

FAST concludes the first decade with fruitful achievements

The Innovation Astronomy Editorial Team*

*Correspondence: astronomy@the-innovation.org

Received: September 23, 2026; Accepted: September 24, 2026; Published Online: September 24, 2026; <https://doi.org/10.59717/j.tias.2027.100004>

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Citation: The Innovation Astronomy Editorial Team (2027). FAST concludes the first decade with fruitful achievements. *The Innovation Astronomy* 1:100004.

The China's Five-hundred-meter Aperture Spherical radio Telescope (FAST) marks ten years since its inauguration in September 2016. Its half-kilometer-diameter dish collects more radio energy than any predecessor, and that sensitivity has driven a decade of discoveries.

The pulsar census makes that gain concrete. Half a century of searching had cataloged roughly 2,500 pulsars when FAST was inaugurated. has since discovered more than 1,300, bringing the total to more than half the pre-2016 catalog.¹

For the past 10 years, FAST has completed its own stated missions, which include surveying neutral hydrogen, observing pulsars, studying interstellar molecules, and offering researchers worldwide new avenues to probe the evolution of stars, galaxies and the broader universe. Just as General Secretary of the Communist Party of China (CPC) Central Committee Xi Jinping urged in the congratulatory letter on its inauguration, its completion and operation are of great significance for China to achieve major original breakthroughs in scientific frontiers and accelerate innovation-driven development.

Located in a natural Karst depression in southwestern China's Guizhou Province, FAST turns its 500-meter dish into a steerable 300-meter observing aperture. Its active reflector reshapes the collecting surface as the telescope tracks the sky, while a suspended feed system keeps the receivers aligned with the focus. The combination gives FAST unmatched sensitivity among single-dish radio telescopes, allowing it to pick out faint radio signals from diffuse gas, compact stellar remnants and rapidly evolving cosmic environments.

PULSARS AS PRECISION LABORATORIES

Pulsars are the dense, rapidly rotating remnants left by some massive stars after supernova explosions. Their regular radio pulses make them exceptional clocks and natural laboratories for testing gravity, stellar evolution and the interstellar medium.

One standout discovery was a binary pulsar system with an orbital period of only 53 minutes — the shortest then known for a pulsar binary. The system appears to sit near a critical transition from a "redback" to a "black widow" pulsar, offering a rare view of how such binaries change as a pulsar strips material from its companion.¹

FAST observations also helped identify a compact pulsar–helium-star binary that provides evidence for the long-theorized common-envelope phase of binary evolution. During this brief and difficult-to-observe stage, one star becomes engulfed by the outer envelope of its companion and the pair loses orbital energy as the orbit shrinks. Finding a system linked to that process gives astronomers an observational anchor for models that previously relied heavily on theoretical predictions.¹

Both results turn on the same capability. FAST reaches systems that population synthesis expects to be the hardest to catch, which is where the evolutionary tracks of compact binaries are decided.

MAPPING THE HYDROGEN UNIVERSE

Neutral atomic hydrogen, known to astronomers as HI, is the basic reservoir from which stars form. Its 21-centimeter radio emission can reveal gas that is faint or invisible at optical wavelengths, allowing FAST to trace how galaxies acquire, lose and rearrange the material needed for star formation.

Imaging of Stephan's Quintet and the surrounding sky uncovered an enormous HI structure extending about 2 million light-years — roughly 20 times the diameter of the Milky Way and the largest atomic-gas system detected at the time. Interactions in a compact galaxy group, as the maps showed, affect gas far beyond the galaxies' visible disks. Here, FAST's sensitivity to faint, extended emission was pushed into an extreme regime.¹

The FAST All Sky HI Survey, or FASHI, has meanwhile moved from individual discoveries to population-scale astronomy. Its first catalog, based on

about 7,600 square degrees scanned in three years, released 41,741 galaxy detections. The project's second data release expanded coverage to about 19,500 square degrees and listed 156,411 extragalactic HI sources, forming the largest and most sensitive catalog of its kind to date.^{1,2}

FAST RADIO BURSTS UNDER THE MICROSCOPE

Fast radio bursts (FRBs) are millisecond flashes from distant parts of the universe. Some sources have been seen only once, while others repeat. The physics behind their millisecond durations and enormous brightness remains unsettled. FAST's exceptional sensitivity makes it especially powerful for uncovering faint bursts and tracking subtle changes in their spectra and polarization.

For FRB 121102, the first known repeating fast radio burst, FAST captured what was then 1,652 independent bursts in 59.5 hours spanning 47 days from a single source. That finding disfavors models in which each burst requires an enormous expenditure of total energy.¹ Researchers then proposed using the spread in rotation measure — often described as "RM scatter" — as a concise diagnostic tool to characterize the magnetized plasma surrounding repeating FRBs. A larger spread points to a more variable magneto-ionic environment and may help distinguish relatively young, turbulent systems from more settled ones.³

Observations of the repeating source FRB 180301 showed that both the burst profiles and polarization-angle swings changed from one outburst to another. The diversity points to emission in a varying magnetosphere, and argues against models in which the radiation is produced by a shock far from the source.¹

A separate campaign on FRB 20201124A recorded 1,863 bursts in 82 hours across 54 days. Rapid changes in polarization and rotation measure pointed to a compact, dynamically evolving and strongly magnetized region around the source, on scales of roughly one astronomical unit. The observations shifted attention from a static picture of an FRB's surroundings to one in which plasma and magnetic fields can change measurably over weeks.¹

More recently, FAST observations of FRB 20220529 found that its rotation measure abruptly rose by several orders of magnitude and then returned near its earlier level within about two weeks.

Researchers interpreted the event as the passage of a dense, magnetized plasma clump, with a coronal mass ejection from a possible companion star among the explanations. The observation strengthens the case for examining binary environments. The observations place binary environments among the leading settings for rapid changes in the magnetized plasma surrounding repeating FRBs.¹

LISTENING FOR NANOHERTZ GRAVITATIONAL WAVES

FAST has also become a central instrument in the search for gravitational waves, which are expected largely from populations of orbiting supermassive black-hole binaries. Rather than measuring the waves directly, pulsar timing arrays look for a correlated pattern in tiny deviations from the arrival times of pulses from many millisecond pulsars.

Using three years and five months of observations, the Chinese Pulsar Timing Array reported evidence for the characteristic spatial quadrupolar correlation at a statistical significance of 4.6 σ near 14 nanohertz, with a false-alarm probability below roughly two in a million.

The CPTA result arrived alongside independent evidence from pulsar timing arrays in North America, Europe, India and Australia, together pointing to the emergence of a nanohertz gravitational-wave background. FAST allowed the Chinese array to reach this sensitivity with only three years and five months of observations, manifesting the telescope's exceptional precision for pulsar timing.¹

For decades, Arecibo defined what a giant single-dish radio telescope

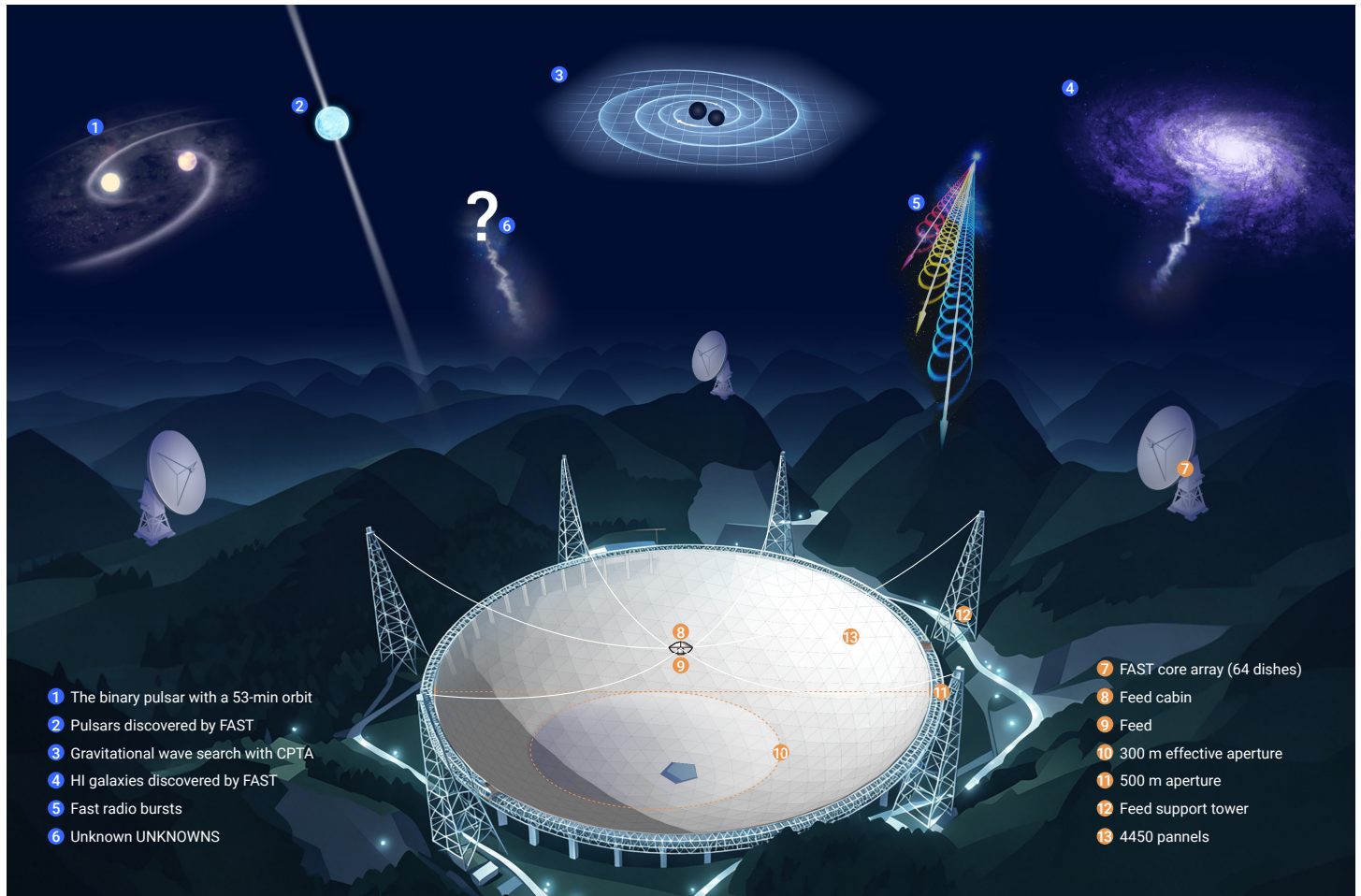


Figure 1. Ten years of FAST: The advance and future plan in technology and science Reproduced from Jiang et al.¹ under CC BY 4.0.

could do. FAST pushed that tradition into a new sensitivity regime, and its first decade has shown what that sensitivity enables: access to fainter sources, larger samples and more precise measurements. From pulsar searches and fast radio bursts to surveys of neutral hydrogen, these gains have opened parts of the radio sky that were previously difficult to reach.

The next frontier is spatial information. A single dish, however sensitive, remains limited in angular resolution and source localization. The Square Kilometre Array Observatory (SKAO), now being built in South Africa and Australia, and the planned Next Generation Very Large Array (ngVLA) in the United States take a different approach, combining signals from many antennas through interferometry. This architecture combines sensitivity with far finer angular resolution, allowing faint radio emission not only to be detected, but also to be precisely localized and resolved.

The FAST Core Array was designed to build dozens of 40-meter radio telescopes around FAST and combine them into an interferometric array. While preserving FAST's exceptional sensitivity, the project would significantly

improve its spatial resolution, imaging, rapid-tracking and precise-localization capabilities, turning the giant telescope into a more versatile astronomical instrument.

The future is open for all with ambitions.

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DECLARATION OF INTERESTS

The author declares no competing interests.