PHYSICAL SCIENCE

A FORCE OF NATURE FOR PUSHING BOUNDARIES

Known for its strength in fundamental science, Lanzhou University has made breakthroughs in areas ranging from mathematics and physics, to mechanics and nuclear studies.

MECHANICS

TESTING THE WINDS OF CHANGE

The speed of desertification will soon be predictable through a new mathematical algorithm designed by Lanzhou University (LZU) researcher, Zheng Xiaojing, and colleagues. The key was to develop a formula that captured the movement of each sand grain, which included the extent of erosion created by wind, and how particles overlap and ricochet off one another.

The researchers tested their calculation on real tracts of land hundreds of kilometres wide and found they could precisely predict the formation and speed of desertification.

Dust storms and desertification are an increasing ecological and environmental problem. Since the 1930s there have been efforts in geoscience and engineering to understand the unseen forces that sculpt sand dunes to inform sand-controlling projects and improved strategies to protect villages from natural disasters. So far, remote-sensing and other sand dune observation methods have not succeeded.

In China's Gansu province, the desertification of Minqin provided a unique opportunity to study sandstorms. The arid landscape is the site of the Qingtu Lake Observation Array, a field observation station that covers 110,000 square metres. Researchers have analyzed more than 100 sand storms, taking measurements such as wind speed, dust concentration and visibility.

The findings have been published in leading academic titles such as the *Journal of Fluid Mechanics*, and the *Journal of Geophysical Research*, and the new model has been implemented in sand control projects at the edge of the Badain Jaran desert.

Huang Ning extended the above researches to study drifting snow, and the spatial and temporal evolution of snow distribution, which have a big impact on the hydrologic cycle, ecosystem, climate change, and other natural processes. Based on field work and theoretical analysis, Huang's team modelled drifting snow and snow distribution in alpine regions, such as Qilian Mountains, and also developed a simulation system to predict snow distribution.

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110TH ANNIVERSARY

LZU School of Mathematics by numbers

- Founded in 1946
- 130 undergraduate and 130 master's students enrolled each year
- Supports around 30 doctoral students each year
- Research groups cover differential equations and dynamic systems, graph theory, scientific computation and numerical algebra, probability theory and statistics.
- 150 papers published every year in high ranking journals listed in the Science Citation Index.
- In 2019 a strategic development committee was established to invest in interdisciplinary mathematics education and research.

NUCLEAR SCIENCE

GUIDING CHINA'S LUNAR LANDER TO SAFETY

The world's first landing of a lunar explorer on the far side of the Moon was a historic achievement in China's space programme and for the future of lunar science. As the Chang'e 4, named after a Chinese goddess of the Moon, reached its destination in late 2018, technology developed at LZU guided the lunar lander to its destination site at the South Pole-Aitken Basin.

Researchers from the LZU School of Nuclear Science and Technology were key players in the design of the Chang'e 4's γ-sensor, which accurately measured the lander's altitude in relation to the curve of the Moon's surface to achieve a successful soft landing. The team introduced innovative nuclear technology to guarantee pinpoint accuracy.

After the landing, the lunar lander deployed its rover, named Yutu-2, and researchers are working to learn more about the early solar system and Earth.

Another breakthrough is in the Radioisotope Thermal Photovoltaic (RTPV) technology, considered the most effective option for the use of isotope power sources. LZU researchers developed three generations of RTPV generators, which have great potential for supplying power for deep sea and space exploration ventures.

LZU researchers also contributed to the discovery of the doubly charmed baryons, formed by two charm quarks and one light quark, a key breakthrough in particle and nuclear physics.

LZU School of Nuclear Science and Technology in numbers

- Founded in 1958
- The school has trained more than 4000 graduates, with alumni including 2 members of the Chinese Academy of Sciences and the Chinese Academy of Engineering.

PHYSICS A QUANTUM LEAP IN PHYSICS

By combining physics and material sciences, the School of Physical Science and Technology at LZU has developed specialities in condensed matter physics, theoretical physics, material physics and chemistry, microelectronics and solid-state electronics.

The strength in theoretical physics has been developing since the 1950s, when Xu Gongou, a nuclear physicist, and Duan Yishi, an expert on particle physics and general relativity joined LZU. In 1957, a programme on magnetic research was established by drawing relevant resources from other domestic universities, making LZU one of a few universities offering undergraduate training on the subject. Since then, generations of LZU physicists have forged a decent reputation for physics research and education.

MAGNETIC QUALITY OF RESEARCH

The Key Laboratory for Magnetism and Magnetic Materials of the Ministry of Education at LZU, officially established in 2000, is renowned in this field. It started from the applied magnetism laboratory established in 1993, and led by an earlier generation of magnetism scientists, including Yang Zheng and Li Fashen, who pioneered the research on magnetic recording materials, and physics and micro-electromagnetic structures of materials. On this foundation, lab researchers are exploring and testing innovative technologies to map the properties and functions of potential new materials.

One example is the discovery of a new functionality of traditional rare-Earth magnetic materials in the GHz band, shedding light on their potential uses in high-frequency devices. This function may lead to significantly improved properties of electric-power and microwave devices.

LZU researchers also revealed a new mechanism for controlling magnetism with an electric field in interfacing ferromagnetic and ferroelectric nanomaterials. Their work demonstrates that the intrinsic interfacial multiferroic effect can be a highly localized and efficient tool for manipulating magnetism with ultralow power consumption.

The exploration and discovery of new magnetic materials can also lead to development of smaller and more efficient electronic devices, including spintronic and new magnetoelectric devices. In the former, the spin current and/or spin wave are used to realize magnetic recording; while in the latter, traditional semi-conductor devices are combined with emerging multi-functional magneto-electronic devices.

THEORETICAL BREAKTHROUGHS

With special funding from the National Natural Science Foundation of China (NSFC), LZU established a theoretical physics exchange platform in 2010, leading to breakthroughs in general relativity and gravitational theory, particle physics, condensed matter theories, quantum optics/information, statistical physics and complex systems.

A group LZU physicists is dedicated to uncovering patterns in how new types of particles might be discovered. This could help physicists better understand how matter can be formed and quarks interact.

The LZU team predicted the best detection approach for subatomic particles in four-quark and five-quark configurations, as well as the internal structure of the five-quark arrangement. These predictions offered key clues supporting the discovery of the four-quark particle by BESIII, and were fulfilled in 2015 when the Large Hadron Collider at CERN reported detecting a new class of subatomic particles, comprising five quarks.

Chaotic systems leave behind 'scars' of paths that seem to be retraced in the quantum world, known as the quantum scar. Focusing on this intriguing phenomenon, LZU physicists and collaborators went a step further to see what quantum scars look like in relativistic systems.

LZU School of Physical Science and Technology in numbers

- Founded in 1946 as the Department of Physics
- Houses cutting-edge research and teaching facilities, including 2 MoE key laboratories, and the most powerful electron microscope centre in Northwest China.
- Comprises more than 200 faculty and staff, including 150 full-time teaching and research personnel
- 1109 undergraduate, 342 master's and 158 doctoral students

By investigating 2D billiards of confined massless spin-half fermions, they identified unequivocal scars with a chiral signature that tells the difference between particles traveling in different orientations. Their work advanced the interesting area called relativistic quantum chaos, and the team was invited to author a *Physics Reports* long review on this emerging field.

In quantum optics, LZU physicists recently proposed an approach to improve precision in noisy quantum optical metrology, making it possible to achieve ultrasensitive measurements. Quantum metrology is an emerging field exploring using quantum effects to realize precision beyond what is possible through classical approaches. It has potential applications in radar imaging, weak field detection, and navigation and positioning technologies. However, the decoherence in quantum metrology hampers these applications. By studying decoherence in quantum optical interferometer, LZU physicists revealed the microscopic mechanism of dissipative noise in quantum metrology, and suggested a way to maintain precision.

In 2017, LZU physicists also proposed a new method to probe extra dimensions by using gravitational waves, which was followed by physicists of renowned universities abroad; suggested a new model to describe the microstructure of black holes; discovered the complex interactions between the ordered state and superconducting state in high temperature superconductivity; and explained low-temperature superfluid density in electron-doped copper-based superconductors. ■