Shing-Tung Yau: Manifolds, Cosmos, China*,†

An interview with Shing-Tung Yau, by Y. K. Leong‡

In a company of three, one will be my teacher.
— Chinese proverb

Shing-Tung Yau has made deep and fundamental contributions to differential geometry and partial differential equations, with an impact that extends beyond mathematics to many scientific disciplines, notably cosmology and theoretical physics.

The story of Yau from grinding poverty to international eminence reads like a modern fairy tale or the script of a Cantonese movie of the 1960s. (See the "Discover Interview" in the June 2010 issue of *Discover* magazine). Born as the fifth of eight children during the final stage of the civil war in China, he was only a few months old when the whole family fled from the village of Shantou in Guangdong and sought refuge in the political haven of Hong Kong in the tumultuous wake of the communist takeover of the mainland. Life was hard, even with the pay (which was poor) that his father could earn as a college professor, and when Yau was 14 years old his father died of some sickness. Though the seed of his interest in mathematics had already been planted in him by his father, Yau would spend much time as the leader of a street gang when not reading the Kung Fu novels popular in Hong Kong at the time. It was at Chung Chi College (which later became one of the colleges of the Chinese University of Hong Kong) that he met his proverbial guardian angel, who appeared as a college teacher from the University of California at Berkeley, and who initiated Yau's successful application for an IBM fellowship to study at Berkeley, even before Yau had completed his undergraduate studies. Two years after arriving in Berkeley, he obtained his doctorate, at the age of 22, with the world-renowned geometer Shiing Shen Chern (1911–2004) as his advisor. In the following years and before he was 30, by dint of perseverance and his intellectual abilities, Yau cracked a tough nut known as the Calabi conjecture, which had hitherto defied the experts. It was no flash in the pan, for the succeeding years saw more contributions, often in joint work with others, to the theory of partial differential equations and to general relativity. This corpus of work led to a Fields Medal being awarded to him at the age of 33.

Since then, his research output has continued unabated, often in collaboration with other mathematicians and physicists. Among the numerous topics and conjectures in differential geometry, algebraic topology, partial differential equations, and string theory to which he has contributed, or which his work has resolved, are: geometric invariant theory, holomorphic vector bundles, symmetric spaces, Kähler manifolds, positive mass conjecture, minimal surfaces, the Yamabe problem, the Smith conjecture, Hermitian Yang-Mills connections, the Frankel conjecture in complex geometry, Ricci flows in 3-dimensional manifolds, the Monge-Ampère equation, uniformization theorem for Kähler manifolds, rigidity of complex structures for Kähler manifolds and extensions to locally symmetric spaces, minimal submanifolds, harmonic functions with controlled growth, rigidity properties of higher

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rank metrics for general manifolds, stability of manifolds, and mirror symmetry.

In contributing to the resolution of numerous conjectures, partly in joint work, Yau's work has laid the foundations for other advances in mathematics. His research publications (numbering more than 300) range widely across the disciplines, and his collaborative research has been prolific. Yau has received numerous awards and honorary degrees from universities and learned academies in the United States, Europe and China—notably the Oswald Veblen Prize, the John J. Carty Award, the Humboldt Research Award, the Crafoord Prize, the U.S. National Medal of Science, the Wolf Prize, the Sloan Fellowship, the Guggenheim Fellowship, and the MacArthur Fellowship.

Yau has a personal sense of commitment to educating future generations of mathematicians. On the academic side, he has successfully mentored more than 60 doctoral students. On the pragmatic side, he has helped raise substantial funds to promote mathematics education and research and international multi-disciplinary interaction. Perhaps less well known is the fact that he has personally donated funds to the establishment of scholarships and awards for undergraduates at the Chinese University of Hong Kong. Yau's active organization of, and participation in, activities for high school and college students have earned him a reputation as an ambassador of mathematics. In a move to popularize mathematics, he co-initiated a series of books entitled *Mathematics and Humanities*. More recently, he has written together with Steve Nadis two books for the general public: *The Shape of Inner Space: String Theory and the Geometry of the Universe's Hidden Dimensions* (Basic Books, 2012) and *A History in Sum: 150 years of Mathematics at Harvard* (Harvard University Press, 2013).

Since the opening up of China in 1979, Yau has been tireless in his efforts to encourage, nurture, and develop mathematical talent in China, from the school level to the research level. He was instrumental in establishing the following research institutes, each of which he is the director: the Institute of Mathematical Sciences at the Chinese University of Hong Kong, the Morningside Center of Mathematics in Beijing, the Center of Mathematical Sciences at Zhejiang University, and the Shing-Tung Yau Center of National Chiao Tung University, Taiwan. In 2009, Tsinghua University established its Mathematical Sciences Center (MSC) and invited Yau to be its inaugural director. Within four years' time, MSC expanded its composition to 22 full-time members and nine part-time members, and supplemented its collaboration with Tsinghua's original Department of Mathematical Sciences with several adjunct appointments from the latter.

Tsinghua University was founded more than 100 years ago in Beijing, at the time when China was throwing off her dynastic yoke. In its formative years, Tsinghua formed one of the three legs (the other two being Peking University and Nankai University) of a tripod supporting the crucible that brewed and distilled a spirit of enquiry and perseverance among the first generation of modern China's influential scientists and mathematicians. This history puts into proper perspective Tsinghua's current ambitious plan to create an international environment of on-going, year-round conferences and workshops at which young researchers can "learn from the masters." To that end, Yau oversees the Tsinghua Sanya International Mathematical Forum, which is held in the city of Sanya on the island of Hainan. On the other side of the straits, in Hsinchu, Taiwan, Yau has played a crucial role in the establishment of the National Center for Theoretical Sciences. All of this, while Yau has actively engaged in research in the United States.

Yau is the first Chinese mathematician to be awarded the Fields Medal, a fact which must have been an inspiration to a whole generation of young Chinese mathematicians given the opportunity to pursue studies and careers outside China, and to strive to reach the pinnacle of excellence. It is true that he does not have the advantage of that particular mystique which derives from achievement fired and tested by the trials of war and revolution. It is also true that he emerged at a time when the Chinese scientific psyche was very much riveted by the successes of the earlier generation, which included major figures such as S. S. Chern, Luogeng Hua (L. K. Hua, 1910–1985), and Chen Ning Yang. Nevertheless, Chern was Yau's PhD advisor and Yau was one of the first young Chinese scholars invited by Hua when China first opened up her academic doors in the 1970s. And he has made significant contributions at the interface of mathematics and physics that is so close to the heart of Yang. It is hard to question Yau's credentials as the mathematical successor of Chern. When one looks at Yau's initiatives and efforts in pushing the development of mathematical talent and research in China, it is hard to dispute his influence upon and "titanic contributions" (in the words of number theorist John Coates) to the advancement of mathematics in China. All of these bear his imprint: the International Congress of Chinese Mathematicians, the Morningside Medals, the Yau High School Mathematics Awards, the New World Mathematics Awards, the Hang Lung Mathematics Awards, and the S. T. Yau College Student Mathematics Contests.

Having been at Harvard University since 1987, Yau is now the William Casper Graustein Professor of Mathematics, and has recently been appointed to the faculty of Harvard's physics department. He has visited Singapore a number of times in the past and is a close and respected friend of many mathematicians at the National University of Singapore. On 4 January 2011, at the invitation of the Institute for Mathematical Sciences, Yau gave a public lecture entitled "The Shape of Inner Space," which is also the title of the popular book written by him and Steve Nadis. The book is in part a personal story of the evolution of the ideas behind Calabi-Yau spaces and its relationship to string theory—a theory which many hope will provide the key to the Holy Grail of physics: the Grand Unification Theory, or "theory of everything."

On the eve of that lecture, he was interviewed by Y. K. Leong on behalf of *Imprints*. The following is an edited and vetted version of this interview, in which he briefly recounts his early years in Hong Kong and Berkeley and gives us a glimpse of the intriguing, if only speculative, connection between geometry (Calabi-Yau spaces) and string theory. He also offers an insight into some of the factors that thwarted the development of mathematics in dynastic China, and assesses the state of mathematical development in modern China.

Imprints: After a few years of study at Chung Chi College of the Chinese University of Hong Kong you went to the University of California at Berkeley for graduate study. Why did you choose to go there?

Shing-Tung Yau: Actually I had no choice. I did not have an undergraduate degree at that point, so basically I could not go to any other university. My teacher in Hong Kong at that point came from Berkeley. He had just graduated from Berkeley and knew quite a few faculty in Berkeley who helped arrange this possibility to go to Berkeley. And, of course, Berkeley was one of the best in the world at that point; so I was pretty happy with that. On the other hand, I did not apply to any other place because I had no other choice.

Imprints: So they waived the requirements?

Yau: Berkeley was able to waive the requirements, and more importantly, could provide me with a fellowship. I was so poor I did not have much money. It was a well-funded fellowship from IBM through Berkeley.

Imprints: That scholarship must have been very competitive, isn't it?

Yau: Oh, yeah. It was extremely competitive. The math department had only two IBM fellowships and they probably gave them to the best applicants. They gave one to me. This shows how flexible they were; [they give it] as long as they feel somebody is good. I was very impressed by their flexibility. Quite likely, my teacher—my later teacher—Chern played a role in this possibility. But I didn't know Chern at the point when I applied. I knew a man who graduated from Berkeley; he was my professor in Hong Kong and is called [Stephen] Salaff. He had just graduated [from Berkeley] a couple of years before. He arranged [it] with Donald Sarason who was in Berkeley; it was very nice of them.[1]

Imprints: He [Salaff] must have been very impressed by you academically.

Yau: Oh, yes. Actually he tried to get me an early undergraduate degree. There was a big fight at the Chinese University of Hong Kong. Of course, they regret it now because I got a Fields Medal. If I was a graduate from Chinese University [of Hong Kong] it would count as a good point for them.

Imprints: You mentioned you didn't know Chern before you went to Berkeley.

Yau: That's right. When I applied, I didn't know him, but after I was admitted Chern was offered an honorary degree by the Chinese University of Hong Kong. I think in June he came to Hong Kong from America to pick up the degree and I met him in the middle of June. That was after I was admitted. But I'm sure he must have helped somewhat.

Imprints: You worked on the Calabi conjecture shortly after getting your PhD. How did you get interested in the Calabi conjecture?

Yau: Actually I was working on it even when I was working on my PhD. I was interested in curvature and its interaction with topology and complex structure and all that. It comes so naturally that it is the most important question I need to solve because that was the only general procedure to construct manifolds with certain properties on Ricci curvature. Up till now it is still the most general way to construct such a manifold. I was fascinated by it and I thought it had to be solved one way or the other because it is basically the building block of the whole foundation. And if I don't go through it, it would not be possible. So I got to solve it.

Imprints: Was your PhD thesis connected with the [Calabi] conjecture?

Yau: No. After I arrived at Berkeley, I read on some problem relating the fundamental group of manifolds with curvature. I wrote two papers on it and they were published in the second year of my PhD. [In my] first

[1] Professor Shoshichi Kobayashi (1932–2012) was the chairman of the admission committee of the mathematics department of Berkeley when I was admitted. He was very proud to have admitted me in 1969.—S. T. Yau.

year, Chern was not in Berkeley; in fact, he was on leave. By the time when he came back, I told him that I did something and he was very friendly. Then I asked him to be my advisor. First year, he was not my advisor. He had agreed, but then after one month, he said, "Well, maybe what you've got is good enough for a PhD thesis." So that was my thesis. On the other hand, I started to change to a different subject. I was influenced by him a lot, of course.

Imprints: You mentioned Morrey [Charles B. Morrey, 1907–1984] in your book *The Shape of Inner Space*.

Yau: The first year, I was taking three different courses. One is by Morrey, which is very important, because I learnt partial differential equations and the non-linear theory from him. The other one is on geometry by [H. Blaine] Lawson; he was teaching elementary differential geometry at that point. I told him what I did, so we started to work on it together. One paper was written with him—he was working on minimal surfaces, but I was interested in fundamental groups and negative curvature. In fact, he worked on the problem because of my suggestion. The third course I took was by Spanier [Edwin Henry Spanier, 1921–1996] on algebraic topology. They were all good courses. Spanier was a great algebraic topologist. He finished writing his famous book *Algebraic Topology* at that time. You know the quarter system—you take three courses. [In the] spring quarter, unfortunately, most people went down to the demonstrations because of the Vietnam War. Basically, Spanier's course and Lawson's course got cancelled because [there were] not enough students. But Morrey's, I still went to. Because I was the only student, and he was very faithful, he taught me one-to-one. It was very nice to be able to see him every day.

Imprints: Could you tell us briefly what Calabi-Yau manifolds are?

Yau: Well, basically, it is a space which is compact, closed without boundary and yet its Ricci curvature is identically zero, which means in terms of general relativity that there is no matter. Matter distribution is described by the Ricci curvature. So it is a space with no matter, and yet as a compact space we want to have gravity. That means the full curvature tensor is not identically zero. A torus is [a space where] the full curvature is identically zero. We are looking for a closed universe where there is no matter and yet there is gravity. So, no Ricci curvature and yet there is still curvature. These are the things we are looking at. Now Calabi-Yau adds one more thing, namely that there is some internal symmetry behind it. In terms of physics, it's called supersymmetry. In terms of mathematics, it's a Kähler manifold with compact structure behind it. So that's the Calabi-Yau manifold.

Imprints: Were their connections with theoretical physics first discovered by physicists or by mathematicians?

Yau: What happened is that I was there with many physicists over the years. One of them, Gary Horowitz, was my postdoc. I hired him. He had a PhD in physics. He was in general relativity. I worked in general relativity also. I told him about this work and that it might be useful some time for physics. In the beginning he didn't know it. And then there was Andrew Strominger who came as a postdoc, but not mine; he was in Princeton. I told him what I had done, but not very clearly. Later the string theorists came up and found out what they wanted was close to what I wanted. So they started to make use of it.

Of course, string theory has not been verified. The extra dimensions have not been verified. Many physicists are trying to verify it. If string theory is correct, supersymmetry should be there; then I think it would appear. The question is how to see it. It probably takes quite a long time. In any case, it's interesting. The mechanism may be useful even if string theory were wrong. That's what we hope. It's so beautiful that it is difficult to imagine that it doesn't have any real practical applications.

Imprints: Are you surprised by the connections?

Yau: I wouldn't say I was very surprised because when I did the Calabi conjecture I felt that it was so beautiful a statement and the flavor so close to general relativity and if there is a general way to construct such a space—that's what I did—it is difficult to imagine that Nature does not use such a space. I think it has to come up somewhere. Although it was eight years later that people were excited about it, I am not surprised by it.

Imprints: You have sometimes called yourself a "physicist". I believe that your wife is a physicist.

Yau: My wife is a physicist. I never really call myself a physicist. I don't mind being called a physicist. I do not have enough physical intuition compared with my friends in physics. But, on the other hand, compared with many mathematicians, I have better insight [in physics] than they. That's all I can say.[2]

Imprints: How much do you interact with experimental physicists?

Yau: I do see them. I go to their seminars and talks. I even listen to astronomy talks and all that. I go to CERN, some of my friends are up there. It's quite in-

[2] Yau has been concurrently appointed professor of physics in Harvard's department of physics in 2013.—*Imprints.*

teresting. I get some interest and insight from them but I don't understand experiments very much.

Imprints: Do you keep up with the results of the LHC (Large Hadron Collider)?

Yau: To the extent that if it has influence on theory, I always listen to them. There are talks in Harvard by people from there. I used to go there to listen.

Imprints: I think that Paul Dirac [1902–1984] believed that mathematical beauty is a good guide in choosing or formulating physical theories. Using this kind of guide, do you think that string theory would be the best model available?

Yau: Well, I won't say that would be the only guideline because beauty is not the only thing. You can be fooled by it. The way string theory has come about is far more complicated than one single beauty. It is related to many aspects of mathematics—geometry, topology, representation theory, and many other aspects. Each of them has such a strong influence and beautiful consequences. Some of the problems in math were solved only using the intuition from string theory although the final proof was given by rigorous mathematics. The fact that it can be proved by mathematics demonstrates that the consequence of the physical intuition is fine. And the proof is not trivial. It's not a question of one or two pages or just an operation. It is really tricky otherwise it is difficult to say that there is beauty. It's not just that you draw a picture of an apple and say that the apple is beautiful and conclude it has applications. Here the proof has many consequences, maybe 100 papers were written in mathematics, and the consequences predict some statements and theorems in math which mathematicians did not dream about before and then they go ahead to prove them. This is true beauty, I feel, with structure, and all can be verified. I think this is something that one could not easily give up. I think, as you just mentioned, beauty is not enough. It should have more depth and structure behind it.

Imprints: I think most physicists are not very comfortable with using too much abstract mathematics in their theory.

Yau: There are two kinds of physicists. In the old days, most physicists used combinatorial arguments—Feynman diagrams, calculations and all that. But now string field theory gives far more geometric insight into algebraic geometry, topology and all that. The more old fashioned physicists are not used to it, so maybe that is one reason why they criticize them. But in these modern days the string theorists are comfortable with using this new geometric terminology. They learn quite a lot, they know how to do the calculations themselves. They are very impressive, they know a lot about that. I would say some of them are even better mathematicians than some mathematicians. I don't know whether there is any criticism about that.

Imprints: Stephen Hawking has recently written a book[3] advocating M-theory. Do Calabi-Yau manifolds still feature in M-theory?

Yau: I didn't read the book. Some of the models from M-theory can be built out of Calabi-Yau models; some of them are not, so far. How closely they are related is quite interesting. The problem about building models in M-theory in 11 dimensions is that the 7-dimensional manifold needed is far more complicated and not understood at this moment, not like the 6-dimensional Calabi-Yau manifolds which are deeper and better understood than the 7-dimensional manifolds. The 7-dimensional manifolds are basically examples but we don't have a clear understanding [of them].

Imprints: Is the 7-dimensional manifold in M-theory related to the Calabi-Yau manifolds?

Yau: Some of the constructions are related, but not all of them. So far, most of the constructions can be traced back to the way we construct Calabi-Yau manifolds. Whether the 7-dimensional manifolds are really exotic is absolutely irrelevant and it is not clear also.

Imprints: Why do they add one extra dimension?

Yau: Well. That's from physical intuition. They have brane theory and all that. Many physicists are comfortable enough with the Calabi-Yau manifolds in the 10-dimensional space.

Imprints: If I understood it correctly, in string theory you have the 4-dimensional space-time together with a Calabi-Yau manifold, and in this space-time there is time, but in the Calabi-Yau manifold there is no dimension corresponding to time, does it?

Yau: The 10-dimensional manifold is a Cartesian product of a 4-dimensional space-time with a 6-dimensional Calabi-Yau manifold. The 4-dimensional space has time there.

Imprints: It seems rather strange that time is not involved in the 6-dimensional Calabi-Yau manifold, doesn't it?

Yau: No, no, the time is there; it's in the other part. Even if you look at 4-dimensional space-time, there is one part that has no time—the 3-dimensional space is separate from time.

[3] *The Grand Design*, written jointly with Leonard Mlodinow.

Imprints: What happens when you do the physics within the Calabi-Yau manifold? Then there is no time involved.

Yau: Well, the 6-dimensional manifold sits inside a 10-dimensional space and you do the physics inside this 10-dimensional space. Time is there.

Imprints: Can you observe this 6-dimensional manifold?

Yau: It's not impossible to see it. There is speculation that during the Big Bang there may be some strings vibrating and then after inflation there may be some cosmic strings, fundamental strings. People try to observe those strings. If those strings are there, you can actually observe them but it's hard to find them. In astronomy you can actually see cosmic strings like the galaxies. Cosmic strings have some effect on the universe—you can see how light is recessed and all that. That is assuming you are looking at the strings right from the beginning of space and time. On the other hand, you are supposed to see an icon from the Calabi-Yau space that is 10^{-33} centimetres—that's too small to be seen. People try to find ways to understand the consequences of it. That part you cannot see, but you can look at the cosmic strings. Then it is something that is possible to be seen.

Imprints: But at the ordinary level in everyday life, it's not possible to see it, isn't it?

Yau: It depends on what you mean by "everyday life." You go up to astronomy, you can actually see cosmic strings. But, of course, in daily life you cannot see a proton or electron either. You don't see them in everyday life even if you see them in experiments. You don't see a quark; a quark can never be seen. There are many things you cannot see but it works.

Imprints: In topology and chaos theory, there is a notion of fractional dimension. Has anyone attempted to introduce a "complex dimension" into the study of manifolds (like complex manifolds)?

Yau: It's always there. The question is how to make use of it. For example, you were asking a question that there is no time. In quantum field theory usually you have space and time but then people discuss what is called Euclidean quantum field theory. What does that mean? They make time to be imaginary time, $z = it$. Now you move from a Lorentz manifold to an Euclidean manifold. In between you have to go through some analytic continuation. What that really means we don't really know. There's no good intuition in it but it's routinely done in quantum field theory nowadays. Because it's difficult to do Lorentzian geometry, people do Euclidean geometry first and then quantum field theory and finally conclude something. In many ways it's built in there but what kind of theoretic intuition there is, it's not clear. It's just like the Riemann zeta function [$\zeta(s)$]—you want analytic continuation, but what it continues to, we don't really know. In the Riemann zeta function when s becomes a negative number what does that mean? $1+2+3+\ldots$ sum up to a number. It's similar to that. It's out of the ordinary intuition we have. People are still doing it.

Imprints: You mentioned imaginary time. I think Stephen Hawking had something like that in one of his early ideas.

Yau: Yeah, Stephen Hawking in the 1970s talked about Euclidean gravity with imaginary time.

Imprints: I believe you have been applying conformal geometry to computer graphics and pattern recognition. Has it been applied to the movie and computer game industry?

Yau: It could be done. But we are not good in marketing or whatever. We have done a very good software applying conformal geometry to computer imaging and all that. What comes out is very beautiful and very nice, much better than what we know to exist.

Imprints: Did you get Hollywood to be interested in it?

Yau: Well, it's very complicated. Hollywood was interested in it. In fact, before the film *Avatar* became very famous, they started to approach us because we could do a good *Avatar* compared to them. Although we have the original idea, in order to work on it as a package you need to hire many people to do the research, to make it as a finished product. It's too complicated. That becomes an industry. Industry is something I'm not comfortable dealing with. So I decided not to work on that.

Imprints: You have been often described as an "ambassador of mathematics" and have, in fact, devoted much time, effort and money in helping young mathematicians and promoting mathematical education and research in China, Hong Kong and Taiwan. Are you driven by some kind of personal mission?

Yau: It's not just in China or Hong Kong. I have been in America for 40 years and tutored many students in America. I consider it a duty of a true mathematician to train younger mathematicians, in China or not. I have many non-Chinese students. Our profession has to continue. In order for it to continue you need to have the younger generation to grow. I feel it's our duty to train them, to make them do well; so I do that. I train many non-Chinese mathematicians but, because I'm Chinese, China sends a lot of Chinese students to study with me. So naturally I have more Chinese students now, and also quite a lot of the Chinese are very good and they are able to continue. I go back to China, yeah. As I said, I try to help the mathematical community. It's easier for me to contact people I know there, and there's a large group of brilliant young students in China. There are 1.4 billion people in China. Even if 0.001 per cent of students have interest, it would be a big deal. It seems to me for my situation it's more effective for me to train the Chinese students than to go to Europe or other places.

Imprints: How often do you go back to China?

Yau: I go back every year, for a few times, to Hong Kong, mainland China and Taiwan.

Imprints: The Chinese-born Swiss geologist Kenneth Hsu wrote, "The scientific revolution did not occur in China, because the truly talented became poets, painters, and creative writers; they chose not to be stifled by the Confucian academic tradition." He wrote this in an article "Why Newton was not a Chinese." What is your view on this?

Yau: I know Kenneth Hsu. He is a controversial guy, trying to make something exciting by publishing something exotic. Well, there are people who became poets and all that but there are many more complicated reasons than that. People who are driven by Confucian thinking are much too practical. They want to see mathematics to be useful right away. This is not quite the Greek style. The Greeks do not insist that mathematics has to be useful in daily life immediately; they think of beauty and truth much more than practical use. Even now I see in China or even in Singapore that practical use is more important than truth or beauty for mathematics. I think that's one of the problems. For example, the Chinese actually knew what a proof means, I think, around the Tang Dynasty but then they didn't really push it too far. Logic, mathematical logic, and the axiomatic approach had never been something that the Chinese care about because they don't see any reason to be axiomatic. They see a direct application to everyday life. So the Newtonian way of writing Newtonian mechanics, the three laws of mechanics, never came to the mind of the Chinese. They don't see what is the point of a law. They don't see any general law. They just say, "You apply to this, you do this and work it out and it is fine." You look at the books that the [early] Chinese have written in mathematics. Basically they give examples—you do this, you do that, you come up with that. They did know what a proof was at some point, but I don't think they exploited it too much. For example, the translation of Euclidean geometry was done very, very late, about 400 years ago. The complete Chinese translation was done in the 19th century. Four hundred years ago, they translated the first six chapters [of Euclid's *Elements*] and then they gave up. Nineteenth century, they finished the translation, but it was too late by then.

Imprints: I think the Chinese way of writing is harder to write for mathematics.

Yau: It's also true but I don't think that's a problem. You know, the Chinese had a lot of connections with Arabian countries quite early. Indian mathematicians came to China around 500 AD. They [the Chinese] had contact with the Arabs quite early because a lot of Arabs came to China. The Chinese were exposed to simpler ways of writing but they insisted on their own way. Even when calculus was introduced in the 19th century the symbols of the Europeans were given up because of the ugly way of writing them in Chinese.

Imprints: I think you also once said that it would be a long time, maybe 50 years or even 100 years, before China would be scientifically equal to the US. From your close association with the scientific and sociopolitical establishments in China during the past decades, do you still see remnants of this kind of Confucian tradition that stifles scientific creativity?

Yau: Well, this statement, of course, is making the assumption that the current inertia is still going on and [the Chinese] does not want to change. But if Chinese leaders or culture has a sudden jump or change, that will make a lot of difference. For example, there are a lot of Chinese mathematicians now in America. Let's say 10 percent of them want to go back, the very good ones. That will make a good change. That will make the gap smaller immediately but it's not clear they would come back. I made the assessment based on the events that had been going on. You know, if the [Chinese] government does the right thing or if something like a disaster happens in America—for example, in the 20th century when the Germans decided to kick out all the Jews—then, of course, that would make a great deal of difference. I think in the late 19th century American mathematics was nowhere compared with Germany. In a matter of 50 years they are better because most of them came from Germany. After all, America is an immigrant country. A lot of these very brilliant mathematicians in America actually come from all over the world. Yes, there are many local [mathematicians] but there are also many Europeans, Chinese, Indians and others. For example, if the American government suddenly becomes crazy and decides to expel all the foreign scholars because they don't want to use American taxpayers' money to pay foreign scholars, which may happen, that will be good for China and some other foreign countries because they will suddenly get a large group of really outstanding people. American policy right now is great. It's best for the environment for foreign mathematicians to come and try to become outstanding mathematicians. If the American government is stupid enough not to realize the value of this, then that's it. So the statement I made depends on events. If America stupidly changes for the worse and China skilfully changes for the better, then the gap will get smaller.

Imprints: At the moment are the incentives in China enough to pull back the Chinese mathematicians?

Yau: Well, there is a question of culture and inertia, as I've said. As far as money is concerned, China can basically do anything equivalent to what the Americans can do for the best ones. For the mediocre ones it's not so clear what they would do. On the other hand, I think the payment is good enough for them. I think in the next 10 years there will be a much bigger change because they have changed the incentives. They realize the importance of the second group of people.

Imprints: I believe you have a lot of students in the past. Do you still have many students?

Yau: I still have five students graduating with PhD this year. It's not easy to have all these students. I'm pleased with these students. It takes a long time to train them.

Imprints: What advice would you give to graduate students who want to do research in mathematics?

Yau: First of all, you have to train yourself to know all the basic skills so that when a problem comes you have the skills to work on it and, of course, once you have found a problem, have the curiosity and good interest in the problem, and get good advice from a good mathematician.