WAS THE UNIVERSE CREATED BY ANGELS?

The discovery that it might be possible to make a universe in the laboratory could have profound implications for the origin of our own Universe

Since the inflationary theory implies that the entire observed universe can evolve from a tiny speck, it is hard to stop oneself from asking whether a universe can in principle be created in the laboratory?

Alan Guth

(The Inflationary Universe)

Teacher told my parent that I am the slowest youngster in my class, but today I made a star in the third quadrant of kindergarten

James E. Gunn

("Kindergarten)

The ultimate experiment is about to begin. On a cold, lonely moon, shrouded in purple-pink fog, a sentient ocean marshals the energy resources of an entire galaxy and focuses them down onto a tiny, unsuspecting mote of matter. A hundred billion stars flicker and dim. The air above the ocean sizzles and catches fire. Crushed by stupendous energies, the tiny mote twists and bucks and, with a violent shudder, implodes like a nuclear explosion in reverse. Smaller and smaller it shrinks. Smaller than an atom. Smaller than the smallest sub-component of an atom. On and on into submicroscopic realms beyond human imagination. Until, suddenly, without warning--puff!--it is gone.

Somewhere else--in another space, another time--a searing- hot fireball explodes out of nothingness and immediately begins to expand and cool. The ultimate scientific experiment has produced the ultimate experimental result: the birth of an entirely new universe!

Could our own Universe have been born in such an experiment? One man thinks it is a real possibility. According to Edward Harrison, formerly of the University of Massachusetts at Amherst, our Universe could easily be the outcome of an experiment carried out by a superior intelligence in another universe!

Why in would anyone suggest such an outlandish idea? The answer is because it can potentially shed light on a deeply puzzling feature of our Universe. The puzzle, highlighted in the last chapter, concerns the laws of physics which orchestrate the life of the cosmos. Physicists have discovered that even very slight deviations in the laws that we observe would result in a universe completely devoid of stars and life.

What are we to make of this fine-tuning" of the laws of physics?[1] There would appear to be only two possible explanations. One is that the Universe was designed specifically for us by God, a Supreme Being. The other is that the Universe is the

[1] Strictly speaking, physicists talk about the fine-tuning of the "fundamental constants" of physics. By this, they mean the strengths of the nature's fundamental forces, the masses of its fundamental particles and so on.

way it is because if it wasn't we would not be here to remark on the fact! According to this curiously topsy-turvy reasoning, known as the "anthropic principle", it is hardly surprising that we find ourselves in a universe which is fine-tuned for the existence of galaxies, stars and life. We could hardly have evolved in a universe that was not!

The anthropic principle leads naturally to the idea that our universe is not alone but instead part of a large ensemble of universes. In each individual universe of this "multiverse", the strengths of the fundamental forces take on different values, the fundamental particles have different masses, and so on. Or, to take the extreme point of view of Max Tegmark, the laws of physics are entirely different.

The possibility that our Universe was designed specifically for life by a Creator is something accepted by many people, including some scientists. "The drawback of this explanation, unfortunately, is that it terminates all further scientific enquiry," says Harrison.

The other logical possibility--that there exist countless other universes besides our own--is also perfectly plausible, according to Harrison. However, an unavoidable consequence of the idea is that the overwhelming majority of universes will not have the very special conditions needed for the birth of galaxies, stars, planets and so on. Harrison finds this unappealing. "The multiverse idea requires the existence of countless uninteresting and lifeless universes," he says. "To me, this is waste on a truly cosmic scale.".

But, surely, if Harrison does not accept the idea of a multiworld wasteland of mostly dark and barren universes, then he has no alternative but to accept that physics was fine-tuned by a Supreme Being beyond all rational enquiry? Not quite. In cosmology, as in politics, there may be a third way. According to Harrison, the multiverse could be as far from a wasteland as it is possible to imagine. In fact, it could be totally dominated by universes with galaxies and stars and life. There is

only one prerequisite. Life-bearing universes must have a very special ability: the ability to reproduce.

<Self-reproducing universes>

Harrison is not the first to propose such an idea. A few years ago, the physicist Lee Smolin, then at Syracuse University in New York, latched onto a speculation about what happens deep inside black holes, formed from the catastrophic shrinkage of stars[2]. The interiors of black holes are deeply mysterious places, forever beyond our view, where the accepted laws of physics provide no guide. This has not, however, discouraged physicists from speculating about what goes on there. One idea is that the shrinking interior of a black hole shrinks only so far before it rebounds as another universe with slightly different laws of physics. Not in our Universe, mind, because it is a law of black holes that nothing that is inside can ever get out again, but somewhere else.

If, as Smolin believes, black holes give birth to baby universes then the universes which are geared up to produce the most black holes will spawn the most offspring universes. If the offspring universes are similar to their parents then, inevitably, universes which make lots of black holes will come to dominate the multiverse[3]. It follows that we ourselves must be living in a universe which is optimally suited for making black holes.

But there is a snag. The prerequisite that life-bearing universes should come to dominate the multiverse is not that universes with lots of black holes should make

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[2] A black hole is a region of space where gravity is so strong that nothing, not even light, can escape. Hence the name. A black hole is commonly believed to form when a very massive star exhausts the fuel in its core and shrinks catastrophically under its own gravity. However, much bigger black holes--as massive as millions or even billions of suns--appear to reside in the central regions of most galaxies, including our own Milky Way. How these monsters formed is at present a mystery.

[3] "The Life of the Cosmos" by Lee Smolin (Oxford University Press, New York, 1997).

more universes with black holes but that life-bearing universes should spawn more life-bearing universes. Smolin is well aware of this. He therefore argues that the very same laws of physics which promote the formation of black holes must also promote the emergence of biology. Harrison, however, finds this a bit hard to swallow. "I can see no compelling reason why universes which make lots of black holes should also be good for life," he says.[4]

Instead, Harrison proposes a novel twist on the idea of self-reproducing universes. Life-bearing universes come to dominate the multiverse, he maintains, because intelligent life actively makes new universes. Forget black holes. Life itself takes over the universe-building business! "In offspring universes which are fit for life, new life evolves to a high level of intelligence then creates further universes," says Harrison. "On the other hand, universes which are unfit for life evolve no life and so fail to reproduce."

In Harrison's scheme, the laws of physics which are most suited for the emergence and evolution of life are naturally selected by life itself. For this reason, he calls his idea the "natural selection of universes". If Harrison is right, then the origin of our Universe is no longer such a mystery. It was created by super-intelligent beings living in another universe entirely!

But how does this explain the fact that the laws of physics in our Universe are fine-tuned for life? According to Harrison, there are two possibilities. The first, already touched upon, is that new universes naturally inherit the characteristics of their cosmic parents much as children inherit the characteristics of their human parents. Small "genetic variations" in the laws of physics between generations would ensure that new universes were not carbon-copies of their predecessors. It follows

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[4] The Russian physicist Andrei Linde has proposed a self- reproducing universe that is "undirected". In his theory, called eternal, or chaotic, inflation, baby universes are constantly springing up spontaneously in a timeless "meta-universe", and giving birth to babies of their own. The Princeton physicist Richard Gott III has pointed out that a baby could beget a baby that might beget a baby that might ultimately give birth to the universe that started it all. In other words, the Universe could end up being its own great-grandmother!

that since the parent of our Universe was fine-tuned for life and similar to our own--if it wasn't, life would never have arisen in it to make our Universe!--our Universe must also be fine-tuned for life.

If, however, the characteristics of a parent universe are not automatically inherited by their offspring, there is another possible explanation for the fine-tuning we have observed. The makers of our Universe actively engineered our Universe to have laws of physics that promoted the evolution of intelligent life. Strictly speaking, this would not be "natural selection", the hallmark of Darwinian evolution. Natural selection occurs only if the variations--in this case, variations in the laws of physics--are random. If conscious life in parent universes engineers, or "programs", the variations, then what is happening is more like genetic engineering. According to Harrison, it should more accurately be called "self-directed selection".

If Harrison is on the right track about the natural selection of universes by intelligent life--or even the self- directed selection of universes by intelligent life--then the mystery of why the Universe appears designed for the benefit of life has a deceptively straightforward solution. It appears designed for life because, at a fundamental level, it was designed for life. However, and this is the novel twist supplied by Harrison, it was designed not by God--a Supreme Being--but by superior beings. Angels, if you like! "Intelligent life takes over the business of making universes," says Harrison. "Consequently, the creation of the universe drops out of the religious sphere and becomes a subject amenable to scientific investigation."

Now, there is a crucial assumption in Harrison's reasoning which has been quietly passed over. The assumption is that it is actually possible for a sufficiently advanced civilisation to engineer a new universe. Surely, this is pure science fiction? Bizarre as it seems, it is not. For more than a decade now, physicists have known--in principle if not in practice--how to trigger the birth of a new universe.

<How to build a universe>

The recipe was discovered independently by the Russian physicist Alexei Starobinsky in 1979 and the American physicist Alan Guth in 1981. Starobinsky and Guth had both been thinking about the first split-second of the Universe's existence and, in particular, the state of the "vacuum" at that time. Most people think of the vacuum as empty space but in the eyes of modern physicists the "quantum vacuum" is a quite different beast--a roiling sea of energy which is anything but empty.

What Guth and Starobinsky realised was that in the first split-second of the life of the Universe, when its density was a staggering 10^94 grams per cubic centimetre (that's 1 followed by 94 zeroes!), the vacuum existed in a very peculiar state indeed. It possessed a sort of "antigravity" which drove the Universe to expand, or "inflate", at a phenomenally fast rate. But this, it turns out, was the least of the vacuum's peculiar properties. Most bizarre of all was its ability to actually conjure energy out of nothing at all.

Normally, when anything expands--for instance, the cloud of hot debris created by the explosion of a bomb--it thins out and becomes less dense. Not so the vacuum at the beginning of the Universe. Unlike anything in the everyday world around us, the vacuum expanded at a constant density and never thinned out. Imagine holding a stack of bank notes between the palms of your hands, pulling them apart and discovering that more and more bank notes materialise out of thin air so that, miraculously, the space between your palms is always filled with bank notes! It's not a very likely money-making scheme. However, according to Starobinsky and Guth, this was exactly how the vacuum at the beginning of time behaved. As it expanded, ever more vacuum was created. Energy simply flooded out of nothing.

Eventually, and this was still within the first split-second of the Universe's existence, this "inflation" ran out of steam. Abruptly, the enormous energy stored in

the vacuum was dumped into the Universe's matter, heating it to a around a billion billion billion degrees. This was the searingly hot fireball we have come to call the Big Bang[5].

If the inflationary picture is correct, then our Universe arose from a super-dense "seed" of matter which triggered a runaway "inflation" of the vacuum. After this phase, which lasted a mere split-second, the balance of matter--the huge amount needed to make the countless stars and galaxies we see around us- -was created from the prodigious energy of the vacuum[6]. The Universe, as proponents of inflation are fond of saying, was the "ultimate free lunch!"

The fact that the birth of our Universe could have been triggered by a tiny seed of matter greatly impressed Guth. Shortly after the discovery of inflation, it prompted him to make one of the most outrageous suggestions in the history of science. Guth suggested that it might be possible to make a universe in the laboratory!

The recipe was clear. Take a seed of matter. According to the Russian cosmologist Andre Lindei, as little as a thousandth of a gram would be enough. Next,

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[5] "Inflation" explains several very puzzling features of our Universe. For instance, if you imagine running the expansion of the Universe back in time like a movie in reverse, you come to an epoch shortly after the birth of the Universe when all of creation was squeezed into a volume just a millimetre across. At that epoch, the distance light could have travelled since the beginning was smaller than a millimetre. In fact, it was smaller by an enormous factor--10 followed by 31 zeroes!

Now, the only way that a region of space can "know" about the conditions in another region of space is if some influence travels between them--and the maximum speed of any influence, according to Einstein, is the speed of light. So the millimetre- sized early universe consisted of 10^93 regions that could not have known about each other.

Here is the problem. If that millimetre-sized universe expanded to become our Universe, how do we explain the fact that the number of galaxies in a given volume of space is the same everywhere? We have to explain how 10^93 regions which could not have known about each other got to know about each other!

Inflation explains the puzzle by saying that our Universe did not evolve from that millimetre-sized primordial universe. Instead, it inflated from just one of the 10^93 regions. Consequently, beyond the "horizon" of our observable universe, there are at least another 10^93 regions like our own.

[6] Matter, according to Einstein, is merely a compact form of energy. It can be converted into other forms of energy, such as light or heat, and other forms of energy can be converted into matter. At the end of inflation, the vacuum energy could therefore have been converted into large quantities of matter which, when it cooled, formed stars and galaxies, including our own Milky Way.

squeeze the seed to the extraordinary density that was once sufficient to trigger the inflation of our own Universe. Matter crushed to such enormous densities will form a black hole, a region of space with such strong gravity that nothing, not even light, can escape. According to Guth's theory, however, the super-dense interior of such a black hole will immediately inflate--not in our universe, but in a bubble-like space-time connected to our own by the "umbilical cord" of the black hole. The umbilical cord is not stable. Tiny black holes have a habit of living for only a split- second before disappearing, or "evaporating", in a sleet of so- called Hawking radiation. The moment this happens, the umbilical cord will snap and, hey presto, a new baby universe will be born!

The devil, of course, is in the details. Harrison, however, is not too concerned. "Precisely how a universe is made in practice is not important," he says. "The important thing is that if beings of our limited intelligence can dream up wild, yet seemingly plausible, schemes for making universes, then beings of much higher intelligence might know theoretically and technically exactly how to do it."

<The universe-building business>

Guth's suggestion that a universe could in principle be made in the lab as a sort of DIY experiment was little more than a bit of fun. After all, recreating the conditions that existed in the first split-second of the Universe involves compressing matter to 10^94 grams per cubic centimetre. Not only is this way beyond our current technical capabilities, it is likely to remain way beyond out capabilities for a very, very long time. But--and this is Harrison's point--the feat may not be entirely impossible. "It's perfectly conceivable that more intelligent beings--perhaps even our own descendants in the far future--might possess not only the knowledge but also the technology to actually build universes," he says.

According to current estimates, our Universe has existed for between about 12 and 14 billion years. The implication is that elsewhere in the cosmos there could be technological civilisations that are millions, or even billions, of years ahead of us[7]. Think how far we have come in only the past century. To an inhabitant of 1900, most of present-day technology--from televisions to mobile phones to computers--would be indistinguishable from magic[8]. What more might we achieve if we manage to survive for another century? Or another thousand years? Perhaps it is not inconceivable that a civilisations millions of years more advanced than us might actually be able to make universes.

But why would they want to? One possibility, Harrison points out, is simply to prove that something can be done and to see what happens. Human beings often do things for no better reason. Perhaps there are some beings so advanced that their children make universes in the same way human children make figures out of plasticine! Such an idea was explored by the science fiction writer James Gunn in his story, "Kindergarten".

Another possibility, says Harrison, is that an advanced civilisation might make new universes out of a spirit of altruism. Our Universe is clearly hospitable to intelligent life- -we are here, after all. However, it may not be the most hospitable universe. Like a benevolent Creator, altruistic beings might want to make universes that are even more hospitable for intelligent life. Such a motivation was, in fact, anticipated by the Medieval philosopher Alphonso the Wise. "Had I been present at

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[7] Some scientists dispute the figure of billions of years. They point out that life like ours requires rocky planets and rocky planets are made of atoms heavier than hydrogen such as silicon and iron. Such atoms did not exist when the Universe was born but have been forged since in the furnaces of stars and blown into space, where they have been incorporated in new generations of stars. The point is that it takes a long time to build up the sort of abundance of heavy elements needed to make an Earth-like planet. Life on Earth may therefore have got started at the earliest possible moment in cosmic history. Add to this the fact it has taken evolution more than 4 billion years to produce us and it could be argued that we may be among the first intelligent races to have arisen. Certainly, this is often cited as the reason our searches for radio signals from extraterrestrial civilisations have so far failed. Another view is that we simply have not been looking long enough.

[8] In fact, the science fiction writer Arthur C. Clarke has even stated this has one of his "three laws". "Any technology that is sufficiently advanced is indistinguishable from magic."

the Creation", he wrote around 1270, "I would have given him some useful hints for the better ordering of the universe."!

It may of course be that advanced beings make new universes for reasons totally beyond our comprehension. Whatever their motivation, however, it is possible to speculate on the number of new universes that might be spawned. There are about 10 billion galaxies like our own Milky Way in the observable Universe. If, during the lifetime of each galaxy, a single civilisation emerges which makes a new universe--a modest figure when you consider that our Galaxy alone has 200 billion suns--then our Universe manages to reproduce 10 billion times! Furthermore, if intelligent life in each galaxy of each daughter universe repeats the ultimate experiment just once, the result is 10 billion times 10 billion granddaughter universes. And so on, ad infinitum. This kind of cosmic birth rate puts a flu virus to shame! It is not difficult to see how life-bearing universes could very quickly come to dominate the multiverse.

<Why is the Universe comprehensible?>

Harrison's idea has real explanatory power. Not only does it explain why the laws of physics in our Universe are fine-tuned for life, it also sheds light on one of deepest puzzles in science. The puzzle was pointed out by Einstein. "The most incomprehensible thing about the universe," he said, "is that it is comprehensible."

What Einstein meant was that it is easy to imagine a universe with laws that are so complex and opaque that they are completely unfathomable by human minds. Instead, the Universe appears to be governed by rather simple laws. So simple that, more than three centuries ago, Newton was able to deduce a universal law--the law of gravity. And, since Newton's time, our amazing success in penetrating nature's

inner workings has given us unprecedented control over the material world. Why has it been so easy?

If Harrison is right, the answer is simple. The reason our Universe is comprehensible is because it was created by comprehensible beings. Beings far in advance of us but basically like ourselves. Intelligent but also intelligible. They made our universe to be like theirs, and their universe was in turn understandable. How could it not be? They had to have enough understanding of it to manipulate it and make a new universe!

"We have found a strange footprint on the shores of the unknown," wrote the English astronomer Arthur Eddington. "We have devised profound theories, one after another, to account for its origin. And at last we have succeeded in reconstructing the creature that made the footprint. And lo! it is our own."[9] Not quite. According to Harrison, the footprint was made not by us, but by beings similar but superior to us. By angels!

In Harrison's picture, life begets life, intelligence begets intelligence. "It is not inconceivable", he says, "that the goal of the evolution of intelligence is the creation of universes to foster intelligence."

But maybe the goal is more prosaic than the spreading of the miracle of life. Piling speculation upon speculation, maybe it is actually possible to travel between universes. "Offspring universes may not be totally inaccessible to their creators," says Harrison. "If intelligent beings know how to create universes, they might also know how to explore and occupy them."

<How did it all begin?>

[9] "Space, Time and Gravitation" by Arthur Eddington (Cambridge UP, 1920).

Harrison's is a mind-blowing vision. But there is one rather serious problem with it. If our Universe was created by superior beings in another universe and theirs in turn was created by superior beings in an earlier universe, and so on, then who or what created the very first universe?

One possibility, says Harrison, was that it was God! At first sight this seems a rather a weak admission. After all, Harrison came up with idea of the natural selection of universes specifically to avoid the other explanations of the Universe's fine-tuning. One was that there are an infinity of barren universes and the other was that God did it. Harrison, however, sees an important distinction between his idea and the religious view. "In my scheme, God starts things," he says. "Thereafter, however, superior beings in universes take over the creation of further universes."

One other possibility for the origin of the first universe is a variation on the barren multiverse idea. In the beginning, says Harrison, there might have been a large ensemble of universes, each with its own random variant of the laws of physics. Most of the universes were dead and uninteresting. But, by chance, the conditions were right in at least one for the evolution of life. Harrison calls this the intelligent "mother" universe. "Thereafter, by virtue of the fact they reproduce, intelligent universes come to dominate the ensemble," he says. "In time, the original unintelligent universes become a vanishingly small fraction of the whole."

We are still left with an unanswered question. If a Supreme Being made the first universe, who or what made the Supreme Being? And if it all began with a mostly-dead ensemble of universe among which happened to be the intelligent mother universe, how did the initial ensemble come about? "Perhaps the supreme being occupied another universe created by an even higher form of intelligence, and perhaps the initial ensemble consisted of botched and bungled creations by a sorcerer's apprentice in another universe," says Harrison.

Here, Harrison is alluding to the words of the philosopher David Hume, who in 1779 wrote: "Numerous universes might have been botched and bungled throughout an eternity ere this system was struck out; much labour lost, many fruitless trials made, and a slow but continual improvement carried out during infinite ages in the art of world-making."

Could Hume have inadvertently put his finger on how it all began? Who knows. One thing, however, follows automatically from Harrison's vision. If humanity avoids its own destruction and manages to survive into the far future, one day our descendants will have to make a rather important decision: whether or not to become parents!

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Humanity is unlikely to be alone in making this decision. For if, as Harrison suggests, our Universe was designed by life specifically so that it would give rise to life, then it is likely that other intelligences in other galaxies will sooner or later face a similar dilemma. Which prompts a rather obvious question. Where are the other intelligences? So far, we know of only one example of biology: our own.

The view of most astronomers is that the most likely place to find extraterrestrial life is on Earth-like planets warmed by sun-like stars. However, a planetary scientist in California thinks that most astronomers could be wrong. According to David Stevenson, the majority of the Universe's life may not reside on cosy planets like our own at all. Far from it. If he is right, the place to look for ET may be the most hostile environment it is possible to imagine: the super-cold vacuum of interstellar space!