THE SCIENCE OF EVERYTHING
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THE SCIENCE OF EVERYTHING

Evolution's big bang

Cloning in California

Margaret Wertheim at the South Pole

Steven Pinker has no soul

Last stand of the kakapo

Rovers on Mars

Fiction by Gregory Benford

THE CSI EFFECT

Is DNA profiling foolproof . . . or full of holes?

THE MAN FROM THE 11th DIMENSION

The strange worlds of Michio Kaku

STORY *Elizabeth Finkel*

FISH OUT OF WATER

He stretches his mind to 11 dimensions; understands what Einstein failed to grasp; and plans for the death of our Sun, five billion years from now. Michio Kaku is a superhero of the incomprehensible.

It was Einstein's unfinished business. The world's best-known and most prolific physicist was driven in his latter years to find a single set of laws for the universe: laws that would apply as readily to the chaotic BeBop of sub-atomic particles as to the majestic waltz of galaxies in deep space. Einstein failed, but on the 100th anniversary of $E=mc^2$, a new generation of physicists is carrying the torch and offering the answer to Life, the Universe and Everything. They say the answer is string theory.

Problem is, string theory is too weird for most people to understand. Some scientists even say it's more fiction than science. But not Michio Kaku, one of the world's best-known theoretical physicists, and one of the key players in string theory.

Kaku is a professor at the City University of New York. Not only is he 'sold' on string theory – and one of the earliest participants in its development – he is also a passionate proselytiser. He has just completed a world tour for his third popular science book, *Parallel Worlds*, and is working with the BBC on a documentary series.

But it is not simply Kaku's desire to spread the word about string theory, physics and the intrinsic value of science that drives him to engage the public in myriad ways. He says he believes the

Getting a new perspective; Michio Kaku was inspired by watching fish in a pond.

PHOTO AND DIGITAL ART: CHRIS CALLAS


ILLUSTRATION: TIM BORGMAN

very future of the human race is on the line. "We're at a precipice; we are experiencing the birth pangs of a Type 1 Civilisation. And there's no guarantee we'll make it."

I MET MICHIO KAKU in San Francisco, and I must confess to great trepidation before the interview. He is an imposing man. Besides being an author of popular books (his earlier book, *Hyperspace*, was a global bestseller), he's also written one of the key textbooks of quantum field theory and, together with Keiji Kikkawa of Osaka University in Japan, published two of the seminal papers describing string field theory. I imagined he would not suffer fools lightly. Nevertheless, repeated desperate efforts to get a handle on this field had led me nowhere. Or rather, to some very weird places: attempting to fathom extra dimensions and parallel universes.

Somehow this was supposed to follow from the proposition that the fundamental building block of matter is not the quark: the sub-particle identified some time ago by atom-smashers as the components of protons and neutrons at the heart of atoms. No, the fundamental unit of all matter is something a million billion times smaller than a quark: a vibrating string.

Presumably all could be fathomed ... if only I understand N-dimensional mathematics. But my background is in biology, and I feared I would be incapable of asking him anything intelligent. As luck would have it, the night before the interview, I had dinner with three bright, mathematically proficient engineers and a Stanford University neuroscience professor. I asked them for help. What would they ask Michio Kaku?

To my great relief, their difficulties were the same as mine. On my right a brilliant PhD engineer from Odessa candidly admitted he couldn't really conceive of extra dimensions. To my left, another smart engineer offered his

THE SCIENCE OF STRING THEORY

STRING THEORY IS SURPRISINGLY EASY to explain. It goes like this. The fundamental particle is not a quark, but a string whose dimensions are calculated to be 10^{-33} centimetres. The important feature of this string is that, in the same manner as the strings of a violin, it vibrates to produce different notes and harmonics. This is how strings create the universe as recounted in Kaku's catechism:

Q. What are the particles of the world we see?
A. *The notes on the string.*
Q. What is chemistry?
A. *The melodies on the string.*
Q. What are the laws of physics?
A. *The laws of harmonies on strings.*
Q. What is the universe?
A. *The symphony of strings.*
Q. What is the mind of God?
A. *Music resonating through hyperspace.*

Unquestionably very poetic but where did this theory come from, and why should anyone believe it?

In biology, theories generally arise to explain data encountered in the real world. For instance, the theory that the structure of DNA was a double helix was developed after Rosalind Franklin took hundreds of X-ray crystallography images of DNA. The idea of a double helix explained her images as well as data obtained in other experiments.

But unlike biological theories, string theory did not arise from data. Instead, it was born of the belief that the universe is elegant and simple, and that the four known fundamental forces of the universe would be unified, as Einstein believed.

In the 19th century, James Clerk Maxwell rocked the world by showing that electricity and magnetism were part of one force – electromagnetism. Ever since then, a mathematical ideal that allowed for the 'unification' of all the major forces in nature has been a primary goal for theoretical physicists. Besides electromagnetism, these include gravity and the two forces that operate at the subatomic level: the weak and the strong force. The strong force holds quarks together inside protons and neutrons and stops atoms from disintegrating. The weak force explains why atoms sometimes do disintegrate – it underlies radioactive decay.

The blithely named 'standard theory', has done a masterful job at explaining the operations of the strong and weak forces. And it has also managed to unify the strong and weak forces with the electromagnetic force. But it hasn't been able to accommodate the existence of gravity.

What Einstein struggled to do – and what has defeated everyone until the 1980s – was to unify all the forces with a single type of law. This law should be as simple and elegant at describing the interactions and manifestations of the four forces as Einstein's equation of $E=mc^2$.

String theory achieves this goal. Just as the mathematics of a vibrating violin string can explain all of music, so the mathematics of tiny vibrating strings that vibrate in 11 dimensions, are capable of explaining the four forces, plus matter and energy; and hence the universe itself.

The gestation of string theory has so far taken the past four decades and is still far from being fully developed. Its beginnings trace to Gabriel Veneziano who, in 1968, while studying at the European Centre for Theoretical Physics (CERN) in Switzerland, stumbled across a mathematical formula that explained the interactions of the strong force.

The formula turned out to describe not 'point particles' but vibrating strings. However string theory as an explanation for the strong force was abandoned because it predicted something absurd: a 'massless spin 2 particle'. Later physicists realised this was just the characteristic of a graviton – the hypothetical particle proposed to carry the force of gravity. With that, a number of enthusiastic physicists proposed that string theory could be used to explain gravity, and in 1984 – after some more mathematical alchemy – John Schwarz at California Institute of Technology and Michael Green at Queen Mary's College in London, found that string theory could also encompass all the other forces.

String field theory is to string theory what the electromagnetic field is to photons: a way of describing how strings act coherently in the real world. In 1974, Michio Kaku and Keiji Kikkawa demonstrated that it could work in 10 dimensions. Nearly 20 years later, in 1993, Ed Witten at Princeton University in the U.S. sparked a mini-revolution when he showed that string theory worked best in 11 dimensions. His seminal demonstration has taken string field theory physicists, Kaku among them, back to the drawing board.

String theory predicts alternate universes because it fits with the physics of the subatomic scale (quantum dynamics) as well as with cosmology (it is the only theory to achieve this unification, and that's why it remains compelling).

At the quantum level, particles of matter such as electrons can be in two places at once. In fact, this seemingly absurd statement is validated by modern electronics. Extrapolated, this means that the building blocks of our world might actually be leading an alternative existence somewhere else … as you sit reading this, there may be another you reading in another parallel world.

String theory as applied to cosmology suggests that strings were the first thing to be created, and they were originally created in 11 dimensions.

Since the world as humans experience it has only four dimensions (three of space plus one of time), these other dimensions are probably out there and our universe is perhaps just one bubble in an infinite sea of bubble universes. *— Elizabeth Finkel*

view that physicists had gone awry by taking mathematical concepts like zero and infinity in a literal way. He believed they were only meant to be used in a symbolic way. Surprisingly, it was the neuroscience professor who was the most receptive to string theory. He offered, "It's up to these physicists to get us out of the mess we're in. We may have to get off this planet."

And so I found my opening line for the interview. I gingerly suggested that the new physics of string theory seems to affront some people (especially engineers) as if they suspect 'real science' had been hijacked. The silver-haired, avuncular Kaku fixed me with kindly brown eyes and settled into what was clearly a familiar role: that of the patient, tolerant, and at times mischievous college professor. It also became immediately clear that the tussle between engineers and physicists was nothing new.

Physicists and engineers have long failed to see eye to eye, he began. "Engineers want to build bridges; physicists want to understand fundamental laws," he said. "Engineers disdained Einstein's theories, but his equations ultimately resulted in the atom bomb." Einstein has been Kaku's hero since, at the age of eight, he learned the scientist had died and left a book with an unsolved mystery. "I wanted to know what was in that book; to me it was more fascinating than any adventure story. What problem was so difficult the great Einstein himself couldn't solve it?

"Today we believe that [the answer to Einstein's quest for the unified field theory] is string theory. It also makes the engineers' eyes go crazy, because we are talking about universes that are unseen." Having expertly trussed his sacrificial engineer to the whipping frame, Kaku proceeded to explain his life's quest to answer Einstein's unsolved mystery.

Understanding other worlds came naturally to him. Perhaps it was an inevitable consequence of being the child of Japanese Americans. His parents, though born in California, spent World War II behind barbed wire, guarded by people with machine guns: incarcerated by their own country as enemy aliens.

Afterwards his father worked as a gardener, his mother a maid: two of the few jobs that were then available to Japanese Americans. So Kaku grew up poor. One of the family treats was to visit the Japanese Tea Garden in San Francisco's Golden Gate Park. It turned out to be the place of a childhood epiphany. Wondering in the way that only a child does, Kaku looked at the carp swimming in a weedy pond at the garden and imagined how the fish would not be able to conceive of other worlds. "A carp engineer would believe that was all there is; but a carp physicist would see the ripples on the surface and start thinking about unseen dimensions," Kaku told me, laying the first of many metaphoric lashes on his token engineer.

Kaku's natural curiosity and penchant for other-worldly thinking were frequently misunderstood during his childhood. This is probably a major contributing factor to the reason he has become a light unto others. "When I was a teenager and asked questions, eyes would glaze over – I didn't want others to go through the trials of fire."

But his teenage curiosity did pay off. "Because my parents were poor, I knew from a very early age that I would have to be self-reliant. Hence, in high school, I constructed a 2.3-million-electron-volt atom smasher, which helped me to get into Harvard. My parents did not understand at all what I was doing, but they realised it was important, and helped in any way they could. The atom smasher used up 22 miles [35km] of copper wire, which my parents and I wound on the high-school football field over Christmas vacation."

The atom smasher consistently blew the fuses at his parents' home but it also impressed atomic scientist Edward Teller, who arranged a scholarship to Harvard University.

Early on, college life proved quite prosaic for Kaku. It involved learning the bread and butter of physics – most tediously having to memorise Maxwell's eight hideous mathematical equations that describe electromagnetic fields. But the physics course kept the best till last. In the advanced class, Kaku experienced a revelation to rival that of the carp in the tea garden. "We physicists have the greatest mind-blowing coming of age; its an existential shock."

What Kaku learned was that Maxwell's eight lines of equations could be reduced to one. The shock was that this equation magically rose out of Einstein's gravity equations if you added a fifth dimension! (that is, a fourth spatial dimension: we are used to three spatial dimensions and one of time). "That's the difference between engineers and physicists: engineers are happy with Maxwell's original equations; they think 'how horrible but how useful'." Physicists, however, are looking for the underlying elegant logic of the universe. And, according to proponents of string theory, that logic is: physical laws become simpler in higher dimensions. The five-dimensional transformation of Maxwell's equations is not controversial: it works. Indeed mathematicians often operate in extra dimensions. Where the controversy lies is whether these mathematical abstractions have any counterpart in the real world. String-theory physicists believe they do; not just in five dimensions ... but in 11!

"Kaku is doing something akin to a musical composer, manipulating chunks of melodies in his head. But his compositions are created from chunks of mathematical formulae. And he is striving for something no less than a cosmic symphony."

The bitter wartime experience of Kaku's parents did not dent his own patriotism. In 1969, just three days after graduating from Harvard, he enlisted into boot camp at Fort Benning in Georgia, one of thousands of raw recruits being hammered into a fighting force to replace the 500 GIs dying every week in Vietnam. While dodging bullets, he would imagine the maths of how strings could move through space as loops: revelations that became the basis for his PhD at the University of California at Berkeley.

It turns out it is no easy matter to create a universe where matter, space and time are stable. For it all to work, the fundamental forces must be unified. And that unification can only take place in higher dimensions.

As Kaku puts it, "Forget building bridges, we're talking about being God. This is what Einstein dreamt about every day of his life. If I'm God, how do I go about the business of creating a stable universe? It's extraordinarily difficult."

WHEN HE IS NOT WORKING, Kaku spends a lot of time popularising science. He is a gifted writer, whose vivid narratives sweep breathtakingly not only across alternate universes, but also across art, history, politics, literature, philosophy and religion. His own religious influences were contradictory: his parents were Buddhist, but he was raised as a Presbyterian. Yet modern physics seems to accommodate both views.

"In Christianity, there in an instant of creation; while in Buddhism there is Nirvana, which is timeless," he says. "I am pleased that modern cosmology provides a beautiful melding of these two otherwise mutually contradictory ideas: that a continual genesis is taking place in a hyper-dimensional timeless Nirvana."

He has also hosted a regular science talkback show on U.S. public radio for the past 20 years. It is not just for the love of physics that he works to popularise: Kaku has peered deep into the future, to the time when the universe is ancient, dying and darkening; a time when Earth's inhabitants will need to find themselves a home in another universe. String theory predicts the existence of parallel universes, which means mass evacuation of humanity through a wormhole might be the key to survival; if we only gain the knowledge necessary to master the physics of 11 dimensions.

It may take a billion years to achieve that mastery. And there is no guarantee that we will survive as a species: Kaku believes human civilisation is currently undergoing its most critical transition. If successful, we will make the transition to a Type 1 Civilisation: one that has acquired the ability to completely harness the energy of a sun, perhaps (as physicist Freeman Dyson has suggested), by enclosing it in a metal sphere. Then, we could go on to colonise the galaxy like characters of the *Star Trek* series, and beyond that to harness dark energy and travel through wormholes. But will we make the first critical transition given the rise of religious fundamentalism and a growing and pervasive anti-science? "We're at the precipice," says Kaku.

THE MUSTY, WOOD-PANELLED LOBBY of the Hotel Rex in downtown San Francisco where we met is like something out of a 1930s Sherlock Holmes film set, evoking a bygone era of gentlemanly refinement laced with an edge of mystery. One bookcase boasted the *Harvard Journal*; in one corner, a parchment-like lampshade painted with Greek figures sat atop a handsome antique desk; club leather recliners made idle conversation with a table inlaid with a multi-coloured star design. Surreally, the surface of a large round table in the centre of the room was painted with an old clock face. As we talked, I could imagine a pipe-smoking Einstein sauntering out from behind a bookcase to read the morning papers. It was a perfect venue for an elating journey into time and space, and for leaving behind of everything that I had heretofore come to accept as reality.

With string theory offering answers to the creation of the universe, I asked Kaku why there was so little excitement from the public at large – in the way there was near hysteria surrounding Albert Einstein and relativity in his latter years, even though most people didn't know what relativity was really all about. Indeed, Kaku rued the day that physicists passed up a golden opportunity to sell the revelatory potential of string theory. In the final days of the U.S. Congress's deliberations on funding for the Superconducting Supercollider – a massive atom smasher that might have helped test elements of string theory – one of the last questions put to a physicist by a congressman was: will we find God? The physicist flubbed the answer, according to Kaku. "He should have said, 'This machine will take us as close as humanly possible'. We learned a lesson from that: we have to engage the public." The Supercollider was eventually cancelled in October 1993.

But if the average person hasn't yet awakened to the powerful message of string theory and higher dimensions, the aficionados of the occult and science fiction certainly have. In 1854, a German mathematician, Georg Bernhard Riemann, proposed the idea that extra dimensions might exist in the real world.

He arrived at this view after imagining a flatworm living in a flat world. Here there would be no such thing as up or down: only side to side, front and back. But what if one day a wrinkle appears in the plane it normally inhabits? The worm will have no way of experiencing it. All the worm will know is that a barrier prevents its progress: some strange and invisible force. But Riemann then made the stunning extrapolation that perhaps the invisible forces encountered in our four dimensional world, like gravity, are also ripples in an unseen higher dimension. It was an idea rejected by scientists, but avidly taken up by members of the occult who divined that the extra dimensions must be the haunts of spirits. To visualise a higher dimension, devotees would stare for hours at a tesseract, a three-dimensional cross that could – so the idea goes – be mentally folded into a fourth physical dimension in the same way a flat cross will fold into a cube. And in science fiction novels, tesseracts and multiple dimensions have long featured. Gratifyingly (for me) Kaku said that it is not actually possible to conceptualise a fourth spatial dimension.

Perhaps because of this, there are a few physicists (as well as engineers) who assert that science fiction novels are precisely where string theory belongs. The size of strings, whose vibrations occur in 11 tiny, curled-up dimensions, are so impossibly miniscule – really, really miniscule – as to be immeasurable using current methods. The energy required to smash matter hard enough to break it up into strings would be akin to the energy released in the Big Bang – the one that created the universe – and therefore monumentally beyond what mere Earthlings could generate. Such a theory, untestable as it seems, riles many a scientist. Nobel Prize laureate Sheldon Glashow (now a professor of physics at Boston University) is a notorious detractor; he likens string theory to the AIDS virus – both infectious and incurable.


PHOTO: CHRIS CALLIS

Kaku is unfazed. He says these early years of the new millennium may well be be the ones in which we are able to gather evidence supporting the existence of the, as yet, ghostly strings. In 2007, the Large Hadron Collider will be turned on. It is an atom smasher that is actually bigger than the city of Geneva, and is being built at the European Particle Physics Laboratory (known as CERN) in Switzerland. After the demise of the Superconducting Supercollider, the Large Hadron Collider is the next best bet for probing the composition of matter. It won't be able to detect the strings themselves; but it will be able to sense their vibrations, potentially in the form of "sparticles" (Sparticles are theoretical ghostly partners of the fundamental particles – leptons, photons and quarks – that were produced in the Big Bang). "It won't clinch it [string theory]. But string theory is the only theory that gives you sparticles."

As for Kaku himself, he will not be one of those gathering the data. The way he works today is not all that different to what he did while he was dodging bullets in basic training, dreaming up mathematical equations – except that his surroundings today are rather more tranquil.

A typical working day is spent gazing out of his office window at the City University of New York doing something akin to a musical composer, seeing and manipulating chunks of melodies in his head. But Kaku's compositions are created from chunks of mathematical formulae. And he is striving for something that is no less than a cosmic symphony.

I FLOATED OUT of the Hotel Rex as if in a dream. It was like that moment in the movie *Men in Black* when Will Smith discovers that the *National Inquirer* – whose tabloid pages read like something out of a tawdry sci-fi pulp magazine – had been reporting the truth all along. I felt freed, no longer dragged down by the sordid parameters of existence: the inexorable passage of time, ageing, death, oblivion ... there were other dimensions, parallel worlds, multiple universes far beyond anything an engineer carp could imagine. In the course of two hours I had become a convert to string theory and maybe even a believer in a God that composed the harmony of the Universe.

Kaku described his own belief in a Higher Being eloquently: "I would say that I lean toward the God of Einstein and Spinoza; that is, a God of harmony, simplicity and elegance, rather than a personal God who interferes in human affairs.

"The universe is gorgeous, and it did not have to be that way. It could have been random, lifeless and ugly but instead it is full of rich complexity and diversity," Kaku mused.

Elizabeth Finkel is a Melbourne science writer.