

Etienne Ghys, Jos Leys

Sol Lederman: Welcome everyone to “Inspired by Math!” In this podcast series, I interview people who are inspired by math and who are inspiring others. I’m very excited this morning to have with me two of the three guys who put together the “Chaos Series” of videos.

This is Jos Leys and Etienne Ghys. Welcome Jos and Etienne.

Etienne Ghys: Welcome.

Jos Leys: Hi Sol. Hi.

Sol Lederman: Hello.

Etienne Ghys: Hello.

Sol Lederman: So let me read the bios of these two gentlemen and then I am going to ask them to tell you what their video series is about, and we’re mostly going to focus on their new series “Chaos” but they also have put together a wonderful film, “Dimensions”.

So let’s see. Jos is a Mechanical Engineer, born in 1952. He worked in the chemical industry for an American company he emphasizes all of his life until he retired seven years ago and his hobby is using computers for mathematical visualizations. And I have to say, that is quite an understatement if you get a chance to look at some of his artwork. You’ll realize he’s being very, very, modest.

Etienne was born in 1954. He’s a French Mathematician. His research focuses mainly on geometry and dynamical systems, though his mathematical interests are broad. He also expresses much interest in the historical developments of mathematical ideas, especially the contribution of Henri Poincare.

Etienne Ghys: Good.

Sol Lederman: Thank you. He co-authored the computer graphics mathematical movie “Dimensions: A Walk Through Mathematics”. He’s an Alumnus of the Ecole normale superieure de Saint-Cloud. He is currently a CNRS directeur de recherche...

Etienne Ghys: Yes.

Sol Lederman: ...at the Ecole normale superieure in Lyon. He is also editor-in-chief of the Publications Mathematiques de l’IHES...

Etienne Ghys: l’IHES.

Sol Lederman: Okay. l’IHES, and a member of the French Academy of Sciences. Once again, welcome Jos and Etienne.

Etienne Ghys: Thank you.

Jos Leys: Sol, thank you.

Sol Lederman: Yes. So I’m very excited to have the two of you on the podcast this morning because I am a huge fan of visual things for exciting people about math. I have spent way too many hours, months, years of my life, sitting in a classroom learning math and it’s very exciting to see that the two of you, use leading edge technology, to make some very difficult ideas,

things like “Chaos” and multidimensional things. How do you visualize the fourth dimension and things like that and you guys have done just an absolutely amazing job. So again, thank you for being here.

So I’ve got a bunch of questions and we can more or less alternate. You guys can fight amongst yourselves to decide who wants to answer first and I’ll sort of be referee if we need that.

Now, there are three of you who made the “Chaos” film and only two of you are able to be on. So when I ask you this first question, please speak a little bit for Aurelian.

Etienne Ghys: Aurelien.

Sol Lederman: Aurelien. Please speak for him as well because he’s also a part of this film. So what inspired the three of you basically to create “Chaos”? What’s exciting about “Chaos”?

Jos Leys: Etienne, you have a go at this one.

Etienne Ghys: Okay. So maybe I should, instead of answering your question about “Chaos” maybe we should begin by the previous one, “Dimensions”.

Sol Lederman: Okay.

Etienne Ghys: Maybe I should tell you the story that maybe it was six years ago. As a Mathematician, I was supposed to give a popular talk and I was looking for images to illustrate my talk. And I found pictures on the web, of course pictures from Jos. At the time, I did not know him, so I sent an email to him asking him to help me with these pictures.

So he lent me some pictures, I used them and I remember them. Well, after the talk, I sent an email to Jos saying, who are you? And Jos told me that he’s an Engineer, he was interested by mathematics and we decided to collaborate.

And we began producing pictures and pictures of pictures, but at some point, I suggested that maybe we should make these pictures move and we began producing the short clips of a few minutes, maybe three minutes at most. And at some time after I gave another talk, Jos wanted to understand those pictures because Jos is not a Mathematician. He was not trained as a Mathematician.

And then I decided; we decided, to produce a movie explaining to Jos what we were doing, and that was the beginning of “Dimensions”. And we soon realized that in order to explain all the story, it would be a very, very long story, and so we decided to move to some more modest movie.

And at the time in my Mathematical Department, there was a young Ph.D. Student, Aurelien, and he joined the group. And so we decided to build a film aiming at explaining the mathematics I am doing and this is the beginning of “Dimensions”.

Of course, “Dimensions” is two hours long and after two hours, it was just the beginning of the story and so you needed to go further. And “Chaos” was maybe the second part of a long, long, long movie, explaining the current research in mathematics especially the mathematics that I love.

Jos?

Jos Leys: Yes. What I just wanted to add to that is, is that the amazing thing also about this collaboration is that halfway through the first movie, we had never even met in person. Everything went over the internet. I’ll tell you that the total count of emails belonging around the “Dimensions” film was, oh I don’t know, couple of thousands Etienne?

Etienne Ghys: Yes, yes.

Jos Leys: And I think the first time we ever met was at some occasion, I forget which one in Paris...

Etienne Ghys: Yeah.

Jos Leys: ...because at the time Aurelien was also in Lyon with Etienne and I'm in the north of Belgium. So Paris is more or less halfway and there we met for the first time and all we did was drink beer. We never even discussed the film. So it has all been an internet collaboration. Without the internet, these films wouldn't exist.

Etienne Ghys: Sol?

Sol Lederman: Yes, yes. Right, the internet is great in its ability to bring people together but Etienne I wanted to ask you just a little bit deeper. So what excites you about multi-dimensions? You said that you really were excited and passionate about "Chaos", a subject of the most recent video that the three of you just came out with.

Etienne Ghys: Yeah.

Sol Lederman: But what about multi-dimensions? I'm trying to understand what excites a Mathematician about multiple dimensions?

Etienne Ghys: Yeah, let me tell you that in a few words. I am basically an expert in dynamical systems. Dynamical systems is the part of mathematics that has been created by Henri Poincare more than one hundred years ago and his approach to understanding the dynamics of things, is to study it through geometry.

But his main contribution was to realize that one can use the geometry in high dimension, not only dimension one, two or three but even dimension four or five or ten or more and to develop some kind of intuition of high dimensional space, in order to understand better the dynamics of things.

So in order to enter in my personal mathematical world, one has to master first; high dimensional spaces and second; dynamical systems. And the first part of high dimensional spaces is basically what our first film "Dimensions" is about and the second part, dynamical systems is basically what the second film "Chaos" is about. So these two films, even though they do not look very much related for me, they are parts of my personal mathematical inner world.

Does that answer your question?

Sol Lederman: Partly, but I'm going to push you a little bit further and Jos if you have some insight, please lend it as well.

Can you explain, and I know it's hard because you don't have a video in the microphone to show us something, but where would somebody, let's say a scientist or a mathematician or an engineer, where would understanding multiple dimensions help them to solve a practical problem? That's what I'm struggling to understand.

Etienne Ghys: Yeah, this I can tell you. Suppose you want to describe say the motion of the planet, let's say the motion of the moon. Of course the moon is moving in our three dimensional space. So if you want to describe the position of one planet, you are doing geometry in the usual three dimensional space but if you want to understand not only the motion of one planet, let's say of two planets together, let's say the moon and the earth, each one has three dimensions and these two objects interact.

So if you want to describe the position of both of them, you are immediately led to consider

geometry in a six dimensional space. This six dimensional space would contain information about both planets. So this is the main idea of Poincare. If you want to understand a very complex mechanical system, which part of it is in our usual space with three dimension, the full body necessitates a huge number of numbers to describe them.

So you try to use the geometry of this high dimensional space to understand the motion of complex bodies, functioning inside our usual three dimensional space. The beauty of it, is that the geometry of this high dimensional space, illuminates the behavior of these mechanical systems.

Am I clear?

Sol Lederman: Yes. Okay, that helps. Thank you. So all right, let me ask you, both of you and it's a slightly different direction.

So Etienne, you are the Mathematician; Jos, you are Mechanical Engineer. So what role did the two of you, what expertise did each of you bring into producing this fascinating animation?

Jos Leys: Well, we had the different roles pretty much defined before we started. Now again being the Mathematician, he also knows best how to explain things to people and from a pedagogic point of view.

So what Etienne did, was to do the scenario. He wrote the whole scenario of the film explaining which chapters we should do, what should be the content of each chapter and the commentary text that went around it. So I was more the technician and I guess, say a bit of the artist, to get what Etienne was explaining into images and animations, to best represent in images what the whole thing was about.

Aurelien had another role that mostly came into being after the images were all done, that's all the practical things because we needed to render all of these images. For moving you need twenty-five (25) images for every second, so you need quite a bit of computing power to calculate all these images. And for the second movie, we did the images in HD, so that takes even longer to calculate and Aurelien set up a whole bank of computers at the university to render all these images.

The other things that came with it later, was rounding up translators, rounding up people to do the commentary voices because we believed to have this film successful and accessible to lots and lots of people, it's important that we do it in different languages. And these are all the sort of things that Aurelien has been doing, to get to the final stage. But again, the main ideas and what we should put in and what we shouldn't put in, that was Etienne's doing.

Is that right, Etienne?

Sol Lederman: Okay. Are you there Etienne?

Etienne Ghys: Yes, I'm here. Yeah.

Sol Lederman: Yes.

Etienne Ghys: While I agree with what Jos said, time passing, Jos has become more Mathematician and I more able to understand what he is doing. So it is more and more an easy job for us.

Long time ago, I had to explain some mathematics that for me were basic to Jos but now Jos is almost as, I wouldn't say almost as good me, mathematics Jos, but he knows a lot. Really this is impressive, how this huge quantity of mathematics that he could digest. So today, our collaboration is more, I would say more intimate.

Jos Leys: Yeah, it's more fluent than in the beginning Etienne?

Etienne Ghys: Sure, sure.

Jos Leys: I had to explain a lot more. Now one sentence is usually enough and I know what he wants to see on the screen.

Sol Lederman: Okay. So Jos, I'm wondering if you can give our listeners a kind of a short overview of the making of "Chaos". I'm curious about people who watch the videos and say boy, this really exciting. I would really like to make my own mathematical animations. You know what kind of technology, how long did this take, how difficult was it? I'm curious about those sorts of things; and Etienne as well from you.

Jos Leys: Well, in making images that move, I'm using a program for practically everything we did that is called POV-Ray. POV-Ray is a free program that you can get off the internet. It's www.povray.org, I think it is.

And what that gives you, it gives you the ability to build three dimensional things, things as simple as showing as sphere or a cube or whatever, but it has the possibility to program it to do just about anything you like. You can put in the most intricate surfaces or curves or whatever into it with the possibility to animate it, to change something a little bit from one frame to the next so can produce a series of images, that when put together, make up a movie.

And it's not all that difficult to learn. And again, the good thing is, it doesn't know all the math but you can program all the math you wanted. Like for instance in the first we used complex numbers a lot. Now natively POV-Ray doesn't know what a complex number is but it's a little bit of programming and it works with complex numbers in a very smooth way. So learning this program, you can do just about anything you like.

Now in the making of the movie, I must say we went a bit more in a project-like manner in the second movie than in the first. What we did in the second movie was first Etienne wrote out the whole scenario and then the scenario was divided up into different chapters creating different topics. And for every topic, we first made just a couple of images just to say; this is what the real filmmakers would call a storyboard.

Sol Lederman: Right.

Jos Leys: Just a few images to say okay, we're going to show. Let's say a billiard table. This is what a billiard table would look like and along with that, I had to do all the programming to see if I could make balls move on the billiard table, just a few simple things and a few simple scenes to make sure that the balls would move in a credible manner and obey the laws of physics.

And that's what we did for every chapter and only after that, did we did start in detail on making all the little clips that were needed to stitch together a whole chapter, first in a rough way then in a more fine way, because we have to take into account the commentary. Like the commentary voice would be saying, there's a billiard table and it has three balls on it. So that text may ten seconds, then we have to figure out what do we show during these ten seconds. And here comes the cue and the cue shoots the cue ball.

There were a lot of timing issues, you see. How long should it take? How long should the ball roll on the table? Because you can't do something where the commentary needs to go very, very quickly, just to keep up with the images, and balancing all that was something that we put a lot of time in.

In all, I think for making the images, took twelve to thirteen months and I worked on it a couple of hours every day. Not the whole day from morning to evening, couple of hours every day but just

over a year. The first production then, the calculation of all the images in high definition, getting, rounding up the translators, rounding up the people who speak the commentary in different languages, took, let's say another year.

“Chaos” in total was twenty-four months. “Dimensions” was a bit shorter. It was eighteen, nineteen. But with “Chaos” we had a few issues at the end so people who has promised to do something for us didn't really work to their deadlines sometimes but in the end we got there and we're quite happy with the result I would say.

Sol Lederman: Yeah, I'm certainly quite happy with the results and I'm curious. You mentioned that, was it your graduate student who did a lot of work on this project as well?

Etienne Ghys: Well Aurelien was a graduate student a few ago. Now he is a professional in some other university. He is a professor at the University of Orléans.

Sol Lederman: Okay. But my question is, Jos, I think you said something about using not just one computer but a farm of computers?

Etienne Ghys: Yes, yes, yes. What Jos was saying that he was working at home or using small pictures and small programs and then he would send the file to Aurelien who would use the big computers in my university, to produce the final film, to compute the final film.

Sol Lederman: Right, because you have to compute many, many, many images that have a lot of complicated mathematics at high resolution.

Etienne Ghys: Sure.

Sol Lederman: Right. So this is like the Pixar model where it takes a farm of servers to generate a few minutes of images or however that works.

Etienne Ghys: Yes. May I add something?

Sol Lederman: Please.

Etienne Ghys: I wanted to say maybe we could discuss the way we are working independently of any financial question. So the film is completely free. You can download it for free on our website. Jos is working for free. I am working for free except that I'm a Mathematician, I have a salary as a Mathematician and I consider this as a part of my job so to speak but we are not making money out of it. It's just for the fun of it and that fun actually.

Sol Lederman: Right. Yes. And often fun is very time consuming. That's right, if it's time consuming, at least you hope that it's fun because to spend two years...

Etienne Ghys: Another point I wanted to mention is that when we prepared the scenario and we were thinking about the structure of the film, we wanted to write the film in such a way that it could be seen by many different people with different mathematical backgrounds. So the idea is that it is not a film starting from minute zero and going to minute one hundred and twenty, you can see it by pieces. You do not have to see it just from the first minute. You can stop after three chapters.

So we did our best so that you can see it at very different levels. You can show it to some people with different culture. We tried to make it in such a way that it a multi-usage film. Do you see what I mean?

Sol Lederman: Yes. Okay.

Etienne Ghys: For example, it is clear that one of the chapters, chapter six, is more elaborate. It would maybe please my colleagues. Maybe it's not easy to follow everything in chapter six but it doesn't matter. You can look at chapter seven without having understood chapter six. We did our best to make this possibility of not understanding everything.

Sol Lederman: Yes, I mean that worked quite well because I did, I have to admit I did pick and choose between different sections of the video. I was like oh, this piece looks interesting so let me watch it.

So I'm curious if you've gotten, I'm sure you've gotten feedback. "Dimensions" has been out for several years, "Chaos" is brand new. But from the feedback that you've gotten, let's say about "Chaos", who do you think is the best audience to appreciate; maybe there are multiple audiences that would appreciate "Chaos"?

Etienne Ghys: Jos, what you think?

Jos Leys: Well it's very general. Like when the whole thing was really finished and I pressed the whole thing on a DVD so I could show it on my big TV screen here at home, I sat down with my wife to watch it. Now Gilberte, my wife, she hates mathematics.

She's afraid of mathematics and she did her best to follow and we went through the whole two hours and she said well you lost me in chapter three, but I continued through the end not because I'm your wife, but because I thought the pictures were really nice and intriguing. And even if we don't understand the really fine details of what you're trying to say, it's an intriguing subject and it's made with nice pictures.

So yeah, I had no trouble to continue watch it and I guess you get a whole scale of people watching it, some that get lost in chapter three, others in chapter four and a lot of people will not be lost until they are at the final chapter nine. But as Etienne said, we tried to cover a whole range of people who would find some interest in it and I think it was same with the "Dimensions" movie.

We start very simple in the "Dimensions" movie like chapter one where we talk about two dimension and how two dimension describe the point on a sphere. You can use that in primary school in a geography lesson or something like that, of course, the intrigue of hop/fibration which is university level. But also there the pictures are nice that people who don't really understand what we're saying mathematically, will still like to continue watching the picture.

Sol Lederman: Etienne, do you have anything to add to that?

Etienne Ghys: No, I fully agree with that of course.

Sol Lederman: My experience was probably somewhat like Jos's wife that I've watched a bunch of it and parts of it I understood and parts of it I didn't understand and the parts that I didn't understand, I kept watching because the video was so compelling and it was so enjoyably animated that it wasn't about understanding it. For me it was about just mathematical entertainment. I read and watch a lot of mathematical things, even if I just get an idea or two, then it's worth watching and then the rest of it even if I don't understand it, maybe I'll come back and watch it again but it's all very enjoyable.

Etienne Ghys: Sol, what is your background in mathematics?

Sol Lederman: So my background is I studied math at Stanford here in the U.S., although I have to say that, boy I don't know if want to say this on a public interview but all right I'll say it. When I was younger through High School, I really, really enjoyed mathematics and I think it was in Middle School, I started to get excited about it and I did a little bit of competition in math and really enjoy recreational math, pure math, the kinds of math that are abstract that's the kind of

thinking I like, puzzles, games; that sort of thing.

And then when I got to Stanford, I lost interest in math because the focus was very different. They were a lot of brilliant math professors at Stanford but their focus isn't so much on teaching, it's really on doing their research, right? Publish or perish, is what we say here.

So for a number of years, I lost my excitement about it and then about five years ago, I decided I'm going to start blogging about math again. So I started the "Wild About Math" blog and then about a year ago, four years into the blog, I realized I'm not so interested in writing blog articles; I'm much more interested in talking to people who are excited about math.

Now I have to also admit, that one of the challenges that I had at Stanford is that I never finished my math degree but in order to finish the math degree, I would have had to take some physics classes and I had a very difficult time with physics because of the way that it was taught there, for me it lost all of its intuition.

Yeah. I remember these problems where we would have to do these calculations and measure forces of things and I could be off by an order of magnitude or by ten orders of magnitude and I had no idea how far off I was. It had just completely lost its sense of intuition and I since have learned that there are different ways of teaching and studying physics that can actually make it much more interesting and better to learn. And I think you guys are definitely doing something in that direction.

So the in the vein of that question, let me ask the both of you, can you think of stories from maybe when you were young about getting excited about math or getting excited about physics. And let me ask you Jos first, I know you're the engineer and I know engineering certainly has a mathematical way of thinking about it.

Jos Leys: Well when I was in what you guys call High School, I was pretty good at mathematics and mathematics interested me a lot. I actually liked to sit down and solve integrals and stuff like that because I felt it was fascinating. But then at the age of eighteen, you have to make your big choice in life, what are you going to do further on in your adversity, and what they told me is that you could make a lot more money as an Engineer than as a Mathematician. So I went for engineering and never regretted that either.

I worked for close to thirty years in industry but always had mathematics as a small hobby and got into it more and more as computers became more and more accessible and better. Mathematical imagery, I started doing that in the nineties because by that time, you could get personal computers with decent calculation speeds, colors, recent screen revolution. And so I got more and more interested in mathematics and my early retirement helped in being able to devote more time to it.

But again, my main decision of choosing engineering verses mathematics was a financial one.
Yeah.

Sol Lederman: And Jos, do you have any, I'm curious. I mean some people do, somebody don't but did you have any early memories of discovering an interesting math problem or something that got you excited? I don't know too many people by the way, who just love to solve integrals.

Jos Leys: Well, I thought it was a fun thing to do. Yeah. And also in the engineering school at university of course, certainly in the first; it's a five-year course. The first two years were filled with practically nothing but mathematics and also some physics, also some chemistry, also some more engineering subjects but the math in the first two years went with me very well. I can't really remember any specific, specific things that struck me then, but I always found complex numbers to be the greatest invention after sliced bread.

Sol Lederman: Okay. All right. So Etienne, how about you?

Etienne Ghys: Well I could say that during many years, for me mathematics and physics were just the same thing. It took me a long time before I could realize that it was using different aspects of my brain and quickly I realized that I was not good at all at physics. But what I like in physics, is its mathematical aspect.

So when I was maybe nineteen, eighteen or nineteen, I decided that physics was over with me and that I was a hundred percent Mathematician. So it was some kind of gradual process when I was thirteen or fourteen, I was a half Physicist and a half Mathematician. But now I know that I would have been a terrible Physicist, no doubt.

Actually I remember very well, you were looking for some kind of memory of contact with mathematics. I remember very well that when I was thirteen or maybe fourteen, you know it was the time when the teacher would say, I give you an equation and you have to draw the curve and I realized that there was a fun game of drawing any curve on your paper and looking for the equation on that curve. As I went to my teacher and I said well, it's more interesting this way.

Drawing the picture of the function, I was much more interested by the opposite situation, looking for the equation of the picture. I remember my teacher was sort of terrified by this kind of question. I remember that. Yeah.

Sol Lederman: Well you it's interesting because I think I'm like you. I think it's a much more interesting puzzle for someone to draw a graph of something and then use what I know to try to figure out what the equation is. I think that can be a really fun game.

Etienne Ghys: It is.

Sol Lederman: So tell me Etienne, you hinted at the distinction between math and physics and I think of; well it's hard to say. I think of "Chaos" as more physics and "Dimensions" is certainly very mathematical to me. How would you explain the difference between math and physics?

Etienne Ghys: Well you know you are right. "Dimensions" is basically a mathematical film with essentially no hint to physics and "Chaos" is more physical. No doubt. Actually if you look carefully at this in "Chaos", you will realize that there is no comment about physics. Each time we start discussing the atmosphere or whatever, each time we can note in the commentary there is a mathematical comment saying well, in truth the problem is much harder in physics. Mathematicians like simple things and things like that.

So for me physics for me is basically a motivation for mathematics. Many Physicists would like Mathematicians to help them solving their problems. As a Mathematician, I like to look at physics as a source of good problems for Mathematicians. Somehow I don't care about the world. I just look for good, interesting mathematical questions and this is I think rather clear in this "Chaos" film, that physics is there but it's there somehow from the outside. You say basically nothing about physics.

Sol Lederman: Yeah, it's an interesting perspective because that tends to be my relationship to mathematics as well. I love the abstract aspect of mathematics, I like thinking about math, finding patterns, finding relationships between ideas. But reality seems to get very messy.

Etienne Ghys: Yes.

Sol Lederman: And maybe that's the difference. Between the inner section of math and physics is maybe where you apply a lot of math to physics but then you have to get into very messy equations. I'm just thinking out loud here. I don't know.

Okay. So Jos, do you have any thoughts on that? Now you're somebody with a more mathematical background that had to learn some of the physics based math, but still math.

Jos Leys: Well as an engineer, I guess I've been more involved over my career with the real world than with the ideal mathematical world. In doing engineering or chemistry, that's typically also something where things get very fast, very chaotic and what we did there to try and control everything, was often more based on imperial knowledge than a real hierarchical knowledge and still it worked very well.

So yes, I have some affinity with physics. I also have an affinity with math and that comes in very handy in the way we work. We work together in describing problems and how to visualize them. Some of the sequences in the film are very physical.

When that little ball roll in the big cup, that's really a physical simulation of what happens in the real world, one that can be calculated very accurately. On the other hand, lots of things cannot be calculated very accurately. And I myself have got a better grasp of what can be done physically correct and what cannot be done physically correct, because as usual there is such a big influence of initial conditions, and all the other chaotic aspects that come into it.

Sol Lederman: Right. Yes, I remember being fascinated by the idea in "Chaos" and I think you showed this in the film that you can have two billiard tables and you start with slightly different, very, very slightly different conditions and you get very different outcomes in terms of positions of balls.

Jos Leys: Yes.

Sol Lederman: So makes "Chaos" very chaotic. Very complicated.

Etienne Ghys: Actually it's a good example because I remember very well when we were working on this portion of the film, it was not so easy to find two positions which were very close together leading to different situations in some kind of artistic way. So Jos had to try many different initial positions in order to get something that could be beautiful. Remember that?

Jos Leys: Yeah.

Sol Lederman: Right. So lot of trial and error, I'm sure in making this kind of animation. So I am curious if actually the two of you have any interesting stories to share about feedback that you've gotten from people about either "Chaos" or "Dimensions".

Jos Leys: For "Dimensions", I think we have nothing but positive things. On the other hand, the people that didn't like it probably don't care about telling us. But yeah, lots, lots and lots of reactions. We have a {unclear 46:02} page on the website and even today, we're getting maybe a couple of comments back a week on "Dimensions". For "Chaos", it's a bit early. The things we have been receiving because people can give comments also through the website. Again, they are all very positive like you are Sol. Thank you.

We have not really seen any negative review of either "Dimensions" or "Chaos" but again for "Chaos" is early days. We've only been online, for what is it now for two or three weeks. The visitors we get on the website are mainly from France. We get very little visits from Americans probably because it is not well known yet that there is a new film out there that's free to look at but we'll probably get there. These things take time, sometimes a lot of time before it gets known.

Sol Lederman: Well...

Etienne Ghys: You know, let me make a comment. I have been spending my

whole life writing papers maybe five or ten papers a week, very obscure papers for a difficult theorem that nobody understands. So for me, publishing such a film with such a wide audience, at least relative to the usual audience I have, was a really new experience.

I can guarantee that receiving for example email in Chinese from a teenager from the middle of China, that you have to translate with Google Translate and thanking us for “Dimensions” for example, is really a great pleasure. I never had this kind of experience of having some contact with a young boy in China. It was something really new for me and happy with that.

Sol Lederman: Well very good. Hopefully you get some publicity here from this podcast and the blog article that I have with it. Hopefully other bloggers will give it some attention and looking forward for it to gaining traction for it.

Let me ask you, this is probably a better question for Jos but Etienne if you have some input on this as well. Let me ask you Jos, if somebody watched the movie, either of them, both of them and said, hey, I’m very inspired. I want to do my own; I want to learn to do my own computer animations with mathematical ideas. What advice would you give to that person?

Jos Leys: Well, the first thing is I would say is are you sure, because it’s a lot of work. Getting together an animated movie of two hours at 25 images per second, you can imagine how many images you need to make and to get it interesting. They can’t be all the same images.

So it takes a hell of a lot of time, so we have to be really, deeply determined to put it to a good end. We have an expression here. I don’t know if it exists in English also it’s that the work of a monk, you know the medieval monks that copied books with extremely beautiful drawings on the side, that took their whole life to copy just one book. Well, I’m not talking about the how or why, but it’s a lot of work. It’s something that you really have to love to do or else you’re not going to get a good result, especially if you do it on your own.

You know if you look at animated movies in the cinema or on television, the techniques there and the quality of the images are certainly ten times better than what we do but then if you look at the credit role of a movie like “Cars” or “Shrek” or any one of those, you see the list of hundreds of people who have worked on it, animators by the dozens. We did it just on our own. So you have to limit yourself obviously but still again, it still takes a lot of time so you really have to be really dedicated to the work because it’s a hell of a lot of work. That’s for sure.

Sol Lederman: Okay. Etienne, do you have any thoughts to add to that?

Etienne Ghys: One comment. In these films, we tried to be honest. By this I mean that the mathematics is accurate. You know in many popular presentations, there is a tendency to cheat. So we decide honest from a to z. So if you want to do a mathematical film, I think it’s good advice. You should not cheat with mathematics. You should present things as they are and this requires much energy and much accuracy and this is I think what we did.

Sol Lederman: Okay. Very good. So I have a final question for the two of you and you can answer whatever order, how ever you want to answer together.

So first there was “Dimensions”, now there is “Chaos”, what’s the next big projects?

Jos Leys: Etienne?

Etienne Ghys: Jos?

Jos Leys: We don’t know yet, do we?

Etienne Ghys: That is a good question.

Jos Leys: I'm ready to start any minute on something new but the key to a good movie is, have a good scenario.

Etienne Ghys: Yeah, yeah.

Jos Leys: So Etienne.

Etienne Ghys: Sol, I think we don't know the answer to the question. We have to discuss that. But I would be happy to start a new adventure, yeah, maybe not the same structure. Sol, I don't know the answer to your question.

Sol Lederman: That's the consistent with the theme of being honest.

Etienne Ghys: Sure.

Sol Lederman: Okay. Any final words? Any question that you wish that I had asked or anything that you'd like to share in closing here?

Jos Leys: Sol?

Sol Lederman: Yes.

Jos Leys: All I wanted to say is that both with "Dimensions" and "Chaos", as I said it was a lot of work and it took a hell of a long time but it was a lot of fun. It was a lot of fun doing that. Yeah. So I am ready to start on something new any minute because, again, it was a lot of fun.

Etienne Ghys: Okay. So Jos, let's do something.

Jos Leys: Yes, Etienne.

Etienne Ghys: Okay.

Sol Lederman: All right. Great. All right.

Etienne Ghys: You know Sol, this final question is actually; this is the first time we discussed that in front of you.

Sol Lederman: Oh.

Etienne Ghys: Yeah, we did not discuss that previously.

Sol Lederman: Okay. Well, I caught you by surprise.

Etienne Ghys: Sure.

Sol Lederman: Well good, good. All right. So this is a great note to close on. So me and all of my listeners and the blog readers are going to be expecting maybe in another couple of years something new because there always has to be something new, right? Creative people are never happy to rest.

Great. So thank you Jos and Etienne. There you have it.

Etienne Ghys: Thank you, Sol.

Sol Lederman: "Inspired by Math!"

Jos Leys:

Okay Sol. Thank you.

[Interview sends at 55:30]