Is the Universe Random?

Stephen Wolfram: We want to address some open-ended questions today[1], such as: 1) is there randomness in the universe, 2) what's the future of randomness, and 3) perhaps we can talk about [what's] the future of meta mathematics.

John Casti: Can you all hear me through this microphone? We'll get some video up here in a minute. Some weeks ago when I was recruited for this job by Hector and I first deluded to look after this session I had some interaction with Stephen, and others, about what a continuum of this panel discussion might be. And I think that the consensus that emerged was that it should be something as vague as possible but no vaguer [big laughs] and I think that everybody in here has some pretty well-established ideas on most of these issues, certainly on randomness, complexity, physics, mathematics, etc. Stephen at one point put forth the idea, or was it a question: "Is the Universe random?" and I thought that was a pretty good question although phrased not quite in the way that I would have phrased it, and for this reason I want to try and sharpen that a little bit, a bit later, if possible. But I'd like to see some graphics on the screen, so can somebody assist me with that please? [Is being helped by the tech staff].

1. Complexity vs. Randomness

John Casti: (after about three minutes on the tape, setup complete): Now I wanted to actually focus not on randomness but on complexity, which is in fact my manifesto, because I think that complexity is a deeper notion than the concept of randomness. And I certainly regard randomness in some sense as the degenerate case of complexity, because I see it as a notion of extreme complexity. And just to give a little bit of a starting point on the idea of complexity I'll start by rephrasing Stephen's question as follows: "Is the Universe (or is the real world) too complex for us?" And in order to even make sense of that question I think one has to de-construct it and ponder almost every word in the question and allow it to be sufficiently vague to the point of having almost any kind of

[1] Panel at the 2007 NKS Conference, July 12-15, 2007 (Burlington, VT)

interpretation. And to further illustrate that point I am going to give you a little list that I got from Seth Lloyd. Years ago, when I first went to the Santa Fe Institute, before Seth Lloyd became "Seth Lloyd" he was a post-doc there (at the Santa Fe Institute) and for fun and just to illustrate the point that complexity is as much in the eye of the beholder as it is inherent in the object itself he wrote an article (I doubt it was ever published) mimicking the Baskin-Robbins story of 31 flavors of ice-cream. It was called: "Thirty-one flavors of complexity." And he identified 31 different notions and definitions that people had used in literature to refer to complexity. Let me just quickly run through the list, I'm not going to say anything about them, I just want to enumerate them to you. So here's one set, having to do with the difficulty of description, and there you see algorithmic complexity right near the top of that list [likely he is projecting some slides at this stage] here's another category, that had to do with the difficulty of creation, and here are, listed, other notions of complexity.

And I don't think there's anybody in this room, certainly not me, that can actually tell you what each one of these things actually is without going to the literature and looking it up. And that's not very important, what matters is that there is somebody out there who's thought seriously about complexity and put forth this list to prove that concept as a meaningful notion of complexity. Here's some more: degree of organization, things like excess entropy, sophistication, metric entropy and so on. And this list even goes on a little bit longer: [ideal] complexity, hierarchical complexity, correlation, stored information, algorithmic [mutual] information etc. Now if you kept track of the slides as I ran through them you would have found not just 31 flavors of complexity, but now more than 40 flavors of complexity, not counting that one [he points to the slides] and this just goes to prove the point that what we mean by complexity is really something that has to be in, my opinion, kind of content-dependent.

And if you ask the question: "Is the real world too complex for us?" then you have to either add [something] to this list, as partly to answer your question or make something of this list, that seems to capture the essence of what you mean by complexity in that particular situation. So let me just show you a couple of artistic examples over here: this first one shows you a picture that I got from Karl Sims and below it you see the Lisp code for that picture. So, if you have a Lisp compiler on your computer and would run that code on it, you would get what you see on this screen. Now this is very much in the spirit of Greg Chaitin's notion of "shortest possible program that can be used to describe a particular object." You can count up the number of characters in that Lisp code and that's not necessarily to be construed that that is the shortest such program, as in general that is unprovable, but it's probably a pretty good approximation to that – and certainly serves a purpose of being an algorithmic description of that particular object. Below it you see what looks like a random mishmash of dots, but in fact there is a pattern in that picture. This is an example of a very popular thing, it's called stereography (or stereoscopy) and if you sort of de-focus your eye and sort of stare at this for a sufficiently long period of time a three dimensional object will emerge out of it. You won't see it now while I am projecting it to you because this picture is probably too small but the point is that it illustrates a different kind of complexity and it has to do with a notion that I personally believe to be the most essential ingredient in a complex adaptive system, which is the idea of emergent phenomena: that the objects that make up the system interact in order to create something that is not there in the objects themselves at first.

Now, here's another example, and I'll just put it up as a question: which of these two do you think is the most complex? Is it this human on the left (those of you who are involved in any way in the arts world will recognize this face, it's the face of a famous British artist named Damien Hurst) and on the right there is a skull which is now the world's most expensive skull in the history, probably. You will have the opportunity to possess this object for a cool $100,000,000 so – what do you think? Why is this thing so expensive? What is it even? It's just a skull! But Damien Hurst, who might even argue that that aspect is in fact secondary, platinum plated it and encrusted it with diamonds and put it into this shop, gallery in London, and said that for a hundred million dollars it's yours. Now, from a standpoint all I ask here is a real world example of a system, two systems in fact – so which one do you think is more complex: the artist or the creation? If you can call this a creation – although it is a creation, but a pretty expensive one actually. But does it really have any actual complexity? Now that's an open question, I think, but an interesting one.

So, just to close this little part, my manifesto, a notion of complexity that I like a lot and is one that is relatively recent is the notion that complexity is not something inherent in the object itself – whether it's the Universe or anything else – instead it has very much to do with the observer. That complexity is a concept that has to be interacted with – by the observer. And just to give you a trivial example, think about a stone in the street. You go up and pick up that stone and wonder, while you look at it, to see how complex it is. Well, if you are a typical person like me, with no special training [in geology,] you probably say that the stone is not very complex, because there are only a limited number of ways you or I as non-specialists can have interaction with the stone. On the other hand if you were a geologist you would have a whole bunch of additional ways in which you can interact with the stone that are [in]applicable and that stone becomes vastly more complex for me as a geologist than for somebody who is untrained and doesn't have this observing capability powers. So complexity might be in this definition the number of inequivalent ways in which you can interact with an object. And I don't mean to imply, or claim that this is a universally accepted or vague-enough definition of complexity but it's one that at least acknowledges that complexity is not just inherent in the object itself[2].

So finally, here's my version of Steve's question:

> "Is the real world (also known as the Universe) too complex for us?"

And my argument is that this question is at least as much if not more a question

[2] Unlike information, apparently. If information is intrinsic to an object (e.g., algorithmic information, in fact, is the very definition of the object,) complexity seems to be the ability to extract that information from the object. This ability depends on the observer. The more the observer can extract the more complex both the observer and the object are. –Adr.

of philosophy than it is a question of physics or mathematics so, with that as my manifesto I would like to ask (the others can't hold any more, Davies starts, says something, Casti notices, asks for clarification) ... excuse me? ...

2. Can We Control the Universe?

Paul Davies: Well, I think it's clear that this introduction has been provocative enough (chain reaction of 2-3 people) to everyone present in this room (they all acknowledge, at the same time, that they'd like to speak too)!

Greg Chaitin: The question is: if the Universe is too complicated for us then obviously we have to re-engineer the human being until the Universe is no longer complex for us.

Stephen Wolfram: So, I guess I have several things to say. One is that it is perhaps fortunate that the field of biology does not necessarily have [does not a priori start from] a definition of life [Wolfram continues, can't understand how he ends but Chaitin laughs: Ah-hah! he probably has heard this argument before and is satisfied with it, Wolfram continues:] I think, otherwise [Chaitin says: "biologists," Wolfram continues:] wouldn't be able to even get started doing biology. There's indeed much to say about these issues of complexity but I think that this question about whether you know, "Is it inevitable that the Universe is too complex for us to the extent that we would have to re-engineer ourselves?" Or could there be situations where it's inevitable that we have the same complexity as the Universe?

Greg Chaitin: So – is it conceivable that if we invented it and if it is conceivable that it has the same complexity as us we just forgot that we invented it? That's a question.

Stephen Wolfram: Well, we didn't invent the Universe! (Very loud reaction after a moment of silence, not entirely sure why[3] but Wolfram's tone was that of humorous, amused indignation.)

John Casti: This question is a little bit similar to something you see in system theory where the complexity of the controller has to be at least as great as the complexity of the object being controlled and so, one might argue by saying: "look, however complex we are as human beings or whatever notion of complexity you choose to use, you can only access that part of the Universe which is as complex or less than you are." This would be the biological correspondent for the definition of complexity based on the number of inequivalent ways of interaction. But what if the Universe has indeed lots of degrees of complexity and we only have one?

[3] But if we invented it then it has the same complexity as us, as long as we all have the same complexity. Does this mean that forgetting means losing complexity? Probably. What is learning then? Answer: support for emergent phenomena, as Casti said. –Adr.

Paul Davies: So then does that mean, if we ask a question much vaguer, that we will never be able to control the whole Universe? That there's a limit to technology? If we imagine there's no limit to money, or time ahead of us is there nevertheless a bound on what is technologically feasible – and we could never conquer the Cosmos. Is that what you're saying?

John Casti: Maybe if I had a crystal ball I could answer this question. But I am not just deflecting I am also saying the question is very difficult to answer.

Stephen Wolfram: I have a thing to say about that. Sometime, perhaps soon, we may have a fundamental theory of physics. We may know everything about how the Universe has been built. (Somebody tries to interfere, Wolfram says: Hold on – then continues). So the only question is: even getting that, what can we do [with it]? So an obvious question is: if you know the fundamental laws of physics can you tell whether such and such difficult problem can be solved? It's not obvious, but depending on the problem we might be able to tell. In general however it may be undecidable whether a solution might be possible for any given hard problem, even knowing all the fundamental laws. So this question is an important one: even if you know the laws of physics, can you ... (reformulates as a statement:) we know[4] it's not sufficient to just know the laws of physics in order to be able to [be able to predict nature better].

Paul Davies: Right, right! I mean, can you for example make the galaxies rotate the other way without doing something outside the galaxies, for example [keeps speaking but is not entirely clear] within the laws of physics, if you did some things – however great the technology you're using[5] [now an equally spaced sound is heard repeatedly, not clear what it is, maybe a cell phone – everybody laughs and Davies stops speaking likely to turn his cell phone off...?]

Paul Davies (continues after small interruption): But within this realm of asking what complexity is, and given that as John is saying there are certain, several degrees of complexity and if we may be able to manipulate the complexity of the unknown then my question would be: is there a sort of a bound on the Universe? I'm talking about a complexity bound that acts on our Universe and that says that you can only achieve so much in controlling the Universe – after that there will be some [insurmountable boundary of capability] that we'll hit.

Stephen Wolfram: Maybe something like the second law of thermodynamics?

Paul Davies (agrees with Wolfram): Yes, like the second law of thermodynamics but not quite the same, because, you see, by doing some things very cleverly – and this is what that interests me – it's not just any sort of information, it's very specific sorts of information that enable us to manipulate our environment. So if we don't figure out the motions of the asteroids in the solar system we can still, with a little push from one asteroid we can cause it to hit a planet, which is now a planet with a different trajectory, and by a sufficiently clever accumu-

[4]He's obviously hinting at the PCI (not the PCE, whose consequence in NKS the PCI is)

[5]He too is also trying to establish that there may be a limit on what we can do in the Universe.

lation of changes I think we could configure our galaxies eventually. But there must be a limit to what we can do! We couldn't be able to work on the Universe and, still not be able to actually explain it, don't you think?

Stephen Wolfram: But, you see, there might be two issues: one of them is that there might be undecidability and/or irreducibility, to figuring out what would happen...

Paul Davies: None of them would be undesirable!

Stephen Wolfram: Right. So then the question is if there exists a way so we can configure the asteroids so that we can write coke [?! is this a joke about advertising?] in the Universe (general laughter) Well, that could easily actually turn out to be [insoluble] I think.

Gregory Chaitin: Let's say we're in a Universe which is a piece of software running on a computer ...

Stephen Wolfram: Yes.

Gregory Chaitin (continues): ... and it might be possible for the software to have a routine somewhere where it rewrites itself so it might be that if you understood the Universe sufficiently you might be able to change the laws of physics, or modify them in the future like through a piece of self-modifying code!

Stephen Wolfram: If I can just interrupt – it seems to be within the general acceptance that we experience the Universe as just an emulation of [the reality of it.] So presumably between the fundamental laws of physics and what we actually experience there's lots of layers [between us and it] because we're not experiencing [things] down, we're experiencing some effective theory of what's going on, so maybe what you're saying is that one could rewrite the lower-level [laws] of the operating system so what we experience is, kind of [matrix-]like, something that is very different from the current laws of physics, and then the question is – given the fundamental laws of physics, is there a way to assemble the matter in the universe so that the effective behavior of the Universe is very different from the behavior that we currently experience?

Gregory Chaitin: But then how would you define a bug in the design? Because one might crash the Universe by getting the code to go the wrong way. In general you want something constructive, but this can turn destructive, so it's harder [quick exchanges, hard to identify what's being said, some laughter too].

Stephen Wolfram (answering to Chaitin): Well, for example, it could be a [new] state of the Universe. To take a very simple possibility it used to be said when I was younger, about the nuclei, that pions make the nucleons subtract, raw mesons make them repel, maybe [half-]mesons make them protract more... [This whole idea] turned out to be nonsense but [the point is that] if you could ever squash a nucleus hard enough, suddenly it would become a different kind of nucleus. Maybe there is a different state of the Universe which has never been triggered.

3. Minds, Observers and the Universe

Paul Davies: It seems though that there could be a mind in the outer space some other kind of mind than ours, some other kind of beings than us, and they would inhabit the same Universe and for them the complexity might be different than what we perceive. Because when we think of complexity we always have this prejudice we always only accept and assume only our position and think we're the only one around, but we can imagine that the complexity of the outer space as seen through the eyes of some other beings might be different, although in a sense it's the same world – but as seen through a different, perhaps computational, perspective.

Stephen Wolfram: But, then, that also ...

Paul Davies: (continues, hard to decipher though ...)

Stephen Wolfram: But then would you then expect that those "beings"... I mean – why do you even call them "beings"?

Paul Davies: Well, ...

Stephen Wolfram: Maybe only because you'd have to identify them as *some* kind of intelligence.

Paul Davies: Yes, yes... observers ...

Stephen Wolfram: What counts as an observer?

Paul Davies: Well, what is it like to be? as famously asked by Thomas Nagel in his paper[6] You can try imagine what is it like to be them. Some kind of existence... what is it like to be [different than what we are now]? (Wolfram says something, others including Chaitin, it's hard to decipher, until Chaitin speaks up a bit louder than everybody else.)

Greg Chaitin: So that's the [basic need for a] foundational model.

Stephen Wolfram(unconvinced): But there are many times when people say "imagine what's like to be a computer" or "imagine what it is to be like [I don't know what else]" and so on. And just trying to imagine is not going to do the job. My favorite of these is: "The weather has a mind of its own" (Chaitin laughs loudly) But maybe it doesn't pass your test. Most people can't really imagine with accuracy what it would be like [to be something else]...

Paul Davies: Right!

Stephen Wolfram(continues): ... but still, we feel that this other existence has to have something like *a mind*.

Paul Davies: Yes. But I am not sure about the weather. (Laughter)

[6] "What is it like to be a bat?" in which he argues we can't ever know, especially if we want to know it in the present.

John Casti: So back to your original question about perhaps existing inherent limitations on our ability to, in some sense, manipulate the Universe...

Paul Davies: I think that could be made into a good science question and a Ph.D. student would be very happy to work on it.

John Casti: What is your belief [on the outcome of that research]?

Paul Davies: I think there is a limit.

Greg Chaitin: Well, who cares if there's a limit?! Just imagine that there is...

John Casti (interrupting): No, I think it's interesting because the question isn't as much as to whether there is indeed a limit, or who cares if there's a limit. The question is: "Where is the limit?" And "What do you have to do to push that boundary out?"

Karl Svozil: Well, I think that my position is that [as he speaks you can barely hear him, so people ask that he get closer to the microphone, he agrees] I think I believe that our ability to manipulate the universe is only limited by our fantasy and our fantasy alone. So I think that anything which we can fantasize about we can do something about, and we can produce [it] in some way or the other.

Stephen Wolfram: So as a simple minded analog to this we can think about the second law of thermodynamics and we can ask the question: given some energy in the form of molecules and random dots in a vacuum can we successfully extract something that we care about from that random configuration of bits. And I suppose one of the lessons of technology is that with [...] and things like that it used to be the case that people would say: once this thing is thermalized all is lost we can't extract useful [work] from it, but as we get to be able to compute more we get to be able to set up some [very close approximations of it] and you can really extract something [that way] – [well, actually (now speaking to Davies)] you must have thought [the same thing, because] your first book was [along these lines] wasn't it?

Paul Davies: Right, right, I think – I am assuming [that there is some thermodynamic price to be paid] and you can approach [some idealized goals in there] but I don't think it's negative entropy per se, because by being clever, you can achieve a lot, by having a strategy, you can minimize the [thermodynamic] damage in order to achieve [some of your goals].

Stephen Wolfram: But we're sort of dealing with [the goal of] decoding the Universe, and not that of being able to know where to push it.

Paul Davies: Right, right, right [but that is why I think that this is directly related to the goal of a mind]. As opposed to just crude intentions that this is why I think that observers are significant and not [an optional exercise or to be viewed simply as constraints.] Because, in a sense, I think that an observer, or a mind if you like, could, in principle [decrease] the relative complexity of the Universe [and I wonder] actually what the limits are.

Stephen Wolfram: But some of us think that much of what the Universe does is computationally just like [what] the mind is [doing].

Paul Davies: Right.

Stephen Wolfram: So it is not the case that [the mind] is above the Universe and because we have minds, you know – (reformulates:) let's say that we are the first "intelligence," in our sense, or the first intelligent beings [things] to arise in our Universe, then it could be that the whole future of the Universe, that one day, you know, our Universe will look vastly different because of the [mind[s] in it] – but I think that's extremely unlikely.

Paul Davies: Do you think that it would achieve that without minds, or that [that can't be achieved at all] ... ?

Stephen Wolfram: There's a great deal, you know, there are all these things in the Universe and you look around [and you ask yourself:] Did they require a mind to make? What would a mind make? If there were an arbitrarily, sort of, future technology one that could move stars and galaxies around with – what would the future mind make?

Paul Davies: Right, so, [well,] I'm not asking [your] question but I'm asking another [which is related] because as a hobby of mine I'm chairman of the SETI [something unintelligible] detection. So the question that is arising is if we pick up a signal from E.T. on my watch – is it going to be anything like a sentient being, or is it possible that we're getting something like the appearance of intelligence emerging without the ...

Stephen Wolfram: I think that the signal ...

Paul Davies (continues): ... without [that signal] coming out of your complexity [as a consequence] ... [and without ...]

John Casti: So you think something like ... [hard to decipher] ... black hole ...

Paul Davies: Yes, a black hole would be a curious intermediate case [hard to decipher] based on the laws of physics and [just as well] a brain has to do what a brain has to do, [difficult to understand, sometimes superimposed with others] ... so I think that sometimes we're not capturing ...

Gregory Chaitin: Let me see if I can synthesize the NKS position on this. The NKS position is that any universal computer is a mind and universal computation is everywhere in the Universe. So the entire Universe has [a] mind!

Stephen Wolfram: Or, more operationally, think about pulsars. When pulsars were first detected the first thought was that this very special signal must be of intelligent origin and that later gave way to [hard to understand[7]] but now if you look at the details of pulsar you'll see that [...] and my claim is that that sequence that you see, from the blips, [in the [magneto]sphere and so on] is every bit as mind-like as any[thing else] you will ever see.

[7]Does he say: "And we know that's not right." ?

4. Communicating Minds

Paul Davies: That might suggest that we could try to look for a message from the pulsars.

Stephen Wolfram: Well – what's a message?

Paul Davies: It would be something that we could recognize as [... infinitesimal? – can't understand what he says ...]

Stephen Wolfram: But that's a very inefficient message!

Paul Davies: May very well be, but that's what we've been practicing.

John Casti: The point is that your perspective basically dramatically anthropomorphizes [Davies agrees: "Sure."] A message is something that we would be able to recognize as meaningful etc. What I'm asking [hard to decipher]. On the other hand the idea that that everything is a mind that's a little bit too generous, perhaps: it's as if every statement is a theorem which is not very helpful, because you can't distinguish between minds and non-minds if everything is a mind.

Stephen Wolfram: But there's sharp distinction between... (pauses for a moment then starts again:) Most of what's been studied in the physics in the past is not mind-like, it's in fact too simple to be mind-like. The idea that people have had since ancient time that [and that was the predominant thought about things] the impression that people had, and I don't think this is wrong, as modern scientists would have people believe was to say that there are many things that you can predict on the basis of thinking that the weather has a mind of itself so to speak – you can know things about the extent to which it is conceivable or predictable and so on. But, with respect to this thing about SETI, I'd be really curious to push on this and find out: *Is* there a message?

Paul Davies: Right!

Greg Chaitin: Can I say what I think that the right message to send would be? It wouldn't be a TV program Fred Hoyle had another [idea], in another book – which was a pretty bad book, I preferred the A for Andromeda[8] – had the idea that the kind of message that you would send would be a piece of software that wanted to propagate. So if you send a computer program and obviously an instruction manual for the computer/machine you would run it on, and then the people in this story of Fred Hoyle's – they construct a computer and then

[8] From `http://www-users.cs.york.ac.uk/susan/sf/dani/028.htm`: "A For Andromeda" was coauthored with John Elliot, a television writer. (I'm not sure about this, but I think "A For Andromeda" started life out as a telefilm script.) It has a premise which other writers have borrowed since: A new radio-telescope picks up what has to be a message coming (for a long time, obviously) from the direction of Andromeda. When the message is finally decoded (it was designed to be decodable) it turns out to include a very complex computer program, the design information needed to run the program, and data. Naturally the computer is built and the program is run. It then provides the researchers with instructions for creating a human being to serve as its interface.

they start to run the program on it, and it's an artificial intelligence. So this would be one way for organisms which would be software to send themselves across the Universe.

Stephen Wolfram: That's the ultimate computer worm.

Gregory Chaitin (continues): Yes, this would be a life form that would transmit itself as a message. And it seems to me that that would be the only interesting message: a message that wants to come here and start running here because that's the only interesting way to send yourself across the Universe: as a message, if you're software. You're an AI program that comes to Earth and starts running. And now you're here!

Paul Davies: This raises an interesting question [...] the most efficient message would be ... [...]

Greg Chaitin: But the message is – but the way you tell the message, the viewpoint is that you start running the software and if starts having a conversation with you and it wants to take over the government, then that was a meaningful message ... [otherwise it would look random] ...

Stephen Wolfram: I see what you're saying. But there's an interesting fact: in the past when you would scan radio bands you would hear all kinds of obviously meaningful stuff. Nowadays with all the cell phones and all the digital stuff and so on increasingly you can't hear anything any more because it's all been compressed. And also the whole idea of broadcasting signals seems to be old news. I don't think that [messages] ...

Paul Davies: Perhaps I happen to be a very skeptic about the more classical SETI approaches. [I think we need] radical new approaches [addressing the question].

Stephen Wolfram: But do you think it even makes sense, I mean does the question even make sense? Because if it is the case that minds are everywhere what does it mean ...

Paul Davies: That's what shocked me in this discussion[9] because that if you think that that is the case then [there's one or more of these things out there and they are trying to communicate] ...

Stephen Wolfram: But I think the issue is just like AI. What does it mean to have AI?

Paul Davies: Well, we know what it means to have a conversation with another human being.

Stephen Wolfram: We know what it means to have human-like AI.

Paul Davies: Yes.

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[9]Wolfram and Davies still building two different perspectives, in spite of the deceiving appearances (the shock that Davies mentioned,) that they might be the same. Wolfram is building the case very, very patiently.

Stephen Wolfram: It's something that is being very much like us.

Gregory Chaitin: More like a historical accident.

Stephen Wolfram: So the question's how much you can abstract away from the details of humanness and still have something that you know is intelligent.

Paul Davies: Let me answer this question. We can imagine life on another planet [...] classical SETI [...] but can we imagine getting a message [...] that nevertheless cancels non-trivial [...] from a physical system that did not go through this process of [emergence of] organic complexity and evolution of culture? (Argues a bit with Chaitin, not able to determine precisely all the details, then Wolfram steps in.)

Stephen Wolfram: So here's a case that might be relevant: you know whales songs, right? Whales songs presumably are communicating something of relevance. Presumably, because it's not clear, I don't think anyone is completely sure either way. (I mean is there a correlation between what one whale says, or sings, and what that whale does?)

Paul Davies: My wife does. (Perhaps his wife is working in the field, etc. – it's not possible to research this as thoroughly as I'd like to, so I am not sure what he means.)

Greg Chaitin (and others): ... likely becomes more complex ... (more people speak)

Stephen Wolfram (tries to sum up): So let's assume there is a message. When we listen to whales' songs it's really hard to say what they're about. Here's an amusing historical anecdote: in the distant past, when the radio was new, Marconi who was one of the developers of radio had a yacht and he went to cross the Atlantic in his yacht, and in the middle of the Atlantic he was listening on his radio mast and he heard this kind of [woo-eeeo-ooaah] ... I can't really imitate the thing (people kind of laugh) but that's what they sound when you listen to them. From his radio mast. OK, so what did he conclude that these things were? His best hypothesis was that they were the martians ... radio messages from the martians. They turned out to be ionospheric [Whistler bars?] from magnetohydrodynamics. So this is a case where (the whales, that is) where we hear something which is at least seemingly undistinguishable from what is a mind-like physical system and presumably a mind-like biological system.

John Casti: Actually I think that this whale business raises a very interesting and important message for SETI and that is: we have, through the years, seen a lot of different experiments (people trying to talk to dolphins and chimpanzees and octopuses and whatever) and by and large my impression has been that in most of these experiments – I would just call them failures. Failures in the sense that the level of actual communication was pretty minimal. So here we are trying to communicate with organisms that we have shared a very long evolutionary history with, for so many centuries, and we do a very poor job in establishing any meaningful communication – even if we believe that these are messages. Why do we ever imagine that if we ever get a signal from a beam [coming from a distant civilization] that we'd understand the message?

Paul Davies: Well, yeah, yeah, but ...

Greg Chaitin: Can I invert this question, if I can interrupt, I think that you should go about this the other way, Paul: we should be the SETI, we should be the message, so what we should do would be to send a message and hope that somebody that receives it would run it on the computer, and it would be us [the program's output] – or a copy of us. It would be an AI exploratory program which will look around and see the planet it's on and then send us the information [about it in a] message [that we could understand it in the slightest].

Paul Davies: It's been done.

Greg Chaitin: Oh, it has?

Paul Davies: Yes, but not (entirely) like that...

Stephen Wolfram: Well, not like that, nothing like that! What was sent out was an *absurd* thing.

Paul Davies agrees and is a bit chagrined about it, explains but doesn't try to argue it too much. (People laugh).

Greg Chaitin: OK, to be more precise let me explain what I would send out: I would be sending out examples of very simple lists, so that it becomes clear what the semantics of your programming language is. Then I would start sending out pictures of the list in the box interacting with the outside world, because I would like the list to have a camera and ...

Stephen Wolfram: What is all this picture business?

Greg Chaitin: Excuse me?

Stephen Wolfram: What about ... [he raises a valid issue with what it's proposed but I can't be sure what it is]

Greg Chaitin: Well, I know, it's difficult, this is not a complete program or I would have done it already. And then you send out this long program that is in fact you, that would start going around and interact with the natives trying to find information and send it back to us. And there we go: zoom! We're the SETI and the idea is to attract attention to yourself so that you will get to be run. You want to send a piece of code that people would be curious to try running on the computers and see what happens! That's how we get there: we put ourselves into [this other environment] ...

Stephen Wolfram: By the way I think that this thing about communicating with/to animals and so on, my own guess with respect to that (I guess I should be warning you I will say something slightly outrageous) but my own guess is that in the next few years if anybody [is indeed working on this] with modern techniques [...] and so on, it would be possible to do a lot more, and here's how

– right now, we we don't record (when we talk to a chimpanzee or something) we don't record everything in the chimpanzee's life and every kind and/or way that they interact and so on. I bet that if that was actually recorded and correlated with its experiences and so on that one could actually start to figure out a reasonable communication mechanism. I mean even now there are some promising devices, and my favorite example is (and I saw this as a product marketed under the name) Bow-Lingual[10], which some of you may have seen, which is this thing where you type what you want to say in English and it comes out in dogs' barks. And then there's also a thing where it listens to the barks of the dog – and you have to adjust it, adjust it to the particular type of dog you have – and it analyzes based on you know [the format of a selection] out of a small collection of mostly emotional state kind of communication things and it tells you what the dog had to say.

John Casti: Does this sound vaguely like this famous New Yorker cartoon: two dogs sitting in a room, one of them sitting at a computer terminal typing away while the other one the other one down the floor, while the one doing the typing says: "You know, on the Internet nobody knows that you're a dog!" (big spontaneous laughs, but Wolfram cuts quickly in, he doesn't want to let what he said be washed away by the change of focus).

5. The Issue of AI

Stephen Wolfram: You know what, the issue is [that] when you look at (thinks, then reformulates:) let's say you succeed to establish at some level a communication with whatever [type of] being the issue then is: what are the topics you talk about and, you know, what are the purposes that seem to [make sense in the context of this conversation?] You talked about meaning, and meaning gets closely associated with purpose: how do you know if the thing has a purpose it has a meaning and a purpose and so on. What are the premises and/or purposes of SETI, the ETIs and so on.

Paul Davies: Right – well, the thinking behind classical SETI, if we can go over [that] a bit, is incredibly parochial. It goes along the lines that they are like us but they have been around a lot longer and have got more money (laughs) and so they will send us messages and they will take it as a matter of fact, that is, they will assume that we have just sort of stumbled on the radio technology, so they will make it very obvious that this is a message and – in other words, they will take the lead! But of course we can't [bear] that ... [out there anyway!]

Stephen Wolfram: I think that the ...

John Casti: Maybe acting a little bit like missionaries when they were going to recruit the natives for the church, and we know that this has not been an especially successful experiment, for the natives especially (Davies says: Right!)

[10] `http://www.crunchgear.com/2009/07/13/bowlingual-portable-dog-language-translator/`

...

Stephen Wolfram: Well, as successful, as Greg said, simply. But I think that the best argument that I've heard from the SETI community is: we might as well do what we *can* do.

Paul Davies: Yes, it's true and right that [essentially] we're just listening out there (Wolfram seems to agree) ...

Paul Davies (continues): But what we saw and maybe [I'll] go off track, but my point of view on this is that there is no reason that E.T. would beam messages out until they can be sure that we're here and they don't know we're here beyond about a hundred light years away and so it's most unlikely that there will be any advanced civilization within that distance. So, the strategy may be sound but it's maybe a few hundred years [a bit] too soon to start [this] ...

Stephen Wolfram: I think honestly [and ultimately] ... I have to say, I think that all these things – I mean this question about what counts as a mind and what purposes – (Davies cuts in).

Paul Davies: Well, that's what interests me!

Stephen Wolfram (continues): ... well, I think that this issue is deeply muddled. I mean, I used to be a big enthusiast of SETI and I figured out all sorts of things about how you could use commercial communication satellites to do wonderful, you know, radio telescope stuff by using spares that got used [we hear Davies: Really? not sure though if he's surprised or not] there's a lot of great things one can do. But I kind of – after I started working on NKS – I kind of became much more pessimistic about it ...

Paul Davies: Well, but then you'd have to – because if your view is that the Universe is full of mind and maybe communicating minds and maybe this would occur in systems as diverse as pulsars as you mentioned, and (Wolfram starts speaking over him to ask a question) and so on, then you'd have to (stops, listens)

Stephen Wolfram: OK, but what is a communicating mind? Whenever a physical system has an effect on another ... it is a communicating mind!

Paul Davies: That's right.

Paul Davies (continues): But then we would have to be the rather idiosyncratic example ... it's a rather impoverished idiosyncratic example as the [one] mind of the Universe otherwise you can show that if we represent a whole class, you know, of biologically instantiated intelligence, or something, whatever you call it, then there may be superminds, or bizarre minds – just as are our minds – swirling around too, so if there are some guys like us out there then all of it is worth doing ...

Stephen Wolfram: Well, so then the question is what is the probability that there is mind – minds may be common – the question of whether, you know, "How human like are those minds in the distribution of all minds?" What's the – I mean, if you look at the distribution of all minds, how thick in this distribution is the (Davies starts answering, hard to keep up with what Wolfram is saying) ...

Paul Davies: Well this is where having an ensemble of 1 (one) is a terrible thing because it is very easy to think of all sorts of reasons as to why it had to be this way: so, if you play out evolution somewhere else you say "Well, yes, of course it makes sense to have information processing and sense organs, and then obviously you want that one off the ground and then in case you get hit, you need something that will prevent damage, etc." and you can easily talk us, and the argument into a humanoid type of entity – if we're not careful!

Stephen Wolfram: That's because we can't figure out something else – although that, in and of itself, is very embarrassing!

Paul Davies: But I think that – having [followed] SETI myself over 20-30 years – I've been amazed how even minor changes in technology have reflected on the change of the basic SETI strategy. Do you remember how in the early days the main question was what frequency they should use? The main issue was to try to guess a range to cover! Nobody talks about that any more because you can cover billions of channels simultaneously. So the technology just in 10-20 years has evolved so much that it changed the whole search strategy. So in another thousand years we may say "Obviously we have been using such and such..."

Stephen Wolfram: (Davies keeps agreeing): I think the invariant of SETI is that their search effort is centered/focused just around the most significant technological breakthrough on the Earth at the time; so, for example, the canals on Mars where just around the canal building period on the Earth, so there's a big influence from where we are at the moment on Earth (from the technology of the moment on Earth).

Greg Chaitin: There's a wonderful SF story about this. The idea is that some people are doing a SETI experiment on Earth, and it's their big project, and so on. Meanwhile there are people on other planets, these are ETI's [also trying to communicate] – so here we are, having discovered absolutely nothing using radio waves! Meanwhile, neutrino beams (he gets wonderfully excited as he tells the story) which this other planet think they're the only logical possible mode of communication are flashing out with these urgent message we can't see, and the sunset colors are modulating with some other rays, in ways that another group of beings think that would be the most obvious of all possible ways of communicating with another rational human being (which, as they happen to think, would be by colors). So the sky is flashing with neutrino beam broadcasts from one civilization and this meaningful message at sunset from somewhere else (from a second other civilization) and while we keep listening in the radio frequency spectrum *nobody* is communicating with anybody else!

There's laughter but supressed as Chaitin is absolutely fantastic when he gets excited. He himself is very amused of what he said. There's a moment of pause, nobody knows where the discussion will be heading, Wolfram tries to renew the conversation in the topic it was before.

Stephen Wolfram: Maybe we should come back to [the reality of ...] (everybody laughs, all the suppressed laughter comes out now.)

6. Is Mathematics Inevitable?

Cris Calude: May I? ... I think that the Universe is random. And even if it is not true it is still productive for the human mind to believe in the randomness of the Universe and I will give you my very very short explanation as to why that may be so. All the laws of nature are mathematical idealizations of – essentially ways to approximate the finite by the infinite. The power of the mathematics as a modeling tool is based on the fact that it introduces the infinite as the approximation of the very large finite. The use of unbounded quantification makes every test to be finite so everything in the area of modeling can be falsified by not being validated. All the equations that you use in physics – they introduce essentially the infinity which is very nice and perfect from a mathematical point of view but that cannot be checked in reality except for a very small sample. So I think that it is better [more appropriate] to not even speak about the Universe in general, but to speak about only local [rules] and probably the simplest example is say, somehow I will give you not 40 digits of Ω but, say, one million of digits of Ω and then one could believe that we face the laws of the Universe – well this sample is just a local regularity in the infinite randomness.

Stephen Wolfram: There's something (one part of) what you said that I don't quite understand, or maybe I just don't agree with it. Which is the claim that physics somehow talks about the infinite. If this may appear to be so, it is only because the traditional physics as it has been formulated in the last three hundred years happens to use the ideas of calculus – and has been developed around the ideas from calculus. Had CAs been developed before calculus I think history would have been entirely different. That is to say that physics as we currently see it happens to be using differential equations but nothing in physics says that's the reality. There's nothing in physics that is precisely a differential equation, absolutely nothing. You're looking at fluid dynamics or something, you see a bunch of molecules bouncing around and they happen to be well approximated by Navier-Stokes. The motion of planets is not differential equations but they happen to be well described by them. There's a lot of detail that is not that. I think that the laws of physics as they happen to have been formulated in the last 300 years in terms of this infinite mathematics happen to be just a coincidence of history. I don't think it reflects something (or anything) core about physics.

John Casti: I want to comment on that because it would be meaningful to do the following thought experiment: imagine that Newton had had a super computer. What would mathematics have looked today? I think that all sorts of things that were part of the traditional mathematics, like all the stuff about infinite series and limits and calculus and all the traditional mathematics as we know it today, and calculus itself would have never developed at all, or to the level where they are today and instead we would have had developed finite theories and finite mathematics, combinatorics various kinds of things having to do with computing so I completely subscribe to that view that it was an accident of history. Even the notion of the continuum is simply a matter of computational convenience ...

Stephen Wolfram: I think this is a controversial view! But I'd be fascinated in what other people have to say about this, or think about this question: "Is the continuum [indeed] an accident oh history?"

John Casti: Or a matter of computational convenience?

Paul Davies: Maybe it is a matter of platonic idealization.

Greg Chaitin: Well, don't some people think that geometry is built into the human brain, and the eye and the way images are processed [by humans]. That the human brain has tremendous intuition for geometrical processing, for images and a lot of the brain is processing this [through dedicated hardware].

Stephen Wolfram: So you're saying the continuum ... the reason we think about the continuum is because our brains are built in such a way that makes it a useful way for us to think. Which would make the continuum necessary, in some sense, so we can think about the surrounding world.

Greg Chaitin: Perhaps. I'm sorry, I am giving you a parody of Kant.

Cris Calude: I agree with what you said, both about you know calculus being a historical accident for physics, [and the other things you pointed out] but I don't see how it changes my point because CAs are still useful to the degree that they model the properties of the infinite by the finite and then if you think that most non-trivial properties of CAs in general are undecidable then this reduces you immediately to your program where you have small interesting CAs that display high complexity. But this in a sense says "Well I [accept to] downgrade my [meek?] grandeur and I am happy to look at the local instead of global."

Stephen Wolfram: But I think that it is the case that if we finally find a fundamental theory of physics which ...

Greg Chaitin: You will, Stephen, you will...

Stephen Wolfram: Well, thanks... Greg thinks if we just keep trying harder (people laugh). Or, if I am not making Mathematica v. 8 or, whatever. No, let's [just] go back to what we were saying, so the question was: if we find a simple, sort of, ultimate rule for physics and maybe it is a discrete program and we just run this thing and if we believe that when we find this thing and we run it we will see every single detail of the Universe in this program's run. And maybe it's a practical matter [not relevant] but I don't see how the infinite comes into it ...

Cris Calude: But if you run it for a very short time this will only give you a very primitive description and definitely you would leave aside many interesting properties of the Universe. How would you know, for example, that there is a finite (Wolfram slowly starts interjecting because he sees a potential cause for confusion) limit for running this program (Wolfram now starts answering, over Calude who is finishing the question)?

Stephen Wolfram: But, but, but: this program is not a model in the same sense that Navier-Stokes is in the numerical analysis sense is a model. This program would be a precise representation of the Universe of every second and [every] detail and feature in the Universe. So it's not that as you run it you're getting closer and closer to what the Universe is (in the sense that you try to obtain a better approximation of it). No! If you run it for 10^{-200} you will see exactly the first 10^{-200} second of the Universe. If you run it 10^{200} times longer than that you get the first second of the Universe, the whole second but I mean absolutely exactly, just as ...

John Casti: ... in every little detail ...

Stephen Wolfram: ... that's right, in every single little detail, so I don't see how the infinite gets in there at all! For example, if you ask the question: "Can there ever arise in the Universe (to intelligent beings, for example, like us) a super intelligence" then that question, if the Universe is unbounded, could in principle be an undecidable question, and then the infinite is in there. But when it comes to the basic description of the Universe, I don't see how the infinite enters in that idea of how physics will play out.

Greg Chaitin: Yes, Stephen, but Cris is only saying that the infinite was for a while a convenient approximation to the finite, because it was just that continuous mathematics was more developed than combinatorial mathematics which is a little harder to work with, and so it's a historical accident. He's just saying it's a convenient approximation. He's not saying the Universe is continuous, he's saying ...

Cris Calude: Even worse: I say it is random. Or it is more productive to be thought as random for the human mind that we try to extract as much information about it. It makes you a little bit modest in what you try to achieve ... and then perhaps ...

6. Is the Universe Computable?

Stephen Wolfram: I think one of the key questions one that we would certainly like to know the answer of, and one that I mentioned earlier: "Is the Universe like π or is it like Ω?" This is clearly a question that is of [great importance] if you're interested in the foundations of ...

Paul Davies: Could I sharpen that by giving a very clear metaphor? Imagine that we – forget about the holographic principle, [and] – imagine that we pixelate the whole Cosmos into [fantasized queues?] and there's a finite number of variables that you can specify with each of these. Now imagine that we take the digits of π in binary and we label each of those pixels by the numbers in the pixel so it's like a gigantic CA, we label each of them by the digits of π, so then you have a mess but then you go on [to the next level of digits of π] and it's still a mess, but when you're running out [of digits] – you [will] get this Universe, that's for sure: it's there, this Universe... Or any other Universe!

Stephen Wolfram: Well, but that's muddling some things.

Paul Davies: OK, what am I muddling? (Laughs).

Stephen Wolfram: Well, OK, so what you're muddling is this: given any universal computer you can emulate... (ponders a moment, then starts again:) So one thing you can say is [that] while you're looking for a fundamental theory of physics, once you have any universal computer if you believe that the universe is computable, then you've already got the answer.

Paul Davies: That's right. It's there, just don't know where it.

Stephen Wolfram: So that's the muddle. What I am claiming is something much more extreme [about it,] I am saying that if we succeed in finding a fundamental theory of physics, I know this is going to give us some law of evolution, so I'm going to say: this initial condition, this law of evolution you will get precisely every detail of the Universe. So that means that as we work out the digits of pi the first digit is what happens in the first 10^{-200} seconds, the next digit is what happens next ...

Paul Davies: Right! But I ... but ... I could ...

John Casti: Stephen, are you suggesting that the Universe is computable?

Stephen Wolfram: Yes.

John Casti: But then, I have to ask, do you think it is computable within every possible model of computation, or do you just confine yourself to the Turing model of computation?

Stephen Wolfram: I'm saying that it is computable in the Turing sense (at the Turing level of computation).

Cris Calude: So then randomness is just an illusion.

Stephen Wolfram: That's what I am saying – for our Universe. Randomness is a fascinating thing to study, [no doubt, but] we just don't have it ... we can't produce it. It just doesn't happen to be produceable in our Universe.

Greg Chaitin: But we have pseudo-randomness.

Stephen Wolfram: Yes, we have very good pseudo-randomness ...

Greg Chaitin: Like the digits of π. You look at them – it looks random.

Stephen Wolfram: The question is with your effort to compute Ω: is it actually possible [to do that] in our Universe? If you had more tools, any tools you can build in this Universe: is Ω actually there [for us to find it, and look at it] in our Universe? And I think, but I don't know, because we won't know until we have a fundamental theory of physics, yet my claim – my working hypothesis, if you will – is that there is no way you can extract Omega from our Universe, and that true randomness in Greg's sense simply does not exist in our Universe!

Cris Calude: How do you reconcile under this hypothesis the fact that in this Universe we cannot extract this kind of information with the fact that in this Universe we can talk about things that are so opaque?

Stephen Wolfram: So that's a non-trivial fact that there is this symbolic ... and I think it's a fascinating fact that we can talk about infinity even though we can't count to infinity we can have even in Mathematica we have the symbol for infinity and it has various properties and we can reason about infinity. So I think it's a very interesting thing ...

Greg Chaitin: We can talk about Unicorns too!

Stephen Wolfram: ? (Doesn't know what to say. Everybody laughs. Wolfram is amused too. Chaitin is absolutely hilarious and his delivery is simply genius!)

Paul Davies: Stephen, could I just ask: how is your computation of the Universe and my facetious example about extending the digits of π differ from having to specify one number and one number only which is the [...] of the finite exponentiation of where we need to go? So ...

Stephen Wolfram: That's fine, that's fine ... I mean, it's a practical matter to say our Universe it's somewhere in π, and to say where [exactly it is located] – for algorithmic information reason/purposes – the saying *where* is [going to contain] as much information as [actually] giving the whole Universe [as a program] ...

Paul Davies: Ri-ii-ght... (seems to agree to this distinction).

Stephen Wolfram (continues): So you didn't get to this. And what I am saying is that the whole Universe you could just hold it in your hand, as a little piece of Mathematica code and then you just run it and you make the whole Universe. And, it's a non-trivial question, whether that is conceivable or whether we need a higher level of computation beyond the Turing model of computation or something else ...

Greg Chaitin: It seems to me that your point of view is that Turing computation is a priori, this notion of computation is given before we start discussing the physical Universe. David Deutsch has the position that what we consider to be a universal Turing machine or a possible computation depends utterly on the physics of our Universe and could be totally different from [the Turing model].

Cris Calude: Then you have a circularity!

Greg Chaitin: Yes. Such as you (Is he addressing Calude? Is he referring to the impossibility of calculating the digits of Ω? Hard to tell from my perspective.)

(At this point Wolfram starts tries to continue the ideas he was describing before: "So, what I'm saying is...")

Greg Chaitin (to Wolfram): I am on your side but there are people on the other side ...

Stephen Wolfram: It is one of the remarkable – I mean, the fact that we in the last century happened to have discovered *the* invariant idea of what computation is (if we're right about that [idea,] it's just a nice [historical] accident.) I mean it could be the case that [and] what we seem to be learning in Physics is that every sixty years somebody says that everything you knew in Physics so far is wrong and there is another level of stuff going on in Physics and from that intuition you might say: "Similarly, in sixty years, everything you know about computation is wrong and another level of computation will be possible" You might say: "Everything you knew about mathematics will have to change as well and in sixty years another kind of mathematics is going to be possible!" But we don't think that's going to happen, do we?

Paul Davies: Well, wrong will [still] be wrong, no? I hope... (laughter)

7. Is There a Fundamental Theory of Physics?

John Casti: It would be more accurate to say that everything you do is only an approximation to the real thing and the next level has all sorts of different properties and so on. But I think that that argument that you just made, if it's true that it will continue to have an approximation and then a better approximation, and then a better approximation, and so on – and you will never get to the end – [then] that's a pretty strong argument against the ultimate theory of physics, right?

Stephen Wolfram: No, that's what I am [actually] saying: the empirical observations of the last few centuries have been such that it seems to be a bottomless pit, that we don't seem to [be able to ever hope that we'll be done.] I don't think that's correct. I don't think that that's the correct intuition. I think the reason [for which] people have tended to have that [inaccurate] intuition is that people have not seen examples where little simple things can build into things as rich as we might imagine the Universe [to be]. Look, it's worth seeing the same thing in mathematics. And if we look at mathematics we could ask: is mathematics also [the same kind of] bottomless pit? That is, is it the case that the mathematics of today will necessarily be superseded by the mathematics of tomorrow and is it the case that the unsolved problems of today will necessarily be solved tomorrow - in the mathematics of tomorrow? And that seems to be the analogous issue and my claim would be (and I think Greg used to agree with this, at least, but I am not sure about the others) so, if you look at mathematics, and one my favorite example is the diophantine equations, equations of the integers: in antiquity they learned how to do linear diophantine equations. Later in 1800s they learned how to do quadratic diophantine equations. Later in the early part of 1900s they learned to do elyptic diophantine equations, which were [leading] towards cubic diophantine equations, and so on. But there are still plenty of diophantine equations which we don't know how to solve, and the question is: if we just project the future of mathematics, will we, just like apparently in the future of physics, will we, every fifty years, be able to get further into the world of diophantine equations? So my guess is: no, my guess is that we're going to run into [a wall, that] we're basically at the edge of where we can go and everything beyond this edge is likely to be undecidable. And that will be the case where the ultimate level of knowledge [becomes[something of a logical necessity[11], having to do with the ultimate limits of knowledge ... rather than ... this is a place where we really reach the edge ... and ... maybe one doesn't believe that ... [he stops to allow other opinions to be expressed]

Greg Chaitin: You've been using the word "muddle-headed." And that's a very good word[, because] if you eliminate the muddle-headed you [then] sort of force the NKS!

Stephen Wolfram: That's an interesting claim! (He's amused but satisfied with this statement. People laugh).

Greg Chaitin: No, no – because ... let me say why. Because let's talk about the notion of real randomness in the physical universe. That means that there are things that you can't understand, things that are irrational. Now my understanding of you and the principle of sufficient reason of Leibniz which Gödel believed in also is this: if you believe that everything is rational and that everything in the Universe one should be able to understand using reason, then I think you're necessarily driven to look for a discrete Universe along the lines of ... [commotion, Chaitin louder:] ... highly deterministic ...

Stephen Wolfram: Yes, it might be deterministic ... yes, but it might also be that there might be another level or reasoning. It may be that Turing level of reasoning wasn't the right level of reason for our Universe [there's more content to, you know ...] Leibniz didn't know about the Turing level of reason, he just had an intuitive level of reason, we think we have a precise sense of reason which is the one that ... right now it seems to be all we need to describe what we do in computation. I think this point though that you can describe things that you can't actually make is an interesting point, which is kind of the key to the success of symbolic mathematics. But there's one question that is far from clear which is how far can you go in describing things that you cannot make? That is, is it the case – I know in the higher [reaches] in set theory people are always concerned whether as you start naming more and more and more infinite kinds of things, does it all eventually fall apart? Can you go on to even describing things as you get to more level of infinities so to speak?

[11]Again hinting at the PCI and its manifestations. –Adr.

Greg Chaitin: Maybe [there won't be enough [infinities?]] to go around ... ?!

Paul Davies: What about hyper-computation, which is something we can imagine but can't ever do?

Stephen Wolfram: I think it's a question of physics, whether hyper-computation is something that we can really imagine but can't ever do, or whether the Universe does actually allow hyper-computation ...

Paul Davies: Oh, so we're back to this business of what is in principle doable but may in practice be not achievable because it's outside of the capacity of the Universe to provide us with whatever it is we need from the technology in order to [ever be able to] do it.

Stephen Wolfram: Right.

Paul Davies: So there are things which are logically possible, but it's not achievable because they're beyond [the capacity of physics].

Stephen Wolfram: Right. So your question whether there are things that we can't achieve in our Universe – that would be an answer [the question of] what is achievable. But I think Karl [has prepared some notes and] wants to say something.

Karl Svozil: This is for all the younger people out there: Let me just point out that this discussion was an excellent demonstration that in order to be successful it's not enough just to be a genius, but you must also be able to communicate. So communication and domination these are very [interconnected] issues (laughter, he said 'domination' with a very heavy German accent, not sure why.)

Karl Svozil (continues) : So (laughs) if you look at speaker's house, you can immediately deduce, or rather interpolate, the celebrity of the (excuse me) research that he is doing. But I would like first to comment on the issues that have been mentioned here before: finite versus infinite, continuum versus discrete, randomness versus deterministic. And in doing that I would like to use a concept (or an approach) that we can derive from the Freudian psychology and that they call '[evenly-]suspended attentiveness[12]' but before I even start doing I want to say that I am more on the side of Stephen's ideas, that is I too think that the Universe is discrete [because this idea is more] iconoclastic to think that. On the other hand I am also very interested in the technology of the continuum because there should be some sort of correspondence with the powers of the infinite [which would then be in line with the continuum]. Let's say for instance my perfect example from a long time ago would be the [Banach-]Tarski paradox[13], which started out with [an arbitrary ...] which just translate in [rotations with] finite numbers [of additions] and so on and so forth [...] but [this could be an example of] how all these technologies [might be] some day[14].

[12]http://www.answers.com/topic/evenly-suspended-attention

[13]http://en.wikipedia.org/wiki/Banach%E2%80%93Tarski_paradox

[14]Just search Banach-Tarski paradox, he says maybe there will be technological applications of it one day. Well explained there.

So, all in all, I think we should discuss this in threefold: scientific perspective, metaphysical perspective and the historic[al] perspective. We should cover all three of them, but let me start by addressing one thing that is what interests me at the moment. I think that in order to go beyond what we are discussing at the moment two things are necessary – this is my view, you know, so I encourage everybody to have their own belief system just like I have my own belief system – so, my belief system, is that [...] the observer needs to be integrated into the system and that [...] new systems [are necessary] in order to be able to understand physics [... the infinite ... go on forever ... and] for example as Gödel once said [quotes in German?] [... that is, that completeness ... physical systems ...] even within the problem [... intrinsic perception] very important also important because ... and by the way the devices used in Greg's first paper are Moore automata, because Moore was interested in modeling complementarity in this kind of automata and I believe that complementarity is a generic feature of all computers in the Universe. But I don't want to speak about that and what I want to speak about is something that is very exciting for me at the moment (and I've had this paper in mind for quite some time, but got distracted with various personal things) [that] for something to be a bound [not sure] nowadays if you're in quantum mechanics ... we are omniscient ... [... that we believe classically] ... our measure ... this is not ... this is basically [Kochen-Specker?] theorem, but I think we need to go beyond that. And, most importantly the historical aspect that all is preliminary [...] computer theory like ... you know, quantum mechanics, for instance, is a hybrid theory ... the continuum combined with discrete [...] but ... infinite space they are continuous ... So I am just excited! I'd love to live for a period of much longer than I can and will, because I would like to see what happens – and I am looking forward [and with the new ideas and theories] to what comes after that.

Stephen Wolfram: Can I try to ask a question that I am curious about? OK, so let's say that one day we have the fundamental laws of the Universe. We know them, we have them, we can write them out as code, in Mathematica or whatever.Then – what kind of thing can we conclude from that? That is, once we know that our Universe is six lines of Mathematica code and here they are – what would we then [do with it]? What will we then conclude [from that]?

Paul Davies: I can ... May I? I think that the first question to ask is clearly to be otherwise, or is that just one of maybe an infinite number of different Universes that you can have [... bits of ...] in other words is there any other way or this is the only way?] and I suspect that the answer has to be "No." (Wolfram agrees) So then the question is: is this the simplest way of doing it consistent with the existence of observers such as ourselves?

Stephen Wolfram: What does 'simplest' mean? That might be ... well, [let me just say that] we would feel very special if we were the simplest Universe that could be made.

Paul Davies: Right, [it would be] somewhat arbitrary ...

8. The Hunt for Our Universe

Stephen Wolfram: My guess is that out there in the universe of possible Universes there are zillions that are rich enough to support something kind of intelligent and kind of like us, and whether we write it in Mathematica or write it in Java or something else – which would end up with a different ordering, and there would be a different ordering as to which one is the simplest Universe, and whether there is any invariance [remains to be seen]. So one possibility would be that it will be a simple looking Universe because we live in that Universe and the primitives we put into our [computer languages] are such that our Universe will end up simple.

Paul Davies: That we couldn't discover our Universe if it's more complicated. In other words we will never complete the program you're talking about unless it is simple enough, of course, for us. So by definition either it's a mystery or it's simple.

John Casti: So the other real worlds are too complex?

Paul Davies: Right.

Stephen Wolfram: So that, OK – so one possiblity would be that there is no way ... no, but I don't think that's right, I think that we need to unpack a little more. I was hoping ... you guys ...

Cris Calude: Assuming, assuming by absurdity that this Universe is 60 lines of Mathematica, how you would realize that this is true?

Stephen Wolfram: In the same way that you would do it for 6 lines. You run it ...

Cris Calude: Oh, oh, OK ... then how would you do it for six lines?

Stephen Wolfram: ... (pause) ... so, that's a good question. But the fact is that it's hard! I'm in this business, I actually hunt for Universes, OK? I can tell you that [being on] the front line it's quite difficult. You make something that is candidate Universe you can often tell that is hopeless, quite quickly. Sometimes there's a candidate, this thing we caught in the net, that is not obviously hopeless so, when that happens you start them off, [you let them run,] they run out of memory, etc. Now one's hope is that before they do that they appear to exhibit have some features that we can recognize some feature of our [real] Universe, like a finite dimensional space. As I keep on saying, my goal is to recapitulate the history of physics in a millisecond by being able to take the actual natural thing that is this Universe and be able to deduce from it the effective physical laws and then compare them with the other's [...] that's the only way, but you're right, we will never know whether this Universe that we have [is] exactly our Universe. It could be that it would get, you know, we check off on the feature list we check off 20 features, and they all work perfectly. But unfortunately, it is exactly our Universe except the poor lepton is missing

...

Karl Svozil: ... my question would be ... first generate ... three-dimensional ... you have to create an observer, intrinsic observer ... realizing ... you have to give meaning to the concept of three-dimension ...

Stephen Wolfram: Oh, yes, yes – this gets us into deep technicality, but ... yes, you are entirely correct that one of the non-trivial things is recognizing that we need a very operational definition for all these kind of things within the context ...

Karl Svozil: Extremely interesting ... I was [...] by your ideas that it's not only the physical Universe that is interesting, but there's a vast collection of Universes out there ... and practically ...

Stephen Wolfram: My own guess is that if the Universe is simple then then chances are we won't miss it by just a single bit. That it's very unlikely that among the simple Universes there's one that is exactly ours but for a small bug. That's what seems to be going around, out there in the trenches of the Universe hunters these days, that there are either ... [But] they're really way wrong, because I think that the distance ... between each ...

Karl Svozil: Stephen ... I think that [you might have left out the possibility that] there might be just one Universe that is consistent. And this might be our Universe, and this might be the only consistent Universe.

Stephen Wolfram: What does consistency mean?

Karl Svozil: Consistence means for instance ... [...]

Stephen Wolfram: I don't think that make any sense.

Greg Chaitin: Not for programs.

Paul Davies: Not even for theoretical physics it doesn't. The phrase "consistent Universe" is a lot like (or brings to mind) the [tearing?] model in quantum field theory, which is my favorite [example]. It's exactly solvable to its one plus one dimensional non-linear or self-interacting quantum field theory which people have started to study because it's sort of an impoverished model of reality but it's exactly solvable. It's not our Universe but it's a self consistent possible Universe [... counter examples with self-consistent Universes ...] not this one.

Stephen Wolfram: I don't think consistency [has anything] to do with programs. I mean: you take the thing and you run it, it may do something that you don't like, but [there's no such notion of] axiomatic consistency. I still want to push this point a little bit further ...

Greg Chaitin: Well, one possibility: we have entire genomics now. We have the complete genome of hundreds of different creatures and people are comparing them, so one possible future is that there are lots of candidates that you can come up with, and it gets very very hard to see if they are right or wrong (because it's at the 10^{-200} scale or something) so you might end up having a future subject which is "comparative universality" – we have all these laws for the universe that cannot be eliminated as ours and [you] study them you talk about them, you compare them, this could be a future subject. Students would be required to pass exams on their ten possible favorite universe ...

Stephen Wolfram: Right now we don't know the fundamental laws of physics. What you're saying is [that] in the future we may have this whole collection of possible [fundamental or] candidate Universes ...

Paul Davies: ... fairly good universes. And it's easy to imagine that you have two which are practically indistinguishable ...

Stephen Wolfram: But I don't think that it is that easy to imagine ... because if the laws are simple enough the distance between ...

Paul Davies: That's true...

Greg Chaitin: ... on the other hand you do admit that it's very hard ... it might be very hard to see if the Universe actually is out ...

Stephen Wolfram: ... I agree ... but I don't think they'll be close ...

Paul Davies: ... you have to make the assumption of immutable laws ... because you can always imagine tweaking things ...

Stephen Wolfram: I don't think that makes any sense.

Paul Davies: Well, then, I think it's horrible.

Stephen Wolfram: No, but it doesn't make any sense. Once you have universal computation, it's the same as – so here's the thing with something like with cellular automata, people are always saying "Couldn't you get richer behavior if you let the rules change as evolve the CA (or as the CA is running)? That's a muddle. And the reason that's a muddle is because once, particularly if the actual rules ... it's like the Universe of computing, you might say: you could never get richer behavior by changing the underlying hardware because you can always emulate any other form of hardware within the hardware that you already have ... I think maybe Greg has a better way to say this ...

Greg Chaitin: No, I'll give you a slightly different thing ...

Stephen Wolfram: No, he needs to understand that. Because he doesn't understand it. Explain it to him.

Greg Chaitin: Oh, he doesn't understand it?

Stephen Wolfram: He doesn't. No, no, explain it to him. You can probably explain it better than me.

Greg Chaitin: [Hesitates.]

Stephen Wolfram: No, no, describe it to him. [People laugh.]

Greg Chaitin: (Tries to change the subject) Let's say you find ...

Stephen Wolfram: No, no – this is an important point! (People laugh).

Paul Davies: But do you know about ... the Parrondo[15] games ...?

Stephen Wolfram: No.

Paul Davies: Ah-haah! ... Well, you see ... (Starts explaining:) so here ... in effect you have a game of chance which has an expectation of loss. And you have another game of chance which also has an expectation of loss. You can play them in combination with an expectation of gain even if that combination is random. So it shows [that] randomly changing ... it's not any of those, but some examples ... where randomly changing the rules as we go along actually has a creative aspect. So this is a bit like having your automata changing their rules, even randomly, may give you more, may give you ... (Wolfram intervenes)

Stephen Wolfram: Not so sure about the case where they change randomly! Because as soon as you talk about randomness you're talking about injecting some information from outside the system ...

Paul Davies: Well, you don't have to do it that way, you can actually do it systematically ...

Stephen Wolfram: But as soon as you do it systematically why isn't it just an extra bit in the rules?

Paul Davies: Oh, then it would be!

Greg Chaitin: Can we go back to your original question? (Wolfram agrees wants to hear it) So let's say you have the laws of the Universe in front of you. Then what happens? One possible scenario is the following: let's say this law is very simple; then you might think we are the only possible Universe, you know, that there is some kind of logical necessity that it should only be like this, etc. But let's say you find the laws of the Universe and they're actually rather complicated. Not too complicated that we never find them but that they turn out to be really very complicated. At that point you might suspect all possible universes might exist, otherwise why should we be in this complicated Universe, rather than in a simpler one that was a possibility but doesn't give us our Universe, it gives a different kind of Universe, but, you know, in some ways is a good Universe too – even if it's not ours. So, is that a conceivable ...

Stephen Wolfram: Yes, I think it is the case [that] if it seems like in our enumeration of Universes this would be the very first one that occured it would seem, even though it's kind of an illusion, because it depends on the kind of primitives we choose ...

Greg Chaitin (agrees): ... on the ordering of complexity, yes ...

Stephen Wolfram: But, in that case it would indeed seem like there's something logical and inevitable to that ...

[15] `http://en.wikipedia.org/wiki/J._M._R._Parrondo`

Greg Chaitin: And maybe we're unique then, maybe this is the only Universe.

Stephen Wolfram(continues) : But if we are just random planet no. 3 on [a] star at the edge of a random galaxy, it would then seem [that] there should be a lot more like us, no? I don't know, I am just curious – because I just haven't figured this out yet, I haven't unpacked this problem yet. So let's say if the Universe is reasonably simple in our representation [and suppose] there are ten candidate universes sort of in [the] range of where one would think that our Universe would be, [but] they have eighteen and a half dimensions of space and [suppose] that they have various problems that they are not really quite right ... so what we would conclude, what would we say, would we [then] ... it's ...

Greg Chaitin: ... well we might believe that it's arbitrary and then the idea of an ensemble or landscape of the alternate universes acquires some [persuasion,] perhaps starts having some reality [starts to seem more] persuasive whereas if we have very simple universe and there are no other fairly good candidates nearby then we start to think that we are unique, that we're the only Universe, because this was the only possibility [that] there's sort of a logical necessity ...

Paul Davies: Yeah, I think that you can rule that one [as a general statement] but it might be the simplest class ... [... complexity ... as observers]. So maybe special in that sense, there may be something special about it. It may not be the simplest, it may be of some other character.

Stephen Wolfram: Can I try one more question, [which] I think might engage everybody here. Which is about mathematics. I have a definite position on this on this question, of how inevitable the mathematics that we have is. I guess everybody here knows that I have a very definite position on this, which is that it is not inevitable at all, and it's just a historical accident basically. But I am just whether other people are sharing that point of view – or not.

John Casti: What do you mean by being inevitable ... the inevitability of mathematics ... in the axiomatic framework, or ... ?

9. The Future of Meta-Mathematics

Stephen Wolfram: So what I say is that the axioms of mathematics that have given is the $3 \cdot 10^6$ papers that have been written about mathematics, these are that – if you look in the space of all possible axioms systems, these are just a few axioms systems that are [...] around that space of axiom systems and that there is nothing particularly special about it [them]. I've done this thing with boolean algebra where I found which serial number of axiom system is boolean algebra and the answer was about the 50,000th axiom system. And so the question is [that] people nevertheless say: "God created the integers" for example. That's something somehow that seems more inevitable. But my point is ...

Cris Calude: But do you disagree with this?

Stephen Wolfram: Yes. I disagree with it.

Paul Davies: I think I disagree with this to. Because you can imagine a different kind of Universe where the natural numbers may not be natural at all.

Stephen Wolfram: Yes, that's what I think.

Stephen Wolfram: So, Cris doesn't ...

Cris Calude: Well ... I don't know ... it's very un-natural for me to think that a natural number will come out in an unnatural way. I can fully agree with the fact that the various axiomatical systems we're using are [entirely] accidental and probably they will disappear very quickly. But that are some building blocks of mathematics which seem to have much more reasons to remain than the others. And the natural numbers [are in that category].

Paul Davies: But that's only because of the physical structure of our Universe. I mean David Deutsch pointed this out a long time ago that [... something that I don't understand ... is tied to ... not under the laws of Physics but the stuff of the Universe that we see]. [I mean] a Turing machine is a physical machine. So if we imagine a Universe with a different goals and different [stuff] – what is computable in that universe is not computable in this one. And so we live in ...

Cris Calude: OK, so in this quest to find new Universes do you have an example of toy Universe strictly strictly simple where you know the mathematics is radically different ... (Davies is trying to reply, others talk too)

Paul Davies: ... is a primary example ... [he mentions topos theory?] ...

Cris Calude: ... you can't talk about topos theory without natural numbers.

Paul Davies: Can you not? Well, then, I don't know.

Stephen Wolfram: Well ... take an axiom system ... (Everybody talks now.)

Paul Davies (concluding): So you need natural numbers!

Cris Calude: Yes, you need natural numbers ... Actually I think this belief could be much more substantiated if you could construct a very simple Universe in which the natural mathematics would be unrecognizable from this Universe (or, from the mathematics in this Universe.)

Stephen Wolfram: So one question is: does our Universe give us our mathematics? I don't think that it does.

Paul Davies: Well, I think that it probably does. We live in an Universe that has a certain type of natural mathematics [and] in which there are certain types of processes that we call computable [...] brain recognizes [...] but we could have [...] logic [...] and it could be a completely different world ...

Stephen Wolfram: Yes, but but ... (or is it Calude?)

Cris Calude: ... but the natural numbers remain invariant for all different [mathematical] objects that you have enumerated ... they're different mathematics but you cannot do ...

Stephen Wolfram: No.

Paul Davies: All I'm saying is that you need natural numbers in all of these.

Stephen Wolfram: So imagine a world in which, the weather has a mind of its own so to speak, and we exist as a gaseous intelligence. Where there are things that are going on that but there's nothing really to count ... you know, imagine something something that ...

Greg Chaitin: No fingers ... that's it! No fingers – no natural numbers! ... (Now everybody laughs)

Stephen Wolfram: But will it explain ... so one possible claim would be that in any axiom system that is rich enough to describe something interesting there exists some copy, there exists something analogous to natural numbers ...

Greg Chaitin: Euclidean geometry doesn't have it. And it's also [complete?]

Stephen Wolfram: But Euclidean geometry is decidable.

Greg Chaitin: Yes, it's complete. It's decidable. No natural numbers.

Stephen Wolfram: OK, so this will be interesting. There's a precise claim that can be made which is that (ponders, for a moment) so, decidable (starts again:) let's explain the technicalities because this is kind of interesting. In theories of mathematics you can have those that are closed and decidable, where truth statements could be established in finite ways and so on. So boolean algebra is an example of one of those, Euclidean geometry is another example of one of those, real algebra is another example of one of those, integer, you know, Peano arithmetic integer equation (and so on) is not an example – it's an open thing that is undecidable and so is set theory and so are other axiom systems of mathematics. So the question might be (let's see, maybe this is obviously true) the claim might be that within any undecidable theory in mathematics you can create objects that are similar to integers (which have the properties of integers). I think that is obviously true – because I think it's universality that supports this argument, I mean Peano axioms for arithmetic define a certain axiom system that allows you to prove things about the integers, but I think that as soon as you have an axiom system (actually it's probably not totally obvious) if you have an axiom systems that is universal, in which you can essentially support Turing computation – then I claim that it follows that you can construct, you can emulate within that axiom system Peano arithmetic ...

Cris Calude: You can emulate natural numbers in various ways, so the difference between what your Universe and what Greg said about geometry is that you can emulate natural numbers in both universes but with different properties. So the properties in geometry [are] much weaker than the ones in Peano arithmetic – so this is why you have this degree [of] decidable and undecidable.

Stephen Wolfram: But I think that the claim would be that as soon as the system is sort of universal you will be able to emulate it or construct it with the Peano axioms. Now there is one [...] thing which maybe is getting in technicalities of computability theory but in the case of systems that can be universal computers there is this possibility that there are things for which there are undecidable propositions. It is claimed – I don't think this is really right but – it is often claimed that there could be things where you have undecidability but not universality. So that's the Friedberg-Muchnik theorem[16] which is a rather obstruse piece of computability theory. So the question would be: "Could there be axiomatic systems where there is undecidability but where you cannot embed ... (doesn't finish because Chaitin starts talking with the answer)?"

Greg Chaitin: So I suspect that the answer is: "Yes" but that it [requires, or relies on] some other construction, like the Friedberg-Muchnik theorem. In fact doesn't that give it to you immediately?

Stephen Wolfram: Yes, it does.

Greg Chaitin: The Friedberg-Muchnik immediately gives us as a corollary that you have an axiom system that is undecidable but which is not equivalent to ...

Stephen Wolfram: I don't think that's right, because I think if you take apart – so my claim is that about the Friedberg-Muchnik theorem is that (this is getting deeply technical)

Greg Chaitin: ... for most of the audience, yes...

Stephen Wolfram: Is that if you look inside the construction there's a universal computer running around ...

Greg Chaitin: Well, yes, yes – but you can't get to it by that universal computer. That's the whole point. It is there but you can't get to it.

Audience Member: No, no, no – the Friedberg-Muchnik theorem says that ... if you take two sets which are both intermediate but if you're taking the two sets together they're complete ... (Now people start to think, there's a moment of silence where they ponder, so Wolfram notices that and wants to keep the discussion going...)

Stephen Wolfram: This is getting far too technical ...

Karl Svozil: It is worth mentioning that there is one instance of the undecidability ... complementarity. And this refers to the [...] that if you are inside a system and you decide you want to measure A then you can't measure B or, viceversa, you want to measure B you can't measure A ... this is something that is completely different ...

Stephen Wolfram: Is that really the same phenomenon at all?

Karl Svozil: It's totally different from [...]

[16] See page 1130 in the NKS book.

Greg Chaitin: It's more like Heisenberg complementarity.

Karl Svozil: Yes, it was invented ... informal ... algorithmic ... this model ... to formalize ... complementarity ... and in doing so ... this guy ... [Moore] ... created an entire field of computer science ... in the 50s ...

Greg Chaitin: 1956.

Stephen Wolfram: But automata theory went off in a totally different direction.

Karl Svozil: Yes, but this thing is robust [...] ... and ... one candidate ... just sent myself e-mail to remind myself about Greg's remark regarding ... comparative universes ... this should be a new research topic.

Greg Chaitin: Yes, this is E. F. Moore paper "Gedanken Experiments on Sequential Machines" pulished in 1956. Wonderful volume called "Automata Studies"

Cris Calude: Shannon was an editor.

Greg Chaitin: Yes, Shannon and McCarthy were editors, von Neumann had a contribution this book is marvelous, it's the beginning of theoretic universality, it's the first book (of its kind). I saw it reviewed in Scientific American a very perceptive review, I immediately ran to the bookstore, I had saved my lunch money and bought a copy and then I started doing computer experiments with Moore's stuff. Moore's book is epistemological, automata theory went off unfortunately in algebraical directions, you'll see from this that I don't like algebra but the original paper dealt with complementarity and models of induction [...] epistemology. It's a wonderful paper, and I met him once, he had another paper – I guess he's probably dead by now, but I remember him well, he was red headed, (to himself) I guess that's useful information (people laugh) – and he had another paper on self-reproducibility of CAs ...

Stephen Wolfram: Ah, so he is the guy that had ...

Greg Chaitin: ... the Garden of Eden

Stephen Wolfram: Yes, but he also had the self-reproducing fish[es] in the ocean ...

Greg Chaitin: I think so.

Stephen Wolfram: He had this paper in Scientific American in which he talked how sometime in the future there will be self-reproducing ...

Greg Chaitin (remembers): ... artificial self-reproducible plants, yes! That then you harvest and they go all over the sea ...

Karl Svozil: I would be interested in this, for example I would like to run an experiment [...] propositional type of space [based] on these computational issues. [...] compare finite to quantum logics it is provable that all finite quantum logics can be simulated with [...] but there's ... [Moore] ... quantum logic has a richer structure, but if you only look at the finite [part of] structures then it's almost equivalent, almost equivalent. So my suspicion, or my claim is that if you believe in a computer generated universe then you would experience complementarity very much you would experience quantum mechanics ... the complementary of quantum mechanics. What you would [...] experience would be [...]. But this is an entirely different ...

Greg Chaitin: Very technical work.

Stephen Wolfram: Could degenerate quickly.

Greg Chaitin: But this is [still] about the future of meta mathematics?

Stephen Wolfram: This is sort of related to this question whether our mathematics – that is, if integers are inevitable and what aspects of our mathematics are kind of inevitable, and what aspects are just a feature of the Universe we happen to be in, you know, what is the relationship between the Universe we're in, the mathematics that we make, what we're like and, sort of, the space of possible mathematics.

Greg Chaitin: That about covers it, for sure!

Stephen Wolfram: ... but the future of mathematics ...

Greg Chaitin(mischievously, on purpose): Well, then I think that all possible answers have an element of truth! (Big laughter from the audience.)

Stephen Wolfram: ?

Greg Chaitin: It's a complicated question ...

Greg Chaitin (tries to explain his joke and to make up for it): Well, when you think that the mathematics is just axiomatic systems then the whole thing is very arbitrary, because it's very artificial, but if you believe in mathematics as a kind of description of a platonic world of ideas which has an independent existence, then mathematics tries to describe it and there's some necessity to it.

Stephen Wolfram: So your question is: is mathematics about something?

Greg Chaitin: Is it about something? – exactly, or is it just symbol manipulation? So I believe that there is a two level structure, and the way you are looking at it it is a one level structure ...

Stephen Wolfram: So if it's about something maybe it's about our Universe.

John Casti: But if you look at Gödel's theorem, it says that number theory is about numbers – [which are] an irreducible semantic component ...it's not just symbolic.

Stephen Wolfram: But wait a minute ... isn't Gödel theorem ... doesn't it say that number theory as practiced in the Peano axioms ... [it] is effectively saying that isn't necessarily about numbers ... because the whole point is that Gödel's theorem shows ...

John Casti: ... excuse me, that numbers are just not part of a sumbolic structure, that numbers have a semantic content. Number theory is about something. It's not a ...

Greg Chaitin: Otherwise ...

Stephen Wolfram: But wait a minute! The problem with, I mean, one of the results of Gödel's theorem is that – so Gödel theorem's says that given the Peano axioms (the axiomatic system that's supposed to describe numbers,) that in a sense any axiomatic says that there are things out there, somewhere, in the platonic world (or wherever else) that have the following properties. And then the purpose of an axiom system is to sculpt those properties so well that the only thing that the axiom system can't be describing ...

Greg Chaitin: But that's impossible.

Stephen Wolfram: Well, that's the whole point ... for logic it is possible.

Cris Calude: But axiomatic systems are themselves an accident of history. You know, this is what we have done in the last one hundred years and we are trying to turn it into a religion, but (others start talking at the same time while he is saying this, Wolfram says: "I agree, but it's interesting, having said that") but there is nothing intrinsic to get stuck on these systems.

Greg Chaitin: Well, because they are self-destructive. I mean what Gödel did, in a way, formal axiomatic systems did he showed that they're useless, and that's Godel's result. He's working from within (Hilbert's program, he explodes Hilbert's program). So where are we [after that,] and what are we left with ...

Cris Calude: Well, random... it's all random.

Greg Chaitin: ... and Gödel says "intuition". (Towards Calude:) What?

Cris Calude: Randomness. [... but] this is one possibility. This is again by all means not a unique but there is an alternative – a credible alternative ...

Stephen Wolfram: We should say for people that don't know, this is kind of interesting fact actually what Gödel theorem actually establishes [which is] that there exists in addition to the ordinary integers, that satisfy the axioms of Peano arithmetic, there is an infinite hierarchy, of bizarre kinds of non-standard arithmetics ... where even the operation of addition is not computable ...

Greg Chaitin: ... which is not ours but that satisfy the same axioms ...

Stephen Wolfram: ... so the axiom system is not an adequate way to say what you're talking about, so to speak. But your statement of axiomatic systems – I tend to agree with you that axiomatic theory are an unfortunate accident ...

Greg Chaitin: ... and one from which we will hopefully recover ... as [...] said about set theory I would say about ...

Stephen Wolfram: ... and what I certainly think, and perhaps this is a very biased group that the kind of, you know, the programs and things that you can specify by computing rules are that things that we should look at, rather than these axiom systems as ways to describe things ...

Paul Davies: In which case this raises an issue that has interested me for a long while, which is that if we assume that the laws of the Universe are computable then we can imagine different sorts of Universes, in which different types of mathematical functions would be computable functions but they didn't obey the rules of classical Turing machines [...] we'd have a different definition of computability. So then there is a self-consistent loop: if our laws are indeed computable, given a Universe which has the right type of physical structure to give the right type of computability to make the laws which describe it as computable (that's what I call a nice consistent loop) – is that loop unique? Or are there any other number of self consistent loops, where the physics and the stuff and laws and computability ... [Chaitin starts talking at the same time] ... [would be nice enough] to exhibit something?

Greg Chaitin: Well the answer is: probably. There probably are, but Stephen and I believe that (Davies is still speaking. Chaitin stops, listens, Davies ends. Chaitin starts answering again:) I believe that there probably aren't. David Deutsch probably believes there are but Stephen and I seem to think that the current notion of Turing computability is a priori and is [indistinguishable] from the physical universe, Deutsch says :"No!" ...

Stephen Wolfram: No, it's not that I necessarily that I say ...

Paul Davies: [speaks along with all the others]

Stephen Wolfram: No – [the current notion of Turning computability] is enough for our Universe. But your question is a good question and a precise question. Is there a way ... I mean what seems to be the case is that Turing computability is a nice robust notion. All these different things that we come up with: potential models of computation, all seem to be equivalent. What has happened in the world of hyper-computation, or super-computation there are a variety of names and there are lots of various definitions and unlike what happened historically with Turing computability, which is that all definitions seem to converge [in hyper-computation] that is not what seems to be happening, I mean everybody will claim that their definition is the right definition but it seems to me a perfectly valid question ...

Greg Chaitin: ... you are offering them a number of alternatives. Add to a Turing machine an oracle for the halting problem. That gives you a new kind of Turing machine. It, in turn, has its own halting problem. If you add an oracle for that to a Turing machine you get a still higher Turing machine that can compute even more stuff [and] you have an infinite hierarchy ... and in fact it's much more than ... just this complicated structure.

Stephen Wolfram: So: can you make a consistent model of the Universe in which you have a Turing machine plus oracle as the fundamental stuff running in the system?

Paul Davies: Remember it's machine ... a real machine with real laws ... made of real stuff ...

Greg Chaitin: Well, you can certainly have a consistent notion of computation, an infinite number of possibilities where you can compute things that are not computable in our world and it just keeps going on like that. So I suspect there are perfectly consistent physical universes in which each of these levels of uncomputability is the level of computability that corresponds to that next physical Universe (Davies, Wolfram, Chaitin, everybody speaks. Chaitin finally continues louder than everyone else:) So we would take as the most natural thing being able to compute the halting probability for *our* machine but not for their own Turing machines.

Cris Calude: In this context an interesting question is how much knowledge do you get in these higher and higher models of computation. I can tell you that for instance that algorithmic randomness that we discussed here is level zero, and Ω numbers are in a sense the weakest random numbers that are random but they have the maximal compressed knowledge in them. You can construct higher and higher more random numbers, none of them having the knowledge compressed as much as the Ω number. So the question is not only how much you can compute but with what result. What knowledge can you deduce from more powerful computation?

Greg Chaitin: ... at our level? And the answer is: not much.

Cris Calude: ... as a level of randomness ...

Stephen Wolfram: No, but one issue is: you're asking what kind of computations can you do in a particular type of system or what kind of computations are easy to do with a particular kind of system. There's a question of whether in that kind of system you can do a lot of computations that you care about, or whether there are computations that you care about that you can't do. So when you say "not much knowledge is obtained" ... you've only got the Ω number...

Greg Chaitin: Well, what we can perceive at our level, you know, if you saw an Ω at a higher level, Ω at our level is in principle giving you an immense amount of information. But given an Ω at a higher level (I'm just explaining what Cris explained somewhat mistakenly) if you see an Ω from a higher level (where there's an oracle for a halting problem for every Turing machine) that Ω (unlike our Omega down here, which gives a lot of information to us down here) that higher order Ω gives absolutely no information.

Stephen Wolfram: So you're saying that from our level we can't make much use of an Ω.

Greg Chaitin: ... a higher order Ω ...

Cris Calude: Let me give you some examples. With Ω for instance you need about three thousand eight hundred bits to solve the Goldbach conjecture. With about 8000 bits you can solve the Riemann hypothesis ...

Paul Davies: Where did you come up with ... these numbers?

Cris Calude: I computed them.

Paul Davies: But the Riemann hypothesis is not solved.

Stephen Wolfram: *To solve it* if you had the Ω number.

Cris Calude: And *if you had* the Ω number.

Paul Davies: Oh, if you had the Ω number!

Greg Chaitin: Cris has programmed a program that large which holds if and if the Riemann hypothesis holds. So that's how ...

Cris Calude: But if you go to any higher parts of Ω you won't find any finite number of bits that would give you the solution for the Riemann hypothesis, for example – so, in spite of the fact that you get incredible more power, this power doesn't help you to solve anything ...

Stephen Wolfram: But it would help you if there were problems formulated at the next level up then it would help you. (Both Chaitin and Calude agree.) But the point is – so this relates to what we consider to be interesting [and] at this point we don't have the possibility to even imagine [what is interesting to ask as a question] ...

Cris Calude: We don't know.

John Casti: So we come back to the problem of an observer and the complexity that is in fact relative to the observer.

Stephen Wolfram: That's true.

Greg Chaitin (to Wolfram): I definitely agree with your statement that the notion of computation in my opinion also is more basic than logics and axiom systems and it's a better way to think about things. I may have formulated that in a different flavor than yours ... but I think we agree on that.

Paul Davies: I need to go.

John Casti: So if everybody is in agreement [we can] bring this panel discussion to a close. Thank you all. Some of us will still be here, others need to go.

Paul Davies: I need to go to the airport! Right now.

John Casti: Right. So I'd like to thank all of the [members of the panel].

Applause. End of recording.

Note

Recording: Jeff Grote. Transcription: Adrian German (who, alone, is responsible for any inaccuracies). Last modified: `Sun Oct 18 20:52:49 EDT 2009`