ANNUAL SPECIAL | CAS Research 2024 in Retrospect

The year 2024 witnessed a series of important breakthroughs in fundamental research made by scientists at the Chinese Academy of Sciences (CAS). As a special presentation, BCAS takes a retrospective overview on some milestone events and outstanding discoveries in the past year.

This special section begins with the first return of lunar farside samples in human history by *Chang'e*-6 mission and the subsequent discoveries based on the analyses of the returned samples: the compositions of the samples, the ancient volcanism on the lunar farside and the possible magnetic evolution of the Moon recorded by the samples, and the age of the South Pole-Aitken basin — the landing site of CE-6 (page 17). Some of the discoveries were also listed into the Top 10 Science Advances of China for the year 2024 (page 42).

The launch of *Chang'e*-6 mission. (Image: CNSA)

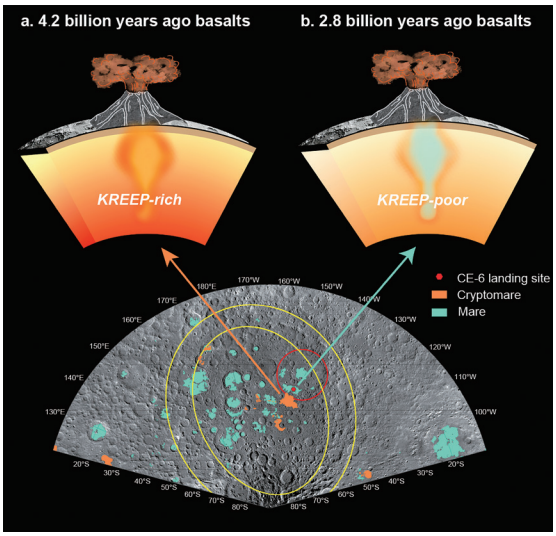
Another event prominent in 2024 was the successful launch of Einstein Probe (EP), an astronomical satellite initiated and sponsored by CAS and developed in cooperation with European Space Agency (ESA), the Max Planck Institute for Extraterrestrial Physics (MPIEP) in Germany and the Centre National d'Études Spatiales (CNES) in France. It is also named "*Tianguan*" in Chinese after "*Tianguan Kexing*", a supernova detected in 1054 by Chinese scientist YANG Weide in Taurus, which was called "*Tianguan*" in ancient China. Launched in January, the satellite was only delivered to science users at the end of last October after calibration and tests; but it even started making miracle discoveries in March, during its commissioning phase. The past few months has seen its productivity and great potential in the research of time-domain astronomy. In the annual special section, we brief the latest results from its observations (page 26), in conjunction with two in-depth reports appearing in the column Highlights (page 48 and page 51).

2024 also witnessed pivotal advances in wearable technologies and sustainable materials. CAS scientists redefined wearable tech with semiconductor fibers — glass-clad germanium and silicon threads flexible enough for 100 laundry cycles, enabling Li-Fi textiles and medical monitors (page 30). Meanwhile, a breakthrough in lignin conversion transformed this stubborn plant polymer into bio-bisphenols via catalytic "molecular traps," achieving 48% yield and slashing estrogenic activity by 110-fold compared to BPA (page 32).

Further, CAS scientists tackled biological puzzles with translational impact. Researchers decoded plant regeneration via a peptide called REF1 — a molecular "911 call" that triggers stem cell reprogramming at wound sites. When applied to recalcitrant crops, REF1 boosted soybean regeneration rates by 900% and maize regeneration capacity fourfold, offering a universal key to unlocking genetic modification bottlenecks in staple crops (page 34). Ancient viral tools were repurposed into precision gene editors, with an all-RNA retrotransposon system achieving 99% on-target gene integration in human T cells and mouse embryos. This RNA-driven platform minimizes immune risks while enabling CAR-T therapy optimization and transgenic model development, bridging evolutionary biology and next-generation medicine (page 36). CAS scientists also battled with cellular aging with surgical precision. Their genetic toolkits distinguished destructive senescent macrophages from reparative endothelial cells in fibrotic livers. Selectively deleting the former reduced scarring by 40%, while reprogramming the latter reversed damage. This work breaks the traditional blindness of lumping all senescent cells into a single category, advocating for GPS-guided cell-type-specific anti-aging therapies (page 40). From crop resilience to gene therapy, researchers are translating fundamental discoveries into tools that reshape food security, medicine, and our fight against time itself.

IN FOCUS | Annual Top 10 Science Advances Revealed

On March 27, the National Science Foundation of China released the Top 10 Science Advances for the year 2024. Topping the list was the discovery of lunar farside volcanism occurring 2.8 billion years ago, as revealed with the samples brought back by *Chang'e*-6 mission from the enigmatic hemisphere of our closest neighbor. Other two advances in the list, respectively ranked 3rd and 5th, were also accomplished by CAS scientists. One successfully revealed the transport mechanism of monoamine neurotransmitters and the regulation process of related drugs for psychiatric diseases; and the other features the dual discovery of giant magnetocaloric effect in a material exhibits superfluidity — an exotic condensed state where the constituent particles of the matter align in a special way to form a solid that exhibits superfluidity, flowing without any friction between each other.



Based on analyses of *Chang'e*-6 samples, the discovery of ancient lunar farside volcanism 2.8 billion years ago leads the list of the annual Top10 Science Advances of China for the year 2024. (Image: IGG)

For detail, please turn to page 42.

HIGHLIGHTS | LEIA Finds Out New Clues about Origin of GRBs

How gamma-ray bursts (GRBs), the most powerful and spectacular explosions known in the universe since the Big Bang, fuel their high-energy radiations? What kind of physical reactions can trigger and sustain such violent, energetic outflow? This has captivated astronomers. Over the past decades, thousands of GRBs have been observed; however, the origin and the product of the burst — the central celestial body, or the "central engine", is still pending for identification. An instrument provided clues about this soon after its launch.

LEIA, the Lobster Eye Imager for Astronomy, was sent into orbit in July 2023 as an experimental module for the wide-field X-ray telescope (WXT) onboard Einstein Probe (EP), to verify its performance before launch. Covering a field of view measuring 1/16 the area of WXT-EP's, it still outstood as the best wide-field X-ray focusing imager at the time. It successfully picked up the signals from an extremely bright gamma-ray burst (GRB 230307A) in a joint observation with the Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor (GECAM). Analytical result, published on December 16, 2024 in *National Science Review*, indicated that the signals offer clear-cut evidence for the magnetar model of central engine. Turn to page 48 for detail.

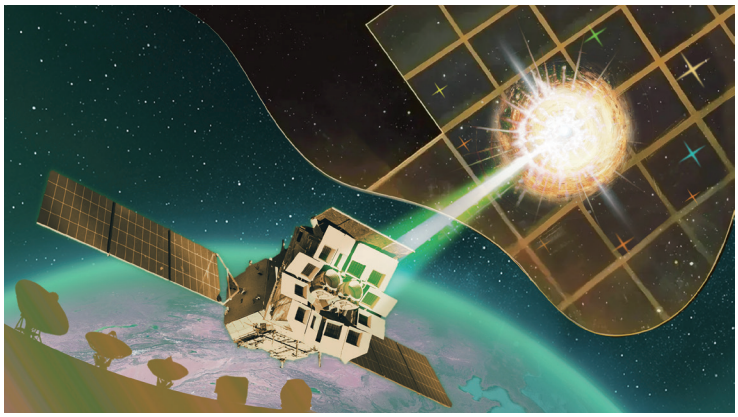
HIGHLIGHTS | EP Demonstrates Great Potential in Observation on High-redshift X-ray Sources

A team of researchers from the Beijing Normal University and the Chinese Academy of Sciences reported in *Nature Astronomy* on January 23, 2025 their discovery of an X-ray flash about 12.5 billion lightyears away. This means the signals burst out only 1.2 to 1.5 billion years after the Big Bang, when our 13.8-billion-year-old universe was still in its infancy. The signals, dim and faint after the travel across the cosmic vastness, were swiftly picked up and recorded by EP, a science satellite

newly launched and was still in its commissioning phase.

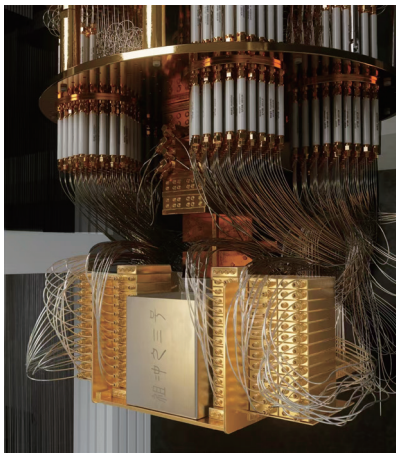
The recorded data give high-quality detail about the sources — an X-ray counterpart for the gamma-ray burst GRB240315C, revealing long-duration nuances unseen in the gamma-ray lens. This hence challenges the existing practice of analyzing GRB signals based on gamma-ray observational data.

More excitingly, the team's simulation indicates that EP is able to detect soft X-ray sources at a red-shift as high as 7.5 at a good signal-noise ratio. For more, please turn to page 51.



Einstein Probe satellite offers unique opportunities to peer into the early X-ray cosmos. (Image credit: EP Team)

HIGHLIGHTS | "*Zuchongzhi*-3" Outpaces Most Powerful Supercomputer



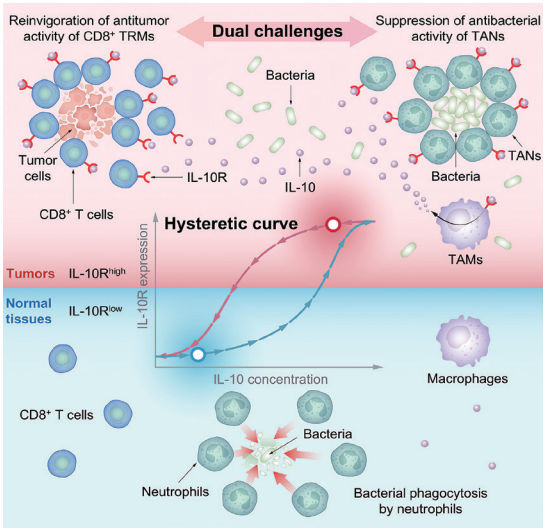
Schematic diagram of the *Zuchongzhi*-3 chip, which integrates 105 qubits and 182 couplers to perform quantum random circuit sampling tasks. (Image by USTC)

Researchers from the University of Science and Technology of China (USTC) of the Chinese Academy of Sciences (CAS) and partners made significant advancement in random quantum circuit sampling with *Zuchongzhi*-3, a superconducting quantum computing prototype featuring 105 qubits and 182 couplers.

Operating at a speed 10^{15} times faster than the most powerful supercomputer currently available and one million times faster than Google's latest published results, the success marks a major milestone in quantum computing ensuing the success of its predecessor, *Zuchongzhi*-2. Turn to page 55 for detail.

HIGHLIGHTS | Rewriting Cancer Immunotherapy with Microbial Espionage

A breakthrough study published in *Cell* (March 3, 2025) unveils a microbial masterstroke: engineered *Salmonella* bacteria that infiltrate tumors, hijack immune memory, and orchestrate their self-destruction. Co-led by Dr. LIU Chenli (Shenzhen Institutes of Advanced Technology, CAS) and Dr. XIAO Yichuan (Shanghai Institute of Nutrition and Health, CAS), the research demonstrates how Designer Bacteria 1 (DB1) — stripped of virulence and armed with synthetic tools — exploits a



Engineered *Salmonella* exploits tumor-primed IL-10^{Rhigh} immune cells to simultaneously evade host defenses and amplify antitumor immunity — reconciling the longstanding dual challenge in bacterial cancer therapy. (Graphic: CAS)

paradoxical immune "memory" forged by tumors themselves. By flooding tumors with IL-10, DB1 paralyzes tumor-protecting neutrophils while reviving exhausted cancer-killing T cells, achieving near-complete tumor eradication in mice and conferring lasting immunity.

This work may transform bacterial cancer therapy from blunt force to precision warfare. For further insights, please refer to page 57.

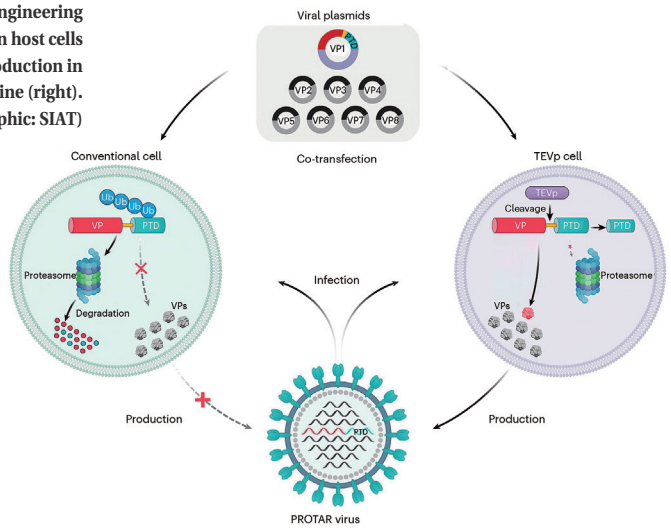
HIGHLIGHTS | Outsmart Flu's Relentless Mutations

Researchers from the CAS Shenzhen Institutes of Advanced Technology (SIAT) have developed a novel strategy for creating live attenuated influenza vaccines by harnessing the cellular ubiquitin-proteasome system (UPS), a built-in "shredder" that degrades unwanted proteins, to selectively dismantle the influenza virus's M1 protein — a highly conserved component critical for viral assembly but rarely prone to mutation.

This innovative approach, detailed in *Nature Microbiology* on January 15, offers a systematic way to generate vaccines that are both safe and highly effective, with the potential to protect against a wide range of influenza strains. Unlike traditional vaccines that rely on predicting fast-evolving surface proteins (*e.g.*, hemagglutinin), PROTAR vaccines focus on destabilizing structurally essential viral components, offering a universal defense mechanism against viral escape.

To delve into the detail, please refer to page 60.

PROTAR vaccine: Engineering viral self-destruction in host cells (left) and vaccine production in a specialized cell line (right). (Graphic: SIAT)



HIGHLIGHTS | From Protector to Perpetrator

In a recent *Nature Aging* study published on January 8, 2025, researchers at the CAS Institute of Neuroscience (ION) discovered that astrocytes, one of the most abundant cell types in the mammalian central nervous system, undergo a dynamic transition from a neuroprotective state to a neurotoxic state. This revelation challenges the traditional binary view of astrocyte function — either "protectors" or "destroyers" — and offers new insights into the pathogenesis of neurodegenerative diseases like Alzheimer's and Parkinson's.

For further insights, please refer to page 63.

A shift from traditional binary view of astrocyte function (left), either neurotoxic or neuroprotective, to a dynamic transition (right). (Graphic: ION)