THE BIRTH OF THE EARTH

A *Wanderlied* Through Space, Time, and the Human Imagination

DAVID E. FISHER

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For Hans Frese
Professor of German,
Trinity College, 1952/3

and

for my parents
Henry R. and Grace S. Fisher

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WHAT TOMAS SAID IN A PUB

I saw God! Do you doubt it?
Do you dare to doubt it?
I saw the Almighty Man! His hand
Was resting on a mountain! And
He looked upon the World, and all about it:
I saw Him plainer than you see me now
—You mustn't doubt it!

He was not satisfied!
His look was all dissatisfied!
His beard swung on a wind, far out of sight,
Behind the world's curve! And there was light
Most fearful from His forehead! And He sighed—
—That star went always wrong, and from the start
I was dissatisfied!—

He lifted up His hand!
I say He heaved a dreadful hand
Over the spinning earth! Then I said,—Stay,
You must not strike it, God! I'm in the way!
And I will never move from where I stand!—
He said,—Dear child, I feared that you were dead.—
. . . And stayed his hand.

—James Stephens (1880–1950).

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CONTENTS

INTRODUCTION

Stories told of the history of science all too often portray a smoothly rolling film sequence of discovery, refutation, modification, and final verification. Someone conceives of a scenario to explain a concept such as our existence, and others find faults with it; point by point the arguments are attacked and experimentally or theoretically they are demolished, modified, or established. The scientific process thus described is a lovely fairy tale, but in my own experience I have found it to be usually more random and chaotic, explicable as much in terms of fashion and passion as in those of logic and measurement. Points of argument are often ignored, points of view skirted around; various counterarguments are presented simultaneously so that future impetus is split into skewed directions, nevermore to meet again; theories as well as experimental data are forgotten, resurrected, rediscovered, reforgotten; they are proven wrong one year, accepted the next, discarded without argument the third. And somehow, out of all this chaos, we slowly learn. It is not a calm, reasoned, logical learning experience: but it's not only the best we have, it's the only game in town.

The historian of science as well as of other torturous human paths cannot tell a story without inserting a thread through the holes to hold it together, to make a pleasing or at least an organized quilt out of the various ill-fitting patches. To tell it as it truly occurred would be bewildering, but to tell it as a coherent story is often untrue. So a compromise must be reached, in which we pick and choose among the refuse of history to find a scheme which approximates both the truth and a story with a beginning, a middle, and an end, and finally then we say, "This is the way it happened."

Right, then. This is the way it happened.

CHAPTER ONE
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IN THE BEGINNING

In the Beginning God created the Heavens and the Earth.
Well, not exactly.

THAT FIRST SENTENCE represents an astonishing leap of human imagination. It replaced a universe of chaos with one of order. The universe—and the day-to-day fortunes of humanity—were no longer at the mercy of the whimsies of innumberable gods known and unknown, but were created by and subject to the one overriding purpose and stern discipline of a just (if occasional vengeful) God. The sun did not rise in the morning, bringing the light and warmth necessary for our survival because the god Shamash felt like driving his chariot across the sky, but because the sun was created by the Lord aeons ago precisely to bring us light by day; it existed for that purpose and would never stop, would never fail to appear. It was no longer necessary to worry each night whether Shamash might change his mind the next morning and fail to appear; there was no need to cut out the gizzards of chickens or the hearts of virgins and spread them on altars to induce Ushas to bring the dawn or Enki to send the fish for supper or Immer to water the fields with rain: the universe had an order, a discipline, a purpose, and so did we. That first sentence established the foundation of an understandable universe and became the basis of a system of moral and religious values that has lasted thousands of years and, though observed more in the breach than in the practice, still underlies the fabric of our civilization.

The second sentence is even more astonishing. It became possible to formulate it only in the second half of this present century: incredibly, we can now say with the utmost certainty something about the creation of our world. We know quite clearly that the Earth was not created *in the Beginning* at all: many billions of years actually elapsed between the creation of the first heavens and that of the Earth, many stars were born and passed into oblivion before ever the Earth was even a mote of dust in its Creator's eye, to coin a symbolic phrase.

The evidence for this comes from several different lines of scientific enquiry, from nuclear physics and geology as well as astronomy, and all the evidence fits together to form a proof beyond all reasonable doubt. We know, to begin with, that the universe we live in was created in a fantasic explosion we call the Big Bang. We don't know what happened or existed before this event, whether other universes existed in an unending chain beyond the beginning of time and whether the process will continue infinitely far into the future, or whether our present universe is the sum total of existence. Our imaginations boggle and collapse under the weight of such heavy questions. But we do know that our present universe was created in that moment of the Bang: we see the evidence of that event in the nearly homogeneous background radiation that now pervades the universe, the slowly dying relic of that first radiation flash. We see the evidence also in the motions of the galaxies, which are still being blown away from us and from each other with the force of that initial explosion. This latter observation, that of the motion of the galaxies, was the first hint we ever had of the overall structure of the universe. It depends on measurements of the spectra of wave lengths of light emitted by hot gases.

It was discovered early in this century that when a gas is heated to incandescence the light it emits consists of a series of discrete wavelengths which are typical of the type of gas; in fact, the spectrum of wavelenghts provides a spectroscopic fingerprint by which the identity of the gas is revealed. In this way astronomers analyzed the light coming to us from the stars in our galaxy, and found that all the stars were composed overwhelmingly of hydrogen. When they looked at the spectra of light coming from other galaxies, however, it was subtly different: it showed the characteristic relative spectrum of hydrogen, but the absolute values were always shifted to higher wavelenghts. This became explicable in terms of Einstein's General Theory of Relativity and an experimental observation known as the Doppler Shift.

In 1917, even before his theory of general relativity had been proven correct, Einstein attempted to apply it to the entire universe. He managed to find a unique solution to the relativistic equations which specified a homogeneous universe with no motion, space curved and without limit, yet finite, and with time uniform but infinite. He was mildly disturbed when the Dutch mathematician Willem deSitter found another solution in which the universe was empty but had the peculiar quality that if any small amounts of matter were introduced into it they flew apart spontaneously and continued to recede into infinity. Since, however, our universe was demonstrably not empty, it was possible to dismiss the DeSitter solution as irrelevant.

Nothing, however, is irrelevant to mathematicians, and by 1924 the Russian mathematician Alexander Friedmann had discovered a whole spectrum of possible solutions in which matter, which here was as natural a component as in the Einstein universe, spontaneously flew apart as in the deSitter universe. This model was extrapolated backward in time by the Belgian Abbe Georges Lemaitre, to a point of infinite density at zero time known as a "singularity." This word is used to denote a situation that is physically impossible—that is, impossible within our laws of physics. It arises mathematically as a function that is not well-behaved: noncontinuous, with a noncontinuous derivative.* An example might be something like a radar plot of a jet airplane's trail from Miami to New York which instantaneously becomes zero over Richmond and then just as abruptly reverts to its proper value again. This would be impossible as a plot of a real airplane in our real world; if it showed up this way on a radar screen the operator would conclude that the system was malfunctioning. And that is what Einstein and many others thought at first when the Friedmann/Lemaitre solutions to the relativistic equations showed a singularity at the beginning of time.

*To be more precise, if $f(z) = u(x,y) + iv(x,y)$ and if *u* and *v* and their partial derivatives with respect to *x* and *y* are continuous and satisfy the Cauchy-Riemann conditions

$$\partial u/\partial x = \partial v/\partial y \text{ and } \partial v/\partial x = -\partial u/\partial y$$

in a given region, then f(z) is said to be *analytic*. A *singularity* is a point at which f(z) is *not* analytic. "Real" functions are analytic everywhere under conditions we consider normal in our universe.

The flinging apart of matter in these solutions was also disturbing; it meant that the universe could not exist as a stable, static system. Rather it had to be continually expanding. (Actually, as I mentioned, the Friedmann solutions are an entire family of possibilities, including the possibility of contraction as well as expansion; but certainly a static, nonmoving, time-independent universe is not one of them.)

These two problems suddenly became the solution known as the Einstein-Friedmann universe when it was realized what they mean: that the universe began as a singularity, in a state which does not correspond to any aspect of physical reality today, a state of infinite compression and density which *in the Beginning* exploded and sent all the matter in the universe spinning outwards. Today that matter, in the form of galaxies, is still spinning out, expanding, receding from itself.

We see this expansion of the universe in the Doppler Effect. The shift in wavelength of the lines of the hydrogen spectrum is due to the motion of the light source—the distant galaxies. When an object emitting light waves is moving toward the observer, the wavelength of the light appears to him to be shortened; when the object is moving away, the wavelength appears lengthened. This effect was first discovered by the Austrian scientist Christian Johann Doppler, who thought that observations of starlight would show random motions of the stars: some moving toward us, some away from us. Within our galaxy, such motions are so small as to be all but indiscernible, but the light from other galaxies all show a shift to longer wavelengths: every galaxy is moving away from us and away from each other. Not only that, but the further ones are receding at faster velocities, proportionally to their distances. This is precisely the effect to be seen as the aftermath of an explosion, and so the observations together with the theory tell us clearly the story of the Big Bang.

They tell us more: they tell us *when* it happened. Simply by taking the measured distances of the various galaxies together with their measured velocities, we can tell how long it took them to get where they are; the calculation is simply the inverse of determining how far an airplane has traveled, from a knowledge of its take-off time and its speed. Unfortunately, it's not quite so simple: there are large errors in our measurement of the distance of the galaxies. But taking these into account, we can place the time of the Big Bang at certainly within 12 to 40 billion years ago, and