On the Best Use of Science to Safeguard Humanity

For 50 years, the astrophysicist Martin Rees has contributed to our understanding of cosmology. Now he is speaking up about the promise and potential dangers of the science and technology that will arrive over the next 50 years and beyond.

By Claudia Dreifus

Tom Medwell for Quanta Magazine

Martin Rees at his home in Cambridge, England.

Over in Great Britain, the 76-year-old Cambridge-based astrophysicist Martin Rees, Lord Rees of Ludlow, is a respected figure not only for his scientific contributions but also for how he straddles the difficult territory between science, politics and literature with rare ease and confidence.

Since the 1960s, in more than 500 papers, Lord Rees has been adding to our understanding of key cosmological discoveries — especially those relating to the early universe, galaxy formation, dark matter, extreme cosmic phenomena and the possibility of a multiverse.

In the public square, Rees holds the honorary title of Astronomer Royal and is one of the 23 holders of the Order of Merit, an award personally made by the queen. Among the many academies to which he belongs is the Pontifical Academy of Sciences — an international group of up to 80 scientists of all faiths and none — where he participates in discussions on earthbound issues like climate change and bioethics. As a lifetime member of the House of Lords, he speaks and legislates on science policy issues.

A past president of the Royal Society, the British equivalent of the American National Academy of Sciences, Lord Rees is also the author of eight books of popular writing on scientific and political subjects. Rees' latest book, *On the Future: Prospects for Humanity*, has just been released by Princeton University Press.

In it, Daniel Ackerman of *Scientific American* writes, "Rees neatly packages his sprawling subject matter into a guidebook for the responsible use of science to build a healthy and equitable future for humanity."

We spoke with Rees last month while he made a breathless visit to New York City to promote the book. Between calls at Neil deGrasse Tyson's office, a luncheon at *The New York Times* and a speech at the 92nd Street Y, Lord Rees sat down with *Quanta* for a two-hour one-on-one.

An edited and condensed version of the interview and of an hourlong subsequent telephone conversation follows.

Are you one of those people who knew from childhood on that you wanted to be an astronomer?

No. I didn't know from the start what my vector would be. I was good at maths. And so, when, at the age of 15, I was required to pick an area to specialize in — that's standard in the British system — I chose mathematics. Later, while at Trinity College, Cambridge, I came to realize that I didn't enjoy mathematics enough to spend my life doing it.

For a while, I thought I might become an economist. However, through a series of fortunate accidents, I ended up being taken into the applied mathematics department in Cambridge, where I expressed an interest in cosmology and astrophysics. I chose the subject before I was knowledgeable about it, but after a year I was happy that I made that choice. The 1960s were a remarkable moment in astronomy. The field was opening up dramatically right then.

The other thing was that this department had an outstanding supervisor, Dennis Sciama, a great lecturer about relativity and the author of *The Unity of the Universe*. Sciama attracted many interesting students to his group. Stephen Hawking was one.

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What was Hawking like in those days?

He was two years ahead of me and doing his doctorate with Sciama. His disease had just been diagnosed, and he thought it would kill him off in two years. One could see how that really galvanized him. He got married. He did some very good work, including his Ph.D. thesis.

What is amazing is that he survived for 55 more years. I've said this before: Astronomers are used to large numbers. But few are as large as the odds I'd have given of him surviving for another half century and enjoying this amazing crescendo of achievements and fame.

Did you and Hawking collaborate at all?

Our lines of work somewhat diverged. He went to sort of mathematical physics, whereas I stayed with phenomenology physics. My work had more links to observation.

Can you tell us more about why the 1960s were such a remarkable moment in astronomy?

Well, so much new information was coming in. You saw the first evidence of the Big Bang, black holes, quasars.

Think about this: I was only a first-year graduate student in 1964 when Robert Wilson and Arno Penzias discovered signs of the cosmic microwave background radiation [CMB], a relic of the Big Bang.

At the time, there were people who didn't believe in the Big Bang. Some people believed in the steady state theory, according to which the universe was there forever with an infinite past. But once we had that first observation of the CMB, then, very quickly, two or three more observations came in, and the Big Bang was accepted. Similarly, the first pulsar was observed in 1967, and a consensus that pulsars were neutron stars emerged very quickly.

By the late 1960s, cosmology was a burgeoning subject. I think it's very important for a young scientist to work in an area where new things are happening.

Why do you say that?

Because if you go into an area that is fairly stagnant, the only problems you'll be allowed to tackle are those that the older researchers got stuck on. Or couldn't do.

Whereas, where things are developing — either new observations, new theories or new techniques — you might have a chance to do things that the earlier generation couldn't. In such situations, the experience of the old guys is at a heavy discount.

How did that work out for you?

I got the chance to build on these discoveries. I was able to make contributions to our understanding of the origins of the cosmic microwave background radiation and also on galaxy clustering and formation.

Frankly, my style of thinking, which I'd describe as synoptic or synthetic rather than involving long

inductive chains, is well suited to a subject in its early stages. I like to be at the beginning of a subject and think out the general ideas rather than the details.

That's been a feature of much of the work I've done. That was certainly true when I put forward early ideas on how quasars might be powered — by enormous black holes. And it was true of the papers I wrote in the 1970s on the key physical processes in galaxy formation.

With the CMB, it was important to explore whether there were alternative explanations that didn't attribute it to the Big Bang. That remained an open issue until the early '70s. I wrote a somewhat perverse paper in 1972 to explore the possibility that it could have been generated by shock waves during the cosmic expansion — but the observations soon became precise enough to rule this out. There was further corroboration of the Big Bang model: It explained the proportions of helium and deuterium in the universe. By the 1970s we had, at least in outline, a model for cosmic history extending back to the first second — huge progress from the early 1960s, when there was no clear evidence of a Big Bang at all.

I think I was also the first person to publish a paper discussing the polarization of the microwave background. I did that in 1968. It would be about 30 years before that was observed.

Did you find the gap discouraging?

No. Astronomers know that it's possible to imagine something and that it might take decades for it to be observed. The Higgs boson took 50 years to go from prediction to observation.

Is patience a professional requirement for a cosmologist?

I'm not patient. I've got a short attention span. That's why, at any one time, I'm working on a variety of things.

Over the years, this has been an advantage. It's meant that I didn't have a huge stake in any particular idea. There are scientists who work on one idea for so many years that they feel proprietary about it. I've tended to square my bets.

There are times when I'll work simultaneously on two different interpretations of the same phenomenon. I don't feel the need to commit to a particular belief in order to be motivated. I just want to know the answer. Sometimes, the best way to know the answer is to explore different options and see which one hits the bottom first.

You suggested earlier that the 1960s were a golden age for discovery. Are we living in a similar time today?

I think so. The last five years have seen significant breakthroughs.

To list a few: We've had the detection of gravitational waves, more understanding of exoplanets, detailed observations of the microwave background, new theoretical ideas on galaxy formation and on observing the pre-galactic stage of the universe.

These were facilitated by two developments. One: more powerful telescopes on the ground and in space. Two: better computers.

In astronomy, we can't do experiments, and so we depend on computer simulations to a greater extent than other scientists. For example, we cannot crash two galaxies together. But a computer

might be able to calculate what that would look like. We can then compare that model to things we see in the sky.

Of the recent breakthroughs, which excites you most?

Exoplanets. Well, I think *everyone* is excited by that.

At the most obvious level, it makes the night sky far more interesting. You realize that every star is orbited by a retinue of planets, just as the sun is orbited by the Earth and other planets. You recognize that there are probably in our galaxy billions of planets like the young Earth — in the sense that they are about the size of the Earth and at a distance from their parent star so that water can exist.

There's a hope that within 10 or 15 years we'll be able to directly observe some of those Earth-like planets circling around nearby stars. We can't do that yet. The evidence on extrasolar planets is indirect. Observers detect their effect on the brightness or motions of the star they are orbiting. But there are new telescopes coming that should be able to detect and analyze the light from exoplanets orbiting nearby stars. I'm thinking here of the James Webb telescope, and even more the ELT, short for Extremely Large Telescope, being built by a European consortium in Chile.

That will be the world's biggest telescope. And it should tell us if those exoplanets have continents and oceans, and perhaps if there's evidence that they have a biosphere.

Conventional wisdom has it that scientists do their best work while young. As an astrophysicist in his mid-70s, what do you think?

There may be something to that. Young people do have more powers to concentrate and a lot more time.

I've noticed that there are three ways in which scientists grow old. Some stop doing research and drop out to do other things. The second group gets bored and overreaches by going into new fields where they don't have the background — Linus Pauling, William Shockley and Fred Hoyle come to mind there.

A third way is just to keep on doing what you're good at and accept that you may not be scaling more than a plateau.

Where are you?

I would say a mixture of the first and the third. I still look at the arxiv every morning, but I'm spending a larger fraction of my time with nonresearch things like writing books and participating in public affairs.

Freeman Dyson says old people shouldn't write papers, they should write books.

Tom Medwell for Quanta Magazine

Rees' latest book was released in the U.S. by Princeton University Press in October.

You've certainly been doing that. *On the Future* is your new book. You are also a non-Catholic member of the Papal Academy and an active participant in the House of Lords.

I've always been politically engaged. As a student, I went on marches and protests. I've been a member of the Labour Party for more than 40 years. In the last few years, I got to an age when I felt I could do something else in addition to my research, and I've done more public engagement.

As a member of the House of Lords, the second part of Parliament, I've been involved in ethical issues. Should we allow assisted dying, embryo research?

I haven't introduced any important legislation, though I've been involved in the production of reports on various issues in science and technology. Mostly, there I've become involved in long-term issues that are underdiscussed: these high-consequence, low-probability threats arising from a heavier footprint on the planet and also from new technology, which is one of the main themes of my new book.

However, my day job is still to think about the universe. That's still what I'm paid to do.

In your book, you make some forecasts about the future. Are scientists good at prediction?

We have no worse a record than anyone else. We're better at it than economists!

In my book I distinguish things we can forecast with confidence and those we can't. I look at the next 50 or so years. And what we can predict are two things. First, the world is getting more crowded. Barring some utter disaster, we can predict there will be 9 billion or thereabouts people by 2050. The second firm prediction is that the world is getting warmer because of the effect of CO_2.

And do you see any solutions to these?

Well, I do write about how challenging the climate change issue is. You're asking people today to make some sacrifices for the benefit of people in remote parts of the world and 50 years in the future. That's difficult for politicians to do.

I think the only effective recipe is a win-win situation where we try to promote more rapid development of clean energy. The only realistic way to stabilize carbon emissions is enhanced R&D in the hope that it will bring the cost of clean energy down to that of coal-fired power stations — so that India, for instance, can leapfrog directly to carbon-free energy.

As enthusiastic as you are about improved technologies, you also sound alarms about some possible dangers with biotech and cybertechnology. You write that both may require some curtailment of individual liberty.

I say that because of them, there is a growing tension between privacy, security and liberty.

With cyber, one organized group can create a serious catastrophe by destroying the electricity grid in a big chunk of the United States. In the bio area, it's the same. It's been shown in experiments on the influenza virus that you can make it more virulent, more transmittable.

My worst nightmare involves some fanatic somewhere who thinks that the world has too many human beings. Such a person would have no compunction about releasing some kind of pathogen. And this is the kind of thing that could be done by someone with access to a laboratory. It's nothing very special. It's not like making an atomic bomb, where you need large conspicuous facilities.

So my concern is that these potentially dangerous techniques are often easy to do and difficult to regulate on a worldwide basis, even though their impact can be worldwide. Global regulation of the drug trade and tax laws hasn't worked well. In fact, we've had precious little success in either of those.

The reality is that the global village will have its village idiots, and we can tolerate them less because they could have global range.

In the book, you spend six pages discussing the Large Hadron Collider. Before it went online, you wrote of potential long-shot concerns the LHC might trigger a destructive process. Why?

Other people brought up these concerns. I was one of those who responded to them with reassurance. But I mention them in my book because whenever the stakes are high, it's prudent —

indeed it should be obligatory — to conduct an exhaustive risk assessment.

As it turned out, the physical processes and the collision speeds you get in the LHC are not unprecedented: They have occurred in nature owing to collisions of cosmic ray particles. I myself wrote one of the papers saying that these conditions had happened naturally and that we shouldn't be worried.

But why bring it up at all?

When the stakes are this high — on this and any other similar issue — you've got to be confident at the level of one in a billion. You just can't be wrong. The idea of "tearing the fabric of space" had earlier been raised in a serious paper by an eminent Harvard professor [Sydney Coleman]. So the public surely expects physicists to explore the possibility and reassure them, at the level of a billion to one, that this can't happen.

And I think it's right that if people are going to explore domains of physics not previously explored — or if biologists are releasing a novel pathogen — they should surely think hard first.

Looking to the future of your own field, what discoveries do you see coming in the next 20 to 50 years?

A lot of what will happen will depend on advances in technology. Improved computing will give us the power to model and understand the new information we'll be receiving from more powerful telescopes. For example, the European GAIA satellite found data on more than a billion stars. We can now analyze that. It's something we couldn't have done a few years ago.

I think a second area is understanding extreme phenomena. The study of gamma ray bursts, one of my main interests, goes back 25 years, and we now have at least the outlines of a model. And fast radio bursts are a new phenomenon that's still a mystery, which will be debated until a general consensus firms up.

And I hope we also have advances in the study of angular fluctuations (and perhaps polarization) of the CMB. That will perhaps give us some diagnostics of the very early era — the first trillionth of a trillionth of a trillionth of a second — which is when inflation might have occurred. There's hope of that from the Simons Observatory in Chile and the University of Chicago–led experiments at the South Pole.

I'm hoping we'll see more theoretical ideas from particle physics, which has given us little firm theoretical progress in recent years. The goal is a theory that could unify the strong interactions and electroweak interactions — and better still bring in gravity. That would allow us to firm up some physical ideas that will be applicable to the very early universe.

The problem is that before the first nanosecond was up, the physical conditions in the universe were far more extreme than we can simulate in the lab, even in a big accelerator. And so we don't have any firm data.

Nor do we have good theory. I would hope that in 20 years we will have some better data and better theories that will allow us to understand the very, *very* early stages of the Big Bang and that will tell us why our universe contains the mixture of atoms, dark matter and radiation that we observe.

And it will also perhaps tell us a bit more about why the universe is expanding the way it is — and whether our Big Bang was the only one.

All of those questions are still speculative. But if I look back to when I was a student, at that time, there was no evidence really that there was a Big Bang. Today, we can talk with confidence about the Big Bang back to a nanosecond.

That’s huge progress.