Cédric Villani: Ambassador of Mathematics *Extraordinaire*

Y K Leong

Cédric Villani made fundamental contributions to the study of the Boltzmann equation [Ludwig Eduard Boltzmann (1844–1906)] in statistical mechanics, nonlinear Landau dampening [Lev Davidovich Landau (1908–68)] in plasma physics and the theory of optimal transport. He is also well-known for his extraordinary efforts in promoting mathematics to the public.

In addition to major contributions to the theory of partial differential equations occurring in statistical mechanics, Villani provided a deep mathematical interpretation of the physical concept of entropy with unexpected ramifications in mathematics as well as physics. Jointly with Laurent Desvillettes and Giuseppe Toscani, he gave a rigorous answer to the problem of convergence of solutions not near to equilibrium for uniformly smooth solutions. With Clément Mouhot, he settled the problem of nonlinear Landau damping and vindicated the counter-intuitive conjecture of the Russian physicist Lev Landau (1908–68) about the behaviour of plasmas. Another ground-breaking contribution is his joint work with Felix Otto which makes a surprising connection between gas diffusion and optimal transport theory, thus linking statistical physics and economics. An off-shoot of this connection is the modelling of the motion of a gas in an abstract landscape in which the theory of Ricci curvature can be applied. This interpretation enabled Villani, in joint work with John Lott, to arrive at a new and deeper level understanding of curvature.

He was awarded the Fields Medal in 2010 "for his proofs of nonlinear Landau damping and convergence to equilibrium for the Boltzmann equation." He has received numerous awards for his mathematical work: Louis Armand Prize, Peccot-Vimont Prize, Jacques Herbrand Prize, European Mathematical Society Prize, Henri Poincare Prize and Fermat Prize.

Cédric Villani [Photo credit: Marie-Lan Nguyen/Wikimedia Commons/CC-BY 3.0]

Villani was educated at the *Lycée Louis-le-Grand* and the *École Normale Supérieure* in Paris. He obtained his doctorate from Paris Dauphine University under the supervision of Pierre-Louis Lions (Fields Medal 1988). From 2000–2010 he was professor at the *École Normale Supérieure de Lyon*. In 2010 he moved to Lyons University (*Université Claude Bernard Lyon I*) and also serves as the director of *Institut Henri Poincaré*, which is the mathematical research part of University of Paris VI (*Université Pierre-et-Marie-Curie*). In 2011 he coordinated the setting up of a national centre of excellence *Laboratoire d'Excellence CARMIN* (*Centres d'Accueil et de Rencontres Mathématiques Internationales*) which is financed by *Investissements d'Avenir* and which comprises all the French national mathematical institutes *Institut Henri Poincaré (IHP)*, *Institut des Hautes Études Scientifiques (IHÉS)*, *Centre International de Rencontres Mathématiques (CIRM)*, *Centre International de Mathématiques Pures et Appliquées (CIMPA)*.

Besides delivering invited lectures at many leading universities and major scientific meetings, he has made extraordinary efforts in promoting awareness in mathematics and reaching out to the public not only in France but around the world from the United States to Asia. His willingness and commitments in media presentations and participation clearly reflect a personal mission which is unmatched in the mathematical community. The fervour with which he spreads the message of the ubiquity and relevance of mathematics in daily life is so strong that the media has variously dubbed him as an ambassador, evangelist and proselytizer for mathematics. Members of the public who meet him for the first time will be invariably and pleasantly surprised at the colourful style of his dressing (a three-piece suit, velvet cravat, pocket watch and brooch) which one does not usually associate with a mathematician. In actual fact, this signature dressing of his has been adopted by him when he was a student at the age of 20. Together with his personable style, this has undoubtedly presented a friendlier and more approachable image of mathematics to the public. It is fair to say that no scientific personality in France has received as much national recognition as he has with the national awards of Chevalier in the National Order of Merit and of the Legion of Honour and medals from the National Assembly, *Conférence des Grandes Écoles* and the cities of Lyon, Brive and Toulouse.

In spite of the toll on his research schedule, he continues to be actively involved in both voluntary professional and obligatory administrative work. He serves on the editorial boards of major journals such as *Inventiones Mathematicae, Journal of Functional Analysis, Journal of Mathematical Physics* and *Journal of Statistical Physics*. He has also served in scientific bodies such as the pro-European Think-Tank EuropaNova and the Scientific Advisory Board of the Panafrican institute, African Institute for Mathematical Science (AIMS), of which he is currently the vice-chair. He has recently been appointed a member of the High-Level Group of the Scientific Advisory Mechanism of the European Commission (the Scientific Committee of the European Commission).

In May 2015 French President François Hollande alarmed and shocked the French scientific community with a proposed budget cut of 256 million euros in national spending for research and higher education. In a bid to reverse this unexpected policy move, five of France's illustrious Nobel laureates and one Fields Medalist met with the President. The Fields Medalist who actively gave his unwavering active support for the wider good was Villani. This unprecedented historic meeting resulted in the President agreeing to repay the whole cut, but only a part of it could be repaid that year because of budget timing issues. [The part which was immediately repaid was the critical one. — Villani]

In addition to numerous research papers, articles and monographs, he has written a popular book which was first published in French in 2012 as *Théorème Vivant* and had become an instant best-seller in France. This was translated into English as *Birth of a theorem: A mathematical adventure* by Malcolm DeBevoise and has received rave reviews. It gives a blow-by-blow account of a two-year research collaboration with his former student Clément Mouhot on a 60-year old mathematical problem (Landau dampening) in plasma physics. It attempts to portray the surreal realm of mathematical research with all its mental agony and joy set amidst the real world of human existence with all its passion and ambition.

Villani was on the organising committee of the IMS (Institute for Mathematical Sciences, National University of Singapore) program *Hyperbolic Conservation Laws and Kinetic Equations: Theory, Computation, and Applications* (1 November – 19 December 2010). He was invited to the inaugural Global Young Scientists Summit (in Singapore) organised by the National Research Foundation of Singapore from 20 to 25 January 2013. Modelled after Germany's Lindau Nobel laureates meeting, it invited and brought together 280 post-doctoral fellows, PhD students and research scientists from Singapore and developed countries in a brain-storming atmosphere to pick the brains of 15 leading scientists who have won the Nobel Prize, Millennium Prize, Turing Award and Fields Medal. Villani was the Fields medallist invited. He gave a talk "On curvature, gas and human beings — From Monge to Boltzmann to Riemann" on 22 January 2013 at the Institute for Infocomm Research in Fusionopolis. During his short visit, Y K Leong took the opportunity to interview him on behalf of *Imprints* on 23 January 2013 at the Department of Mathematics, National University of Singapore. The following is an edited and vetted transcript of the interview in which he spoke with frankness and passion about his first love (Boltzmann equation) which led him to revolutionise mathematically the physical concept of entropy and his other love (popularisation of mathematics) which has given him an international celebrity status. We also get a rare insight into the grand scientific tradition that has produced France's illustrious engineers, scientists and mathematicians.

Note. In June 2017, Cedric Villani was elected to the National Assembly in the parliamentary elections of France to begin a different phase of his career in the French government formed by the new centrist and reformist party (*La République En Marche!*) of French President Emmanuel Macron.

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Imprints (I): What made you get interested in questions in mathematical physics?

Cédric Villani (V): Okay, first to tell the truth, if one looks back on my early training, it is a big surprise that I have been into mathematical physics. I was not very good in physics as a high school student. I mean, I had good grades but nothing spectacular. There was a big gap between my ease [ability] in physics and my ease [ability] in mathematics. After I entered *L'École Normale Supérieure*, it was clearly the mathematics specialty [for me] although I did follow a few courses in physics and even one course in chemistry for a little while, done just out of curiosity. But later I went back to questions of physics. One of the main reasons was just accidental and the fact that my tutor of the time, Yann Brenier in *École Normale Supérieure* wanted me to work with Lions. And he suggested that the subject of Boltzmann equation was very good to put me as an equal to Laurent Desvillette, who was an assistant professor before I took the position. And before that, my goal was to do something like image processing, for instance. I did not think of doing something in mathematical physics. The second factor was that when I had to choose my PhD subject, not only was there this incentive of Brenier for me to work with Lions but also for some reason it was in the middle of a period of doubt for me whether mathematics was a good thing to do. And I was a bit depressed about the potential of mathematics activity and it was important for me at that time to work on a subject that would have real implications to, so to speak, real life, like the work of an engineer and so on. And so it's one of the questions that I asked Lions the first time we met when he presented me with the Boltzmann equation: "Is it really useful, etc?" And for me it was important. However, after some time spent with the darned equation, I literally fell in love with it and I found it too beautiful for many reasons — for reasons of history, for conceptual reasons and so on — that I really didn't care if you can have applications or not. At some point it was really the subject in itself that I liked and then I started to understand a lot of physics. I am one of those people who don't have physical intuition but that can be developed by looking at the mathematics. So I managed to understand some points about physics that physicists had missed because I came with a mathematical intuition. It's important that we work with different points of view to have a richer result. And I think one of my particularities is extreme curiosity. I read books about the Boltzmann equation, etc, discussed with people and so it grew until I became quite a decent mathematical physicist. It is one of my great pride to have won the Henri Poincaré Prize of Mathematical Physics in 2009. This really meant much to me especially given that I was not from the start gifted in physics.

I: In some sense you are a self-made physicist.

V: In some sense, yes. When you go in, you sometimes see that the distinction between mathematics and physics is very much blurred. Some of the great physicists of the past were, in fact, mathematicians as well, like [Isaac] Newton [Isaac Newton (1642–1726)]. The influence of Boltzmann on mathematics was considerable. Even in the 20th century, the work of the physicist Landau is very much mathematical. What changes for sure is that physicists and mathematicians don't always have the same appreciation of what are the important problems, the intuition and, of course, the appreciation of whether something is proven or not. One should not underestimate the role of the vocabulary. I think one of my strengths is that I am rather good at adapting my speech to the persons that they have in front of me. The physicists like to invite me because they know that I will adapt the vocabulary and concepts in such a way that they can understand.

I: Did Pierre-Louis Lions have any influence on your philosophy of research?

V: Obviously, yes. You know, the relation that you establish with your PhD advisor is usually a strong one. And you often define your identity with respect to this either in the same direction or by your own position. I like to think that there were four researchers that influenced me a lot during my early career. So, one was Lions and from him, in particular, I retain the importance of working on hard problems and unleashing whatever mathematical tools from analysis there are for a certain problem. And the second one was Yann Brenier (I mentioned earlier that he had an influence on me choosing Lions). He (Brenier) is a specialist in fluid mechanics. He was my tutor in *École Normale Supérieure*. He also was the head (director) of studies for the math department at that time. He pushed me to work with Lions. He also put me in contact with one of my first collaborators, Felix Otto, which was extremely important. And he [Otto] initiated me into the field of optimal transport of which he was a specialist. And I gained a lot of influence from him — this time very different from that of Lions. And, in particular, from Brenier I retained the importance to work on simple problems and to look for structure coincidences. Lions was more like let's do it with force and we want general things that are not related to a particular nature of the solution. With Brenier it was more of the inverse — let's try to find the special nature of things and their relation. And it's work on the simple things that Brenier was very excited about — discovering connections more than proving rigorous theorems. It had a lot of influence on me. Neither Lions nor Brenier gave me a lot of technical advice and Lions was very busy. I did not see him much and this was rather good for me because I wanted to be independent. But both of them always listened to my suggestions and what I had to say with a benevolent ear. Then there was Eric Carlen from Rutgers, who was one of the first to introduce tools from information theory into the field of the Boltzmann equation. Carlen had worked with Elliot Lieb and other people and had been raised in a spirit in which you are living in a beautiful world with nice inequalities, problems related to quantum physics, sharp inequalities and so on, and he had managed to move on to areas such as fluid mechanics and the Boltzmann equation which are much more "dirty" and hands-on and in which there is much more trouble. He arrived with new ideas and I admired very much his way of working. There was him and there was also Michel Ledoux, a well-known probabilist at the interface between analysis and probability, also working on topics related to Carlen's. Both Ledoux and Carlen were crazy about inequalities. Whenever there is a good problem there should be a nice inequality behind it and it is very clear from my PhD that you see the influence of these four people appearing in the various papers and sometimes combined. And at some point I diverged from some of them; for instance, I started with Lions in the field of generalised solutions, renormalised solutions of kinetic equations, and at some point I decided that, on the contrary, I would never again work on a generalised solution and only worked on classical solutions. While a lot of the work of Lions was his beautiful use of compactness theory, it was absolutely just his way to use compactness. At some point I decided — no more compactness — I would do things completely explicitly. So part of my style was inherited from him and part of my style was more like determined in contradiction with him.

I: I counted twelve Fields Medalists who were originally of French nationality. This is quite a high proportion for a nation of moderate size (about seventy million) which is about between that of UK and Germany. UK and Germany has eight and one Fields Medalists respectively. Do you think that this could be the result of a long tradition of unfettered rational enquiry instilled since the time of Blaise Pascal [(1623–1662)] and René Descartes [(1596–1650)], perhaps reinforced by the spirit of the French Revolution?

V: Okay. I'm not sure about the numbers but you can check it. I thought it was eleven, maybe twelve, of French nationality, maybe it's a bit less but the order of magnitude is this. It's true that it's a huge number and very high number among the promising internationally recognised young mathematicians (I mean in their thirties). Nowadays there are even a lot of French ones. I think that indeed, in part, this is a result of a long tradition. It is true that rational enquiry plays a role and the French take pride in this rational sense since the time of Pascal and Descartes. There is also a tradition of elegance and imagination, mostly simplified by the work of another of the great French mathematicians of the time, I mean Fermat [Pierre de Fermat (1607–1665)]. Extraordinarily inventive. Another, although a bit less important mathematician of the time was Girard Desargues [(1591–1661)] who was I think very influential and important, next to Pascal and Descartes, in his time. So indeed, the French people are known to like things that are rational and to like things a little abstract. It has often been rightly contrasted to a more hands-on practical spirit of the Anglo-Saxons and it is true also that the spirit of the French Revolution reinforced this at a time in which the political power was very much fond of revolution, very much fond of scientists. Let me comment more on the history of

France. First, the cultural history of France is well-known for being one of the centres of the Enlightenment period. France is one of the more developed countries where a lot of people take pride in thinking and it was not only the philosophers but the mathematicians and the scientists. It all went together at the time. It was a matter of pride to be well versed in the sciences, at least for some of them like Voltaire [François-Marie Arouet (1694–1778)], Diderot [Denis Diderot (1713–1784)], Condorcet [Nicolas de Condorcet (1743–1794)], etc. And so the Enlightenment period is important. Then came the revolution. In both cases not only did it come with great people but also with great institutions. For instance, for engineers the *Arts et Métiers [ParisTech]* school was founded in the middle of the 18th century. Many of the schools that are most famous in France nowadays, were founded around the time of the revolution. And then came the Empire. Both the Empire of Napoleon I [Napoléon Bonaparte (1769–1821)] and Napoleon III [Louis-Napoléon Bonaparte (1808–1873)] were very much favourable to science, especially Napoleon I. It is known that he was able to sustain a scientific discussion with the best scientists of his time and he was not a scientist himself. It is very clear that if he had wanted, he could have become a top scientist. This is remarkable and the people in the government made sure that science was enforced.

Just for me to come here, in particular, one of these reasons is that you are one of the rare countries in the world in which at the highest level of the state you find scientists. And, by the way, we can see here that the state seems to be pretty efficient in setting up a national scientific programme. So, in France you see from the history of the institutions, they are continued after the Empire. There was another big period which was favourable to the sciences, which was between the two world wars. At least from this, plans for INRIA (*Institut national de recherche en informatique et en automatique*) started and some important institutions were founded in France again. And also at that time they took seriously the problem of communicating to citizens. Now what can make a field successful is that some famous people act as role models and propagate the culture of the institutions that I spoke about. And another thing that is important is the idea of the formation of a community. And here also the organisation of France was very helpful with the big cultural centre Paris, very large and predates the wars. Paris has remained since the 18th century a mythical city for mathematics. No other city can compete with Paris in terms of the number of mathematicians. Of course, in some of the most prestigious American universities, you will find a high proportion of very famous researchers but in none of these famous universities you have the same density as in the Paris area. So this played an important role.

I: And it seems to me that the cultural centre of Paris has gone continuously, uninterrupted even by the wars, isn't it?

V: In some sense this is true that Paris remained an important cultural centre in spite of the wars. Its reputation remains to this day. It is still a place that makes people dream. However, things were difficult at times. After the First World War, the system was kind of bankrupt, and communications with the outside world were very difficult. My institute, *Institut Henri Poincaré* was born precisely with the goal to revive the changes by attracting foreign visitors and researchers. Nowadays we do have many structural problems in France about academia. The university system has become very complicated. People are grumpy and there is a lot of tension. The government has been a bit clumsy in trying to make things move. There are many problems, bureaucracy has increased — not only in Paris, by the way, but in many other developed countries we also see these tendencies. Let me add that there has been over the past decades (although it is right now reversing a bit), during the period 1980–2000 approximately, a big scientific and cultural development in regions outside Paris. I belong to this generation. I made my important discoveries in Lyon; I consider myself to be from Lyon. It was typical of many young people seeking better living conditions and, after being trained in Paris, to travel outside to develop themselves more freely than they would have in the Parisian environment.

I: France has a long and continuous tradition of fundamental research at the interface of mathematics and physics, starting from Pascal, Laplace, Lagrange, Poisson, Fourier and others. Has this tradition been somehow woven into the fabric of the school system or at least into the university system of the main universities in France?

V: In the school system the short answer is "No". And people getting out of the French school system have a very poor idea of the relation between mathematics and physics. Some systems do it much better. When you discuss, for instance, with French journalists, they are often very surprised to hear of all the connections between mathematics and physics. They just do not realise how useful mathematics is for the study of physics; they think it's some form of abstract game. On the contrary, often I noticed journalists from Germany know this very well — that in many cases mathematics is a way to solve a physical problem. In the UK too, it's more practical. So, in the first approximation, we have failed to implement this link, and school teachers in mathematics in France are very uneasy with physics. These things tend to change because it has been understood and recognised and we are making progress on this. At the university level, it is not that well implemented either. And again you usually would develop mathematics or physics in France in a rather specialised way. There are countries in which the distinction is much more blurred. I see it in my colleagues who have been trained in Germany or in Italy — for them it's much more mixed. Some of them don't even bother to decide if they are mathematicians or physicists. In France we have this tendency rather to separate things into categories and define ourselves as in this category or that category, etc. I never wanted to belong to a particular category and always look for ambiguity in a way. All that being said, it is true we have a great tradition of fundamental research at the interface of mathematics and physics. As you know, as an example, I'm at the interface of mathematics and physics but I really had a mathematical training and it was only when I started my PhD that I really went into physics. Nowadays I regret that I don't have a better physics feeling in some stuff. This morning I was visiting the Quantum Computation Centre here — beautiful centre, all the experiments are nice and I had just a vague idea what they are doing and I wished I had a better intuition of all those things they were doing. Okay, I know that if I really want to, I can study and understand exactly what they are doing. But this will require some effort.

I: I believe that the family name of Villani has Italian roots and that you speak Italian. Is your interest in Italian related to the roots of the Villani family?

V: I think so, unconsciously, definitely. This is a part of my origin. Villani means "peasant" in Italian as opposed to "nobleman". Because I don't like categories I like the fact that my first name is a typical noble name from the Anglo-Saxon world and my family name is, on the contrary, a peasant name from the Mediterranean world. I also have a Greek origin as well as French both from the southwest and from Paris. I also have some origin from the Alsace region. And my Greek ancestors went to Corsica. They also were in Algeria. I am an heir of so many places. I like this too. Nowadays it is well perceived to be a mixture. I am a "mix" at a scientific level and also a "mix" at a personal level. Now, I did not learn Italian from my family. My father speaks some Italian but I did not learn with him. I learned by myself when I started during my first stay in Italy in 1997. So it was important for me to learn Italian and I did it in a serious way. I was a student at that time and so I was housed with many other students. I had asked everybody to speak to me only in Italian. I had this grammar that I would work on every night before going to sleep and so I learned seriously and very quickly. I am not very fluent in Italian because I did not practice since then. But after a few weeks I could sustain a conversation. If I had continued a bit, now I will be fluent for sure.

I: The concept of entropy arises from both the Boltzmann and Vlasov [Anatoly Alexandrovich Vlasov (1908–1975)] equations which are both classical in nature. Does entropy manifest itself mainly at the macroscopic level? Does entropy have any significance at the subatomic level?

V: It is true that the concept of entropy was formalised first by Boltzmann in classical mechanics and plays also an important role in the Vlasov equation, I would say by contradiction, in the fact that the Vlasov equation preserves the entropy. As a physical implication, it's completely different from the behavior of entropy for the Boltzmann equation. The concept of entropy, by definition, is a macroscopic one but it depends what you call macroscopic. The concept of entropy arises as soon as you have a discrepancy between several levels of description. There is a microscopic and a macroscopic level. The difference in the information that you gain at the macroscopic level from the information at the microscopic level will generate entropy. So whenever there are two different scales, two different degrees of accuracy in the description, you will have entropy coming in. At the subatomic level it is hard to know what it would be. I'm not aware of entropy defined at the subatomic level. I am aware of entropy which arises in a quantum context for gas of boson particles or something like this but, always, you need to have something which is macroscopic with respect to something else.

I: In your work on optimal transport theory, the distribution of goods is likened to a configuration of gas particles and a finer configuration to an equilibrium state. This is a striking analogy between real life scenarios and inanimate physical systems. It seems that analogies do play a role in bridging different disciplines. How much has analogy played a role in your thinking?

V: I think analogy plays an enormous role in my thinking, probably also for many other researchers. Analogies give you hindsight for finding relations and many of my works were about discovering, bumping into some unexpected relation, and then analogy helps you to think of proofs. You introduce an analogy; then it will naturally generate some link or direction where to pursue your reasoning. I like to offer it in my expository lectures and in my books. I like to put analogies. I put detailed proofs often but then I also explain in words what is the strategy of the proofs and so I often put analogies to help the reader form a mental image of the field.

I: Some scientists believe that there is an unexplored potential in applying physical models and theories such as gauge theory to economics and quantitative finance. Have you ever thought of applying your ideas to mathematical finance?

V: I'm not too keen about mathematical finance and I have never considered working in that area myself. However, some people are very good at playing ideas from classical physics (statistical mechanics) to finance. In France, the two best known people in that spirit are Jean-Philippe Bouchaud and Cont (Iranian by origin). They come from statistical mechanics like the study of hydrodynamic limits of particle systems, things like this, and they applied their reasoning and intuition to problems in finance. Here again analogies play a very important role. And they obtain some very interesting results, some great new points of view. I think it is completely true that, in part, financial exchanges can be thought of as physical systems with some strange rules that often are not clearly known. All the more with the proliferation of everything in directions that came with high speed trading. I have heard, for instance, George Papanicolau advocating for taxing on financial exchanges based on the idea that dissipative activity will stabilise the system, thinking of these exchanges as a fluid mechanics problem. I think this is a very interesting analogy. I think also that one has to, by the way, mention this because, you know, after the 2008 financial crisis, many people blame mathematicians for devising bad formulas and so on, and they forget that in most cases the biggest problems came from the application of mathematical theories outside the conditions for which they had been devised. People knew theories like the one you mentioned without caring really if the assumptions were there.

I: You have been very active in promoting mathematics to the general public. I think Wendelin Werner, your compatriot and Fields medalist in 2006 also believes that there is a need to improve communication between the public and mathematicians. But university academics are generally caught up in the process of publishing papers for the purpose of tenure and so on. How do we reconcile one's personal need and the more professional responsibility at the community level?

V: Well, this is tricky. First, yes, Wendelin also worked hard on improving communication between the public and the mathematicians, quite more than some of his predecessors. And I worked even quite harder than Wendelin on this. For me there was an opportunity that presented itself in the sense that the media response to my personality was extremely strong. There were factors which had nothing to do with mathematics such as my way of dressing, the fact that I am rather fluent on TV and radio — things like this. Recently I did, I think, a bit of a daring experiment since I published a popular book that goes completely at odds with the usual standards of communication from mathematicians, and this has been one of the library's successes of this year and has been a big boost again. Nowadays we get invitations for participating in public debates or broadcasting, either public lectures or radio interviews. So I think that one of the reasons why the response has been very strong is that precisely mathematicians usually are not so prepared to do it and there was a need and then I was ready to do this job. It is very much demanding and I understand very well why university academics don't have so much time to work with the media or they may be a bit shy. First they don't like to be exposed personally. They know that it is a whole community that should be exposed. They are afraid of the fact that the media work at a very fast pace. They write many mistakes; they don't care. All these make mathematicians uneasy. Nobel laureates, I think, are more prepared than we are for that. I could see here that the Nobel laureates invited in GYSS [Global Young

Scientists Summit] were on the whole rather good in making a good show with the audience, making people laugh, talking with passion, etc. Mathematicians are less familiar with this. I guess it has to do with the fact that these Nobel laureates also had to fight for funding, they had to be team leaders; it's much more important than in mathematics. And so they developed all these communication skills I think more than the mathematicians. The question that you are asking (the way to reconcile personal needs and responsibilities at community level) is a really tricky one. We know that various activities can go into negative interaction together, becoming cumbersome for each other. On the other hand, things like teaching and research go well together. Often they reinforce each other, but administration, not so. It takes time and when you are in administration, first you need to handle the ego of people. You need to resolve some conflicts. You need to make decisions at a rather fast pace; you have to make a decision by a certain date whereas in research you can take your time to explore, check, investigate. When you go to a media presentation, it's even worse. Sometimes you have to decide by the hour. You have to give short interviews and then it's a question of minutes. Sometimes you are invited to some tea and you have thirty seconds to give an answer, or three minutes — then it's not bad — and so sometimes it's longer. So I don't have a general answer to your question. It is quite difficult to reconcile the personal needs of the researcher and professional responsibilities. And it's obvious that one has to protect some time. One has to make sure you are in an environment in which you don't lose your time. But apart from the general things I cannot really say. I have not managed myself really to resolve this because it is very clear that since the past year or two my presentation activity in particular has been a nuisance for my research activity. With the administrative activity it was okay. I managed rather well to do the two together in particular because I have a dedicated staff to help me at the *Institut Henri Poincaré*. But with the media activity I did not manage well. I will have to reduce the media activity if I want to increase research again.

I: Would you agree that mathematicians are somehow, by nature, more introverted, so that exposure to the media is less attractive?

V: On the whole, maybe mathematicians are a bit more introverted, and maybe they are more fussy about details. And then maybe they are less at ease with the media but this rule has important exceptions both within mathematicians and outside mathematicians. I think the way that the community looks at these activities has been changing and that people don't regard this nowadays as just a nuisance. The need to communicate is regarded as part of their duty as scientists to talk with society, also the duty of civil servants. Most of the researchers in France, at least, are state employed.

I: You have once said that computer simulation gives important insight into understanding phenomena and formulation of theories. The computer technology and hardware have improved by leaps and bounds. Yet basically at the software level the corresponding advances have not been so dramatic and far-reaching. Do you think that in the near future there will be some fundamental breakthrough in the theoretical understanding of algorithms and computer science that will contribute to the solution of fundamental problems in mathematics and physics such as the Navier–Stokes equations?

V: Progress in theoretical understanding of algorithms is stronger than one usually believes. There was a study, I think, by the AMS [American Mathematical Society] or maybe the EMS [European Mathematical Society] a few years ago about certain benchmarking algorithms that they use often in computer science and it was shown that over a certain period of time (I don't remember how much) the factor in time that has been gained from the progress in technology was comparable to the factor in time that would have been gained through the algorithmic. So, well-thought algorithms can really make a change and has really made changes on the efficiency. Now it is true that globally the software level lags behind the technology level. I am not sure whether this discrepancy will continue or whether, on the contrary, we will reach a limit in new technology and then know that progress would have to be made on the algorithms and their theoretical understanding. I think that we are making a lot of progress currently on the theoretical understanding of algorithms and there are all these fascinating works about the art of automatic verification and so on. However, I really don't see anything emerging for more complicated systems such as Navier–Stokes or Boltzmann equations or the problems I've been working on. I really don't see them occurring. I cannot imagine how this can occur. But this may be just a question of limitation of my imagination. Yes, it is clear that theoretical computer science has beautiful days ahead. As a sign of the times, in 2014, we at *Institut Henri Poincaré* shall house our first trimester devoted to theoretical computer science, its programme centered precisely on these questions of logic of computing and formal proofs and automatic programs to check automatically the very details of the proof. I think this is one of the exciting areas of computer science nowadays. And we can ask ourselves if some day some computer programs will be useful as a help for finding proofs. For the moment, it's very far away but then at one time people believed that computers could never beat human beings in chess and now they do this routinely. So soon we may see computers able to check complicated proofs. Who knows in time to come, we will have the computer help us find complicated reasoning.

"Interview of Cedric Villani by Y K Leong
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