New Scientist

WEEKLY 12 March 2022

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Life, the universe and everything

In a career spanning more than half a century, **Martin Rees** has contributed to some of our most intriguing theories about the universe and beyond. *New Scientist* met him at his home in Cambridge, UK, to look back at his scientific life and discuss everything from black holes to billionaires

AS ASTRONOMER Royal, you have to assume Martin Rees isn't in it for the money: £100 a year is the reward for advising the UK monarch on all matters astronomical.

It is just one of many hats Rees has worn, though – including president of both the Royal Astronomical Society and the Royal Society and, since 2005, as an appointed member of the UK's House of Lords. His work as a government adviser and public face of science has come on the back of an equally distinguished career in cosmology stretching back more than half a century, encompassing seminal research on the nature of the big bang and black holes, extreme phenomena throughout the cosmos, the search for life elsewhere in the universe and, latterly, humanity's own fate within it.

DAVID STOCK

Richard Webb: When you started out in cosmology, the idea that the universe began in a big bang wasn't even accepted science. How have things changed in the past half-century?
Martin Rees: Amazingly. When I started research in the mid-1960s, the [late] astronomer Fred Hoyle was still advocating the idea of a steady state universe that had existed from everlasting to everlasting. Evidence for the big bang theory was very weak. The debate was settled in most people's minds in 1964 when cosmic microwave background radiation was found – a relic of a hot, dense, early phase of the universe.

It was a good time to be starting research. Objects such as black holes and neutron stars were being found where Einstein's general relativity was important, not just a tiny correction as it is in our solar system. At the same time, theorists like Roger Penrose were developing new techniques to solve Einstein's equations, which was a big leap forward.

Is the big bang theory set in stone now?
As in all of science, every advance opens up new questions. We can understand the physics of the universe right back to when it was a microsecond old. That's an amazing achievement. But why is the universe expanding the way it is? Why does it contain the mixture of atoms, radiation and dark matter that it does? And why did it have the kind of irregularities that resulted in it not remaining a uniform gas, but developing clusters of galaxies?

The answer to those questions lies before the first microsecond, when the entire universe was just the size of a tennis ball. As yet, we've got no experimental foothold on the very extreme physics involved.

Can we claim any sort of understanding when 95 per cent of the universe comes in forms we can't explain – that is to say, dark matter and dark energy?
Clearly, our knowledge is incomplete. We know dark matter behaves like neutral particles in a swarm that don't collide with each other. We notice about five times as much mass in that form as within atoms, and that allows us to get a good model of how galaxies form. What it is, we don't know. But it is easy to envisage particles we haven't discovered yet and that are harder to discover. There's no reason why everything in the universe should shine.

Dark energy is telling us something we don't understand about space itself. It's saying that the vacuum itself has properties: it exerts a force that causes the universe to accelerate when you'd expect it to be decelerating through gravity's pull. I think this is one of the big challenges related to the very, very early universe. With dark matter, I think there's a reasonable hope, within the next 20 years, of making progress. With dark energy, I think it will be much longer.

Meanwhile, cosmology is increasingly embracing outlandish concepts such as the multiverse. Do you subscribe to that idea?
The multiverse comes from the theory of inflation, the best theory we have to explain why the universe is as large and uniform as it is now. It implies that it started off small enough that quantum fluctuations could have shaped the entire universe. One idea developed out of that, mainly by the cosmologist Andrei Linde, is eternal inflation, this idea that inflation might go on, producing many big bangs and many universes.

I was once at a panel discussion with Linde. Someone asked: would you bet your goldfish, your dog or your life on the multiverse? I said I was dealing with a dog level. Linde said he had spent 25 years on this theory, so he would almost bet his life. When asked his views at a later conference, [physics Nobel laureate] Steven Weinberg said he would happily bet Martin Rees's dog and Andrei Linde's life. But I think Andrei Linde, my dog and I will all be dead before it's settled.

One idea associated with the multiverse is the anthropic principle – that certain features of the universe are just so because if they were any different, we wouldn't exist to observe them. Isn't that a bit of a cop-out?
One of the theories that would explain what happened under the extreme conditions of the big bang – string theory – suggests that empty space, the vacuum, is not simple. It's got a microstructure, so there may be many different versions of it. Many big bangs might cool down in such a way that they ended up with a space with different conditions – a different strength of gravity or nuclear forces, a different mass of the electron. Only a subset of them would have had the properties that allowed life to emerge: for example, if gravity was very strong, objects as big as us couldn't exist without being crushed, so we need gravity to be important, but very weak. It's all speculative, but what it's saying is that reality is very complicated. There are many things we can't predict: the weather a month ahead, for example, because of chaos theory. What we now regard as universal laws prevailing throughout the observable universe may, in the grander perspective of the multiverse, be just parochial bylaws applying in our cosmic patch. I don't think you can call that a failure, just as you can't blame weather forecasters for not giving an exact weather forecast.

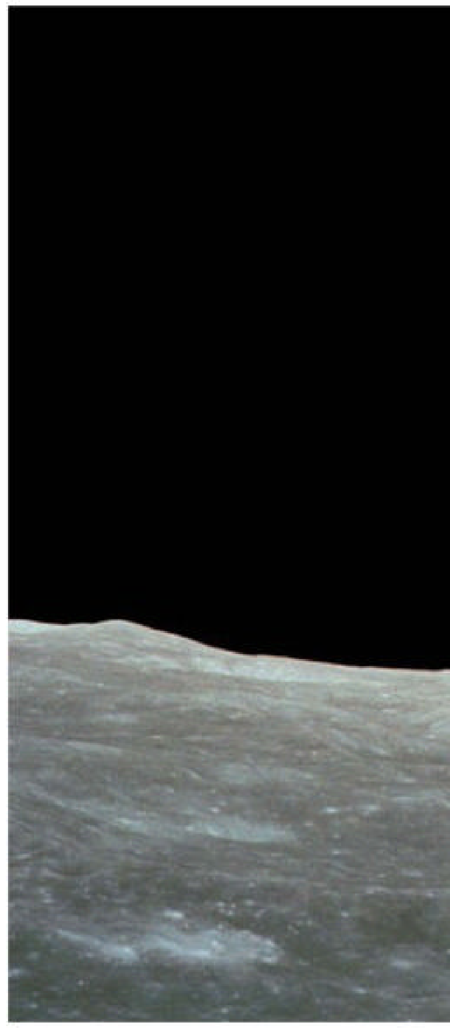
We have just seen the launch of the James Webb Space Telescope. What answers will it give us?
There are two important fields that it's going to illuminate. One is the very early stages of galaxy formation. About a half a million years after the big bang, the universe enters a literal dark age until the first stars form and light it ›

up again. We'd like to know whether these first stars form already in galactic structures or separately.

The second is the search for life in the universe. One of the most exciting developments in the past two decades has been the realisation that our solar system isn't that special. If there were an Earth-like planet around one of the nearest stars, the Webb telescope might be able to take a crude spectrum of its light.

We might be able to use this to show evidence of life. It is probably just about the limit of what it can do. But if I look ahead 50 years, I would hope there will be large telescopes in space that will not merely detect light from extrasolar planets, but even a blurred picture revealing their surface features. It would be great if by 2068 – 100 years after the famous 'Earthrise' picture (see right) – we could display an image of another Earth.

> "Any intelligent life out there is unlikely to be a flesh-and-blood civilisation, but some exotic, electronic entity"



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Is not just life, but intelligent life, out there?
My view is that any intelligent life is unlikely to be a flesh-and-blood civilisation, but some exotic and possibly malfunctioning electronic entity. The timespan of our technological civilisation is just a few thousand years, and it could be less than another 1000 before it's usurped by electronic entities. That is a very thin sliver of time, not only compared with the three and a half billion years of Darwinian evolution, but also to the billions of years that lie ahead. If there were another planet in the galaxy that had evolved like ours, it would be most unlikely we would catch it in this sliver.

Why stop at electronic organisms?
I completely agree. Since we are not the culmination of intelligence, we've got to be mindful that there could be aspects of reality of which we are unaware, which our brains couldn't grasp. And so it could be that there is complexity and intelligence out there of a kind different from anything we can envisage.

Talking of lifespans, two decades ago, you put the probability of our own extinction by 2100 at about 50 per cent.
I've since refined the arguments. I think the chance of something wiping out every human is small. On the other hand, I think the chance of some serious global setback to civilisation is quite high. This century is special: it's the first in which one species has the power to determine the future of life on Earth. Of course, we started saying things like that when nuclear weapons were developed. But they are expensive, they need special facilities to build and we can monitor them. Now we have bio and cyber weapons and genetic modification, for example "gain of function" experiments to make a virus more virulent or transmissible. Threats that can cause a serious setback to our interconnected civilisation can be created in labs, or even in someone's bedroom.

How should we be responding to these threats?
One thing we need is more resilience. Covid-19 has shown how dependent we are on networks: suppose the internet had failed during lockdown. We shouldn't depend on supply chains where a single link disrupts manufacturing, and we should keep a lot more slack in our hospitals.

But the ability of a few disaffected people to create a global catastrophe means we're also going to have to contend with a tension between three things we want to preserve: freedom, privacy and security. We may be forced to accept more intrusive surveillance as the price we have to pay to minimise the risk of catastrophe.

Climate change and biodiversity loss represent a different form of existential threat that we are failing to tackle...
The problem is that when something sudden like covid-19 happens, politicians and the public are immediately aware that they must do something about it, whereas, with these slow-burners, we are rather like the frog in the pot of water that is being heated – not taking action until it is too late to escape.

Do you despair at our inability to think longer term?
There's a paradox that strikes me whenever I visit Ely Cathedral, an amazing building just a few miles away from where we are sitting. It was built by masons as a structure that wasn't to be finished in their lifetime, but which still inspires us 800 years later. We can't think long term like they did. I think the reason is that those masons thought their grandchildren would live similar lives to them. Now, however, the pace of technological change means we

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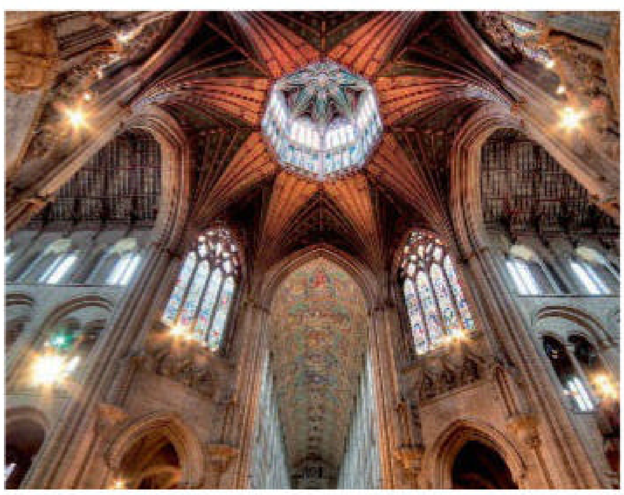

IVAN VDOVIN/ALAMY

"Earthrise" – an iconic photo taken aboard the Apollo 8 lunar mission (above). Ely Cathedral in Cambridgeshire, UK (below)

don't know enough about the preferences of people half a century in the future to be able to make confident plans. Although our horizons in space and time have hugely expanded, our capacity to do reliable long-term planning is less than it was in medieval times.

So meeting climate targets isn't enough to plan for future generations?
Even if a country such as the UK meets its net-zero target by 2050, that is only a small contribution. What's more important is what happens to the 4 billion people who will be in India or sub-Saharan Africa by 2050, and who are going to need more per-capita energy if they are to develop. If we can somehow enable them to leapfrog directly to clean energy, just as they've leapfrogged directly to smartphones having never had landlines, then that will be something which does more for the world than simply meeting our own targets.

When you started out as a scientist, it was the middle of the space race. Now, we're back there again. Is space the solution to our problems?
I think it's a dangerous delusion to imply, as Elon Musk does, and as my late colleague Stephen Hawking did, that there could be mass migration to Mars to avoid Earth's problems. Dealing with climate change on Earth is a doddle compared to terraforming Mars to make it habitable.

Should we be sending astronauts to space at all?
If I was from the US, I wouldn't want my tax money to go to NASA's space programme for human space flight. Miniaturisation and robotics are advancing fast, so the practical case for astronauts is getting weaker all the time.

What about Elon Musk, Jeff Bezos and the other billionaires attempting it?
They can do it more cheaply and can afford to take higher risks than NASA or any Western government could impose on publicly funded civilians. If you look back to the space shuttle, it was launched 135 times and failed twice, resulting in catastrophic crashes.

Each of those was a big trauma in the US. But a less than 2 per cent failure rate is acceptable to test pilots and thrill seekers. If Messrs Bezos and Musk want to have a programme of human space flight for thrill seekers prepared to take a risk, that is great. But they shouldn't present it as tourism.

One reason why I wish them luck is that human enhancement is going to be strongly regulated on Earth. But if there are these guys in a hostile environment on Mars, they would have every incentive to adapt themselves to that environment and they'd be away from the regulators. So if there is to be a post-human species, then it could evolve fastest from the progeny of these bold pioneers.

Which achievements are you most proud of when you look back on your life as a scientist?
I wouldn't claim any great individual achievements, but I think I've been very lucky to have contributed to exciting debates that have led to a growth in the understanding of the cosmos, galaxies and stars.

I think when the history of science in this half-century is written, then the expansion in our understanding of the cosmos will be one of the exciting chapters. ▮

Richard Webb is executive editor at *New Scientist*