SCIENTIST AT WORK | TERENCE TAO

# Journeys to the Distant Fields of Prime

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LOS ANGELES —Four hundred people packed into an auditorium at U.C.L.A. in January to listen to a public lecture on prime numbers, one of the rare occasions that the topic has drawn a standing-room-only audience.

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Monica Almeida/The New York Times
Terence Tao, 31, is one of the world's top mathematicians.

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8 Out of 8 (and Not Yet 8)

Monica Almeida/The New York Times; above, The Advertiser of Adelaide, Australia
Mr. Tao earned his Ph.D. at 20 and gained broad acclaim. At age 7, he was taking high school math classes.

Another 35 people watched on a video screen in a classroom next door. Eighty people were turned away.

The speaker, Terence Tao, a professor of mathematics at the university, promised "a whirlwind tour, the equivalent to going through Paris and just seeing the Eiffel Tower and the Arc de Triomphe."

His words were polite, unassuming and tinged with the accent of Australia, his homeland. Even though prime numbers have been studied for 2,000 years, "There's still a lot that needs to be done," Dr. Tao said. "And it's still a very exciting field."

After Dr. Tao finished his one-hour talk, which was broadcast live on the Internet, several students came down to the front and asked for autographs.

Dr. Tao has drawn attention and curiosity throughout his life for his prodigious abilities. By age 2, he had learned to read. At 9, he attended college math classes. At 20, he finished his Ph.D.

Now 31, he has grown from prodigy to one of the world's top mathematicians, tackling an unusually broad range of problems, including ones involving prime numbers and the compression of images. Last summer, he won a Fields Medal, often considered the Nobel Prize of mathematics, and a MacArthur Fellowship, the "genius" award that comes with a half-million dollars and no strings.

"He's wonderful," said Charles Fefferman of Princeton University, himself a former child prodigy and a Fields Medalist. "He's as good as they come. There are a few in a generation, and he's one of the few."

Colleagues have teasingly called Dr. Tao a rock star and the Mozart of Math. Two museums in Australia have requested his photograph for their permanent exhibits. And he was a finalist for the 2007 Australian of the Year award.

"You start getting famous for being famous," Dr. Tao said. "The Paris Hilton effect."

Not that any of that has noticeably affected him. His campus office is adorned with a poster of "Ranma ½," a Japanese comic book. As he walks the halls of the math building, he might be wearing an Adidas sweatshirt, blue jeans and scruffy sneakers, looking much like one

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of his graduate students. He said he did not know how he would spend the MacArthur money, though he mentioned the mortgage on the house that he and his wife, Laura, an engineer at the NASA Jet Propulsion Laboratory, bought last year.

After a childhood in Adelaide, Australia, and graduate school at Princeton, Dr. Tao has settled into sunny Southern California.

“I love it a lot,” he said. But not necessarily for what the area offers.

“It’s sort of the absence of things I like,” he said. No snow to shovel, for instance.

A deluge of media attention following his Fields Medal last summer has slowed to a trickle, and Dr. Tao said he was happy that his fame might be fleeting so that he could again concentrate on math.

One area of his research — compressed sensing — could have real-world use. Digital cameras use millions of sensors to record an image, and then a computer chip in the camera compresses the data.

“Compressed sensing is a different strategy,” Dr. Tao said. “You also compress the data, but you try to do it in a very dumb way, one that doesn’t require much computer power at the sensor end.”

With Emmanuel Candès, a professor of applied and computational mathematics at the California Institute of Technology, Dr. Tao showed that even if most of the information were immediately discarded, the use of powerful algorithms could still reconstruct the original image.

By useful coincidence, Dr. Tao’s son, William, and Dr. Candès’s son attended the same preschool, so dropping off their children turned into useful work time.

“We’d meet each other every morning at preschool,” Dr. Tao said, “and we’d catch up on what we had done.”

The military is interested in using the work for reconnaissance: blanket a battlefield with simple, cheap cameras that might each record a single pixel of data. Each camera would transmit the data to a central computer that, using the mathematical technique developed by Dr. Tao and Dr. Candès, would construct a comprehensive view. Engineers at Rice University have made a prototype of just such a camera.

Dr. Tao’s best-known mathematical work involves prime numbers — positive whole numbers that can be divided evenly only by themselves and 1. The first few prime numbers are 2, 3, 5, 7, 11 and 13 (1 is excluded).

As numbers get larger, prime numbers become sparser, but the Greek mathematician Euclid proved sometime around 300 B.C. that there is nonetheless an infinite number of primes.

Many questions about prime numbers continue to elude answers. Euclid also believed that there was an infinite number of “twin primes” — pairs of prime numbers separated by 2, like 3 and 5 or 11 and 13 — but he was unable to prove his conjecture. Nor has anyone else in the succeeding 2,300 years.

A larger unknown question is whether hidden patterns exist in the sequence of prime numbers or whether they appear randomly.

In 2004, Dr. Tao, along with Ben Green, a mathematician now at the University of Cambridge in England, solved a problem related to the Twin Prime Conjecture by looking at prime number progressions — series of numbers equally spaced. (For example, 3, 7 and 11 constitute a progression of prime numbers with a spacing of 4; the next number in the sequence, 15, is not prime.) Dr. Tao and Dr. Green proved that it is always possible to find, somewhere in the infinity of integers, a progression of prime numbers of any spacing and any length.

“Terry has a style that very few have,” Dr. Fefferman said. “When he solves the problem, you think to yourself, ‘This is so obvious and why didn’t I see it? Why didn’t the 100 distinguished people who thought about this before not think of it?’ ”

Dr. Tao’s proficiency with numbers appeared at a very young age. “I always liked numbers,” he said.

A 2-year-old Terry Tao used toy blocks to show older children how to count. He was quick with language and used the blocks to spell words like “dog” and “cat.”

“He probably was quietly learning these things from watching ‘Sesame Street,’ ” said his father, Dr. Billy Tao, a pediatrician who immigrated to Australia from Hong Kong in 1972. “We basically used ‘Sesame Street’ as a babysitter.”

The blocks had been bought as toys, not learning tools. “You expect them to throw them around,” said the elder Dr. Tao, whose accent swings between Australian and Chinese.

Terry’s parents placed him in a private school when he was 3 ½. They pulled him out six weeks later because he was not ready to spend that much time in a classroom, and the teacher was not ready to teach someone like him.

At age 5, he was enrolled in a public school, and his parents, administrators and teachers set up an individualized program for him. He proceeded through each subject at his own pace, quickly accelerating through several grades in math and science while remaining closer to his age group in other subjects. In English classes, for instance, he became flustered when he had to write essays.

“I never really got the hang of that,” he said. “These very vague, undefined questions. I always liked situations where there were very clear rules of what to do.”

Assigned to write a story about what was going on at home, Terry went from room to room and made detailed lists of the contents.

When he was 7 ½, he began attending math classes at the local high school.

Billy Tao knew the trajectories of child prodigies like Jay Luo, who graduated with a mathematics degree from Boise State University in 1982 at the age of 12, but who has since vanished from the world of mathematics.

“I initially thought Terry would be just like one of them, to graduate as early as possible,” he said. But after talking to experts on education for gifted children, he changed his mind.

“To get a degree at a young age, to be a record-breaker, means nothing,” he said. “I had a pyramid model of knowledge, that is, a very broad base and then the pyramid can go higher. If you just very quickly move up like a column, then you’re more likely to wobble at the top and then collapse.”

Billy Tao also arranged for math professors to mentor Terry.

A couple of years later, Terry was taking university-level math and physics classes. He excelled in international math competitions. His parents decided not to push him into college full time, so he split his time between high school and Flinders University, the local university in Adelaide. He finally enrolled as a full-time college student at Flinders when he was 14, two years after he would have graduated had his parents pushed him only according to his academic abilities.

The Taos had different challenges in raising their other two sons, although all three excelled in math. Trevor, two years younger than Terry, is autistic with top-level chess skills and the musical savant gift to play back on the piano a musical piece — even one played by an entire orchestra — after hearing it just once. He completed a Ph.D. in mathematics and now works for the Defense Science and Technology Organization in Australia.

The youngest, Nigel, told his father that he was “not another Terry,” and his parents let him learn at a less accelerated pace. Nigel, with degrees in economics, math and computer science, now works as a computer engineer for Google Australia.

“All along, we tend to emphasize the joy of learning,” Billy Tao said. “The fun is doing something, not winning something.”

Terry completed his undergraduate degree in two years, earned a master’s degree a year after that, then moved to Princeton for his doctoral studies. While he said he never felt out of place in a class of much older students, Princeton was where he finally felt he fit among a group of peers. He was still younger, but was not necessarily the brightest student all the time.

His attitude toward math also matured. Until then, math had been competitions, problem sets, exams. “That’s more like a sprint,” he said.

Dr. Tao recalled that as a child, “I remember having this vague idea that what mathematicians did was that, some authority, someone gave them problems to solve and they just sort of solved them.”

In the real academic world, “Math research is more like a marathon,” he said.

As a parent and a professor, Dr. Tao now has to think about how to teach math in addition to learning it.

An evening snack provided him an opportunity to question his son, who is 4. If there are 10 cookies, how many does each of the five people in the living room get?

William asked his father to tell him. “I don’t know how many,” Dr. Tao replied. “You tell me.”

With a little more prodding, William divided the cookies into five stacks of two each.

Dr. Tao said a future project would be to try to teach more non-mathematicians how to think mathematically — a skill that would be useful in everyday tasks like comparing mortgages.

“I believe you can teach this to almost anybody,” he said.

But for now, his research is where his focus is.

“In many ways, my work is my hobby,” he said. “I always wanted to learn another language, but that’s not going to happen for a while. Those things can wait.”

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