The origins of the universe in science and philosophy

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It is [good] to be here in this planetarium… and I shall play the role of a star in this planetarium, but as I shall try to convince you it will be not a star, a shining star, it will be rather a black hole, because this will come out of my talk.

So let's go to what I want to present this evening and my topic is the origin of the universe in science and philosophy, and my talk, my presentation will be divided into two parts: part one is the origin of the universe in science and the second will be of course the origin of the universe in philosophy. So let's start with science.

PART ONE: in science

Science is a very great adventure of humankind and science is a little bit totalitarian – it aims at understanding everything. For instance, if we investigate a little small aspect or part of the universe, a little model of a small theory, so we want to comprehend, to understand something, it is only a part or an aspect of an entirety, and after all if that entirety should be unexplainable then why should this little fragment of our knowledge lend itself to explanation? In this sense every, even the smallest, success scored by the sciences is a sort of promise that somewhere, maybe still very distant, very far away beyond the horizon, there is an ultimate explanation. So in the background of all models and theories in the sciences there is a longing for the ultimate explanation. In the sciences there are small questions and there are big questions, but in fact even the small questions are somehow connected with the big questions and I think that the biggest question is 'how, when and why did the universe come into being?', and this is the subject matter of this talk.

Let's start with the beginning of modern science. In 1693 Richard Bentley, Canon Bentley, was supposed to deliver a talk about the religious and theological implications of the new science and he wrote a couple of letters to Newton asking him some very important questions, and Newton answered to Bentley, and one of the questions was the following: If the universe is dominated by the gravitational field, by the universal gravity, then why all the stars do not come into a single point? If everything is gravitating the universe should collapse to a single point. And Canon Bentley asked how to explain that the universe is stable, and Newton answered him that this question is very important, and he himself conceived

> "The reason why matter evenly scattered through a finite space would convene in the midst you conceive the same with me, but that there should be a central particle so accurately placed in the middle as to be always equally attracted on all sides, and thereby continue without motion, seems to me a supposition as fully as hard as to make the sharpest needle stand upright on its point upon a looking glass...
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> "And much harder is to suppose all the particles in an infinite space should be so accurately poised one among another as to stand still in a perfect equilibrium. For I reckon this is as hard as to make, not one needle only, but an infinite number of them stand accurately poised upon their points."
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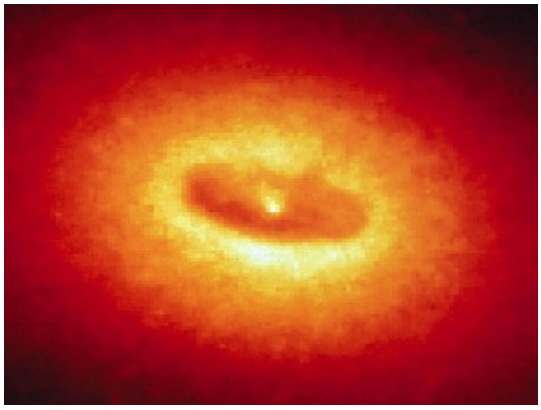
> **Isaac Newton, 1693**

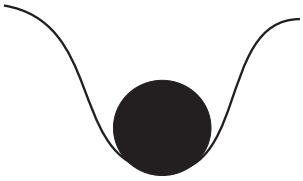
the same idea as Bentley thus, and he said it is a kind of miracle [if] there should be a central particle so accurately placed in the middle as to be always equally attractive of all sides and thereby continue without motion, it seems to me, Newton writes, a supposition as fully as hard as to make the sharpest needle stand upright on its own on a looking glass. So it is very hard to explain why the universe is not collapsing, and Newton adds it is much harder to suppose that an infinite number of particles would form a stable configuration, for I think this is as hard as to make not one needle only but an infinite number of them stand accurately poised on their points. And this is a problem of the gravitational stability, of the stability of the universe and this question is very important also in modern cosmology, and in fact we know nowadays that the universe is not stable as far as gravity is concerned.



Here we have a picture taken by the Hubble Space Telescope, it is the centre of a galaxy with New General Catalogue [NGC] 4262 (number of this galaxy). This is the centre of this galaxy and in the centre of this galaxy is a black hole and this black hole has engulfed matter into it and this circle here is a belt of radiation which matter is engulfed to the singularity, and this is exactly the gravitational instability that was foreseen by Bentley and Newton. But if we look carefully at this picture we cannot say whether this black hole is exploding or is collapsing because from the point of view of laws of physics almost the same. It is in fact collapsing; the matter is engulfed by the central black hole in it. Probably in many other galaxies there are black holes, also in the centre of our galaxy there is a black hole, so the problem of the gravitational instability is a very common one.

So let's look at that in the reverse time – let's imagine that this is explosion and this is how our universe seems to be evolved. This is a picture representing the explosion of the universe, also a type of gravitational instability but in a reverse time direction. So we have in the centre the Big Bang and from the Big Bang various cosmological eras develop. Here we have also our Galaxy era, Radiation era, all the history of the universe was in a kind of, as a seed in the initial what is technically called singularity, popularly the Big Bang. So the problem raised by Newton, the problem of the cosmological stability is in fact the question concerning the origin of the universe.

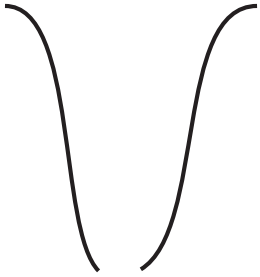
Let's try to understand this phenomenon a little bit closer. The modern theory of gravity is Einstein's General Theory of Relativity, and the main idea of general relativity […] you have here on that picture. Here, imagine it is a kind of rubber and we put on the rubber a little iron ball and the rubber is just distorted, is a curvature here. This is the main idea of general relativity: if there is no matter the space-time is flat, if there is matter, say a star or some conglomeration of matter, then the space-time around the star is curved and this is exactly the gravitational field. If we put here a little smaller ball it will roll down to the bigger star, we could say that the



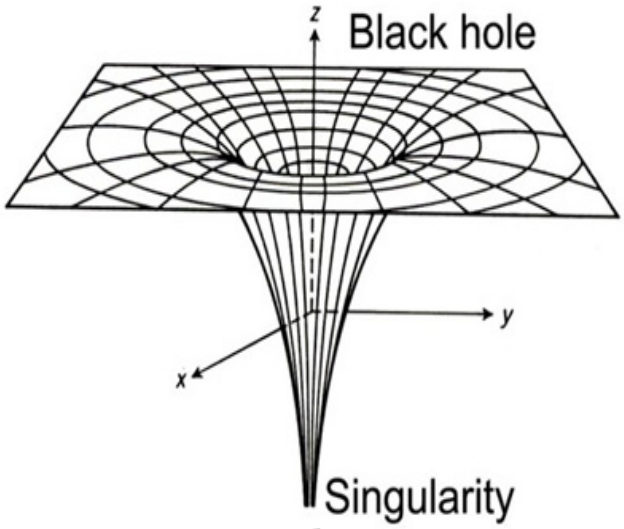
bigger mass is attracting gravitationally the smaller one, and this is the main idea of general relativity. We describe the geometry of space-time, the distribution of masses, and we compute the strength of the gravitational field. What happens if we put on the same rubber a heavier more massive piece of iron? And then of course the curvature will be more pronounced, the gravitational field is stronger. The main idea of general relativity is expressed in this equation which is called the Einstein equation […].

$$R_{ab} - \frac{1}{2} R\, g_{ab} = \frac{8\pi G}{c^4} T_{ab}.$$

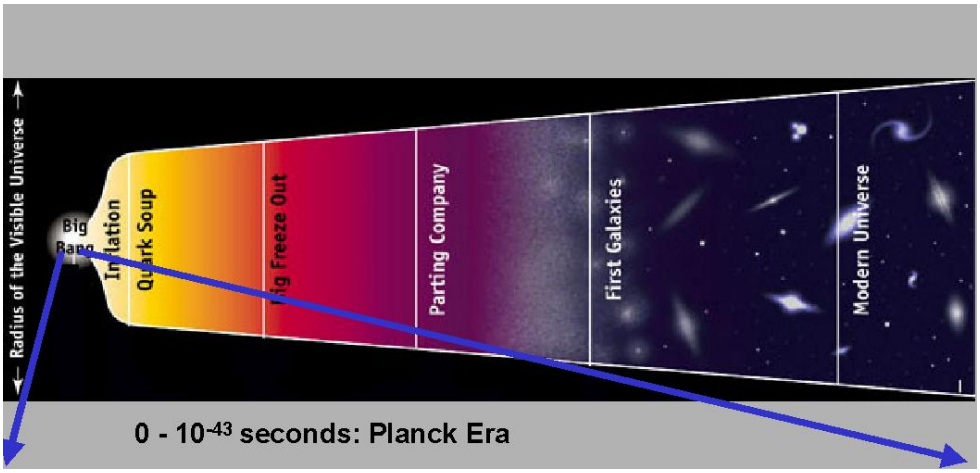
On this left side of the equation we have the geometrical expression which describes the geometry of space-time, the curvature of space-time, and on the [right] side we have the term which describes the matter, this ball here for instance, and the equation tells us how the matter here curves the space-time or how the space-time determines the motions of matter. This is the general idea of general relativity. And now let us put even heavier ball on the rubber, what happens? The ball will be just broken here, broken down, and this is in fact what is the singularity in cosmology. In popular books you will often read how the Big Bang is the point from which everything started, all the masses were congregated, were agglomerated in one point; it is not correct. The correct answer is that in the singularity, the Big Bang, space-time just breaks down and we do not know what happens. Even the concept of point is meaningless because point is meaningful only where there is a space-time, and there is no space-time here, everything breaks down here, and this is what is called the singularity at least as far as it is understood from the mathematical point of view. And here we have the same picture of this accretion disk, it's the astronomical name for this phenomenon, and this we have here the singularity and inside the black hole the space-time has been broken down and so this is the theory, theoretical model and we have here astronomical result […] and the begin of the universe was something like that, at least from the point of view of classical general relativity – classical means we do not take into account quantum gravity effects.



This picture is taken from a theoretical book on singularities. You have here space-time which is very strongly curved, here is singularity and space time is broken down here, and what was, let's use the term 'before' but not quite legally because 'before' supposes time and when space-time is broken there is no time, but we are sentenced to use our human language; so we can ask what was before and we do not know what was before, so this is the question mark. So if



we treat that picture as picture of the black hole, the matter is going back down the singularity and – question mark; if we think about beginning of universe there was something and suddenly the universe starts to expand so this big event…

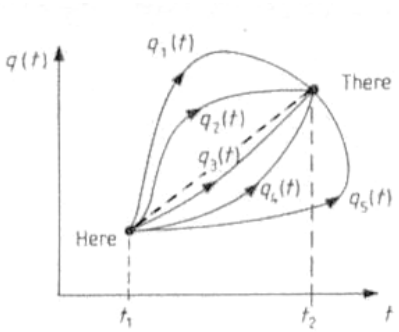


This is the history of our universe as discovered, as deciphered by modern cosmology; here we have the Modern era where the universe is [filled] with galaxies, here is the Radiation era and then we go back in the history, as time goes back the universe is contracting and contracting and here there should be a singularity, but before, if we will agree to put our cosmic clock here and to say that the time here is zero, then at time 10 to the minus 43 seconds, very tiny time after the big event, after the initial event, there is something which is called by cosmologists the Planck Era. The Planck Era is the threshold to which our knowledge of the evolution of the universe is quite responsible. Of course our knowledge here [Modern Universe era] is very secure, very sure; when we approach here [middle part of diagram] it's also very good; here we know a lot about the universe by observations of satellites called the […] which measure that part of the Planck […] radiation; but of course if we approach the beginning our knowledge is less and less secure, but before even we reach the initial singularity our present theories of physics break down because they do not take into account quantum gravity effects, so in fact we do not know what happened at the Planck threshold here.

Of course there are many attempts to create a theory which will tell us what was before, below the Planck threshold and here I listed a couple of theories which are most common now; they are theories which are not yet ready, not yet proved observationally, but they are some attempts to understand what happens below the Planck threshold. So the most common is perhaps the Superstring theory, and its new development known as the 'M' theory, some people say 'mysterious theory'. There is also another approach that is called Loop Quantum Gravity theory; there is approach also using so-called quantum groups and also non-commutative geometry. I will not explain all the details because it would take us a lot of time, but it's just only to say that people are looking beyond the Planck threshold just to decipher what happened before this borderline of our knowledge and these theories are very highly mathematical, very difficult but also very exciting I would say.

Okay, I will at the end of this part of my talk mention only one model, proposed in the 80s by two scientists, Jim Hartle and Steve Hawking who is very well known to

everybody in the world; and they proposed in 1983 what is called Quantum Creation Model and the model is really very clever. Here in this picture we have a standard procedure which is used in quantum mechanics; we have let's imagine a quantum system, for instance a proton or some other elementary particle, and here is the state of that particle, the initial state and we want to compute the state of this particle here, and in quantum mechanics which is a probabilistic theory we cannot compute in an exact way, we only have some probabilities; we can compute various trajectories or various histories of that system. This is one of them, this is another one, this is another one… and we compute the probabilities attached to all of these possible histories. And Hartle and Hawking adapted that model to cosmology and they, of course the model had to be changed a lot, several rather bold assumptions had to be made, but they succeeded in adapting this method to cosmology, to the environment of general theory of relativity; so if we have here a state of the universe, not a particle, and we want to compute a state of the universe here, we have to compute all these histories and all the probabilities which are linked to these histories, and this method works in at least some cases. And then they put the following question: Let us suppose that the state here does not exist; so which is the probability for the universe to go from nothing to that state? And this can be in principle answered by using the methods of quantum mechanics adapted to the environment of cosmology. So the initial state is empty and we can compute the probability for the universe to be in this state here, so this is justly called the creation out of nothingness with the help of the laws of physics; and I think now nobody believes in the correctness of that model, it's so-called 'toy' model because too many just working and artificial assumptions have to be made in order to enable that model to work, but nevertheless this model is very significant at least from a philosophical point of view because it shows us how far physical methods can go – even they are touching almost nothingness; they are touching the moment or the process owing to which the universe started to exist, and I think this is sort of a borderline to which science can go. But the tacit assumption of this model and all other models used in cosmology is that the laws of physics, and especially quantum physics in the case of Hartle-Hawking model, are valid; this is a tacit assumption that before we start doing anything we must assume that the laws of physics are valid, because if we do not assume that we cannot move any step forward. And then the question arises, where do the laws of physics come from? And this is already a philosophical question, and this way we go to our second part, the origin of the universe in philosophy.



PART TWO: in philosophy

Here is the picture of great philosopher Leibniz and he discusses with the Queen Sophie Charlotte, which was very wise queen and she wrote a lot of letters to Leibniz and they discussed a lot of metaphysical and polemical questions; and one of the questions asked by Leibniz and discussed with her was 'why is there something rather

> **"***Why is there something rather than nothing?* After all, *nothing* is simpler and easier than *something*.**"**
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> **G.W. Leibniz, *Principles of Nature and Grace, Based on Reason***

than nothing?' This is exactly the question concerning the genesis of the universe, the genesis of everything, and Leibniz adds 'after all nothingness is simpler and easier than something': if there is nothing there is no problem, there is nobody to ask the question and there is no problem in solving it; and the doctrine of creation is a philosophical attempt to answer that question. Of course Leibniz was not the first person to ask that question but he did that in a very dramatic way, and nowadays everybody likes to repeat Leibniz's question.

I will present now sources, various sources of the doctrine of creation, and of course one of the first sources is Greek ideas […] concerning the genesis of the universe; and we can distinguish at least three various approaches to the problem of the genesis of the universe there. The ancient Greek atomists claimed that there was no beginning and in modern parlance we would say that the matter was eternal but chaotic, and the order of the universe is due to some chancy events. Another approach was that of Aristotle; also he claimed that there was no beginning, the universe was always like it was now, but he attempted to explain everything in terms of teleology, it means finality, and this was a big world stream of ancient philosophy of nature. And the third approach was Plato in his dialogue *Timaeus*, and he claimed that the universe was made out of chaos and there was a demiurge, an intelligent being, who looked, he was looking at a model which was we would say now is a mathematical model and he implemented that by creating the universe out of pre-existing chaos, chaotic matter, so there was chaos at the beginning and then cosmos. Cosmos is a counterpart of the chaos, chaos is a disorder and *cosmos* in Greek means beautiful, full of symmetries.

And of course another source of the doctrine of creation is the Hebrew Bible and the Christian New Testament, and of course we should mention the first chapter of Genesis with the famous story of creation, but I think more important is the text from the book of Maccabees chapter 7 when the Maccabee's mother exhorts her son to suffer courageously the martyrdom, and she says to him 'my son, look upon heaven and earth and all that is in them, and consider that God made them out of nothing'. This is the first formulation of that doctrine, creation of nothingness – in the first chapter of Genesis there is [not] that expression – and this is significant because it was a simple woman, the mother Maccabee, so this means the doctrine was already a very common one.

Another source of the doctrine of creation was strangely enough the problem of evil. In the first centuries of Christianity there was a heresy known under the name of Manichaes after the creator of that stream called Mani, and they believed there were two forces in the universe, there is a good force, a God, and a sort of anti-God which they believed to be matter, inert matter which is a principle of evil, and these two forces are fighting with each other; and this heresy was very influential in the Christian church, and the church put a lot of effort just to contradict that doctrine and the first church's documents concerning the creation were directed against [Manichaean] heresies. For instance the First Council of Braga, 563, the doctrine was condemned, the document

Manichaean theology was dualistic in regards to good and evil. A key belief in Manichaeism is that there is no omnipotent good power. This addresses a theoretical part of the problem of evil by denying the infinite perfection of God and postulating two equal and opposite powers.

which claimed that the bodies which are principle of sin, they were not created by God, this was condemned; and then the [Ecumenical] Council of Florence [1442] in a long document repeated [the] doctrine that 'preaches that the one true God, Father, Son and Holy Spirit is the creator of all things… both spiritual and corporeal, good indeed because they are made by the supreme good, but mutable because they are made from nothing, and it asserts that there is no nature of evil because every nature, in so far as it is a nature, is good'. So the doctrine of creation was a kind of remedy against that sort of idea, and strangely enough even in the 19th century the first Vatican Council [1870] also repeated the same thing. I must say that when I was studying quite recently the history of the doctrine of creation I was very surprised that the main concern was the moral problem, the problem of evil and not the metaphysical problem how the universe came out of being, and strangely enough of course in the church's documents in the councils and others there is something about the creation of nothingness but like in the background. And then this metaphysical work was done by theologians and philosophers not by church's magisterium.

The most famous is St Augustine and he wrote a lot about it. I quote here one little aspect of that very well known, in many popular books St Augustine is ridiculed because according to some authors to the question 'what did God before he made heaven and earth' he gave an answer that he was preparing hell for those who inquire such mysteries of God. But in fact in 11th book of Confessions of St Augustine is something very different. St Augustine says that this question of what did God before he made heaven and earth, and answer that he was preparing a hell, it is one thing to make enquires and another to make sport of enquiries, so he said this is a very serious question and I shall try to answer them and I will not imitate those who give such a stupid answer. And then in the prayer directed to God in the next pages of Confessions he says that God is a being who lives outside time and he created the universe together with time so before the heaven and earth there was not time, and why is it demanded what Thou then did when there was no 'then' and no time? So St Augustine connected the problem of creation with the metaphysics of time.

> **"**See, I answer him that asketh, 'What did God before He made heaven and earth?' I answer not as one is said to have done merrily (eluding the pressure of the question), 'He was preparing hell (saith he) for pryers into mysteries.' It is one thing to answer enquiries, another to make sport of enquirers.**"**
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> **"**…For that very time didst Thou make, nor could times pass by, before Thou madest those times. But if before heaven and earth there was no time, why is it demanded, what Thou then didst? For there was no 'then', when there was no time.**"**
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> **St. Augustine, *Confessions*, book 11**

Another great philosopher of the Middle Ages, St Thomas Aquinas, wrote a very interesting small booklet which is called *De Aeternitate Mundi* which means about the eternity of the world and the subtitle is *contra murmurantes*, against those who are against that doctrine, who are not happy with it. And his problem was the following: let us suppose that the universe was created by God, is it necessary to assume that the world had a beginning? So he distinguished two notions, the notion of the creation and notion of the beginning, they are related somehow and he says there is no necessity to accept that the universe had a beginning because he says the creation is a relationship between the creature and the creator, and this relationship consists of the

continual dependence, dependence in the existence, of the creature on the God and the relationship of this dependence can be eternal; and he gives a very nice picture, that picture goes back to St Augustine, let us imagine a man who stays barefoot on the seashore in the sand and he stays there from minus infinity, from eternity, and let us ask the question 'is the footstep caused by that man, or not?' So it is of course caused but it has no beginning, so St Thomas says it is the same with the universe, there is no necessity to assume the universe had a beginning even if it is created because the creation is a dependence in the existence.

[Missed out of lecture as originally presented due to time constraints:]

Newton: 'Absolute, true and mathematical time, of itself, and from its own nature flows equably without regard to anything external, and by another name is called duration'... 'Absolute space, in its own nature, without regard to anything external, remains always similar and immovable'

Leibniz: 'I hold space to be something merely relative, as time is; . . . For space denotes, in terms of possibility, an order to things which exist at the same time, considered as existing together.'

Newton:
- Eternity = existence from temporal 'minus infinity' to temporal 'plus infinity'
- Creation in time

Leibniz:
- Eternity = atemporal existence
- Creation with time

The present popular view follows Newton.

Now what's my comment to all that? I think that two questions are very important: the one that was asked by Leibniz, why is there something rather than nothing, no […] physical theory can answer that question; but there is another question which is also very important, that question that was asked by Einstein, 'why is the universe comprehensible?' The fact that the universe is comprehensible is a presupposition of all scientific efforts and every success of science a corroboration of that assumption, and this is a very important question why is the universe comprehensible. Einstein was used to say this is the mystery we shall never comprehend, and I think these two mysteries, the mystery of existence and the mystery of comprehensibility are very strict link with each other, and in fact there are two faces of the same mystery; something which would not be possible to comprehend probably could not be, could not come into existence. The world is rational. In the present philosophy of science sometimes some people talk about the rationality of the world, this is not meant as it were that the universe has kind of intellect but the world is rational in the sense that it can rationally be investigated and this was very firm belief of Einstein, the rationality of the world.

The mystery of existence is the same as the mystery of comprehensibility

And now we go back to philosophy to look for some at least comments to that rationality of the universe, and we find in Greek philosophy the concept of 'Logos' (λόγος), and Logos was an important term in Greek philosophy. Heraclitus was probably the first who used that term in western philosophy and he understood Logos as the source of and fundamental order of the cosmos, the kind of cosmic sort of intellect. Sophists also used that term to mean the discourse and Asristotle applied the term to rational discourse, and the stoic philosophers identified the term with the divine principle pervading the universe responsible for the harmony, for understandability of the universe, and Philo of Alexander adapted that term to Jewish philosophy. So the term Logos was a kind of technical term in Greek philosophy, and the same term was used by Christian thinkers and it appears in the introduction to the gospel of John, the chapter 1 of John. The chapter begins, 'in the beginning was the Word', exactly Logos, John's gospel was written originally in Greek, εν αρχη ην ο λογος, 'and the Word was with God and the Word was God, all thingss were made by him', so it's a doctrine of creation, 'and without him was not anything made that was made', so in the gospel of God John identifies Jesus as incarnation of Logos through which everything has been created, so this mystery of understandability is present in philosophy and theological thinking as well.

$$R_{ab} - \frac{1}{2} R\, g_{ab} = \frac{8\pi G}{c^4} T_{ab}.$$

$$\partial_t \varphi = -\tfrac{1}{6}\alpha\, K + \beta^i \partial_i \varphi + \tfrac{1}{6}\partial_i \beta^i$$

$$\partial_t K = -\gamma^{ij} D_j D_i \alpha + \alpha(\tilde{A}_{ij}\tilde{A}^{ij} + \frac{1}{3}K^2) + 4\pi\alpha(\rho + S) + \beta^i \partial_i K$$

$$\partial_t \bar{\gamma}_{ij} = -2\alpha \tilde{A}_{ij} + \beta^k \partial_k \bar{\gamma}_{ij} + \bar{\gamma}_{ik}\partial_j \beta^k + \bar{\gamma}_{kj}\partial_i \beta^k - \frac{2}{3}\bar{\gamma}_{ij}\partial_k \beta^k.$$

$$\begin{aligned}\partial_t \bar{\Gamma}^i = & -2\tilde{A}^{ij}\partial_j \alpha + 2\alpha\left(\bar{\Gamma}^i_{jk}\tilde{A}^{kj} - \tfrac{2}{3}\bar{\gamma}^{ij}\partial_j K - 8\pi\bar{\gamma}^{ij}S_j + 6\tilde{A}^{ij}\partial_j \phi\right) \\ & + \beta^j \partial_j \bar{\Gamma}^i - \bar{\Gamma}^j \partial_j \beta^i + \tfrac{2}{3}\bar{\Gamma}^i \partial_j \beta^j + \tfrac{1}{3}\bar{\gamma}^{li}\beta^j_{jl} + \bar{\gamma}^{lj}\beta^i_{lj}.\end{aligned}$$

$$\begin{aligned}\partial_t \tilde{A}_{ij} = & \; e^{-4\phi}\left(-(D_i D_j \alpha)^{TF} + \alpha(R^{TF}_{ij} - 8\pi S^{TF}_{ij})\right) \\ & + \alpha(K\tilde{A}_{ij} - 2\tilde{A}_{il}\tilde{A}^l{}_j) \\ & + \beta^k \partial_k \tilde{A}_{ij} + \tilde{A}_{ik}\partial_j \beta^k + \tilde{A}_{kj}\partial_i \beta^k - \tfrac{2}{3}\tilde{A}_{ij}\partial_k \beta^k.\end{aligned}$$

Where to look for logos? Here this is the picture which perhaps needs some comment. This part of the formula is already familiar to us; they are famous Einstein gravitational field equations. I explained this is the geometrical part, this is the physical part, they explain how matter curves space-time, but this equation is written in a very abrogated form, in a very compressed form and if you wanted to write this equation in full without any abrogations at all then it's hard to believe but people computed that it would contain about 13,000 terms. This is why Einstein was inclined to say that God was sophisticated because he gave us such a very difficult problem to

solve, and happily enough, and this is just a part of these 13,000 terms, these 13,000 are already someone has computed them and they are present in the internet and I copied only a very little part of them and, but happily enough when you wanted to model our present universe we made some simplifying assumptions which are very well corroborated by astronomical observations, and all this huge mound of formula shrinks to two rather simple, not quite simple but much more simple than that, two differential equations called Friedmann equations. This is why Einstein was used to say God is sophisticated but he is not malicious because we can approximate the universe… and these equations are indeed the 'logos' of the universe because when Einstein wrote them down in 1915 nobody knew about gravitational waves, quasars, [later states] of star evolution, pulsars and things like that and black holes, and everything, all that, was contained in these equations, what people [did] afterwards they solved the equations for various configurations, for various initial conditions and boundary conditions and they learned about the existence of gravitational […], black holes etc, etc, and after that astronomers looked into the sky and saw them, so this is indeed a kind of logos of the universe.

And so when we speak about doctrine of creation I think we should not look in the loopholes of our science, like for instance the initial singularity where we do not know what happened, but we should look for those aspects of science which are very well founded, where the logos of the universe is visible to us.

[Well I had only had one last slide – the last slide was a big radio telescope looking at the sky and the sky was a big question mark!]

Jocelyn Bell Burnell: Thank you very much indeed, that was a remarkably clear talk on such a complex set of topics.