New Scientist

WEEKLY November 19-25, 2022

BIRDS THAT LIVE IN ETERNAL SUMMER

QUANTUM TIME FLIP

ROGER PENROSE ON THE ORIGINS OF THE UNIVERSE

COP27 CLIMATE SUMMIT LATEST

SPECIAL REPORT

PAIN

How pain is created in the brain

The future of pain treatments

A new way to measure your pain

A mysterious new type of pain

What causes chronic pain – and how to treat it

Why emotions can physically hurt

No3413 US$7.99 CAN$9.99

Cosmic thoughts

During a career spanning more than seven decades, mathematician **Roger Penrose** has never shied away from big, bold ideas. He gives Michael Brooks his latest take on theories of the universe, consciousness and how we might contact beings from another cosmological aeon

EARLY in his career, the University of Oxford mathematician Roger Penrose inspired the artist M. C. Escher to create *Ascending and Descending*, the visual illusion of a loop of staircase that seems to be eternally rising. It remains a fitting metaphor for Penrose's ever enquiring mind. During his long career, he has collaborated with Stephen Hawking to uncover the secrets of the big bang, developed a quantum theory of consciousness with anaesthesiologist Stuart Hameroff and won the Nobel prize in physics for his prediction of regions where the gravitational field would be so intense that space-time itself would break down, the so-called singularity at the heart of a black hole. Undeterred by the march of time – Penrose turned 91 this year – he is continuing to innovate, and even planning communications with future universes.

Michael Brooks: In 1965, near the start of your career, you used general relativity to make the first prediction of the existence of singularities, as in the centres of black holes. How did it feel to see the first photograph of a black hole more than half a century later?

Roger Penrose: If I'm honest, it didn't make much impression on me because I was expecting these things by then. However, back when I first proved this [singularity] theorem, it was quite a curious situation: I was visiting Princeton to give a talk and I remember Bob Dicke – a well-known cosmologist, a very distinguished man – came and slapped me on the back and said, "You've done it, you've shown general relativity is wrong!" And that was quite a common view. I suspect that even Einstein would probably have had that reaction because he was very much against the existence of singularities. I think he would have thought, "No, no, there must be something wrong with the theory".

It seems the view had been that instead of generating a singularity, everything would swish around and come swirling out again. And I showed that this is not what happens. What I proved then doesn't mean general relativity is wrong, but you do have to have singularities.

But despite the existence of singularities, the idea of black holes wasn't a wild idea?

No, because at the time the quasars [extremely bright objects at the centres of galaxies] had been observed. And the strength of the signal indicated that they must be enormously large – as in massive – but also small in terms of spatial dimensions. That kind of large and small together indicated something very dense like what we now call a black hole. So it did suggest that quasars were things that were very compressed, concentrated bodies, down to the sort of level where you would see this kind of [singularity] problem arising.

Even so, at the time, black holes were not considered things you would actually get [from the mathematics]. But these arguments were looking at exact models such as the symmetrical Schwarzschild solution to the equations of general relativity, which specifically models a black hole that is not spinning and has no charge, or as in the Kerr model, a rotating, but still neutral, black hole. They don't tell you anything about a general situation [where the presence of charge or rotation, for example, isn't specified]. I wasn't convinced by these arguments. The alternatives were these complicated computer calculations, which were very rudimentary at the time. They just said, "Well look: everything's broken down!" You didn't know whether that was because it had run out of memory or because the calculations had given up for some reason. So they didn't tell you that singularities exist either.

Has the 2020 Nobel prize for discovering black holes mathematically made a difference to your work?

In 2020, there was a good thing and a bad thing that happened to me. I had been travelling around and didn't have much time to think about problems. But because of the [pandemic] lockdown, I was able to work out certain ideas that have been buzzing around in my head. I wrote down some notes and sent them around to colleagues, and this then ended up being a paper – which may well end up being a book that I hope to do at some stage. This was the good thing.

The bad thing was getting the Nobel prize because it stopped the whole thing dead. I'm being a bit unfair really, but I haven't done anything on these notes since getting the Nobel prize; there's just been no time. I should add that it's a bit misleading to say I got the Nobel prize for black holes. The citation said that I showed black holes are a robust prediction of Einstein's general theory of relativity. What I really showed is that singularities are a robust prediction of general relativity.

Could a singularity exist without giving rise to a black hole?

We believe you only get singularities that are hidden behind event horizons [boundaries beyond which nothing, not even light, can

DAVE STOCK

escape from the gravitational pull] – that is, a black hole. But maybe you could get "naked" singularities without an event horizon around them, and information could come out of them.

As far as I'm aware, there is still no proof that, in the general case, you do not get naked singularities: it's still a conjecture. Nobody seems to talk seriously about it much – the general community is sort of resigned to the idea that what you get is black holes. But then lots of questions arise, and I feel that most of these questions are going along the wrong track.

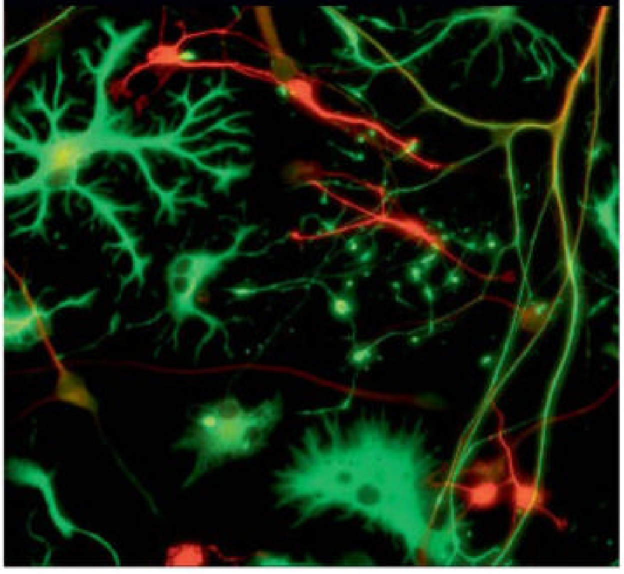
What new cosmological ideas are you working on now?

I'm just writing a paper with a colleague about "conformal cyclic cosmology" (CCC). This is the view that the big bang was not actually the origin of our universe, but the continuation of the remote future of a previous aeon. So the universe expands and contracts and then indulges in this exponential expansion which we now see in our own aeon, where the expansion of the universe accelerates. And it continues.

So with CCC you're arguing that the universe cyclically balloons and compresses and what we refer to as the big bang is merely the beginning of this aeon, the period of the universe's life that we are living through, rather than the actual start of everything. Would it be fair to say that this idea hasn't had a lot of pick up from the rest of the physics community?

You're absolutely right: it does not get a lot of pick up. I find that when I give talks to people who are not physicists, they latch on to it much more easily than the people who are conventional cosmologists, very few of whom take me seriously. But I don't fully understand why because CCC does have observational implications and the evidence for it is really quite strong. What we claimed to see in this paper is something we called a "Hawking Point" – a point ringed with polarised light, left by a black hole from a previous aeon. I hate to say this, but this reluctance to consider a new idea in the face of strong evidence is one reason why I think people should worry about science.

"My claim is much more outrageous than 'it's quantum mechanics in the brain' "



RICCARDO CASSIANI-INGONI/SCIENCE PHOTO LIBRARY

Left: Neuron microtubules (stained red), which may be involved in a quantum theory for consciousness. Right: Centaurus A, which has a supermassive black hole at its centre

Another of your controversial ideas is the one put forward in your 1989 book *The Emperor's New Mind*: that consciousness involves quantum effects. I know it has evolved into the idea of "orchestrated objective reduction" (Orch OR), but is it something that you still stand by?

When I wrote that book, I had thought that I would see how quantum mechanics comes into the manifestation of consciousness by the time I got to the end of it. But I sort of gave up on that hope in the end – I had to finish the book somehow, so I did something I didn't really believe in and I shut up about that particular idea.

However, I thought the exploration of how computing and physics relate to the mind might at least stimulate young people to do physics. Yet pretty much all the letters I got were from old, retired people. However, there was one from [US anaesthesiologist] Stuart Hameroff. He had the view that consciousness had to do not with nerve transmission, as everybody else seemed to think, but with microtubules, these little tiny structures much, much smaller than nerves. It seemed much more promising. So we got together and did things – though we didn't quite know what we were doing. There are certain rough edges to our Orch OR argument, but whatever consciousness is, it must be beyond computable physics.

If you think consciousness is beyond computation, does that mean you think it is beyond what science can discern?

No, it's just beyond current science. My claim is much worse, much more serious, much more outrageous than "it's quantum mechanics in the brain". It's not that consciousness depends on quantum mechanics, it's that it depends on where our current theories of quantum mechanics go wrong. It's to do with a theory that we don't know yet.

But I think we have made some progress. There are about four mainstream views about what consciousness is, and one of them is this Orch OR idea that Hameroff and I developed. That's a bit of a shift. People used to say it is completely crazy, but I think people take it seriously now. There are also experiments looking at phenomena to do with quantum effects and to do with effects of general anaesthetics, and there do seem to be some connections there. So it's coming into the area of experimental confirmation or refutation; I find that exciting.

Can you remember what it was that first excited you about maths and physics?

I got a lot from my father: we used to do things like making polyhedra and variations

ESO/IDA/DANISH 1.5 M/R. GENDLER, J.-E. OVALDSEN & S. GUISARD

of "platonic solids" [polyhedra with sides of equal lengths] and other things in mathematics. Also, I learned quite a bit from my older brother Oliver. He was very precocious – unlike me. I was very slow at school. This was still the case when I did mathematics at University College London.

I remember that I chose two geometric projects for my special topics and those were not my best papers. I could see how to do the problem using the geometrical part of the brain, if you like, but I had to translate that into words and that was slow, so I didn't finish the papers. I tend to think visually, and I think there's a big selection effect: people who think visually tend not to do so well as the people who think the other way. You probably lose quite a lot of people who would be good mathematicians because they're largely visual.

What is your advice for people starting their career in physics now – what to get involved in or what to avoid?

That's a difficult one: it would be very easy for me to impose my prejudices. There's a lot of work in particle physics, for instance, and clearly a lot of progress is made in that subject. But I find it very hard. A lot of what you have to do in particle physics depends on doing things which aren't logical: if something crops up as infinite, you can ignore it. It's probably a kind of instinct that some people have; I don't think I have that kind of instinct. I want to be logical. If it doesn't hang together, I can't see my way through it.

You have spent decades thinking about the structure of the universe, and about consciousness. Does this give you any sense of whether there is inherent meaning in the universe?

In a certain sense you might say that the universe has a purpose, but I'm not sure what the purpose is. I don't believe in any religion I've seen. So in that sense, I am an atheist. However, I would say that there is something going on that might resonate with a religious perspective.

I think the presence of consciousness, if I can put it like that, is not an accident. It's a bit complicated to say what I really mean by this, but it has a connection with the fact that nobody knows where the fundamental constants of nature come from. If they didn't have the particular values that they have, then maybe we wouldn't have interesting chemistry, and then wouldn't have life. I find that a difficult argument to make clear, because you don't know – if the numbers were different – what kind of thing you might call life. However, it raises a question to do with conformal cyclic cosmology: do the constants get jumbled up each time you go round to the next aeon?

Do you mean that according to CCC, consciousness and the fundamentals of physics would look different from one aeon to the next?

It's an interesting question, and it relates to something I wrote with a colleague where we look into conformal cyclic cosmology for a signal coming from the previous aeon, which would suggest some consistency in the underlying physics between one aeon and the next. It's due to the collision between supermassive black holes: they produce gravitational wave signals, which we should be able to see the implications of in our aeon. And the claim is that we do. Again, people dispute this, but I think they are pretty strong arguments: there's something going on there.

So these signals that traverse the aeons might support some underlying purpose in the universe?

Well, our argument starts from the fact that I'm not all that optimistic we're going to go on for a huge length of time. The probability that something will trigger a nuclear catastrophe is not that tiny – in fact, I think we're pretty lucky to be around now. But maybe other civilisations will be more sensible and settle down. In fact, I think some version of SETI [the search for extraterrestrial intelligence] should look for different civilisations, successful ones that survived very late in the previous aeon. That may be more promising in some respects. But maybe we, maybe others, will learn how to send signals into the next aeon. Probably gravitational wave signals are the best bet, but very, very low variations in the electromagnetic field could get through too. And we might be able to get them to do better than we have, by saying, "No, you stupid idiots, that's what we're doing!" ▮

Michael Brooks is a consultant for *New Scientist* and author of *The Maths That Made Us* (Scribe)