the tremendous energies of quasars and gamma-ray bursters are beyond ordinary comprehension. And the moment we think ourselves so extraordinary because of our new powers of cosmic comprehension, another thought crosses the mind like a shadow: perhaps we are not alone. Other intelligent beings may share this universe. And perhaps ours is only one of many parallel universes.

At each moment of surprise and insight in today's cosmology, someone inevitably brings up the name of Nicolaus Copernicus. In 1543, the Polish churchman shook the foundations of classical cosmology by removing Earth from the center of the universe; Earth was actually orbiting the Sun with all the other known planets. A few early Greeks had speculated on the heliocentric theory, though their views had largely been forgotten in the geocentric triumph. The very idea of human displacement from the center of all creation was stubbornly resisted until, nearly seventy years after Copernicus, Galileo first pointed a telescope to the sky and observed four moons orbiting Jupiter. He was seeing a kind of solar system in miniature. It was the first tangible evidence supporting the heliocentric theory. Subsequent discoveries have nudged humans further from the center: our Milky Way is only one of billions of galaxies, the Sun is in the suburbs of the Milky Way, and many Sunlike stars, we now learn, also have planetary systems. Cosmologists have even had to accept the evidence that most matter in the universe is undetected exotic material unlike the stuff out of which stars and planets and all living things are made. Little wonder that cosmologists expect current explorations, when fully developed and understood, to produce a new Copernican Revolution in cosmic perspective.

We humans are a recent phenomenon in a universe that is very old, mostly unseen, and beyond mundane measure. It has been a struggle getting our bearings. At the start of the twentieth century, no one could conceive of the vast dimensions or the many mysterious phenomena of the universe. Few then imagined that the universe had a history and that some of it might be decipherable by ordinary mortals.

At that time, the cosmos was widely thought to be relatively small and static. Then along came Albert Einstein, whose theory of relativity changed forever fundamental thinking about space and time. In the early twentieth century, Einstein added the dimension of time to the familiar three dimensions of space. We live in a space-time continuum, Einstein said, that places the universe in a relativistic perspective that is as much temporal as it is spatial. Others followed with efforts to understand the smallest components in the universe. They conceived of quantum theory to explain the behavior of matter on the most elemental subatomic scales. Upon these bedrocks of theory—relativity and quantum mechanics—the edifice of modern cosmology would be erected.

In 1905, an historian of astronomy confidently proclaimed the one-galaxy universe a "practical certainty," and added, "with the infinite possibilities beyond, science has no concern." Less than twenty years later, Edwin P. Hubble discovered that the Milky Way, Earth's home galaxy, was not the entire universe. He observed that Andromeda was a separate congregation of stars, and many more separate galaxies stretched out beyond. As their powers of observation improved, astronomers learned that each typical galaxy comprises billions of stars bound loosely by gravity. Each of these galaxies extends some one hundred thousand light-years across and is separated from the others by distances of at least one hundred million light-years. Still there is space enough for upwards of eighty billion galaxies of many shapes and sizes, with plenty of room to spare. If all the luminous matter in the universe—the planets, gas clouds, stars, and galaxies—were smoothed out and spread uniformly throughout the universe, the result would be a virtual vacuum everywhere, no more than a single atom occupying each cubic meter of space.

In 1929, Hubble made an even more astounding discovery, one that even Einstein had not foreseen. The stock market might have contracted disastrously that year, but the universe, Hubble found, was expanding. The expansion was a central fact of nature. Galaxies are moving away because space—everything there is—is stretching in all directions like an inflating balloon, carrying the galaxies along with it. The farther away they are, Hubble determined, the faster they are receding.

A striking new picture of cosmic history began to emerge. If the universe is expanding, it must have been smaller and denser in the past.

Hubble himself was an observer and contributed little to interpreting the full implications of his discovery. But others of a more theoretical bent had already been thinking along these lines. In 1922, a young Russian mathematician, Alexander Friedmann, had pointed out errors in Einstein's calculations. Corrected, relativity theory thus showed that a static universe would be unstable and an expanding one was the only possibility. A few years later, a Belgian cleric and physicist, Georges Lemaître, made independent calculations and confirmed Friedmann's findings. Friedmann, though, had died in the meantime. It was Lemaître who was among the first to recognize the cosmological significance of Hubble's research, and he went a step further in emphasizing that an expanding universe must have had a beginning as a kind of exploding primeval atom. On May 19, 1931, a story of this concept appeared in the *New York Times* under the headline: "Lemaître Suggests One Single Great Atom, Embracing All Energy, Started the Universe."

Friedmann and Lemaître had planted the seed of what would become known as the Big Bang theory, today's prevailing model of how the universe originated and evolved.

In the beginning, according to the theory, all the mass in the universe was compressed in a compact and tremendously hot state. (To the inevitable question of what there was before, scientists often respond that the answer is unknowable. Or they fall back on a variation of the answer St. Augustine is supposed to have given to the question of what God was doing before He created the universe: He was preparing hell for people who might ask such questions.) Then there was the titanic explosion, the beginning of expansion. The flow of time as we know it also began with the Big Bang—time zero. (So another answer to that inevitable question might be, there was no "before" in any sense that we can ever know.) The fireball spread rapidly enough to keep from collapsing from its own gravity. Spreading out, it grew cooler and thinner. In the first few minutes, energy was transformed into matter, and the nuclei of the lightest elements formed. In a million years or so, the expanding universe became cool enough for whole atoms to appear, followed by simple molecules. Matter could then start to condense into stars and galaxies.

The Big Bang theory rests on three foundation stones, the first being the observed expansion of the universe. Scientists were slower in recognizing the other two. These were introduced in the late 1940s by George Gamow, Ralph A. Alpher, and Robert Herman. If the universe began in a hot, dense state, these American physicists postulated, the thermonuclear processes in the first few minutes should have produced elements slightly heavier than hydrogen, including deuterium, helium, and lithium, in certain abundances. Also, the explosive event should have left a uniform glow of radiation of a certain temperature.

Although their ideas made little impression at first, once verified, they were hailed as the essential evidence tipping the balance of scientific thinking in favor of the Big Bang. Detection of the cosmic background microwave radiation was made serendipitously by two researchers at Bell Telephone Laboratories, Arno A. Penzias and Robert W. Wilson. In 1964, their radio antenna picked up crackling signals, the echoes of cosmic creation. Astronomers at this time were also finding that the abundances of the lightest elements—roughly 75 percent hydrogen, 25 percent helium—matched the theory's predictions, confirming the idea that they were produced by nuclear fusion in the early fireball. This afforded an indirect glimpse back to conditions immediately after the beginning.

With these two successes, support evaporated for the principal alternative theory: the steady-state universe, which held that the universe, on average, does not change in time, the continuous creation of new material compensating for any dilution caused by expansion. Such a universe was always essentially the same and had no beginning, and would have no ending. About the only lasting legacy of the steady-state theory is the term Fred Hoyle, one of its originators, coined to disparage the rival theory: the Big Bang.

The theory has become widely accepted by scientists as the modern creation story. "We feel certain that our theories have more truth than the beliefs of our ancestors, yet are we so much smarter than they were?" writes Dr. Joseph Silk of the University of California at Berkeley in his book, *A Short History of the Universe*. "Perhaps a thousand years in the future, the big bang theory will itself be regarded as a twentieth-century myth." But he finally yields to his enthusiasm for the theory. "I am an optimist, however, who finds our current paradigm so compelling that I can only imagine it will eventually be subsumed into a greater theory, without losing its essential features."

The last decade of the twentieth century has been an especially lively time in astronomy and cosmology. Although the Big Bang theory continued to gain strength, astronomers, cosmologists, and particle physicists still had more than enough open questions to contend with. What is the age of the universe? What is its mass density, and what is the composition of this mass—the mystery of the missing mass and now, it seems, the missing vacuum energy? Is the universe's expansion, contrary to assumptions, speeding up, not slowing down? What are the implications of an accelerating universe for its large-scale geometry and its ultimate fate?

With their new powers of observation, astronomers have brought into focus unsuspected phenomena beyond ready explanation and peered deep into the universe without yet finding the boundary where galaxies began forming. They have followed the life cycles of stars and detected for the first time planets around distant stars. Their computer projections have looked one hundred trillion years into the future of an expanding universe.

Their spacecraft have raised anew the questions of whether life once existed on Mars, or whether some organisms could still exist in places like the water under the ice surface of Europa, one of Jupiter's moons. Radio astronomers have fine-tuned their giant antennas to listen for possible signals from extraterrestrials on distant worlds. Stay tuned.

A few journalists who write about science have had ringside seats as

observers and communicators of these fascinating and often perple explorations of the cosmos. We have sat up nights with astronomers at telescopes. At times like these, I sometimes think of the little boy ar grandfather, the one being guided by the other to an understanding of what they were seeing. Where I see a smudge of light appearing on a video screen in the observatory's control room, the astronomer sees signs of a planet orbiting a distant star. He is able to inform my wonder, and through me the wonder of a wider audience, as he had already informed himself.

We science journalists have also listened with varying degrees of comprehension to cosmologists patiently explaining the import of new findings. We have tried to cut through abstruse equations and scientific phrases and find ways to translate this into a common language. In nearly all cases, the scientists have been liberal with their time and knowledge, even though they must despair at some of our simple-minded questions and simplified presentations of what they have invested lifetimes in learning.

The *New York Times,* I happen to think, has provided more comprehensive reporting on astronomy and cosmology than any other newspaper. This book is a collection of our dispatches from the front lines in the human engagement with the cosmos. The articles selected for inclusion, out of so many worthy candidates, seemed to chronicle the dynamic of scientists at work on the most important issues of cosmic exploration over a decade: the excitement and puzzlement engendered by new discoveries, the contention and competition between rival teams of scientists and those with differing interpretations, the rising optimism that they are on the right track in their long journey toward understanding cosmic history, and the stimulation of new lines of inquiry sure to bring more surprises in coming years. The universe is very much a work in progress, and so is the human quest to comprehend it.

The articles, written in language accessible to the general reader, reflect the momentum of cosmic exploration at this crucial time. They have not been changed in any essential way (some dated or repetitious material has been excised). Anthony Zirilli provided indispensable help in preparing the articles for publication. Notes at the head of each chapter put the reports in context and take into account any subsequent revisions in thinking based on new findings and interpretations. Read and share with us the ringside seat on astronomy and cosmology.

If, as it is often said, journalism is the first draft of history, then these dispatches are first drafts of our cosmic history.