The Dance of the Fertile Universe
George V. Coyne, S.J.

Introduction

Did we come about by chance or by necessity in the evolving universe? The first thing to be said is that the problem is not formulated correctly. It is not just a question of chance or necessity because, first of all, it is both. Furthermore, there is a third element here that is very important. It is what I call the "fertility" of the universe. This is the dance of the fertile universe, a ballet with three ballerinas: chance, necessity and fertility. What this means is that the universe is so fertile in offering the opportunity for the success of both chance and necessary processes that such a character of the universe must be included in the search for our origins in the universe. In this light I am going to try to present in broad strokes what I think is some of the best of our modern scientific understanding of the universe and then ask the question at the end: What does this say about the God who loves us and who made this universe?

The Universe of Modern Science

The universe is 13.7 billion years old; it contains about 100 billion galaxies each of which contains 100 billion stars of an immense variety. As these stars live and die they provide the chemicals necessary for the evolution of life.

But before we pursue that story, it is always helpful, I think, to see things as our ancestors did, even though they did not have anything like the scientific view we have of the universe. But if we can capture the spirit of their view of things, sometimes it is helpful to us today. Take for example Stonehenge, a megalithic monument on the plains of Salisbury in England. It dates to about 5,000 years before Christ, the time of the prophet Abraham. This and many other monuments like it were simultaneously an astronomical observatory and a place of worship. Our ancestors offered sacrifices to their gods on top of the horizontal stone tablets but they also used the alignment of the vertical stones to observe the heavens to detect when the sun rose and set, the beginning of spring, the beginning of summer, etc. They did these observations in a very careful technical way. We might even think of such a monument as a telescope without optics. But note that they were observing the heavens in order to live better on the surface of the earth. Their mentality was not to understand the heavens; it was to know when to sow, when to reap, when the rainy season was coming, and all such things, so that they could live better on the surface of the earth.

Well, where were their gods? Their gods were in those very heavens they were observing. For instance in the constellation of Orion they linked up the brightest stars to form a figure. Today we know that many of these stars have nothing do with one another. Many of them are thousands if not millions of miles farther away than others, so they are not necessarily physically associated with one another. But our ancestors saw their gods, their heroes, in this case their great hero the Hunter. Their heroes, their gods, were in the very heavens they were observing in order to live better on the surface of the earth.

If we look today in infrared light at the center of Orion we see boiling gas and dust. If we look even closer up we see incandescent regions buried in that gas and with the Hubble Space Telescope we see the fine separation of blue gas and red gas in the midst of a rather chaotic structure. The fact is that stars are being born in this gas. And where the hottest, most massive and, therefore, brightest stars are already born, they are irradiating the gas, and it is giving off hydrogen alpha radiation, which is red light. In this way we can identify star birth regions.

The region of star birth in Orion is just a little part of our Milky Way. Our Milky Way, like most other spiral

galaxies, measures 100,000 light years across and it contains about a hundred billion stars. It has several beautiful spiral arms and the sun is located in one of the outer arms, about 2/3 of the distance from the nucleus of our galaxy. We have reconstructed the plane of our galaxy the Milky Way with a mosaic taken by an infrared satellite. We see myriads of stars but we also see dark areas where there are none or very few stars. Is this truly a lack of stars? Absolutely not. In fact, it is precisely this dark stuff out of which stars are born. This dark area is really a veil of gas and dust hanging down and hiding the stars that are imbedded in it.

How is a star born? It happens by the laws of physics. A cloud of gas and dust, containing about 100 to 1,000 times the mass of our sun, gets shocked by a supernova explosion or something similar and this causes interplay between the magnetic and gravity field. The cloud begins to break up and chunks of the cloud begin to collapse. And as any gas collapses, it begins to heat up; as it expands, it cools down. In this case the mass is so great that the internal temperature reaches millions of degrees and thus turns on a thermonuclear furnace. A star is born. Thermonuclear energy is the source whereby a star radiates to the universe. You need a very hot piece of the universe to do this, and so you can only get this thermonuclear furnace by having a cloud collapse and raise the temperature. You can only get it, in other words, in stars, with one exception, namely, in the very hot early universe before galaxies or stars were born.

Stars also die. A star at the end of its life can no longer sustain a thermonuclear furnace and so it can no longer resist against gravity. It collapses for a final time, explodes and expels its outer atmosphere to the universe. This may happen nice and peacefully or it may happen in a violent cataclysmic explosion, called a supernova. The most famous of these is the Crab Nebula which has a pulsar at the middle as its dead star.

So stars are born and stars die. And as they die they spew left over star matter out to the universe. The birth and death of stars is very important. If it were not happening, you and I would not be here, and that is a scientific fact. In order to get the chemical elements to make the human body, we had to have three generations of stars. A succeeding generation of stars is born out of the material that is spewed out by a previous generation. But now notice that the second generation of stars is born out of material that was made in a thermonuclear furnace. The star lived by converting hydrogen to helium, helium to carbon, and if it were massive enough, carbon to oxygen, to nitrogen, all the way up to iron. As a star lives, it converts the lighter elements into the heavier elements. That is the way we get carbon and silicon and the other elements to make human hair and toe nails and all of those things. To get the chemistry to make amoebas we had to have the stars regurgitating material to the universe.

There is one exception to making heavier elements in the universe. Some helium and other light elements were made in the early universe from hydrogen. In fact, that is an indication that there was a very hot stage to the early universe. The early universe itself was as hot if not hotter than the interior of a star, but it expanded very rapidly and cooled down. So it made some of the elements slightly heavier than hydrogen but then it cooled and could do no more. To have the heavy elements made, we needed hot spots in the universe and those hot spots are what we call stars.

Obviously this story of star birth and death is very important for us. Out of this whole process around one star, which we call the sun, a group of planets carne to be, among them the little grain of sand we call the Earth. An amazing thing happened with that little grain of sand. We know it happened and we deal with it every day, but we do not reflect sufficiently about the amazing occurrence in the 16th and 17th Centuries with the birth of modem science. We developed the capacity to put the universe in our heads. We do that by using mathematics and physics, and to some extent the laws of chemistry and biology.

How is it that I can claim without hesitation, as I did above, that there are a hundred billion stars in our

galaxy and that the galaxy is 100,000 light years across. I obviously could not go out there and measure those quantities directly. And yet I claim that those measurements are as accurate as the measure of my height and weight. I can have the same certainty because I have been able to use the laws of physics and mathematics and chemistry and biology to put a galaxy, the universe, in my head and work with it. Of course, some measurements in cosmology are more certain than others, but we really are certain about the mass of our galaxy. Because it rotates we can use the law of gravity to measure the mass of the galaxy in the same way as I measure the mass of the earth and the other planets going about the sun. The law of gravity will give you the total mass of the galaxy. So I know the mass of our galaxy and the mass of the sun, and the first thing any physicist will do is a simple calculation of divide, subtract, add or multiply. In this case you divide and you come up with how many suns there are in our galaxy. Do you see? You know the total mass, and you know the mass of the sun. You have to make a few corrections because 30% of the mass is not in stars but rather in gas and dust; furthermore, not all stars are the mass of the sun. Some stars are more massive and some less massive, but the sun is a normal star of medium mass, so you come up with a pretty good number: a hundred billion stars, plus or minus a few million. That is a good number, and probably the exactness is even better than that.

The Questioning Human Brain

Once we developed this capacity to put the universe in our heads, we became passionately interested in asking all kinds of questions. I would like to ask a few, first some scientific ones and then some about the philosophical and theological implications.

Did our planetary system come about by a miracle? Absolutely not. Although we do not know everything about how it came about, we know that it happened in conjunction with the formation of the sun. Gas and dust were left over from the birth of the sun, and this gas and dust had to form into a disk by the law of physics to conserve angular momentum. Once all of this mass is concentrated into a disk, there is a much greater chance that the particles of gas and dust will collide and, in some cases, stick together. And, just like the rolling snowball effect, planetesimals, about 100 kilometers in diameter, are built up through accretion and finally planets are accreted from the planetesimals. We do not know everything about this process, but we know enough about it to know that it did not happen by a miracle. It happened by ordinary physical and chemical processes.

So, a further question arises: Did what we have just described happen elsewhere? First of all we look at those nearby stars that we suspect may be something like the sun. We have detected thus far about 150 planets about other stars due to the center of mass motion of the star. That is an indirect way but a very solid one of detecting planets. We detect a wobble in the star due to the fact that there is mass outside of it so that the center of mass of the system is not at the geometrical center of the star. Furthermore, with the Hubble Space Telescope we have discovered disks around very young stars. We know for certain that they are very young stars by their spectra. We call the disks proto planetary because we have indirect evidence that the first planets have begun to form in the inner regions of the disk. We are beginning to see about other stars the process that we think formed the planets about the sun.

Since we have the capacity to put the universe in our heads, a further question comes to us. Where did galaxies come from? Most of the radiating material in the universe is concentrated in galaxies and their environs. Galaxies are the building blocks of the universe. Hubble Space Telescope has been able to photograph some of the most distant objects we have ever seen in the universe. They are at a distance of about ten billion light years from us. So we are seeing these objects as they were ten billion years ago. We should review this phenomenon. We never see anything as it is. That is not a statement about epistemology, it is about physics. Light travels at a finite velocity. We see the moon as it was about one and one-half

seconds ago, and the sun as it was about eight minutes ago. The light from the center of our galaxy took 30,000 years to reach us. Hubble Space Telescope has seen objects as they were ten billion years ago. We think that Hubble is seeing proto galaxies. We see, for instance, a case of two blobs which seem to be merging and perhaps building up a galaxy. However, this is very controversial. We are uncertain about galaxy formation, whether it is bottom up with small units that build into a galaxy, or top down with a big cloud that collapses to form a galaxy, and then the stars form within it. Nevertheless, when we compare distant galaxies to nearby galaxies, we see clear differences in the stellar populations. Galaxies as they are born and age go through an evolutionary process. Galaxies are participating in the expansion of the universe. When we look at them on a large scale we see that they are not distributed homogeneously. There are large empty spaces and many dense alignments.

Let us now review what we know of the history of the expanding universe. As it aged, distances got larger in the universe. As this happened, certain key events took place. Quarks combined to form elementary particles, which in turn formed atoms and then molecules. The universe became transparent and the cosmic background radiation came to be. Galaxies and stars were formed. The first microscopic life forms came to be after twelve billion years in a fourteen billion year old universe. Why did it take so long to make even an amoeba? We have already discussed one reason. We did not have the chemistry to make even an amoeba until we had had three generations of stars.

How did we humans come to be in this evolving universe? It is quite clear that we do not know everything about this process. But it would be scientifically absurd to deny that the human brain is a result of a process of chemical complexification in an evolving universe. After the universe became rich in certain basic chemicals, those chemicals got together in successive steps to make ever more complex molecules. Finally in some extraordinary chemical process the human brain came to be, the most complicated machine that we know. I should make it clear that, when I speak about the human brain as a machine, I am not excluding the spiritual dimension of the human being. I am simply not referring to it and am limiting myself to talking about the human brain as a biological, chemical mechanism, evolving out of the universe.

If we take all kinds of objects in the universe including the universe itself, the visible universe from the proton on up, and measure two of the simplest things you can measure: how big is something and how much does it weigh, we find quite an amazing correlation. Atoms, trees, birds, humans, galaxies, the visible universe itself, all fit the same relationship. There may be many hidden reasons for this correlation, but it surely indicates that we, together with all other beings, came out of the evolving universe.

Let us now measure two parameters a little more complicated and make a comparison between them as we did with size and mass. We measure the capacity to store data and the capacity to compare one piece of data to another. First, how much data can you cram? How much jelly can you put into a certain size jar? We are not at all speaking about intelligence. We are measuring very simple basic things. A library, for instance, can store a great deal of data but it cannot compare one kind of data with another. Books do not talk to one another, so that you have to store the data from books into a computer and then you can compare the data from one book with the data from another. Again the human being fits the relationship, but we are not at the top. The elephant and the whale are. Again, my only purpose in discussing these relationships is to say that we are part of it all. We are not exceptional in the universe with respect to these very basic measurements: size, mass, data storage, data comparisons. This is one indication that in some way we carne out of it all.

The Dance

Let us now return to the question asked in the Introduction. Did we come about by chance or by necessity in the evolving universe? From the best of modem science I respond by describing the dance of the fertile

universe. We might illustrate what the fertility of the universe means in the following way. Einstein said that God does not play at dice. He was referring specifically to quantum mechanics, but his statement can be applied in general to his view of the universe. For him God made a universe to work according to established laws. This is referred to as a Newtonian Universe. It is like a clock that just keeps ticking away once you supply it energy. There are many scientists, especially evolutionary biologists, who challenge this point of view. They claim that God does play at dice because he is certain to win. The point being made is that, whether or not you believe that God made it, the universe is so fertile with the possibilities for these processes to have success that we have to take the nature of the universe into consideration when we talk about how we carne to be.

For 13.7 billion years the universe has been dancing a fertile ballet. One of the ballerinas is chance. When we speak about chance we mean that it is very unlikely that a certain event would happen. The "very unlikely" can be calculated in mathematical terms. Such a calculation takes into account how big the universe is, how many stars there are, how many stars would have developed planets, etc. In other words, it is not just guesswork. There is a foundation in fact for making each successive calculation.

A good example of a chance event would be two very simple molecules wandering about in the universe. They happen to meet one another and, when they do, they would love to make a more complex molecule because that is the nature of these molecules. But the temperature and pressure conditions are such that the chemical bonding to make a more complex molecule cannot happen. So they wander off, but they or identical molecules meet billions and billions of times, trillions if you wish, in this universe, and finally they meet and the temperature and pressure conditions are correct. This could happen more easily around certain types of stars than other types of stars, so you can throw in all kinds of other factors. The point is that from a strictly mathematical analysis of this, called the mathematics of nonlinear dynamics, one can say that as this process goes on and more complex molecules develop, there is more and more direction to this process. As the complexity increases, the future complexity becomes more and more predetermined.

There are also necessary, deterministic processes occurring. But there is a lot of chance as to what the exact conditions are when certain molecules meet, so that the necessary process may take place. There are definitely both of these processes, but they are happening in a universe that is so fertile that the eventual outcome has a kind of predetermined nature. This predetermined nature may be represented by a tree, the Tree of the Universe. It is a strange tree in that everything that ever happened in the universe, from the making of quarks to the making of toenails, is all here. Even those processes that never succeeded, that failed, every dead leaf and dead branch has been conserved. Every meeting of molecules in inopportune circumstances is there. The tree has never been pruned. But blow a quiet breeze through this tree and what will you see? You will inevitably see something that resembles the bare trunk of a tree with certain branching to various forms of life and ending at the top with the human being. The result is inevitable because with a combination of chance and necessary processes in a very fertile universe with so many opportunities there is a narrowing down of the evolutionary process due to the nature of physics, chemistry, biology and nonlinear dynamics.

If we truly accept that there are chance processes involved, then the branching of the tree could be somewhat different. But since complexity proceeds towards an ever more determined direction the trunk of the tree could not be very different. The paleontology, biology, and chemistry behind all of this is quite uncertain, but it is clear that something like this would happen. Why is the human being at the top? It is because we are ignorant. We do not know what else to put at the top. The human brain is the most complicated mechanism we know.

Do we need God to explain this? Is there a certain finality, directedness, purpose behind this? My personal

answer is: "Absolutely not. I do not need God. Thank you, I can do perfectly well in trying to understand the universe by using the capacity that I have to put the universe in my head." I do believe, by the way, that such a capacity has been given to me by God.

Knowing God through Science

That having been said, then several approaches can be taken in the Science-Religion dialogue. Here is one approach that I would like to share with you. I truly believe that God is a person and revealed himself personally to us, to his chosen people and by means of his chosen people to all of us. He did that in history, in Church traditions and in Scripture. This is not the occasion to talk about this in any detail, but there are certainly good solid foundations for believing that God is revealing himself to us, in Scripture. And it is certainly very firm in the Christian traditions that God also reveals himself in everything he made in Creation: in personal creation and in objective non-personal creation.

The technical approach to this self revelation of God in creation is called "Analogy." It comes from the Thomistic Scholastic tradition and it refers to a relationship of similitudes, or of things that are similar. For instance, God is perfect love, and you can compare that with other kinds of love that you witness, such as the love of a mother for her child, or the faithful, long-standing love of a husband and wife for one another in a stable marriage. You see these human loves and you say: “"That must be something like God's love." But then you see imperfections in human love. There are squabbles, jealousies, infidelity, and you have to deny that those are present in God's love. That is the use of analogy. The only knowledge we can have of God, excepting those who have had mystical experiences, is indirect and through analogy. And if that is the case, and if God does wish to tell us about himself, then he is doing so in his creation. It follows, therefore, that I as a scientist and as a religious believer should try to use my science to see what it has to say about the God that I believe in?

Now, do notice the process. I am being very careful about this. I have never come to believe in God, nor do I think anyone has come to believe in God, by proving God's existence through anything like a scientific process. God is not found as the conclusion of a rational process like that. So the path that I am taking is that I believe in God because God gave himself to me. That was not a miracle. I did not get knocked off a horse like St. Paul or anything like that. I had no private revelations. But I had parents who taught me and educated me in religious ways, and I went to religious schools, and then I challenged it and I thought about it, and I said: “Who could ever believe that?”-- just like most of us do. I went through life doing this, and finally I said: “You know, it is not that it makes complete sense; the point is that it enriches my life. And it does make sense that there is a personal God who deals with me and loves me and who has given himself to me." Now, you do not have to accept that, but my itinerary has certainly been that. I have never come to love God or God to love me because of any of these reasoning processes. I have come to love God because I have accepted the fact that he first made the move towards me.

If that is the case, why should I not use my best knowledge of science to try to get an idea of what God is like? It will be only a glimmer, a shadow, but it is the one thing I have to go on, and I have a passionate desire to want to know more about this person who loves me so much. And that is what I am going to try to do now. I am going to try to present in broad strokes what I think is the best of our modem understanding of the universe, and then ask the question at the end: What does this say about the God who loves me and who made this universe?

God of the Universe and of Us

When science detects such directedness in the evolution of life in the universe, it inevitably leads us to talk

about purpose in some fashion. The fear among scientists is that in talking about purpose we are inevitably going to bring God into the picture. That is not true. We do not need God to explain the universe as we see it today. But once I believe in God, the universe as I see it today says a great deal about that God in whom I believe.

If we take the results of modem science seriously, it is difficult to believe that God is omnipotent and omniscient in the sense of the scholastic philosophers. Science tells us of a God who must be very different from God as seen by the medieval philosophers and theologians. Let us ask the hard question. Could, for instance, God after a billion years in a fourteen billion year old universe have predicted that human life would come to be? Let us suppose that God possessed the theory of everything, knew all the laws of physics, all the fundamental forces. Even then could God know with certainty that human life would come to be? If we truly accept the scientific view that, in addition to necessary processes and the immense opportunities offered by the universe, there are also chance processes, then it would appear that not even God could know the outcome with certainty. God cannot know what is not knowable. A short answer for the theologian is, of course, that God is transcendent, outside of space and time, and knows everything simultaneously. But God is also immanent in the universe.

But this reasoning about God's knowledge from within the universe does not place a limitation upon God. Far from it. It reveals a God who made a universe that has within it a certain dynamism and thus participates in the very creativity of God. If they respect the results of modem science, religious believers must move away from the notion of a dictator God, a Newtonian God who made the universe as a watch that ticks along regularly. Perhaps God should be seen more as a parent. Scripture is very rich in this thought. It presents, indeed anthropomorphically, a God who gets angry, who disciplines, a God who nurtures the universe. Theologians already possess the concept of God's continuous creation. I think to explore modem science with this notion of continuous creation would be a very enriching experience for theologians and religious believers. God is working with the universe. The universe has a certain vitality of its own like a child does. You discipline a child but you try to preserve and enrich the individual character of the child and its own passion for life. A parent must allow the child to grow into adulthood, to come to make its own choices, to go on its own way in life. In such wise does God deal with the universe.

These are very weak images, but how else do we talk about God. We can only come to know God by analogy. The universe as we know it today through science is one way to derive analogical knowledge of God. For those who believe modem science does say something to us about God, it provides a challenge, an enriching challenge, to traditional beliefs about God. But there is always the temptation in this reasoning to make God into our own image and likeness. This would be idolatry.

The Idolatry of Religious Belief

The important thing here from the religious point of view is that the first motion in any religious relationship comes from God himself. God makes the first move. We do not reason our way to God, we do not earn our way to God, we do nothing to deserve that God gives himself to us and calls us into the ranks of his chosen people. The first motion is always from God, and we can never drag God under our control. A kind of idolatry is always present in religious culture. We want to bring God under our control. That is the kind of attitude many believers have, and it reveals precisely that kind of idolatry.

There is another part of this idolatry, which can only be understood if we see the idol that is associated with modem science. This is the idolatry of making God "explanation." We bring God in to try to explain things that we cannot otherwise explain: how did the universe begin?, how did we come to be?, and all such questions. We latch onto God, especially if we do not feel that we have a reasonable scientific explanation.

He is brought in as the Great God of the Gaps.

The Idolatry of Science

But this kind of idolatry of God as explanation can only be understood against the background of modem science. If for purposes of illustration we speak only of the Judaic/Christian tradition, the roots of religious belief reach to some thousands of years before Christ with the prophet Abraham. But modern science cannot be dated before the 16th or 17th Centuries, roughly from the time of Galileo and then through many others to Newton. One may even wish to go back to the beginnings of the experimental method with Roger Bacon and others in the 13th century. But, at any rate, the modem science that speaks to religion today is born much later than the religion to which it speaks. It has to be recognized that the religious tradition is historically much longer and to a certain extent has that richness of the past that modem science does not.

It is a well-established historical fact that at the precise time at which modem science was being born, all of the great scientific figures were religious believers. That just happens to be the case. Newton, Leibniz, Descartes, Mersenne, Galileo were all religious believers. And without exception, although to some more than to others, the astounding success of the new scientific method was a great temptation to them. They were tempted to establish the foundations for religious belief with the same kind of rationalistic certainty that they had with respect to scientific results. Many see the roots of modem atheism in precisely this kind of extreme rationalistic approach to religious belief. Trying to establish religious belief on the same sort of firm rational basis as scientific results are founded is a temptation that is always present.

The idolatry of science is two-fold: we drag science in, certainly in Western society, to try to establish the basis of religious belief on purely rationalistic grounds. And more than that, and more generally, science lures religious people to see God first of all as "explanation" and then only secondarily to come to worship and honor him as the all loving person. It is common to our Western mentality to make an idol of the scientific method. Some scientists and many non scientists think that scientists know everything and that science is the only way to true and certain knowledge. They do not exclude that it is nice to read some poetry and it may even be nice to go to church, but when you want to know something, then the scientific method is the way to know it. That is not Science but Scientism since it makes science a kind of god. That is idolatry. And yet any practicing scientist will tell you that we struggle always to come to an understanding by using the hypothetical deductive method. We collect data, we go back to our models, we revise our models, we do more computer calculations, we gather more data, and we find that they do not quite fit. In this fashion we are always struggling to come to a more complete and more certain knowledge. But we do not have it. We do not possess the truth; we hope that we are making our way towards the truth.

If we do not recognize the idolatry that is a constant factor in both science and religion, and I am not talking only about past history but about today, then when science and religion talk to one another, all that will occur is a lot of noise. There will be no progress in the dialogue unless this kind of idolatry is recognized for what it is.