Western Trained Topologists Serving China: MA Xiaonan

First article in this series

Western Trained Topologists Serving China

This is a series of articles exploring China's efforts to advance mathematics to aid the development of AI-models. Specifically, the recruitment of foreign experts or West-trained Chinese scientists in the field of topology. These individuals are an important resource in China's efforts to catch up to and surpass other countries in this critical dual-use technology area.

Chinese recruitment of key topologists has shown some notable successes. Here we examine these mathematicians and their relevant research. The first mathematician we explore is trained in the West and recently returned to China. A subsequent article will study a French scientist still based in Europe, working for the Chinese company Huawei.

While undertaking research about these two mathematicians, at least five other Western trained topologists were identified as recent returnees to China, and as many as eight more are known to be in Europe working for Chinese organizations, making this a topic ripe for further research.

This article will discuss MA Xiaonan (麻小南) who after decades studying and researching in Europe, returned to Nankai University in China in November of 2024. He is an expert in differential geometry and topology, the winner of several awards, and was a professor in the Department of Mathematics at the University of Paris. But first let's look at topology's contribution to AI development.

Mathematical Topology Use to Advance AI Models

China is recruiting mathematical topologists to spur AI development, hoping to surpass the West in this critical field. How exactly can the field of topology advance AI? New mathematical methods are constantly emerging to improve and advance AI models. When it comes to AI model development, for years mathematicians took a back seat to computer scientists and engineers. This is changing as datasets become even more massive and AI systems become more complex.

Topology has the ability to describe and analyze shapes and sizes and works together with other mathematical disciplines to obtain a greater understanding of data. For instance, linear algebra provides the algebraic foundation for understanding and manipulating spaces, while topology provides the framework for studying their qualitative properties, such as their connectedness, compactness, and shape. They work together in areas like algebraic topology and topological data analysis (TDA) to provide powerful tools for understanding complex systems and can structure and drive network dynamics, perhaps leading to algorithms that "mimic the adaptability and efficiency of natural systems." This can be used to advance large language models (LLM).

Unaided humans are unable to extract meaningful information from a massive dataset, but topology, geometry, and algebra can help scientists understand interesting spaces in the data. Geometric topology can enhance AI models by providing tools to understand and represent the underlying

structure of data, particularly when data possesses spatial or geometric properties. This allows for more robust and efficient AI algorithms, especially in fields like computer vision, materials science, protein prediction, and drug discovery, all of which have military application.

For instance, modern topology can help predict how proteins fold and how they are structured, aiding in protein prediction. This plays a key part in understanding the fundamental units of life. This is also, however, a dual use technology and can be used to build a bioweapon by enabling the design of proteins with tailored properties, such as enhanced heat stability, solubility, or binding specificity—traits that could increase their efficacy as weapons.

MA Xiaonan

In November 2024, renowned mathematician **Ma Xiaonan** (麻小南) left France to join Nankai University as the chair professor at the Chern Institute of Mathematics (CIM). He brings with him expertise in differential geometry and topology, fostered through more than 18 years of collaboration with top mathematicians at the University of Paris. His history of awards and global recognition highlight his potential contributions in fostering a new generation of mathematical talent in China and perhaps signifies a shift in China's mathematical landscape.

MA Xiaonan (麻小南), born in 1972, is a Chinese mathematician trained in China, Germany, and France. He is involved in research in the fields including symplectic geometry (辛几何), multi-complex variables, and Atiyah-Singer index theorem and its applications. His professional and academic accomplishments are as follows:

- November 2024 to present, Chair Professor at the Chern Institute of Mathematics (CIM).
- From 2007 to November 2024, Professor at the Department of Mathematics at the University of Paris-Cité.
- In 2009, he was appointed as a young researcher of the French University Institute (IUF-InsitutUniversitaire de France), a role he held concurrently with his professorship at University of Paris-Cité.
- Ma Xiaonan graduated from the Sino-French Mathematics Experimental Class of Wuhan University in 1993 and received his doctorate from the University of Paris-Sud in 1998.
- Ma studied under Professor Jean-Michel Bismut, a famous French mathematician and international authority.
- Ma held a postdoctoral position at Humboldt University of Berlin in the Jochen Brüning Laboratory and was visiting Professor at the University of California, Santa Cruz.
- His international awards include the Sophie Germain Prize awarded by the French Academy of Sciences.

In November 2024 Ma took a position as a chair professor at Nankai University's **Chern Institute of Mathematics (CIM, 陈省身数学研究所)**, founded by Chinese mathematician Shing-Shen

CHERN (陈省身), an early advocate of sending China's brightest abroad to study with well-known Western mathematicians to help develop China's science and technology scholarship. CHERN (1911-2004) was a mentor to several topologists including both MA Xiaonan and his colleague ZHANG Weiping (张伟平). Other Chern topologist mentees include YANG Zhongdao (杨忠道), a topology expert and University of Pennsylvania professor; CAS mathematician and Zhejiang University professor ZHANG Sucheng (张素诚), who obtained a PhD from Oxford University and was mainly engaged in the research of differential geometry and topology; and Nanjing University professor YE Yanqian (叶彦谦) who studied qualitative theory of quadratic differential systems and differential equations on two-dimensional manifolds.

CIM is a Nankai University-based research institute focused on the development of pure and applied mathematics. The guidelines proposed by its founder, Professor Chern, emphasize serving China by collaborating with overseas mathematicians to advance the development of domestic mathematicians. Chern's motto was: Serving China and embracing the world.

An initial search of funding streams for CIM revealed Chinese Ministry of Education and National Science Fund of China support. While this is common support for civilian science research in China, an April 2023 article mentions the CIM's research contributions to national defense, declining any details. The focus of this article was a CIM meeting to increase cooperation with Harbin Institute of Technology and Chongqing Institute of Technology, both schools with PLA ties.

Ma Xiaonan's return is characterized as a successful case of China's "bringing phoenixes back to the nest" policy, but further exploration reveals his ongoing involvement in strengthening China's math scholarship over the years – long before returning to his homeland.

In 2017 Ma was a "Changjiang Scholar Program" selectee, a Chinese government supported talent recruitment program, to the University of Science and Technology of China (USTC, 中国科学技术大学). Notably, Ma's older brother, MA Xinan (麻希南) is a mathematics professor at USTC, and collaborated with Princeton University in the 2010's – although in what capacity was not stated.

While serving in this USTC role, Ma helped establish academic ties between the School of Mathematical Sciences of USTC and French universities. Notably, during this time Ma Xiaonan was funded by the Overseas and Hong Kong and Macao Scholars Cooperation Research Fund.

Xiaonan Ma also had strong ties with Nankai University prior to returning to China. He frequently collaborates with ZHANG Weiping, a member of the Chinese Academy of Sciences and professor

at the CIM. Dating back to the 1990's, both Ma and Zhang were handpicked by Chern to study in France with Jean-Michel Bismut at the University of Paris (then called Paris XI University).

- Under Bismut's mentorship, in 1992 Zhang founded the "Bismut-Zhang Theorem," which was called "profound" by the American *Mathematical Reviews* when it came out. Rather than stay in Europe, however, in 1993 Zhang returned to Nankai University's CIM after

completing his PhD at University of Paris. In 2004, when Professor Shiing-Shen Chern passed away, the baton of CIM director was handed over to 40-year-old Zhang.

Ma and Zhang both study the Atiyah-Singer index theory in differential geometry, which is a cornerstone of modern mathematics that connects analysis, topology, and geometry by relating the index of an elliptic differential operator on a compact manifold to topological invariants of the manifold. Essentially, it provides a formula to calculate the index of an elliptic operator (a measure of the "size" of its solution space) in terms of topological features of the underlying space.

In 2022, Ma and Zhang coauthored a paper titled “Superconnection and family Bergman kernels” in *Mathematische Annalen*. Family Bergman kernels provide a powerful tool for studying families of geometric structures, including those that vary or degenerate. They allow mathematicians to explore the relationship between the geometry of these families and the properties of the associated Bergman kernels, including how the Bergman kernel changes as the underlying domain or manifold varies.

Ma has also collaborated with LIU Bo (刘博), a Zhang mentee and CIM PhD. Liu and Ma together solved the localization formula of η-invariant in 2018 in a paper titled “Differential K-theory and localization formula for η-invariants.” By providing a way to connect the analytical data of the Dirac operator to topological invariants, the APS η-invariant allows mathematicians and physicists to gain a deeper understanding of the interplay between the geometry of a manifold and its topology. It's a powerful tool for studying manifolds with boundaries and understanding their topological properties.

Even in papers not coauthored with Ma and Zhang, LIU Bo acknowledges the help of both Zhang and Ma in academic articles ranging from 2010 to 2023.

Other Ma collaborators include Dan Coman of Syracuse University in New York State, who may have befriended Ma when he was a research fellow as Humboldt University of Berlin in 1998; and George Marinescu of Germany’s Universität zu Köln, Department of Mathematics and Computer Science.

Marinescu and Ma were awarded the Ferran Sunyer i Balaguer Prize in 2006 for the book “Holomorphic Morse inequalities and Bergman kernels.” On 7 April 2025 Marinescu traveled to China to give a lecture titled “Distribution of zeros of random holomorphic sections” at East China Normal University (华东师范大学).