Astronomers' Universe

David A.J. Seargent

Weird Universe

Exploring the Most Bizarre Ideas in Cosmology

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For Andrew, Claudia, Theodore
and Persephone (a very new arrival
in this weird universe!)

Preface

In my first two volumes of the "weird" series—*Weird Astronomy* and *Weird Weather*—I concentrated on what could best be described as anomalous phenomena and observations that did not quite 'fit' straightforward explanations. The next volume in the series—*Weird Worlds*—took a somewhat broader view insofar as recent discoveries about other planets have uncovered many features and phenomena which may certainly be regarded as "weird" or anomalous in comparison with anything experienced on Earth. The present volume continues this approach. Strange observations are certainly included within its pages, but the "weirdness" of this wonderful universe in which we live is definitely not confined to these.

Even to begin explaining the universe as revealed by modern science is to stretch the boundaries of what we normally consider to be common sense. Not only must we somehow get our heads around vast expanses of space and incredible depths of time, but we are also confronted with seemingly contradictory notion such as a vacuum which nevertheless appears to be filled with vast amounts of energy, particles which are also waves, "empty" space which can nevertheless stretch as if it is some kind of expandable fabric and so forth. Most scientists understand these things as being relatively established and non-controversial. But then there are more speculative possibilities such as multiple universes, fundamental entities existing in a hyperspace of many dimensions and the theory that the entire universe is—or can be represented mathematically as being—a giant hologram. Gone are the days when the universe seemed to be a relatively straightforward clockwork system of material particles in motion!

Needless to say, in the face of such a complicated subject as the nature of the universe, not all of the theories put forward over the years have won the general acceptance of the scientific community. Sometimes the reason for this is pretty obvious—the theory simply fails to deliver the goods; fails to give a satisfactory account of observed phenomena. Yet, at other times a theory looks good but simply does not jell with the general line of thinking at the time. Sometimes, theories of this type eventually have their day in the Sun as evidence in their favor mounts and/or attitudes change within the scientific community. A sample of such left-field hypotheses is included here.

Together with the other books of this series, several projects are provided for readers who may like to be more hands-on with this subject. These are, in the main, less astronomical than their counterparts in the earlier works, but that is inevitable considering the nature of the subject matter. Although astronomy is intimately involved with the study of the universe as a whole, the deepest issues cannot be resolved at the telescope alone. The physics laboratory, the computer, and those interesting exercises of reason and imagination that go under the name of thought experiments have equally vital roles to play in unraveling the mysteries of this incredible, beautiful, complex, and wonderfully weird universe!

Let the cosmic adventure begin!

The Universe is not only [weirder] than we imagine, but [weirder] than we *can* imagine.

J.B.S. Haldane (1892–1964) (altered).

Acknowledgments

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No book about this "weird" universe in which we live would be possible without the long and complicated research of generations of scientists, both past and contemporary. To all of these, I extend my gratitude for at least partially unveiling this wonderful realm in which we live, as well as my admiration for their genius and patience in deciphering its message.

Cowra, NSW, Australia David A.J. Seargent

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1. From Water World to Inflation; Humanity Faces the Universe

The First Cosmologists

From the earliest of times, human beings have asked questions about the world around us. What really *is* this world in which we live? What is its true nature and from whence did it come? Many and varied have been the attempts at answering these questions. Stories of universal genesis, most frequently framed in the symbolism of myth, date to the earliest stirrings of human consciousness, but the first accounts that we might recognize as scientific cosmologies and cosmogonies (i.e. theories of the nature and origin of the universe) come from a school of Greek thinkers living on the Ionian coast of what is nowadays Turkey. The man honored by today's historians of scientific thought as deserving the title of the first known scientist was Thales of Miletus (circa 624–circa 546 BC).

We will come back to old Thales in a moment. First however a few words should be said about the so-called Milesian school in general. The natural philosophers of this school, exemplified by the three outstanding thinkers Thales, Anaximander and Anaximenes, were united in the belief that there was a single substance from which the universe was made. The first and last of the trio identified this basic substance with a familiar form of matter. Anaximander's cosmology was rather more subtle and complex, albeit remaining within the school's overall framework.

Although it is probably pointless to speculate as to why the germ of what we now call scientific cosmology first appeared amongst this group of sages in an ancient Greek colony, the philosopher Alexander ("Sandy") Anderson, son of the prominent Scottish/Australian thinker John Anderson, suggested that their motives may not have been entirely driven by pure intellectual curiosity. Noting that at the time these men were living, Miletus

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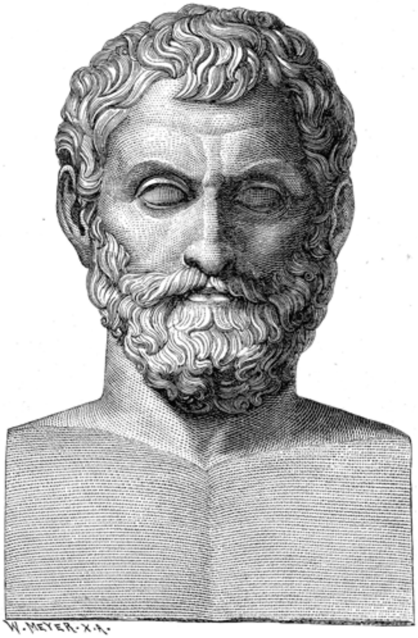

FIGURE 1.1 Thales of Miletos c624–c546 BC. The first cosmologist (*Credit*: Published by E. Wallis et al. 1875–1879)

was a thriving commercial port where a wide variety of goods were constantly being exchanged, Anderson wondered if, at least at a subconscious level, these philosophers may have entertained the thought that if the basic substance of the universe—the stuff from which all objects were ultimately made—could be discovered, might it not be possible to manipulate this substance in such a way that materials now needing importation from distant lands could be manufactured right at home in Miletus? If everything is ultimately made of (say) water, then the basic substance of wood and gold is the same, i.e. water. Might it not, therefore, be possible to turn wood into gold? Or to somehow process the water of the river straight into gold? If anyone found a way to do that …!

Of course, we have no way of knowing whether such thoughts ever occurred to the Milesian sages, even at a subconscious level, but Anderson's speculation is an interesting one and, ironically, would make these sages spiritual ancestors, not simply of later generations of speculative scientists but equally of alchemists and (dare we say it?) engineers!

Be that as it may, let's return to the founder of the school; Thales.

All we know of his theories comes from a trio of statements preserved by Aristotle and which may be summarized as something like:

Water is the cause of all things,
The Earth floats on water,
All things are full of gods. The magnet is alive because it has the power of moving iron.

The last need not concern us, but the first two statements, when taken together, imply a cosmological system in which water is the ultimate "stuff" of the universe. Although we don't know how Thales arrived at this conclusion, it is not difficult to believe that it was not so much an exercise of pure reason as a deduction made from simple observation. Miletus, we might note, was then situated on the Gulf of Latmos at the mouth of the Meander River. Today, the Gulf is dry land and Miletus is well inland. The water which lapped its periphery in the days of Thales has now turned into solid ground! Maybe Thales heard old stories of areas of the Gulf which, even in his time, had turned into dry land. Indeed, he probably lived long enough to recall from his boyhood how parts of the Gulf had receded, leaving small expanses of solid earth in their wake. And beyond all of this, had he not seen mists rising from the waters (water turning into air) and later falling again as rain (air turning back into water)? What more natural conclusion could there be than that water is the underlying substance of all material existence?

Anderson, however, also raises the suggestion that maybe Thales was really arguing that the chief *property* of water—fluidity—rather than literal water per se, was the real underlying principle of the universe. Everything is therefore "like" or "a form of" water rather than water in the usual sense of the word. A later Greek sage, Heraclitus, stressed the fluidity of the world by comparing it to a constantly changing fire. Although sometimes interpreted as teaching that the world is composed of literal fire, Heraclitus seems rather, to be *comparing* it to a fire in the way that fire is, in one sense, always in motion—flames extinguishing as others burst to life—whilst in another sense remaining constant. Perhaps Thales was saying the same thing. Yet, just as Heraclitus seems vague at times in his distinction between what really is fire and what merely resembles it, perhaps Thales never truly distinguished between literal water and (shall we say) metaphorical water. Looking back over so many years, we simply cannot know. But whatever his exact thoughts may have been, the important issue for us is that in these speculations, Thales launched a new endeavor in human though; scientific cosmology or the employment of observation and reason in the bold attempt to work out the nature of the universe. His conclusions might appear naive and even quaint to us, but the task upon which he embarked remains just as intriguing now as it was in his long-ago day.

Thales' two successors in the Milesian school were Anaximander and Anaximenes. The former was truly an ancient polymath whose range of speculation swept across fields as diverse as astronomy and biology but, in the tradition of Thales, his chief cosmological quest was for the ultimate principle of the universe; the basic substance from which all else is made. Unlike Thales (at least, assuming the traditional interpretation of this thinker's position), he understood this as something other one of the familiar materials of everyday experience. For Anaximander, the ultimate reality of the universe was the "Boundless" or infinite and eternal "primary matter" (if I may use this anachronistic term) from which all forms of observed matter arise and into which they all must eventually disappear.

The third Milesian sage, Anaximenes, in a sense stepped back from the more sophisticated cosmology of his immediate predecessor to something more reminiscent of Thales, i.e. to a position that elevated one of the familiar forms of matter into the role of the basic substance of the world. Yet, in so doing, he also introduced something of vital importance to scientific progress—experiment. Anaximenes reasoned that air could become water and even solid earth through a process of condensation. In short, water is moderately condensed air and rock is air condensed to an even greater degree. On the opposite side of the coin, fire is air that has become more rarefied. That is why the more condensed phases of air settle on the ground while fire always rises upward. Moreover, fire is hot and (Anaximenes argued) this is also easily explained because air becomes warmer as it is increasingly rarefied. Now, according to Plutarch, this is where the experiment enters the scene, and it is one that we can all perform for ourselves even as we read this book (see Project 1).

Project 1: The Experiment of Anaximenes

To replicate what seems to have been the first recorded scientific experiment, first breathe on the palm of one hand with your mouth open. Does the exhaled air feel warm or cold when it touches your hand? Now purse your lips and blow on your hand. What does the exhaled air temperature feel like this time—warmer or cooler?

Now repeat the experiment in a more modernized form by blowing onto the bulb of a thermometer. What is the result?

On this simple experiment, Anaximenes based his cosmology of compressed and rarefied air.

From the result of this simple exercise, Anaximenes concluded that air grows hotter as it is rarefied and colder as it condenses. (As an aside, Sandy Anderson confessed that he had never heard a satisfactory explanation for the result of this little experiment. The adiabatic process, cooling due to the rapid drop in pressure as the air "compressed" between the lips expands, has been put forward, but Anderson seriously doubted that the small changes in pressure concerned here would be adequate to explain the result. The strength of the flow of exhaled air is clearly not the issue either, as the result is the same even if the air is exhaled strongly through the open mouth and blown very gently between the lips).

The actual speculations of these early thinkers and their successors during the following centuries are of little more than historical interest today. But it is the method of observation, experiment and hypothesis which they employed that stands as their real contribution to our understanding of the world in which we live. The way in which this method is employed may have become more complex and sophisticated over time, but the procedure itself is essentially the same for us as it was for Anaximenes.

In some respects, the Miletian school was a false dawn of scientific cosmology. Certain later philosophers of ancient Greece thought scientific speculation to be a waste of time and, like Alexander Pope many centuries later, decreed the that "the proper study of mankind is man"; especially human morality and political organization. The two greatest Greek philosophers—Socrates and Plato—were especially strong on this point. Their most influential pupil—Aristotle—took a somewhat broader perspective but unfortunately came to be considered by later generations as such an overwhelming authority on just about everything that his own speculations tended to stifle future scientific enquiry rather than stimulate it. Later still, the cosmological model of Ptolemy came to be seen as so self evident as to be open to nothing more radical than a little tweaking here and there; always stopping well short of wholesale revision!

By the way, whatever other mistakes they made, it is not correct to say that Ptolemy and his medieval disciples believed in a small universe. With respect to the fixed stars, he specifically stated that the distance between Earth and these objects is so vast as to make the area of Earth appear as a geometric point by comparison! Because a geometric point is defined as having position but no magnitude, this is tantamount to saying that the distance of the fixed stars is infinite. Ptolemy probably did not mean this quite so literally, but the force of his assertion may still be appreciated. The stars are a very, *very* long way away and the universe is very, *very*, large!

It may be of interest to mention in this connection that the oft-reproduced picture of the intrepid traveler poking his head through the veil of stars to witness the grand workings of the celestial machinery is not, as frequently implied, a mediaeval painting depicting the current and largely Ptolemaic beliefs of the period, but a late nineteenth century woodcut representing the then *popular notion* of what the folk of earlier centuries believed. If belief in the sort of limited universe through which the traveler in this woodcut journeyed ever existed, it was not amongst those who best represented the knowledge of earlier times. Such ideas were no more typical of mediaeval times than those of, say, D. H. Lawrence (whose views about the nature of the Sun were, to put it mildly, unconventional) or William Blake (who believed the Earth to be flat and claimed to have touched the sky with his finger) typify the general opinion of the last couple of hundred years.

Another frequently misunderstood teaching of the cosmology based upon Aristotle and Ptolemy is the supposition that because

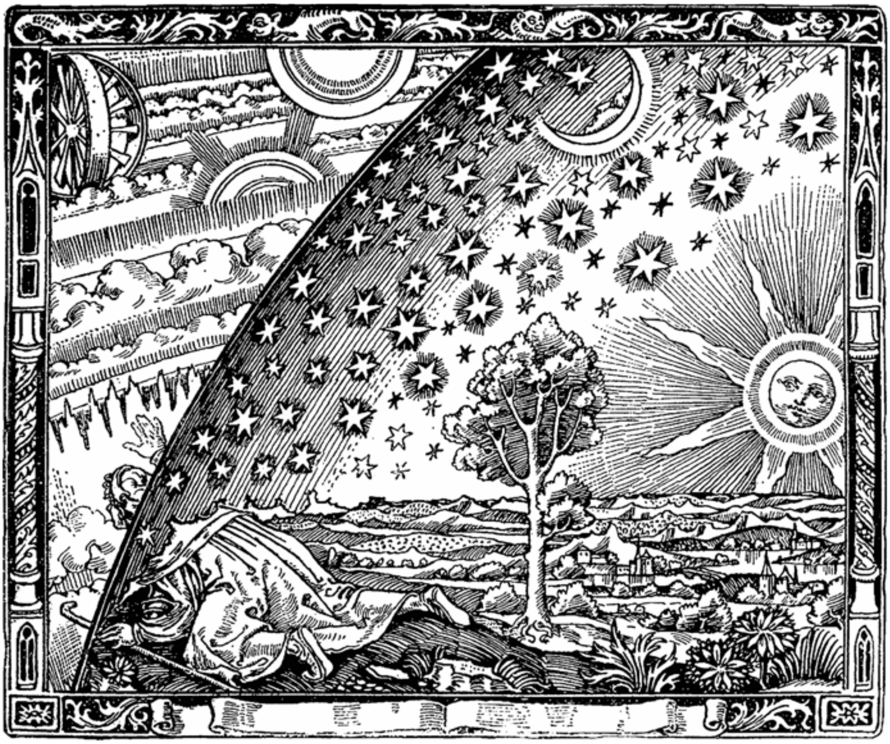

FIGURE 1.2 This is *not* what medieval philosophers believed! (*Credit*: Artist unknown. From C. Flammarion's *L'atmosphere: meteorologie populaire*, 1888)

the universe was thought to revolve around Earth, we were somehow the throne of creation. In fact, we were thought more as the sump of creation; the place where gross matter settled, leaving the celestial realms beyond the Moon in a state of unsullied purity. The cosmology of Copernicus and the confirming discoveries of Galileo, in so far as they placed Earth amongst the celestial orbs, actually exalted the position and nature of the Earth just as the discovery of sunspots and other changes in the skies (such as the occasional appearance of nova and supernova and the variability in brightness of certain of the fixed stars) degraded the superlunary realms.

The real revolution in thought that became the birth pangs of the modern scientific era was not the dethroning of Earth and the human beings living upon it, but the realization that we, too, are part of a single universal system, of one material with the stars themselves. This realization was in no small degree fostered by the spread of monotheism, principally in the form of Christianity in Europe but also of Islamic influence in the East. Strictly speaking, the polytheism of ancient Greece did not necessitate a single set of laws governing the entire universe. A multiplicity of gods could imply a multiplicity of "natural" laws! But if the universe is the creation of a single God, a theological foundation is provided for the existence of an all-encompassing set of laws, thereby opening the universe to the scrutiny of a curious human race. In short, if one type of material, governed by a single set of laws, comprises both the earthly and superlunary realms alike, why should the whole thing not be the subject of our study? Paradoxically though, as we shall see as our story continues, this more homely universe has turned out to be weirder than any of the wildest stories of ancient mythology.

A Truly Radical Discovery

We now skip over the years and centuries to that turbulent year of 1914. As armies prepared for what was to become one of history's most bloody wars, in the far more peaceful environment of a meeting of the *American Astronomical Society* being held in Evenston, Illinois, an astronomer was presenting a paper detailing a discovery that was to prove as radical to our understanding of the universe as any of the many social changes triggered by the War would be to the future of the political world. The astronomer was V. Slipher and his paper detailed his remarkable discovery of a peculiar feature of the spectrum of the so-called spiral nebulae. These objects—sometimes called white nebulae to differentiate them from the gaseous green nebulae that appeared to be essentially great clouds of cosmic gas—had long been known, but their nature had always been a subject of controversy. Once upon a time they were thought to be other solar systems in the making or some other variety of Milky Way denizen, but gradually it became apparent that they were island universes; vast systems of stars at immense distances from our home planet. They were, in point of fact, other Milky Ways—other *galaxies* more or less similar to the one in which we live. Slipher had observed the spectra of a number of these galaxies and what he found was most intriguing. The spectrum of an object enables its composition to be determined by noting the characteristic lines of emission of its constituent atoms, but an object's spectrum can also tell us other things about that object as well. It can tell us whether the object is approaching or receding from us and can even enable its velocity to be calculated. This is possible because the emission lines in the spectrum appear at fixed wavelengths for a source that is stationary relative to the observer. However, if an object emitting the light being examined is moving toward the observer, the light is (in a manner of speaking) "compressed"—its wavelength is shortened—and the emission lines in that object's spectrum appear displaced toward the shorter wavelength or blue end of the spectrum. The greater the velocity of approach, the greater that displacement or blueshift will be. Conversely, for a receding object, the light will be "stretched out" and emission lines displaced toward the red end of the spectrum. Something similar happens with sound waves as well. This is most commonly noticeable in the case of a speeding vehicle with a siren. The tone of the siren perceptibly lowers in pitch as the vehicle passes by. The effect is also apparent when radar is bounced off an approaching or receding object; a technological development beloved by police but hated by speeding motorists!

Astronomers had already noted this *Doppler Effect* (to give it its proper title) in the spectrum of stars. Some of these were found to be approaching, others receding from, Earth. No doubt, when Slipher began his spectroscopic examination of galaxies, he anticipated finding a similar mixture of Doppler red and blue shifts there as well. But he was in for a surprise as, indeed, was the entire astronomical community. For what he discovered was that the overwhelming majority of these objects revealed spectra that was redshifted. In other words, the majority of other galaxies appeared to be rushing away from the Milky Way! The only exceptions were the handful of objects which, together with the Milky Way, comprise the so-called "Local Group", to which nearby galaxies such as the two Magellanic Clouds, the Great Andromeda Nebula and M33 in Triangulum belong.

FIGURE 1.3 A fine example of a spiral galaxy; UGC 12158. The bright star at lower left is a supernova exploding in the outer fringes of UGC 12158 (*Credit*: ESA/Hubble & NASA)

This did not mean that the Milky Way was suffering from cosmic BO or in some way repelling its neighbors. It seemed that most of the galaxies were actually rushing away from *one another*, but the reason for this was obscure.

Slipher, it is recorded, was given a standing ovation at the completion of his paper but unfortunately, his epoch-making discovery seems then to have become largely buried in relatively obscure publications. An extended abstract appeared the following year in *Popular Astronomy* and in the 1917 issue of the *Proceedings of the American Astronomical Society*, but appears to have been overlooked by the wider astronomical community and still less by the scientific community in general. Einstein, clearly, could not have known of Slipher's work when he made his "biggest mistake"

FIGURE 1.4 The Great Andromeda Galaxy M31. This is one of the earliest photographs of this object, taken by Isaac Roberts sometime between 1887 and 1899

FIGURE 1.5 The Triangulum Galaxy M33 (*Credit*: Alexander Meleg)

of introducing a *Cosmological Constant* to cancel one of the consequences of General Relativity—cosmic expansion! Had he been aware of Slipher's finding, he would surely have seen it as a brilliant confirmation of his theory. (Ironically, the Cosmological Constant is back in favor again; not to cancel out cosmic expansion this time, but to explain why it seems to be increasing—but more of that anon).

Be that as it may, the redshift of galaxies remained in a backwater until E. Hubble published his rediscovery of this same phenomenon in 1929. It seems that Hubble was unaware of Slipher's earlier work as he made no mention of it in his own publication (something about which Slipher was not very happy, so the story goes). Nevertheless, as well as confirming Slipher's results, Hubble also found that the redshift of galaxies increased in proportion to their distance from the Milky Way. He derived a coefficient for this cosmic retreat (suitably known as the *Hubble Constant*), the refinement of which has ever since been one of the goals of observational cosmology.

The Slipher-Hubble discovery that the galaxies of the universe are racing away from each other is, quite frankly, weird. But even weirder (at least to our workaday-world-conditioned minds) is the fact that this cosmic expansion is *not*, strictly speaking, a Doppler effect at all! It is certainly *like* a Doppler effect, but there is one important difference. A true Doppler effect, whether manifested in the siren of a speeding police car or in the spectrum of a star within our galaxy, relates to an object moving *through* space at a specific velocity and direction relative to an observer. The cosmic expansion, on the other hand, is a manifestation of the stretching of space itself. It is not that galaxy A and galaxy B are flying away from each other through an existing spatial framework. Rather, there is an increasing distance between them because more intervening space is being created! The conventional model is that of an inflating balloon. As more air is pumped or blown into the balloon, so its skin stretches, in a sense creating more surface area or (in other words) more space. Of course, the model must not be pressed too far. For one thing, no more surface fabric is actually created when a balloon is inflated. It is simply that the already-existing material is stretched out so that it covers a greater area at the expense of decreasing thickness. Again, the expansion only takes place in two dimensions instead of three as in the actual universe. Also, demonstrations of cosmic expansion which add spots painted on a balloon's surface to represent individual galaxies or clusters of galaxies can give an erroneous picture as the spots themselves will increase in size along with the surface of the balloon. This does not happen in the real universe and, as we shall see later, confusion about just this issue has led to at least one mistaken criticism of the entire scenario. Nevertheless, with these warning caveats, the inflating balloon model at least does provide us with some level of visualization of this very counter-intuitive phenomenon.

Cosmic Fireworks on a Grand Scale!

However accurate or otherwise is the comparison between the universe and an inflating balloon, this cosmic expansion, at least taken at face value, seems suspiciously like the aftermath of a mighty explosion at some time in the remote past. One may say the "explosion to end all explosions" except that it would better be called "the explosion to *begin* all explosions"—along with everything else. In other words, a truly radical (not to say profoundly weird!) model of the universe seemed to emerge from the discovery of universal expansion. Far from being the eternal and globally unchanging cosmos of Victorian science, the real universe gave every sign of being an evolving closed system of finite age; the dispersing debris cloud of a cosmic catastrophe with the individual galaxies as the "shrapnel" of this mighty blast.

That, at least, was the thesis of Jesuit priest and astronomer Monsignor Georges Lemaitre. Lemaitre first aired his theory in a mathematical paper delivered in 1931. Following from the observations of an expanding universe, he drew the logical conclusion that if the universe was now growing larger, the further one looked back into the past, the smaller it must have then been. Based on the data available at the time he presented his paper, it seemed that little more than 1 billion years ago, the entire universe approached the dimensions of a point! Presumably, that was about the time when the great cosmic explosion that marked its birth took place. But what exactly was it that actually blew up at that remote date? What was the nature of the *cosmic egg* that so explosively hatched our universe?