Overview

Professor George Ellis delivered the lecture "The multiverse, ultimate causation and God" on 6 November 2007 at the Howard Building, Downing College, Cambridge. A transcript of the lecture can be viewed at:

http://www.st-edmunds.cam.ac.uk/faraday/CIS/Ellis/

The lecture was followed by questions from the audience and later a dinner/discussion at St Edmunds College. A transcript of the discussion follows. The contributors are described at the end of the discussion.

The multiverse, ultimate causation and God

Post-dinner Discussion – 6nd March 2007

Bob White: I have asked John to give some thoughts to start us off.
John Polkinghorne: Well, fairly briefly, I must say. Let me start off by thinking a little bit about the explanatory power of the multiverse. It's pretty clear that simply being allowed to hypothesize a large ensemble of entities, with as many different properties as you like, can't explain anything because obviously you can insert anything into it. So the ensemble has to be specified in some way and consequently there has to be a motivation for the particular form that the multiverse takes. The motivations are the ones that you discussed, of course, in your talk: string theory, or replacement theory, or some combinations of those and so that's an absolutely indispensable part of the business.

Now I have to say – I'm an old chap, remember – I was in particle physics in the twenty five years that it took to essentially bring into being the standard model of structure of matter and of course during that time there were some very brilliant physicists around, Feynman and Gell-Mann and people like that, but it was basically experimentally-driven. Later it began to change. I think it's fair to say in the last thirty years fundamental theoretical physics has been extraordinarily speculative in its character and it's given itself a great deal of liberty in doing that.

Let's for example think about string theory – and I realise I'm speaking in the presence of string theorists. It's entirely sensible to explore the richness of relativistic quantum theory, which we know is a very deep and remarkable theory, and to look at it in terms of one-dimensional or higher-dimensional structures is a very worthwhile thing to do. But to suppose that somehow or other we can second-guess nature sixteen orders of magnitude beyond that to which we have direct experimental access is a pretty bold thing to do. And the lessons of history are strongly against such a project. So it seems to me that people are essentially saying (some more tactfully than I'm saying it) that there has been a degree of speculative licence that needs reigning in. String theory was just starting as I left the subject (I think there was some sort of connection between those two - I knew my limitations!) Initially the hope was it was going to be an almost unique theory. Now of course we know it's not because of all the problems presented by the extra dimensions. People now say perhaps 10^{500} different universes result and they don't hesitate to say that therefore there must be 10^{500} different universes in which all these things are realised. Well maybe, but equally maybe not. I think that's pretty bold. And even if there were, even if we have a landscape and all that fantastic variety, it isn't quite clear to me that it solves all the fine-tuning problems. Lurking in the back of certainly popular expositions which is all I'm capable of reading these days, is the hope that if you have enough different possibilities you're bound to find what you're looking for. But that isn't obviously true. You can have an infinite ensemble which totally lacks the property that you might need.

To take a trivial example: there are an infinite number of even integers but you won't find the property of oddness among them. It's not clear to me whether, for example, the extraordinary small value of the cosmological constant is to be found in the landscape. It seems to me that's a speculative hope.

So I think these are the jaundiced, grumpy remarks of an older man, not totally out of chime with your own remarks, George, even though you're nowhere near as old as I am! I think we have to be careful. I must of course say that, obviously, if you want to explain fine-tuning theistically you have to motivate also belief in the existence of God. I think there is a cumulative case for the existence of God which might include fine tuning but which certainly has a number of other components to it, such as religious experience and such as the rational structure in the world, rational beauty and transparency and so on. So there is a cumulative case on one side and it seems to me that the multiverse is there essentially to explain or try to explain away, the threat of theism.

Bob White: There's a challenge! Jeff, do you want to come back as a grumpy old man?!

Jeff Murugan: I guess I'm neither old nor grumpy so I guess the way I feel about it is that any sort of claim that string theory is the theory of everything and all of that stuff is significantly over-hyped. Even after thirty years we still don't understand what the fundamental degrees of freedom the theory are, and so claiming that it's the theory of everything or even if it's the theory of fundamental interactions at this stage is still very, very early.

The hardest questions to ask about string theory are questions of a cosmological nature. They are very easy questions to pose but they are notoriously difficult to even formulate properly. So asking questions about whether string theory is able to explain inflation or even the ability to get a solution out of string theory is a very, very difficult thing to do. Personally I feel that it's very pre-emptive and very immature to say that string theory has 10^{500} solutions or even an infinity of solutions, whatever infinity means, basically because you are setting up a straw man and then you're shooting down the straw man and saying this is it for string theory. I'd rather we'd take time, even if only some settled scientists insist on continuing with this, to understand the degrees of freedom in the theory before actually setting down something like this. So that was one point.

The second point that I'd like to make is that the question of the predictability or testability of anything involving the multiverse comes down for me, I guess, to the question of what actually explanatory power means. If I ask why this glass sits on this table, sure, if I have an infinite ensemble of universes somewhere, in one of those universes there's going to be a glass that sits on the table as opposed to falling through. I wouldn't consider that an explanation, though. Any explanation for me would come from understanding the molecular structure of the glass that makes it structurally stable against falling through the table, even though molecules consist of atoms and atoms are mostly space. That's what I would consider an explanation, so from the point of view of the multiverse I wouldn't say particularly that it has explanatory power at all until you tell me that in some ensemble of universes there's a measure on which I can make any observations, so I've got to tell you the probability of getting out a particular solution.

For me a stronger statement would be one of dynamics. I think everybody that says things about, you know, I have six fundamental numbers and I've got to explain to you what these numbers are, that's six dimensional spatial parameters if you want to think about it that way, a huge space. So if you can find the dynamical mechanism that allows some basis of attraction, that tells you where in this six-dimensional parameter space you're allowed to be, because I don't believe that there's one unique point in the six-dimensional space for which all of these values will be fixed the only value that will allow that. I think that if you say to an order of magnitude I need to get the fine structure constant to be one over one-thirty-seven, that's one order of magnitude I have to play with in a six dimensional space. I think it's more likely – I shouldn't use a word like likely – but I think it's more *plausible* that in a six dimensional parameter space there's a basin of attraction that dynamically allows my solution, whatever the initial conditions are, to evolve towards this. That's what I would be looking for as opposed to one specific point that I need to explain specifically why one over one-thirty-seven is OK.

Bob White: Anybody else?

George Ellis: Well, firstly, Susskind was absolutely explicit in his book that he was producing a multiverse as an alternative to theism.

John Polkinghorne: Yes, I've read the book

George Ellis: Whereas some of the other ones aren't but in his case the motivation is absolutely clear. Martin Rees writes a lot about this issue precisely because Martin sees so clearly the problem of anthropic fine tuning. Martin has thought about it and really sees the problem of anthropic fine tuning which is why he's bought into the multiverse.

In terms of Jeff's point, the question of the measure is a crucial one, which just isn't sorted out yet. As to the physical basis of life, that's a really interesting one in terms of the anthropic kind of issues. You've got life over here, and over there you've got your fundamental theory and in the middle you've got an effective theory. Now what we know from the parameter studies on the anthropic side is that there's a subspace in this parameter theory which allows life to exist. If there was a mechanism whereby your fundamental theory always made the effective theory of parameters move into that subspace, or if you have a fundamental theory that gives you a unique point, it actually doesn't solve the problem, it makes it worse because you've got your mechanism there which is based on symmetries and SO10 and U-5 or whatever, and it produces a single point or small region here in the basin of attraction. *Why* does that lie in the domain here which allows life to exist? That would become a far more difficult problem to solve.

John Polkinghorne: That would be the greatest coincidence of all

George Ellis: Yes, that would be the greatest coincidence of all. If SU 10 or 25 has got written into it in some sense an anthropic result because it necessarily lands you up in the effective theory precisely in such a place that allows life to exist, that would seem to be a really amazing and extraordinary thing to explain.

Bob White: Thank you. Does anybody have comments on this issue of multiverses being postulated to explain away theism?

Bernard Carr: I'd like to make a comment here because I'm organising a meeting entitled "God or Multiverse?" in a few weeks time. In 1979 I wrote a paper with Martin Rees on the anthropic fine-tunings. At the time it was regarded as quite a fringe idea and a lot of physicists were very opposed to anthropic arguments. The notion of the multiverse has led to a shift of opinion because some physicists see the multiverse as a legitimisation of the anthropic principle. As a result of my paper with Martin, I was quite often invited to theological or science-and-religion meetings, and I found myself in a sort of schizophrenic state, where I was saying to the theologians “Look at these coincidences - they could be seen as evidence of a creator” and to the physicists “Well you can explain them if you have an ensemble of universes” for even before the multiverse became a popular idea through string theory, we were talking about the possibility of many universes as an alternative to a creator. From a sociology-of-science perspective, this was important because I think part of the antipathy to the anthropic principle from physicists arose because they felt it smelt of theology. They were afraid that the only way to explain it would be *was* to invoke a fine-tuner.

Now there is a famous quote from Neil Manson that “the multiverse is the last refuge for the desperate atheist” and I partly agree with this. For if there really is only one universe, you’ve got a problem trying to explain these fine-tunings and might well be forced into a theological direction. But if there is a multiverse, you’re not compelled to invoke God. However, to back up something George said in his talk, in another sense the existence of a mulitverse is irrelevant. For if God could create a universe, He could clearly create a multiverse, so I don’t think it’s fair to say that if there’s a multiverse there can’t be a God. On the other hand, if there’s only one universe, you may need to invoke God, so that’s why I think the issue of whether there is multiverse is crucial to theology.

One point where I would differ from George is that he is saying there’s no evidence for these other universes, so it’s not proper science. However, if you have a theory which predicts the multiverse, then verifying that theory would provide indirect evidence for the multiverse. For example, some people say that M theory predicts the multiverse, but the trouble is that maybe M theory itself can’t be tested, so that’s another problem.

John Polkinghorne: So do you think there is a theory that predicts this that encourages the speculation?

Bernard Carr: Well in principle M theory does, at least if you believe the “landscape” interpretation. This particular form of theory suggests that there is a different universe associated with each possible vacuum state and that there are many possible vacuum states.

John Polkinghorne: I think it’s a possibility but as I said, it isn’t clear how big the landscape is or whether it necessarily has the point of everything you want.

Bernard Car: I agree that might be the case but it all comes down to whether M theory - or whatever the theory turns out to be – is independently testable. All I would say is that it’s not fair to say the string theory doesn’t qualify because it hasn’t solved all our problems after only twenty years. Because it might take a hundred years and the question is how long are you prepared to wait before you say it’s proper science.

John Polkinghorne: I once met Pauli and Pauli used to wag his finger at people and say “No credits for the future”.

Bob White: Paul – another cosmologist

Paul Shellard: I wanted to follow up the discussion about whether the multiverse really solves the problem of design since we have these fine tunings because you know the fine tunings that life depends on, it's not one fine tuning it's a coincidence of fine tunings. In the space of all universes there are small parameter regions, for each parameter there's a small region, and for some reason they coincide, they overlap it's like Venn diagrams, they have to have an intersection for life to be possible in the multiverse. So if they didn't intersect, and logically it's possible, then the multiverse would be frustrated in some sense, sterile and lifeless, so I was wondering if the multiverse really does the job in solving these problems. It doesn't necessarily logically solve it, it's just expected to. I say this following up from what John said.

George Ellis: Just one comment: there's kind of this assumption in the multiverse community that all of these universes are different, however if you think of this machine that stamps out universes in the spirit of evolving and testing things, this machine might discover a good universe and then stamp out 10^{500} copies of this one, instead of all different universes!

Bernard Carr: You have to take the view that some of these constants are contingent, otherwise there's no point.

George Ellis: But where is the space in which the mechanism lives which governs the constants of things?

Bernard Carr: Well, in M theory the hope is that everything is related to the vacuum. That is, once you've got a particular vacuum state, you have a unique theory. But I'm not an expert on M theory.

Jeff Murugan: I have a point regarding Susskind's statements about the multiverse and so on. When people talk about the 10^{500} vacua they are talking about specific solutions to specific couplings fixed and specific fluxes fixed and stuff like that. It's all very well for them to say there's 10^{500} of these guys but there is, as far as I know, just one explicit construction and it's an incredibly difficult construction, an entire *tour de force* that involves algebraic geometry to fix all these fluxes consistently and that's in a very technical paper by Florien, Deneff and Douglas? To talk about these 10^{500} vacua actually showing that one of these vacua solutions itself is a consistent solution is an incredibly difficult problem, so it comes down to what I was saying earlier in that we really don't fully understand the theory at all. So never mind finding solutions to these things, it's actually identifying what it is you are working with in the first place that makes it so difficult. So there's a long way to go before we can start answering questions about what exactly it's able to tell us about the nature of the Universe.

Bob White: Can I ask whether biologists here want to contribute anything because it's said that the human brain is the most complex thing in the universe and the Universe is simple by comparison with biological systems. Do any of you biologists have any reflections on this?

Derek Burke: I'm afraid that can't help you there. I'm sitting here, envying you people talking about the theory of everything, even if you think that there is still more to do. As a biologist, and I've been in biology ever since the Watson and Crick structure in 1953, we've had a different sort of experience in that we know there are parts of the biological world we understand very little, for example how the brain works. But our experience is perhaps a little bit like yours in that totally disparate areas of biology have pulled together to give a coherent picture. For me it started when I was on the Cunard liner 'Georgic' in September 1953, going to Yale as a post-doc, and Jim Watson was on the boat and he said about their famous paper which had been published quite recently: "Oh we just built some models and it all came out". Well, it wasn't quite as simple as that but the Watson and Crick structure for DNA was profoundly influential for 50 years.

I worked for many years with viruses and immune system regulators and they became increasingly complex but what is extraordinary is that, as you work away at each area, what you find is totally consistent with what's coming out of other areas. There is a coherent picture 'out there'.

We biologists work with rather simple analogies – for us it's like taking the skin off an onion, and finding another layer, which is often more complicated than expected, but it has pattern and structure and significance; and then you take off that layer and there's another layer underneath. So it's a different experience but in some ways perhaps the same, in that the very stuff of which we're made has a unity. Of course from a Christian point of view that's perfectly compatible with our faith, but I think that we biologists don't have anything to offer about life in multiverses.

Bob White: Paul, you see life in another universe because you're head of a college – you see all kinds of life!

Denis Alexander: Just a slightly different point to Derek's. We were talking earlier about physics as a hard science, the bedrock of the other sciences, with biology emerging out of physics. Yet it's ironic that at the moment physics seems to be going through this extremely speculative phase which you've outlined for us, whereas biology is going through a very mechanistic, 'physical' phase in a way. Look at a review paper about cellular signalling pathways or molecular biology and its Figures are full of mechanistic detail. Machine analogies work just fine at the moment in the biological sciences, whereas in much of physics, machine analogies were left behind a long time ago.

I actually want to come back to a question that Bob was hinting at earlier on. I thought that there might be more scope for discussion of the degree to which the cultural atmosphere within a society facilitates the emergence of particular scientific theories at certain periods. I wonder whether post-modernity isn't playing a role here in terms of people's attitudes towards these highly speculative theories, which in a more modernistic era might not have been received so favourably. I wondered if that thought could be batted round a bit.

Jason Rampelt: These fashions come and go and you tend to take the long view as a historian. I think Denis is right, there are some more heavily theoretical, more heavily empirical periods. I wouldn't be equipped to judge about cosmology in modern physics at the moment so I had better leave that to the professionals!

Simon Mitton: What I would say from my studies in the history of cosmology is that most of the time throughout history the cosmologists have thought themselves to have the correct point of view. Most of the time until very recently the number of cosmologists stalking the planet has been between zero and one in the times of Ancient Greece, and three or four when you get to the modern era. Even when you reach the time of the mid-twentieth century with people like Eddington, Hubble, Le Maitre, the Robertson-Walker Metric and so on, you are talking about only a dozen people in the whole world who are taking cosmology seriously. Now, in modern times, we've got this enormous industry and what worries me as a former publisher is that in string theory and multiverse and so on and so forth I see an absence of the strict application of the scientific method. I regard string theory and speculations about the multiverse as being metaphysics because they are not available for testing through experiment and measurement and so on, and I wonder if there aren't too many people doing this.

Amanda Weltman: Firstly, I want to separate between cosmology and string theory. Historically there may have been fewer cosmologists because it was certainly harder for it to be an observational science, which is not the case now: there's an enormous amount of data coming in. In many ways it's a very concrete hard science and it requires a lot of people to understand (**Simon Mitton:** I agree) so the question of string theory and the multiverse is perhaps separate to where cosmology itself is at in its current state. I would claim that having some percentage of people working on "out there" stuff which may never turn out to be true has always happened through the history of science in almost every field (**Simon Mitton:** I agree with that). I guess I'm saying we shouldn't curb our enthusiasm.

John Polkinghorne: These things always seem to go in phases. The reason that biology is so mechanical these days is that it's really come of age. You always make the mechanical discoveries first because they are the easiest ones to understand, which is very powerful and worth doing, but not the whole story. String theory came out of particle physics partly because particle physics was running out of experimental input and in fact it still has a fair dearth. As you say, cosmology has a fantastic amount of input.

Amanda Weltman: That's right, and possibly in the next ten years particle physics will ..

John Polkinghorne: We'll have to see what happens there.

Paul Shellard: There's the standard cosmology which is built on former experimental triumphs and there was a Nobel prize in cosmology last year from the cosmic microwave background, so it's a very firm experimental science but the general public lumps it all together with the latest speculative ideas and doesn't realise this.

George Ellis: Let's be a little bit fair about this, it's not the public who do that, it's mainly the people who write about it.

Paul Shellard: There's this point where the author finishes discussing cosmology and moves on to their own ideas and the reader is not always made very clear about this.

George Ellis: And that distinction is not always very clear.

Bob White: Jeff, and then perhaps we'll give George a chance.

Jeff Murugan: I'd also like to make one statement. Your statement was a very broad brush statement. String theory itself has a number of different subtexts. I in particular don't work on the theory of everything and unification, I'm trying to understand the structure of matter through … development. In my case there's a very specific set of problems we study. For example, I am trying to understand why hadrons collide together to give you specific experimental results. So what the number of people in the community do is very, very good for one experiment. And practically everyone that's up there is interested in understanding this problem so I would make a distinction between string theory and the multiverse stuff as well. I think a lot of the public take the very romantic notions of what string theory is and the theory of everything and Garnd Theory of unification and all that stuff.

Simon Mitton: But String Theory has not yet made any prediction which has been successfully tested experimentally.

Jeff Murugan: Absolutely. I agree with that – to some extent I do. Here's a prediction. The .. of reality for example predicts if you take a quartz?.. through a plasma .. .. if it's moving past the speed of sound there's a sonic boom generates, there's a .. angle that you cannot calculate in anything other than well .. has not managed to produce a definition of ..there's a prediction that comes out of it. If you test this, if it comes out wrong, would that disprove string theory? No it wouldn't because this is just one aspect of it that is testing. But I don't see string theory as a specific theory, it's like Quantum Field theory has evolved in the last couple of years to the status of a set of idea as opposed to a specific theory. So if you make an experimental prediction out of quantum field theory and the prediction comes out wrong, you wouldn't say that quantum field theory is wrong you would say that the specific model within quantum field theory is wrong.

Bob White: That's a "Get out of gaol free" card!

Keith Moffat: I think the whole thing has a sort of poetic quality, cosmology, string theory, the whole lot is beautiful, it's very appealing and it's an act of faith. I have a poem that I composed last year on this topic and I would like to if I may read it. I composed it because there was a competition called the *Moon Bounce* competition published by *The Times* and they invited poems as it was the 50th anniversary of the Jodrell Bank telescope and they proposed to send the winning poem to the moon and bounce it back (laughter) in two and a half seconds – and they did it. There was a beautiful poem that won – this one didn't! It was to be on the theme of space and time so if you permit me to read it.

Genesis: Cosmological Echoes

There was a time when Time itself stood still
And Triune Space was formless, void and vast;
No matter stirred, there was no eye to see
Nor mind to comprehend the vacant past.

And yet within this carapace of calm,
In subjugation to the laws of chance
Dark Energy lurked stealthy in the shade,
Provoking random waves in ghostly dance.

As when Earth's winds and waves perchance conspire
To focus energy in gathering storm,
In hurricane of chiral power immense,
Or maelstrom far exceeding any norm,

So these primordial space-time waves converged
With flux of energy t'ward caustic point,
Focus of pressure, infinite, intense,
Where graviton and photon were conjoint.

Such fusion of extremes could scarce endure:
Explosive stress induced chaotic schism,
Releasing pent-up energy as mass
In sonoluminescent cataclysm.

There was a time when molecules converged
In replicative mode precursing Life,
Genetic coding, helices that merged,
A spiral staircase to our world of strife.

Dark Energy still roams athwart the bound

Where lightning flits and quarks have ceased to churn,
That sphere in spectral darkness all begowned,
That bourne from which no echo can return.

Bob White: Well Keith, that will be the first poem on the Faraday Website.
I think I'll ask George to wrap up and give us some final thoughts in response to the comments we've heard this evening. Does anybody else want to say anything before we do that?
George Ellis: Where does this highly speculative stuff come from? It's partly because of the lack of data and so people have to speculate. Actually I will make one slightly caustic comment from the view of cosmologists. In my view the quality of argumentation in cosmology drastically declined when the particle physicists moved in [laughter!] because they brought in attitudes and a way of doing things which are fine in the particle physics context – you can make a rough and ready theory and it didn't matter how rough and ready it was because you could go to the collider and test it, but when you use that same method in cosmology you can't go to the collider and test it, then it becomes a bit disastrous. But where does the speculative stuff come from? It actually comes really from Einstein and Dirac, particularly Dirac. Before Einstein and Dirac people didn't speculate in this kind of way. Dirac predicted anti particles and they were discovered and everybody thought OK just by pure thinking we can work this stuff out, but of course Aristotle had tried this and totally and dismally failed. It was Dirac who persuaded people back into the idea that just by pure thinking, as Einstein did, you can predict the way the world is. So they unleashed these floodgates of speculation which we've had since then and I do think that this is now a tendency which we are seeing in cosmology from the particle physics side.

We've just done a special issue on dark energy for the Journal of General Relativity and Gravitation and people appear to think if you write down a Lagrangian, now that's physics. Just because you've written it down this matter or field exists. But just because you write down a Lagrangian does not mean that there's actually anything like that which exists out there in the real universe. But people seem to think that they do, they confuse their *models* of reality with reality and I think that's a real problem.
Bob White: I think that's a good note to finish on! Thank you very much everyone.

Who's Who

Prof. George Ellis FRS, is Emeritus Professor of Applied Mathematics and Honorary Research Associate, Mathematics Department, University of Cape Town; general relativity theory, cosmology, complex systems, the brain; co-author of *The Large Scale Structure of Space Time* (Cambridge University Press, 1973) and *On the Moral Nature of the Universe* (Fortress Press, 1995).

Dr Denis Alexander, Director of the Faraday Institute and Fellow of St. Edmund's College, cancer and immunology research, The Babraham Institute; Editor of the journal *Science & Christian Belief*; author of *Rebuilding the Matrix* (2001, Lion).

Prof Derek Burke, Honorary Fellow of St Edmund's, a former Vice-Chancellor of the University of East Anglia, a former Chairman of the Advisory Committee on Novel Foods and Processes, a former Specialist Adviser to the House of Commons Science and Technology Committee and a member of the Societal Issues Panel of the EPSRC.

Prof. Bernard Carr, Astronomy Unit, Queen Mary, University of London. Editor of "Universe or Multiverse?" (CUP 2007). Contributed article "Cosmology and Religion" in "Oxford Handbook of Religion and Science" (OUP 2006).

Judith Croasdell, PA to Stephen Hawking

Revd. Stephen Day, Assistant Curate, Waltham Abbey; graduated in Natural Sciences; worked in scientific and technical roles in research and industry for 20 years; trained for ordained ministry at Ridley Hall; ordained 2005.

Stephen W. Hawking CH, CBE, FRS, Lucasian Professor of Mathematics, Department of Applied Mathematics and Theoretical Physics, Centre for Mathematical Sciences, Cambridge. Author of many books, and prolific contributor to all areas of gravitational physics, in particular the origin and evolution of the universe. Best known for his work on Black Holes and for his popular best-seller, 'A Brief History of Time'. In 2006 he was awarded the Copley Medal.

Prof Antony Hewish, Emeritus Professor of Radio Astronomy, Cavendish Lab.
FRS, Nobel Laureate (Physics 1974, for the discovery of Pulsars).

Prof Paul Luzio FMedSci, Master of St Edmund's College; Professor of Molecular Membrane Biology, Department of Clinical Biochemistry and Director of the Cambridge Institute for Medical Research (CIMR); cell biology, protein localisation and function in cells; molecular mechanisms of disease.

Dr Simon Mitton is Fellow (elected 1973) and Treasurer of St Edmund's College. His Ph D in high-energy astrophysics was supervised by Martin Ryle at the Cavendish Laboratory. He was a research fellow and then departmental administrator at the Institute of Astronomy for seven years, following which he spent 22 years at Cambridge University Press as its science publisher and then executive director. Since 2000 he has been based at the College where his research interests are the history of astronomy and cosmology. He is the biographer of Sir Fred Hoyle. He is working on a biographical essay on Georges Lemaitre, cosmologist and prelate, the most distinguished alumnus of the College from the long period when it was named St Edmund's House.

Keith Moffatt, FRS, Emeritus Professor of Mathematical Physics, Fellow of Trinity College, and formerly Director of the Isaac Newton Institute for Mathematical Sciences; past President, International Union of Theoretical and Applied Mechanics.

Dr Jeff Murugan, Lecturer at the University of Cape Town in South Africa with a research interest in String Theory.

Revd Dr John Polkinghorne KBE FRS, Retired president of Queens' college and formerly Professor of Mathematical Physics (elementary particle physics). Author of many books on science and religion. In 2002 awarded a Templeton Prize.

Dr Jason M Rampelt completed his Ph.D. in the History and Philosophy of Science at Cambridge University and is pursuing the Institute's first research project in scientific biography. Dr Rampelt has also earned degrees in Philosophy (B.A., Case Western Reserve University, Cleveland; M.A. University of Pennsylvania, Philadelphia) and Theology (M.A.R., Th.M. Westminster Theological Seminary, Philadelphia). He is a research associate with the Faraday Institute.

Dr Alan Roberts, Faraday Associate and Research Associate in Geophysics; Dept of Earth Sciences; deep seismic structure of continental margins.

Dr Paul Shellard, Reader in Cosmology, Department of Applied Mathematics and Theoretical Physics; research on the early universe, cosmic strings, inflation, gravitational waves, cosmic microwave sky; director of the COSMOS supercomputer.

Radka Visnakova, Carer for Stephen Hawking

Dr Amanda Weltman, Postdoctoral Researcher in the Department of Applied Mathematics and Theoretical Physics and Visiting Fellow of Wolfson College; Faculty member of the University of Cape Town, South Africa; Research in Theoretical Cosmology and String Theory.

Prof. Bob White FRS, Associate Director of the Faraday Institute and Fellow of St. Edmund's College; Dept of Earth Sciences; volcanoes, earthquakes, climate change and other catastrophes; co-author of *Beyond Belief – Science, Faith and Ethical Challenges* (Lion, 2004).